NEW PARTICLE SEARCHES AND DISCOVERIES

A Supplement to the 1976 Edition of "Review of Particle Properties"

Particle Data Group

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This supplement to the 1976 edition of "Review of particle properties", Particle Data Group [Rev. Mod. Phys. 48, No. 2, Part II (1976)], contains tabulations of experimental data bearing on the "new particles" and related topics; categories covered include charmed particles, ψ's and their decay products, and heavy leptons. Errata to the previous edition are also given.

As in 1975, we have decided this year to publish only a supplement to the previous edition of the "Review of Particle Properties", rather than a complete update; the latter will appear instead in April 1978 in Physics Letters B.

[1] The Berkeley Particle Data Center is jointly supported by the U.S. Energy Research and Development Administration, the Office of Standard Reference Data of the National Bureau of Standards, and the National Science Foundation.

This supplement consists primarily of a *Table* and *Data card listings* giving results relating to charmed particles, ψ's and their decay products, heavy leptons, quarks, magnetic monopoles, intermediate bosons, and other proposed states. Several mini-reviews in the *Listings* discuss various aspects of these particles. Also presented are some cross section plots for e^+e^- and νN scattering, which were not included in the 1976 edition. Finally, errata to the 1976 edition are given.

Charmed Particle Table

April 1977
(Approximate closing date for data: February 1, 1977)

Our normal policy to include only well established results in the Tables has been temporarily relaxed for the Charmed Particle Table. This is because many important results are preliminary or unconfirmed. We have put some such results into the Table but have parenthesized them. The more speculative results have not been included in the Table at all, but are described in the Data Card Listings which follow. The charmonium results, on the other hand, are not as new and are treated in the Charmonium Table in the traditional manner.

Particle	$I(J^P)$	Mass (MeV)	Full width (MeV)	Partial Decay Mode: Mode	Partial Decay Mode: Fraction (%)	Partial Decay Mode: p or p_{max}[a] (MeV/c)
CHARMED MESONS[b]						
$D^+(1870)$	$\frac{1}{2}(\ )$[c]	1876 ± 15	< 40	weak decay: $K^-\pi^+\pi^+$		849
$D^o(1870)$	$\frac{1}{2}(\ )$[c]	1865 ± 12[d]	< 2.4	weak decay: $K^-\pi^+$		861
				weak decay: $K^-\pi^+\pi^+\pi^-$		813
				weak decay: $(K^o_S\pi^+\pi^-)$[e]		842
		$\dfrac{\Gamma(D^o \to \bar{D}^o \to K^+\pi^-)}{\Gamma(D^o \to K\pi)}$	< 0.16			
$D^{*+}(2010)$	$(\ )$[c]	2010 ± 12	< 2.4	$D^o\pi^+$		~ 39[f]
				$(D^+\gamma)$[e]		~ 130[f]
	$m_{D^{*+}} - m_{D^o} = 145.3 \pm 0.5$ MeV					
$D^{*o}(2010)$	$(\ )$[c]	(2005 ± 3)[e]	(< 5)[e]	$(D^o\pi^o)$[e]	$(\sim 55\text{-}65)$[e]	~ 39[f]
				$(D^o\gamma)$[e]	$(\sim 45\text{-}35)$[e]	~ 136[f]
	$(m_{D^{*o}} - m_{D^o} = 141 \pm 5$ MeV$)$[e]					
CHARMED BARYONS[b] (TENTATIVE ENTRY — SEE DISCUSSION IN REVIEW BELOW)						
$\Lambda_c^+(2260)$	$(\ )$[c]	2260 ± 10	< 75	$\Lambda\pi^+\pi^+\pi^-$		789
Λ_c^+ and $\bar{\Lambda}_c^-$ states observed						
$\Sigma_c(2430)$	$(\ )$[c]	2426 ± 12		$\Lambda_c^+\pi$		~ 87[f]
Σ_c^{++} and $\bar{\Sigma}_c^o$ states observed. $\Sigma_c^{++,+,o}$ expected from SU(4).						

[a] For single decays into more than two particles, p_{max} is the maximum momentum that any particle can have.

[b] For antiparticle, charge conjugate all particles; e.g., $D^o \to K^-\pi^+$ becomes $\bar{D}^o \to K^+\pi^-$.

[c] The quantum numbers expected from charm are: $I(J^P) = \frac{1}{2}(0^-)$ for D states, $\frac{1}{2}(1^-)$ for D* states, $0(\frac{1}{2}^+)$ for Λ_c^+, and $1(\frac{1}{2}^+)$ for Σ_c.

[d] A more precise but preliminary result is given in the Data Card Listings.

[e] Parentheses indicate a preliminary result.

[f] These decay momenta are sensitive to the mass differences.

Charmonium Table

April 1977
(Approximate closing date for data: February 1, 1977)

Particle	$I^G(J^P)C_n$ estab.	Mass (MeV)	Full width (MeV)	Mode	Fraction (%)	p or p_{max}‡ (MeV/c)
				Partial Decay Mode		
→						
J/ψ(3100)	$0^-(1^-)-$	3098 ± 3	0.067 ± 0.012	e^+e^-	7 ± 1	1549
				$\mu^+\mu^-$	7 ± 1	1545
				hadrons	86 ± 2	
				† [identified hadron modes	~15] ¶	
				† [identified radiative modes	~0.4] ¶	
χ(3415)	$0^+(0^+)+$	3413 ± 5		ππ	¶	1701
				$K\bar{K}$	¶	1634
				4π (including ππρ)	¶	1678
				6π	¶	
				$\pi\pi K\bar{K}$ (incl. $\pi K\bar{K}^*$)	¶	1579
				γ J/ψ(3100)	¶	300
→						
P_c or χ(3510)	$0^+(A)+$ J > 0	3510 ± 4		4π (incl. ππρ)	¶	1727
				6π	¶	
				$\pi\pi K\bar{K}$ (incl. $\pi K\bar{K}^*$)	¶	1632
				γ J/ψ(3100)	dominant	388
χ(3550)	$0^+(N)+$ J > 0	3554 ± 5		ππ	¶	1772
				$K\bar{K}$	¶	1707
				4π (incl. ππρ)	¶	1750
				6π	¶	
				$\pi\pi K\bar{K}$ (incl. $\pi K\bar{K}^*$)	¶	1655
ψ(3685)	$0^-(1^-)-$	3684 ± 4	0.228 ± 0.056	e^+e^-	0.9 ± 0.2	1842
				$\mu^+\mu^-$	0.8 ± 0.2	1839
				hadrons	98.1 ± 0.3	
				† [J/ψ $\pi^+\pi^-$	33 ± 3]	474
				† [J/ψ $\pi^0\pi^0$	17 ± 3]	478
				† [J/ψ η	4.2 ± 0.7]	189
				† [other identified hadron modes	~0.6] ¶	
				† [γ χ(3415)	7 ± 2]	261
				† [γ χ(3510)	7 ± 2]	170
				† [γ χ(3550)	7 ± 2]	128
→						
ψ(4415)	$(1^-)-$	4414 ± 7	33 ± 10	e^+e^-	0.0013 ± 0.0003	2207
				hadrons	dominant	

→ Indicates entries in the Charmonium Data Card Listings [X(2830), X(3455), and ψ(4030)] omitted from this Table. We do not regard these as established resonances.

¶ See Charmonium Data Card Listings.

† Square brackets indicate a subreaction of the previous (unbracketed) decay mode(s).

‡ For decays into more than two particles, p_{max} is the maximum momentum that any particle can have.

CHARMED PARTICLES

A prime motivation for the publication of this supplement has been the discovery of charm in May 1976 (GOLDHABER 76 in the D^o section of the Data Card Listings) shortly after the regular biannual editon of the "Review of Particle Properties" was published in April 1976. The analogous situation occurred two years earlier with the discovery of the J/ψ (AUBERT 74 and AUGUSTIN 74 in the Charmonium section). We plan to continue our biannual publication policy with the next regular edition scheduled for April 1978.

This charm review and the Table and Data Card Listings on the D, D^*, Λ_c^+, and Σ_c and on charm searches are intended to summarize the experimental evidence on charmed particles. There are many excellent reviews of charm, a few of which are listed in references 1 and 2. Others, related to specific particles or searches, are listed in the appropriate reference sections below.

In the discussions of charm expectations which follow, we mean charm as in the standard GIM model[3] with four spin-1/2, fractionally-charged, baryon number B = 1/3 quarks with quantum number assignments as follows:

Symbol	Q	I_3	S	C
u	2/3	1/2	0	0
d	-1/3	-1/2	0	0
s	-1/3	0	-1	0
c	2/3	0	0	1

where the charge is related to the third component of the isospin, baryon number, strangeness, and charm by

$$Q = I_3 + \tfrac{1}{2}(B+S+C) \ .$$

The conventional model for describing the weak interactions involving these quarks and leptons is a Weinberg-Salam theory[4] with left-handed weak isodoublets

$$\begin{pmatrix}\nu_e \\ e^-\end{pmatrix} \quad \begin{pmatrix}\nu_\mu \\ \mu^-\end{pmatrix} \quad \begin{pmatrix}u \\ d'\end{pmatrix} \quad \begin{pmatrix}c \\ s'\end{pmatrix}$$

and right-handed weak isosinglets. Here

$$d' = d\cos\theta + s\sin\theta$$
$$s' = s\cos\theta - d\sin\theta,$$

where θ is the Cabibbo mixing angle ($\sin^2\theta \cong 0.055$).

Then, following Jackson's (ref. 1) shorthand notation, the weak interaction has a current-current structure

$$H_W = \frac{G}{\sqrt{2}} J J^\dagger \text{ with } J = J_C + J_N \quad ,$$

where the charged and neutral currents are

$$J_C = \bar{\nu}_e e + \bar{\nu}_\mu \mu + \bar{u}\,(d\cos\theta + s\sin\theta) + \bar{c}\,(s\cos\theta - d\sin\theta)$$

$$J_N = \bar{\nu}_e\nu_e + \bar{\nu}_\mu\nu_\mu - \bar{e}e - \bar{\mu}\mu + \bar{u}u + \bar{c}c - \bar{d}d - \bar{s}s$$

ignoring the Lorentz group structure. Thus only the charged current has terms which change charm, and the Cabibbo-favored transition is to a strange quark ($c \to s$), giving $\Delta C = \Delta S$.

The experiments related to charm are divided below into four sections:

1) Charmed Mesons — the D and D* states.
2) Charmed Baryons — the Λ_c and Σ_c states.
3) Charm Searches and Evidence — charm information not relatable to a given state.
4) Charmonium — the J/ψ states.

References

1. Proceedings of Summer Institute on Particle Physics, Aug. 2-13, 1976, Report No. SLAC-198 (Nov. 1976), especially: J.D. Bjorken, p.1; S.G. Wojcicki, p. 43; J.D. Jackson, p. 147 (also available separately as LBL-5500); D. Hitlin, p. 203; G. Goldhaber, p. 379 (also available separately as LBL-5534); S.L. Glashow, p. 473; A. De Rujula (a pictorial review), p. 483; also F.J. Gilman, 1976 Particles and Fields Conference at Brookhaven National Lab, SLAC-PUB-1833, Nov. 1976.
2. M.K. Gaillard, B.W. Lee, and J.L. Rosner, Rev. Mod. Phys. 47, 277 (1975).

3. S.L. Glashow, J.Iliopoulos, and L. Maiani, Phys. Rev. D2, 1285 (1970); also B.J. Bjorken and S.L. Glashow, Phys. Lett. 11, 255 (1964).
4. S. Weinberg, Phys. Rev. Lett. 19, 1264 (1967) and A. Salam, in Elementary Particle Theory, ed. N. Svartholm (Almqvist and Wiksell, Stockholm, 1968), p. 367.

CHARMED MESONS

Note that D and D^* are used throughout this review to mean the apparently charmed states at ~1870 MeV and ~2010 MeV, respectively, and should not be confused with the uncharmed D(1285) meson.

There is very strong evidence for the charm interpretation of the narrow $K\pi$, $K2\pi$, $K3\pi$ states observed in e^+e^- collisions at SPEAR. In agreement with the expectations for charmed mesons,[1-3] the following are observed (GOLDHABER 76, PERUZZI 76, WISS 76, GOLDHABER2 76, FELDMAN 77, and GOLDHABER 77 - see data cards and comments in the D and D* sections below):

a) The D state appears to be produced only in association with equal (~1870 MeV) or higher mass states. Electromagnetic production of charm via a massive virtual photon would produce charm-anticharm pairs.

b) The D^+ decays via the exotic charge mode $K^-\pi^+\pi^+$ and not $K^+\pi^+\pi^-$. A charmed charge-plus ($c\bar{d}$) meson decays weakly to an uncharmed negative strangeness state as expected for $\Delta C=\Delta S$.

c) The observed decay modes of the D are Cabibbo-favored (strange). The Cabibbo-suppressed modes ($c\rightarrow d$, $\Delta S=0$) are not observed within present statistics.

d) An excited state appears at ~2010 MeV in agreement with mass predictions.[4]

e) The masses suggest that the D states and D^* states are isospin multiplets. There are two distinct neutral states as is known from the D^0-$\bar{D}^0$ mixing studies (see D^0 branching ratio R5 section), suggesting the isodoublet structure (D^+, D^0) and (D^-, $\bar{D}^0$) as expected for charmed nonstrange mesons ($c\bar{d}$, $c\bar{u}$) and ($\bar{c}d$, $\bar{c}u$).

f) Parity violation indicates that the ground state decays weakly. Charm conservation prevents strong decay.

g) There is evidence that semileptonic decay modes exist as would be expected from elementary processes such as $c\rightarrow se^+\nu_e$. In e^+e^- collisions at DESY, BRAUNSCHWEIG 76 (DASP) see single electrons with hadrons and BURMESTER 76 (PLUTO) see a correlated $e^+K_S^0$ signal (see Charm Searches and Evidence section of the Data Card Listings, subsection CE, below). Identification with a particular charm state is not possible, but the threshold and cross section are compatible with D production.

There is evidence for the existence of the D^0 state outside e^+e^- collisions. KNAPP 76 report a weak signal in $K_S^0\,\pi^+\pi^-\pi^+\pi^-$ in Fermilab photoproduction data at the D^0 mass. Their current experiment with better acceptance should be able to make a more definitive statement.

The data are listed in the Data Card Listings and summarized in the Table at the beginning of this report. Preliminary results of which we are aware are included but are parenthesized.

References

1. M.K. Gaillard, B.W. Lee, and J.L. Rosner, Rev. Mod. Phys. 47, 277 (1975).
2. M.B. Einhorn and C. Quigg, Phys. Rev. D12, 2015 (1975).
3. A. De Rujula, H. Georgi, and S.L. Glashow, Phys. Rev. Lett. 37, 398 (1976).
4. A. De Rujula, H. Georgi, and S.L. Glashow, Phys. Rev. D12, 147 (1975).

$D^{\pm}(1870)$, $D^0(1870)$, $D^{*\pm}(2010)$, $D^{*0}(2010)$

Data Card Listings

Please note that the meaning of the columns and the various abbreviations appearing below can be found in the 1976 edition of the Review [Rev. Mod. Phys. 48, No. 2, Part II (1976)].

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CODE EVENTS QUANTITY  ERROR+  ERROR-  REFERENCE YR TECN SIGN COMMENTS         DATE
     AB. V.                                                                 PUNCHED
  BACKGROUND
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$D^{\pm}(1870)$

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31  CHARGED D(1870,JP=  )
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                 31  CHARGED D MASS (MEV)

M        50 1876.      15.              PERUZZI   76 SMAG +-  K+-PI+-PI+-      1/77*
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                 31  CHARGED D WIDTH FROM MASS SPECTRUM (MEV)

W     P  50   40.   OR LESS  CL=.90   PERUZZI   76 SMAG +- K-+PI+-PI+-         1/77*
W     P  PERUZZI 76 WIDTH IS CONSISTENT WITH THEIR EXPERIMENTAL RESOLUTION.    1/77*
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                 31  EVIDENCE FOR WEAK DECAY OF D

WK       70                             WISS      76                           1/77*
WK       WISS 76, USING A SAMPLE OF ABOUT 70 D+- --> K-+ PI+- PI+-             1/77*
WK       EVENTS WHICH INCLUDE THE PERUZZI 76 EVENTS, FINDS THAT THIS FINAL     1/77*
WK       STATE IS INCOMPATIBLE WITH NATURAL SPIN AND PARITY.  THE NATURAL      1/77*
WK       SPIN PARITY FINAL STATE IN DO --> K- PI+ (GOLDHABER 76) INDICATES     1/77*
WK       PARITY VIOLATION IN THE D+- AND DO DECAYS IF BOTH ARE MEMBERS OF      1/77*
WK       THE SAME ISOMULTIPLET AS SUGGESTED BY THEIR SIMILAR MASSES.           1/77*
WK       THIS SUGGESTS A WEAK DECAY AND CONSEQUENTLY A NARROW WIDTH OF ORDER   1/77*
WK       10**13 SEC-1 OR 10**-8 MEV.                                           1/77*
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                 31  CHARGED D  PARTIAL DECAY MODES

                                                          DECAY MASSES
P1       D+- INTO K+- PI+- PI+-                         493+ 139+ 139

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                 REFERENCES FOR CHARGED D
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GOLDHABE 76 PRL 37 255      GOLDHABER,PIERRE,ABRAMS,ALAM+     (LBL+SLAC)
PERUZZI  76 PRL 37 569      +PICCOLO,FELDMAN,NGUYEN,WISS+     (SLAC+LBL)
WISS     76 PRL 37 1531     +GOLDHABER,ABRAMS,ALAM,BOYARSKI+ (LBL+SLAC)
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$D^0(1870)$

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32  NEUTRAL D(1870,JP=  )
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                 32  NEUTRAL D MASS (MEV)

M       234 1865.      15.              GOLDHABER 76 SMAG CHGD K PI AND K 3PI  1/77*
M          (1864.)    (5.4)             GOLDHAB2  76 SMAG K+PI-/ RECOIL INFO   3/77*
M              . . . . . . . . . . .
M    FIT    1865.      12.      FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)  4/77*
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                 32  NEUTRAL D WIDTH FROM MASS SPECTRUM (MEV)

W       234   40.   OR LESS             GOLDHABER 76 SMAG CHGD K PI AND K 3PI  1/77*
W            (5.)   OR LESS             GOLDHAB2  76 SMAG K+PI-/ RECOIL INFO   3/77*
W        30   2.4   OR LESS             FELDMAN   77 SMAG D*+ TO DO PI+        3/77*
W        WIDTHS ARE CONSISTENT WITH EXPERIMENTAL RESOLUTION. SEE NOTE ON       3/77*
W        WEAK DECAY IN CHARGED D SECTION ABOVE.                                3/77*
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                 32  NEUTRAL D PARTIAL DECAY MODES

                                                          DECAY MASSES
P1       DO INTO K- PI+                                 493+ 139
P2       DO INTO K- PI+ PI+ PI-                         493+ 139+ 139+ 139
P3       DO INTO KS PI+ PI-                             497+ 139+ 139
P4       DO INTO KS PI+ PI- PI+ PI-
P5       DO INTO PI- PI+                                139+ 139
P6       DO INTO K+ PI- (VIA DOBAR)                     493+ 139

         DOBAR MODES ARE CHARGE CONJUGATES OF ABOVE MODES
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                 32 NEUTRAL D BRANCHING RATIOS

R1       DO INTO (K- PI+)/TOTAL                         (P1)
R1       110 SEEN                       GOLDHABER 76 SMAG    E+E- 3.9-4.6 GEV  3/77*

R2       DO INTO (K- PI+ PI+ PI-)/TOTAL                 (P2)
R2       124 SEEN                       GOLDHABER 76 SMAG    E+E- 3.9-4.6 GEV  3/77*

R3       DO INTO  (PI- PI+)/(K- PI+)                    (P5)/(P1)
R3        24   (0.065)  (0.04)          GOLDHAB2  76 SMAG    CONSIS.WITH ZERO  3/77*

R4       DO INTO (KS PI+ PI-)/TOTAL                     (P3)
R4           SEEN                       SCHWITTER 76 SMAG    E+E- 4.03GEV ECM  3/77*

R5       DO INTO (KS PI+ PI- PI+ PI-)/TOTAL             (P4)
R5           POSSIBLY SEEN              KNAPP     76 SPEC    PHOTOPRODUCTION   3/77*

R6       DO INTO (K+ PI- VIA DOBAR)/(K PI)              (P5)/(P1+P5)
R6        THIS IS THE DO-DOBAR MIXING LIMIT
R6            (0.17) OR LESS  CL=.90    GOLDHABER 77 SMAG                      3/77*
R6             0.16  OR LESS  CL=.90    FELDMAN   77 SMAG    D*+ TO DO PI+     3/77*

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                 REFERENCES FOR NEUTRAL D
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GOLDHABE 76 PRL 37 255          GOLDHABER,PIERRE,ABRAMS,ALAM+       (LBL+SLAC)
GOLDHAB2 76 SLAC CONF. 379      G.GOLDHABER (AVAIL. AS LBL-5534)  (LBL+SLAC)
KNAPP    76 BNL CONF.           B.KNAPP                                 (COLU)
SCHWITTE 76 BNL CONF.           R.F.SCHWITTERS (SLAC-PUB-1871,1977)   (SLAC)
FELDMAN  77 SUBMITTED TO PRL    +PERUZZI,PICCOLO,ABRAMS,ALAM+       (SLAC+LBL)
GOLDHABE 77 CHICAGO APS         G.GOLDHABER                         (LBL+SLAC)
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$D^{*\pm}(2010)$

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62 CHARGED D*(2010,JP=  )
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                 62  CHARGED D*(2010) MASS (MEV)

M        18 2010.      20.              PERUZZI   76 SMAG +- E+E- RECOIL       1/77*
M     F  30(2010.)    (15.)             FELDMAN   77 SMAG +- E+E- DIRECT DEC   3/77*
M     F  FELDMAN 77 MASS IS NOT INDEPENDENT OF MASS DIFFERENCE BELOW AND THE   3/77*
M     F  GOLDHABER 76 DO MASS.                                                 3/77*
M             . . . . . . . . . . .
M    FIT    2010.      12.      FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)  4/77*
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                 62 (D*+) - (DO) MASS DIFFERENCE (MEV)

DM       30  145.3      0.5             FELDMAN   77 SMAG    D*+ TO DO PI+     3/77*
DM            . . . . . . . . . . .
DM   FIT     145.3      0.5     FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)  4/77*
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                 62  CHARGED D*(2010) WIDTH (MEV)

W        18  (20.0)  OR LESS            PERUZZI   76 SMAG +- E+E-,PSI(4030)    1/77*
W        30    2.4   OR LESS            FELDMAN   77 SMAG    D*+ TO DO PI+     3/77*
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                 62  CHARGED D*(2010) DECAY MODES

                                                          DECAY MASSES
P1       D*+(2010) INTO DO PI+                          1865+ 139
P2       D*+(2010) INTO D+ GAMMA                        1876+   0

         D*-(2010) MODES ARE CHARGE CONJUGATES OF ABOVE MODES
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                 62  CHARGED D*(2010) BRANCHING RATIOS

R1       D*+(2010) INTO (DO PI+)/TOTAL                  (P1)
R1        30 SEEN                       FELDMAN   77 SMAG    DIRECT DECAY      3/77*

R2       D*+(2010) INTO (D+ GAMMA)/TOTAL                (P2)
R2          SEEN                        GOLDHABER 77 SMAG    RECOIL SPEC       4/77*

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                 REFERENCES FOR CHARGED D*(2010)
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PERUZZI  76 PRL 37 569          +PICCOLO,FELDMAN,NGUYEN,WISS,+      (SLAC+LBL)
FELDMAN  77 SUBMITTED TO PRL    +PERUZZI,PICCOLO,ABRAMS,ALAM+       (SLAC+LBL)
GOLDHABE 77 CHICAGO APS         G.GOLDHABER                         (LBL+SLAC)
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$D^{*0}(2010)$

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63  NEUTRAL D*(2010,JP=  )
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                 63  NEUTRAL D*(2010) MASS

M          (2005.)    (3.)              GOLDHAB2  76 SMAG    E+E- TO D*D*      3/77*
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                 63 (D*0) - (DO) MASS DIFFERENCE

DM    G    (141.)     (5.1)             GOLDHAB2  76 SMAG    E+E- TO D*D*,D*D  3/77*
DM    G  NOT INDEPENDENT OF GOLDHABER2 76 D*0 AND DO MASS VALUES.              3/77*
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                 63  NEUTRAL D*(2010) WIDTH (MEV)

W            (5.)   OR LESS             GOLDHAB2  76 SMAG    E+E- TO D*D*      3/77*
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                 63  NEUTRAL D*(2010) PARTIAL DECAY MODES

                                                          DECAY MASSES
P1       D*0(2010) INTO DO PIO                          1865+ 134
P2       D*0(2010) INTO DO GAMMA                        1865+   0

         D*0(2010)BAR MODES ARE CHARGE CONJUGATES OF ABOVE MODES
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                 63  NEUTRAL D*(2010) BRANCHING RATIOS

R1       D*0(2010) INTO (DO GAMMA)/(DO PIO + DO GAMMA)     (P2)/(P1+P2)
R1            (APPROX. 35 TO 45 PERCENT) GOLDHAB2  76 SMAG   E+E- TO D*D*,D*D  3/77*

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                 REFERENCES FOR NEUTRAL D*(2010)
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GOLDHAB2 76 SLAC CONF. 379      G.GOLDHABER (AVAIL. AS LBL-5534) (LBL+SLAC)
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CHARMED BARYONS

The evidence for the observation of charmed baryons, though not as strong as for charmed mesons, is quite consistent with the charmed baryon picture.[1,2] A single event, identified with high probability as $\nu p \to \mu^- \Lambda \pi^+ \pi^+ \pi^+ \pi^-$ observed at BNL (CAZZOLI 75 in Λ_c^+, Σ_c Data Card Listings below) has $\Delta S = -1$ and $\Delta Q = +1$ for the hadrons. For this event, rate arguments indicate a $\Delta S = -\Delta Q$ strength comparable to $\Delta S = \Delta Q$. For non-charmed particles, no $\Delta S = -\Delta Q$ semileptonic processes have been observed, and limits on such rates are a few percent of $\Delta S = \Delta Q$ rates. With charm, such events are expected at rates comparable to $\Delta S = \Delta Q$ rates. Production can occur via the Cabibbo-suppressed transition $\nu d \to \mu^- c$ ($\Delta Q = +1$, $\Delta S = 0$), while the Cabibbo-favored nonleptonic decay involves the transition $c \to s u \bar{d}$ ($\Delta Q = 0$, $\Delta S = -1$) resulting in $\Delta Q = +1$, $\Delta S = -1$ as observed. Thus charm provides a natural explanation for this event. The $(\Lambda 4\pi)^{++}$ mass and one of the $(\Lambda 3\pi)^+$ mass combinations are in good agreement with charm predictions[3] for the lowest lying charmed baryon states with charge +2 and +1 and $J^P = 1/2^+$, the $\Sigma_c^{++}(2430)$ and the Λ_c^+ (2260).

CAZZOLI 75 state that the most likely alternative to charm for this event is associated production of a missing K_L^0 with a probability of $\simeq 3 \times 10^{-5}$.

We adopt the names Λ_c and Σ_c used by CAZZOLI 75. The name Λ or Σ indicates the isospin (u,d quark) structure, while the subscript c indicates that the strange quark in an uncharmed Λ or Σ has been replaced by a charmed quark giving $c(ud)_{I=0}$ for Λ_c^+ and $c(ud)_{I=1}$ for Σ_c. Alternative names to Λ_c and Σ_c are C_0 and C_1, used e.g. in ref. 1 and ref. 2.

Additional charmed baryon evidence comes from Fermilab photoproduction data (KNAPP 76) on the reaction

$$\gamma + \text{Be} \to \bar{\Lambda} + \text{pions} \; .$$

A narrow peak is observed in $\bar{\Lambda}\,\pi^- \pi^- \pi^+$ at 2.26 GeV and not in $\bar{\Lambda}\,\pi^+ \pi^+ \pi^-$. A higher mass (~2.5 GeV) peak in $(\bar{\Lambda} 4\pi)^0$ is seen to cascade into this state. Their results are consistent with being

$$\left\{ \begin{array}{l} \bar{\Sigma}_c^0 \; (2430,\; J^P = 1/2^+) \\ \bar{\Sigma}_c^0 \; (2480,\; J^P = 3/2^+) \end{array} \right\} \longrightarrow \bar{\Lambda}_c^- \; (2260)\pi^+ , \quad \bar{\Lambda}_c^- \longrightarrow \bar{\Lambda}\pi^-\pi^-\pi^+$$

in striking agreement with the CAZZOLI 75 event.

Uncharmed Σ states are known to exist[4] in the neighborhood of the observed states. However, the narrow width of the $\bar{\Lambda}\pi^-\pi^-\pi^+$ peak and the absence of the opposite-charge state tend to favor the charm interpretation. One disturbing feature of the KNAPP 76 data which is contrary to charm expectations is the absence of a signal in the $\Lambda\pi^+\pi^+\pi^-$ state.

BARISH 77 in an ANL deuterium exposure find one neutrino dilepton candidate, which they identify as

$$\nu_\mu d \to \mu^- p \pi^+ \pi^- \pi^0 e^+ \nu_e (n_s) ,$$

where the π^0 is inferred from the observation of a single converted photon, and the neutrino and spectator neutron are not seen. This event has a possible, but highly speculative interpretation as a semileptonic decay of a charmed baryon:

$$\nu_\mu d \to \mu^- \Sigma_c^{++}(2430)\,(n_s)$$

$$\Sigma_c^{++} \longrightarrow p\pi^+\pi^-\pi^0 e^+ \nu_e$$

or

$$\Sigma_c^{++} \longrightarrow p\pi^+\pi^-\pi^0 \bar{K}^0 e^+ \nu_e \; ,$$

where the $\bar{K}^0$ escaped detection. With the second interpretation and the charm expectation that $\Sigma_c^{++}(2430) \to \Lambda_c \pi^+$, they speculate that they may have observed the semileptonic decay

$$\Lambda_c^+ \to p \pi^- \pi^0 \bar{K}^0 e^+ \nu_e \; .$$

This interpretation would require that mass$(\Sigma_c^{++}) > 2439$ MeV and mass$(\Lambda_c^+) > 2248$ MeV, limits consistent within errors with the CAZZOLI 75 mass values. It would also require a fairly unlikely spectator neutron momentum of 260 MeV. Other interpretations exist for this event including a lighter mass, ~2 GeV charmed baryon or a background non-dilepton event.

We put the Λ_c^+ and Σ_c into the table but consider these entries preliminary.

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$\Lambda_c^+(2260)$

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33  LAMBDA/C+(2260,JP=  )
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                    33  LAMBDA/C+ MASS (MEV)

M    C  1 2260.      20.              CAZZOLI   75 HBC  +  LAMBDA 2PI+ PI-   3/77*
M   S    1(2360.)   (590.)            SUGIMOTO  75 EMUL    INTO SIGMA PIO    3/77*
M   S    1(2230.)   (560.)            SUGIMOTO  75 EMUL    INTO SIGMA ETAO   3/77*
M    K 60 2260.      (10.)            KNAPP     76 SPEC -  ANTILAM 2PI- PI+  3/77*
M   B    1(2248.)   OR MORE           BARISH    77 DBC     MODE P4 BELOW     3/77*
M    C  CAZZOLI 75 IS BNL EXPT.  SEES (NEUTRINO P --> MU- LAMBDA 3PI+ PI-)    3/77*
M    C  EVENT WITH M(LAMBDA 4PI)=2426+-12MEV.  LARGE DS=-DQ RATE (SAME AS     3/77*
M    C  DS=DQ) SUGGESTS CHARM.  DERUJULA 75 PREDICTS 2 STATES NEAR THIS       3/77*
M    C  MASS WHICH DECAY STRONGLY BY PI+ EMISSION (MASS DIFF 160 AND 220MEV   3/77*
M    C  FOR THE TWO STATES) TO THE LOWEST MASS CHARMED BARYON.  THE THREE     3/77*
M    C  POSSIBLE PI+ EMISSION MASS DIFFS FOR THIS EVT ARE 338+-12, 327+-12    3/77*
M    C  AND 166+-15MEV.  WE USE THE LATTER FOR THE ABOVE QUOTED MASS.         3/77*
M   S   SUGIMOTO 75 VALUES ASSUME DECAY TRACK IDENTIFICATION AS SIGMA+-.      3/77*
M   S   VALUES TAKEN FROM GAISSER 76 TABLE 3. VERY SPECULATIVE INTERP.        3/77*
M    K  KNAPP 76 IS FNAL WIDE BAND PHOTON BEAM ON BE TARG. THEY SEE PEAK IN   3/77*
M    K  ANTILAM 2PI- PI+ BUT NOT IN ANTILAM 2PI+ PI-.  THEY ALSO SEE AN       3/77*
M    K  ANTILAM  2PI+ 2PI- STATE AT 2.5GEV CASCADING VIA PI- EMISSION TO      3/77*
M    K  THE 2.26 GEV STATE.                                                   3/77*
M   B   BARISH 77 IS ANL EXPT.  SEES ONE DILEPTON EVENT WHICH IS CONSISTENT   3/77*
M   B   WITH NEU P --> MU- SIGMA/C++, SIGMA/C++ --> LAMBDA/C+ PI+  AND        3/77*
M   B   LAMBDA/C+ --> P PI- PIO KOBAR E+ NEU.  THIS INTERPRETATION GIVES      3/77*
M   B   ABOVE MASS LIMIT. IT IS A VERY SPECULATIVE INTERPRETATION.            3/77*

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                    33  LAMBDA/C+ MEAN LIFE (UNITS 10**-12 SEC)
T   S    1   (4.5)                    SUGIMOTO  75 EMUL    INTO SIGMA PIO    3/77*
T   S    1   (0.68)                   SUGIMOTO  75 EMUL    INTO SIGMA ETAO   3/77*
T   S   SUGIMOTO 75 VALUES ASSUME DECAY TRACK IDENTIFICATION AS SIGMA+-.      3/77*
T   S   VALUES TAKEN FROM GAISSER 76 TABLE 3.  VERY SPECULATIVE.              3/77*

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                    33  LAMBDA/C+ WIDTH FROM MASS SPECTRUM

W    C  60   75.     OR LESS          KNAPP     76 SPEC -  ANTILAM 2PI- PI+  3/77*
W    C  KNAPP 76 MEASURES WIDTH 40+-20MEV CONSISTENT WITH THEIR EXPT          3/77*
W    C  RESOLUTION (30MEV) FOR A ZERO WIDTH STATE.                            3/77*

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                    33  LAMBDA/C+ PARTIAL DECAY MODES

                                                        DECAY MASSES
P1      LAMBDA/C+ INTO LAMBDA PI+ PI+ PI-              1115+ 139+ 139+ 139
P2      LAMBDA/C+ INTO SIGMA+ PIO                      1189+ 134
P3      LAMBDA/C+ INTO SIGMA+ ETA                      1189+ 548
P4      LAMBDA/C+ INTO P PI- PIO KO E+ NEU

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N       NOTE ON VERY TENTATIVE MODES P2, P3, AND P4                           3/77*
N        THESE MODES ARE VERY TENTATIVE.  P2 AND P3 ARE FROM SUGIMOTO 75      3/77*
N        (SEE GAISSER 76 REVIEW) AND P4 IS FROM BARISH 77.  EACH IS FROM A    3/77*
N        SINGLE EVENT.  SEE DETAILS IN TYPED REVIEW ABOVE.                    3/77*

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                         REFERENCES FOR LAMBDA/C+

CAZZOLI  75 PRL 34 1125      +CNOPS,CONNOLY,LOUTTIT,MURTAGH+          (BNL)
SUGIMOTO 75 PTP 53 1540      +SATO,SAITO                        (WASEDA+TOKY)
KNAPP    76 PRL 37 882       +LEE,LEUNG,SMITH +          (COLU+HAWA+ILL+FNAL)
BARISH   77 PR D15 1         +DERRICK,DOMBECK,MUSGRAVE +           (ANL+PURD)

                         THEORY AND REVIEW

DERUJULA 75 PR D12 147       +GEORGI,GLASHOW                           (HARV)
GAISSER  76 PR D14 3153      T.K.GAISSER,F.HALZEN                (BARTOL+WISC)
LEE      77 PR D15 157       +QUIGG,ROSNER                             (FNAL)

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$\Sigma_c(2430)$

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104  SIGMA/C(2430,JP=  )
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                    104  SIGMA/C MASS

M    C   1 2426.      12.             CAZZOLI   75 HBC  ++ LAMBDA/C+ PI+      3/77*
M   KC   9(2500.)                     KNAPP     76 SPEC 0  ANTILAMBDA/C-PI+   3/77*
M    C   1(2439.)   OR MORE           BARISH    77 DBC  ++ LAMBDA/C+ PI+      3/77*
M    C  SEE NOTES IN LAMBDA/C+ MASS SECTION ABOVE.                             3/77*
M   K   KNAPP 76 MAY NOT BE THE SAME STATE AS CAZZOLI 75.  DERUJULA 75         3/77*
M   K   PREDICT TWO SIGMA/C STATES AROUND 2.4-2.5 GEV.  THIS COULD BE BOTH.    3/77*

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                    104  SIGMA/C(2430) PARTIAL DECAY MODES

                                                        DECAY MASSES
P1      SIGMA/C(2430) INTO LAMBDA/C+ PI                2260+ 139

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                         REFERENCES FOR SIGMA/C(2430)

CAZZOLI  75 PRL 34 1125      +CNOPS,CONNOLY,LOUTTIT,MURTAGH+          (BNL)
KNAPP    76 PRL 37 882       +LEE,LEUNG,SMITH +          (COLU+HAWA+ILL+FNAL)
BARISH   77 PR D15 1         +DERRICK,DOMBECK,MUSGRAVE +           (ANL+PURD)

                         THEORY AND REVIEW

DERUJULA 75 PR D12 147       +GEORGI,GLASHOW                           (HARV)
LEE      77 PR D15 157       +QUIGG,ROSNER                             (FNAL)

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CHARM SEARCHES AND EVIDENCE

Evidence for charm not directly relatable to a given state is listed in this section. Neutrino-induced dilepton events and the high-y anomaly in neutrino and antineutrino interactions are discussed. Short-lived tracks in emulsions are also dealt with, as are cross-section upper limits for charm searches. Direct lepton production in pN collisions is discussed in the Other New Particle Searches section below rather than in this section, because recent results favor other interpretations than charm.

For a more thorough treatment of some of the above topics, we refer the reader to other recent reviews of which we are aware (refs. 1-8).

Neutrino-induced Dilepton Events

The Harvard-Penn-Wisconsin-Fermilab collaboration (BENVENUTI 75) and the Caltech-Fermilab group (BARISH 76) have observed neutrino events with two muons in the final state. Most of these events have opposite-charge muons.

Bubble chamber experiments have observed neutrino-induced $\mu^- e^+$ events, many associated with strange particle production in the reaction

$$\nu N \to \mu^- e^+ K^0 (\text{or } \Lambda) + \text{anything}$$

(see DEDEN 75, BLIETSCHAU 75, VON KROGH 76, BARISH 77 in the Data Card Listings and the BARISH 77 discussion in the charmed baryon section above).

Data Card Listings

CHARM SEARCHES

Dilepton events have no conventional explanation. Production of charmed hadrons, heavy leptons, and intermediate bosons have been proposed as potential explanations. Production of charmed particles (C) in neutrino interactions would be expected to give rise to such events via the mechanism

$$\nu_\mu N \to \mu^- C + \text{hadrons}$$
$$\hookrightarrow \ell^+ \nu_\ell + \text{hadrons},$$

where the Cabibbo-favored transition would predict a strange particle among the hadrons. Thus the appearance of neutrino-induced dimuon events, $\mu^- e^+$ events, and associated strange particles can be understood via the charm mechanism.

The "High-y Anomaly"

In the naive quark-parton model one may write the double differential cross section for charged-current neutrino and antineutrino nucleon scattering as

$$\frac{d^2\sigma^\nu}{dxdy} = \frac{G^2 M E_\nu}{\pi}\left[q(x) + \bar{q}(x)(1-y)^2\right]$$

$$\frac{d^2\sigma^{\bar{\nu}}}{dxdy} = \frac{G^2 M E_{\bar{\nu}}}{\pi}\left[q(x)(1-y)^2 + \bar{q}(x)\right] .$$

Here $x = Q^2/2ME_h$ and $y = E_h/E_{\nu,\bar{\nu}}$ are scaling variables, M is the nucleon mass, E_h is the energy transferred to the final-state hadrons, $E_{\nu,\bar{\nu}}$ is the beam energy, both in the laboratory frame, $-Q^2$ is the square of the four-momentum transferred from incident neutrino to final-state μ (assuming muon neutrinos), and $G^2 M E_\nu = 1.56 \times 10^{-38}$ cm^2/GeV. In these relations, valid for isoscalar nuclei (a reasonable approximation for real targets), $\frac{1}{x}q(x)dx$ and $\frac{1}{x}\bar{q}(x)dx$ are the probabilities of quarks and antiquarks being involved in the interaction while carrying a fraction x (evaluated in the infinite-momentum frame) of the target momentum. One frequently rewrites these in terms of $B(x) = 1 - 2\bar{q}(x)/[q(x) + \bar{q}(x)]$. Integrating over x,

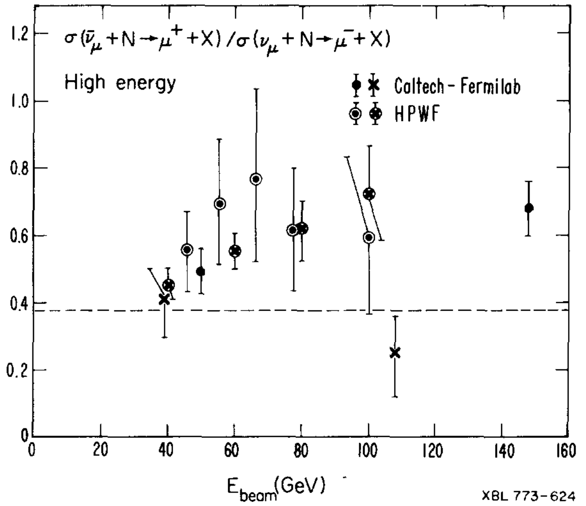
$$\frac{d\sigma^{\nu,\bar{\nu}}}{dy} \propto E_{\nu,\bar{\nu}}\left[(1 - y + \frac{y^2}{2}) \pm By(1 - \frac{y}{2})\right]$$

where B here is a weighted average of B(x) over all x. Then (1-B)/2 is interpreted as the contribution of the antiquark fraction in the nucleon to the scattering. B near 1.0 means the antiquark contribution to the nucleon is small. In this case the above equations reduce to $d\sigma^\nu/dy \propto E_\nu$ and $d\sigma^{\bar{\nu}}/dy \propto E_{\bar{\nu}}(1-y)^2$.

B may be most easily measured from $d\sigma/dy$ for antineutrino beams, which is more sensitive to B than its counterpart for incident neutrinos. At low energies, the antiquark component seems to be small, and is confined to small x, as one might expect from a quark-antiquark "sea" in the nucleon, according to the conventional three-quark model (see, for example, review papers by Roe,[6] Perkins,[7] Steinberger,[8] and Wojcicki[4]). Recent experimental data at very high energies indicate an increasingly flat antineutrino y distribution (see for example, Barish et al.[9] and Benvenuti et al.,[10] and also the review papers above). That is, B apparently is increasing, at least in $\bar{\nu}$ reactions.

Both experiments which report this effect (sometimes called the "high-y anomaly" — an anomaly may be defined as something unaccounted for by conventional three-quark models) utilize electronic detectors with acceptances which are poor in various parts of the kinematical region, and both report rather large error bars for their determinations of B (collected and illustrated by Nezrick[11] and Roe[6]). Linear fits to the world's data on B as a function of energy, over the full energy range (Nezrick,[11] Roe[6]), yield slopes that are about 2-3 standard deviations from zero. Taken by themselves, the data for $E_{\bar{\nu}} < 70$ GeV are perfectly consistent with no energy dependence for B, with a value of about 0.8 or 0.9; hence there may be a threshold for a new effect at ~70 GeV (in which case a linear fit over all energies would not be appropriate). The strongest evidence for an anomaly comes from the HPWF experiment (for example, Benvenuti[10]), which finds under certain assumptions, $B^{\bar{\nu}} = 0.94 \pm 0.09$ averaged over the 10-30 GeV incident energy range, and 0.41 ± 0.13 for $E_{\bar{\nu}} > 70$ GeV. These experimenters also report B^ν different from $B^{\bar{\nu}}$, in this energy range, at the two standard deviation level.

Note from the above formulas that $B^{\bar{\nu}}$ decreasing with energy implies a rising ratio of antineutrino-to-neutrino charged-current cross sections. The accompanying figure shows current data for $E_{\nu,\bar{\nu}} > 40$ GeV. A rising trend may be present, although there is a single low point at 110 GeV (which represents only 11 events however).



Ratio of $\bar{\nu}_\mu$ to ν_μ charged-current cross sections at incident energies above 40 GeV. For lower energies, the ratio is approximately 0.38 (dashed line). Encircled points: Harvard-Penn-Wisconsin-Fermilab collaboration [A. Benvenuti et al., Phys. Rev. Lett. 37, 189 (1976)]; non-circled points: Caltech-Fermilab collaboration [B.C. Barish et al., preprint CALT 68-560 (1976)]. Points denoted by X depend upon knowledge of the flux; solid points are a flux-independent (but model-dependent) determination.

A high-y anomaly of the magnitude reported by the HPWF group appears to be inconsistent with the conventional three-quark model. It may also be too large to be accommodated even with the addition of a fourth, charmed quark in the GIM picture. Hence, much work is being done concerning the possibility of additional (more than 4) quarks. These quarks are usually massive, to force an energy threshold, and right-handed, to force a $\bar{\nu}$ y anomaly (see, e.g., Barnett[12]). For example, Barish et al.[9] find a good fit to their data with a right-handed "b" quark of mass 5.1 GeV.

In conclusion, there is growing experimental evidence for an anomaly in the y-distribution for $\bar{\nu}$-induced events. This anomaly takes the form of a flattening of the $d\sigma/dy$ distribution relative to that expected from three-quark models with a $q-\bar{q}$ "sea", and occurs only at high energies. The relationship between this effect and the observation of prompt dileptons in ν and $\bar{\nu}$ production is unclear, but the high-y effect may have a higher energy threshold.

Short-lived tracks in emulsions

The mean life of a weakly decaying charmed meson or baryon of mass M (in GeV) is expected to be in the range[13]

$$\tau = (10^{-11} \text{ to } 10^{-13} \text{ sec}) \times \frac{1}{M^5}$$

with a corresponding mean path length for lab momentum p (in GeV/c) of

$$\ell = \frac{pc\tau}{M} = (1\mu \text{ to } 100\mu) \times p$$

Thus even at Fermilab energies, these would be hard to see as tracks in bubble chambers.

A number of cosmic ray experiments (e.g., NIU 71, TASAKA 73, and SUGIMOTO 75) have seen short-lived charged tracks which decay into a charged track and a π^0 or η. Charged-particle identification problems preclude unique determinations of masses and lifetimes. Table III of Gaisser and Halzen's review[5] of these events gives values in the range 1.5 GeV < M < 3.0 GeV and 2×10^{-14} sec < τ < 3×10^{-12} sec for the three strongest charm candidates (they involve possible pair production). Of these, one event (SUGIMOTO 75) is consistent with production of a $\Lambda_c^+\bar{\Lambda}_c^-$ pair with subsequent decays to $\Sigma^+\eta$ and $\bar{\Sigma}^-\pi^0$. None are consistent with $D^\pm$ production. Accelerator events with lifetimes $\sim10^{-13}$ sec (KOMAR 75) and 6×10^{-13} sec (BURHOP 76) have also been reported.

Charm Searches

We list cross-section upper limits for the many unsuccessful charm searches. In cases where limits are given for many channels and mass ranges, we list only a range or a few likely channels and indicate in the comment cards the extent and location of the tables of data included in the paper.

Data Card Listings

CHARM SEARCHES

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CE      CHARMED HADRON PRODUCTION CROSS SECTION(E+ E-) (UNITS 10**-35 CM**2)
CE      THESE VALUES ARE (CROSS SECTION)X(BR. RATIO TO MODE INDICATED)
CE   B   0    18.    OR LESS  CL=.90   BOYARSKI   75 SMAG K- PI+, K+ PI-        2/76
CE   B   0    40.    OR LESS  CL=.90   BOYARSKI   75 SMAG KOS PI+ PI-           2/76
CE   B   0    13.    OR LESS  CL=.90   BOYARSKI   75 SMAG PI+ PI-               2/76
CE   B   0    12.    OR LESS  CL=.90   BOYARSKI   75 SMAG K+ K-                 2/76
CE   B   0    49.    OR LESS  CL=.90   BOYARSKI   75 SMAG K-PI+PI+, K+PI-PI-    2/76
CE   B   0    27.    OR LESS  CL=.90   BOYARSKI   75 SMAG KOS PI+, KOS PI-      2/76
CE   B   0    33.    OR LESS  CL=.90   BOYARSKI   75 SMAG KOS K+, KOS K-        2/76
CE   B   0    38.    OR LESS  CL=.90   BOYARSKI   75 SMAG PI+PI-PI+,PI+PI-PI-   2/76
CE   B   0    90.    OR LESS  CL=.90   BOYARSKI   75 SMAG K+PI-,KOPI+PI- + CC   2/76
CE   B   0    16.    OR LESS  CL=.90   BOYARSKI   75 SMAG K+ K-, PI+ PI-        2/76
CE   B   0    51.    OR LESS  CL=.90   BOYARSKI   75 SMAG K+PI-PI-,KOPI+ + CC   2/76
CE   B   0    76.    OR LESS  CL=.90   BOYARSKI   75 SMAG KOK+,PI+PI+PI- + CC   2/76
CE  P   64   (1.9)    (0.5)            PERL       75 SMAG    E(OR MU) NEUTRI.   2/76
CE   R  28    50.    OR MORE           BRAUNSCHW  76 DASP    E+- +HADRONS       3/77*
CE   U       300.     300.             BURMESTER  76 PLUT    KO E+- +ANYTHING   3/77*
CE   G 110    20.       5.0            GOLDHABER  76 SMAG    K-+PI+-            1/77*
CE   G 124    67.      11.0            GOLDHABER  76 SMAG    K-+PI+-PI+PI-      1/77*
CE   E  50    30.      15.             PERUZZI    76 SMAG    K-+PI+-PI+-        1/77*
CE   F 246    25.      10.             FELDMAN    77 SMAG    MUON .GE.3PRONG    3/77*
CE   B  BOYARSKI 75 IS SLAC(SPEAR) EXPT.  LOOKED FOR E+E- --> D ANYTHING        2/76
CE   B  AT ECM=4.8 GEV WHERE CHARMED MESON D DECAYED VIA CHANNELS SHOWN.        2/76
CE   B  ABOVE VALUES ARE FOR D MASS=1.85-2.40 GEV.  SIMILAR LIMITS ARE          2/76
CE   B  GIVEN FOR MASS=1.50-1.85, 2.40-4.00 GEV IN THEIR TABLE 1.               2/76
CE  P   PERL 75 IS SLAC(SPEAR) EXPT .  EVENTS ARE E+E- TO E+-MU-+ AND 2 OR      2/76
CE  P   MORE MISSING PARTICLES.  CS IS FOR ECM=4.8 GEV AND THETA=50-130DEG.    2/76
CE  P   CROSS SECTION RISES FROM 5X10**-36 AT E=4 TO ABOVE MAX. THEN DROPS     2/76
CE  P   TO 6E-36  AT E=7.5.   AUTHORS SAY THESE EVENTS HAVE NO CONVENTIONAL    2/76
CE  P   EXPLANATION.  SUGGEST HEAVY LEPTON OR CHARMED HADRON, M=1.6-2.0GEV.    2/76
CE  P   NOT CORRECTED FOR DETECTOR ACCEPTANCE.
CE   R  BRAUNSCHWEIG 76 SEES SINGLE ELECTRONS IN E+E- COLLISIONS AT DORIS.     3/77*
CE   R  ESTIMATED 2*CS*BR TO(E + HADRONS) IS 1 NB. MASS BETW 1.8 AND 2.1GEV    3/77*
CE   R  INFERRED FROM PROD THRESHOLD BEING BETW 3.7 AND 4.0 GEV.  E+-          3/77*
CE   R  MOMENTUM SPECTRUM AND OBSERVED MULTIPLICITY ARE INCONSISTENT WITH      3/77*
CE   R  HEAVY LEPTON HYPOTHESIS.                                                3/77*
CE   U  BURMESTER 76 IS A DORIS E+E- EXPT. THEY SEE KOS+PROMPT ELECTRONS AT    3/77*
CE   U  ECM=4.0-4.1 GEV. SUGGESTS PAIR PROD OF CHARMED PARTICLE OF MASS        3/77*
CE   U  1.8 TO 2.0 GEV.                                                         3/77*
CE   G  GOLDHABER 76 IS A SPEAR E+E- EXPT WITH ECM=3.9 TO 4.6 GEV. THEY SEE    1/77*
CE   G  PEAK AT 1865+-15 MEV, WIDTH LT 40 MEV. PROBABLY NEUTRAL STATE OF       1/77*
CE   G  SAME PARTICLE SEEN IN PERUZZI 76.  A PEAK IS ALSO OBSERVED IN THE      1/77*
CE   G  MASS SPECTRUM RECOILING AGAINST THESE STATES WITH MASS 1.96-2.2GEV.    1/77*
CE   E  PERUZZI 76 IS SPEAR E+E- EXPT AT 4.03 GEV. THEY SEE EXOTIC PEAK AT     1/77*
CE   E  M=1876+-15, WIDTH LT 40 MEV. NO STRUCTURE SEEN IN KPI+PI- CHANNEL.     1/77*
CE   F  FELDMAN 77 IS A CONTINUATION OF PERL 75.  ABOVE DATA IS FOR            3/77*
CE   F  ECM=5.8-7.8 GEV.  HEAVY LEPTONS COULD ACCOUNT FOR ONLY 20 PERCENT      3/77*
CE   F  OF THIS CS.  THEY SUGGEST EXCESS IS FROM WK. DECAYS OF NEW HADRONS.    3/77*

CG      CHARMED HADRON PRODUCTION CROSS SEC (GAMMA NUCLEON)  (CM**2)
CG   K  60 EVENTS                      KNAPP      76 SPEC LAMBDABAR PI-PI-PI+  2/77*
CG   Q   0  1.1E-29 OR LESS  CL=.95    QUINN      76 HBC      B++ M-           2/77*
CG   Q   0  1.2E-29 OR LESS  CL=.95    QUINN      76 HBC      B+ MO            2/77*
CG   K  KNAPP 76 SEES A PEAK AT M=2.26+-0.01 GEV/C**2. WIDTH IS 40+-20 MEV,    2/77*
CG   K  CONSISTENT WITH ZERO WIDTH STATE (RESOLUTION=30 MEV). NO PEAK SEEN     2/77*
CG   K  IN LAMBDABAR PI+ PI+ PI-. THEY ALSO SEE A LAMBDABAR (4PI)0 PEAK AT     2/77*
CG   K  2.5 GEV CASCADING DOWN TO THE PEAK AT 2.26. EXPT USED WIDE-BAND        2/77*
CG   K  PHOTON BEAM AT FNAL.                                                    2/77*
CG   Q  QUINN 76 USED A 9.3 GEV PHOTON BEAM AT SLAC. SEE TABLES 1 AND 3 FOR    2/77*
CG   Q  INDIVIDUAL CHANNELS. ABOVE LIMITS ARE FOR ALL CHANNELS WITH ONE OR     2/77*
CG   Q  NO MISSING NEUTRALS.                                                    2/77*

CPI     CHARMED HADRON PRODUCTION CROSS SECTION (PI NUCLEON)   (CM**2)
CPI  B   0 1.5 TO 3.7 E-30 OR LESS     BALTAY     75 HBC      15 GEV PI+P      7/76*
CPI  B   0 0.2 TO 35  E-30 OR LESS     BALTAY     75 HBC      15 GEV PI+P      7/76*
CPI  U   0 0.5 TO 15 E-30 OR LESS      BUNNELL    76 STRC     CL=.97           1/77*
CPI  C   0  1. TO 8. E-31  OR LESS     CESTER     76 SPEC     15 GEV/C PI-     2/77*
CPI  K   0  4.8E-32 OR LESS            COOK       76 STRC     225 GEV/C PI-    3/77*
CPI  G   0  4. TO 8. E-32  OR LESS     GHIDINI    76 SPEC     19 GEV/C PI P    2/77*
CPI  H   0  4. E-30 OR LESS  CL=.95    HAGOPIAN   76 DBC   SHORT LIVED 2-5GEV  2/76
CPI  H   1  7. E-31 OR LESS  CL=.95    HAGOPIAN   76 DBC  LONG LIVED 1.9-2GEV  2/76
CPI  H   0  3. E-31 OR LESS  CL=.95    HAGOPIAN   76 DBC  LONG LIVED1-1.9,2-5  2/76
CPI  A   0  3.8E-31 OR LESS  CL=.95    BLANAR     77 SPEC     200 GEV/C PI+    4/77*
CPI  B  BALTAY 75 SENSITIVE TO CHARMED PARTICLES WITH M=1.5 TO 4.0 GEV AND     7/76*
CPI  B  TAU LT 10**-11 WHICH THEN DECAY INTO STRANGE PARTICLES.                7/76*
CPI  B  THE FIRST VALUE ABOVE IS FOR ASSOC PROD OF CHARMED PARTICLES.          7/76*
CPI  B  SEE HIS TABLE 1 FOR SPECIFIC DECAY MODES.  THE SECOND RANGE OF         7/76*
CPI  B  VALUES IS FOR INCLUSIVE PROD OF CHARMED MESONS AND BARYONS WITH        7/76*
CPI  B  CHARGES -2 TO +2. SEE HIS TABLE 2 FOR SPECIFIC DECAY MODES.            7/76*
CPI  U  BUNNELL 76 IS A SLAC 15.5 PI+P EXPT. ALL POSSIBLE 2 TO 5-BODY MASS     1/77*
CPI  U  COMBINATIONS WERE STUDIED FOR NARROW RESONANCES PRODUCED IN COINC      1/77*
CPI  U  WITH SINGLE MUONS. MASS RANGE STUDIED WAS UP TO 3.1 GEV. SEE TABLE     1/77*
CPI  U  1 ON PG 87 FOR DETAILED RESULTS OF INDIVIDUAL CHANNELS.                1/77*
CPI  C  CESTER 76 LOOKS AT MASS RANGE 1.8 TO 2.5 GEV. SEE TABLE 1 FOR          2/77*
CPI  C  INDIVIDUAL CHANNELS. VALUES GIVEN ARE CROSS-SEC/NUCLEON ON CARBON.     2/77*
CPI  K  COOK 76 USES 225 GEV PI- BEAM. LOOKS FOR CORRELATION BETW VOS AND      3/77*
CPI  K  PROMPT MUONS TO SIGNAL DECAY OF CHARMED PARTICLE. LIMIT FOR M=2GEV.   3/77*
CPI  G  GHIDINI 76 LOOKED FOR CHARMED MESONS OF MASS GT 1.5 GEV AND BARYONS    2/77*
CPI  G  OF MASS GT 2.0 GEV. LIMITS ARE CL=.95. LIMITS FOR MOST CHANNELS LIE    2/77*
CPI  G  IN THE ABOVE RANGE.  SEE TABLE 2 FOR INDIVIDUAL CHANNELS.              2/77*
CPI  H  HAGOPIAN 76 IS A SLAC 15GEV PI+ D EXPT.  ALL POSSIBLE TWO AND THREE    2/76
CPI  H  BODY MASS COMBINATIONS WERE STUDIED FOR NARROW RESONANCES WITH MASS    2/76
CPI  H  1.5-5GEV FOR MESONS AND 2-5GEV FOR BARYONS.  INDIVIDUAL LIMITS FOR     2/76
CPI  H  TWO AND THREE BODY DECAY FROM MANY REACTIONS ARE GIVEN.                2/76
CPI  H  VEES WERE STUDIED FOR THE POSSIBILITY OF A NEW LONG LIVED (MEAN        2/76
CPI  H  LIFE 1E-11 SEC. OR MORE) NEUTRAL PARTICLE.  ONE CANDIDATE WITH MASS    2/76
CPI  H  1.9-2 GEV WAS FOUND.  SECOND LONG LIVED LIMIT FOR M=1-1.9, 2-5 GEV.    2/76
CPI  A  BLANAR 77 IS FNAL EXPT.  LIMIT IS FOR CS*BR TO MUONS.  ASSUMES         4/77*
CPI  A  DIFFRACTIVE CHARMED 2GEV MESON PAIR PRODUCTION.  OTHER LIMITS FOR      4/77*
CPI  A  PI AND P BEAMS GIVEN IN TABLE 1.                                        4/77*

CP      CHARMED HADRON PRODUCTION CROSS SECTION (P NUCLEON)   (CM**2)
CP   A   0  1. E-33 OR LESS            AUBERT     75 SPEC    PI+ K-            2/76
CP   A   0  4. E-33 OR LESS            AUBERT     75 SPEC    K+ PI-            2/76
CP   A   0  1. E-33 OR LESS            AUBERT     75 SPEC    K+ K-             2/76
CP   A   0  8. E-33 OR LESS            AUBERT     75 SPEC    PI+ PI-           2/76
CP   A   0  7. E-33 OR LESS            AUBERT     75 SPEC    P K-              2/76
CP   A   0  2. E-33 OR LESS            AUBERT     75 SPEC    K+ PBAR           2/76
CP   A   0  4. E-32 OR LESS            AUBERT     75 SPEC    P PI-             2/76
CP   A   0  2. E-33 OR LESS            AUBERT     75 SPEC    PI+ PBAR          2/76
CP   H   0  5. TO 20. E-30    OR LESS  AAHLIN     76 HBC     BARYON,M LT 2GEV  2/77*
CP   H   0 15. TO 100.E-30    OR LESS  AAHLIN     76 HBC     BARYON,M 2-3 GEV  2/77*
CP   H   0 10. TO 35. E-30    OR LESS  AAHLIN     76 HBC     MESON, M 1-2 GEV  2/77*
CP   G 0-2 SEE COMMENT G BELOW         BINKLEY    76 SPEC                      1/77*
CP   B   0  2. E-30 OR LESS            BINTINGER  76 SPEC    M=2 GEV/C**2      1/77*
CP   B   0  5. E-32 OR LESS            BINTINGER  76 SPEC    M=4 GEV/C**2      1/77*
CP   A  AUBERT 75 IS A BNL 30 GEV EXPT.  LOOKS FOR P BE --> JPRIME ANYTHING    2/76
CP   A  WHERE JPRIME DECAYED VIA THE CHANNEL SHOWN.  ABOVE VALUES ARE          2/76
CP   A  FOR M=2.25GEV AND ASSUME A WIDTH SMALL COMPARED TO THE RESOLUTION.     2/76
CP   A  UPPER LIMITS ARE ALSO GIVEN FOR THE ABOVE CHANNELS AND P PBAR FOR      2/76
CP   A  M=3.1 AND 3.7 GEV.  THOSE LIMITS RANGE FROM 7E-36 TO 4E-33.            2/76
CP   A  MA 77 SAYS AUBERT 75 LIMITS SHOULD BE AN ORDER OF MAG. LARGER.         2/77*
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CHARM SEARCHES, CHARMONIUM STATES

Data Card Listings

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CP   H  AAHLIN 76 IS A 19 GEV/C P-P EXPT AT CERN. VALUES GIVEN ARE CL=.975.  2/77*
CP   H  SEE TABLE 28, PG 479 FOR INDIVIDUAL LAMBDA (OR KS) +PIONS CHANNELS.  2/77*
CP   G  BINKLEY 76 MEASURES BR(C TO MU + OTHERS)*R WHERE R IS THE RATIO OF    1/77*
CP   G  THE CROSS-SEC FOR PRODUCING THE J/PSI TOGETHER WITH A C-CBAR PAIR     1/77*
CP   G  TO THE TOTAL CROSS-SEC FOR PRODUCING THE J/PSI AT THIS ENERGY. THE    1/77*
CP   G  EXPT WAS A 300 GEV/C FNAL RUN, AND SAW 2 TRI-MUON EVENTS. THIS GAVE   1/77*
CP   G  A .90 CL UPPER LIMIT OF .003 FOR THE MEASURED QUANTITY DESCRIBED      1/77*
CP   G  ABOVE.                                                                1/77*
CP   B  BINTINGER 76 IS CROSS-SEC TIMES BR INTO K- PI+.  WE SHOW TWO VALUES   1/77*
CP   B  FROM THEIR FIG.4 WHICH COVERS MASS RANGE 1.7-4 GEV.  SIMILAR LIMITS   1/77*
CP   B  ARE GIVEN FOR K+ PI- AND PI+ PI- CHANNELS.  LIMITS ARE PROPORTIONAL   1/77*
CP   B  TO CS*BR FOR J/PSI INTO MU+ MU-, TAKEN=10NB FOR ABOVE VALUES.         1/77*

CN      CHARMED HADRON PRODUCTION CROSS SECTION (N NUCLEON)  (CM**2)
CN   B   0  1.9E-31 OR LESS             BLESER    75 SPEC K+PI-, M=1.8 GEV    2/77*
CN   B   0  1.0E-31 OR LESS             BLESER    75 SPEC K+PI-, M=2.5 GEV    2/77*
CN   B   0  1.0E-31 OR LESS             BLESER    75 SPEC K- P , M=2.5 GEV    2/77*
CN   W   0  2.5E-29 OR LESS  CL=.975    WARD      75 HBC     KS PI+ PI-       1/77*
CN   A   0  6. E-32 OR LESS             ABOLINS   76 SPEC    PI+ PI-          1/77*
CN   A   0  7. E-32 OR LESS             ABOLINS   76 SPEC    PBAR P           1/77*
CN   A   0  4. E-32 OR LESS             ABOLINS   76 SPEC    K- PI+           1/77*
CN   A   0  6. E-32 OR LESS             ABOLINS   76 SPEC    K- P             1/77*
CN   B  BLESER 75 USES NEUTRONS UP TO 300 GEV/C, BE TARGET. EXAMINES MASS     2/77*
CN   B  RANGE UP TO 3.5 FOR KPI, UP TO 4.0 FOR KP. VALUES ARE CROSS-SEC/NUC   2/77*
CN   W  WARD 75 IS N-P EXPT WITH MOM UP TO 24 GEV/C. THIS VALUE IS FOR MASS   1/77*
CN   W  RANGE 1.5-2.5 GEV.  SEE TABLE 1 PG 31 FOR UPPER LIMITS ON C++,C+,     1/77*
CN   W  CO,D+,DO,D- DECAYS INTO VARIOUS FINALSTATES IN MASS RANGE 1.5-5GEV.   1/77*
CN   W  UPPER LIMIT FOR SEEING DECAY OF CHGD CHARMED PARTICLE INTO VO FOR     1/77*
CN   W  TAU GT 10**-11 SEC GIVEN AS 1.5*EXP(T) FOR VO =LAMBDA OR SIGMA, AND   1/77*
CN   W  3.0*EXP(T) FOR VO=KO. HERE, T=10*-11/TAU, CS GIVEN IN MICROBARNS.     1/77*
CN   A  ABOLINS 76 IS FNAL 240 GEV/C NEUTRON-BE EXPT. TYPICAL VALUES ABOVE    1/77*
CN   A  ARE FOR M=3.0 GEV. SEE FIG 4 FOR MASS RANGE 2.0-4.0 GEV. OBSERVES     1/77*
CN   A  POSSIBLE K- PI+ ENHANCEMENT AT 2.29+-.03 GEV                          1/77*

CAP     CHARMED HADRON PRODUCTION CROSS SECTION (PBAR NUCLEON)  (CM**2)
CAP  C   0  5. E-29 OR LESS  CL=.95   CARLSSON  75 HBC      PBAR P ANYTHING   2/77*
CAP  C   0  3. E-29 OR LESS  CL=.95   CARLSSON  75 HBC      PBAR P PI+ PI-    2/77*
CAP  E   0  .8 TO 4.4 E-30   OR LESS  CESTER    76 SPEC     12.4 TO 15 GEV/C  2/77*
CAP  C  CARLSSON 75 IS A 9GEV PBAR P CERN EXPT.  LIMITS ARE FOR P PBAR PEAK   2/77*
CAP  C  IN CHANNELS INDICATED. K KBAR CHANNELS CHECKED BUT NO LIMITS GIVEN.   2/77*
CAP  E  CESTER 76 LOOKS AT MASS RANGE 1.8 TO 2.5 GEV. SEE TABLE 1 FOR         2/77*
CAP  E  INDIVIDUAL CHANNELS. VALUES GIVEN ARE CROSS-SEC/NUCLEON ON CARBON.    2/77*

Y       CHARMED HADRON EVIDENCE IN NEUTRINO NUCLEON --> 2 LEPTONS ANYTHING
Y    B  14MU+MU-  OMU-MU-  OMU+MU+    BENVENU1  75 SPEC     PREDOM. NEU BEAM  2/76
Y    B  51MU+MU-  7MU-MU-  3MU+MU+    BENVENU3  75 SPEC     6/7 NEU BEAM      2/76
Y    B   5MU+MU-  OMU-MU-  2MU+MU+    BENVENU5  75 SPEC     9/10ANTINEU BEAM  2/76
Y        4MU+MU-  4 OTHER MU PAIRS    BARISH    76 SPEC     NEU BEAM          7/76*
Y    A   1 EVENT  MU-E+               BARISH    77 DBC      NEU BEAM          3/77*
Y    B  BENVENUTI 75 ARE FNAL NEUTRINO NUCLEON EXPERIMENTS WHICH LOOKED FOR   2/76
Y    B  TWO OR MORE MUONS IN THE FINAL STATE.  NO TRIMUON EVENTS WERE SEEN.   2/76
Y    B  AUTHORS STATE THAT THESE DIMUON EVENTS REQUIRE THE EXISTENCE OF ONE   2/76
Y    B  OR MORE NEW PARTICLES WITH M=2-4GEV AND TAU=10**-10SEC. OR LESS.      2/76
Y    B  BENVENUTI4 75 SHOW THAT THE OBSERVED PROPERTIES OF THESE EVENTS       2/76
Y    B  DO NOT AGREE WITH HYPOTHESES OF HEAVY LEPTON OR INTERMEDIATE VECTOR   2/76
Y    B  BOSON.  THEY SUGGEST A HADRON (Y) WITH A NEW QUANTUM NUMBER.          2/76
Y    A  BARISH 77 EVENT COULD BE NEU P TO MU+ B++. SEE CHARMED BARYON NOTE    3/77*
Y    A  AND LAMBDA/C+ SECTION ABOVE.                                          3/77*

VO      CHARMED HADRON EVIDENCE IN NEUTRINO NUCLEON --> MU- E+ VO ANYTHING
VO       WHERE THE VO IS A KOS OR A LAMBDA
VO   B   1 EVENT                      DEDEN     75 HLBC                       2/76
VO   B   1 EVENT                      BLIETSCHA 76 HLBC                       2/76
VO   V   4 EVENTS                     VONKROGH  76 HLBC                       2/76
VO   E   0 EVENTS                     BERGE     77 HLBC    ANTINEU BEAM       3/77*
VO   B  THE DEDEN 75 AND BLIETSCHAU 76 EVENTS ARE FROM CERN                   2/76
VO   B  GARGAMELLE NEUTRINO EXPOSURES.  THE MASSES OF THE E+ VO SYSTEM FOR    2/76
VO   B  THE TWO EVENTS ARE 1.24, 1.91 GEV FOR LAMBDA OR 0.65, 1.57 FOR KO.    2/76
VO   V  THE VON KROGH 76 EVENTS ARE FROM AN FNAL 15 FT NEON BUBBLE CHAMBER    2/76
VO   V  EXPOSURE.  ALL FOUR E+ EVENTS FOUND HAVE ASSOCIATED KOS.              2/76
VO   E  BERGE 77 USED FNAL 15 FT CHAMBER FILLED WITH H-NEON. SAW TWO          3/77*
VO   E  POSSIBLE BUT UNLIKELY MU E EVENTS, NEITHER WITH ASSOCIATED VO.        3/77*

R1      CHARMED HADRON (Y) BRANCHING RATIO INTO (MU NEU ANYTHING)/HADRONS
R1   B   8    A FEW PERCENT           BENVENU2  75 SPEC    FNAL NEUTRINO NU   2/76
R1   B  BENVENUTI2 75 LOOKS AT ANTINEUTRINO NUCLEON --> MUON HADRONS.  SEES   2/76
R1   B  EXCESS EVENTS ABOVE INCIDENT ENERGY 30 GEV.  COMPARES BENVENUTI1 75   2/76
R1   B  DIMUON EVENTS WITH EXCESS EVENTS TO GET BRANCHING RATIO.              2/76

R2      CHARMED HADRON (ASSOC. VO) BRANCHING RATIO INTO SEMILEPTONICS/ALL
R2   B   2    0.1    OR MORE          BLIETSCHA 76 HLBC    M=2.5-4 GEV        2/76
R2   B  THIS BR.RATIO AND MASS ARE REQD. BY OBSERVED RATE AND CHARM SCHEME.   2/76

CC      CHARMED HADRON EVIDENCE IN COSMIC RAYS
CC   N   1 EVENT                      NIU       71 EMUL                       9/76*
CC   N  NIU 71 DETECTS CHGD PARTICLE DECAYING INTO HADRON+PIO. MASS=1.78GEV   9/76*
CC   N  AND TAU=2.2 E-14 IF SECONDARY IS PION. MASS=2.95 GEV AND TAU=3.6      9/76*
CC   N  E-14 IF IT IS PROTON. POSSIBLE EVIDENCE OF PAIR PRODUCTION.           9/76*
CC   T   8 EVENTS                     TASAKA    73 EMUL                       9/76*
CC   T  SAME TYPE AS NIU EVENT. TAU BETW 1.5 AND 175 E-13.                    9/76*
CC   S   1 EVENT                      SUGIMOTO  75 EMUL                       1/77*
CC   S  SAME TYPE AS NIU EVENT. TWO SUCH PARTICLES PRODUCED TOGETHER.         1/77*
CC   S  TAU1=6.E-13, DECAYS TO CHARGED PRONG + ETA. TAU2=4.E-12, DECAYS TO    1/77*
CC   S  CHARGED PRONG + PIO. MASSES OF BOTH PARTICLES ARE ABOUT 2.0 GEV IF    1/77*
CC   S  DECAY PRONG IS PROTON, 1.7 IF DECAY PRONG IS KAON, AND 1.55 IF        1/77*
CC   S  DECAY PRONG IS PI. COMBINED MASS OT THE TWO NEW PARTICLES = 4.1 GEV   1/77*
CC   S  OR 3.8 GEV ASSUMING THE DECAY PRONGS TO BE KAONS OR PIONS             1/77*
CC   S  RESPECTIVELY. CONSISTENT WITH LAMBDA/C+ LAMBDABAR/C-.SEE GAISSER 76   1/77*

EM      CHARMED HADRON CROSS SEC. IN MISC. EMUL. EXPTS, WHERE LIFETIME SEEN   3/77*
EM   J   1 EVENT                      JAIN      75 EMUL TAU APROX. 10E-13     2/77*
EM   K   2 EVENTS                     KOMAR     75 EMUL   TAU .LT. E-15       4/77*
EM   B   1 EVENT                      BURHOP    76 EMUL   TAU APPROX E-13     3/77*
EM   C   0  1.5E-30 OR LESS  CL=.90   COREMANS  76 EMUL   TAU E-12 TO E-14    3/77*
EM   J  JAIN 75 IS A FNAL 300 GEV PROTON EXPT. EVENT SHOWS DECAY OF NEUTRAL   2/77*
EM   J  INTO HADRON-E-NEU, TAKING PLACE .019 CM FROM THE PROD VERTEX. MAY     2/77*
EM   J  BE LEPTONIC DECAY OF CHARMED PARTICLE.                                2/77*
EM   K  KOMAR 75 IS FNAL 200 GEV/C PROTON EXPT.  SEE 2 EVENTS WITH SINGLE     4/77*
EM   K  ELECTRON EMITTED FROM NEAR INTERACTION.                               4/77*
EM   B  BURHOP 76 EXPT DONE AT FERMILAB HIGH ENERGY NEUTRINO BEAM. USED A     3/77*
EM   B  COMBINATION OF EMULSION AND SPARK CHAMBERS. THEY SEE A PARTICLE       3/77*
EM   B  WITH TAU=ABOUT 6 E-13 SEC DECAYING TO VO + 3 CHGD TRACKS. DECAYING    3/77*
EM   B  PARTICLE NOT CONSISTENT WITH CHARMED D OR LAMBDA/C+.                  3/77*
EM   C  COREMANS 76 USED 300 GEV/C PROTONS, AND LOOKED FOR ABOVE LIFETIMES.   3/77*

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REFERENCES FOR CHARMED HADRON SEARCHES


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NIU       71 PTP 46 1644     +MIKUMO,MAEDA                      (TOKY+YOKOHAMA)
TASAKA    73 PTP 50 1879     +YAMAMOTO                                  (KONAN)

AUBERT    75 PRL 35 416      +BECKER,BIGGS,BURGER,CHEN+            (MIT+BNL)
    ALSO  77 PRL 38 172      Z. MING MA, B. Y. OH                      (MSU)
BALTAY    75 PRL 34 1118     +CAUTIS,COHEN,CSORNA,KALELKAR + (COLU+BING)
BENVENU1  75 PRL 34 419      BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
BENVENU2  75 PRL 34 597      BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
    ALSO  74 PRL 33 984      AUBERT,BENVENUTI+     (HARV,PENN,WISC,FNAL)
BENVENU3  75 PRL 35 1199     BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
BENVENU4  75 PRL 35 1203     BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
BENVENU5  75 PRL 35 1249     BENVENUTI,CLINE,FORD+ (HARV,PENN,WISC,FNAL)
BLESER    75 PRL 35 76       +GOBBI,KENAH,KEREN+   (FNAL+NWES+ROCH+SLAC)
BOYARSKI  75 PRL 35 196      +BREIDENBACH,BULOS,DAKIN,FELDMAN+(SLAC+LBL)
CARLSSON  75 NP B99 451      +EKSPONG,HOLMGREN,NILSSON+         (STOH+LIVP)
DEDEN     75 PL 58B 361            (AACH+BRUX+CERN+EPOL+MILA+ORSA+LOUC)
JAIN      75 PRL 34 1238     P. L. JAIN, B. GIRARD                    (BUFF)
KOMAR     75 JETPL 21 239    +ORLOVA,TRETYAKOVA,CHERNYAYSKII          (LEBD)
PERL      75 PRL 35 1489     +ABRAMS,BOYARSKI,BREIDENBACH +           (SLAC)
SUGIMOTO  75 PTP 53 1540     +SATO,SAITO                        (WASEDA+TOKY)
WARD      75 NP B101 29      +ANSORGE,CARTER,MOUNT,NEALE+             (CAVE)

AAHLIN    76 NP B107 476     +ALPGARD,ANDERSEN,BERGVATN+(OSLO+STOH+HELS)
ABOLINS   76 PRL 37 417      +CARDIMONA,MATTHEWS,SIDWELL+ (MSU+OSU+CARL)
BARISH    76 PRL 36 939      +BARTLETT,BODEK,BROWN,BUCHHOLZ + (CIT+FNAL)
BINKLEY   76 PRL 37 578      +GAINES,PEOPLES,KNAPP+ (FNAL+COLU+HAWA+ILL)
BINTINGE  76 PRL 37 732      BINTINGER,LUNDY,AKERLOF+    (FNAL+MICH+PURD)
BLIETSCH  76 PL 60B 207            (AACH+BRUX+CERN+EPOL+MILA+ORSA+LOUC)
BRAUNSCH  76 PL 63B 471      BRAUNSCHWEIG +    (AACH+DESY+HAMB+MPIM+TOKY)
BUNNELL   76 PRL 37 85       +CHENG,DELPAPA,DORFAN,DOUNGVAN+ (UCSC+SLAC)
BURMESTE  76 PL 64B 369      BURMESTER,CRIEGEE+     (DESY+HAMB+SIEG+WUPG)
BURHOP    76 PL 65B 299      (LOUC+FNAL+BELG+DUUC+CERN+LOIC+ROMA+STRB+)
CESTER    76 PRL 37 1178     +FITCH,KADEL,WEBB,WHITTAKER +      (PRIN+BNL)
COOK      76 PL 64B 221      +CSORNA,HOLMGREN,JONCKHEERE+(WASH+LALO+UCO)
COREMANS  76 PL 65B 480      +SACTON+     (BELG+DUUC+LOUC+ROMA+STRB+WARS)
GHIDINI   76 NP B111 189     +NAVACH,DOWELL,KENYON+       (OMEGA GROUPS)
GOLDHABE  76 PRL 37 255      GOLDHABER,PIERRE,ABRAMS,ALAM+     (LBL+SLAC)
HAGOPIAN  76 PRL 36 296      +WILKINS,WIND,HAGOPIAN,ALBRIGHT+ (FSU+BRAN)
KNAPP     76 PRL 37 882      +LEE,LEUNG,SMITH +       (COLU+HAWA+ILL+FNAL)
PERUZZI   76 PRL 37 569      +PICCOLO,FELDMAN,NGUYEN,WISS +    (SLAC+LBL)
QUINN     76 PR D14 2857     D. J. QUINN, R. H. MILBURN              (TUFTS)
VONKROGH  76 PRL 36 710      +FRY,CAMERINI,CLINE+    (WISC+LBL+CERN+HAWA)

BARISH    77 PR D15 1        +DERRICK,DOMBECK,MUSGRAVE +       (ANL+PURD)
BERGE     77 PRL 38 266      +DIBIANCA,EMANS +       (FNAL+SERP+ITEP+MICH)
BLANAR    77 PRL 38 192      +BOYER,FAISSLER,GARELICK,GETTNER +     (NEAS)
FELDMAN   77 PRL 38 117      +BULOS,LUKE,ABRAMS,ALAM,BOYARSKI+(SLAC+LBL)
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REVIEWS REFERRED TO IN DATA CARDS


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GAISSER   76 PR D14 3153     T.K.GAISSER,F.HALZEN              (BARTOL+WISC)
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CHARMONIUM STATES

We group into this section those meson states commonly believed to consist of charmed-quark-charmed-antiquark pairs. Since the discovery of the $J/\psi(3100)$ (AUBERT 74, AUGUSTIN 74[1]) this family has increased to at least 9, of which we tabulate 6 as well-established particles. The current situation is summarized in the accompanying level diagram.

In the 4-4.5 GeV region there is resonance-like structure in at least two places in the ratio R of the total hadronic cross section to the μ-pair production cross section (see accompanying figure). According to FELDMAN 76[1], "[The 4 GeV] region is quite complicated and is not well understood. There are probably several resonances and many thresholds for charmed meson production conspiring to create the complex structure seen in [the figure]. There appears to be an isolated resonance at 4414 MeV/c^2."

Data Card Listings

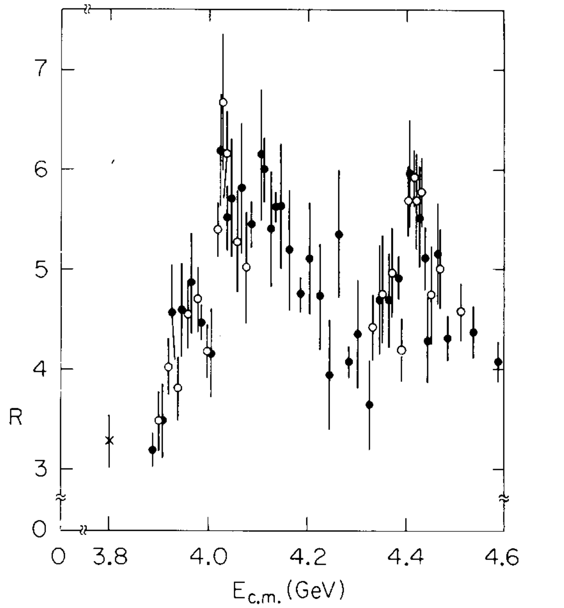
CHARMONIUM STATES

Excellent reviews on charmonium are given by, for example, FELDMAN 76, WIIK 76, WIIK 77[1], which may be consulted for further details.

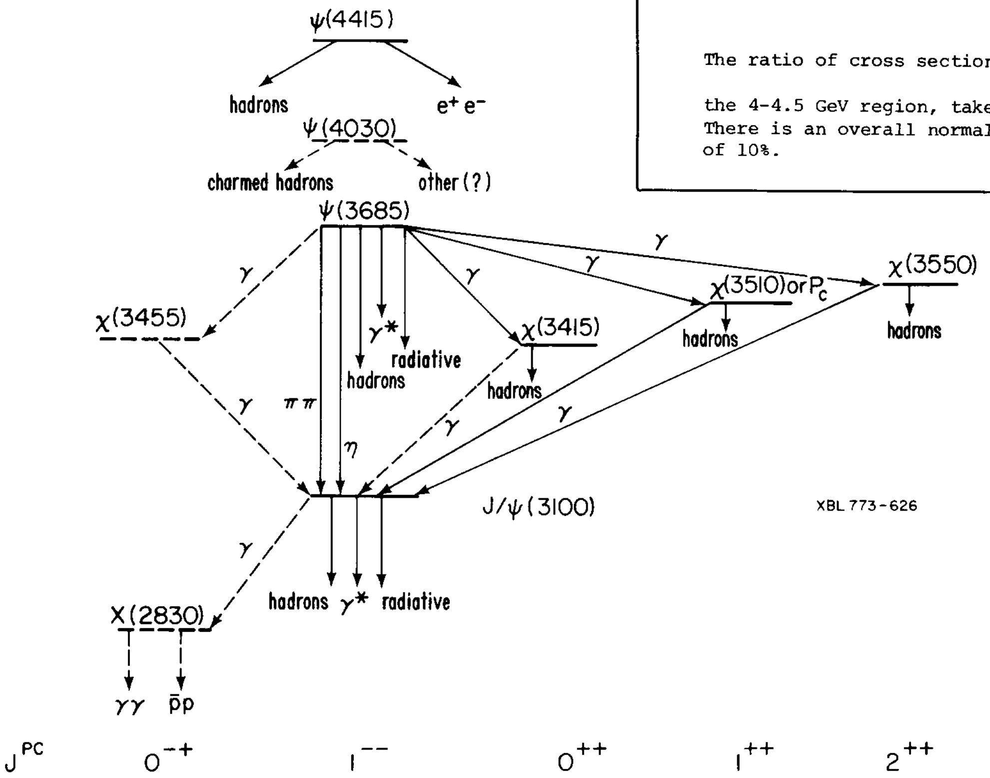
The method of extracting narrow resonance widths from e^+e^- colliding beam formation experiments is, by now, well known. For a summary of this method, see p. 140 of our previous edition.[2]

References

1. See reference section of the J/ψ(3100).
2. Particle Data Group, Rev. Mod. Phys. 48, No. 2, Part II (1976).



The ratio of cross sections $\frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$ in the 4-4.5 GeV region, taken from SIEGRIST 76. There is an overall normalization uncertainty of 10%.



Summary of observed charmonium states and transitions (adapted from FELDMAN 76[1]). Uncertain states and transitions are indicated by dashed lines. J^{PC} quantum number assignments are in some cases tentative, but all are at least consistent with experiment; see individual particle listings for discussion. The notation γ* refers to decay processes involving intermediate virtual photons, including decays to e^+e^- and $\mu^+\mu^-$.

X(2830)

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                  54  X(2830,JPG=    ) I=

                  CBSERVEC IN THE SEQUENTIAL RADIATIVE DECAY OF THE
        J/PSI(3100) INTO X(2830) GAMMA, X(2830) INTO GAMMA GAMMA.
        THIS SUGGESTS QUANTUM NUMBER ASSIGNMENTS C=+, IG=0+ OR 1-.
        NEEDS CONFIRMATICN. CMITTED FROM TABLE.

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                  54  X(2830) MASS (MEV)

M     B   8(2700.0)                  BARTEL     76 CNTR    E+E-,3 GAMMA      1/76
M         15(2830.0)    (30.0)       BRAUNSCHW 77 DASP    E+E-,3 GAMMA      1/77*
M     B   SIGNAL IS ONLY 2 STD EFFECT IN BARTEL 76.                         3/77*

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                  54  X(2830) PARTIAL DECAY MODES

                                                          DECAY MASSES
P1      X(2830) INTO GAMMA GAMMA
P2      X(2830) INTO PBAR P

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                  54  X(2830) BRANCHING RATIOS

R       SEE BRANCHING RATIOS R70,R76,R77,R79 OF J/PSI(3100)
R       SEE BRANCHING RATIOS R54 OF PSI(3685)

R1      X(2830) INTO (PBAR P)/TOTAL                    (P2)
R1        2 POSSIBLY SEEN             WIIK      75 CASP          E+E-        1/76

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                         REFERENCES FOR X(2830)

WIIK      75 STANFORD SYMP.69  B.H.WIIK                           (DESY)

BARTEL    76 TBILISI CONF.N56  +DUINKER,CLSSCN,HEINTZE,+          (DESY+HEID)
FELDMAN   76  SLAC-PUB-1851    G.J.FELDMAN                        (SLAC+LBL)
WIIK      76 TBILISI CCNF.N 75 B.H.WIIK RAPPORTEUR                (DESY)

BRAUNSCH  77  DESY 77/02       BRAUNSCHWEIG,+      (AACH+DESY+HAMB+MPIM+TOKY)
WIIK      77  DESY 77/01       +WOLF                              (DESY)

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J/ψ(3100)

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                  70  J/PSI(3100,JPG=1--) I=0
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                  70  J/PSI(3100) MASS (MEV)

M          (3100.)                   AUBERT     74 SPEC    28. PP(E+E-)     2/75
M    L     (3105.)      (3.)         AUGUSTIN   74 SMAG          E+E-       2/75
M    D      3095.        4.          BOYARSKI   75 SMAG          E+E-       3/75
M    S      3089.5      31.          CRIEGEE1   75 PLUT          E+E-       2/75
M           3098.        6.          PREPOST    75 SPEC   13.-21.GAMMA D    1/76
M           3103.        6.          BEMPORAD   75 FRAB          E+E-       1/76
M           3096.0      30.0         SNYDER     76 SPEC   400 P BE,E+E-     1/77*
M
M    L   BOYARSKI 75 IS A REEVALUATICN OF AUGUSTIN 74 BASED
M    L   ON A RECALIBRATICN OF THE SPEAR BEAM ENERGY.
M
M    D   MASS, WIDTH, PARTIAL WIDTHS, AND BRANCHING RATIOS ALL OBTAINED    3/75
M    D   FROM CNE CVERALL FIT TO DATA OF THIS EXPERIMENT.                  3/75
M
M    S   ERROR OF ABOUT 1 PER CENT FROM THE UNCERTAINTY IN CALIBRATION OF  2/75
M    S   THE BEAM ENERGY.                                                  2/75
M         . . . . . . . . .
M   AVG    3097.5       2.9      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M   STUDENT3097.5       3.2      AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

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                  70  J/PSI(3100) WIDTH (KEV)

W           69.         15.          BOYARSKI   75 SMAG          E+E-       3/75
W           68.         26.          BALDINI1   75 FRAG          E+E-       1/76
W           60.         25.          ESPOSITO   75 FRAM          E+E-       1/76
W         . . . . . . . . .
W   AVG     66.9        11.5     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
W   STUDENT 66.9        12.4     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

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                  70  J/PSI(3100) PARTIAL CECAY MODES

                                                          DECAY MASSES
P1      J/PSI(3100) INTO E+ E-                            .5+  .5
P2      J/PSI(3100) INTO MU+ MU-                          105+ 105
P3      J/PSI(3100) INTC HACRONS
P4      J/PSI(3100) INTO VIRTUAL GAMMA INTC HADRONS

P       HADRONIC DECAYS
P       ---------------
P11     J/PSI(3100) INTO PI+ PI-
P12     J/PSI(3100) INTO PI+ PI- PIO
P13     J/PSI(3100) INTO 2(PI+ PI-)
P14     J/PSI(3100) INTC 2(PI+ PI-) PIO
P15     J/PSI(3100) INTO 3(PI+ PI-)
P16     J/PSI(3100) INTO 3(PI+ PI-) PIO
P17     J/PSI(3100) INTC 4(PI+ PI-)
P18     J/PSI(3100) INTC 4(PI+ PI-) PIO
P19     J/PSI(3100) INTC K KBAR
P20     J/PSI(3100) INTO K KBAR PI
P21     J/PSI(3100) INTO PI+ PI- K+ K-
P22     J/PSI(3100) INTO 2(PI+ PI-) K+ K-
P23     J/PSI(3100) INTC PI+ PI- PIO K+ K-
P24     J/PSI(3100) INTO RHO PI
P25     J/PSI(3100) INTO RHO PI PI PI
P26     J/PSI(3100) INTO OMEGA PI PI
P27     J/PSI(3100) INTO OMEGA 4PI
P28     J/PSI(3100) INTC OMEGA K KBAR
P29     J/PSI(3100) INTC CMEGA F
P30     J/PSI(3100) INTO CMEGA F PRIME
P31     J/PSI(3100) INTO PHI PI PI
P32     J/PSI(3100) INTO PHI 2(PI+ PI-)
P33     J/PSI(3100) INTO PHI K KBAR
P34     J/PSI(3100) INTO PHI ETA
P35     J/PSI(3100) INTO PHI ETA PRIME
P36     J/PSI(3100) INTO PHI F
P37     J/PSI(3100) INTO PHI F PRIME
P38     J/PSI(3100) INTO A2 PI
P39     J/PSI(3100) INTO A2 RHO
P40     J/PSI(3100) INTC K K*(892)
P41     J/PSI(3100) INTC K K*(1420)
P42     J/PSI(3100) INTC K*(892) K*(892)
P43     J/PSI(3100) INTO K*(1420) K*(1420)
P44     J/PSI(3100) INTO K*(892) K*(1420)
P45     J/PSI(3100) INTO P PBAR
P46     J/PSI(3100) INTO P PBAR PI
P47     J/PSI(3100) INTO P NBAR PI
P48     J/PSI(3100) INTC P PBAR PI+ PI-
P49     J/PSI(3100) INTO P PBAR PI+ PI- PIO
P50     J/PSI(3100) INTO P PBAR ETA
P51     J/PSI(3100) INTC P PBAR OMEGA
P52     J/PSI(3100) INTC LAMBDA ANTILAMBDA
P53     J/PSI(3100) INTO LAMBDA ANTISIGMA
P54     J/PSI(3100) INTC XI ANTIXI

P       RADIATIVE DECAYS
P       ----------------
P70     J/PSI(3100) INTC GAMMA GAMMA
P71     J/PSI(3100) INTO 3 GAMMA
P72     J/PSI(3100) INTC PIO GAMMA
P73     J/PSI(3100) INTO ETA GAMMA
P74     J/PSI(3100) INTO ETA PRIME GAMMA
P75     J/PSI(3100) INTO X(2830) GAMMA

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                  70  J/PSI(3100) PARTIAL WIDTHS (KEV)

W1      J/PSI(3100) INTO E+ E-                          (G1)                2/75
W1            4.8       0.6            BOYARSKI   75 SMAG        E+E-       3/75
W1   B       (4.6)      (.8)           BALDINI1   75 FRAG        E+E-       1/76
W1            4.6       1.0            ESPCSITO   75 FRAM        E+E-       1/76
W1   B  ASSUMING EQUAL PARTIAL WIDTHS FOR (E+E-) AND (MU+MU-)
W1        . . . . . . . . .
W1  AVG       4.75      0.51     AVERAGE (ERRCR INCLUDES SCALE FACTOR OF 1.0)
W1  STUDENT   4.75      0.55     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

W2      J/PSI(3100) INTO MU+ MU-                        (G2)                2/75
W2            4.8       0.6            BOYARSKI   75 SMAG        E+E-       3/75
W2            5.0       1.0            ESPCSITC   75 FRAM        E+E-       1/76
W2
W2        . . . . . . . . .
W2  AVG       4.85      0.51     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
W2  STUDENT   4.85      0.55     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

W3      J/PSI(3100) INTO HADRONS                        (G3)                2/75
W3            59.       14.            BOYARSKI   75 SMAG        E+E-       3/75
W3            59.       24.            BALDINI1   75 FRAG        E+E-       1/76
W3            50.       25.            ESPOSITO   75 FRAM        E+E-       1/76
W3        . . . . . . . . .
W3  AVG       57.3      10.9     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
W3  STUDENT   57.3      11.7     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

W4      J/PSI(3100) INTC GAMMA INTC HADRCNS
W4 C          12.        2.            BOYARSKI   75 SMAG        E+E-       1/76
W4 C     INCLUDED IN W3

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                  70  J/PSI(3100) BRANCHING RATIOS

         FOR THE BRANCHING RATIOS R1 - R4, SEE ALSO THE PARTIAL
         WIDTHS ABOVE, AND (PARTIAL WIDTHS)*R1 BELCW.

R1      J/PSI(3100) INTO (E+ E-)/TOTAL                  (P1)                3/75
R1          0.069     0.009            BOYARSKI   75 SMAG        E+E-       3/75

R2      J/PSI(3100) INTO (MU+ MU-)/TOTAL                (P2)                3/75
R2          0.069     0.009            BOYARSKI   75 SMAG        E+E-       3/75

R3      J/PSI(3100) INTO (HADRONS)/TOTAL                (P3)                3/75
R3          0.86      0.02             BOYARSKI   75 SMAG        E+E-       3/75

R4      J/PSI(3100) INTO (E+ E-)/(MU+ MU-)              (P1)/(P2)           2/75
R4          1.00      0.05             BOYARSKI   75 SMAG        E+E-       3/75
R4          0.93      0.10             FORD       75 SPEC        E+E-       2/75
R4           .91       .15             ESPCSITC   75 FRAM        E+E-       1/76
R4        . . . . . . . . .
R4  AVG     0.980     0.043    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R4  STUDENT 0.980     0.047    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R5      J/PSI(3100) INTO (GAMMA INTC HADRCNS)/TCTAL
R5 C         .17       .02             BOYARSKI   75 SMAG        E+E-       1/76
R5 C     INCLUDED IN R3


R       HADRONIC DECAYS
R       ---------------

R8      J/PSI(3100) INTO (PI+ PI-)/TOTAL         (UNITS 10**-4)
R8       2    1.0       0.7            BRAUNSCHW 76 DASP         E+E-       1/77*
R8       1    1.6       1.6            VANNUCCI  77 SMAG         E+E-       1/77*
R8
R8        . . . . . . . . .
R8  AVG       1.10      0.64     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R8  STUDENT   1.10      0.69     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R9      J/PSI(3100) INTO (2(PI+ PI-))/TOTAL
R9       76     .004      .001             JEAN-MARI 76 SMAG     E+E-       1/76

R10     J/PSI(3100) INTO (2(PI+ PI-) PIO)/TOTAL
R10     675     .04       .01              JEAN-MARI 76 SMAG     E+E-       1/76
R10           (0.044)   (0.005)            BURMESTER 77 PLUT     E+E-       1/77*

R11     J/PSI(3100) INTO (3(PI+ PI-))/TOTAL
R11      32     .004      .002             JEAN-MARI 76 SMAG     E+E-       1/76

R12     J/PSI(3100) INTO (3(PI+ PI-) PIO)/TOTAL
R12     181     .029      .007             JEAN-MARI 76 SMAG     E+E-       1/76
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Data Card Listings

J/ψ(3100)

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R13      J/PSI(3100) INTO (4(PI+ PI-) PI0)/TOTAL
R13       13     .009      .003               JEAN-MARI 76 SMAG            E+E-          1/76

R14      J/PSI(3100) INTO (PI+ PI- K+ K-)/TOTAL
R14      205    0.0072    0.0023              VANNUCCI  77 SMAG            E+E-          1/77*

R15      J/PSI(3100) INTO (2(PI+ PI-) K+ K-)/TOTAL
R15       30    0.0031    0.0013              VANNUCCI  77 SMAG            E+E-          1/77*

R16      J/PSI(3100) INTO (RHO PI)/(PI+ PI- PI0)
R16             (.7)  OR MORE  CL=0.90  JEAN-MARI 76 SMAG            E+E-          1/76

R17      J/PSI(3100) INTO (RHO0 PI0)/(RHO+- PI-+)
R17             0.63      0.22                BARTEL 1  76 CNTR            E+E-          1/77*
R17              .59       .17                JEAN-MARI 76 SMAG            E+E-          1/76
R17           . . . . . . . . . .
R17 AVG         0.60      0.13    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R17 STUDENT     0.60      0.14    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R18      J/PSI(3100) INTO (RHO PI)/TOTAL
R18      543    0.010     0.002               BARTEL 1  76 CNTR            E+E-          1/77*
R18       99    0.012     0.003               BRAUNSCHW 76 DASP            E+E-          1/77*
R18      153     .013      .003               JEAN-MARI 76 SMAG            E+E-          1/76
R18           . . . . . . . . . .
R18 AVG         0.0112    0.0015  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R18 STUDENT     0.0112    0.0016  AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R19      J/PSI(3100) INTO (OMEGA PI PI)/(2(PI+ PI-) PI0)
R19  J          (.2)                          JEAN-MARI 76 SMAG            E+E-          1/76

R20      J/PSI(3100) INTO (RHO PI PI PI)/(2 (PI+ PI-) PI0)
R20  J          (.3)                          JEAN-MARI 76 SMAG            E+E-          1/76
R20  J  FINAL STATE  2(PI+PI-)PI0

R21      J/PSI(3100) INTO (PHI PI+ PI-)/TOTAL
R21       23    0.0014    0.0006              VANNUCCI  77 SMAG            E+E-          1/77*

R22      J/PSI(3100) INTO (K0S K0L)/TOTAL  (UNITS 10**-4)
R22            (0.89) OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R23      J/PSI(3100) INTO (K+ K-)/TOTAL     (UNITS 10**-4)
R23        1    1.4       1.4                 BRAUNSCHW 76 DASP            E+E-          1/77*
R23        2    2.0       1.6                 VANNUCCI  77 SMAG            E+E-          1/77*
R23           . . . . . . . . . .
R23 AVG         1.7       1.1     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R23 STUDENT     1.7       1.1     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R24      J/PSI(3100) INTO (K0 K*(892)0)/TOTAL
R24       45    0.0027    0.0006              VANNUCCI  77 SMAG            E+E-          1/77*

R25      J/PSI(3100) INTO (K+- K*(892)-+)/TOTAL
R25       39    0.0041    0.0012              BRAUNSCHW 76 DASP            E+E-          1/77*
R25       48    0.0032    0.0006              VANNUCCI  77 SMAG            E+E-          1/77*
R25           . . . . . . . . . .
R25 AVG         0.00338   0.00054  AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R25 STUDENT     0.00338   0.00059  AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R26      J/PSI(3100) INTO (K0 K*(1420)0)/TOTAL
R26            (0.002) OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R27      J/PSI(3100) INTO (K+- K*(1420-+)/TOTAL
R27            (0.0033)OR LESS  CL=0.90  BRAUNSCHW 76 DASP            E+E-          1/77*
R27            (0.0015)OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R28      J/PSI(3100) INTO (K*(892)0 K*(892)0)/TOTAL
R28            (0.0005)OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R29      J/PSI(3100) INTO (K*(1420)0 K*(1420)0)/TOTAL
R29            (0.0029)OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R30      J/PSI(3100) INTO (K*(892)0 K*(1420)0)/TOTAL
R30       40    0.0067    0.0026              VANNUCCI  77 SMAG            E+E-          1/77*

R31      J/PSI(3100) INTO (PBAR P)/TOTAL    (UNITS 10**-3)
R31  A  70      2.3       0.3                 BRAUNSCHW 76 DASP            E+E-          1/77*
R31  A 300     (2.0)     (0.15)               GOLDHABER 76 SMAG            E+E-          1/77*
R31  A  ASSUMING ANGULAR DISTRIBUTION (1.+COS(THETA)**2)

R32      J/PSI(3100) INTO (PBAR P)/(MU+ MU-)
R32  A  20     (.051)    (.02)                CRIEGEE2  75 PLUT            E+E-          1/76
R32  A  ASSUMING ANGULAR DISTRIBUTION (1.+COS(THETA)**2)

R33      J/PSI(3100) INTO (LAMBDA ANTILAMBDA)/TOTAL
R33       19     .0016     .0008              ABRAMS    75 SMAG            E+E-          1/76

R34      J/PSI(3100) INTO (P PBAR PI0)/TOTAL
R34            (0.0010) (0.0002)              FELDMAN   76 SMAG            E+E-          1/77*

R35      J/PSI(3100) INTO (P PBAR PI+PI-)/TOTAL
R35            (0.0041) (0.0008)              FELDMAN   76 SMAG            E+E-          1/77*

R36      J/PSI(3100) INTO (P PBAR PI+ PI- PI0)/TOTAL
R36            (0.0011) (0.0004)              FELDMAN   76 SMAG            E+E-          1/77*

R37      J/PSI(3100) INTO (LAMBDA ANTISIGMA)/(LAMBDA ANTILAMBDA)
R37            (.22) OR LESS  CL=0.90  GOLDHABER 75 SMAG            E+E-          2/76

R38      J/PSI(3100) INTO (PI+- A2)/TOTAL
R38            (0.0043)OR LESS  CL=0.90  BRAUNSCHW 76 DASP            E+E-          1/77*

R39      J/PSI(3100) INTO (OMEGA PI PI)/TOTAL
R39            (0.007)  (0.002)               BURMESTER 77 PLUT            E+E-          1/77*
R39      348    0.0068    0.0019              VANNUCCI  77 SMAG            E+E-          1/77*

R40      J/PSI(3100) INTO 2(K+ K-)/TOTAL
R40             0.0007    0.0003              VANNUCCI  77 SMAG            E+E-          1/77*

R41      J/PSI(3100) INTO (OMEGA K+ K-)/TOTAL
R41       22    0.0008    0.0005              VANNUCCI  77 SMAG            E+E-          1/77*

R42      J/PSI(3100) INTO (PHI K+ K-)/TOTAL
R42       14    0.0009    0.0004              VANNUCCI  77 SMAG            E+E-          1/77*

R43      J/PSI(3100) INTO (PHI ETA)/TOTAL
R43        5    0.0010    0.0006              VANNUCCI  77 SMAG            E+E-          1/77*

R44      J/PSI(3100) INTO (PHI ETA PRIME)/TOTAL
R44            (0.0013)OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R45      J/PSI(3100) INTO (PHI F PRIME)/TOTAL
R45        6    0.0008    0.0005              VANNUCCI  77 SMAG            E+E-          1/77*

R46      J/PSI(3100) INTO (P NBAR PI-)/TOTAL
R46            (0.0038) (0.0008)              FELDMAN   76 SMAG            E+E-          1/77*

R47      J/PSI(3100) INTO (P PBAR ETA)/TOTAL
R47            (0.0019) (0.0004)              FELDMAN   76 SMAG            E+E-          1/77*

R48      J/PSI(3100) INTO (P PBAR OMEGA)/TOTAL
R48            (0.0005) (0.0001)              FELDMAN   76 SMAG            E+E-          1/77*

R49      J/PSI(3100) INTO (K0S K+- PI-+)/TOTAL
R49      126    0.0026    0.0007              VANNUCCI  77 SMAG            E+E-          1/77*

R50      J/PSI(3100) INTO (PHI F)/TOTAL    (UNITS 10**-4)
R50            (3.7)  OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R51      J/PSI(3100) INTO (PHI 2(PI+PI-))/TOTAL
R51            (0.0015)OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R52      J/PSI(3100) INTO (OMEGA F)/TOTAL
R52       81    0.0019    0.0008              VANNUCCI  77 SMAG            E+E-          1/77*

R53      J/PSI(3100) INTO (OMEGA F PRIME)/TOTAL  (UNITS 10**-4)
R53            (1.6)  OR LESS  CL=0.90  VANNUCCI  77 SMAG            E+E-          1/77*

R54      J/PSI(3100) INTO (PI+PI-PI0 K+K-)/TOTAL
R54      309    0.012     0.003               VANNUCCI  77 SMAG            E+E-          1/77*

R55      J/PSI(3100) INTO (RHO A2)/TOTAL
R55       36    0.0084    0.0045              VANNUCCI  77 SMAG            E+E-          1/77*

R56      J/PSI(3100) INTO (OMEGA 4PI)/TOTAL
R56      140    0.0085    0.0034              VANNUCCI  77 SMAG            E+E-          1/77*

R57      J/PSI(3100) INTO (XI- ANTIXI-)/TOTAL
R57            (0.0004)                       FELDMAN   76 SMAG            E+E-          1/77*

R58      J/PSI(3100) INTO (RHO+- PI-+)/(K*(892)+- K-+)
R58            (0.26)   (0.09)                PIERRE    76 SMAG            E+E-          4/77*


R        RADIATIVE DECAYS
R        ----------------

R70      J/PSI(3100) INTO (X(2830) GAMMA)/TOTAL  (UNITS 10**-3)
R70 S          (50.)   OR LESS  CL=0.90  BADTKE    76 CNTR            E+E-          1/77*
R70            (39.)   OR LESS  CL=0.90  WHITAKER  76 SMAG            E+E-          4/77*
R70            (17.)   OR LESS  CL=0.90  BIDDICK   77 CNTR            E+E-          3/77*
R70 S   BADTKE 76 IS SUPERCEDED BY BIDDICK 77.                                       3/77*

R71      J/PSI(3100) INTO (2 GAMMA)/TOTAL  (UNITS 10**-3) (P4)
R71            (3.)    OR LESS  CL=0.90  WIIK      75 DASP            E+E-          1/77*
R71            (0.5)   OR LESS  CL=0.90  BARTEL    77 CNTR            E+E-          4/77*

R72      J/PSI(3100) INTO (PI0 GAMMA)/TOTAL (UNITS 10**-3)                           2/75
R72  B         (4.0)   OR LESS  CL=.90   BACCI     75 FRAG            E+E-          1/76
R72  B         (0.5)   OR LESS  CL=0.90  BARTEL    77 CNTR    E+E-,3 GAMMA          1/77*
R72  U    9    (0.075)  (0.048)          BRAUNSCHW 77 DASP    E+E-,3 GAMMA          1/77*
R72  B    RE-STATED BY US USING (HADRONS)/TOTAL=0.86
R72  U    RE-STATED BY US USING TOTAL WIDTH 67 KEV.

R73      J/PSI(3100) INTO (ETA GAMMA)/TOTAL (UNITS 10**-3)
R73            (16.)   OR LESS  CL=.90   BACCI     75 FRAG            E+E-          1/76
R73       21   (1.3)    (0.4)            BARTEL    77 CNTR    E+E-,3 GAMMA          1/77*
R73  U    40   (0.82)   (0.19)           BRAUNSCHW 77 DASP    E+E-,3 GAMMA          1/77*
R73  U    RE-STATED BY US USING TOTAL WIDTH 67 KEV.

R74      J/PSI(3100) INTO (ETA PRIME GAMMA)/TOTAL  (UNITS 10**-3)
R74  B         (15.)   OR LESS  CL=.90   BALDINI2  75 FRAG            E+E-          1/76
R74            (3.3)   OR LESS  CL=.90   BACCI     76 FRAG            E+E-          4/77*
R74       57    2.4      0.7             BARTEL 1  76 CNTR    E+E-,2 GAMMA RHO      1/77*
R74  U     3   (2.27)   (1.75)           BRAUNSCHW 77 DASP    E+E-,3 GAMMA          1/77*
R74  B    RE-STATED BY US USING (HADRONS)/TOTAL=0.86
R74  U    RE-STATED BY US USING TOTAL WIDTH 67 KEV.

R75      J/PSI(3100) INTO (ETA PRIME GAMMA)/(ETA GAMMA)
R75            (1.8)    (0.8)            BARTEL    77 CNTR    E+E-,3 GAMMA          3/77*

R76      J/PSI(3100) INTO (X(2830) GAMMA)/TOTAL,X TO 2 GAMMA (UNITS 10**-3)
R76  X         (0.14)   (0.08)           BARTEL 2  76 CNTR    E+E-,3 GAMMA          1/77*
R76  U   15    (0.124)  (0.052)          BRAUNSCHW 77 DASP    E+E-,3 GAMMA          1/77*
R76  X  EXISTENCE OF X(2830) IN BARTEL 2 76 DATA IS ONLY 2 STD EFFECT                3/77*
R76  U   RE-STATED BY US USING TOTAL WIDTH 67 KEV.

R77      J/PSI(3100) INTO (X(2830) GAMMA)/TOTAL,X TO P PBAR GAM (UNITS 10**-3
R77            (0.04) OR LESS  CL=0.90   GOLDHABER 76 SMAG            E+E-          1/77*
R77            (0.2)  OR LESS  CL=0.90   WIIK      76 DASP            E+E-          1/77*

R78      J/PSI(3100) INTO (3 GAMMA)/TOTAL  (UNITS 10**-3)
R78  U         (0.08) OR LESS  CL=0.90   BRAUNSCHW 77 DASP    E+E-,3 GAMMA          1/77*
R78  U   RE-STATED BY US USING TOTAL WIDTH 67 KEV.

R79      J/PSI(3100) INTO (X(2830) GAMMA)/TOTAL,X TO RHO GAMMA (UNITS 10**-3)
R79            (0.3)  OR LESS  CL=0.90   BARTEL 2  76 CNTR    E+E-,2 GAMMA RHO      1/77*

R80      J/PSI(3100) INTO (GAMMA + 2 OR MORE NEUTRALS)/TOTAL    (UNITS 10**-3)
R80             7.0      2.0             BARTEL    77 CNTR            E+E-          1/77*

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                    70  J/PSI(3100)   G(I)*G(E+E-)/G(TOTAL)  (KEV)


         THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH
         INTO E+E- AND WITH THE TOTAL WIDTH IS OBTAINED FROM THE INTEGRATED
         CROSS-SECTION INTO CHANNEL(I) IN THE E+E- ANNIHILATION.
         WE ONLY LIST DATA NOT HAVING BEEN USED TO DETERMINE THE PARTIAL
         WIDTH G(I) OR THE BRANCHING RATIO G(I)/TOTAL.

G1       G(E+E-)*G(E+E-)/G(TOTAL)
G1   S          (.32)     (.07)              BALDINI1  75 FRAG            E+E-          1/76
G1               .34       .14               BEMPORAD  75 FRAB            E+E-          1/76
G1               .41       .06               DASP1     75 DASP            E+E-          1/76
G1   S          (.34)     (.09)              ESPOSITO  75 FRAM            E+E-          1/76
G1   S          (.36)     (.10)              FORD      75 SPEC            E+E-
G1            . . . . . . . . . .
G1   AVG        0.399     0.055   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
G1   STUDENT    0.399     0.060   AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT
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J/ψ(3100), χ(3415), χ(3455)

Data Card Listings

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G2      G(MU+MU-)*G(E+E-)/G(TOTAL)
G2              .31       .09             BEMPORAD   75 FRAB        E+E-          1/76
G2             (.32)     (.08)            CRIEGEE2   75 PLUT        E+E-          1/76
G2              .51       .09             DASP1      75 DASP        E+E-          1/76
G2   S         (.38)     (.05)            ESPOSITO   75 FRAM        E+E-          1/76
G2   S         (.46)     (.10)            LIBERMAN   75 SPEC        E+E-          1/76
G2              . . . . . . . . . .
G2   AVG       0.41      0.10     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.6)
G2   STUDENT   0.410     0.079    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

G3      G(HADRONIC)*G(E+E-)/G(TOTAL)
G3   S        (4.)       (.8)             BALDINI1   75 FRAG        E+E-          1/76
G3   S        (3.9)      (.8)             ESPOSITO   75 FRAM        E+E-          1/76

G    S    SEE THE BRANCHING RATIOS AND PARTIAL WIDTHS ABOVE.

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REFERENCES FOR J/PSI(3100)


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CHRISTEN 70 PRL 25 1523         CHRISTENSEN,HICKS,LEDERMAN+ (COLU+BNL+CERN)

ABRAMS   74 PRL 33 1453         +BRIGGS,AUGUSTIN,BOYARSKI+          (LBL+SLAC)
ASH      74 NCL 11 705          +ZORN,BARTOLI+     (FRAS+UMD+NAPL+PADO+ROMA)
AUBERT   74 PRL 33 1404         +BECKER,BIGGS,BURGER,CHEN,EVERHART(MIT+BNL)
AUGUSTIN 74 PRL 33 1406         +BOYARSKI,ABRAMS,BRIGGS+            (SLAC+LBL)
BACCI    74 PRL 33 1408         +BARTOLI,BARBARINO,BARBIELLINI+  (FRASCATI)
    ALSO 74 PRL 33 1649         FOR ERRATA
BALDINI- 74 NCL 11 711          BALDINI-CELIO,BACCI+          (FRASCATI+ROMA)
BARBIELL 74 NCL 11 718          BARBIELLINI,BEMPORAD+ (FRAS+NAPO+PISA+ROMA)
BRAUNSCH 74 PL 53B 393          BRAUNSCHWEIG+      (AACHEN+HAMB+MUNICH+TOKYO)

ABRAMS   75 STANFORD SYMP.25    G.S.ABRAMS                              (LBL)
ANDREWS  75 PRL 34 231          +HARVEY,LOBKOWICZ,MAY,NORDBERG   (ROCH+CORN)
AUBERT   75 NP B 89 1           +BECKER,BIGGS,BURGER,GLENN,+       (MIT+BNL)
BACCI    75 NCL 12 269          +PENSO,STELLA,BALDINI-CELIO,+    (ROMA+FRAS)
BALDINI1 75 PL 58B 471          BALDINI-CELIO,BOZZO,CAPON,BACCI+(FRAS+ROMA)
BALDINI2 75 PL 58B 475          BALDINI-CELIO,CAPON,DEL FABBRO+ (FRAS+ROMA)
BEMPORAD 75 STANFORD SYMP.113 C.BEMPORAD                    (PISA+FRASCATI)
BLANAR   75 PRL 35 346          +BOYER,FAISSLER,GARELICK,GETTNER,+    (NEAS)
BOYARSKI 75 PRL 34 1357         +BREIDENBACH,BULOS,FELDMAN,+      (SLAC+LBL)JPC
BRAUNSCH 75 PL 53B 491          BRAUNSCHWEIG+     (AACHEN+HAMB+MUNICH+TOKYO)
CAMERINI 75 PRL 35 483          +LEARNED,PREPOST,ASH,ANDERSON,+ (WISC+SLAC)
CRIEGEE1 75 PL 53B 489          +DEHNE,FRANKE,HORLITZ,KRECHLOCK+     (DESY)
CRIEGEE2 75  DESY PREP.75/32    +DEHNE,FOX,FRANKE,HORLITZ,KNIES,+    (DESY)
DAKIN    75 PL 56 B 405         +KREISLER,BOLON,HEILE+        (MASA+MIT+SLAC)
DASP1    75 PL 56B 491          BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
DASP2    75 PL 57B 297          BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
ESPOSITO 75 NCL 14 73           +BARTOLI,BISELLO,+    (FRAS+NAPO+PADO+ROMA)
FORD     75 PRL 34 604          +BERON,HILGER,HOFSTADTER+        (SLAC+PENN)
GITTELMA 75 PRL 35 1616         GITTELMAN+HANSON+LARSON+LOH+           (CORN)
GOLDHABE 75  LBL-4224           GOLDHABER,JOHNSON,KADYK,+         (LBL+SLAC)
GRECO    75 PL 56B 367          +PANCHERI-SRIVASTAVA,SRIVASTAVA        (FRAS)
HEINTZE  75 STANFORD SYMP.97    J.HEINTZE                        (HEIDELBERG)
JACKSON  75 NIM 128 13          J.D.JACKSON,D.SCHARRE                   (LBL)
KNAPP1   75 PRL 34 1040         +LEE,BRONSTEIN+     (COLU+HAWA+CORN+ILL+FNAL)
KNAPP2   75 PRL 34 1044         +LEE,BRONSTEIN+     (COLU+HAWA+CORN+ILL+FNAL)
LIBERMAN 75 STANFORD SYMP.55    A.D.LIBERMAN                       (STANFORD)
MARTIN   75 PRL 34 288          +BOLON,DAKIN,FELDMAN,HANSON+(MIT+MASA+SLAC)
PREPOST  75 STANFORD SYMP.241 R.PREPOST                           (WISCONSIN)
SIMPSON  75 PRL 35 699          +BERON,FORD,HILGER,HOFSTADTER,+ (STAN+PENN)
WIIK     75 STANFORD SYMP.69    B.H.WIIK                               (DESY)
YENNIE   75 PRL 34 239          D.R.YENNIE                          (CORNELL)

ANTIPOV  76 TBILISI CONF.N 8    +BESSUBOV,PUDANOV,BUSHNIN,DENISOV,+  (IHEP)
BACCI    76 LNF-76/60(P)        +BALDINI-CELIO,CAPON+        (FRAS+ROMA+GENO)
BADTKE   76  PREPRINT           +BARNETT,+    (UMD+PAVI+PRIN+UCSD+SLAC+STAN)
BARTEL 1 76 PL 64 B 483         +DUINKER,OLSSON,STEFFEN,HEINTZE+(DESY+HEID)
BARTEL 2 76 TBILISI CONF.N56    +DUINKER,OLSSON,HEINTZE,+        (DESY+HEID)
BRAUNSCH 76 PL 63 B 487         BRAUNSCHWEIG,+   (AACH+DESY+HAMB+MPIM+TOKY)
FELDMAN  76  SLAC-PUB-1851      G.J.FELDMAN                       (SLAC+LBL)
GOLDHABE 76  LBL-4884           G.GOLDHABER                       (SLAC+LBL)
JEAN-MAR 76 PRL 36 291          +ABRAMS,BOYARSKI,BREIDENBACH,+   (SLAC+LBL)IG
PIERRE   76 SACLAY-DPHPE76-21 F.PIERRE                            (SLAC+LBL)
SNYDER   76 PRL 36 1415         +HOM,LEDERMAN,PAAR,APPEL,+ (COLU+FNAL+STON)
VANNUCCI 76  SLAC-PUB-1724      +ABRAMS,BOYARSKI,BREIDENBACH,+    (SLAC+LBL)
WHITAKER 76 PRL 37 1596         +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)
WIIK     76 TBILISI CONF.N75    B.H.WIIK RAPPORTEUR                    (DESY)

BARTEL   77  DESY 76/65         +DUINKER,OLSSON,HEINTZE,+        (DESY+HEID)
BIDDICK  77 PRINT-77-0244UCSD +BURNETT+    (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BRAUNSCH 77  DESY 77/02         BRAUNSCHWEIG,+   (AACH+DESY+HAMB+MPIM+TOKY)
BURMESTE 77  QUOTED BY WIIK76 PLUTO COLLABORATION                      (DESY)
VANNUCCI 77 TO BE PUB PR D      +ABRAMS,ALAM,BOYARSKI,+            (SLAC+LBL)
WIIK     77  DESY 77/01         +WOLF                                  (DESY)
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χ(3415)

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        56  CHI(3415,JPG=0++) I=0

                OBSERVED IN THE RADIATIVE DECAY OF PSI(3685) INTO
        CHI(3415) GAMMA.THEREFORE C=+. THE OBSERVED DECAY INTO (PI+PI-)
        OR (K+K-) IMPLIES G=+,JP=0+,2+,... . THE ANGULAR DISTRIBUTION
        IS CONSISTENT WITH J=0.

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                    56  CHI(3415) MASS (MEV)

M    W   2 3412.0       8.0           WIIK       75 DASP   E+E-,J/PSI 2 GAM  1/77*
M        1(3413.0)    (10.0)          FELDMAN    76 SMAG   E+E-,J/PSI 2 GAM  1/77*
M          3415.0      10.0           TRILLING   76 SMAG   E+E-,HADRONS GAM  1/77*
M    Q    (3418.0)     (7.0)          VERNON     76 CNTR   E+E-,MONOCHR.GAM  1/77*
M          3413.0      11.0           WHITAKER   76 SMAG   E+E-,MONOCHR.GAM  1/77*
M          3413.0       9.0           BIDDICK    77 CNTR   E+E-,MONOCHR.GAM  3/77*
M    W   INCREASED 4 MEV BY FELDMAN 76 TO CORRECT FOR ENERGY CALIBRATION.
M    Q   VERNON 76 IS SUPERCEDED BY BIDDICK 77
M          . . . . . . . . . .
M   AVG    3413.1       4.7     AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M   STUDENT3413.1       5.0     AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

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                    56  CHI(3415) PARTIAL DECAY MODES

                                                              DECAY MASSES
P1      CHI(3415) INTO PI+ PI-                                139+ 139
P2      CHI(3415) INTO K+ K-                                  493+ 493
P3      CHI(3415) INTO 2(PI+ PI-)                             139+ 139+ 139+ 139
P4      CHI(3415) INTO 3(PI+ PI-)
P5      CHI(3415) INTO PI+ PI- K+ K-                          139+ 139+ 493+ 493
P6      CHI(3415) INTO J/PSI(3100) GAMMA                     3098+   0
P7      CHI(3415) INTO 2 GAMMA
P8      CHI(3415) INTO PI+ PI- P PBAR                         139+ 139+ 938+ 938
P9      CHI(3415) INTO RHO0 PI+ PI-                           773+ 139+ 139
P10     CHI(3415) INTO K*(892)0 K+/- PI-/+                    892+ 493+ 139

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                    56  CHI(3415) BRANCHING RATIOS

R         SEE ALSO BRANCHING RATIOS R54 OF PSI(3685)

R1         CHI(3415) INTO (2 GAMMA)/TOTAL
R1           (0.0057)OR LESS  CL=0.90  BRAUNSCHW 77 DASP    E+E-,3 GAMMA       1/77*

R2      CHI(3415) INTO 2(PI+ PI-)/TOTAL
R2   T          (.043)    (.017)           TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*
R2   T   CALCULATED USING PSI(3685) TO (GAMMA CHI(3415))/TOTAL=.075+/-.026     1/77*

R3      CHI(3415) INTO (PI+ PI- K+ K-)/TOTAL
R3   T          (.036)    (.015)           TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R4      CHI(3415) INTO 3(PI+ PI-)/TOTAL
R4   T          (.02)     (.01)            TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R5      CHI(3415) INTO (PI+ PI-)/TOTAL
R5   T          (.01)     (.005)           TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R6      CHI(3415) INTO (K+ K-)/TOTAL
R6   T          (.01)     (.005)           TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R7      CHI(3415) INTO (PI+ PI- P PBAR)/TOTAL
R7   T          (.005)    (.002)           TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R8      CHI(3415) INTO (J/PSI(3100) GAMMA)/TOTAL
R8   T          (.03)     (.03)            TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R9      CHI(3415) INTO (RHO0 PI+ PI-)/2(PI+ PI-)
R9               .39       .12             TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

R10     CHI(3415) INTO (K*(892)0 K+/- PI-/+)/(PI+ PI- K+ K-)
R10              .41       .10             TRILLING  76 SMAG PSI(3685)TO GAM CHI  1/77*

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REFERENCES FOR CHI(3415)


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FELDMAN  75 PRL 35 821          +JEAN-MARIE,SADOULET,VANNUCCI,+  (LBL+SLAC)
    ALSO 75 PRL 35 1189  (ERRATA)
TANENBAU 75 PRL 35 1323         TANENBAUM,WHITAKER,ABRAMS,+       (LBL+SLAC)
WIIK     75 STANFORD SYMP.69    B.H.WIIK                               (DESY)

FELDMAN  76  SLAC-PUB-1851      G.J.FELDMAN                       (SLAC+LBL)
PIERRE   76  LBL-5324           F.PIERRE                          (SLAC+LBL)
TRILLING 76 STANFORD SYMP.437 G. H. TRILLING                          (LBL)
VERNON   76 TBILISI CONF.N63    W.VERNON       (UMD+PAVI+PRIN+UCSD+SLAC+STAN)
WHITAKER 76 PRL 37 1596         +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)
WIIK     76 TBILISI CONF.N75    B.H.WIIK RAPPORTEUR                    (DESY)

BIDDICK  77 PRINT-77-0244UCSD +BURNETT+      (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BRAUNSCH 77  DESY 77/03         BRAUNSCHWEIG,+   (AACH+DESY+HAMB+MPIM+TOKY)
WIIK     77  DESY 77/01         +WOLF                                  (DESY)
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χ(3455)

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                  58  CHI(3455,JPG=    ) I=

                OBSERVED IN THE CASCADE RADIATIVE DECAY OF PSI(3685)
        INTO CHI(3455) GAMMA, CHI(3455) INTO J/PSI(3100) GAMMA
        WHITAKER 76), THEREFORE C=+.  NOT SEEN IN HADRONIC MODES.
        NOT SEEN IN OTHER EXPERIMENTS LOOKING ONLY FOR MONOCHROMATIC
        PHOTONS.  AMBIGUOUS, WITH A (BROADER) STATE AT ABOUT 3340 NOT
        EXCLUDED.  NEEDS CONFIRMATION.  OMITTED FROM TABLE

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                  58  CHI(3455) MASS (MEV)

M          4 3454.0      10.0           WHITAKER  76 SMAG    E+E-,J/PSI 2 GAM  1/77*

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                  58  CHI(3455) PARTIAL DECAY MODES

                                                              DECAY MASSES
P1      CHI(3455) INTO J/PSI(3100) GAMMA                     3098+   0

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                  58  CHI(3455) BRANCHING RATIOS

R         SEE BRANCHING RATIOS R62 OF PSI(3685)

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REFERENCES FOR CHI(3455)


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FELDMAN  76  SLAC-PUB-1851      G.J.FELDMAN                       (SLAC+LBL)
WHITAKER 76 PRL 37 1596         +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)
WIIK     76 TBILISI CONF.N75    B.H.WIIK RAPPORTEUR                    (DESY)

WIIK     77  DESY 77/01         +WOLF                                  (DESY)
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Data Card Listings

P_c or $\chi(3510)$

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55  PC OR CHI(3510, JPG=  +) I=0

        OBSERVED IN THE RADIATIVE SEQUENTIAL DECAY OF THE
   PSI(3685) INTO PC GAMMA, PC INTO J/PSI(3100) GAMMA. THEREFORE C=+.
   THE LACK OF DECAYS INTO (PI+PI-) OR (K+K-) IS SUGGESTIVE OF
   JP = ABNORMAL. THE DECAYS INTO 4PI AND 6PI IMPLY C=+, THUS I=0.
   J=0 IS EXCLUDED BY THE ANGULAR DISTRIBUTION IN THE (GAMMA J/PSI)
   DECAY(FELDMAN 76).

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                      55  PC MASS (MEV)

M   W   40(3500.)     (10.)           TANENBAUM 75 SMAG          HADRONS GAM  1/76
M    W   7 3512.0      7.0            WIIK      75 DASP    E+E-,J/PSI 2 GAM   1/77*
M           3510.0    20.0            BARTEL    76 CNTR    E+E-,J/PSI 2 GAM   1/77*
M       12 3504.0     10.0            WHITAKER  76 SMAG    E+E-,J/PSI 2 GAM   1/77*
M   S     (3512.0)    (7.0)           VERNON    76 CNTR    E+E-,MONOCHR.GAM   1/77*
M          3511.0      7.0            BIDDICK   77 CNTR    E+E-,MONOCHR.GAM   3/77*
M   W   TANENBAUM 75 SUPERCEDED BY WHITAKER 76                                3/77*
M    W  INCREASED 4 MEV BY FELDMAN 76 TO CORRECT FOR ENERGY CALIBRATION.
M   S   VERNON 76 IS SUPERCEDED BY BIDDICK 77                                 3/77*
M          . . . . . . . . . .
M   AVG    3510.0      4.3    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M   STUDENT3510.1      4.7    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

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                      55  PC PARTIAL DECAY MODES

                                                          DECAY MASSES
P1      PC INTO J/PSI(3100) GAMMA                        3098+   0
P2      PC INTO PI+ PI-                                   139+ 139
P3      PC INTO K+ K-                                     493+ 493
P4      PC INTO GAMMA GAMMA
P5      PC INTO 2(PI+ PI-)                                139+ 139+ 139+ 139
P6      PC INTO 3(PI+ PI-)
P7      PC INTO PI+ PI- K+ K-                             139+ 139+ 493+ 493
P8      PC INTO PI+ PI- P PBAR                            139+ 139+ 938+ 938
P9      PC INTO RHO0 PI+ PI-                              773+ 139+ 139
P10     PC INTO K*(892)0 K+/- PI-/+                       892+ 493+ 139

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                      55  PC BRANCHING RATIOS

R       SEE ALSO BRANCHING RATIOS R60 OF PSI(3685)

R1      PC INTO (J/PSI(3100) GAMMA)/TOTAL
R1  D       DOMINANT                 DASP      75 DASP        E+E-            1/76
R1  T        (.26)                   TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*
R1  D   USING THE UPPER LIMITS OF SIMPSON 75
R1  T   ESTIMATED USING PSI(3685) TO (GAMMA PC)/TOTAL=.09

R2      PC INTO (PI+PI- AND K+K-)/TOTAL
R2         NOT SEEN                  FELDMAN   75 SMAG        E+E-            1/76
R2  T      LESS THAN .002            TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

R3      PC INTO (GAMMA GAMMA)/TOTAL
R3         (0.0030)OR LESS  CL=0.90  BRAUNSCHW 77 DASP    E+E-,3 GAMMA        1/77*

R4      PC INTO 2(PI+ PI-)/TOTAL
R4  T        (.012)                  TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

R5      PC INTO (PI+ PI- K+ K-)/TOTAL
R5  T        (.007)                  TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

R6      PC INTO 3(PI+ PI-)/TOTAL
R6  T        (.019)                  TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

R7      PC INTO (PI+ PI- P PBAR)/TOTAL
R7  T        (.001)                  TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

R8      PC INTO (RHO0 PI+ PI-)/2(PI+ PI-)
R8            .24       .20          TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

R9      PC INTO (K*(892)0 K+/- PI-/+)/(PI+ PI- K+ K-)
R9            .35       .18          TRILLING  76 SMAG PSI(3685) TO GAM PC    1/77*

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                         REFERENCES FOR PC

DASP     75 PL 57B 407          BRAUNSCHWEIG,KONIGS,+ (AACH+DESY+MPIM+TOKY)
FELDMAN  75 STANFORD SYMP.39    G.J.FELDMAN                            (SLAC)
HEINTZE  75 STANFORD SYMP.97    J.HEINTZE                        (HEIDELBERG)
SIMPSON  75 PRL 35 699          +BERON,FORD,HILGER,HOFSTADTER,+ (STAN+PENN)
TANENBAU 75 PRL 35 1323         TANENBAUM,WHITAKER,ABRAMS,+       (LBL+SLAC)
WIIK     75 STANFORD SYMP.69    B.H.WIIK                               (DESY)

BARTEL   76 TBILISI CONF.N56    +DUINKER,OLSSON,HEINTZE,+         (DESY+HEID)
FELDMAN  76  SLAC-PUB-1851      G.J.FELDMAN                        (SLAC+LBL)
TRILLING 76 STANFORD SYMP.437   G. H. TRILLING                          (LBL)
VERNON   76 TBILISI CONF.N63    W.VERNON        (UMD+PAVI+PRIN+UCSD+SLAC+STAN)
WHITAKER 76 PRL 37 1596         +TANENBAUM,ABRAMS.ALAM,BOYARSKI,+(SLAC+LBL)
WIIK     76 TBILISI CONF.N75    B.H.WIIK RAPPORTEUR                    (DESY)

BIDDICK  77 PRINT-77-0244UCSD   +BURNETT+       (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BRAUNSCH 77  DESY 77/03         BRAUNSCHWEIG,+    (AACH+DESY+HAMB+MPIM+TOKY)
WIIK     77  DESY 77/01         +WOLF                                  (DESY)

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$\chi(3550)$

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57  CHI(3550,JPG=  +) I=0

          OBSERVED IN RADIATIVE DECAY OF PSI(3685) INTO
   CHI(3550) GAMMA. THEREFORE C=+. THE OBSERVED DECAY INTO 4PI
   AND 6PI IMPLY G=+, THUS I=0.
   J=0 IS EXCLUDED BY THE ANGULAR DISTRIBUTION IN THE HADRONIC
   DECAYS (FELDMAN 76)

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                      57  CHI(3550) MASS (MEV)

M          3550.0     10.0            TRILLING  76 SMAG   E+E-,HADRONS GAM    1/77*
M        4 3543.0     10.0            WHITAKER  76 SMAG   E+E-,J/PSI 2 GAM    1/77*
M   Q     (3561.0)    (7.0)           VERNON    76 CNTR   E+E-,MONOCHR.GAM    1/77*
M          3561.0      7.0            BIDDICK   77 CNTR   E+E-,MONOCHR.GAM    3/77*
M   Q   VERNON 76 IS SUPERCEDED BY BIDDICK 77                                 3/77*
M          . . . . . . . . . .
M   AVG    3553.8      5.4    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.1)
M   STUDENT3553.8      5.9    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

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                      57  CHI(3550) PARTIAL DECAY MODES

                                                          DECAY MASSES
P1      CHI(3550) INTO PI+ PI-                            139+ 139
P2      CHI(3550) INTO K+ K-                              493+ 493
P3      CHI(3550) INTO 2(PI+ PI-)                         139+ 139+ 139+ 139
P4      CHI(3550) INTO 3(PI+ PI-)
P5      CHI(3550) INTO PI+ PI- K+ K-                      139+ 139+ 493+ 493
P6      CHI(3550) INTO J/PSI(3100) GAMMA                 3095+   0
P7      CHI(3550) INTO 2 GAMMA
P8      CHI(3550) INTO PI+ PI- P PBAR                     139+ 139+ 938+ 938
P9      CHI(3550) INTO RHO0 PI+ PI-                       773+ 139+ 139
P10     CHI(3550) INTO K*(892)0 K+/- PI-/+                892+ 493+ 139

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                      57  CHI(3550) BRANCHING RATIOS

R       SEE ALSO BRANCHING RATIOS R58 OF PSI(3685)

R1       CHI(3550) INTO (2 GAMMA)/TOTAL
R1         (0.0025)OR LESS  CL=0.90  BRAUNSCHW 77 DASP    E+E-,3 GAMMA        1/77*

R2      CHI(3550) INTO 2(PI+ PI-)/TOTAL
R2  T        (.02)                   TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*
R2  T   ESTIMATED USING PSI(3685) TO (GAMMA CHI(3550))/TOTAL=.08              1/77*

R3      CHI(3550) INTO (PI+ PI- K+ K-)/TOTAL
R3  T        (.016)                  TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

R4      CHI(3550) INTO 3(PI+ PI-)/TOTAL
R4  T        (.01)                   TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

R5      CHI(3550) INTO (PI+ PI- AND K+ K-)/TOTAL
R5  T        (.002)                  TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

R6      CHI(3550) INTO (PI+ PI- P PBAR)/TOTAL
R6  T        (.002)                  TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

R7      CHI(3550) INTO (J/PSI(3100) GAMMA)/TOTAL
R7  T        (.12)                   TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

R8      CHI(3550) INTO (RHO0 PI+ PI-)/2(PI+ PI-)
R8            .21       .17          TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

R9      CHI(3550) INTO (K*(892)0 K+/- PI-/+)/(PI+ PI- K+ K-)
R9            .25       .13          TRILLING  76 SMAG PSI(3685)TO GAM CHI    1/77*

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                       REFERENCES FOR CHI(3550)

FELDMAN  75 PRL 35 821          +JEAN-MARIE,SADOULET,VANNUCCI,+   (LBL+SLAC)
    ALSO 75 PRL 35 1189  (ERRATA)
TANENBAU 75 PRL 35 1323         TANENBAUM,WHITAKER,ABRAMS,+       (LBL+SLAC)

FELDMAN  76  SLAC-PUB-1851      G.J.FELDMAN                        (SLAC+LBL)
PIERRE   76  LBL-5324           F.PIERRE                           (SLAC+LBL)
TRILLING 76 STANFORD SYMP.437   G. H. TRILLING                          (LBL)
VERNON   76 TBILISI CONF.N63    W.VERNON        (UMD+PAVI+PRIN+UCSD+SLAC+STAN)
WHITAKER 76 PRL 37 1596         +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)
WIIK     76 TBILISI CONF.N75    B.H.WIIK RAPPORTEUR                    (DESY)

BIDDICK  77 PRINT-77-0244UCSD   +BURNETT+       (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BRAUNSCH 77  DESY 77/03         BRAUNSCHWEIG,+    (AACH+DESY+HAMB+MPIM+TOKY)
WIIK     77  DESY 77/01         +WOLF                                  (DESY)

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$\psi(3685)$

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71  PSI(3685,JPG=1--) I=0

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                      71  PSI(3685) MASS (MEV)

M   L     (3695.)     (4.)            ABRAMS    74 SMAG          E+E-         2/75
M  S       3680.3     37.             CRIEGEE   75 PLUT          E+E-         2/75
M          3684.       5.             LUTH      75 SMAG          E+E-         1/76
M          3684.       9.             PREPOST   75 SPEC    21. GAMMA C        1/76
M
M   L   LUTH 75 IS A REEVALUATION OF ABRAMS 74.                               2/75
M   S   ERROR OF ABOUT 1 PER CENT FROM THE UNCERTAINTY IN CALIBRATION OF      2/75
M   S   THE BEAM ENERGY.                                                      2/75
M          . . . . . . . . . .
M   AVG    3683.9      4.3    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
M   STUDENT3683.9      4.7    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

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DM                 PSI(3685) - J/PSI(3100) MASS DIFFERENCE (MEV)

DM          588.7       .8            LUTH      75 SMAG

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                      71  PSI(3685) WIDTH (KEV)

W           228.       56.            LUTH      75 SMAG

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                      71  PSI(3685) PARTIAL DECAY MODES

                                                          DECAY MASSES
P1      PSI(3685) INTO E+ E-                               .5+ .5
P2      PSI(3685) INTO MU+ MU-                            105+ 105
P3      PSI(3685) INTO HADRONS
P4      PSI(3685) INTO VIRTUAL GAMMA INTO HADRONS
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ψ(3685)

Data Card Listings

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P       DECAYS INTO J/PSI(3100) + ANYTHING
P       -------------------------------
P11     PSI(3685) INTO J/PSI(3100) + ANYTHING
P12     PSI(3685) INTO J/PSI(3100) + NEUTRALS
P13     PSI(3685) INTO J/PSI(3100) PI+ PI-                      3098+ 139+ 139
P14     PSI(3685) INTO J/PSI(3100) PIO PIO                      3098+ 134+ 134
P15     PSI(3685) INTO J/PSI(3100) ETA                          3098+ 548
P16     PSI(3685) INTO J/PSI(3100) GAMMA GAMMA

P       HADRONIC DECAYS
P       ---------------
P21     PSI(3685) INTO PI+ PI-
P22     PSI(3685) INTO RHO PI
P23     PSI(3685) INTO K+ K-
P24     PSI(3685) INTO 2(PI+ PI-)
P25     PSI(3685) INTO 2(PI+ PI-) PIO
P26     PSI(3685) INTO PI+ PI- K+ K-
P27     PSI(3685) INTO PBAR P
P28     PSI(3685) INTO LAMBDA ANTILAMBDA
P29     PSI(3685) INTO XI ANTIXI

P       RADIATIVE DECAYS
P       ----------------
P51     PSI(3685) INTO GAMMA GAMMA
P52     PSI(3685) INTO PIO GAMMA
P53     PSI(3685) INTO ETA GAMMA
P54     PSI(3685) INTO ETA PRIME GAMMA
P55     PSI(3685) INTO X(2830) GAMMA                            2830+   0
P56     PSI(3685) INTO CHI(3415) GAMMA                          3413+   0
P57     PSI(3685) INTO CHI(3455) GAMMA                          3454+   0
P58     PSI(3685) INTO PC(3510) GAMMA                           3510+   0
P59     PSI(3685) INTO CHI(3550) GAMMA                          3554+   0
P60     PSI(3685) INTO PC(3510) + ANYTHING
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FITTED PARTIAL DECAY MODE BRANCHING FRACTIONS

The matrix below is derived from the error matrix for the fitted partial decay mode branching fractions, P_i, as follows: The diagonal elements are $P_i \pm \delta P_i$, where $\delta P_i = \sqrt{\langle \delta P_i \delta P_i \rangle}$, while the off-diagonal elements are the normalized correlation coefficients $\langle \delta P_i \delta P_j \rangle / (\delta P_i \cdot \delta P_j)$. For the definitions of the individual P_i, see the listings above; only those P_i appearing in the matrix are assumed in the fit to be nonzero and are thus constrained to add to 1.

	$J/\psi\,\pi^+\pi^-$	$J/\psi\,\pi^0\pi^0$	$J/\psi\,\eta$	J/ψ+OTHER	NON-J/ψ
$J/\psi\,\pi^+\pi^-$	.3289+-.0251				
$J/\psi\,\pi^0\pi^0$	.4707	.1734+-.0178			
$J/\psi\,\eta$	-.0216	-.0102	.0416+-.0071		
J/ψ+OTHER	.2593	-.4156	-.1526	.0334+-.0258	
NON-J/ψ	-.9014	-.4243	-.0537	-.5365	.4227+-.0445

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                    71  PSI(3685) PARTIAL WIDTHS (KEV)

W1      PSI(3685) INTO E+ E-                              (G1)                2/75
W1            2.1        .3            LUTH        75 SMAG          E+E-       1/76

W3      PSI(3685) INTO HADRONS                            (G3)
W3            224.       56.           LUTH        75 SMAG          E+E-       1/76
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                    71  PSI(3685) BRANCHING RATIOS

R1      PSI(3685) INTO (E+ E-)/TOTAL
R1 L          .0093      .0016         LUTH        75 SMAG          E+E-       1/76
R1 L     FROM AN OVERALL FIT ASSUMING EQUAL PARTIAL WIDTHS FOR (E+E-)
R1 L     AND (MU+MU-). FOR A MEASUREMENT OF THE RATIO SEE THE ENTRY R4 BELOW

R2      PSI(3685) INTO (MU+ MU-)/TOTAL
R2 H          .0077      .0017         HILGER      75 SPEC          E+E-       1/76
R2 H     RE-STATED BY US USING (J/PSI(3100)+ANYTHING)/TOTAL =0.55

R3      PSI(3685) INTO (HADRONS)/TOTAL
R3    P       .981       .003          LUTH        75 SMAG          E+E-       1/76
R3    P  INCLUDES CASCADE DECAY INTO J/PSI(3100)                               4/77*

R4      PSI(3685) INTO (MU+ MU-)/(E+ E-)
R4           (.89)      (.16)          BOYARSKI    75 SMAG          E+E-       1/76

R5      PSI(3685) INTO (GAMMA INTO HADRONS)/TOTAL
R5 C          .029       .004          LUTH        75 SMAG          E+E-       1/76
R5 C     INCLUDED IN R3


R       DECAYS INTO J/PSI(3100) + ANYTHING
R       -------------------------------

R10     PSI(3685) INTO (J/PSI(3100) + ANYTHING)/TOTAL
R10           .57        .08           ABRAMS      75 SMAG          E+E-       1/76
R10         . . . . . . . . . .
R10 FIT      0.577      0.044   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R11     PSI(3685) INTO (J/PSI(3100) + NEUTRALS)/(J/PSI(3100) + ANYTHING)
R11           .41        .02           TANENBAUM 76 SMAG            E+E-       2/76
R11         . . . . . . . . . .
R11 FIT      0.410      0.020   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R12     PSI(3685) INTO (J/PSI(3100) PI+ PI-)/TOTAL
R12           .32        .04           ABRAMS1     75 SMAG          E+E-       1/76
R12           .36        .06           WIIK        75 DASP          E+E-       1/76
R12         . . . . . . . . . .
R12 AVG      0.332      0.033    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R12 STUDENT  0.332      0.036    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT
R12 FIT      0.329      0.025   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R13     PSI(3685) INTO (J/PSI(3100) PIO PIO)/TOTAL
R13          0.17       0.029          ABRAMS1     75 SMAG          E+E-       1/77*
R13           .18        .06           WIIK        75 DASP          E+E-       1/76
R13         . . . . . . . . . .
R13 AVG      0.172      0.026    AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R13 STUDENT  0.172      0.028    AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT
R13 FIT      0.173      0.018   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R14     PSI(3685) INTO (J/PSI(3100) PIO PIO)/(J/PSI(3100) PI+ PI-)
R14 H        (.64)      (.15)          HILGER      75 SPEC          E+E-       1/76
R14          0.53       0.06           TANENBAUM 76 SMAG            E+E-       1/77*
R14 H    IGNORING THE (J/PSI ETA) AND (J/PSI GAMMA GAMMA) DECAYS
R14         . . . . . . . . . .
R14 FIT      0.527      0.050   FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R15     PSI(3685) INTO (J/PSI(3100) ETA)/TOTAL
R15           .043       .008          TANENBAUM 76 SMAG            E+E-       1/76
R15           .037       .015          WIIK        75 DASP          E+E-       1/76
R15         . . . . . . . . . .
R15 AVG      0.0417     0.0071   AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R15 STUDENT  0.0417     0.0076   AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT
R15 FIT      0.0416     0.0071 FROM FIT (ERROR INCLUDES SCALE FACTOR OF 1.0)

R16     PSI(3685) INTO (J/PSI(3100) GAMMA OR J/PSI(3100) PIO)/TOTAL
R16          (.0015)OR LESS CL=.90     TANENBAUM 76 SMAG            E+E-       2/76


R       HADRONIC DECAYS
R       ---------------

R20     PSI(3685) INTO (PI+ PI-)/TOTAL   (UNITS 10**-4)
R20        (3.7)   OR LESS  CL=0.90   BRAUNSCHW 76 DASP            E+E-       1/77*
R20        (0.5)   OR LESS  CL=0.90   FELDMAN   76 SMAG            E+E-       1/77*

R21     PSI(3685) INTO (RHO0 PIO)/TOTAL
R21          (.001)OR LESS  CL=.90    ABRAMS     75 SMAG            E+E-       1/76

R22     PSI(3685) INTO (2(PI+ PI-) PIO)/TOTAL
R22           .0035      .0015         ABRAMS     75 SMAG            E+E-       1/76

R23     PSI(3685) INTO (K+ K-)/TOTAL   (UNITS 10**-4)
R23      2  (14.)    OR LESS  CL=0.90   BRAUNSCHW 76 DASP            E+E-       1/77*
R23         (0.5)    OR LESS  CL=0.90   FELDMAN   76 SMAG            E+E-       1/77*

R24     PSI(3685) INTO (PI+ PI- K+ K-)/TOTAL
R24         (0.0014) (0.0004)          PIERRE 1   76 SMAG            E+E-       1/77*

R25     PSI(3685) INTO (PBAR P)/TOTAL   (UNITS 10**-4)
R25         (4.7)   OR LESS  CL=0.90   BRAUNSCHW 76 DASP            E+E-       1/77*
R25         (2.3)      (0.7)           FELDMAN   76 SMAG            E+E-       1/77*

R26     PSI(3685) INTO (RHO PI)/TOTAL
R26         (0.001)OR LESS  CL=0.90    BARTEL 1   76 CNTR            E+E-       1/77*

R27     PSI(3685) INTO 2(PI+PI-)/TOTAL
R27         (0.0008) (0.0002)          PIERRE 1   76 SMAG            E+E-       1/77*

R28     PSI(3685) INTO (LAMBDA ANTILAMBDA)/TOTAL
R28         (0.0004)OR LESS            FELDMAN    76 SMAG            E+E-       1/77*

R29     PSI(3685) INTO (XI- ANTIXI-)/TOTAL
R29         (0.0002)                   FELDMAN    76 SMAG            E+E-       1/77*


R       RADIATIVE DECAYS
R       ----------------

R41     PSI(3685) INTO (GAMMA GAMMA)/TOTAL
R41  U       (.005)OR LESS  CL=.95    HUGHES     75 SPEC            E+E-       1/76
R41          (.008)OR LESS  CL=.90    WIIK       75 DASP            E+E-       1/76

R42     PSI(3685) INTO (PIO GAMMA)/TOTAL
R42  U       (.007)OR LESS  CL=.95    HUGHES     75 SPEC            E+E-       1/76
R42          (.01) OR LESS  CL=.90    WIIK       75 DASP            E+E-       1/76

R43     PSI(3685) INTO (ETA GAMMA)/TOTAL (UNITS 10**-2)
R43  U       (1.8)  OR LESS  CL=.95   HUGHES     75 SPEC            E+E-       1/76
R43  A       (0.04) OR LESS  CL=.95    9 4   86  77 DASP            E+E-
R43  U  RE-STATED BY US USING (MU+MU-)/TOTAL = .0077
R43  A   RESTATED BY US USING TOTAL DECAY WIDTH 228 KEV.

R44     PSI(3685) INTO (ETA PRIME GAMMA)/TOTAL (UNITS 10**-2)
R44          (0.11) OR LESS  CL=0.90  BARTEL 1   76 CNTR            E+E-       1/77*
R44  A       (0.6)  OR LESS  CL=0.90  BRAUNSCHW 77 DASP            E+E-       1/77*
R44  A   RESTATED BY US USING TOTAL DECAY WIDTH 228 KEV.

R53     PSI(3685) INTO (X(2830) GAMMA)/TOTAL (UNITS 10**-2)
R53 S        (5.0)  OR LESS  CL=0.90  BADTKE     76 CNTR            E+E-       1/77*
R53          (1.1)  OR LESS  CL=0.90  WHITAKER   76 SMAG            E+E-       4/77*
R53          (1.0)  OR LESS  CL=0.90  BIDDICK    77 CNTR            E+E-       3/77*
R53 S   BADTKE 76 IS SUPERCEDED BY BIDDICK 77                                  3/77*

R54     PSI(3685) INTO (X(2830) GAMMA)/TOTAL (UNITS 10**-2)
R54                     X(2830) INTO CHANNEL SPECIFIED IN COMMENTS
R54          (0.3)  OR LESS  CL=0.95  HUGHES     75 SPEC    X TO (2 GAMMA)     1/76
R54          (0.034)OR LESS  CL=0.90  BRAUNSCHW 77 DASP    X TO (2 GAMMA)     1/77*
R54          (0.042)OR LESS  CL=0.90  BARTEL 2   76 CNTR    X TO (RHO GAMMA)   1/77*

R55     PSI(3685) INTO (CHI(3415) GAMMA)/TOTAL  (UNITS 10**-2)
R55  A        7.5        2.6           WHITAKER   76 SMAG          E+E-        1/77*
R55 QA       (8.)       (3.)           VERNON     76 CNTR    E+E-,MONOCHR.GAM  1/77*
R55  A        7.2        2.3           BIDDICK    77 CNTR    E+E-,MONOCHR.GAM  3/77*
R55  A  ANGULAR DISTRIBUTION (1+COS**2) ASSUMED
R55 Q   VERNON 76 IS SUPERCEDED BY BIDDICK 77                                  3/77*
R55         . . . . . . . . . .
R55 AVG       7.3        1.7      AVERAGE (ERROR INCLUDES SCALE FACTOR OF 1.0)
R55 STUDENT   7.3        1.8      AVERAGE USING STUDENT10(H/1.11) -- SEE 1976 TEXT

R56     PSI(3685) INTO (CHI(3415) GAMMA)/TOTAL  (UNITS 10**-2)
R56                     CHI(3415) INTO CHANNEL SPECIFIED IN COMMENTS
R56      1   (0.2)      (0.2)          WHITAKER  76 SMAG CHI TO(J/PSI GAMMA)   1/77*
R56      1   (1.0)                     WIIK      76 DASP CHI TO(J/PSI GAMMA)   4/77*
R56          (3.3)      (1.7)          BIDDICK   77 CNTR CHI TO(J/PSI GAMMA)   3/77*
R56          (0.04) OR LESS  CL=0.90   BRAUNSCHW 77 DASP CHI TO (2 GAMMA)      1/77*
R56          (0.07)     (0.02)         PIERRE 2  76 SMAG CHI TO (K+K-)         1/77*
R56          (0.07)     (0.02)         PIERRE 2  76 SMAG CHI TO (PI+PI-)       1/77*
R56          (0.12)     (0.04)         PIERRE 1  76 SMAG CHI TO (PI+PI-RHO0)   1/77*
R56          (0.17)     (0.08)         PIERRE 1  76 SMAG CHI TO (PI+K-K*0)     1/77*
R56          (0.32)     (0.06)         PIERRE 2  76 SMAG CHI TO 2(PI+PI-)      1/77*
R56          (.04)      (.013)         TRILLING  76 SMAG CHI TO(PI+PI-PBARP)   1/77*
R56          (0.27)     (0.07)         PIERRE 2  76 SMAG CHI TO (K+K-PI+PI-)   1/77*
R56          (0.14)     (0.05)         PIERRE 2  76 SMAG CHI TO 3(PI+PI-)      1/77*

R57     PSI(3685) INTO (CHI(3550) GAMMA)/TOTAL  (UNITS 10**-2)
R57 QB       (8.)       (3.)           VERNON     76 CNTR    E+E-,MONOCHR.GAM  1/77*
R57  B        7.0        2.0           BIDDICK    77 CNTR    E+E-,MONOCHR.GAM  3/77*
R57  B  VALID FOR ISOTROPIC DISTRIBUTION OF THE PHOTON
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Data Card Listings

$\psi(3685)$, $\psi(4030)$, $\psi(4415)$

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R58     PSI(3685) INTO (CHI(3550) GAMMA)/TCTAL   (UNITS 10**-2)
R58                        CHI(3550) INTO CHANNEL SPECIFIED IN COMMENTS
R58           (1.0)      (.6)               TRILLING  76 SMAG CHI TO(J/PSI GAMMA)  1/77*
R58           (2.2)      (1.0)              BIDDICK   77 CNTR CHI TO(J/PSI GAMMA)  3/77*
R58            (.02) OR LESS  CL=0.90       BRAUNSCHW 77 DASP CHI TO (2 GAMMA)     1/77*
R58           (0.023)  (0.013)              PIERRE 2  76 SMAG CHI TO (PI+PI-,K+K-  1/77*
R58           (0.050)  (0.030)              PIERRE 1  76 SMAG CHI TO (PI+PI-RHOO   1/77*
R58           (0.053)  (0.030)              PIERRE 1  76 SMAG CHI TO (PI+K-K*0)    1/77*
R58           (0.16)   (0.04)               PIERRE 2  76 SMAG CHI TO 2(PI+PI-)     1/77*
R58            (.002)   (.001)              TRILLING  76 SMAG CHI TO(PI+PI-PBARP)  1/77*
R58           (0.14)   (0.04)               PIERRE 2  76 SMAG CHI TO (PI+PI-K+K-)  1/77*
R58            (.008)   (.005)              TRILLING  76 SMAG CHI TO 3(PI+ PI-)    1/77*

R59     PSI(3685) INTO (PC(3510) GAMMA)/TCTAL   (UNITS 10**-2)
R59 QB        (9.)       (3.)               VERNON    76 CNTR    E+E-,MONOCHR.GAM  1/77*
R59  B         7.1        1.9               BIDDICK   77 CNTR    E+E-,MUNOCHR.GAM  3/77*
R59  B  VALID FOR ISOTROPIC DISTRIBUTION CF THE PHCTON

R60     PSI(3685) INTO (PC(3510) GAMMA)/TOTAL   (UNITS 10**-2)
R60                        PC(3510) INTO CHANNEL SPECIFIED IN COMMENTS
R60           (4.0)      (2.0)              WIIK      75 DASP PC TO (J/PSI GAMMA)  1/77*
R60           (2.4)      (.8)               TRILLING  76 SMAG PC TO (J/PSI GAMMA)  1/77*
R60           (5.0)      (1.5)              BIDDICK   77 CNTR PC TO (J/PSI GAMMA)  3/77*
R60            (.026)OR LESS  CL=0.90       BRAUNSCHW 77 DASP PC TC (2 GAMMA)      1/77*
R60           (0.015)CR LESS  CL=0.90       PIERRE 2  76 SMAG PC TO (PI+PI-,K+K-)  1/77*
R60           (0.026)  (0.022)              PIERRE 1  76 SMAG PC TC (PI+PI-RHOO))  1/77*
R60           (0.032)  (0.019)              PIERRE 1  76 SMAG PC TO (PI+K-K*0)     1/77*
R60           (0.11)   (0.04)               PIERRE 2  76 SMAG PC TO 2(PI+PI-)      1/77*
R60            (.01)    (.008)              TRILLING  76 SMAG PC TC (PI+PI-PBARP)  1/77*
R60           (0.06)   (0.03)               PIERRE 2  76 SMAG PC TO (PI+PI-K+K-)   1/77*
R60            (.17)    (.06)               TRILLING  76 SMAG PC TC 3(PI+ PI-)     1/77*

R61     PSI(3685) INTC (CHI(3455) GAMMA)/TOTAL   (UNITS 10**-2)
R61 SB        (5.)   OR LESS  CL=0.90       BADTKE    76 CNTR          E+E-        1/77*
R61  B        (2.5)  OR LESS  CL=0.90       BIDDICK   77 CNTR          E+E-        3/77*
R61  B  VALID FOR ISOTROPIC DISTRIBUTION OF THE PHOTON
R61 S   BADTKE 76 IS SUPERCEDED BY BIDDICK 77                                      3/77*

R62     PSI(3685) INTC (CHI(3455) GAMMA)/TCTAL   (UNITS 10**-2)
R62                        CHI(3455) INTO CHANNEL SPECIFIED IN COMMENTS
R62       4   (0.8)      (0.4)              TRILLING  76 SMAG CHI TO(J/PSI GAMMA)  1/77*
R62           (0.031)OR LESS  CL=0.90       BRAUNSCHW 77 DASP CHI TO (2 GAMMA)     1/77*

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                      71  PSI(3685)     G(I)*G(E+E-)/G(TOTAL)  (KEV)

        THIS COMBINATION OF A PARTIAL WIDTH WITH THE PARTIAL WIDTH
        INTC E+E- AND WITH THE TCTAL WIDTH IS OBTAINED FROM THE INTEGRATED
        CROSS-SECTION INTO CHANNEL(I) IN THE E+E- ANNIHILATION.
        WE CNLY LIST DATA NOT HAVING BEEN USED TO DETERMINE THE PARTIAL
        WIDTH G(I) CR THE BRANCHING RATIC G(I)/TCTAL.

G3      G(HADRONIC)*G(E+E-)/G(TCTAL)
G3              2.2        .4               ABRAMS    75 SMAG          E+E-        1/76

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                         REFERENCES FOR PSI(3685)

ABRAMS    74 PRL 33 1453          +BRIGGS,AUGUSTIN,BOYARSKI+          (LBL+SLAC)

ABRAMS    75 STANFORD SYMP.25     G.S.ABRAMS                               (LBL)
ABRAMS1   75 PRL 34 1181          +BRIGGS,CHINOWSKY,FRIEDBERG,+       (LBL+SLAC)
AUBERT    75 PRL 33 1624          +BECKER,BIGGS,BURGER,GLENN+          (MIT+BNL)
BOYARSKI  75 PALERMO CONF. 54     +BREIDENBACH,BULCS,ABRAMS,BRIGGS+(SLAC+LBL)
CAMERINI  75 PRL 35 483           +LEARNED,PREPOST,ASH,ANDERSON,+ (WISC+SLAC)
CRIEGEE   75 PL 53B 489           +DEHNE,FRANKE,HCRLITZ,KRECHLOCK+       (DESY)
DASP3     75 PL 57B 407           BRAUNSCHWEIG,KCNIGS,+ (AACH+DESY+MPIM+TOKY)
FELDMAN   75 PRL 35 821           +JEAN-MARIE,SADOULET,VANNUCCI,+   (LBL+SLAC)
FELDMAN1  75 STANFORD SYMP.39     G.J.FELDMAN                             (SLAC)
GRECO     75 PL 56B 367           +PANCHERI-SRIVASTAVA,SRIVASTAVA         (FRAS)
HEINTZE   75 STANFORD SYMP.97     J.HEINTZE                         (HEIDELBERG)
JACKSON   75 NIM 128 13           J.D.JACKSON,C.SCHARRE                    (LBL)
HILGER    75 PRL 35 625           +BERON,FORD,HOFSTADTER,HOWELL,+ (STAN+PENN)
HUGHES    75  PREP.HEPL 765       +BERON,CARRINGTON,FORD,HILGER,+ (STAN+PENN)
LUTH      75 PRL 35 1124          +BOYARSKI,LYNCH,BREIDENBACH,+     (SLAC+LBL)JPC
LIBERMAN  75 STANFORD SYMP.55     A.D.LIBERMAN                        (STANFORD)
PREPOST   75 STANFORD SYMP.241    R.PREPOST                          (WISCONSIN)
SIMPSON   75 PRL 35 699           +BERON,FORD,HILGER,HCFSTADTER,+ (STAN+PENN)
TANENBAU  75 PRL 35 1323          TANENBAUM,WHITAKER,ABRAMS,+       (LBL+SLAC)
WIIK      75 STANFORD SYMP.69     B.H.WIIK                                (DESY)

BADTKE    76  PREPRINT            +BARNETT,+    (UMD+PAVI+PRIN+UCSD+SLAC+STAN)
BARTEL 1  76 PL 64 B 483          +DUINKER,OLSSCN,STEFFEN,HEINTZE+(DESY+HEID)
BARTEL 2  76 TBILISI CONF.N56     +DUINKER,OLSSON,HEINTZE,+         (DESY+HEID)
BRAUNSCH  76 PL 63 B 487          BRAUNSCHWEIG,+    (AACH+DESY+HAMB+MPIM+TOKY)
FELDMAN   76  SLAC-PUB-1851       G.J.FELDMAN                         (SLAC+LBL)
PIERRE 1  76  LBL-5324            F.PIERRE                            (SLAC+LBL)
PIERRE 2  76 TBILISI CONF.N46     F.PIERRE                       (SLAC+LBL+SACL)
PIERRE 3  76 SACLAY-DPHPE76-21    F.PIERRE                            (SLAC+LBL)
SNYDER    76 PRL 36 1415          +HOM,LEDERMAN,PAAR,APPEL,+ (COLU+FNAL+STON)
TANENBAU  76 PRL 36 402           TANENBAUM,ABRAMS,BCYARSKI,BULOS,+(SLAC+LBL)IG
TRILLING  76 STANFORD SYMP.437    G. H. TRILLING                           (LBL)
VERNON    76 TBILISI CONF.N63     W.VERNON      (UMD+PAVI+PRIN+UCSD+SLAC+STAN)
WHITAKER  76 PRL 37 1596          +TANENBAUM,ABRAMS,ALAM,BOYARSKI,+(SLAC+LBL)
WIIK      76 TBILISI CONF.N75     B.H.WIIK RAPPORTEUR                     (DESY)

BIDDICK   77 PRINT-77-0244UCSD    +BURNETT+     (UCSD+UMD+PAVI+PRIN+SLAC+STAN)
BRAUNSCH  77  DESY 77/03          BRAUNSCHWEIG,+    (AACH+DESY+HAMB+MPIM+TOKY)
WIIK      77  DESY 77/01          +WCLF                                   (DESY)

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$\psi(4030)$

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                  72  PSI(4030,JPG=1- ) I=

                  SEEN AS A NARROW PEAK IN E+E- INTO HADRONS.  SEE
        CHARMONIUM MINI-REVIEW.  NEEDS CCNFIRMATICN.  NO EXPERIMENTAL
        ATTEMPT HAS BEEN MADE TO IDENTIFY SPECIFIC STATES IN THE
        4000-4300 GEV REGION.  THE NUMBER CF C ANC C* MESONS SEEN
        ASSOCIATED WITH THIS REGICN IS LARGER THAN EXPECTED FOR A MERE
        CHARMED PARTICLE PRODUCTION THRESHOLD EFFECT, SUGGESTING
        RESONANCE INTERPRETATICN FOR AT LEAST PART OF THE DATA.  OMITTED
        FROM TABLE.

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                  72  PSI(4030) MASS (MEV)

M          (4030.)                  PERUZZI   76 SMAG          E+E-        1/77*

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                  72  PSI(4030) PARTIAL DECAY MCDES

                                                             DECAY MASSES
P1      PSI(4030) INTC  D DBAR
P2      PSI(4030) INTO  D* DBAR AND D*BAR D
P3      PSI(4030) INTC  D* D*BAR
P4      PSI(4030) INTO J/PSI(3100) HADRCNS

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                  72  PSI(4030) BRANCHING RATIOS

R1      PSI(4030) INTO (D D*)/TOTAL                          (P2)
R1          SEEN                    PERUZZI   76 SMAG          E+E-        1/77*

R2      PSI(4030) INTO J/PSI(3100) HADRONS                   (P4)
R2          LOOKED FCR              BURMESTER 77 PLUT          E+E-        4/77*

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                         REFERENCES FOR PSI(4030)

AUGUSTIN 75 PRL 34 764         +BCYARSKI,ABRAMS,BRIGGS+           (SLAC+LBL)
BACCI    75 PL 58B 481         +BIDOLI,PENSO,STELLA,+             (ROMA+FRAS)
BOYARSKI 75 PRL 34 762         +BREIDENBACH,ABRAMS,BRIGGS,+       (SLAC+LBL)
ESPCSITO 75 PL 58B 478         +FELICETTI,PERUZZI,+  (FRAS+NAPO+PADO+RCMA)
SCHWITTE 75 STANFORD SYMP.5    R.F.SCHWITTERS                         (SLAC)

FELDMAN  76  SLAC-PUB-1851     G.J.FELDMAN                        (SLAC+LBL)
PERUZZI  76 PRL 37 569         +PICCOLO,FELDMAN,NGUYEN,WISS,+     (SLAC+LBL)

BURMESTE 77 DESY 77/19         +CRIEGEE,DEHNE+          (DESY+HAMB+SIEG+WUPP)
WIIK     77  DESY 77/01        +WCLF                                  (DESY)

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$\psi(4415)$

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                  73  PSI(4415,JPG=1- ) I=

                  RESONANCE-SHAPED STRUCTURE IN E+E- INTO HADRONS.
        NUMBER OF STATES IN THIS REGION, ANC SPECIFIC DECAY MODES UNKNOWN.

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                  73  PSI(4415) MASS (MEV)

M          4414.       7.           SIEGRIST  76 SMAG          E+E-        2/76

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                  73  PSI(4415) WIDTH (MEV)

W            33.       10.          SIEGRIST  76 SMAG          E+E-        2/76

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                  73  PSI(4415) PARTIAL DECAY MCDES

                                                             DECAY MASSES
P1      PSI(4415) INTO E+ E-                                   .5+  .5

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                  73  PSI(4415) BRANCHING RATICS

R1      PSI(4415) INTO (E+ E-)/TOTAL (UNITS 10**-5)
R1            1.3       .3          SIEGRIST  76 SMAG          E+E-        2/76

R2      PSI(4415) INTO HADRONS/TOTAL
R2          DOMINANT                SIEGRIST  76 SMAG          E+E-        1/77*

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                         REFERENCES FOR PSI(4415)

SCHWITTE 75 STANFCRD SYMP.5    R.F.SCHWITTERS                         (SLAC)

FELDMAN  76  SLAC-PUB-1851     G.J.FELCMAN                        (SLAC+LBL)
SIEGRIST 76 PRL 36 700         +ABRAMS,BOYARSKI,BREIDENBACH,+     (LBL+SLAC)

WIIK     77  DESY 77/01        +WOLF                                  (DESY)

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HEAVY LEPTON SEARCHES AND EVIDENCE

This review is intended to summarize the recent experimental evidence for the existence of heavy leptons produced in e^+e^- collisions and the recent searches in neutrino and proton beams. For a more complete review up to 1974, see Perl and Rapidis.[1] See also the recent review of Llewellyn Smith.[2]

The known leptons are the electron and its neutrino (e^-, ν_e), the muon and its neutrino (μ^-, ν_μ), and their four antiparticles $(e^+, \bar{\nu}_e)$ and $(\mu^+, \bar{\nu}_\mu)$. Some of their properties are summarized in Table I.

TABLE I. Established leptons†

	Charge	Mass (MeV)	Lepton number	Interaction: weak	e.m.	strong
e^-	-	0.51100	$n_e = +1$	yes	yes	no
ν_e	0	~0(<0.00006)	$n_e = +1$	yes	no	no
μ^-	-	105.659	$n_\mu = +1$	yes	yes	no
ν_μ	0	~0(<0.65)	$n_\mu = +1$	yes	no	no

†For antileptons, $(e^+, \bar{\nu}_e)$ and $(\mu^+, \bar{\nu}_\mu)$, change sign of charge and lepton number.

All are spin-1/2 fermions. The lepton numbers n_e and n_μ are found experimentally to be separately conserved as is indicated by the absence (at a level $< 2.2 \times 10^{-8}$, ref. 3) of the decay $\mu \to e\gamma$. Experiments are now being carried out to test this at a lower level.

Several types of heavy leptons (that is non-strongly-interacting fermions other than those in Table I) have been proposed. For purposes of discussion we distinguish four types.[1,2] Each has a corresponding antiparticle with opposite charge and lepton number. For convenience we omit writing the antiparticles in the following descriptions. The four types are:

<u>Sequential Leptons (L^-, ν_L).</u> Such a pair is assumed to have its own separately strictly conserved lepton number $n_L = +1$. This means that the radiative decays

$$\left.\begin{array}{l} L^- \to e^- \gamma \\ L^- \to \mu^- \gamma \end{array}\right\} \text{ are forbidden}$$

while the weak decays (assuming m_{L^-} sufficiently massive)

$$\left.\begin{array}{l} L^- \to \nu_L e^- \bar{\nu}_e \\ L^- \to \nu_L \mu^- \bar{\nu}_\mu \\ L^- \to \nu_L \text{ hadrons} \end{array}\right\} \text{ are allowed .}$$

There could be an increasing mass sequence of such pairs. It is frequently assumed that the neutrinos are massless.

Decay rates are assumed calculable from conventional weak interactions theory. For L^- mass between 1 and 3 GeV, the branching fraction to each of the two leptonic modes should be roughly 10% to 20%. For L^- mass above 1 GeV, the mean life should be $\lesssim 10^{-12}$ sec, too short to be observed in a track chamber.[1]

<u>Paraleptons (E^+, E^0) and (M^+, M^0).</u> These pairs have the same lepton numbers as the opposite-charge ordinary leptons, i.e., e^- and μ^-, respectively. Radiative decays are again forbidden and decays similar to those allowed for L^- are allowed here, e.g.,

$$M^+ \to \nu_\mu e^+ \nu_e$$

$$\text{or} \quad M^+ \to \nu_\mu \mu^+ \nu_\mu \quad .$$

However, the lightest member is not stable as is the case for sequential leptons, so that bizarre decay schemes such as (assuming $m_{E^0} < m_{E^+}$)

$$E^+ \to E^0 \mu^+ \nu_\mu, \quad E^0 \to e^- e^+ \nu_e$$

are allowed.

Heavy leptons of this type (and/or a neutral intermediate boson Z^0) are desired in unified gauge theories of weak and electromagnetic interactions to cancel unphysical high energy behavior in such processes as $e^+e^- \to W^+W^-$.[4]

<u>Ortholeptons $(F^-$ and $N^-)$.</u> These have the same lepton numbers as e^- and μ^-, respectively. They may or may not have associated neutral leptons.

Radiative decays are allowed in addition to weak modes similar to those of sequential leptons. The radiative mode can dominate or can be relatively unimportant depending on the model.[5] Decays such as

$$F^- \to e^- + \text{hadrons}$$

are also allowed.

Long-lived Penetrating Particles. Heavy leptons could have long mean lives under certain circumstances. For example, if $m_{\nu_L} > m_{L^-}$, then L^-, the sequential lepton, is completely stable since its lepton number is conserved.

Experimental Results

Recent experimental efforts related to heavy leptons come primarily from e^+e^- experiments, neutrino beam experiments, and proton beam experiments.

e^+e^- colliding beam experiments provide a powerful tool for investigating heavy lepton hypotheses. Charged heavy leptons, regardless of type, are expected to be pair-produced via a massive virtual photon in e^+e^- collisions.

Strong evidence for the existence of a heavy lepton with mass in the range 1.6 - 2.0 GeV has been obtained. PERL 75-76, a SLAC SPEAR magnetic detector experiment, looks for anomalous $e\mu$ events of the form

$$e^+e^- \to e^\pm\mu^\mp + \text{missing momentum} \quad .$$

They find 105 examples after subtracting a 34 event background from hadron misidentification, weak decays of charmless hadrons, $e \to \mu$ misidentification, and other known sources. The missing momentum could include charged tracks or photons outside the acceptance of the detector, neutrons, K^o_L, or neutrinos. Electromagnetic processes (e.g., $e^+e^- \to e^+e^-\mu^+\mu^-$ with two missed charged tracks) can be ruled out by their calculated rates and by the absence of events with $e^+\mu^+$ and $e^-\mu^-$ pairs.

These events have no conventional explanation and signal the existence of an unknown process. Production and weak leptonic decay of a pair of charged heavy leptons (L) or charmed bosons (B) are obvious candidates for the process, e.g.,

$$e^+e^- \to L^+L^- \quad ; \quad L^- \to \nu_L\mu^-\bar{\nu}_\mu \ , \quad L^+ \to \bar{\nu}_L e^+\nu_e$$

or

$$e^+e^- \to B^+B^- \quad ; \quad B^- \to \mu^-\bar{\nu}_\mu \ , \quad B^+ \to e^+\nu_e \quad .$$

The charged-particle momentum spectrum strongly favors three-body decays and limits the mass of the undetected particles to less than 700 MeV (CL = 95%). An analysis of events with an $e^\pm\mu^\mp$ and photons, K^o_S, or additional charged tracks puts an upper limit of 39% (CL = 90%) on the fraction of the anomalous events which could have an undetected γ, π^o, K^o, η, or charged track. Thus if a single hypothesis is to explain all of the data then the heavy lepton hypothesis is strongly favored. However, a conspiracy of charmed particle leptonic and semileptonic decays could conceivably give rise to similar results. PERL 75 estimate the heavy lepton mass to be 1.6 - 2.0 GeV.

Inclusive anomalous (not from well known sources) muon production,

$$e^+e^- \to \mu^\pm \text{ anything} \quad ,$$

has been reported by CAVALLI-SFORZA 76 and FELDMAN 77. CAVALLI-SFORZA 76, another SPEAR experiment, finds ~9 two-prongs and ~0 with three or more prongs. Snow[6] argues that these results are compatible with heavy lepton decay but not with higher multiplicities expected in charmed meson decay. FELDMAN 77, with higher statistics in the same experiment as PERL 75-76, sees both two-prong and three-or-more prong anomalous muon signals with cross sections consistent with CAVALLI-SFORZA 76. A heavy lepton hypothesis can explain the FELDMAN 77 two-prong data for all energies 3.9 GeV < $E_{c.m.}$ < 7.8 GeV, and their lower energy three-and-more-prong data. However, for energies 5.8 - 7.8 GeV, additional sources, e.g., charmed particles, are required to explain the large three-and-more-prong signal.

HEAVY LEPTON SEARCHES AND EVIDENCE

Inclusive anomalous electron production has been studied by BRAUNSCHWEIG 76 (see reference section of Charm Searches and Evidence Data Card Listings), a DORIS DASP experiment at c.m. energy 4.0 - 4.2 GeV. The electron momentum spectrum and the observed multiplicity indicate that these events do not come from sequential lepton production but could come from charmed hadron production. The electron momenta observed here are so low (<800 MeV) that the SLAC experiments would have excluded most of these events from their sample. Based on the FELDMAN 77 anomalous muon cross sections, one expects to see only a few events with electron momentum above 800 MeV, so there is no conflict between these two results.

Assuming that the heavy lepton exists, its type is still undetermined. Neutrino experiments discussed below rule out paramuons M^+ and tend to rule out orthomuons N^-. Ali and Yang[8] suggest that the PERL 75 ee:μe:$\mu\mu$ ratio indicates that the τ (as it is now called by the PERL 75-76, FELDMAN 77 authors) is not a para-electron E^+. This leaves the sequential lepton L^- and the ortho-electron F^- as the most likely candidates.

Neutrino experiments which have a ν_μ beam can produce single heavy leptons which have the same muon number as a μ^-. Signature heavy lepton events are those leading to final-state charged leptons other than the normal charged current μ^-, e.g.,

$$\nu_\mu N \to N^- \text{ hadrons}, \quad N^- \to \nu_\mu e^- \bar{\nu}_e$$

$$\nu_\mu N \to M^+ \text{ hadrons}, \quad M^+ \to \nu_\mu \mu^+ \nu_\mu \text{ or } \nu_\mu e^+ \nu_e$$

$$\nu_\mu N \to M^o \text{ hadrons}, \quad M^o \to \mu^- e^+ \nu_e \quad .$$

BARISH 74, a Caltech-Fermilab narrow-band neutrino beam experiment has searched for M^+ via the μ^+ mode. The small μ^+ signal observed is consistent with beam contamination by $\bar{\nu}_\mu$. The expected number of events is calculated as a function of M^+ mass assuming a weak coupling constant equal to the universal Fermi constant and a branching fraction to muons of 30%. Their null signal sets a 90% confidence lower limit of 8.4 GeV < M^+ mass. This poses difficulties for those gauge models using M^+ which require its mass to be less than about 7 GeV in order to be consistent with experimental measurements of the muon magnetic moment.[9]

EICHTEN 73 looks for M^+ via the e^+ decay mode, and, assuming a 15% branching fraction, sets a limit of 2.4 GeV < M^+ mass.

ASRATYAN 74 use the data of EICHTEN 73 on electron and positron production in ν_μ and $\bar{\nu}_\mu$ beams to obtain a lower limit 1.8 GeV < N^- mass at the 90% confidence level. Albright[5] argues that even a 1.8 GeV N^- can probably be ruled out if the y distribution and neutral-to-charged-current ratio are considered.

Proton-nucleon collisions have the advantage of large available c.m. energy for production of heavy particles. They have the disadvantage that the lepton production mechanism is not as well understood as it is for e^+e^- collisions and neutrino collisions. Also, backgrounds from copious strong processes pose problems. Pair production from virtual electromagnetic processes is the expected mode of production.

Several approaches have been used in these searches. One is to assume the existence of long-lived charged heavy leptons and to pass the secondaries through an absorber to filter out strongly interacting particles, and a system of scintillation counters and Čerenkov counters to identify hadrons and muons. The cross-section and differential-cross-section limits given in the Data Card Listings for charged heavy lepton production are done in this manner. Mass limits can also be obtained if a model for the production is assumed. BUSHNIN 73 assumes pair production analogous to $\mu^+\mu^-$ production and scales lower energy μ-pair production to obtain cross-section predictions which rule out stable or long-lived charged leptons in the mass range 0.55 to 4.5 GeV.

Data Card Listings

HEAVY LEPTON SEARCHES AND EVIDENCE

FAISSNER 76 looked for long-lived neutral heavy leptons in

$$pN \rightarrow L^{+} \text{ anything}$$
$$\quad\quad\quad \hookrightarrow L^{o} \text{ anything}$$

in a "beam dump" type CERN Gargamelle experiment. The L^{+} and L^{o} here mean any type charged and neutral heavy leptons. The L^{o} could be detected by its decay or its interaction in the bubble chamber. Protons struck a mercury target in a 22-meter-thick steel muon shield. Most hadrons were absorbed before weak decay, thus suppressing normal neutrino flux. However, prompt decays such as expected of the L^{+} would not be suppressed. No signal above background was observed, ruling out L^{o} with lifetime 1 μsec - 1 msec as proposed by DE RUJULA 75 to explain the KRISHNASWAMI 75 Kolar Gold Mine cosmic ray events.

Another approach to heavy lepton hunting in pN collisions has been to search for high-transverse-momentum direct lepton production, i.e., for high p_T leptons not originating from well known weak decays. Other possible candidates for parents of direct leptons are charmed particles, intermediate bosons, high p_T vector mesons, and massive virtual photons; so we have listed these papers in the Other New Particle Searches section of the Data Card Listings. Recent evidence on absence of muon polarization (LAUTERBACH 76, LEIPUNER 76) and μ-pair origin (KASHA 76, BRANSON 77) favors an electromagnetic origin. However, contradictory evidence indicating non-zero muon polarization and weak decay has also been reported (ANISIMOVA 76).

References

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7. C. H. Albright, Phys. Rev. D13, 2508 (1976).
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9. J. Primack and H. Quinn, Phys. Rev. D6, 3171 (1972). Additional references in reference 3 of BARISH 74.


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M      HEAVY LEPTON MASS LIMITS (GEV)
M   B  0   0.6   OR MORE             BACCI     73 ELEC +- ORTHOELECTRON(F)  1/76
M   B  0   2.2   OR MORE             BACCI     73 ELEC +- ORTHOELECTRON(F)  1/76
M   C  0   2.0   OR MORE   CL=.90    BARISH    73 ASPK +  PARAMUON (M)      2/74
M   D  0   1.4   OR MORE   CL=.95    BERNARDIN 73 ASPK +- ANY NON-RAD TYPE  2/74
M   D  0   1.0   OR MORE   CL=.95    BERNARDIN 73 ASPK +- ANY NON-RAD TYPE  2/74
M   N  NONE BETWEEN 0.55 AND 4.5     BUSHNIN   73 CNTR -  LONG-LIVED        2/74
M   E  0   2.4   OR MORE   CL=.90    EICHTEN   73 HLBC +  PARAMUON (M)      3/74
M   A      1.8   OR MORE   CL=.90    ASRATYAN  74 HLBC +- ORTHOMUON (N)    11/75
M   F      8.4   OR MORE   CL=.90    BARISH    74 SPEC +  PARAMUON (M)      7/74
M   O  0   1.15  OR MORE   CL=.95    ORITO     74 ASPK +- ANY NON-RAD TYPE 11/75
M   P  64 BTWN 1.6 AND 2.0           PERL      75 SPEC +- ANY NON-RAD TYPE  1/76
M
M                                    COMMENTS                              3/77*
M      LIMITS APPLY ONLY TO HEAVY LEPTON TYPE GIVEN IN COMMENT AT RIGHT ON 3/77*
M      DATA CARD.  SEE REVIEW ABOVE FOR DESCRIPTION OF TYPES.              3/77*
M      IN COMMENTS BELOW; ALL BEAMS ARE MU TYPE NEUTRINO OR ANTINEUTRINO.  3/77*
M      L,E,M,F,N STAND FOR SEQUENTIAL LEPTON,PARA-ELECTRON,PARA-MUON,      3/77*
M      ORTHO-ELECTRON,ORTHO-MUON RESPECTIVLY.                              3/77*
M
M   B  BACCI 73 IS FRASCATI E+E- EXPT. LOOKS FOR F --> E GAMMA.            1/76
M   B  MASS LIMIT DEPENDS ON COUPLING CONSTANT LAMBDA FOR THIS DECAY.      1/76
M   B  FIRST VALUE ABOVE IS FOR LAMBDA**2 GT 9*10**-5, 2ND IS FOR          1/76
M   B  LAMBDA**2 GT 10**-3.                                                1/76
M   C  BARISH 73 IS FNAL 50,145 GEV NEU EXPT.  LOOKS FOR (NEU NUCLEON -->  3/77*
M   C  M+ ANYTHING). ASSUMES (M+ --> MU+ NEU NEU) WITH BR=.3.              3/77*
M   D  BERNARDINI 73 IS FRASCATI E+E- EXPT. FIRST VALUE ASSUMES UNIVERSAL  2/74
M   D  COUPLING TO ORDINARY LEPTONS.  SECOND VALUE ALSO ASSUMES COUPLING   2/74
M   D  TO HADRONS.                                                         2/74
M   N  BUSHNIN 73 IS SERPUKOV 70 GEV P EXPT. MASSES ASSUME MEAN LIFE ABOVE 2/74
M   N  7E-10 AND 3E-8 RESPECTIVELY. CALCULATED FROM CROSS SEC(DC BELOW)    2/74
M   N  AND 30 GEV MUON PAIR PRODUCTION DATA.                               2/74
M   E  EICHTEN 73 IS CERN 1-10GEV NEU EXPT. LOOKS FOR M+ PRODUCED IN       2/76
M   E  NEU NUCL --> M+ HADRONS ASSUMING 15 PERCENT DECAY TO E+ NEU NEU.    2/76
M   A  ASRATYAN 74 USES EICHTEN 73 DATA ON NEU NUCL --> E- HADRONS AND     2/76
M   A  ANTINEU NUCL --> E+ HADRONS TO SET LIMITS ON ORTHOMUON PRODUCTION.  2/76
M   F  BARISH 74 IS FNAL 50,135 GEV NEU EXPT.  LOOKS FOR (NEU NUCLEON -->  7/74
M   F  M+ ANYTHING).  ASSUMES (M+ -->MU+ NEU NEU) WITH BR=.3.              7/74
M   O  ORITO 74 LOOKED FOR H+H- PAIRS GIVING MU-E PAIRS. MASS LIMIT REFERS 3/74
M   O  TO ANY NON-RADIATIVE TYPE HEAVY LEPTON: L, E, M, F, N.              3/74
M   O  COUPLING TO HADRON ASSUMED FROM THEORETICAL MODELS.                 3/74
M   P  PERL 75 EVENTS ARE E+ E- TO E+- MU-+ AND TWO OR MORE MISSING        1/76
M   P  PARTICLES,DONE AT SLAC (SPEAR). AUTHORS CLAIM NO CONVENTIONAL       1/76
M   P  EXPLANATION FOR THESE EVENTS.  TOTAL CM ENERGY 3-7.5 GEV.           1/76

CE     HEAVY LEPTON PRODUCTION CROSS SECTION (E+ E-) (UNITS 10**-35 CM**2)
CE  P   64  (1.9)  (0.5)          PERL      75 SMAG   ECM=4.8 GEV          2/76
CE  C    9  28.5   15.1    11.3   CAVALLISF 76 SPEC   ECM=4.8 GEV          8/76*
CE  P  105  (1.9)  (0.5)          PERL      76 SMAG   ECM=4.8 GEV          3/77*
CE  F   15  19.4    7.1           FELDMAN   77 SMAG   ECM=3.9-4.3 GEV      2/77*
CE  F   18  25.3    8.6           FELDMAN   77 SMAG   ECM=4.5-4.8 GEV      2/77*
CE  F  103  21.2    4.9           FELDMAN   77 SMAG   ECM=5.8-7.8 GEV      2/77*
CE  P   PERL 75 IS SLAC(SPEAR) EXPT .  EVENTS ARE E+E- TO E+-MU-+ AND 2 OR 2/76
CE  P   MORE MISSING PARTICLES.  CS IS FOR ECM=4.8 GEV AND THETA=50-130DEG. 2/76
CE  P   CROSS SECTION RISES FROM 5X10**-36 AT E=4 TO ABOVE MAX. THEN DROPS 2/76
CE  P   TO 6E-36  AT E=7.5.   AUTHORS SAY THESE EVENTS HAVE NO CONVENTIONAL 2/76
CE  P   EXPLANATION.  SUGGEST HEAVY LEPTON OR CHARMED HADRON, M=1.6-2.0GEV. 2/76
CE  P   PERL 76 INCLUDES PERL 75. NOT CORRECTED FOR DETECTOR ACCEPTANCE.   3/77*
CE  C   CAVALLISF 76 IS SLAC(SPEAR) EXPT AT 4.8 GEV CM. RESULT GIVEN ABOVE 8/76*
CE  C   IS TOTAL MUON INCLUSIVE CS FOR 2 CHARGED PRONGS AND MU MOMENTUM GT 8/76*
CE  C   1.05 GEV/C. ASSUMES ISOTROPY. DIFF CS AT THETA=90 DEG IS 23 PB/SR. 8/76*
CE  C   SNOW 76 SAYS RESULT COMPATIBLE WITH HEAVY LEPTON,NOT CHARMED MESON. 8/76*
CE  F   FELDMAN 77 IS A CONTINUATION OF PERL 75. ABOVE DATA IS FOR TWO-    2/77*
CE  F   PRONG EVENTS. DATA ON 3-PRONG EVENTS IS ALSO GIVEN. FOR THIS DATA, 2/77*
CE  F   SEE MORE ANOMALOUS MUON PROD THAN EXPECTED FROM HEAVY LEPTON DECAYS 2/77*
CE  F   ALONE. COULD BE FROM DECAYS OF CHARMED HADRONS.                    2/77*

DC     HEAVY LEPTON PRODUCTION DIFF. CROSS SEC. (P NUCLEON) (CM**2/SR-GEV)
DC   G  0  1.6E-37 OR LESS  CL=.90   GOLOVKIN  72 CNTR- 70GEV P, SERPUKHOV 1/76
DC B    0  4. E-38 OR LESS  CL=.90   BUSHNIN   73 CNTR- 70GEV P, SERPUKHOV 2/74
DC   G  MASS RANGE 1 TO 4.5 GEV,THETA=0,P=25 GEV/C.                        1/76
DC B    BUSHNIN 73 HEAVY LEPTON PATH TRAVERSES 6800 GM/CM**2 ABSORBER.     2/74
DC B    DIFFERENTIAL CROSS-SECTION MEASURED AT P=30 GEV/C THETA= 2 MRAD.   3/74

IC     INVARIANT HEAVY LEPTON PROD. CROSS SEC. (P NUCLEON) (CM**2/GEV**2)
IC   S  0  5.4E-39 OR LESS  CL=.90   CRONIN    74 SPEC -  M=1-6.8 GEV      1/76
IC   B  0  6.4E-35 OR LESS  CL=.90   BINTINGER 75 SPEC +- M=1-5 GEV        2/76
IC   S  CRONIN 74 IS AN FNAL 300 GEV P CU EXPT.  LOOKED FOR LONG LIVED     2/76
IC   S  PENETRATING PARTICLES.  ABOVE LIMIT ASSUMES STABLE.  MULTIPLY IT BY 2/76
IC   S  EXP(1.22E-8*M/TAU) FOR MASS M(GEV) AND LIFETIME TAU(SEC). LIMIT    2/76
IC   S  OBTAINED AT THETA(LAB) = 77 MRAD, PT = 2.38 GEV/C.                 4/77*
IC   B  BINTINGER 75 IS A 30-300 GEV P C EXPT.  LOOKED FOR LONG LIVED      2/76
IC   B  PENETRATING PARTICLES.  ABOVE LIMIT ASSUMES STABLE.  MULTIPLY IT BY 2/76
IC   B  EXP(3.5E-8*M/TAU/P) FOR MASS M(GEV), LIFETIME TAU(SEC), MOM.P(GEV). 2/76
IC   B  OBTAINED AT THETA(LAB) = 91 MRAD, PT = 1-2.25 GEV/C.               4/77*

CN     NEUTRAL HEAVY LEPTON PRODUCTION CROSS SECTION  (CM**2)
CN  K   5 (1. E-37 OR MORE)           KRISHNASW 75 CNTR +0-  M=2-5 GEV     2/76
CN   B  0                             BENVENUTI 75 SPEC  0                 2/76
CN  K   KRISHNASWAMY 75 IS KOLAR GOLD MINE COSMIC RAY EXPT.  TYPICAL EVENT 2/76
CN  K   HAS VERTEX IN AIR 70 CM FROM WALL WITH THREE OBSERVED CHARGED      2/76
CN  K   TRACKS.  AUTHORS SUGGEST NEU+ROCK GIVES NEW PARTICLE WITH MEAN LIFE 2/76
CN  K   10E-9 SEC OR LONGER.  DE RUJULA 75 GIVES ANOTHER INTERPRETATION.   2/76
CN  K   SEE ALSO RAJASEKARAN 75.                                           8/76*
CN   B  BENVENUTI 75 IS AN FNAL EXPERIMENT WHICH ROUGHLY SIMULATES THE     2/76
CN   B  KRISHNASWAMY 75 EXPT. BUT APPARENTLY CONTRADICTS IT, FINDING NO    2/76
CN   B  EVENTS. SENSITIVE TO DECAYS OF NEUTRAL PENETRATING PARTICLES       3/77*
CN   B  PRODUCED BY THE PRIMARY PROTONS OR BY SECONDARY NEUTRINO           3/77*
CN      [illegible] THE 1 KM. NEUTRINO BEAM EARTH SHIELD.                  3/77*
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CP      NEUTRAL HEAVY LEPTON PROD. CROSS SEC. (PROTON NUCLEON) (CM**2)
CP   F   0  1. E-29 OR LESS               FAISSNER  76 HLBC 0            1/77*
CP   F  FAISSNER 76 LIMIT ASSUMES STABLE NEUTRAL WEAKLY INTERACTING LEPTON.  1/77*
CP   F  ALSO RULES OUT DE RUJULA 75 INTERP. OF 5 KRISHNASWAMY 75 EVENTS AS   1/77*
CP   F  (P NUCLEON --> L+ X, L+ --> LO X) UNLESS L+ MASS IS ABOVE 3 GEV.    1/77*

R1      HEAVY LEPTON BR INTO (E+ OR MU+ + 2 NEUTRINOS)/(TOTAL)               3/77*
R1   P 105    0.17      0.06      0.03  PERL        76 SPEC                 3/77*
R1   P  ASSUMES EQUAL DECAY RATES TO E- AND MU- MODES, V-A COUPLING, MASS   3/77*
R1   P  OF HEAVY LEPTON=1.8 GEV/C**2, MASS OF ASSOCIATED NEUTRINO=0.        3/77*
R1   P  PERL 76 EXPT IS CONTINUATION OF PERL 75,INCLUDES THE 64 OLD EVENTS.  3/77*

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                                REFERENCES FOR HEAVY LEPTON SEARCHES

GOLOVKIN 72 PL 42B 136          +GRACHEV,KHODYREV,KUBAROVSKY+         (SERP)

BACCI    73 PL 44B 530          +PARISI,PENSO,SALVINI,STELLA+   (ROMA+FRAS)
BARISH   73 PRL 31 410          +BARTLETT,BUCHHOLZ,HUMPHREY+     (CIT+FNAL)
BERNARDI 73 NC 17A 383          BERNARDINI,BOLLINI,BRUNINI+(CERN+BGNA+FRAS)
    ALSO 70 LNC 4 1156          ALLES-BORELLI,BERNARDINI,BOLLINI+     (CERN)
BUSHNIN  73 NP B58 476          +DUNAYTZEV,GOLOVKIN,KUBAROVSKY +      (SERP)
    ALSO 72 PL 42B 136          GOLOVKIN,GRACHEV,SHODYREV +           (SERP)
EICHTEN  73 PL 46B 281          +DEDEN+(AACH+BELG+CERN+EPOL+MILA+LALO+LOUC)

ASRATYAN 74 PL 49B 488          +GERSHTEIN,KAFTANOV,KUBANTZEV,LAPIN+ (SERP)
BARISH   74 PRL 32 1387         +BARTLETT,BUCHHOLZ,MERRITT +     (CIT+FNAL)
CRONIN   74 PR D10 3093         +FRISCH,SHOCHET,BOYMOND,MERMOD + (EFI+PRIN)
CRITO    74 PL 48B 165          +VISENTIN,CERADINI,CONVERSI +    (FRAS+ROMA)

BENVENUT 75 PRL 35 1486         BENVENUTI,CLINE,FORO+ (HARV+PENN+WISC+FNAL)
BINTINGE 75 PRL 34 982          BINTINGER,CURRY+        (EFI+HARV+PENN+WISC)
KRISHNAS 75 PL 57B 105          KRISHNASWAMY,MENON+           (BOMBAY+OSAKA)
    ALSO 75 PRL 35 628          DE RUJULA,GEORGI,GLASHOW               (HARV)
    ALSO 75 PRAMANA 5 78        RAJASEKARAN,SARMA                      (TATA)
PERL     75 PRL 35 1489         +ABRAMS,BOYARSKI,BREIDENBACH +   (LBL+SLAC)

CAVALLIS 76 PRL 36 558          CAVALLI-SFORZA,GOGGI +        (PAVI+PRIN+UMD)
    ALSO 76 PRL 36 766          GEORGE SNOW                             (UMD)
FAISSNER 76 PL 60B 401          +HASERT+(AACH+BELG+CERN+EPOL+MILA+OXF+LOUC)
PERL     76 PL 63B 466          +FELDMAN,ABRAMS,ALAM,BOYARSKI +  (SLAC+LBL)

FELDMAN  77 PRL 38 117          +BULOS,LUKE,ABRAMS,ALAM,BOYARSKI+(SLAC+LBL)

                                PAPERS NOT REFERRED TO IN THE DATA CARDS

                                ORTHOLEPTONS WITH LEPTON GAMMA COUPLING
BEHREND  65 PRL 15 900          +BRASSE,ENGLER,GANSSAUGE+       (DESY+KARL)
BETOURNE 65 PL 17 70            +NGUYEN NGOC,PEREZ Y JORBA+           (ORSA)
BUDNITZ  66 PR 141 1313         +DUNNING,GOITEIN,RAMSEY,WALKER,WILSON(HARV)
BOLEY    68 PR 167 1275         +ELIAS,FRIEDMAN,HARTMANN,KENDALL+ (MIT+CEA)
BERNARDI 69 NCL 1 15            BERNARDINI,FELICETTI+       (FRAS+NAPL+ROMA)
LIBERMAN 69 PRL 22 663          +HOFFMAN,ENGELS,IMRIE+(HARV+CASE+MCGI+SLAC)
LICHTENS 70 PR D1 825           LICHTENSTEIN,ASH,BERKELMAN,HARTILL+  (CORN)
HANSON   73 NCL 7 587           +LEONG,NEWMAN,LAW,LITKE+(MIT+HARV+CEA+HAIF)

                                LONGLIVED
COCCONI  60 PRL 5 19            +FAZZINI,FIDECARO,LEGROS,LIPMAN+      (CERN)
COOK     61 PR 123 655          +KEEFE,KERTH,MURPHY,WENZEL,ZIPF        (LRL)
FRANZINI 65 PRL 14 196          +LEONTIC,RAHM,SAMIOS,SCHWARTZ    (BNL+COLU)
BARNA    68 PR 173 1391         +COX,MARTIN,PERL,TAN,TONER,ZIPF+(SLAC+STAN)
ANSORGE  73 PR D7 26            +BAKER,KRZESINSKI,NEALE,RUSHBROOKE+  (CAVE)

                                RAMM TYPE
ROTHE    69 NP B10 241          K.W.ROTHE,A.M.WOLSKY                  (PENN)
RAMM     70 NATURE 227 1323     C.A.RAMM                              (CERN)
RAMM     71 NAT.PH.SC.230 145   C.A.RAMM                              (CERN)
CLARK    72 NATURE 237 388      +ELIOFF,FIELD,FRISCH,JOHNSON,KERTH+    (LBL)

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INTERMEDIATE BOSON SEARCHES

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M       W BOSON MASS LIMITS (GEV)
M    B   0    1.7   OR MORE  CL=.99   BERNARDIN 65 HYBR +  NEU N, CERN         2/74
M    B   0    2.0   OR MORE  CL=.90   BURNS     65 OSPK +  NEU N, BNL          2/74
M    C   0    3.8   OR MORE  CL=.90   BARISH    73 ASPK +  W+ TO LEP+NEU=.2    2/74
M    C   0    4.5   OR MORE  CL=.90   BARISH    73 ASPK +  W+ TO LEP+NEU=.5    2/74
M    C   0    4.7   OR MORE  CL=.90   BARISH    73 ASPK +  W+ TO LEP+NEU=.8    2/74
M    E   0    5.0   OR MORE  CL=.95   BERGESON  73 ELEC                        1/76
M    U   0 NONE WITH MASS 10-20 GEV   BUSSER    74 WIRE +-0 P-P,52.7 GEV CM    8/76*
M    B  LOOKED FOR (NEU N) TO (W+ MU- N), W+ TO (MU+ NEU, E+ NEU, OR HORNS)    2/74
M    C  BARISH 73 LOOKED FOR (NEU N) TO (W+ MU- N), W+ TO (MU+ NEU) AT NAL.    2/74
M    C  RESULT GIVEN FOR THREE ASSUMED BR.FRACS. W+ TO (LEPTON NEU)/ALL.       2/74
M    E  BERGESON 73 LOOKED AT ENERGY DISTR OF NEU-INDUCED MUON FLUX UNDER-     1/76
M    E  GROUND. SCALE INVARIANCE OF THE INELASTIC STRUCT FN ASSUMED.           1/76
M    U  BUSSER 74 IS CERN ISR EXPT. LOOKED FOR ELECTRONS OF LARGE              8/76*
M    U  TRANSVERSE MOMENTUM. RESULT QUOTED ABOVE IS MODEL DEPENDENT.           8/76*

C       W BOSON PRODUCTION CROSS SECTION (10**-36 CM**2)
C    A   0    6.0   OR LESS               ANKENBRAN 71 CNTR +- W TO(MU NEU)=1.0  2/74
C    A  ANKENBRANDT 71 LOOKED FOR (P N)TO(W HADRONS), W TO (MU NEU) AT BNL.    2/74
C    A  THIS ASSUMES BR OF W TO MU NEU IS 1.  IN GENERAL THIS VALUE IS         2/74
C    A  6.0/BR, WHERE BR=(W TO MU NEU)/(W TO ALL).                             2/74

S       SCALAR BOSON MASS LIMITS (GEV)
S    C   0   10.0   OR MORE  CL=.90   CONVERSI  73 ASPK  0 E+E- FRASCATI       3/74
S    C  CONVERSI 73 LOOKED FOR QED VIOLATION IN E+E- SCATTERING AT 2.8 GEV     3/74
S    C  AND ASSUMED W BOSON MASS=10 GEV.  FOR MW=15 GEV, MS LIMIT= 6.5 GEV     3/74

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                                REFERENCES FOR INTERMEDIATE BOSON SEARCHES

BERNARDI 65 NC 38 608           BERNARDINI,BIENLEIN,BOHM,DARDEL,+     (CERN)
BURNS    65 PRL 15 42           +GOULIANOS,HYMAN,LEDERMAN,LEE +  (COLU+BNL)
ANKENBRA 71 PR D3 2582          ANKENBRANDT,LARSEN,LEIPUNER+     (BNL+YALE)
BARISH   73 PRL 31 180          +BARTLETT,BUCHHOLZ,HUMPHREY+     (CIT+FNAL)
BERGESON 73 PRL 31 66           +CASSIDAY,HENDRICKS                   (UTAH)
CONVERSI 73 PL 46B 269          +D'ANGELO,GATTO,PAOLUZI               (ROMA)
BUSSER   74 PL 48B 371          +CAMILLERI,DI LELLA +      (CERN+COLU+ROCK)

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QUARK SEARCHES

We have attempted to make the listings of free quark searches more complete in this edition. To that end, we have relied heavily on the recent review of L. Jones.[1]

There is currently no confirmed evidence for the existence of free quarks. The best searches for quarks in cosmic rays yield upper limits on the flux of quarks of about $10^{-11} cm^{-2} ster^{-1} sec^{-1}$. Cross-section upper limits established from proton accelerator experiments and calculations based on production models[2] imply that free quarks have a mass greater than about 5 GeV. Mass limits from photon and electron beam searches are slightly lower, but more reliable, depending only on the QED calculations for quark pair production. Limits on free quark concentrations in stable matter vary enormously depending on the source of matter and the technique.

We group quark searches by experimental technique — proton accelerators, electron accelerators, cosmic rays, and stable matter. Proton accelerator experiments generally measure quark production cross sections (we quote these in section C) and differential cross sections (section D). Searches with photon or electron beams may measure differential cross sections (section G) and set limits on the quark mass (section M). Cosmic ray experiments measure quark flux (section F), and searches in stable matter measure quark concentration (section RHO). Most of the accelerator and cosmic ray experiments have searched for fractionally charged particles, but some have searched for massive stable particles which would have low velocity. The latter searches are usually sensitive to a range of charges and may appear in the section below on Other New Particle Searches.

References

1. L.W. Jones, Michigan preprint UM-HE-76-42, to be published in Rev. Mod. Phys., Oct. 1977.
2. T.K. Gaisser and F. Halzen, Phys. Rev. D11, 3157 (1975).

Data Card Listings

QUARK SEARCHES

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       SEARCHES FOR INTEGRALLY CHARGED QUARKS APPEAR ALONG WITH OTHER
       SIMILAR SEARCHES IN 'OTHER NEW PARTICLE SEARCHES' SECTION BELOW.

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C         QUARK PRODUCTION CROSS SECT. FROM PROTON ACCELERATOR EXPTS. (CM**2)
C            0 2.0E-34 OR LESS  CL=.90     BINGHAM    64  HBC Q= -1/3 M=.5-2.0GEV   3/77*
C            0 1.0E-34 OR LESS  CL=.90     BINGHAM    64 HLBC Q= -2/3 M=.5-2.5GEV   3/77*
C            0 2.0E-35 OR LESS             BLUM       64  HBC Q= -1/3 M=0-2.5GEV    3/77*
C    Z       0 9.5E-36 OR LESS             HAGOPIAN   64  HBC Q= +1/3 M=.5-2.5GEV   3/77*
C            0 1.0E-34 OR LESS             LEIPUNER   64 CNTR Q= -1/3 M=0-2.0GEV    3/77*
C            0 4.0E-34 OR LESS             MORRISON   64  HBC Q= -1/3 M=.5-2.5GEV   3/77*
C            0 1.0E-35 OR LESS             MORRISON   64  HBC Q= -2/3 M=.5-2.5GEV   3/77*
C    W       0 2.0E-35 OR LESS             FRANZINI   65 CNTR Q= -2/3 M=0-2.5GEV    3/77*
C    Y       0 3.2E-39 OR LESS  CL=.90     ALLABY     69 CNTR Q= -1/3 M=2GEV        1/76
C    Y       0 5.5E-38 OR LESS  CL=.90     ALLABY     69 CNTR Q= -2/3 M=2GEV        1/76
C    Y       0 1.8E-35 OR LESS  CL=.90     ALLABY     69 CNTR Q= +1/3 M=2GEV        1/76
C    Y       0 1.0E-35 OR LESS  CL=.90     ALLABY     69 CNTR Q= +2/3 M=2GEV        1/76
C    A       0 4.0E-37 OR LESS  CL=.90     ANTIPOV1   69 CNTR Q= -2/3 M=0-5GEV      2/74
C    A       0 3.0E-39 OR LESS  CL=.90     ANTIPOV2   69 CNTR Q= -1/3 M=4.5-5GEV    1/76
C    A       0 3.0E-37 OR LESS  CL=.90     ANTIPOV2   69 CNTR Q= -2/3 M=2-5GEV      1/76
C    V       0 1.0E-36 OR LESS  CL=.90     ANTIPOV    71 CNTR Q= -4/3 M=4GEV        1/76
C    B       0 3.0E-34 OR LESS             BOTT-BODE  72 CNTR Q=+-1/3 M=0-22GEV     2/74
C    B       0 6.0E-34 OR LESS             BOTT-BODE  72 CNTR Q=+-2/3 M=0-13GEV     2/74
C    P       0 1.0E-32 OR LESS  CL=.90     ALPER      73 SPEC Q=  2/3 M=4-24 GEV    1/76
C    P       0 1.0E-32 OR LESS  CL=.90     ALPER      73 SPEC Q=  4/3 M=4-24 GEV    1/76
C    L       0 1.0E-35 OR LESS             LEIPUNER   73 CNTR Q=  1/3 M=0-12GEV     2/74
C    L       0 1.0E-35 OR LESS             LEIPUNER   73 CNTR Q=  2/3 M=0-12GEV     2/74
C    L       0 5.0E-31 OR LESS             LEIPUNER   73 CNTR Q=  4/3 M=0-12GEV     2/74
C    N       0 5.0E-39 OR LESS  CL=.90     NASH       74 CNTR Q= -1/3 M=4 GEV       2/77*
C    N       0 5.0E-38 OR LESS  CL=.90     NASH       74 CNTR Q= -2/3 M=4 GEV       2/77*
C    F       0 4.0E-35 OR LESS  CL=.90     FABJAN     75 ELEC Q=  1/3 M=0-20 GEV    1/77*
C    F       0 8.0E-35 OR LESS  CL=.90     FABJAN     75 ELEC Q=  2/3 M=0-20 GEV    1/77*
C    Z    HAGOPIAN 64 CROSS SECTION INFERRED FROM FLUX DATA.                        3/77*
C    W    FRANZINI 65 CROSS SECTION INFERRED FROM FLUX DATA.                        3/77*
C    Y    ALLABY 69 IS A CERN 27 GEV P+BE EXPT.  STUDIES MASSES 0-2.7GEV            1/76
C    Y    ASSUMING NN=NNQQ.  CROSS SECTIONS ASSUME ISOTROPIC PROD. IN CM.           1/76
C    Y    CROSS SECTIONS AT 2GEV ARE GIVEN HERE.  SEE FIG.9 FOR MASS DEPEN.         1/76
C    A    ANTIPOV1 69 IS A SERPUKHOV 70 GEV P EXPT.  MASS LIMIT FROM NN=NNQQ.       2/74
C    A    ANTIPOV1 69 AND ANTIPOV2 69 ARE SERPUKHOV 70GEV P EXPTS.  ANTIPOV2        1/76
C    A    GIVES RESULTS FOR M=2-5GEV ASSUMING NN-->NNQQ. HADRONIC OR LEPTONIC       1/76
C    A    QUARKS.  WE QUOTE TYPICAL VALUES.                                         1/76
C    V    ANTIPOV 71 IS A SERPUKHOV 70 GEV P+AL EXPT.  STUDIES DIQUARK MASSES       1/76
C    V    1.9-4.4GEV.  WE SHOW 4GEV VALUE.  SEE THEIR FIG.2 FOR MASS DEPEN.         1/76
C    B    BOTT-BODENHAUSEN 72 IS A CERN ISR 26+26 GEV P+P EXPERIMENT.               2/74
C    P    ALPER 73 IS CERN ISR 26+26 GEV P+P EXPT. ASSUMES ISOTROPIC C.M.           1/76
C    P    PRODUCTION.  SENSITIVE TO ANY Q>2/3.                                      1/76
C    L    LEIPUNER 73 IS AN NAL 300 GEV P EXPERIMENT.                               2/74
C    N    NASH 74 IS FNAL EXPT USING 200 AND 300 GEV PROTONS. SEE FIG 2,PG861       2/77*
C    N    FOR OTHER MASS VALUES AND VARIOUS PRODUCTION MECHANISMS.                  2/77*
C    F    FABJAN 75 IS CERN ISR P+P EXPT AT S=2830 GEV**2.  INCLUDES RESULTS        1/77*
C    F    OF BOTT-BODE 72 EXPT.                                                     1/77*

D         QUARK PROD. DIFF. CROSS SEC. FROM PROTON ACCL. EXPTS. (CM**2/SR-GEV)
D    D       0 1.5E-36 OR LESS             DORFAN     65 CNTR BE TARG  M=3-7GEV     2/74
D    D       0 3.0E-36 OR LESS             DORFAN     65 CNTR FE TARG  M=3-7GEV     2/74
D    Y       0 7.2E-39 OR LESS  CL=.90     ALLABY     69 CNTR Q=-1/3  THETA= 0 MR   1/76
D    Y       0 5.2E-38 OR LESS  CL=.90     ALLABY     69 CNTR Q=-2/3  THETA=6.5MR   1/76
D    Y       0 2.6E-35 OR LESS  CL=.90     ALLABY     69 CNTR Q=+1/3  THETA=44 MR   1/76
D    Y       0 1.5E-35 OR LESS  CL=.90     ALLABY     69 CNTR Q=+2/3  THETA=44 MR   1/76
D    A       0 7.0E-38 OR LESS  CL=.90     ANTIPOV2   69 CNTR Q=-1/3   M=0-5GEV     1/76
D    A       0 4.0E-38 OR LESS  CL=.90     ANTIPOV2   69 CNTR Q=-2/3   M=0-2.5GEV   1/76
D    V       0 1.6E-36 OR LESS  CL=.90     ANTIPOV    71 CNTR Q=-4/3  THETA=47 MR   1/76
D    V       0 3.8E-36 OR LESS  CL=.90     ANTIPOV    71 CNTR Q=-4/3  THETA=47 MR   1/76
D    N       0 5.6E-36 OR LESS  CL=.90     NASH       74 CNTR Q=-1/3                2/77*
D    N       0 5.0E-35 OR LESS  CL=.90     NASH       74 CNTR Q=-2/3   M GT 1.76    2/77*
D    N       0 8.5E-35 OR LESS  CL=.90     NASH       74 CNTR Q=-2/3   M LT 1.76    2/77*
D    L       0 1.6E-33 OR LESS  CL=.90     ALBROW     75 SPEC Q=+-4/3  M=5-20 GEV   1/77*
D    J       0 5.0E-34 OR LESS  CL=.90     JOVANOVIC  75 CNTR Q=1/3  M=7-15 GEV     2/76
D    J       0 2.0E-34 OR LESS  CL=.90     JOVANOVIC  75 CNTR Q=1/3  M=15-26 GEV   11/75
D    J       0 1.3E-34 OR LESS  CL=.90     JOVANOVIC  75 CNTR Q=2/3  M=10-26 GEV   11/75
D    J       0 8.0E-35 OR LESS  CL=.90     JOVANOVIC  75 CNTR Q=4/3  M=10-26 GEV   11/75
D    B       0 3.9E-36 OR LESS  CL=.90     BALDIN     76 CNTR Q=-2/3  M=1.4-6 GEV   1/77*
D    B       0 2.0E-36 OR LESS  CL=.90     BALDIN     76 CNTR Q=-4/3  M=2.7-12GEV   1/77*
D    D    DORFAN 65 IS A 30 GEV/C P EXPERIMENT AT BNL.   V=.18-.995                 2/74
D    Y    SEE FOOTNOTE Y IN SUBSECTION C ABOVE.                                     2/76
D    A    SEE FOOTNOTE A IN SUBSECTION C ABOVE.                                     2/76
D    V    FIRST ANTIPOV 71 VALUE IS FOR M=1.9-2.3,2.7-4.4GEV.'SECOND IS FOR         1/76
D    V    M=2.3-2.7GEV.  SEE ALSO NOTE V IN SECTION C ABOVE.                        1/76
D    N    NASH 74 IS FNAL EXPT USING 200 AND 300 GEV PROTONS.  VALUES ARE FOR       2/77*
D    N    A IMRAD LAB PROD. ANGLE AND OUTGOING MOMENTUM AT MAX OF FOUR BODY         2/77*
D    N    PHASE SPACE FOR QUARK-PAIR PROD.  SEE TABLE I PG. 860 FOR OTHER           2/77*
D    N    LIMITS.                                                                   2/77*
D    L    ALBROW 75 IS A CERN ISR EXPT WITH ECM=53 GEV. THETA=40 MR. SEE            1/77*
D    L    FIG. 5 FOR MASS RANGES UP TO 25 GEV.                                      1/77*
D    J    JOVANOVICH 75 FIG.4 COVERS RANGES Q=1/3 TO 2 AND M=3 TO 26 GEV.          11/75
D    J    THIS IS A CERN ISR 26+26. 22+22 GEV P+P EXPERIMENT.                       2/76
D    B    BALDIN 76 IS A 70 GEV SERP EXP.  VALUES ARE PER AL NUCLEUS AT             1/77*
D    B    THETA=0.  ASSUMES STABLE PARTICLE INTERACTING WITH MATTER IN SAME         1/77*
D    B    MANNER AS ANTIPROTON.                                                     1/77*

DG        QUARK PROD. DIFF. CROSS SEC. FROM PHOTOPROD. (CM**2/SR-EQUIV.QUANTA)
DG   G       5.0E-35 OR LESS  CL=.90     GALIK      74 CNTR       THETA=1.2,7 DEG. 11/76*
DG   G    GALIK 74 IS 20 GEV(MAX) GAMMA CU EXPT. USING SLAC 20 GEV SPTRMETER.      11/76*

M         LIMIT ON QUARK MASS FROM ELECTRON ACCELERATORS (GEV/C**2)
M          *LEP QUARK  INDICATES LEPTONIC QUARK
M          *STR QUARK  INDICATES STRONG QUARK
M                 .85    OR MORE  CL=.99   BATHOW     67 CNTR Q=1/3    *LEP QUARK   3/77*
M                 .90    OR MORE  CL=.99   BATHOW     67 CNTR Q=2/3    *LEP QUARK   3/77*
M                 .70    OR MORE  CL=.90   FOSS       67 CNTR Q=1/3    *LEP QUARK   3/77*
M                 .84    OR MORE  CL=.90   FOSS       67 CNTR Q=2/3    *LEP QUARK   3/77*
M                1.0     OR MORE           BELLAMY    68 CNTR Q=1/3    *LEP QUARK   3/77*
M                1.5     OR MORE           BELLAMY    68 CNTR Q=2/3    *LEP QUARK   3/77*
M                0.5     OR MORE           BELLAMY    68 CNTR Q=1/3    *STR QUARK   3/77*
M                 .75    OR MORE           BELLAMY    68 CNTR Q=2/3    *STR QUARK   3/77*
M    G           3.6     OR MORE  CL=.90   GALIK      74 CNTR Q=1/3    *STR QUARK   7/76*
M    G           4.5     OR MORE  CL=.90   GALIK      74 CNTR Q=2/3    *STR QUARK   7/76*
M    G           1.4     OR MORE  CL=.90   GALIK      74 CNTR Q=1/3    *LEP QUARK   7/76*
M    G           1.8     OR MORE  CL=.90   GALIK      74 CNTR Q=2/3    *LEP QUARK   7/76*
M    G    FIRST TWO MASS LIMITS ARE FOR STRONGLY INTERACTING QUARKS,INFERRED        7/76*
M    G    FROM CROSS-SEC LIMITS USING DRELL MODEL. LAST TWO ARE FOR LEPTONIC        7/76*
M    G    QUARKS. EXPT USES PHOTOPRODUCTION ON COPPER.                              7/76*

F         QUARK FLUX FROM COSMIC RAY EXPERIMENTS  (NUMBER/CM**2-SR-SEC)
F          *TD IN THE RIGHT HAND COLUMNS INDICATES A SEARCH FOR MASSIVE
F             QUARKS USING TIME DELAY AFTER AIR SHOWERS. SENSITIVE TO A RANGE
F             OF CHARGES
F          *AS IN THE RIGHT HAND COLUMNS INDICATES A SEARCH IN AIR SHOWERS
F          ALL SEARCHES ARE AT SEA LEVEL UNLESS OTHERWISE INDICATED
F            0 1.6E-8    OR LESS  CL=.90   BOWEN     64 CNTR Q=-1/3  ALT=2750M     3/77*
F            0 2.0E-7    OR LESS  CL=.90   SUNYAR    64 CNTR Q=1/3                 3/77*
F            0 8.7E-9    OR LESS  CL=.90   DELISE    65 CNTR Q=1/3   ALT=2750M     3/77*
F            0 1.8E-8    OR LESS  CL=.90   DELISE    65 CNTR Q=2/3   ALT=2750M     3/77*
F            0 5.0E-8    OR LESS  CL=.90   MASSAM    65 CNTR Q=2/3                 3/77*
F    V       0 1.4E-10   OR LESS           BARTON    66 CNTR Q=2/3                 3/77*
F            0 1.5E-9    OR LESS  CL=.90   BUHLER-BR 66 CNTR Q=1/3   ALT= 450M     3/77*
F            0 1.4E-9    OR LESS  CL=.90   BUHLER-BR 66 CNTR Q=2/3   ALT= 450M     3/77*
F            0 2.6E-9    OR LESS           KASHA     66 CNTR Q=1/3                 3/77*
F            0 2.1E-9    OR LESS           KASHA     66 CNTR Q=2/3                 3/77*
F            0 4.5E-10   OR LESS  CL=.90   LAMB      66 CNTR Q=1/3                 3/77*
F            0 1.6E-9    OR LESS  CL=.90   LAMB      66 CNTR Q=2/3                 3/77*
F    W       0 1.4E-10   OR LESS           BARTON    67 CNTR Q=2/3                 3/77*
F    Q       0 1.6E-7    OR LESS           BUHLER-1  67 CNTR Q=4/3   ALT= 450M     3/77*
F    Q       0 4.5E-10   OR LESS  CL=.90   BUHLER-2  67 CNTR Q=1/3   ALT= 450M     3/77*
F    Q       0 1.7E-10   OR LESS           BUHLER-2  67 CNTR Q=2/3   ALT= 450M     3/77*
F            0 1.7E-10   OR LESS  CL=.90   GOMEZ     67 CNTR Q=1/3                 3/77*
F            0 3.4E-10   OR LESS  CL=.90   GOMEZ     67 CNTR Q=2/3                 3/77*
F            0 2.0E-9    OR LESS  CL=.90   KASHA     67 CNTR Q=2/3                 3/77*
F    C       0 3.0E-10   OR LESS           BJORNBOE  68 CNTR M=5GEV OR MORE *TD    2/74
F    R       0 1.8E-10   OR LESS  CL=.90   BRIATORE  68 CNTR Q=1/3                 5/76*
F    R       0 1.8E-10   OR LESS  CL=.90   BRIATORE  68 CNTR Q=2/3                 5/76*
F    R       0 3.7E-8    OR LESS  CL=.90   BRIATORE  68 CNTR Q=4/3                 5/76*
F    Y       0 2.2E-8    OR LESS           FRANZINI  68 CNTR V=.5-.9C  M=2GEV UP   2/74
F            0 6.6E-11   OR LESS  CL=.95   GARMIRE   68 CNTR Q=1/3                 3/77*
F            0 8.8E-11   OR LESS  CL=.95   GARMIRE   68 CNTR Q=2/3                 3/77*
F            0 3.1E-10   OR LESS  CL=.90   HANAYAMA  68 CNTR Q=1/3                 3/77*
F            0 2.4E-8    OR LESS  CL=.95   KASHA1    68 OSPK V=.5-.75C M=5-15GEV   2/74
F            0 1.2E-10   OR LESS  CL=.90   KASHA2    68 CNTR Q=2/3                 3/77*
F            0 1.3E-10   OR LESS  CL=.90   KASHA3    68 CNTR Q=4/3                 3/77*
F    Z       0 5.0E-11   OR LESS           CAIRNS    69 CC   Q=2/3                 3/77*
F     F      0 5.0E-11   OR LESS  CL=.90   FUKUSHIMA 69 CNTR Q=1/3                 2/74
F     F      0 7.5E-10   OR LESS  CL=.90   FUKUSHIMA 69 CNTR Q=2/3                 2/74
F    M       1  EVENT CLAIMED              MCCUSKER  69 CC   Q=2/3           *AS   2/74
F    U       1  EVENT CLAIMED              CHU       70 HLBC                 *AS   5/76*
F            0 1.9E-9    OR LESS  CL=.90   FAISSNER  70 CNTR Q=1/3                 3/77*
F            0 9.8E-11   OR LESS  CL=.90   KRIDER    70 CNTR Q=1/3   ALT=750M      3/77*
F            0 1.6E-10   OR LESS  CL=.90   KRIDER    70 CNTR Q=2/3   ALT=750M      3/77*
F            0 1.3E-10   OR LESS  CL=.90   CHIN      71 CNTR Q=1/3                 3/77*
F            0 5.7E-11   OR LESS  CL=.90   CHIN      71 CNTR Q=1/3   ALT=2770M     3/77*
F            0 3.0E-10   OR LESS  CL=.90   CLARK     71 CC   Q=1/3           *AS   3/77*
F            0 3.0E-11   OR LESS  CL=.90   CLARK     71 CC   Q=2/3           *AS   3/77*
F            0 1.0E-10   OR LESS  CL=.90   HAZEN     71 CC   Q=1/3,2/3       *AS   2/77*
F            0 4.1E-10   OR LESS           BEAUCHAMP 72 CNTR Q=4/3   ALT=2750M     3/77*
F            0 1.0E-10   OR LESS  CL=.90   BOHM      72 CNTR Q=1/3           *AS   2/74
F            0 1.0E-10   OR LESS  CL=.90   BOHM      72 CNTR Q=2/3           *AS   2/74
F            0 8.3E-11   OR LESS  CL=.90   COX       72 ELEC Q=1/3   ALT=2750M     3/77*
F            0 9.6E-11   OR LESS  CL=.90   COX       72 ELEC Q=2/3   ALT=2750M     3/77*
F            0 2.2E-10   OR LESS  CL=.90   CROUCH    72 CNTR Q=2/3                 3/77*
F    X       0 3.0E-8    OR LESS           DARDO     72                      *TD   3/77*
F            0 4.0E-9    OR LESS  CL=.95   EVANS     72 CC   Q=1/3           *AS   1/77*
F            0 1.5E-9    OR LESS           TONWAR    72 CNTR M.GT.10GEV      *TD   3/77*
F            0 8.0E-11   OR LESS           ASHTON    73 CNTR Q=1/3           *AS   3/77*
F    H       0 1.7E-8    OR LESS  CL=.90   HICKS     73 CNTR Q=1/3                 1/76
F    H       0 1.7E-8    OR LESS  CL=.90   HICKS     73 CNTR Q=2/3                 1/76
F            0 1.0E-7    OR LESS  CL=.90   CLARK     74 CC   Q=1/6           *AS   1/77*
F            0 7.0E-10   OR LESS  CL=.90   CLARK     74 CC   Q=1/4           *AS   1/77*
F            0 8.0E-11   OR LESS  CL=.90   CLARK     74 CC   Q=1/3           *AS   1/77*
F            0 1.0E-6    OR LESS  CL=.90   CLARK     74 CC   Q=4/9           *AS   3/77*
F            0 2.0E-11   OR LESS  CL=.90   CLARK     74 CC   Q=2/3           *AS   1/77*
F    K       0 3.0E-10   OR LESS  CL=.95   KIFUNE    74 CNTR Q=1/3                 7/76*
             0 1.2E-11   OR LESS  CL=.90   HAZEN     75 CC   Q=1/3           *AS   7/76*
             0 7.0E-11   OR LESS  CL=.90   KRISOR    75 CNTR Q=1/3                 3/77*
S            0 5.0E-11   OR LESS  CL=.90   KRISOR    75 CNTR Q=2/3  GAMMA = 10     3/77*
S            0 1.5E-10   OR LESS  CL=.90   KRISOR    75 CNTR Q=2/3  GAMMA GT1000   3/77*
F            0 1.0E-9    OR LESS           BRIATORE  76 ELEC                 *TD   1/77*
F    V    BARTON 66 HAD 220000 G/CM**2 EXTRA SHIELDING                             3/77*
F    W    BARTON 67 HAD 6000 G/CM**2 EXTRA SHIELDING                               3/77*
F    Q    BUHLER-1 67 AND BUHLER-2 67 HAD 760 G/CM**2 EXTRA SHIELDING              3/77*
F    C    BJORNBOE 68 -TWO EXPERIMENTS HAVING 1650 AND 3600 G/CM**2 SHIELDING      3/77*
F    R    BRIATORE 68 SEARCHES FOR LEPTONIC QUARKS WITH 6300 G/CM2 SHIELDING       3/77*
F    R    BRIATORE 68 GIVES (1.1+-1.8)E-10 FOR Q=4/3  . WE CONV. TO CL=.90         3/77*
F    Z    CAIRNS 69 OBSERVED 4 POSSIBLE QUARK CANDIDATES                           3/77*
F    Y    FRANZINI 68 MEASURES VELOCITY DIRECTLY BY TOF                            3/77*
F     F   FUKUSHIMA 69 DOES NOT RULE OUT QUARKS HEAVIER THAN 10 GEV.               7/76*
F    M    MC CUSKER 69 CLAIMS 1 CANDIDATE.   LATER SIMILAR EXPTS. SEE NONE.        2/74
F    U    Q=2/3 IF MASS LT 6.5 GEV, Q=1/3 IF MASS = 8 GEV.                         5/76*
F    U    COULD BE AN EARLY-TIME NORMALLY CHARGED COSMIC RAY. SEE ALLISON 70.      2/77*
F     X   DARDO 72 HAD 7000 G/CM**2 EXTRA SHIELDING                                3/77*
F     H   HICKS 73 LOOKED AT LARGE ZENITH ANGLES, THUS USING THE ATMOSPHERE        1/76
F     H   AS AN EXTENDED FILTER FOR HADRONIC QUARKS. THEIR SEARCH PUTS AN          1/76
F     H   UPPER LIMIT ON LEPTONIC QUARK FLUX IN COSMIC RAYS.                       1/76
F     K   KIFUNE 74 LOOKED AT LARGE ZENITH ANGLES. FROM THEIR FLUX LIMIT,THEY      7/76*
F     K   GET A LOWER LIMIT ON QUARK MASS OF 20 GEV.                               7/76*

RHO       QUARK CONCENTRATION IN MATTER (QUARKS PER NUCLEON)
RHO  S       0 1.0E-22   OR LESS                HILLAS    59                       3/77*
RHO  R       0 1.0E-10   OR LESS                BENNETT   66 SOLAR SPECTRUM        3/77*
RHO          0 1.0E-17   OR LESS                CHUPKA    66 METORITES             3/77*
RHO          0 1.0E-16   OR LESS                GALLINARO 66   GRAPHITE LEVITOMETER . 3/77*
RHO          0 4.0E-19   OR LESS                STOVER    67 IRON LEVITOMETER      2/74
RHO          0 1.0E-17   OR LESS                BRAGINSKI 68 GRAPHITE LEVITOMETER  3/77*
RHO          0 1.0E-20   OR LESS                RANK      68 OIL DROPS             3/77*
RHO  T       0 1.0E-18   OR LESS                RANK      68 SEA WATER'            3/77*
RHO  T       0 1.0E-17   OR LESS                RANK      68 SEA SALT, ETC.        3/77*
RHO  T       0 1.0E-18   OR LESS                RANK      68 LAKE WATER            3/77*
RHO  V       0 1.0E-24   OR LESS                COOK      69  SEAWATER             2/74
RHO  V       0 1.0E-23   OR LESS                COOK      69  ROCK SAMPLES         2/74
RHO  V       0 1.0E-23   OR LESS                COOK      69 LAVA                  3/77*
RHO  V       0 5.0E-23   OR LESS                COOK      69 LIMESTONE             3/77*
RHO          0 1.0E-15   OR LESS                ELBERT    70 ION SPECTROMETER      3/77*
RHO          0 5.0E-19   OR LESS                MORPURGO  70 GRAPHITE LEVITOMETER  3/77*
RHO  Z       0 1.0E-21   OR LESS                STEVENS   76 DEEP OCEAN SEDIMENT   3/77*
RHO  Z       0 1.0E-22   OR LESS                STEVENS   76 LUNAR SOIL            3/77*
RHO  S    HILLAS 59 WAS INSENSITIVE TO QUARKS ACCORDING TO SUNYAR 64.              3/77*
RHO  R    BENNETT 66 LIMIT INFERRED BY JONES 76.                                   3/77*
RHO  T    RANK 68 USES U.V. SPECTROSCOPY.                                          3/77*
RHO  V    COOK 69 USES MOLECULAR BEAMS.                                            3/77*
RHO  Z    STEVENS 76 USES AN ION SPECTROMETER.                                     3/77*

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QUARK SEARCHES, MAGNETIC MONOPOLE SEARCHES

Data Card Listings

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                              REFERENCES FOR QUARK SEARCHES

HILLAS   59 NATURE 184 892    HILLAS,CRANSHAW                             (AERE)

BINGHAM  64 PL 9 201          +DICKINSON,DIEBOLD,KOCH,LEITH+   (CERN+EPOL)
BLUM     64 PRL 13 353A       +BRANDT,COCCONI,CZYZEWSKI,DANYSZ+      (CERN)
BOWEN    64 PRL 13 728        BOWEN,DELISE,KALBACH,MORTARA           (ARIZ)
HAGOPIAN 64 PRL 13 280        +SELOVE,EHRLICH,LEBOY,LANZA,RAHM+(PENN+BNL)
LEIPUNER 64 PRL 12 423        LEIPUNER,CHU,LARSEN,ADAIR          (BNL+YALE)
MORRISON 64 PL 9 199          MORRISON                               (CERN)
SUNYAR   64 PR 136B 1157      SUNYAR,SCHWARZSCHILD,CONNORS            (BNL)

DELISE   65 PR 140B 458       DELISE,BOWEN                           (ARIZ)
DORFAN   65 PRL 14 999        +EADES,LEDERMAN,LEE,TING               (COLU)
FRANZINI 65 PRL 14 196        +LEONTIC,RAHM,SAMIOS,SCHWARTZ     (BNL+COLU)
MASSAM   65 NC 40A 589        MASSAM,MULLER,ZICHICHI                 (CERN)

BARTON   66 PL 21 360         BARTON,STOCKEL                         (NOPL)
BUHLER-B 66 NC 45A 520        BUHLER-BROGLIN,FORTUNATO,MASSAM+       (CERN)
CHUPKA   66 PRL 17 60         CHUPKA,SCHIFFER,STEVENS                 (ANL)
GALLINAR 66 PL 23 609         GALLINARO,MORPURGO                     (GENO)
KASHA    66 PR 150 1140       KASHA,LEIPUNER,ADAIR               (BNL+YALE)
LAMB     66 PRL 17 1068       LAMB,LUNDY,NOVEY,YOVANOVITCH            (ANL)

BARTON   67 PRSL 90 87        BARTON                                 (NOPL)
BATHOW   67 PL 25B 163        BATHOW,FREYTAG,SCHULZ,TESCH            (DESY)
BUHLER-1 67 NC 49A 209        BUHLER-BROGLIN,FORTUNATO,MASSAM+       (CERN)
BUHLER-2 67 NC 51A 837        BUHLER-BROGLIN,DALPIAZ,MASSAM,ZICHICH(CERN)
FOSS     67 PL 25B 166        +GARELICK,HOMMA,LOBAR,OSBORNE,UGLUM     (MIT)
GOMEZ    67 PRL 18 1022       +KOBRAK,MOLINE,MULLINS,ORTH,VANPUTTEN+(CIT)
KASHA    67 PR 154 1263       +LEIPUNER,WANGLER,ALSPECTOR,ADAIR(BNL+YALE)
STOVER   67 PR 164 1599       +MORAN,TRISCHKA                        (SYRA)

BELLAMY  68 PR 166 1391       +HOFSTADTER,LAKIN,PERL,TONER     (STAN+SLAC)
BJORNBOE 68 NC B53 241        +DAMGARD,HANSEN,CHATTERJEE+      (BOHR+BERN)
BRAGINSK 68 JETP 27 51        BRAGINSKII,ZELDOVICH,MARTYNOV          (MOSU)
BRIATORE 68 NC 57A 850        +CASTAGNOLI,BOLLINI,MASSAM+      (TORI+CERN)
FRANZINI 68 PRL 21 1013       FRANZINI,SHULMAN                       (COLU)
GARMIRE  68 PR 166 1280       GARMIRE,LEONG,SREEKANTAN                (MIT)
HANAYAMA 68 CJP 46 S734       +HARA,HIGASHI,KITAMURA,MIONO+          (OSAK)
KASHA1   68 PR 172 1297       +STEFANSKI                         (BNL+YALE)
KASHA2   68 PRL 20 217        KASHA,LARSEN,LEIPUNER,ADAIR        (BNL+YALE)
KASHA3   68 CJP 46 S730       KASHA,LARSEN,LEIPUNER,ADAIR        (BNL+YALE)
RANK     68 PR 176 1635       D.M.RANK                               (MICH)

ALLABY   69 NC 64A 75         +BIANCHINI,DIDDENS,DOBINSON,HARTUNG+ (CERN)
ANTIPOV1 69 PL 29B 245        +KARPOV,KHROMOV,LANDSBERG,LAPSHIN+     (SERP)
ANTIPOV2 69 PL 30B 576        +BOLOTOV,DEVISHEV,DEVISHEVA,ISAKOV+    (SERP)
CAIRNS   69 PR 186 1394       +MCCKUSKER,PEAK,WOOLCOTT             (SYDNEY)
COOK     69 PR 188 2092       +DEPASQUALI,FRAUENFELDER,PEACOCK +      (ILL)
FUKUSHIM 69 PR 178 2058       FUKUSHIMA,KIFUNE,KONDO,KOSHIBA+        (TOKY)
MCCUSKER 69 PRL 23 658        MCCUSKER,CAIRNS                      (SYDNEY)

CHU      70 PRL 24 917        CHU,KIM,BEAM,KWAK              (OSU+ROSE+KANS)
  ALSO   70 PRL 25 550        ALLISON,DERRICK,HUNT,SIMPSON,VOYVODIC (ANL)
ELBERT   70 NP B20 217        +ERWIN,HERB,NIELSEN,PETRILAK,WEINBERG(WISC)
FAISSNER 70 PRL 24 1357       +HOLDER,KRISOR,MASON,SAWAF,UMBACH      (AACH)
KRIDER   70 PR D1 835         KRIDER,BOWEN,KALBACH                   (ARIZ)
MORPURGO 70 NIM 79 95         MORPURGO,GALLINARO,PALMIERI            (GENO)

ANTIPOV  71 NP B27 374        +KACHANOV,KUTJIN,LANDSBERG,LEBEDEV + (SERP)
CHIN     71 NC 2A 419         CHIN,HANAYAMA,HARA,HIGASHI,TSUJI       (OSAK)
CLARK    71 PRL 27 51         +ERNST,FINN,GRIFFIN,HANSEN,SMITH+ (LLL+LBL)
HAZEN    71 PRL 26 582        W.E.HAZEN                              (MICH)

BEUCHAMP 72 PR D6 1211        BEUCHAMP,BOWEN,COX,KALBACH             (ARIZ)
BOHM     72 PRL 28 326        +DIEMONT,FAISSNER,FASOLO,KRISOR+       (AACH)
BOTT-BOD 72 PL 40B 693        BOTT-BODENHAUSEN,CALDWELL+        (CERN+MPIM)
COX      72 PR D6 1203        COX,BEUCHAMP,BOWEN,KALBACH             (ARIZ)
CROUCH   72 PR D5 2667        CROUCH,MORI,SMITH                      (CASE)
DARDO    72 NC 9A 319         DARDO,NAVARRA,PENENGO,SITTE            (TORI)
EVANS    72 PRSE A70 143      +FANCEY,MUIR,WATSON               (ECIN+LEED)
TONWAR   72 JPA 5 569         TONWAR,NARANAN,SREEKANTAN              (TATA)

ALPER    73 PL 46B 265          (CERN+LIVP+LUND+BOHR+RHEL+STOH+BERG+LOUC)
ASHTON   73 JPA 6 577         ASHTON,COOPER,PARVARESH,SALEH          (DURH)
HICKS    73 NC 14A 65         +FLINT,STANDIL                         (MANI)
LEIPUNER 73 PRL 31 1226       +LARSEN,SESSOMS,SMITH,WILLIAMS+   (BNL+YALE)

CLARK    74 PR D10 2721       +FINN,HANSEN,SMITH                      (LLL)
GALIK    74 PR D9 1856        +JORDAN,RICHTER,SEPPI,SIEMANN +  (SLAC+NAL)
KIFUNE   74 JPSJ 36 629       +HIEDA,KUROKAWA,TSUNEMOTO,KIMURA+(TOKY+KEK)
NASH     74 PRL 32 858        +YAMANOUCHI,NEASE,SCULLI      (FNAL+CORN+NYU)

ALBROW   75 NP B97 189        +BARBER,BENZ+ (CERN+DARE+FOM+LANC+MCHS+UTR)
FABJAN   75 NP B101 349       +GRUHN,PEAK,SAULI,CALDWELL+       (CERN+MPIM)
HAZEN    75 NP B95 189        +HODSON,WINTERSTEIN,GREEN,KASS+(MICH+LEEDS)
JOVANOVI 75 PL 56B 105        JOVANOVICH+ (MANI+AACH+CERN+GENO+HARV+TORI)
KRISOR   75 NC 27A 132        KRISOR                                 (AACH)

BALDIN   76 SJNP 22 264       +VERTOGRADOV,VISHNEVSKII,GRISHKEVICH+(JINR)
BRIATORE 76 NC 31A 553        +DARDO,PIAZZOLI,MANNOCCHI+  (LCG+FRAS+FREI)
STEVENS  76 PR D14 716        +SCHIFFER, CHUPKA                       (ANL)

                                  REVIEW ARTICLES

ZAITSEV  72 SJNP 15 656       +LANDSBERG                             (SERP)
JONES    76 MICH-HE-76-42     JONES (TO BE PUB. IN REV.MOD.PHYS.)    (MICH)

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MAGNETIC MONOPOLE SEARCHES

There is little new to report in this section. However, we include the listings for completeness. One interesting development is the proposed reinterpretation of the PRICE 75 event by HAGSTROM 77 as a heavy antinucleus.

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C        MONOPOLE PROD. CROSS SECTION - ACCELERATOR EXP.      (CM**2)/NUCLEON
C    A   0    1 E-40 OR LESS   CL=.95   AMALDI    63 EMUL    M=0 TO 3 GEV        12/75
C    A   0    5 E-41 OR LESS   CL=.95   AMALDI    63 EMUL    M=0 TO 3.4 GEV      12/75
C    P   0    2 E-40 OR LESS            PURCELL   63 CNTR    M=0 TO 3 GEV        12/75
C    G   0    4 E-43 OR LESS   CL=.95   GUREVICH  72 EMUL    M=0-5 GEV            3/74
C    C   0    6 E-42 OR LESS   CL=.95   CARRIGAN  73 CNTR Q=1/6-24 DIRAC CHAR     3/74
C    M   0    5 E-42 OR LESS   CL=.95   CARRIGAN  74 CNTR    Q=1/30 TO 24        12/75
C    N   0    1 E-39 OR LESS   CL=.95   CARRIGAN  75 HLBC    NEU ENERGY=1.0       1/76
C    N   0    4 E-38 OR LESS   CL=.95   CARRIGAN  75 HLBC    NEU ENERGY=5.0       1/76
C    N   0    1 E-37 OR LESS   CL=.95   CARRIGAN  75 HLBC    NEU ENERGY=8.0       1/76
C    E   0    5 E-44 OR LESS   CL=.95   EBERHARD  75 CNTR    M=0 TO 12 GEV       11/75
C    I   0    2 E-36 OR LESS   CL=.95   GIACOMELL 75 PLAS    M=0 TO 20 GEV        2/76
C    A   AMALDI 63 USES 28 GEV PROT BEAM AT CERN PS. FIRST RESULT IS FOR         12/75
C    A   PROTON TARGET, SECOND IS FOR NUCLEON TARGET INSIDE NUCLEUS.             12/75
C    P   PURCELL 63 LOOKS FOR MONOPOLES PRODUCED BY 30 GEV PROT AT THE AGS.      12/75
C    G   GUREVICH 72 IS A SERPUKHOV 70 GEV/C P EXP. MASS LIMIT FROM PP=PPMM       3/74
C    C   CARRIGAN 73 IS NAL 300 GEV P EXP. MASS LIMIT 0-12 GEV FROM PP=PPMM       3/74
C    M   CARRIGAN 74 IS NAL 400 GEV EXP.  MASS LIMIT 0-13.7 GEV/MONOPOLE.        12/75
C    N   CARRIGAN 75 REEXAMINES OLD CERN NEUTRINO EXPTS IN HLBC. NEU ENERGY       1/76
C    N   GIVEN AT RIGHT REPRESENTS NEUTRINO THRESHOLD ENERGY.                     1/76
C    N   THESE VALUES ARE IN UNITS CM**2/NUCLEUS.                                 1/76
C    E   EBERHARD 75 USED NAL TARGETS - 300 GEV AND 400 GEV P ON ALUMINUM.        2/76
C    E   Q=1-7 DIRAC CHGS.  USED SAME TYPE OF DETECTOR AS ROSS 73.                2/76
C    I   GIACOMELLI 75 IS CERN ISR EXP., M=0-30 GEV, Q=0.4-2.5 DIRAC CHGS.        2/76

CS       MONOPOLE PROD. CROSS SECTION - SEARCH IN MATTER      (CM**2)/NUCLEON
CS   G   0    5 E-38 OR LESS            GOTO      63 EMUL    M=1 GEV             12/75
CS   G   0    5 E-36 OR LESS            GOTO      63 EMUL    M=10 GEV            12/75
CS   G   0    5 E-33 OR LESS            GOTO      63 EMUL    M=100 GEV           12/75
CS       0    3 E-40 OR LESS   CL=.95   PETUKHOV  63 CNTR    METEORITE           12/75
CS   C   0    1 E-38 OR LESS   CL=.90   CARITHERS 66 ELEC    M=2 GEV             12/75
CS   C   0    7 E-37 OR LESS   CL=.90   CARITHERS 66 ELEC    M=10 GEV            12/75
CS   C   0    1 E-35 OR LESS   CL=.90   CARITHERS 66 ELEC    M=25 GEV            12/75
CS   F   0    5 E-43 OR LESS   CL=.90   FLEISCH1  69 CNTR    M=1 GEV              2/76
CS   F   0    2 E-40 OR LESS   CL=.90   FLEISCH1  69 CNTR    M=10 GEV             2/76
CS   F   0    3 E-37 OR LESS   CL=.90   FLEISCH1  69 CNTR    M=100 GEV            2/76
CS   F   0    5 E-34 OR LESS   CL=.90   FLEISCH1  69 CNTR    M=1000 GEV           2/76
CS   F   0    1 E-29 OR LESS   CL=.90   FLEISCH1  69 CNTR    M=10000 GEV          2/76
CS   K   0    1 E-42 OR LESS   CL=.95   KOLM      71 CNTR    M=1.5 GEV            3/74
CS   K   0    1 E-42 OR LESS   CL=.95   KOLM      71 CNTR    M=10 GEV             3/74
CS   K   0    1 E-37 OR LESS   CL=.95   KOLM      71 CNTR    M=100 GEV            3/74
CS   K   0    1 E-34 OR LESS   CL=.95   KOLM      71 CNTR    M=1000 GEV           3/74
CS   K   0    1 E-31 OR LESS   CL=.95   KOLM      71 CNTR    M=1500 GEV           3/74
CS   R   0    1 E-43 OR LESS   CL=.95   ROSS      73 ELEC    M=2 GEV              3/74
CS   R   0    5 E-41 OR LESS   CL=.95   ROSS      73 ELEC    M=10 GEV             3/74
CS   R   0    5 E-38 OR LESS   CL=.95   ROSS      73 ELEC    M=100 GEV            3/74
CS   G   GOTO 63 EXAMINES MAGNETITE ROCK IN THE ADIRONDACK MOUNTAINS.            12/75
CS   C   CARITHERS 66 LIMITS ABOVE ARE FOR NUCLEON-NUCLEON INTERACTIONS.         12/75
CS   C   LIMITS FOR PHOTONUCLEON PRODUCTION ARE 10**3 TIMES LARGER.              12/75
CS   F   FLEISCHER 69 LOOKED FOR MONOPOLES IN SEDIMENTS AT BOTTOM OF OCEAN        3/74
CS   F   DEPOSITED DURING THE LAST 16 MILLION YEARS. Q=60 DIRAC CHAR.OR LESS      3/74
CS   K   KOLM 71 TRIED TO DETECT MONOP. IN DEEP SEAWATER Q=.2-27 DIRAC CHAR.      2/76
CS   R   ROSS 73 TRIED TO DETECT MONOP. IN LUNAR DUST     Q=.4-36 DIRAC CHAR      2/76
CS   R   OR LARGER CHARGES EXCEPT FOR G= N*36*GO, WITH N INTEGER.  THEY ALSO      3/74
CS   R   REPORT LIMIT OF DENSITY IN LUNAR MATERIAL AS 1.7*10**-4 MONOP./GM.       2/76

F        MONOPOLE FLUX IN COSMIC RAYS (NUMBER/CM**2-SEC-SR)
F        0    1 E-13 OR LESS            GOTO      63 EMUL    KE TO 10**4 GEV     12/75
F        0    5 E-15 OR LESS   CL=.90   CARITHERS 66 ELEC                        12/75
F    F   0    3 E-19 OR LESS   CL=.90   FLEISCH2  69 SCAN    KE TO 10**10 GEV    12/75
F        0    2 E-18 OR LESS            KOLM      71 CNTR    KE TO 10**5 GEV     12/75
F    R   0    5 E-19 OR LESS   CL=.95   ROSS      73 ELEC    KE TO 10**4 GEV     12/75
F   P    1    1 E-13                    PRICE     75 EMUL    M GT 200 GEV        12/75
F    F   FLEISCHER 2 69 LOOKED FOR MONOPOLE TRACKS LEFT IN OBSIDIAN AND MICA     12/75
F    F   OVER GEOLOGICAL TIMES.                                                  12/75
F    R   ROSS 73 INCLUDES DATA OF EBERHARD 71 PAPER.                             12/75
F    P   THE PRICE 75 EVENT COULD BE EXPLAINED AS DUE TO A FRAGMENTING HEAVY     11/76*
F    P   NUCLEUS.  SEE ALVAREZ 75, FLEISCHER 75, FRIEDLANDER 75,AND ROSS 76.     11/76*
F    P   SEE EBERHARD 75 FOR DISCUSSION OF CONFLICT WITH OTHER EXPERIMENTS.      12/75
F    P   NOT CONSIDERED CONVINCING EVIDENCE FOR THE EXISTENCE OF MONOPOLES.      12/75
F    P   HAGSTROM 77 GIVES A REINTERPRETATION AS A HEAVY ANTINUCLEUS.             3/77*

D        MONOPOLE DENSITY IN MATTER     (NUMBER/LITER)
D    S   0  1.6E-4   OR LESS            SCHATTEN  70 ELEC  MOON                   4/77*
D    C   0  4.4E-5   OR LESS   CL=.95   CARRIGAN  76 CNTR    AIR                  1/77*
D    C   0  1.8E-3   OR LESS   CL=.95   CARRIGAN  76 CNTR    SEA WATER            1/77*
D    S   SCHATTEN 70 EXAMINED SATELITE DATA FOR PERTURBATIONS IN THE LUNAR        4/77*
D    S   MAGNETIC WAKE. LIMIT IS FOR THE DIFFERENCE IN NUMBERS OF NORTH AND       4/77*
D    S   SOUTH MONOPOLES.                                                         4/77*
D    C   CARRIGAN 76 IS SENSITIVE TO MONOPOLES WITH DIRAC CHARGE Q=1/6 TO 24      1/77*
D    C   AND MASS AS LARGE AS (7500 GEV)*Q.                                       1/77*

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                          REFERENCES FOR MAGNETIC MONOPOLE SEARCHES

AMALDI   63 NC 28 773         +BARONI,MANFREDINI,BRADNER+(ROMA+UCSD+CERN)
GOTO     63 PR 132 387        +KOLM,FORD                    (TOKY+MIT+BRAN)
PETUKHOV 63 NP 49 87          +YAKIMENKO                             (LEBD)
PURCELL  63 PR 129 2326       +COLLINS,FUJII,HORNBOSTEL,TURKOT (HARV+BNL)
CARITHER 66 PR 149 1070       CARITHERS,STEFANSKI,ADAIR              (YALE)
FLEISCH1 69 PR 184 1393       FLEISCHER,HART,JACOBS+       (GESC+UNCS+GSCO)
    ALSO 70 JAP 41 958        FLEISCHER,HART,JACOBS,PRICE,SCHWARTZ+(GESC)
FLEISCH2 69 PR 184 1398       FLEISCHER,PRICE,WOODS                  (GESC)
    ALSO 70 JAP 41 958        FLEISCHER,HART,JACOBS,PRICE,SCHWARTZ+(GESC)

SCHATTEN 70 PR D1 2245        SCHATTEN                               (NASA)
KOLM     71 PR D4 1285        +VILLA,ODIAN                       (MIT+SLAC)
GUREVICH 72 PL 38B 549        +KHAKIMOV,MARTEMIANOV+       (KIAE+NOVO+SERP)
    ALSO 70 PL 31B 394        GUREVICH,KHAKIMOV +          (KIAE+NOVO+SERP)
    ALSO 72 JETP 34 917       BARKOV, GUREVICH,            (KIAE+NOVO+SERP)
CARRIGAN 73 PR D8 3717        +NEZRICK,STRAUSS                       (FNAL)
ROSS     73 PR D8 698         +EBERHARD,ALVAREZ,WATT             (LBL+SLAC)
    ALSO 71 PR D4 3260        EBERHARD,ROSS,ALVAREZ,WATT         (LBL+SLAC)
CARRIGAN 74 PR D10 3867       +NEZRICK,STRAUSS                       (FNAL)

CARRIGAN 75 NP B91 279        +NEZRICK                               (FNAL)
    ALSO 71 PR D3 56          CARRIGAN,NEZRICK                       (FNAL)
EBERHARD 75 PR D11 3099       +ROSS,TAYLOR,ALVAREZ,OBERLACK      (LBL+MPIM)
GIACOMEL 75 NC 26A 21         GIACOMELLI,ROSSI+     (BGNA+CERN+SACL+ROMA)
PRICE    75 PRL 35 487        +SHIRK,OSBORNE,PINSKY           (UCB+HOUSTON)
    ALSO 75 LBL-4260          LUIS ALVAREZ                            (LBL)
    ALSO 75 LBL-4289          PHILIPPE EBERHARD                       (LBL)
    ALSO 75 PRL 35 1412       R.L. FLEISCHER,R.M.WALKER         (GESC+WUSL)
    ALSO 75 PRL 35 1167       M.W. FRIEDLANDER                       (WUSL)
    ALSO 76 LBL-4665          RONALD ROSS                             (LBL)
    ALSO 77 PRL 38 729        RAY HAGSTROM                            (LBL)

CARRIGAN 76 PR D13 1823       +NEZRICK,STRAUSS                       (FNAL)

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OTHER NEW PARTICLE SEARCHES

We collect here those searches which do not fit neatly into one of the above search categories.

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LEP       DIRECT LEPTON PRODUCTION IN PROTON NUCLEON INTERACTIONS
LEP       THOSE LEPTONS DO NOT RESULT FROM PIO, ETA OR KNOWN WEAK DECAYS.
LEP       CANDIDATES FOR PARENTS OF DIRECT LEPTONS INCLUDE VIRTUAL MASSIVE
LEP       PHOTONS, HIGH PT VECTOR MESONS, INTERMEDIATE BOSONS, CHARMED
LEP       PARTICLES AND HEAVY LEPTONS.
LEP   A                              APPEL2    74 SPEC FNAL 300GEV P+BE      3/77*
LEP   A  APPEL2 74 OBSERVE DIRECT ELECTRON AND MUON SIGNALS 10**-4 TIMES THE  3/77*
LEP   A  PION YIELD FOR PPERP RANGE 1.-4 GEV.  ELECTRON SOURCE LIFETIME LESS  3/77*
LEP   A  THAN (10**-11 SEC)*(PARENT MASS/GEV).  SUGGESTS LIGHT VEC.MES.(PHI).  3/77*
LEP   B                              BOYMOND   74 SPEC FNAL 300GEV P+CU,W    3/77*
LEP   B  BOYMOND 74 SEE DIRECT MUON SIGNAL 0.8E-4 TIMES THE PION YIELD FOR   3/77*
LEP   B  PT RANGE 1.5-4.4GEV.  SUGGEST STRONGLY INTERACTING, SHORT LIFETIME  3/77*
LEP   B  SOURCES.  RHO AND PHI ARE POSSIBLE SOURCES.                         3/77*
LEP   U                              BUSSER    74 SPEC CERNISR 26+26GEV PP   3/77*
LEP   U  BUSSER 74 SEE DIRECT ELECTRON SIGNAL 10**-4 TIMES PION YIELD FOR    3/77*
LEP   U  PT RANGE 1.6-4.7GEV.  CANT BE PHI ALONE SINCE PHI TO K+K- NOT SEEN.  3/77*
LEP   L                              LEDERMAN  75 RVUE                       3/77*
LEP   L  LEDERMAN 75 DISCUSSES ABOVE EXPTS AND RECENT UNPUBLISHED RESULTS.   3/77*
LEP   L  SUGGESTS NEW LIGHT(1-5 PION MASSES) VECTOR MESON, WEAKLY DECAYING.  3/77*
LEP   -                              ABRAMOV   76 CNTR 35-70 GEV P+BE,CU     3/77*
LEP   -  ABRAMOV 76 SEE DIRECT MUON SIGNAL 2.5E-5 TIMES PION YIELD FOR       3/77*
LEP   -  PT RANGE 1.9-3.1 GEV. RATIO MU+/MU- = 1.2. RATIO MU+/PI+ INCREASES  3/77*
LEP   -  WITH INCREASING PROTON ENERGY, INDICATING DECAY OF HEAVY PARTICLE   3/77*
LEP   -  WITH TAU LT 10**-11 SEC.                                            3/77*
LEP   N                              ANISIMOVA 76 ELEC 70 GEV PROT ON CU     3/77*
LEP   N  ANISIMOVA 76 MEASURES LONG. POLARIZ. OF DIRECT MUONS WITH PT=2 -2.8  3/77*
LEP   N  GEV/C. FIND POL.=-0.85+-0.36. THIS WOULD INDICATE THAT MUONS COME   3/77*
LEP   N  FROM PARTICLE DECAYING VIA WK INTERACTIONS. OPPOSITE RESULT IS      3/77*
LEP   N  SEEN BY LAUTERBACH 76 AND LEIPUNER 76.                              3/77*
LEP   K                              KASHA     76 CNTR FNAL 400GEV P+NUCL    3/77*
LEP   K  KASHA 76 FIND THAT MUON PAIR PRODUCTION CAN ACCOUNT FOR MOST OF THE  3/77*
LEP   K  DIRECT MUONS INDICATING ELECTROMAGNETIC PRODUCTION MECHANISM.       3/77*
LEP   T                              LAUTERBAC 76 CNTR FNAL 400GEV P+CU      3/77*
LEP   T  LAUTERBACH 76 MEASURES LONG. POLARIZ. OF HIGH PT DIRECT MUONS TO BE  3/77*
LEP   T  P=-0.125+-0.20 AS EXPECTED FOR ELECTROMAGNETIC PROCESS, NOT WK.DEC.  3/77*
LEP   F                              LEIPUNER  76                            3/77*
LEP   F  LEIPUNER 76 MEASURES LONG. POLARIZ. OF FORWARD DIRECT MUONS TO BE   3/77*
LEP   F  P=-0.00+-0.10 AS EXPECTED FOR ELECTROMAGNETIC PROCESS, NOT WK. DEC.  3/77*
LEP   S                              BRANSON   77 SPEC 200 GEV/C PROT + FE   3/77*
LEP   S  BRANSON 77 FINDS MU/PI RATIO= 3.E-5 FOR PT LESS THAN 1 GEV/C.       3/77*
LEP   S  ALSO FINDS THAT 0.7+-0.2 OF ALL PROMPT MUS ARE PRODUCED IN PAIRS.   3/77*

ICL       CHARMONIUM-LIKE STATES - INTEG. CROSS SECTION * B.P. (CM**2-MEV)
ICL   B    0  1.5E-30 OR LESS  CL=.90   BOYARSKI  75 SMAG                    4/77*
ICL   A    0  9.0E-31 OR LESS           BARBIELLI 76 CNTR M=2.5-3 GEV        4/77*
ICL   C    0  5.5E-31 OR LESS  CL=.90   BACCI     76 CNTR M=2.5-3 GEV        4/77*
ICL   E    0  9.0E-31 OR LESS           ESPOSITO  76 CNTR M=2.5-3 GEV        4/77*
ICL   B  BOYARSKI 75 IS A SPEAR EXPT. LIMIT IS FOR ECM=3.2-5.9 GEV,          4/77*
ICL   B  EXCLUSIVE OF THE PSI(3700). LIMIT RANGES FROM 1.1 TO 1.7 E-30.      4/77*
ICL   B  FOR A WIDTH OF 10 MEV, FROM E+E- HADRONS.                           4/77*
ICL   A  BARBIELLINI 76 IS AN ADONE E+ E- EXPT. CROSS SECT. CONVERTED FROM   4/77*
ICL   A  RATIO TO E+E- --> J/PSI CROSS SECT.                                 4/77*
ICL   C  BACCI 76 IS AN ADONE E+ E- EXPT.                                    4/77*
ICL   E  ESPOSITO 76 IS AN ADONE E+ E- EXPT. CROSS SECT. CONVERTED FROM      4/77*
ICL   E  RATIO TO E+E- --> J/PSI CROSS SECT.                                 4/77*

CL        CHARMONIUM-LIKE STATES   CROSS-SECTION * B.P. (CM**2)
CL    A    0  1.0E-34   OR LESS             APEL      75 CNTR  M=2-5 GEV           4/77*
CL    E                                     EARTLY    76 CNTR  SHOULDER AT 6 GEV   4/77*
CL    H   12  5.2E-36      2.0E-36          HOM1      76 CNTR    PEAK AT 6 GEV     4/77*
CL    H    0  2.0E-36   OR LESS             HOM2      76 CNTR                      4/77*
CL    T    0  2.0E-33   OR LESS             THEODOSIO 76 CNTR    M=1.2-3.5 GEV     4/77*
CL    A  APEL 75 IS A 40 GEV PI- P EXP. SENSITIVE TO MULTI-GAMMAS. DOES NOT  4/77*
CL    A  SEE J/PSI OR PSI(3700).                                             4/77*
CL    E  EARTLY 76 IS A 300 GEV P NUCLEUS EXPT. STRUCTURE AT 6 GEV IS        4/77*
CL    E  ABOUT 5 PER CENT THE J/PSI CROSS SECT. DOES NOT SEE THE PSI(3700).  4/77*
CL    H  HOM1 76 AND HOM2 76 ARE FROM A 400 GEV P NUCLEUS EXPT. CROSS SECTS.  4/77*
CL    H  ARE FOR THE 6 GEV MASS REGION, WHERE AN ENHANCEMENT IS REPORTED IN  4/77*
CL    H  E+E-(HOM1 76) BUT NOT IN MU+MU-(HOM2 76). E+E- BUMP MAY BE A        4/77*
CL    H  STATISTICAL FLUCTUATION.                                            4/77*
CL    T  THEODOSIOU 76 IS A CORNELL GAMMA BE EXPT., WITH MAX. ENERGY OF      4/77*
CL    T  11 GEV. LOOKING FOR ELECTRONS AND/OR GAMMAS. CROSS SECTION IS       4/77*
CL    T  CONVERTED FROM DIFF. C.S. GIVEN AS 130EXP(3T) NP/GEV2 EXPECTED FOR  4/77*
CL    T  THE U- CHARM-ANTICHARM STATE                                        4/77*

CH        HEAVY PARTICLE PRODUCTION CROSS SECTION (CM**2)
CH    L    0  1. E-31 OR LESS        LEIPUNER  73 CNTR +- M=3-11 GEV         5/76*
CH    L  LEIPUNER 73 IS AN NAL 300 GEV P EXPT. WOULD HAVE DETECTED PARTICLES  4/76*
CH    L  WITH LIFETIME GREATER THAN 200 NSEC.                                4/76*

CS        HEAVY PARTICLE PRODUCTION CROSS-SECTION (CM**2/NUCLEON)
CS    G    0  2.5E-35 OR LESS        GUSTAFSON 76 CNTR 0   TAU GT 10**-7     1/77*
CS    G  GUSTAFSON 76 IS A 300 GEV FNAL EXPT LOOKING FOR HEAVY (M GT 2 GEV)  1/77*
CS    G  LONGLIVED NEUTRAL HADRONS IN THE M4 NEUTRAL BEAM. THE ABOVE TYPICAL  1/77*
CS    G  VALUE IS FOR M=3 GEV AND ASSUMES AN INTERACTION CROSS SECTION OF    1/77*
CS    G  1 MB. VALUES AS A FUNCTION OF MASS AND INTERACTION CROSS SECTION    1/77*
CS    G  ARE GIVEN IN FIG. 2.                                                1/77*

D         HEAVY PARTICLE PRODUCTION DIFFERENTIAL CROSS SECTION (CM**2/SR-GEV)
D     D    0  1.5E-36 OR LESS                  DORFAN     65 CNTR BE TARGET  M=3-7GEV   5/76*
D     D    0  3.0E-36 OR LESS                  DORFAN     65 CNTR FE TARGET  M=3-7GEV   5/76*
D          0  2.4E-35 OR LESS      CL=.90      BINON      69 CNTR Q=- M=1-1.8 GEV       3/77*
D     S    0  2.4E-35 OR LESS      CL=.90      ANTIPOV1   71 CNTR Q=- M=1.2-1.7,2.1-4   3/77*
D     T    0  1.2E-35 OR LESS      CL=.90      ANTIPOV2   71 CNTR Q=- M=2.2-2.8         3/77*
D     L    0  5.8E-34 OR LESS      CL=.90      ALPER      73 SPEC +- M=1.5-24 GEV       5/76*
D     A    0  1. E-31 OR LESS      CL=.90      APPEL1     74 CNTR +- M=3.2-7.2 GEV      2/76
D     L    0  2.2E-33 OR LESS      CL=.90      ALBROW     75 SPEC Q=+-1 M=4-15 GEV      1/77*
D     L    0  1.1E-33 OR LESS      CL=.90      ALBROW     75 SPEC Q=+-2 M=6-27 GEV      1/77*
D     J    0  8. E-35 OR LESS      CL=.90      JOVANOVIC  75 CNTR +- M=15-26 GEV        2/76
D     J    0  1.5E-34 OR LESS      CL=.90      JOVANOVIC  75 CNTR Q=+-2, M=3-10 GEV     2/76
D     J    0  6. E-35 OR LESS      CL=.90      JOVANOVIC  75 CNTR Q=+-2, M=10-26 GEV    2/76
D     B    0  2.6E-36 OR LESS      CL=.90      BALDIN     76 CNTR Q=-1, M=2.1-9.4 GEV   1/77*
D     D  DORFAN 65 IS 30 GEV P EXPT AT BNL. UNITS ARE PER GEV MOMENTUM       5/76*
D     D  PER NUCLEUS.                                                        5/76*
D     S  ANTIPOV1 71 LIMIT INFERRED FROM FLUX RATIO. 70 GEV P EXPERIMENT.    3/77*
D     T  ANTIPOV2 71 IS FROM SAME 70 GEV P EXP. AS ANTIPOV1 71 AND BINON 69.  3/77*
D     L  ALPER 73 IS CERN ISR 26+26 GEV P+P EXPT.  P>.9 GEV, .2< BETA <.65.  5/76*
D     A  APPEL1 74 IS NAL 300 GEV P+W EXPERIMENT. STUDIES FORWARD PRODUCTION  2/76
D     A  OF HEAVY (UP TO 24 GEV) CHARGED PARTICLES WITH MOMENTA 24-200GEV(-)  2/76
D     A  AND 40-150GEV (+CHG).  ABOVE TYPICAL VALUE IS FOR 75 GEV AND IS     5/76*
D     A  PER GEV MOMENTUM PER NUCLEON.                                       5/76*
D     L  ALBROW 75 IS A CERN ISR EXPT WITH ECM=53 GEV. THETA=40 MR. SEE      1/77*
D     L  FIG. 5 FOR MASS RANGES UP TO 35 GEV.                                1/77*
D     J  JOVANOVICH 75 IS A CERN ISR 26+26 AND 15+15 GEV P+P EXPERIMENT.     2/76
D     J  FIG.4 COVERS RANGES Q=1/3 TO 2 AND M=3 TO 26 GEV.                   2/76
D     J  VALUE IS PER GEV MOMENTUM.                                          5/76*
D     B  BALDIN 76 IS A 70 GEV SERP EXP.  VALUE IS PER AL NUCLEUS AT         1/77*
D     B  THETA=0.  FOR OTHER CHARGES IN RANGE -0.5 TO -3.0, CL=.90 LIMIT IS  1/77*
D     B  (2.6E-36)/ABS(CHARGE) FOR MASS RANGE (2.1 TO 9.4GEV)*ABS(CHARGE).   1/77*
D     B  ASSUMES STABLE PARTICLE INTERACTING WITH MATTER AS DO ANTIPROTONS.  1/77*

CA        CROSS-SEC FOR PROD AND CAPT OF LONG-LIVED MASSIVE PARTICLES (CM**2)
CA    F    0   .1-9E-36 OR LESS        FRANKEL    74 CNTR TAU=1 TO 1000 HRS    7/76*
CA    R    0  1.4-9E-36 OR LESS        FRANKEL    75 CNTR TAU=50 MS TO 10 HRS  2/77*
CA    A    0   2-20E-34 OR LESS        ALEKSEE1   76 ELEC TAU=100 MS TO 1 DAY  4/77*
CA    A    0   .2-8E-34 OR LESS        ALEKSEE2   76 ELEC TAU=5 MS TO 1 DAY    3/77*
CA    F  FRANKEL 74 LOOKS FOR PARTICLES PRODUCED IN THICK AL TARGETS BY      7/76*
CA    F  300-400 GEV/C PROTONS.                                              7/76*
CA    R  FRANKEL 75 IS EXTENSION OF FRANKEL 74.                              2/77*
CA    A  ALEKSEEV(1,2) 76 ARE 61-70 GEV P SERP EXPT. CS IS PER PB NUCLEUS.   3/77*

F         HEAVY PARTICLE FLUX IN COSMIC RAYS (NUMBER/CM**2-SEC-SR)
F          0  3.0E-10 OR LESS            BJORNBOE  68 CNTR     M ABOVE 5 GEV      4/77*
F          0  5.0E-11 OR LESS  CL=.90    JONES     67 ELEC     M=5 TO 15 GEV      3/77*
F          0  3.0E-8  OR LESS            DARDO     72 CNTR                        4/77*
F          0  1.5E-9  OR LESS            TONWAR    72 CNTR     M GT 10 GEV        4/77*
F     Y    5  6. E-9  OR MORE            YOCK      74 CNTR     M GT 6 GEV         1/76
F          0  7. E-10 OR LESS  CL=.90    YOCK      75 ELEC +- Q GT 7 OR LT -7E    9/76*
F          0  1.0E-9  OR LESS            BRIATORE  76 ELEC                        4/77*
F     Y  YOCK 74 EVENTS COULD BE TRITONS.                                    1/76

C         LIGHT (BETWEEN MU AND E MASSES) PARTICLE MASS(UNITS-ELECTRON MASSES)
C          0    NONE BETWEEN 6 AND 25      BELOUSOV  60 CNTR   SPINOR,TAU>1 E-8      5/76*
C          0    NONE BETWEEN 2 AND 25      GORBUNOV  60 CC     SPINOR,TAU>1 E-9      5/76*
C          0    NONE BETWEEN 5 AND 175     COWARD    63 CNTR   SPINOR,TAU>22 E-10    5/76*
C          0    NONE BETWEEN 5 AND 175     COWARD    63 CNTR   SCALAR,TAU>68 E-10    5/76*
C     D    0    NONE BETWEEN 2 AND 13      BLAGOV    75 CNTR   SPINOR,TAU>2E-10SEC   2/76
C     D    0    NONE BETWEEN 2 AND 10.6    BLAGOV    75 CNTR   SCALAR,TAU>2E-10SEC   2/76
C     D  BLAGOV 75 BOUNDS ON LIFETIME DEPEND ON MASS AND IMPROVE AS MASS     4/77*
C     D  DECREASES.  AT 2 GEV THE EXPERIMENT IS SENSITIVE TO TAU>3E-11 SEC   4/77*
C     D  FOR SPINOR, TAU>5E-11 SEC FOR SCALAR.                               4/77*

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REFERENCES FOR OTHER NEW PARTICLE SEARCHES


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BELOUSOV  60 JETP 11 1143      +RUSAKOV,TAMM,CERENKOV                    (LEBD)
GORBUNOV  60 JETP 11 51        +SPIRIDONOV,CERENKOV                      (LEBD)
COWARD    63 PR 131 1782       +GITTELMAN,LYNCH,RITSON                   (STAN)
DORFAN    65 PRL 14 999        +EADES,LEDERMAN,LEE,TING                  (COLU)
JONES     67 PR 164 1584        (MICH+WISC+LBL+UCLA+MINN+COSU+COLO+MURA)
BJORNBOE  68 NC B53 241        +DAMGARD,HANSEN,CHATTERGEE+      (BOHR+BERN)
BINON     69 PL 30B 510        DUTEIL,KACHANOV,KHROMOV,KUTYIN+           (SERP)

ANTIPOV1  71 PL 34B 164        +DENISOV,DONSKOV,GORIN,KACHANOV+          (SERP)
ANTIPOV2  71 NP B31 235        +DENISOV,DONSKOV,GORIN,KACHANOV+          (SERP)
DARDO     72 NC 9A 319         DARDO,NAVARRA,PENENGO,SITTE               (TORI)
TONWAR    72 JPA 5 569         TONWAR,NARANAN,SREEKANTAN                 (TATA)
ALPER     73 PL 46B 265         (CERN+LIVP+LUND+BOHR+RHEL+STOH+BERG+LOUC)
LEIPUNER  73 PRL 31 1226       +LARSEN,SESSOMS,SMITH,WILLIAMS+   (BNL+YALE)

APPEL1    74 PRL 32 428        +BOURQUIN,GAINES,LEDERMAN,PAAR+ (COLU+FNAL)
APPEL2    74 PRL 33 722        +BOURQUIN,GAINES,HOM,LEDERMAN+  (COLU+FNAL)
BOYMOND   74 PRL 33 112        +MERMOD,PIROUE,SUMNER,CRONIN+     (PRIN+EFI)
BUSSER    74 PL 53B 212        +CAMILLERI,DILELLA+    (CERN+COLU+ROCK+SACL)
FRANKEL   74 PR D9 1932        +FRATI,RESVANIS,YANG,NEZRICK     (PENN+NAL)
YOCK      74 NP B76 175        P.C.M.YOCK                (UNIV OF AUCKLAND)

ALBROW    75 NP B97 189        +BARBER,BENZ+ (CERN+DARE+FOM+LANC+MCHS+UTR)
APEL      75 PL 56B 190        +AUGENSTEIN,BERTOLUCCI,DONSKOV,+(SERP+CERN)
BLAGOV    75 YAD.FIZ. 21,300   +KOMAR,MURASHOVA,SYREISHCHIKOVA+          (LEBD)
FRANKEL   75 PR D12 2561       +FRATI,RESVANIS,YANG,NEZRICK     (PENN+FNAL)
JOVANOVI  75 PL 56B 105        JOVANOVICH+ (MANI+AACH+CERN+GENO+HARV+TORI)
LEDERMAN  75 PRL 35 1543       +WHITE                                    (COLU)
YOCK      75 NP B86 216        P.C.M. YOCK          (UNIV OF AUCKLAND+SLAC)

ABRAMOV   76 PL 64B 365        +SULYAEV,BONDARENKO,DOBRETSOV + (SERP+MEPI)
ALESKEE1  76 SJNP 22 531       ALESKEEV,ZAITSEV,KALININA,KRUGLOV+      (JINR)
ALEKSEE2  76 SJNP 23 633       ALEKSEEV,ZAITSEV,KALININA,KRUGLOV+      (JINR)
ANISIMOV  76 PL 65B 85         ANISIMOVA,BONDARENKO,GOVOROV +   (SERP+MEPI)
BACCI     76 PL 58B 190        +BIDOLI,PENSO,STELLA,+           (ROMA+FRAS)
BALDIN    76 SJNP 22 264       +VERTOGRADOV,VISHNEVSKII,GRISHKEVICH+(JINR)
BARBIELL  76 PL 64B 359        BARBIELLINI,NICOLETTI+(FRAS+NAPL+PISA+ROMA)
BRIATORE  76 NC 31A 553        +DARDO,PIAZZOLI,MANNOCCHI+ (LCG+FRAS+FREI)
EARTLY    76 PRL 36 1355       +GIACOMELLI,PRETZL              (FNAL+BGNA+MUNI)
ESPOSITO  76 PL 64B 362        +FELICETTI,MARINI,+     (FRAS+ROMA+PADO+NAPL)
GUSTAFSO  76 PRL 37 474        GUSTAFSON,AYRE,JONES,LONGO,MURTHY       (MICH)
HOM1      76 PRL 36 1236       +LEDERMAN,PARR,SNYDER+       (COLU+FNAL+STON)
HOM2      76 PRL 37 1374       +LEDERMAN,PAAR,SNYDER,+      (COLU+FNAL+STON)
KASHA     76 PRL 36 1007       +KELLOGG,LAUTERBACH,ADAIR+  (YALE+BNL+FNAL)
LAUTERBA  76 PRL 37 1436       LAUTERBACH,ADAIR,CARTER,GRANNAN+ (YALE+BNL)
LEIPUNER  76 PRL 36 1011       +LARSEN,ADAIR,CARTER+          (BNL+YALE+FNAL)
THEODOSI  76 PRL 37 126        THEODOSIOU,GITTELMAN,HANSON,LARSON+  (CORN)

BRANSON   77 PRL 38 457        +SANDERS,SMITH,THALER,ANDERSON+   (PRIN+EFIN)
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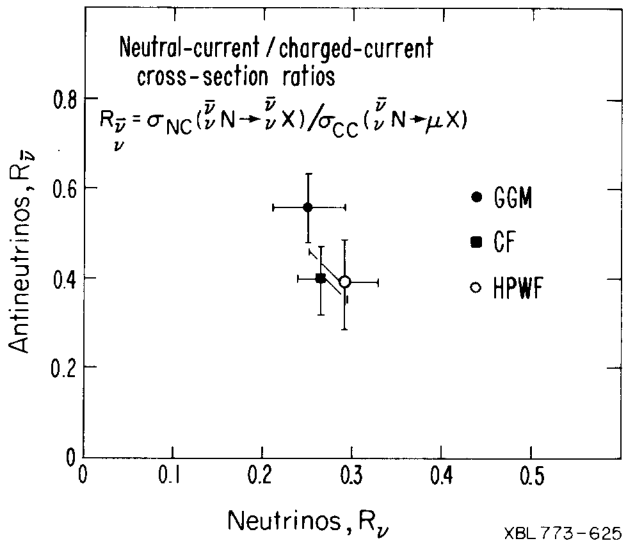
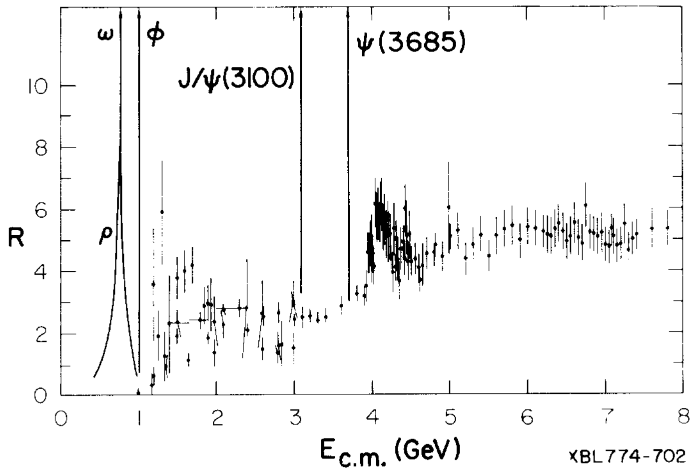
CROSS SECTION PLOTS



Neutral-current-to-charged-current cross-section ratios, neutrinos vs. antineutrinos. Determination by three separate experiments: Gargamelle collaboration [J.Blietschau et al., Nucl. Phys. B118, 218 (1977)]; Caltech-Fermilab [F.S.Merritt, Ph.D. Thesis, California Institute of Technology (1977); point has been corrected for experimental cuts assuming a scaling model for charged currents and an antiquark fraction in the nucleon of 17%]; and Harvard-Penn-Wisconsin-Fermilab [A.Benvenuti et al., Phys. Rev. Lett. 37, 1039 (1977)]. Because of the different energy regions and experimental cuts involved, some care should be exercised in making direct comparisons.



A summary of the cross-section ratio $R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$ where $\sigma(e^+e^- \to \mu^+\mu^-)$ is taken from QED as $86.8/E^2_{c.m.}$ nb-GeV^2, and $\sigma(e^+e^- \to \text{hadrons})$ is generally taken as the cross section of 3-or-more-prongs plus non-coplanar 2-prongs, as compiled by Schwitters and Straunch [Ann. Rev. Nucl. Sci. 26, 89 (1976)]. Between 3 and 8 GeV there is an overall normalization uncertainty of the order of 10%, and a further slowly varying uncertainty of as much as 15%. Below 3 GeV, the normalization uncertainty is of the order of 50%.

ERRATA

The following corrections should be made in the 1976 edition of "Review of Particle Properties", Particle Data Group [Rev. Mod. Phys. 48, No. 2, Part II (1976)]. A second page number given in parentheses following the first number refers to the corresponding page in the 1976 Particle Properties Data Booklet; where the second number is absent, the correction was already made in the Data Booklet before it was issued.

Page S21: The mass squared of the π^0 should read 0.0182 instead of 0.182.

Page S24 (8): The magnetic moment of the μ should read 1.001 165 897 $\frac{e\hbar}{2m_\mu c}$ instead of 1.001 166 897 $\frac{e\hbar}{2m_\mu c}$.

Page S26: The width of the π^0 should read 7.95±0.55 eV instead of 7.8±0.9 eV; the width of the η should read 0.85±0.12 keV instead of 2.63±0.58 keV; and the percentage decay of the η into neutral and charged modes should read 71.0 and 29.0, respectively, instead of 71.1 and 28.9. These values (or their equivalents) are all given correctly in the Stable Particle Table.

Page S32: The J^P of the $\Lambda(1860)$ should read $3/2^+$ instead of $1/2^+$.

Page S33: The mass of the $\Sigma(1765)$ should read 1773 instead of 1723.

Page S35 (39): On the line giving the value of what is called "μ_p", the notation should be changed to "μ_N"; this is the nuclear magneton, not the proton magnetic moment. The next line, giving μ_p/μ_{Bohr}, should be completely replaced by

$$\mu_p/\mu_{Bohr} = 0.001521032210(18) \qquad 0.012 \; ;$$

the μ_p appearing here is the proton magnetic moment. Additionally, the third expression for R_∞ should read $m_e c\alpha^2/2h$ instead of $m_e c\alpha^2/2\hbar$; the numerical value is correct as it stands. Also, the gravitational constant should read $6.6720(41)\times10^{-8}\,cm^3 g^{-1} sec^{-2}$ instead of $6.6732(31)\times10^{-8}\,cm^{-3} g^{-1} sec^{-2}$. And finally, on the line giving the pressure of 1 atmosphere, the word "dynes" should be replaced by "g(force)"; also note that 1 bar = 10^6 dynes/cm^2.

Pages S40-S41 (52-53): Equation II-19 should be deleted; also, both parts of Eq. II-20 and the first part of Eq. II-23 (defining u) should be marked to indicate that they apply in the (ab) c.m. system only.

Page S45 (72): In Section C.3, on multiple Coulomb scattering, the expression given for $\theta^{1/e}_{proj}$ should have referred to θ^{rms}_{proj} [see V. L. Highland, Nucl. Instr. and Meth. 129, 497 (1975); also private communication]; the proper equation, for θ^{rms}_{proj}, is given below. The correct description of multiple scattering is as follows. The probability of scattering through a space angle θ into an element of solid angle $d\Omega = \sin\theta d\theta d\phi$ in terms of a parameter θ_0 is given to a good approximation by

$$f(\theta)d\Omega = Ke^{-\theta^2/\theta_0^2}\,d\Omega \, ,$$

with $K \cong 1/(\pi\theta_0^2)$. For this distribution, $\theta^{1/e}$, the angle such that $f(\theta^{1/e})/f(0) = 1/e$, is equal to $\theta^{rms} = \sqrt{\langle\theta^2\rangle} = \theta_0$. This distribution may be expressed in terms of the two projected angles θ_x and θ_y, with $d\Omega = d\theta_x d\theta_y$, and the probability of one of the projected angles, say θ_x, derived as

$$g(\theta_x)d\theta_x = \frac{1}{\sqrt{2\pi}\,\theta_x^{rms}}\, e^{\left\{-\frac{\theta_x^2}{2(\theta_x^{rms})^2}\right\}}\, d\theta_x$$

with $2(\theta_x^{rms})^2 = \theta_0^2$. For this distribution, $\theta_x^{rms} = \theta_x^{1/e}/\sqrt{2}$ is given by the expression

$$\theta^{rms}_{proj} = z\,\frac{14\,\mathrm{MeV}/c}{p\beta}\sqrt{\frac{L}{L_R}}\left[1+\frac{1}{9}\log_{10}\left(\frac{L}{L_R}\right)\right]\left[1+\frac{M^2}{Em_s}\right]$$

for the scattering of a particle of mass M, charge $z|e|$, velocity β, and energy E in a thickness L of a medium of radiation length L_R and atomic mass m_s. The distribution for $g(\theta_x)$ is accurate experimentally at the 5-10% level except in the tails, which are broader than the Gaussian form. For this reason, the notation "rms", which has come into general use in this problem, is somewhat of a misnomer. It should be understood that this refers to the $1/\sqrt{e}$ point of the distribution, i.e., $g(\theta^{rms}_{proj})/g(0) = e^{-1/2} = 0.606$, and not to the true rms projected scattering angle (which is larger than θ^{rms}_{proj} due to the large tails). Note that for incident electrons, positrons, or heavy nuclei, this formula is inaccurate.

ACKNOWLEDGMENTS

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A SPECIAL REQUEST

The Particle Data Group is currently compiling a database of experimental high energy physics reports and proposals. We publish an account of active high energy physics experiments (LBL-91) and will publish an index of high energy physics reports (LBL-90). Our database will eventually become directly accessible to users at any institution. An important feature of our system will be a link between each report and the experimental proposal that generated the data in that report. In order to help make this link, we request that publications include the accelerator and proposal number in a footnote.