

# Particle Data Group



October 2008

# US Department of Energy (DOE) Review of PDG on September 12 (all day) in Washington DC

Never done before, but a new administration in DOE-HEP, and they want to review all programs. It was triggered by our request for substantial funds for a major computing upgrade, but the review was of the entire PDG program. Many slides taken from that.

# Significance and Relevance of the PDG to HEP



**Particle Data Group collaboration  
of 170 authors  
from 20 countries and 108 institutions  
+ 700 consultants in the HEP community**



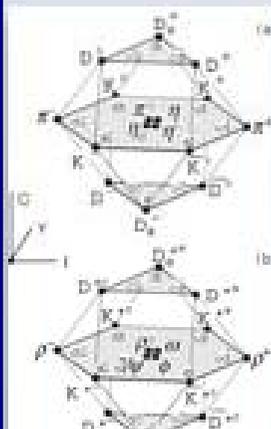
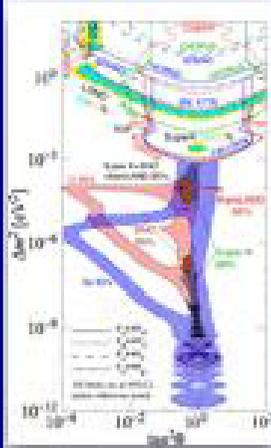
M. Barnett – October 2008

## PDG 50th ANNIVERSARY FESTIVITIES

Date: Saturday, September 23, 2006

Location: Lawrence Berkeley National Laboratory  
 Building 50 Auditorium

Also celebrating  
 75th birthday of Matts Roos  
 80th birthday of Art Rosenfeld



### PROGRAM

- Art Rosenfeld** - PDG History
- Matts Roos** - Meson Team History
- Chris Quigg** - Standard Model Theory
- Michael Riordan** - Toward the Standard Model
- Hiroaki Aihara** - B Physics
- Boris Kayser** - Neutrinos
- Lina Galtieri** - Top Quark
- Michael Turner** - Cosmology
- John Ellis** - Searches for New physics
- Michelangelo Mangano** - LHC and its Impact on PDG
- Michael Barnett** - Summary
- Banquet

**645** new papers with **2778** measurements

**108** Reviews written or edited by PDG

RPP: **1344** pages (in 2008)

Booklet: **320** pages (in 2006)

The Web allows us to see what most interest our readers.

The hits on

Data Listings = Reviews

almost exactly equal.

Clearly people care about both.

**10 years ago:** Very little

**Now:**

**Astrophysical Constants**

**Big Bang Cosmology**

**Cosmological Parameters:**

**$H_0$ ,  $\Lambda$ ,  $\Omega$ , etc.**

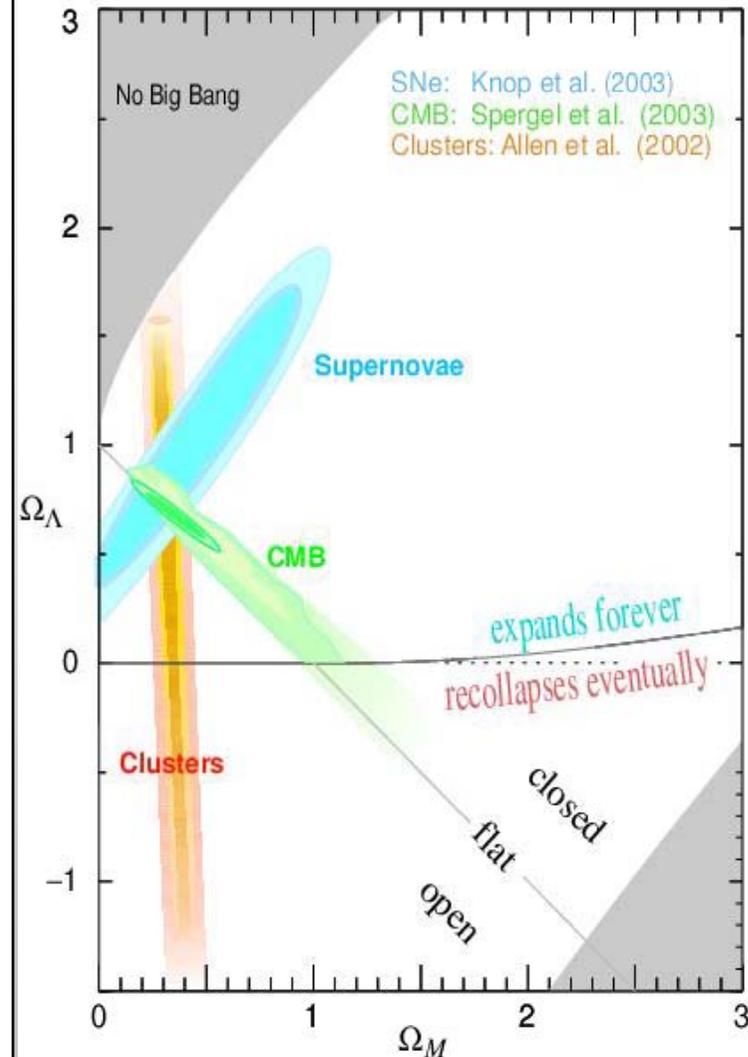
**Experimental Tests of**

**Gravitational Theory**

**Dark Matter**

**Cosmic Background Radiation**

**Cosmic Rays**



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# B Meson Section 1984

Entire section was one page

**B<sup>±</sup>, B<sup>0</sup>, B**

**B<sup>±</sup>**

41 CHARGED B(5271, JP= ) I=

SEE ALSO THE LISTING FOR THE B (FOLLOWING THE ENTRY FOR THE NEUTRAL B) FOR MEASUREMENTS WHICH DO NOT IDENTIFY THE CHARGE STATE.

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41 CHARGED B MASS (MEV)

|   |   |   |        |     |         |    |   |       |
|---|---|---|--------|-----|---------|----|---|-------|
| M | A | 6 | 5270.8 | 3.0 | BEHREND | 83 | CLEO +- D*0- PI+ PI+ + CC   | 4/83* |
| M | A |   |        |     |         |    | STATISTICAL (2.3 MEV) AND SYSTEMATICAL (2.0 MEV) ERRORS COMBINED. | 4/83* |

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41 CHARGED B PARTIAL DECAY MODES

|    |                           |                |
|----|---------------------------|----------------|
| P1 | B+ INTO DOBAR PI+         | DECAY MASSES   |
| P2 | B+ INTO D*(2010)- PI+ PI+ | 1865+ 140      |
|    |                           | 2007+ 140+ 140 |

B- MODES ARE CHARGE CONJUGATES OF THE ABOVE MODES.

---

41 CHARGED B BRANCHING RATIOS

|    |                           |       |   |
|----|---------------------------|-------|---|
| R1 | B+ INTO DOBAR PI+         | (P1)  |   |
| R1 | 2                         | 0.042 | 0.042 BEHREND 83 CLEO +- E+ E-, UPSIL(4S) 4/83* |
| R2 | B+ INTO D*(2010)- PI+ PI+ | (P2)  |   |
| R2 | 6                         | 0.048 | 0.030 BEHREND 83 CLEO +- E+ E-, UPSIL(4S) 4/83* |

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REFERENCES FOR CHARGED B

BEHREND 83 PRL 50 881 + (ROCH+RUTG+SYRA+VAND+CORN+ITHA+HARV+OSU)

\*\*\*\*\*

**B<sup>0</sup>**

42 NEUTRAL B(5274, JP= ) I=

SEE ALSO THE LISTING FOR THE B (FOLLOWING THIS ENTRY) FOR MEASUREMENTS WHICH DO NOT IDENTIFY THE CHARGE STATE.

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42 NEUTRAL B MASS (MEV)

|   |   |   |        |     |         |    |   |       |
|---|---|---|--------|-----|---------|----|---|-------|
| M | A | 5 | 5274.2 | 2.8 | BEHREND | 83 | CLEO 0 D*0- PI+ + CC  | 4/83* |
| M | A |   |        |     |         |    | STATISTICAL (1.9 MEV) AND SYSTEMATICAL (2.0 MEV) ERRORS COMBINED. | 4/83* |

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42 (B0) - (B+) MASS DIFFERENCE (MEV)

|    |   |  |     |     |         |    |   |       |
|----|---|--|-----|-----|---------|----|---|-------|
| DM | A |  | 3.4 | 3.6 | BEHREND | 83 | CLEO E+E-, UPSIL(4S)                                      | 3/84* |
| DM | A |  |     |     |         |    | STATISTICAL (3.0) AND SYSTEMATICAL (2.0) ERRORS COMBINED. | 3/84* |

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39 B PARTIAL DECAY M

|    |                                  |
|----|----------------------------------|
| P1 | B INTO ELECTRON NEUTRINO HADRONS |
| P2 | B INTO MUON NEUTRINO HADRONS     |
| P3 | B INTO E+ E- ANYTHING            |
| P4 | B INTO MU+ MU- ANYTHING          |
| P5 | B INTO KAON ANYTHING             |
| P6 | B INTO J/PSI ANYTHING            |
| P7 | B INTO D0 ANYTHING               |
| P8 | B INTO PROTON ANYTHING           |
| P9 | B INTO LAMBDA ANYTHING           |

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39 B BRANCHING RATIO

|    |                                      |
|----|--------------------------------------|
| R1 | B INTO (ELECTRON NEUTRINO HADRONS)   |
| R1 | A (0.13) (0.042) BEB                 |
| R1 | B (0.136) (0.039) SPE                |
| R1 | C 0.127 0.021 CHA                    |
| R1 | D 0.132 0.016 KLO                    |
| R1 | E (0.116) (0.027) NEL                |
| R1 | A THE STATISTICAL AND SYSTEMATIC ER  |
| R1 | B THE STATISTICAL AND SYSTEMATIC ER  |
| R1 | AB THE ELECTRON ENERGY SPECTRA IN BO |
| R1 | AB B-TO-C OVER B-TO-U QUARK TRANSITI |
| R1 | C THE STATISTICAL AND SYSTEMATIC ER  |
| R1 | D STATISTICAL AND SYSTEMATIC ERRORS  |
| R1 | E RATIO CS(B-->E NU UP)/CS(B-->E NU  |
| R1 | E THE STATISTICAL AND SYSTEMATIC ER  |
| R1 | ONLY THE EXPERIMENTS AT THE UPSIL    |
| R1 | AVG 0.130 0.013 AVERAGE              |
| R2 | B INTO (MUON NEUTRINO HADRONS)/TOT   |
| R2 | A (0.094) (0.036) CHA                |
| R2 | B (0.105) (0.020) ADE                |
| R2 | C 0.124 0.035 CHA                    |
| R2 | D (0.155) (0.054) (0.029) FER        |
| R2 | E (0.117) (0.028) ALT                |
| R2 | A THE STATISTICAL AND SYSTEMATIC ER  |
| R2 | B THE STATISTICAL AND SYSTEMATIC ER  |
| R2 | THE AVERAGE OF THE THREE HIGH-ENE    |
| R2 | THESE EXPERIMENTS PRODUCE OTHER B    |
| R2 | THE B MESON.                         |
| R3 | B INTO (E+ E- ANYTHING)/TOTAL        |
| R3 | (0.05) OR LESS CL=.90 BEB            |
| R4 | B INTO (MU+ MU- ANYTHING)/TOTAL      |
| R4 | (0.017)OR LESS CL=.90 CHA            |
| R4 | 0.007 OR LESS CL=.95 ADE             |
| R4 | 0.007 OR LESS CL=.95 BAR             |
| R4 | (0.02) OR LESS CL=.95 ALT            |
| R5 | B INTO (DILEPTON ANYTHING)           |

Section  
is 144  
pages

## BOTTOM, CHARMED MESONS ( $B = C = \pm 1$ )

$$B_C^+ = c\bar{b}, B_C^- = \bar{c}b, \text{ similarly for } B_C^{*'}\text{'s}$$

$B_C^\pm$

$$I(J^P) = 0(0^-)$$

$I, J, P$  need confirmation.

Quantum numbers shown are quark-model predictions.

### $B_C^\pm$ MASS

| VALUE (GeV)                      | DOCUMENT ID                 | TECN | COMMENT                |
|----------------------------------|-----------------------------|------|------------------------|
| <b>6.276 ± 0.004 OUR AVERAGE</b> |                             |      |                        |
| 6.2756 ± 0.0029 ± 0.0025         | <sup>1</sup> AALTONEN 08M   | CDF  | $p\bar{p}$ at 1.96 TeV |
| 6.4 ± 0.39 ± 0.13                | <sup>2</sup> ABE 98M        | CDF  | $p\bar{p}$ at 1.8 TeV  |
| 6.2857 ± 0.0053 ± 0.0012         | <sup>1</sup> ABULENCIA 06C  | CDF  | Repl. by AALTONEN 08M  |
| 6.32 ± 0.06                      | <sup>3</sup> ACKERSTAFF 980 | OPAL | $e^+e^- \rightarrow Z$ |

<sup>1</sup>Measured using a fully reconstructed decay mode of  $B_C \rightarrow J/\psi\pi$ .

<sup>2</sup>ABE 98M observed  $20.4^{+6.2}_{-5.5}$  events in the  $B_C^+ \rightarrow J/\psi(1S)\ell\nu_\ell$  with a significance of  $> 4.8$  standard deviations. The mass value is estimated from  $m(J/\psi(1S)\ell)$ .

<sup>3</sup>ACKERSTAFF 980 observed 2 candidate events in the  $B_C \rightarrow J/\psi(1S)\pi^+$  channel with an estimated background of  $0.63 \pm 0.20$  events.

### $B_C^\pm$ MEAN LIFE

| VALUE ( $10^{-12}$ s)               | DOCUMENT ID                | TECN | COMMENT                |
|-------------------------------------|----------------------------|------|------------------------|
| <b>0.46 ± 0.07 OUR AVERAGE</b>      |                            |      |                        |
| $0.463^{+0.073}_{-0.065} \pm 0.036$ | <sup>4</sup> ABULENCIA 060 | CDF  | $p\bar{p}$ at 1.96 TeV |
| $0.46^{+0.18}_{-0.16} \pm 0.03$     | <sup>4</sup> ABE 98M       | CDF  | $p\bar{p}$ 1.8 TeV     |

<sup>4</sup>The lifetime is measured from the  $J/\psi(1S)e$  decay vertices.

### $\Gamma(J/\psi(1S)\pi^+)/\Gamma_{\text{total}} \times B(\bar{b} \rightarrow B_C)$

| VALUE  | CL% | DOCUMENT ID                  | TECN | CL    |
|--|-----|------------------------------|------|-------|
| <b>&lt; 8.2 × 10<sup>-5</sup></b>                                      | 90  | <sup>9</sup> BARATE 97H      | ALEP | e     |
| • • • We do not use the following data for averages, fits, limits, etc |     |                              |      |       |
| < 2.4 × 10 <sup>-4</sup>   | 90  | <sup>10</sup> ACKERSTAFF 980 | OPAL | e     |
| < 3.4 × 10 <sup>-4</sup>   | 90  | <sup>11</sup> ABREU 97E      | DLPH | e     |
| < 2.0 × 10 <sup>-5</sup>   | 95  | <sup>12</sup> ABE 96R        | CDF  | $\mu$ |

<sup>9</sup>BARATE 97H reports  $B(Z \rightarrow B_C X)/B(Z \rightarrow qq) \cdot B(B_C^+ \rightarrow J/\psi(1S)\pi^+)/B(B_C^+ \rightarrow b\bar{b})$  at 90%CL. We rescale to our PDG 96 values of  $B(Z \rightarrow b\bar{b})$ .

<sup>10</sup>ACKERSTAFF 980 reports  $B(Z \rightarrow B_C X)/B(Z \rightarrow qq) \times B(B_C^+ \rightarrow J/\psi(1S)\pi^+)/B(B_C^+ \rightarrow b\bar{b})$  at 90%CL. We rescale to our PDG 98 values of  $B(Z \rightarrow b\bar{b})$ .

<sup>11</sup>ABREU 97E value listed is for an assumed  $\tau_{B_C} = 0.4$  ps and  $\text{imp} \tau_{B_C} = 1.4$  ps.

<sup>12</sup>ABE 96R reports  $B(b \rightarrow B_C X)/B(b \rightarrow B^+ X) \cdot B(B_C^+ \rightarrow J/\psi(1S)\pi^+)/B(B_C^+ \rightarrow b\bar{b}) < 0.053$  at 95%CL for  $\tau_{B_C} = 0.8$  ps. It changes to  $0.17 \text{ ps} < \tau_{B_C} < 1.6$  ps. We rescale to our PDG 96 values of  $B(b \rightarrow b\bar{b})$  and  $B(B^+ \rightarrow J/\psi(1S)\pi^+) = 0.00101 \pm 0.00014$ .

### $\Gamma(J/\psi(1S)\pi^+\pi^+\pi^-)/\Gamma_{\text{total}} \times B(\bar{b} \rightarrow B_C)$

| VALUE                             | CL% | DOCUMENT ID             | TECN | CL |
|-----------------------------------|-----|-------------------------|------|----|
| <b>&lt; 5.7 × 10<sup>-4</sup></b> | 90  | <sup>13</sup> ABREU 97E | DLPH | e  |

<sup>13</sup>ABREU 97E value listed is independent of  $0.4 \text{ ps} < \tau_{B_C} < 1.4$  ps.

### $\Gamma(J/\psi(1S)a_1(1260))/\Gamma_{\text{total}} \times B(\bar{b} \rightarrow B_C)$

| VALUE                             | CL% | DOCUMENT ID                  | TECN | CL |
|-----------------------------------|-----|------------------------------|------|----|
| <b>&lt; 1.2 × 10<sup>-3</sup></b> | 90  | <sup>14</sup> ACKERSTAFF 980 | OPAL | e  |

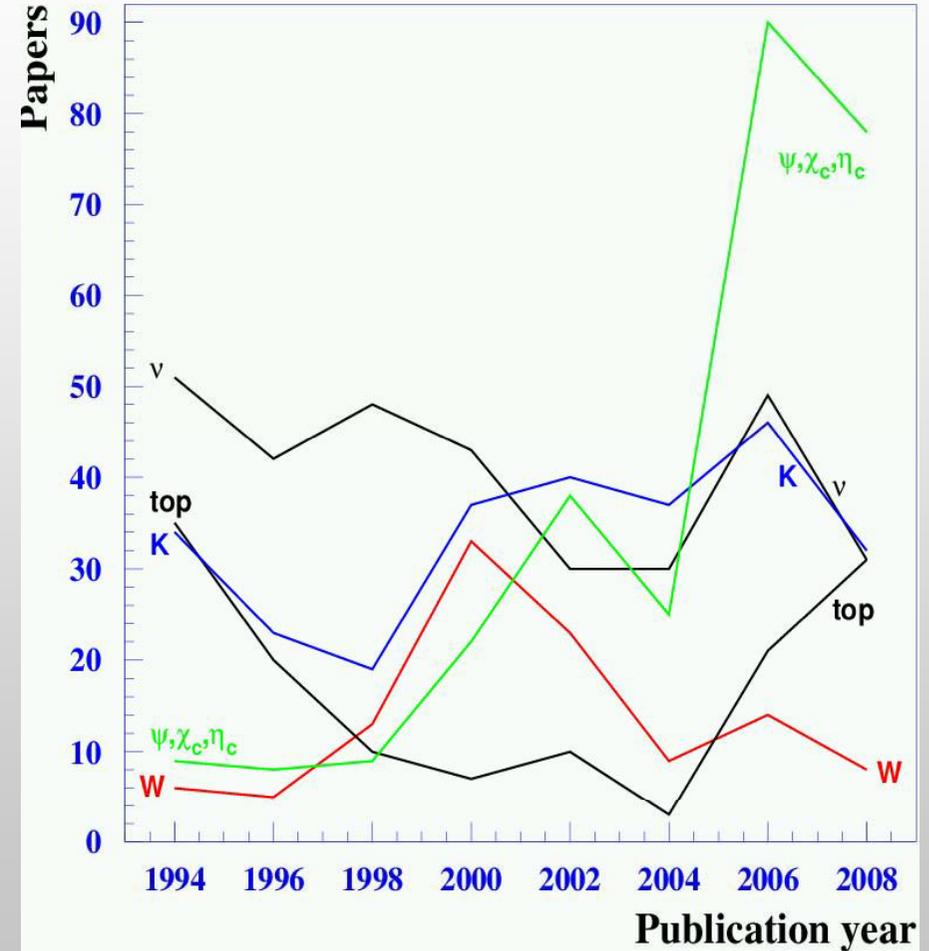
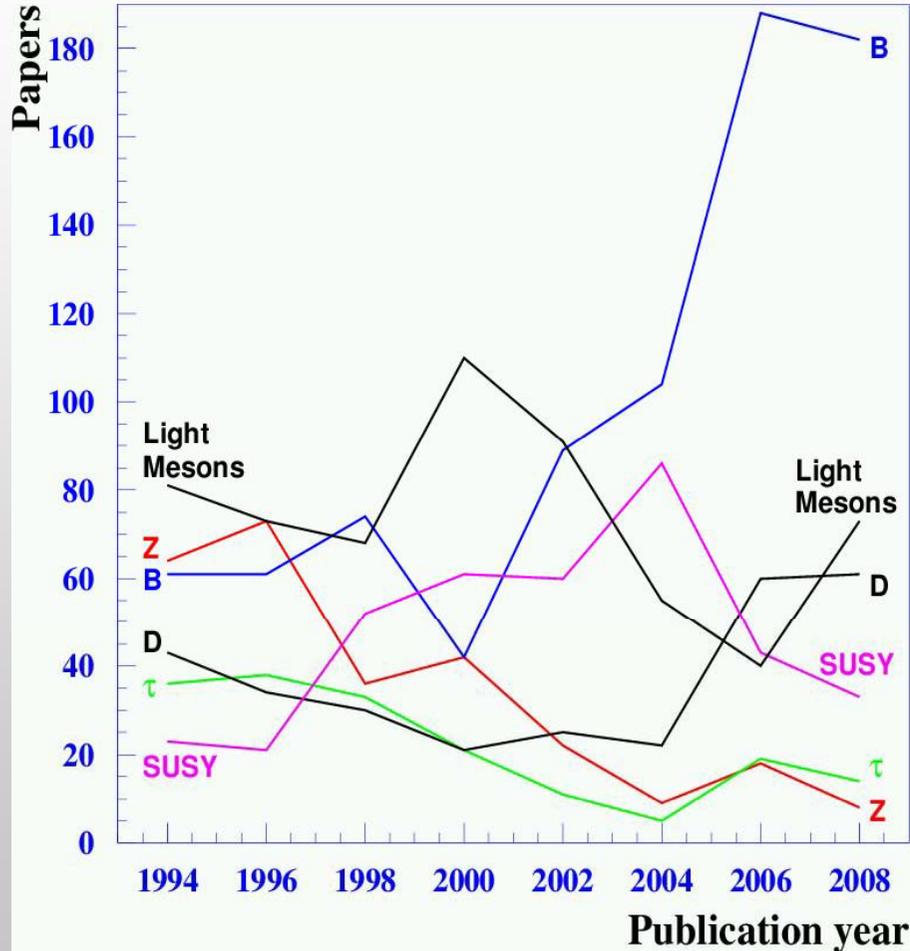
<sup>14</sup>ACKERSTAFF 980 reports  $B(Z \rightarrow B_C X)/B(Z \rightarrow qq) \times B(B_C^+ \rightarrow J/\psi(1S)a_1(1260))/B(B_C^+ \rightarrow b\bar{b}) < 5.29 \times 10^{-4}$  at 90%CL. We rescale to our PDG 98 values of  $B(Z \rightarrow b\bar{b})$ .

### $\Gamma(D^*(2010)^+\bar{D}^0)/\Gamma_{\text{total}} \times B(\bar{b} \rightarrow B_C)$

| VALUE                             | CL% | DOCUMENT ID              | TECN | CL |
|-----------------------------------|-----|--------------------------|------|----|
| <b>&lt; 6.2 × 10<sup>-3</sup></b> | 90  | <sup>15</sup> BARATE 98Q | ALEP | e  |

<sup>15</sup>BARATE 98Q reports  $B(Z \rightarrow B_C X) \times B(B_C^+ \rightarrow D^*(2010)^+\bar{D}^0)/B(B_C^+ \rightarrow b\bar{b})$  at 90%CL. We rescale to our PDG 98 values of  $B(Z \rightarrow b\bar{b})$ .

186/182 B papers in 2006/2008 editions

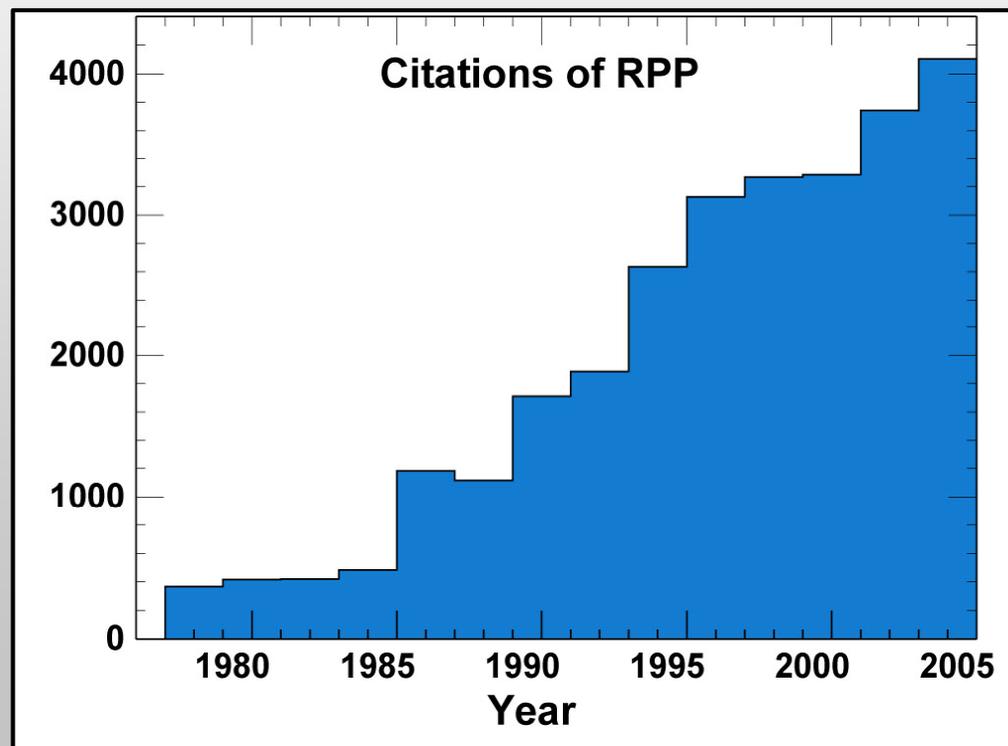


Notice different vertical scales

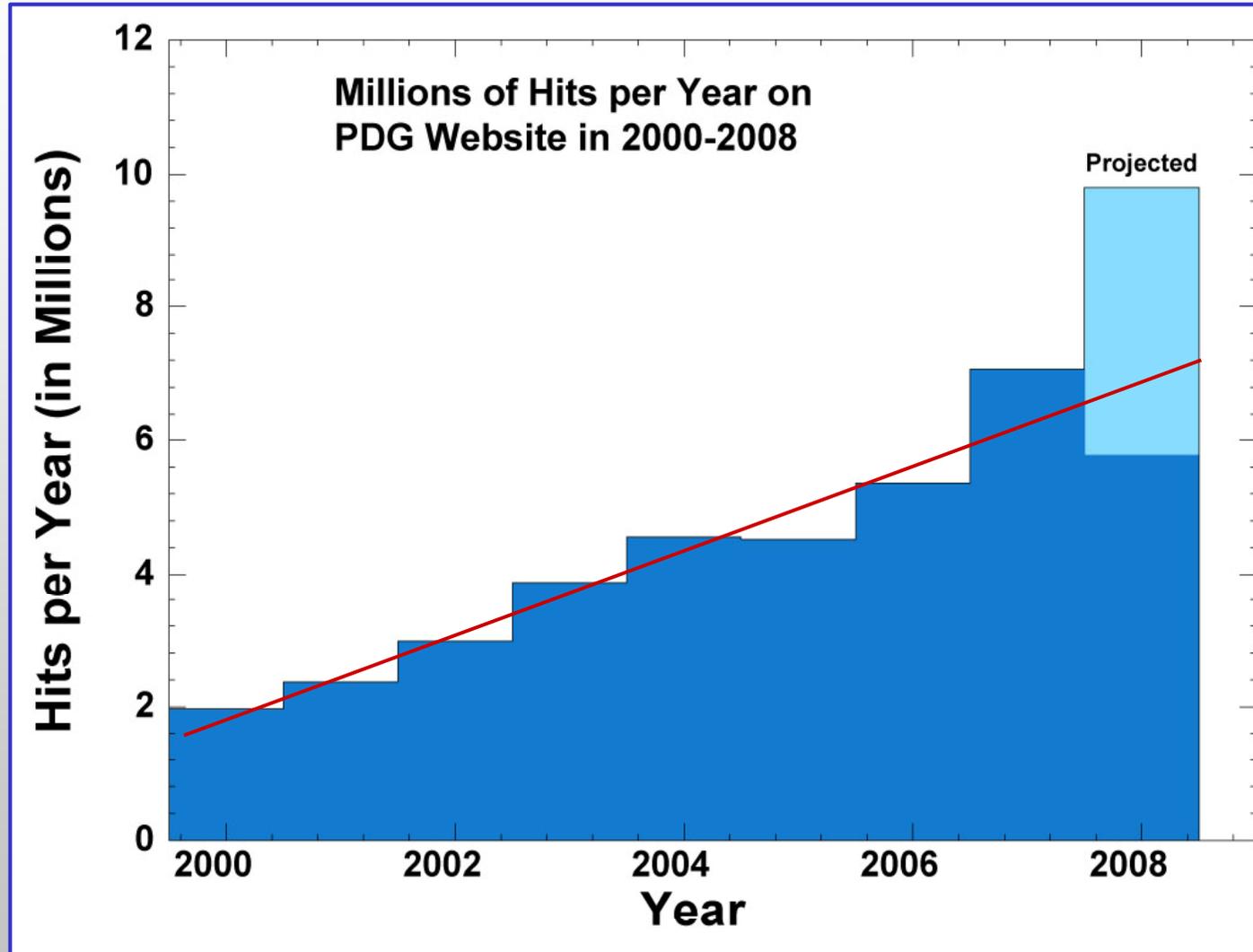
| <u>Papers</u>                                  | <u>2004</u> | <u>2006</u> | <u>2008</u> | <u>Measurements</u>                            | <u>2004</u> | <u>2006</u> | <u>2008</u> |
|--|-------------|-------------|-------------|--|-------------|-------------|-------------|
| W Boson  | 8           | 14          | 8           | W Boson  | 12          | 39          | 18          |
| Z Boson  | 9           | 18          | 8           | Z Boson  | 19          | 32          | 11          |
| $\tau$ Lepton                                  | 5           | 19          | 14          | $\tau$ lepton                                  | 15          | 82          | 77          |
| Neutrinos and mixing                           | 30          | 49          | 31          | Neutrinos and mixing                           | 43          | 142         | 77          |
| Charged hvy leptons                            | 1           | 0           | 0           | Charged hvy leptons                            | 1           | 0           | 0           |
| Quarks (u,d,c,s,b)                             | 19          | 14          | 18          | Quarks (u,d,c,s,b)                             | 31          | 24          | 42          |
| Top quark                                      | 3           | 21          | 31          | Top quark                                      | 4           | 29          | 38          |
| b', t' quarks                                  | 1           | 0           | 3           | b', t' quarks                                  | 1           | 0           | 3           |
| $\gamma, e, \mu, \pi, \eta$                    | □7          | 20          | 22          | $\gamma, e, \mu, \pi, \eta$                    | 12          | 32          | 44          |
| K mesons                                       | 36          | 46          | 32          | K mesons                                       | 87          | 134         | 70          |
| D and D <sub>s</sub> mesons                    | 29          | 60          | 61          | D and D <sub>s</sub> mesons                    | 123         | 251         | 241         |
| B and B <sub>s</sub> mesons                    | 106         | 188         | 179         | B and B <sub>s</sub> mesons                    | 466         | 784         | 862         |
| Supersymmetry                                  | 83          | 43          | 33          | Supersymmetry                                  | 157         | 73          | 50          |
| Axions   | 12          | 11          | 18          | Axions   | 15          | 13          | 18          |
| Higgs  | 19          | 23          | 12          | Higgs  | 25          | 30          | 15          |
| W', Z'   | 9           | 13          | 18          | W', Z'   | 13          | 24          | 32          |
| Compositeness                                  | 7           | 6           | 6           | Compositeness                                  | 21          | 12          | 15          |
| Extra dimensions                               | 16          | 11          | 11          | Extra dimensions                               | 28          | 15          | 12          |
| Other searches                                 | 8           | 11          | 4           | Other searches                                 | 15          | 23          | 10          |
| Free q, monopoles                              | 3           | 3           | 1           | Free q, monopoles                              | 3           | 10          | 1           |
| Baryons  | 48          | 46          | 33          | Baryons  | 197         | 206         | 362         |
| $\Psi, \eta_c, \chi_c, \chi_b, \text{upsilon}$ | 30          | 90          | 78          | $\Psi, \eta_c, \chi_c, \chi_b, \text{upsilon}$ | 90          | 454         | 422         |
| Other unstable mesons                          | 60          | 42          | 66          | Other unstable mesons                          | 335         | 221         | 355         |
| <b>TOTAL</b>                                   | <b>505</b>  | <b>689</b>  | <b>645</b>  | <b>TOTAL</b>                                   | <b>1708</b> | <b>2633</b> | <b>2778</b> |

- ➔ 31,000 Booklets requested
- ➔ 16,000 RPP books requested
- ➔ 7 million hits/year on website (>180 countries)  
2008 is projected at 10 million.
- ➔ 30,000 citations of RPP
- ➔ Most cited publication in HEP

The Review is the all-time top cited article in High Energy Physics with 30,000 citations (SLAC-SPIRES)



Excluding  
mirror sites  
and  
excluding  
Education  
webpages



**Following the publication of the ISI Journal Citation Reports, ...**

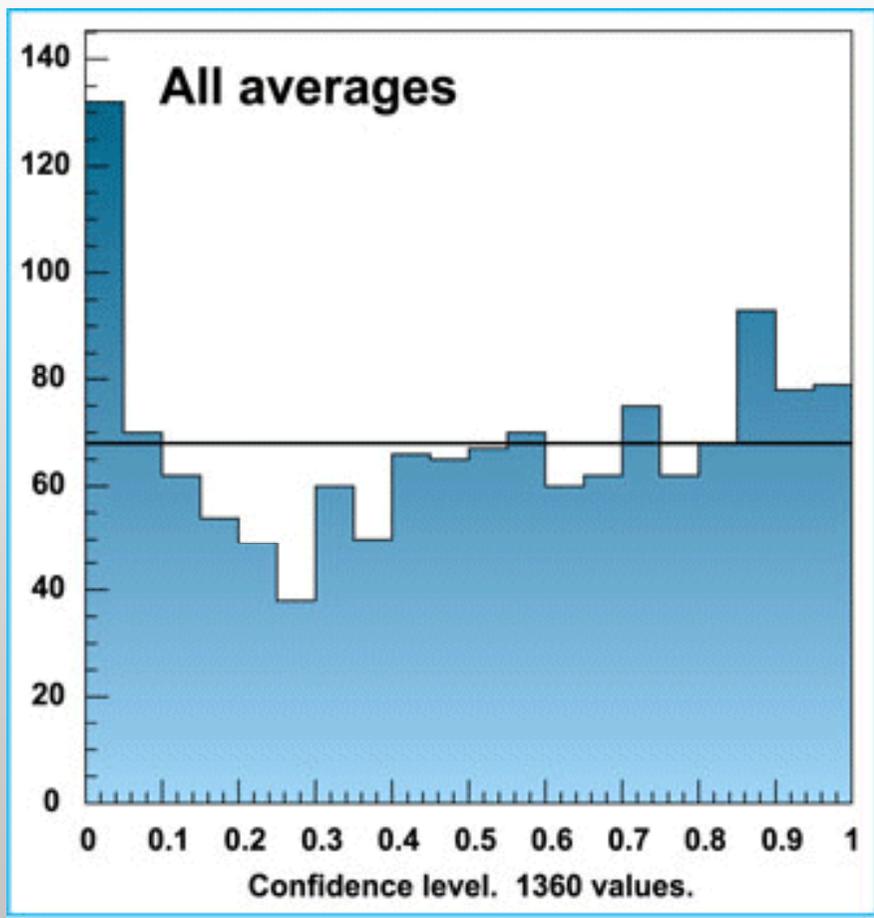
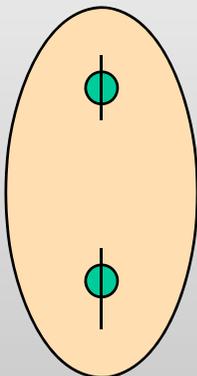
**Journal of Physics G has increased its Impact Factor to 3.485. This is a 96% increase on last year's result and shows that researchers who publish with us are in the right place to be cited by their peers. JPhysG is also the highest impact factor of any original research journal in ISI's category of Nuclear Physics!**

**With the increase in Impact Factor, there has never been a better time to publish with JPhysG to achieve worldwide visibility for your work. ...**

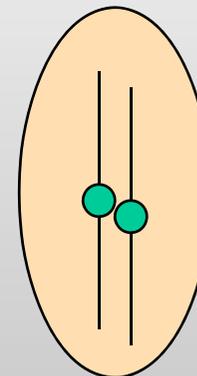
**Sarah Thompson  
Senior Marketing Executive, Journal of Physics G...  
IOP Publishing**

Each point is one average.

Peak at left due to conflicting measurements.



Broad peak at right due to conservative error bars.



# Vital roles of CERN, Japan, SLAC, Retirees

(written for DOE Review)

## 50-year collaboration

**Administration for CERN funding (Michael Doser, deputy chair of Physics Division).**

**Pays publisher directly for their copies.**

**Oversees support for the Meson Team (space, travel), which is mostly non-CERN people who meet at CERN.**

**Mirror website maintained.**

**In general, no direct support for the nine CERN members: Doser, Bloch, Ceccucci, Giudice, Gurtu, Hoecker, Mangano, Roesler and Sauli.**

## 22-year collaboration

**Administration for Japanese funding (Ken-ichi Hikasa)**

**Oversees support for Japanese members (travel).**

**Mirror website maintained.**

## Reviews and Data Sections

- Neutrinos
- CKM Quark Mixing
- Top quark
- Higgs bosons
- Supersymmetry
- Compositeness of quarks and leptons
- Axions
- Heavy bosons ( $W'$ ,  $Z'$ , etc.)
- Even more exotic particles.

## Leadership (past and present)

- Dr. Kasuke Takahashi
- Prof. Yoshio Oyanagi
- Prof. Ken-ichi Hikasa (current leader)

## Seven Japanese physicists

- Dr. Kaoru Hagiwara (KEK)
- Prof. Ken-ichi Hikasa (Tohoku University)
- Dr. Kenzo Nakamura (KEK)
- Dr. Yoshihide Sakai (KEK)
- Prof. Takayuki Sumiyoshi (Tokyo Metropolitan U.)
- Prof. Masaharu Tanabashi (Nagoya University)
- Dr. Akira Yamamoto (KEK)

## Many years collaboration (> 20)

Coordination with SLAC SPIRES database via the SLAC Library group.

Yields our ability to link to the papers from which the measurements come.

Many discussions of improved coverage for the HEP community.

No support needed for this collaboration.

## 100 years of experience

### Dependent on retirees for

- Computing
- Data Listings
- Reviews
- Coordination
- Management of non-Berkeley personnel
- Judgment and wisdom

**The End**