be involved in such programs using hadronic beams. For example, plans are underway to study baryon spectroscopy at the Brookhaven National Laboratory AGS [2]. The reactions $\pi^- p \to n\eta$, $K^- p \to \Lambda\eta$, and $K^- p \to \Sigma^0\eta$ will be studied by using the SLAC Crystal Ball to identify multiphoton final states. As by-products of these investigations, new and improved data also will be obtained for $\pi^- p \to n\pi^0$ and for inverse photoproduction on an unstable target, in particular, $K^- p \to \Lambda\gamma$ and $K^- p \to \Sigma^0\gamma$.

References for Section V

1. D. Menze in "Baryon Spectroscopy and the Structure of the Nucleon," *Proceedings of an International Workshop at Saclay, France 23–25 Sep. 1991*, ed. H.P. Morsch and M. Soyeur (Research Center Conference Service, Jülich, 1992), p. 182.
2. AGS Letter of Intent, "Baryon Spectroscopy with the Crystal Ball," spokespersons B.M.K. Nefkens and R.E. Chrien (Aug. 1993).

$N(1440)\ P_{11}$

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$N(1440)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1430 to 1470 (≈ 1440) OUR ESTIMATE				
1462±10	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1440±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1410±12	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1465	LI	93	IPWA	$\gamma N \to \pi N$
1471	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
1411	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1472	[1] BAKER	79	DPWA	$\pi^- p \to n\eta$
1417	BARBOUR	78	DPWA	$\gamma N \to \pi N$
1460	BERENDS	77	IPWA	$\gamma N \to \pi N$
1380	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1390	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$N(1440)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
250 to 450 (≈ 350) OUR ESTIMATE				
391± 34	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
545±170	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
340± 70	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
135± 10	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
315	LI	93	IPWA	$\gamma N \to \pi N$
334	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
113	[1] BAKER	79	DPWA	$\pi^- p \to n\eta$
331	BARBOUR	78	DPWA	$\gamma N \to \pi N$
279	BERENDS	77	IPWA	$\gamma N \to \pi N$
200	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
200	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$N(1440)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1385	[4] HOEHLER	93	SPED	$\pi N \to \pi N$
1360	[5] ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1370	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
1375±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1359	ARNDT	85	DPWA	See ARNDT 91
1381 or 1379	[6] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
1360 or 1333	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
164	[4] HOEHLER	93	SPED	$\pi N \to \pi N$
252	[5] ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
228	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
180±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
200	ARNDT	85	DPWA	See ARNDT 91
209 or 210	[6] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
167 or 234	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$N(1440)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
40	HOEHLER	93	SPED	$\pi N \to \pi N$
109	[5] ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
74	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
52±5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
− 93	[5] ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
− 84	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
−100±35	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$N(1440)$ DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	60–70 %
Γ_2	$N\eta$	
Γ_3	$N\pi\pi$	30–40 %
Γ_4	$\Delta\pi$	20–30 %
Γ_5	$\Delta(1232)\pi$, P-wave	
Γ_6	$N\rho$	<8 %
Γ_7	$N\rho$, S=1/2, P-wave	
Γ_8	$N\rho$, S=3/2, P-wave	
Γ_9	$N(\pi\pi)^{I=0}_{S\text{-wave}}$	5–10 %
Γ_{10}	$p\gamma$	0.04–0.07 %
Γ_{11}	$p\gamma$, helicity=1/2	
Γ_{12}	$n\gamma$	0.001–0.05 %
Γ_{13}	$n\gamma$, helicity=1/2	

$N(1440)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\rm total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.6 to 0.7 OUR ESTIMATE				
0.69±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.68±0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.51±0.05	HOEHLER	79	IPWA	$\pi N \to \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\rm total}$ in $N\pi \to N(1440) \to N\eta$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	[1] BAKER	79	DPWA	$\pi^- p \to n\eta$
+0.328	[7] FELTESSE	75	DPWA	1488–1745 MeV

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\rm total}$ in $N\pi \to N(1440) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.37 to +0.41 OUR ESTIMATE				
+0.39±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.41	[2,8] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.37	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\rm total}$ in $N\pi \to N(1440) \to N\rho$, S=1/2, P-wave — $(\Gamma_1\Gamma_7)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
±0.07 to ±0.25 OUR ESTIMATE				
−0.11	[2,8] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.23	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\rm total}$ in $N\pi \to N(1440) \to N\rho$, S=3/2, P-wave — $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.18	[2,8] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$