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).

\[ I(J^P) = \frac{1}{2}\left(\frac{1}{2}^+\right) \] Status:  ***

## N(1440) BREIT-WIGNER MASS

<table>
<thead>
<tr>
<th>VALUE (MeV)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1420 to 1470 (≈ 1440) OUR ESTIMATE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1468.0 ± 4.5</td>
<td>ARNDT 04</td>
<td>DPWA</td>
<td>π N → π N, η N</td>
</tr>
<tr>
<td>1462 ± 10</td>
<td>MANLEY 92</td>
<td>IPWA</td>
<td>π N → π N &amp; Nππ</td>
</tr>
<tr>
<td>1440 ± 30</td>
<td>CUTKOSKY 80</td>
<td>IPWA</td>
<td>π N → π N</td>
</tr>
<tr>
<td>1410 ± 12</td>
<td>HOEHLER 79</td>
<td>IPWA</td>
<td>π N → π N</td>
</tr>
</tbody>
</table>

- - - We do not use the following data for averages, fits, limits, etc. - - -

1518 ± 5 PENNER 02C DPWA Multichannel
1479 ± 80 VRANA 00 DPWA Multichannel
1463 ± 7 ARNDT 96 IPWA γ N → π N
1467 ARNDT 95 DPWA π N → Nπ
1421 ± 18 BATINIC 95 DPWA π N → Nπ, Nη
1465 LI 93 IPWA γ N → π N
1471 CUTKOSKY 90 IPWA π N → π N
1411 CRAWFORD 80 DPWA γ N → π N
1472 1 BAKER 79 DPWA π − p → nη
1417 BARBOUR 78 DPWA γ N → π N
1460 BERENDS 77 IPWA γ N → π N
1380 2 LONGACRE 77 IPWA π N → Nππ
1390 3 LONGACRE 75 IPWA π N → Nππ

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\begin{center}
\textbf{\(N(1440)\) POLE POSITION}
\end{center}

\begin{center}
\begin{tabular}{llll}
\multicolumn{1}{c}{\textbf{REAL PART}} & \textbf{DOCUMENT ID} & \textbf{TECN} & \textbf{COMMENT} \\
\hline
\textbf{VALUE (MeV)} & & & \\
\hline
1350 to 1380 (\(\approx 1365\)) OUR ESTIMATE & & & \\
1357 & 4 ARNDT & 04 & DPWA \(\pi N \rightarrow \pi N, \eta N\) \\
1385 & 5 HOEHLER & 93 & SPED \(\pi N \rightarrow \pi N\) \\
1375 \pm 30 & CUTKOSKY & 80 & IPWA \(\pi N \rightarrow \pi N\) \\
\hline
\multicolumn{1}{l}{\textbullet \textbullet \textbullet We do not use the following data for averages, fits, limits, etc.} & & & \\
1383 & VRANA & 00 & DPWA Multichannel \\
1346 & 6 ARNDT & 95 & DPWA \(\pi N \rightarrow N\pi\) \\
1360 & 7 ARNDT & 91 & DPWA \(\pi N \rightarrow \pi N\) Soln SM90 \\
1370 & CUTKOSKY & 90 & IPWA \(\pi N \rightarrow \pi N\) \\
1381 or 1379 & 8 LONGACRE & 78 & IPWA \(\pi N \rightarrow N\pi\pi\) \\
1360 or 1333 & 2 LONGACRE & 77 & IPWA \(\pi N \rightarrow N\pi\pi\) \\
\end{tabular}
\end{center}

\begin{center}
\begin{tabular}{llll}
\multicolumn{1}{c}{\textbf{\(-2\times\text{IMAGINARY PART}\)}} & \textbf{DOCUMENT ID} & \textbf{TECN} & \textbf{COMMENT} \\
\hline
\textbf{VALUE (MeV)} & & & \\
\hline
160 to 220 (\(\approx 190\)) OUR ESTIMATE & & & \\
160 & 4 ARNDT & 04 & DPWA \(\pi N \rightarrow \pi N, \eta N\) \\
164 & 5 HOEHLER & 93 & SPED \(\pi N \rightarrow \pi N\) \\
180 \pm 40 & CUTKOSKY & 80 & IPWA \(\pi N \rightarrow \pi N\) \\
\hline
\multicolumn{1}{l}{\textbullet \textbullet \textbullet We do not use the following data for averages, fits, limits, etc.} & & & \\
316 & VRANA & 00 & DPWA Multichannel \\
176 & 6 ARNDT & 95 & DPWA \(\pi N \rightarrow N\pi\) \\
252 & 7 ARNDT & 91 & DPWA \(\pi N \rightarrow \pi N\) Soln SM90 \\
228 & CUTKOSKY & 90 & IPWA \(\pi N \rightarrow \pi N\) \\
209 or 210 & 8 LONGACRE & 78 & IPWA \(\pi N \rightarrow N\pi\pi\) \\
167 or 234 & 2 LONGACRE & 77 & IPWA \(\pi N \rightarrow N\pi\pi\) \\
\end{tabular}
\end{center}

\begin{center}
\textbf{\(N(1440)\) ELASTIC POLE RESIDUE}
\end{center}

\begin{center}
\begin{tabular}{llll}
\multicolumn{1}{c}{\textbf{MODULUS |r|}} & \textbf{DOCUMENT ID} & \textbf{TECN} & \textbf{COMMENT} \\
\hline
\textbf{VALUE (MeV)} & & & \\
\hline
36 & 4 ARNDT & 04 & DPWA \(\pi N \rightarrow \pi N, \eta N\) \\
40 & HOEHLER & 93 & SPED \(\pi N \rightarrow \pi N\) \\
52 \pm 5 & CUTKOSKY & 80 & IPWA \(\pi N \rightarrow \pi N\) \\
\hline
\multicolumn{1}{l}{\textbullet \textbullet \textbullet We do not use the following data for averages, fits, limits, etc.} & & & \\
42 & 6 ARNDT & 95 & DPWA \(\pi N \rightarrow N\pi\) \\
109 & 7 ARNDT & 91 & DPWA \(\pi N \rightarrow \pi N\) Soln SM90 \\
74 & CUTKOSKY & 90 & IPWA \(\pi N \rightarrow \pi N\) \\
\end{tabular}
\end{center}
PHASE $\theta$

<table>
<thead>
<tr>
<th>VALUE ($^\circ$)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-102$</td>
<td>4</td>
<td>ARNDT</td>
<td>DPWA $\pi N \rightarrow \pi N$, $\eta N$</td>
</tr>
<tr>
<td>$-100 \pm 35$</td>
<td>5</td>
<td>CUTKOSKY</td>
<td>IPWA $\pi N \rightarrow \pi N$</td>
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<tr>
<td>$-93$</td>
<td>6</td>
<td>ARNDT</td>
<td>DPWA $\pi N \rightarrow N\pi$</td>
</tr>
<tr>
<td>$-84$</td>
<td>7</td>
<td>ARNDT</td>
<td>DPWA $\pi N \rightarrow \pi N$ Soln SM90</td>
</tr>
</tbody>
</table>

- $\bullet \bullet \bullet$ We do not use the following data for averages, fits, limits, etc. $\bullet \bullet \bullet$

- $101$           | 8           | ARNDT | DPWA $\pi N \rightarrow \pi N$, $\eta N$ |
- $93$            | 9           | ARNDT | IPWA $\pi N \rightarrow \pi N$ |
- $84$            | 10          | CUTKOSKY | IPWA $\pi N \rightarrow \pi N$, $\eta N$ |

N(1440) DECAY MODES

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>Fraction ($\Gamma_i/\Gamma$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Gamma_1$</td>
<td>$N\pi$</td>
</tr>
<tr>
<td>$\Gamma_2$</td>
<td>$N\eta$</td>
</tr>
<tr>
<td>$\Gamma_3$</td>
<td>$N\pi\pi$</td>
</tr>
<tr>
<td>$\Gamma_4$</td>
<td>$\Delta\pi$</td>
</tr>
<tr>
<td>$\Gamma_5$</td>
<td>$\Delta(1232)\pi$, $P$-wave</td>
</tr>
<tr>
<td>$\Gamma_6$</td>
<td>$N\rho$</td>
</tr>
<tr>
<td>$\Gamma_7$</td>
<td>$N\rho$, $S=1/2$, $P$-wave</td>
</tr>
<tr>
<td>$\Gamma_8$</td>
<td>$N\rho$, $S=3/2$, $P$-wave</td>
</tr>
<tr>
<td>$\Gamma_9$</td>
<td>$N(\pi\pi)_{I=0},S$-wave</td>
</tr>
<tr>
<td>$\Gamma_{10}$</td>
<td>$p\gamma$</td>
</tr>
<tr>
<td>$\Gamma_{11}$</td>
<td>$p\gamma$, helicity=1/2</td>
</tr>
<tr>
<td>$\Gamma_{12}$</td>
<td>$n\gamma$</td>
</tr>
<tr>
<td>$\Gamma_{13}$</td>
<td>$n\gamma$, helicity=1/2</td>
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</tbody>
</table>

N(1440) BRANCHING RATIOS

<table>
<thead>
<tr>
<th>$\Gamma(N\pi)/\Gamma_{total}$</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.55$ to $0.75$ OUR ESTIMATE</td>
<td>ARNDT</td>
<td>94</td>
<td>DPWA $\pi N \rightarrow \pi N$, $\eta N$</td>
</tr>
<tr>
<td>$0.69 \pm 0.03$</td>
<td>MANLEY</td>
<td>92</td>
<td>IPWA $\pi N \rightarrow \pi N$ &amp; $N\pi\pi$</td>
</tr>
<tr>
<td>$0.68 \pm 0.04$</td>
<td>CUTKOSKY</td>
<td>80</td>
<td>IPWA $\pi N \rightarrow \pi N$</td>
</tr>
<tr>
<td>$0.51 \pm 0.05$</td>
<td>HOEHLER</td>
<td>79</td>
<td>IPWA $\pi N \rightarrow \pi N$</td>
</tr>
</tbody>
</table>

- $\bullet \bullet \bullet$ We do not use the following data for averages, fits, limits, etc. $\bullet \bullet \bullet$

| $0.57 \pm 0.01$ | PENNER | 02 | DPWA Multichannel |
| $0.72 \pm 0.05$ | VRANA | 00 | DPWA Multichannel |
| $0.68$          | ARNDT | 95 | DPWA $\pi N \rightarrow N\pi$ |
| $0.56 \pm 0.08$ | BATINIC | 95 | DPWA $\pi N \rightarrow N\pi$, $N\eta$ |

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We do not use the following data for averages, fits, limits, etc.

\( \Gamma(N\eta)/\Gamma_{\text{total}} \)

<table>
<thead>
<tr>
<th>Value</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 ± 0.01</td>
<td>VRANA</td>
<td>00</td>
<td>DPWA Multichannel</td>
</tr>
</tbody>
</table>

Note: Signs of couplings from \( \pi N \rightarrow N \pi \pi \) 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 \( \Delta(1232) \pi \).

\( (\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \) in \( N \pi \rightarrow N(1440) \rightarrow \Delta(1232) \pi \), \( P \)-wave

<table>
<thead>
<tr>
<th>Value</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.37 to +0.41 OUR ESTIMATE</td>
<td>MANLEY 92</td>
<td>IPWA</td>
<td>( \pi N \rightarrow \pi N ) &amp; ( N \pi \pi )</td>
</tr>
<tr>
<td>+0.39 ± 0.02</td>
<td>2,10 LONGACRE 77</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi \pi )</td>
</tr>
<tr>
<td>+0.41</td>
<td>3 LONGACRE 75</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi )</td>
</tr>
<tr>
<td>+0.37</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( \Gamma(D(1232)\pi, P\)-wave)/\Gamma_{\text{total}} \)

<table>
<thead>
<tr>
<th>Value</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.16 ± 0.01</td>
<td>VRANA</td>
<td>00</td>
<td>DPWA Multichannel</td>
</tr>
</tbody>
</table>

\( (\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \) in \( N \pi \rightarrow N(1440) \rightarrow N(\rho, S=1/2, P\)-wave

<table>
<thead>
<tr>
<th>Value</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.11</td>
<td>2,10 LONGACRE 77</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi \pi )</td>
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<tr>
<td>+0.23</td>
<td>3 LONGACRE 75</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi )</td>
</tr>
</tbody>
</table>

\( (\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \) in \( N \pi \rightarrow N(1440) \rightarrow N(\rho, S=3/2, P\)-wave

<table>
<thead>
<tr>
<th>Value</th>
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<th>TECN</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>+0.18</td>
<td>2,10 LONGACRE 77</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi \pi )</td>
</tr>
</tbody>
</table>

\( (\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \) in \( N \pi \rightarrow N(1440) \rightarrow N(\pi \pi)^{1/2}_{S\text{-wave}}

<table>
<thead>
<tr>
<th>Value</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.17 to ±0.25 OUR ESTIMATE</td>
<td>MANLEY 92</td>
<td>IPWA</td>
<td>( \pi N \rightarrow \pi N ) &amp; ( N \pi \pi )</td>
</tr>
<tr>
<td>+0.24 ± 0.03</td>
<td>2,10 LONGACRE 77</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi \pi )</td>
</tr>
<tr>
<td>-0.18</td>
<td>3 LONGACRE 75</td>
<td>IPWA</td>
<td>( \pi N \rightarrow N \pi )</td>
</tr>
<tr>
<td>-0.23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
\[
N(1440) \rightarrow p\gamma, \text{ helicity-1/2 amplitude } A_{1/2}
\]

\[
\Gamma(N(\pi\pi)^{I=0}_{S\text{-wave}})/\Gamma_{\text{total}}
\]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12 \pm 0.01</td>
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<td>00</td>
<td>DPWA</td>
</tr>
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</table>

\[
\Gamma_9/\Gamma
\]

\[
N(1440) \rightarrow n\gamma, \text{ helicity-1/2 amplitude } A_{1/2}
\]

<table>
<thead>
<tr>
<th>VALUE (GeV(^{-1/2}))</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.065 \pm 0.004 OUR ESTIMATE</td>
<td>ARNDT</td>
<td>96</td>
<td>IPWA</td>
</tr>
<tr>
<td>-0.069 \pm 0.018</td>
<td>CRAWFORD</td>
<td>83</td>
<td>IPWA</td>
</tr>
<tr>
<td>-0.063 \pm 0.008</td>
<td>AWAJI</td>
<td>81</td>
<td>DPWA</td>
</tr>
<tr>
<td>-0.069 \pm 0.004</td>
<td>ARAI</td>
<td>80</td>
<td>DPWA</td>
</tr>
<tr>
<td>-0.066 \pm 0.004</td>
<td>ARAI</td>
<td>80</td>
<td>DPWA</td>
</tr>
<tr>
<td>-0.079 \pm 0.009</td>
<td>BRATASHEV...</td>
<td>80</td>
<td>DPWA</td>
</tr>
<tr>
<td>-0.068 \pm 0.015</td>
<td>CRAWFORD</td>
<td>80</td>
<td>DPWA</td>
</tr>
<tr>
<td>-0.0584 \pm 0.0148</td>
<td>ISHII</td>
<td>80</td>
<td>DPWA</td>
</tr>
</tbody>
</table>

\[
N(1440) \text{ FOOTNOTES}
\]

1 BAKER 79 finds a coupling of the $N(1440)$ to the $N\eta$ channel near (but slightly below) threshold.

2 LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \rightarrow N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
3 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

4 ARNDT 04 also finds a second-sheet pole with real part = 1385 MeV, $-2 \times$ imaginary part = 166 MeV, and residue with modulus 82 MeV and phase = $-51^\circ$.

5 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of $N$ and $\Delta$ resonances as determined from Argand diagrams of $\pi N$ elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

6 ARNDT 95 also finds a second-sheet pole with real part = 1383 MeV, $-2 \times$ imaginary part = 256 MeV, and residue = (78–153i) MeV.

7 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \rightarrow N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

9 An alternative which cannot be distinguished from this is to have a $P_{13}$ resonance with $M = 1530$ MeV, $\Gamma = 79$ MeV, and elasticity = +0.271.

10 LONGACRE 77 considers this coupling to be well determined.

11 WADA 84 is inconsistent with other analyses; see the Note on $N$ and $\Delta$ Resonances.

12 Converted to our conventions using $M = 1486$ MeV, $\Gamma = 613$ MeV from NOELLE 78.

N(1440) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

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PENNER 02C PR C66 055211 G. Penner, U. Mosel (GIES)

PENNER 02D PR C66 055212 G. Penner, U. Mosel (GIES)


ARNDT 95 PR C52 2120 R.A. Arndt et al. (VPI, BRCO)

BATINIC 95 PR C51 2310 M. Batic et al. (BOSK, UCLA)

Also 98 PR C57 1004 (erratum) M. Batic et al.

HOEHLER 93 $\pi N$ Newsletter 9 1 G. Hohler (KARL)

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Also 84 PR D30 904 D.M. Manley et al. (VPI)

ARNDT 91 PR D43 2131 R.A. Arndt et al. (VPI, TELE) IJP

CUTKOSKY 90 PR D42 235 R.E. Cutkosky, S. Wang (CMU)

WADA 84 NP B247 313 Y. Wada et al. (INUS)

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FUJII 81 NP B187 53 K. Fujii et al. (NAGO, OSAK)

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Also 82 NP B194 251 I. Arai, H. Fujii (INUS)

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ISHII 80 NP B165 189 T. Ishii et al. (KYOT, INUS)

TAKEDA 80 NP B168 17 H. Takeda et al. (TOKY, INUS)

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BERENDS 77 NP B136 317 F.A. Berends, A. Donnachie (LEID, MCHS) IUP

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Also 76 NP B108 365 J. Dolbeau et al. (SAKL) IUP

FELLER 76 NP B104 219 P. Feller et al. (NAGO, OSAK) IUP

FELTESSE 75 NP B93 242 J. Feltesse et al. (SAKL) IUP

LONGACRE 75 PL 55B 415 R.S. Longacre et al. (LBL, SLAC) IUP