

# Δ(1910) P<sub>31</sub>

$$I(J^P) = \frac{3}{2}(\frac{1}{2}^+) \text{ Status: } ****$$

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1984 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

## Δ(1910) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>1870 to 1920 (≈ 1910) OUR ESTIMATE</b>			
2067.9 ± 1.7	ARNDT	06	DPWA π N → π N, η N
1882 ± 10	MANLEY	92	IPWA π N → π N & N π π
1910 ± 40	CUTKOSKY	80	IPWA π N → π N
1888 ± 20	HOEHLER	79	IPWA π N → π N
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1995 ± 12	VRANA	00	DPWA Multichannel
2152	ARNDT	95	DPWA π N → N π
1960.1 ± 21.0	<sup>1</sup> CHEW	80	BPWA π <sup>+</sup> p → π <sup>+</sup> p
2121.4 <sup>+13.0</sup> <sub>-14.3</sub>	<sup>1</sup> CHEW	80	BPWA π <sup>+</sup> p → π <sup>+</sup> p
1790	<sup>2</sup> LONGACRE	77	IPWA π N → N π π

## Δ(1910) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>190 to 270 (≈ 250) OUR ESTIMATE</b>			
543 ± 10	ARNDT	06	DPWA π N → π N, η N
239 ± 25	MANLEY	92	IPWA π N → π N & N π π
225 ± 50	CUTKOSKY	80	IPWA π N → π N
280 ± 50	HOEHLER	79	IPWA π N → π N
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
713 ± 465	VRANA	00	DPWA Multichannel
760	ARNDT	95	DPWA π N → N π
152.9 ± 60.0	<sup>1</sup> CHEW	80	BPWA π <sup>+</sup> p → π <sup>+</sup> p
172.2 ± 37.0	<sup>1</sup> CHEW	80	BPWA π <sup>+</sup> p → π <sup>+</sup> p
170	<sup>2</sup> LONGACRE	77	IPWA π N → N π π

## Δ(1910) POLE POSITION

### REAL PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>1830 to 1880 (≈ 1855) OUR ESTIMATE</b>			
1771	ARNDT	06	DPWA π N → π N, η N
1874	<sup>3</sup> HOEHLER	93	SPED π N → π N
1880 ± 30	CUTKOSKY	80	IPWA π N → π N

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

1880	VRANA	00	DPWA	Multichannel
1810	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
1950	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1792 or 1801	<sup>2</sup> LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

### –2×IMAGINARY PART

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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#### 200 to 500 ( $\approx 350$ ) OUR ESTIMATE

479	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$
283	<sup>3</sup> HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
200±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

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

496	VRANA	00	DPWA	Multichannel
494	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
398	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
172 or 165	<sup>2</sup> LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

## $\Delta(1910)$ ELASTIC POLE RESIDUE

### MODULUS $|r|$

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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45	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$
38	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
20±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

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

53	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
37	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

### PHASE $\theta$

<u>VALUE (°)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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+172	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$
– 90±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

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

– 176	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
– 91	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

## $\Delta(1910)$ DECAY MODES

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

Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1$ $N\pi$	15–30 %
$\Gamma_2$ $\Sigma K$	
$\Gamma_3$ $N\pi\pi$	
$\Gamma_4$ $\Delta\pi$	
$\Gamma_5$ $\Delta(1232)\pi, P$ -wave	

$\Gamma_6$	$N\rho$	
$\Gamma_7$	$N\rho, S=3/2, P\text{-wave}$	
$\Gamma_8$	$N(1440)\pi$	
$\Gamma_9$	$N(1440)\pi, P\text{-wave}$	
$\Gamma_{10}$	$N\gamma$	0.0–0.2 %
$\Gamma_{11}$	$N\gamma, \text{helicity}=1/2$	0.0–0.2 %

### $\Delta(1910)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>		
<b>0.15 to 0.3 OUR ESTIMATE</b>					
$0.239 \pm 0.001$	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$	
$0.23 \pm 0.08$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \ \& \ N\pi\pi$	
$0.19 \pm 0.03$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
$0.24 \pm 0.06$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.29 \pm 0.21$	VRANA	00	DPWA	Multichannel	
0.26	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$	
0.17	<sup>1</sup> CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$	
0.40	<sup>1</sup> CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$	

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(1910) \rightarrow \Sigma K$					$(\Gamma_1\Gamma_2)^{1/2}/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>		
$< 0.03$	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$-0.019$	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$	

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 $N\pi \rightarrow \Delta(1910) \rightarrow \Delta(1232)\pi, P\text{-wave}$					$(\Gamma_1\Gamma_5)^{1/2}/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>		
+0.06	<sup>2</sup> LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$	

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(1910) \rightarrow N\rho, S=3/2, P\text{-wave}$					$(\Gamma_1\Gamma_7)^{1/2}/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>		
+0.29	<sup>2</sup> LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$	

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(1910) \rightarrow N(1440)\pi, P\text{-wave}$					$(\Gamma_1\Gamma_9)^{1/2}/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>		
$-0.39 \pm 0.04$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \ \& \ N\pi\pi$	

$\Gamma(N(1440)\pi)/\Gamma_{\text{total}}$	$\Gamma_8/\Gamma$		
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.56 ± 0.07	VRANA	00	DPWA Multichannel

### $\Delta(1910)$ PHOTON DECAY AMPLITUDES

Papers on  $\gamma N$  amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G **33** 1 (2006).

#### $\Delta(1910) \rightarrow N\gamma$ , helicity-1/2 amplitude $A_{1/2}$

<u>VALUE (GeV<sup>-1/2</sup>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>+0.003 ± 0.014 OUR ESTIMATE</b>			
−0.002 ± 0.008	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
0.014 ± 0.030	CRAWFORD	83	IPWA $\gamma N \rightarrow \pi N$
0.025 ± 0.011	AWAJI	81	DPWA $\gamma N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
0.032 ± 0.003	LI	93	IPWA $\gamma N \rightarrow \pi N$

### $\Delta(1910)$ FOOTNOTES

- <sup>1</sup> CHEW 80 reports four resonances in the  $P_{31}$  wave — see also the  $\Delta(1750)$ . Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.
- <sup>2</sup> 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.
- <sup>3</sup> 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.

### $\Delta(1910)$ REFERENCES

For early references, see Physics Letters **111B** 1 (1982).

ARNDT	06	PR C74 045205	R.A. Arndt <i>et al.</i>	(GWU)
PDG	06	JPG 33 1	W.-M. Yao <i>et al.</i>	(PDG Collab.)
VRANA	00	PRPL 328 181	T.P. Vrana, S.A. Dytman,, T.-S.H. Lee	(PITT+)
ARNDT	96	PR C53 430	R.A. Arndt, I.I. Strakovsky, R.L. Workman	(VPI)
ARNDT	95	PR C52 2120	R.A. Arndt <i>et al.</i>	(VPI, BRCO)
HOEHLER	93	$\pi N$ Newsletter 9 1	G. Hohler	(KARL)
LI	93	PR C47 2759	Z.J. Li <i>et al.</i>	(VPI)
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KENT) IJP
Also		PR D30 904	D.M. Manley <i>et al.</i>	(VPI)
ARNDT	91	PR D43 2131	R.A. Arndt <i>et al.</i>	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	D.J. Candlin <i>et al.</i>	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	R.L. Crawford, W.T. Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9B2	G. Hohler	(KARLT)
PDG	82	PL 111B 1	M. Roos <i>et al.</i>	(HEL5, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also		NP B197 365	K. Fujii <i>et al.</i>	(NAGO)
CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
Also		PR D20 2839	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	P. Livanos <i>et al.</i>	(SACL) IJP
HOEHLER	79	PDAT 12-1	G. Hohler <i>et al.</i>	(KARLT) IJP
Also		Toronto Conf. 3	R. Koch	(KARLT) IJP
LONGACRE	77	NP B122 493	R.S. Longacre, J. Dolbeau	(SACL) IJP
Also		NP B108 365	J. Dolbeau <i>et al.</i>	(SACL) IJP