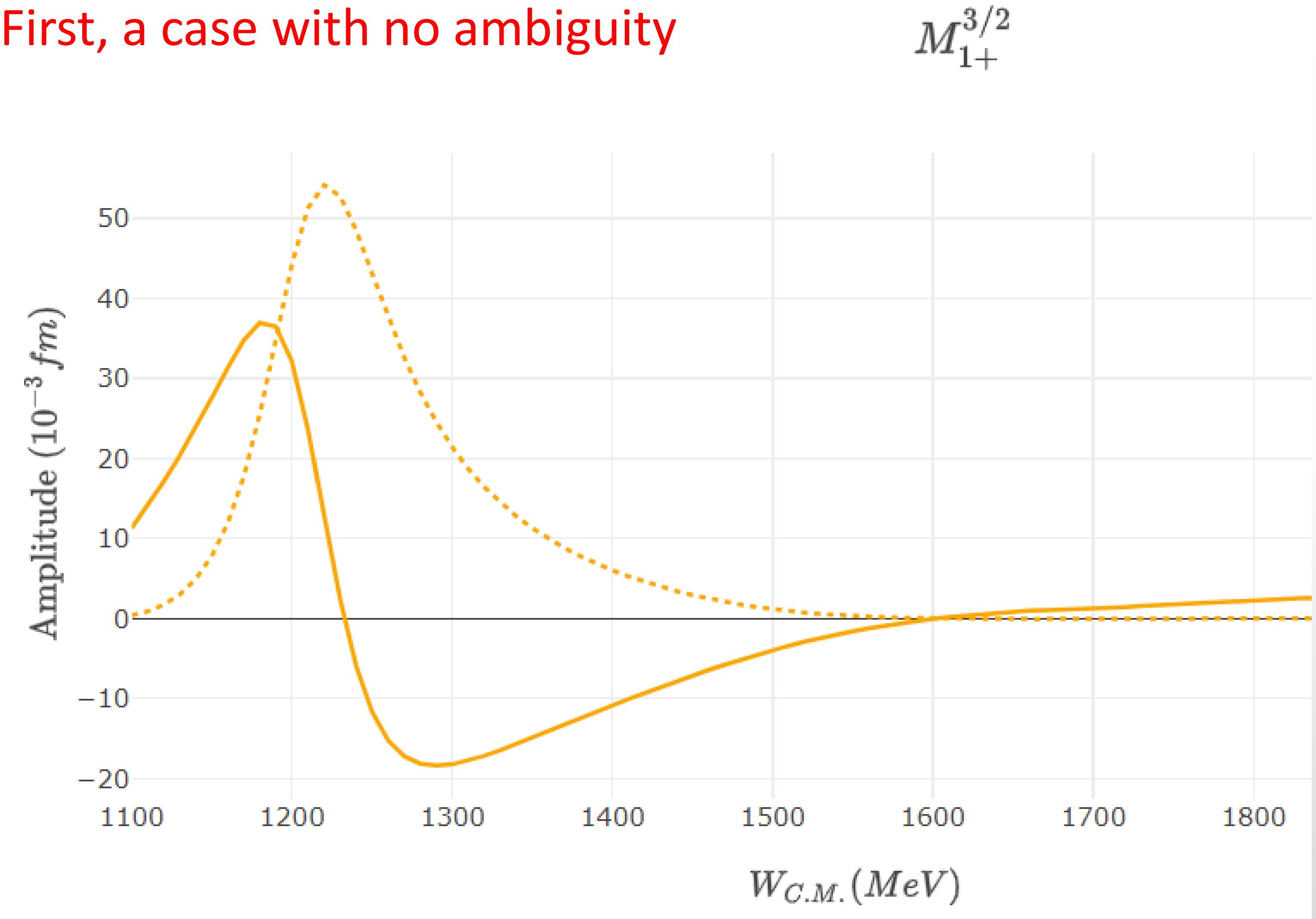
Pole-related (vs Breit-Wigner) quantities for Unstable Baryons

(What has been encoded - a few examples)

First, a case with no ambiguity



P33 channel for πN elastic
Δ(1232) $3/2^+$ resonance
Dominant amplitude plotted for pion photoproduction

$\Delta(1232)$ POLE POSITIONS

REAL PART, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1209 to 1211 (≈ 1210) OUR ESTIMATE				
1211 ±1 ±1	[1] SVARC	14	L+P	$\pi N \to \pi N$
1210.5±1.0	ANISOVICH	12A	DPWA	Multichannel
1210 ±1	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1212.4	HUNT	19	DPWA	Multichannel
1218	ROENCHEN	15A	DPWA	Multichannel
1211 ±1	ANISOVICH	10	DPWA	Multichannel
1211	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
1210	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
1209	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$

[1] Fit to the amplitudes of HOEHLER 79.

[2] See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

−2×IMAGINARY PART, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
98 to 102 (≈ 100) OUR ESTIMATE				
98 ±2±1	[1] SVARC	14	L+P	$\pi N \to \pi N$
99 ±2	ANISOVICH	12A	DPWA	Multichannel
100 ±2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
96.8	HUNT	19	DPWA	Multichannel
92	ROENCHEN	15A	DPWA	Multichannel
100 ±2	ANISOVICH	10	DPWA	Multichannel
99	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
100	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
100	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$

Above the line: most recent values + Cutkosky (one of the classic CMB+KH fits to elastic scattering data)
Below the line: superseded analyses or analyses given without errors.

Pole position is $W_p \sim (1210 - i\,50)$ MeV vs BW mass ~ 1232 MeV and BW width ~ 117 MeV
[BW uncertainties are a few MeV, as is the estimated Δ^0 - Δ^{++} mass/width difference.]

SVARC 14 L+P $\pi N \rightarrow \pi N$: fits Karlsruhe amplitudes with a modified Laurent expansion

ANISOVICH 12A DPWA Multichannel : DPWA (energy-dependent PWA),

CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$: IPWA(single-energy PWA), 1.Data amalgamation, 35 momenta,
2. PWA with dispersion relation constraint, 3. Fit to amplitudes to extract poles, residues.
R.E. Cutkosky et al., Phys. Rev. D20 (1978) { 2782, 2804, 2839}

HUNT 19 DPWA Multichannel : energy-dependent Breit-Wigner fit to existing sets of amplitudes.
The pole extraction described in M. Shrestha and D.M. Manley, Phys. Rev. C86 (2012) 055203.

ROENCHEN 15A DPWA Multichannel : Dynamical coupled-channel analysis. Method for pole extraction discussed in M. Doring et al., Nucl. Phys. A851 (2011) 58 [Appendix C].

ARNDT 06 DPWA $\pi N \rightarrow \pi N, \eta N$: Chew-Mandelstam K-matrix with dispersion relation constraints.

HOEHLER 93 Argand plots $\pi N \rightarrow \pi N$: Speed-plot SP(W) = | dT/dW |
Pion-Nucleon Newsletter 9, 1 (1993)
Available from https://gwdac.phys.gwu.edu/analysis/news.html

$\Delta(1232)$ ELASTIC POLE RESIDUES

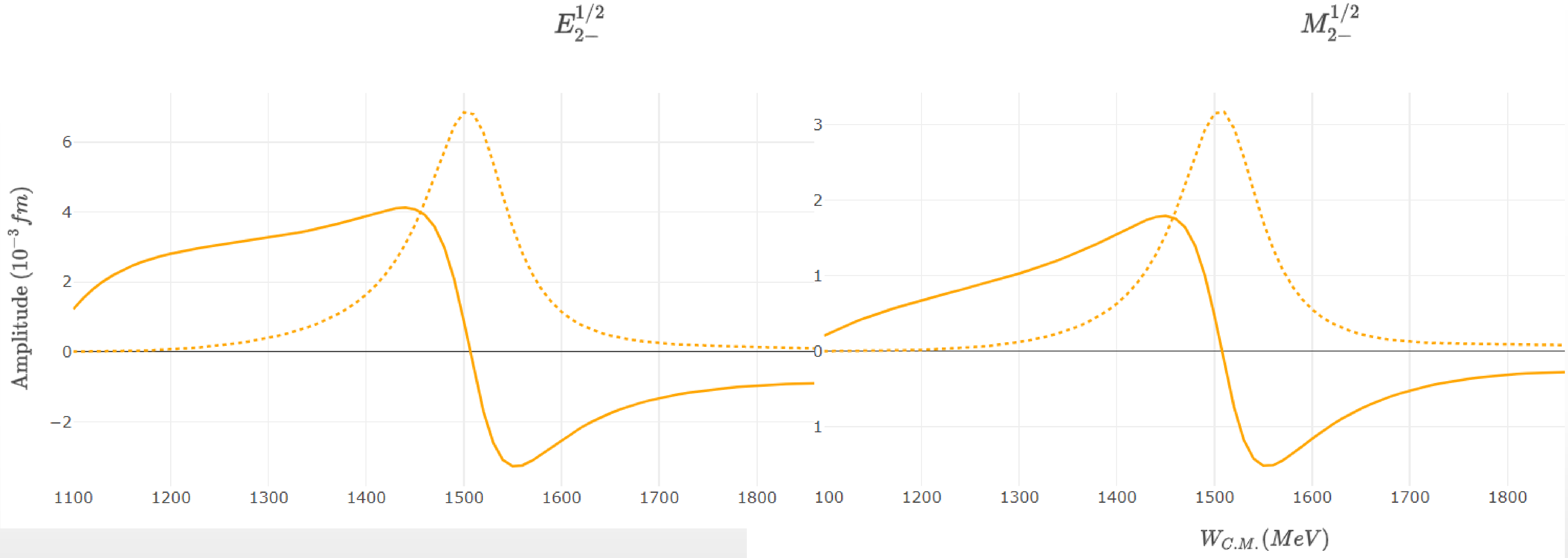
ABSOLUTE VALUE, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
49 to 52 (≈ 50) OUR ESTIMATE				
50 ±1 ±1	[1] SVARC	14	L+P	$\pi N \to \pi N$
51.6±0.6	ANISOVICH	12A	DPWA	Multichannel
53 ±2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
46	ROENCHEN	15A	DPWA	Multichannel
52	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
53	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
50	HOEHLER	93	ARGD	$\pi N \to \pi N$

PHASE, MIXED CHARGES

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−48 to −45 (≈ −46) OUR ESTIMATE				
−46±1±1	[1] SVARC	14	L+P	$\pi N \to \pi N$
−46±1	ANISOVICH	12A	DPWA	Multichannel
−47±1	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−36	ROENCHEN	15A	DPWA	Multichannel
−47	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
−47	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
−48	HOEHLER	93	ARGD	$\pi N \to \pi N$

As before, ‘below the line’ entries are dropped (in this case, because no error has been provided)
This information on πN→πN goes into the relation for ɣN→πN at the pole, leading to the photo-decay helicity amplitudes $A_{1/2}$ and $A_{3/2}$ evaluated at the pole position.



D13 channel for πN elastic
N(1520) 3/2⁻ resonance
Electric and magnetic multipoles are significant and show a clear resonance for pion photoproduction

$N(1520)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1505 to 1515 (≈ 1510) OUR ESTIMATE				
1507 ± 2	SOKHOYAN	15A	DPWA	Multichannel
$1506\pm1\pm1$	[1] SVARC	14	L+P	$\pi N \to \pi N$
1510 ± 5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1500	HUNT	19	DPWA	Multichannel
1512	ROENCHEN	15A	DPWA	Multichannel
1492	SHKLYAR	13	DPWA	Multichannel
1507 ± 3	ANISOVICH	12A	DPWA	Multichannel
1506 ± 9	BATINIC	10	DPWA	$\pi N \to N\pi, N\eta$
1515	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
1504	VRANA	00	DPWA	Multichannel
1510	HOEHLER	93	ARGD	$\pi N \to \pi N$

[1] Fit to the amplitudes of HOEHLER 79.

$-2\times$IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
105 to 120 (≈ 110) OUR ESTIMATE				
111 ± 3	SOKHOYAN	15A	DPWA	Multichannel
$115\pm2\pm1$	[1] SVARC	14	L+P	$\pi N \to \pi N$
114 ± 10	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
117	HUNT	19	DPWA	Multichannel
89	ROENCHEN	15A	DPWA	Multichannel
94	SHKLYAR	13	DPWA	Multichannel
111 ± 5	ANISOVICH	12A	DPWA	Multichannel
122 ± 9	BATINIC	10	DPWA	$\pi N \to N\pi, N\eta$
113	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
112	VRANA	00	DPWA	Multichannel
120	HOEHLER	93	ARGD	$\pi N \to \pi N$

Values above the line are consistent. The **CUTKOSKY** value guides **OUR ESTIMATE**.

Following the reasoning applied to the REAL PART, this could be changed to
105 to 125(~115) **OUR ESTIMATE.**

$N(1520)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
32 to 38 ($\approx$ 35) OUR ESTIMATE				
36 ± 2	SOKHOYAN	15A	DPWA	Multichannel
$33\pm1\pm1$	[1] SVARC	14	L+P	$\pi N \to \pi N$
35 ± 2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
37	ROENCHEN	15A	DPWA	Multichannel
27	SHKLYAR	13	DPWA	Multichannel
36 ± 3	ANISOVICH	12A	DPWA	Multichannel
35	BATINIC	10	DPWA	$\pi N \to N\pi, N\eta$
38	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
32	HOEHLER	93	ARGD	$\pi N \to \pi N$

[1] Fit to the amplitudes of HOEHLER 79.

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
-15 to -5 (≈ -10) OUR ESTIMATE				
-14 ± 3	SOKHOYAN	15A	DPWA	Multichannel
$-15\pm1\pm1$	[1] SVARC	14	L+P	$\pi N \to \pi N$
-12 ± 5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-6	ROENCHEN	15A	DPWA	Multichannel
-35	SHKLYAR	13	DPWA	Multichannel
-14 ± 3	ANISOVICH	12A	DPWA	Multichannel
-7	BATINIC	10	DPWA	$\pi N \to N\pi, N\eta$
-5	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
-8	HOEHLER	93	ARGD	$\pi N \to \pi N$

[1] Fit to the amplitudes of HOEHLER 79.

Error in **OUR ESTIMATE** covers the range of values. **SVARC** and **HOEHLER** are different pole determinations using the Karlsruhe amplitudes.

Error in **OUR ESTIMATE** is less clear. There are many low values below the line. Guided by **CUTKOSKY** results. Note: again **SVARC** and **HOEHLER** are based on the Karlsruhe amplitudes.

$N(1520)$ PHOTON DECAY AMPLITUDES AT THE POLE

$N(1520) \to p\gamma$, helicity-1/2 amplitude $A_{1/2}$

MODULUS ($GeV^{-1/2}$)	PHASE ($^\circ$)	DOCUMENT ID		TECN	COMMENT
-0.023 ± 0.004	-6 ± 5	SOKHOYAN	15A	DPWA	Multichannel
$-0.024^{+0.008}_{-0.003}$	-17^{+16}_{-6}	ROENCHEN	14	DPWA	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
-0.031	-17	ROENCHEN	15A	DPWA	Multichannel

$N(1520) \to p\gamma$, helicity-3/2 amplitude $A_{3/2}$

MODULUS ($GeV^{-1/2}$)	PHASE ($^\circ$)	DOCUMENT ID		TECN	COMMENT
0.131 ± 0.006	4 ± 4	SOKHOYAN	15A	DPWA	Multichannel
$0.117^{+0.006}_{-0.010}$	26 ± 2	ROENCHEN	14	DPWA	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.075	1.7	ROENCHEN	15A	DPWA	Multichannel

The helicity-1/2 amplitude appears more stable than the helicity-3/2. But looking below the line, it may be premature to give **OUR ESTIMATE**. The paper: Workman,Tiator,Sarantsev, PRC87(2013)068201 has examples of pole determinations based on an old SAID single-channel fit. The helicity-1/2 value agrees with the above while, for the helicity-3/2 case, the value differs significantly.

$N(1520)$ INELASTIC POLE RESIDUE

The "normalized residue" is the residue divided by $\Gamma_{pole}/2$.

Normalized residue in $N\pi \to N(1520) \to \Delta\pi$, *S*-wave

MODULUS	*PHASE (°)*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.33 ± 0.04	155 ± 15	SOKHOYAN	15A	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.33 ± 0.05	150 ± 20	ANISOVICH	12A	DPWA	Multichannel

Normalized residue in $N\pi \to N(1520) \to \Delta\pi$, *D*-wave

MODULUS	*PHASE (°)*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.25 ± 0.03	105 ± 18	SOKHOYAN	15A	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.25 ± 0.03	100 ± 20	ANISOVICH	12A	DPWA	Multichannel

Normalized residue in $N\pi \to N(1520) \to N\eta$

MODULUS	*PHASE (°)*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.026	95	ROENCHEN	15A	DPWA	Multichannel

Normalized residue in $N\pi \to N(1520) \to \Lambda K$

MODULUS	*PHASE (°)*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.069	158	ROENCHEN	15A	DPWA	Multichannel

Table of Inelastic Pole Residues shows a common problem. Values are available from only one group (here, **SOKHOYAN** and **ANISOVICH**: both BnGA). Or values are given without errors, as is the case for **ROENCHEN**.

Pole-valued quantities are given for most N and Delta states

The same is true for the Lambda and Sigma resonances

A pole position is given for one Xi resonance Xi(1530)

No pole-valued quantities given for the Omega resonances

In general, the Listings contain both BW and pole values if they are available.

Some relations between pole and BW quantities are found in the 2012 and 2022 Notes on
N and Delta Resonances. The Lambda section has two reported poles in the Lambda(1405)
leading to an awkward placement in the Listings.