Baryon Spectroscopy: Resonance parameter determination

HaSP Task 4.1 summary

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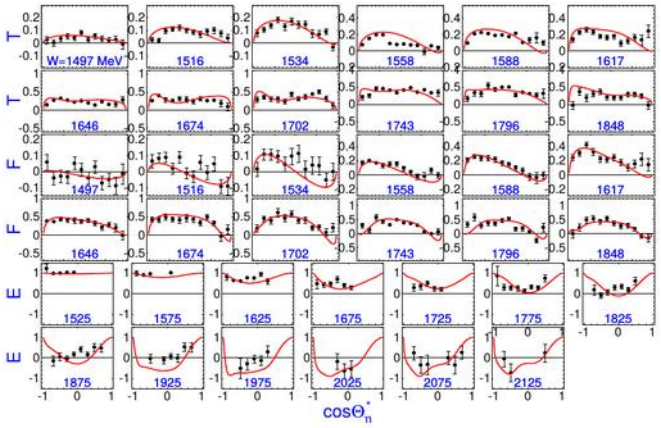
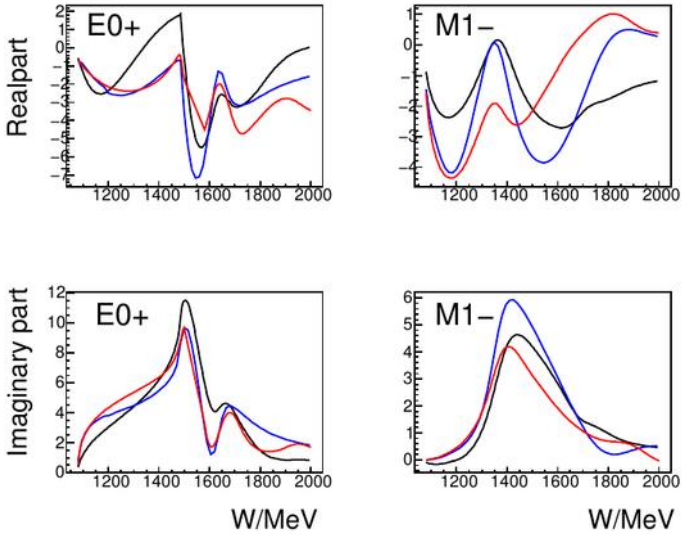
From data to resonances

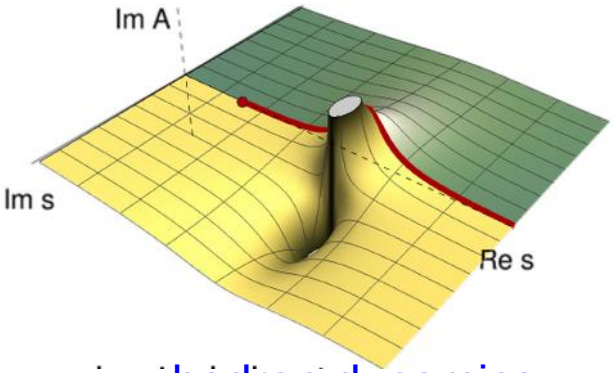
experiment/data observables



- hierarchy of precision
- kinematic limits
- many channels
- sytematics
- unknown phases



- complex continuation
- „background“
- interpretation

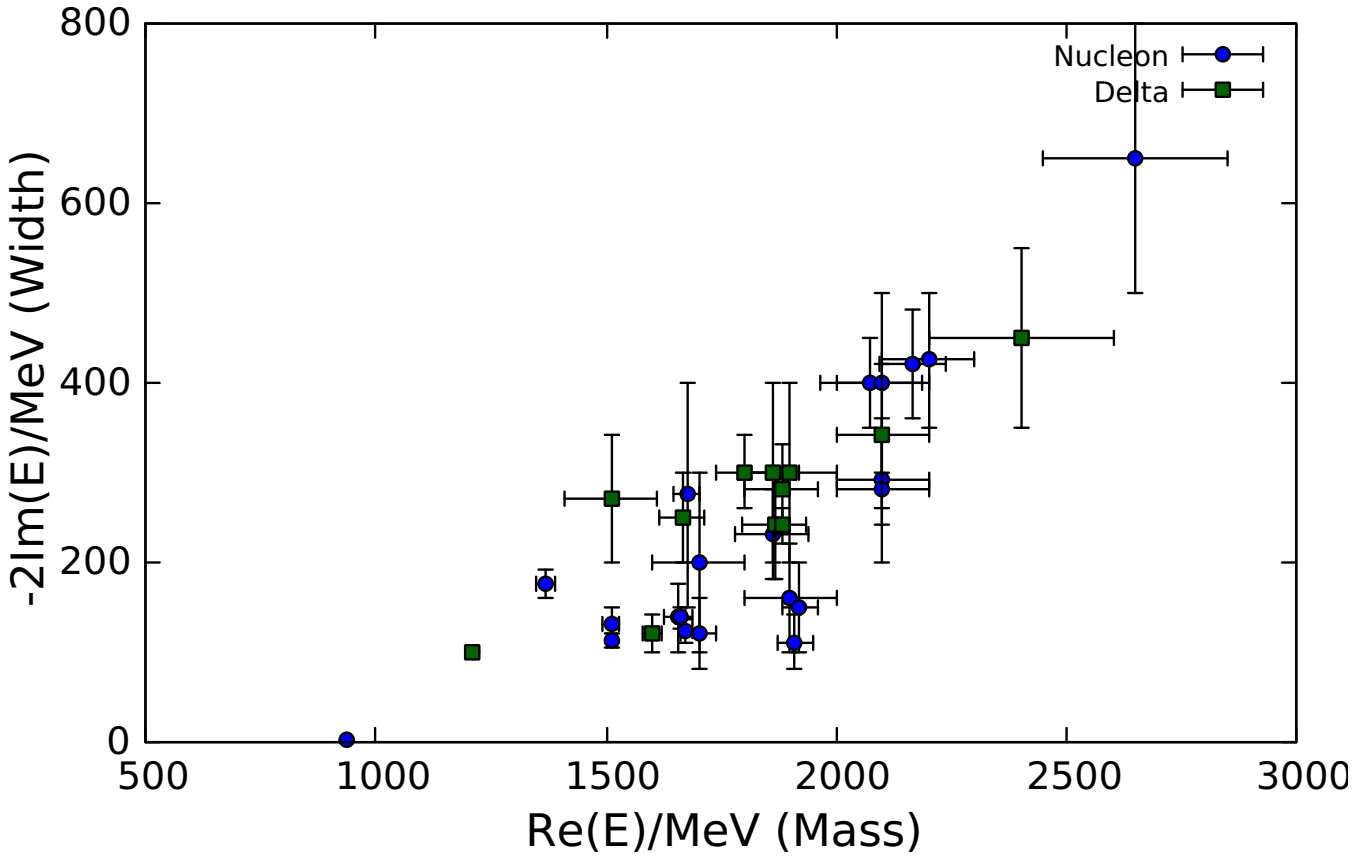


hadron dynamics resonances

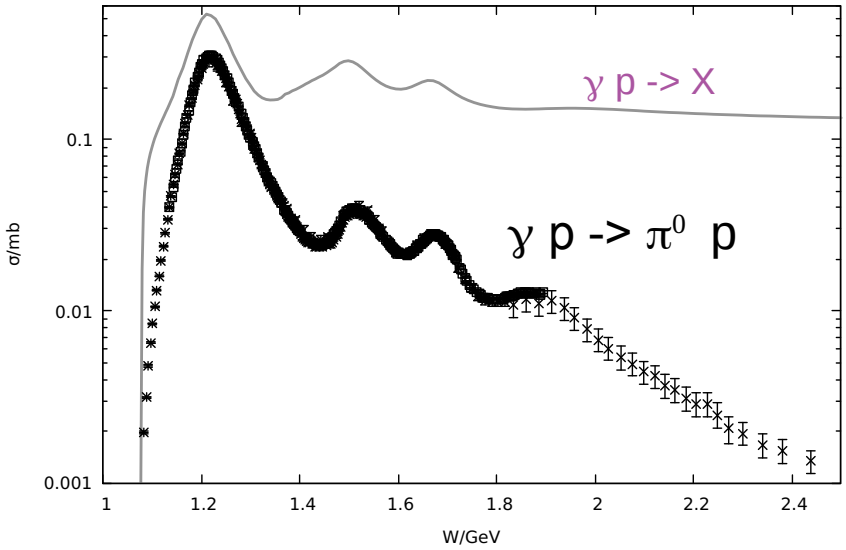
partial wave/spin amplitudes

Light baryon resonances

Resonance poles: N*/Δ*: PDG2018



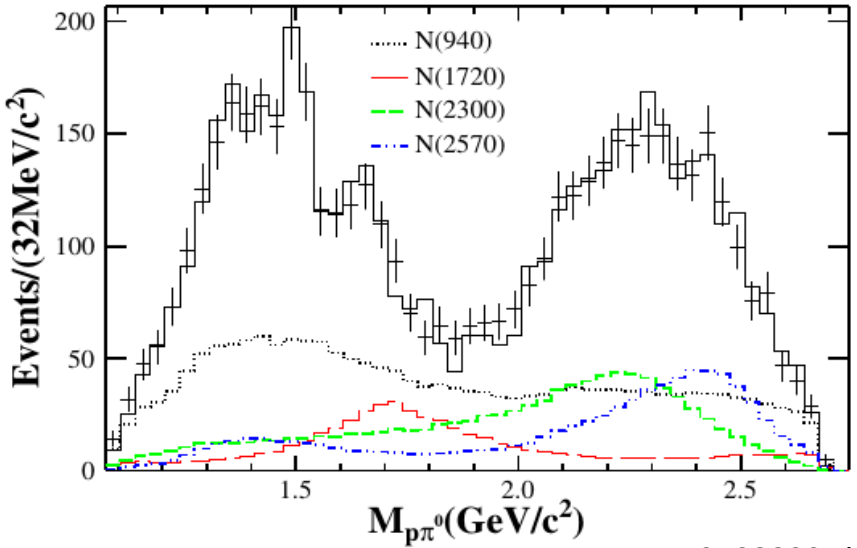
Experiments/Reactions



Photoproduction:

ELSA, JLAB, MAMI, GRAAL, ...

Ψ(3698) → pp̄π⁰

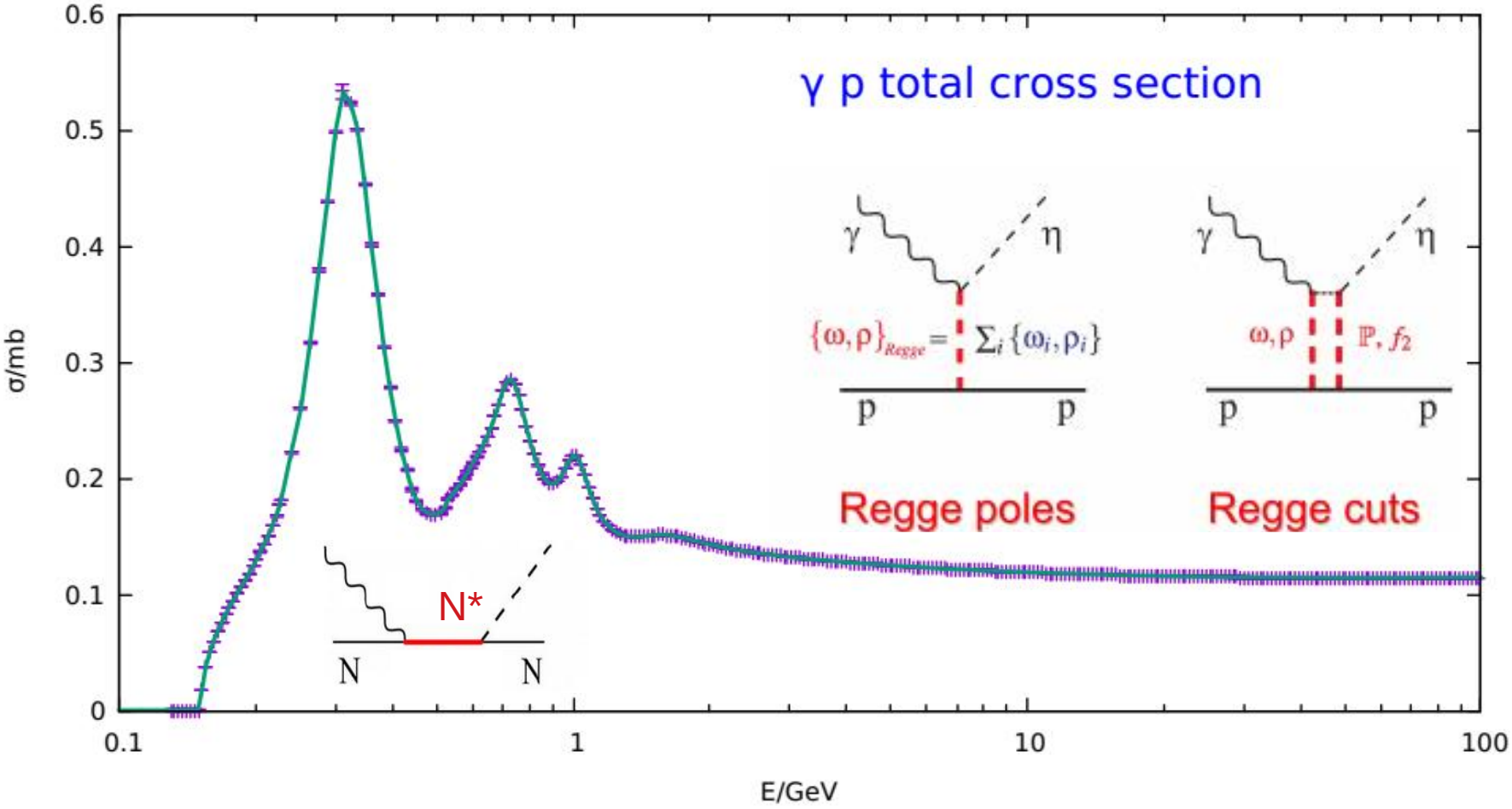


PRL110, 022001(2013)

Charmonium **decays:**

BESIII ...

Energy regimes



Recent Regge-Models:

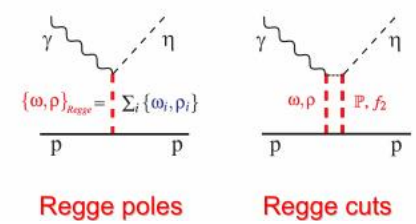
JPAC: Nys et al, Phys.Rev.D 95 (2017) 3, 034014

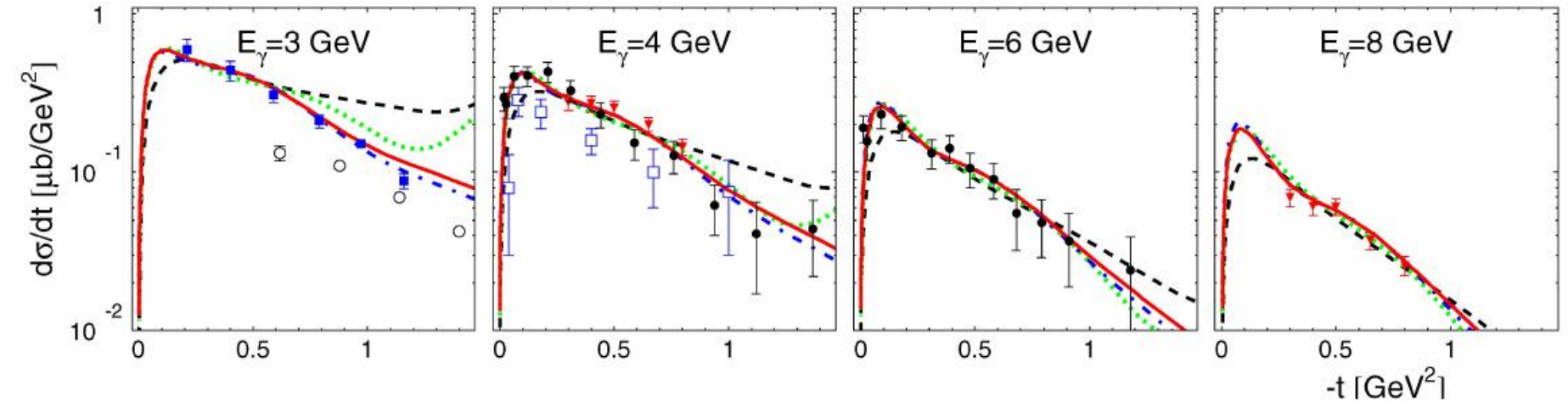
MAID: Kashevarov et al., Phys.Rev.C 96 (2017) 3, 035207

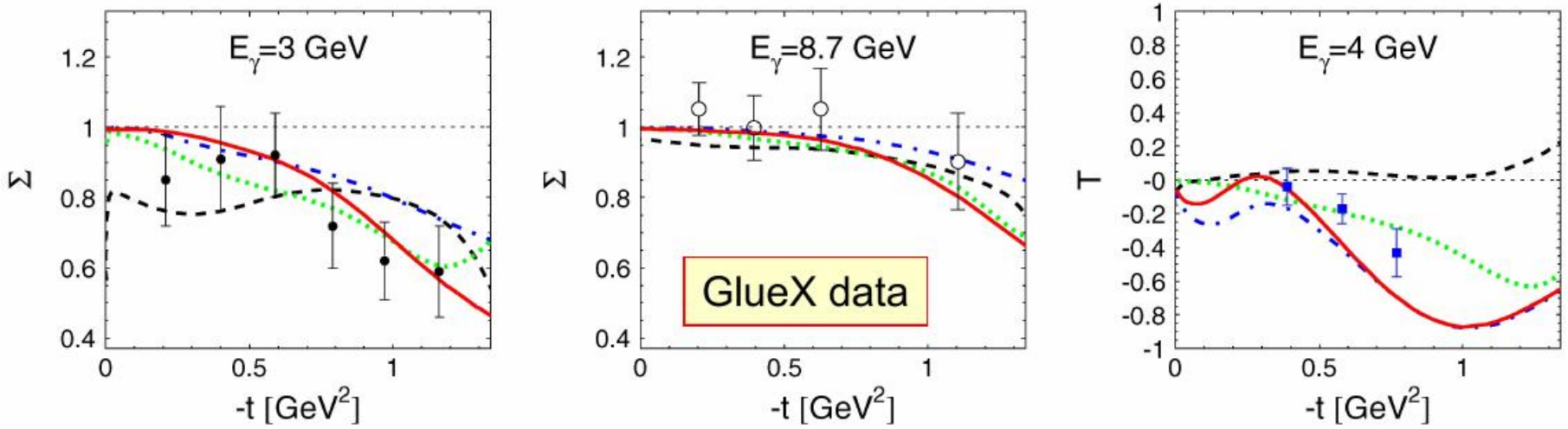
Regge phenomenology of γp → ηp

Regge-cut model (favored by MAID)

Model similar to JPAC approach

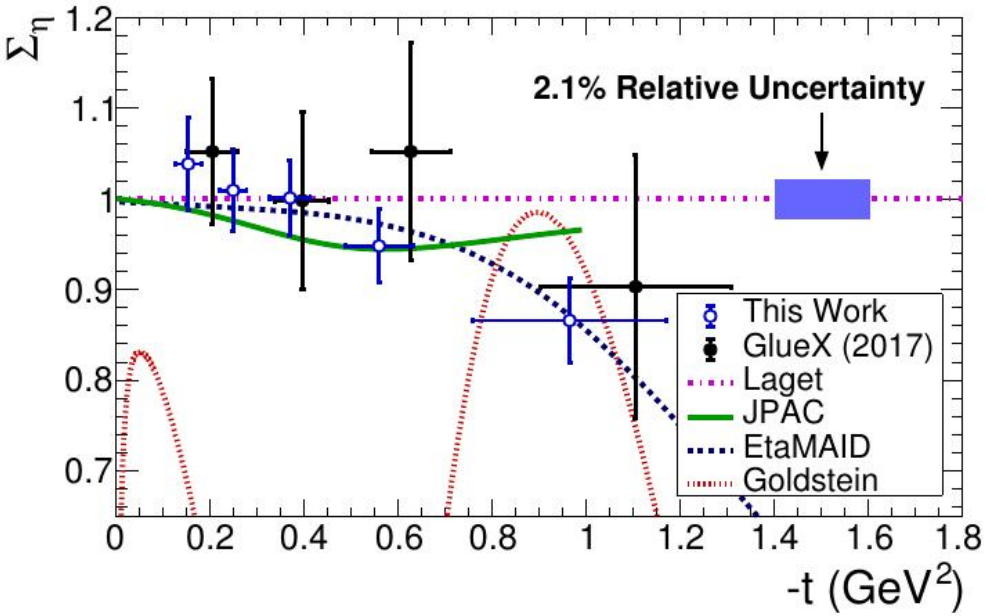




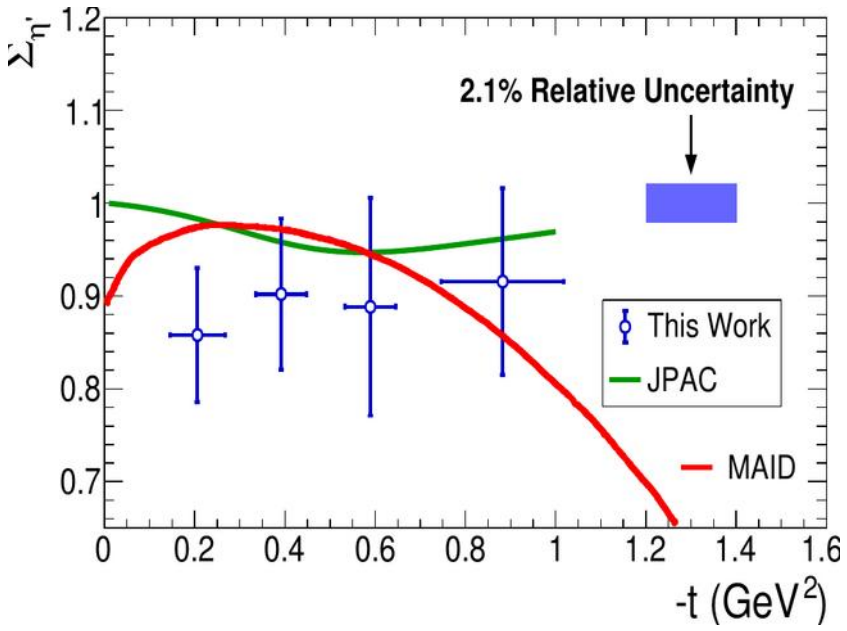


GlueX: new beam asymmetries at 8.8 GeV

$\gamma p \rightarrow \eta p$



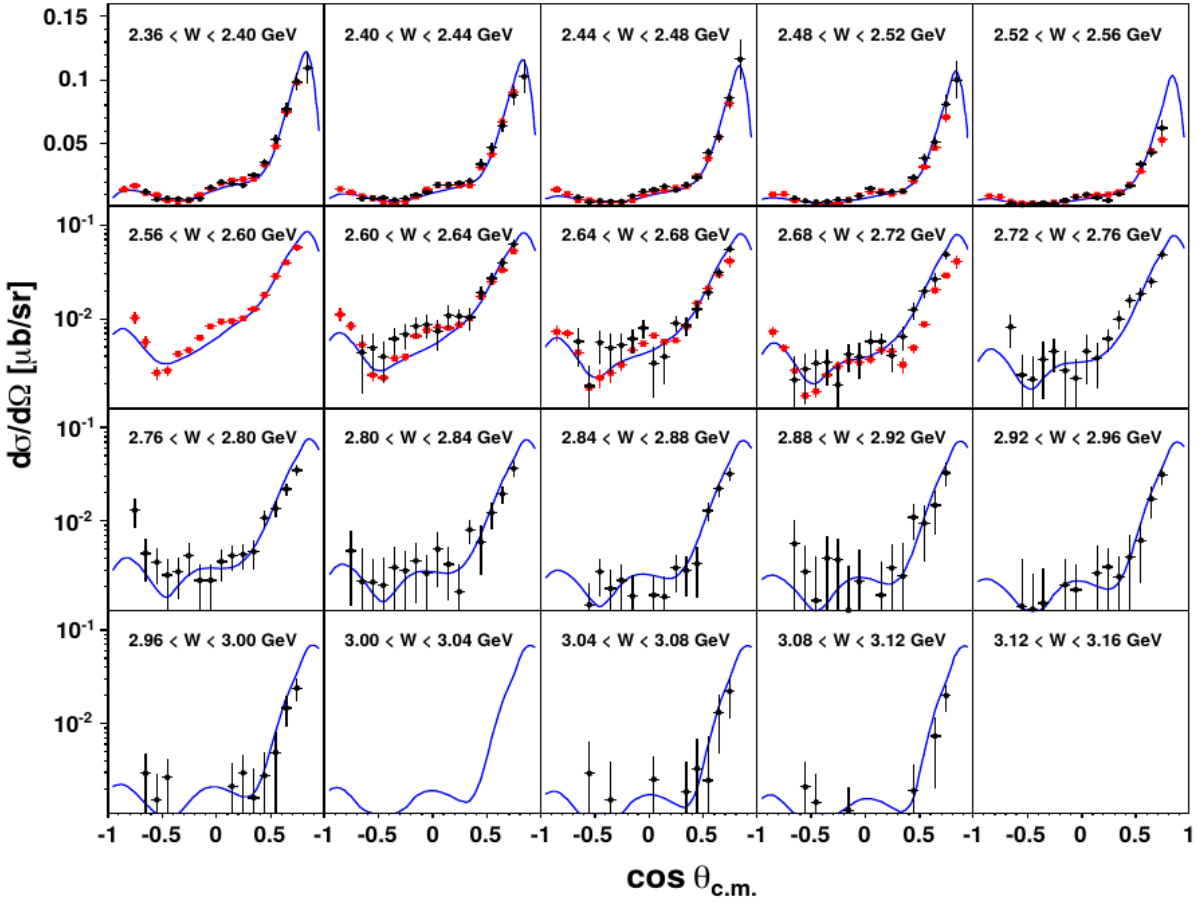
$\gamma p \rightarrow \eta' p$

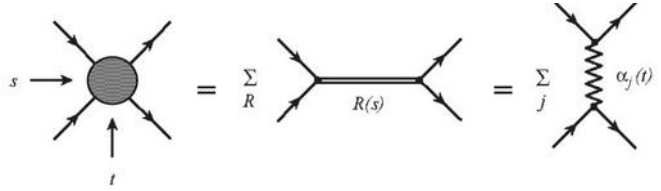


S. Adhikari et al, PRC 100 (2019) 052201

New CLAS data for γp → ηp

T.Hu et al, arXiv:2006.01361v2

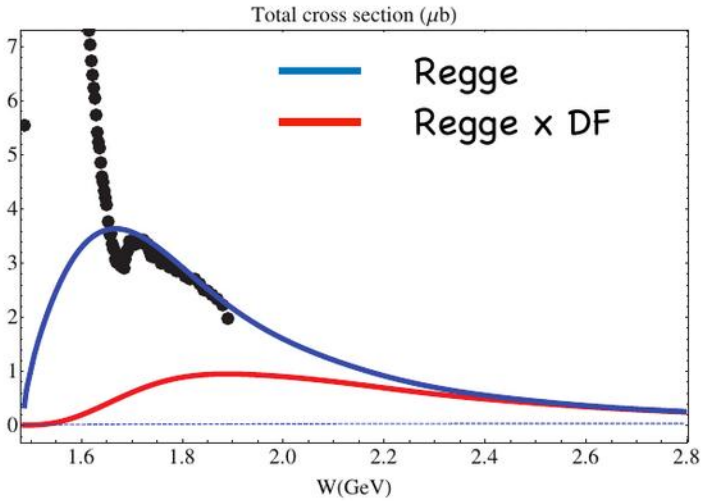




EtaMAID :

$$\sum_{i=1}^{N} M_s^{Res_i} + M^{Regge} \cdot F_d(W)$$

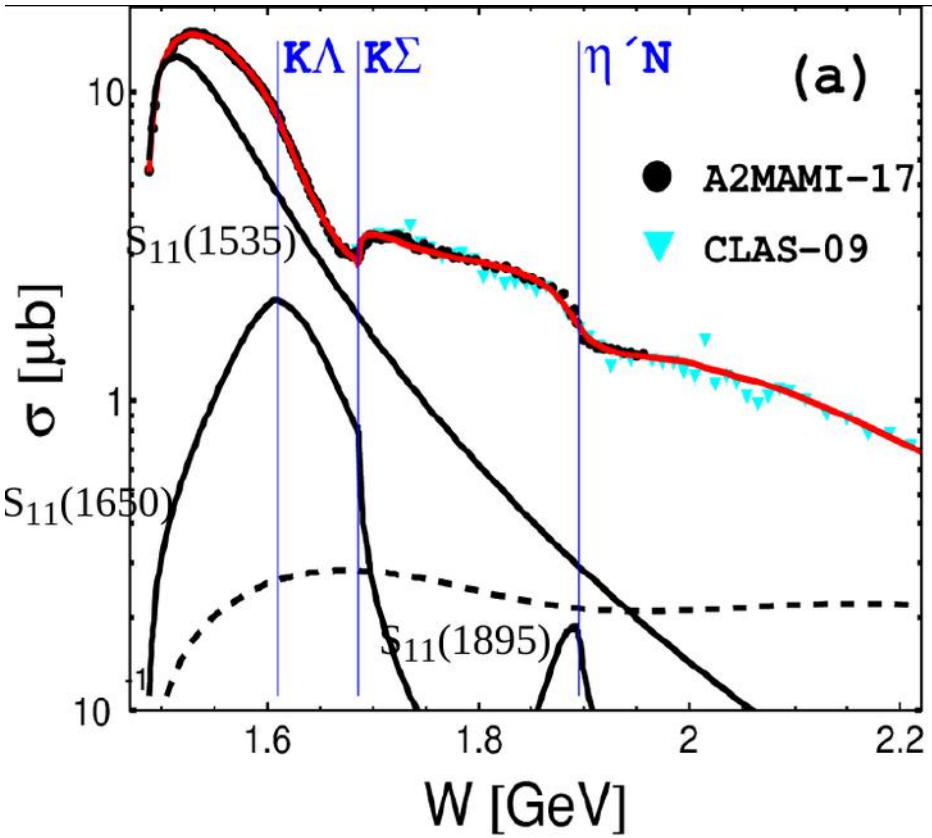
phenom. Damping factor



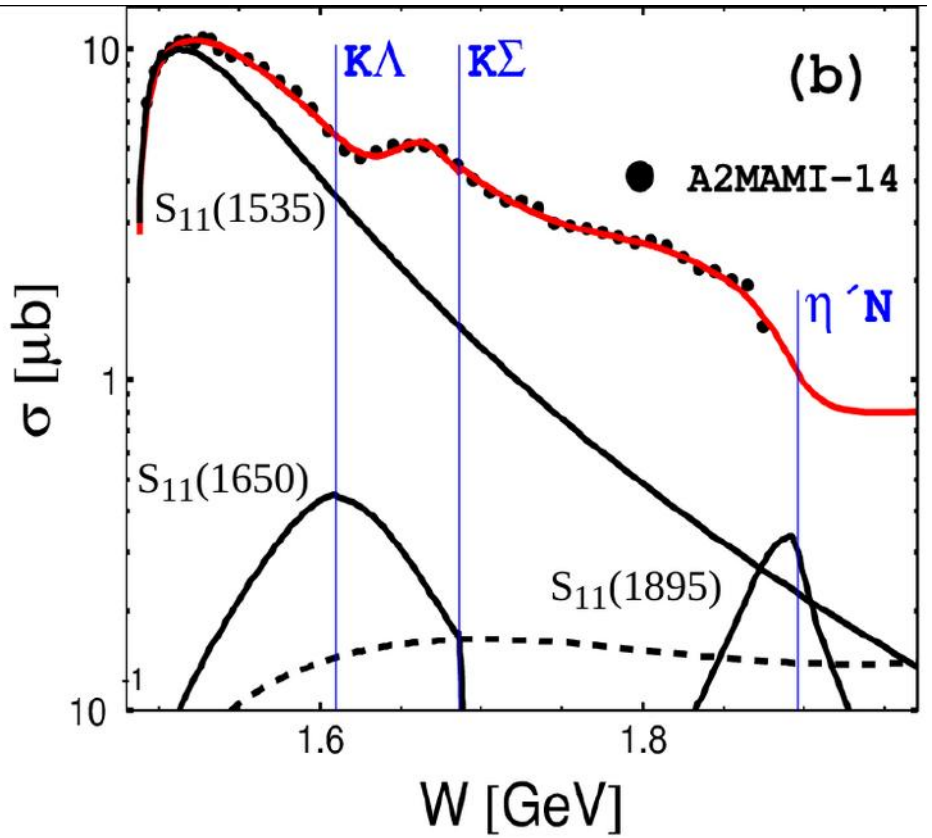
γN → ηN: Resonances and Cusps

Total cross sections in EtaMAID

Proton



Neutron

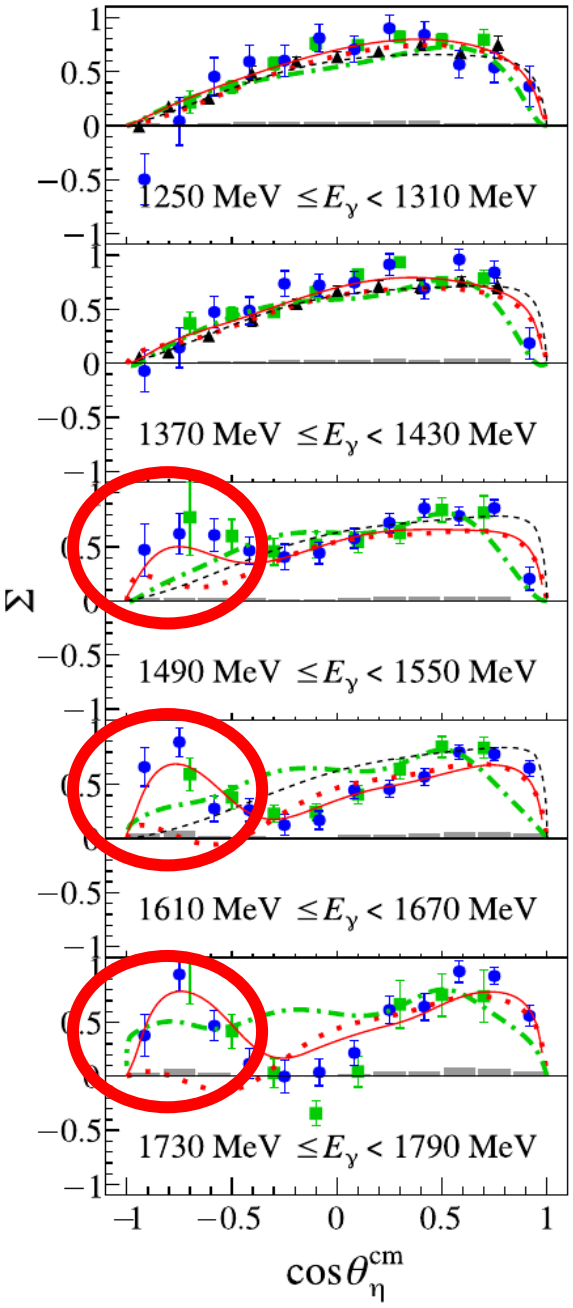


$S_{11}(1650)$ produces the cusp effect in (γ,η) at $K\Sigma$ threshold

$S_{11}(1895)$ produces the cusp effect in (γ,η) at η' threshold

- - - - Born+Regge

γN → ηN: Resonances and Cusps



W=1812MeV

W=1873MeV

W=1883MeV

W=1990MeV

W=2045MeV

Photon Beam asymmetry

- New CBELSA/TAPS **(F. Afzal et al, PRL 25 (2020) 152002)**
- Graal
- CLAS

EtaMAID(2003)
(single → multi) channel fit

BnGa-2014-02
multi channel fit

JüBo-2015 (FitB)
dynamically coupled channels,
generation of poles by interaction

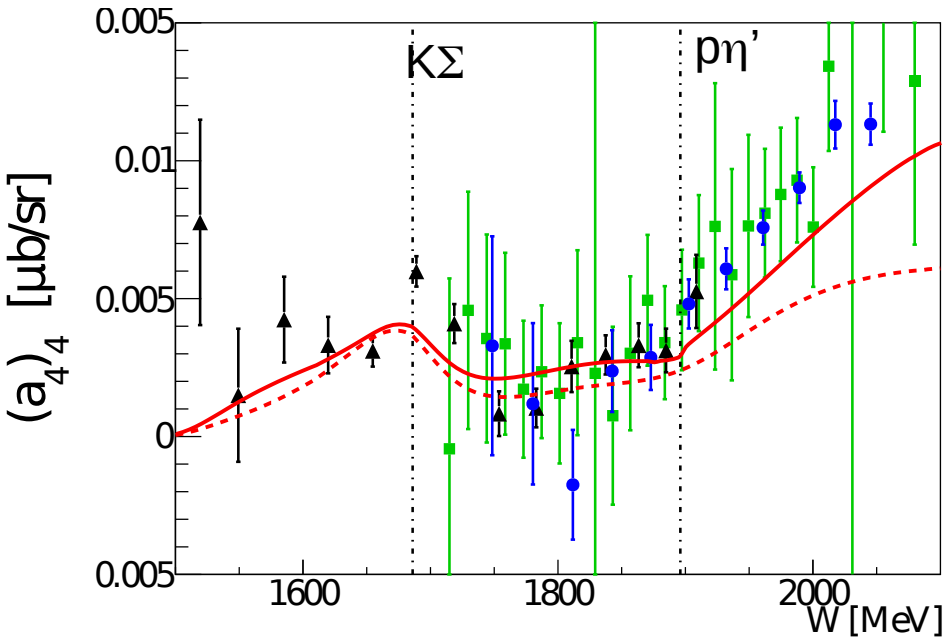
BnGa new fit

γN → ηN: Resonances and Cusps

Legendre expansion with $L_{max} = 4$

4th coefficient → S-G interference

See: Y. Wunderlich EPJ Web Conf. 241 (2020) 03006



S wave resonances

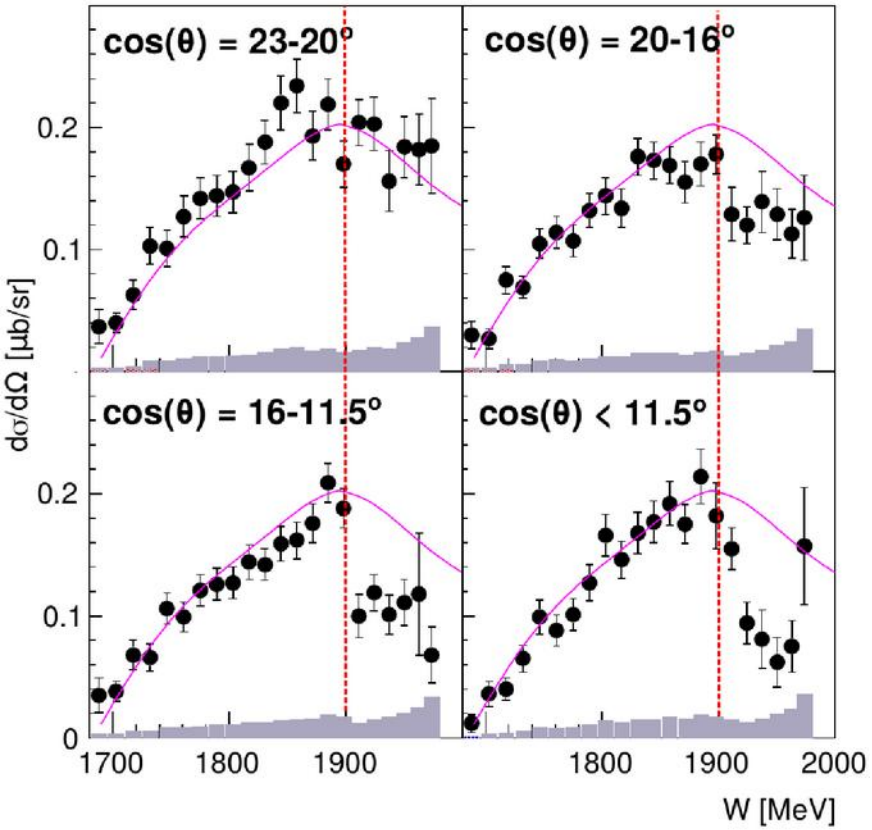
Res.		$M_{pole/BW}$	$\Gamma_{pole/BW}$	$BR(N^* \to N\eta)$
$N(1535)\frac{1}{2}^-$ (S_{11})	BnGa-2019	1496 ± 4	125 ± 6	0.41 ± 0.04
	JüBo-2017	1495 ± 2	112 ± 1	0.64 ± 0.02
	ηMAID-2018	1522 ± 8	175 ± 25	0.34 ± 0.05
	PDG (pole)	1500 - 1520	110 - 150	0.30 - 0.55
	PDG (BW)	1515 - 1545	125 - 175	
$N(1650)\frac{1}{2}^-$ (S_{11})	BnGa-2019	1664 ± 4	98 ± 6	0.33 ± 0.04
	JüBo-2017	1674 ± 3	130 ± 9	0.07 ± 0.02
	ηMAID-2018	1626^{+10}_{-5}	133 ± 20	0.19 ± 0.06
	PDG (pole)	1640 - 1670	100 - 170	0.15 - 0.35
	PDG (BW)	1635 - 1665	100 - 150	
$N(1895)\frac{1}{2}^-$ (S_{11})	BnGa-2019	1907 ± 10	100^{+40}_{-10}	0.10 ± 0.05
	JüBo-2017	not seen	-	-
	ηMAID-2018	1894.4^{+5}_{-15}	71^{+25}_{-13}	0.033 ± 0.015
	PDG (pole)	1890 - 1930	80 - 140	0.15 - 0.40
	PDG (BW)	1870 - 1920	80 - 200	

(see PRL 25 (2020) 152002)

$\gamma N \rightarrow K^+ \Sigma^0$: Resonances and Cusps

New data from the **BGO-OD at ELSA**:

T.C. Jude et al., arXiv:2006.12437 (2020)



- High resolution in forward direction
- Cusp around 1.9 GeV
- pronounced at extreme forward angles
- New BnGa-Fit
  $D_{13}(1895)$, $S_{31}(1900)$, $P_{31}(1910)$, $P_{13}(1900)$
- No clear conclusion yet, work in progress:

  JüBo updating their recent fits of $\gamma N \rightarrow KY$

As close to data as possible - single energy PWA

- Truncation necessary
- Not possible without model constraints (non-linear, unknown phases)

  See e.g.: Phys.Rev.C 96 (2017) 6, 065202 and Phys.Rev.C 97 (2018) 5, 054611

- 2 recent approaches:

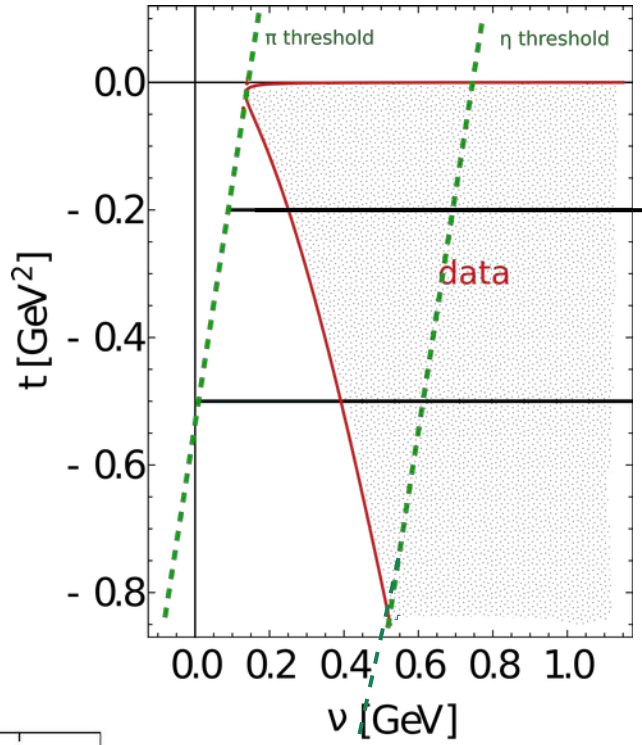
  1) Constrain phases and fit moduli to data
     (A. Švarc, Y. Wunderlich, .. arXiv:2008.01355)

  2) Iterated fits at fixed-t and fixed-W
     (H.Osmanović, J.Stahov, et al. PRC 97 (2018), 015207 PRC C 100 (2019), 055203)

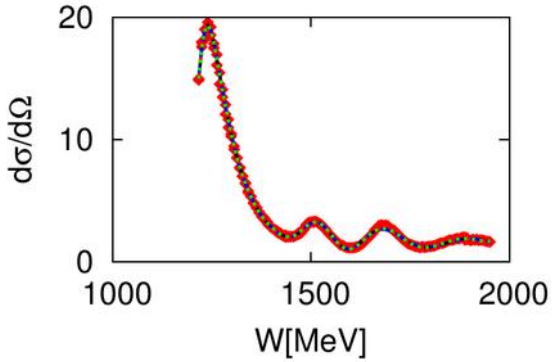
As close to data as possible - single energy PWA

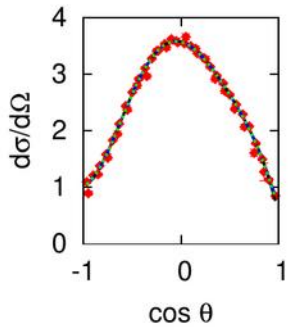
$\gamma\ p \rightarrow \pi^0 p$:

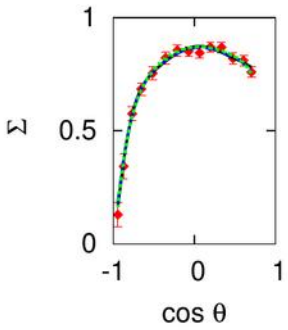
→ PRC C 100, 055203 (2019)



„Pietarinen“ - expansion at fixed-t





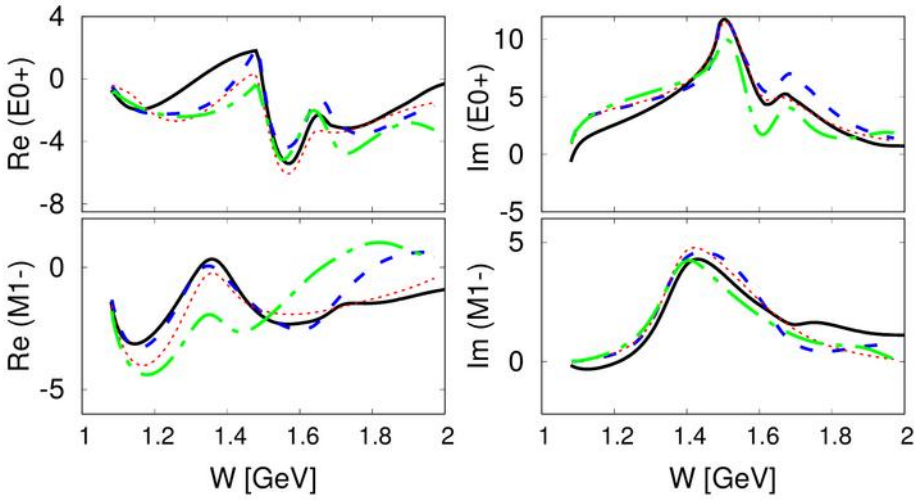


Multipole fit at Fixed energy

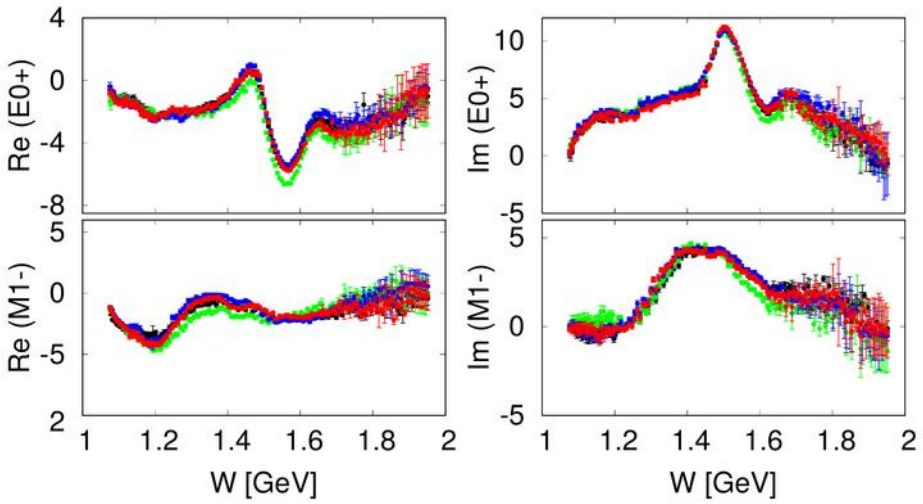
As close to data as possible - single energy PWA

$\gamma\ p \rightarrow \pi^0 p$:

Model input (0th step)



Results (3rd-4th iteration)



→ PRC C 100, 055203 (2019)

BnGa

MAID

JüBo

SAID

Work in progress:

- Isospin separation
- Pole analysis → Laurent plus Pietarinen expansion (L+P)
  pioneered by Zagreb/Tuzla group (PR C88, 035206 (2013))

Summary

- Resonance poles: precision data **and** sophisticated theory
- Photoproduction (ELSA, JLAB, MAMI, …)
  Charmonium decays (BES), Heavy quark baryons (LHCb)
- Future: - coupled channels
  - light-quark baryons: mass region W ≥ 2 GeV
  - heavy quark baryons
  - exotic baryons