EPJA special talk

Lothar Tiator, Johannes Gutenberg Universität Mainz

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MESON 2018, Kraków, Poland, 7-12 June

Eta and Etaprime Photoproduction with EtaMAID

Lothar Tiator for the Mainz-Tuzla-Zagreb collaboration

MESON 2018, Kraków, Poland, 7-12 June

https://maid.kph.uni-mainz.de

M A I D

Photo- and Electroproduction of Pions, Etas and Kaons on the Nucleon

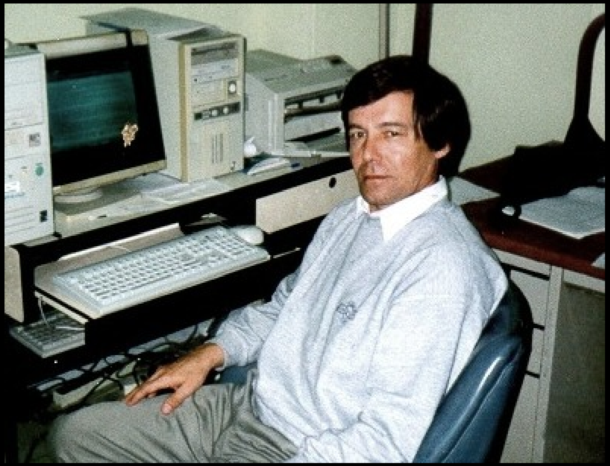
Institut für Kernphysik, Universität Mainz

Mainz, Germany

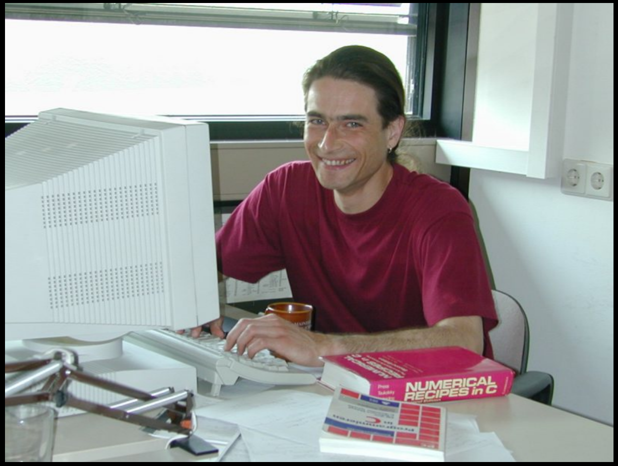
MAID2007	unitary isobar model for (e,e'π)
DMT2001	dynamical model for (e,e'π)
KAON-MAID	isobar model for (e,e'K)
ETA-MAID	isobar model for (e,e'η) reggeized isobar model for (γ,η)
Chiral MAID NEW	chiral perturbation theory approach for (e,e'π)
2-PION-MAID	isobar model for (γ,ππ)
archive	MAID2000 MAID2003 DMT2001original ETAprime2003

MAID went on the web in 1998

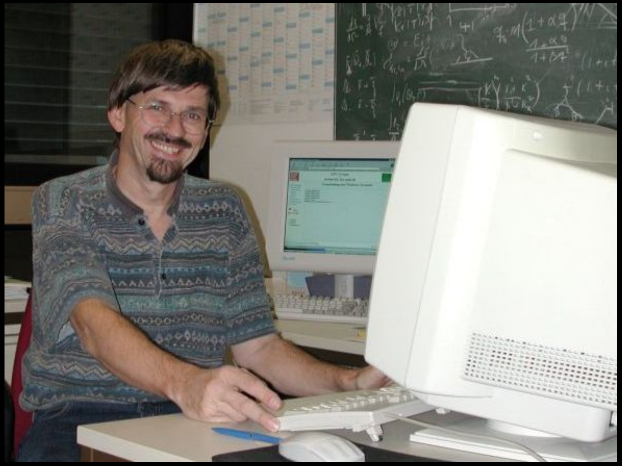
Dieter Drechsel



Sabit Kamalov



Olaf Hanstein



Lothar Tiator

MAID collaboration (1998 – 2018)

Mainz:	Dieter Drechsel, Olaf Hanstein, Marc Vanderhaeghen Stefan Scherer, Marius Hilt (γ,π in χPT)
Dubna:	Sabit Kamalov
GWU:	Cornelius Bennhold (γ,K)
Depok:	Terry Mart (γ,K)
Taipei:	Shin Nan Yang, Wen Tai Chiang (e,e',π ; e,e',η)
Tomsk:	Alexander Fix ($\gamma,\pi\pi$)

most recent MTZ collaboration on γ,η γ,η' and Regge models :

Mainz:	Victor Kashevarov, Michael Ostrick, Misha Gorchteyn, Kirill Nikonov
Tuzla:	Jugoslav Stahov, Hedim Osmanovic, Mirza Hadzimehmedovic, Rifat Omerovic
Zagreb:	Alfred Svarc

MAID has been used for:

- comparison with experimental data
- comparison with theoretical models
- comparison with partial wave analyses
- predictions for new measurements
- proposals for new experiments
- event generators
- input for dispersion relations for Compton and virtual Compton scattering
- input for nucleon polarizabilities
- input for Finite Energy Sum Rules
- input for GDH and related Sum Rules
- and more

up to now:

MAID web pages have been called more than 7.7 Million times

first EtaMAID isobar model for photo- and electroproduction

MAID 2000

Institut für Kernphysik, Universität Mainz, Germany

MAID update info

An Isobar Model for Eta Photo- and Electroproduction on the Nucleon

Wen-Tai Chiang (National Taiwan University), C. Bennhold (George Washington University) and L. Tiator

References:

W.-T. Chiang, S.-N. Yang, L. Tiator, D. Drechsel, Nucl. Phys. A 700 (2002) 429-453 nucl-th/0110034

G. Knöchlein, D. Drechsel and L. Tiator, Z. Phys. A 352 (1995) 327-343 nucl-th/9506029

- **Electromagnetic Multipoles** ($E_{l\pm}$, $M_{l\pm}$, $L_{l\pm}$, $S_{l\pm}$)
- **CGLN and Helicity Amplitudes** ($F_1,...,F_6$, $H_1,...,H_6$)
- **Polarized Response Functions** ($R_T, R_L, R_{LT}, R_{TT}, R_{LT'}, R_{TT'}$)
- **Unpolarized 2-fold Diff. Cross Sections** (L,T,L,T,TT,LT')
- **5-fold Diff. Cross Section**
- **Total Cross Sections** (T,L,LT,LT',TT')
- **Transverse Polarization Observables** ($d\sigma/d\Omega, T, \Sigma, P, E, F, ...$)
- **Target Polarization** (P_x, P_y, P_z)
- **Recoil Polarization** (P_x, P_y, P_z)

short history of EtaMAID

2000: isobar model with 7 N* resonances and t-channel ρ,ω pole contributions

2003: isobar model with 7 N* resonances and t-channel ρ,ω Regge trajectories

2007: search for narrow pentaquark state N(1685) in $\gamma n \to \eta n$

after 2007 a lot of new measurements were performed at:

MAMI, ELSA, JLAB

with high statistics and beam-target polarization techniques

2017/2018: EtaMAID update of 4 coupled channels: ηp, ηn, $\eta' p$, $\eta' n$

with up to 20 N* resonances and Regge phenomenology

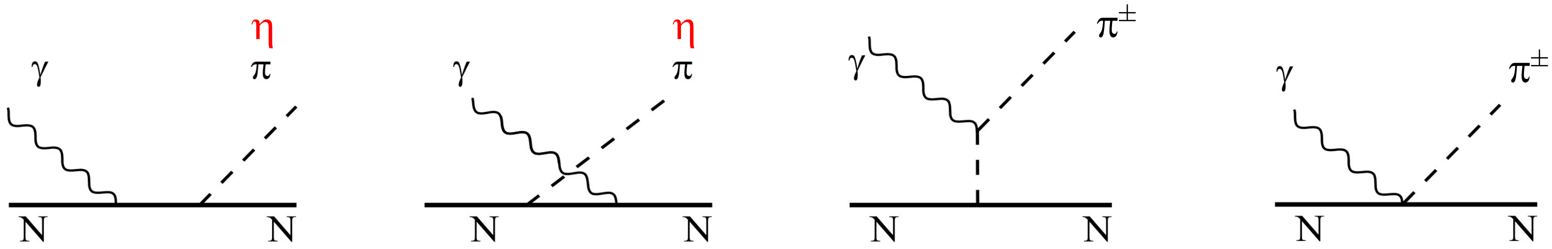
photoproduction amplitudes in an isobar model

$$t_\alpha(W) = t_\alpha^{Bgr}(W) + t_\alpha^{Res}(W)$$

$\alpha = \alpha(\, L,\ J,\ I,\ E/M\,)$: set of partial wave quantum numbers

t_α^{Bgr} : Born $+\, t$-channel vector and axial-vector exchanges

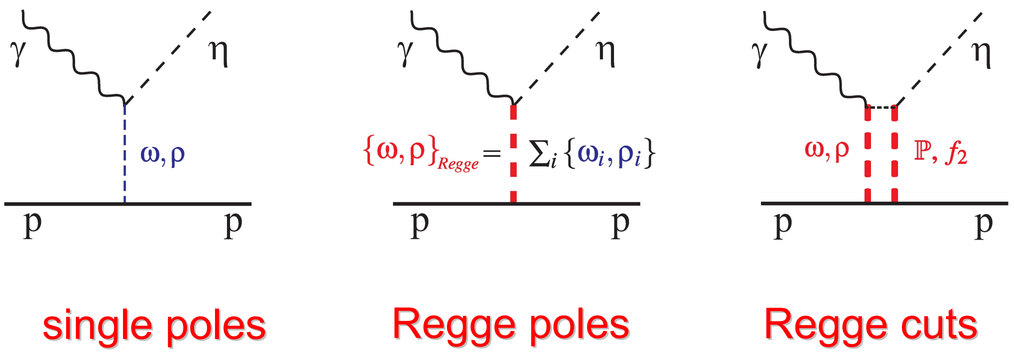
Born terms



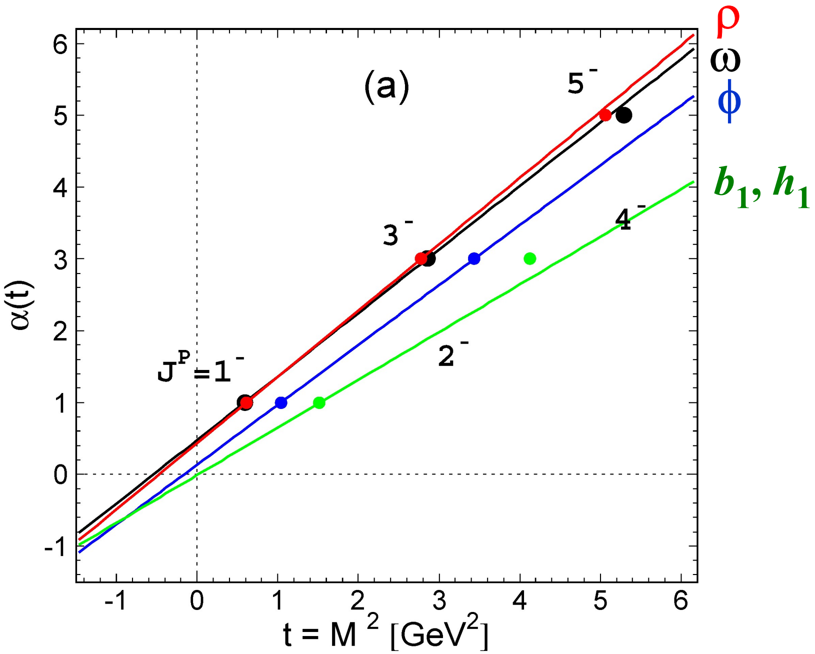
Born terms play a very different role in pseudoscalar photoproduction:

- very important for γ,π with well-known coupling constant ≈ 14
- small for γ,η and γ,η‘ with coupling constants < 0.1
- important for γ,K with practically unknown coupling constants

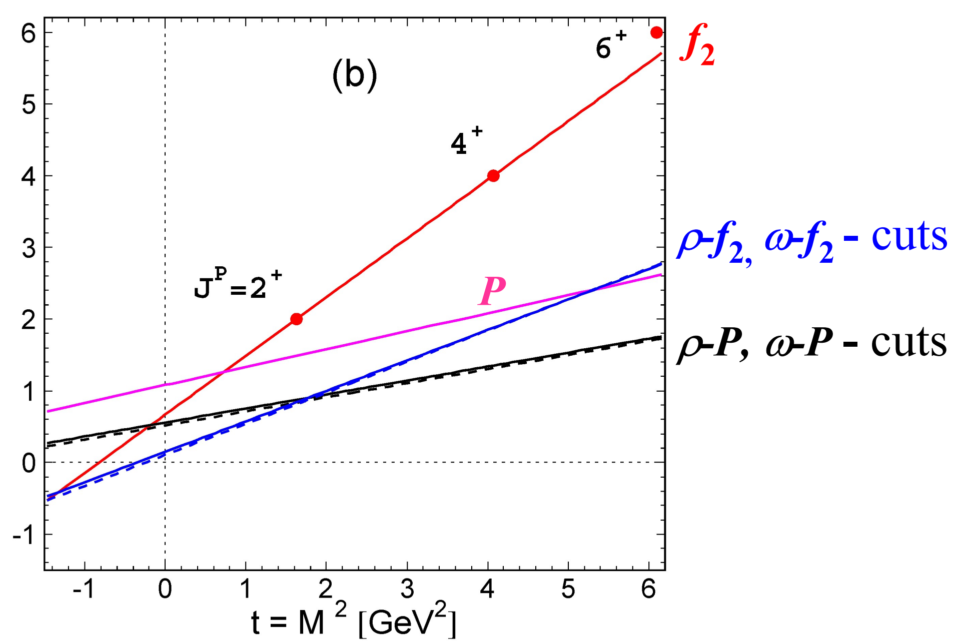
t-channel exchanges (single poles, Regge poles and Regge cuts)



Regge trajectories for: ω, ρ, ϕ, b_1, h_1



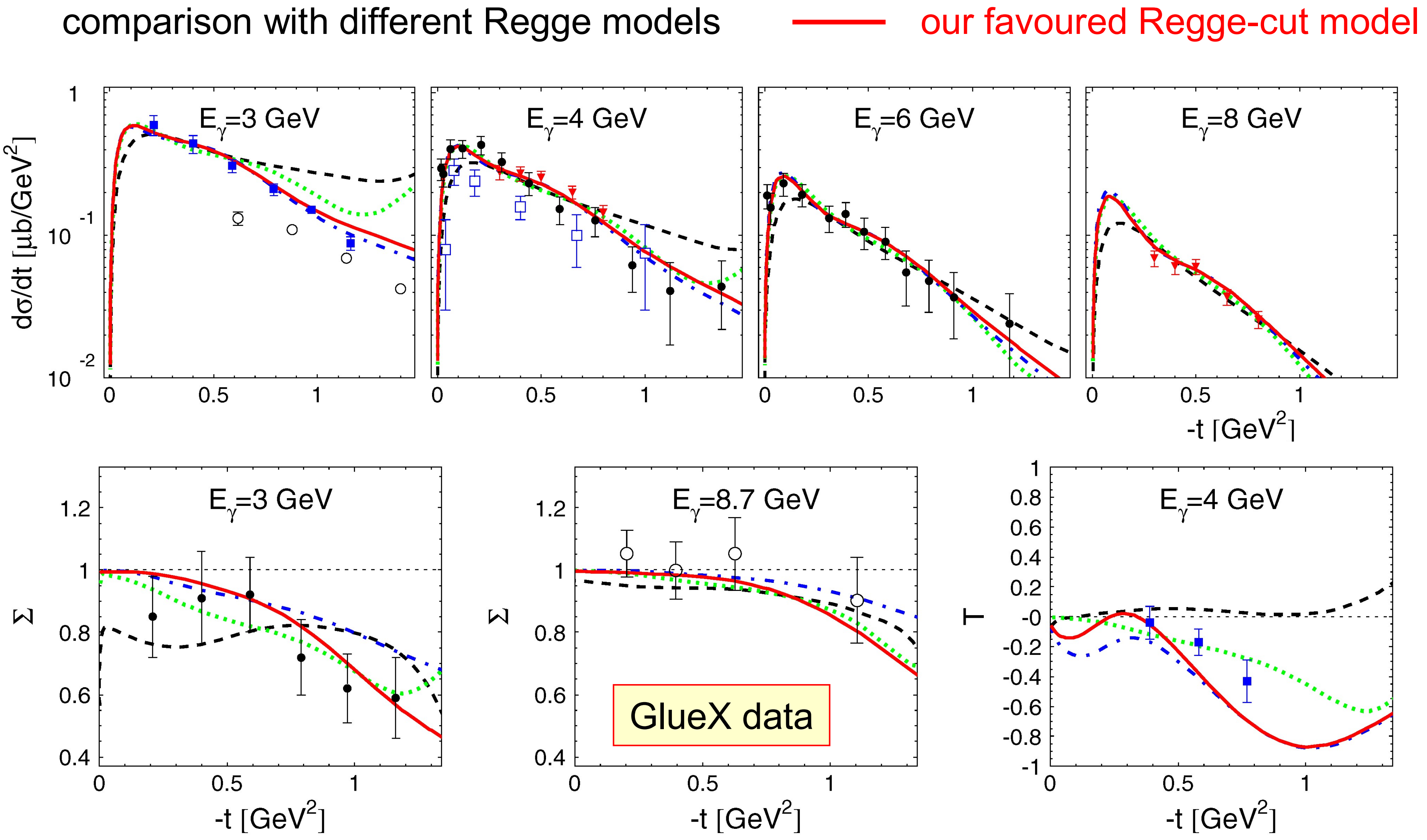
Regge trajectories for: f_2, P and cuts



diff cross sections and beam asymmetry for γ,η at high energy

V. Kashevarov, M. Ostrick, L. Tiator , Phys. Rev. C**96** (2017) 045207

comparison with different Regge models — our favoured Regge-cut model



photoproduction amplitudes

$$t_\alpha(W) = t_\alpha^{Bgr}(W) + t_\alpha^{Res}(W)$$

t_α^{Bgr} : Born + t-channel vector and axial-vector exchanges

t_α^{Res} : $\sum_{i=1}^{n}\{\text{Breit-Wigner resonances } N, \Delta\}$

MAID2007 (γ,π) : 2 S_{11}, for all other channels only 1 resonance N and Δ

EtaMAID2018 (γ,η) : 4 P_{11}, 3 S_{11}, 4 D_{13}, … only N no Δ

problems:

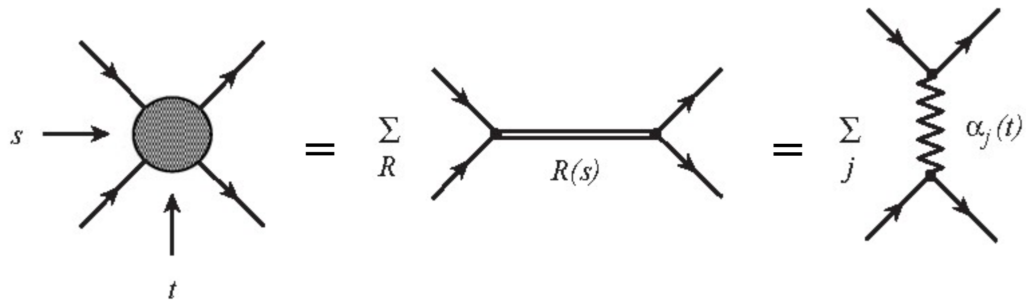
- unitarity (Watson‘s theorem, coupled channels !)
- fixed-t analyticity (dispersion relations !)
- duality (problematic with Regge models !)

quark–hadron duality

from quark-hadron duality it is known:

sum over all s-channel resonances is equivalent to sum over all t-channel resonances

therefore: keeping both leads to double counting



$$M = \sum_{i=1}^{\infty} M_s^{Res_i} = \sum_{i=1}^{\infty} M_t^{Res_i} = \sum_{i=1}^{N} M_s^{Res_i} + \left[\sum_{i=1}^{\infty} M_t^{Res_i} - \sum_{i=1}^{N} M_s^{Res_i} \right]$$

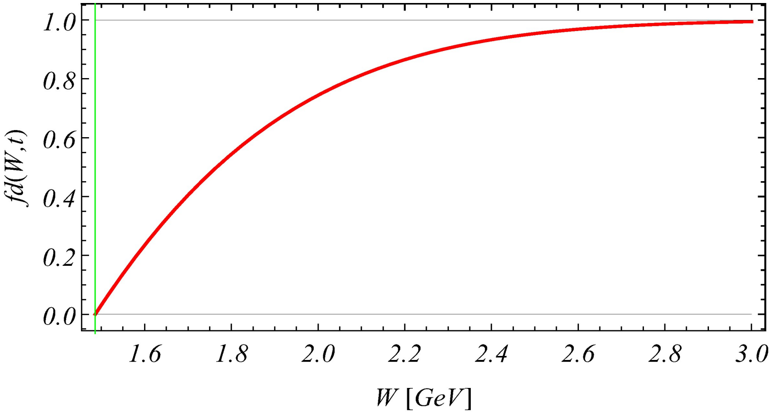
$$\approx \sum_{i=1}^{N} M_s^{Res_i} + M^{Regge} \cdot F_d(W)$$

: our approach

modelling the background

- Born
- Born + *t*-channel poles
- Born + Regge (RPR models)
- Born + Regge – *s, p, d, f* partial waves
- Born + Regge ∗ damping factor $f_d(\mathrm{W})$: our approach

$$f_d(W) = 1 - e^{-\frac{W - W_{thr}}{\Lambda}}$$



alternative approach: Finite Energy Sum Rules

the Unitary Isobar Model MAID for pion production

$$t^{\alpha}_{\gamma,\pi} = v^{\alpha}_{\gamma,\pi}(Born + \omega, \rho)\ (1 + i\, t^{\alpha}_{\pi,\pi})$$

K-matrix unitarization of background

$$+\ t^{\alpha}_{\gamma,\pi}(Resonances)\ e^{i\Phi(W)}$$

unitarization phase
determined by the Watson theorem, below 2π threshold
relaxed above 2π threshold

unitarity aspects

for eta production we don't have such a powerful constraint,
in previous versions EtaMAID 2000-2017 we simply ignored this phase
in the new EtaMAID2018 version we use this phase as a free parameter

$$t^{\alpha}_{\gamma,\eta}(W) = t^{\alpha,Born}_{\gamma,\eta}(W) + t^{\alpha,VM(Regge)}_{\gamma,\eta}(W) \cdot F_d(W)$$

$$+ \sum_{j=1}^{N_\alpha} t^{\alpha,BW,j}_{\gamma,\eta}(W) \cdot e^{i\Phi_j}$$

phenomenological phase
taken as a free parameter

Status of N* Resonances in Particle Data Tables 2018

M. Tanabashi et al. (Particle Data Group) Phys. Rev. D98, 030001 (2018)

	Particle	J^P	overall	$N\gamma$	$N\pi$	$\Delta\pi$	$N\sigma$	$N\eta$	ΛK	ΣK	$N\rho$	$N\omega$	$N\eta\prime$
	N	$1/2^+$	****										
	$N(1440)$	$1/2^+$	****	****	****	****	***						
	$N(1520)$	$3/2^-$	****	****	****	****	**	****					
	$N(1535)$	$1/2^-$	****	****	****	***	*	****					
	$N(1650)$	$1/2^-$	****	****	****	***	*	****	*				
	$N(1675)$	$5/2^-$	****	****	****	***	***	*	*	*			
	$N(1680)$	$5/2^+$	****	****	****	****	***	*					
	$N(1700)$	$3/2^-$	***	**	***	***	*	*			*		
	$N(1710)$	$1/2^+$	****	****	****	*		***	**	*	*	*	
	$N(1720)$	$3/2^+$	****	****	****	***	*	*	****	*	*	*	
	$N(1860)$	$5/2^+$	**	*	**		*	*					
	$N(1875)$	$3/2^-$	***	**	**	*	**	*	*	*	*	*	
upgraded	$N(1880)$	$1/2^+$	***	**	*	**	*	*	**	**		**	
upgraded	$N(1895)$	$1/2^-$	****	****	*	*	*	****	**	**	*	*	****
upgraded	$N(1900)$	$3/2^+$	****	****	**	**	*	*	**	**		*	**
	$N(1990)$	$7/2^+$	**	**	**	*	*	*	*	*			
	$N(2000)$	$5/2^+$	**	**	*	**	*	*				*	
	$N(2040)$	$3/2^+$	*		*								
upgraded	$N(2060)$	$5/2^-$	***	***	**	*	*	*	*	*	*	*	
upgraded	$N(2100)$	$1/2^+$	***	**	***	**	**	*	*		*	*	**
upgraded	$N(2120)$	$3/2^-$	***	***	***	**	**		**	*		*	*
	$N(2190)$	$7/2^-$	****	****	****	****	**	*	**	*	*	*	

new N* Resonances in EtaMAID2018 updates

7 N* in 2001/2003

21 N* in 2018 for γ,η

12 N* in 2018 for γ,η‘

Particle	J^P	overall	$N\gamma$	$N\pi$	$\Delta\pi$	$N\sigma$	$N\eta$	ΛK	ΣK	$N\rho$	$N\omega$	$N\eta'$	
N	$1/2^+$	****											
$N(1440)$	$1/2^+$	****	****	****	****	***							
$N(1520)$	$3/2^-$	****	****	****	****	**	****						
$N(1535)$	$1/2^-$	****	****	****	***	*	****						
$N(1650)$	$1/2^-$	****	****	****	***	*	****	*					
$N(1675)$	$5/2^-$	****	****	****	***	***	*	*	*				
$N(1680)$	$5/2^+$	****	****	****	****	***	*						
$N(1700)$	$3/2^-$	***	**	***	***	*	*			*			
$N(1710)$	$1/2^+$	****	****	****	*		***	**	*	*	*		
$N(1720)$	$3/2^+$	****	****	****	***	*	*	****	*	*	*		
$N(1860)$	$5/2^+$	**	*	**		*	*						
$N(1875)$	$3/2^-$	***	**	**	*	**	*	*	*	*	*		
$N(1880)$	$1/2^+$	***	**	*	**	*	*	**	**		**		
$N(1895)$	$1/2^-$	****	****	*	*	*	****	**	**	*	*	****	upgraded in 2018
$N(1900)$	$3/2^+$	****	****	**	**	*	*	**	**		*	**	
$N(1990)$	$7/2^+$	**	**	**	*	*	*	*	*				
$N(2000)$	$5/2^+$	**	**	*	**	*	*				*		
$N(2040)$	$3/2^+$	*		*									
$N(2060)$	$5/2^-$	***	***	**	*	*	*	*	*	*	*		
$N(2100)$	$1/2^+$	***	**	***	**	**	*	*		*	*	**	
$N(2120)$	$3/2^-$	***	***	***	**	**		**	*		*	*	
$N(2190)$	$7/2^-$	****	****	****	****	**	*	**	*	*	*		
$N(2220)$	$9/2^+$	****	**	****			*	*	*				
$N(2250)$	$9/2^-$	****	**	****			*	*	*				

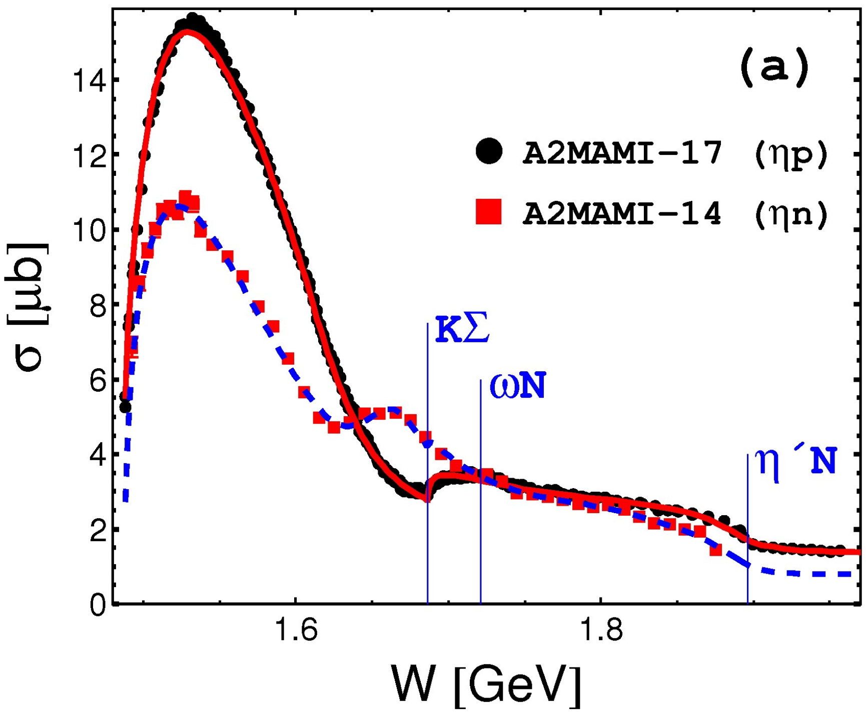
χ^2 results for individual data sets of 4 channels

total number of data points: 10,700 - our overall χ^2/data in the fit is 2.46

		Observable	Reaction	used	W [MeV]	N	χ^2	χ^2/N	Reference
η p	5 observables	σ_0	$p(\gamma,\eta)p$	—	1488 – 1870	2880	9502	3.3	A2MAMI-17 (Run I)
		σ_0	$p(\gamma,\eta)p$	√	1488 – 1891	2712	4437	1.6	A2MAMI-17 (Run II)
		σ_0	$p(\gamma,\eta)p$	√	1888 – 1957	288	329	1.1	A2MAMI-17 (Run III)
		σ_0	$p(\gamma,\eta)p$	√	1965 – 2795	634	2276	3.6	CLAS-09
		σ_0	$p(\gamma,\eta)p$	—	1588 – 2370	680	8640	13.	CBELSA/TAPS-09
		Σ	$p(\gamma,\eta)p$	√	1496 – 1908	150	394	2.6	GRAAL-07
		Σ	$p(\gamma,\eta)p$	√	1700 – 2080	214	617	2.9	CLAS-17
		T	$p(\gamma,\eta)p$	√	1497 – 1848	144	246	1.7	A2MAMI-14
		F	$p(\gamma,\eta)p$	√	1497 – 1848	144	246	1.7	A2MAMI-14
		E	$p(\gamma,\eta)p$	√	1525 – 2125	73	155	2.1	CLAS-16
		E	$p(\gamma,\eta)p$	√	1505 – 1882	135	255	1.9	A2MAMI-17
η n	3 obs	σ_0	$n(\gamma,\eta)n$	√	1492 – 1875	880	3079	3.5	A2MAMI-14
		σ_0	$n(\gamma,\eta)n$	—	1505 – 2181	322	2986	9.3	CBELSA/TAPS-11
		Σ	$n(\gamma,\eta)n$	√	1504 – 1892	99	177	1.8	GRAAL-08
		E	$n(\gamma,\eta)n$	√	1505 – 1882	135	209	1.5	A2MAMI-17
η‘ p	2 obs	σ_0	$p(\gamma,\eta')p$	√	1898 – 1956	120	198	1.7	A2MAMI-17
		σ_0	$p(\gamma,\eta')p$	√	1925 – 2795	681	2013	3.0	CLAS-09
		σ_0	$p(\gamma,\eta')p$	—	1934 – 2351	200	278	1.4	CBELSA/TAPS-09
		Σ	$p(\gamma,\eta')p$	√	1903 – 1913	14	35	2.5	GRAAL-15
		Σ	$p(\gamma,\eta')p$	√	1904 – 2080	62	85	1.4	CLAS-17
η‘ n	1	σ_0	$n(\gamma,\eta')n$	√	1936 – 2342	170	191	1.1	CBELSA/TAPS-11

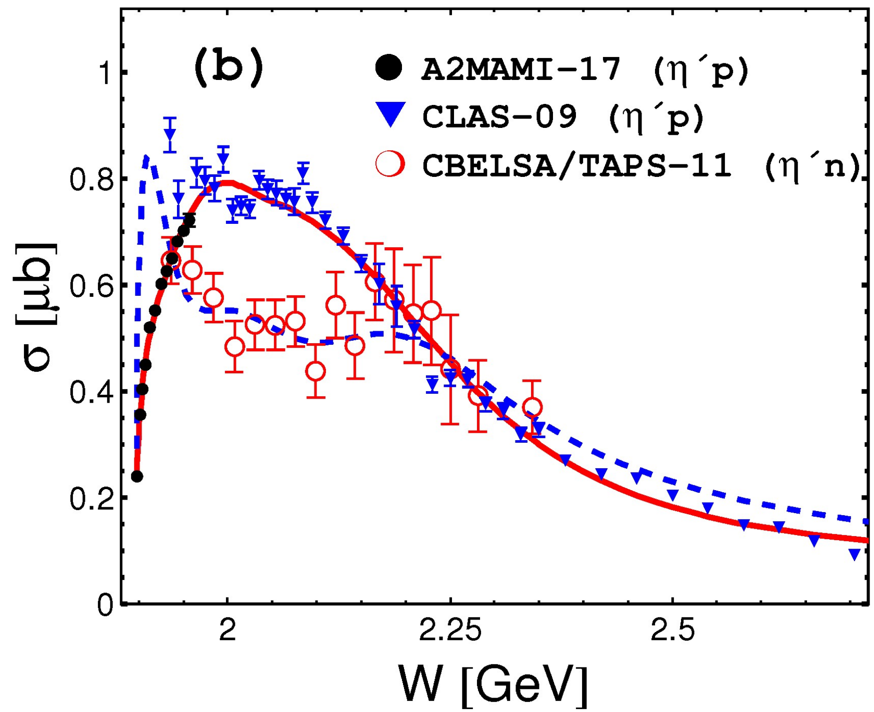
total cross sections

γ,η on **proton** and **neutron**



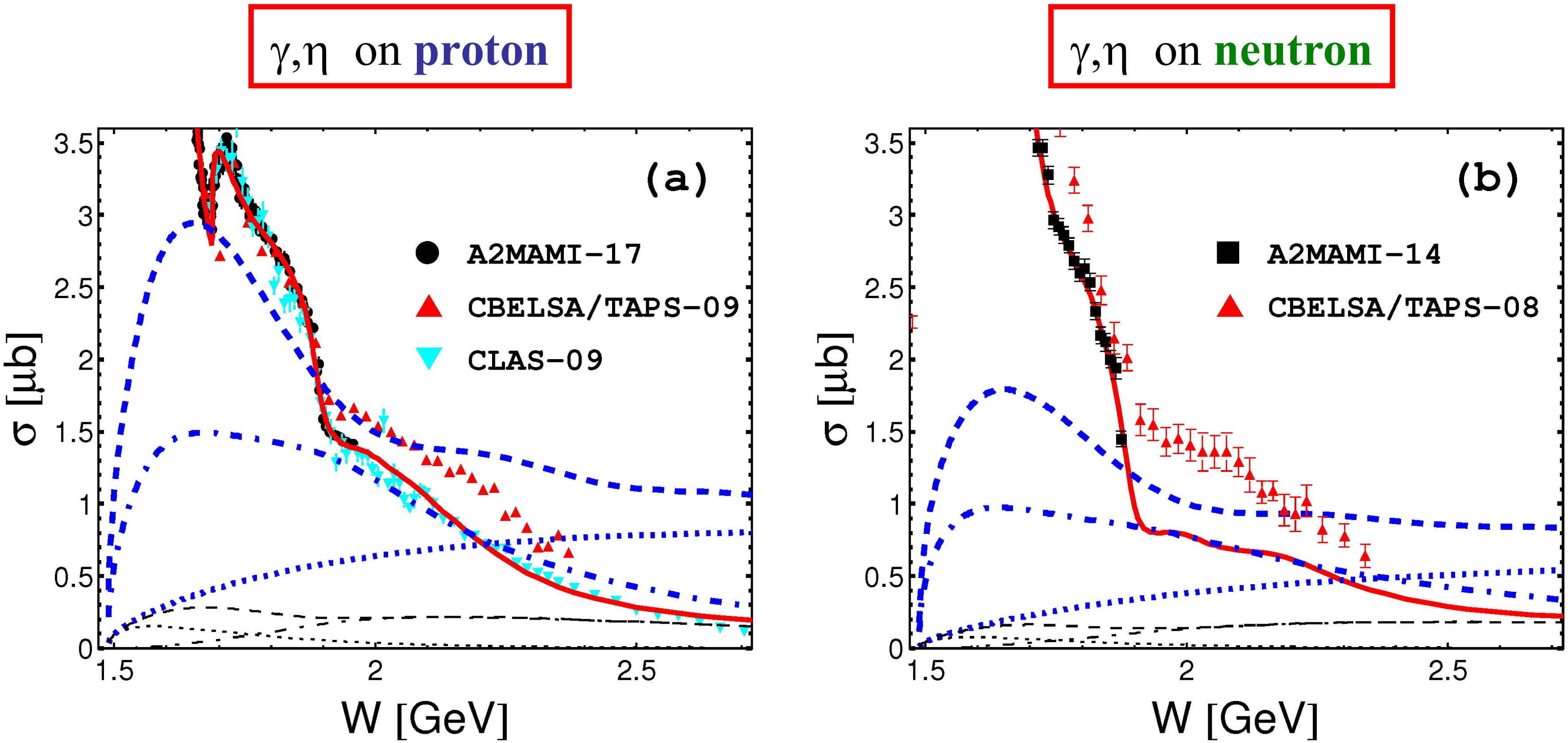
MAMI data have very high statistics and syst. errors are well under control

γ,η' on **proton** and **neutron**



MAMI energy stops at E = 1.6 GeV
W_{max} = 1.957 GeV

total cross sections for η : bg contributions: Born + Regge

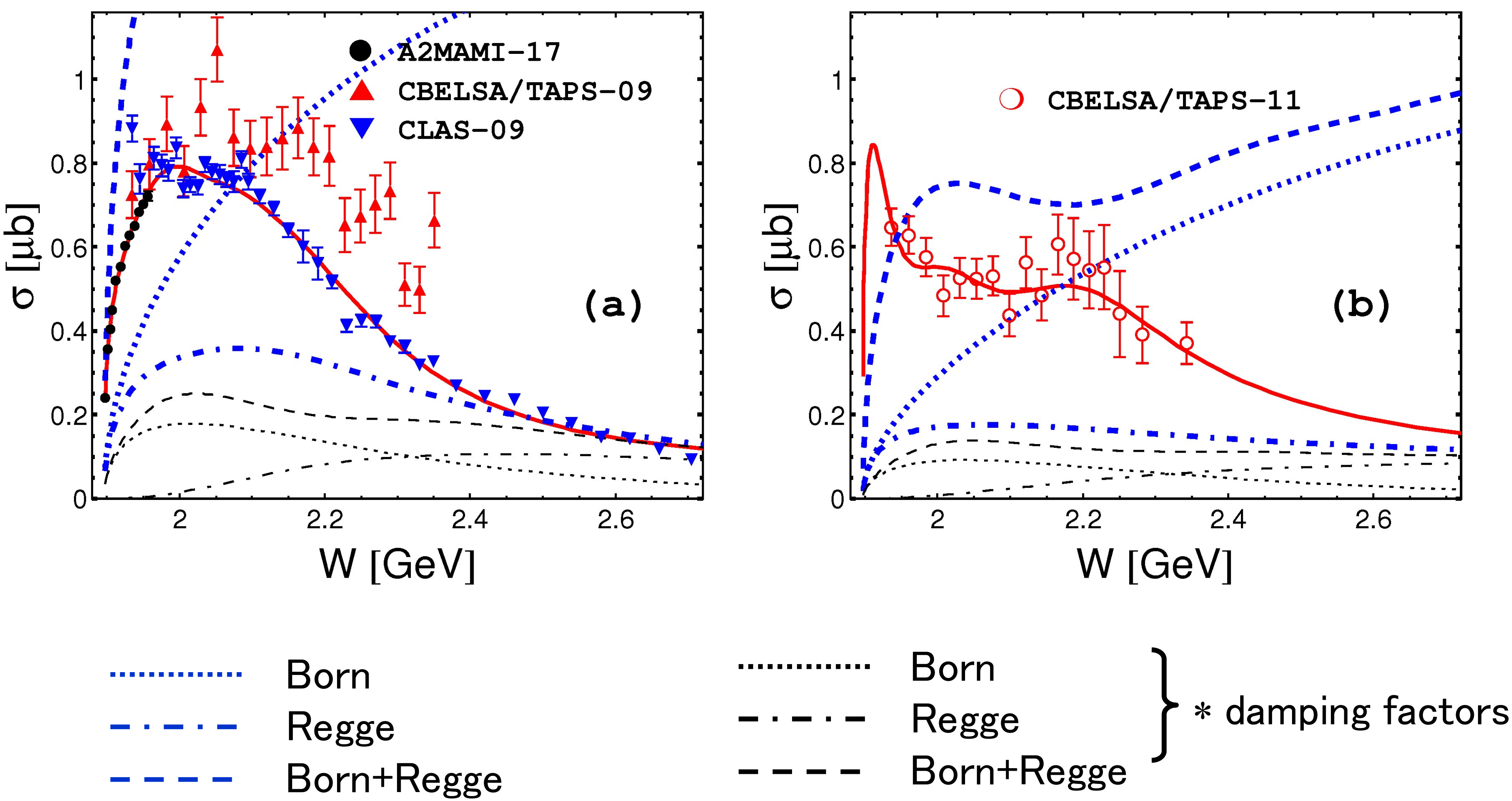


blue dotted	Born
blue dash-dot	Regge
blue dashed	Born+Regge
black dotted	Born
black dash-dot	Regge
black dashed	Born+Regge

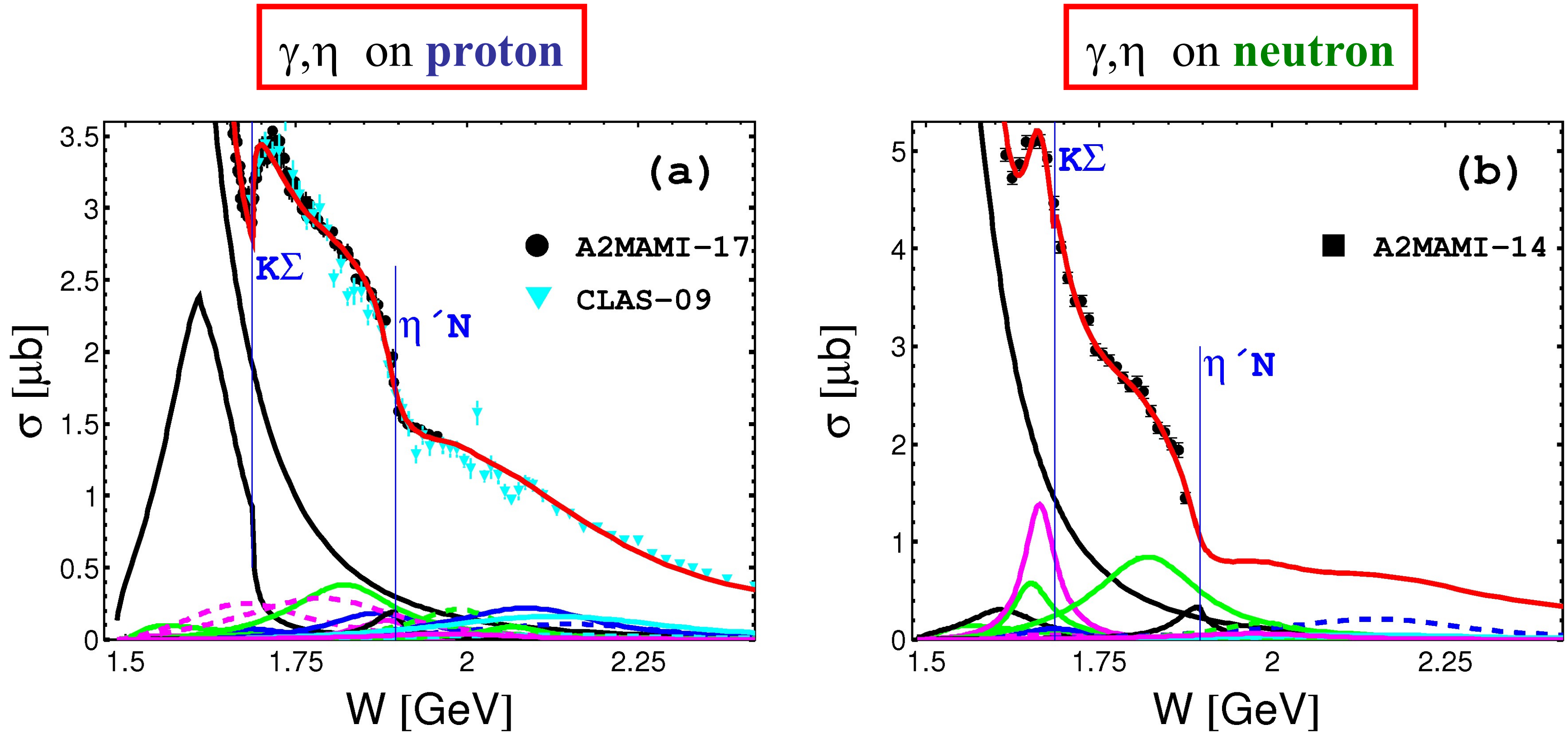
The three black curves (Born, Regge, Born+Regge) carry the note: * damping factors

total cross sections for η‘ : bg contributions: Born + Regge

γ,η‘ on **proton** | γ,η‘ on **neutron**



total cross sections for η : Resonances and Cusps



below 1.7 GeV completely dominated by $S_{11}(1535)$

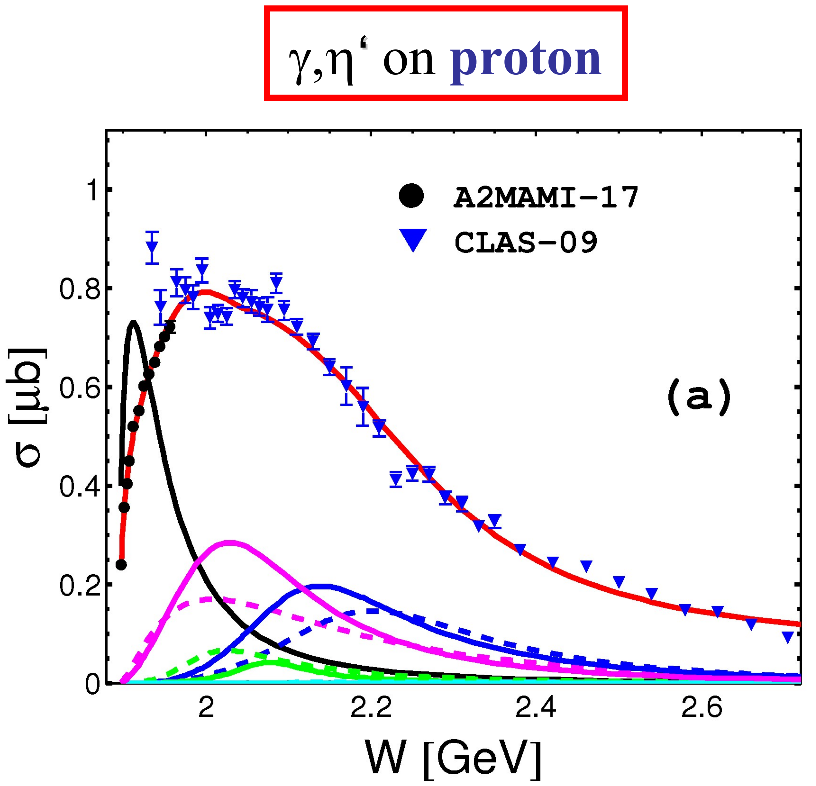
<u>very pronounced cusp effects:</u>

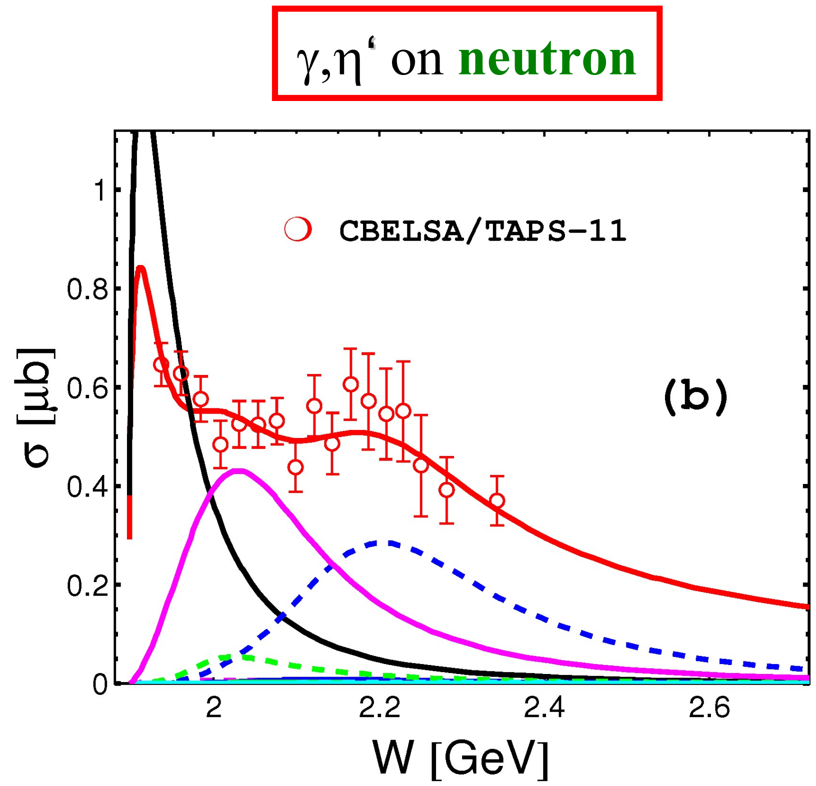
$S_{11}(1535)$ produces a cusp effect in (γ,π) at η threshold (not shown here)

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

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

total cross sections for η' : Resonances and Cusps



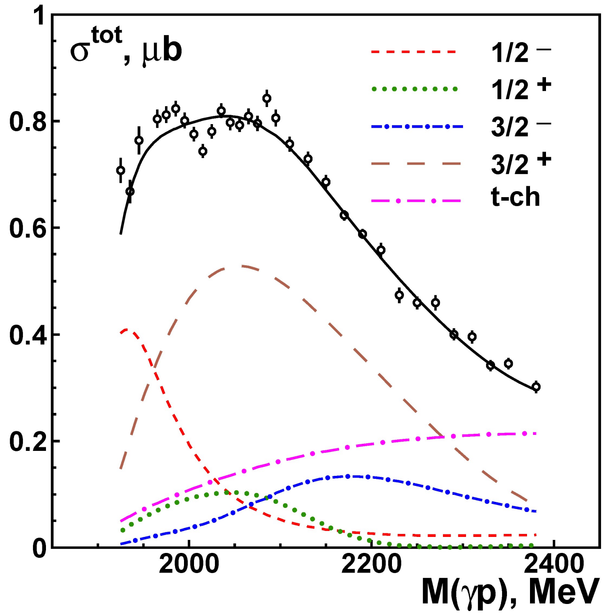


dominant resonance contributions found in η' with EtMAID2018

- **N(1895)**$1/2^-$ **S_{11}** : M_{BW} = 1894.4 MeV (1.6 MeV below η' thresh)
- **N(2100)**$1/2^+$ **P_{11}** : M_{BW} = 2010 MeV
- **N(1900)**$3/2^+$ **P_{13}** : M_{BW} = 1899 MeV
- **N(2000)**$5/2^+$ **F_{15}** : M_{BW} = 2117 MeV
- **N(1990)**$7/2^+$ **F_{17}** : M_{BW} = 2227 MeV

from Andrey Sarantev ‘s talk on Friday :

The analysis of the $\gamma p \to \eta' p$ data.



very different resonance contributions!
(for γ,η we are much more similar)

the reason for that is:

large ambiguity in PWA solutions
due to very incomplete experiments
in etaprime production

only 2 observables: **dσ/dΩ** and **Σ**
have been measured

Strong contribution from the $S_{11}(1895)$, $P_{13}(1900)$, $P_{11}(2100)$ and $D_{13}(2120)$ states.

with EtaMAID2018 we find strongest contributions for $S_{11}(1895)$, $P_{11}(2100)$ and $F_{15}(2000)$

other PWA groups analyzing new (γ,η) data

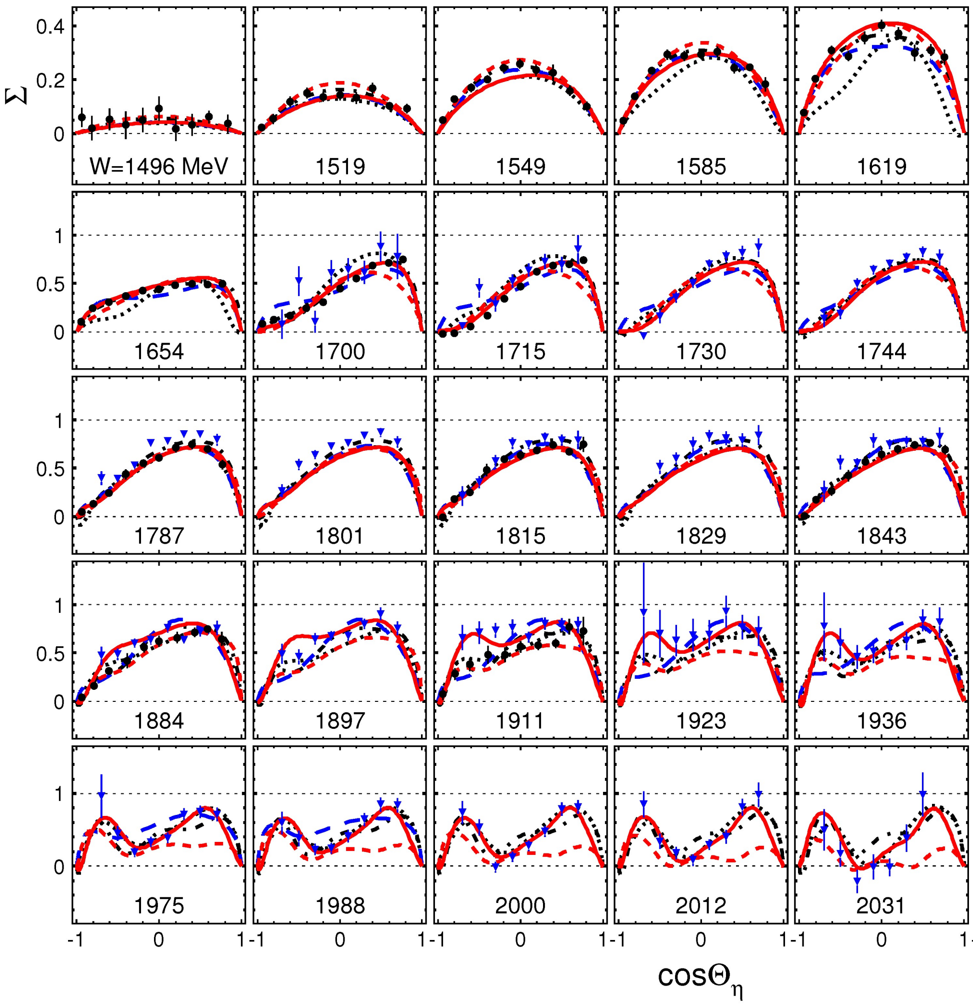
BNGA: Bonn-Gatchina group:
A.V. Anisovich, E. Klempt, V.A. Nikonov, A.V. Sarantsev and U. Thoma
multi-channel K-matrix model and N/D dispersion approach

JÜBO: Jülich-Bonn group:
D. Rönchen, M. Döring, H. Haberzettl, J. Haidenbauer, U.-G. Meißner and K. Nakayama
covariant multi-channel dynamical model

KSU: Kent-State University group:
B.C. Hunt and D.M. Manley
multi-channel K-matrix model

comparison with other PWA for $p(\gamma,\eta)p$

beam asymmetry Σ, GRAAL and CLAS data



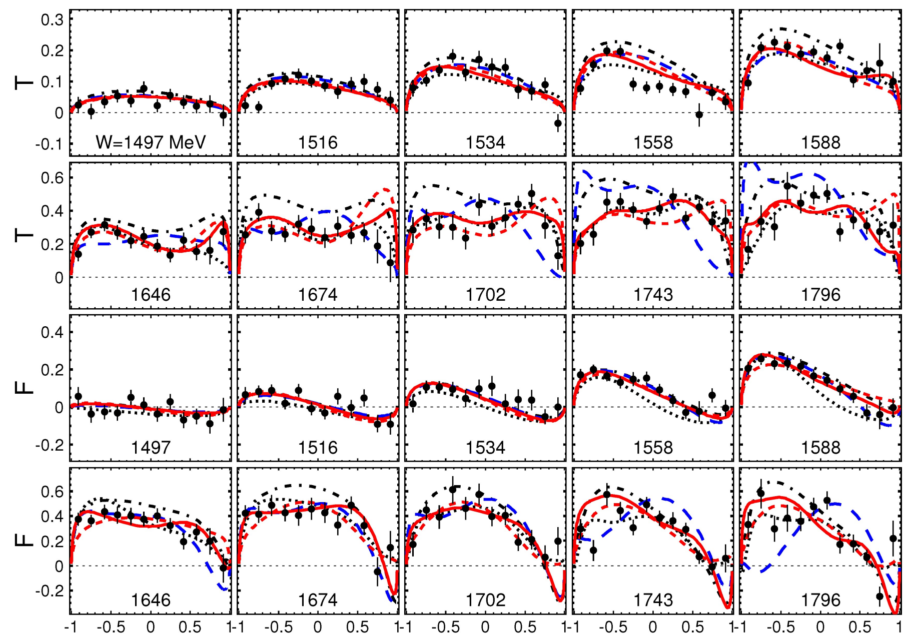
EtaMAID2018

BnGa 2018

KSU 2018

JüBo 2018

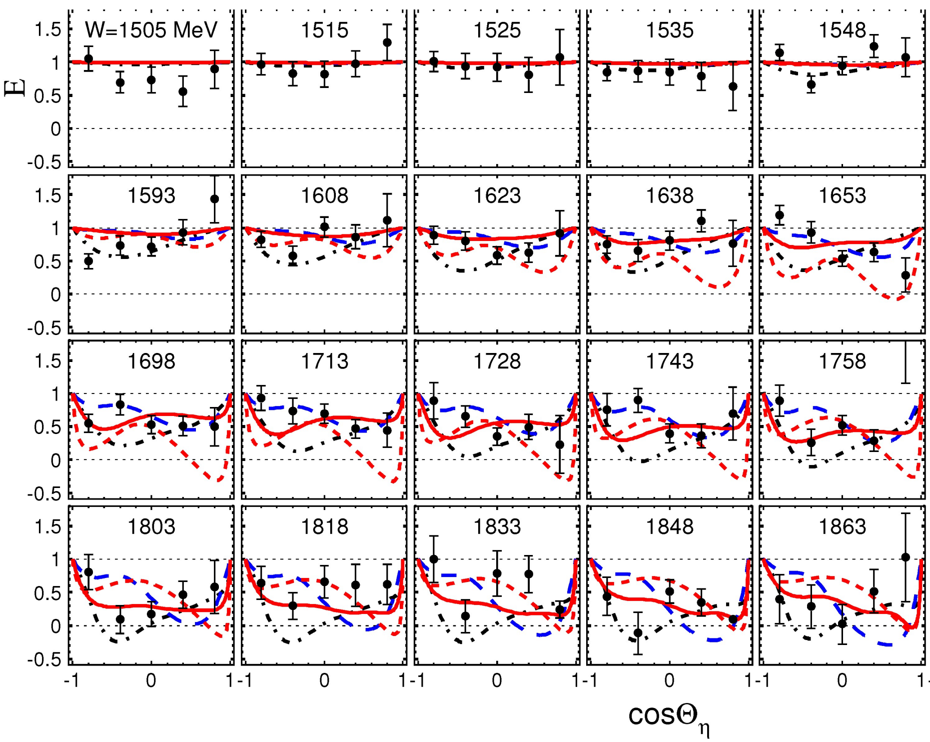
T and F asymmetries, MAMI data



EtaMAID2015 (with single t-channel poles)

comparison with other PWA for $n(\gamma,\eta)n$

E asymmetry, MAMI data

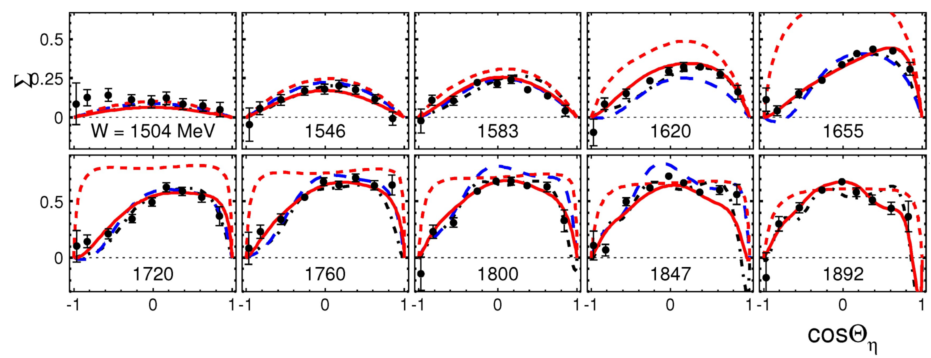


EtaMAID2018

BnGa 2018

KSU 2018

beam asymmetry Σ, GRAAL data



EtaMAID2015 (with single t-channel poles)

comparison of partial waves after phase rotation for p(γ,η)p

comparison of S and P waves

between new (2018) PWA

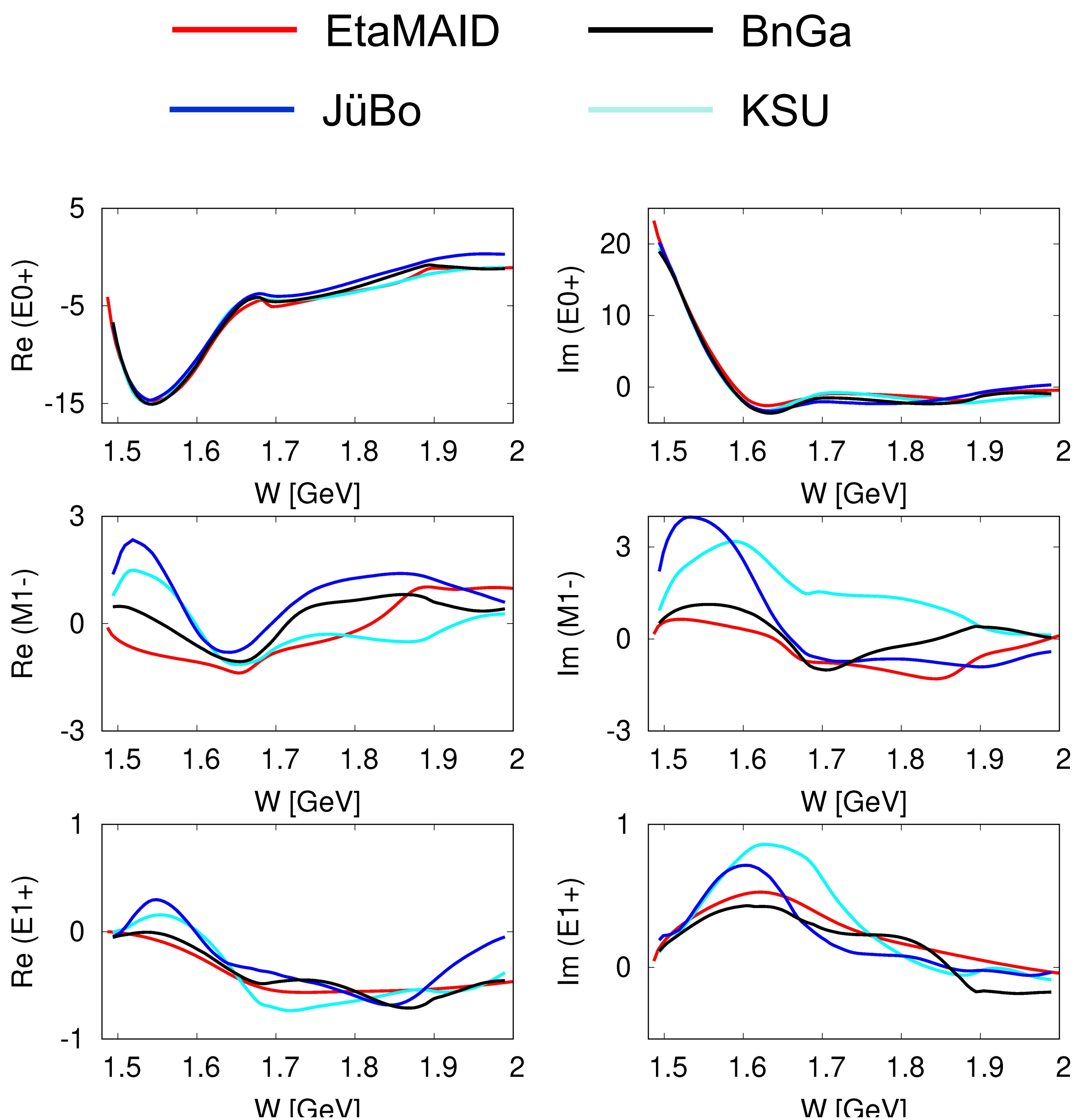
from:

our MAID solution

Bonn-Gatchina

Jülich-Bonn

Kent-State



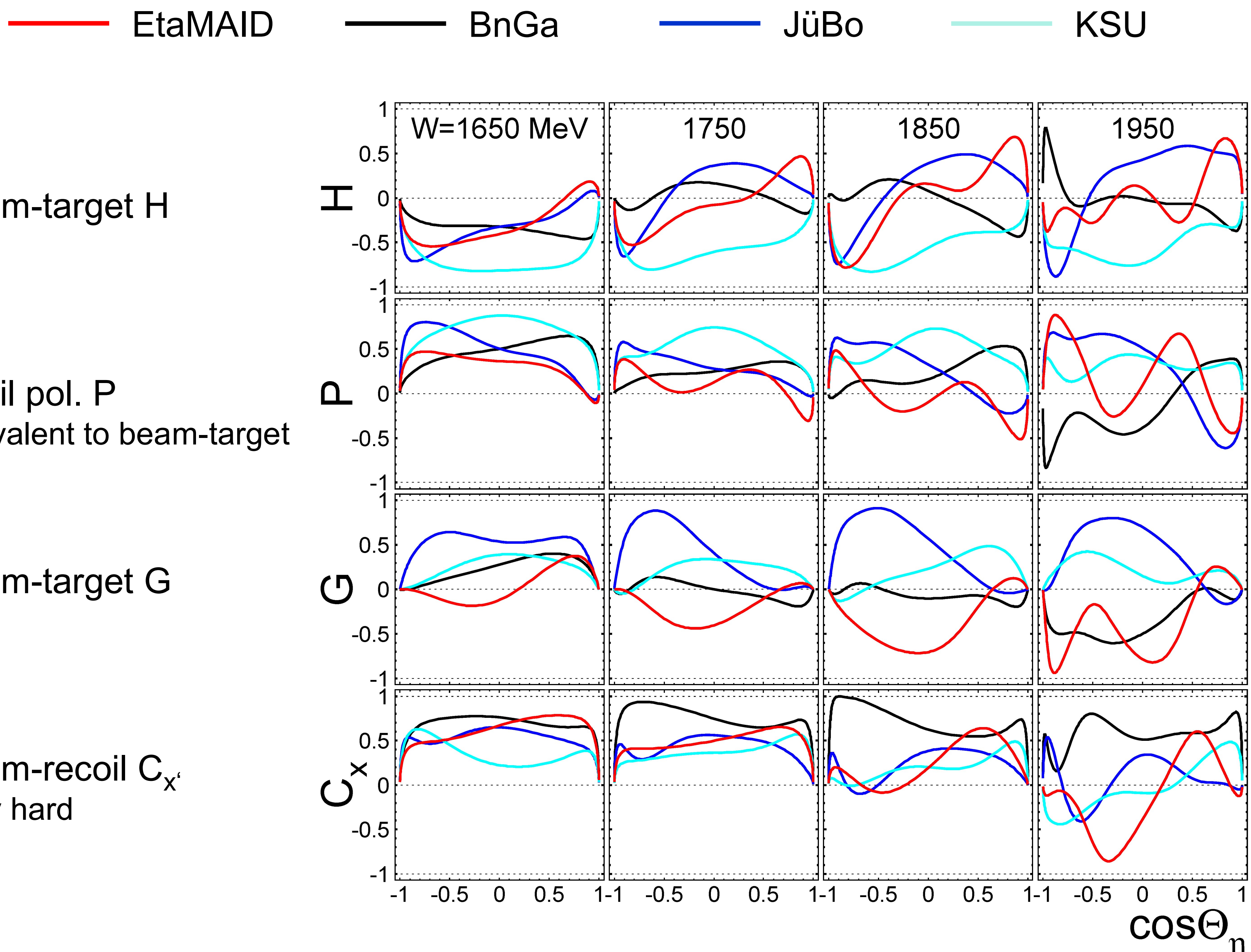
S waves are almost identical

some higher pw are close

other pw differ a lot,

due to incomplete experiments!

predictions for unmeasured polarization observables p(γ,η)p



beam-target H

recoil pol. P
equivalent to beam-target

beam-target G

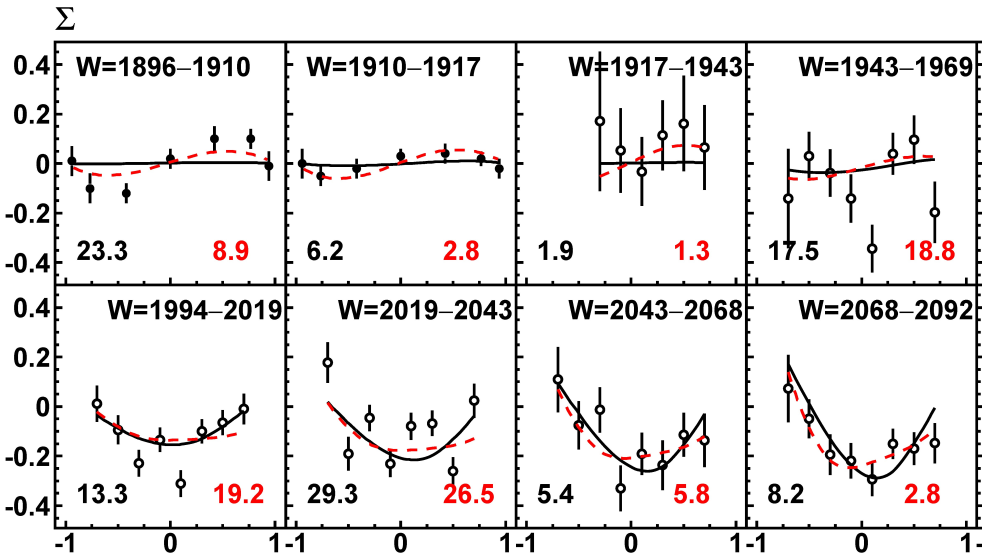
beam-recoil $C_{x'}$
very hard

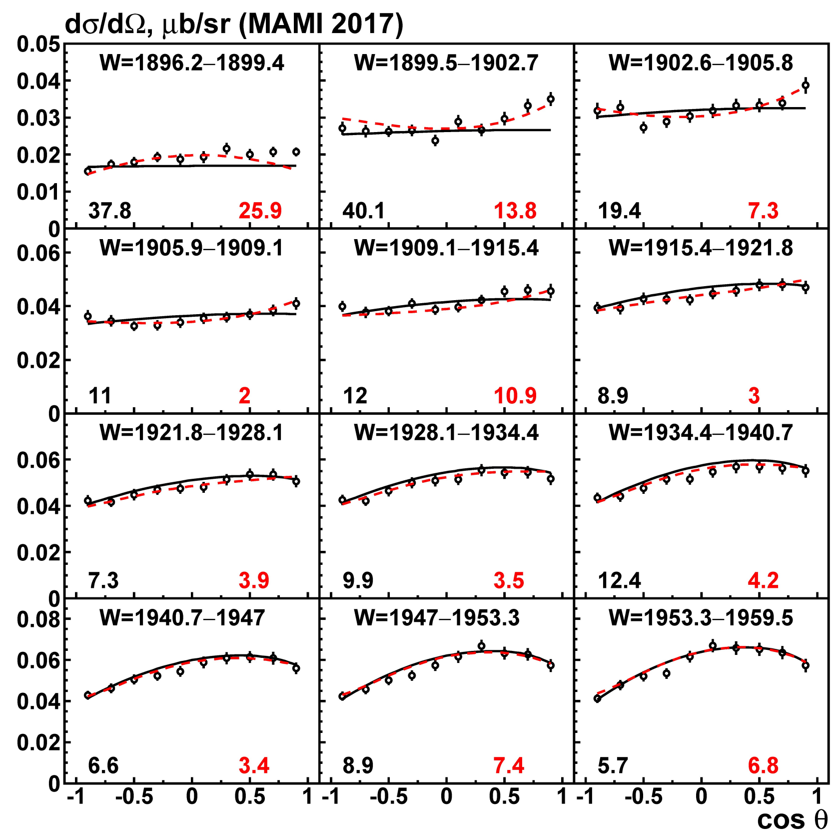
a narrow resonance in etaprime photoproduction?

Anisovich, Burkert, Dugger, Klempt, Nikonov, Ritchie, Sarantsev, Thoma, arXiv:1803.06814

——— BnGa2018 solution, std. without narrow resonance

- - - - - - - BnGa2018 solution with a narrow D_{13} : M_R = 1900 ± 1 MeV, Γ < 3 MeV

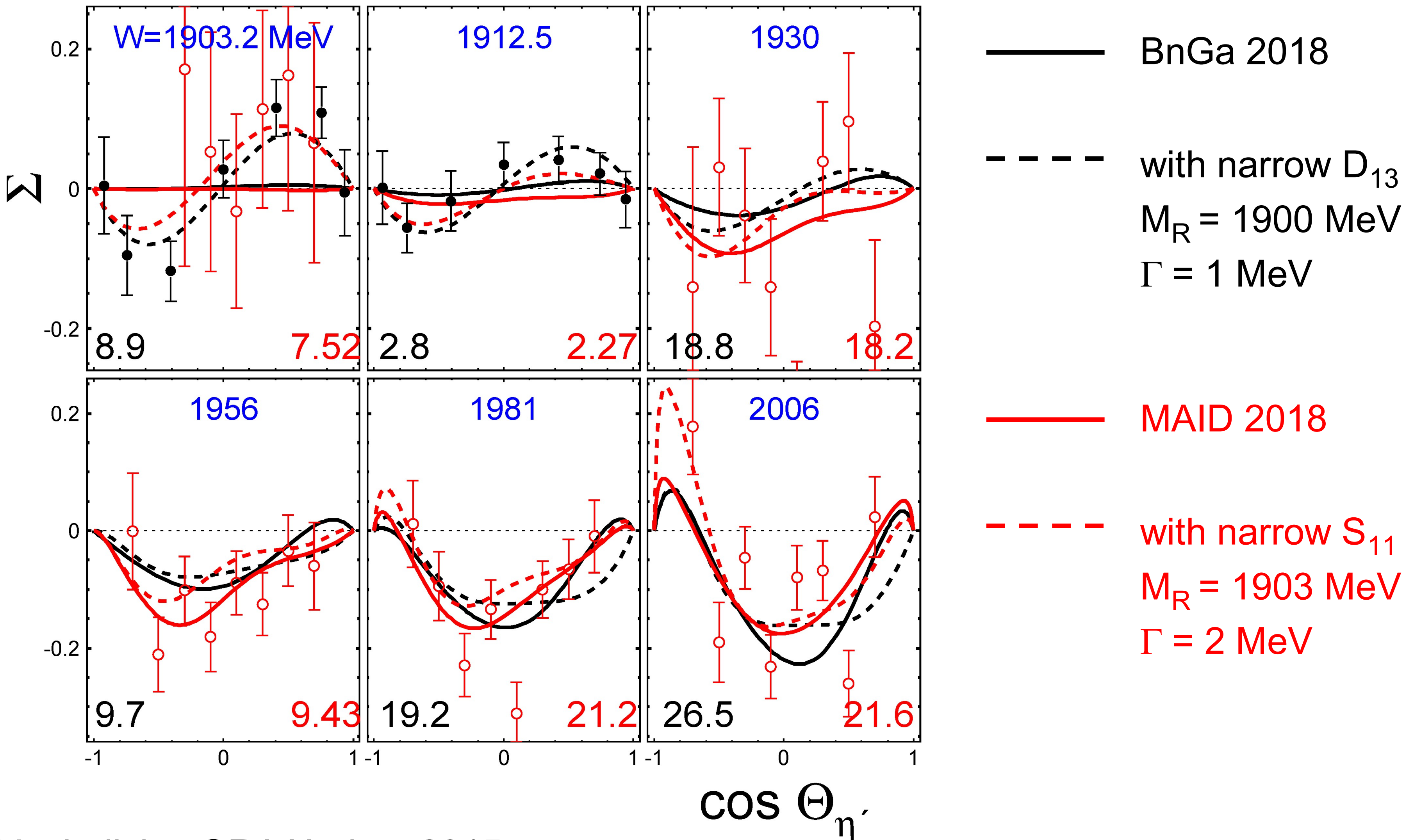




beam asymmetry Σ:
black disks: GRAAL data 2015
red circles: CLAS data 2017

diff. cross sect. dσ/dΩ:
MAMI data 2017

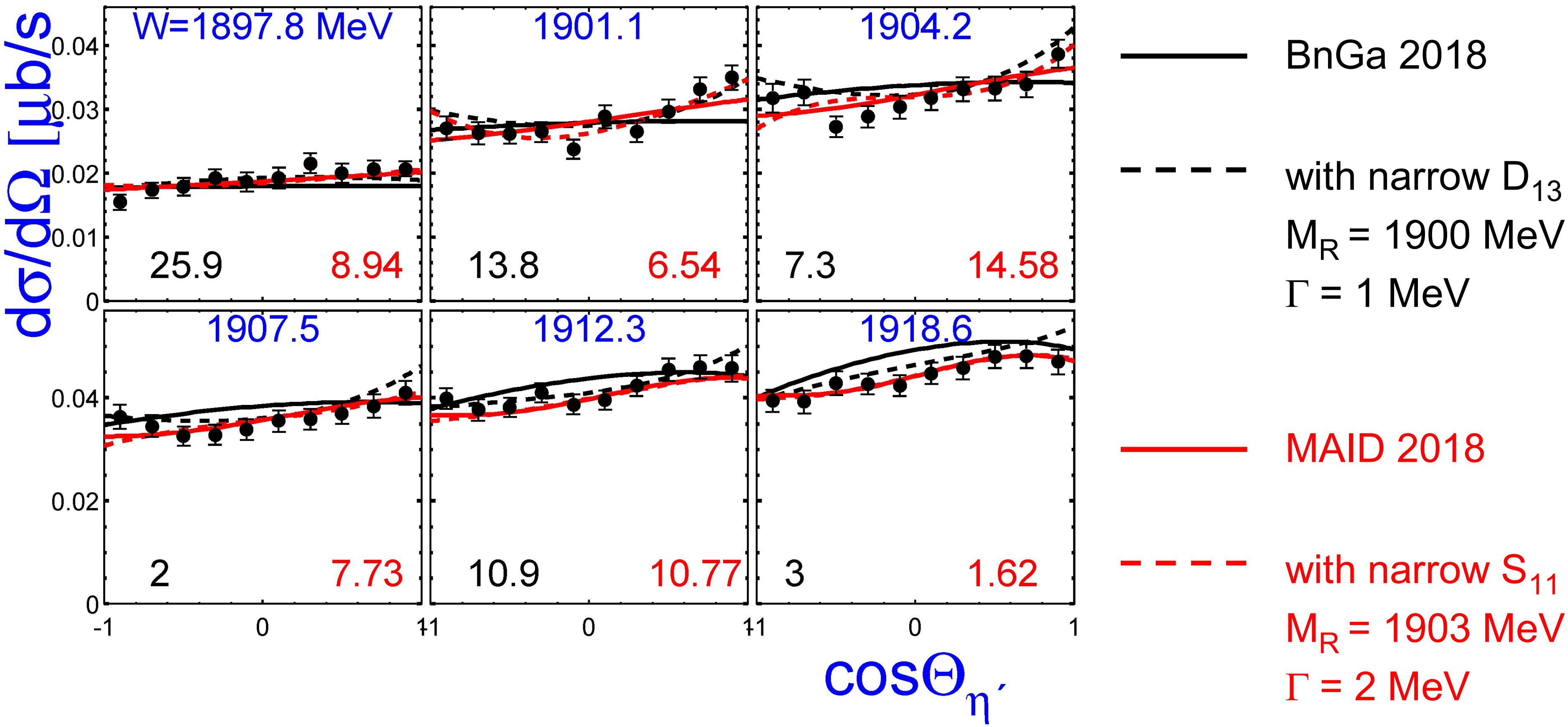
narrow resonance S_{11}/D_{13} in $p(\gamma,\eta')p$ MAID vs. BNGA



black disks: GRAAL data 2015

red circles: CLAS data 2017

narrow resonance in p(γ,η')p – MAID vs. BNGA



Σ and dσ/dΩ data can well be fitted with a very narrow resonance at W_R=1900 MeV
in the total c.s. such a resonance is invisible
it shows up in interferences between *S-F* or *P-D* resonances

summary and conclusions

in Mainz we have just finished an EtaMAID update
which will soon become available on our MAID webpage

it is based on Regge phenomenology at high energies
and nucleon resonances below 2.5 GeV

the well-known duality problem is addressed in a new approach
with a damping factor removing most of Regge background in the resonance region

the new EtaMAID2018 describes all data of 4 channels very well,

$\gamma + p \dashrightarrow \eta + p$
$\gamma + n \dashrightarrow \eta + n$
$\gamma + p \dashrightarrow \eta' + p$
$\gamma + n \dashrightarrow \eta' + n$

including novel polarization observables

in comparison of MAID with BnGa, JüBo, KSU we find that
PWA is still not unambiguous
for a complete experiment some polarization observables are still missing

Complete Experiment for pseudoscalar meson photoproduction

$$\gamma + N \rightarrow \eta + N$$

4 spin degrees of freedom: 2(γ) x 2(N) x 1(η) x 2(N´) / 2(parity) = 4

4 complex amplitudes: $F_1(W,\theta), F_2(W,\theta), F_3(W,\theta), F_4(W,\theta)$

16 observables:

group $\mathcal{S}$	(single-spin)	:	σ_0, Σ, T, P	
group $\mathcal{BT}$	(beam-target)	:	G, H, E, F	
group $\mathcal{BR}$	(beam-recoil)	:	$O_{x'}$, $O_{z'}$, $C_{x'}$, $C_{z'}$	very difficult for π or η
group $\mathcal{TR}$	(target-recoil)	:	$T_{x'}$, $T_{z'}$, $L_{x'}$, $L_{z'}$	

complete experiment analysis with at least 8 observables

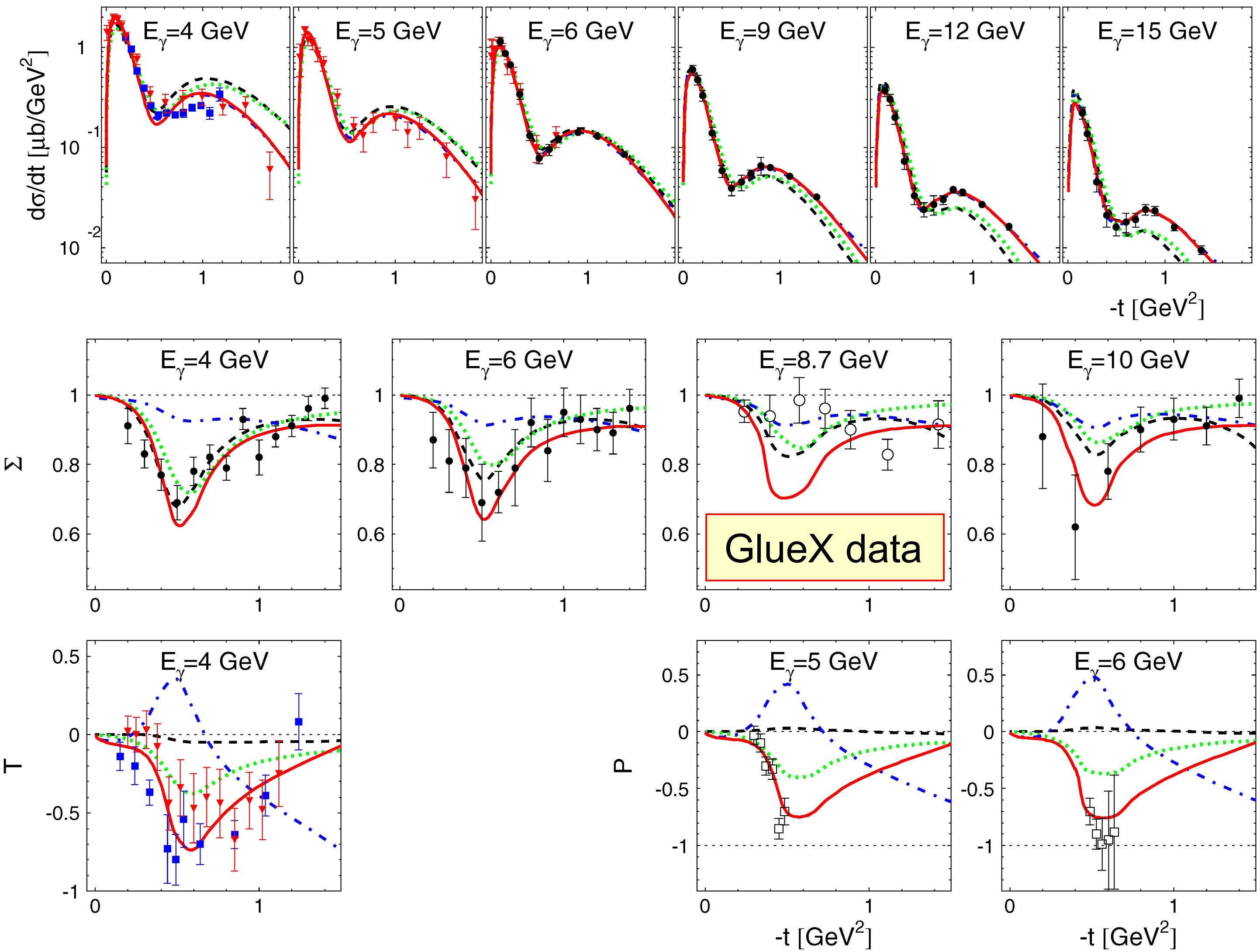
e.g. σ_0, Σ, T, P, E, F, $O_{x'}$, $C_{x'}$: in principle recoil polarization is unavoidable

but we hope that unitarity constraints from coupled channels
and analytical constraints from fixed-t dispersion relations
will compensate this lack of data

diff cross sections and polarization observables for γ,π^0 at high energy

V. Kashevarov, M. Ostrick, L. Tiator , Phys. Rev. C**96** (2017) 045207

comparison with different Regge models —— our favoured Regge-cut model



differential cross sections and polarization observables at high energy

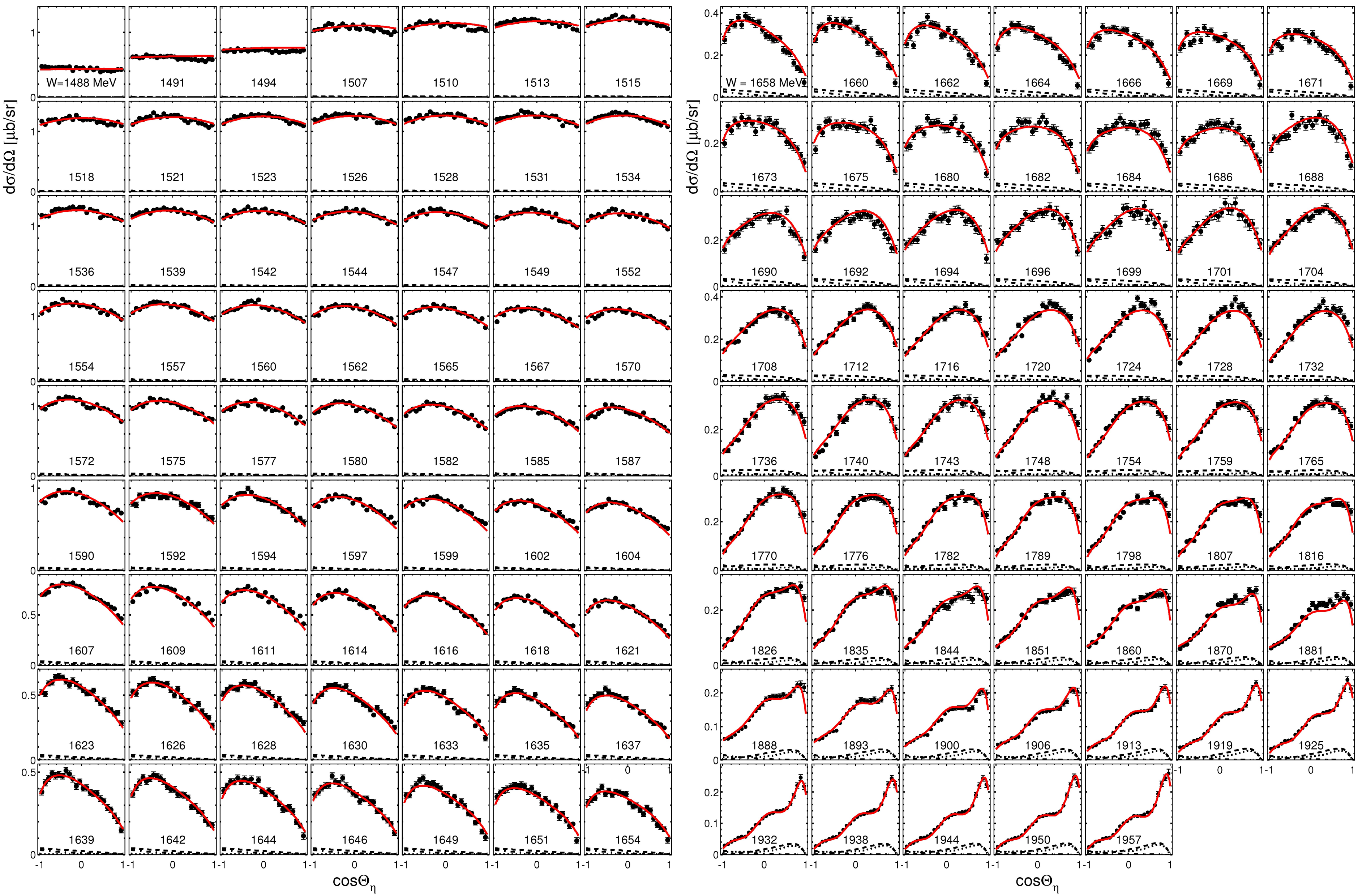
Four solutions for Regge parametrization, discussed in our paper:

V. Kashevarov, M. Ostrick, L. Tiator , Phys. Rev. C**96** (2017) 045207

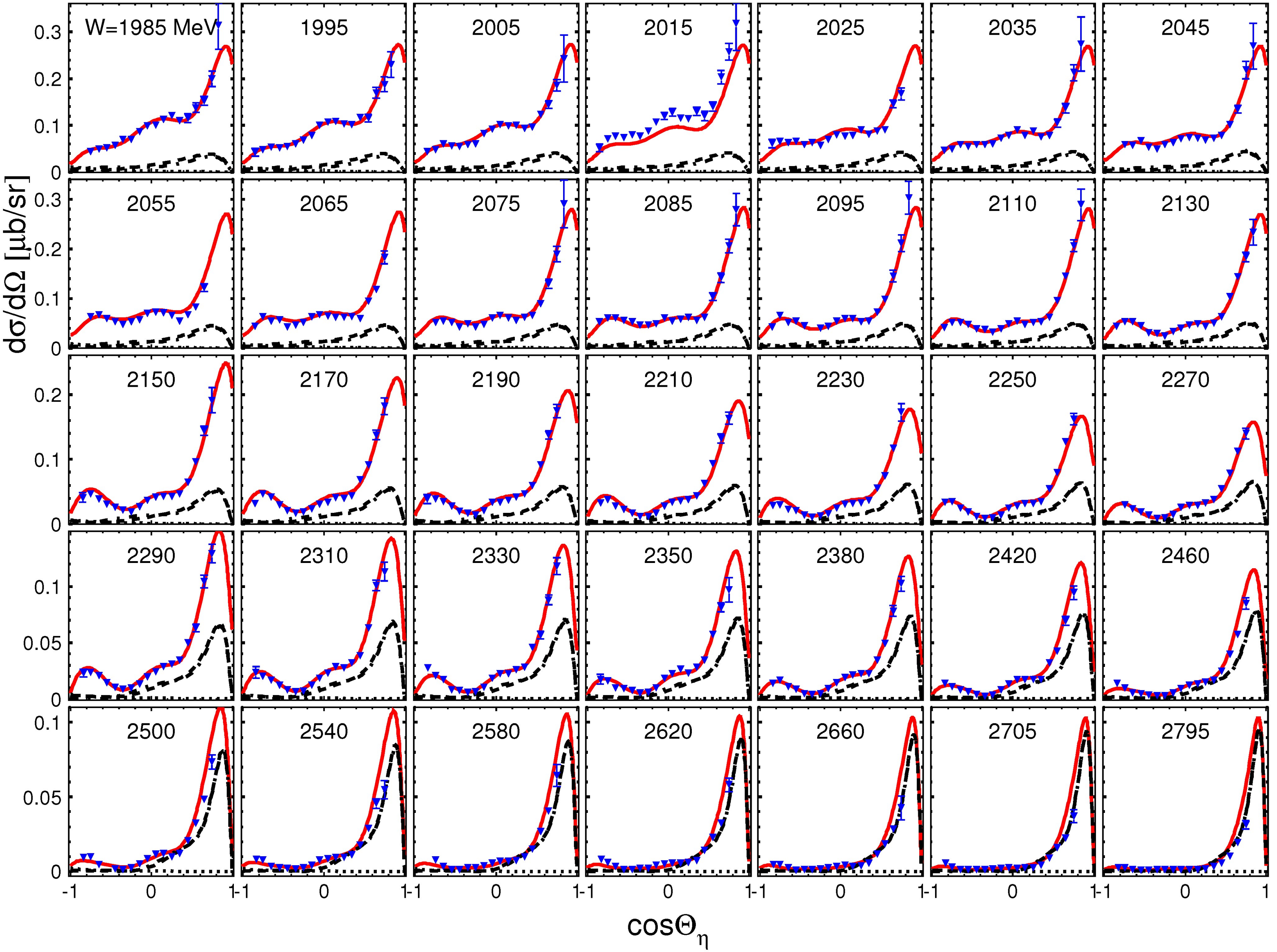
TABLE VI. Four solutions using different models and data sets shown in our analysis.

Solution	Line in figures	Model	Data set	$\chi^2_{\rm red}(\pi)$	$\chi^2_{\rm red}(\eta)$
I	Solid red	Regge cut	All	1.46	1.25
II	Dashed black	JPAC	All	5.59	2.73
III	Dashed-dotted blue	Regge cut	$d\sigma/dt$ + GlueX Σ	0.92	1.07
IV	Dotted green	JPAC+ϕ	All	4.17	1.86

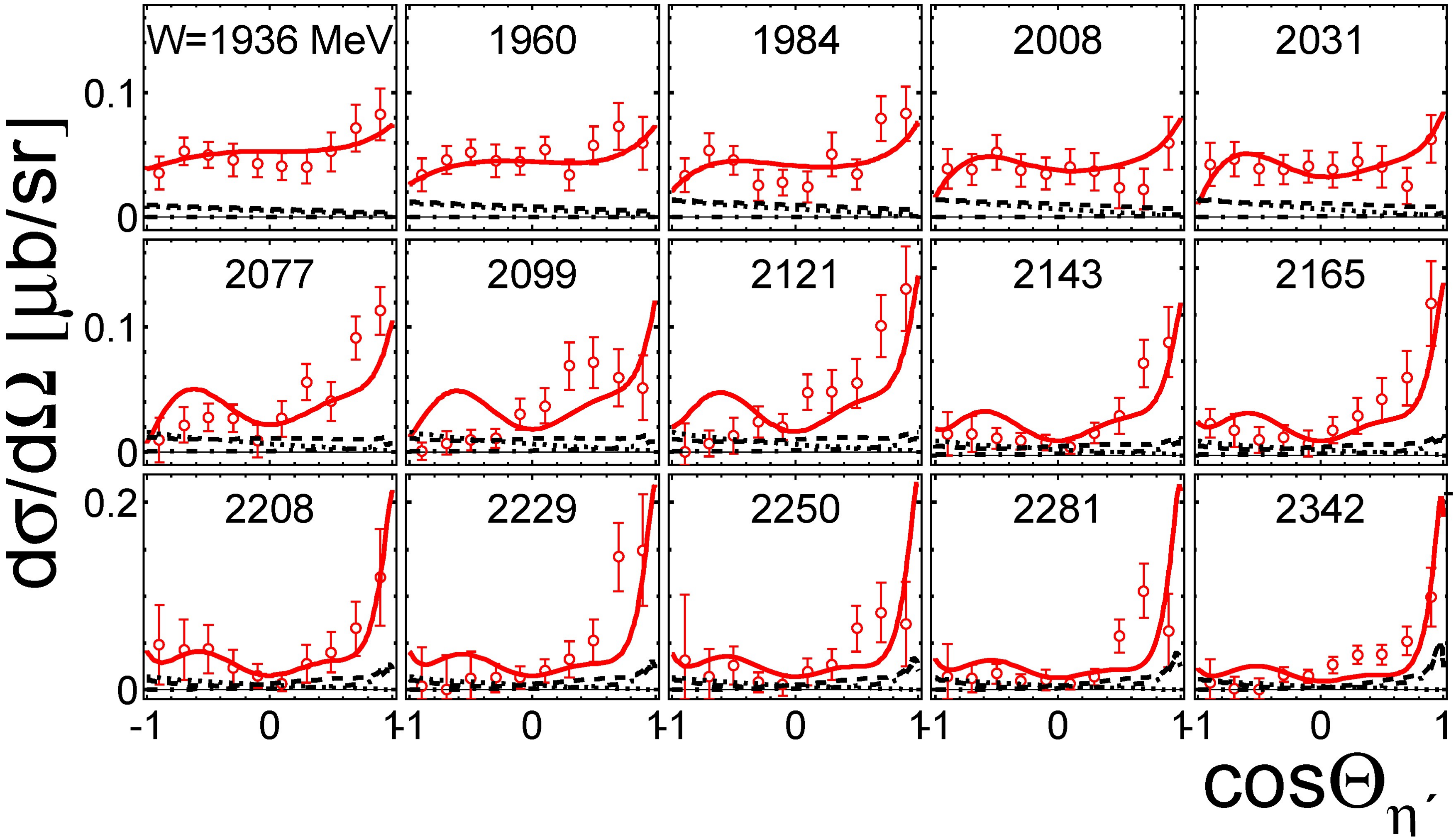
differential cross sections compared to MAMI data



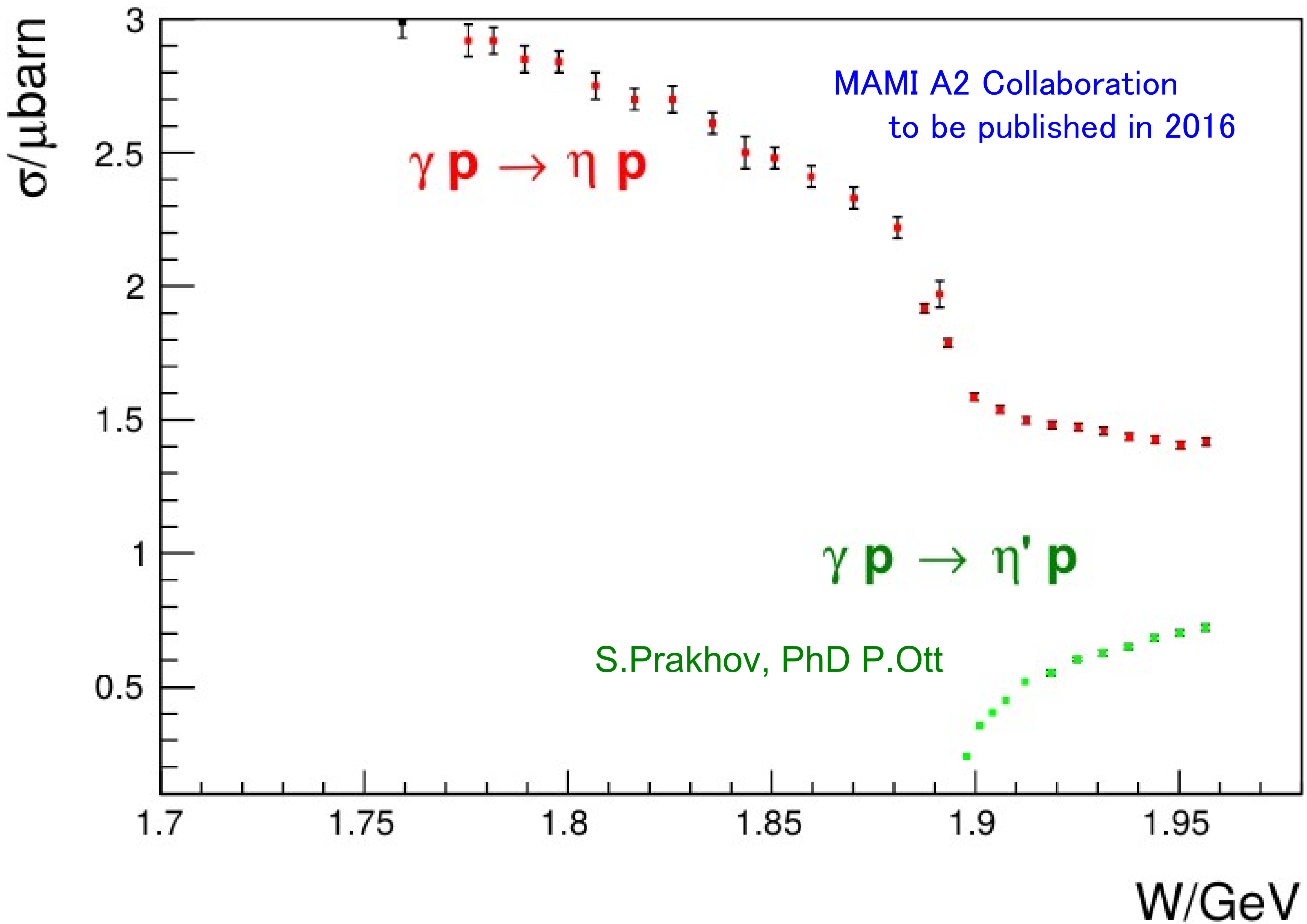
differential cross sections compared to CLAS data



differential cross section for γ,η' on the neutron

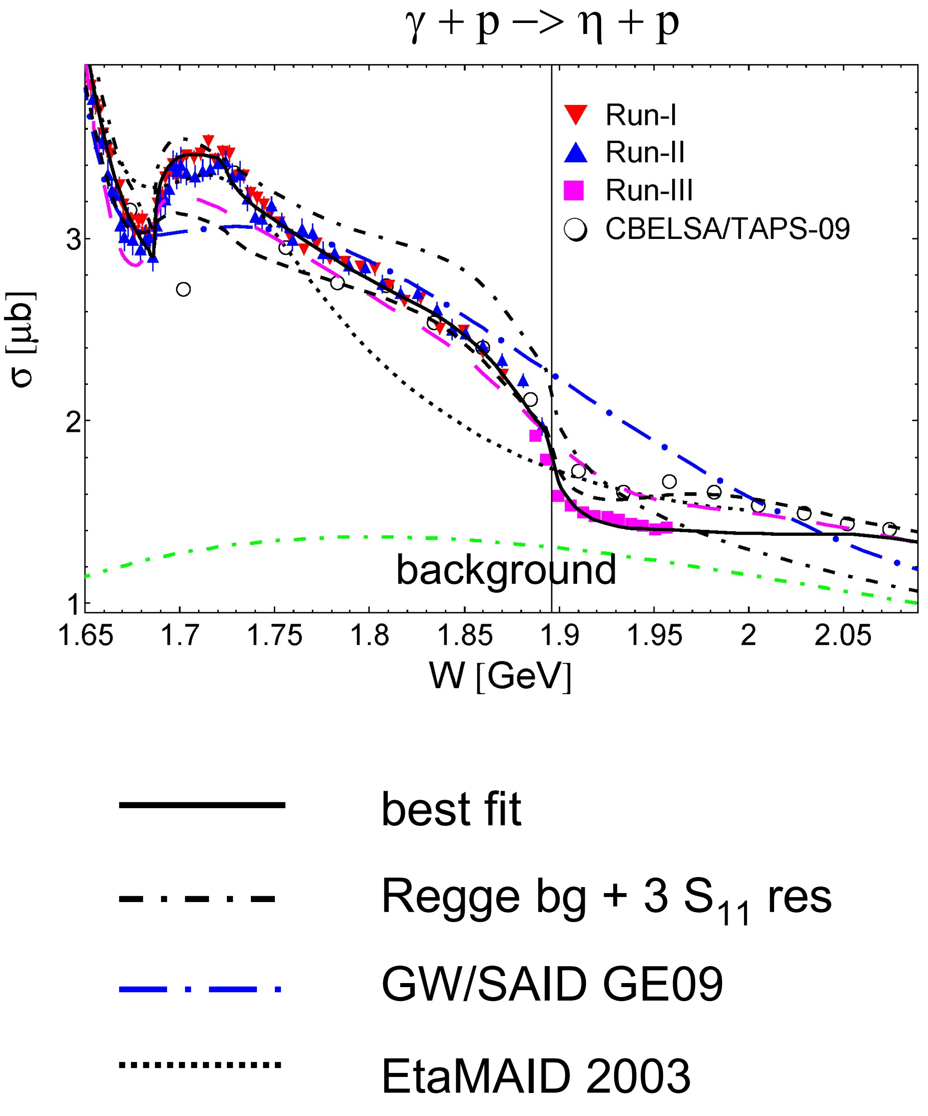


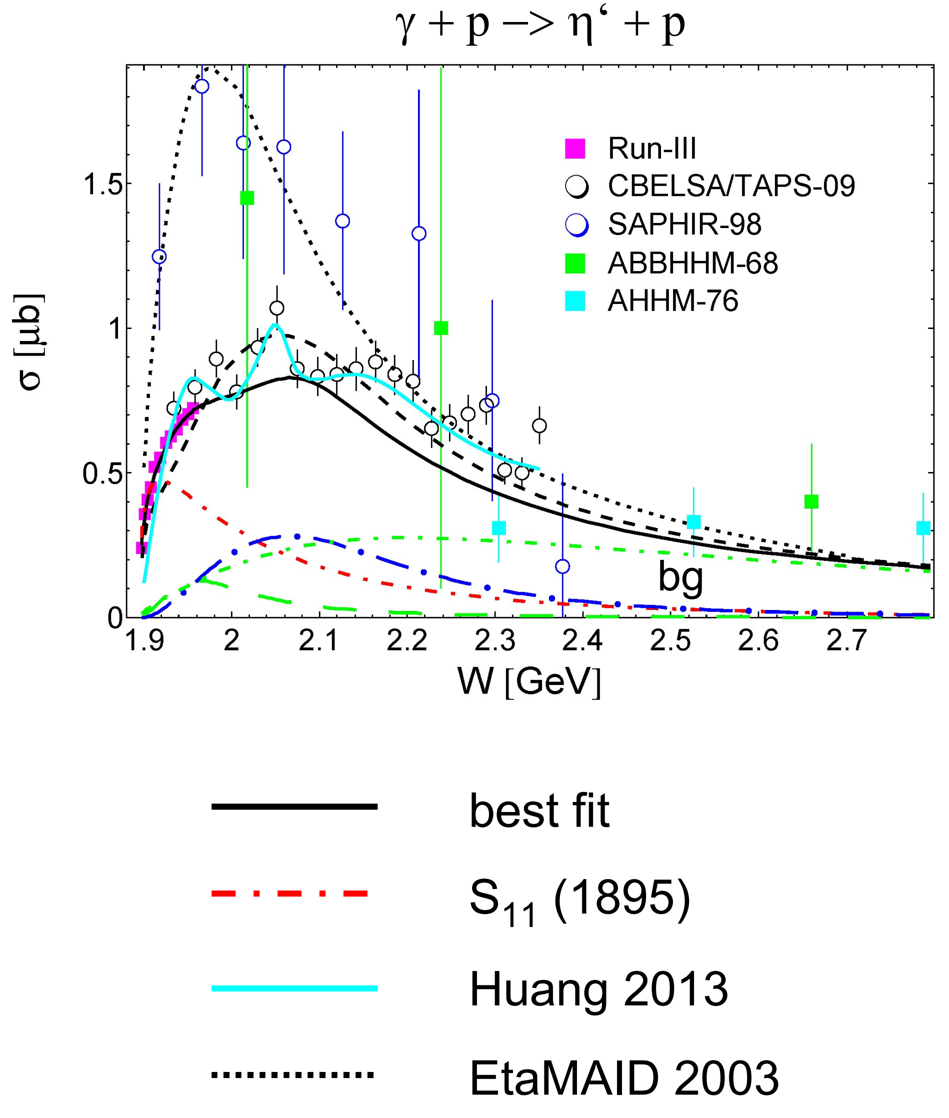
the cusp at the η ‘ threshold



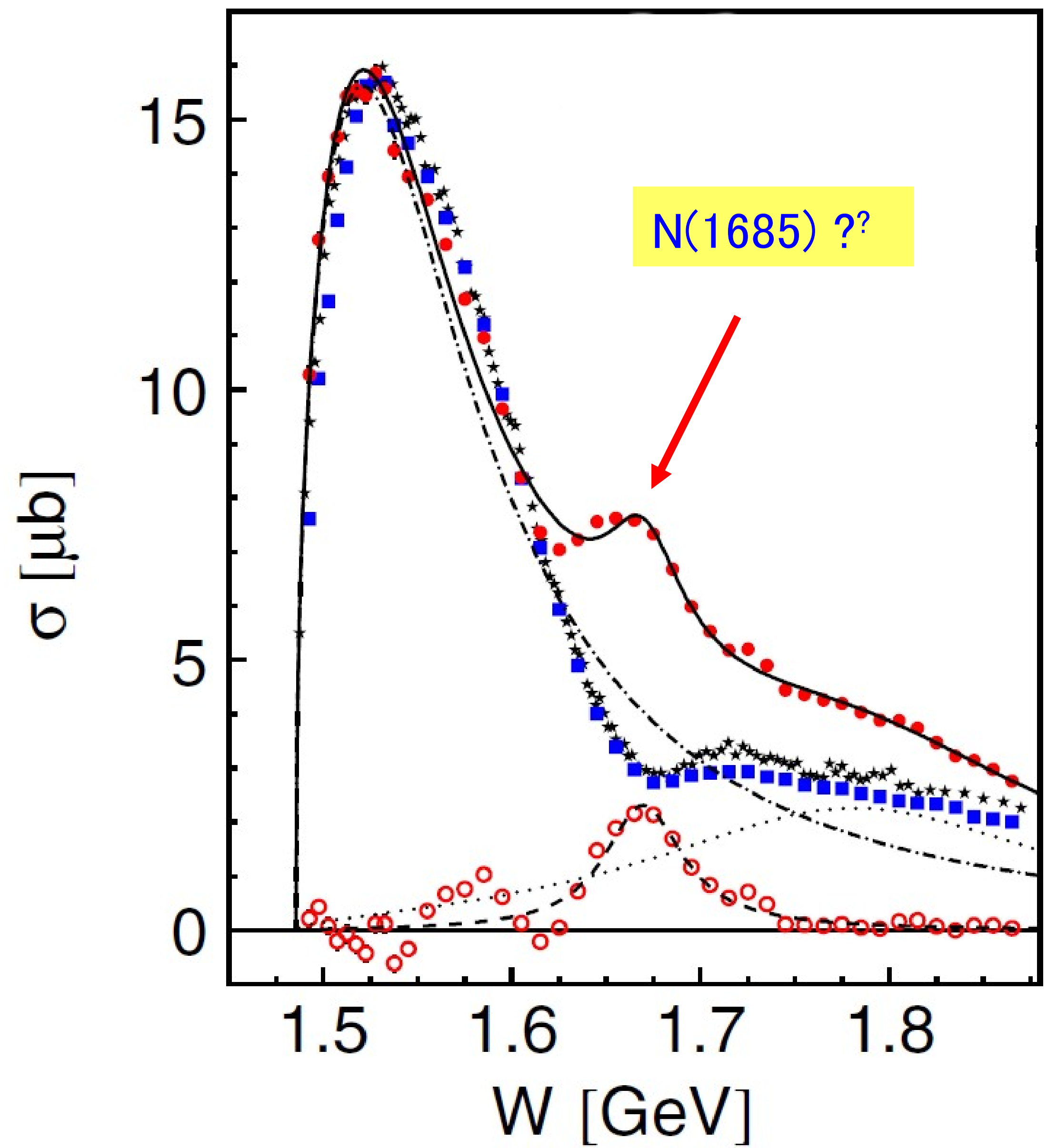
Eta-MAID update: total cross sections for γ,η and γ,η'

V. Kashevarov et al. (A2 collaboration at MAMI), PRL **118** (2017) 212001





a bump in the neutron γ,η cross section



Is it

- a narrow resonance
  W=1670, Γ=30 MeV ?
- a coupled-channels
  effect of KΛ and KΣ ?
- an interference
  of S11(1535) and S11(1650) ?

a bump in the neutron γ,η cross section

from: Anisovich et al., EPJ A51(2015)72: Interference phenomenon in the $J^{\pi}=1/2^{-}$ partial wave

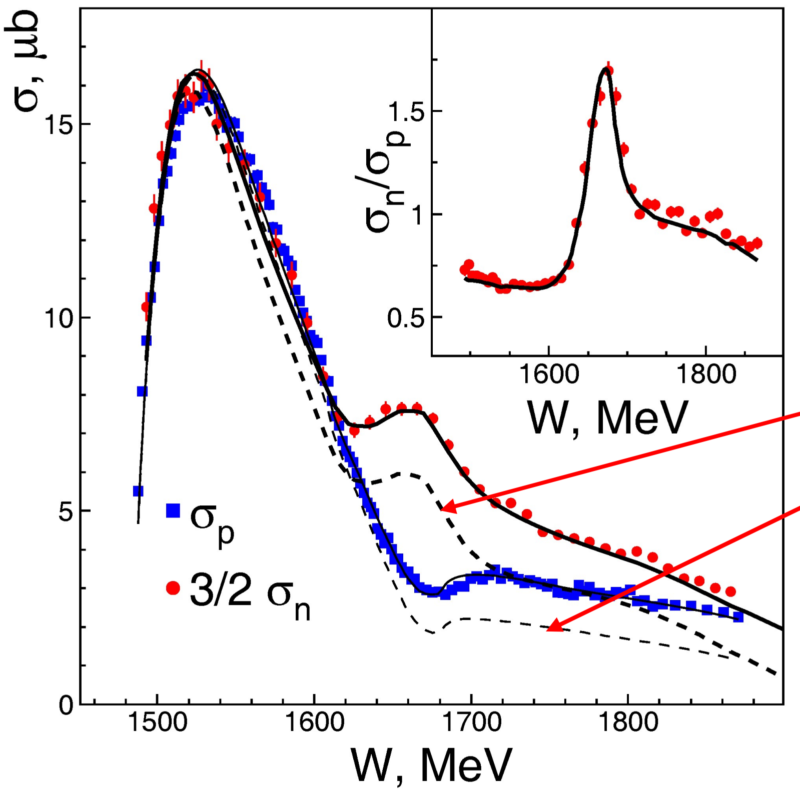


Fig. 1. (Color online) The total cross section for $\gamma n \to \eta n$, $\gamma p \to \eta p$, and their ratio as functions of the ηN invariant mass. The solid curves represent our final fits, dashed curves the $J^P = 1/2^-$ contributions.

$J^{\pi}=1/2^{-}$ (S_{11}) contribution

most likely not a genuine resonance

or even a pentaquark state