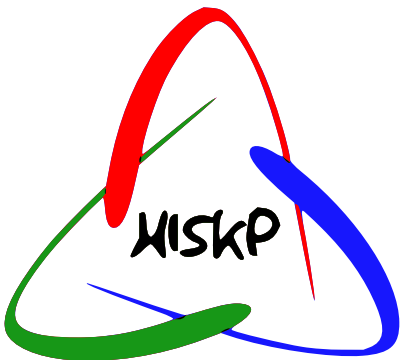
Baryon Spectroscopy

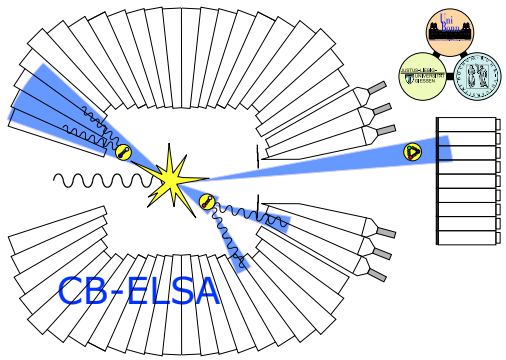
Recent Results from the CBELSA/TAPS Experiment

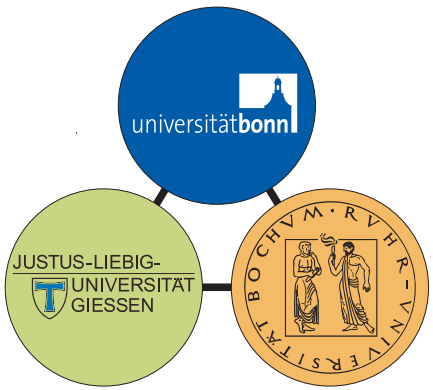
Jan Hartmann

for the CBELSA/TAPS collaboration

HISKP, University of Bonn







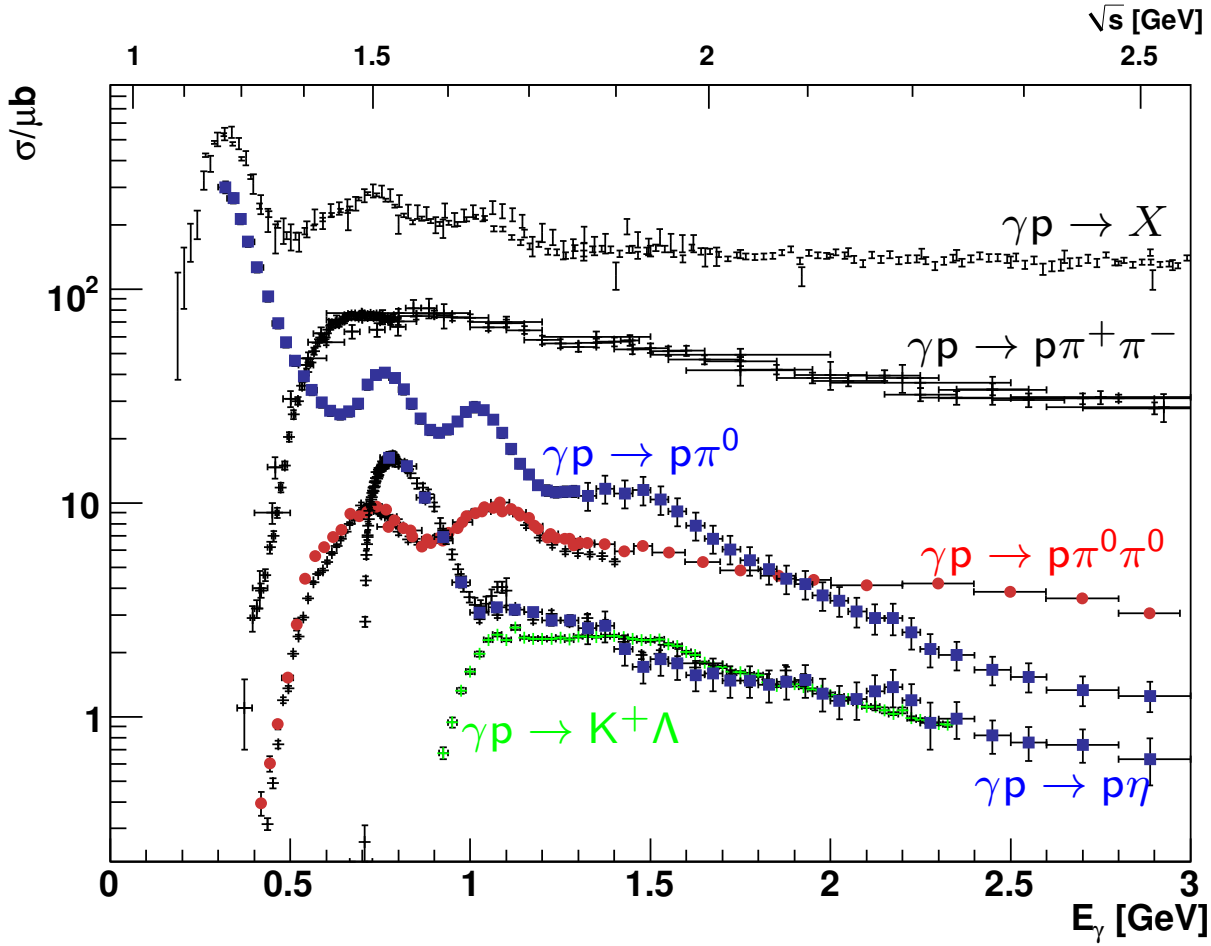
September 17, 2015

Baryon Spectroscopy

Recent Results from the CBELSA/TAPS Experiment

Light Baryon Spectroscopy

- Until 2010: Almost all resonances from πN scattering
- Resonances with small πN coupling?
  - photoproduction
  - different final states



Light Baryon Spectroscopy

- Until 2010: Almost all resonances from πN scattering
- Resonances with small πN coupling?
  - photoproduction
  - different final states
- PDG 2012: photoproduction data included $\rightsquigarrow$ new baryons

	PDG 2010	BnGa PWA	PDG 2012
$N(1860)\,5/2^+$		$\star$	$\star\star$
$N(1875)\,3/2^-$		$\star\star\star$	$\star\star\star$
$N(1880)\,1/2^+$		$\star\star$	$\star\star$
$N(1895)\,1/2^-$		$\star\star$	$\star\star$
$N(1900)\,3/2^+$	$\star\star$	$\star\star\star$	$\star\star\star$
$N(2060)\,5/2^-$		$\star\star\star$	$\star\star$
$N(2160)\,3/2^-$		$\star\star$	$\star\star$
$\Delta(1940)\,3/2^-$	$\star$	$\star$	$\star\star$

A.V. Anisovich *et al.*, Eur. Phys. J. A48 (2012) 15

Polarization Observables

Single pseudoscalar meson photoproduction:

Photon		Target			Recoil			Target - Recoil								
		x	y	z	$-$	$-$	$-$	x	y	z	x	y	z	x	y	z
		$-$	$-$	$-$	x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
unpolarized	σ_0		T			P		$T_{x'}$		$L_{x'}$				$T_{z'}$		$L_{z'}$
linear pol.	Σ	H		G	$O_{x'}$		$O_{z'}$									
circular pol.		F		E	$C_{x'}$		$C_{z'}$									

- 1 unpolarized observable: σ_0
- 3 single polarization observables: Σ, T, P
- 12 double polarization observables: 4 BT, 4 BR, 4 TR

Polarization Observables

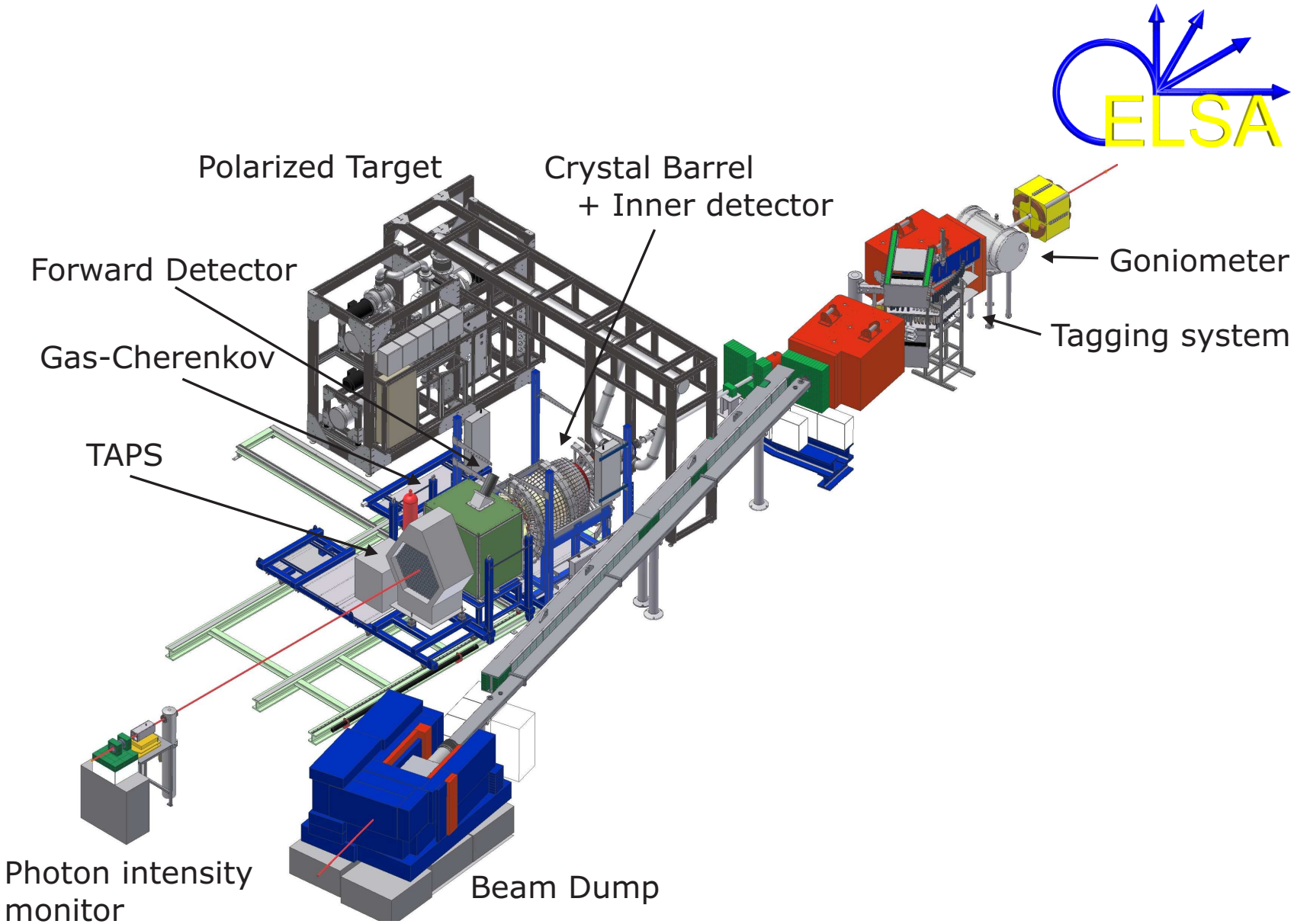
Single pseudoscalar meson photoproduction:

Photon		Target			Recoil			Target - Recoil								
		x	y	z	$-$	$-$	$-$	x	y	z	x	y	z	x	y	z
		$-$	$-$	$-$	x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
unpolarized	σ_0		T			P		$T_{x'}$		$L_{x'}$		Σ		$T_{z'}$		$L_{z'}$
linear pol.	Σ	H	P	G	$O_{x'}$	T	$O_{z'}$	$L_{z'}$	$C_{z'}$	$T_{z'}$	E	σ_0	F	$L_{x'}$	$C_{x'}$	$T_{x'}$
circular pol.		F		E	$C_{x'}$		$C_{z'}$		$O_{z'}$		G		H		$O_{x'}$	

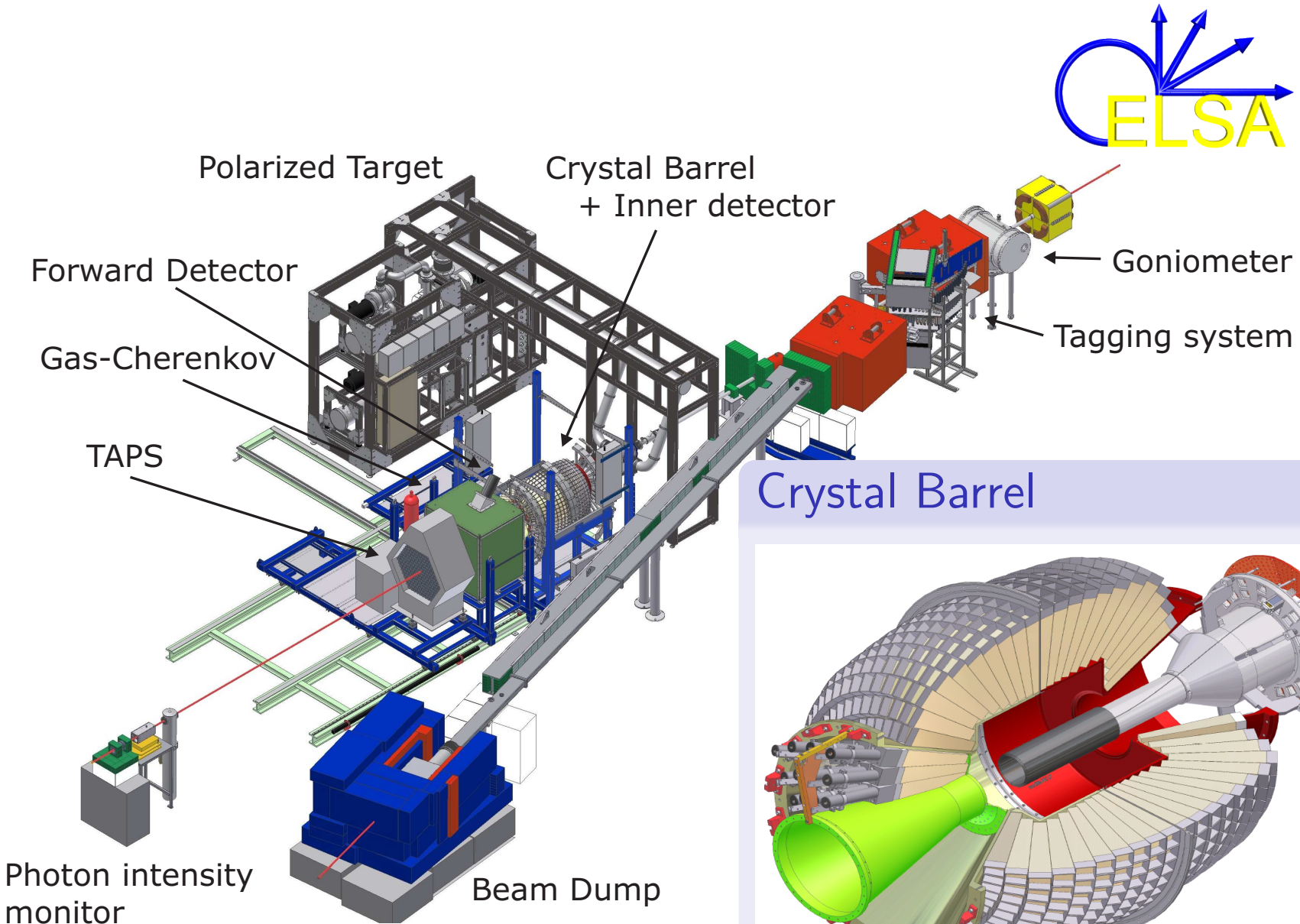
- 1 unpolarized observable: σ_0
- 3 single polarization observables: Σ, T, P
- 12 double polarization observables: 4 BT, 4 BR, 4 TR
- redundant observables:
  - single pol. observables $\longleftrightarrow$ double pol. experiment
  - double pol. observables $\longleftrightarrow$ triple pol. experiment

Complete experiment: at least 8 (carefully chosen) observables

The Crystal Barrel/TAPS experiment



The Crystal Barrel/TAPS experiment

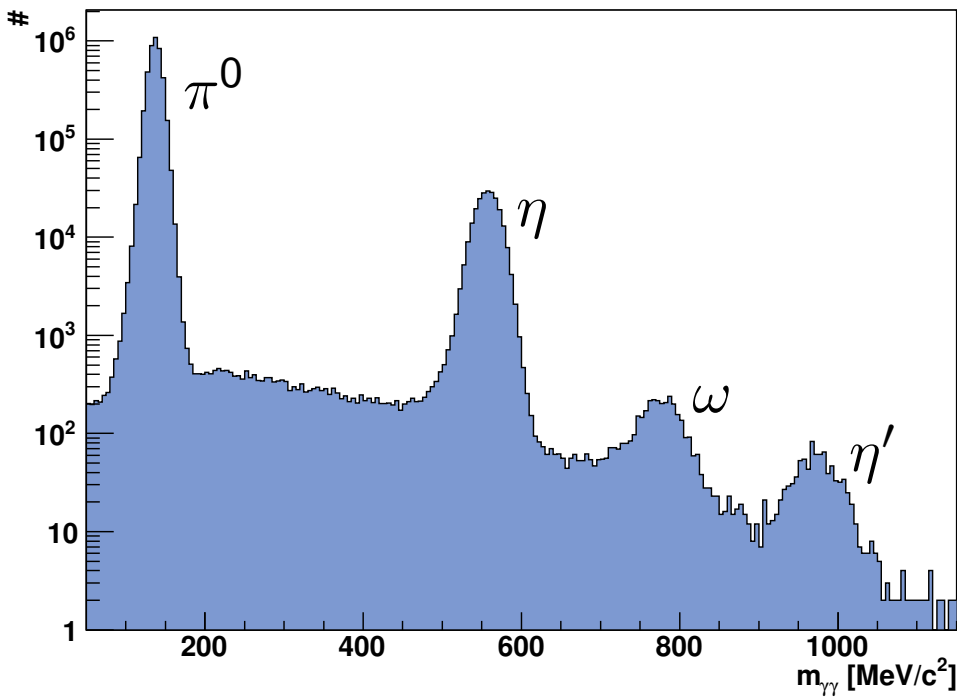


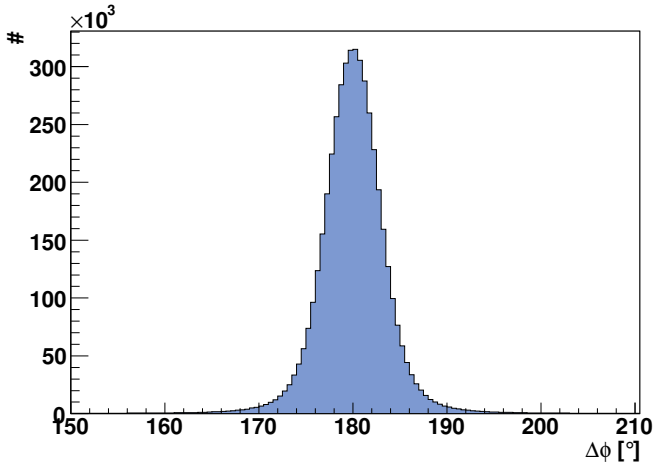
Crystal Barrel

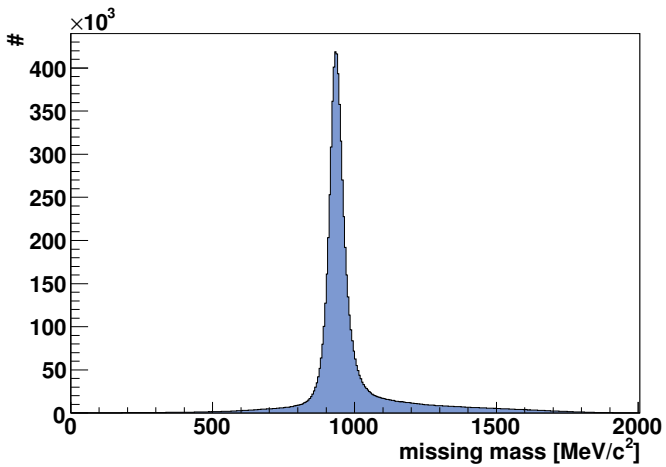
Event Reconstruction

$\gamma p \rightarrow p\pi^0 \rightarrow p\gamma\gamma$, $\gamma p \rightarrow p\eta \rightarrow p\gamma\gamma$

- photons detected (E, θ, ϕ)
- proton direction measured (θ, ϕ)

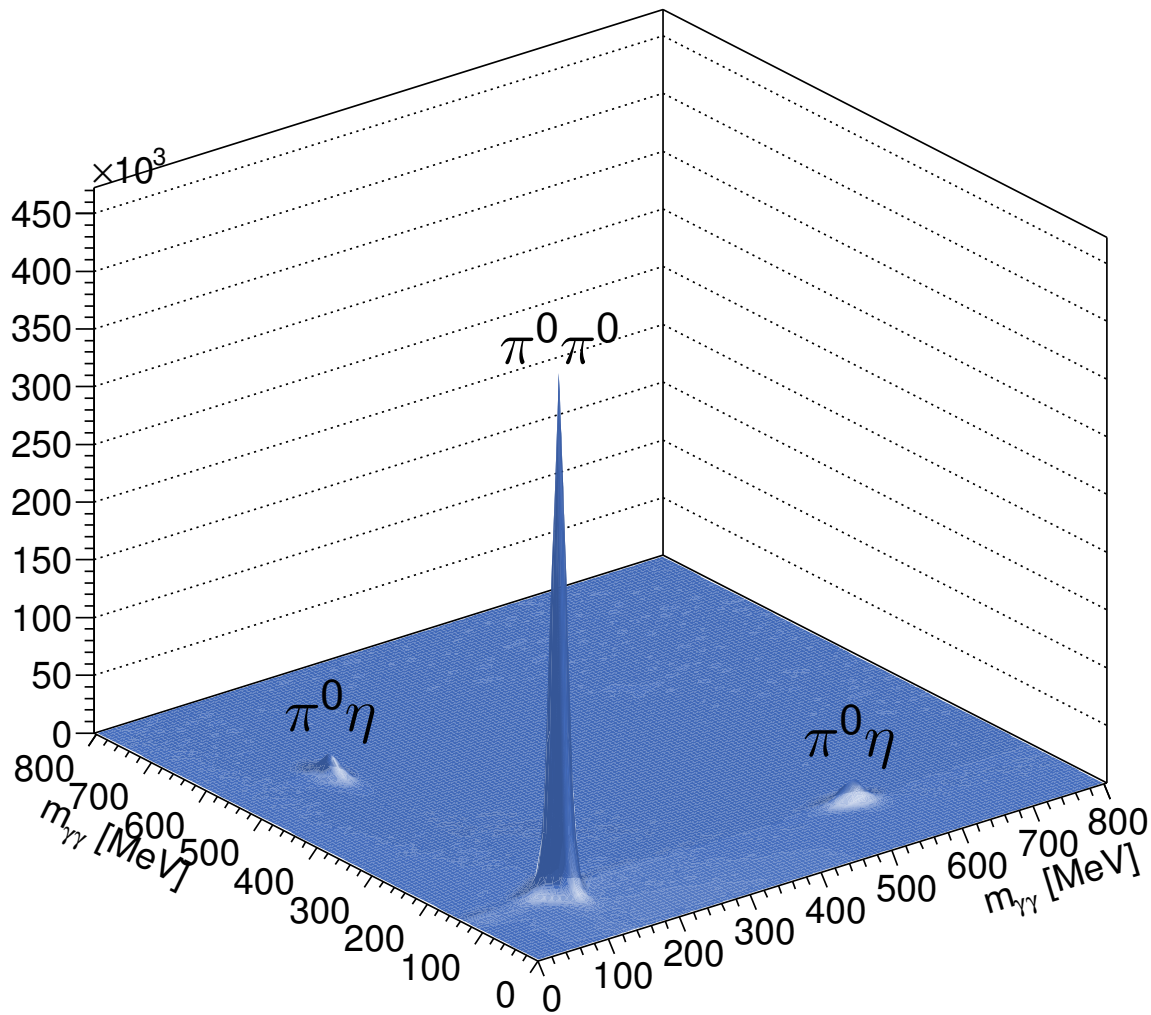






Event Reconstruction

Multi-meson final states, e.g. $\pi^0\pi^0$ or $\pi^0\eta$:

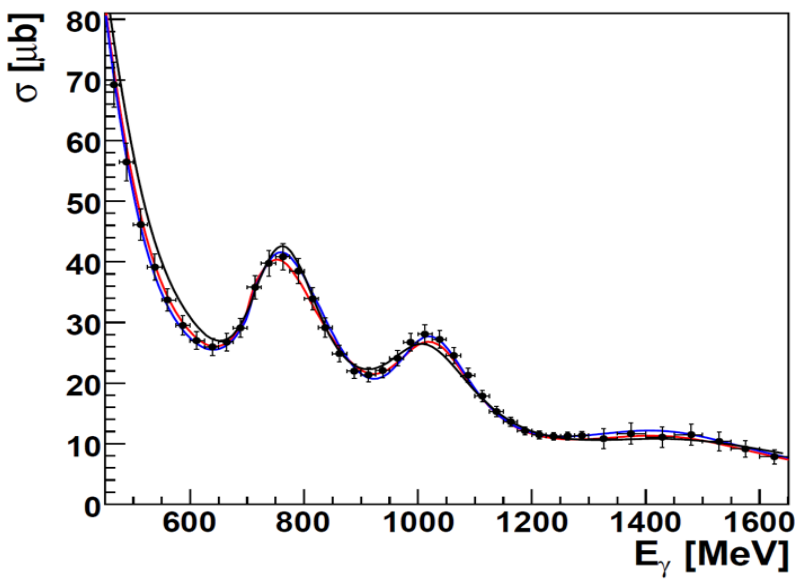


Single-Meson Photoproduction

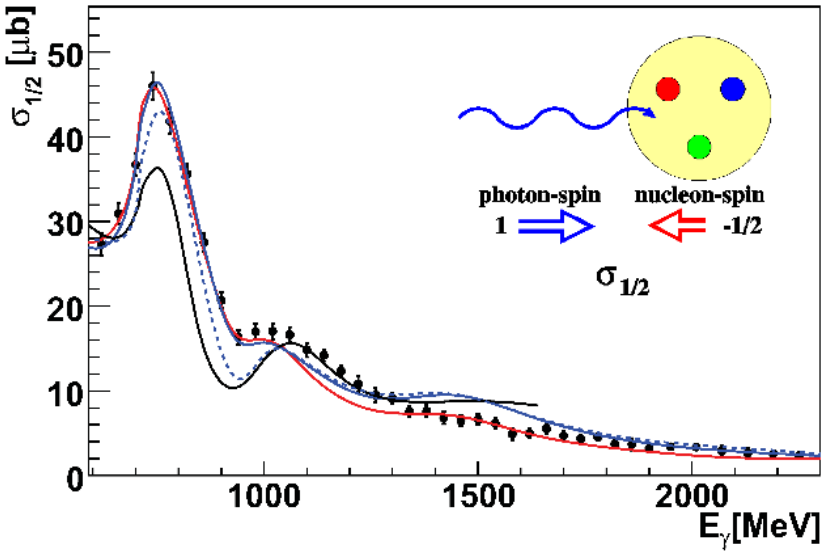
$\gamma p \to p\pi^0$:

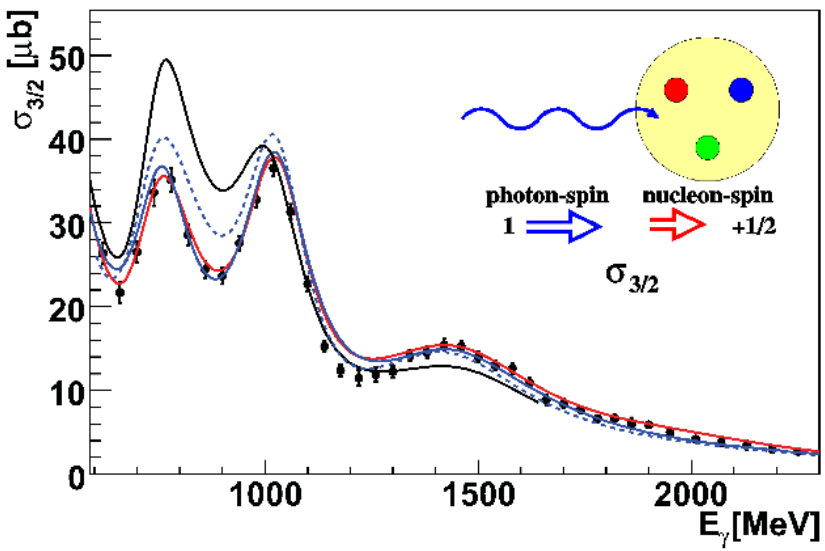
- π^0: lightest meson
- well measured differential cross section
- precise data on beam asymmetry Σ available
- contains πN coupling measured using elastic scattering

$\rightsquigarrow$ should be well understood



$\gamma p \to p\pi^0$: Helicity Asymmetry E

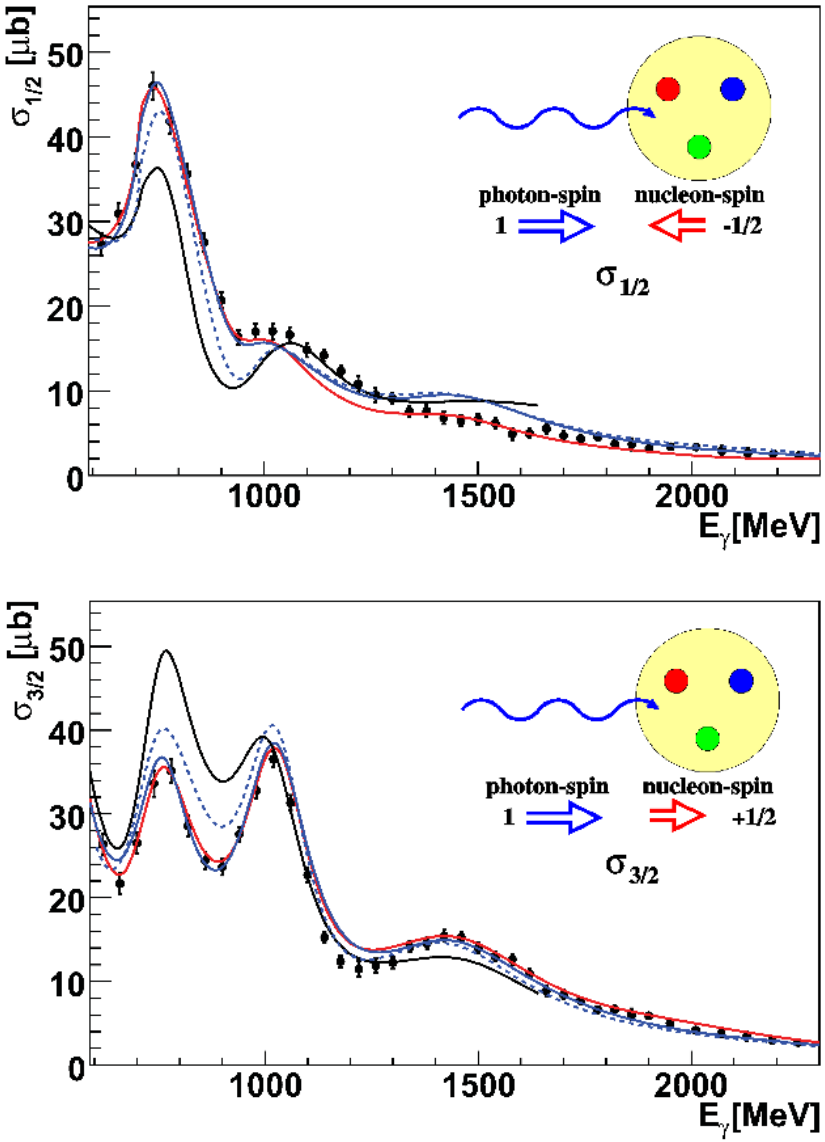


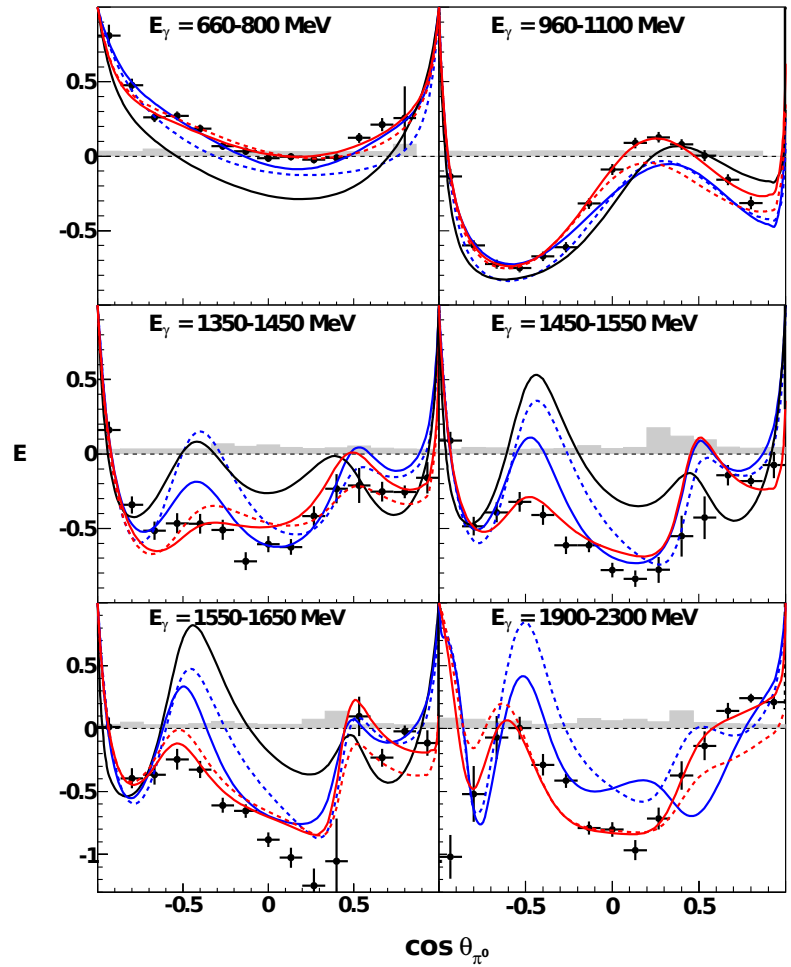


SAID (dashed: SN11, solid: CM12) MAID BnGa (dashed: 2011-02, solid: refit)

M. Gottschall *et al.*, Phys. Rev. Lett. 112 (2014) 012003

$\gamma p \to p\pi^0$: Helicity Asymmetry E

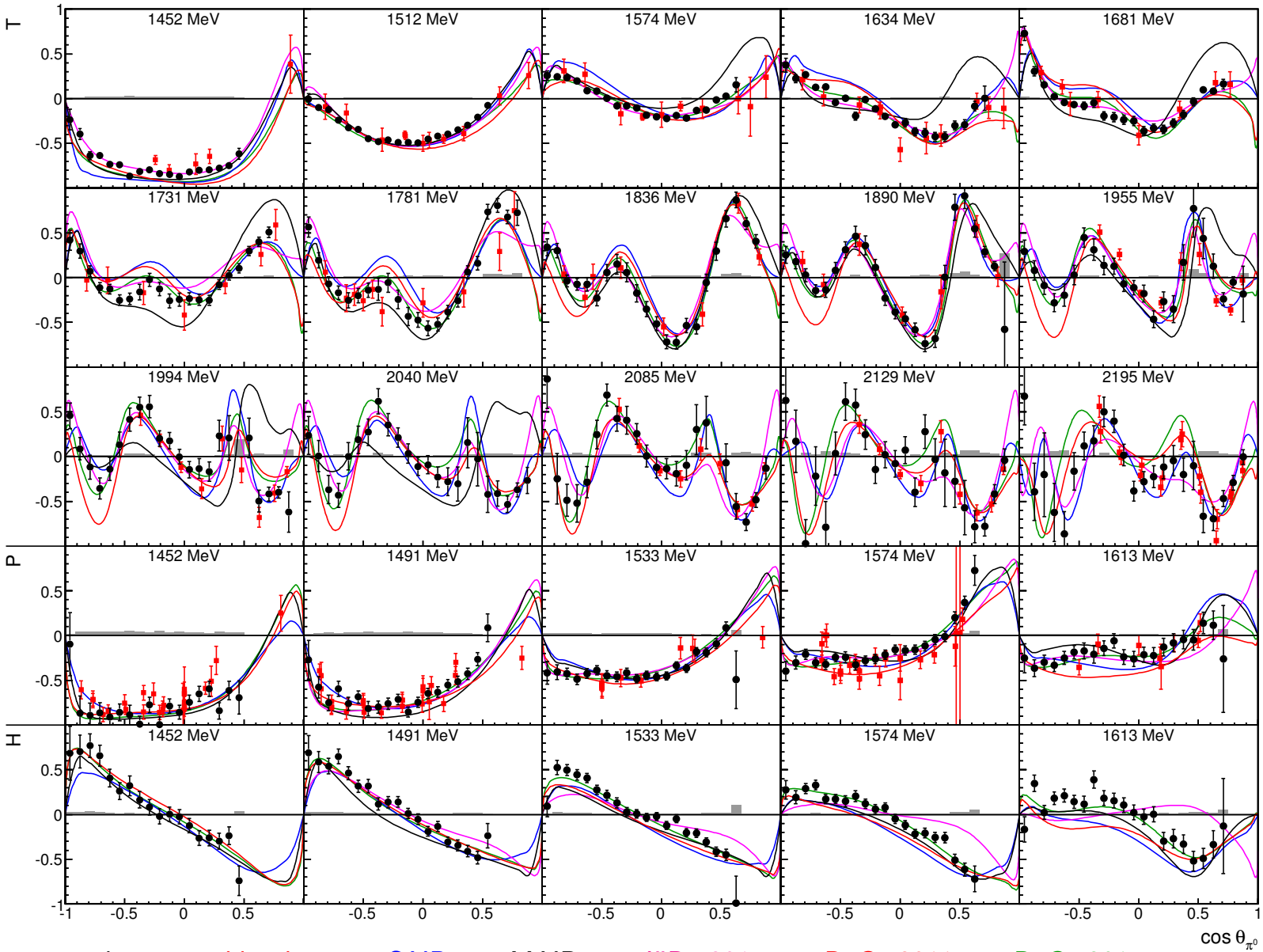




SAID (dashed: SN11, solid: CM12) MAID BnGa (dashed: 2011-02, solid: refit)

M. Gottschall *et al.*, Phys. Rev. Lett. 112 (2014) 012003

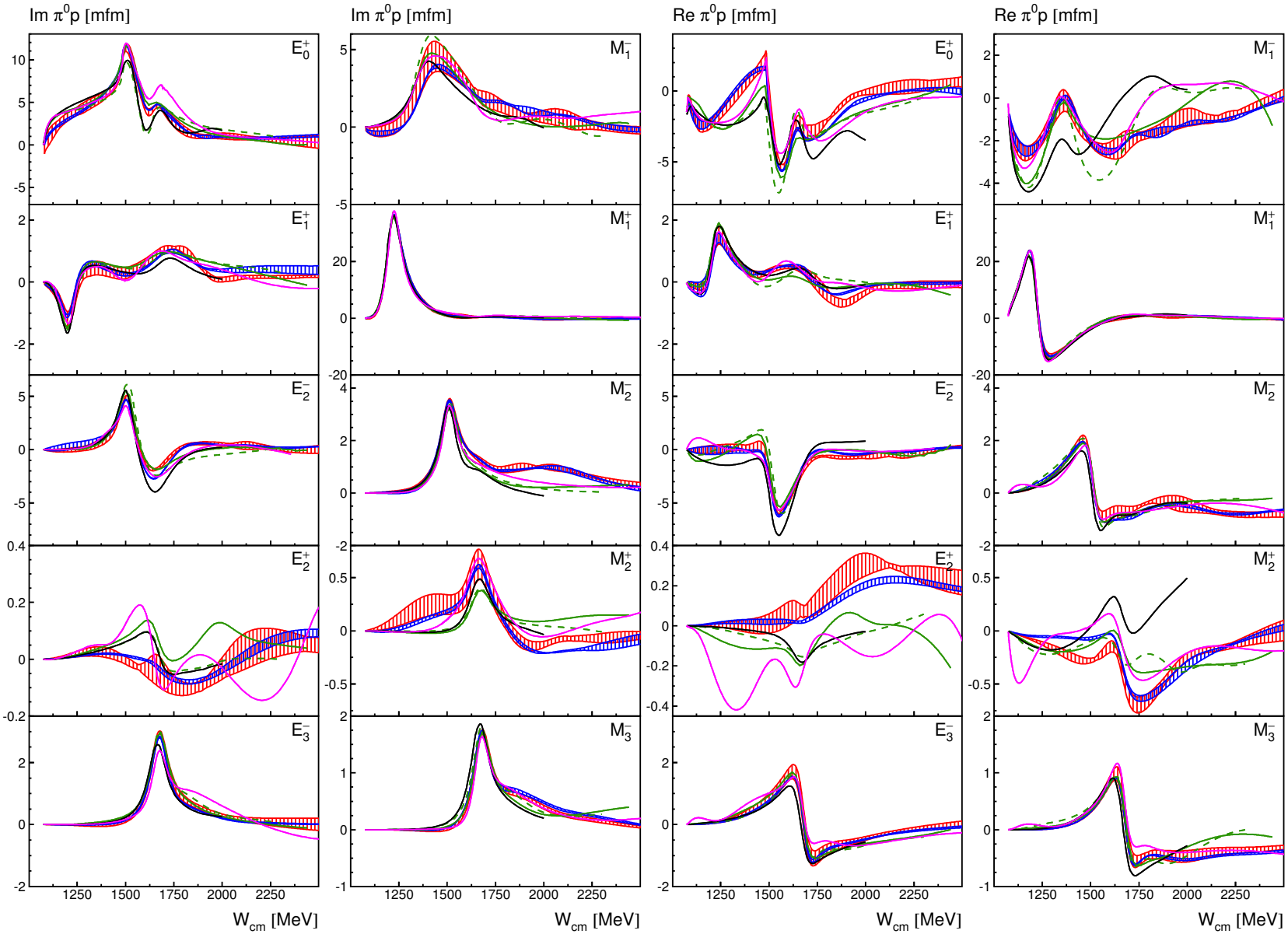
$\gamma p \to p\pi^0$: Observables T, P, and H



● our data ● older data – SAID – MAID – JüBo 2015 – BnGa 2011 – BnGa 2014

J. Hartmann, H. Dutz, A. Anisovich *et al.*, Phys. Rev. Lett. 113 (2014) 062001

Impact of the New Double Polarization Data



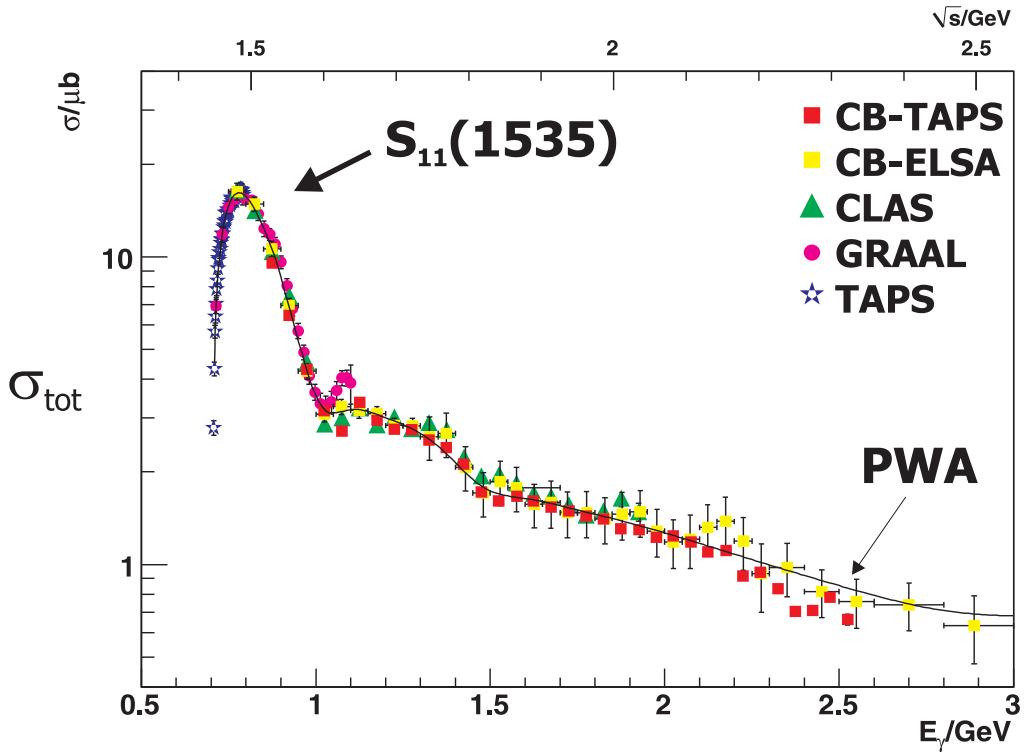
– BnGa 2014 – BnGa 2011 – MAID – SAID CM12 – JüBo 2015

J. Hartmann, H. Dutz *et al.*, Phys. Lett. B748 (2015) 212

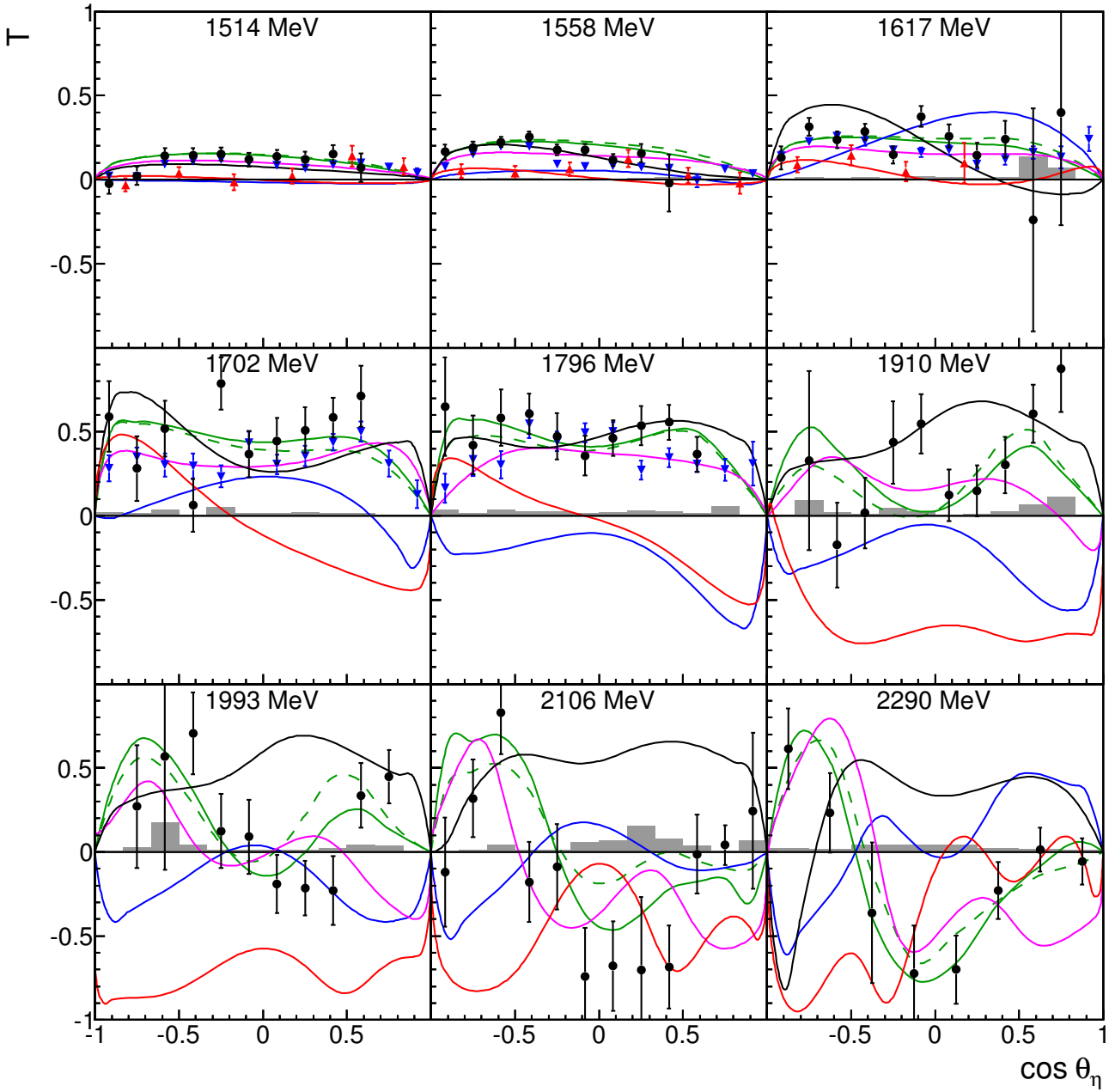
Single-Meson Photoproduction

$\gamma p \to p\eta$:

- η: $I = 0$
- only N^* resonances contribute
- ideal to investigate resonances with very small πN, but large ηN coupling.



$\gamma p \to p\eta$: Target Asymmetry T



- old ELSA data
  PRL 81 (1998) 534
- MAMI data
  PRL 113 (2014) 102001
- our data

– SAID

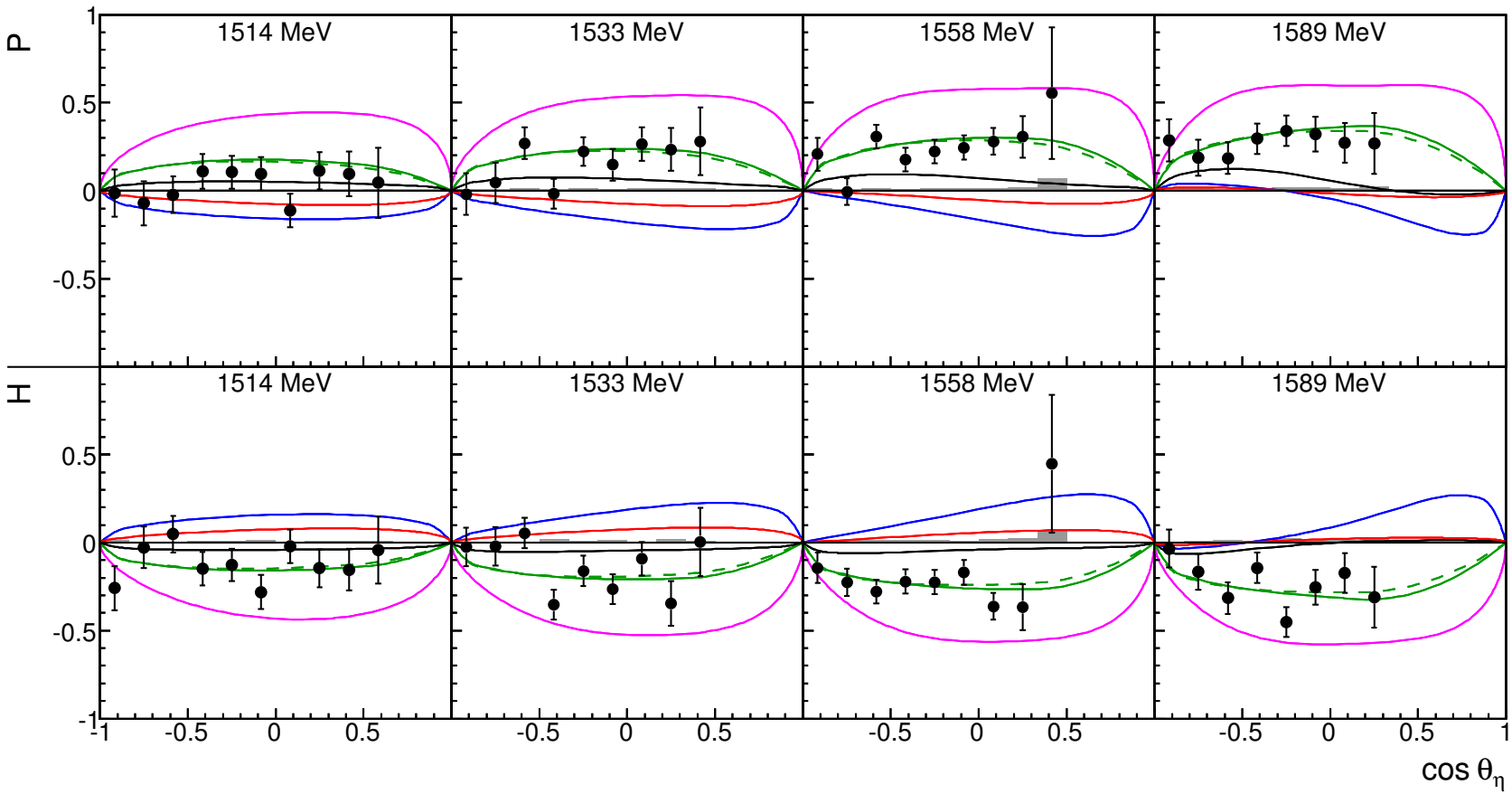
– MAID

– JüBo 2015

– BnGa 2011

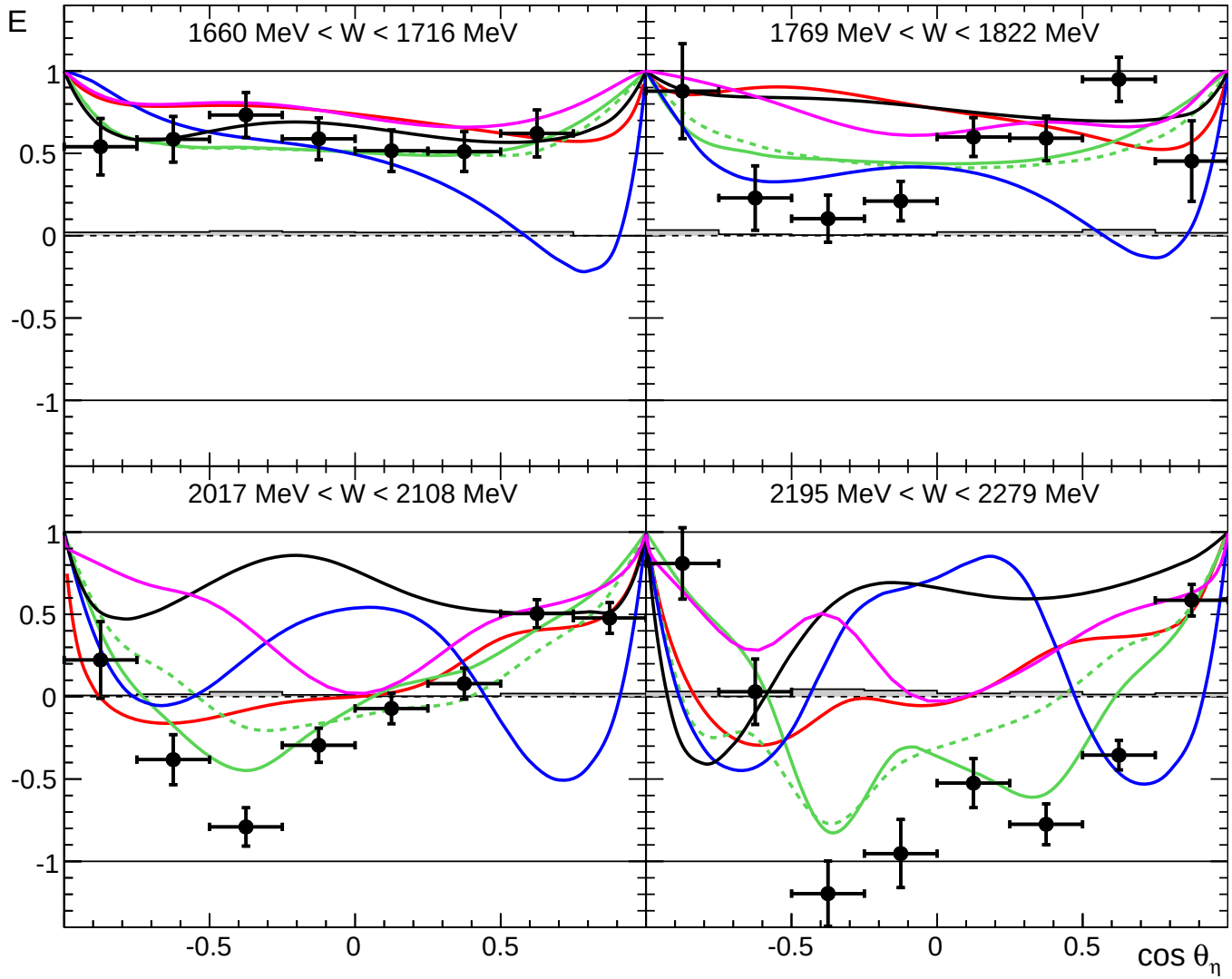
– BnGa 2014

$\gamma p \to p\eta$: Recoil Polarization P and Observable H



– SAID – MAID – JüBo 2015 – BnGa 2011 – BnGa 2014

$\gamma p \to p\eta$: Helicity Asymmetry E



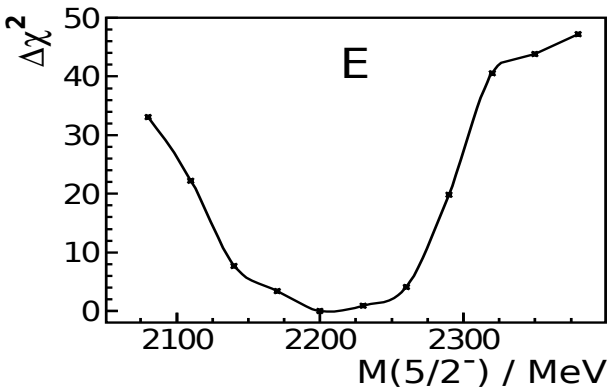
– SAID – MAID – JüBo 2015 – BnGa 2011 – BnGa 2014

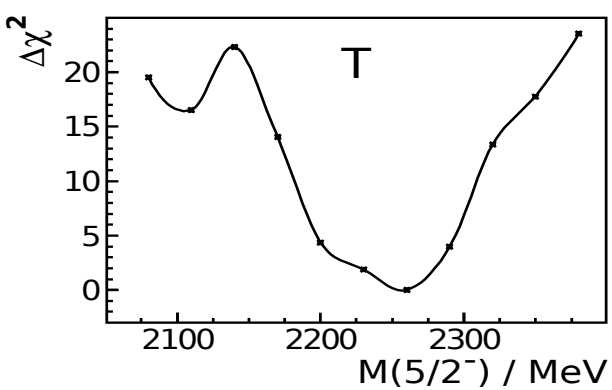
J. Müller, CBELSA/TAPS Collaboration

Impact of the New Double Polarization Data

BnGa 2014 refit to the new $\gamma p \to p\eta$ data:

- Indications for new resonance around 2.2 GeV



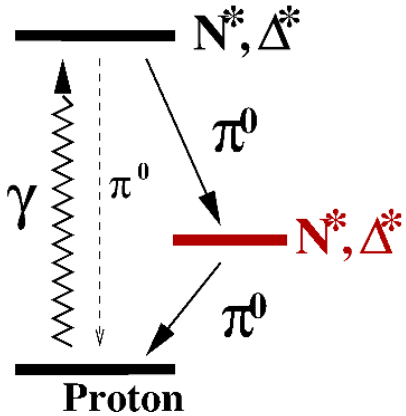


- Changed $N^* \to N\eta$ branching ratios

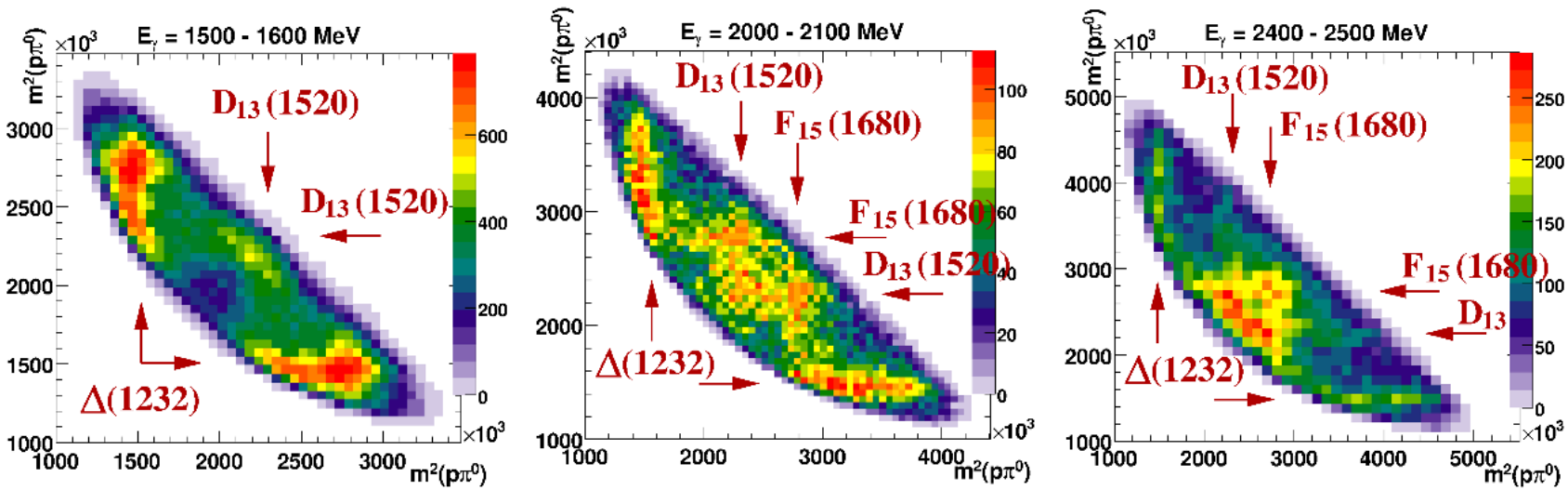
Res.	$N(1535)\frac{1}{2}^-$	$N(1650)\frac{1}{2}^-$	$N(1710)\frac{1}{2}^+$	$N(1720)\frac{3}{2}^+$	$N(1900)\frac{3}{2}^+$
BnGa	0.42 ± 0.04	0.32 ± 0.04	0.27 ± 0.09	0.03 ± 0.02	0.03 ± 0.01
PDG	0.42 ± 0.10	0.05 to 0.15	0.10 to 0.30	0.021 ± 0.014	≈ 0.12

- Still preliminary, systematic studies in progress

Multi-Meson Photoproduction

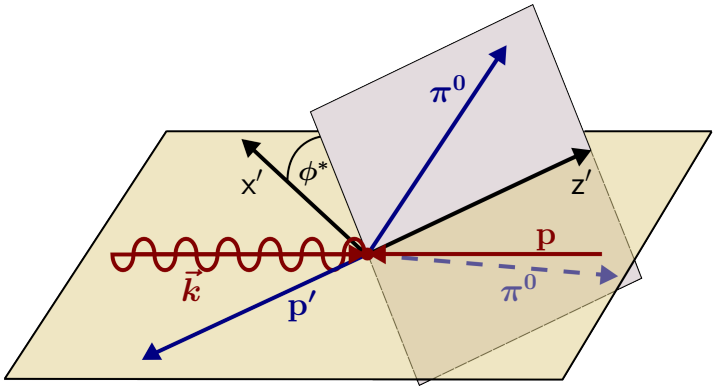


- Resonances can decay into $\Delta^*\pi^0$, $N^*\pi^0$, $N\sigma$
- $\gamma p \rightarrow p\pi^0\pi^0$ provides access to baryon cascade decays
- Rich environment to find new resonances



V. Sokhoyan *et al.*, Eur. Phys. J. A51 (2015) 95

3-Body Kinematics



photon pol.		target pol. axis		
		x	y	z
unpol.	σ	P_x	P_y	P_z
linear $\sin(2\phi)$	I^s	P_x^s	P_y^s	P_z^s
linear $\cos(2\phi)$	I^c	P_x^c	P_y^c	P_z^c
circular	$I^\odot$	$P_x^\odot$	$P_y^\odot$	$P_z^\odot$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \frac{\mathrm{d}\sigma_0}{\mathrm{d}\Omega} \cdot \Big\{ (1 + \Lambda_x P_x + \Lambda_y P_y) + \delta_\ell \cdot \Big[\sin(2\phi) \cdot \big(I^s + \Lambda_x P_x^s + \Lambda_y P_y^s\big) + \cos(2\phi) \cdot \big(I^c + \Lambda_x P_x^c + \Lambda_y P_y^c\big) \Big] \Big\}$$

W. Roberts, T. Oed, Phys. Rev. C 71 (2005)

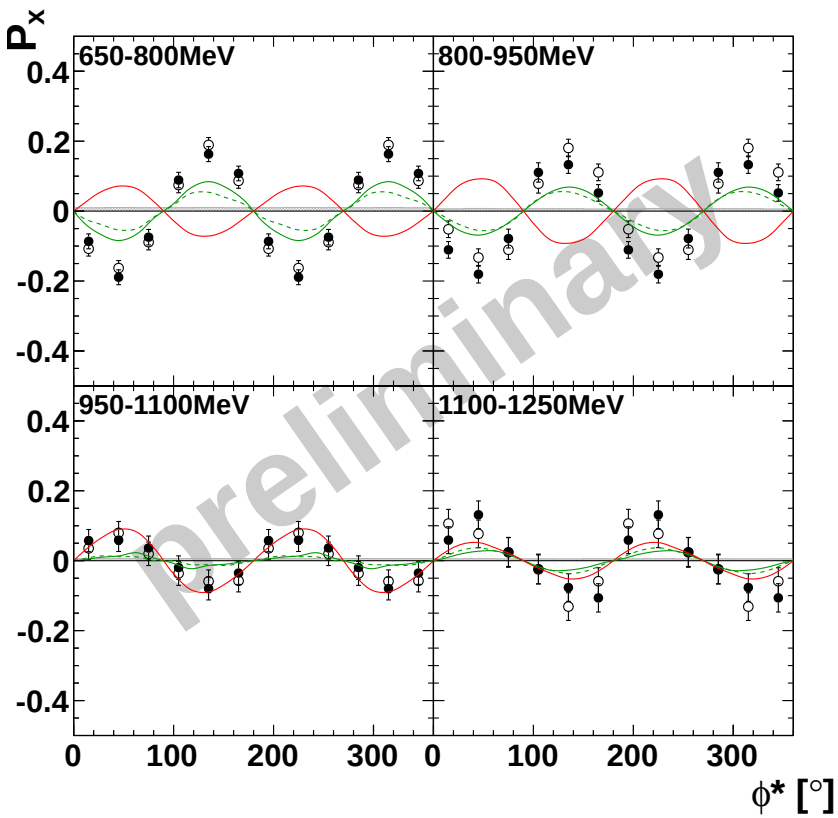
symmetry properties

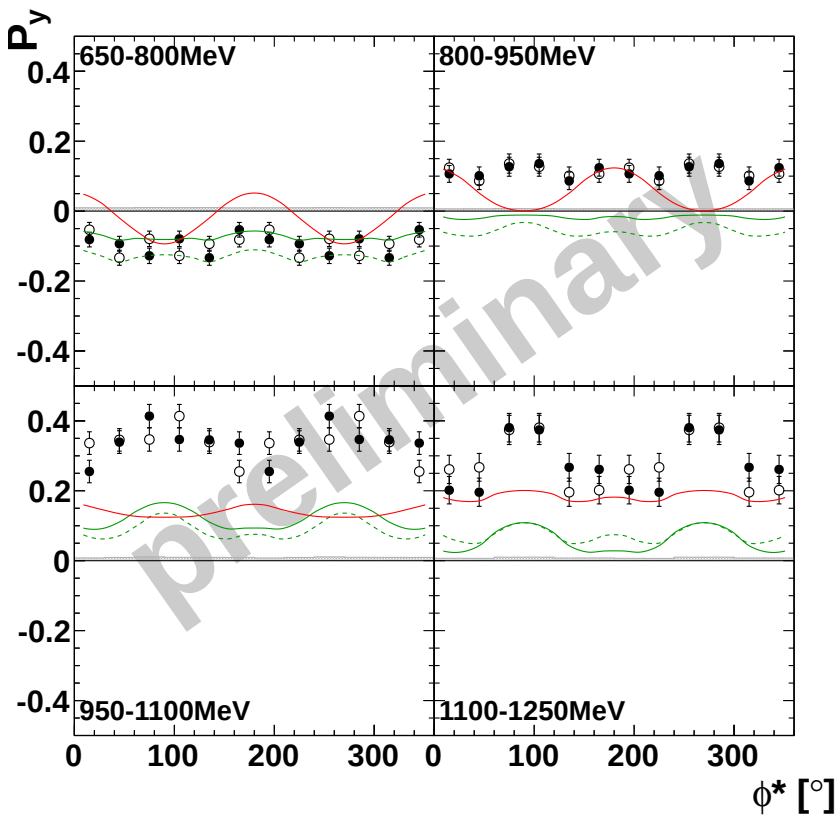
$$I^s(2\pi - \phi^*) = -I^s(\phi^*) \qquad P_x(2\pi - \phi^*) = -P_x(\phi^*)$$
$$I^c(2\pi - \phi^*) = +I^c(\phi^*) \qquad P_y(2\pi - \phi^*) = +P_y(\phi^*)$$

in case of identical particles in the decay plane:

$$O(\phi^*) = O(\phi^* + \pi)$$

$\gamma p \to p\pi^0\pi^0$: Target Asymmetries P_x and P_y





• this analysis ○ symmetrized data — BnGa 2011 — BnGa 2014

- predictions do not match data
- many more polarization observables under analysis

T. Seifen, to be published

Summary

- Double polarization data has been taken with the Crystal Barrel/TAPS experiment at ELSA:
  - longitudinally or transversely polarized target
  - linearly or circularly polarized photon beam
- π^0 photoproduction: precision measurements
  $\rightsquigarrow$ large impact on PWA:
  - significantly smaller errors on multipoles
  - better determination of resonance parameters
- η photoproduction: first data for many observables
  $\rightsquigarrow$ important constraints for the PWA
  - $N^* \to \eta N$ branching ratios
- Multi-meson photoproduction, e.g. $\pi^0\pi^0$:
  $\rightsquigarrow$ just the tip of the iceberg
- Detector upgrade in progress
  Access to more final states (including off the neutron)

Thank you for your attention!