Measurement of the beam asymmetry Σ in π^0- and η-photoproduction

Farah Noreen Afzal
for the
CBELSA/TAPS collaboration

HISKP, University of Bonn

05/25/2015

Outline

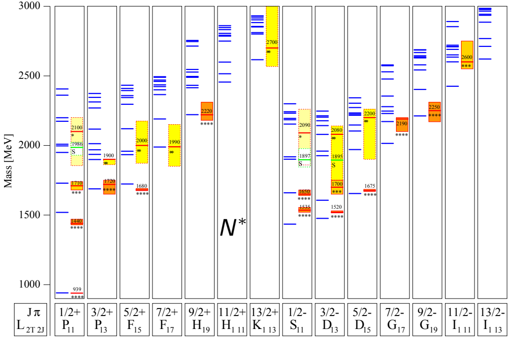
1. Motivation
2. The CBELSA/TAPS experimental setup
3. Event selection
4. Determination of the beam asymmetry Σ
5. Preliminary results

Why baryon spectroscopy?

Goal: Understanding nucleon excitation spectra
$\leftrightarrow$ Understanding dynamics of the constituents inside the nucleon

- many more resonances expected in quark models or lattice QCD than experimentally observed
- What are the relevant degrees of freedom?
- most resonances observed in πN $\rightarrow$ some resonances might not couple to πN

Quark model vs. experimental data

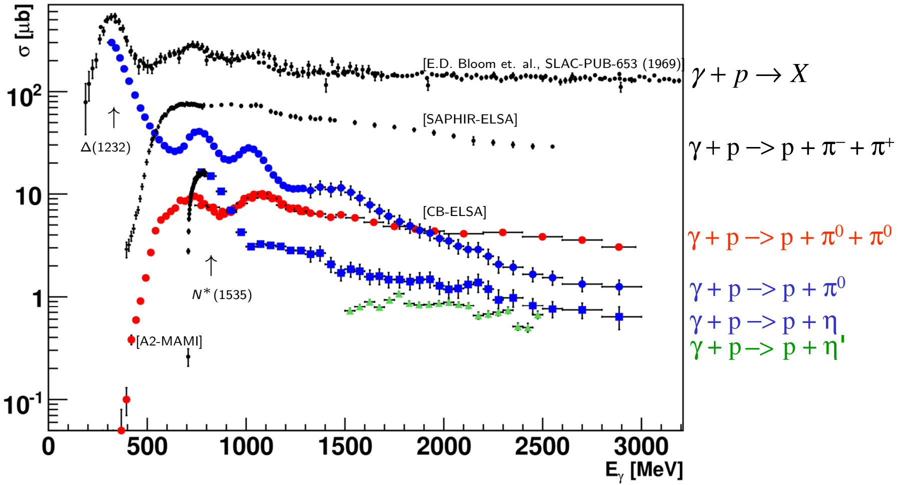


U. Loering, B.C. Metsch, H.R. Petry, Eur.Phys.J.A10:395-446,2001

Photoproduction reactions are excellent tool to probe excitation spectra!

Photoproduction reactions

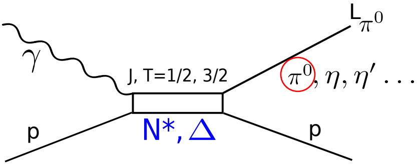
Study of different reaction channels gives access to different resonant structures
$\Rightarrow$ Worldwide effort to get high precision data (ELSA, JLab, MAMI,...)



Why study π^0 and η in the final state?

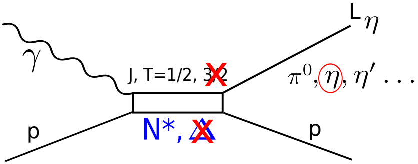
π^0-photoproduction

- high cross section
  $\rightarrow$ Large statistics



η-photoproduction

- η (T=0) $\rightarrow$ exclusive access to intermediate states N^* with T=1/2
- low contributions from non-resonant terms

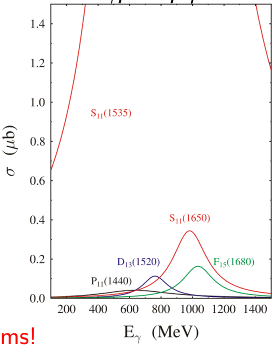


Importance of polarization observables

- Scattering amplitude $f \longleftrightarrow$ 4 complex amplitudes (CGLN amplitudes)
  $f(F_1(W,\cos\theta_{cm}), F_2(W,\cos\theta_{cm}), F_3(W,\cos\theta_{cm}), F_4(W,\cos\theta_{cm}))$
- PWA: $F_1 = \sum_{l=0}^{\infty}(lM_{l+} + E_{l+})P'_{l+1} + [(l+1)M_{l-} + E_{l-}]P'_{l-1}$
  - $E_{l\pm}(W), M_{l\pm}(W)$: Multipoles
  - $P'_{l\pm 1}(\cos\theta_{cm})$: Legendre polynomials
- Measurable observables $\longleftrightarrow$ Multipoles $\longleftrightarrow$ Resonance parameters

Photon polarization		Target polarization			Recoil nucleon polarization			Target and recoil polarizations			
		X	Y	Z(beam)	X'	Y'	Z'	X' X	X' Z	Z' X	Z' Z
unpolarized	σ	-	T	-	-	P	-	$T_{x'}$	$L_{x'}$	$T_{z'}$	$L_{z'}$
linear	$-\Sigma$	H	(-P)	-G	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(L_{x'})$	$(-T_{x'})$
circular	-	F	-	-E	$C_{x'}$	-	$C_{z'}$	-	-	-	-

$\gamma p \to p\eta$

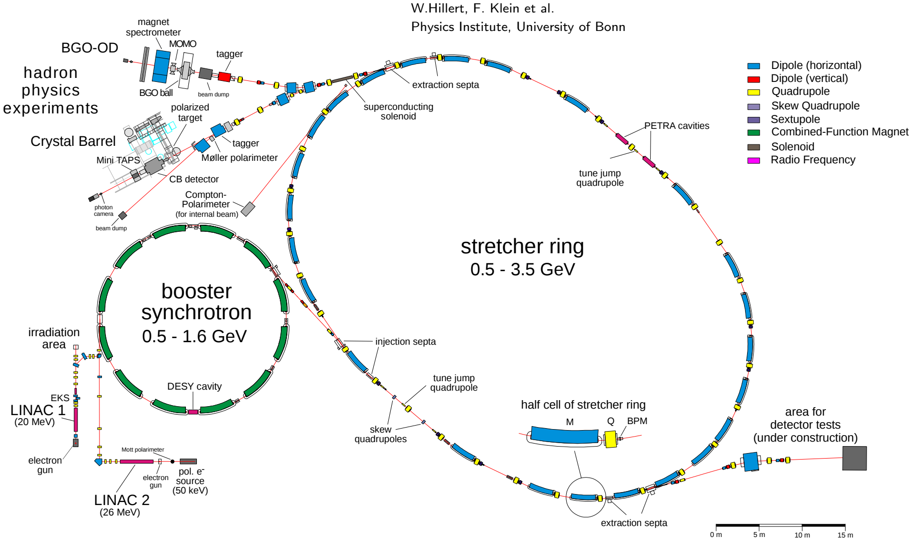


$$\sigma \sim |E_{0+}|^2 + |E_{1+}|^2 + |M_{1+}|^2 + |M_{1-}|^2 + \ldots$$

$$\Sigma \sim -2E^*_{1+}M_{1+} + 2M^*_{1-}E_{1+} - 2M^*_{1-}M_{1+} + \ldots$$

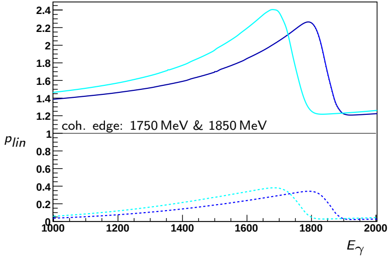
$\Rightarrow$Polarization observables are sensitive to interference terms!

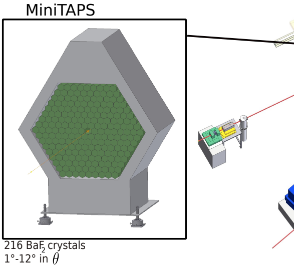
The Electron Stretcher Accelerator (ELSA)

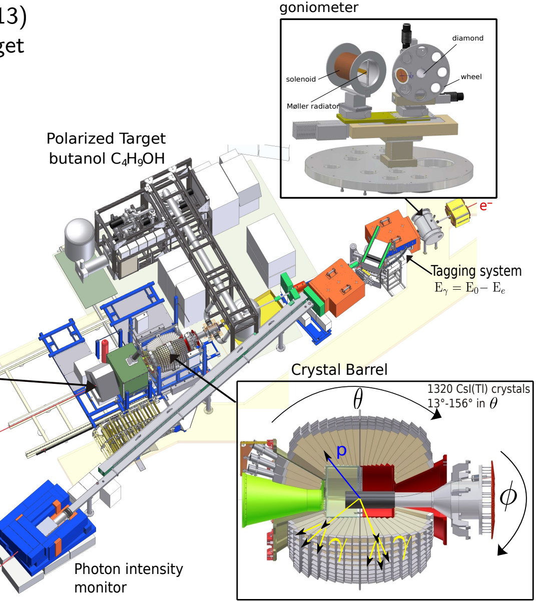


The CBELSA/TAPS experiment at ELSA in Bonn

Measurement of Σ (July-October 2013)
Linearly polarized photons + lH_2 target



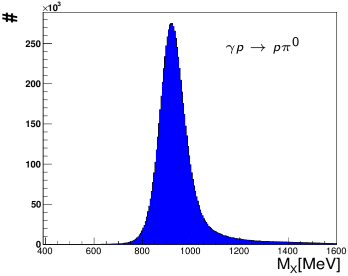


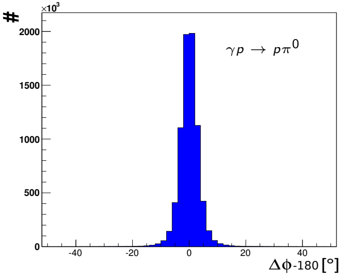


Selection process of $\gamma p \rightarrow \gamma\gamma p$

Selected events had to fulfill kinematic constraints:

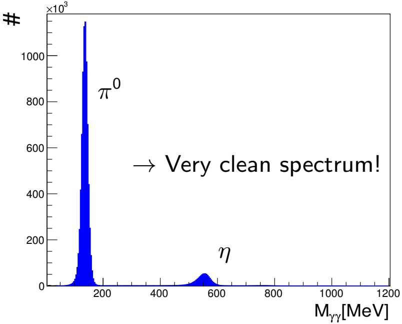
- 3 hits in calorimeters (p+2γ)
- Proton: calculated as missing particle of $\gamma p \rightarrow \gamma\gamma X$
- Angular-cuts:
  - Agreement of missing mass and measured charged particle in θ
  - Coplanarity-cut: $\Delta\Phi = |\Phi_{\gamma\gamma} - \Phi_p| = 180^\circ$ within 2.5σ
- Beam photon: $E_\gamma > E_{prod.threshold}$ and time coincidence with reaction products

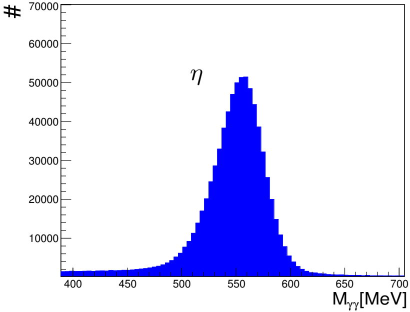




Selection process of $\gamma p \to \gamma\gamma p$

- The $\gamma\gamma$ invariant mass:



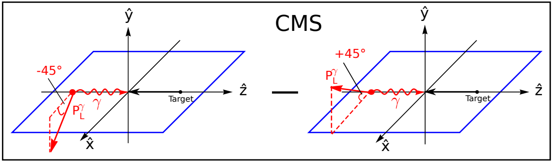


- $5.4 \cdot 10^6$ π^0-events were selected
- $6.6 \cdot 10^5$ η-events were selected

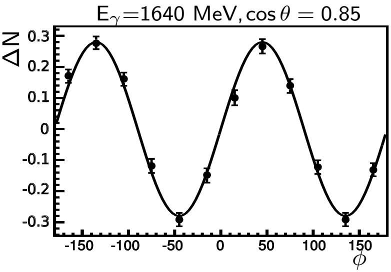
Determination of the beam asymmetry Σ

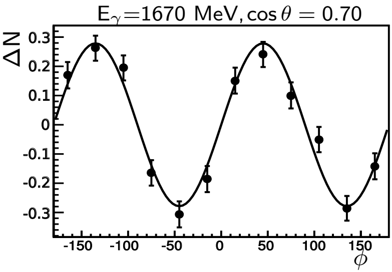
- linearly polarized beam, unpolarized liquid hydrogen target

$$\Delta N = \frac{N_{-45^\circ} - N_{+45^\circ}}{N_{-45^\circ} + N_{+45^\circ}} = p_\gamma^{lin} \Sigma \sin(2\phi)$$

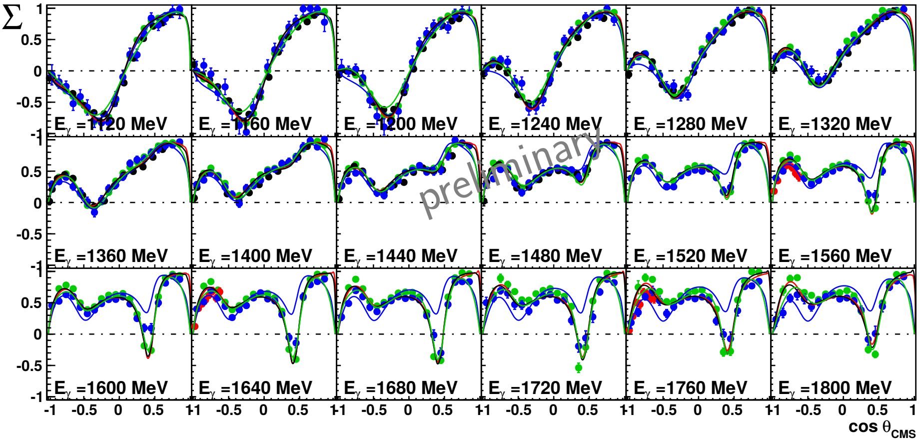


$\gamma p \to \pi^0 p$ $\qquad\qquad$ $\gamma p \to \eta p$





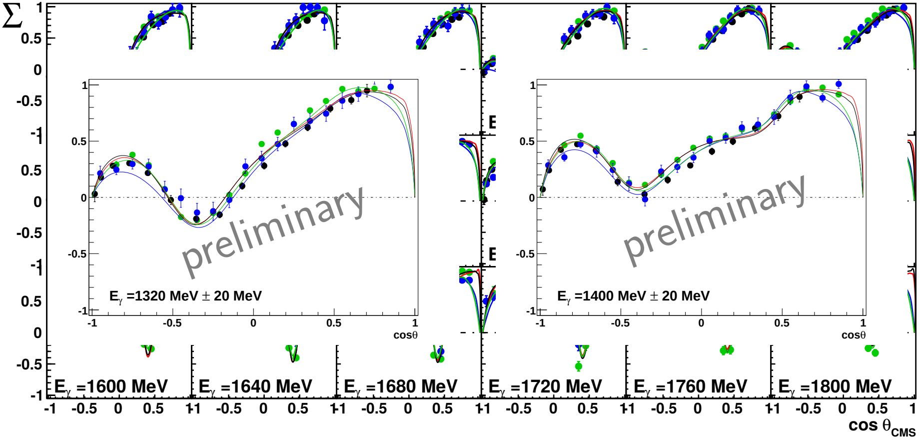
The beam asymmetry Σ in π^0-photoproduction



• this work • CLAS data (M.Dugger et al., Phys.Rev.C 88, 2013) • GRAAL data (O. Bartalini et al., Eur.Phys.J.A26, 399, 2005)
• LEPS data (M.Sumihama et al., PLB657, 32, 2007)

PWA solutions: —BnGa(2014_01) —BnGa(2014_02) —SAID(CM12) —2015 Jülich model Fit B

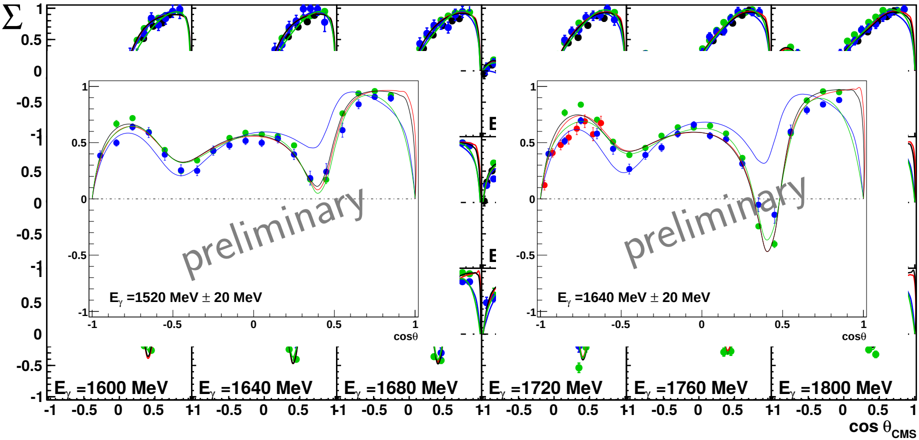
The beam asymmetry Σ in π^0-photoproduction



● this work ● CLAS data (M.Dugger et al., Phys.Rev.C 88, 2013) ● GRAAL data (O. Bartalini et al., Eur.Phys.J.A26, 399, 2005) ● LEPS data (M.Sumihama et al., PLB657, 32, 2007)

PWA solutions: —BnGa(2014_01) —BnGa(2014_02) —SAID(CM12) —2015 Jülich model Fit B

The beam asymmetry Σ in π^0-photoproduction

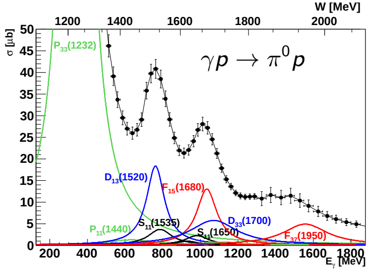


• this work • CLAS data (M.Dugger et al., Phys.Rev.C 88, 2013) • GRAAL data (O. Bartalini et al., Eur.Phys.J.A26, 399, 2005)
• LEPS data (M.Sumihama et al., PLB657, 32, 2007)

PWA solutions: —BnGa(2014_01) —BnGa(2014_02) —SAID(CM12) —2015 Jülich model Fit B

Truncated PWA (which L_{max} is seen in the data?)

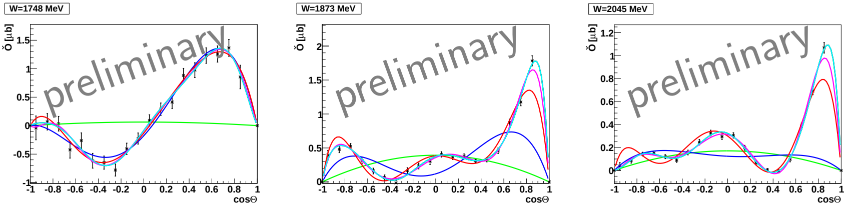
$$\hat{\Sigma}(W, \cos\theta) = \Sigma(W, \cos\theta) \cdot \frac{d\sigma}{d\Omega}(W, \cos\theta) = \sum_{k=2}^{2+2L_{max}} (a_L(W))_k \cdot P_k^2(\cos\theta)$$



four-star resonances listed in PDG

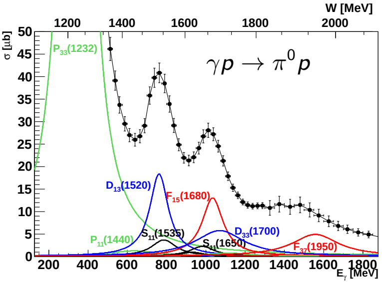
$L_{max} = 0$ S-wave	$L_{max} = 1$ P-wave	$L_{max} = 2$ D-wave
$S_{11}(1535)$	$P_{11}(1440)$	$D_{13}(1520)$
$S_{11}(1650)$	$P_{13}(1720)$	$D_{15}(1675)$
$S_{31}(1620)$	$P_{33}(1232)$	$D_{33}(1700)$

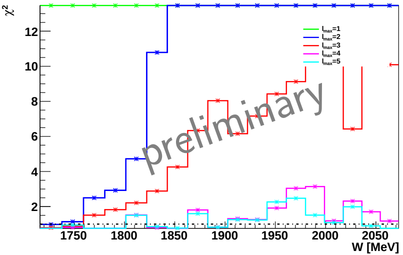
$L_{max} = 3$ F-wave	$L_{max} = 4$ G-wave
$F_{15}(1680)$	$G_{17}(2190)$
$F_{35}(1905)$	
$F_{37}(1950)$	



Truncated PWA (which L$_{max}$ is seen in the data?)

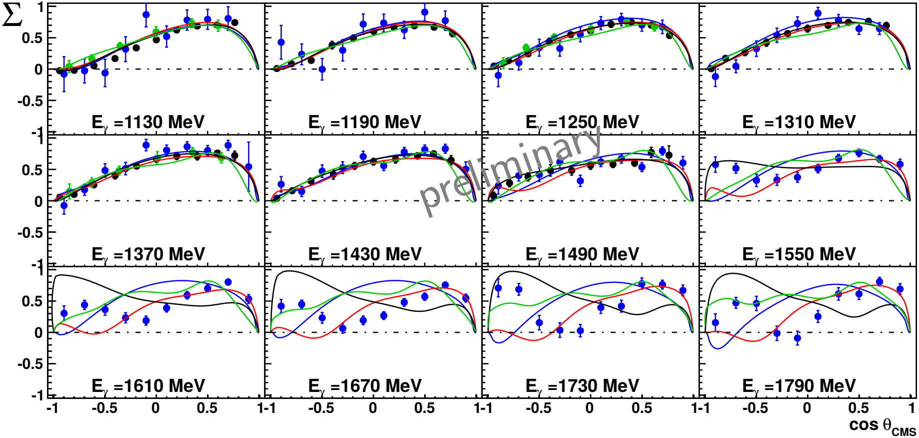
$$\hat{\Sigma}(W,\cos\theta) = \Sigma(W,\cos\theta)\cdot\frac{d\sigma}{d\Omega}(W,\cos\theta) = \sum_{k=2}^{2+2L_{max}}(a_L(W))_k\cdot P_k^2(\cos\theta)$$





- A.V. Anisovich et al. find evidence for the one-star resonance $\Delta(2200)7/2^-$ in a coupled channel analysis including the new beam asymmetry data in $\pi^0 p$ and $\pi^+ n$ [arXiv:1503.05774]

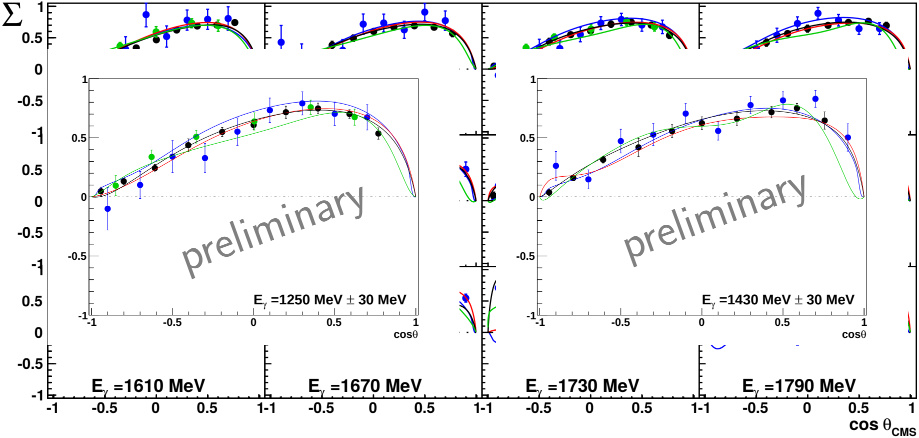
The beam asymmetry Σ in η-photoproduction



• this work • GRAAL data (O.Bartalini et al., Eur.Phys.J. A33, 169, 2007) • CB-ELSA (D.Elsner et al., Eur.Phys.J. A33, 147, 2007)

PWA solutions: —BnGa(2014_01) —BnGa(2014_02) —SAID(GE09) —2015 Jülich model Fit B

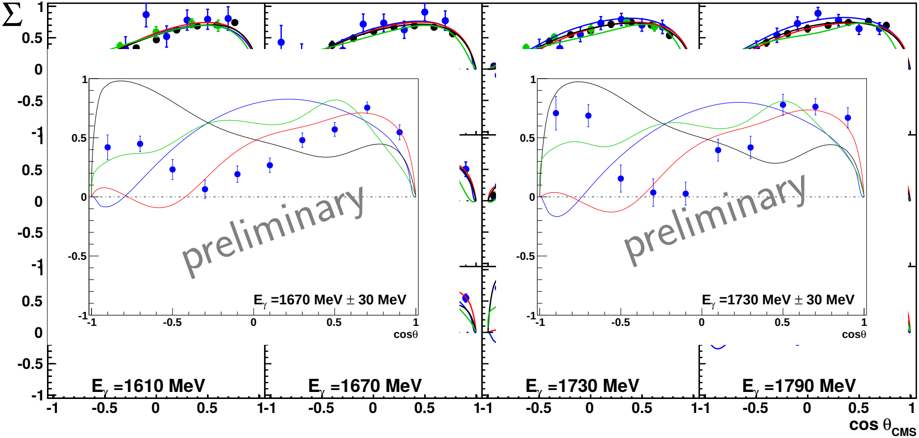
The beam asymmetry Σ in η-photoproduction



• this work • GRAAL data (O.Bartalini et al., Eur.Phys.J. A33, 169, 2007) • CB-ELSA (D.Elsner et al., Eur.Phys.J. A33, 147, 2007)

PWA solutions: —BnGa(2014_01) —BnGa(2014_02) —SAID(GE09) —2015 Jülich model Fit B

The beam asymmetry Σ in η-photoproduction



● this work ● GRAAL data (O.Bartalini et al., Eur.Phys.J. A33, 169, 2007) ● CB-ELSA (D.Elsner et al., Eur.Phys.J. A33, 147, 2007)

PWA solutions: —BnGa(2014_01) —BnGa(2014_02) —SAID(GE09) —2015 Jülich model Fit B

Summary and Outlook

- The beam asymmetry Σ was determined in π^0- and η-photoproduction by the CBELSA/TAPS collaboration
- Results:
  - very precise π^0 data was measured for E_γ =1100 MeV - 1800 MeV
  - evidence for the one-star $\Delta(2200)7/2^-$ resonance
  - precise η data was measured for E_γ =1100 MeV - 1800 MeV
  - η data can not be described by different PWA models
  - data will provide new constraints for the PWA
- Outlook:
  - Beam asymmetry Σ in η'-photoproduction

Thank you!

SFB/TR 16

gefördert durch DFG Deutsche Forschungsgemeinschaft

Truncated PWA (which L_{max} is seen in the data?)