Measurement of the beam asymmetry Σ in η- and η'-photoproduction

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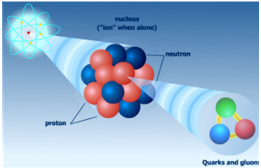
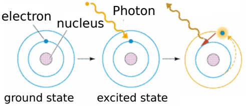
Outline

Why baryon spectroscopy?

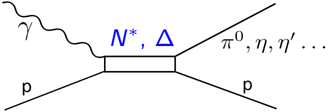


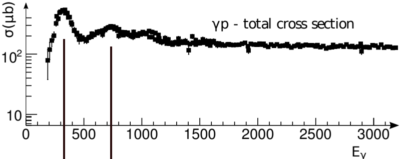
Study dynamics inside atom



Argon:

Study dynamics of constituents inside the nucleon

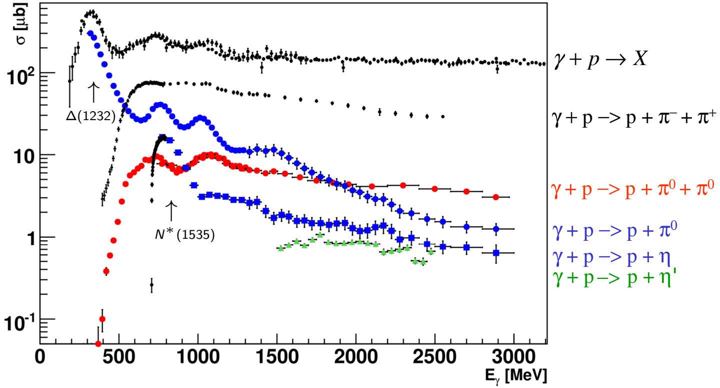




Difficulty: Due to short lifetime, resonances are broad and strongly overlap

Photoproduction reactions

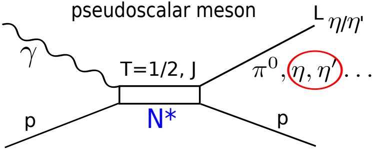
Study of different reaction channels gives access to different resonant structures
⇒ Worldwide effort to get high precision data (ELSA, JLab, MAMI,...)



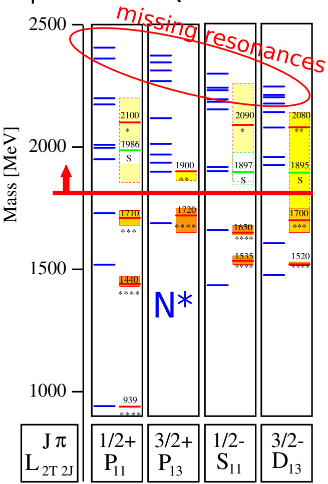
Why study η and η' in the final state?

- η/η' (T=0) $\rightarrow$ exclusive access to intermediate states N^* with T=1/2
- $\eta'(958\,\mathrm{MeV})$ probe mass range $W > 1896\,\mathrm{MeV}$
- low contributions from non-resonant terms

Photoproduction of single pseudoscalar meson



Experiment vs. Quark models

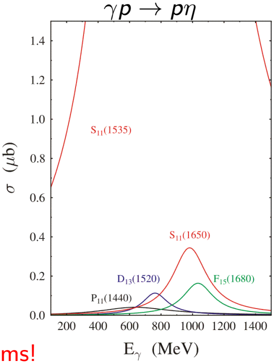


U. Loering et al., Eur.Phys.J. A, 10:395-446, 2001

Which observables to measure?

- 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
  - $P'_{l\pm1}(\cos\theta_{cm})$: 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	$C_{x'}$	-	$C_{z'}$	-	-	-	-

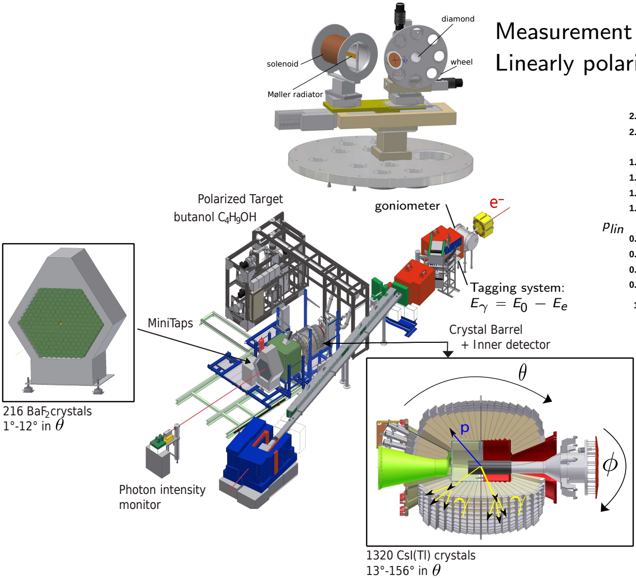


$$\sigma \sim |E_{0+}|^2 + |E_{1+}|^2 + |M_{1+}|^2 + |M_{1-}|^2 + \ldots$$

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

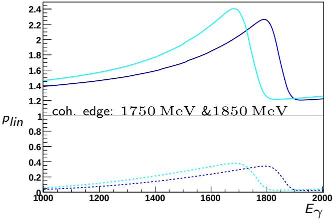
$\Rightarrow$Polarization observables are sensitive to interference terms!

The CBELSA/TAPS experiment at ELSA in Bonn



Measurement of Σ (July-October 2013)

Linearly polarized photons + H_2 target



Decay modes of η and η'

The CBELSA/TAPS experiment is ideally suited for the detection of photons
$\Rightarrow$ Choose decay modes with photons in the final state for analysis

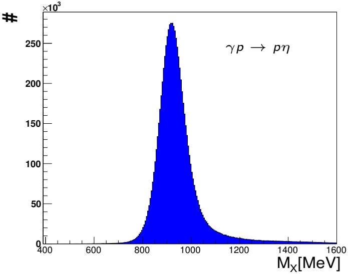
No.	decay mode of η	Branching ratio
I	$\gamma\gamma$	39.31%
II	$\pi^0\pi^0\pi^0(\rightarrow 6\gamma)$	32.57% (30.65%)
III	$\pi^+\pi^-\pi^0$	22.74%
IV	$\pi^+\pi^-\gamma$	4.60%

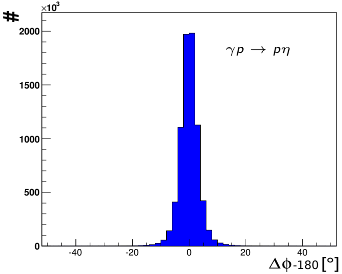
No.	decay mode of η'	Branching ratio
I	$\pi^+\pi^-\eta$	43.2%
II	$\rho^0\gamma(\rightarrow \pi^+\pi^-\gamma)$	29.3% (29.3%)
III	$\pi^0\pi^0\eta(\rightarrow 6\gamma)$	21.7% (8.6%)
IV a)	$\omega\gamma(\rightarrow \pi^+\pi^-\pi^0\gamma)$	2.8% (2.5%)
b)	$\omega\gamma(\rightarrow \pi^0\gamma\gamma)$	2.8% (0.23%)
V	$\gamma\gamma$	2.2%

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

Selected events had to fulfill kinematic constraints:

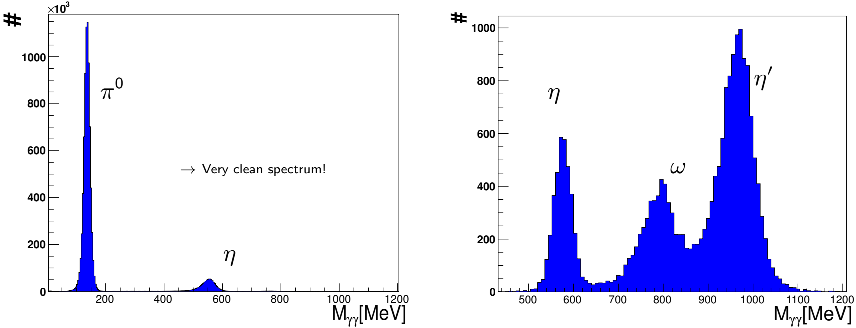
- 3 hits in calorimeters (p+2γ)
- Proton: calculated as missing particle of $\gamma p \rightarrow \gamma\gamma X$
- Angular-cuts:
    - Agreement of missing mass and measured charged particle in θ
    - Coplanarity-cut: $\Delta\Phi = |\Phi_{\gamma\gamma} - \Phi_p| = 180^\circ$ within 2.5σ
- Beam photon: $E_\gamma > E_{prod.threshold}$ 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
- $1.0 \cdot 10^4$ η'-events were selected with a background contamination of 30% (mainly $\pi^0\pi^0$)

Determination of the beam asymmetry Σ

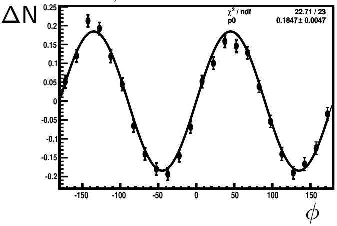
- linearly polarized beam, unpolarized liquid hydrogen target

$$\Delta N = \frac{N_{-45^\circ} - N_{+45^\circ}}{N_{-45^\circ} + N_{+45^\circ}}$$

$$= p_\gamma^{lin} \Sigma \sin(2\phi)$$

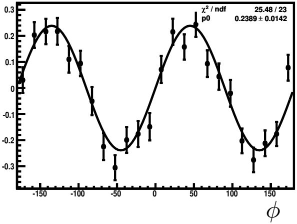
$\gamma p \to \pi^0 p$

E_γ=1600 MeV, $\cos\theta = -0.15$



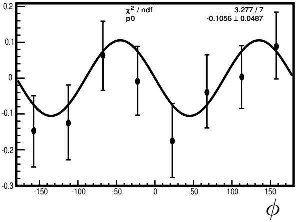
$\gamma p \to \eta p$

E_γ=1600 MeV, $\cos\theta = 0.44$

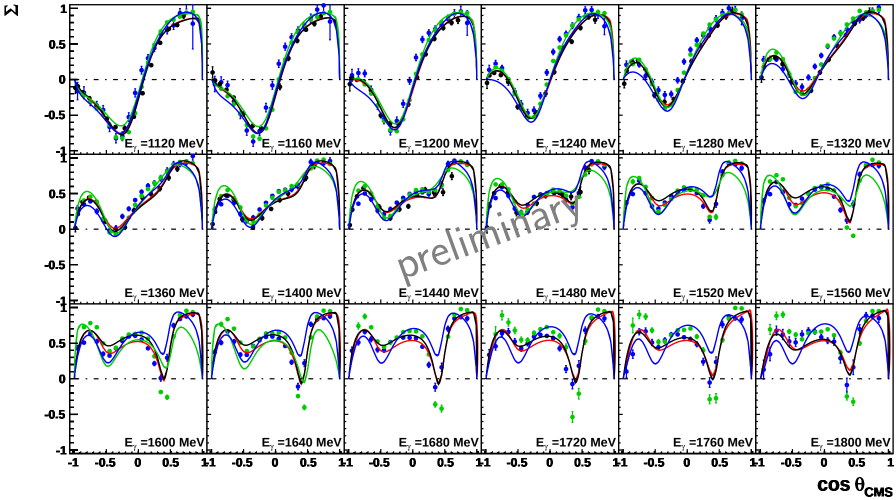


$\gamma p \to \eta' p$

E_γ=1600 MeV, $\cos\theta = -0.7$



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)

PWA solutions: —BnGa(2011_01) —BnGa(2011_02) —SAID(CM12) —MAID2007

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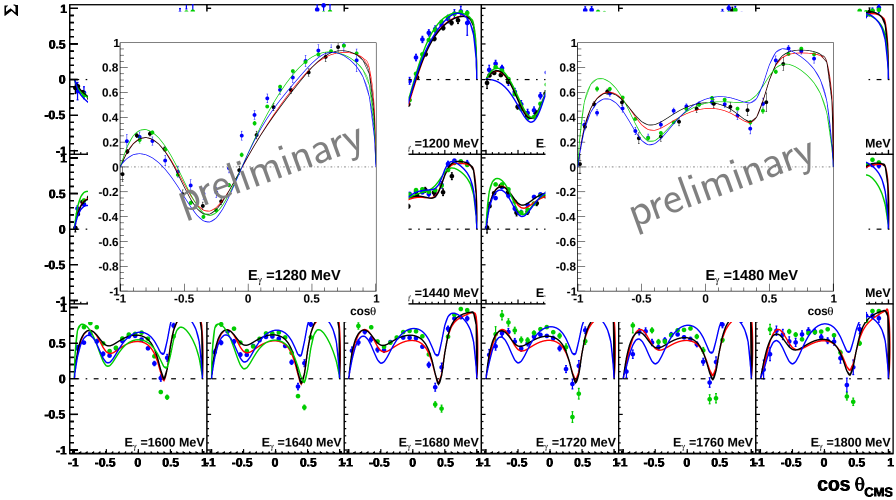

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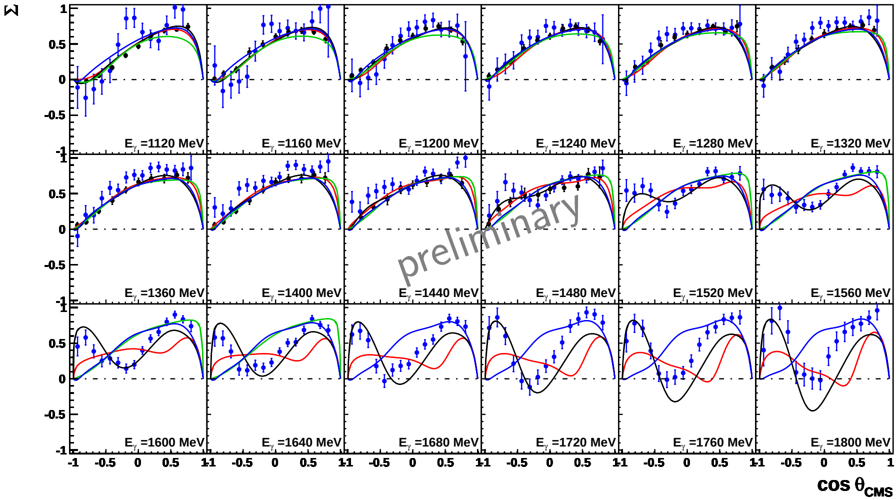
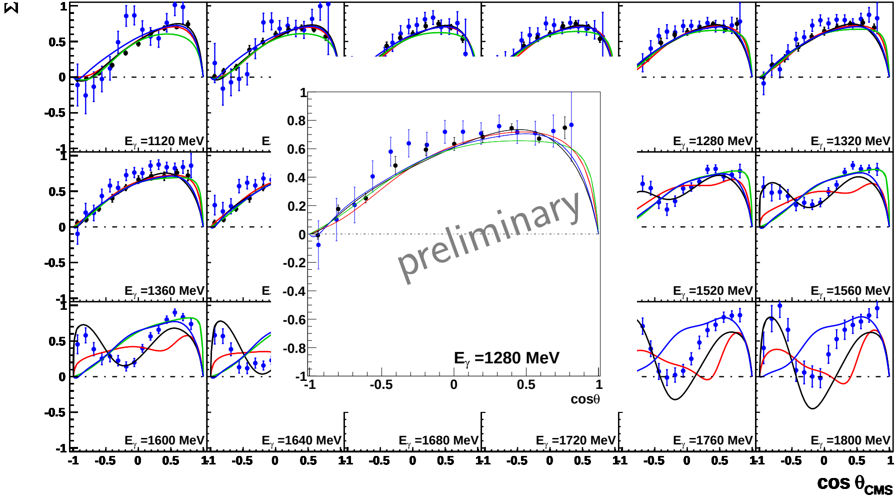
The beam asymmetry Σ in η-photoproduction



• this work • GRAAL data (O.Bartalini et al., Eur.Phys.J. A33, 169, 2007)

PWA solutions: —BnGa(2011_01) —BnGa(2011_02) —SAID(E429) —η-MAID

The beam asymmetry Σ in η-photoproduction



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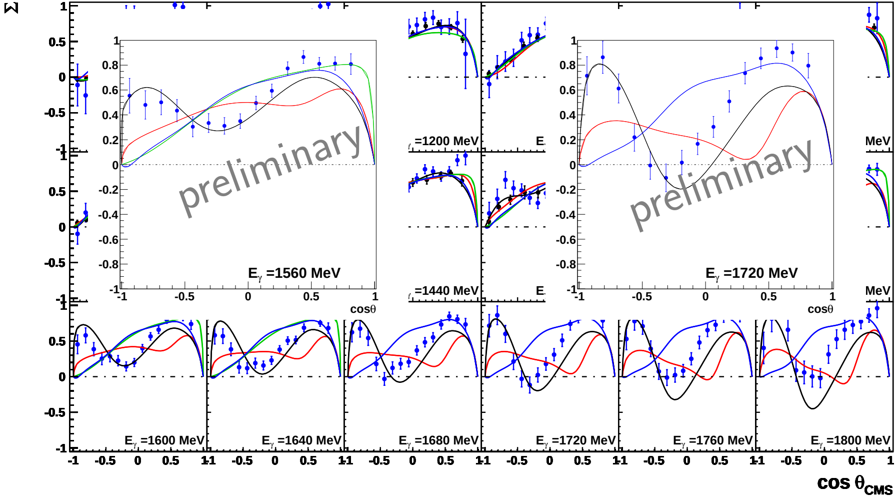

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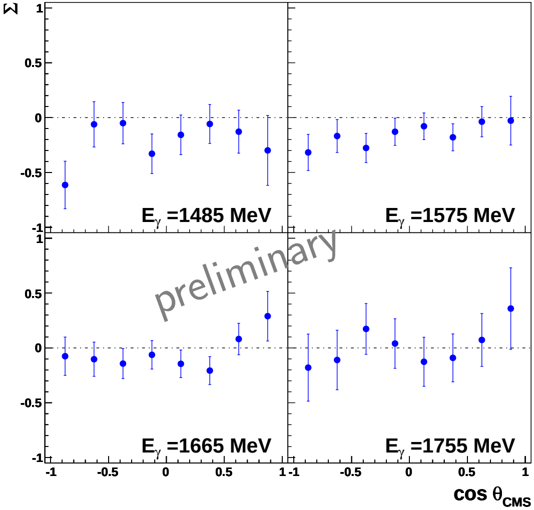

Summary and Outlook

- The beam asymmetry Σ was determined in π^0-, η- and η'-photoproduction
- Results:
  - very precise π^0 data was measured for $E_\gamma = 1100\,\mathrm{MeV}$ - $1800\,\mathrm{MeV}$
  - precise η data was measured for $E_\gamma = 1100\,\mathrm{MeV}$ - $1800\,\mathrm{MeV}$
  - η data can be described by BnGa(2011_01) model for $E_\gamma = 1520\,\mathrm{MeV}$ - $1640\,\mathrm{MeV}$
  - the beam asymmetry is very small in η'-photoproduction
  - data will provide new constraints for the PWA
- Enhancement of statistics with additional decay modes $\eta \rightarrow \pi^0\pi^0\pi^0 \rightarrow 6\gamma$ and $\eta' \rightarrow \pi^0\pi^0\eta \rightarrow 6\gamma$ possible