Recent Polarization Observable Results in η- and η'-photoproduction off the proton

Master thesis for the CBELSA/TAPS collaboration

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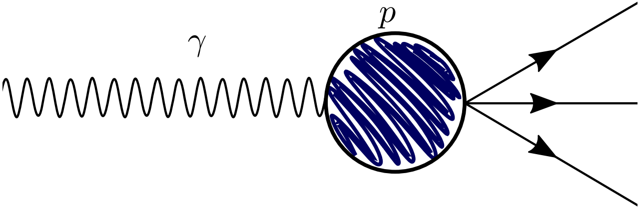
Setting the scene

The Standard Model of Particle Physics

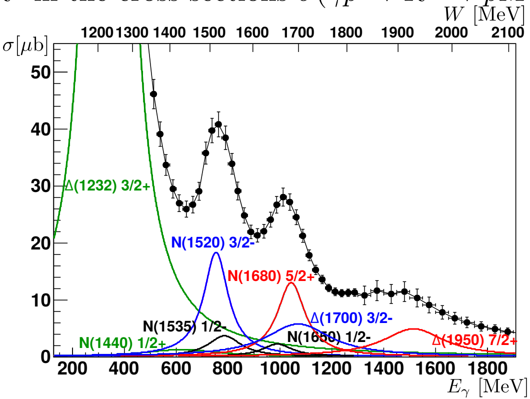
- matter consists of 12 (anti-)*fermions*
- quarks interact via *strong interaction*
- form bound states: mesons ($q\bar{q}$) and baryons (qqq)

baryon spectroscopy (photoproduction) gives insight in strong interaction



Setting the scene

Observe resonances R^* in the cross sections $\sigma(\gamma p \to R^* \to pM)$



Total cross section $\sigma(\gamma p \to R^* \to p\pi^0)$ [Wunderlich et al. 2017]

→goal: (help to) identify contributing resonances as strong bound states!

1. Theoretical Basics
2. Experimental Setup
3. Preliminary results
4. Conclusion

Theoretical Basics

Unpolarized differential cross section

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \frac{1}{4}\rho \sum_{\text{spins}} |\langle f|\mathcal{F}|i\rangle|^2,$$

where

$$\mathcal{F} = i(\vec{\sigma}\cdot\vec{\epsilon})F_1 + (\vec{\sigma}\cdot\hat{q})(\vec{\sigma}\cdot(\hat{k}\times\vec{\epsilon}))F_2 + i(\vec{\sigma}\cdot\hat{k})(\hat{q}\cdot\vec{\epsilon})F_3 + i(\vec{\sigma}\cdot\hat{q})(\hat{q}\cdot\vec{\epsilon})F_4$$

F_i : complex CGLN Amplitudes

[Chew et al. 1957]

$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} \in \mathbb{R}$, not sufficient do determine $\mathcal{F}$ unambiguously
$\rightarrow$ Polarization Observables

Theoretical Basics

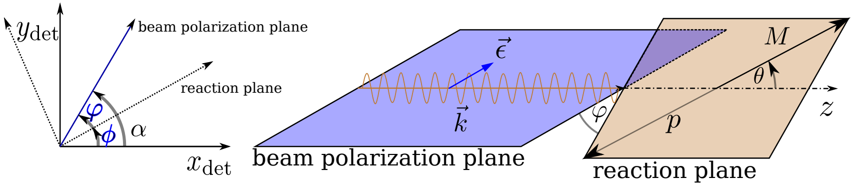
- resonances are broad, overlapping, require sophisticated analysis (PWA)
- constraints feeding the analysis can be derived from Polarization observables

Beam asymmetry $\boldsymbol{\Sigma}$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}(\varphi) = \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}_0 \left[1 - p_\gamma^{\mathrm{lin}} \boldsymbol{\Sigma} \cos(2\varphi)\right]$$

polarization angle φ, polarization degree p_γ^{lin}

[Sandorfi et al. 2011]



Definition of the polarization angle

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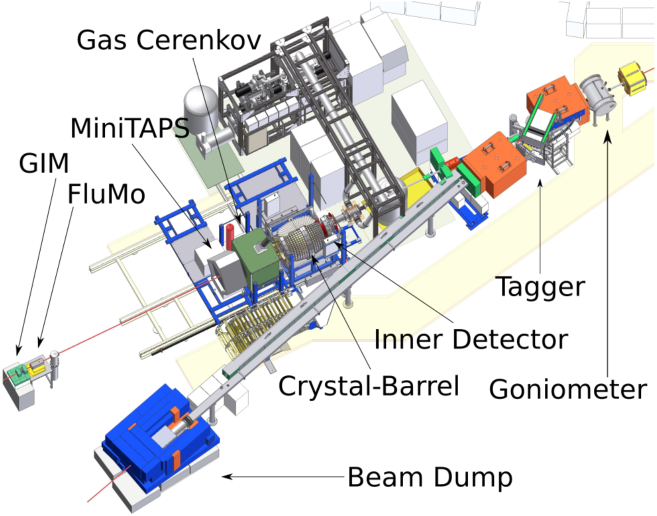
Experimental setup

- generate photon beam from accelerated electrons via bremsstrahlung, with $E_\gamma \leq 3.2\,\mathrm{GeV}$
- photon beam impinges on liquid butanol target: $\gamma p \to pM \to pX$
- measure decay products X of different final states: $M = \pi^0/\eta/\eta'/\ldots$



Overview of the experimental area, adapted from [Walther 2022]

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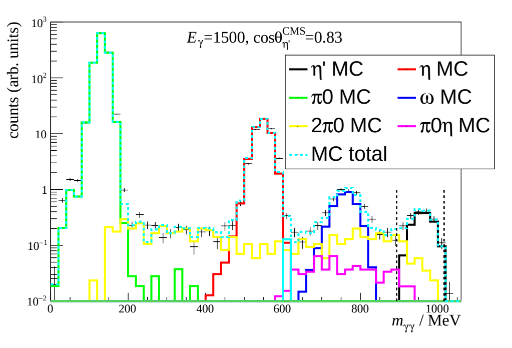
Preliminary results

Event selection (η')

analysis performed in 2x6 bins of $(E_\gamma, \cos\theta_{\eta'}^{\mathrm{CMS}})$, $E_\gamma \in [1400, 1800]$ MeV

- 3 detector hits, 2 uncharged, 1 charged
- coincident detector hits
- kinematic cuts derived from energy-momentum conservation $p_\gamma + p_p = p'_p + p_{\eta'}$
- additional cuts to reduce background contributions



Preliminary results (η')

Method

- measure in 2 distinct orthogonal polarization settings $\perp, \parallel$
- χ^2-fit to event yield asymmetries
  $A(E_\gamma, \theta, \phi) = \frac{N^\perp(E_\gamma,\theta,\phi) - N^\parallel(E_\gamma,\theta,\phi)}{p_\gamma^\parallel N^\perp(E_\gamma,\theta,\phi) + p_\gamma^\perp N^\parallel(E_\gamma,\theta,\phi)} = \Sigma(E_\gamma, \theta) \cos\left(2\left(\alpha^\parallel - \phi\right)\right)$

plot of event yield asymmetries and sigma

Preliminary results (η)

Event selection (η)

analysis performed in 11x12 bins of ($E_\gamma, \cos\theta$) by Farah Afzal *cite Farahs Paper*

Method

- fit to event yield asymmetries using BAYESIAN inference
- $p(\theta|y) \propto \mathcal{L}(\theta, y) \cdot \pi(\theta)$, obtained using Markov-Chain-Monte-Carlo (MCMC)

plot of eta sigma

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