

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

Master thesis for the CBELSA/TAPS collaboration

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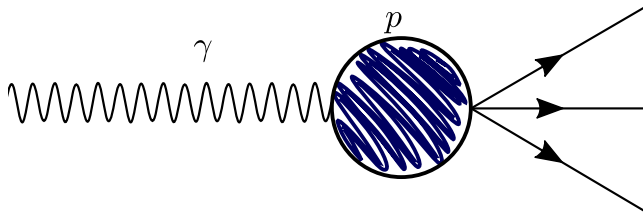
30th March 2022

Setting the scene

The Standard Model of Particle Physics

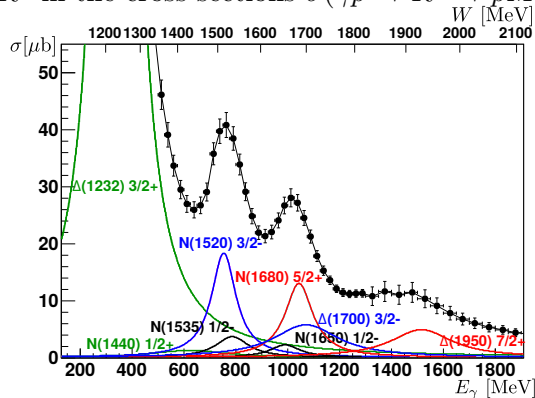
- ▶ matter consists of 12 (anti-) *fermions*
- ▶ quarks interact via *strong interaction*
- ▶ form bound states: mesons ($q\bar{q}$) and baryons (qqq)

baryon spectroscopy (photoproduction) gives insight in strong interaction



Setting the scene

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



Total cross section $\sigma(\gamma p \rightarrow R^* \rightarrow p\pi^0)$ [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

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Theoretical Basics

Unpolarized differential cross section

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

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]

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

Theoretical Basics

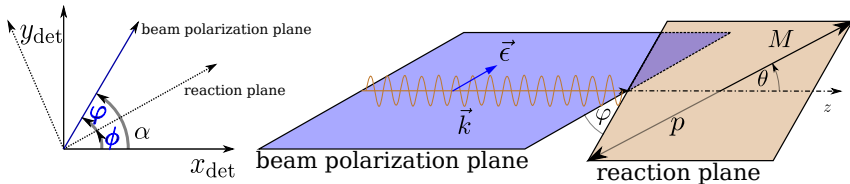
- ▶ resonances are broad, overlapping, require sophisticated analysis (PWA)
- ▶ constraints feeding the analysis can be derived from Polarization observables

Beam asymmetry Σ

$$\frac{d\sigma}{d\Omega}(\varphi) = \frac{d\sigma}{d\Omega_0} \left[1 - p_{\gamma}^{\text{lin}} \Sigma \cos(2\varphi) \right]$$

polarization angle φ , polarization degree p_{γ}^{lin}

[Sandorfi et al. 2011]

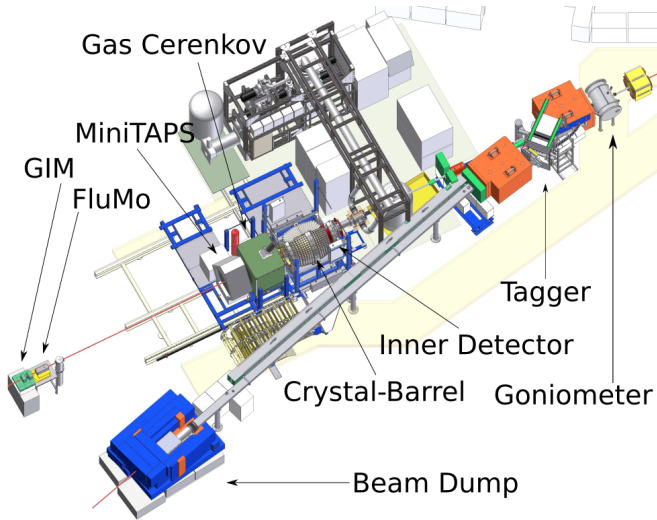


Definition of the polarization angle

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Experimental setup

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



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

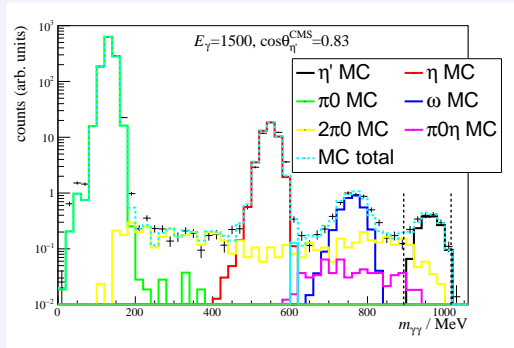
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Preliminary results

Event selection (η')

analysis performed in 2×6 bins of $(E_\gamma, \cos \theta_{\eta'}^{\text{CMS}})$, $E_\gamma \in [1400, 1800]$ 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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