Status and Recent Results from the CBELSA/TAPS Experiment at ELSA

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Outline

• Introduction

• Recent Results from CBELSA/TAPS
  \[ \gamma p \rightarrow p\pi^0 \]
  \[ \gamma p \rightarrow p\eta \]

• Summary

• Outlook – CB Upgrade
Experimental Program for N*:

Common effort of ELSA, JLab and MAMI:
- Precise data for different final states ($\rho\pi^0$, $n\pi^+$, $\rho\eta$, $K^+\Lambda$, $\rho\pi^0\pi^0$, ...).
- Polarization experiments (beam, target and recoil).
- Find a unique PWA solution.
Unique PWA Solution - Problems

8 carefully chosen polarization observables have to be measured in order to determine the full production CGLN amplitudes ($F_1$, $F_2'$, $F_3$ and $F_4$).

Problem scenarios:

- **From $\pi$ threshold (>144 MeV) till $\Delta^+(1232)$:**
  Additional constraints:
  
  a) **s- and p-wave approximation sufficient**
  b) **Fermi-Watson theorem (photoproduction)**

$$M'_{l+}(W)=|M_{l+}(W)|e^{i\delta_{lJ}+i\pi}, \delta_{lJ} \text{ is } \pi N' \text{ scattering phase}$$

$$\gamma+N \rightarrow N'+\pi$$

$$\pi+N \rightarrow N'+\pi \rightarrow \text{ same } I,J \text{ in final state, same scattering phase}$$

Two observables sufficient for „complete data base“:
- differential cross section: $d\sigma/d\Omega$
- beam asymmetry: $\Sigma$

- **Above $\pi\pi$ threshold (>306 MeV):**
  Fermi-Watson theorem not valid in this range,
  More observables needed to get a unique partial wave solution
Partial Waves for the Resonance $P_{33}^{33}(1232)$

- Energy dep. (global) fit, Hanstein et al
- Energy indep. (local) fit, Hanstein et al
- Exp. analysis, Krahn et al, Mainz 1997

$W_{\text{res}} = 1232$ MeV
To determine all photoproduction amplitudes unambiguously, one has to measure at least 8 polarization observables. [W.-T. Chiang & F. Tabakin, Phys. Rev. C55, 2054 (1997)]

New experiments will deliver data for single and double polarization observables.

ELSA, JLab, MAMI: polarized photons, polarized target, 4π detectors -> access to required observables.
CBELSA/TAPS Setup at ELSA

Polarized Target
Crystal Barrel
+ Inner detector
Goniometer
Tagging system
Forward Detector
Gas Čerenkov Detector
TAPS
Photon intensity monitor
Beam Dump
Access to Polarization Observables

With the CBELSA/TAPS experiment
- The unpolarized cross section \( (\sigma) \),
- 3 single polarization observables \( (\Sigma, T, P) \) and
- 4 double polarization observables \( (H, G, F, E) \)
can be measured.

\[
\frac{d\sigma}{d\Omega} (\theta, \phi) = \frac{d\sigma}{d\Omega} (\theta) \cdot \left[ 1 - P^\text{lin}_\gamma \Sigma(\theta) \cos(2\phi) 
+ P_x \cdot (-P^\text{lin}_\gamma H(\theta) \sin(2\phi) + P^\text{circ}_\gamma F(\theta)) 
+ P_y \cdot (P^\text{lin}_\gamma P(\theta) \cos(2\phi) - T(\theta)) 
- P_z \cdot (-P^\text{lin}_\gamma G(\theta) \sin(2\phi) + P^\text{circ}_\gamma E(\theta)) \right]
\]
Resonance Contributions Beyond $\Delta(1232)$

Reaction:
$$\gamma p \rightarrow p \pi^0$$

Partial wave analysis:
- BnGa
- SAID(SN11)
- MAID

Small discrepancies in total c.s. -> polarization observables
Helicity Dependant Cross Section for $p\pi^0$

Reaction: $\gamma p \rightarrow p\pi^0$

- CBELSA/TAPS (M. Gottschall et al.)

CBELSA/TAPS (M. Gottschall et al.)

![Graphs showing partial wave analysis predictions](image)

- $\sigma_{1/2}$
- $\sigma_{3/2}$

Partial wave analysis predictions:
- BnGa
- SAID(CM12)
- MAID

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17.06.13
Helicity Asymmetry $E$ for $p\pi^0$

\[ E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \]

Reaction: $\gamma p \rightarrow p\pi^0$

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Preliminary Angular Distributions

Partial wave analysis predictions:  
- BnGa  
- SAID(CM12)  
- MAID

CBELSA/TAPS at ELSA (M. Gottschall)

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Helicity Asymmetry $E$ for $p\pi^0$

$$E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$

Reaction: $\gamma p \rightarrow p\pi^0$

partial wave analysis predictions:  
- BnGa  
- SAID(CM12)  
- MAID

CBELSA/TAPS (M. Gottschall)
Asymmetry $G$ for $p\pi^0$
Asymmetry $G$ for $p\pi^0$

- PWA predictions fail already in 2. res. Region
- Below 1 GeV the discrepancies can traced back to the $E_{0^+}$ and $E_{2^-}$ multipoles
- $s$- and $d$-wave contributions

Partial wave analysis predictions:
- Red: BnGa
- Blue: SAID(SN11)
- Black: MAID
Asymmetry $G$ for $p\pi^0$ 

$\theta_\pi = 90 \pm 5^\circ$

$\theta_\pi = 130 \pm 5^\circ$

partial wave analysis predictions:  
- $E_{0+}$ multipoles: $S_{11}(1535), S_{11}(1650), S_{31}(1620)$
- $E_{2-}$ multipoles: $D_{13}(1520), D_{33}(1700)$


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Access to Polarization Observables

With the CBELSA/TAPS experiment
- The unpolarized cross section ($\sigma$),
- 3 single polarization observables ($\Sigma$, $T$, $P$) and
- 4 double polarization observables ($H$, $G$, $F$, $E$) can be measured.

$$\frac{d\sigma}{d\Omega}(\theta, \phi) = \frac{d\sigma}{d\Omega}(\theta) \cdot \left[ 1 - P_{\gamma}^{\text{lin}} \Sigma(\theta) \cos(2\phi) ight.$$  
$$+ P_x \cdot (-P_{\gamma}^{\text{lin}} H(\theta) \sin(2\phi) + P_{\gamma}^{\text{circ}} F(\theta))$$  
$$+ P_y \cdot (+P_{\gamma}^{\text{lin}} P(\theta) \cos(2\phi) - T(\theta))$$  
$$- P_z \cdot (-P_{\gamma}^{\text{lin}} G(\theta) \sin(2\phi) + P_{\gamma}^{\text{circ}} E(\theta)) \right]$$
Beam Asymmetry $\Sigma$ for $p\pi^0$

Note: target material butanol ~ also small contribution from C

Polarization Observables $T$, $P$ and $H$ for $p\pi^0$
Very Preliminary Results for

\[ \gamma p \rightarrow p\eta \]
Very preliminary angular distributions

T

750 MeV  900 MeV  1102 MeV  1249 MeV  1450 MeV

P

750 MeV  801 MeV  850 MeV  900 MeV  951 MeV

H

750 MeV  801 MeV  850 MeV  900 MeV  951 MeV

\[ \text{this analysis} \quad \eta \rightarrow \gamma \gamma \quad \eta \rightarrow 3\pi^0 \quad \text{Bock et al.} \quad \text{BnGa} \quad \text{Maid} \quad \text{Said} \]
Asymmetry $G$ for $p\eta$

Very preliminary angular distributions

CBELSA/TAPS at ELSA (M. Grüner et al.)

$G$

$E_\gamma = 750 \pm 50$ MeV

$E_\gamma = 850 \pm 50$ MeV

$E_\gamma = 950 \pm 50$ MeV

$E_\gamma = 1100 \pm 100$ MeV

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Very Preliminary Fit from BnGa

- Using additional observables causes smaller uncertainties in the fits.
- Still large differences in the PWA approaches visible.

MAID, SAID CM12 (solid) SN11 (dashed), BnGa, BnGa with double pol. obs.

(very preliminary)
Summary

- First double polarization experiments at ELSA are finished.

- Preliminary results for the polarization observables $T, P, G, E, H$ and the beam asymmetry $\Sigma$ were shown for the final states $p\pi^0$ and $p\eta$ on the proton.

- We are on the way to a unique partial wave analysis
  - polarization observables are essential,
  - different final states are essential.

- New polarization data will determine the nucleon excitation spectrum.

- Neutral channels allow access to barely explored sets of final states.

-> Trigger upgrade of the Crystal Barrel detector.
Outlook – Trigger Upgrade

• Up to now: low acceptance for pure neutral reactions
• e.g.: $\gamma n \rightarrow n\pi^0$

H. van Pee

preliminary
Outlook – Trigger Upgrade

• Include whole CB-calorimeter into single stage trigger

• Timing signals necessary for each CB-crystal (within 200 - 300 ns)

• Use of Avalanche Photo Diodes (APDs)

• Build timing and energy branch for CB as trigger at high energy resolution

• Build new trigger electronics for CB.

• Modification of CB starts End of 2013.
Thank you! / Srdečné diky!