Investigation of $K^0\Sigma^+$ photoproduction with the CBELSA/TAPS experiment

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On behalf of the CBELSA/TAPS Collaboration
Supported by the DFG
Investigation of $K^0\Sigma^+$ photoproduction with the CBELSA/TAPS experiment

- Physics motivation and polarisation observables
- The CBELSA/TAPS experiment
- Identification of the $\gamma(p,K^0)\Sigma^+$ channel
- The kinematic fit
- Cross section measurements, preliminary measurement of beam-target asymmetry “E”
- Future plans with the BGO-OD experiment and concluding remarks
Polarisation observables in photoproduction experiments

- Crucial in the determination of baryon resonance structure
- Global effort to determine sufficient single and double observables for a “complete”, model independent analysis
- Certain observables are particularly sensitive for a given reaction channel

Polarisation observables in strangeness photoproduction

- Measurement of beam-recoil observables, $C_x$ and $C_z$ for $\gamma(p,K^+)\Lambda$
- $C_z \sim 1$, $C_x \sim 0$ over all energies and angles [1]
- “Toy” model proposed [2]:

For a partial wave analysis of s-channel contributions in $\gamma(p,K^+)\Lambda$ (a), t-channel contributions (b) must first be understood:

(a) $\gamma$\hspace{1cm}K
\hspace{1cm}$p$\hspace{1cm}$\Lambda, \Sigma$

(b) $\gamma$\hspace{1cm}K
\hspace{1cm}$p$\hspace{1cm}$\Lambda, \Sigma$

The lesser investigated $\gamma(p,K^0)\Sigma^+$ is an “easier” channel to understand due to the absence of contributions from (a) (photon cannot couple to neutral $K^0$)

Contributions from t-channel vector meson exchange are still expected (c), and could give large changes in $\gamma(p,K^0)\Sigma^+$ photoproduction above and below $K^*$ threshold

(c) $\gamma$\hspace{1cm}K
\hspace{1cm}$p$\hspace{1cm}$K^*$\hspace{1cm}$\Lambda, \Sigma$
The Electron Stretcher Accelerator (ELSA)

See F. Klein's talk, Friday 10:50
The CBELSA/TAPS experiment

ELSA $e^-$ beam (3.2 GeV, 2.35 GeV longitudinally polarised)

Crystal Barrel.
1380 CsI(Tl) crystals $30^0 - 160^0$.

Forward plug.
$30^0 - 12^0$

MiniTAPS.
216 BaF$_2$ crystals, < $12^0$
Identify 1 charged and six neutral particles or just six neutral particles (with timing cuts)

Photon beam energy $> 1047.5$ MeV (production threshold)

Construct three $\pi^0$ with invariant masses $110 - 160$ MeV (15 possible combinations)

Reject $\gamma (p, \eta) p$ by identifying events with $3\pi^0$ invariant mass $470 - 620$ MeV

Neutral events from the electron beam dump rejected through angular topology
Kinematic fitting

- A least squares fit with constraints (for example, reaction vertex, momentum conservation)
- Test the hypothesis: $\gamma p \rightarrow p \pi^0 \pi^0 \pi^0$ on an event by event basis
- Input errors for particle energies and directions
- Allow measured variables to shift and compare to known errors (pull distributions)
- For events matching the hypothesis the confidence level should be flat
Select $K^0\Sigma^+$ events by selecting $2\pi^0$ invariant mass consistent with $\Sigma^+ \rightarrow p\pi^0$ invariant mass.

- Subtract background from uncorrelated $3\pi^0$ events using simulated data.
- The nearly $4\pi$ detector system gives a nearly flat detection efficiency.

R Ewald, PhD thesis, Universität Bonn, 2010
6 particles identified (red)
7  particles identified (green)
All events

R Ewald, PhD thesis, Universität Bonn, 2010, agrees well with:
Cross sections exhibit increasing forward peaking (t-channel) up to 1800 MeV. Above this beam energy, cross sections are flat (s-channel).

Total cross section: adjusted Kaon-MAID [1] fit (switch off K* exchange above threshold, change S_{31}(1900) couplings to G_1 = 0.3 & G_2 = 0.3)

[1] www.kph.uni-mainz.de/MAID/ (version 29.03.07)
No existing partial wave parameterisation reproduces total cross section. Summing cross sections from $K^0\Sigma^+$ and $K^*\Sigma^+$ [3] yields red points.

- The strength of the dip in the cross section for $K^0\Sigma^+$ contributes to the $K^*\Sigma^+$ channel.

- Speculate that just below threshold, $K^*$ couples strongly to a $K^0$ and $\pi$. $K^0$ is observed in the final state, $\pi$ reabsorbed by the hyperon.

(d) therefore contributes to $K^0\Sigma^+$ contribution below $K^*$ threshold. Above threshold it does not contribute and $K^*$ is produced as a free particle.

[1] www.kph.uni-mainz.de/MAID/ (version 29.03.07)
[2] gwdac.phys.gwu.edu/
Motivation for measuring beam-target observable, $E$

- $E$: circularly polarised photon beam, longitudinal polarised target (butanol)

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

- $E$ acts as spin filter for resonance contributions in s-channel

- Coupling of an initial photon to a $K^*$-hyperon dynamically generated state?

A pure t-channel contribution would give $E = 0$
Preliminary asymmetry measurements suggest a negative value for “E”

Refinement of the kinematic fit and calibrations still required

Target dilution factor, target and beam polarisations still need to be accounted for

(See H. Eberhard's talk, Parallel session III-C, Thursday, 4:30)

**Beam-target double polarisation observable, E**

\[ E_\gamma = 1.25 - 1.50 \text{ GeV} \]

Preliminary, example plot

Counts

Parallel (\( \sigma_{3/2} \))

Anti-Parallel (\( \sigma_{1/2} \))

K\(^0\) invariant mass [MeV]
Future plans with the BGO-OD experiment at ELSA

- **BGO-Ball**: large acceptance calorimeter designed for multiple-photon measurements with high energy and time resolution.
- Forward angles covered by the forward spectrometer.
- Ideal for investigation of strangeness photoproduction, recoil polarisation, vector meson production, excited hyperons, e.g., \( \Lambda(1405) \).
- Commissioning ongoing, first data taking expected 2nd half of 2011.
Conclusions

- $\gamma(p,K^0)\Sigma^+$ investigated from threshold to a beam energy of 2250 MeV with the CBELSA/TAPS experiment

- Cross section at forward angles has “cusp” like structure where it drops by a factor of four

- Speculate that this is due to the formation of a $K^*$ - hyperon quasibound state in $K^*$ sub-threshold production

- Polarisation observable measurements required to shed more light

- Further measurements of strangeness photoproduction planned with the new BGO-OD experiment
Measurement of polarisation observables in $K^0\Sigma^+$ photoproduction with the CBELSA/TAPS experiment

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Spare slides
Identifying t-channel contributions with “E”

- Beam-target double polarisation observable “E”: circularly polarised photon beam, longitudinal polarised target (butanol)
- Pure t-channel contributions should give $E = 0$

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

$$E = \frac{N_{1/2} - N_{3/2}}{N_{1/2} + N_{3/2}} \frac{1}{P_T P_B}$$