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

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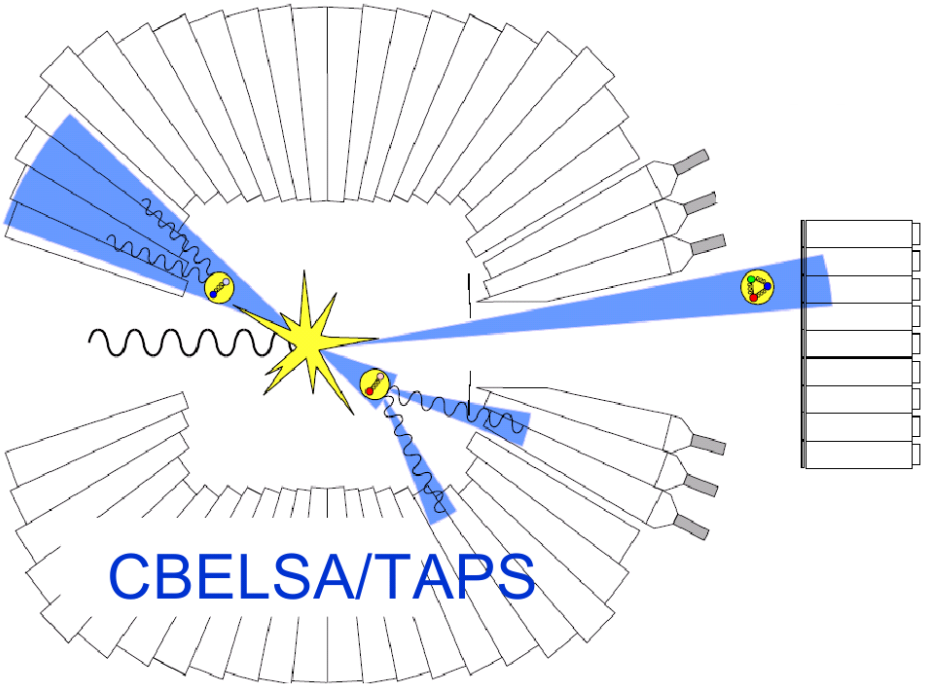
Supported by the DFG



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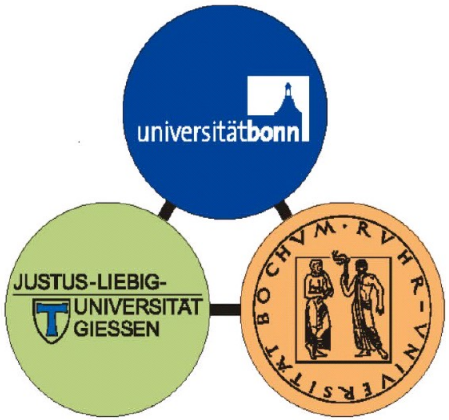
Investigation of $K^0\Sigma^+$ photoproduction with the CBELSA/TAPS experiment

- 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



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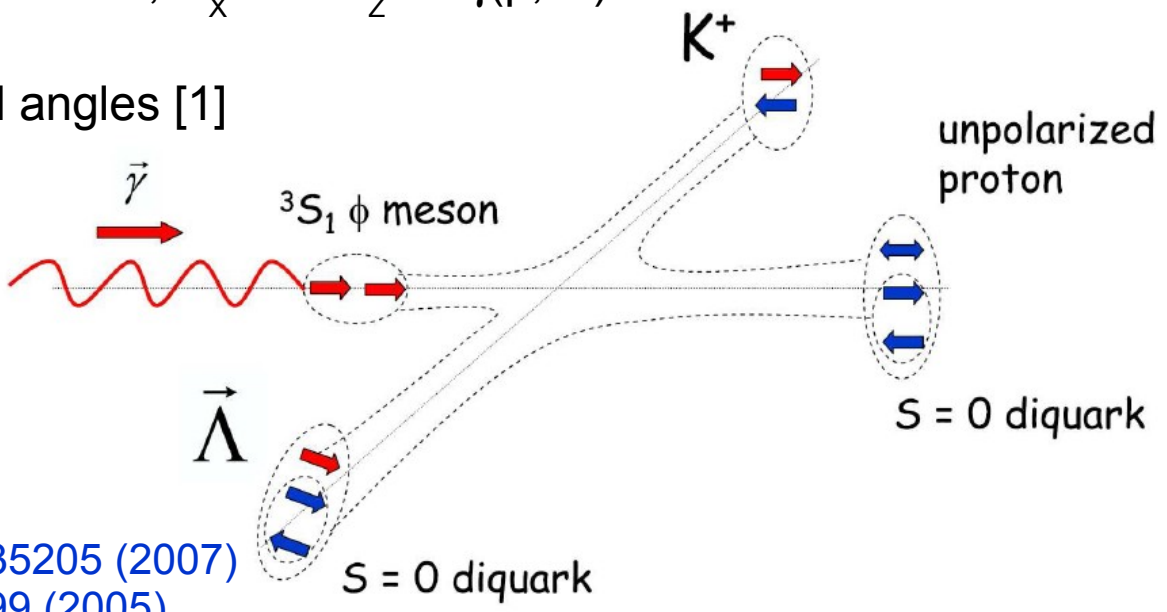
Polarisation observables in photoproduction experiments

- 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

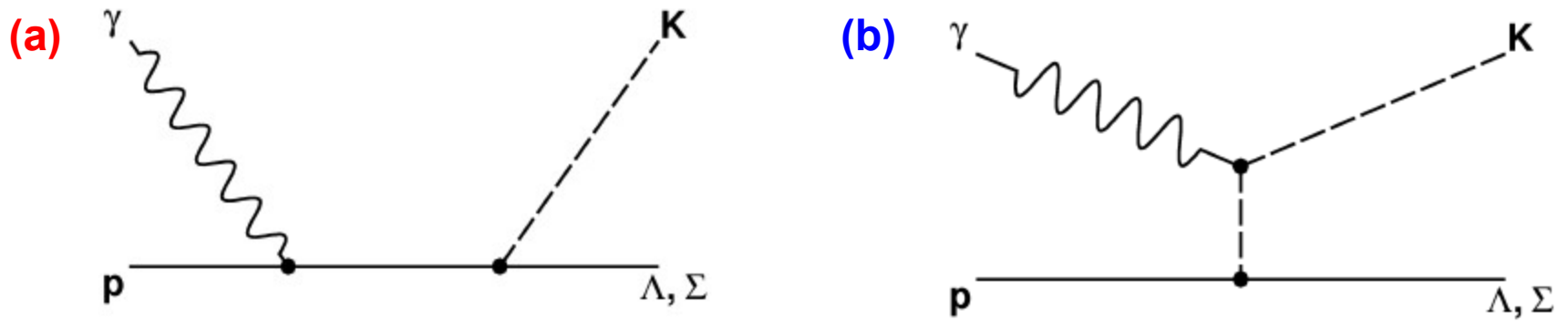
Polarisation observables in strangeness photoproduction

- 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]:



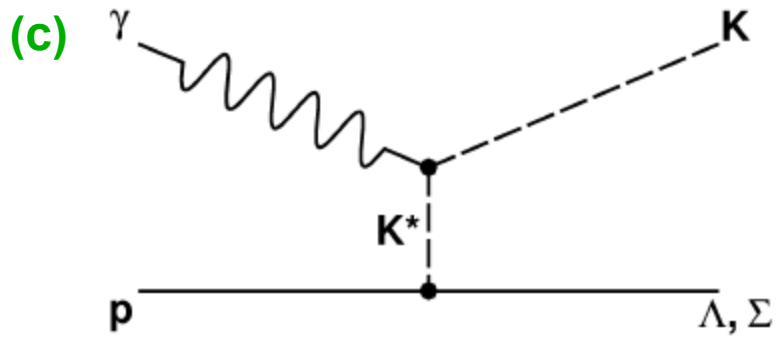
[1] R. Bradford et al. Phys. Rev. C, 75:035205 (2007)
[2] R. Schumacher. Eur. Phys. J. A 35:299 (2005)

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



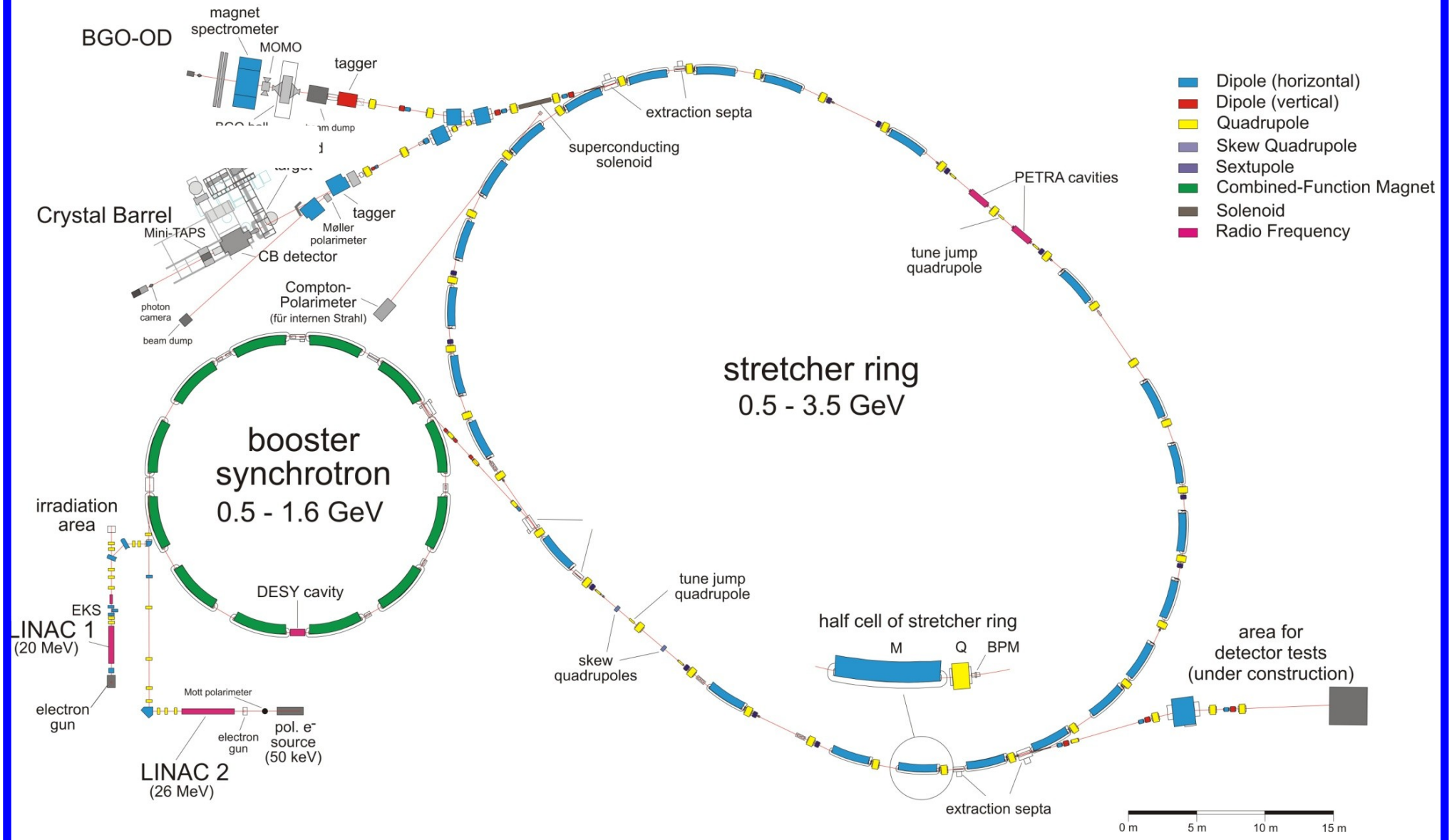
- The lesser investigated $\gamma(p,K^0)\Sigma^+$ is an "easier" channel to understand due to the absence of contributions from **(a)** (photon cannot couple to neutral K^0)

- 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



The Electron Stretcher Accelerator (ELSA)

See F. Klein's talk, Friday 10:50

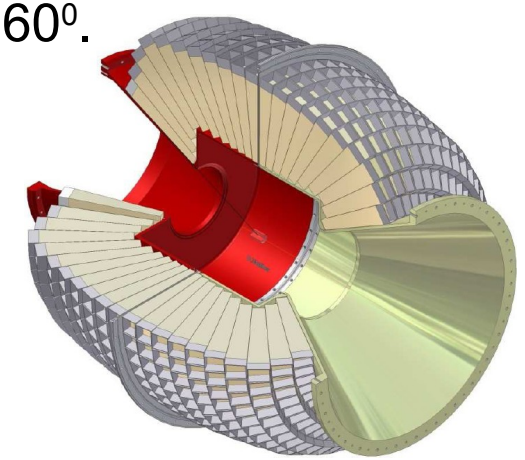


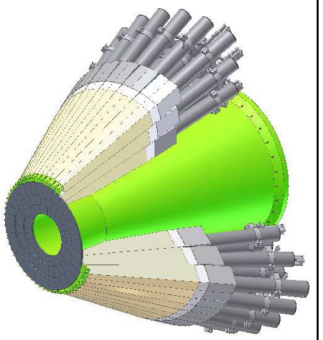
The CBELSA/TAPS experiment

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

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

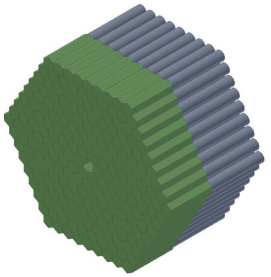
Forward plug.
30^0 - 12^0



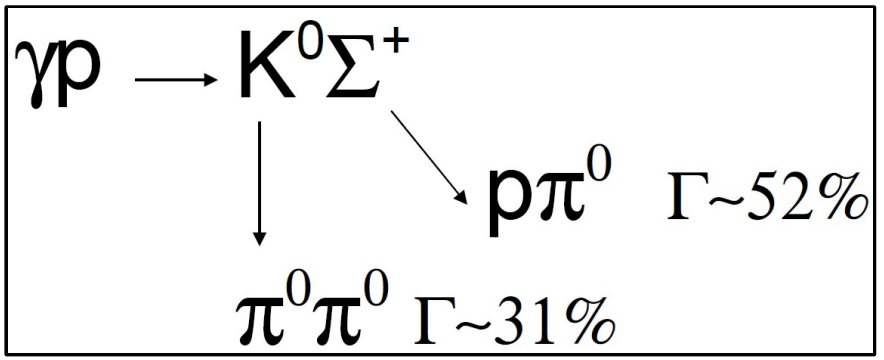


MiniTAPS.

216 BaF_2 crystals, < 12^0



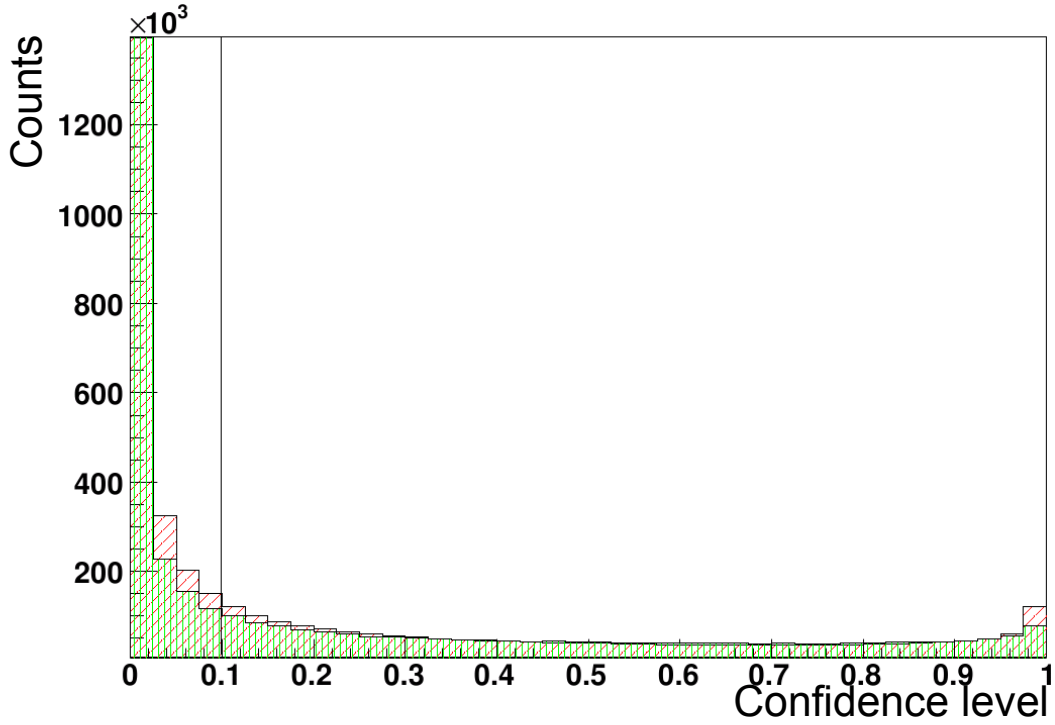
Event selection

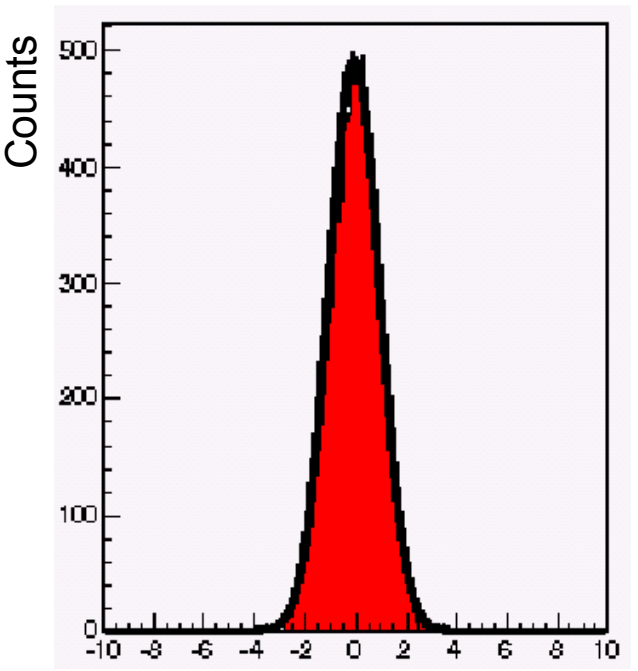


- Identify 1 charged and six neutral particles or just six neutral particles (with timing cuts)
- Photon beam energy > 1047.5 MeV (production threshold)
- Construct three π^0 with invariant masses 110 – 160 MeV (15 possible combinations)
- Reject γ (p,η)p by identifying events with $3\pi^0$ invariant mass 470 – 620 MeV
- Neutral events from the electron beam dump rejected through angular topology

Kinematic fitting

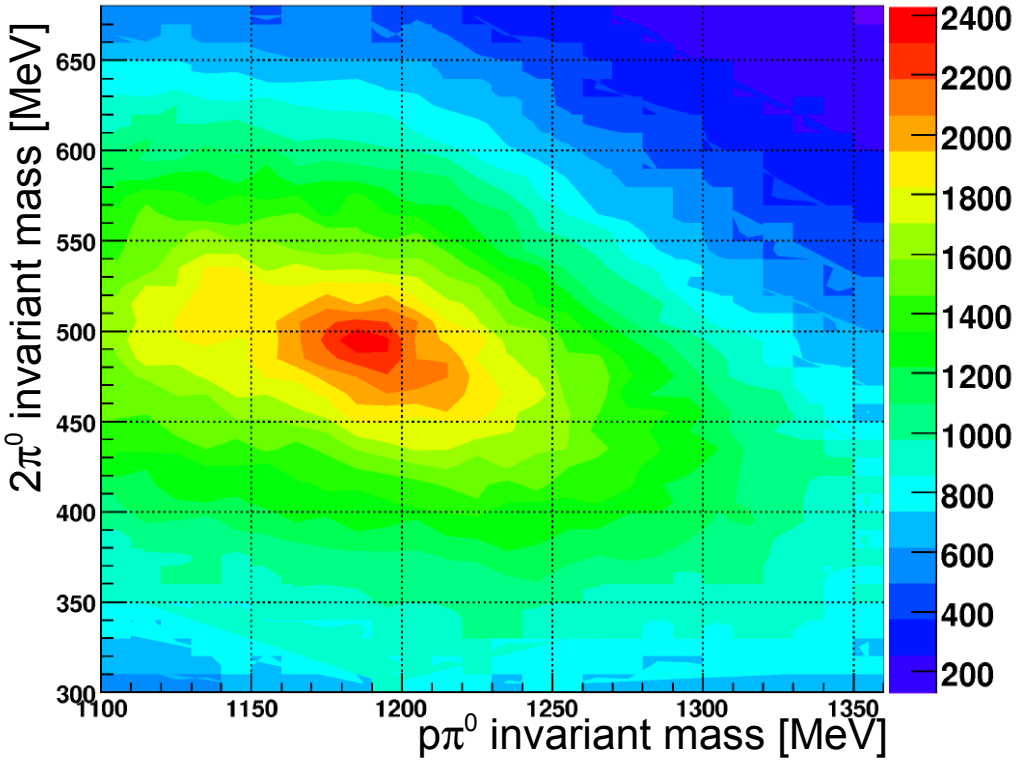
- A least squares fit with constraints (for example, reaction vertex, momentum conservation)
- Test the hypothesis: $\gamma p \rightarrow p \pi^0 \pi^0 \pi^0$ on an event by event basis
- Input errors for particle energies and directions
- Allow measured variables to shift and compare to known errors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

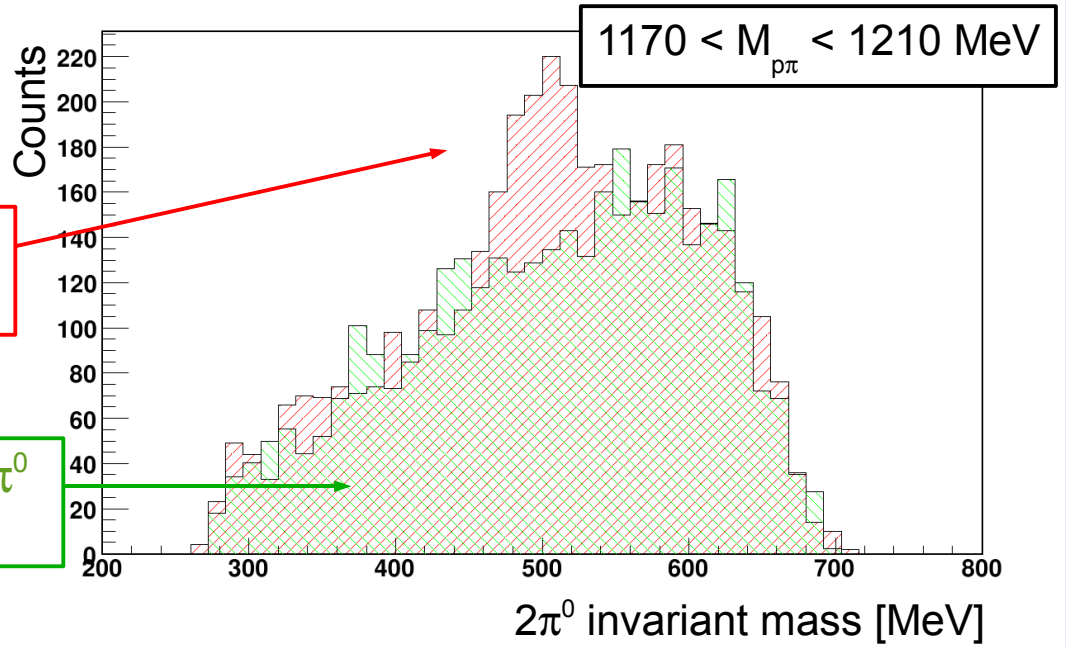




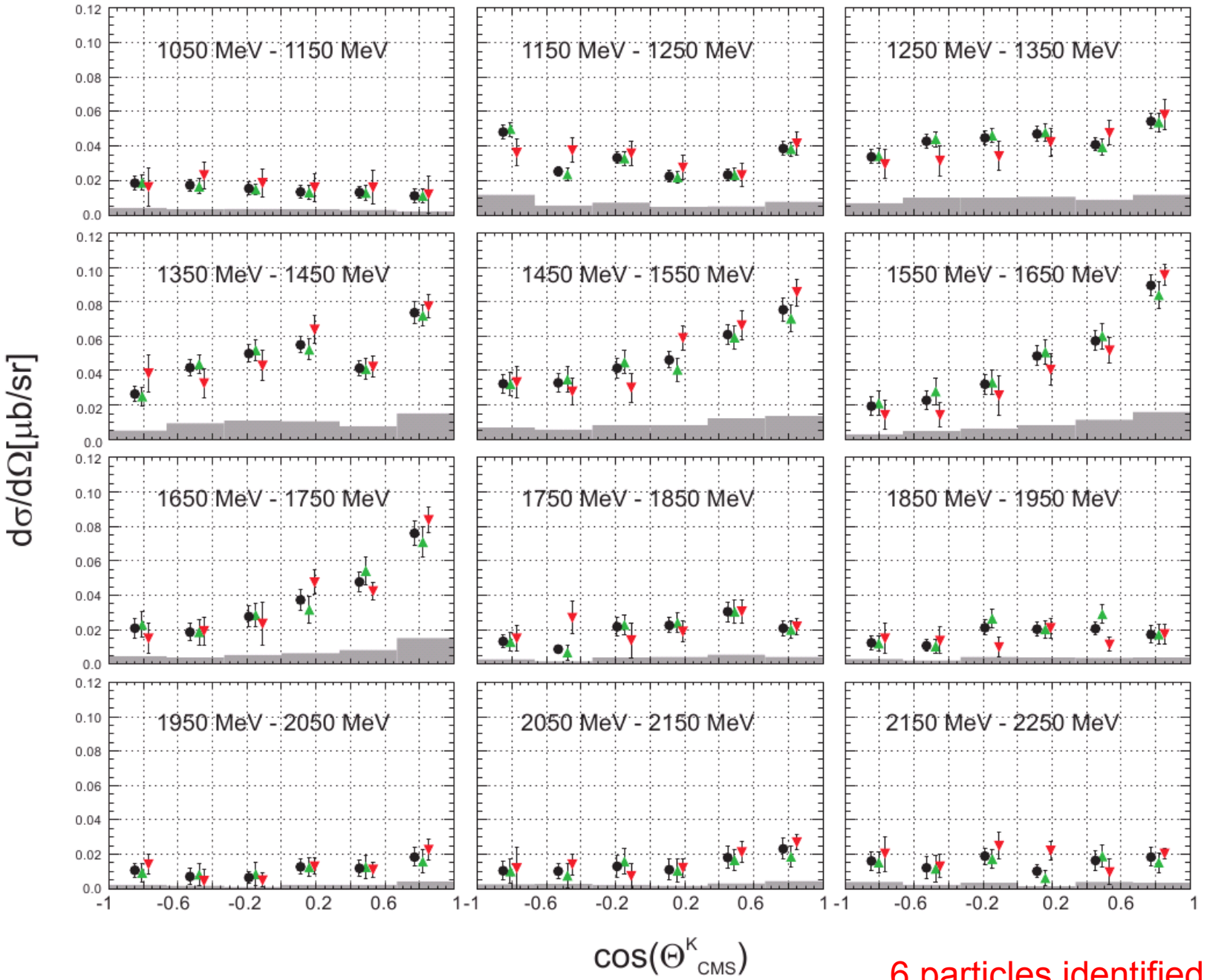
Photon θ pull distribution

- 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 4π detector system gives a nearly flat detection efficiency





R Ewald, PhD thesis, Universität Bonn, 2010

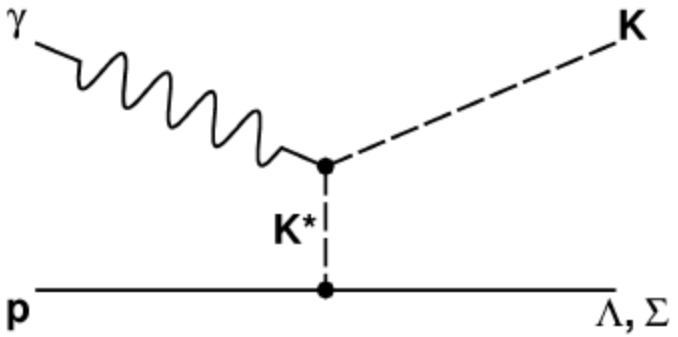


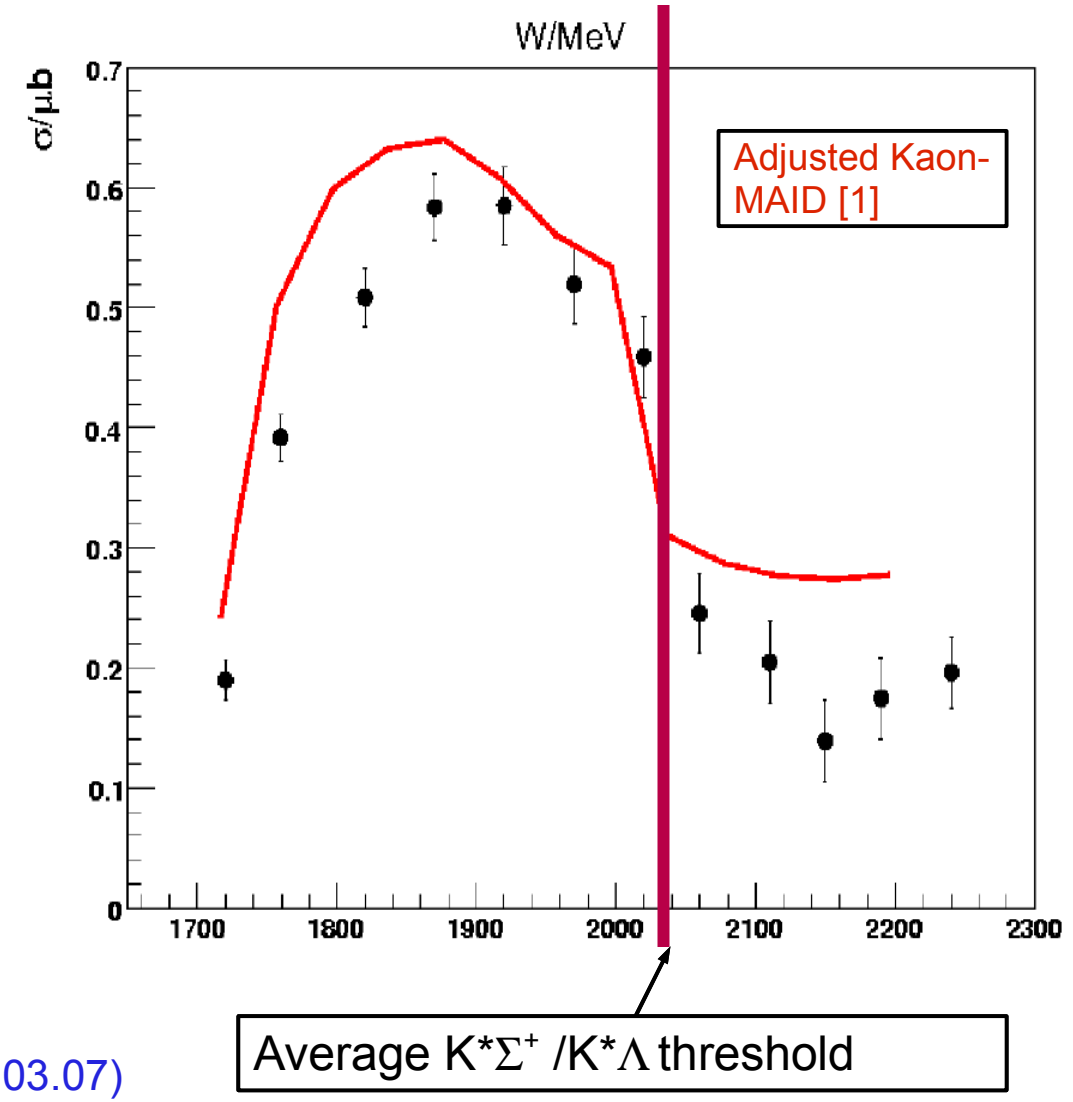
R Ewald, PhD thesis, Universität Bonn, 2010, agrees well with:
R. Casteljins *et al.* (CBELSA/TAPS) Eur. Phys. J. A 35, 39 (2008)
R. Lawall *et al.* (SAPHIR) Eur. Phys. J. A 24, 275 (2005)

6 particles identified (red)
7 particles identified (green)
All events

- 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 $G_1 = 0.3$ & $G_2 = 0.3$)





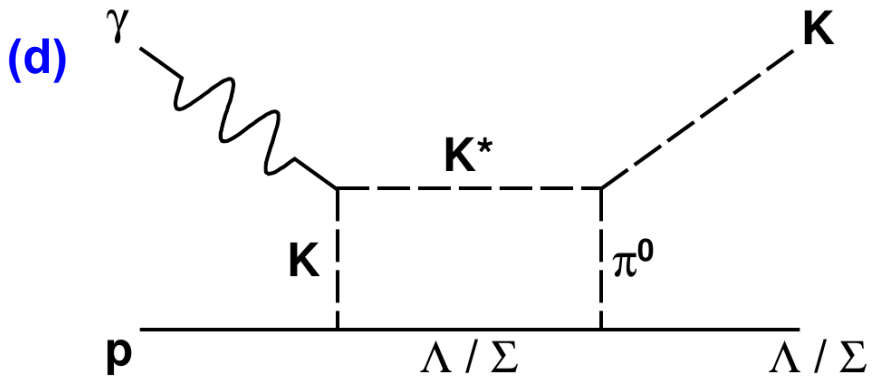
[1] www.kph.uni-mainz.de/MAID/ (version 29.03.07)

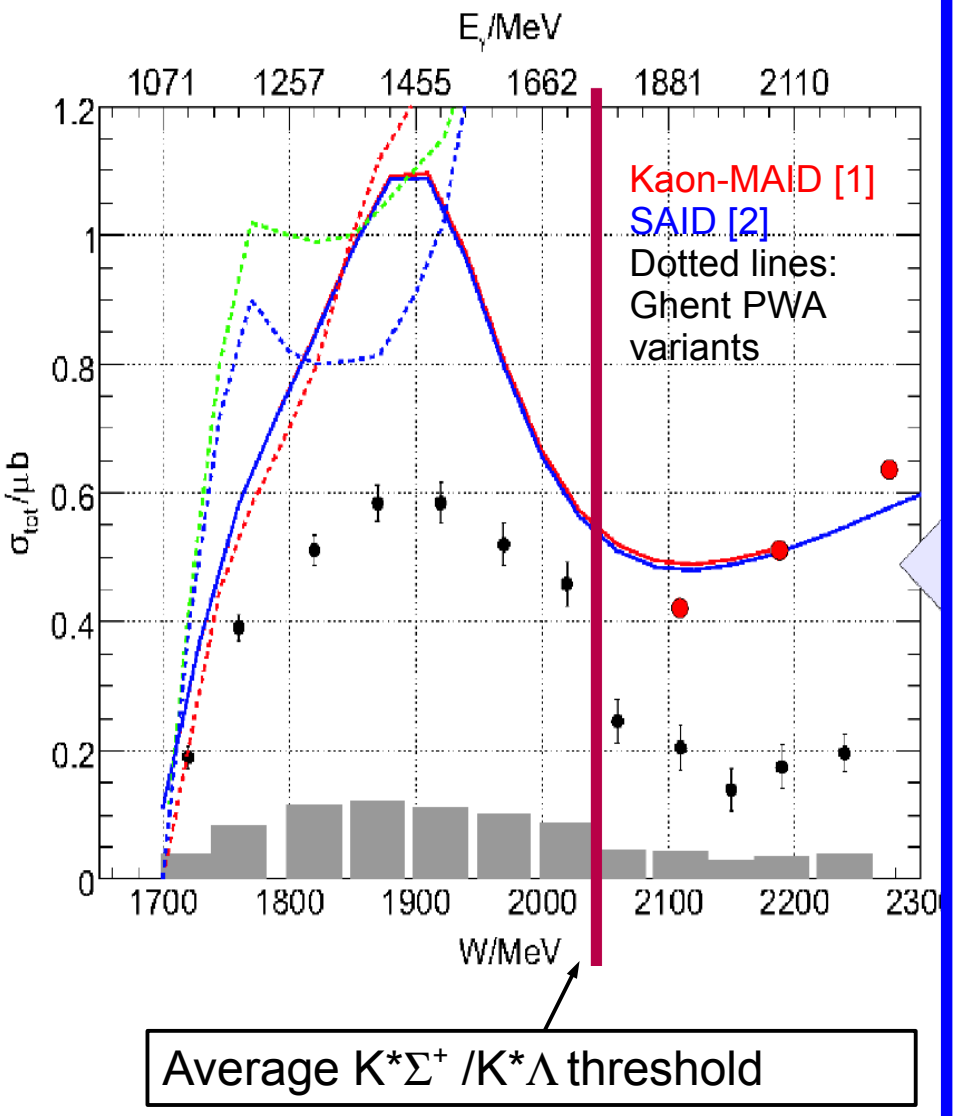
- No existing partial wave parameterisation reproduces total cross section. Summing cross sections from $K^0\Sigma^+$ and $K^*\Sigma^+$ [3] yields red points

- 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 π. K^0 is observed in the final state, π 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

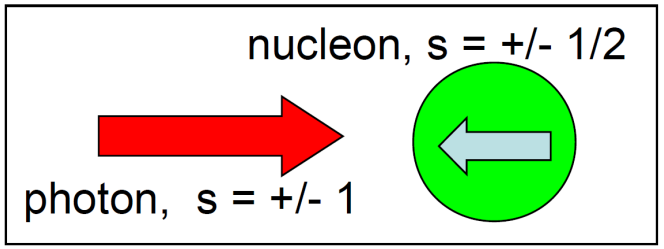




[1] www.kph.uni-mainz.de/MAID/ (version 29.03.07)
[2] gwdac.phys.gwu.edu/
[3] M.Nanova et al. (CBELSA/TAPS Collab.) Eur.Phys. J. A35 (2008) 333

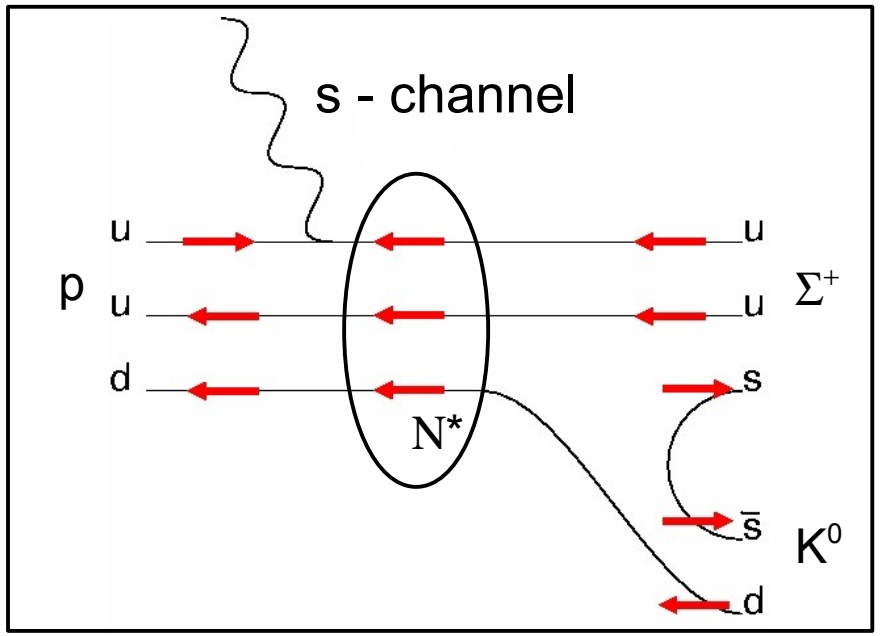
Motivation for measuring beam-target observable, E

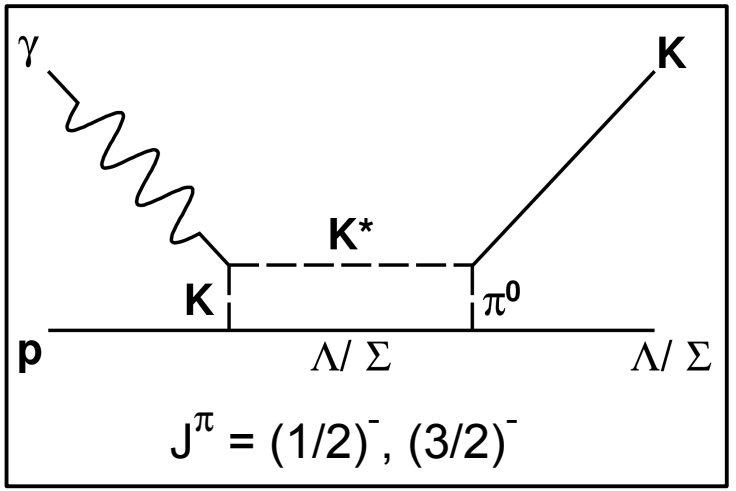
- E: circularly polarised photon beam, longitudinal polarised target (butanol)



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

- E acts as spin filter for resonance contributions in s-channel
- Coupling of an initial photon to a K*-hyperon dynamically generated state?

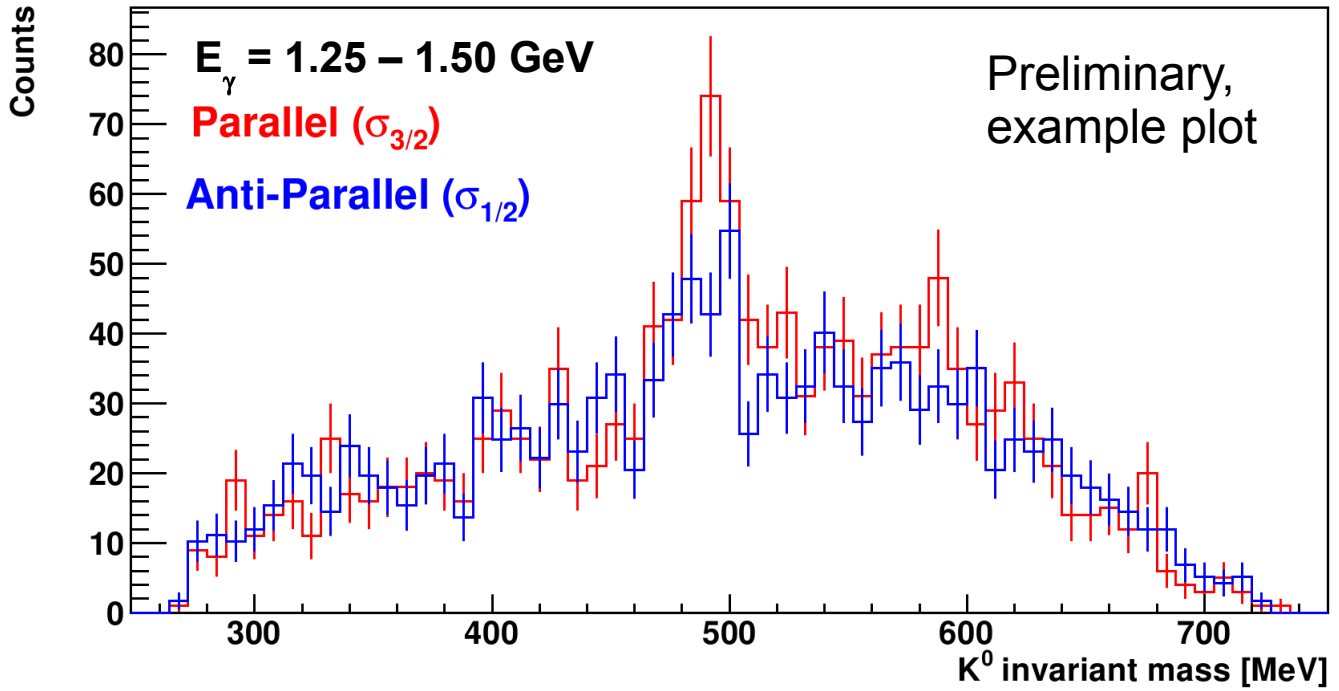




A pure t-channel contribution would give E = 0

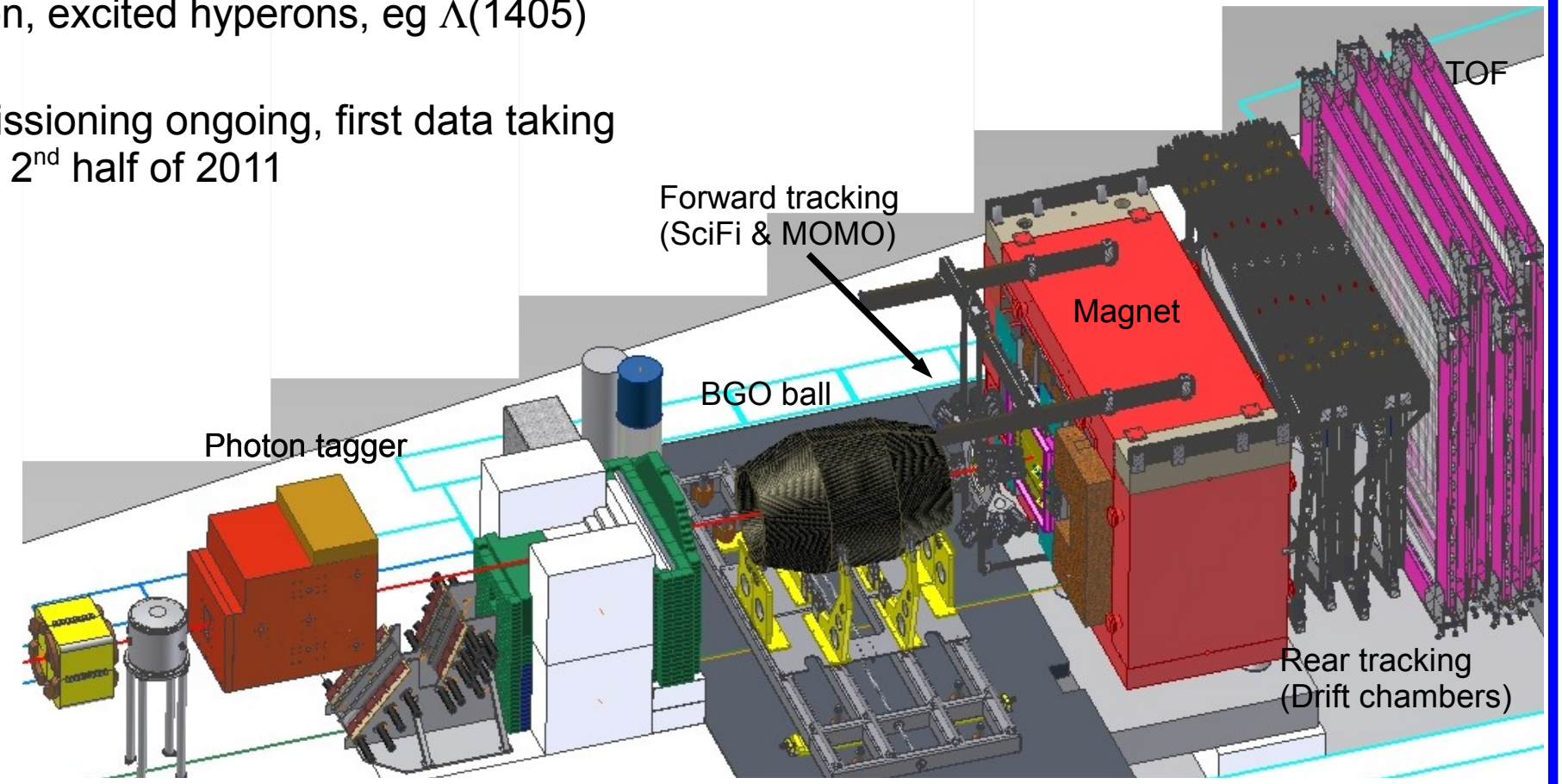
Beam-target double polarisation observable, E

- 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)



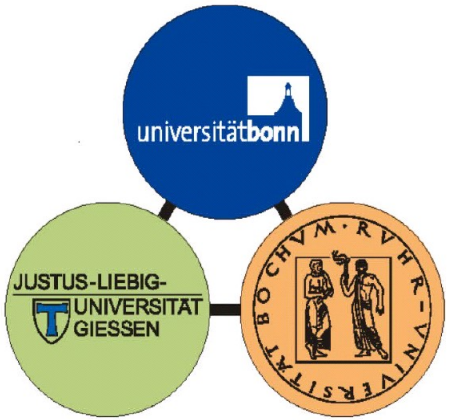
Future plans with the BGO-OD experiment at ELSA

- 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 strangeness photoproduction, recoil polarisation, vector meson production, excited hyperons, eg $\Lambda(1405)$
- 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



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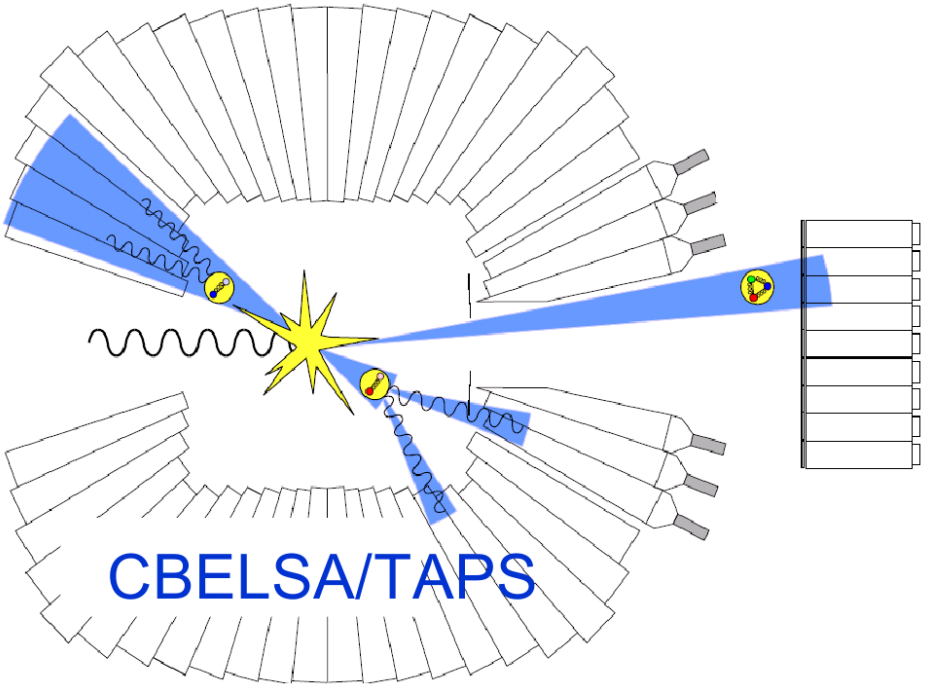

Spare slides

Identifying t-channel contributions with “E”

- Beam-target double polarisation observable “E”: circularly polarised photon beam, longitudinal polarised target (butanol)

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

- Pure t-channel contributions should give E = 0

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