Hyperon production in photonuclear reactions on proton: $K^0 \Sigma^+$ channel

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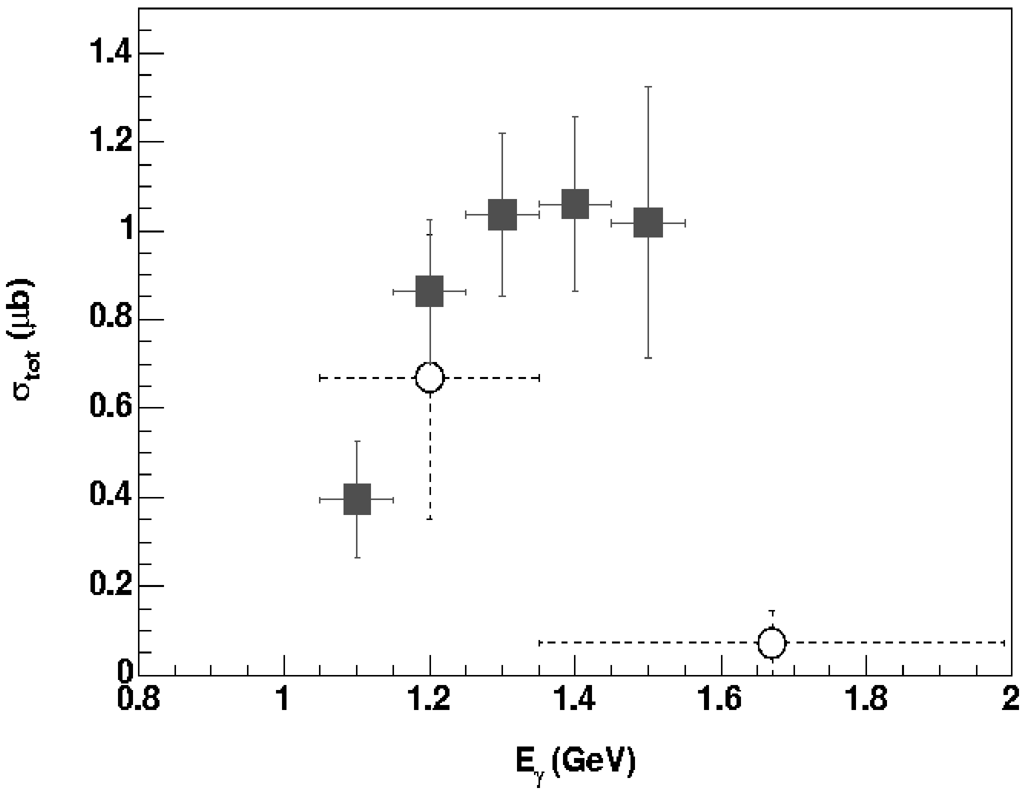
outline

- motivation
- the setup at ELSA (Bonn)
- results on $K^0 \Sigma^+$ production
- comparison to theory
- conclusion

Σ hyperon production

SAPHIR and ABBHHM data



SAPHIR:

- **Experiment at ELSA (1997)**
- **Using electromagnetic spectrometer**
- **Large error bars**
- **Up to 1.5 GeV**

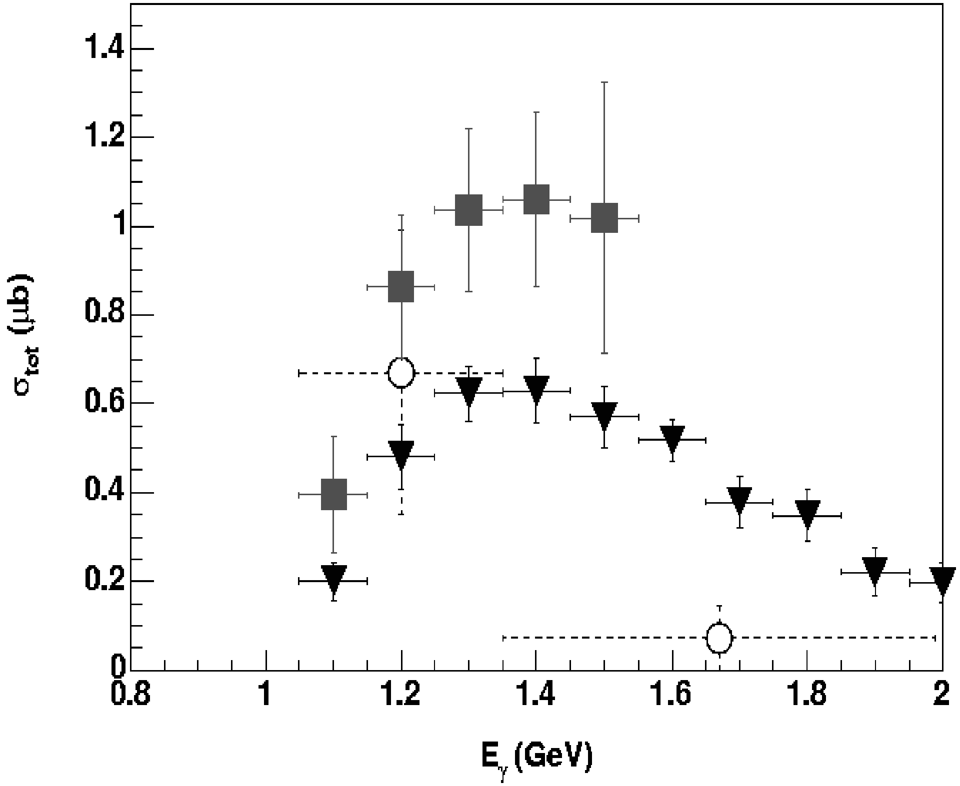
ABBHHM:

- **Bubble chamber**
- **Large error bars**

Coupled channels calculations require better data in $K^0 \Sigma^+$ channel

Σ hyperon production

New SAPHIR and CLAS data



SAPHIR:

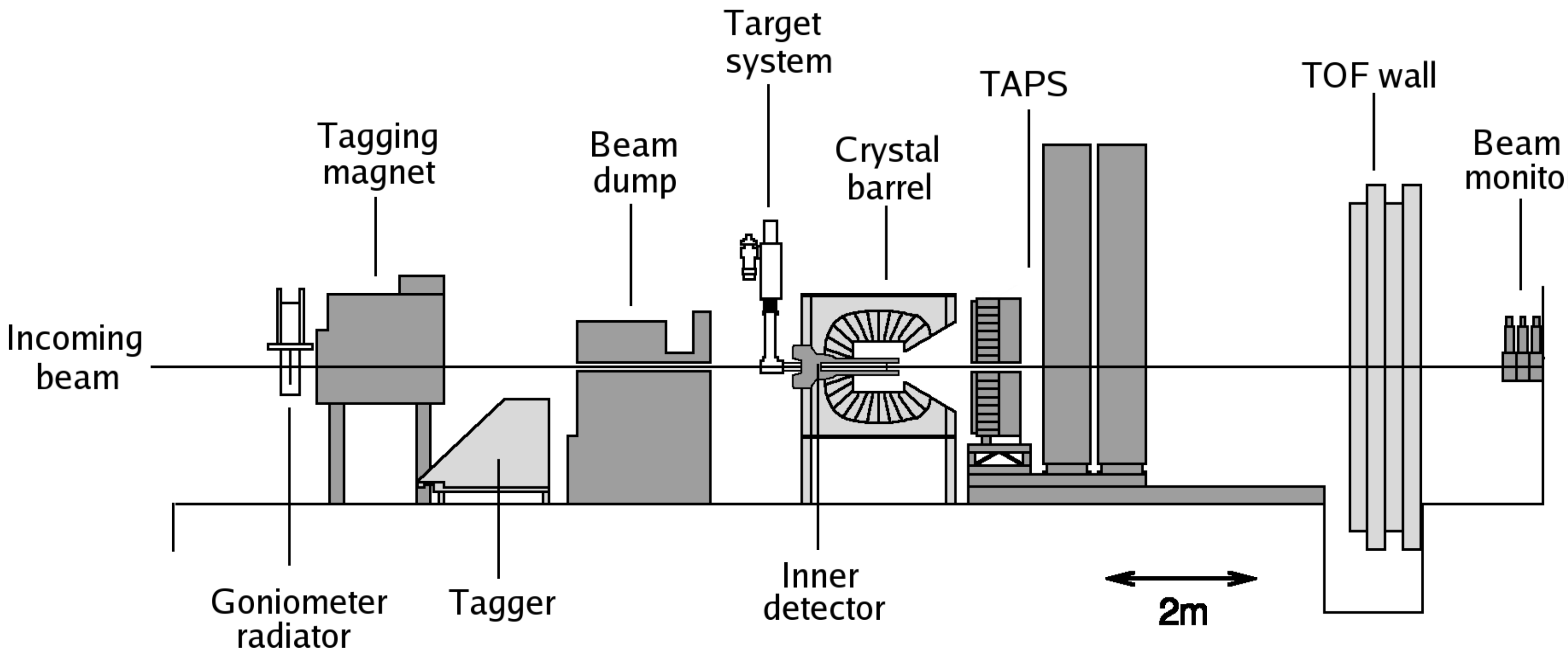
- **New analysis**
- **Improved error bars**
- **Higher energies**
- **50 % lower due to better background subtraction**

CLAS:

- **Similar in quality**
- **Differential cross sections need to be extracted due to limited acceptance**

Experimental setup

CB and TAPS photon spectrometers



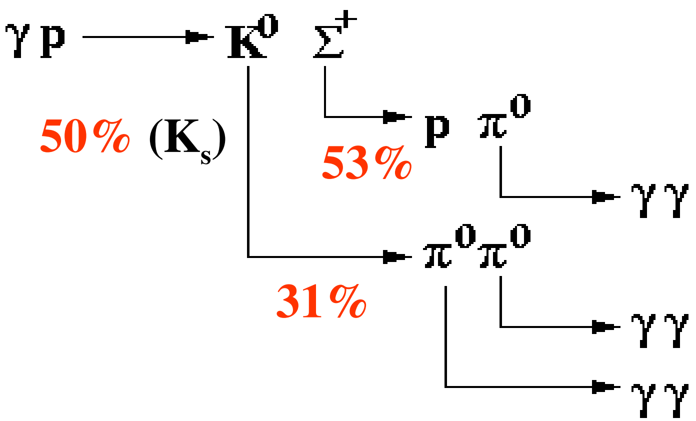
Unique setup: two photon spectrometers cover almost 4π solid angle

Channel of interest

neutral decay

We are investigating:

$\gamma + p \rightarrow K^0 \Sigma^+ \rightarrow 3\pi^0 + p \rightarrow 6\gamma + p$



This requires:

- **Photon spectrometer**
- **High granularity**
- **High acceptance**
- **CB/TAPS acceptance is 95%**

photons	80% of 4 π	90% of 4 π
1 photon	80%	90%
2 photons	64%	81%
3 photons	51%	72%
4 photons	41%	65%
5 photons	32%	59%
6 photons	26%	53%

Kinematical fitting

Improving the resolution

In a kinematical fit the measured values are varied, to minimize certain constraints:

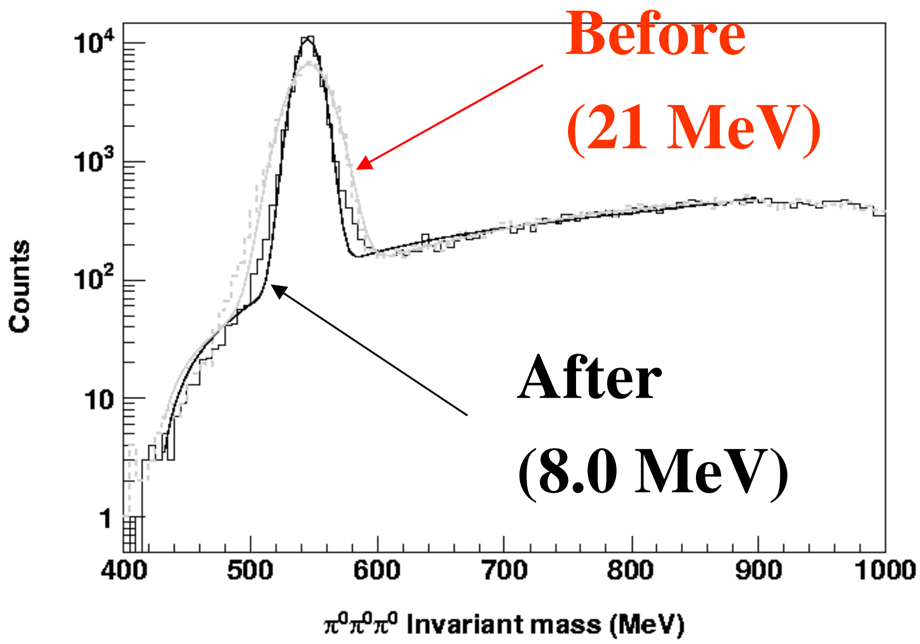
Conservation of energy (1)
Conservation of momentum (3)
Pion invariant mass (3)

+

Unknowns:
Proton energy (punch through)

-

6 times overdetermined



Confidence level cut at 10 %
Background not altered

The $\pi^0 \pi^0 \pi^0$ channel

Selecting the data

Channel of interest :

$\gamma + p \rightarrow K^0 \Sigma^+ \rightarrow 3\pi^0 + p \rightarrow 6\gamma + p$

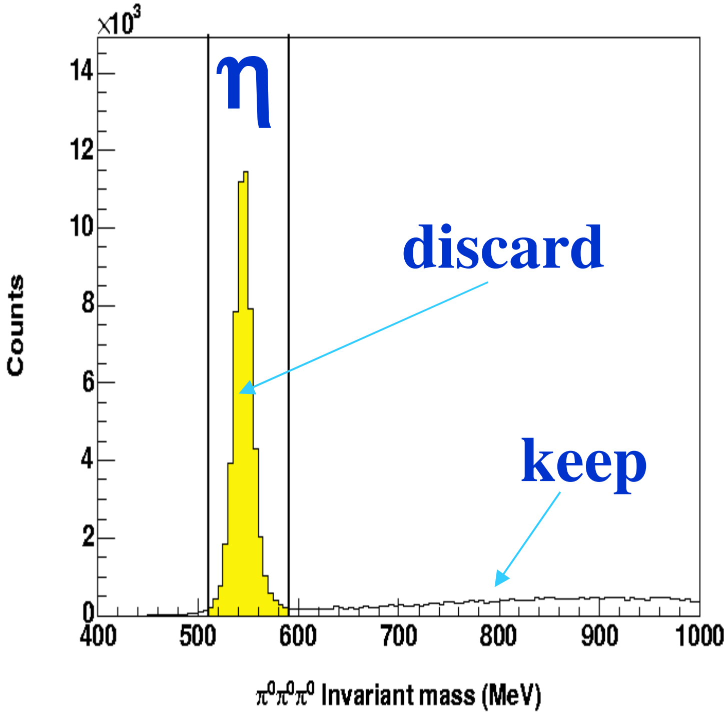
Background:

$\gamma + p \rightarrow \eta + p \rightarrow 3\pi^0 + p \rightarrow 6\gamma + p$

$\gamma + p \rightarrow 3\pi^0 + p \rightarrow 6\gamma + p$

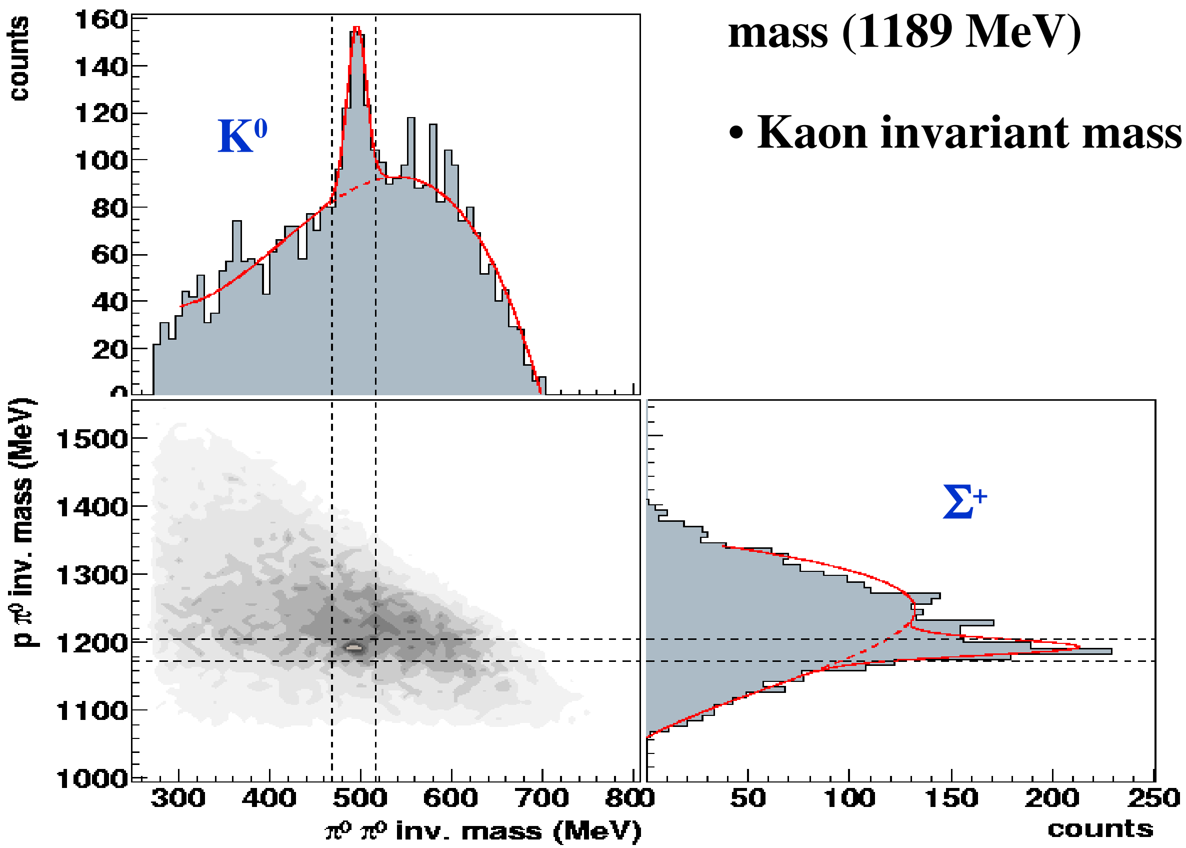
combinatorics …

The η channel is used for normalisation



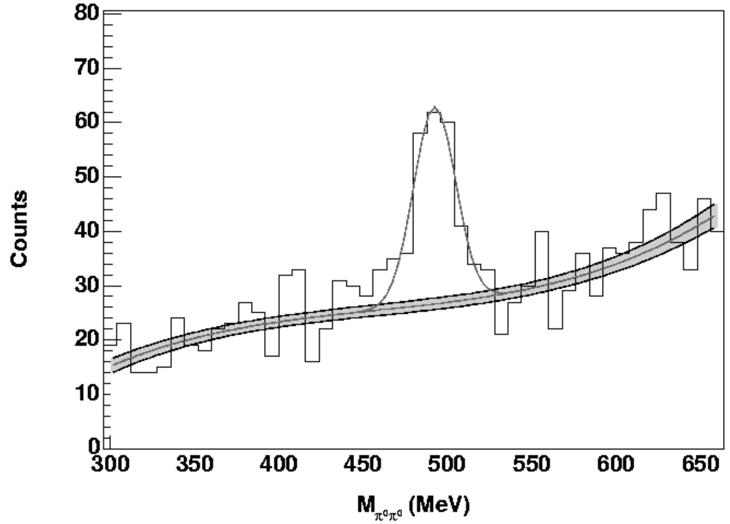
Identifying K^0_S and Σ^+

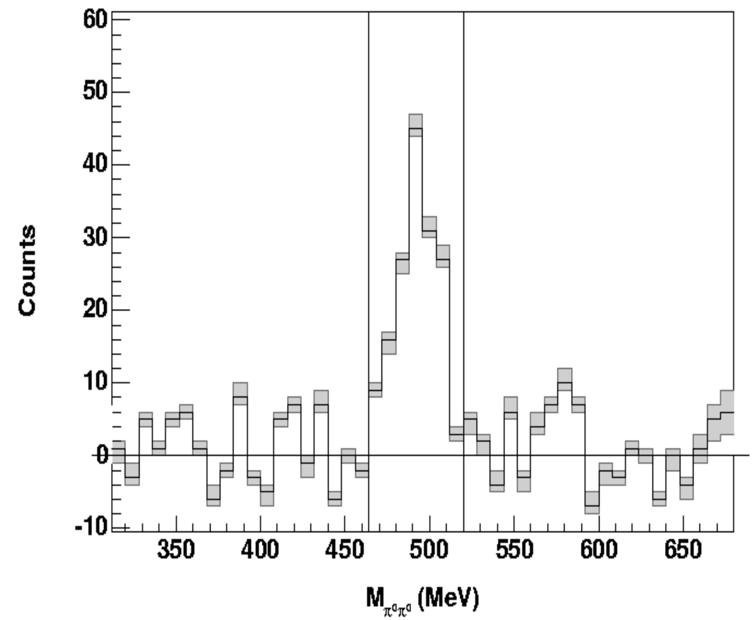
The invariant mass spectra



- Cut on the $p\pi^0$ invariant mass around the Σ^+ mass (1189 MeV)
- Kaon invariant mass resolution 10 MeV (σ)

Background subtraction

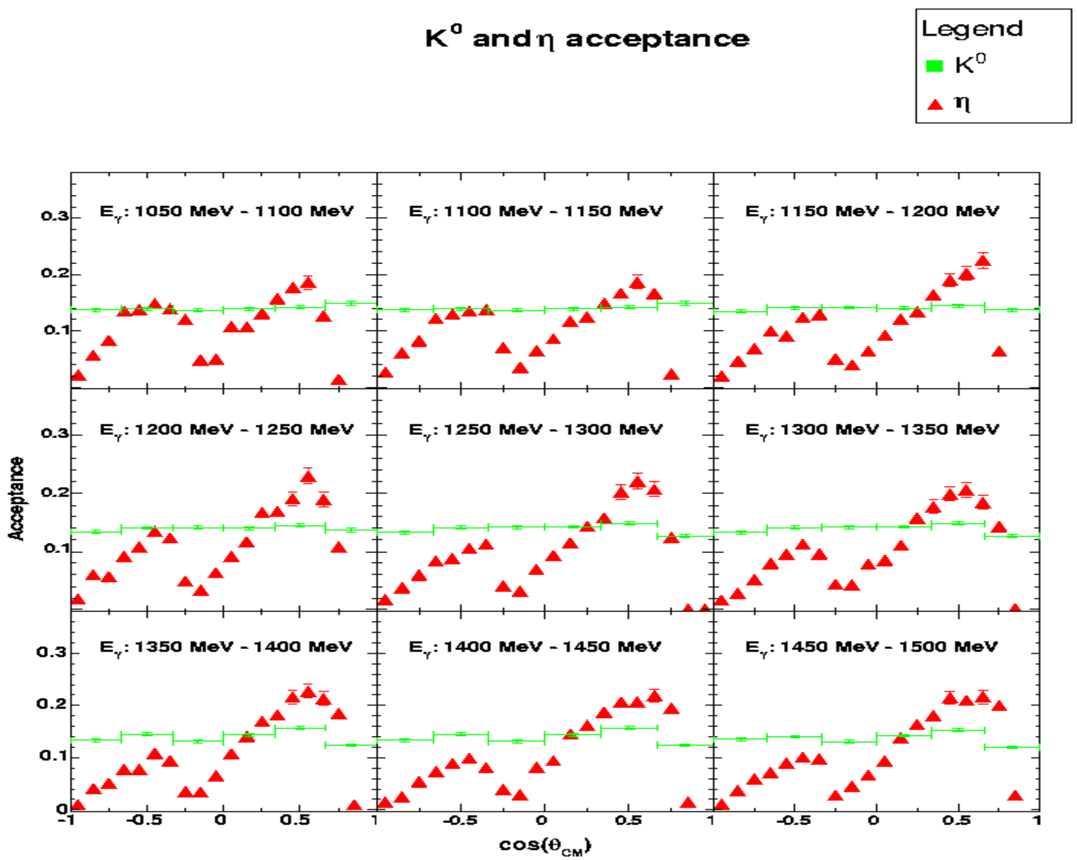




- Background subtraction using polynomial
- Integration of the subtracted signal

Acceptance

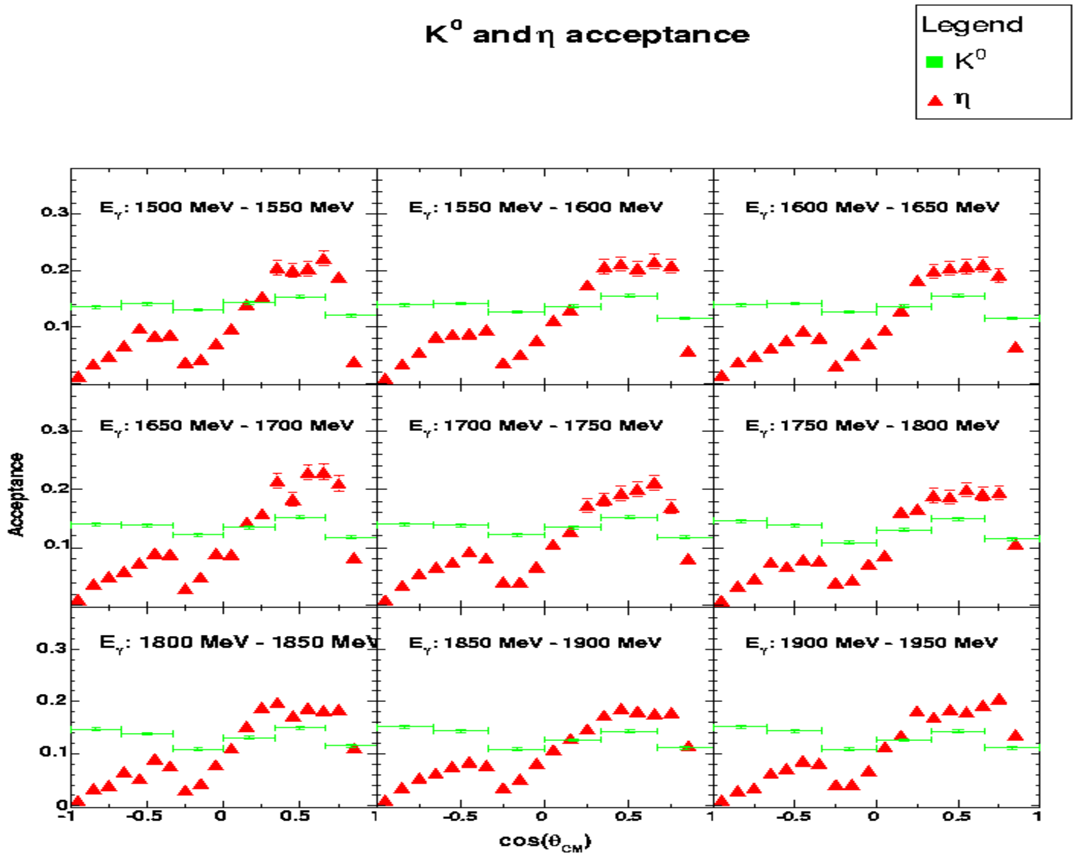
angular distributions in bins of photon energy



- Using phasespace MC
- Acceptance is shown for K^0 channel and the normalisation channel (η)
- The acceptance for K^0 is flat
  - due to decay of the K^0 and Σ^+
- Covers full angular range
  - no extrapolation

Acceptance

angular distributions in bins of photon energy



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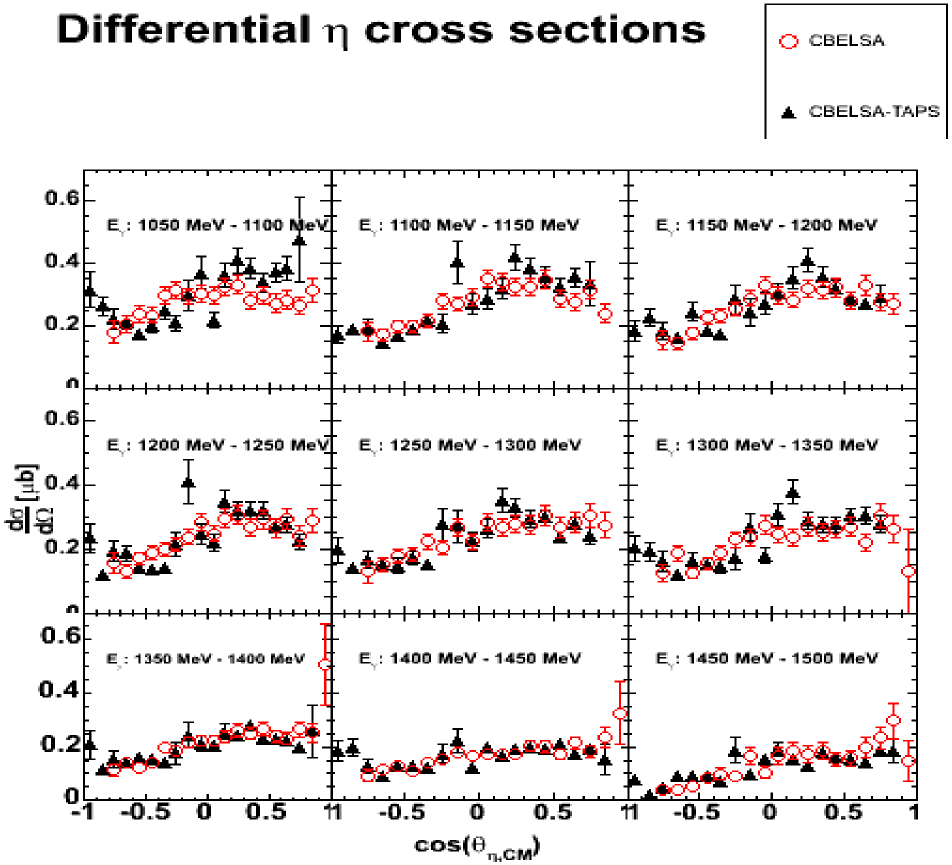
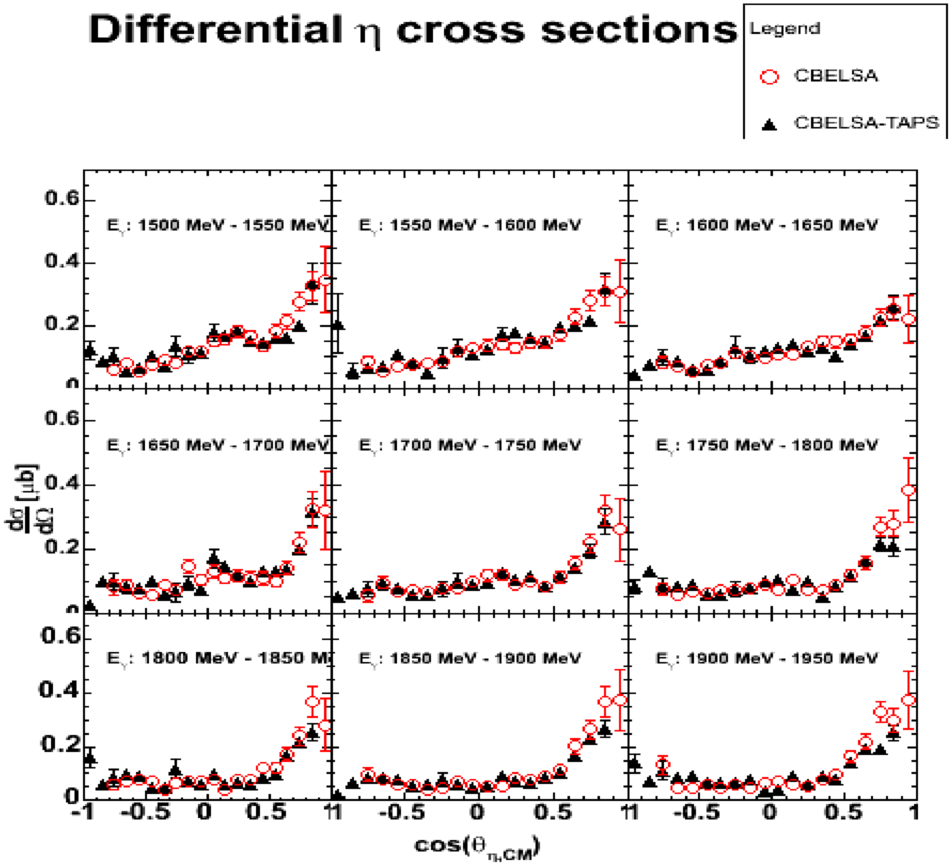
Normalisation using η channel



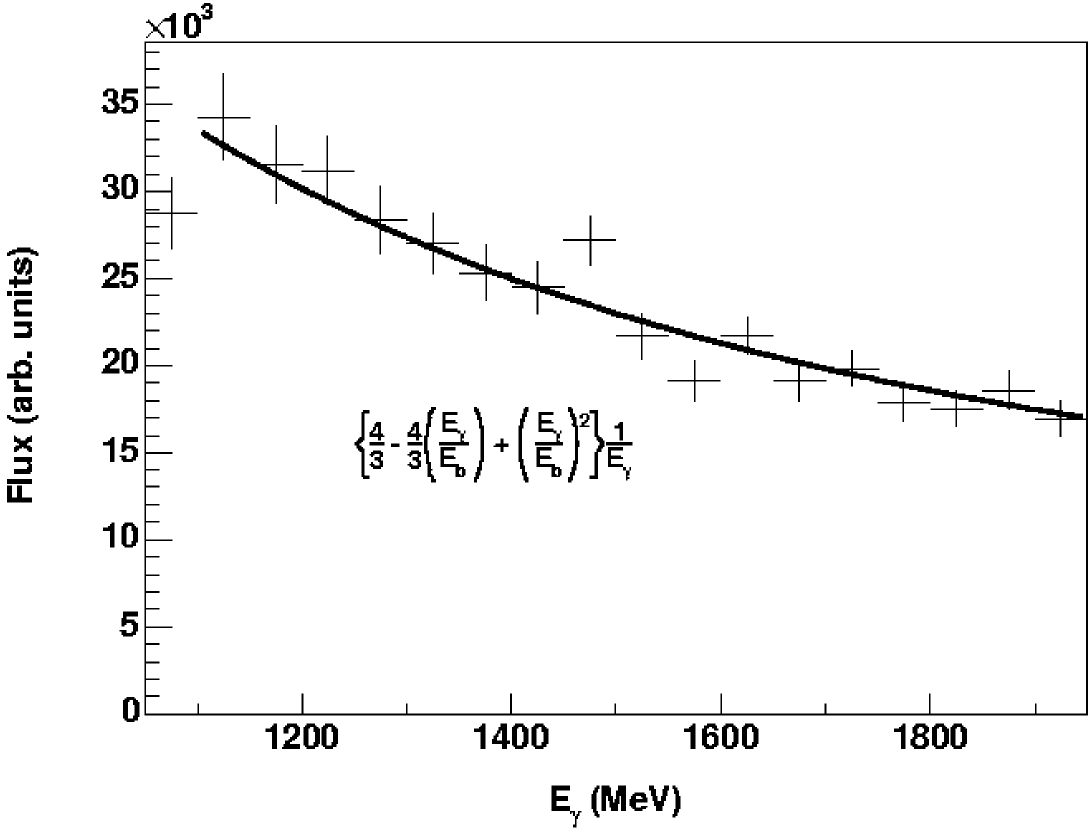
- Comparison to CB data (2002) V. Crede et al., PRL 94, 012004, (2005).
- good agreement
- acceptance well understood

Normalisation using η channel



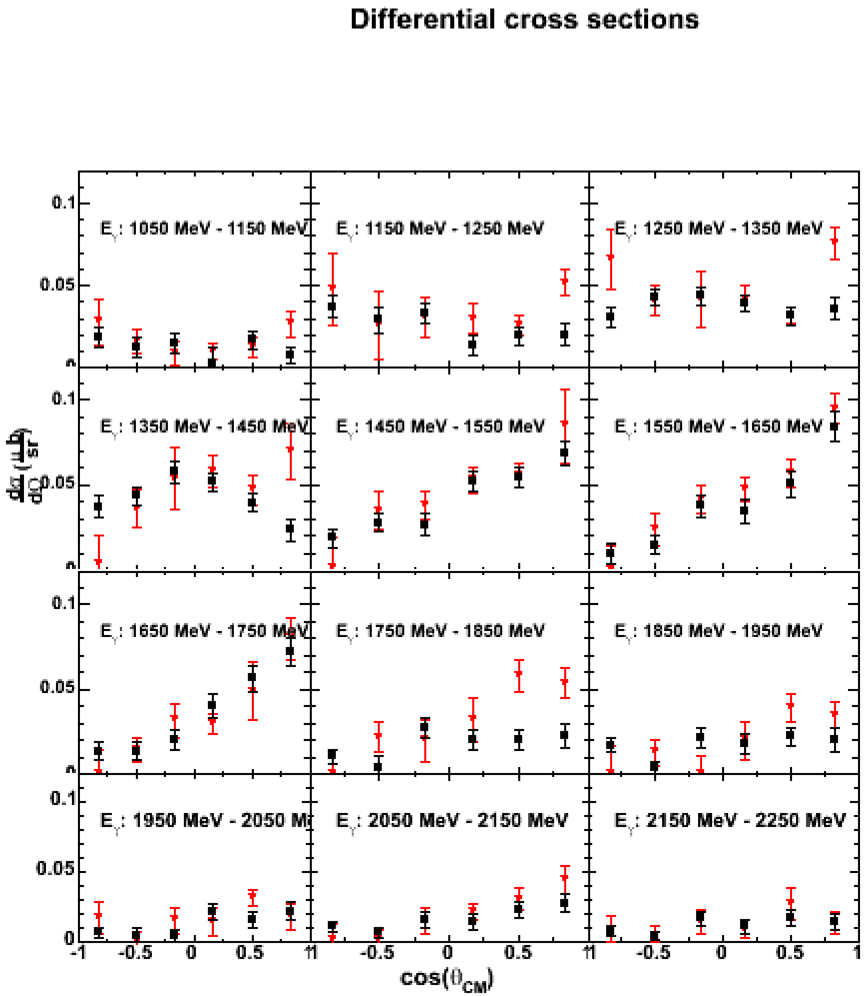
- Comparison to V. Crede et al., PRL 94, 012004, (2005).
- good agreement over entire energy range
- acceptance well understood

The photon flux



- Obtained flux follows: 1/E form with polynomial modification
- Agrees with online flux estimate, obtained using scalers

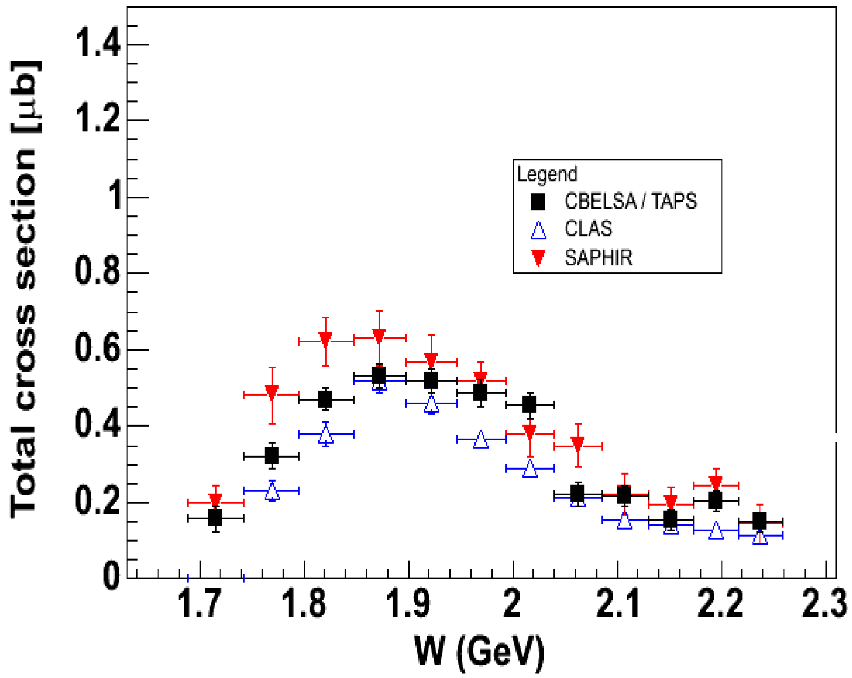
Differential cross section



- The differential cross sections agree with the SAPHIR result except at forward angles
- The CBELSA / TAPS result is flatter for the lower energies

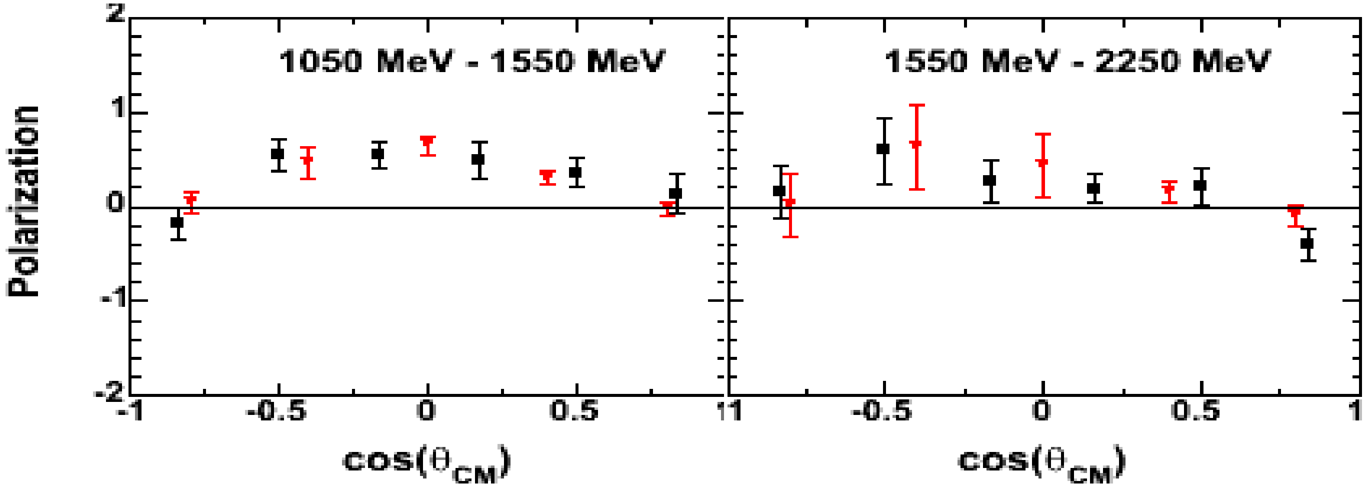
Excitation function

comparison to SAPHIR and CLAS



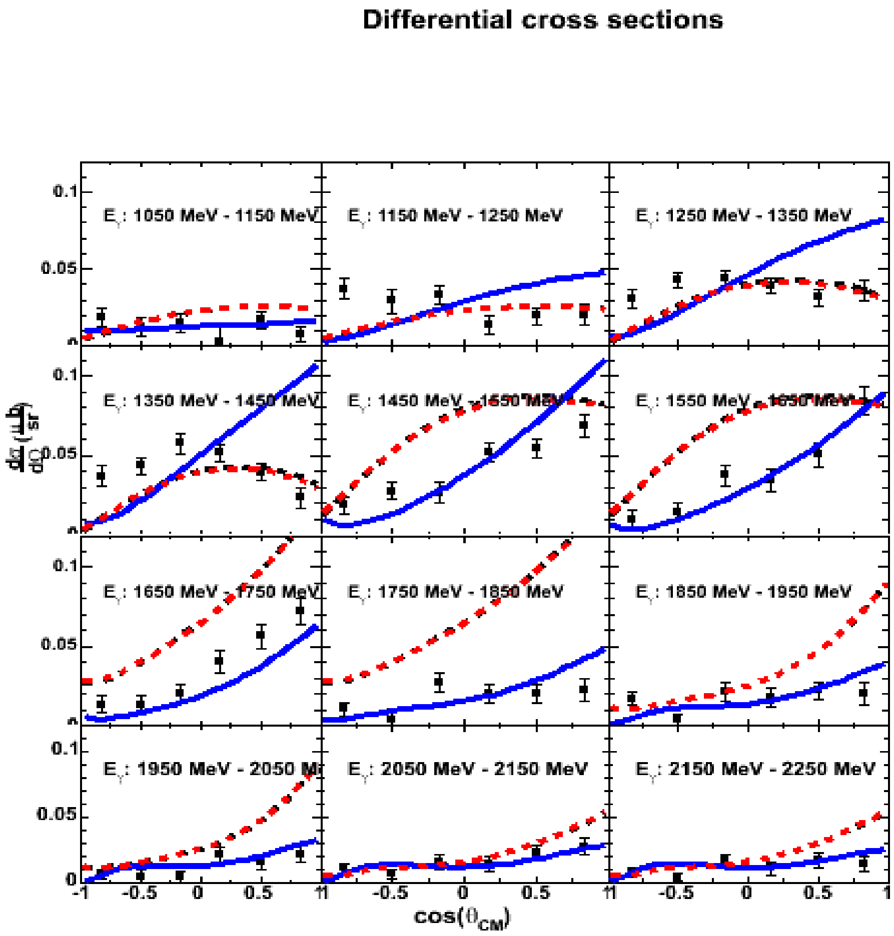
- The excitation function is slightly above the CLAS result
- The excitation function lies below the SAPHIR result at around 1.8 GeV
- Due to disagreement in the forward angles

Recoil polarisation



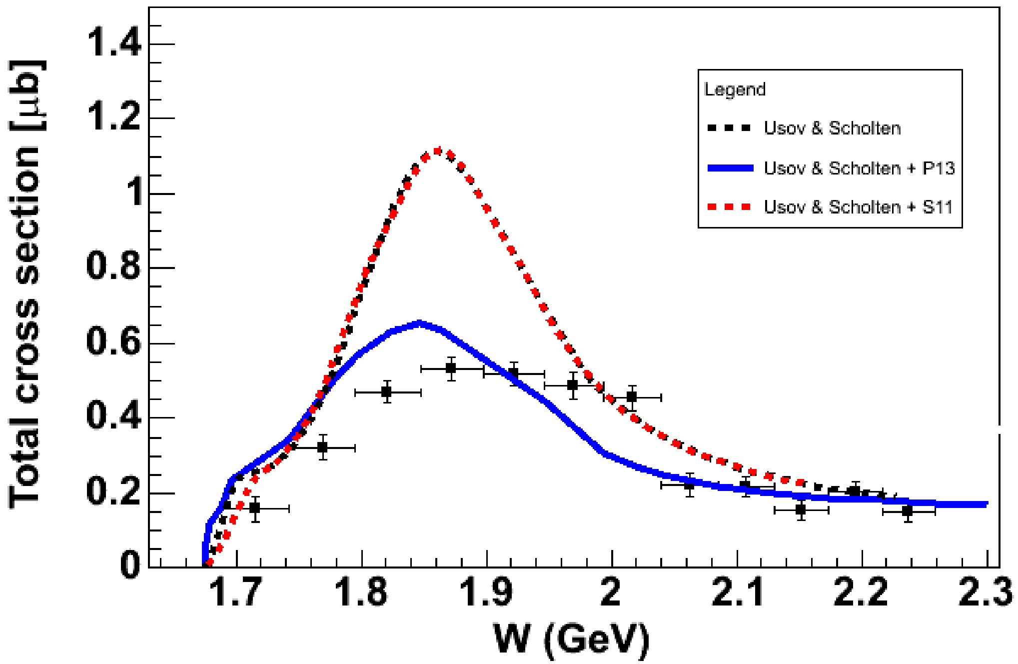
- Σ^+ is self analyzing
- Polarisation defined by the number of protons emitted above and below the reaction plane
- Recoil polarisation agrees with the new SAPHIR results
  - finer binning

Comparison to K-matrix calculations



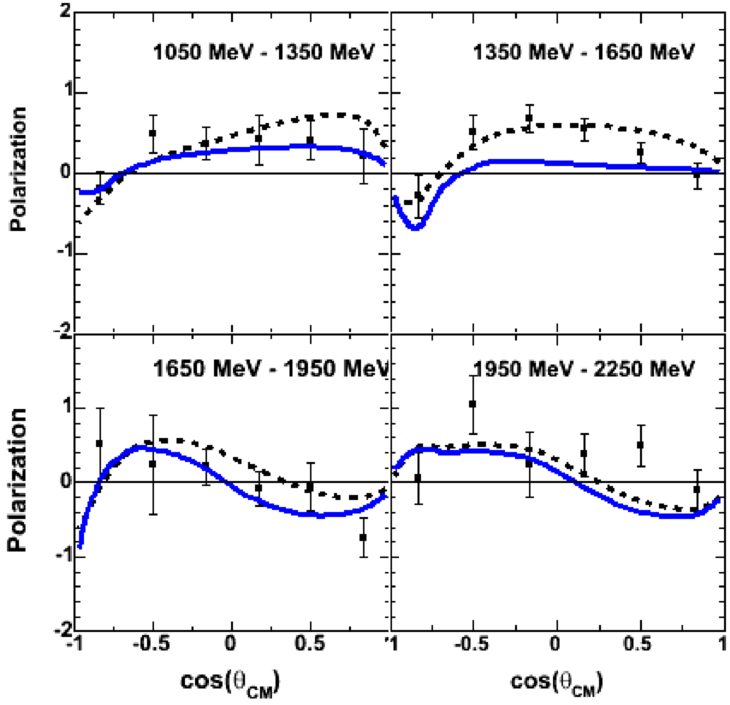
- Comparison between the data and K-matrix calculation by Usov and Scholten (dashed)
  - using all known resonances
  - using coupled channels approach
- Including additional P_{13}(1830) describes the data better (solid)
- More details in talk of O. Scholten

Excitation function



- The excitation function shows the difference between the different model inputs more clearly

Recoil polarisation



- Polarisation observables are also calculated within the K-matrix framework
- Sensitivity of recoil polarisation data does not allow to discriminate between the different model inputs

Summary & outlook

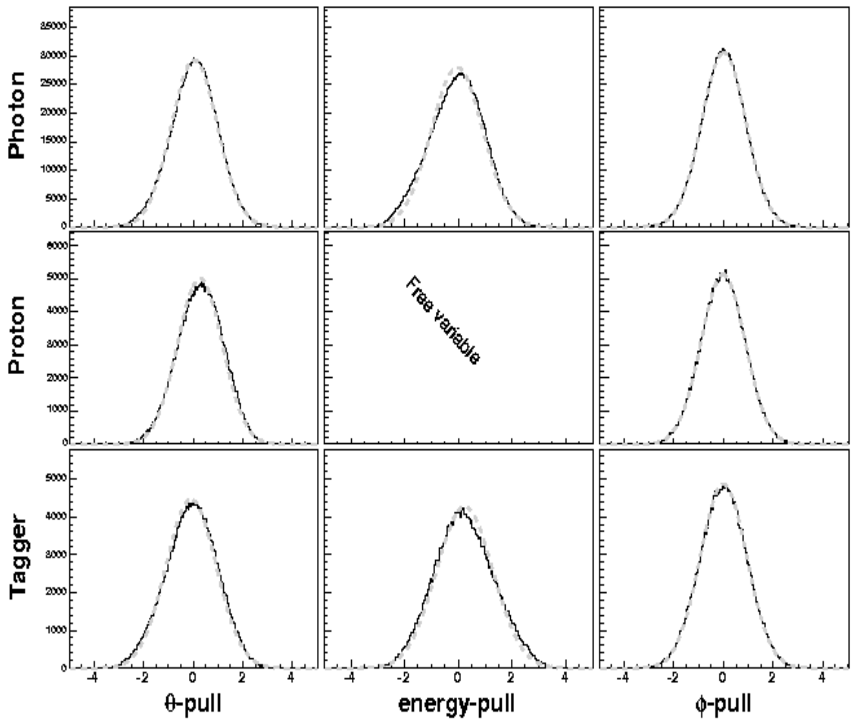
Summary:

- Photoproduction cross sections and recoil polarisations of $K^0 \Sigma^+$ channel have been obtained using neutral decay mode
- Results agree with new Saphir analysis and Jlab results
- The K-matrix calculations of Usov and Scholten reproduce the measured data significantly better when an additional P_{13} is included at 1830 MeV

Outlook:

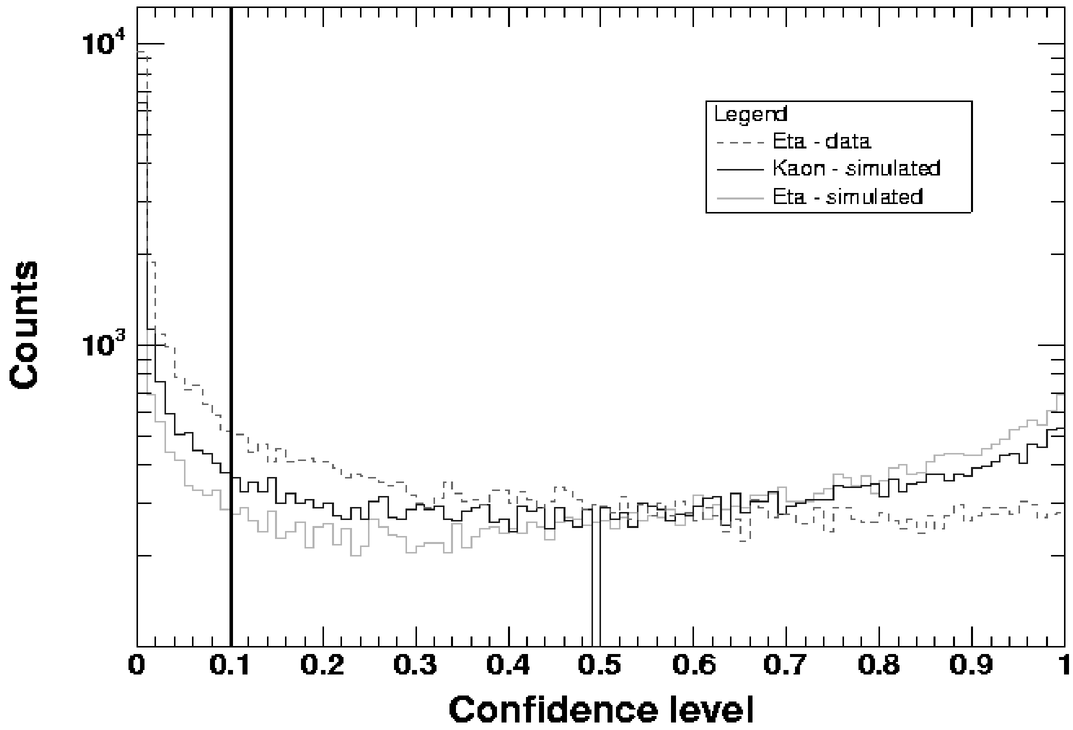
- Analysis of the data taken with a polarized beam
- Analysis of the data taken with a deuteron target
  - to obtain information on the hyperon-nucleon interaction

Pull distributions of the fit



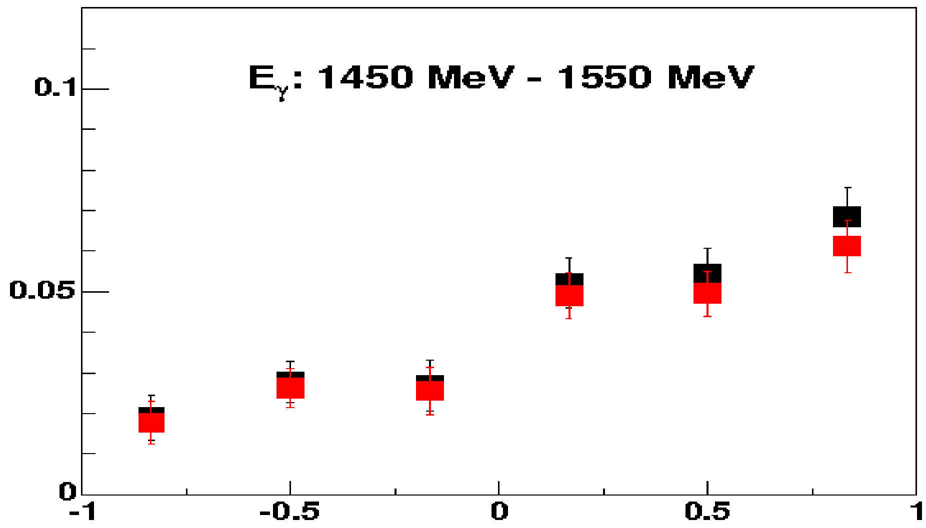
- Pull distributions compared to Gaussian:
  - sigma = 1
  - mean = 0
- Systematic errors under control

Confidence level distribution

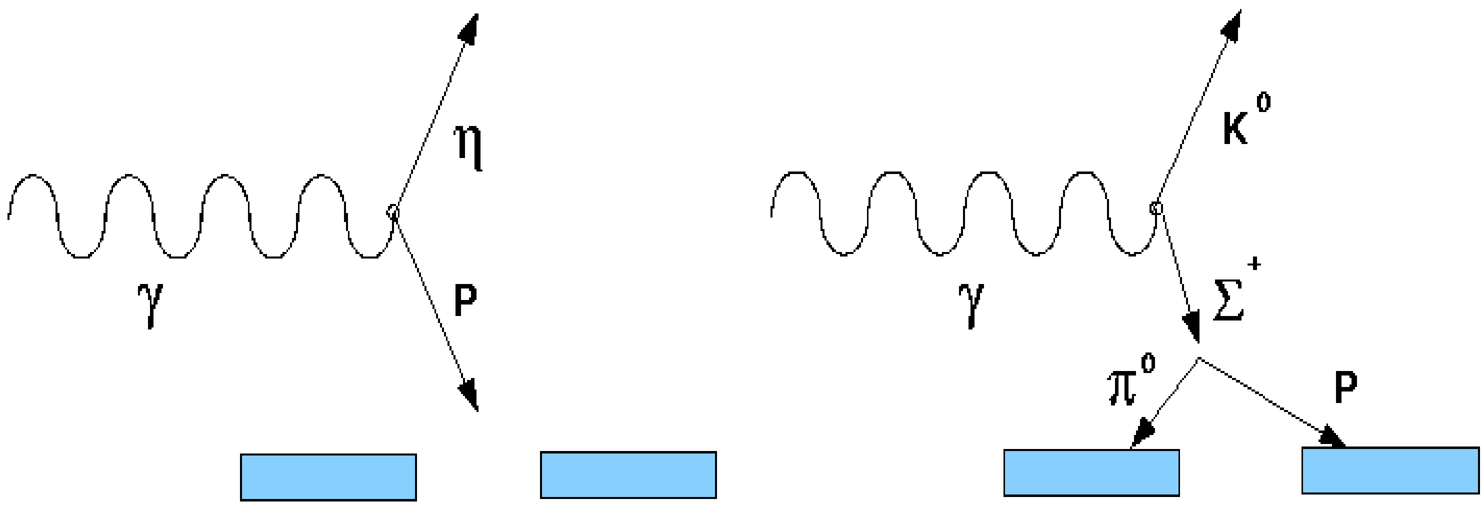


- Important: confidence level distribution for η and K^0 are the same
- Calibration relative to η

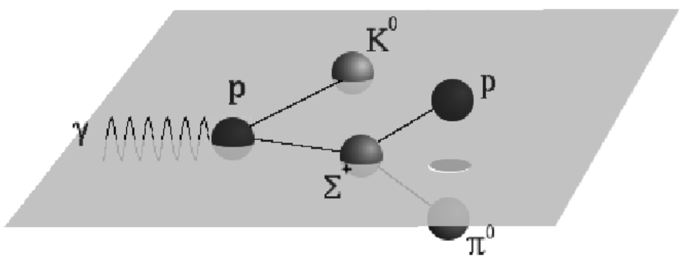
Effect of thresholds on differential cross sections



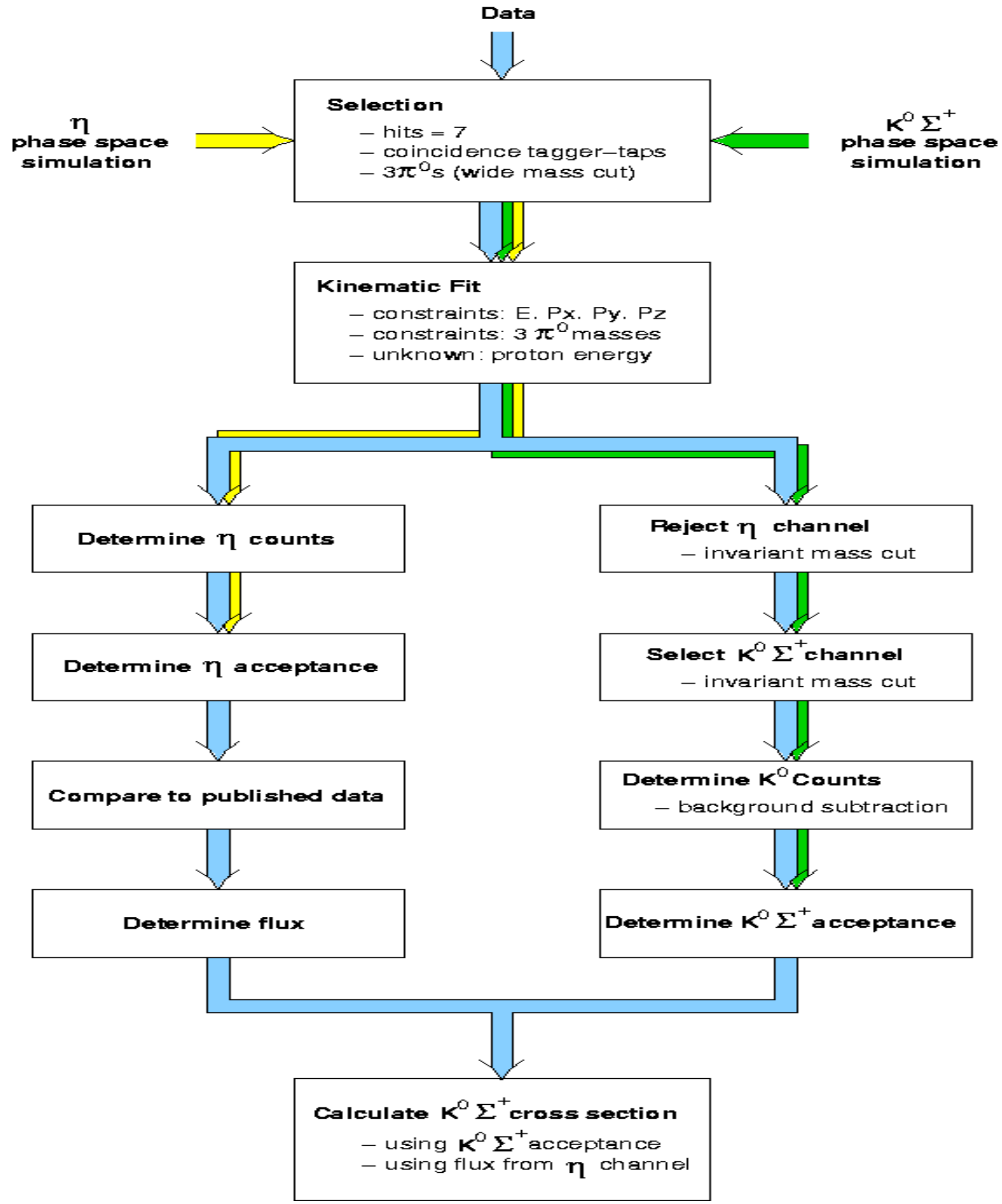
Acceptance holes for η



Recoil polarisation determination



- Reaction plane defined by kaon and sigma
- Recoil polarisation determined by counting the number of times the proton is emitted above (N1) or below the plan (N2)
- $P = (N1 \quad N2)/(\alpha(N1 + N2))$
- $\alpha = 0.980$ (PDG)


Data
Selection
– hits = 7
– coincidence tagger–taps
– 3π⁰s (wide mass cut)
η
phase space
simulation
K⁰ Σ⁺
phase space
simulation
Kinematic Fit
– constraints: E, Px, Py, Pz
– constraints: 3 π⁰ masses
– unknown: proton energy
Determine η counts
Reject η channel
– invariant mass cut
Determine η acceptance
Select K⁰ Σ⁺ channel
– invariant mass cut
Compare to published data
Determine K⁰ Counts
– background subtraction
Determine flux
Determine K⁰ Σ⁺ acceptance
Calculate K⁰ Σ⁺ cross section
– using K⁰ Σ⁺ acceptance
– using flux from η channel