Measurement of the $\gamma\, n(p) \rightarrow K^{+}\, \Sigma^{-}(p)$ at Jefferson Lab

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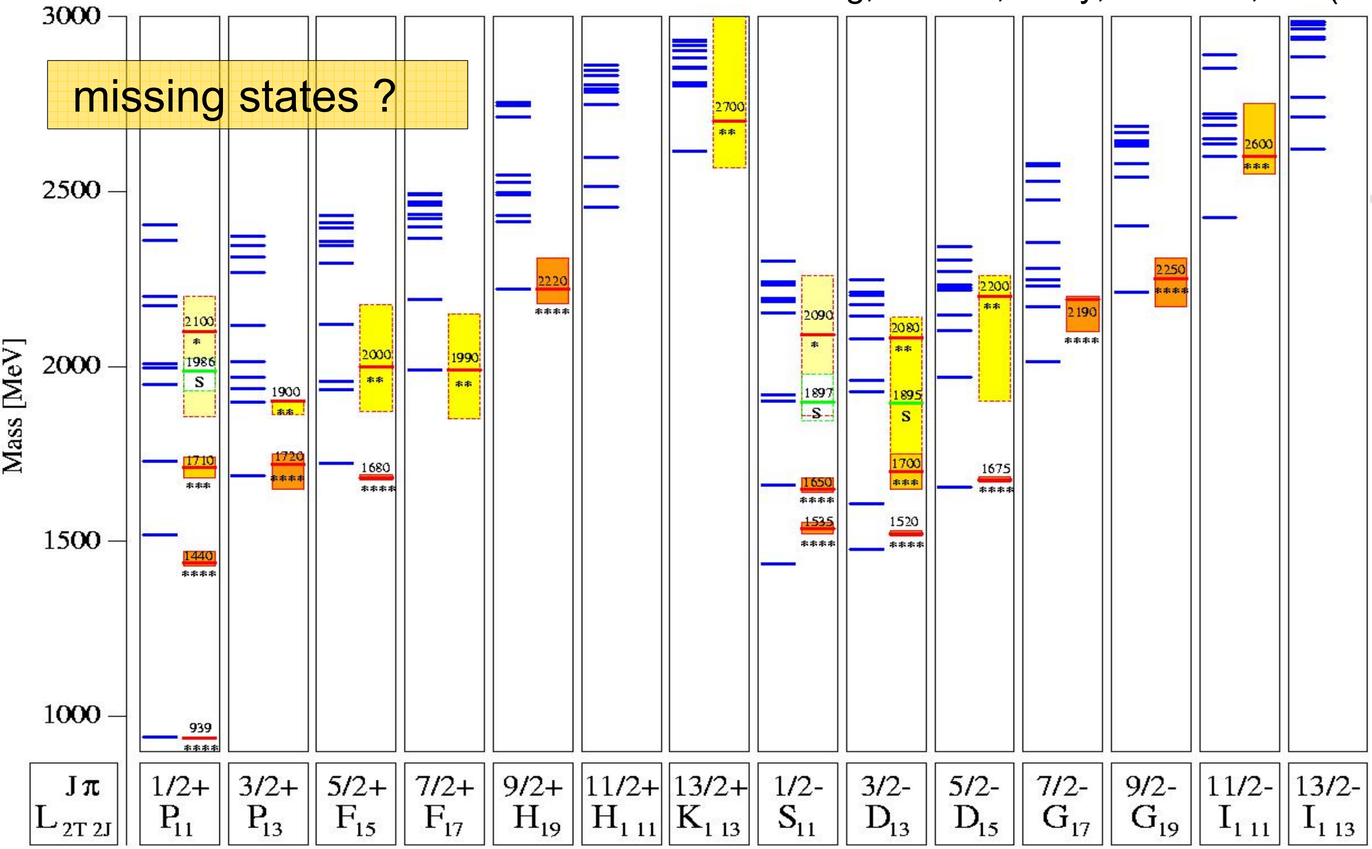
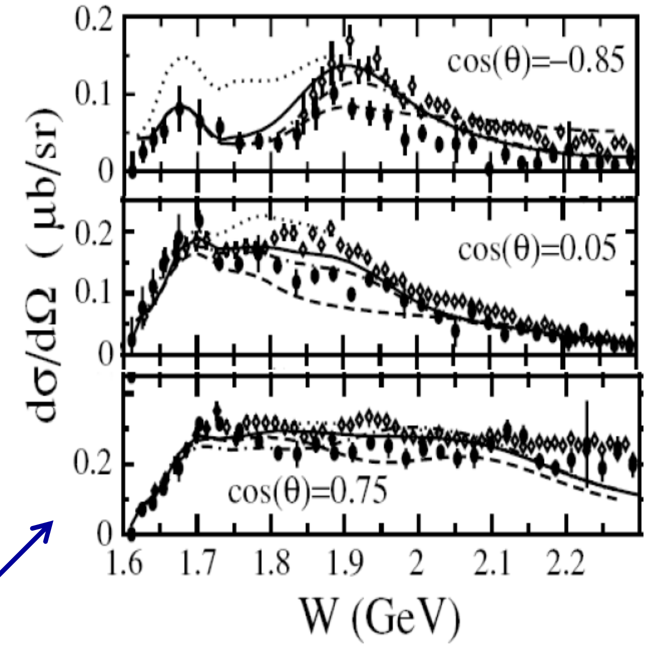
Physics Motivation

Löhring, Metsch, Petry, EPJ A10, 395(2001)



Why investigate the spectrum of baryon (N* and Δ) resonances, with the decay in KY (Y ≡ Λ or Σ)?

- **Couplings of nucleon resonances to KY final states will differ from the πN, ηN and ππN final states.**



<u>Λ K⁺ channel on proton</u>

full line: full model with additional S_{11}, P_{13} and D_{13} resonances

dotted line: no S_{11} resonance

dot-dashed line: no P_{13} resonance

dashed line: no D_{13} resonance

Physics Motivation (2)

• It's important to provide data to investigate the spectrum of baryon (N^* and Δ) resonances, with the decay in KY ($Y \equiv \Lambda$ or Σ).

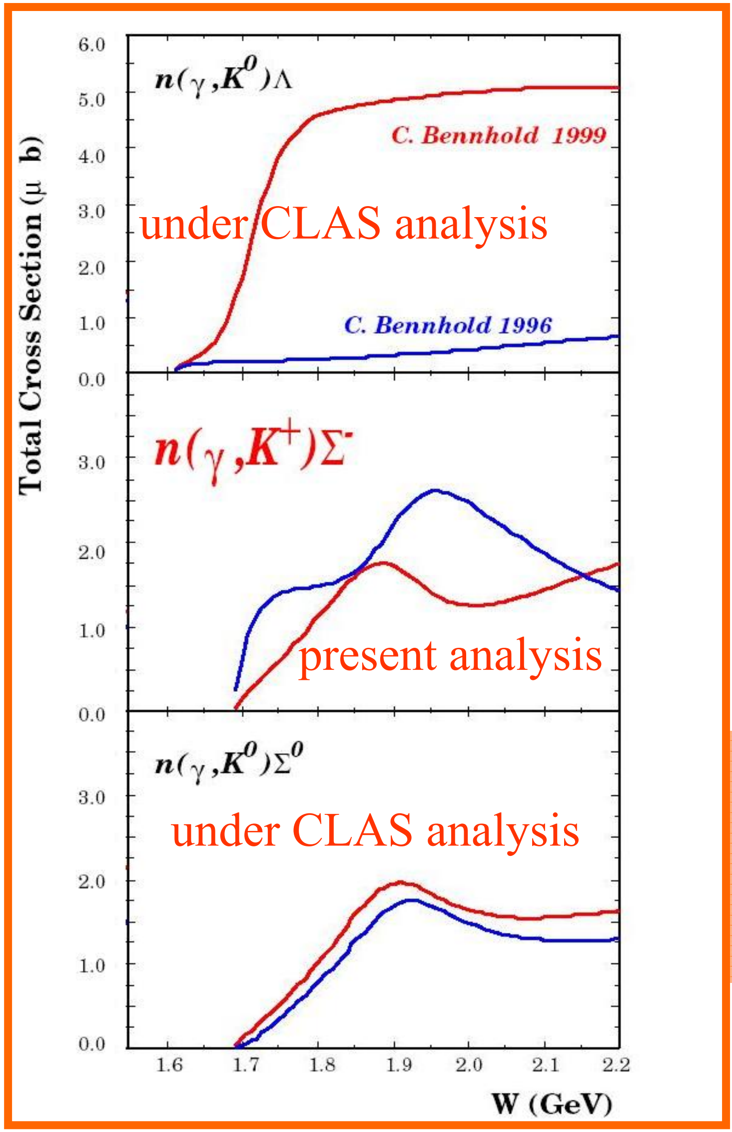
• Although the branching fractions of most resonances to KY final states are small compared to 3-body modes there are some advantages:

- More often 2-body final states are easier to analyze than 3-body system states,
- Couplings of nucleon resonances to KY final states will differ from the πN, ηN and $\pi\pi N$ final states.

Goals of this work: study the $\gamma n \rightarrow K^+ \Sigma^-$ channel to

1) ***study the baryon resonances not otherwise revealed,***
2) ***obtain information about couplings of nucleon resonances to KY final states***

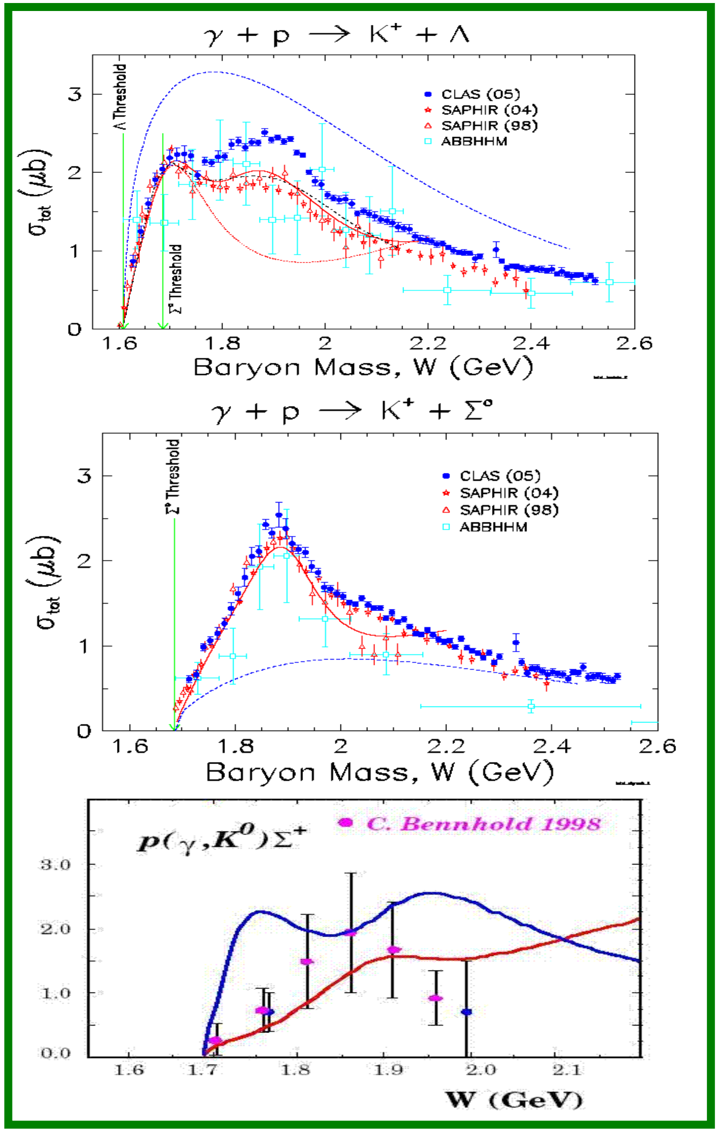
Total cross section γ N → K Y



γ p → $K^+ \Sigma^0$
γ p → $K^+ \Lambda$
γ p → $K^0 \Sigma^+$

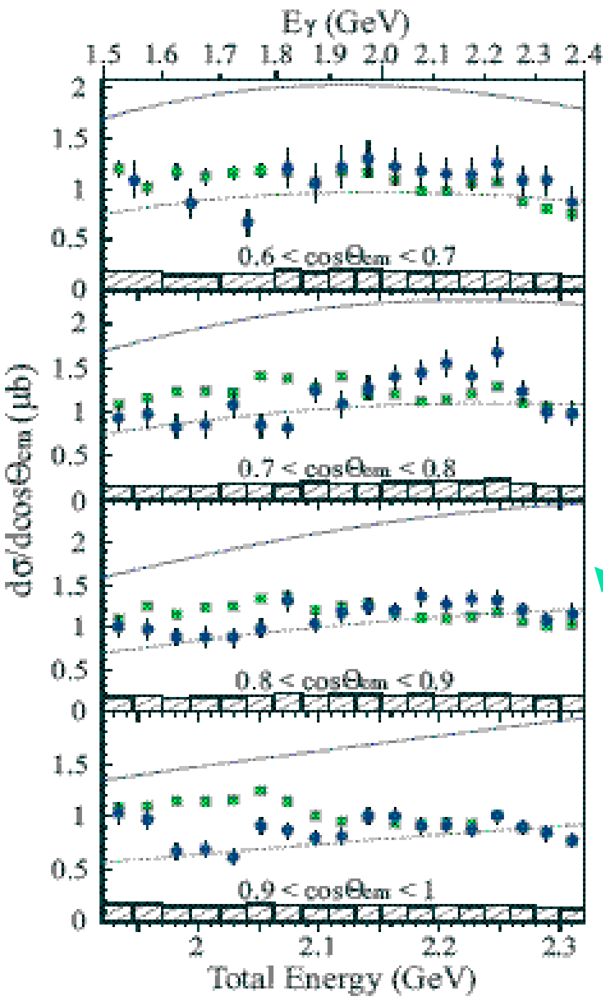
γp data from ABBHHM, SAPHIR and CLAS

there is no Total Cross section data for γn reactions



Differential Cross Sections

$\gamma + n \rightarrow \Sigma^- + K^+$



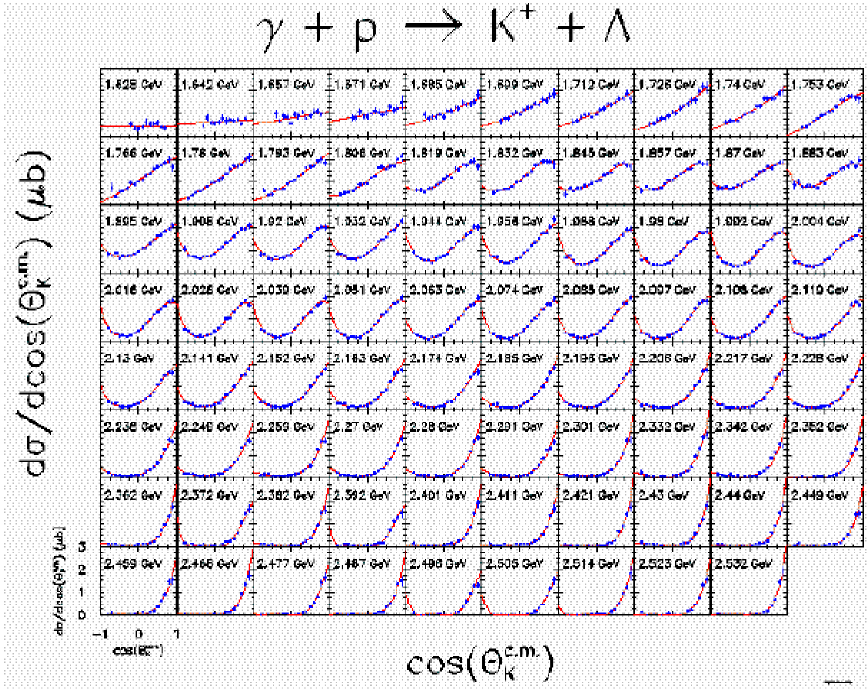
Λ

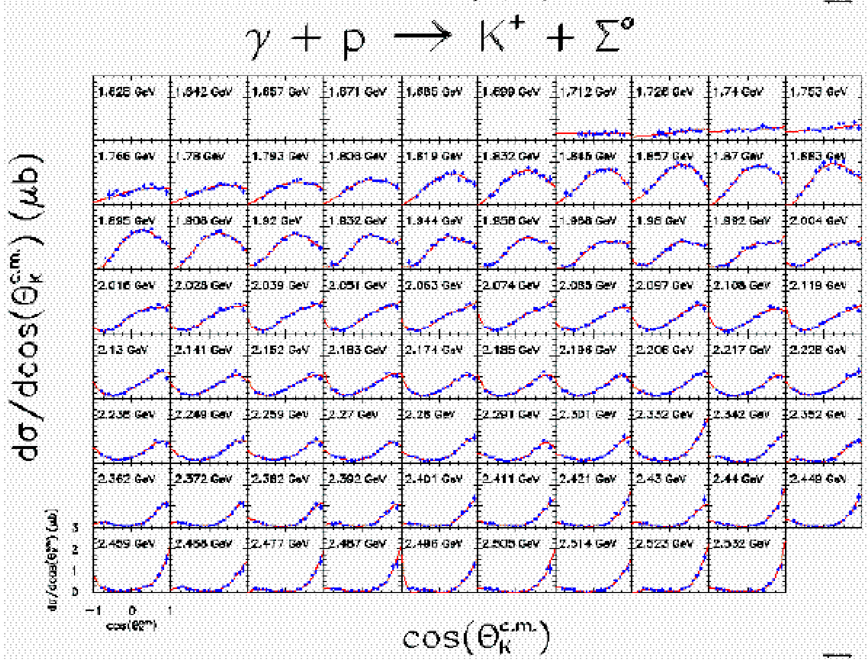
data on ***γp*** **(CLAS)**
Eγ = 1.019 – 2.949 GeV
Cos Θ^{CM} = -0.8 – 0.9
there are also SAPHIR and ABBHHM collab. (not shown here)

Σ^-

Σ^0

data on **(LEPS)**
Eγ = 1.5 – 2.4 GeV
Cos Θ^{CM} = 0.6 – 1.0
γn→K⁺Σ⁻ (blue points)
γp→K⁺Σ⁰ (green squares)





Experimental status @ JLab

A comprehensive study of the electromagnetic strangeness production has been undertaken at Thomas Jefferson National Accelerator Facility (Jefferson Lab), using the CLAS detector. The related KY experiments are:

γ p → (g1) Differential Cross Sections for $\gamma p \to K^+ Y$ for Λ and Σ^0 hyperons
Phys. Rev. C 035202 (2006)

γ p → (g1) First Measurement of Beam-Recoil Observables C_x and C_z in Hyperon Photoproduction, *Phys. Rev. C **75**, 035205 (2007)*,

γ d → (g2) Study of $\gamma n \to K^+ \Sigma^-$ channel (very low statistics), unpublished

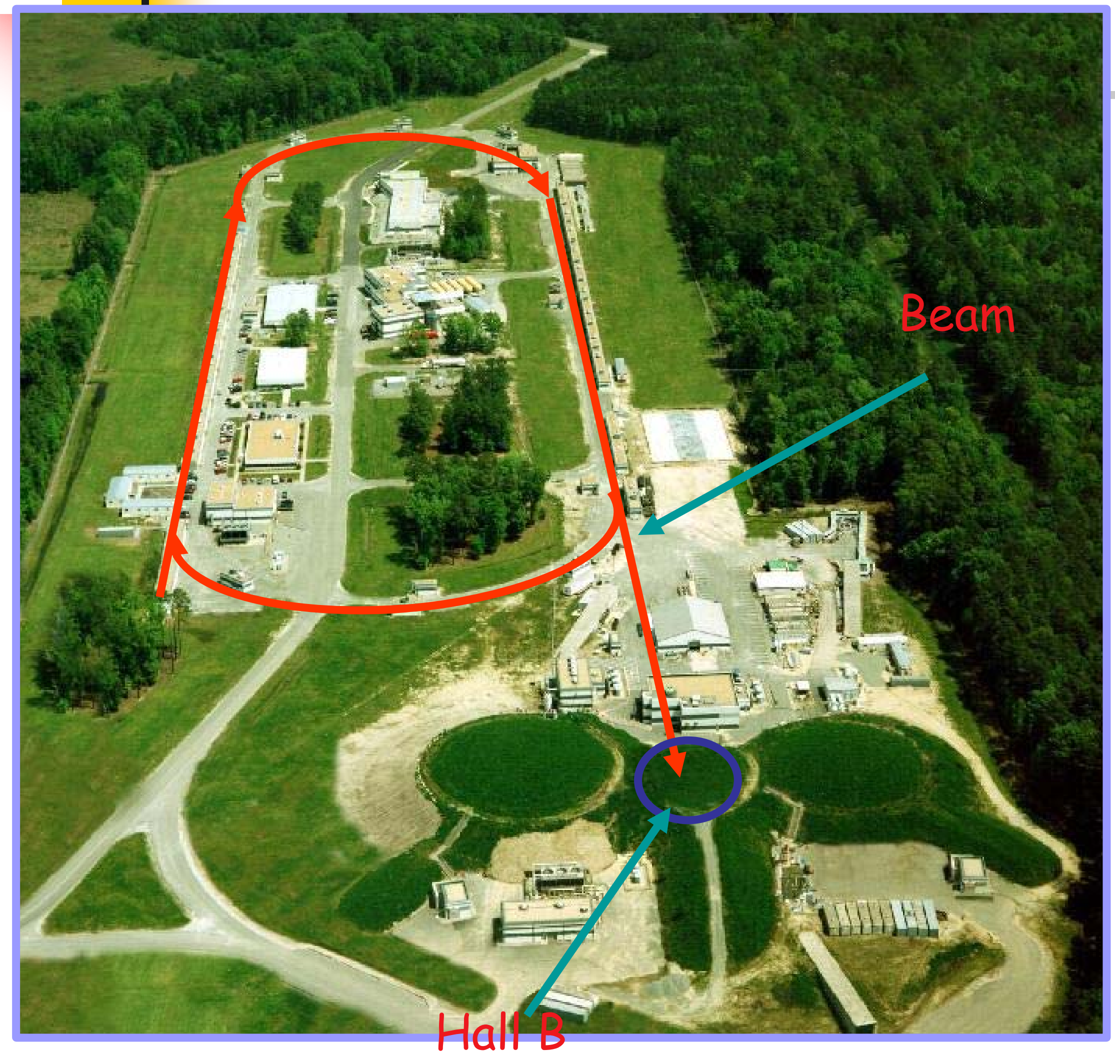
γ d → (g10) Study of $\gamma n \to K^+ \Sigma^-$ reaction channel **(present work)**

γ d → (g13) Kaon production on Deuteron using polarized photons (running completed in 2007, data processing underway)

γ p → (FROST) Kaon production on proton with linearly and circularly polarized photons using novel FRozen Spin Target (longitudinal and transverse polarization), running completed in 2007, data processing underway

γ d → (HD-ICE) Kaon production on Deuteriun with linearly and circularly polarized photons using polarized HD-Ice target from BNL modified for CLAS (run in 2010)

JLab Accelerator CEBAF



Superconducting recirculating electron accelerator

- Continuous Electron Beam
- Energy 0.8-5.7 GeV
- 200μA, polarization 80%
- Simultaneous delivery to 3Halls

Hall B: Cebaf Large Acceptance Spectrometer + Tagger

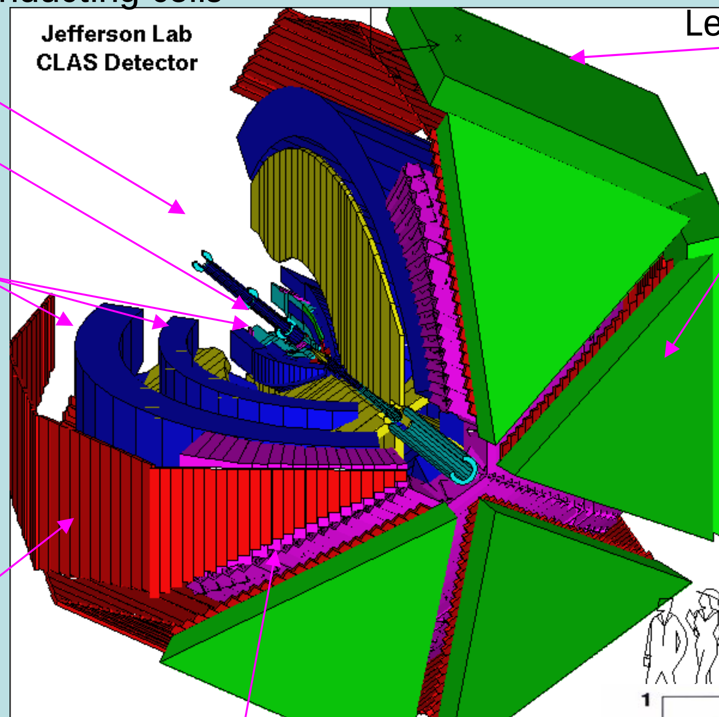
beam

Torus magnet
6 superconducting coils

Liquid D_2 (H_2)target +
γ start counter; e minitorus

Drift chambers
argon/CO_2 gas, 35,000 cells

Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers



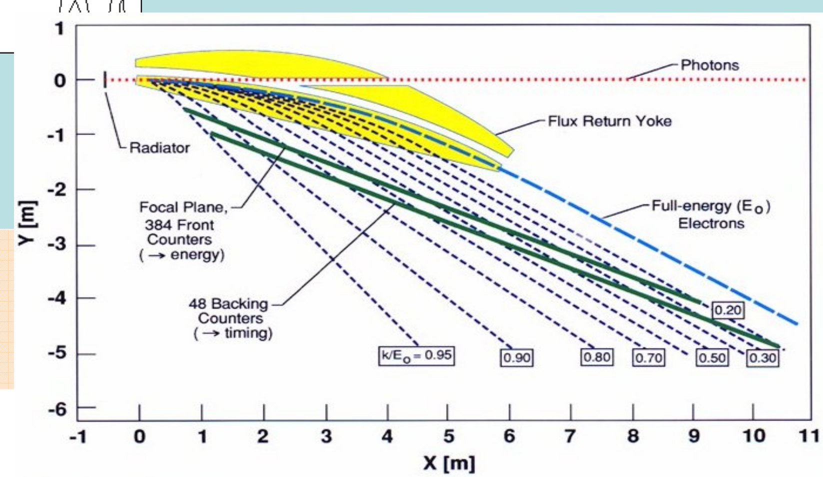
- Broad angular coverage (8° ÷ 140° in LAB frame)
- Charged particle momentum resolution ~0.5% forward dir

CLAS is designed to measure exclusive reactions with multi-particle final states

Time-of-flight counters
plastic scintillators, 684 photomultipliers

Gas Cherenkov counters
e/π separation, 216 PMTs

- E_γ = (20% - 95%) E_e
- Tagged photon beam with energy resolution $\delta k/k \sim 0.1\%$



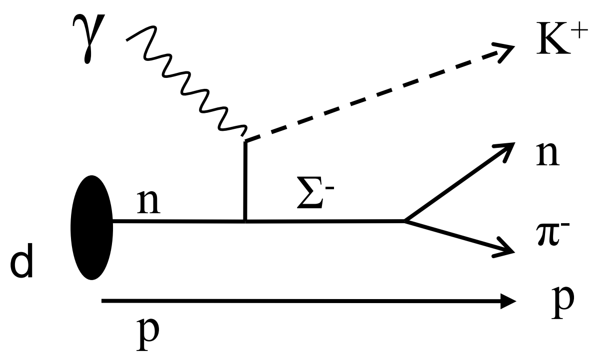
G10 Experiment

Approved experiment for the Pentaquark search on Deuterium

- **Target: 24cm liquid deuterium**
- **Data taking: March 13 - May 16, 2004**
- **Beam Current: 30 nA**
- **$E(e^-)$ = 3.767 GeV, $E(\gamma)$: 0.75-3.58 GeV**
- **Integrated luminosity: ~ 50 pb^{-1}**
- **Trigger – two charged particles in any of 2 sectors of CLAS**
- **Two settings of the torus magnet**
  - I=**2250** A : increased acceptance for forward going negative particles
  - I=**3375** A : the similar geometrical acceptance

Analysis procedure

- Studied channel $\gamma n \rightarrow K^{+} \Sigma^{-}$
- Energy range (Eγ): from threshold to 3.59 GeV;
- θ_K^{lab} range: from 10 to 140 degrees;

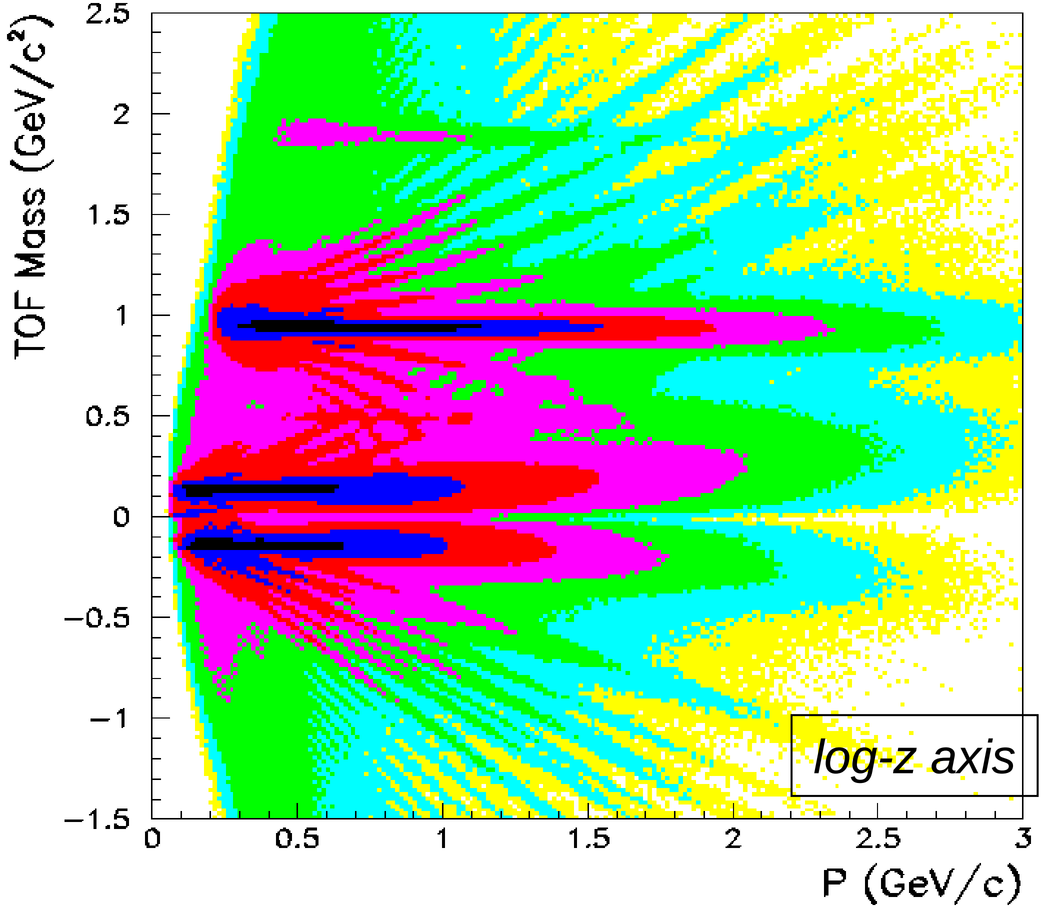


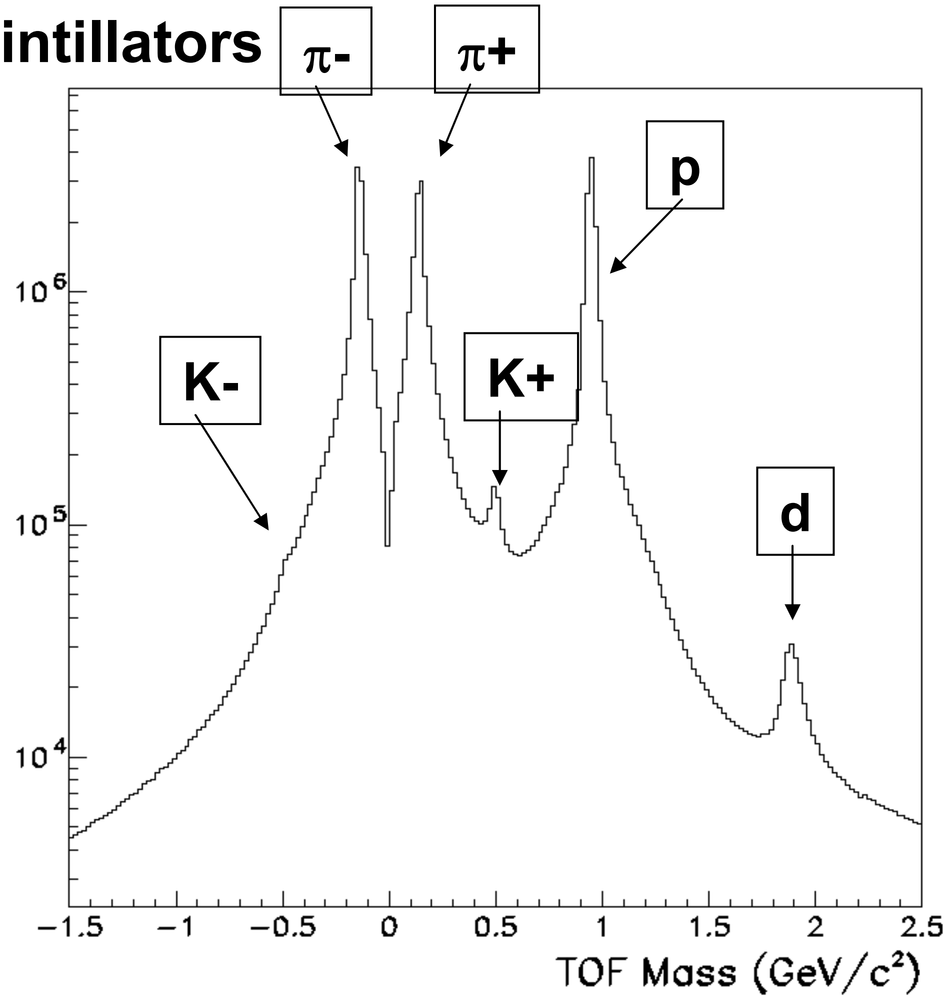
Exclusive measurement:

- ***detection of K^{+}, π^{-} and n***
- ***proton as a missing particle***
- ***Σ^{-} as invariant mass of (π^{-} n)***

CLAS capabilities: charged hadrons

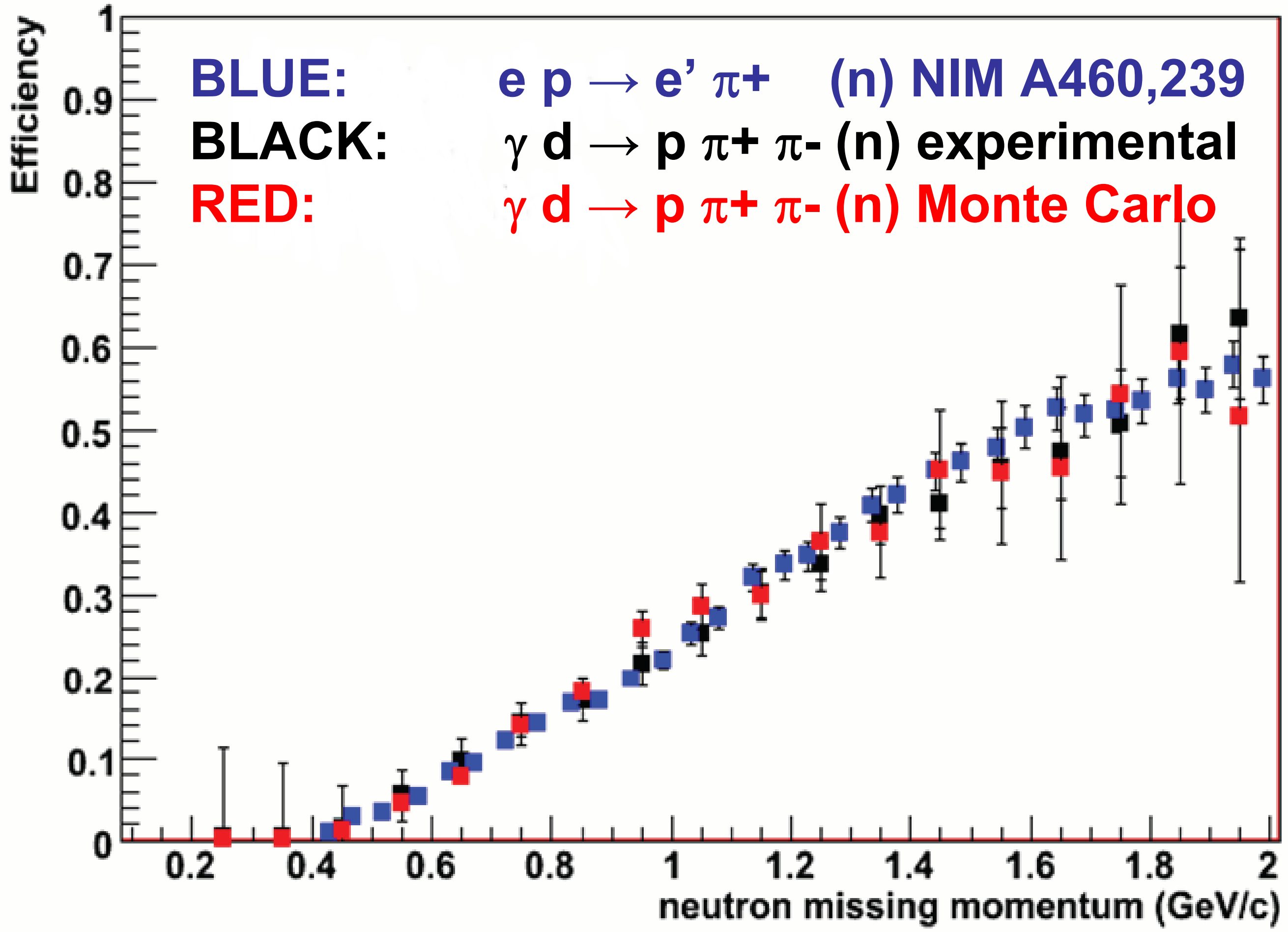
- Track reconstruction in DC
- β measurement with TOF scintillators





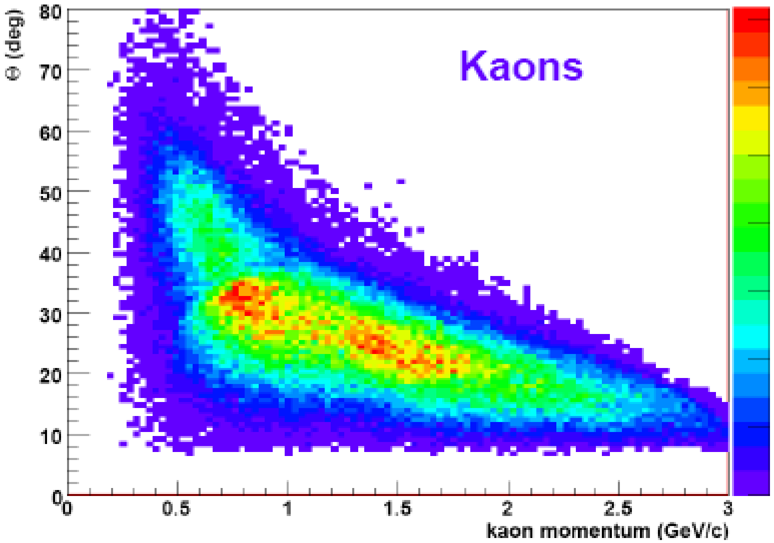
CLAS capabilities: neutrons

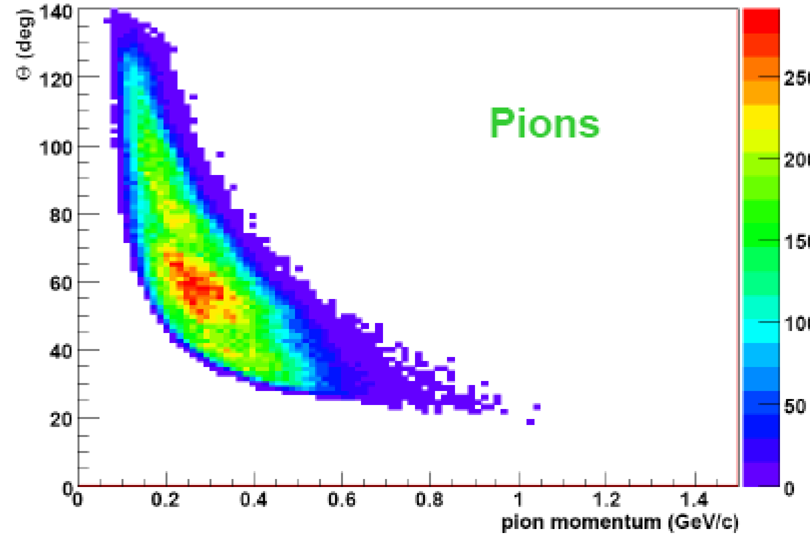
- Calorimeter hits not associated to charged tracks
- n/γ separation at β=0.9

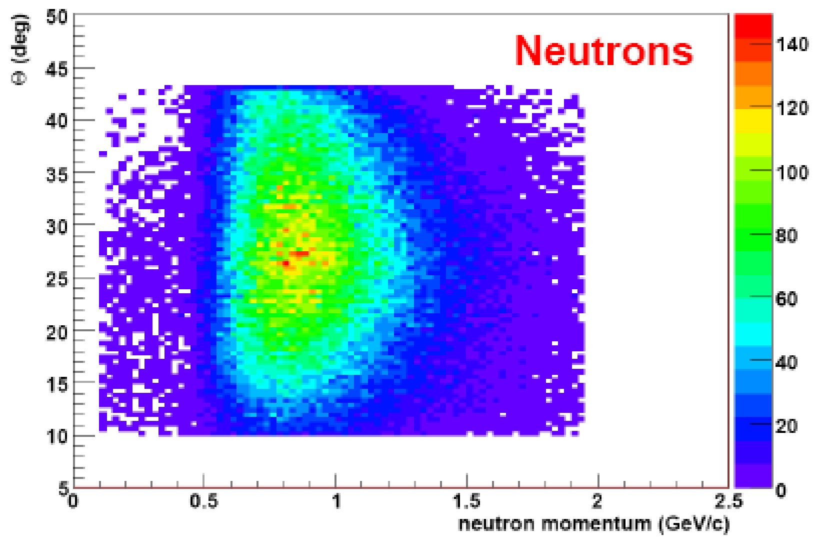


Kinematics

low field







γ d → K+ π- n X events

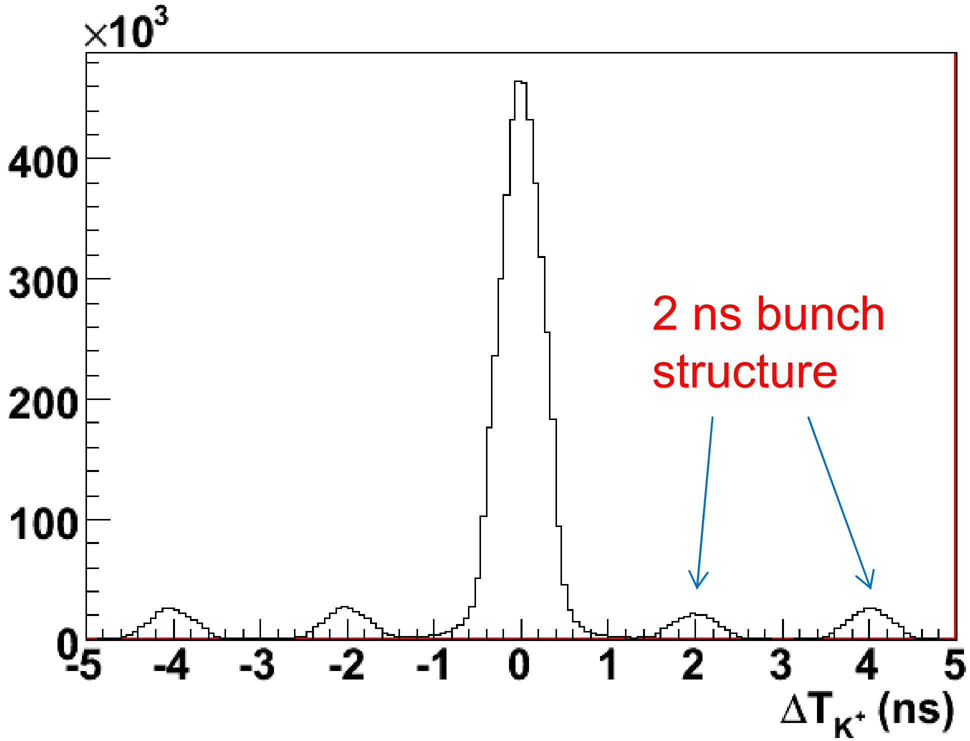
Kaons: forward angles with high momenta

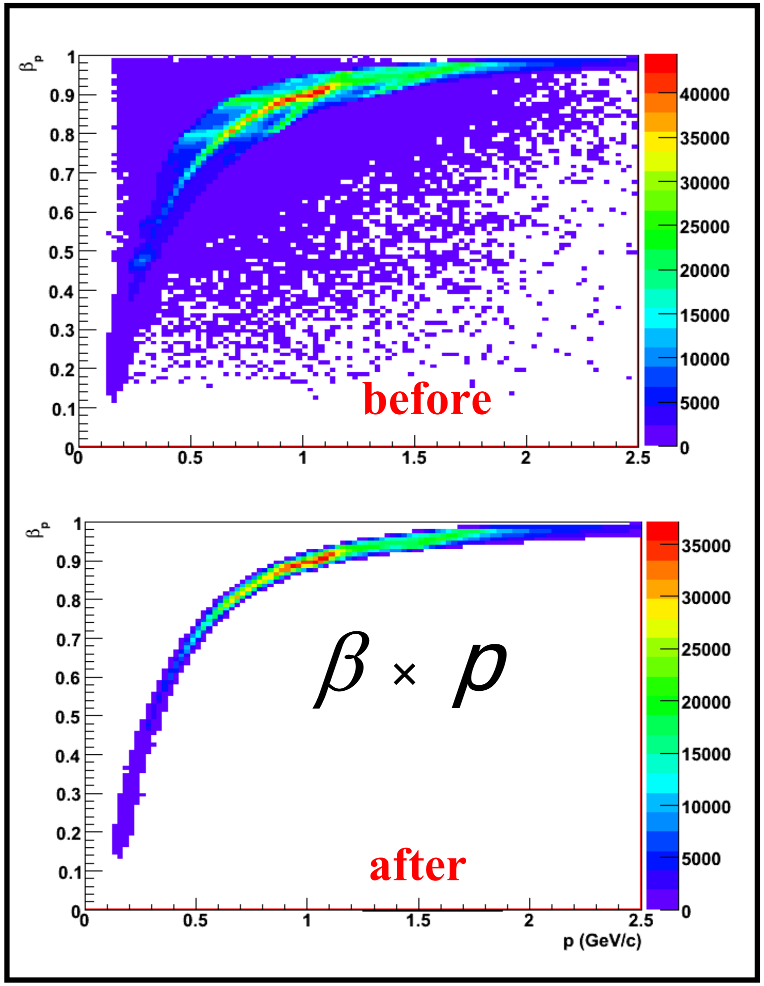
Pions: central angles and low momenta

Neutrons: forward angles (calorimeter)

K^+ identification

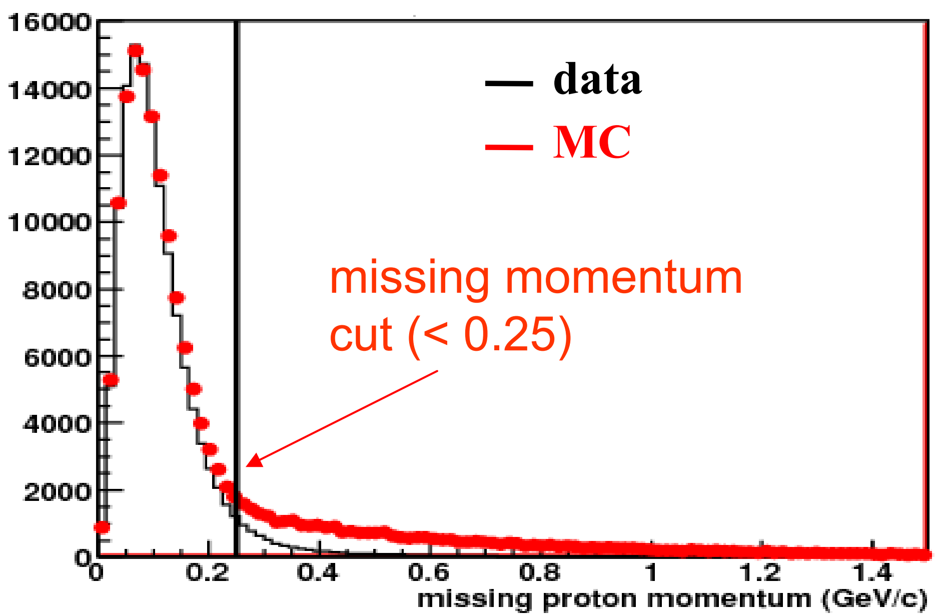
- since K^+ is the only detected particle produced in the initial interaction, a cut on the difference between particle time and photon time is applied.

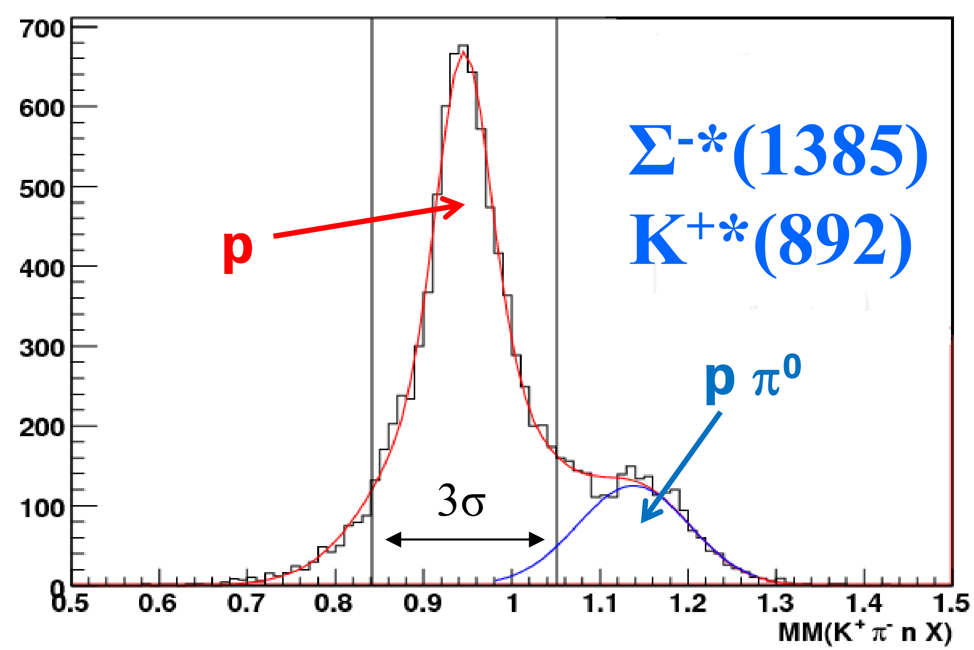




Channel identification

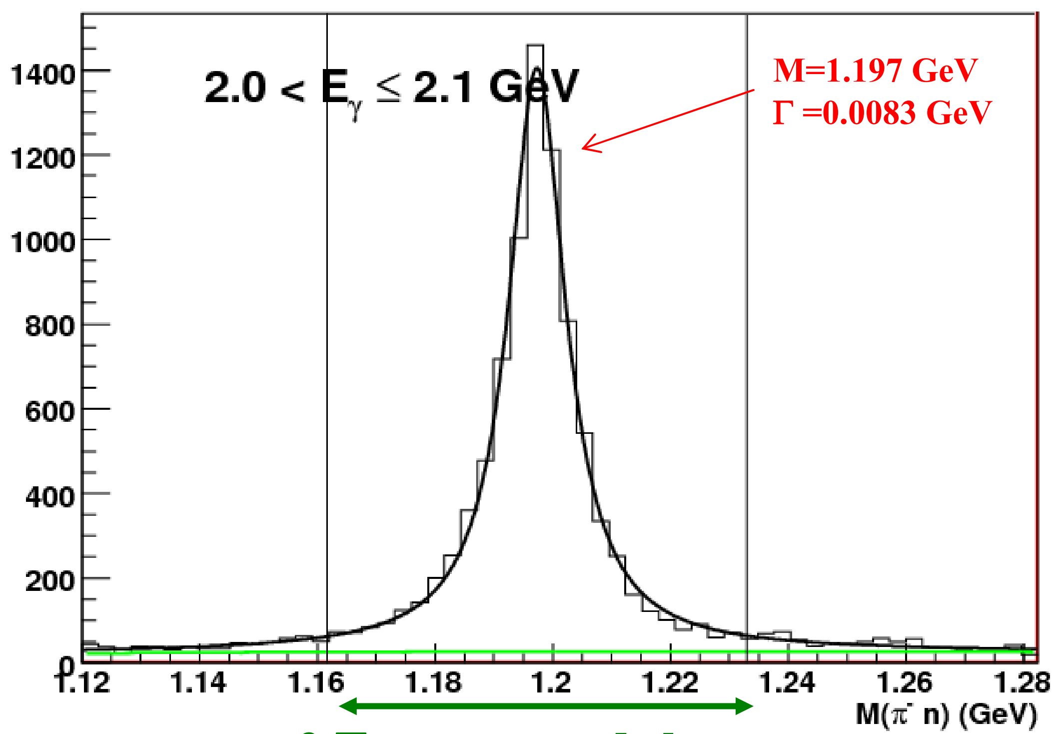
- the missing particle is identified as MM($K^+ \pi^- n$) in $\gamma d \rightarrow K^+ \pi^- n X$.
- a cut on the missing particle momentum is then applied ($p < 0.25$ GeV/c)
- after K^+ selection and missing momentum cut, the proton missing mass is calculated



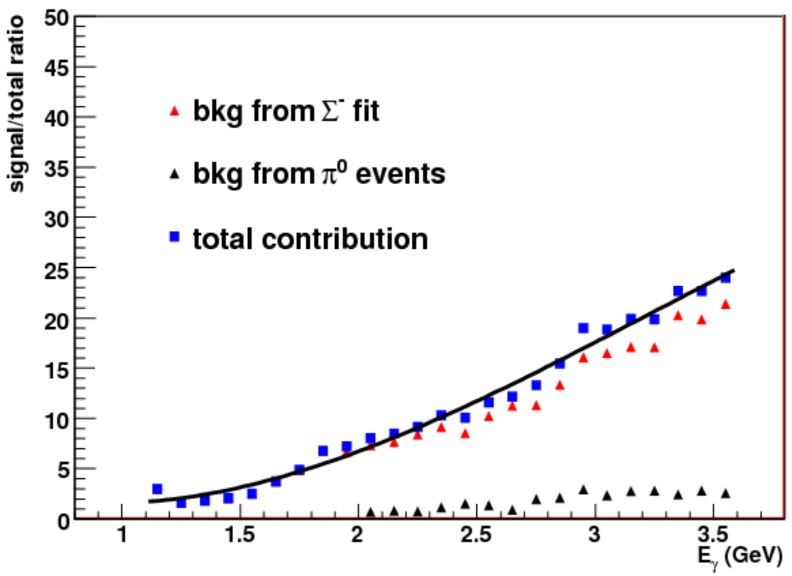


Σ^- identification

- after particle identification cuts, the Σ^- is identified as M($\boldsymbol{\pi}^-$ $\boldsymbol{n}$)



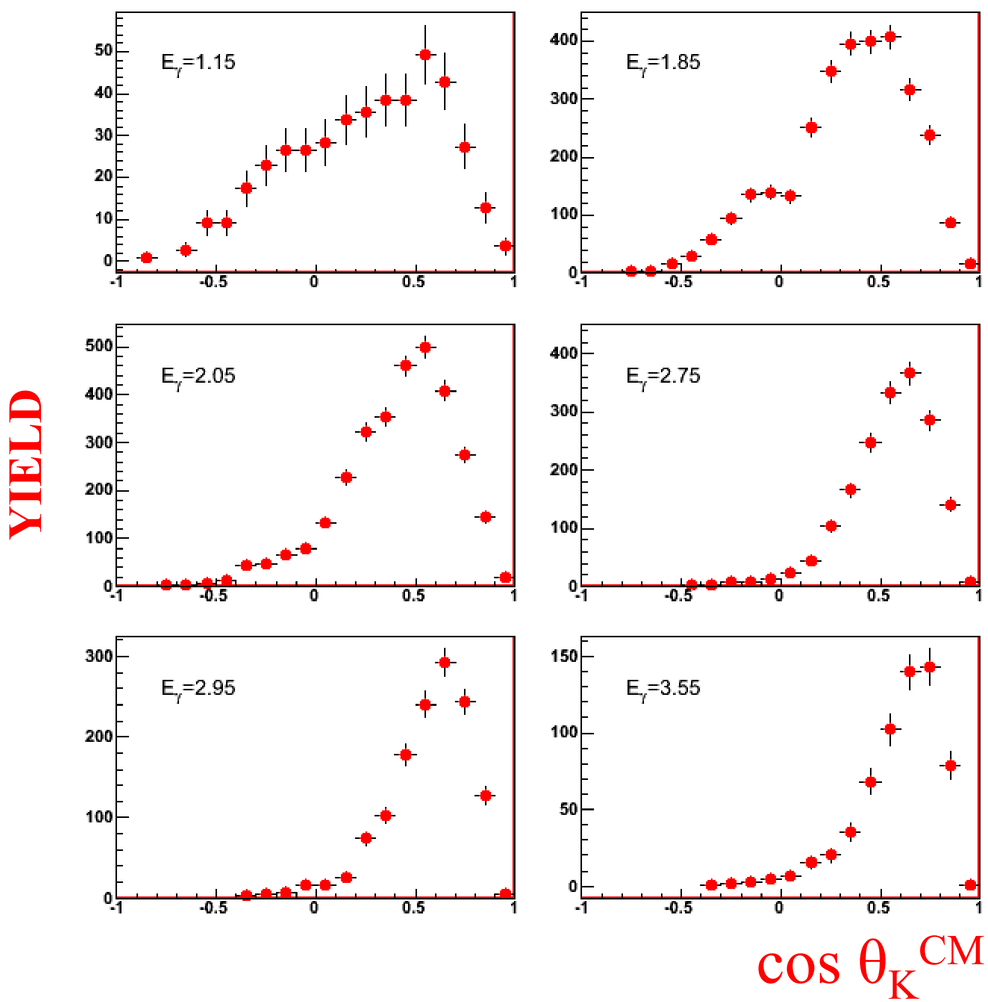
3 Γ cut around the Lorentzian fit is applied

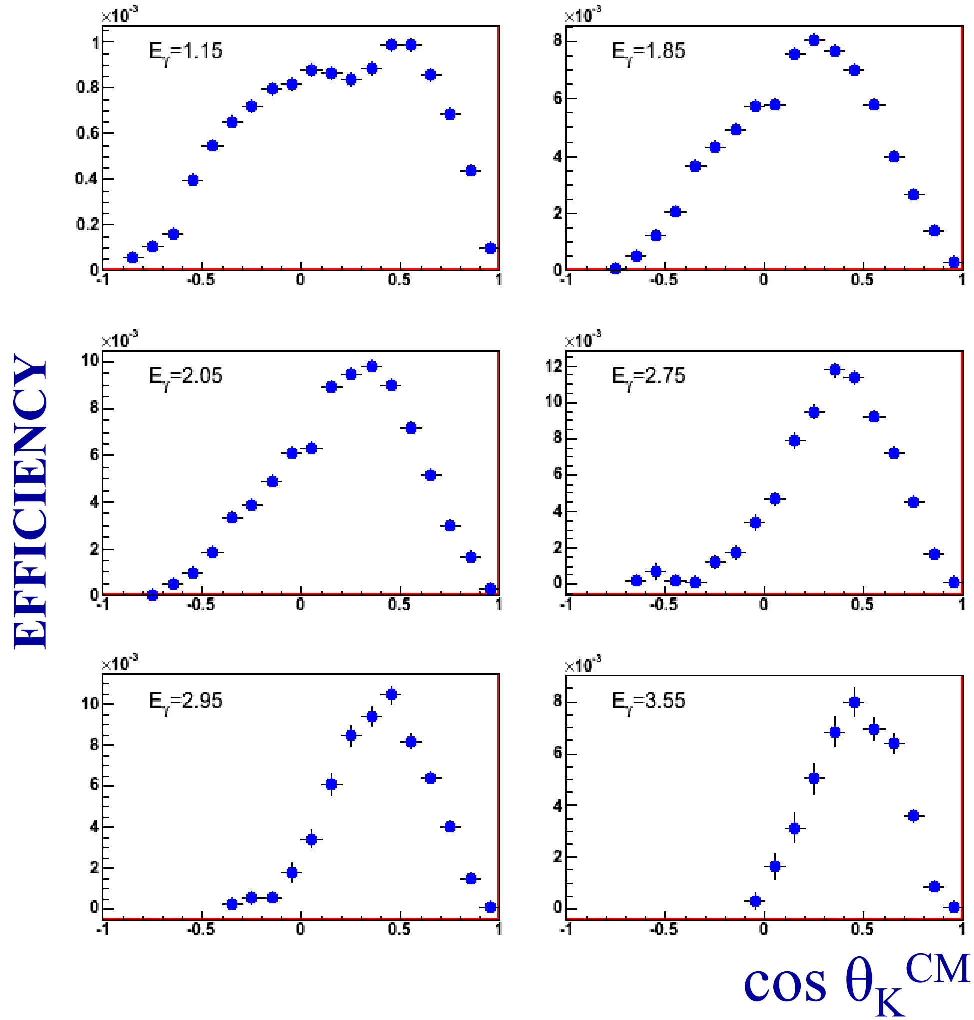


Very clean sample, with a small background

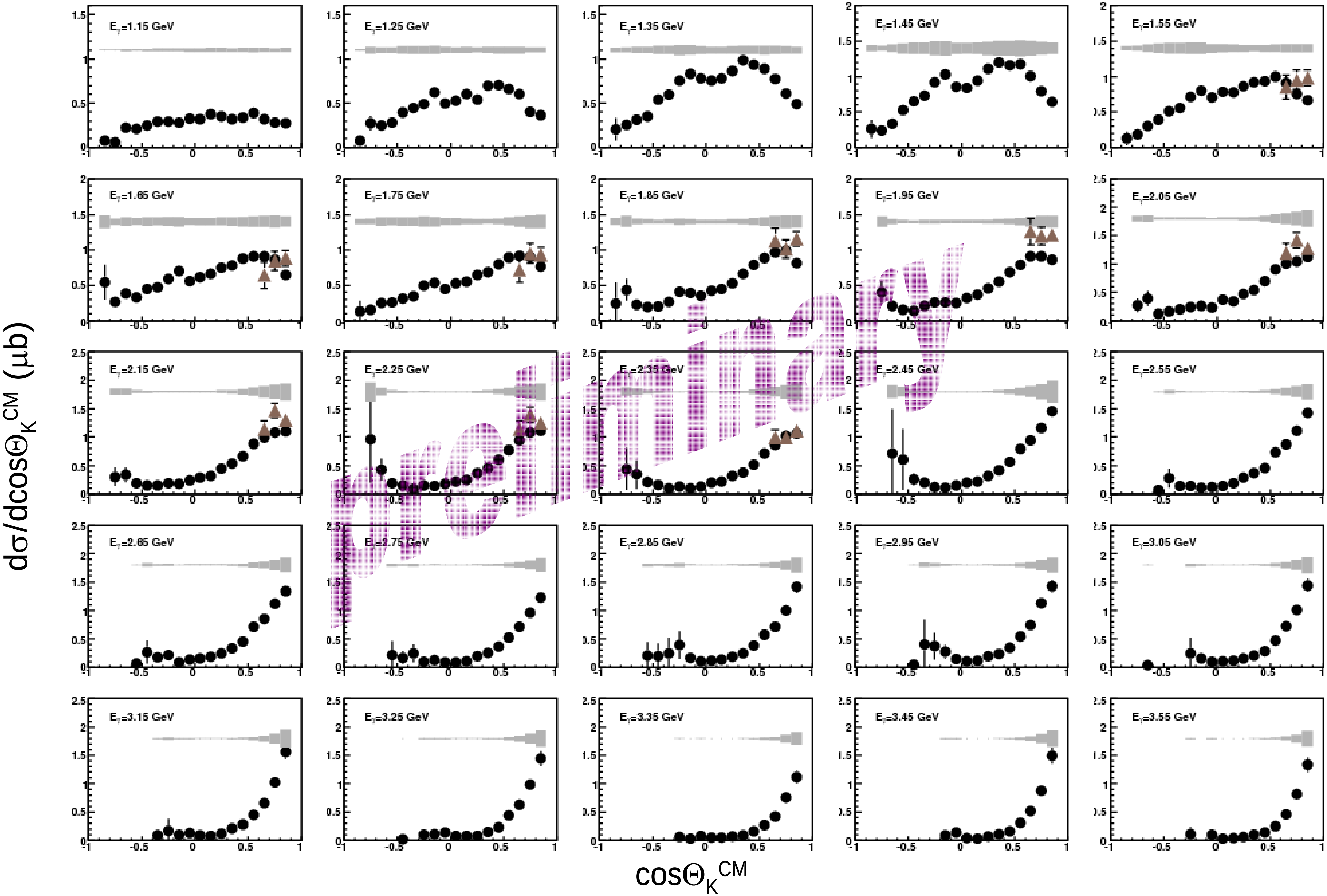
Yield and Efficiency calculation

- after background subtraction, the yield is extracted. Monte Carlo simulation was used to calculate the efficiency.
- the final binning is: 100 MeV in Eγ and 0.1 Cos θ^{CM} (in total 26 Eγ bins)

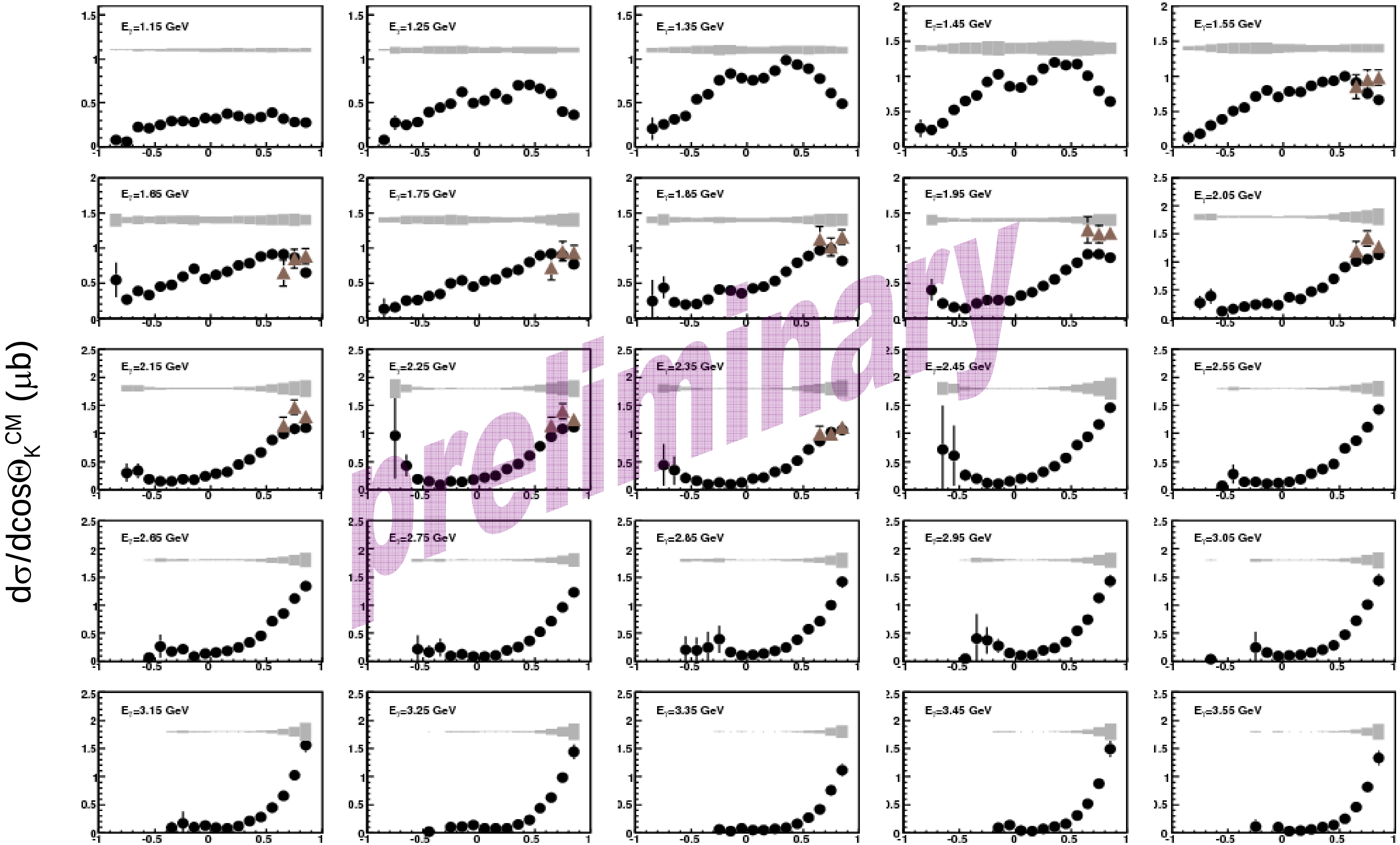




$\gamma\ n(p) \rightarrow K^+\ \Sigma^-(p)$ cross sections



γ n(p) ⟶ K⁺ Σ⁻ (p) cross sections



- at **lower Eγ** bins, relatively flat distribution (***s-channel mechanism near threshold***)
- at **Eγ ~ 1.8 GeV**, a forward peak starts to appear and becomes more prominent as energy increases (***t-channel mechanism***)
- the ***γ n ⟶ K⁺ Σ⁻*** cross sections are of the same order of magnitude of ***γ p ⟶ K⁺ Σ⁰*** channel

Summary

- The $\gamma n \rightarrow K^{+} \Sigma^{-}$ cross sections in a wide Eγ range from 1.1 to 3.6 GeV and angular range from 10 to 140 deg. in laboratory frame was extracted for the first time using the CLAS detector;
- These results improve significantly the precision on the previous one;
- These data will significantly contribute to the improvement of the phenomenological analysis of photoproduction data and of theoretical models aiming to solve the missing resonance problem.
- The data will be ready for publication soon.

Backup slides