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

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Physics Motivation

- Many baryon resonances are predicted studying the channels with π, but very few were established.

- It's important to provide data to investigate the spectrum of baryon (N* and Δ) resonances, with the decay in KY (Y ≡ Λ 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 ππN 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***

Physics Motivation

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 experiments are:

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

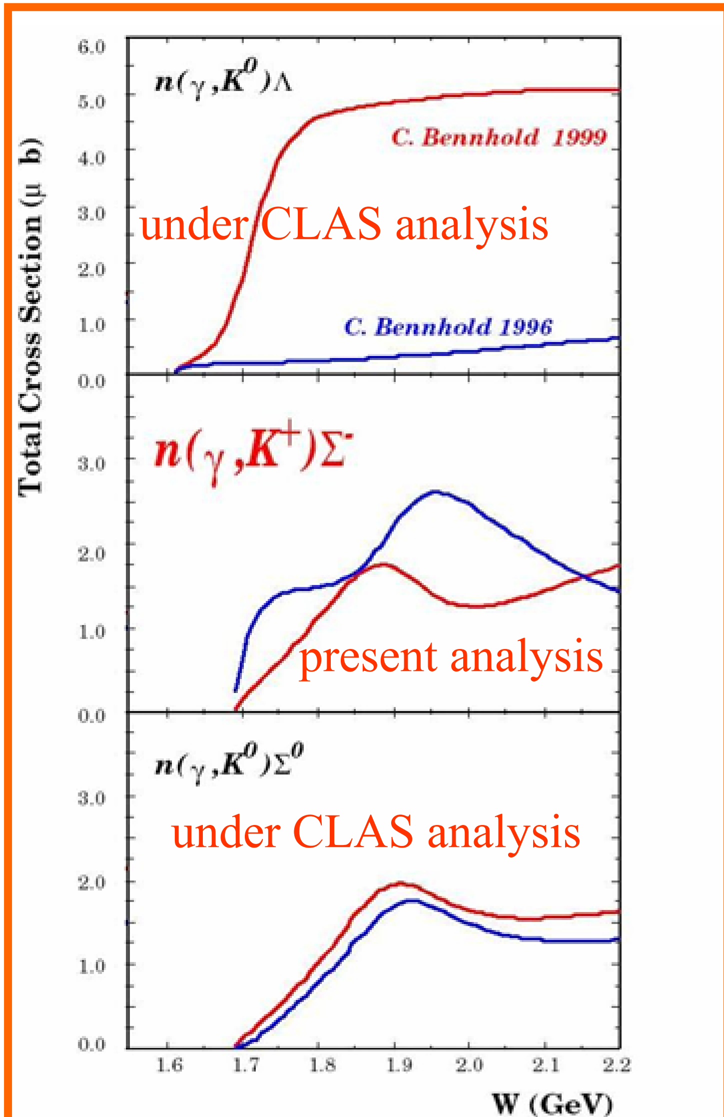
γ p → (g1) First Measurement of Beam-Recoil Observables C_x and C_z in Hyperon Photoproduction, *Phys. Rev. C **75**, 035205 (2007)*,

γ d → (g2) Study of $\gamma n \rightarrow K^+ \Sigma^-$ channel (very low statistics), unpublished

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

γ d → (g13) Kaon production on Deuteron using polarized photons

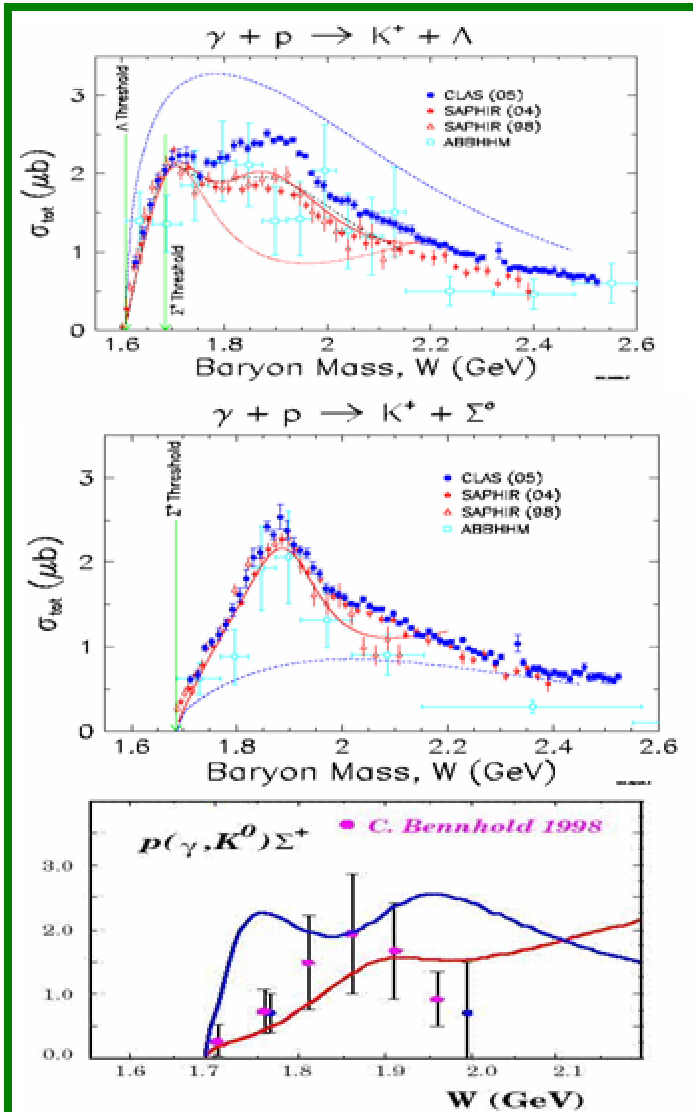
Total cross section γ N → K Y



$\gamma\, p \rightarrow K^+\, \Sigma^0$
$\gamma\, p \rightarrow K^+\, \Lambda$
$\gamma\, p \rightarrow K^0\, \Sigma^+$

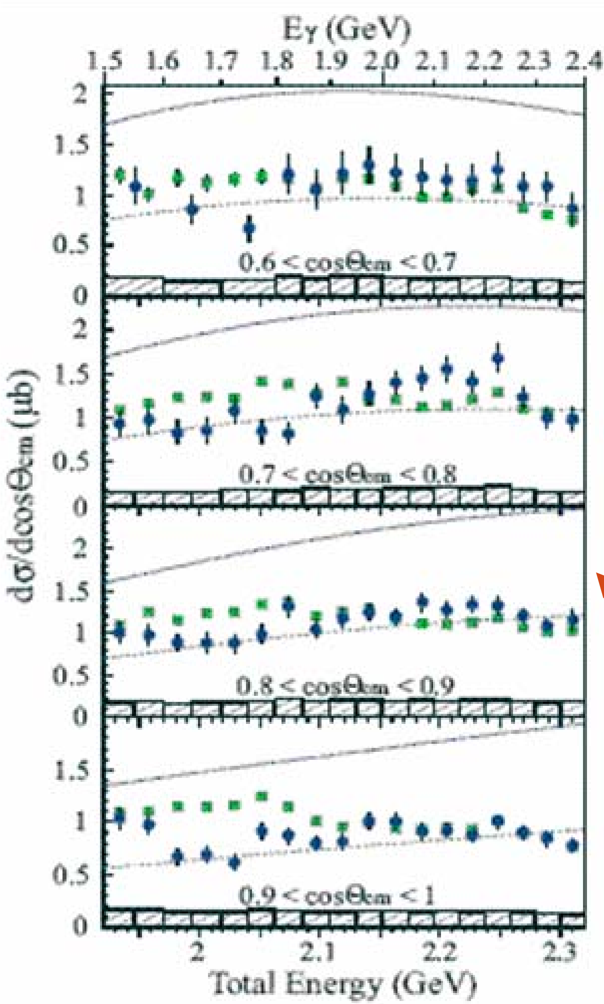
γp data from ABBHHM, SAPHIR and CLAS

there is no Total Cross section data for γn reactions



Differential Cross Sections

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



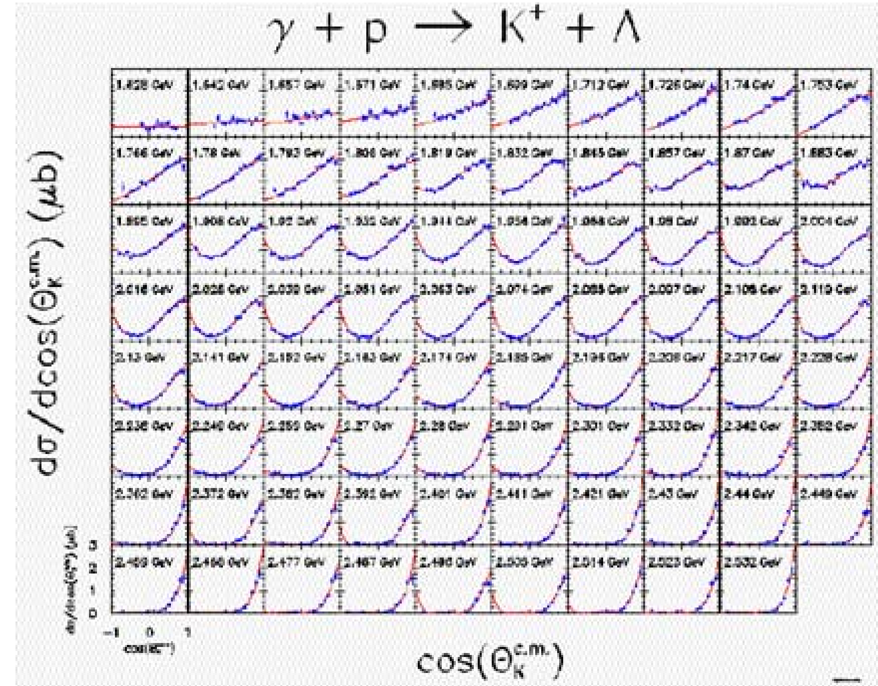
Λ

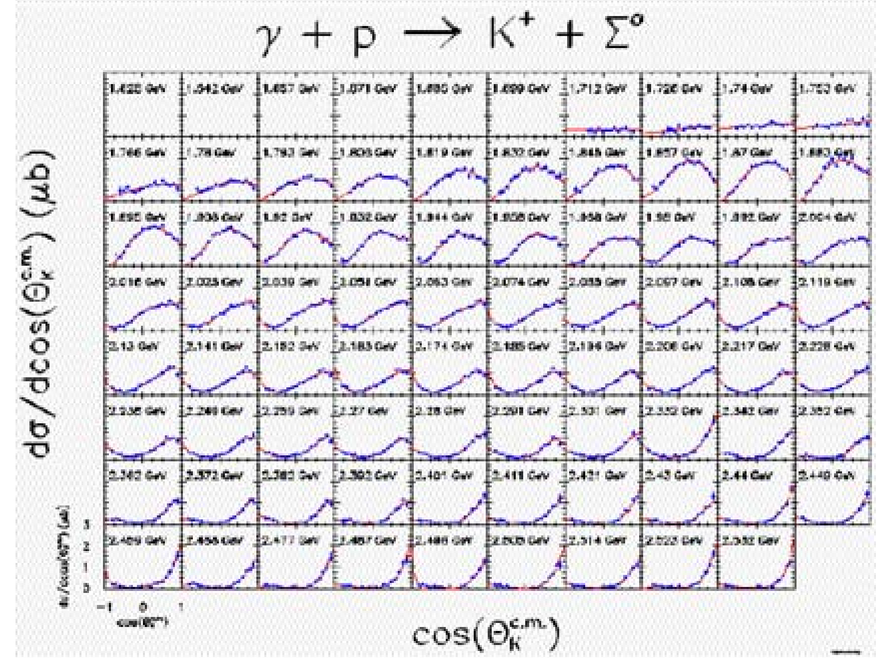
data on *γp* **(CLAS)**
Eγ = 1.019 – 2.949 GeV
Cos Θ^{CM} = -0.8 – 0.9
there are also SAPHIR and ABBHHM collab. (not shown here)

Σ⁰

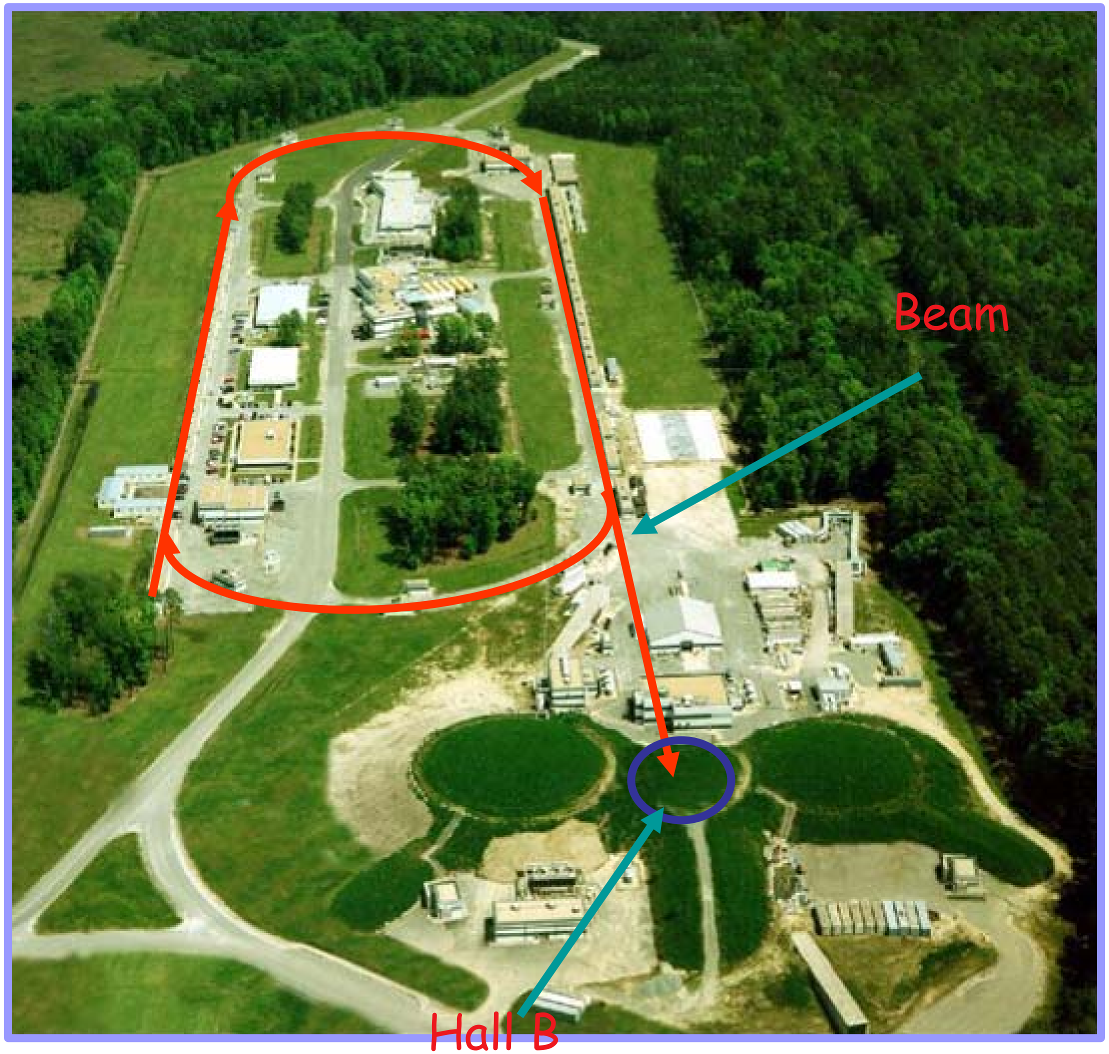
Σ⁻

data on **(LEPS)**
Eγ = 1.5 – 2.4 GeV
Cos Θ^{CM} = 0.6 – 1.0
$\gamma n \rightarrow K^+ \Sigma^-$ (blue points)
$\gamma p \rightarrow K^+ \Sigma^0$ (green squares)





JLab Accelerator CEBAF



Superconducting recirculating electron accelerator

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

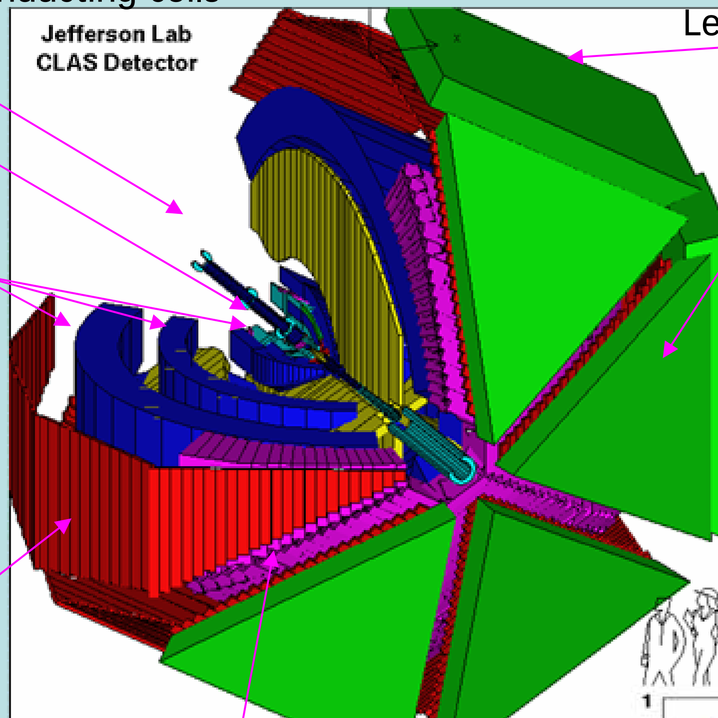
Hall B: Cebaf Large Acceptance Spectrometer + Tagger

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

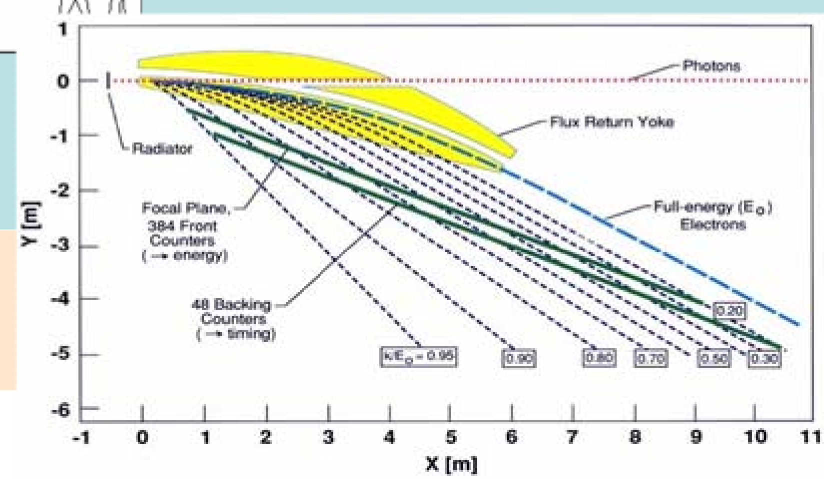
CLAS is designed to measure exclusive reactions with multi-particle final states

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 $\delta k/k \sim 0.1\%$



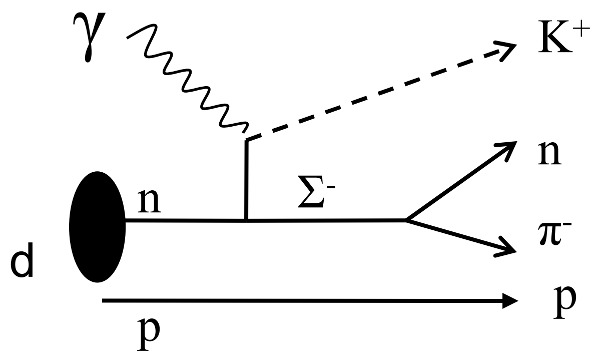
G10 Experiment

Approved experiment for the Pentaquark search on Deuterium

- Data taking - March 13 – May 16, 2004;
- Tagged photons in the energy range from 0.8 GeV to 3.59 GeV;
- Target - 24 cm long liquid deuterium at Z = -25cm;
- Integrated luminosity ~ 50 pb^{-1} .

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:

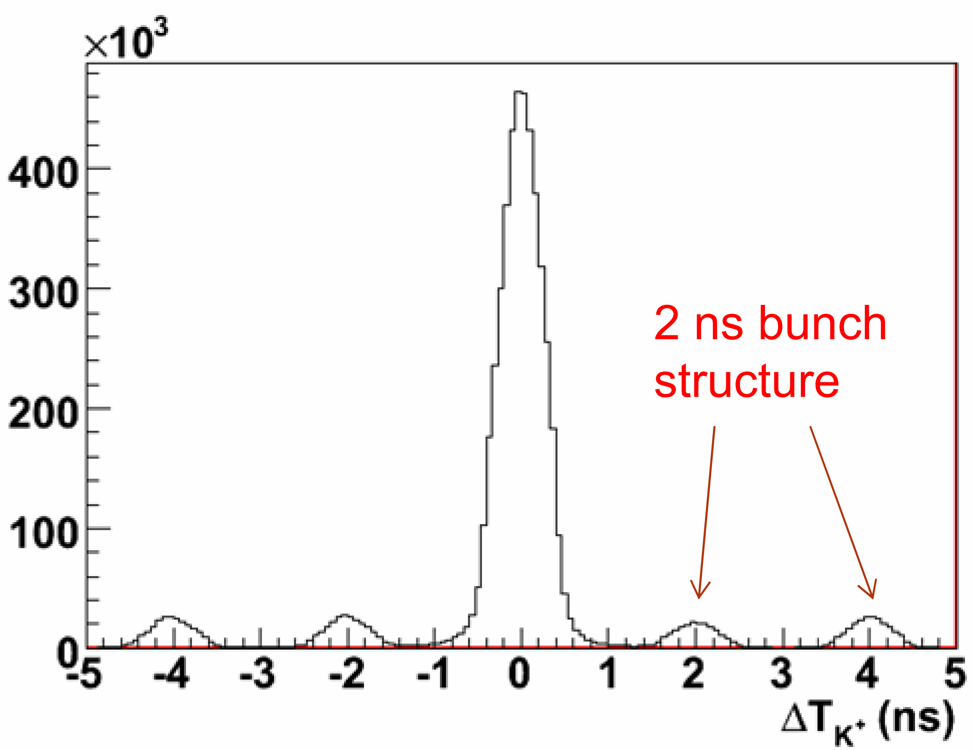
- ***detection of K^+, π^- and n***
- ***proton as a missing particle.***

The key points:

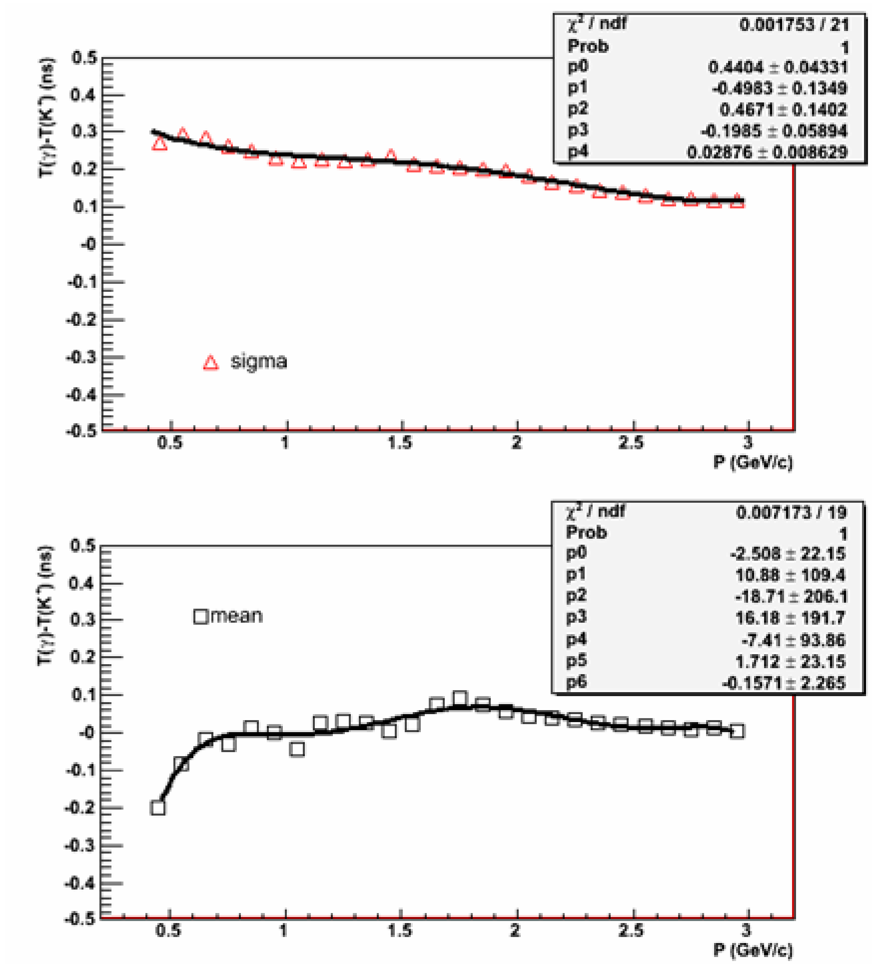
- The correct identification of K+
- The correct identification of neutron

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.

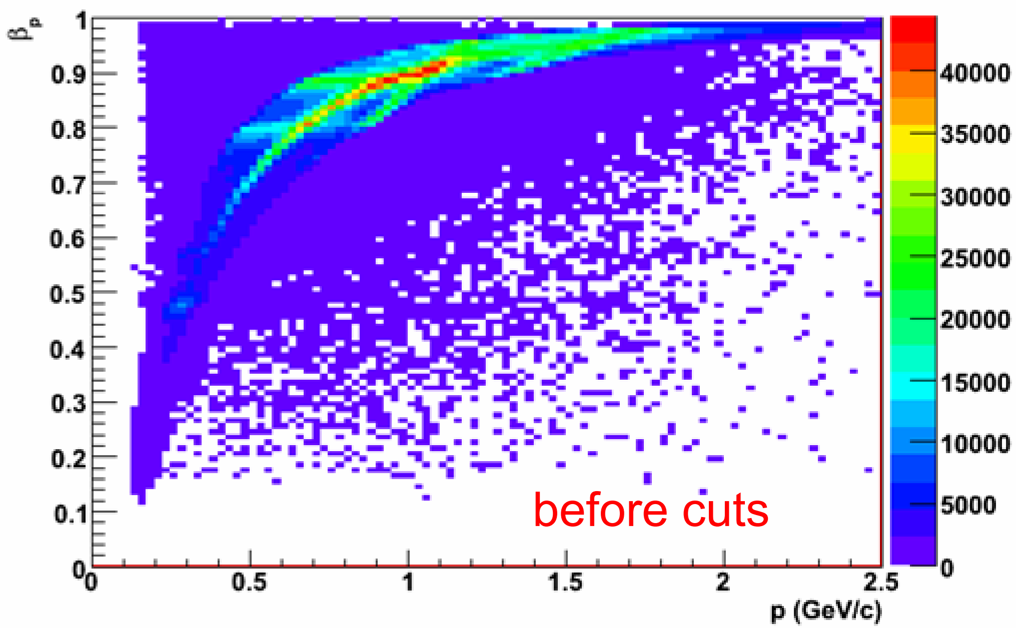


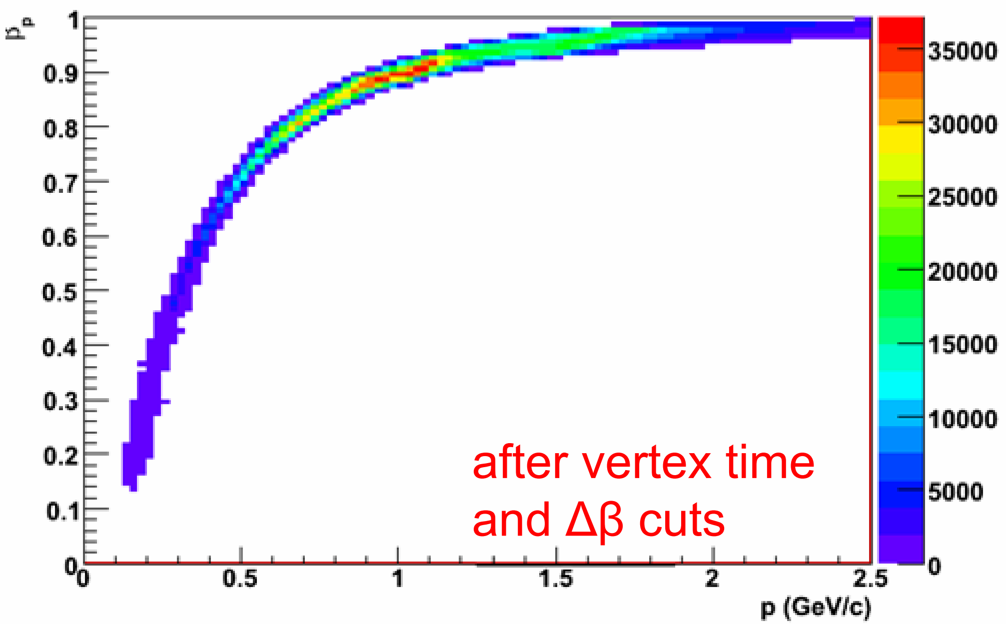
❑ the timing cut is applied as function of K^+ momentum.



K^+ identification

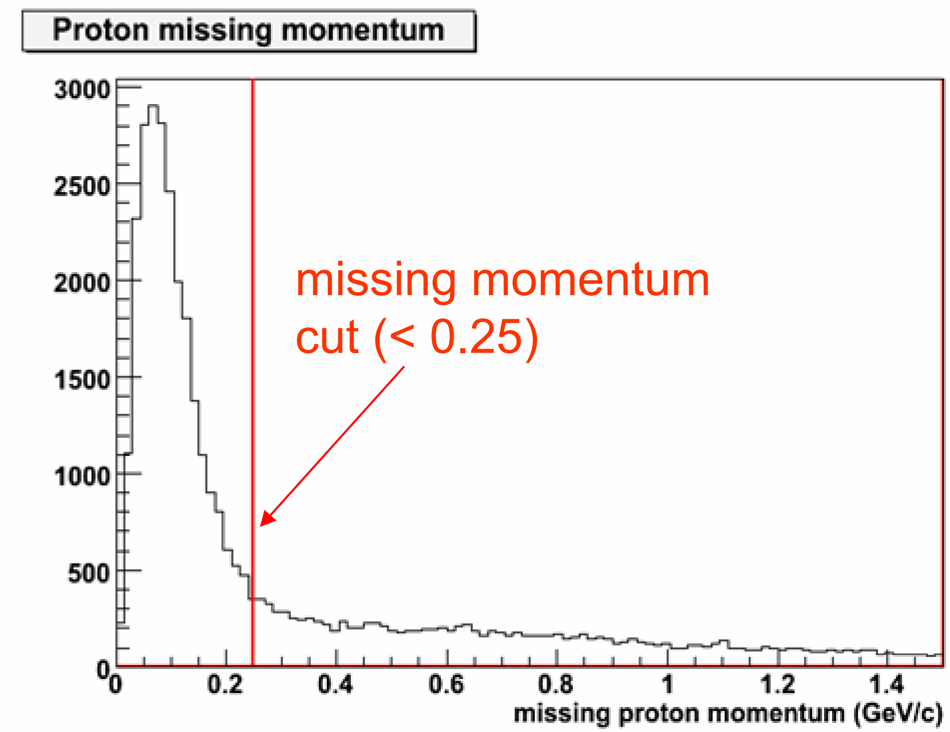
- Kaon identification cuts:
  - $\Delta\beta$ cut = $\beta_{TOF} - \beta_P$, where β_{TOF} is calculated from time-of-flight detectors and β_P is computed from momentum, $p/\sqrt{(p^2+m_K^2)}$;



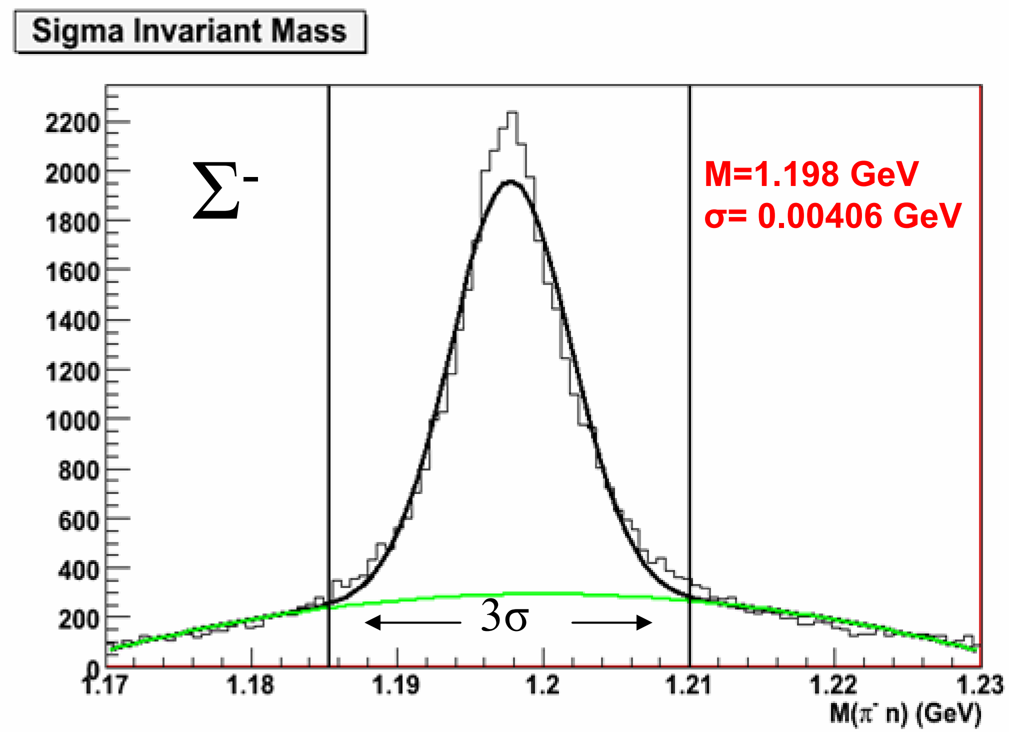


Σ^- identification

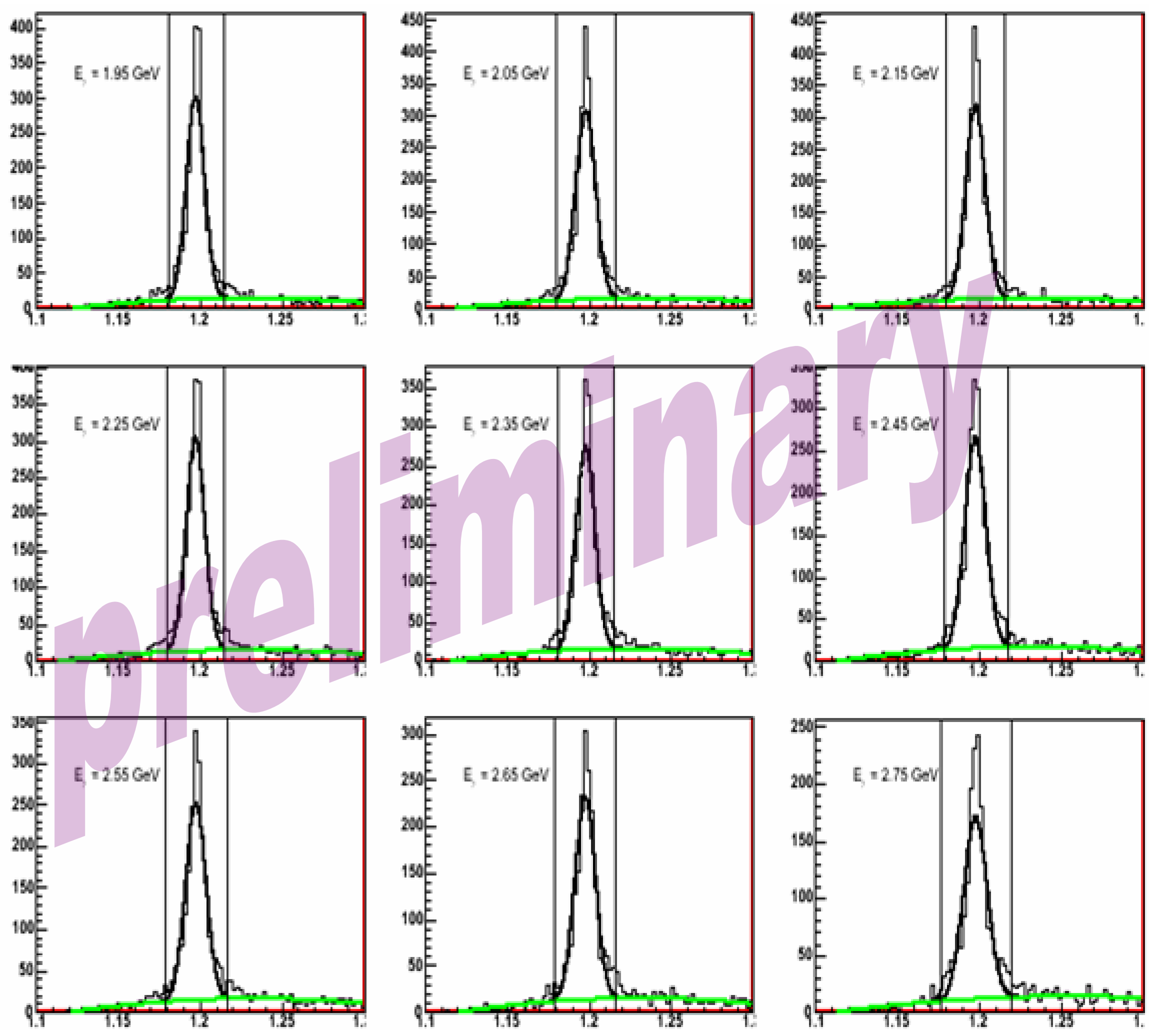
- the missing particle is identified as MM($K^+ \pi^- n$) in $\gamma d \rightarrow K^+ \pi^- n X$.
- a cut on the missing particle momentum is then applied (p < 0.25 GeV/c)



- after Kaon selection and missing momentum cut, the Σ^- is identified as M($\pi^- n$) in $\gamma d \rightarrow K^+ \pi^- n X$



Background subtraction



- the background subtraction was done fitting the Σ^- invariant mass distributions, in 100 MeV $E\gamma$ bins, with a Gaussian (black curves) + second order polynomial (green curves).

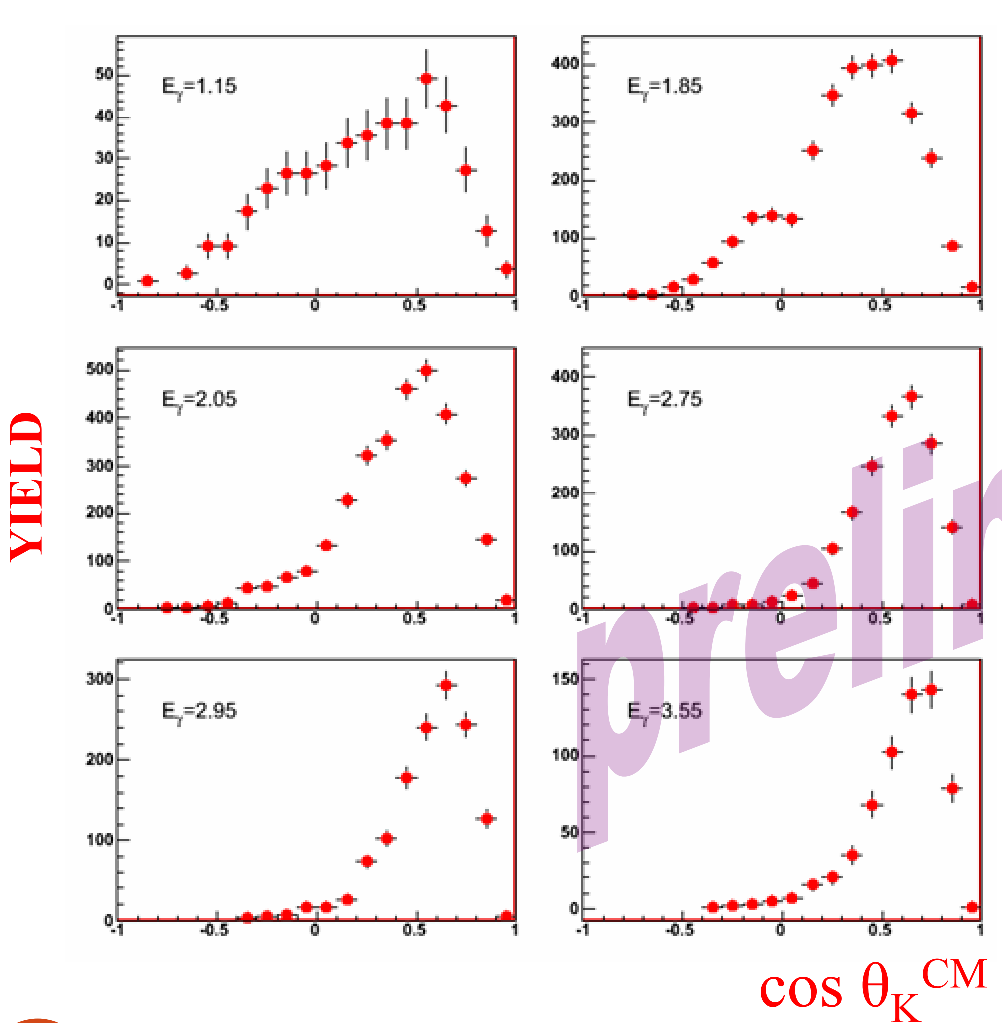
The Gaussian fits the peak and the polynomial fits the background.

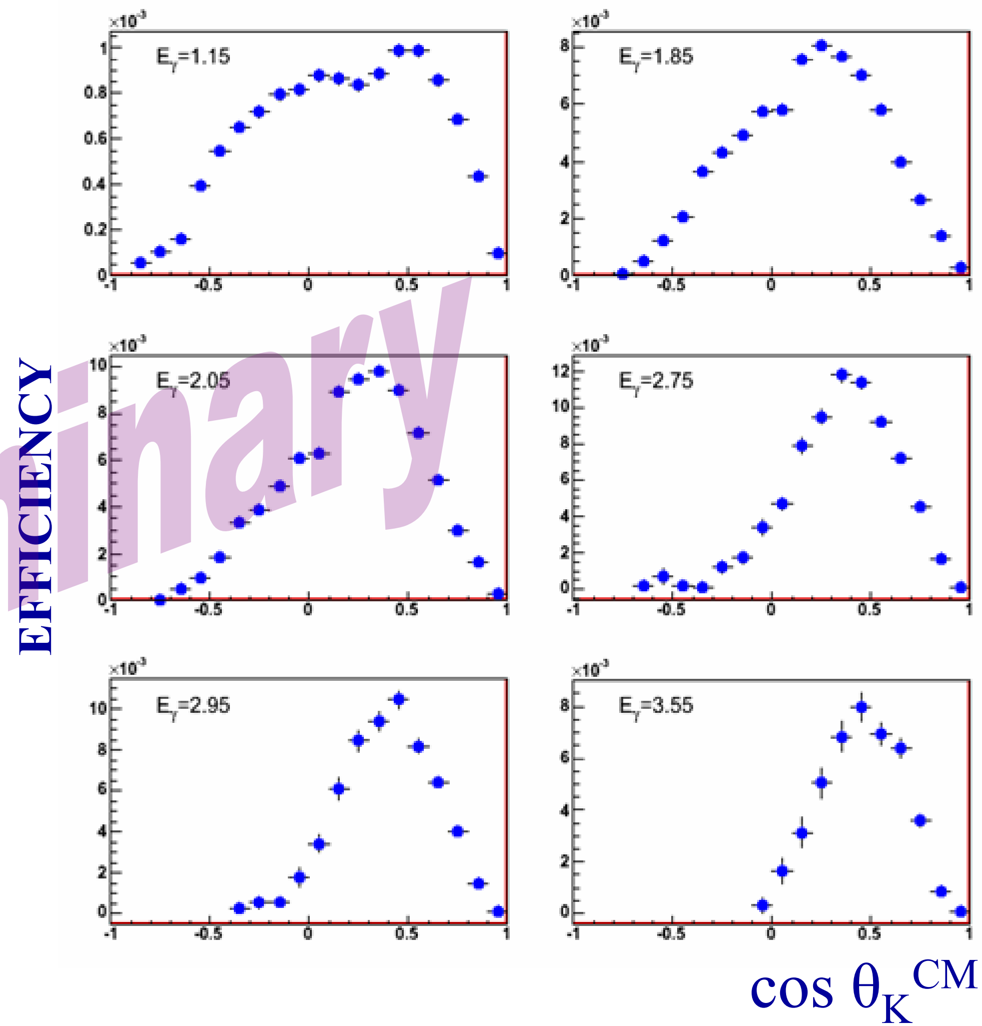
The horizontal lines are the 3σ cuts on the Gaussian fit.

The real Σ^- events are defined as the number of events within 3σ cut and above the polynomial fit.

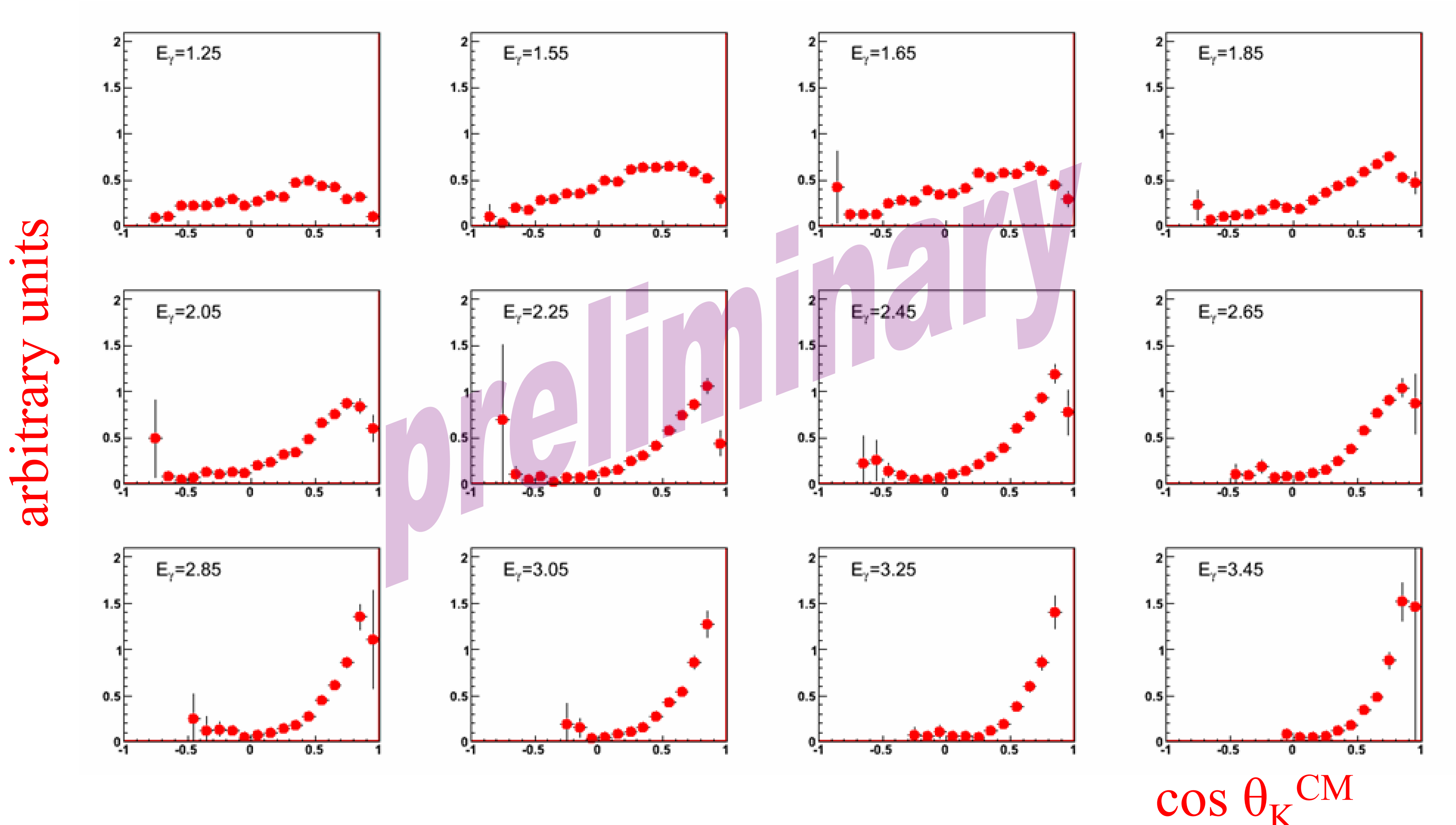
Yield and Efficiency calculation

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





Normalized Yield



Summary

- It is very important to investigate baryon resonances which decay into KY in the final state in order to study the lack of the predicted resonances;
- There are almost no experimental data on neutrons;
- The study of $\gamma n \rightarrow K^{+} \Sigma^{-}$ reaction channel using the CLAS G10 data will give a set of results in gamma-neutron interactions in a wide Eγ range from 1.1 to 3.6 GeV and angular range from 10 to 140 deg. in laboratory frame;
- The preliminary results have shown that the studied channel can be well identified;
- The yield corrected by the efficiency was extracted;
- **Cross section calculations are underway!!**

THANK YOU !!!

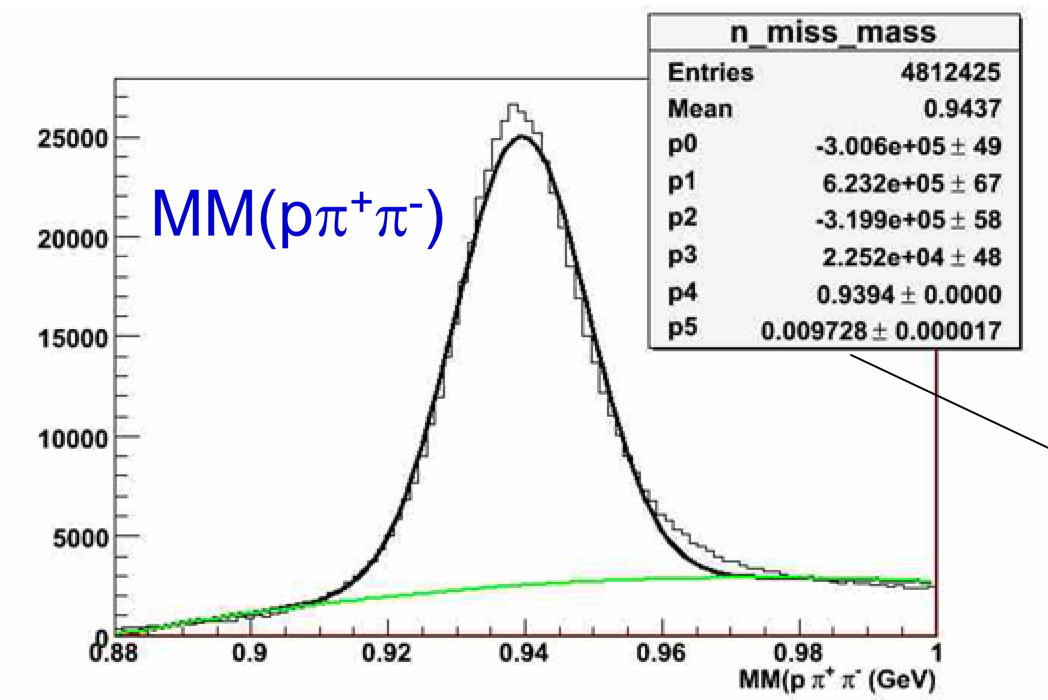
Backup slides

Neutron detection efficiency (g10 data)

Chosen reaction $\gamma d \rightarrow p\, n\, \pi^+ \pi^-$

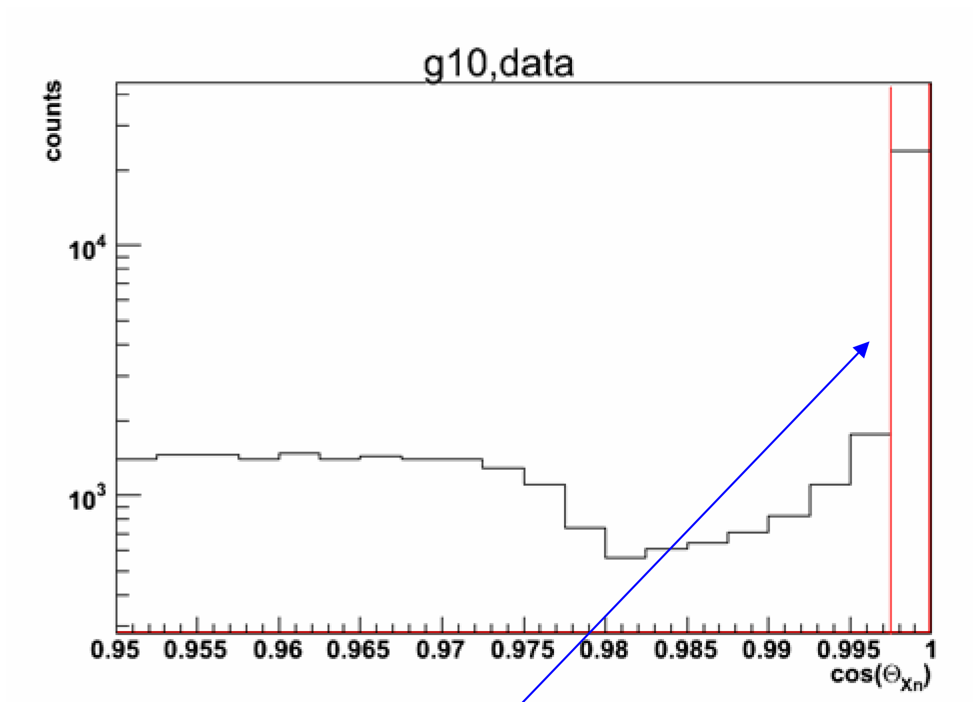
Applied cuts to isolate this channel:

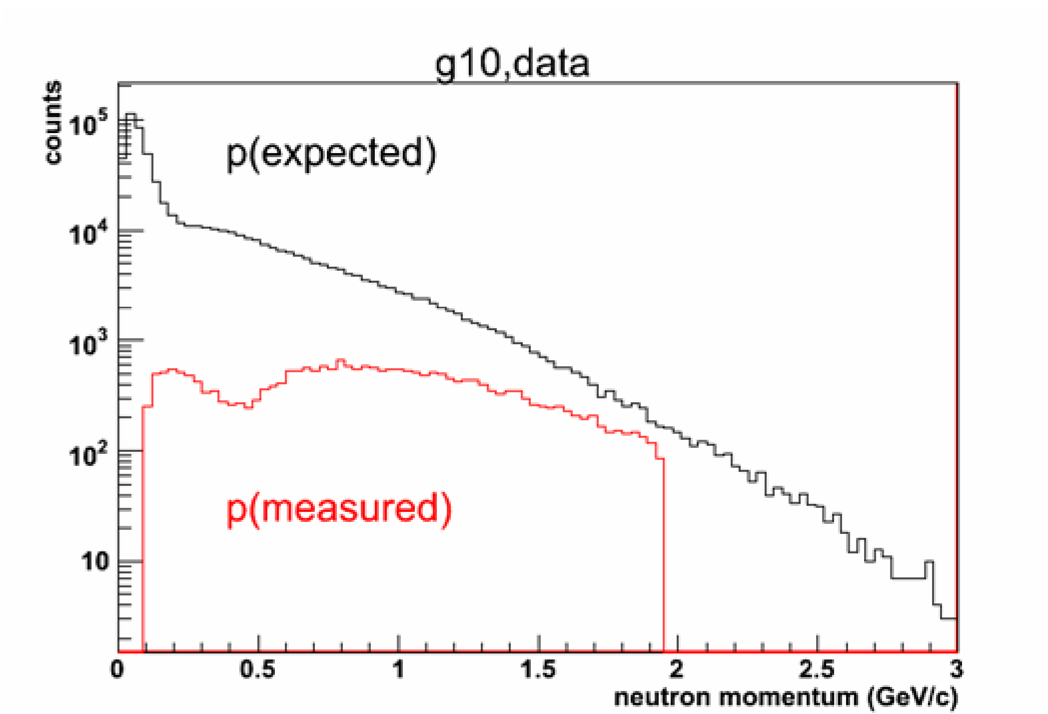
- **missing mass of $\gamma d \rightarrow p\, \pi^+ \pi^- X$**
- **angle between the direction of expected and measured neutron**
- **polar angle Θ_{miss} between 10° and 45°**
- **azimuthal angle Φ_{miss} in the sector reference frame**
- **background subtraction under missing mass peak**



Mass = 0.9394 GeV

Neutron detection efficiency (g10 data)





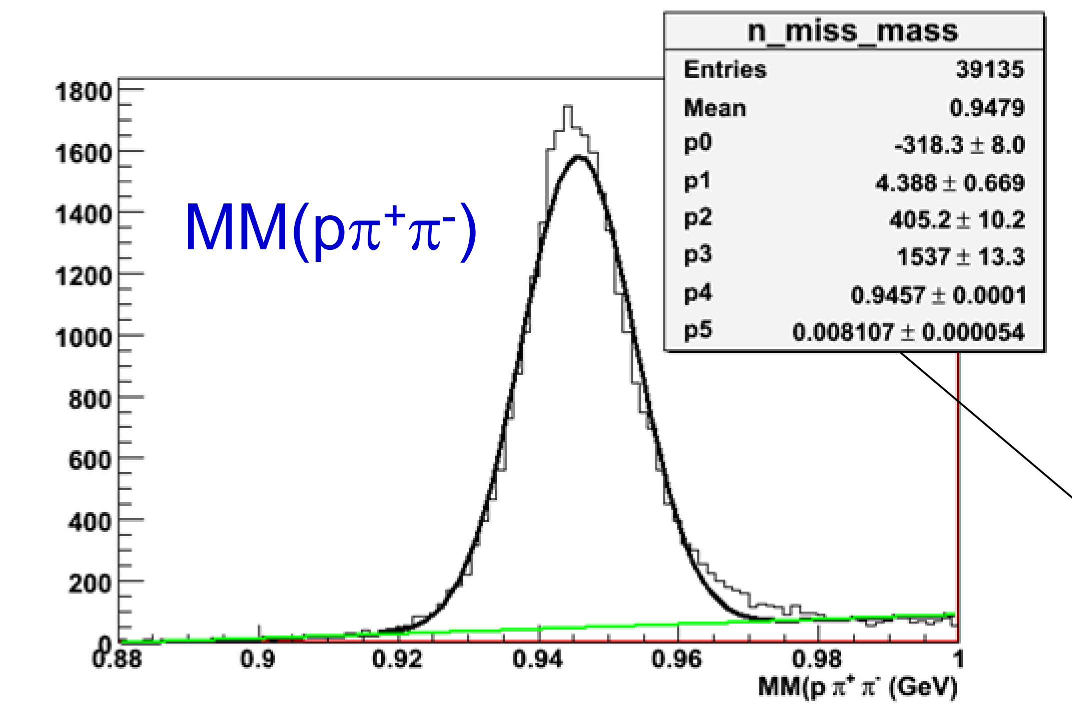
Applied cut on the Cos $\Theta_{X,n}$

Neutron detection efficiency (MC)

Same reaction $\gamma d \rightarrow p\ n\ \pi+\ \pi^-$

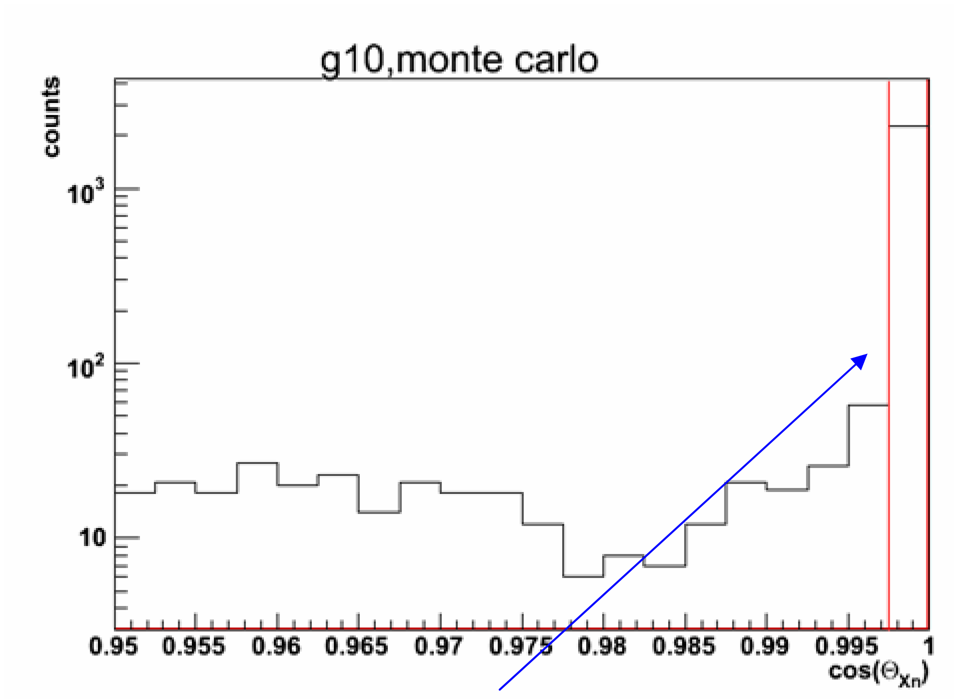
Applied cuts to isolate this channel:

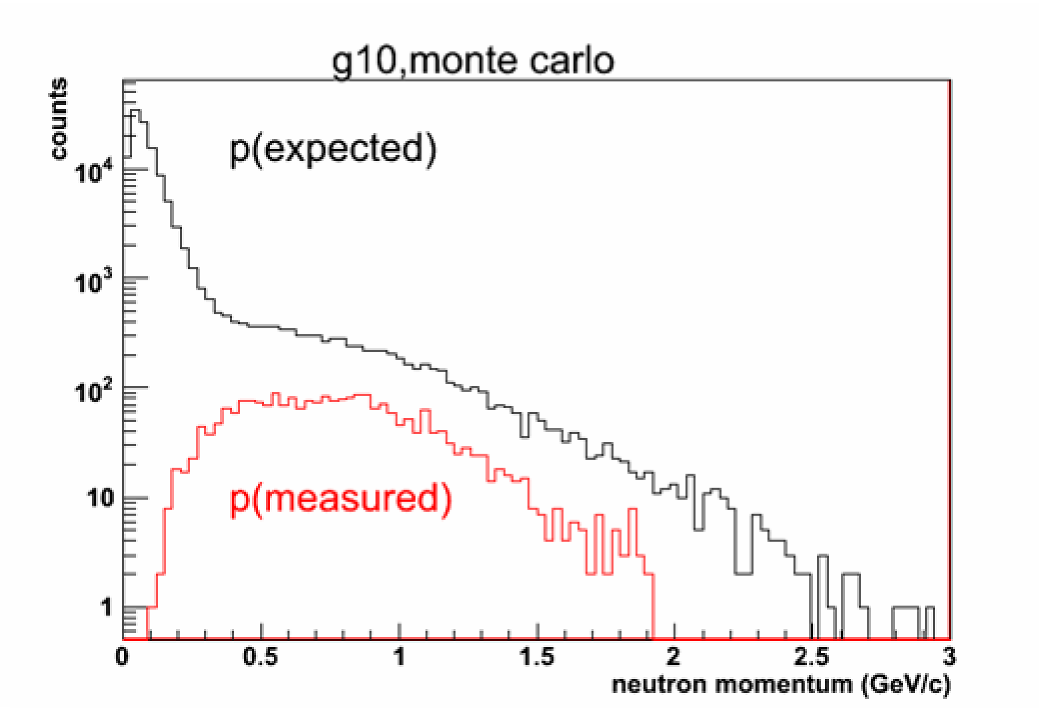
- **missing mass of $\gamma d \rightarrow p\ \pi+\ \pi-\ X$**
- **angle between the direction of expected and measured neutron**
- **polar angle Θ_{miss} between 10° and 45°**
- **azimuthal angle Φ_{miss} in the sector reference frame**
- **background subtraction under missing mass peak**



Mass = 0.9457 GeV

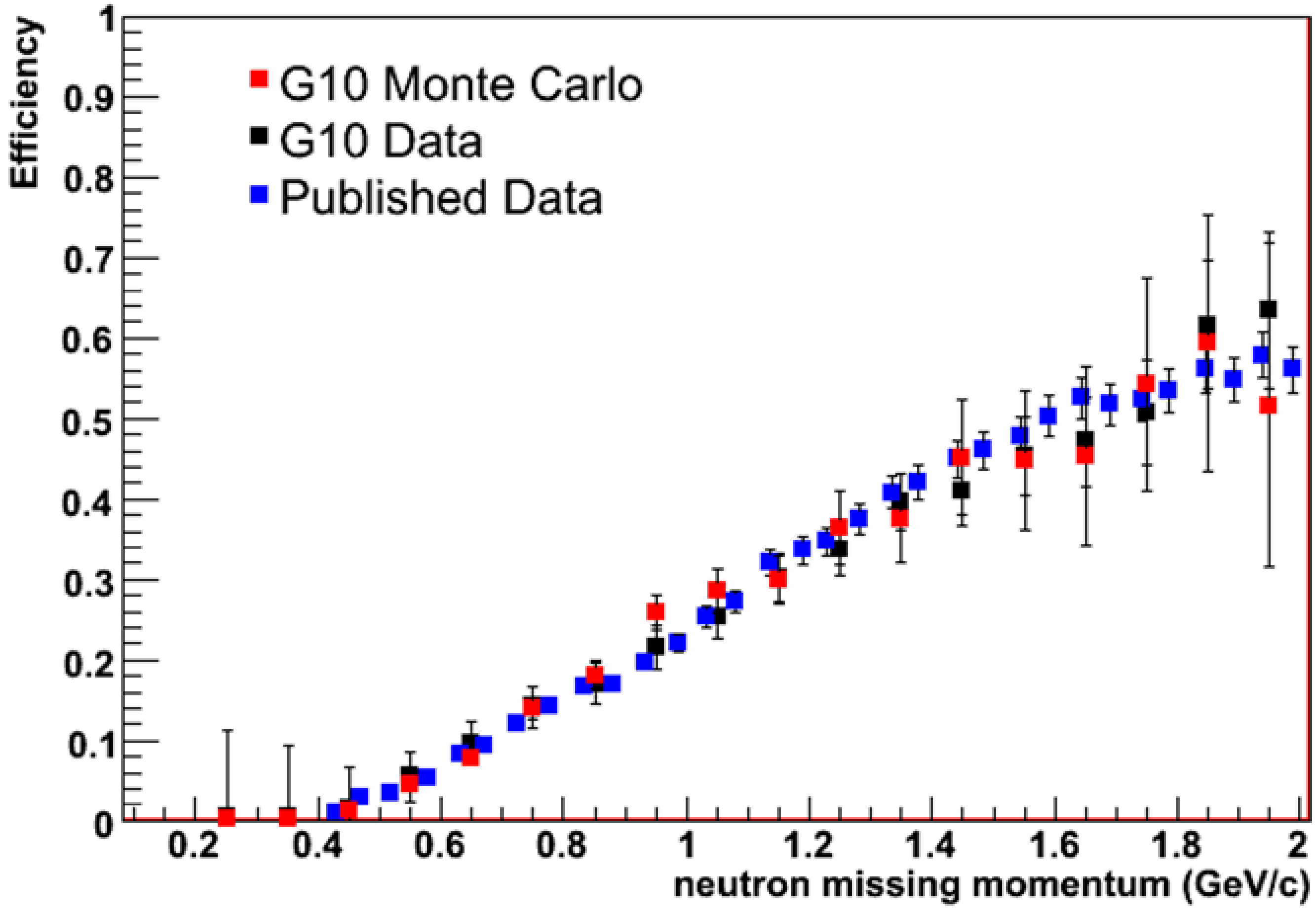
Neutron detection efficiency (MC)



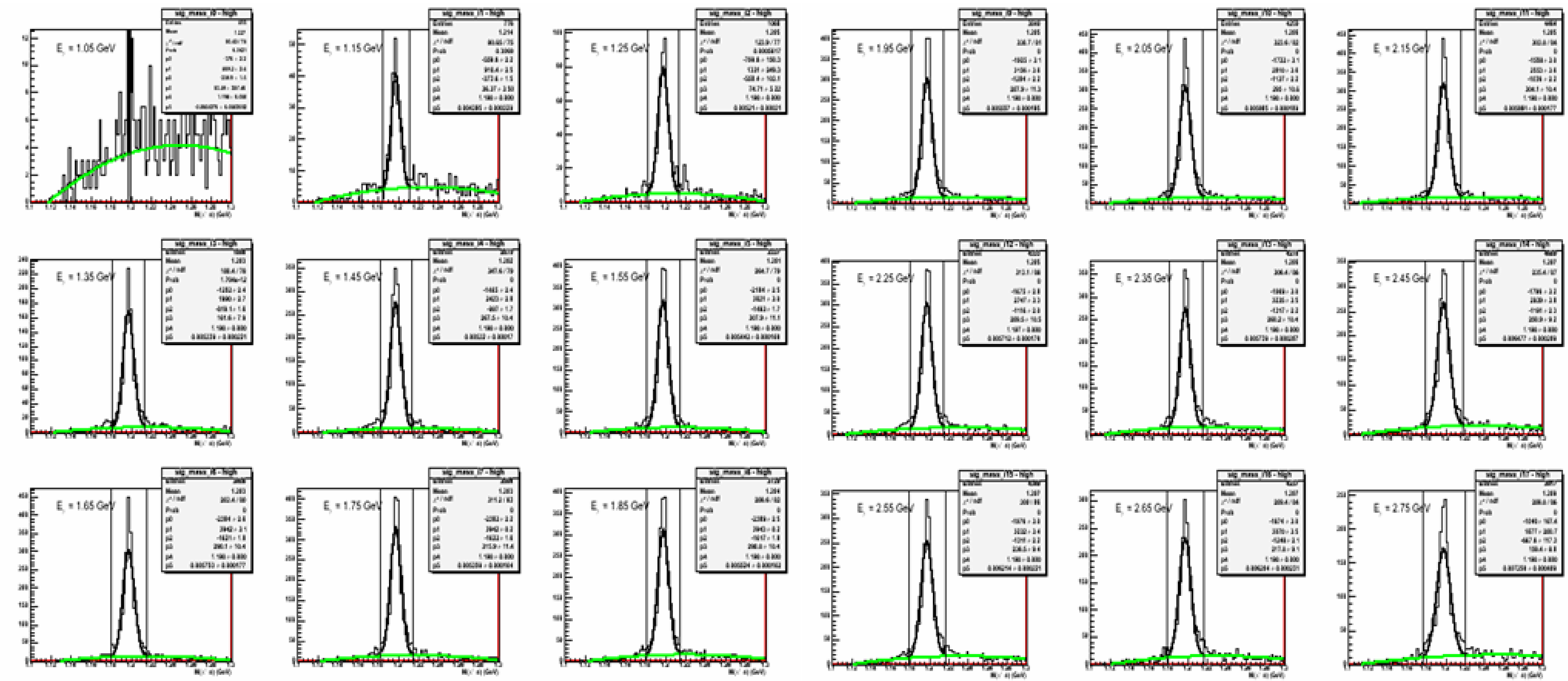


applied cut on the Cos $\Theta_{X,n}$

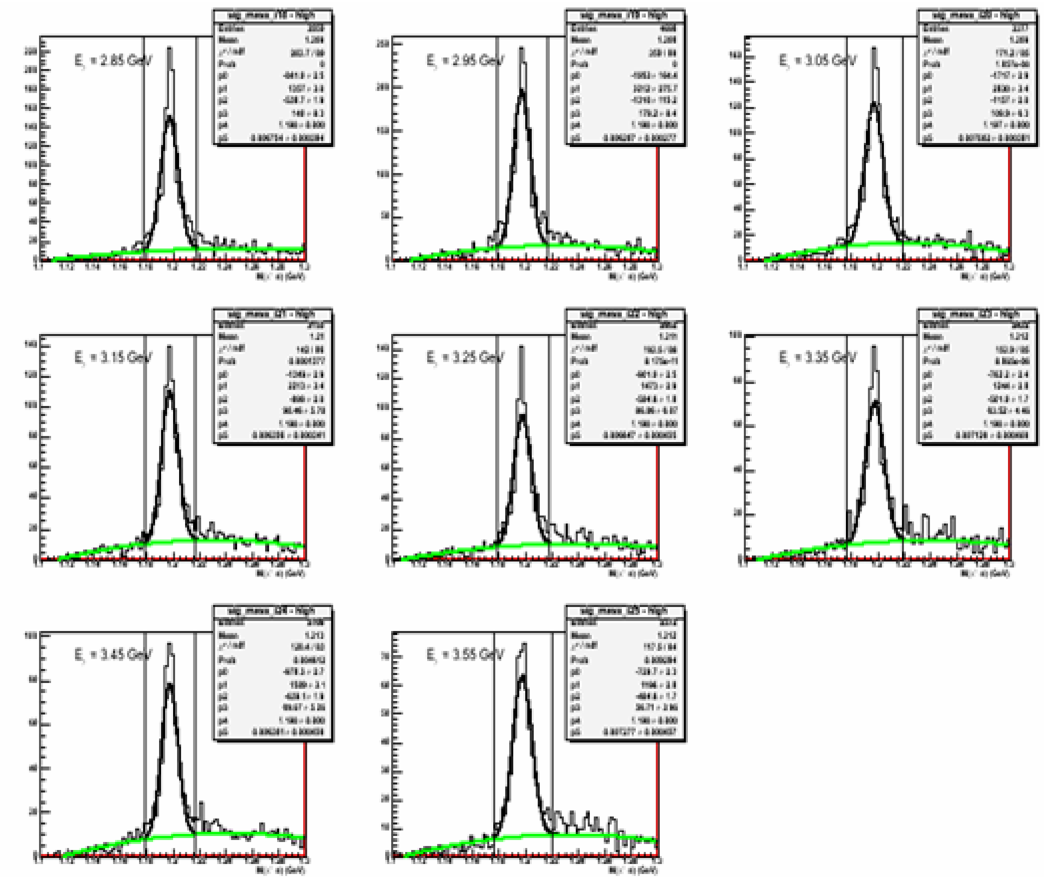
Neutron detection efficiency

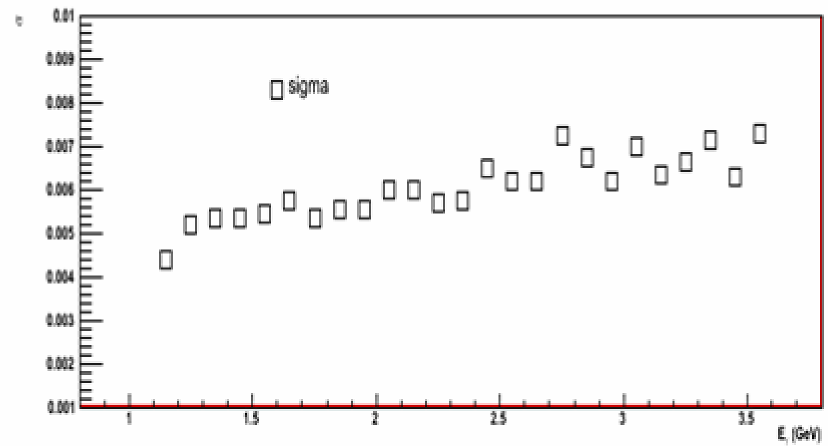


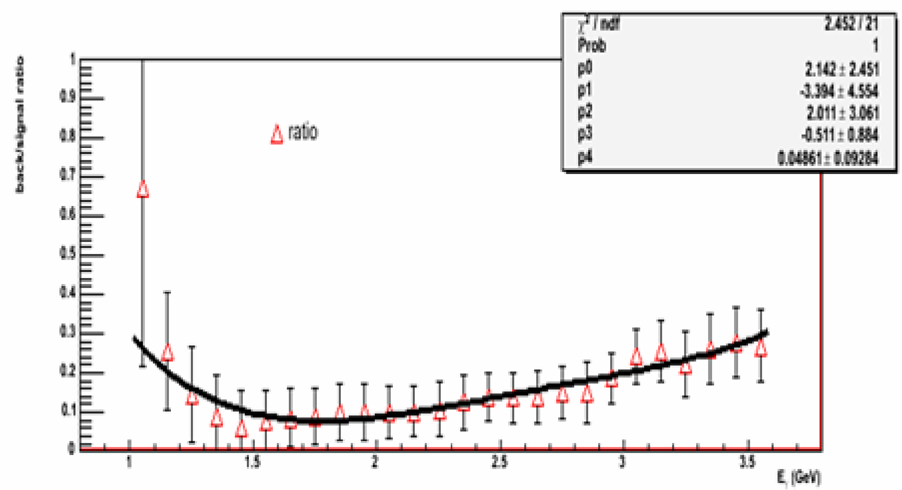
Background subtraction – high field



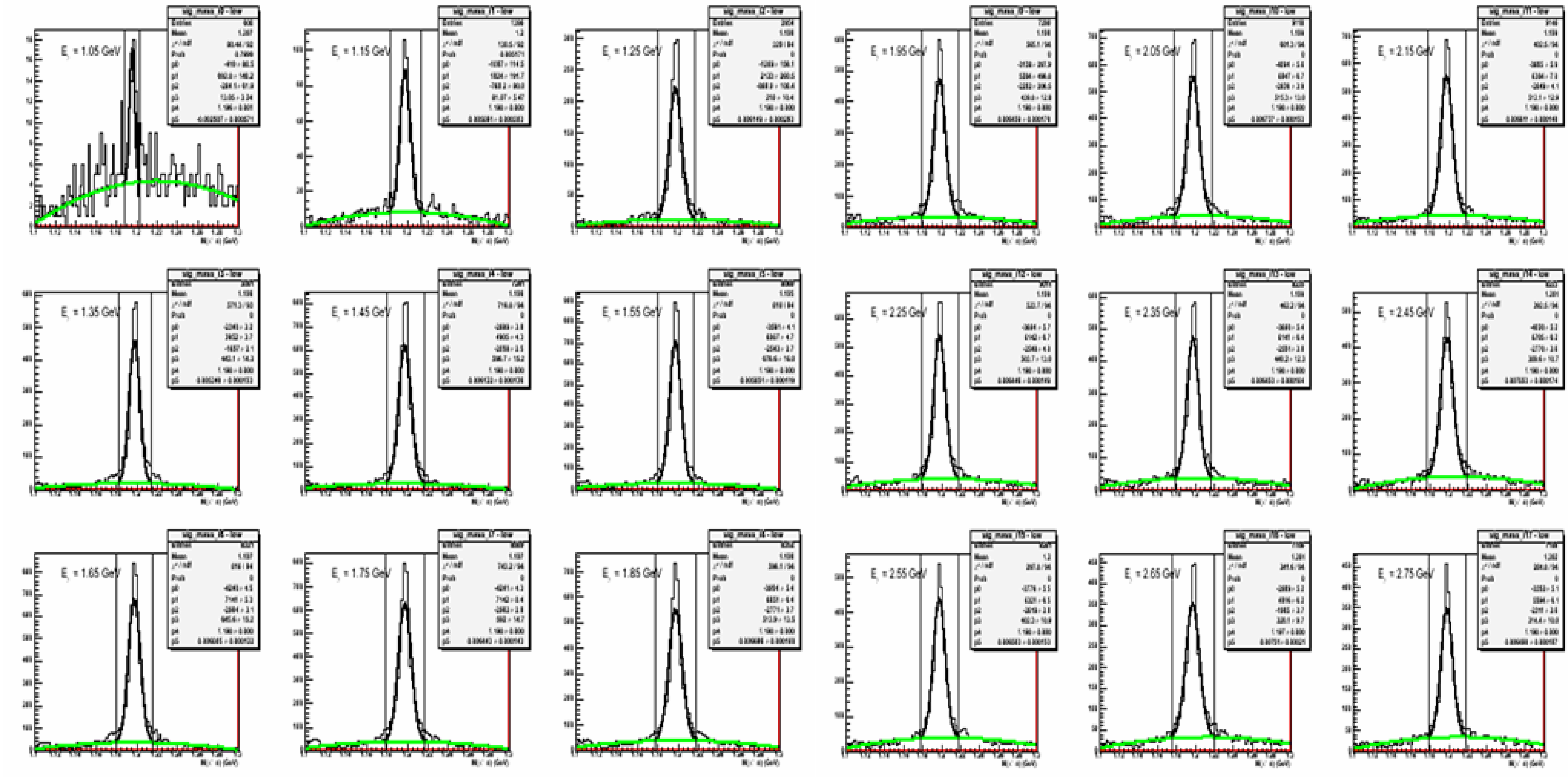
Background subtraction – high field







Background subtraction – low field



Background subtraction – low field