Cross Sections of $K^0\Lambda$ Photoproduction off the Deuteron

Presented by: Nick Compton
Co-authors: Ken Hicks, Max Camp
Ohio University
Data from CLAS (g10) at JLAB

Motivation and Significance

- It is possible that current missing resonances may yield a better signal for different initial and final states (i.e. neutron excitations or strange sector decay).
- The photocouplings to that of a neutron are different than that of a proton, therefore could yield results unique to the neutron.
- Data for neutron resonances are not very abundant. Specifically, there is minimal world data on the reaction $\gamma d \rightarrow K^0 \Lambda\,(p)$, if any.
- Investigated here are the differential and total cross section of $\gamma d \rightarrow K^0 \Lambda\,(p)$ on an unpolarized target with an unpolarized real photon beam with beam energies of 1.0-3.0 GeV.

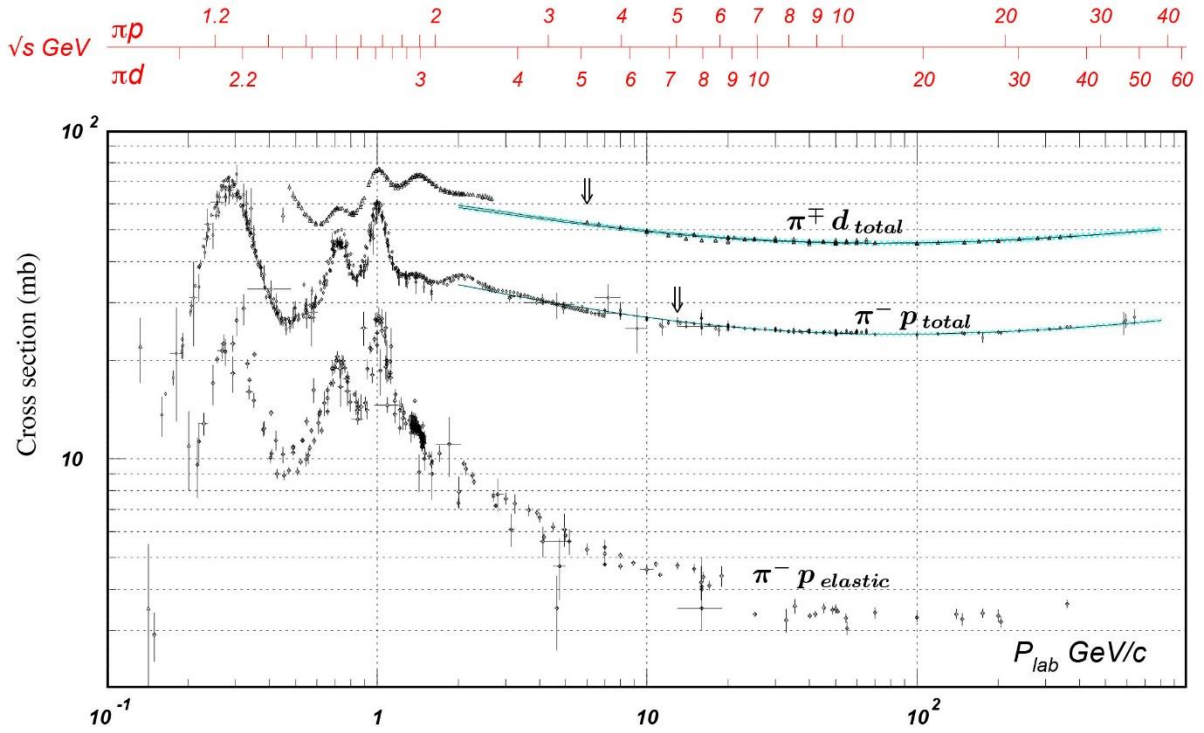
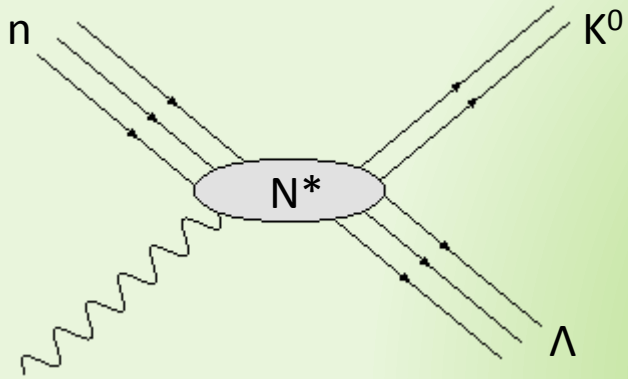
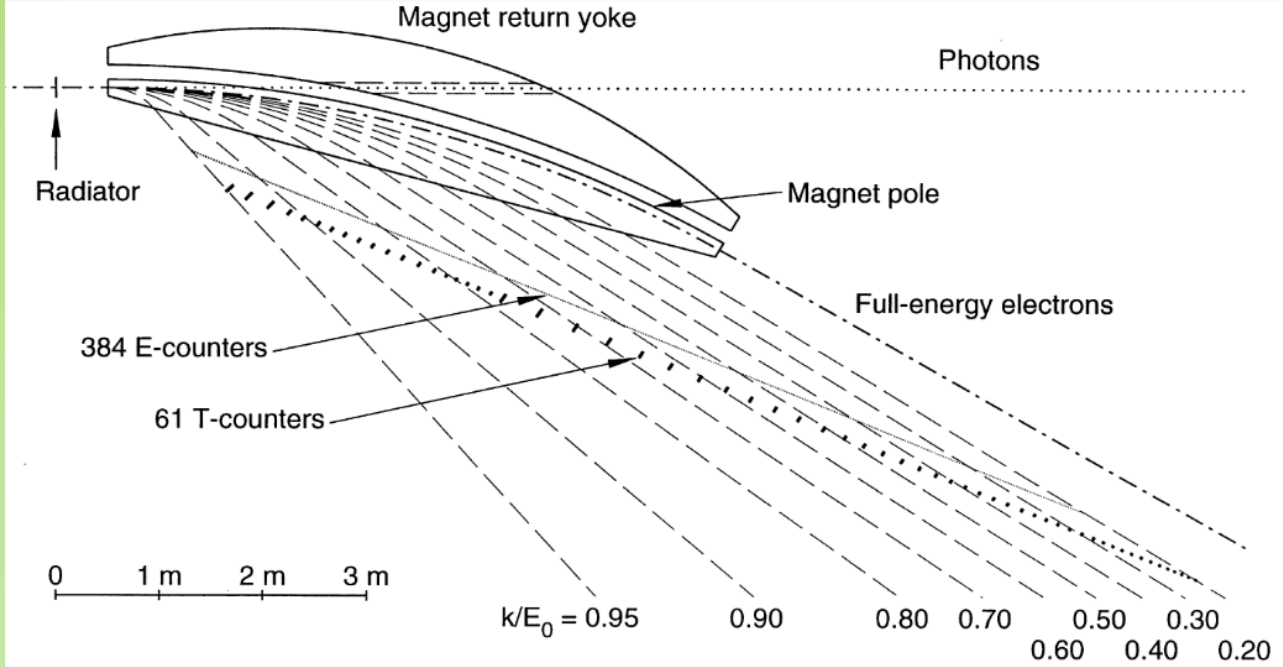


Figure 40.13: Total and elastic cross sections for $\pi^{\pm}p$ and $\pi^{\pm}d$ (total only) collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at `http://pdg.lbl.gov/xsect/contents.html`. (Courtesy of the COMPAS Group, IHEP, Protvino, August 2005.)

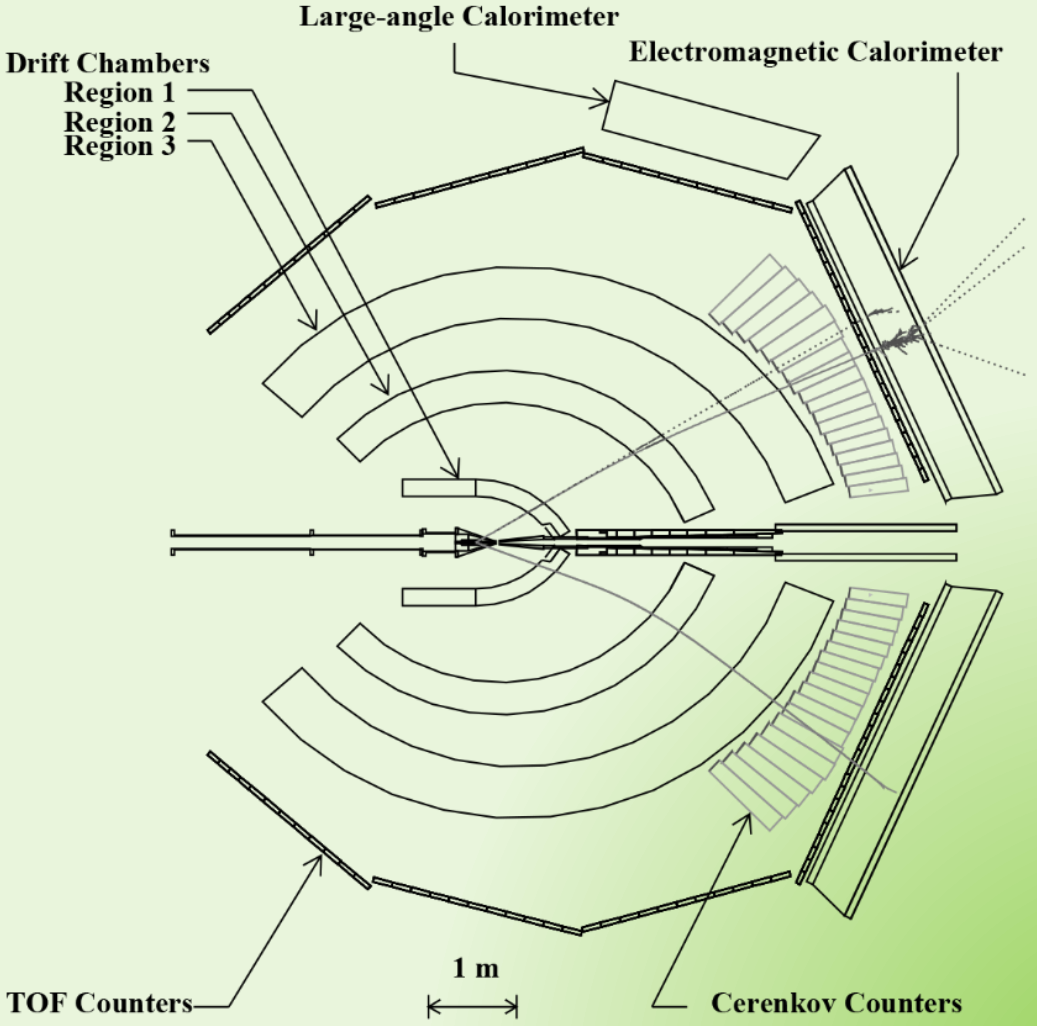


CLAS

Photon Tagger: Photons are created by a gold foil radiator, and tagged by detecting the electron

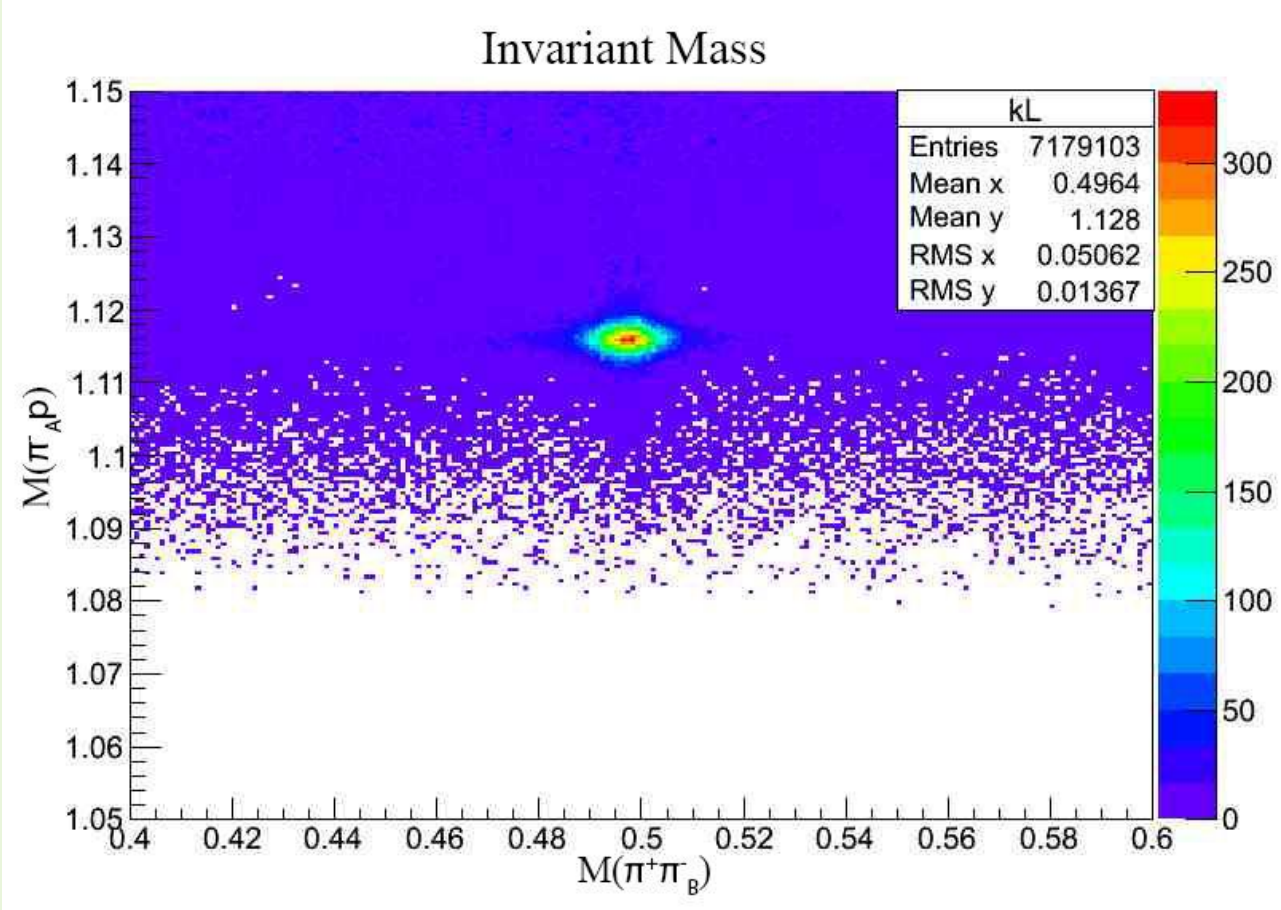


CLAS particle detection



Reaction: $\gamma d \rightarrow K^0\Lambda(p)$

- Real Photon Beam
  - Created by Bremsstrahlung Radiation
  - Reviewed reactions with beam energies in the range of 1.0 to 3.0 GeV
- Required detection of all final state particles
  - $\pi^+\pi^-\pi^-p$
  - Three branching ratios come into play to obtain final state shown to the right
  - Use detection of K_S^0 decay products
- Initial invariant mass plots show a clear peak at the PDG values of K_S^0 and Λ
  - $M(K_S^0) = 0.498\ \mathrm{GeV}$
  - $M(\Lambda) = 1.116\ \mathrm{GeV}$



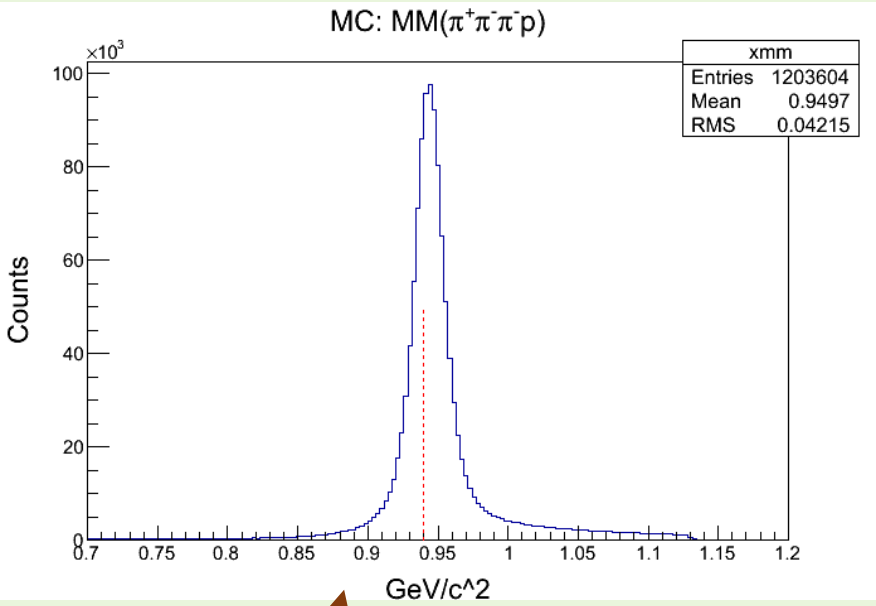
$$\gamma d \rightarrow K^0\Lambda(p) \rightarrow \pi^+\pi^-\pi^-p(p)$$

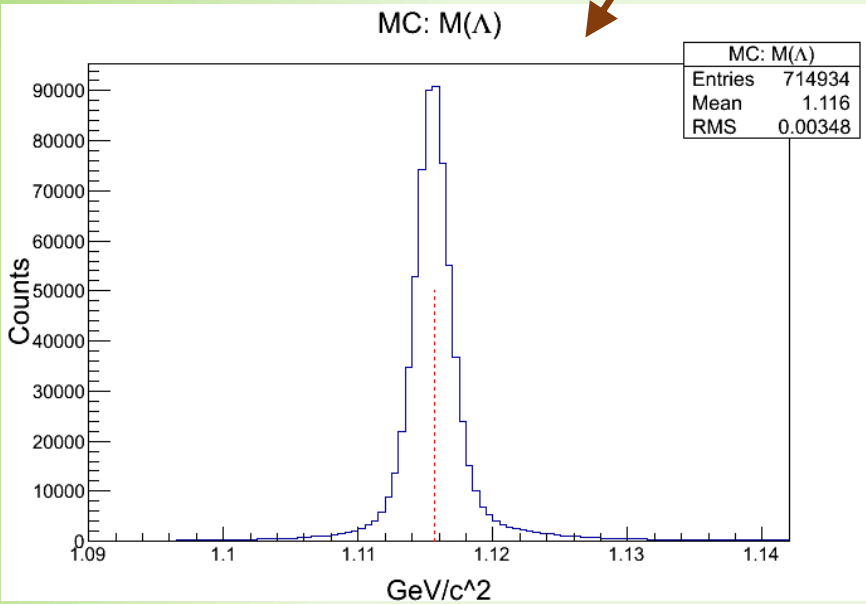
$K_S^0 \rightarrow \pi^+\pi^-$ 69.2%

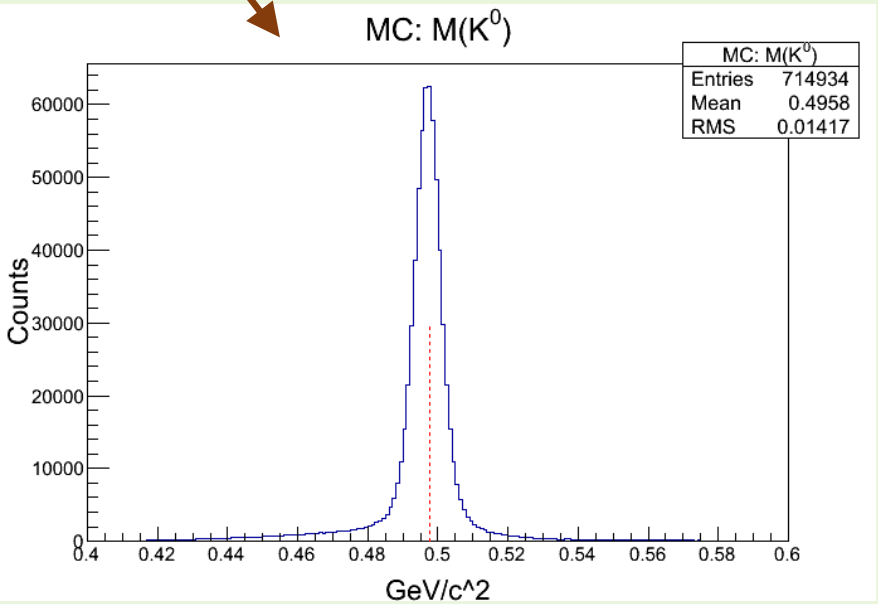
$\Lambda \rightarrow \pi^-p$ 63.9%

Simulation of $K^0\Lambda$ Production

There is a clear signal at both the invariant mass of the Lambda and Kaon







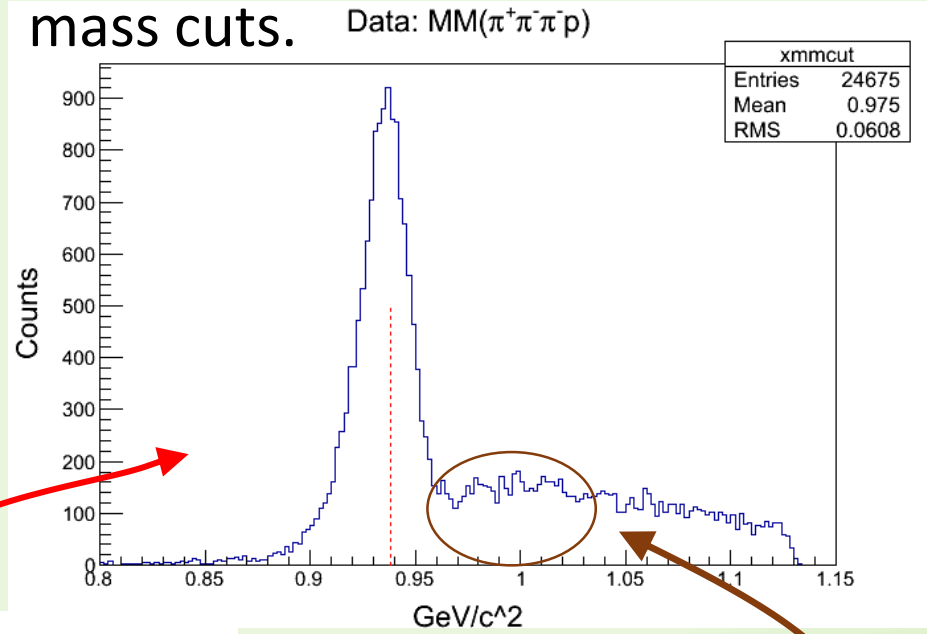
The missing mass technique results in a mass equal to the spectator proton

$$m_p(spec) = \sqrt{{P_p}^2}$$

$$P_p(spec) = (P_\gamma + P_d - P_K - P_\Lambda)$$

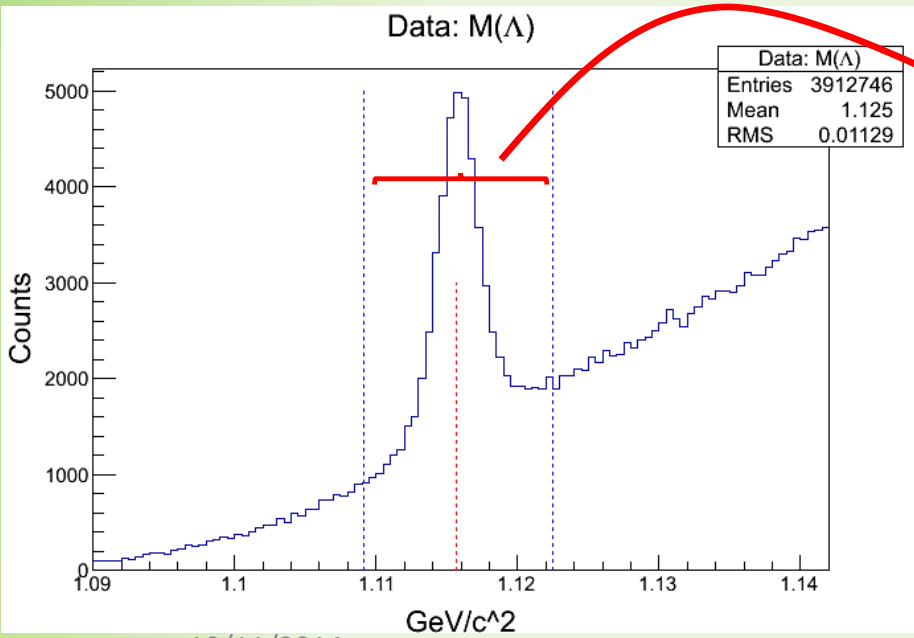
Distributions within the Data

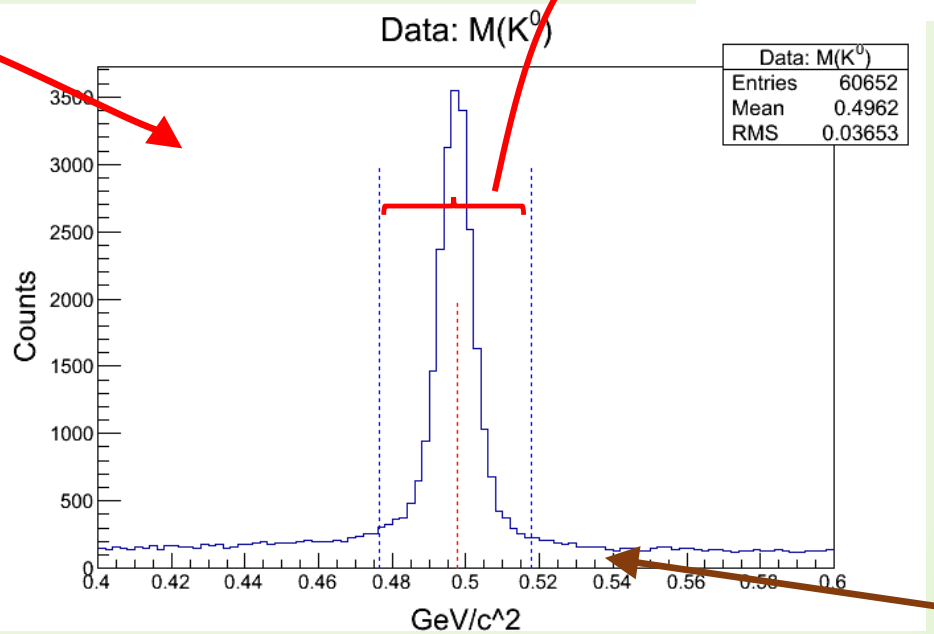
Missing mass with both invariant mass cuts.



Invariant mass of the Lambda shown without any other invariant mass cut

Invariant mass of the Kaon shown with a cut about the Lambda invariant mass





There are clearly a couple background processes

- Right of the spectator proton peak
- Under the invariant mass of the Kaon

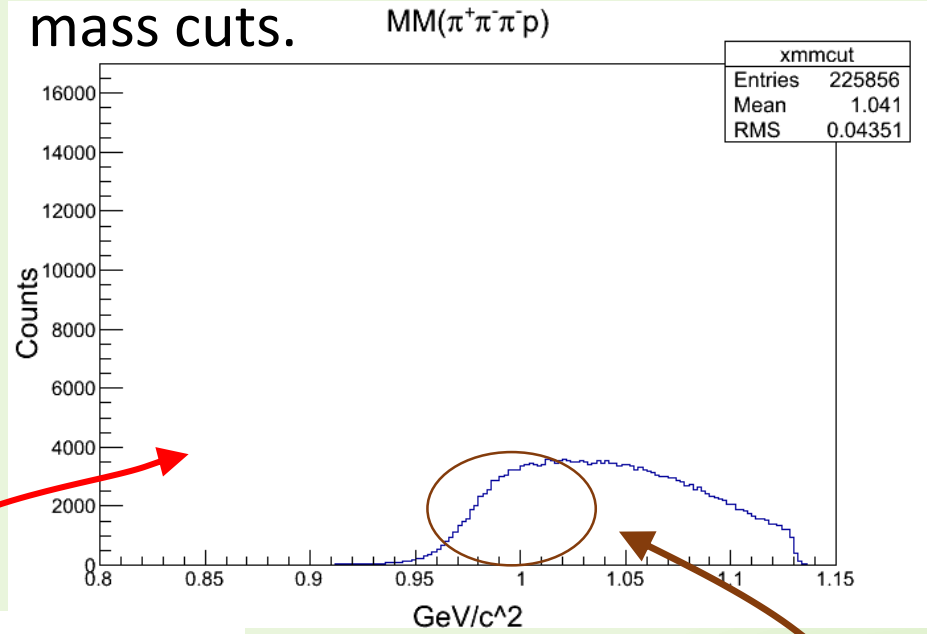
Simulation of $\gamma d \rightarrow K^0\Sigma^0(p)$

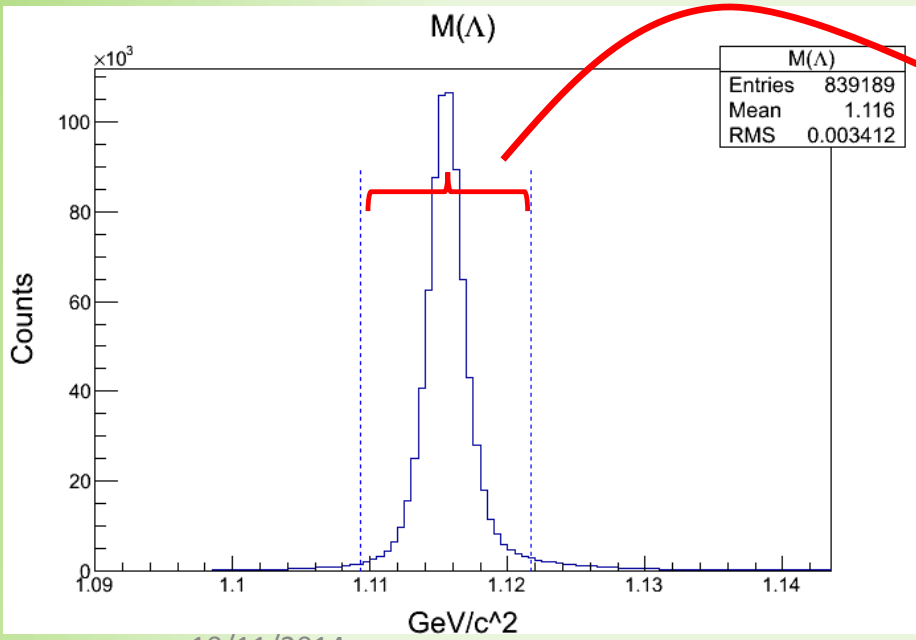
$$\Sigma^0 \rightarrow \Lambda\gamma$$

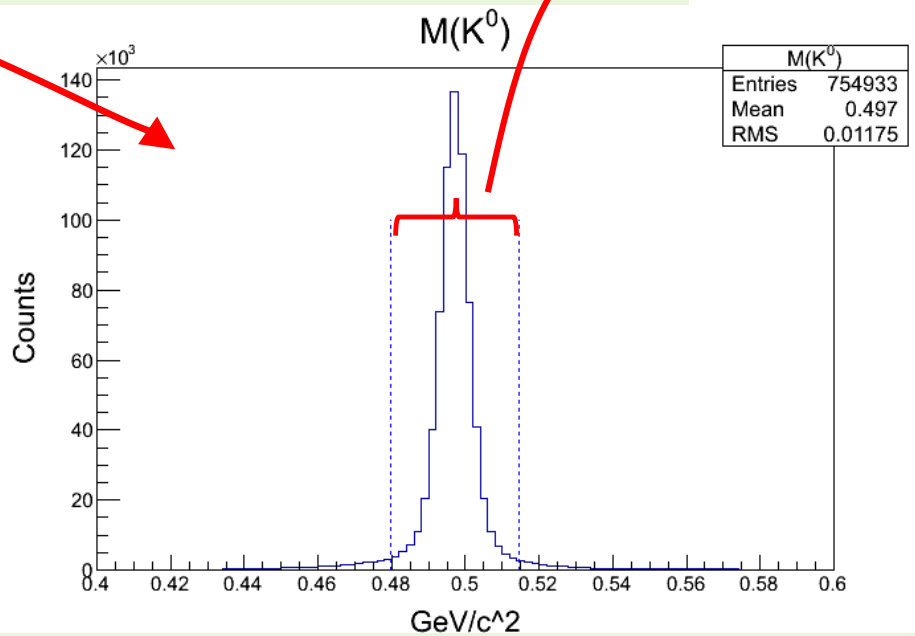
Invariant Mass of the Lambda shown without any other invariant mass cut

Invariant Mass of the Kaon shown with a cut about the Lambda invariant mass

Missing mass with both invariant mass cuts.





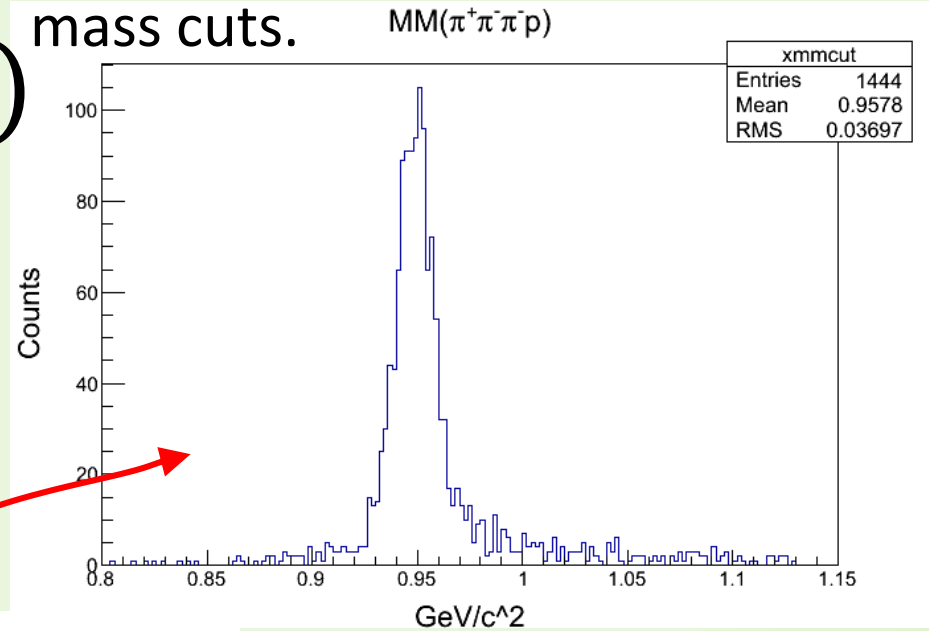


This type of background can account for the distribution to the right of the $m_p(spec)$ peak within the missing mass spectrum

Simulation of $\gamma d \rightarrow \pi^+\pi^-\pi^- p(p)$

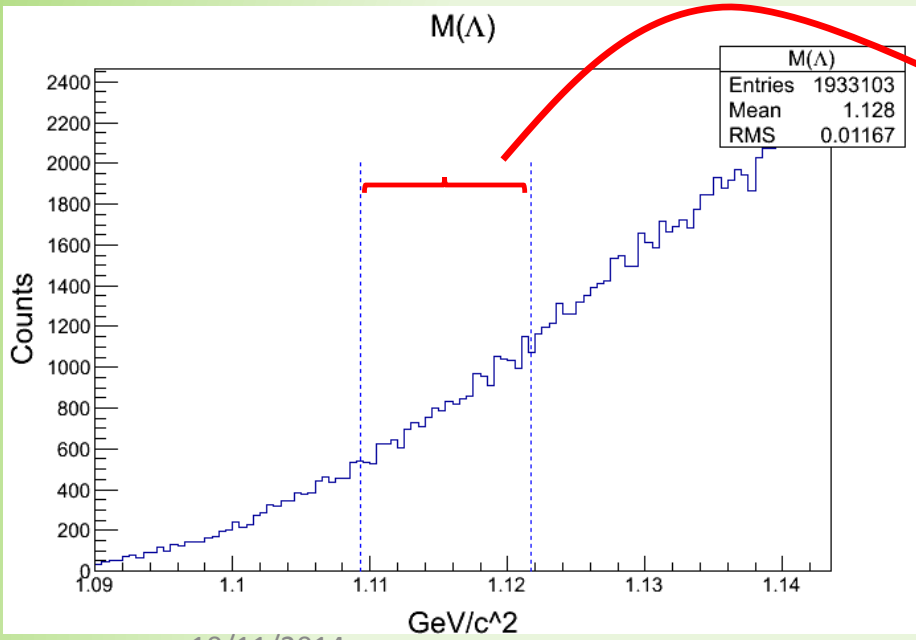
Simulation was a generated 4-Body phase space

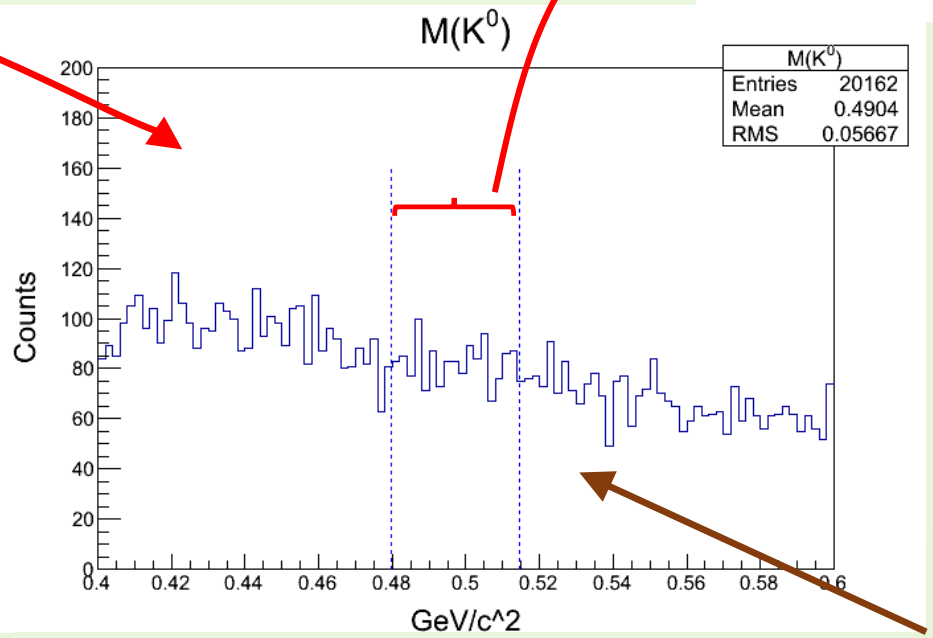
Missing Mass with both invariant mass cuts.



Invariant Mass of the Lambda shown without any other invariant mass cut

Invariant Mass of the Kaon shown with a cut about the Lambda invariant mass

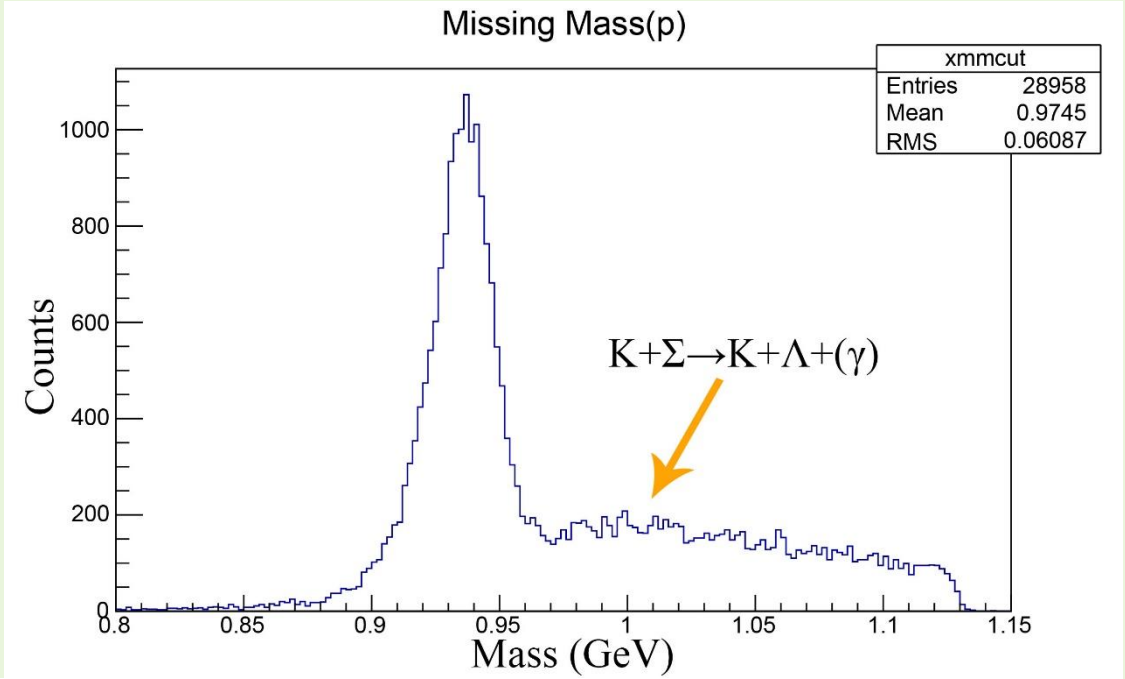


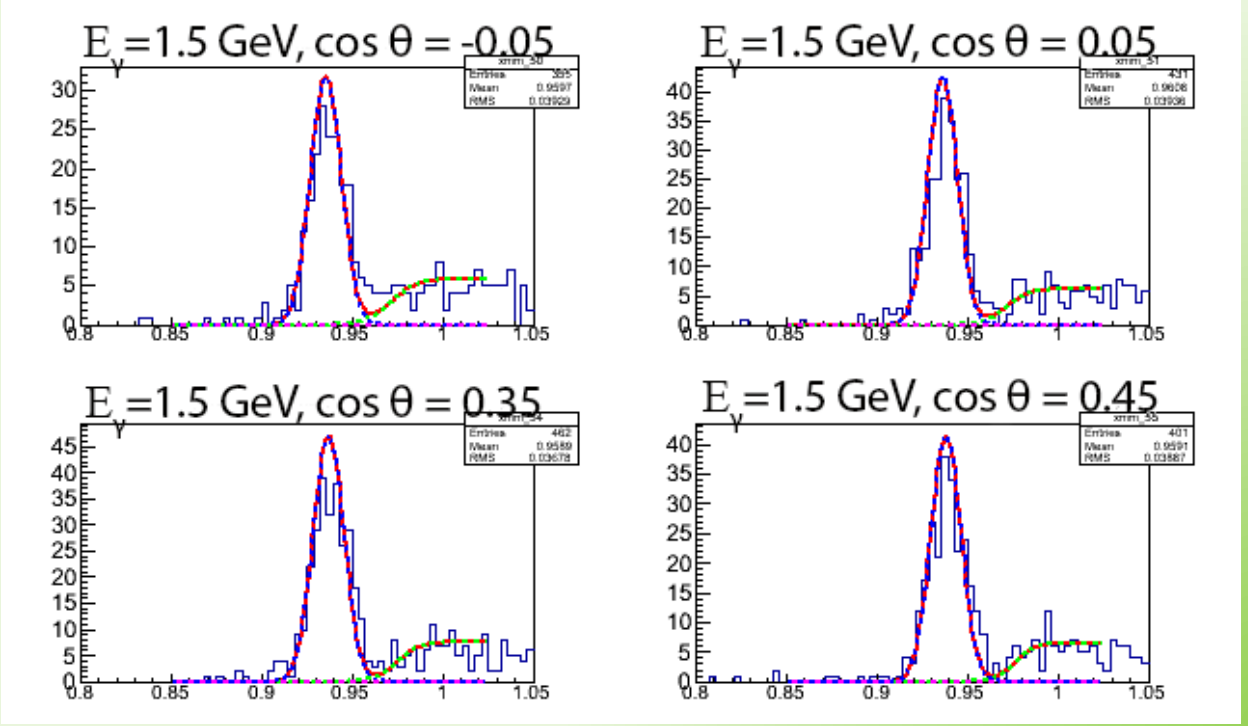


This type of background will be hidden under the $m_p(spec)$ signal. A sideband subtraction can be done by looking at the sideband of K^0.

Extraction of Yields

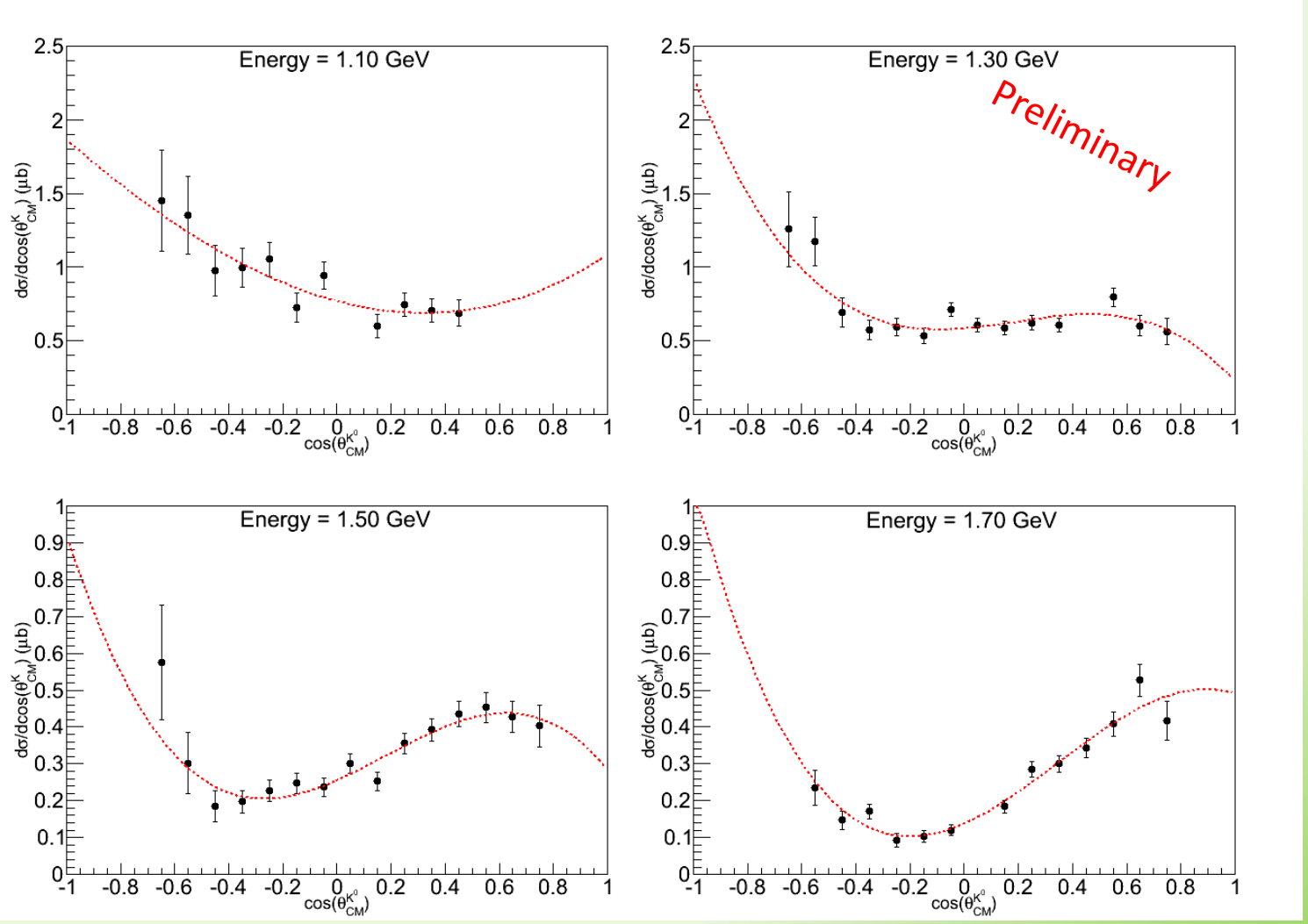
- Cut on the invariant mass of Lambda
- Cut on the invariant mass of Kaon
- Fit missing mass spectrum
- Σ^0production still produces real signal in the K^0 and Λ invariant mass spectrum
  - Fit the edge of the MC missing mass of Σ^0 production
- Subtract phase space type background
  - $\gamma d \rightarrow \pi^+\pi^-\pi^- p(p)$
  - Fit sideband and subtract





Differential Cross Section

- $\frac{d\sigma}{d\cos\theta} = \frac{Y(E,\theta)}{\delta(\cos\theta)AN_\gamma(E)}\frac{d_{MM}}{\rho L N_A}$
- The plot to the right
  - Fit to 3rd order Legendre Polynomial
  - Error bars are statistical only
  - Systematic Uncertainty is ~10%
  - Point geometrically centered on angular bin
  - Energy bins of 200 MeV



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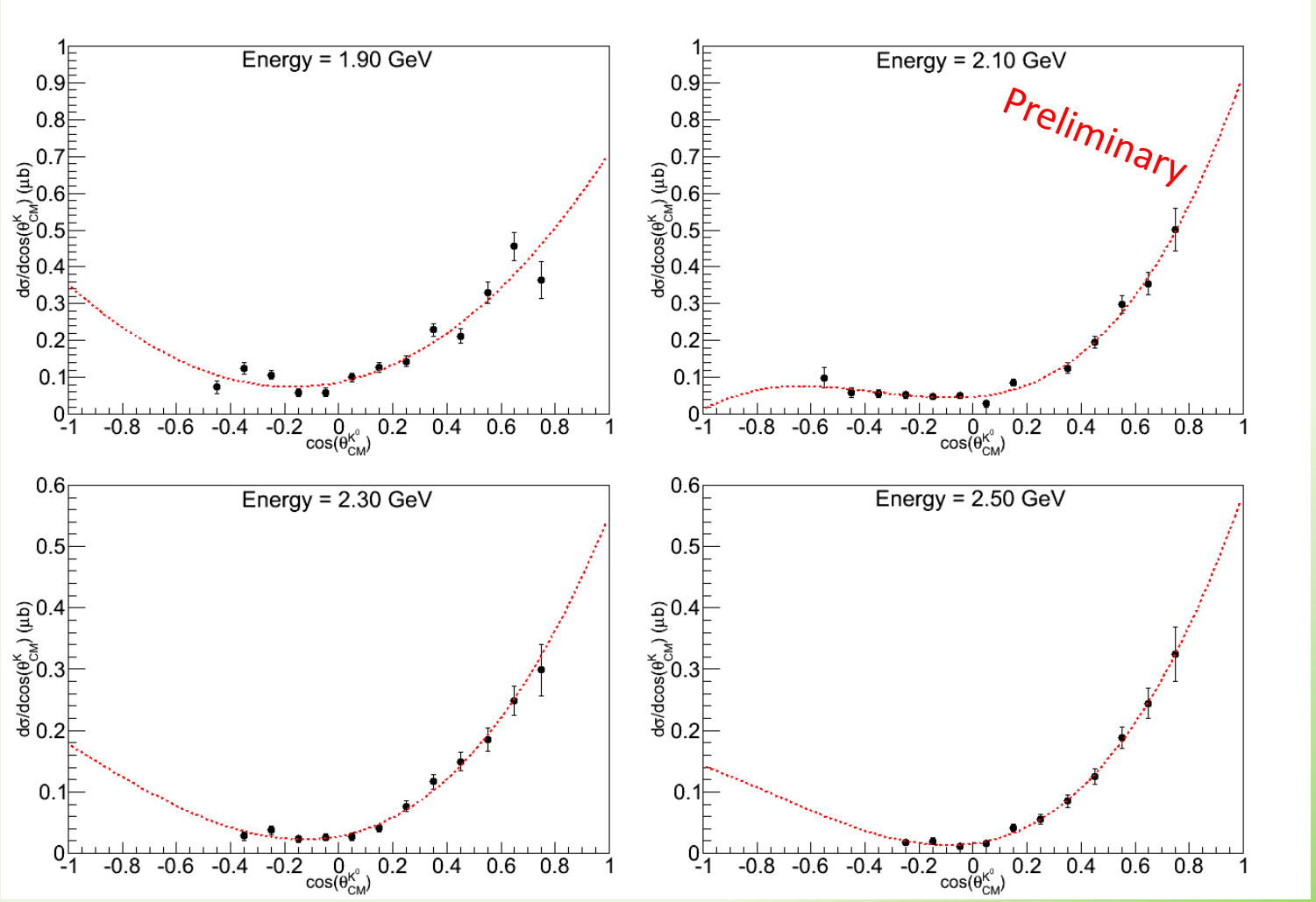
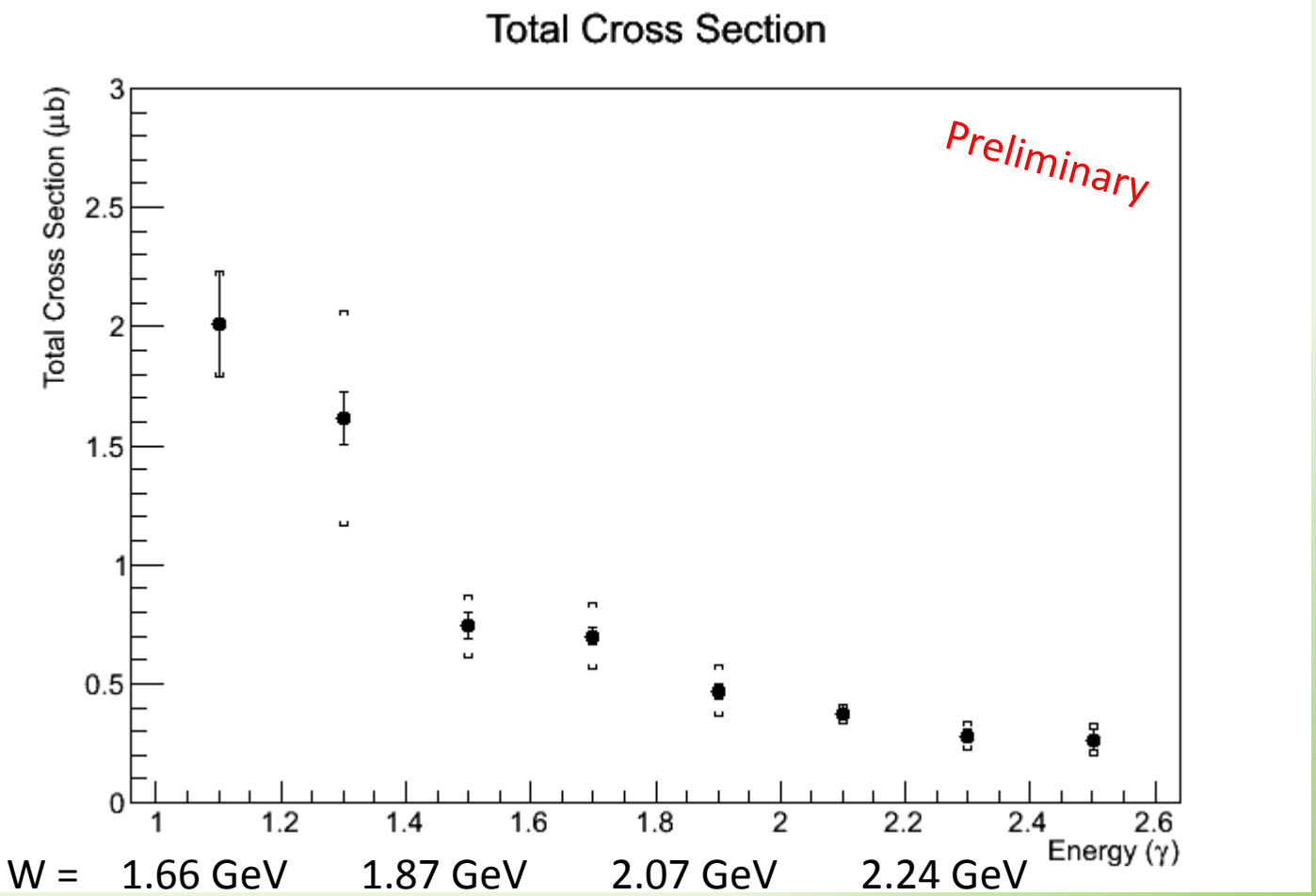


Total Cross Section: $\gamma d \rightarrow K^0\Lambda(p)$

- Integrate Polynomial to obtain a total cross section
  - Several fits were applied to obtain an idea of systematic effects
- An increase in the cross section is seen in the energies below W = 1.87 GeV
  - Indicative of resonance coupling to this channel
  - There are several nucleon resonances within these energies
- Theoretical work still needs to be done but we will learn more about them in these data



Summary and Conclusion

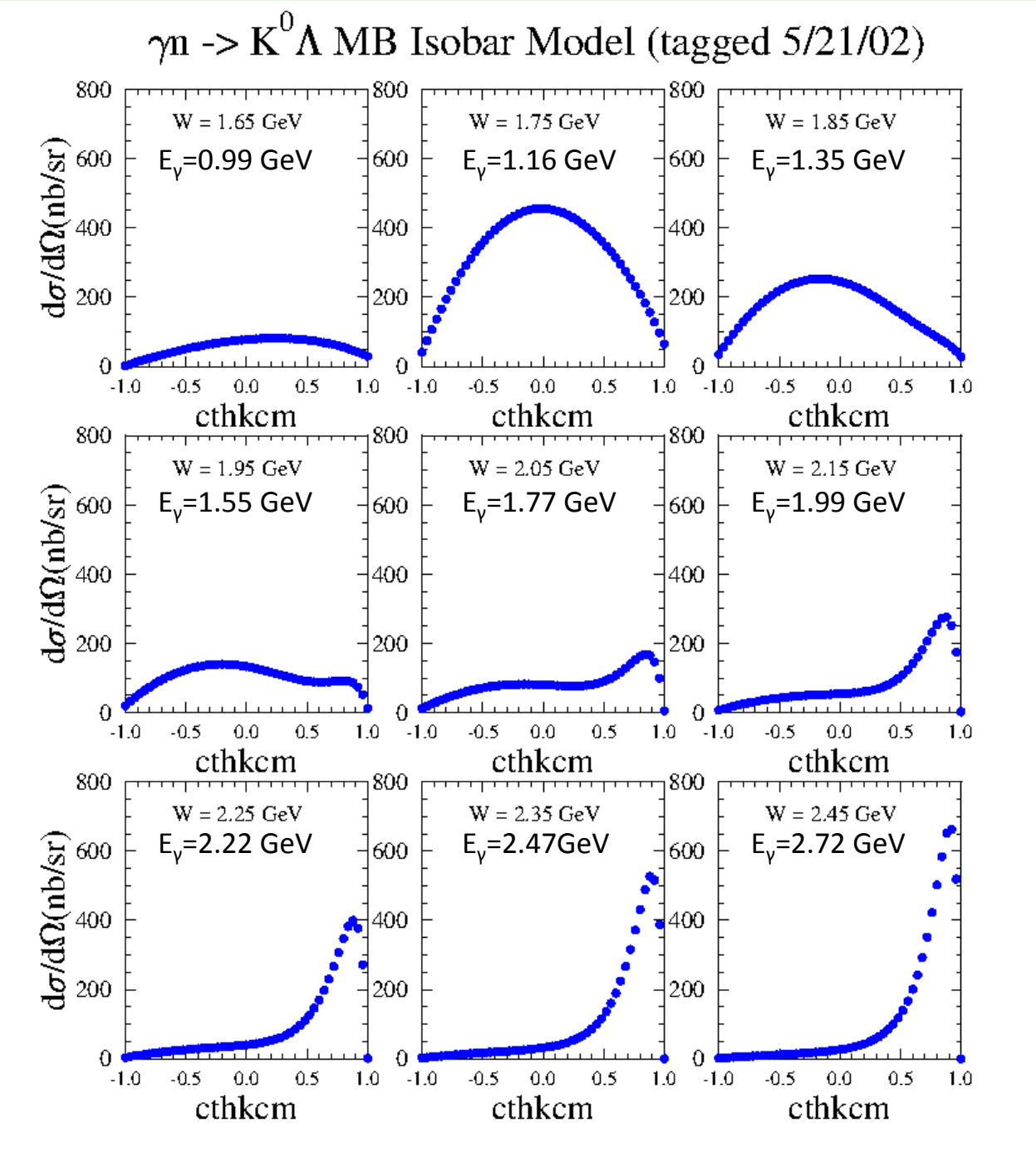
- Demonstrates that a nucleon resonance may be coupled to this reaction channel
- More CLAS results to come shortly
  - Working concurrently with g13
    - Independent study is also being done
    - Much more statistics
    - Finer binning available
  - A comparison between two methods and two different data sets can be made
- These results are preliminary
  - An analysis note is in the review process within the CLAS collaboration
  - Plan to publish soon

Back-Up Slides

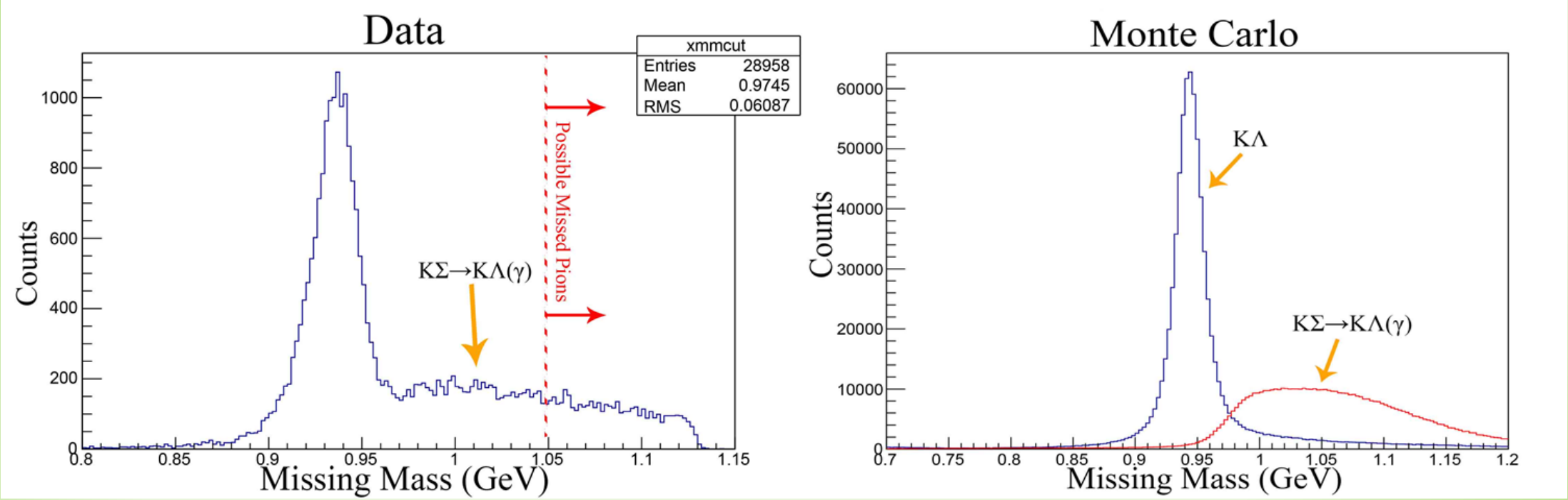
Theory Plots

Model created by
T. Mart and C. Bennhold

Code executed by Dan Carman



Comparison of the Σ^0 background to the Data



Comparison of the phase space background to the Data

- Each plot is shown after a cut about the invariant mass of the lambda particles.
- As seen previously the phase space background has a linear distribution in the calculated K^0 mass.
- This background can be removed by subtracting the events between the colored dotted lines.

Here "Mix" represents a subset of K0Lam mixed with a 4 body phase space distribution