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

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Data from CLAS (g10) at JLAB

CEBAF Large Acceptance Spectrometer

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 spectroscopy are not very abundant. Specifically, there is minimal world data on the reaction $\gamma d \rightarrow K^0 \Lambda\,(p)$, if any.
- Investigated 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.

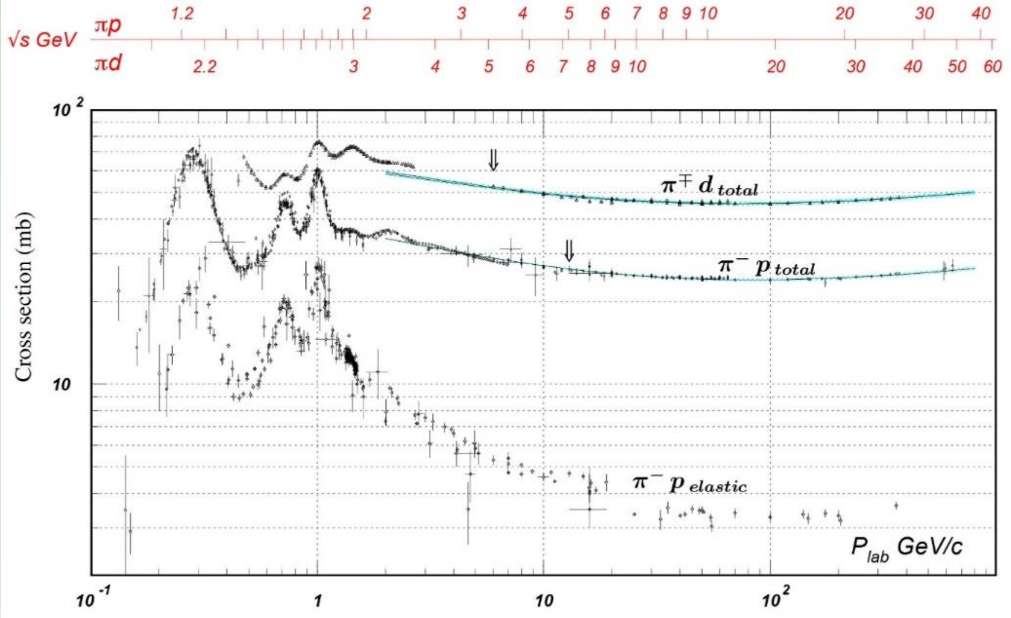
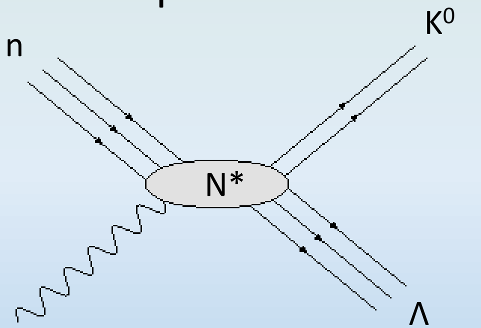


Figure 40.13: Total and elastic cross sections for $\pi^{\pm}p$ and $\pi^{\pm}d$ (total only) collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html. (Courtesy of the COMPAS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

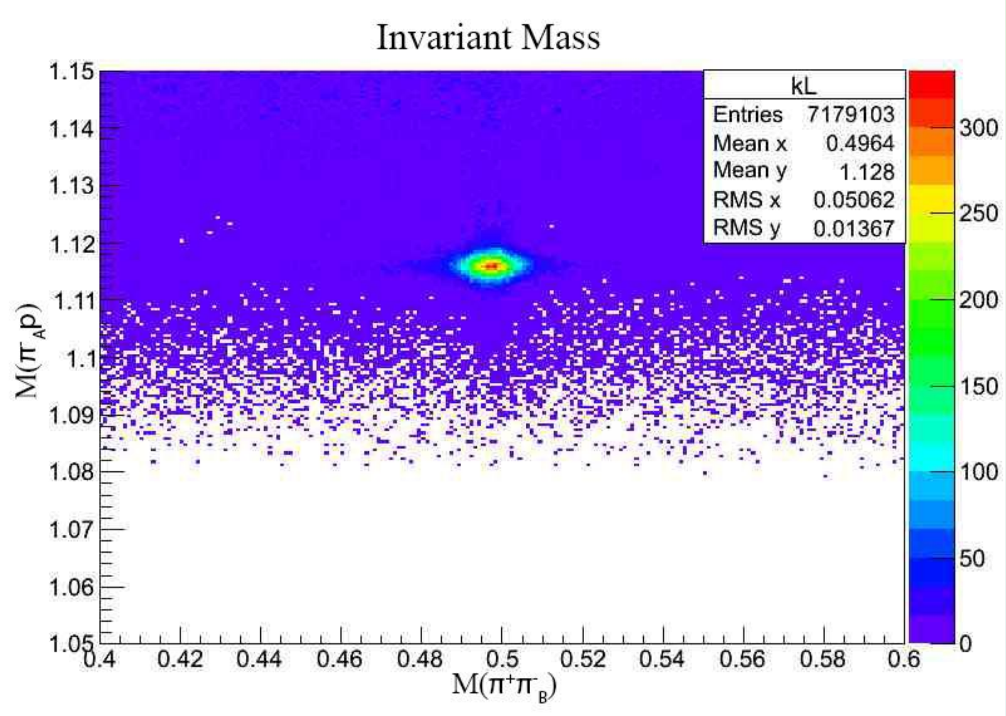
One possible production channel:



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

- G10 data set
  - Incident electron energies of roughly 3.8 GeV
  - Magnetic field with +2250A
  - Reviewed are events with tagged 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
  - $M(K_S^0) = 0.498\ \text{GeV}$
  - $M(\Lambda) = 1.116\ \text{GeV}$

Raw data where events contain the 4 final state products

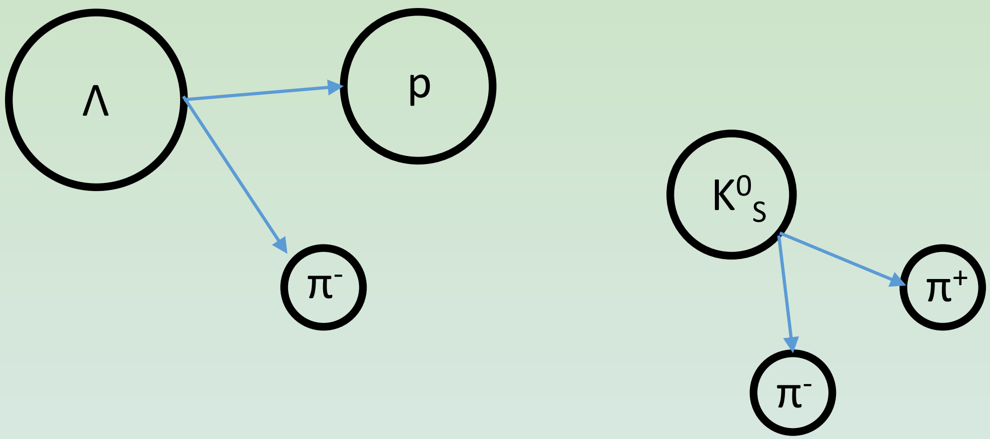


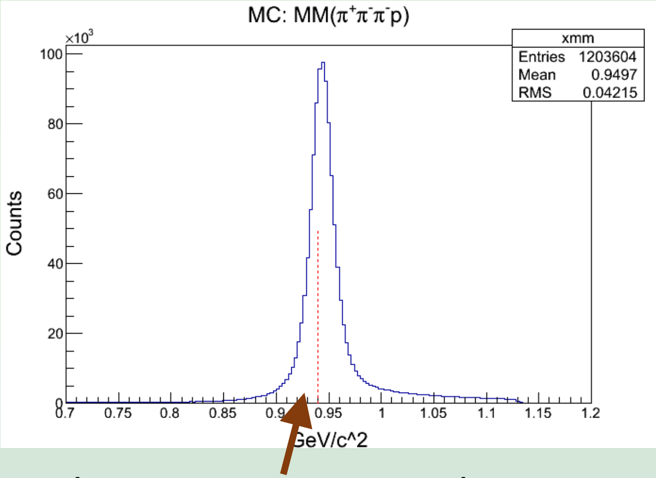
$$\gamma d \to K^0 \Lambda(p) \to \pi^+\pi^-\pi^-p(p)$$

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

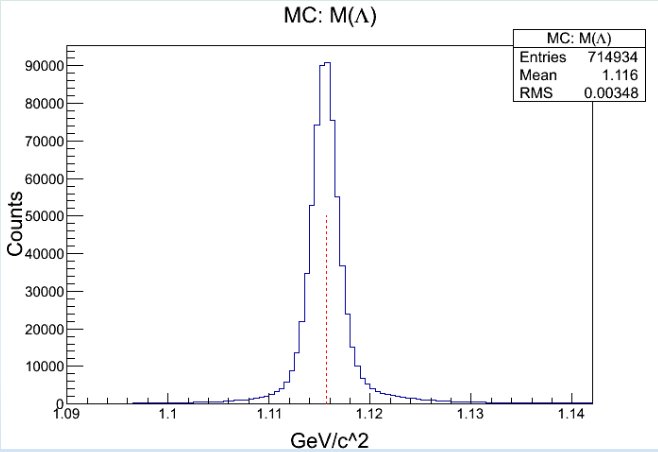
$\Lambda \to \pi^-p$ 63.9%

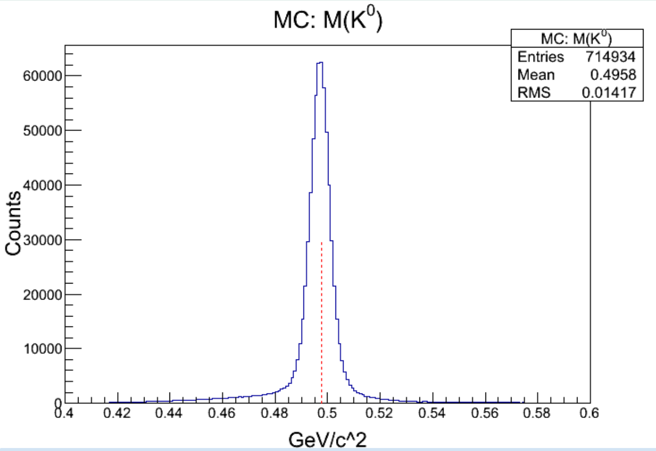
Simulation of $K^0\Lambda$ Production





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



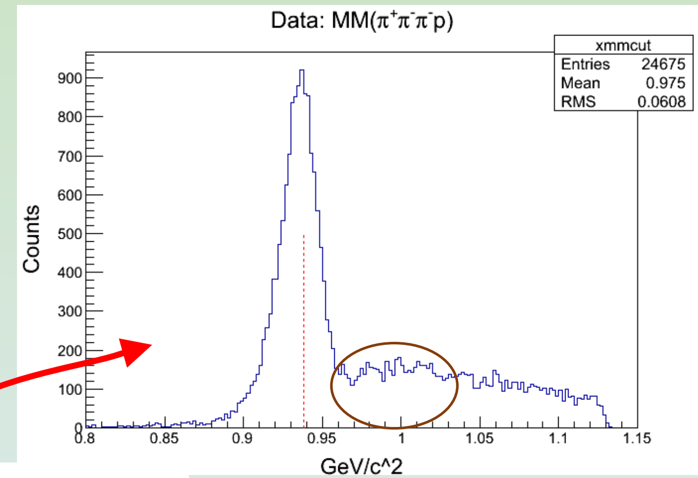


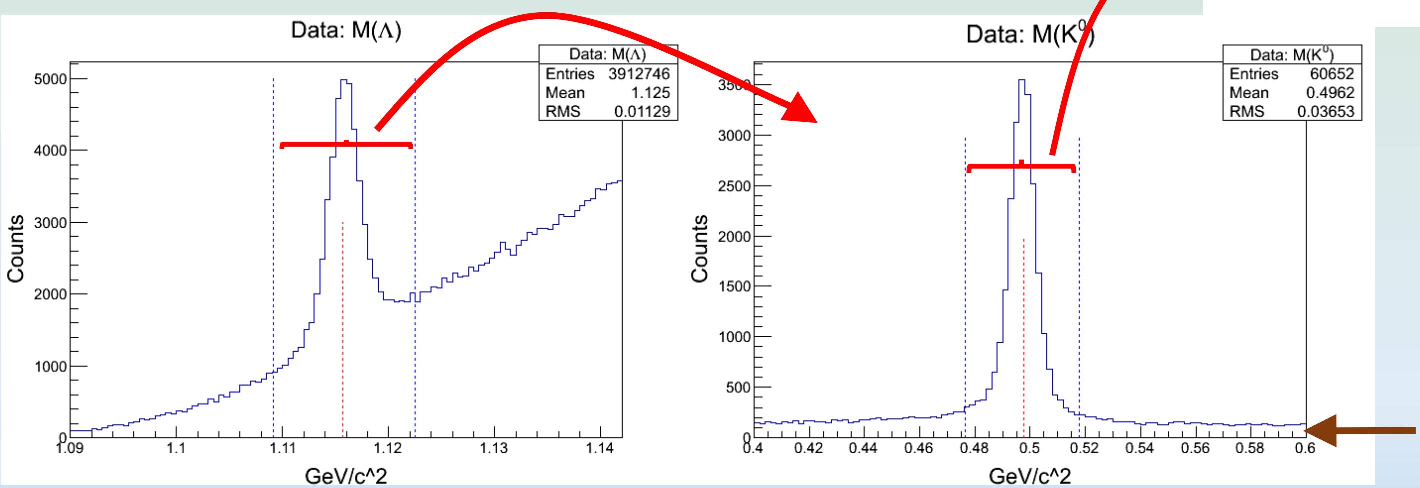
$$m_p(spec) = \sqrt{{P_p}^2}$$

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

Distributions within the Data

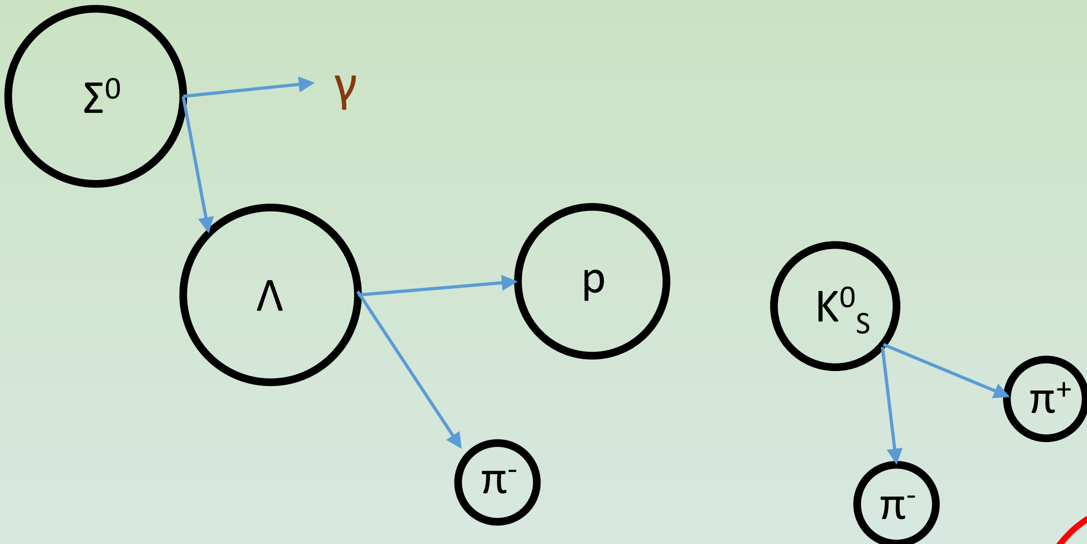
- Successive cuts about invariant masses cleans up the signal
- Signal is not completely isolated
  - One background is under the Kaon distribution (brown arrow)
  - Another background is to the right of the spectator proton (brown circle)

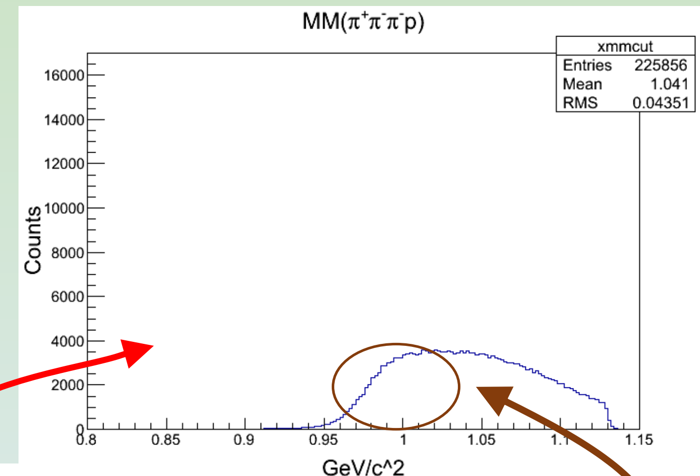


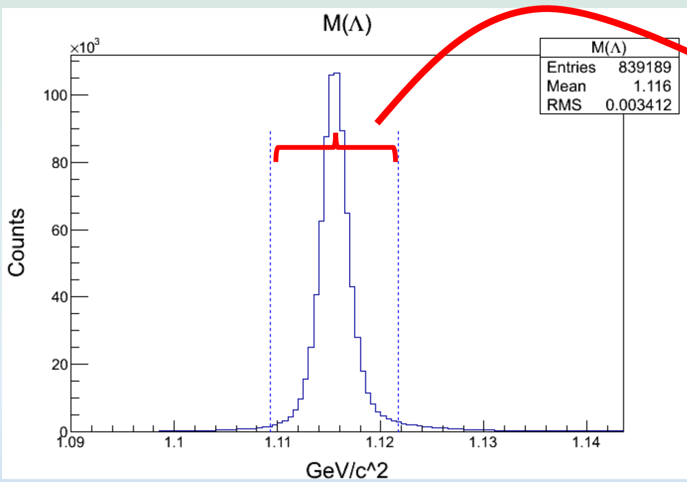


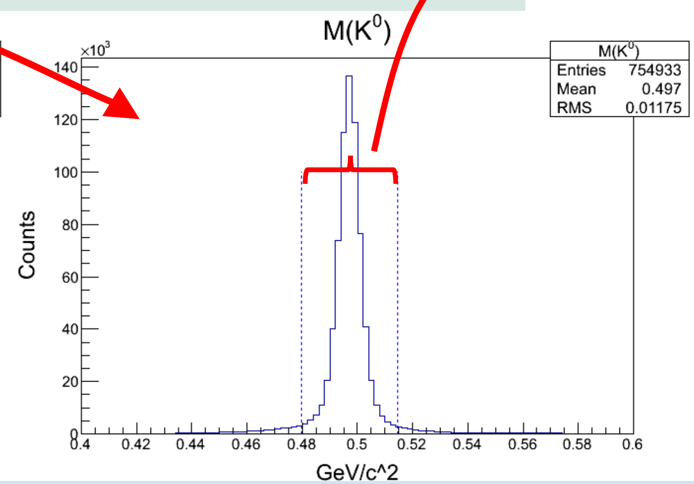
Simulation of $\gamma d \rightarrow K^0\Sigma^0(p)$

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





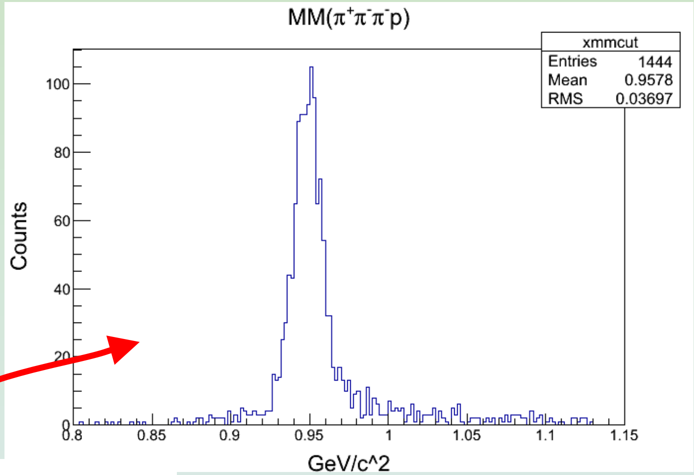


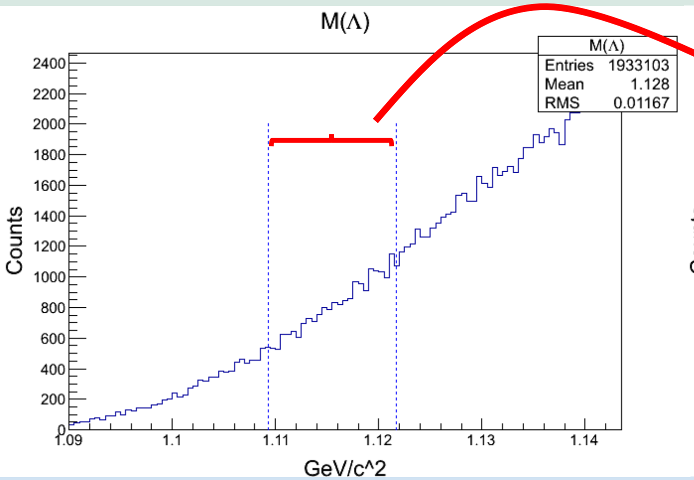


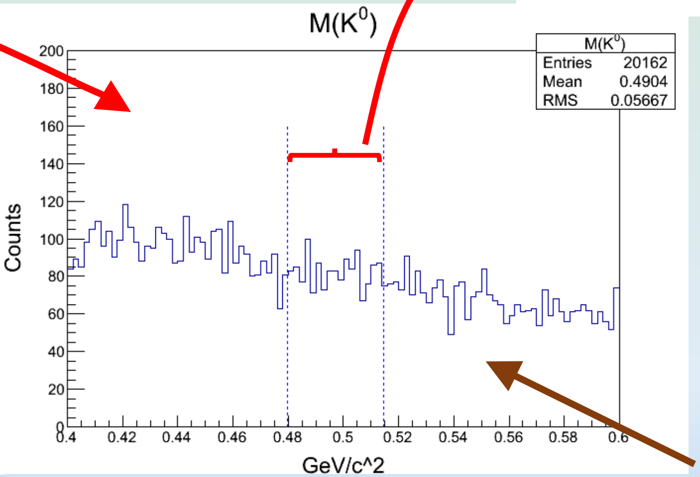
This type of background can account for the distribution to the right of the $m_p(spec)$ peak within the missing mass spectrum

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

- A generated 4-Body phase space distribution can model the background in the data reasonably well
  - Most likely due to a variety of production channels not producing K0Lam at a variety of kinematics
  - No matter the invariant mass cuts, a peak should form about the proton mass



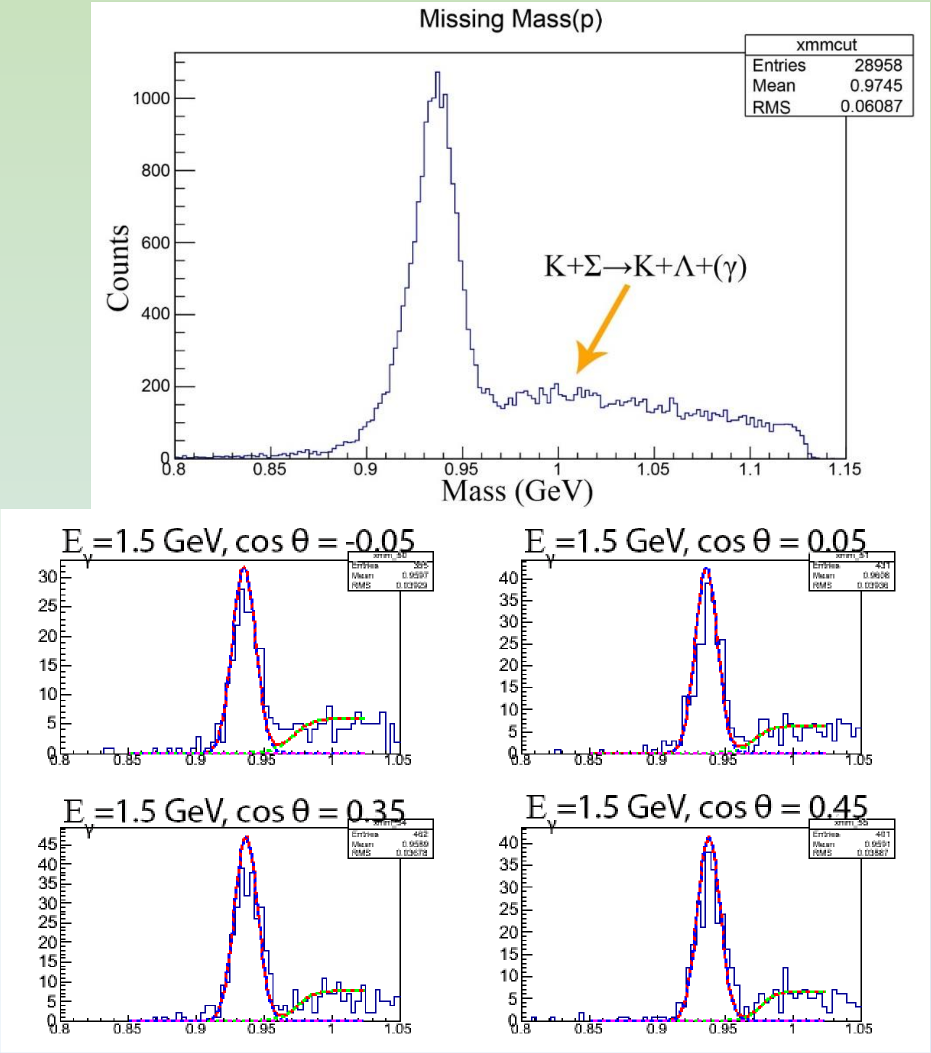




This type of background will be hidden under the $m_p(spec)$ signal. A pion background subtraction can be done by looking at the sidebands of K^0.

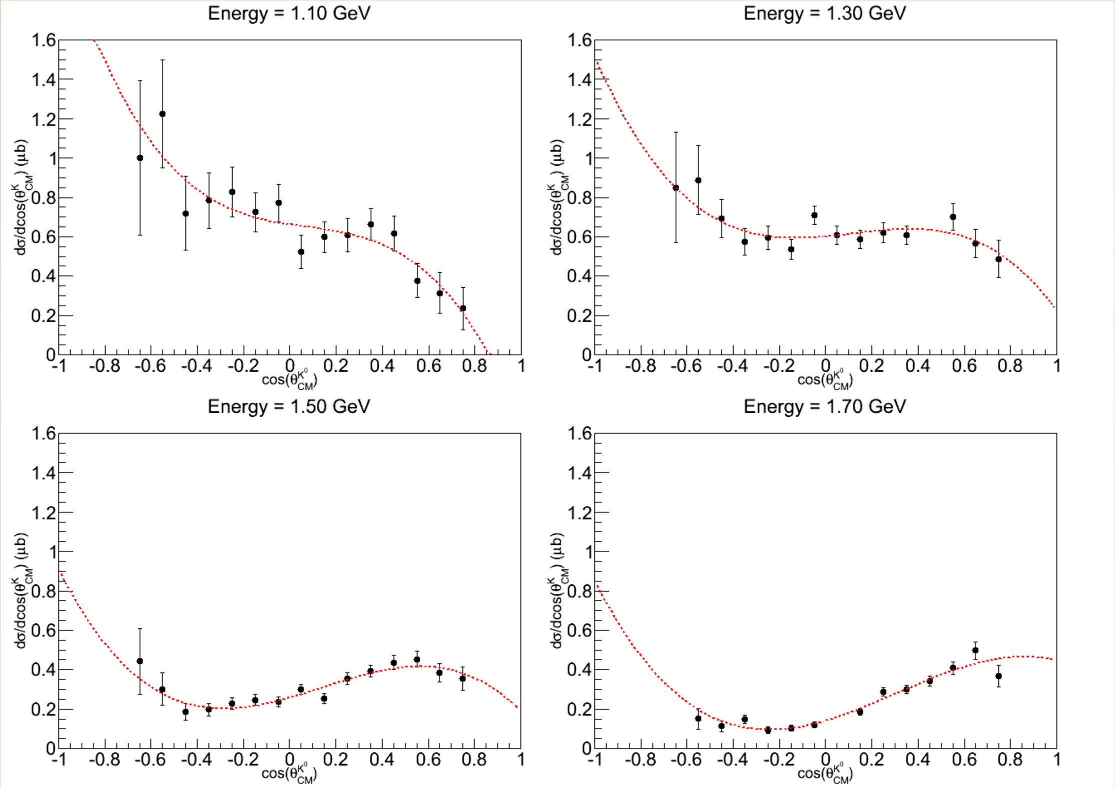
Yield Extraction

- Cut on the invariant mass of Lambda
- Cut on the invariant mass of Kaon
- Fit missing mass spectrum
- Σ^0 production 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 pion background 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



Differential Cross Section

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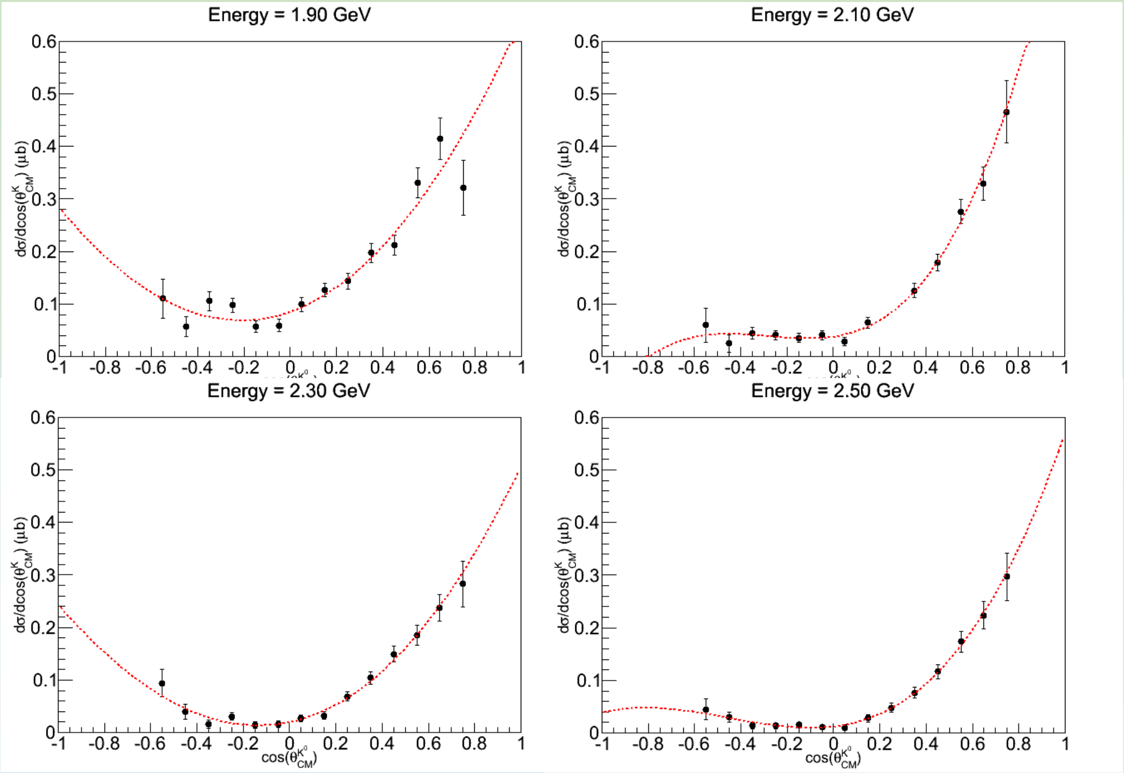
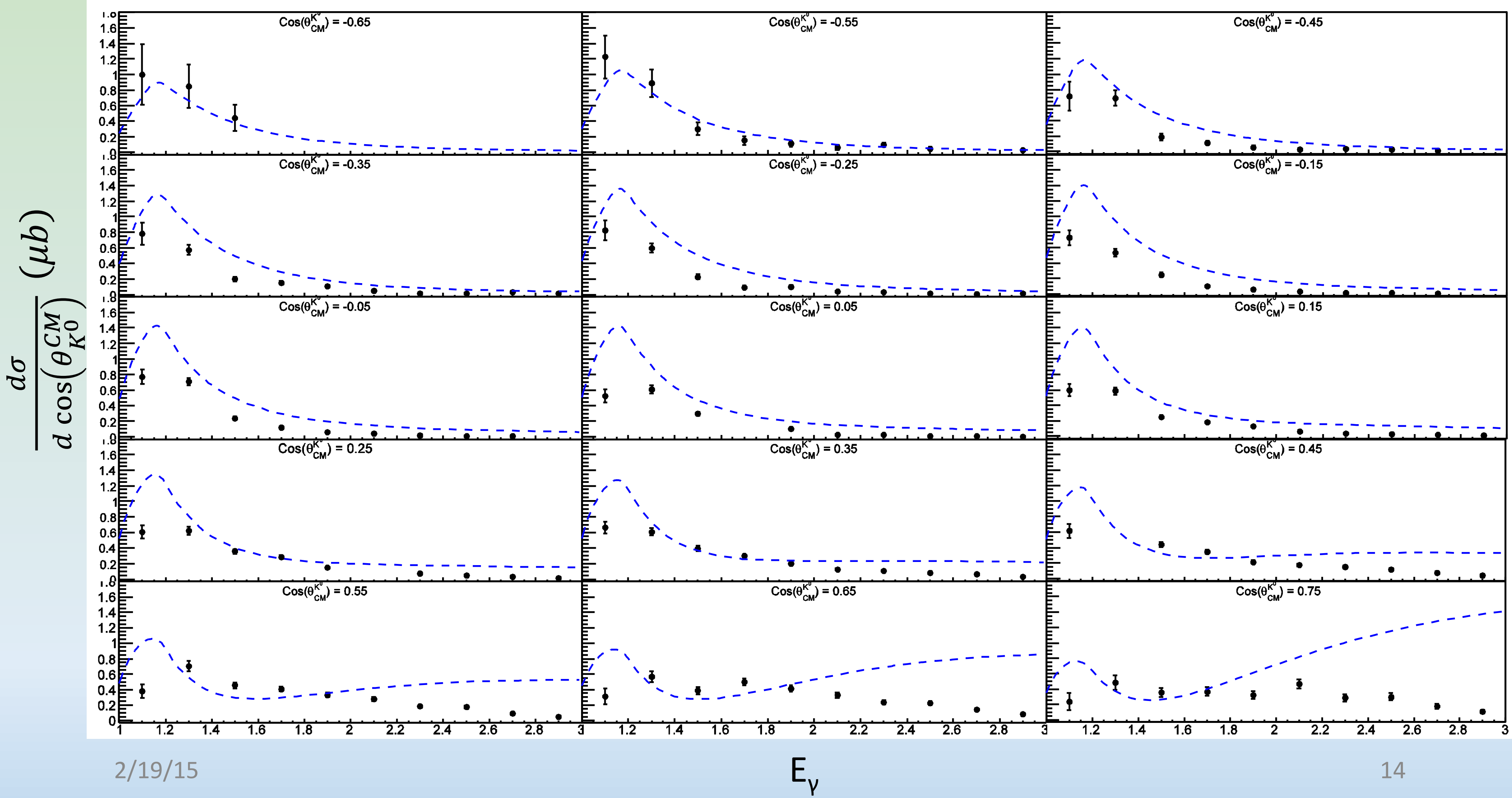


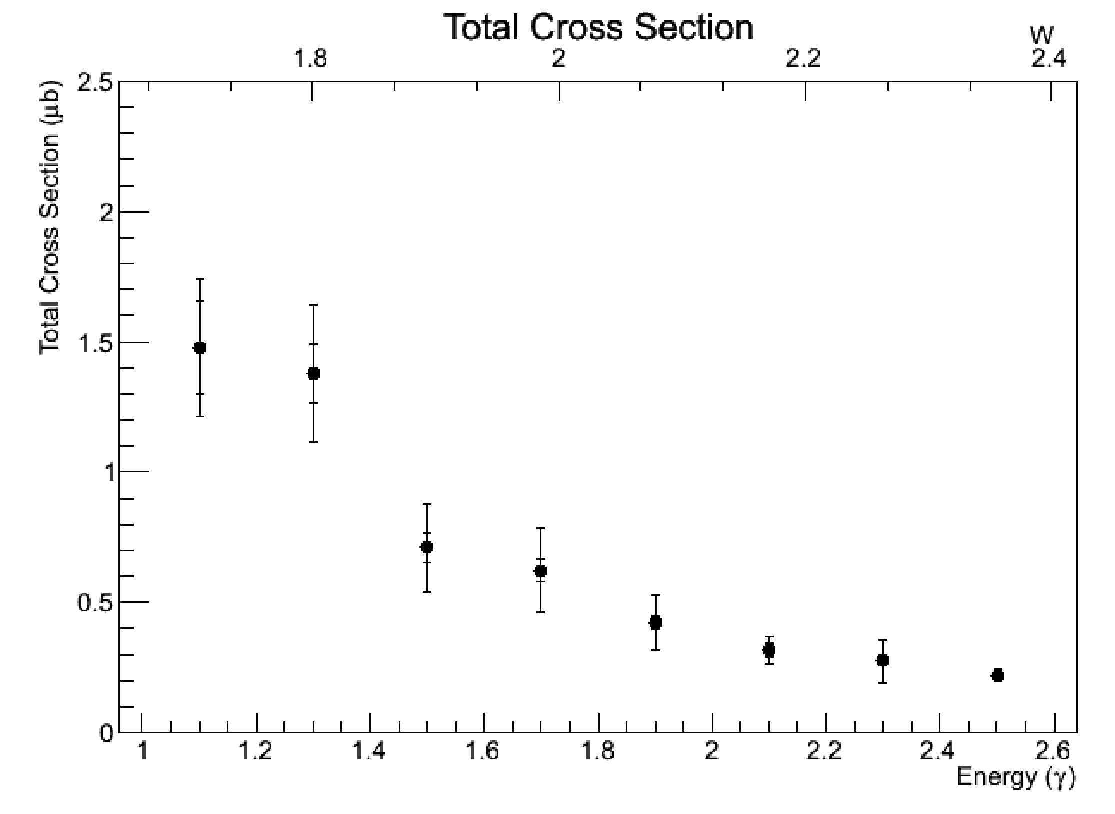
Model Comparison

- Blue dotted line is an old isobar model calculation from T. Mart
  - Created for energies near threshold
  - Updated model comparison to come shortly



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

- Integrated 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 for W < 1.87 GeV
  - Indicative of resonance coupling to this channel
  - There are several nucleon resonances within these energies
- Theoretical models could utilize this data to predict and/or set limits on couplings to this channel

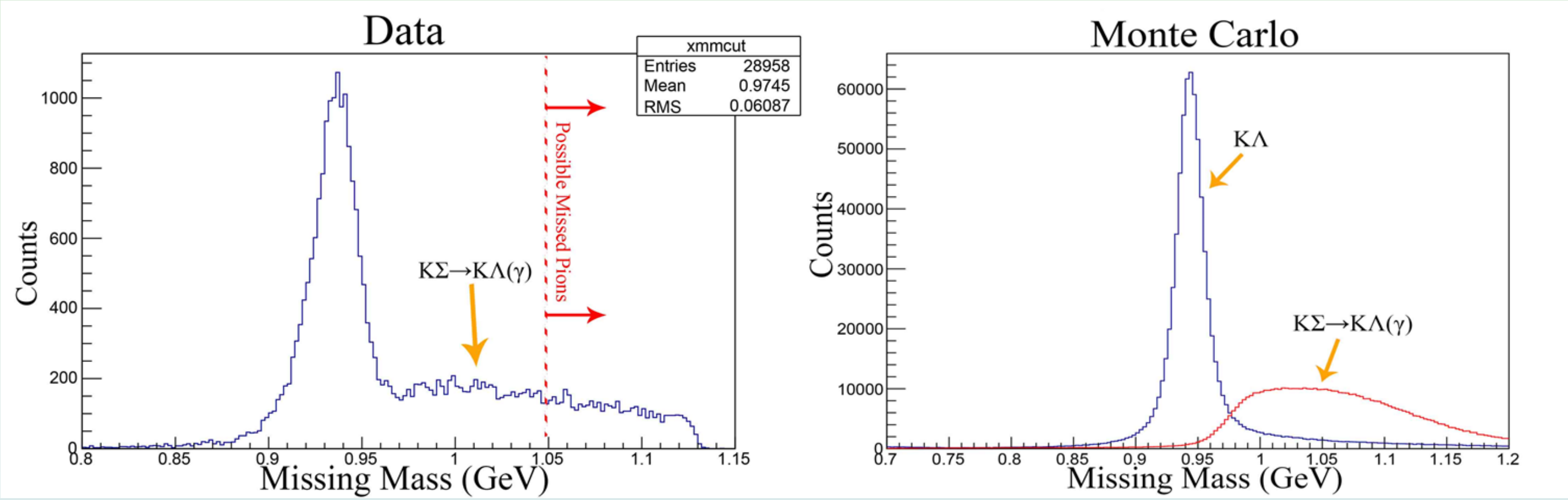


Summary and Conclusion

- Passed the internal CLAS analysis review
- Demonstrated where a nucleon resonance may be coupled to this reaction channel
- Provided a comparison for current work with g13
  - Independent study is also being done (C. Taylor)
  - Much more statistics
  - Finer binning available
  - A comparison between two methods and two different data sets would offer a powerful result
- Waiting for a comparison to a current theoretical model
  - In contact with T. Mart, who is almost completed with such a model

Back-Up Slides

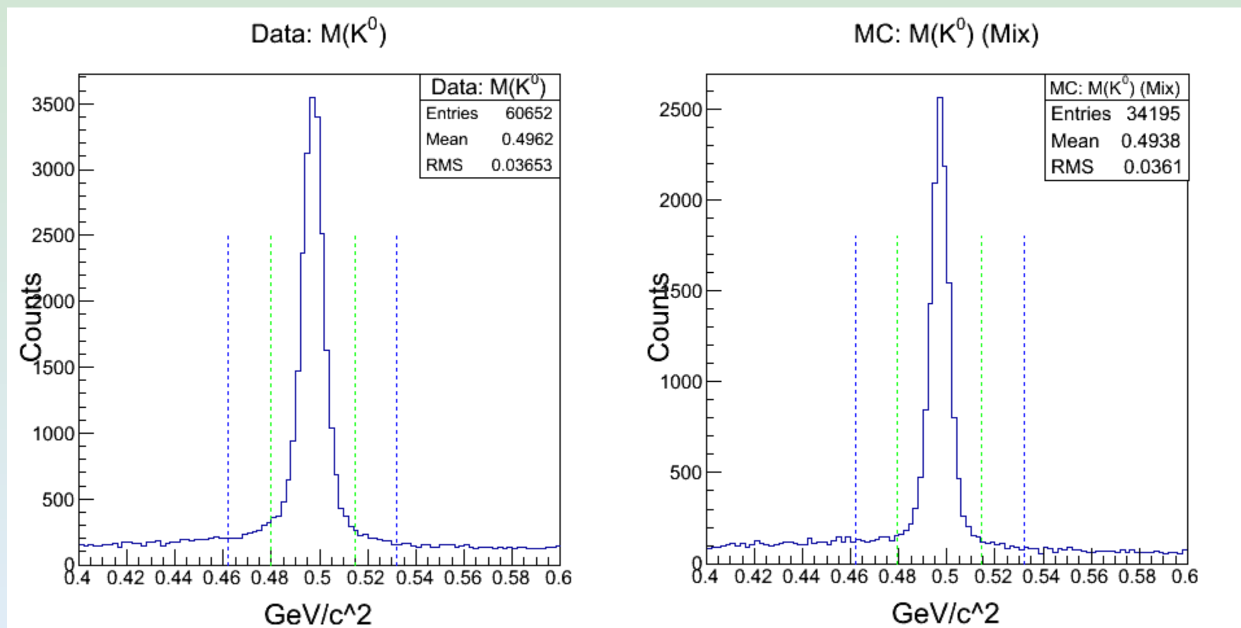
Comparison of the Σ^0 background to the Data



Comparison of the pion 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



Sideband subtraction

- Using 3 of the plots in the figure to the left, a plot that resembles the upper left plot can be constructed
  - Signal (K0Lam), Sigma0, and other non signal producing background
- The figure below shows the sideband cuts