Jefferson Lab

The Photoproduction of Excited Strange Mesons in $\gamma p \rightarrow \Lambda K^+ \pi^+ \pi^-$ With CLAS at Jefferson Lab

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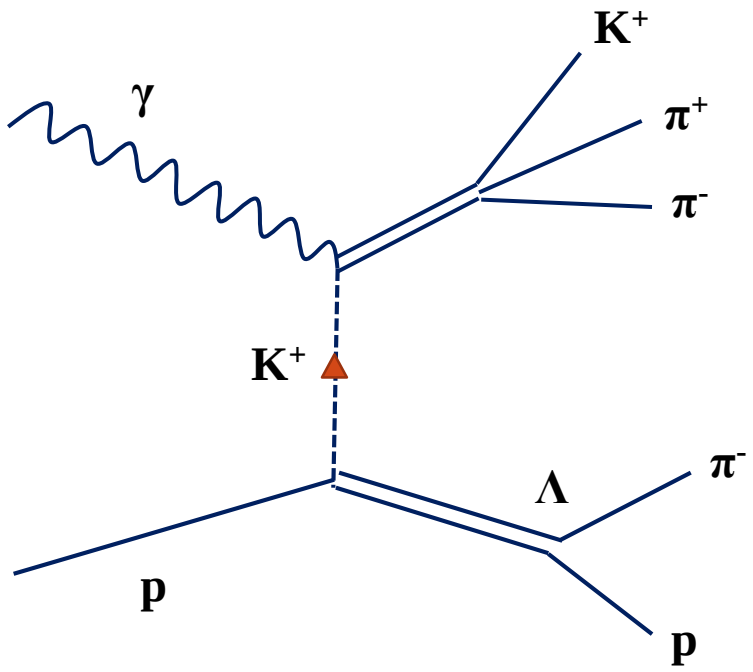
Florida State University

CLAS Collaboration Fall Meeting 2015

clas

Overview

- Analysis
- Summary & Future Plans



Data Selection

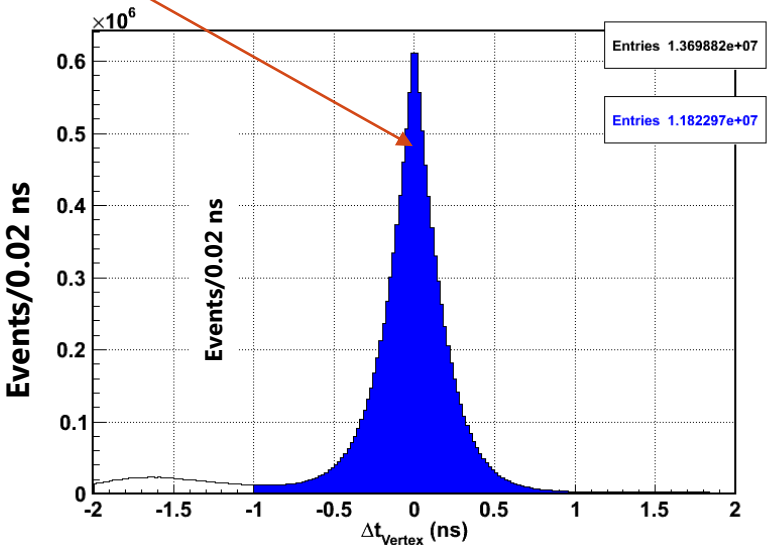
- 4 charged particles are selected : Proton, K^+ , π^+ , π^-

- Initial topology: $\gamma\, p \rightarrow p\, K^+\, \pi^+\, \pi^-$ [Missing Particle]

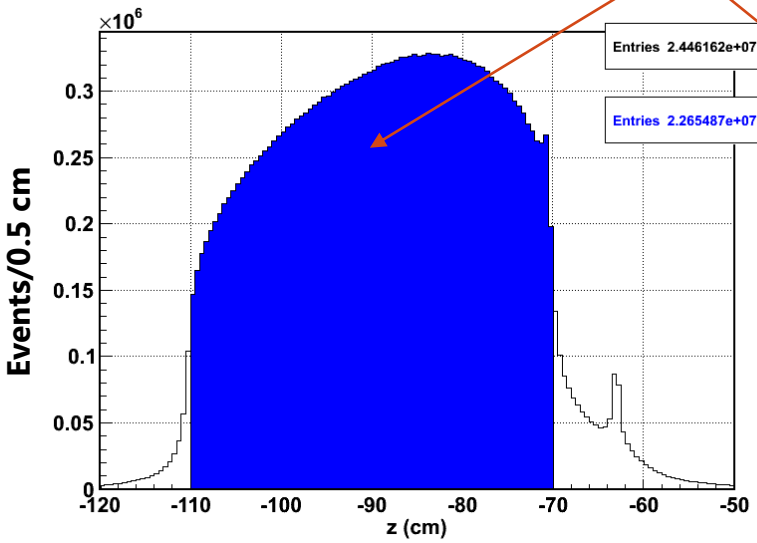
$$P_{Miss} = (P_\gamma + P_{Target}) - (P_{K^+} + P_P + P_{\pi^+} + P_{\pi^-})$$

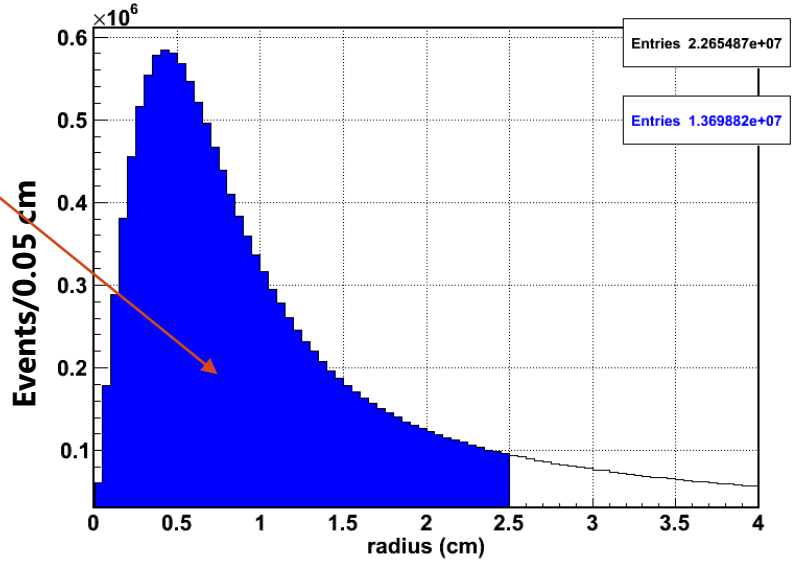
- About 24 million events with the above topology.

events within vertex timing

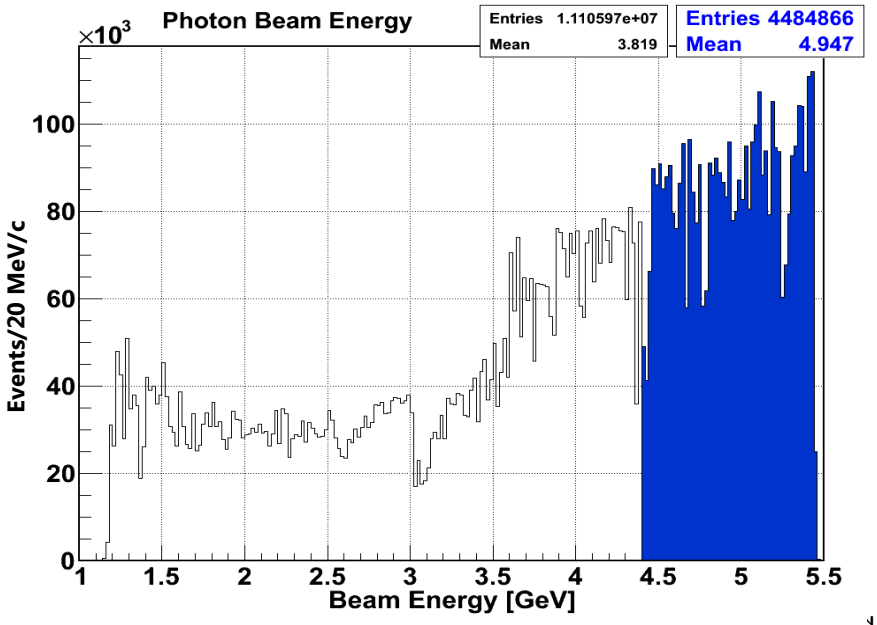


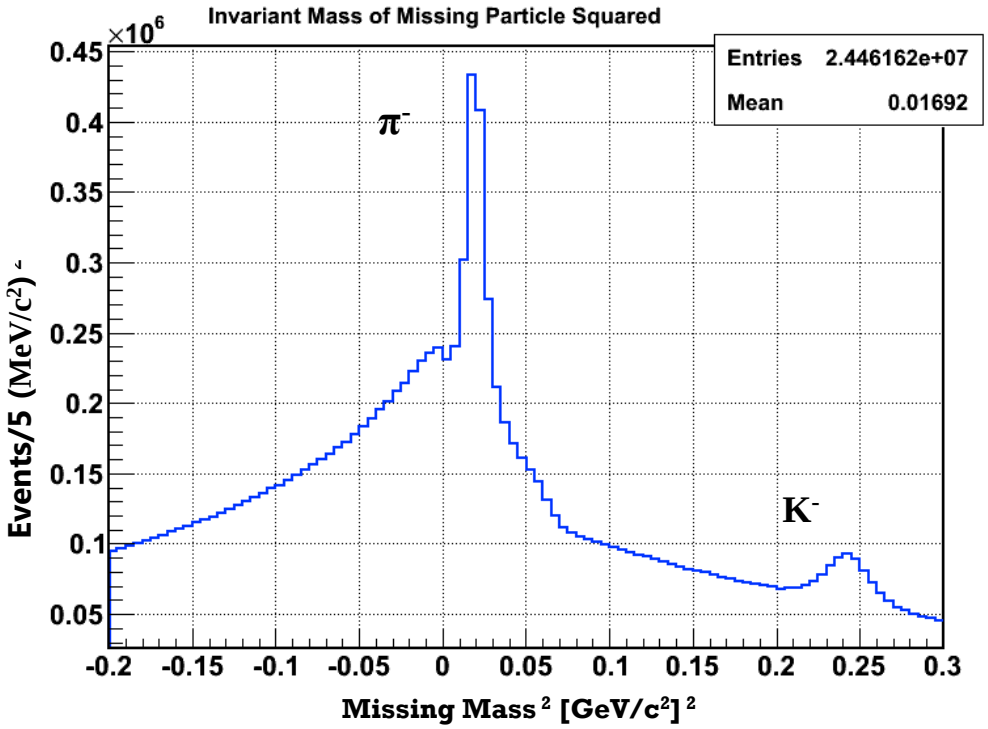
events inside target





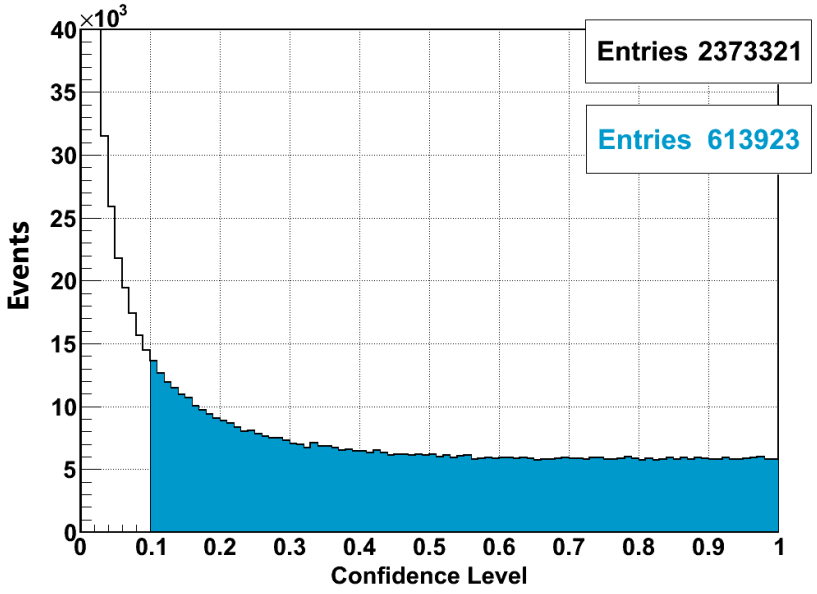
Data Selection

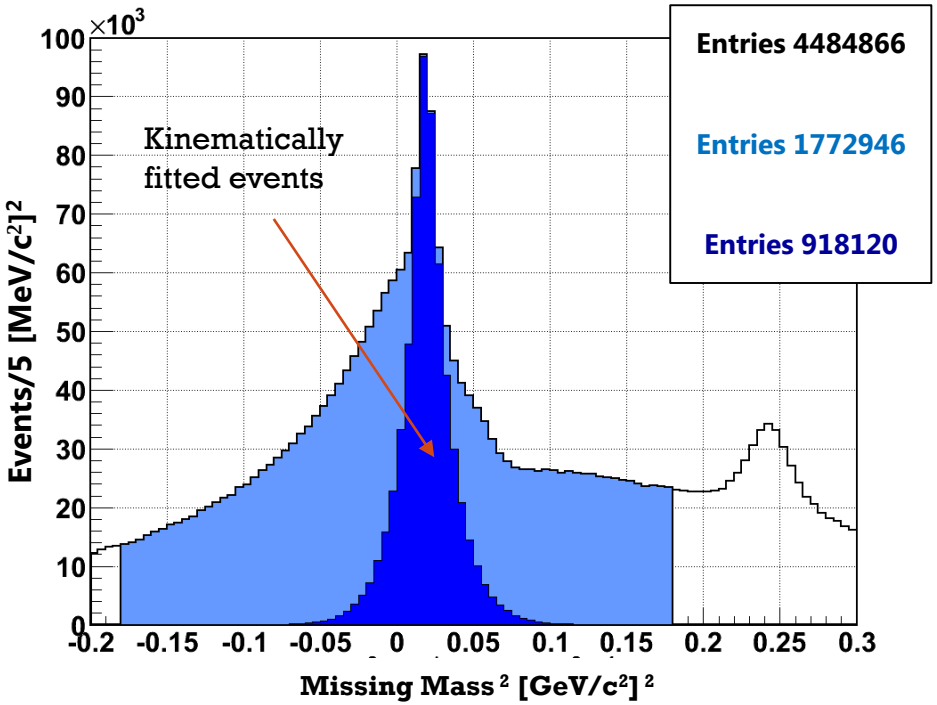




Kinematic Fitting

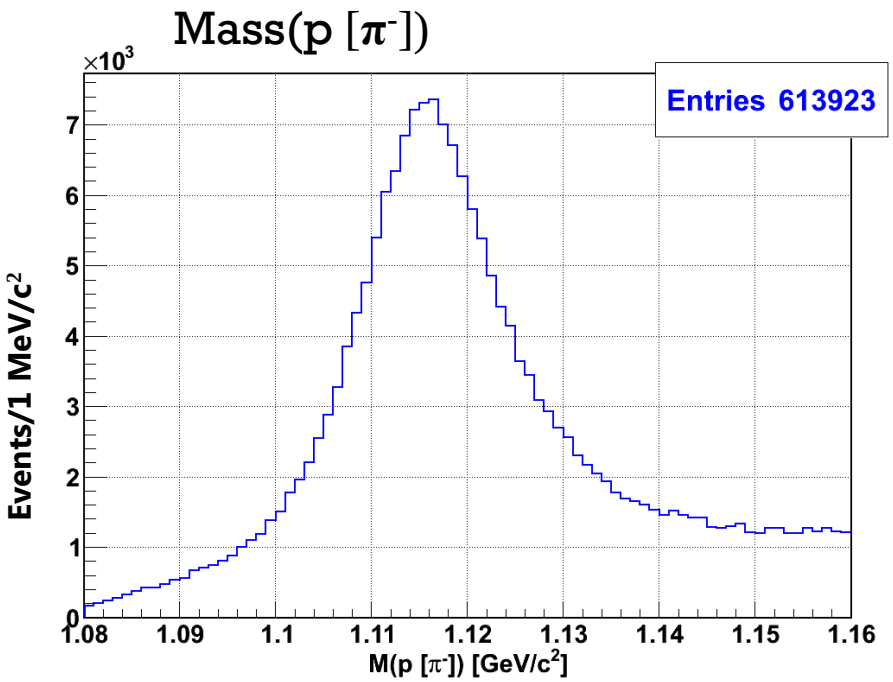
- Other cuts include particle beta cuts.

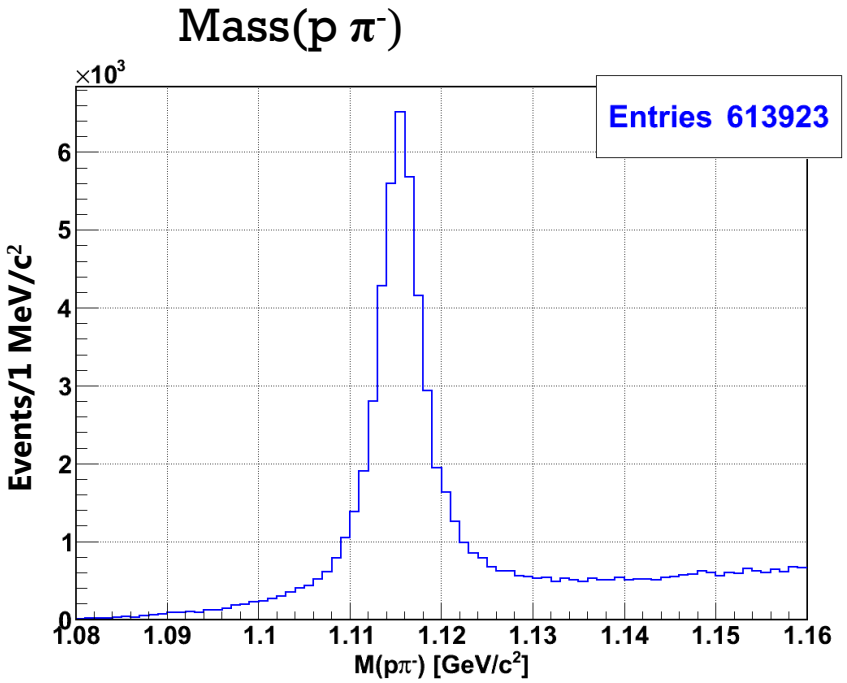


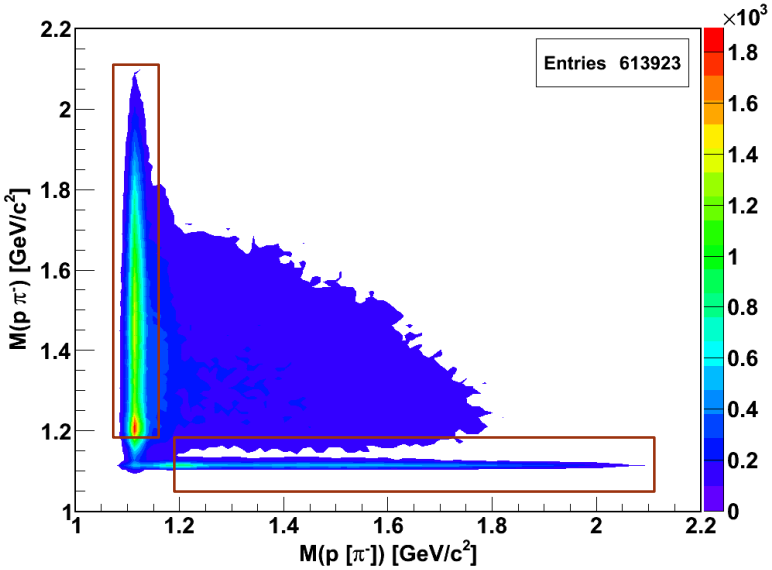


Lambda Mode

Λ decays into p [π^-] or p π^-

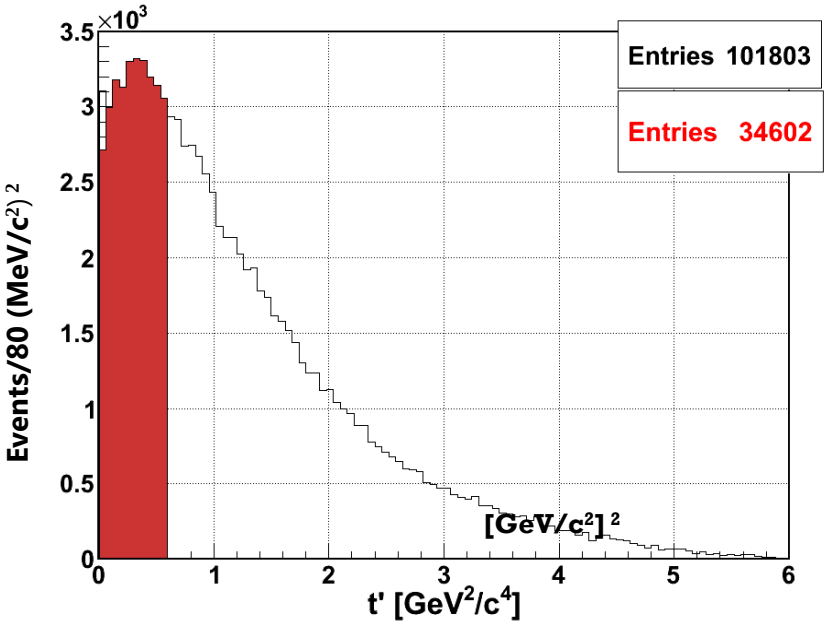


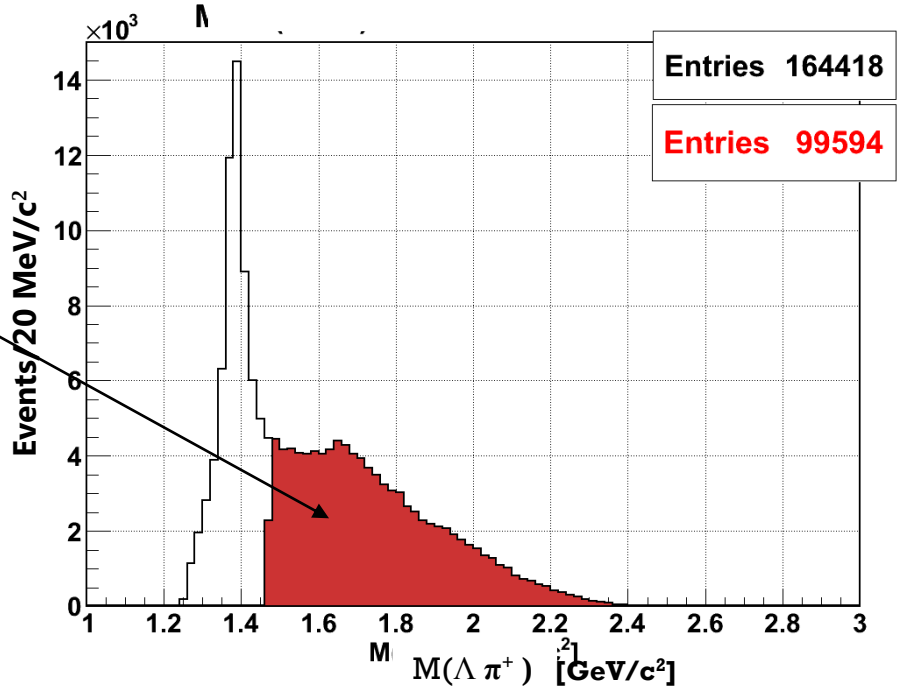




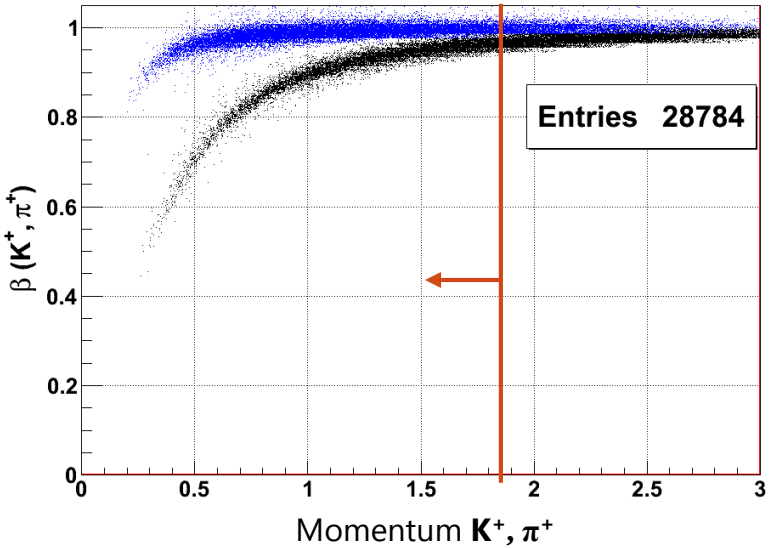
Background Reduction

Σ(1385) Background Eliminated

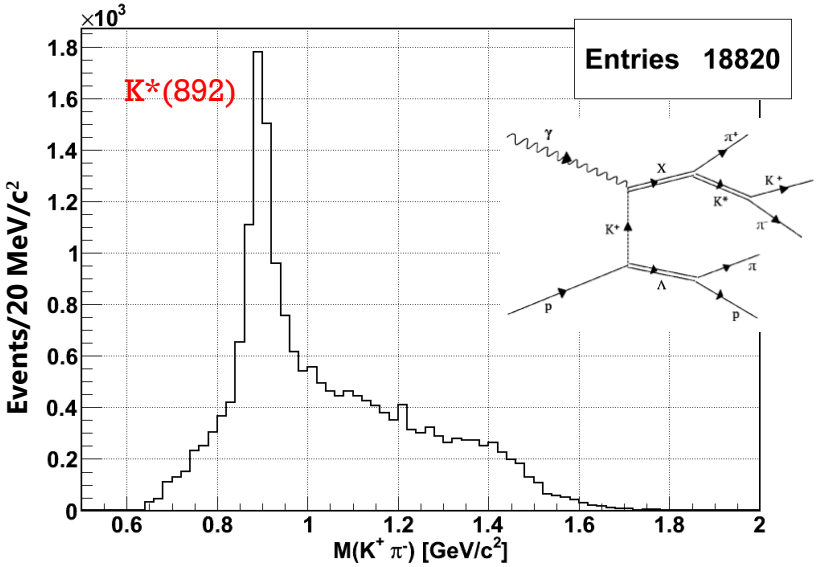


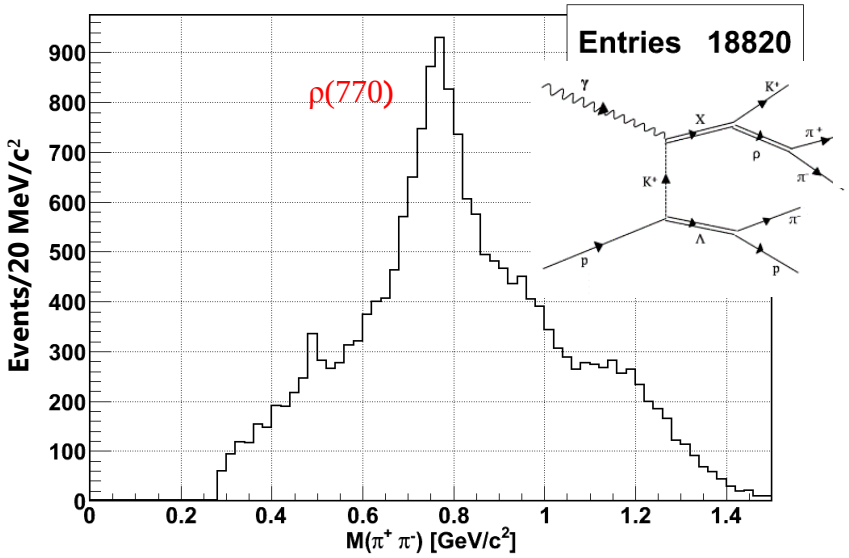


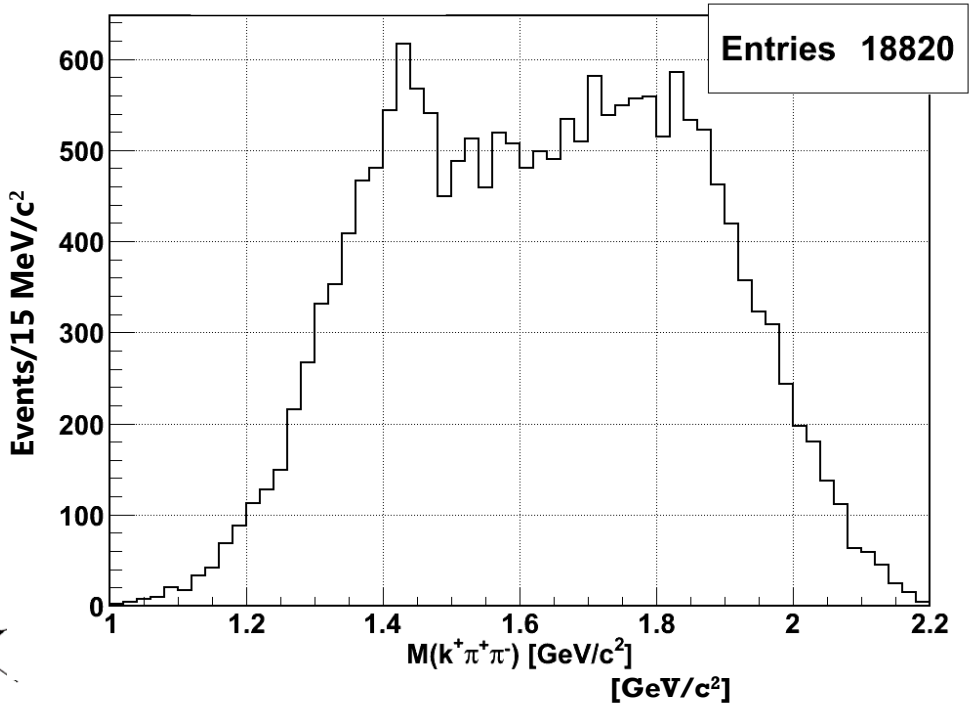
Only Events below the K/π separation threshold are chosen.



Final Features

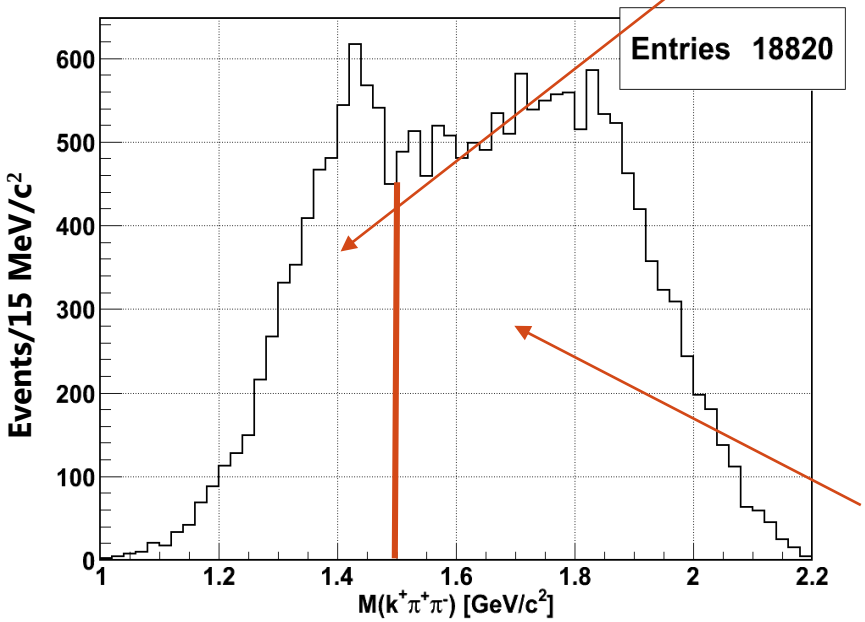


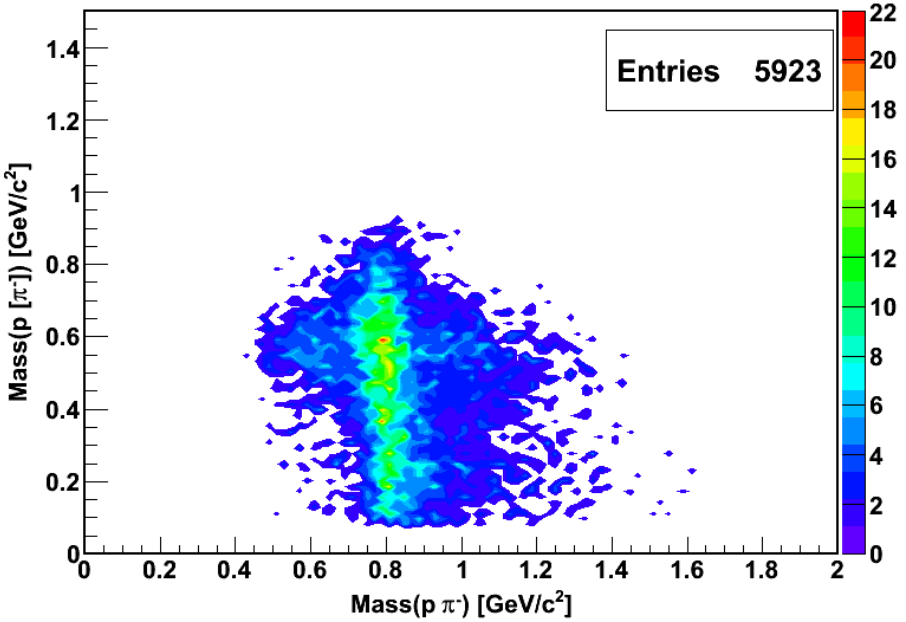


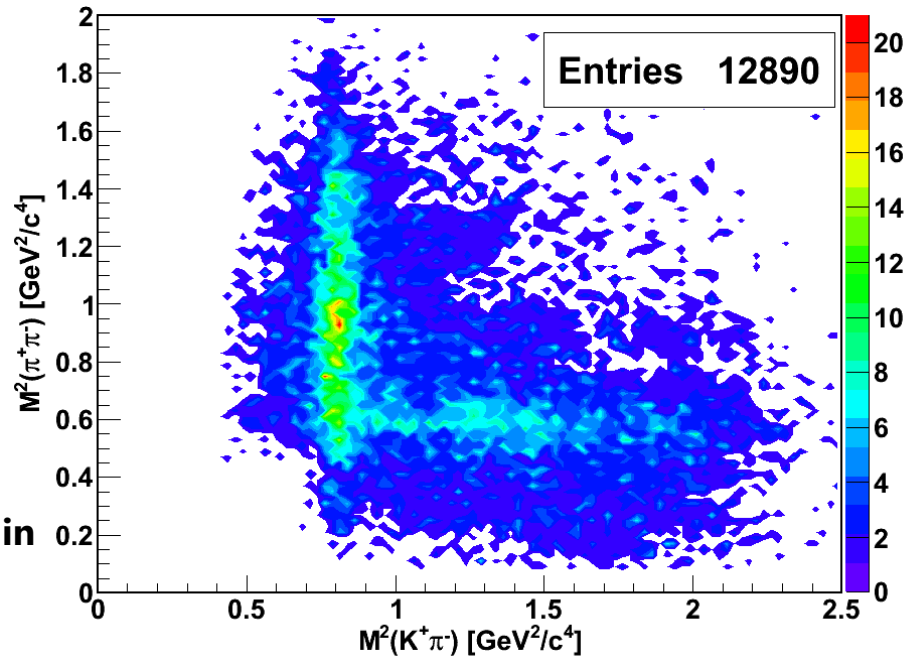


Final Features

K*(892) π^+ decay mode is dominant in the low Mass Region



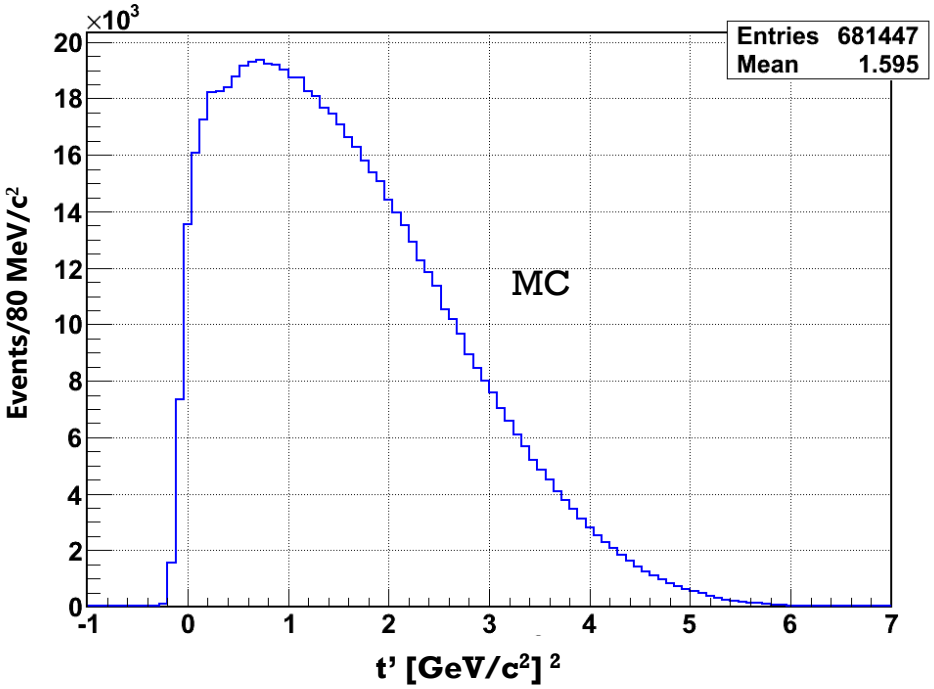


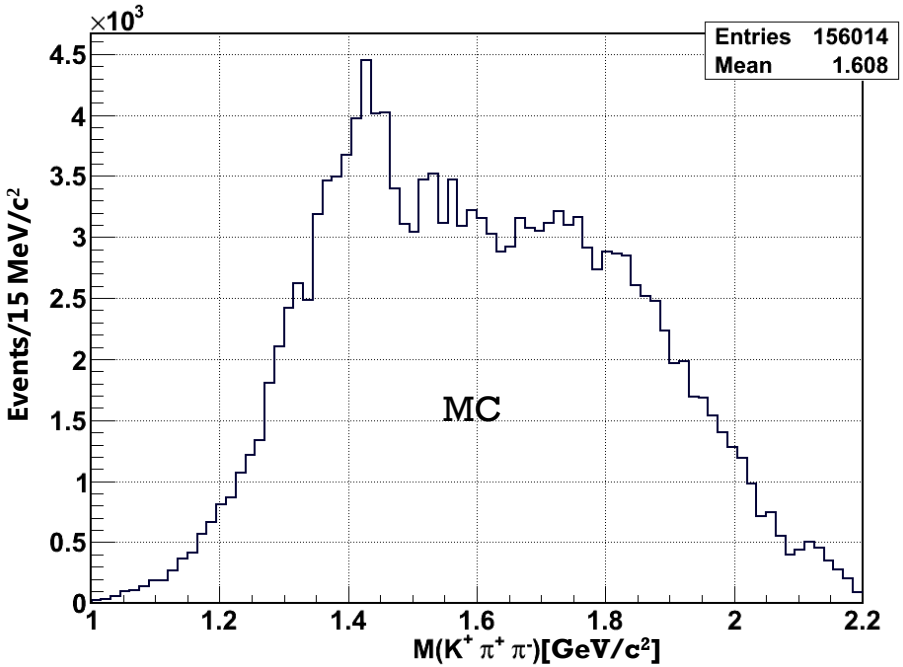


ρ K^+ decay mode is more significant in the high mass region

Montecarlo Events Simulation

- Generate Kππ phase space similar to data.
- Events are generated in Kππ such that the accepted events are 10 times the data in every bin.





Partial Wave Analysis

- A mass independent partial wave analysis was performed using an event based likelihood fit.
- Montecarlo events are used to determine the normalization integrals.

Minimize likelihood function to get production amplitudes

Calculate decay Amplitudes using the isobar model

$$\mathcal{I}(\tau) = \sum_{k\epsilon\alpha\alpha'} {}^{\epsilon k}V^*_{\alpha}\ {}^{\epsilon k}V_{\alpha}\ {}^{\epsilon}A^*_{\alpha}(\tau)\ {}^{\epsilon}A_{\alpha}(\tau)$$

Eigen states in the reflectivity basis

$$|\epsilon, a, m\rangle = \left[|a, m\rangle + \epsilon P(-1)^{(J-m)}|a, -m\rangle\right]\Theta(m)$$

where

$$\Theta(m) = \frac{1}{\sqrt{2}}, \quad \text{if } m > 0$$

$$\Theta(m) = \frac{1}{2}, \quad \text{if } m = 0$$

$$\Theta(m) = 0, \quad \text{if } m < 0$$

$$\log\ \mathcal{L} = \sum_{i}^{n} \log\left[\sum_{k\epsilon\alpha\alpha'} {}^{\epsilon k}V_{\alpha}\ {}^{\epsilon k}V^*_{\alpha}\ {}^{\epsilon}A_{\alpha}(\tau_i)\ {}^{\epsilon}A^*_{\alpha}(\tau_i)\right] - n\left[\sum_{k\epsilon\alpha\alpha'} {}^{\epsilon k}V_{\alpha}\ {}^{\epsilon k}V^*_{\alpha}\ {}^{\epsilon}\Psi^a_{\alpha\alpha'}\right]$$

Normalization integrals from the accepted MC

$${}^{\epsilon}\Psi^r_{\alpha\alpha'} = \frac{1}{n_r}\sum_{i}^{n_r} {}^{\epsilon}A_{\alpha}(\tau_i)\ {}^{\epsilon}A^*_{\alpha}(\tau_i)$$

$${}^{\epsilon}\Psi^a_{\alpha\alpha'} = \frac{1}{n_a}\sum_{i}^{n_a} {}^{\epsilon}A_{\alpha}(\tau_i)\ {}^{\epsilon}A^*_{\alpha}(\tau_i)$$

- Eigen State for 1+1+S waves

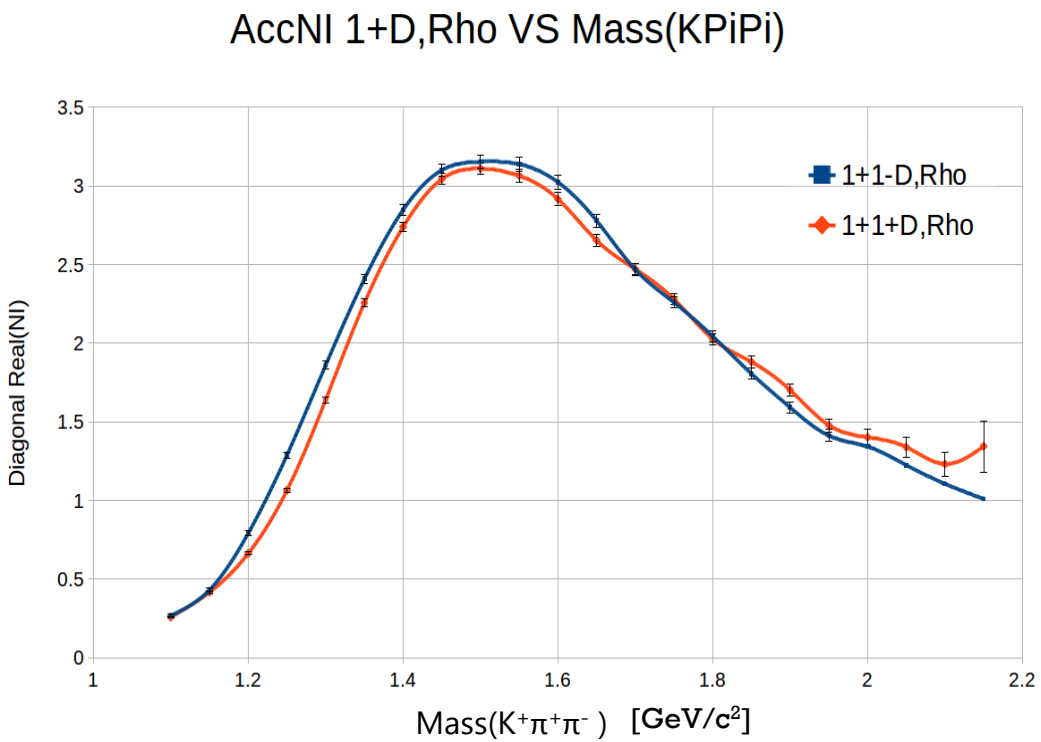
  |1111> = 1/√2 (|111> + |1-11>)

Normalization Integrals

$$\Psi = \int A_\alpha(\tau_i) A^*_\alpha(\tau_i) \eta(\tau_i) d\tau_i$$

- A Study of the dependence of the decay amplitudes on the ($K^+ \pi^+ \pi^-$) mass

- Mass independent fit
- Data is binned in 100 MeV bins, then shifted by 50 MeV
- 19 waves included in the fit
- Flat background included in the fit
- Rank 1 Spin density matrix

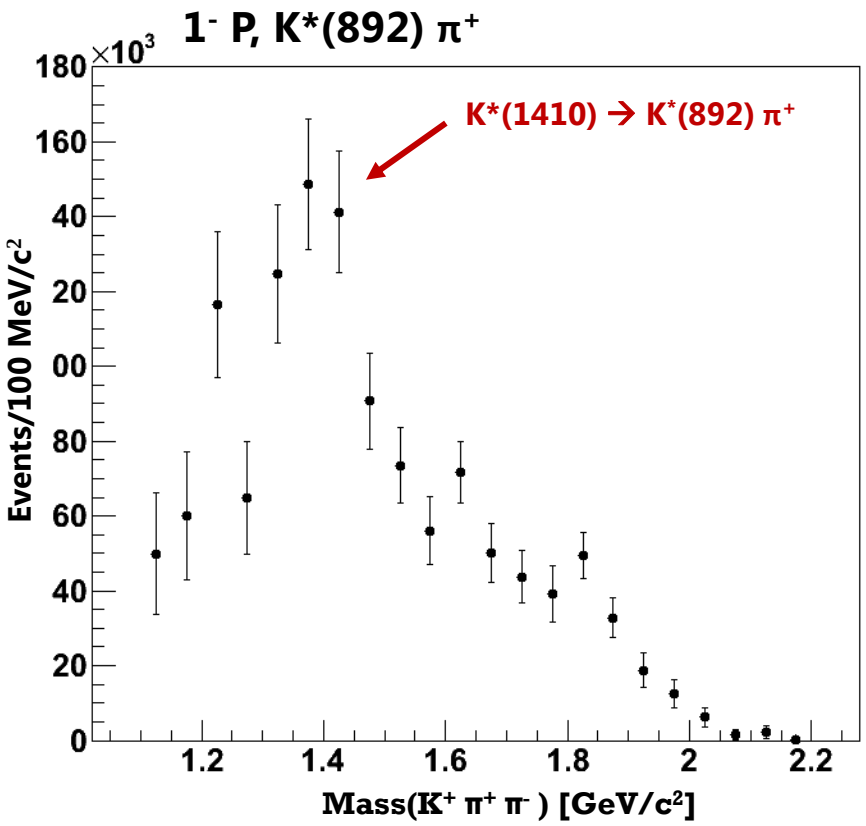


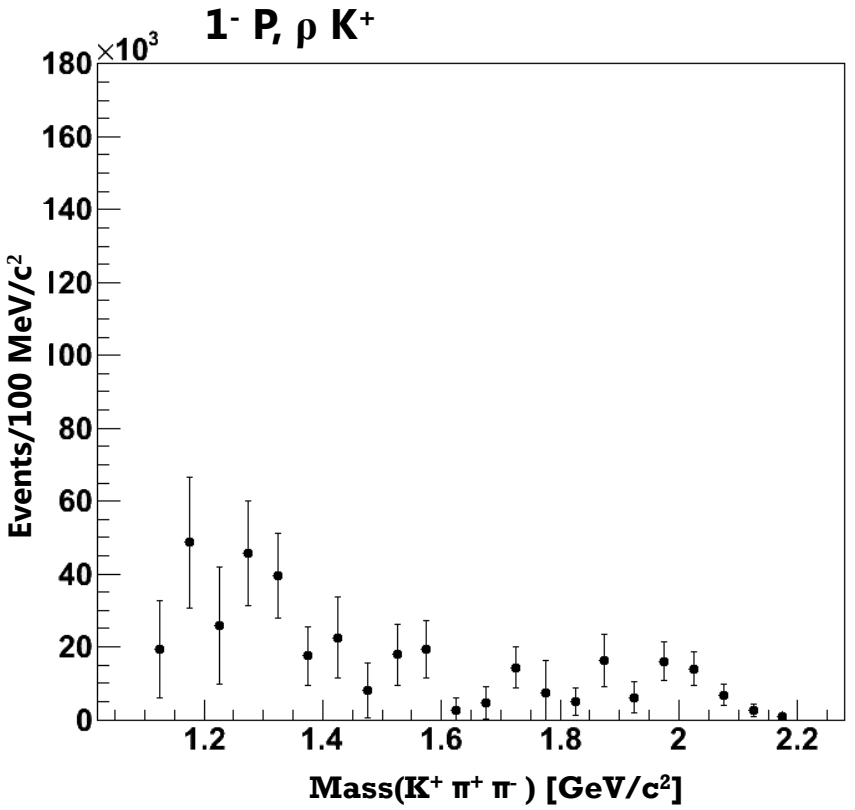
PWA Results

K*(1410) $I(J^P) = \frac{1}{2}(1^-)$ **1⁻ P**

Mass $m = 1414 \pm 15$ MeV (S = 1.3)
Full width $\Gamma = 232 \pm 21$ MeV (S = 1.1)

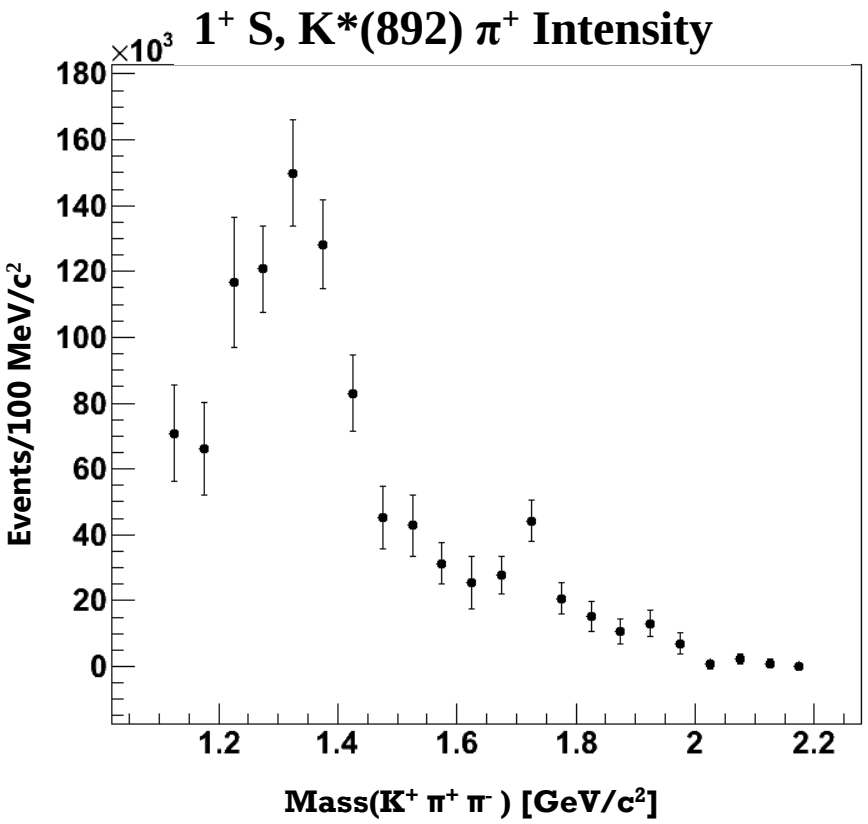
K*(1410) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$K^*(892)\pi$	> 40 %	95%	410
$K\pi$	(6.6±1.3) %		612
$K\rho$	< 7 %	95%	305
γK^0	seen		619

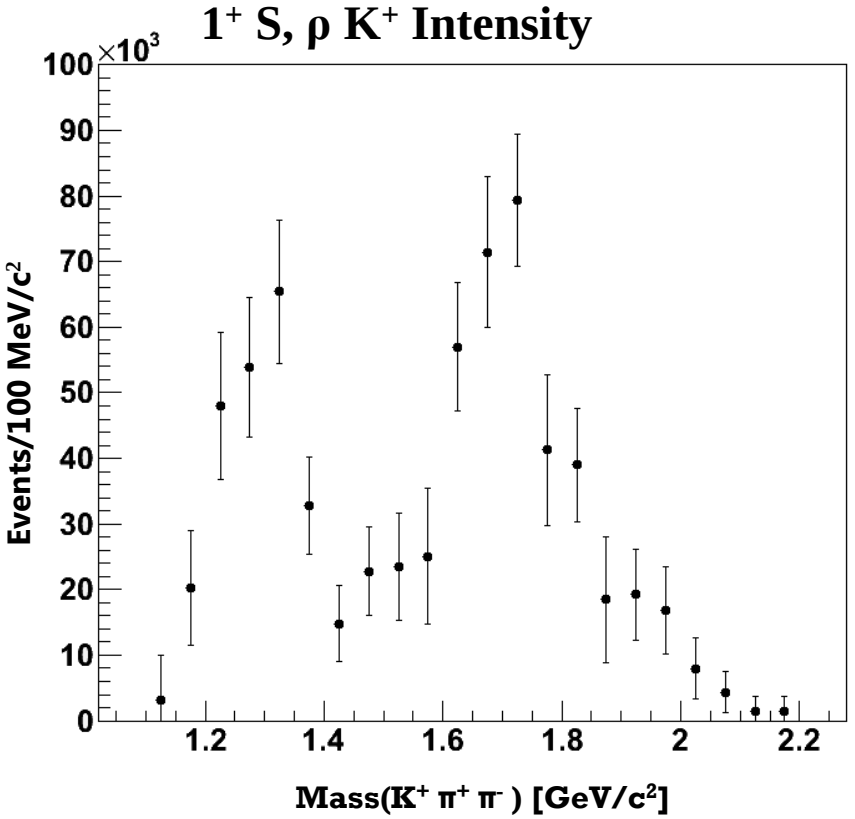




PWA Results

1^+ S





$K_1(1270)$

$I(J^P) = \frac{1}{2}(1^+)$

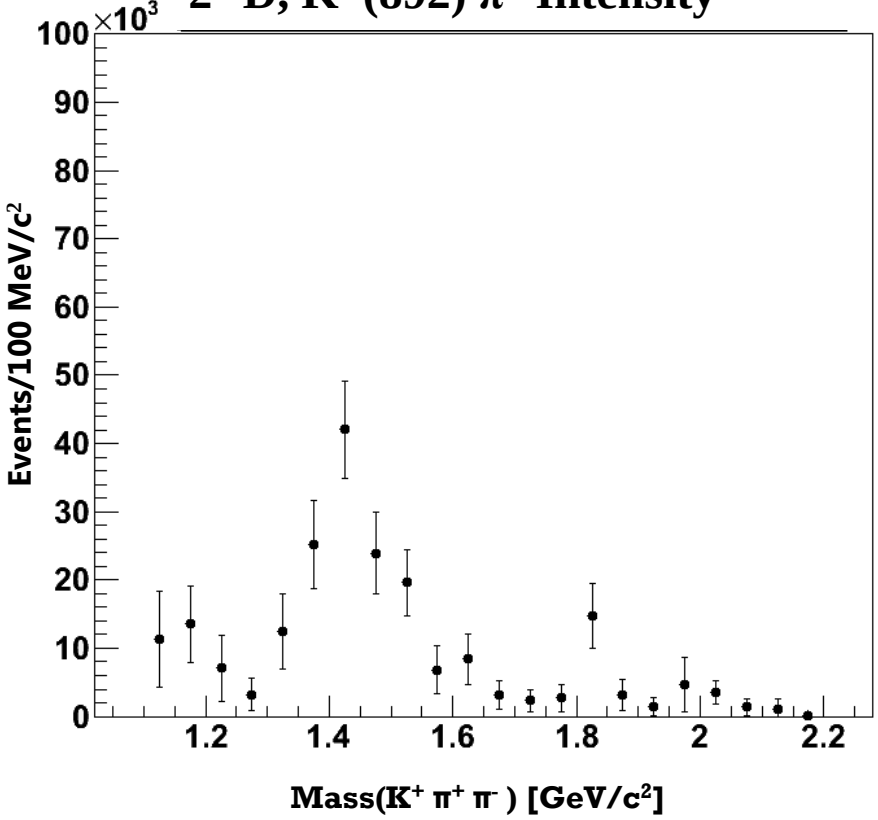
Mass $m = 1272 \pm 7$ MeV [u]

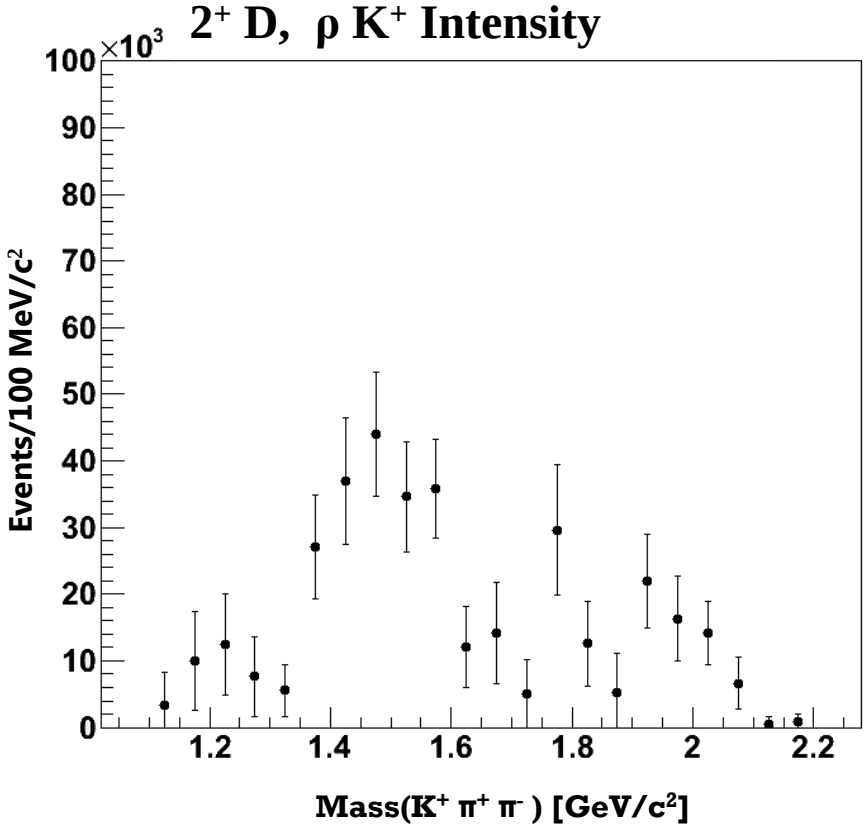
Full width $\Gamma = 90 \pm 20$ MeV [u]

The $K_1(1650)$, reported but not confirmed
- Mass: 1600-1900 MeV
- Width: 150 – 250 MeV
- Reported decay modes: K π π , KΦ

2^+ D

PWA Results





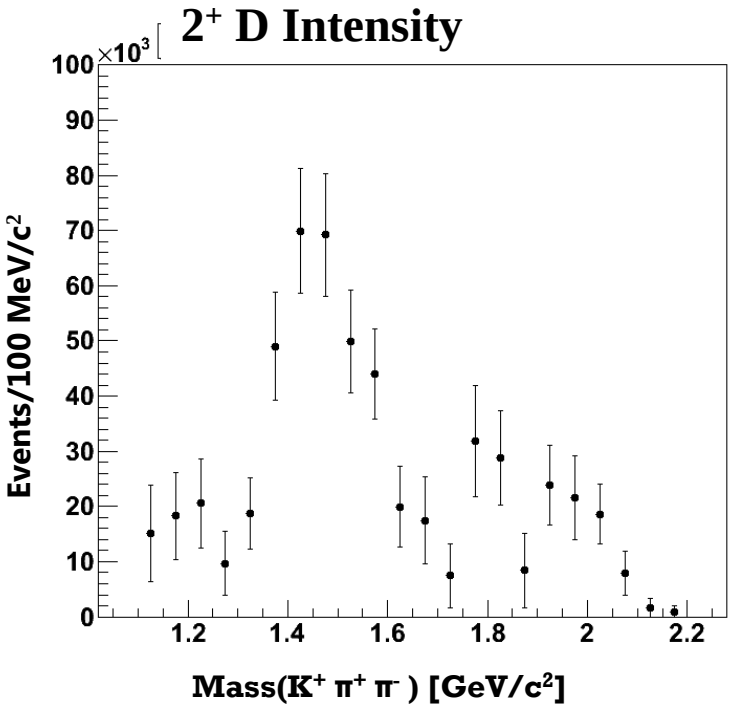
$K_2^*(1430)$

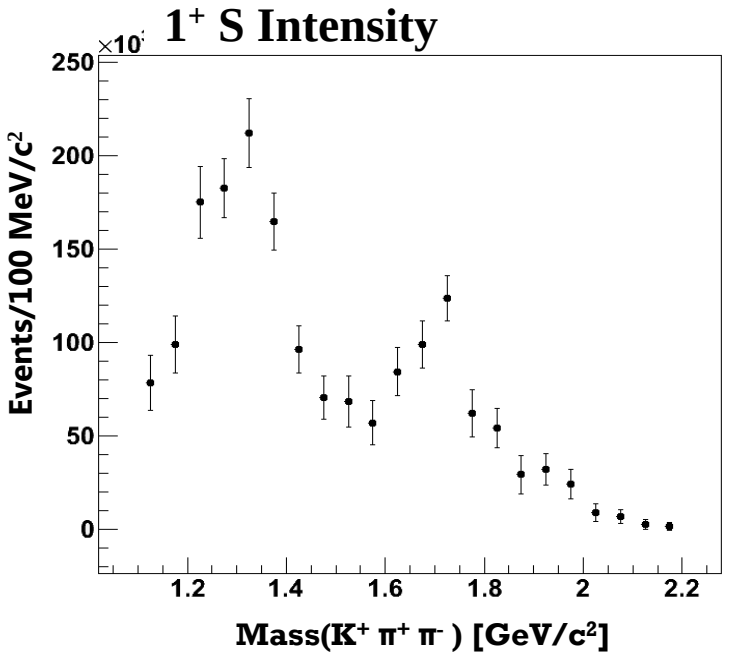
$I(J^P) = \frac{1}{2}(2^+)$

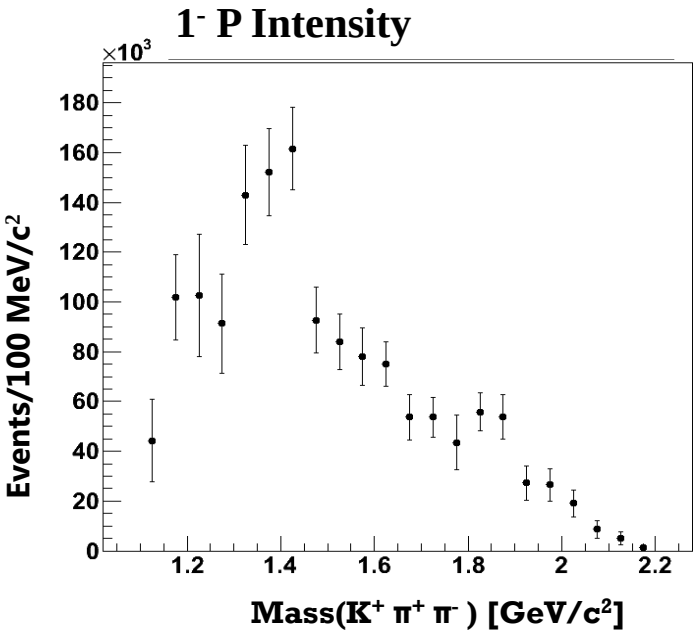
$K_2^*(1430)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$K\pi$	(49.9±1.2) %		619
$K^*(892)\pi$	(24.7±1.5) %		419
$K^*(892)\pi\pi$	(13.4±2.2) %		372
$K\rho$	(8.7±0.8) %	S=1.2	318

$K_2^*(1430)^{\pm}$ mass $m = 1425.6 \pm 1.5$ MeV (S = 1.1)
$K_2^*(1430)^0$ mass $m = 1432.4 \pm 1.3$ MeV
$K_2^*(1430)^{\pm}$ full width $\Gamma = 98.5 \pm 2.7$ MeV (S = 1.1)
$K_2^*(1430)^0$ full width $\Gamma = 109 \pm 5$ MeV (S = 1.9)

PWA Results


2+ D Intensity
×10³
Events/100 MeV/c²
Mass(K⁺ π⁺ π⁻) [GeV/c²]

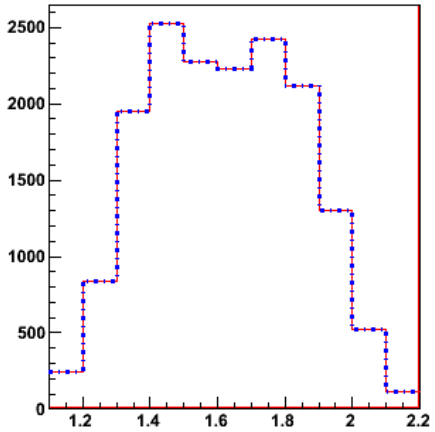

1+ S Intensity
Events/100 MeV/c²
Mass(K⁺ π⁺ π⁻) [GeV/c²]


1- P Intensity
×10³
Events/100 MeV/c²
Mass(K⁺ π⁺ π⁻) [GeV/c²]

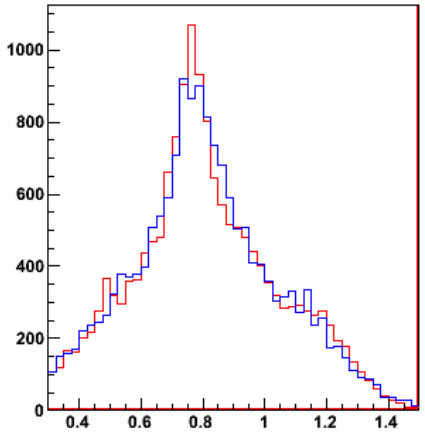
PWA Results – Predicted Distributions

$$W_{i,\alpha} = V_\alpha^* V_\alpha A_{i,\alpha}^* A_{i,\alpha}$$

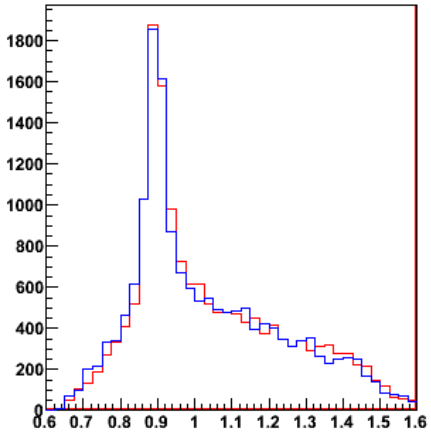
M($K^+ \pi^+ \pi^-$)



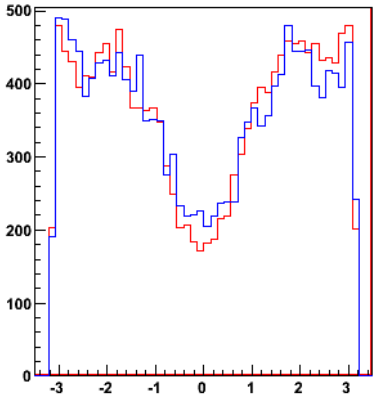
M($\pi^+ \pi^-$)



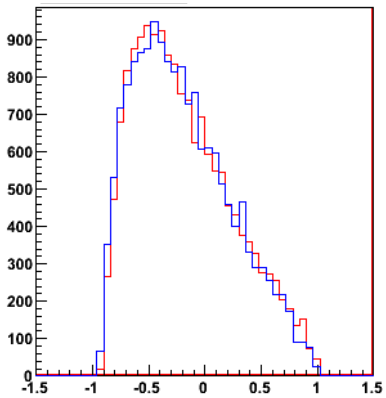
M($K^+ \pi^-$)



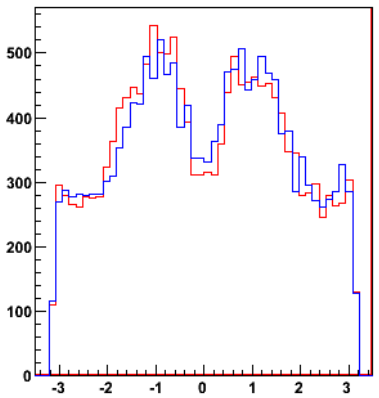
φ_{GJ} of $K^+ \pi^-$



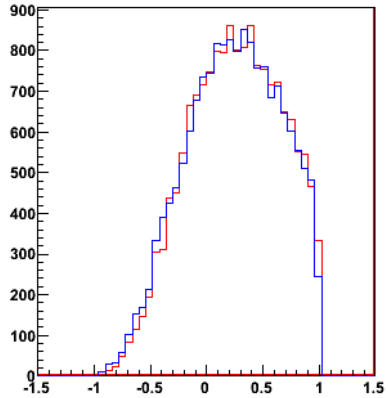
$\text{Cos}(\theta_{GJ})$ of $K^+ \pi^-$



φ_{GJ} of $\pi^+ \pi^-$

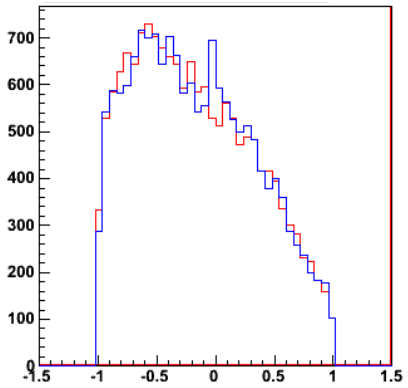


$\text{Cos}(\theta_{GJ})$ of $\pi^+ \pi^-$

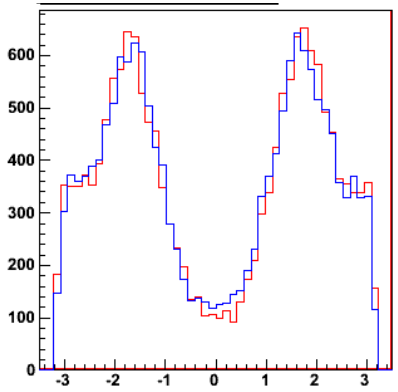


PWA Results

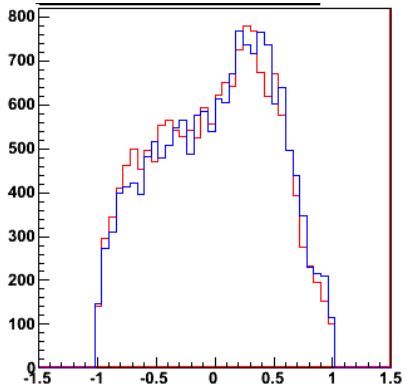
$\mathrm{Cos}(\theta_H)$ of K^+



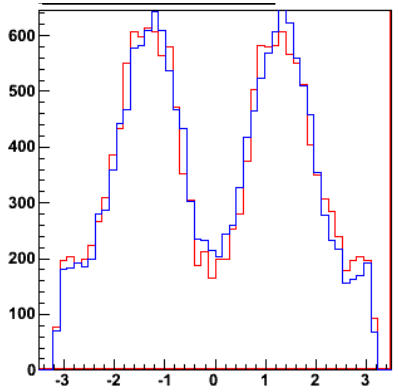
φ_H of K^+



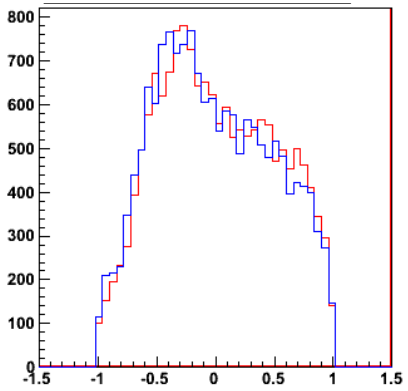
$\mathrm{Cos}(\theta_H)$ of π^+



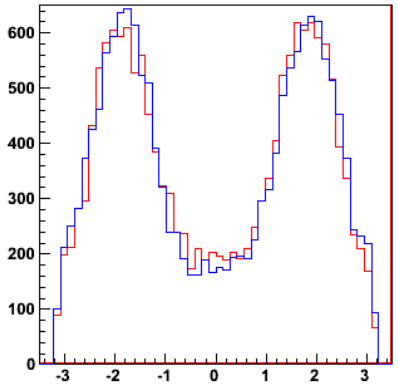
φ_H of π^+



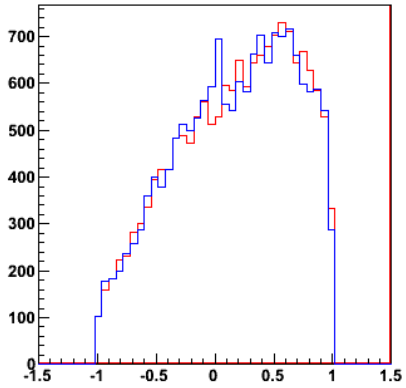
$\mathrm{Cos}(\theta_H)$ of π^-



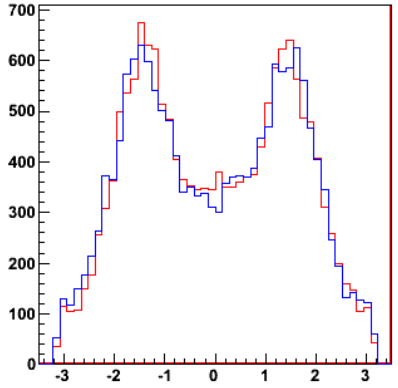
φ_H of π^-



$\mathrm{Cos}(\theta_H)$ of π^-



φ_H of π^-



Summary

- Over 18,800 events of the type $\gamma\, p \rightarrow \Lambda\, K^+\, \pi^+\, \pi^-$ have been acquired in a search for photoproduction of excited strange mesons.
- Largest $(\Lambda\, K^+\, \pi^+\, \pi^-)$ photoproduction dataset to date.
- Two dominating decay modes observed in the $K^+\, \pi^+\, \pi^-$ system: $K^*(892)\, \pi^+$ and $\rho\, K^+$.
- A mass independent partial wave analysis was performed.
- Preliminary results for $J^P = 1^-$ are consistent with a $K^*(1410)$ decaying dominantly to a $K^*(892)\, \pi$ relative to $\rho\, K$ in agreement with known observations.
- Other features include the 1^+ consistent with a $K_1(1270)$ and significant enhancement in the 2^+ wave

BACKUP SLIDES →

Motivation

- Most Excited strange states have been hadroproduced, few are photoproduced

$n\,^{2s+1}\ell_J$	J^{PC}	I = 1 $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d}-u\bar{u})$	I = $\frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $-\bar{u}s$	I = 0 f'	I = 0 f
$1\,^1S_0$	0^{-+}	π	K	η	$\eta'(958)$
$1\,^3S_1$	1^{--}	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$
$1\,^1P_1$	1^{+-}	$b_1(1235)$	$K_{1B}{}^\dagger$	$h_1(1380)$	$h_1(1170)$
$1\,^3P_0$	0^{++}	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$
$1\,^3P_1$	1^{++}	$a_1(1260)$	$K_{1A}{}^\dagger$	$f_1(1420)$	$f_1(1285)$
$1\,^3P_2$	2^{++}	$a_2(1320)$	$K_2^*(1430)$	$f_2'(1525)$	$f_2(1270)$
$1\,^1D_2$	2^{-+}	$\pi_2(1670)$	$K_2(1770)^\dagger$	$\eta_2(1870)$	$\eta_2(1645)$
$1\,^3D_1$	1^{--}	$\rho(1700)$	$K^*(1680)$		$\omega(1650)$
$1\,^3D_2$	2^{--}		$K_2(1820)$		
$1\,^3D_3$	3^{--}	$\rho_3(1690)$	$K_3^*(1780)$	$\phi_3(1850)$	$\omega_3(1670)$
$1\,^3F_4$	4^{++}	$a_4(2040)$	$K_4^*(2045)$		$f_4(2050)$
$1\,^3G_5$	5^{--}	$\rho_5(2350)$			
$1\,^3H_6$	6^{++}	$a_6(2450)$			$f_6(2510)$
$2\,^1S_0$	0^{-+}	$\pi(1300)$	$K(1460)$	$\eta(1475)$	$\eta(1295)$
$2\,^3S_1$	1^{--}	$\rho(1450)$	$K^*(1410)$	$\phi(1680)$	$\omega(1420)$

† The $1^{+\pm}$ and $2^{-\pm}$ isospin $\frac{1}{2}$ states mix. In particular, the K_{1A} and K_{1B} are nearly equal (45°) mixtures of the $K_1(1270)$ and $K_1(1400)$. The physical vector mesons listed under 1^3D_1 and 2^3S_1 may be mixtures of 1^3D_1 and 2^3S_1, or even have hybrid components.

Hussein Al Ghoul, CLAS Meeting 2015

Motivation

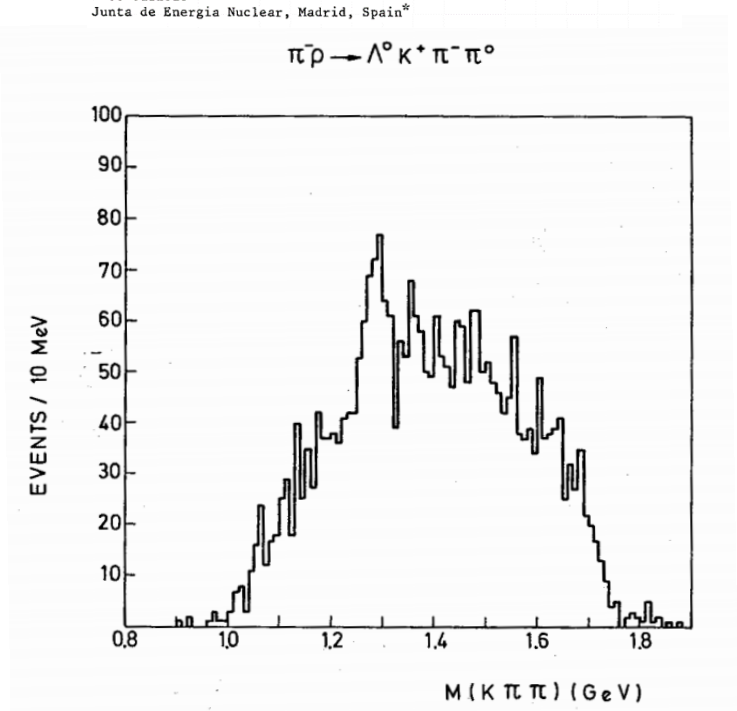
- Most of the available Kππ data is produced with a Kaon beam incident on a proton target (COMPASS, ACCMOR ..)

A PARTIAL WAVE ANALYSIS OF THE (Kππ) SYSTEM IN THE REACTION

$\pi^- p \to (K^+ \pi^- \pi^0)\Lambda$ AT 3.95 GeV/c

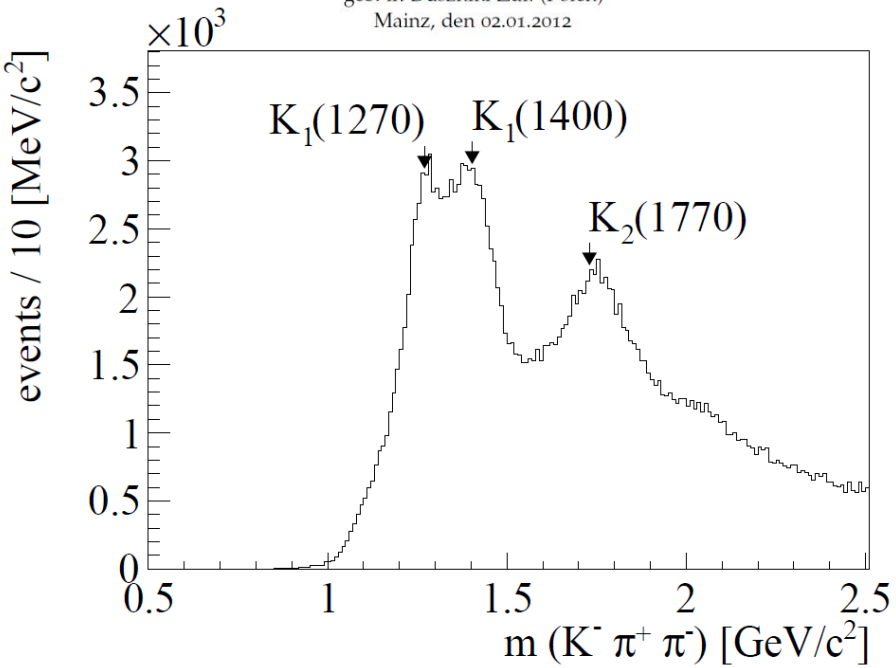
CERN-Collège de France-Madrid-Stockholm Collaboration

C. Fernández, M. Aguilar-Benítez, M. Cerrada, J.A. Garzón, J.A. Rubio and José Salicio
Junta de Energia Nuclear, Madrid, Spain*



ANALYSIS OF DIFFRACTIVE DISSOCIATION OF K^- INTO $K^-\pi^+\pi^-$ ON A LIQUID HYDROGEN TARGET AT THE COMPASS SPECTROMETER

PROMETEUSZ KRYSPIN JASINSKI
geb. in Duszniki Zdr. (Polen)
Mainz, den 02.01.2012



Our dataset is the first photoproduction dataset to study a ($K^+ \pi^+ \pi^-$) system produced off a Λ