Measurement of the Photon Beam Asymmetry Σ for

$$\gamma + p \rightarrow K^+\Sigma^0 \text{ at } E_\gamma = 8.5 \text{ GeV in GlueX}$$

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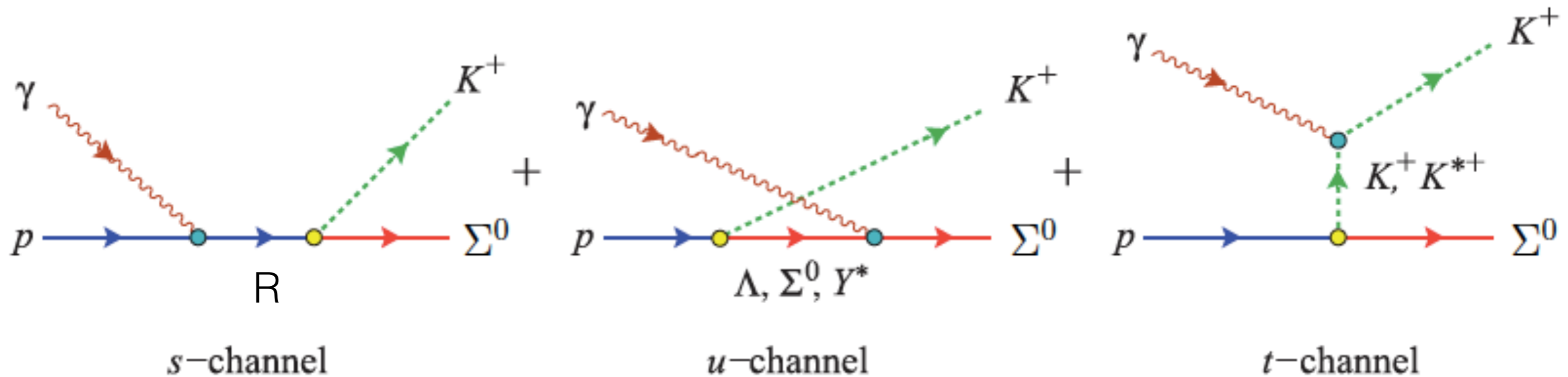**On behalf of the GlueX Collaboration**

MENU-2019, Pittsburgh, PA

06/06/2019

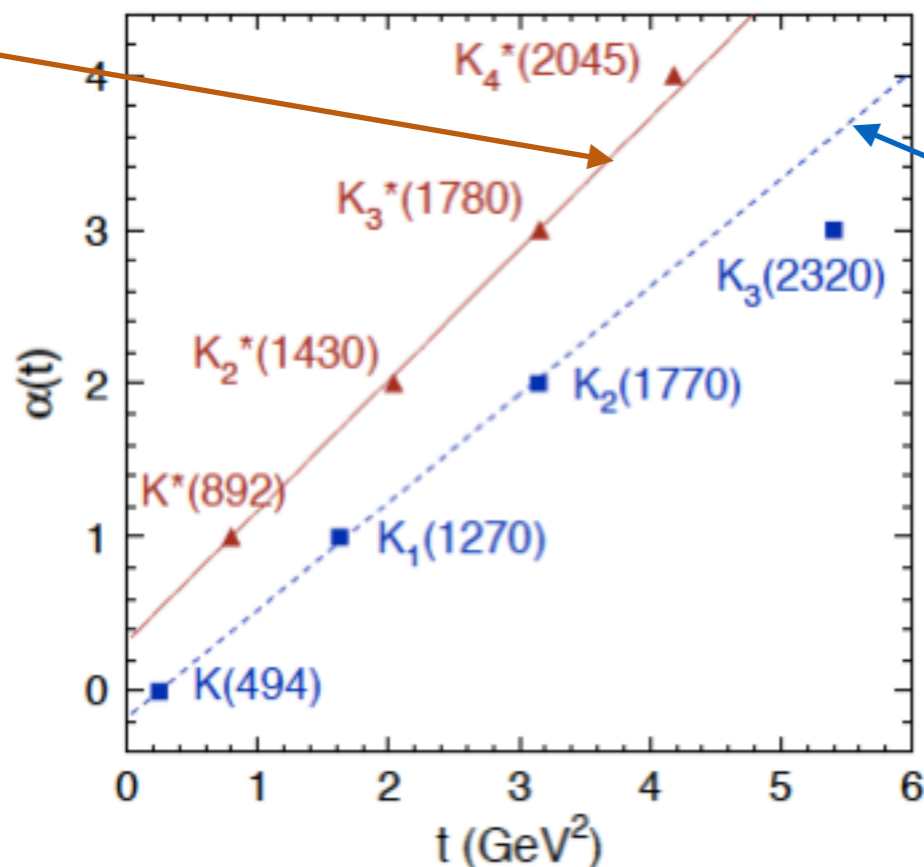# Introduction

- Important channels in kaon photoproduction

  $$\gamma p \to KY \, (Y = \Lambda \,, \Sigma)$$

- Useful to study pair creation of strange and anti-strange quarks

- Different channels can contribute

Regge Model

natural-parity

un-natural-parity

- Scattering amplitude ➡ exchange of Regge trajectories at high energies

- Regge trajectory ➡ resonances with identical internal quantum numbers but different spins J

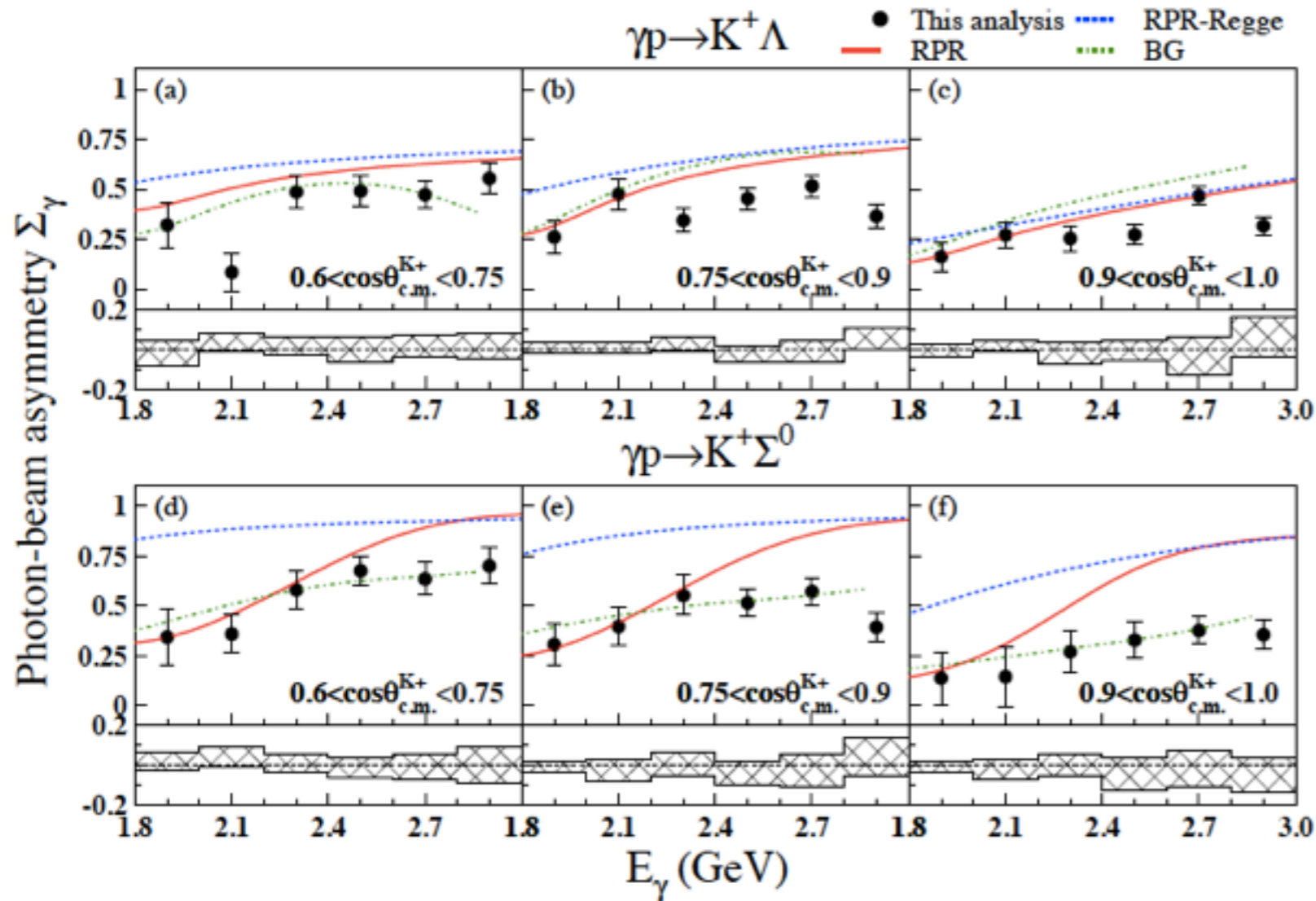- Have relation $J_i = \alpha(m_i^2)$ for different masses

3

Regge Plus Resonance Model

- RPR-2007 model ➡ T. Corthals, T. Van Cauteren, J. Ryckebusch, and D. G. Ireland, Phys. Rev. C 75, 045204 (2007)

$$\mathcal{M}_{RPR} = \sum_{K^*} \left(\underset{(pK^*Y)}{\overset{(\gamma KK^*)}{}} \alpha_{K^*}(t) \right)_{Regge} + \sum_{R} \left(\underset{(\gamma pR)}{\overset{(RKY)}{}} R \right)_{Feyn}$$
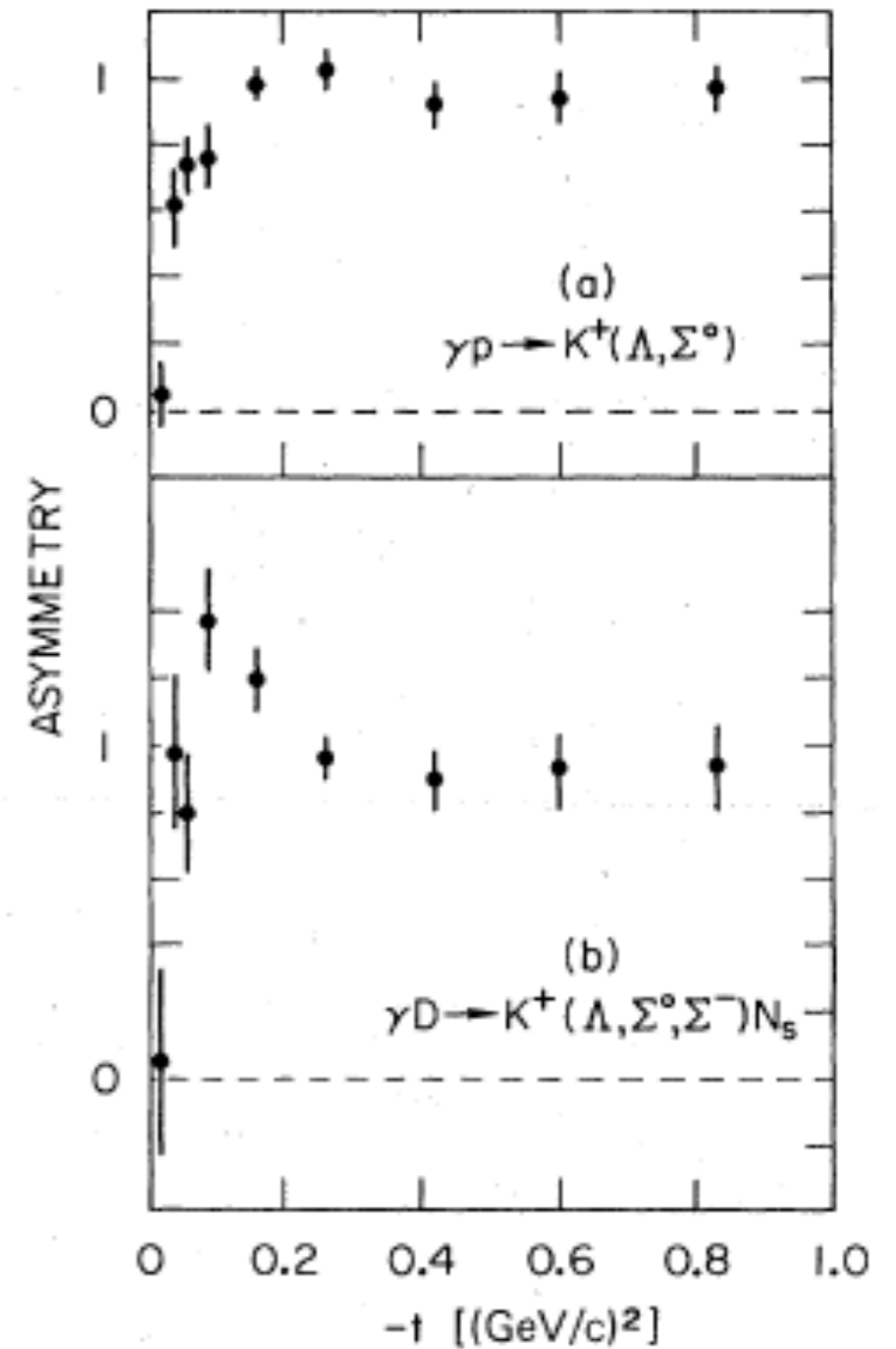
- *t*-channel ➡ K* trajectories

- For photon lab energies ≥ 4 GeV resonant contribution vanish

- GlueX energies ➡ only Regge part of amplitude

Previous Measurements

LEPS 1.5-3.0 GeV

Phys. Rev. C 97, 015208 (2018)

SLAC 16 GeV

Phys. Rev. D 20 1553 (1979)

Physics Motivation

- Linearly polarized photon beam to study exchange of parity

- natural-parity ➡ $P = (-1)^J$ (e.g. K*(892))

- unnatural-parity ➡ $P = (-1)^{J+1}$ (e.g. K(494))

- "Stichel's theorem" (Z. Phys. 180, 170 (1964))

  - to the leading power in *s*, cross section for photon polarized $\perp$ to production plane dominated by natural-parity exchange

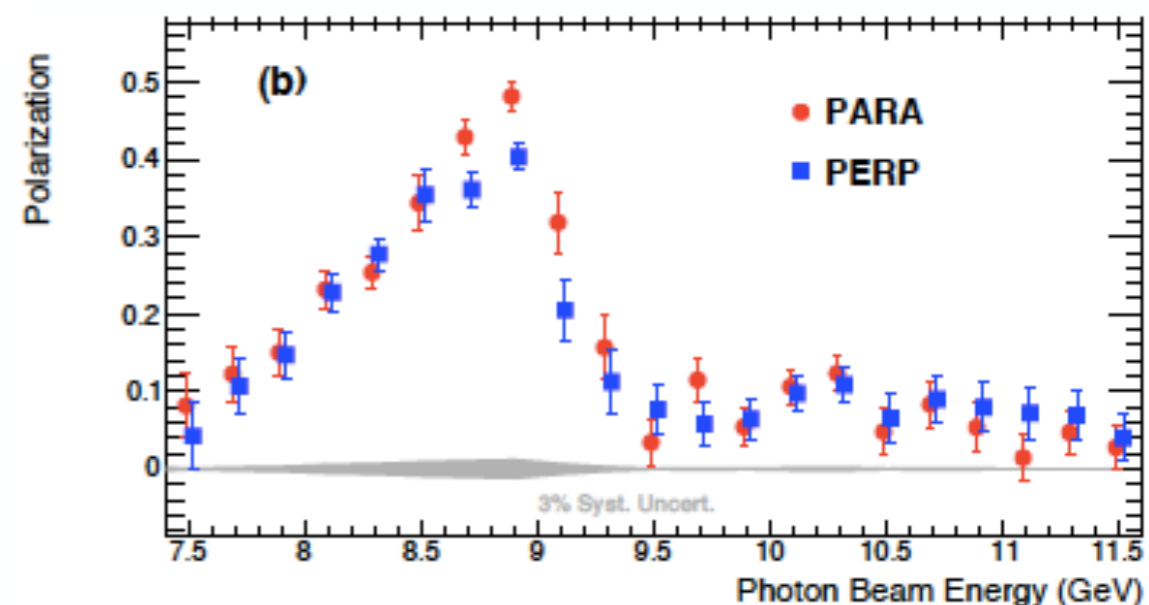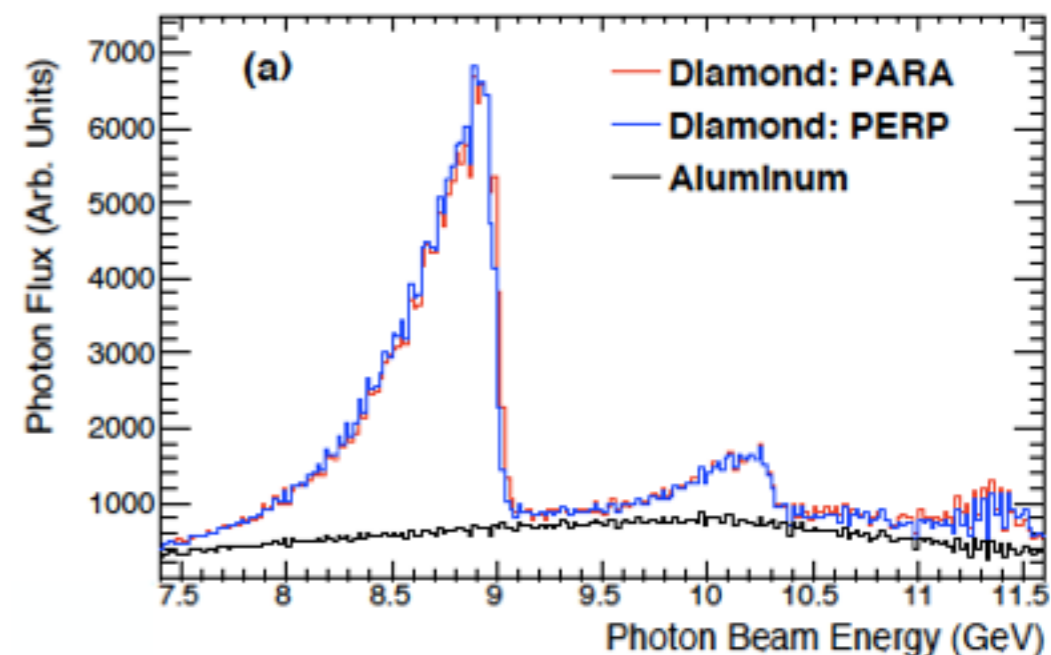 - for photon polarized $\parallel$ to production plane dominated by unnatural-parity exchange

$$\text{Beam Asymmetry} \quad \Sigma = \frac{(d\sigma_\perp/dt) - (d\sigma_\parallel/dt)}{(d\sigma_\perp/dt) + (d\sigma_\parallel/dt)}$$

GlueX Detector

- Jefferson Lab, Newport News, VA, USA

- Hall D

- CEBAF ➡ 12 GeV electron beam
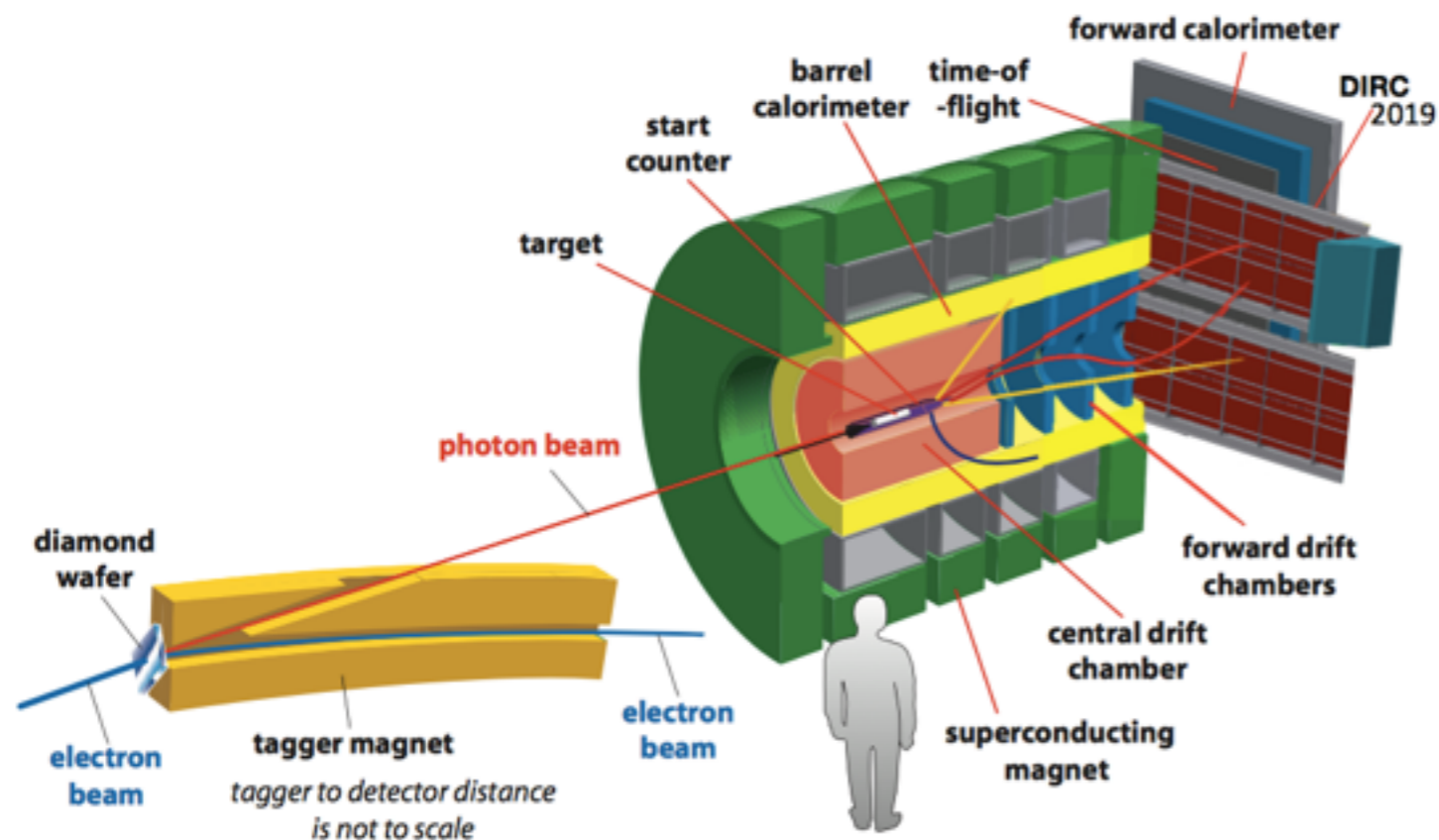
- Photons are linearly polarized relative to crystal axes in the diamond
- Coherent bremsstrahlung
- Two orthogonal polarization modes:
  PERP, **PARA** ➡ (0/90 and 45/135)

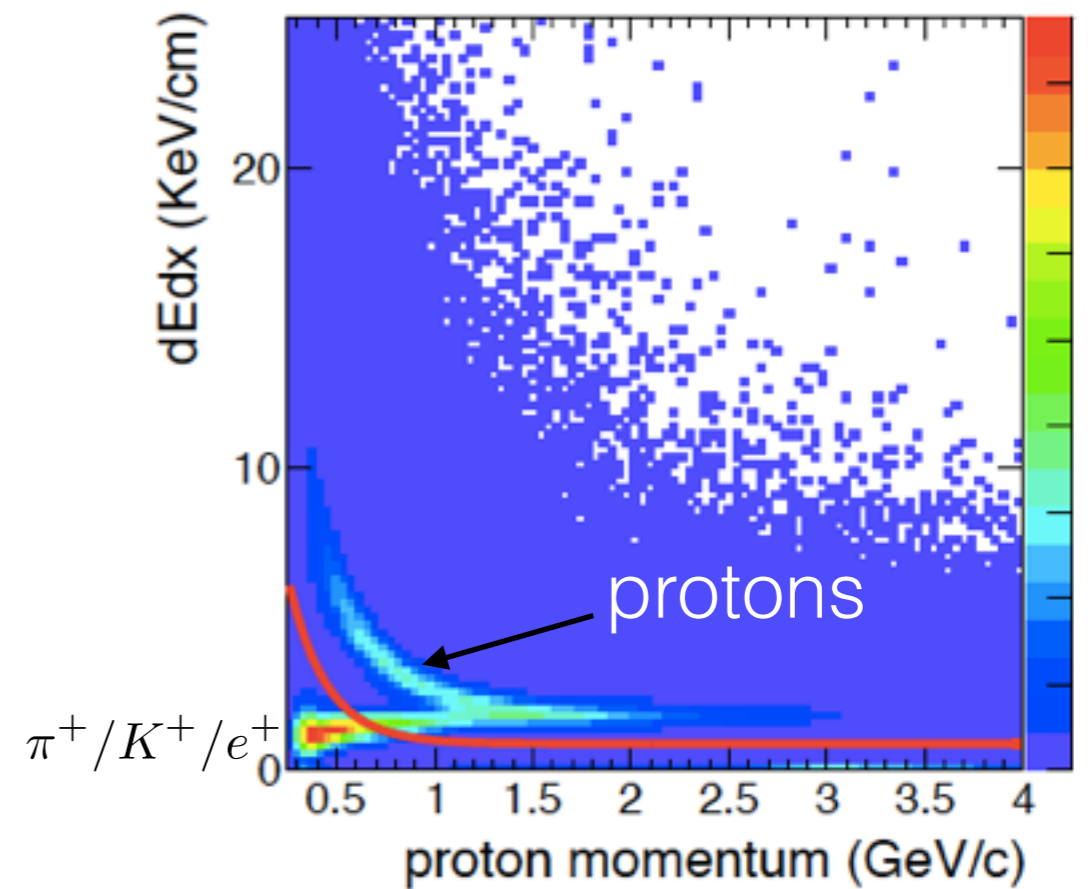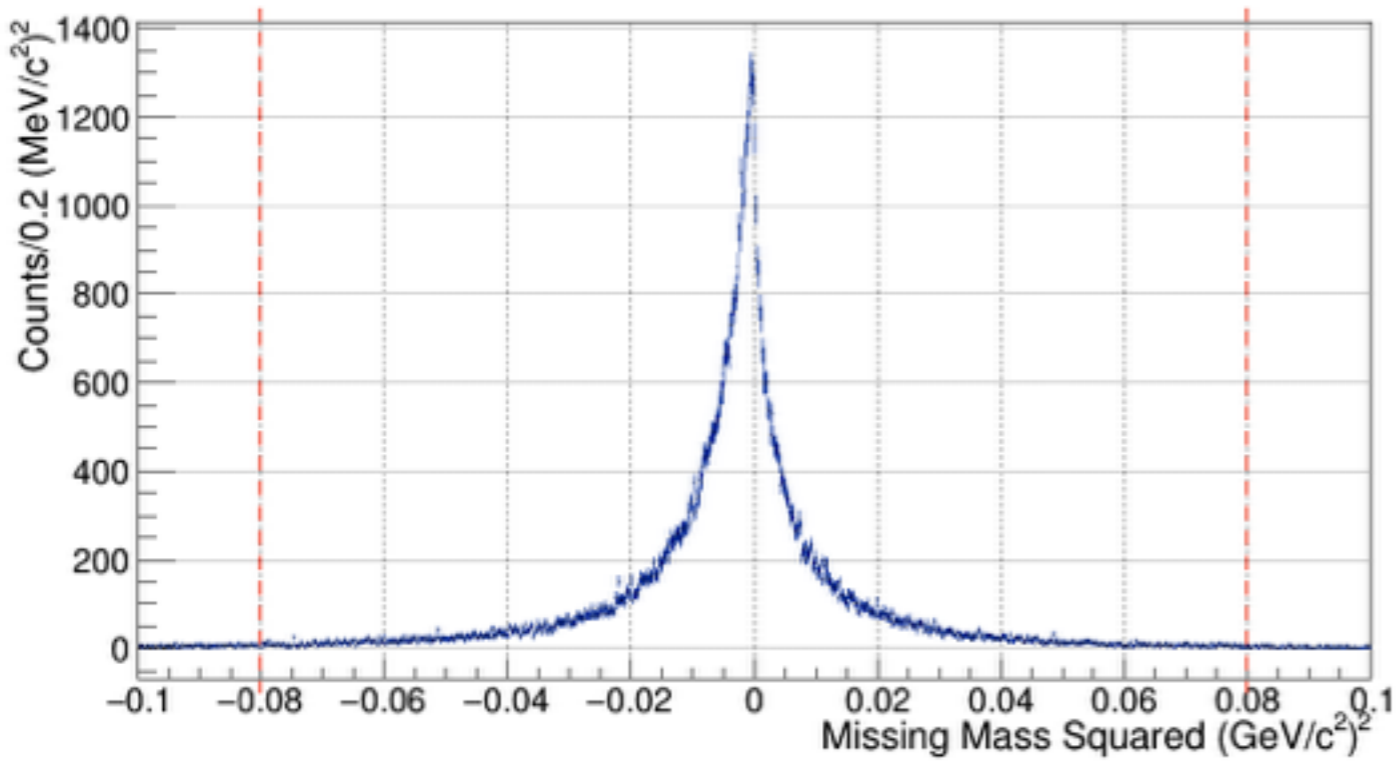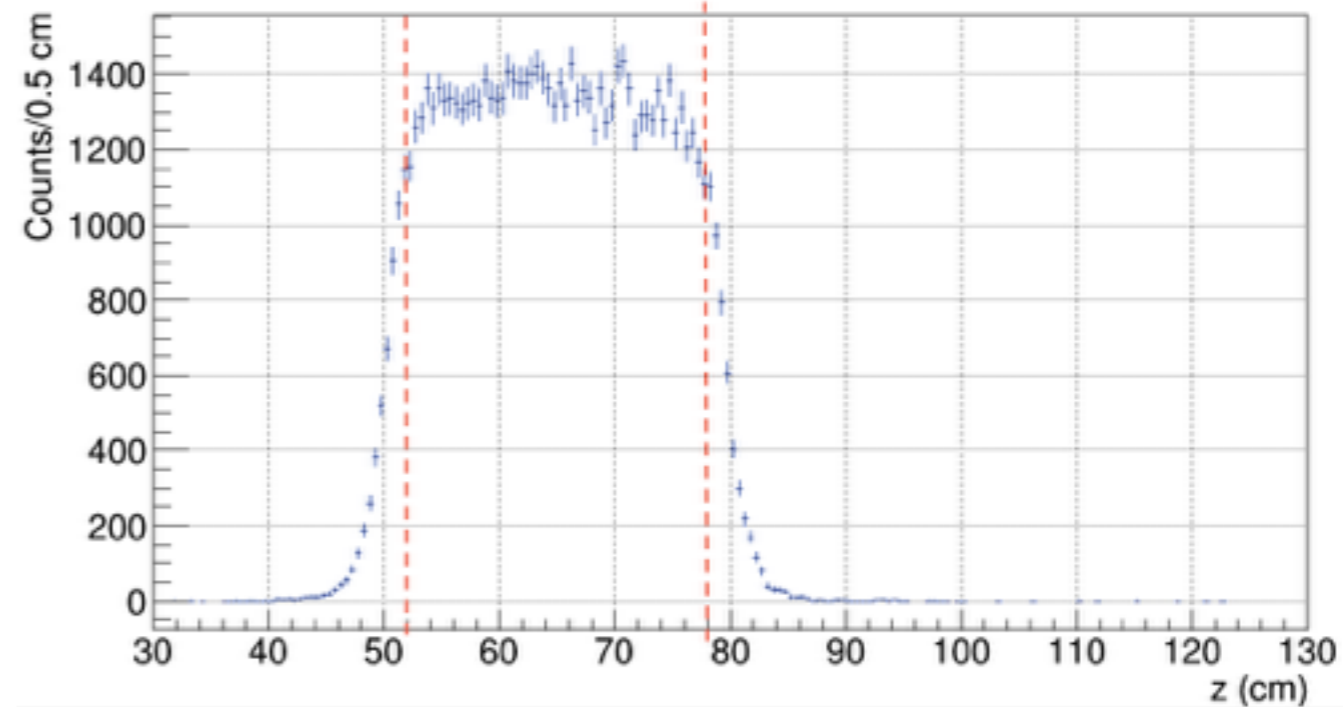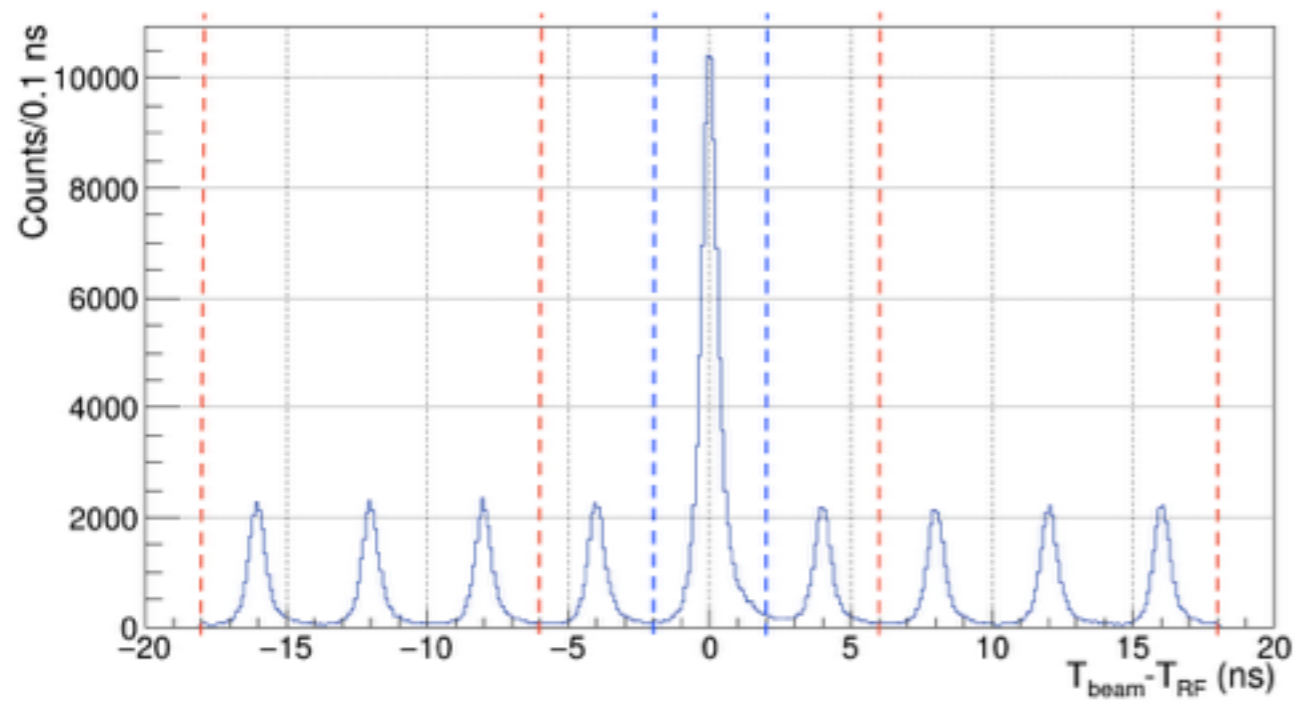# Event Selection

$$\gamma + p \rightarrow K^+ + \Sigma^0(1193) \quad \Rightarrow \Sigma^0 \rightarrow \Lambda\gamma$$

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

- Two positive tracks, one negative track and one neutral shower in final state
- Missing Mass Squared cut (exclusive reaction)
- Kinematic fit satisfying the conservation of energy and momentum
- Vertex cuts to select kaons within the target region

- PID using TOF
- dE/dx cut for proton selection
- **FCAL shower quality > 0.5**

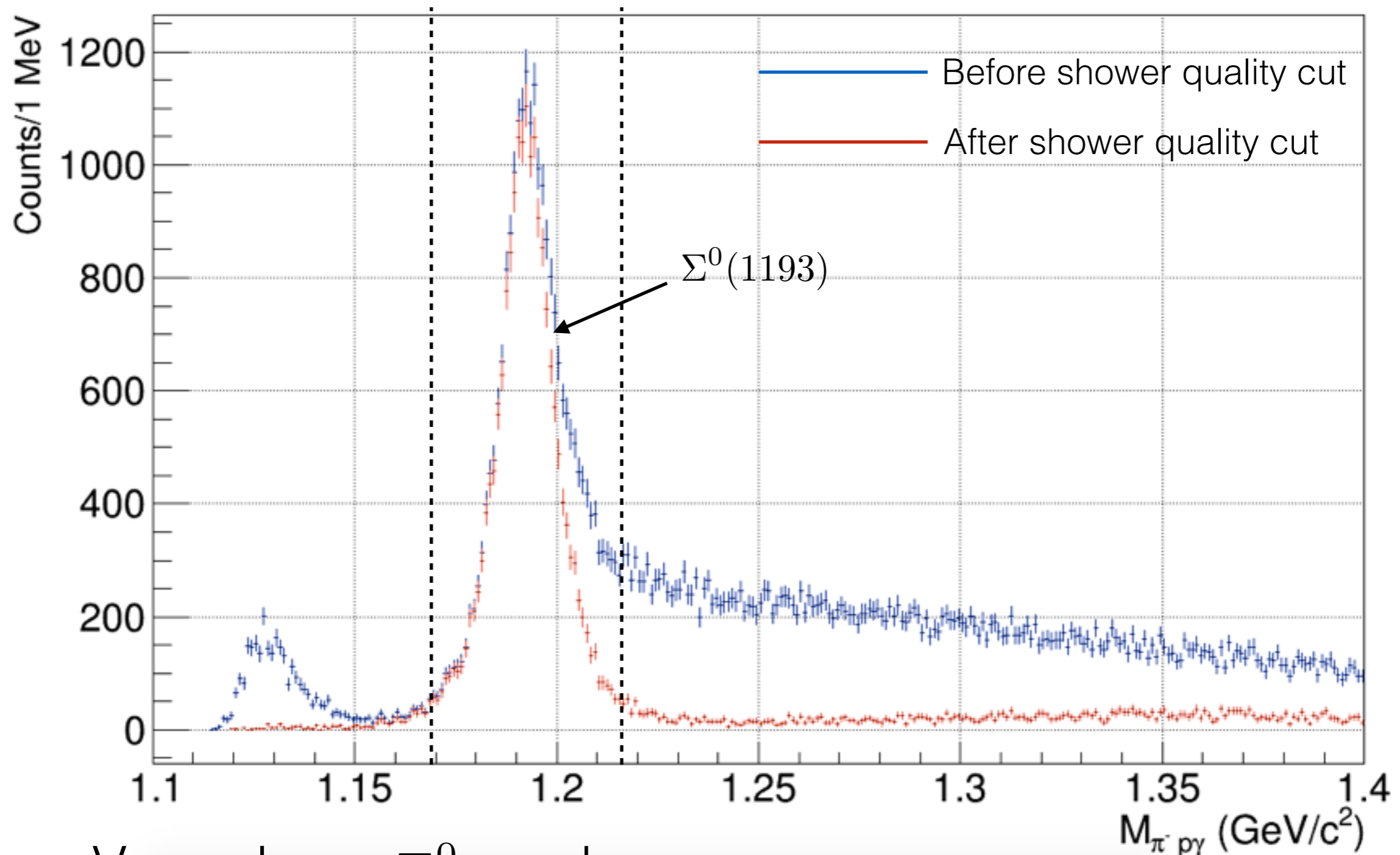# Event Selection

Invariant Mass of $\pi^- p$

- Coherent peak ➡ $8.2 < E_{beam} < 8.8\,\mathrm{GeV}$
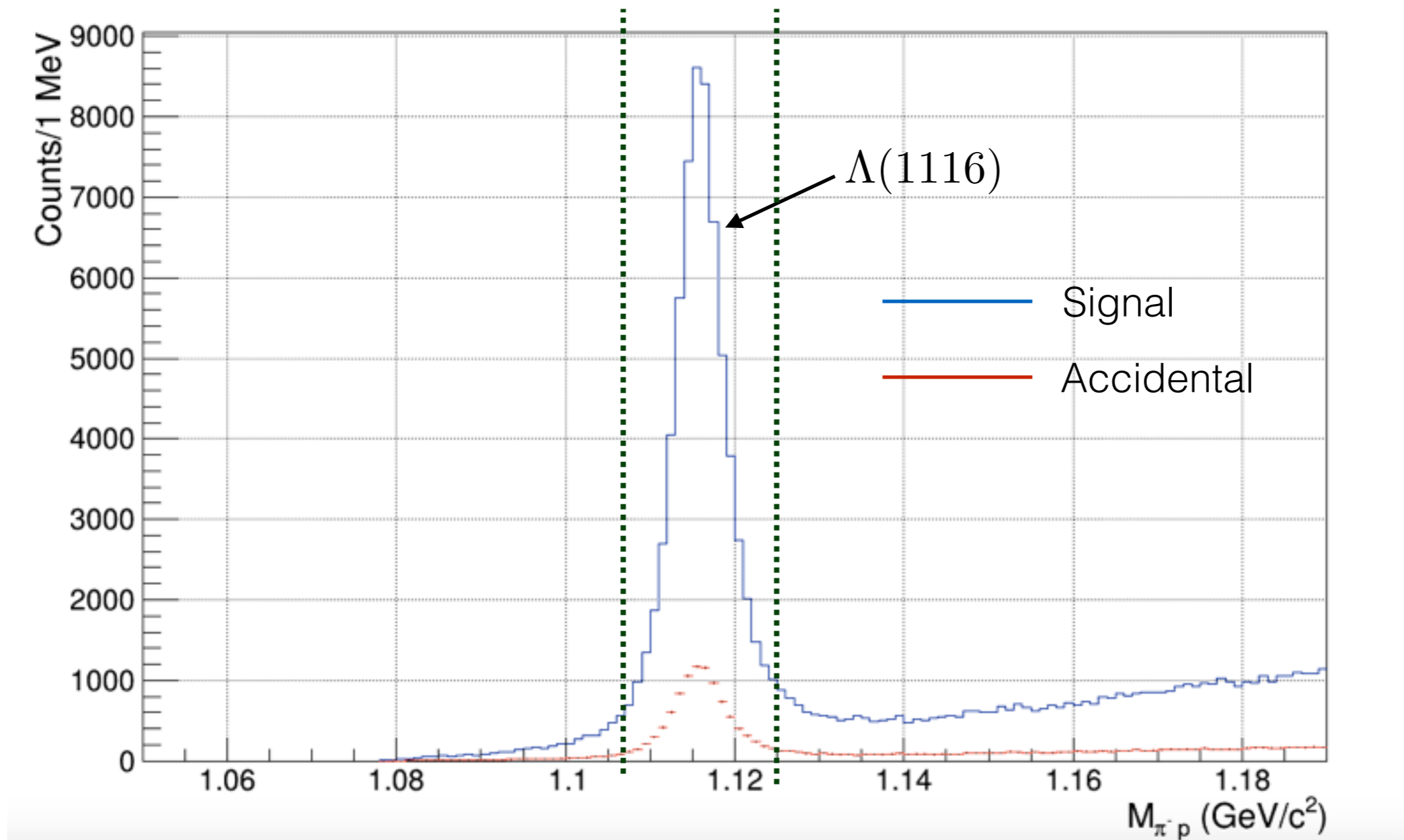
- Accidentals are scaled by the time window
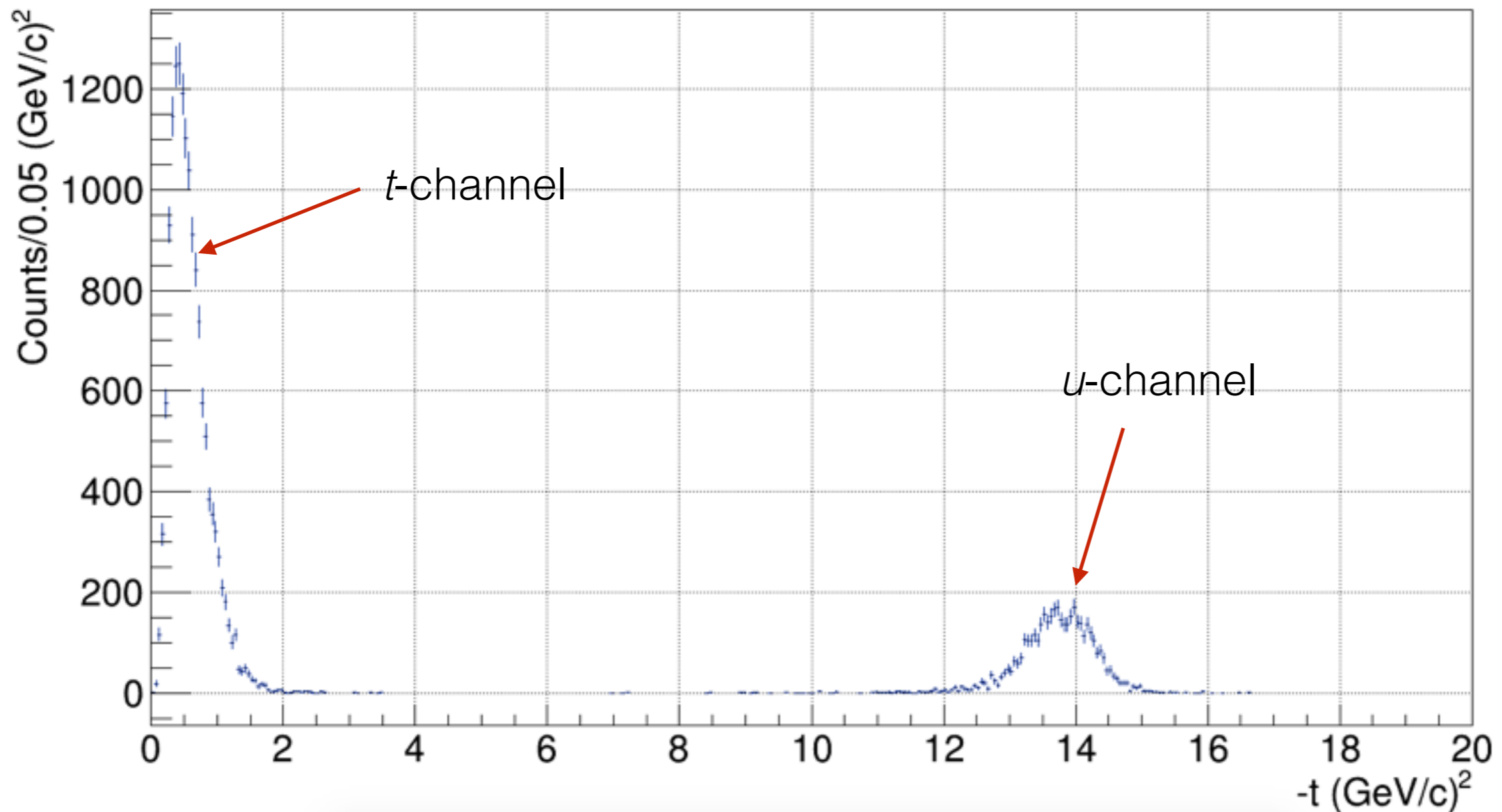
Invariant Mass of $\pi^- p \gamma$

- Events within $1.107 < M_{\pi^- p} < 1.125$ GeV/c^2

- Very clean Σ^0 peak

-t distribution

- Events within $1.169 < M_{\pi^- p\gamma} < 1.217\ GeV/c^2$

t-channel

u-channel

$$t = (p_{beam} - p_{K+})^2$$

- Both t- and u-channel contributions

Photon Beam Asymmetry

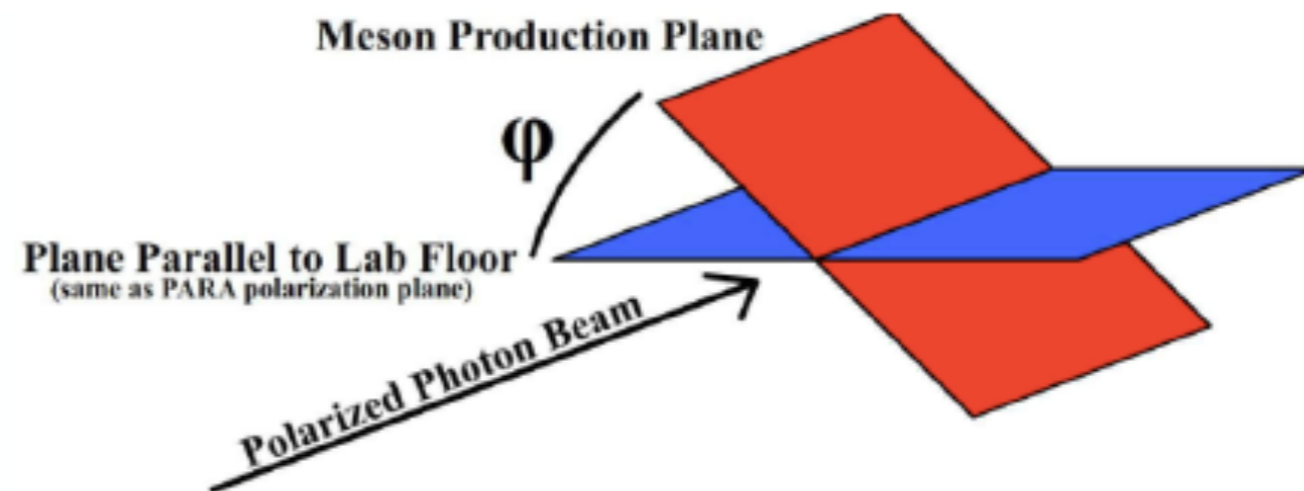$$\sigma = \sigma_0[1 - P_\gamma \Sigma \cos 2(\phi_{K^+} - \phi_\gamma^{lin})]$$

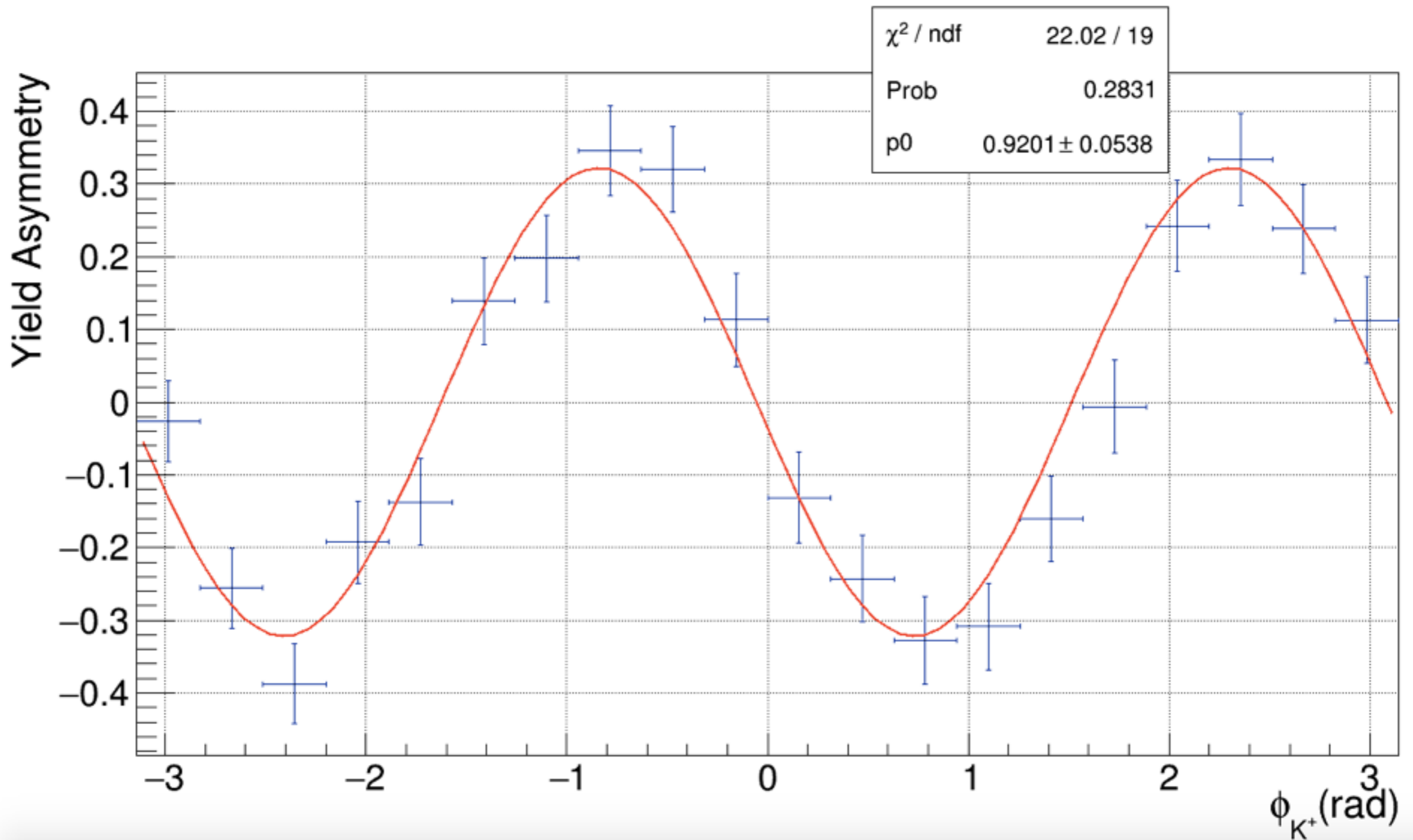In terms of PARA and PERP yields and polarizations

Yield
Asymmetry

$$\frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma \cos 2\phi}{2 + (P_\perp - P_\parallel)\Sigma \cos 2\phi}$$
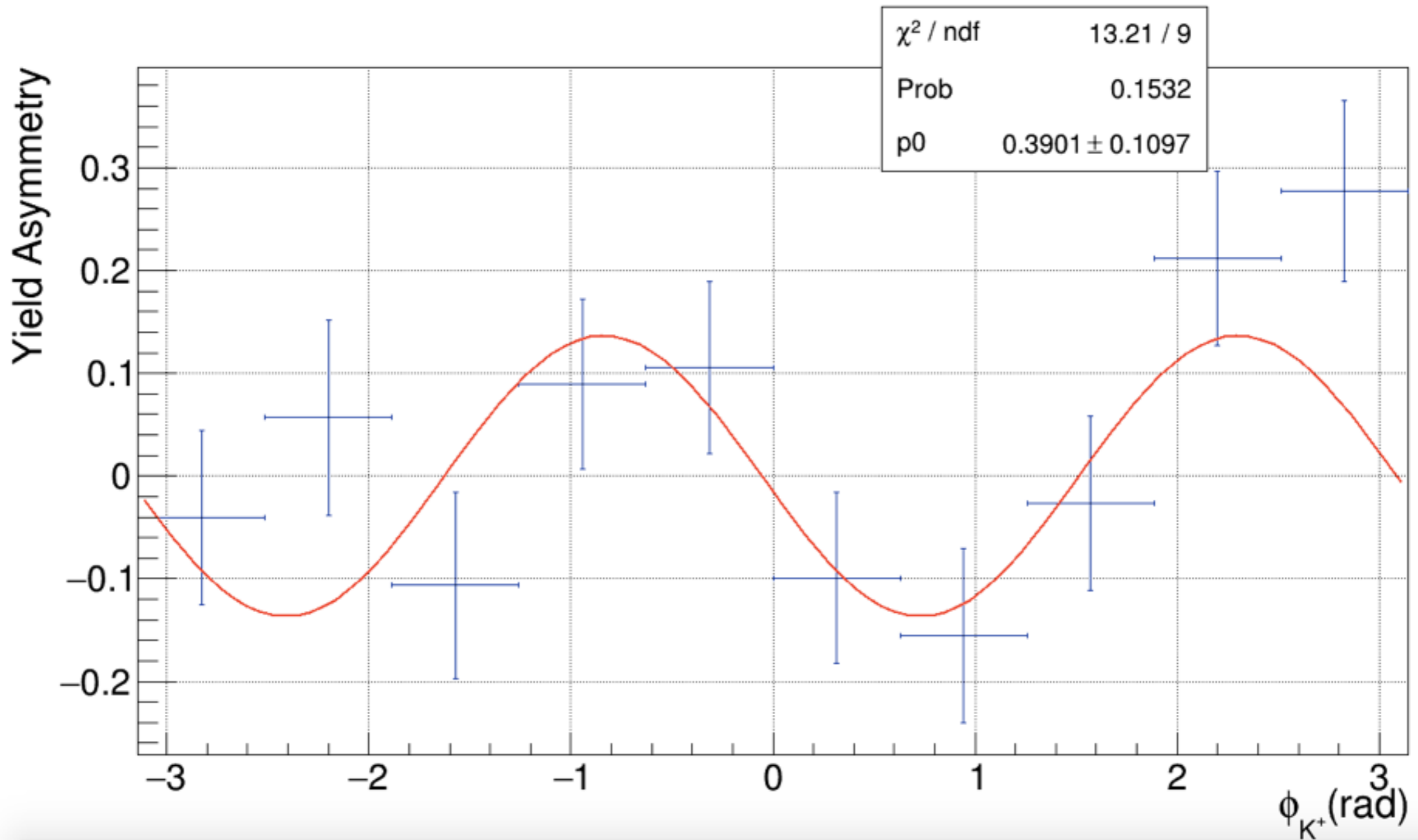
Cancels acceptance effects

- Σ - Beam asymmetry

- P_γ - Degree of photon polarization

- ϕ - Azimuthal angle of production plane

- ϕ_γ^{lin} - Azimuthal angle of photon beam

    linear polarization   plane

Meson Production Plane

φ

Plane Parallel to Lab Floor
(same as PARA polarization plane)

Polarized Photon Beam

Yield Asymmetry for t-channel

Yield Asymmetry for u-channel

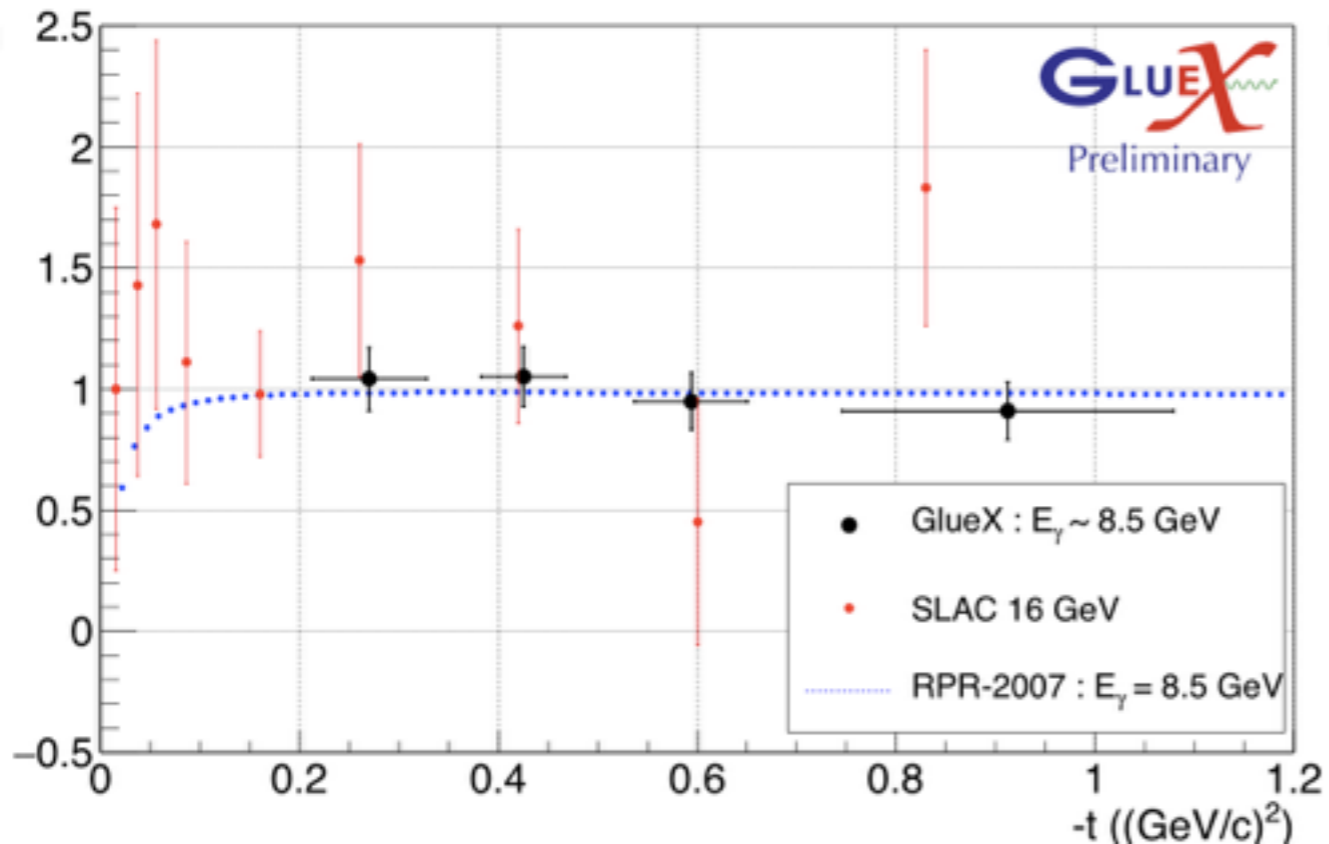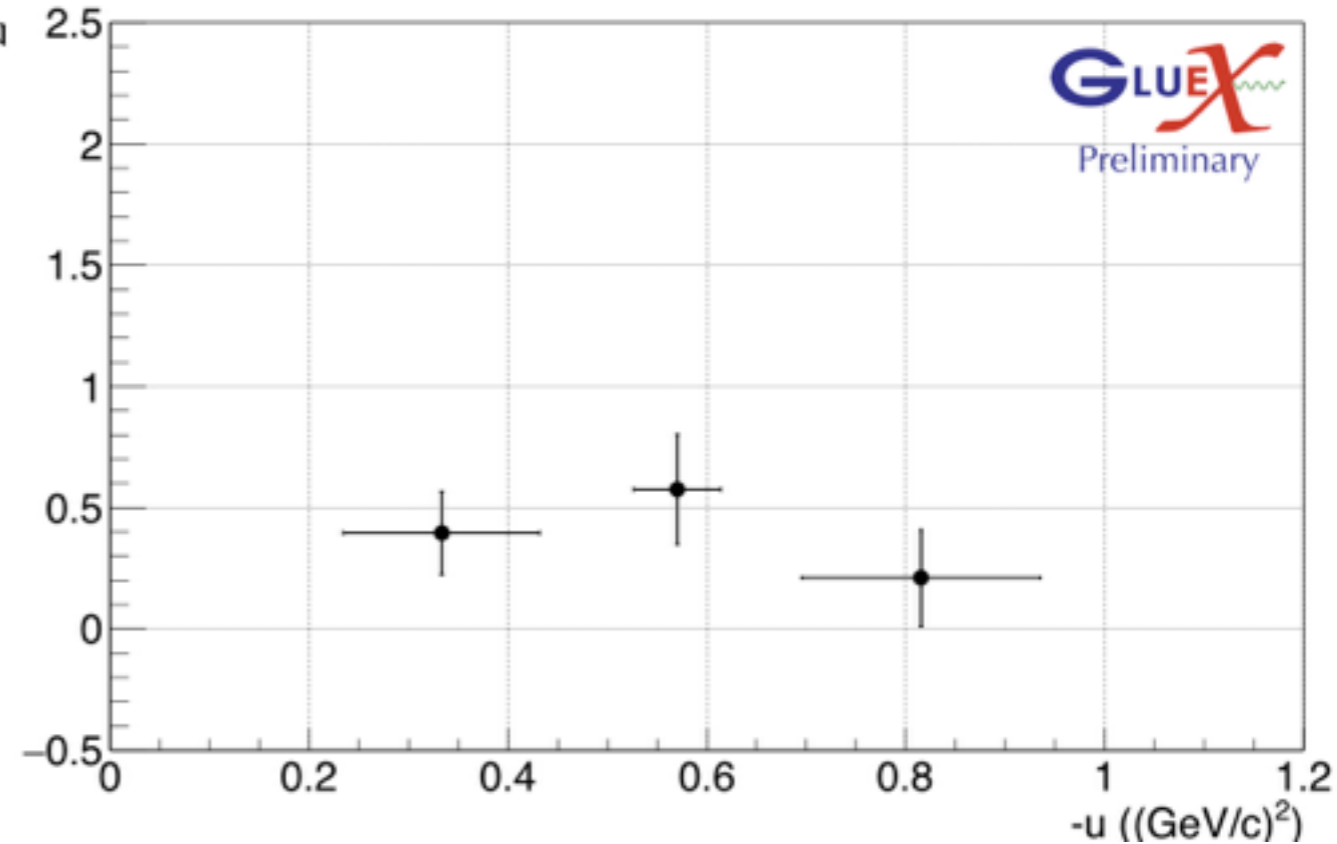|	
χ^2 / ndf	13.21 / 9
Prob	0.1532
p0	0.3901 ± 0.1097

Beam Asymmetry of $\gamma p \rightarrow K^+ \Sigma^0$

- Combined result from two orientation sets
- Errors are statistical $\oplus$ systematic

Σ ~ 1

Natural parity exchange (K*(892))

First ever measurement for beam asymmetry vs. -u !

RPR-2007 model: Phys. Rev. C 75, 045204 (2007)

SLAC data: Phys. Rev. D 20 1553 (1979)

Summary

- Photon beam asymmetry above resonance region in t-channel is measured with much higher precision than at SLAC

- It is well described by RPR model and confirms dominance of natural parity exchange

- Photon Beam Asymmetry for u-channel has been measured for the first time and there are no theory model predictions yet to perform any comparison

- Presented results have been released by the GlueX Collaboration as preliminary and soon will be submitted for a publication
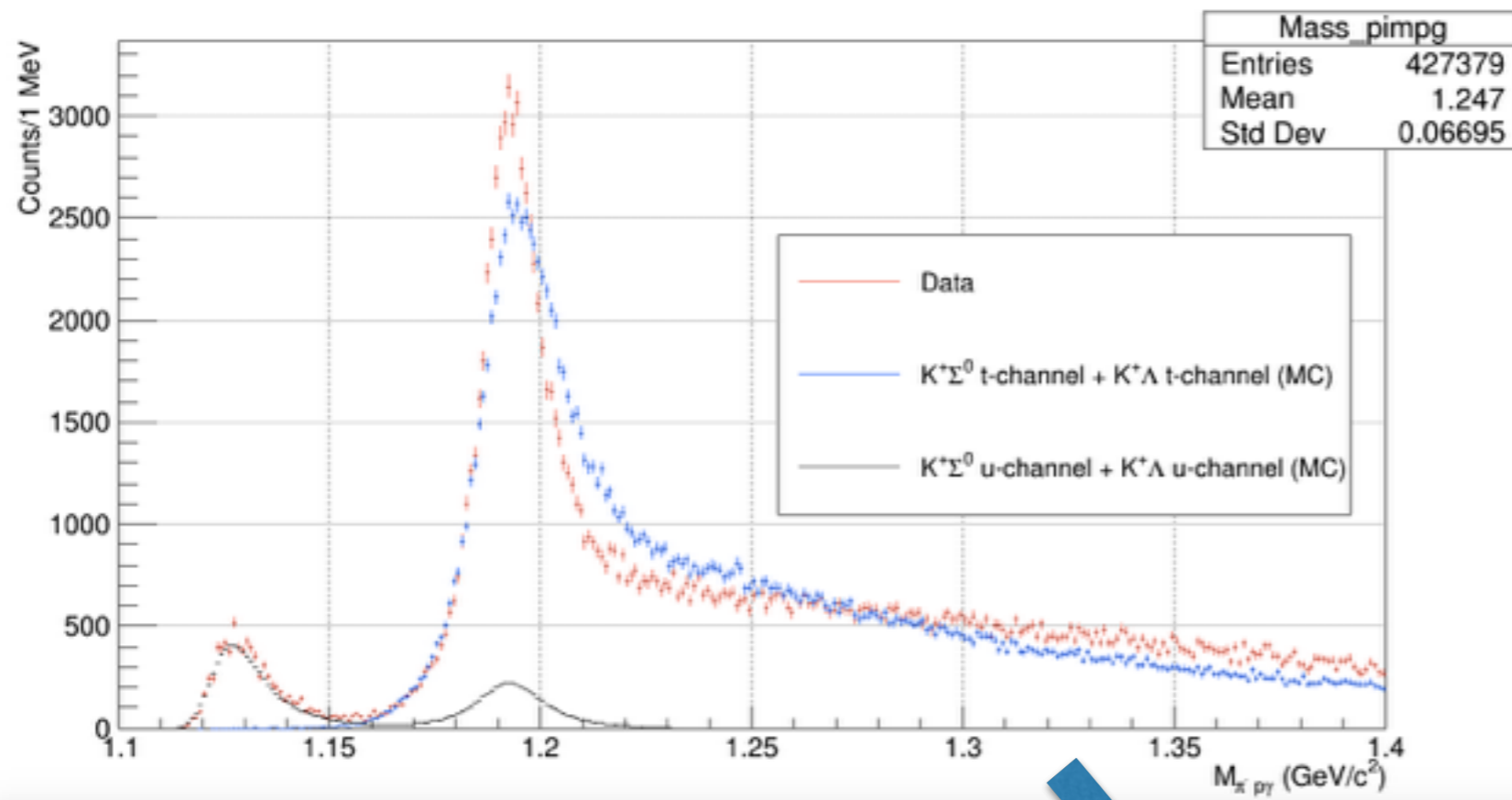
Backup : -t and -u distributions

- Events within $1.169 < M_{\pi^- p \gamma} < 1.217\ GeV/c^2$
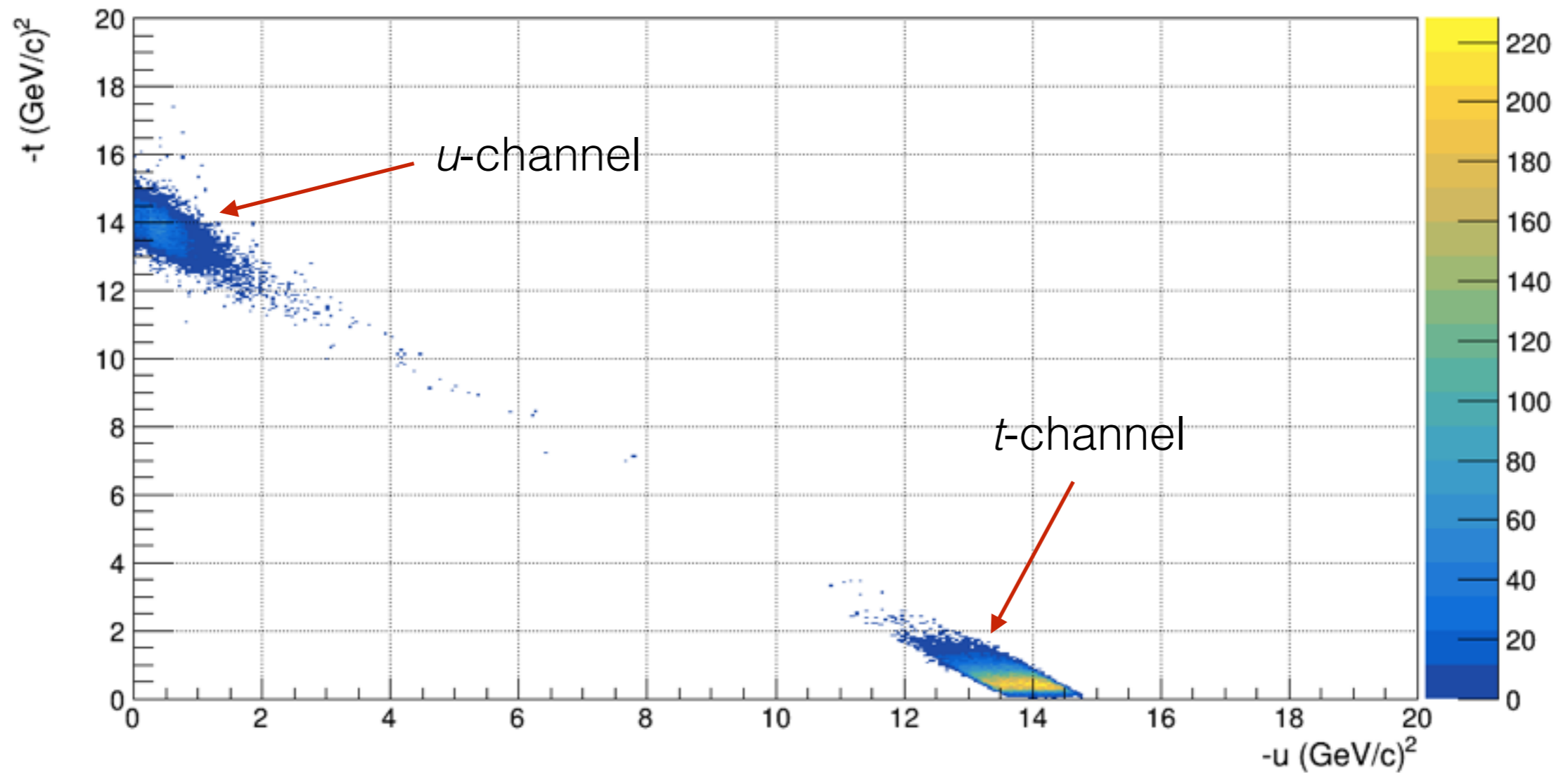
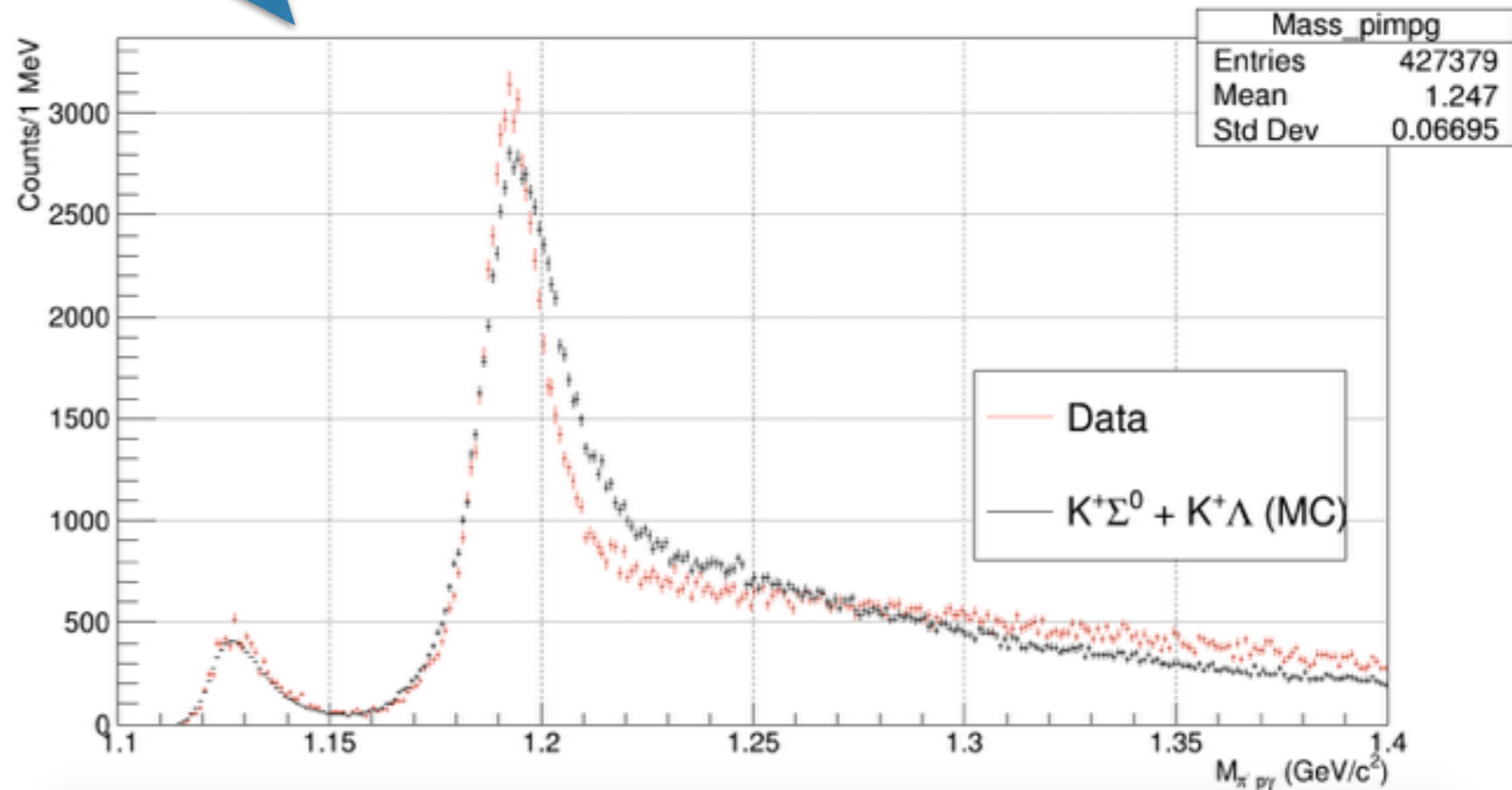$$t = (p_{beam} - p_{K+})^2 \qquad\qquad u = (p_{target} - p_{K+})^2$$

- Both t- and u-channel contributions
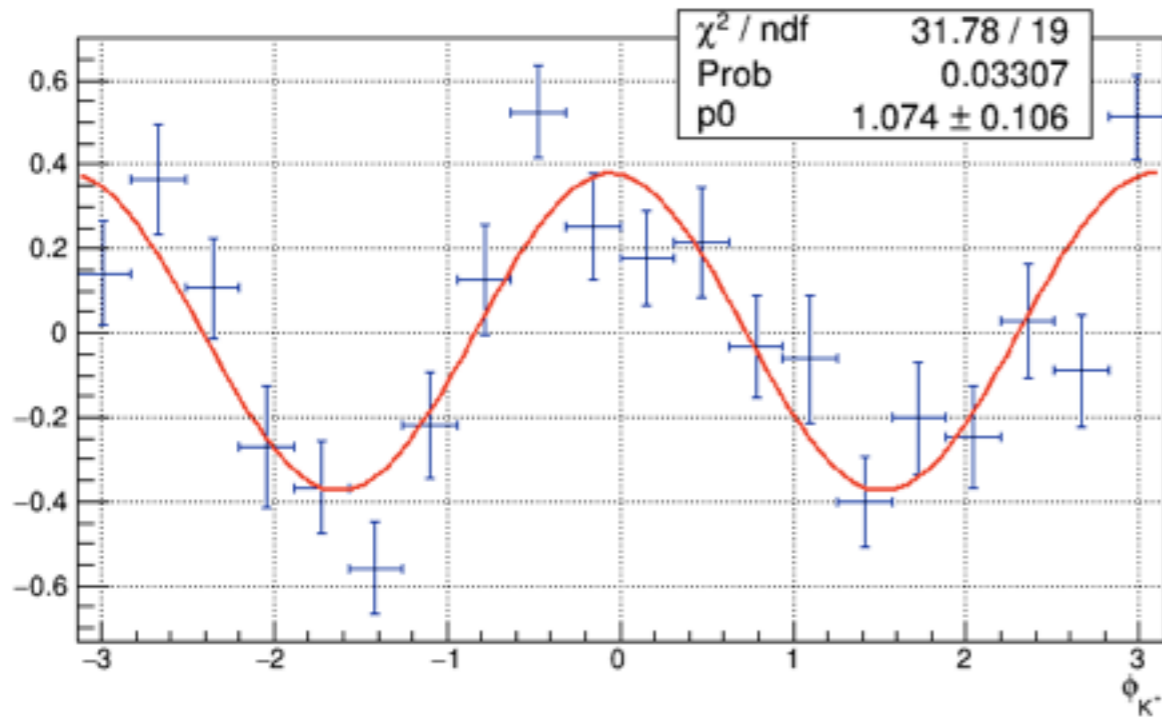
t-channel and u-channel
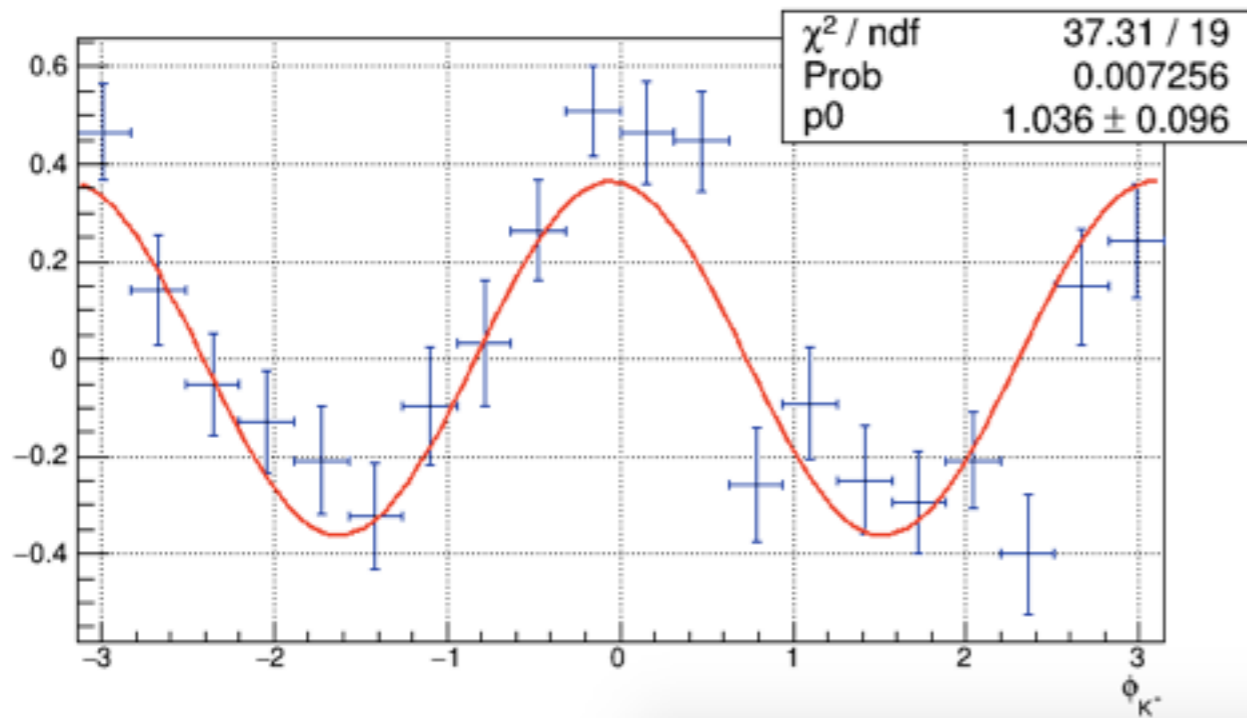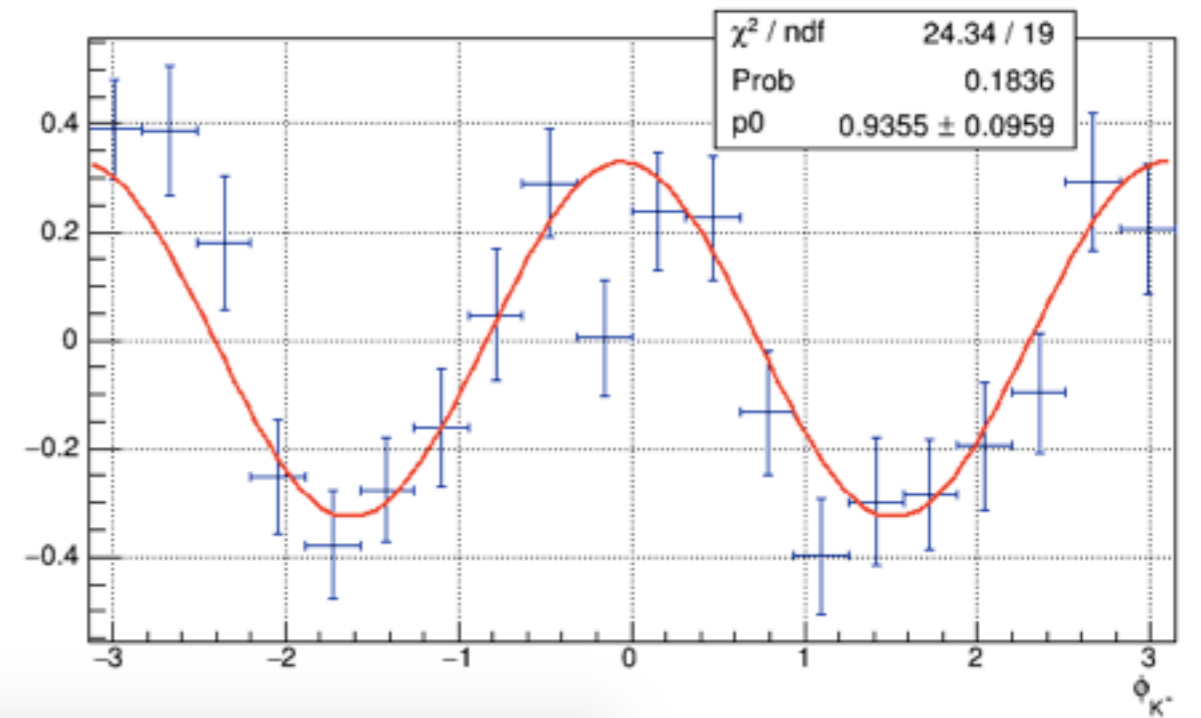separate MC

sum of all MC

Yield Asymmetry (0/90) for *t* bins

-*t*=0.1-0.35 $(GeV/c)^2$

-*t*=0.35-0.50 $(GeV/c)^2$

χ^2 / ndf	31.78 / 19
Prob	0.03307
p0	1.074 ± 0.106

χ^2 / ndf	25.43 / 19
Prob	0.1469
p0	1.076 ± 0.099

χ^2 / ndf	37.31 / 19
Prob	0.007256
p0	1.036 ± 0.096

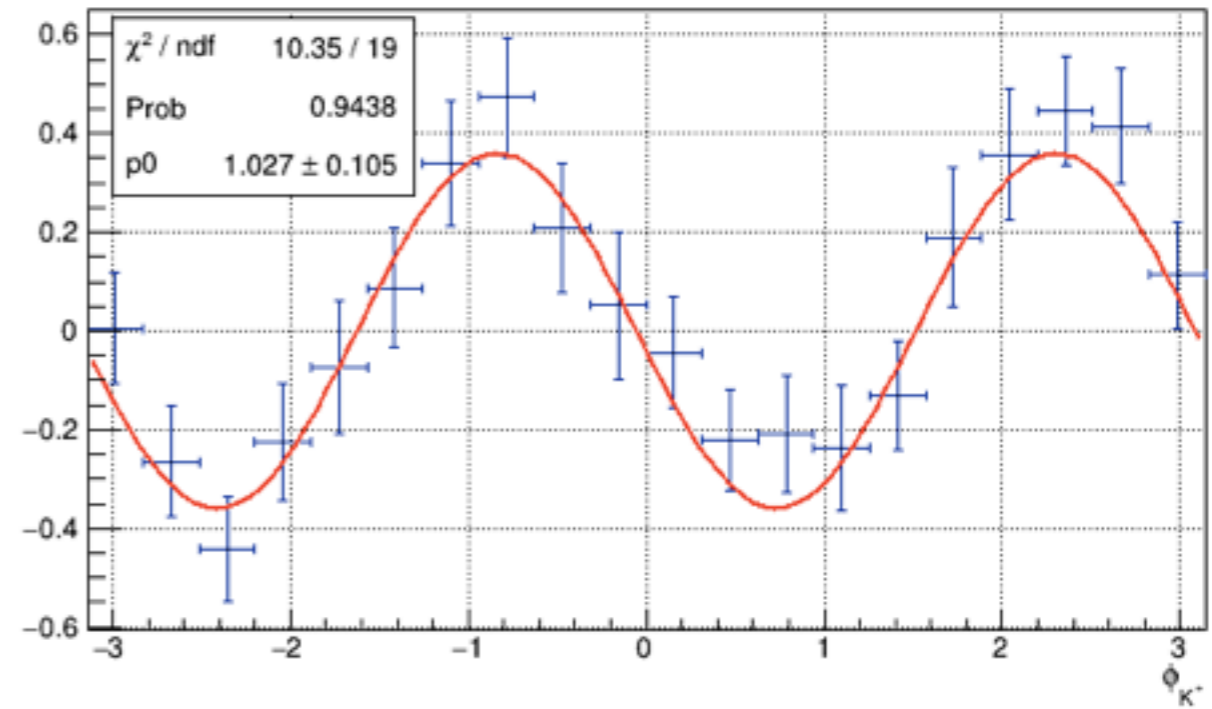| χ^2 / ndf	24.34 / 19
Prob	0.1836
p0	0.9355 ± 0.0959
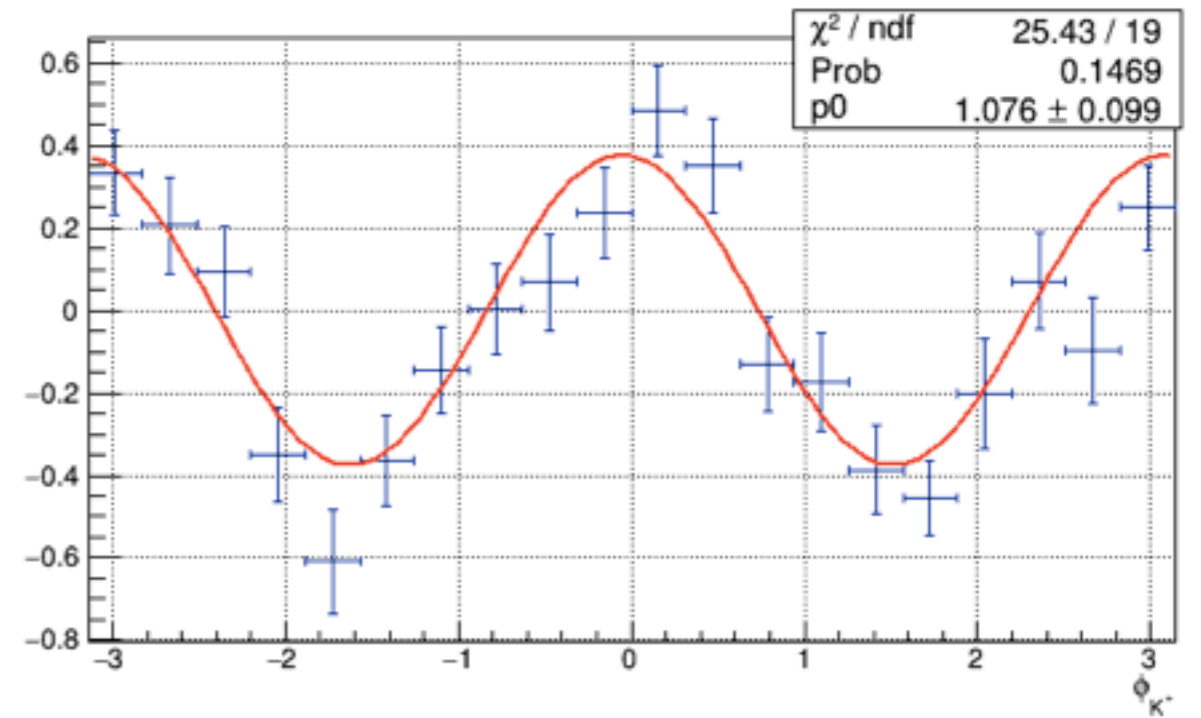
-*t*=0.50-0.70 $(GeV/c)^2$

-*t*=0.70-1.40 $(GeV/c)^2$

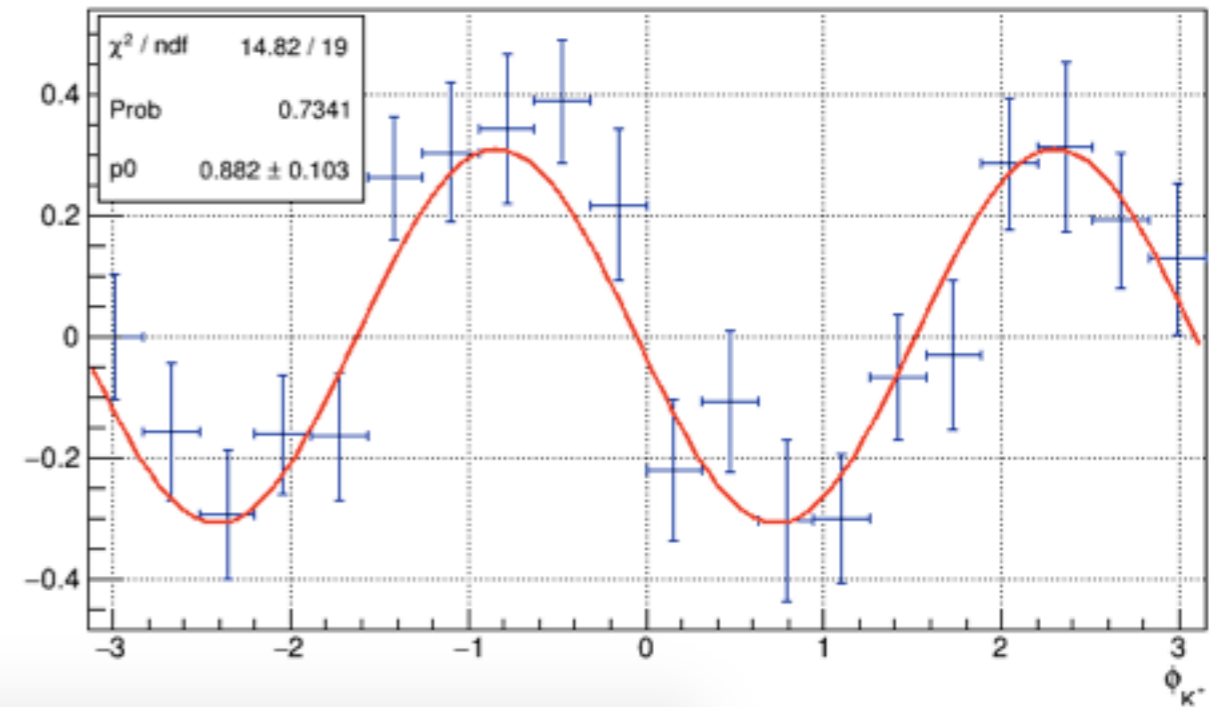# Yield Asymmetry (45/135) for *t* bins

-*t*=0.1-0.35 $(GeV/c)^2$
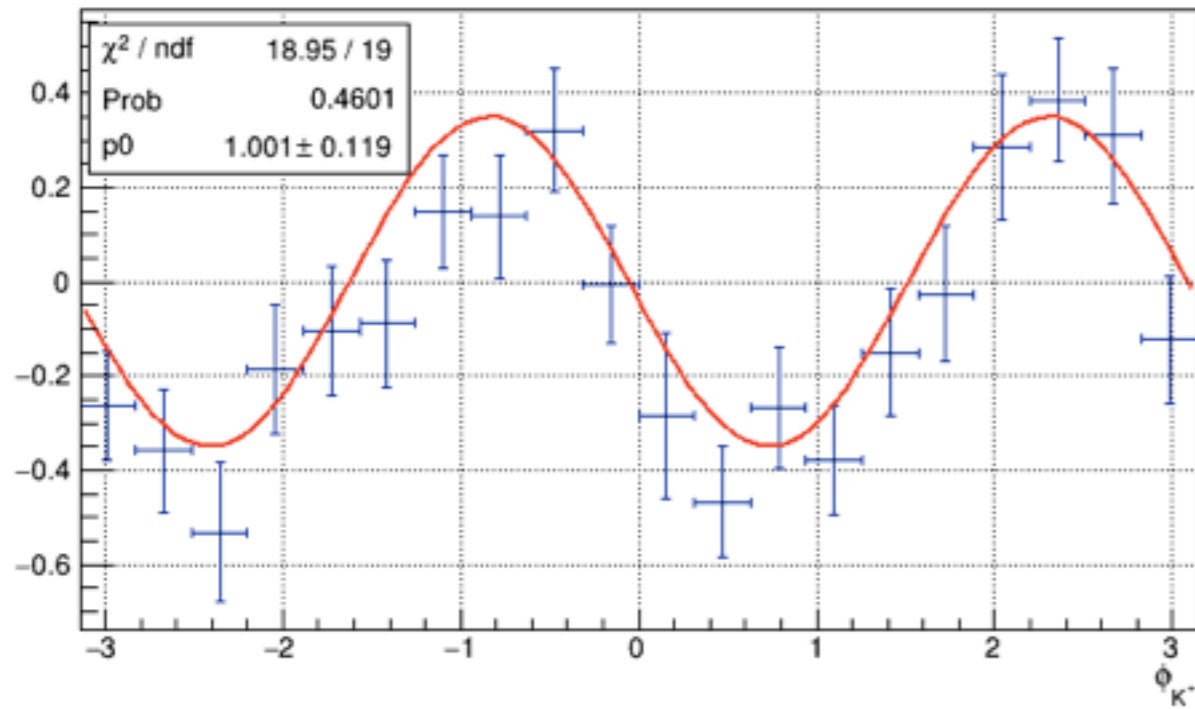
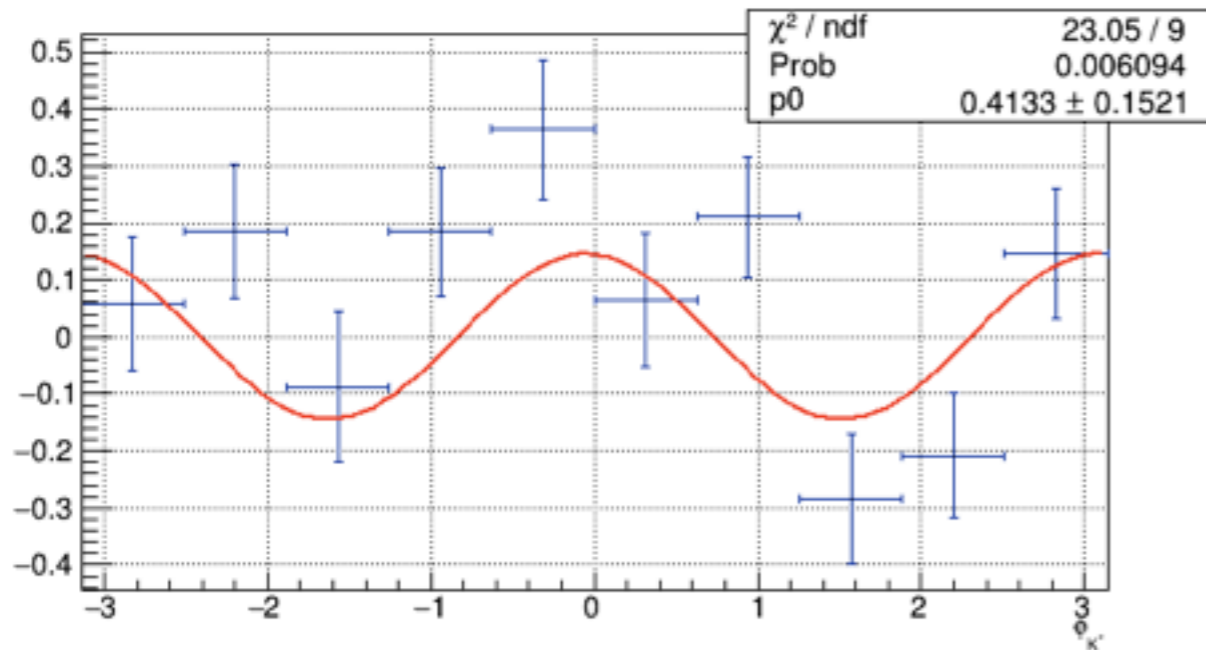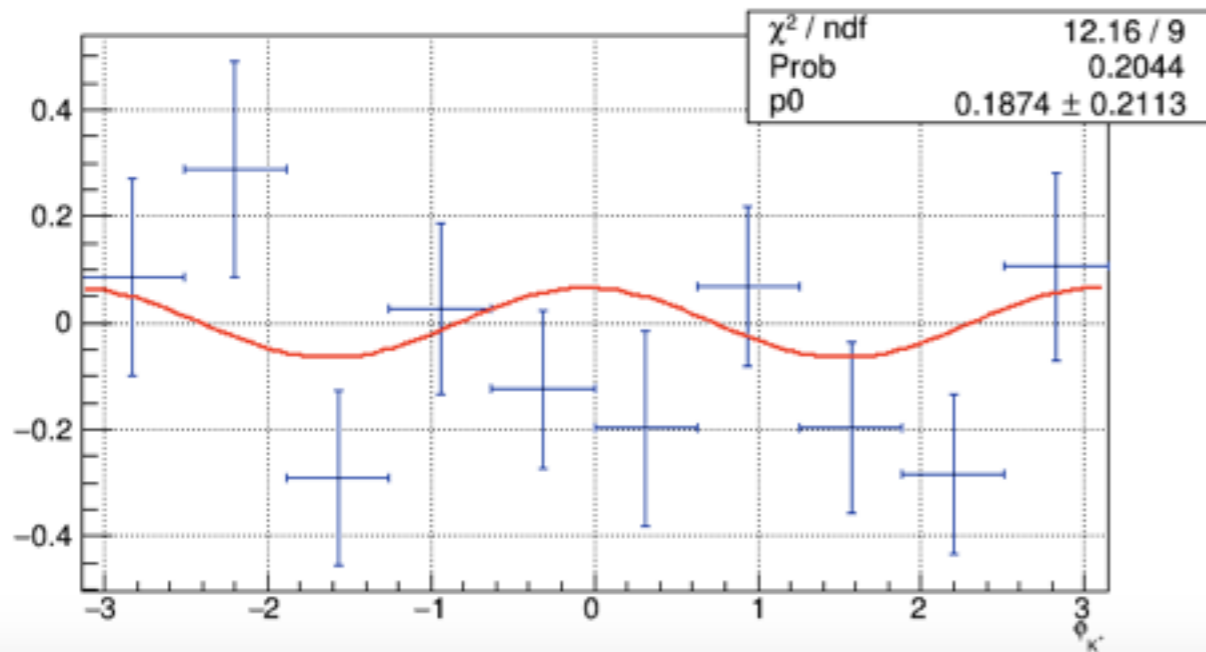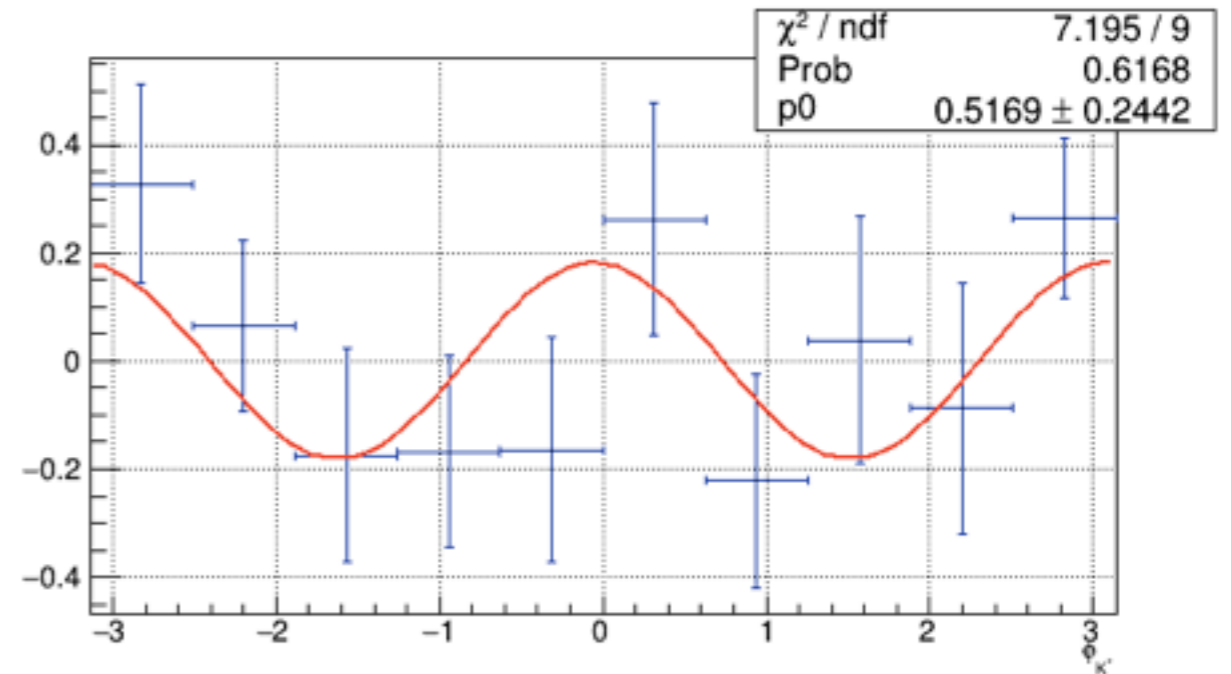-*t*=0.35-0.50 $(GeV/c)^2$
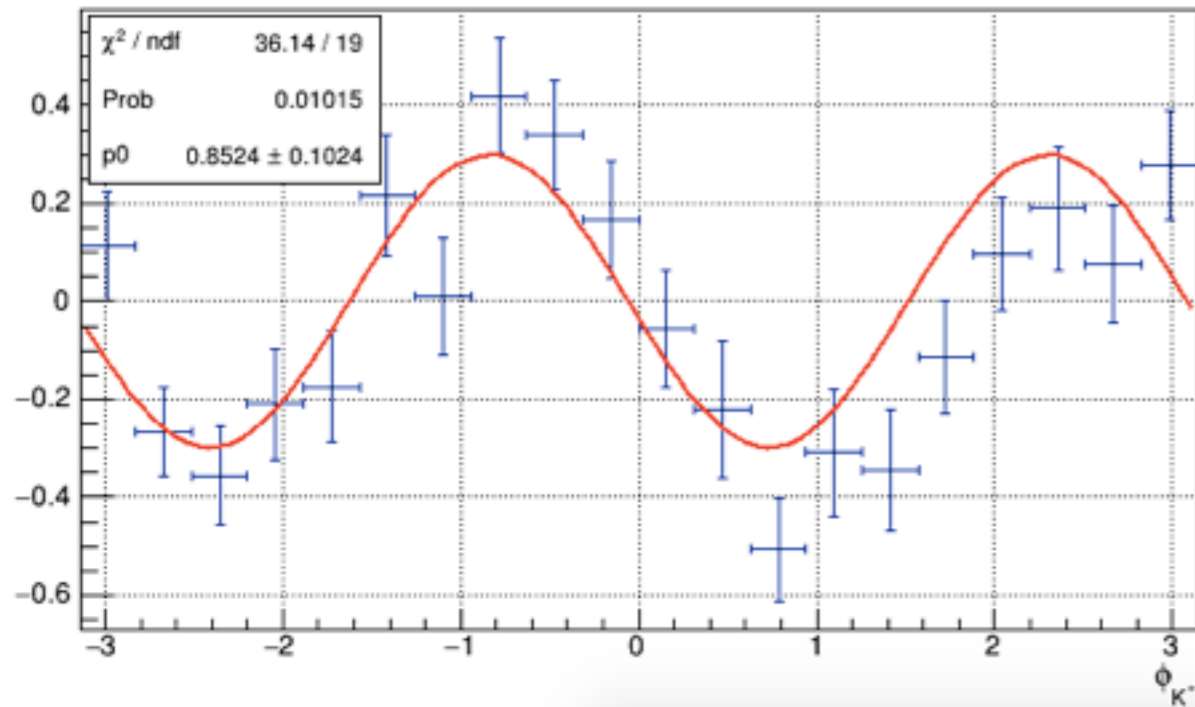
-*t*=0.50-0.70 $(GeV/c)^2$

-*t*=0.70-1.40 $(GeV/c)^2$

Yield Asymmetry (0/90) for *u* bins

-*u*=0.1-0.5 $(GeV/c)^2$

-*u*=0.5-0.65 $(GeV/c)^2$

χ^2 / ndf	23.05 / 9
Prob	0.006094
p0	0.4133 ± 0.1521

χ^2 / ndf	7.195 / 9
Prob	0.6168
p0	0.5169 ± 0.2442

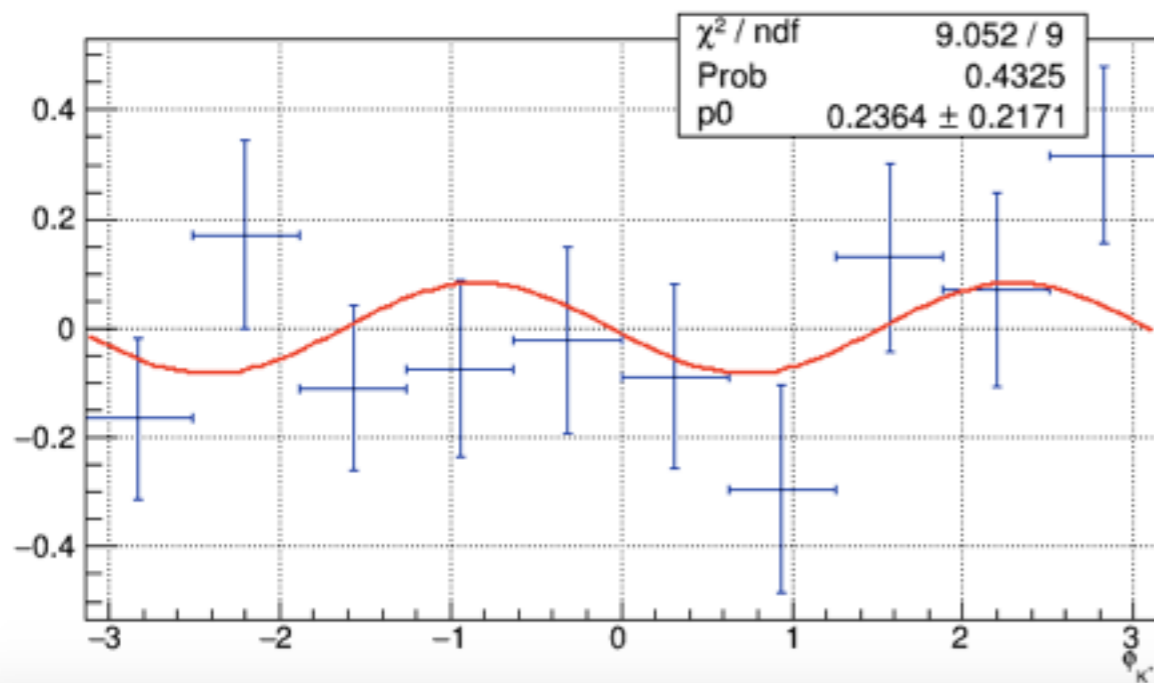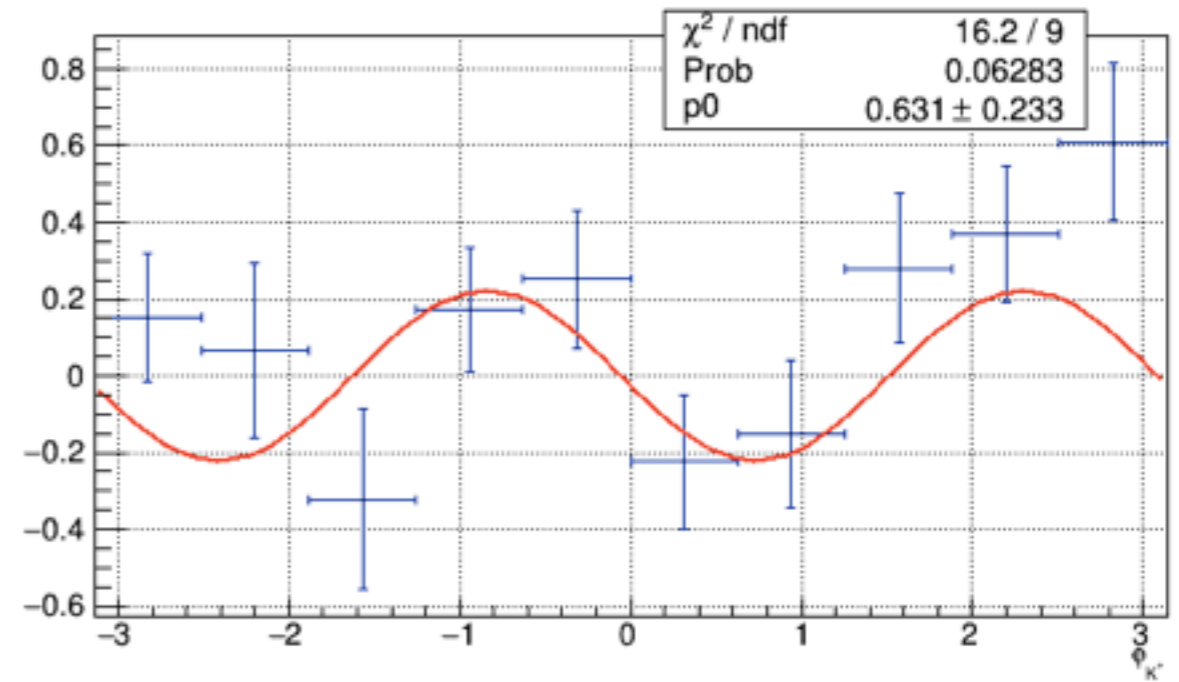| χ^2 / ndf | 12.16 / 9 |
| Prob | 0.2044 |
| p0 | 0.1874 ± 0.2113 |

-*u*=0.65-1.1 $(GeV/c)^2$

Yield Asymmetry (45/135) for *u* bins

$-u$=0.1-0.5 $(GeV/c)^2$
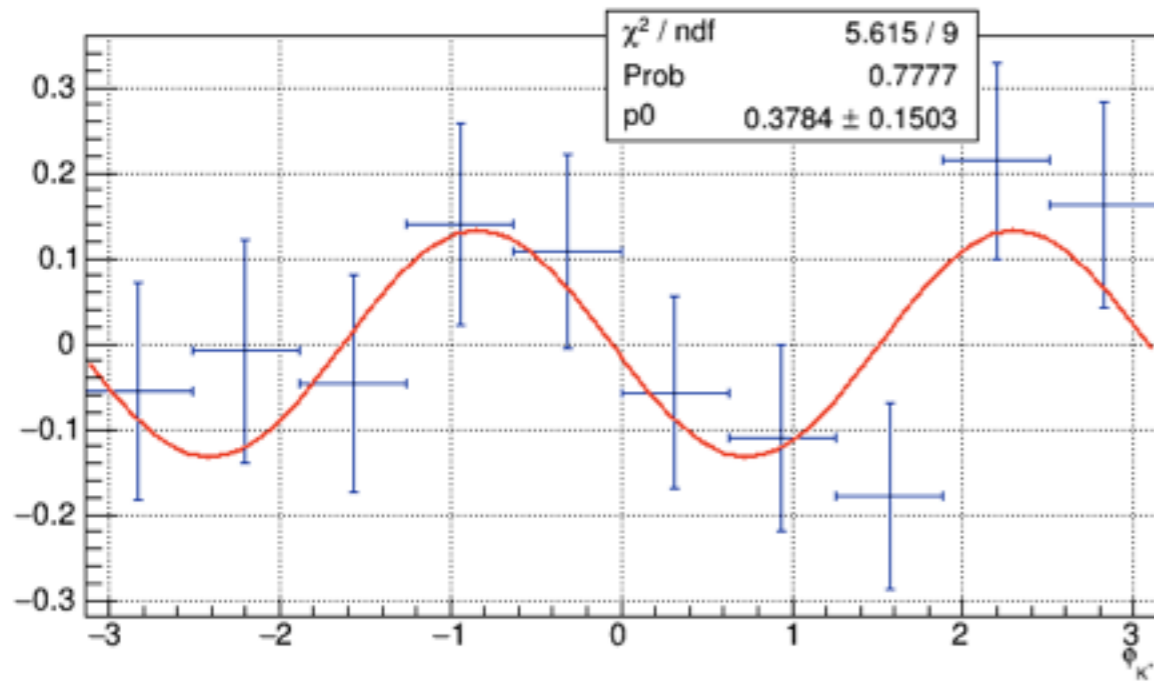
$-u$=0.5-0.65 $(GeV/c)^2$

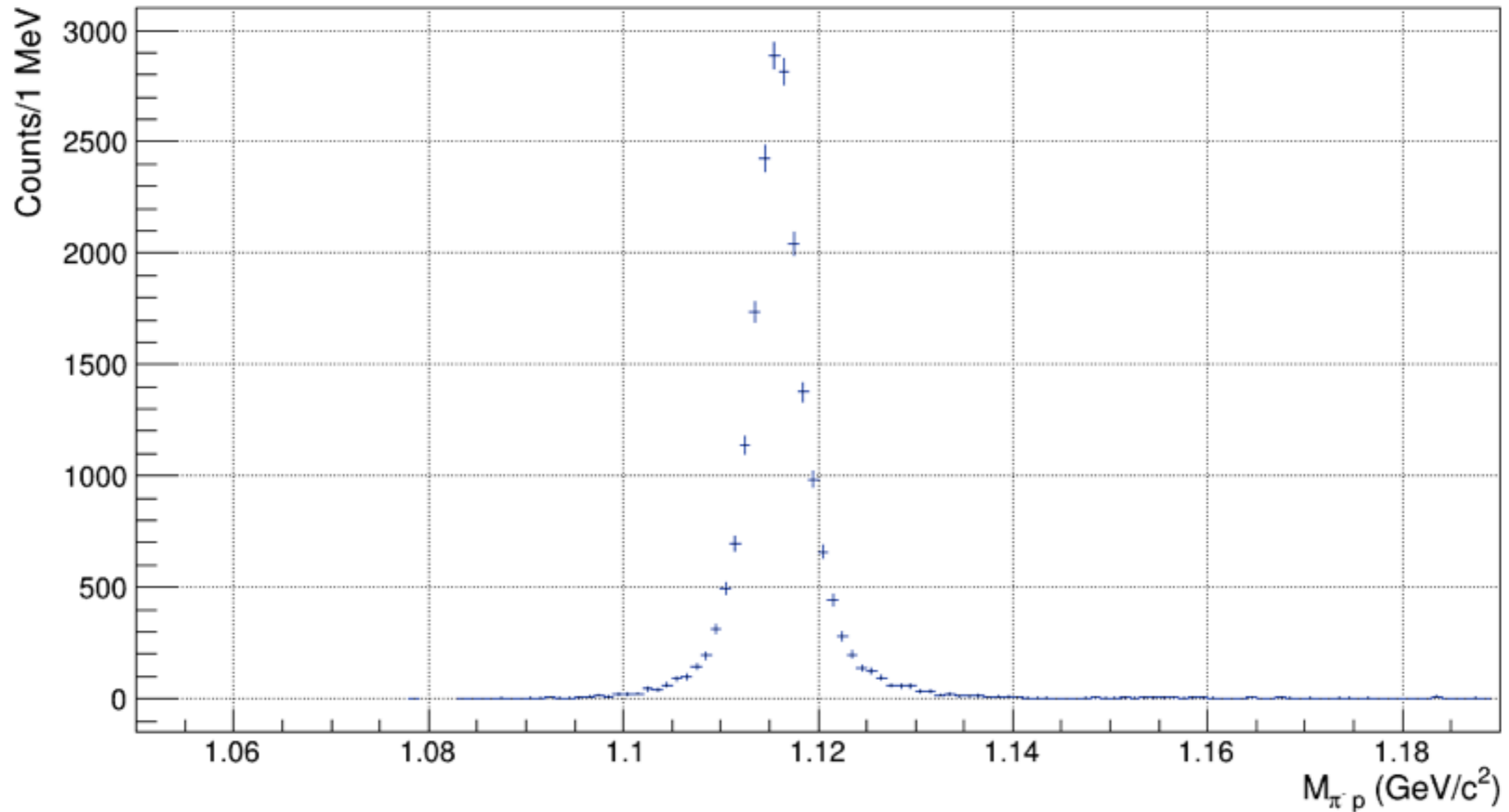$-u$=0.65-1.1 $(GeV/c)^2$

Λ peak within Σ region

$$M_{\pi^- p}$$

- Very clean Λ peak !