



Jefferson Lab

$K\pi$ simulation study for KLF

$$K_L p \rightarrow K^* p \rightarrow K^+ \pi^- p$$

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Motivation

$K\pi$ scattering enables direct investigations of scalar and vector K^* states.

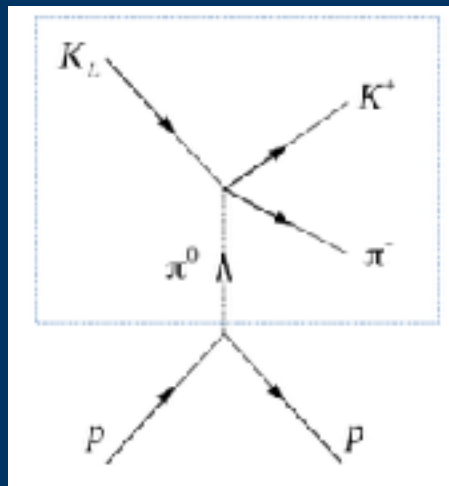
$K_0^*(800)$, $K_0^*(1430)$, $K_1^*(892)$, $K_1^*(1410)$, $K_2^*(1430)$, $K_3^*(1780)$...

κ / $K_0^*(800)$ light scalar meson. "needs confirmation" @PDG (since 2018).

K-long Facility

- Study of $k\pi$ scattering at KLF will support the existence of $\kappa(800)$ and significantly improve on the uncertainties of determination of its mass and width

$K\pi$ Scattering Amplitude

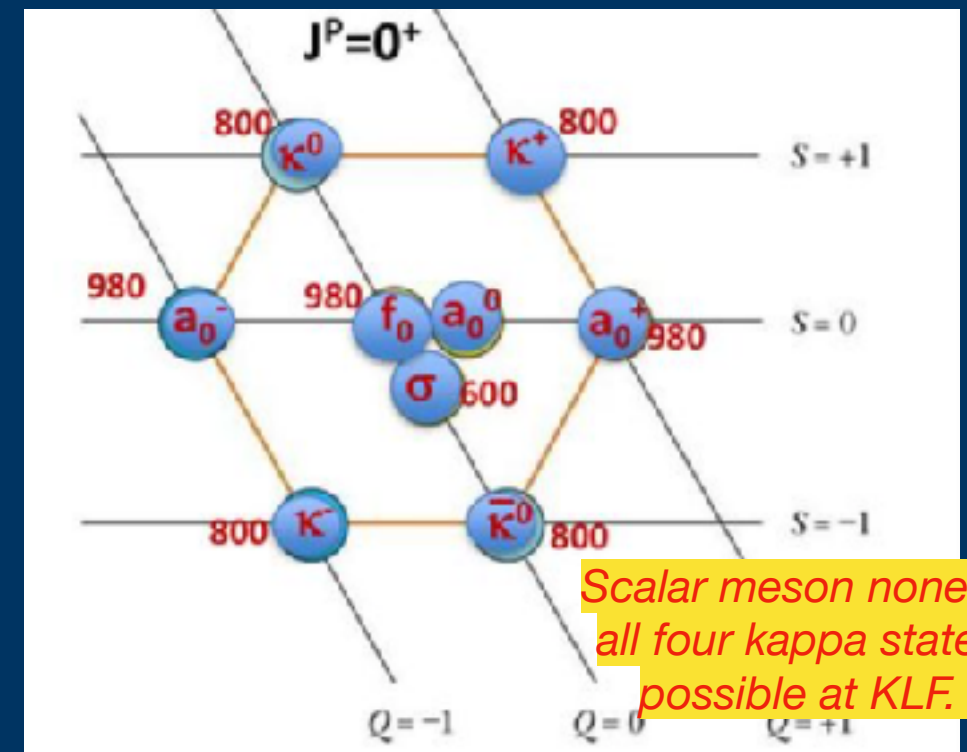


... is dominant at low momentum transfer region (pion pole).

S- wave: $\kappa(800)$, $K_0^*(1430)$, ...

P- wave: $K^*(892)$, $K^*(1680)$, ...

D- wave: $K_2^*(1430)$, ...



Scalar meson nonets, all four kappa states possible at KLF.

???...at KLF, Does it reach down to pion pole

KLF will contribute significantly the world existed database for $K\pi$ scattering.

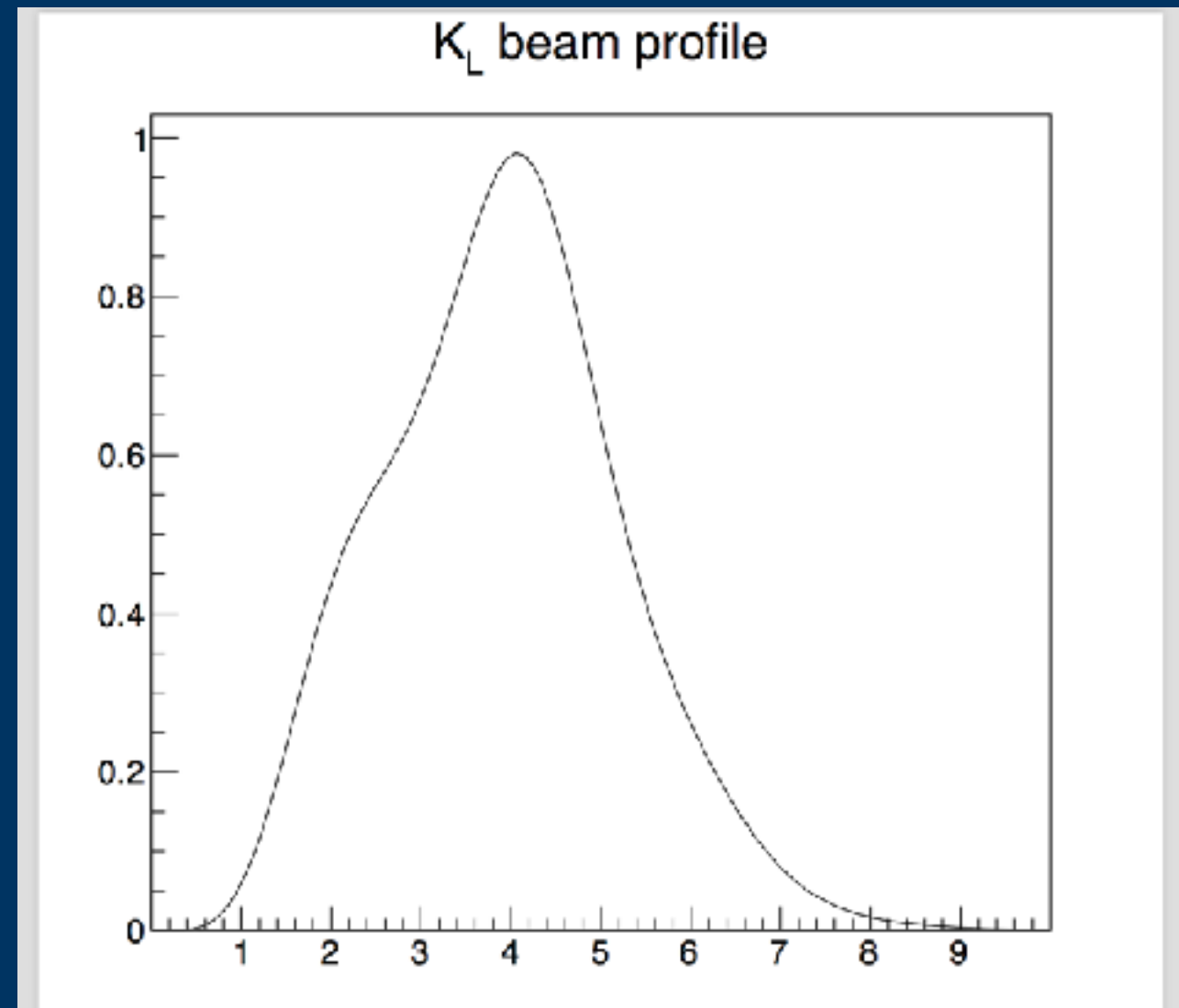
Event Generation

K_L beam generated

- assuming the K_L beam originates from Be target at 24 m upstream of glueX target.
- using momentum distribution provided by I. Larin.

$K\pi$ production: $K_L p \rightarrow K^+ \pi^- p$

- Generated based on Regge model described in *Nucl.Phys.B10(1969) 151-168*.
- Developed by Maroune Baalouch
- More details can be found in the KLF proposal.



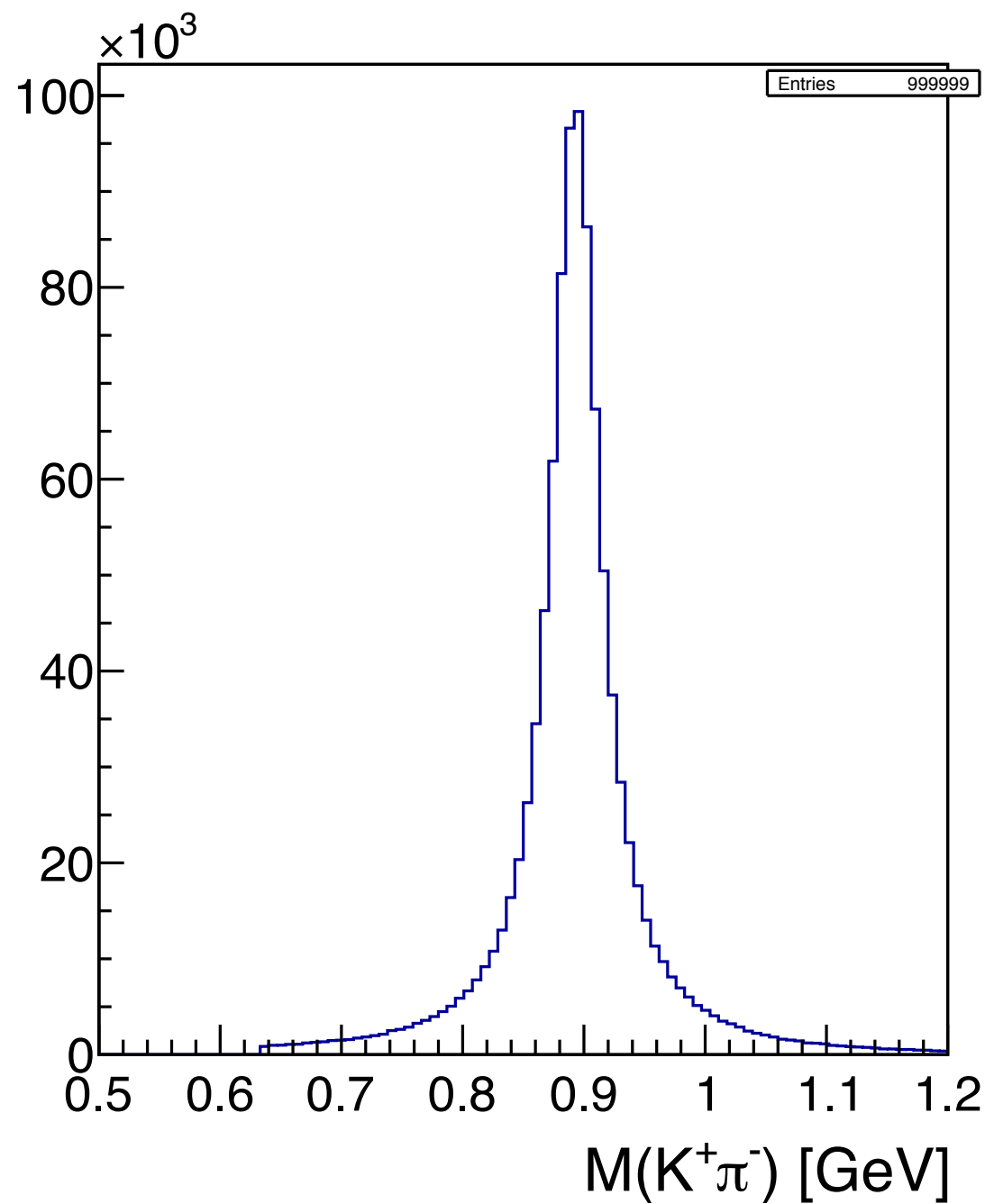
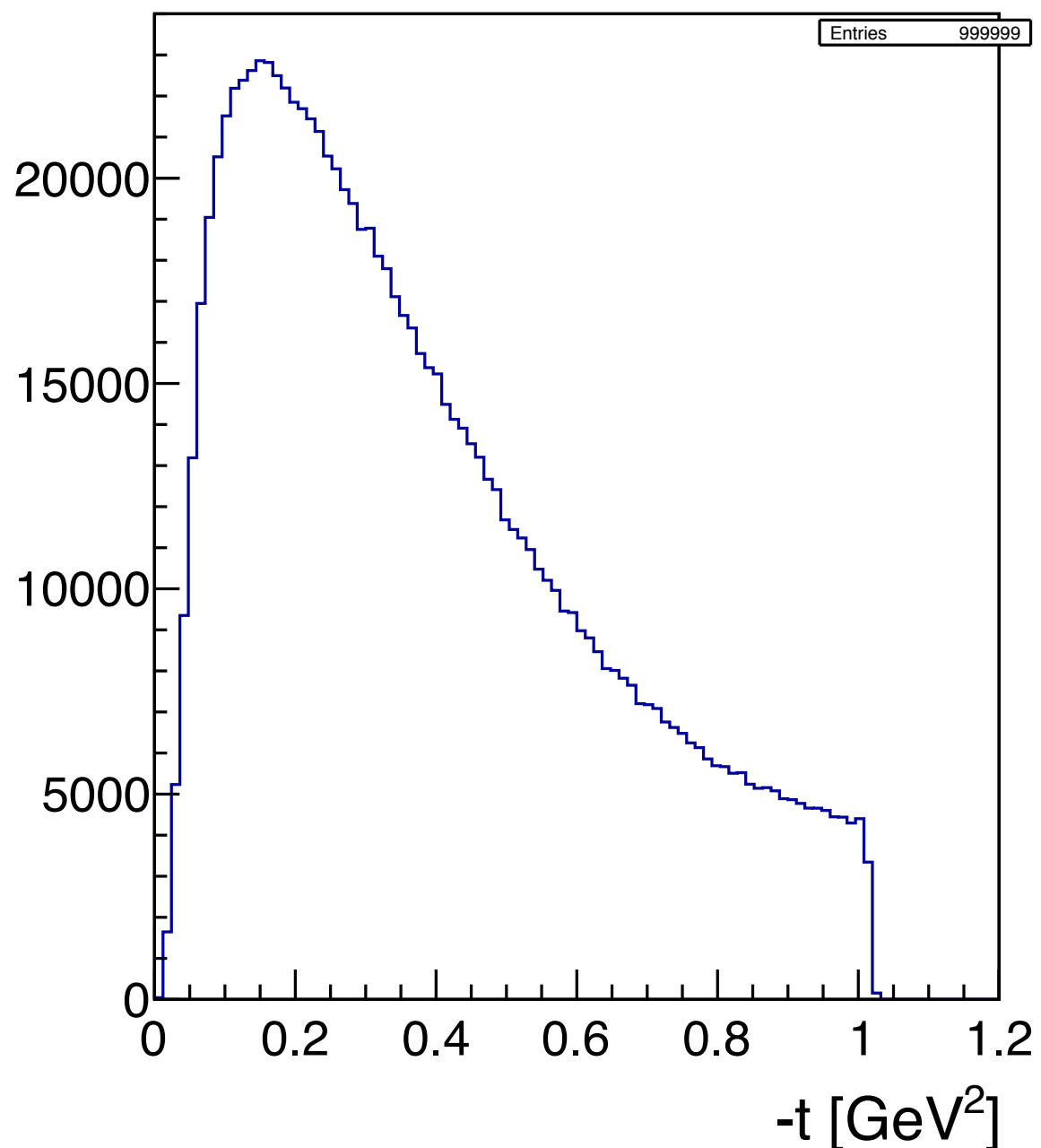
Beam Profile

Generation $K_L p \rightarrow K^*(892)p$

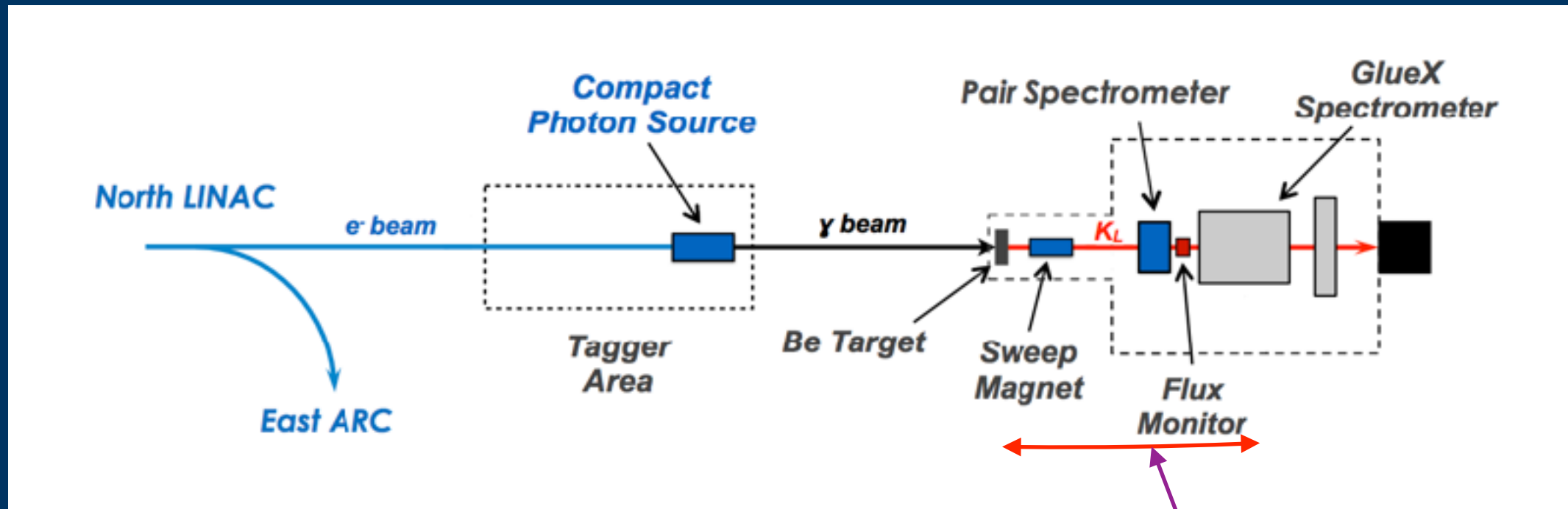
Generated Monte Carlo using Regge Model for $K_L p \rightarrow K^*(892)p \rightarrow K^+ \pi^- p$

Four Momentum transfer (-t)

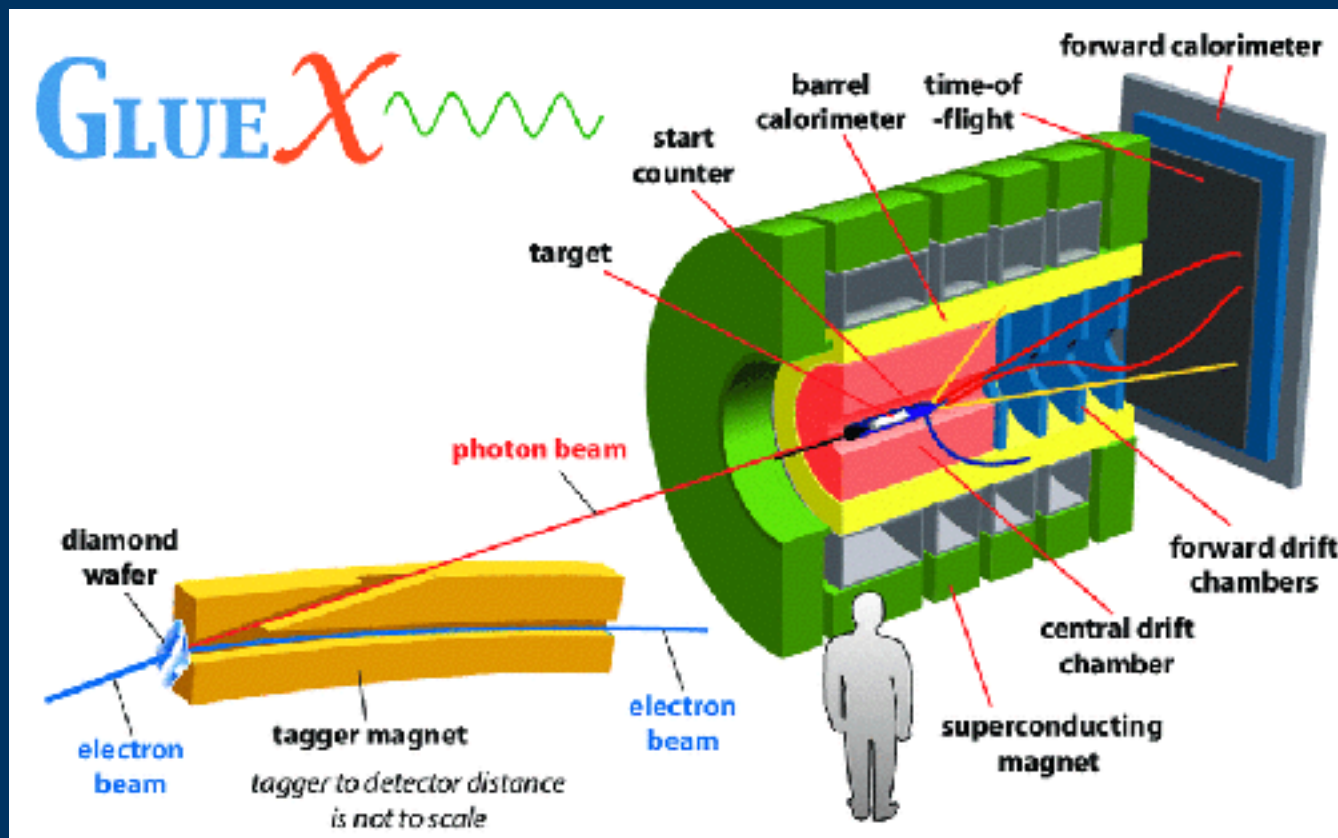
$M(K^+ \pi^-)$



K-Long Facility and GlueX Detector



24 m; K_L beam reconstruction



Reconstruction in GlueX detector

K_L momentum reconstruction:

- from time-of-flight between kaon time at "vertex" and time at Be target.

$$\text{Flight_distance (L)} = 2400 + \text{vertex_z} - 63.8 + \text{Delta}$$

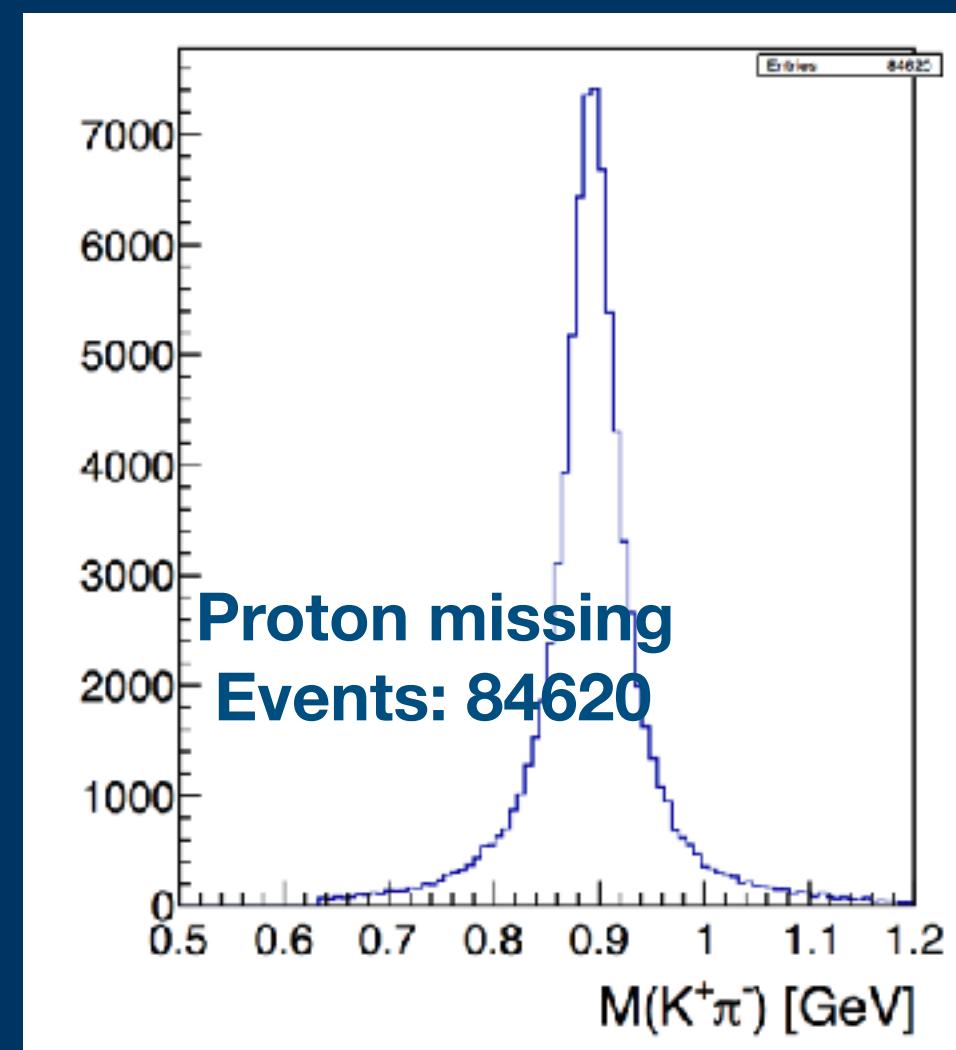
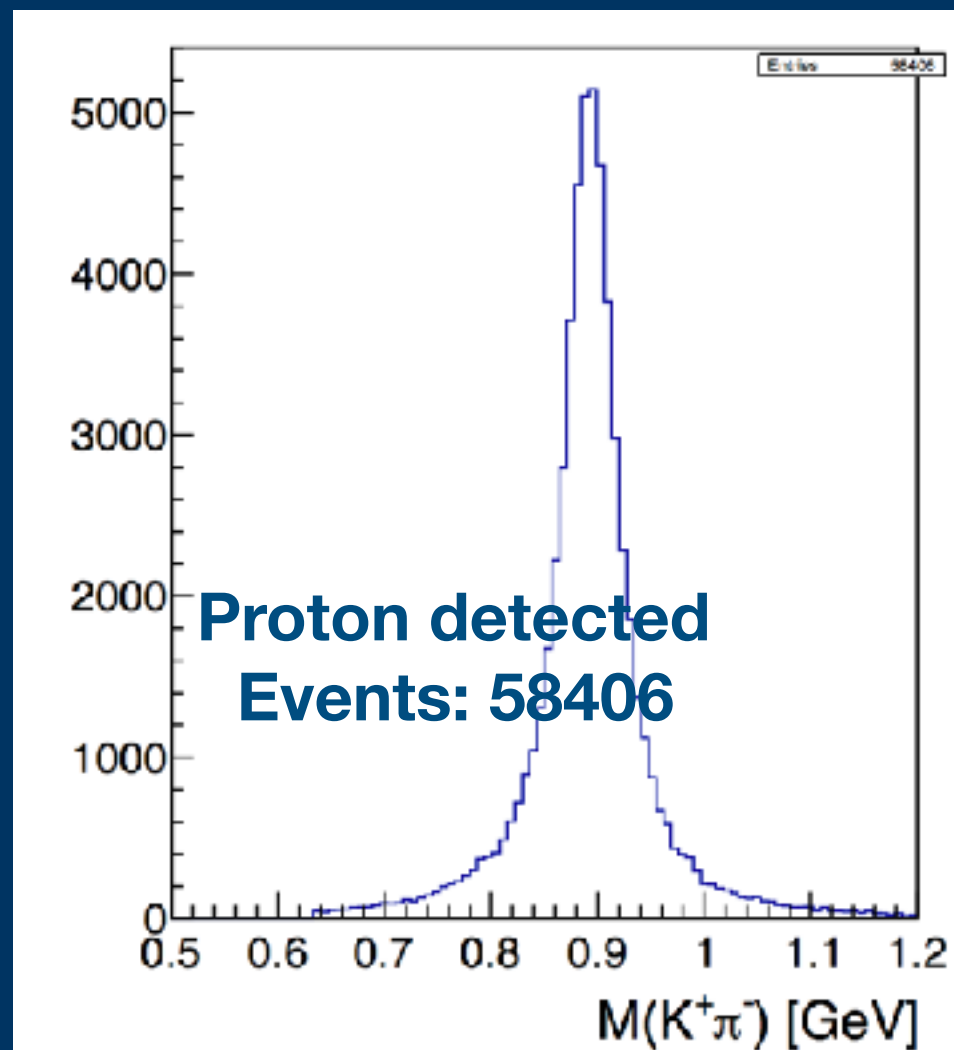
$$\text{flight_time} = \text{Flight_distance}/(c*\text{beta_thrown})$$

$$\text{time_difference} = k_vertex_time - \text{flight_time}; k_vertex_time: \text{TOF time at vertex}$$

Final State particle reconstruction $K_L p \rightarrow K^* p \rightarrow K^+ \pi^- p$

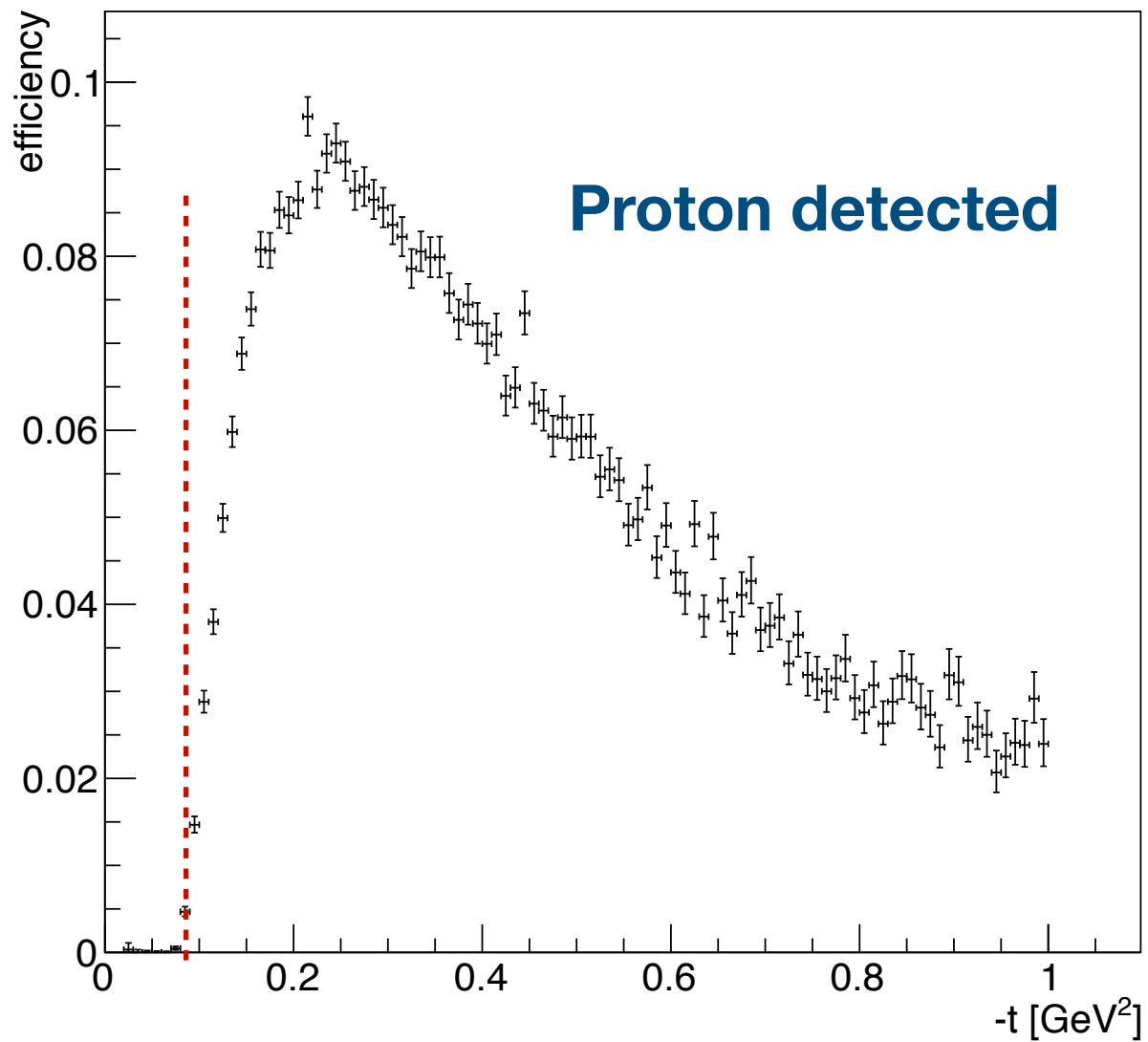
- K^+ , π^- and proton
- K^+ , π^- and (proton)

Well Reconstructed Kpi system in both cases; More stat for proton missing



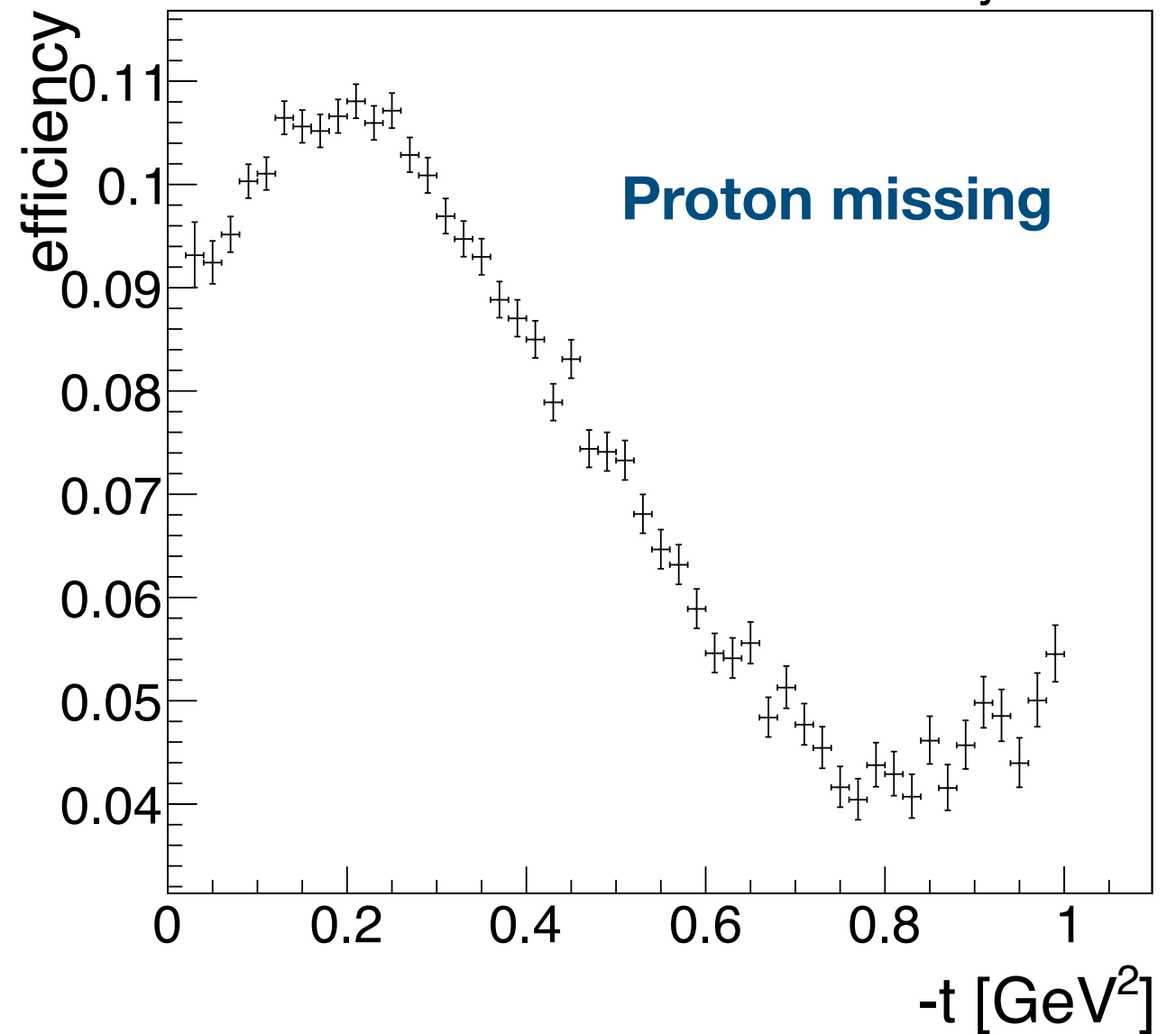
Efficiency

Transfer Four Momentum Efficiency



With proton being detected,
 $-t$ stop at 0.08 GeV²

Transfer Four Momentum Efficiency

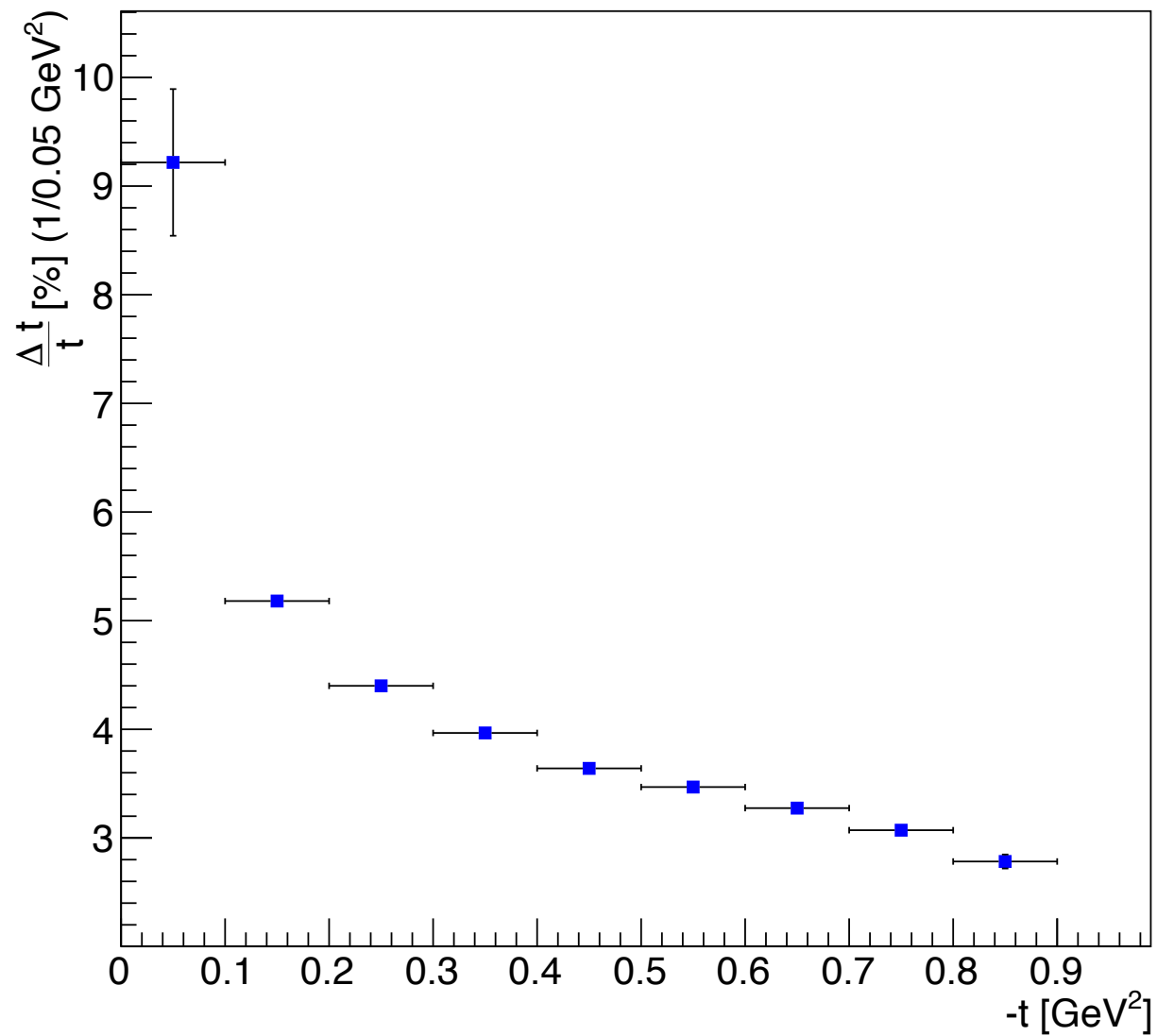


$-t$ reach to pion pole for the
missing proton

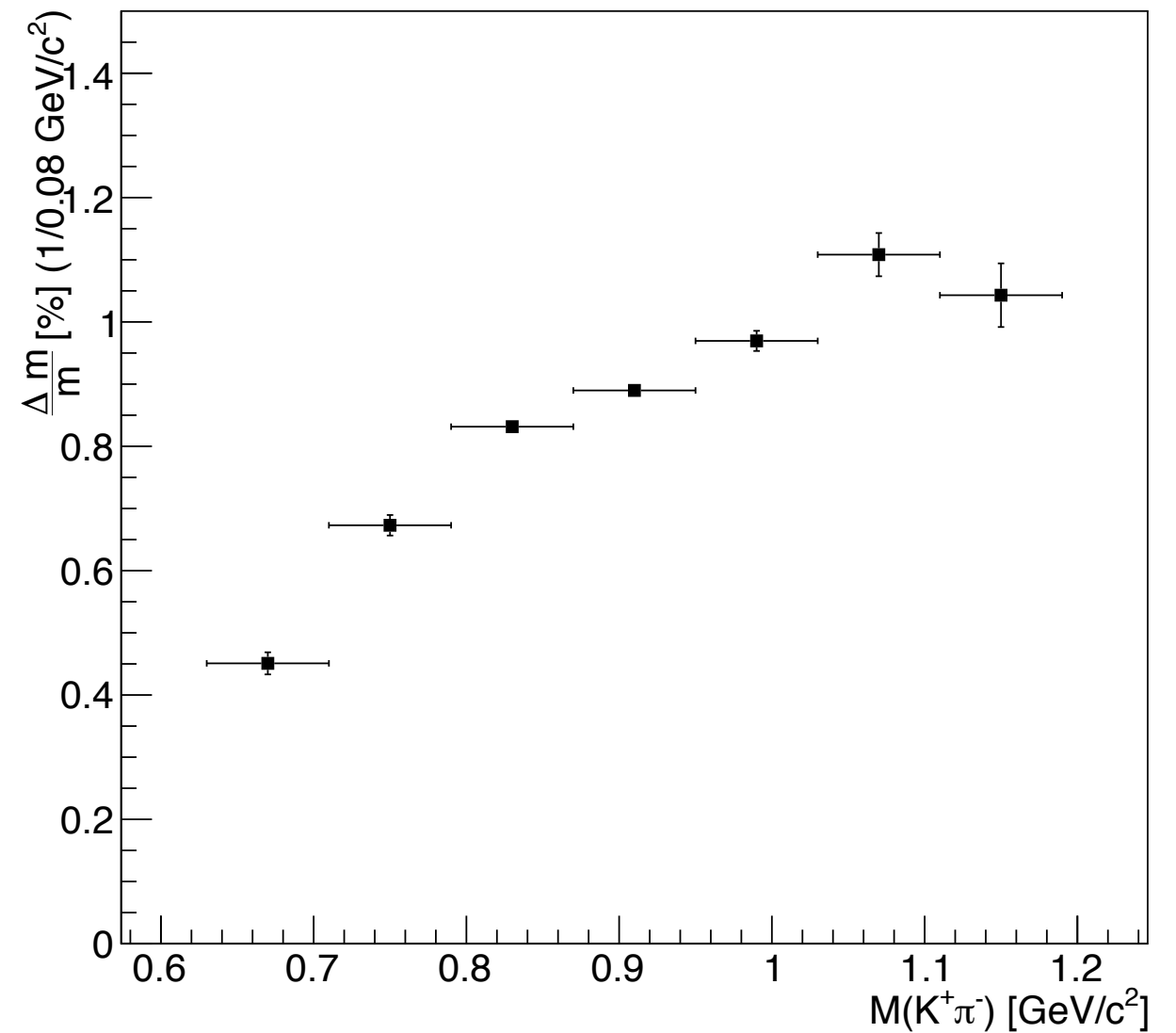
Resolution

Proton detected

Four Momentum Resolution for $K_L p \rightarrow K^+ \pi^- p$



$K^+ \pi^-$ Invariant Mass Resolution for $K_L p \rightarrow K^+ \pi^- p$

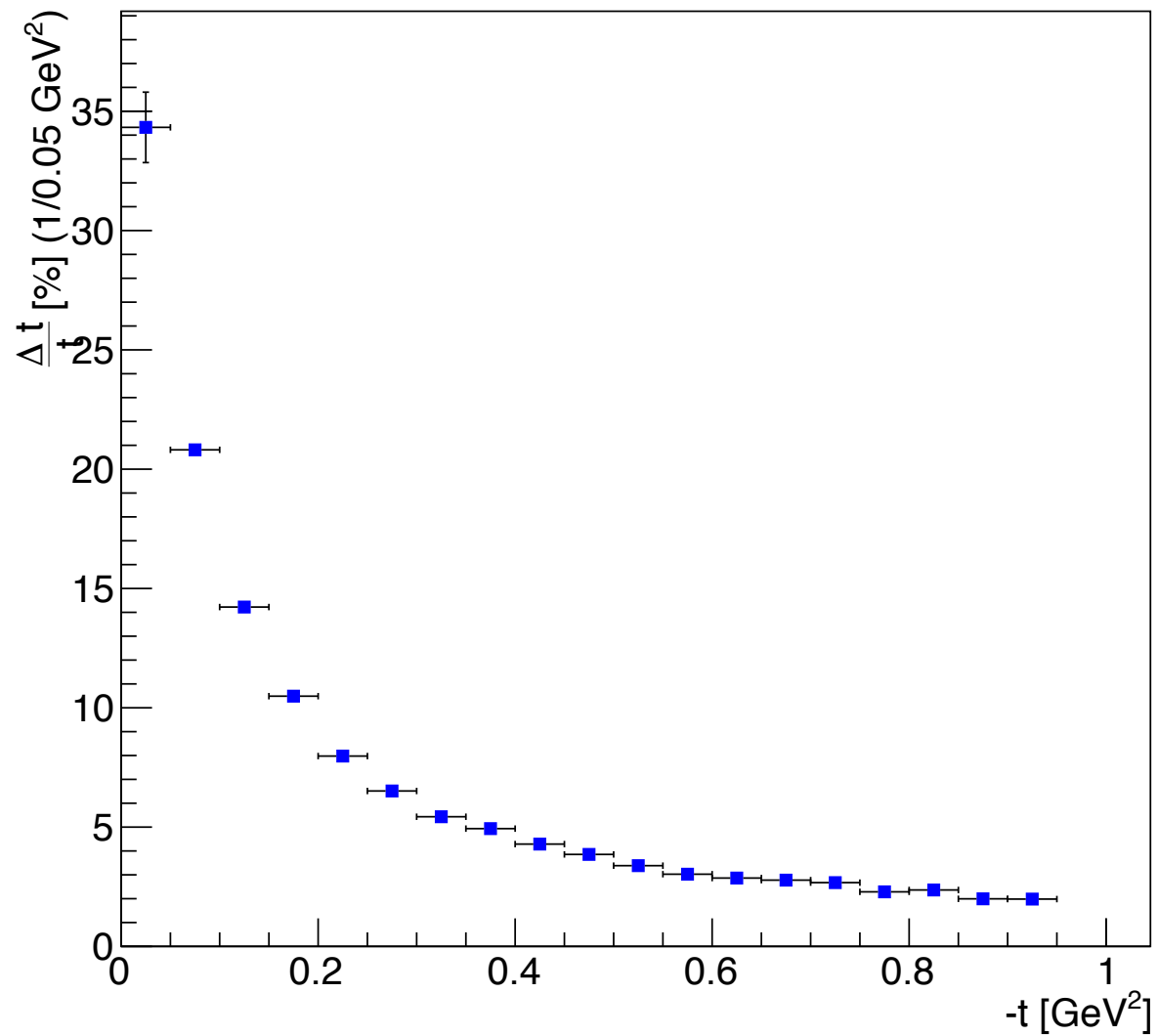


t is calculated using recoil proton
and target

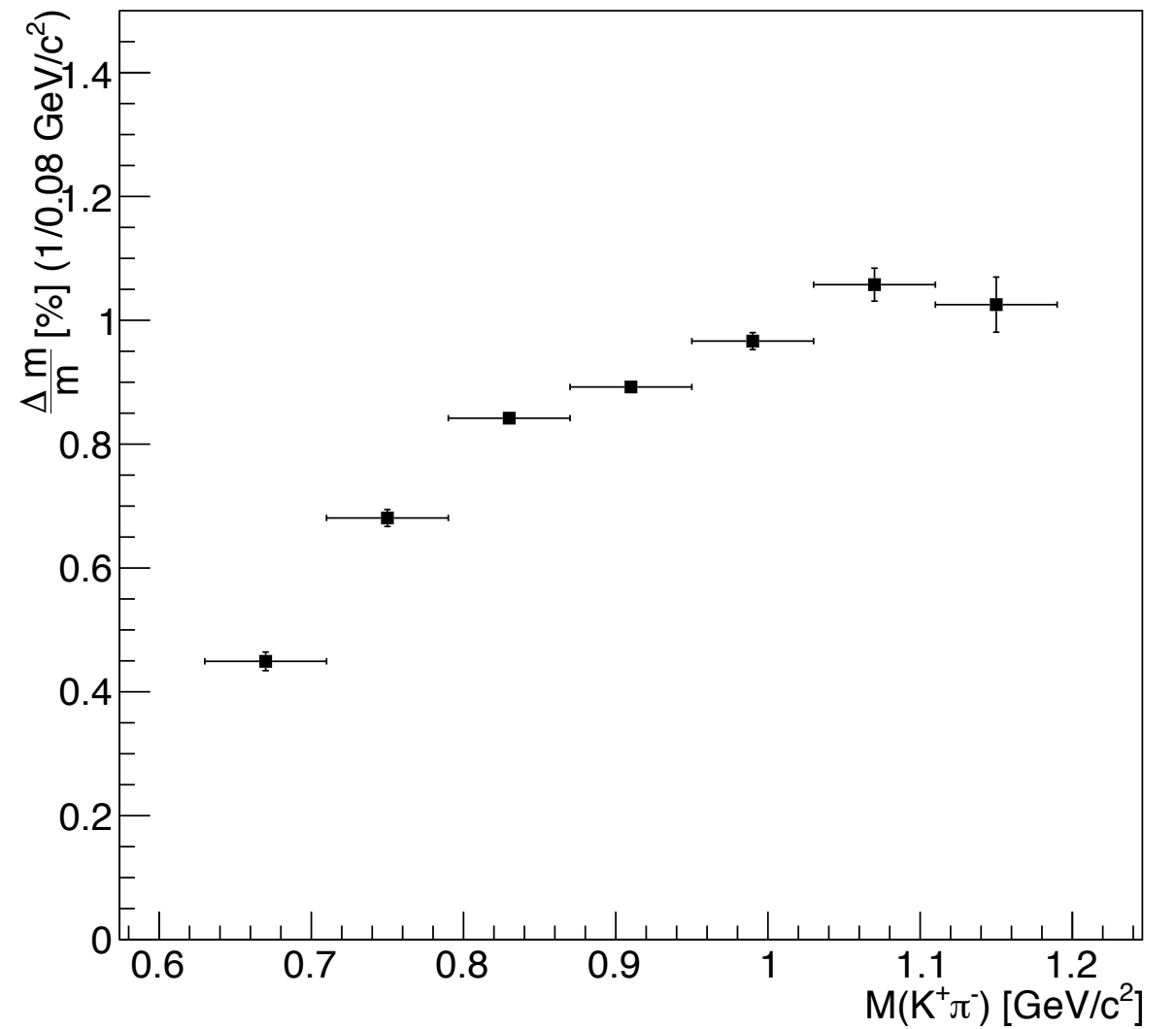
Resolution

Proton missing

Four Momentum Resolution for $K_L p \rightarrow K^+ \pi^- (p)$

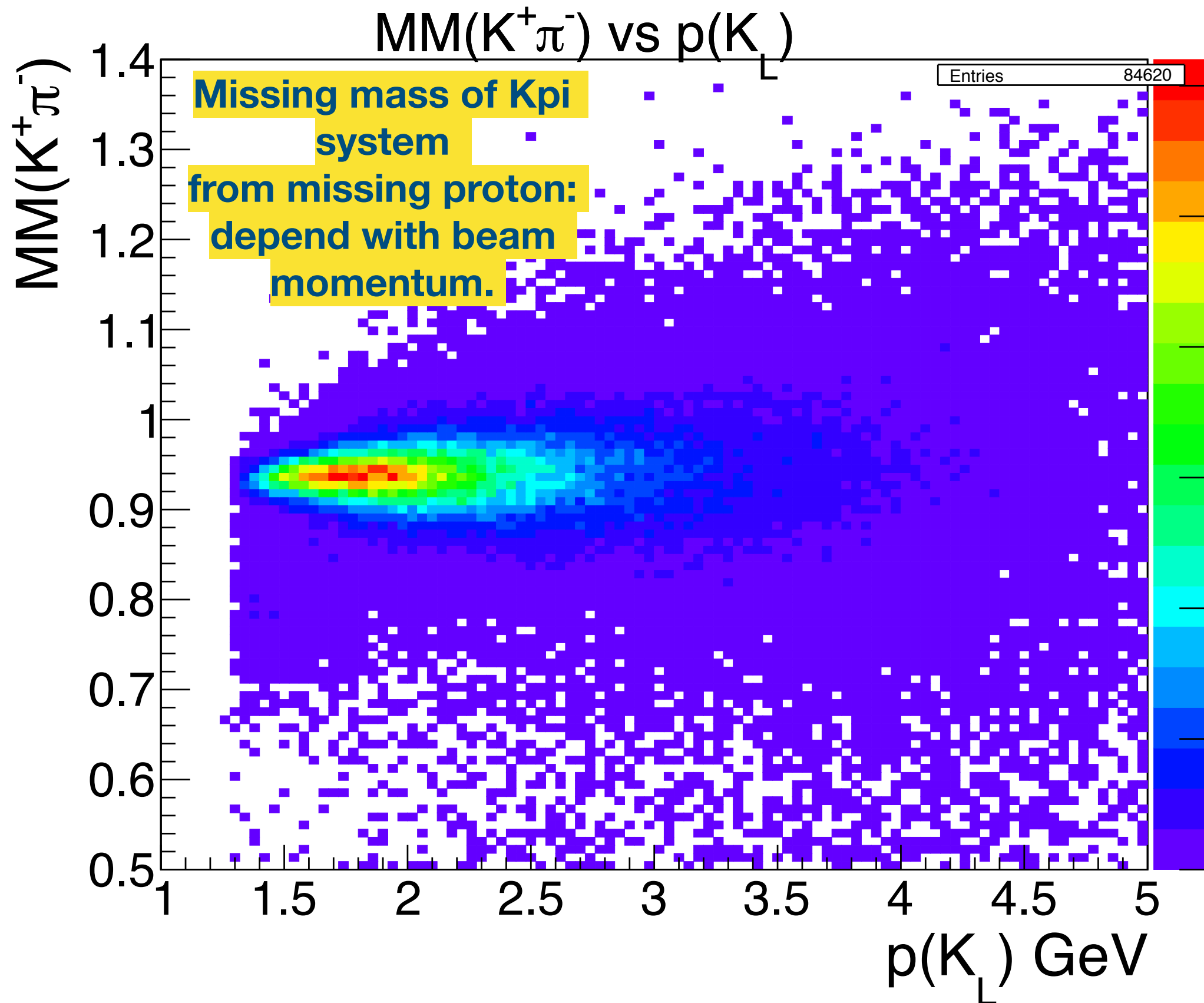


$K^+ \pi^-$ Invariant Mass Resolution for $K_L p \rightarrow K^+ \pi^- (p)$



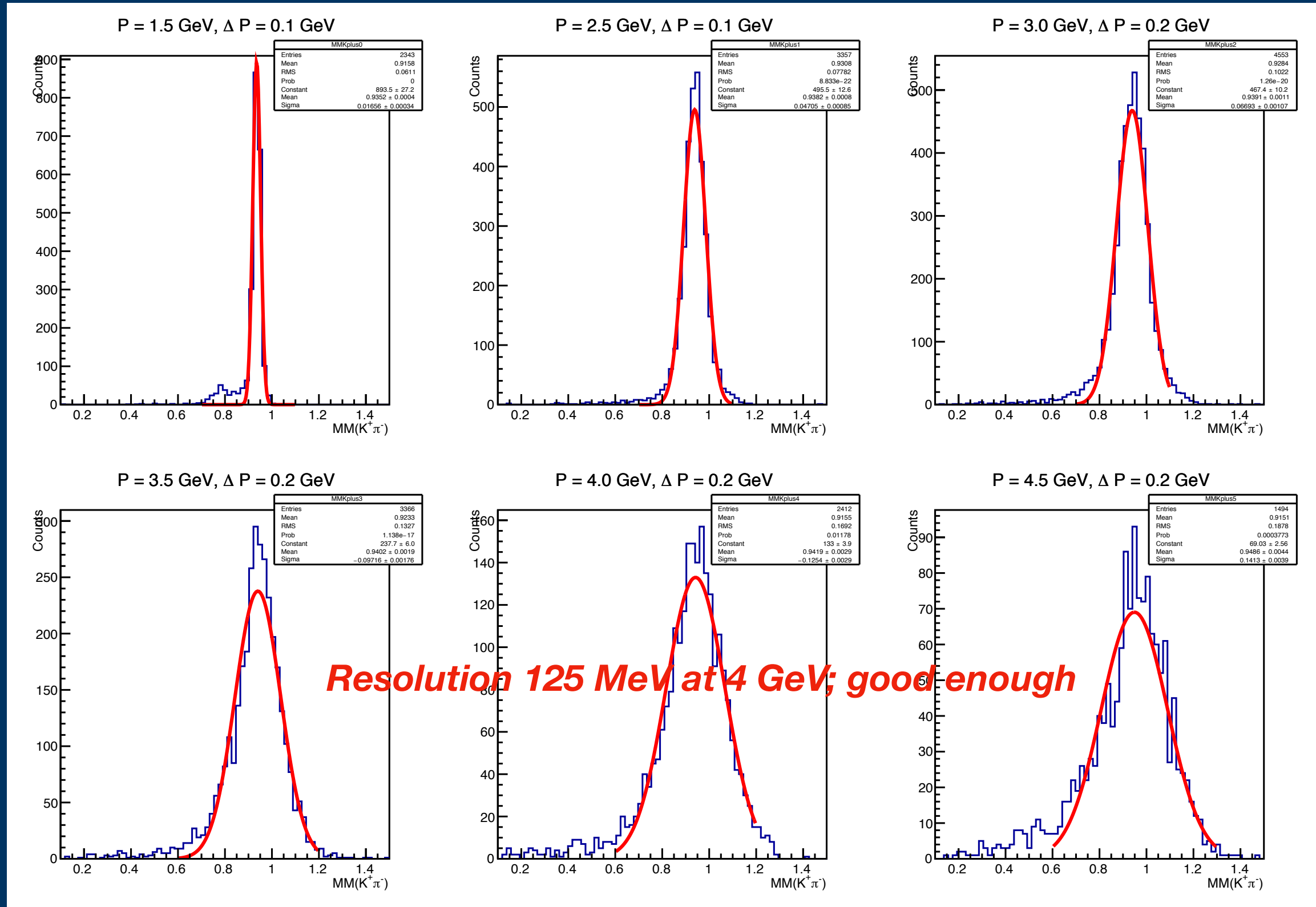
t is calculated from beam and kpi system.

Missing mass of $K^+\pi^-$

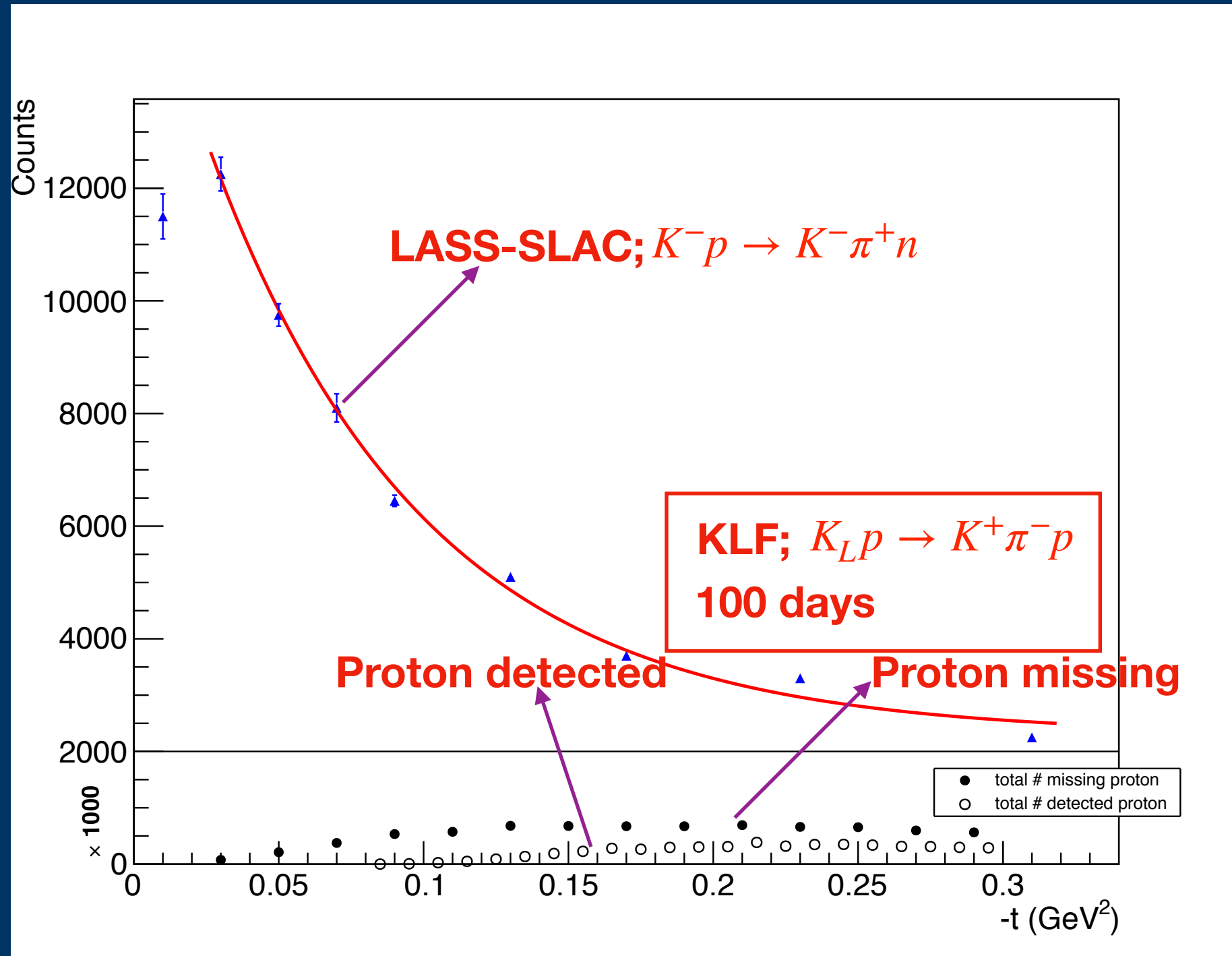


Missing mass of $K^+\pi^-$

Missing mass at different beam momentum



Comparison with SLAC



- Two order of more statistics compared to previous SLAC measurement.

Amplitude Analysis: moment extraction

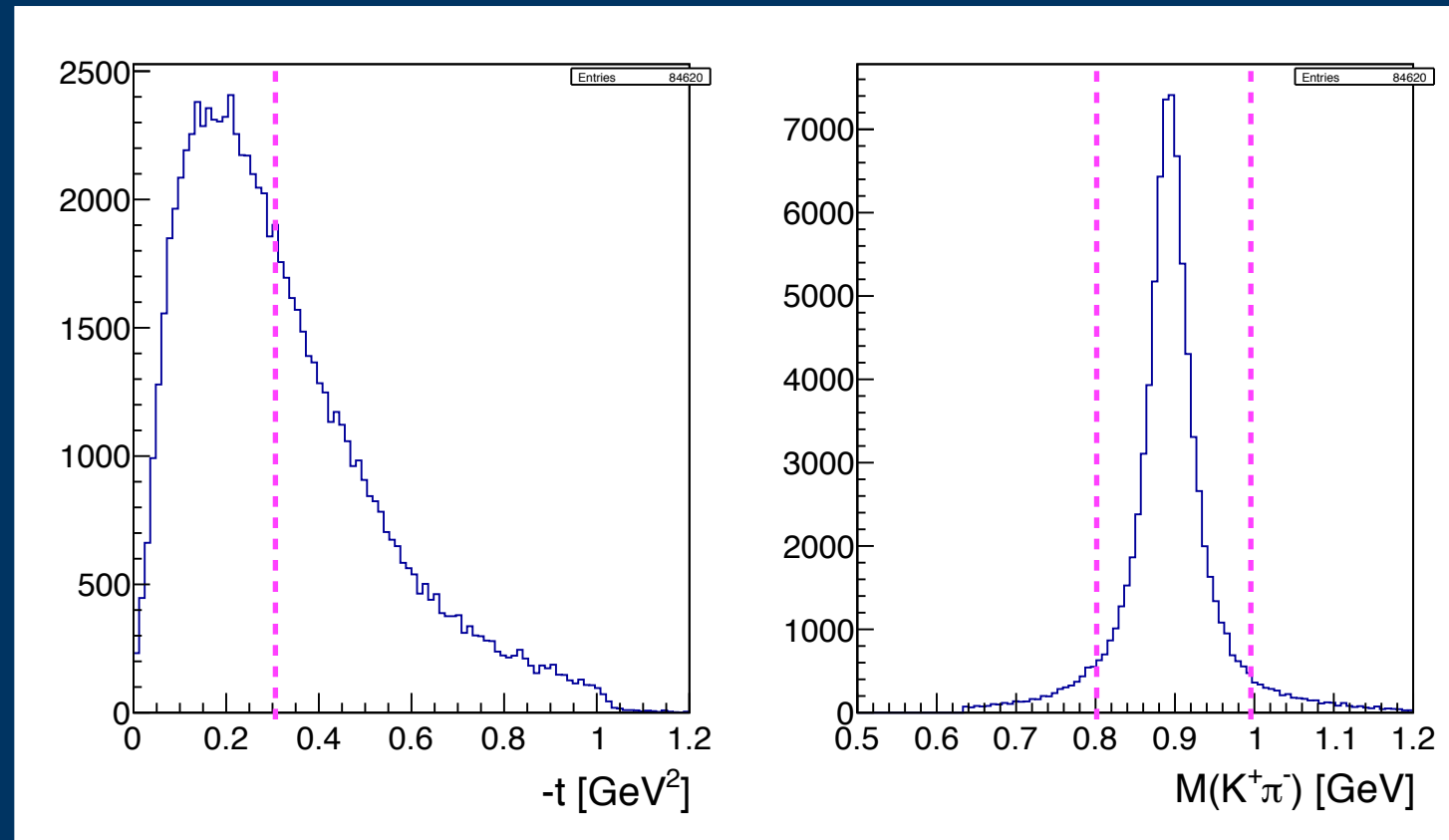
(work in progress)

Amptool library: binning on mass and $-t$

S- wave: $\kappa(800)$, $K_0^*(1430)$, ...

P- wave: $K^*(892)$, $K^*(1680)$, ...

D- wave: $K_2^*(1430)$, ...



Moments: projection of amplitudes

$$H(0,0) = + 1 |S0|^2 + 1 |P0|^2 + 1 |P-|^2 + 1 |D0|^2 + 1 |D-|^2 + 1 |P+|^2 + 1 |D+|^2$$

$$H(1,0) = + 1.1547 \text{Re}(P0 * S0) + 1.0328 \text{Re}(D0 * P0) + 0.894427 \text{Re}(D- * P-) + 0.894427 \text{Re}(D+ * P+)$$

$$H(1,1) = + 0.816497 \text{Re}(P- * S0) - 0.365148 \text{Re}(D0 * P-) + 0.632456 \text{Re}(D- * P0)$$

$$H(2,0) = + 0.4 |P0|^2 - 0.2 |P-|^2 + 0.894427 \text{Re}(D0 * S0) + 0.285714 |D0|^2 + 0.142857 |D-|^2 - 0.2 |P+|^2 + 0.142857 |D+|^2$$

$$H(2,1) = + 0.489898 \text{Re}(P- * P0) + 0.632456 \text{Re}(D- * S0) + 0.202031 \text{Re}(D- * D0)$$

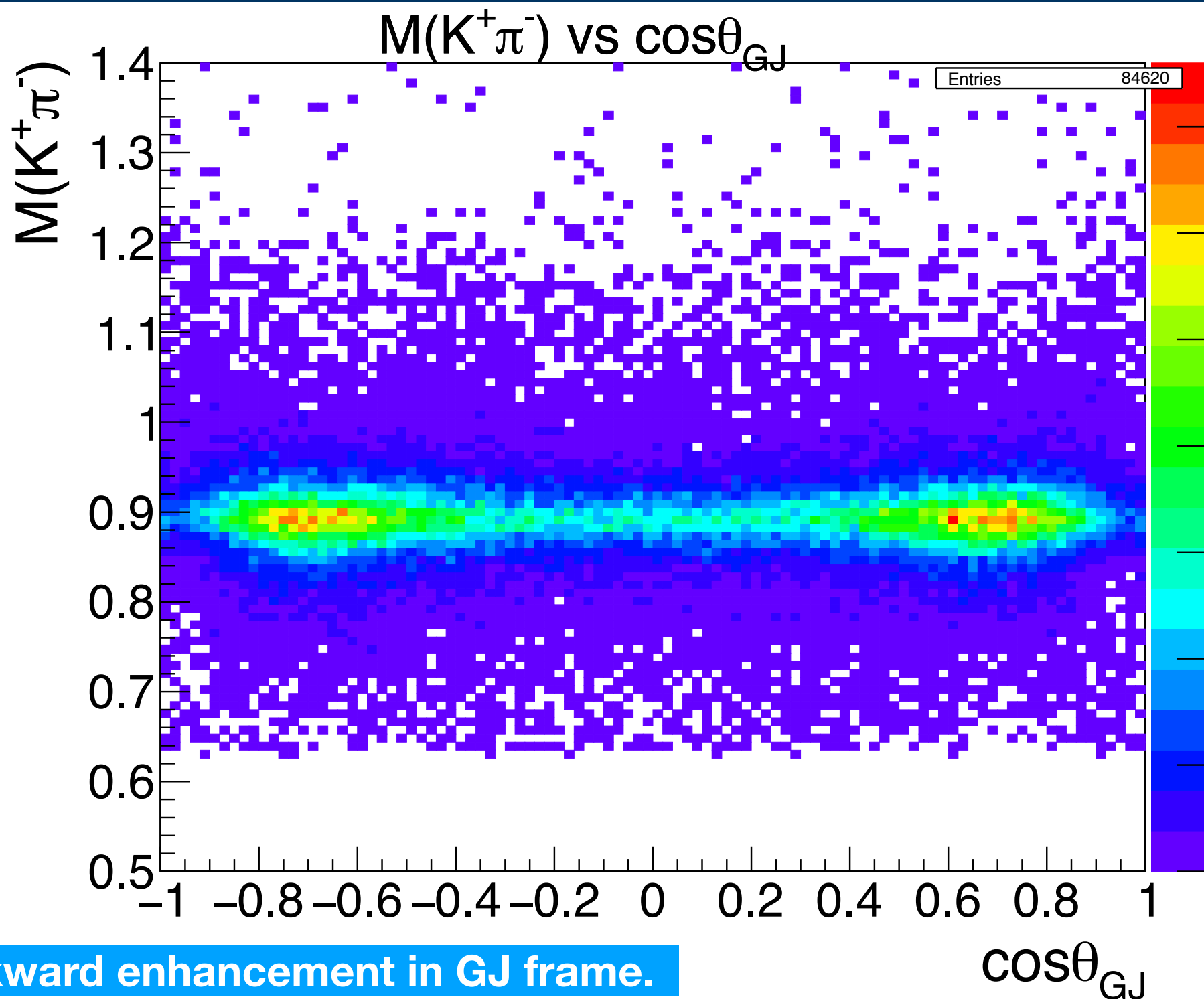
$$H(2,2) = + 0.244949 |P-|^2 + 0.174964 |D-|^2 - 0.244949 |P+|^2 - 0.174964 |D+|^2$$

Phys.Rev. D80 (2009) 072005

Angular distribution at GJ frame

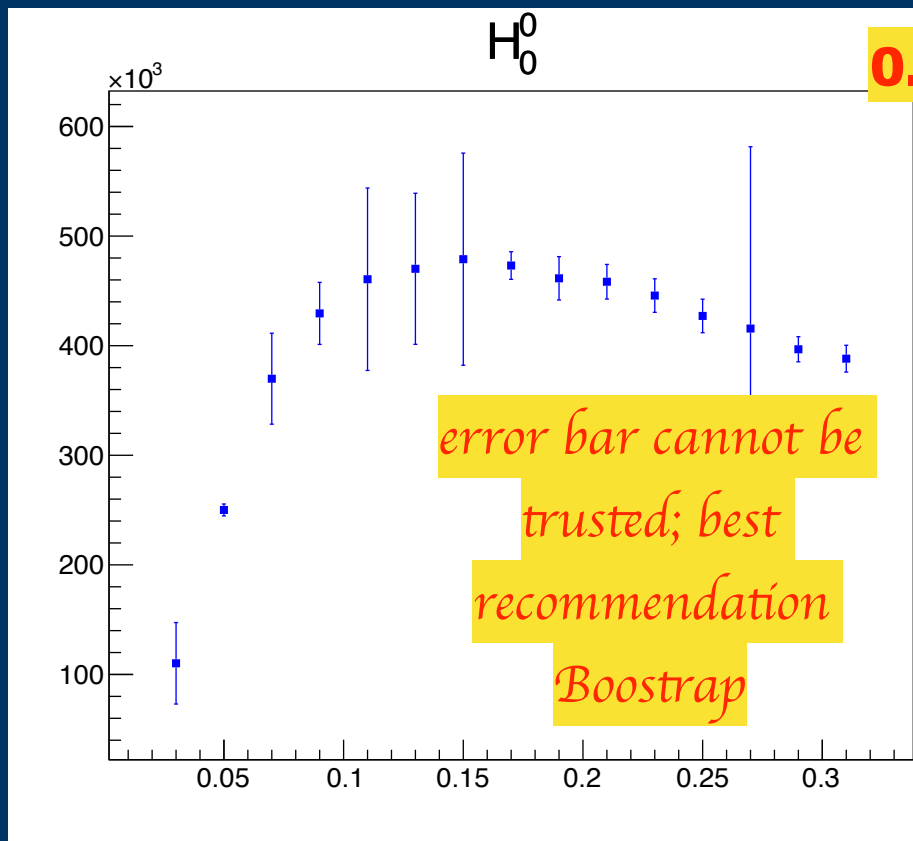
Reconstructed distribution:

- data generated with Regge model, multiple exchanges : π, ρ, A_2, \dots [*Nucl.Phys.B10(1969) 151-168*]



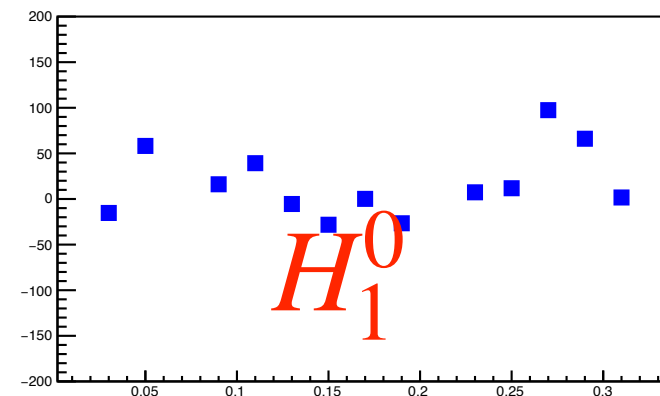
forward and backward enhancement in GJ frame.

-t dependent Moments

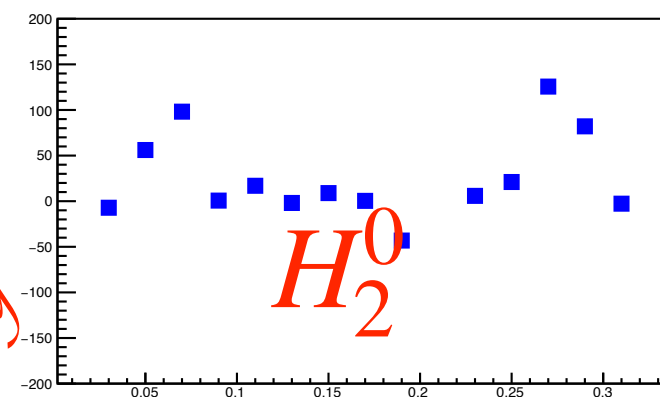
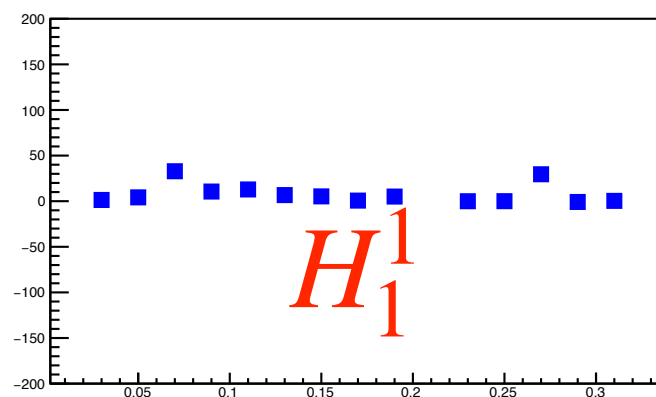


0.02 < -t < 0.3 : 15 bins:

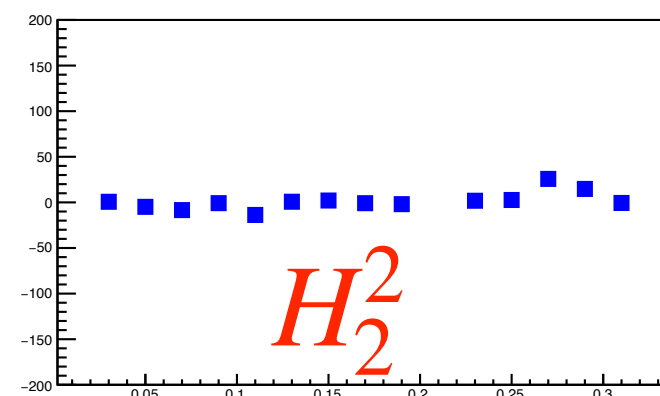
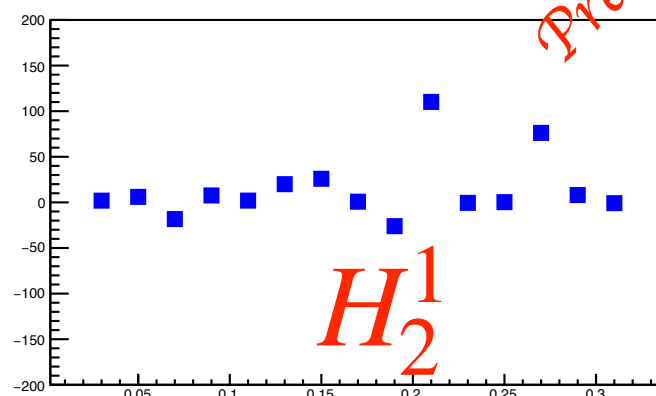
0.8 < $M(K^+\pi^-)$ < 1.0



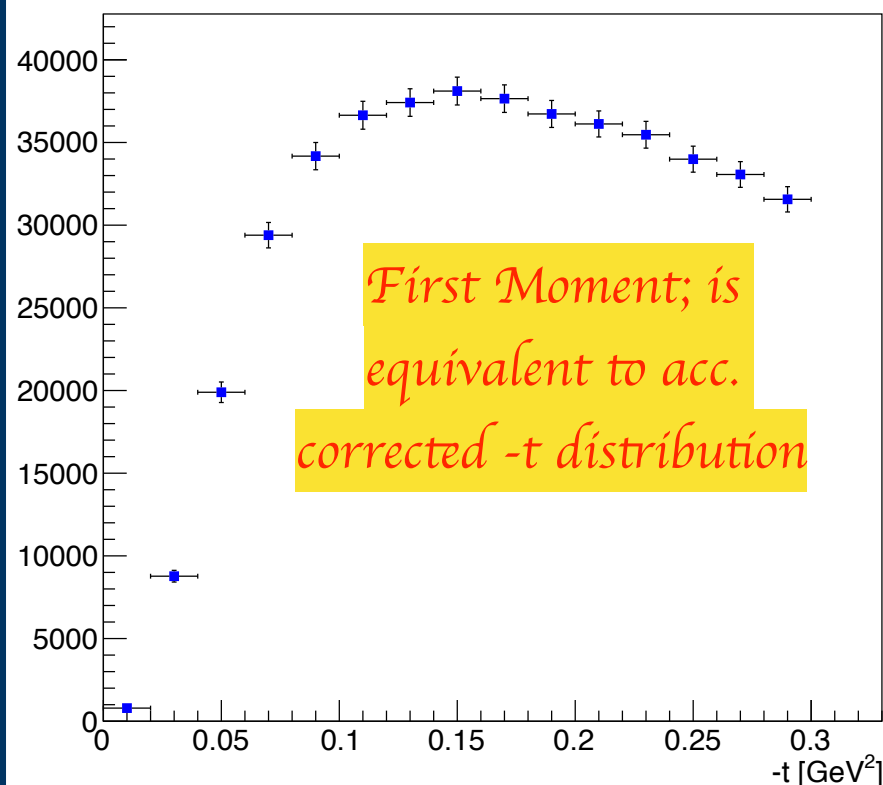
Errors are excluded



Preliminary



-t for $K_L p \rightarrow K^+\pi^-(p)$



Conclusion

$K\pi$ simulation was performed using Geant4.

- Resolution look good enough for $-t$ and $M(K^+\pi^-)$ for both missing and detected proton cases.
- Missing proton help to reach down to pion pole in the small $-t$ region whereas detected proton in the final state, stop $-t$ at 0.08 GeV^2
- KLF could produce two order of more statistics compared to previous SLAC measurement.

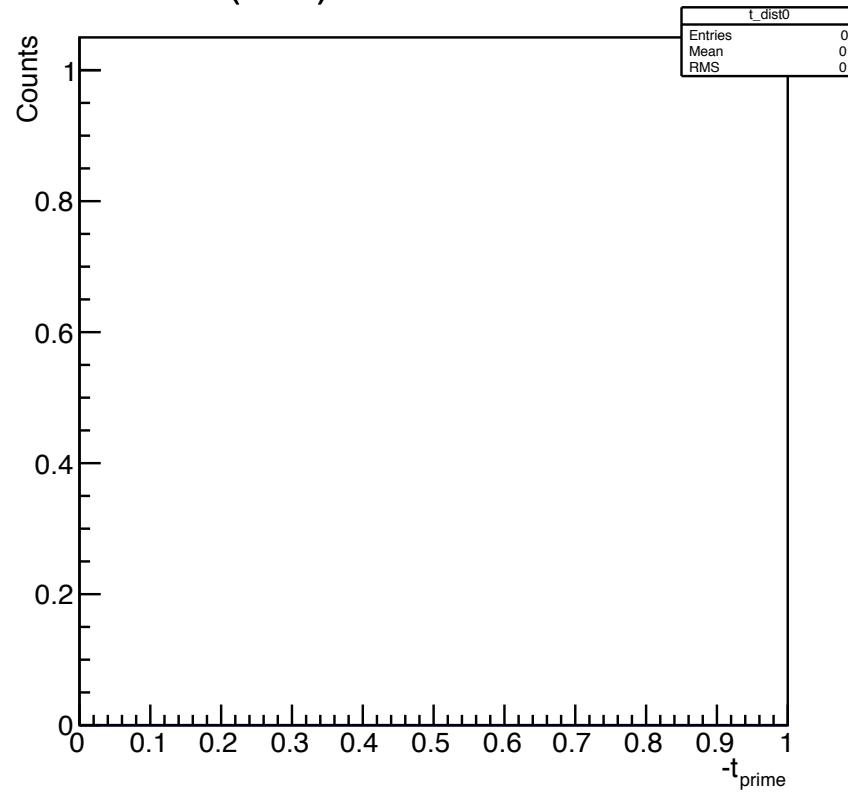
$K\pi$ Scattering amplitude (work in progress)

- Amptools; Binning on $-t$ and $M(K^+\pi^-)$
- Fit includes up to D-wave
- First few moments were extracted.

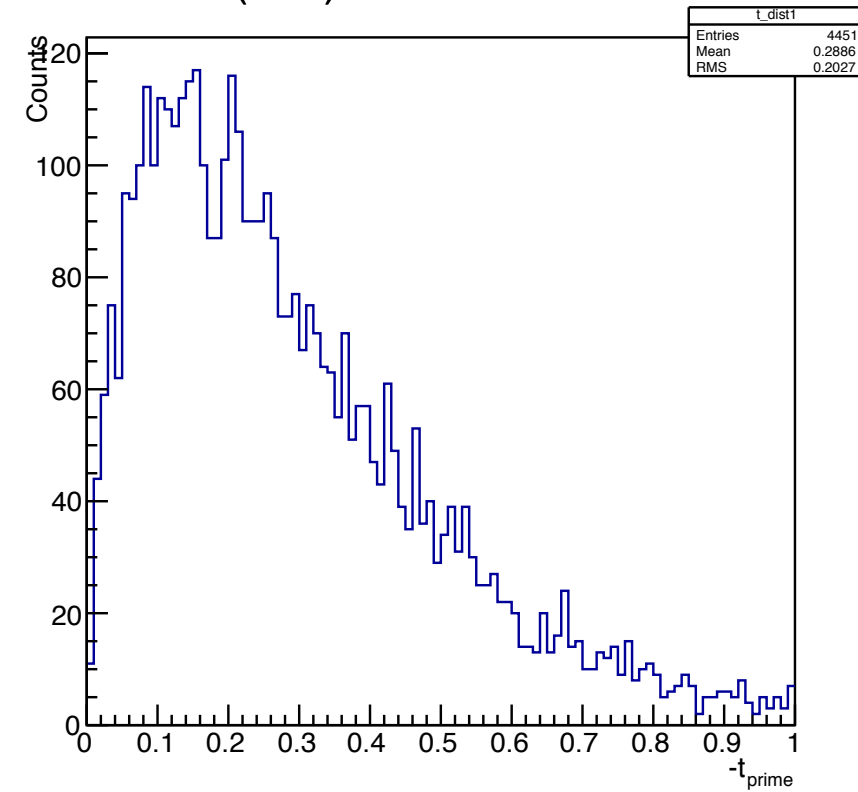
Back Up

M(K⁺π⁻) binned for t

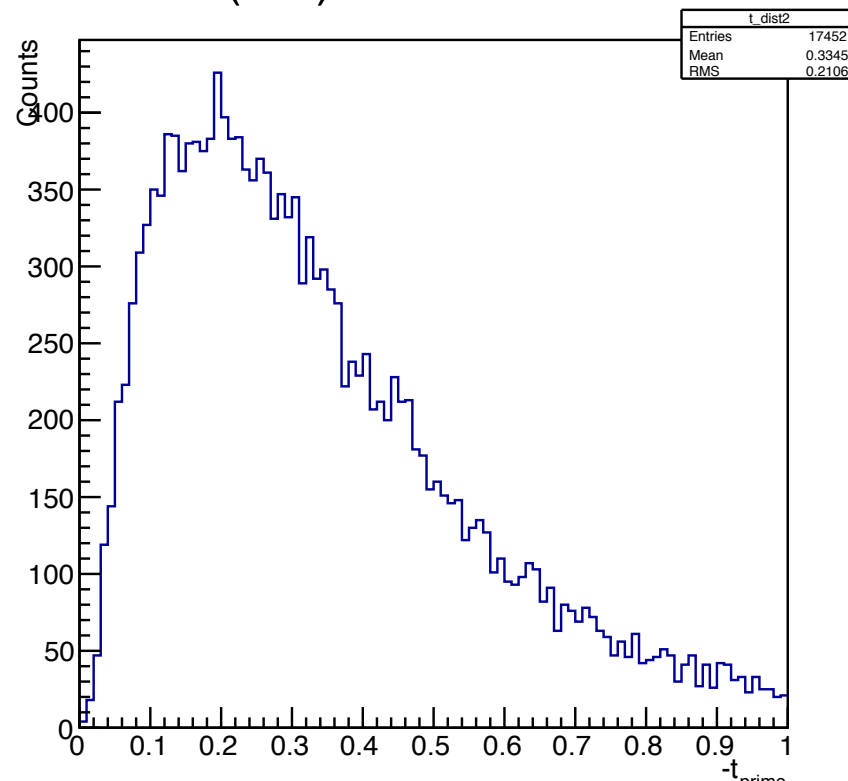
M(K⁺π⁻) = 0.60 - 0.70 GeV



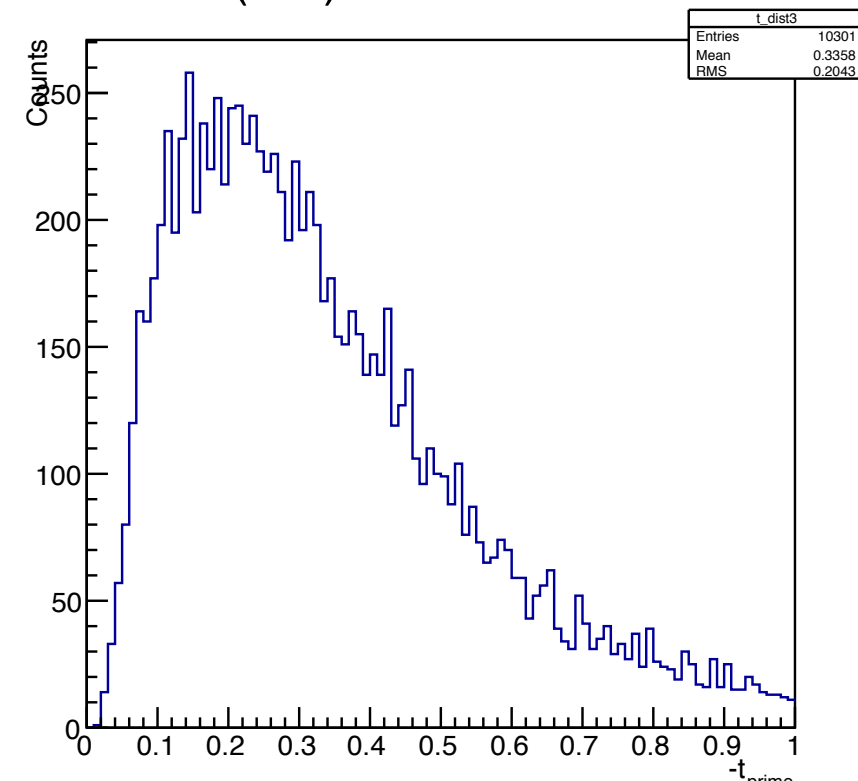
M(K⁺π⁻) = 0.70 - 0.80 GeV



M(K⁺π⁻) = 0.80 - 0.90 GeV



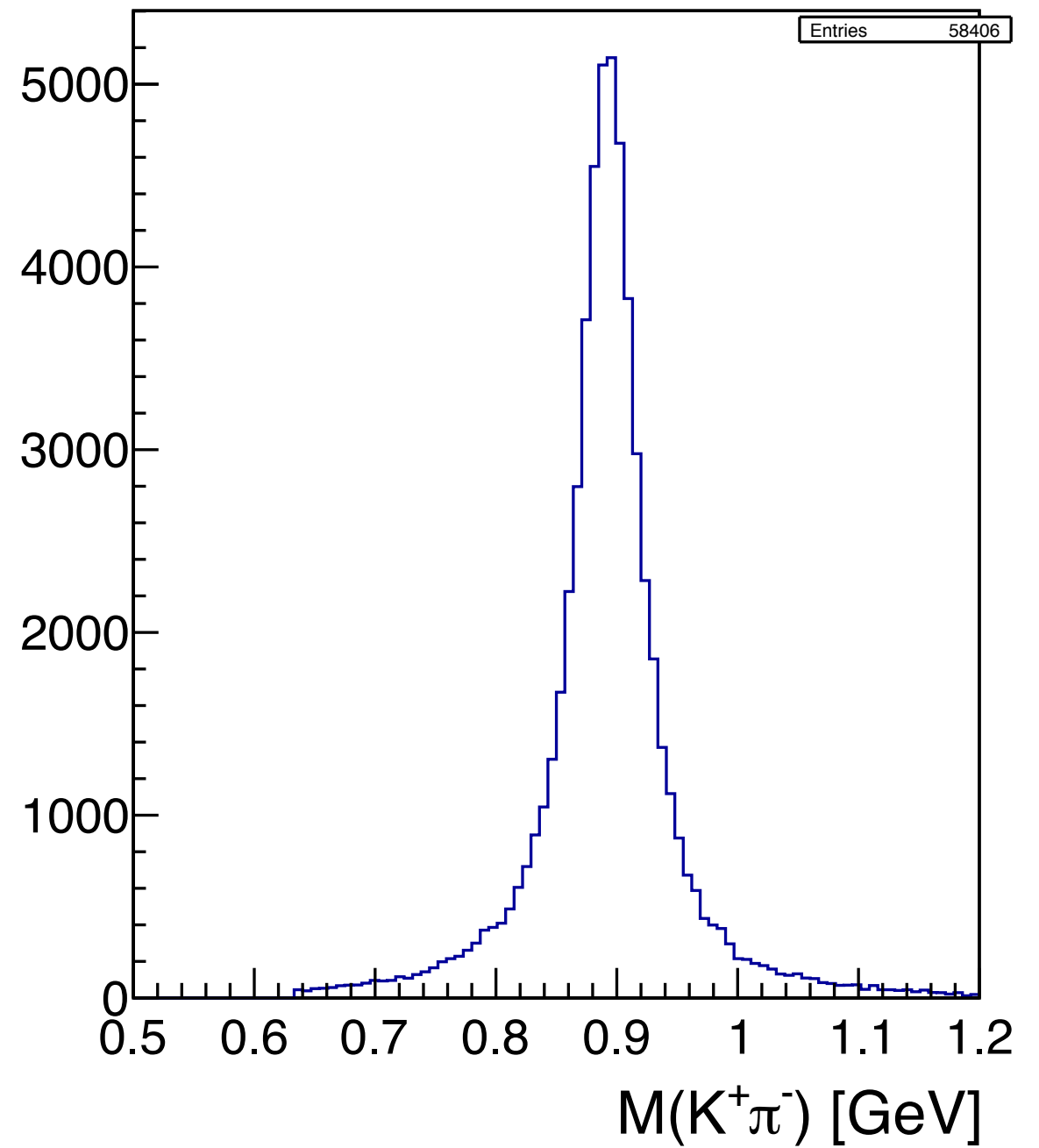
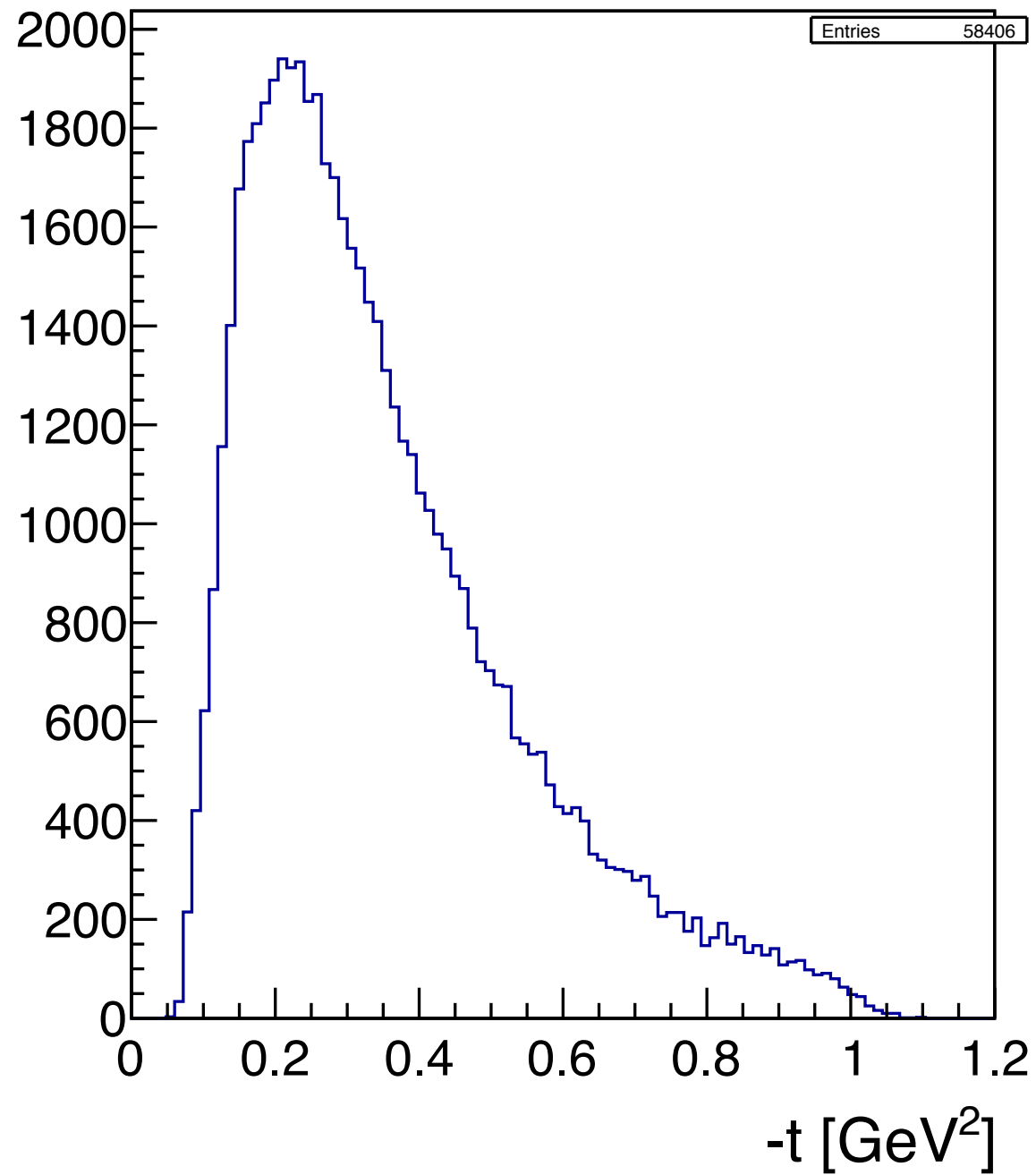
M(K⁺π⁻) = 0.90 - 1.00 GeV



Kpi production

Reconstruction detected proton

$K_L p \rightarrow K^*(892)p$



$M(p\pi^-)$ Vs $-t$

