$K\pi$ simulation study for KLF

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

Shankar Adhikari

Old Dominion University

Motivation

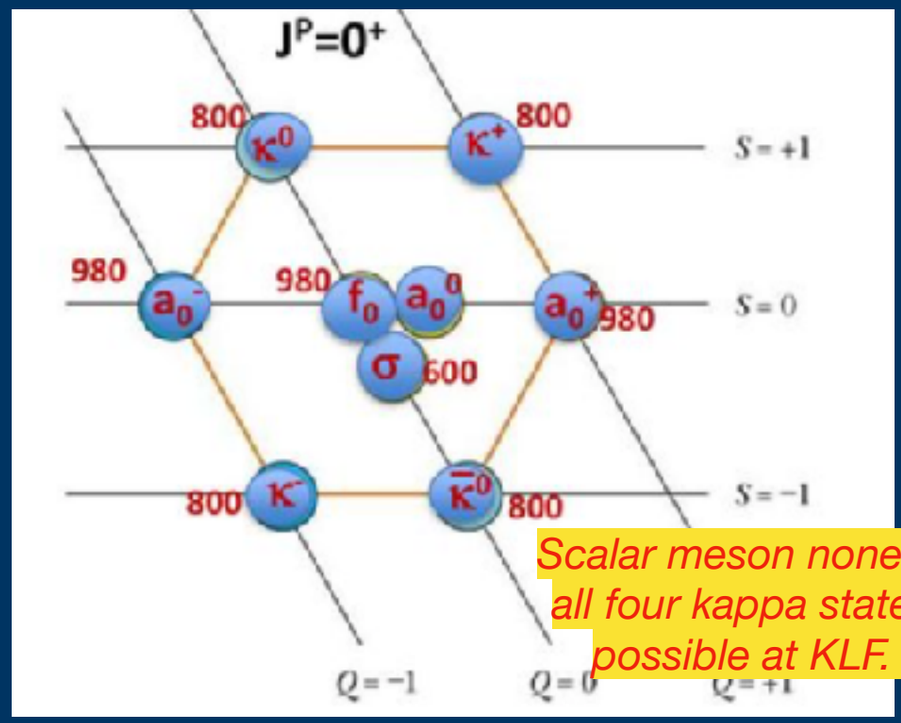
$K\pi$ scattering enables direct investigations of scalar and vector K* states.

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

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

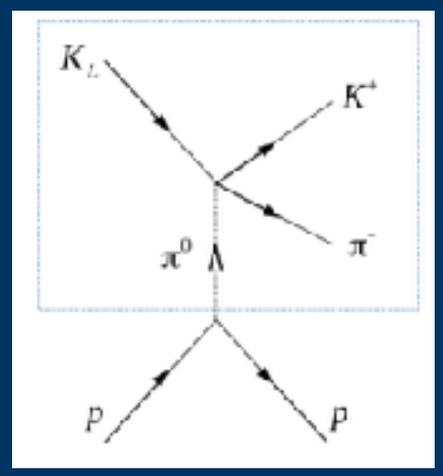
K-long Facility

- **Study of kpi scattering at KLF will support the existence of κ(800) and significantly improve on the uncertainties of determination of its mass and width**



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

$K\pi$ Scattering Amplitude



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

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

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

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

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

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

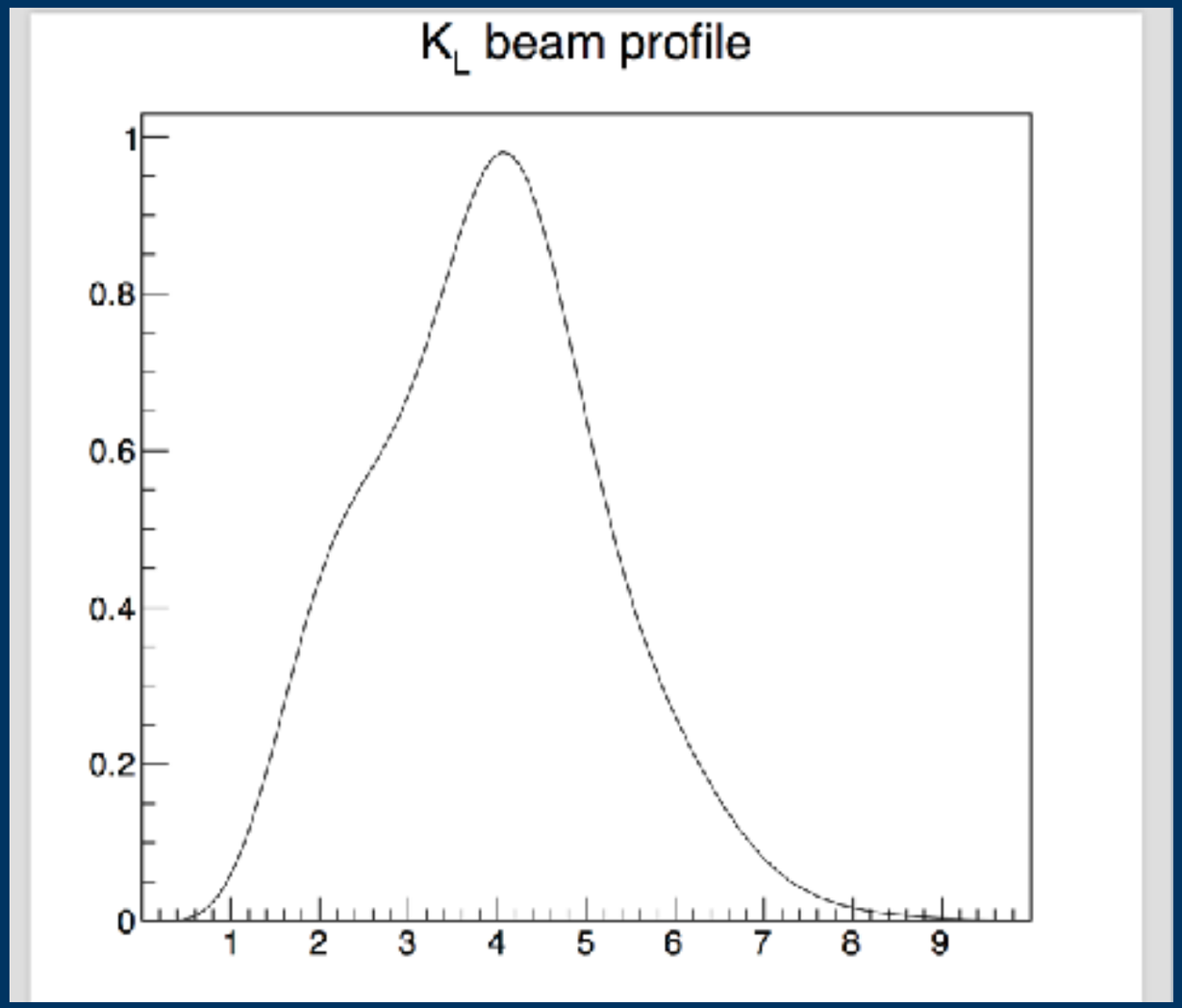
Event Generation

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.

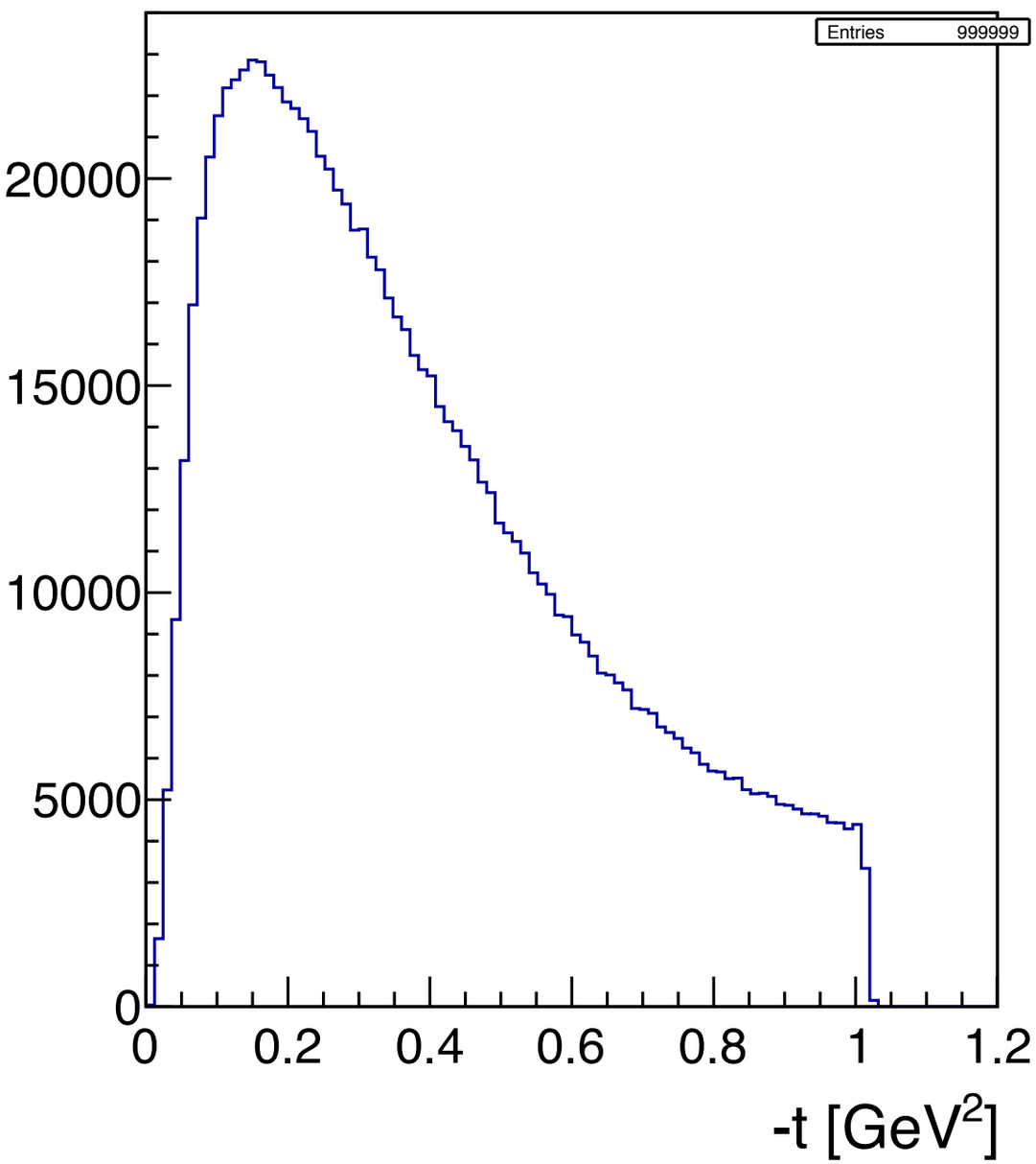


Beam Profile

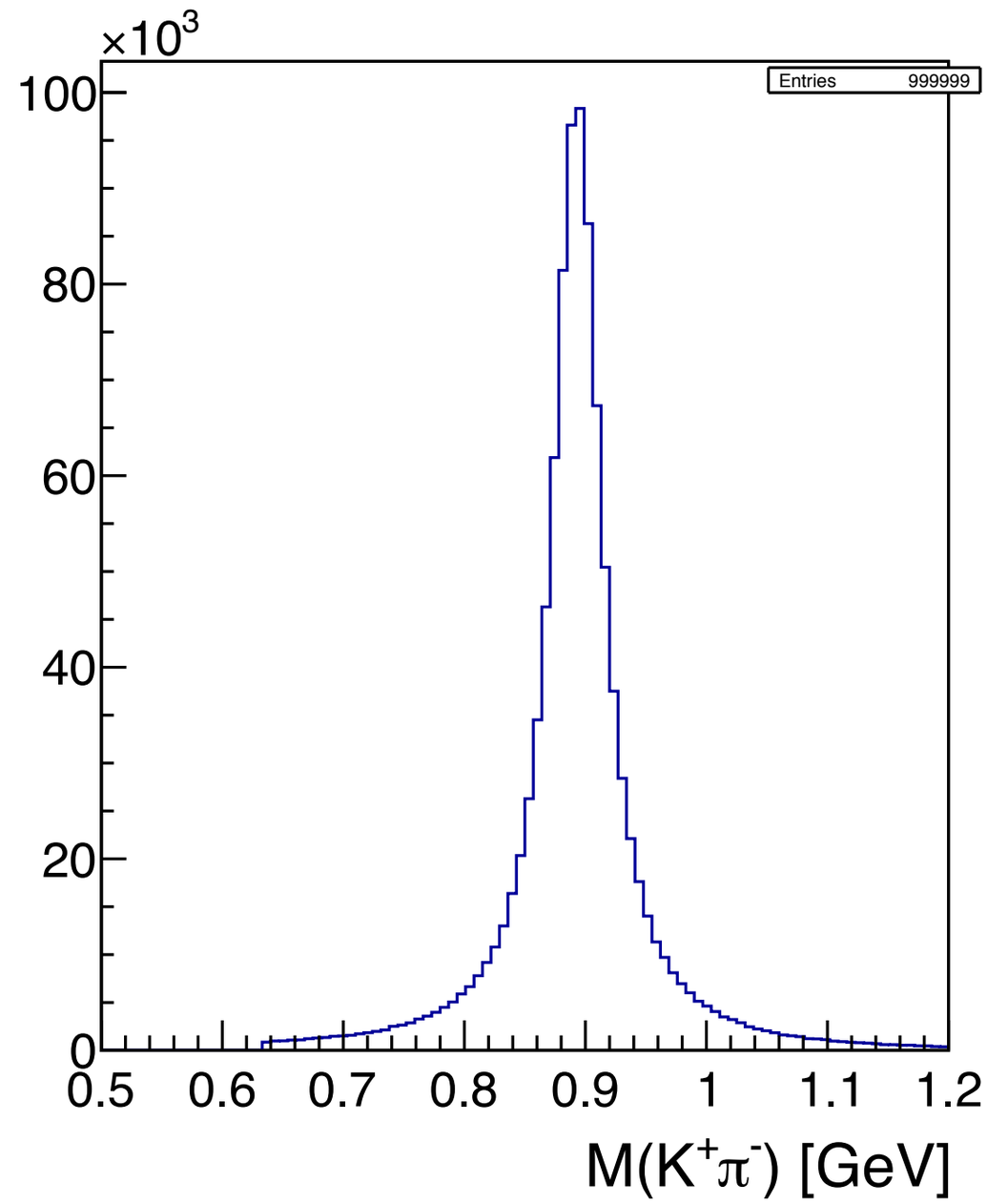
Generation $K_L p \to K^\star(892) p$

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

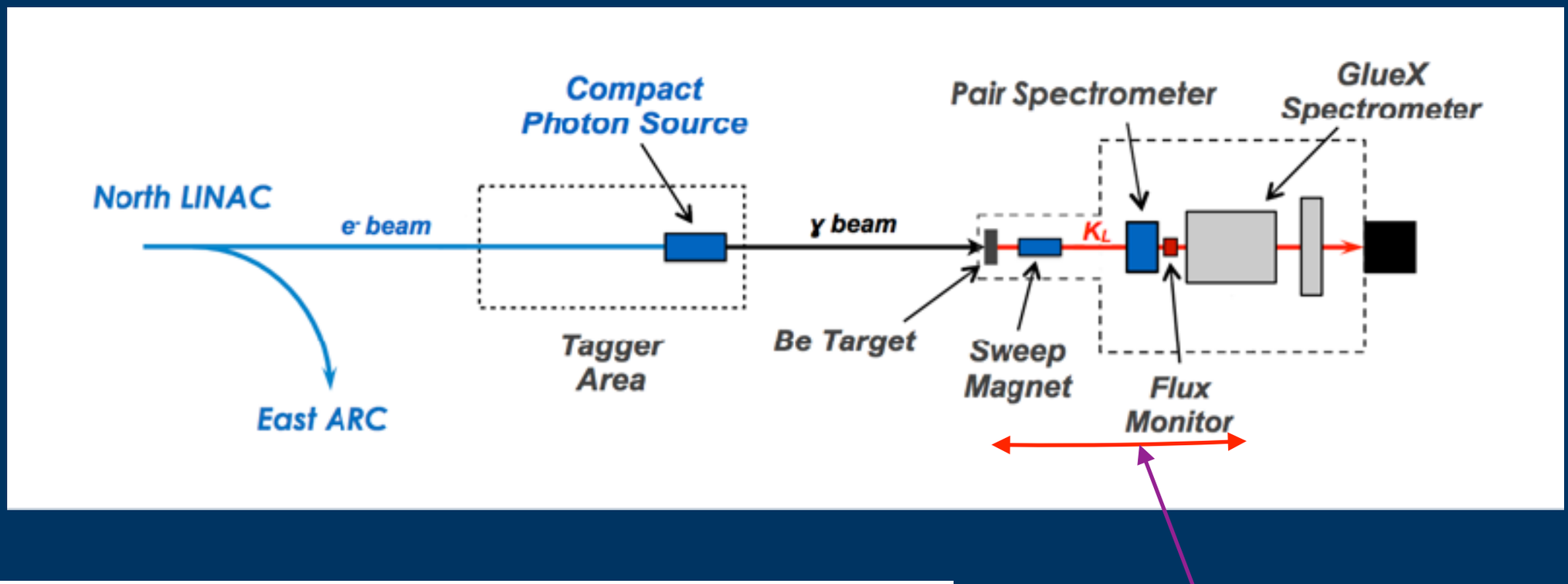
Four Momentum transfer (-t)

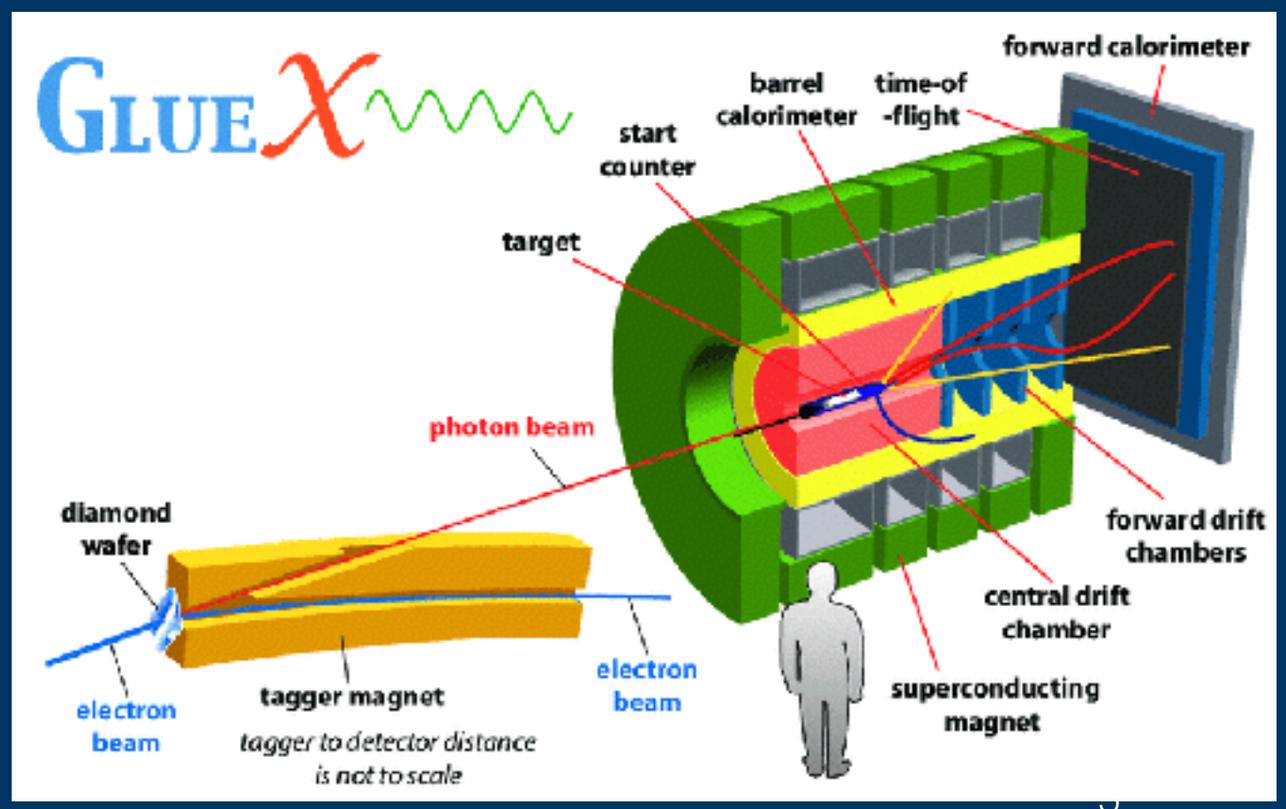


$M(K^+\pi^-)$



K-Long Facility and GlueX Detector





24 m; K_L beam reconstruction

Reconstruction in GlueX detector

K_L momentum reconstruction:

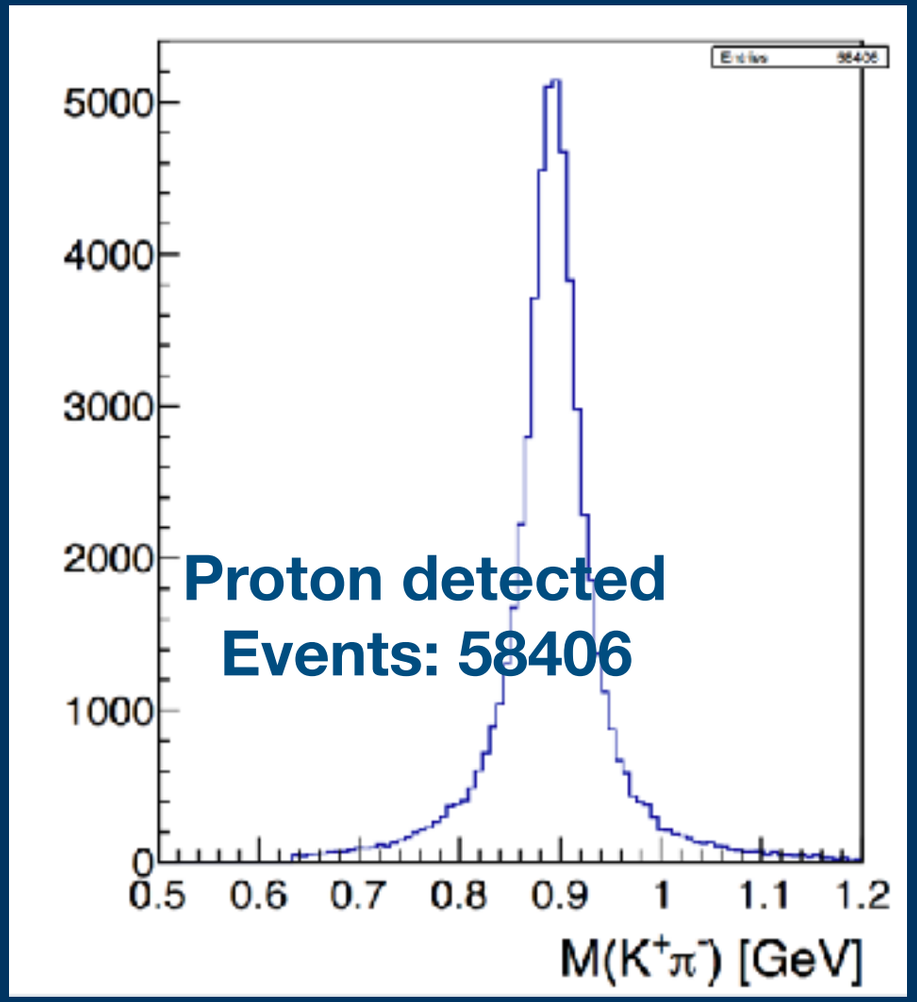
- from time-of-flight between kaon time at "vertex" and time at Be target.

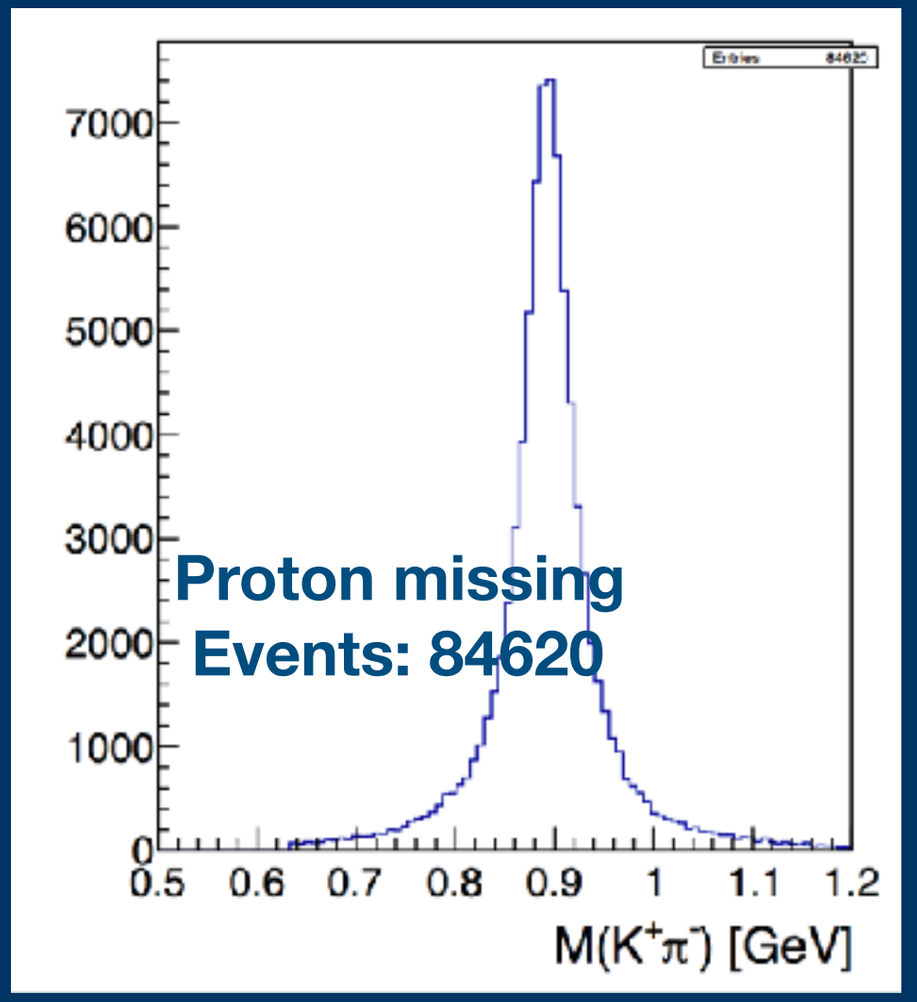
Flight_distance (L) = 2400 + vertex_z - 63.8 + Delta
*flight_time = Flight_distance/(c*beta_thrown)*
time_difference = k_vertex_time - flight_time; k_vertex_time: TOF time at vertex

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

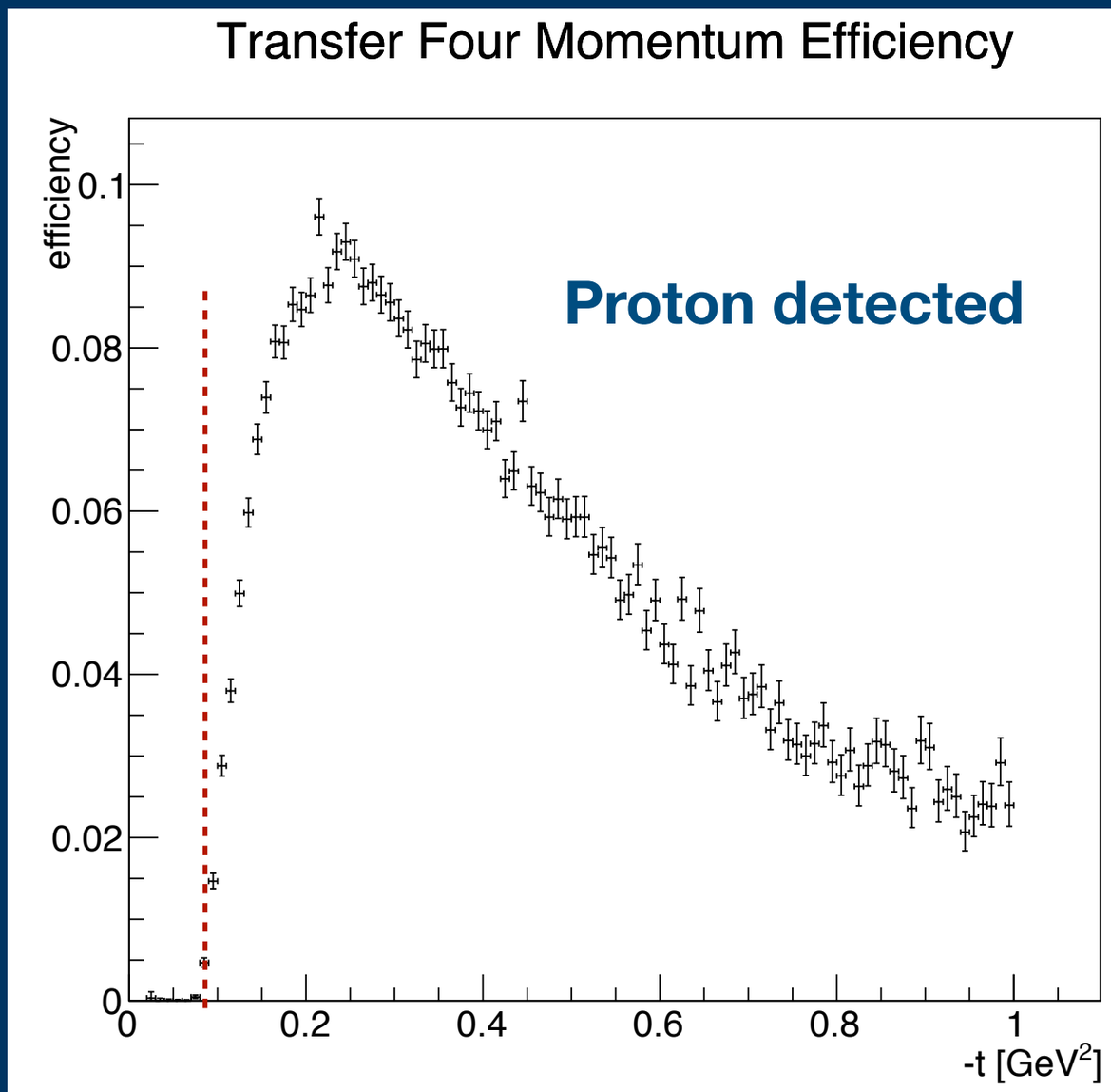
- $K^+, \pi^- and\ proton$
- $K^+, \pi^- and\ (proton)$

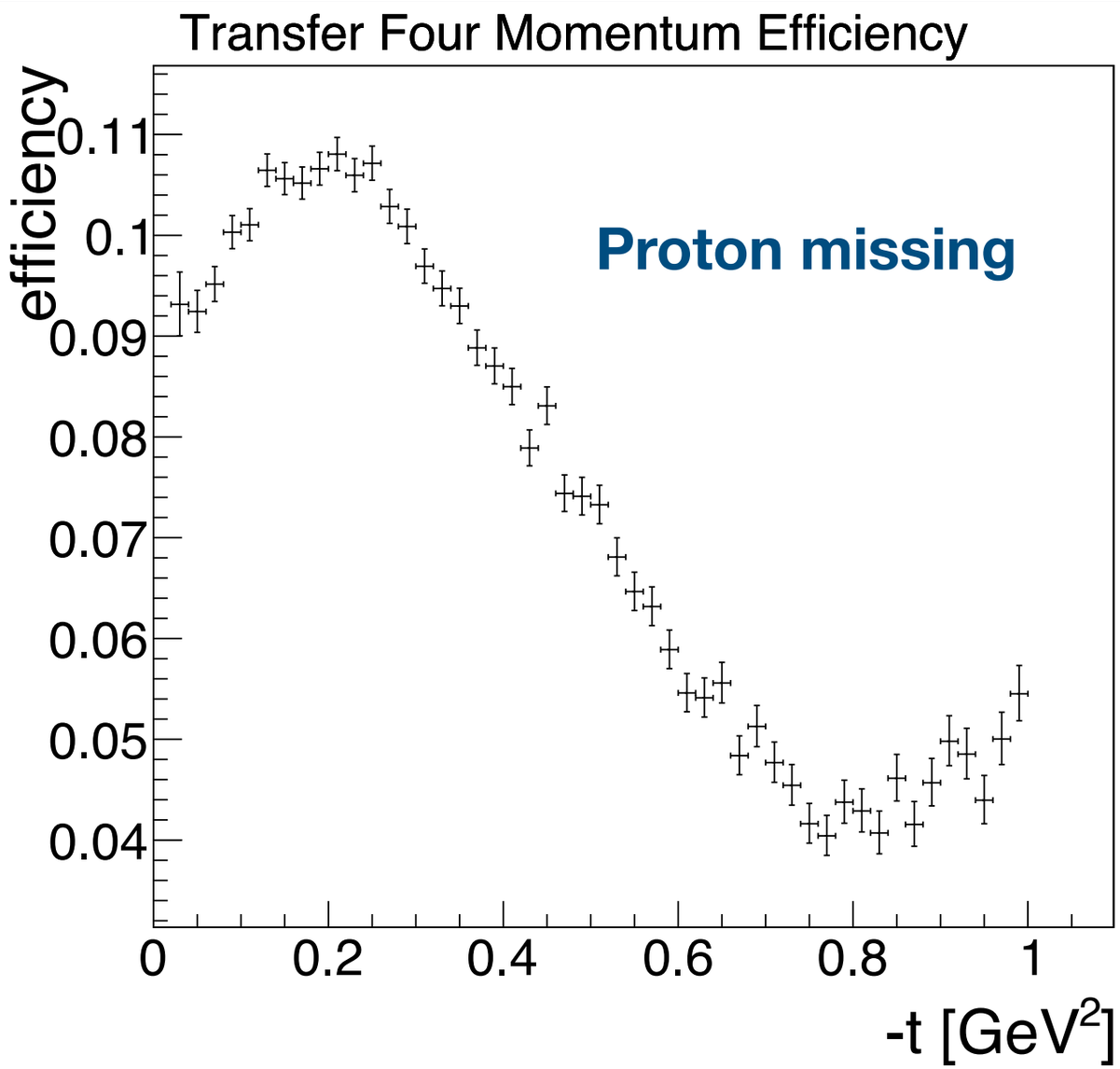
Well Reconstructed Kpi system in both cases; More stat for proton missing





Efficiency



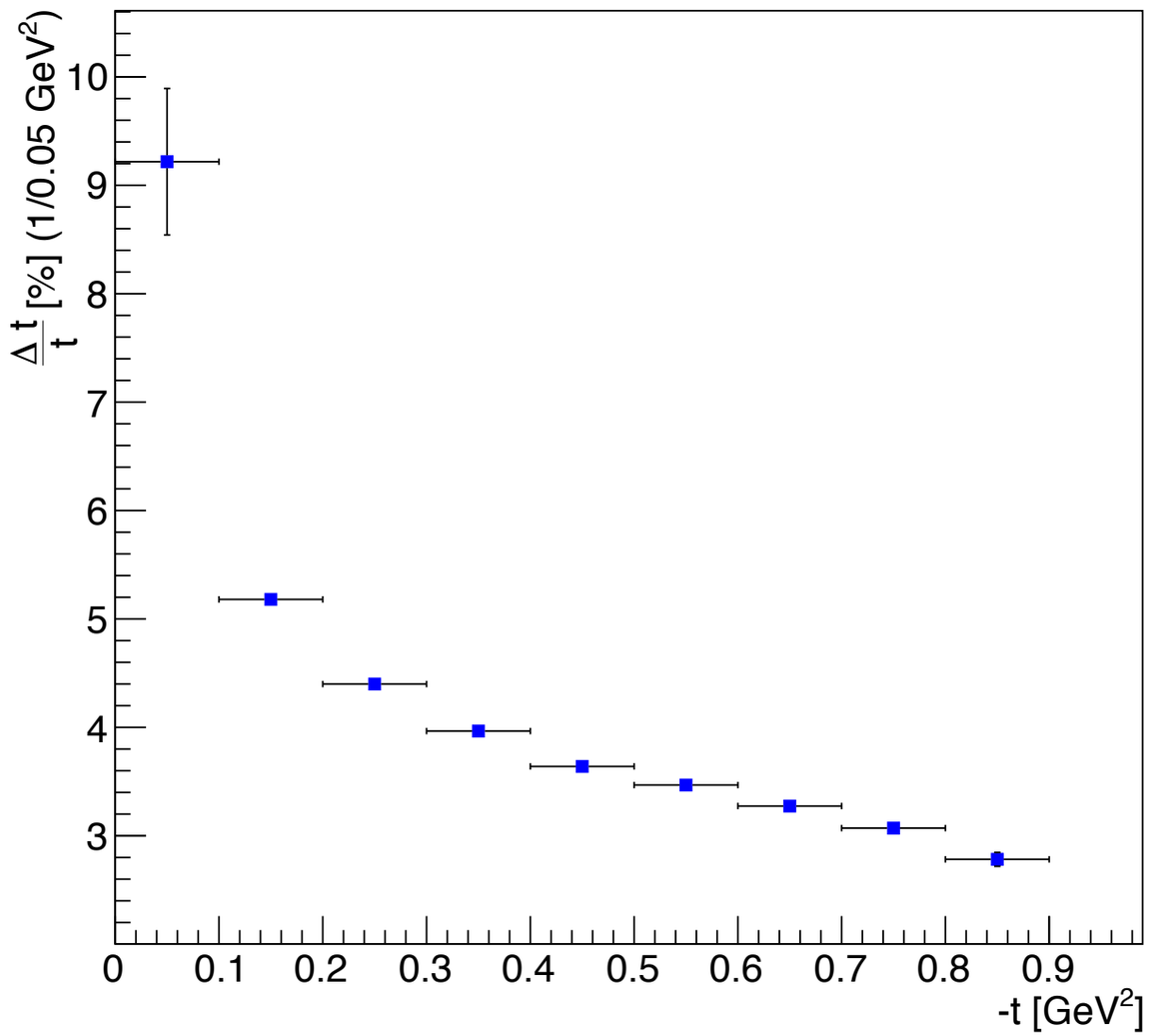


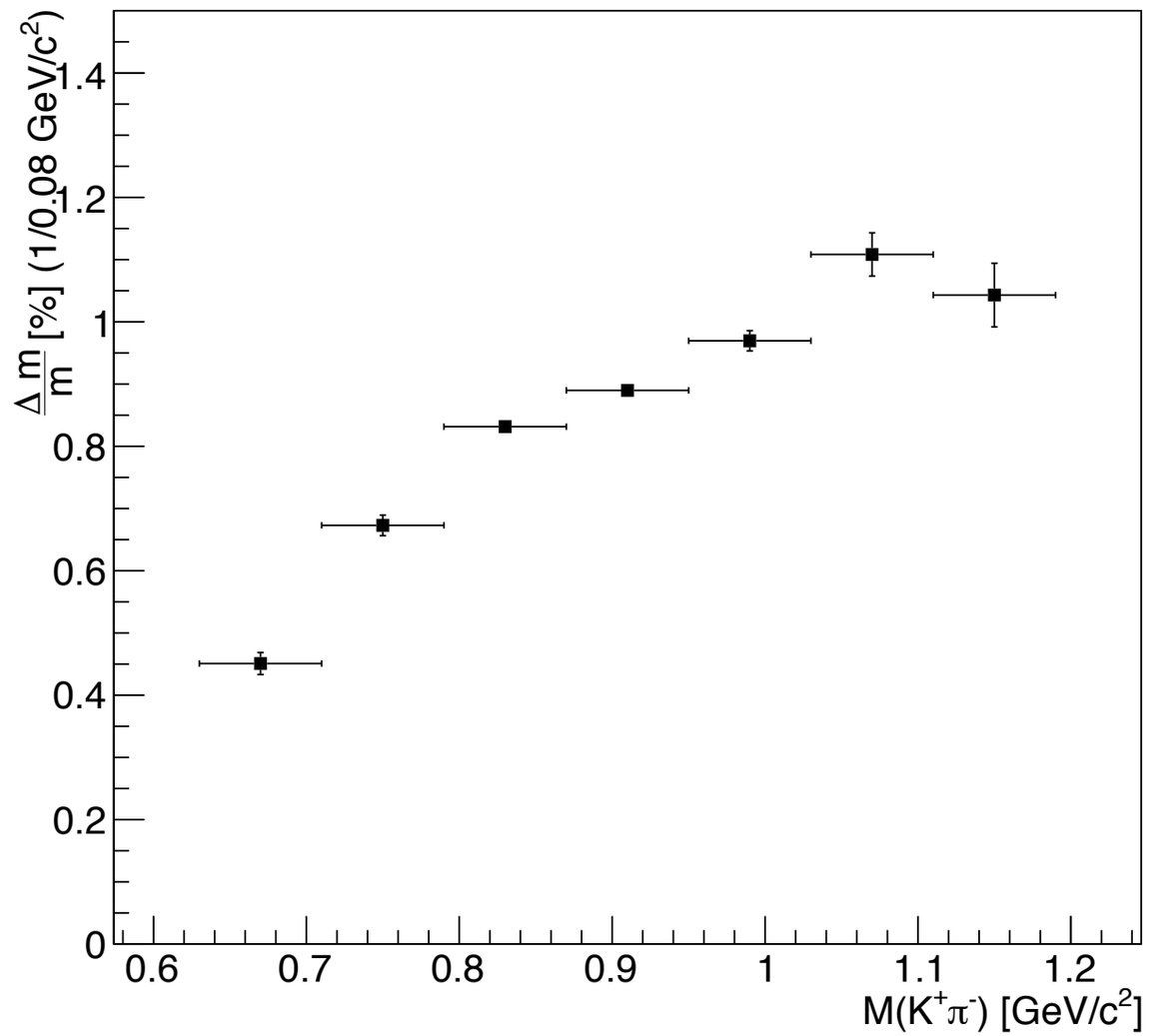
With proton being detected, -t stop at 0.08 GeV²

-t reach to pion pole for the missing proton

Resolution

Proton detected

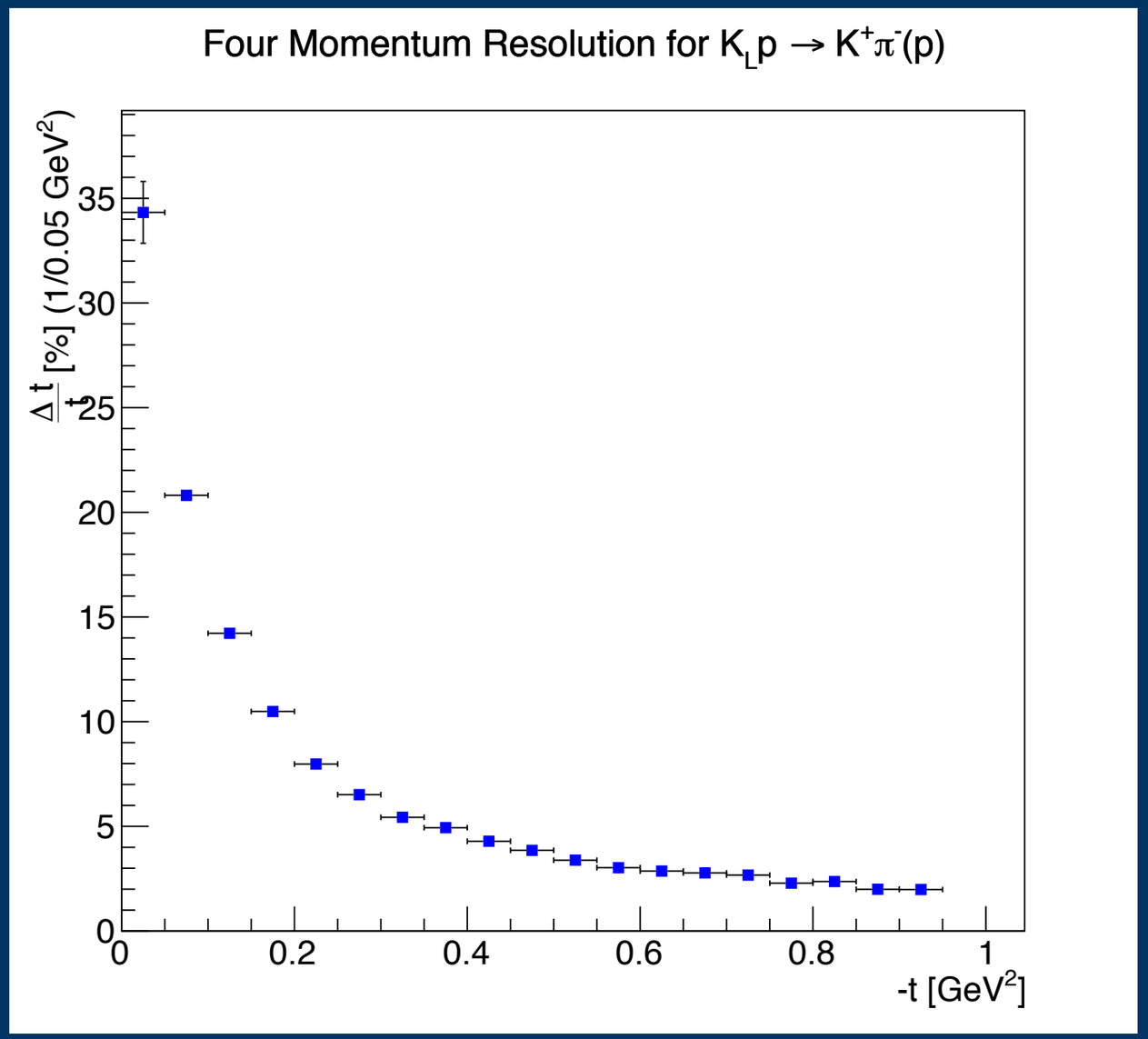


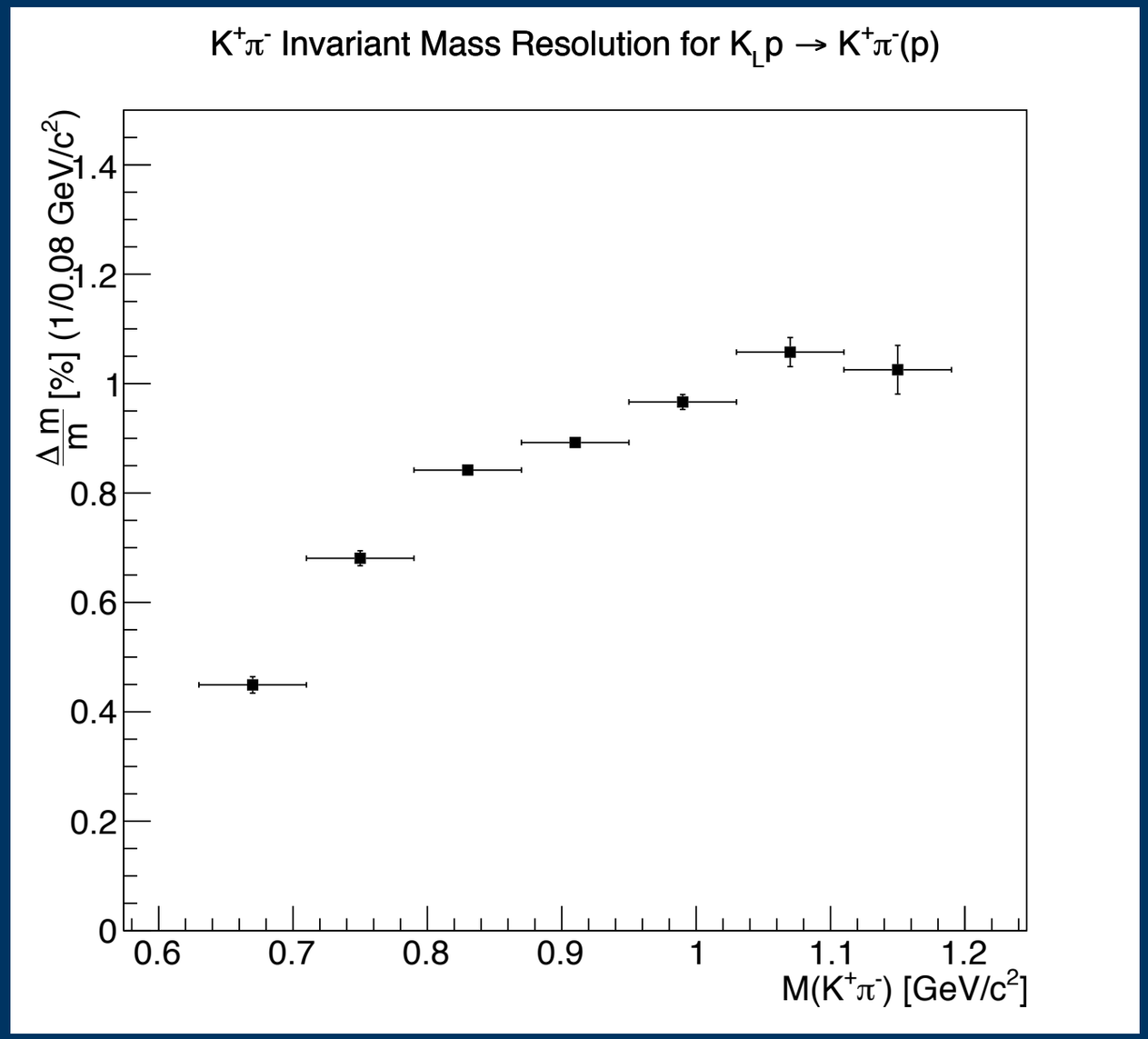


t is calculated using recoil proton and target

Resolution

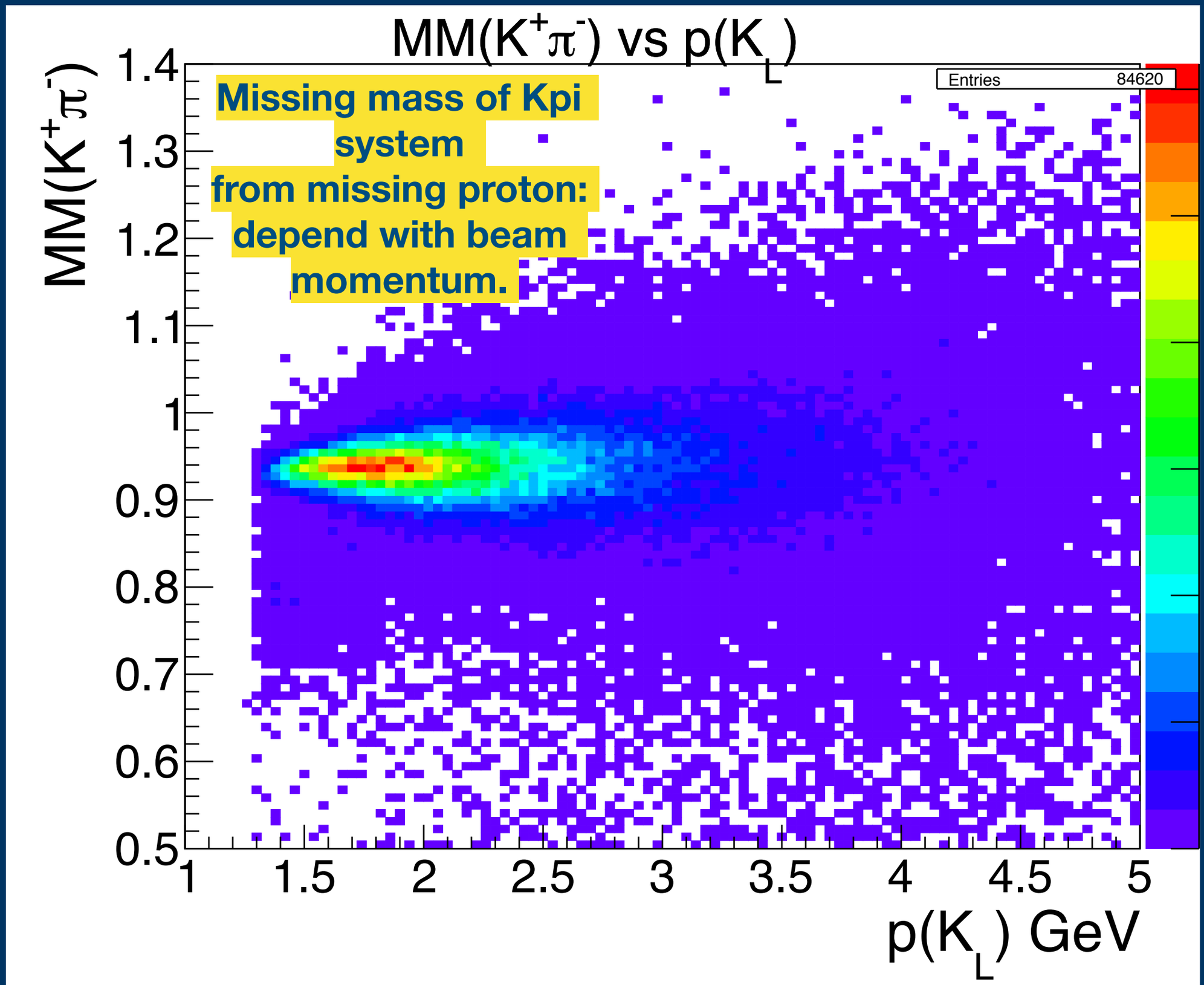
Proton missing





t is calculated from beam and kpi system.

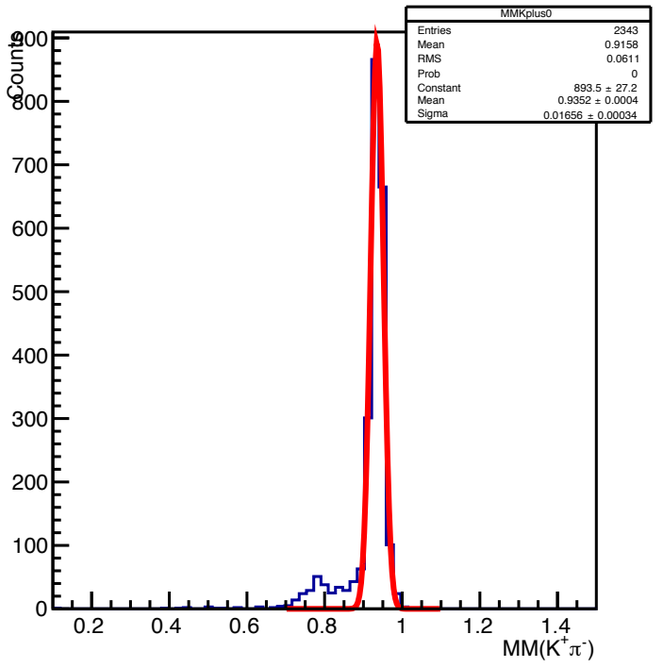
Missing mass of K+pi-



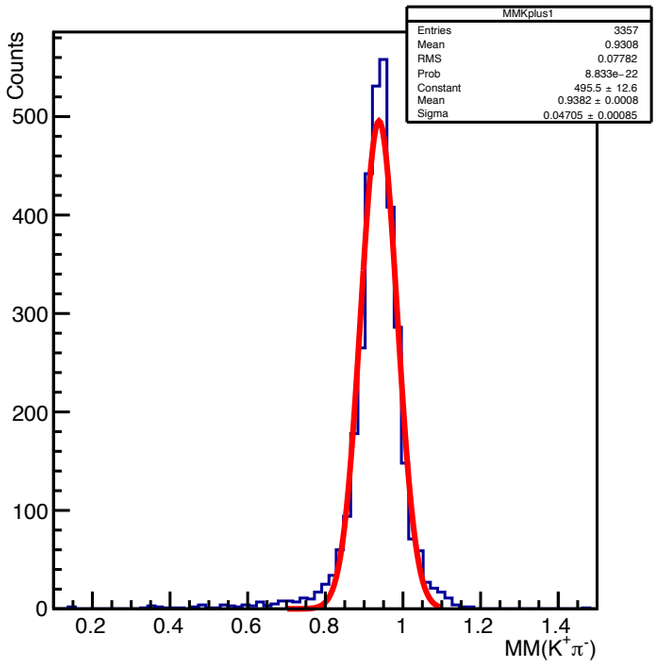
Missing mass of K+pi-

Missing mass at different beam momentum

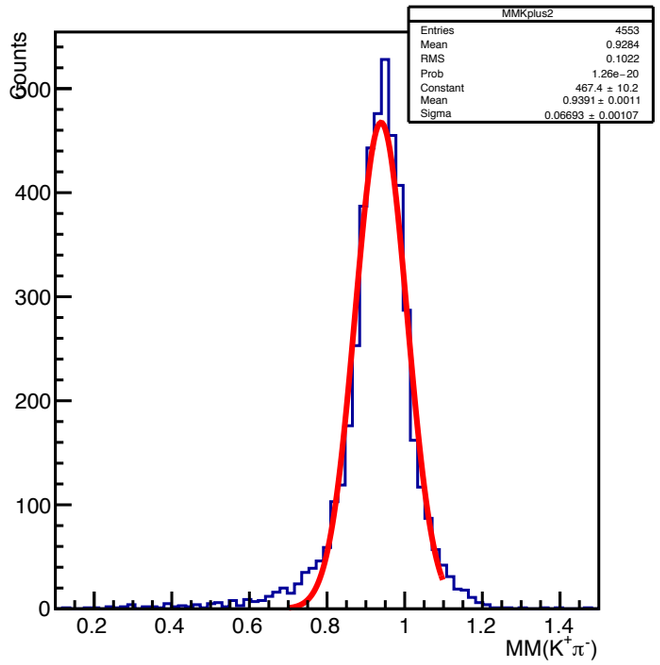
P = 1.5 GeV, Δ P = 0.1 GeV



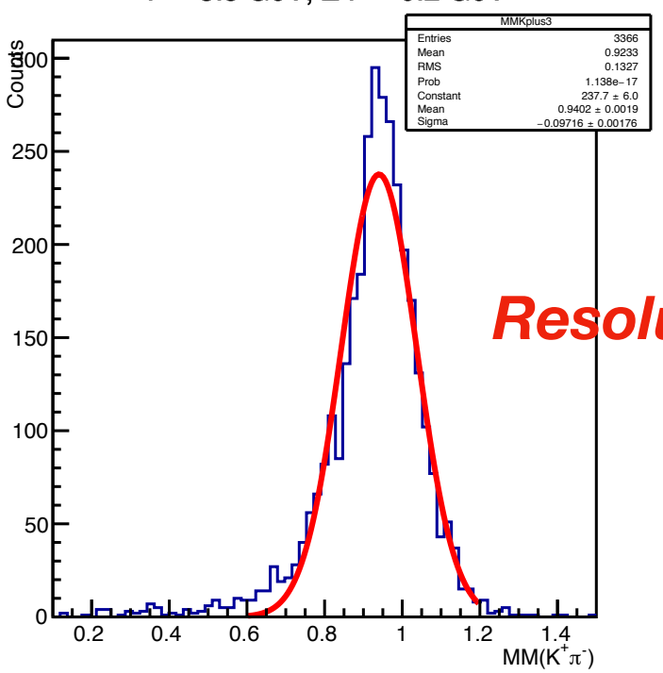
P = 2.5 GeV, Δ P = 0.1 GeV



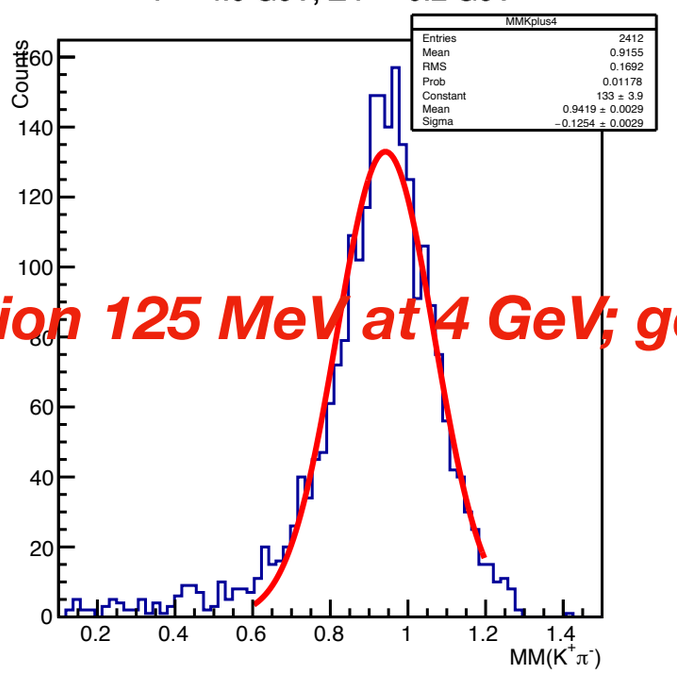
P = 3.0 GeV, Δ P = 0.2 GeV



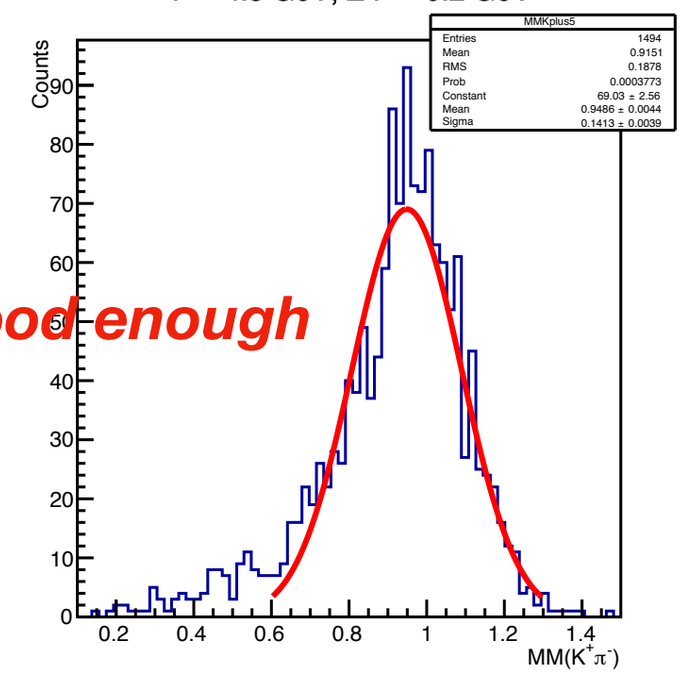
P = 3.5 GeV, Δ P = 0.2 GeV



P = 4.0 GeV, Δ P = 0.2 GeV

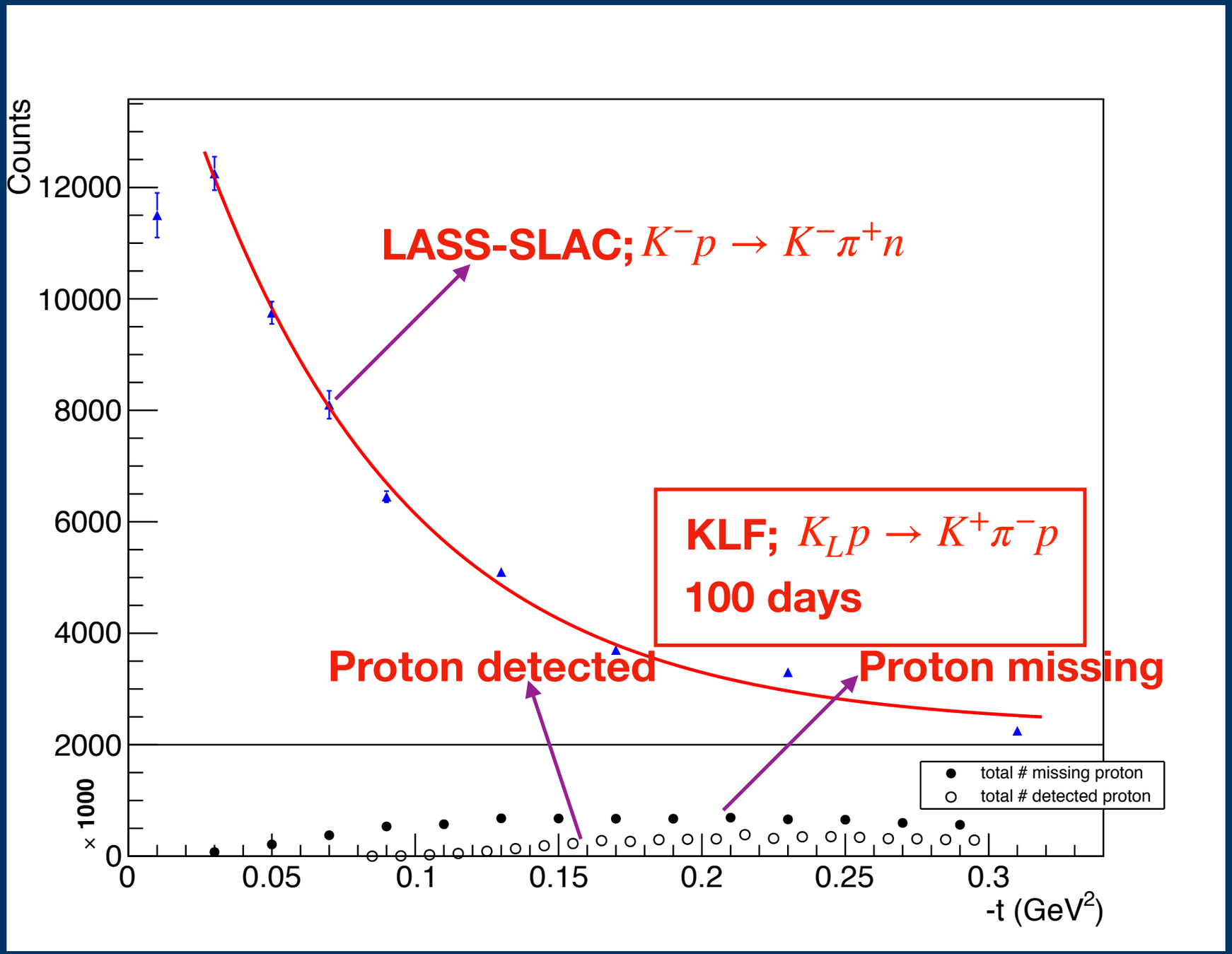


P = 4.5 GeV, Δ P = 0.2 GeV



Resolution 125 MeV at 4 GeV; good enough

Comparison with SLAC



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

Amplitude Analysis: moment extraction

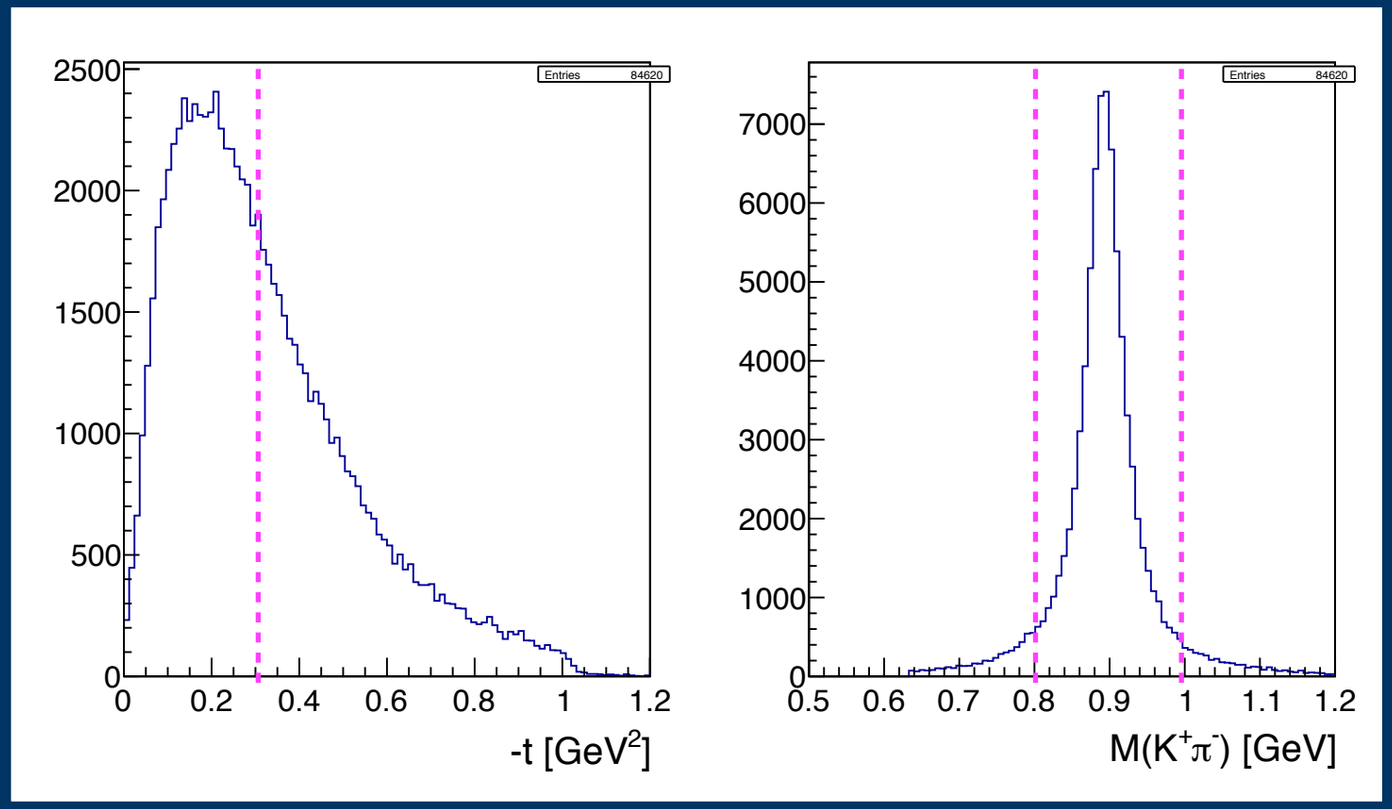
(work in progress)

Amptools: binning on mass and -t

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

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

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



Moments: projection of amplitudes

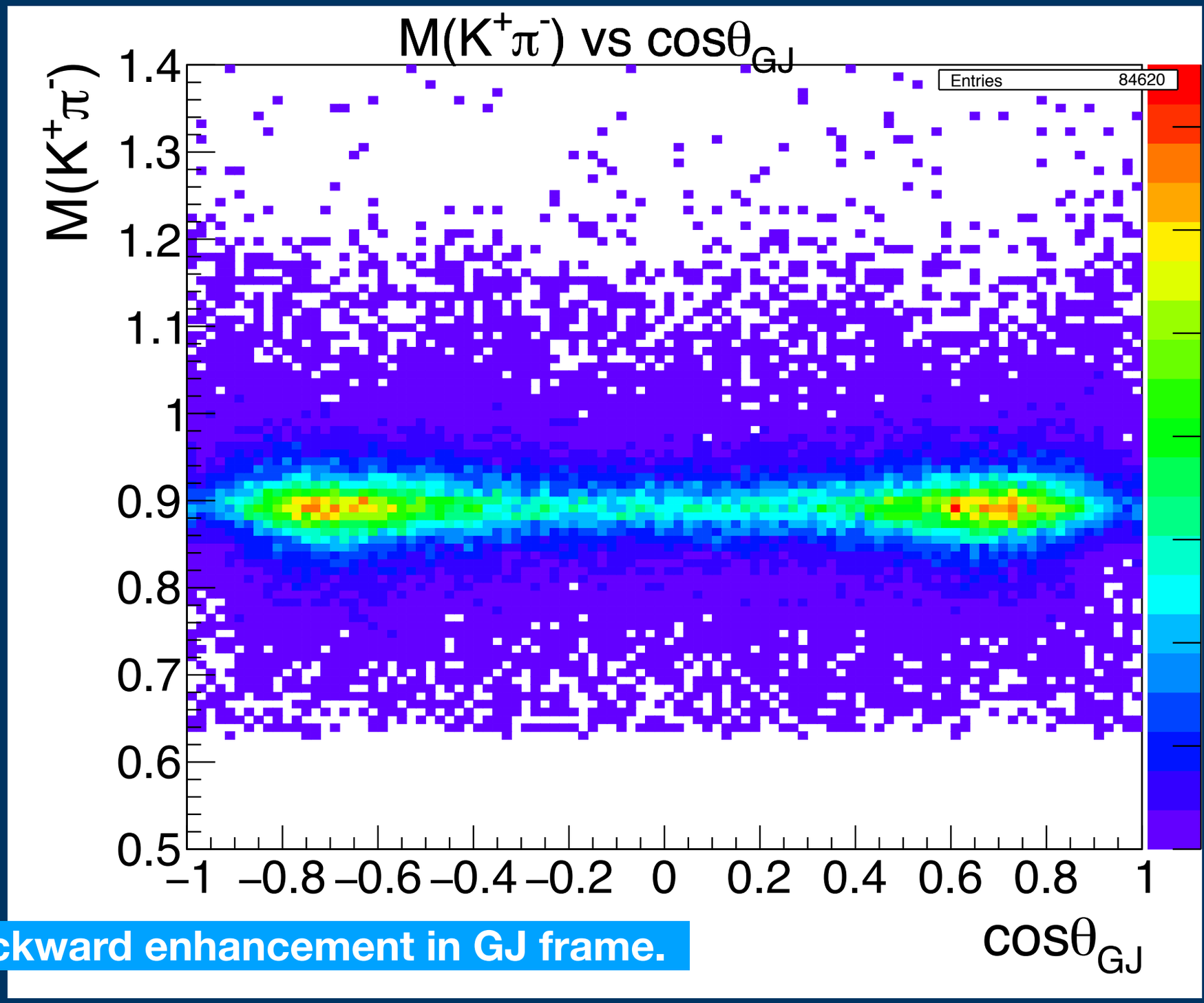
$$H(0,0) = +1\,|S0|^2 + 1\,|P0|^2 + 1\,|P-|^2 + 1\,|D0|^2 + 1\,|D-|^2 + 1\,|P+|^2 + 1\,|D+|^2$$
$$H(1,0) = +1.1547 Re(P0 * S0) + 1.0328 Re(D0 * P0) + 0.894427 Re(D- * P-) + 0.894427 Re(D+ * P+)$$
$$H(1,1) = +0.816497 Re(P- * S0) - 0.365148 Re(D0 * P-) + 0.632456 Re(D- * P0)$$
$$H(2,0) = +0.4\,|P0|^2 - 0.2\,|P-|^2 + 0.894427 Re(D0 * S0) + 0.285714\,|D0|^2 + 0.142857\,|D-|^2 - 0.2\,|P+|^2 + 0.142857\,|D+|^2$$
$$H(2,1) = +0.489898 Re(P- * P0) + 0.632456 Re(D- * S0) + 0.202031 Re(D- * D0)$$
$$H(2,2) = +0.244949\,|P-|^2 + 0.174964\,|D-|^2 - 0.244949\,|P+|^2 - 0.174964\,|D+|^2$$

Phys.Rev. D80 (2009) 072005

Angular distribution at GJ frame

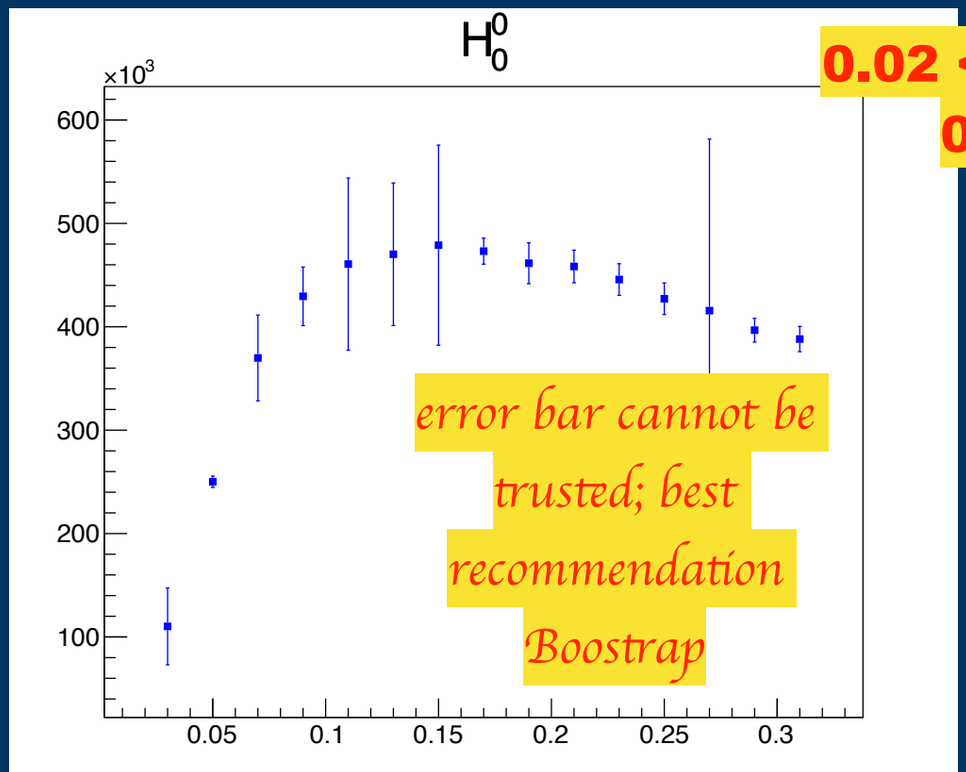
Reconstructed distribution:

- data generated with Regge model, multiple exchanges : $\pi, \rho, A_2, \ldots$ [*Nucl.Phys.B10(1969) 151-168*]

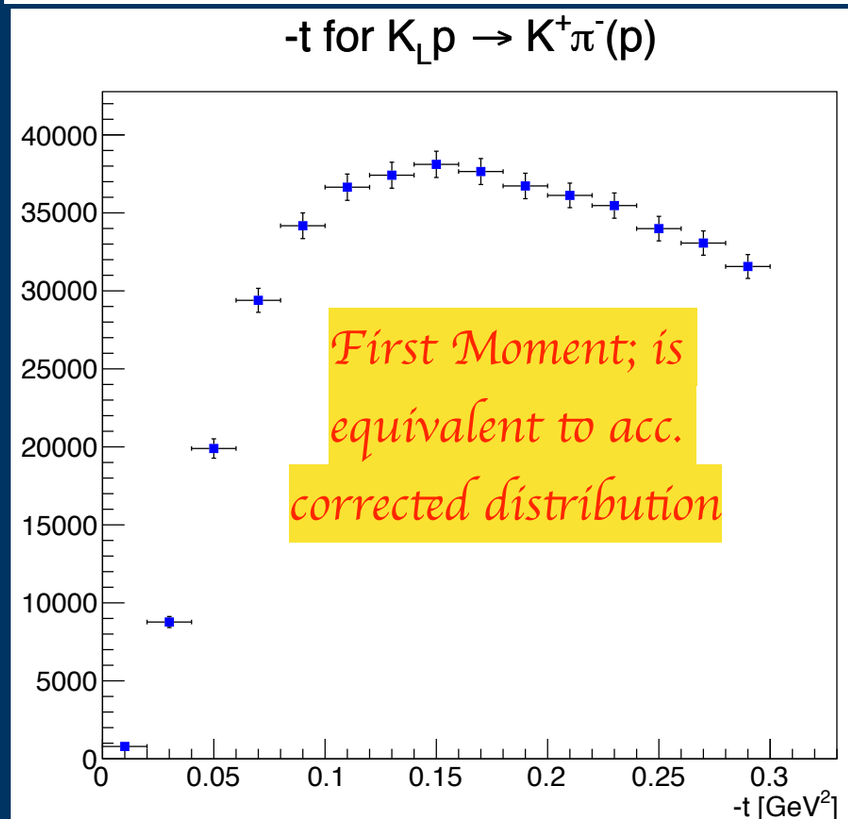


forward and backward enhancement in GJ frame.

-t dependent Moments



error bar cannot be trusted; best recommendation Boostrap

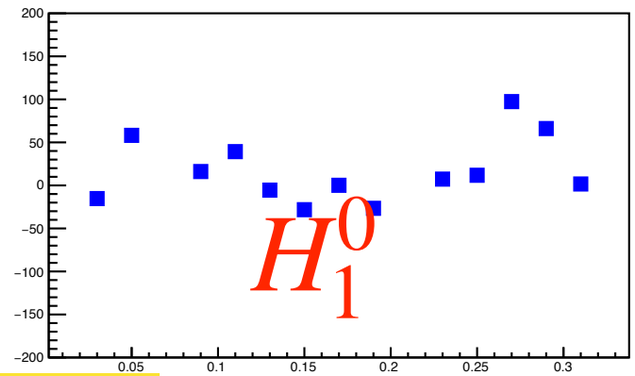


First Moment; is equivalent to acc. corrected distribution

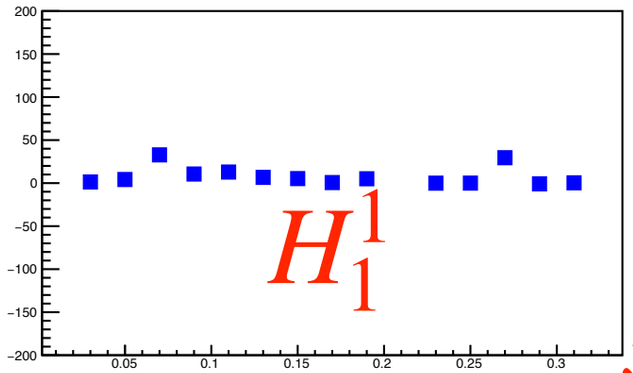
0.02 < -t < 0.3 : 15 bins:

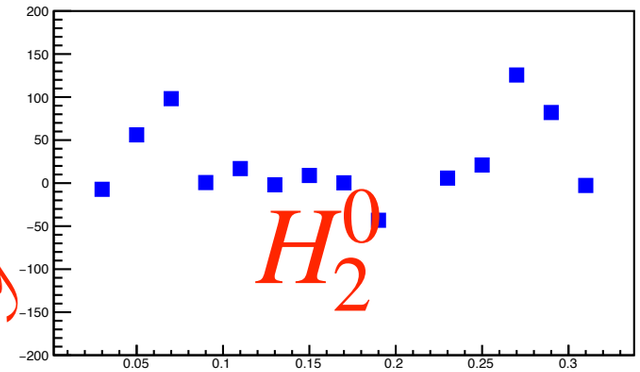
0.8< $M(K^+\pi^-)$ <1.0

H_0^0

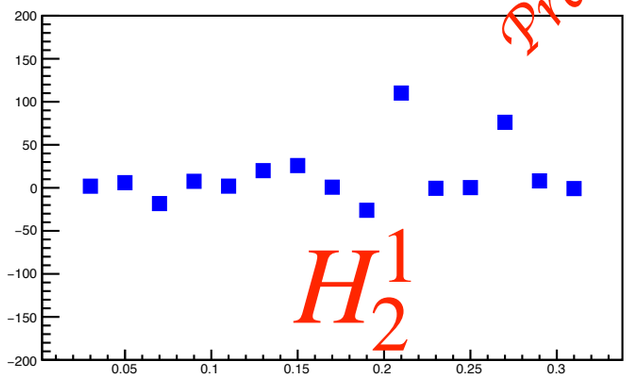


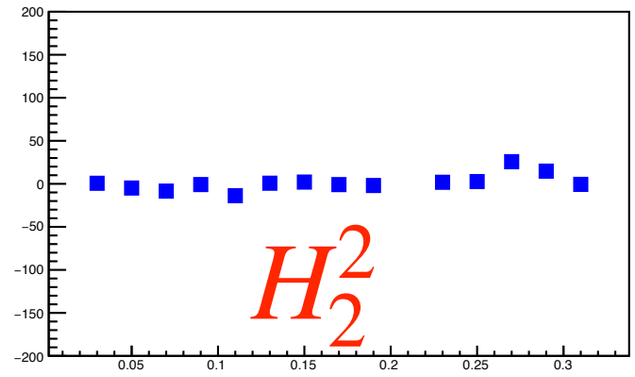
Errors are excluded





Preliminary





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

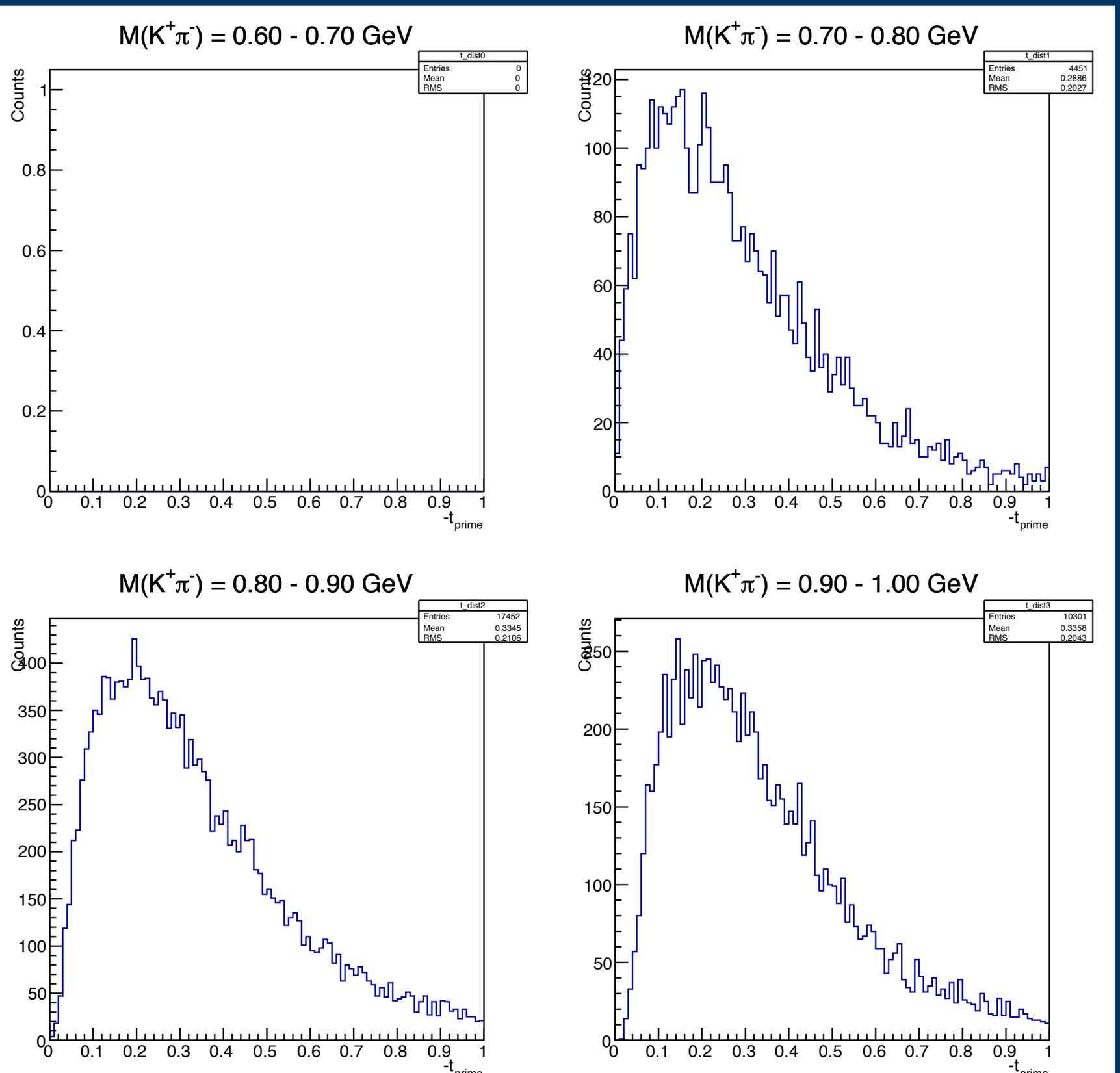
- KLF could produce two order of more statistics compared to previous SLAC measurement.

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

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

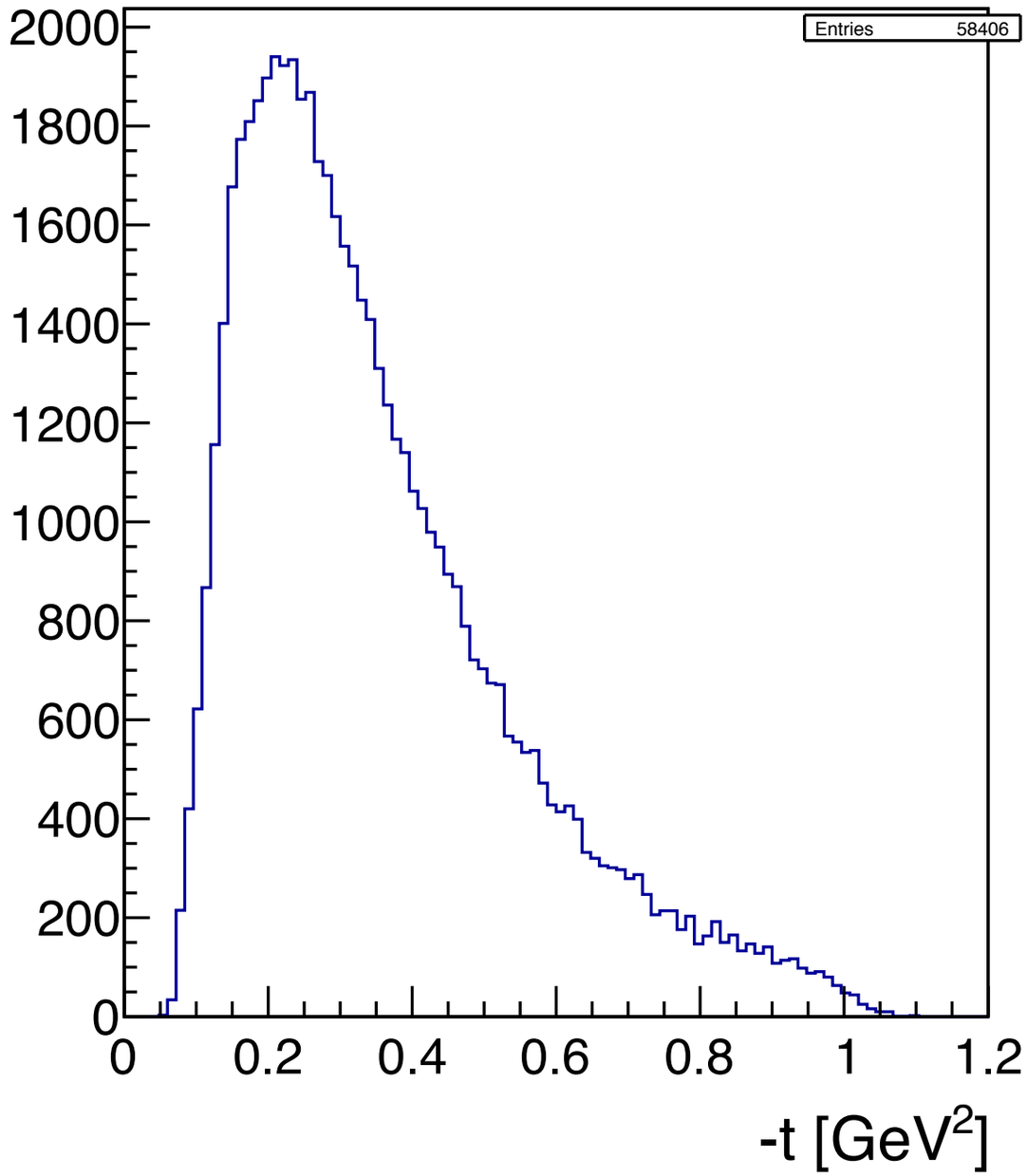
Back Up

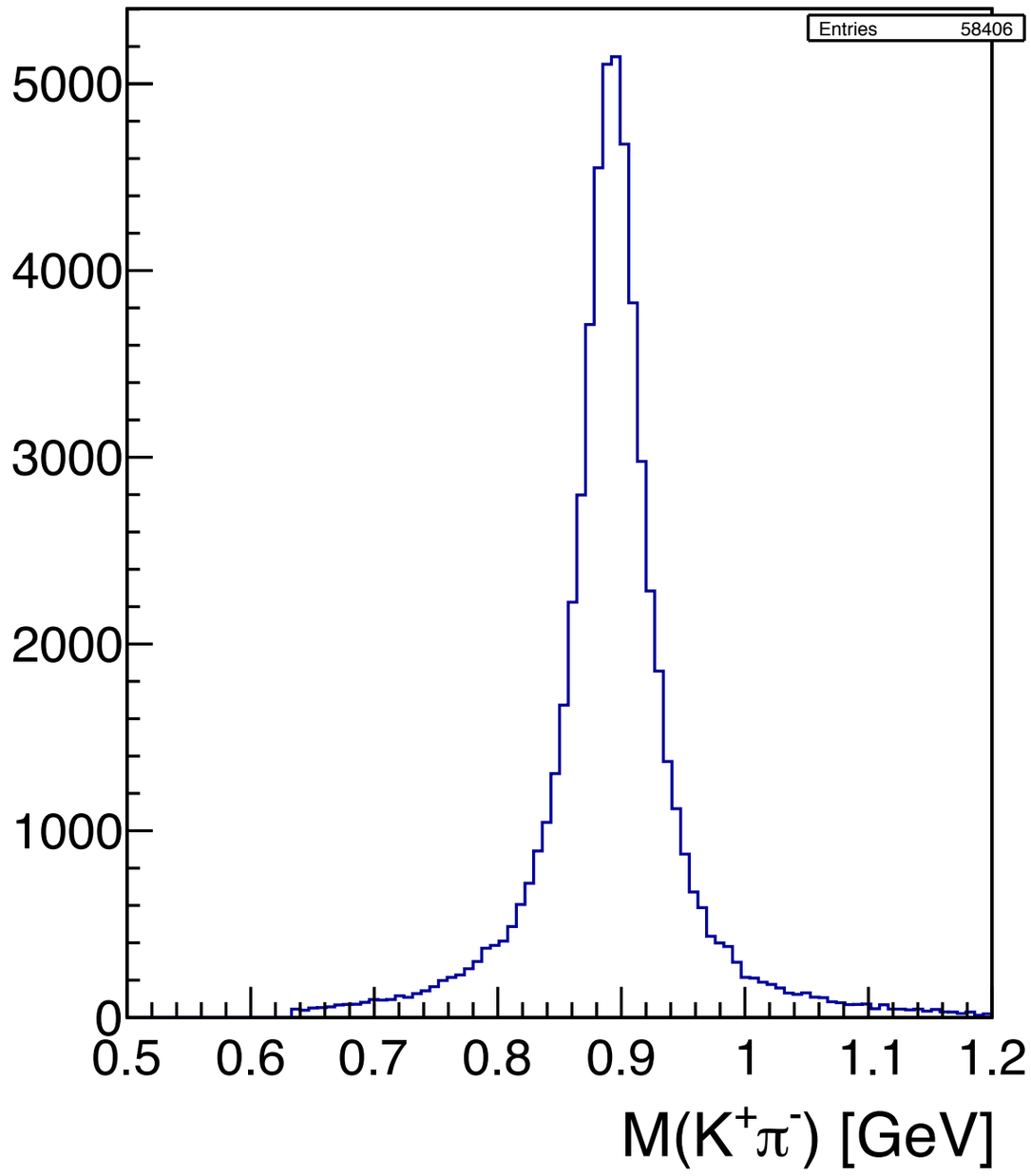
M(K+pim) binned for t



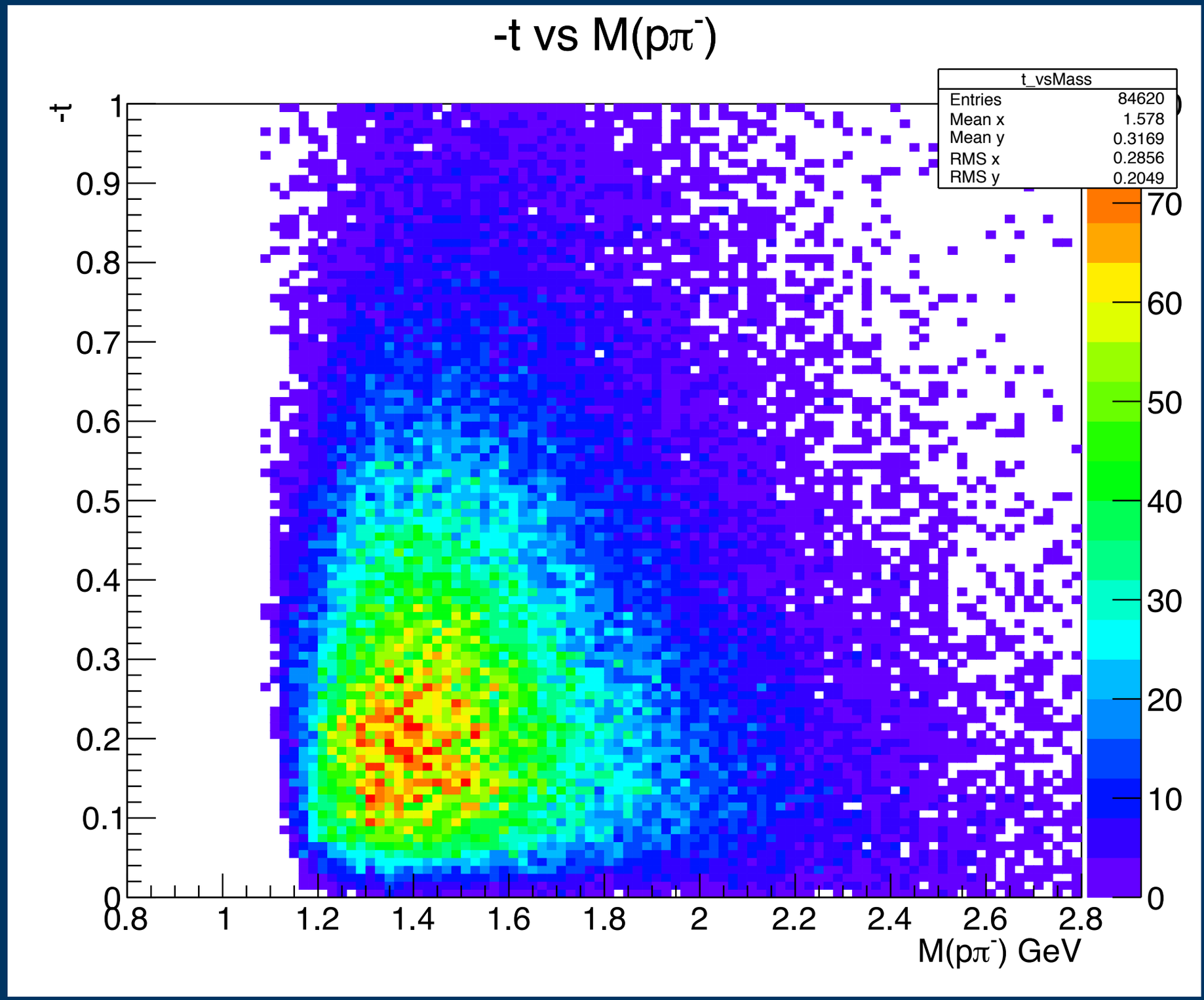
Kpi production

Reconstruction detected proton $K_L p \rightarrow K^{\star}(892)p$





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


-t vs M(pπ⁻)
t_vsMass
Entries 84620
Mean x 1.578
Mean y 0.3169
RMS x 0.2856
RMS y 0.2049
-t
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
M(pπ⁻) GeV
70
60
50
40
30
20
10
0