K_L studies with the GlueX detector

Simon Taylor / JLab

- Event generation
- GlueX detector
- $K_L p \rightarrow K_S p$
- $K_L p \rightarrow \Lambda \pi^+$
- $K_L p \rightarrow K^+ \Xi^0$

Event generation

- Generated K_L beam using momentum distribution provided by I. Larin
  - Assume K_L beam originates from 40 cm-long Be target 16m upstream from LH2 target (inside GlueX detector)
- pK_S cross section model
  - Developed parametrization of fits to $d\sigma/d\Omega$ data for low W
  - Power law fall-off for higher W ($\sigma = A p_{KL}^{-n}$)
- $\Lambda\pi^+$ cross section model
  - Based on "A Study of the reactions K0bar p->Lambda pi+ and K0bar p->Sigma0 pi+ from 1GeV/c to 12GeV/c", Robert J. Yamartino, Jr., SLAC-177 report Sep. 1974, PhD disser. May 1974
- $K^+\Xi^0$ cross section model
  - Parametrization of functions from "K + N -> K + Xi reaction and S=-1 hyperon resonances", B. C. Jackson, et al arXiv:1503.00845v1 [nucl-th] 3 Mar 2015.

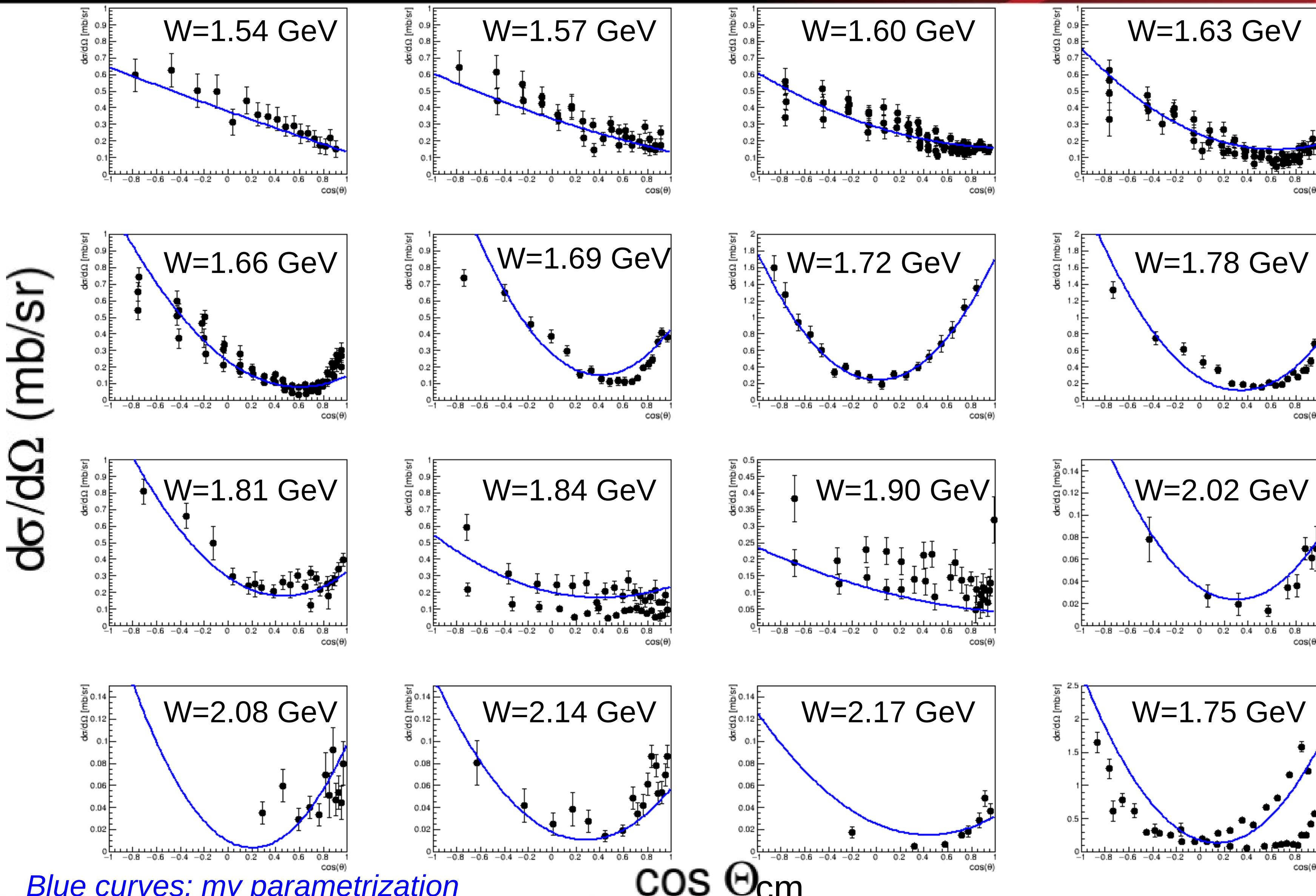
Parametrization of pK_S cross section

- W<2.17 GeV:
  - Expansion in Legendre polynomials:
    - $d\sigma/d\Omega = f_0(W)P_0(\cos\theta)+f_1(W)P_1(\cos\theta)+f_2(W)P_2(\cos\theta)$
    - f_0, f_1, f_2 from fits to data (next slide)

- W≥2.17 GeV:
  - Total cross section: $\sigma_{tot} = Ap_K^{-2.1}$
    - $p_K = K_L$ momentum in lab
  - Forward angle: $d\sigma/dt = Bp_K^{-1.33}e^{(3.1+2.8\ln(s))\,t}$
  - Backward angle: $d\sigma/du' = Cp_K^{-5.24}e^{5.4u'}$, $u' = u-u_{max}$
    - A,B,C = scale factors matching low W parametrization at W=2.17 GeV

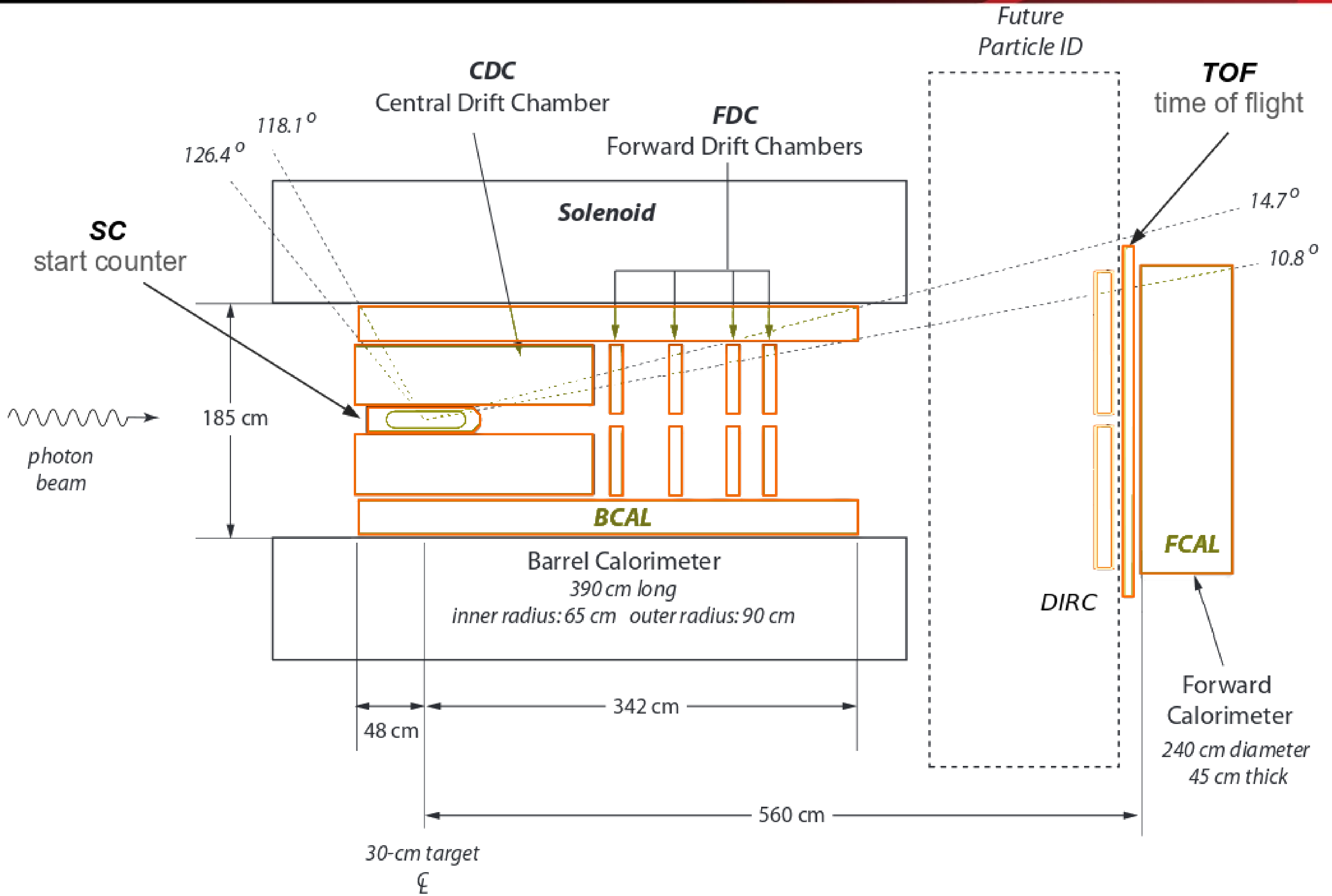
Ref: Brandenburg, et al., Phys.Rev.D9.7(1974)

Fit to existing $K_L p \to K_S p$ data



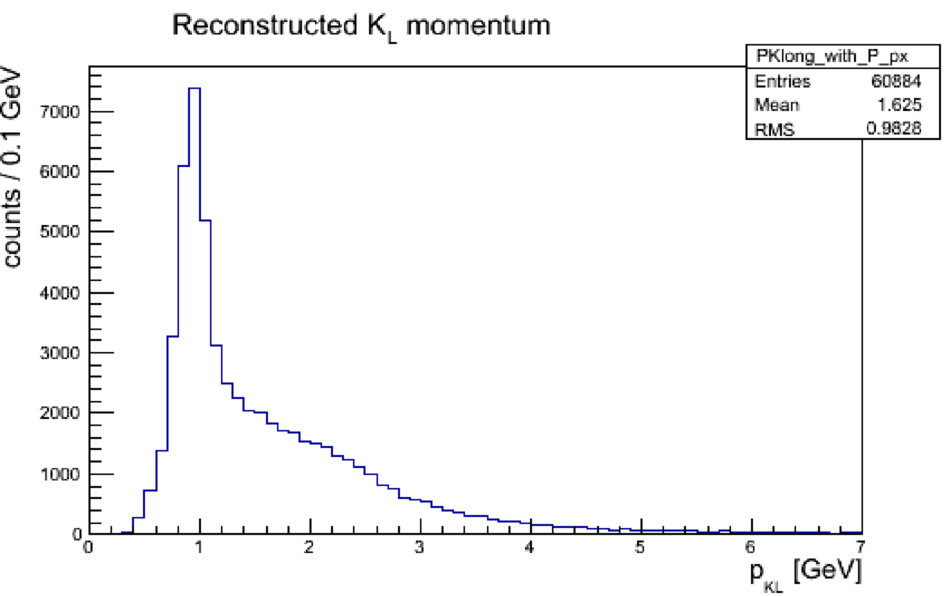
Blue curves: my parametrization

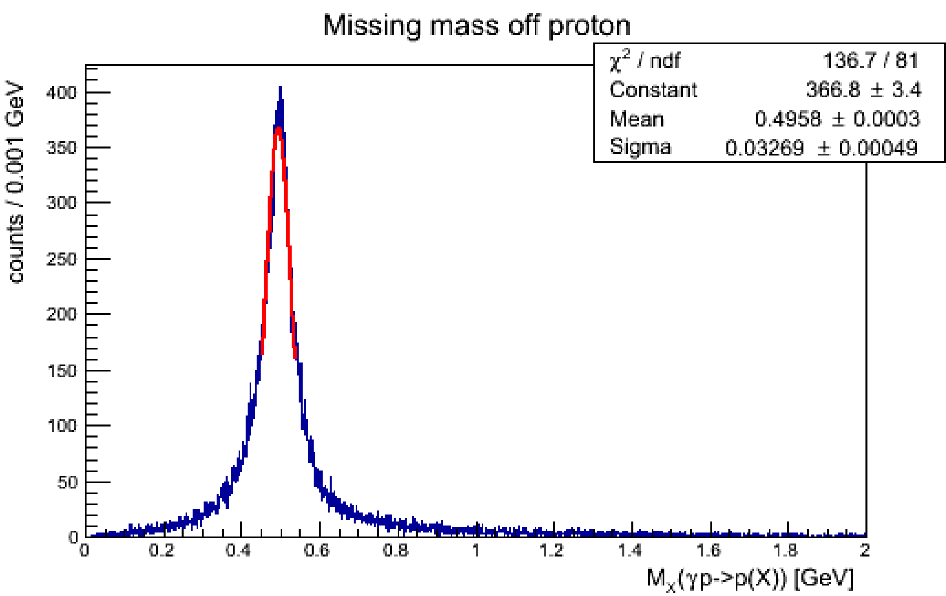
The GlueX detector



Reconstruction of pK_S events

- Generated 100,000 events
  - Allowed GEANT to decay K_S
- Require detection of recoil proton → primary "vertex"
- K_L momentum reconstructed from time-of-flight between proton time at "vertex" and time at Be target
- Particle identification: dE/dx in drift chambers, time-of-flight

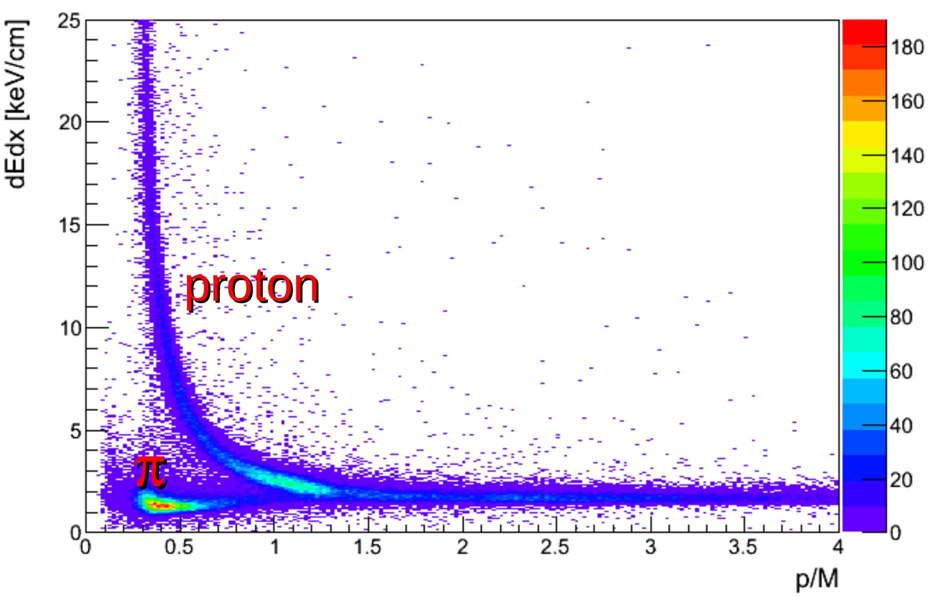


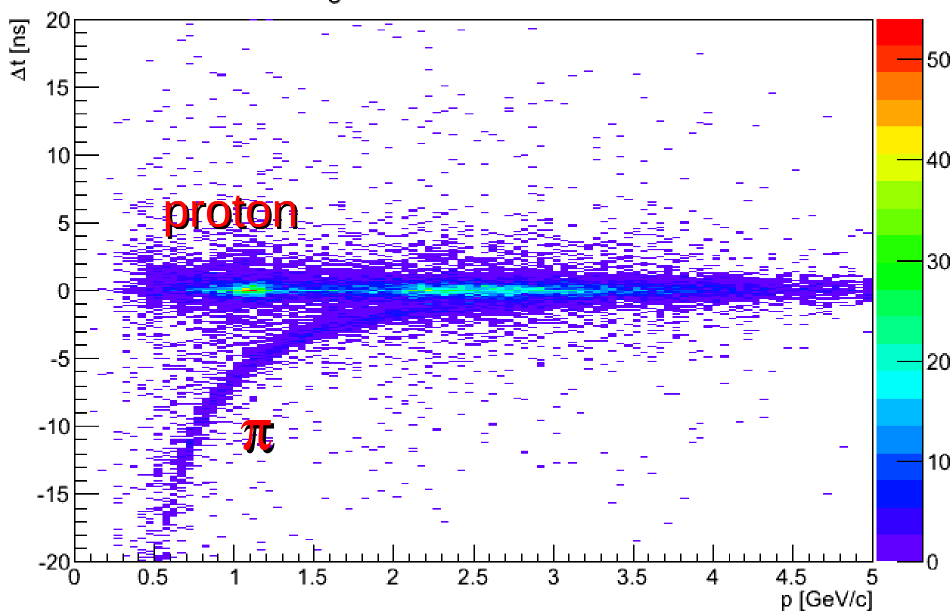


Particle identification

- We can do better if we also reconstruct $K_S \to \pi^+\pi^-$, at the expense of statistics...

pK_S events

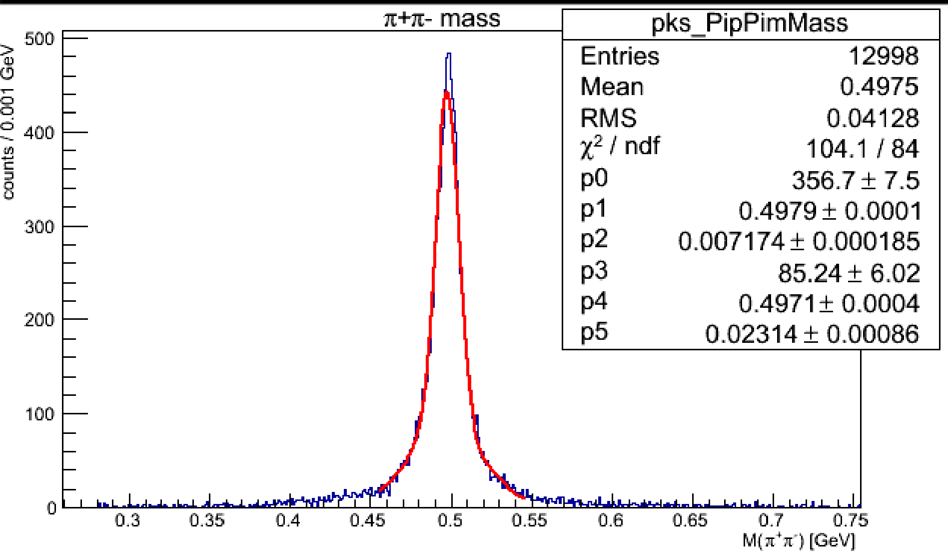


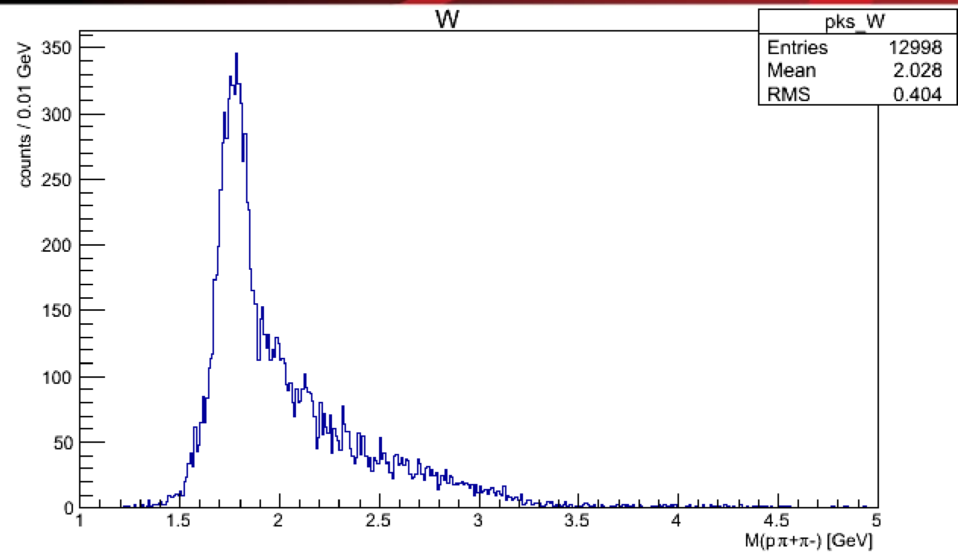


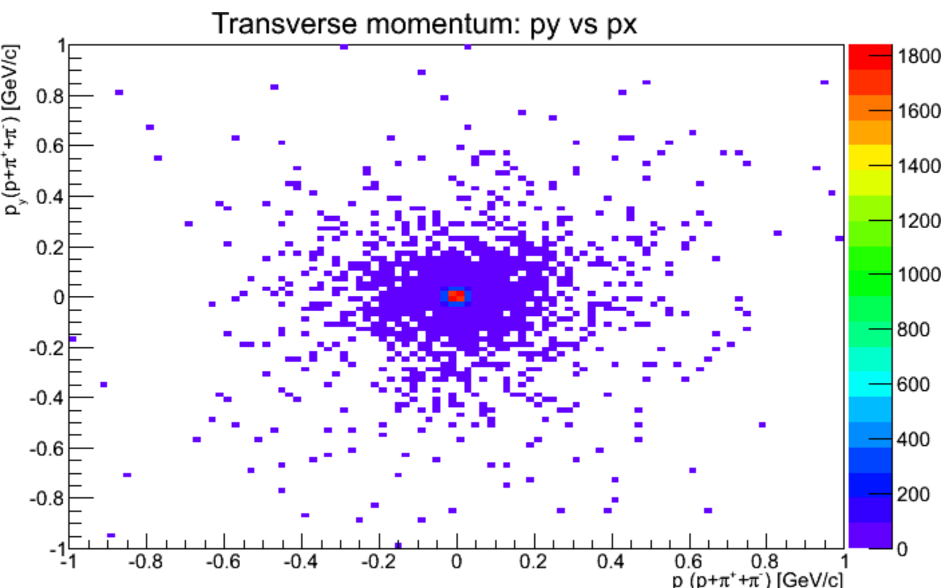
- Each track fitted using several mass hypotheses: $\{p, K^+, \pi^+\}$ for +, $\{K^-, \pi^-\}$ for -
- Measure dE/dx, compute Δt at vertex for each hypothesis $\to$ convert to probability

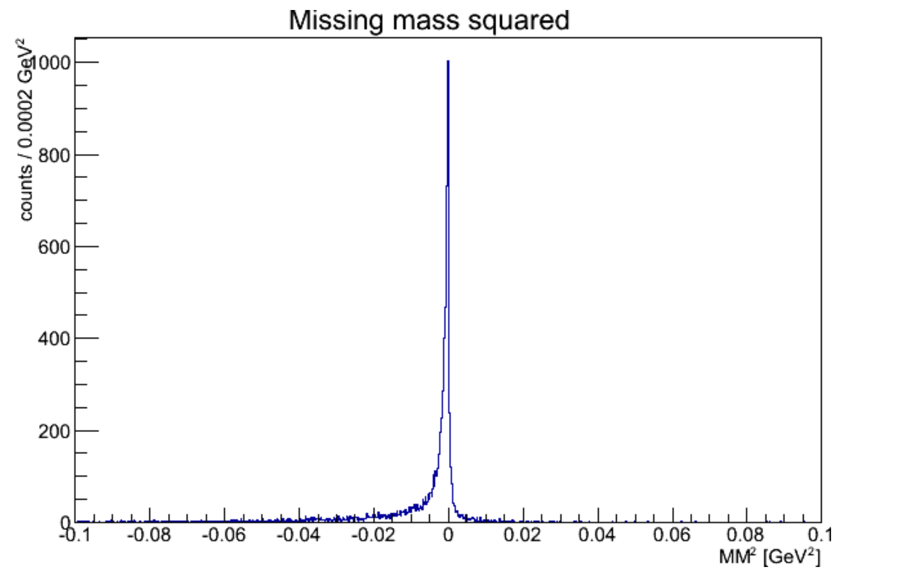
Requiring $\pi^+\pi^-$

$BR(K_S \to \pi^- \pi^+) = 69.20 \pm 0.05\%$

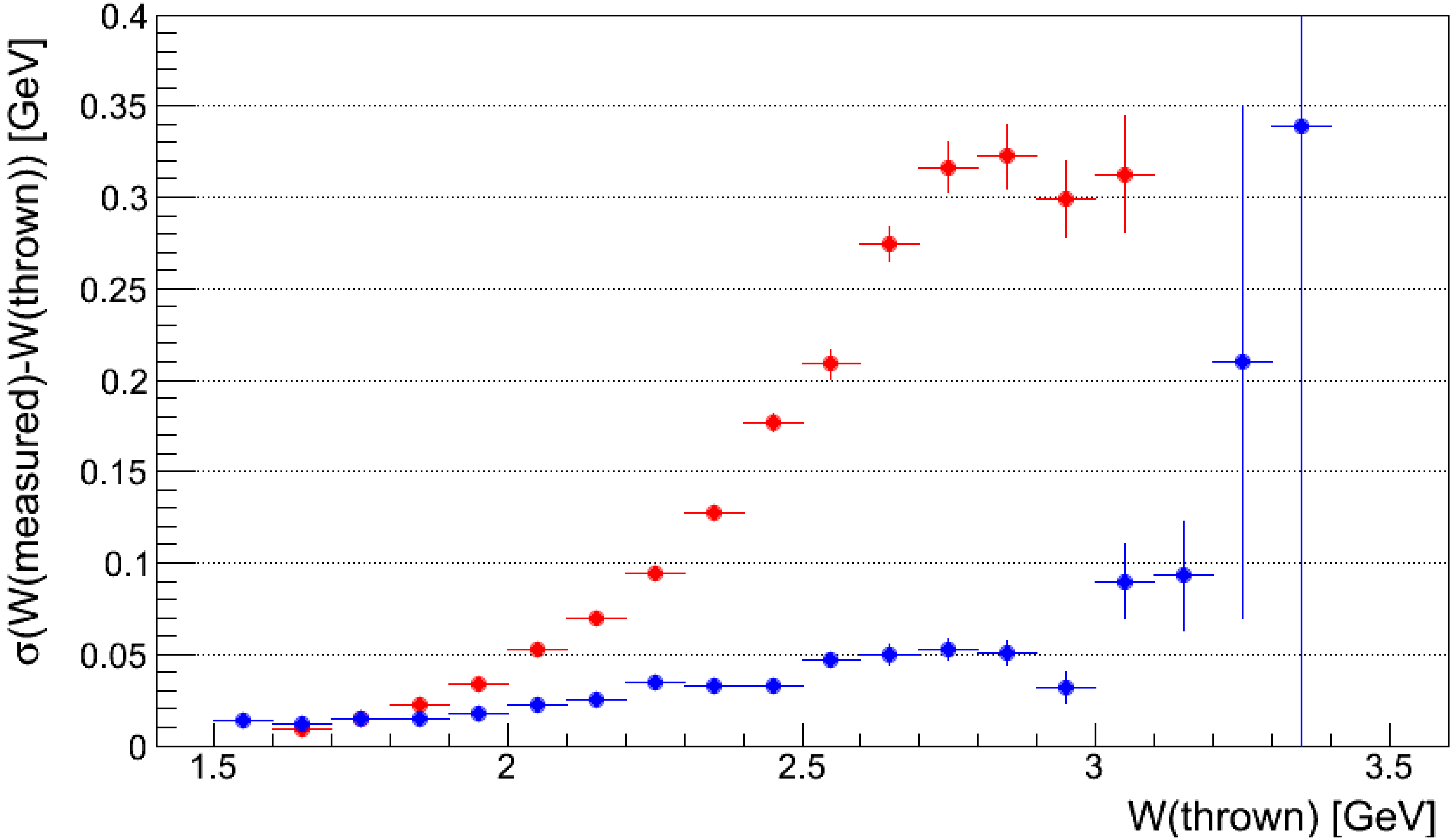








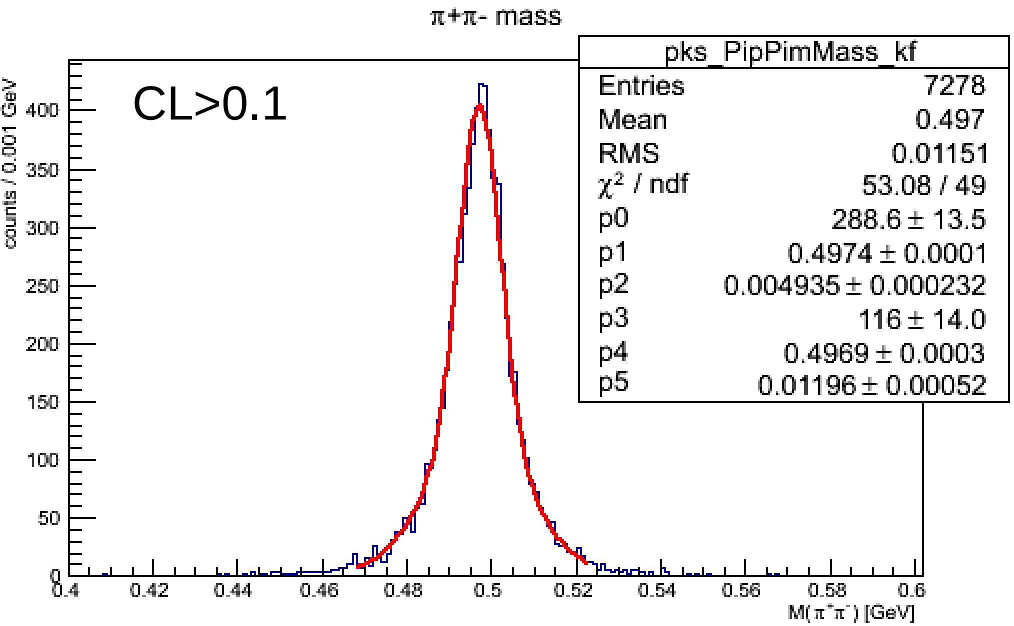
W resolution

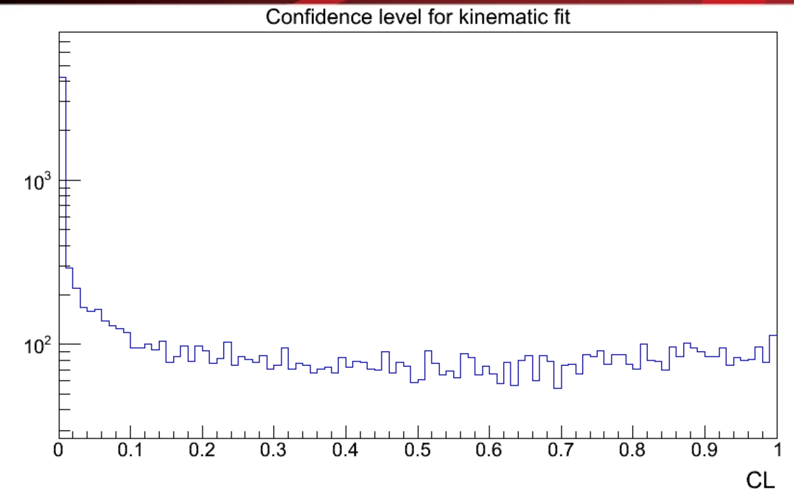


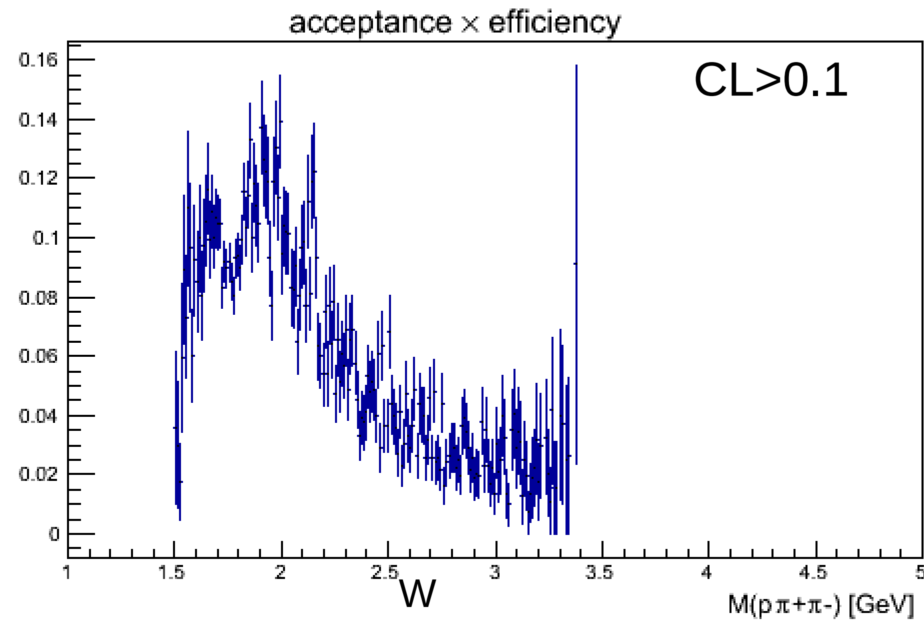
Invariant mass technique

K_L momentum (time-of-flight) technique

Kinematic fit for pK_S channel





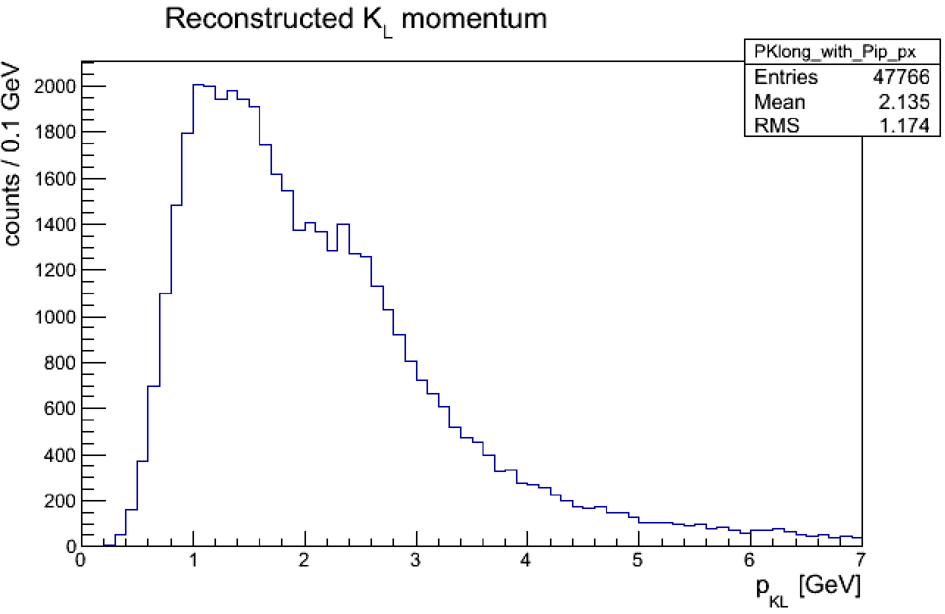


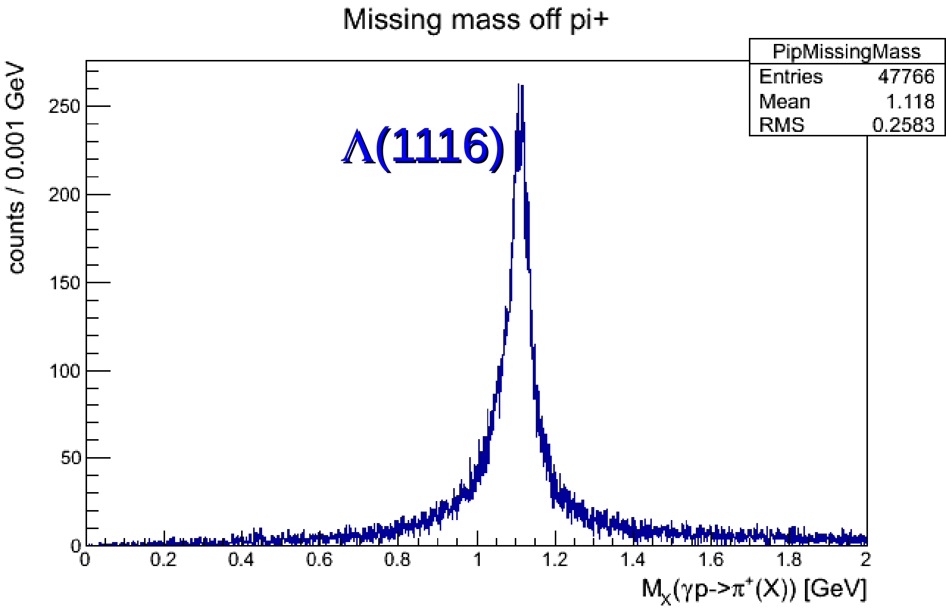
- Required energy and momentum conservation

Average acceptance×efficiency ≈ 7%

Reconstruction of $\Lambda\pi^+$ events

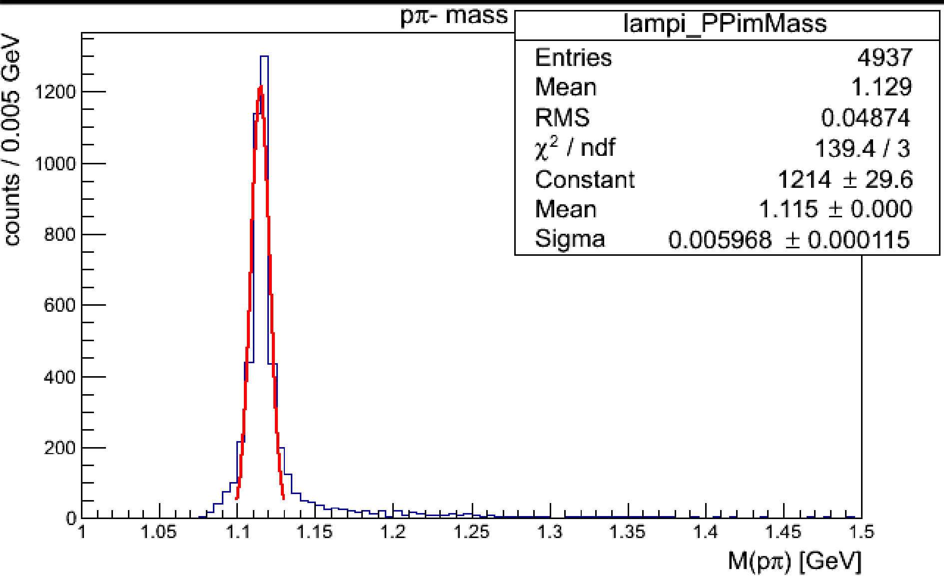
- Generated 100,000 events
  - Allowed GEANT to decay Λ
- Require detection of recoil $\pi^+ \rightarrow$ primary "vertex"
- K_L momentum reconstructed from time-of-flight between π^+ time at "vertex" and time at Be target

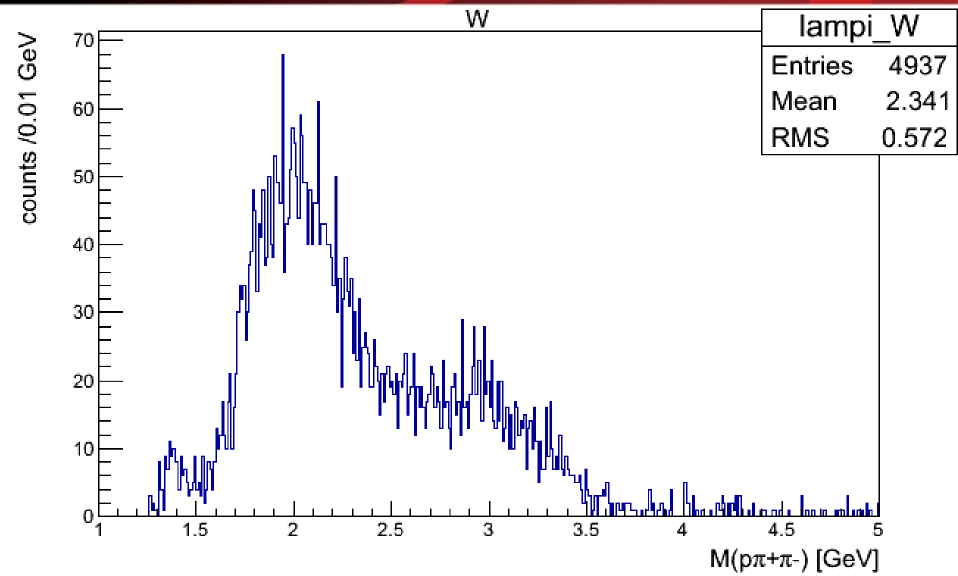


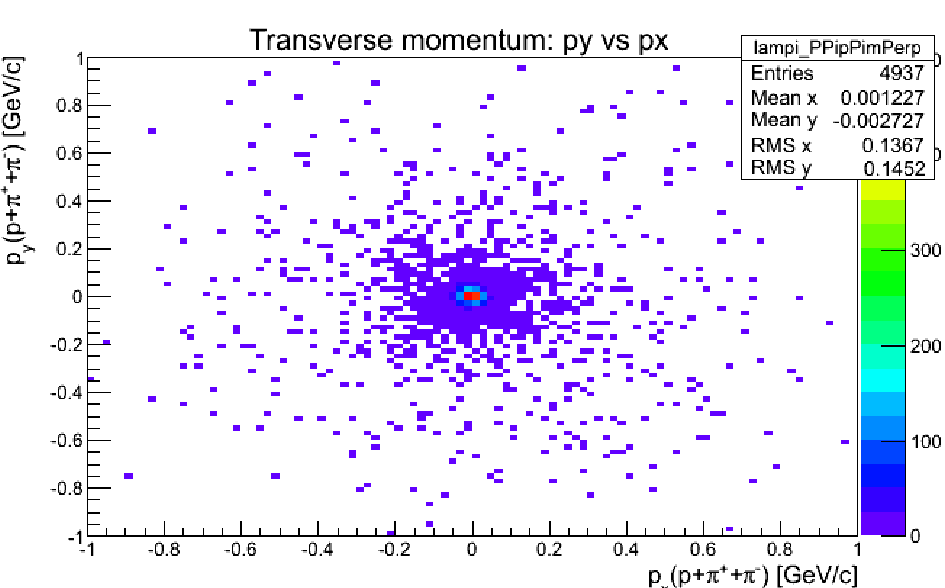


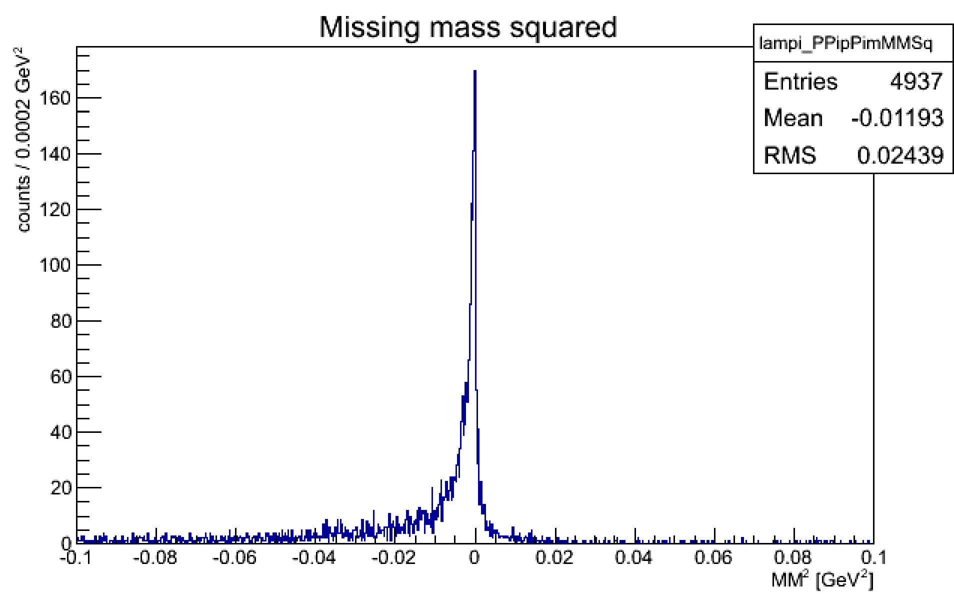
Requiring $p\pi^-$

$BR(\Lambda \to p\pi^-) = 63.9 \pm 0.5\%$

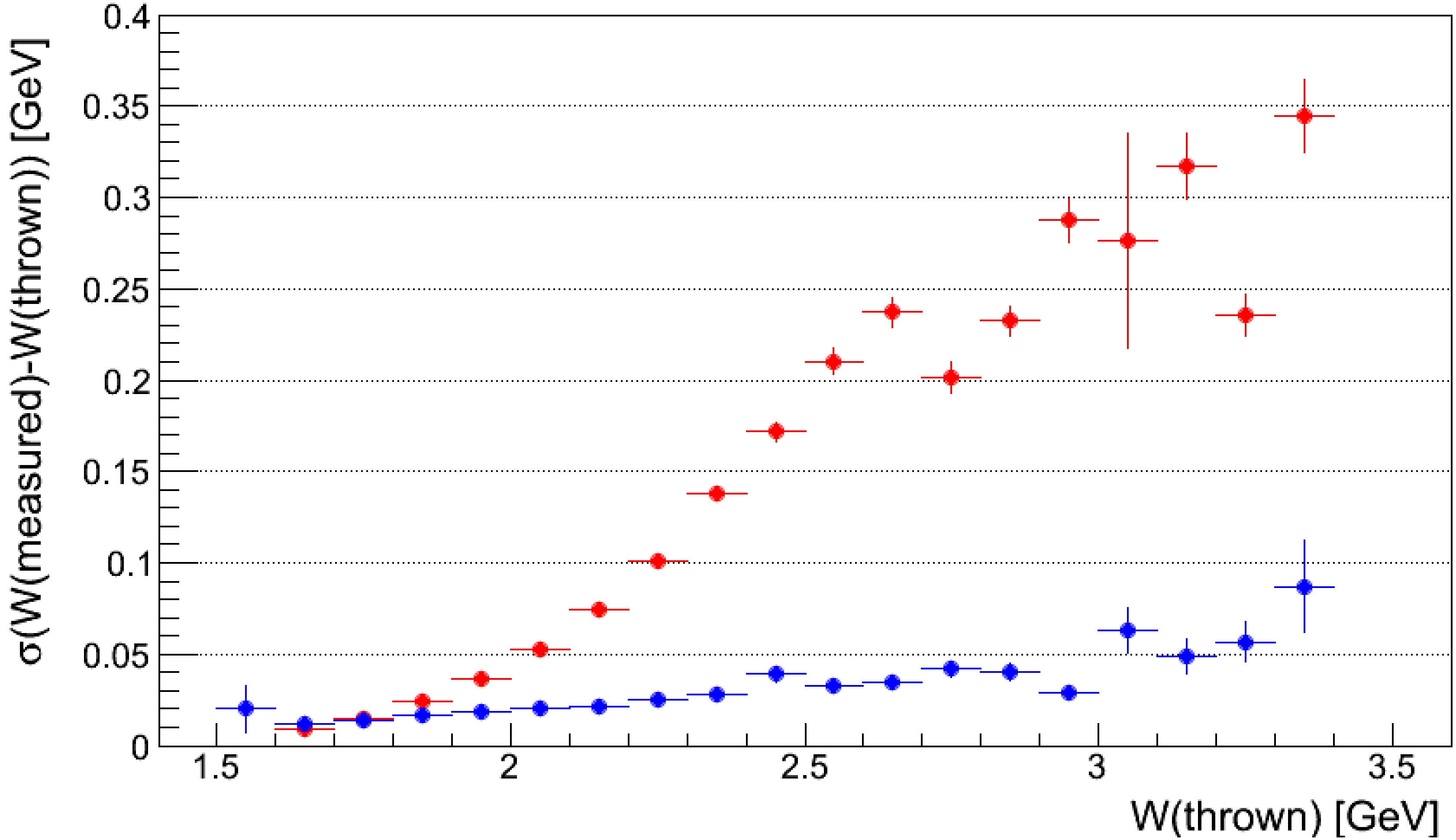








W resolution



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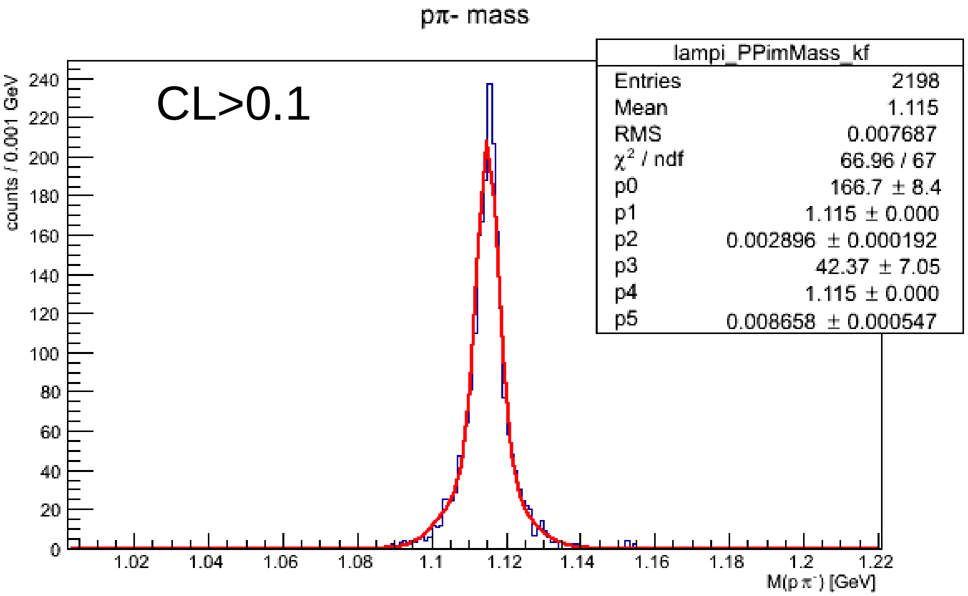
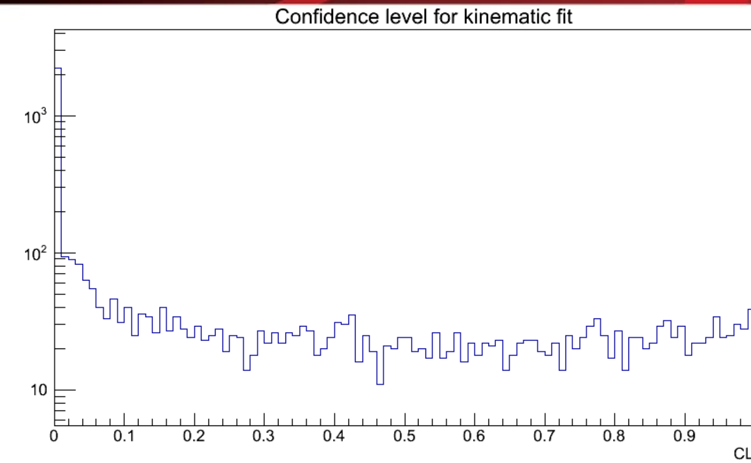
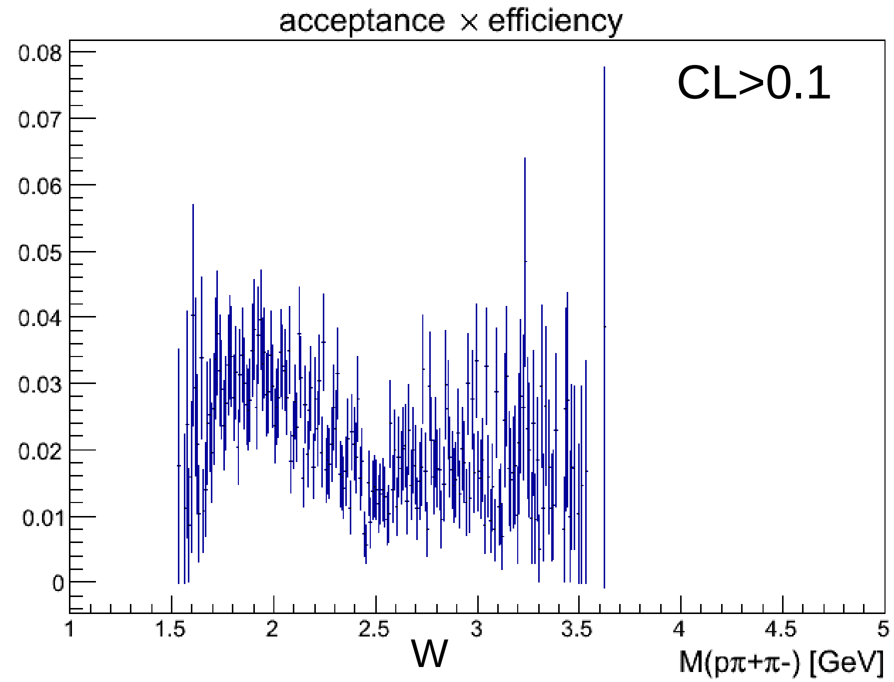
Kinematic fit for $\Lambda\pi^+$ channel





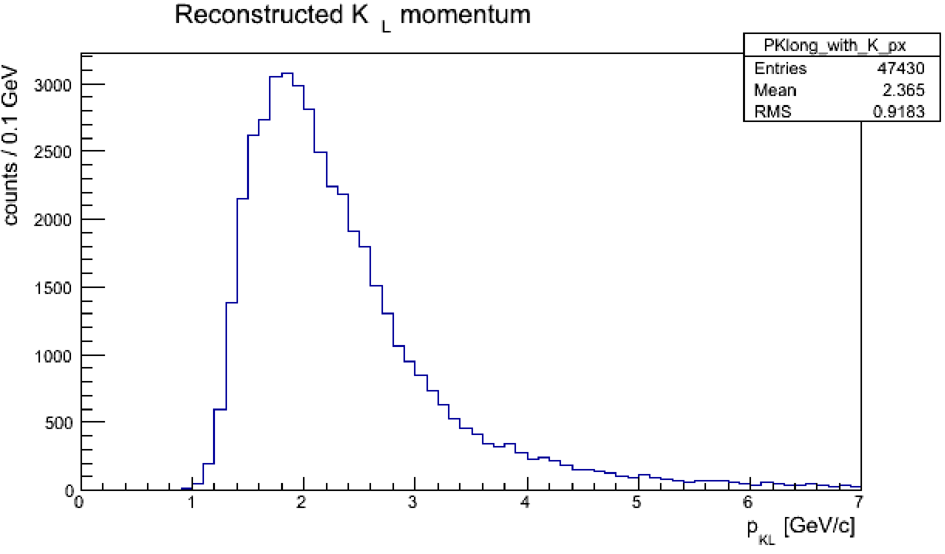


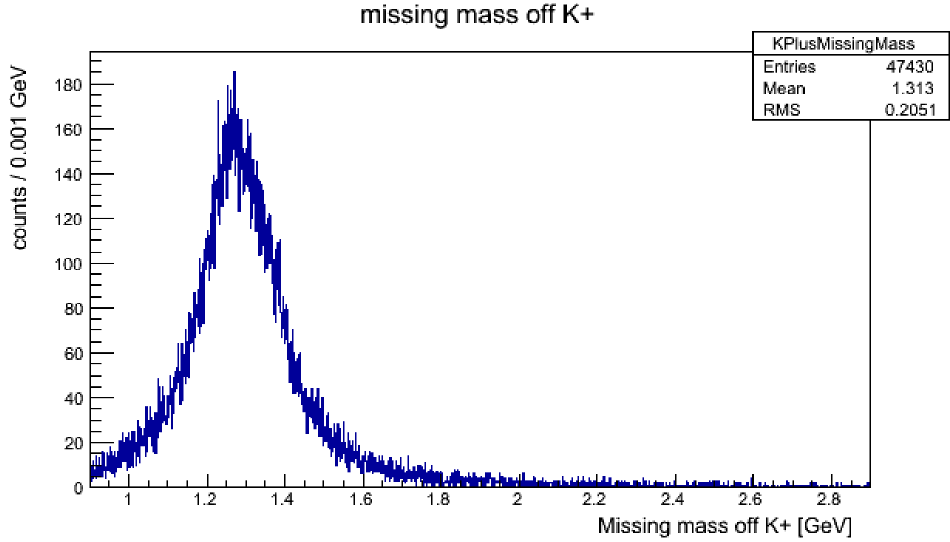
- Required energy and momentum conservation

Average acceptance×efficiency ≈ 2%

Reconstruction of $K^+\Xi^0$ events

- Generated 100,000 events
  - Allowed GEANT to decay Ξ^0
- Require detection of recoil $K^+ \rightarrow$ primary "vertex"
- K_L momentum reconstructed from time-of-flight using K^+ time at "vertex" and time at Be target

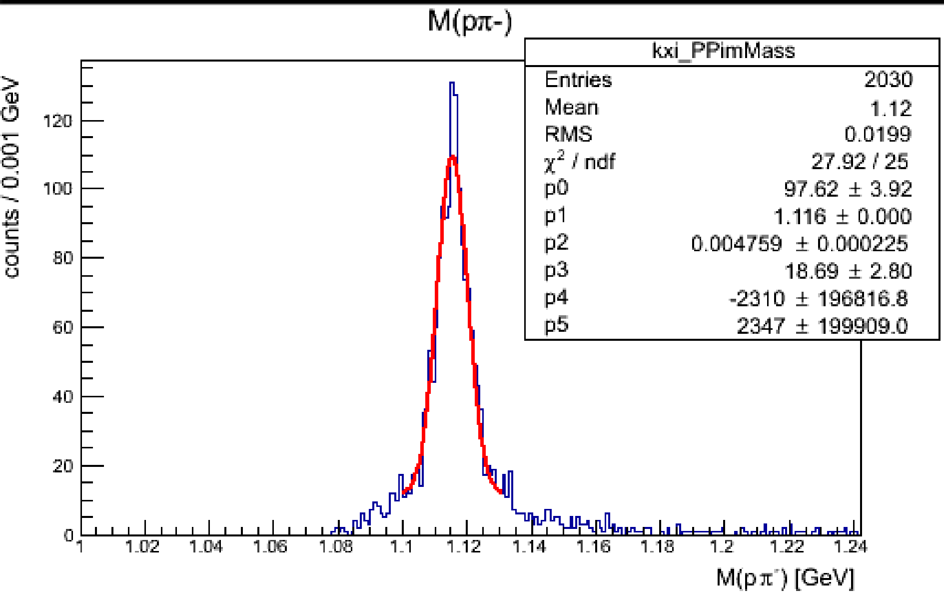


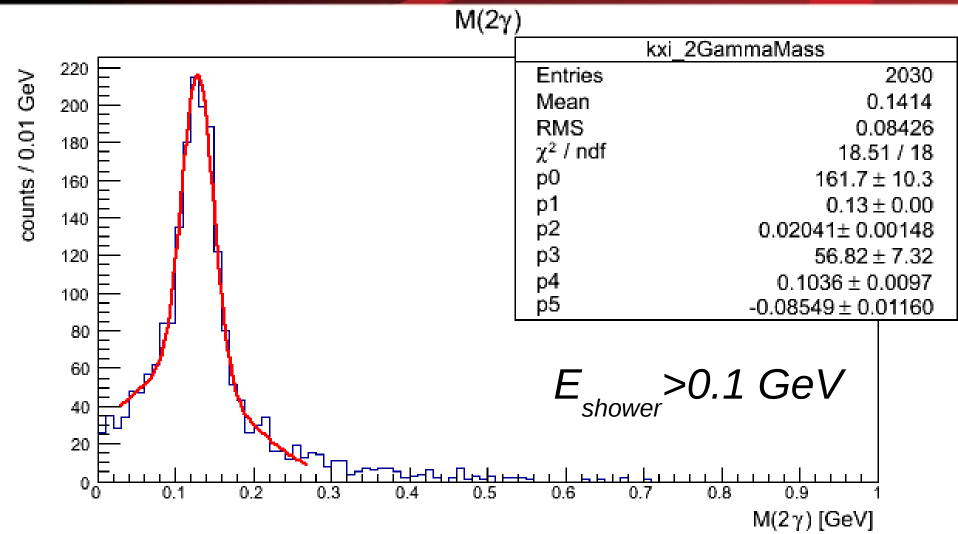


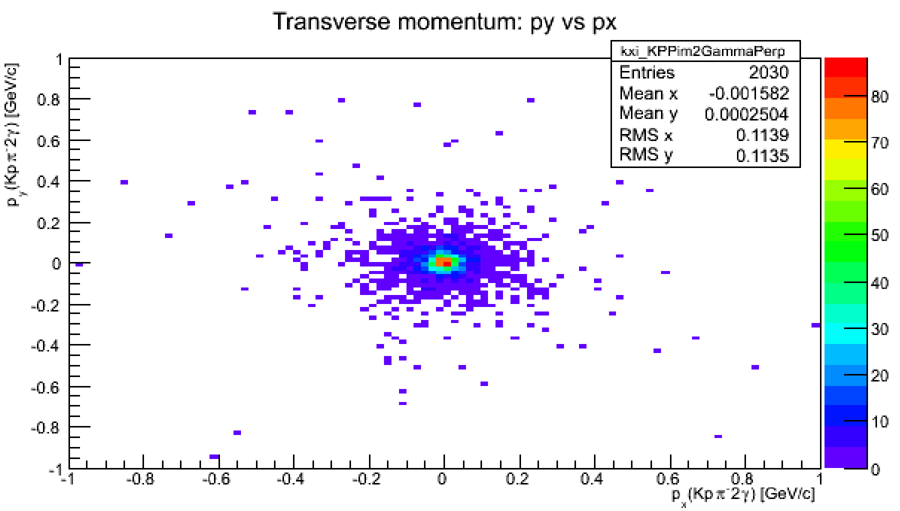
- Look for decay particles...

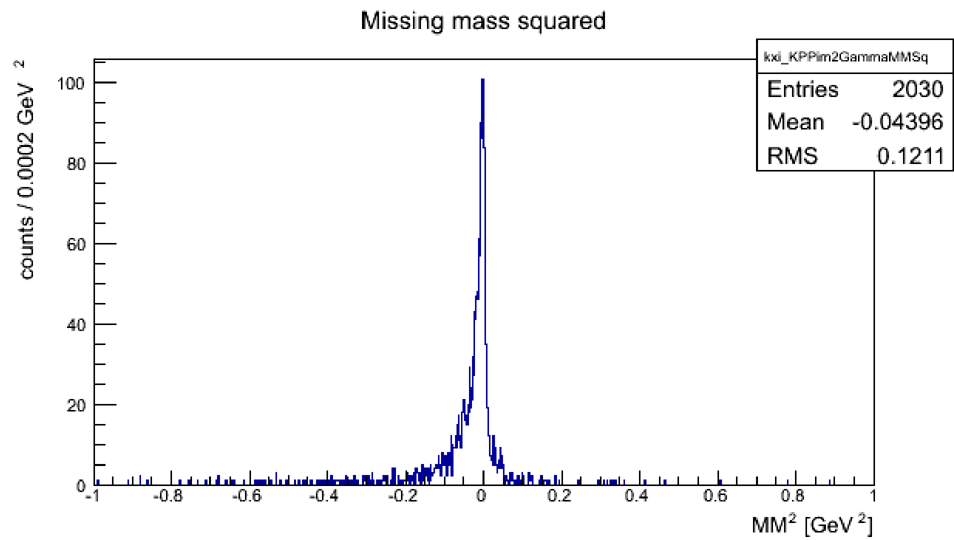
Ξ^0 decays to $\Lambda\pi^0$ almost 100% of the time...

Requiring p, π^-, 2γ

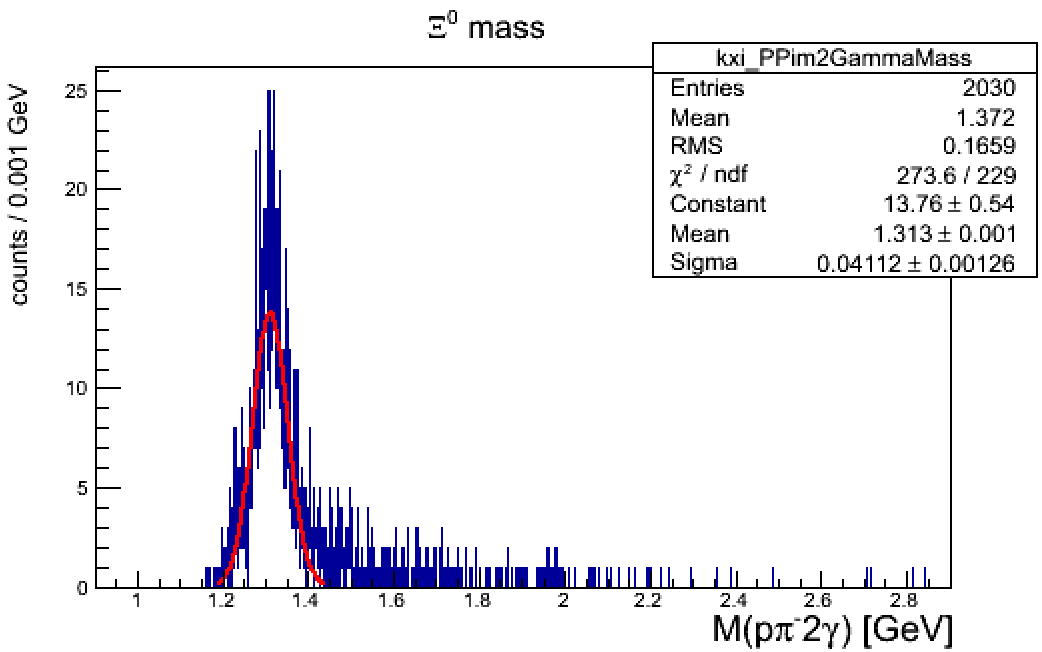




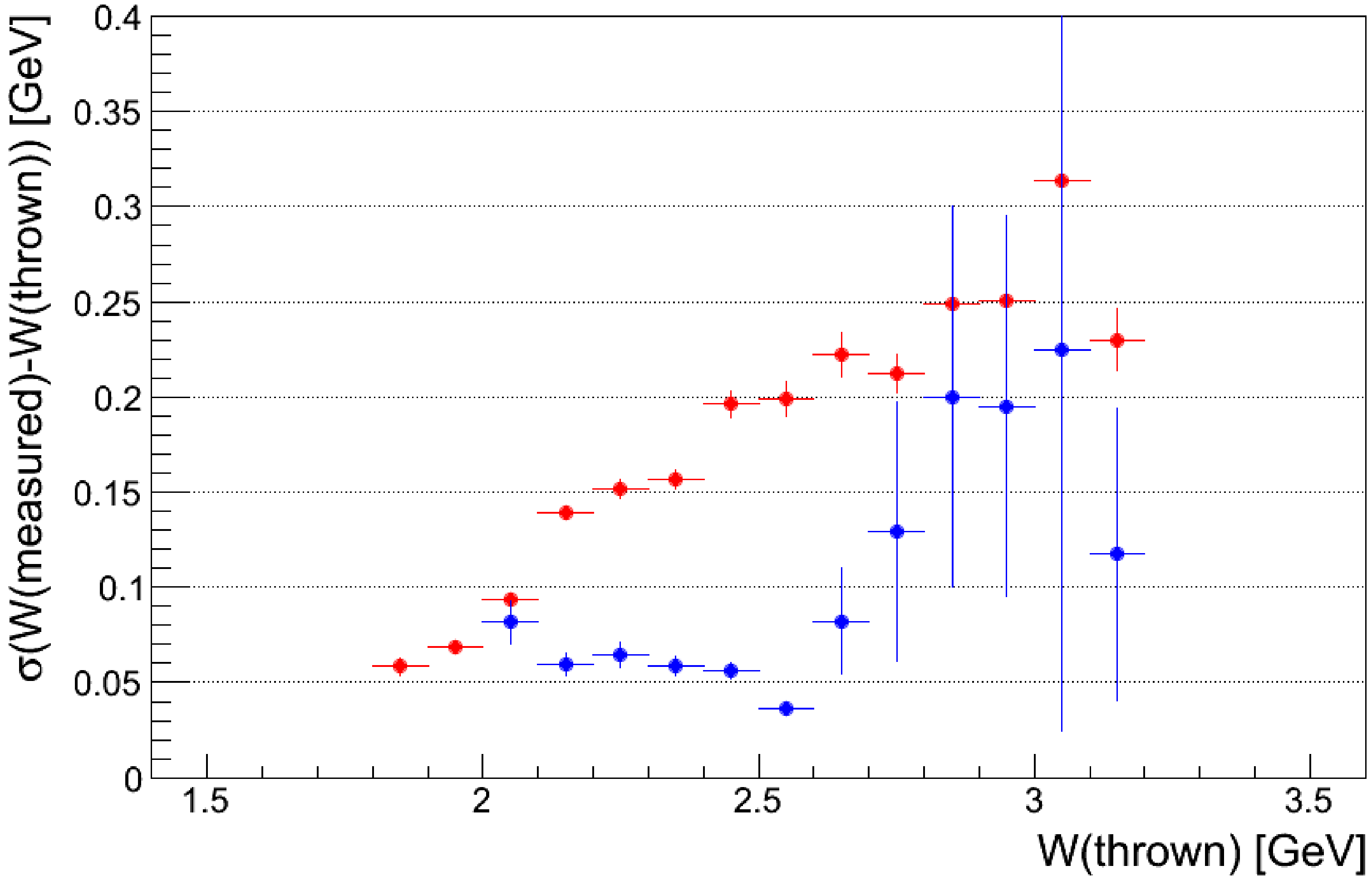




Reconstruction of Ξ^0 invariant mass



W resolution



Invariant mass technique

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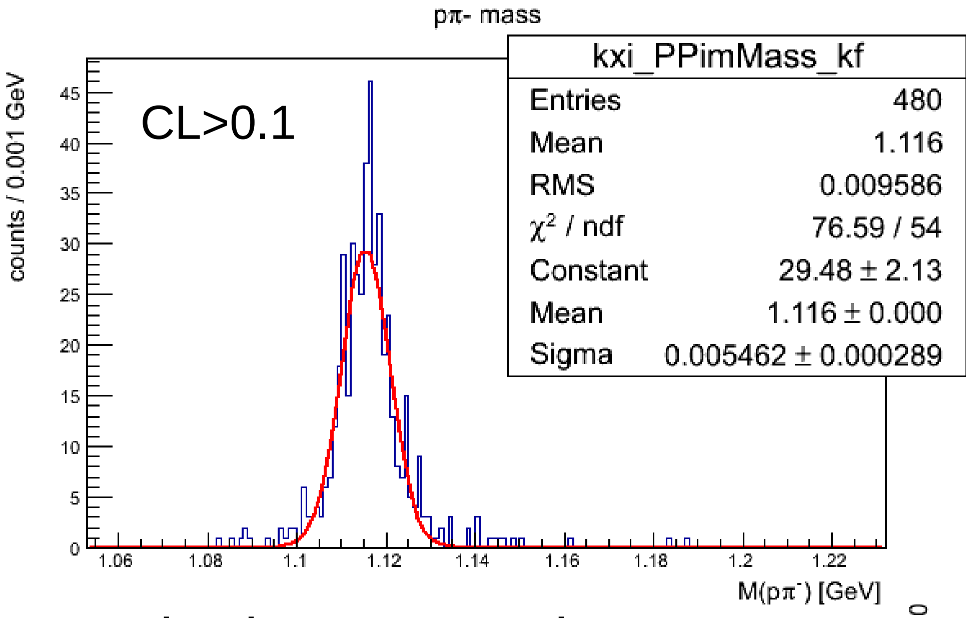
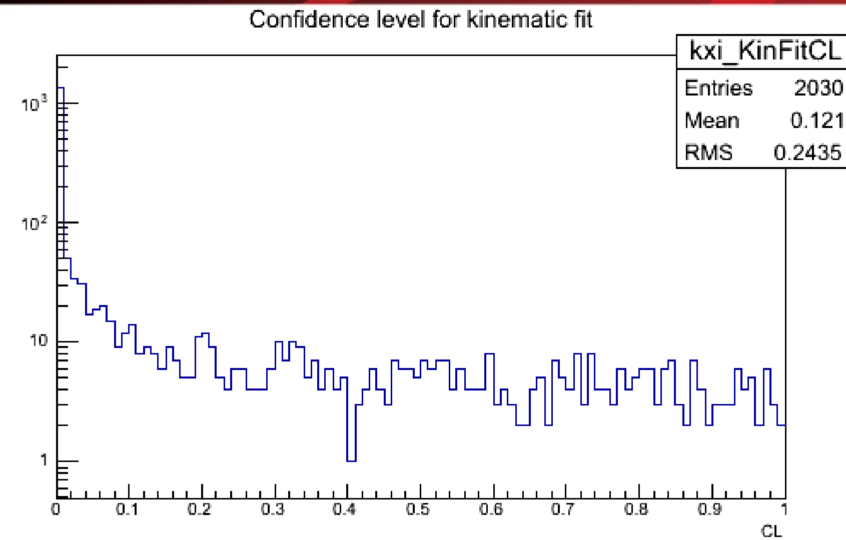
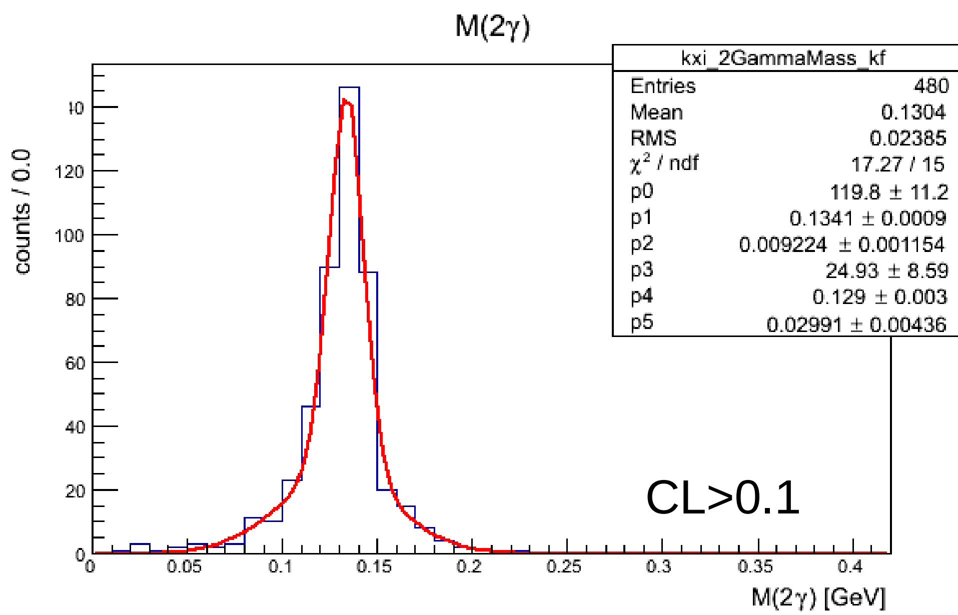
Kinematic fit for $K^+\Xi^0$ channel

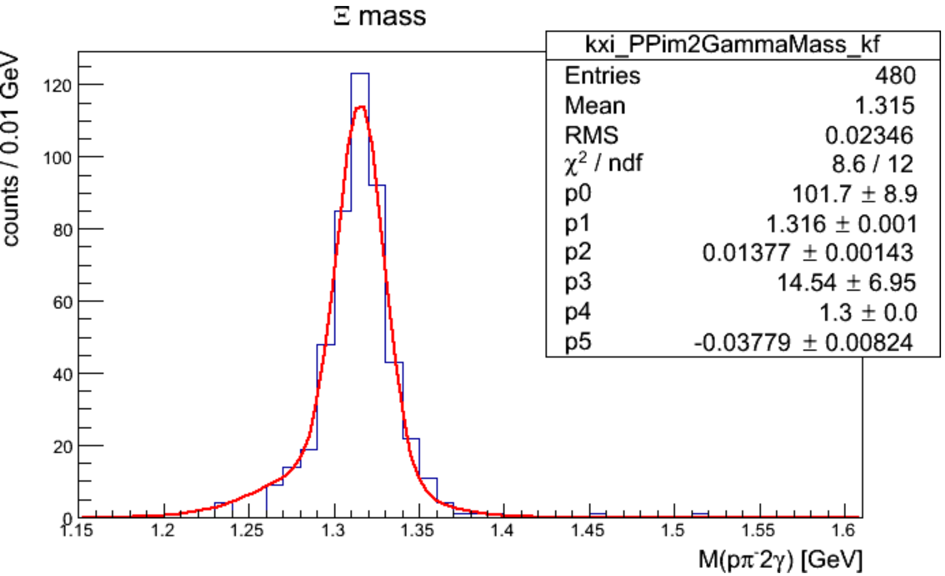




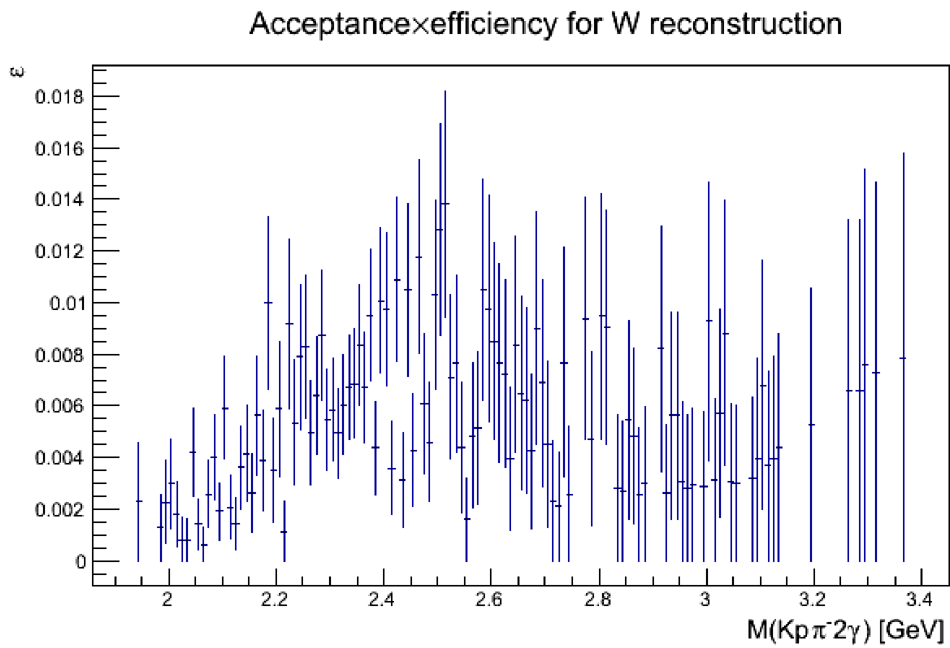


- Required energy and momentum conservation

More kinematic fit results



CL>0.1



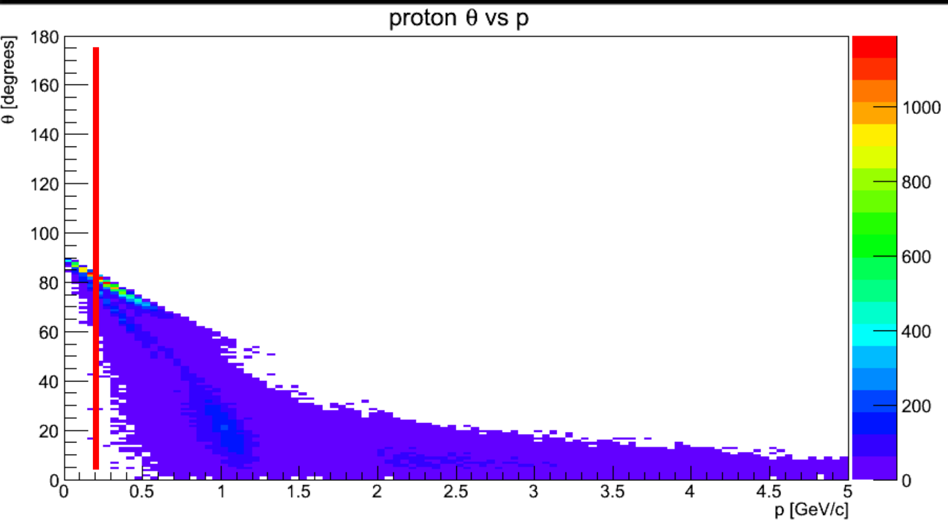
Average "efficiency" ~ 0.5%

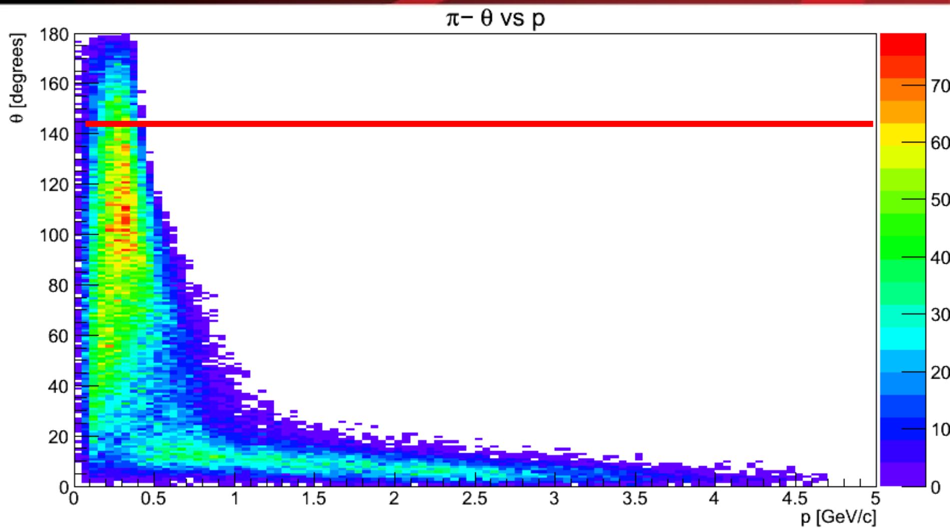
Summary

- Simulations were performed using a GEANT-based Monte Carlo for $K_L p \to p K_S$, $\Lambda\pi^+$, and $K^+\Xi^0$
  - W resolution for time-of-flight technique rises with W
  - W resolution using invariant mass technique better for high W
  - Kinematic fitting looks promising
    - Additional constraints on $\pi^+\pi^-$ mass for K_s channel and $p\pi^-$ mass for $\pi^+\Lambda$ channel will help improve W resolution for invariant mass technique

Backup slides

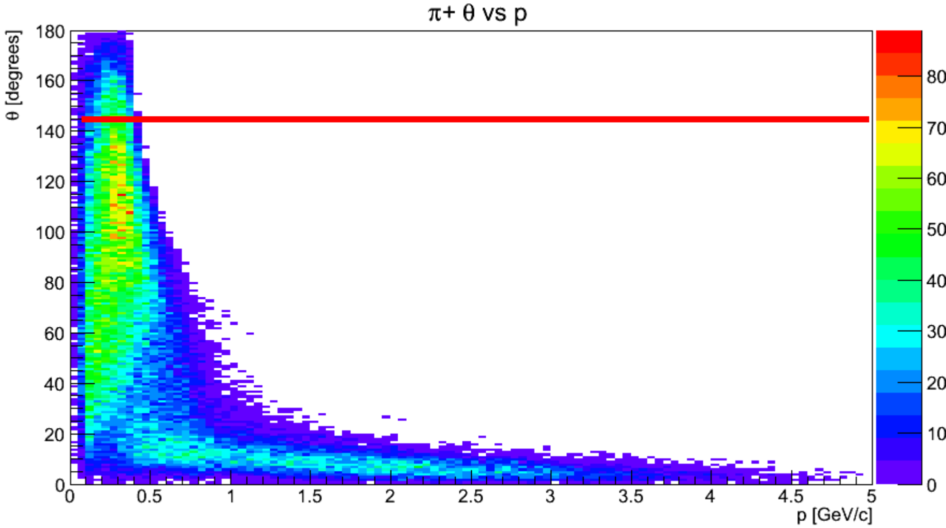
Kinematic distributions for pK_S



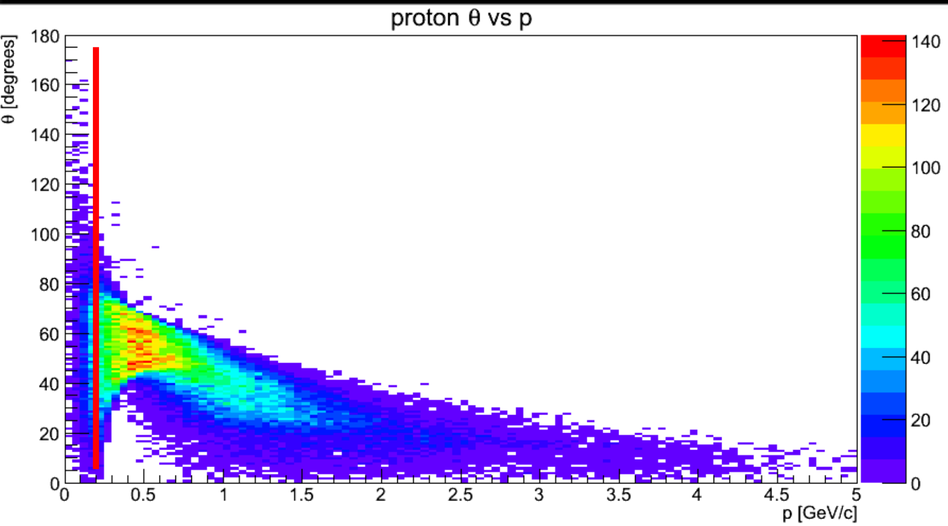


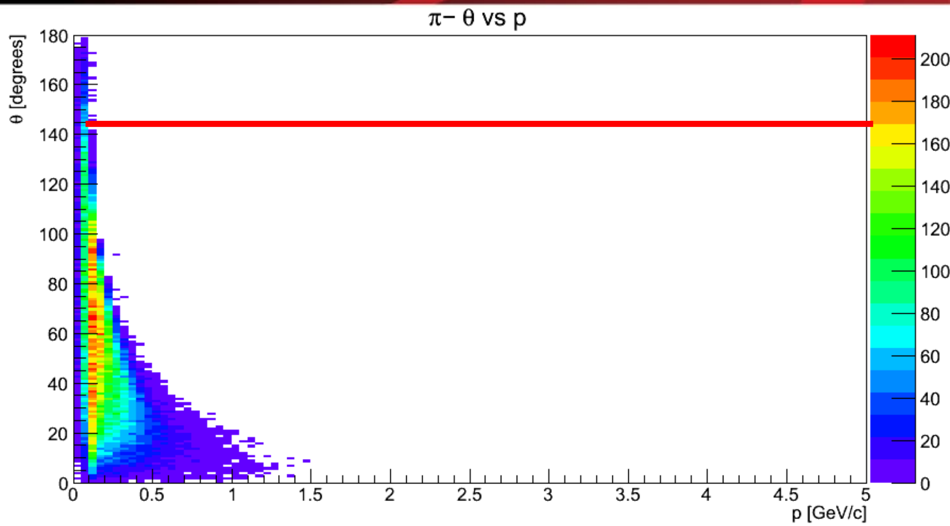
Thrown distributions

Protons with p<0.25 GeV/c do not make it to CDC layers

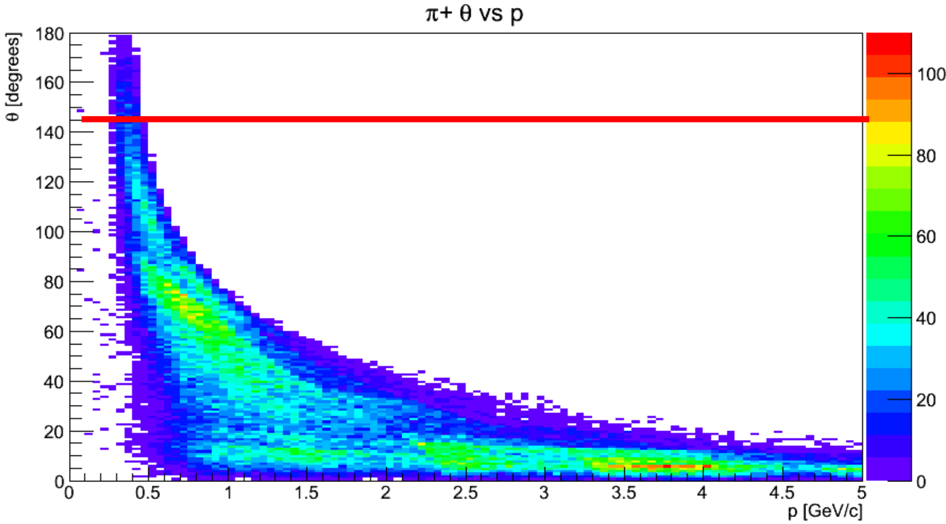


Kinematic distributions for $\Lambda\pi^+$





Thrown distributions



Kinematic distributions for $K^+\Xi^0$