University of Glasgow

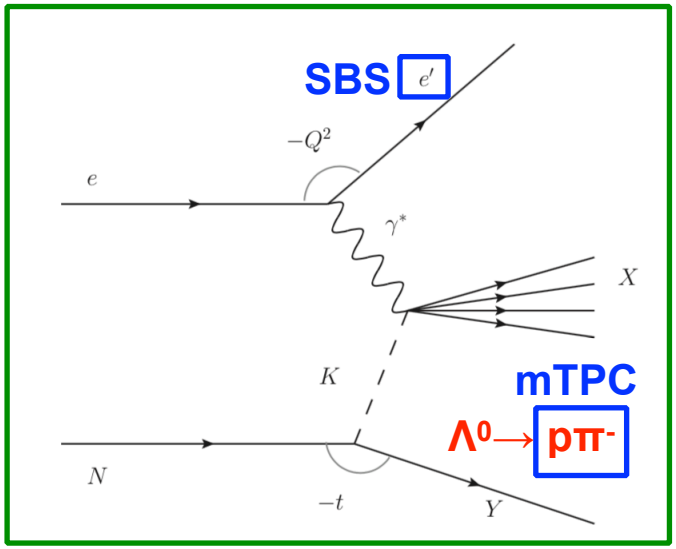
# Kaon TDIS Simulation Studies Status Update

Rachel Montgomery

TDIS Collaboration Meeting,

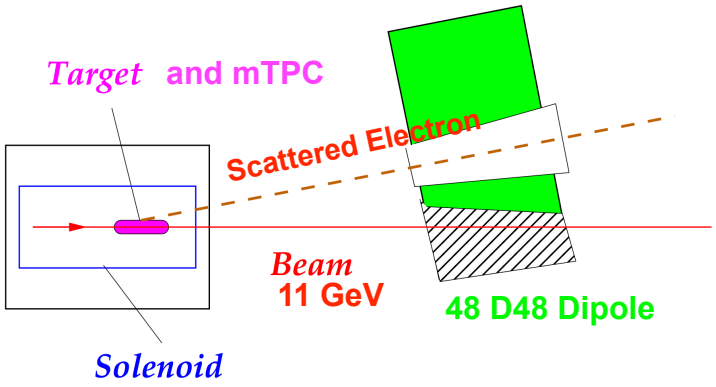
Jefferson Lab, 22/02/18

# Kaon TDIS Measurement




- e- scattering from kaon cloud of hyperon
- Access to kaon SF (world first)
- Probe strangeness content in nucleon
- Evolution of PDFs - important to include not only valence quarks, but also sea and glue at hadronic scale
- Improve understanding of background processes in πTDIS

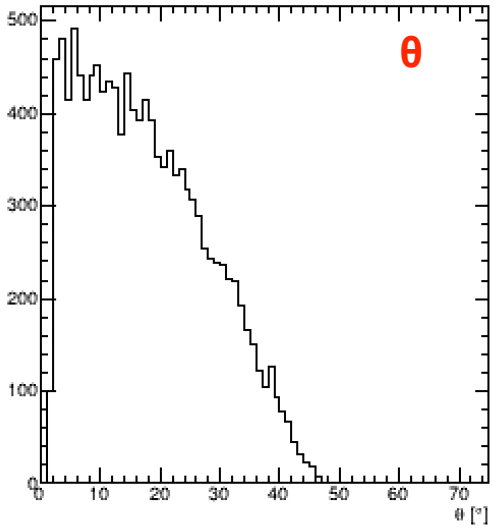
**Electron arm – SuperBigbite**

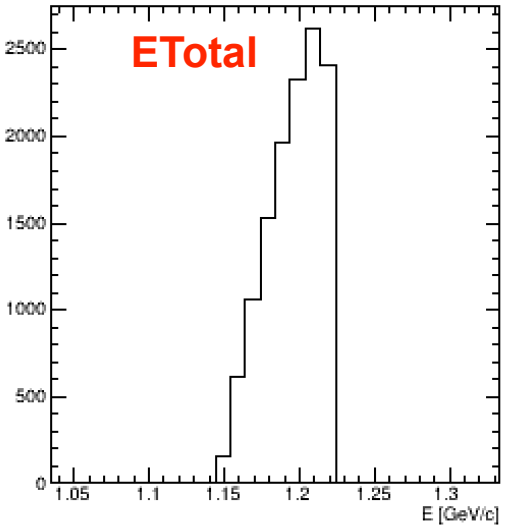



- Measure semi-inclusive H(e,e'Λ)X
- $W^2$=8-18GeV$^2$, $Q^2$=1-3GeV$^2$, $x_{Bj}$=0.05-0.2
- $\Lambda^0$ momenta similar to proton in πTDIS

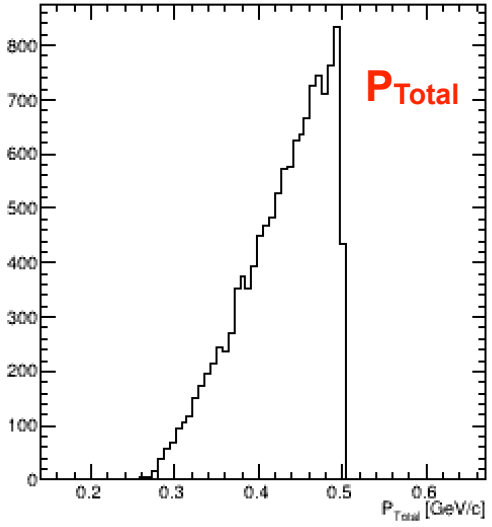
- Set up same as for πTDIS
- SBS for DIS e'
- mTPC for $\Lambda^0$
- $\Lambda^0$ uncharged, creates no track in mTPC
- mTPC detects p, $\pi^-$ in $\Lambda^0 \rightarrow p\pi^-$, to reconstruct $\Lambda^0$
- ($\Lambda^0$ $\tau$~2.632x10$^{-10}$s, mean $c\tau$ 7.89cm)

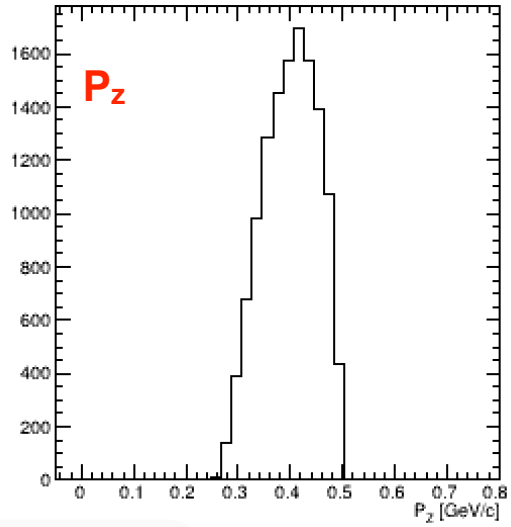
# Kaon TDIS Events: $\Lambda^0$

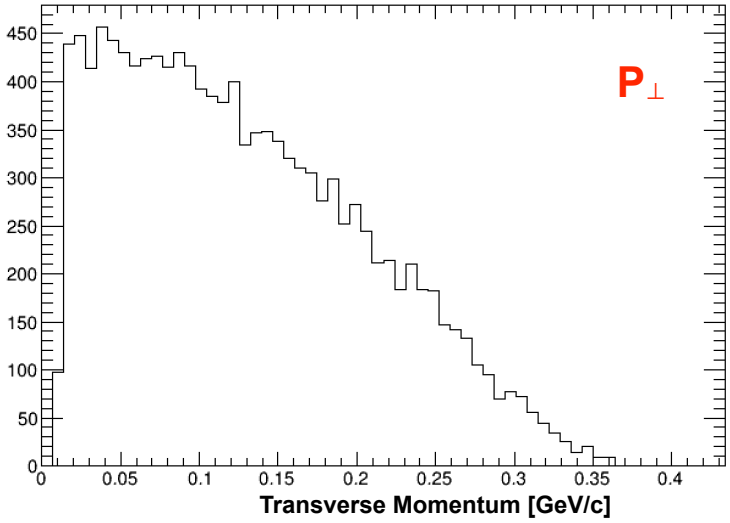


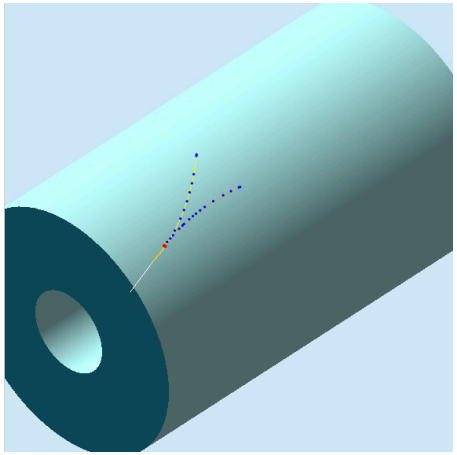

- Example $\Lambda^0$ kinematics from kTDIS EG (K. Park)
- EG specifically written for kTDIS H(e,e'$\Lambda$)X reaction. Details of EG physics included found in proposal
- $\Lambda^0$ from EG input to simulations and resulting p, $\pi^-$ tracks studied
- Vertex distributed randomly along entire length of target

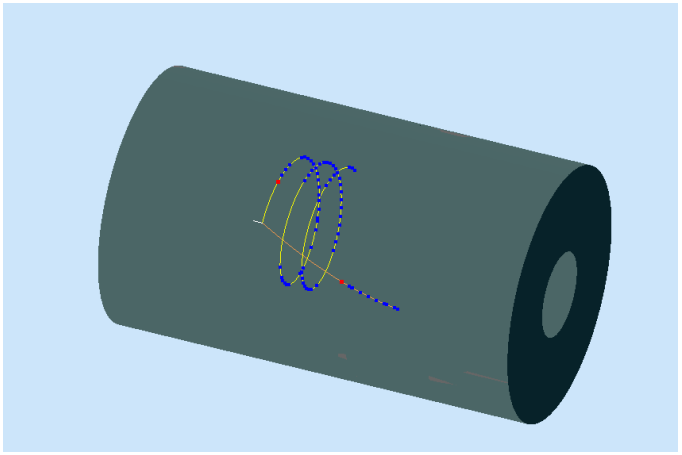


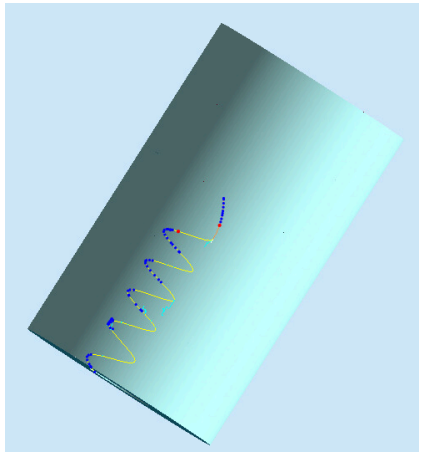



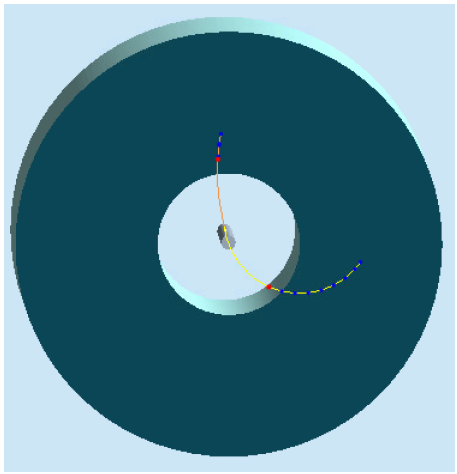



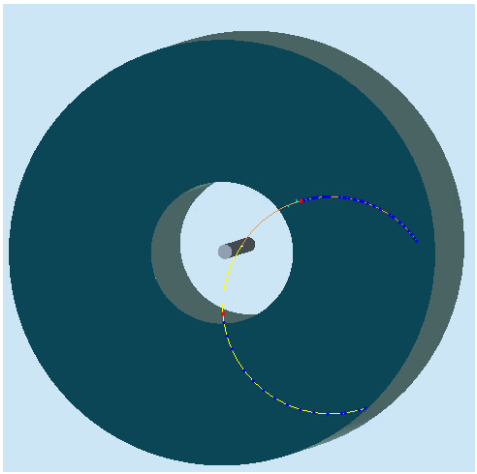
# Kaon TDIS Events in mTPC GEMC Geometry







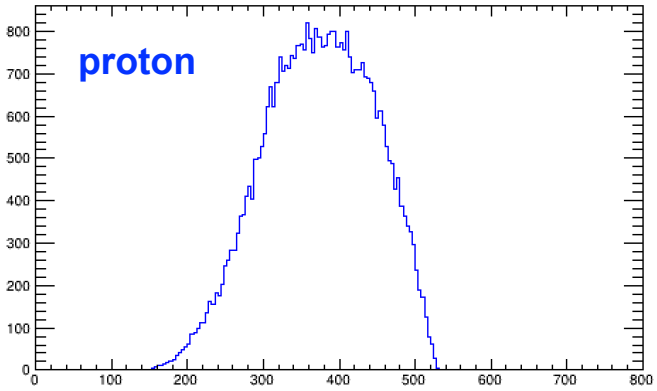


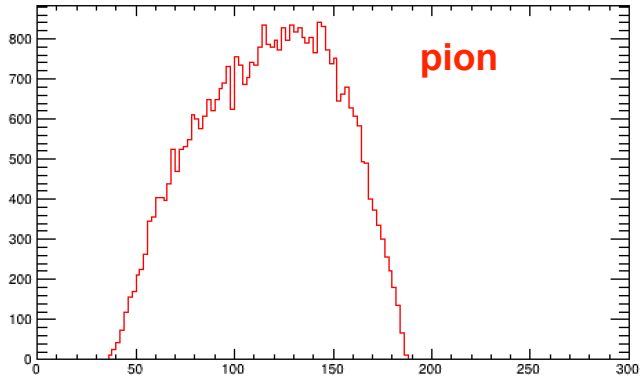


- Events from kTDIS EG have now been input to mTPC GEMC sim (geometry from M. Carmignotto)
- Significant fraction of low momentum pions “spiral”
- “Curvature” of pion track will help ID
- Track reconstruction will assist accidental rejection, since e.g.:
  - Λ(pπ) decay angle back to back in CM frame
  - Time/position vertex correlations in pπ tracks, along with e’ vertex

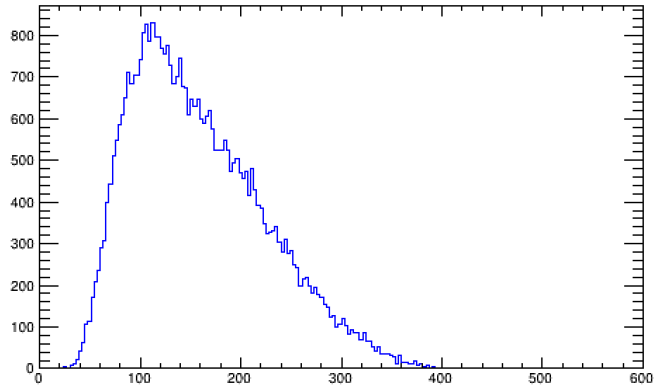
# Kaon TDIS Events: p, π-

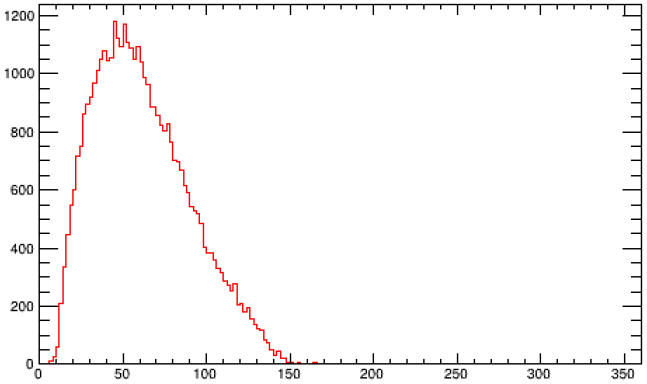
- Example p, π- kinematics after Λ decay in mTPC geometry



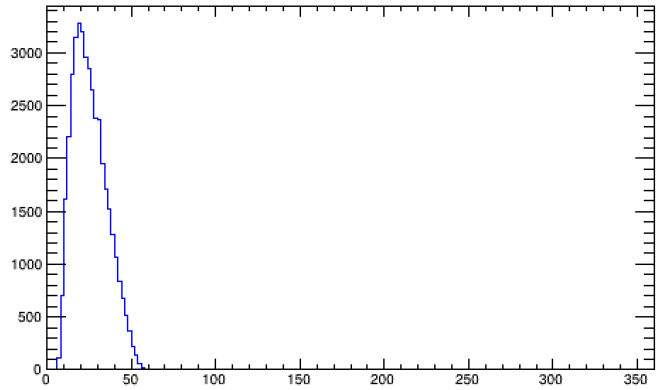



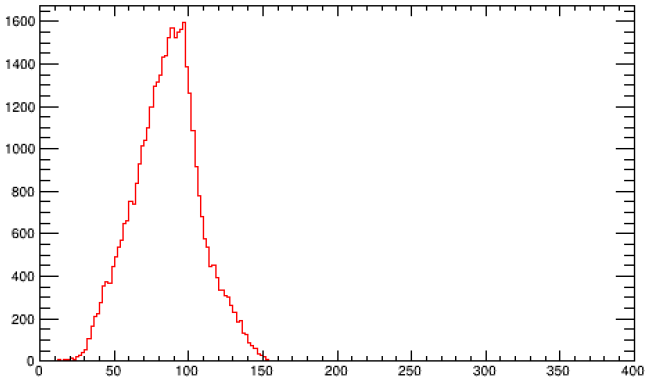

$P_{Total}$ [MeV/c]





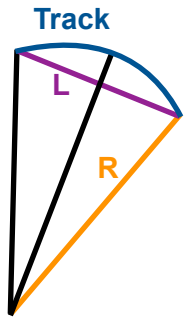
$P_{\perp}$ [MeV/c]





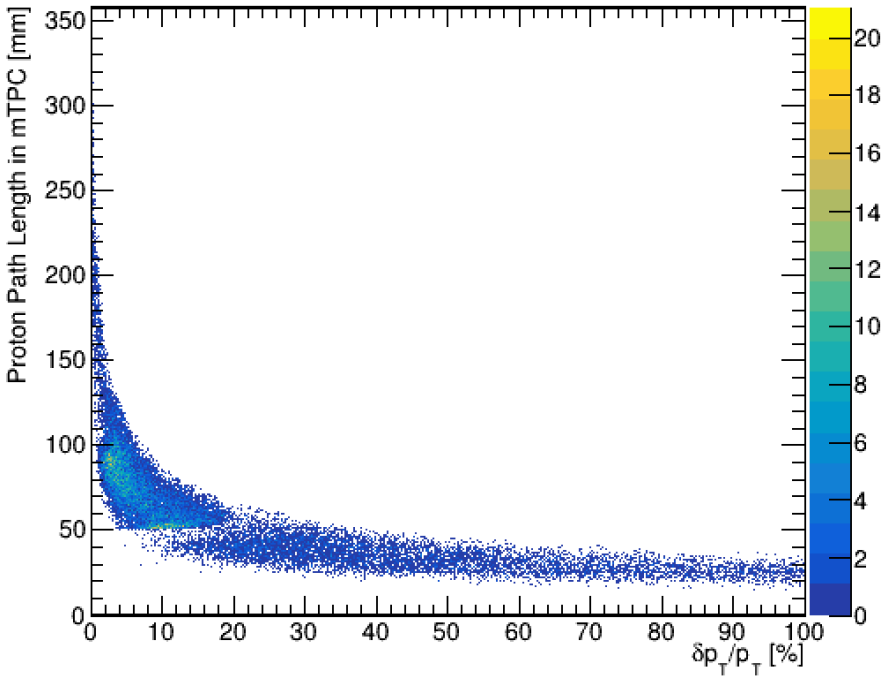
θ[°]

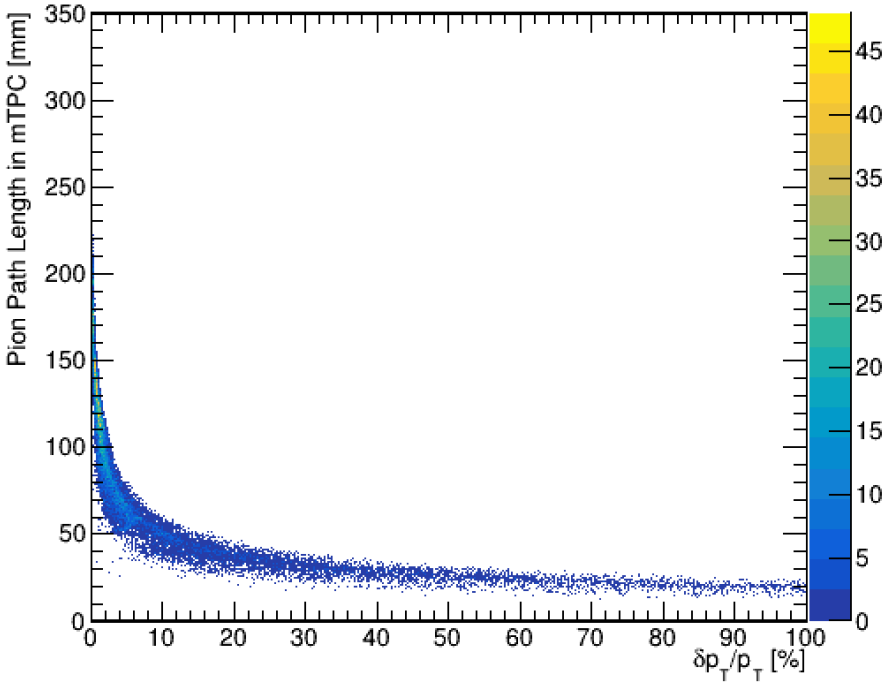
# Transverse Momentum Resolution



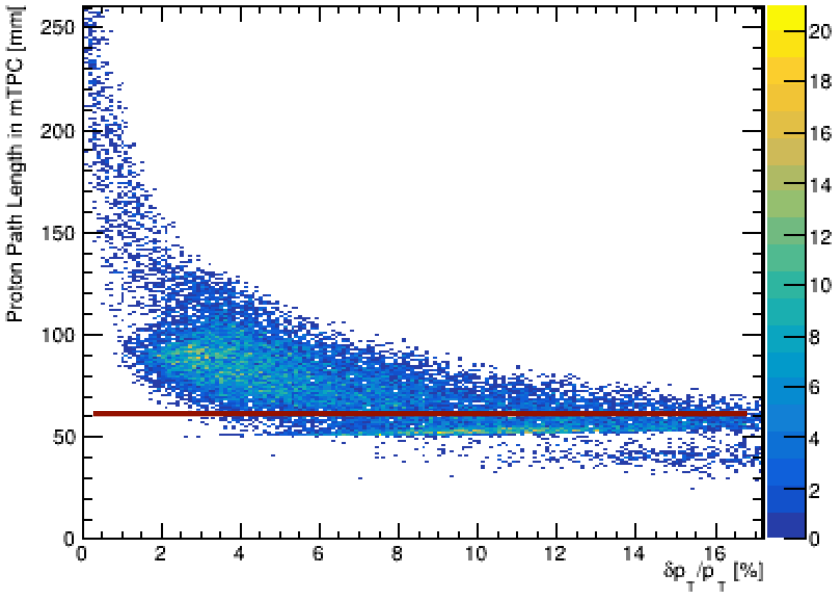

- Fractional momentum resolution $\delta p_\perp / p_\perp$ estimated for p, π tracks
- $\delta p_\perp / p_\perp \sim ( 8 p_\perp / (0.3BL) ) * \sigma_x$
- $\sigma_x$ ~ (strip resolution/number strips hit per track)
- strip resolution ~ 5mm/sqrt(12)

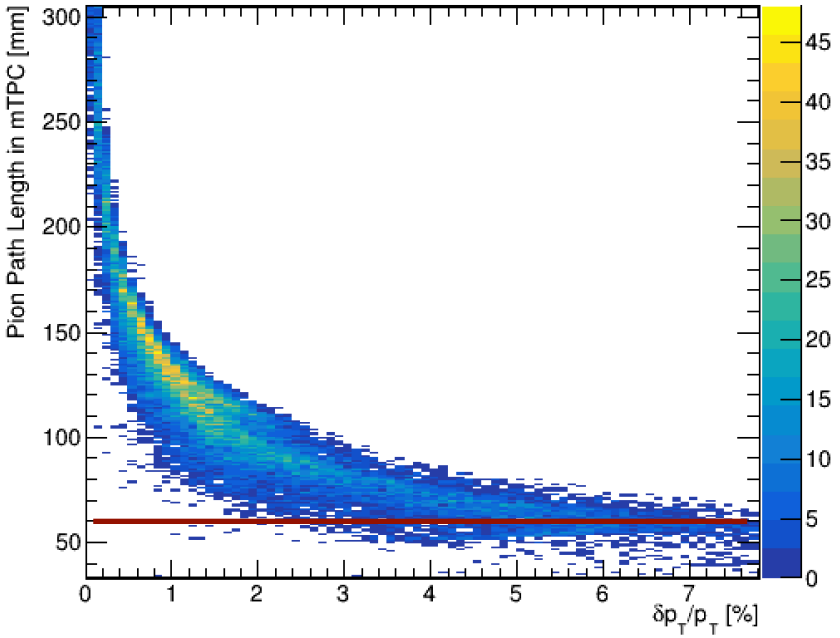
- Resolution from multiple scattering not estimated for now
- Possible future study - may be important for final gas selection



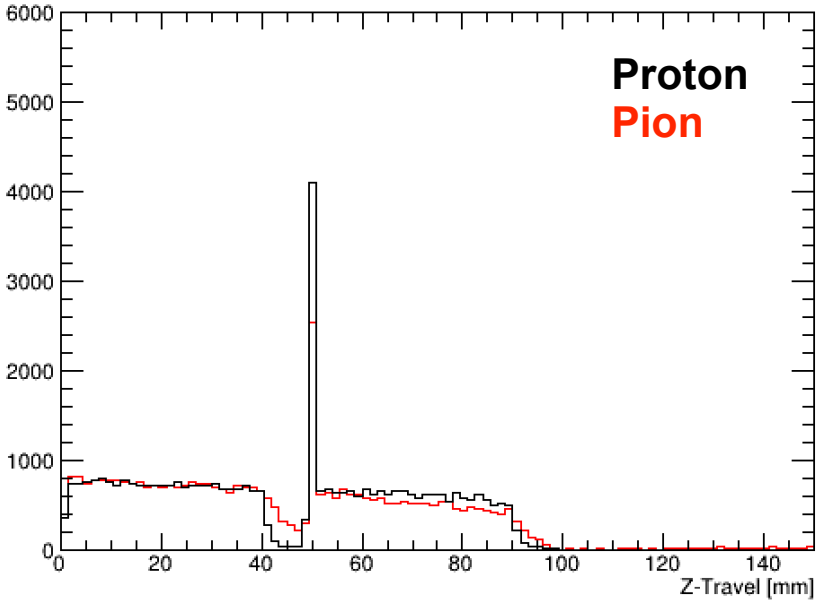
# Transverse Momentum Resolution




- Differences in path lengths, “spiralling” of π
- Subsequent studies required a min path length of 60mm

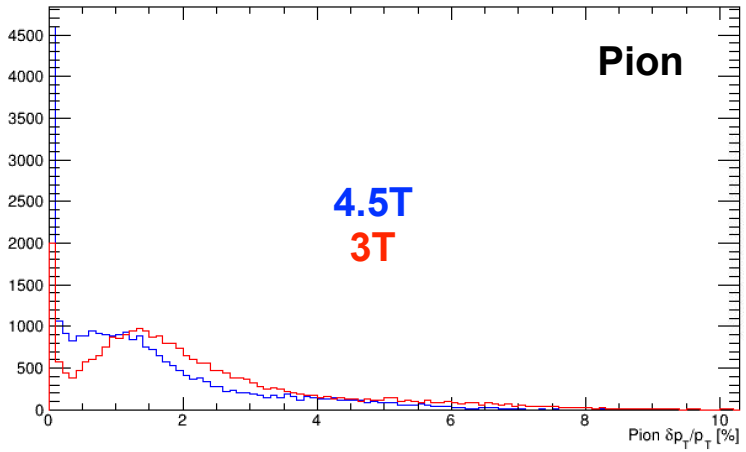
- Time of arrival of drift e on readout plane and time resolution of readout should be ok to resolve the π spiral path
- Max electron distance 50mm, assume roughly 2μs drift time achievable
- (p track mean time 0.5ns; π mean time 1ns)

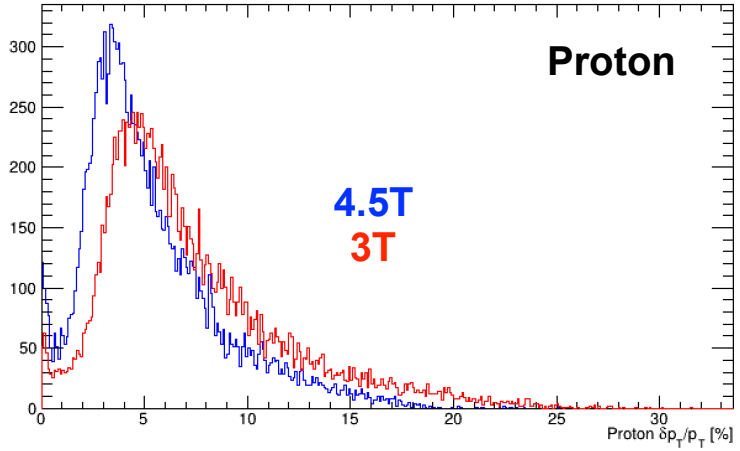


# Magnetic Field Scan

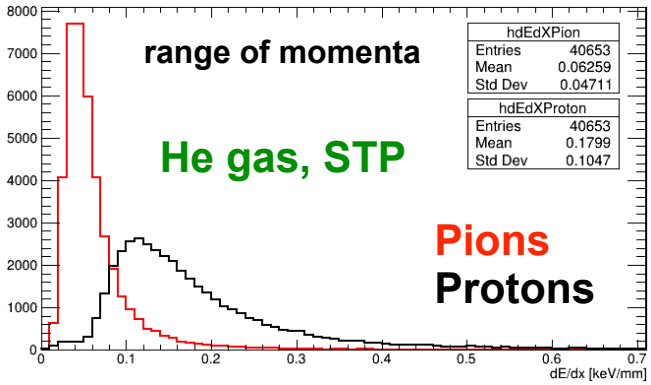
- Solenoid field affects acceptance of the kTDIS events
- Proton acceptance appears to have the larger influence on efficiency
- Although, as expected, transverse momentum resolution superior for higher field
- Since increase in efficiency is not a large effect, larger field strength is optimal
- Next step would be to check similar scan for πTDIS in mTPC

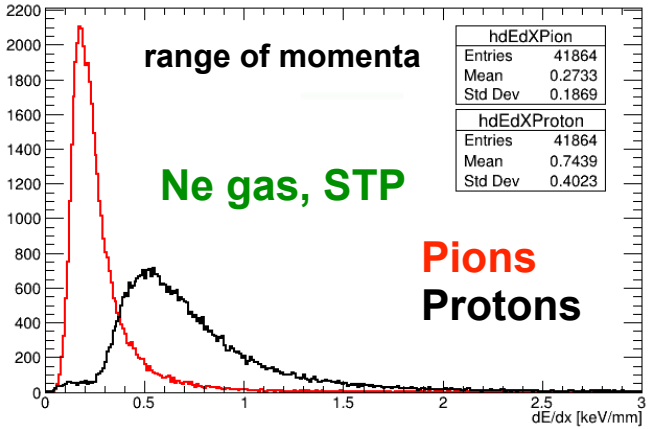
| Field (T) | Efficiency p [%] | Efficiency π [%] | Efficiency (pπ) [%] | Efficiency (pπ) w/ path>cut [%] |
|---|---|---|---|---|
| 4.5 | 42.5 | 54.7 | 32.2 | 8.0 |
| 4.0 | 42.6 | 55.5 | 32.7 | 8.5 |
| 3.5 | 42.9 | 56.1 | 33.1 | 8.5 |
| 3.0 | 42.8 | 55.9 | 33.1 | 8.5 |
| 2.5 | 42.9 | 56.3 | 33.3 | 8.5 |



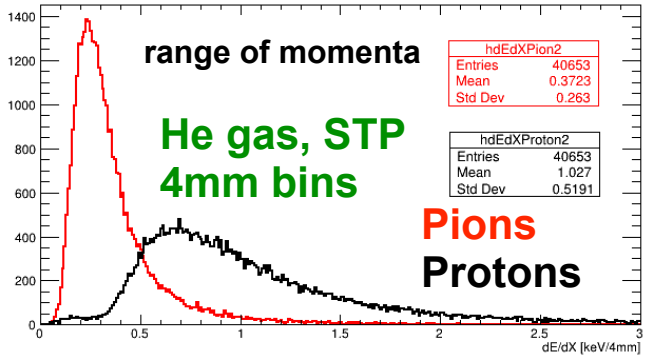



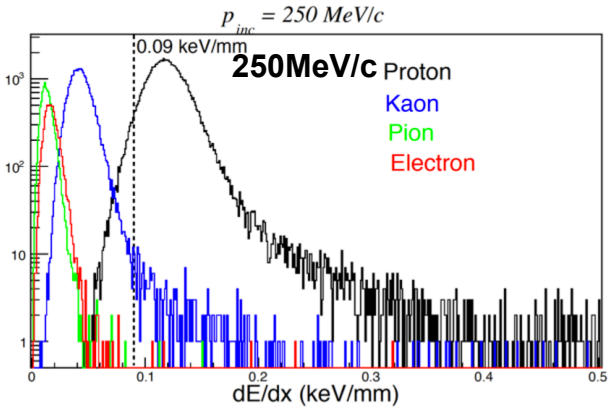
# Energy Deposit by p and π⁻ in Gas Volume



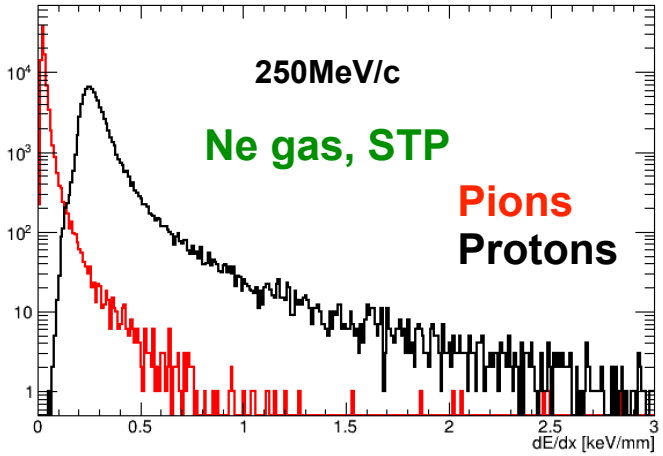




Same gas, increased binning



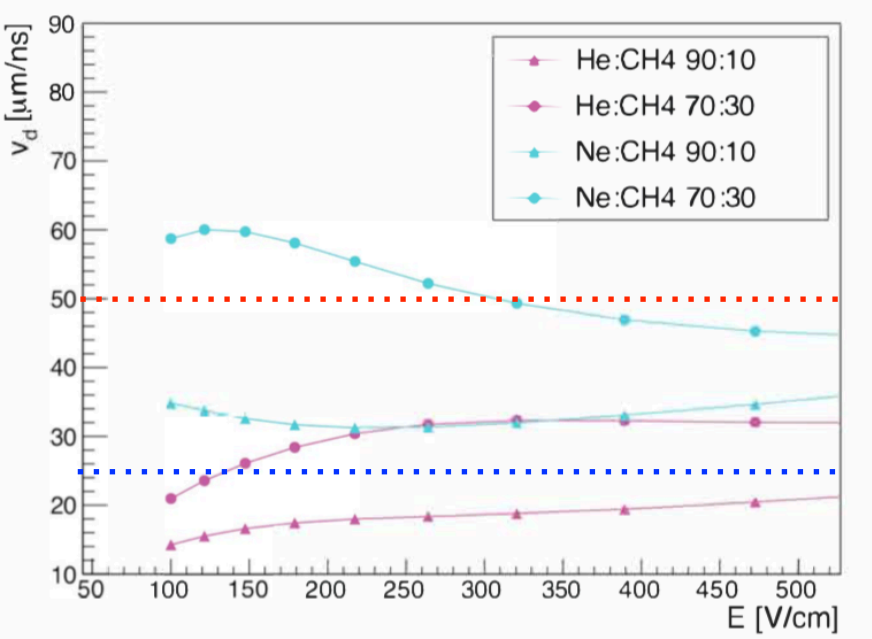




**Energy deposit in He of original RTPC for different particles**




- dE/dx resolution is outstanding to be studied further, as a function of momentum
- Situation could be improved for π. Increasing Z of gas will increase dE/dx, but want Z as low as possible, also will depend on/trade-off w/ gain GEMs
- Distributions at 250MeV/c for proton slightly higher than RTPC behaviour due to different He pressure

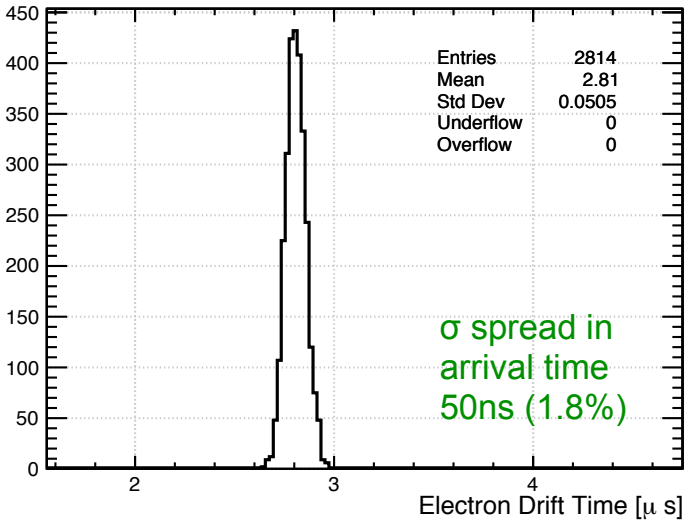
# Drift Gas and Ionisation

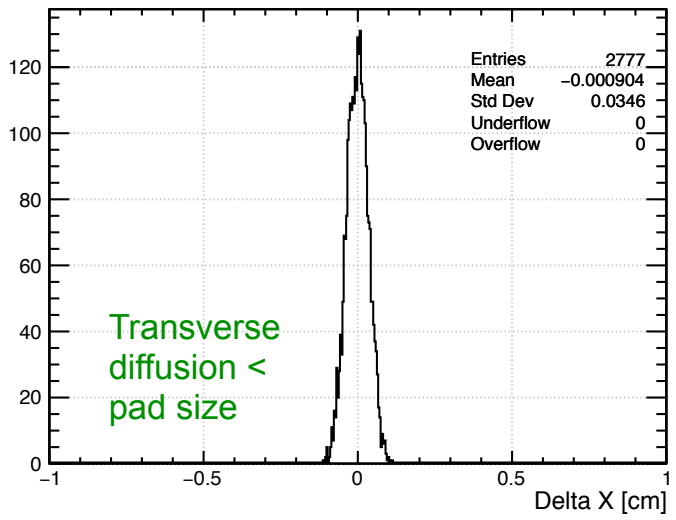



- Garfield++ simulations
- He and Ne mixes with CH4, @115K, 0.1atm
- Ne faster, but higher density and effective Z

- $v_d$ scales as E/P, e.g. 200V/cm @ 0.1atm equivalent 2000V/cm @ 1atm
- For 1μs drift, want $v_d$~50μm/ns
- For 2μs drift, want $v_d$~25μm/ns

- Ionisation yield untrustworthy at these momenta for incident p/π in Garfield++
- Comparison with prototype will be useful to verify simulations, especially ionisation yield




| *Gas* | *Ionisation Threshold @STP [eV]* |
|---|---|
| *He* | *24.6* |
| *Ne* | *21.6* |
| *CH4* | *12.7* |

Mean dE/dx for p and π @250MeV in He@STP from mTPC= ~314eV/mm and ~36eV/mm (~1208 and 138 primary e-/5cm)

**Example: He:CH4; 90:10; 115K; 0.1atm, 5cm drift e-**

# Toy MC Event Generator

- Applying software cut on $\Lambda^0$ invariant mass from $p\pi^-$ reconstruction may reduce inclusion of background events

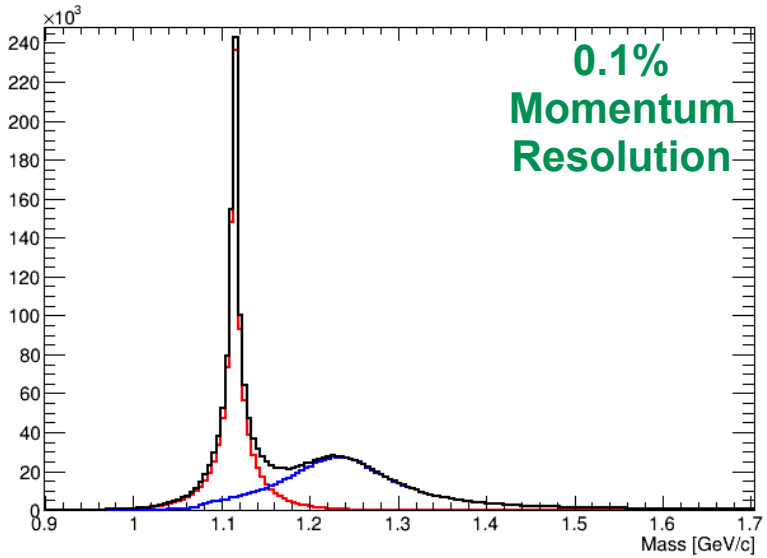
- Toy MC to give rough idea of where $\Lambda^0$ reconstruction sits beside other processes

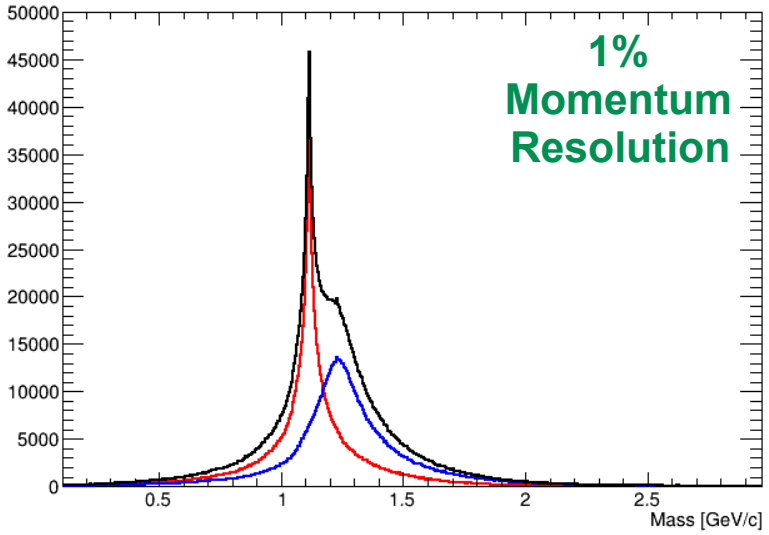
- ROOT TGenPhaseSpace generator to generate n-body event
- Based on EdGen generator from CLAS HASPECT collaboration
- Reaction simulated over all phase space
- Output: 4-mom of outgoing particles
- Models:
  - phase space single E for e-beam
  - Breit-Wigner mass models from PDG for particles

- Apply momentum resolution smearing
  - randomly sampled smearing from Gaussian with σ=mom resolution

- No reaction mechanism cross-section weighting made!
- Looked at:
  - $\Lambda^0 \rightarrow p\pi^-$
  - $\Delta^0 \rightarrow p\pi^-$ (next most competing process in πTDIS)
  - $(\Sigma^0 \rightarrow \Lambda^0\gamma \rightarrow p\pi^-\gamma)$
  - $\Sigma^0$ not relevant for mTPC, since γ would not be detected

# Toy MC Event Generator

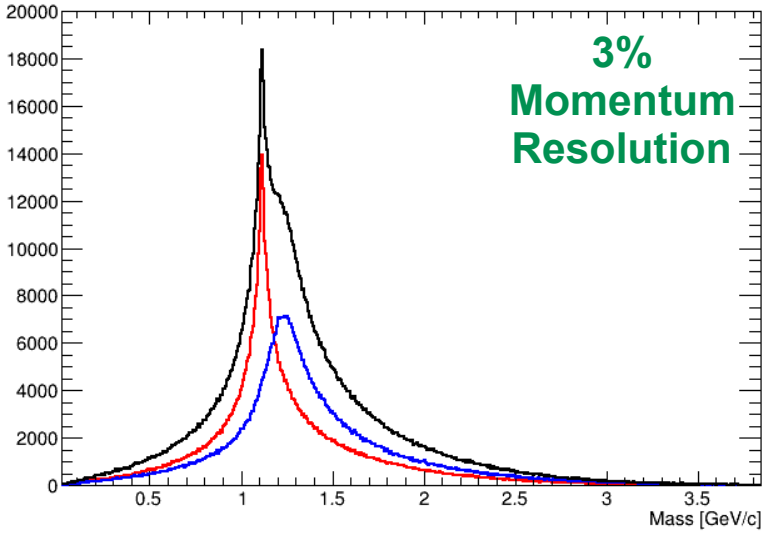


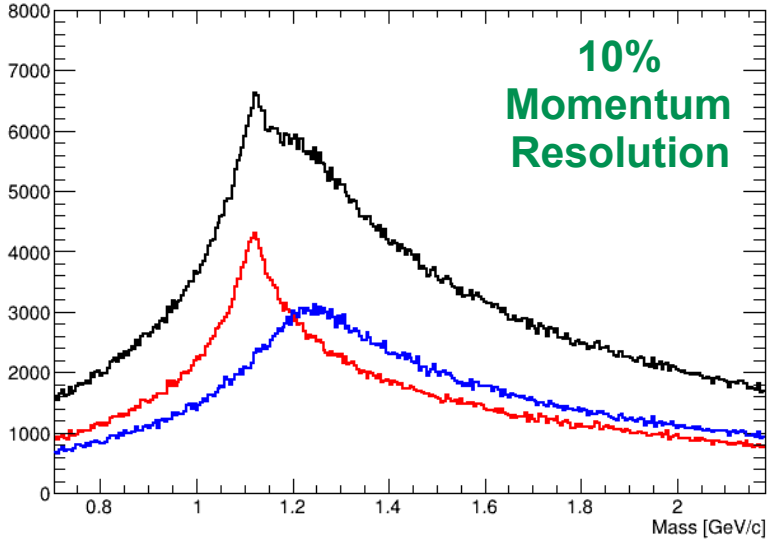




$\Delta^0 \rightarrow p\pi^-$

$\Lambda^0 \rightarrow p\pi^-$

All

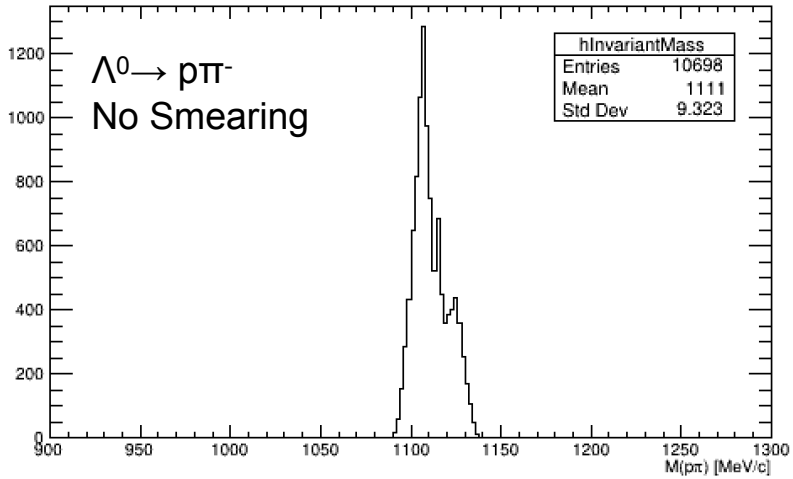


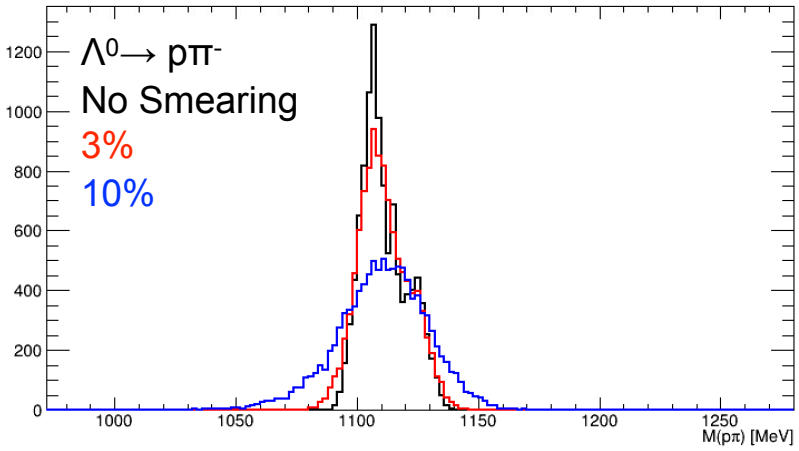



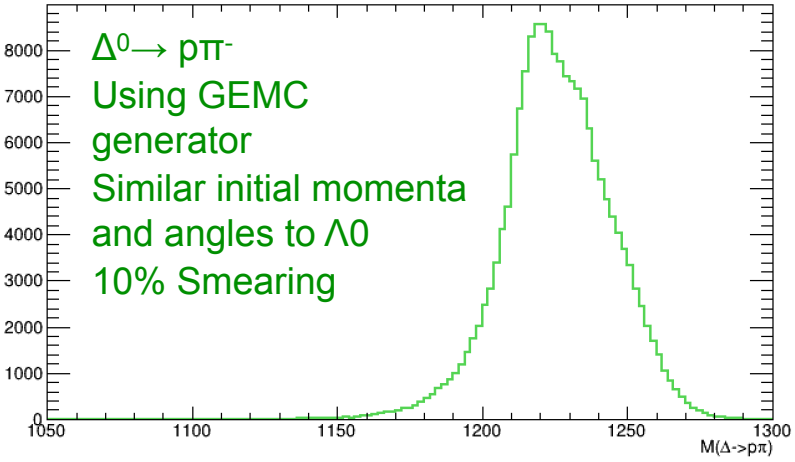
# Invariant Mass Reconstruction

- Initial look at invariant mass of (pπ) with path lengths >60mm in mTPC
- Next step will be to include mis-identification from accidentals

| Momentum Smearing [%] | Width Λ [σ, MeV] | Peak Resolution [%] |
|---|---|---|
| 0 | 9.32 | 1.97 |
| 0.1 | 9.33 | 1.97 |
| 1.0 | 9.47 | 2.00 |
| 3.0 | 10.53 | 2.23 |
| 10.0 | 18.63 | 3.94 |



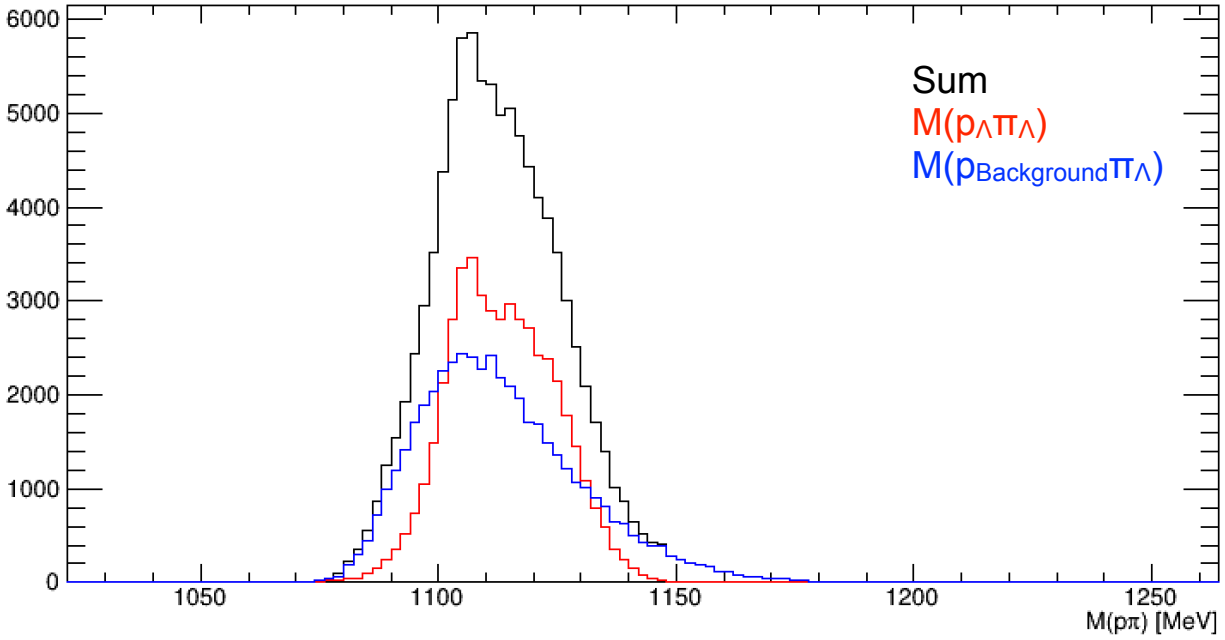



# On-going Studies: Inclusion of Background

- Currently studying inclusion of mis-identified background/accidentals
- Expect inclusion of background p/π to smear invariant mass peaks

- Working on sampling double differential x-sections calculated from EPC/Wiser models for electroproduction of p, π
- J.W. Lightbody, J.S. O'Connell (https://doi.org/10.1063/1.168298)
- Need to weight appropriately in relation to kTDIS events

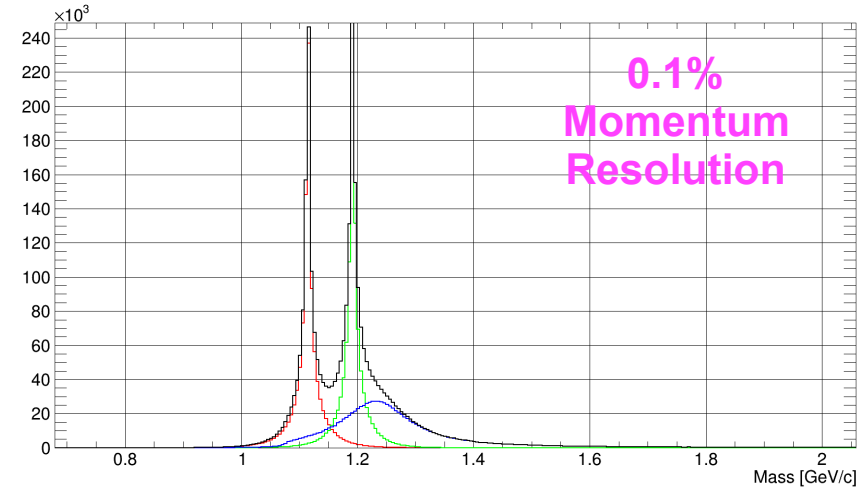
- Example, inclusion of equally weighted background protons with similar kinematics to expected background protons and reconstruction with π from Λ decay

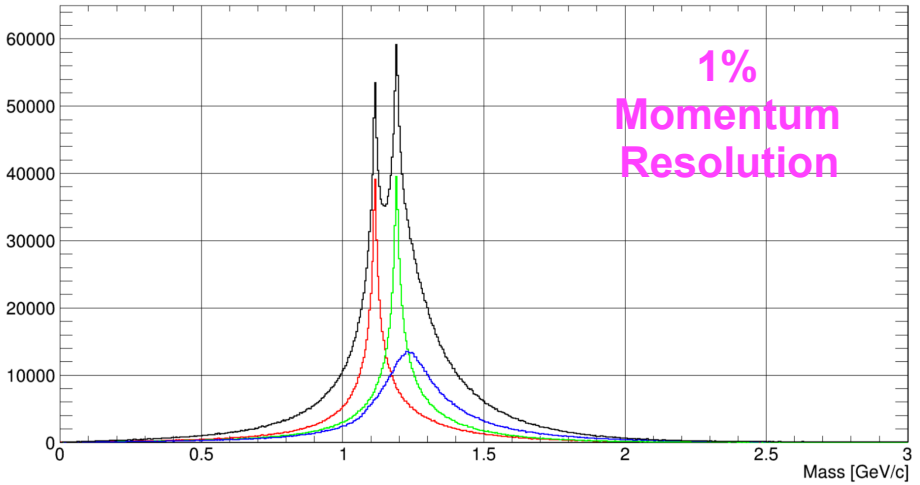


# Summary and Outlook

- Studies of kTDIS events in new mTPC geometry are on-going
- Pions from lambda decay typically have longer path lengths than protons
- Reducing the solenoid field increases p/π- acceptance, however at the cost of transverse momentum resolution
- Improvement of dE/dx resolution for pions must be studied further; binning >mm
- M(pπ) reconstructed in "perfect" case within new mTPC geometry
- First look indicates resolution of about a few % seems reasonable, but requires background study to confirm
- Study into background generation using EPC/Wiser models for proton and pion electroproduction is underway
- Next step is to look at how to combine these events with kTDIS EG events, with the correct weighting, and looking at resulting invariant mass reconstruction for the lambda
- Suggestions/comments/questions welcome…

# Toy MC Event Generator




$\Delta^0 \rightarrow p\pi^-$

$\Sigma^0 \rightarrow \Lambda^0\gamma \rightarrow p\pi^-\gamma$

$\Lambda^0 \rightarrow p\pi^-$

All