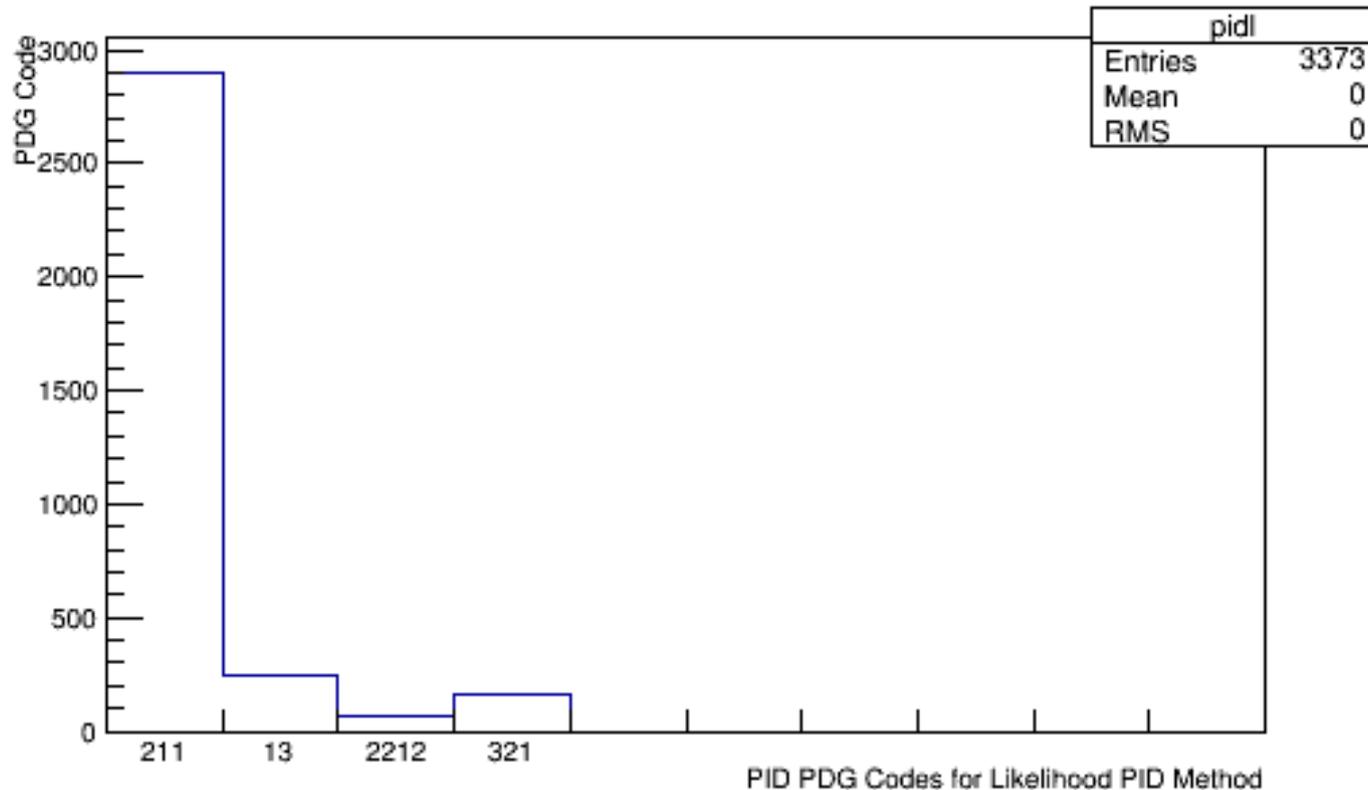


# Pion Absorption Progress: Particle Identification



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Presented at the LArIAT Analysis Summit on December 4,  
2015

# Recap: Environment and Reconstruction Chain

- lariatsoft v01\_07\_00 e7:prof: future jobs ready to be run on develop branch
- Samples:
  - 10000 protons, ka+, mu-, pi+ with momenta uniform in [0.3, 0.90]
  - 2000 protons, ka+, mu-, pi+ with momenta uniform in [0.1, 0.5]
  - Z0 set to -39.5388 (front flange from gdml file)
- Reco\_MC.fcl
  - lariat\_calroi
  - gaus\_hitfinder
  - standard\_clustercrawlerhit
  - standard\_clustercrawler
  - standard\_linecluster
  - standard\_cosmictracker
  - standard\_pmalgtrackmaker
  - standard\_cctrackmaker
  - standard\_calomc
  - standard\_chi2pid
  - lariat\_primaryvertex

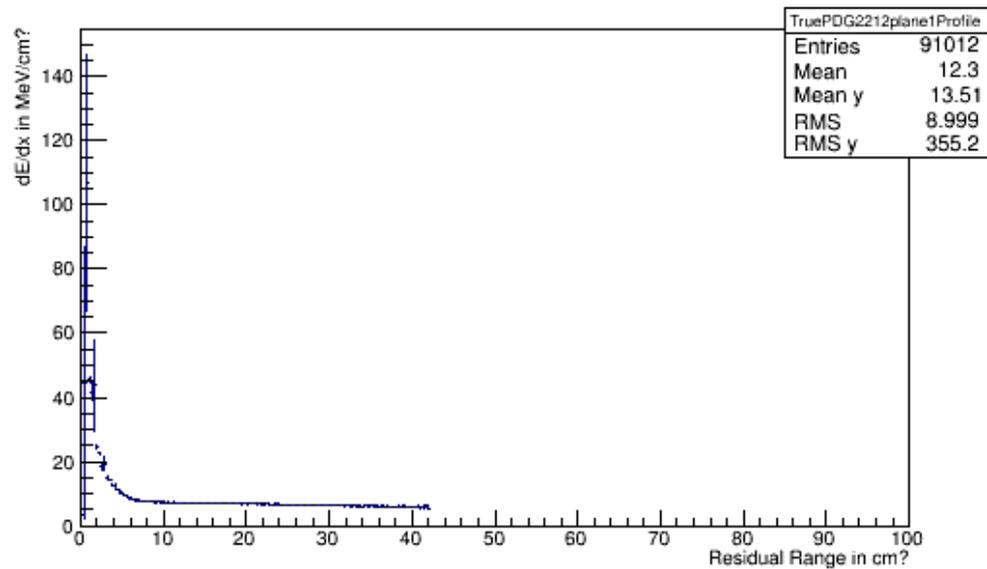
# Recap: Modified Parameters

- KinkAngCut set to [0.2, 0.2, 0.2] to improve cluster splitting efficiency for small kinks
- standard\_pmalgtrackmaker
  - AutoFlipdQdx and FlipToBeam set to true to facilitate vertexing
  - TimeOffsetV from DetectorProperties set to 0 at Tingjun's recommendation. This fixes offset in y direction.
- lariat\_primaryvertex
  - Modified with help of Brian Rebel to produce vertex to track associations
  - Currently seems to only match one vertex per track. Should this be changed?
  - VertexWindow set to 5 cm
  - Currently seems to create vertices in correct places with most of correct tracks associated, but will only associate each track to one vertex
- standard\_chi2pid
  - Using new TProfile made from LArIAT MC samples of 5000 protons, negative muons, positive pions, and positive kaons

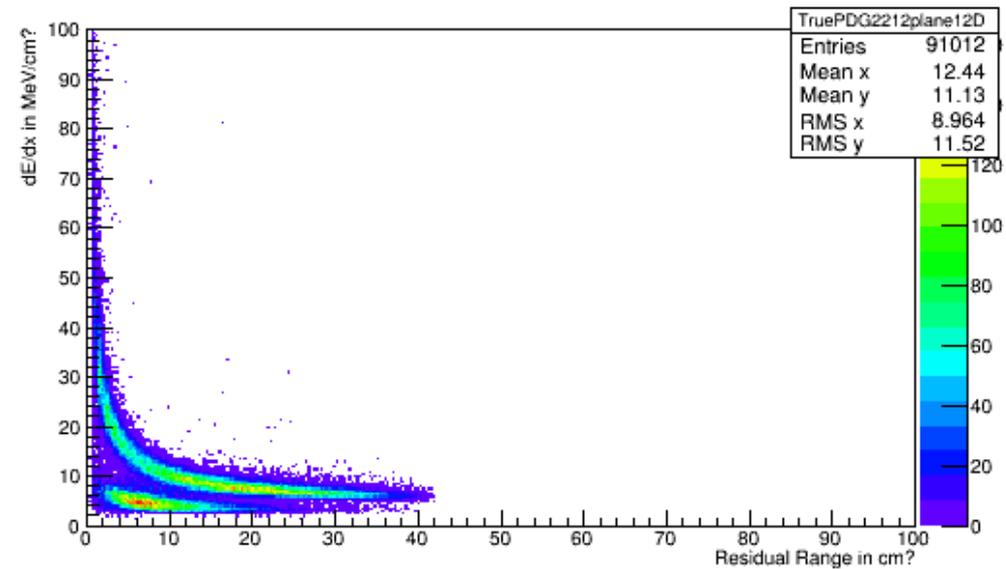
# Improving PID Efficiency

- TProfile "hides" populations evident in TH2D
- Tried a chi squared fit using TH2D instead of TProfile with marginally better results
- New Approach: Calculate likelihood for each particle species using the  $dE/dx$  versus residual range TH2D as a PDF
  - Each calorimetry object is identified as the particle species for which it has the largest likelihood value
  - Ratios of different particle species' likelihoods for a given sample demonstrate resolving power
  - Preliminary PID looks much more efficient
  - Cuts in Current Analysis
    - Primaries only (matching reco tracks to true primaries by start positions and angles for now)
    - Contained in TPC
    - Stop using residual range points after 30 cm

# Proton dE/dx Versus Residual Range

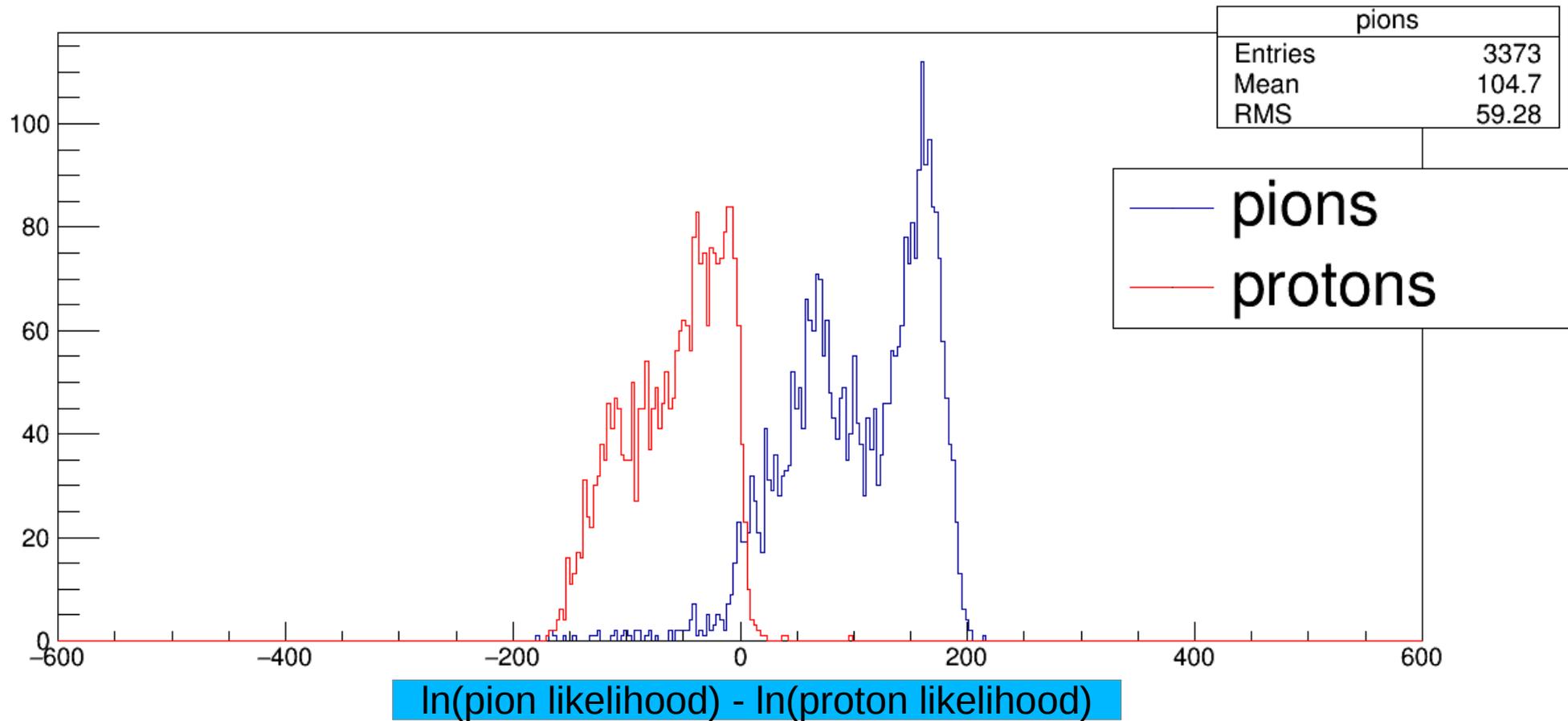


Current TProfile

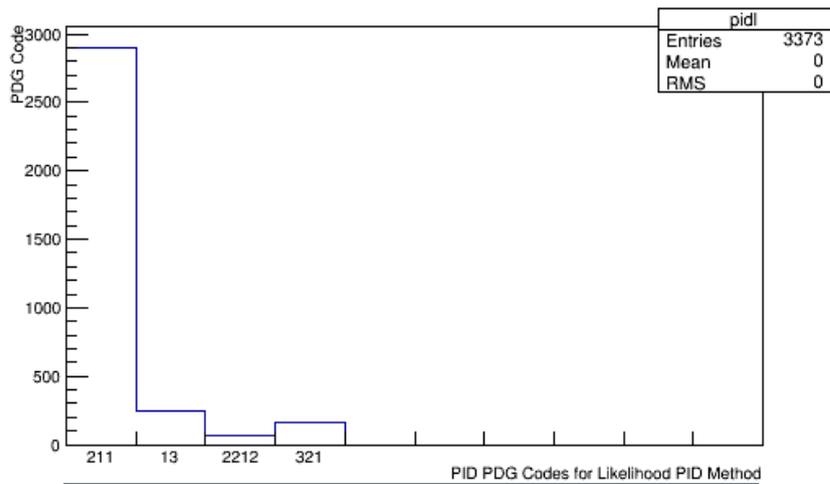


Current TH2D

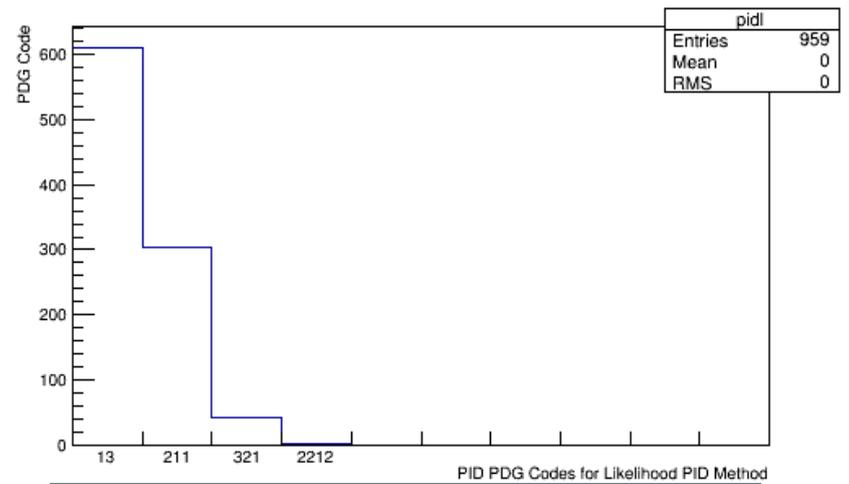
# Pion/Proton Likelihood Ratios for Pion and Protons Samples



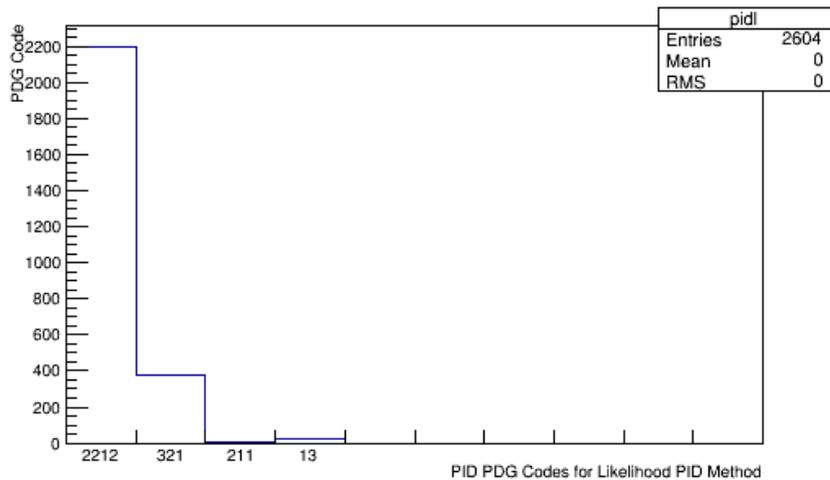
# Likelihood PID Plots



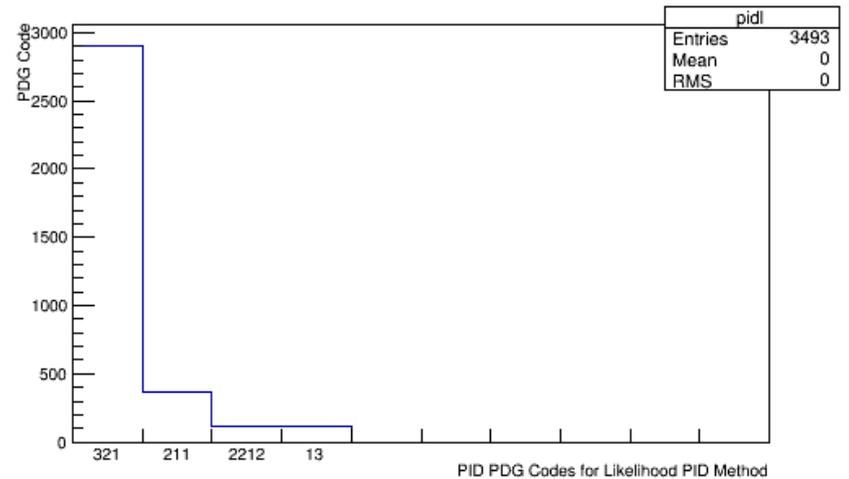
Pi Plus



Mu Minus



Proton



Ka Plus

# Conclusions and Future Work

- Conclusions
  - Likelihood PID may offer better efficiency for LArIAT than current chi squared PID
- Future Work
  - Generate better PDFs
    - Preparing a PDF from a MC sample with more particles
    - Prepare a PDF from a MC sample using the beam flux generator
    - Prepare a PDF from LArIAT data
  - Implement a module to produce `anab::ParticleID` objects using a likelihood-based PID algorithm
  - Implement other tests to further improve PID
    - Compare likelihood ratio plots
    - Likelihood ratio versus range
  - Currently implementing analysis module to count pion absorption events

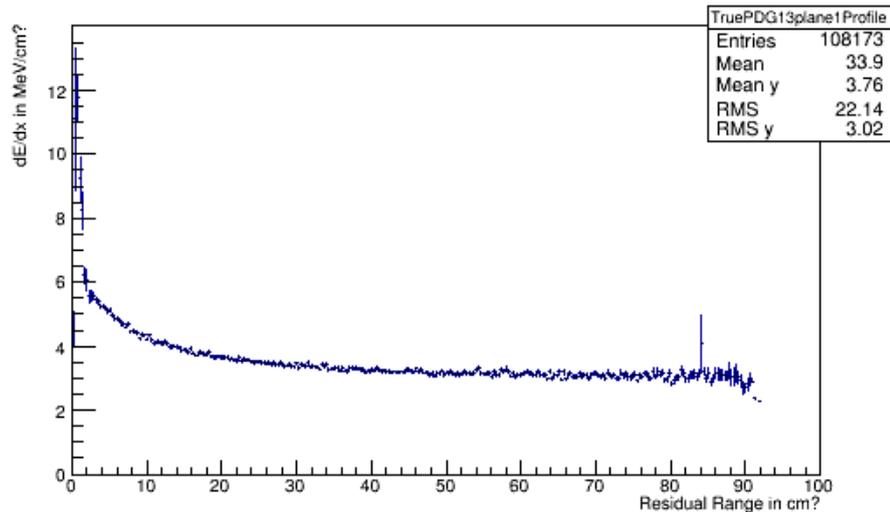
# Questions

- Beam generator
  - Module runs, but with default cuts from develop branch (Dec. 2), I only get 54 event frames. Is there a way to get more useful event frames with these or different cuts?
  - Also fails with same problem with trigger set to false after 10 events
- `anab::ParticleID` objects
  - How should I fill PIDA values?
  - In which repositories do the module and PDF files belong?

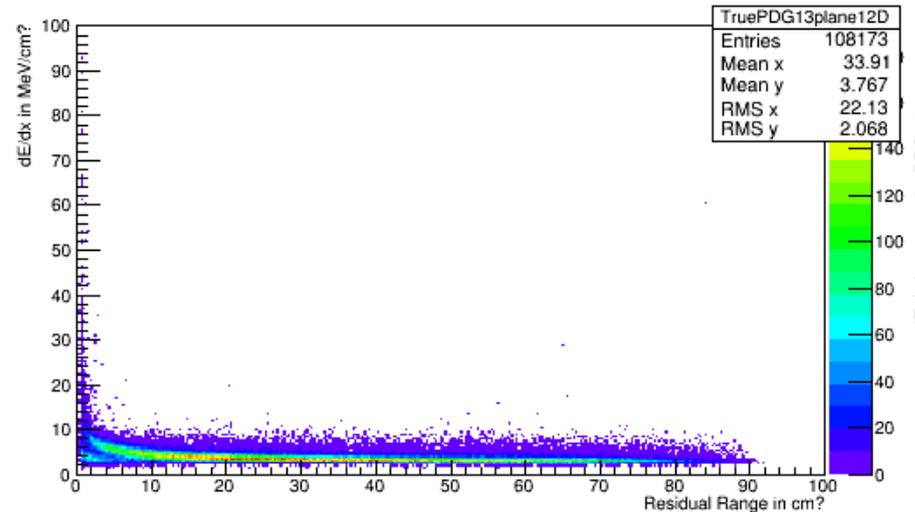
# Backup Slides

- Begin Backup Slides Below

# Backup: Muon $dE/dx$ Versus Residual Range

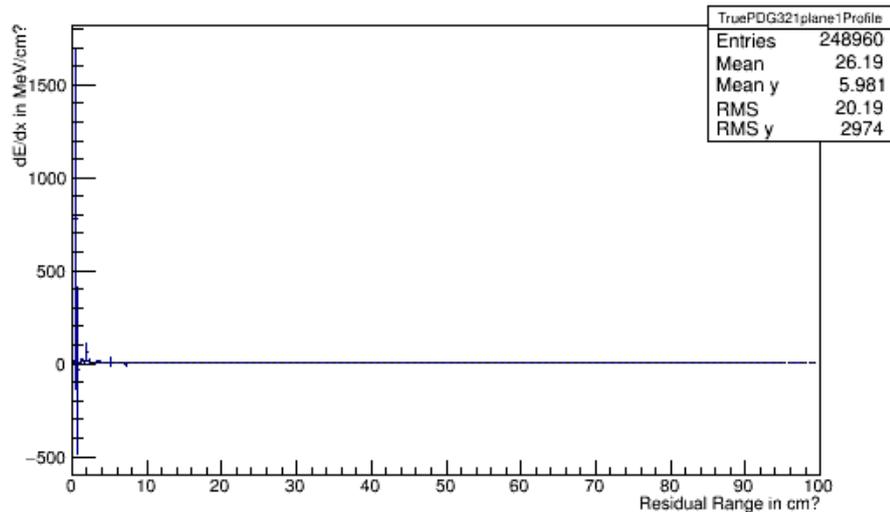


Current TProfile

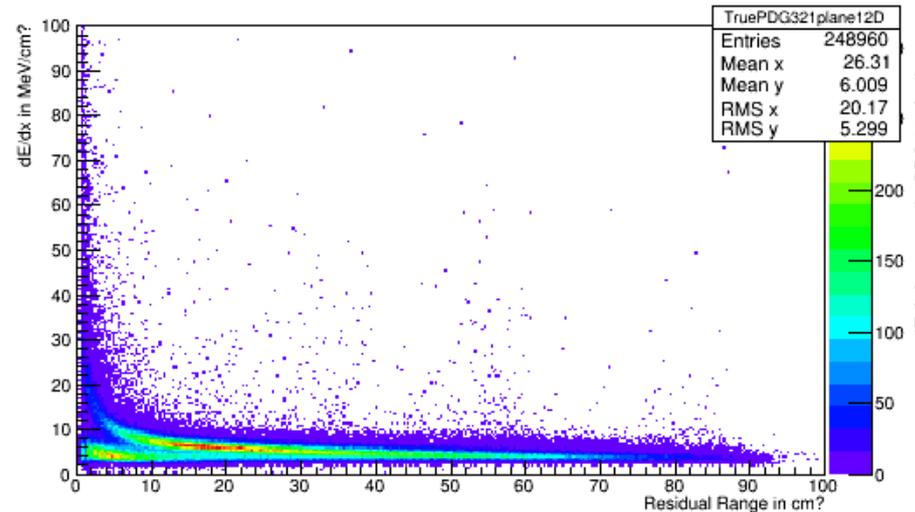


Current TH2D

# Backup: Kaon $dE/dx$ Versus Residual Range

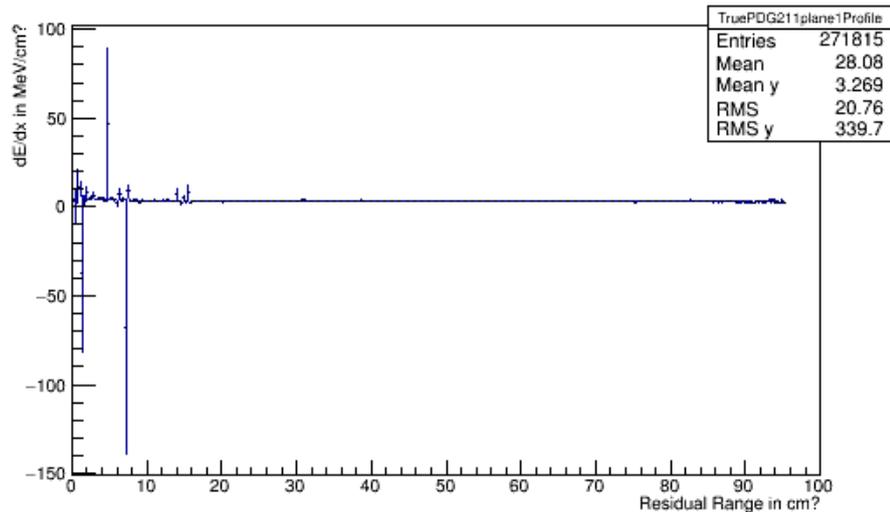


Current TProfile

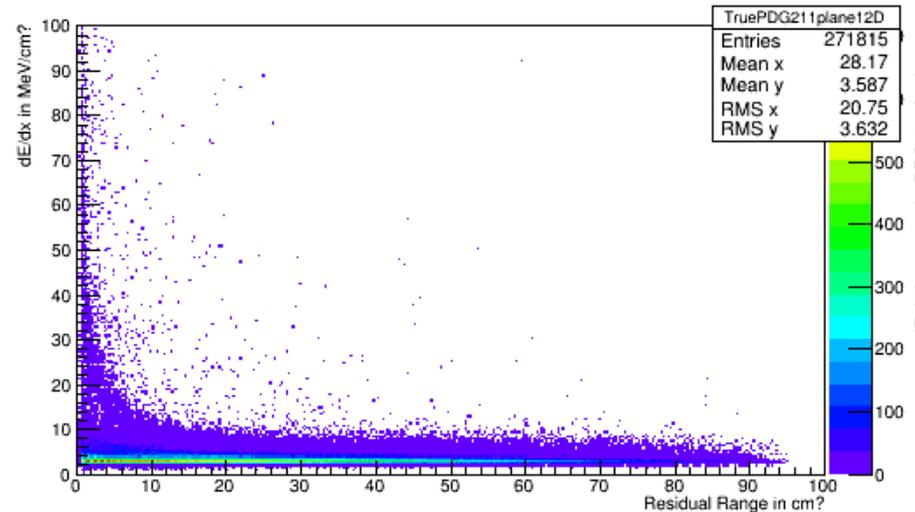


Current TH2D

# Backup: Pion $dE/dx$ Versus Residual Range

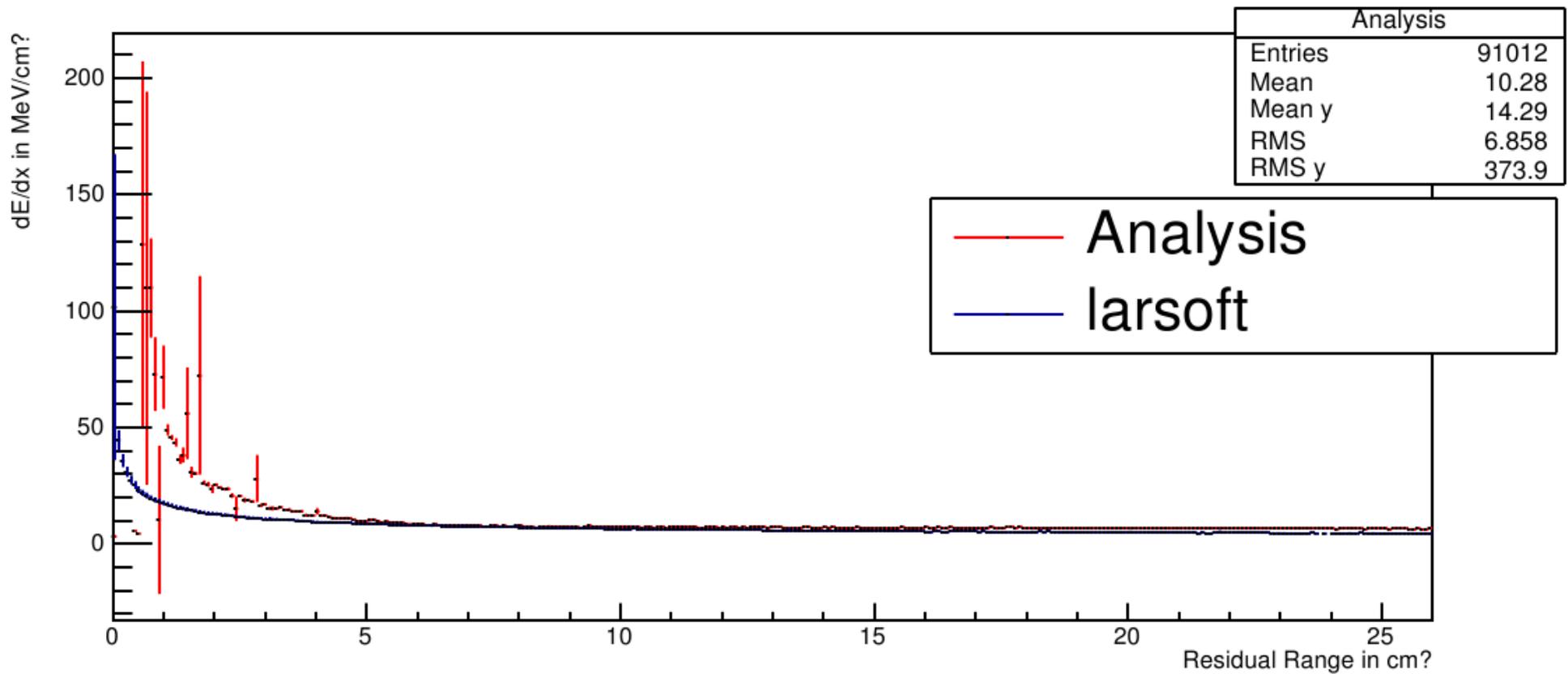


Current TProfile

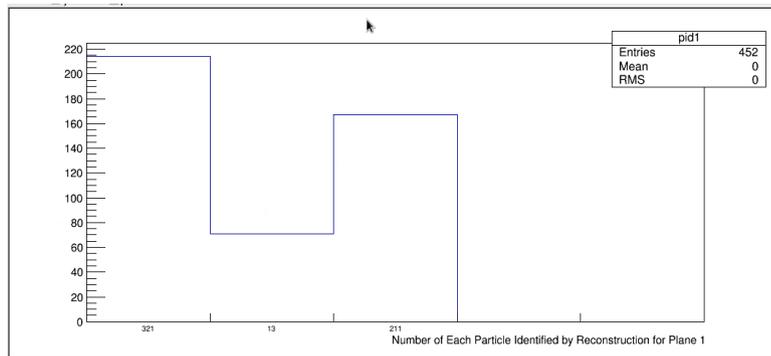


Current TH2D

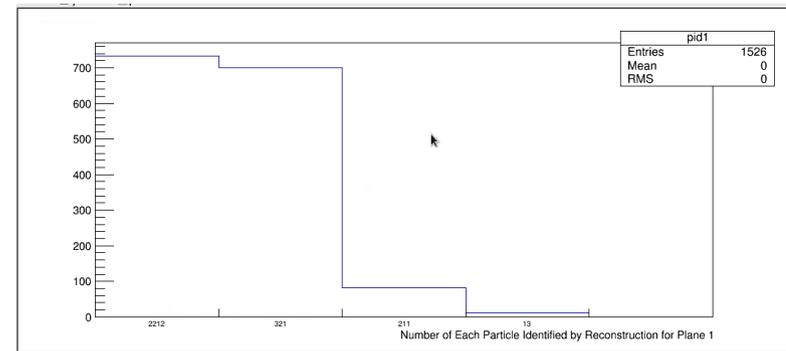
# Backup: Proton dE/dx Versus Residual Range: Old and New TProfiles



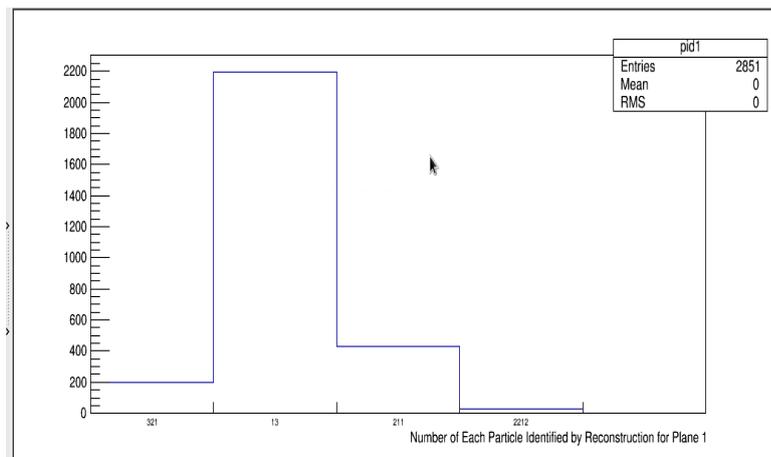
# Backup: Old PID: Efficiencies for Various PDG Codes



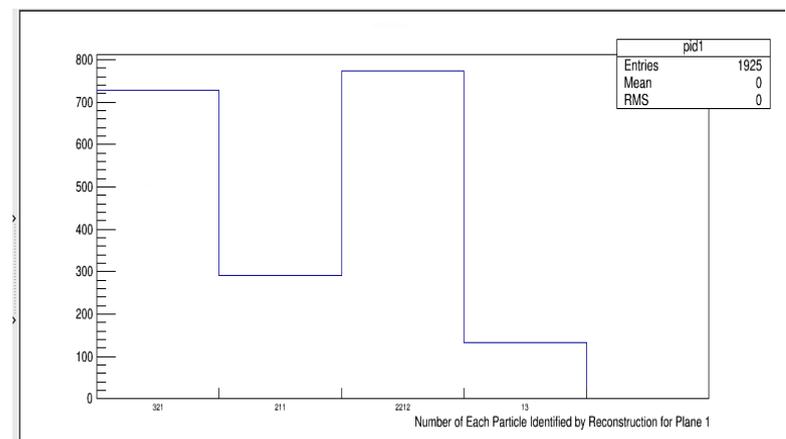
Muon



Proton



Pion



Kaon

# Backup: Likelihood Definition

- Given some set of points  $\{(x_i, y_i)\}$ , (dE/dx, residual range) from an anab::Calorimetry object
- Given a probability density function  $f(x, y)$ , a TH2D of dE/dx Versus Residual Range for the purposes of this presentation
- $\ln(L(x_1, x_2, \dots, x_n, y_1, y_2, \dots, y_n)) = \sum_i \ln(f(x_i, y_i))$
- To make the best use of double precision values,  $\ln(L)$  is calculated as a sum of natural logs rather than as a product
- $\ln(L_{\text{pion}}/L_{\text{proton}}) = \ln(L_{\text{pion}}) - \ln(L_{\text{proton}})$  is plotted in the likelihood ratio plots in this presentation