Update on Proton Analysis

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Outline

- Calorimetric reconstruction of 1 GeV/c protons
  - Data sample & event selection
  - dQ/dx to dE/dx calibration
  - dE/dx versus residual range for both data and MC
  - Performance of the calorimetric reconstruction

- Proton analysis with different cathode voltage configurations
  - Selection of data sample

Data Sample & Event Selection

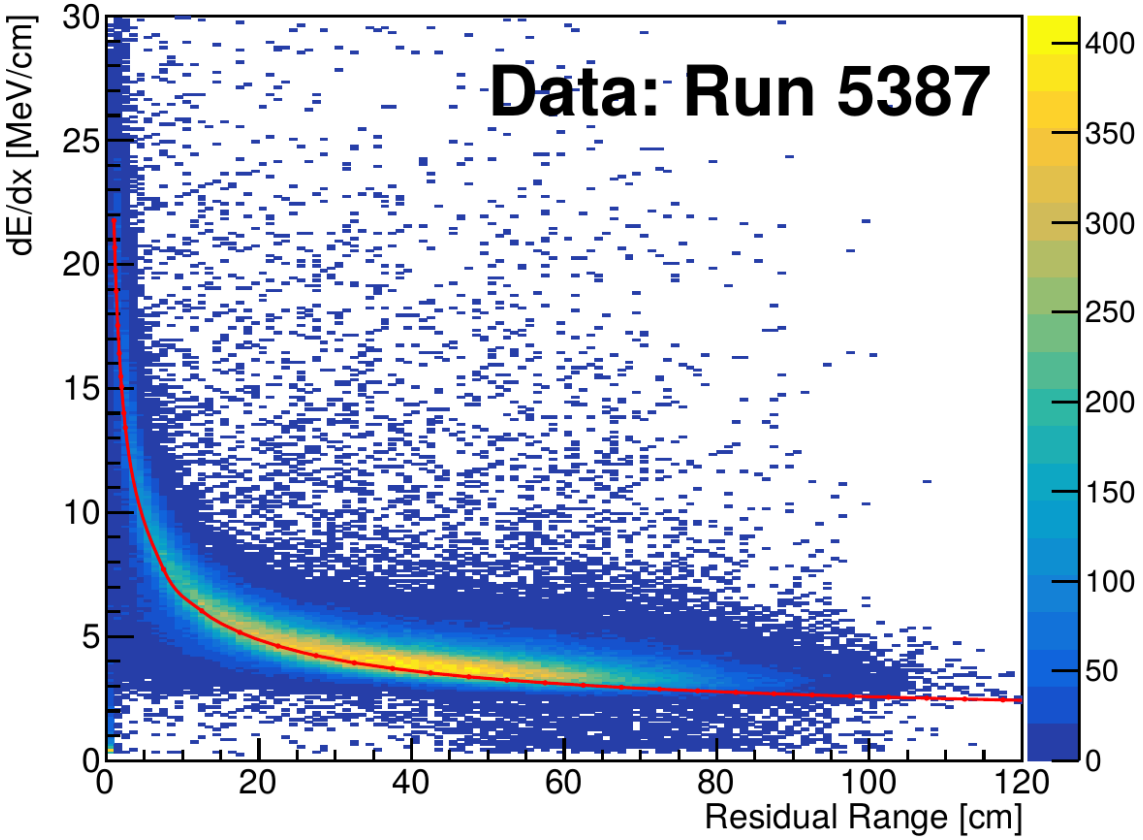
- Data sample : Run 5387 [1 GeV/c] / 180 kV / ~5 msec
- Use Pandora algorithm for reconstruction
- Event selection cuts:
  - Details of the cuts can be found in my previous talk:
    https://indico.fnal.gov/event/19376/contribution/2/material/slides/0.pdf
  - Cuts that have been used
    + Angle cut
    + Position cut: start positions of primary tracks & beam positions
    + Ratio cut (track length/CSDA) to select the stopping protons

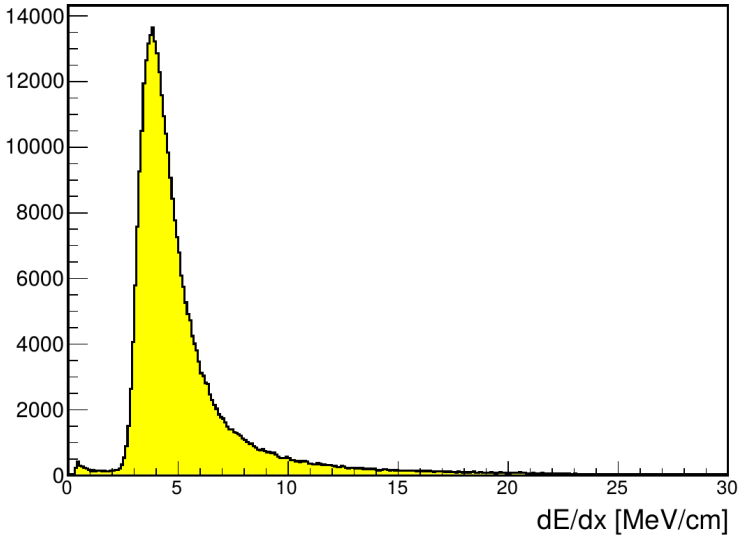
Calibration

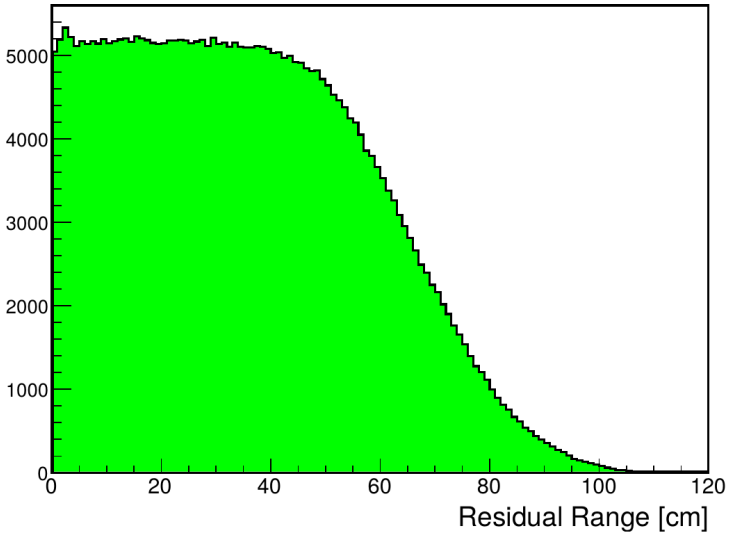
- Get dQ/dx information from the PFpartice associtation
- Calibration: dQ/dx → dE/dx
- Calibration work all done by Ajib!
- Calibration procedure:
  - Use TPC crossing tracks for the dQ/dx distribution
  - Correct the non-uniform dQ/dx distribution caused by both attenuation and SCE to the uniform dQ/dx distribution (calibration along x-direction)
  - Use the stopping muons as a standard candle to convert dQ/dx to dE/dx (using the modified box model*)
  - Details of Ajib's work on calibration can be found: https://indico.fnal.gov/event/19132/contribution/1/material/slides/0.pdf

*Reference:
"A study of electron recombination using highly ionizing particles in the ArgoNeuT Liquid Argon TPC" (https://arxiv.org/abs/1306.1712)

Proton dE/dx Versus Residual Range

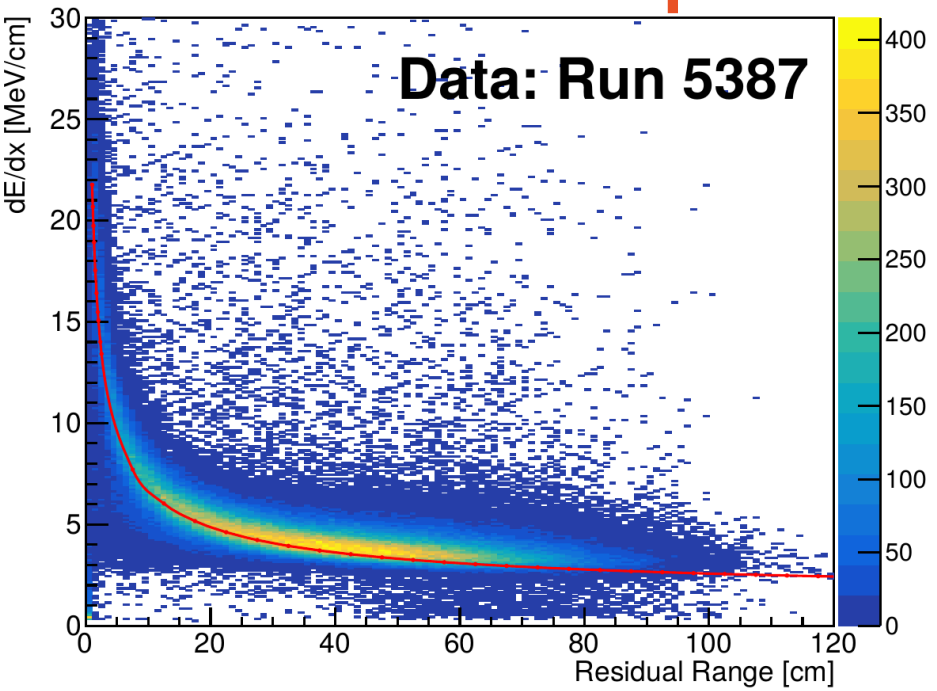


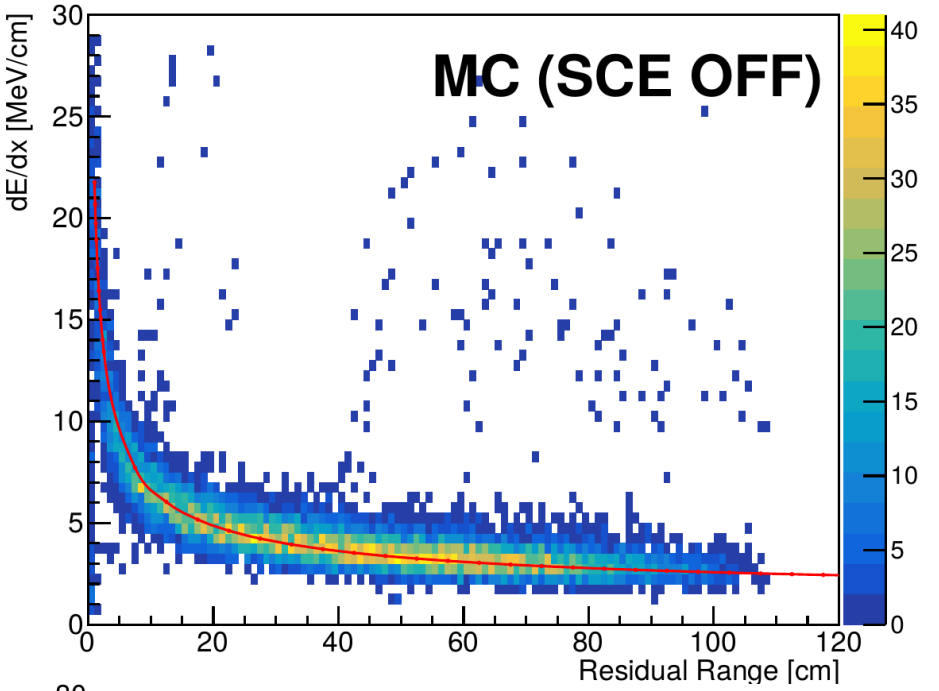


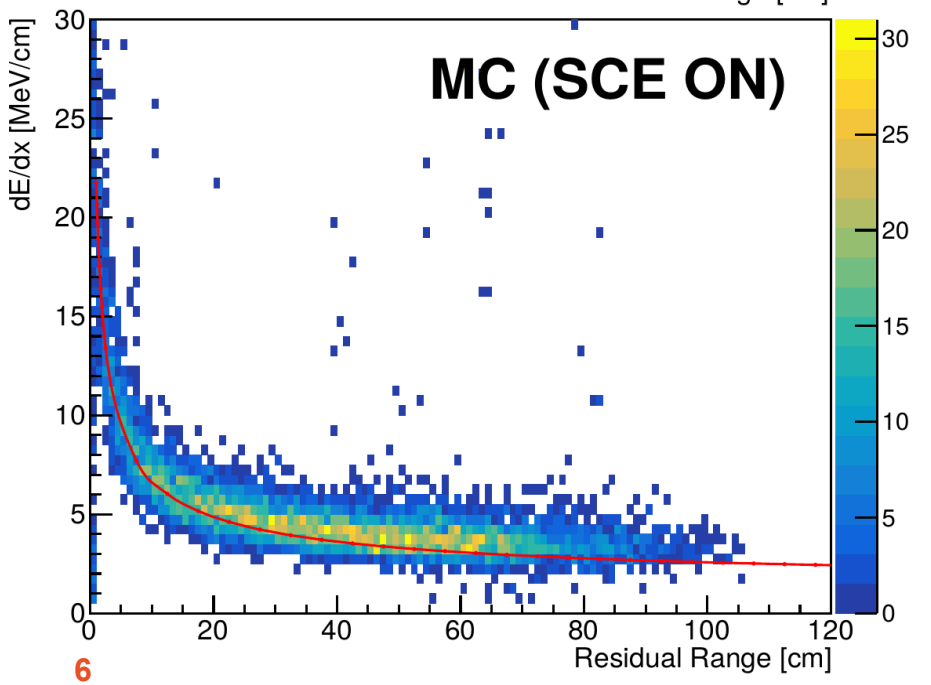


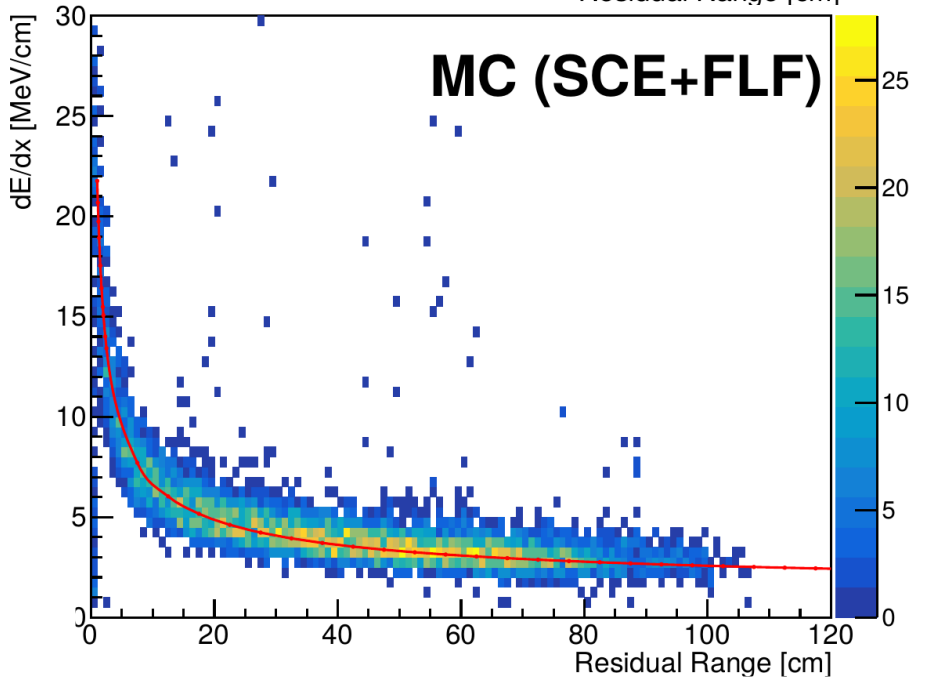
- Theoretical predition for proton dE/dx versus residual range (shown in red): Landau-Vavilov distribution (work done by Ajib)

Data & MC Comparison

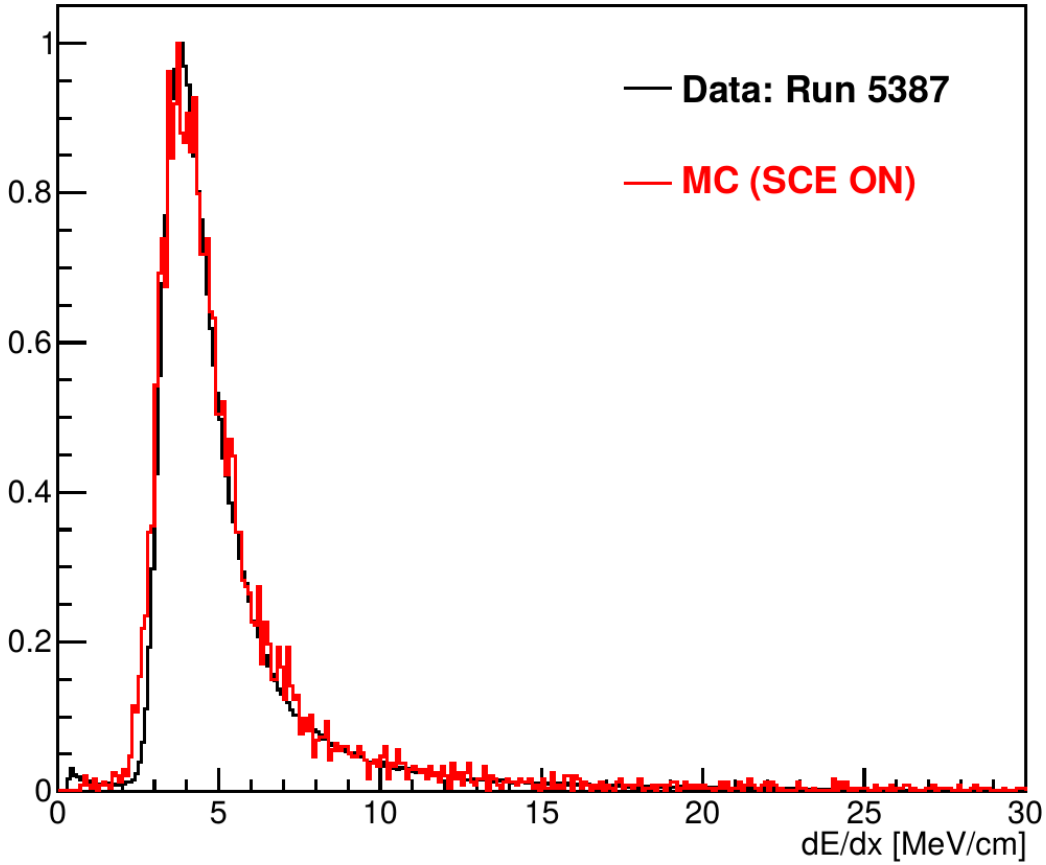


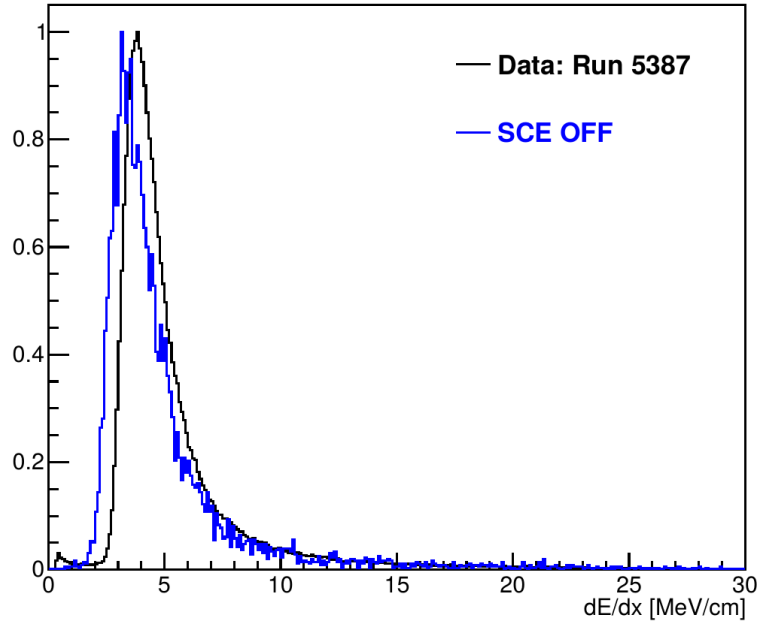


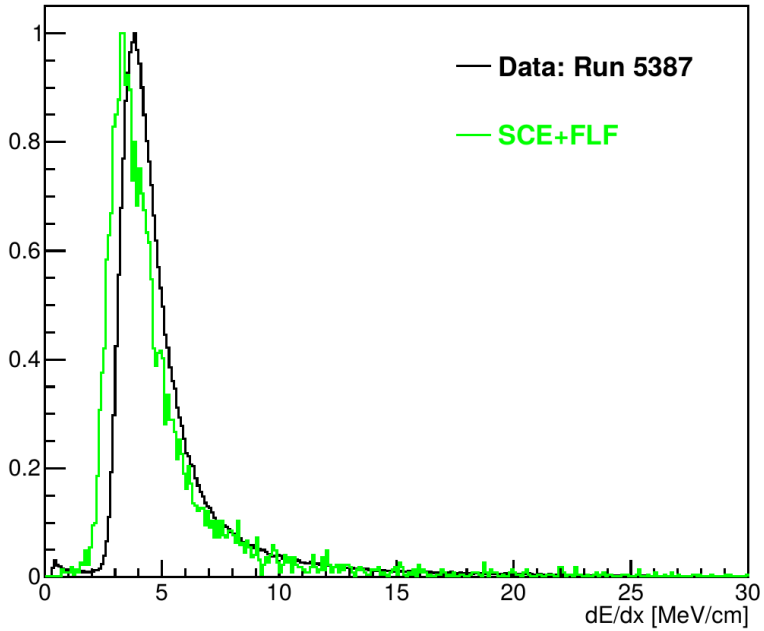




dE/dx – Data & MC







- MC (SCE ON) agrees well with data!
- dE/dx peak position:
  Data/SCE OFF/SCE/SCE+FLF
  3.88/3.31/3.83/3.37 [MeV/cm]

Calorimetric Reconstruction

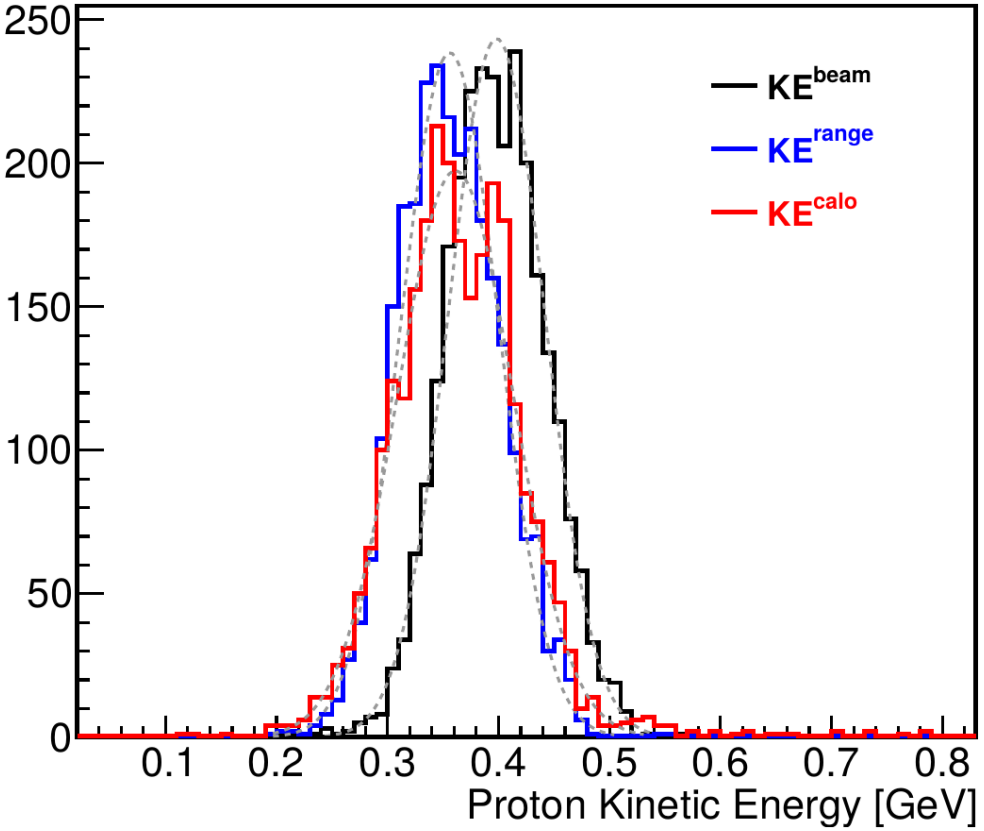
- Apporaches to measure proton kinetic energy:
  (1) Beam instrumentation (source)
  P^{beam} (beam momentum) → KE^{beam} (beam kinetic energy)
  (2) Reconstructed track length of the stopping protons*
  Track length → KE^{range}
  (3) Reconstructed kinetic energy of the stopping protons

$$KE^{calo} = \sum_j \frac{dE_j}{dx_j} dX_j \quad \text{(sum over all hits)}$$

- Benchmark quantities of the reconstruction
  (1) KE^{range}/KE^{beam}
  (2) KE^{calo}/KE^{beam}
  (3) KE^{calo}/KE^{range}

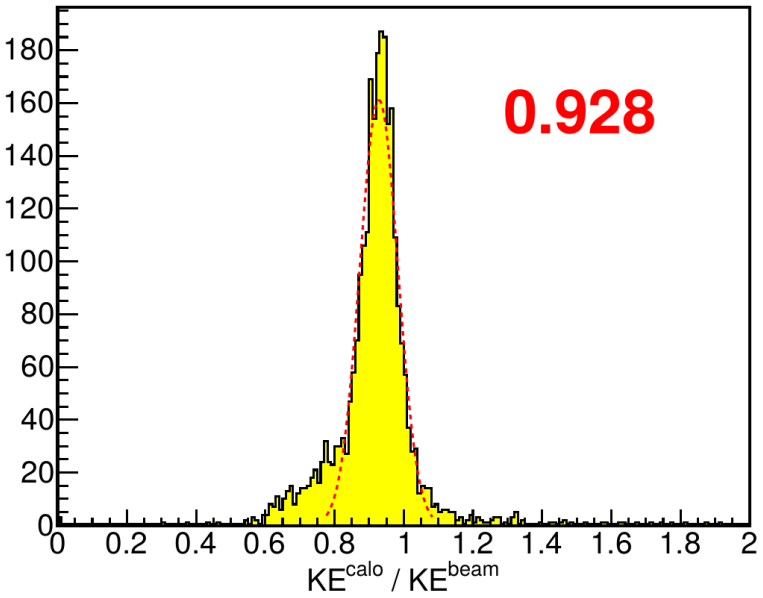
*Reference: NIST Data base (https://physics.nist.gov/PhysRefData/Star/Text/PSTAR.html)

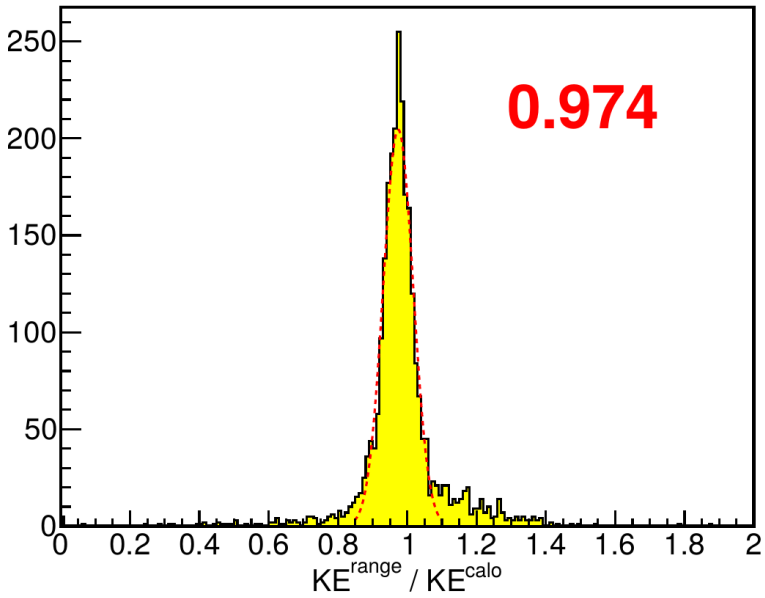
Calorimetric Reconstruction

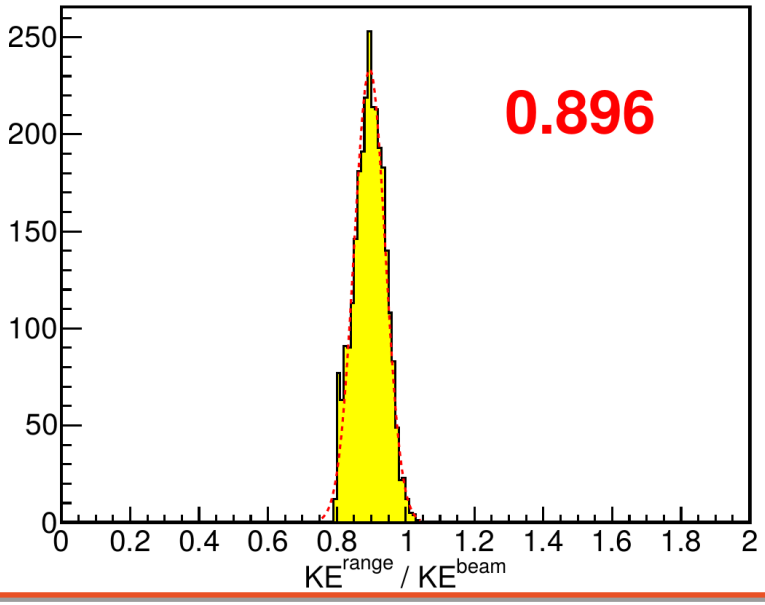


	Mean [GeV]	FWHM [GeV]
KE^{beam}	0.398	0.102
KE^{range}	0.356	0.103
KE^{calo}	0.361	0.122

Benchmark Quantities







Benchmark Quantity	Mean	Sigma
KE^{range}/KE^{calo}	0.974	0.043
KE^{calo}/KE^{beam}	0.928	0.045
KE^{range}/KE^{beam}	0.896	0.055

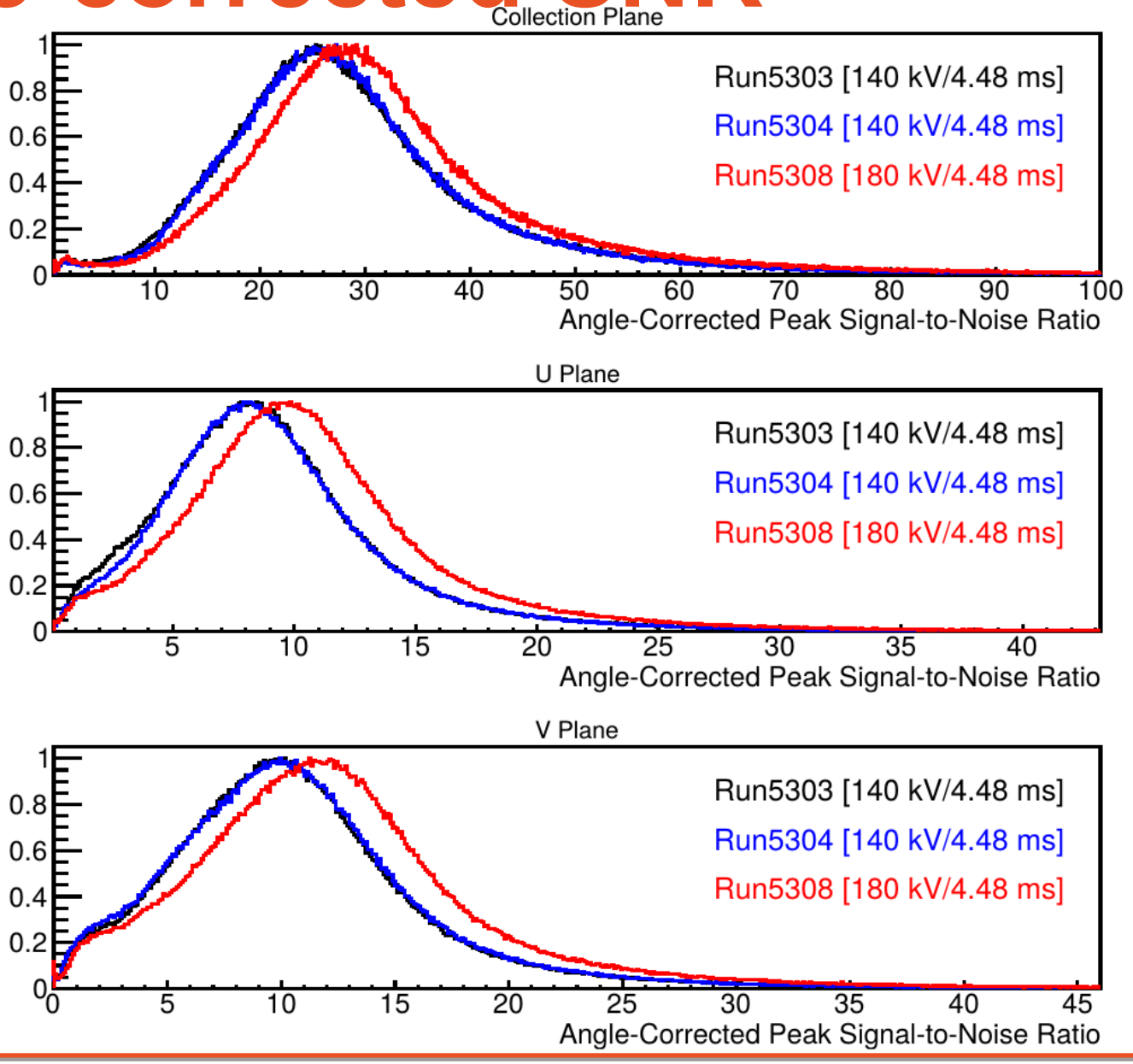
- The calo-based reco is well consistent with the range-based reco
- Calorimetric reconstruction works very well

Proton analysis – High Voltage Effect

- Cathode voltage affects both attenuation & recombination
  - Low voltage may have a worse S/N performance and SCE may get worse with a lower cathode voltage
  → Check data first!

- Kick-off analysis
  - Selection of two data samples which have the same Argon purity but with different cathode voltages
  → Run 5308 (180 kV)
  Run 5303 & 5304 (140 kV)

Angle-corrected SNR



Notes: [1] Lifetime: Value extracted from the top purity monitor
[2] Definition of SNR: See https://indico.fnal.gov/event/19015/contribution/5/material/slides/0.pdf

Summary & Outlook

- We have made the dE/dx calibration for the 1 GeV/c proton data
- MC dE/dx distribution with SCE ON matches data well
- Offset between the measured and the theoretical predicted curve for the dE/dx-versus-residual range
- The calorimetric reconstruction seems to work very well
- Kick-off proton analysis with different cathode voltages

- Next:
  -Calorimetric reconstruction of MC
  -Re-processing the reco files of the 140 kV data
  -Work on analyzing the new 140 kV reco files