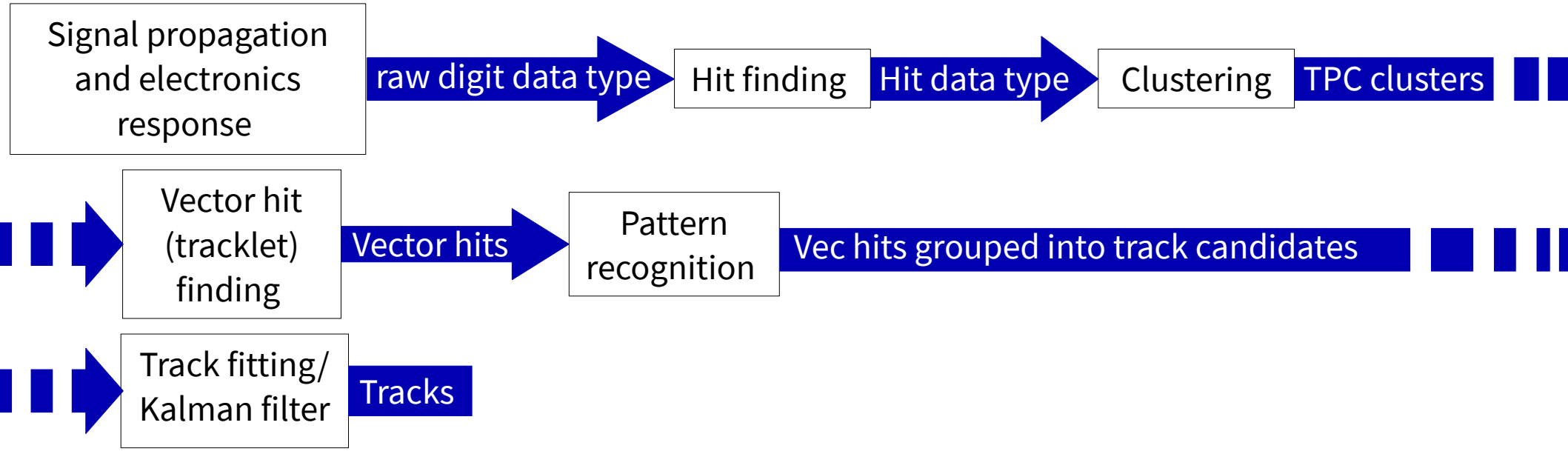
Overview of HPgTPC Software Tools – GArSoft

Tanaz Angelina Mohayai, for the GArSoft team
GArSoft Team: Tom Junk, Leo Bellantoni, Susan Born, Eldwan Brianne, Andrew Cudd, Tanaz Mohayai et al.
July 28, 2020

Fermilab

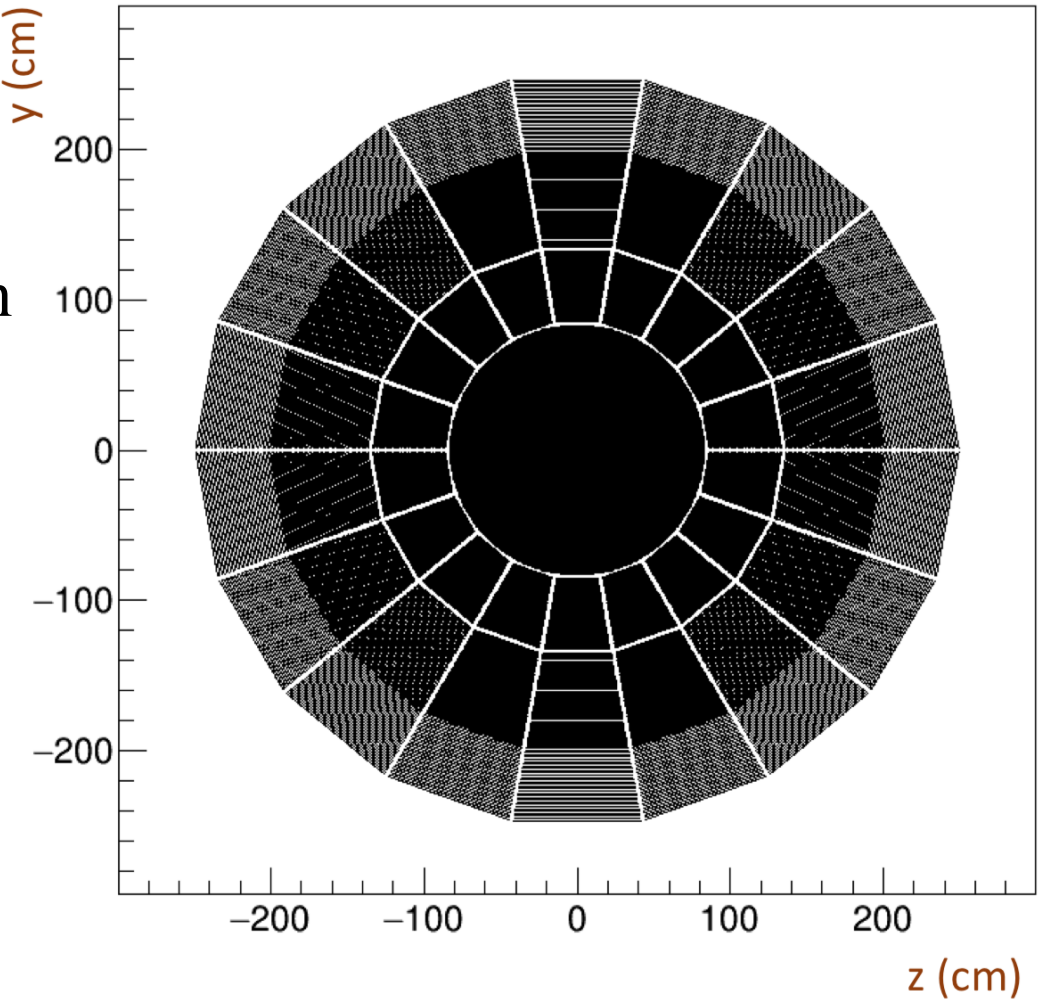
GArSoft – Official ND-GAr/HPgTPC Software

- GArSoft:
  - Based on ART framework (widely-used framework)
  - Detailed detector modeling – drift, diffusion, field response, electronics response, digitization, clustering, pattern recognition and track fitting, with on-going optimizations



Relevant GArSoft Features – Pad Geometry

- IROC, OROC pad geometry from ALICE TDR:
  - 18 sectors IROCs and OROCs on both sides with nominal ALICE geometry
  - Rectangular array of pixels filling the hole in the center
    - Pixel size: 6mm x 6mm
- Total channels per side: 339,068
- Total combined: 678,136

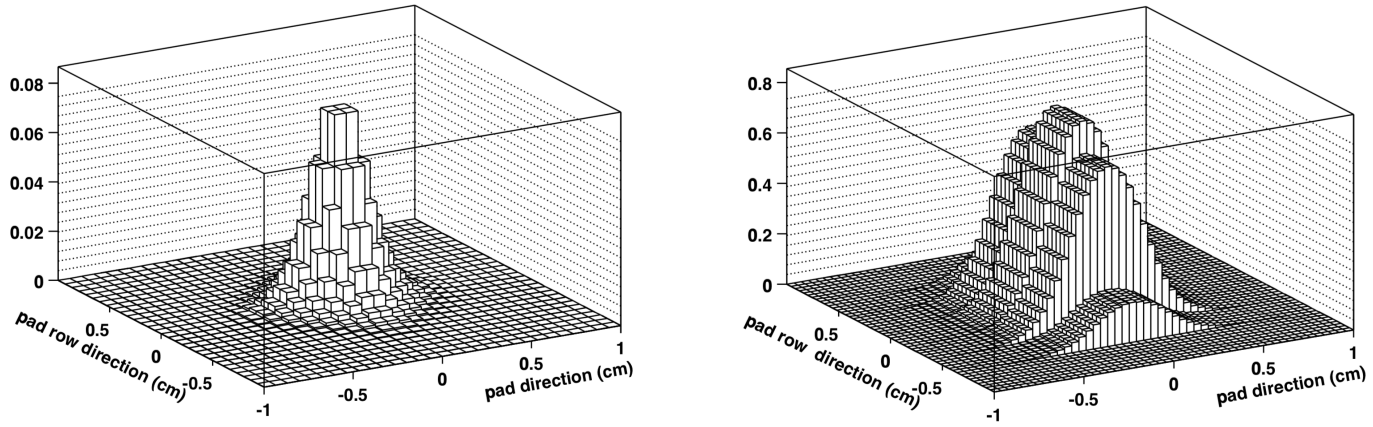


Relevant GArSoft Features – Gas Parameters, Electronics Response

- Drift velocity and diffusion from Magboltz (constants set in GArProperties fcl fle in GArSoft)

Vdrift	3.011 in cm/us
$\perp$ diffusion	160.285 microns/sqrt(cm)
$\parallel$ diffusion	201.250 microns/sqrt(cm)

- Spatial pad response functions from ALICE TDR

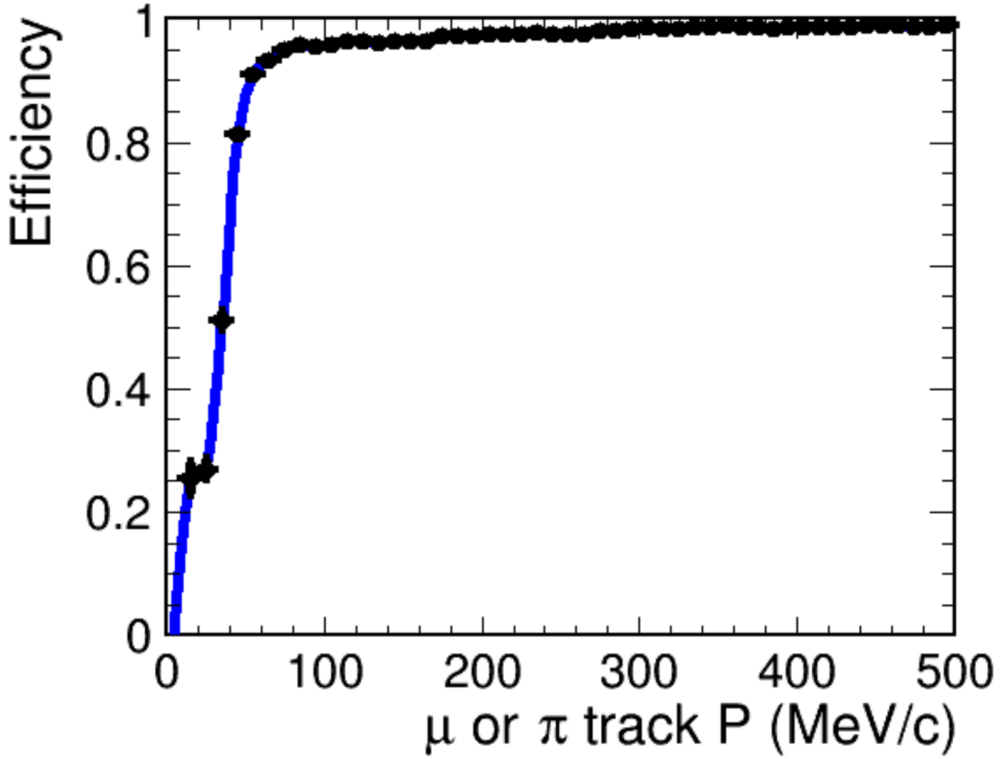


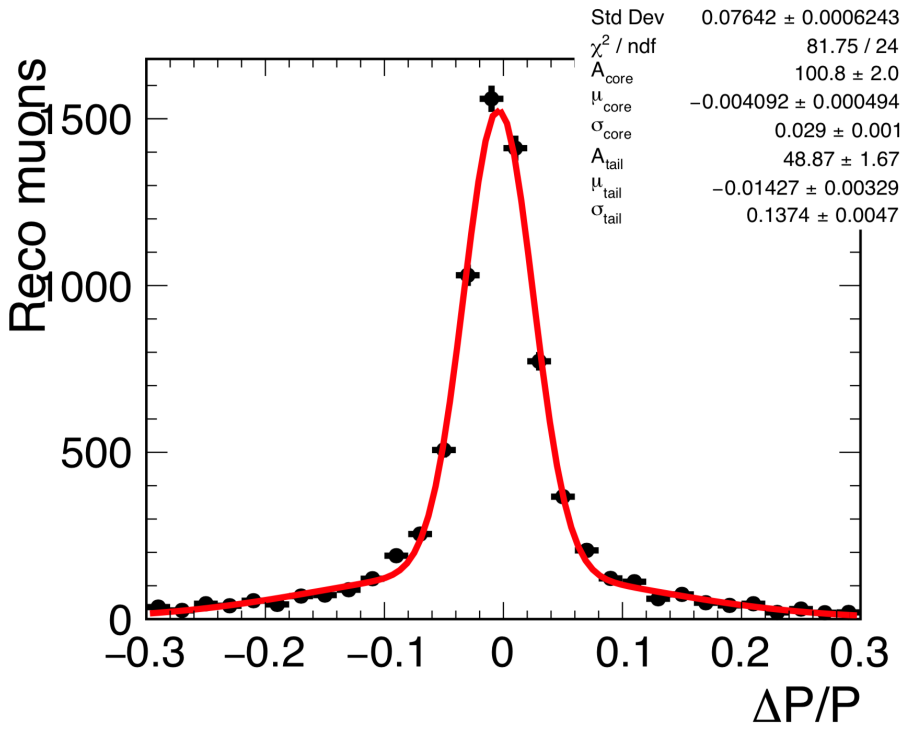
https://cds.cern.ch/record/451098/files/open-2000-183.pdf

- Electronics noise to be implemented – under development in GArSoft

GArSoft Performance Plots

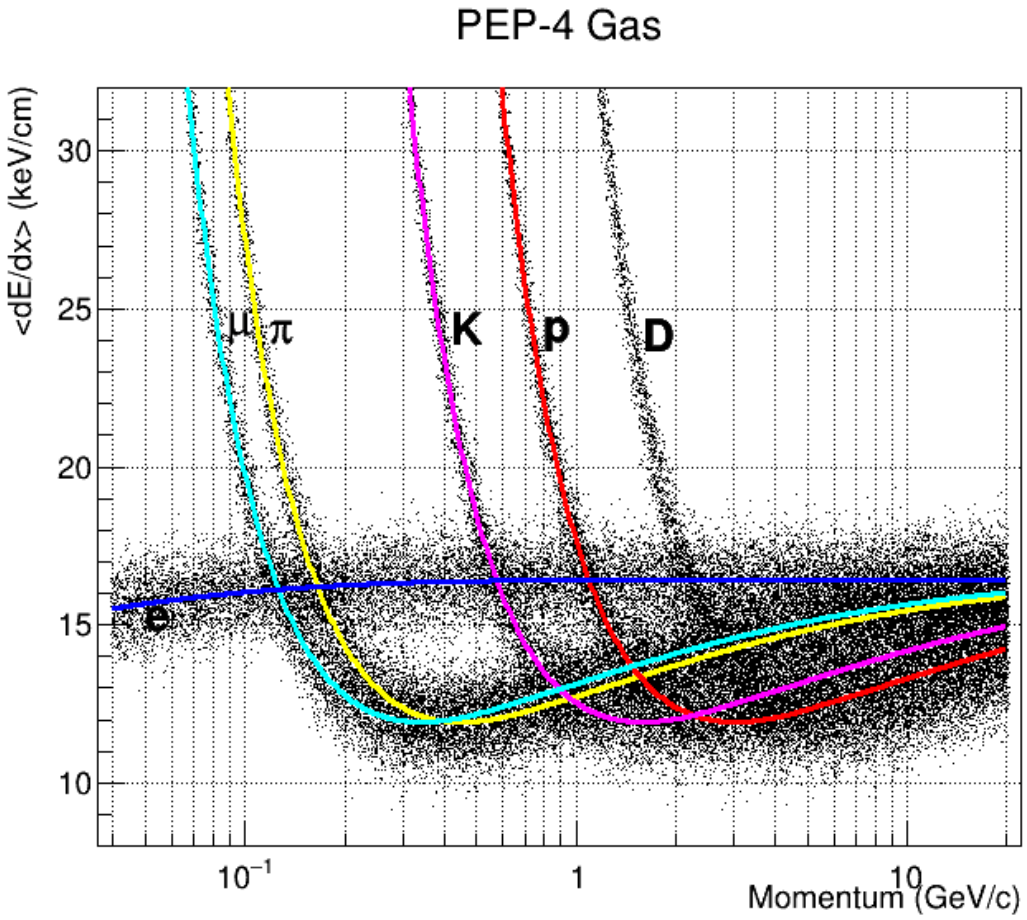
- Tracking efficiency and momentum resolution
  - Sample: ν_μ CC events generated using the optimized LBNF beam, GENIE v2.12.10c, and reference design geometry (with Ar-CH4 90-10 gas at 10 bar)





GArSoft Performance Criteria/Requirement

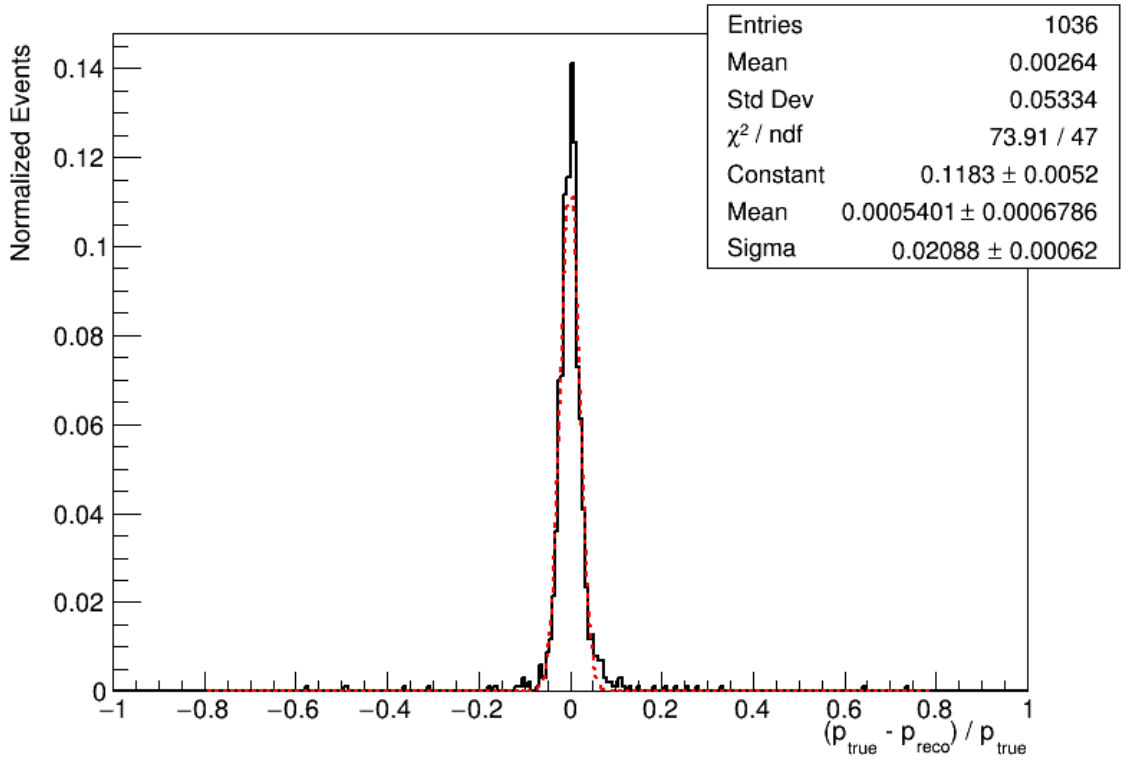
- dE/dx (implemented in a parametric module in GArSoft)
  - Re-purposing PEP-4 (8.5 atm) dE/dx – 0.8 keV/cm dE/dx resolution
- Sources:
  - https://home.fnal.gov/~trj/mpd/dedx_sep2019/
  - https://github.com/tmohayai/ParamSim



GArSoft Performance Criteria/Requirement

- Current software integration among all near detectors requires
  - Parametric module (in addition to dE/dx) – tracking using Gluckstern, serves as reference for full reco
- Sample for momentum resolution plot, below: ν_μ CC events generated using the optimized LBNF beam, GENIE v2.12.10c, and reference design geometry (with Ar-CH4 90-10 gas at 10 bar)

momentum resolution using Gluckstern

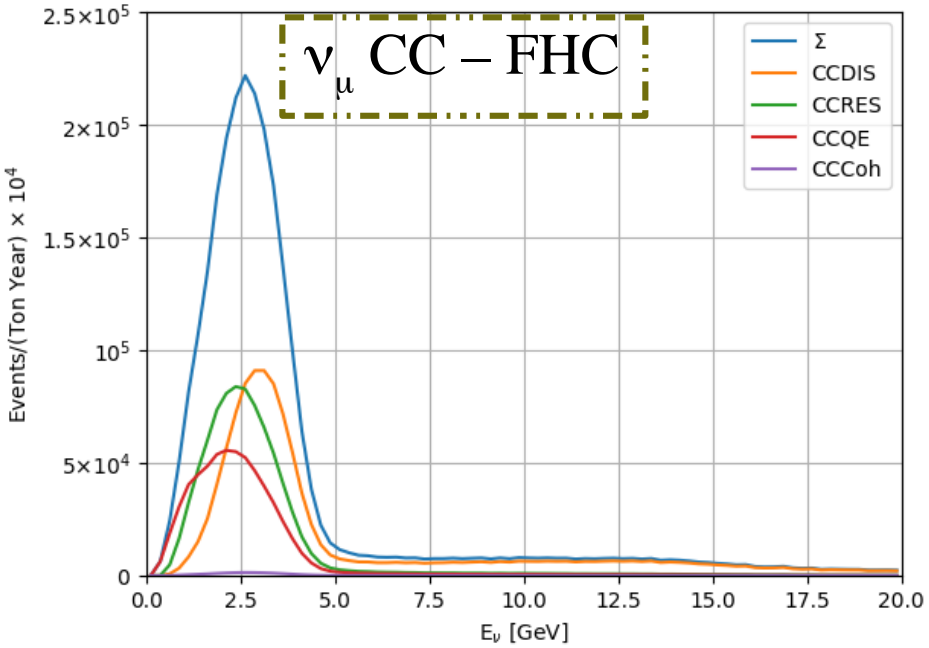


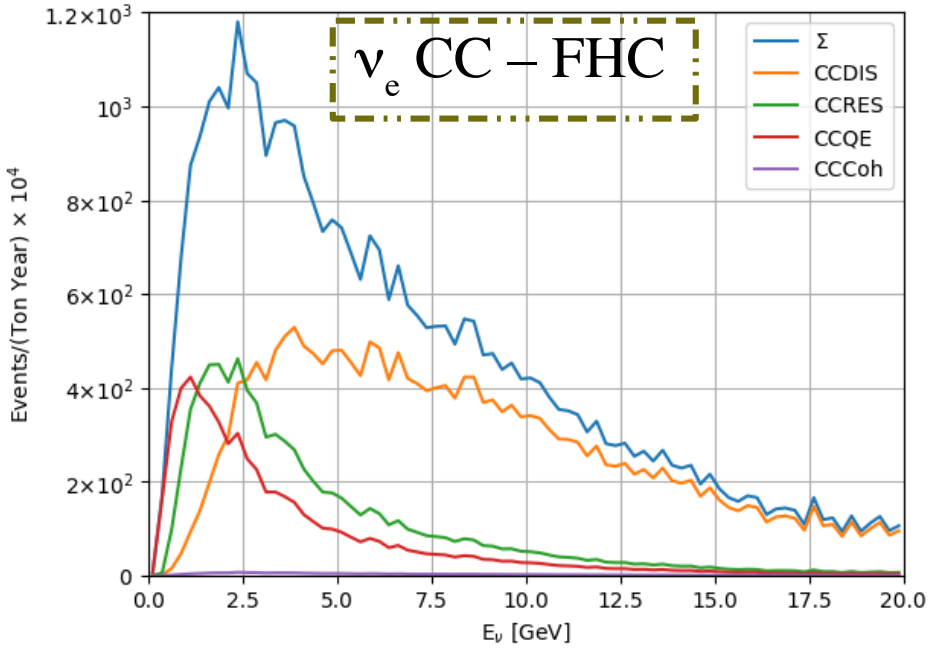
One Comment on Rate Requirements

- Baseline gas, Ar-CH4 90-10 gas at 10 bar gives us 97% interactions on Ar

FHC Mode, Optimized DUNE flux (Oct 2017), GENIE v2.12.10

Event Category	Events/Ton-year	Event Category	Events/Ton-year
ν_μ CC total	2E+06	ν_e CC total	3.6E+04



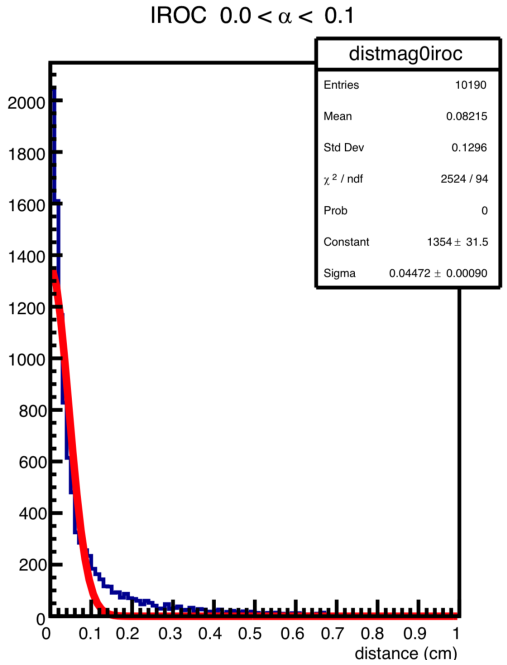


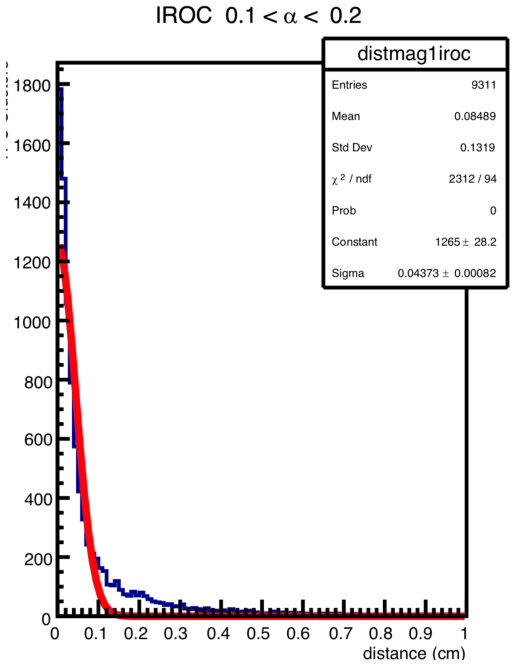
Summary

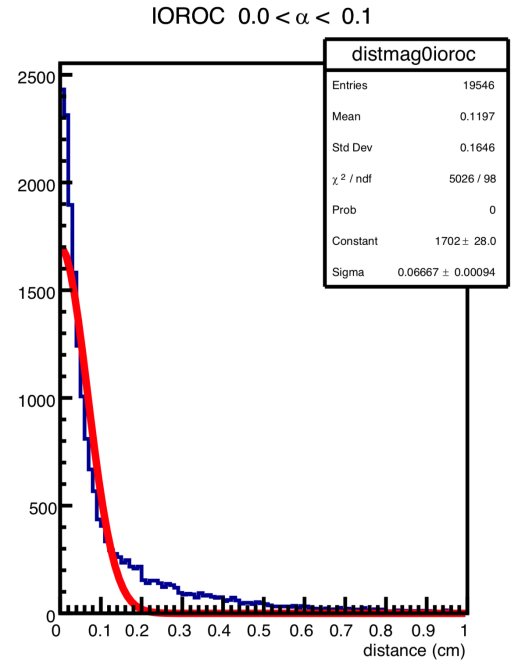
- We have a number of performance criteria for the baseline gas mixture and pressure in GArSoft:
  - Shows performance comparable to ALICE
  - More optimizations will improve the performance even more
  - These performance criteria can be applied towards evaluating other gas mixtures
- Adding other gas mixture files to GArSoft:
  - Starts with putting together a new geometry file, e.g. need to fill the TPC volume with HYDROGEN_elm element name instead of ARGON_elm in the gdml file
  - Additional fcl files containing the parameters of other gas mixtures can be added, e.g. there is a GArProperties fcl file which gets called by detector performance and properties fcl files and that can be replaced with a fcl that contains Hydrogen-based gas mixture properties and parameters
  - Please feel free to get in contact with GArSoft team for guidance on how to start this process

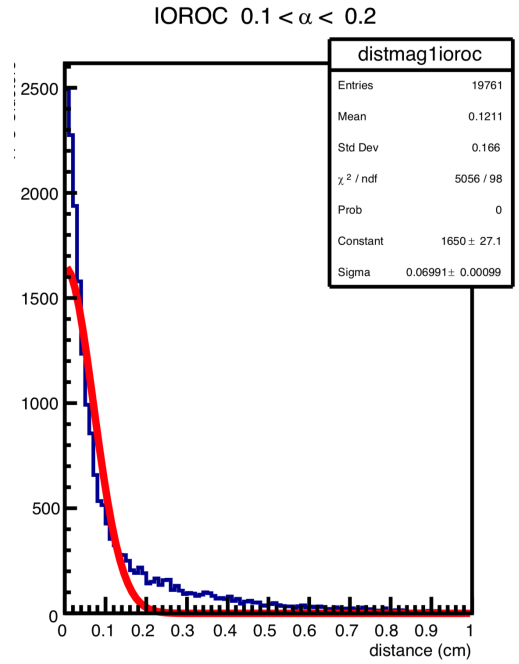
Addition Slides

GArSoft Performance Plots – Hit Residuals









GArSoft – Official ND-GAr Software

- GArSoft also has a parametrized reco module, ParamSim:
  - Parametrically recos momentum and angle using Glucksten for long tracks and range for short tracks, does PID from dE/dx, preliminary μ/π, e/γ separation & $n/\pi^0/\gamma$ energy reconstruction using ECAL, preliminary ν_μ CC selection (if μs stop in ECAL or have a > 1m long m track), preliminary ν_e selection (selection efficiency of ~90%)

Measurement Term

$$\left(\frac{\sigma_{P_\perp}}{p_\perp}\right)^2 = \left(\frac{\sigma_{\text{point}}\ p_\perp}{0.3\ B\ L^2}\sqrt{\frac{720}{N+4}}\right)^2 + \left(\frac{0.05}{B\ L}\sqrt{\frac{1.43\ L}{X_0}}\right)^2$$

Scattering Term