Far Detector Electron Lifetime Calibration Using Crossing Muons

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Motivation and Goals

- Tracks crossing both APA and CPA provide tracks with a measurable T0
- Hits from these tracks can be used to calibrate electron lifetime in the TPC due to the known drift time
- We'd like to understand how sensitive we can be to the lifetime using these tracks

Motivation

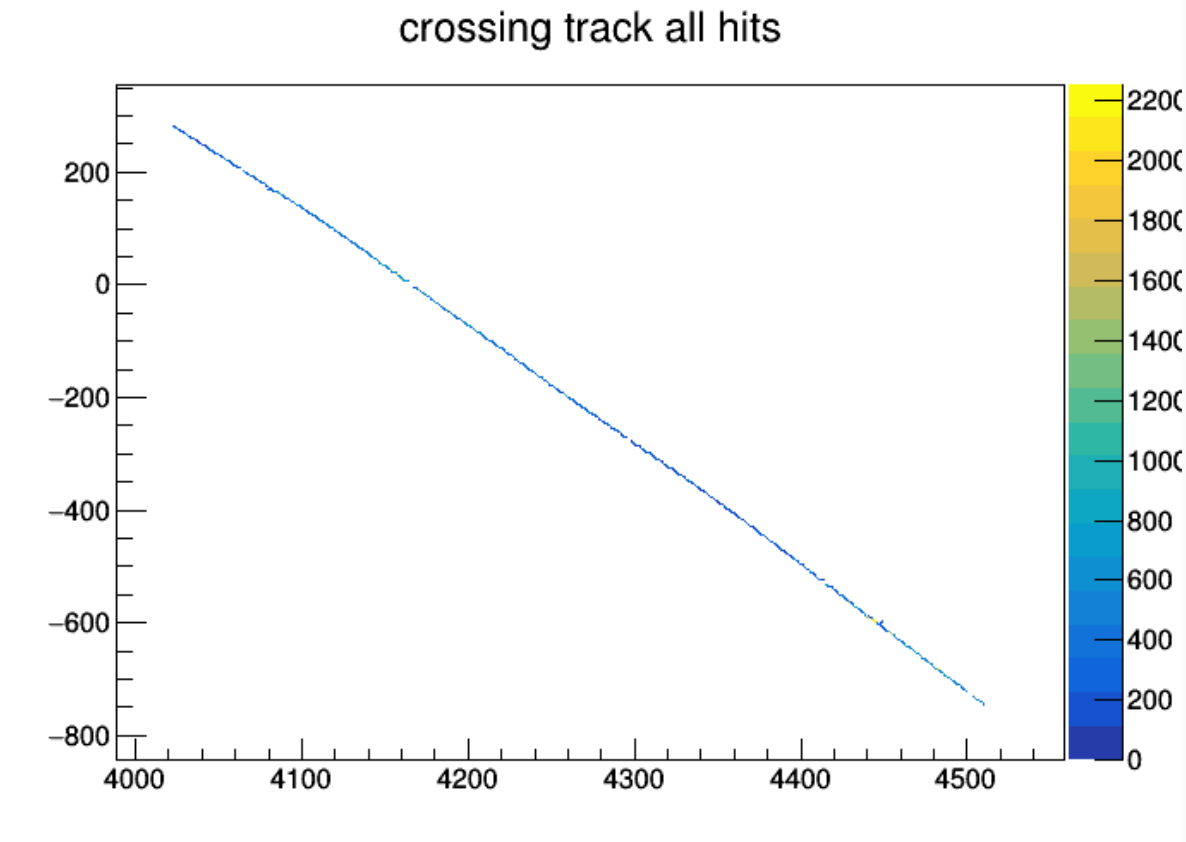
- Understand granularity possible in lifetime measurements based on realistic event selection purity and efficiency

Goal

- Develop lifetime measurement method based on hits collected from T0 tagged crossing tracks

MC Sample

- An MCC9 cosmic ray sample, MUSUN, was used to study crossing track selection in the far detector
- The cosmics in this data are mostly very vertical so only 6% of all tracks cross an anode or cathode
- This sample is "cosmic triggered" so all tracks have a T0 of 0



Selecting Crossing Tracks in DUNE

In DUNE we can take advantage of a track stitching algorithm developed by Leigh Whitehead for ProtoDUNE to select crossing tracks

- `https://indico.fnal.gov/event/13933/material/slides/0?contribId=2`

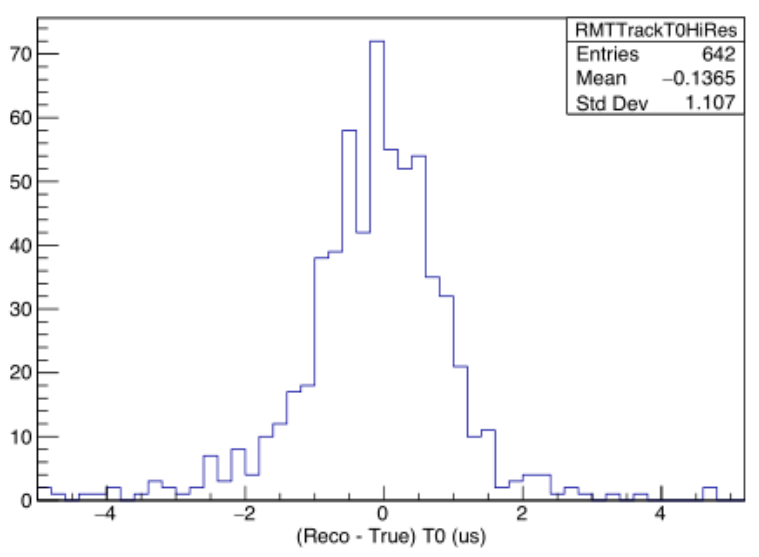
Tracks with start and end in different APA/CPA corridor selected and quality cuts applied, T0 has O(μs) resolution from stitching algorithm

- `https://indico.fnal.gov/event/14581/session/8/contribution/161/material/slides/`

Note on MUSUN Sample

Cosmic triggered nature of MUSUN sample means few tracks are stitched due to small T0's

- Gaussian spread of 1μs applied to true T0's instead



Selection Performance

- This event selection was tested on the MUSUN cosmic data sample and produced a sample of 3300 tracks
  - This is about 6% of all tracks
  - A crossing track is found in 1 out of 5 events.
- This selection had purity 97% and efficiency 36%

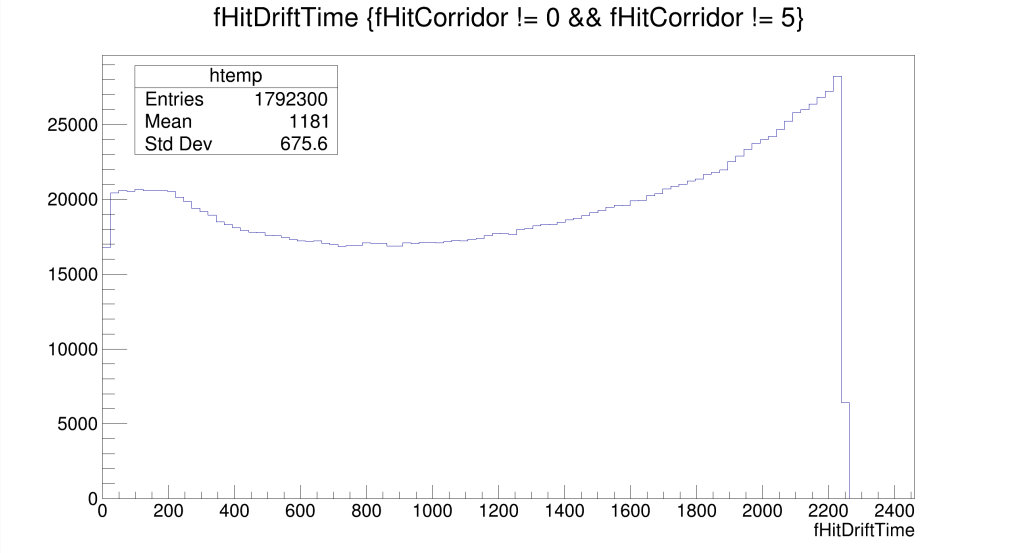
Number Events	17,800
Total Number of Tracks	142,447
True Crossing Tracks	8710
Selected before Angular Cut	3374
Selected before NHits Cut	3358
Selected Tracks	3301

Lifetime Calibration Method

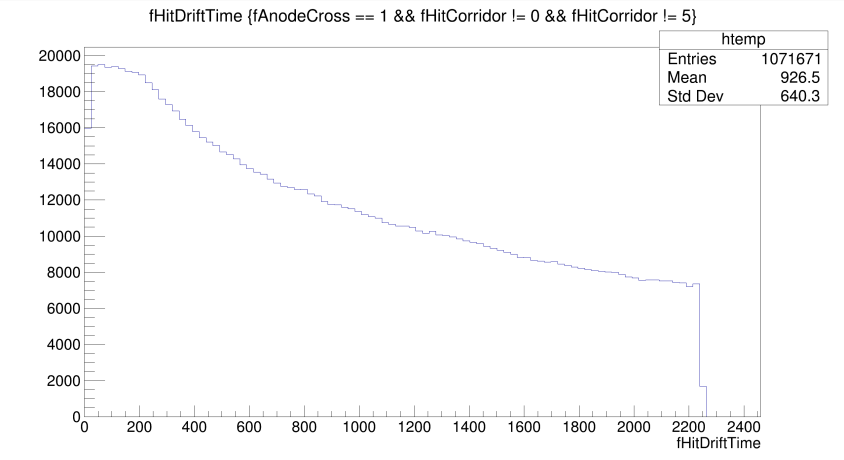
- Electron lifetime measured from decay of charge deposition with drift distance
- Most Probable Value (MPV) is used due to large tails of distribution
- MPV taken from Landau-Gaussian Fits to charge distribution with drift time
  - recob::Hit::Integral() used for charge values
  - Charge distributions binned in 100μs time bins
  - MPVs fitted around peaks of charge distributions

Drift Time Distributions

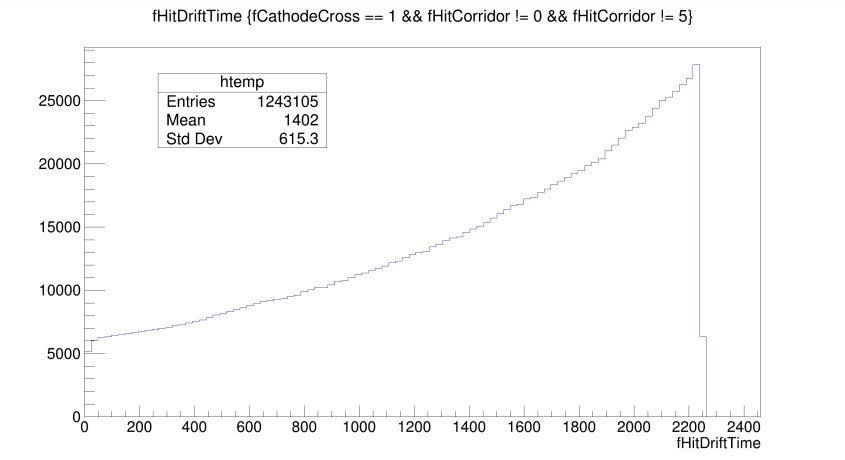
All Tracks



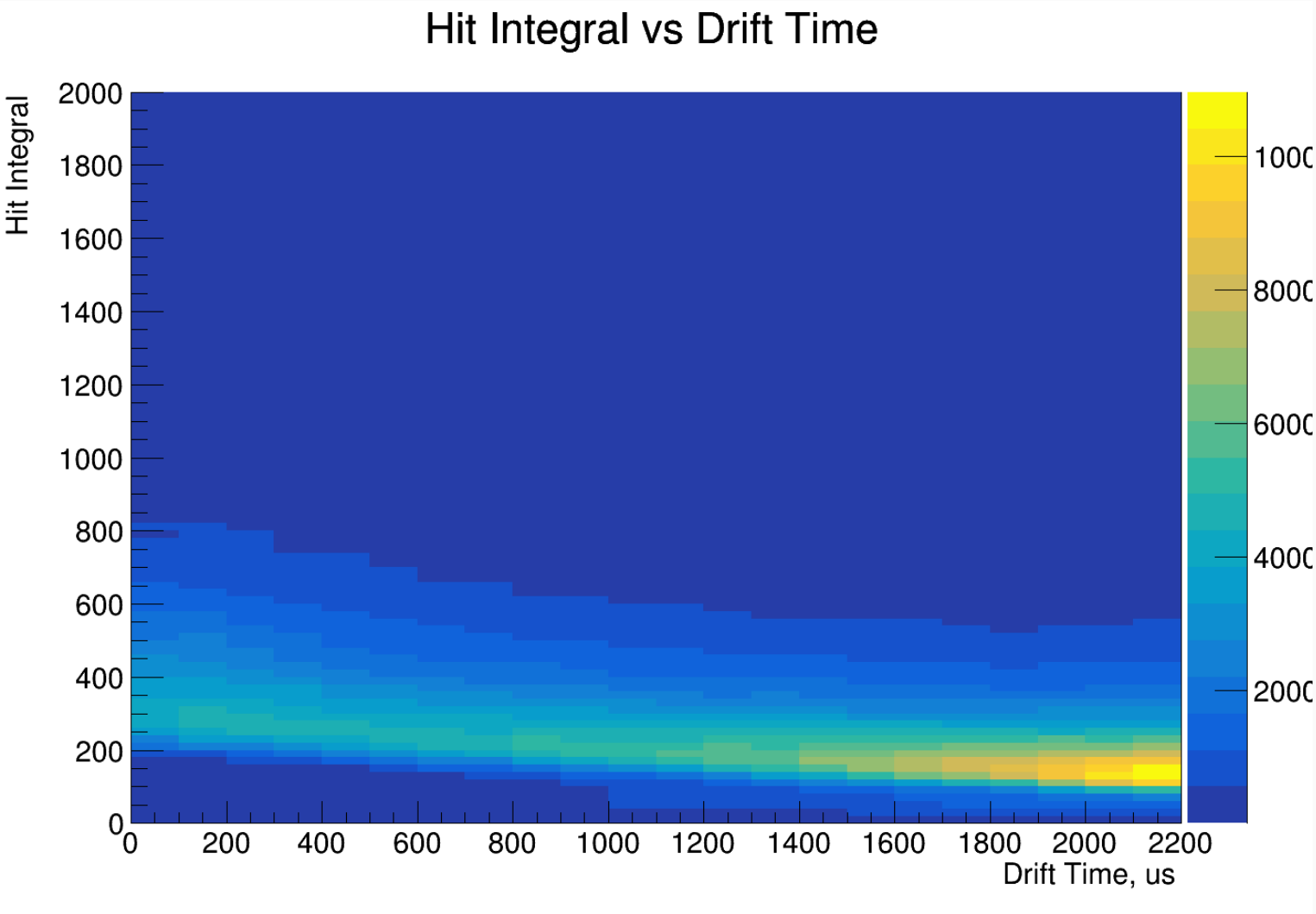
Anode Crossers



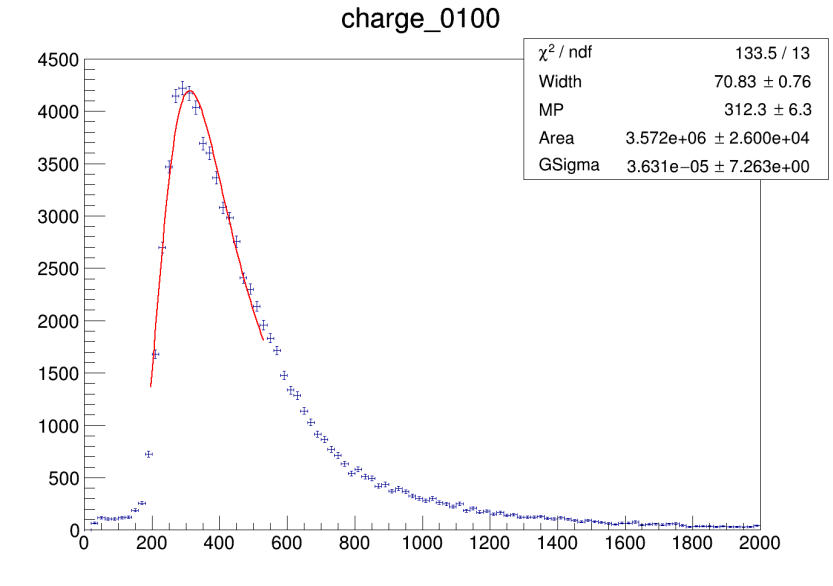
Cathode Crossers

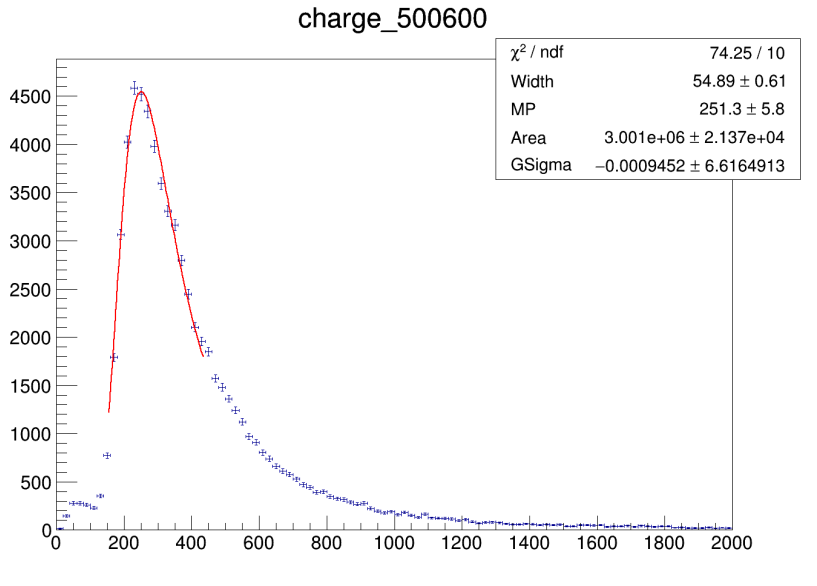


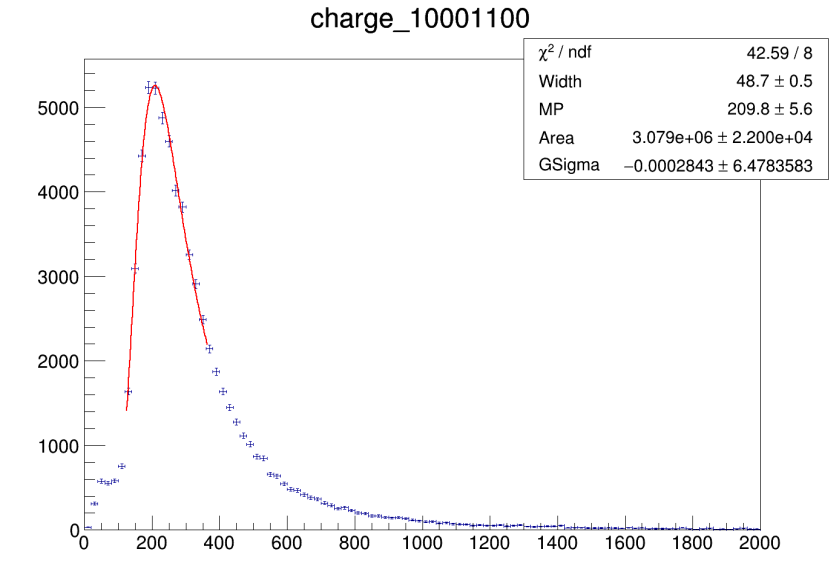
Charge – Drift Time Distributions

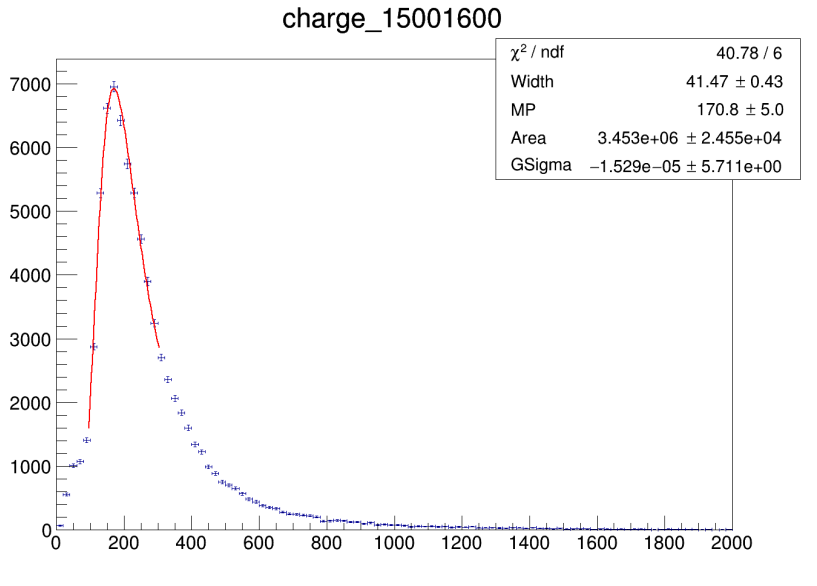


Charge Distributions and MPV Fit Examples



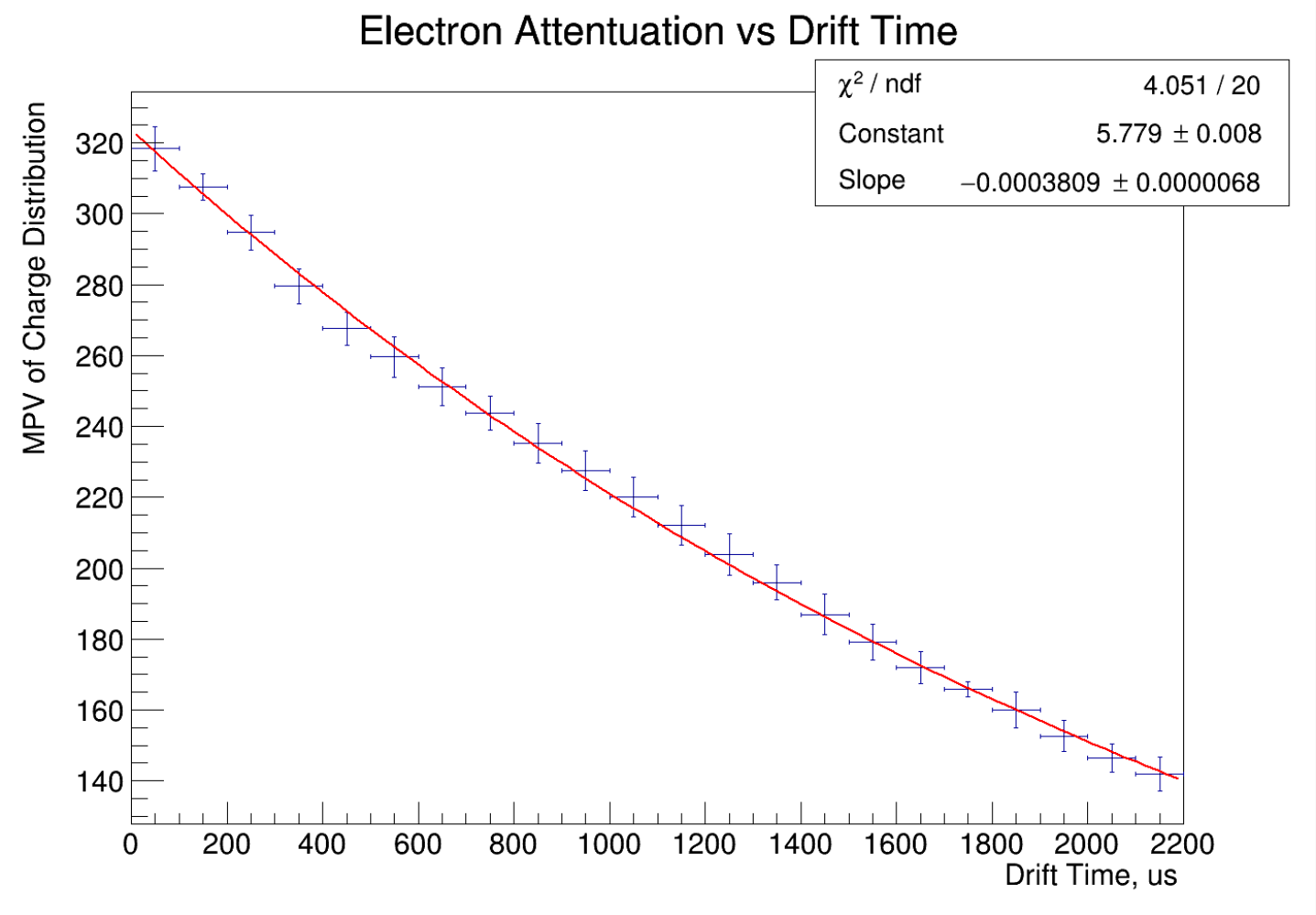






Lifetime Estimation

Lifetime estimate from exponential fit to MPV vs Drift Time distribution



Prediction: $2.62 \pm 0.05\ \mu s$ (stat only)

Simulation: $3\mu s$

Considerations and To-Do's

- Not yet attempted to remove sources of high charge density
  - Delta rays, MCS
- Reduced lifetime estimate if selection favours cathode crossers
  - Muon energy loss as track approaches anode could mimic electron attenuation
- This study uses a sample of 3300 selected tracks over the full FD volume
  - Spatial granularity based on this sample will be minimal
  - To what level do we want to know electron lifetime in each spatial bin?

Summary

- Framework to understand lifetime calibration based on the minimal sample of T0 tagged tracks is in place
- Initial predictions show 10% discrepancy from simulated lifetime
  - Possible causes for investigation:
    - Delta rays and other large charge deposits along tracks
    - Anode vs Cathode selection bias (energy loss during traversal)
- Moving forward we wish to use this framework to understand the lifetime sensitivity over the whole far detector based on a minimal T0 tagged sample
  - Spatial granularity
  - Sensitivity with optical T0 tagging