35ton Measurements

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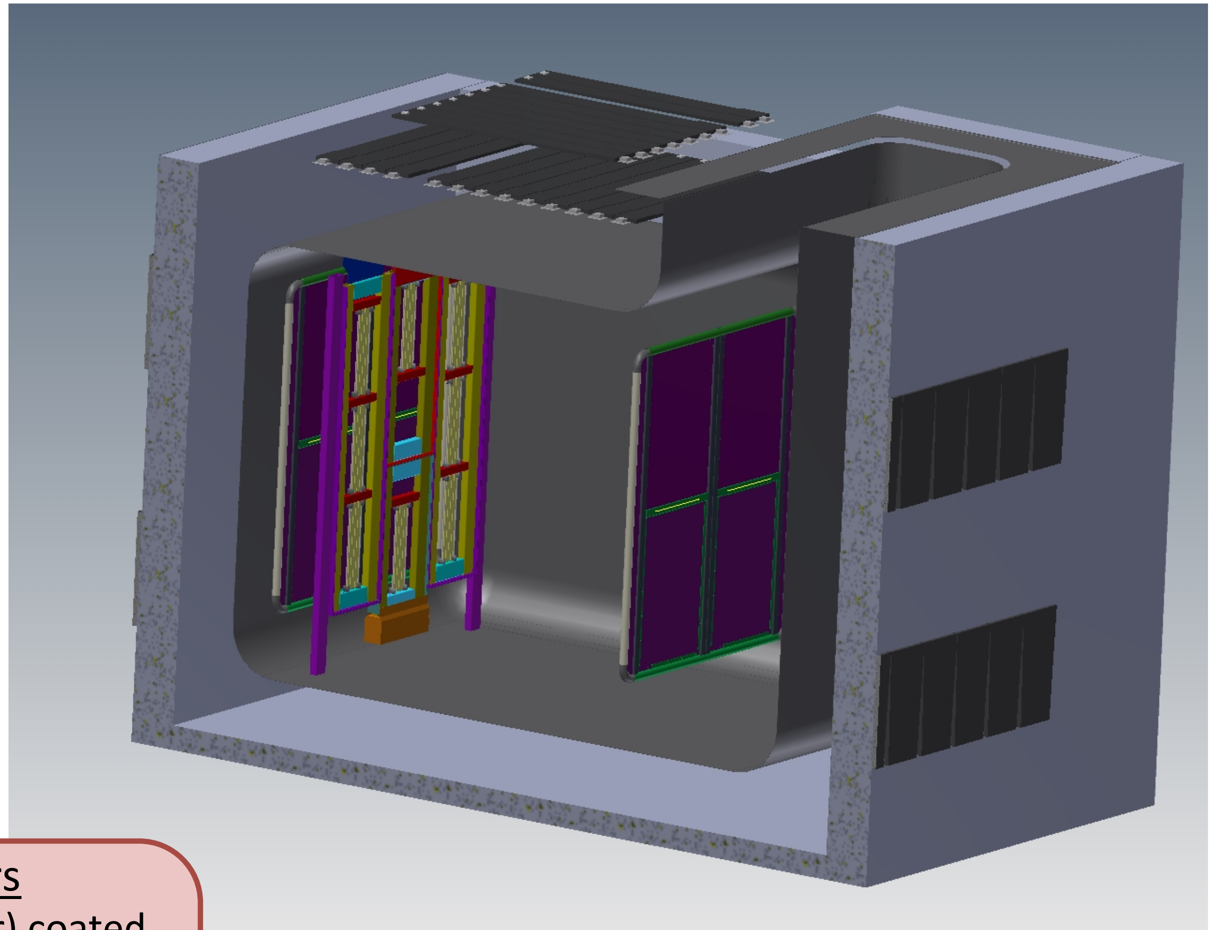
"One prototype's measurements are another's calibrations"

LBNE 35-ton prototype
(what makes it special)



Cryostat

Membrane cryostat technology from LNG industry

Cold Electronics

Amplify and digitize signals inside cryostat

DAQ

Continuous readout of TPC and Photon Detectors

Photon Detectors

- TPB (wavelength shifter) coated light guides with SiPMs
- Absolute SiPM calibration being developed
- Simulation of light production and collection

TPC

- Cathode HV up to 200 kV, 2.2 m electron drift
- Wrapped wire planes (ambiguity associating induction plane hits to drift volume)
- 8 sets of wire planes, 8 drift volumes, 2 drift directions

"Integrated system test that incorporates as many features of the far detector as possible"

- Build the pieces and put them together

"Scaling up to 10 kTon requires that we implement many new and untested features in the detector design"

- FR4 field cage
- modular design (APAs)
- light-guide style photon detectors
- wrapped wire planes
- 180 kV
- Membrane cryostat
- Triggerless data acquistion (non-beam physics)
- Cold electronics chain (pre-amp -> ADC -> zero suppression and multiplexing)

No laser calibration system or sources

35ton deliverables

- Reconstruct tracks and showers with wrapped wires (needs disambiguation algorithm, pileup?) works in simulation, can be improved/ refined
- Measure event time resolution of the photon detectors (requirement is < 1 us) straightforward
  - External counters provide truth information
  - APA crossing tracks provide truth information
- Characterize electronics performance: straightforward, been done before
  - Fine tune wire calibration inputs (electronics response function) with data.
  - Measure S/N for MIPs (noise as function of wire length)
  - Study signal shape as a function of wire plane bias voltages
- Use TPC data to study purity profile inside the drift volume
  http://arxiv.org/abs/1504.00398 hard, but been done before
- Measure resolution loss in APA gaps, tune simulation new but straightforward
- Simulate light production and collection, tune to match data code is working

35ton desirables

- Look for distortions in through-going muon tracks and compare with space charge models. Vary drift field to isolate space charge effects. (LBNE-docdb 9587 and 10404, slide 14)
- Study non-uniformity of drift field near field cage edges/corners (again, CR muon track distortions, very difficult)
- Reconstruct stopping muons, measure Michel parameter
- Shower reconstruction, pi0 mass
- Measure dE/dx for protons and muons (and . . .)
- Measure diffusion coefficients as function of drift field and tune simulations (LBNE-docdb 11139) – requires high purity?
- Measure light and charge yield as a function of drift field

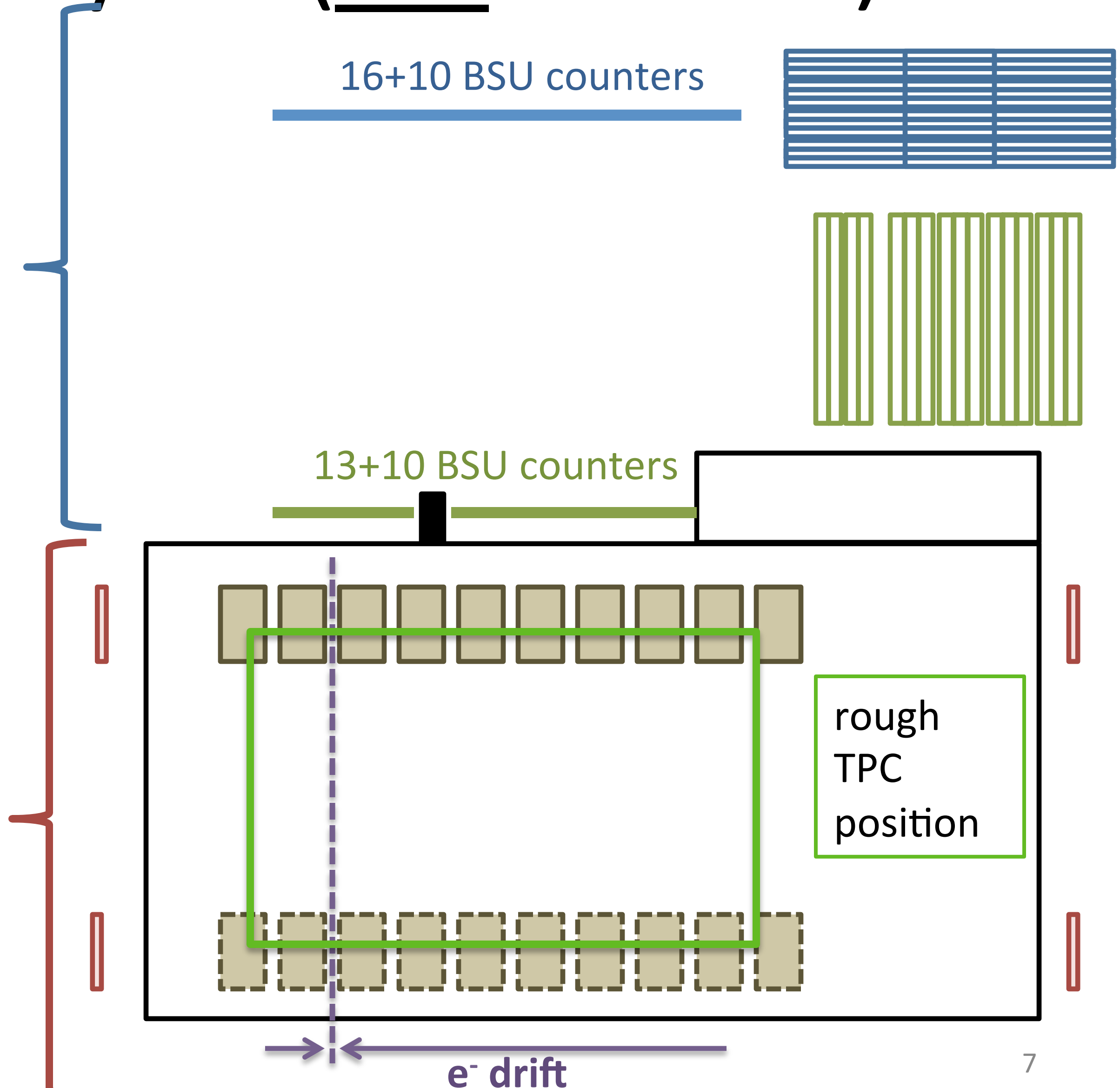
Any preliminary work is noted, but most are still at the idea stage. Look for future talks!

External counter system

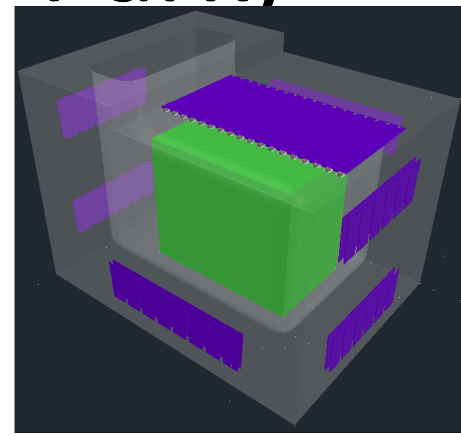
- Using experienced counters recovered from CDF (don't assume that segmentation is optimized)
- The concept of the external counter system arrived after the cryostat construction. Lots of obstacles from cryo system where we'd like to have counters.
- Custom "Penn trigger board" streams individual hit information (hit time and channel only) to DAQ plus trigger bits from logic combinations. All preserved in the data record.

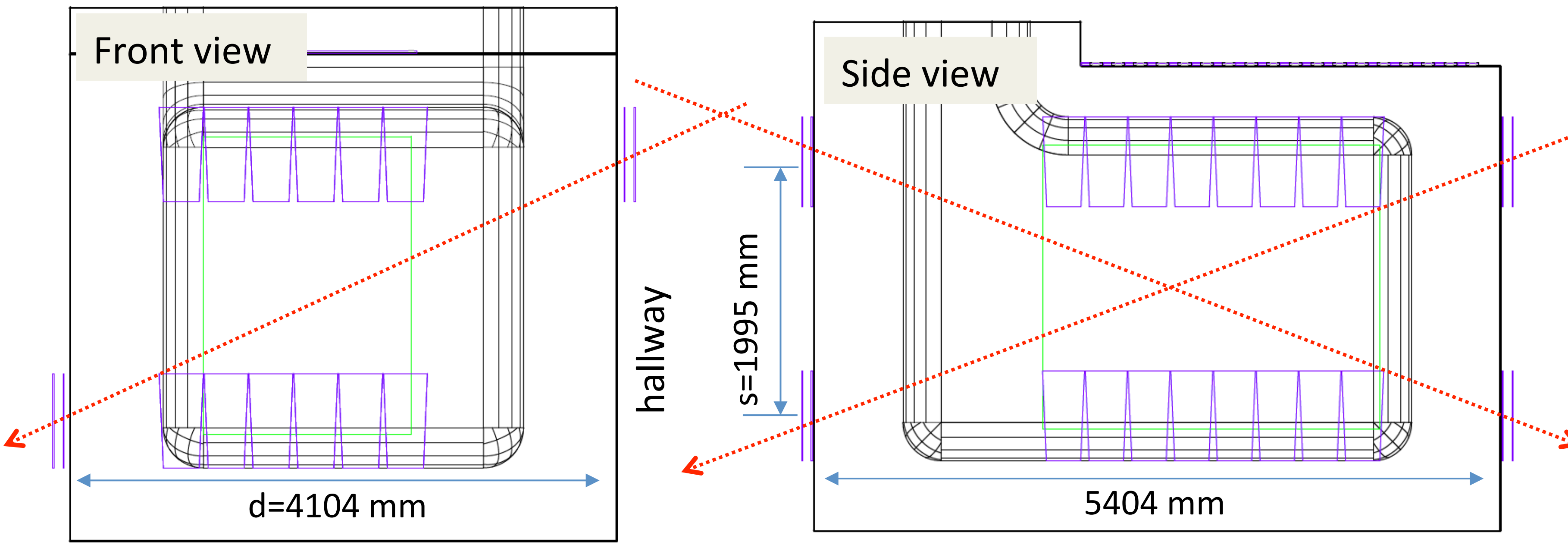
Counter layout (not to scale)

- Muon Telescope above, 2+2 layers of counters, ~20 feet separation. Limited by (non-existent) budget.
- Through-going muons : TSU counters on the tank sides (in pairs for CR shower rejection)
  - Upper and lower rows of 6 pairs each
  - Upper row of 10 pairs on one side of trench and lower row of 10 on other side (dashed)



Better visual (Seongtae Park)





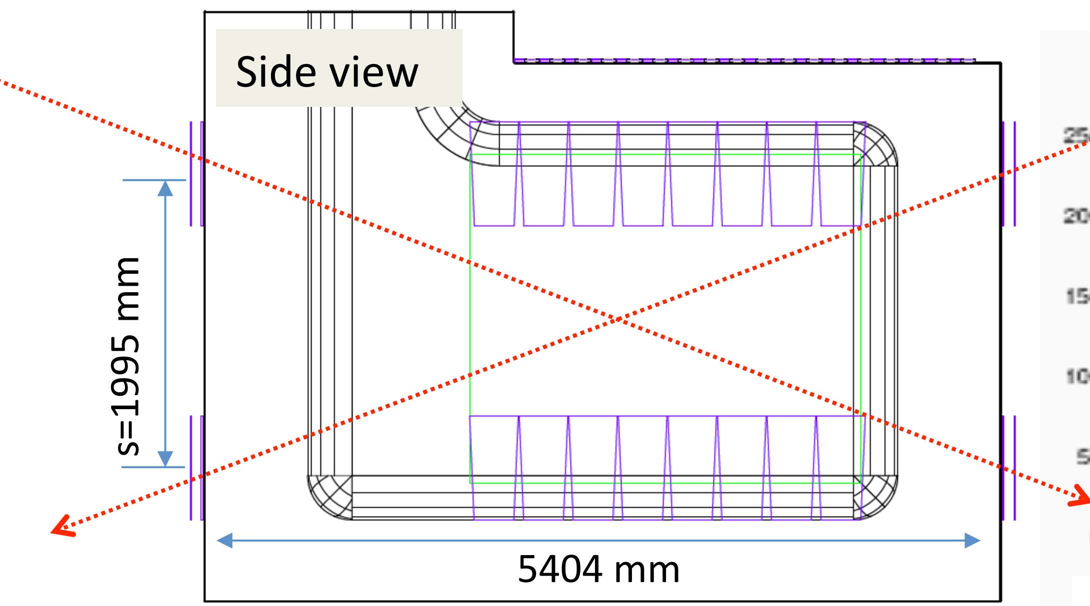
Why the counters are handy . . . .

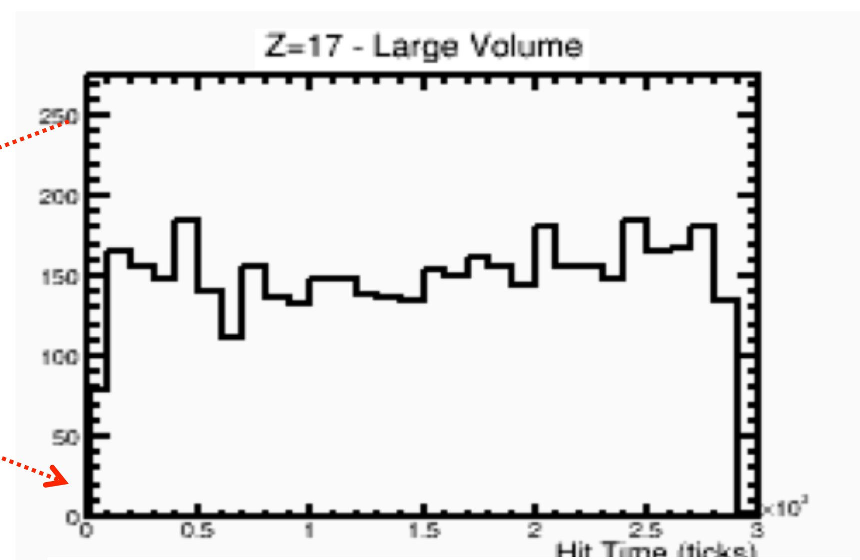
- Online purity monitoring (see next talk)
- Online crude drift field monitoring (see next slide)
- Online evaluation of gap deflector
- Offline - crude position information helps with disambiguation
- Commissioning with low purity – possible to preselect tracks close to wire planes
- Triggered running for an enhanced sample of horizontal-ish muons. (safety blanket!) If we can't run the DAQ untriggered, arbitrary prescales would kill these rare but precious tracks.
- Rejection of low momentum tracks with large multiple scattering effects
  - ~80 cm of foam and concrete between counters and active TPC volume. **Additional material between the cryostat and the exiting counters would effectively raise the momentum threshold.**

Online drift field monitoring

- Use cathode to anode tracks with large side-to-side angle
- Histogram the hit times (Raw hit finder developed for online)
- Drift velocity = drift distance/Δt for perfectly uniform field
  - Width of distribution still a good measure of average field
- See space charge build up? (rate too low on 35ton)

***Histogram also useful for trigger timing offset determination



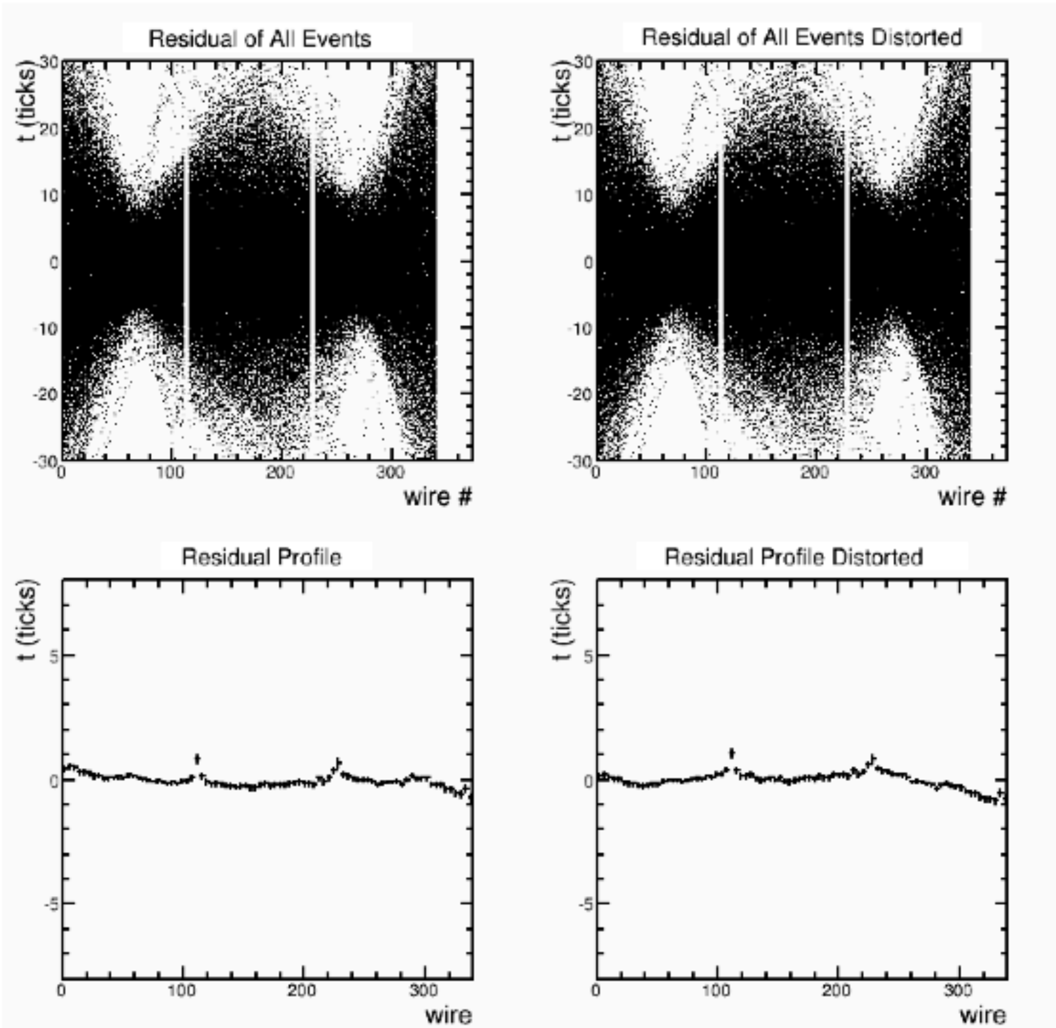


Very simple study in lbne-docdb 10090

Space Charge measurement

- Summer 2014 – U. Cincinnati undergraduate Micah Groh did preliminary studies to see if this is possible with CR muon tracks (LBNE docdb 9454, 9587 – next 4 slides from here)
- Simplified model of space charge – no edge effects and no fluid flow
- Tells us a lot about multiple scattering effects
- More detailed simulations planned, including fluid flow and edge effects, and data sample.
- Actual measurement looks dicey

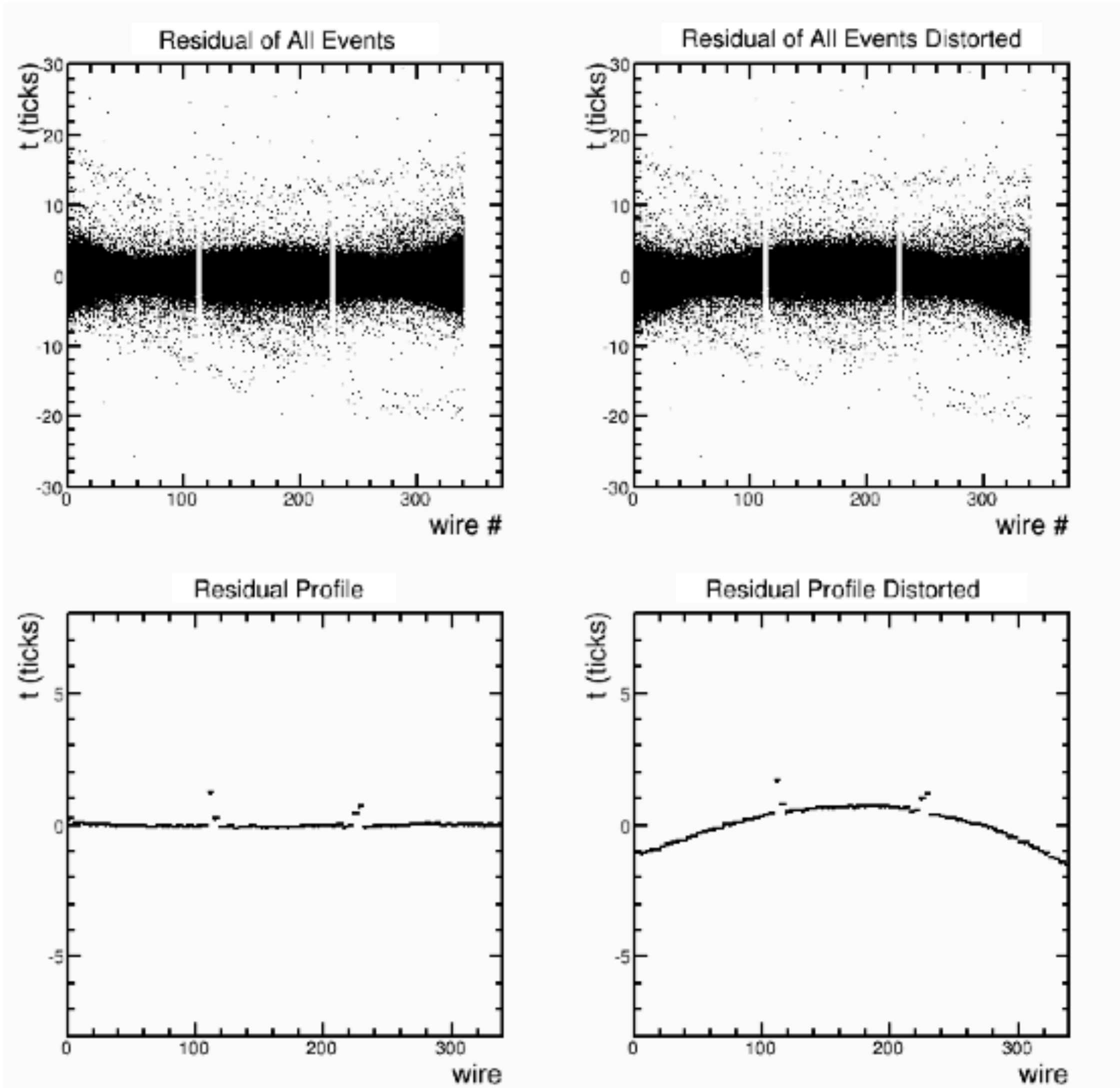
500 V/cm - 1.0 GeV



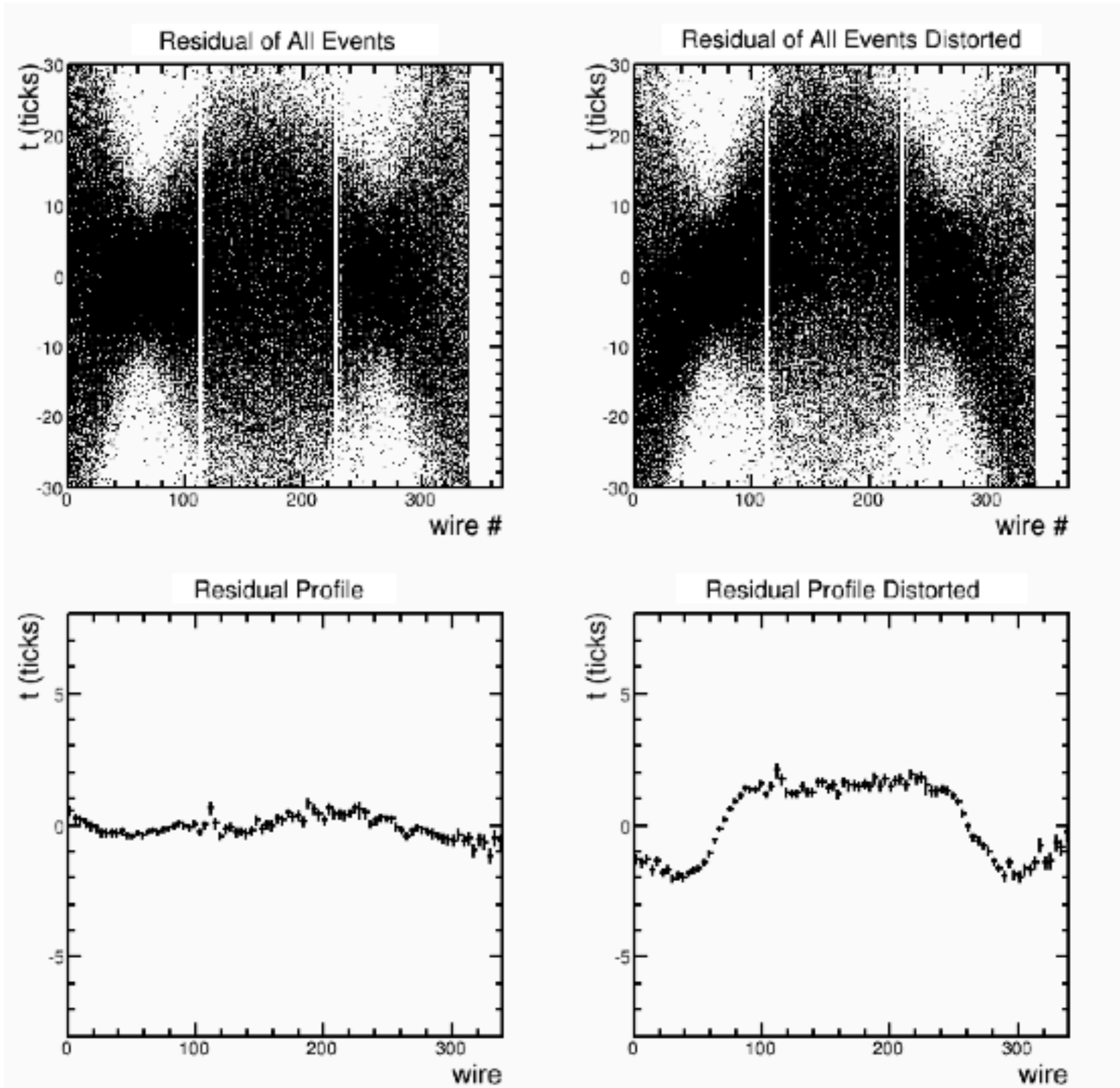
Simulated muons at same angle, energy and starting position

- Multiple scattering in simulation step
- Hits given time offset calculated from space charge field distortions
- Straight tracks become arcs
- Distorted time vs wire number (collection plane only) fitted to a straight line
- Residuals: individual hits compared with best line fit

500 V/cm - 6.0 GeV



250 V/cm - 1.0 GeV



250 V/cm - 6.0 GeV