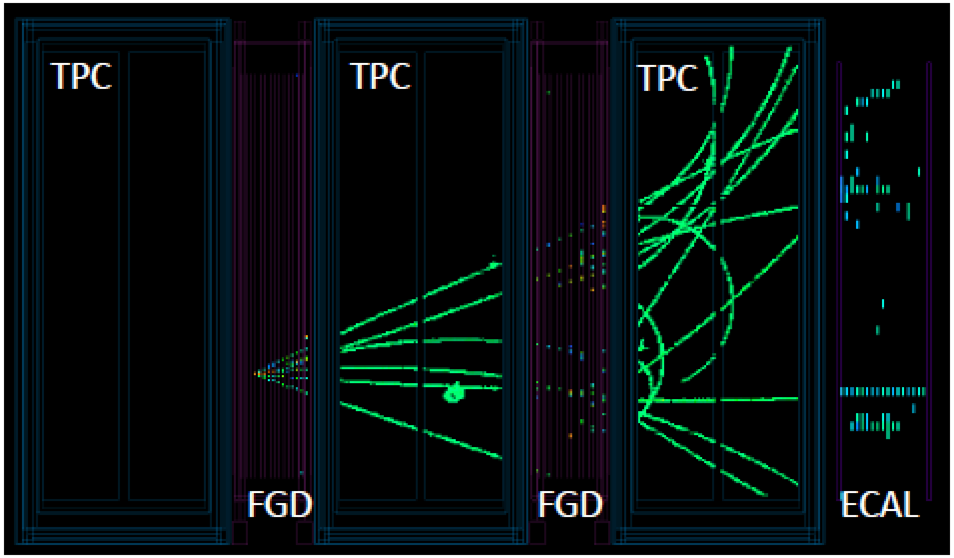

T2K TPC Laser Calibration

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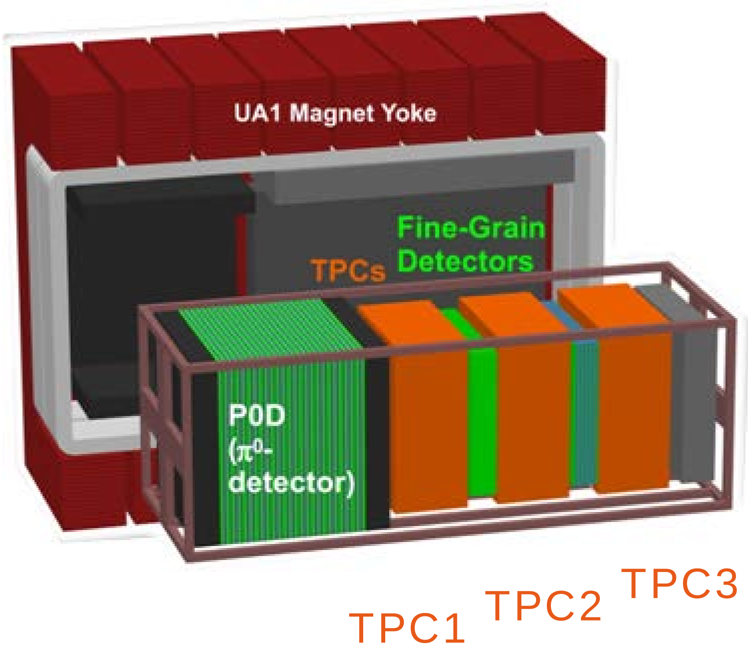
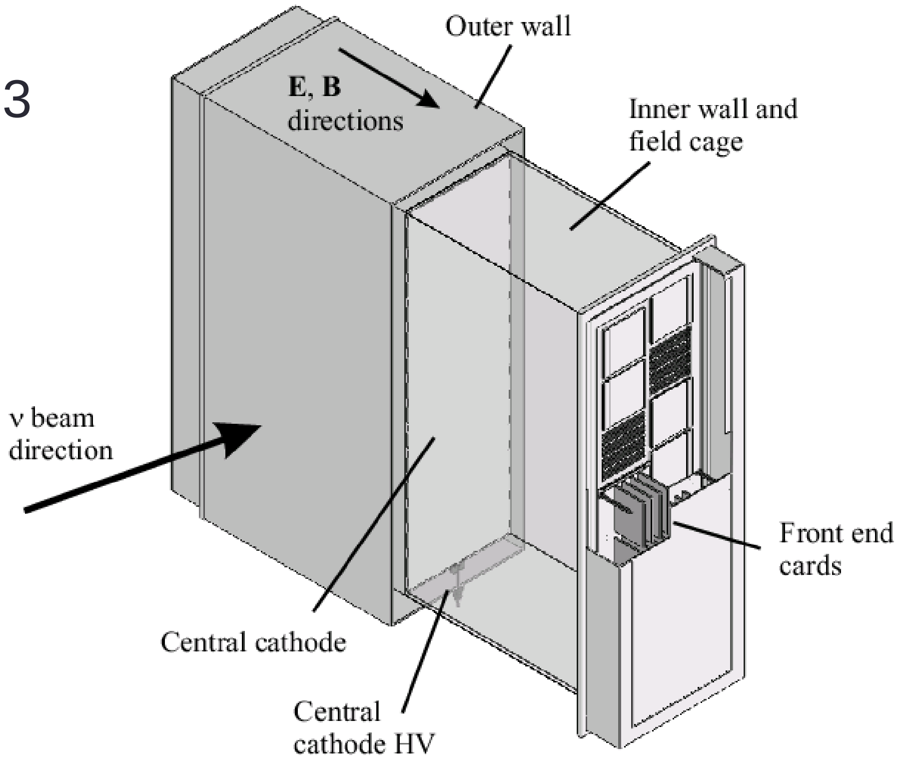
LCTPC Collaboration Workshop
March 26, 2012

T2K TPC design

- Detectors designed to fit inside UA1 magnet volume
  - Each TPC approx: 2.5 m x 2.5 m x 1 m
  - Maximum drift: 0.9 m
  - Field non-homogenous for TPC3



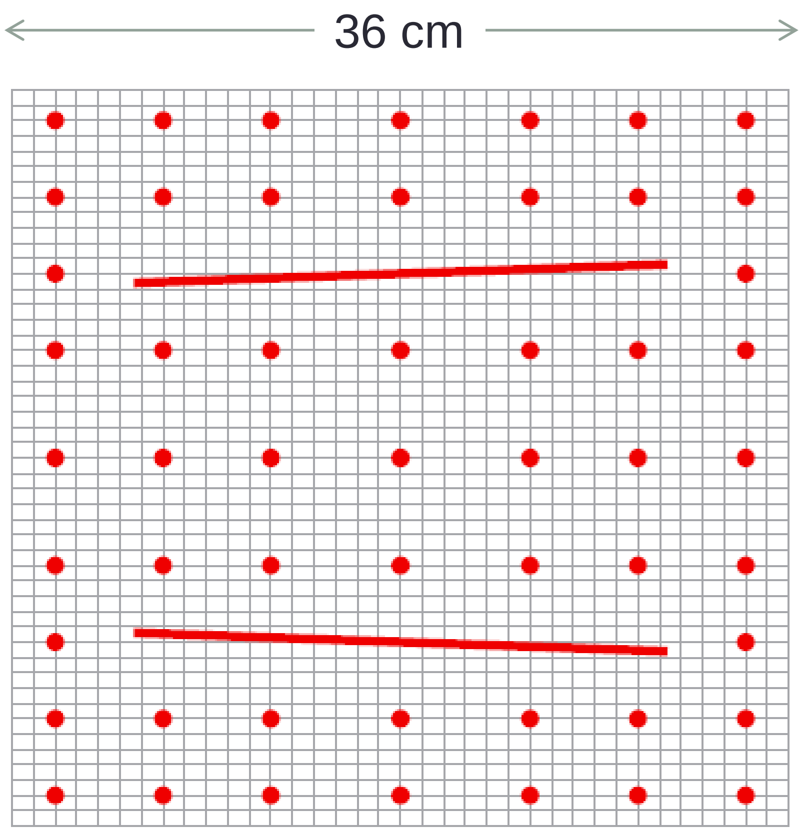


TPC laser calibration system

- Illuminate the central cathode with pulses of UV light
  - Use 266 nm laser and 18 quartz fibers (mechanical mux.)
- Aluminum features emit more photoelectrons than copper
  - Nominal setting: 2 pe/mm^2 for aluminum, 0.03 pe/mm^2 for copper
- Calibration capabilities:
  - **Time domain**: drift velocity, relative time offsets between separate readout modules, shifts in timing offsets
  - **Gain calibration:** use Poisson nature of photoelectron emission to estimate absolute gain of system and relative gains
  - **Field distortions:** measure displacements of photoelectrons transverse to drift direction, due to non-homogenous B field

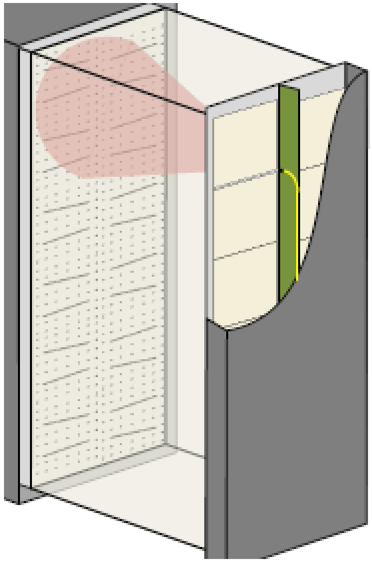
Aluminum pattern

- Common pattern for each readout module
  - 8 mm diameter dots and 4 mm wide strips
  - 7 mm x 10 mm pads

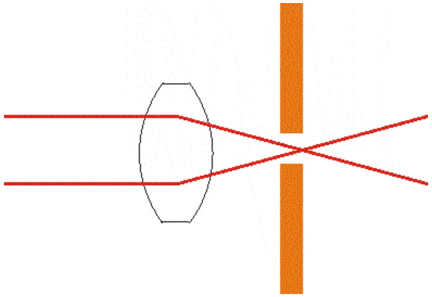


- Points much more useful than lines of ionization to understand field distortions
  - particularly for T2K as there is no “preferred” track orientation, unlike ILC where tracks originate from a fixed point

Bringing in the light



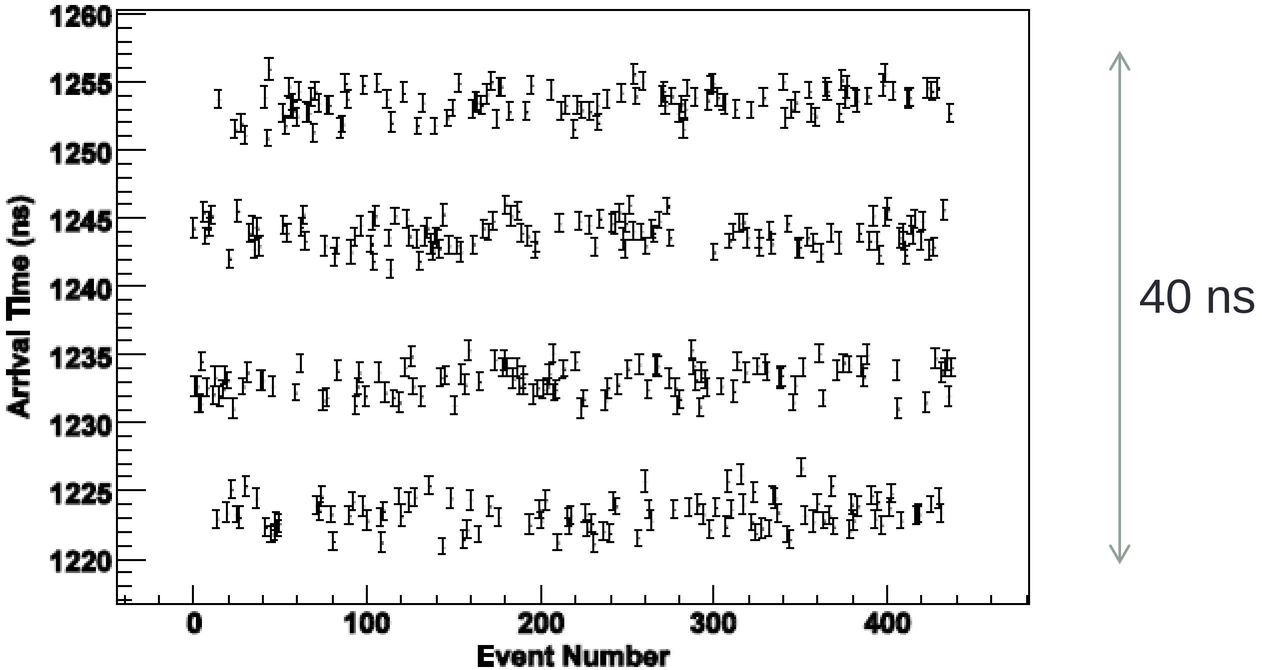
- Focused through ~1 mm hole in module frame



Operational Experience

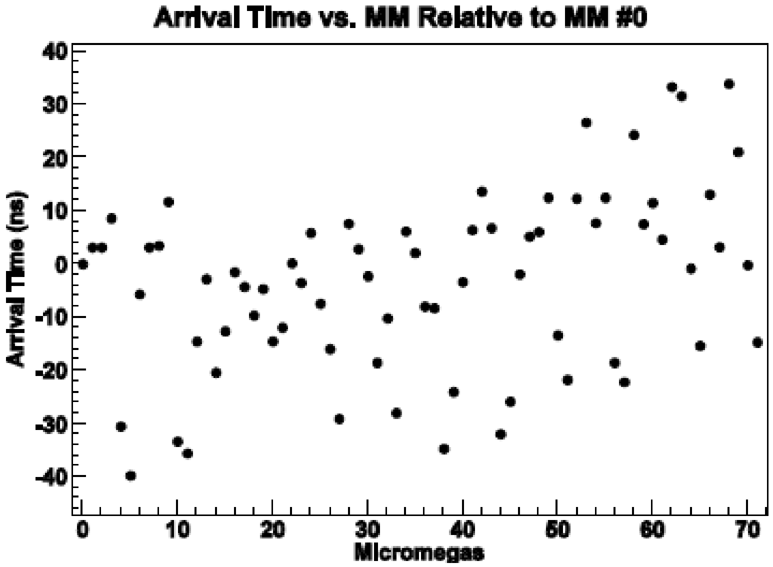
Time domain

- Digitization: 25 MHz (40 ns samples) 12 bit
- Arrival time for single calibration pulse: σ ~ 1 ns
- Used to discover/fix random event-event phase shifts
  - 25 MHz clock derived from 100 MHz clock – 4 phases

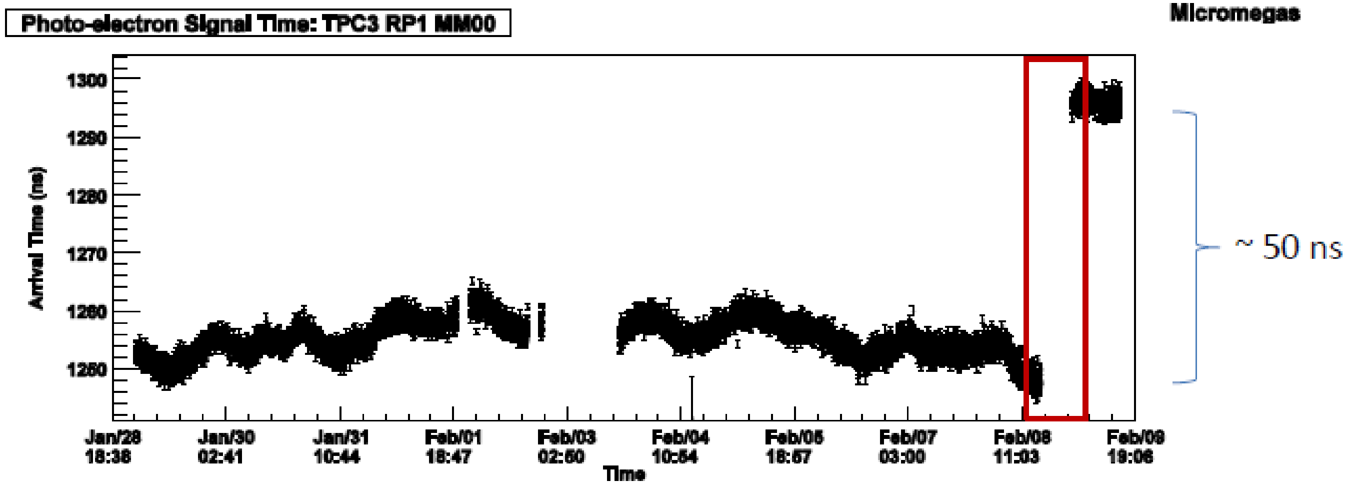


Time domain

- Relative timing between modules (range 80 ns = 6 mm)



- Timing shift detection:



- Drift velocity monitoring done with mini-TPC connected into gas system (in continuous operation)

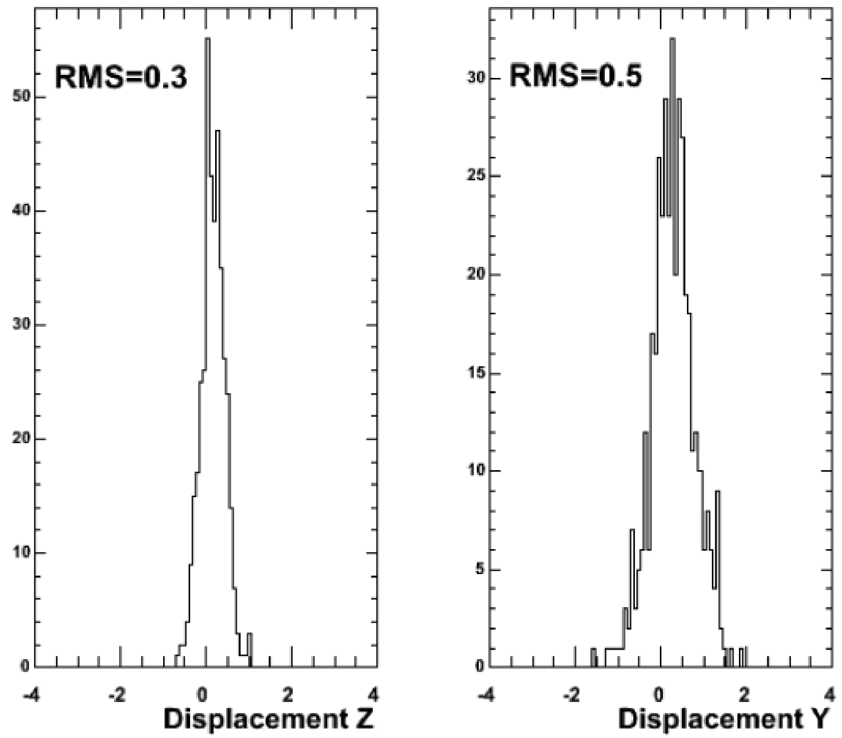
Field distortions

- Goal: account for field distortions so that systematic uncertainty on the momentum scale is: $\delta\left(\frac{1}{p_t}\right) < 0.02\ \mathrm{GeV}^{-1}$
  - Note: momentum resolution is $\sigma\left(\frac{1}{p_t}\right) \cong 0.1\ \mathrm{GeV}^{-1}$
- Sagitta: $s = \kappa\, L^2/8$ $\quad \frac{1}{p_t} = \frac{\kappa}{0.3\, B} = \frac{8}{0.3\, B\, L^2} s$
  - κ = 1/radius of curvature, L = track length
- T2K: B = 0.2 T, L = 0.8 m $\rightarrow \frac{1}{p_t} = 0.25\, s$ [GeV, mm]
  - distortions need to be understood at level of 0.1 mm
- LCTPC: B = 3.5 T, L = 1.8 m $\rightarrow \frac{1}{p_t} = 0.002\, s$ [GeV, mm]
  - ILD goal*: $\delta\left(\frac{1}{p_t}\right) < 2 \times 10^{-5}\ \mathrm{GeV}^{-1} \rightarrow \delta(s) < 0.01$ mm

* not sure what number to use here

Field distortion measurements

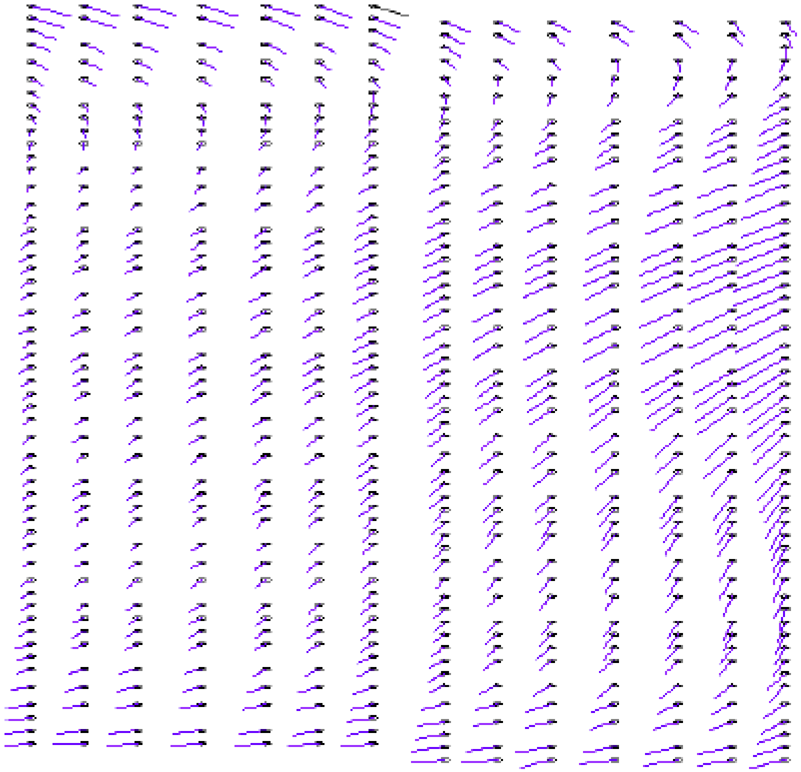
- B-field mapped prior to installation of detectors
  - special purpose apparatus built by CERN technical group
  - precision goal: transverse field components known to 1-2 Gauss
- Measure displacement of calibration dots centres when B field is turned on
  - Compare with the expected displacements from B-field map
  - Difference between two: empirical correction and uncertainty
  - 100 flashes $\rightarrow$ $\sigma \sim 0.04$ mm



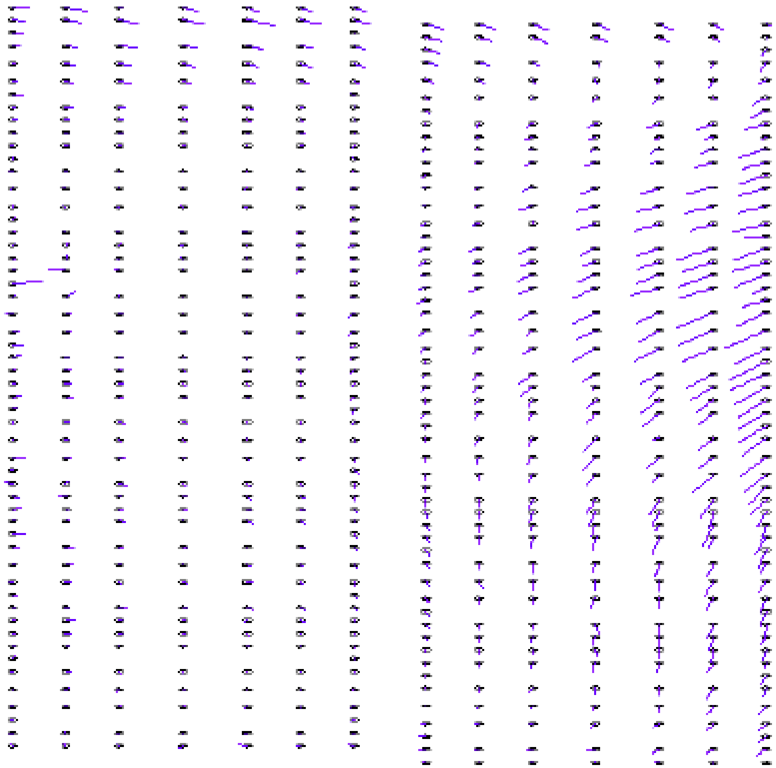
TPC3 distortions

- Lines show displacements (x 20) for dots on one readout plane (aspect ratio not preserved) (maximum few mm)

simulated from field map



measured



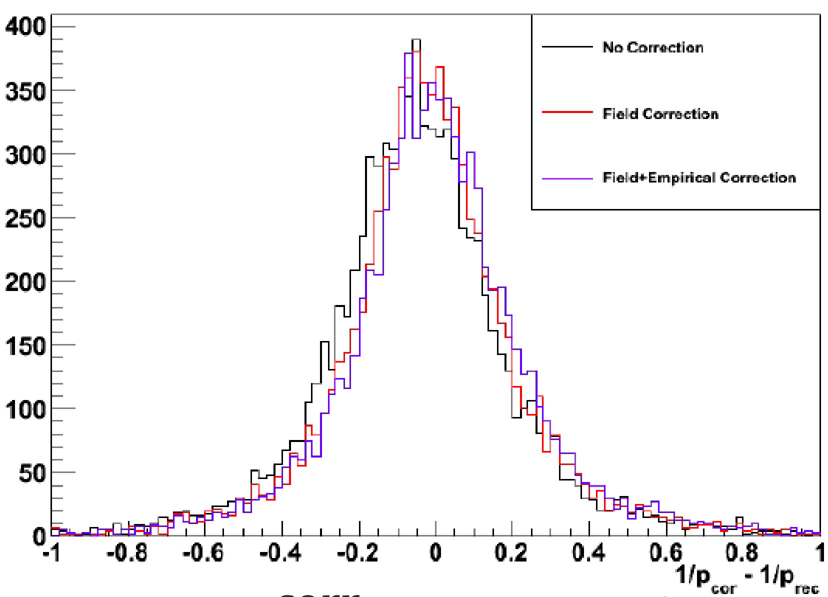
Observations

- Displacements follow similar pattern as simulation
  - initially not the case: field map had sign error on transverse components

- Displacements smaller than expected, using $\omega\tau$ as determined from the ratio of transverse diffusion with and without magnetic field ($\omega\tau = 0.42$)

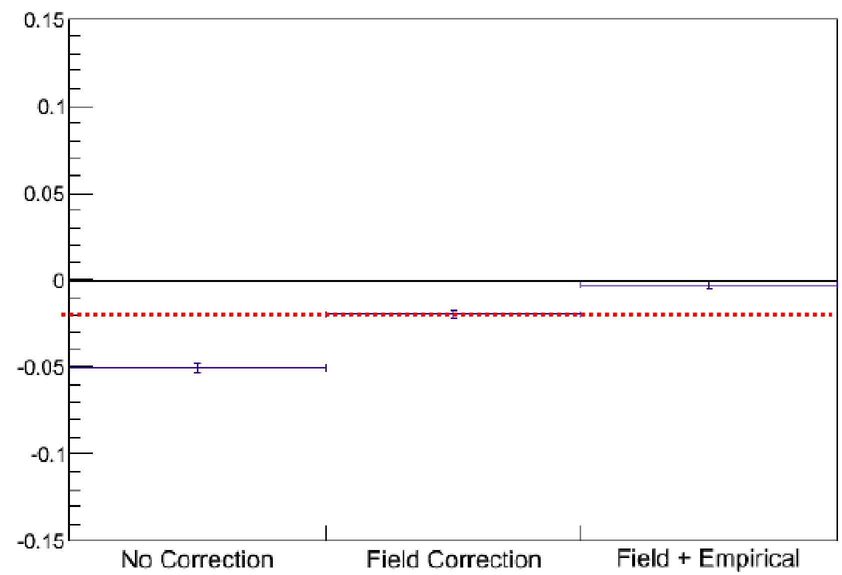
Fitting with field distortions

- Likelihood fit to ionization pattern on pads modified to account for displacements of drifting ionization
- Check with data: using μ^- that pass through TPC2 and TPC3 (and account for energy loss in FGD2)



$1/p_2^{\mathrm{corr}}$ - $1/p_3$ (GeV^{-1})

$1/p_2^{\mathrm{corr}}$ - $1/p_3$ (GeV^{-1})



Unplanned application

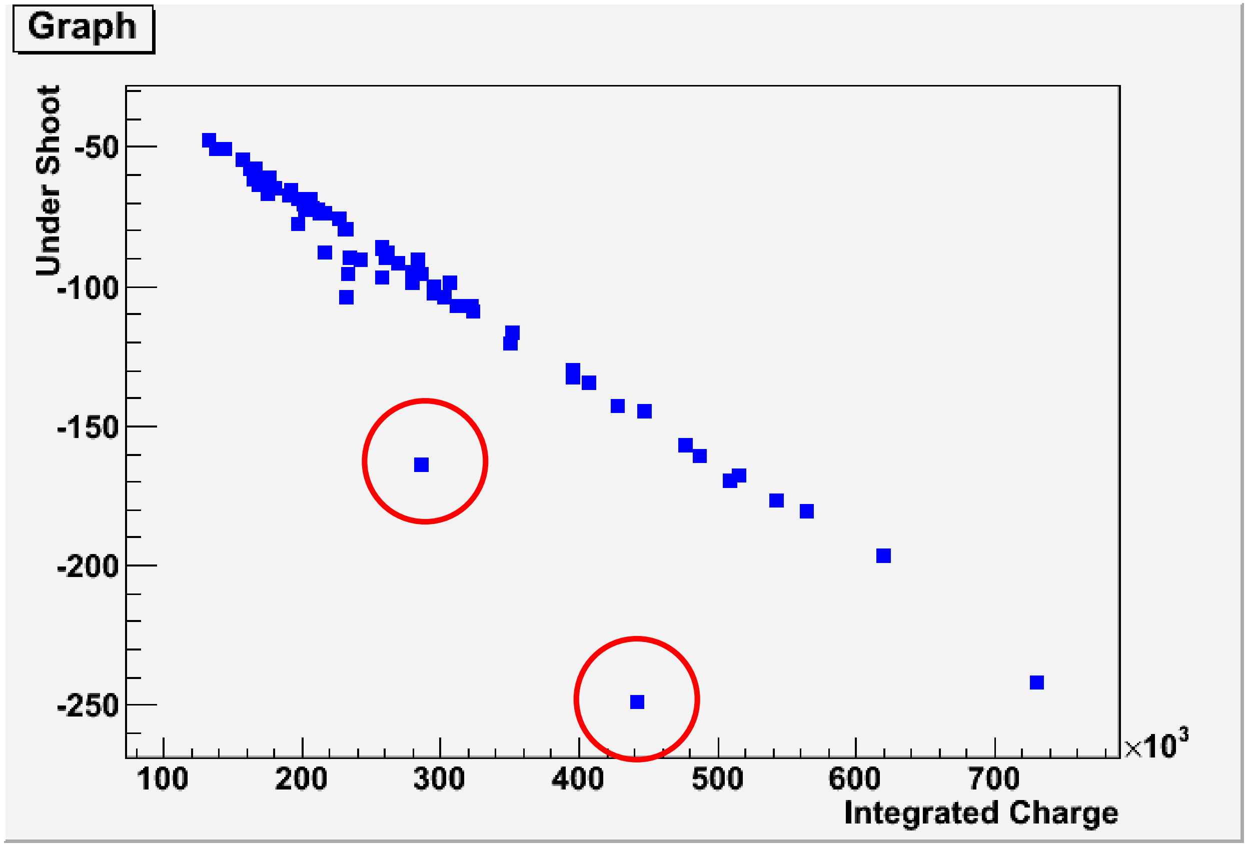
- The electrons arrive at readout plane all at once
  - higher instantaneous charge than from ionizing tracks (not parallel to the tracking plane, less charge overall)
  - a burst of charge passing through a micromegas (and to a lesser extent, a GEM) momentarily reduces the electric potential
  - a signal of inverted polarity is observed on all pads of equal amplitude (somewhat masked on pads that collect charge)
  - the amplitude depends on the capacitive coupling between the pads and the amplification structure

- Measurement of the undershoot is a check of the overall capacitance between mesh and pads.

- Plot on next page, shows 2 of 72 modules unusual capacitance
  - one of which had a HV filter failure
  - the HV filter of the other was replaced, just in case

Unplanned application

- undershoot: negative pulse on region without Al
- integrated charge: total charge collected from Al features



Summary

- Photoelectron calibration system an important tool to understand subtle timing issues and distortions in electron transport in the T2K TPCs

- Issues:
  - laser (Quantel/Big Sky) power degrades by a several % over the period of week running
    - requiring several returns to manufacturer for repair
    - not present for all data collection periods
  - significant effort required to design and laser transport system
    - multiplexer
    - fibres than have modest minimum bending radius)
  - needs to be included early in design stage of LCTPC

Backup Slides

Gain

- Use variance of repeated laser shots
- Not presently used for gain calib