First look at FNAL tracking chamber alignment

Paul Dauncey, with lots of help from Daniel and Angela

FNAL tracking

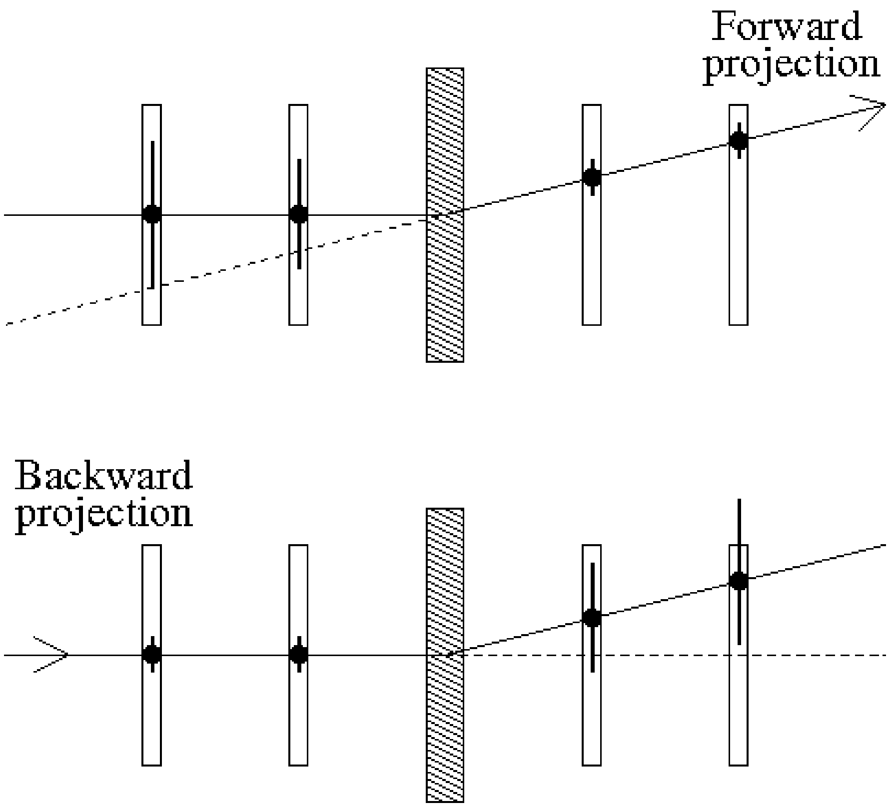
- Used the four "Japanese" tracking chambers
  - Each chamber has X and Y layers
  - Single drift wire at edge of each layer
  - Readout using CAEN767 TDC; 1TDC unit = 25/32 ~ 0.78 ns
  - No coupling between X and Y; totally independent alignment/tracks
- Same chambers as used at DESY, different from CERN
  - Different TDC, different trigger T_0, different gas (?), etc…
  - No attempt to correlate with DESY values
- Drift velocity not known a priori
  - Use ECAL as fixed "ruler" to set overall scale
  - Must not fold in ECAL clustering systematic effects; simply take highest energy ECAL cell
  - Need reconstructed data to get calibrated ECAL readout; only first two 2008 run periods with SiW ECAL (so far)
  - Used every run available

Alignment

- Convert TDC hit time (in TDC units) to spatial coordinate
  - $x = v_d (T - T_0) + q (T - T_0)^2$
  - Alignment constants are T_0, v_d and q
  - Same for y coordinate but constants independent
- Intrinsic chamber/TDC error ~0.3mm
  - Would like alignment errors to be smaller than this
- $dx/dT_0 \sim v_d \sim 0.03$mm/TDC unit
  - Need to know T_0 to better than 10 TDC units
- $dx/dv_d = T\text{-}T_0 \sim 1000$ TDC units at edge of chamber
  - Need to know v_d to better than 0.0003 mm/TDC unit
- $dx/dq = (T\text{-}T_0)^2 \sim 10^6$ TDC units at edge of chamber
  - Need to know q to better than 3 10^{-7} mm/TDC unit^2

Scattering

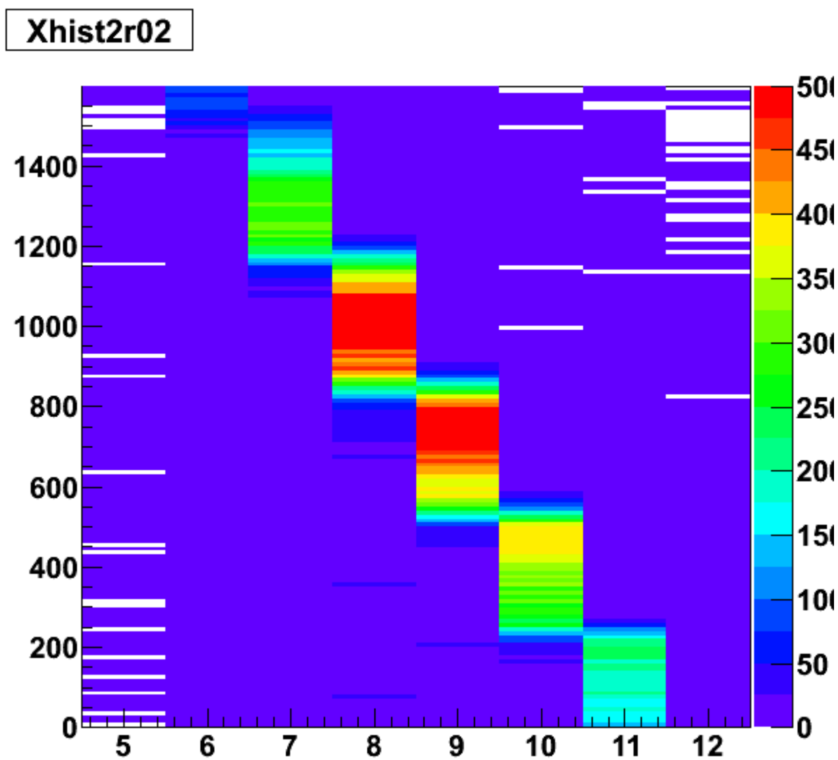
- Daniel has done a lot of work checking for scattering effects
  - Need scattering contribution to fit error matrix including correlations
  - For both forward (to ECAL) and backward (to beam origin) fits



- He finds good agreement between
  - "Theoretical" error matrix (based on known material)
  - Actual scatter measured in MC events for geometries which have been simulated
- Also, ~20% difference between electron and hadron scattering
- I use his matrices here

Alignment method 1

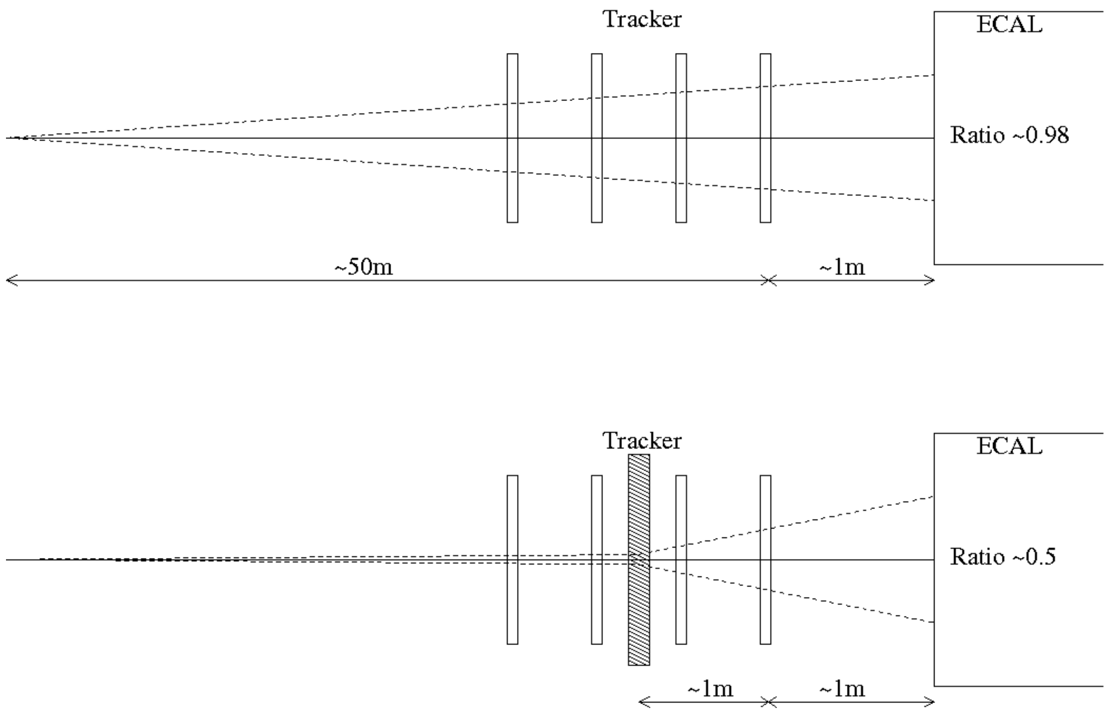
- Project track "envelope" from beam origin to tracker and ECAL
  - Fit for beam size and divergence at origin as well as alignment constants
  - Fit for correlation matrices of all combinations of pairs of track layers and track layer vs ECAL
  - Log likelihood fit, integrating over (large) bin size of ECAL



- E.g. Track layer 0 TDC value vs ECAL cell number in X
  - Drift velocity "simply" slope of this correlation, correct?
- But…

Balance of beam and scattering

- Actual correlation ratio depends on both beam and scattering
  - Beam size at origin ~10mm << scattering for most energies
  - Scattering contribution ~70mm at 2GeV, ~4mm at 40GeV
  - Width at ECAL usually due to angular divergence and/or scattering

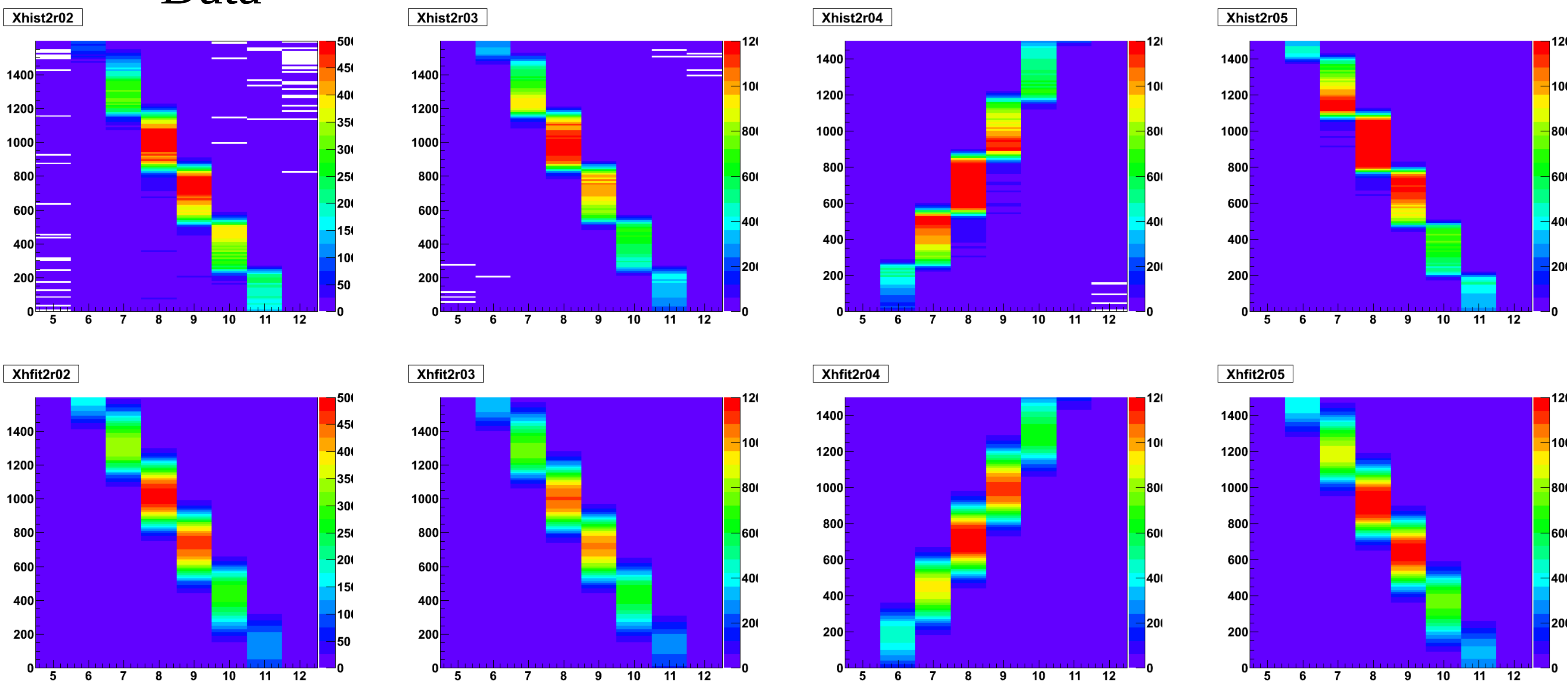


- Not uniform illumination
  - High correlation between position and angle in both cases
- Must model scattering to get drift velocity right
  - Need to know beam energy per run
  - Thanks to Angela for getting this done

Alignment method 1 typical results

- Correlation of ECAL with all four track layers

Data

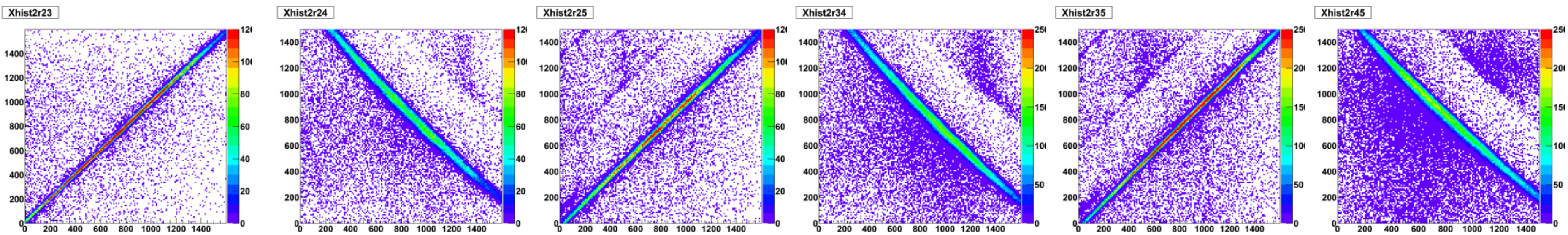


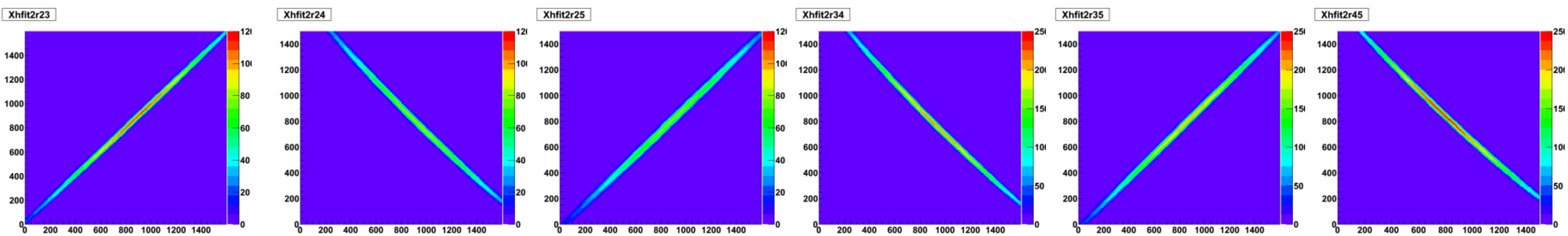
Fit

Alignment method 1 typical results (cont)

- Correlation of all track layers with each other

Data



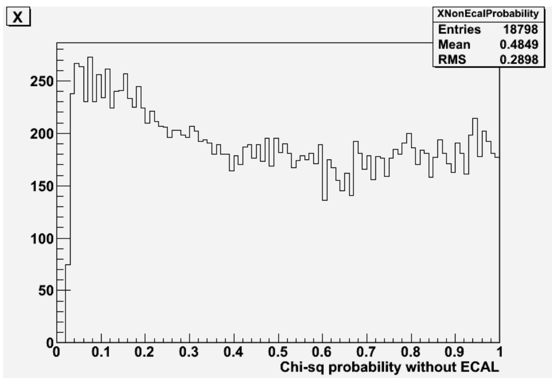


Fit

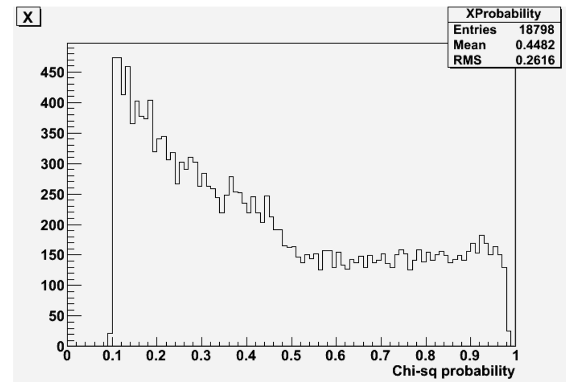
- Note significant non-linearities in some combinations

Alignment method 2

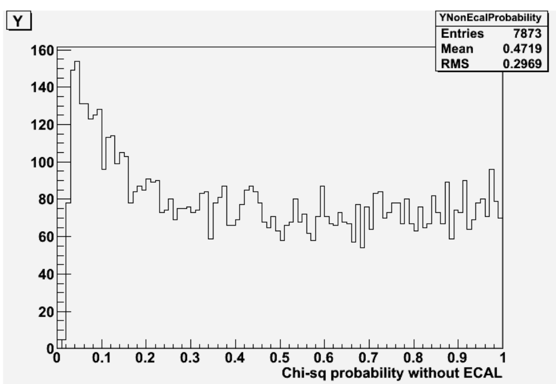
- Use ECAL as “fifth layer” in track fit
  - Fit for alignment constants by minimising sum of separate track fits
  - Either chi-squared (have to assume ECAL has Gaussian errors with size 10mm/√12 ~ 3mm)
  - Or log likelihood fit, treating ECAL as Gaussian-smeared flat top

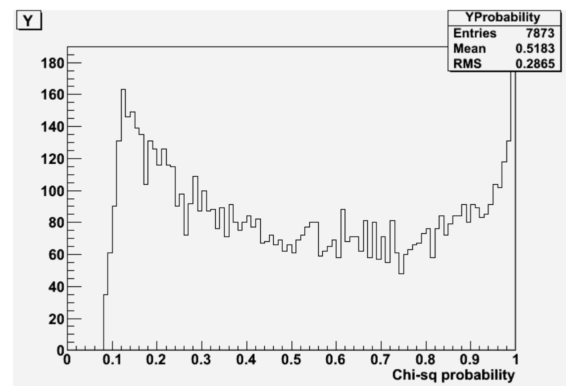


Without ECAL



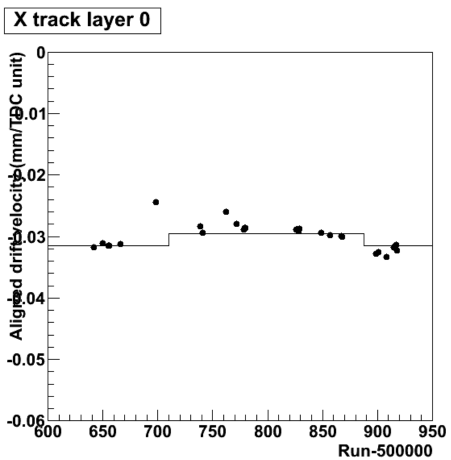
With ECAL



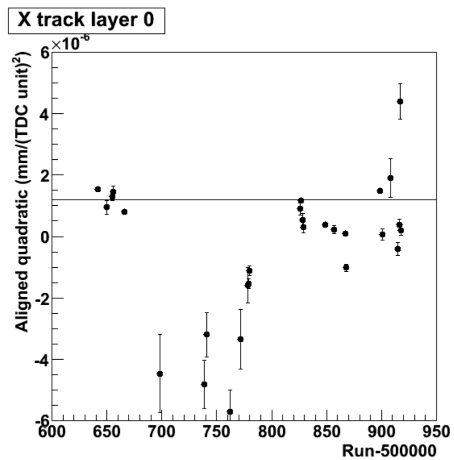


Define coordinate system

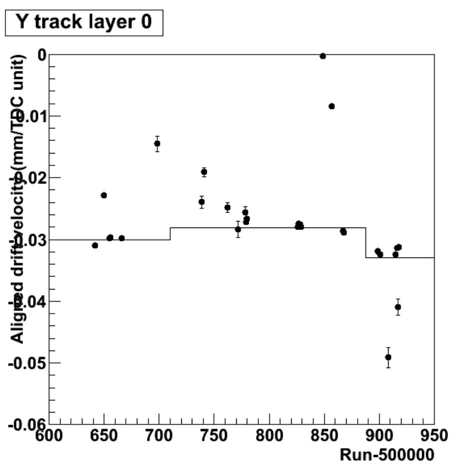
- Upstream track layer fixed, downstream track layer T_0 (constant) term fixed
- Determine downstream track drift velocity (linear) and quadratic terms comparing to ECAL

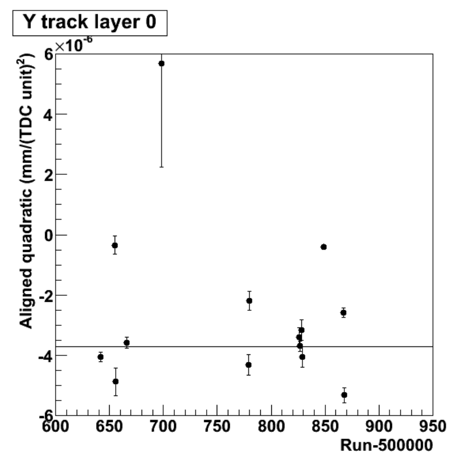


Linear

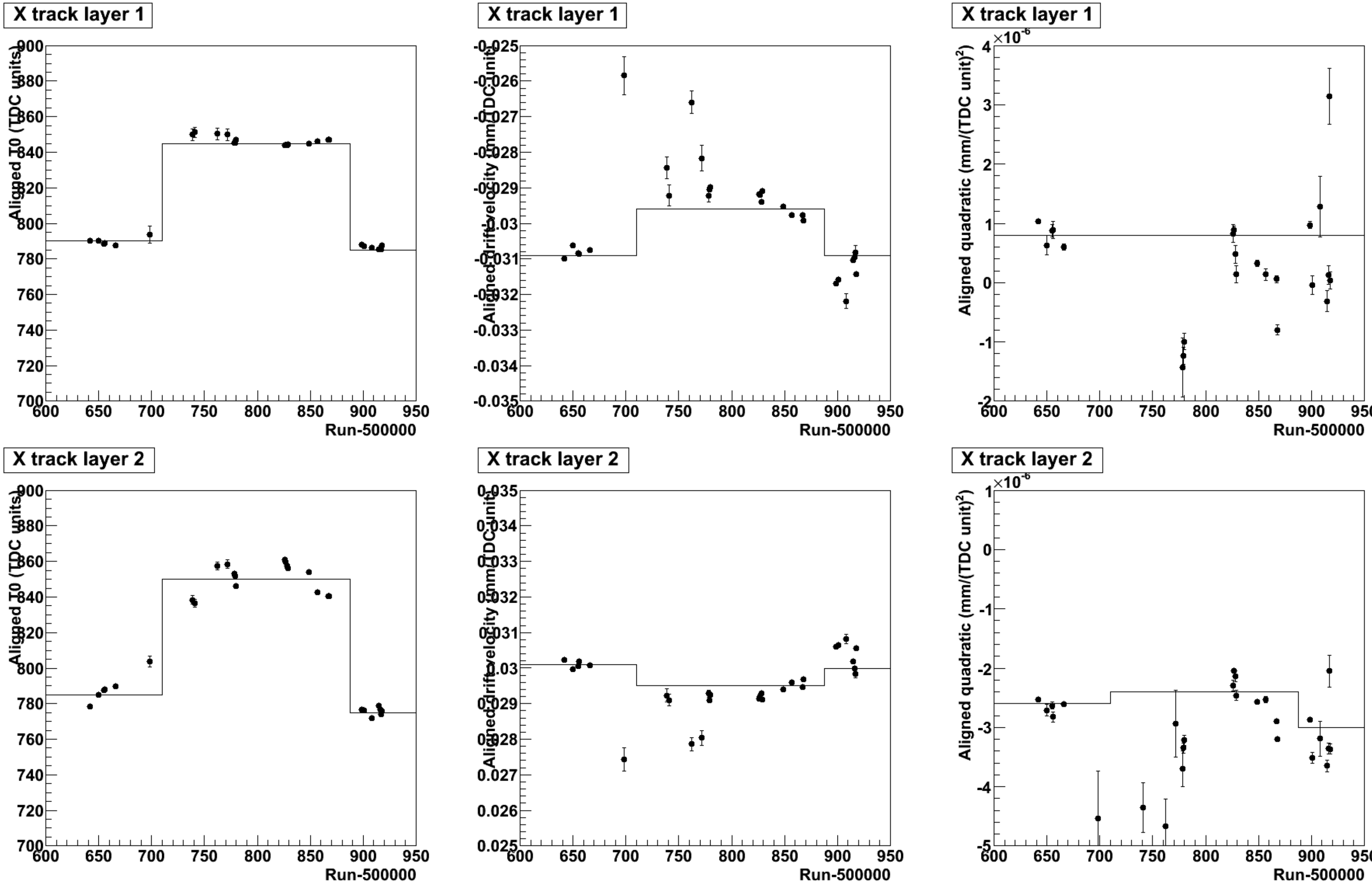


Quadratic



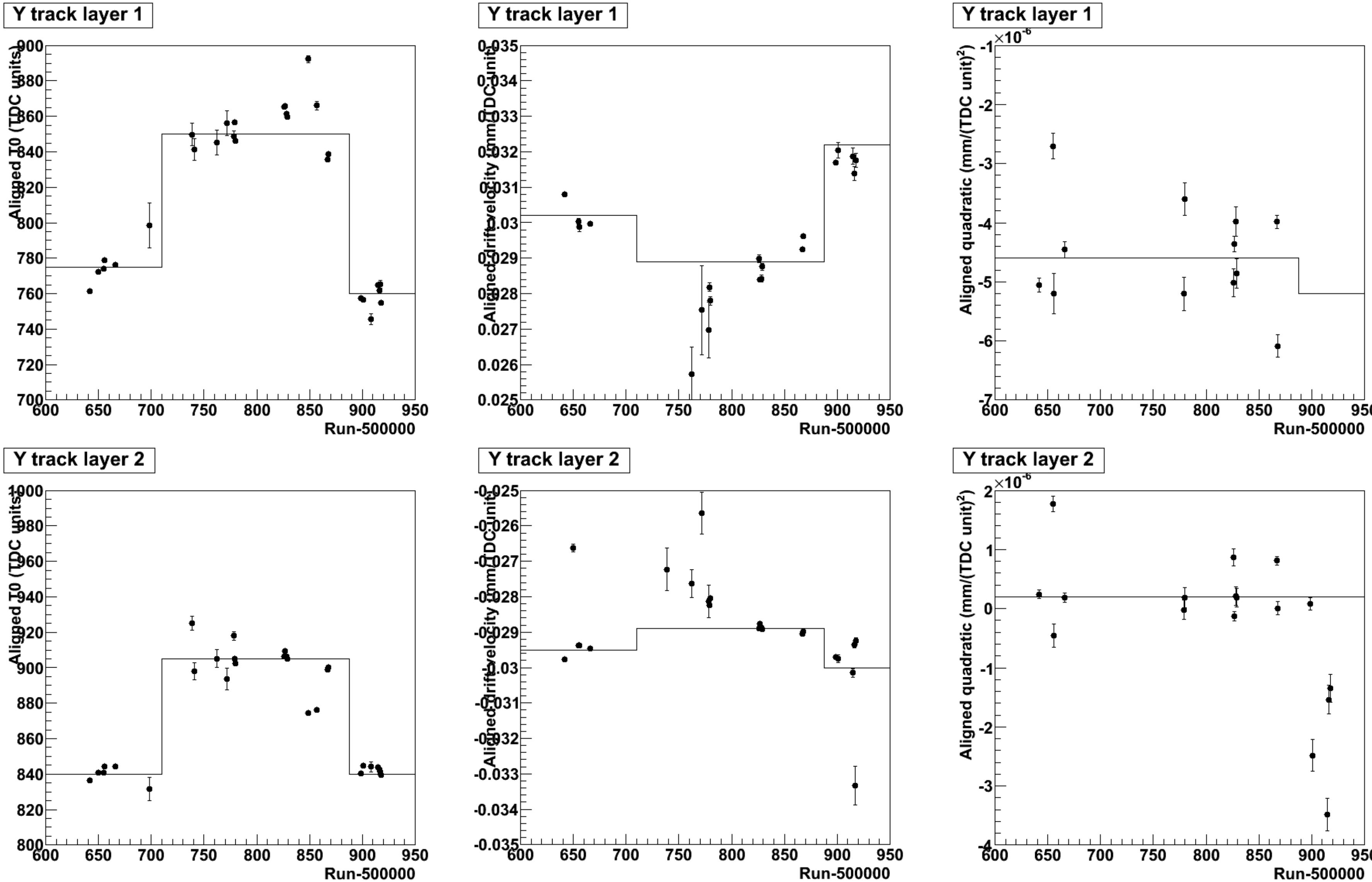


Fit other layers between outer two: X



Constant | Linear | Quadratic

Fit other layers between outer two: Y



Constant Linear Quadratic

Results reasonably compatible

- Neither works ideally
  - Method 1 has many more parameters; does not converge reliably. Also assumes track distribution is Gaussian
  - Method 2 always (apparently) converges but does not allow for backgrounds, assumes Gaussian errors
- In all cases X works better than Y
  - Y has efficiency loss (< ½ number of tracks per run than X) and is less stable
  - Cannot get any convergence for Y in earlier 2008 runs
- Results unstable to large degree
  - Temperature? Pressure? Non-modeled scattering material?
  - Errors due to alignment uncertainties are bigger than intrinsic errors
- Would need many more runs and major study of possible environmental or other influences to nail down
  - Probably not something I will be able to do…