Global Track Matching and Fitting

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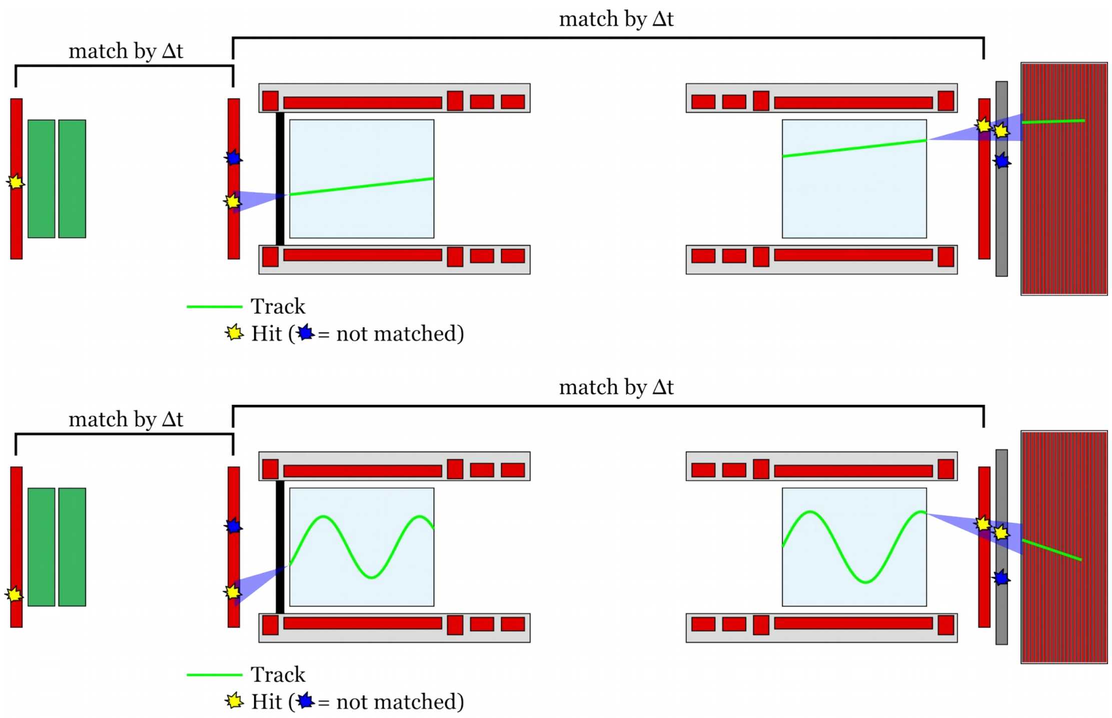
Track Matching and Fitting

- Seek to determine whether detector responses are consistent
  - Propagate tracks from trackers to PID detectors
  - Integrate Lorentz force law using Runge Kutta (RK4)
  - Propagate track through materials and apply mean energy loss
  - Determine whether extrapolated track corresponds to e.g. TOF hit
  - **Track Matching** (J. Greis)
- Seek to improve the detector reconstruction provided by individual detectors
  - Propagate tracks **and errors** from trackers to PID detectors
  - Integrate Lorentz force law and derivatives using RK4
  - Propagate track through materials and apply
    - Mean energy loss
    - Mean multiple Coulomb scattering – increases uncertainty
    - Energy straggling (not implemented)
  - Determine likelihood that tracker track corresponds to e.g. TOF hit
  - Minimise chi^2
  - **Track Fitting**

Track Matching (J. Greis)

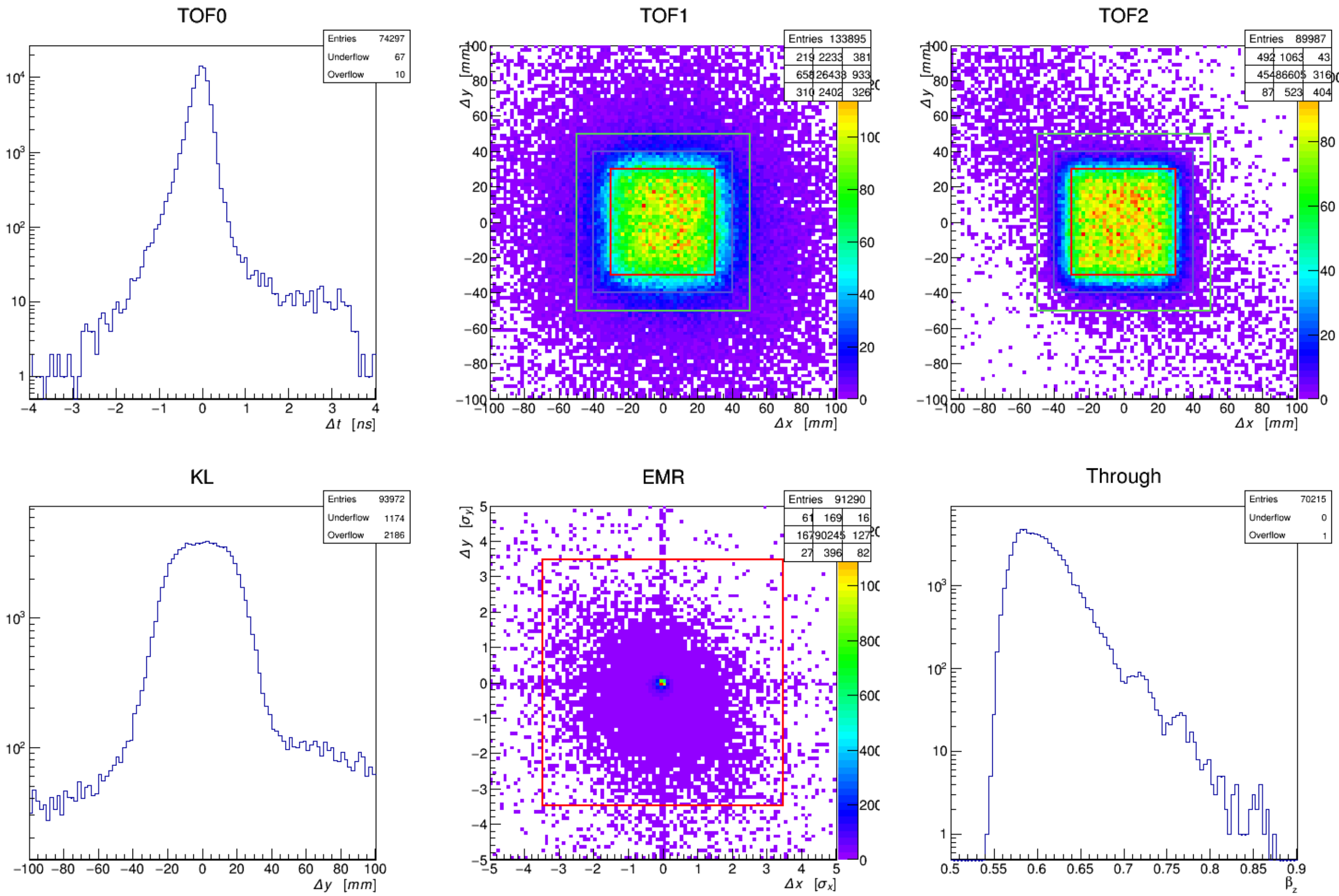
- Propagate track centroid using Lorentz force law
  - **F = q (v** x **B** + **E**)
- Energy loss in materials using Bethe Bloch

J. Greis



Track Matching vs Monte Carlo (J. Greis)

- Track matching is in MAUS production
  - Track matching is consistent with MC



J. Greis

Error Propagation thru Fields

- We have a trajectory with accelerator phase space vector (Kalman state vector) $\underline{u}_{in}$ at a given measurement plane and $\underline{u}_{out}$ at the next measurement plane
- Consider accelerator transfer matrix (Kalman propagator) **M**, defined by

$$\underline{u}_{out} + \mathbf{M}\ \underline{du}_{in} = \underline{u}_{out} + \underline{du}_{out}$$

- $\underline{u}$ is the and $\underline{du}$ is a small deviation from the vector
  - This is the first term in a Taylor series
- **M** is found by differentiating the equation of motion for $\underline{u}$
- Quote

$$\underline{F} = d\underline{p}/dt = q\ \underline{v}\ \mathbf{x}\ \underline{B}$$

- Then

$$d\underline{p}/dz = q\ d\underline{x}/dz\ \mathbf{x}\ \underline{B}$$

- Also

$$d\underline{x}/dz = \underline{p}/p_z$$

- Derivatives of this wrt $\underline{u}$ give the analytical transfer matrix...

Error Propagation thru Fields (2)

- Consider the accelerator beam ellipse (covariance matrix) **V** with elements

$$V_{ij} = \langle u_i u_j \rangle$$

  and centroid $\underline{u}$
- Then error matrix **V** propagates like

$$\mathbf{V}_{\mathbf{out}} = \mathbf{M}\,\mathbf{V}_{\mathbf{in}}\,\mathbf{M}^{\mathbf{T}}$$

- I want to integrate V, so I want d**V**/dz = [**V**(z+dz)-**V**(z)]/dz
- For small dz, **M** ~ **1**+**dM** so

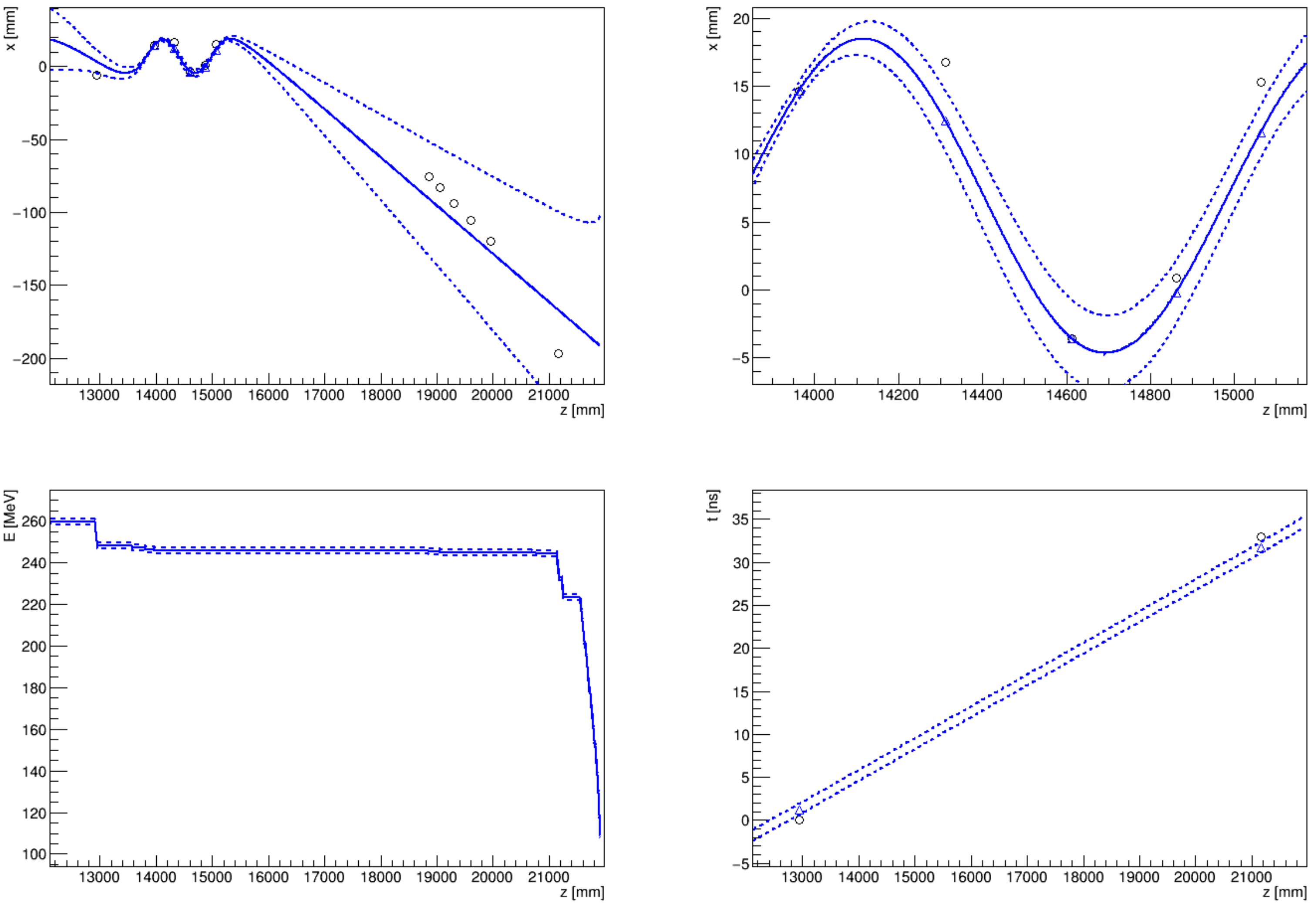
  $\mathbf{V}(z+dz)-\mathbf{V}(z) = \mathbf{dM}\,\mathbf{V}\,\mathbf{dM}^{\mathbf{T}} + \mathbf{dM}\,\mathbf{V} + \mathbf{V}\,\mathbf{dM}^{\mathbf{T}}$
- Note that this is a specialisation to Lorentz force law for the generalised problem of error propagation between two (sets of) variables using Jacobian
  - But generalisation of the accelerator physics transfer matrix
- The algebra is quite fiddly
- I work in coordinate system $\underline{u}$ = (x, y, t, px, py, total energy)

Track fitting

- Track fitting is intended to be done using Kalman filter (mostly implemented, needs tuning)
  - Some seed is assumed at a tracker station with large uncertainty
  - Track is extrapolated to adjacent tracker station
  - Track is updated as weighted mean of measured position and extrapolated track
    - Mean weighted by certainty of the extrapolated track and measured position
- Coding elements of Kalman filter are implemented, but it needs some tuning
  - Lean heavily on tracker code (C. Hunt, E. Santos)
- For now I use minuit
  - Takes a long time to converge!
  - Fitted track uncertainty not properly calculated!

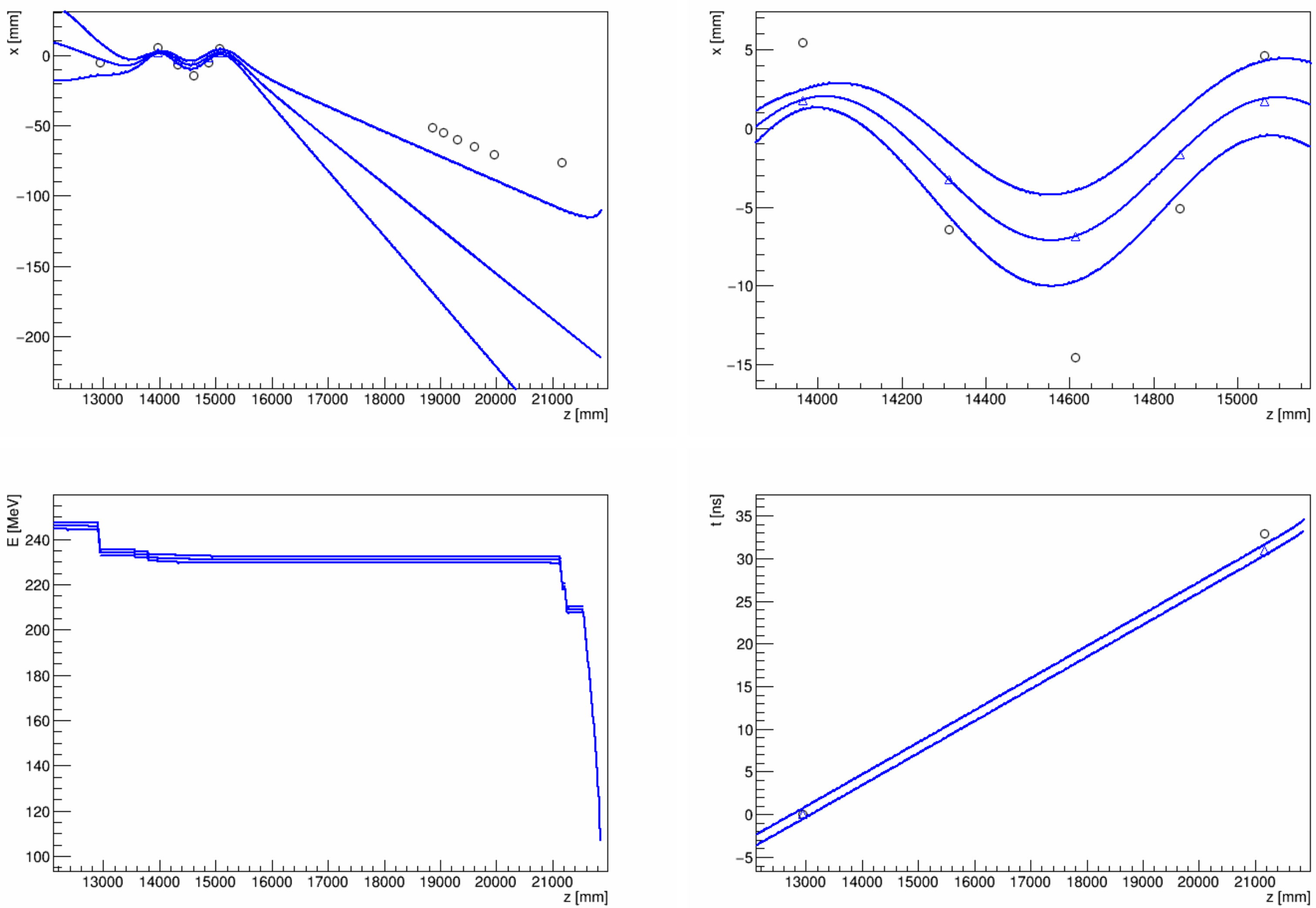
Fit – event display

Data (run 7475)



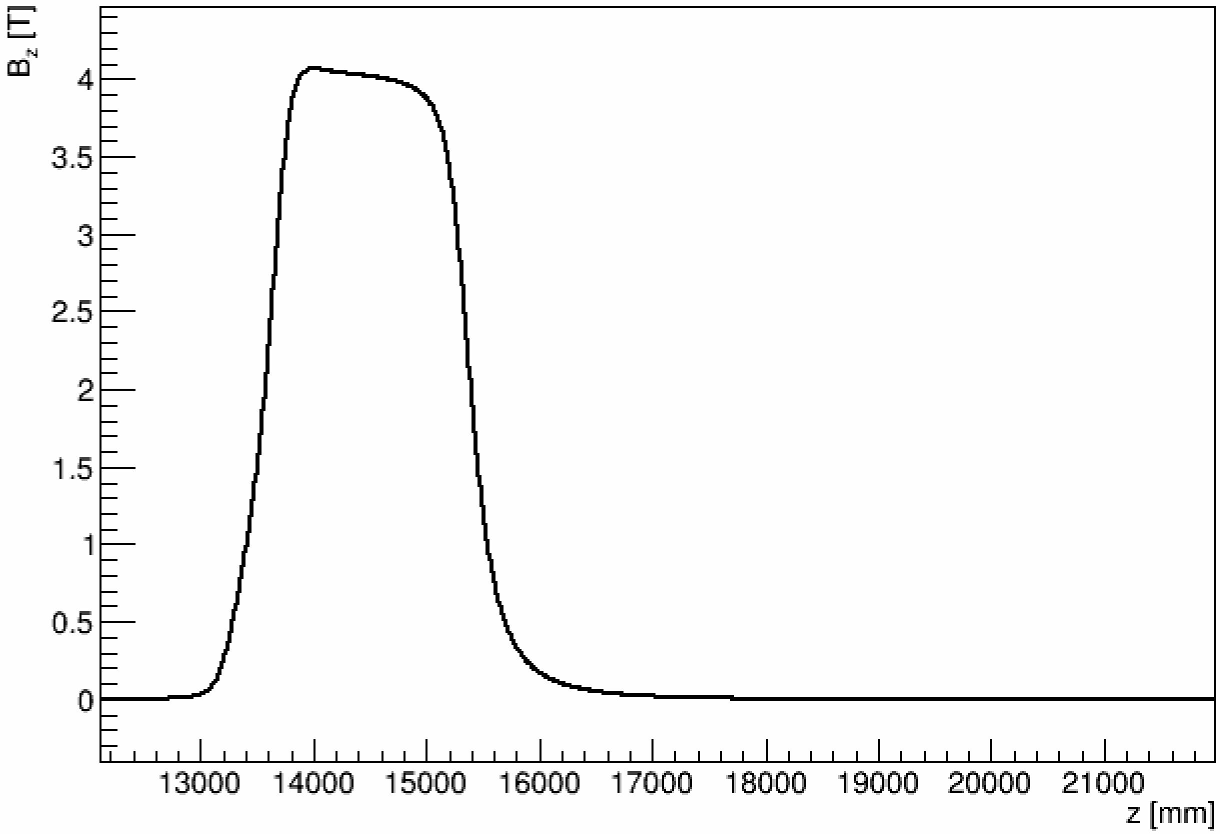
Fit – event display

Data (run 7475)



Bz

- B_z taken from Holge Witte field map (run 7475)



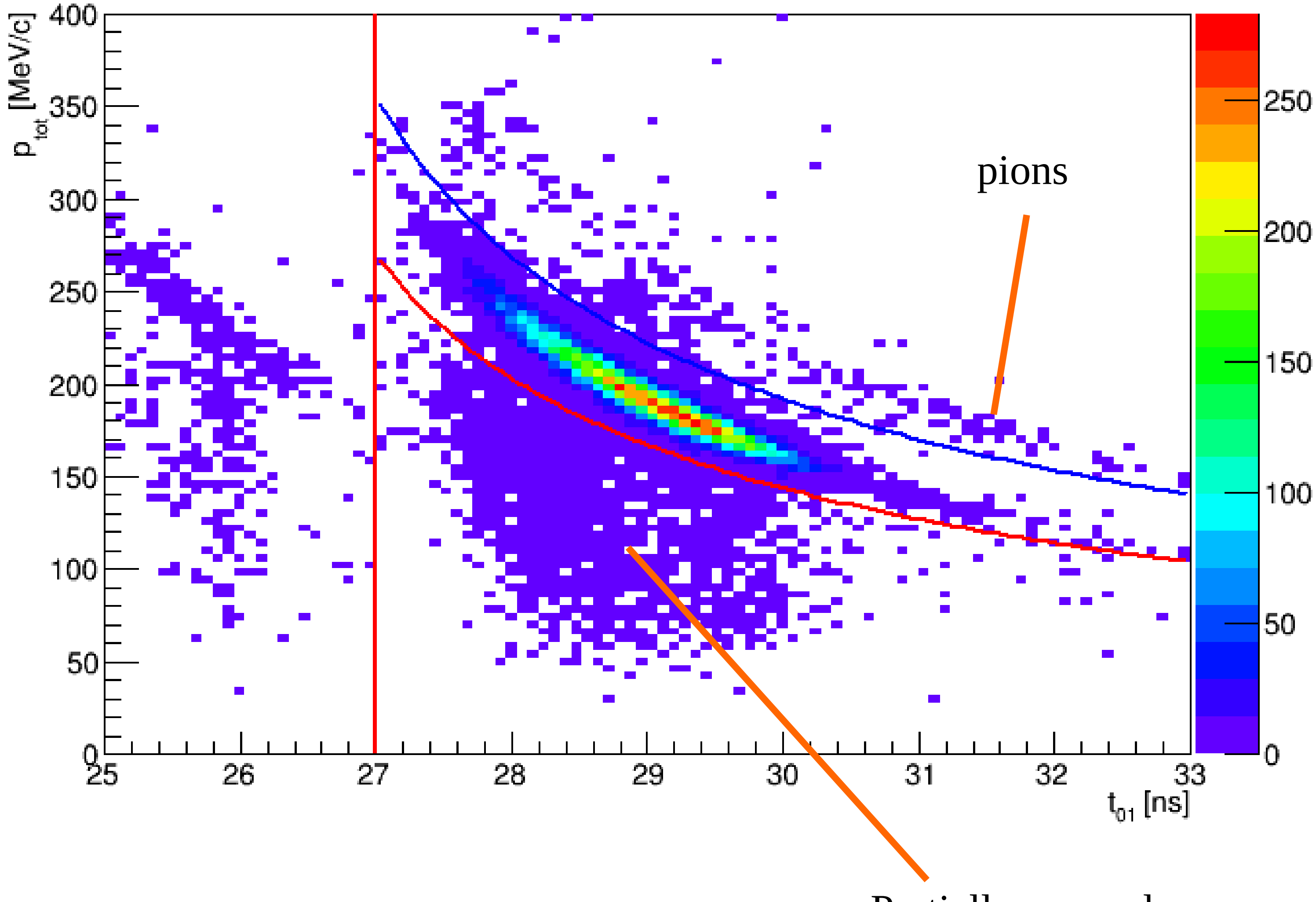
Comments

- Anecdotally, looks like the fit is essentially working
  - Black circles are space points
  - Blue line is the fitted track
  - Blue triangles are points on fitted track
- Note these events were the first and second events that met following quality criteria:
  - 1 space point in TOF0, 1, 2
  - 5 triplets in TKU and TKD (ignore doublets)

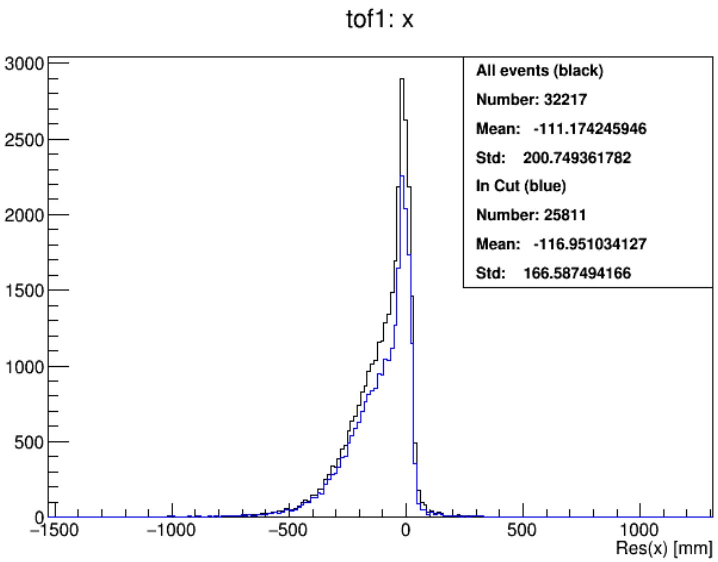
Run 7469 (V. Blackmore)

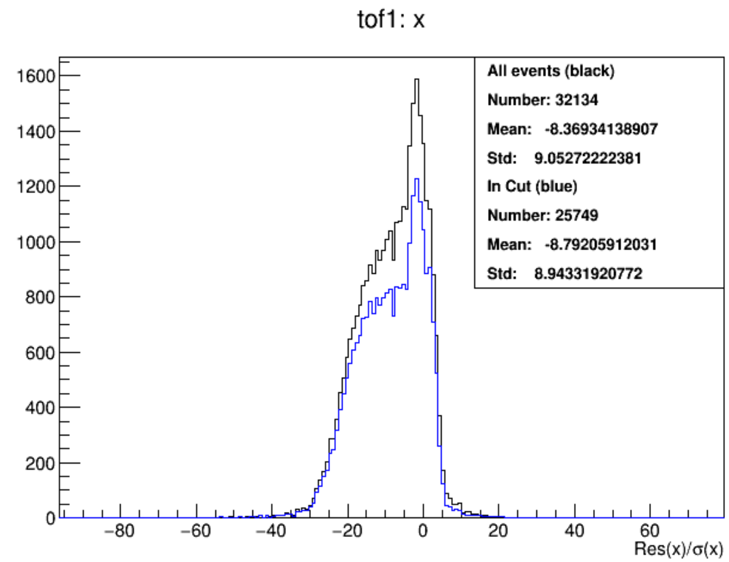
- Analysis of run #7469
  - Can we propagate TKU to TOF0/TOF1 and see reasonable results?
  - Are the measured TOF and tracker consistent?
  - Here I use track propagation including error propagation
- So far, cuts included are (V. Blackmore)
  - Single TOF0 and TOF1 calibrated space point
  - Good TOF01 track
  - TOF01 cut
  - TKU single track with hit in 5 stations
  - TKU p-value
- Victoria will present tomorrow
- **No tracker vs TOF01 cut**
- Discovered problem with MAUS geometry (F. Drielsma)
  - Incorrectly defined quadrupoles
    - Too short
    - Wrong z position
  - Fix not implemented in plots that follow...

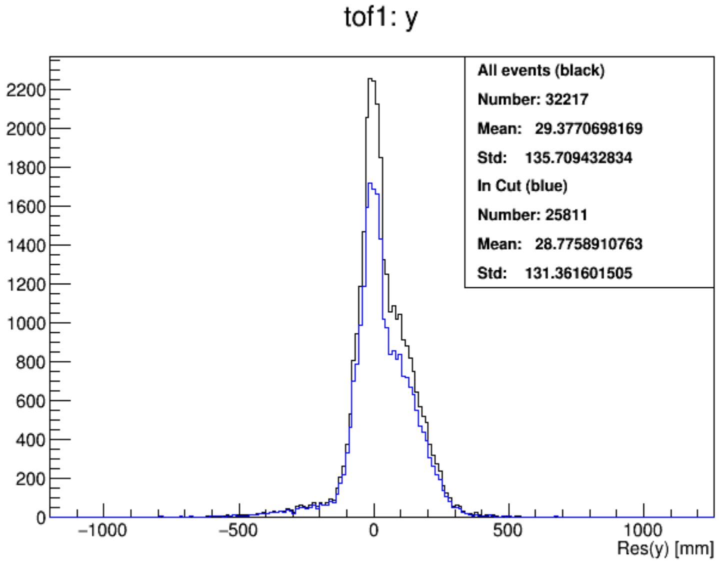
Run 7469 – Raw TOF01 vs TKU

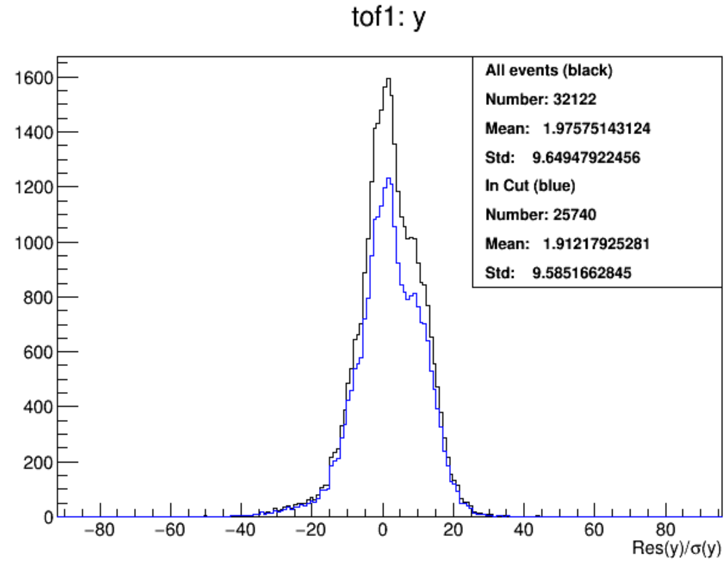


Run 7469 – TOF1

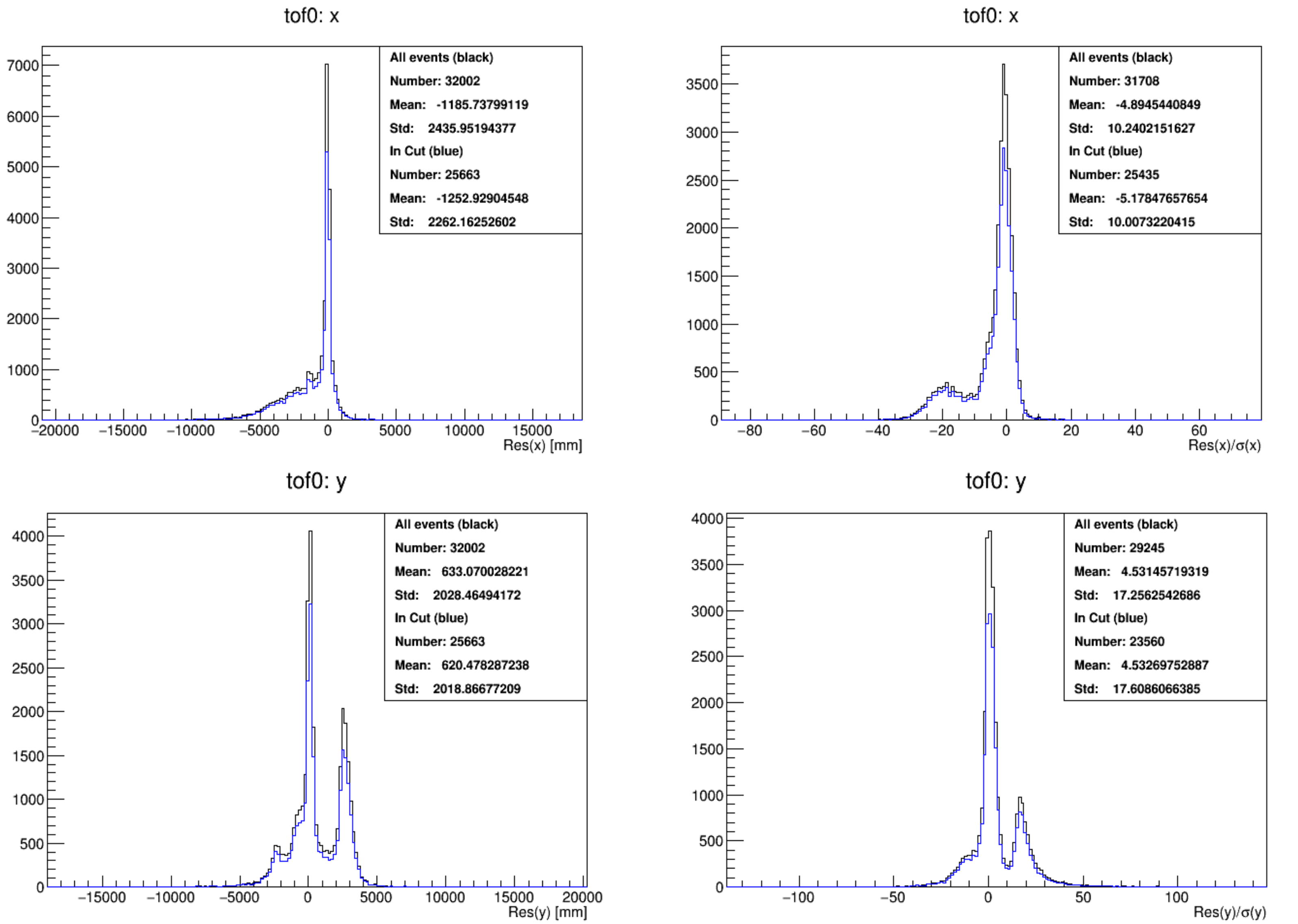




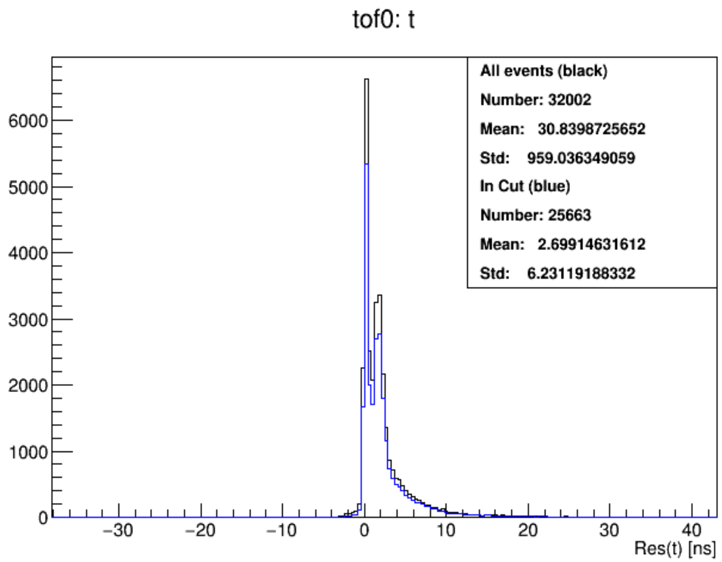


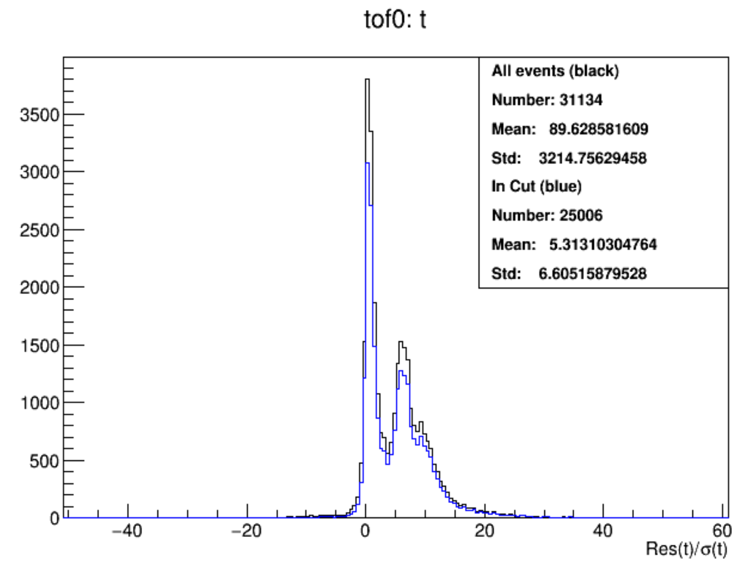


Run 7469 – TOF0



Run 7469 – TOF0





- Of 53452 total recon events
  - 32217 were successfully extrapolated
  - 25817 were in cuts
  - 25811 were in cuts AND successfully extrapolated
- Note there is some inconsistency in the event counts (to debug)
- Nb: gaussian fit to peak near 0
  - Mean = 0.80 s.d.
  - Sigma = 0.87 s.d.

Conclusions

- Track matching routines have been added to MAUS (J. Greis)
  - Propagation of tracks through fields
  - Propagation of tracks through materials
  - Show good agreement with MC
- Error propagation routines have been implemented
  - Propagation of errors through fields
  - Propagation of errors through materials
  - Partial implementation of track fitting, needs tuning
  - Not yet in production
- First pass comparison of TKU with TOF01 has been performed
- To do:
  - Implement energy straggling (Fano model)
  - Generalised track fitting using Kalman filter
  - Many minor code cleanup tasks
  - Extend testing, documentation
  - Push code to production
  - Use fixed MAUS quad model (currently in preproduction)