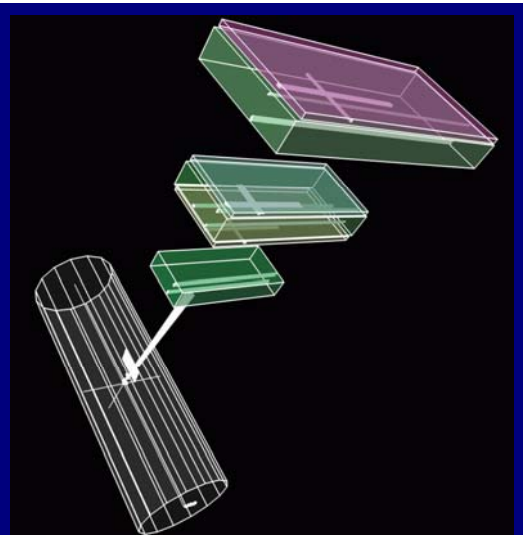
Kalman Filtering for Muon Track Reconstruction and Detector Alignment in ATLAS



source: GraXML gallery

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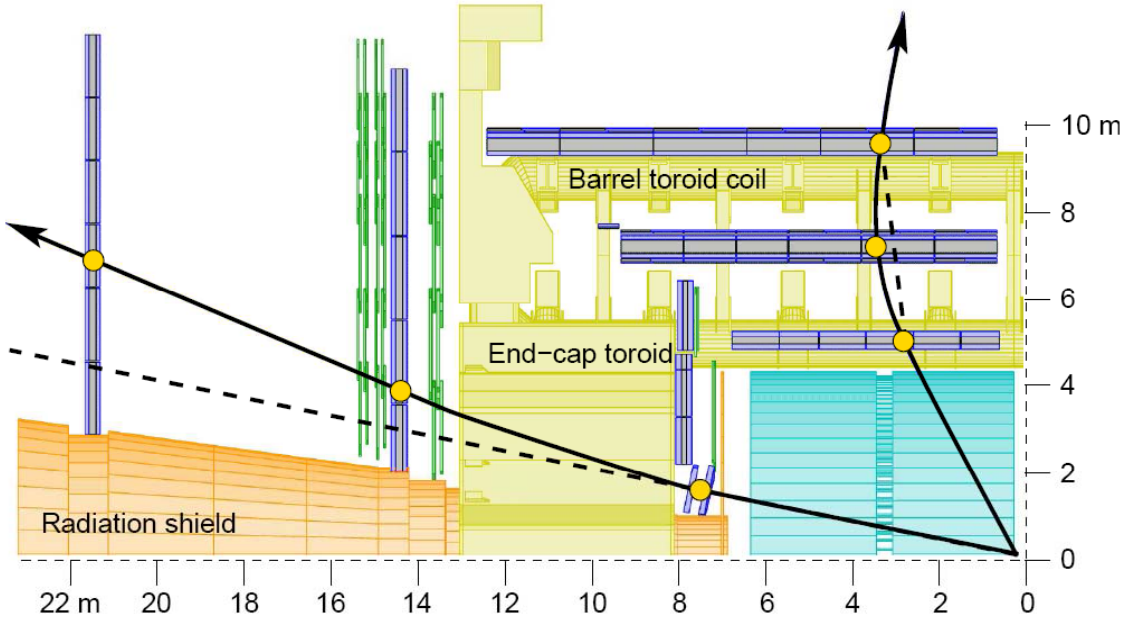
Track Reconstruction



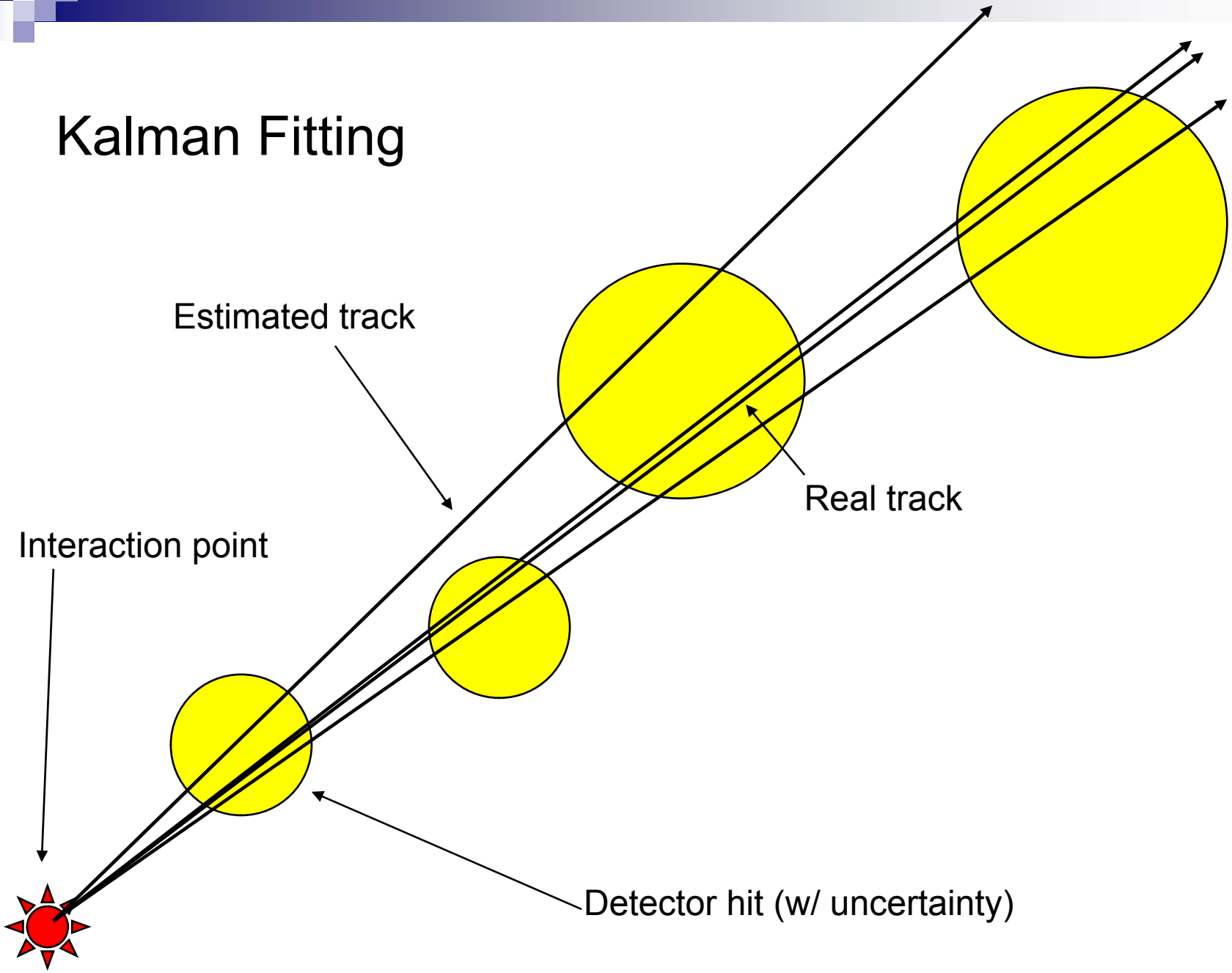
Source: Oliver Kortner, “Alignment of the ATLAS Muon Spectrometer with Curved Tracks”

- Unfortunately, detectors do not actually see full tracks
- Detectors only register if a pixel is hit
  - Muon Drift Tubes (MDTs) cannot directly register momentum
- Particles leave trails of hits – prone to error and detector misalignment

What is and why use a Kalman Filter?

- Computational method
- Estimates the true state from a set of noisy measurements
- Aids in both track reconstruction and detecting detector misalignments
  - Track parameters – 5 parameters (position, momentum)
  - Detector unit states – 6 parameters (position, rotation)
- Optimally, far more efficient than using χ^2-fitting

Kalman Fitting



(source: S. Todorova, Muon Calibration and Alignment Workshop, 30/11/05)

Kalman Fitting

track and alignment parameters treated independently!

- **Estimated parameters:** t = track parameters; a = alignment parameters
- **Parameter covariances:** T = track covariance; A = alignment covariance

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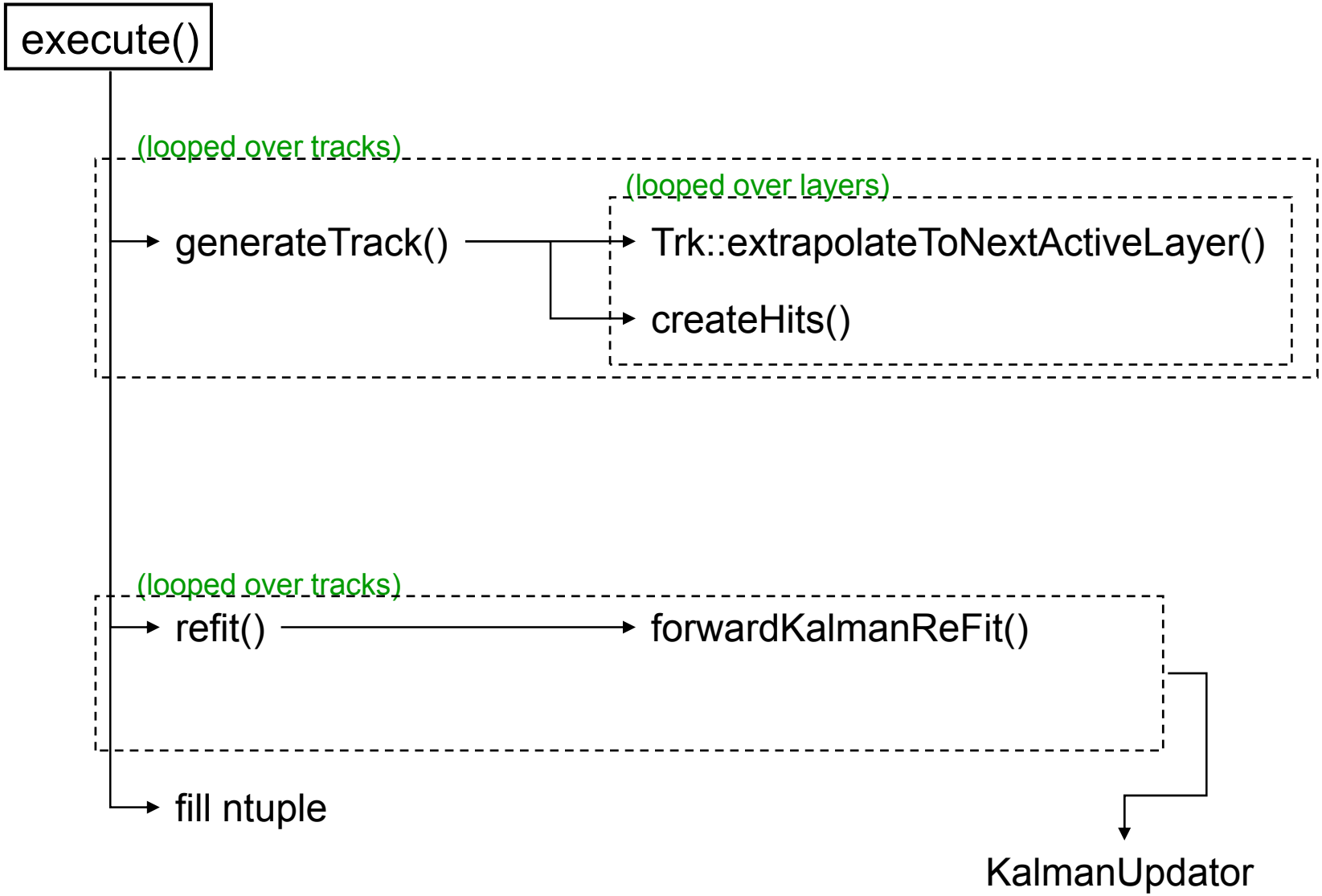
- m is the **measurement**, with **covariance** E
- $f(t,a)$ is a model that generates a **measurement estimate**

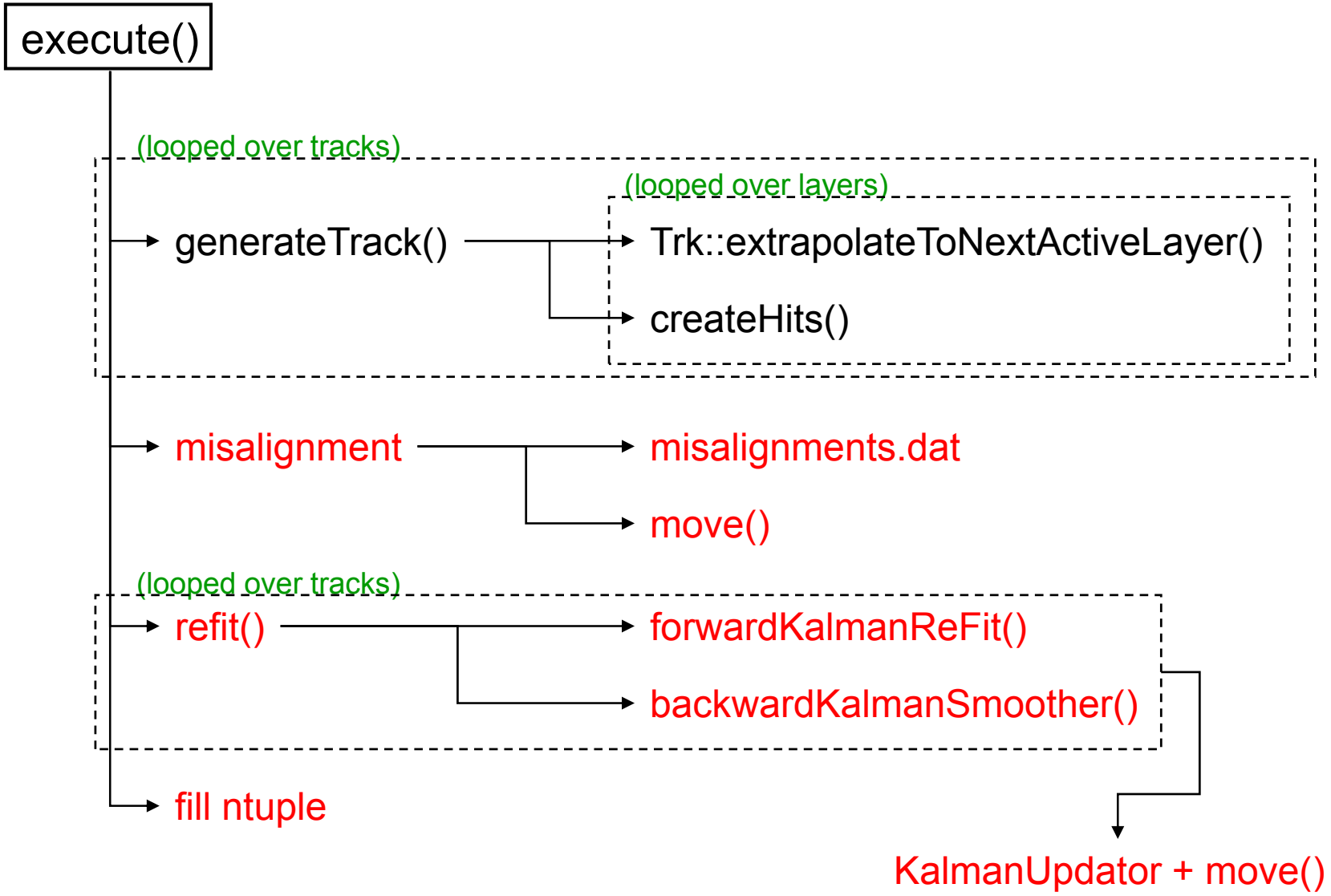
- **Jacobians:** $H = \partial f / \partial t$ $\quad D = \partial f / \partial a$
- **Residual covariance:** $R = E + HTH^T + DAD^T$
- **Gain matrices:** $K = TH^T R^{-1}$ $\quad L = AD^T R^{-1}$

- **Parameter updates:** $t' = t + K[m - f(t,a)]$ $\quad a' = a + L[m - f(t,a)]$
- **Covariance updates:** $T' = (I - KH)T$ $\quad A' = (I - LD)A$

Program Structure

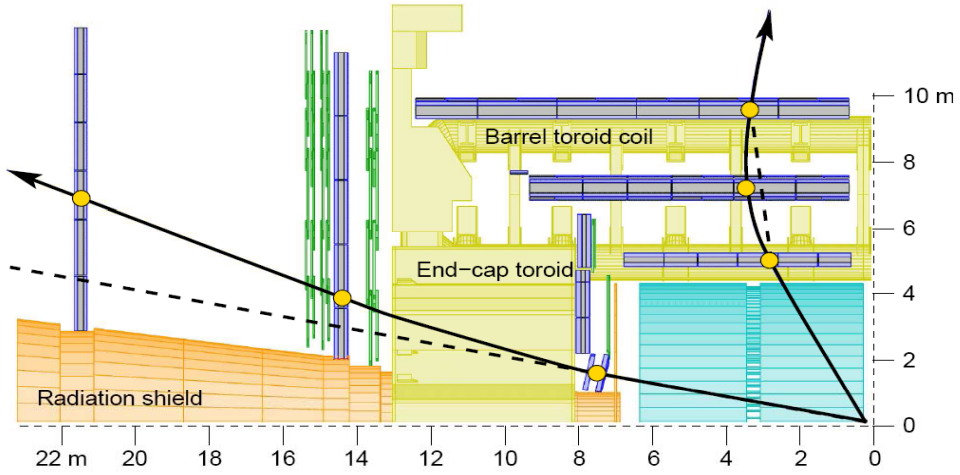


Program Structure



Performance settings

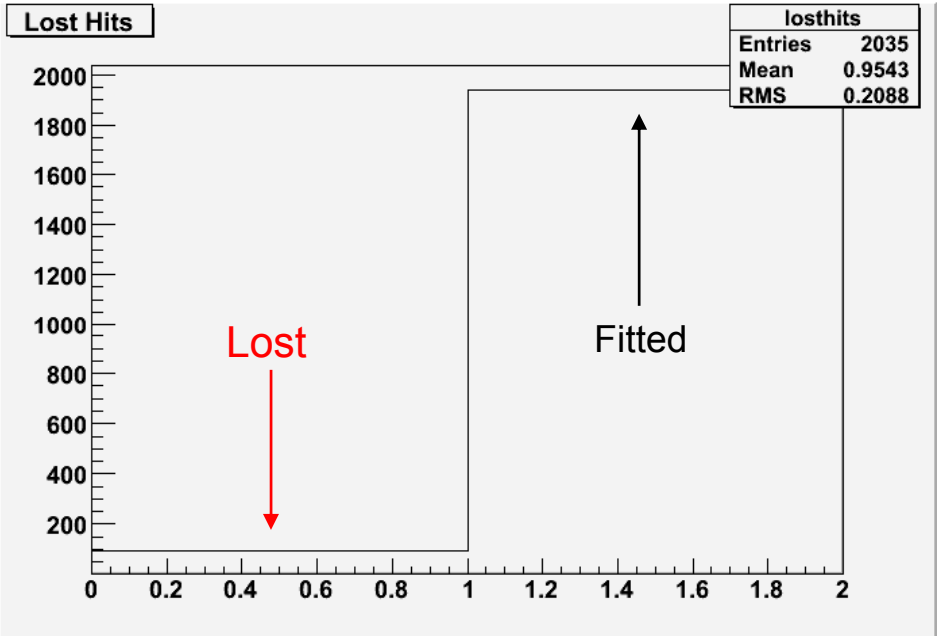
- 100 tracks generated, p = 100000
- Aimed at only three detector units (one unit in each layer)
  - $1.35 \leq \theta \leq 1.45$
  - $-0.1 \leq \varphi \leq 0.1$
- Rotational misalignments not yet implemented
  - Only translations considered so far
- Middle detector unit misaligned in the negative z-direction by 50mm
  - MDTs are only sensitive to the z-coordinate



Performance results

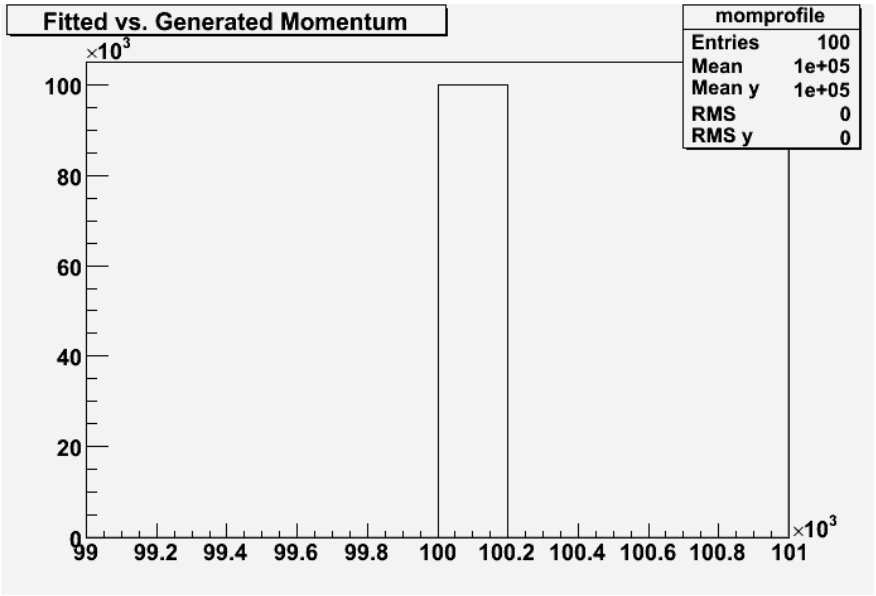
- Fitting did not work when Resistive Plate Chamber (RPC) hits were included!
  - 2-dimensional readings
  - RPC hits were excluded – future study needed

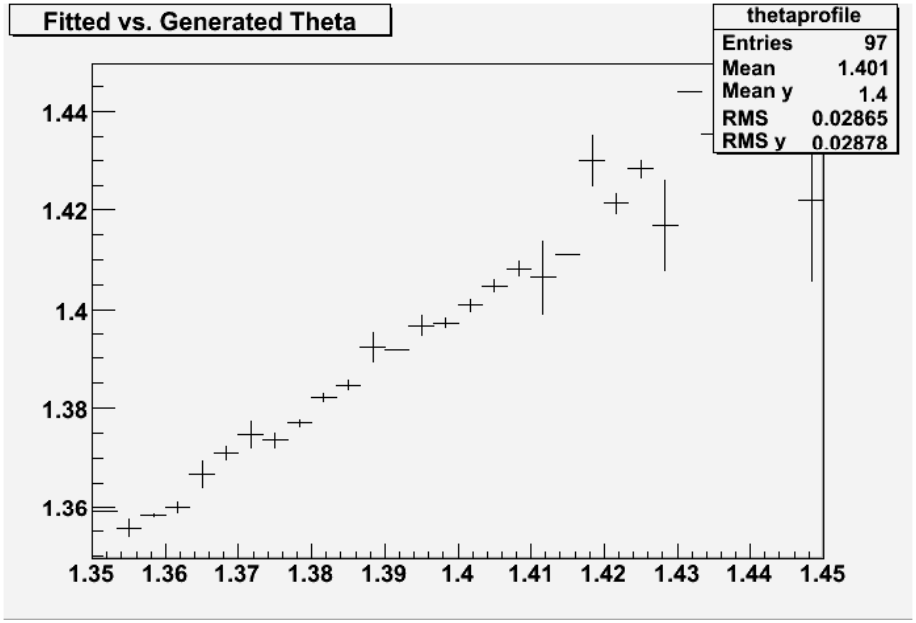
- Few lost hits:

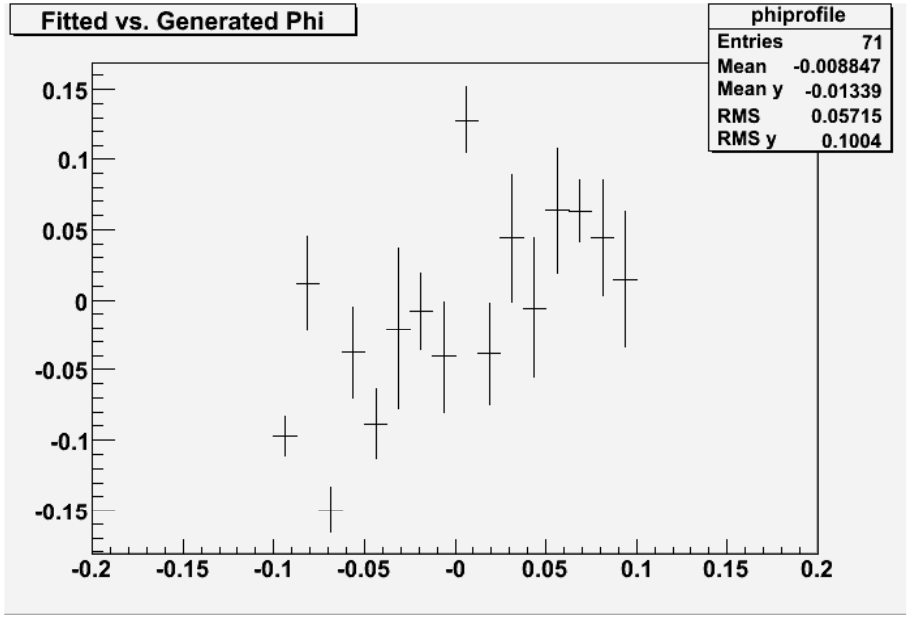


Performance results

- Fitted vs. generated track parameter profiles

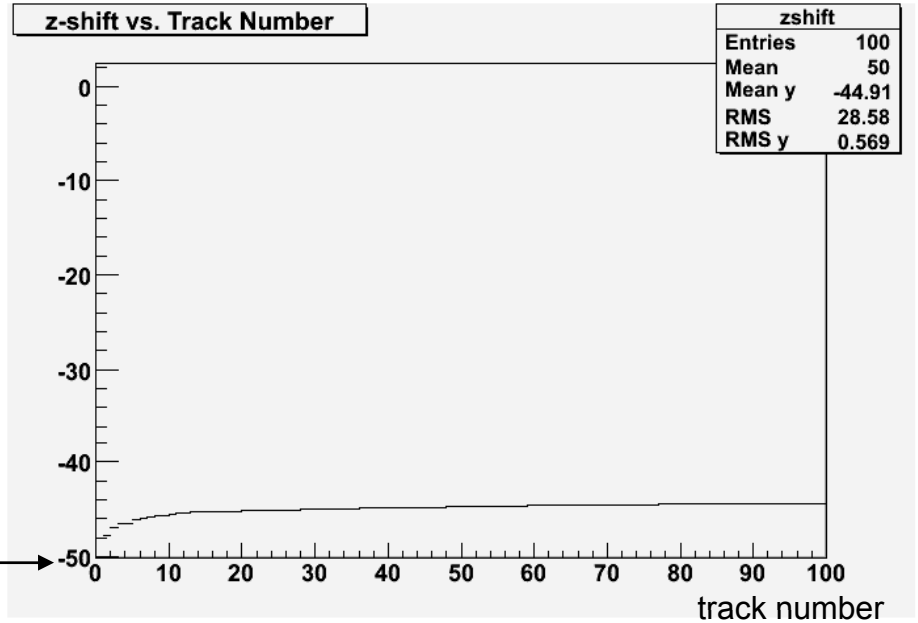




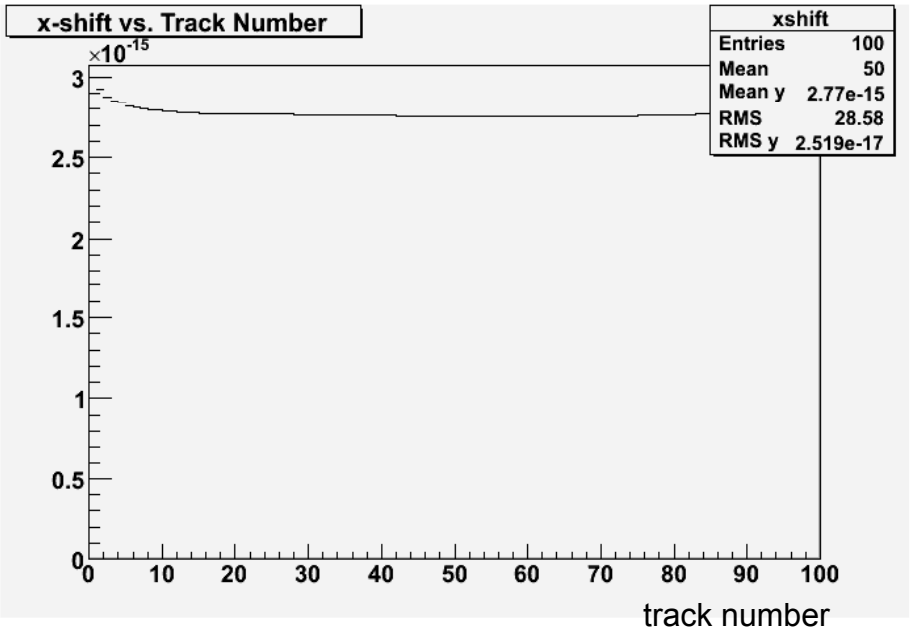


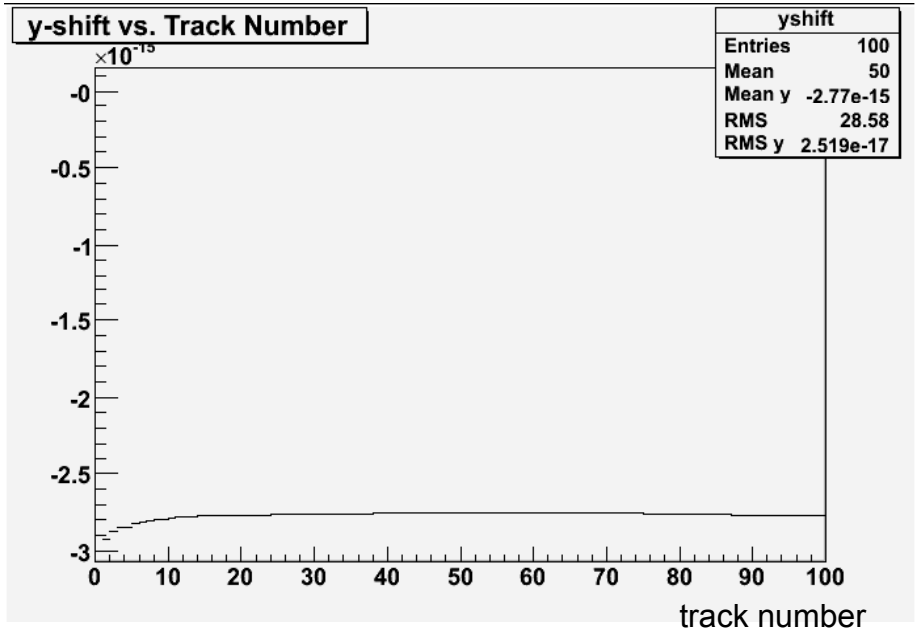
Performance results

- Misalignment estimates over time
  - MDTs only sensitive to the z-coordinate



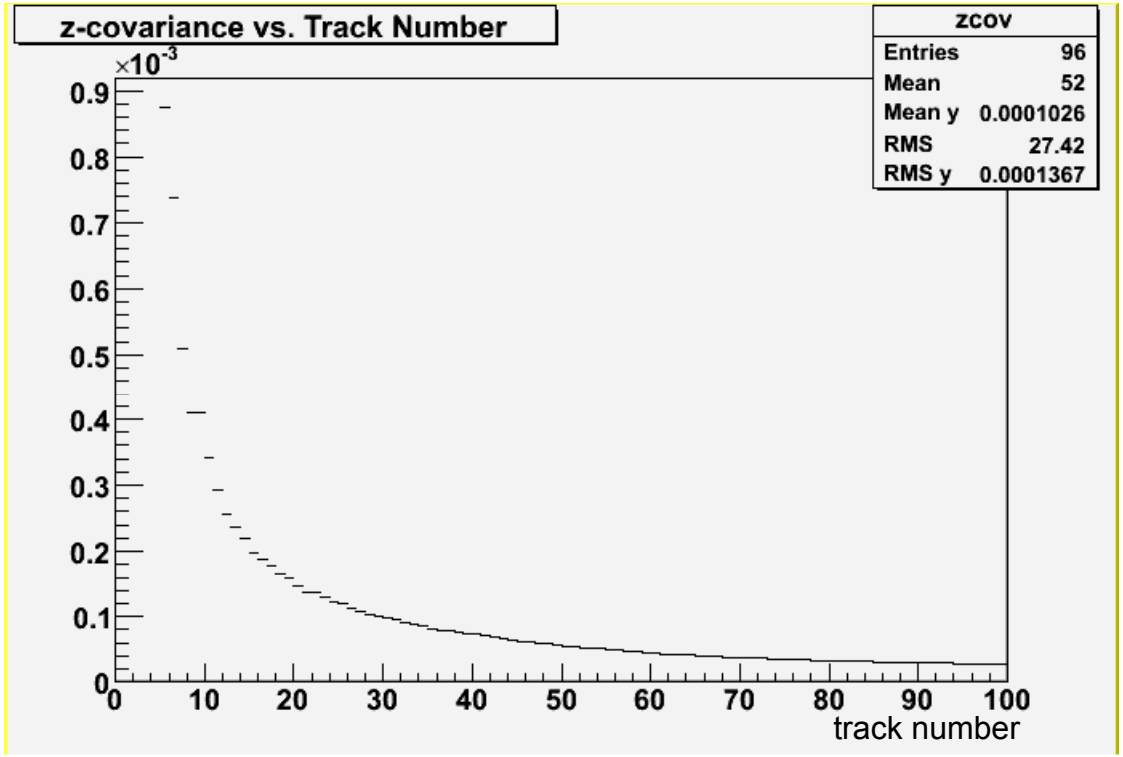
true misalignment →





Performance results

- z-shift covariance lowered over time significantly
- x- and y-shift covariances stayed at original levels (~10^{11})



Summary and future work

- Kalman filtering may be a viable option for track reconstruction and misalignment detection

- RPC hit anomaly needs to be investigated
- Runs must be done with more than one misaligned detector unit
- Misalignments need to be extended to include rotations
  - Partially completed
- Need to investigate covariance relations
  - Between track and alignment parameters
  - Between separate detector units

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