CEBAF Large Acceptance Spectrometer

Tracking Status

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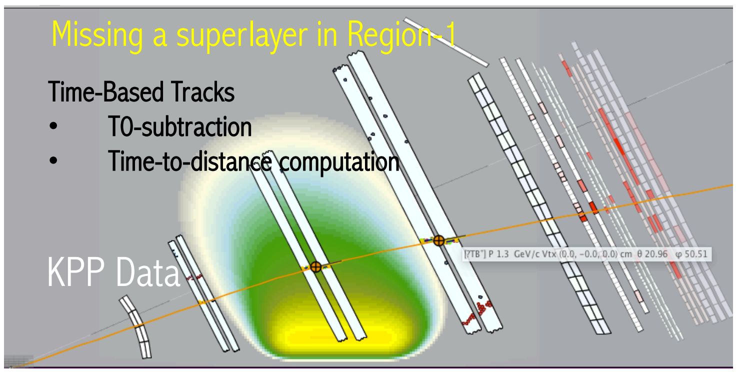
CLAS12 First Experiment Workshop

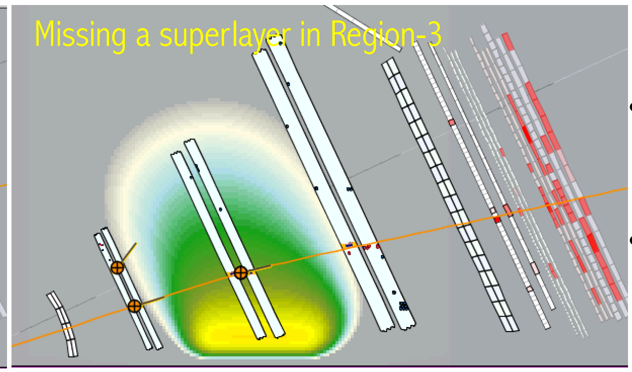
06/13/2017

Status at the last meeting

DC Tracking Status

5-Out-Of-6 superlayers tracking

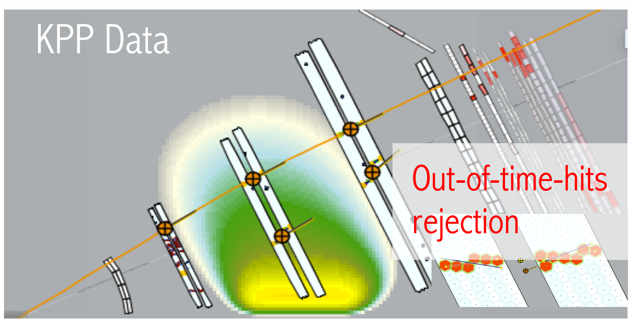


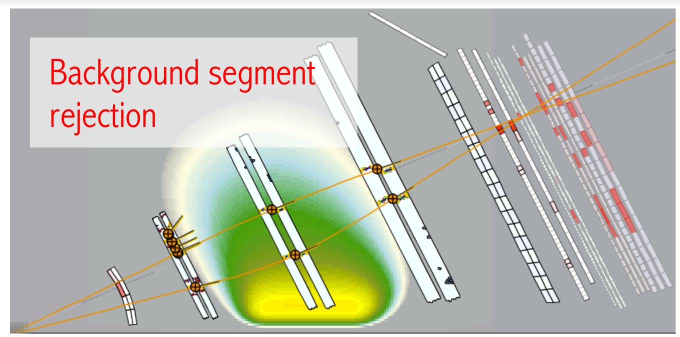


MC Studies

- Loosing a superlayer has a minimal effect on tracking resolutions
- Inefficiencies due to missing SL: 5% for SL1, 10% for SL2, less than 3% for all other SLs

Noise rejection algorithms validation on KPP data

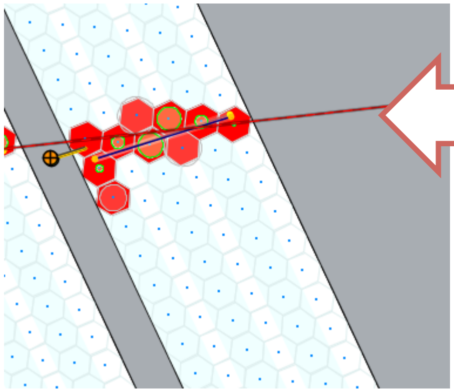




* FMT in simulation (Maxime) → after geometry validation use FMT points to refit the track

DC Tracking Updates

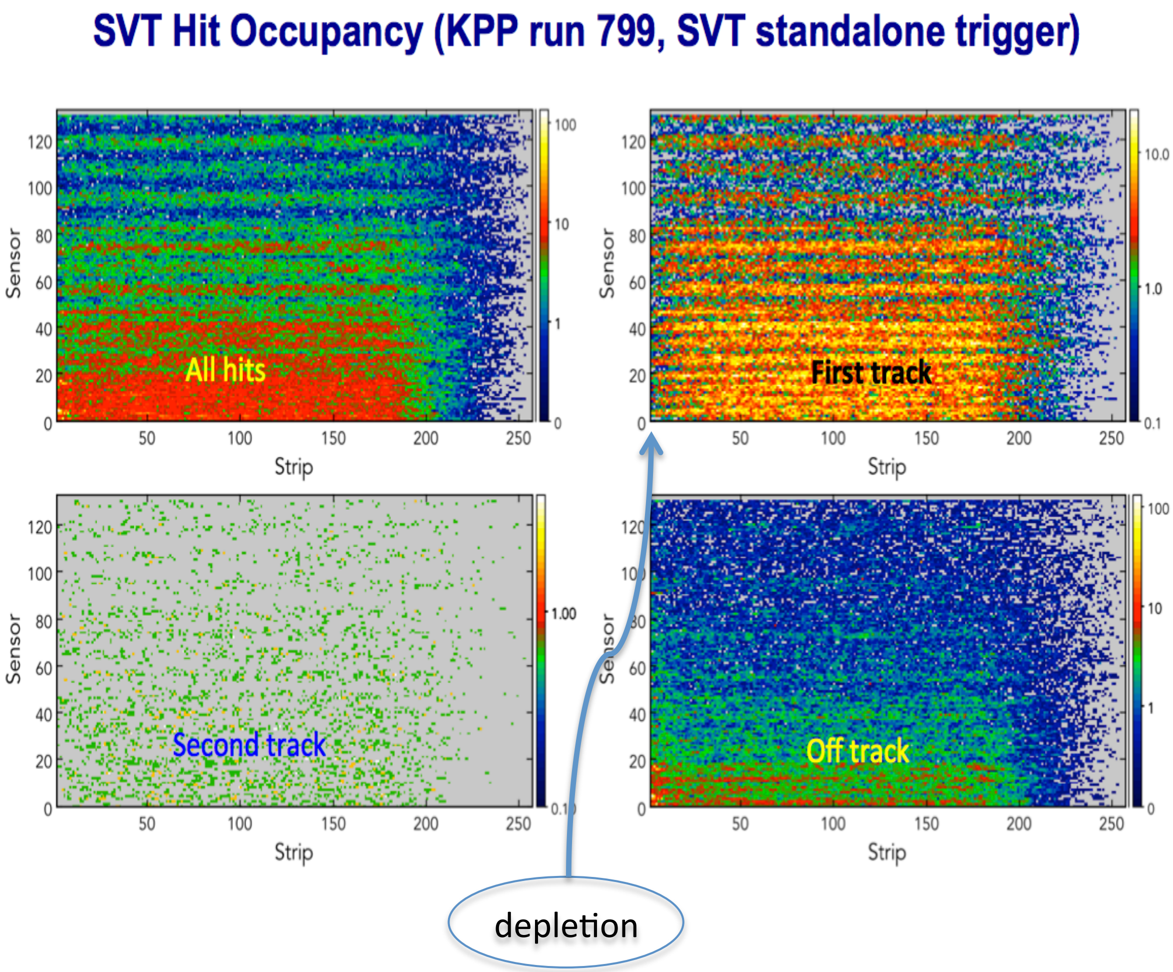
- Improved Kalman Filter code (significant memory footprint improvements & track parameters propagation calculation speed improvements [c.f. Gagik's talk]
- Ongoing validation using KPP data
  – Understanding tracking inefficiencies and tuning the algorithms

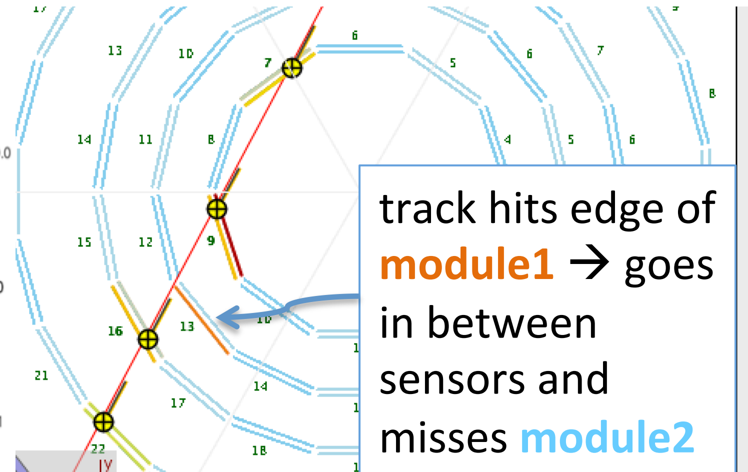


reject hits with poor time residulas from fit

Status at the last meeting

SVT Tracking on cosmics





track hits edge of **module1** → goes in between sensors and misses **module2** ➔ no cross, **hence hits were not used to fit the track**

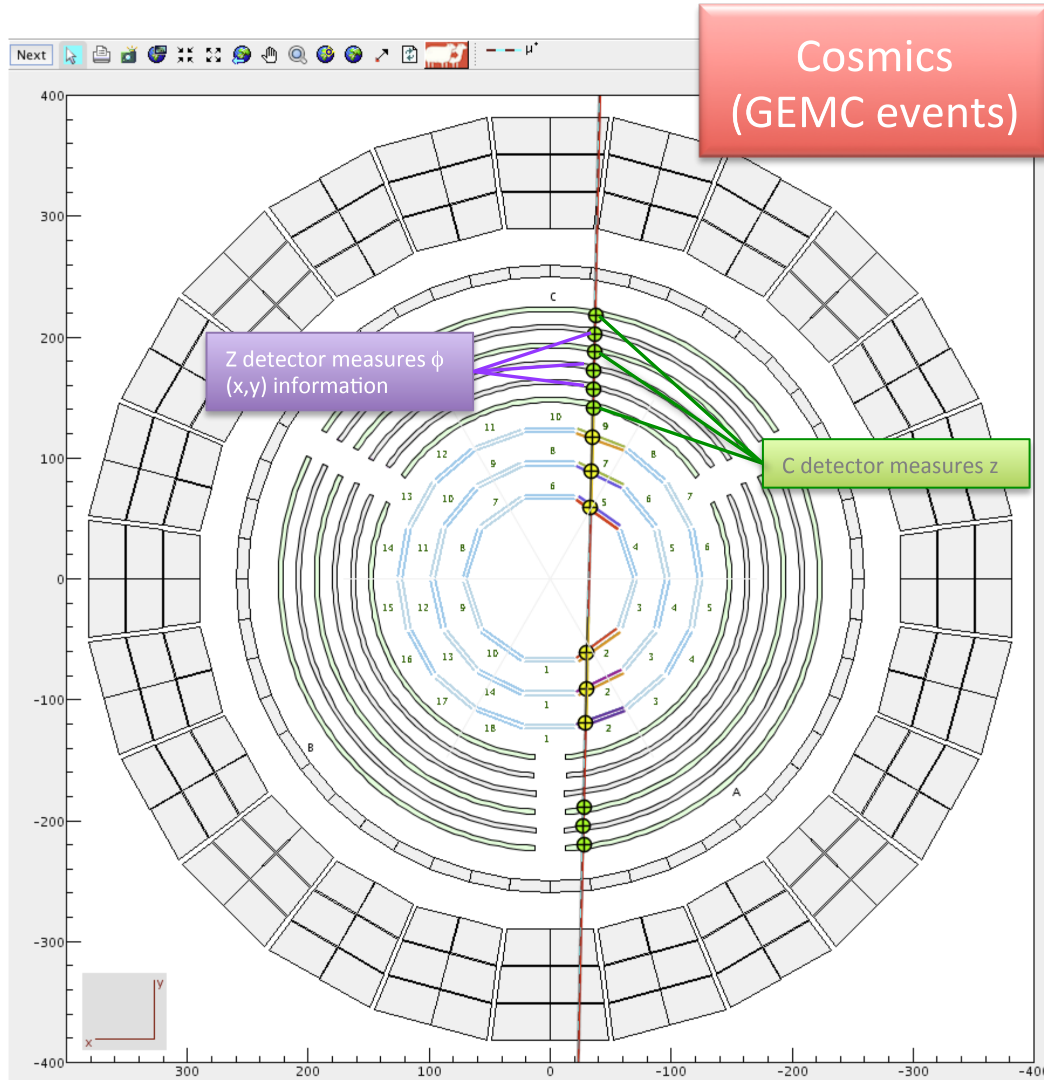
After fitting search for unassociated hits on track trajectory (|calcCentroid – clusterCentroid| <3)

CVT Reconstruction

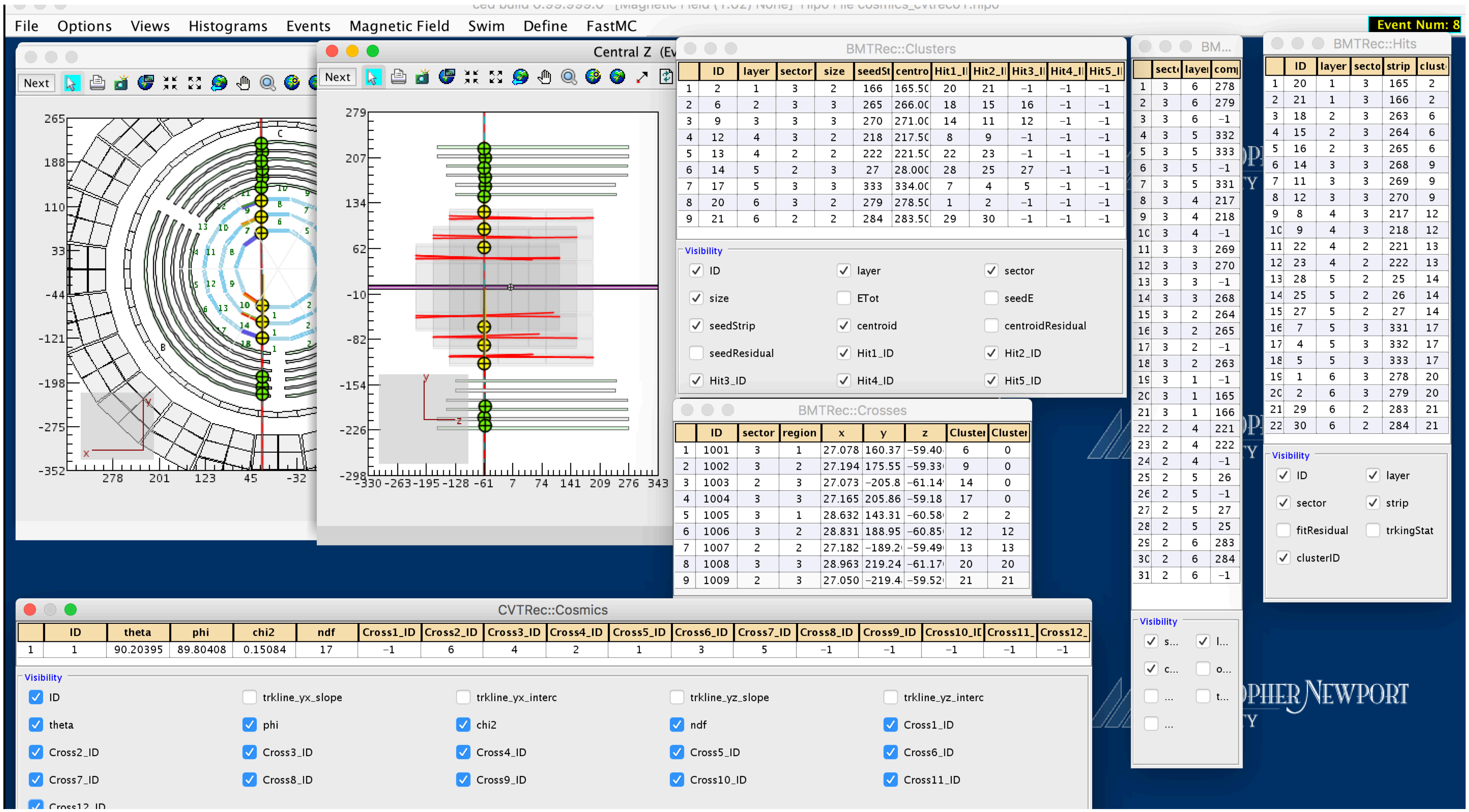
- New package includes Barrel Micromegas Tracker (BMT).
- BMT digitization in GEMC (Maxime).
  - Geometry constants accessed from ccdb (in simulation & reco.)
- Validation of agreement of digitization & de-digitization, geometry, Lorentz angle correction between simulation and reconstruction.

Barrel Micromegas Tracker (BMT) Pattern Recognition

1. Pattern recognition in BMT
   1. Reconstruct clusters of strip (todo: energy-weighted centroid)
   2. Obtain pseudo crosses
      1. Z detectors P=(x,y), C detector P=(r,z)
2. Store information in fit arrays:
   1. extract helix parameters (2-step fit: 1. x,y projection fit to extract $\mathbf{d}_0$, ϕ_0, ρ; 2. r,z projection fit to extract $\mathbf{z}_0$, $\tan\lambda$)
   2. HT to select straight track candidate (use XY projection, check coincidence in r.z projection)



Validation & geometry checks using simulated cosmics (Y. Gotra)

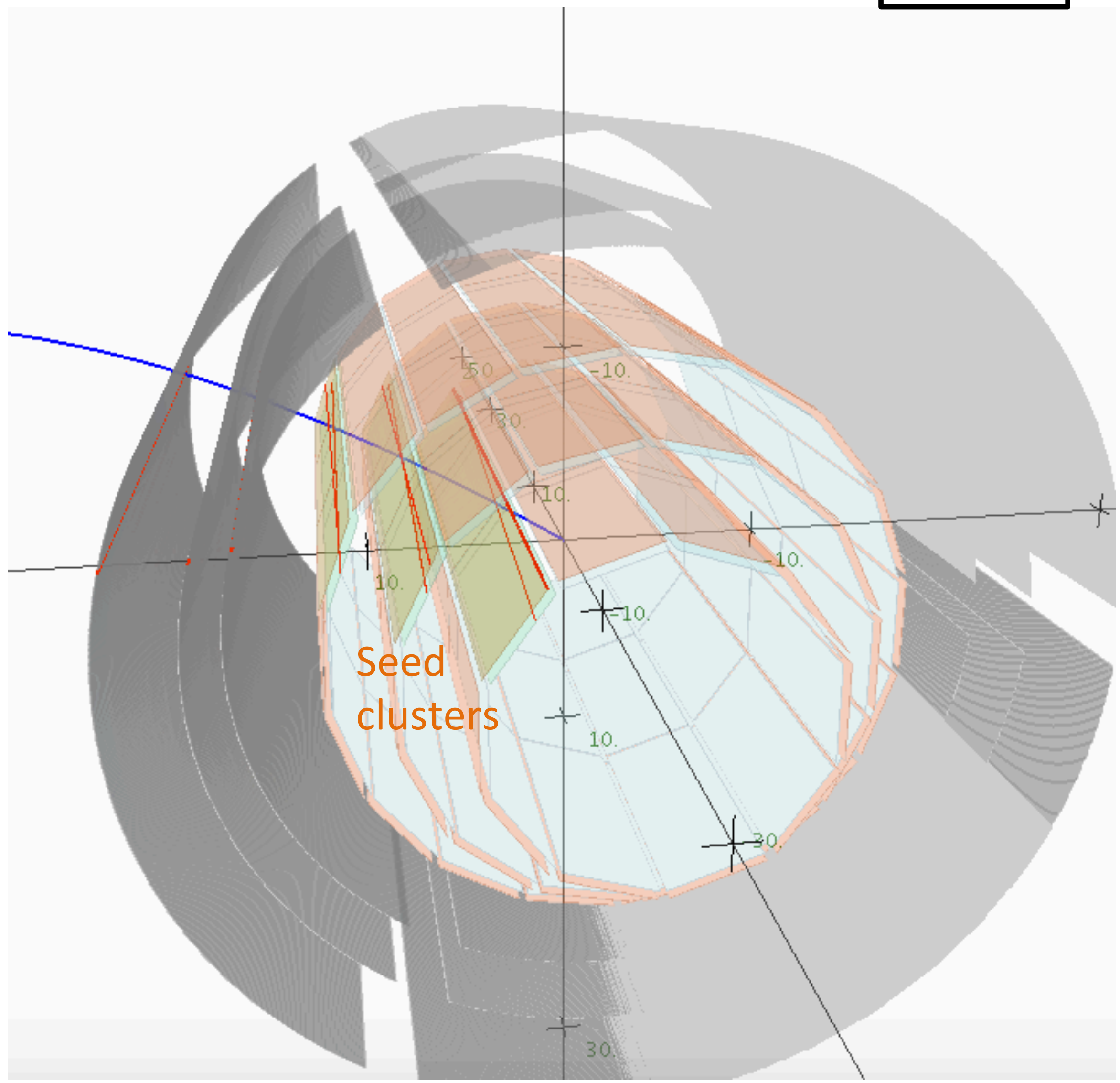


CVT (SVT+BMT) Reconstruction Algorithms

1. Use SVT as a track seeder
    1. Reconstruct clusters of strip and compute energy-weighted centroid
    2. Obtain position of these centroid wrt lab frame
    3. Fit cluster endpoints (upstream side) XY projection to a circle after HT-type selection to select clusters belonging to a track candidate.
    4. Find crosses and refit to match to BMT crosses
    5. Refit using all SVT and BMT crosses
        - Todo: recheck SVT clusters to verify matching

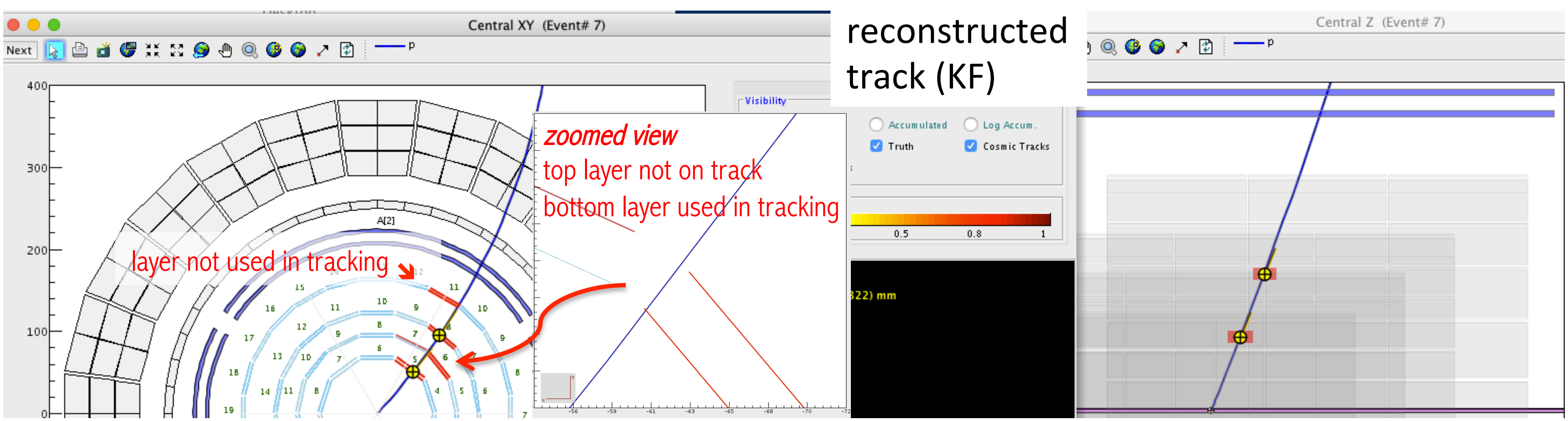
- This is the track ***seed***, it contains SVT clusters + BMT pseudo-crosses

ced 3-D



CVT Seeding

- Track seeding… require 2 SVT crosses (4 out of 6 layers using MM)
  - use all SVT clusters + (if available C & Z BMT detector infomations) as measurements for subsequent Kalman Fit
  - Initialize Kalman fit parameters with the result of a global fit to the combined system crosses



Tracking in CLAS12 CVT

1) The State Vector

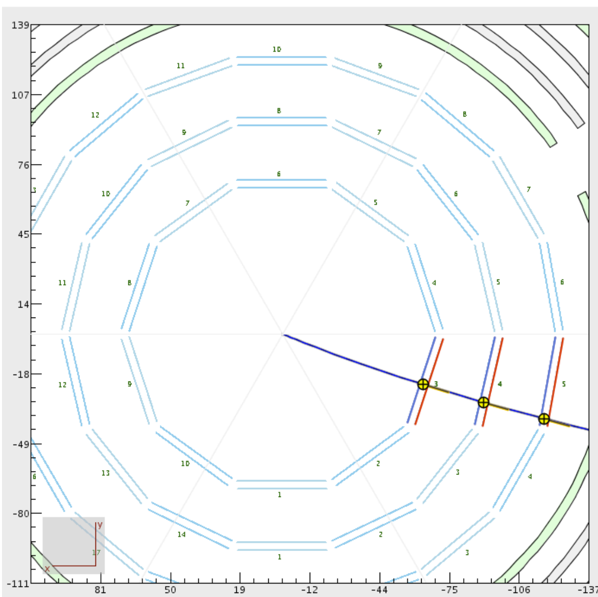
Track parameters and Covariance matrix estimated from Global Fitting method prior to starting Kalman Filter

- **site**: SVT module layer where a strip or cluster of strip fired (k = 1…8)

- **state**: 5-parameter helical track representation

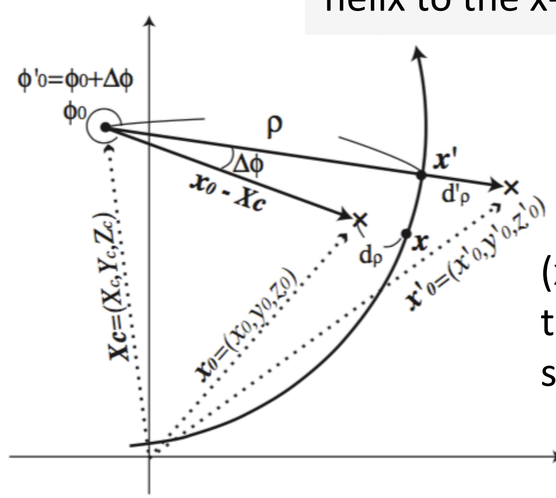
$$a_k = \begin{pmatrix} d_\rho \\ \phi_0 \\ \kappa \\ d_z \\ \tan\lambda \end{pmatrix}_k$$

d_ρ: distance between the helix and the site ref. point (x_0,y_0,z_0) in x-y plane
ϕ_0: azimuthal angle of the ref. wrt helix center
$\kappa \equiv Q/Pt$
dz: distance between helix and reference point in the z direction
$\tan\lambda$:dip angle, i.e., the angle of the helix to the x-y plane.



$B \sim B_z \sim 5$ T

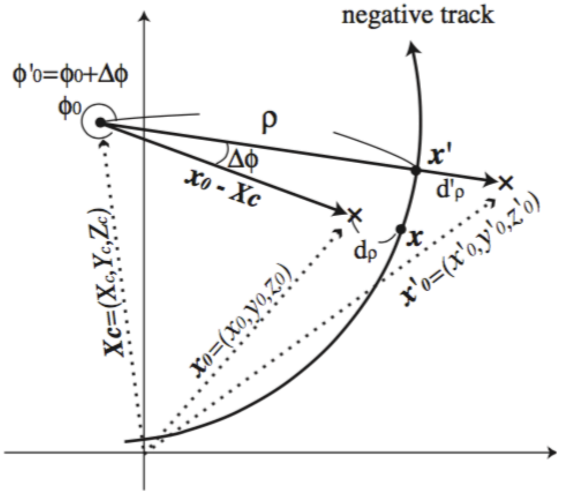
Event display of reconstructed tracks in CLAS12 SVT



(x_0,y_0,z_0): intersection of the track with the signal strip or centroid

Tracking in CLAS12 CVT

2) The Propagator



(x_0,y_0,z_0): intersection of the track with the signal strip or centroid

- **Propagate from initial state estimated at DOCA to beam line to outermost SVT layer**
- **<u>state propagator</u>**: follows equations of motion for helical track $\boldsymbol{a}' \equiv \boldsymbol{a}_k^{k-1} = (d'_\rho, \phi'_0, \kappa', d'_z, \tan\lambda')^T = \boldsymbol{f}_{k-1}(\boldsymbol{a}_{k-1})$

$$\begin{cases} d'_\rho &= (X_c - x'_0)\cos\phi'_0 + (Y_c - y'_0)\sin\phi'_0 - \frac{\alpha}{\kappa} \\ \phi'_0 &= \begin{cases} \tan^{-1}\left(\frac{Y_c - y'_0}{X_c - x'_0}\right) & (\kappa > 0) \\ \tan^{-1}\left(\frac{y'_0 - Y_c}{x'_0 - X_c}\right) & (\kappa < 0) \end{cases} \\ \kappa' &= \kappa \\ d'_z &= z_0 - z'_0 + d_z - \left(\frac{\alpha}{\kappa}\right)(\phi'_0 - \phi_0)\tan\lambda \\ \tan\lambda' &= \tan\lambda, \end{cases}$$

$$\begin{cases} X_c &\equiv x_0 + \left(d\rho + \frac{\alpha}{\kappa}\right)\cos\phi_0 \\ Y_c &\equiv y_0 + \left(d\rho + \frac{\alpha}{\kappa}\right)\sin\phi_0 \, . \end{cases}$$

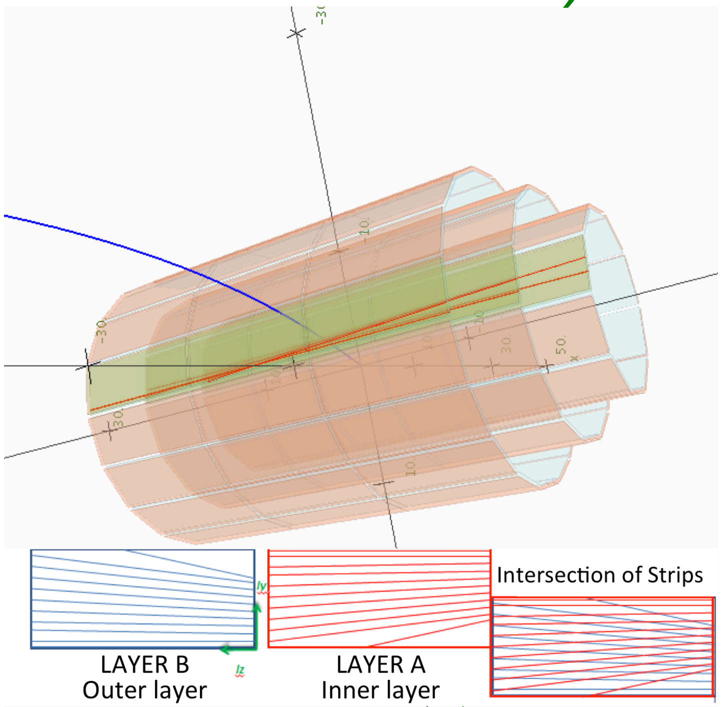
- **<u>state covariance matrix propagator</u>**: Jacobian of state projector

$$\boldsymbol{F}_{k-1} \equiv \left(\frac{\partial \boldsymbol{a}'}{\partial \boldsymbol{a}}\right) = \begin{pmatrix} \frac{\partial d'_\rho}{\partial \boldsymbol{a}} \\ \frac{\partial \phi'_0}{\partial \boldsymbol{a}} \\ \frac{\partial \kappa'}{\partial \boldsymbol{a}} \\ \frac{\partial d'_z}{\partial \boldsymbol{a}} \\ \frac{\partial \tan\lambda'}{\partial \boldsymbol{a}} \end{pmatrix}$$

*Eqts. from paper
Extended Kalman Filter Keisuke Fujii
[The ACFA-Sim-J Group]

Tracking in CLAS12 SVT

3) The Measurement

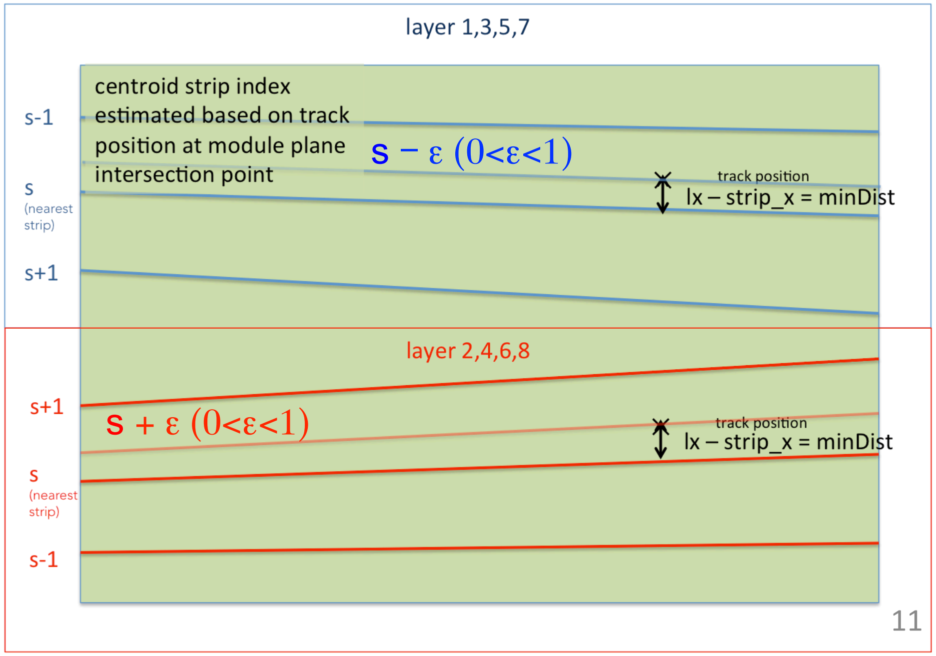


SVT Geometry:

256 strips at 156 μm pitch oriented at graded angle from 0 to 3 deg.

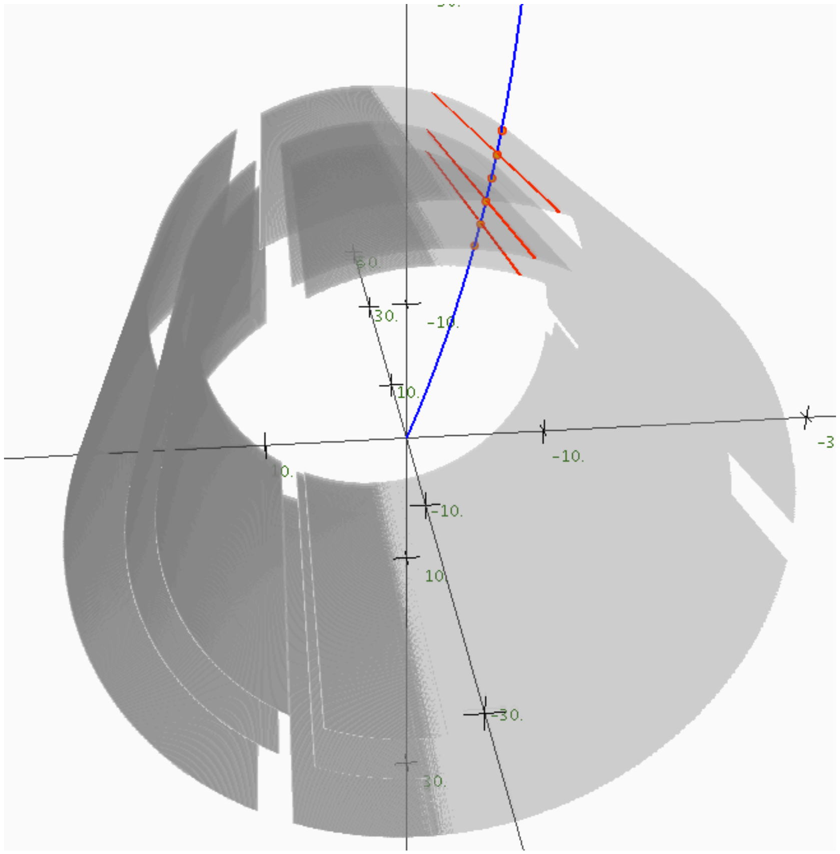
- Measurement: strip or cluster of strips centroid; error: strip/cluster resolution
- Projector $(h_k(a))$ = estimated centroid value based on track parameters at measurement site:

$$\begin{cases} x = x_0 + d_\rho \cos\phi_0 + \frac{\alpha}{\kappa}(\cos\phi_0 - \cos(\phi_0+\phi)) \\ y = y_0 + d_\rho \sin\phi_0 + \frac{\alpha}{\kappa}(\sin\phi_0 - \sin(\phi_0+\phi)) \\ z = z_0 + d_z - \frac{\alpha}{\kappa}\tan\lambda\cdot\phi, \end{cases}$$



Tracking in CLAS12 BMT

3) The Measurement



- Measurement: ϕ (Z-det), z (C-det)
  - error: phi, z resolution
- Projector $(\boldsymbol{h}_k(\boldsymbol{a}))$ = estimated value based on track parameters at measurement site (i.e atan2(y,x); z):

$$\begin{cases} x = x_0 + d_\rho \cos\phi_0 + \frac{\alpha}{\kappa}(\cos\phi_0 - \cos(\phi_0+\phi)) \\ y = y_0 + d_\rho \sin\phi_0 + \frac{\alpha}{\kappa}(\sin\phi_0 - \sin(\phi_0+\phi)) \\ z = z_0 + d_z - \frac{\alpha}{\kappa}\tan\lambda \cdot \phi, \end{cases}$$

Tracking in CLAS12 SVT

4) The Projector Matrix

Projector matrix calculation:

$$H = \frac{\partial c_k}{\partial X_k} \frac{\partial X_k}{\partial a_k}$$

a_k : the state vector at site k

$X_k = (x, y, z)$: the projected track (i.e. a_k)

intersection point with site k plane

$$\begin{cases} x = x_0 + d_\rho \cos\phi_0 + \frac{\alpha}{\kappa}(\cos\phi_0 - \cos(\phi_0 + \phi)) \\ y = y_0 + d_\rho \sin\phi_0 + \frac{\alpha}{\kappa}(\sin\phi_0 - \sin(\phi_0 + \phi)) \\ z = z_0 + d_z - \frac{\alpha}{\kappa}\tan\lambda \cdot \phi, \end{cases}$$

c_k : the centroid estimated from $X_k = (x, y, z)$

Tracking in CLAS12 BMT

4) The Projector Matrix

Projector matrix calculation:

$$H = \frac{\partial c_k}{\partial X_k} \frac{\partial X_k}{\partial a_k}$$

a_k : the state vector at site k

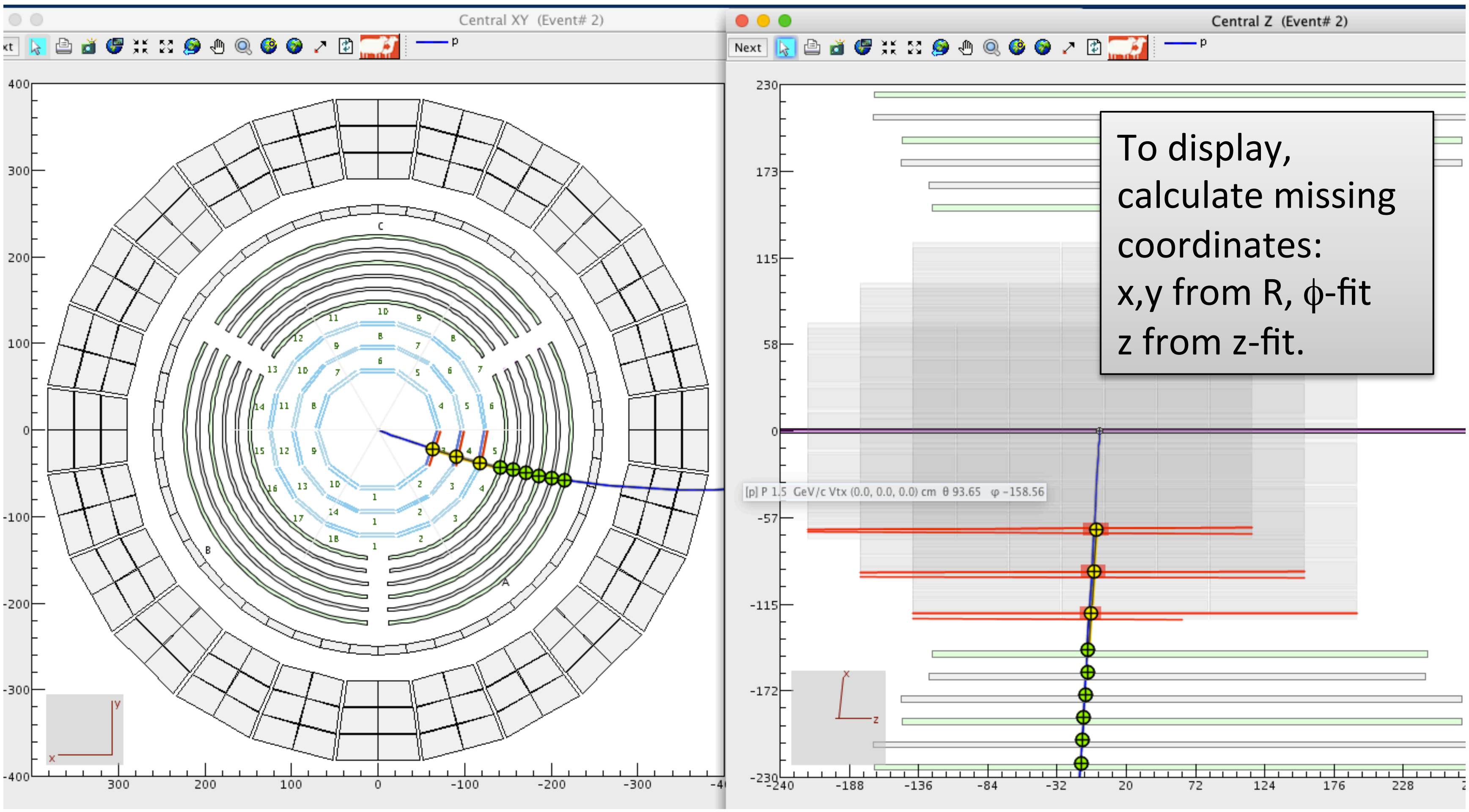
$X_k = (x, y, z)$: the projected track (i.e. a_k) intersection point with site k plane

$$\begin{cases} x = x_0 + d_\rho \cos\phi_0 + \frac{\alpha}{\kappa}(\cos\phi_0 - \cos(\phi_0 + \phi)) \\ y = y_0 + d_\rho \sin\phi_0 + \frac{\alpha}{\kappa}(\sin\phi_0 - \sin(\phi_0 + \phi)) \\ z = z_0 + d_z - \frac{\alpha}{\kappa}\tan\lambda \cdot \phi, \end{cases}$$

ϕ_k : estimated from $X_k = (x, y, z)$

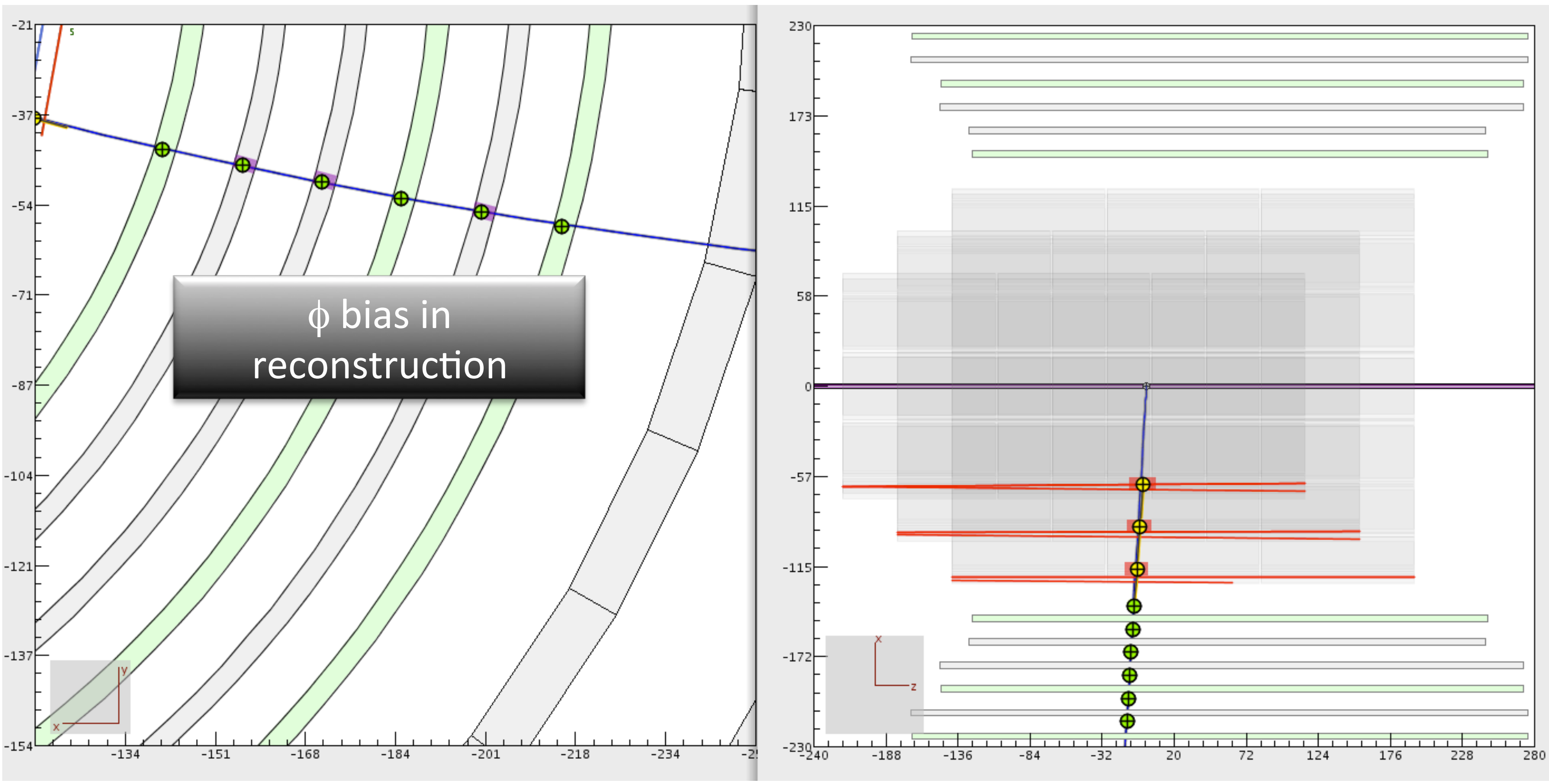
z_k : estimated from $X_k = (x, y, z)$

Validation using single track events simulated within acceptance for Central Tracks



To display, calculate missing coordinates:
x,y from R, ϕ-fit
z from z-fit.

Debugging…. ☹

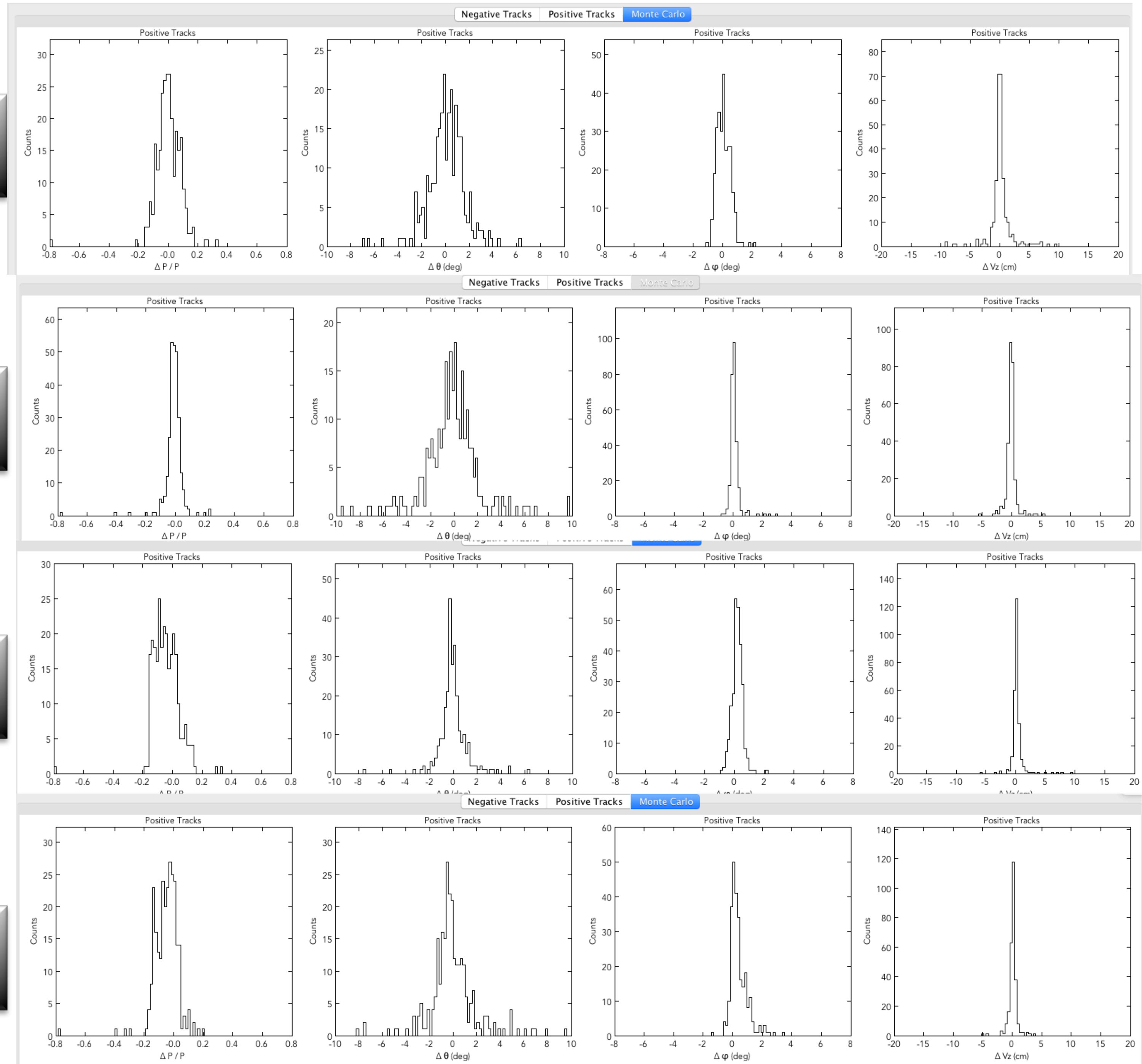


SVT Stand-alone Global Fit

SVT Stand-alone Kalman Fit

SVT +BMT Global Fit

SVT +BMT Kalman Fit

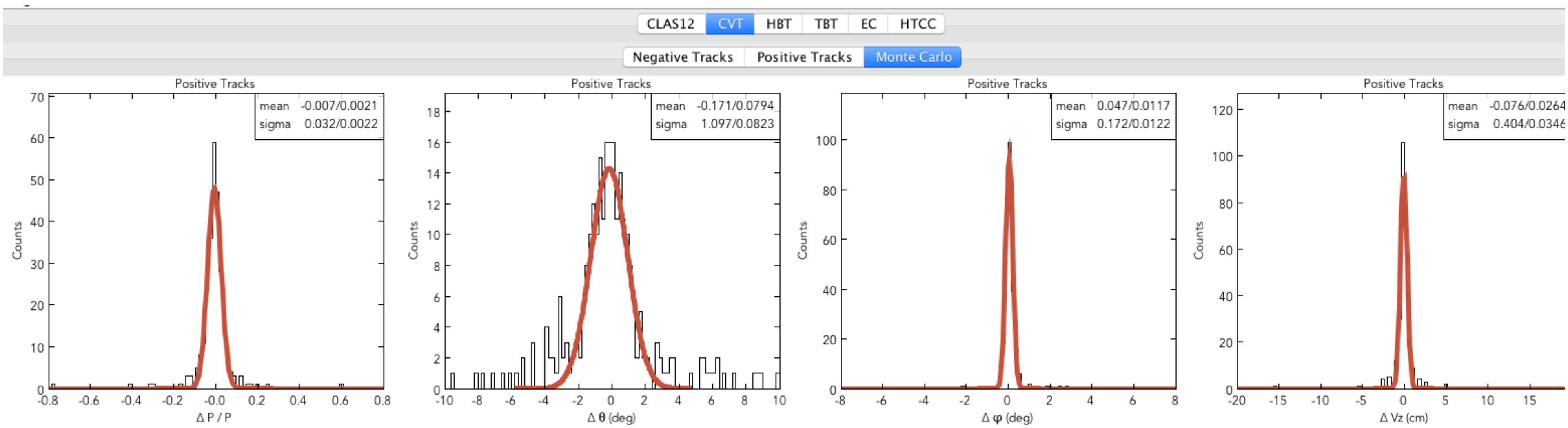


Next Steps… until the Fall

- Verify MM geometry implementation
- Add ADCs to simulation output (proper centroid calculation in reco.)
- Validate BMT pattern recognition
- Verify proper treatment of errors in KF & determine the cause of lack of convergence of fit
- Write KF fit algorithm to use FMT in forward tracking.

BACKUPS

Resolutions



CVT