CLAS12 Track-Based Alignment
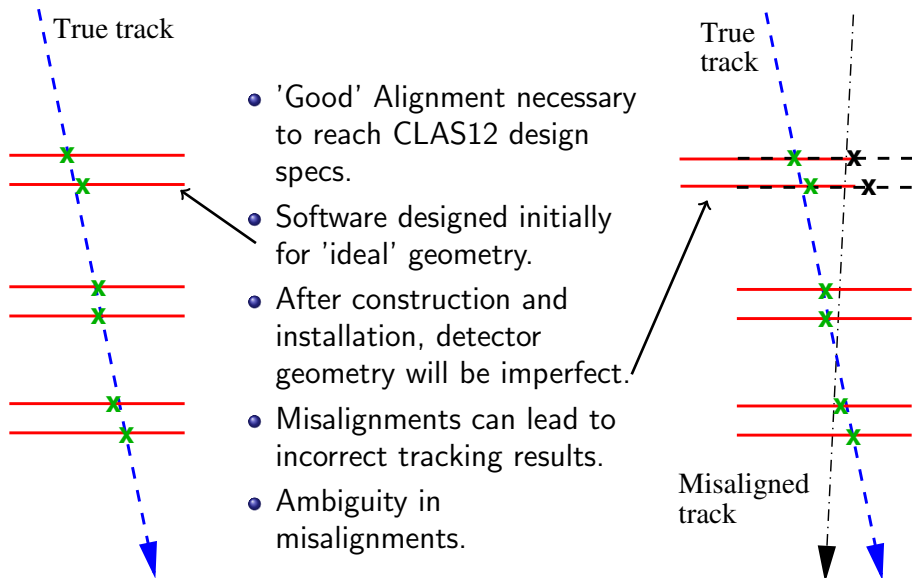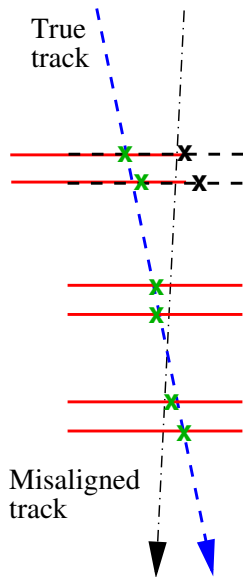
G.P. Gilfoyle, V.Ziegler, Y. Gotra

Outline: Statement of the problem
           CLAS12 Silicon Vertex Tracker (SVT) Alignment Studies
           What's next for SVT?
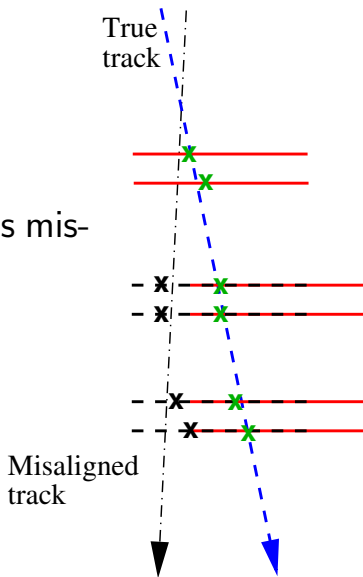   Other subsystem track-based alignment efforts
           Summary

True track

- 'Good' Alignment necessary to reach CLAS12 design specs.
- Software designed initially for 'ideal' geometry.
- After construction and installation, detector geometry will be imperfect.
- Misalignments can lead to incorrect tracking results.
- Ambiguity in misalignments.

True track

Misaligned track

True track
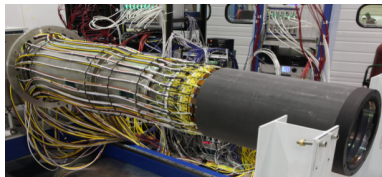
True track

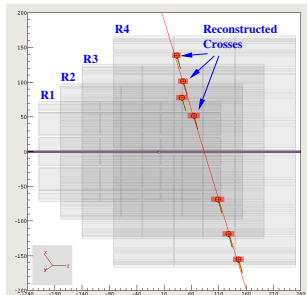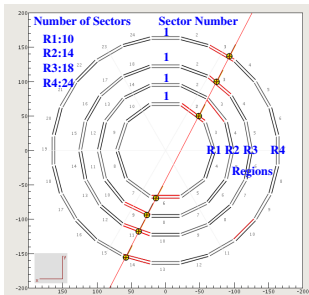Which layer is misaligned??

Misaligned track

Misaligned track

CLAS12 Silicon Vertex Tracker

- Needed to obtain few percent resolution for low-momentum, large-angle particles.

- Assembled, integrated, calibrated, and now being commissioned in the EEL.

- Cosmic ray data now being collected for validation and alignment.
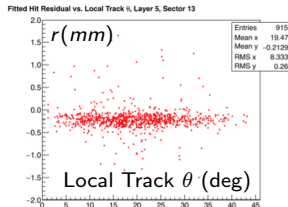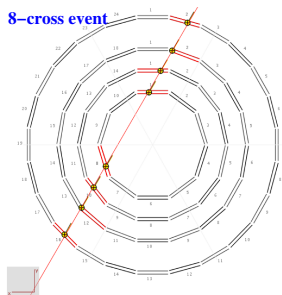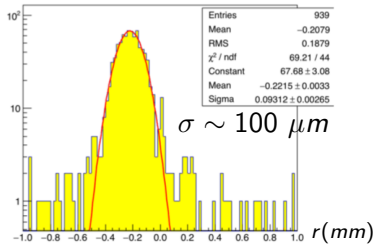

SVT Cosmics →

SVT Cosmic Ray Studies

- Cosmic rays
  - Full SVT DAQ using CODA.
  - Standalone trigger, $\sim 10\ Hz$.
  - One double hit in R1/R2, R3, and R4.

- Taking cosmics for weeks now - extensive validation studies.

- Initial alignment studies.
  - Select 'good' tracks - eight crosses.
  - Residuals show need for alignment.
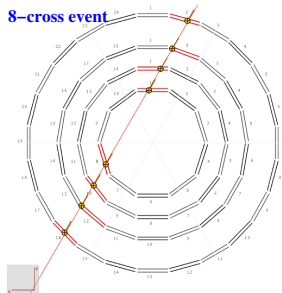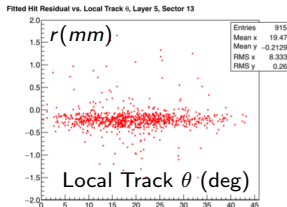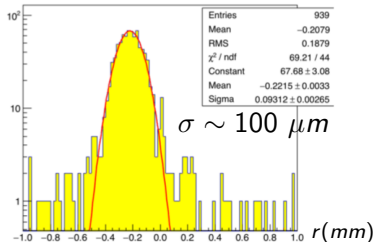 - Dependence on fit parameters

8–cross event

Fitted Hit Residual vs. Local Track θ, Layer 5, Sector 13

| Entries | 915 |
Mean x	19.47
Mean y	-0.2129
RMS x	8.333
RMS y	0.26

$r(mm)$

Local Track θ (deg)

Residual, Layer 5, Sector 13

Entries	939
Mean	-0.2079
RMS	0.1879
χ^2 / ndf	69.21 / 44
Constant	67.68 ± 3.08
Mean	-0.2215 ± 0.0033
Sigma	0.09312 ± 0.00265

$\sigma \sim 100\ \mu m$

$r(mm)$

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- Cosmic rays
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8–cross event

Results are summed over 8-cross topologies.

Fitted Hit Residual vs. Local Track θ, Layer 5, Sector 13

Entries	915
Mean x	19.47
Mean y	-0.2129
RMS x	8.333
RMS y	0.26

$r(mm)$

Local Track θ (deg)

Residual, Layer 5, Sector 13

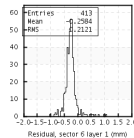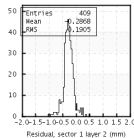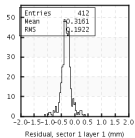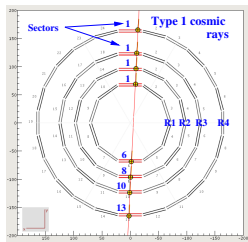| Entries | 939 |
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$\sigma \sim 100 \; \mu m$

$r(mm)$

SVT Cosmic Rays - Type 1 Tracks

- Isolate individual sectors and 'simple' tracks - type 1 tracks.
- Select tracks
  - Exactly eight crosses.
  - Topology: R4S1+R3S1+R2S1+R1S1+R1S6+R2S8+R3S10+R4S13
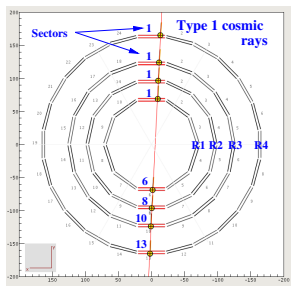 - Reduced χ^2 cut: $\chi^2/\nu < 20$.
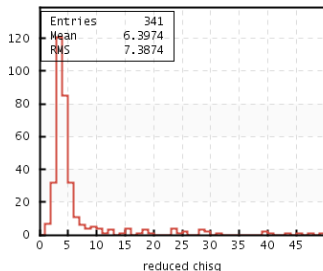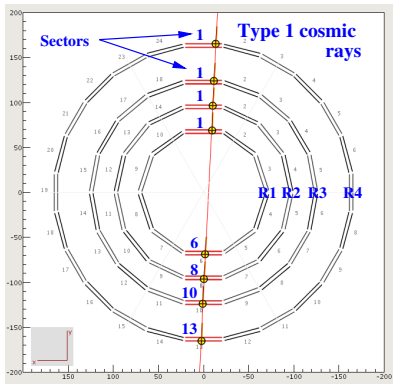
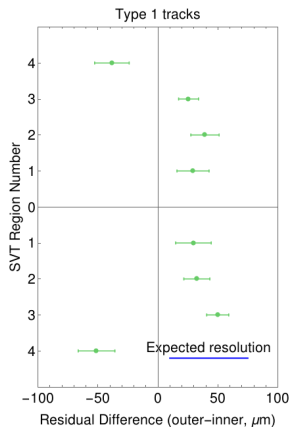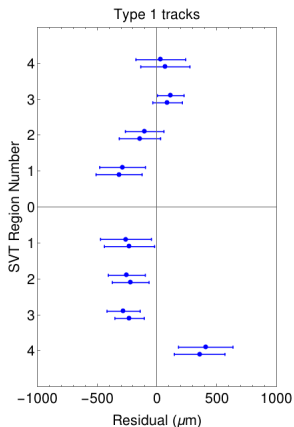# SVT Cosmic Rays - Type 1 Track Residuals
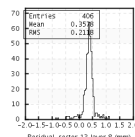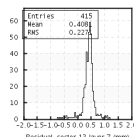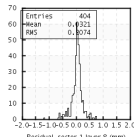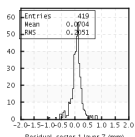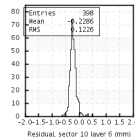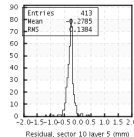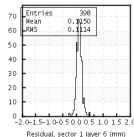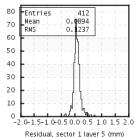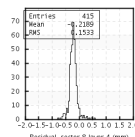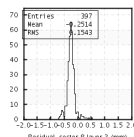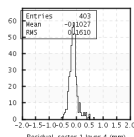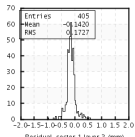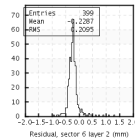
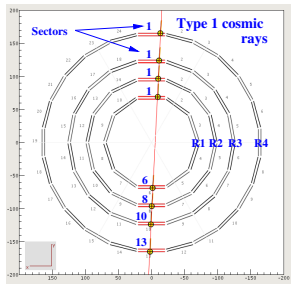# SVT Cosmic Rays - Type 1 Track Residuals and Differences

- Plot centroid and RMS as error bar to represent residual distribution.
- Take difference between residuals within each region (outer-inner).
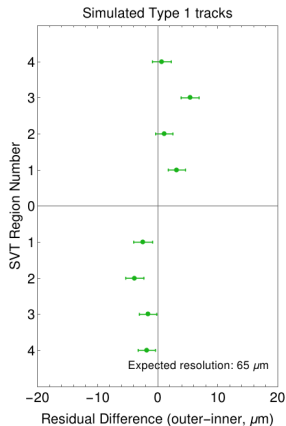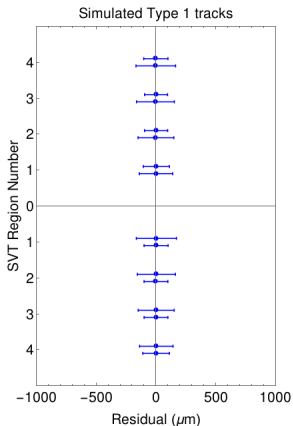- Misalignment between Region 4 and Regions 1-3?

Type 1 tracks.

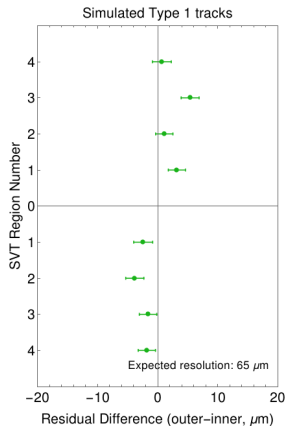# SVT Cosmic Rays - Test Reconstruction with Simulation
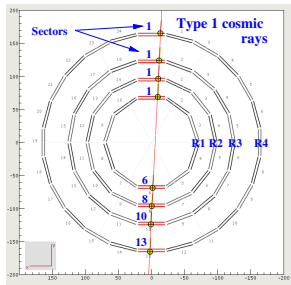
Type 1 tracks.

Type 1 tracks.
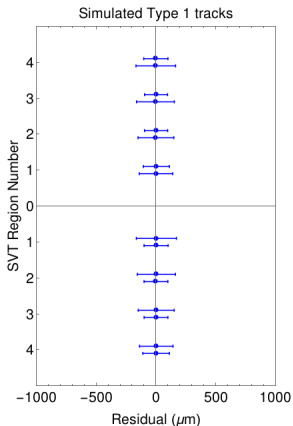
Validates reconstruction code.

Resolving Alignment Ambiguities

- Recall relative shift in residual centroid for R4S13 and Regions 1-3.
- Regions 1-3 and Region 4 are on different supports.
- Take the same event set and reconstruct only using Regions 1-3.

Type 1 tracks

Resolving Alignment Ambiguities

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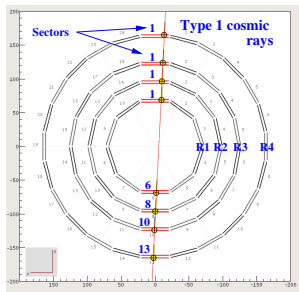
Type 1 tracks

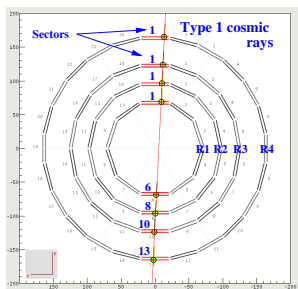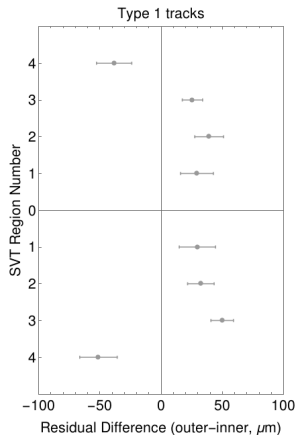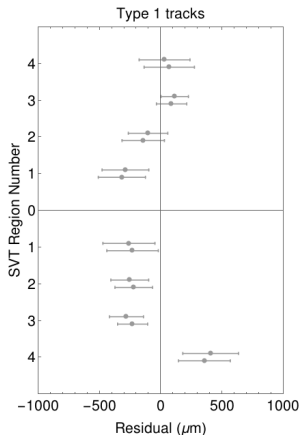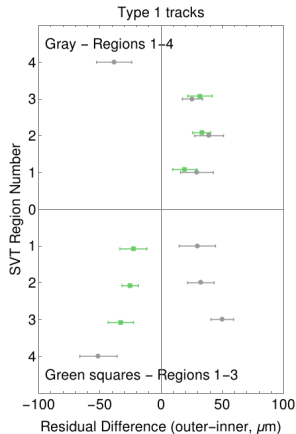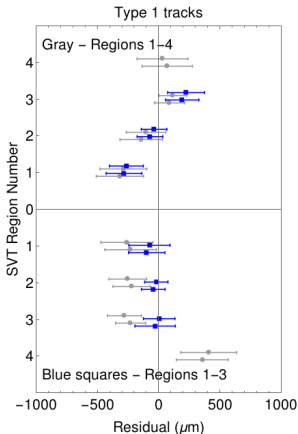# Preliminary Survey Results - 1

Survey data can complement/validate track-based alignment results.
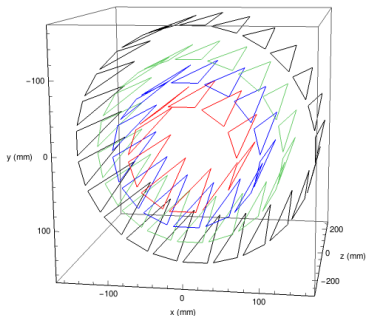
All survey points on modules.

Fiducial displacement in X, mm
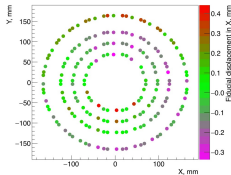
Fiducial displacement in Y, mm
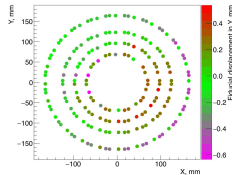
Fiducial displacement in Z, mm
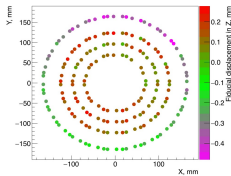
Fiducial displacement in XY plane, mm
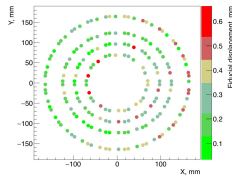
Fiducial displacement in space, mm
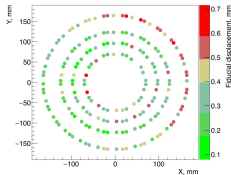
Displacements of fiducials from ideal values (color) in $x - y$ plane.

Type-1 track sectors are nominally horizontal so average the position to look for shifts.

All survey points

Type-1 track sectors are nominally horizontal so average the position to look for shifts.
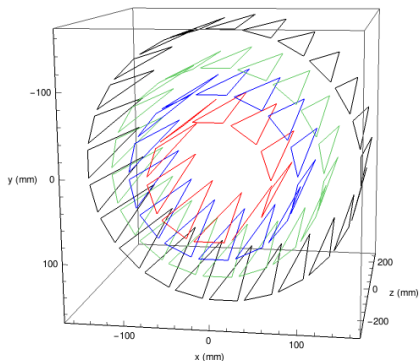
All survey points
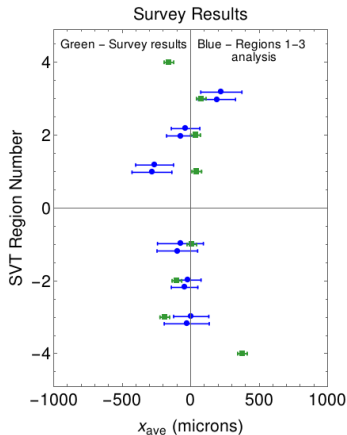
What's Next for SVT?

- Incorporate these measurements into the reconstruction code to correct misalignments - SVT is test case for other subsystems.
- Fit the track data AND the geometry parameters simultaneously.
  - Let the residual be $z_i = y_i - f(\vec{p}, \vec{q}_i)$ where
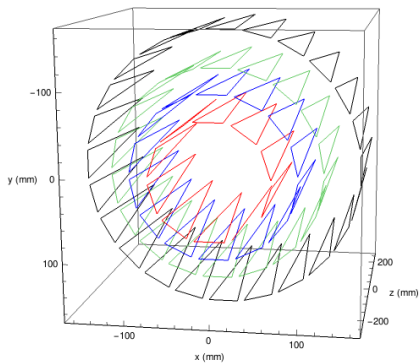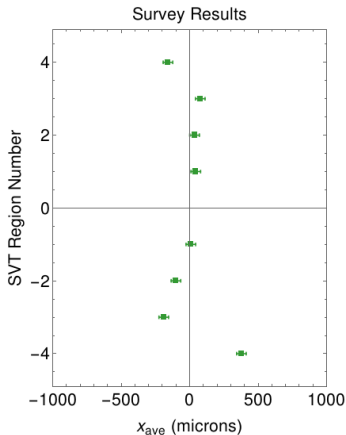 y_i - measured value $\vec{p}$ - global parameters (geometry)
    $\vec{q}_i$ - local parameters (the fit) $f(\vec{p}, \vec{q}_i)$ - parameterization.
  - The sum of z_i^2/σ_i^2 is minimized in the χ^2.
  - Typically the number of global parameters is large.
  - For the SVT: 66(no. of sectors) $\times$ 3(no. of fiducials) $\times$ 3 = 594!
  - The Millepede package (Blobel *et al* Comput.Phys.Commun., 182:17601763, 2011) is used at the LHC for alignment and can handle tens of thousands of global parameters.
  - Millepede is already being used for alignment in Hall D and HPS and is running on the JLab farm (M.Staib, CMU).

Other Subsystem Track-Based Alignment Efforts

- FTOF
  - Being used now with PCAL/EC to detect cosmic rays and study FTOF-PCAL-EC alignment.
  - Awaiting analysis of survey data.
  - More studies planned for the spring.
- PCAL/EC
  - Possible issues appearing in π^0 analysis of *gemc* data.
  - Will use cosmics to align strips with box.
- DC
  - Need to know chamber alignment accurately.
  - Used straight tracks ($\vec{B} = 0$) with empty target to measure alignment in CLAS6.
- HTCC - Use survey and laser measurements - no track-based.

Summary

- The SVT is collecting cosmic ray data to validate the detector response and study its alignment.
- Eight-cross tracks have resolution $\sigma \sim 100$ μm, little dependence on fit parameters, and average misalignments ~ 200 μm.
- Type 1 tracks have similar properties for Regions 1-4.
- Test of the reconstruction code with simulations validates the code.
- Type 1 tracks reconstructed without Region 4 show improvement in accuracy and resolution.
- Survey results are now available and being studied.
- Program `Millepede` can simultaneously fit track parameters and the geometry.
- Listed other track-based alignment efforts.