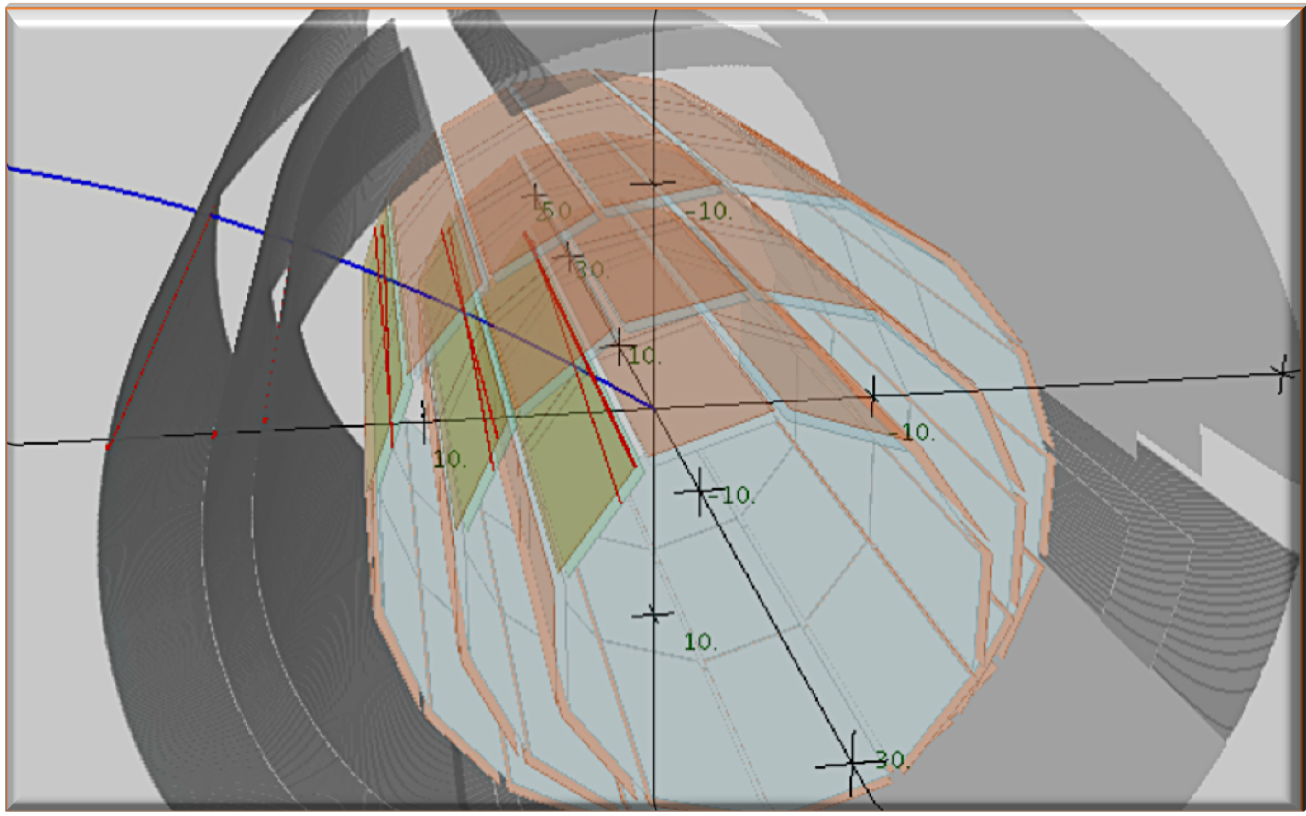
CLAS12 Collaboration meeting

March 5, 2020

# SVT Reconstruction Updates

Veronique Ziegler

For the CVT Team

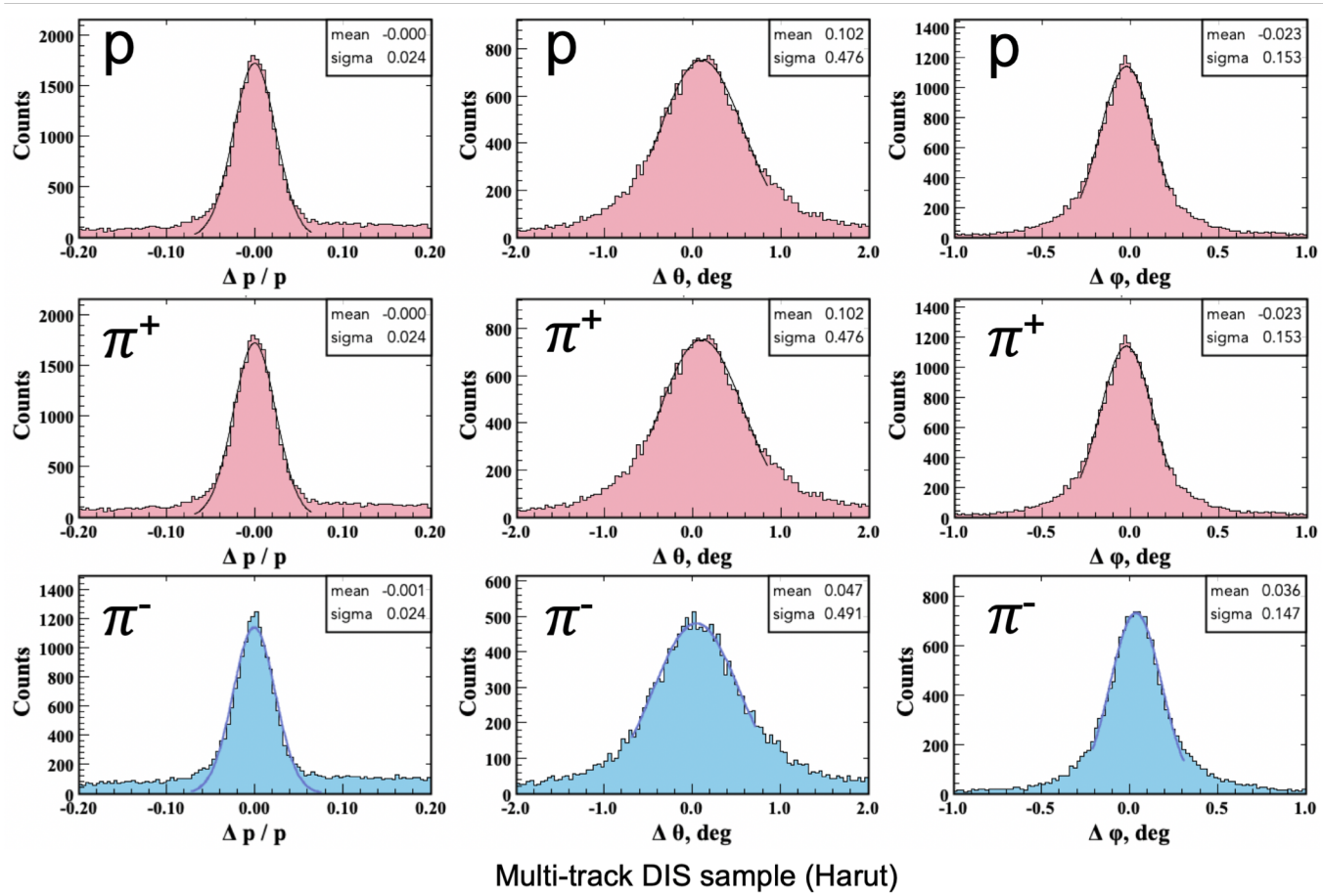


# CVT Updates Overview

Advanced restructuring of reconstruction code:

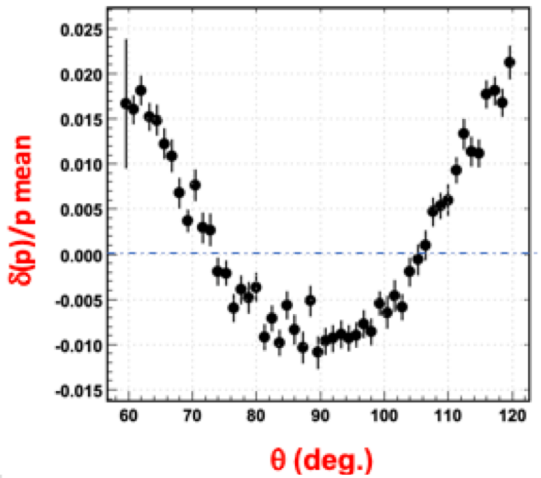
–Most distortions observed with old code understood and resolved, few remaining anomalies being debugged
–Algorithm improvements impacting efficiency and resolution
–New geometry package and layer removal functionality to support alignment
–Functionality to reconstruct zero field beam data and cosmic data

- Systematic validations with MC, data, BG merging

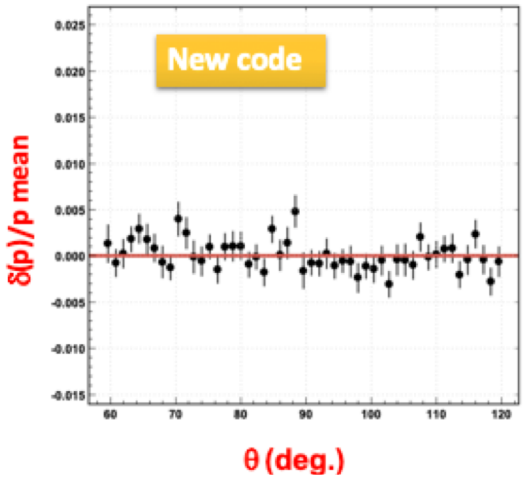


# Polar Angle Bias Resolution

--using Dave's adaptive swimmer package




MC protons

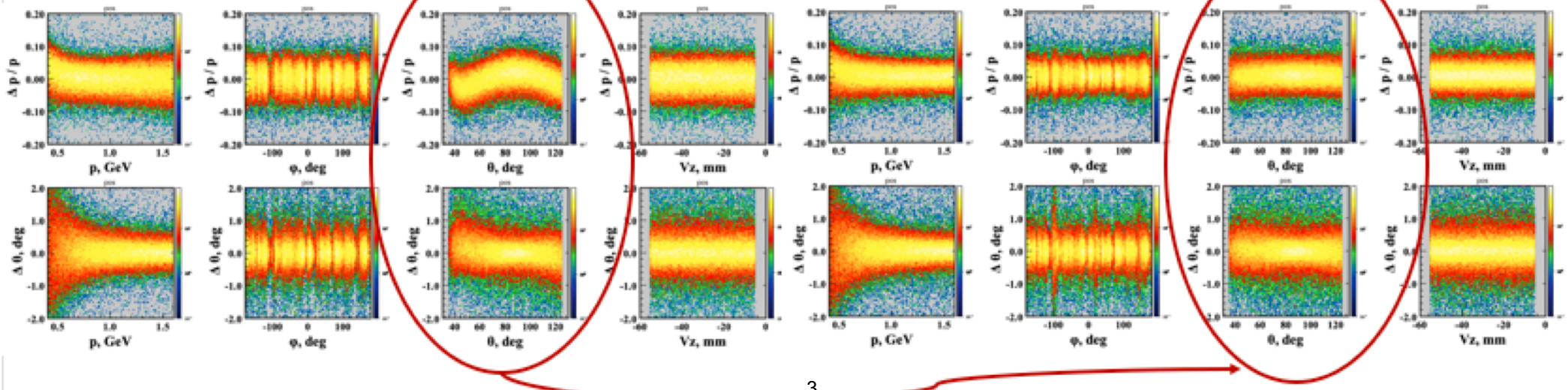



- Bias in momentum resolution as a function of θ resolved by swimming to the BMT surfaces

6.5.12

RG-B, 11014, 5 nA

new



# CVT Software Overview

**Hit selection**
- Studying timing cuts (ongoing)

**Cluster selection**
- Line representation (track doca to line used in fitting) → pseudoline representing cluster taking into account alignment params

**Cross selection**
- Used for seeding
- SVT isolated clusters on track search → functionality to search nearby hits and compute residuals

**Track seeding**
- Straight track finder
- CA
- Secondary pattern rec → + efficiency
- SVT stand-alone tracking
- Layer exclusion functionality

**Geometry with functionality to do rotations and shifts (alignment)**
- SVT geometry
- BMT geometry → allows for arbitrary cylinder (rotations & shifts read from ccdb)

## Services

**Straight Tracks**
- From the target (helical track parameter repr. – assume fixed p = 10 GeV)
  - Input to Kalman Filter
- Cosmics (line parametrization)
  - Global fit only

**Helical Tracks**
- Track helix parameters
- Doca wrt ref. axis (beam spot)
- Input to Kalman Filter

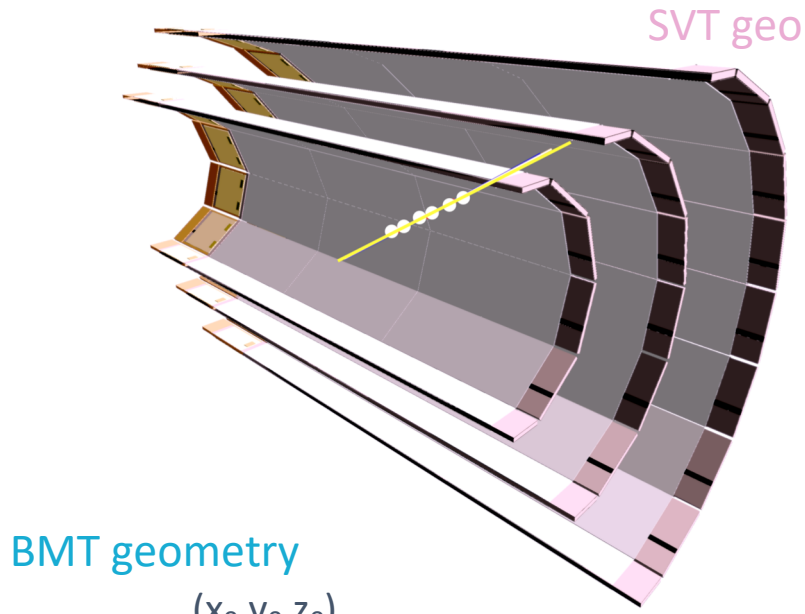
**Track fitting**
- Helical track parameters

**Generic Kalman filter**
- Fitter → filtering
- Measurements → uses Surface class; MeasVecs class to handle projection to the measurement surfaces; generic cylinder BMT surface
- State Vector class to handle propagation of state vector and covariance matrix
- Produces a trajectory (state vecs components, residuals)
- Outlier rejection & Hit exclusion functionality

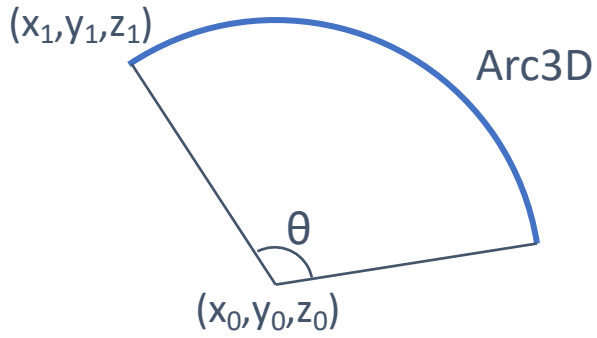
- New development

# CVT geometry

- Update of SVT and BMT geometry to support alignment
- SVT:
  - Using already available geometry service
  - Implementation of global position
  - Independent alignment of individual top/bottom parts of a module (in progress)
  - In use in KF-based alignment
- BMT:
  - Z and C strips described as Line3D and Arc3D
  - Shifts and rotations for each layer and sector
  - Methods to identify closest strip to a point in local or lab frames. (Raffaella)
  - Generic cylinder representing the BMT instantiated and passed to KF
  - Switch to new geometry completed (validation in progress)



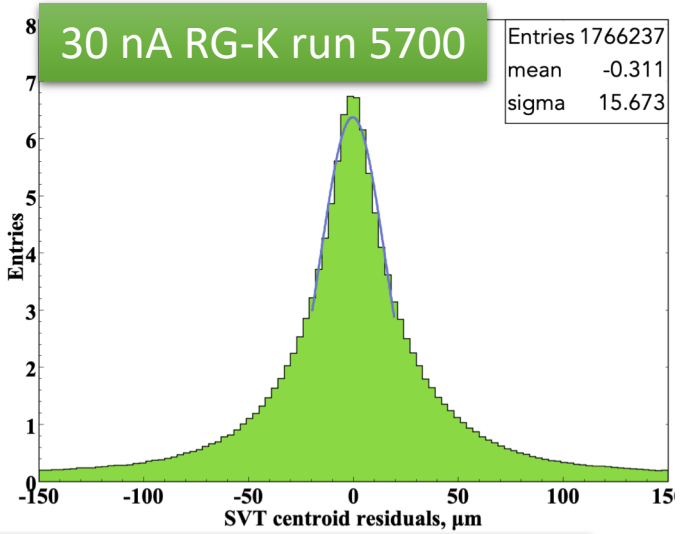

BMT geometry

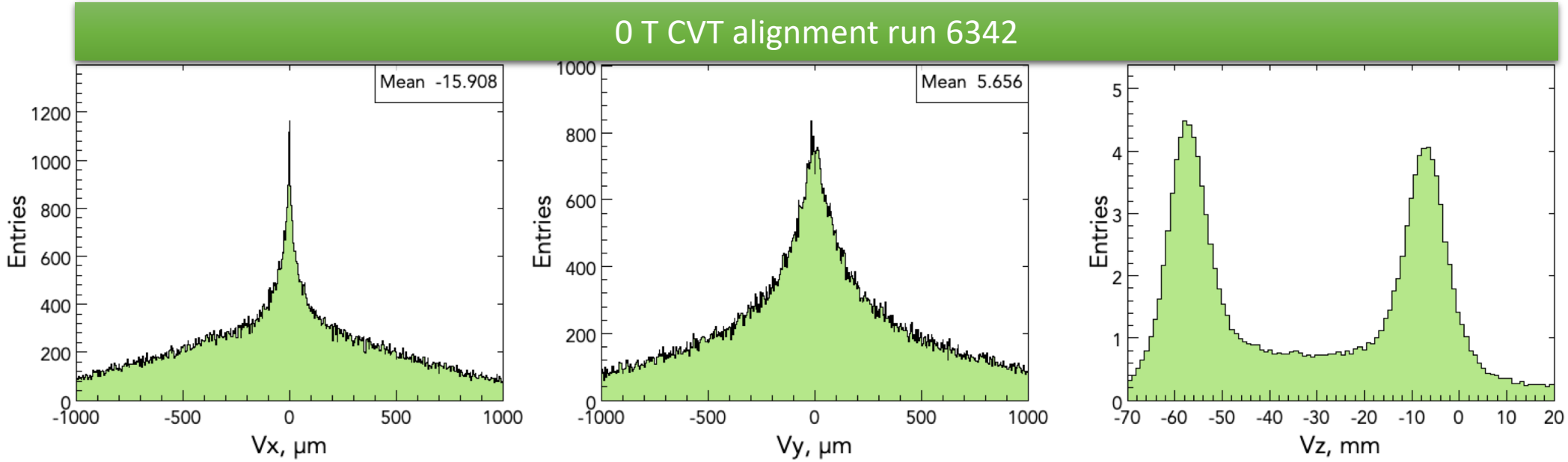



# Layer Exclusion algorithm

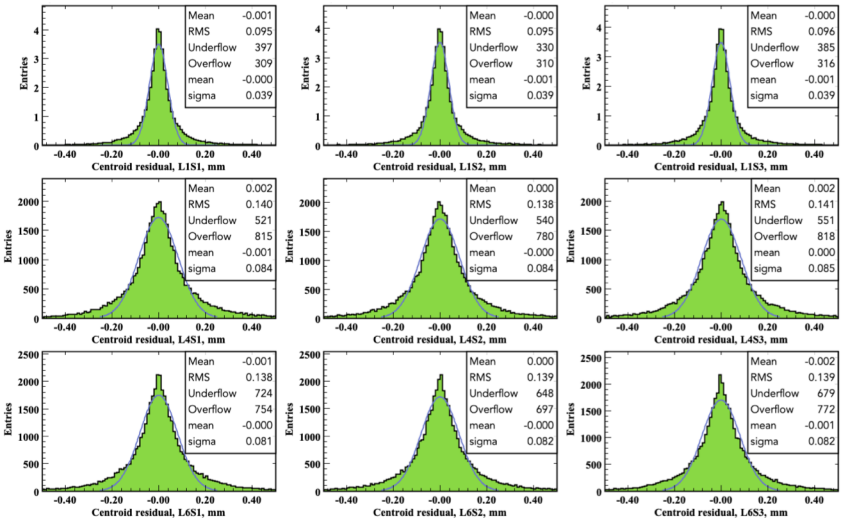
1. Find seed using all hits → e.g. SVT L1,…6, BMT L1,…6.
2. Refit seed, resetting the hits (tracking corrections, associated tracking ids, etc…) and using only the hits not specified as belonging to the list of excluded layers (specified in YAML)
3. Compute special residuals for all layers

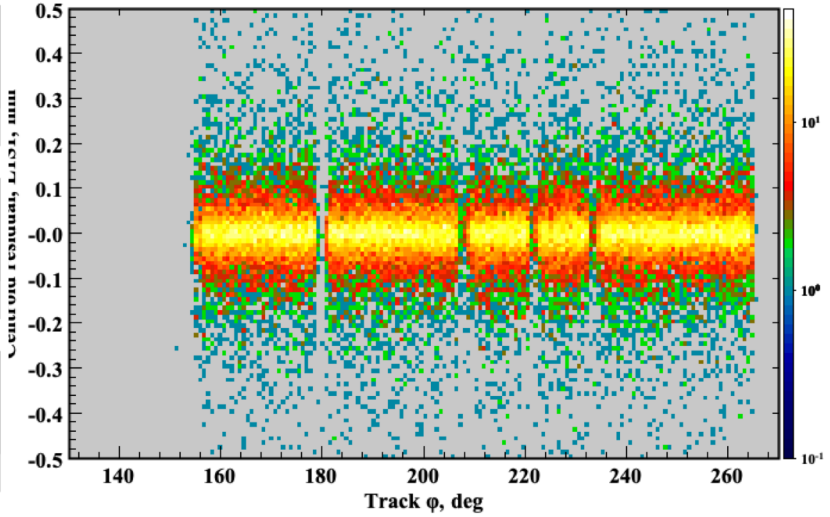
- **Used to extract alignment parameters (successfully employed for SVT)**

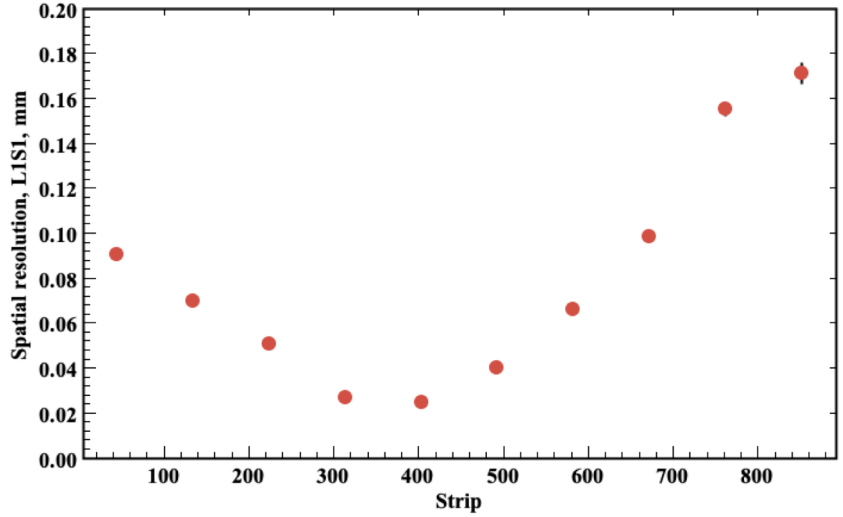


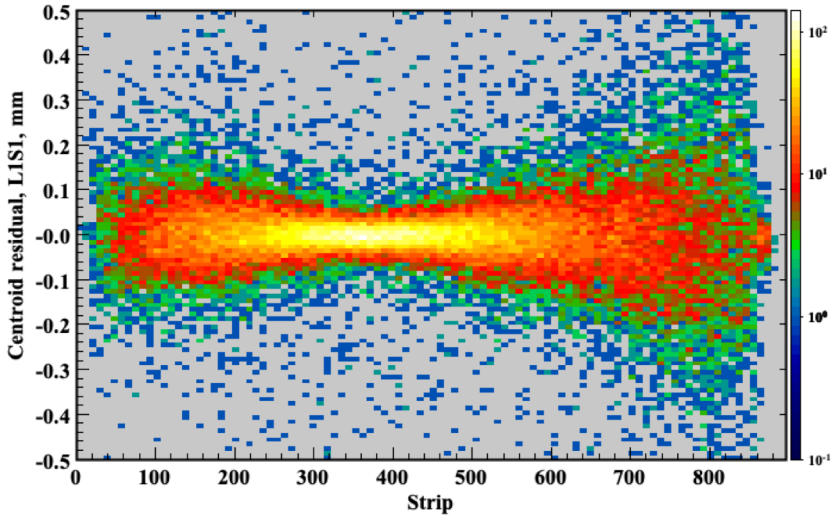



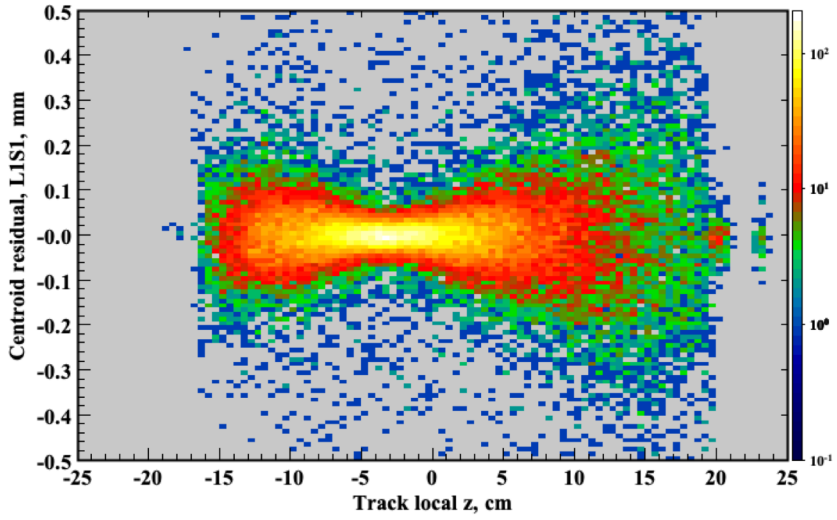
# O T proton MC, BMT-C residuals (CVT reco, TracTools-ExLayr) [Yuri]

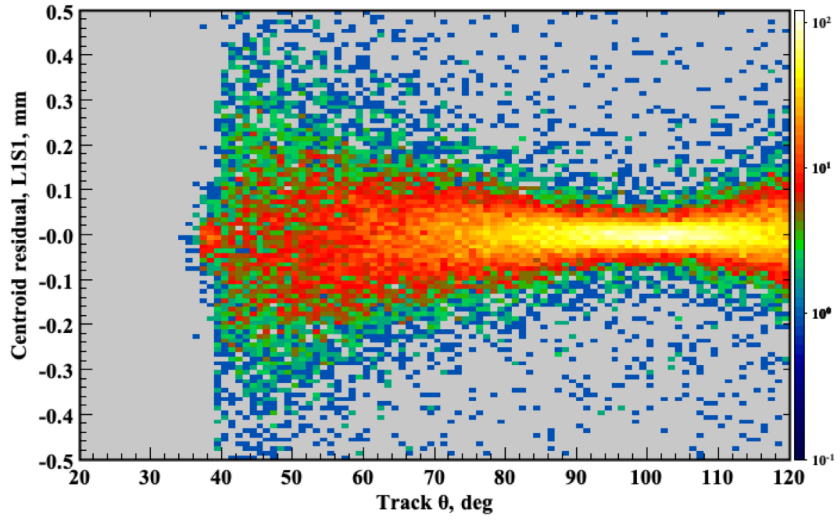


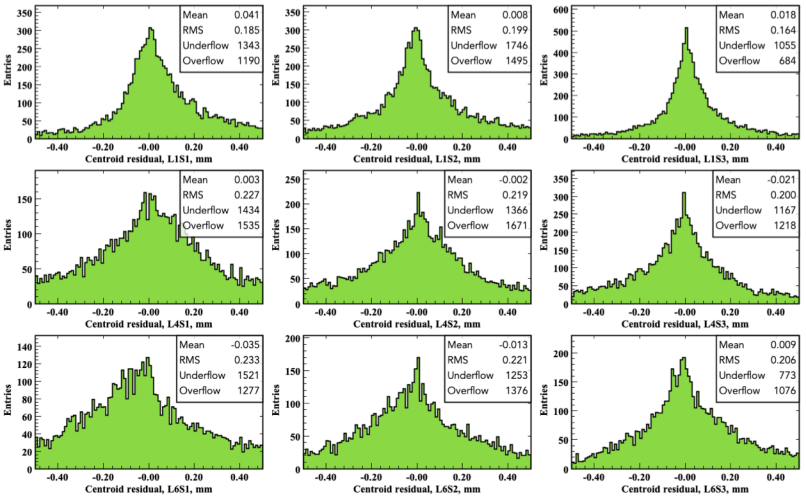



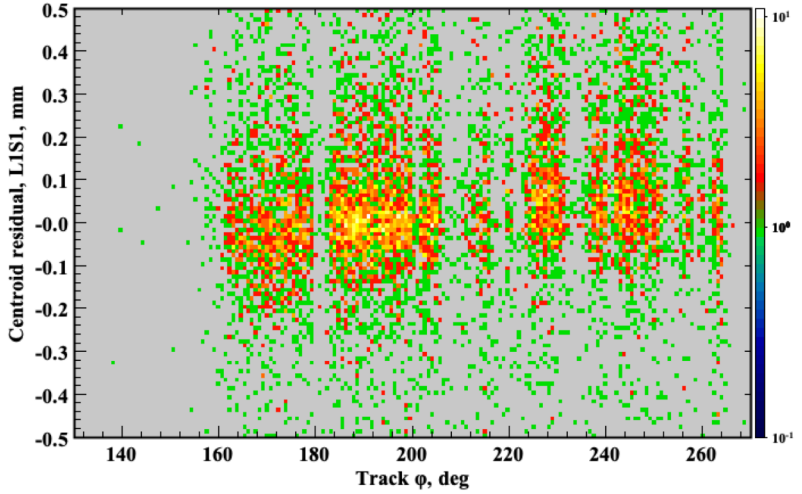



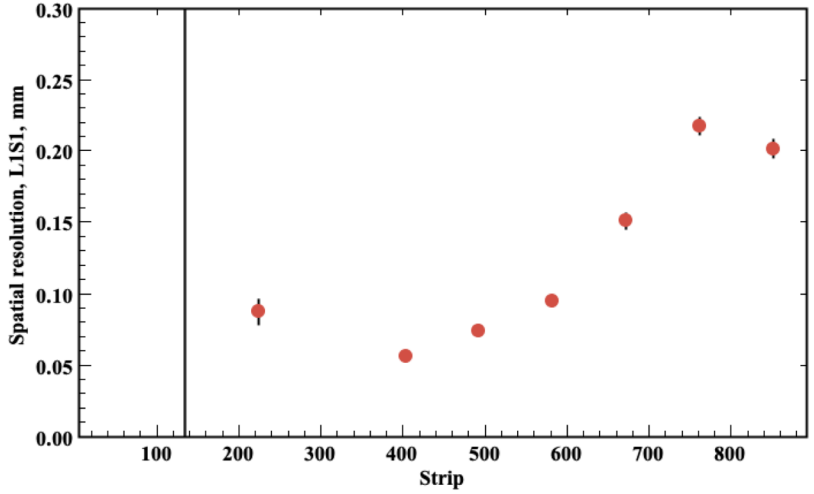



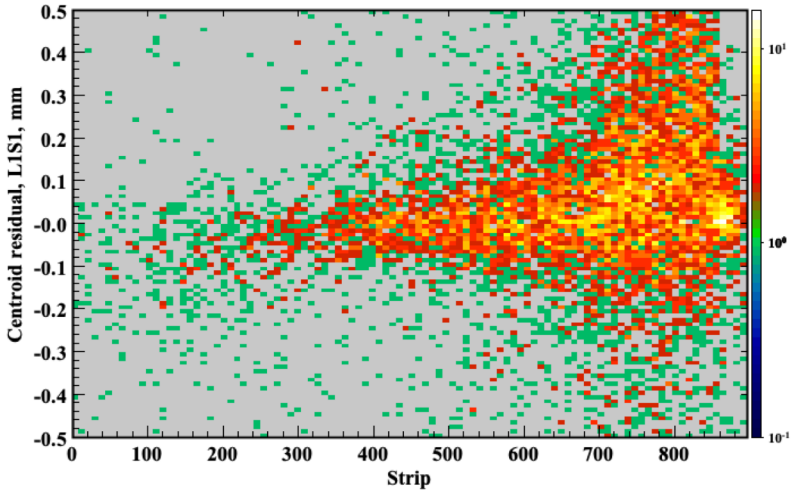



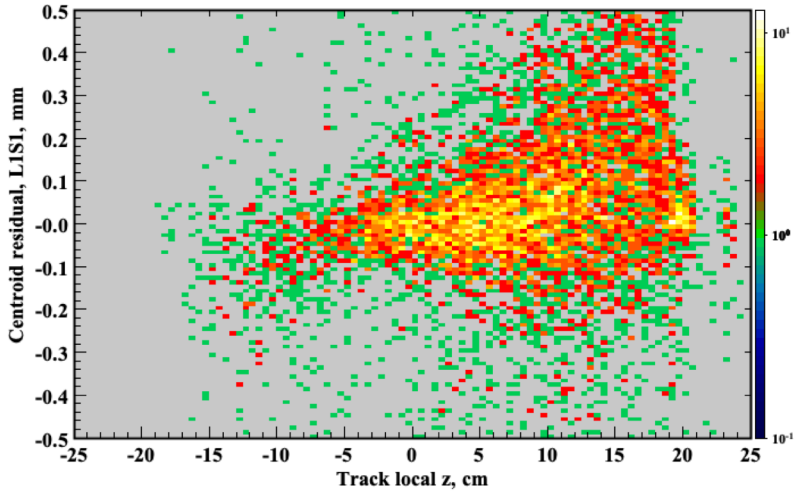
# CVT alignment run 6342, BMT-C residuals (CVT reco, TracTools-ExLayr) [Yuri]

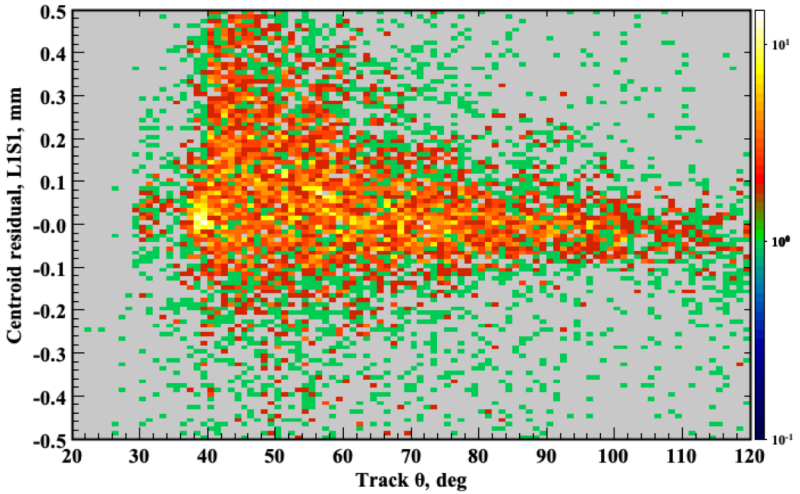


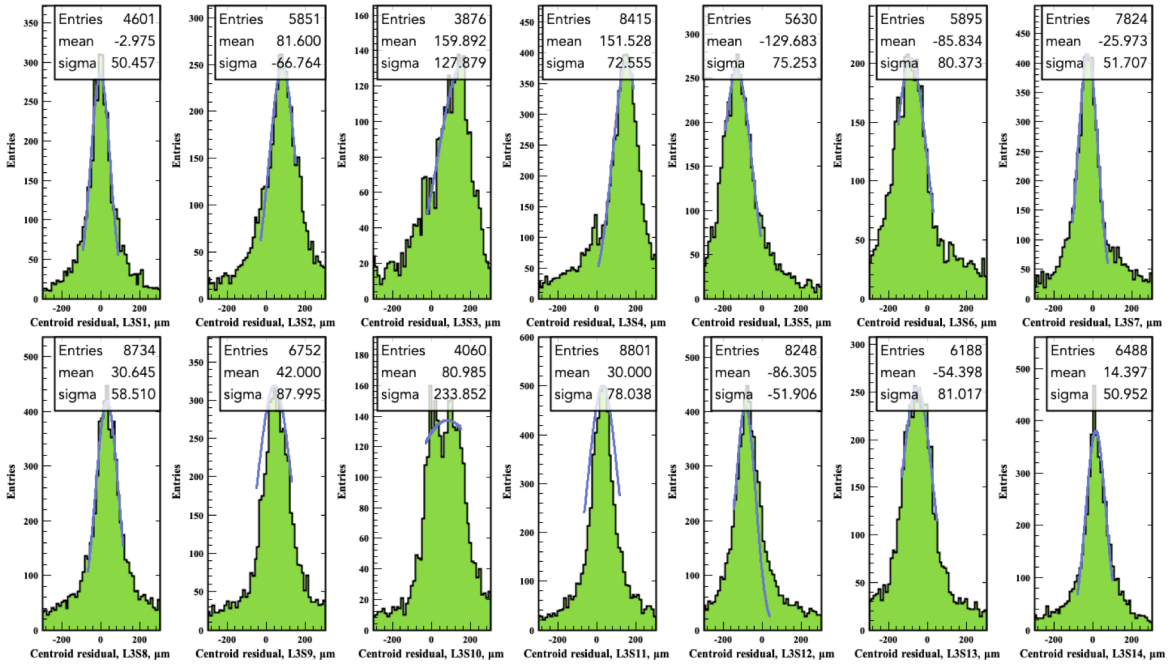



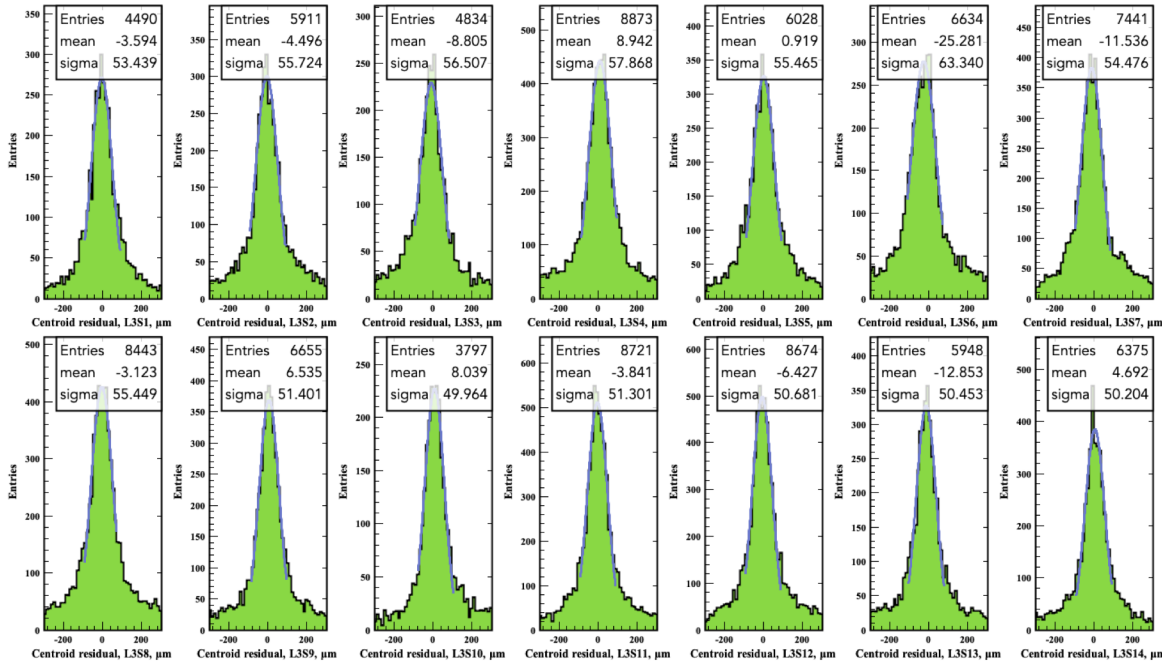



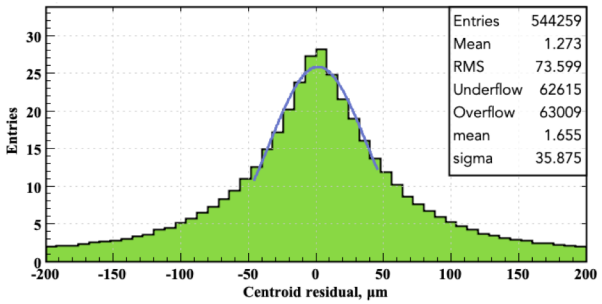



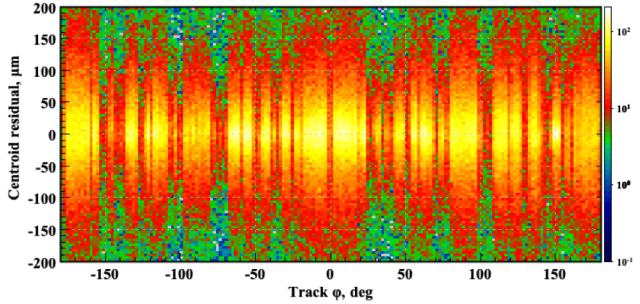



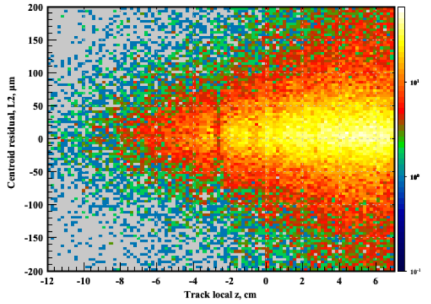
# CVT alignment run 6342, SVT residuals (CVT reco, TracTools-ExLayr) [Yuri]

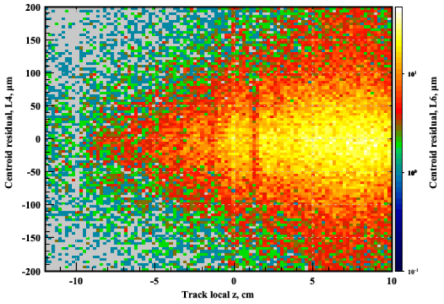


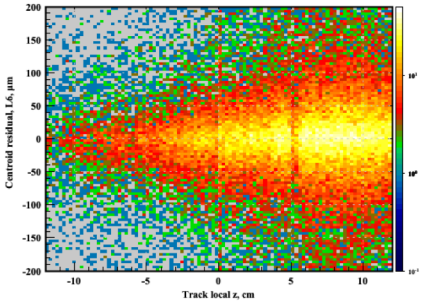



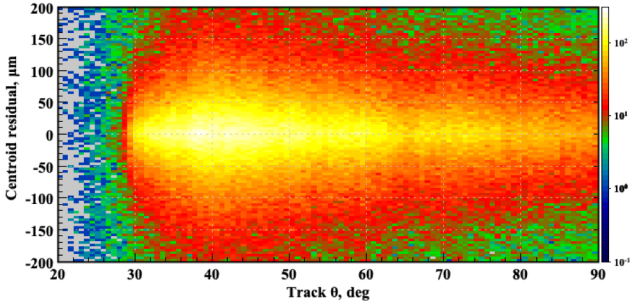



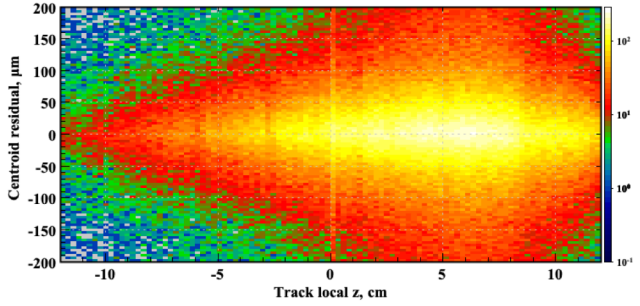



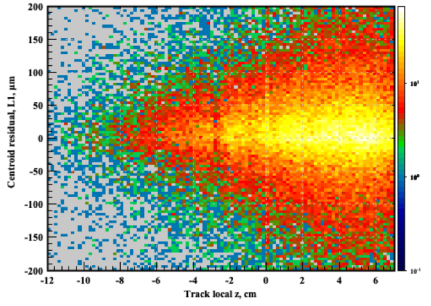



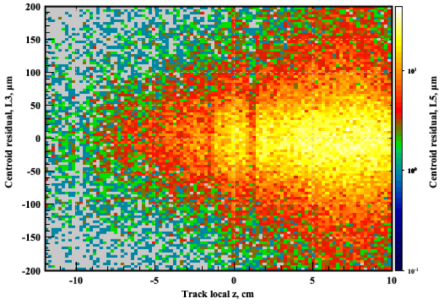



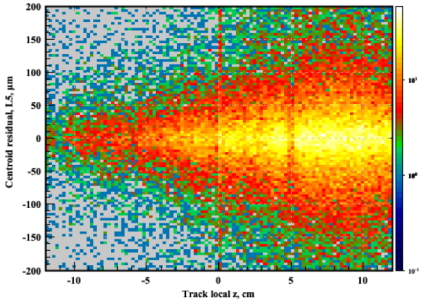



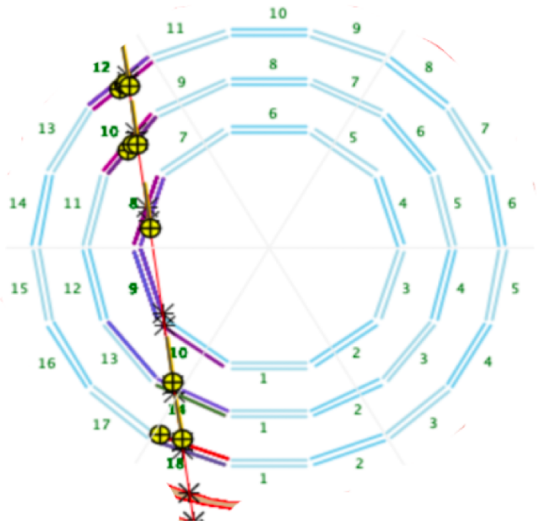



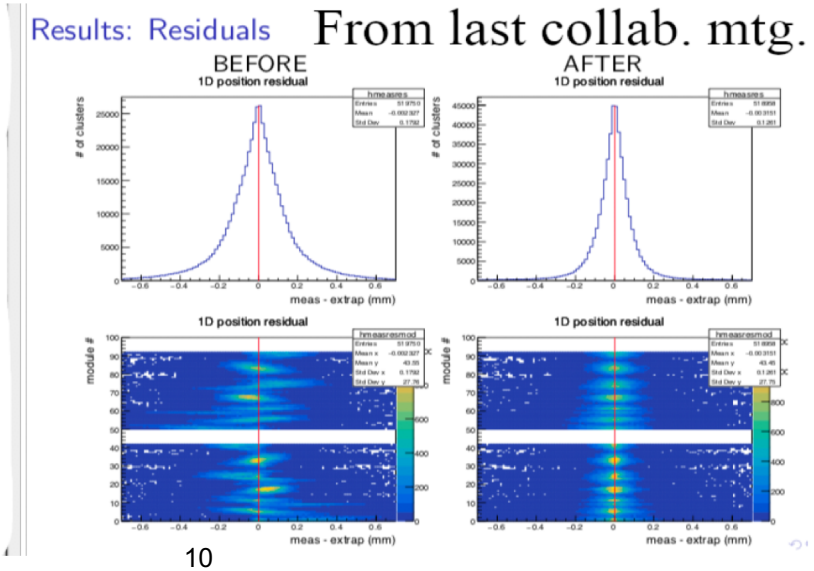



# Alignment Studies (Sebouh)

## CVT Alignment with Kalman Filter: Status (1/2)

- We revived an abandoned Kalman-filter alignment (KFA) program developed by the LHC to use with the CLAS-12 CVT
- We then developed an interface between the clas12 data and the KFA program.
- We used the KFA program to align the SVT internally using only cosmic tracks, greatly reducing residuals, we have shown in the previous collaboration meeting.





# Alignment Studies (Sebouh)

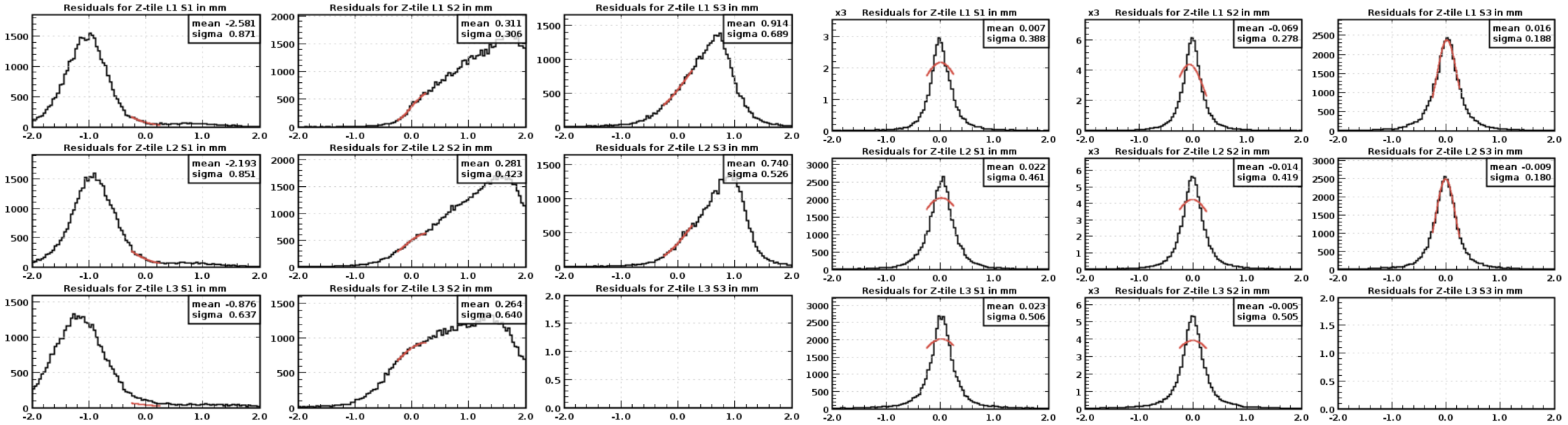
## CVT Alignment with Kalman Filter: Status (2/2)

- Since then, we've expanded our interface between CLAS12 data and the KFA program to include the following "alignables"
  - BMT
  - relative position of detectors to beam.
- We attempted to use the SVT internal alignment obtained from cosmics as a starting point for SVT+BMT alignment and alignment of field-off tracks from the target, however this hasn't been successful
- Further optimization, and bias removal is needed in order to get convergent results from the KFA for the full alignment.

# Alignment Studies (Maxime)

- Promissing results using MILLEPEDE code to align entire CVT (Top/Bottom layers of SVT treated independently)
- Steps
  1) reconstruction of cosmics + beam data
  2) PEDE is run on both datasets simultaneously

cosmic data




BEFORE ALIGNMENT

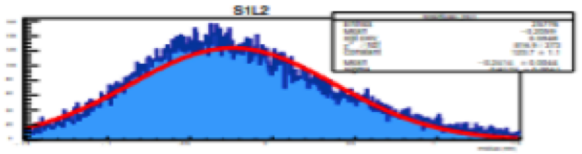
AFTER ALIGNMENT

# Alternative BMT Clustering and Lorentz Angle Correction (Maxime)

- Promissing results implemeting an **alternative clustering algorithm** to reduce sensitivity to Lorentz effect in Micromegas
  - CCDB entries for Lorentz angles and HV values tested
  - Tests performed using SACLAY suite → new clustering to be merged into new tracking

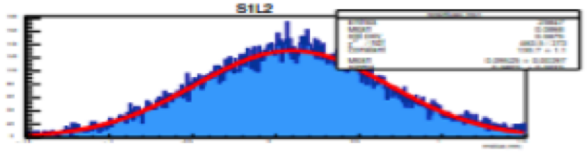
e.g. Run 5990
Representative tile

No alignment,
Old clustering:



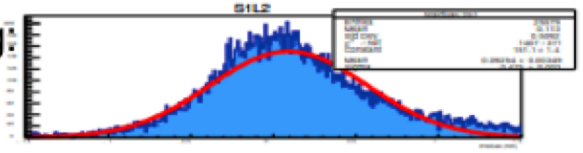

Mu = -0,2 mm
sig = 0,62 mm

Alignment :




Mu = 0,1 mm
sig = 0,55 mm

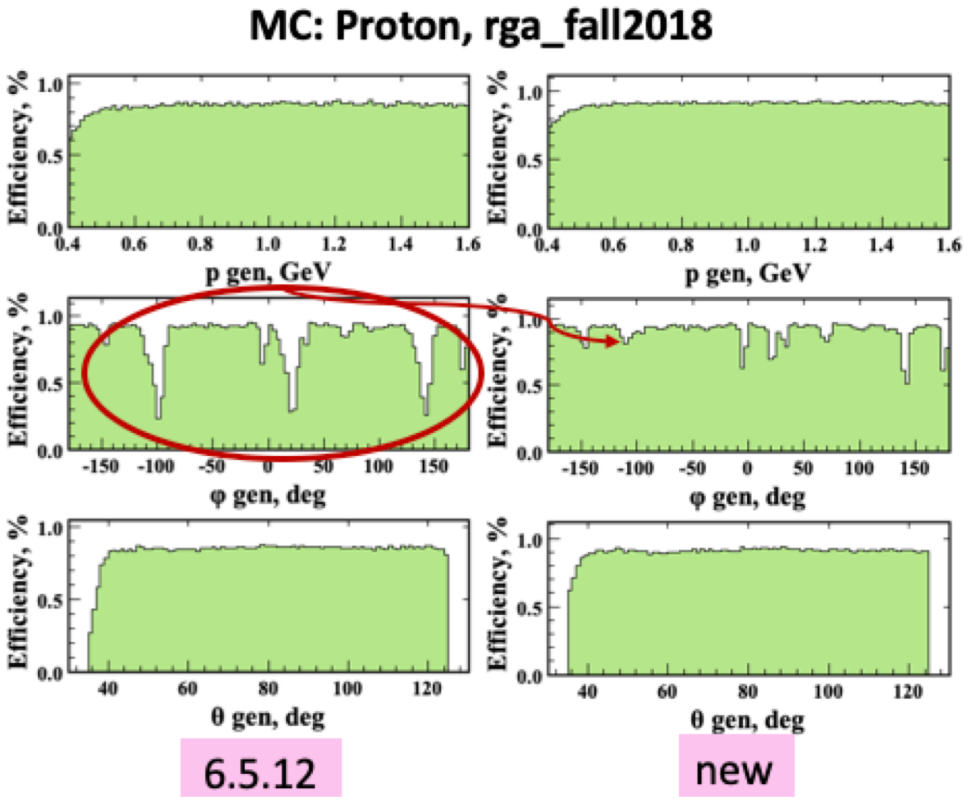
Alignment + new clustering:



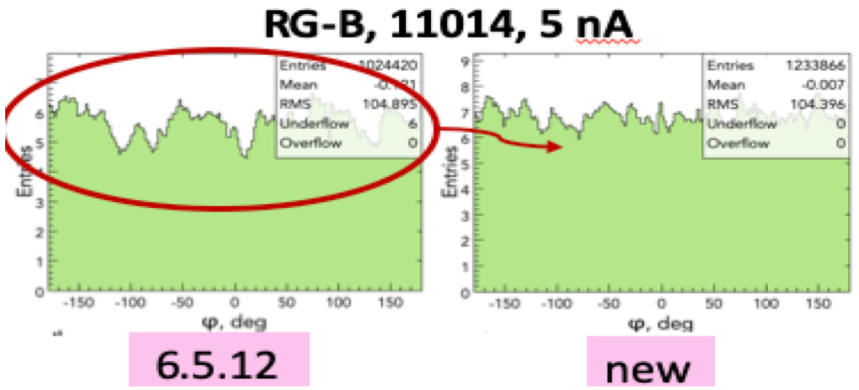

Mu = +0,1 mm
sig = 0,47 mm

# CVT Tracking Efficiency (1)

- Algorithm inefficiencies address → seeding improvements (SVT cross correction, hit matching, …)
- Secondary seeder to search for hits on track not identified by CA ➔ increase in reconstructed tracks




2nd algorithm for tracks passing through the BMT sector gaps



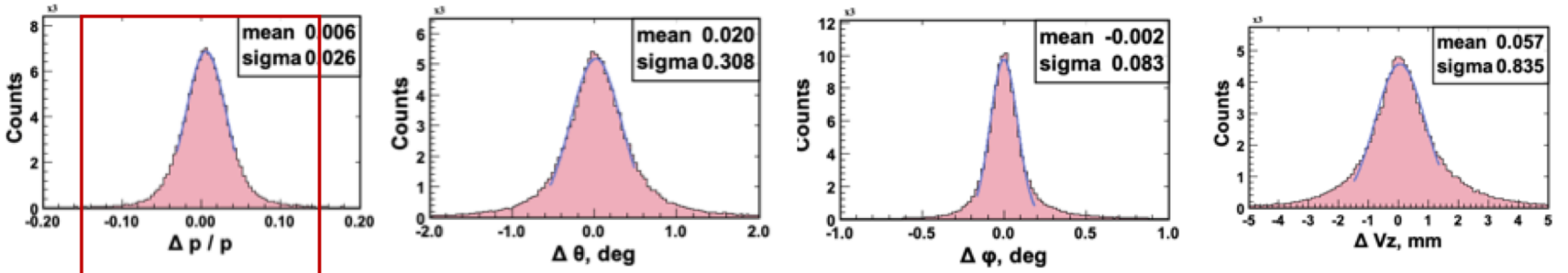
# CVT Tracking Efficiency (2)

- Efficiency drop at higher beam current → same sigma cut employed for all lumi. samples
- Ongoing work to improve the removal of ghost/split/duplicate tracks
- Ongoing work to improve seeding efficiency under high background conditions

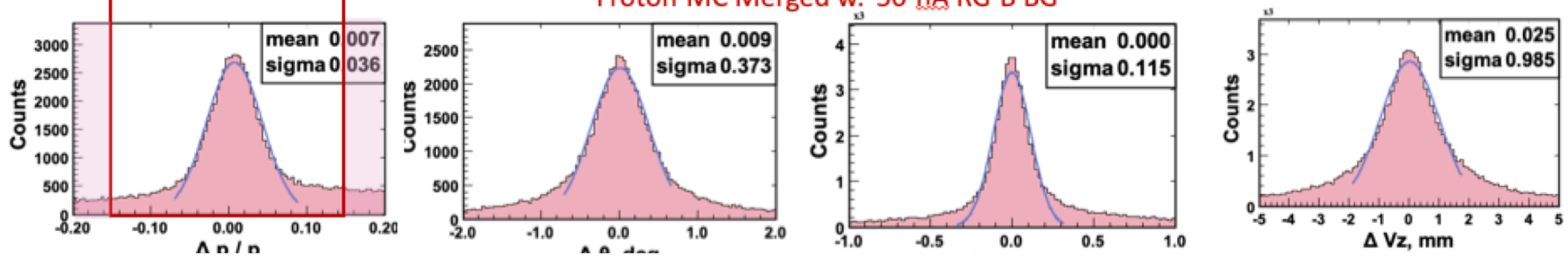
| BG merging | proton 0.4-1.6 GeV | with 45 nA RG-A BG | with 50 nA RG-B BG |
|---|---|---|---|
| Events with reconstructed tracks,% | 95 | 97 | 99 |
| passed 3σ cut (Δp/p=5% Δφ=5 mrad, Δθ=10 mrad), % | 91 | 71 | 58 |
| Δp/p resolution, % | 2.6 | 3.1 | 4 |
| Δφ resolution, mrad | 1.5 | 3 | 4 |
| Δθ resolution, mrad | 5 | 6 | 7 |

Momentum, angular, and vertex resolutions are within the specs

Proton MC



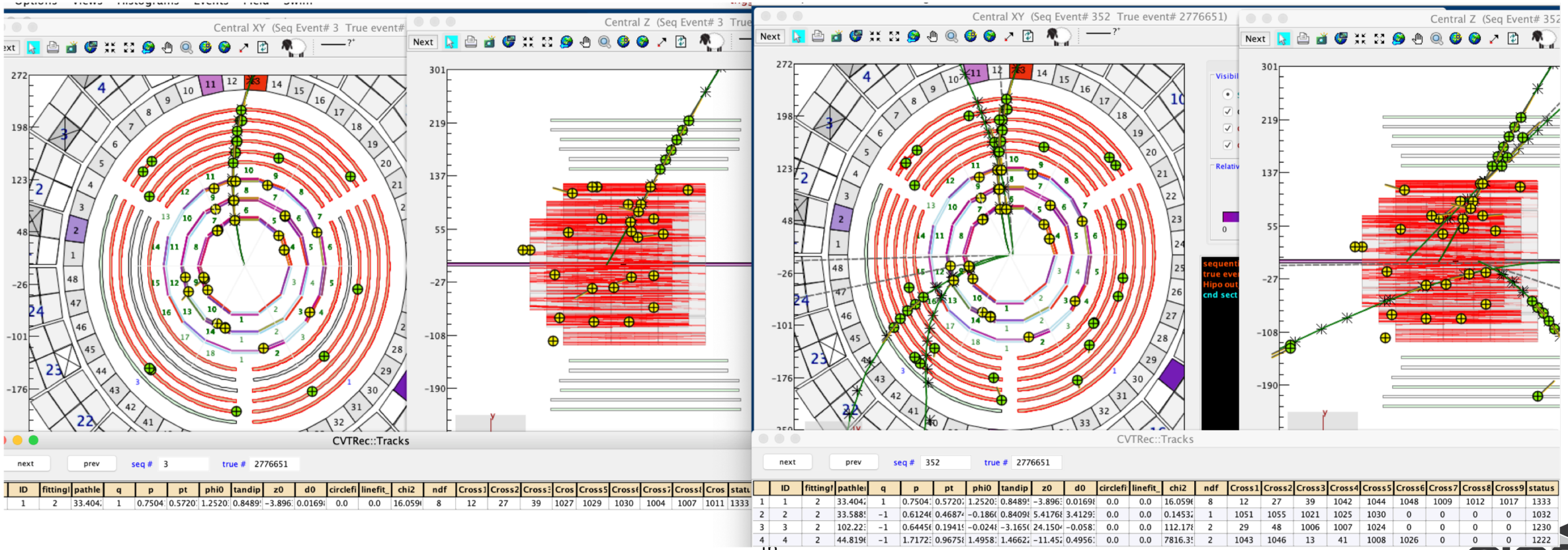

Proton MC Merged w. 50 nA RG-B BG



# CVT Tracking Efficiency (3)

- **Out-of-time background hit rejection**: for RG-B 50 nA data, hit occupancy reduced from 1.6% to 1.1 % while gaining 2%of CTOF+CND matched tracks using a 50 nA cut on BMT hit timing; SVT timing studies in progress (Yuri)

**Removing out-of-time BG (RG-B 50 nA)**



# Energy Loss in CVT Tracking Development

- Implemented Eloss class in Common KF package to compute Eloss thru material
  - Using Bethe Bloch
- Updated Surface class with fields and methods for material budget and thicknesses
- Modified KF to compute Eloss in state vector propagation (assumes chosen hypothesis based on MC for testing/debugging)

- Checking the implementation and studying effect on low momentum tracks.

# Reconstruction Remaining Tasks

- CVT Efficiency improvements
  - Study timing cuts (Yuri)
  - Further studies of seeding under high background conditions
- Complete E-loss package
- Check chi2 and covariance matrix
- Improve reconstruction speed
  - 5x5 matrix; remove Jama dependency and switch to jnp matrix
  - Code cleanup
- Implementation of new BMT clustering and Lorentz angle algorithm developed by Maxime
- Investigate remaining biases
  - Vz mean,
  - Top/bottom SVT modules shift offset (order of few microns),
  - Lorentz angle correction,
  - Cluster residuals (BMT)
  - Cosmic track reconstruction (residuals)

# BACKUPS

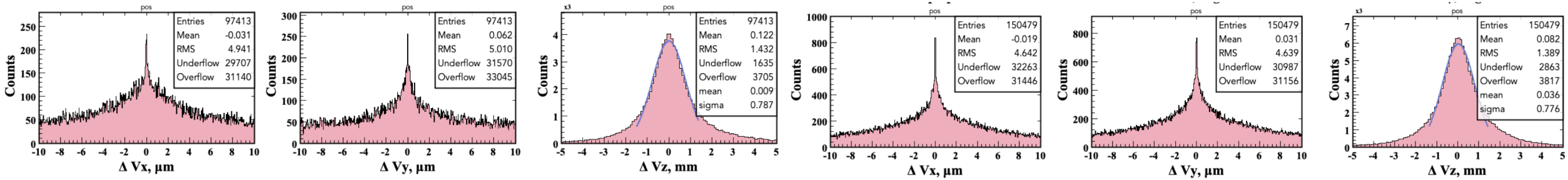
# Track Fitting - Generic Kalman Filter

- New Kalman Filter package included in track-tools (part of common tools in coatjava)
- Developed for any tracking in a solenoidal field (could be extended for torus)
- KFitter, StateVec, MeasVec classes do not have any ”built-in” geometry to propagate state vector to measurement sites, and to compute projector value and matrix.
- Surface class and surface Type enum to represent measurement surfaces and objects ➔ surfaces constructed to allow all translations and rotations degrees of freedom
  - Surfaces: planes & cylinders with measurement points, lines, strips.
  - Strips/clusters object with centroid, position and uncertainty on position
  - Projector computed as track doca to cluster line
  - Functionality to choose unit (cm, mm)
- Generic implementation of multiple scattering (process noise) in fit [implementation in Surface class]
- E-Loss package under development
- Ability to reject hits in fit (outliers)
- Can run on 0-T samples (tracks from target)
- Implementation for CVT
  - Computation of pseudo-line representing clusters in lab frame
  - CVT service creates surfaces (aligned to CLAS12) ➔ passed to KF in initialization

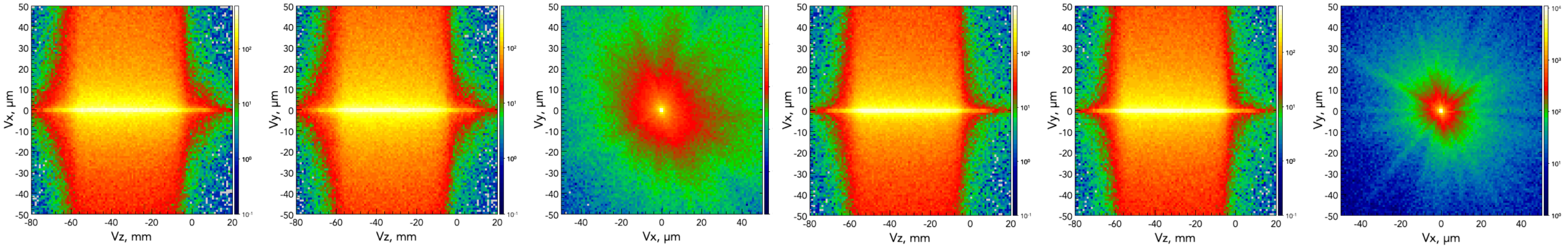
# Improvements: xy Vertex Resolution

6.5.12

new




**MC: Proton, rga_fall2018**




**RG-B, 11014, 5 nA**

# Improvements: Spacial Resolution

- MC (protons)
  - SVT residuals: 6.5.12: ~63 μm → 23 μm
  - BMT residuals
    - Computation fix
- Data: BMT alignment needed

SVT centroid residuals (RGB data) SVT standalone:
~60-45 μm w/o alignment, ~35-40 μm w alignment