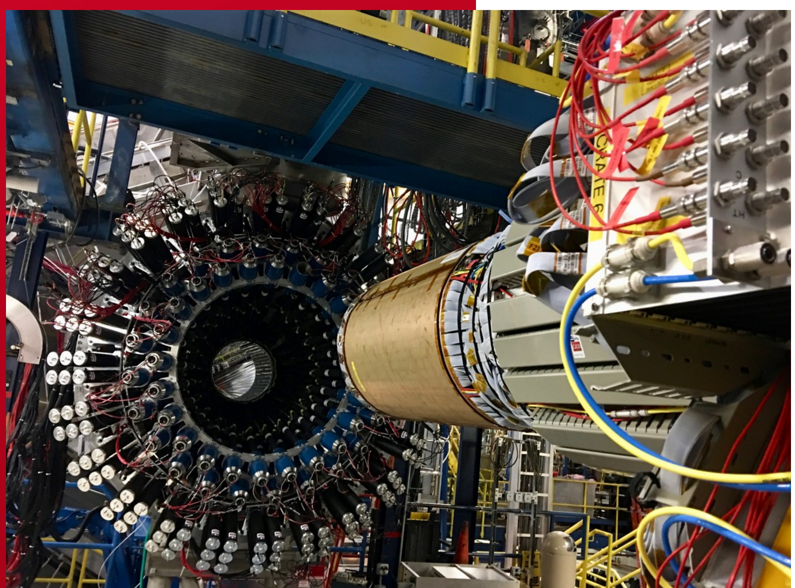
Tracking and Alignment status
Central **V**ertex **T**racker



On behalf of the CVT team:

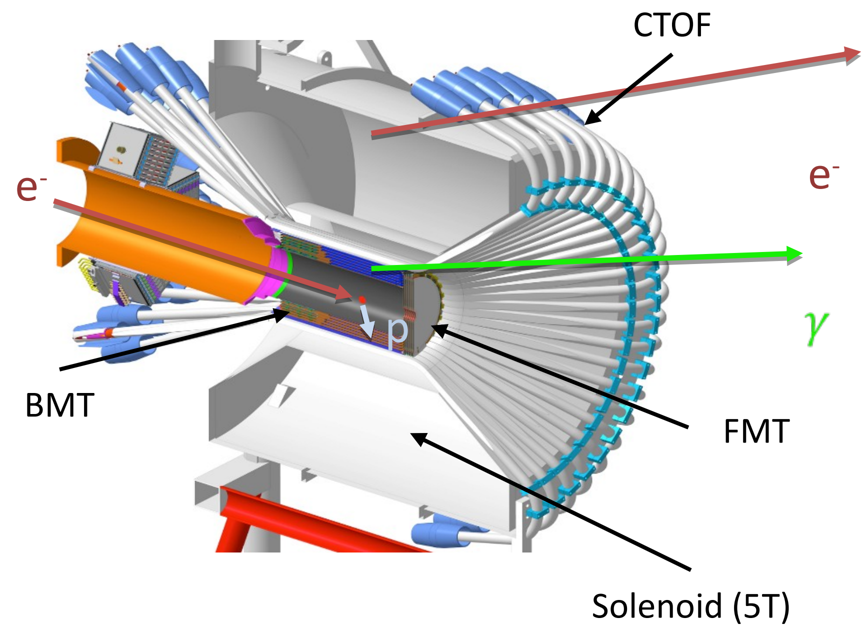
-Francesco Bossu
-Maxime Defurne
- Yuri Gotra
- Jerry Gilfoyle
- Veronique Ziegler
- Marouen Baalouch

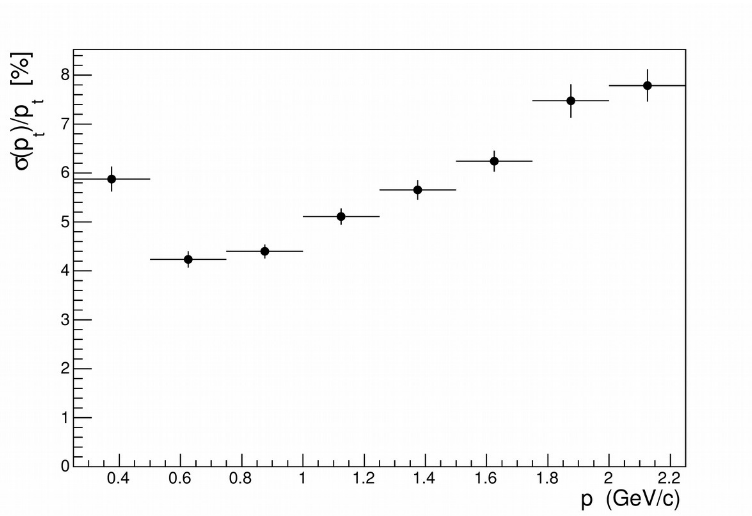
A central vertex tracker for CLAS12

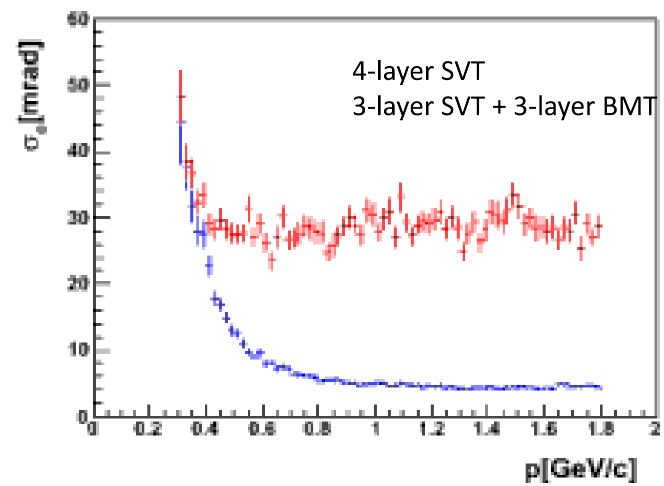
- B field: 5T solenoid field
- Two technologies:
  - Silicon strip detector: SVT
  - Micromegas tiles: BMT

- Expected performance:
  - 5% resolution on momentum at 1GeV/c
  - 5 mrad in azimuthal angle.
  - 5 mrad in polar angle.
  - vx and vy resolution at 500 um.

- Central Time-of-flight completes the tracker for particle identification.

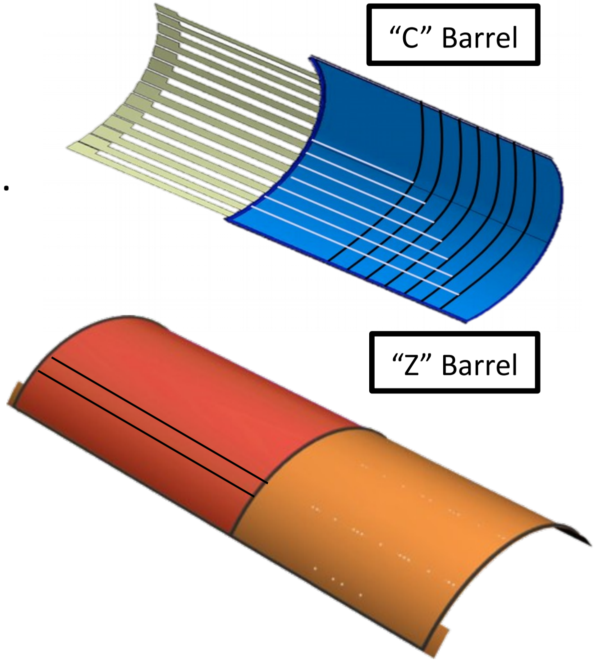


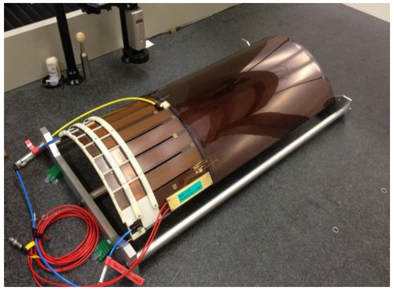


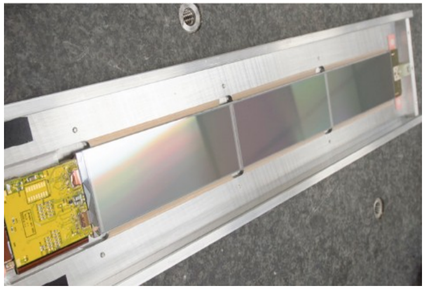


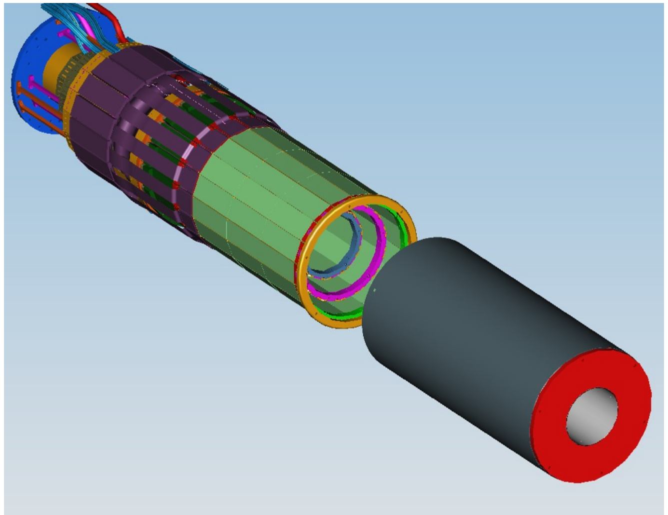
CVT description

- Barrel Micromegas tracker is made of 6 single layers with **radii from 140 mm to 225 mm**.
- Each layer is made of 3 tiles covering approximately 120 degrees each.
- There are two kind of tiles for the **azimuthal ("Z") and polar ("C") angle**.
- **Z-tiles** have a constant pitch of about **500 um**.
  C-tiles have a varying **pitch from 330 to 600um**.
- The Silicon Vertex Tracker is made of **three double layers**.
- Four regions were made but three are currently used in CVT.
- Strips on bottom and top have a **stereo angle**.
- Silicon strip pitch 78um, readout pitch 156-200um
- Spatial resolution is expected to be **50um.**
  CVT = A TOTAL OF 92 ELEMENTS with 3 different geometries

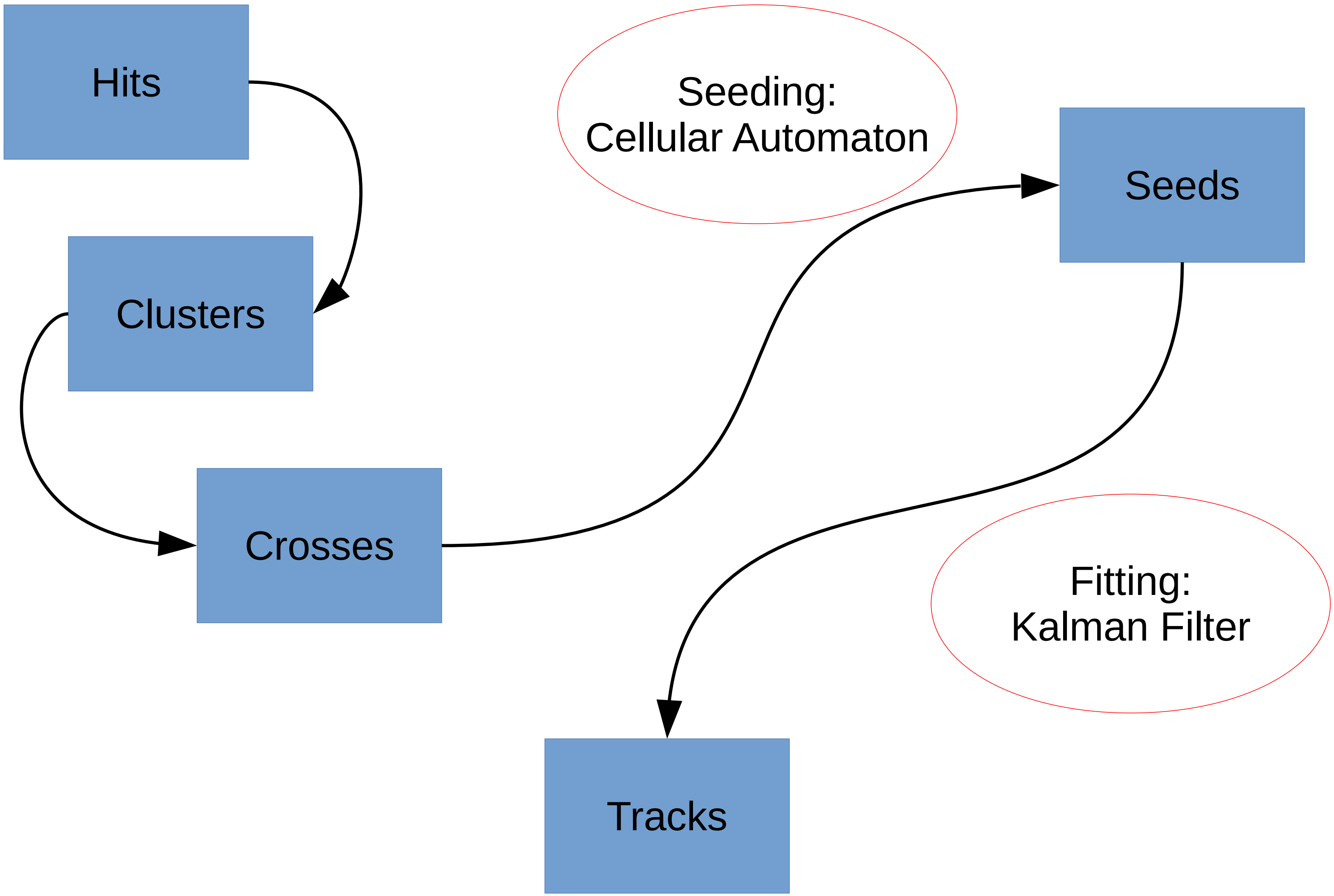








Tracking algorithm

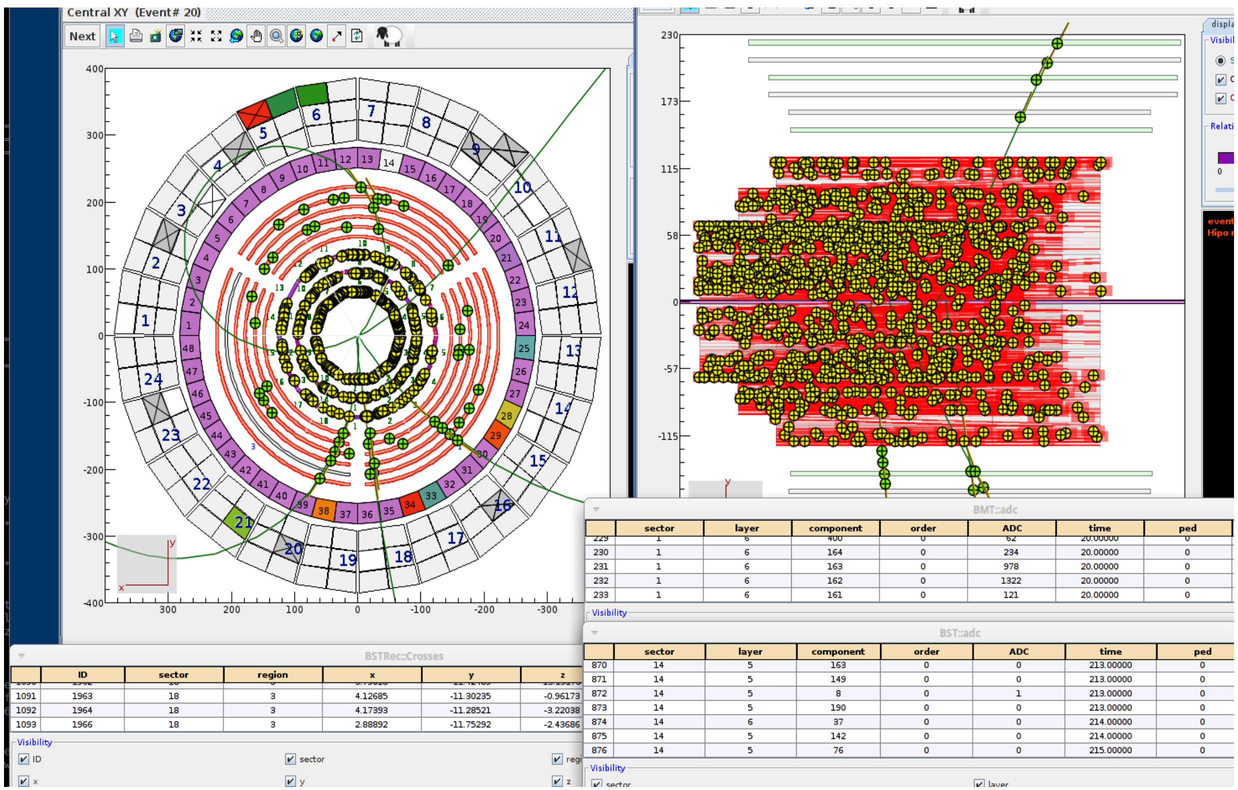


High occupancy events

Very rare high occupancy events dramatically slow down CVT

- With cut at #hit In SVT < 1000
- Still more than 1000 crosses created
- Many events skipped, though on average ~25s/ev

- Decision to implement tighter cut:
  - **#svt hits < 700**
  - **#svt cross < 1000**



<u>Worst case example</u>
Run 2327: Jan 2018
I = 120 nA
No tungsten foil yet

In RGB, a negligible fraction of events is above the chosen cut

SVT Occupancy is 1% for RGA and 1.5% for RGB

Efficiency: background merging

Yuri

Data only approach based on Veronique's event merger code:

- Skim tracks from low luminosity run (5 nA)
- Skim Faraday cup and pulser trigger events from high luminosity (50 nA) run (no tracks)
- Filter both samples leaving only raw CVT banks
- Run event-merger
- Reconstruct output samples (same number of events):
  - 5 nA sample
  - 5 nA sample with merged background events
- Check event-by-event track matching using the cuts:
  - $\sigma_{\Delta p/p}$ = 10%, $\sigma_{\Delta\phi}$, $\sigma_{\Delta\theta}$ = 10 mrad (0.57 degrees)
  - Apply N*σ cuts and calculate percentage of the tracks matched in both samples

N	Matched tracks, %
3	62
4	64
5	67
10	74
100	91

Efficiency: background merging

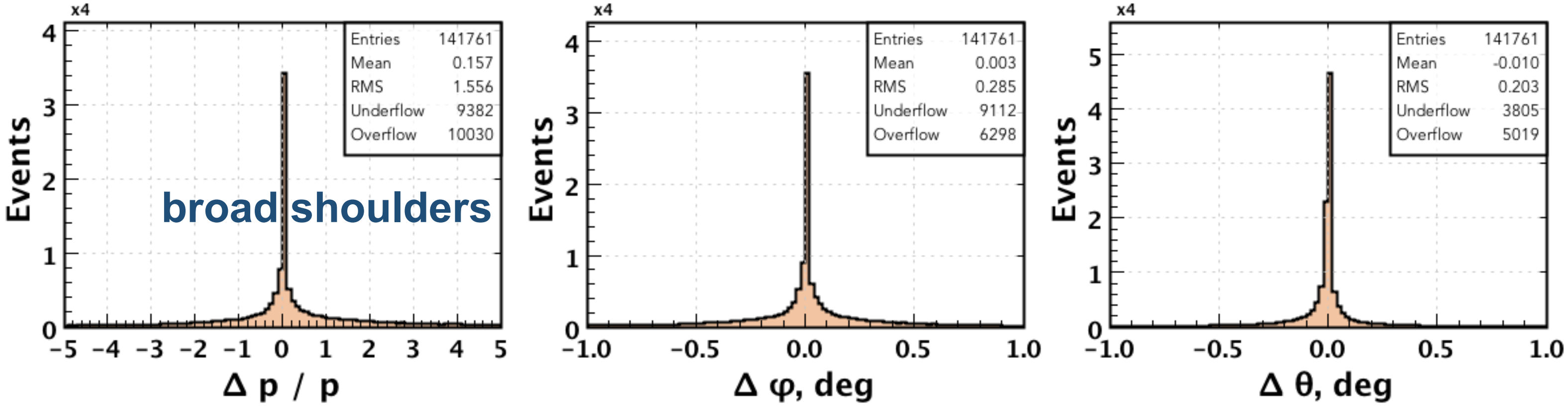
Yuri

- **99% of 5nA tracks are reconstructed even with high 55 nA background**
- Background hits cause substantial degradation of resolution
- Due to lower track quality (loosing BST crosses)
- Mitigation:
  - change seeding algorithm to keep lost BST crosses in seed candidates
  - To be carefully validated as can increase CVT reco time
  - Assess why fits to seeds with lower NDF may give very different pars
  - Switch from BST crosses to BST clusters in seeding (requires more studies)
  - CVT alignment would help to select the good seeds

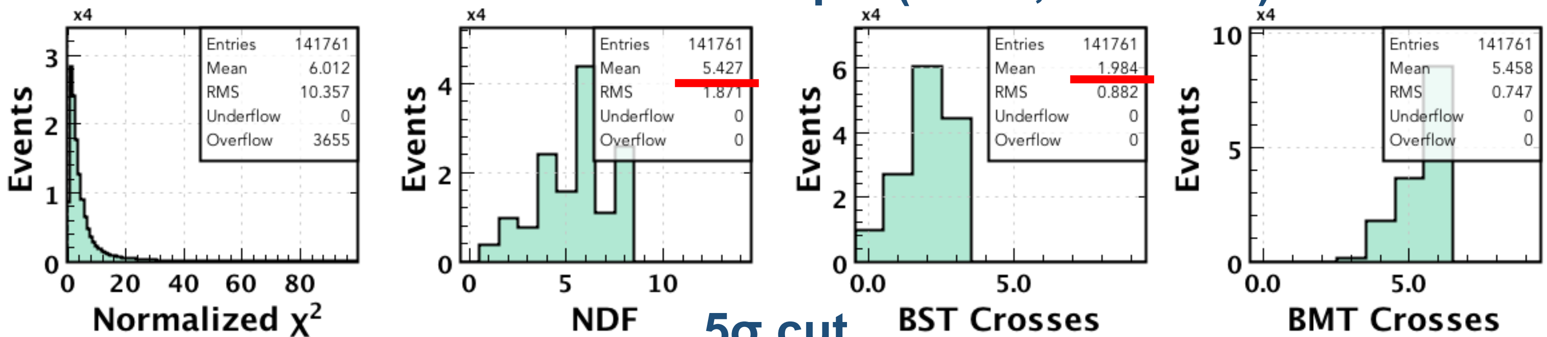
N	Matched tracks, %
3	62
4	64
5	67
10	74
100	91

Efficiency: background merging

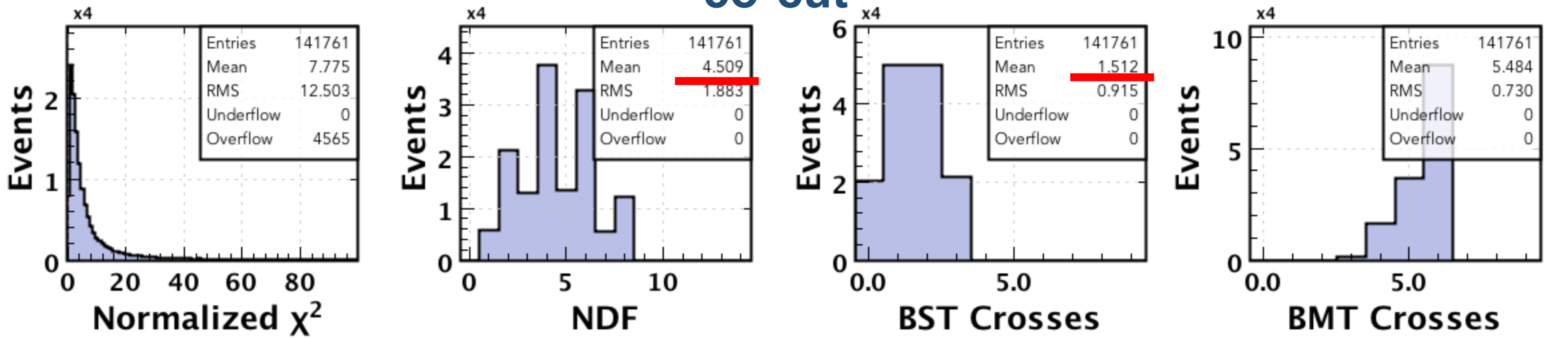
Yuri



5 nA sample (RG-B, run 6371)



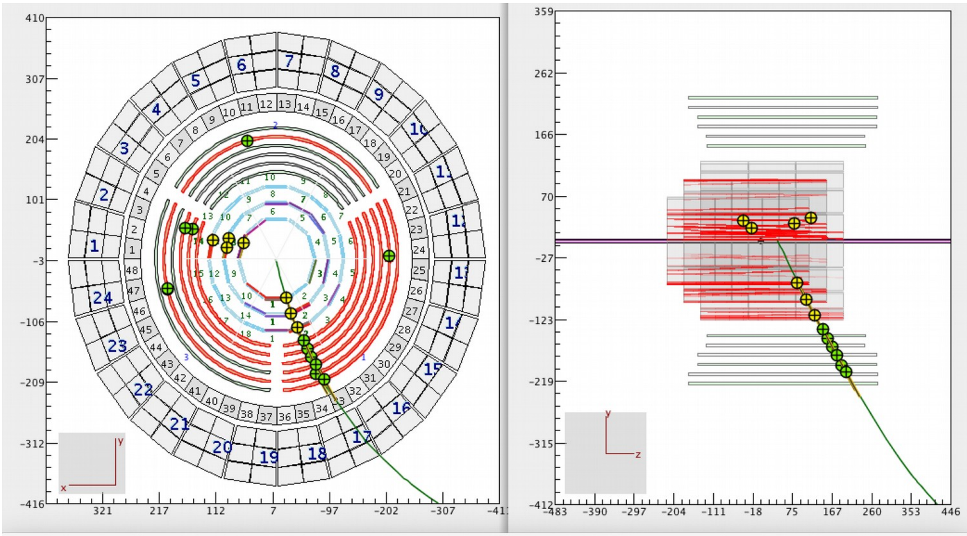
5σ cut



5 nA sample with 50 nA background merged (runs 6367, 6368, 6369)

Efficiency: background merging

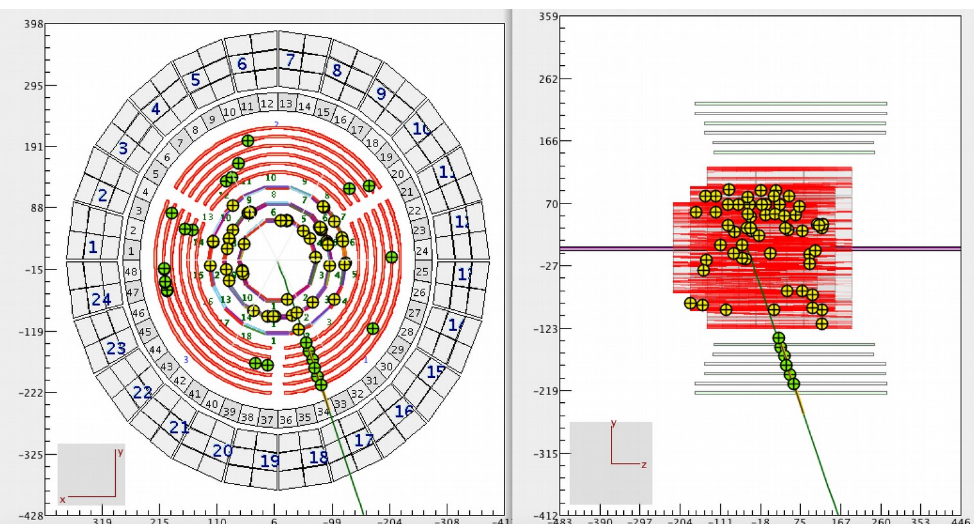
Yuri



	ID	pathleng	q	p	pt	phi0	tandip	z0	d0	chi2	ndf	Cross1_I	Cross2_I	Cross3_I	Cross4_I	Cross5_I	Cross6_I	Cross7_I	Cross8_I	Cross9_I
1	1	22.40224	−1	1.25032	1.01660	−1.80145	0.71601	3.99871	0.15178	527.7097	8	1	2	3	1010	1012	1013	1001	1002	1004

5 nA sample

NDF = 8, 3 BST on-track crosses



	ID	c_uz	pathlen(	q	p	pt	phi0	tandip	z0	d0	chi2	ndf	Cross1_I	Cross2_	Cross3_	Cross4	Cross5_	Cross6_	Cross7	Cross8_ID	Cross9_ID
1	1	75.566!	26.65267	1	17.52131	15.80801	−1.94409	0.47803	−4.85027	0.07441	85.20484	2	1024	1028	1040	1001	1002	1005	0	0	0

5 nA sample with 50 nA background

NDF = 2, no BST on-track crosses

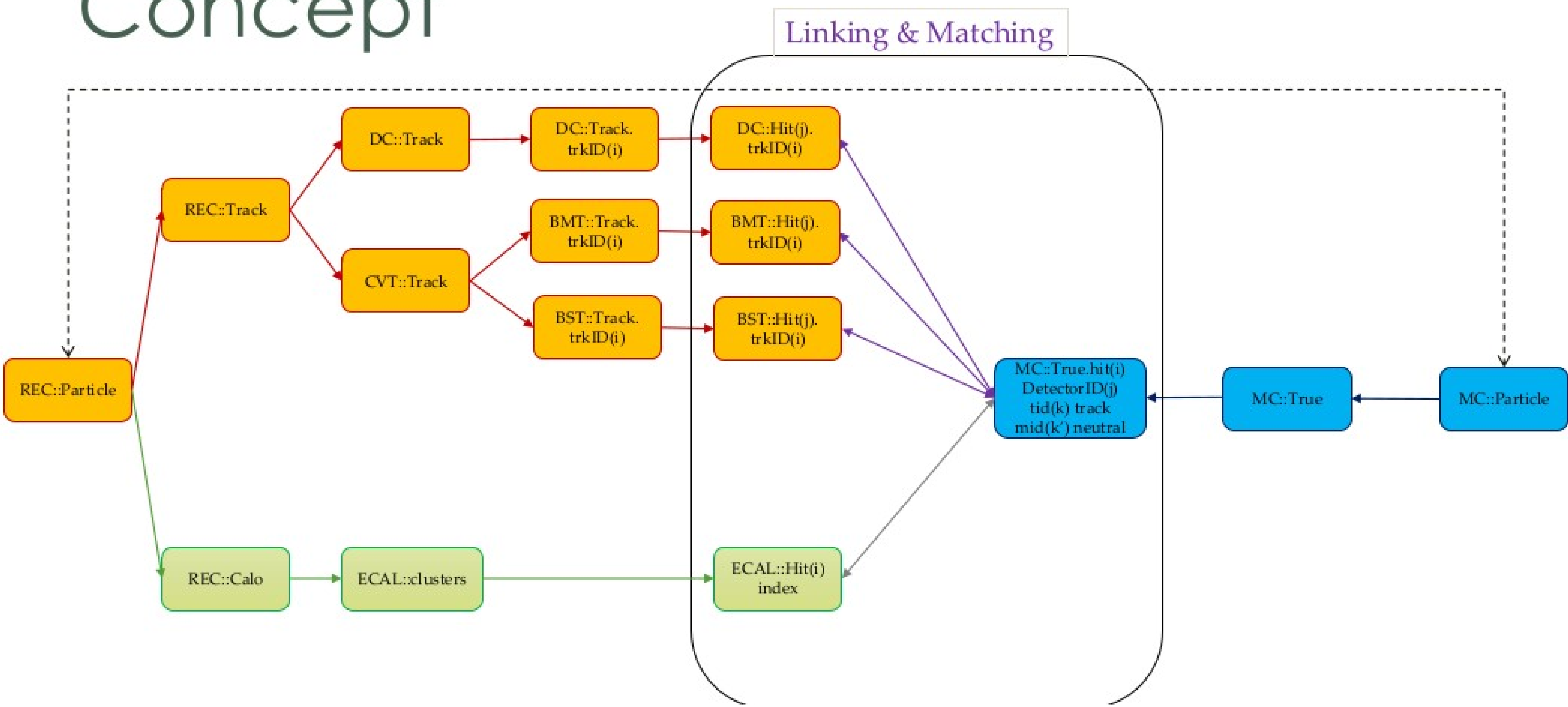
M. Baalouch

Purpose of Monte Carlo Matching

- Study and test the reconstruction.
- Helps to update the reconstruction algorithm (e.g. smearing the detector response to be more realistic).
- Measure efficiency.
- Measure the resolution.

M. Baalouch

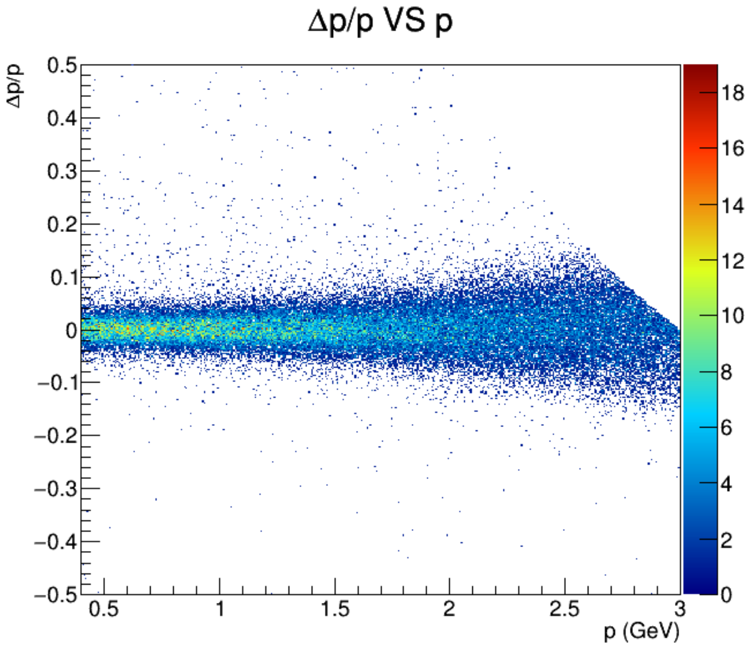
Concept

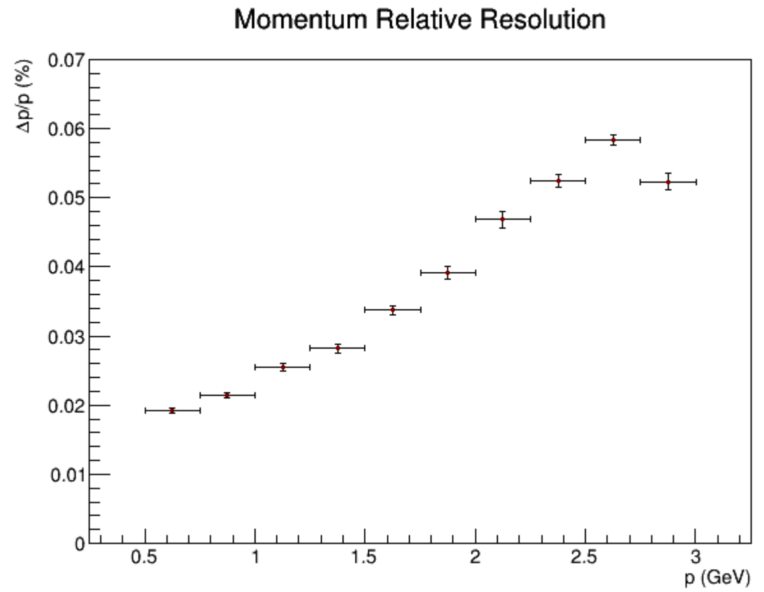


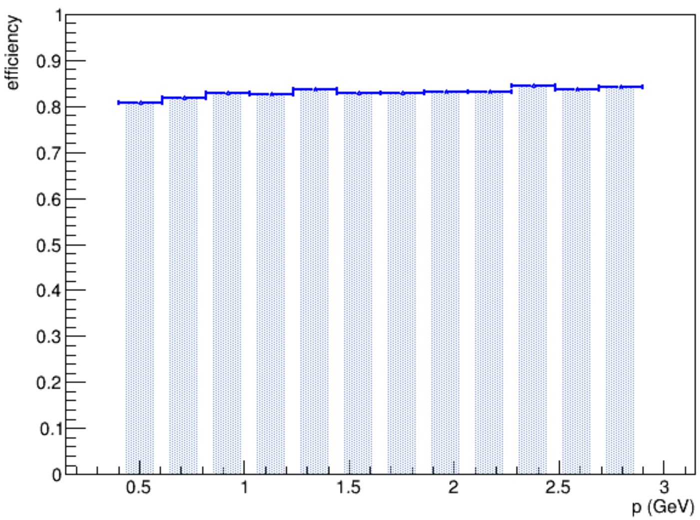
Criterion of track matching based on fraction of MC hits used the reconstruction

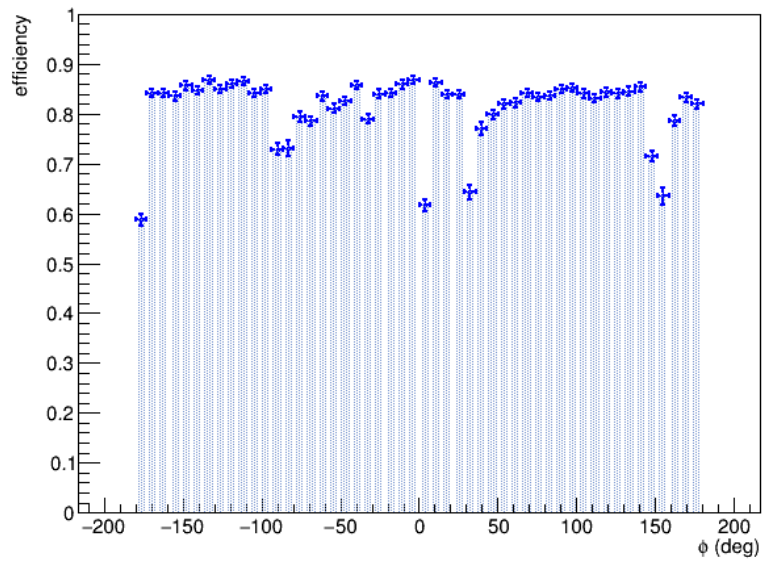
Monte Carlo hit based matching

M. Baalouch



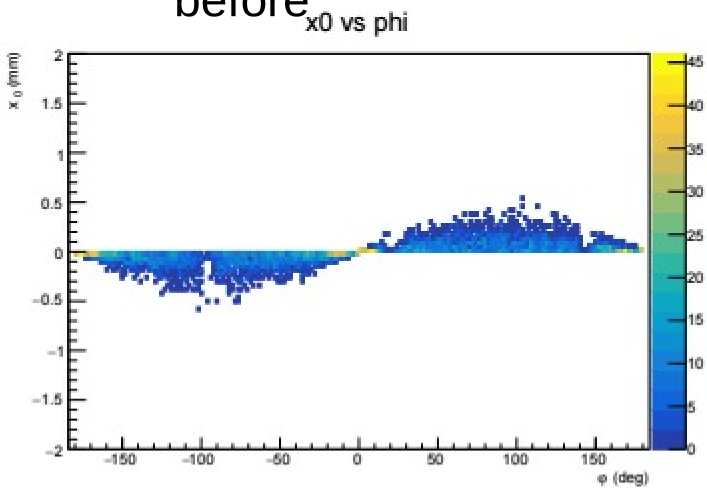


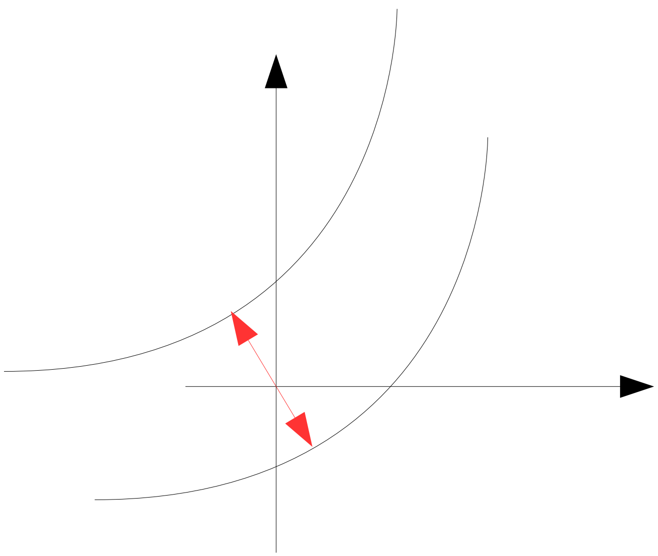




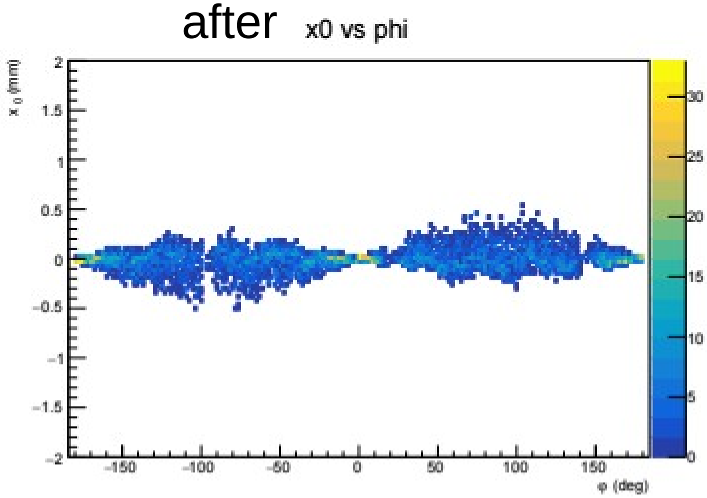
- Distance of closest approach was unsigned
- Resolve degeneracy in x,y position of vertex

before



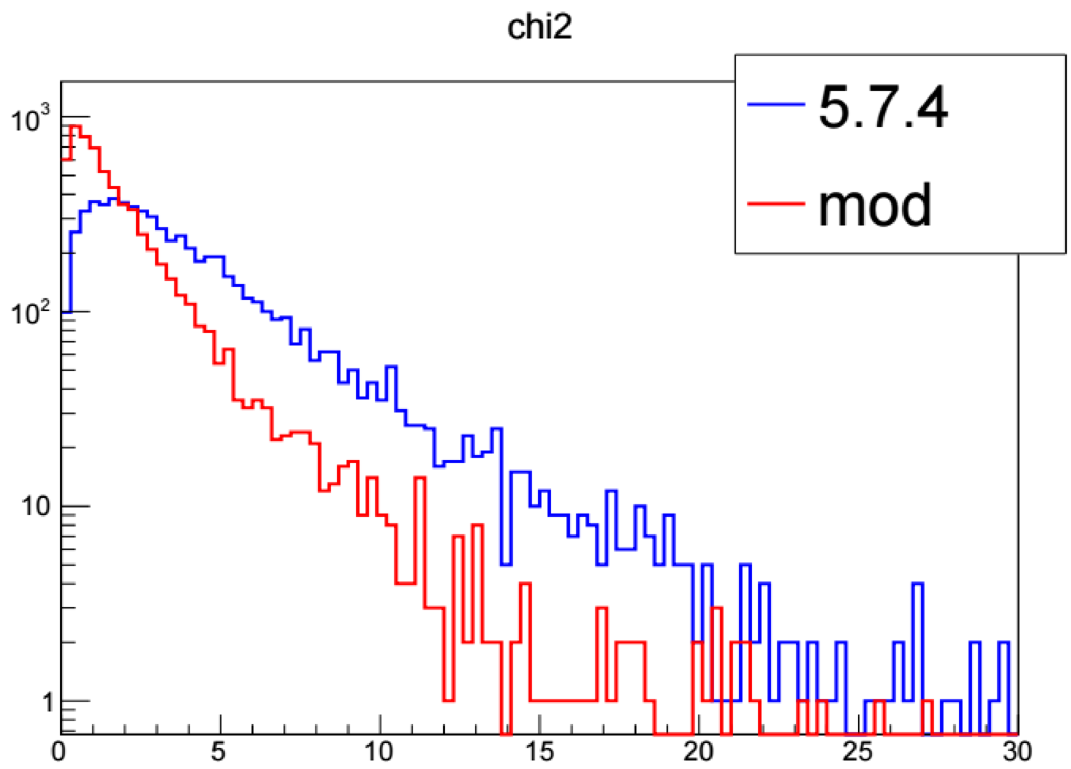


after



- Chi2 was not correctly assigned at the end of the Kalman fitter

- Now sharper distribution.
- It also helps in keeping the best tracks when removing clones



Alignment

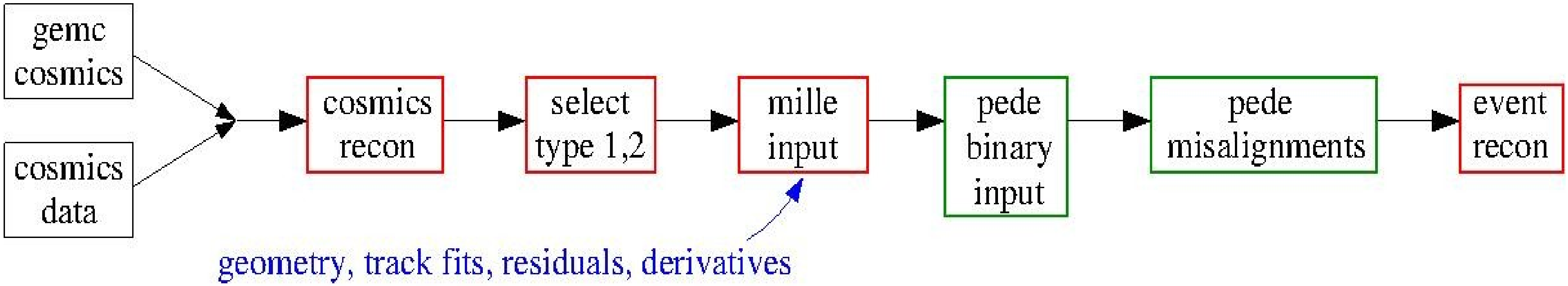
Two independent approaches:
- Millepide based
- Iterative method

- Alignment data (0-field run and cosmic) currently being organized in time-period to extract all alignment constants up-to-now.
- CCDB tables for alignment constants in /test/mvt and /test/svt for MC and regular data.
- MVT geometry code modified to load and use alignment constants. Still in progress for SVT for the iterative method.
- To get the best out of the alignment, we need to completely validate CVT tracking code

Track-based (Millipede) SVT alignment

Jerry

- Track-based alignment of SVT requires many parameters - up to 792.
- Program **millepede** does linear least squares with many parameters.
  - Matrix form of least squares method.
  - Global parameters - the geometry misalignments. Same in all events.
  - Local - individual track fit parameters. Change event-to-event.
  - Requires first partial derivatives of residuals with respect to the local (fit) parameters and global parameters (geometry misalignments).
- Analysis chain: red boxes - Java; green boxes - C ++ .



- Full chain has been tested and validated using *gemc* simulation and cosmic data for simplified case (Type 1 events – only horizontal sensors).
- Recent improvements in the CVT reconstruction have restarted the application of the **millepede** algorithm to more event types.

Procedure for alignment

Maxime

- Step 1: Find Tx, Ty, Tz and Rx, Ry, Rz (6 parameters) to align MVT frame and SVT frame.
  => Correct for major misalignments expected between the two subsystems… Speed up convergence.

- Step 2: Exclude 1 tile or 1 module from the tracking.
  Then try to find rotations and translations to decrease residuals of the excluded elements.
  This step should be iterated until rotations and translations don't change any more.

  To align one detector, you take into account the results of the detectors previously aligned.

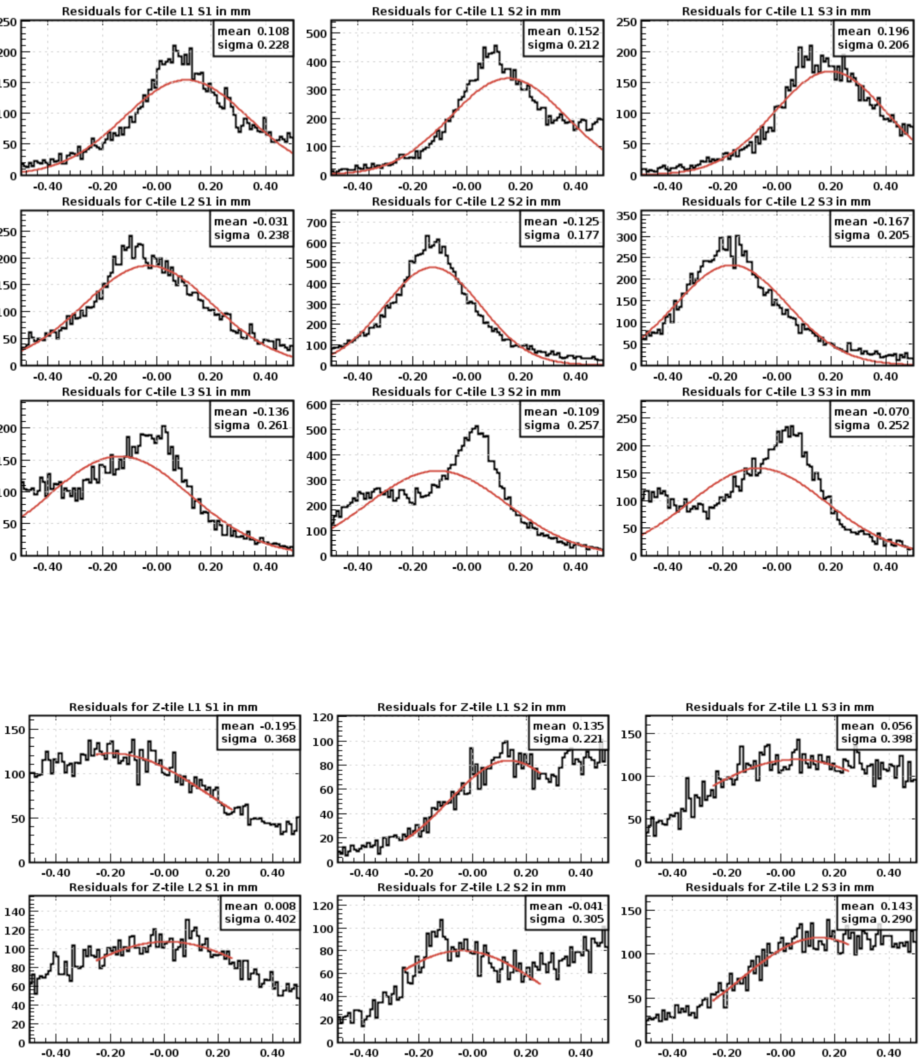
- Step 3: In step 2, both layers of a SVT module are moved together. But top and bottom layers can be misaligned.
  Try to find one translation to align both layers.
  A second iteration might be required.

- Results shown later are still preliminary. A few translations/rotations are still **forbidden**
  -BMT-Z tile: The **translation along the z-axis** is forbidden because in the direction of the strips.
  -BMT-C tile: The **rotation along the beam axis** is forbidden for same reasons.
  -SVT module: The translation along the z-axis is forbidden as well (but we will come back later on this point).

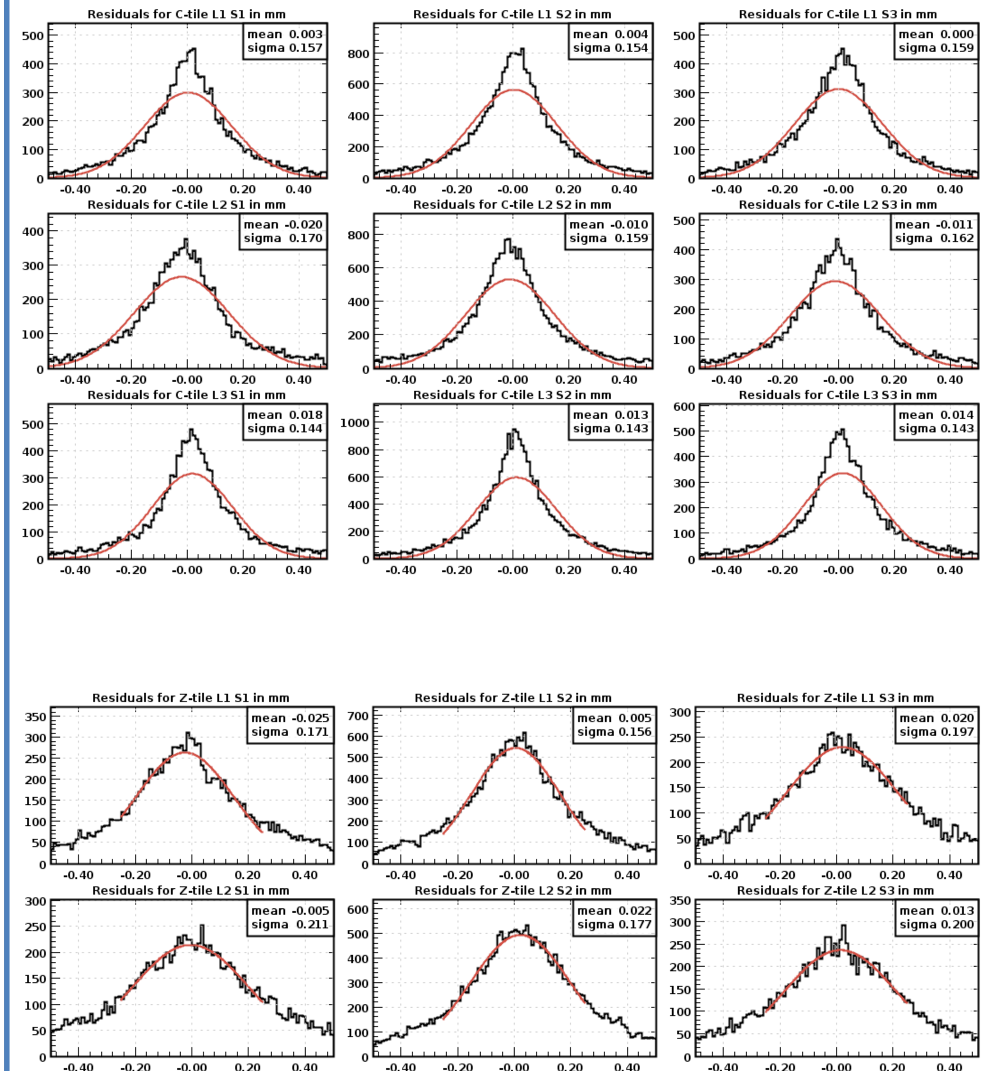
- Advantage: Easy to implement.
  Drawback: Time needed for convergence depends on the sequence in aligning the detectors.

Result BMT with cosmics

before

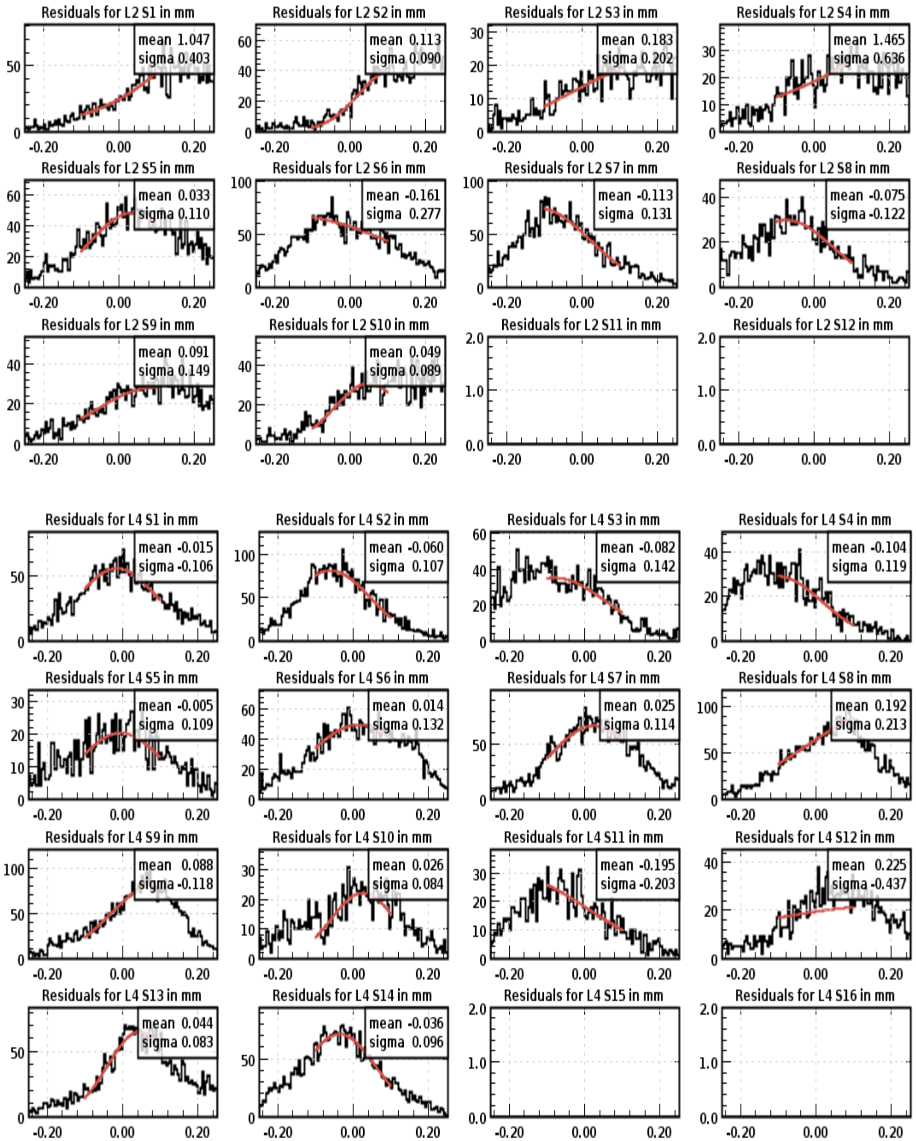


after

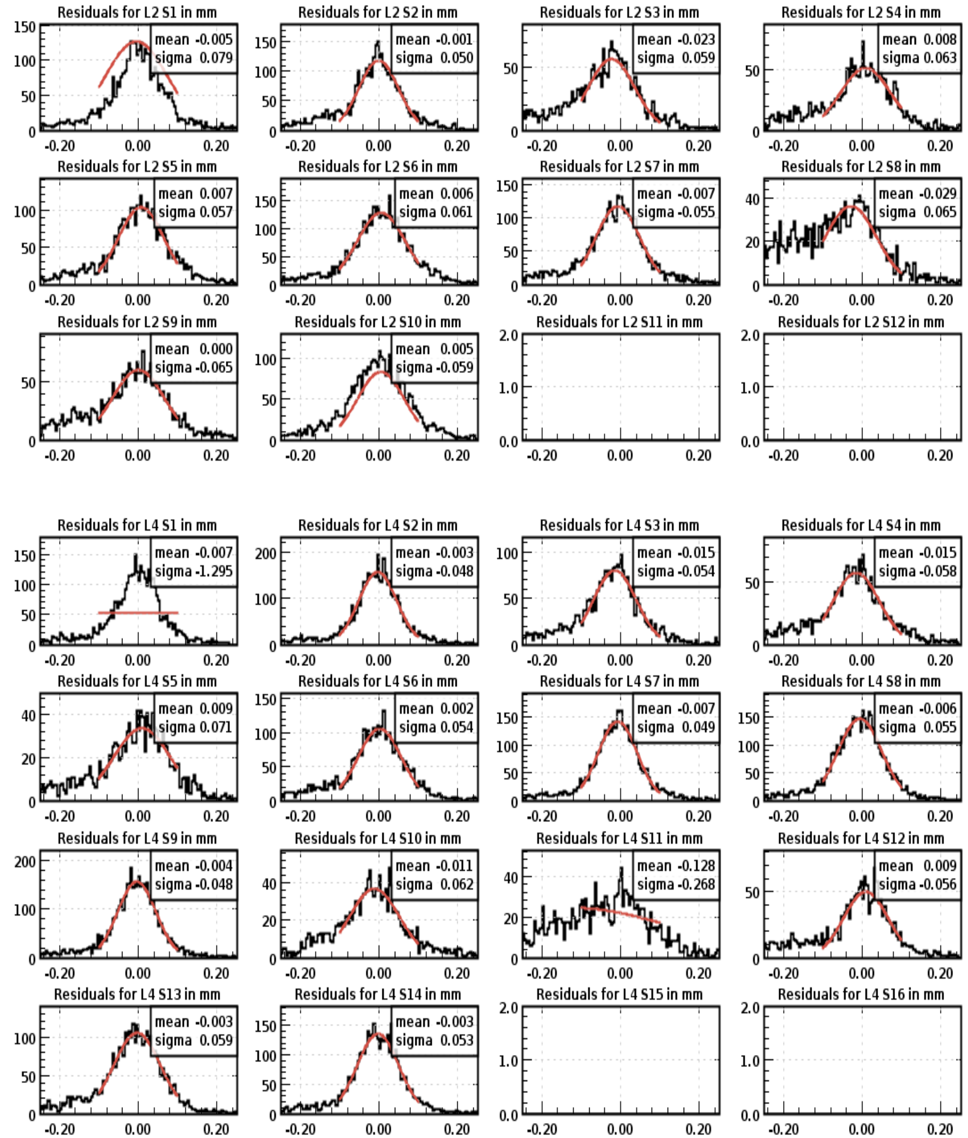


Result SVT with cosmics

before



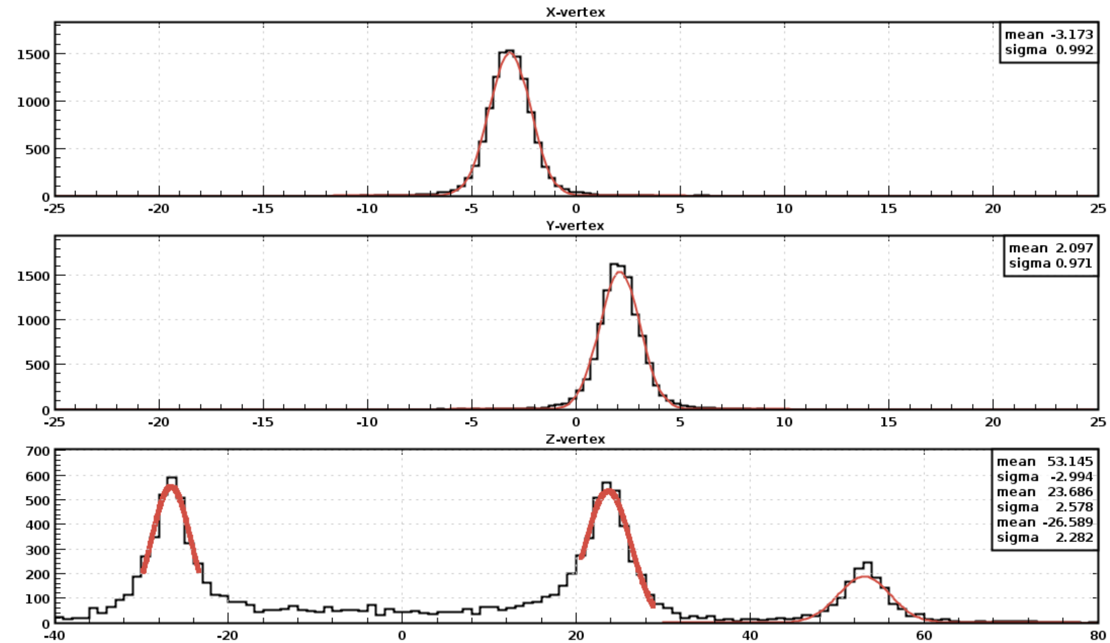
after



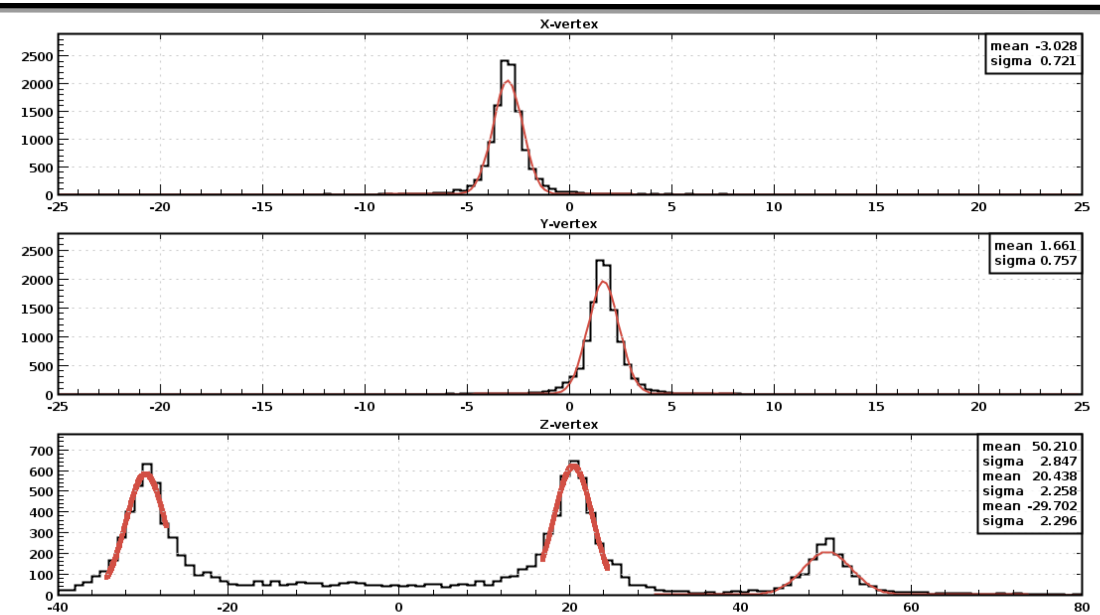
Vertexing improved as well

Beam position in CVT frame
Not the lab frame.

Before Alignment	
X-position	-3.173 +/- 0.992
Y-position	2.097 +/- 0.971
Upstream-z	-26.589 +/- 2.282
Downstream-z	23.686 +/- 2.578



After alignment	
X-position	-3.028 +/- 0.721
Y-position	1.661 +/- 0.757
Upstream-z	-29.702 +/- 2.296
Downstream-z	20.438 +/- 2.258



Target position quite sensitive to misalignment.

Helix vs misaligned detectors

- Alignment precision down to 10um. A challenge is to compute the intersection between helical track and tilted/displaced SVT and MVT with a 1um accuracy (especially for SVT)… Keeping a reasonable computation time.

- The helix is paramterized by the curvilinear abscissa.

- Step 1 : Find the abscissa s_i for the intersection between the Helix and the ideal detector.

  Step 2: The squared distance between Helix points at abscissa s to the cylinder has a parabolic shape close to the intersection a*s^2+b*s+c.
  With the squared distances of points at s_i, s_i-epsilon and s_i+epsilon (**In the det frame this time!**), we extract a, b and c. A better estimate of the intersection is then given at -b/2a.

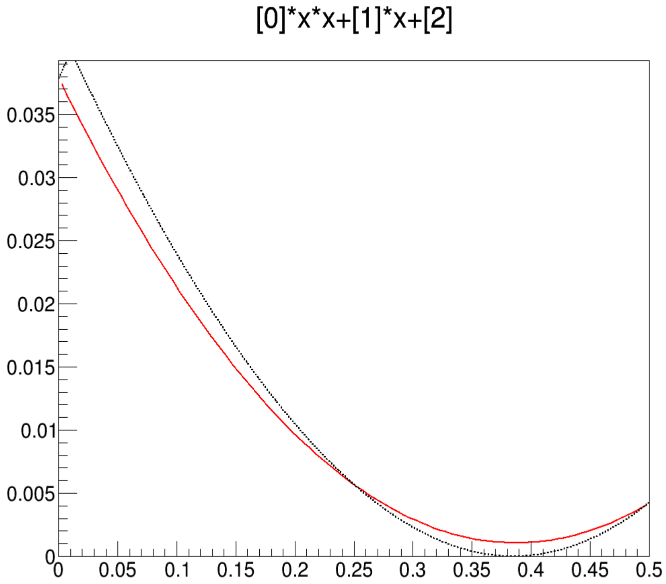
  Step 3: Iterate step 2 with updated s_i at -b/2a and epsilon=|s_i-(-b/2a)|/10. (epsilon is initialized to 1 cm).

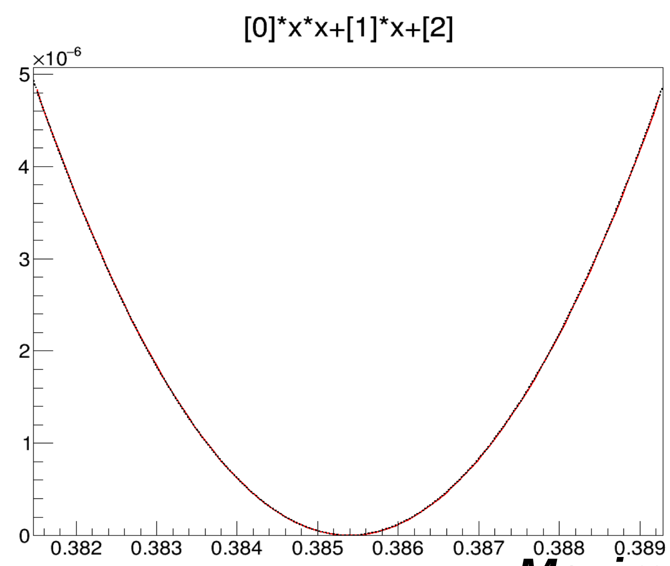
- Convergence within 3 iterations to reach the um-accuracy. No speed loss.
  Same strategy will be applied to SVT.

Maxime

Helix vs misaligned detectors

- Example for BMT
- D^2 as function of s (m).
- Particle from 0;0;0, with Pt=0.5 GeV, theta=50deg.
- Rotation by 10 deg, translation up to 5mm in x.
- Converge in 3 iterations
- Similar approach for intersection with SVT





Maxime

Summary

- Thanks to all the “CVT team” for the work done so far

Extensive effort to get CVT tracking ready for pass 1

- Validation of track fitting and geometry
- Handling of misalignments in code is almost ready to be validated
- Alignment runs and cosmics data have decoded and ready to be processed
  Storage and reading of rotations and translations tables both for SVT and MVT is in place
- Test possible solutions to maximise the SVT crosses used
- Use of MC hit-base matching to properly evaluate efficiencies and resolutions

Longer time scale:

- Seeding: move from crosses to clusters
- MC hit-base matching implementation in Java
- Cross validation between the two alignment methods

Backup

Alignment and definitions

- In this alignment study, all Tile/Module are attached to a frame in which you know absolutely the position of the detector. The frame is chosen to be the ideal x-y-z lab frame.
  In ideal situation,

- MVT frame: Frame in which all the tiles should be aligned with each other.

- SVT frame: Frame in which all modules are aligned with each other.

- In ideal, SVT frame = MVT frame.
  In reality, misalignment between both.
  => Main misalignments due to MVT versus SVT position.

- Beam rays are tracks collected during an alignment run at field B=0,

- Cosmic rays were also collected. They provide correlations between the sectors of CVT, whereas beam rays are going only through one sector.

- For this reason, the code must run on cosmic and beam rays simultaneously.