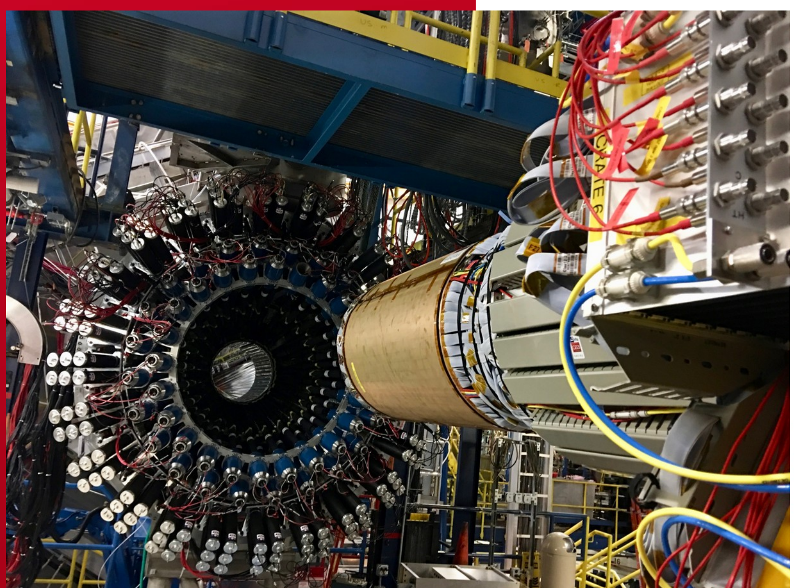
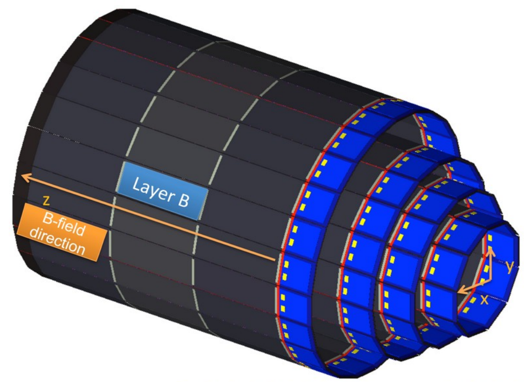
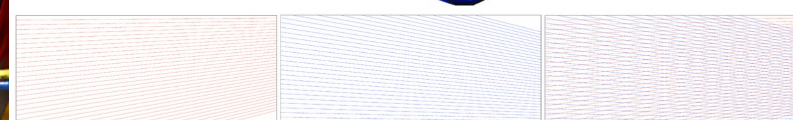
DE LA RECHERCHE À L'INDUSTRIE

Central Tracking status

Francesco Bossù
Maxime Defurne







LAYER A   LAYER B   Intersection of Strips

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Outline

- CVT Tracking code: features and validation
- BMT and SVT alignment procedure
- Conclusions

Introduction

- Nomenclature:
  - **Old** Tracking code: Coatjava 6.3.1 used for DNP cooking.
  - **New** Tracking code: Code developed by Maxime and myself since February 2019, corresponding to CVTAlignment_swim branch.

- Why the new code was started:
  - Handle **mis-alignments** for Barrel Micromegas and Barrel Silicon trackers

- Main differences between Old and New code:
  - Pattern recognition still based on **cellular automaton but with additional features**.
  - **Kalman filter revised, improved** with additional features.
  - And obviously, **mis-alignments corrections** can be applied.

- IMPORTANT: This talk won't present any comparison between old and new software. Such comparison have been already shown and they can be found at:
  - last collaboration meeting in June 2019 (link)
  - software meeting on July 11th 2019 (link)

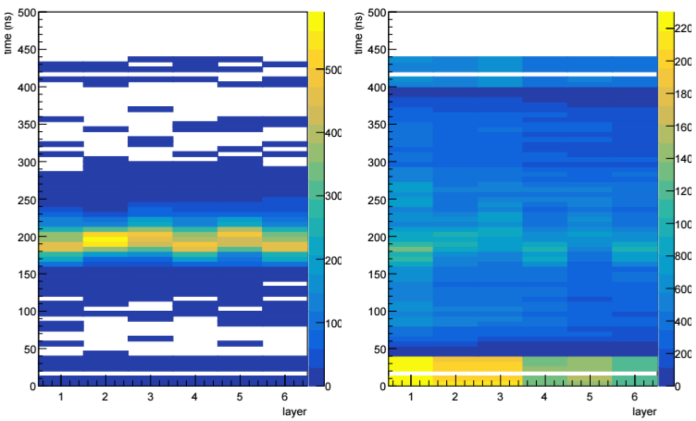
- This talk summarizes the additional features mentioned above and their validation

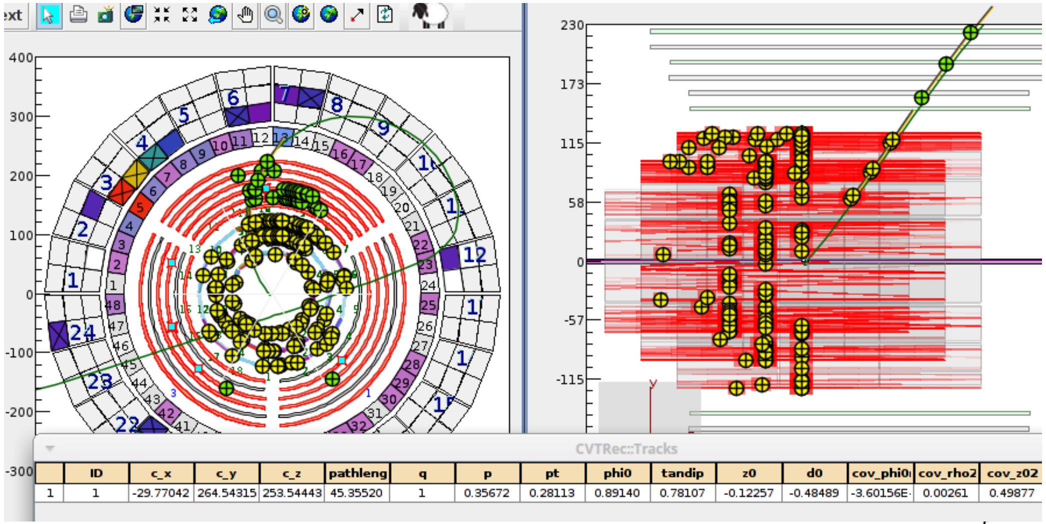
- The alignment procedure and results are not the CVT tracking algorithm

Pattern recognition and seeding

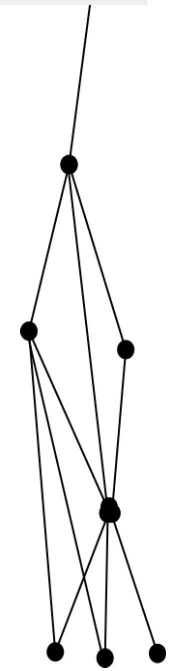
Time of cluster

On track *Not on track*





- The pattern recognition is handled with a cellular automaton.
- Based on clusters, not crosses, also for SVT
- Time cuts on BMT clusters remove off-time tracks => Increase the purity of the track sample returned by the tracking code.
- At the cellular automaton level, Micromegas tiles or Silicon modules are <u>ignored if the hit multiplicity is higher</u> than a given value.

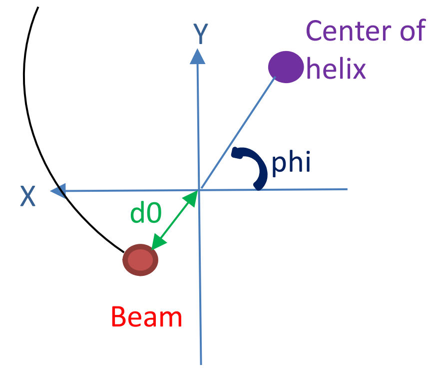


- Following a set of criteria, track candidates are built and then passed to the Kalman Filter for reconstruction
- Possible duplicates are removed after the KF

At 50nA, New code processes one event in 45 ms with an estimated efficiency of 88,5% on simulation._

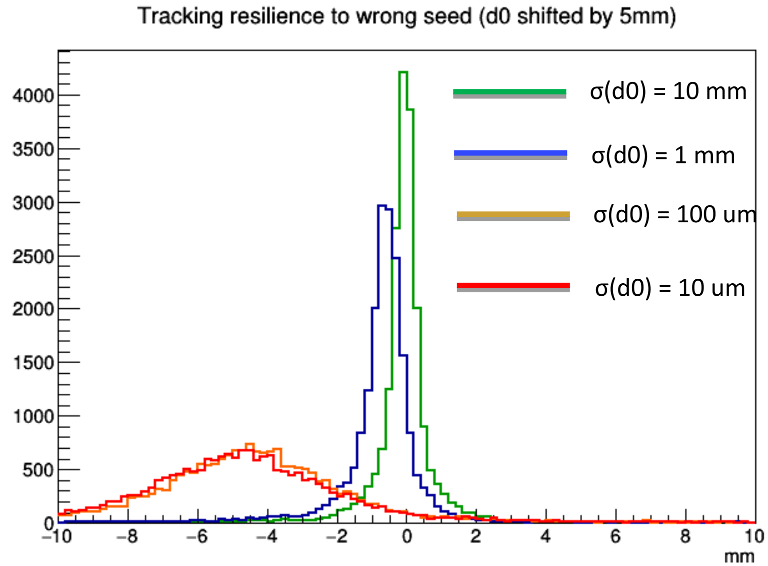
Kalman filter improvements

- First, let's introduce the track parameters:
  - d0 = distance of closest approach to ref point in XY-plane
  - phi = angular position of helix center wrt to ref point
  - z = distance of closest approach to ref point along z-axis
  - tandip = tan(Pz/Pt)
  - kappa=Q/Pt



This ref point is (0,0,0) by default. It will be beam position once calibrated.

- An initial guess of track parameters is passed to the Kalman Filter by fitting circle and straight line. This guess must be refined by the Kalman filter running over the clusters. Improvements are:
  - **Increased resilience to bad seeding**.
  - Able to **handle displaced vertices**.
  - **Misalignment corrections**.
  - Kalman filter **running CTOF-target or target-CTOF**.
  - **Increased resilience to background** by rejecting clusters too far from track candidate.



- Residuals including or excluding clusters available
  => Opens the door for alignment in beam.

About validation procedure

- Validation is performed on Monte-Carlo simulation on various process and particle types, with various beam current conditions (merging background hit from data).

- **<u>List of validation tests:</u>** (agreed with Raffaella)
  - Mu minus with and without 50-nA background
  - Proton with and without 50-nA background
  - Proton with and without 50-nA background with a missing tile
  - Lambda0 with and without 50-nA background
  - Off z-axis beam with and without 50-nA background
  - Mis-aligned simulation w/ and w/o correction tables
  - Elastic with and without 50-nA background

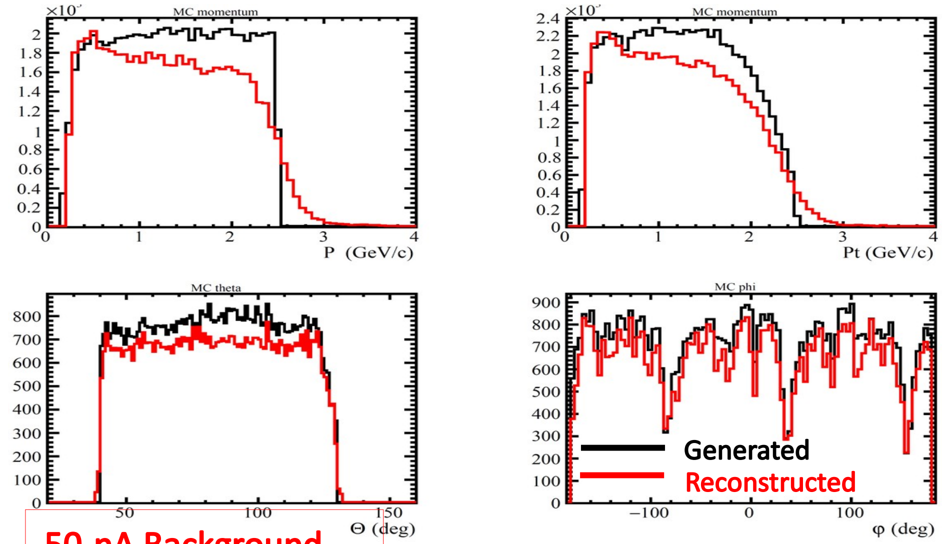
- Main conclusions are:
  - Efficiency drops by **<u>-0.25% per nA</u>**.
  - **<u>Resolution preserved with 50-nA background</u>** for all observable mentioned above.

- Let's go through some of the example above.

More details about the validation on simulation have been presented at the last software meeting: (link)

Mu minus

- Muons are perfect to study the tracking code and minimize sensitivity to energy loss and multiple scattering.
- Dp/p with 4%-sigma, integrated over the whole momentum range.



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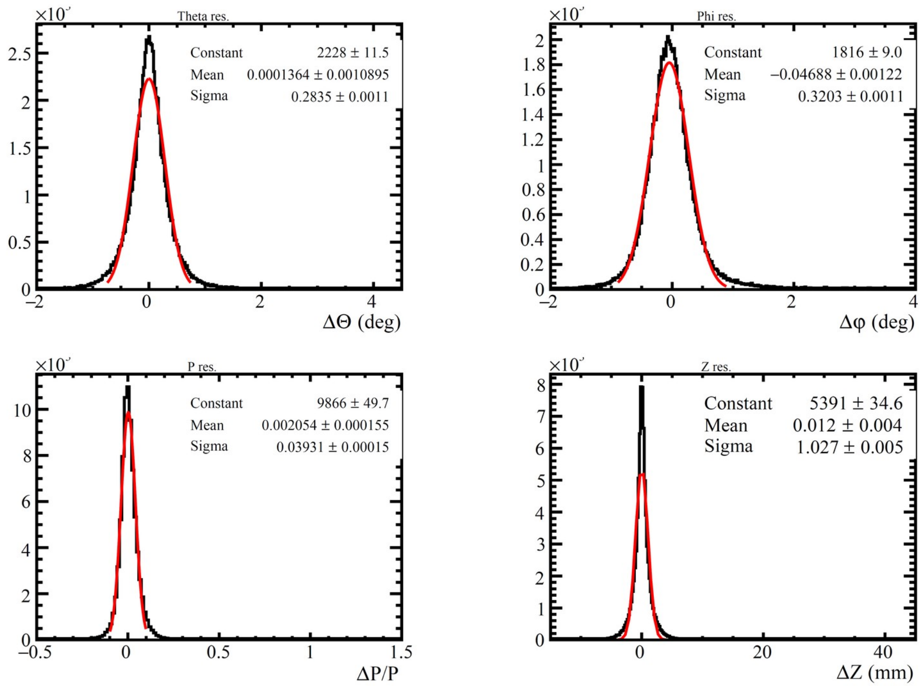
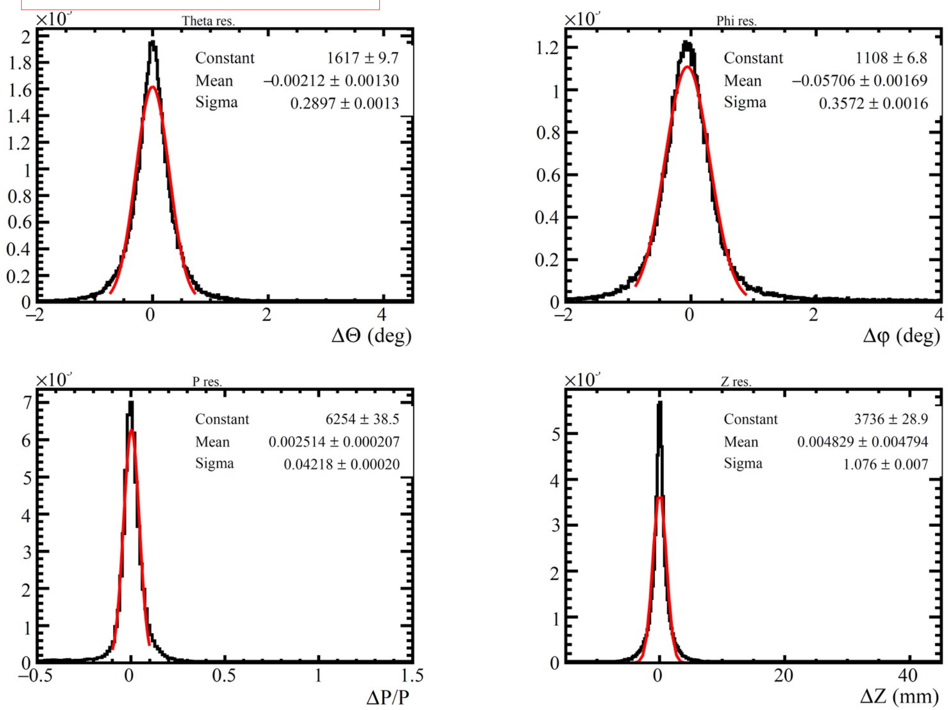


50-nA Background

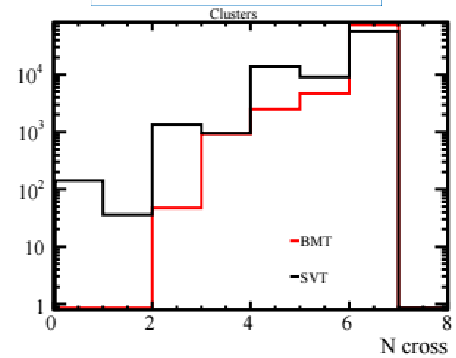


Mu minus

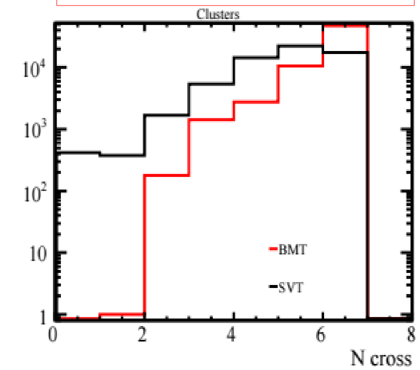
- Muons are perfect to study the tracking code and minimize sensitivity to energy loss and multiple scattering.

- Differential Dp/p resolution stable. Even with bkg
- About 1-2% tracks without SVT hits with bkg

No Background



50-nA Background



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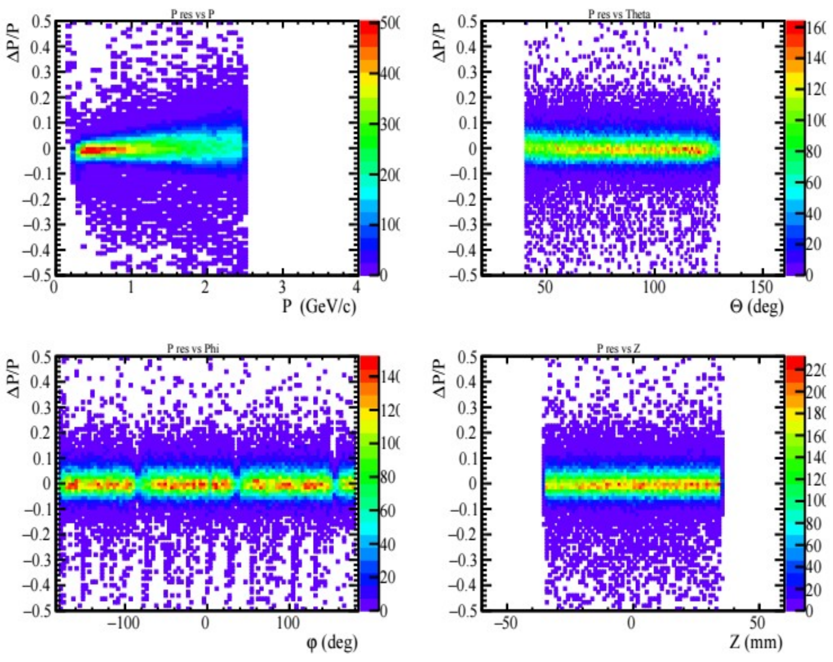
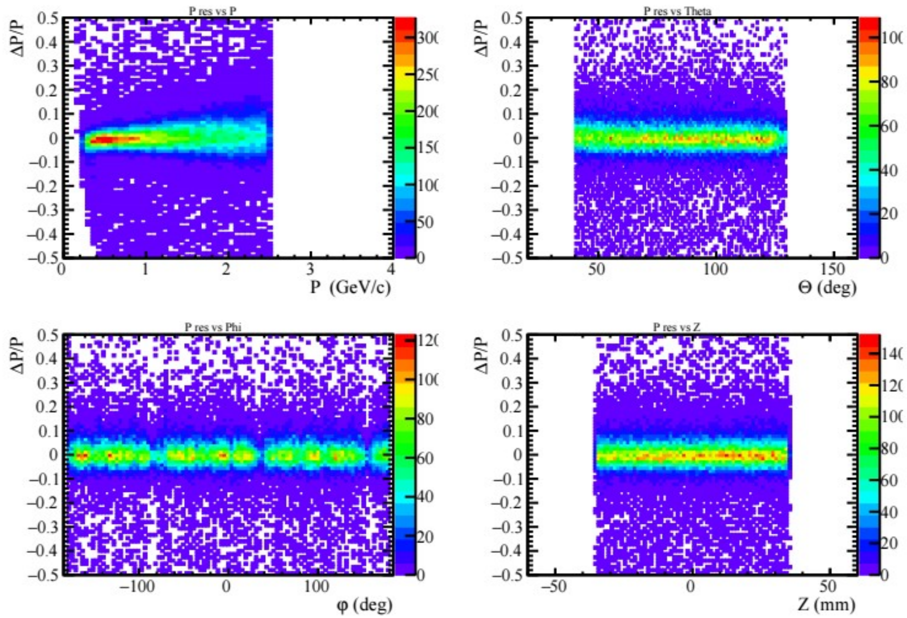
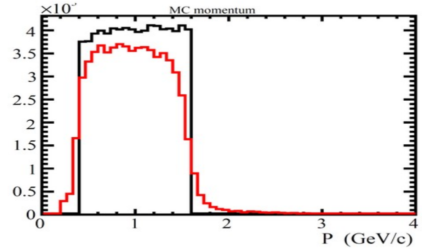


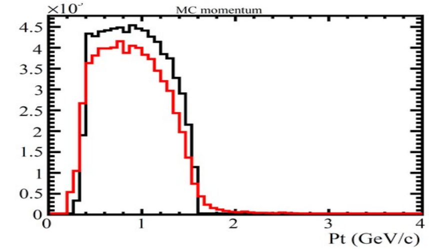
50-nA Background

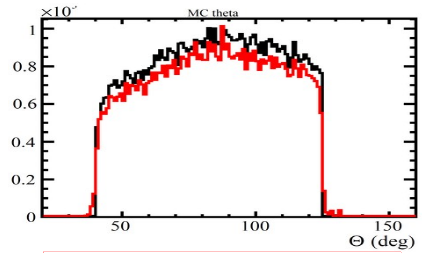


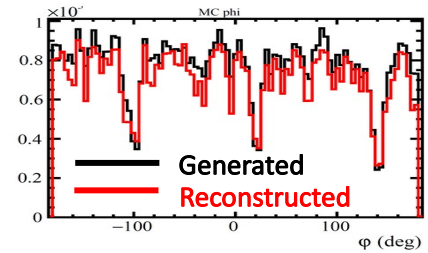
Protons

- Of course we are mainly interested in protons.
- Mean Dp/p shifted by 2% => averaged energy loss correction for proton in CVT.
- Degraded phi-resolution due to Lorentz angle and energy loss of slow protons









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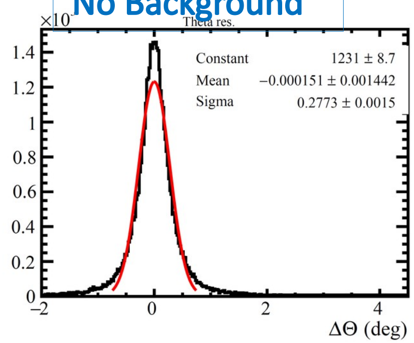
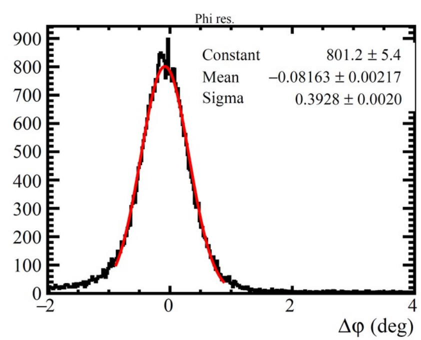
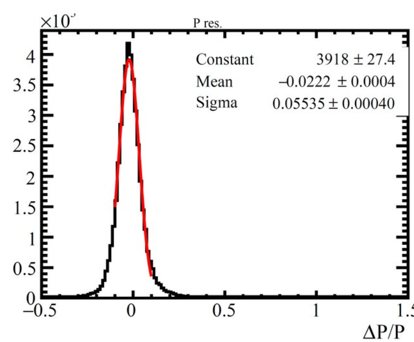
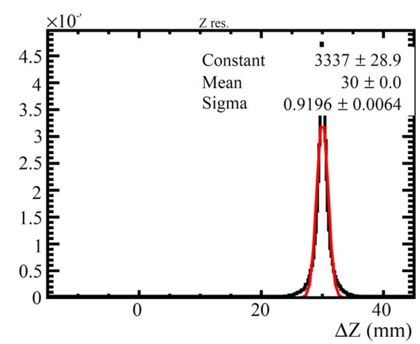
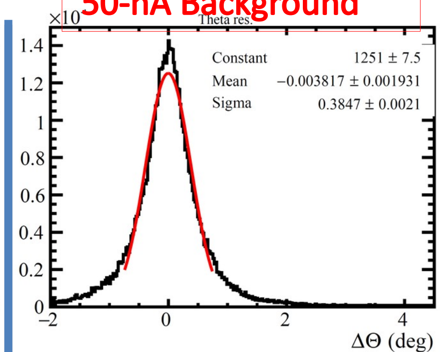


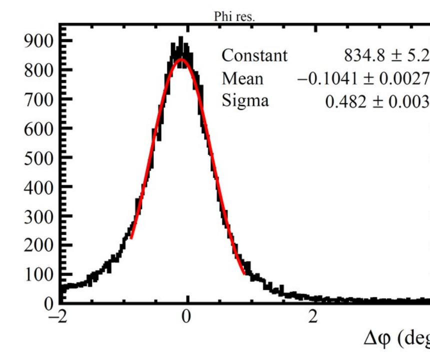


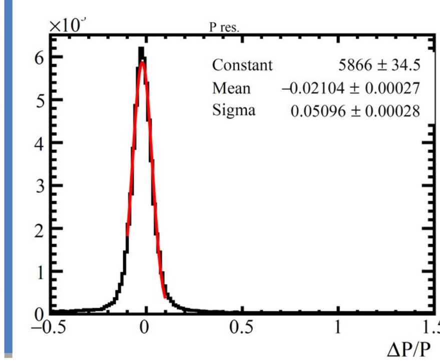


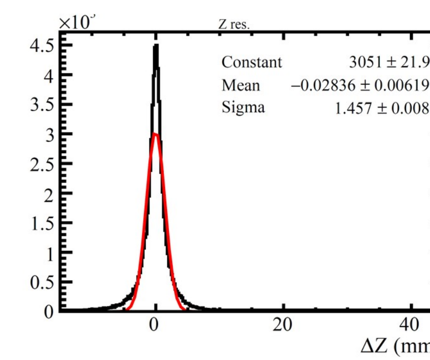


50-nA Background





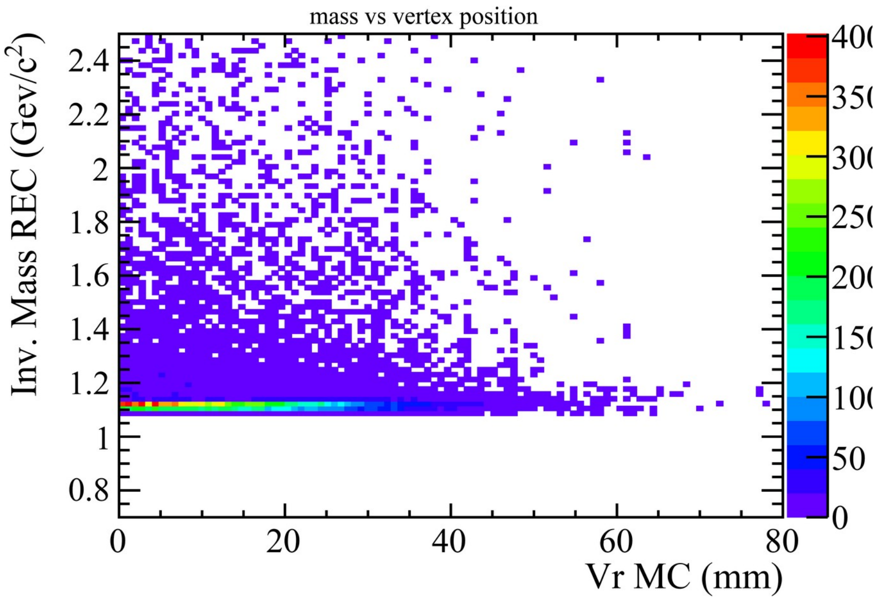




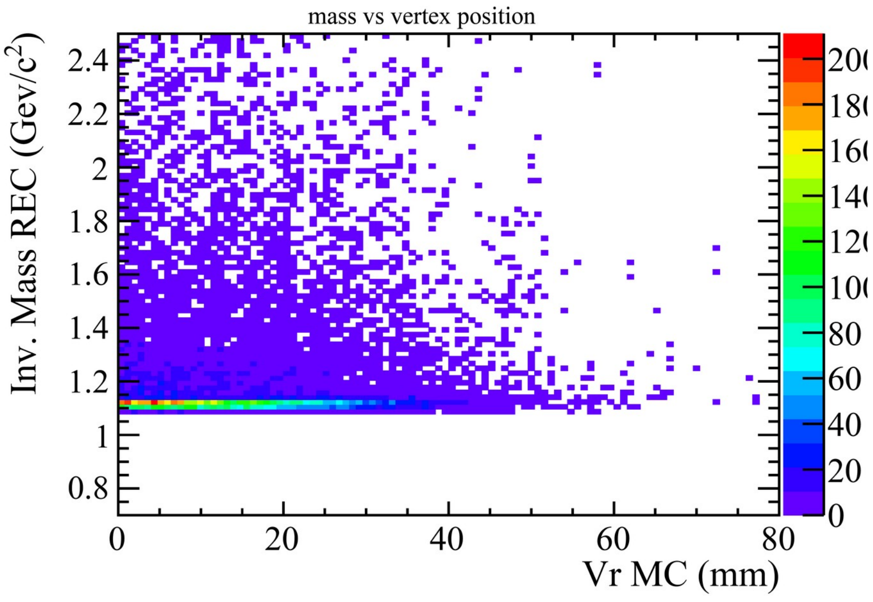
Λ^0 within reach of new code

- Λ^0 decays into proton and π^-.
- We are using TGenPhaseSpace with decay vertex radial position generated with a Gaussian centered around 0 with 30-mm sigma.
- The invariant mass is insensitive to vertex position as far as 5 cm away from CVT center.
- Invariant mass resolution is insensitive to background as well.

No Background



50-nA Background

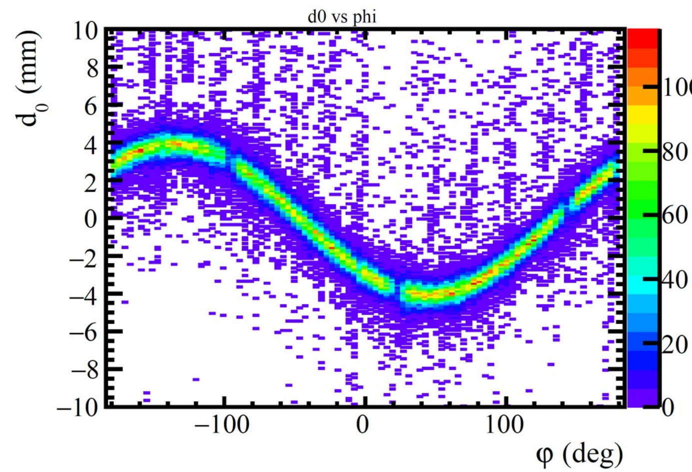


Finding Beam Position

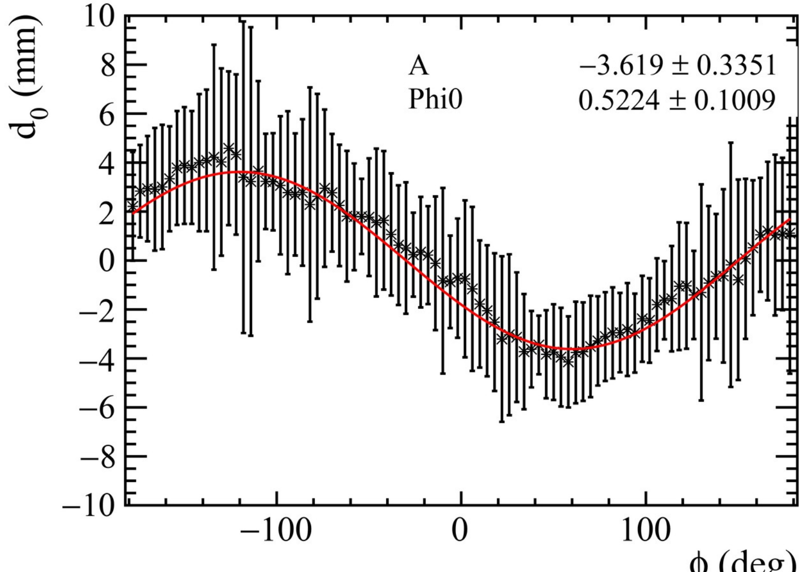
- We can even locate the beam position to refine vertex determination:
  d0 = A*Sin(phi+phi0)
  With A = distance of beam to (0,0) and phi0 = angular position of beam

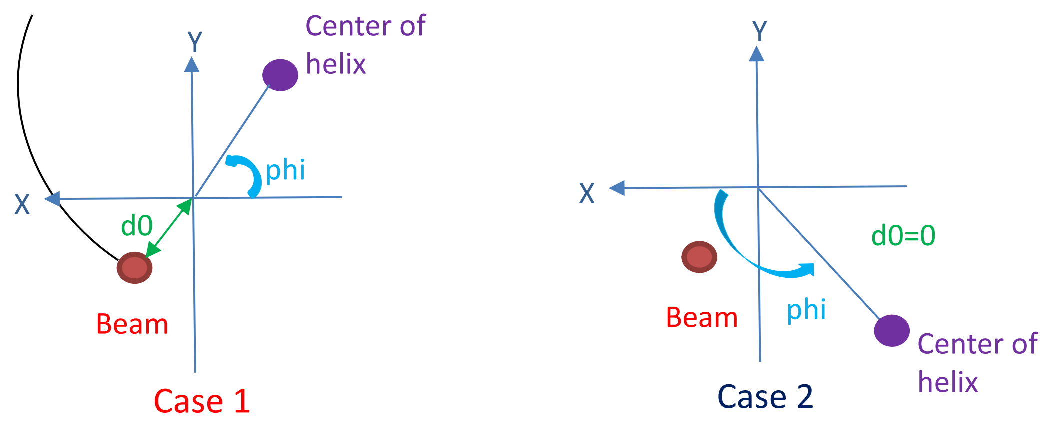
- For run 4013, x_beam~=-3.1 mm and y_beam~=1.8 mm

Simulation, mu+, vertex=(-2.8,2.8)



Data, run 4013

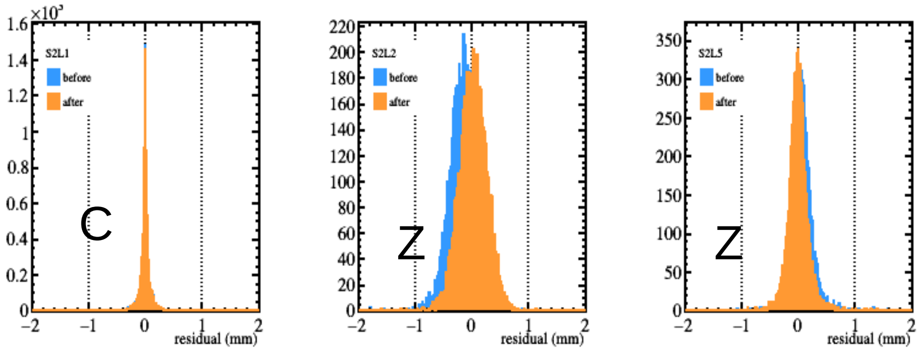




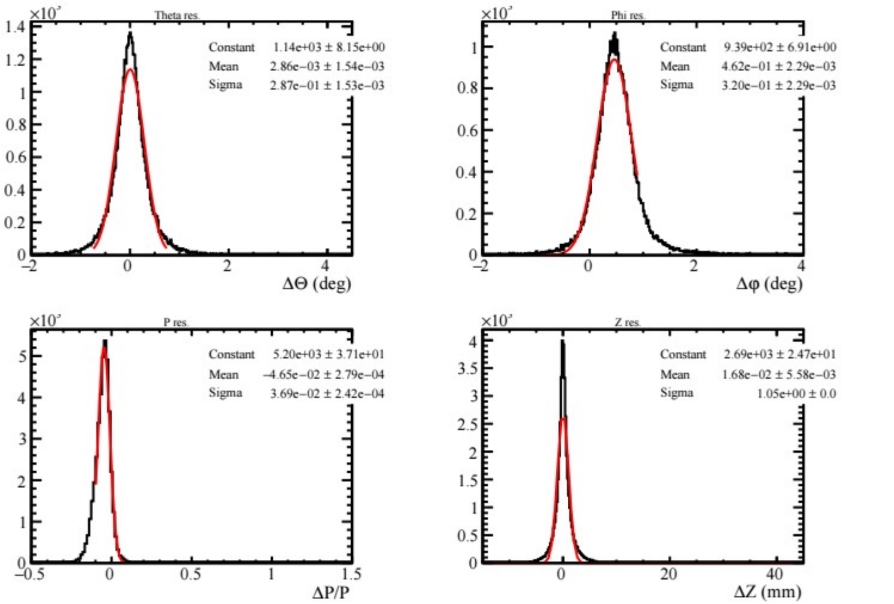
Handling mis-alignments

- Simple example that the new code handles alignment corrections
- Mu- simulation with SVT rotated around z-axis of **2.1 mrad**
- Before correction: phi and momentum resolutions not centered to 0
- A test ccdb table with the inverse rotation was prepared
- After correction**: resolutions back to normal**

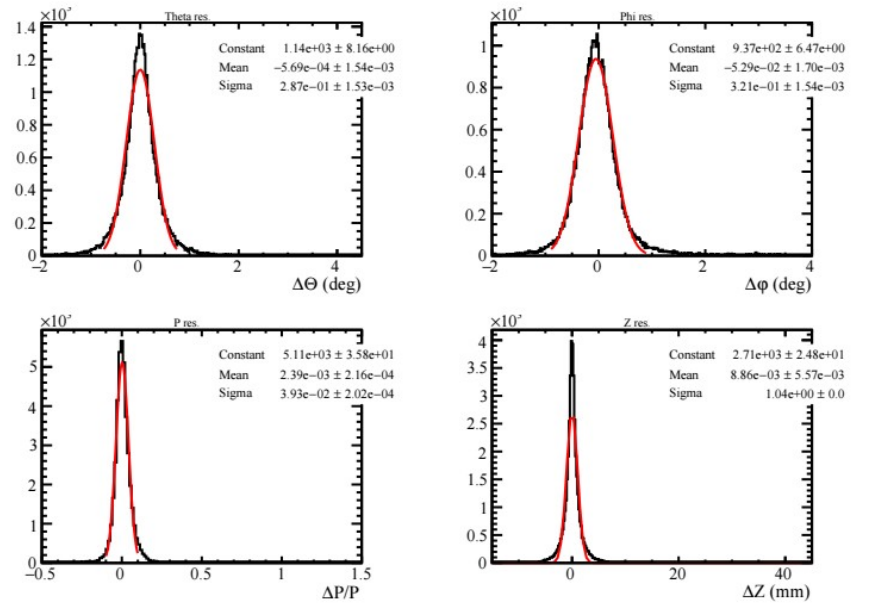
BMT residuals examples



Before correction



After correction

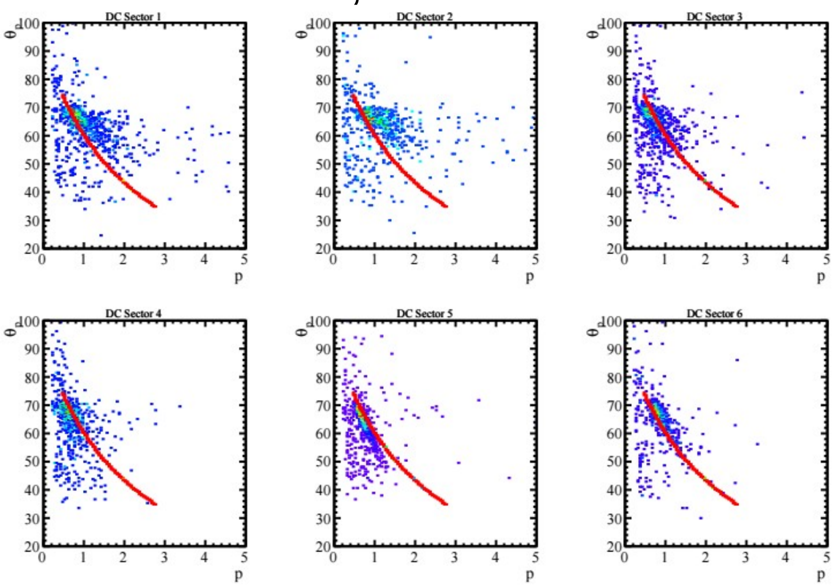


Confronting the data: The elastic puzzle

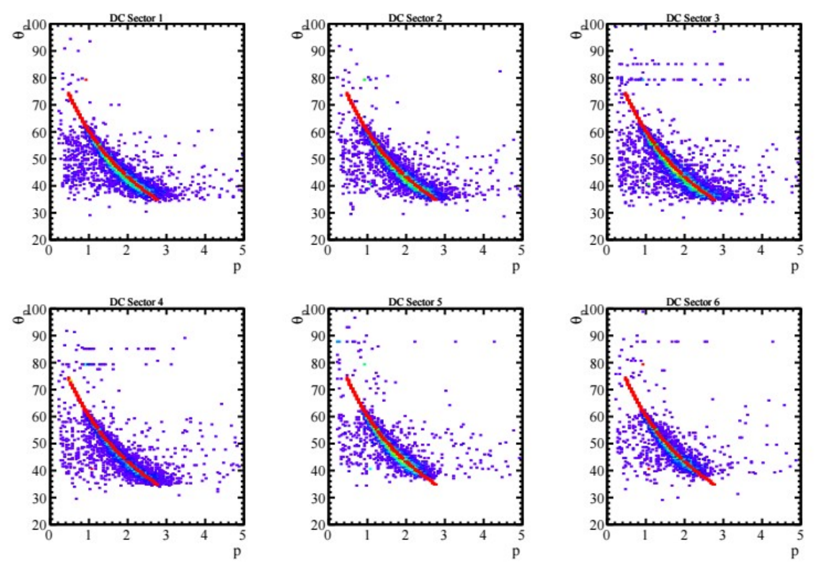
- Scattering angle of recoil proton seems to be mis-reconstructed, with a dependence in phi.

- Elastic simulation tests:
  - No bkg
  - With bkg
  - Removing BMT S2L1
  - Removing BMT S2L1 with bkg
- None of the above simulations can reproduce the pattern seen in data

Data, run 5893



Simulation, NO BMTS2L1, with 50nA bkg

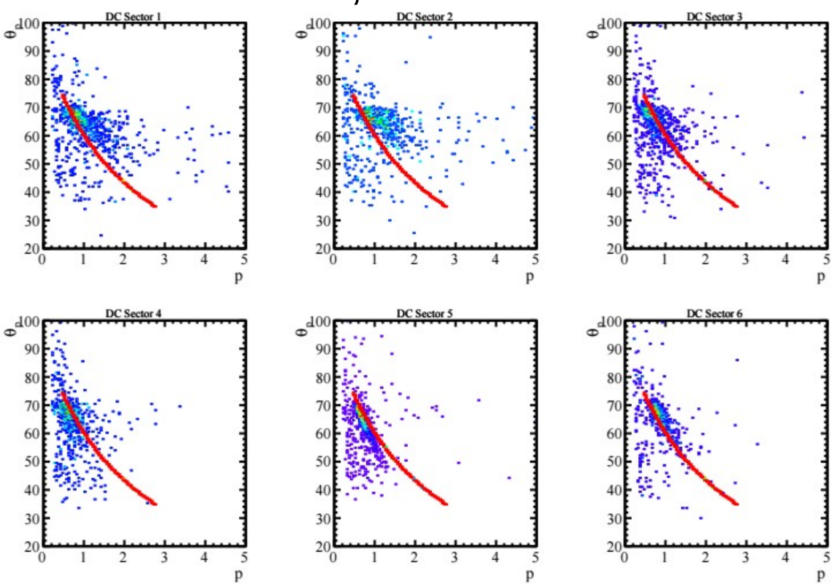


Confronting the data: The elastic puzzle

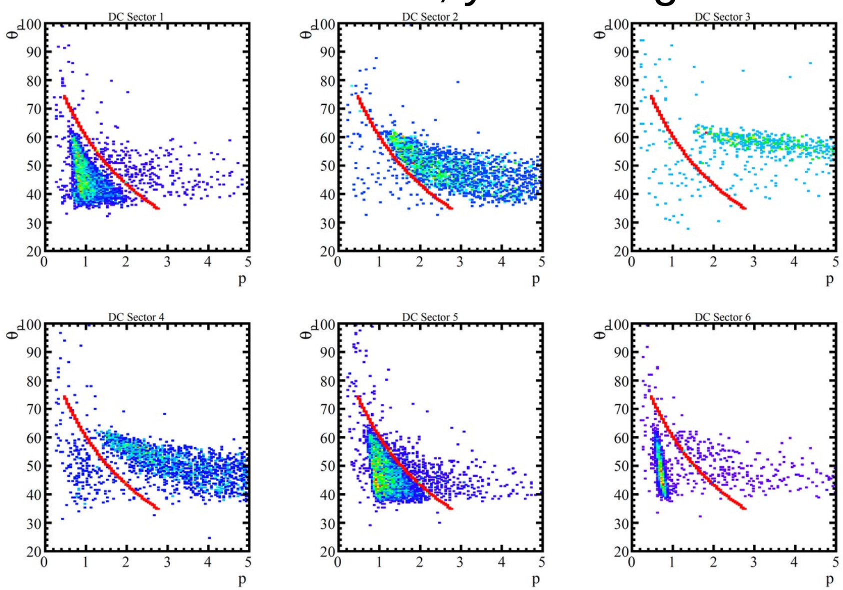
- Scattering angle of recoil proton seems to be mis-reconstructed, with a dependence in phi
- Simulations of elastic events do not show this dependence

- However, tilting by 2 degrees the CVT axis wrt to the solenoid magnetic field has reproduced the same pattern

Data, run 5893



Simulation, y-rot 2deg



- **This kind of rotation can be handled in the new code**

Procedure for alignment

- 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 anymore.

  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.
  Several iterations will be required... But how many? That is a big question.

- Results shown later in this talk 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.

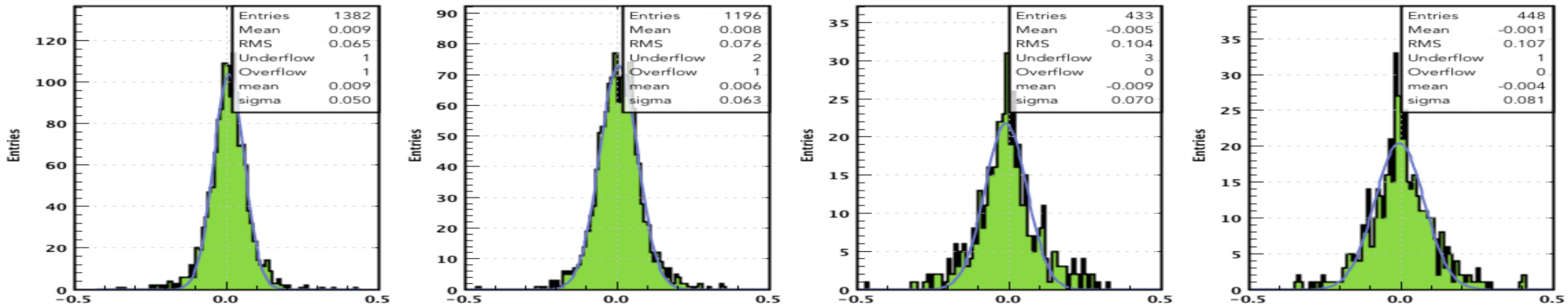
- Advantage: Fairly easy to implement.
  Drawback: Time needed for convergence depends on the sequence in aligning the detectors, as well as the number of detectors (<u>CVT is composed of 92 elements to be aligned!</u>)

Two codes for alignment

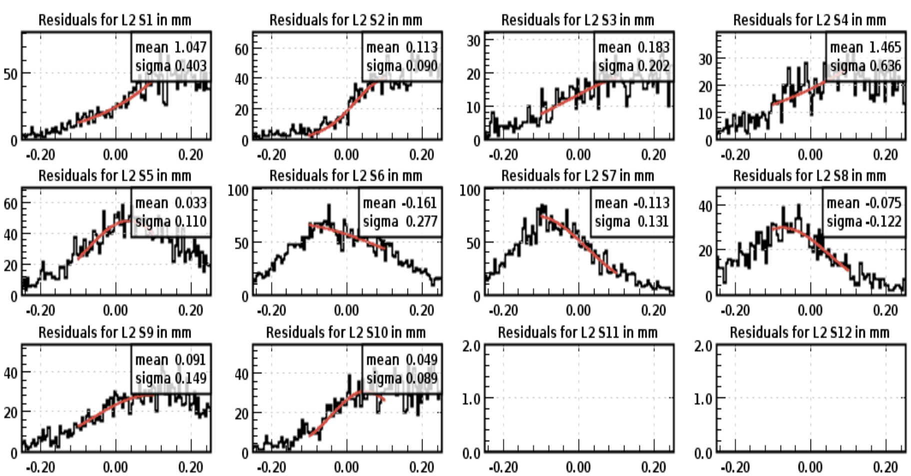
- Tracker.jar: A fully validated tracking code for straight track (cosmics and no-field beam data).

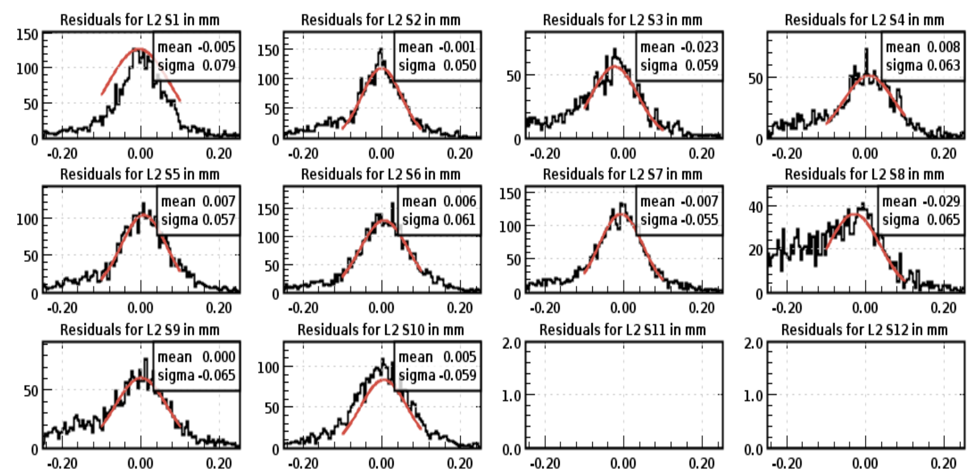
- Alignator.jar: A script finding best rotations and translations of SVT modules and MVT tiles, using Tracker.jar.

SVT residuals with ideal simulation



- The codes were run on Spring 18 data.

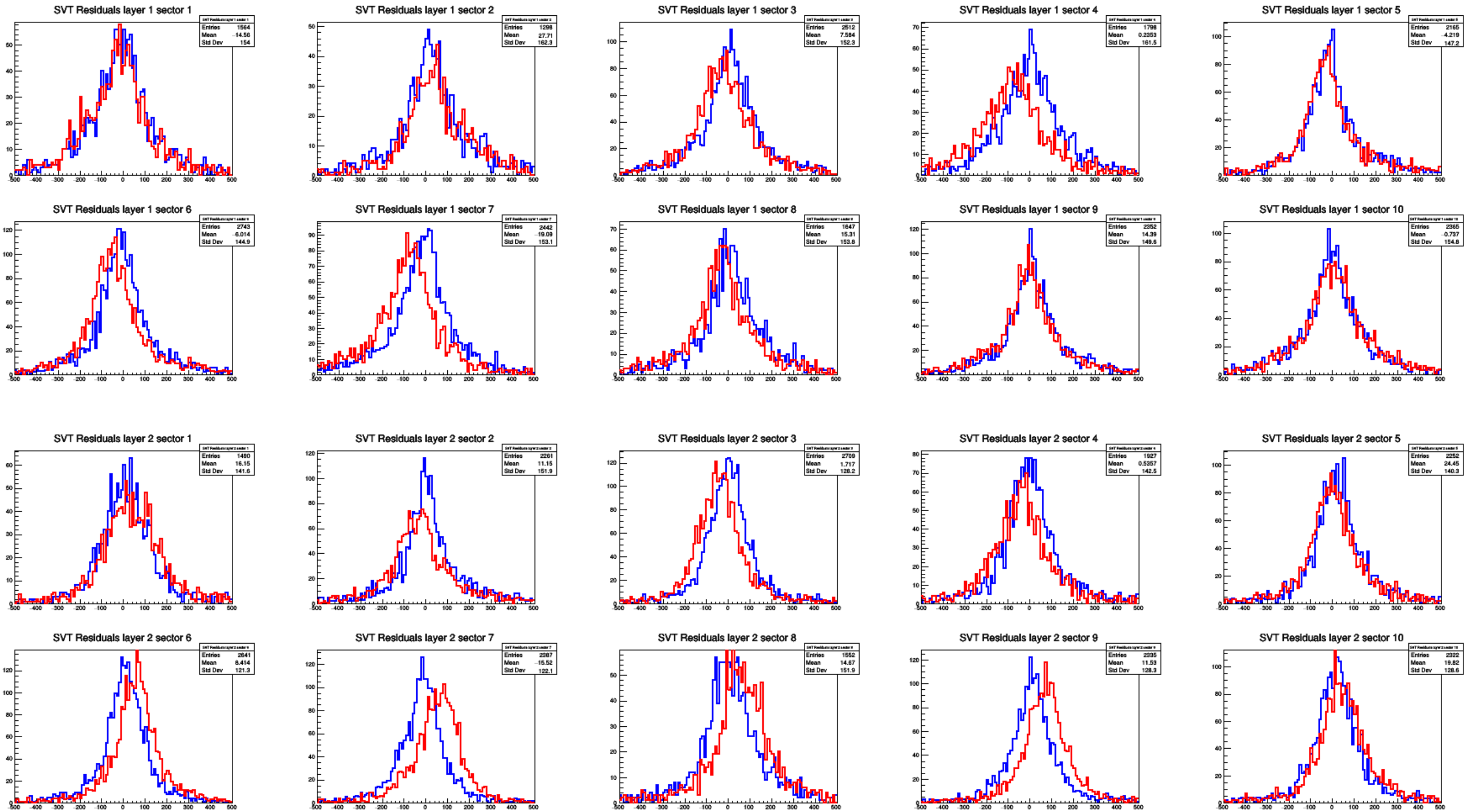




- CCDB tables have been created to store the constants… But old tracking code is not designed to handle misalignment corrections.

Preliminary alignment for Spring with New code

- Alignment constants for Spring are improving residuals for SVT.
  (red= no alignment and blue = with alignment)



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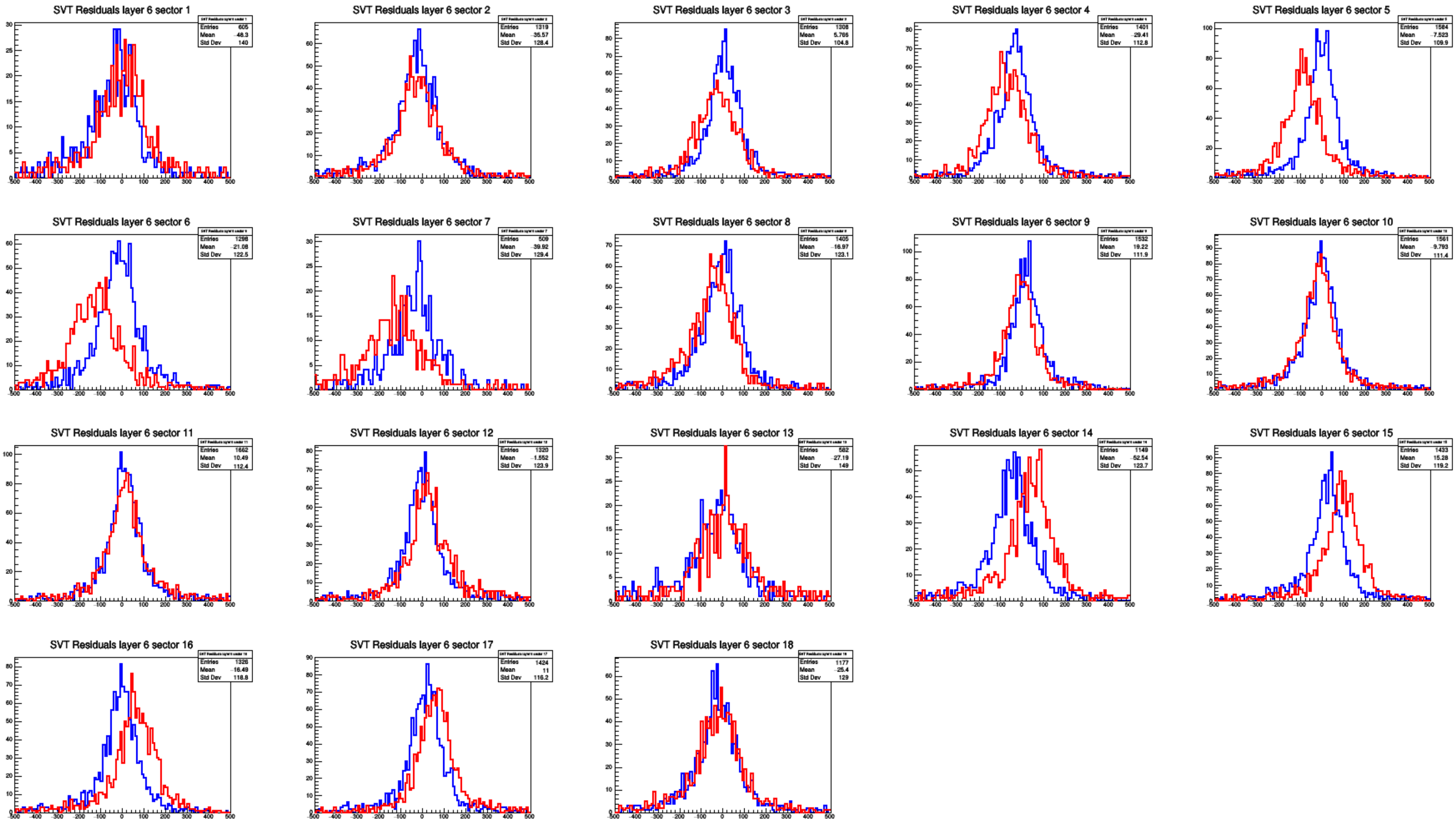

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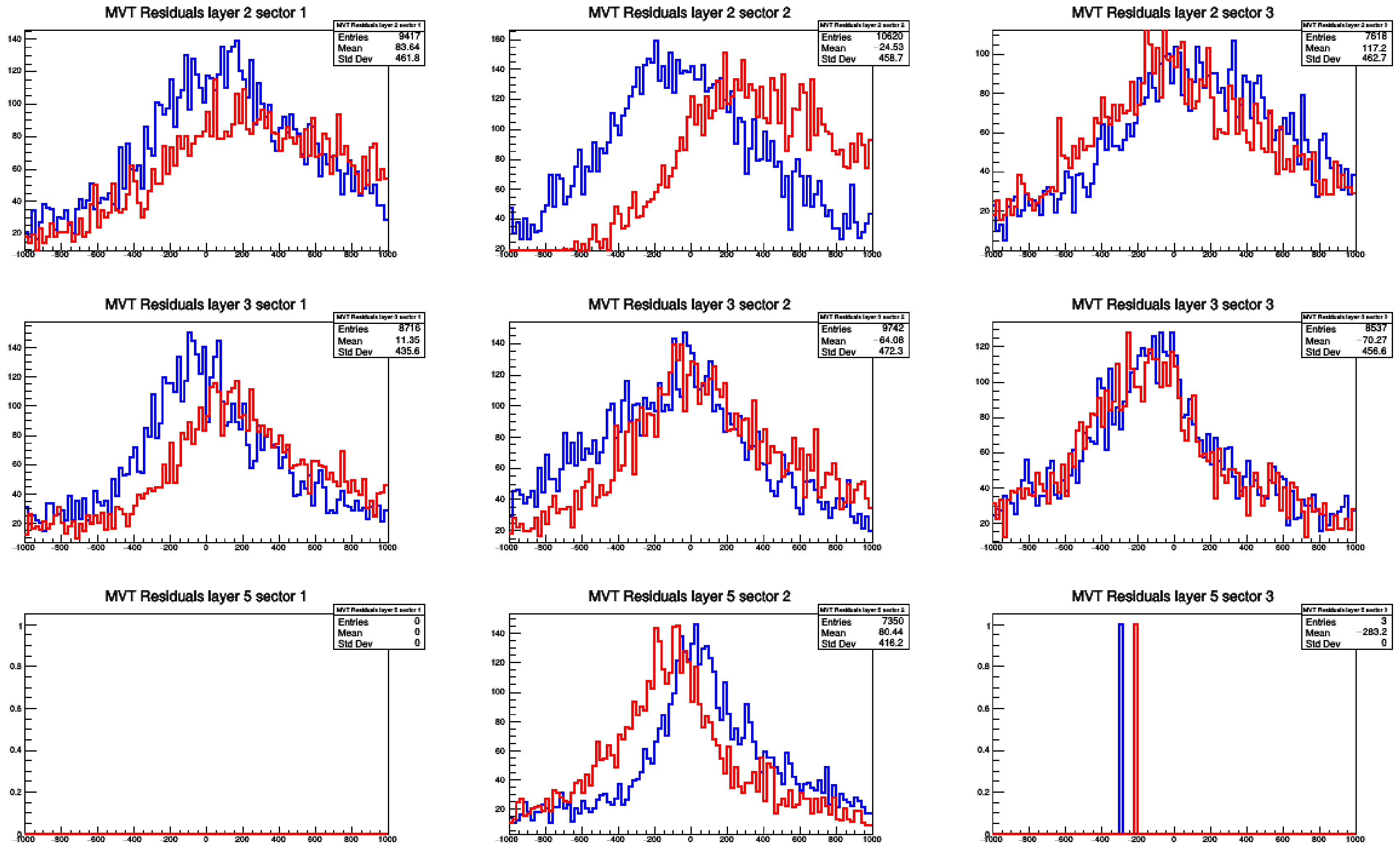
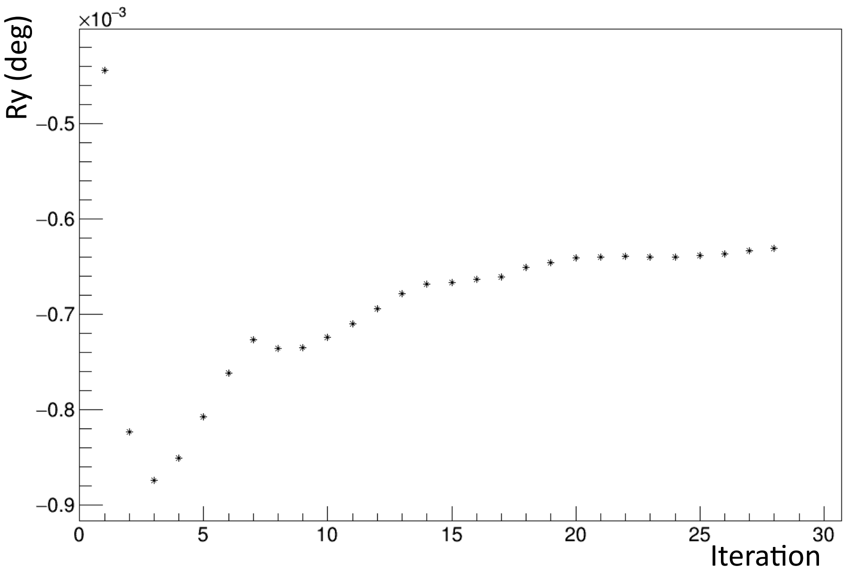


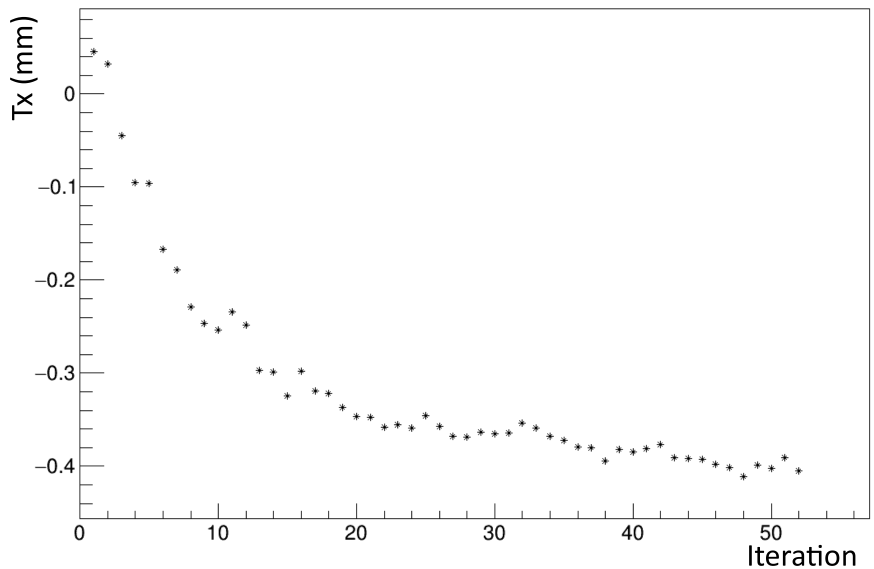
Challenging Fall 2018 Alignment

- Entire barrel dismounted and re-assembled in the Hall B in summer 2018 on a scaffold.
  => Not the best condition to ensure proper re-installation of Micromegas tiles.

- Complicated challenge since major misalignments has been induced. But it also helped in optimizing the procedure.

- Step 1: MVT only alignment.





- Up to 50 iterations might be needed to reach convergence for alignment in MVT-only alignment.

- SVT convergence will require more iterations to converge

Conclusions

- According to Maxime and me, the **new code is validated**. It is ready to be used on data.
- Further investigations on data will be done in the next days together with Raffaella
- M.Battaglieri expressed the will to set up an "external" validation committee

- **New valuable features** brought by the new tracking code includes:
  - <u>Unbiased momentum reconstruction</u> with respect to vertex position.
  - <u>Accurate determination of beam position</u>.
  - <u>Resolution preserved</u> with 50-nA background.
  - <u>Improved efficiency</u> with 50-nA background.
  - <u>Misalignment corrections</u> between the detectors and with respect to solenoid magnetic field.

- The **<u>new tracking code opens interesting perspectives</u>** such as:
  - Finding secondary vertices.
  - Alignment using beam data.

- **<u>Preliminary alignment procedure is correcting the bulk of misalignments</u>** (used only in the new tracking code). But alternative approaches should be studied regarding the slow convergence of the current alignment procedure.

- **<u>Elastic events puzzle</u>**: missing Micromegas tiles do not induce shifts in momentum reconstruction. A tilt of CVT axis with respect solenoid magnetic field seems to be responsible.
  - Further investigations needed
  - <u>Such tilts and translations can be handle only in new code.</u>

Acknowledgments: to Raffaella for the validation supervision, to Maurizio and Yuri for the help with GEMC

Preliminary alignment for Spring with New code!

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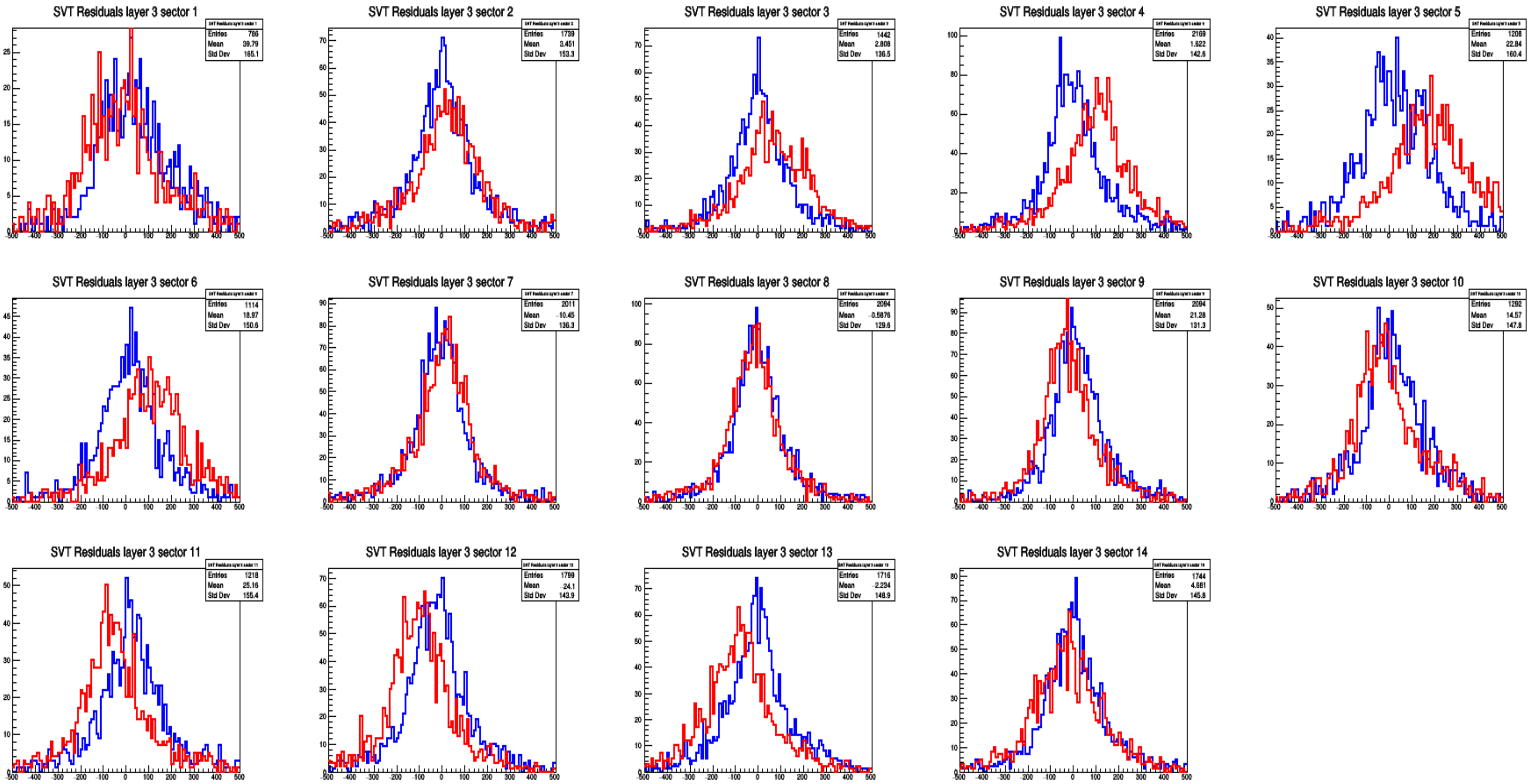
  (red= no alignment and blue = with alignment)



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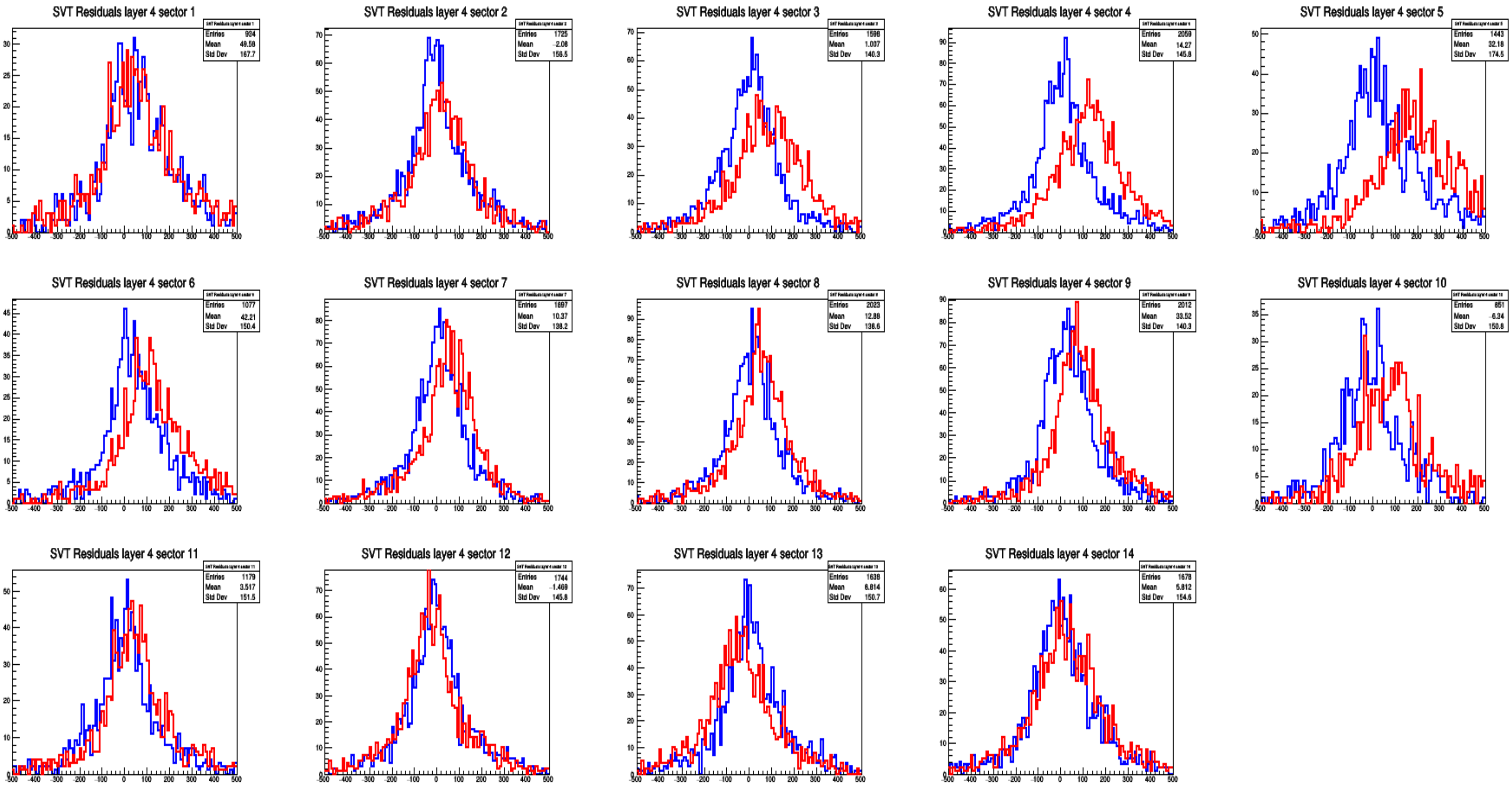

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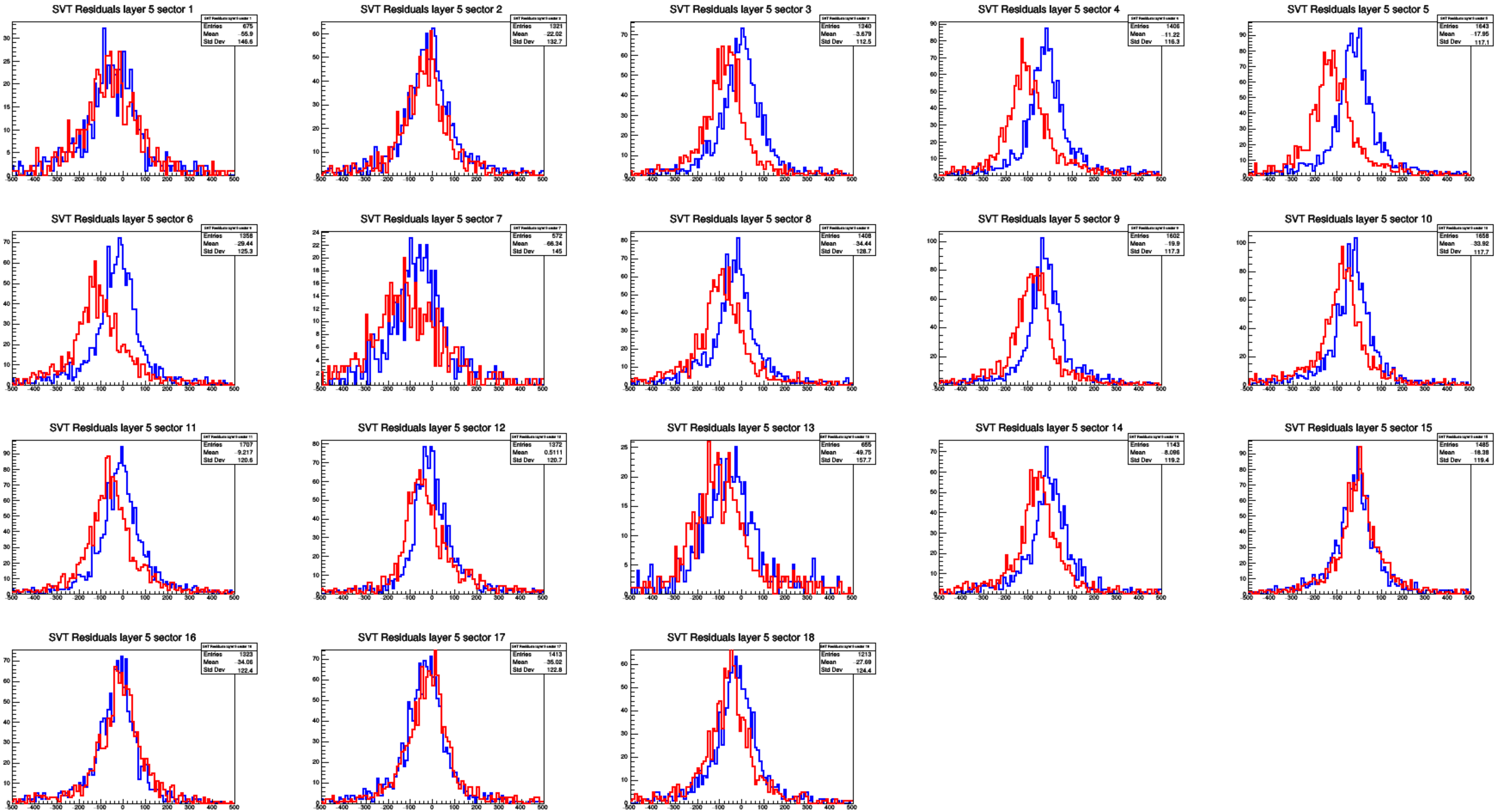
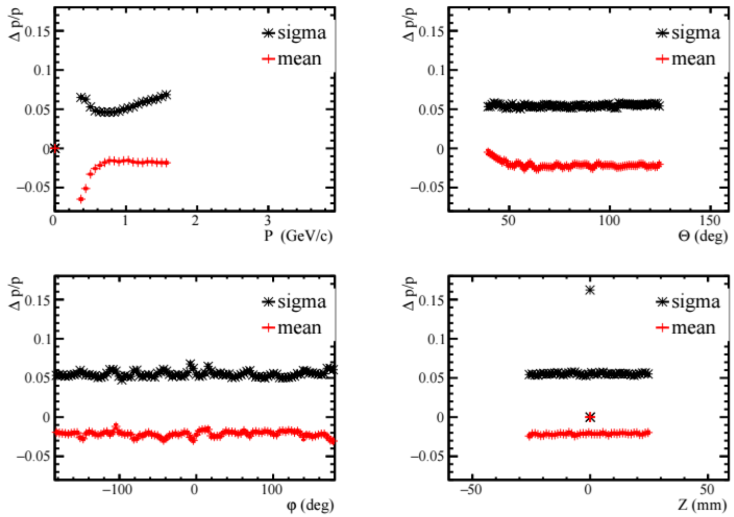
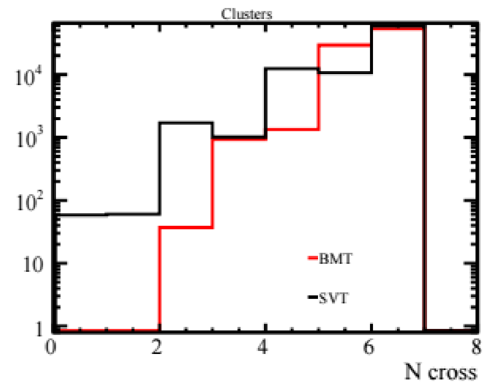
  (red= no alignment and blue = with alignment)



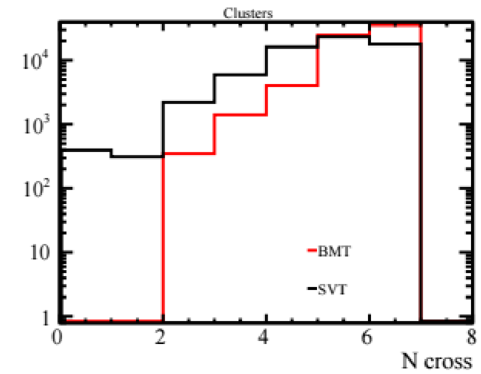
Proton – missing BMT S2L1

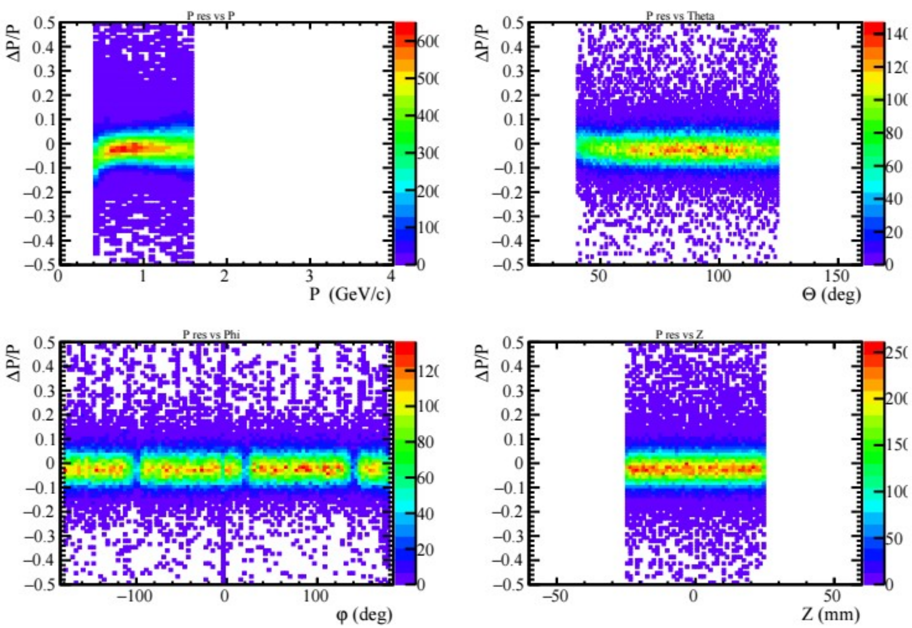


No Background



50-nA Background





50-nA Background