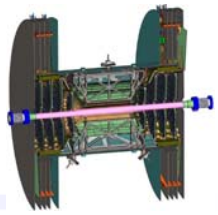
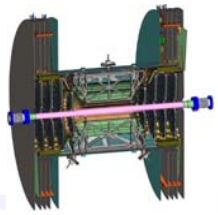


FVTX Simulation and Analysis Software

Cesar L da Silva(LANL), Xiaorong Wang(NMSU)
For the FVTX group

Physics Goals with FVTX



Measurement in p + p, d + Au and Au + Au Collisions

Single Muons measurements:

- Precision heavy flavor and hadron measurements.
- Separation of c and b in semi-leptonic decays via decay kinematics.
- Improve W background rejection.

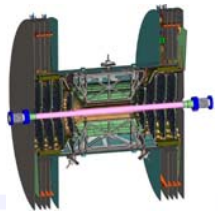
Dimuons measurements:

- Separation of ψ' from J/ψ at forward rapidity.
- B$\rightarrow$J/ψ, golden channel to measure B cross section.
- Drell-Yan measurement at RHIC.

Physics FVTX Can Access:

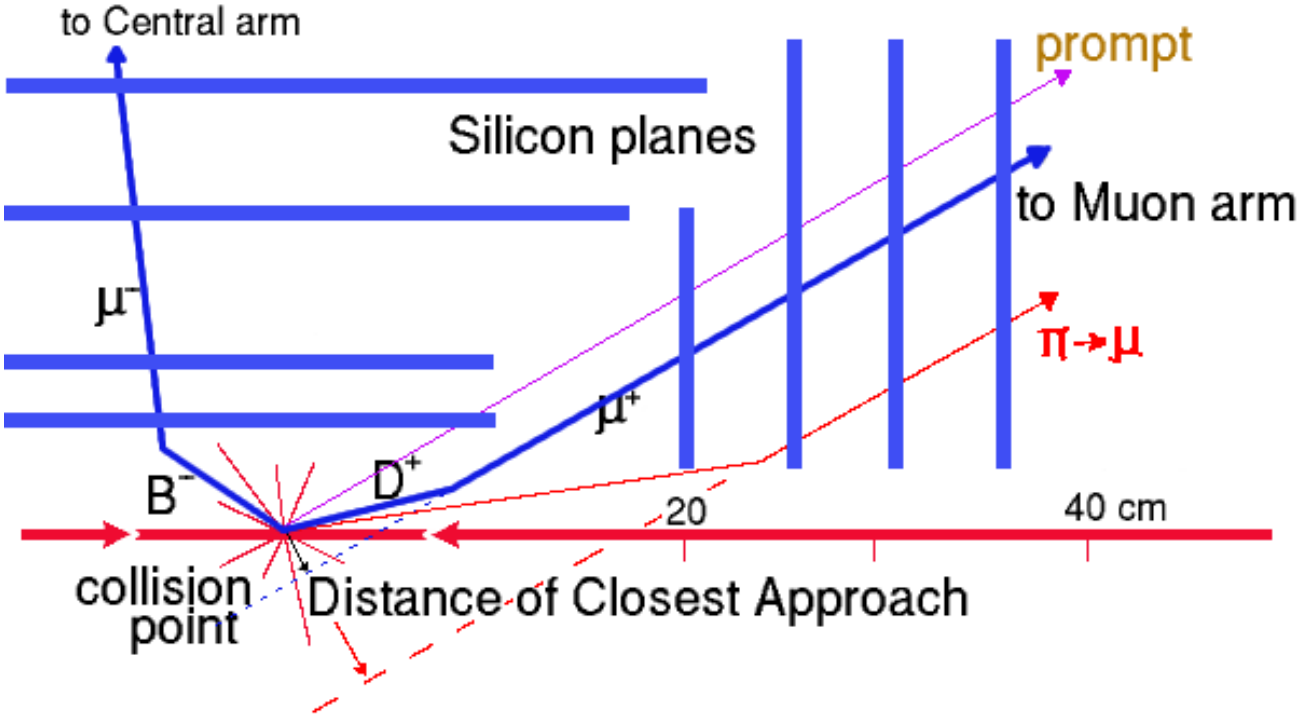
- Energy loss mechanism in hot dense medium (Heavy flavor $R_{AA,}$ v_2)
- Cold nuclear effects (Heavy flavor R_{dAu})
- Gluon polarization $\Delta G/G$ (Heavy flavor A_{LL})
- Sivers function, higher twist (Heavy flavor A_N)
- Crucial test of QCD universality (Drell-Yan A_N)

Forward Vertex Detector (FVTX)

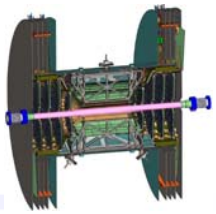


The challenge: backgrounds (π ->μ and K-> μ) overwhelm the signal.

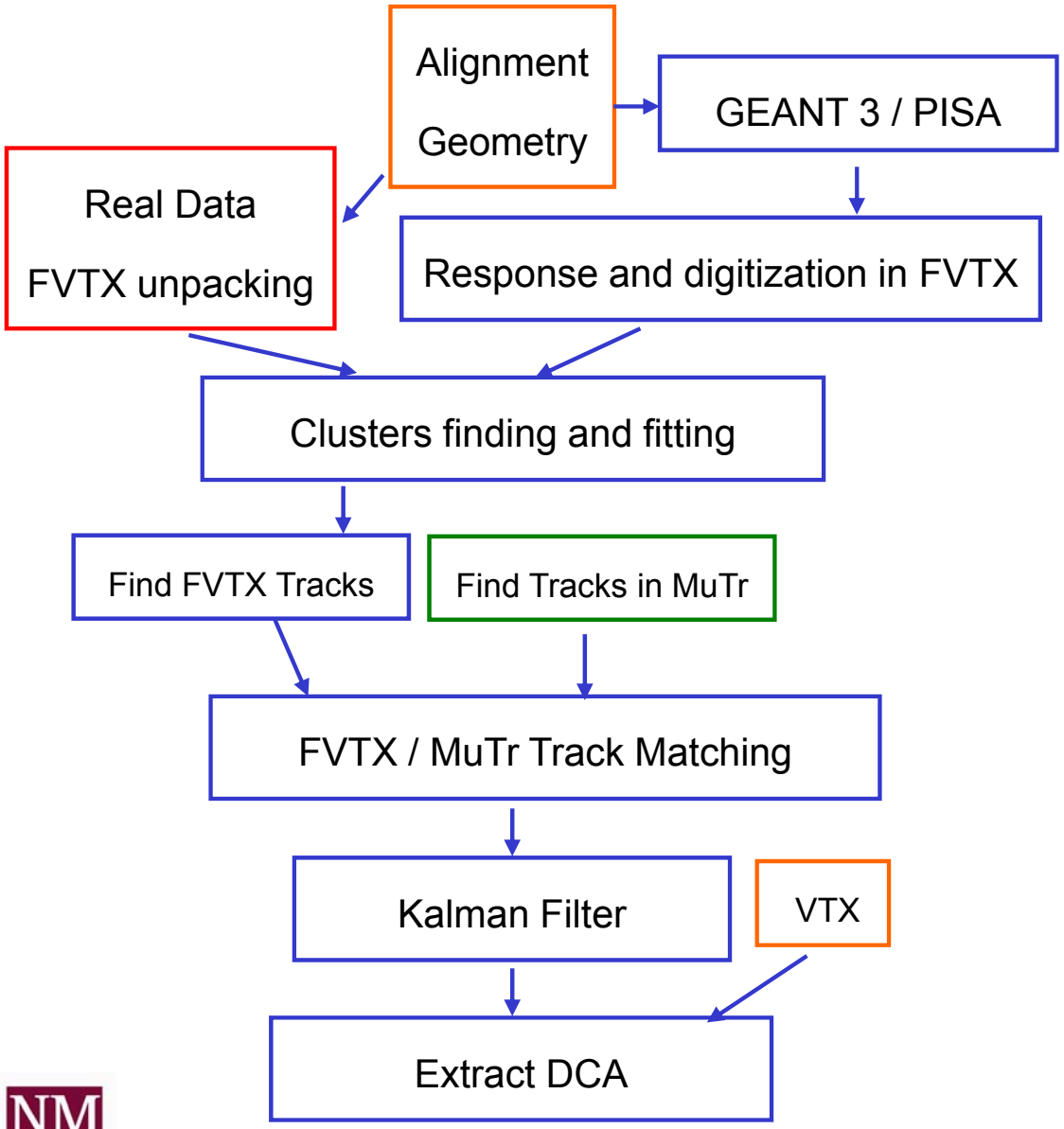
- Flying distance and decay angle are different. Get DCA components in r (higher resolution) and phi (moderate resolution).
- Significant improvement in angular resolution of track leading to dimuons mass resolution
- Track isolation cut will suppress hadrons from jet for W measurement
- Joint tracking with MuTr. Track χ^2 cut will discriminate muon from hadron background.



FVTX Software Overview



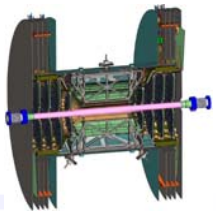
➢ Offline Track Reconstruction

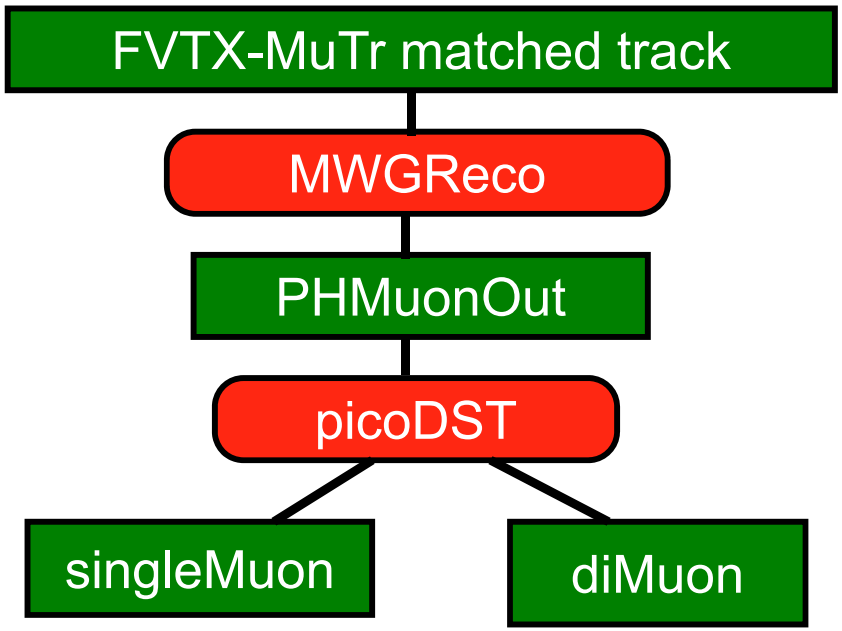


Current status

- FVTX disks have updated to reflect as-built geometry.
- Detector response includes noise and digitization.
- Reconstructed FVTX tracks in real data and macthed with MuTr tracks. Fine Tuning is in process.
- Will add primary vertex-finding module which can use FVTX hits.

Variables of FVTX-MuTr Matched Track





PHMuonOut content

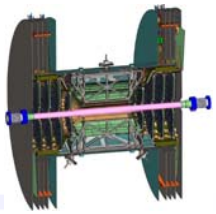
each MuTr+FVTX associated track
x,y,z vertex
px, py, pz at vertex
MuTr-FVTX phi residual
MuTr-FVTX theta residual
chi^2 from Kalman Filter
covariant matrix
nFVTX tracks around MuTr track (dphi, dtheta)

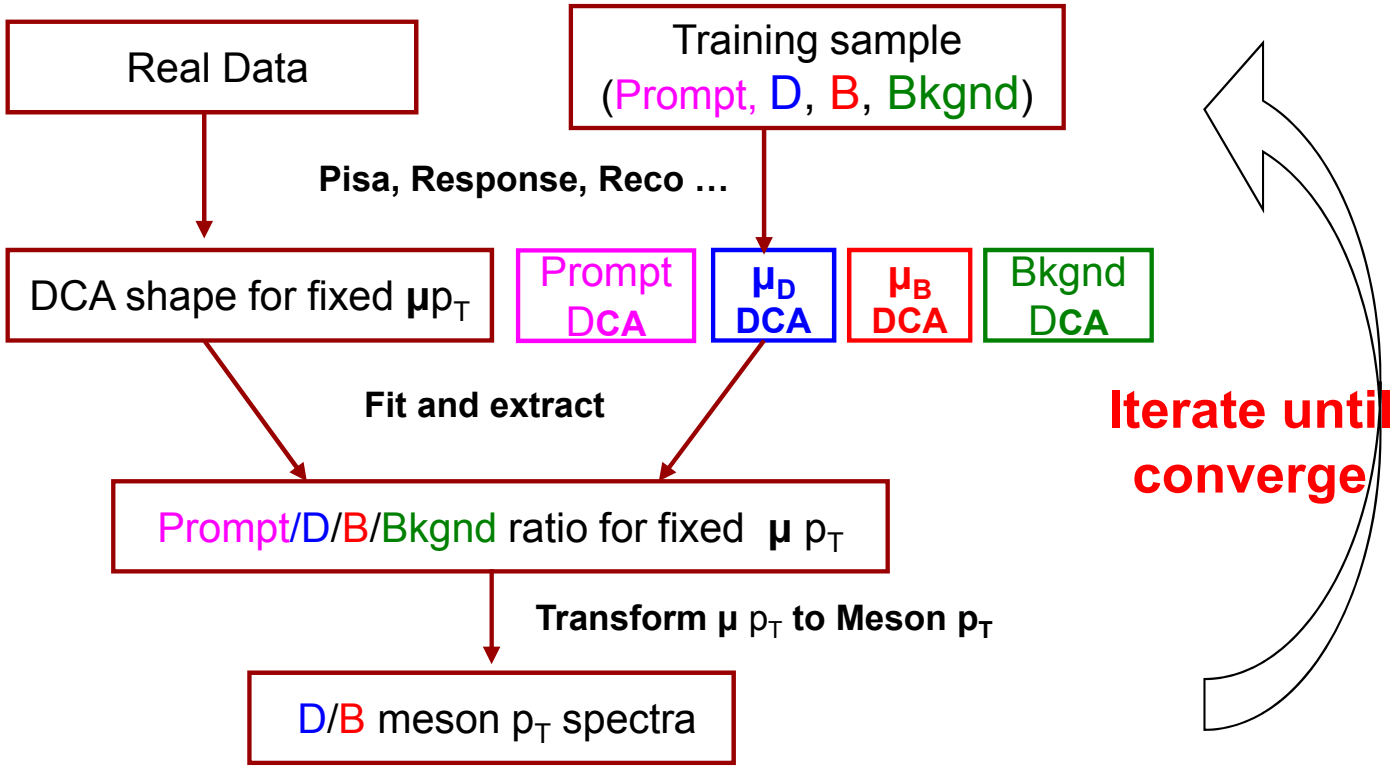
for each FVTX station projection
cluster size(station)
cluster charge(station)
(cluster peak) - (track projection)
peak strip index

Two FVTX filtered Golden Event Raw Data sets are stored on disk

- **Events with reconstructed dimuons from MuTr (Golden J/Ψ sample)**
  - **Check FVTX-MuTr matching**
  - **Check DCA for the prompt μ**
  - **Study dimuons mass resolution improvement**
- **Events with good reconstructed single μ with moderate to high momenta.**

FVTX Single Muon Analysis



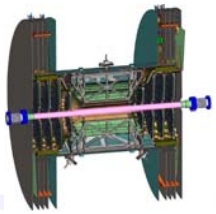


$$N_{total}^{measure}(p_T, DCA_R) = N_p(p_T) f_p^{sim}(p_T, DCA_R) + N_D(p_T) f_D^{sim}(p_T, DCA_R) + N_B(p_T) f_B^{sim}(p_T, DCA_R) + N_{BG}(p_T) f_{BG}^{sim}(p_T, DCA_R)$$

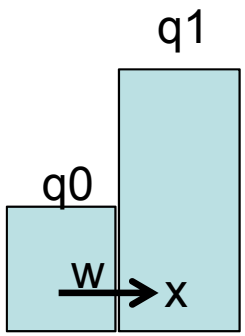
$$N_p(p_T) + N_D(p_T) + N_B(p_T) + N_{BG}(p_T) = N_{total}^{measure}(p_T);$$

$$where,\ f_i^{sim}(p_T, DCA_R) = \frac{N_i(p_T, DCA_R)}{N_i(p_T)}, i = prompt, B, D, BG$$

Clustering, Tracking and Residuals

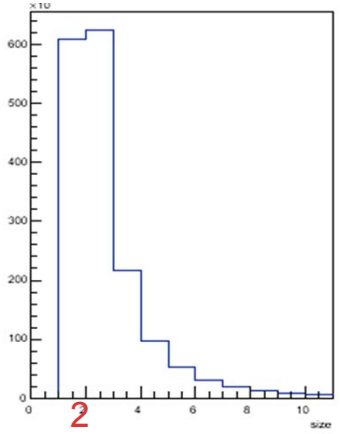


➢ Clustering



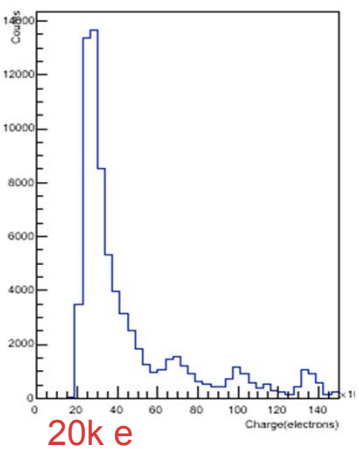
x = extracted coordinate

Size



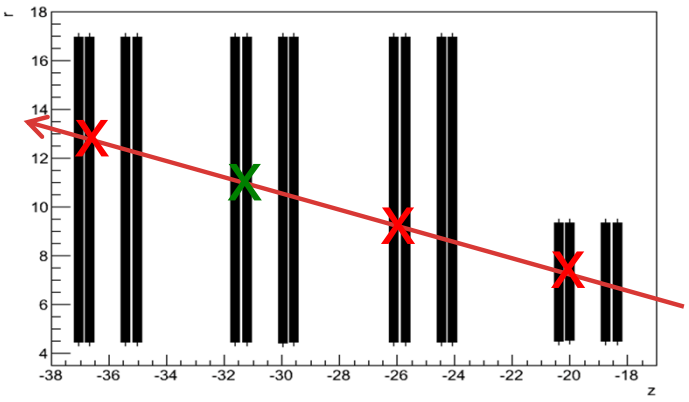
2

Total Charge

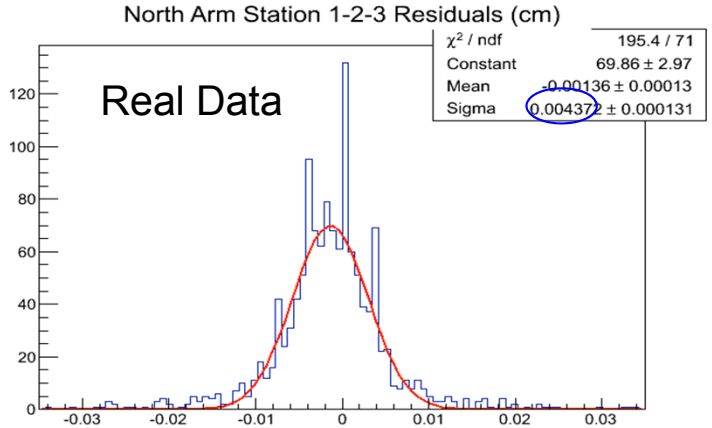


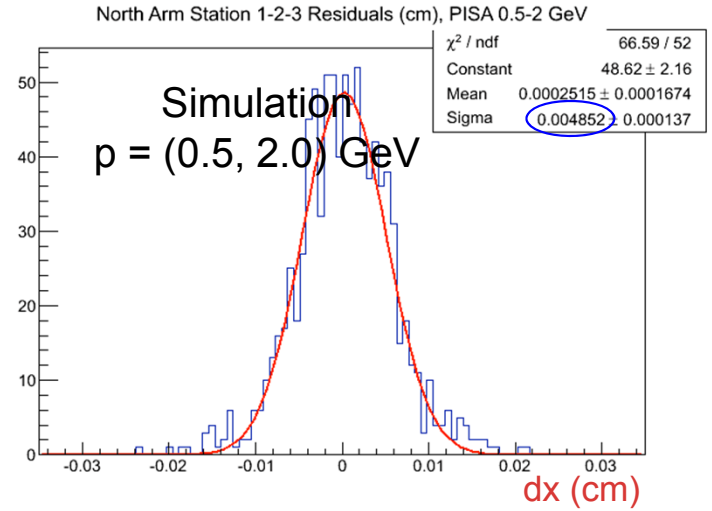
20k e

➢ Track Finding



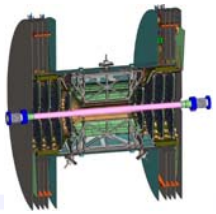
➢ Extract Residuals



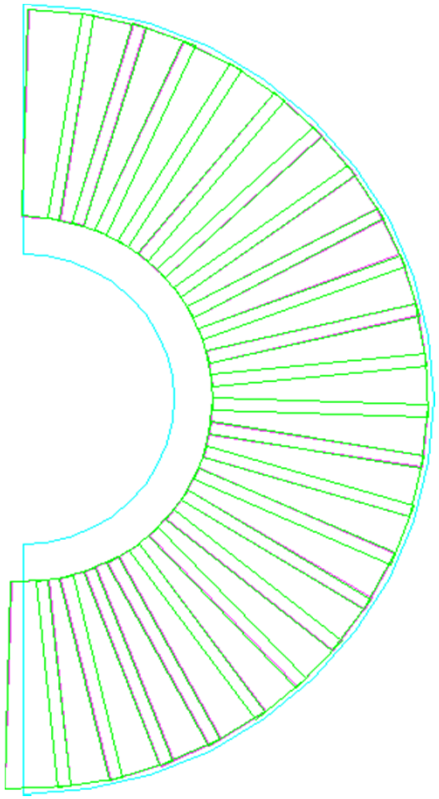


Less than 50 μm resolution in real data and simulation, which includes detector intrinsic resolution (25μm) + multiple scattering + projection errors met our deliverables.

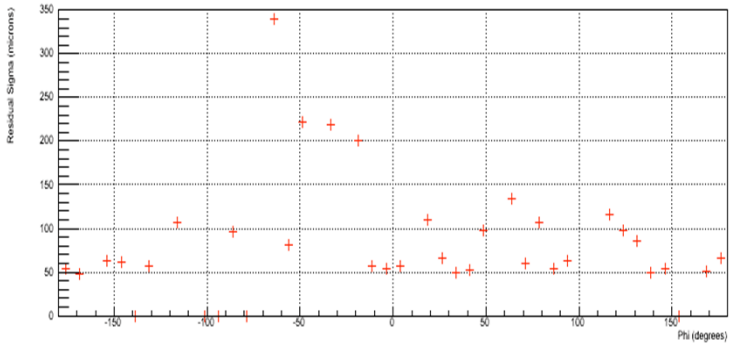
Alignment (I) Survey

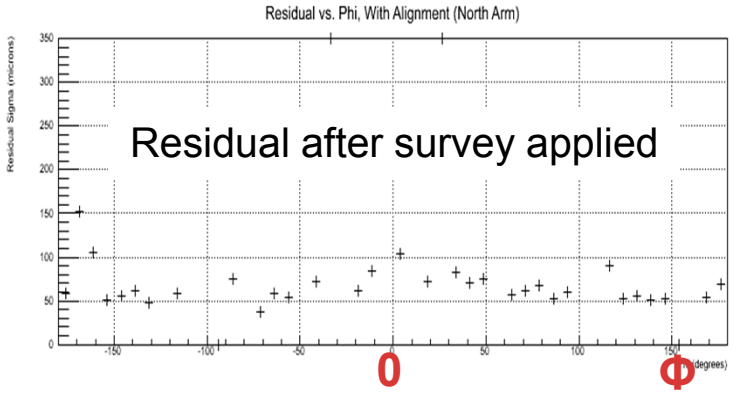


- Mechanical alignment, allows corrections for each wedge .
- Survey data for the big disks entered into the database.
- Sigma of residuals improved after survey corrections were made.

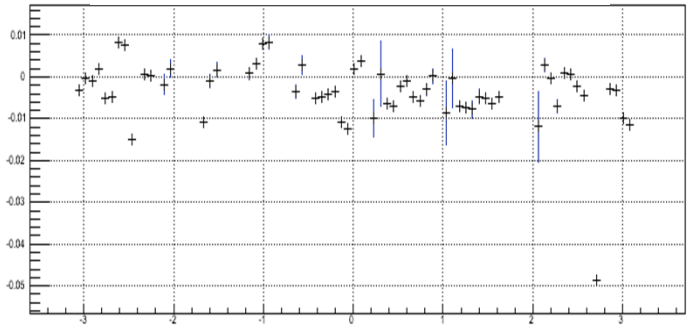


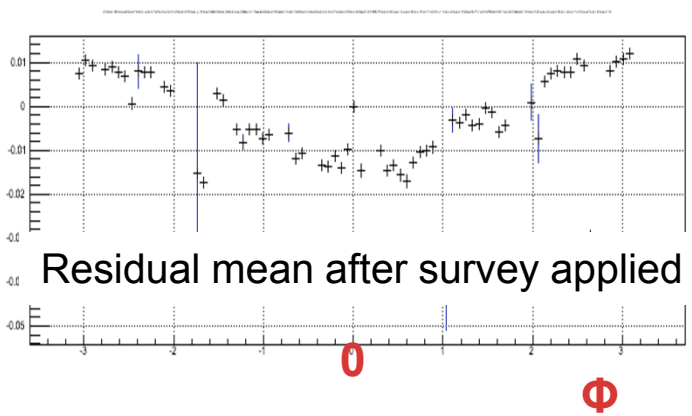
Residual sigma vs. phi



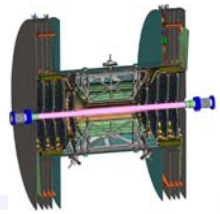


Residual mean vs. phi

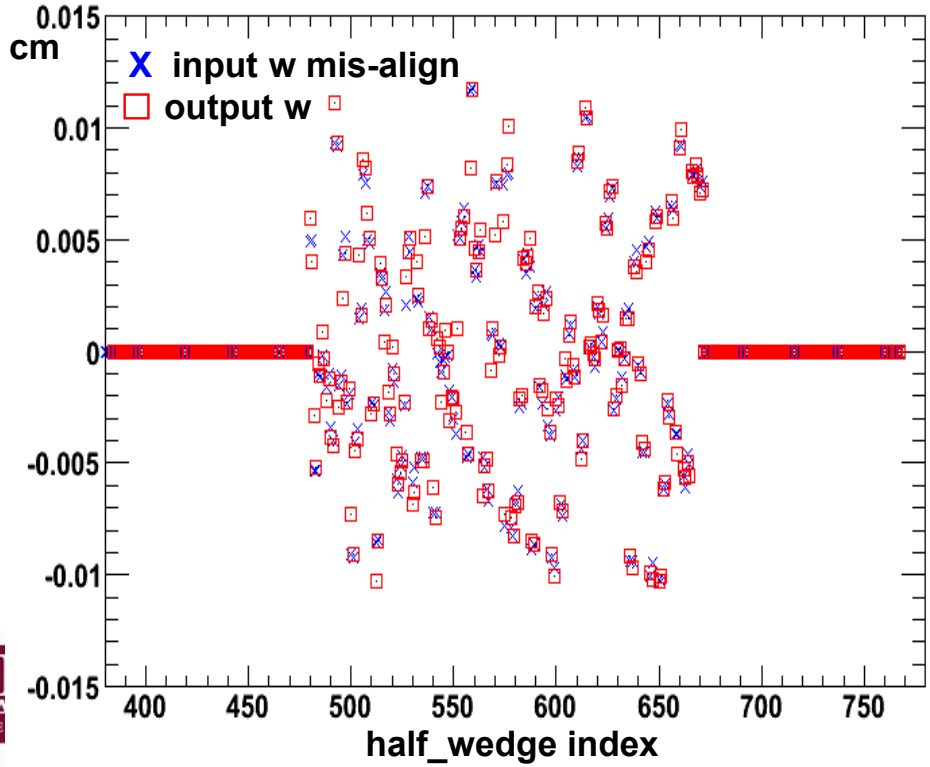


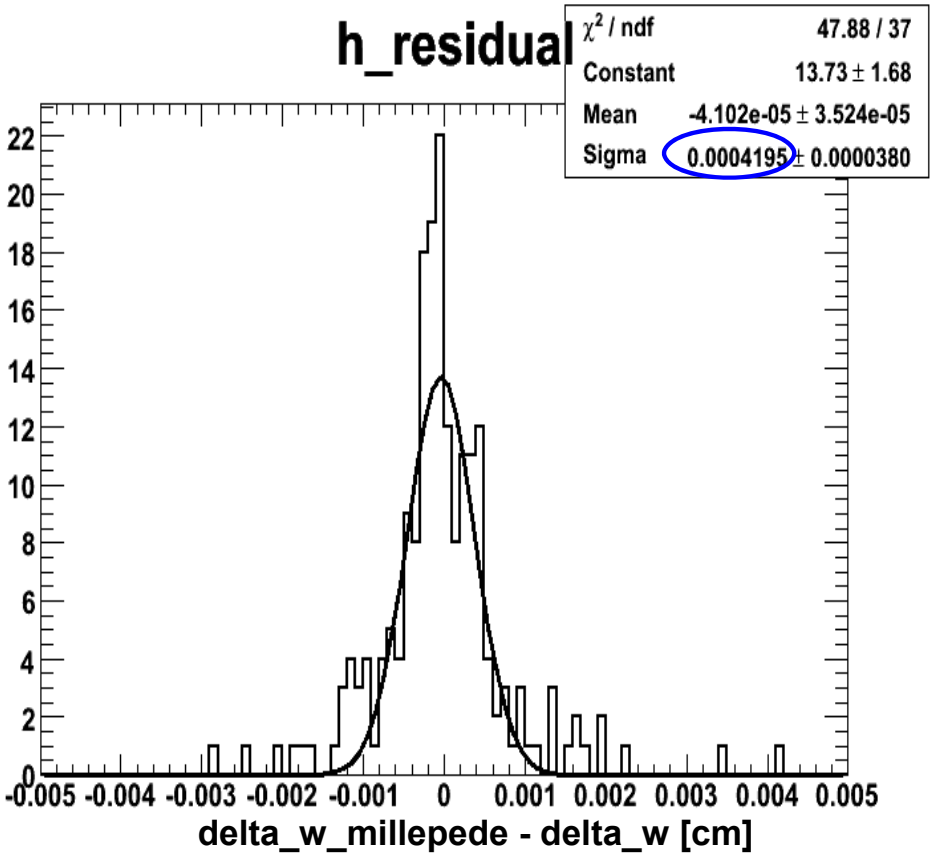


Alignment (II) – Offline Alignment

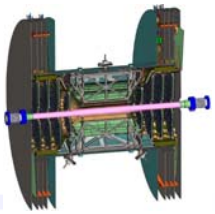


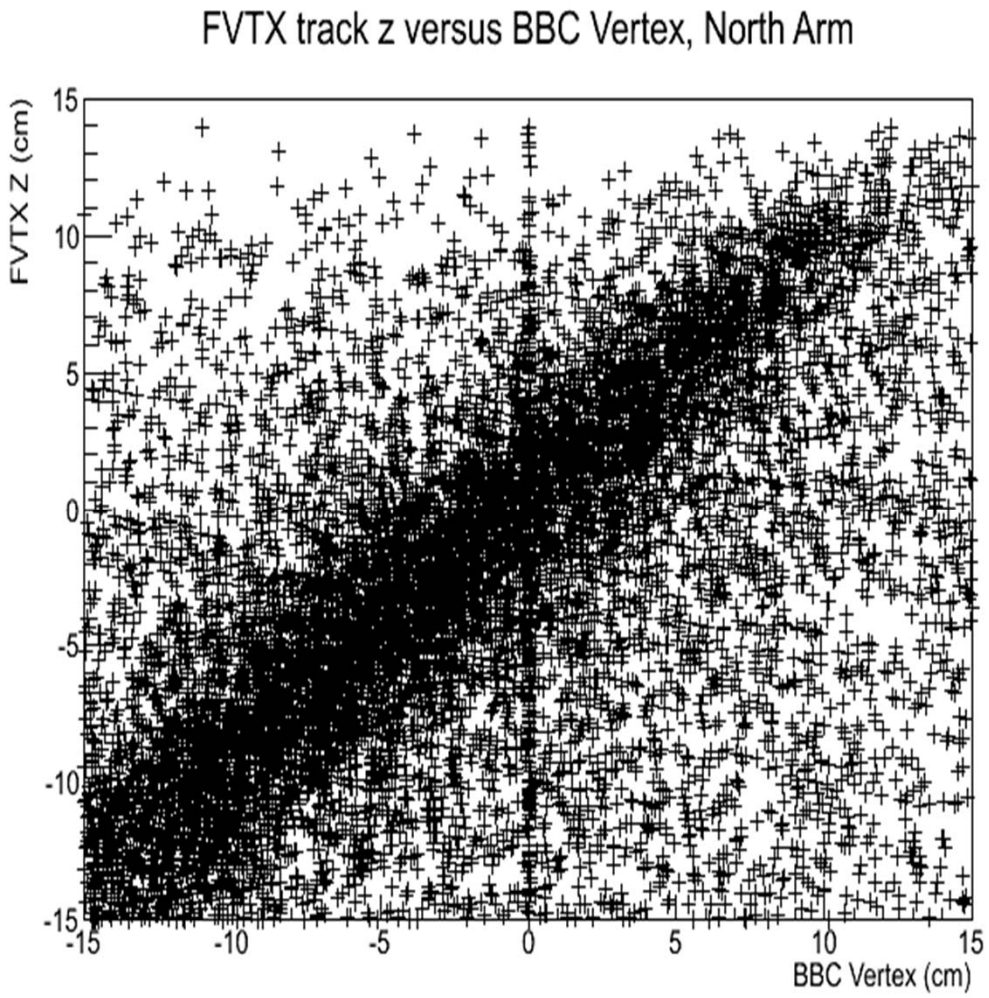
- Offline alignment, an algorithm (Millepede) which uses straight tracks align detectors. The algorithm has been working well in PHENIX MuTr system, is now being implemented in FVTX.
- Tested with simulation
  - Data Introduction mis-alignment for each wedge randomly [-100, 100] μm;
  - Test with 50k MC single muon zero-field tracks.
  - The input mis-alignments are well reproduced, with Residual sigma ~4 μm;
- Ready to use for real data.

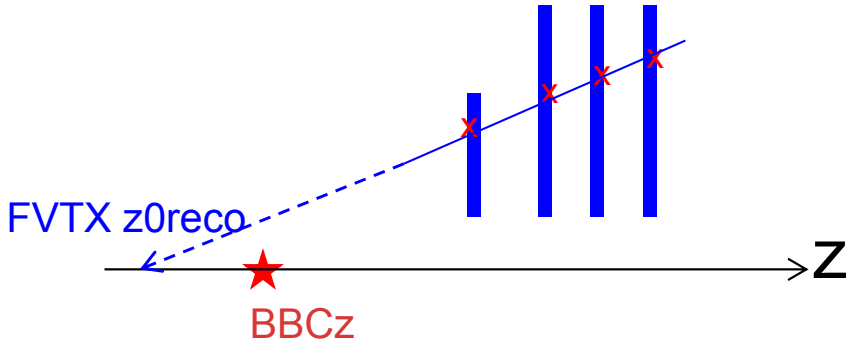




Correlations Between FVTX and BBC

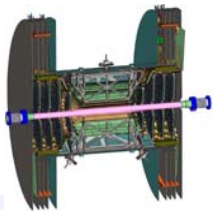


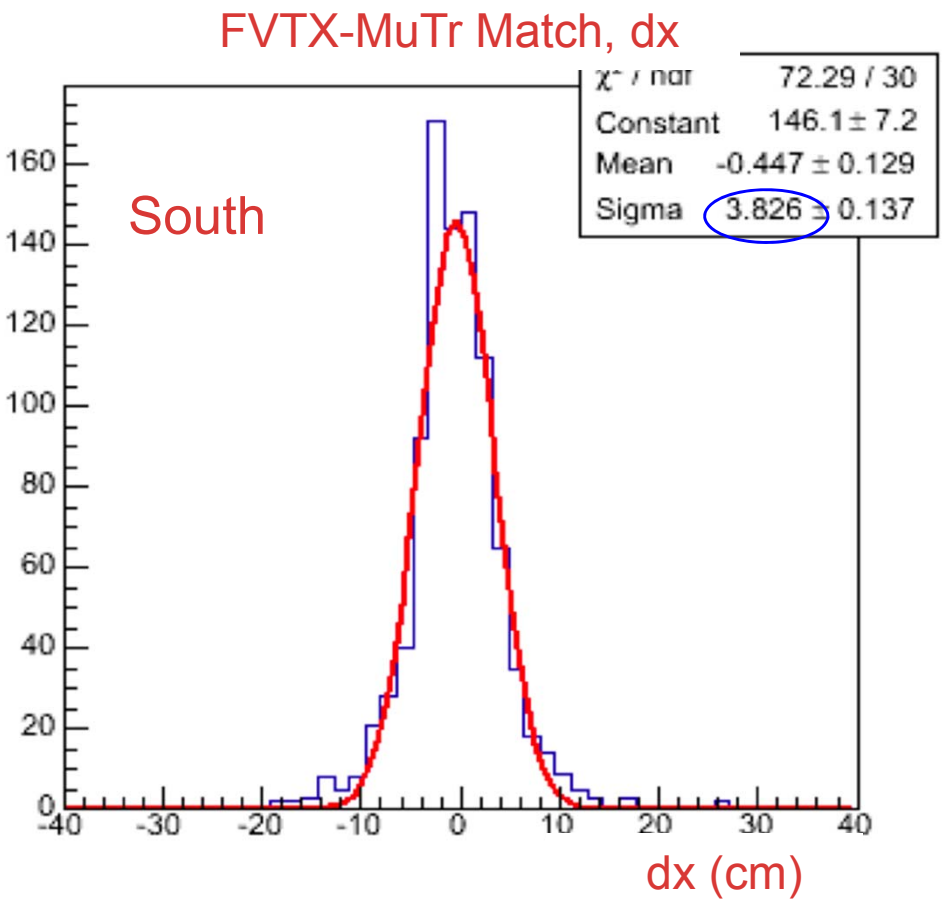


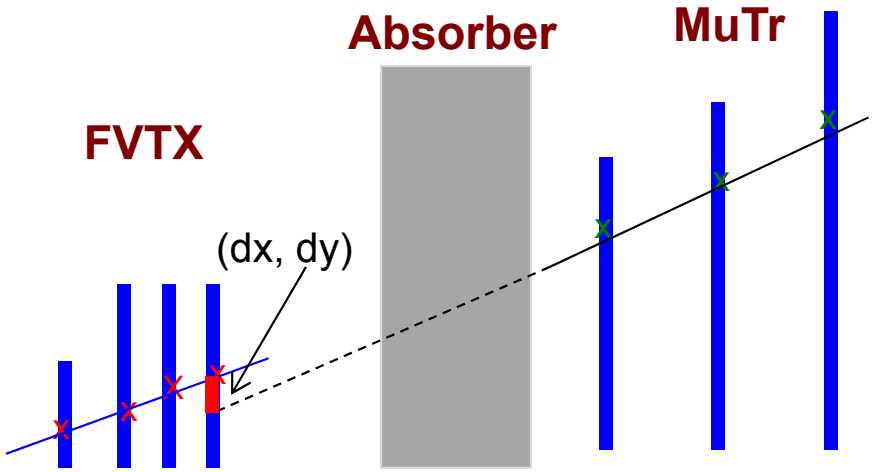


- Select FVTX tracks which have 4 coordinates with good χ^2.
- Project track back to z axis (FVTXz0reco) compare with BBC z vertex.
- Can see the arm can not reconstruct when vertex is underneath FVTX, but it can project to either side.
- Indicate that FVTX has been timed in and roughly aligned with PHENIX other detectors.

FVTX and MuTr Match

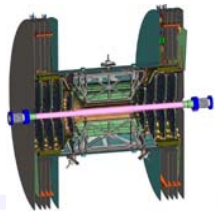






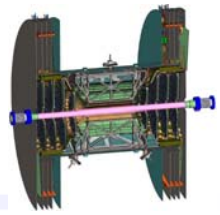
- Loop over MuTr tracks and look for matched FVTX tracks.
- Best matching tracks peaks at 0.
- We expect a few cm window due to the multiple scattering in absorber. Simulations use 3cm windows for matching.
- It will be improved once we finish the detector alignment. (FVTX alignment and global alignment)

Database Status



- FVTX disks have been updated to reflect as-built geometry.
  - Survey data has been added into database
  - Alignment constant from Millepede need to be stored into database
- Detector response includes noise and digitization from calibration data.
  - Need to add database connection
- FVTX DAQ download parameters already stored by expert GUI
  - Already put into database
- QA scan: store running time electronics failure
  - Need to add database class
- High Voltage history during the run has been stored in log file.
  - Need to add database class

FVTX Group



LANL: Cesar Luiz da Silva, Hubert van Hecke, Melynda Brooks, Ming Liu, Pat McGaughey, Xiaodong Jiang, Christine Aidala Huang Jin, Matt Durham, Kwangbok Lee

NMSU: Xiaorong Wang, Feng Wei, Elaine Tennant, Abraham Meles, Darshana Perera, new student

UNM: Douglas E. Fields, Amaresh Datta, Sergey Butsyk, Aaron Key Kathy Deblasio, Dillon Thomas

Columbia University: Beau Meredith, Aaron Veicht

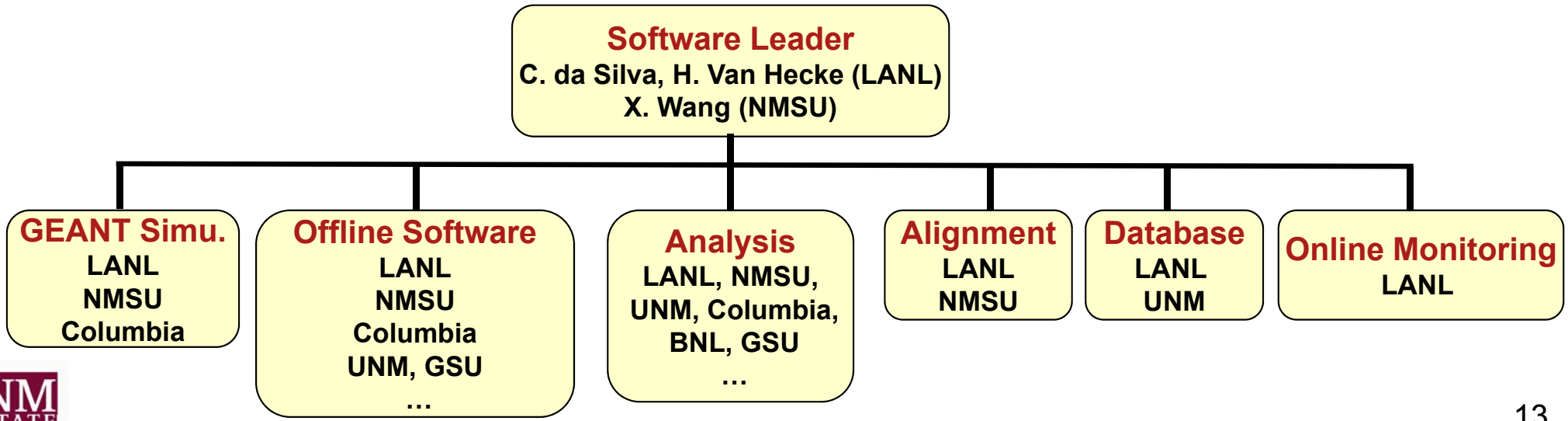
Georgia State University: Xiaochun He, Jezghani,Margaret

*** student**

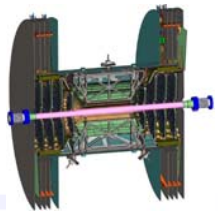
-- *Institutes now working on Muon Arm analyses*

BNL, Colorado, ISU, Korea U., RIKEN, UCR, UIUC …

Will continue muon related analyses with FVTX, like W measurement.

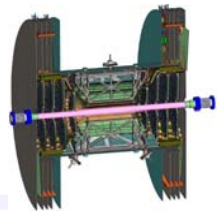


Summary and Future Work

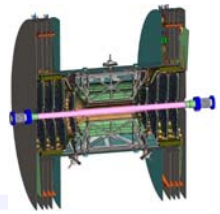


- FVTX software has been used in real data analysis. FVTX tracks have been reconstructed and matched with MuTr tracks and correlated with BBC. Fine tuning is still underway.
- Filtered golden dimuon and single muon raw data has been stored on-disk. They will allow us to do alignment, fine tune our software and physics analysis.
- Adding more information into database.
- Finishing importing survey information and use millepede to get final alignment correction (Software is ready).
- Will add VTX both in track finding and primary vertex finding. Will get improved DCA measurement and start physics analysis.

backups



FVTX Real Data Status



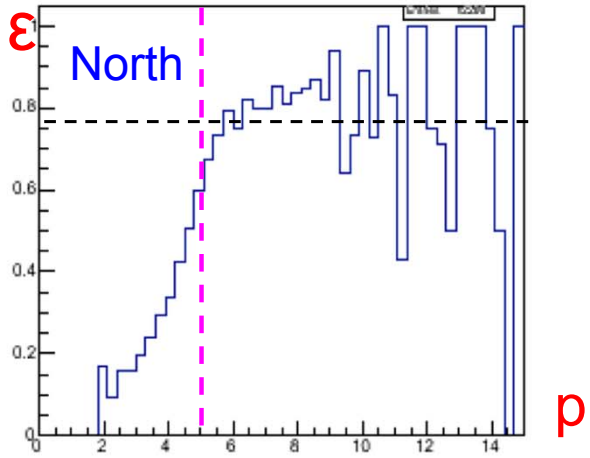
- Collecting Physics data in PHENIX Big Partition
  - 200 GeV p+p: 100M events with 1/6 of the FVTX
  - 500 GeV p+p: 4.1B events
- Lower momentum single muon trigger has been implemented successfully.

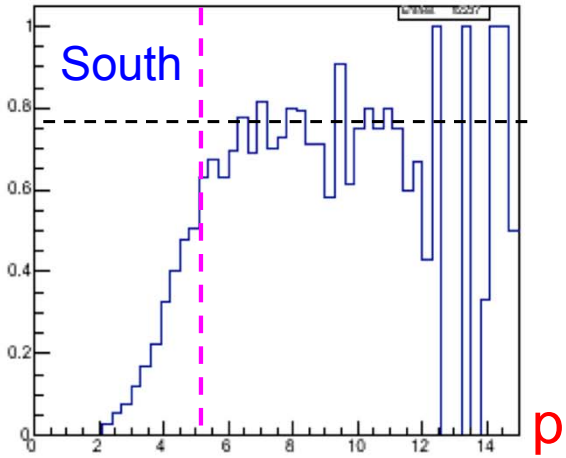
  Goal: open heavy flavor measurement (c and b)

  Trigger: MUON_S(N)_SG3&MUIDLL1_S(N)1D&BBCLL1(noVtx)

  Offline Efficiency:

  (>80% for p > 5 GeV)



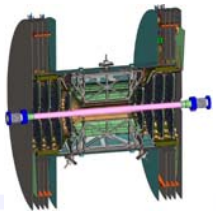


- PRDF Filtering will keep all single muon and dimuon golden events on disk.

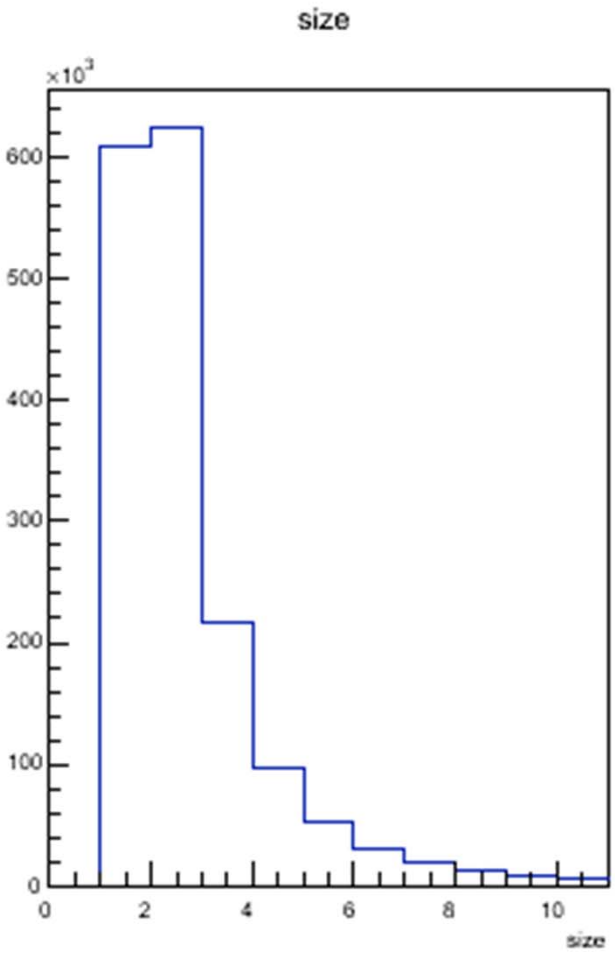
  GoldenEvent_Dimuon.PRDF (MuID_2Deep trigger)

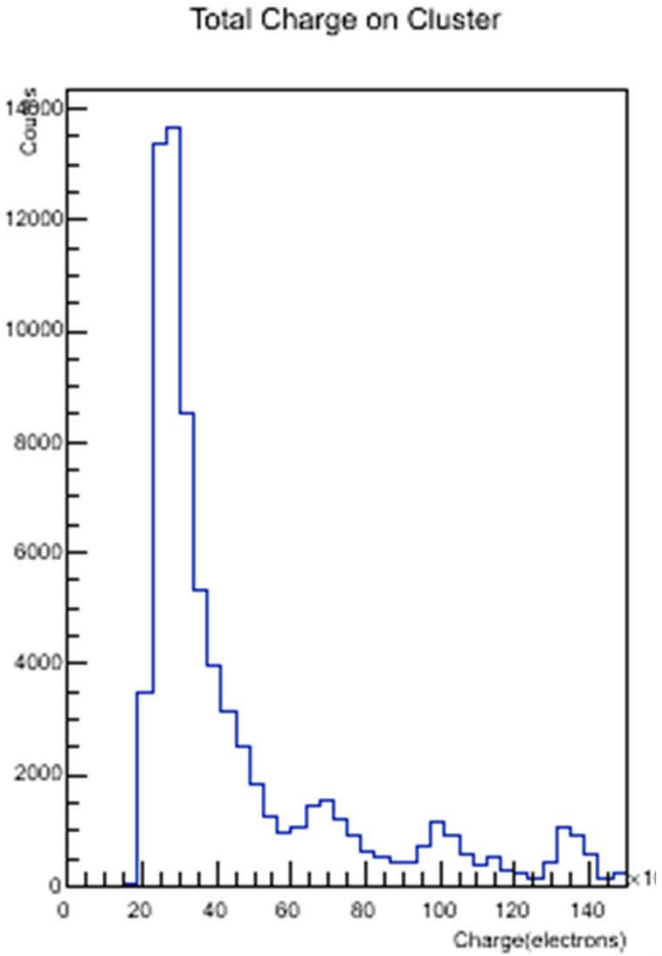
  GoldenEvent_FVTX.PRDF (SG1(SG3) &1Deep trigger)

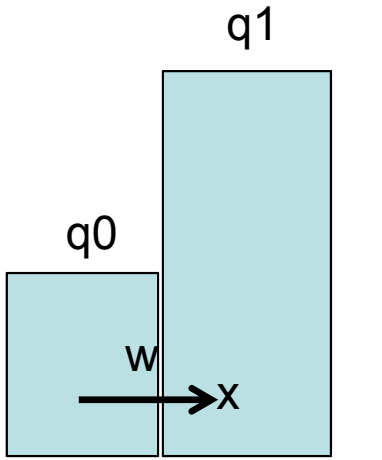
Clustering, Tracking and Residuals



- Cluster distributions look reasonable
  - Cluster size peaks at 2 strips wide
  - Total charge in the ball-park of expected (need to update ADC→electron conversions).

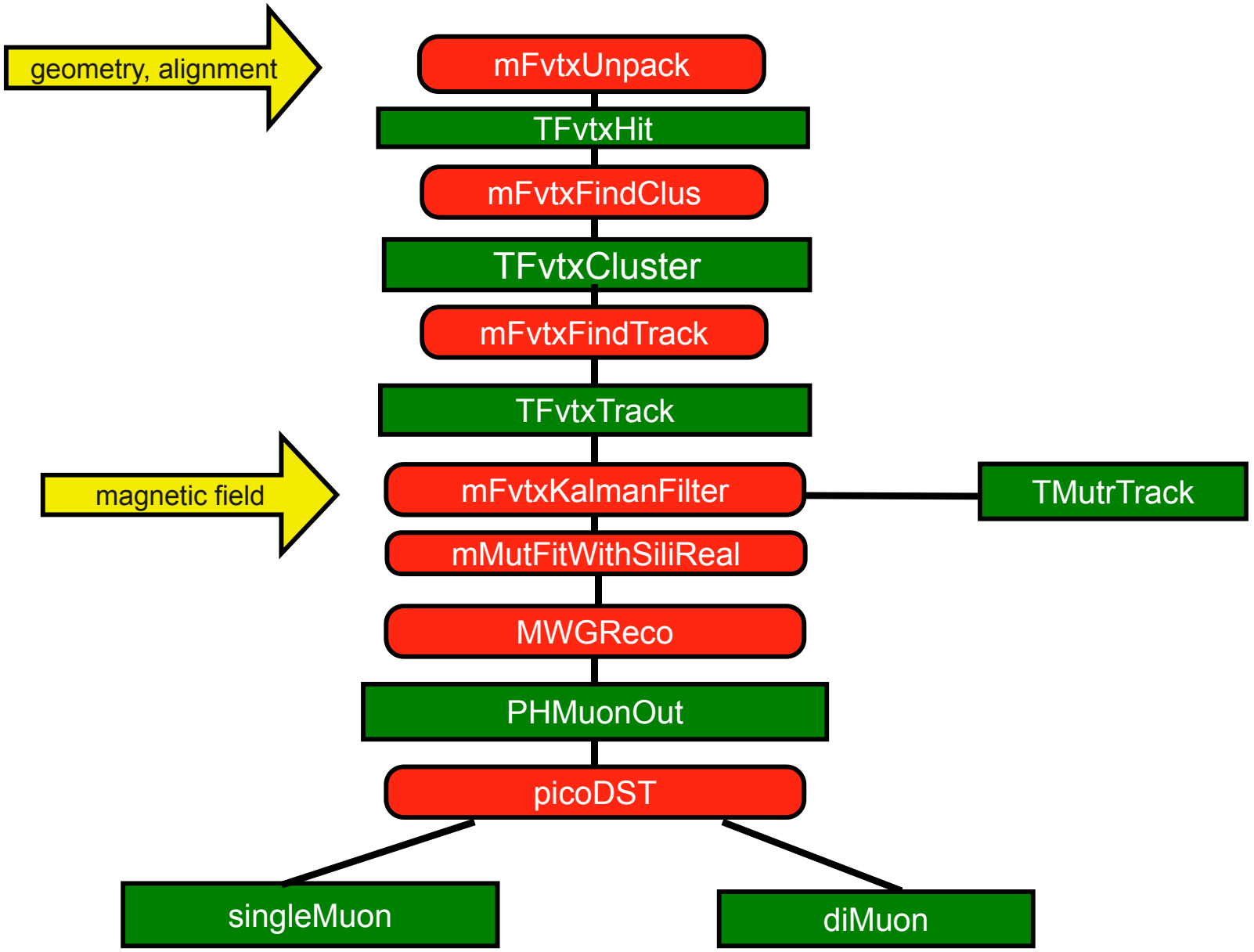




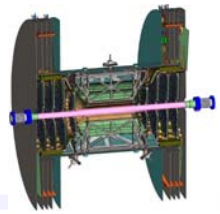


x = extracted coordinate

FVTX Software Flow Chart



Variables FVTX – MuTr Matched Track



PHMuonOut content

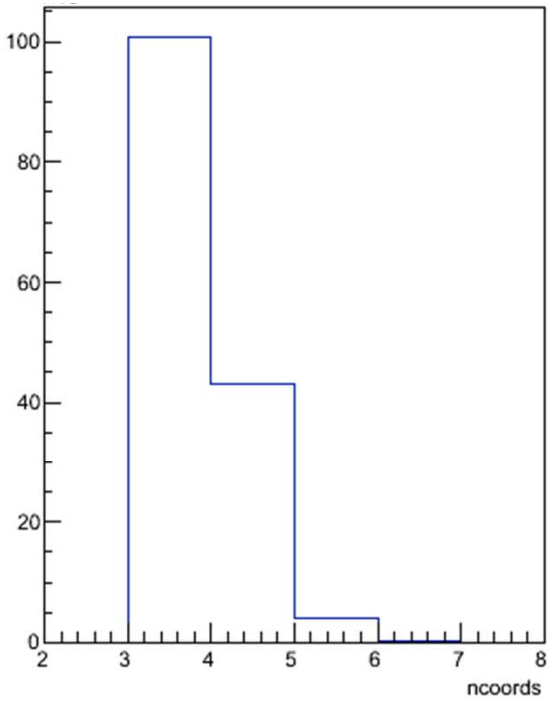
each MuTr+FVTX associated track
x,y,z vertex
px, py, pz at vertex
MuTr-FVTX phi residual
MuTr-FVTX theta residual
chi^2 from Kalman Filter
covariant matrix
nFVTX tracks around MuTr track (dphi, dtheta)

for each FVTX station projection
cluster size(station)
cluster charge(station)
(cluster peak) - (track projection)
peak strip index

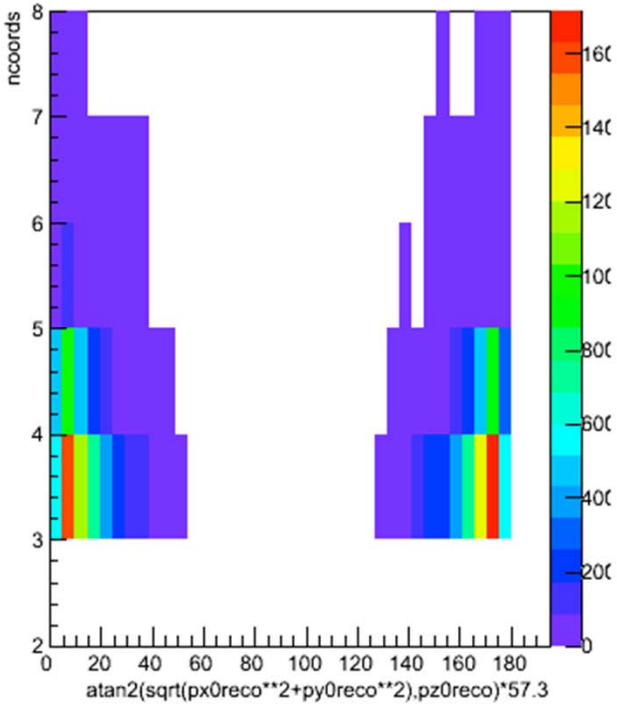
Track Finding

- Track finding has some good and not-so-good distributions
  - Number of coords = 3, 4, 5…
  - Number of hits versus angle seems to make sense
  - Chi-square distributions have some oddities – this actually looks better now when placing cuts on tracks that have appropriate hits, but still tuning to do

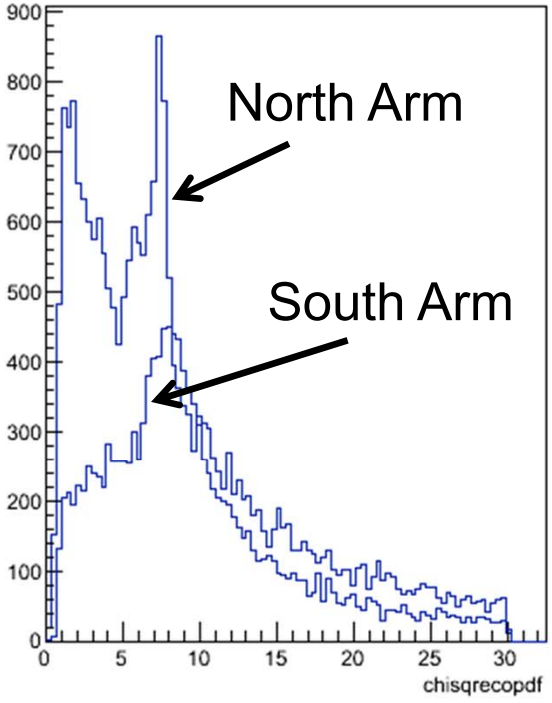
Number of coordinates on a track



Number of coordinates versus theta

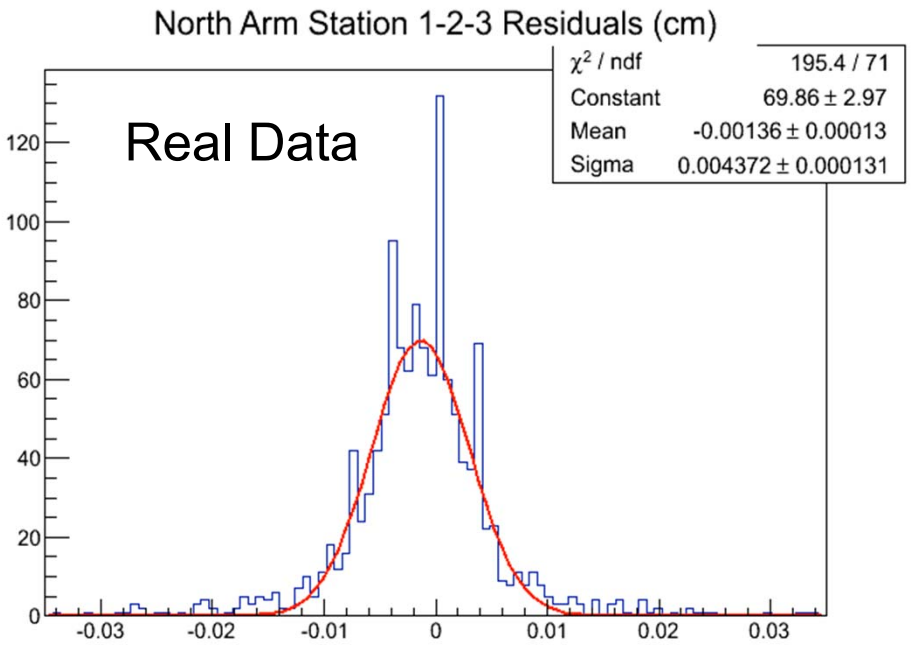


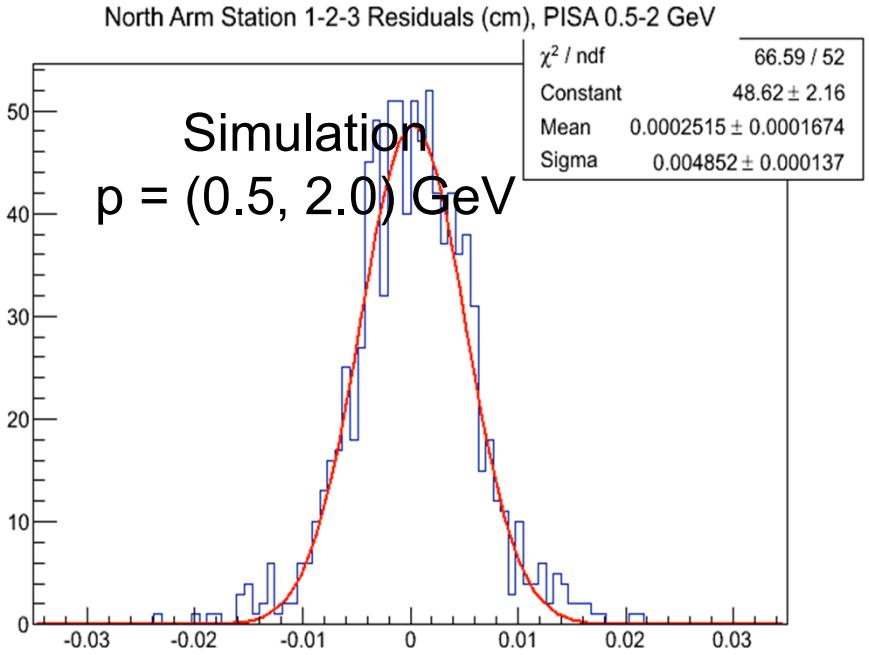
χ^2 of track



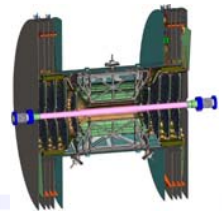
Residuals Extracted

- Residuals for each wedge now getting to about what you would expect compared to Monte Carlo, but survey and alignment needed for all residuals to line up
- We will run over large filtered sample and make residual versus muon p and see if correlation is as expect.

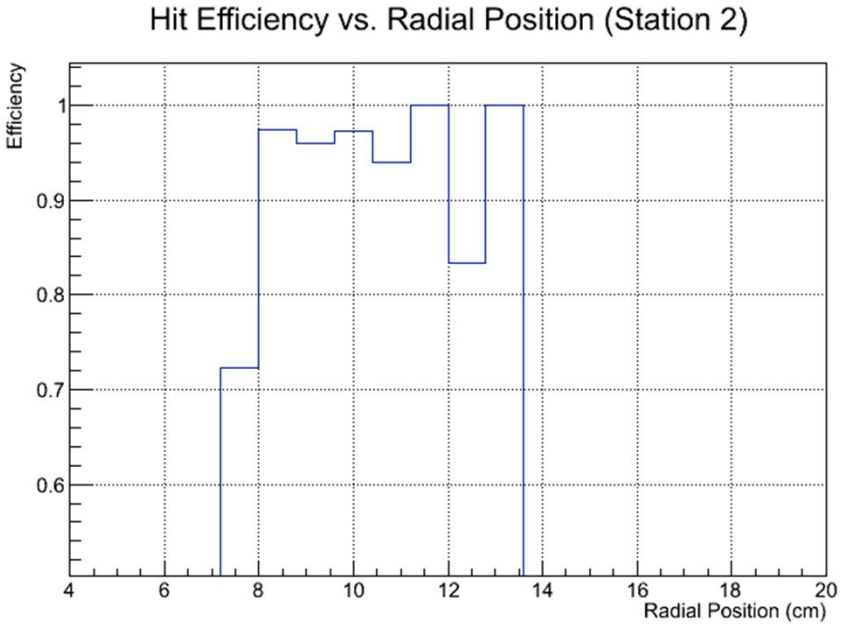


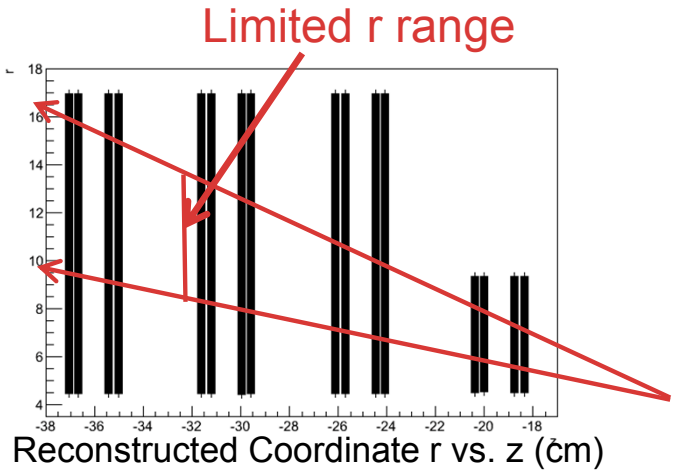


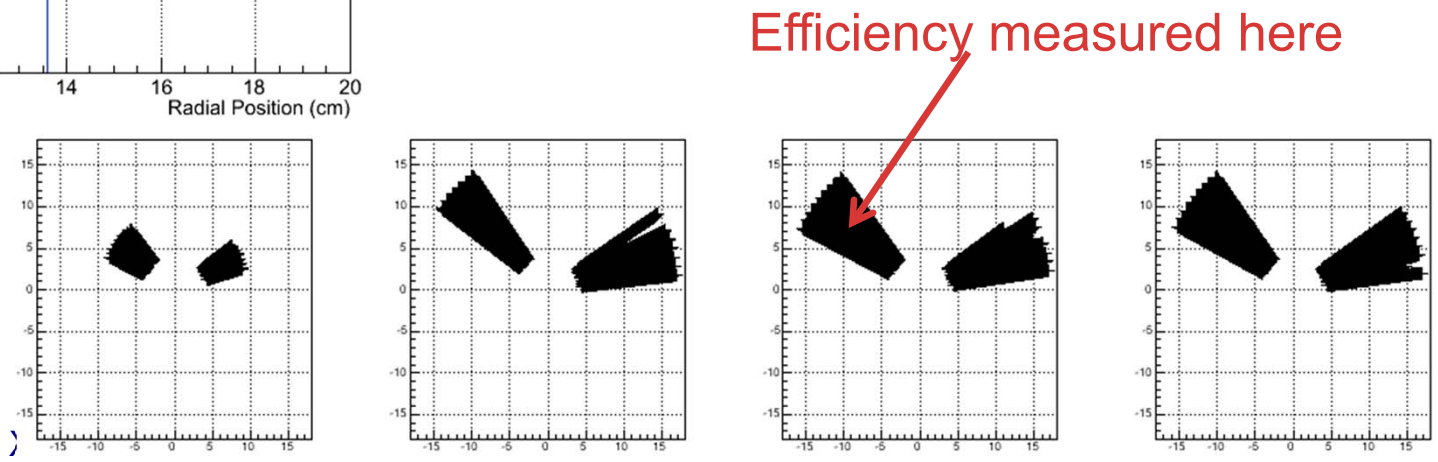
Detector Efficiencies



- Take station 0-1-3 tracks
- Require that the 0-1-3 residual be less than some value
- Require that the theta and phi of the 0,1,3 track be in some window
- Now create histogram of (# that pass cuts and have a good station 2 residual)/(# that pass cuts), versus whatever variable you want

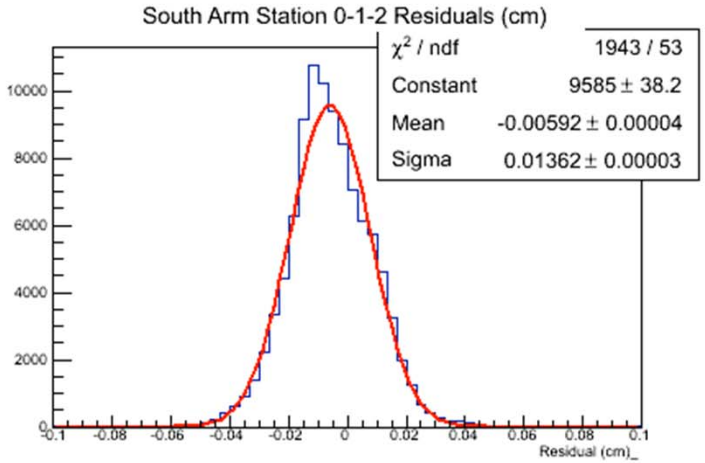


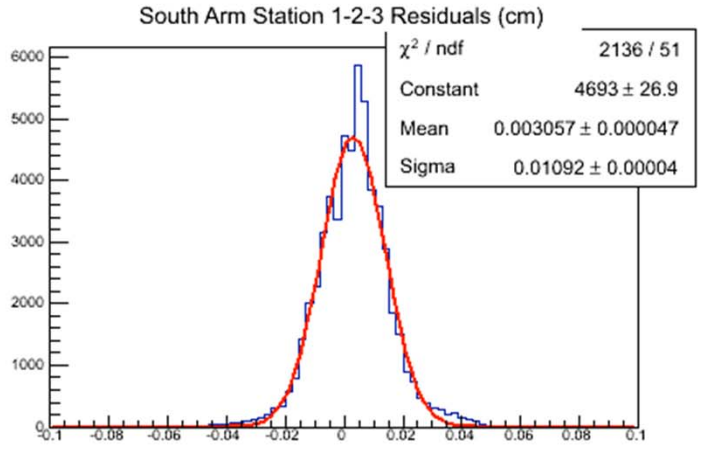


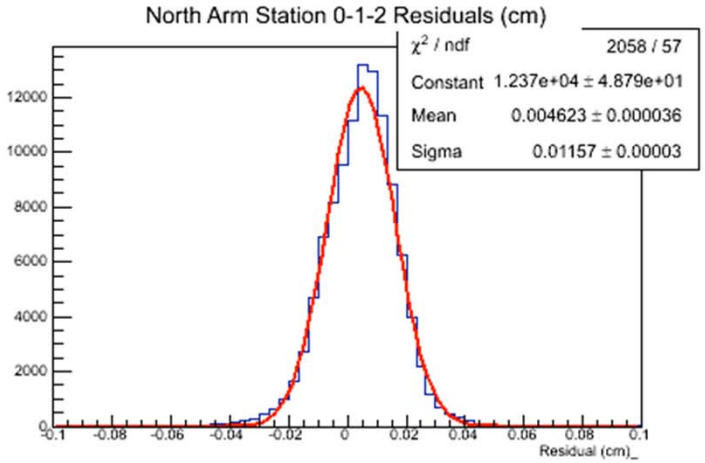


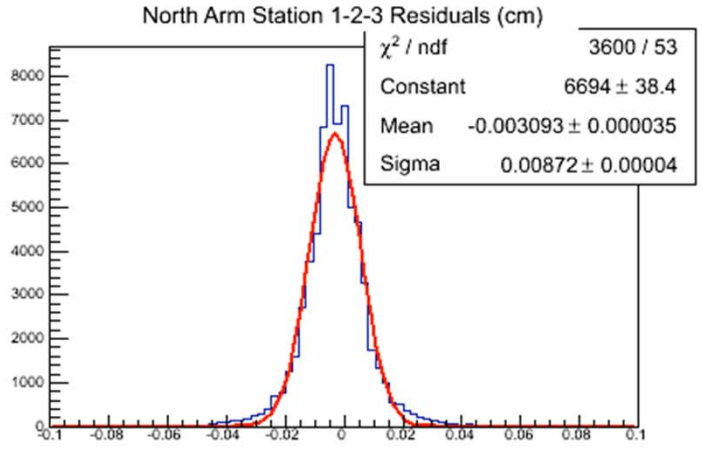
Residuals Extracted

- Station 0-1-2 residuals not as good as station 1-2-3
- South arm has more issues than North Arm
- Probably some remaining geometry issues and/or coordinate calculation issues

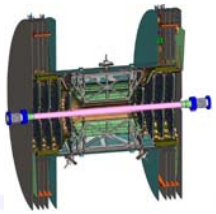




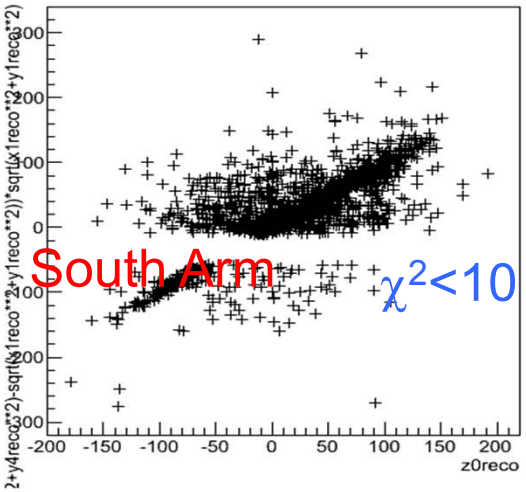


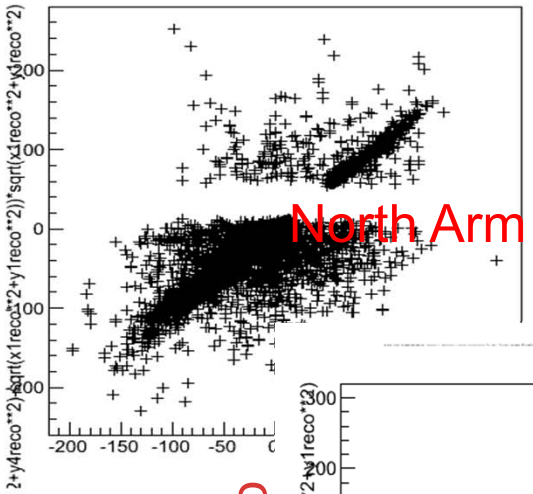


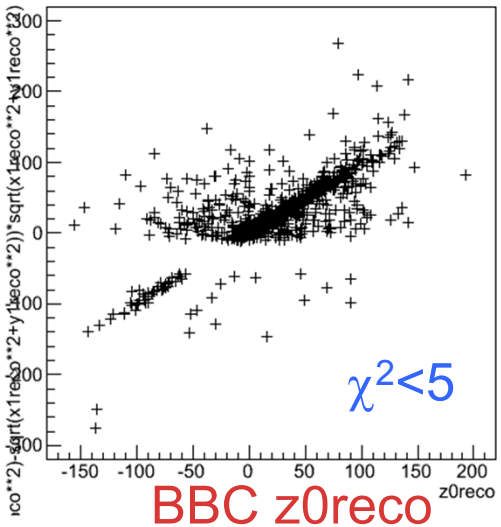
FVTX-BBC Correlations

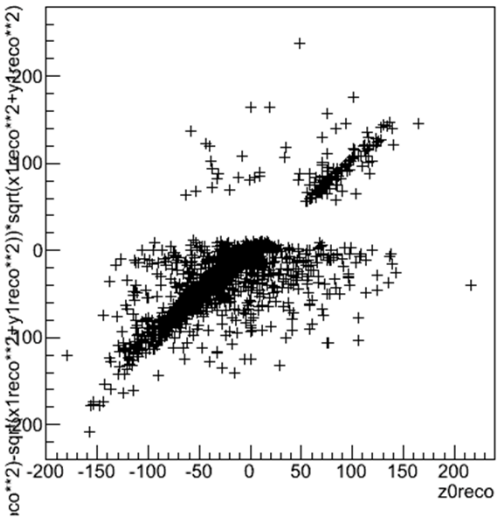


- Select FVTX tracks which have 4 coordinates and a good chi-square fit
- Project track back to the z axis and compare z value to the value of the BBC reconstructed vertex.
- Can see the arm cannot reconstruct when vertex is underneath it but can project to either side
- May be some alignment work to do, shouldn't be difficult

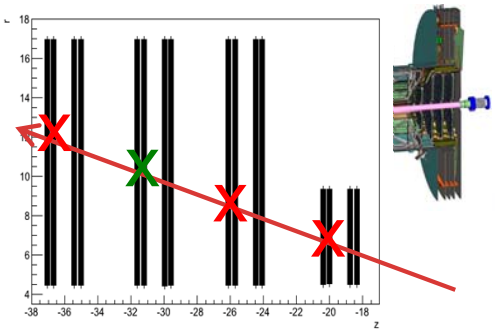






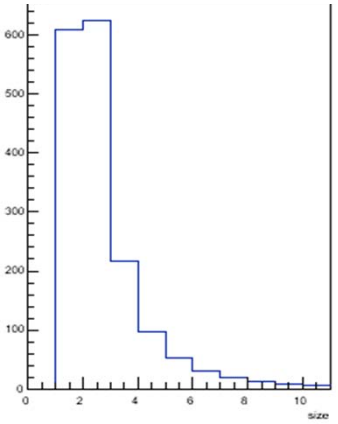


Clustering, Tracking and Resid

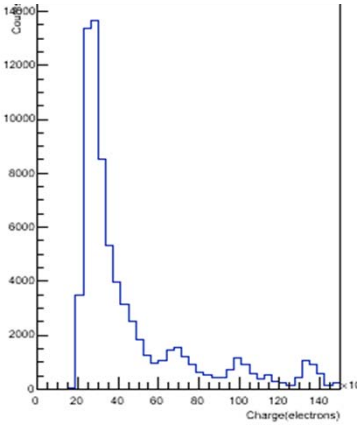


➢ Clustering

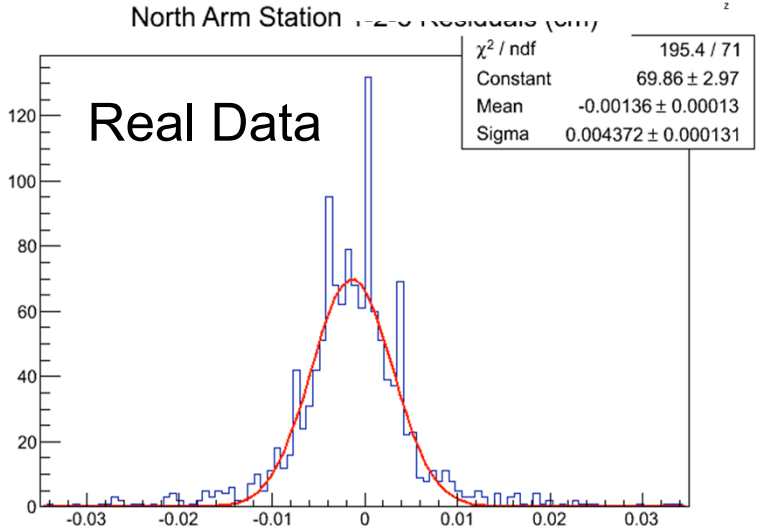
Size



Total Charge

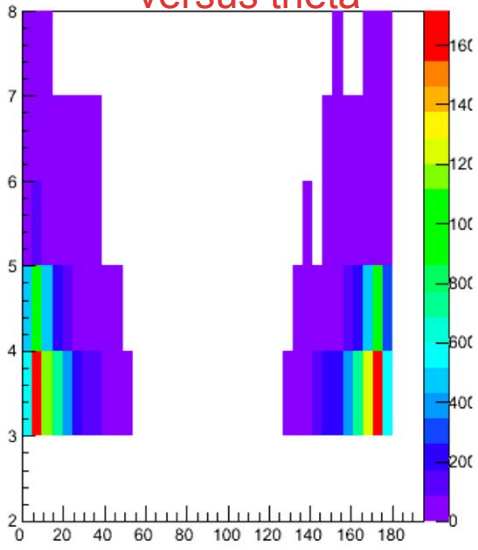


➢ Extract Resid

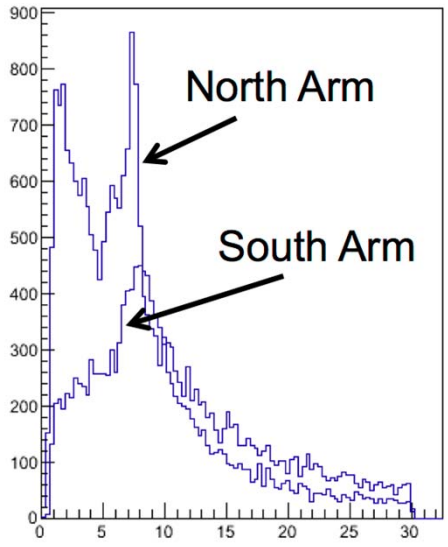


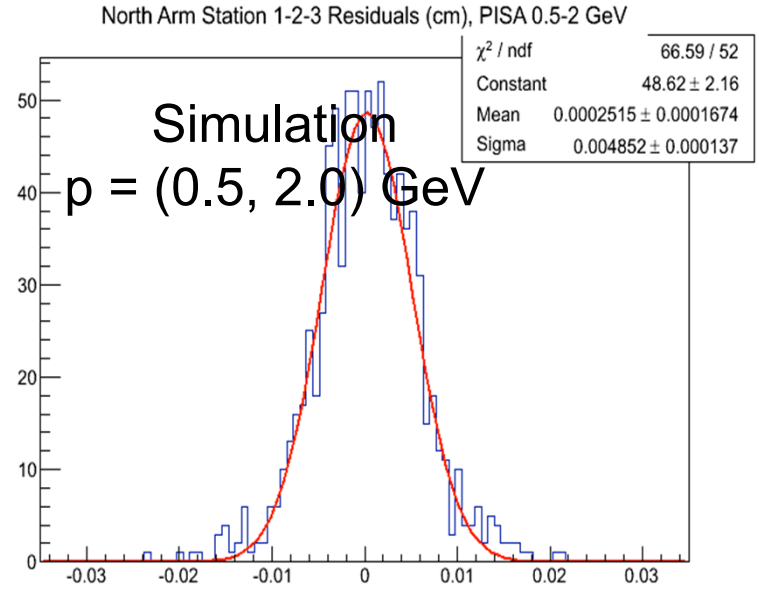
➢ Track Finding

Number of coordinates versus theta

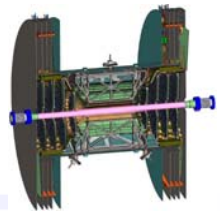


χ^2 of track

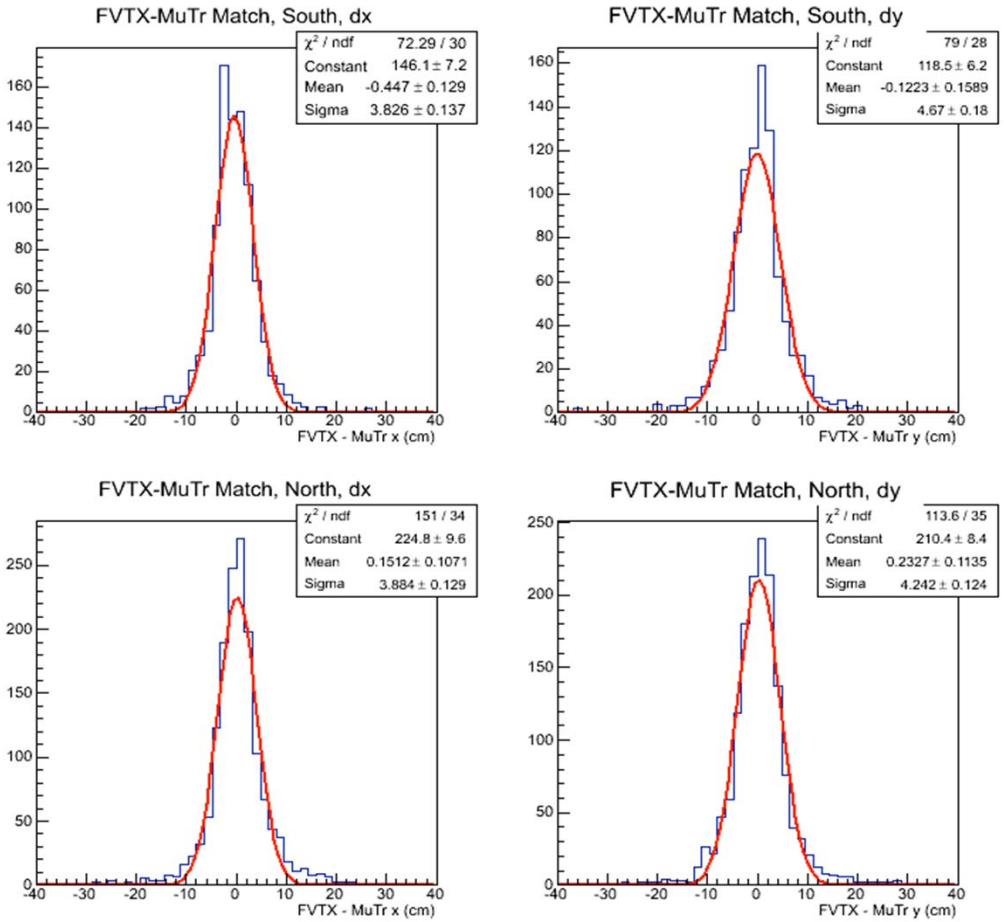




FVTX - MuTr Correlations

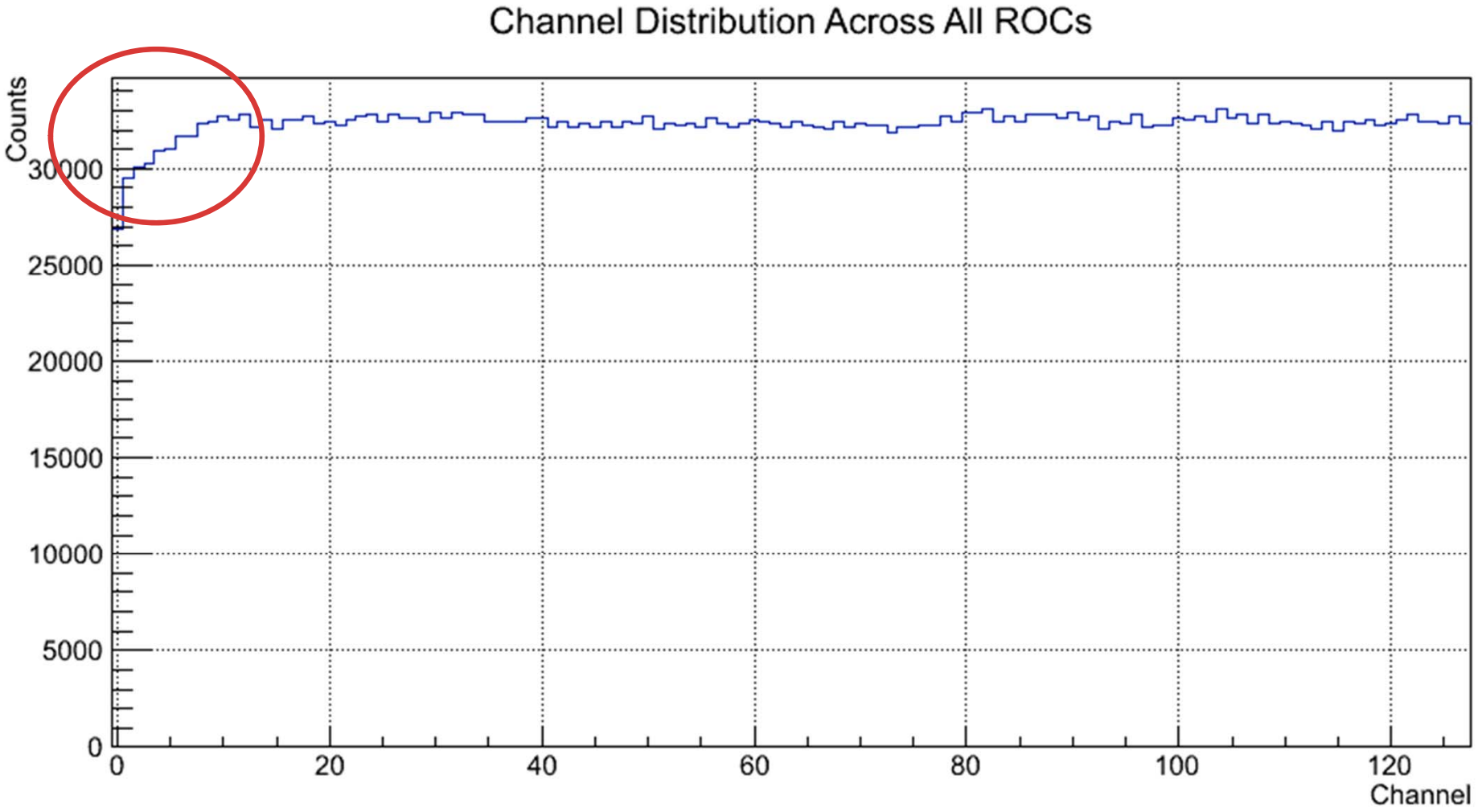


- Loop over MuTr tracks and look for candidate matches in the FVTX system
- Best matching track peaks at ~0 and has close to the expected resolution
- Alignment should be done
- Efficiency should be measured for good MuTr tracks
- Plots should be made with matching tracks, using filtered data sets



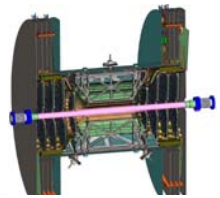
Detector Efficiencies

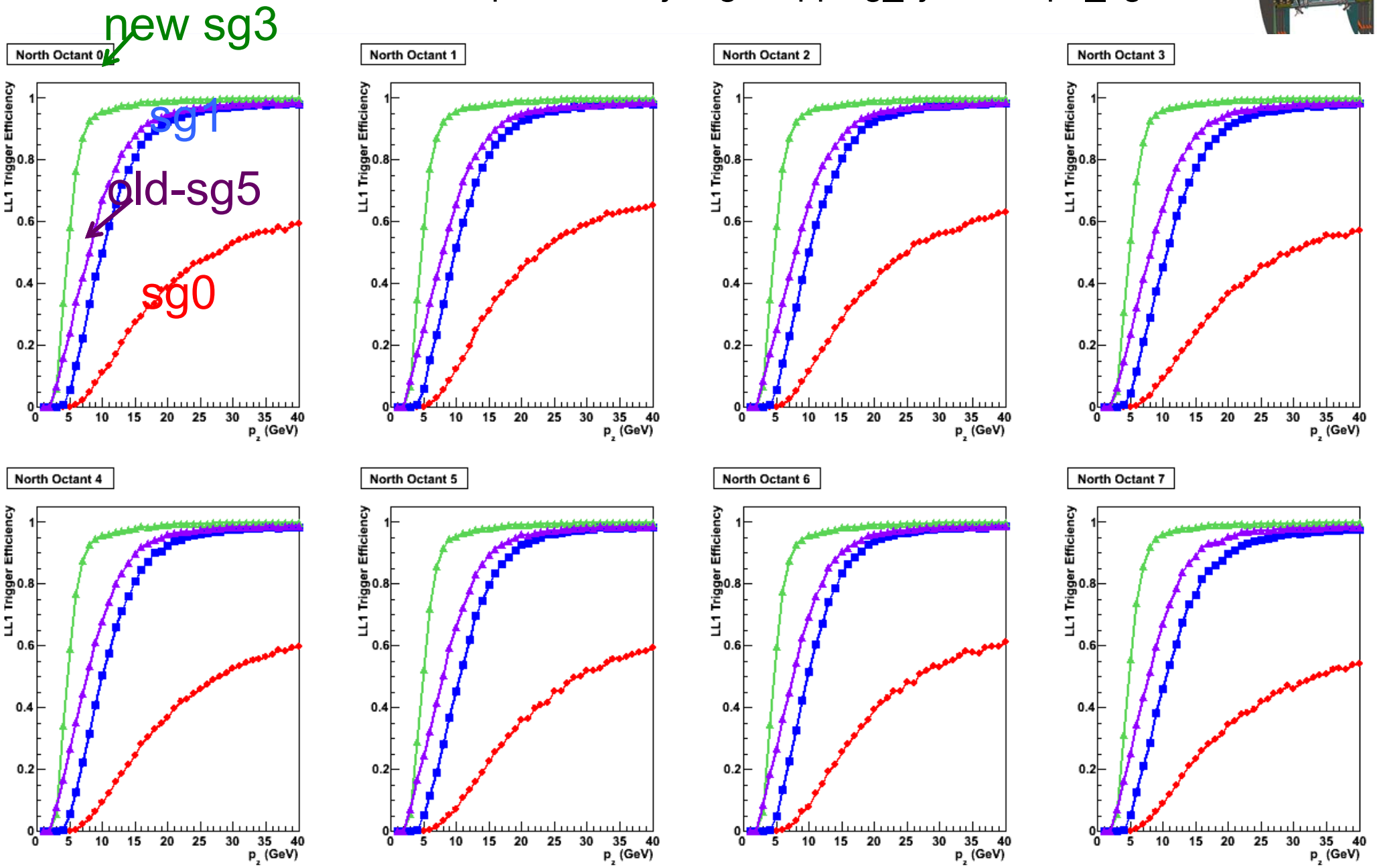
- Some inefficiency seen in integrated distributions of channel number
- Saw similar issues in the lab when trying to tune the BCO→ReadClk phase. Will have to see if this can be improved or is the limit of the board layout



North Arm new-sg3 turn-on at ~5 GeV/c

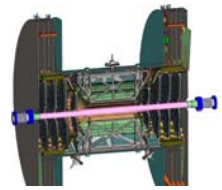
used file: /direct/phenix+u/xjiang/mapping_xj021012p1_sg3.txt

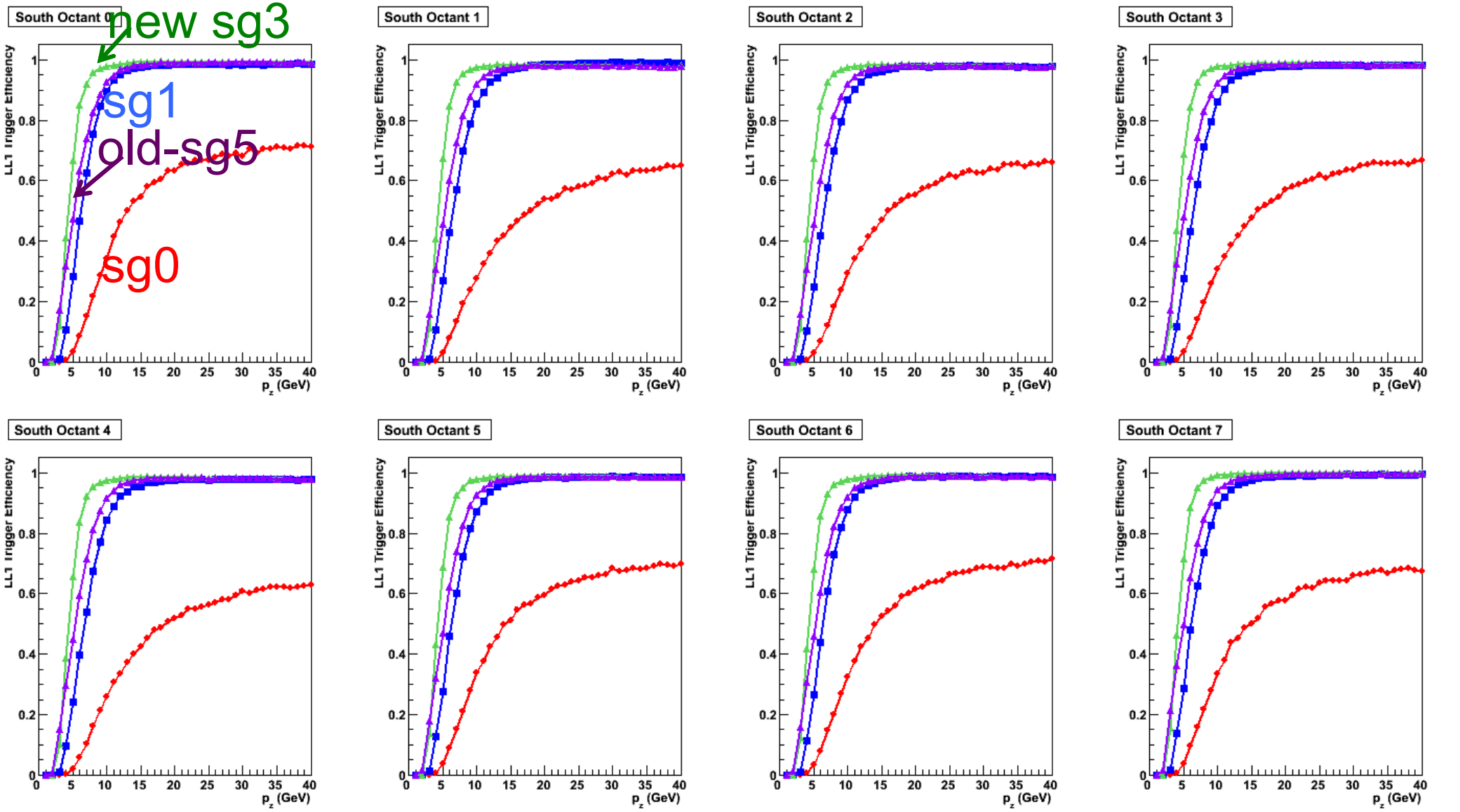




Thanks John !

South Arm sg3 turn on ~5 GeV/c,
used file: /direct/phenix+u/xjiang/mapping_xj021012p1_sg3.txt





Thanks John !