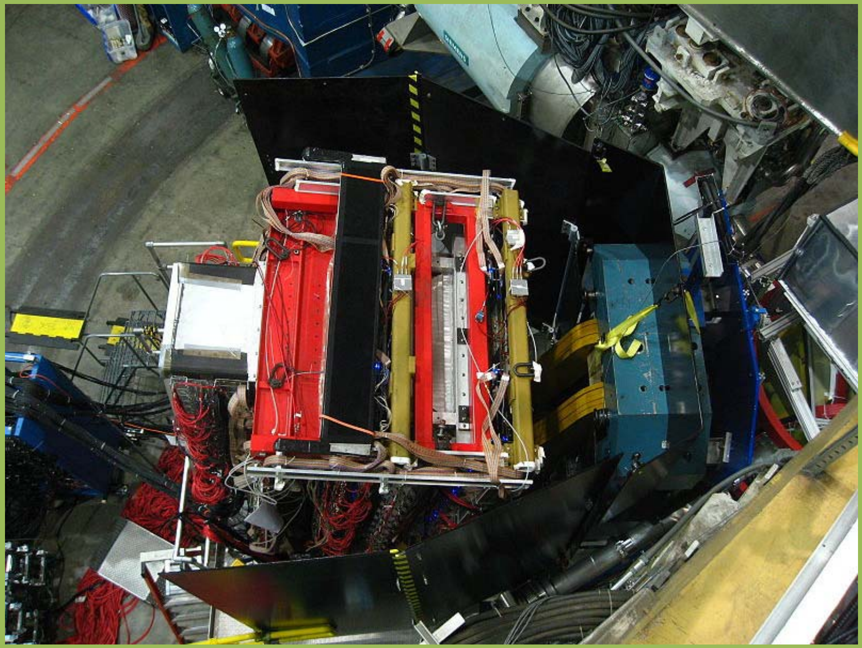
# BigBite Wire Chamber Calibration/Tracking/Optics in E06-010



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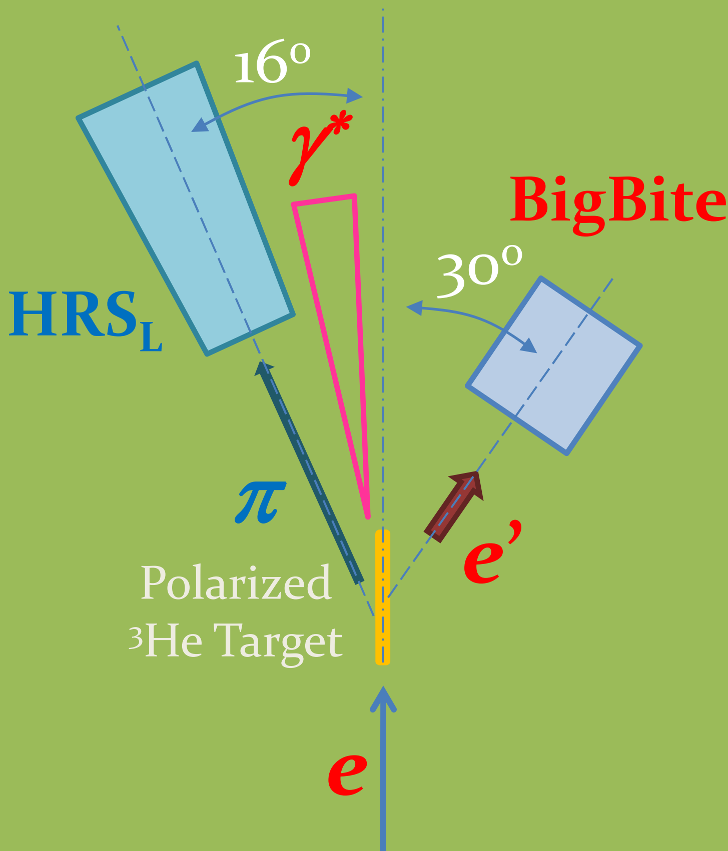
# Outline

- Introduction to E06-010
- BigBite Wire Chamber Calibration  in E06-010
- BigBite Tracking Performance in E06-010
- BigBite Optics Model in E06-010 and E06-014
- Summary

# E06-010: Neutron Transversity

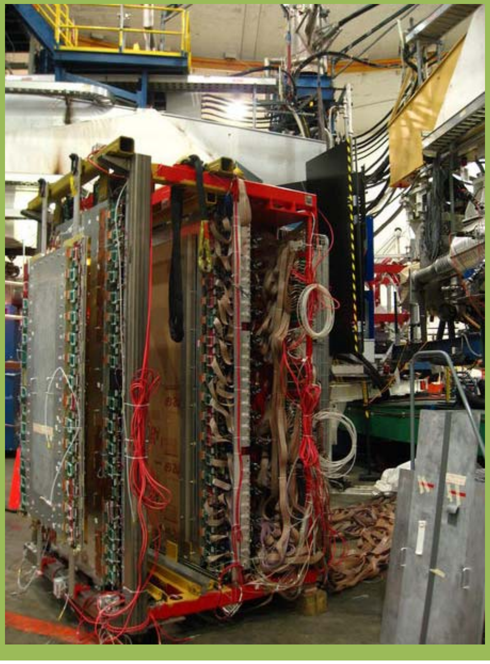
- Probe neutron Transverse Momentum Dependent Parton Distribution Functions (TMDs) through measurements of Single Target Spin Asymmetries (SSA) with a transversely polarized $^3He$ target.
- Transversity Distribution function:
  - 3rd PDFs in addition to $f_1$ and $g_1$.
- Sivers Distribution function:
  - Parton level QCD FSI and quark orbital angular momentum.
- Semi-inclusive DIS:
  - Catch the leading hadron to tag the hitting quark flavor
  - DIS kinematics ensure to direct probe nucleon structure at partonic level.

# Experimental Setup

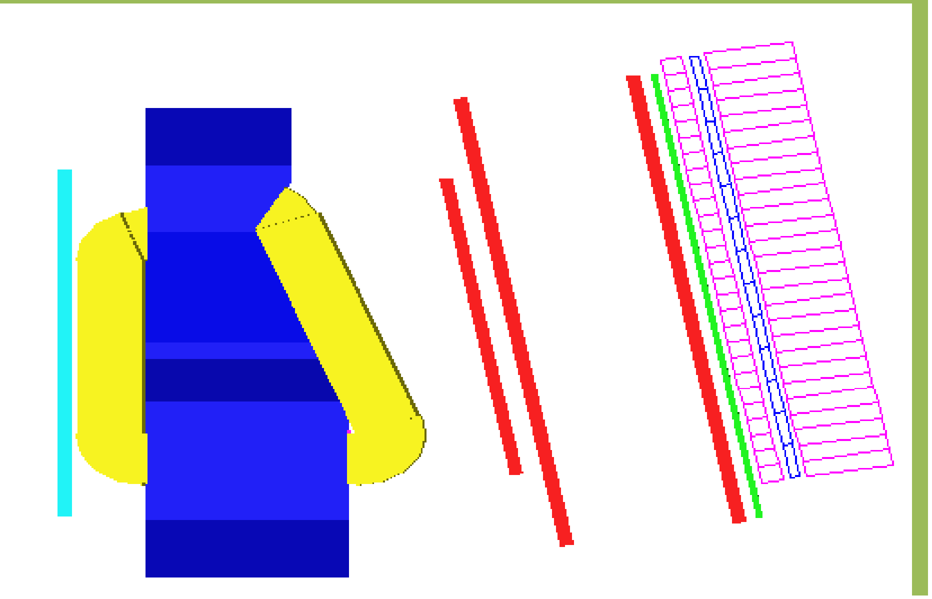



- Electron beam: ***E*** = 5.9 GeV
- 40 cm transversely polarized $^3$He target (effective polarized neutron)
- BigBite at 30° as **electron** arm:
  $P_e$ = 0.6 ~ 2.5 GeV/*c*
- HRSL at 16° as **hadron** arm:
  $P_h$ = 2.35 GeV/*c*
- Average beam current 12 uA (max: 14 uA, 15 uA in proposal)
- Preliminary $^3$He polarization is 65%. (42% in proposal)

# Electron Arm: BigBite Spectrometer

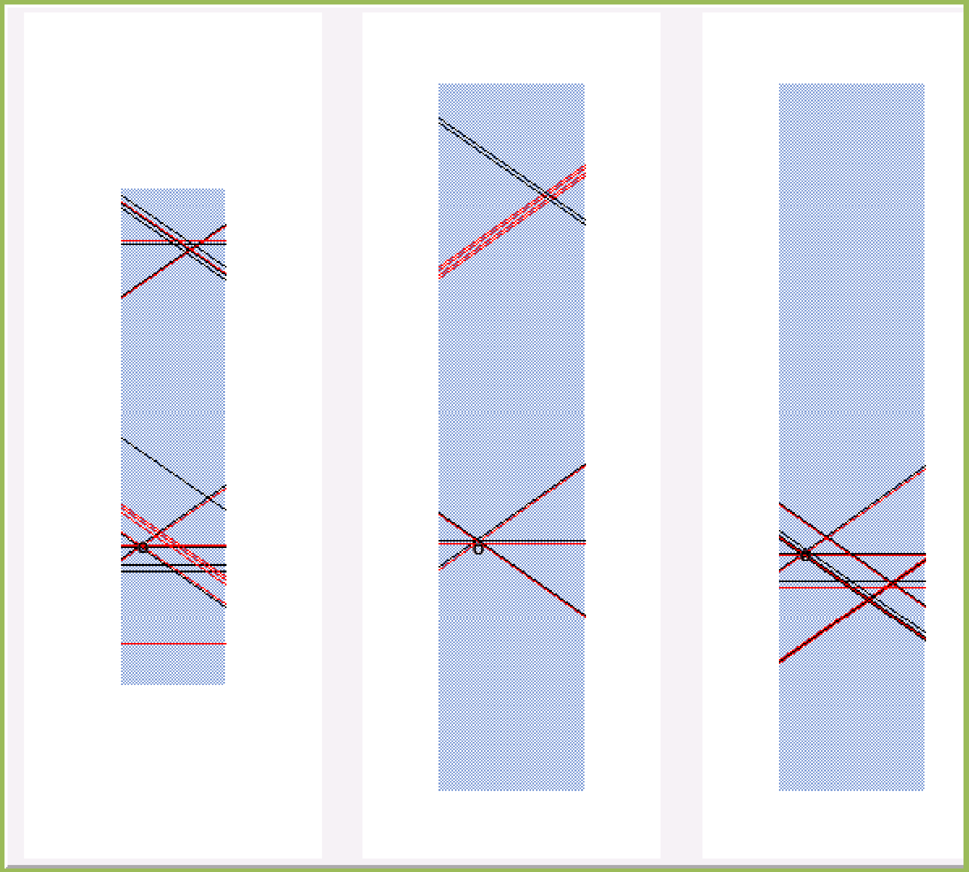


- BigBite Dipole Magnet
- Tracking/Optics:
  - Three sets of multi-wire drift chamber (MWDC)
  - 18 planes with more than 3000 channels
- PID:
  - EM Calorimeter consists preshower and shower counter.
  - 243 blocks
- Timing:
  - Scintillator: 13 bars



# BigBite Multi-Wire Drift Chamber

- Constructed in UVa
- Firstly used in $G_e^n$ Experiment (2 and half chambers)
- Full 3 chambers were used during E06-010 to accommodate the high unpolarized $^3He$ luminosity $3x10^{36}$ $cm^{-2}s^{-1}$ .
- Wire Spacing: 1 cm.
- Six planes per chamber
  - Three orientations
  - 2 planes with same orientation are shifted by 0.5 cm to clear L/R ambiguities.
- Design goal of spatial resolution: 200 µm.
- Tracking software developed by O. Hansen.



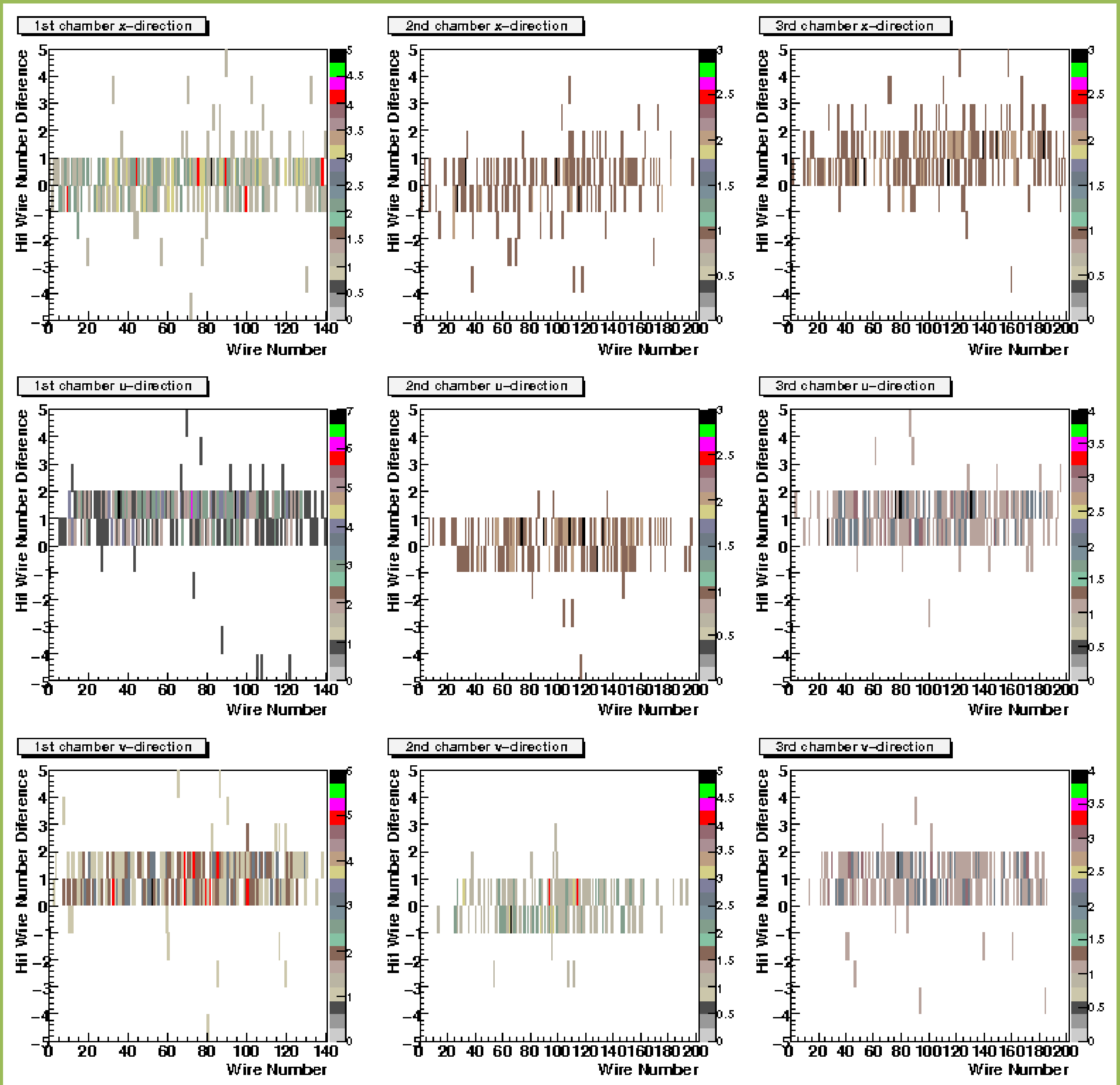
- TDC: FastBus 1877, resolution 0.5 ns.
- Readout
  - Amplifier card -> Ribbon cables -> Level Translator -> TDCs
  - Thanks to B. Craver

# BigBite Wire Chamber Calibration

- Chamber position/geometry from survey report
  - Cable mapping
- Overall drift time $t_0$ calibration.
- Drift time to drift distance conversion.
- Overall chamber position
- Wire-by-wire $t_0$ calibration.
- Wire-by-wire position calibration.
- Iteration procedure is adapted.
- The final spatial resolutions are about 200 µm after calibration.

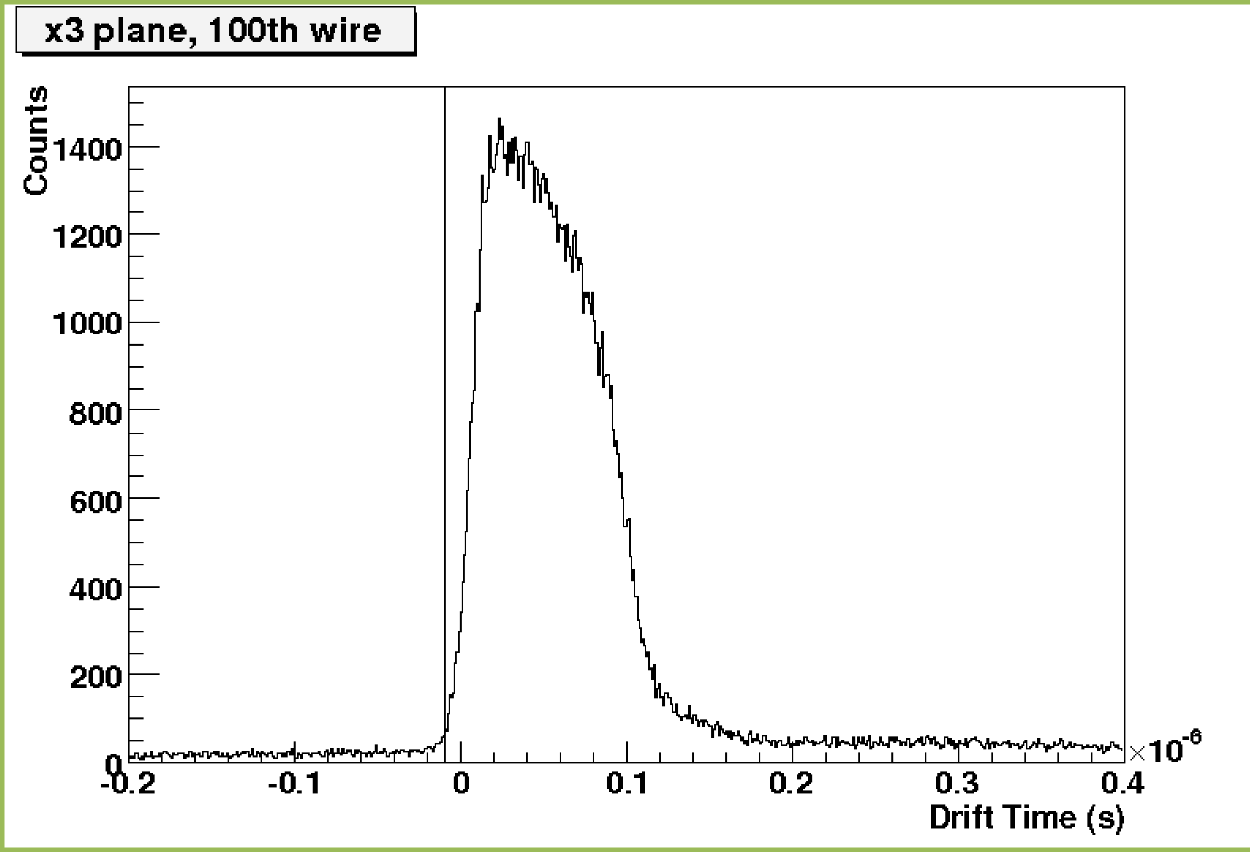
# Mapping

- Mapping can be checked directly from the data (low luminosity run)
- Only adjacent wires will fire with real hit for different planes.
- One mapping problems were found during the check.



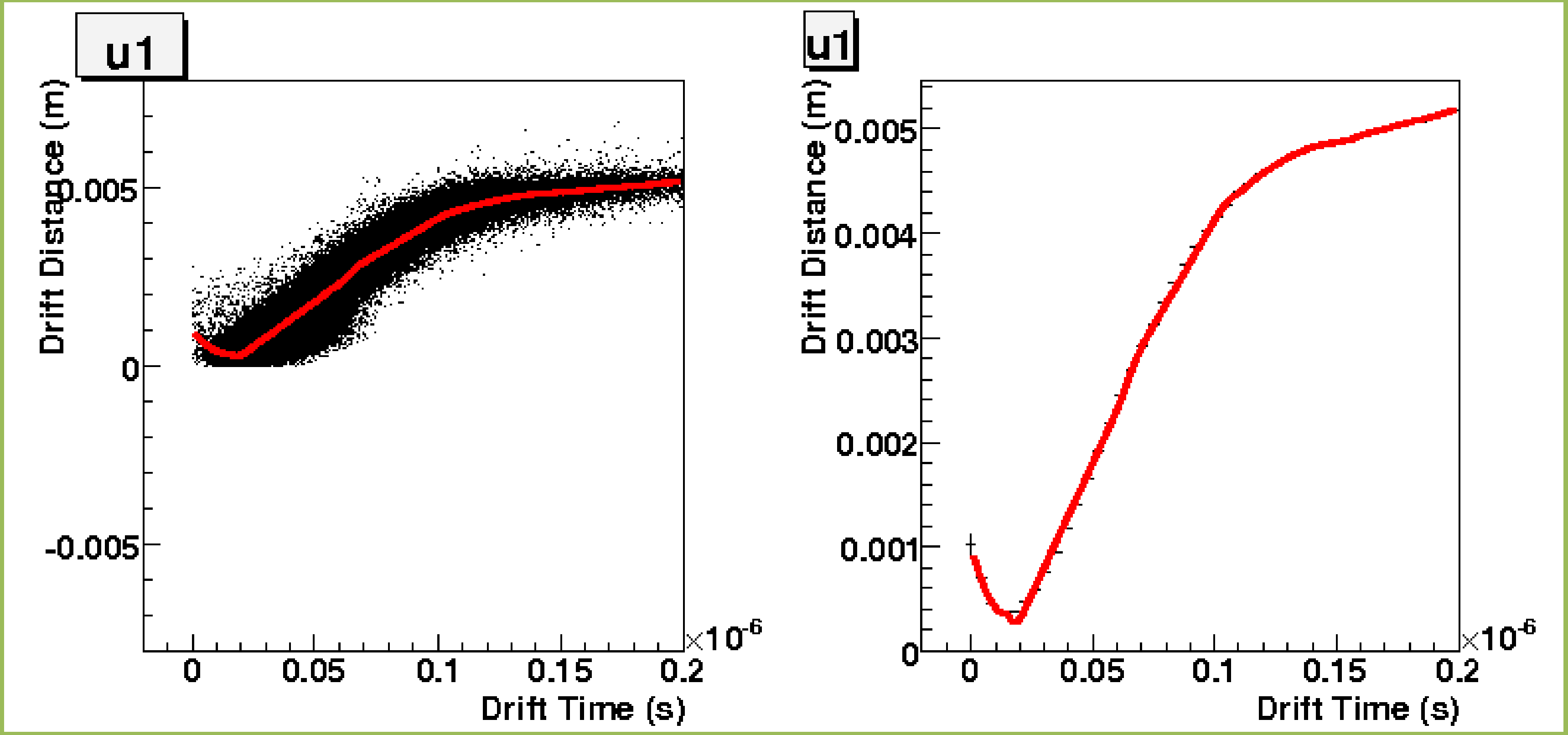
# Initial $T_0$ Calibration

- The initial $T_0$ calibration are obtained by finding sharp increasing edge.
- Here, we show the results for drift time for one single wire with events found one track pass near-by.



# Drift Time to Drift Distance Conversion

- Drift distance is plotted against the drift time.
- We parameterized the drift time to drift distance conversion function into **sectional-continuous function of several polynomial functions.**



# Wire-by-Wire $T_0$/Position Fine-Tuning

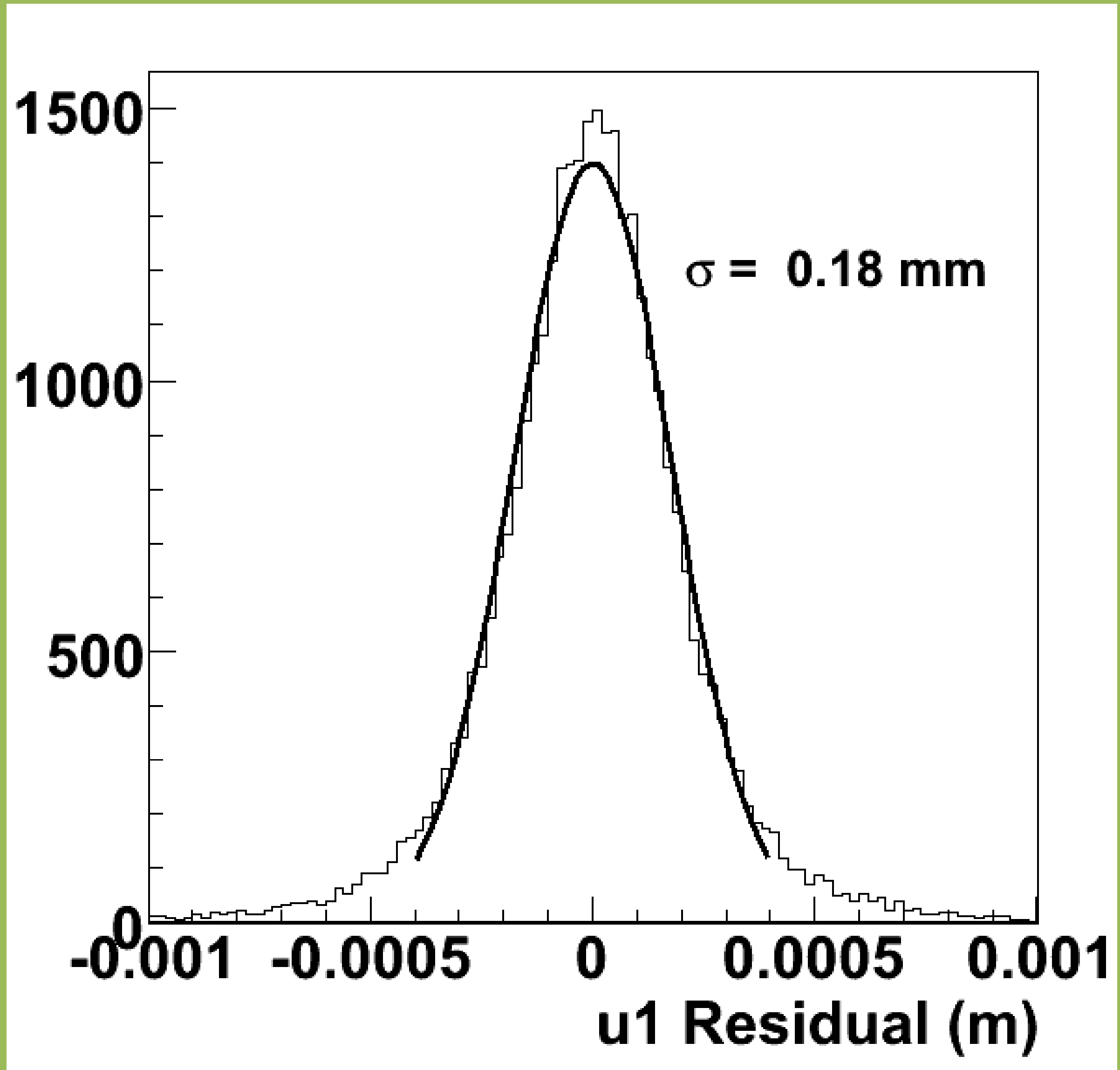
- If the wire position is not centered, the residual peak position will not be centered.
- When the wire position is fixed, we can use the region where the drift-distance can be linearly converted from the drift-time to estimate the wire-by-wire $t_0$ offset.
- However, the residual depends on the tracks that we found. Thus an iteration procedure is adapted.

# Off-line Iteration Procedure

1. Global $T_0$ calibration with tracking.
2. Replay and do 1. again until global $T_0$ is reasonable.
3. Replay low luminosity runs to tune the chamber vertical positions (iteration)
4. Replay and find the best tracks with no missing hit on any wire planes. (hundreds of runs)
5. Find out the drift-distance to drift-time conversion function for every planes
6. Fine tuning the wire vertical positions for every wire
7. Fine tuning the $T_0$ for every wire (cable length may not exactly same)
8. Find the residual with the standard tracking parameters

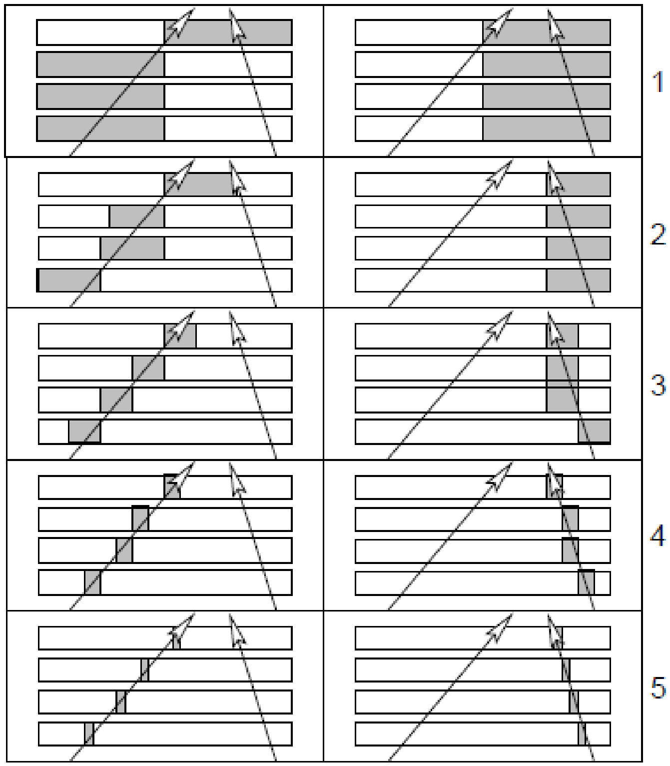
# Results After Calibration

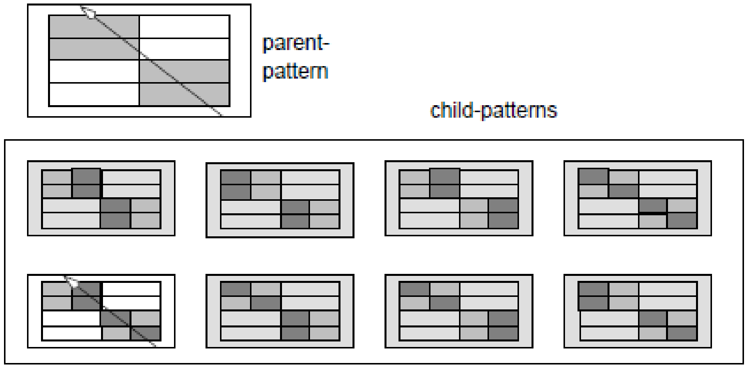
- Before Iteration procedure of off-line calibration, the σ of the residual peak is about 440 μm.
- Now: < 200 μm.



# Tree Search Algorithm

Recursive method for finding straight lines in a hit pattern



# Some Updates Related to Tracking

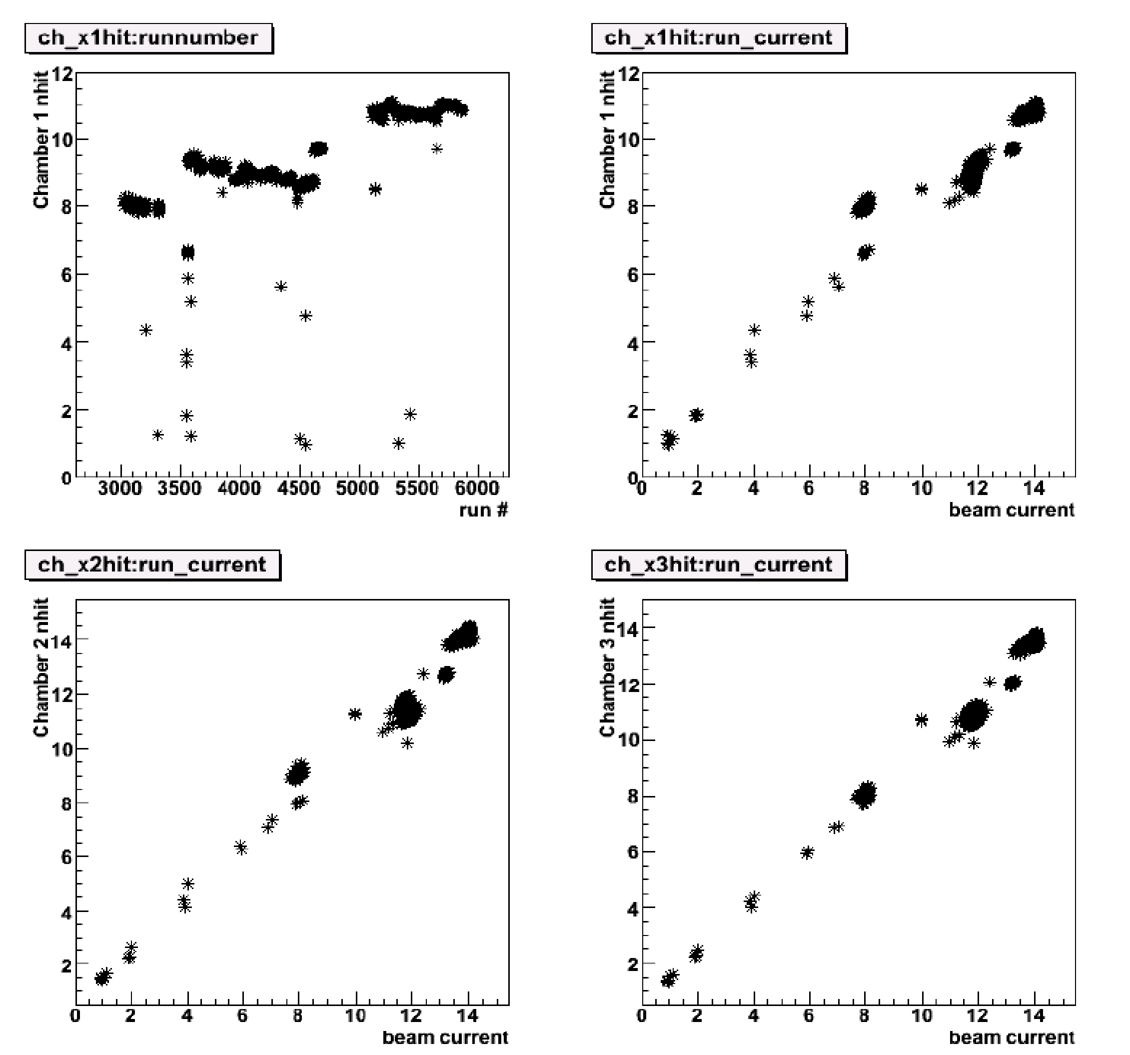
- Add in a special plane for Calorimeter
  - SpecialWirePlane inherited from WirePlane
    - Change the decoding part.
    - Need to include it in the chamber database.
  - Provide a new plane for tracking.
  - The original goal is to improve the speed of tracking. Not used in the E06-010 production.
- Add a new drift-time to drift-distance conversion method (Pol2FitTTD)
- Road::CollectCoordinates(); Road::Fit();
  - Save both Left and Right hit inside the road, more exclusive search
  - Loose the fit condition for a Road, effectively save more roads for the final fit.
  - Some of the identical road are removed at Projection::RemoveDuplicateRoads()
  - Slightly more tracks in exchanging the speed.

# Experience with Tracking

- 1st pass optics run @ 1 uA (hydrogen elastic kinematics):
  - preshower > 150 MeV and total energy > 700 MeV
  - Require three set of 5/6 planes
  - Chi2/ndof < 2.4
  - About 86.5% of the events have tracks (lower bound)
- Chamber hitting efficiency is about 96%, thus the theoretical tracking efficiency is about (0.96^6+6.*0.96^5*0.04)^3 = 93.5 %
  - The chamber HVs were increased during production run to increase the hitting efficiency.
- The Tracking Monte-Carlo with the same software gives about 95% software tracking efficiency assuming 100% hitting efficiency with current setup.
  - 98% were obtained if the middle chamber is really in the middle point of chamber-1 and chamber-3.

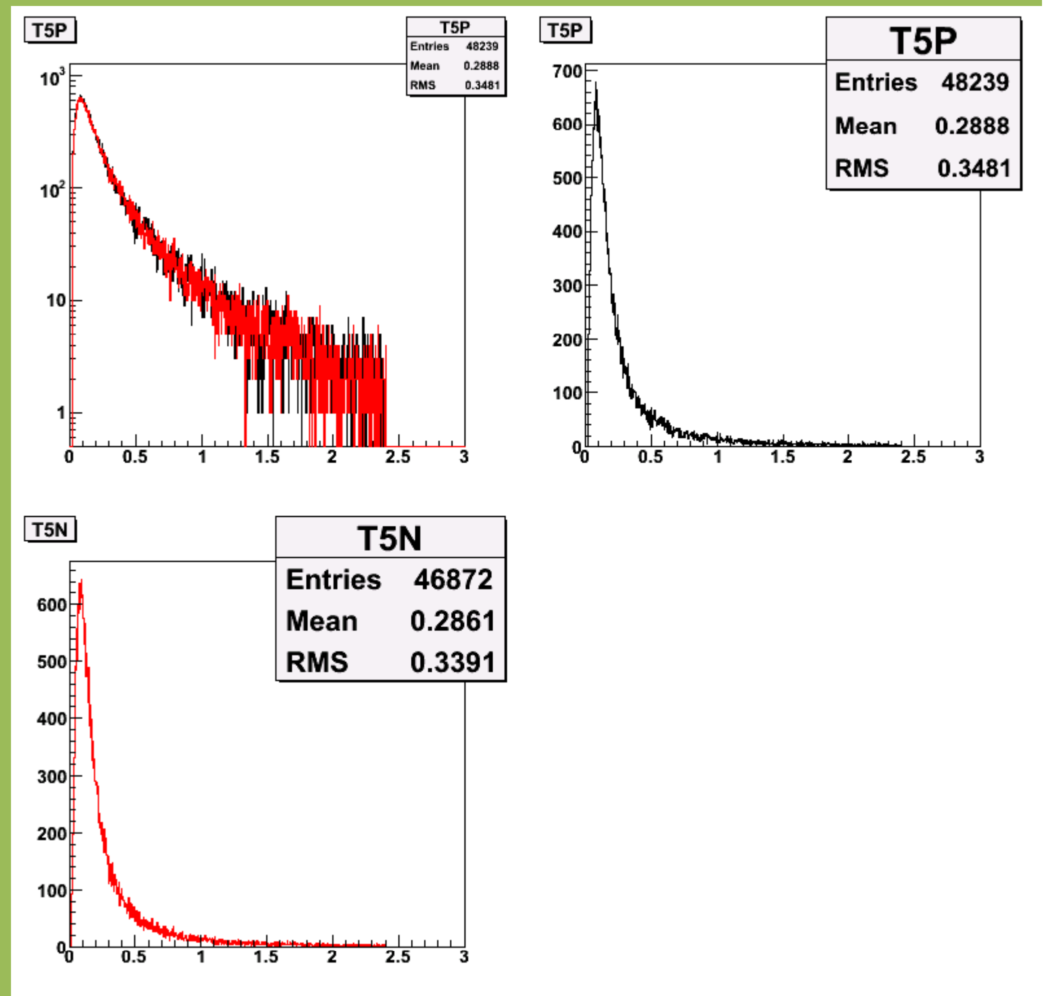
# Multiplicities on Chambers

- Average beam current 12 uA through the entire experiment
- Start with 8uA
- The highest beam current is 14uA



# Experience with Tracking

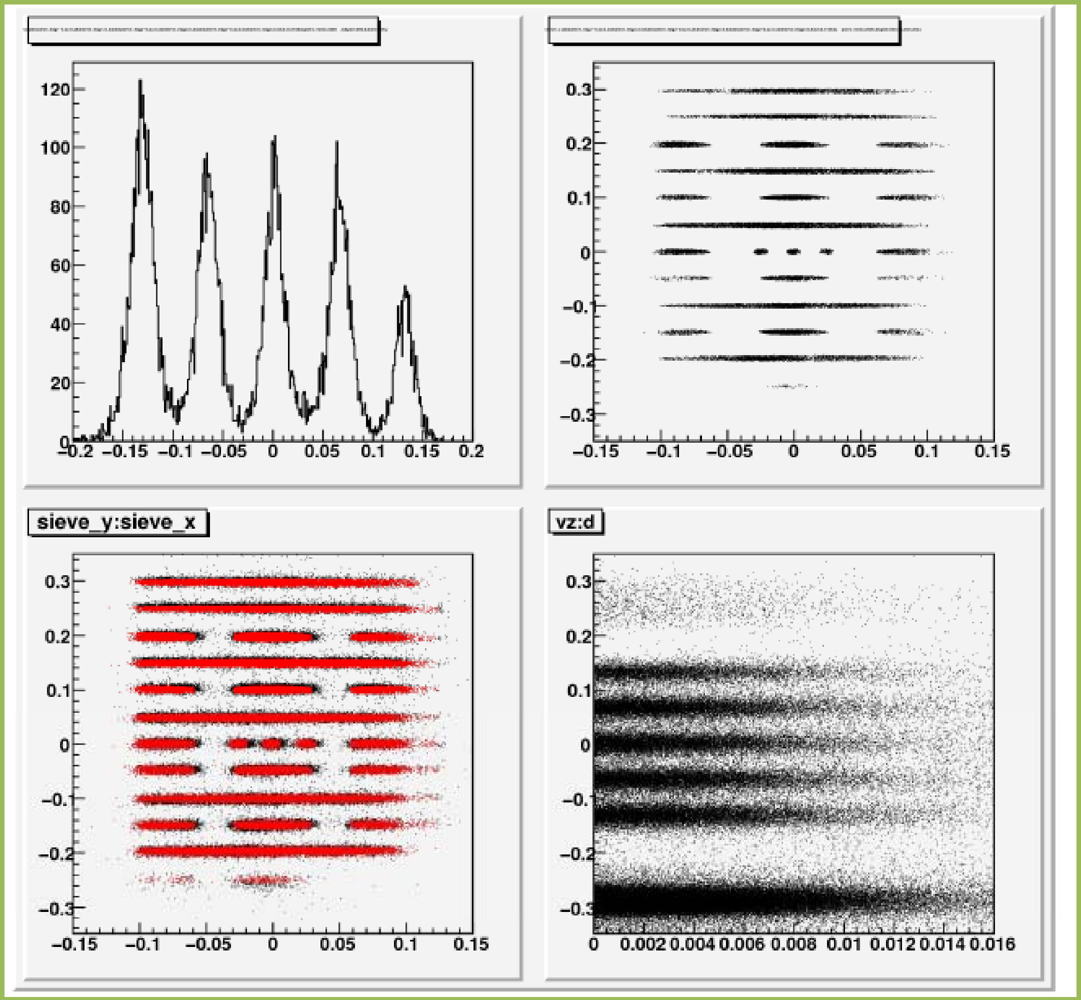
- At high beam current, more tracks are found per trigger.
  - Largely due to false tracks
  - False tracks are reduced significantly with addition cuts on optics, track quality, track match cut with calorimeter, PID
  - Further checked with yield stability (events per accumulated charge)
- Tracking efficiency is not a big issue for the asymmetry measurement
  - We plan to extract the hydrogen elastic cross-section with the 1st and 2nd pass data through MC.

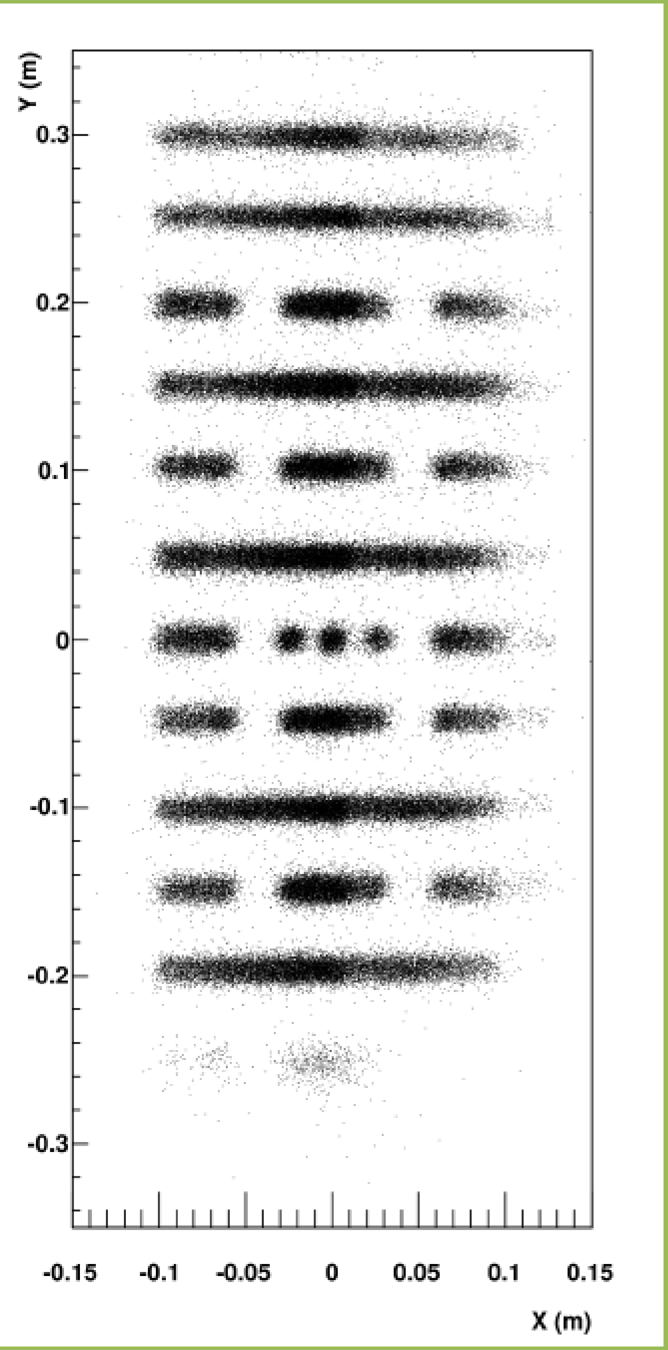


# BigBite Optics Strategy

- Read though the survey report to obtain:
  - Where is the target? (very important)
  - Where is the magnet (sieve)? (very important)
  - Where is the chamber? (not as important as the previous two items, but a good start will save a lot of efforts)
- No field run (Doug) to find out where the chamber is
  - Very low luminosity run to exclude background.
- Carbon foil runs to calibrate vertex
- Use sieve to calibrate the angles
- Use 1$^{st}$ pass and 2$^{nd}$ pass elastic data to calibrate momentum

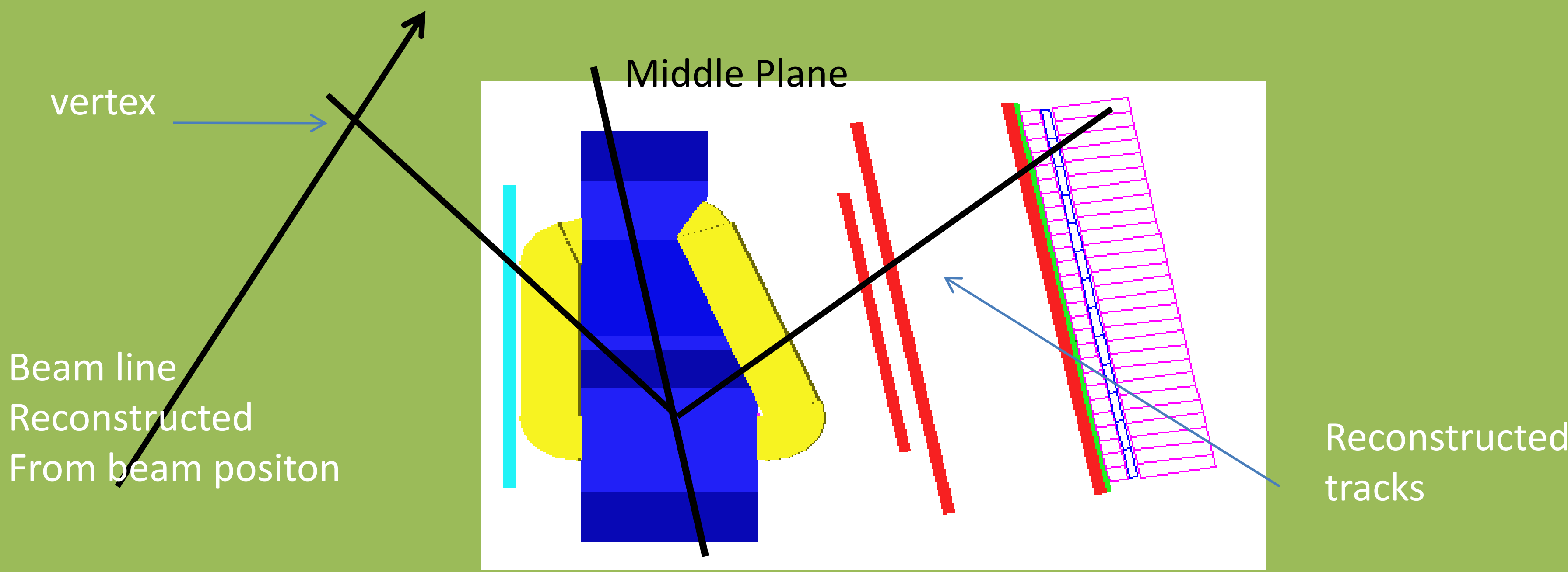
# No field run



# Carbon foil runs (first order model)

- First-order model (idea is developed based on Seamus's work in GEN optics)
  - Define the middle plane
- Assume a perfect dipole, then momentum perpendicular to the field direction will not change (a cone)
- Then vertex can be found, with middle plane, beam line and the reconstructed track from chamber.

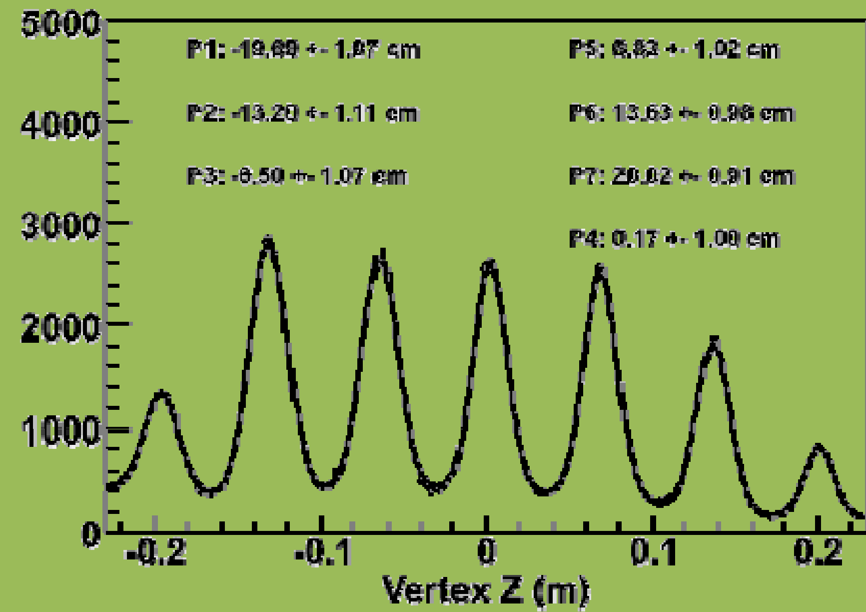


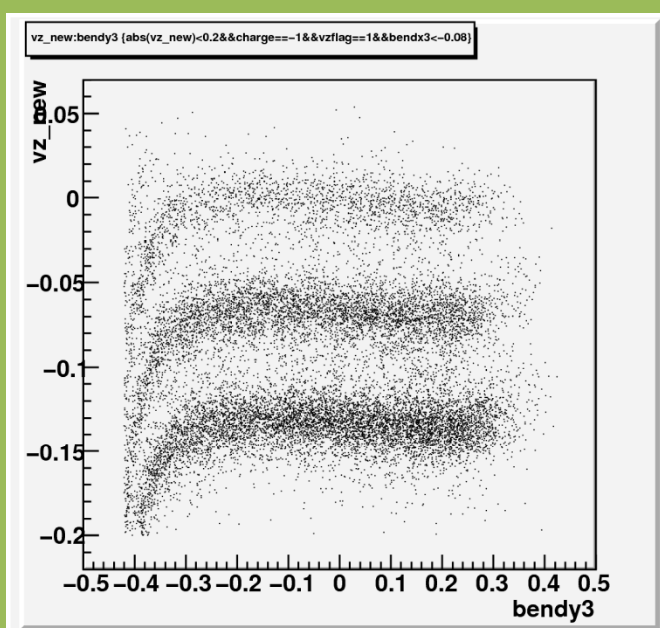
# Vertex Reconstruction

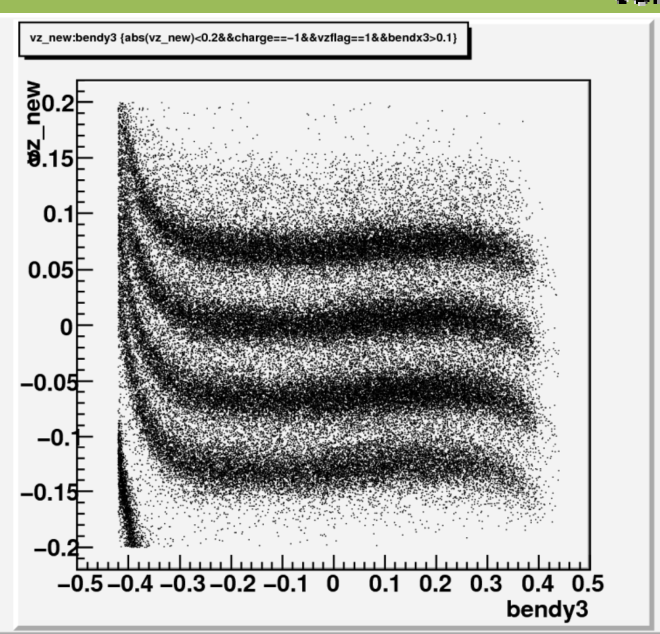
- Plot vertex vs all track variables to do 2nd order correction.
- Plot vertex vs the middle plane variables to do 2nd order correction
- Get 1st order momentum assuming perfect dipole, correct the vertex with kinematics variables (3rd oder)
- Use Minuit to get the multi-dimension fitting.
- Use look-up tables to correct the edge effects or effects due to fringe field at the top and bottom of the magnet (4th order).
- For every correction, we try to use linear form (simplest).

# Vertex Reconstruction

- Vertex: average 0.72 cm through the entire momentum coverage.
- Also show the edge effects
- Acceptance cut to avoid the extreme regions



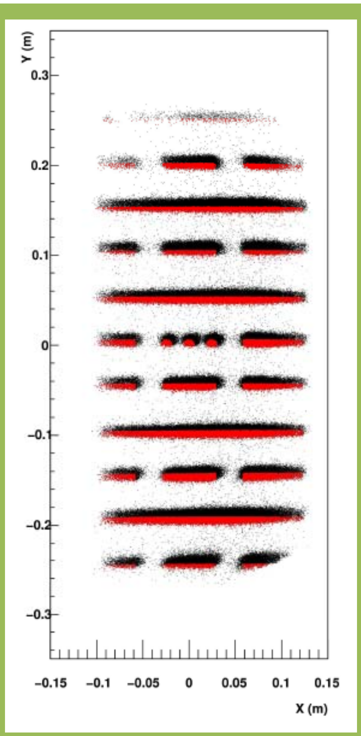



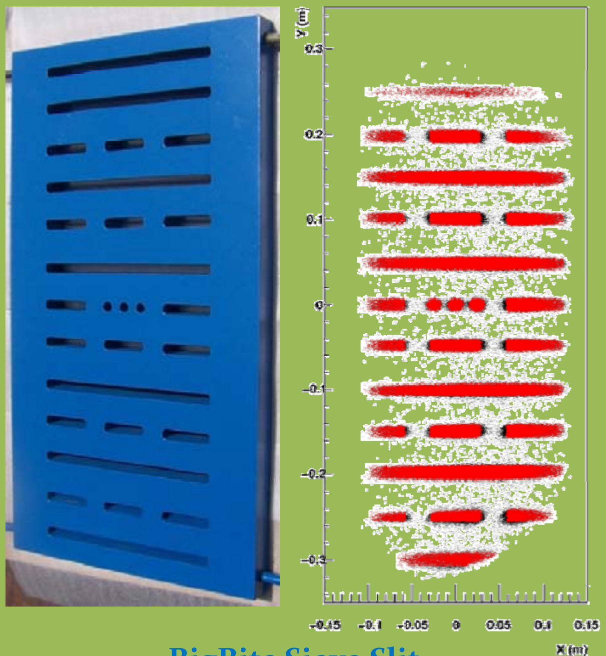



# Angles Reconstruction

- With vertex figured out, just connect the vertex position with the hit point in the middle plane, we get all the angles.
- The angles reconstruction is checked with the sieve pattern.
- Smaller corrections are added.

• First order is already very good.
• The final resolution is estimated as angle: < 10 mrad



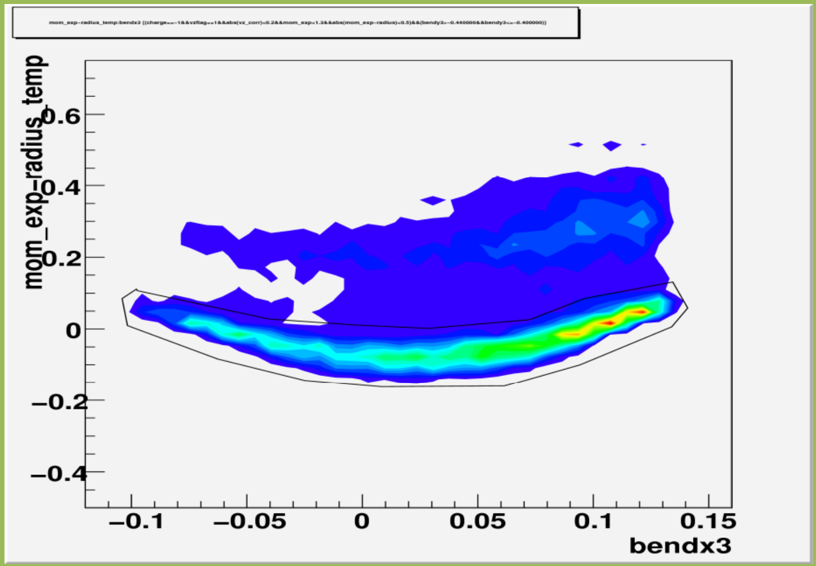
BigBite Sieve Slit

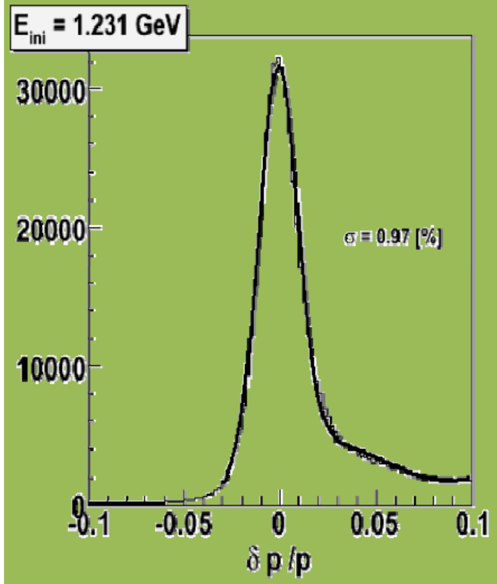
# Momentum Reconstruction

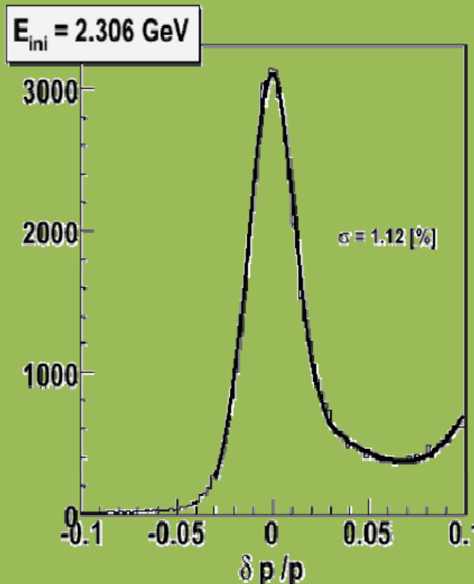
- Select hydrogen elastic data
- With reconstructed angles and vertex, we can get the expected momentum.
- Add in the energy loss effect
- 1st and 2nd pass data cover 0.9-1.8 GeV/c
- The positions of resonances are used to check the moment reconstruction.
- 1st order model based on dipole
- 2nd order correction vs all tracking, known kinematics variables.
- Divide the whole middle plane into small bins (look-up table). Use both 1st and 2nd pass data
- Use graphic cut to select elastic events in each bin.

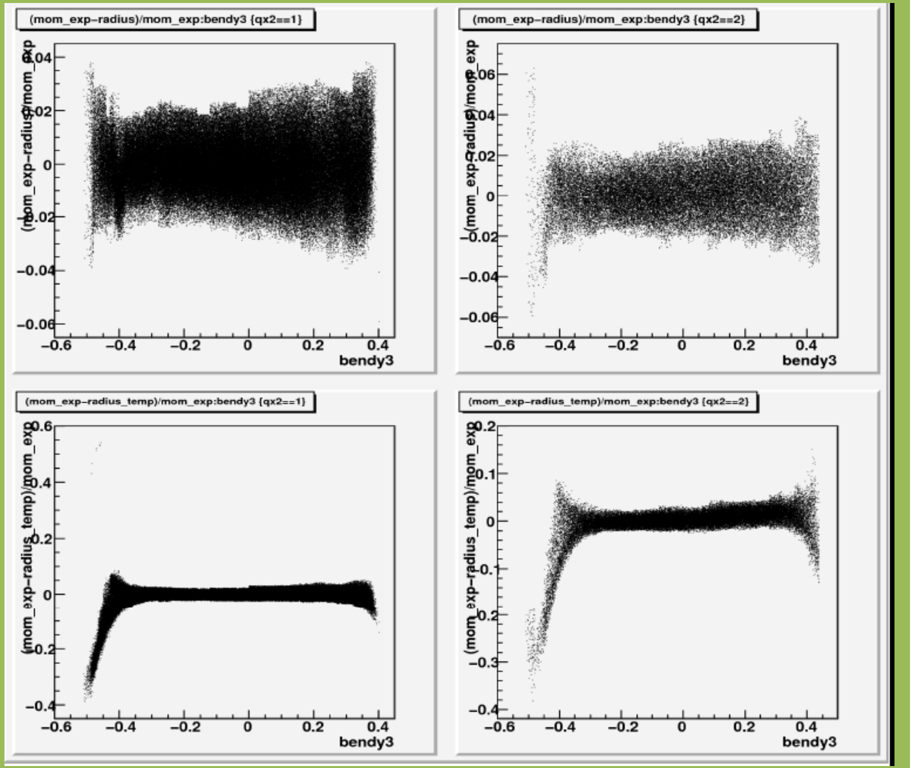
# Momentum Reconstruction

- Edge effects
- Resolution:
  - Momentum: 1%



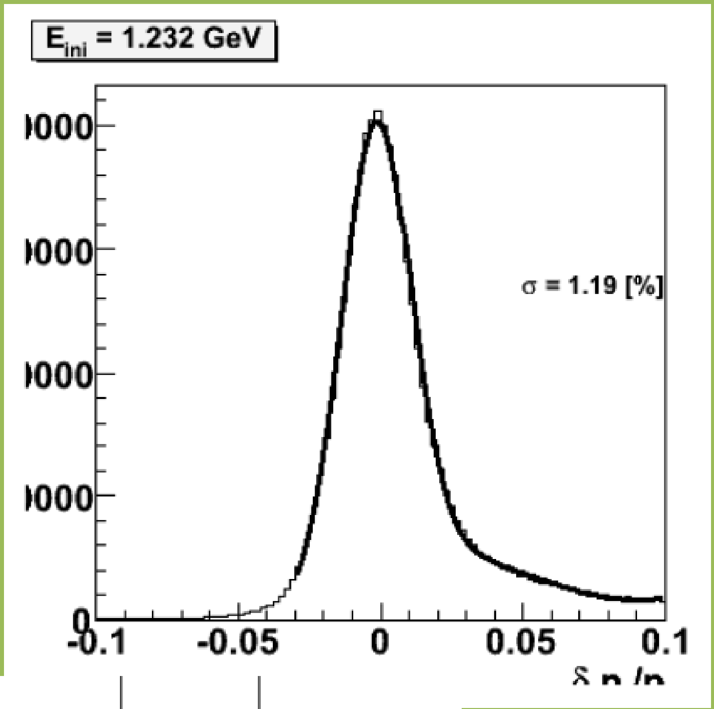



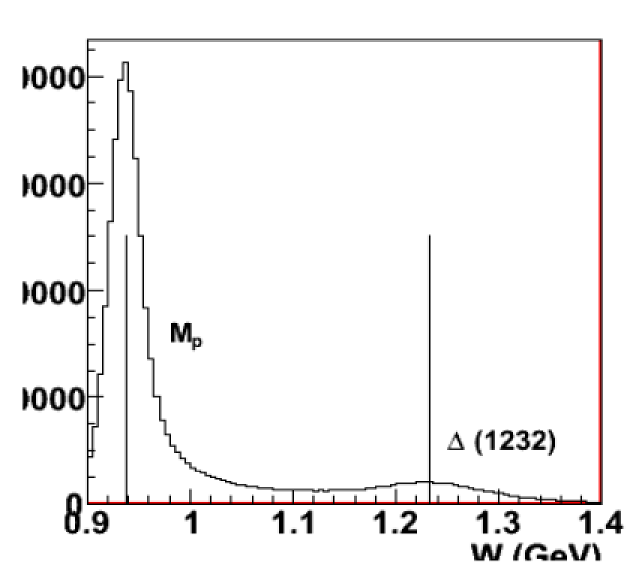



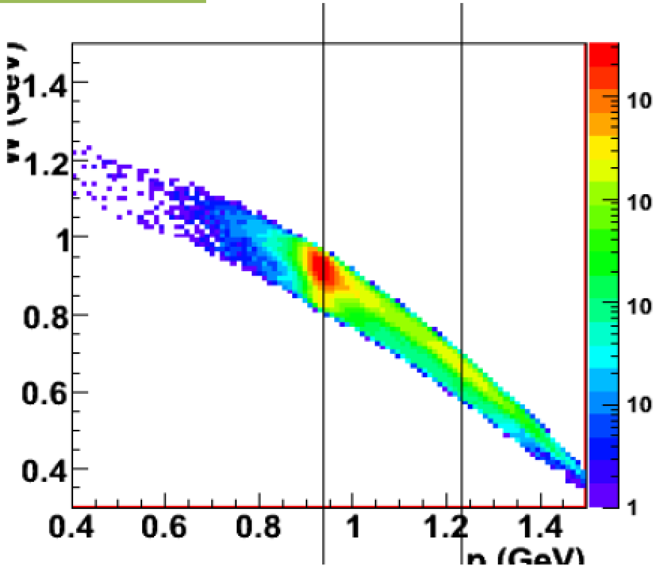



# BigBite Positive Optics

- Use 1st pass $d2_n$ data.
  - BigBite 45 degrees.
- Transversity, BigBite is at 30 degrees.
- Same calibration procedure
- Transformation from 45 to 30 degrees:
  - only in first-order model
  - The higher order correction remain the same.

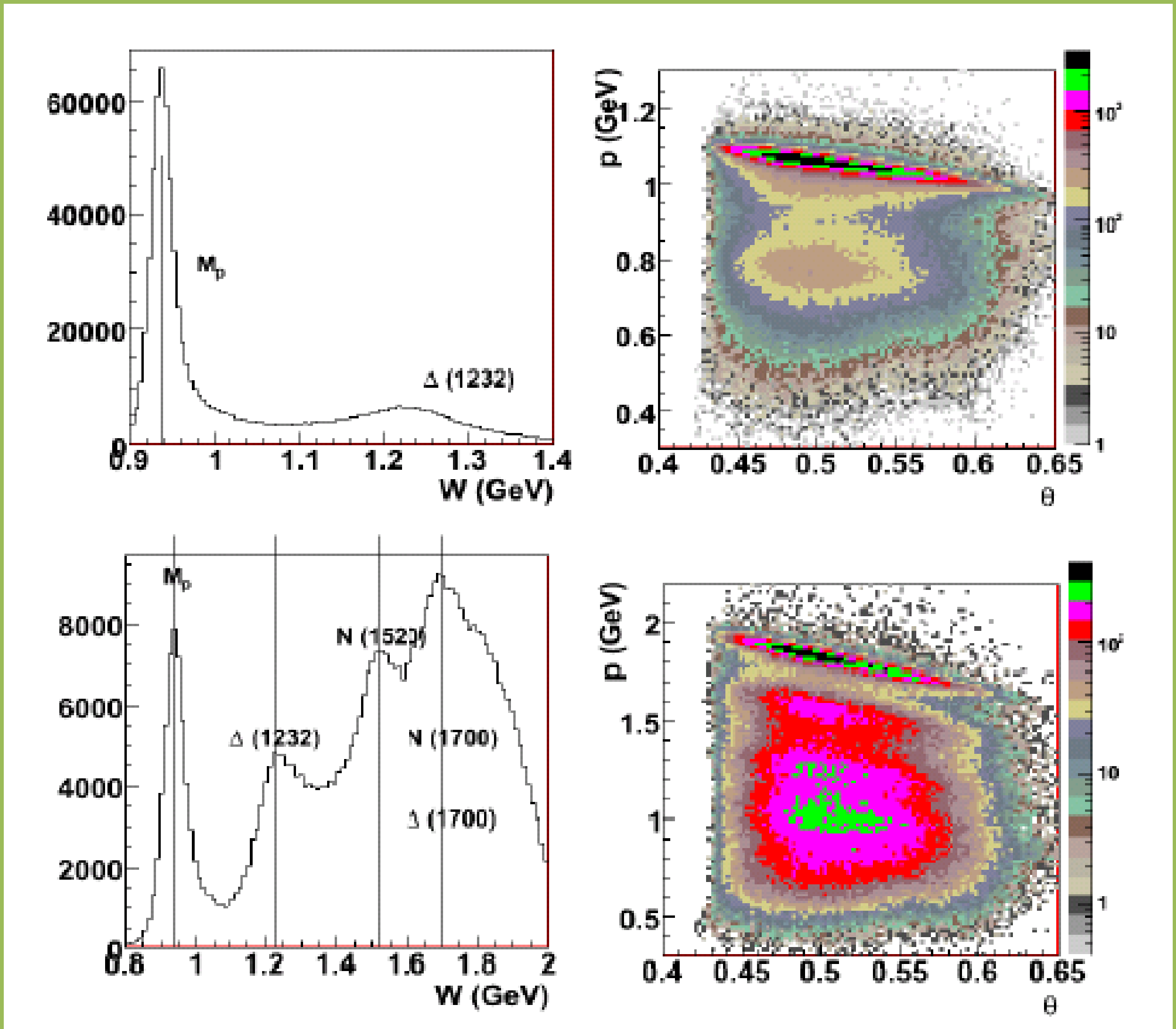


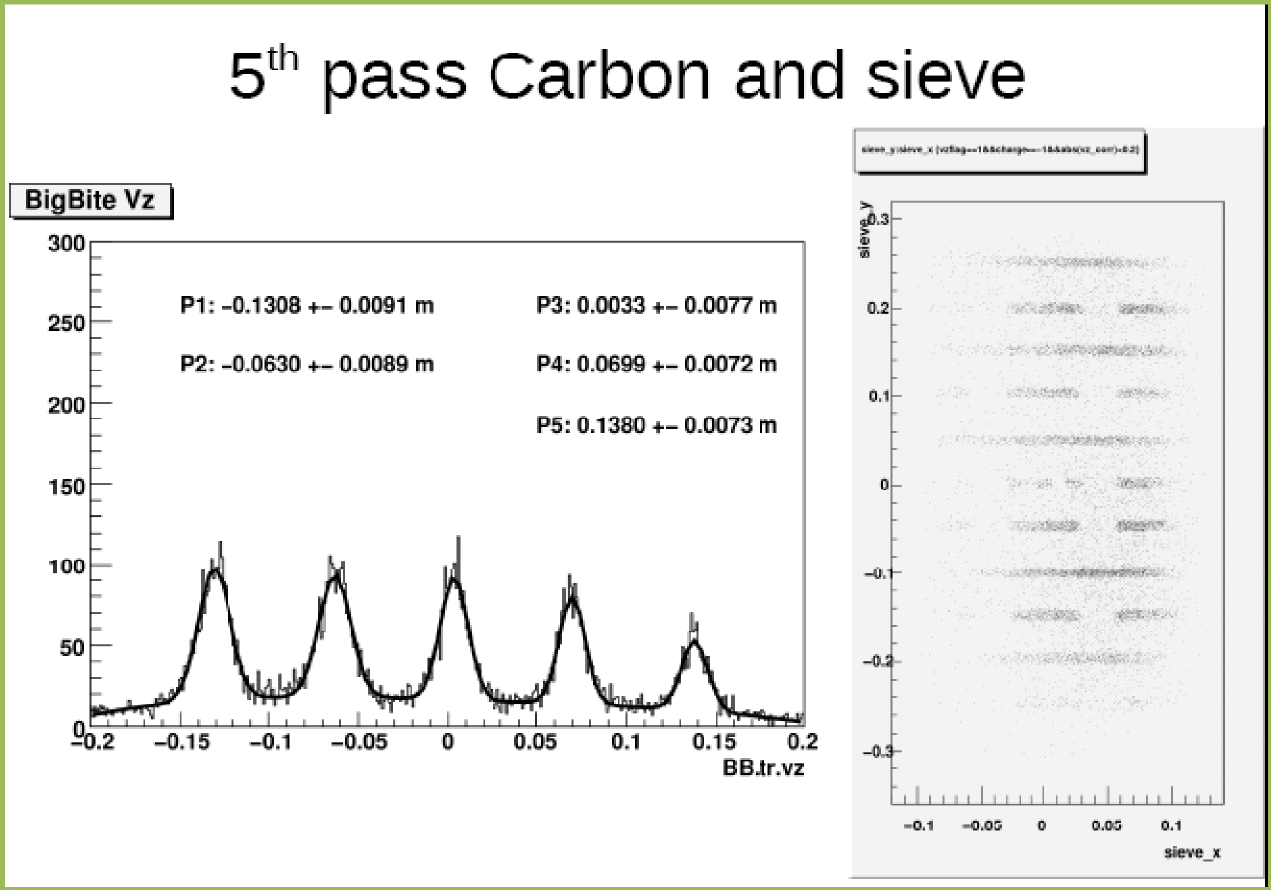
# BB Optics Results

- Good optics in wide p and ΔΩ acceptance.
- Calibrated with elastic data
- Checked with the resonance position.



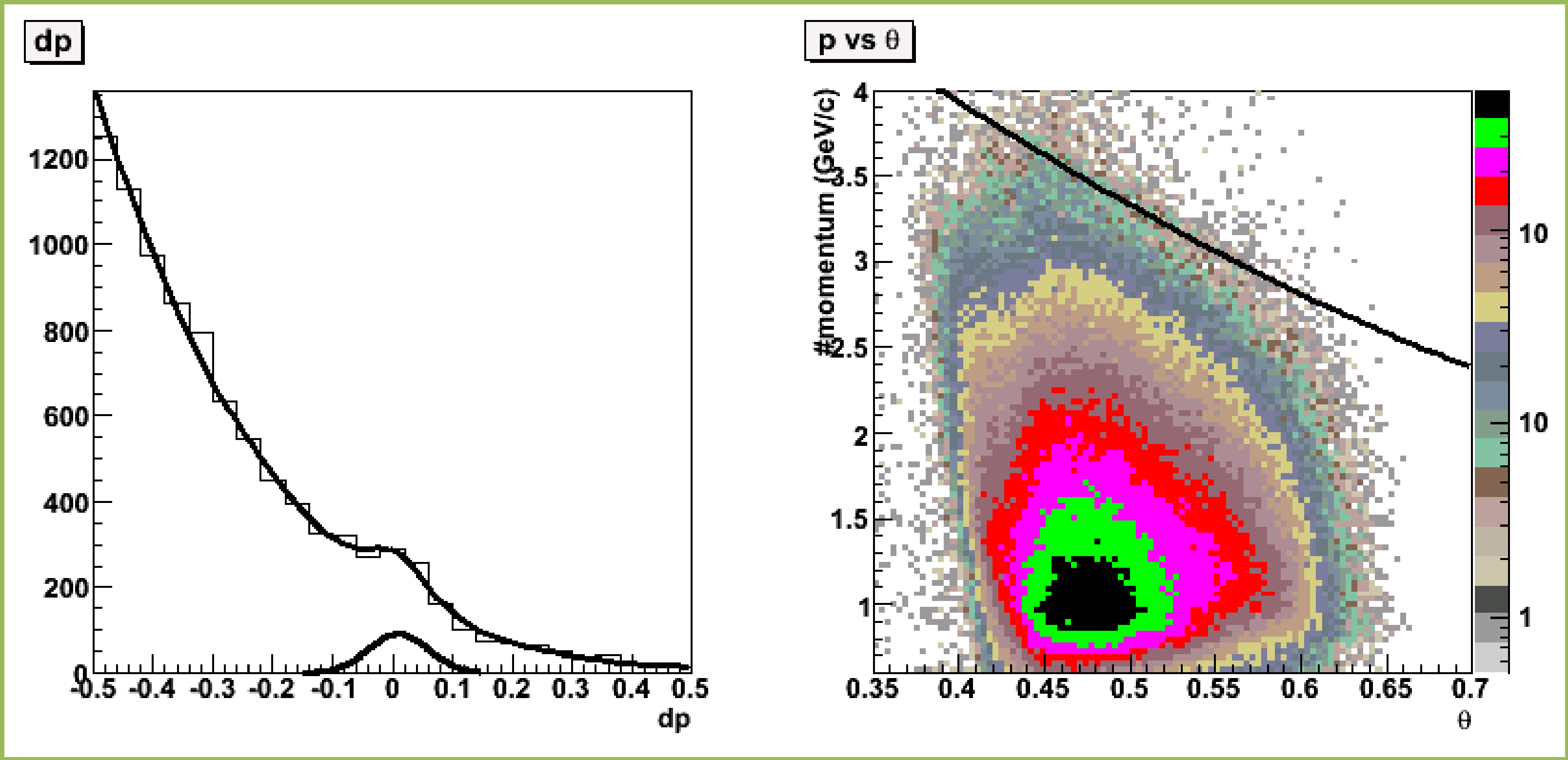
# BB Optics Results

- BB optics stability is checked in 5th pass data.
- BB optics is calibrated with 1st and 2nd pass data.



# BB Optics Results

- The optics works well at high momentum region (3.0 – 3.7 GeV/c). 5th pass hydrogen elastic data
- The optics model is calibrated between 1.0-2.0 GeV/c



# Summary

- BigBite Wire Chambers reach the designed performance goal in transversity experiment.
- BigBite Optics Model for both positive and negative charged particle is developed
  - 0.72 cm average vertex resolution for 0.6-2.5 GeV/c
  - 1% Momentum resolution.
  - 10 mr angular resolutions.
  - Optics model is checked with production data and $^3He$ elastic data.
- Both tracking MC and Data suggest that track efficiency is higher than 85%.
  - Tracking efficiency in production data is higher.

# Acknowledgement

- Brandon Craver
- Seamus Riordan
- Haiyan Gao
- Xiaodong Jiang
- Doug Higinbotham

# BigBite Geant3 Model and Analysis for E06-010

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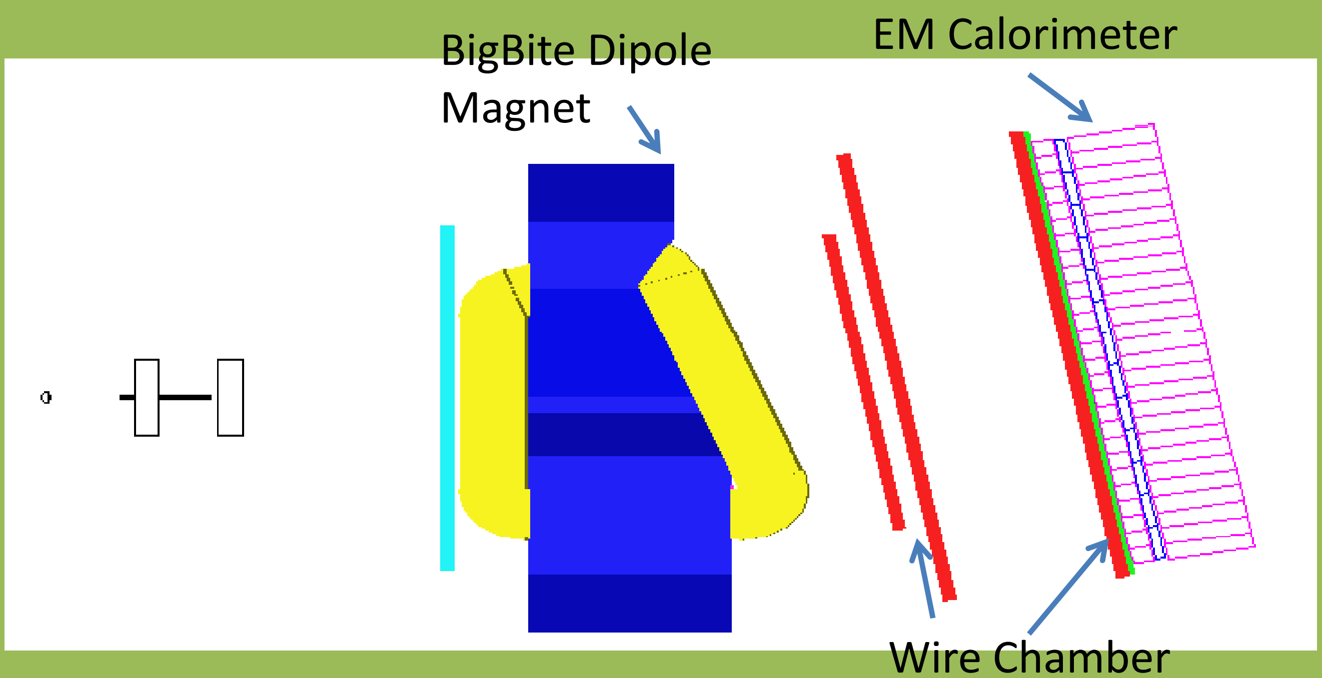


# Outline

- Motivation
- BigBite Geant3 model
  - Interface with Analyzer
  - BigBite Optics model
  - BigBite Collimator/BigBite Acceptance
- Some results from the BigBite Geant3 analysis
- Summary

# Motivation

- The BigBite Geant3 model is developed
  - Understand the background rates on chamber.
  - Serve as tracking Monte-Carlo.
  - Negative pion contaminations in electron sample in the single analysis.
  - Understand the photon background.
  - Prepare for the development of physics simulation
    - Understand the acceptance
    - Understand the collimator
    - Forward optics transportation

# The BigBite GEANT3 Model

- Constructed by E. Chudakov
- Magnetic field model
  - Snake emulation from MAFIA, by V. Nelyubin
- The model has been used to estimate the background rates on wire chamber.
- The model has been used to estimate the acceptance coverage of BigBite for transversity experiment.
- More information about COMGEANT:
  - http://www.jlab.org/~gen/simul/comgeant/

# Detector Digitization

- BigBite Wire Chamber (MWDC):
  - Which wire is fired?
  - The drift time, assuming a linear drift time to drift distance conversion.
- BigBite Calorimeter:
  - Which block is fired?
  - The energy deposited in this block.
- Scintillator can be added also.

# Event Generator

- Default GEANT3 interaction
  - Include all forward angle reactions.
  - 1 MeV EM cut-off.
  - To simulate background.
- Customize event generators
  - Uniformly distributed within the target length.
  - Cross-section can be weighed.
- In addition, the different reaction processes can be turned on/off.
- Absorbers can be added to speed up.

# Interface to Analyzer

- Output from COMGEANT:
  - CERNLIB: Ntuples (The data are packed)
- Fortran code to decode from COMGEANT Ntuples to standard Ntuples
  - Save the initial track information
  - Save the digitizations
- Then use "h2root" to transform it to normal rootfiles
- Another C-based program to add in
  - Background
  - Resolution/efficiency etc
  - Other features like pile-up, etc

# Interface to Analyzer

- The interface follows the idea of "VDCsim"
  - Made by K. Rossato under Ole's guidance
- Structure:
  - THaBBDCSimTrack to store track information, such as direction, position, momentum etc
  - THaBBDCSimWireHit to store wire chamber hit information, such as wire number and drift time
  - THaBBSHSimHit to store shower hit information, such as block number and signal size
  - THaBBPSSimHit to store preshower hit information
  - THaBBSCSimHit to store scintillator hit information
  - THaBBSimEvent to store all the detector responsing information (not the THaBBDCSimTrack)
    - Use TList to store all the hit information .

# Interface to Analyzer

- THaBBSimRun:
  - Init: Set the date for choosing each database (Still need a database to decode)
  - Open:
    - Open the rootfile which contain the simulated data
    - Use SetBranchAddress method to connect the variables in the rootfiles with the variables in the THaBBSimRun
  - ReadEvent:
    - Read the information from the rootfiles using GetEntry and fill the information in the THaBBDCSimTrack and THaBBSimEvent *event
  - Close: Close the rootfile.
  - GetEvBuffer: return the event pointer for decoding purpose.

# Interface to Analyzer

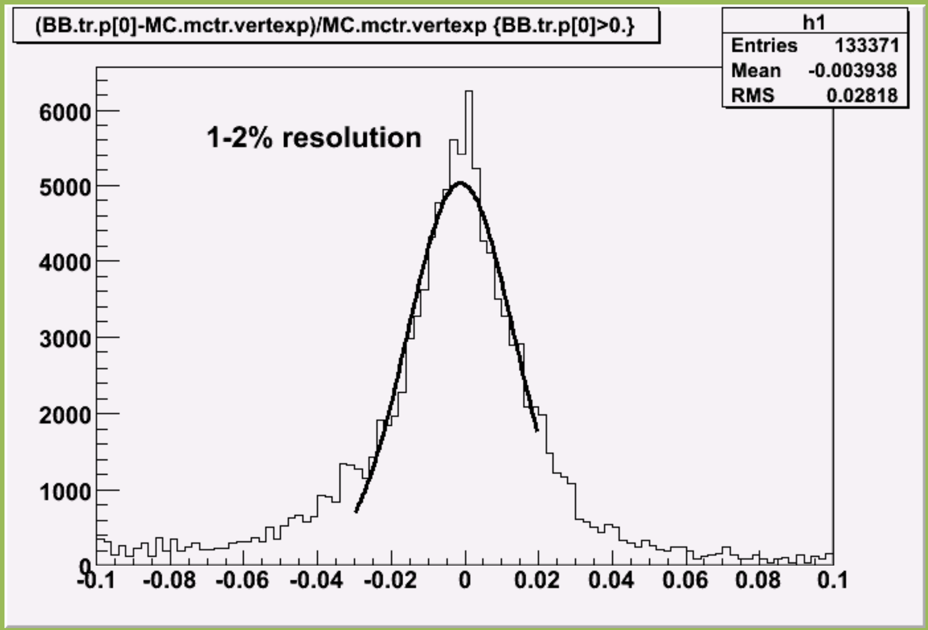
- THaBBSimDecoder:
  - DefineVariables: Save the initial track information stored in THaBBDcSimTrack into the output rootfile.
  - LoadEvent:
    - Mimic the roc, slot and channel
    - Fill the crateslot with crateslot(idx[roc,slot]) -> loadData(“tdc”,chan, raw,raw)
    - Inside the detector decoder, information will be decoded directly from the crateslot.
  - The database files need to match the roc, slot and channel we faked here.

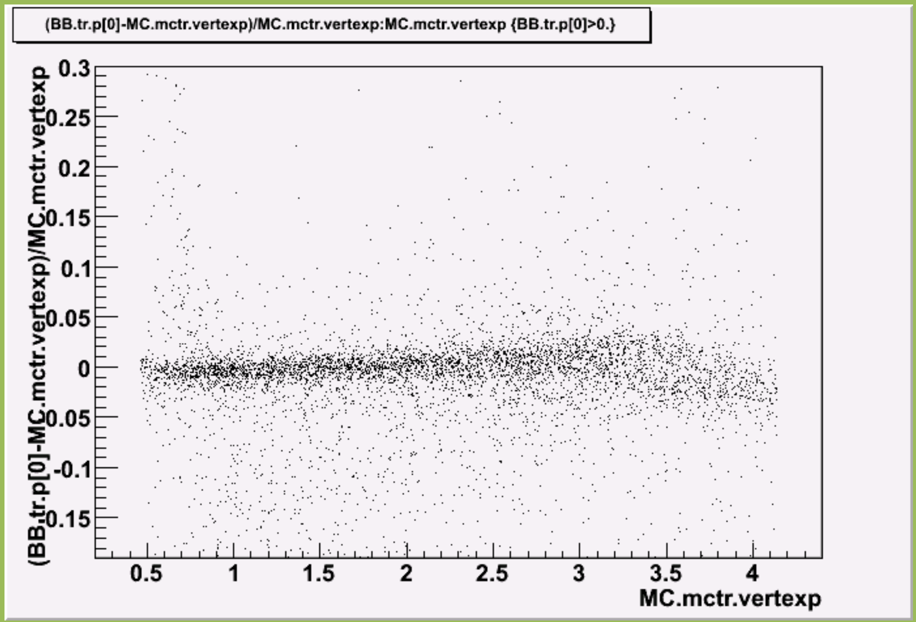
# Interface to Analyzer

- With the new decoder, we can use the standard analysis software, including Tree Search Pattern Match tracking code, Optics software, Shower Clustering, to analyze the Monte-Carlo data.
- Things to check:
  - Magnetic field Model
  - Collimator
  - Acceptance

# Magnetic Field Model in GEANT3

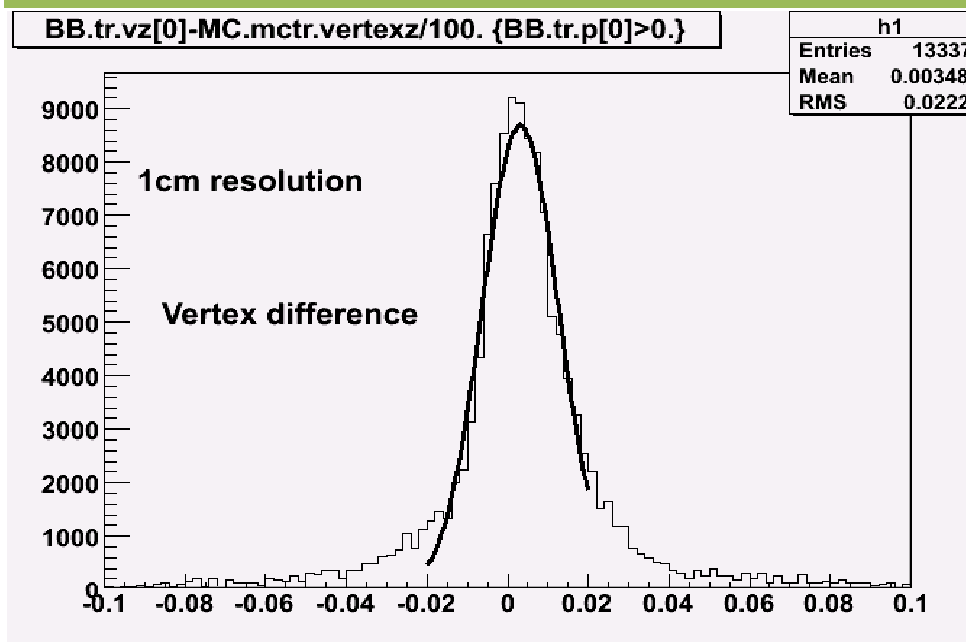
- We tuned the position of detector package slightly to match the optics model.
- Fringe field are not easy to be modelled.
- Reach about 1-2% momentum resolution.

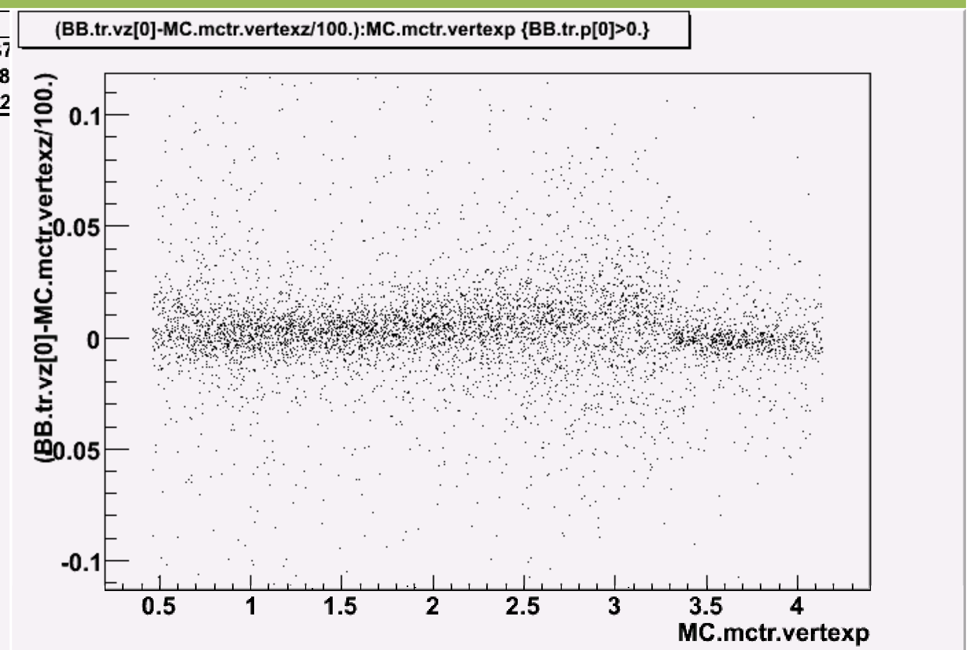


# Magnetic Field Model in GEANT3

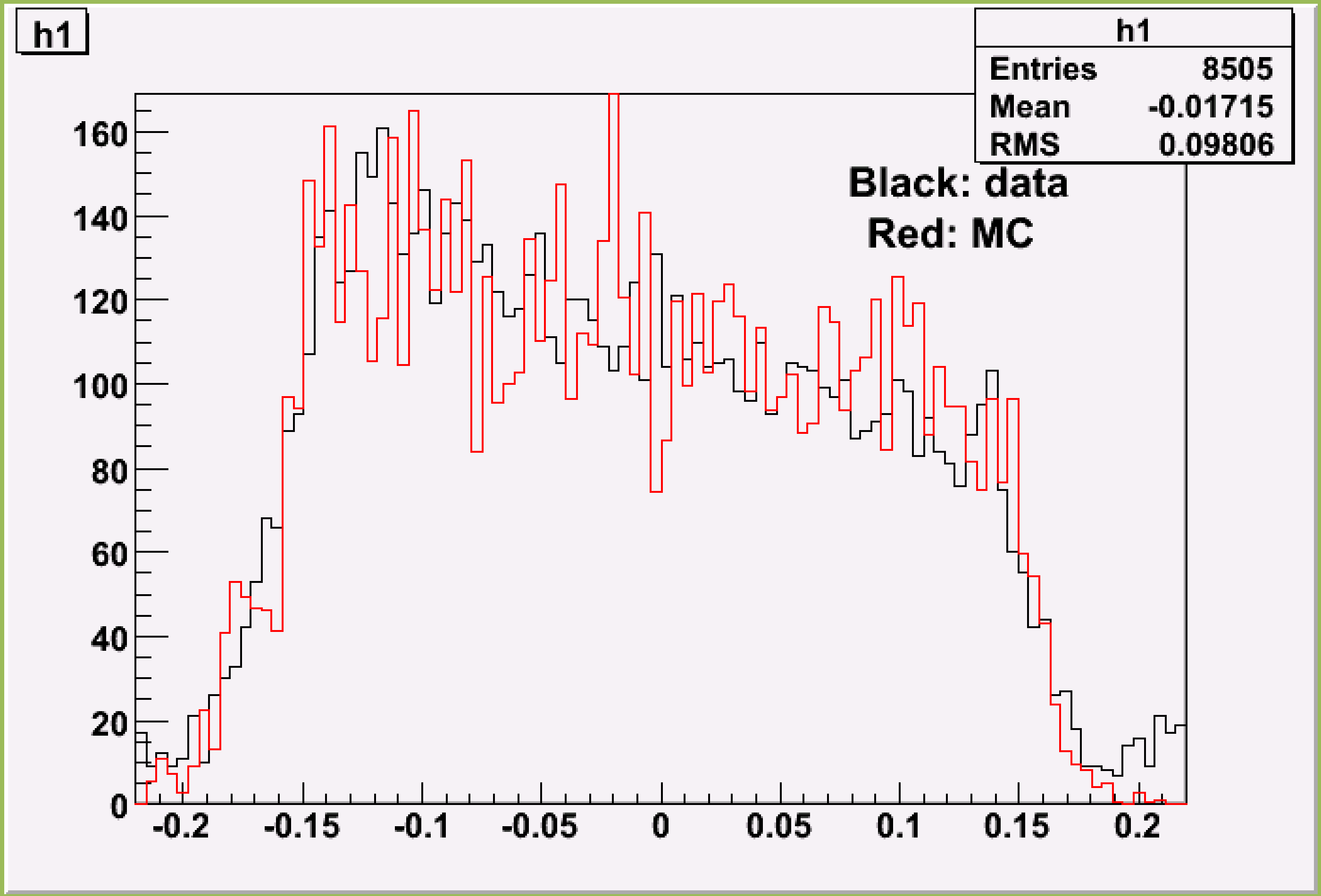
- Vertex is also checked:
- About 1 cm vertex resolution is reached.



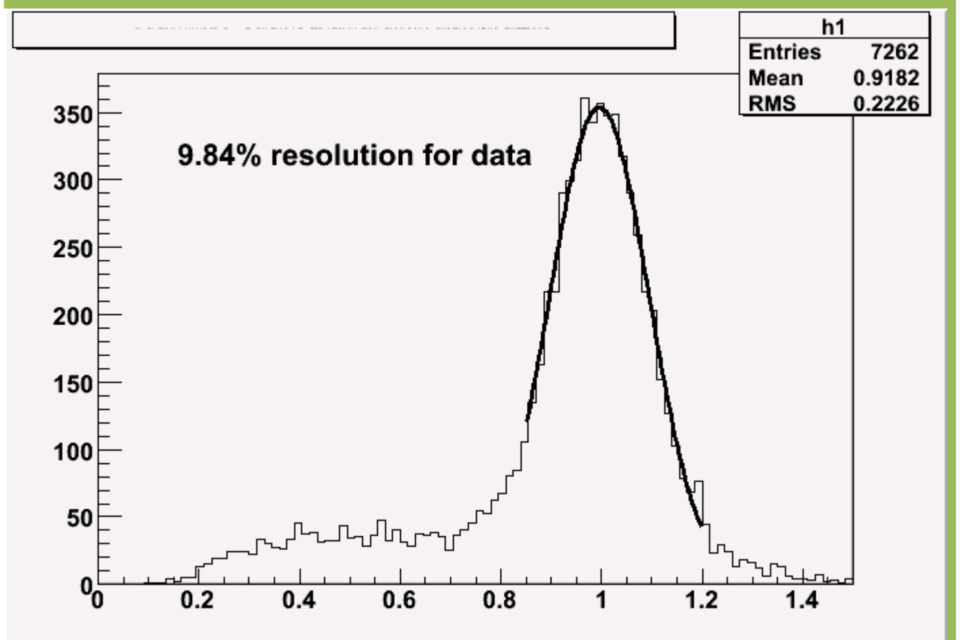
# Target Collimator

- The position of target collimator are tuned.

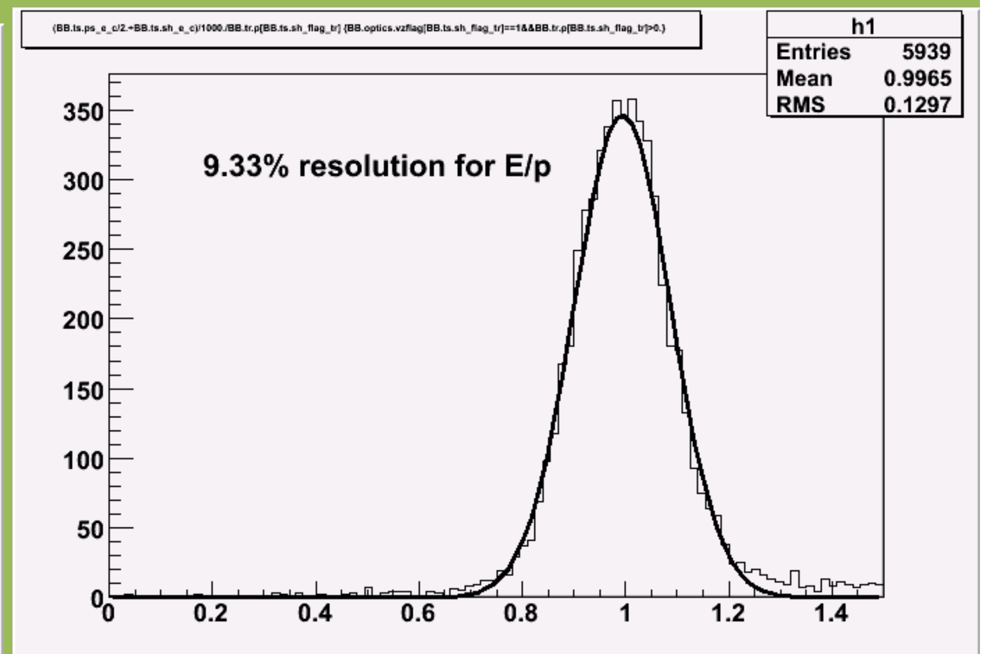


# Calorimeter Energy Resolution

- Calorimeter Energy Resolution is added in



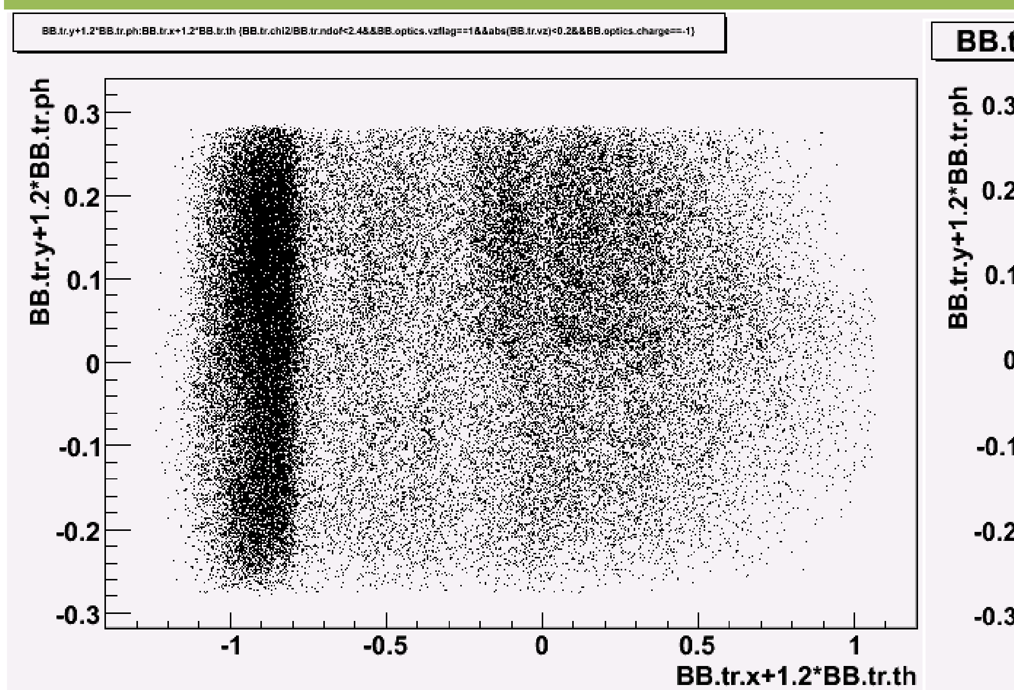

Data



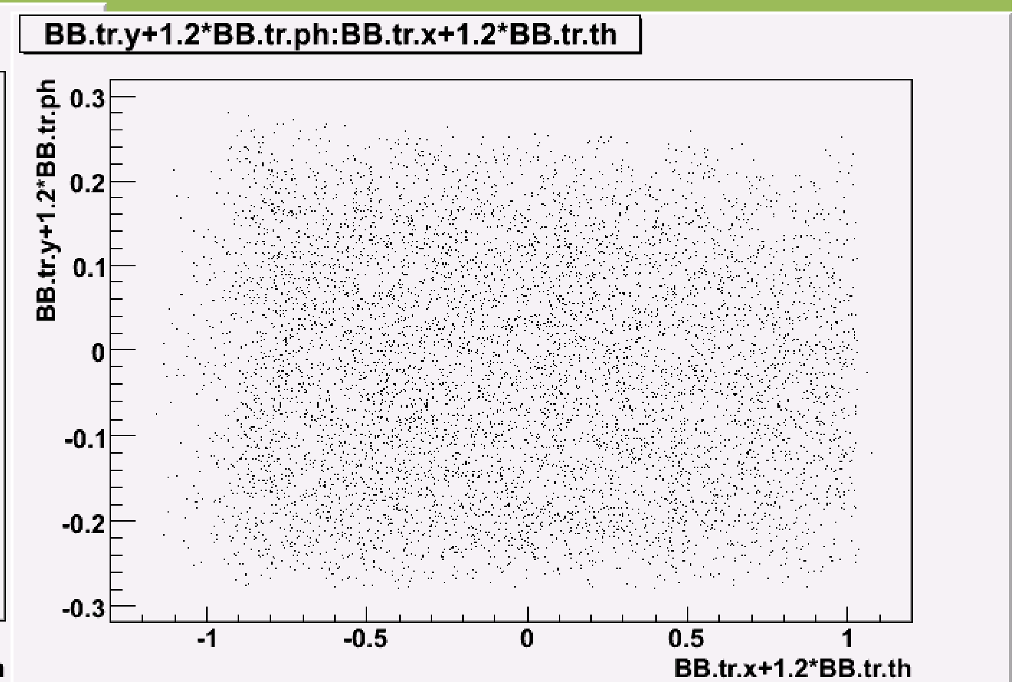

MC

# Acceptance

- The acceptance is checked.
- No physics in MC yet.

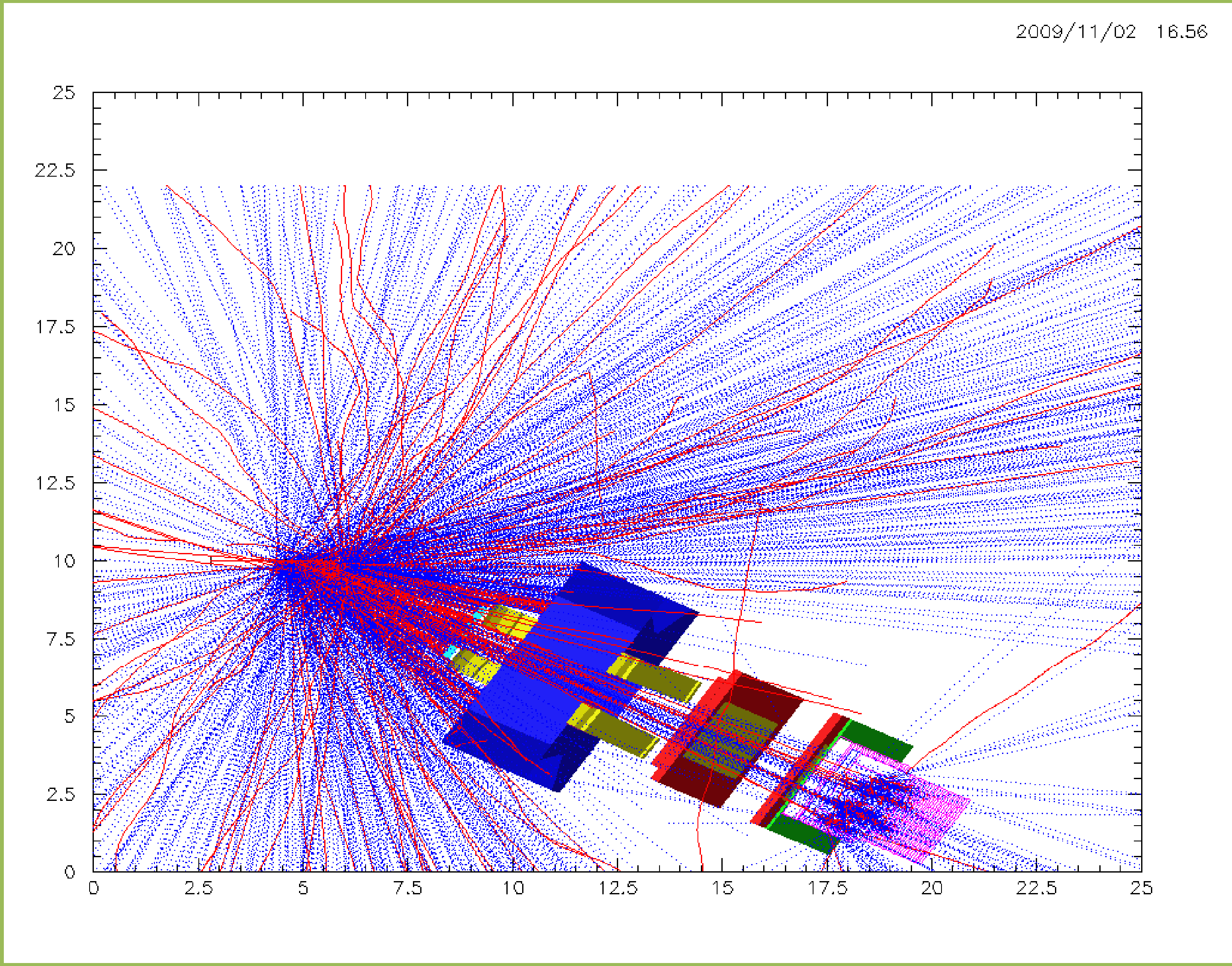



Data

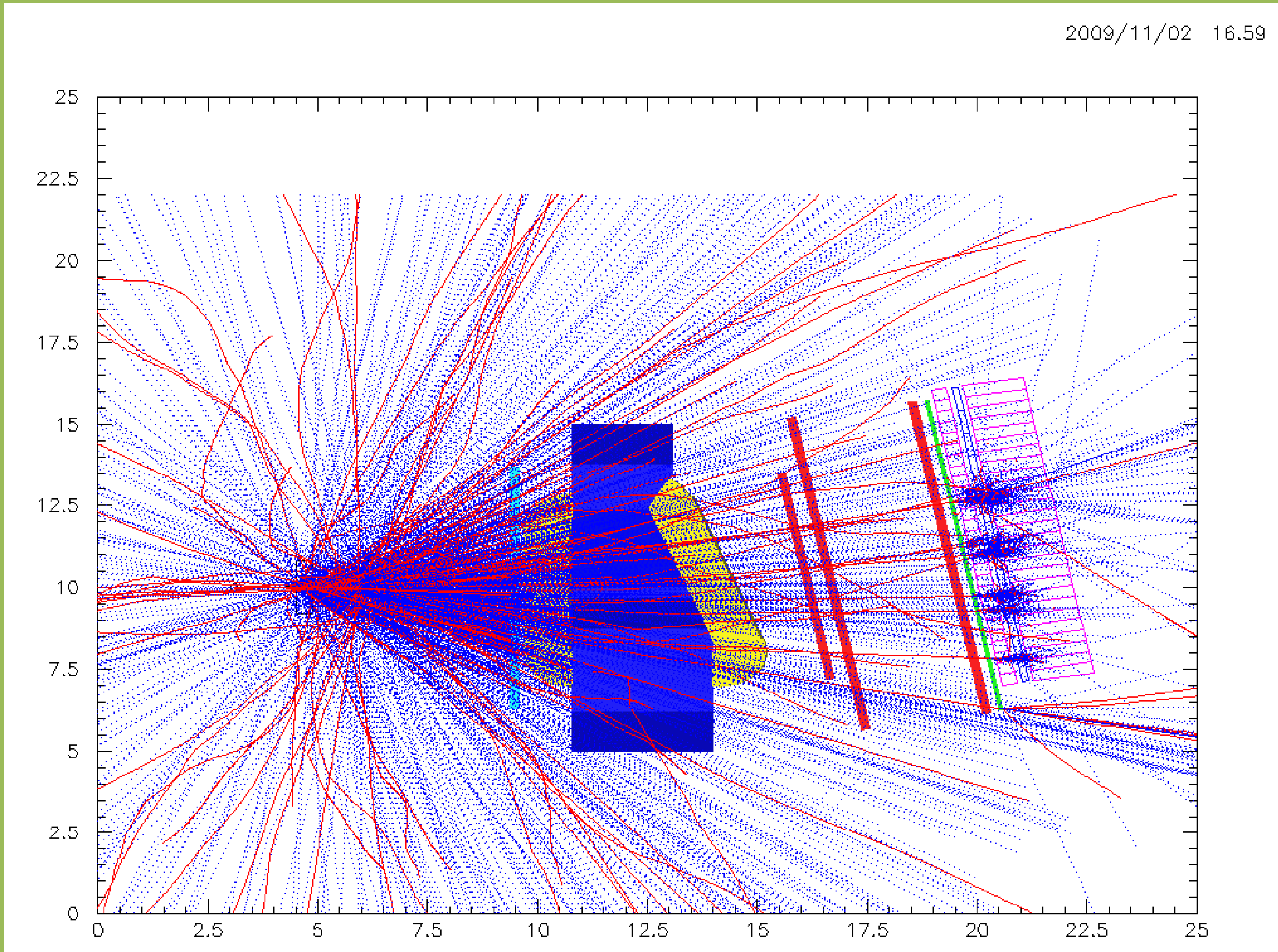



MC

# MC simulation

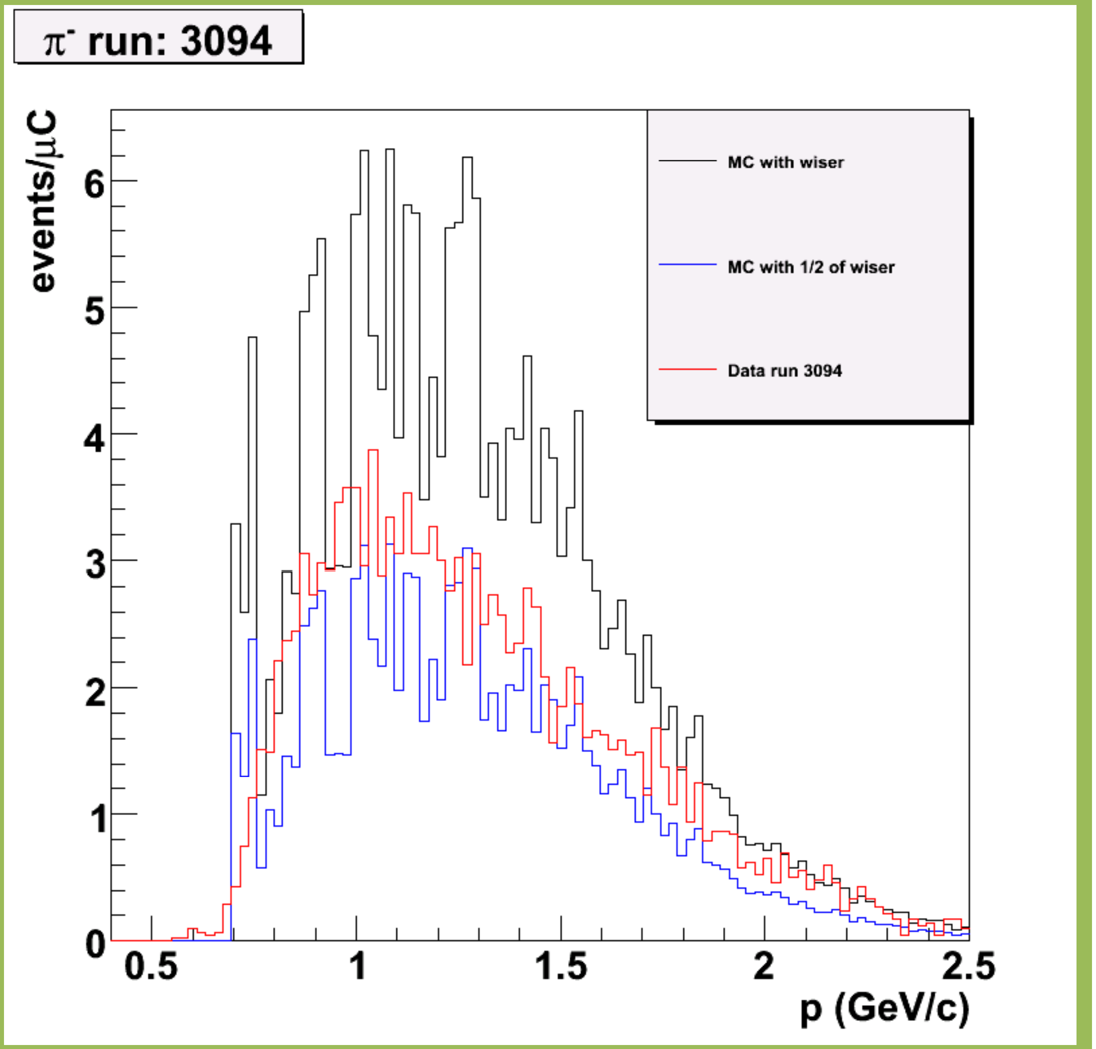


# MC simulation



# $\pi^-$ rate comparison

- The MC is weighed by the cross-section of wiser code
- At high momentum, the data match with the wiser code.
- At low momentum the data is in the middle of wiser and ½ wiser.
- Similar comparison are done for photon and electron.



# Summary

- The Geant3 model of BigBite is updated
- The interface to analyzer is developed.
- Gaols:
  - Understand the data
    - Understand the contamination to the electron sample
  - Understand the single rates for different particles
  - Forward transportation model for future physics Monte-Carlo (SIMC)
    - Acceptance study
- The same idea can be used in the future to test the software performance.