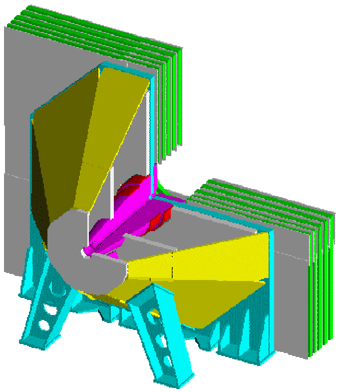
Cluster fitting algorithm for the PHENIX muon tracker



DongJo Kim, Yonsei University
For PHENIX collabration

Quark Matter 2002
Nantes (France), July 18-24, 2002

- ✓ The PHENIX muon Tracker
- ✓ Muon Data Analysis overview
- ✓ Muon Tracker Calibration
- ✓ Cluster fitting algorithm
- ✓ Chamber resolution(CSC Simulation)
- ✓ Results
- ✓ Summary and Outlook

PHENIX Muon Arm

- The Muon Arms provide the muon detection for both the relativistic heavy ion and spin physics programs of the PHENIX

- Detect and characterize Quark Gluon Plasma
  - Simultaneous measurement of various signatures
  - Measurement of vector meson production cross sections
  - Measure differential suppression of J/ψ and ψ' production to probe deconfinement using Upsilon as a control
  - Use high p_T single muons to tag heavy (b, c) quark decay
  - Measurement of Drell-Yan continuum
  - Detect muon in process $D\bar{D} \rightarrow \mu + e + X$
- Spin Physics Program

  >STUDY SPIN STRUCTURE OF THE NUCLEON
  - Investigate spin-flavor structure of the nucleon
  - Measure helicity distributions of flavor separated quarks and antiquarks and gluon polarization in the nucleon

  >PRECISION TESTS OF SYMMETRIES

  >Longitudinally or transversely polarized p + p collisions at $\sqrt{s}$ from 50 to 500 GeV

- **South muon arm was commissioned in spring 2001, and took first beam data in July 2001.** $(1.2 < |\eta| < 2.2 , \Delta\phi=2\pi)$

- **North muon arm is being installed this summer.** $(1.2 < |\eta| < 2.4 , \Delta\phi=2\pi)$

PHENIX Muon Tracker

- Three stations of cathode strip chambers per arm
- Three gaps in stations 1 and 2, two gaps at station3
- Two cathode planes readout per gap
- Less than **100 μm spatial resolution** per cathode plane

To Distinguish Vector Meson Productions

Υ (1S)(9.46GeV) from Υ (2S+3S) (10.02,10.36GeV)

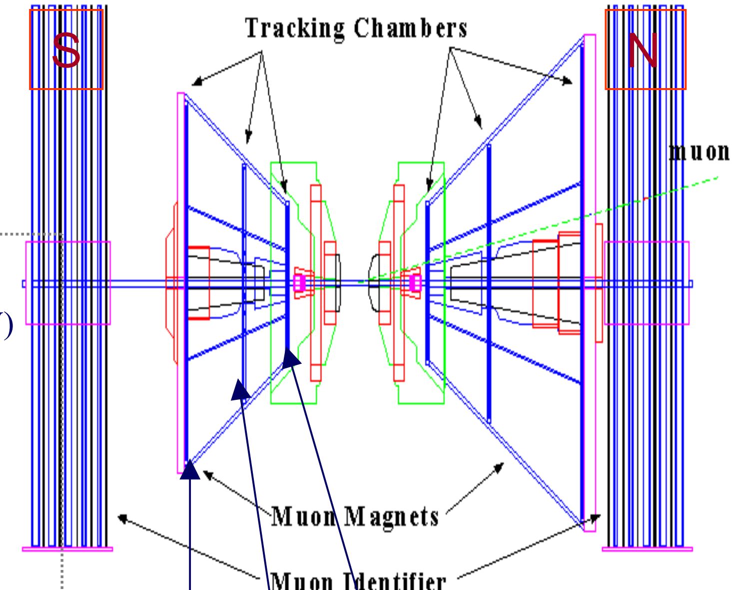
Chamber resolution dominates.

Requirement: 100 micron per cathode.

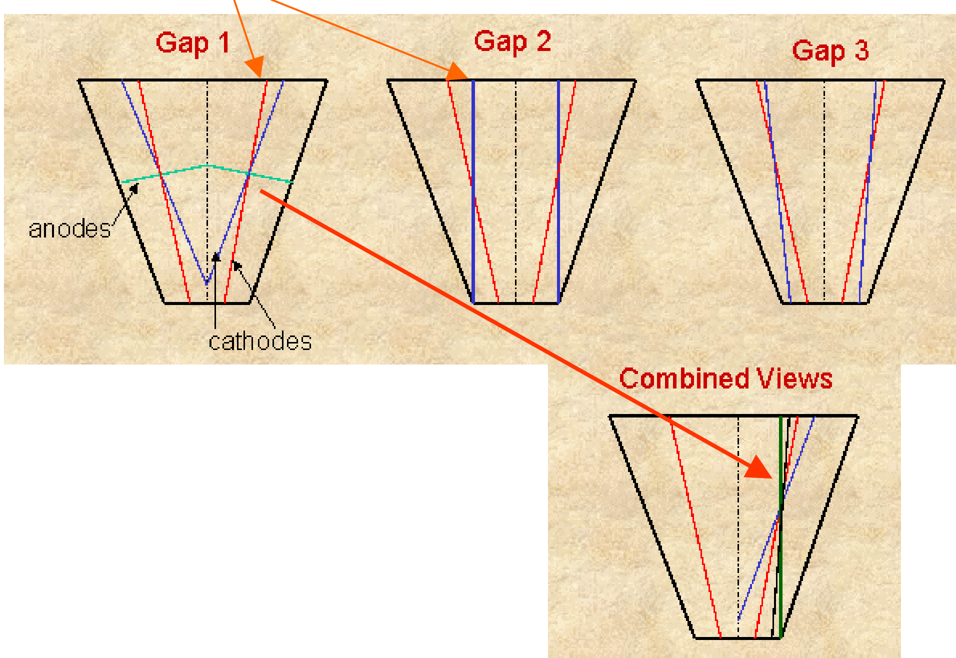
J/Ψ (3.097GeV) from Ψ'(3.686GeV)

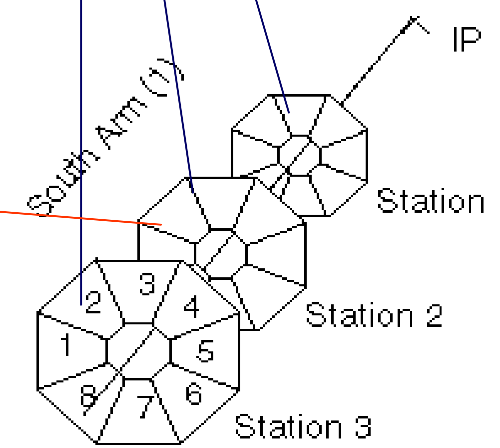
Multiple scattering and chamber resolution.

Requirement: 300 micron per cathode.



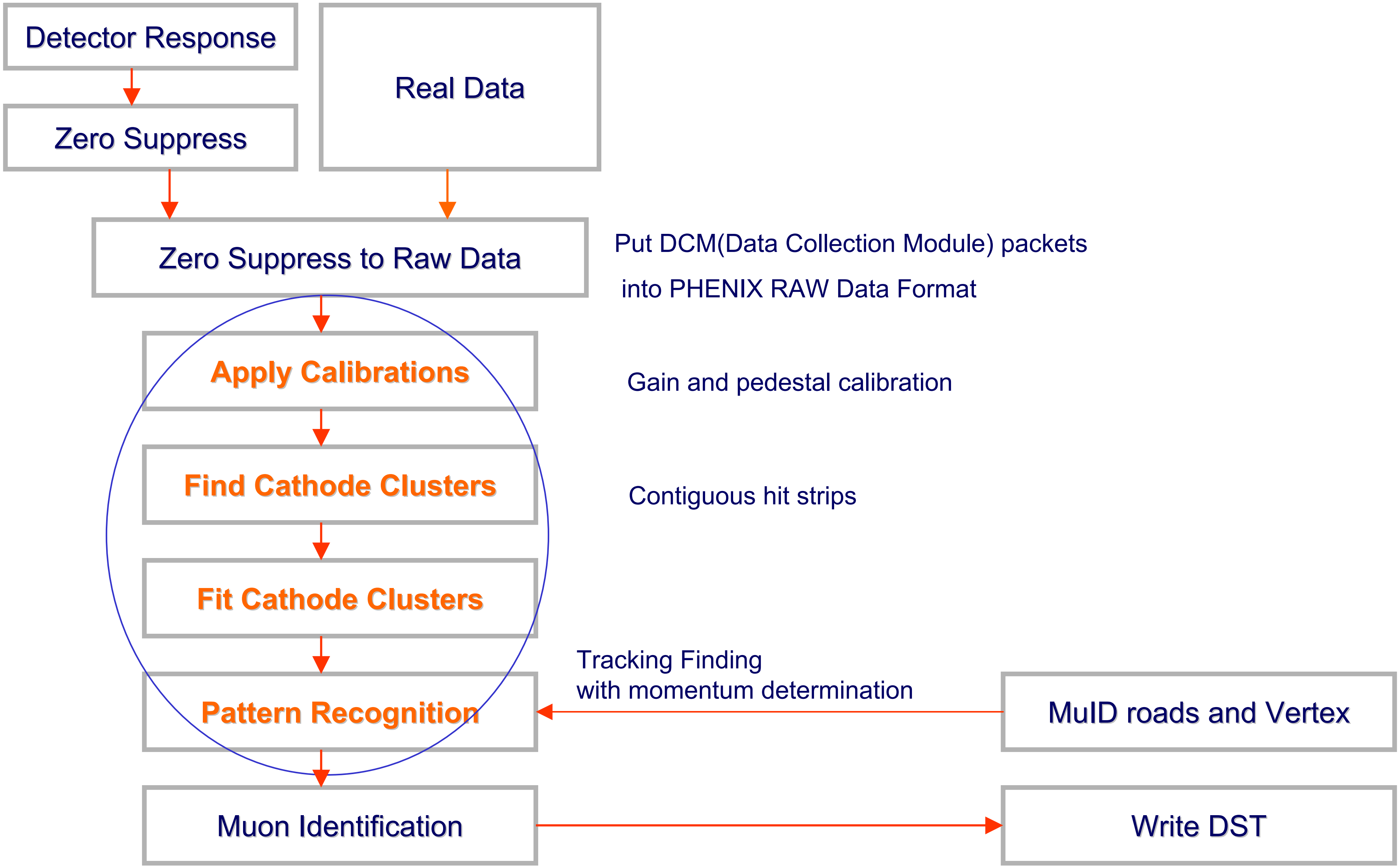
Fitted Cluster position





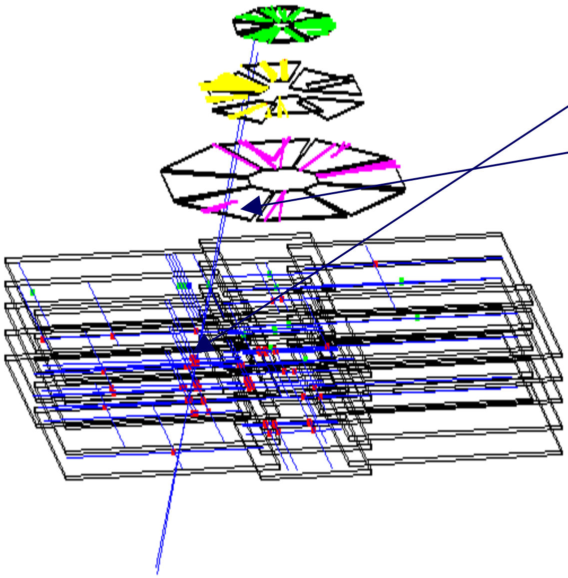
St. 1 : +11.25°, -11.25°, 6°
St. 2 : 11.25°, 7.5°, 3.25°
St. 3: 11.25°, 11.25°

Muon Tracker Software Flow Chart



Muon Tracker Pattern Recognition

Muon Event



A Stub is a group of

fitted cluster peak positions

Pattern Recognition

Muon Identification Roads

Search for hits in last plane of Station3,within "mask area"

If two or more hits, check

- Is candidate cathode within "hit bound" of intersection of other cathodes?
- Is intersection of hits still within the mask area?
- Do cathodes in different planes approximately intersection of other cathodes?

After Stubs within a station are found

- Fit stubs to a straight line(and include vertex point and/or MuID Road points)
- Reject stubs with too high of a chi-square

When all potential tracks have been found

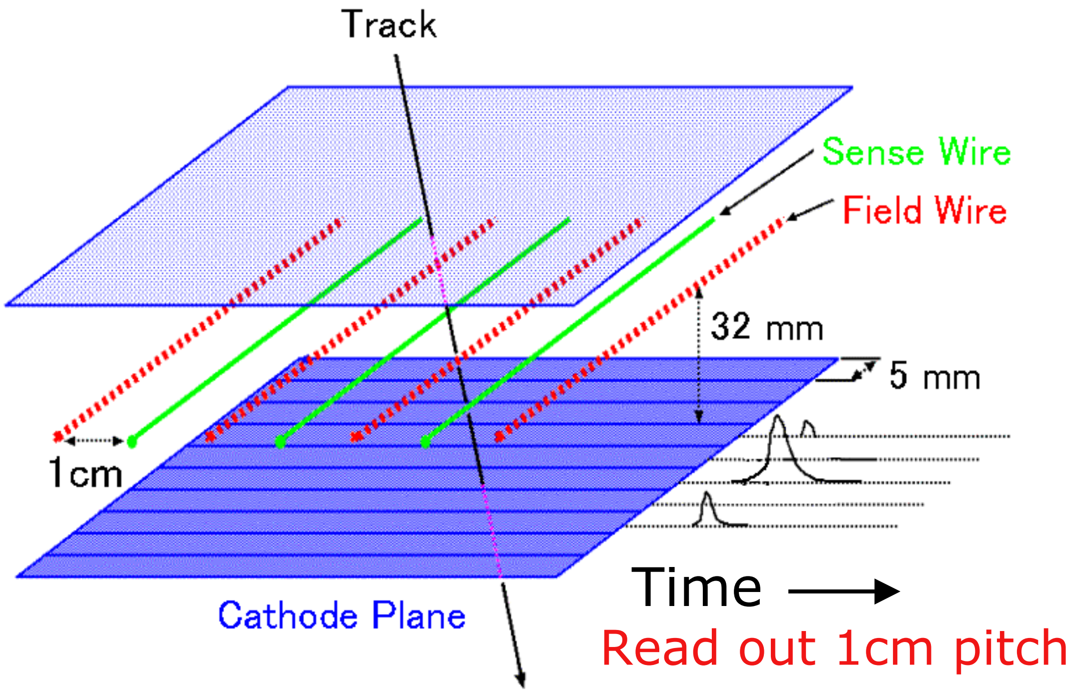
- Fit tracks using Kalman-filter fitting(include vertex and MuID hits)
- Further reject tracks with poor chi-square

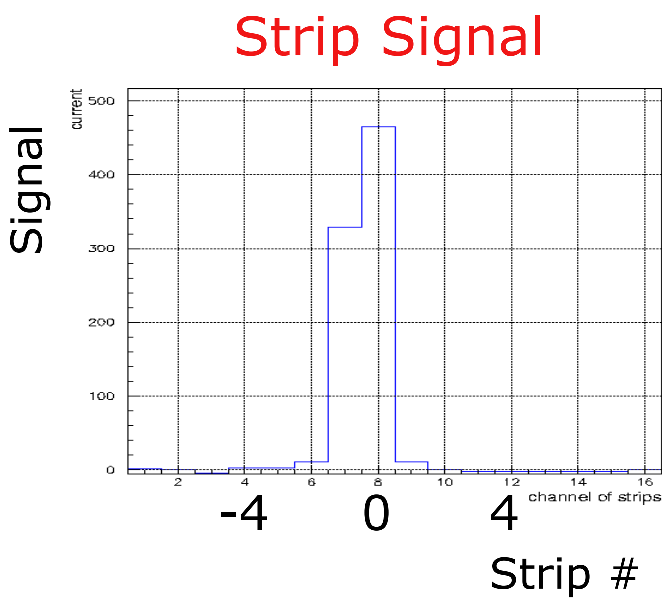
Pass found tracks and roads to Muon Identification Module

Cathode Strip Chamber

- Strip width – 0.5cm, 1.0cm readout
- Anode-cathode spacing – 3.2mm
- Various angles of strips with respect to the anode wires

Requirement
Noise/Signal < 1%





Ar:CO2:CF4 = 50:30:20
HV : ~1850V

Average # of strips/track~2.4

MuTr Calibration

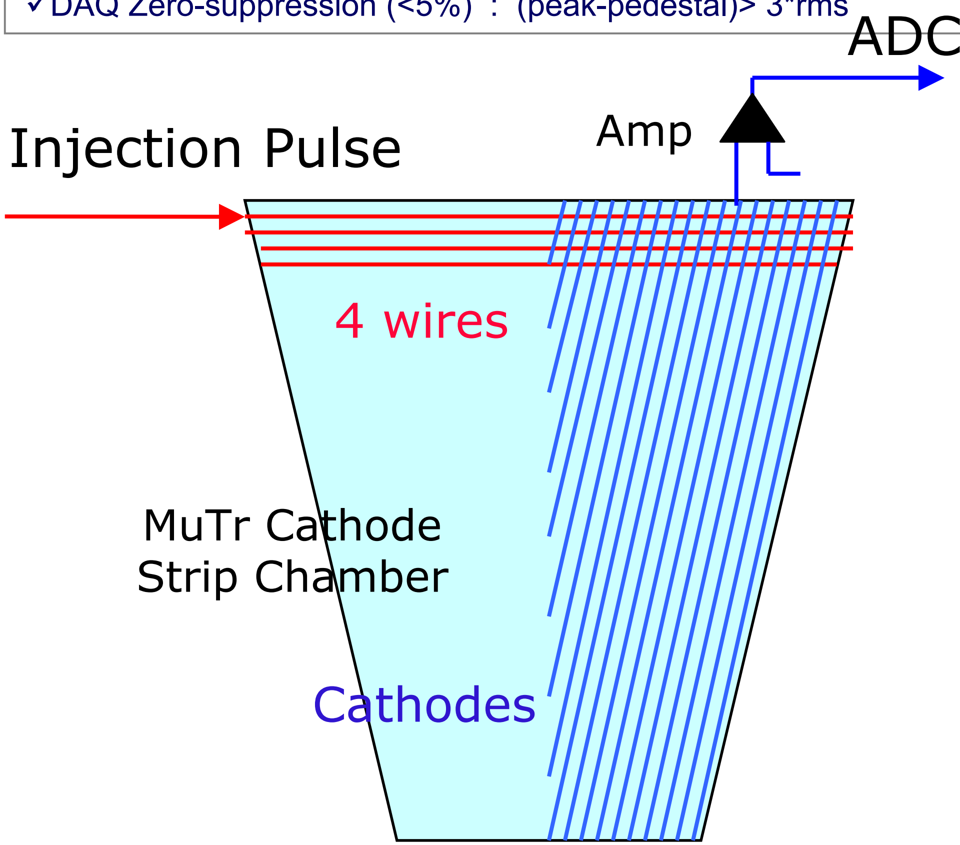
Calibration constants are stable over time

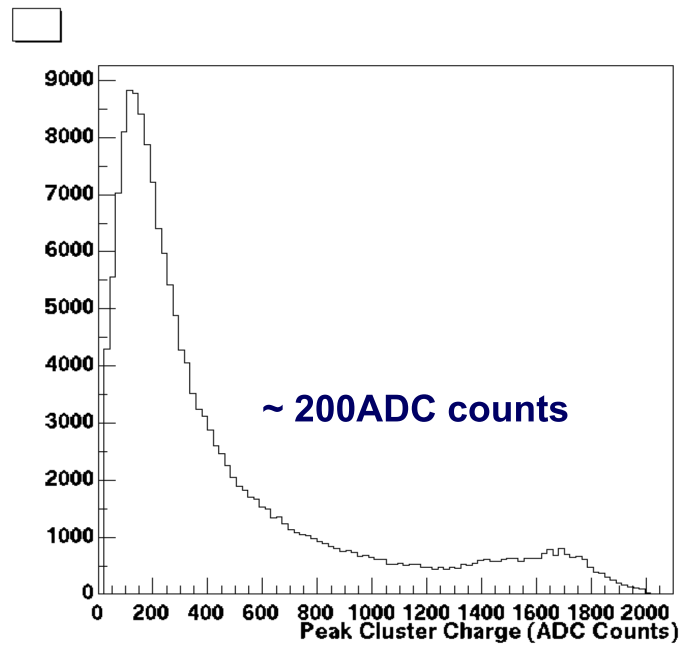
- ✓Determine strip by strip variation of gain and pedestal
- ✓Take them every other day and put into database
- ✓Monitor them by accessing calibration database
- ✓Generate zero-suppression threshold files for DAQ based on calibration database
- ✓DAQ Zero-suppression (<5%) : (peak-pedestal)> 3*rms

⟺

Monitoring …

- ✓Pedestal, gain
- ✓High Voltage
- ✓FEE(Dallas Chip)
- ✓Low Voltage
- ✓Various Temperature





Peak Charge distribution of cluster

Gain and Pedestal Noise

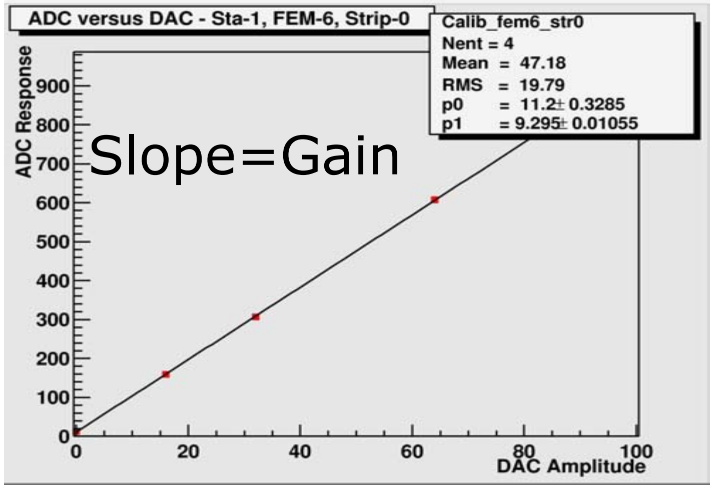
- Cathode Electronics RMS Noise Requirement
  - 0.5 fC (1.5 ADC counts) for a typical pulse of 80 fC. (0.6%)

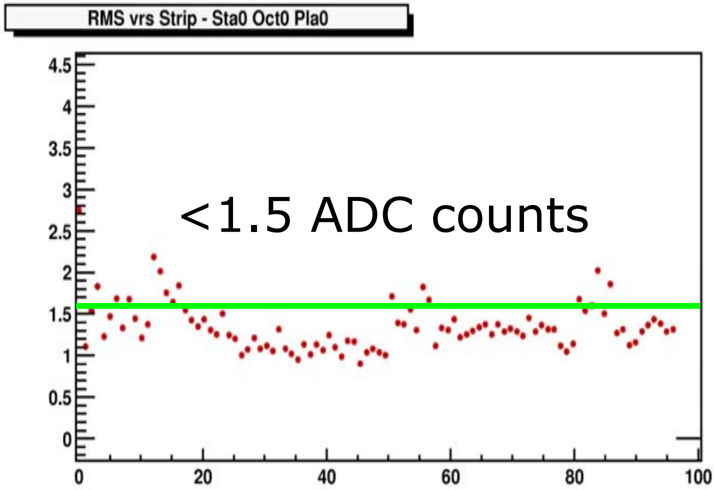
Chamber resolution 100 um : 1cm readout => 1%

Noise 80fC*1% = 0.8fC

Input and Response

Pedestal Noise

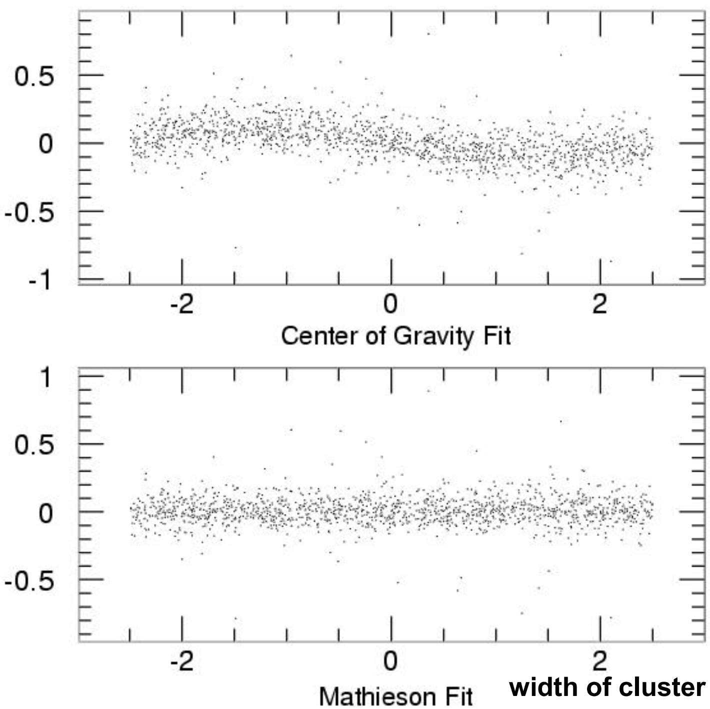




CSC Simulation

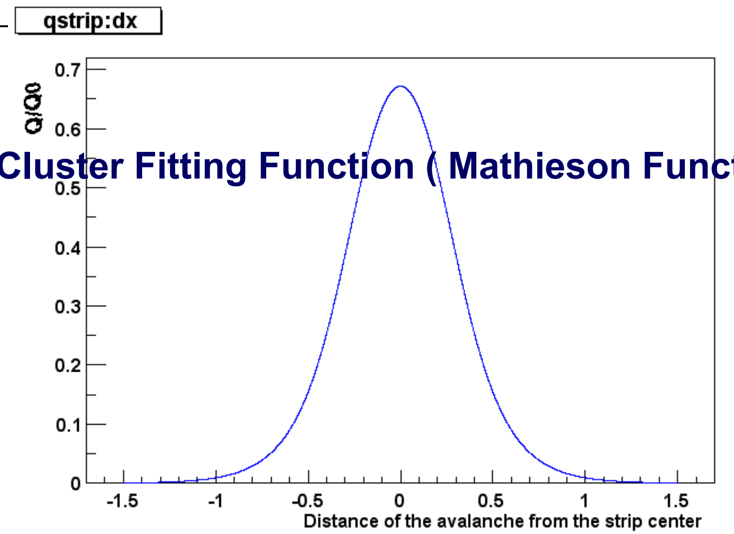
- creates primary electrons in the gas volume of the CSC chamber
- diffuses the electrons as they drift to the anode wire
- shifts the electron positions according to the Lorentz angle, incident angle of the track, and angle of the strips with respect to the anode wires
- multiplies the number of electrons at the anode wire according to the gain of the chamber induces the charge on the cathode strips and then adds electronic noise and calibration uncertainty to the cathode charge measurements
- After the total charge has been deposited onto the cathode strips, the charge distribution is fit and the centroid position is compared to the initial position of the track. The original code extracted the centroids using a center of gravity calculation and a gaussian fitting calculation. A fit using the Mathieson function,which more accurately represents the charge distribution on the strips.

CSC resolution vs the true position on a strip



width of cluster

Cluster Fitting Function (Mathieson Function)



$$\frac{Q(\lambda)}{Q_0} = K_1 \frac{1-\tanh^2(K_2\lambda)}{1+K_3\tanh^2(K_2\lambda)}$$

$$\lambda = \frac{x-x_0}{h}$$, x_0 – *position of the avalanche* , h – *anode–cathode seperation*

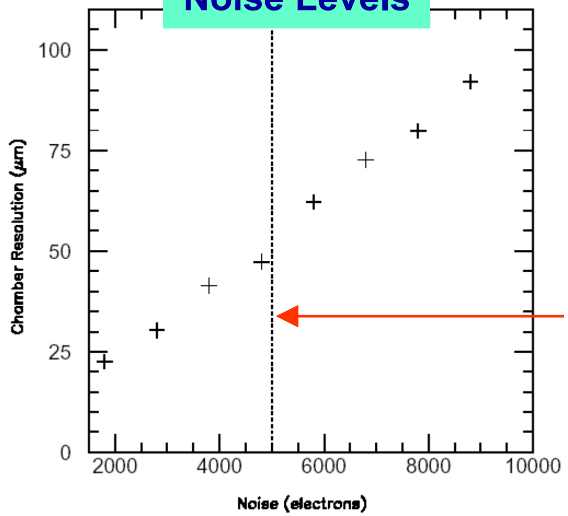
$$K_1 = \frac{K_2\sqrt{K_3}}{4\tan^{-1}\sqrt{K_3}} , \quad K_2 = \frac{\pi}{2}\left(1-\frac{\sqrt{K_3}}{2}\right)$$

K_3 = 0.5 *along the wire*(h/s, r_a/s (s : *anode wire* pitch))

A Mathieson fit gives better resolution than a center of gravity

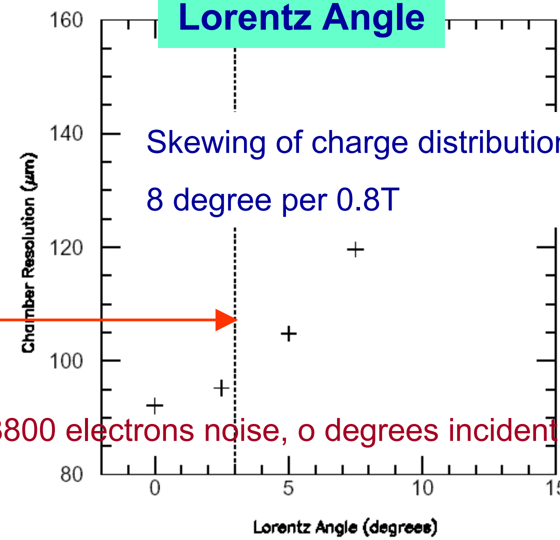
Chamber Resolution VS electronics noise and Lorentz Angle

Noise Levels



Baseline

Lorentz Angle



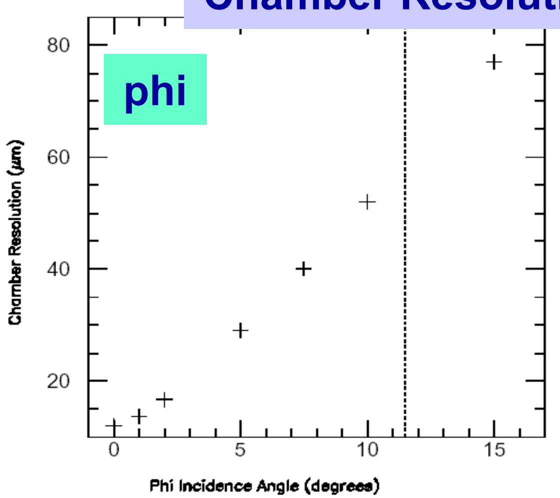
Skewing of charge distribution in phi(B :radial)

8 degree per 0.8T

8800 electrons noise, o degrees incident theta angle

Chamber Resolution VS incident particle conditions

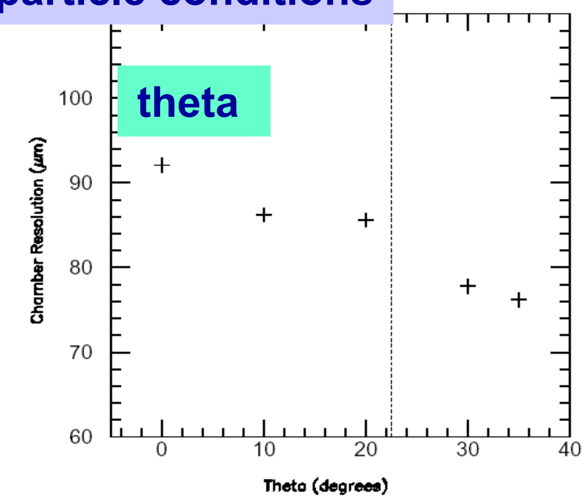
phi



0 electrons noise, o degrees incident theta angle

and 0 degree lorentz angle

theta

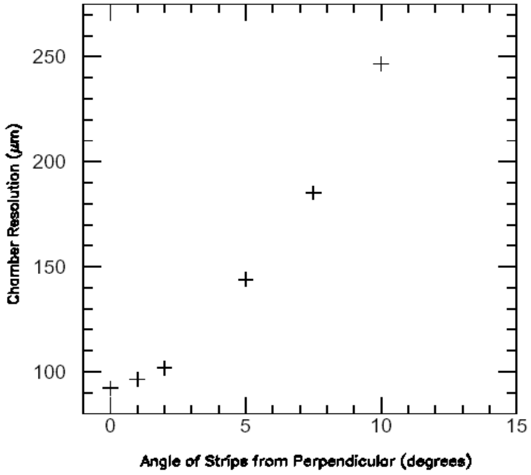


8800 electrons noise, o degrees incident phi angle

and 0 degree lorentz angle

Chamber Resolution VS Geometric condition

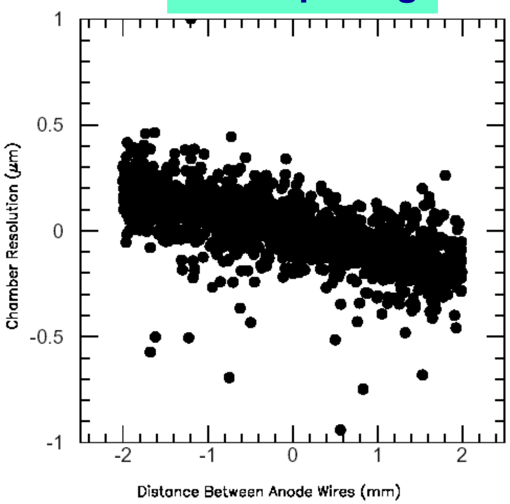
Angle of Strips from Perpendicular



8800 electrons noise, o degrees incident theta angle

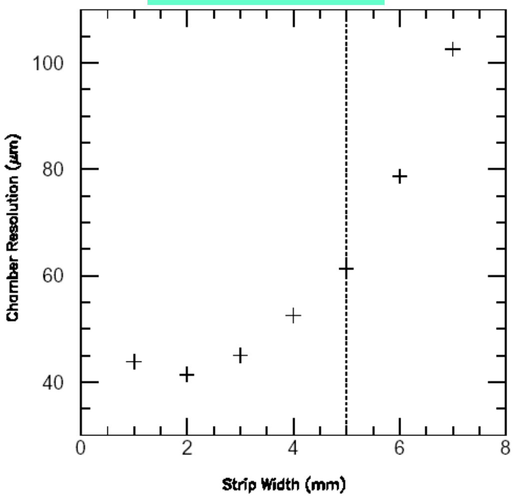
and 0 degree lorentz angle

Wire spacing



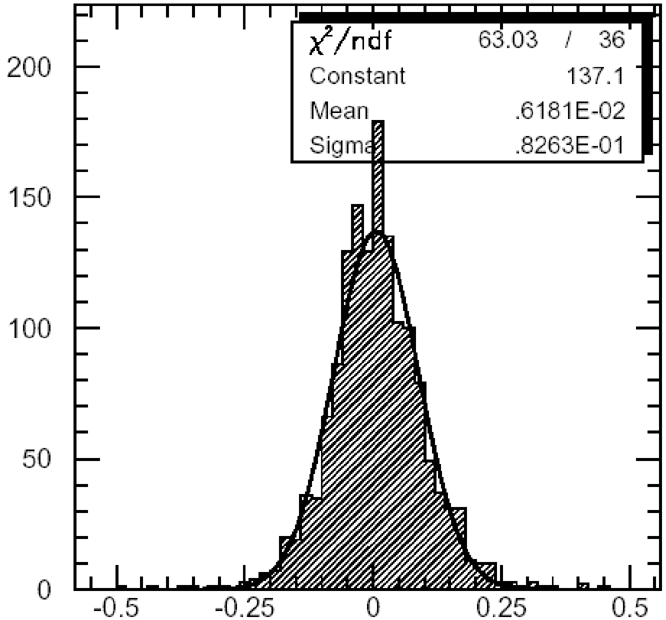
The strips are NOT perpendicular to the anode wires

Strip Width



Baseline values for noise, incident angles and Lorentz angle

CSC Resolution

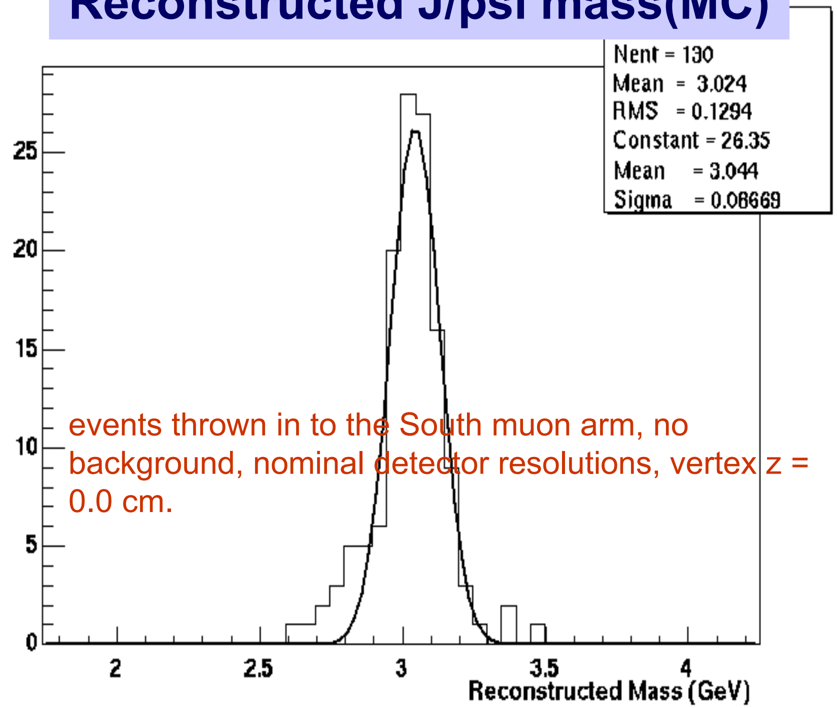


Baseline values for noise, incident angles , Lorentz angle

Strip angle relative to the anode wires, and strip width

Resolution : 82 μm, angle of the strips with respect to the anode wires was taken to be 90 degrees in CSC simulation

Reconstructed J/psi mass(MC)



- **J/psi mass**

with the real cathode strip orientation(Page3),

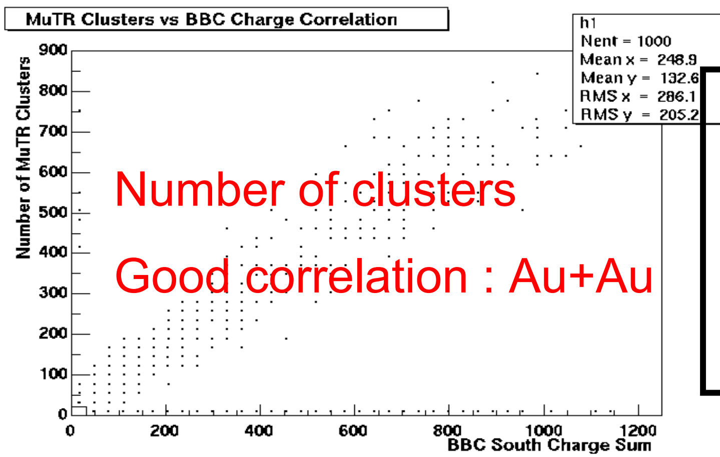
with the known associated resolutions

: the perpendicular strips having 100μm resolution

and the stereo strips having resolutions which are

proportional to their stereo angles

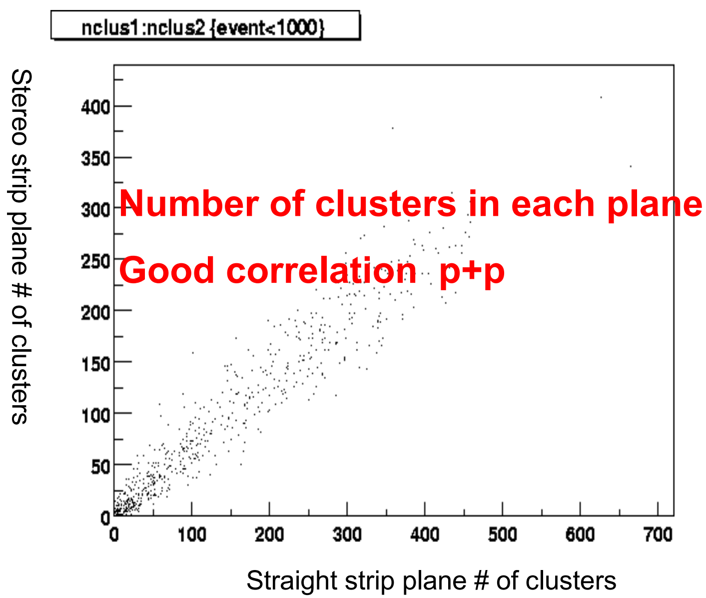
Results from PHENIX RUN2

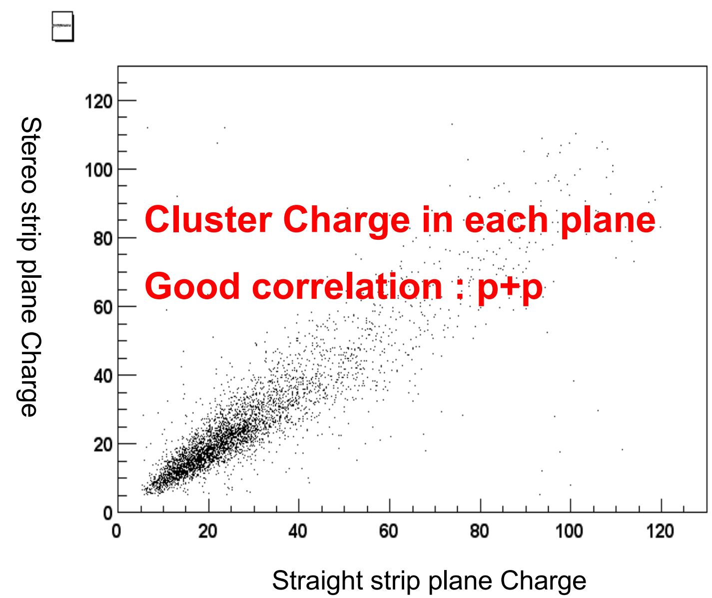


Good Correlation

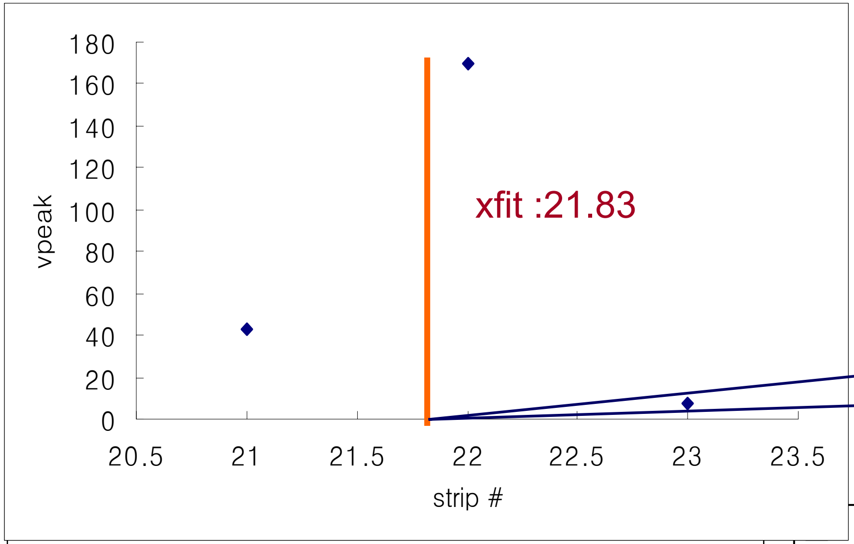
- Number of Clusters (Multiplicity) vs BBC(Beam-Beam Counter) total Charge
- Number of Clusters of each cathode planes in a gap
- Strip charge of each cathode planes in a gap

gives good correlations



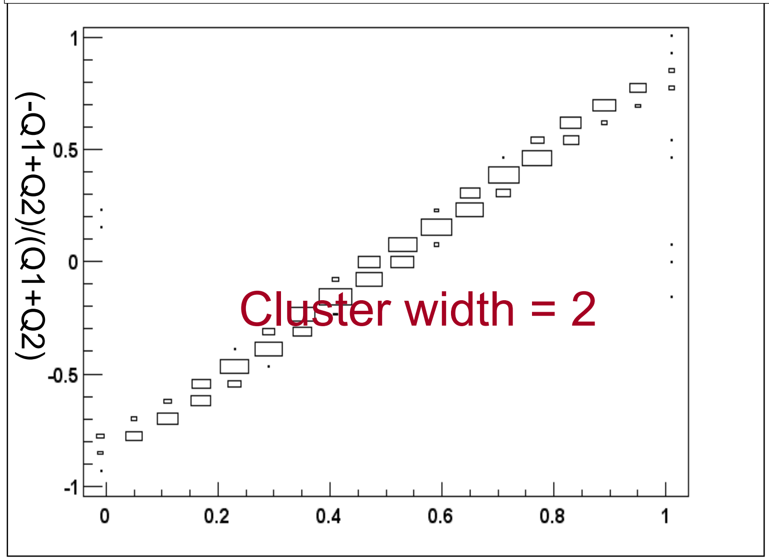


The Mathieson fit vs a center of Gravity in real data(p+p)

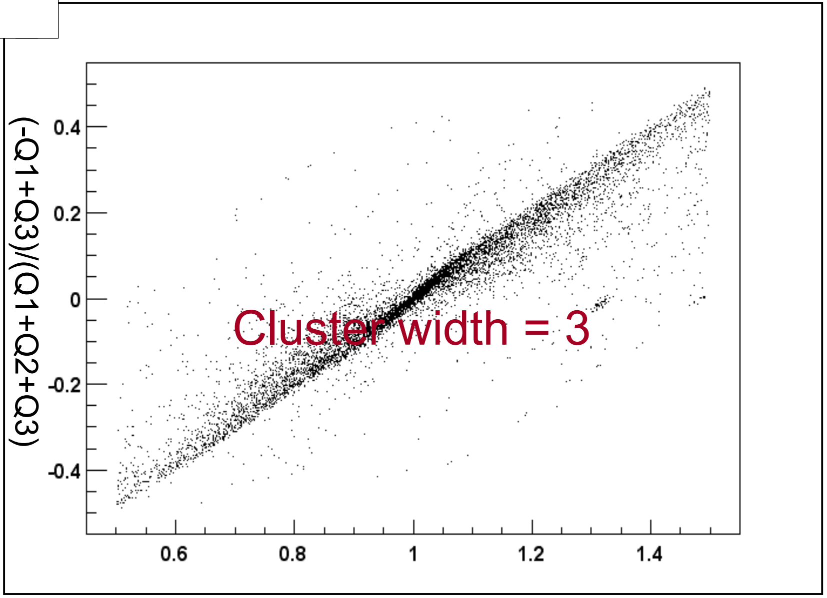


- **Shows a fit result from a 3 strip cluster**
- **Current mathieson function gives good correlations with a Center of Gravity**

Fit a cathode cluster to Mathieson distribution



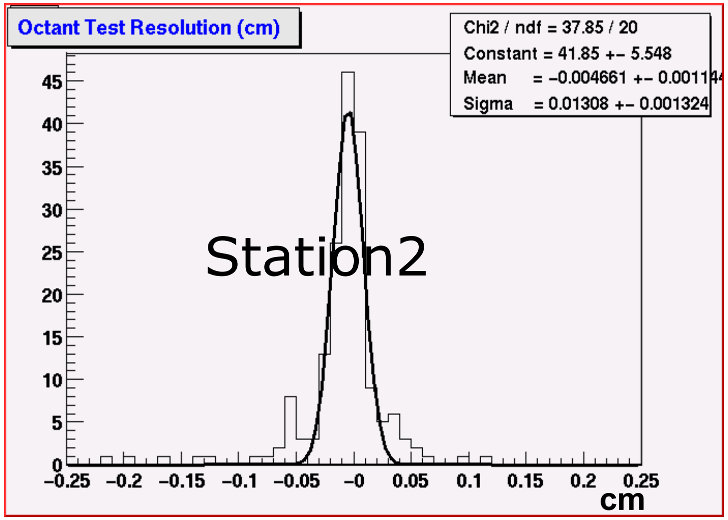
Cluster centroid(Mathieson)



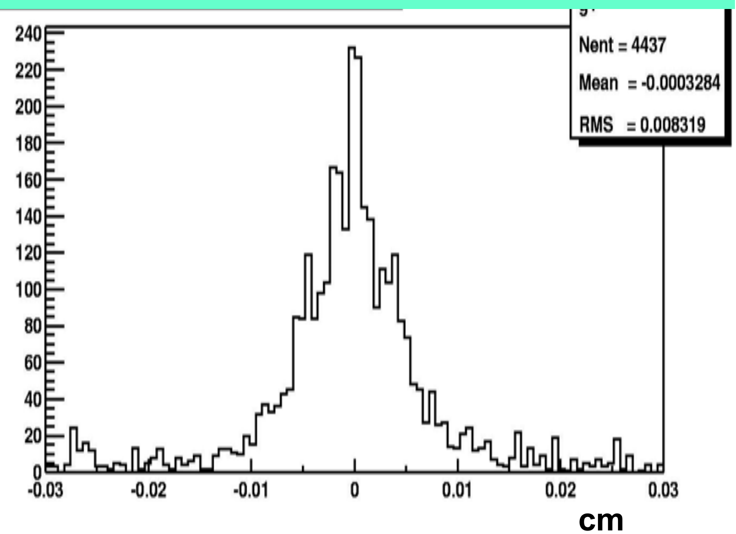
Cluster centroid (Mathieson)

The Performance of RUN2

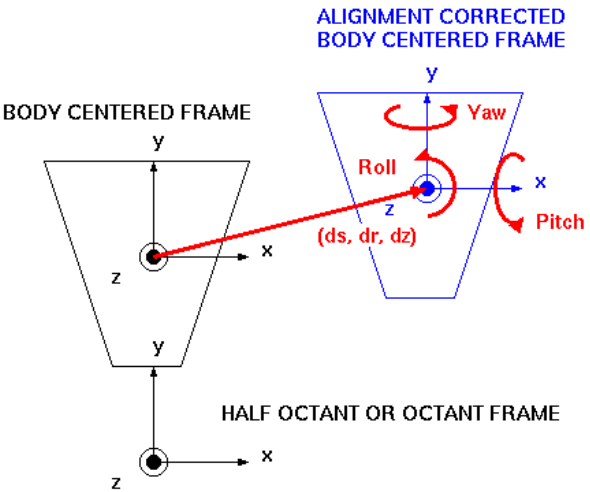
Station2 Octant Cosmic Test



Residual at a Station from Zero Field p+p



- **Octant Test results** : ~130 mm which includes the intrinisic resolution of one of the "perpendicular" planes in the octant test plus the error from projecting a line from the other 5 planes to this plane.
- **Alignment Correction** : Straight tracks from p+p field off data are used to align chambers more precisely(work in progress)



Identified J/psi Siganl from p+p collision

See Hiroki Sato's J/psi poster

Summary and Outlook

- The PHENIX Muon cathode strip chambers have been simulated for a variety of geometric and incident particle conditions.
- The cluster fitting algorithm was proven to work properly.
- To get our ultimate resolution, minor modification of fitting function might be needed.
- To see lots of works having been made in the PHENIX Muon Arm
  See posters(QM2002) of
  - Kenneth F. Read
    "The Performance of the PHENIX South Muon Arm"
  - Jason Newby
    "Reconstruction Performance of the PHENIX South Muon Arm"
  - Ming Xiong Liu
    "Dimuon Production from Au-Au Collisions at $\sqrt{s}$=200 GeV"
  - Hiroki Sato
    "Measurement of $J/\psi \rightarrow \mu^{+}\mu^{-}$ in p+p collisions at $\sqrt{s}$ = 200 GeV"