The Detector Performance Study for the Barrel Section of the ATLAS Semiconductor Tracker (SCT) with Cosmic Rays

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For the ATLAS SCT Collaboration

DPF2006 and JPS2006 joint conference
Sheraton Waikiki Hotel, Honolulu, Hawaii
October 30, 2006

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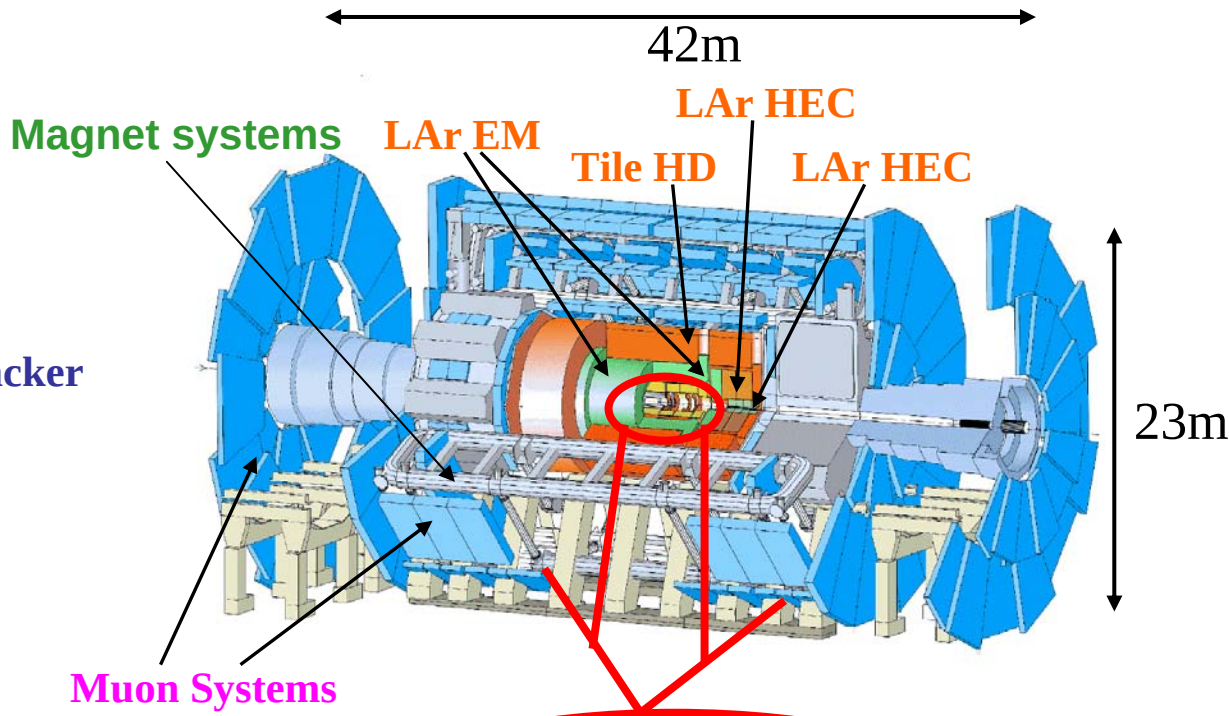
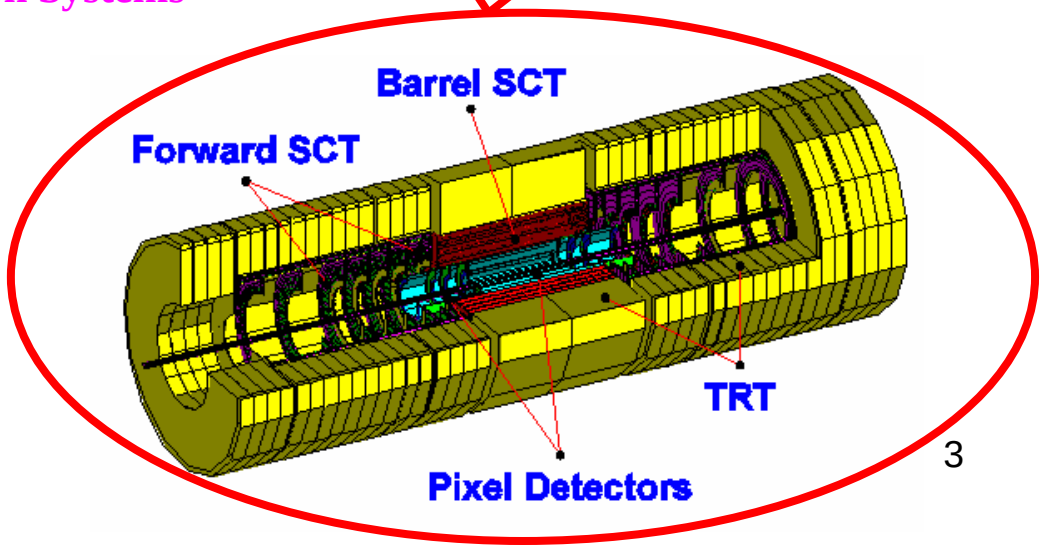
- **Summary**

A Toroidal LHC ApparatuS (ATLAS)

- **Inner Detector**
  - **Pixel : the pixel detector**
  - **SCT : the semiconductor tracker**
  - **TRT : the transition radiation tracker**
- **Calorimeter**
- **Muon Systems**
- **Magnet systems**



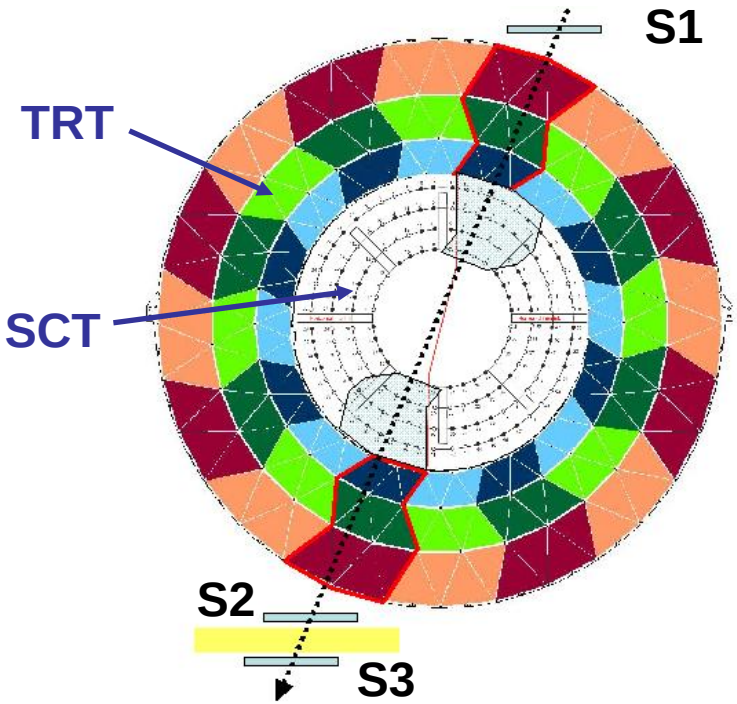


Overall weight : 7000 Tons

Tracker : $|\eta| < 2.5$

Calorimeter : $|\eta| < 4.9$

ID Barrel Combined Cosmic Ray Test



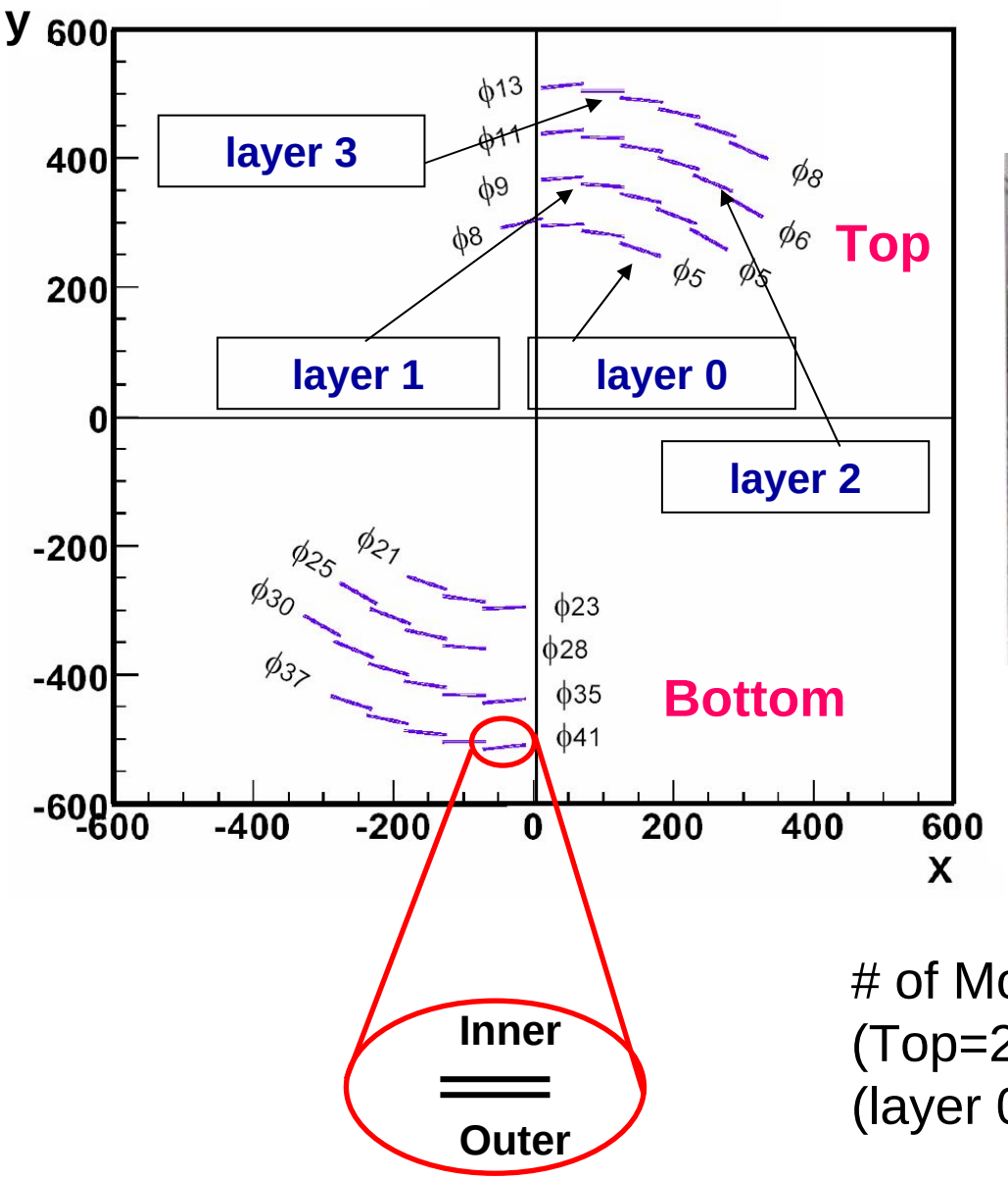
trigger: $S1 \cap S2 \cap S3$ or $S1 \cap S2$

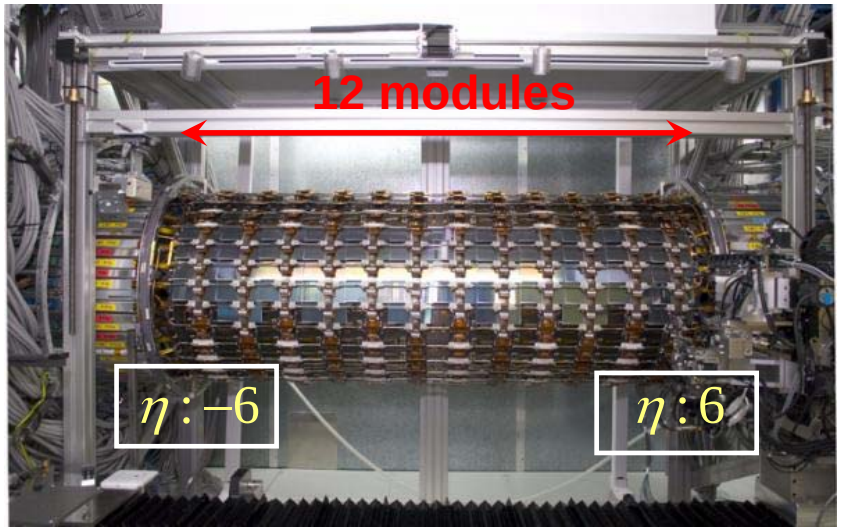
SCT + TRT Combined Run

- The test was performed during 5 weeks on early summer ’06
- Corrected ~0.5M cosmic triggers
- Number of functional channels in SCT Barrel : 99.7 +- 0.03%

For this study, we use ~130K events (~25% of total triggered events)

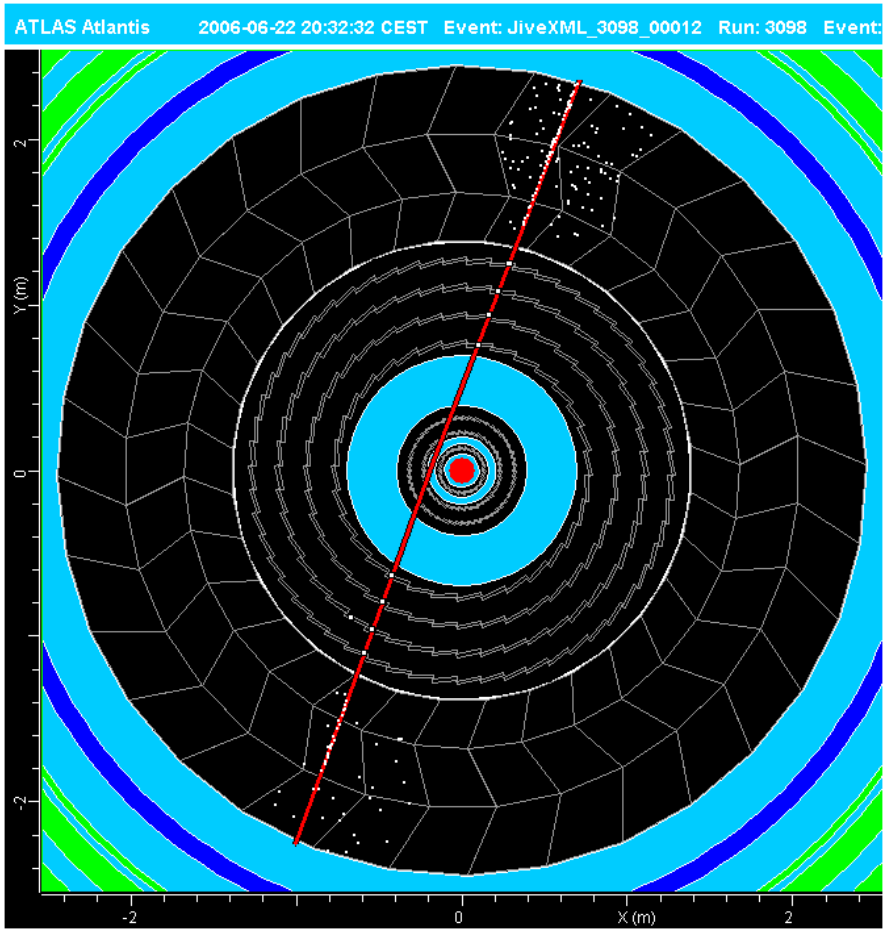
Barrel Configuration of Cosmic test





# of Modules =468 (out of 2112 modules)
(Top=252, Bottom=216)
(layer 0,1,2,3) = (84/108/144/132)

ID Barrel Combined Cosmic Ray Test



Goals of combined cosmic ray test

- <u>The detector performance aspects</u>
  - Test SCT 4 barrels with operating TRT
  - Check detector efficiency, noise level, alignment study, tracking study
  - etc …
- <u>Detector operation & commissioning of system</u>
  - Gain experience with detector operation
  - Test combined detector operation
  - Commission offline software
  - etc …

First combined test of ID with realistic geometry !!

SCT Analysis

1. Track reconstruction
2. SCT Module Efficiency
3. Track Residuals
4. Time of Flight Analysis

1. Track Reconstruction

Tracks are reconstructed in ATHENA (ATLAS software) frame work.
It includes 2 processes, which are

pattern finding and **fitting procedure**

pattern finding

- Space point formation
- Straight line fitting
- Track candidates formation

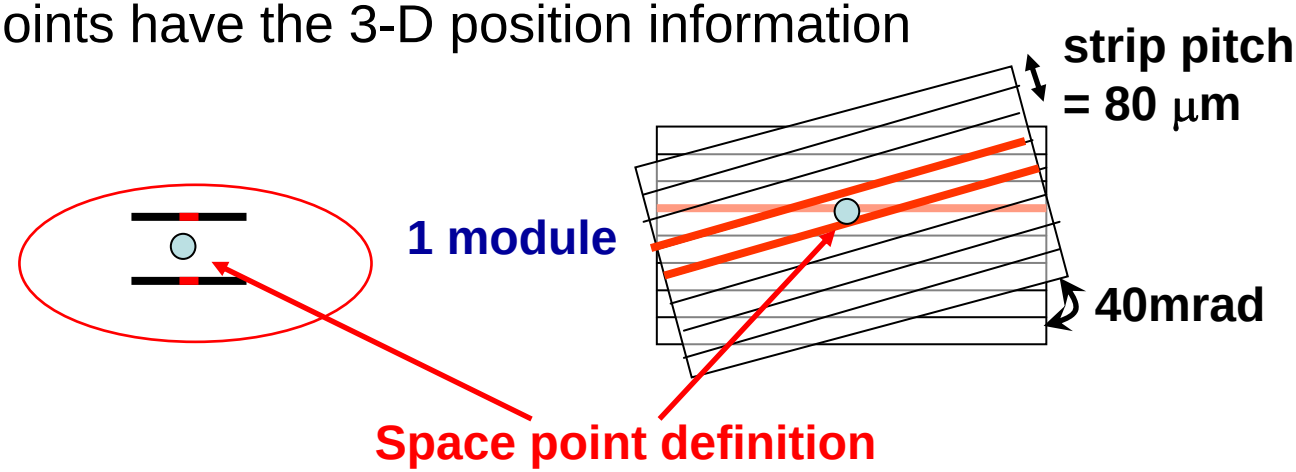
fitting procedure

- Re-fitting track candidates with strip hits
- Fitting with χ^2 minimization

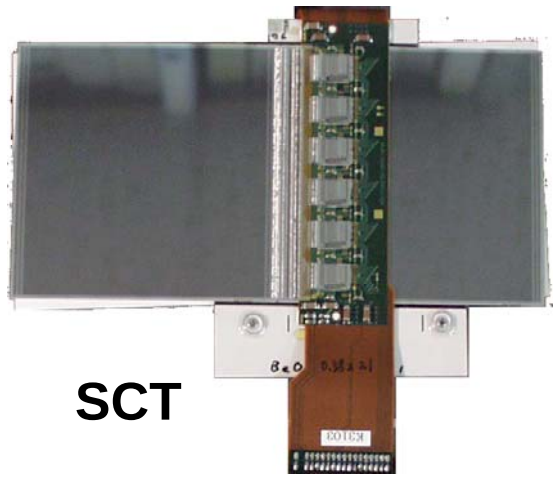
Pattern finding procedure

- **Space point** is formed for every intersection of the strips on the front and back side of a module with SCT stereo information

  -> Space points have the 3-D position information



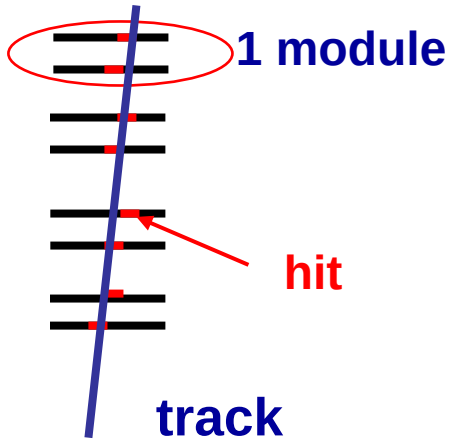
- **Track candidates** are built by fitting these space points with straight- line

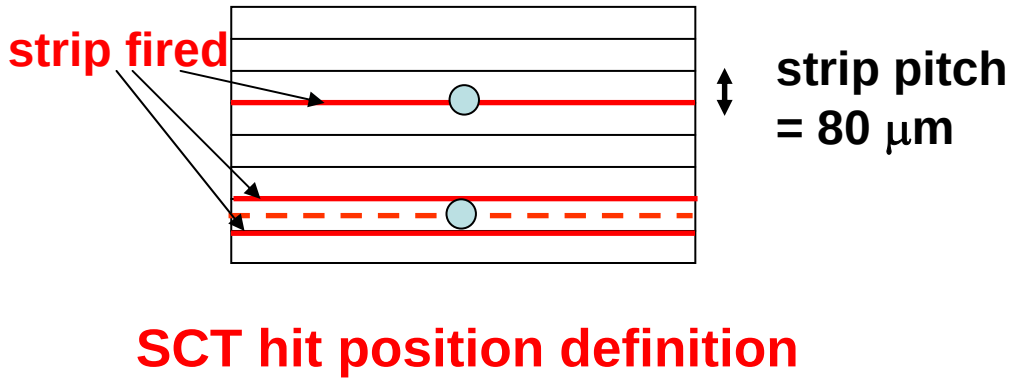


Fitting Procedure

if track candidates are found, then

- Track candidates are re-fitted by hits (single or a few strips)





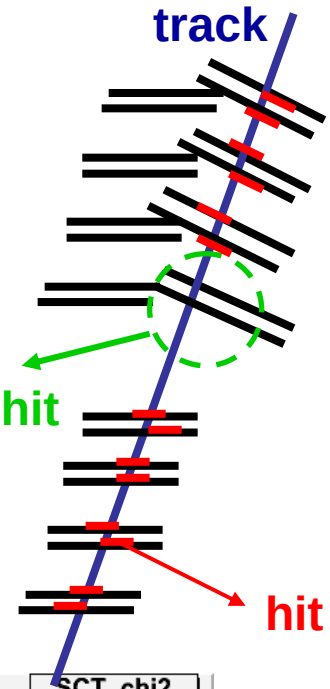
SCT hit position definition

if the track has chi^2 / ndof < 40,
it is accepted !!
(Here, tracks are roughly cut)

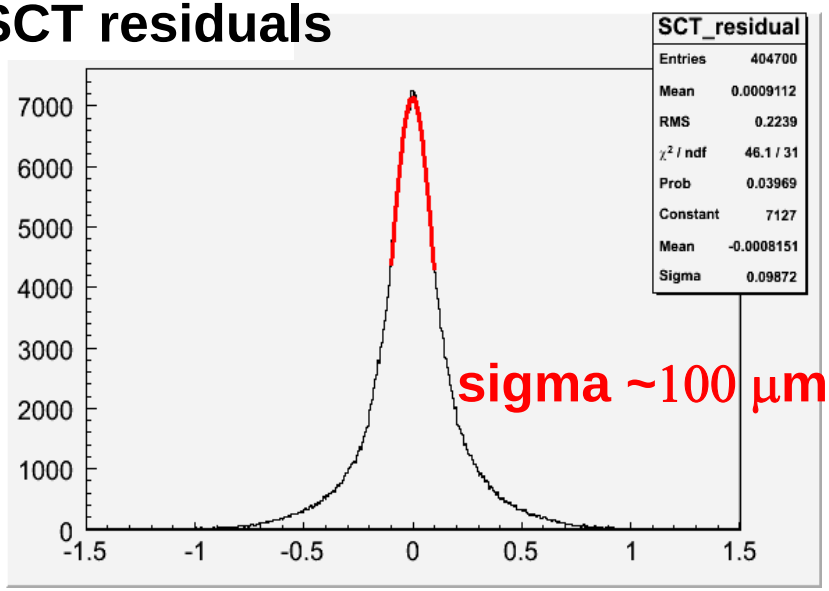
2. SCT Module Efficiency

- For accepted tracks
  - remove one layer hits (e.g. remove hits in layer 0)
  - refit the track

if refitted track fills : chi^2 / ndof < 10 &
Hits in Top sector >= 4 & Hits in Bottom sector >= 4
this track is used for efficiency calculation

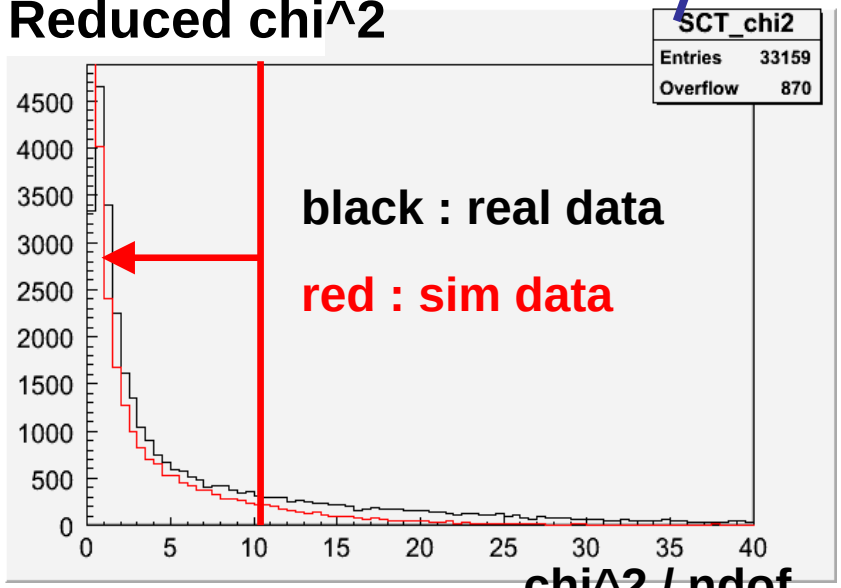


SCT residuals



res = track position – hit position

Reduced chi^2



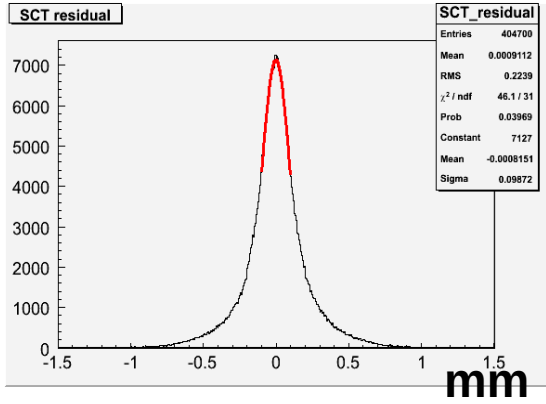
real data with no alignment

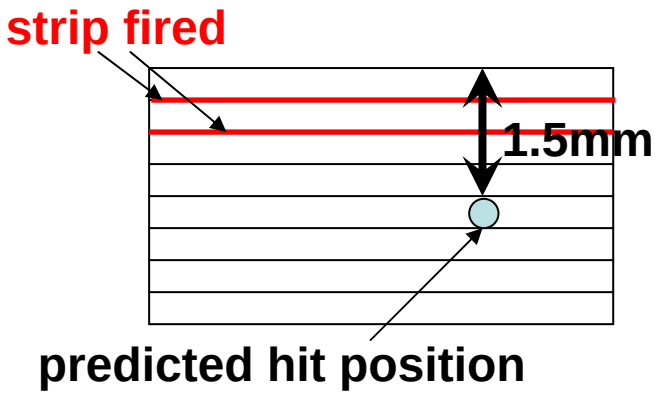
Efficiency Calculation

- extrapolate the refitted track to the module surface which hits removed
  = **predicted hit position**
- search hits from the predicted hit position within 1.5mm
  = **observed hit or not**

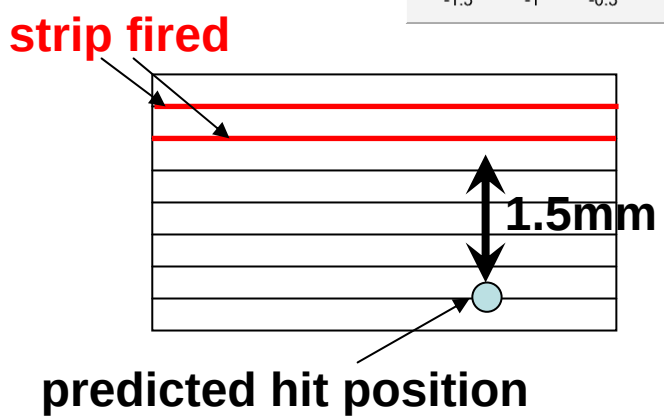
- Efficiency

Eff = # of observed hits / # of predicted hits



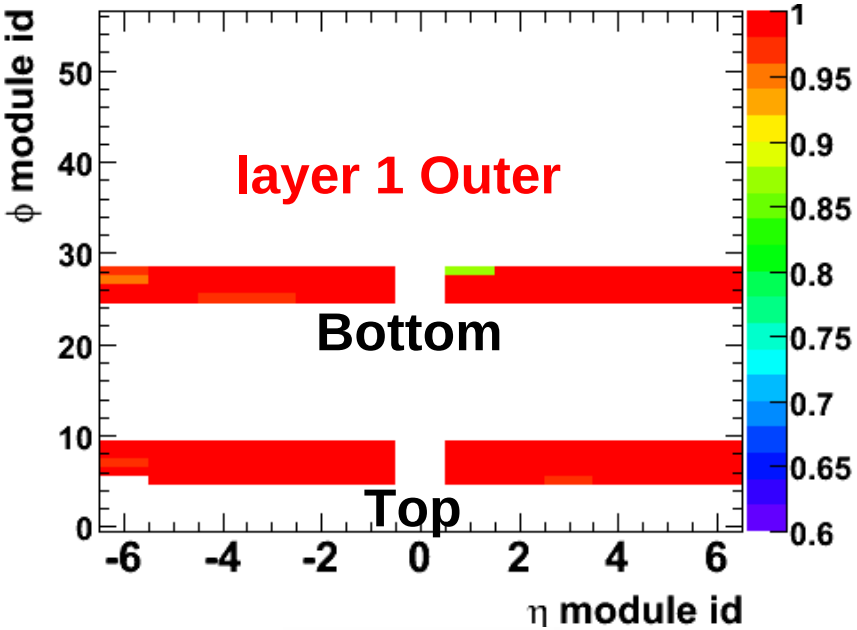


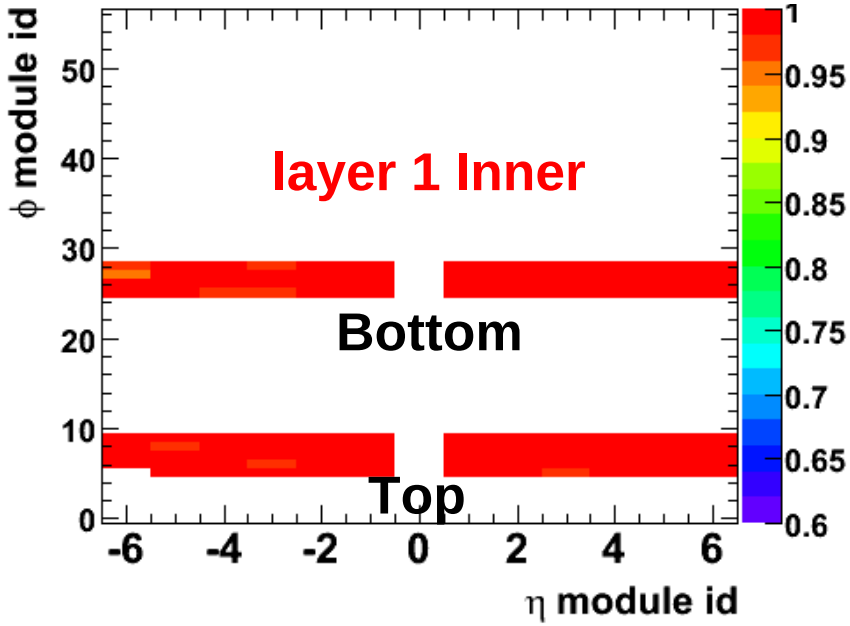
Hit Observed !!

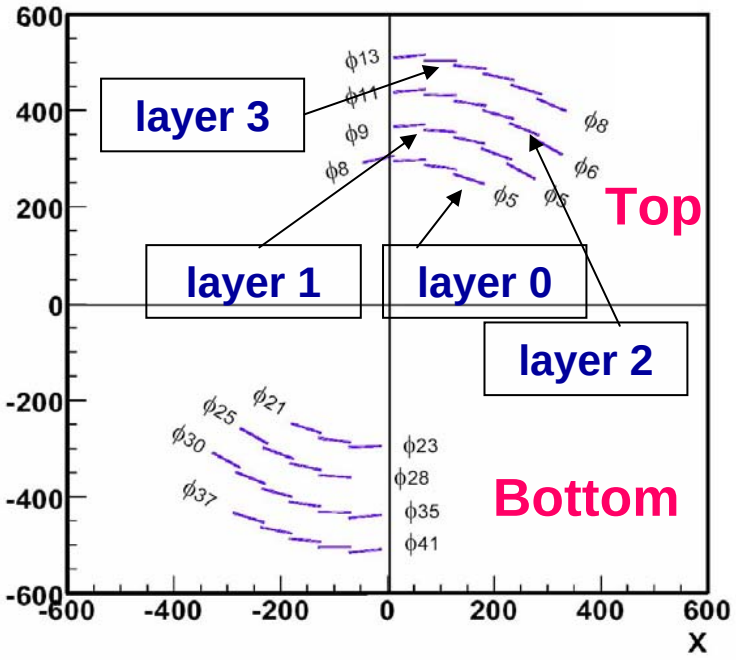


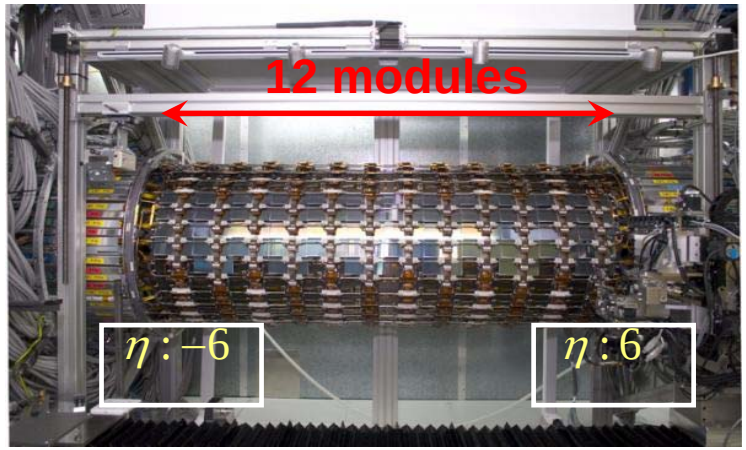
No Hit !!

SCT Module Efficiency





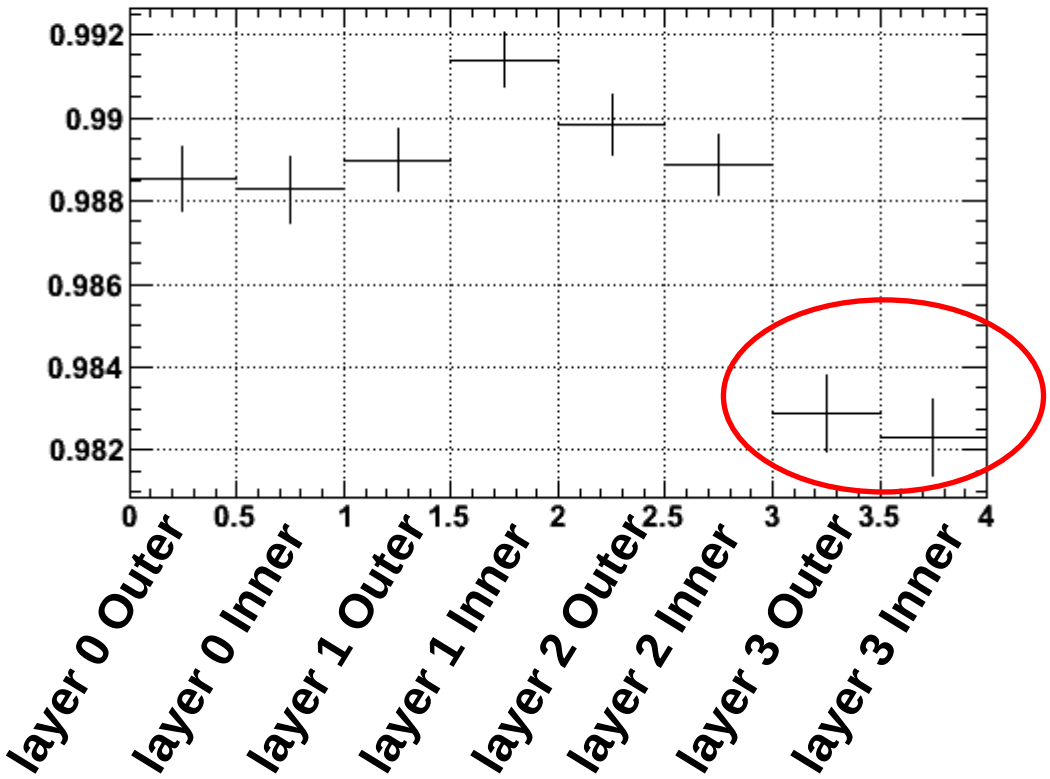




Most of modules show good performance !!

SCT Module Efficiency

Average efficiency for each layer / side

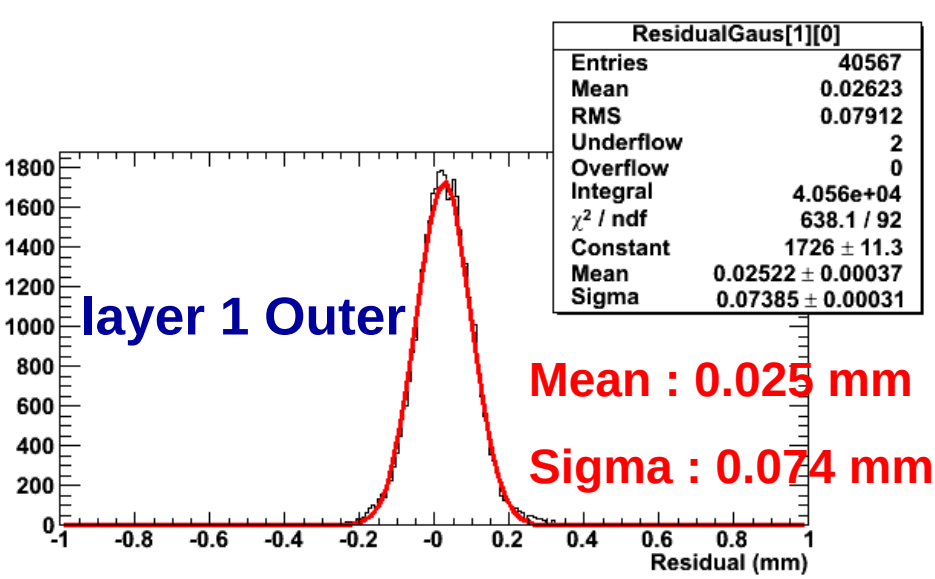


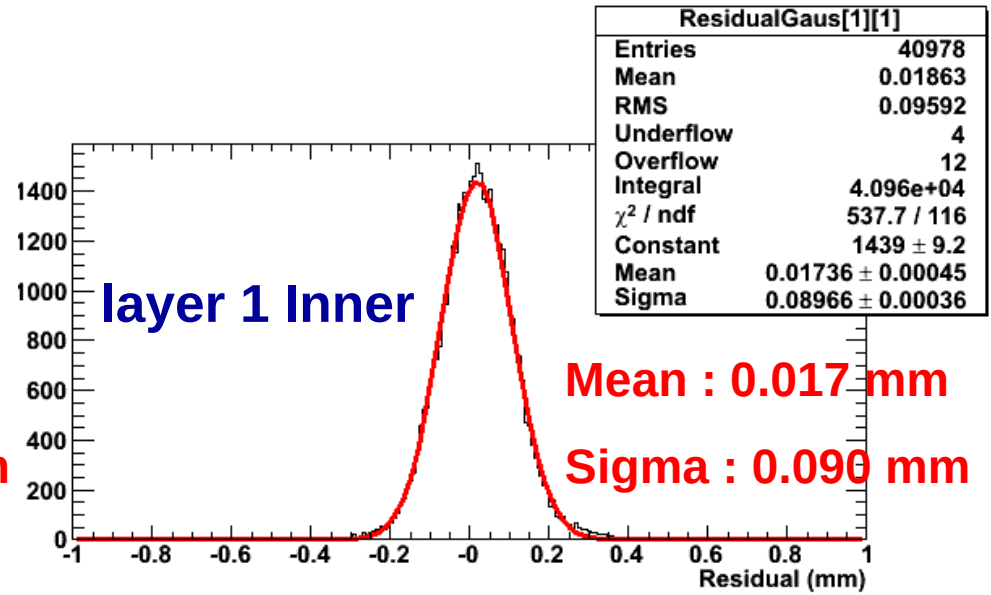
maybe due to cabling mistaken (fiber swap)

Nominal efficiency of layer 0,1,2 are ~ 99% without modules' alignment

(dead channels are included for this calculation)

3. Track Residual





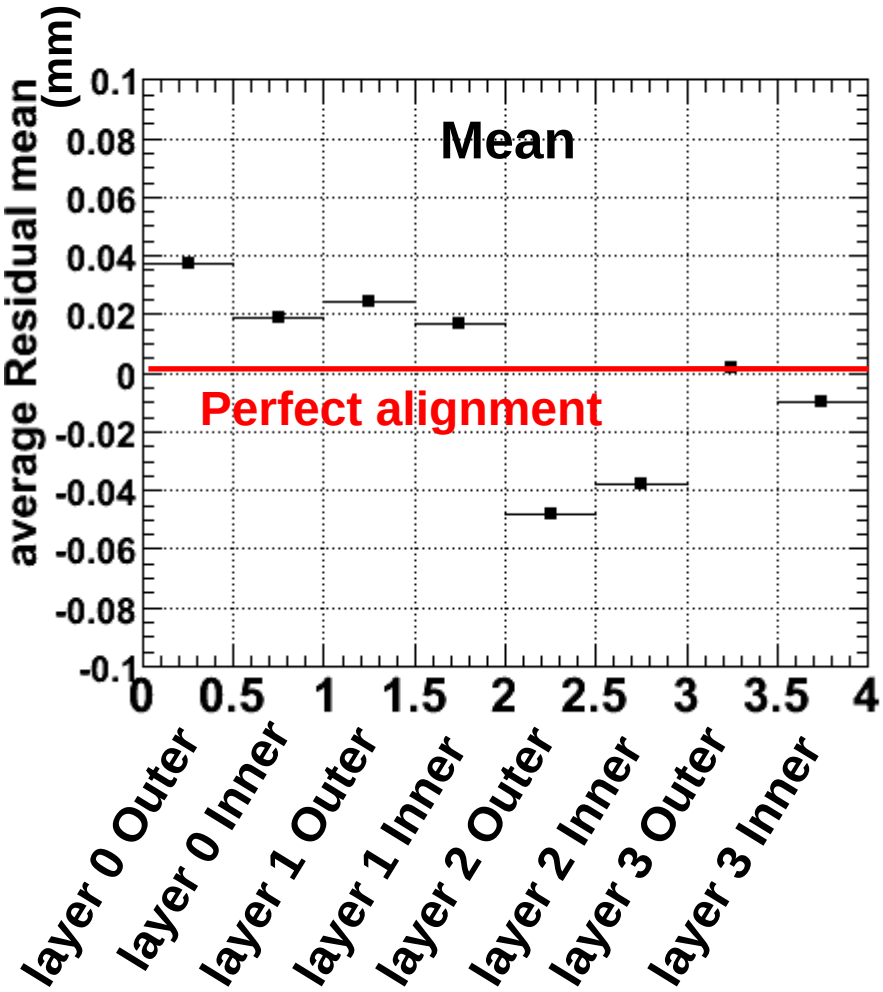
Real data with no alignment

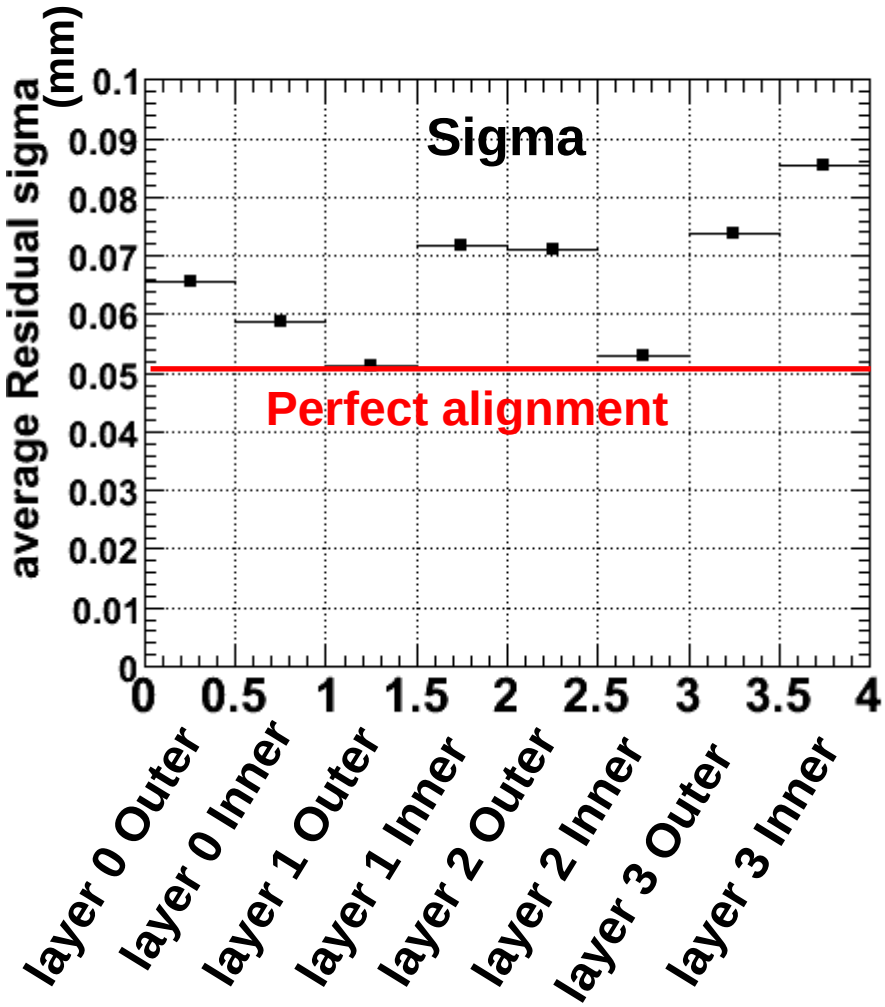
With perfect alignment MC simulation

Mean : ~0.00 mm Sigma : ~0.050 mm are expected.

The real data with no alignment shows good agreement with MC simulation

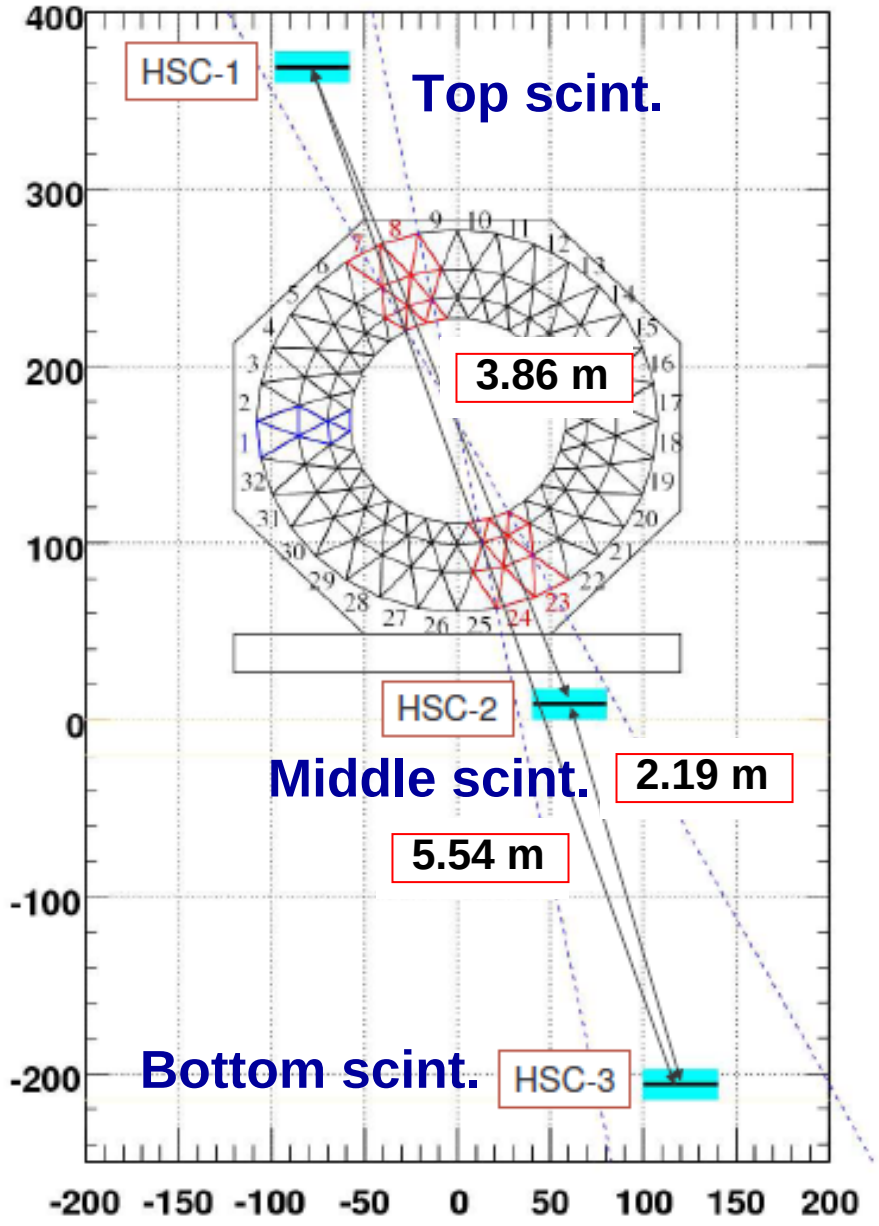
Summary of Track Residual





The SCT barrel detector is already well aligned without specific alignment.

4. Time of Flight Analysis



Purpose

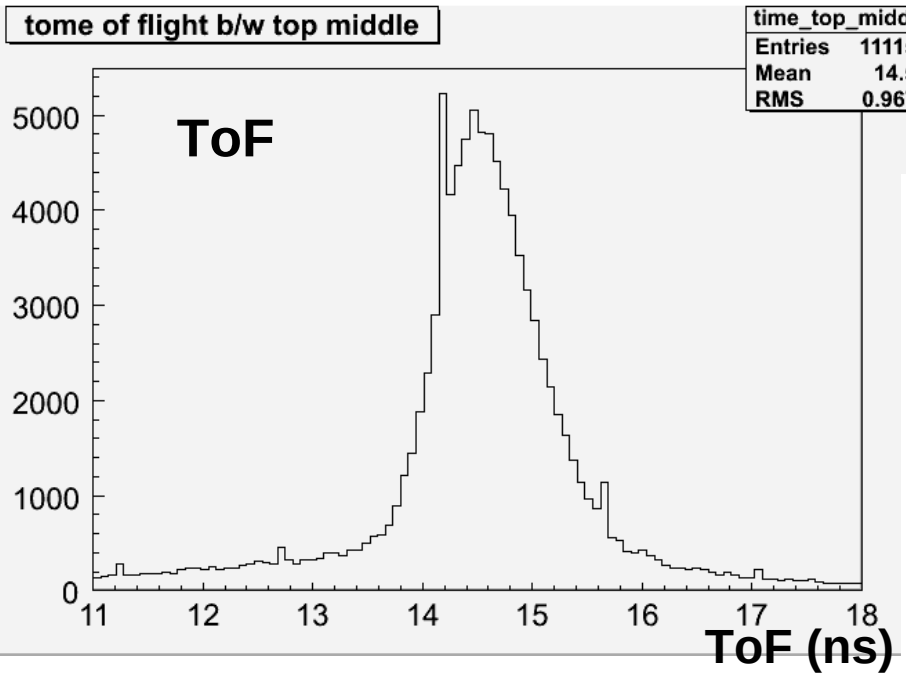
Select high momentum muons for the efficiency and alignment study

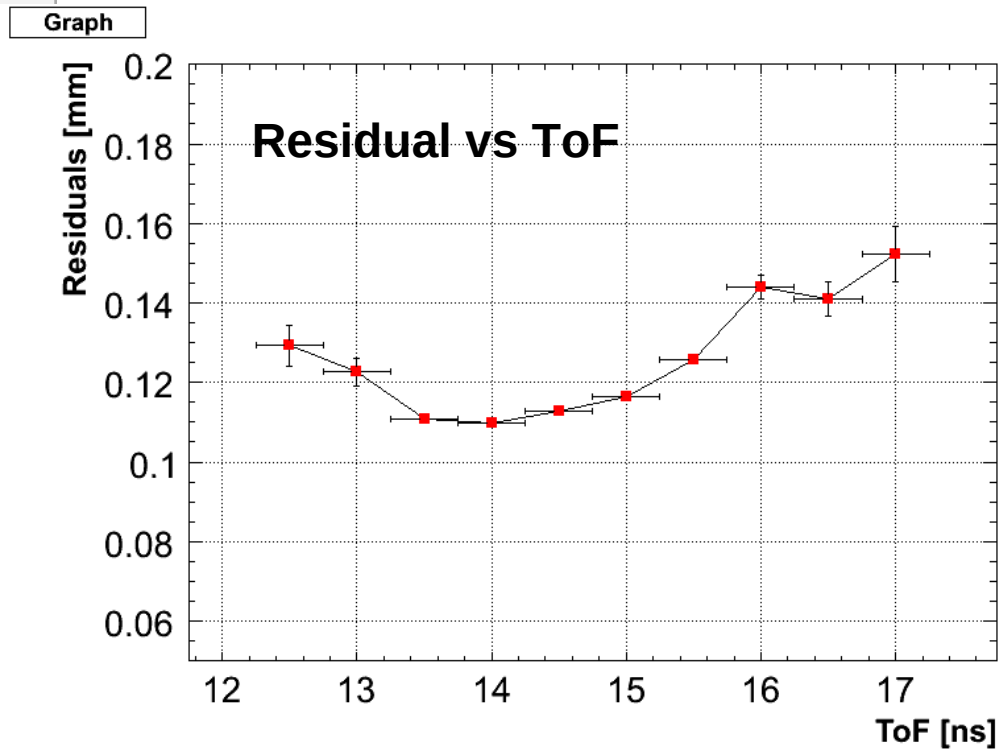
Method

Check dependence between ToF and track residual

- Distance between top and middle scint. is 3.86 m, v=c gives ToF 12.9ns.
- Resolution of scintillator is ~ 0.5ns

ToF between top and middle scintillator





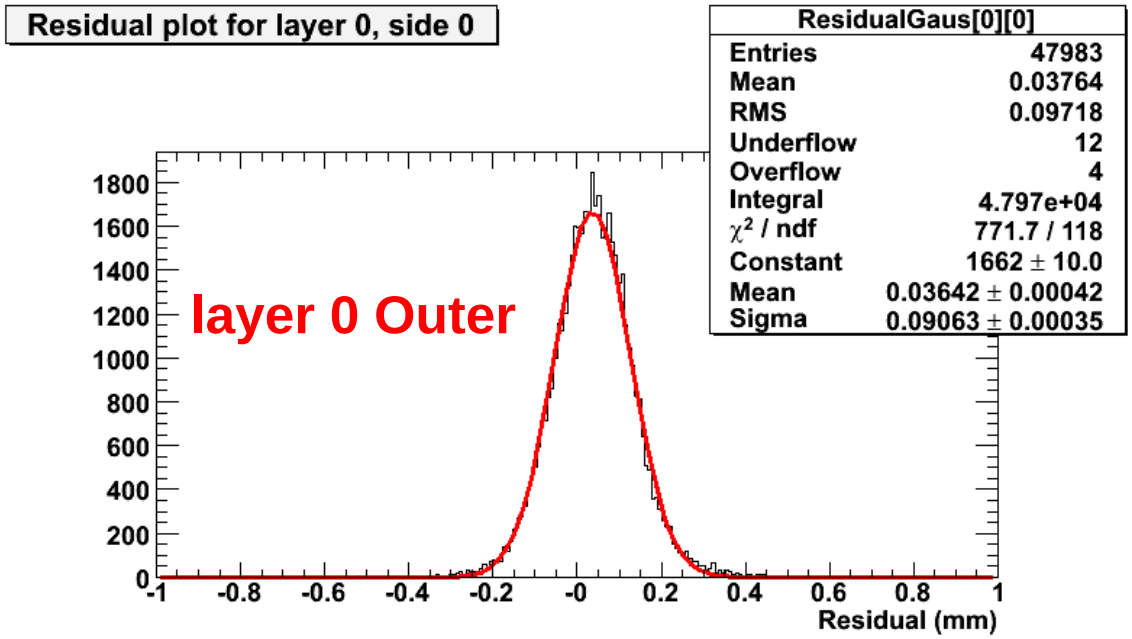
We observe residual increase for larger ToF (lower momentum) probably because of multiple scattering effect.

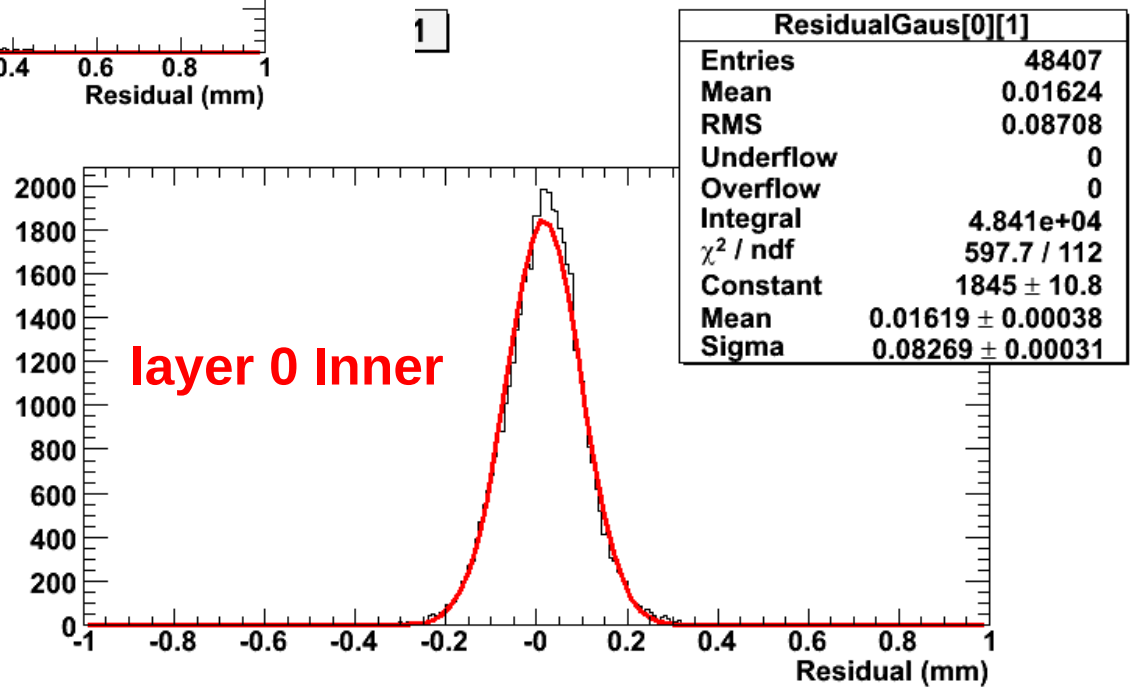
Summary

- SCT+TRT barrel cosmic test was performed at CERN in early summer ’06.
- Functional channels are ~99.7 +- 0.03%
- This study gives ~99% module efficiency, seems SCT modules are healthy (in spec).
- Modules are well aligned without modules alignment.
- ToF analysis gives the possibility to select high momentum muons.

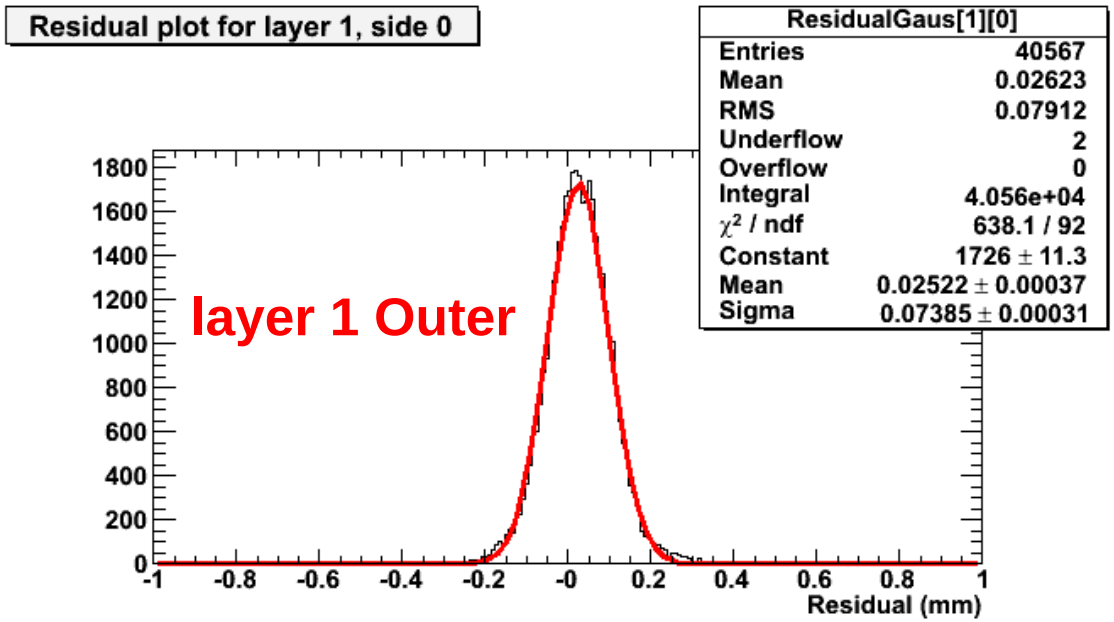
back up

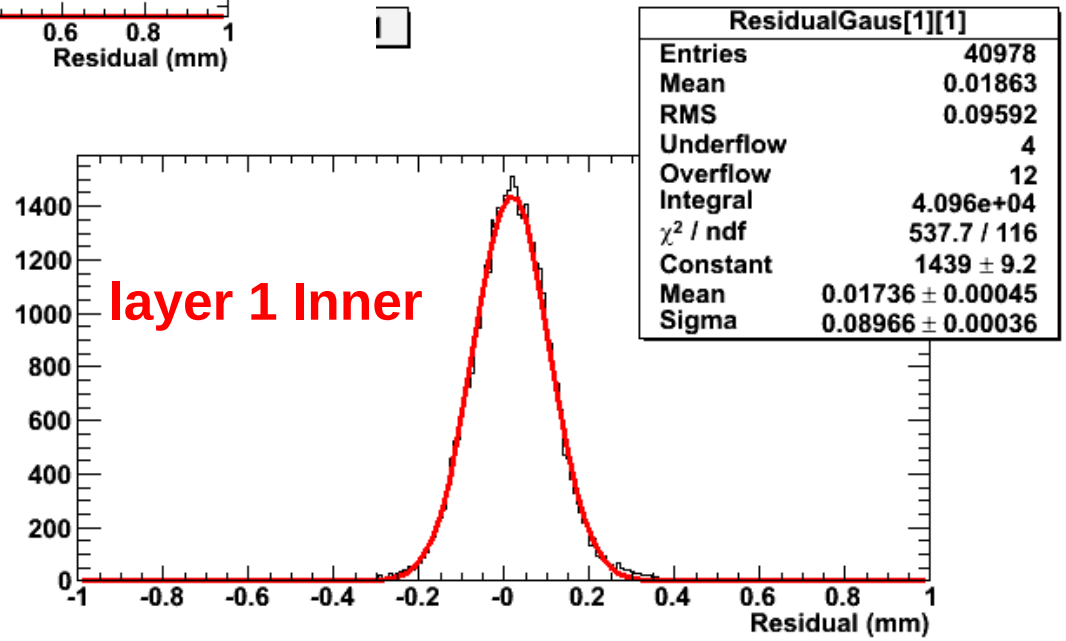
Layer 0 residual for selected track



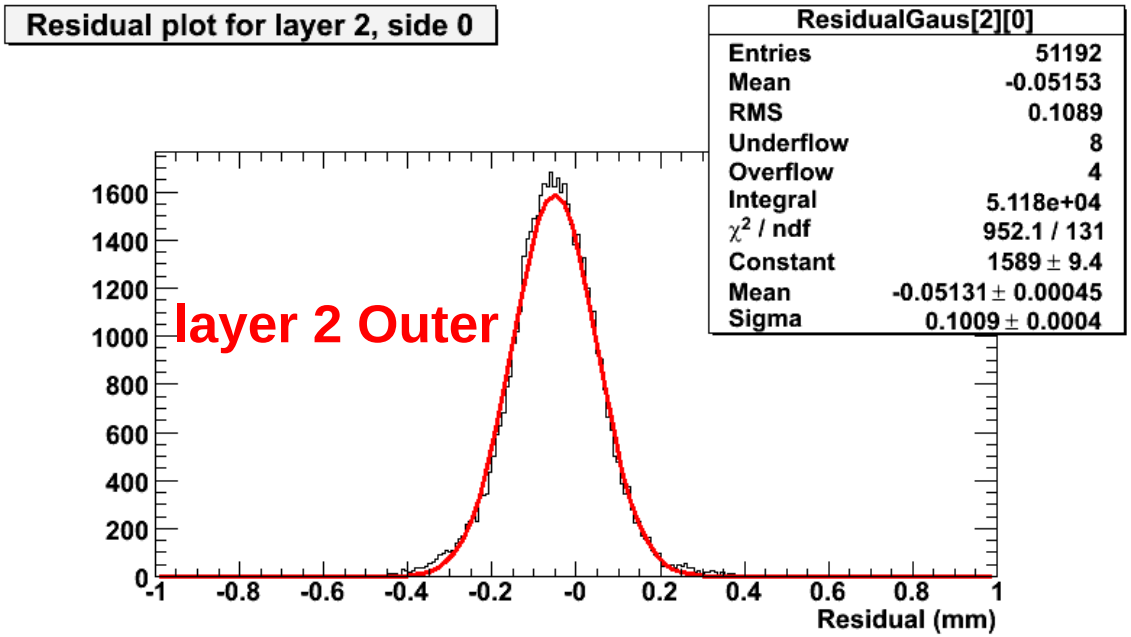


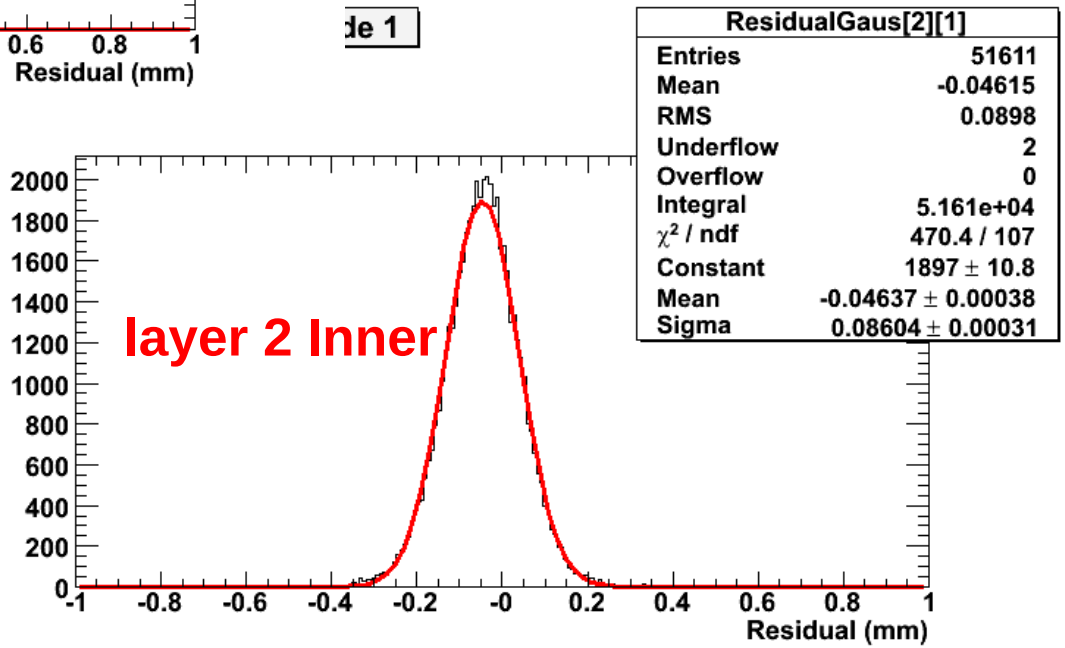
Layer 1 residual for selected track



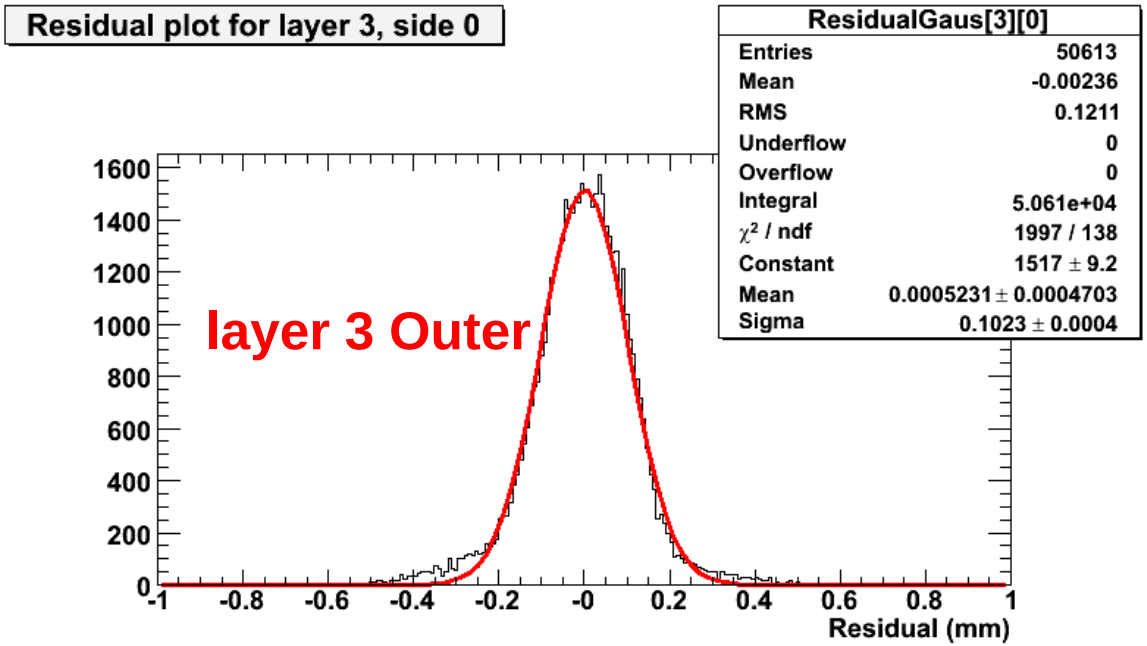


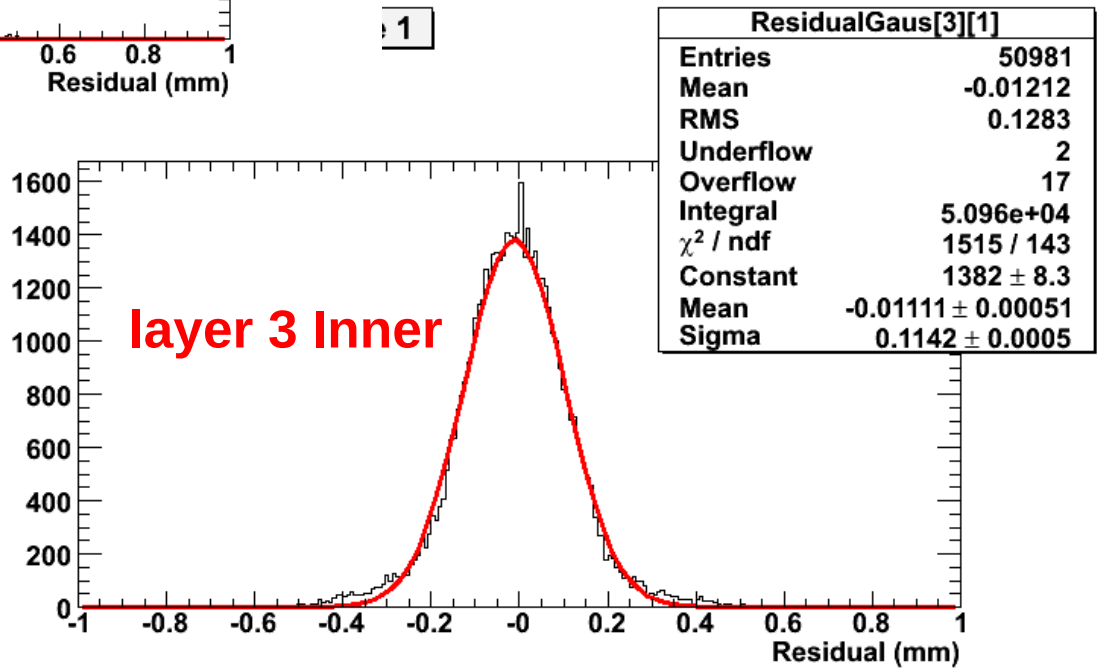
Layer 2 residual for selected track





Layer 3 residual for selected track





ToF between top and bottom scintillator