

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

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 - 4. Time of Flight Analysis

- **Summary**

A Toroidal LHC ApparatuS (ATLAS)

- Inner Detector

Pixel : the pixel detector

SCT : the semiconductor tracker

TRT : the transition radiation tracker

- Calorimeter

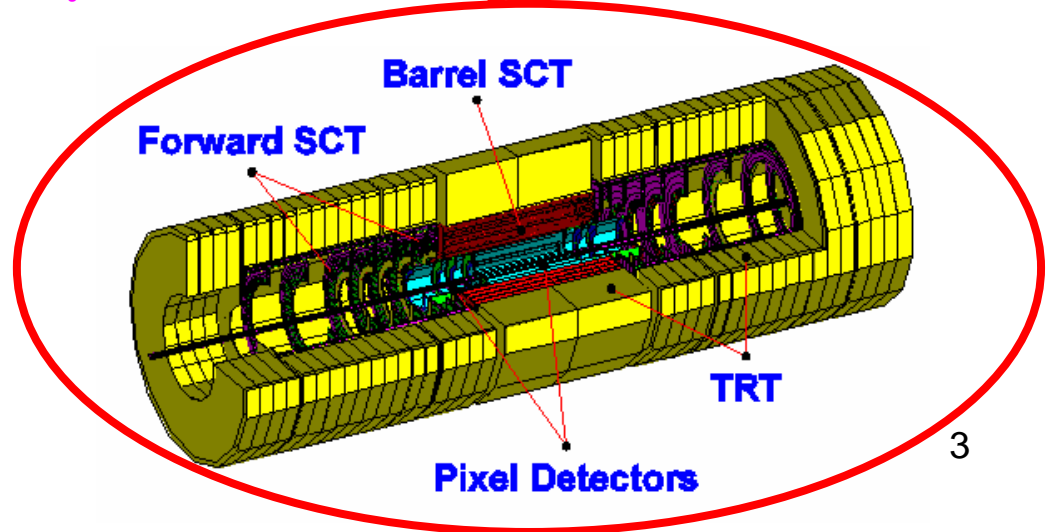
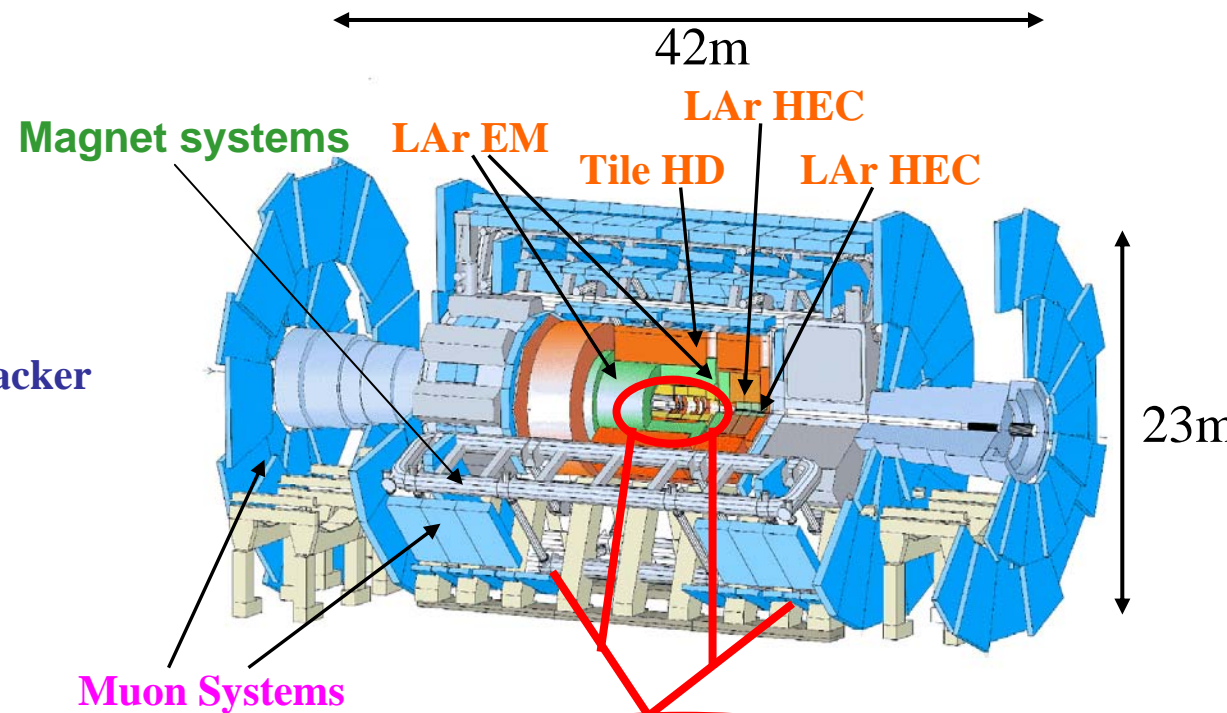
- Muon Systems

- Magnet systems

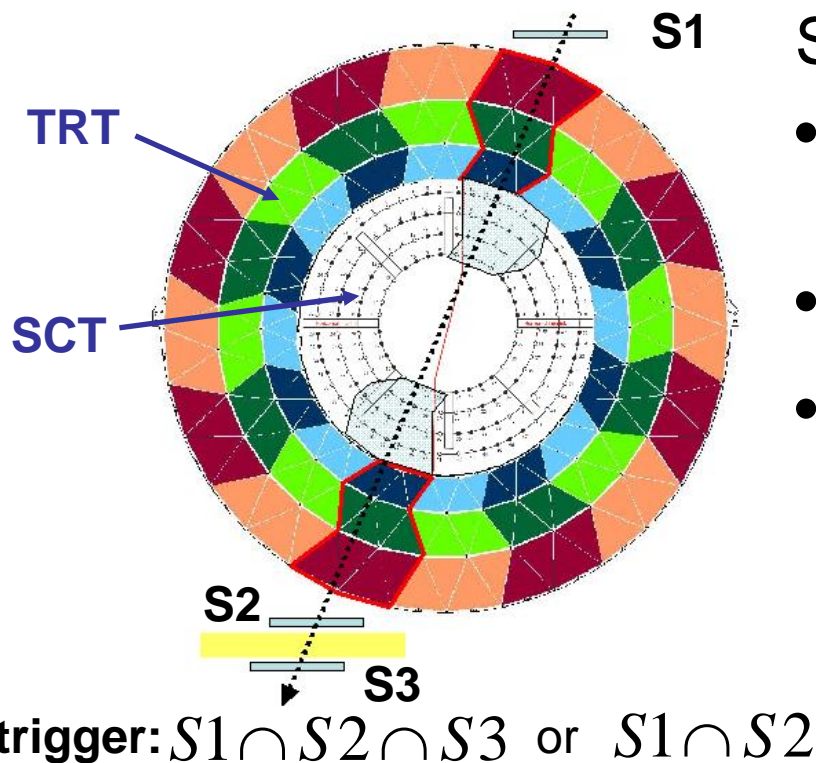
Overall weight : 7000 Tons

Tracker : $|\eta| < 2.5$

Calorimeter : $|\eta| < 4.9$



ID Barrel Combined Cosmic Ray Test

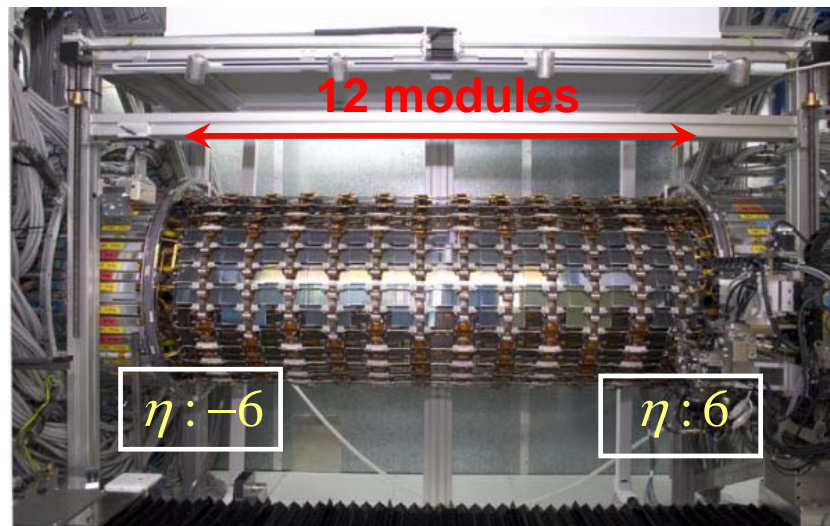
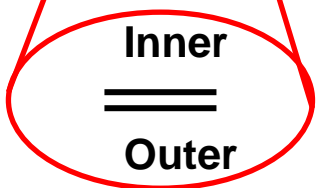
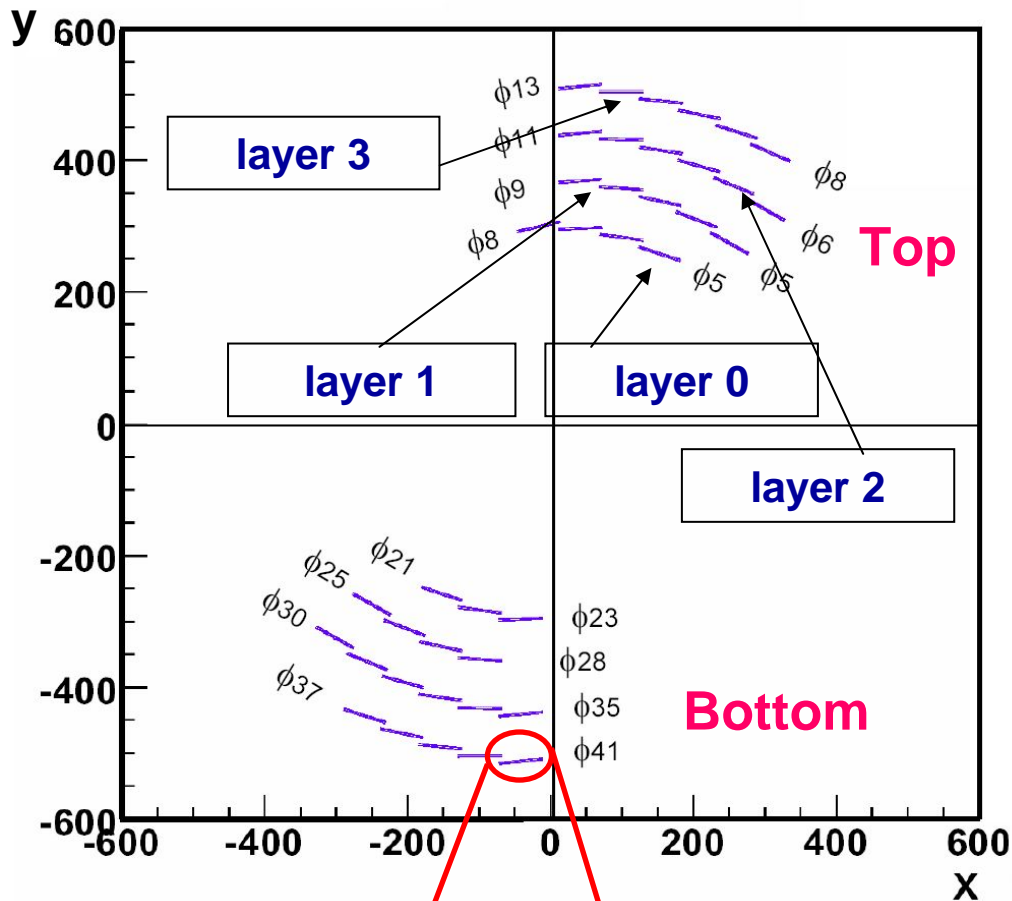


SCT + TRT Combined Run

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

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

Barrel Configuration of Cosmic test

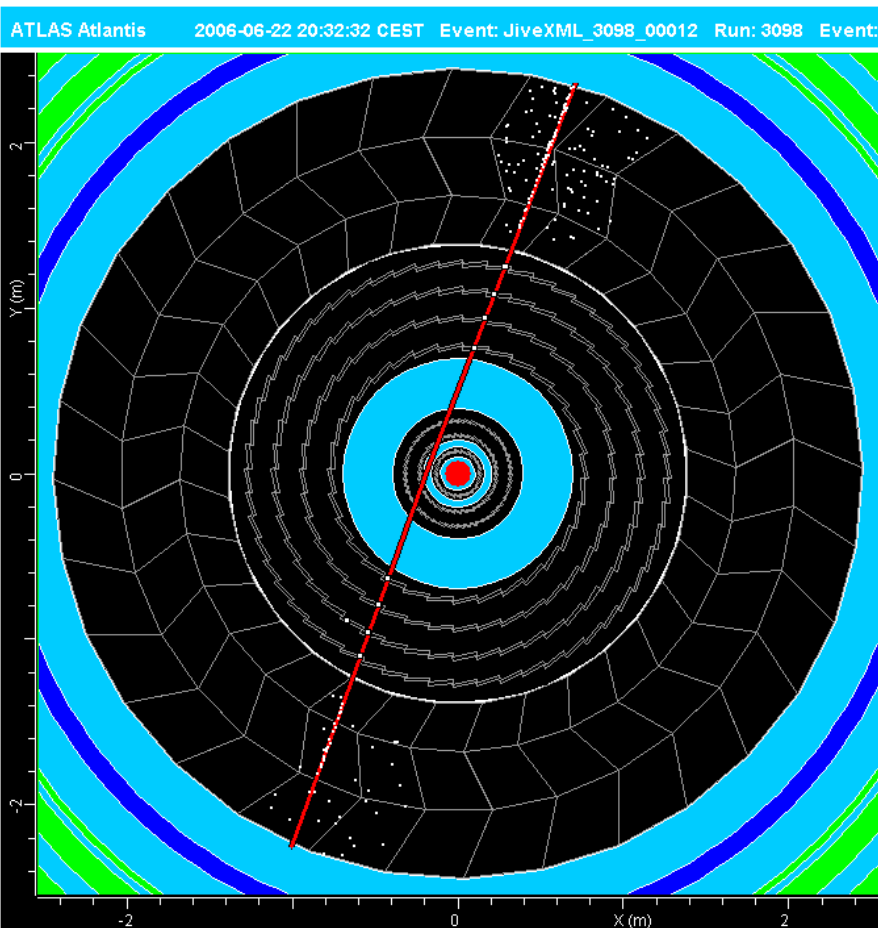


of Modules = 468 (out of 2112 modules)
 (Top=252, Bottom=216)
 (layer 0,1,2,3) = (84/108/144/132)

ID Barrel Combined Cosmic Ray Test

Goals of combined cosmic ray test

- The detector performance aspects
 - Test SCT 4 barrels with operating TRT
 - Check detector efficiency, noise level, alignment study, tracking study
 - etc ...
- Detector operation & commissioning of system
 - 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

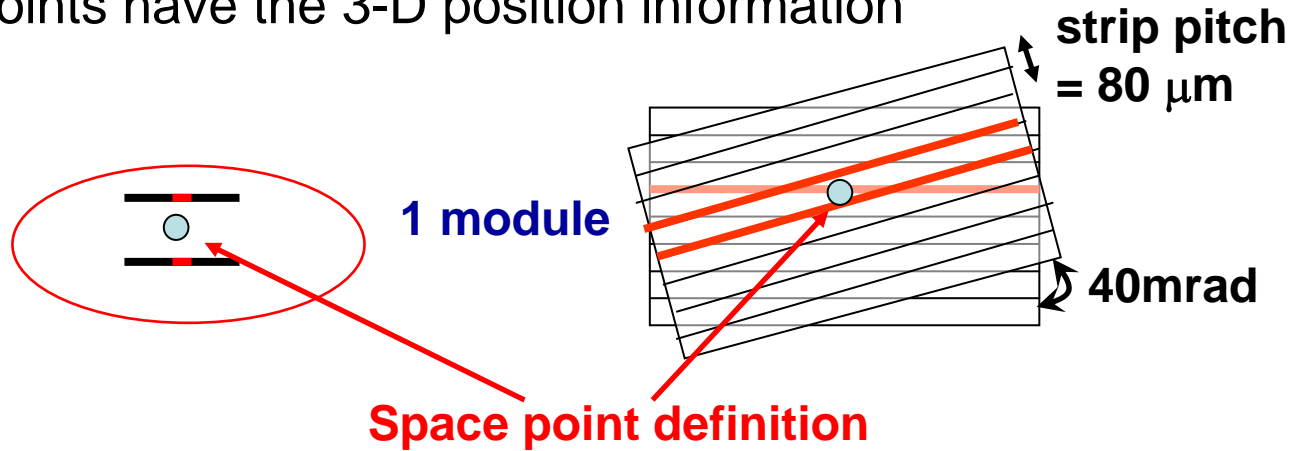
- Space point formation
- Straight line fitting
- Track candidates formation

fitting procedure

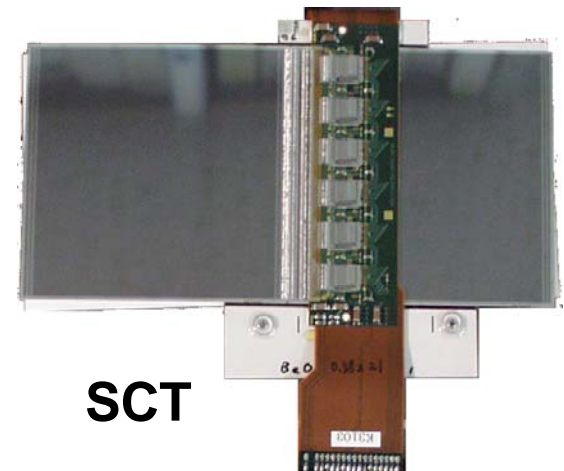
- Re-fitting track candidates with strip hits
- Fitting with χ^2 minimization

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



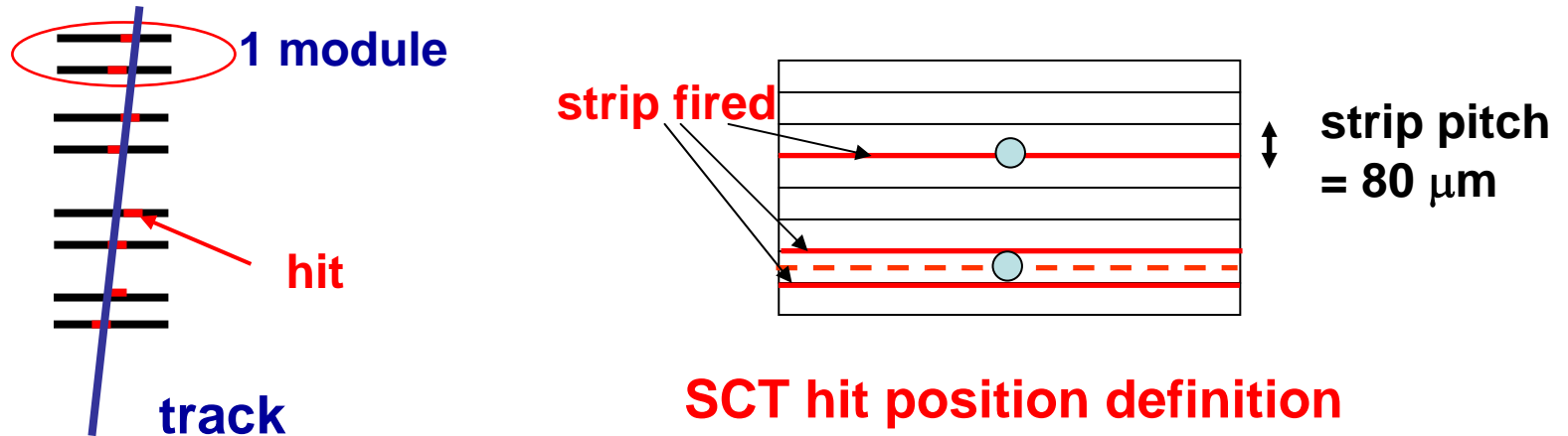
- **Track candidates** are built by fitting these space points with straight- line



Fitting Procedure

if track candidates are found, then

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

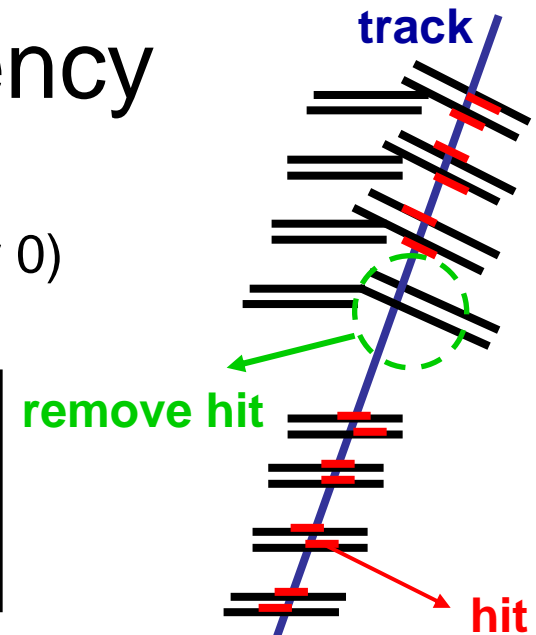


if the track has $\chi^2 / \text{ndof} < 40$,
it is accepted !!
(Here, tracks are roughly cut)

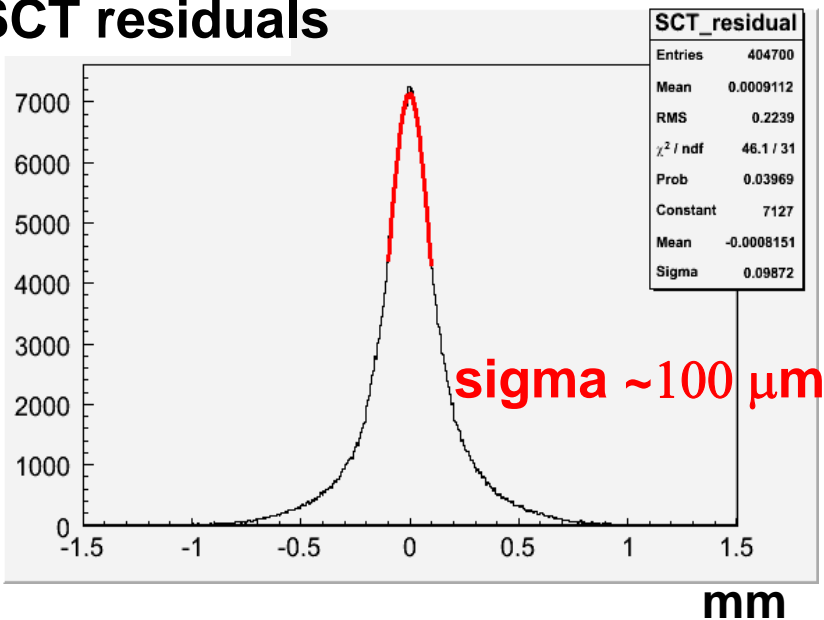
2. SCT Module Efficiency

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

if refitted track fills : $\chi^2 / \text{ndof} < 10$ &
Hits in Top sector ≥ 4 & Hits in Bottom sector ≥ 4
 this track is used for efficiency calculation

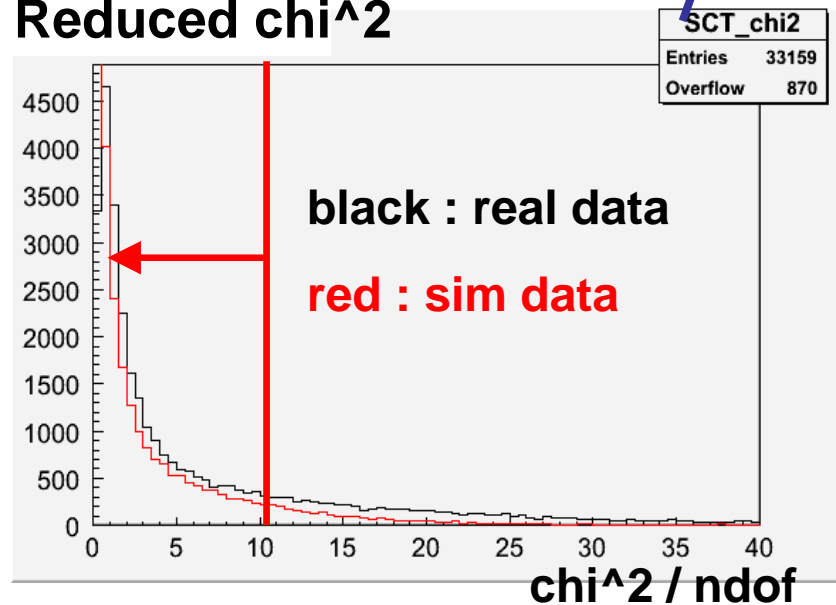


SCT residuals



res = track position – hit position

Reduced χ^2



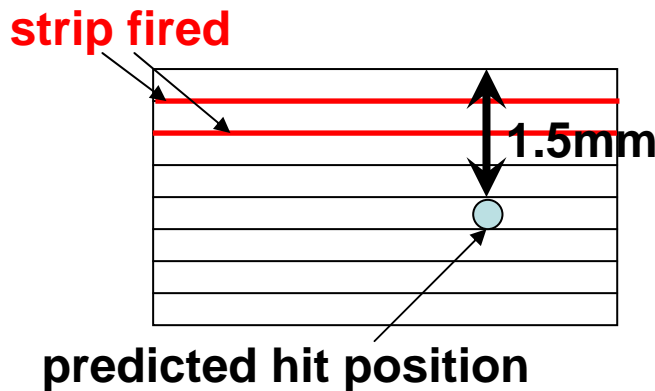
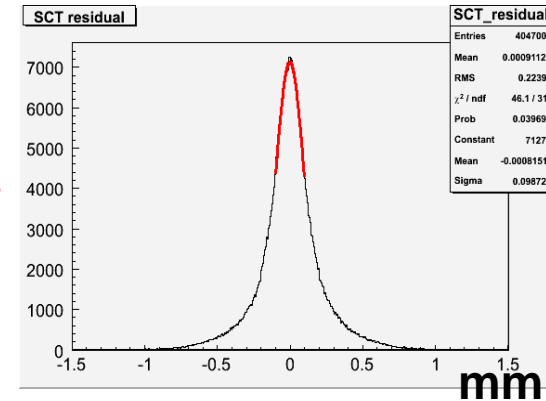
real data with no alignment

Efficiency Calculation

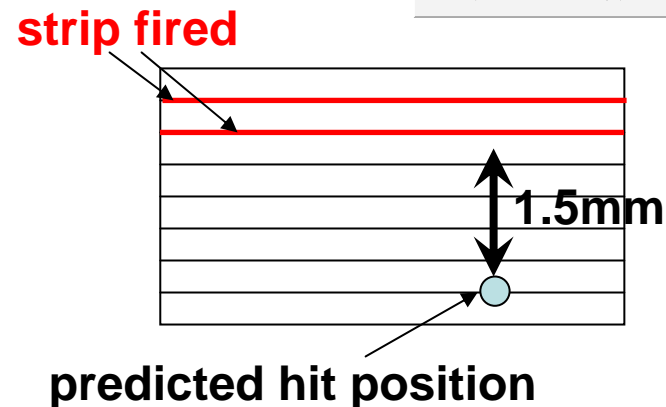
- extrapolate the refitted track to the module surface which hits removed
= **predicted hit position**
- search hits from the predicted hit position within 1.5mm
= **observed hit or not**

- Efficiency

$$\text{Eff} = \# \text{ of observed hits} / \# \text{ of predicted hits}$$

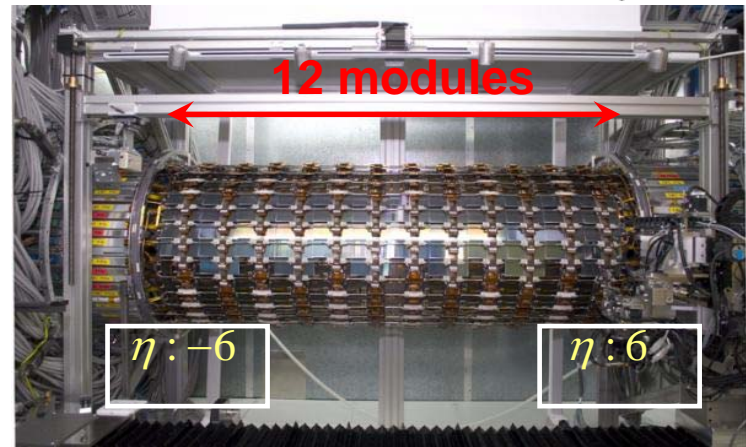
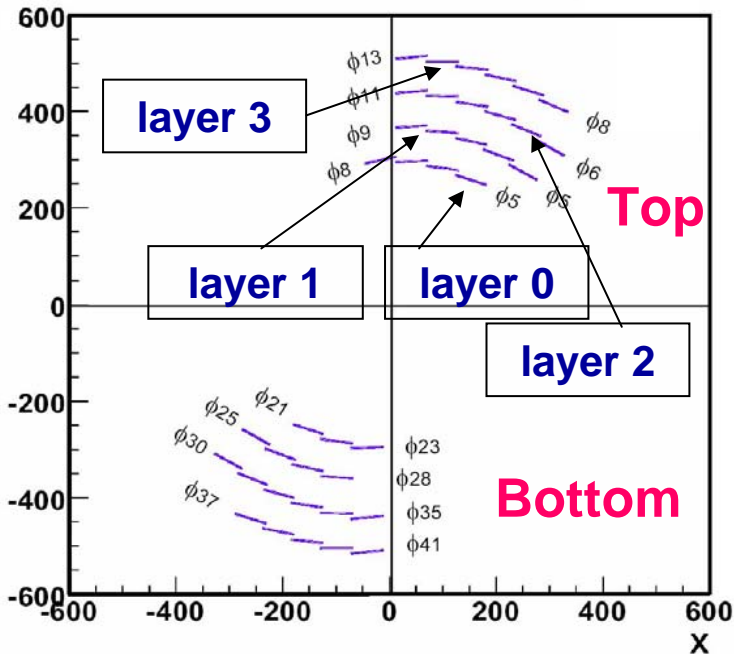
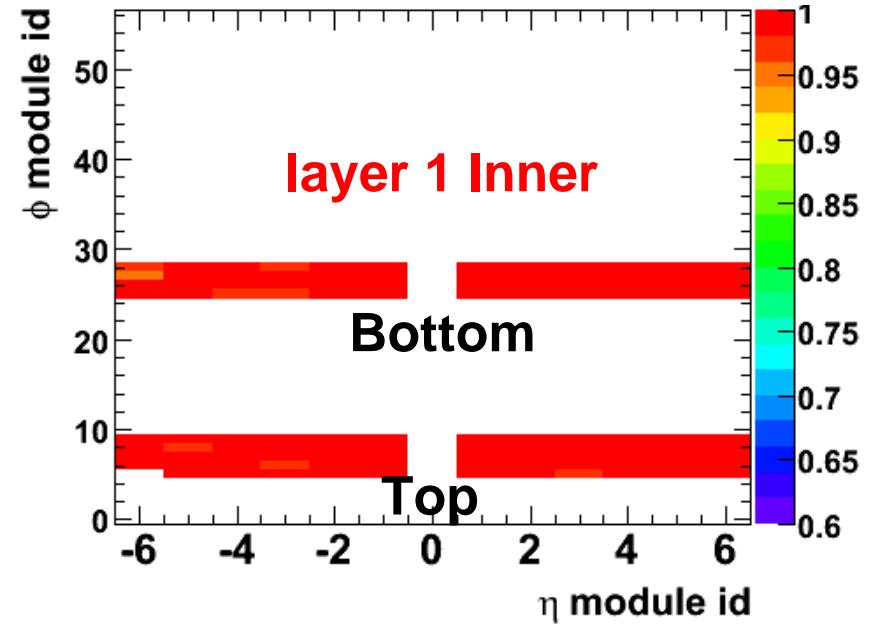
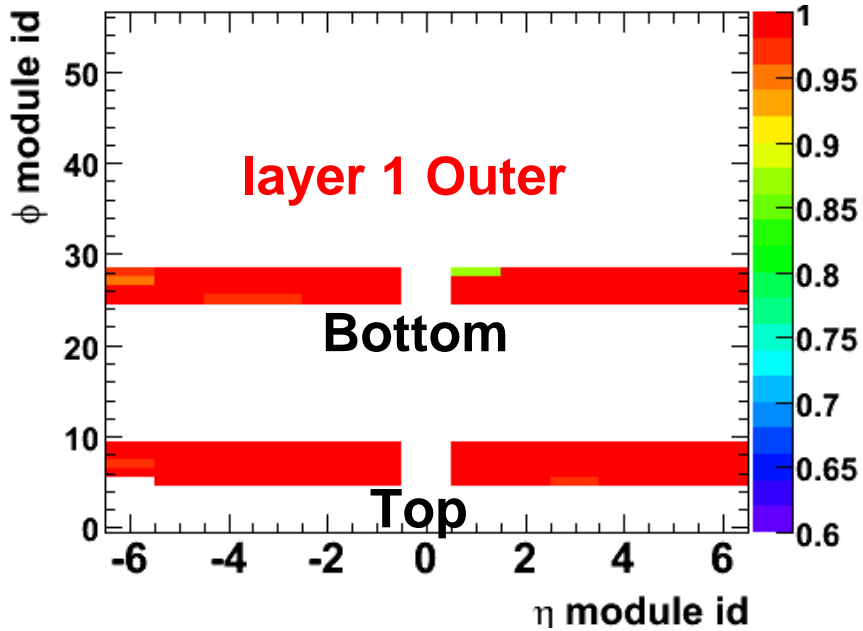


Hit Observed !!



No Hit !!

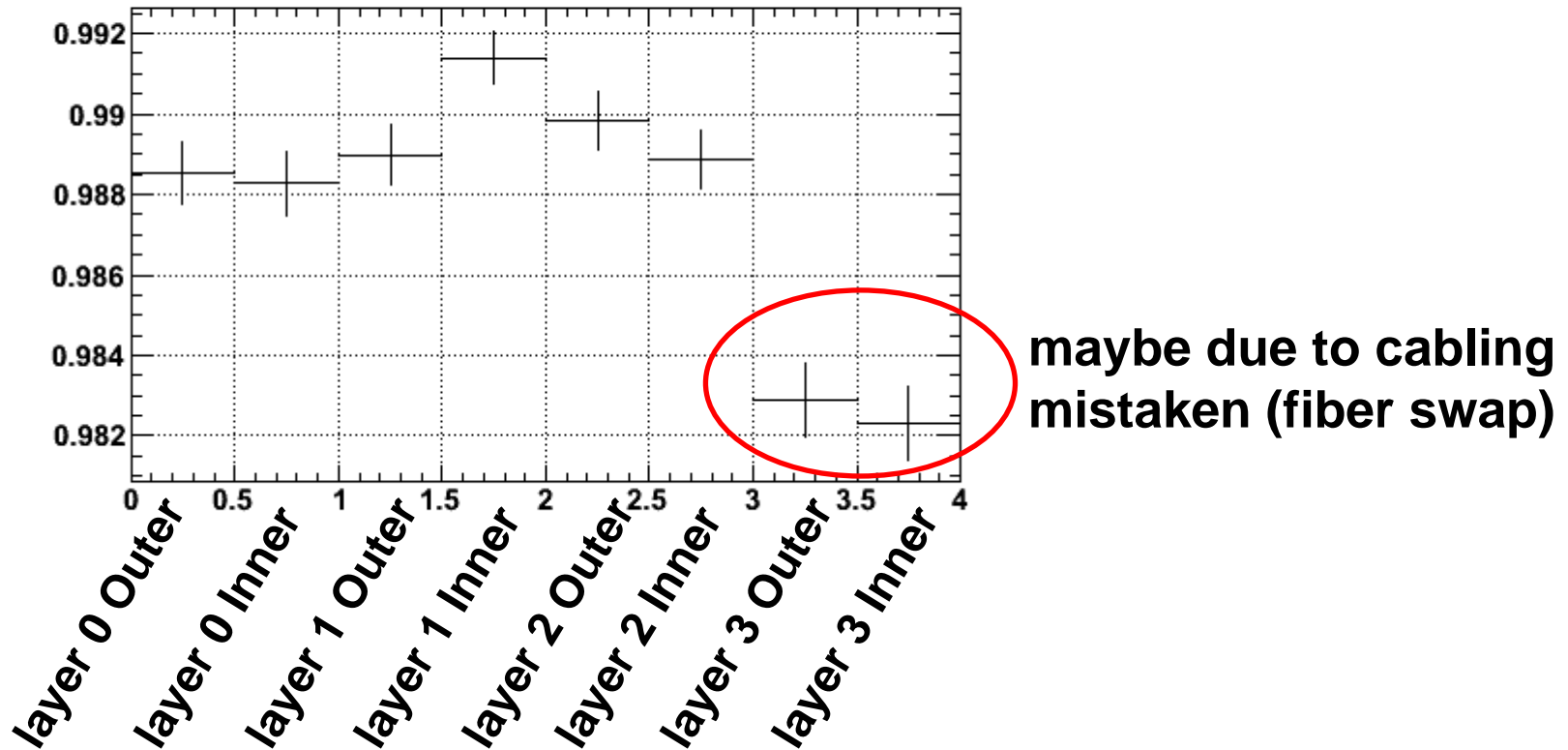
SCT Module Efficiency



Most of modules show good performance !!

SCT Module Efficiency

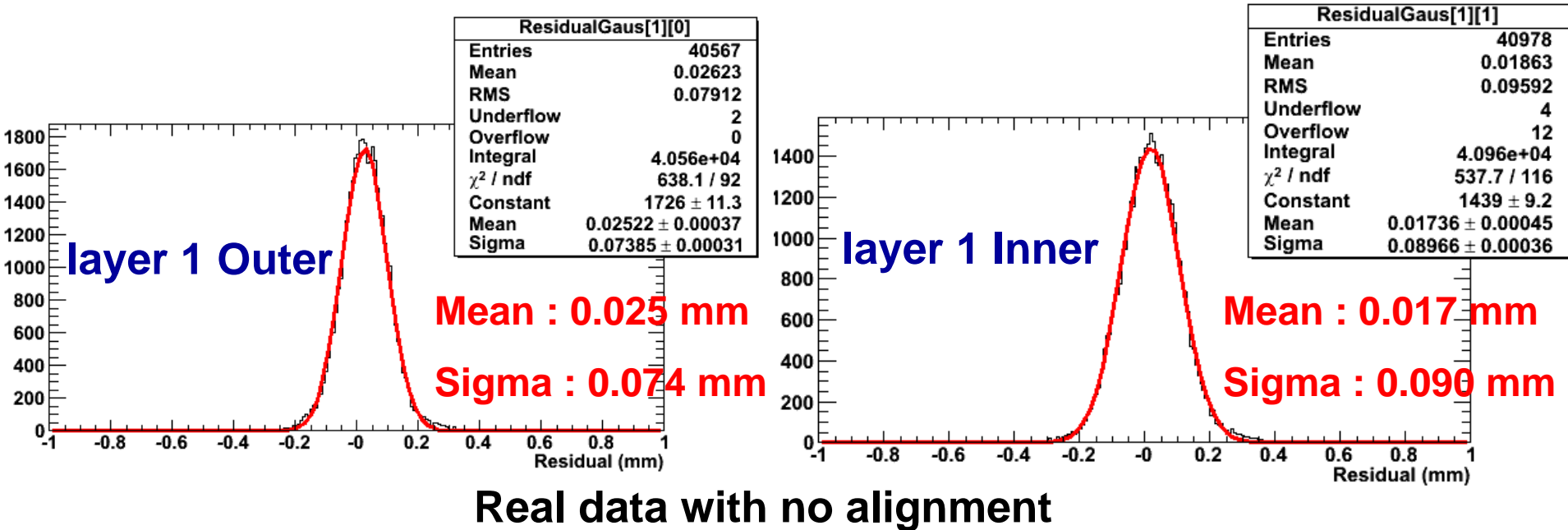
Average efficiency for each layer / side



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

(dead channels are included for this calculation)

3. Track Residual

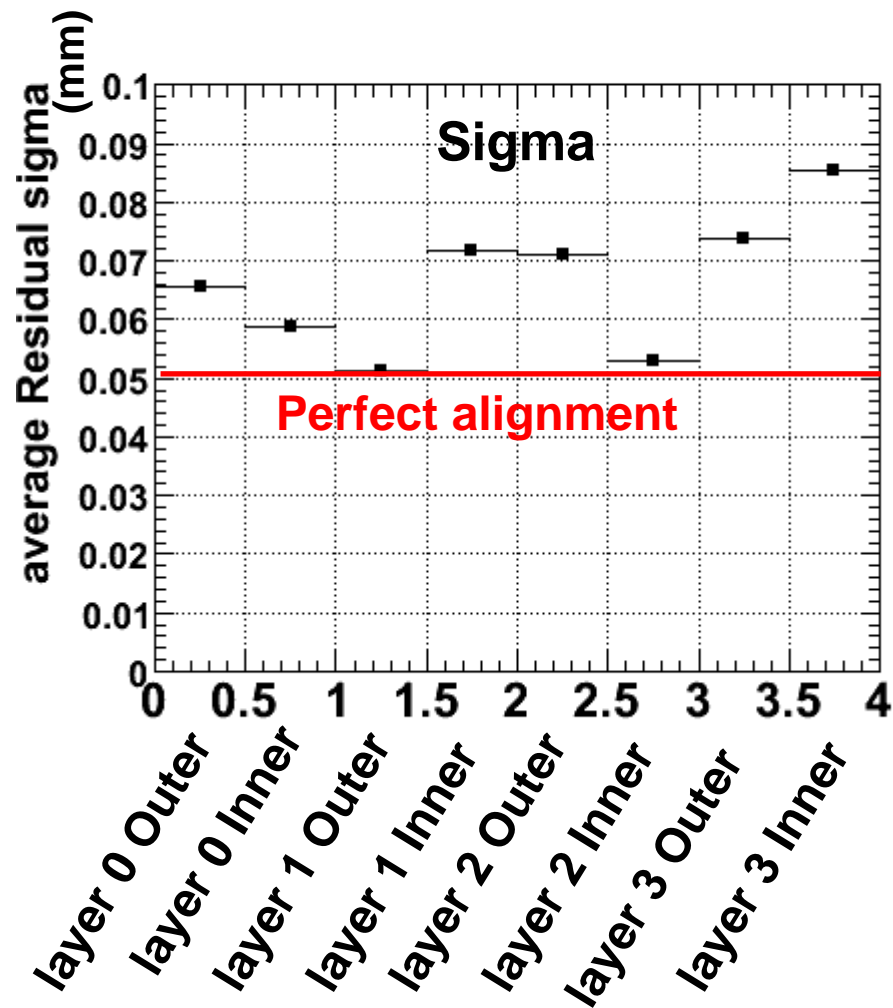
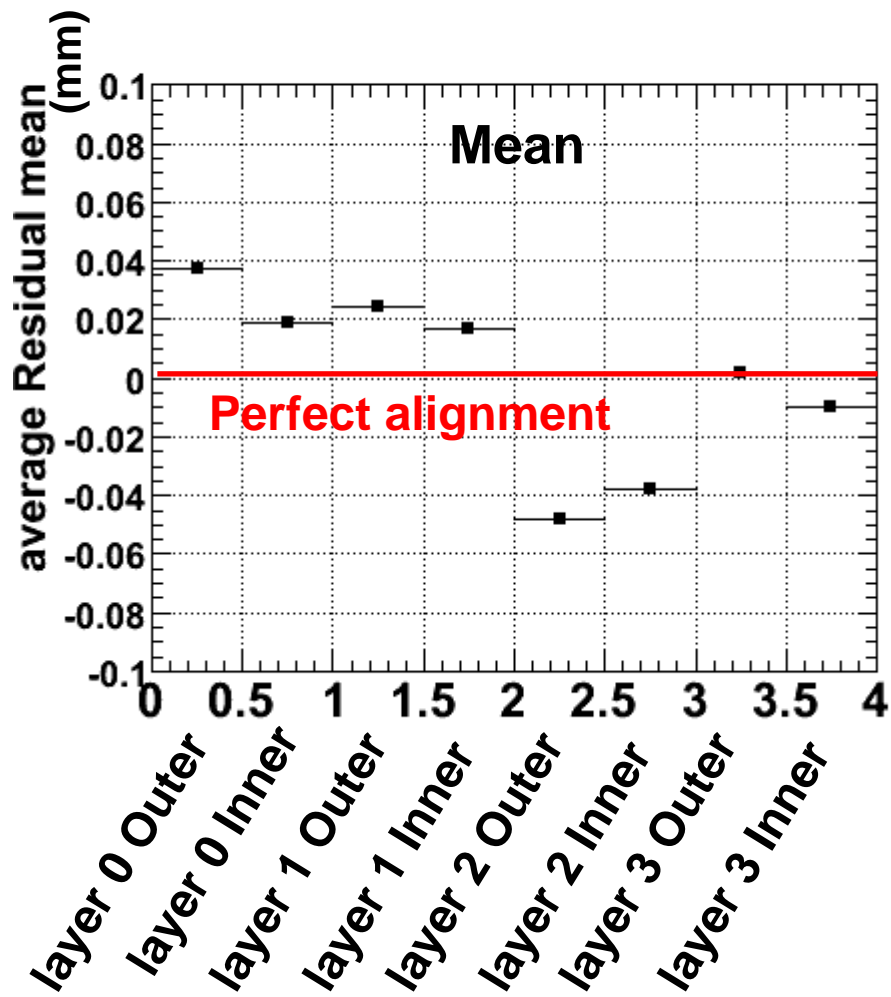


With perfect alignment MC simulation

Mean : \sim 0.00 mm Sigma : \sim 0.050 mm are expected.

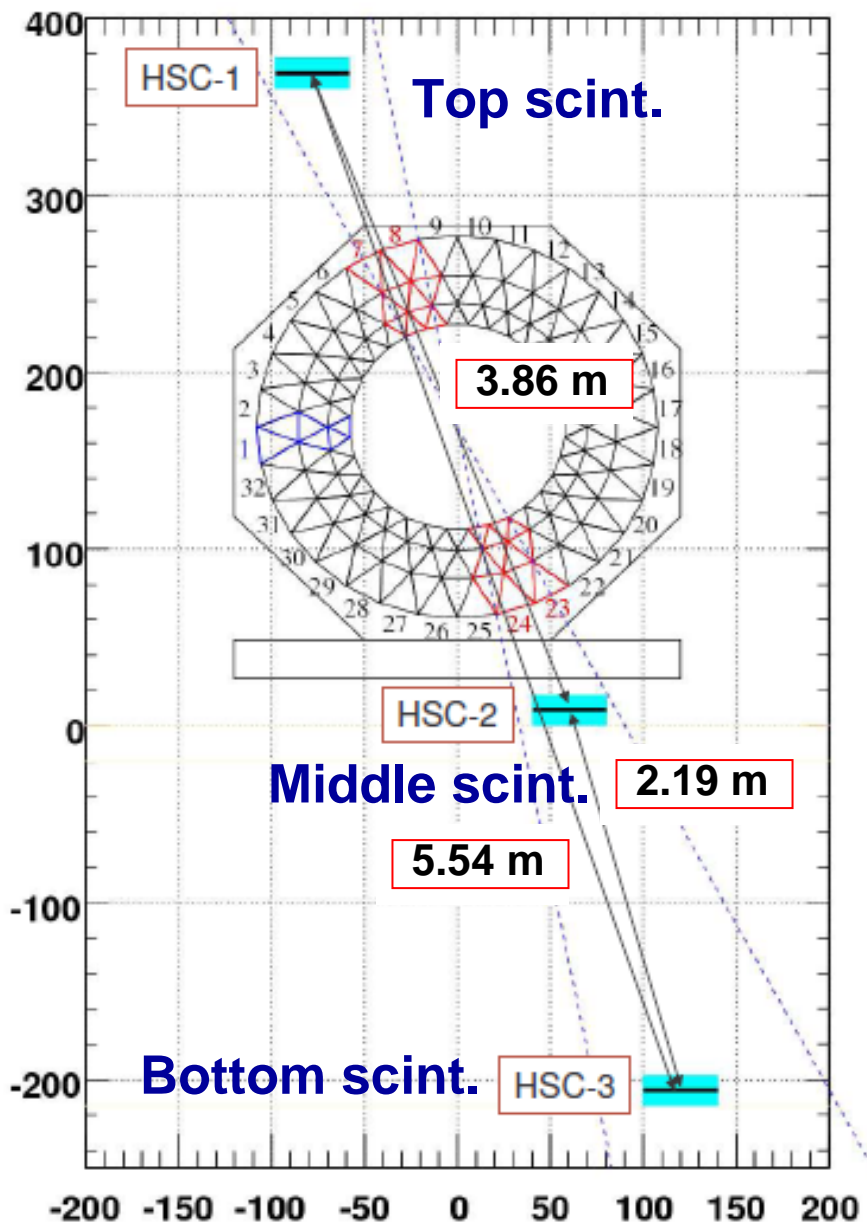
The real data with no alignment shows good agreement with MC simulation

Summary of Track Residual



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

4. Time of Flight Analysis



Purpose

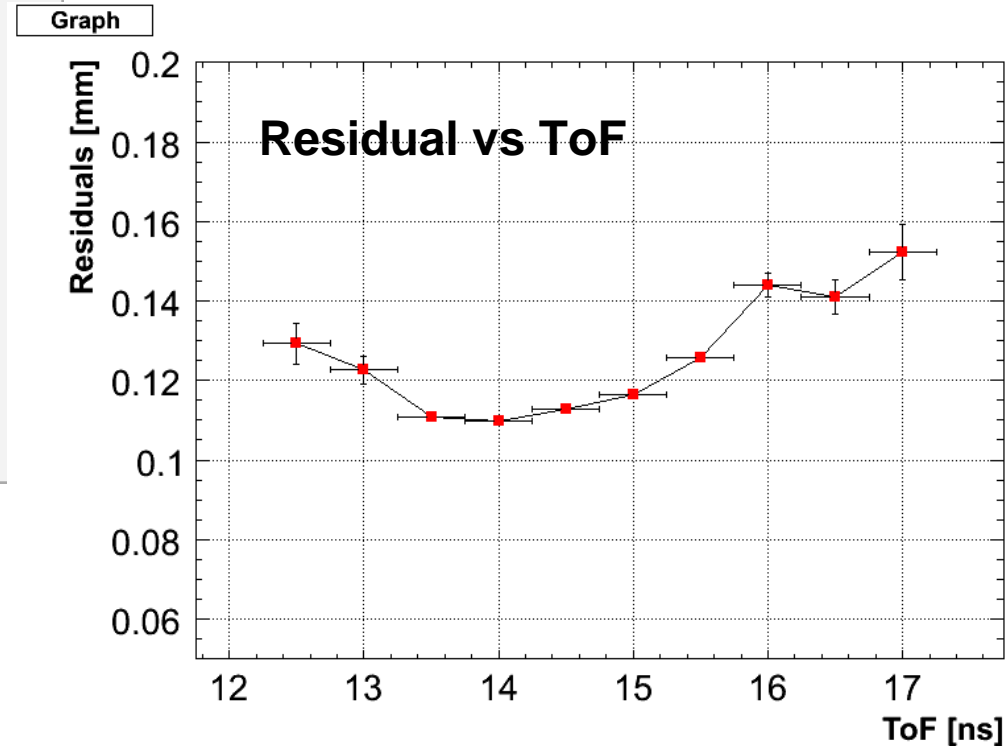
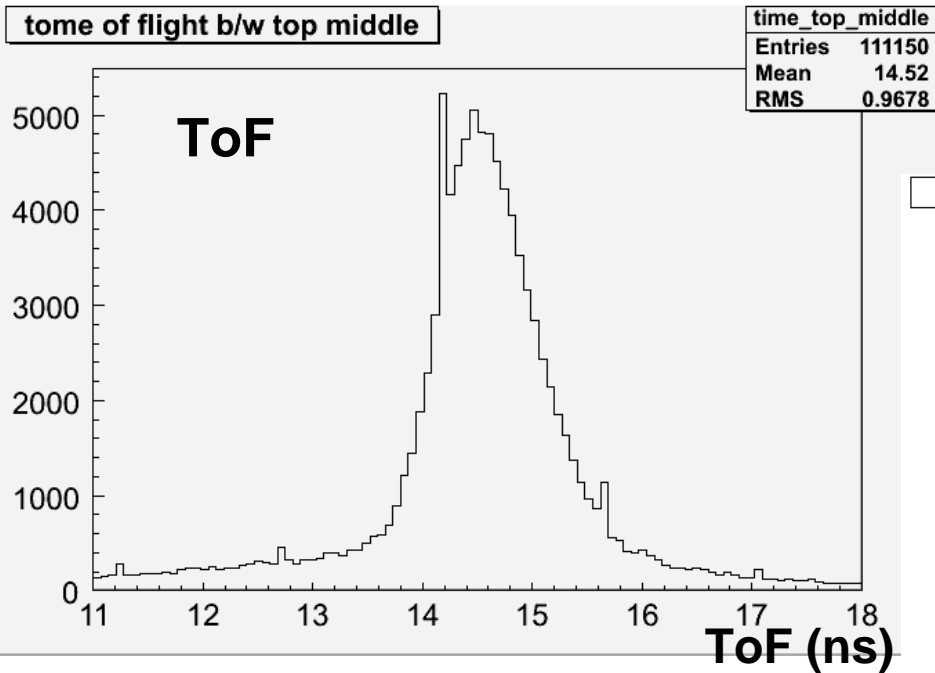
Select high momentum muons for the efficiency and alignment study

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 ~ 0.5 ns

ToF between top and middle scintillator



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

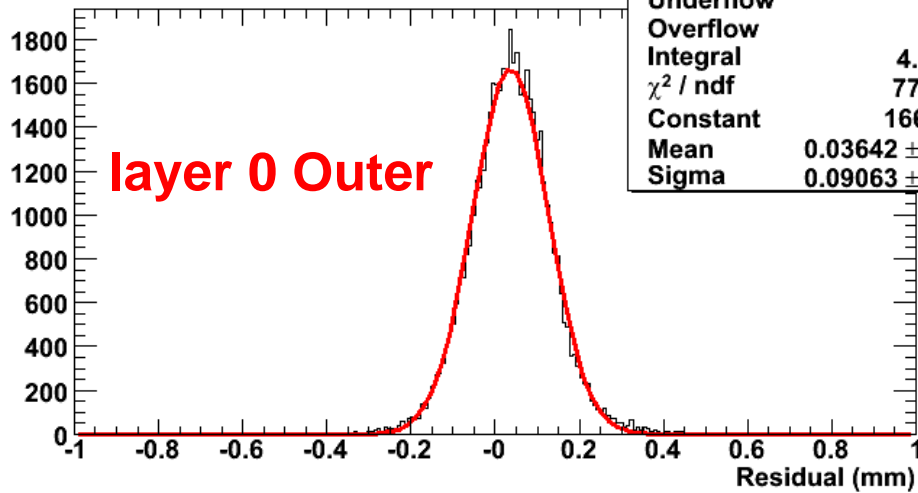
Summary

- SCT+TRT barrel cosmic test was performed at CERN in early summer '06.
- Functional channels are $\sim 99.7 \pm 0.03\%$
- This study gives $\sim 99\%$ 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

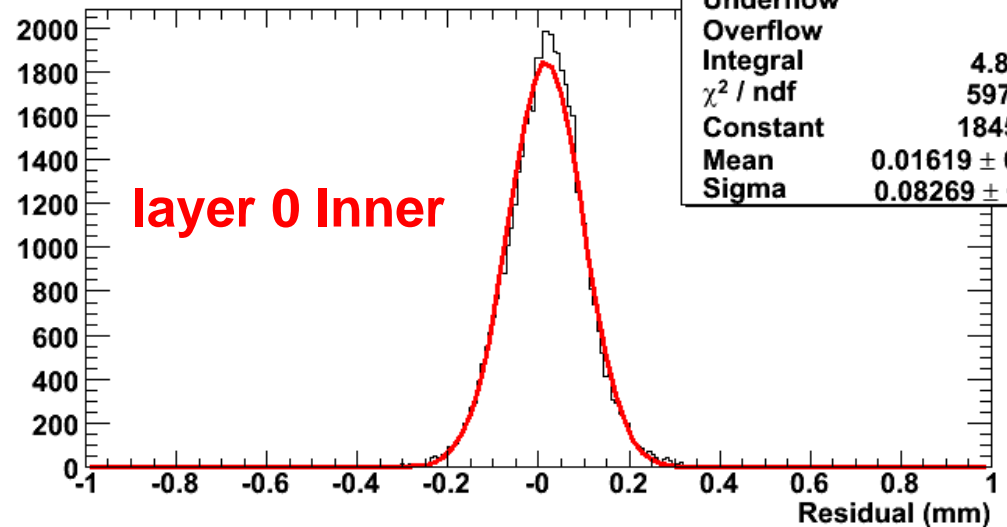
Residual plot for layer 0, side 0



ResidualGaus[0][0]	
Entries	47983
Mean	0.03764
RMS	0.09718
Underflow	12
Overflow	4
Integral	4.797e+04
χ^2 / ndf	771.7 / 118
Constant	1662 \pm 10.0
Mean	0.03642 \pm 0.00042
Sigma	0.09063 \pm 0.00035

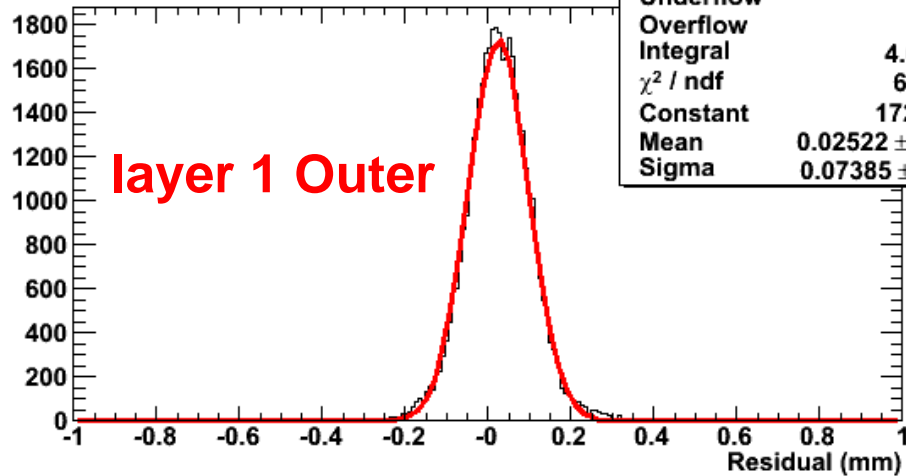
1

ResidualGaus[0][1]	
Entries	48407
Mean	0.01624
RMS	0.08708
Underflow	0
Overflow	0
Integral	4.841e+04
χ^2 / ndf	597.7 / 112
Constant	1845 \pm 10.8
Mean	0.01619 \pm 0.00038
Sigma	0.08269 \pm 0.00031



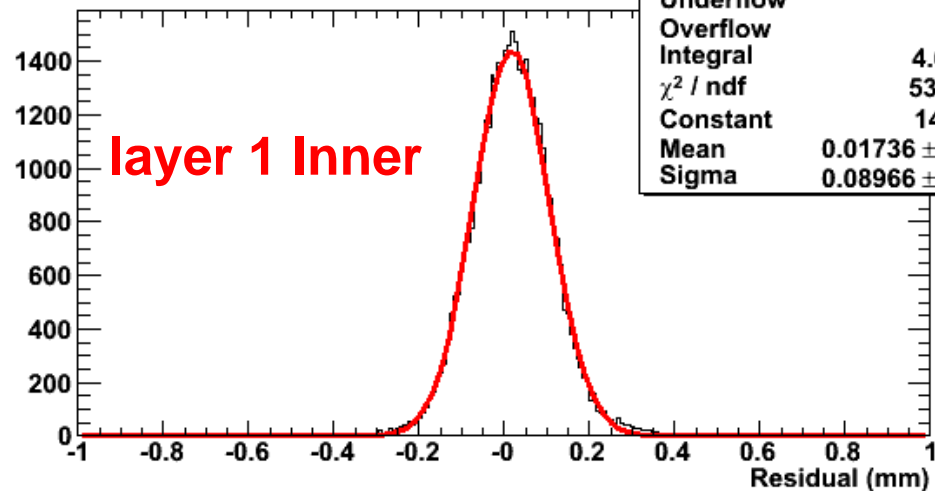
Layer 1 residual for selected track

Residual plot for layer 1, side 0



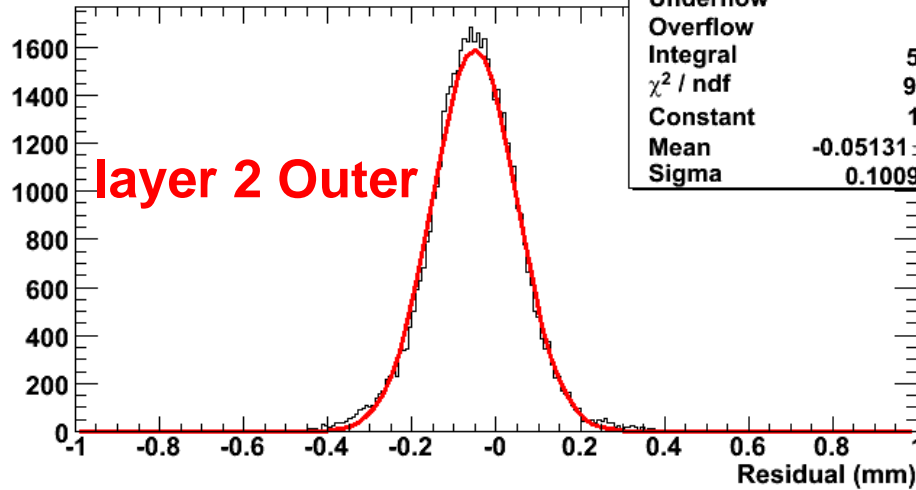
ResidualGaus[1][0]	
Entries	40567
Mean	0.02623
RMS	0.07912
Underflow	2
Overflow	0
Integral	4.056e+04
χ^2 / ndf	638.1 / 92
Constant	1726 \pm 11.3
Mean	0.02522 \pm 0.00037
Sigma	0.07385 \pm 0.00031

ResidualGaus[1][1]	
Entries	40978
Mean	0.01863
RMS	0.09592
Underflow	4
Overflow	12
Integral	4.096e+04
χ^2 / ndf	537.7 / 116
Constant	1439 \pm 9.2
Mean	0.01736 \pm 0.00045
Sigma	0.08966 \pm 0.00036



Layer 2 residual for selected track

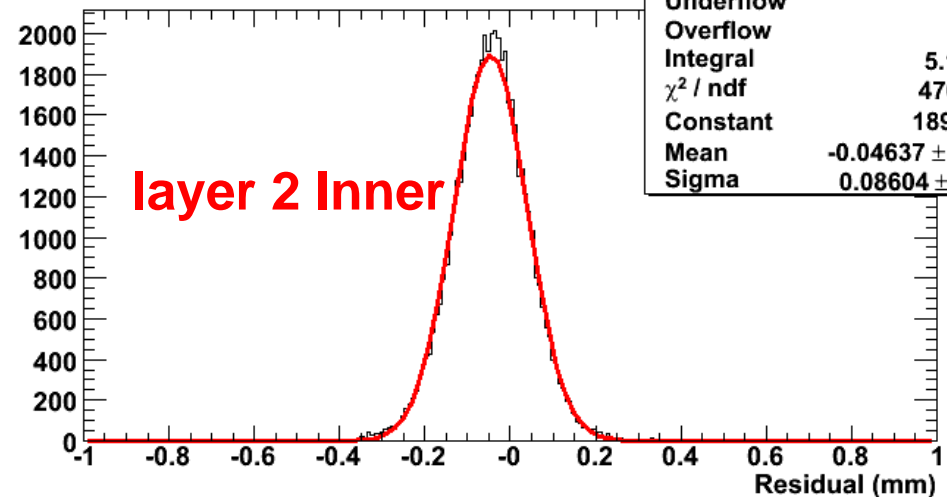
Residual plot for layer 2, side 0



ResidualGaus[2][0]	
Entries	51192
Mean	-0.05153
RMS	0.1089
Underflow	8
Overflow	4
Integral	5.118e+04
χ^2 / ndf	952.1 / 131
Constant	1589 \pm 9.4
Mean	-0.05131 \pm 0.00045
Sigma	0.1009 \pm 0.0004

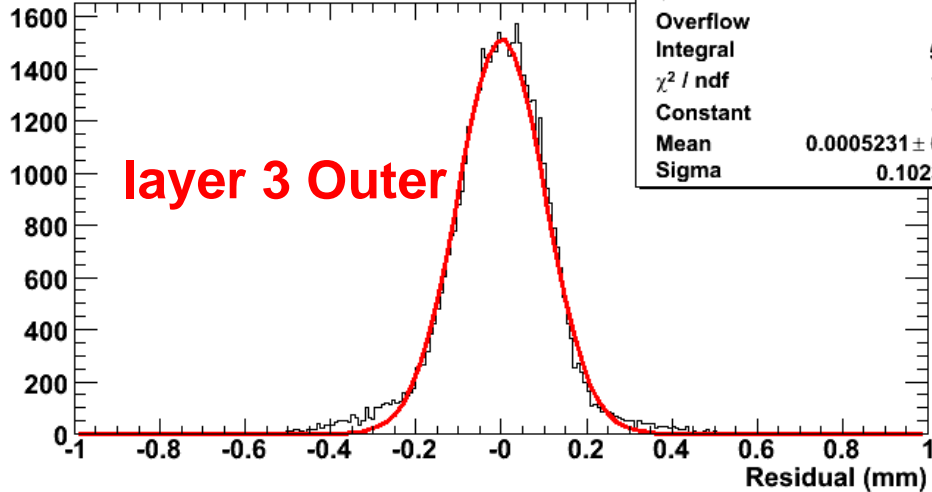
de 1

ResidualGaus[2][1]	
Entries	51611
Mean	-0.04615
RMS	0.0898
Underflow	2
Overflow	0
Integral	5.161e+04
χ^2 / ndf	470.4 / 107
Constant	1897 \pm 10.8
Mean	-0.04637 \pm 0.00038
Sigma	0.08604 \pm 0.00031



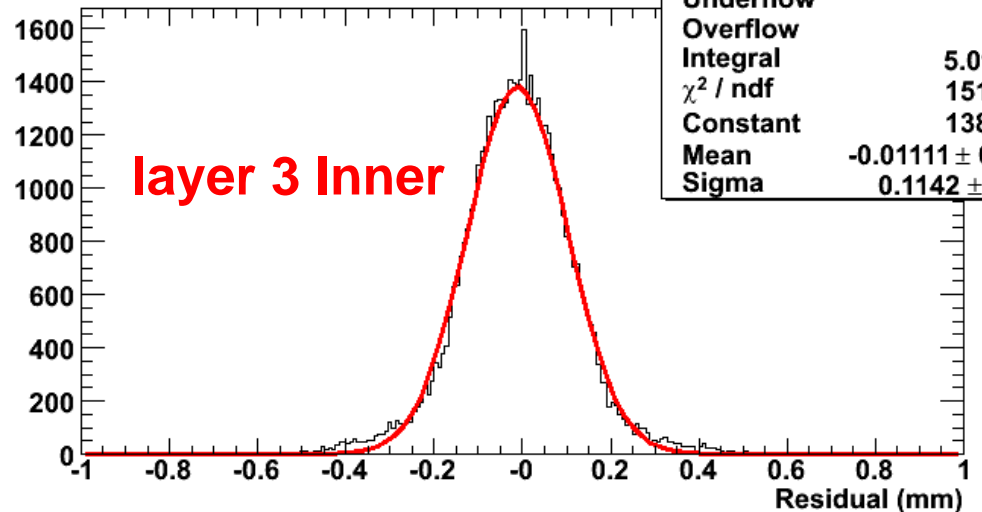
Layer 3 residual for selected track

Residual plot for layer 3, side 0



ResidualGaus[3][0]	
Entries	50613
Mean	-0.00236
RMS	0.1211
Underflow	0
Overflow	0
Integral	5.061e+04
χ^2 / ndf	1997 / 138
Constant	1517 \pm 9.2
Mean	0.0005231 \pm 0.0004703
Sigma	0.1023 \pm 0.0004

1



ResidualGaus[3][1]	
Entries	50981
Mean	-0.01212
RMS	0.1283
Underflow	2
Overflow	17
Integral	5.096e+04
χ^2 / ndf	1515 / 143
Constant	1382 \pm 8.3
Mean	-0.01111 \pm 0.00051
Sigma	0.1142 \pm 0.0005

ToF between top and bottom scintillator

