Results on TOB Integration

C.Bloch,
On behalf of the CMS Tracker
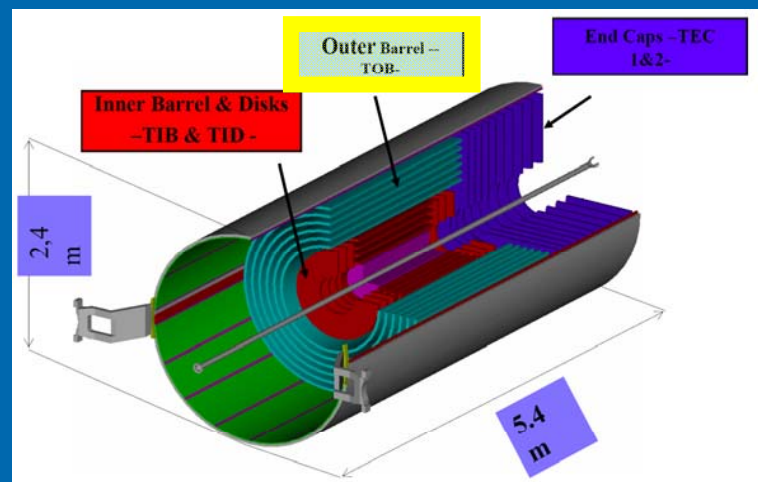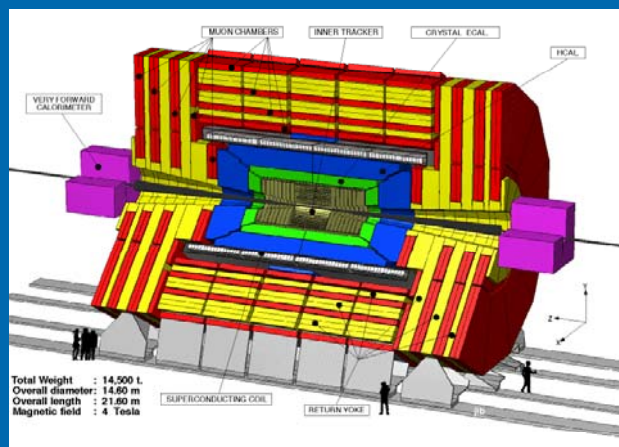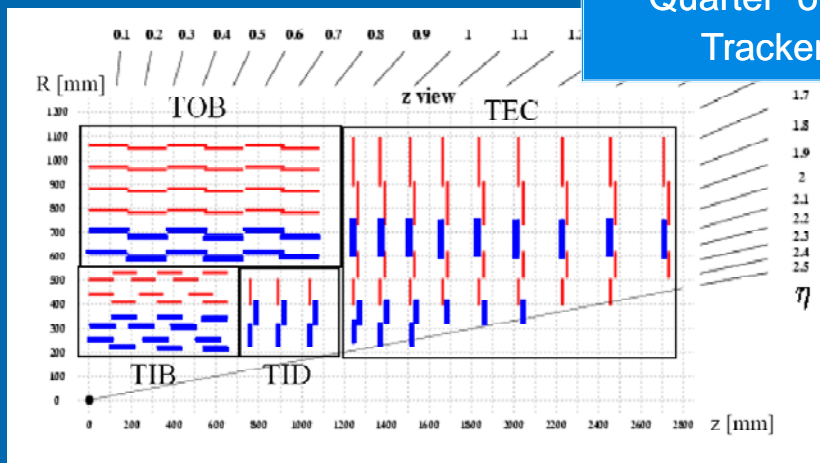Collaboration.

Outline

- Integration of the CMS Tracker Outer Barrel (TOB)

  - Components of the TOB

  - Procedures of Integration

  - Noise and Bad Channels

- Data from Auxiliary Setup

  - Basic Detector Performance

  - Charge Sharing vs. Coupling

  - Geometrical Precision of sub-assemblies from Cosmics

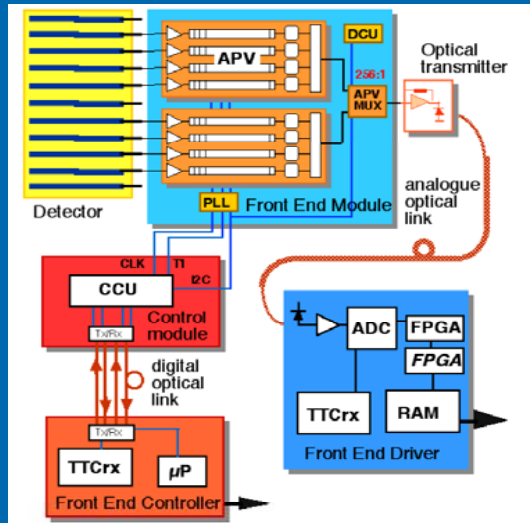# The CMS Tracker

"Quarter" of the Tracker

- ➢ Pixel
- ➢ **Silicon Strip Tracker**
  Largest Silicon Strip Detector ever built:
  ~200m^2 of silicon,
  instrumented volume ~24m^3
  - TIB (4 layers)
  - TID (3 disks, 3 rings)
  - TOB (6 layers)
  - TEC (9 disks, 7 rings)

Sensor and Readout Electronics

CMS Electronics

"CMS TOB module"

500µm thick silicon

Pitch 183 / 122µm

512 / 768 strips

2 Sensors (~10 x 10cm) bounded together

Readout Electronics (APV25)

2 Readout Modes

"Peak Mode"

For low Lumi

• CR-RC pulse shape 50ns Rise Time

"Deconvolution Mode"

For high Lumi

• 25ns Peaking Time
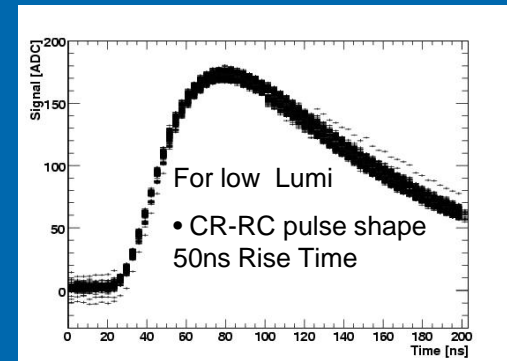
• Reduces Occupancy

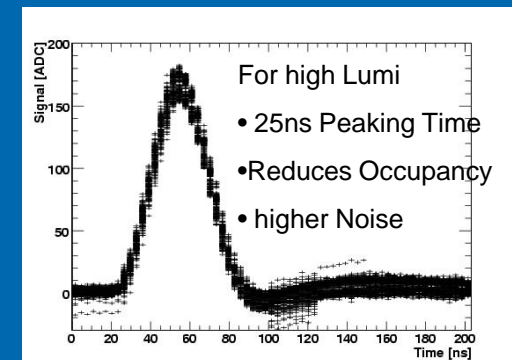• higher Noise

"CMS TOB Rod"

6 (SS-Rod) 12 (DS-Rod) modules

carbon fiber frame, integrated cooling

control electronics, optical data transmission

environmental sensors (humidity, temperature)
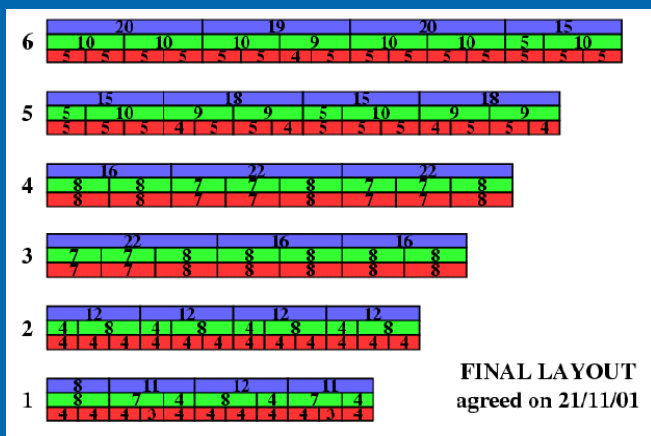
Integration of the TOB

688 Rods in TOB

There are 344 Rods on each TOB side grouped into: 22 cooling groups , 46 control loops and 67 optical readout cables.

FINAL LAYOUT
agreed on 21/11/01

- ➢ Integration in Cooling segments
- ➢ Tests
  - Control Ring Tests
    - (Scan for Devices, Redundancy Check)
  - Soldering of Cooling Pipes (pressure tests)
  - Functional Test
    - Measurement of Optical Gain
    - Noise Measurements
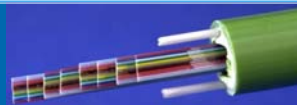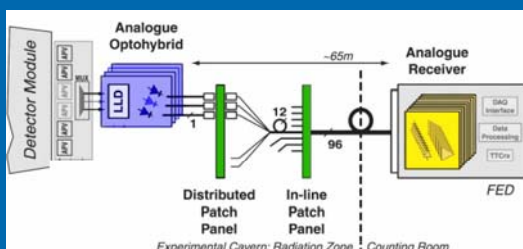   - Internal Calibration Pulse

Optical Link System
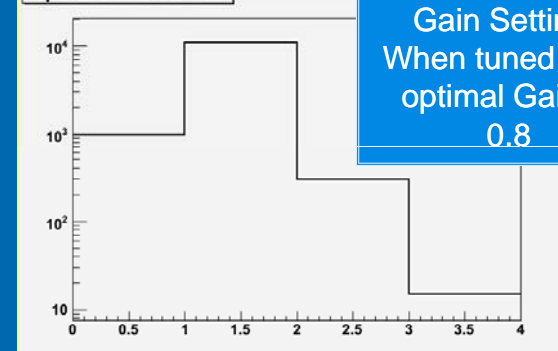
"Readout Ribbon"

"Multi Ribbon Cable"

AOH

Analogue Optohybrid
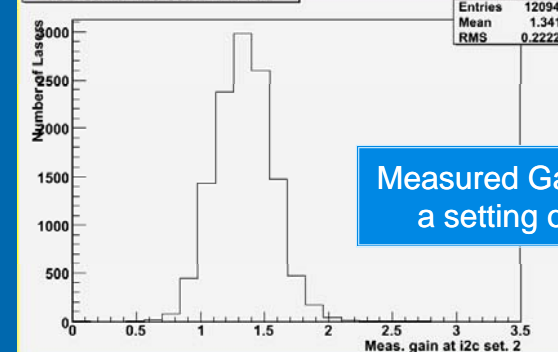
- 4 Gain Settings
    - (~40% steps)
- Bias settings

Optimize the Dynamic Range
Accommodate for variations of
- Components
- Radiation Damage
- Temperature
- Optical Link Quality

3 Optical Connections

- AOH - "Readout Ribbon"
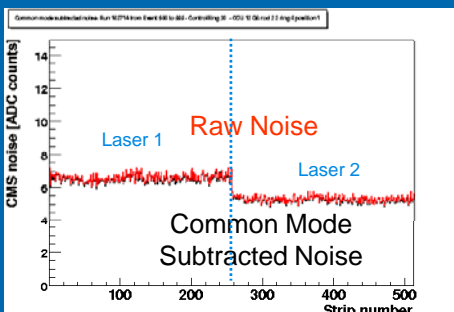- "Readout Ribbon" – "Multi Ribbon Cable"
- "Multi Ribbon Cable" -FED

Optical Link Performance

- Cummulative Plots for all Fibers of TOB

Distribution of Gain Settings When tuned to an optimal Gain of 0.8
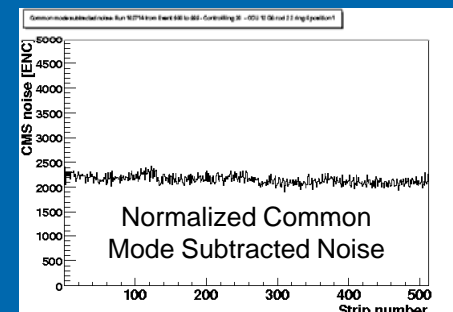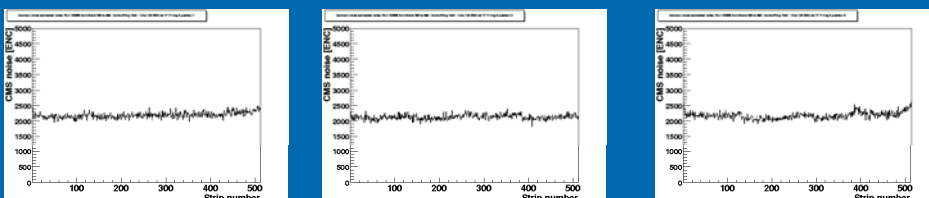
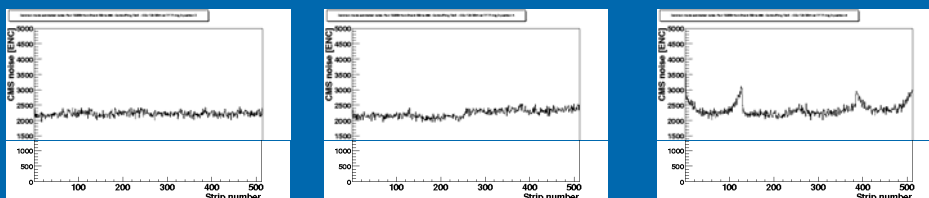Measured Gain for a setting of 2

Noise Performance

"Scaling to Tickmarks"

1 Tickmark ~ 200ke-

Independent of optical gain, suitable for comparisons.

Common Mode Subtracted Noise on a Random Selected SS4 Rod

- General good noise performance
- Noise Profiles flat except Pos 6
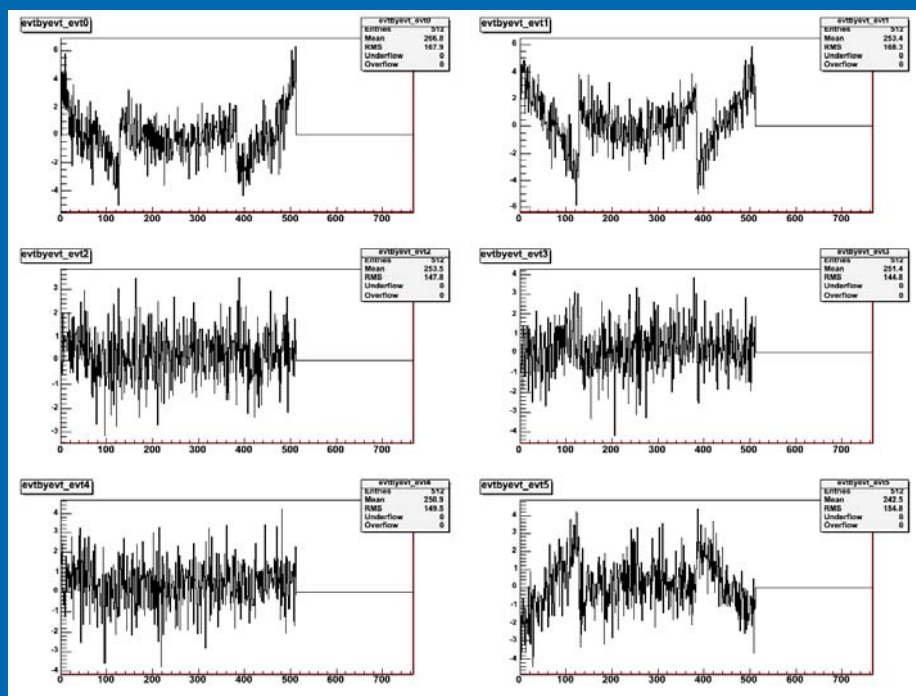- Low Common Mode Noise

"Wing Noise"

- ➤ Wings are a Common Mode effect
  - Slope changes Event by Event
 - Can be removed with a "linear" Common Mode subtraction

- ➤ Modules at position 6 in TOB rods are seen to have non-flat common-mode subtracted noise ("wings")
- ➤ Noise is worst on SS4 rods, best on SS6, intermediate on DS
- ➤ Signal itself is not affected
- ➤ Currently, functionality is not harmed, given our large S/N ratio
- ➤ However noise level might change in the final location and not much margin for cluster cuts when S/N decrease with irradiation (At the top of the wings S/N in dec. mode ~10)

- ➤ Ongoing activity to minimize effect
  - Grounding scheme
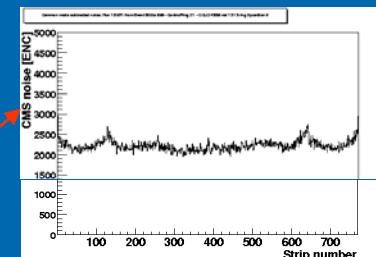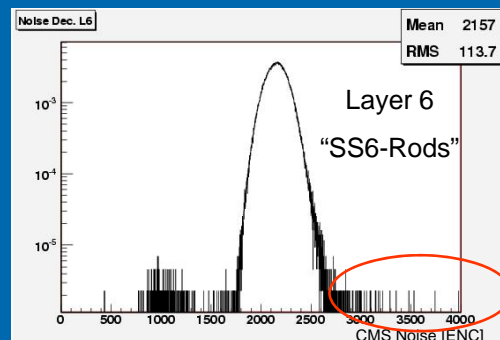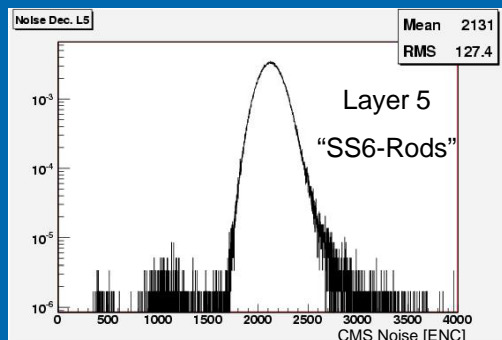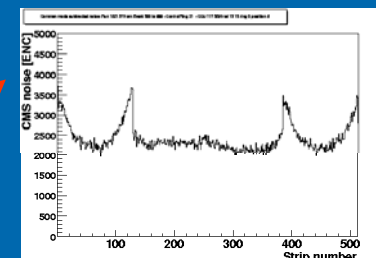 - Linear Common Mode Subtraction under investigation

~1% of channels affected
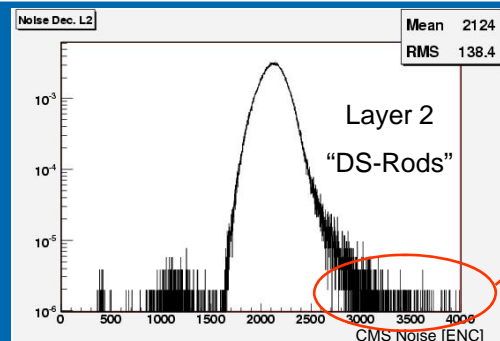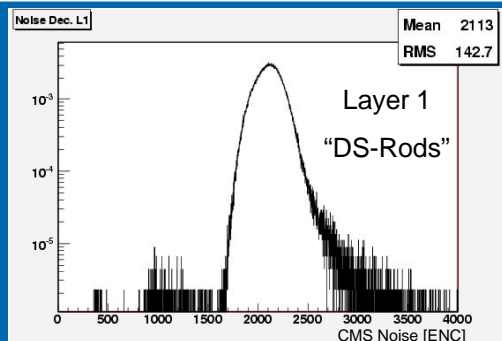
"Typical Bad Case" examples

Bad Channels

Calibration Pulse Height and Raw Noise
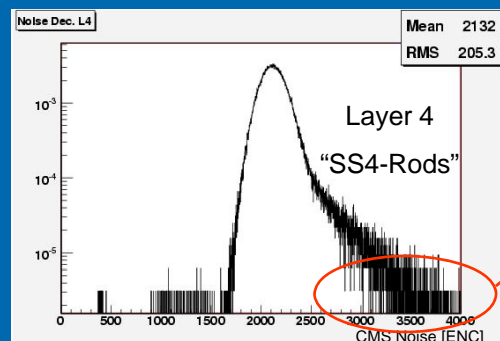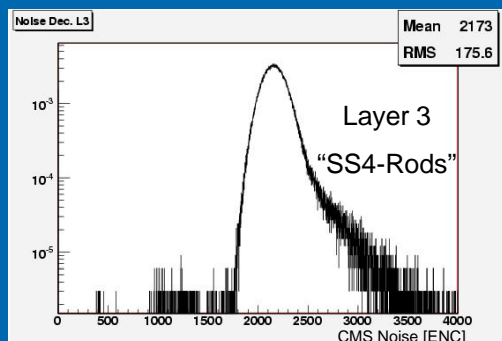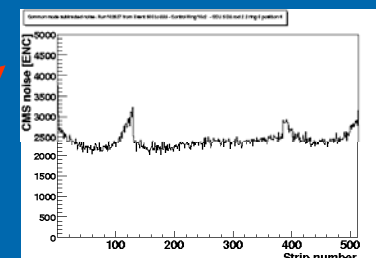
Noise and calibration pulse measured during integration

Flagging from previous tests

ARCS, Rod Reception…
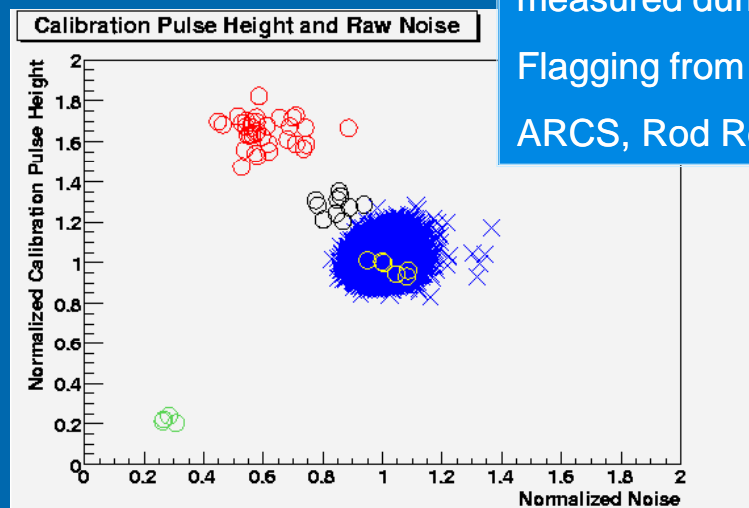
Bad Strip Identification Criteria based on Noise and internal Test Pulse

	Prior	New	Total
Open	1880	375	2255
Noisy	67	213	280
Short	51	18	69
Other	75	16	91
Sum	2073	622	2695

2 (unbound1)	Less noise (70-90%) AND normalized rise time between -4 and -0.5
4 (likeunbound1)	Less noise (70-90%) OR normalized rise time between -4 and -0.5
8 2 Sensor Open	Less noise (<70%) AND normalized rise time between -30 and -4
16 (likeunbound2)	Less noise (<70%) OR normalized rise time between -30 and -4
32 (likeopen)	(Less noise (70-90%) AND normalized rise time between -30 and -4) OR (less noise (<70%) AND normalized rise time between -4 and -0.5)
64 (noisy)	Higher than normal noise (differential) and no other anomaly
128 (short)	Low calibration puls peak hight (<80%) on two adjacent strips
256 (likepin)	Noisy AND rise time < -30 AND peak height < 80%

Summary Bad Channels

- ➤ Two modules lost bias (one short, one open) Layer 6 Layer 5
  - ● Both SS6 modules -> 2 * 768 Strips
- ➤ One broken Readout Laser Fiber
- ➤ # Bad strips 2695

Channels Total	3096576		
Fault	**#**	**# Channels**	**Relative**
Broken Fiber	1	256	0.008%
HV Problems (SS6 Modules)	2	1536	0.050%
Bad Strips	2695	2695	0.087%
		4487	0.14%

TOB delivered with excellent performance:

Fraction of channels with no or limited functionality < 0.15 %
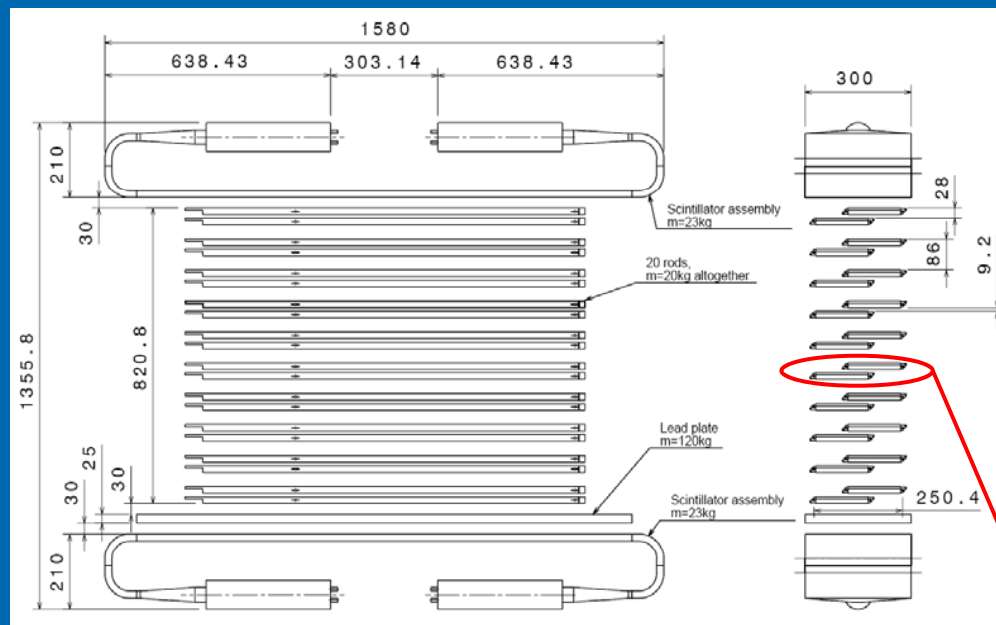
Auxiliary Setup
…the Cosmic Rack

Mechanics engineered by Erkki Anttilla (HIP)

Cosmic Rack Geometry

- Geometry mimics a slice of the TOB, adapted for tracking cosmics (10 layers instead of 6)

- 86mm distance between layers

- 2 Rods per layer

- Filtering low momentum muons by 25mm lead absorber (stopping power ~120MeV, 2% of spectrum removed)

- Housed inside a climatic chamber can be cooled down to -10°C
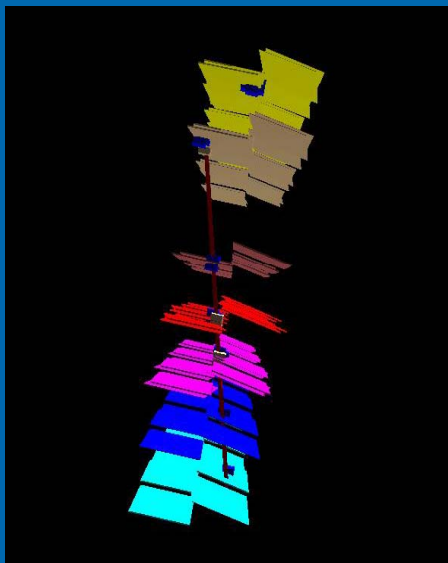
Configuration corresponds to a cooling segment
- 20 Rods (2 Rods in 10 layers)
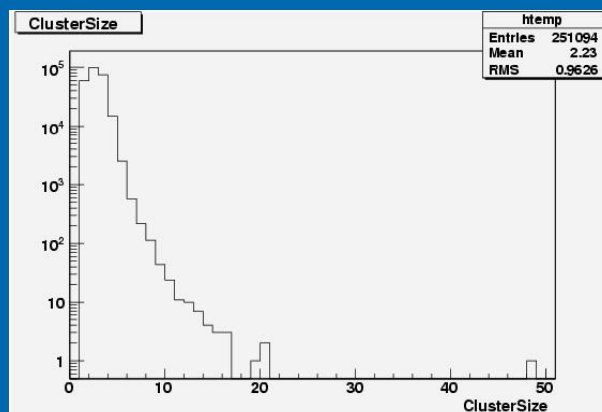- 1-2 control loops

Average angle of Rods in TOB
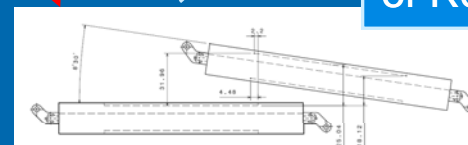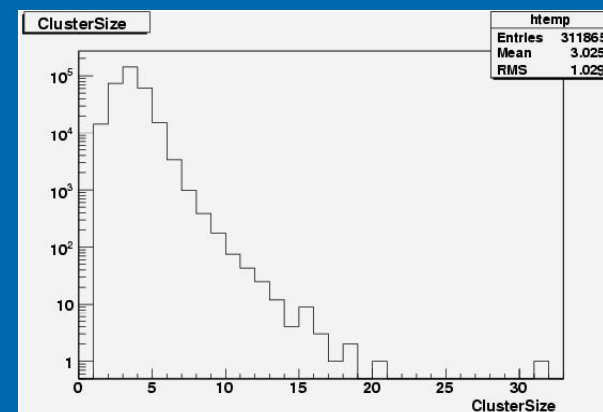
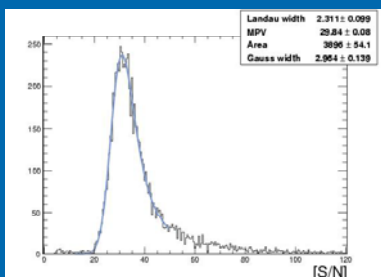# Tracking Cosmic Muons

Cluster Size "Peak Mode"

Mean = 2.3

Cluster Size "Deconvolution Mode"

Mean = 3.0

Cluster Size greater than expected.

Due to tracking / trigger geometry max. inclination angle of the tracks (perpendicular to the strips) is ~ 20 degrees.

$\Rightarrow$ Expected max cluster size: 3 strips.

Clusters with a size greater than that might be due to:
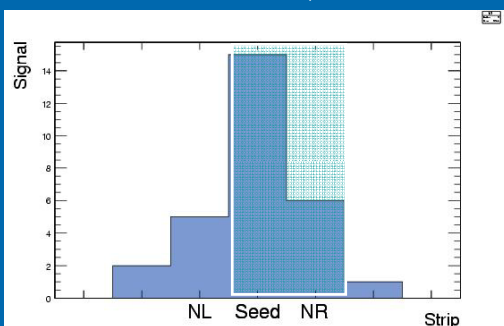
- Noise
- Electronics Crosstalk (Coupling)

"Peak Mode"

MPV (CluCharge/SeedNoise) = 30

"Deconvolution Mode"

MPV (CluCharge/SeedNoise) = 20

Charge Sharing vs. Coupling

Eta-function

$$Eta = L / (L+R)$$

NL > NR: L=NL; R=Seed
NL < NR: L=Seed; R=NR

Local track angle Θ_{uw}
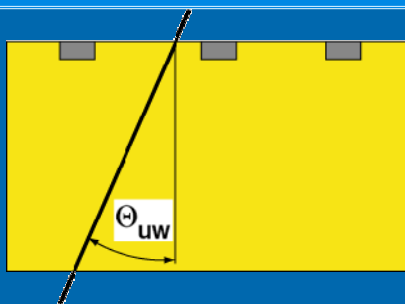
Eta-function for shallow crossings

$| \tan (\Theta_{uw})| > 0.4$

Contributions to Charge Sharing
- Diffusion
  - Small compared to pitch
- Drift in Magnetic Field
- Track Inclination

Eta-function for perpendicular crossings

$| \tan (\Theta_{uw})| < 0.01$

Measurements on Couplings
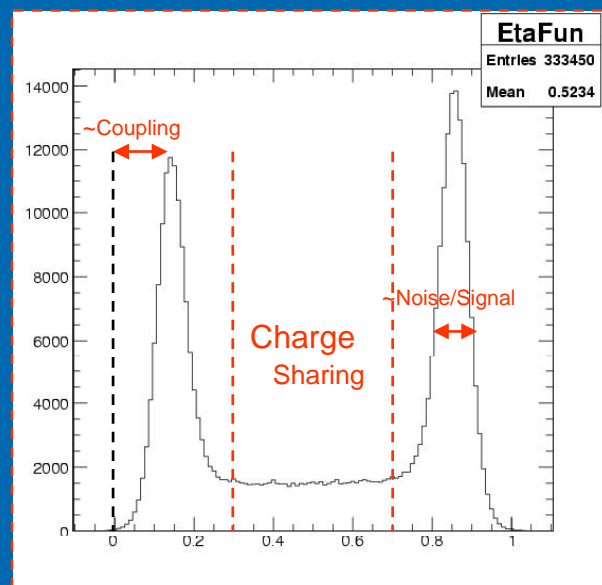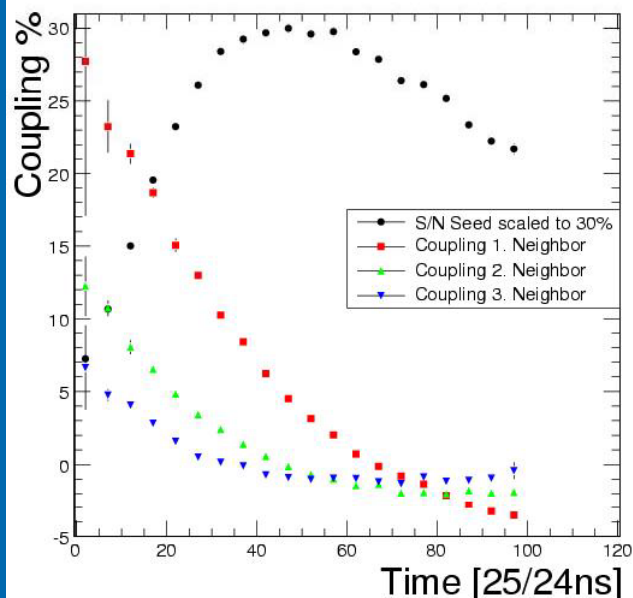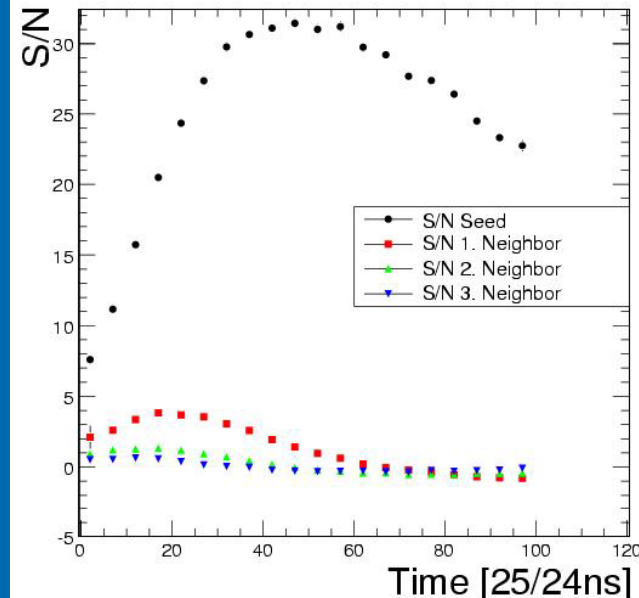## (Shown for a Module with 122 mum pitch)

Couplings Coefficients vs. time

S/N of Coupled Strips vs. time

APV-Mode	Module	C1 (t_opt)	C2 (t_opt)
PEAK	SS6	4.3%	-0.2%
PEAK	SS4	3.3%	-0.3%
DECV	SS6	13.4%	3.4%
DECV	SS4	10.9%	2.4%

Couplings measured in peak and deconvolution. Non negligible effect in deconvolution mode: 11% for 4-chips ,modules, 13% for 6-chips modules, (affects occupancy and position resolution). To be modelled in the tracker simulation.

Measurements on Geometrical Precision

**Track Based Alignment
… with Cosmics**

➢ Using CMS Tracking and Alignment Algorithms (Millepede)

➢ Aligning of individual modules (translation in "u")

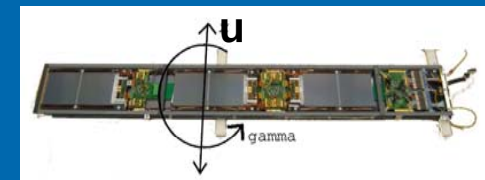➢ First measurements of geometrical precision on fully equipped Rods

"Intrinsic Precision of tested Rods"

Deviation of module positions wrt.nominal positions

Mean 1.269e-15
RMS 51.72

RMS ~50μm

Preliminary

Δ_u [μm]
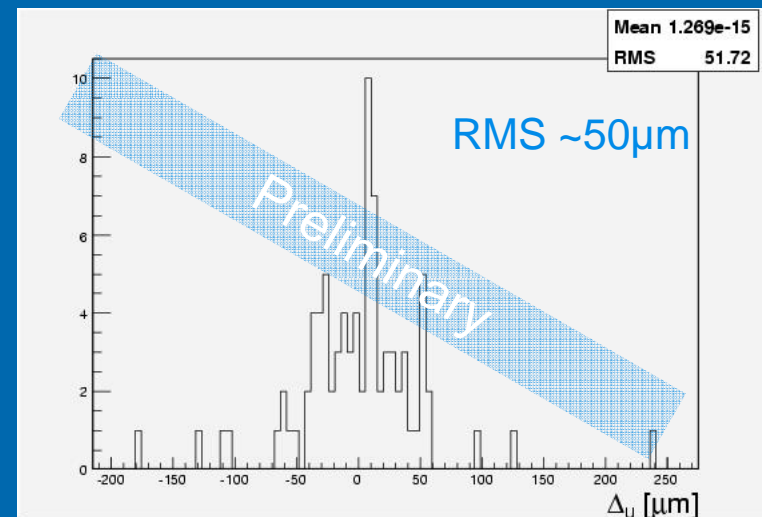
Coordinate System - aligning in "u"
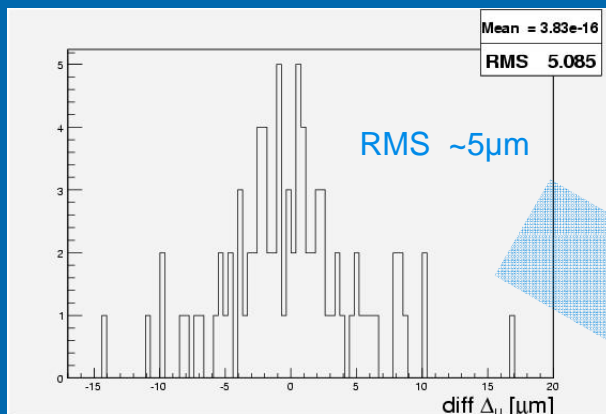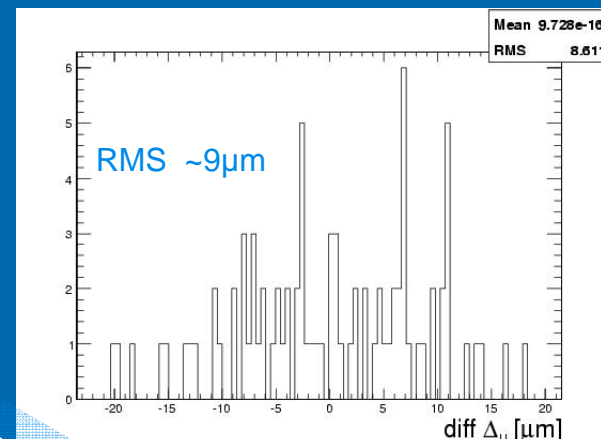
Direction across the Strips

Stability of Supports in Temperature

Comparison of Alignment Corrections two independent datasets Warm vs. Warm

RMS ~5µm

Comparison of Alignment Corrections two independent datasets Warm vs. Cold

RMS ~9µm

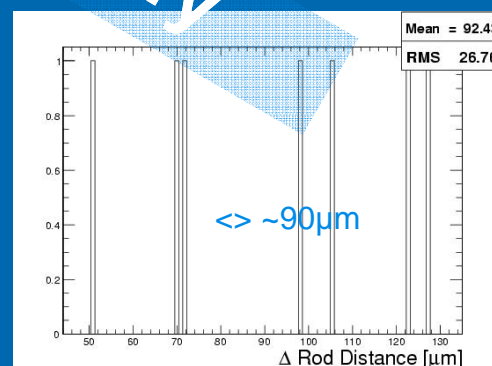*Preliminary*

Comparison of independent data sets.

Data taken at room temperature (20°C) and in cold (-10°C).

No thermal stress observed.

<> ~90µm

Contraction of Test Setup Supports

The Cosmic Rack has aluminum structures.

Not relevant for tracker: main supporting structures in carbon fiber

Summary

- ➤ **TOB delivered with excellent Performance**
  - ● #Bad channels less than 0.15%
  - (goal was 2%)
  - ● General good noise performance

  - ● Capacitive Coupling of neighboring strips measured with auxiliary setup (~12% in deconvolution)
  - ● First measurement of Rod Geometric Precision: displacement of modules from nominal positions ~50mum