Intermediate Silicon Tracker for STAR HFT upgrade

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Outline

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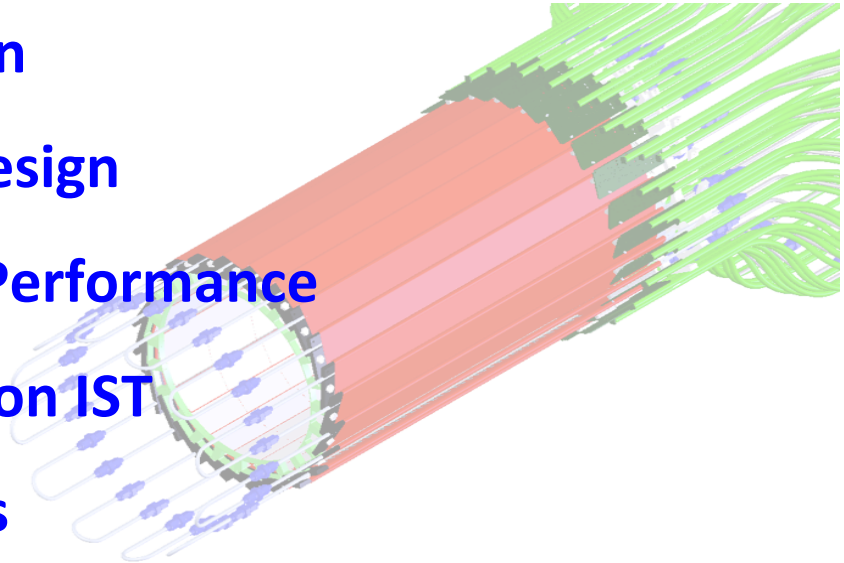
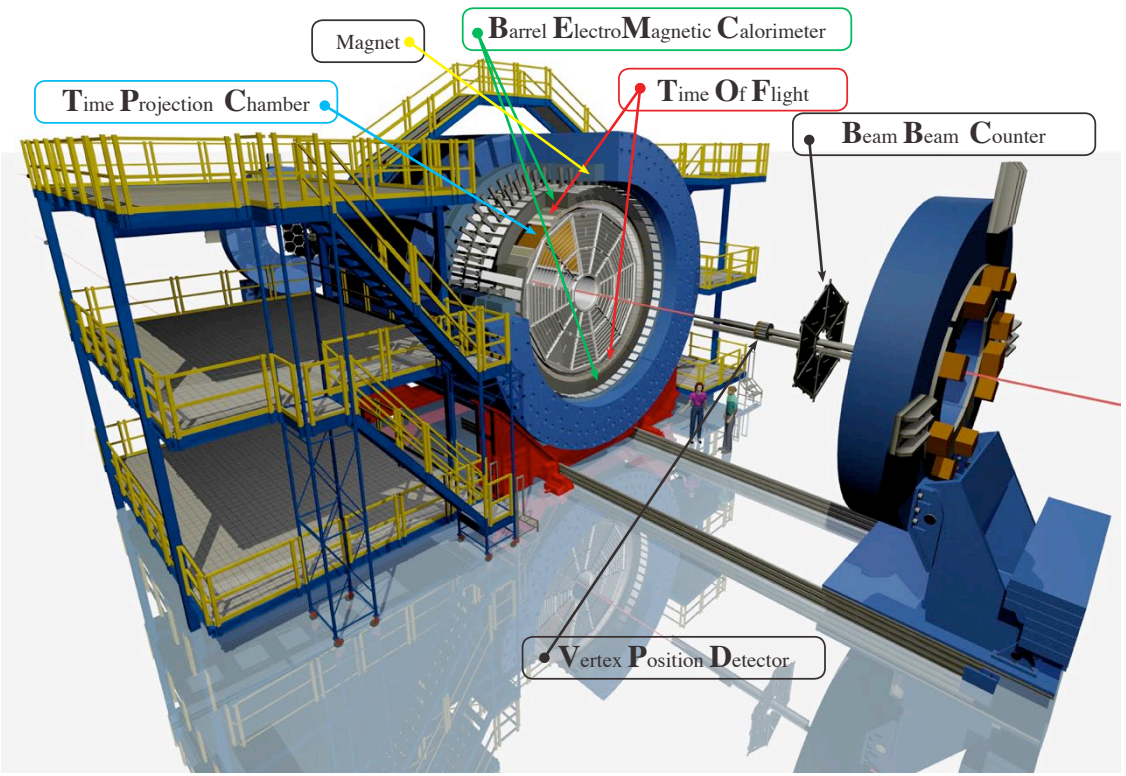
- **Introduction**
- **Detector Design**
- **Prototype Performance**
- **UIC Efforts on IST**
- **Conclusions**



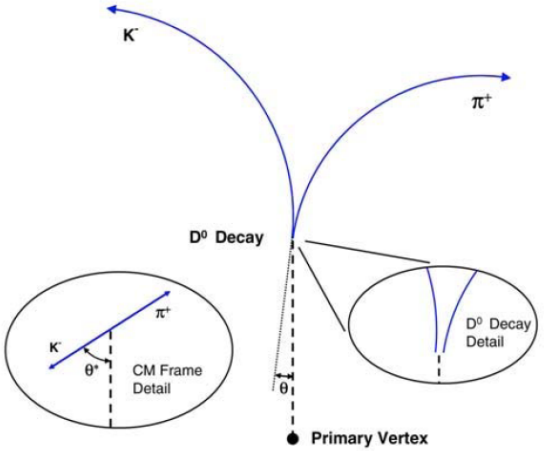
STAR HFT

Solenoidal Tracker At RHIC



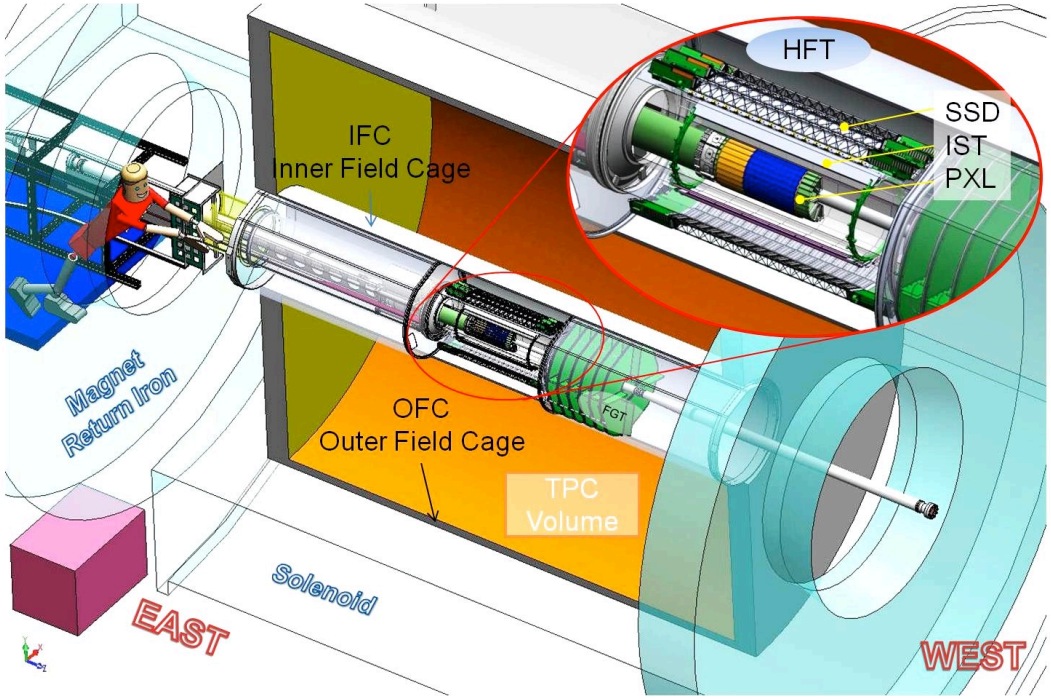
STAR has been taking data at RHIC for over 10 years.

Full azimuthal tracking and PID coverage in midrapidity ($|\eta|$ <1).



Heavy Flavor Tracker (HFT) will greatly enhance the capability of STAR for heavy flavor studies (energy loss mechanism and partonic thermalization), allowing identification of displaced vertices and direct topological reconstruction of open charm hadrons.

Introduction – HFT @ STAR



Detector	Radius (cm)	Hit Resolution R/φ - Z (μm - μm)	Radiation length
SSD	22	20 / 740	1% X_0
IST	14	170 / 1800	<1.5% X_0
PIXEL	8	12/ 12	~0.4% X_0
	2.5	12 / 12	~0.4% X_0

PIXEL

- 2 layers of thin monolithic active pixel sensors, integration time ~ 180 μs
- 18.4x18.4 μm pixel pitch
- Provide ultimate pointing resolution that allows for direct topological identification of charm.

IST (Intermediate Silicon Tracker)

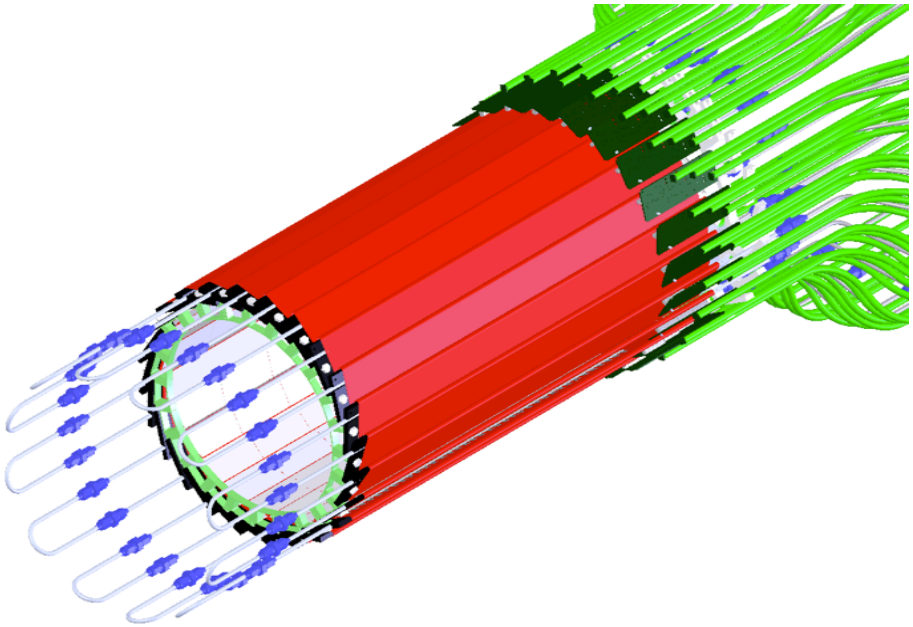
- 1 layer of silicon pad sensors
- Guiding tracks from the SSD to the PIXEL
- Operate without significant event pile-up for 200 GeV Au+Au

SSD (Silicon Strip Detector)

- Existing single layer of double sided strip sensors (electronic upgrade)

Track inward from TPC with graded resolution:

Detector Design – Overview



Radius	14 cm
Length	50 cm
ϕ-Coverage	2π
|η|-Coverage	⩽1.2
Number of Ladders	24
Number of hybrids	24
Number of sensors	144
Number of readout chips	864
Number of channels	110592
R-ϕ resolution	172 μm
Z resolution	1811 μm
Z pad size	6275 μm
R-ϕ pad size	594 μm

Deliverables:

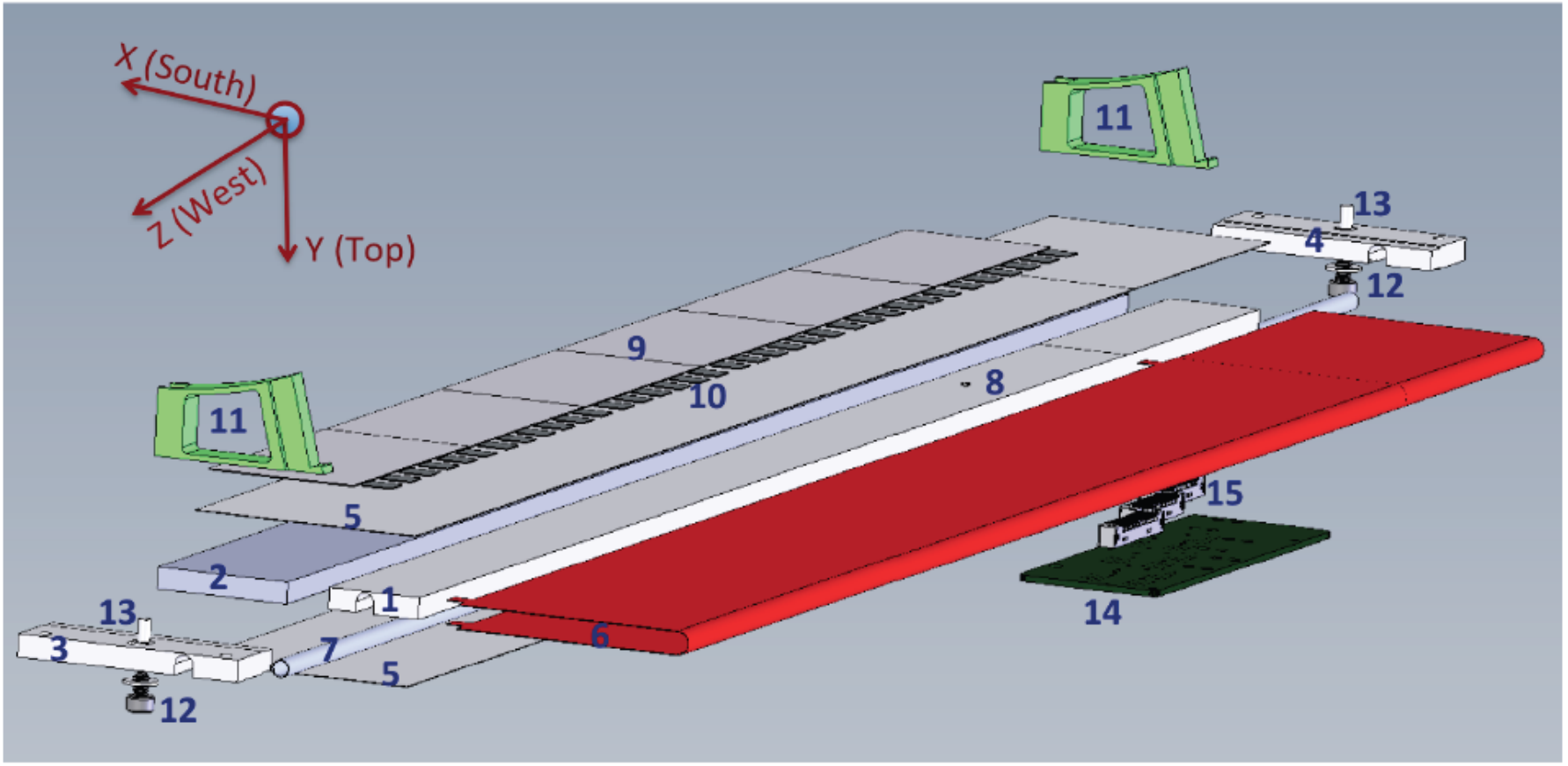
-24 IST staves have been installed in STAR

-Commercial bias supply from Wiener

-Customized readout system

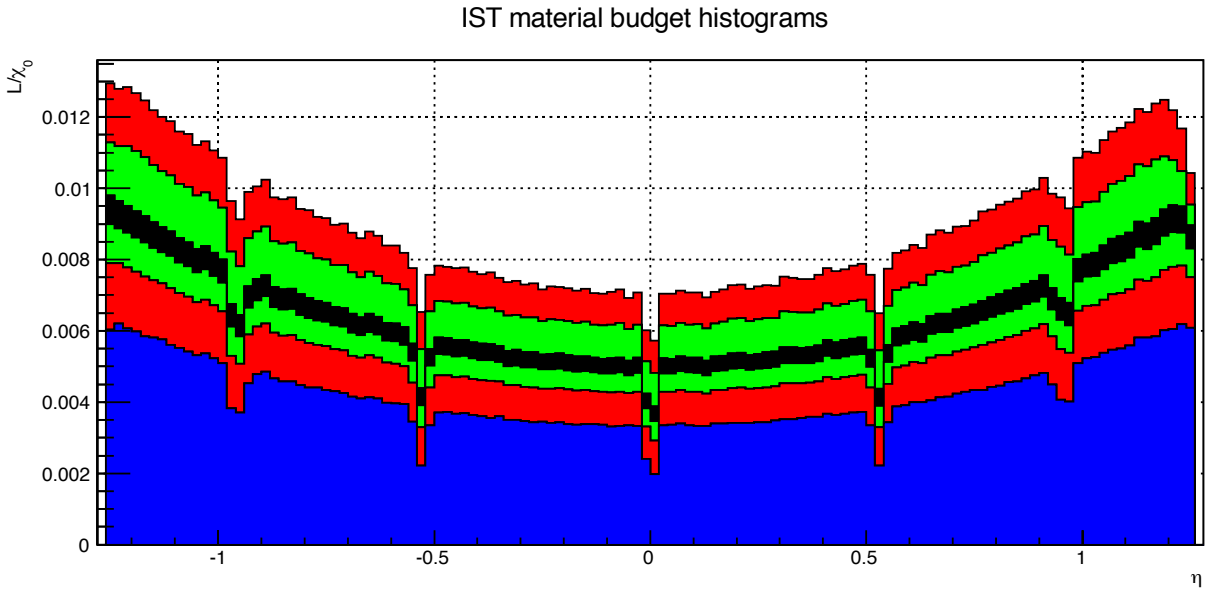
-Cabling and Cooling Services

Detector Design – Stave Structure



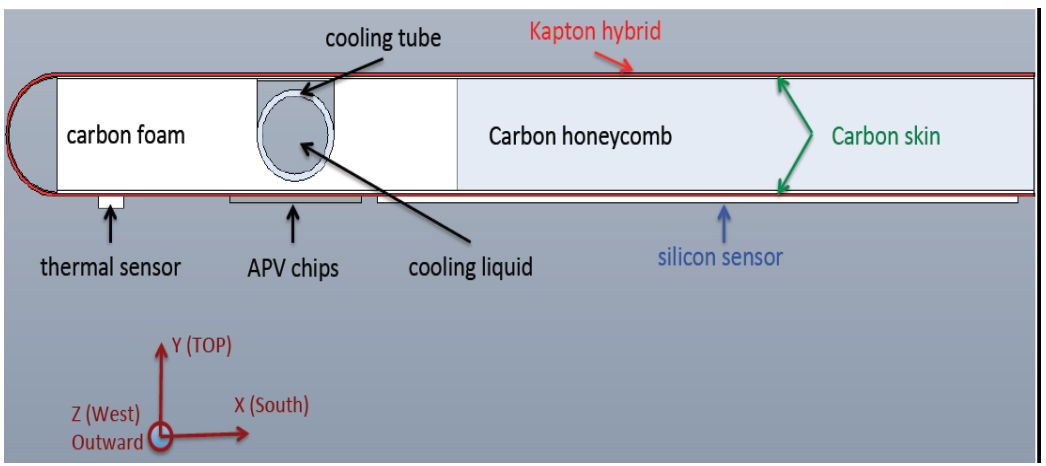
1) carbon foam 2) carbon honeycomb 3) west carbon end-cap 4) east Al end-cap 5) carbon fiber skins 6) Kapton hybrid 7) Al cooling tube with cooling liquid inside 8) thermal sensor 9) silicon sensors 10) APV chips 11) support blocks 12) screws with washers 13) spacers 14) transition board 15) readout connectors.

Detector Design – Material Budget

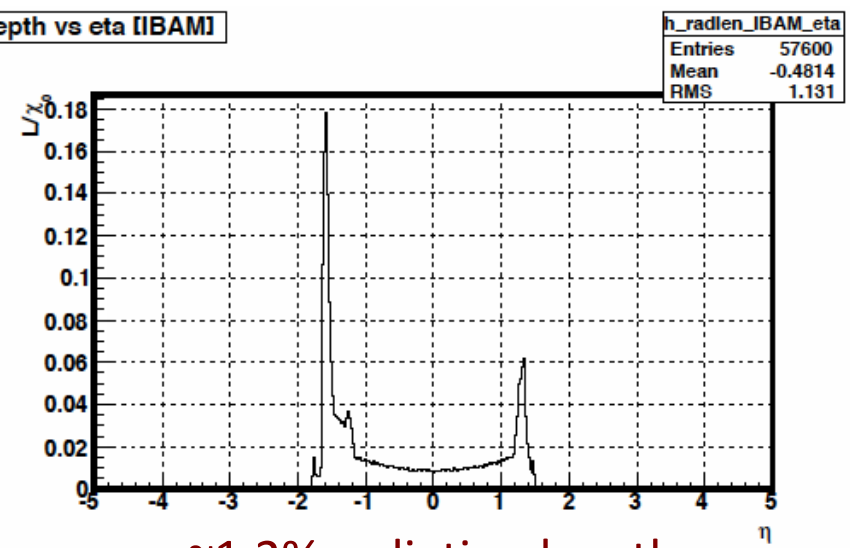


Hybrid layer(top)
Carbon skin layer(top)
Carbon honeycomb layer
Carbon skin layer (bottom)
Hybrid layer (bottom)

Silicon sensor layer

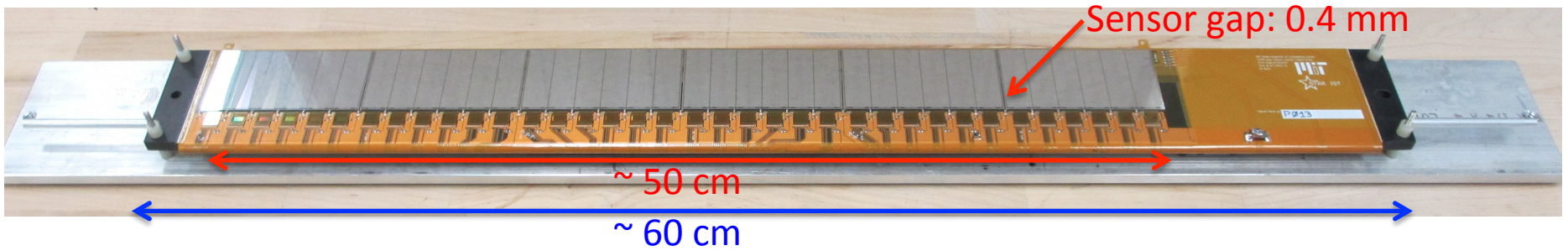


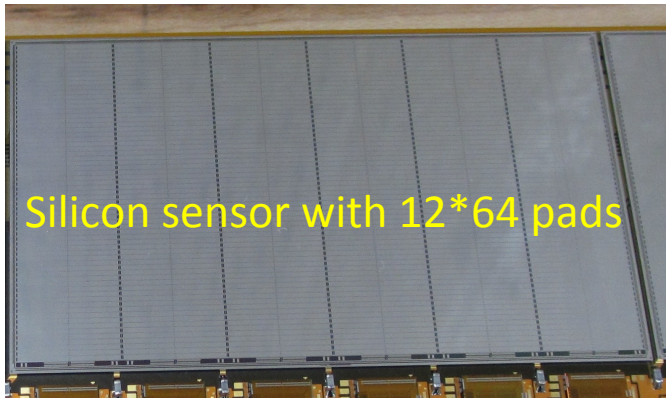
IST stave east view

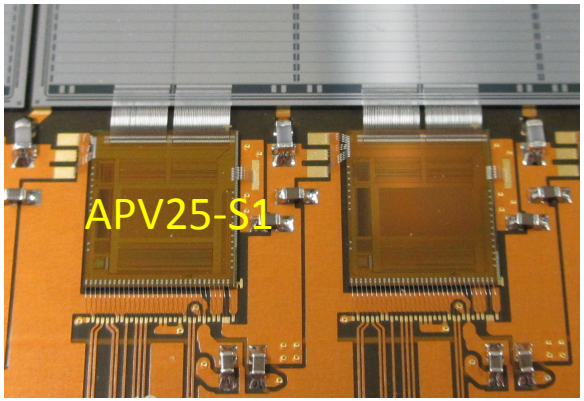


~1.2% radiation length

Detector Design – Sensor & Readout Chip







Silicon sensor:

- Sensor from Hamamatsu Co.
- Full depletion voltage ~ 70 V
- Thickness: 300 µm
- Sensor area: 40.0*76.9 mm^2
  Active area: 38.0*75.3 mm^2
- Pad dimensions: ~0.6*6.3 mm^2

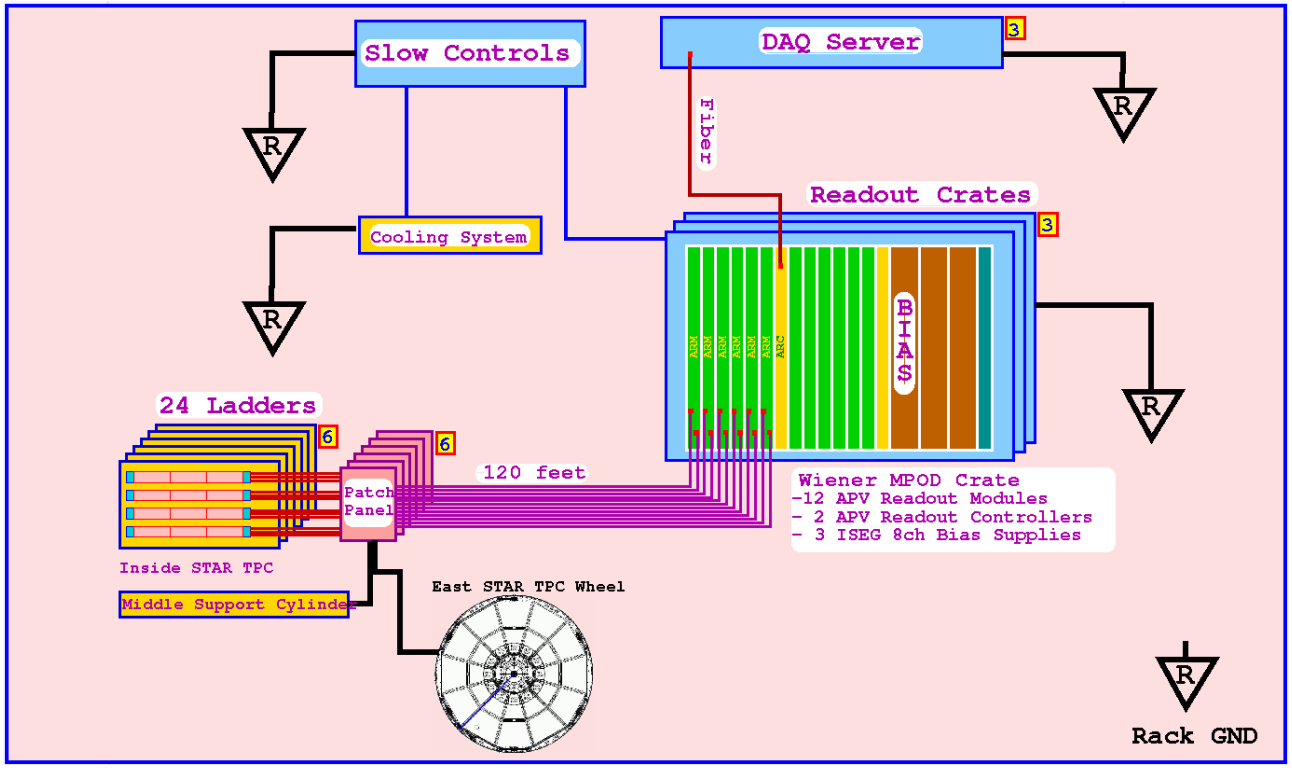
APV25-S1:

- 0.25 µm CMOS, radiation hard
- 128 channels parallel sampling
- 40 MHz sampling rate
- 4 µs analogue pipeline
- > 15:1 signal to noise ratio

IST stave = Carbon fiber ladder + Cooling tube
+ Kapton flex hybrid + Passive components
+ 6 silicon pad sensors +
+ 3 x 12 APV25-S1 readout chips

Electrically divided in 3 units to reduce chance of failure of a full stave

Detector Design – Readout system & Cooling



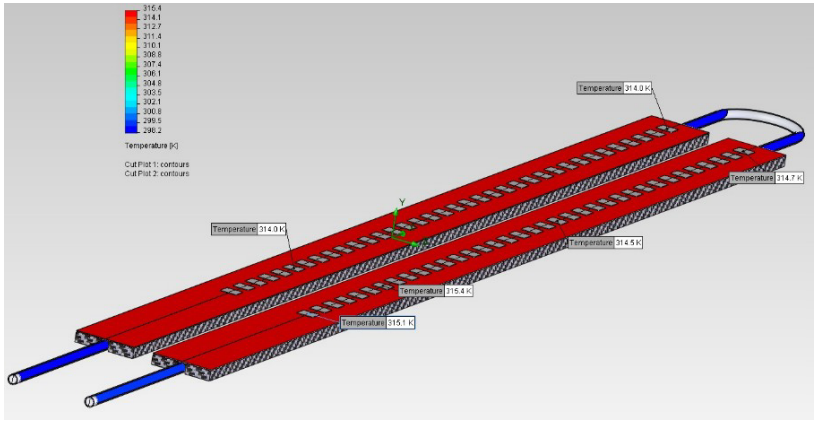
Readout system:

- 3 readout crates
- Each crate has

  (1) 3 ISEG 8-channel Bias Supplies

  (2) 12 APV Readout Modules (ARM)

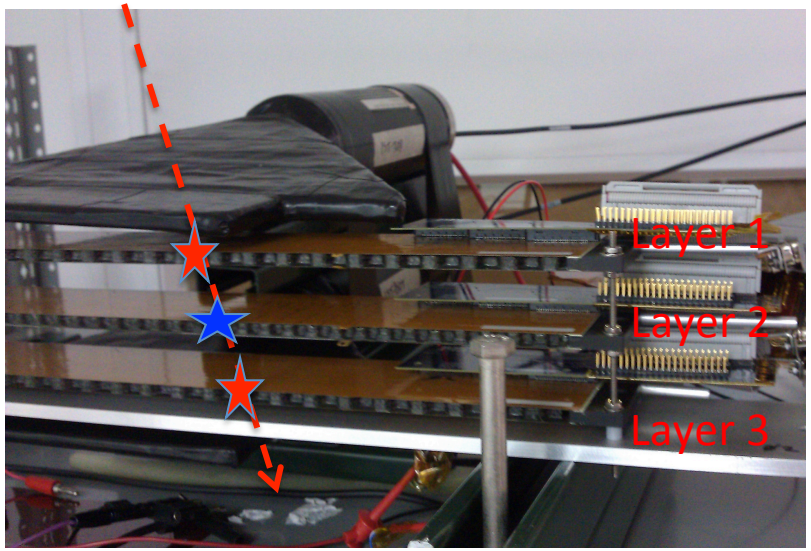
  (3) 2 APV Readout Controllers (ARC)

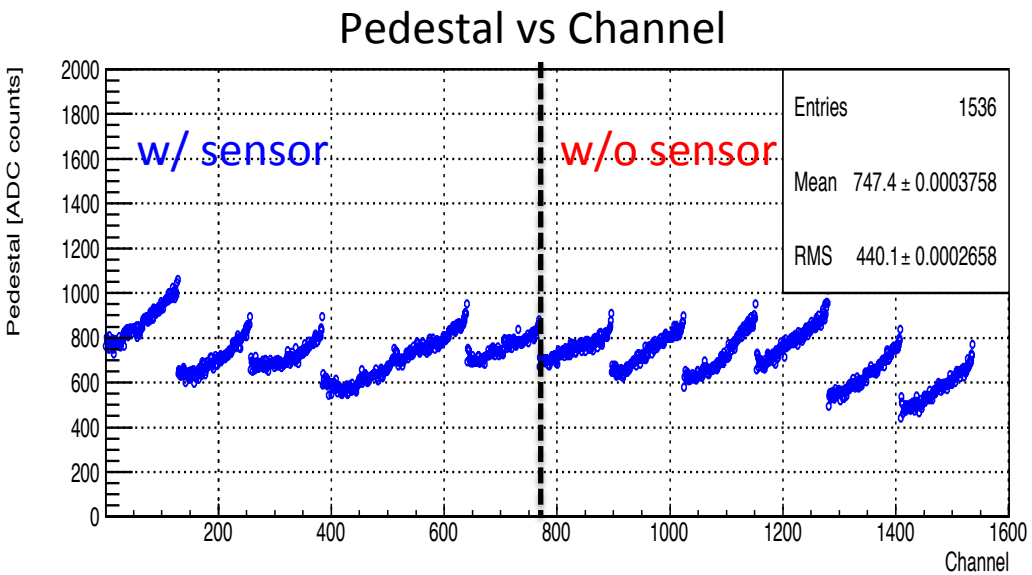


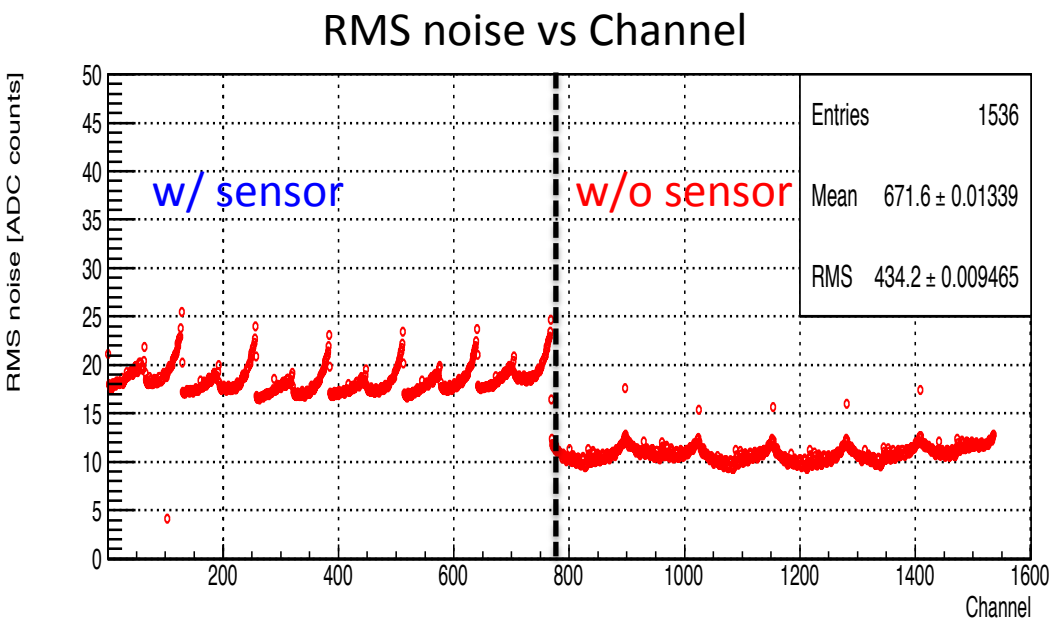
Cooling:

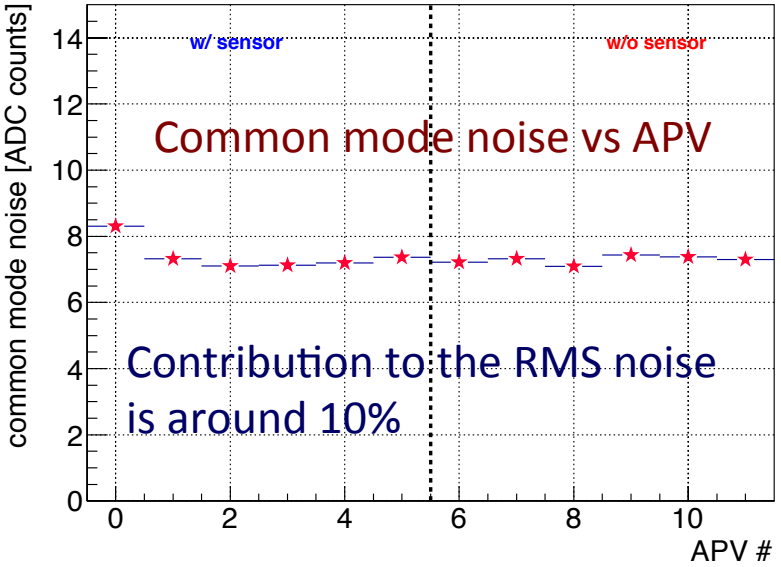
- Low radiation environment (< 30 kRad/year)
- 0.3 W/chip (264 W for the whole IST cooling)
- Integrated Aluminum cooling tube
- Cooling 2 staves in series with 3M Novec 7200 at 25 ^{o}C, and 1 liter/min at 20psi

Prototype Performance – Pedestal & RMS/CM noise









Prototype Performance – Cluster ADC spectrum

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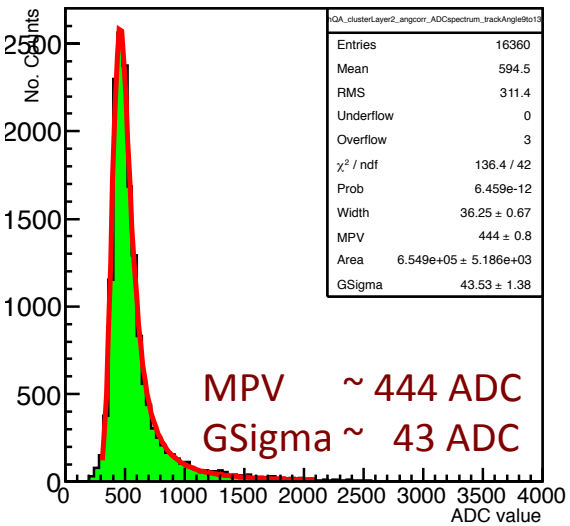
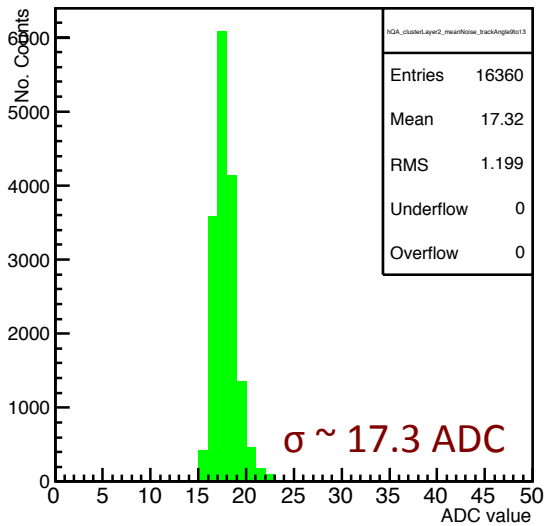
The cluster ADC spectrum was corrected by track angle.

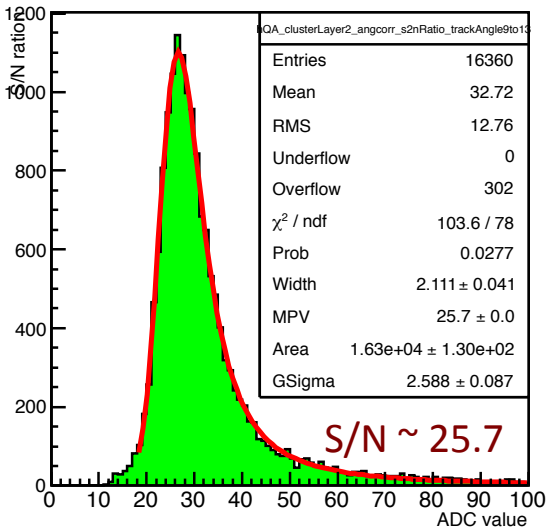
Layer 2: cluster ADC spectrum

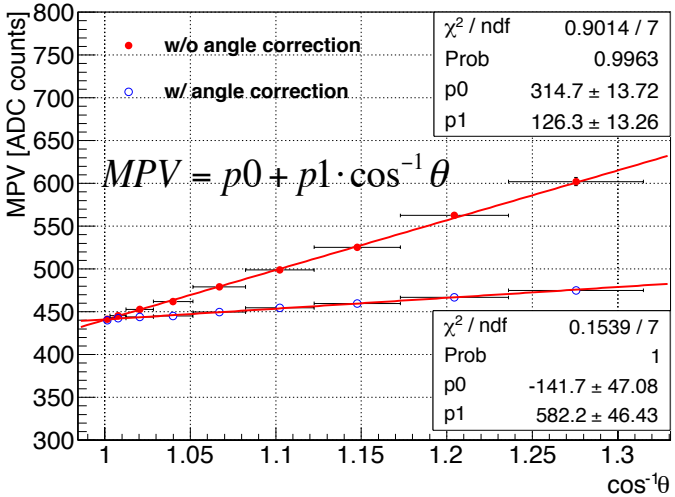


Layer 2: cluster noise spectrum



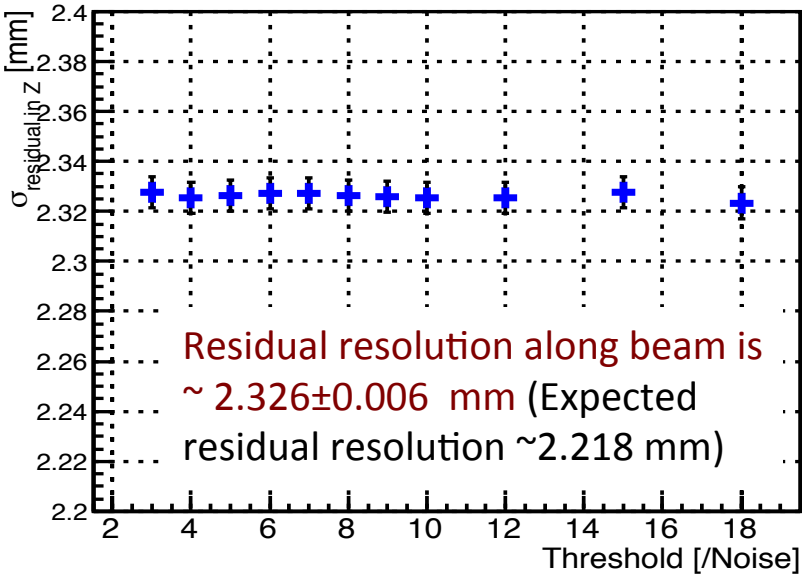
Layer 2: cluster S/N spectrum

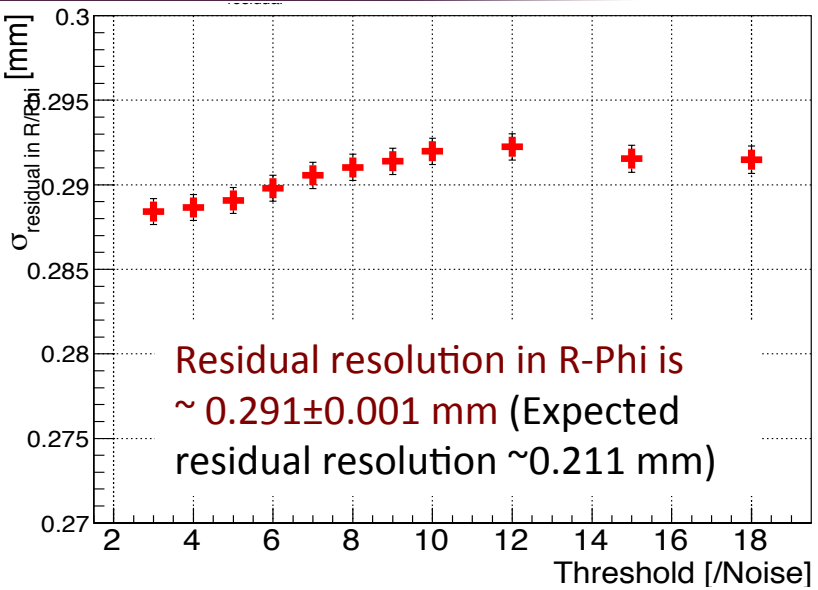


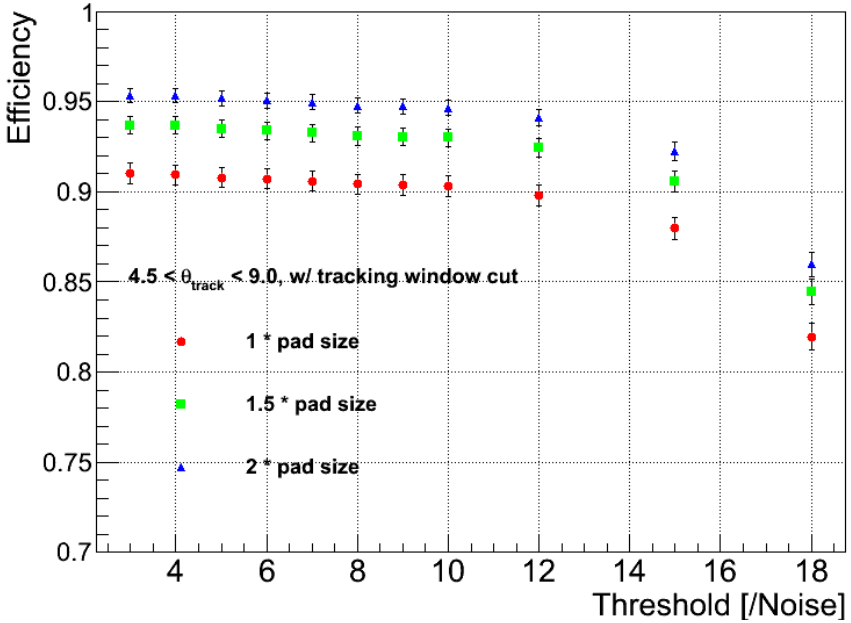


- MPV has a linear dependence on $\cos^{-1}\theta$ as expected
- After track angle correction, MPV vs. $\cos^{-1}\theta$ is not flat due to misalignment
- dE/dx resolution better than 10%

Prototype Performance – Residual & Tracking efficiency

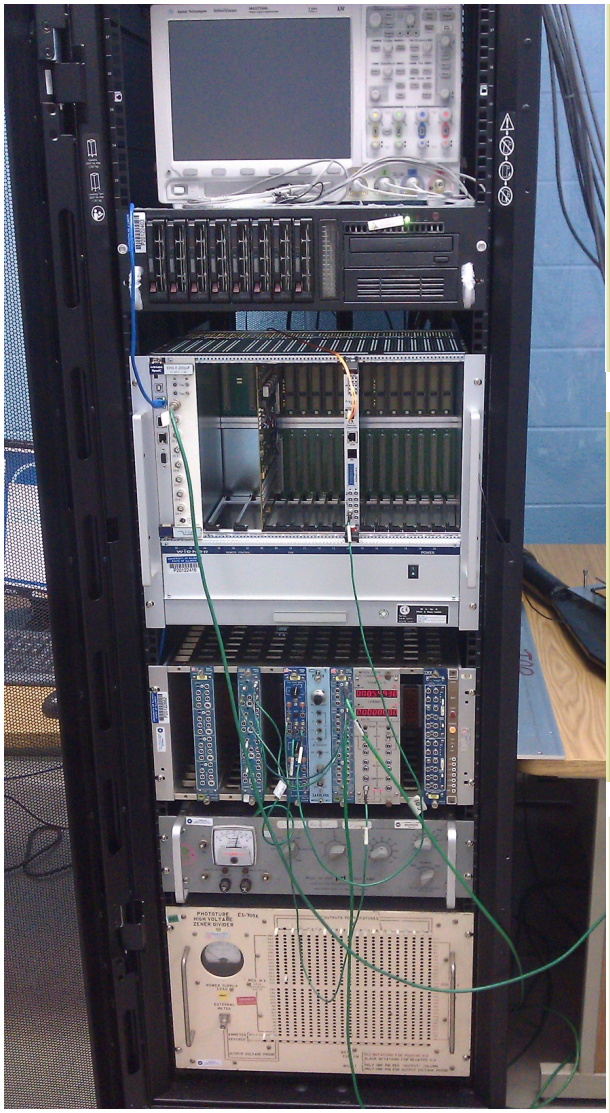




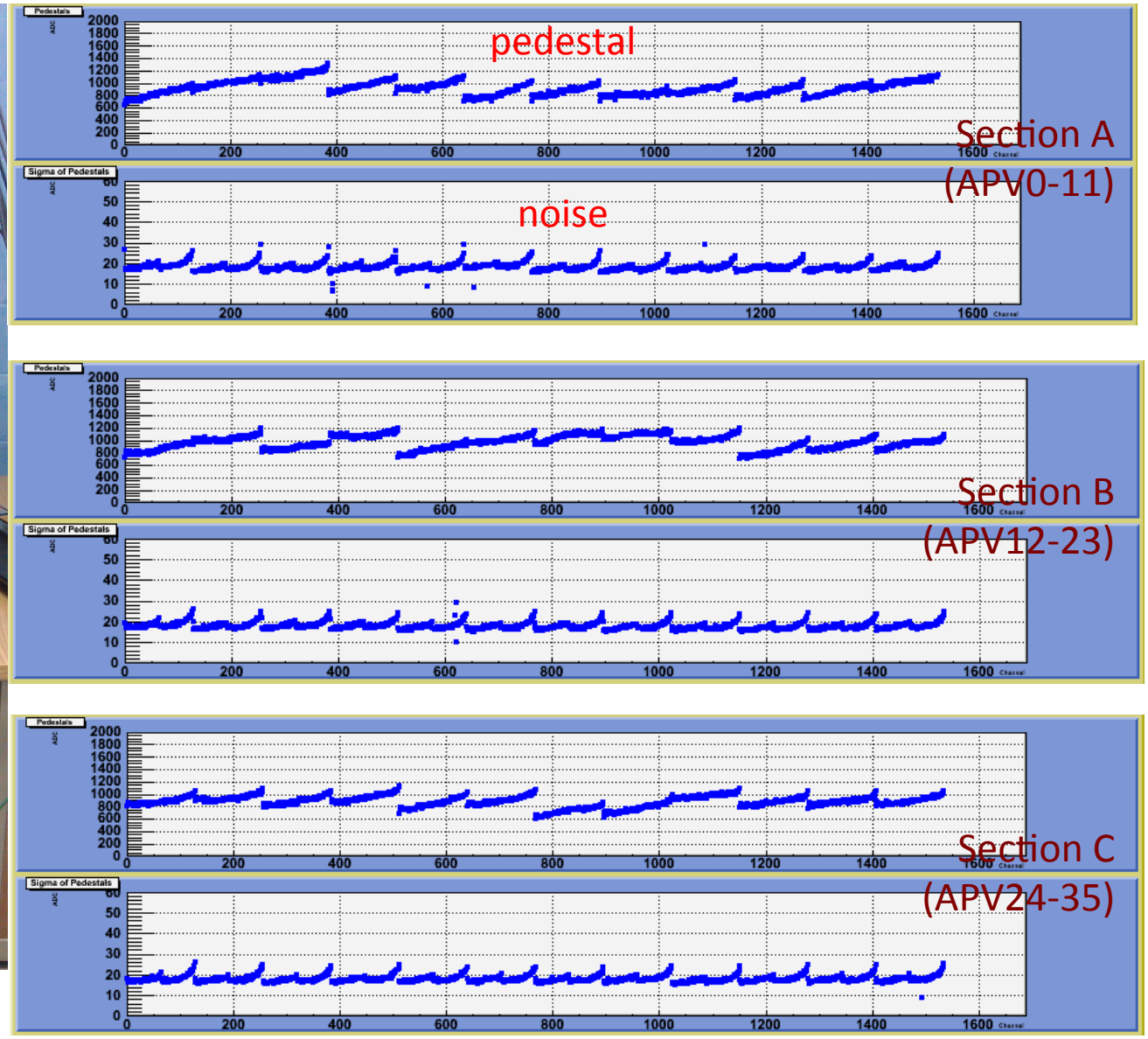


- Residual resolution increases vs threshold, close to expected values
- Efficiency decreases vs threshold, ~95% with 2 pad size tracking window cut

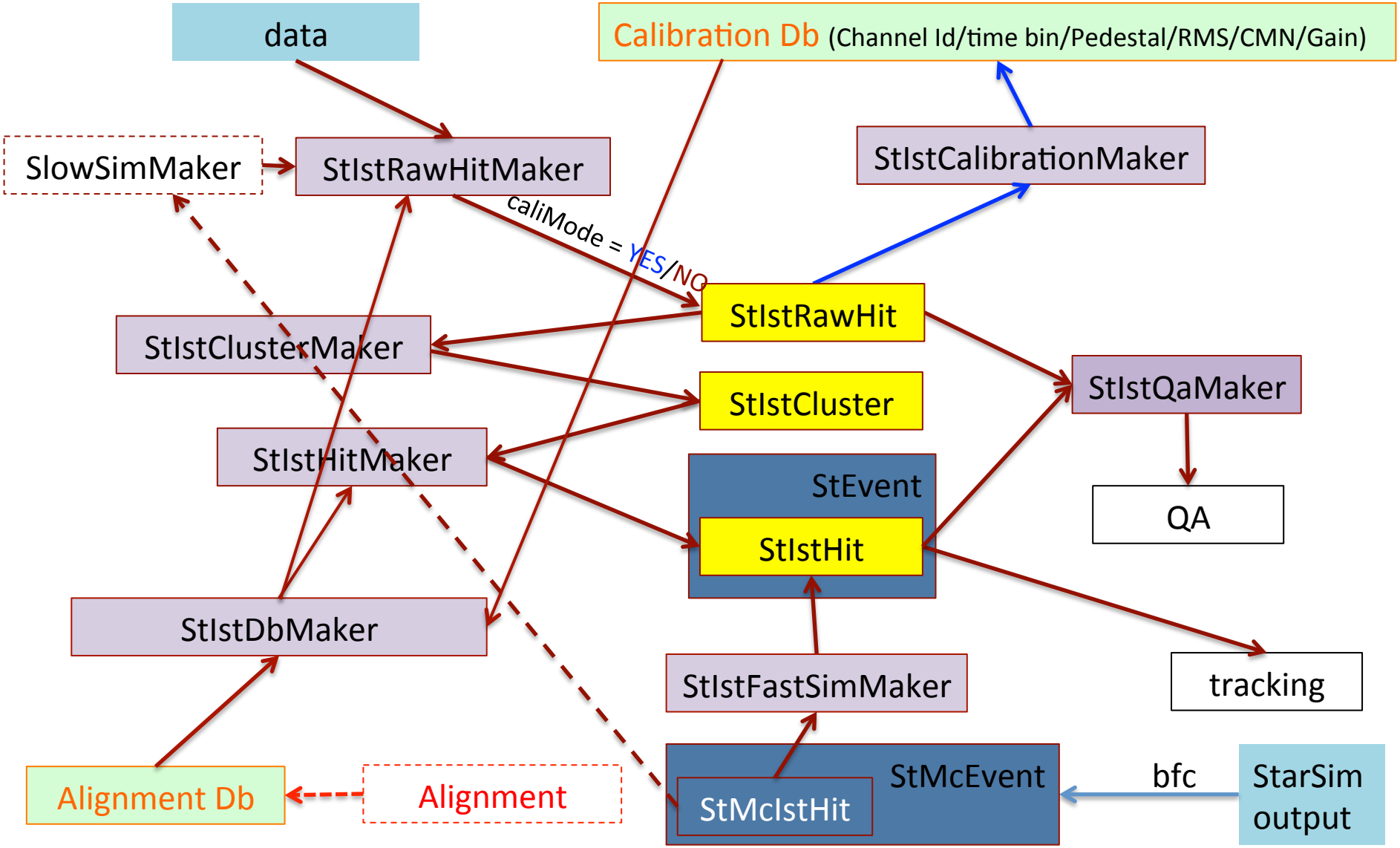
UIC Efforts on IST – Production testing



IST stave test stand



UIC Efforts on IST – Offline Software



UIC Efforts on IST – Offline Software

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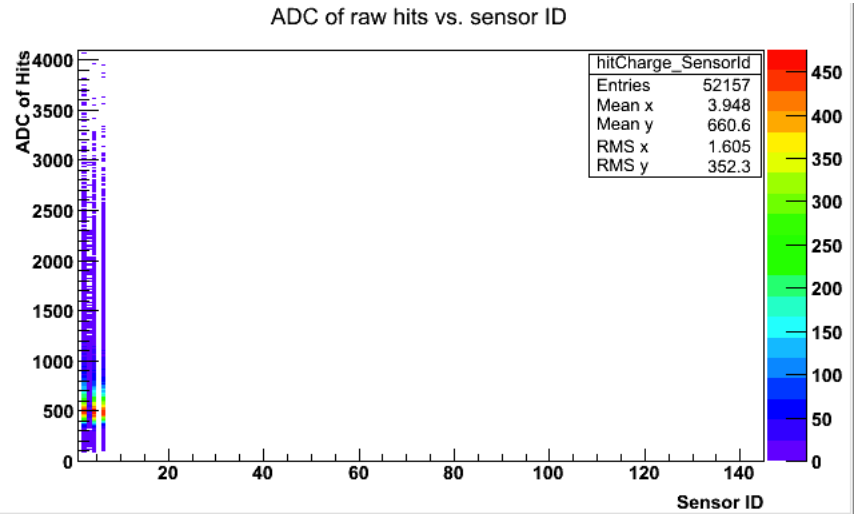
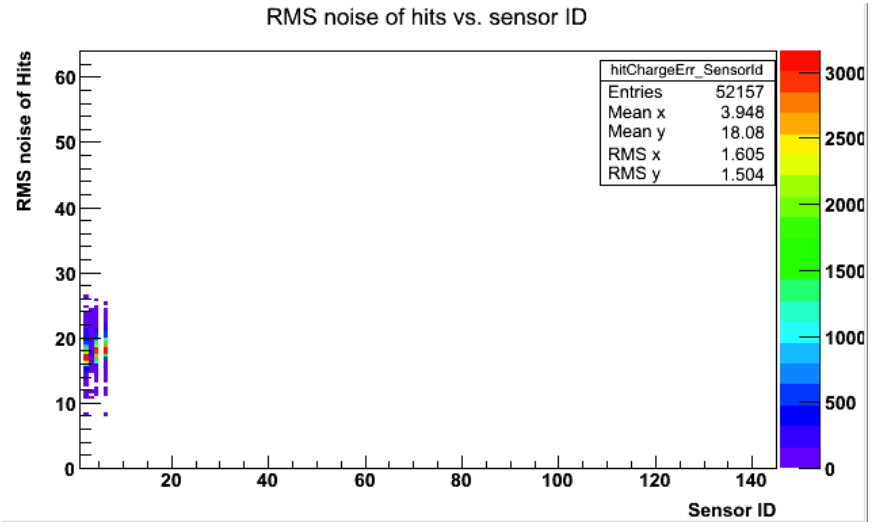
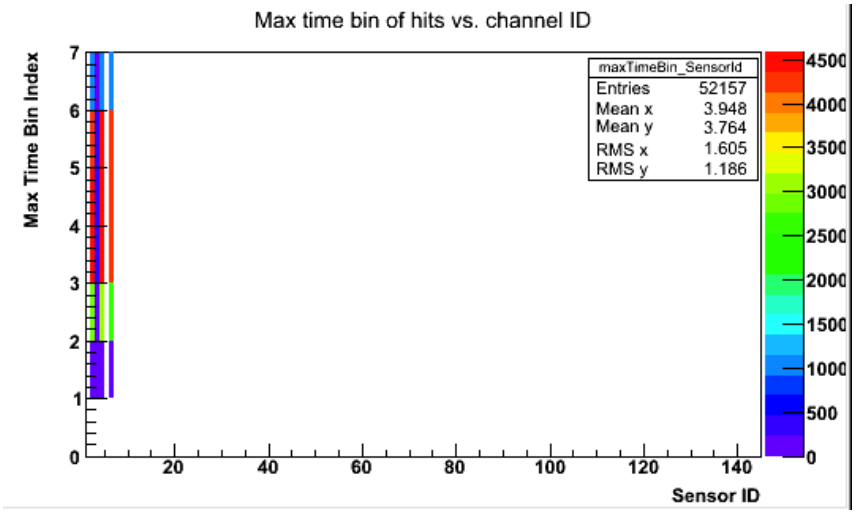
Hit ADC vs. sensor ID



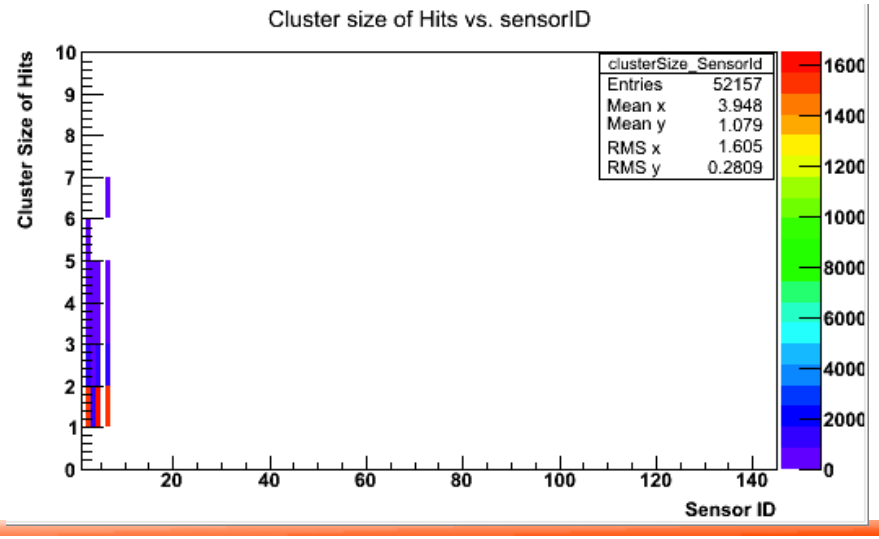
Hit RMS noise vs. sensor ID



Max ADC time bin vs. sensor ID



Cluster size vs. sensor ID



UIC Efforts on IST – Offline Software

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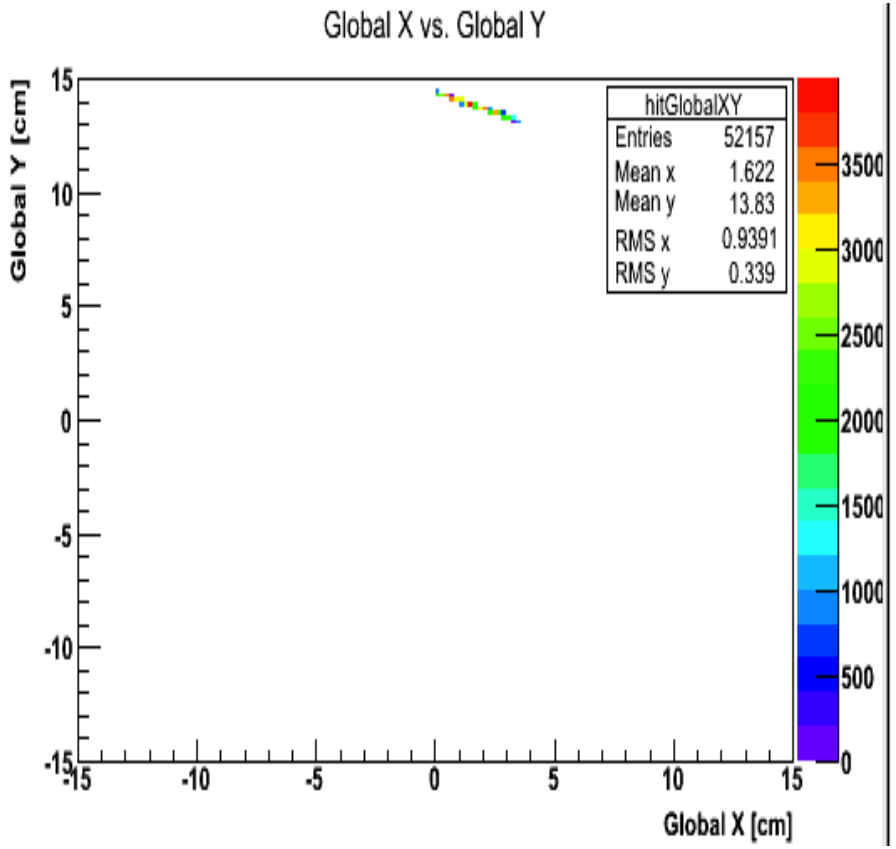
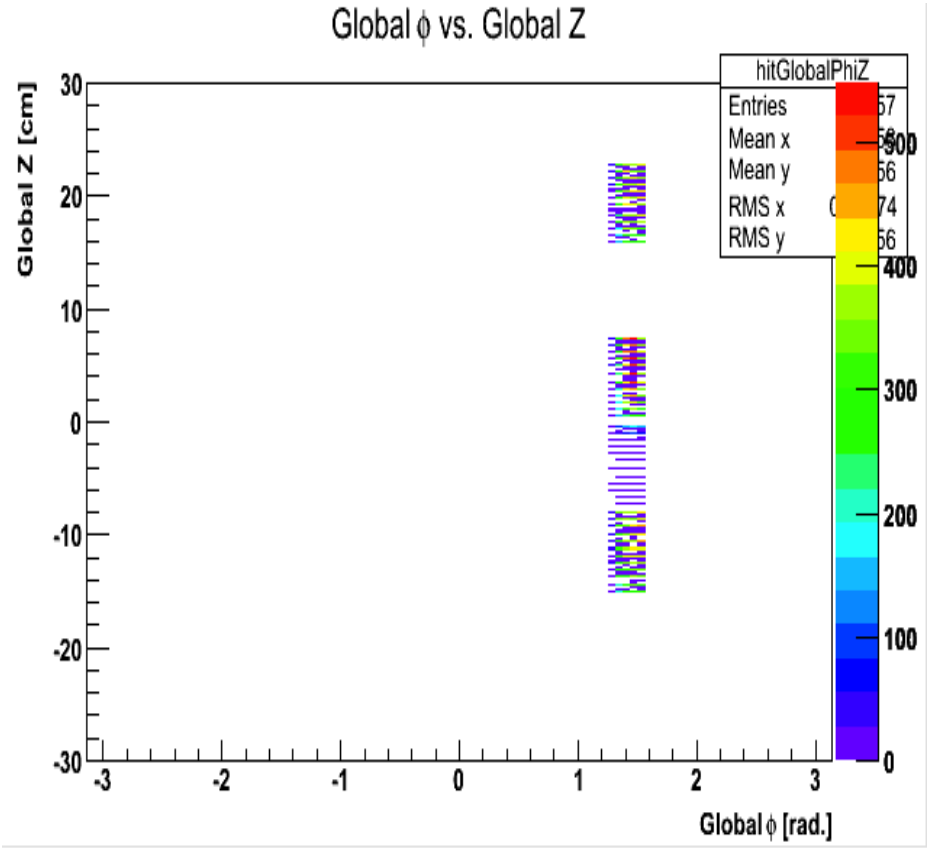
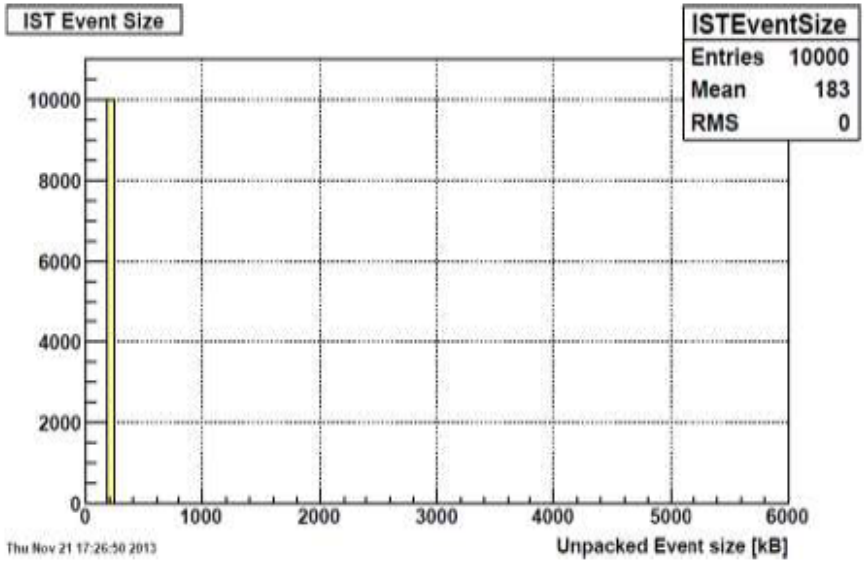
Global X vs. Y

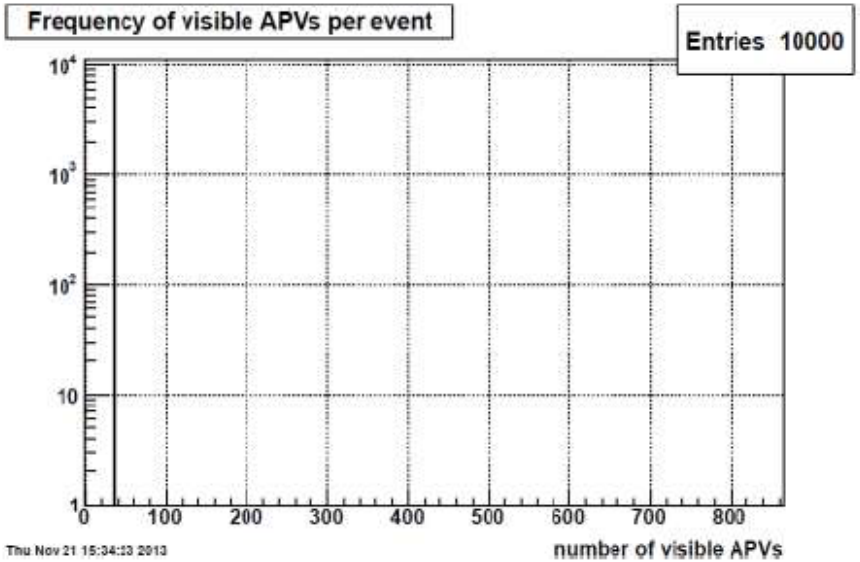


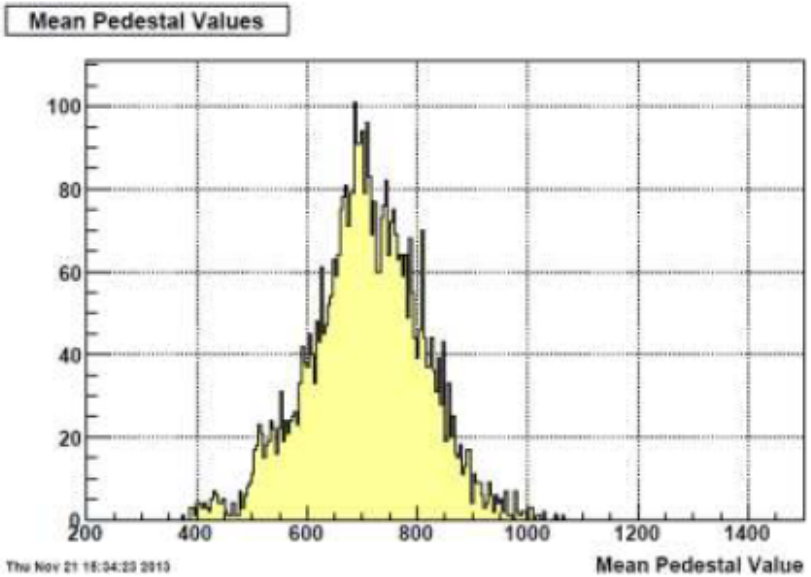
Global Z vs. ϕ

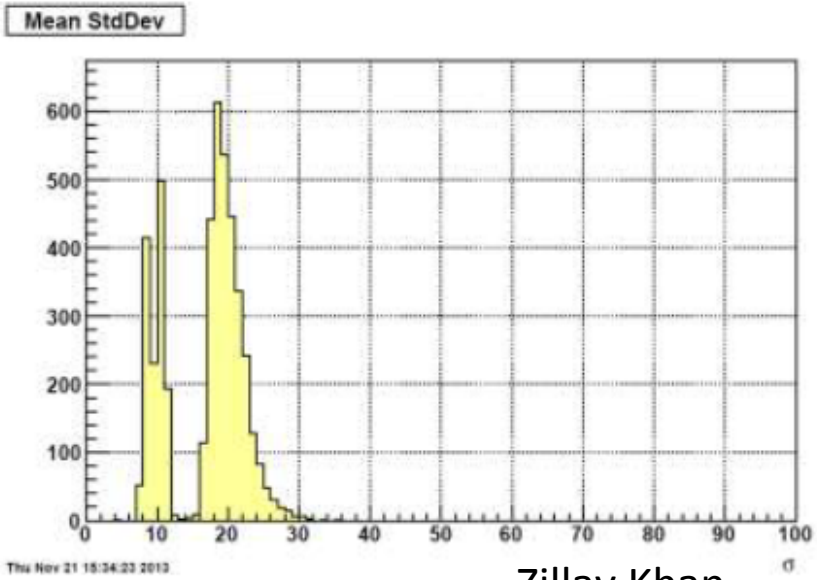


UIC Efforts on IST – Online Software





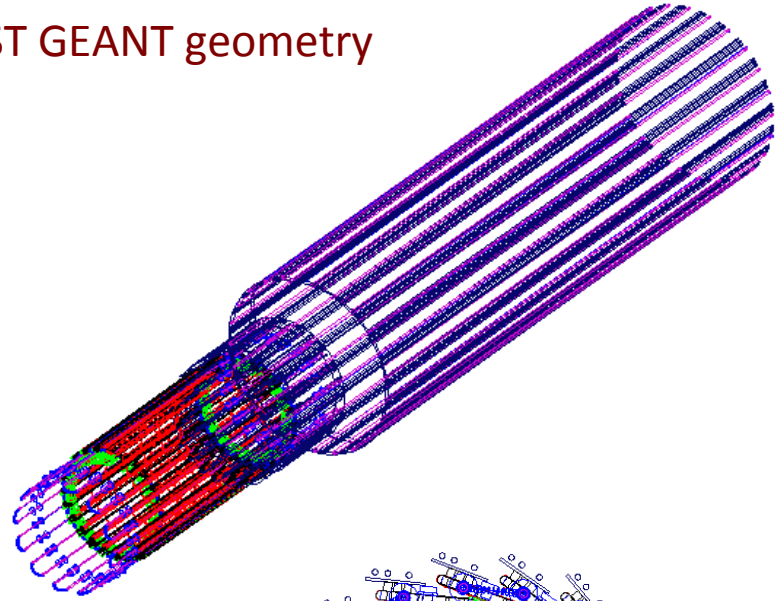


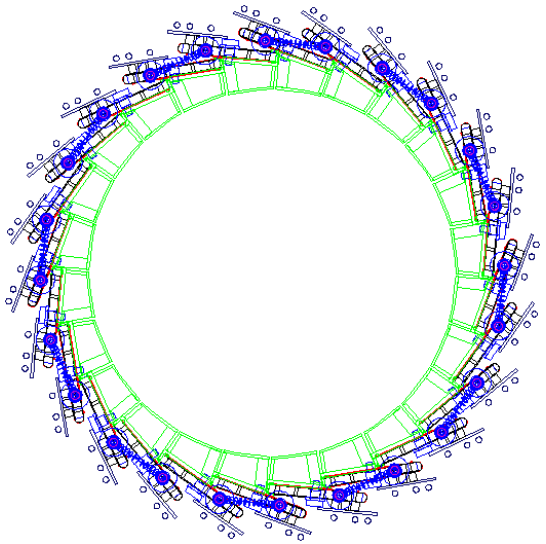


Zillay Khan

UIC Efforts on IST – Simulation

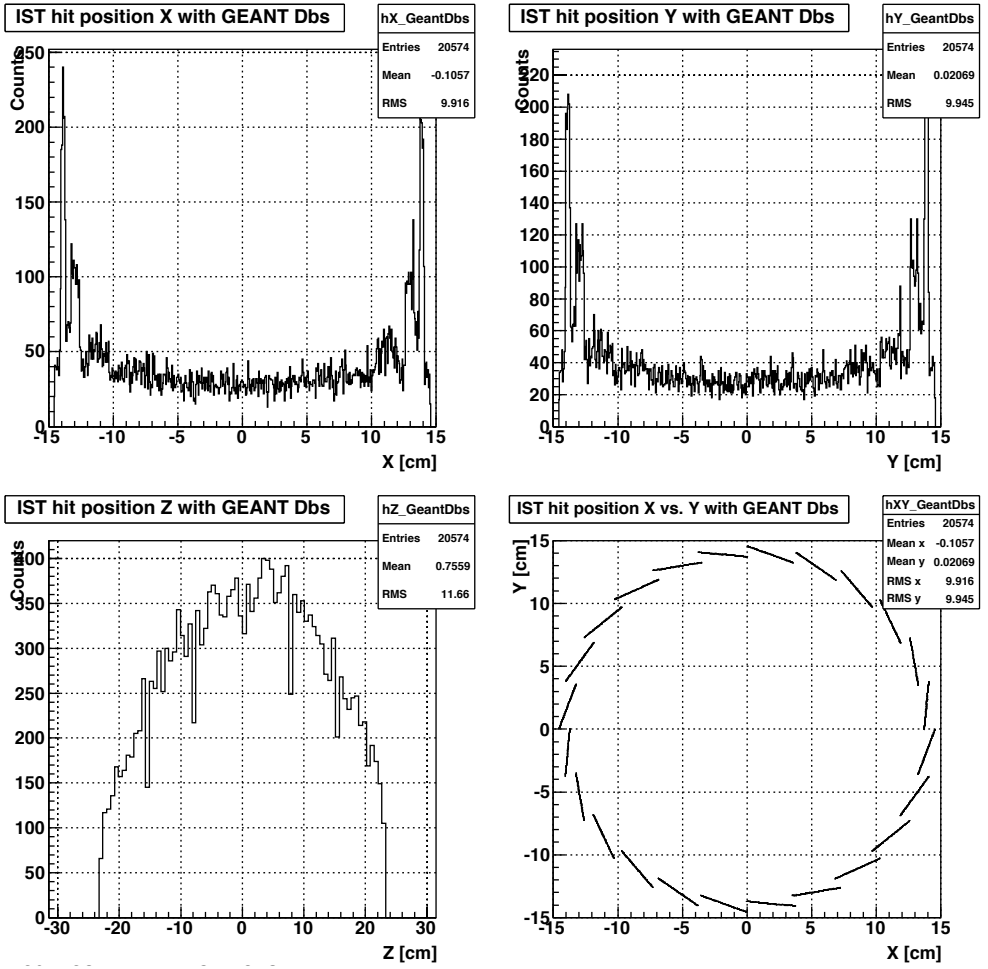
IST GEANT geometry



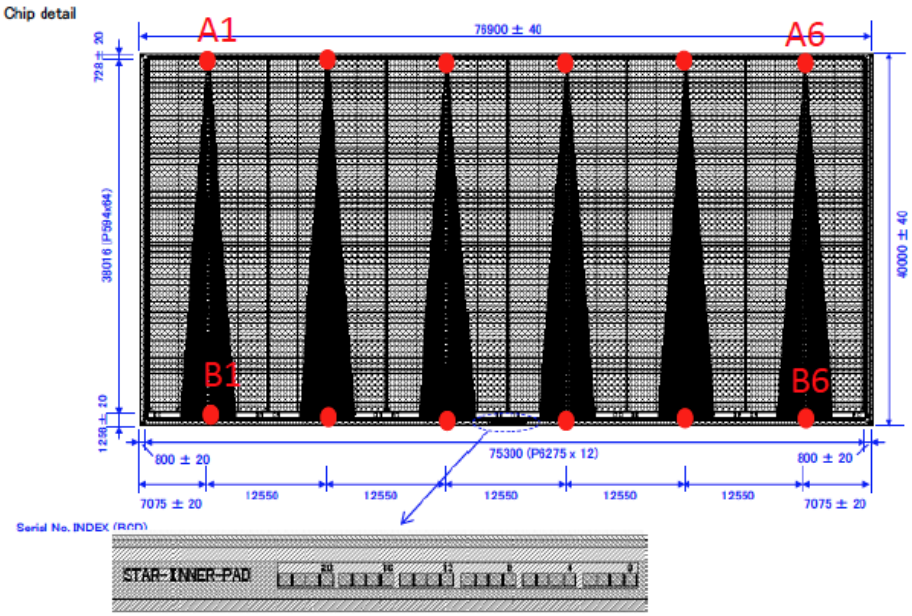


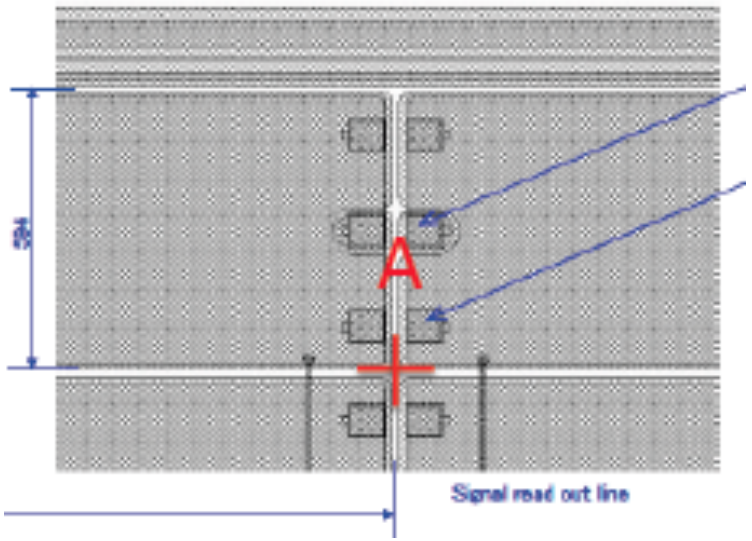
IST east/north view in STAR

IST hit global position (Fast simulation with Smearing on + GEANT Db tables)

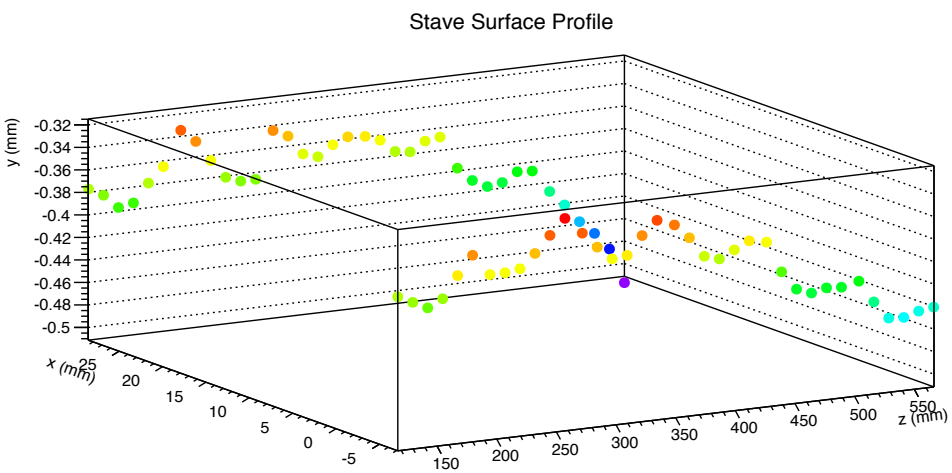


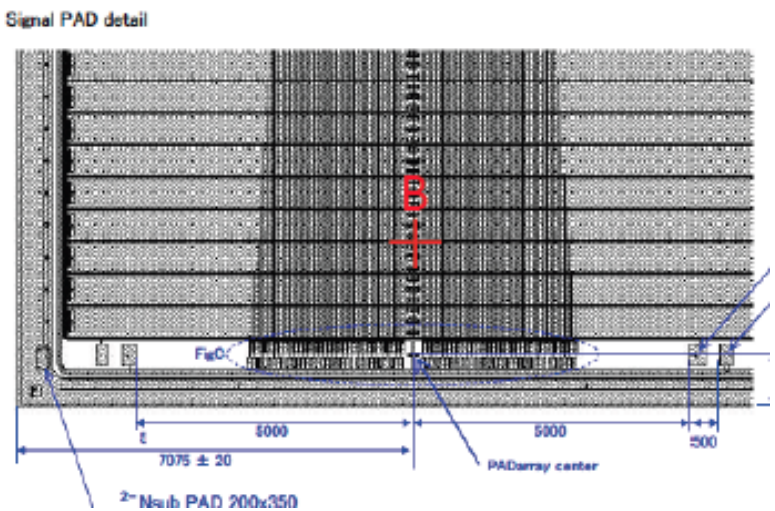
UIC Efforts on IST – Survey



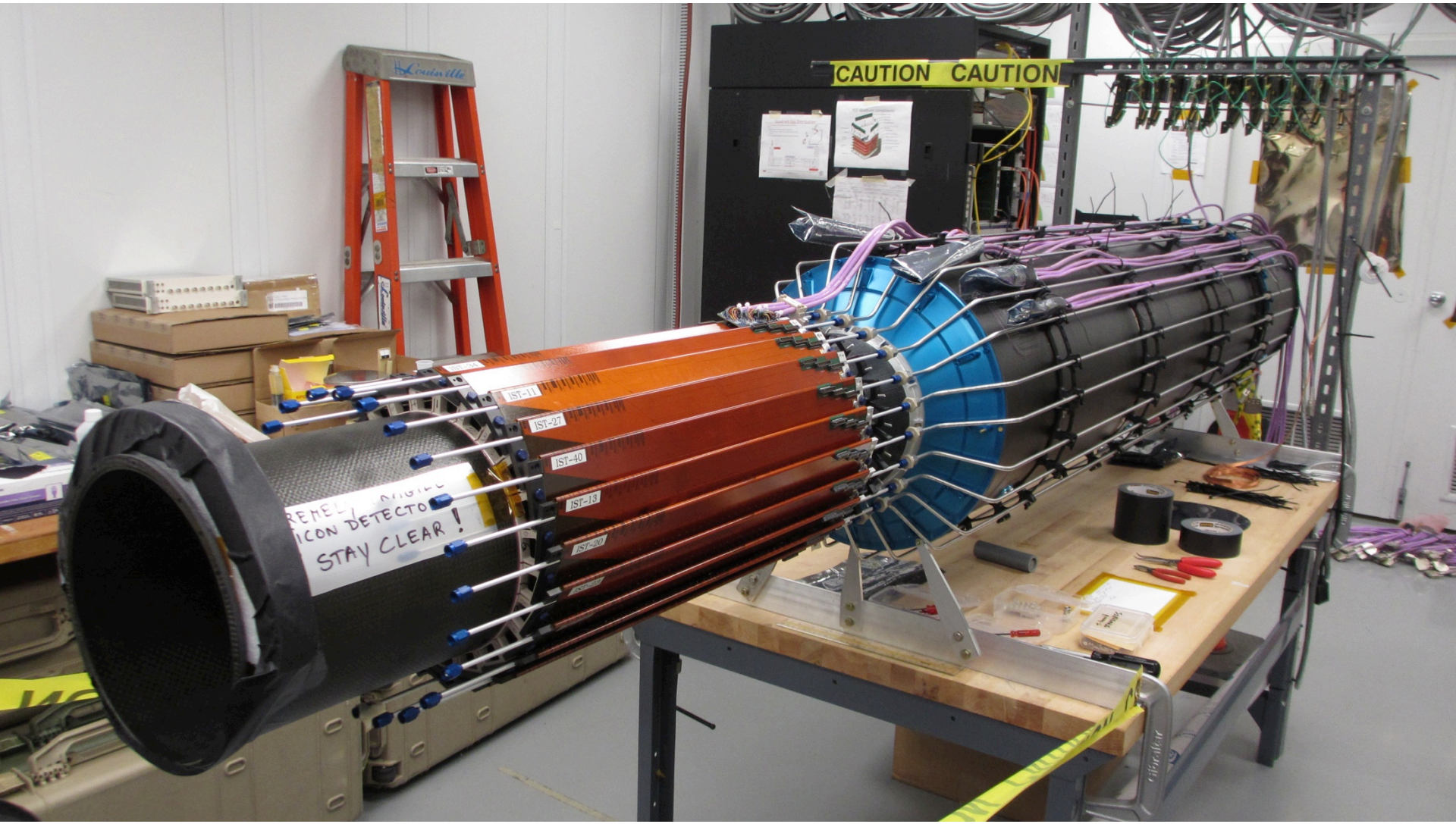


A1-A6, B1-B6: sensor alignment feature

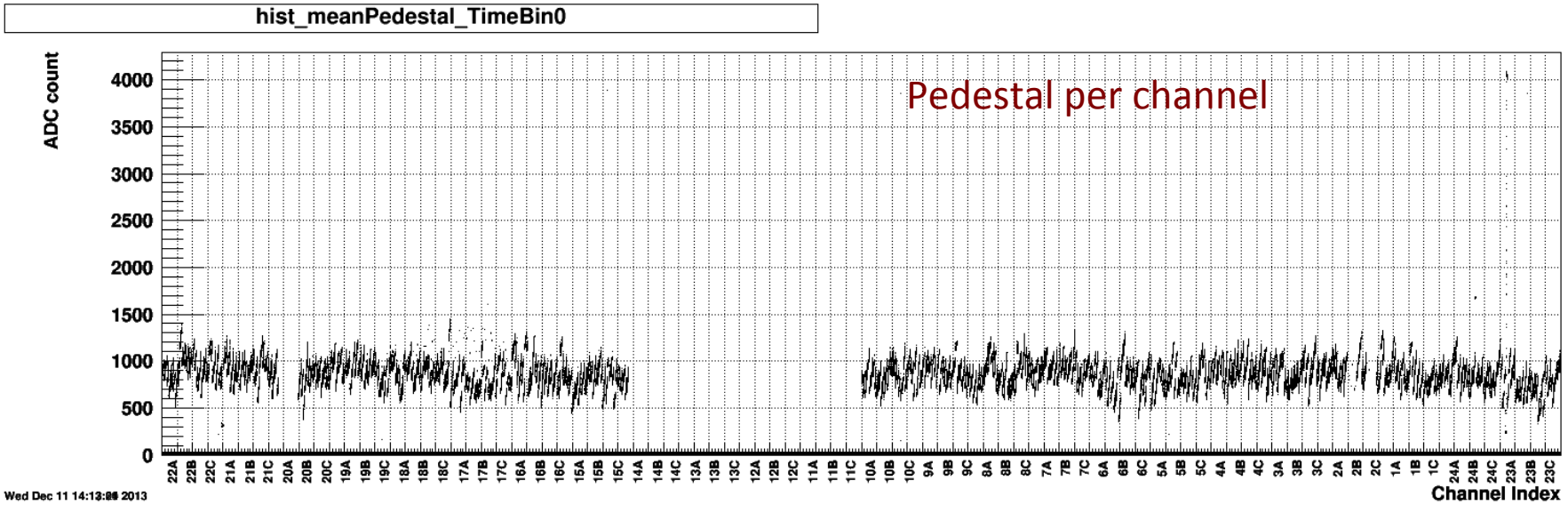


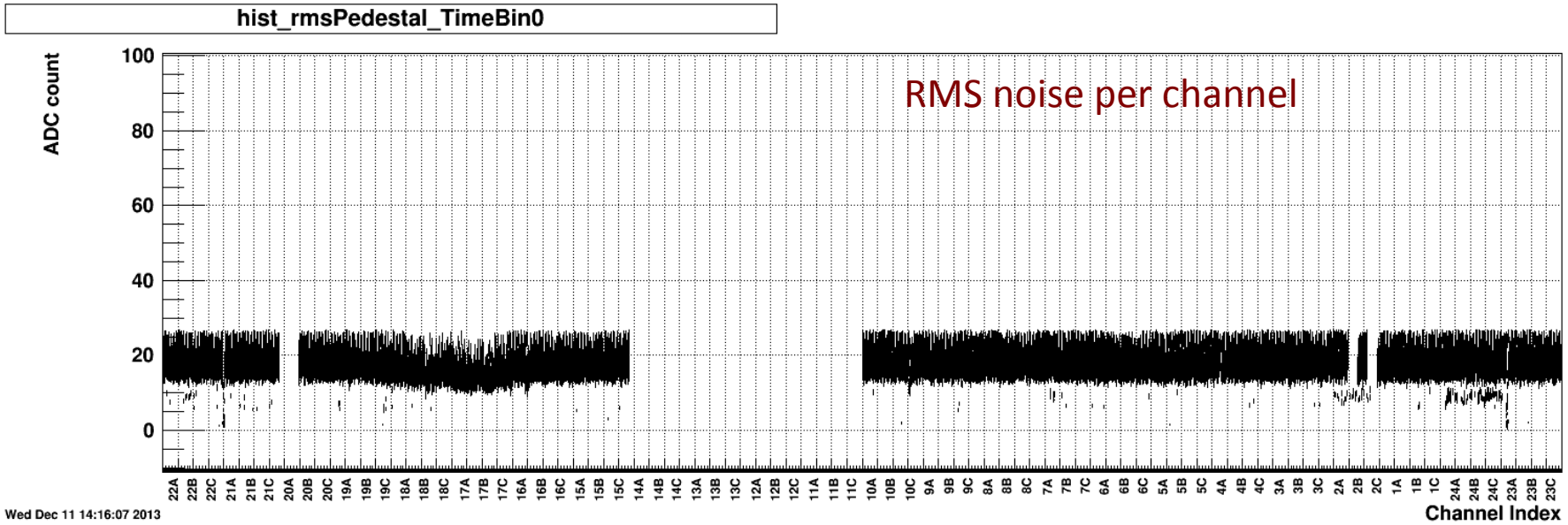


IST barrel assembly



UIC Efforts on IST – Commissioning





Conclusions

STAR HFT

- HFT is designed to enhance STAR's capability for heavy flavor studies.
- IST is a sub-detector system of the HFT:
  - Based on silicon micro-strip detector technology
  - Fast readout and reasonable position resolution
  - Performance of the IST prototypes meets our design goals
- IST software is mostly completed and has been submitted for review.
- IST have been rolled in STAR detector and behaviors in a reasonable good shape by full barrel readout testing.
- IST is ready for cosmic run in Jan. 2014 and following data taking.

Thanks!