10/24/13

Run13 commissioning status of the STAR HFT prototype

1. STAR HFT detector
2. Software status
3. Results of engineering run

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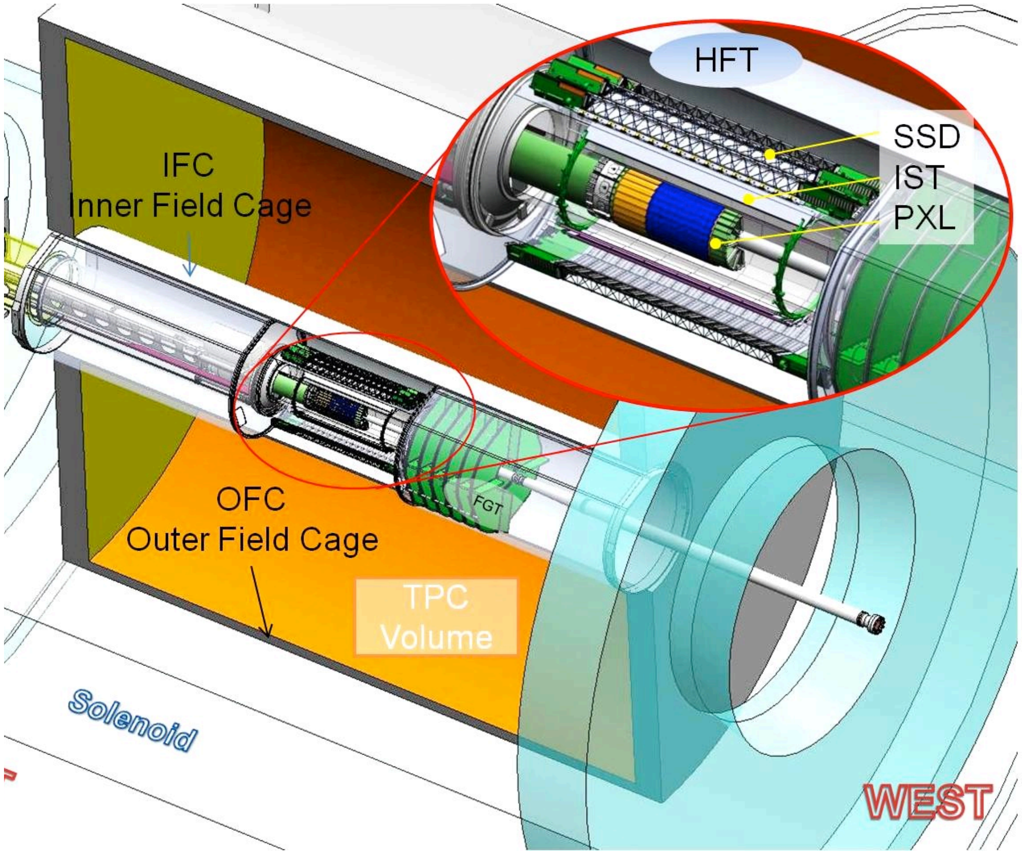
Kent State University

Detector design

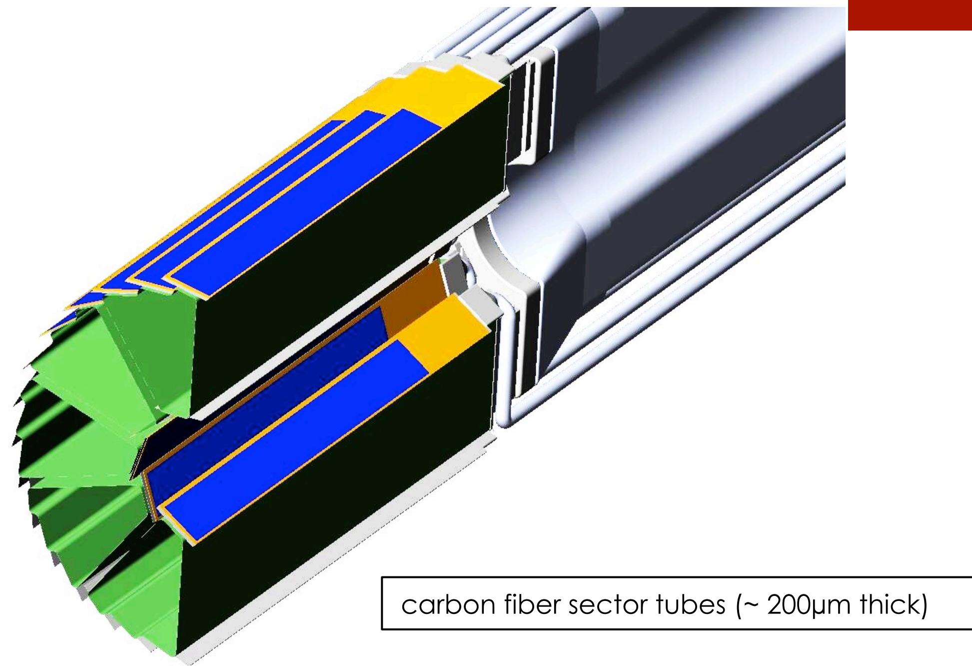


- STAR experiment@RHIC, BNL
- Heavy-quark hadron measurements (v_2, R_{AA})
- Direct topological reconstruction of decay vertex
- Outside-in tracking with graded resolution determines the requirements for the detector subsystems

subsystem	Radius [cm]	technology	Hit resolution : R/φ - Z [μm]	Thickness [% X_0]
SSD	22	Double sided silicon strips	20 - 740	1
IST	14	Silicon strips pad sensors	170 - 1700	<1.5
PXL	2.7 ; 8	Active pixels CMOS	12 – 12	0.4 per layer

PXL Specifications

- 2 layers arranged in 10 sectors
- Each sector has 4 ladders containing 10 sensors (2x2 cm^2) using Monolithic Active Pixel Sensor (MAPS) technology :
  - Low cost
  - Thin - 50 μm silicon
  - Small pixels, high resolution
  - Fast readout



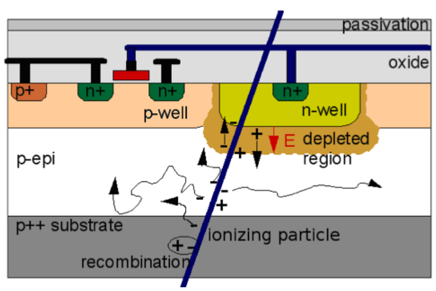
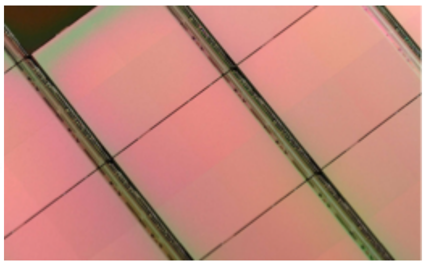
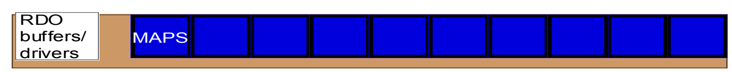


Fig. 1. MAPS principle of operation: electrons created in the epitaxial layer thermally diffuse towards low potential n-well region. A small contribution to the total signal also exists from electrons created in the p++ substrate.





Pixel size : 20.7x20.7 μm^2

Chip size : 20.22 x 22.71 mm^2

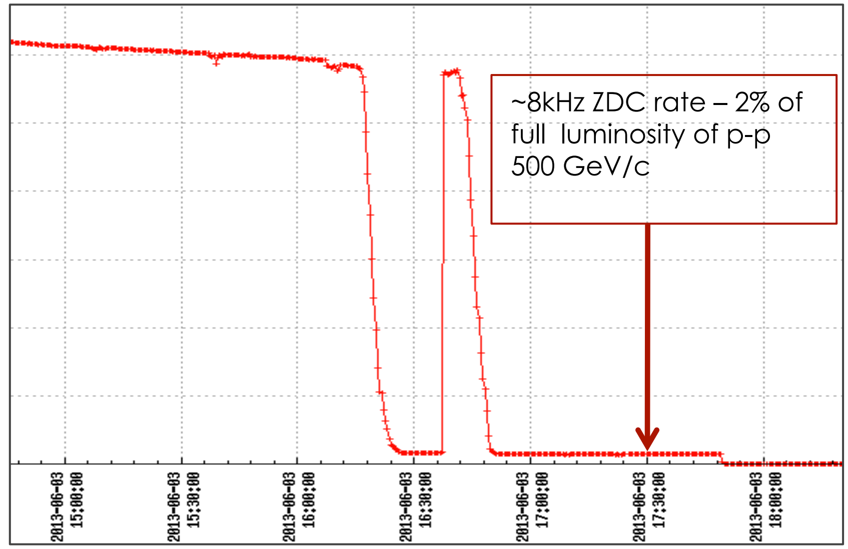
Ladder ~2x10 cm^2

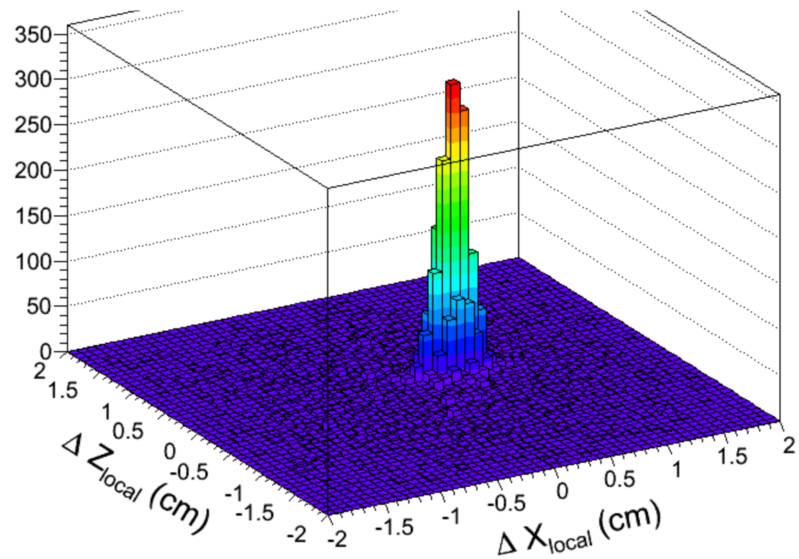
Specific engineering goals

- RHIC Run-13 including PXL detector : May,8th until June,16th
- Test PXL system (3/10 sectors) in beam conditions before deployment of full system
- **ONLINE GOALS** :
  - Test full insertion mechanism
  - Test powering, trigger, readout (sensor threshold tuning), cooling performance
  - Integrate it with the STAR DAQ and Trigger system
  - Explore many configurations/settings to optimize response and identify problems
- **OFFLINE GOALS** :
  - Offline/reconstruction chain development/testing
  - Calibration/Alignment code/procedures development/testing
  - Estimates of efficiency, pointing resolutions

Engineering run

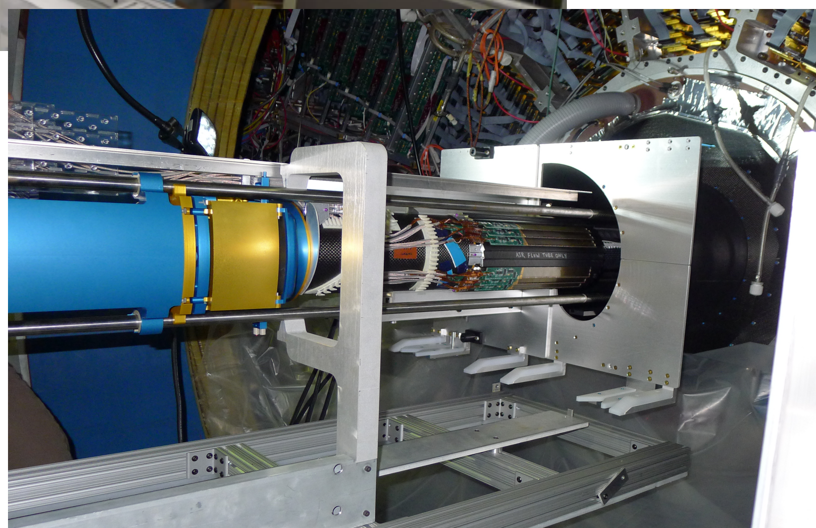
- 510 GeV p+p, mostly in special low-luminosity runs to reduce pileup
- ~ 2% of nominal luminosity
- High multiplicity p+p events selected within PXL acceptance
- Took ~10M events for analysis
- Matching between TPC and PXL hits as expected
  - Low random associations means low background rate in the detector



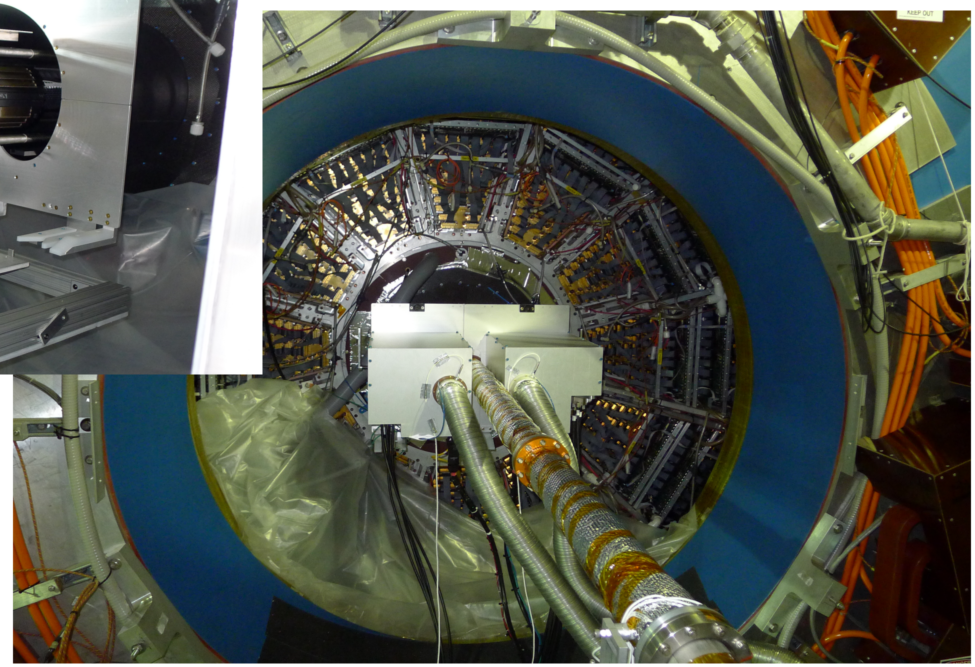


PXL Insertion in STAR

- A PXL prototype : 3 full sectors of functional sensors over the 2 detector halves

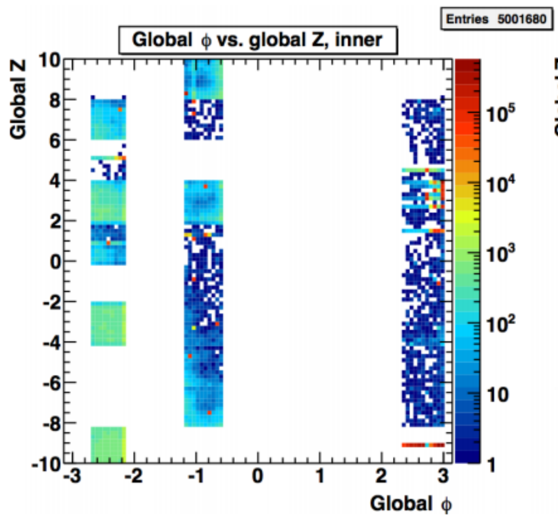


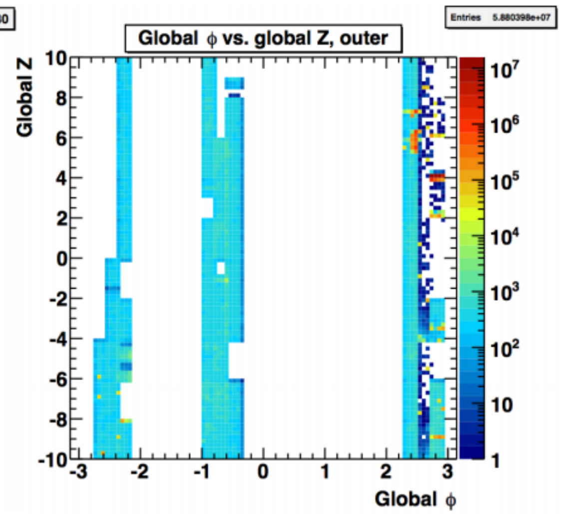
- Right-side insertion

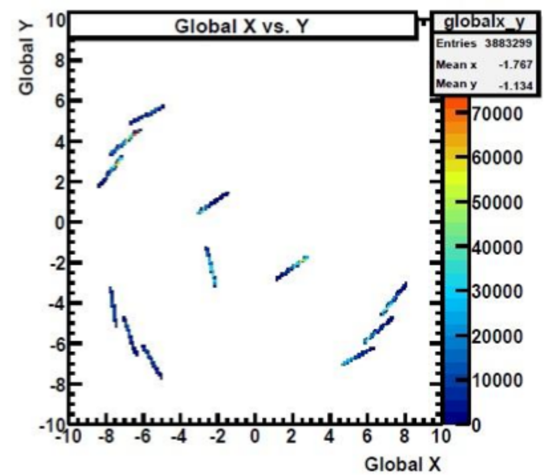


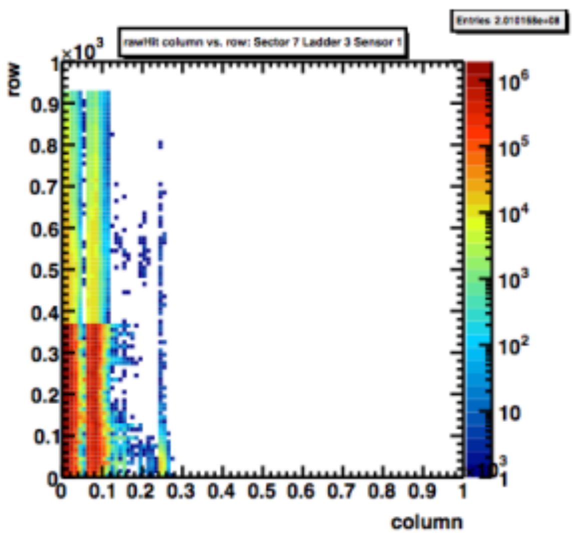
- Successfully inserted in STAR, cabled and powered in 16hours-stop of beam activities

Offline QA histograms



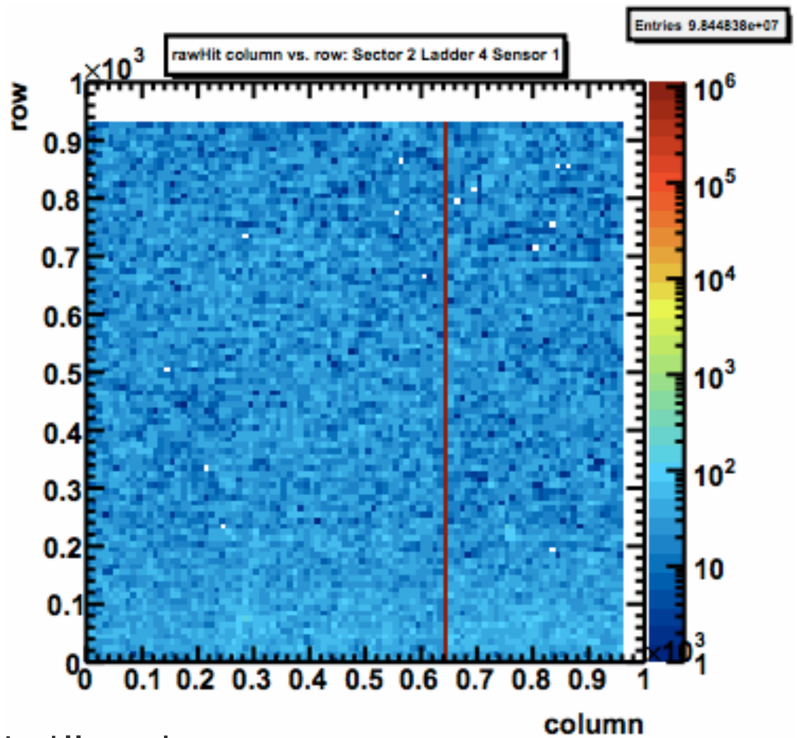




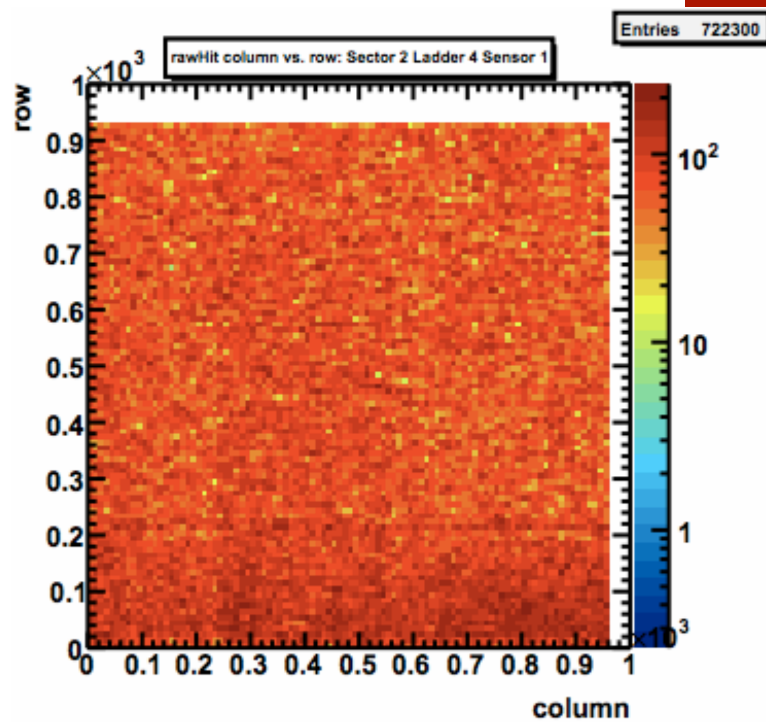


- Histograms created during offline reconstruction :
  - global azimuth Φ vs. global Z for inner and outer ladders
  - status of sensor : column vs. row
- The offline QA software have to provide the basic performance information of the PXL

Calibration : "hot" pixels



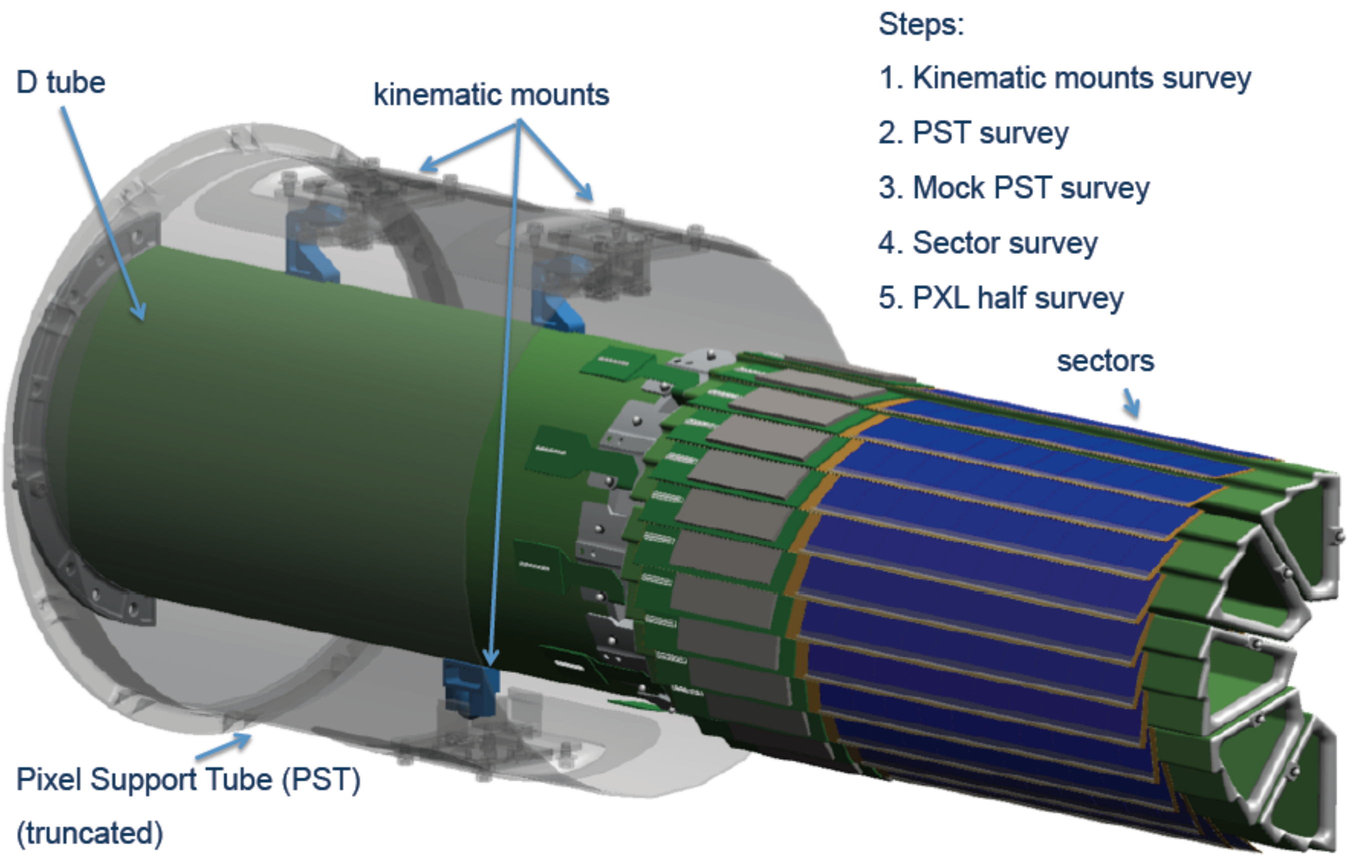
"Hot" column
(due to threshold not set properly)



Same sensor after masking

- Goal of masking individual pixel is to provide clean signal for alignment and to ensure quality of data

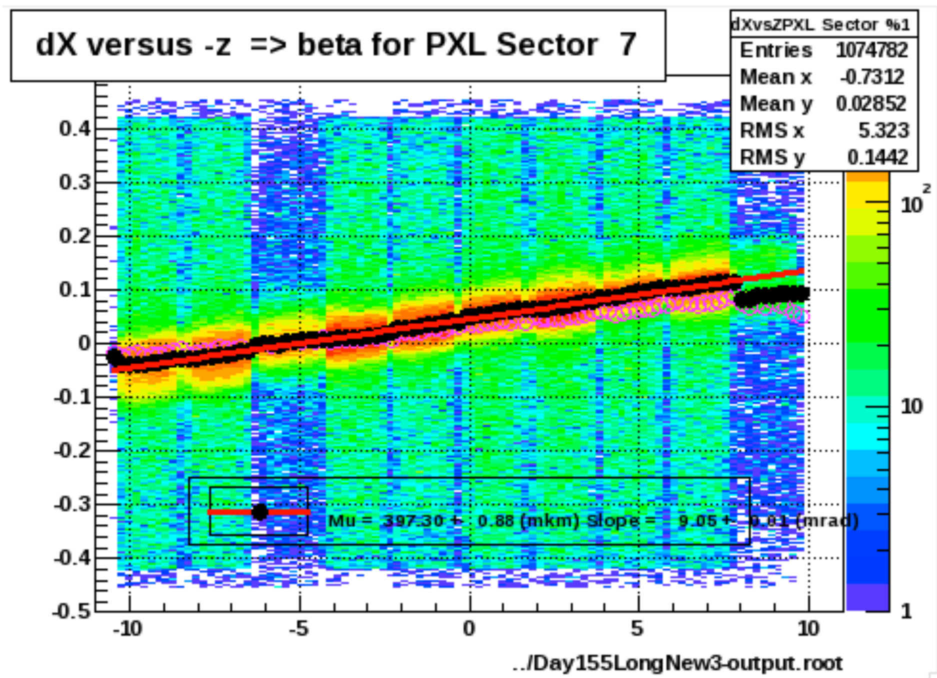
Overall PXL survey plan

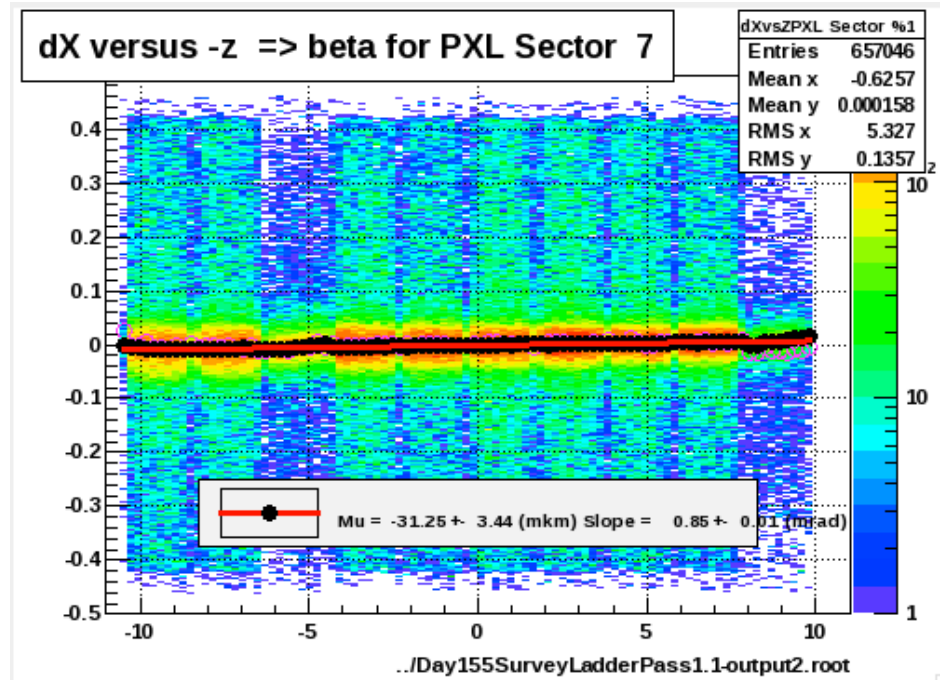


- The goal of the survey is to use the potential of the **PXL precision** by measuring any deviation for each pixel sensor from their designed position

- A Coordinate Measuring Machine (CMM) is used for sector survey by measuring the positions of kinematic mounts (PXL support Tube), tooling balls (sector), features (chip) using either visual and stylus probe with μm level precision

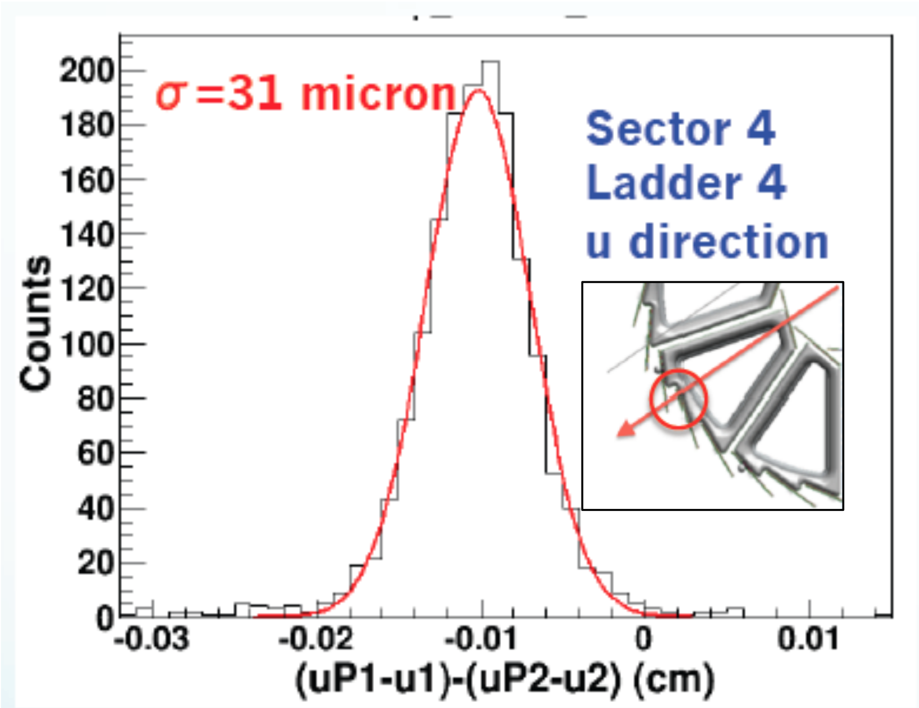
Calibration : global alignment



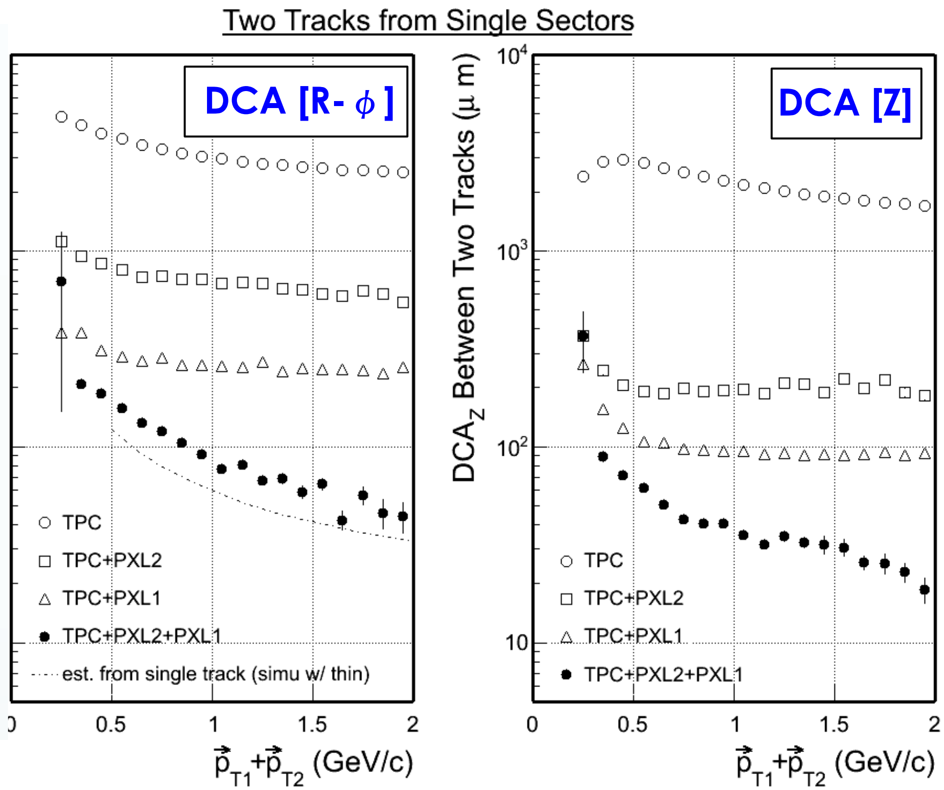


- Iterative alignment procedure :
  - misalignment parameters have been calculated as slopes of straight line fits to histograms of the most probable deviations versus the corresponding derivative matrix component (*"Sensor Alignment by Tracks", V.Karimaki et al.,CMS CR-2004/009, CHEP 2003*)
- More in Long Ma's talk : CG.00007 : *"Calibration/Survey/Alignment studies of STAR HFT Pixel"*

Run-13 PIXEL Prototype results



- Track analysis in overlapping active PXL areas allowed **a first estimation of intrinsic detector resolution**
- The resulted resolution (including all Pt tracks) is = 31/√2~ 22 μm



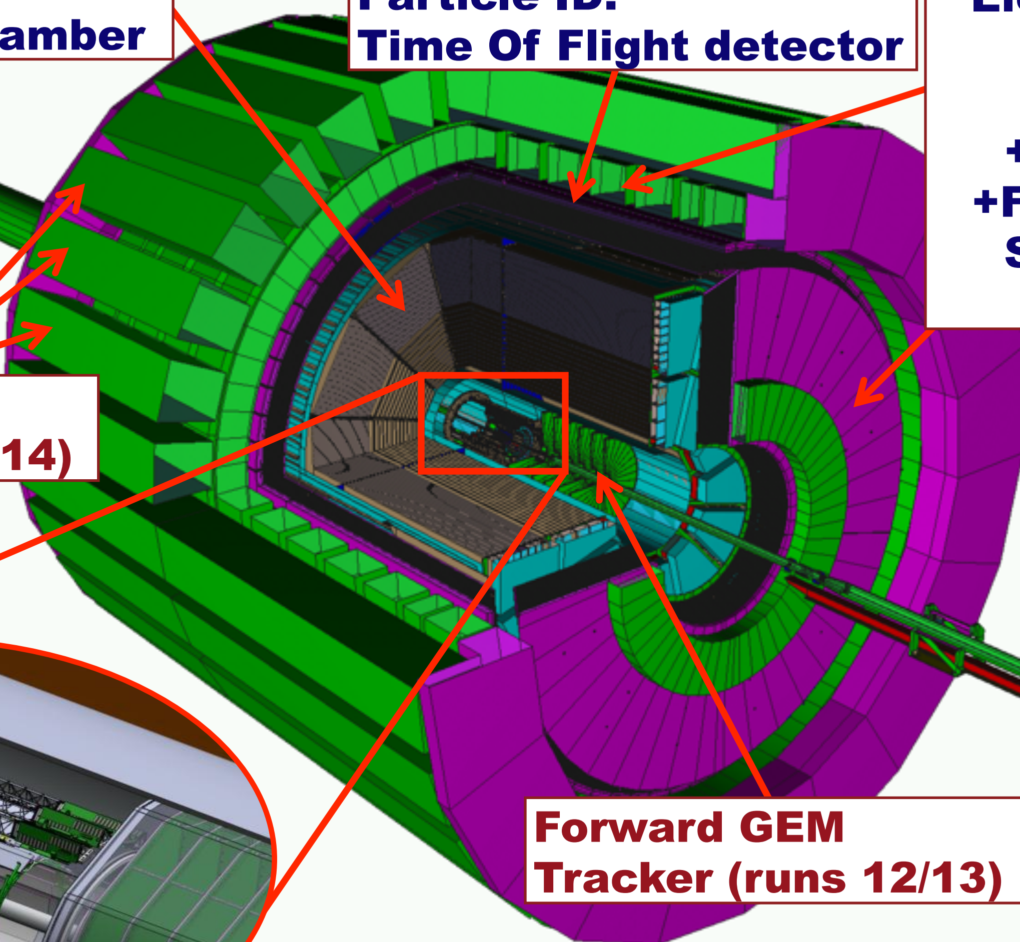
- Two track DCA analysis gives first estimate of PXL pointing accuracy
- The result is close to expectations

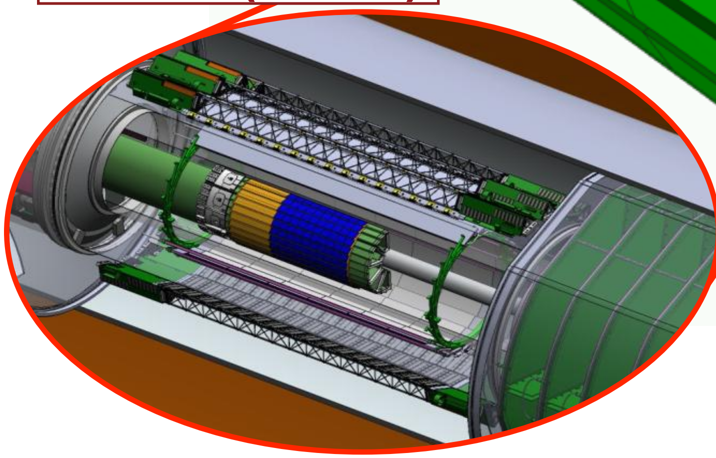
Summary

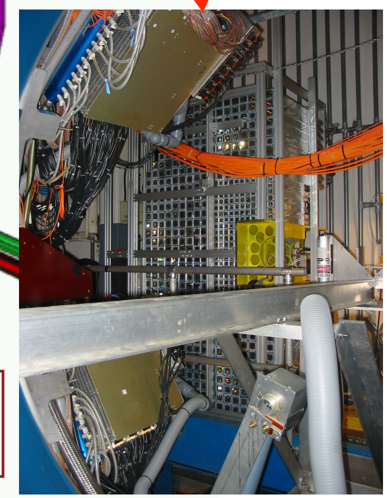
- A successful engineering run with the prototype PXL detector with 3 sectors took place May-June 2013. This allowed for:
  - Integration of PXL readout and slow controls with STAR DAQ and Trigger system
  - Verification of performance, noise levels, thresholds, cooling during pp-500 running
  - Special low-luminosity runs were taken which allowed for ~12M events that is being used for analysis
- Installation of the full HFT (all PXL sectors + IST + SSD subsystems) during the fall for RHIC Run-14

end

STAR DETECTOR

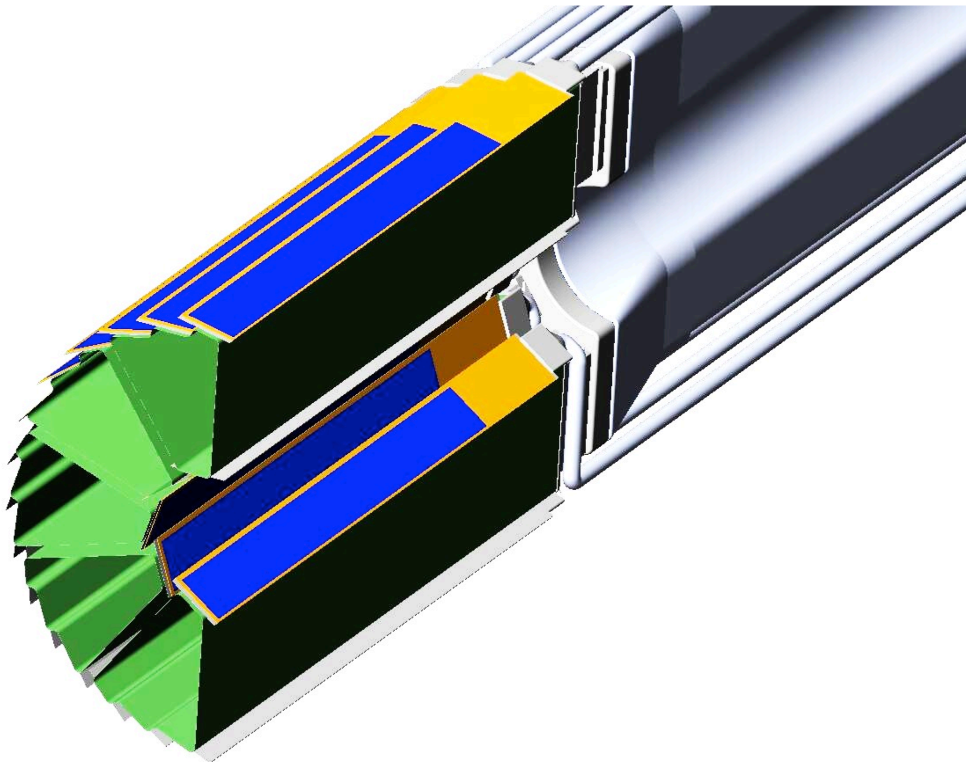






- Full azimuthal particle identification at middle rapidity

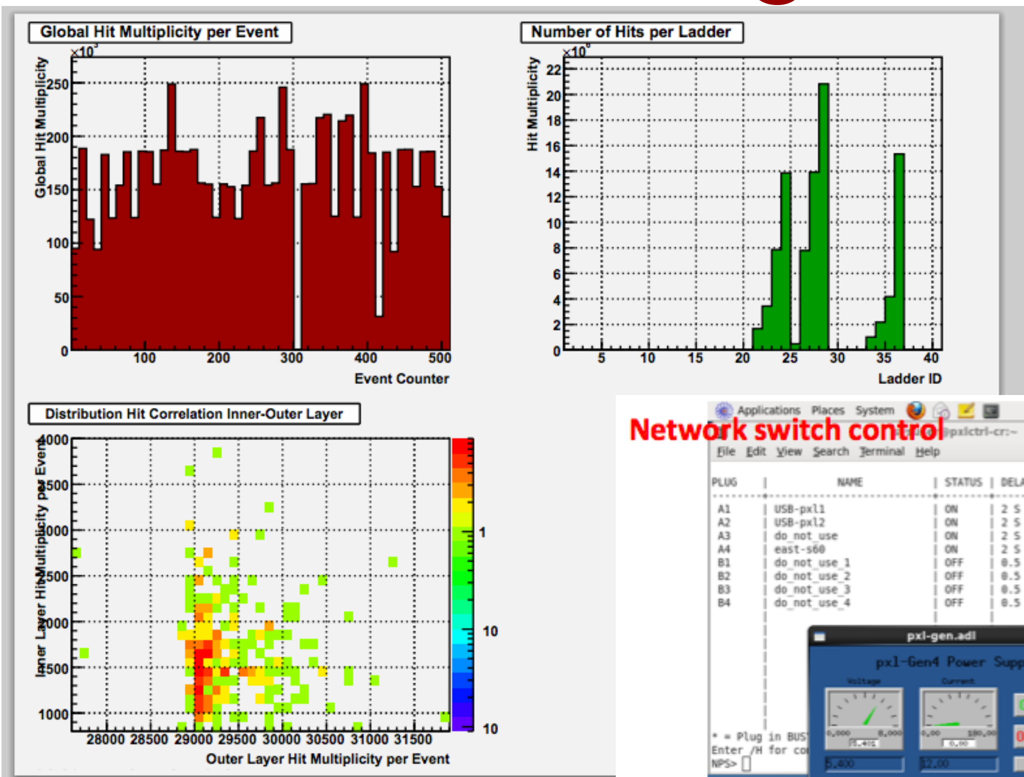
PXL specification

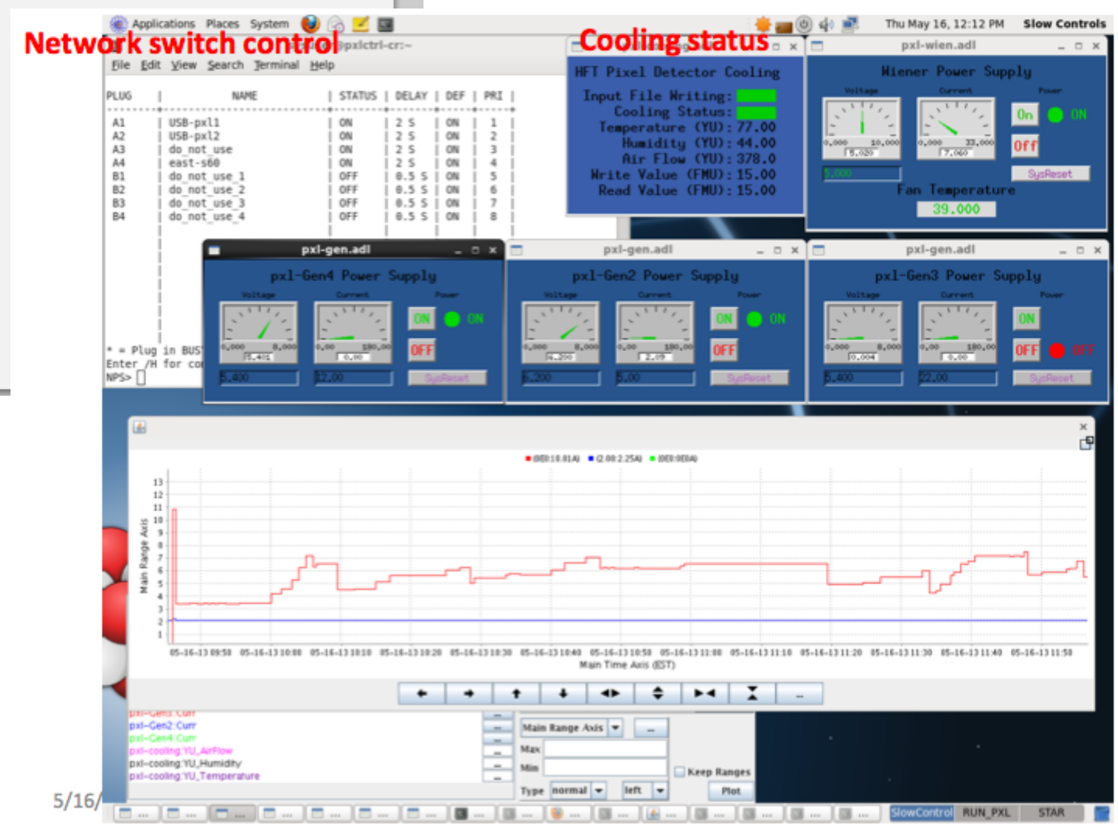


- 2 layers arranged in 10 sectors
- Each sector has 4 ladders containing 10 sensors (2x2 cm^2) using Monolithic Active Pixel Sensor (MAPS) technology

Pointing resolution	(12 ⊕19 GeV/c) μm
layers	Layer 1 at 2.7 cm radius Layer 2 at 8 cm radius
Pixel size	20.7 x 20.7 μm^2
Hit resolution	6 μm
Position stability	6 μm rms (20 μm envelope)
Radiation length per layer	$x/X_0 = 0.37\%$
Number of pixels	356M
Total sensitive area	0.15m^2
Frame integration time	185.6 μs
Radiation environment	20 to 90 kRad/year (or) $2*10^{11}$ to 10^{12} MeV n eq/ cm2
Rapid replacement	< 1day

ONLINE QA histograms & monitoring



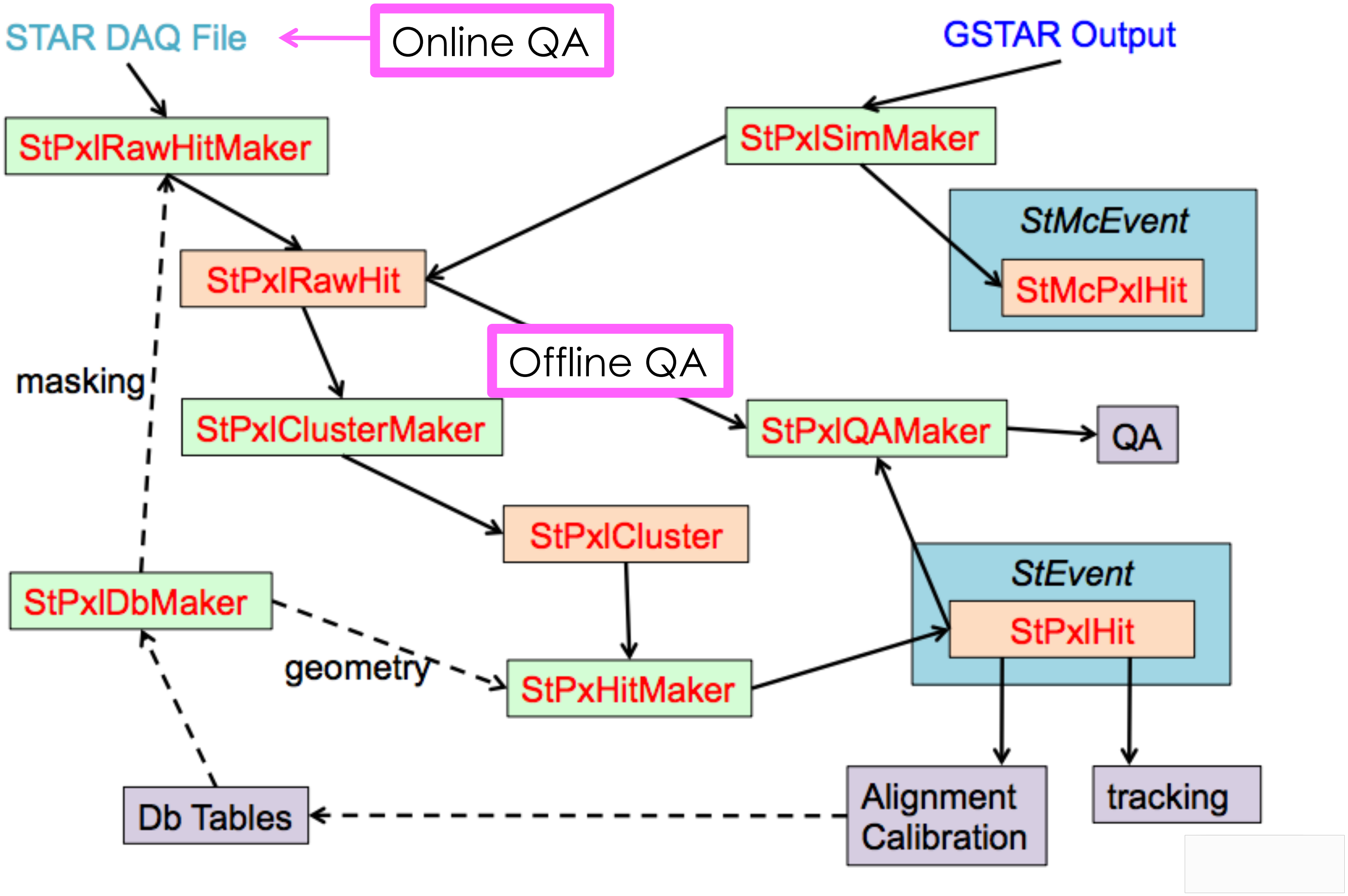


PS control

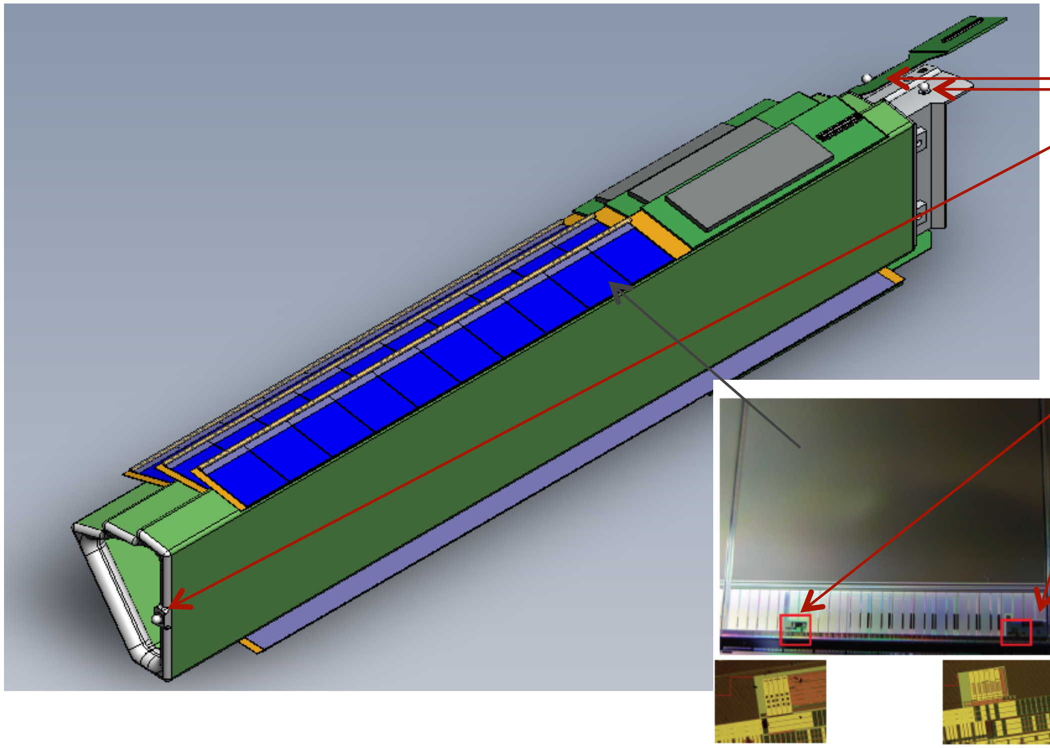
PS/Cooling archive

- Histograms generated during data acquisition (real time) to control the status of the detector

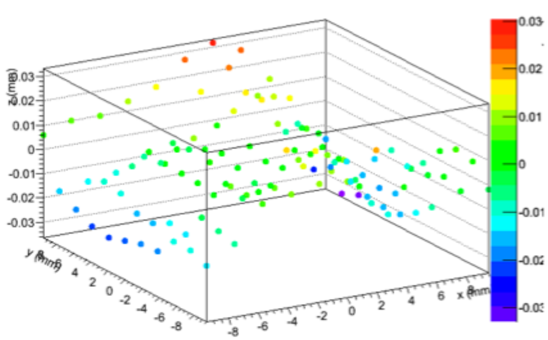
PXL DATA RECONSTRUCTION

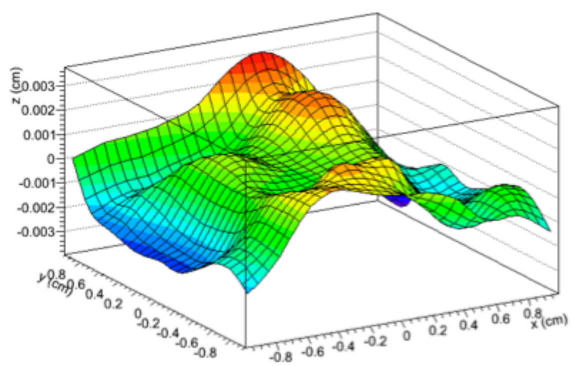


Sector Survey



- 3 tooling balls on each sector are used to define sector coordinate
- 2 features on each chip are used to define its local coordinate
- Each chip is scanned with 121 points to get the surface profile
- Within a sensor, a Thin Plate Spline (TPS*) method is used to describe the surveyed profile of sensors and correction were done to residuals of tracks not perpendicular to the sensor plane





Principal Warps : Thin-Plate Splines and the decomposition of deformations, Bookstein, IEEE Transactions on pattern Analysis and machine Intelligence, Vol 11 no.6 june 1989