SVT Commissioning Status

SVT technical project lead

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CLAS12 Workshop
Jefferson Lab
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Outline

- ❑ SVT System Overview
- ❑ Monitoring and Commissioning Status
- ❑ Integration Status
- ❑ Slow Controls
- ❑ Calibration
- ❑ DAQ and Cosmic Data Taking
- ❑ Data Quality Monitoring and Validation
- ❑ Alignment
- ❑ Monte Carlo Tuning
- ❑ Documentation

CLAS12 SVT Physics Requirements and Technical Parameters

SVT provides standalone tracking capabilities in the central detector region

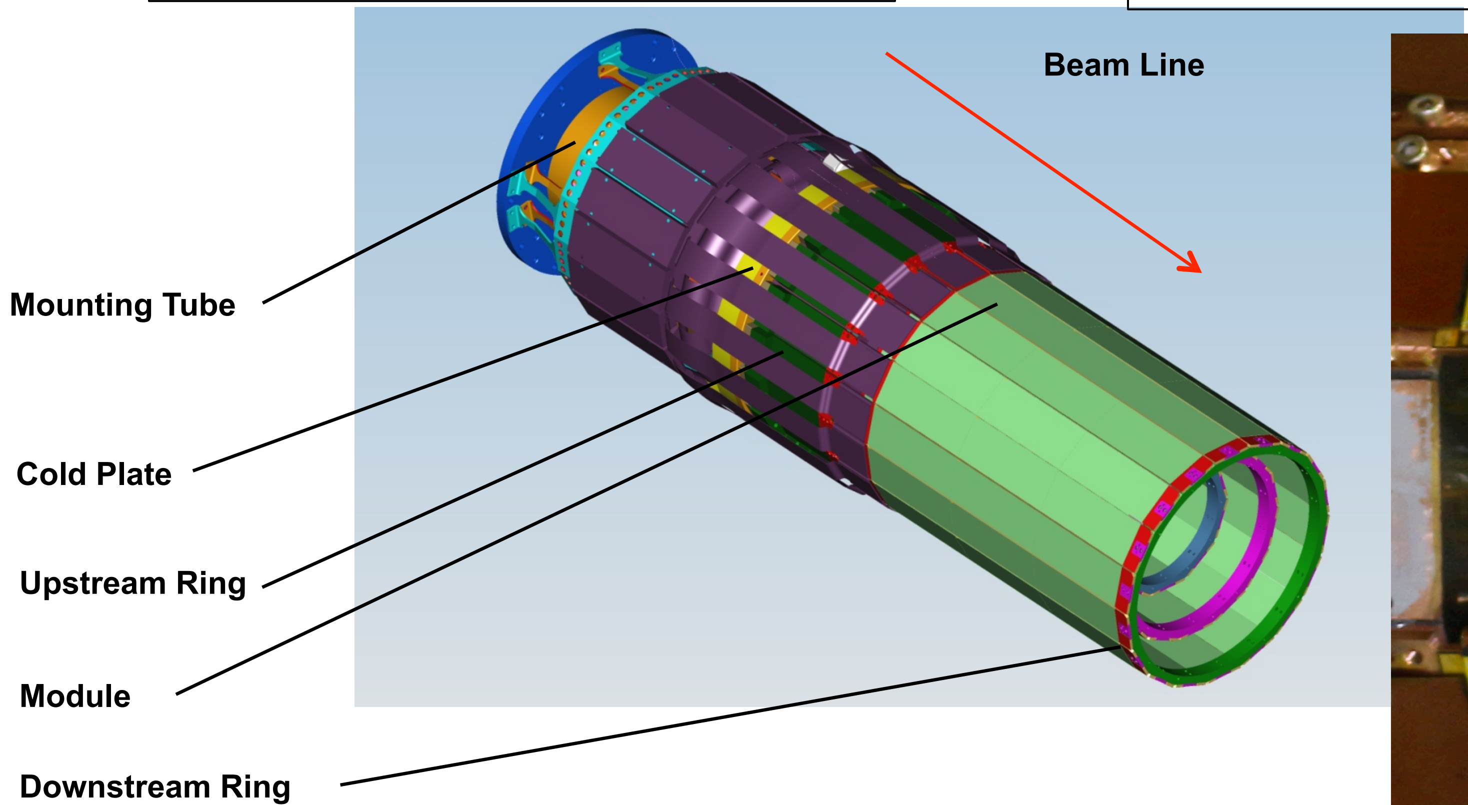
- **Measure recoil baryons & large angle pions, kaons**
- **Match up tracks with hits in the CTOF for β vs. p measurement (particle ID)**

PARAMETER	DESIGN VALUE
Number of regions (radii, mm)	4 (65, 93, 120, 161)
Sectors (modules)/region	10, 14, 18, 24
Module dimensions (L x W x T)	41.9 cm x 4.2 cm x 0.39 cm
Number of silicon layers/module	2 (*U, V*)
Strip layout	(0^o— 3^o) Graded angle
Sensor thickness	320 μm
Readout pitch	156 μm (hybrid side)
Number of readout channels/module	**512**
Total number of readout channels	**33,792**
Readout ASIC	FSSR2
Backend electronics	Custom-made VXS cards
Angular coverage θ	35°–125°
Angular coverage Φ	~2π
Spatial resolution	50-65 μm
Momentum resolution	~6%
θ resolution	10–20 mrad
ϕ resolution	~5 mrad
Tracking efficiency	> 90%
Designed to operate at a luminosity of	10^{35} $cm^{-2}s^{-1}$

SVT Overview

- Silicon Vertex Tracker (SVT)
- Four regions
- Sectors (10, 14, 18, 24)

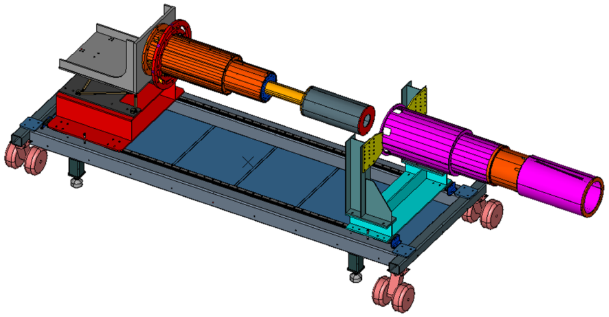
- Silicon area ~ 1.5 m^2
- Channels: ~34,000
- Bonds: ~200,000



- Region radii, mm: 65, 93, 120, 161
- Hybrid temperature 18C with coolant at 6C

SVT Monitoring and Commissioning Status

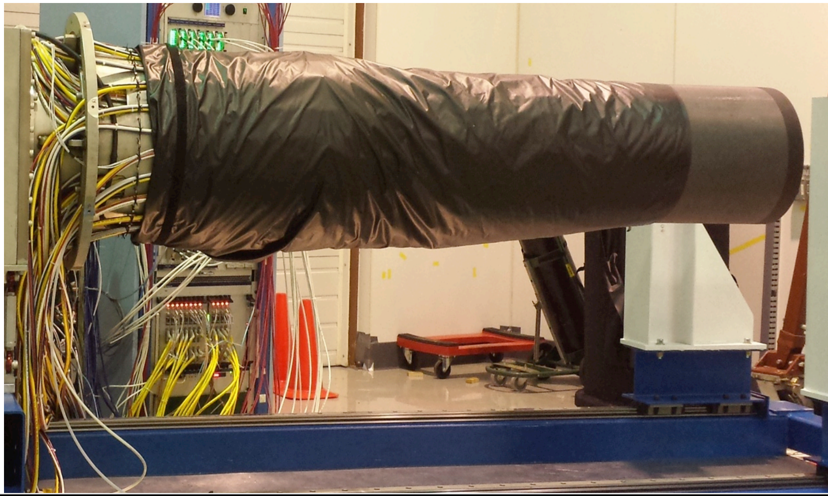
- SVT is integrated with Micromegas tracker (December 2015)
- Both systems calibrated, no extra noise observed after integration
- DAQ synchronized, SVT is providing master trigger to the MVT
- Online cosmic track reconstruction monitoring of SVT/MVT using ET
- Cosmic alignment sample: 100 M SVT and 30 M SVT/MVT tracks collected
- Mechanical survey data analysis complete
- Noise performance monitored by periodic SVT calibration scans
- SVT long term stability is monitored since integration (August 2015)
- CoatJava based calibration suite developed



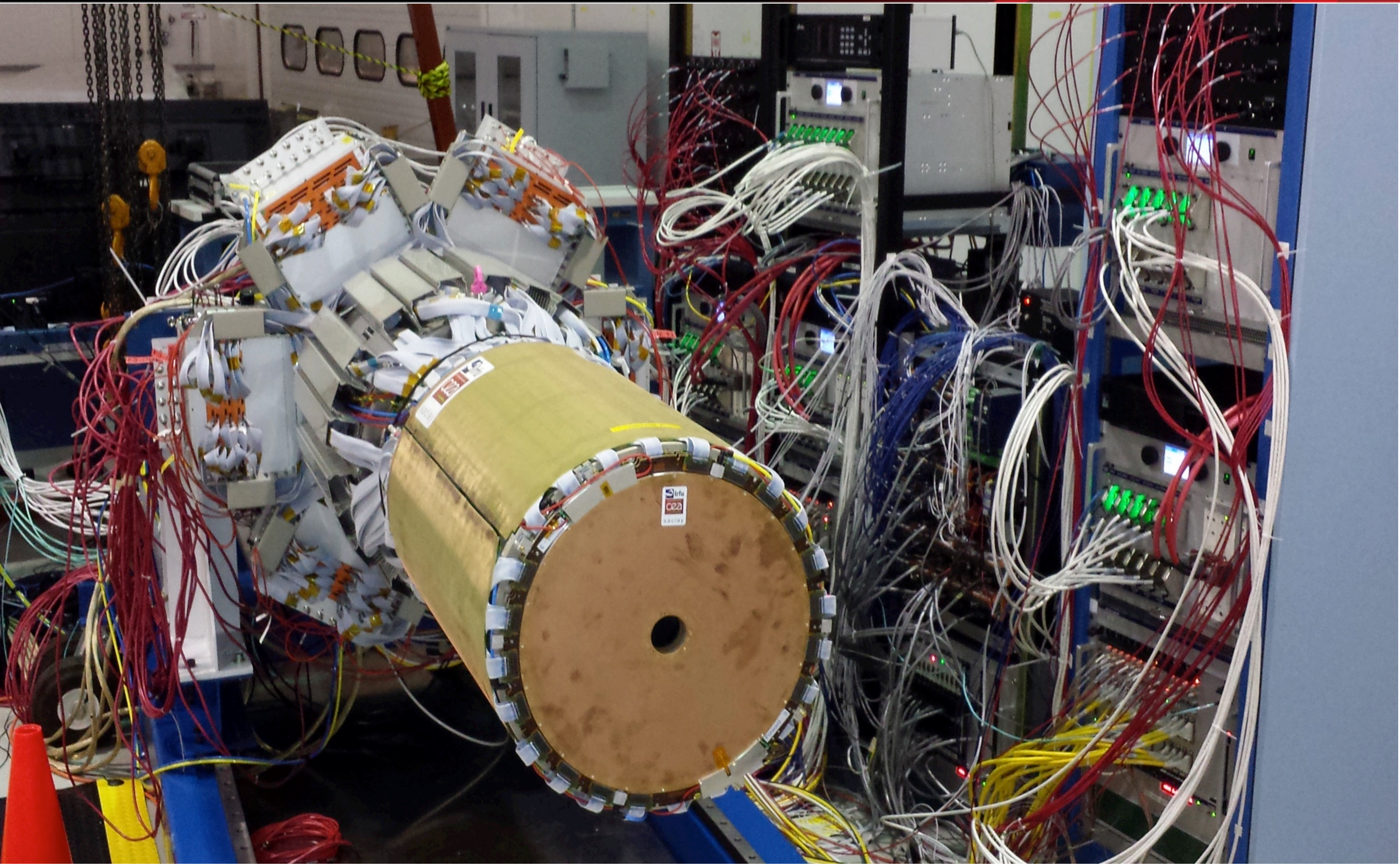
Work in progress

- Central tracker commissioning, taking cosmic data 24/7
- Development of the data validation and monitoring suite
- Validation of local and track reconstruction
- Monte Carlo tuning on the cosmic data
- SVT alignment using Monte Carlo and cosmic data
- Documentation

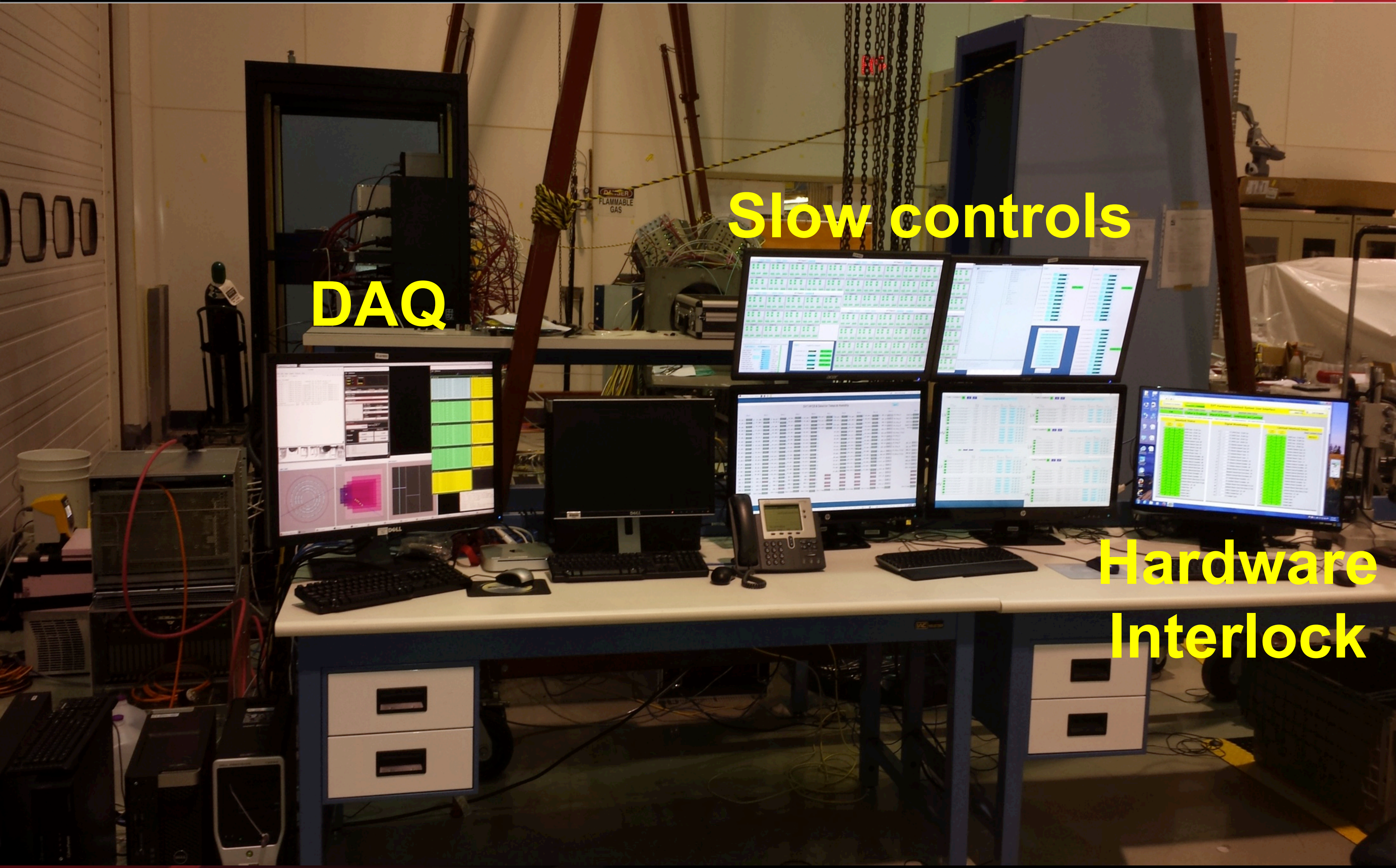
  - Dec. 2015: Integration of the central tracker (SVT/BMT)
  - May 2015 – Sep. 2016: Commissioning of the SVT
  - Dec. 2016: Installation of the SVT in the Hall B



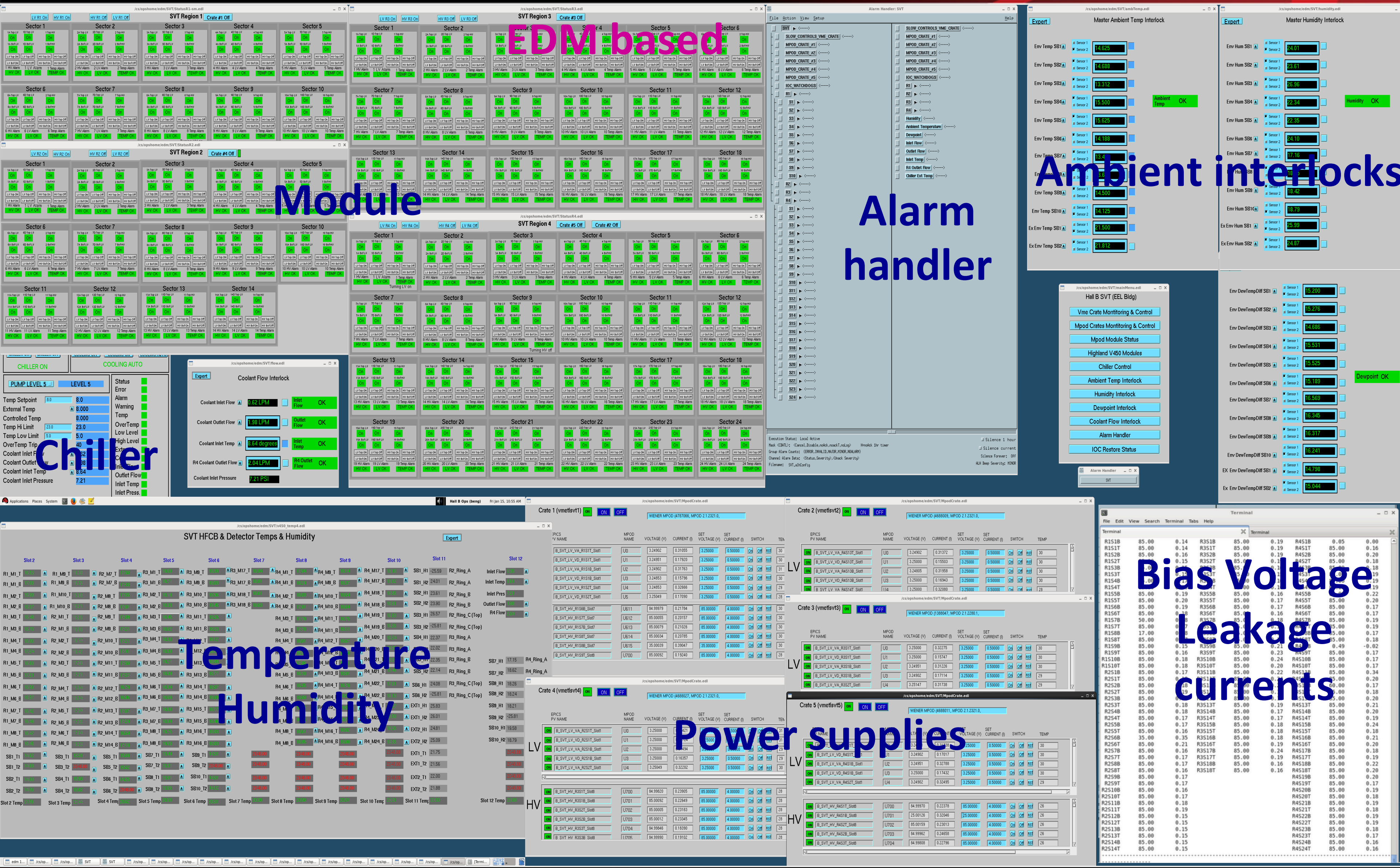
SVT and MVT integrated taking cosmic data



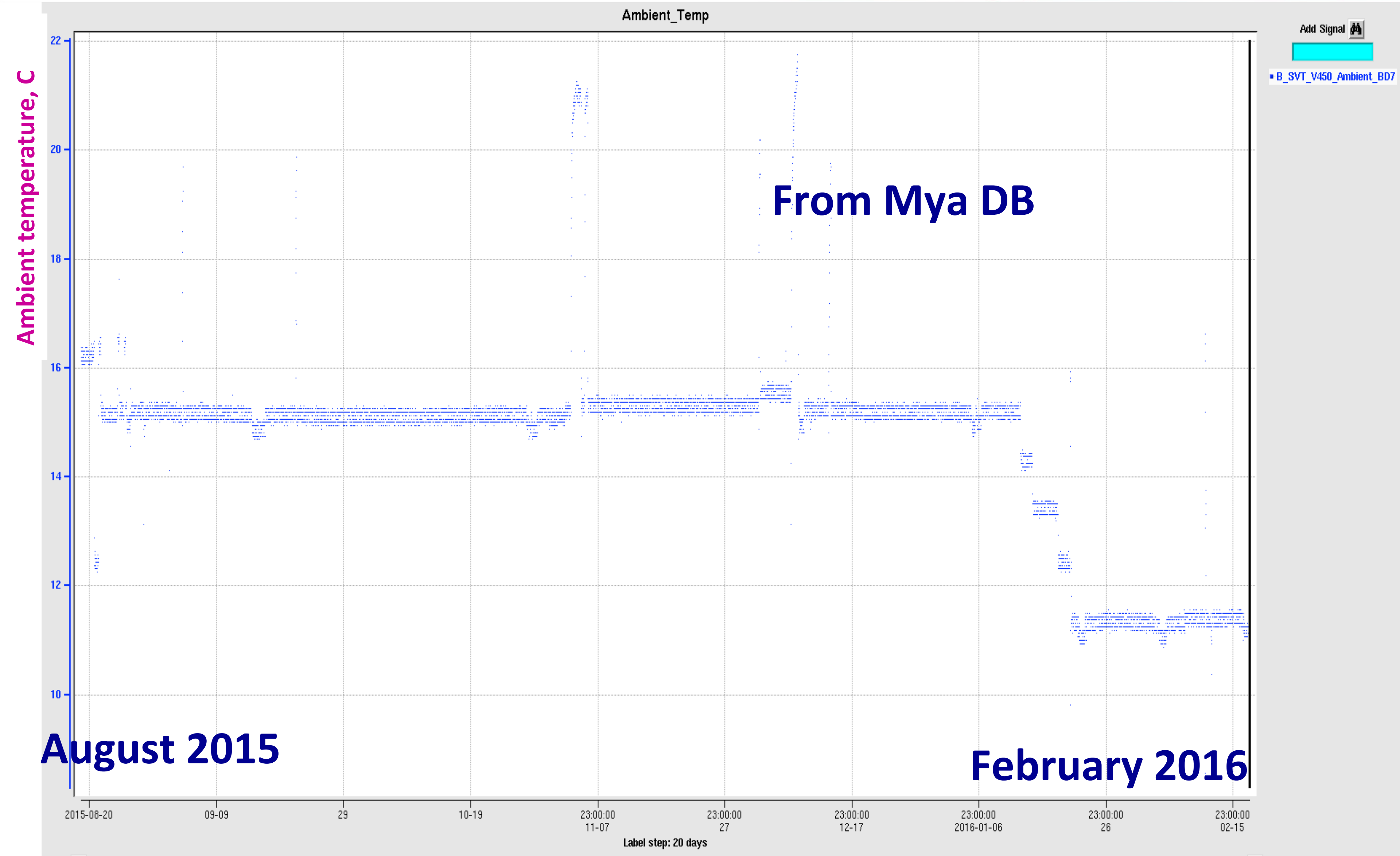
SVT Control and Monitoring Console



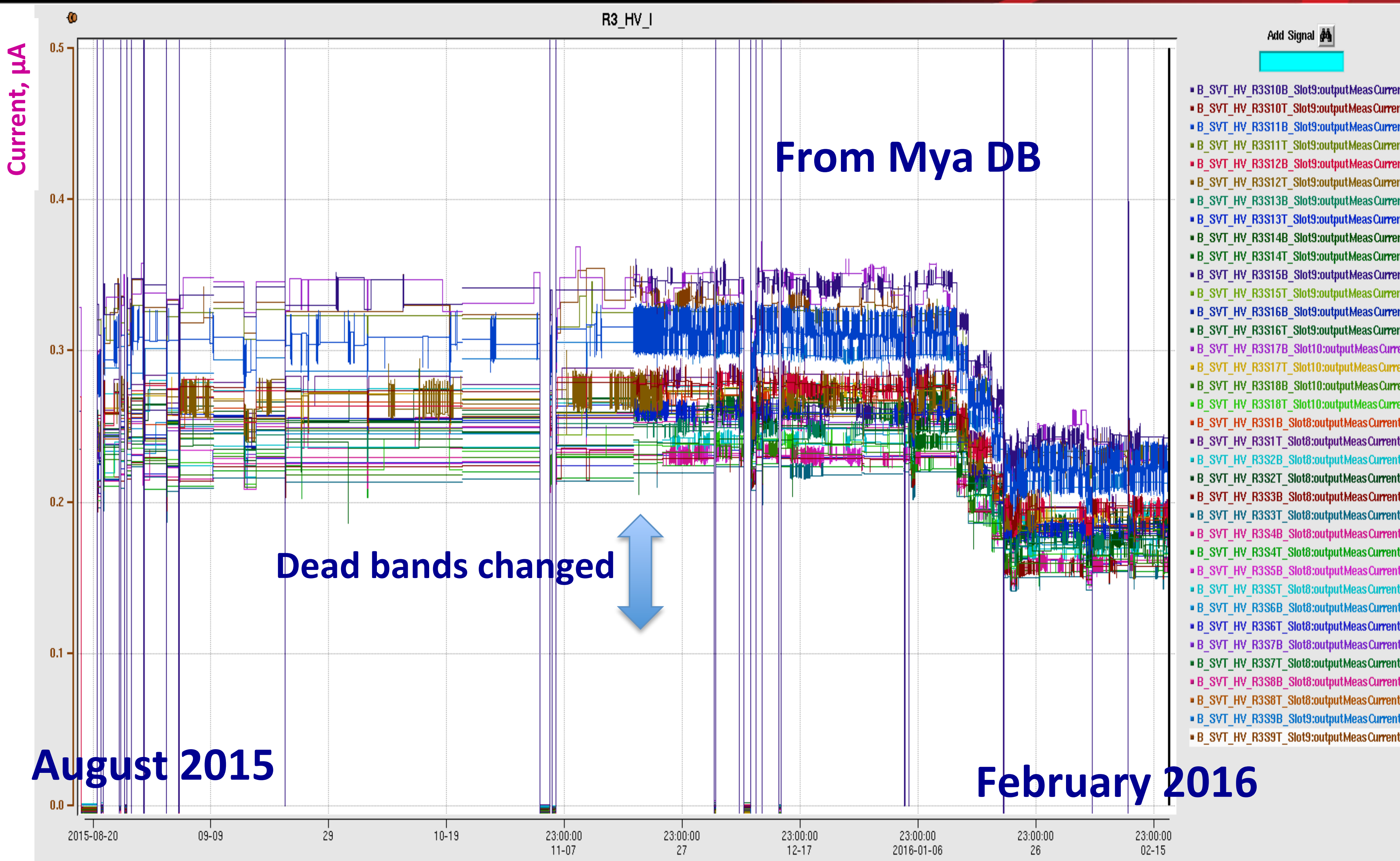
SVT slow control and monitoring



Barrel temperature history (6 months)

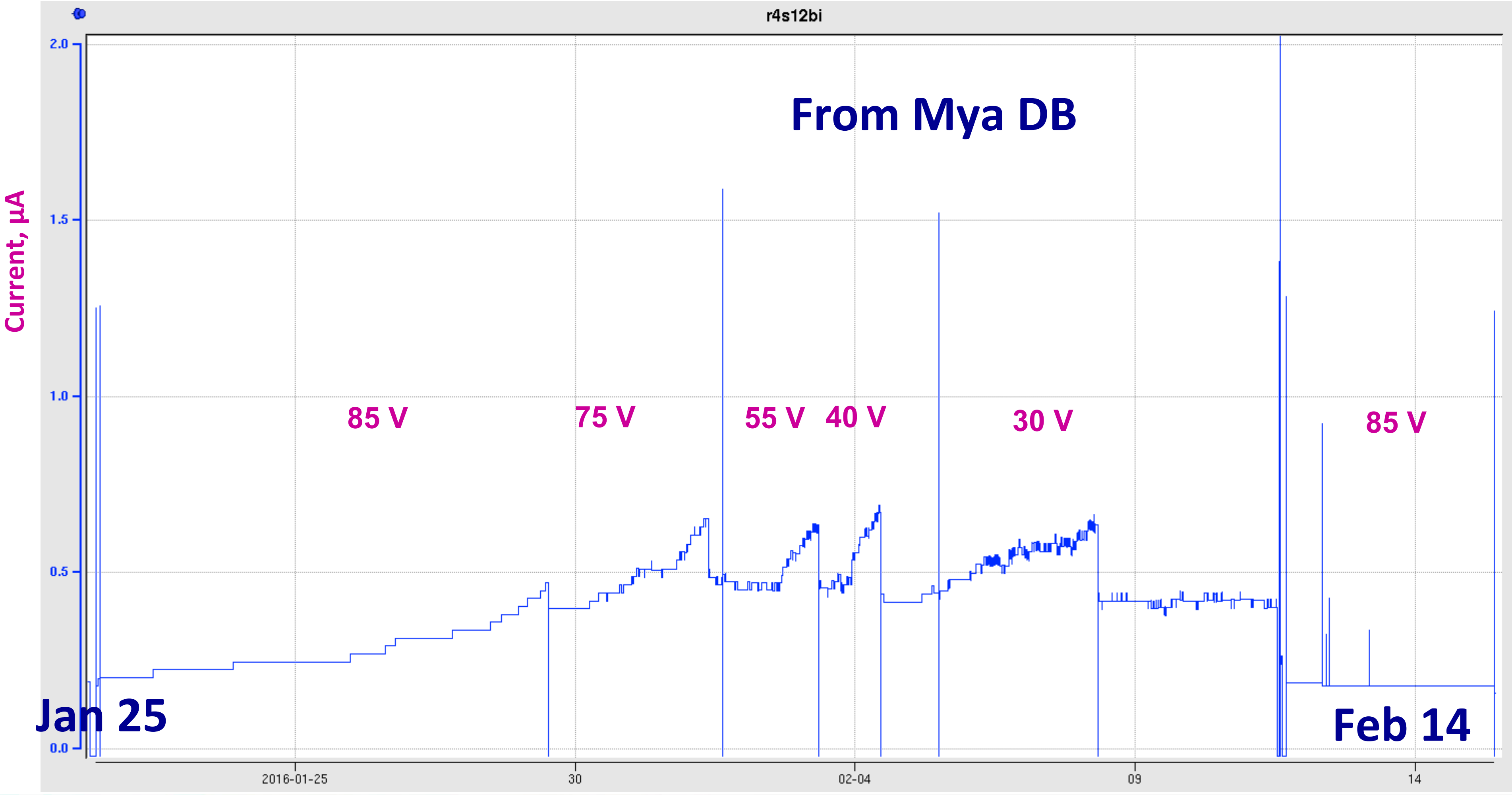


Leakage current history: Region 3

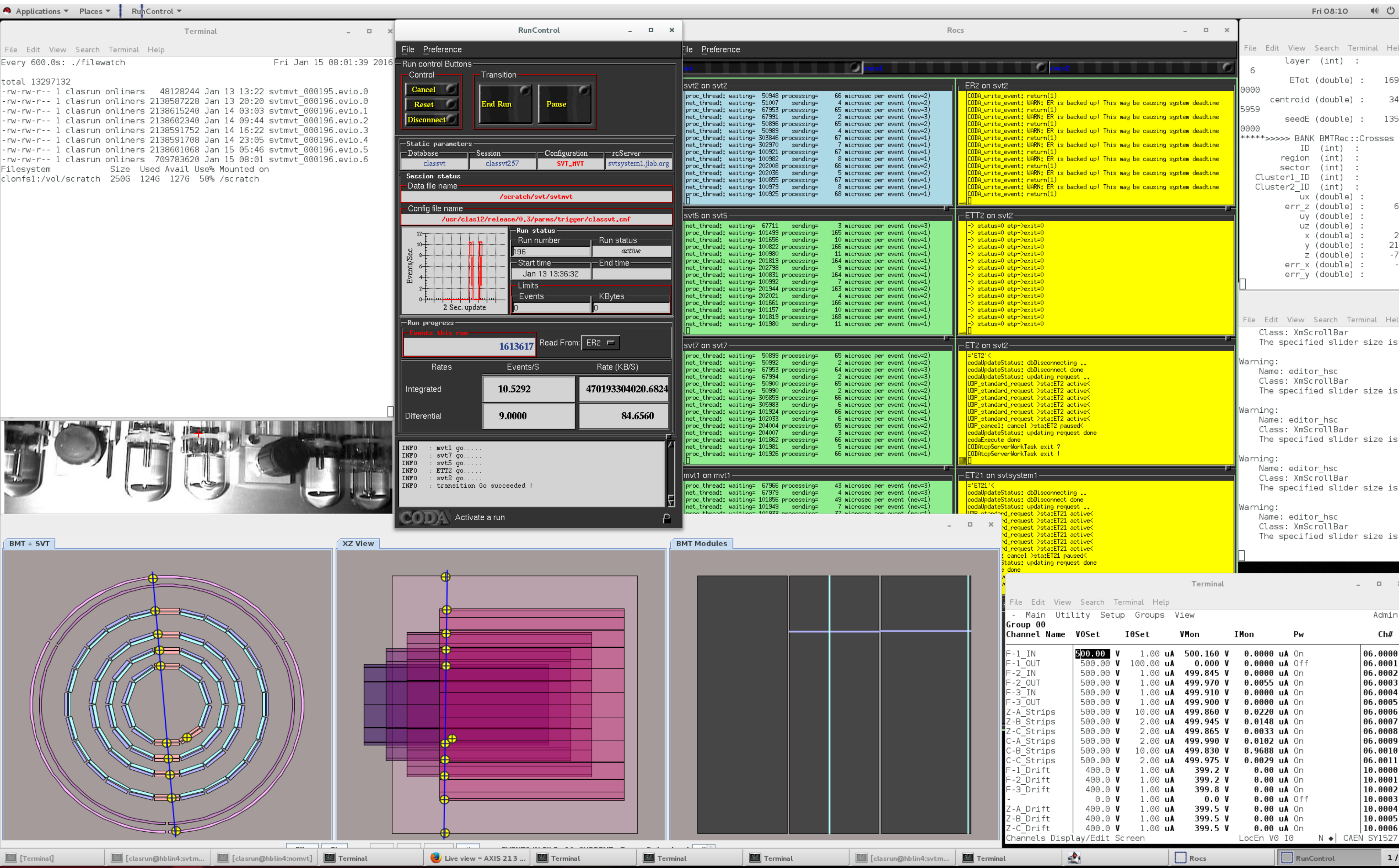


Leakage current stability

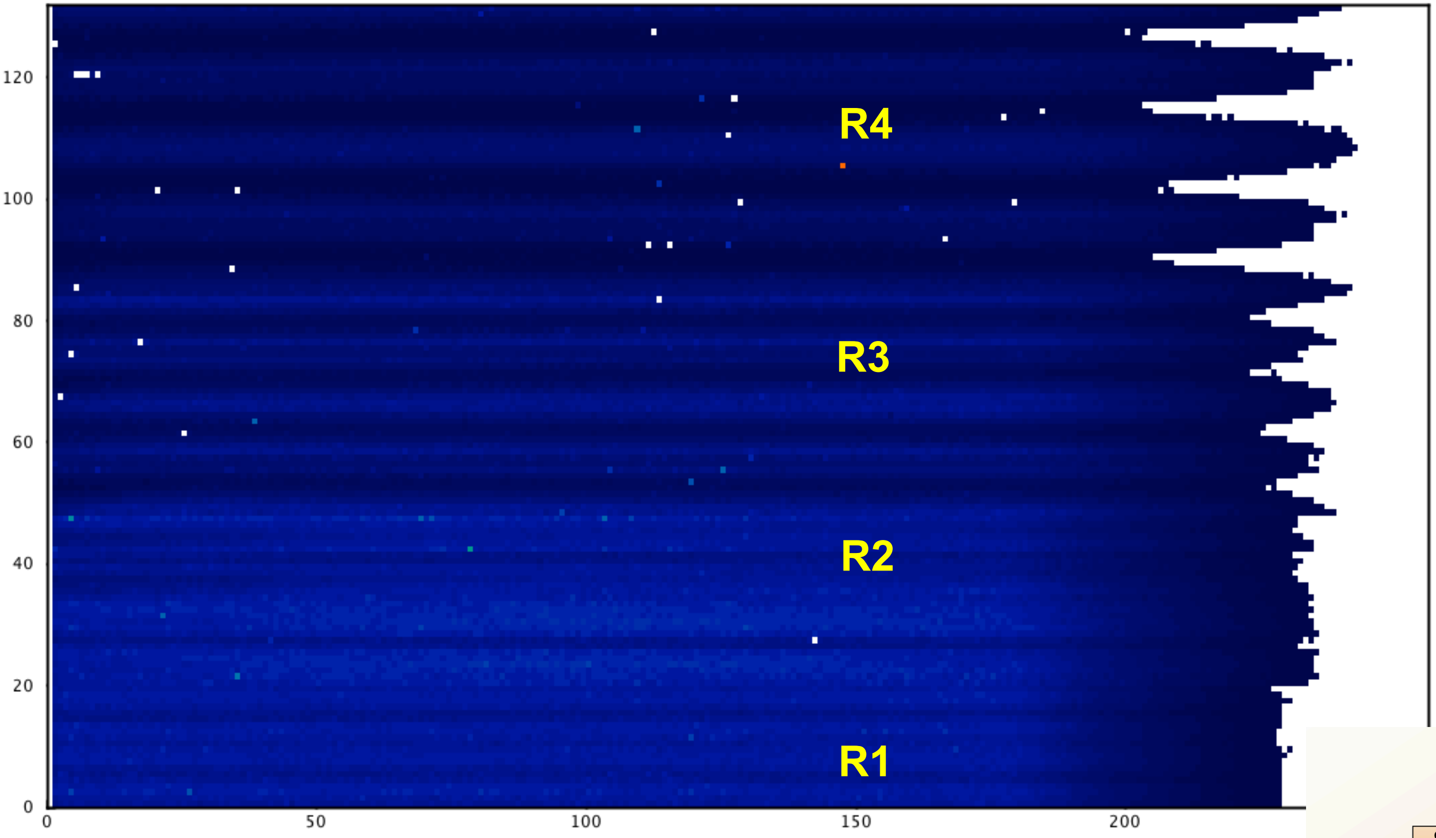
- Leakage current increases with time on few problematic modules
- Plans to replace three region-4 modules in June

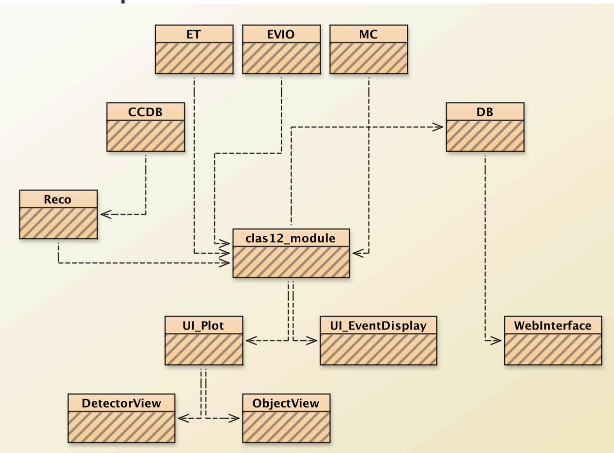


SVT DAQ Control and Monitoring



Strip Occupancy, full event





SVT Calibration Suite

Implemented:

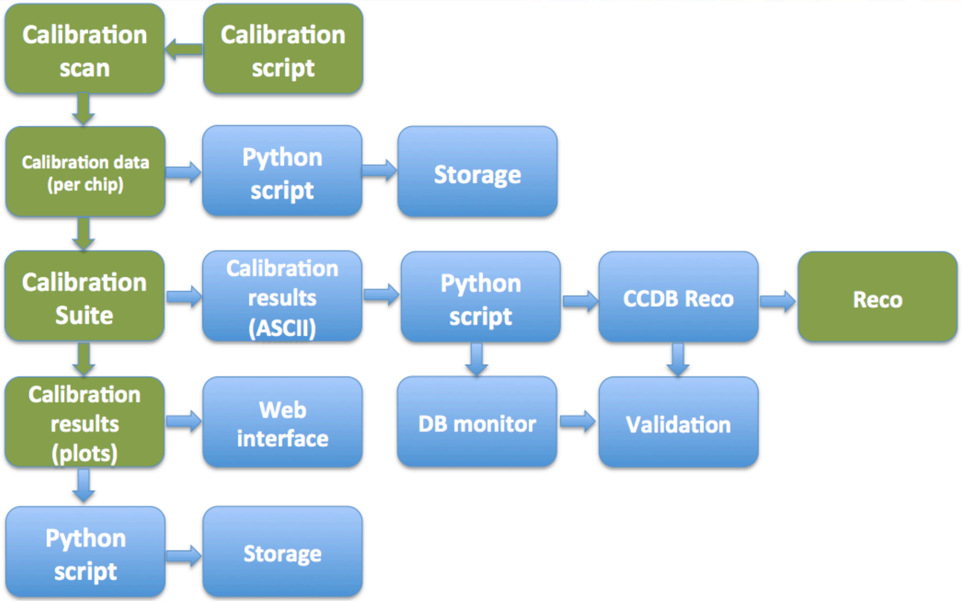
- Scripts for parallel calibration and directory structure
- Translation from engineering to logical component mapping
- Calibration algorithms
- Detector View interface
- Channel level plots (occupancy, response function)
- Channel level data table (ENC, gain)
- Module, region and detector level plots
- Profiling (scan – 20 min, data processing – 5 min per scan)
- Chip level plots:
  - Vs. channel (gain, ENC, offset, Vt_{50})
  - Histograms and fits
- Tuning of fit parameters
- Bad channel mapping

In progress:

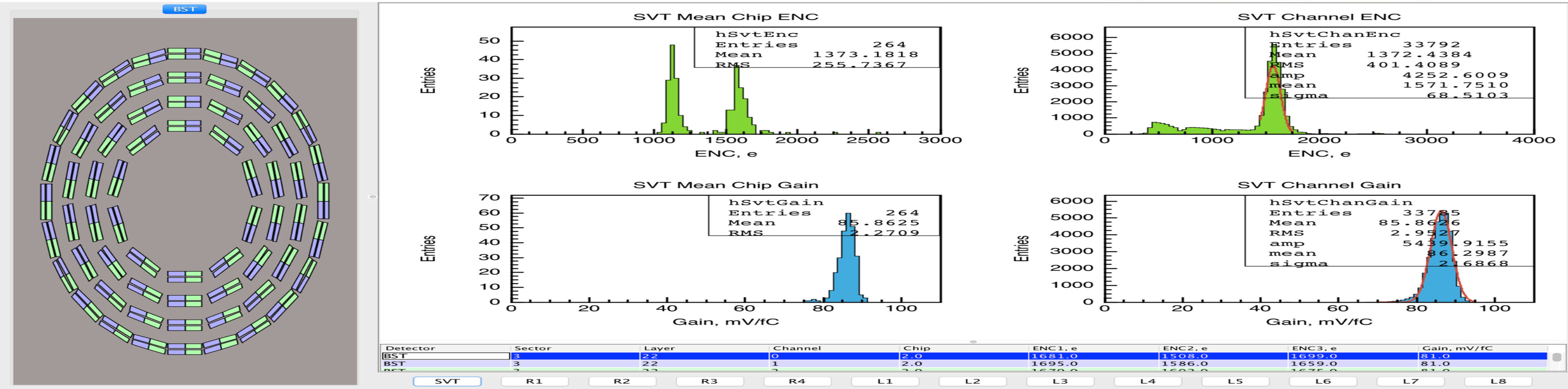
- CCDB interface

To do:

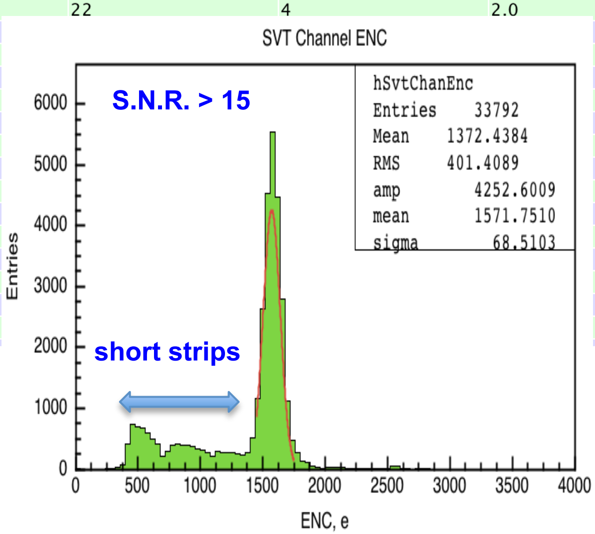
- Trends and Validation
- Web interface
- Permanent storage of the calibration files

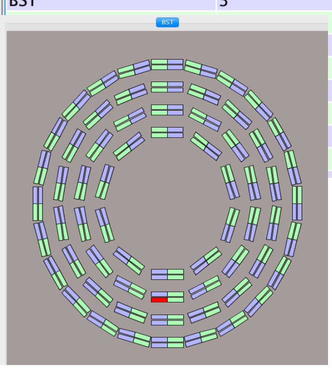


SVT Calibration Suite



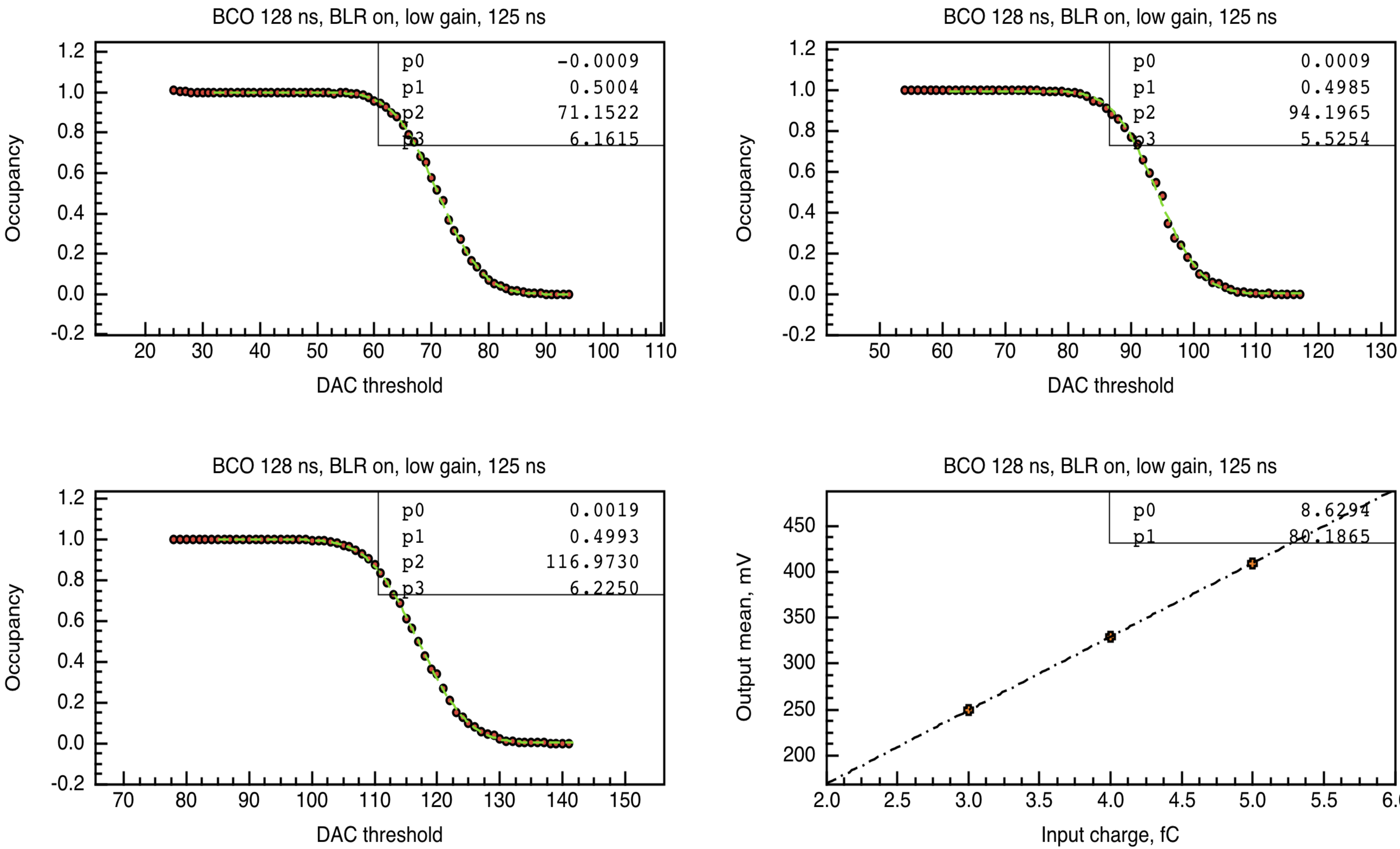
Detector	Sector	Layer	Channel	Chip	ENC1, e	ENC2, e	ENC3, e	Gain, mV/fC
BST	3	22	0	2.0	1681.0	1508.0	1699.0	81.0
BST	3	22	1	2.0	1695.0	1586.0	1659.0	81.0
BST	3	22	2	2.0	1679.0	1602.0	1675.0	81.0
BST	3	22	3	2.0	1679.0	1583.0	1652.0	81.0
BST	3	22	4	2.0	1681.0	1650.0	1686.0	80.0
BST	3				1663.0	1634.0	1641.0	81.0
BST	3				1689.0	1607.0	1668.0	81.0
BST	3				1650.0	1562.0	1633.0	81.0
BST	3				1650.0	1496.0	1651.0	83.0
BST	3				1669.0	1599.0	1640.0	83.0
BST	3				1642.0	1469.0	1655.0	82.0
BST	3				1649.0	1558.0	1603.0	82.0
					1640.0	1539.0	1611.0	84.0
					1642.0	1465.0	1638.0	83.0
					1676.0	1489.0	1642.0	83.0



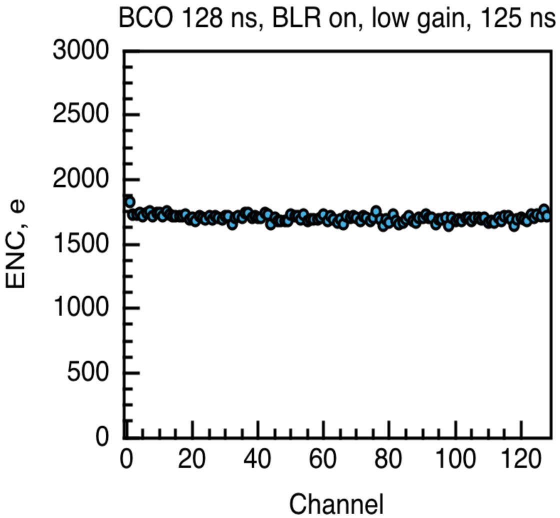


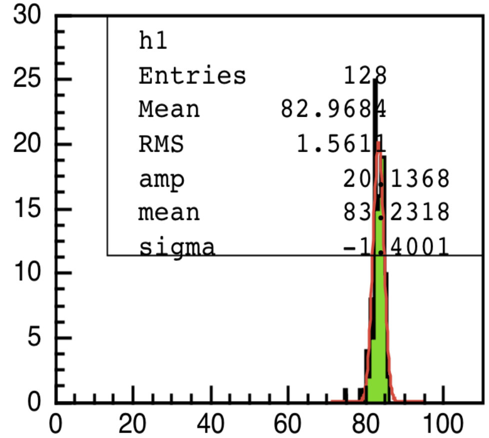
ID	No of entries	Unit	Type	CCDB	Comment
CHANNEL_STATUS	33792	N/A	BYTE	yes	0: good, 1: open, 2: noisy, 3: masked
CHIP_ADC_THRESHOLDS	2112	DAC	INT	yes	set ADC bins, 8 thresholds per chip
CHANNEL_GAIN	33792	mV/fC	FLOAT	no	
CHANNEL_ENC	33792	electrons	FLOAT	no	
CHANNEL_OFFSET	33792	mV	FLOAT	no	
CHANNEL_VT50	33792	mV	FLOAT	no	
CHIP_GAIN_DISPERSION	264	mV/fC	FLOAT	no	
CHIP_THRESHOLD_DISPERSION	264	electrons	FLOAT	no	
CHIP_GAIN_MODE	1	N/A	BYTE	no	0: low (default), 1: high
CHIP_BLR_MODE	1	N/A	BYTE	no	0: off, 1: on (default)
CHIP_SHAPER_TIME	1	ns	INT	no	default: 125 ns
CHIP_BCO_TIME	1	ns	INT	no	default 128 ns

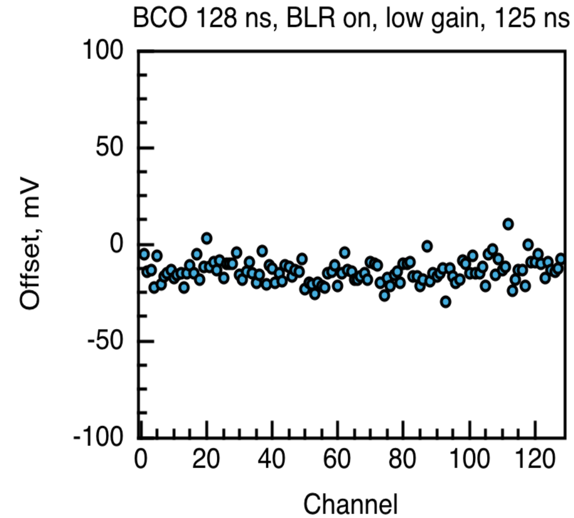
SVT Calibration: Channel

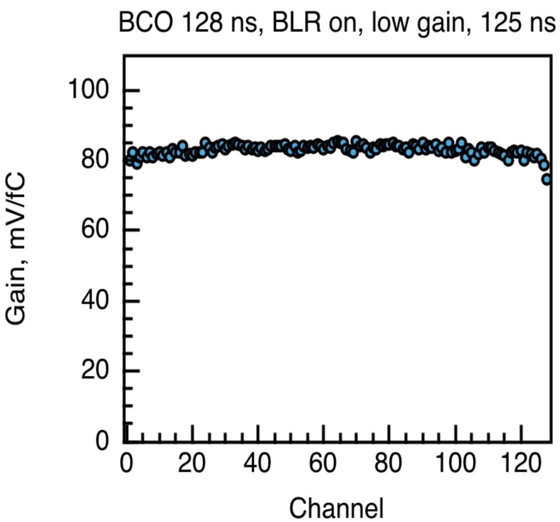


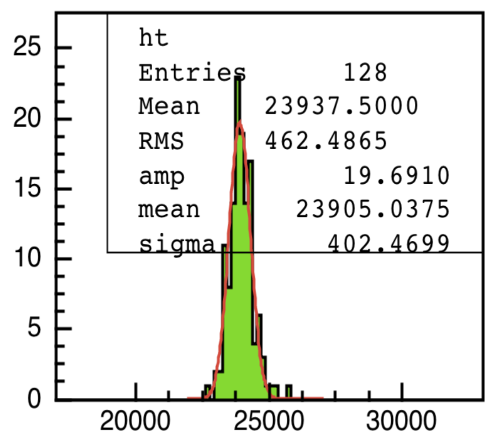
SVT Calibration: Chip (U1, U3)

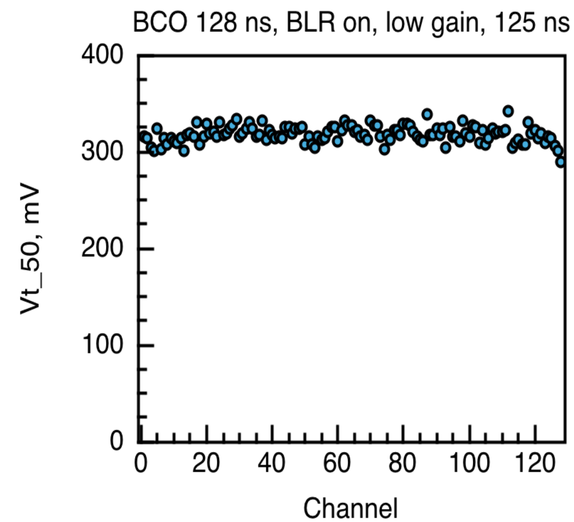




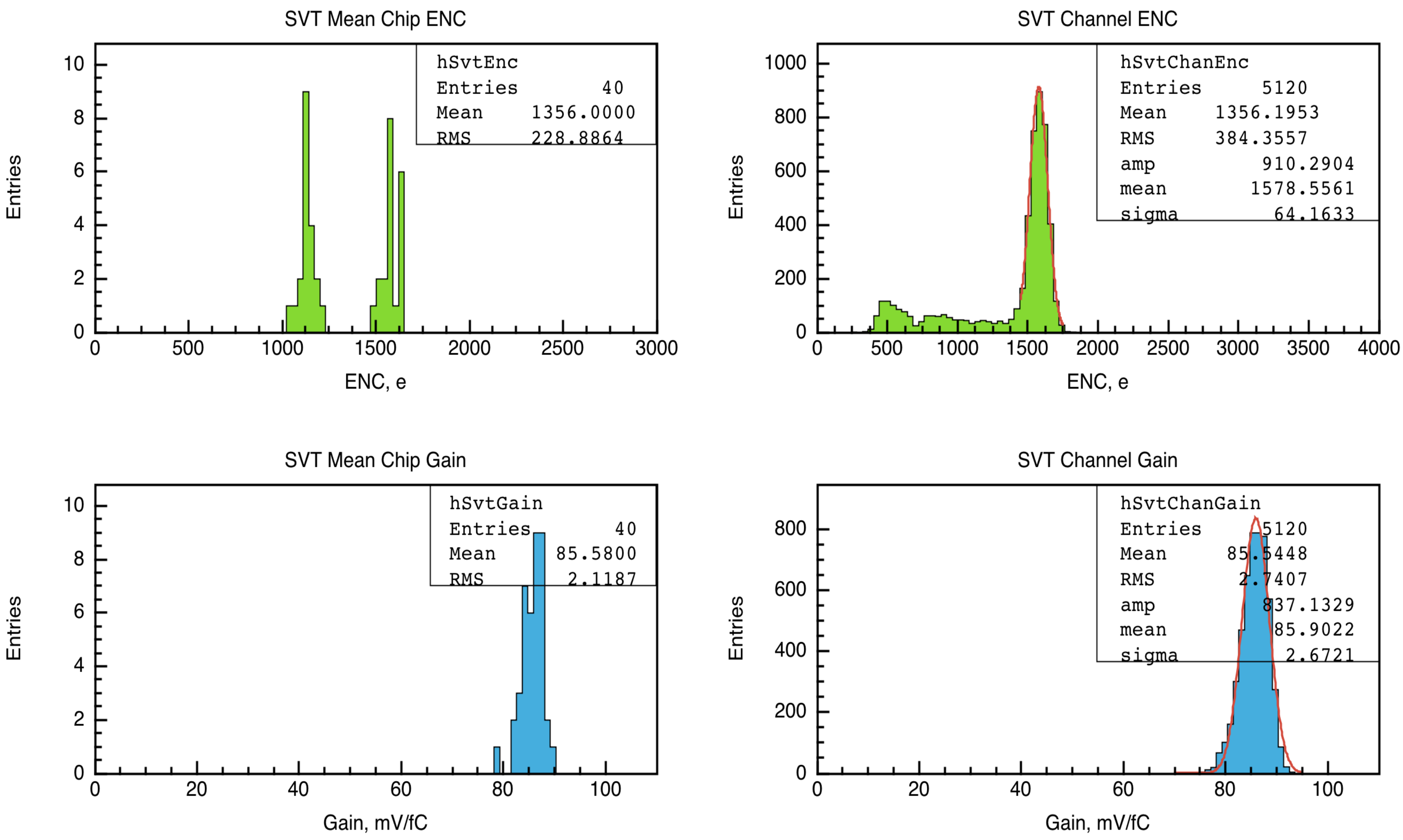




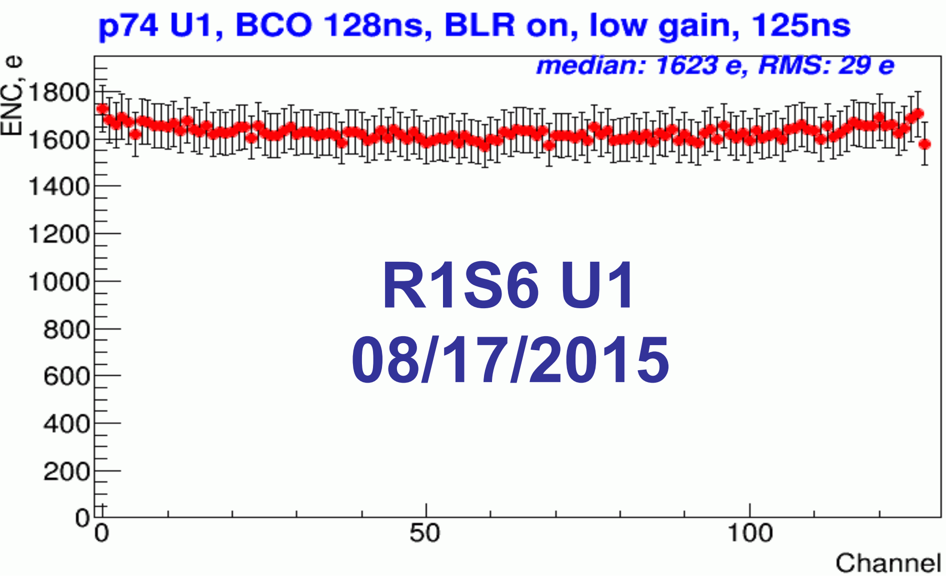


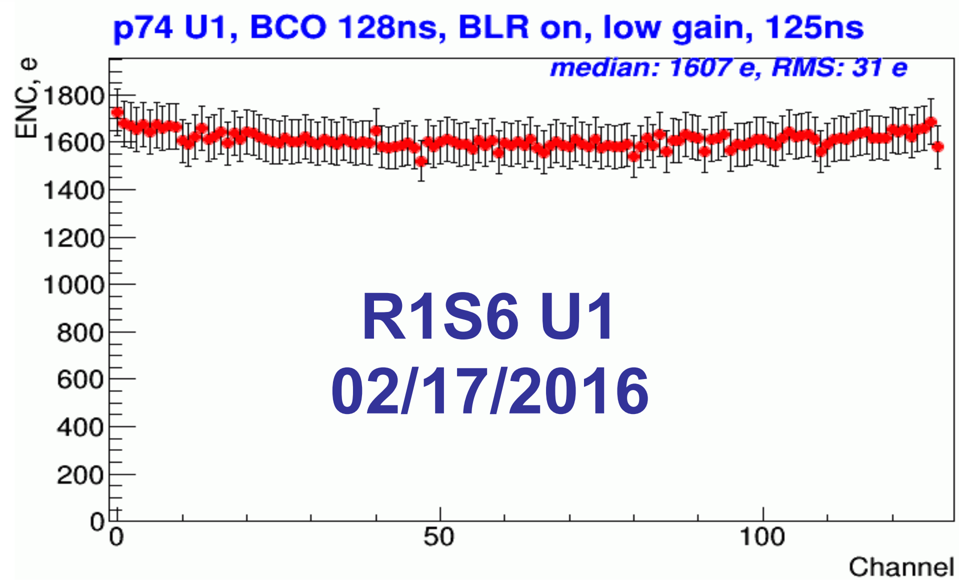


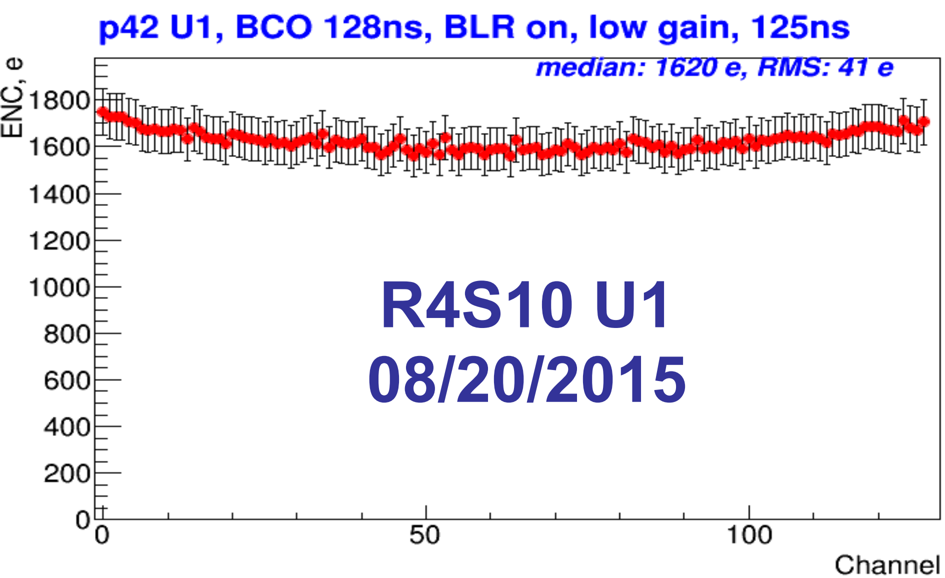
SVT Calibration: Region

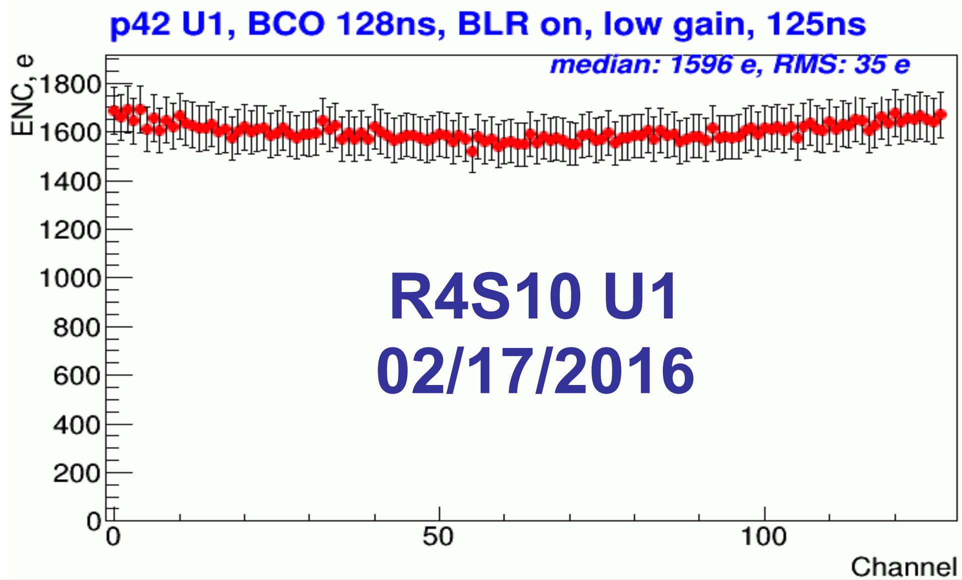


SVT Calibration: Noise stability

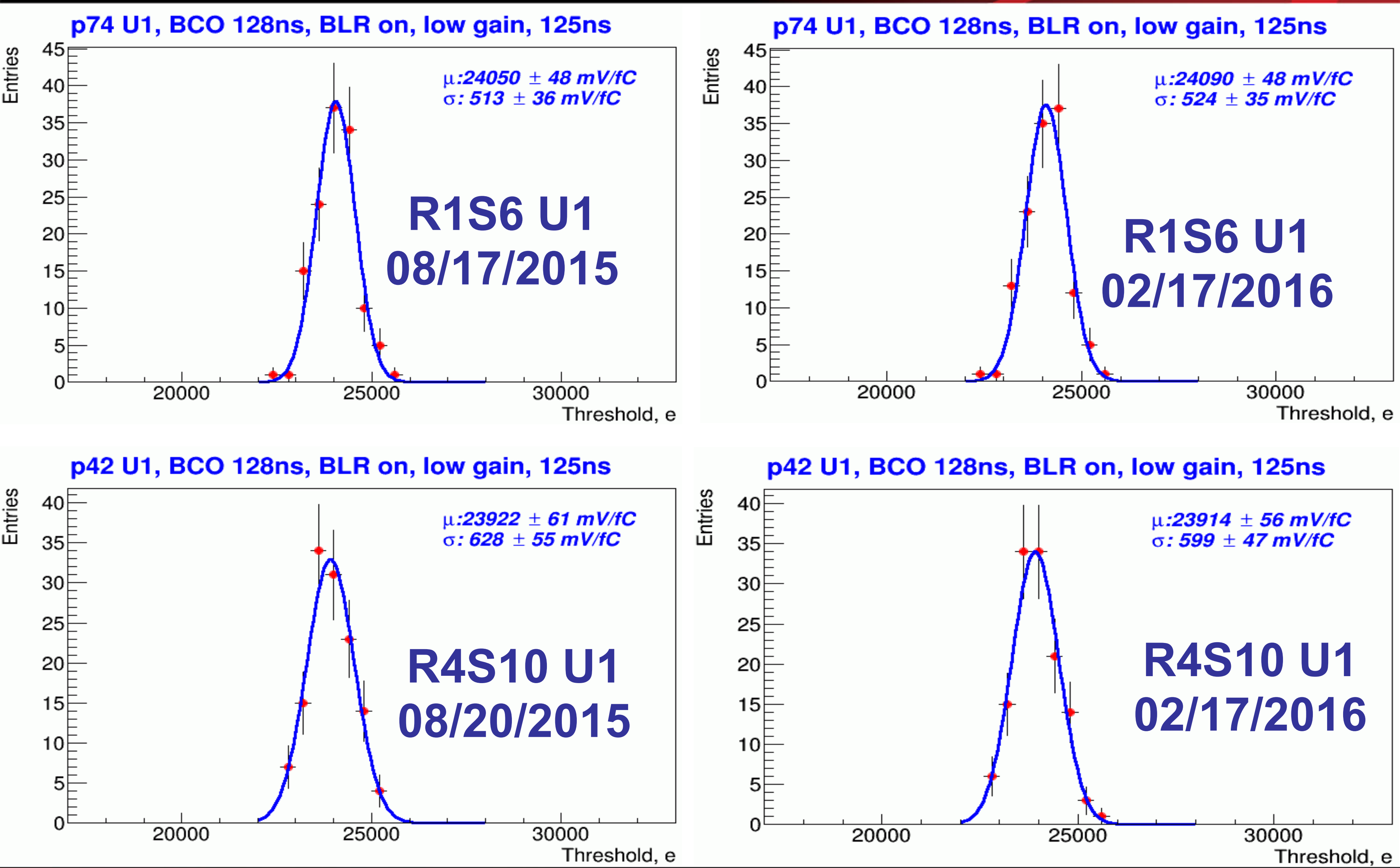






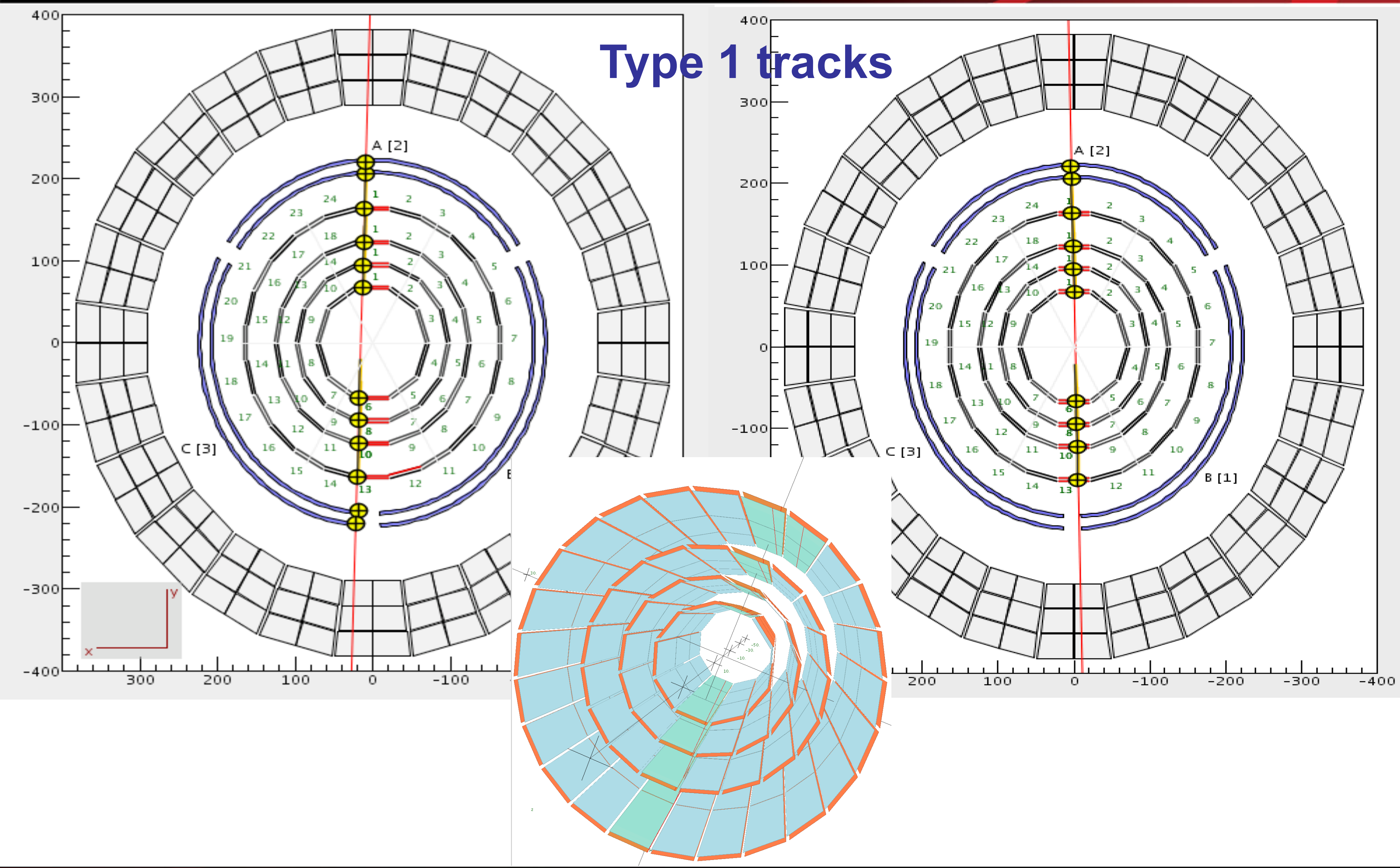


SVT Calibration: Threshold Dispersion

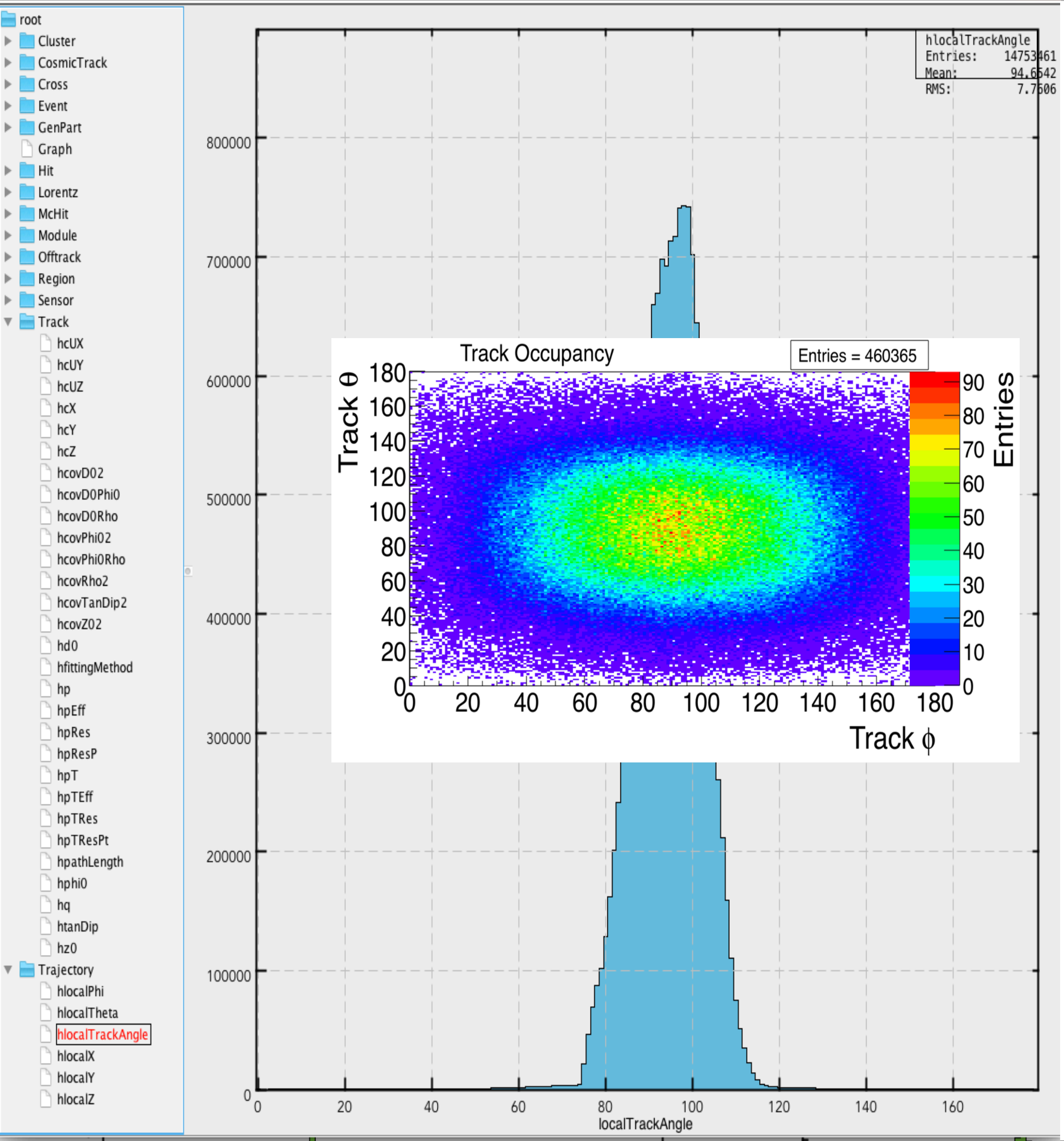


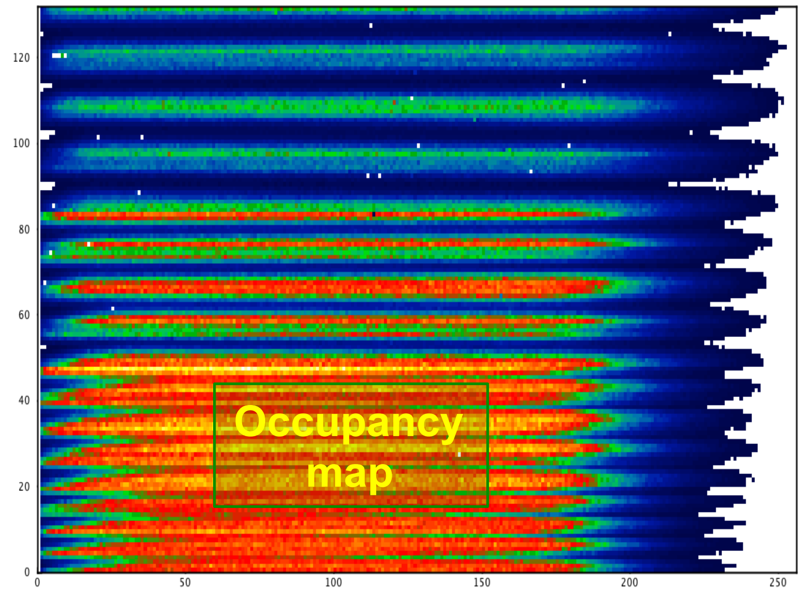
Cosmic Muon Tracks in the Central Tracker

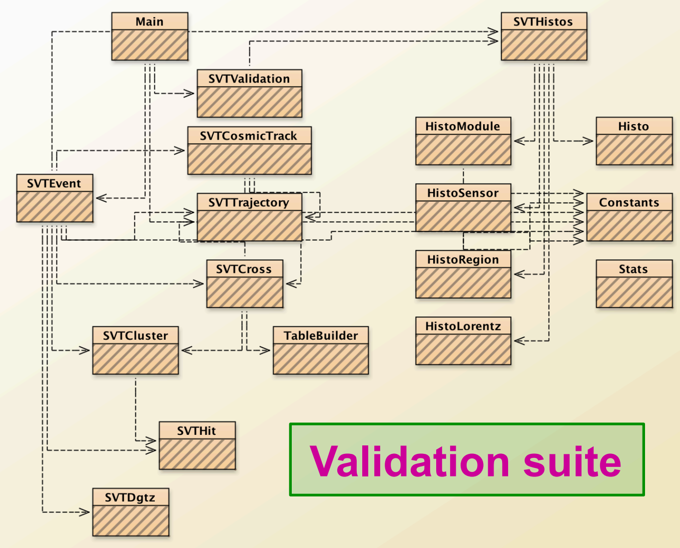
Type 1 tracks



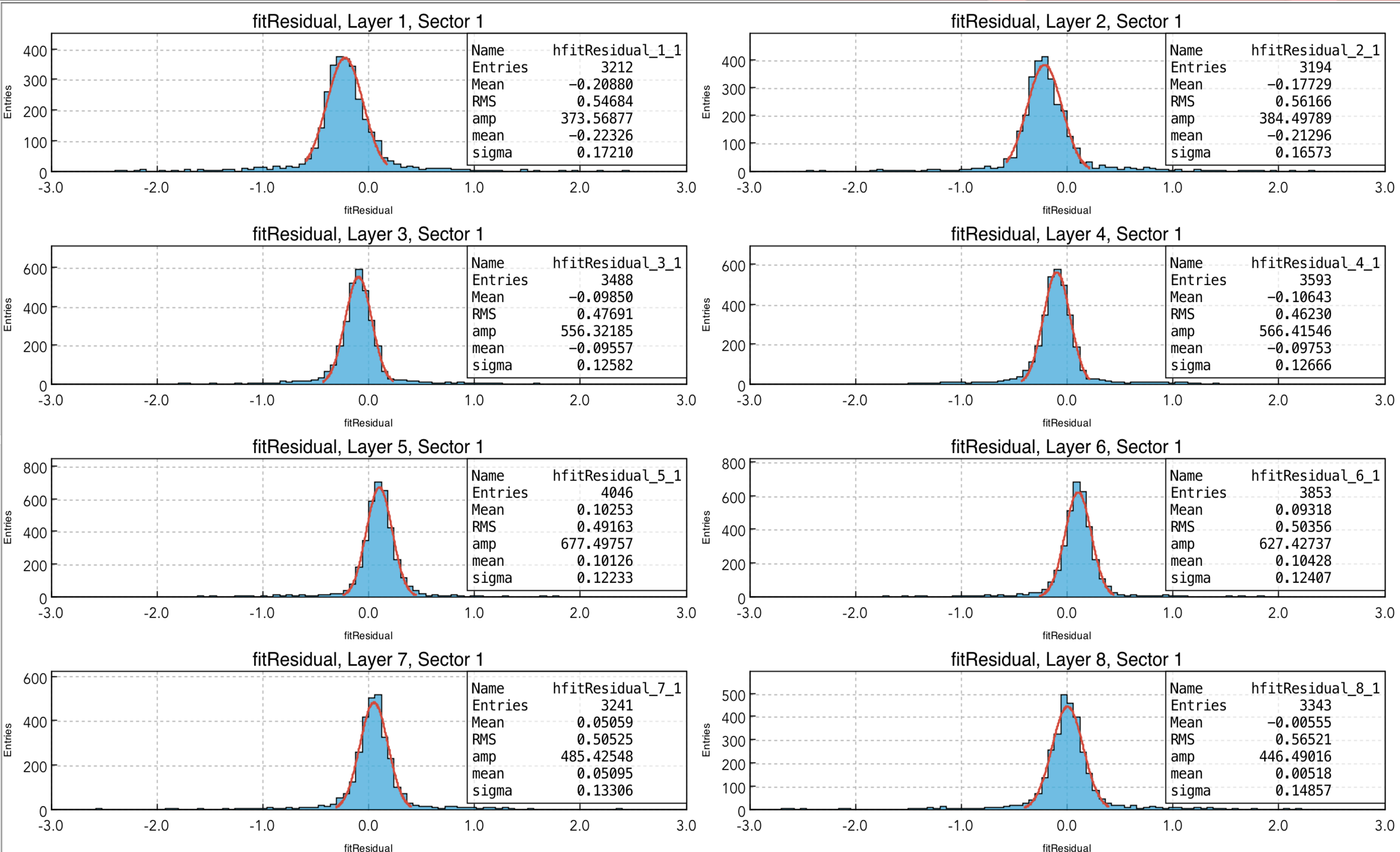
SVT Data Quality Monitoring and Validation





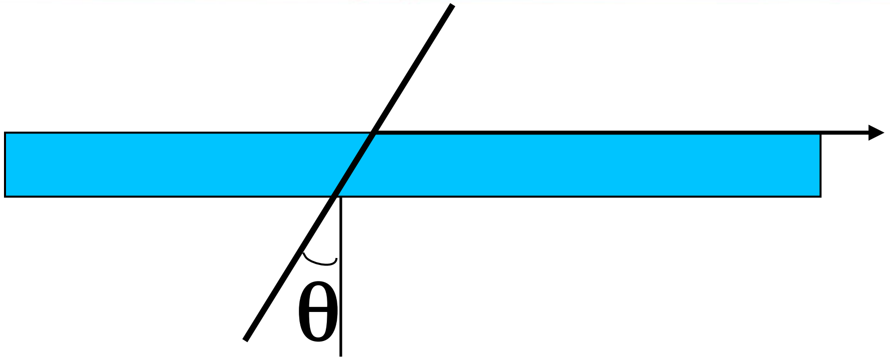


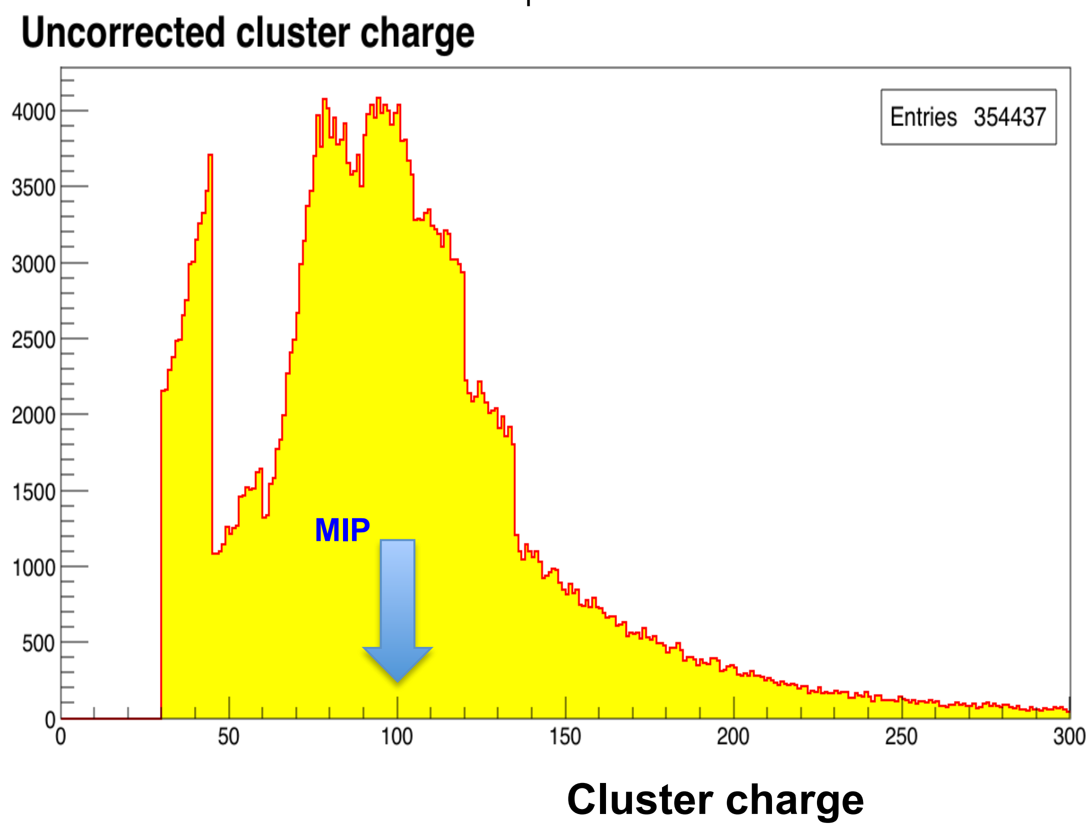
Cosmic Track Residuals



Local Reconstruction: Cluster Properties

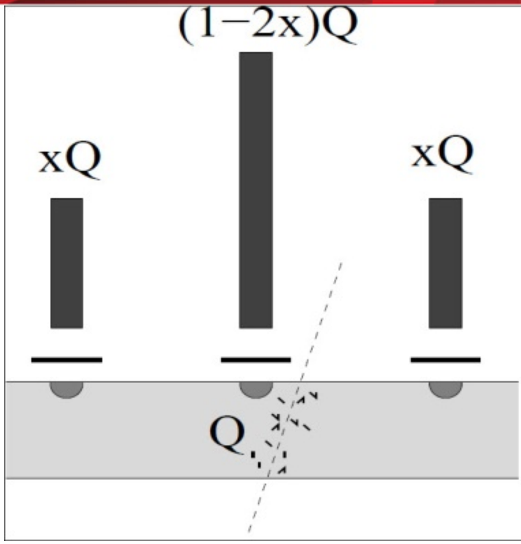
- Plot Q_cl vs. dl (liner dependence)
  - Q_cl – MPV of the cluster charge
  - dl – detector thickness / cos θ
- Correct Q_cl for the dl

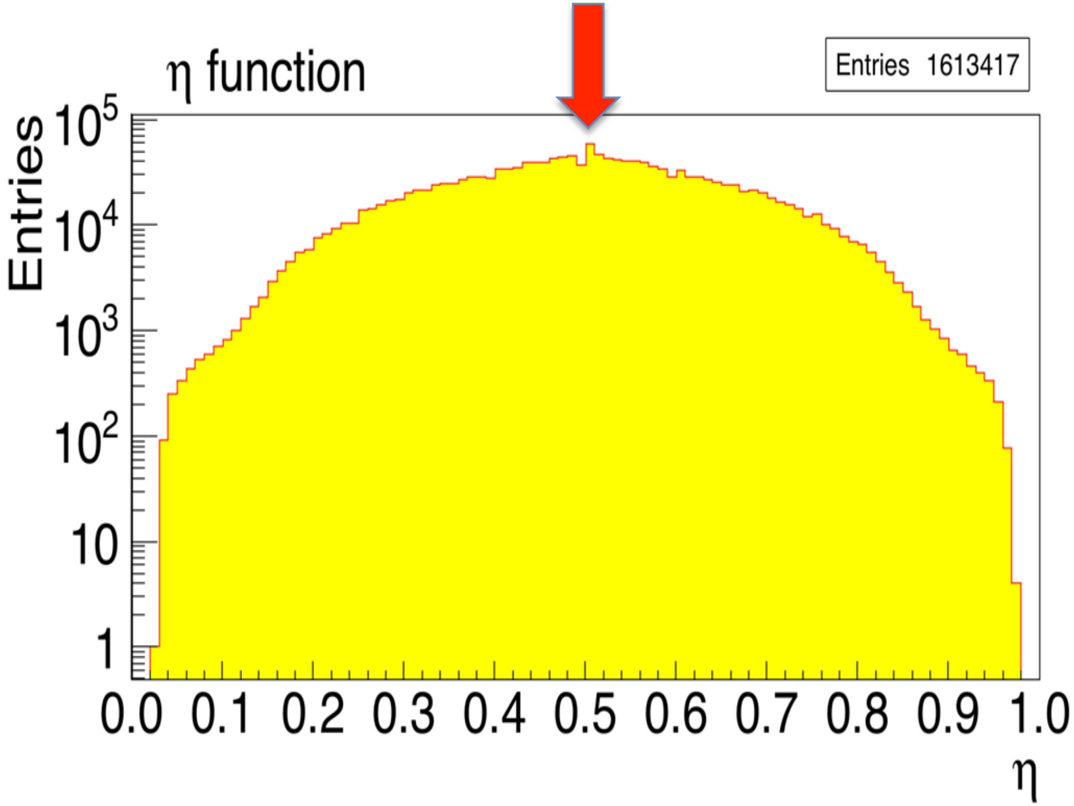


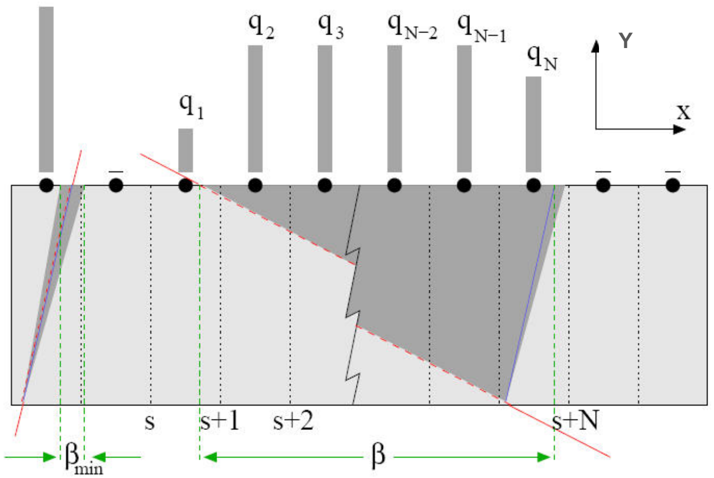


Local Reconstruction: Cross Talk and Cluster Position

- It is important to understand crosstalk (charge capacitive coupling) to accurately evaluate the cluster position and uncertainty
- Charge Ratio = $(Q_{max\pm1})/Q_{max} = x/(1-2x)$
- Response function $\eta = Q_L/(Q_L+Q_R)$, Q_L and Q_R are the charges collected on the strips to the left and to the right of the reconstructed hit position

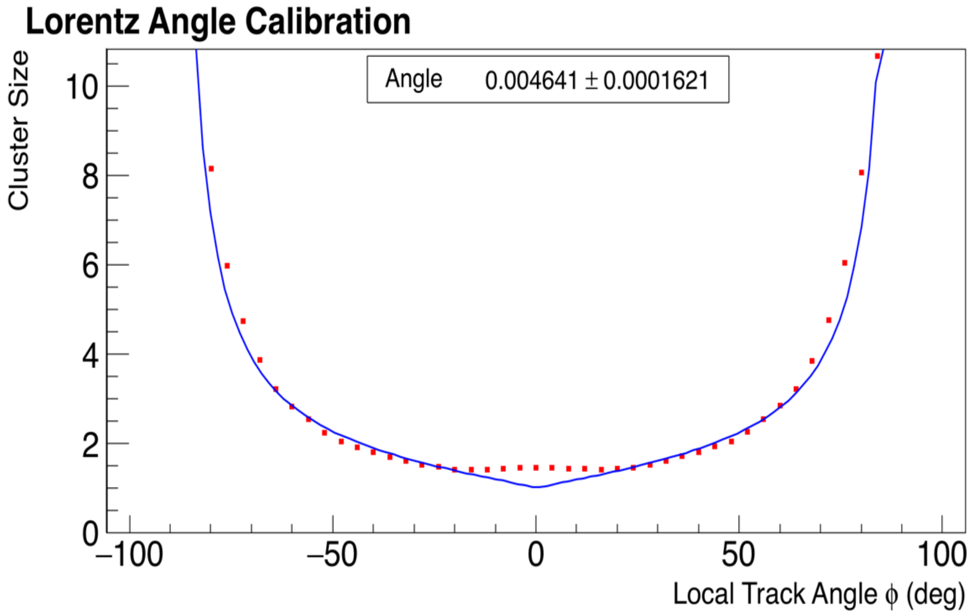


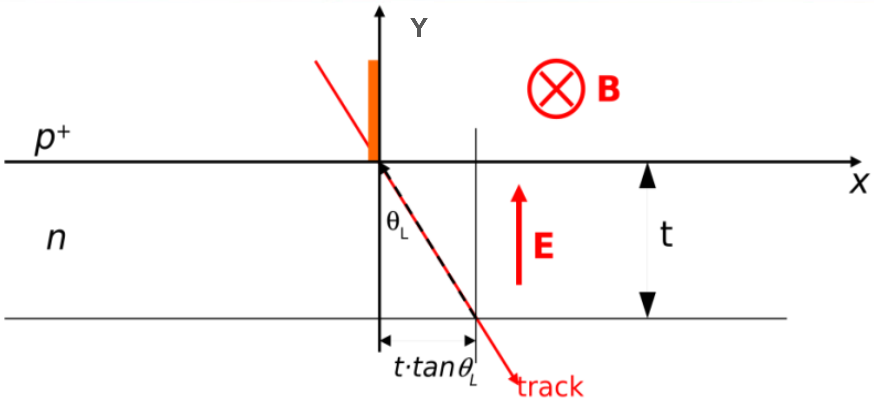


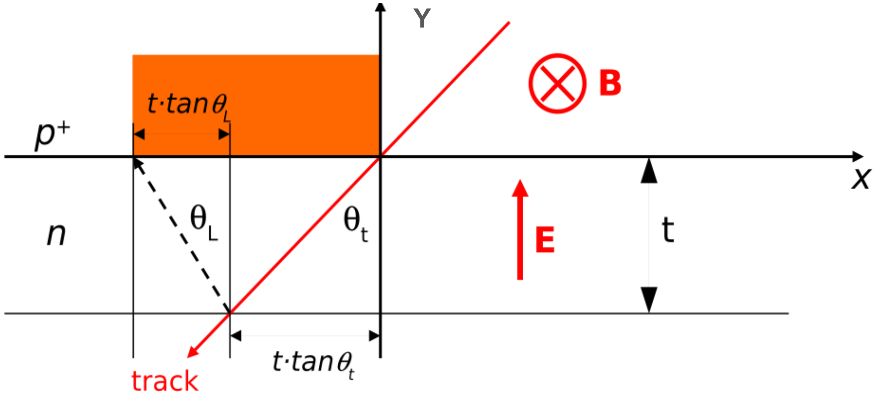


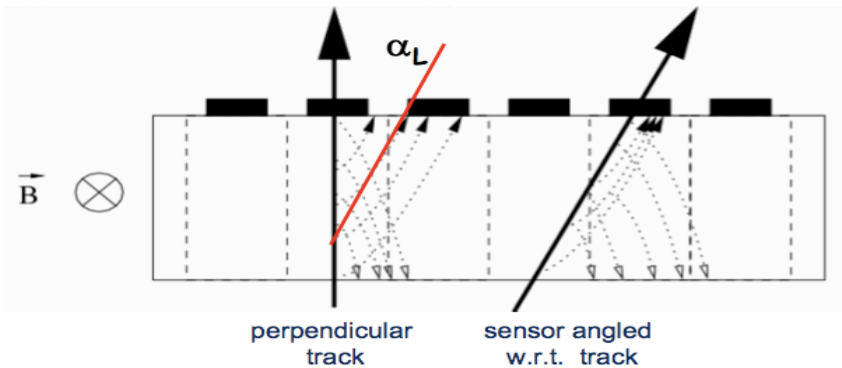
Lorentz Angle Calibration

- In a strong magnetic field, charge in the silicon detector drifts at the Lorentz Angle, which must be taken into account when reconstructing the cluster position
- The Lorentz angle can be calculated as the track incidence angle corresponding to the minimum of the average cluster size
- The minimum is at normal incidence when the solenoid field is off
- Lorentz Angle calibration has strong impact on alignment

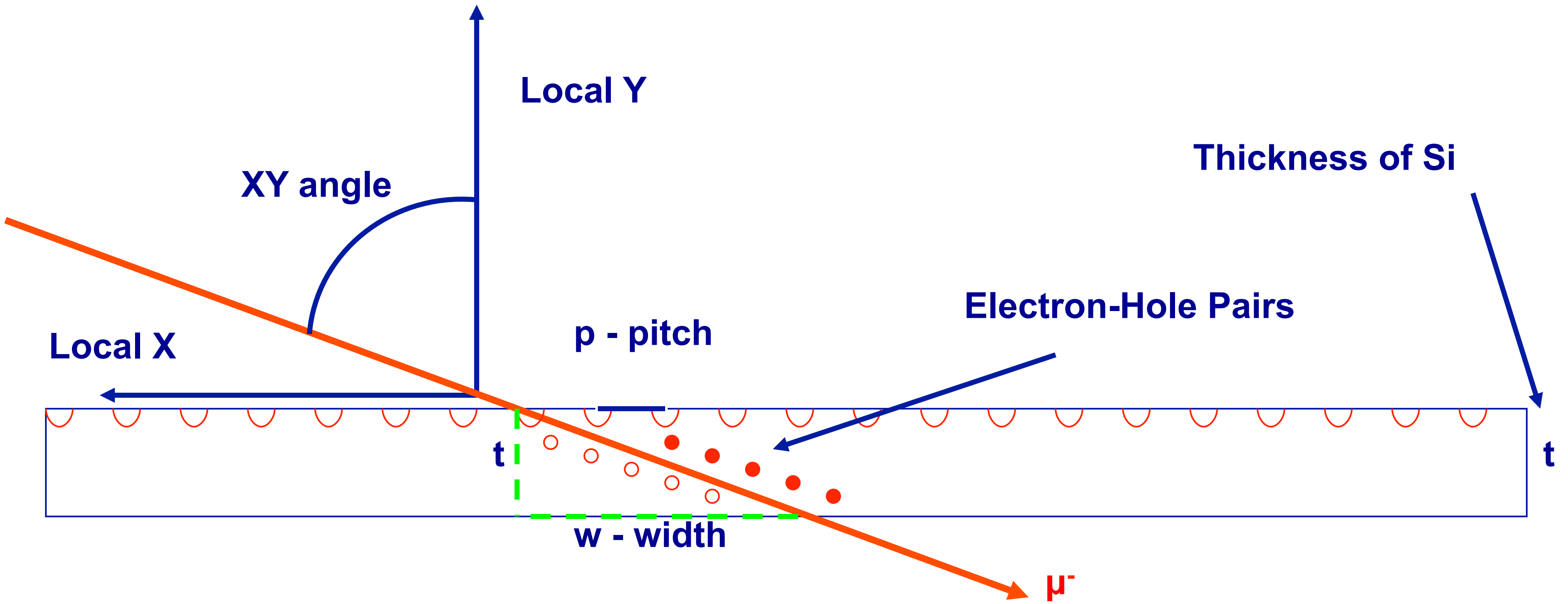








Lorentz Angle Calibration



$$w = t \cdot \tan(angle)$$

$$clustersize = w / p$$

$$clustersize = A \cdot \frac{t}{p} \cdot \tan(angle - \theta_L) + y$$

Fitting Parameters:

A – Correction to expected t/p

Θ_L – Lorentz Angle

y – cluster size when Θ = 0

t/p = 320/156 = 2.05

Alignment

- Alignment of the SVT requires finding small shifts in sensor position and orientation.
  - Number of parameters = $N_{regions}$ x N_{layers} x N_{trans} x N_{rot} = 66 x 2 x 3 x 2 = 792 parameters. BIG!
  - Other experiments face daunting challenges – CMS silicon tracker at LHC has about 50,000 parameters.
- Program millepede (yes, that's how it's spelled) developed to do linear least squares fitting with many parameters.
  - Start with a matrix formulation of the least squares method and divide the matrix elements into two classes.
    - Global parameters – the geometry misalignments. 'Same' values in all the events.
    - Local – individual track fit parameters. Change from event-to-event.
    - Separate out the two classes of parameters.
  - Calculate the first partial derivatives of the fit residuals with respect to the local (i.e. fit) parameters and the global parameters (geometry misalignments).
  - Manipulate the linear least squares matrix to isolate the global parameters (geometry) and invert the results to obtain the solution.
- A simple example.
  - Two-dimensional 'detector' with eight planes (Fig. 1).
  - The fit equation is

$$y_{fit} = f(x, \vec{q}, \vec{p}) = \underbrace{\Delta y_1 + \Delta y_2 + \ldots + \Delta y_8}_{\text{global, } \vec{p}} + \underbrace{a + bx}_{\text{local, } \vec{q}}$$

  - Excellent fit results (Fig. 2) if the constraints are well measured (i.e. survey data).
  - Results sensitive to accuracy of constraints.

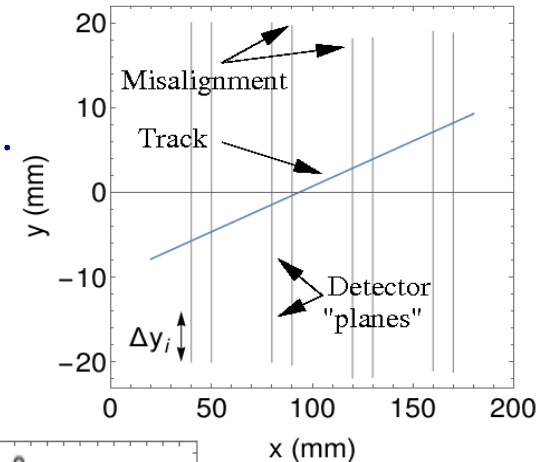


Figure 1

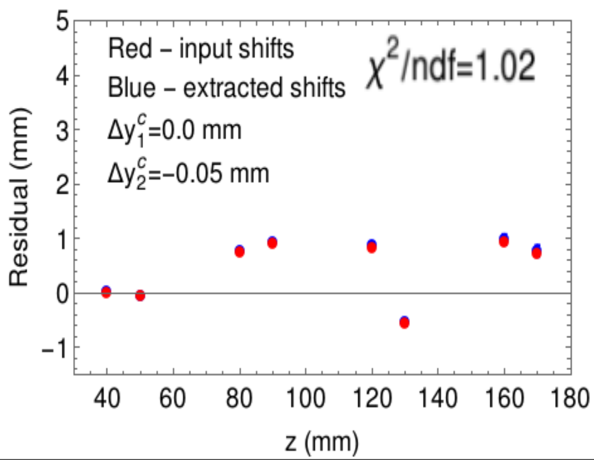
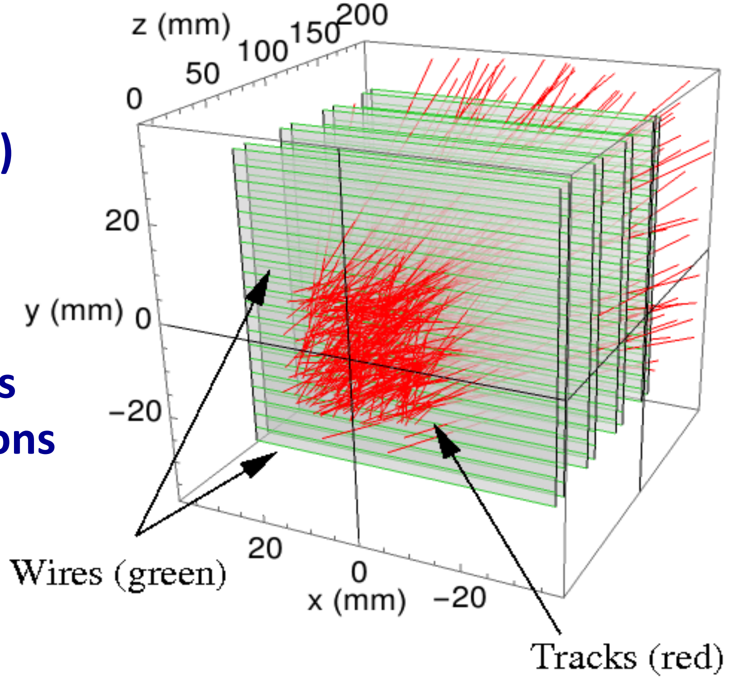


Figure 2

By Jerry Gilfoyle

Alignment

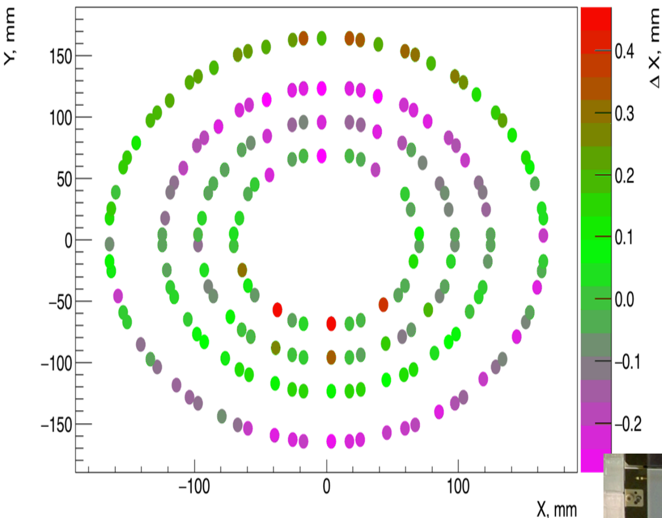
- Status of millepede at JLab
  - Program built and running on the JLab farm by Mike Staib (CMU)
  - Being used for alignment of GlueX CDC (Staib) and HPS silicon tracker (Alessandra Phillipe and Pelle Hansson)
- Introduction to millipede using 2D model
  - Comparatively easy to understand input and interpret results
  - Shows expected behavior
- Developed three-dimensional model with simplified geometry, type 1 SVT tracks (vertical through the center)
  - Easy-to-understand geometry
  - Can easily manipulate misalignments
- Millepede for 3D model
  - First version runs and produces reasonable outputs
  - Implementing and testing first derivative calculations
  - First derivatives can be complex
    - use *Mathematica* for symbolic calculations

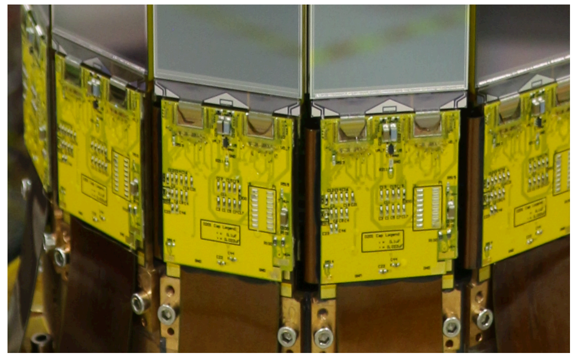


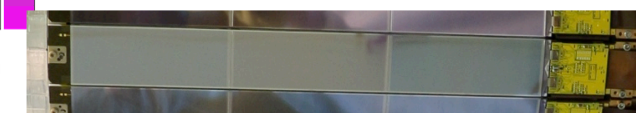
By Jerry Gilfoyle

Survey of Fiducial Displacement

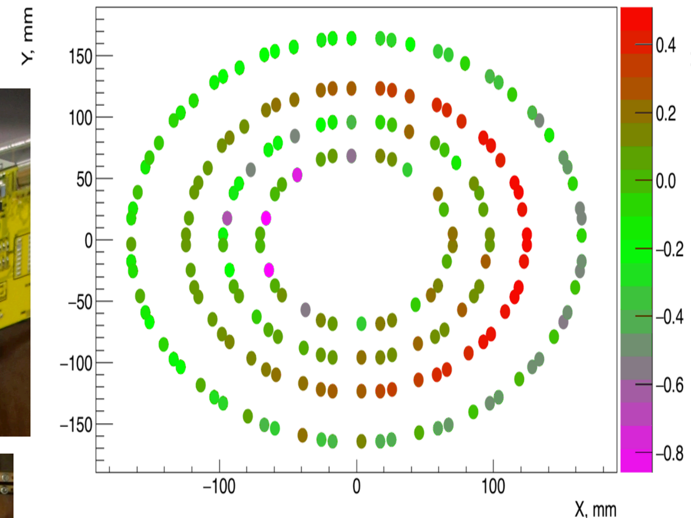
Fiducial displacement in X, mm



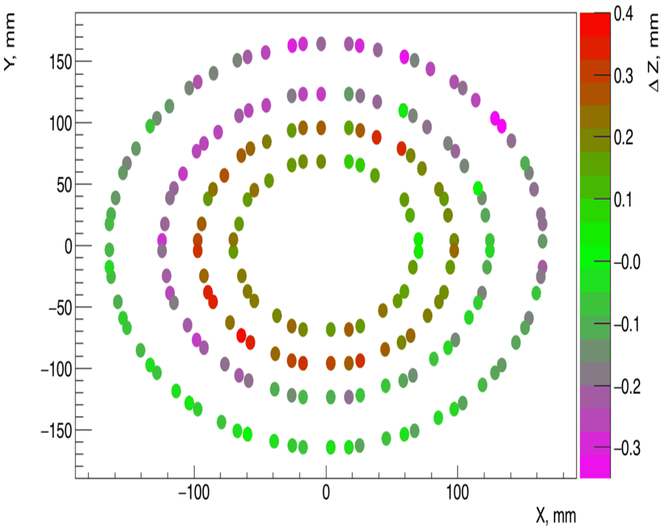


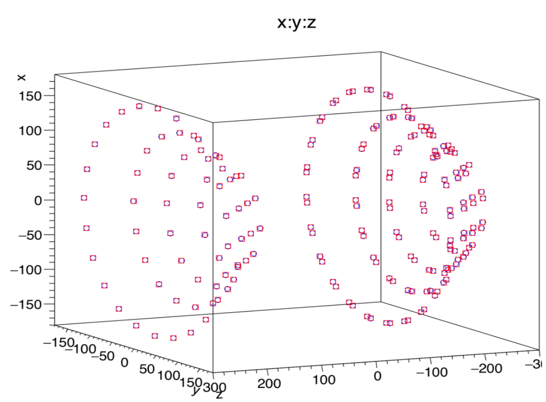


Fiducial displacement in Y, mm

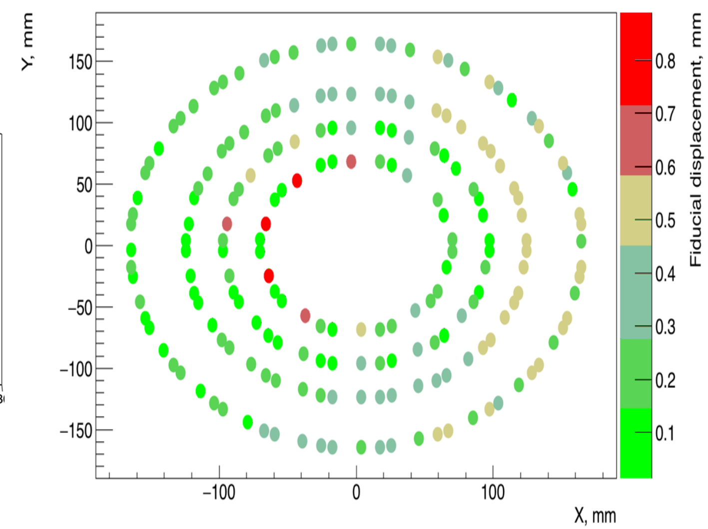


Fiducial displacement in Z, mm

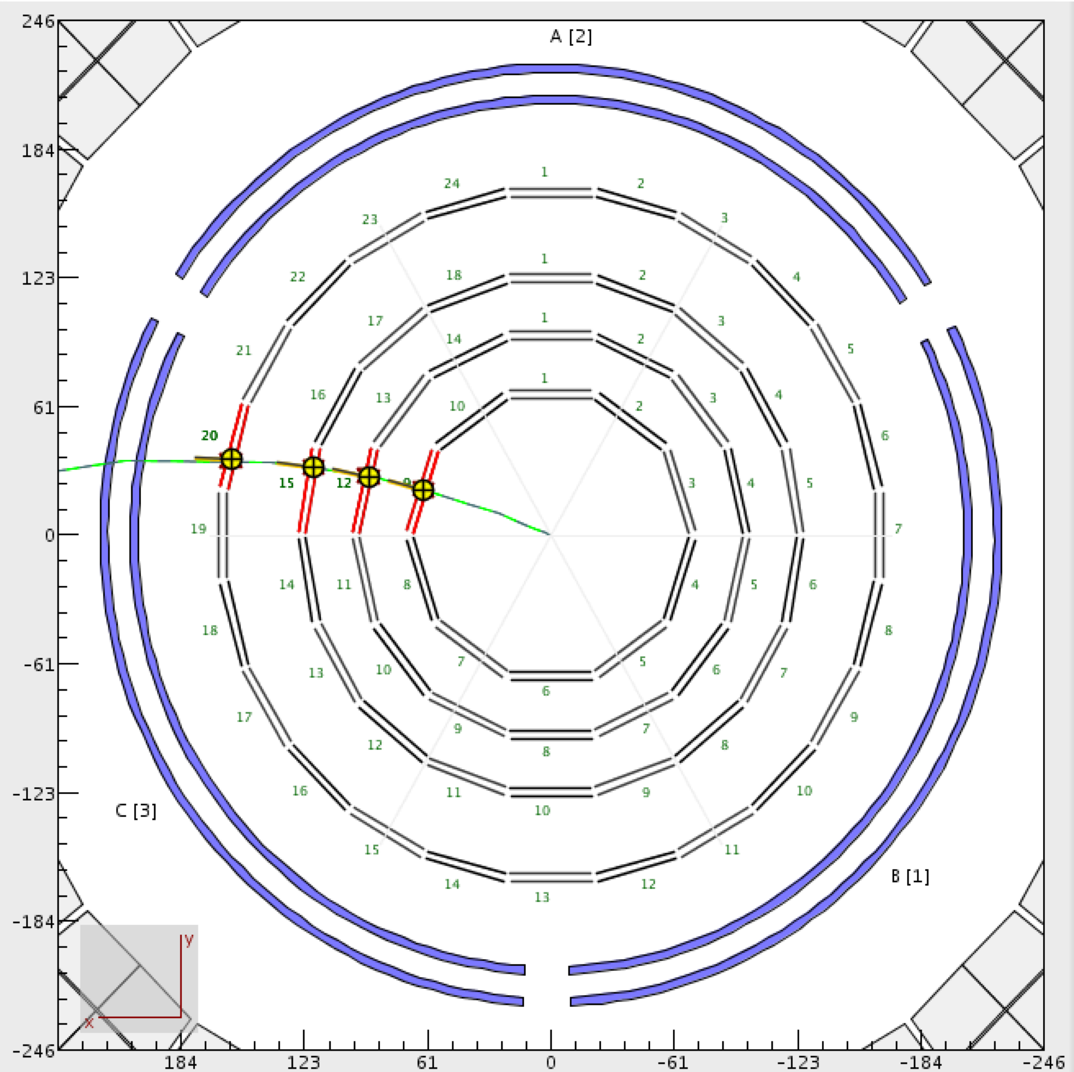


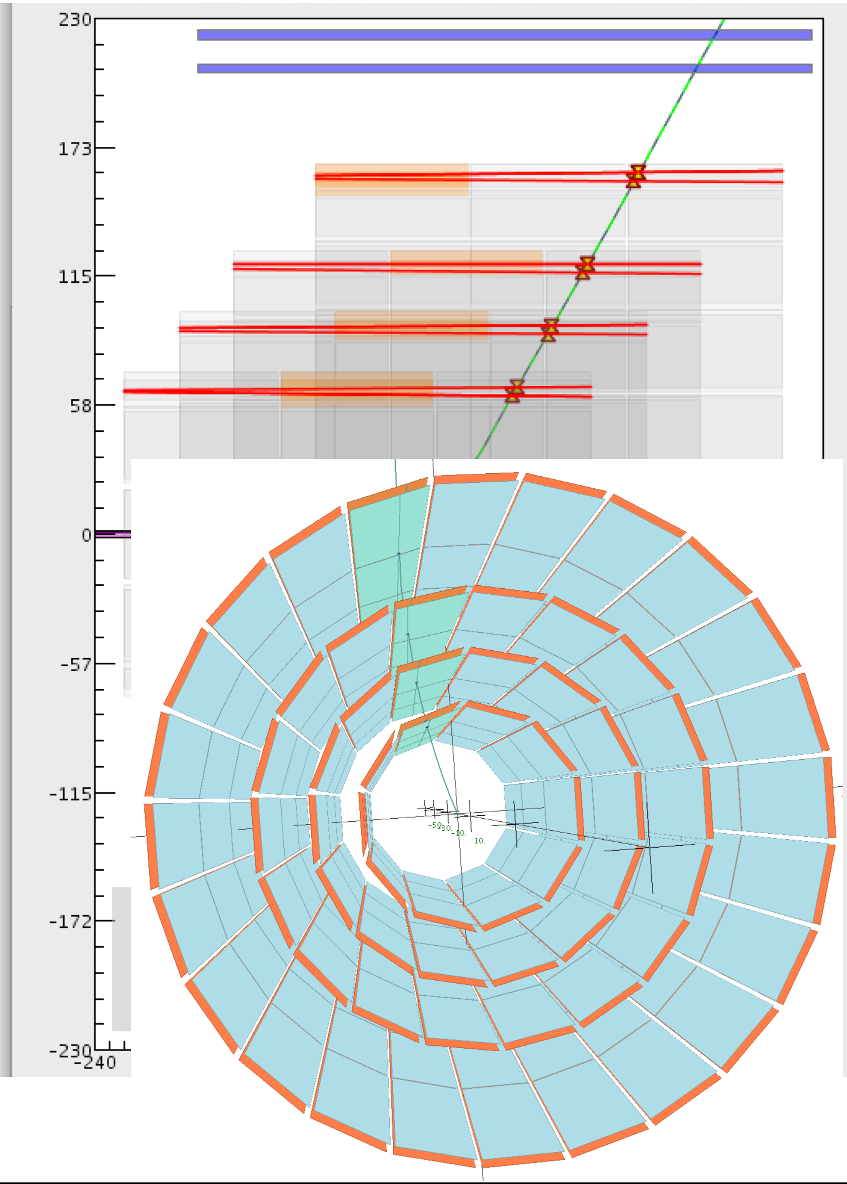


Fiducial displacement, mm

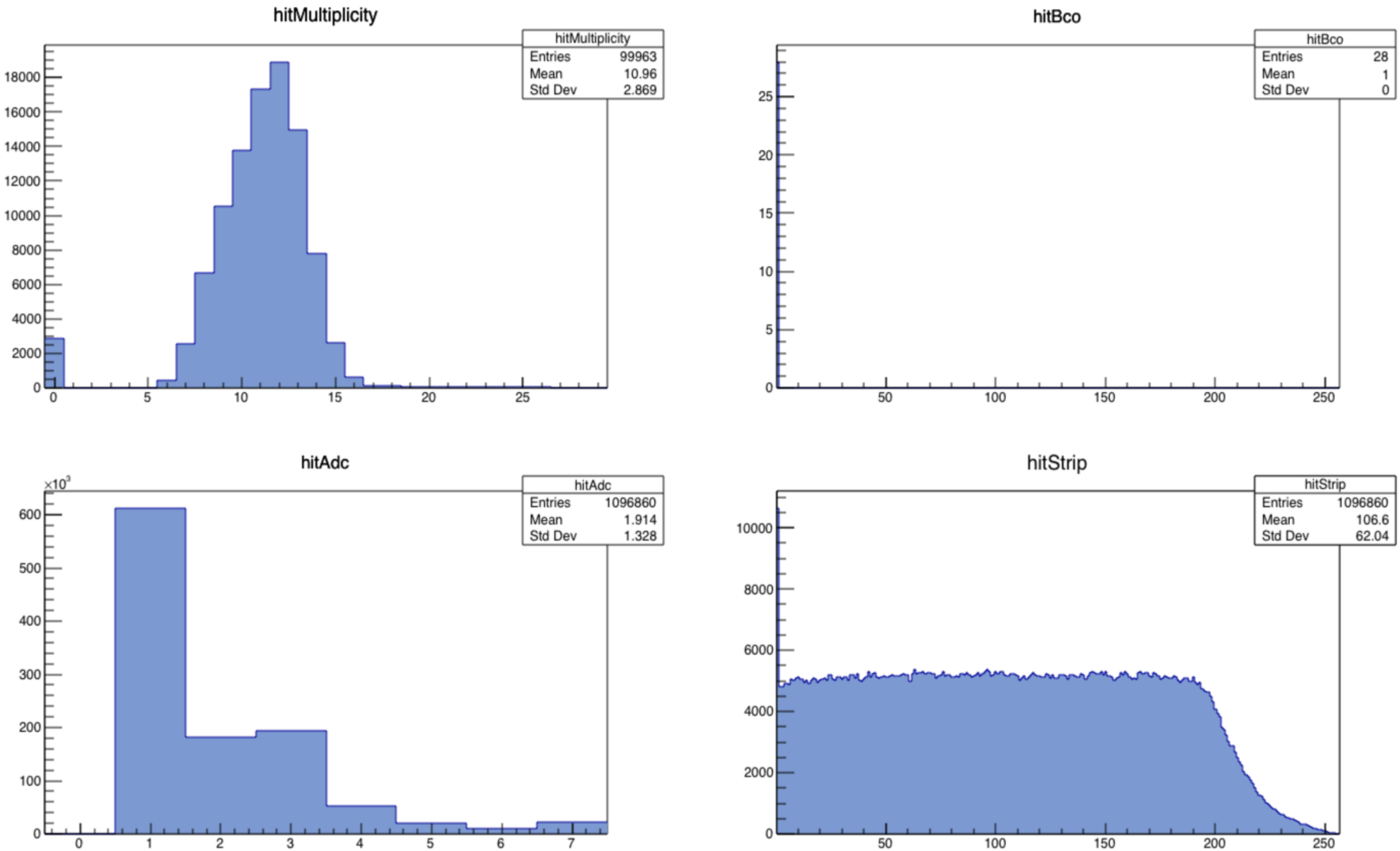


Monte Carlo Tuning

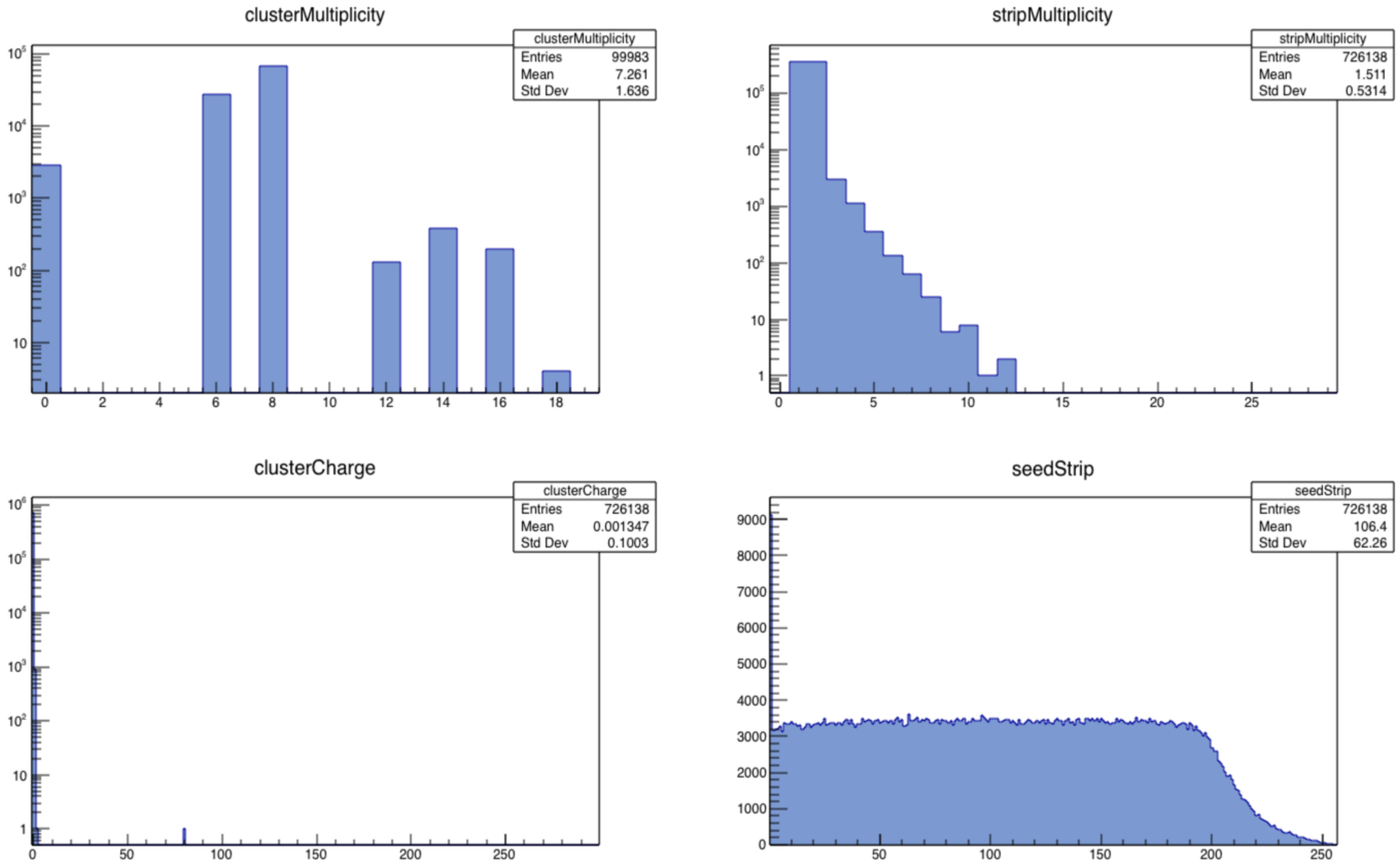




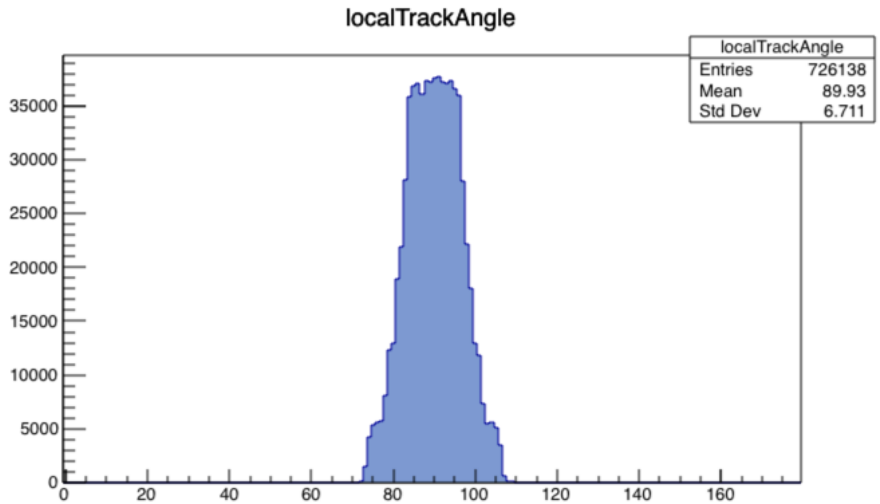
Monte Carlo Tuning: Local Reconstruction

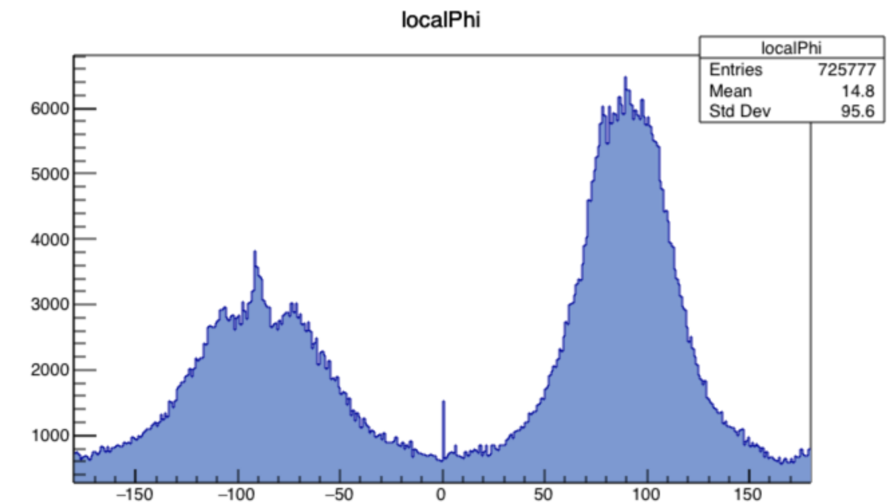


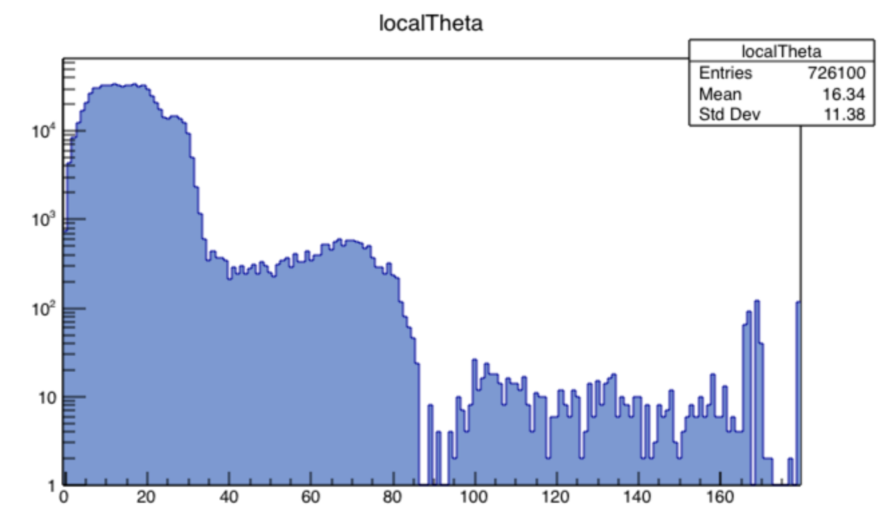
Monte Carlo Tuning: Local Reconstruction

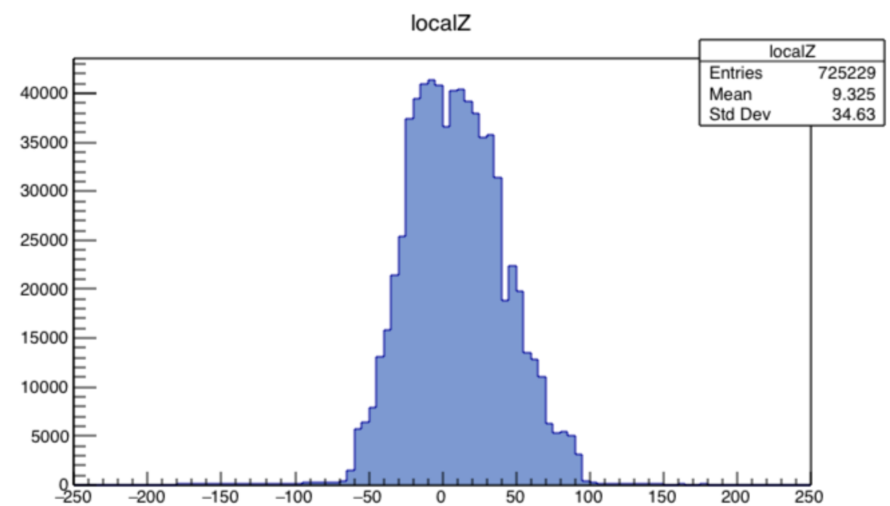


Monte Carlo Tuning: Trajectory

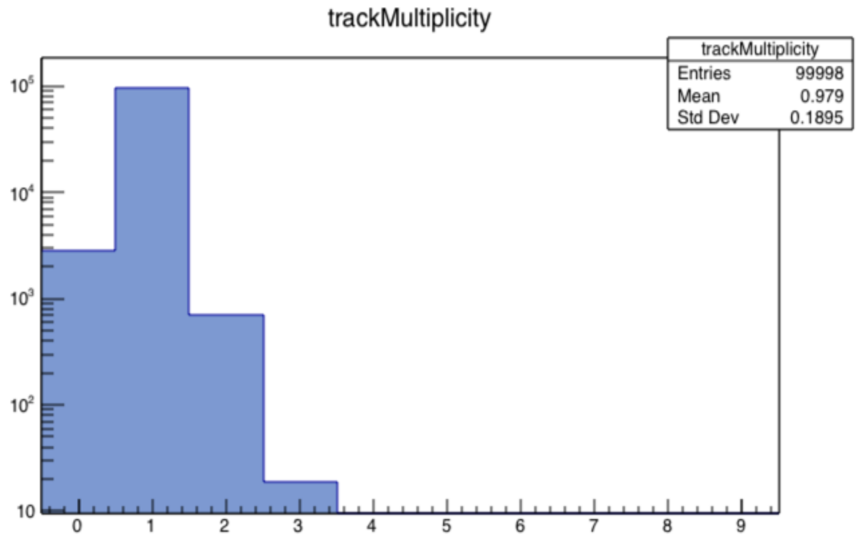


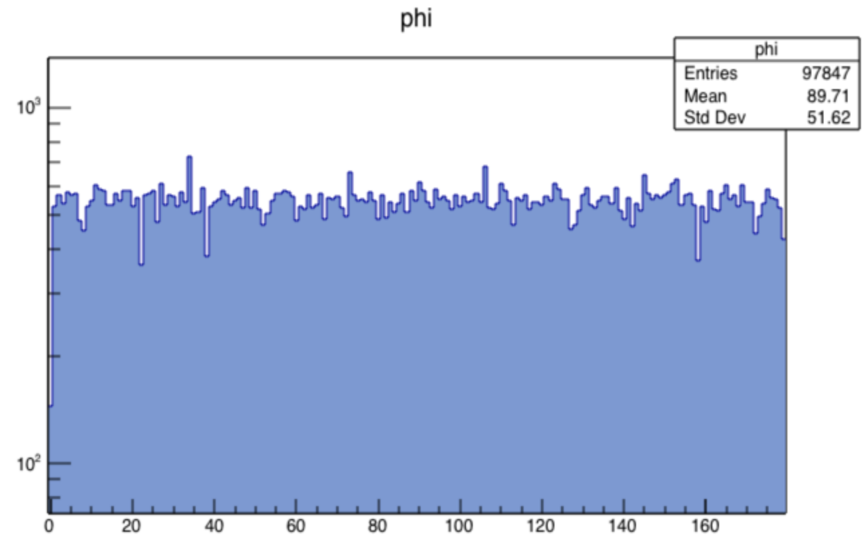


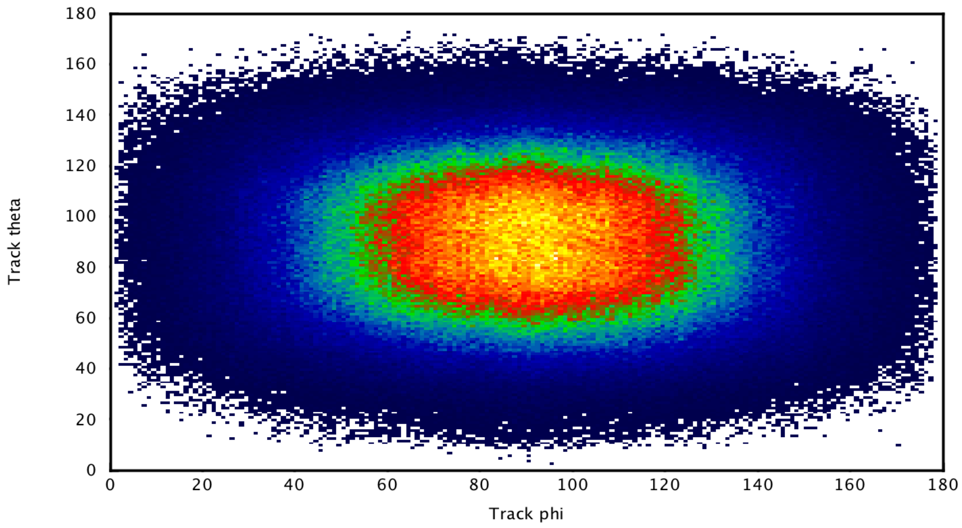


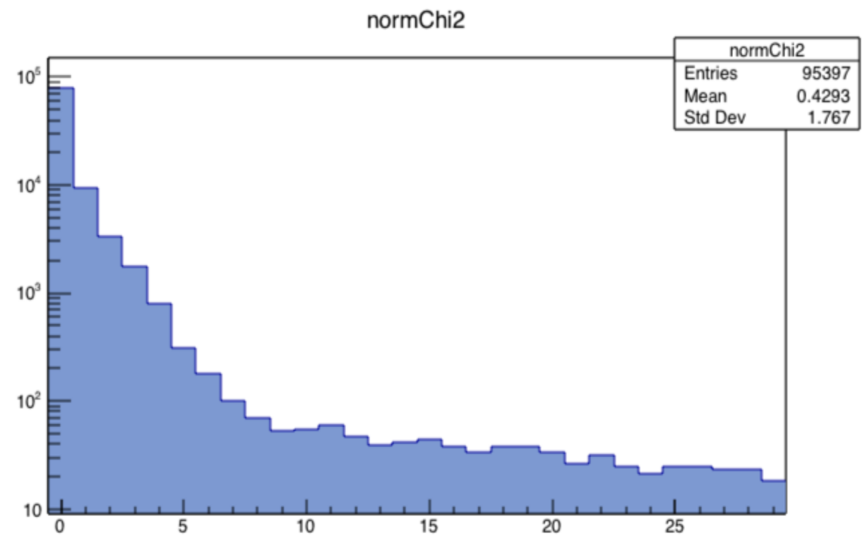


Monte Carlo Tuning: Track Reconstruction

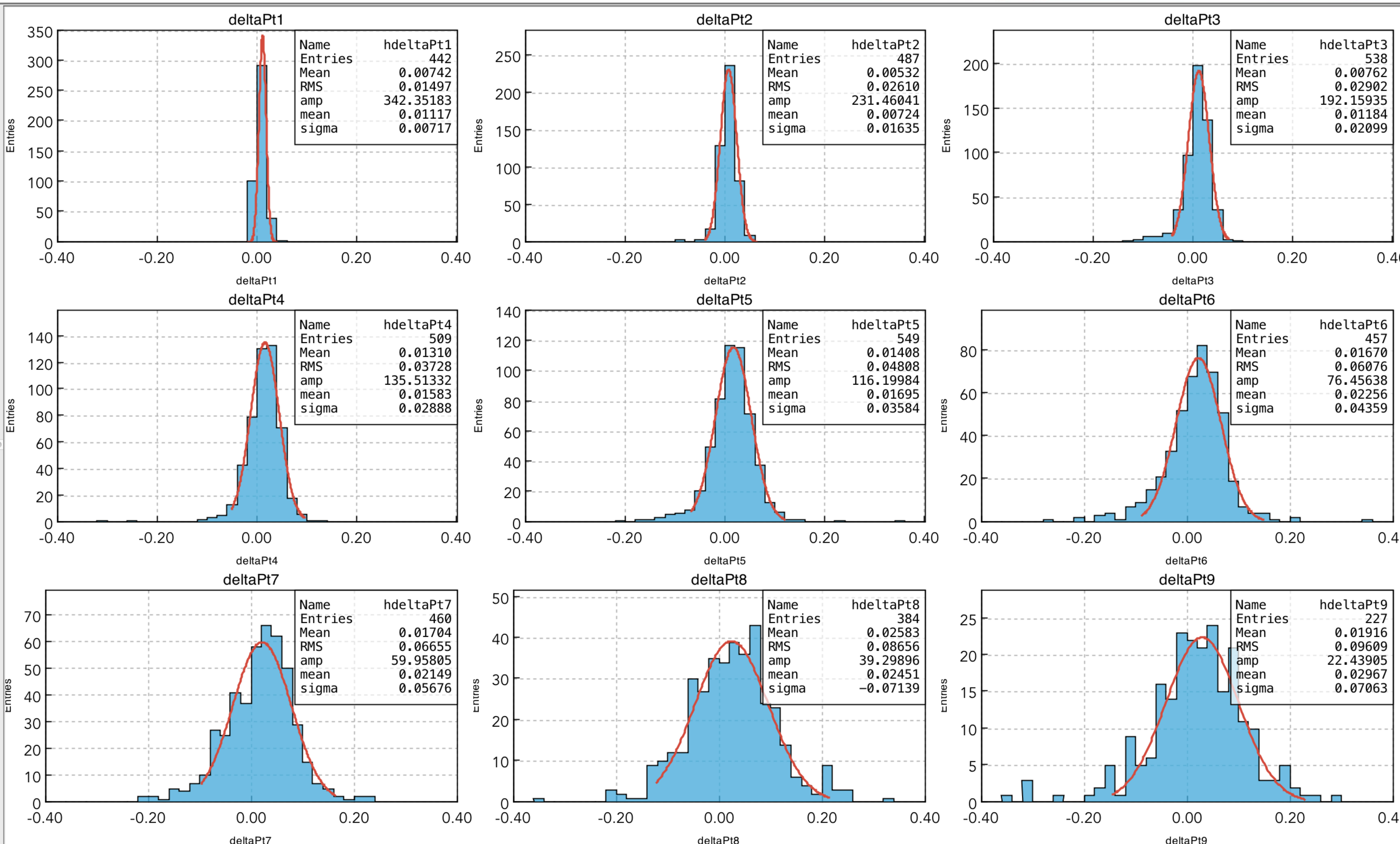




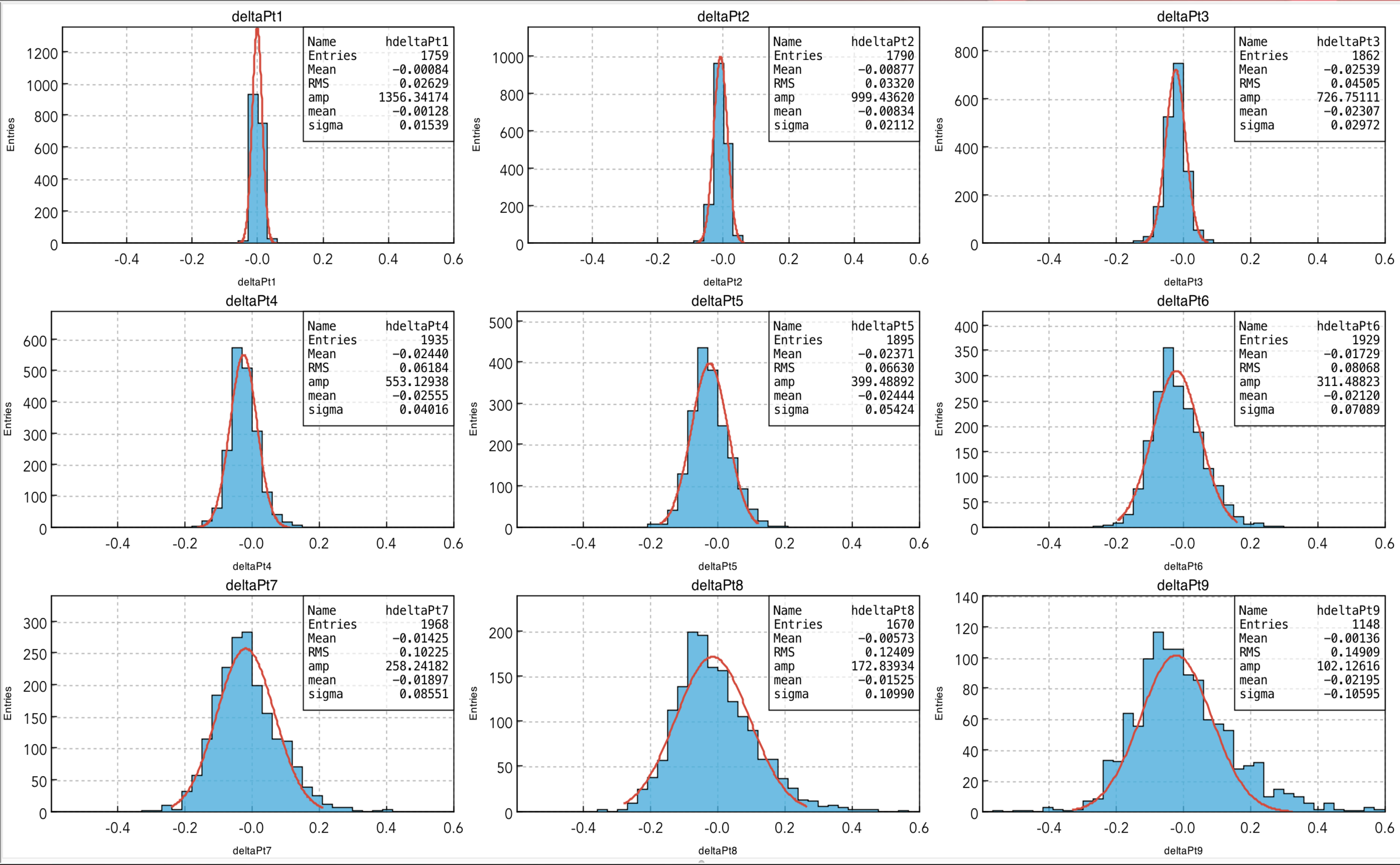




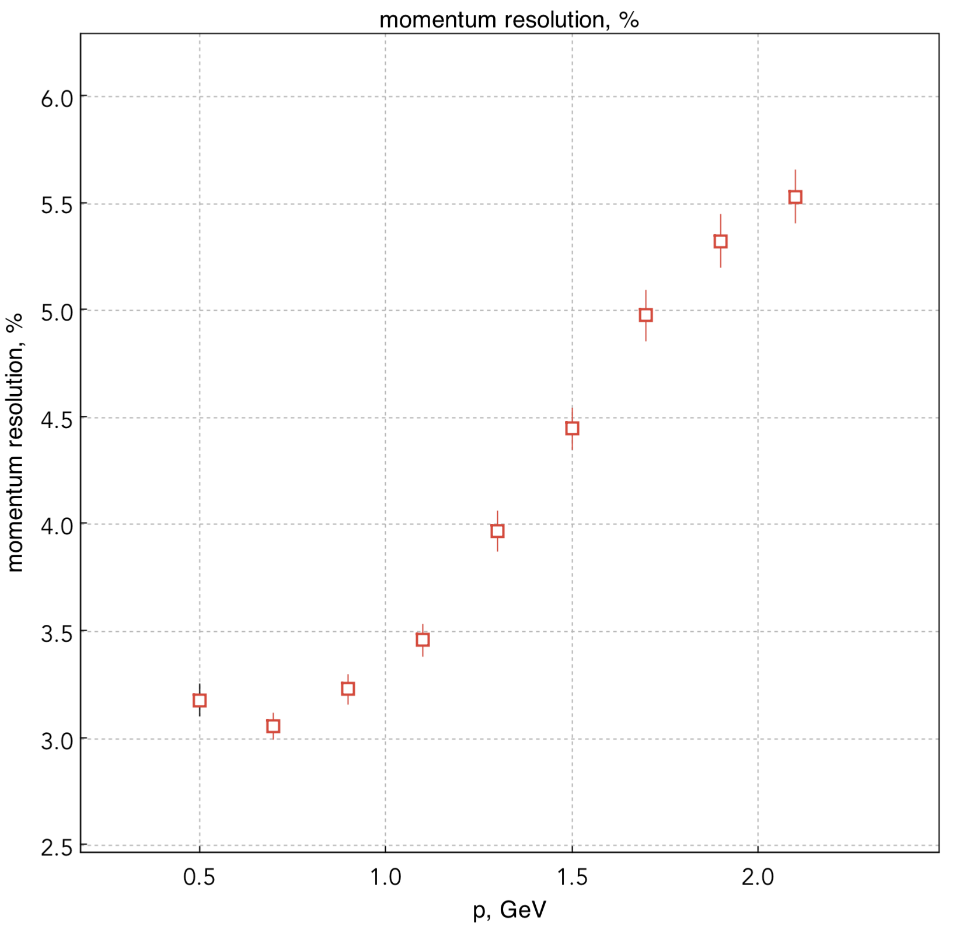
Monte Carlo Tuning: pT – pT_gen

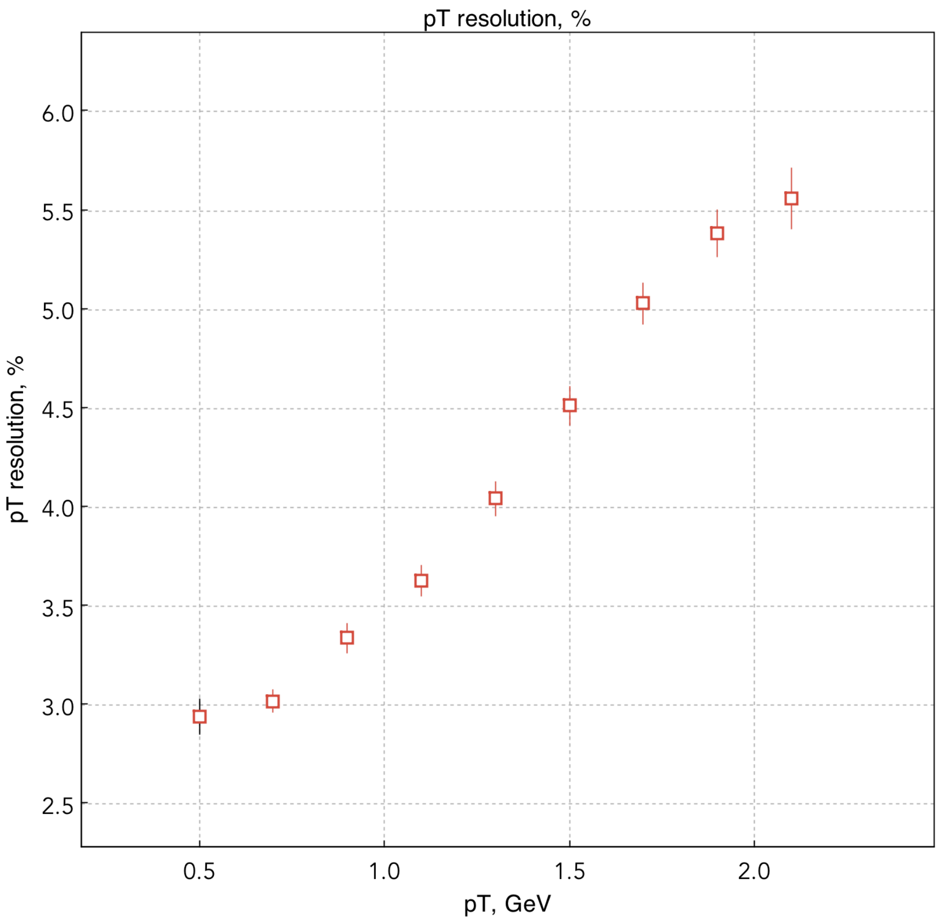


Monte Carlo Tuning: pT – pT_gen

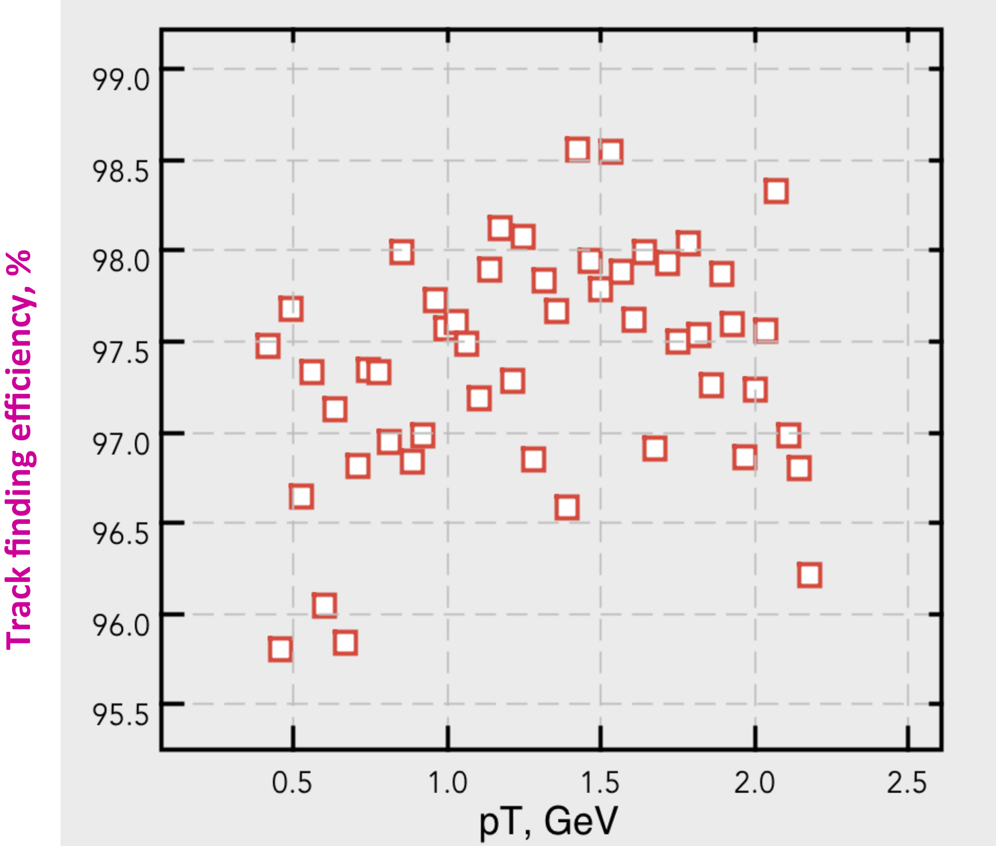


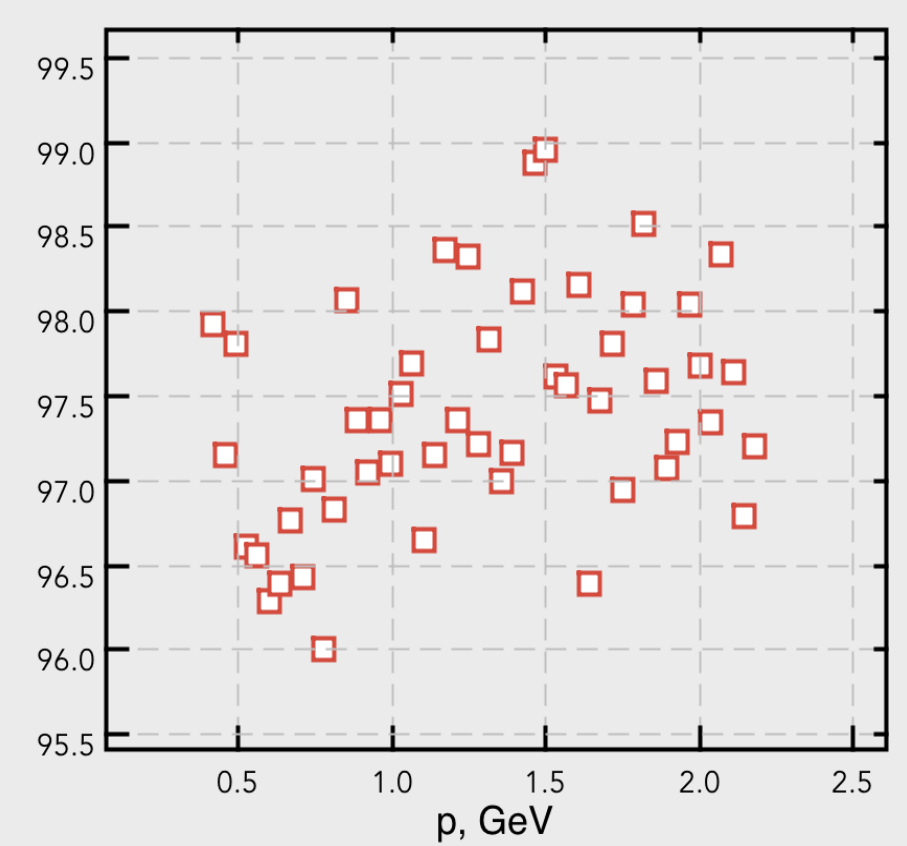
Monte Carlo Tuning: Momentum Resolution

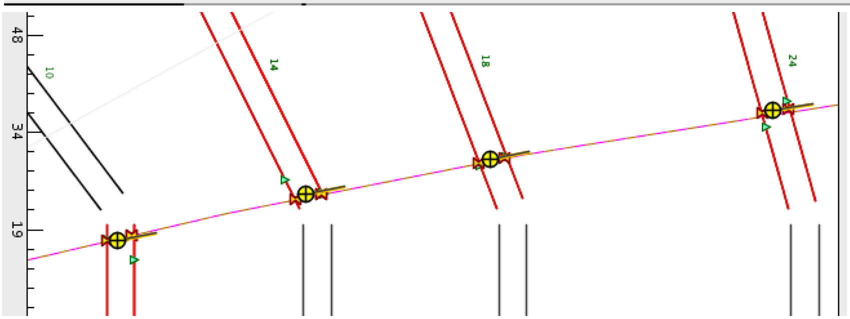


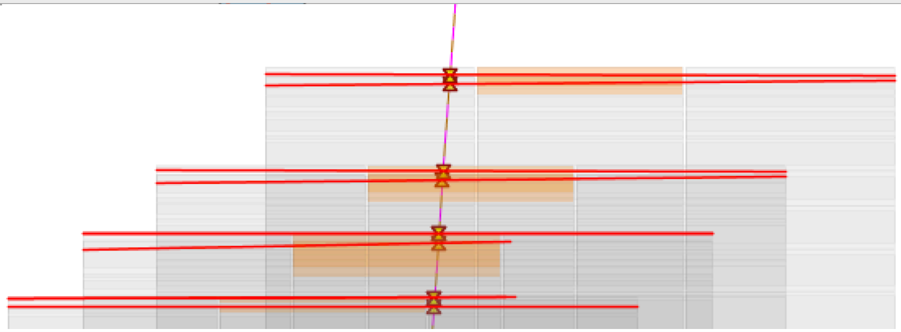


Monte Carlo Tuning: Track Finding Efficiency









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SVT Detector Description

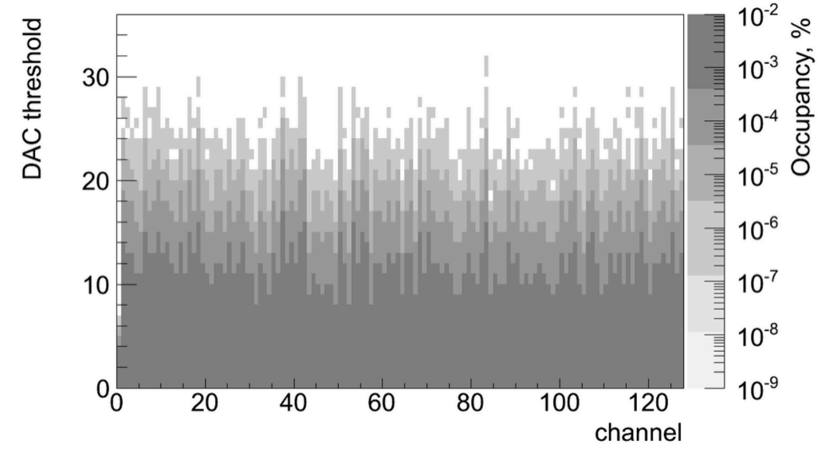
Quick Overview

For the 12 GeV upgrade, the CLAS12 experiment has designed a Silicon Vertex Tracker (SVT) using single sided microstrip sensors fabricated by Hamamatsu. The sensors have graded angle design to minimize dead areas and a readout pitch of 156 μm, with intermediate strip. Double sided SVT module hosts three daisy-chained sensors on each side with full strip length of 33 cm. There are 512 channels per module read out by four Fermilab Silicon Strip Readout (FSSR2) chips featuring data driven architecture, mounted on a rigid-flex hybrid. Modules are assembled on the barrel using unique cantilevered geometry to minimize amount of material in the tracking volume.

Introduction

The Continuous Electron Beam Accelerator Facility's (CEBAF) Large Acceptance Spectrometer (CLAS) is being upgraded for the 12 GeV electron beam to conduct spectroscopic studies of excited baryons and of polarized and unpolarized quark distributions, investigations of the influence of nuclear matter on propagating quarks, and measurements of Generalized Parton Distributions (GPDs). Deep exclusive reactions, in which an electron scattering results in a meson-baryon final state, provide stringent requirements for the CLAS12 tracking system. The central tracker consists of a solenoid, Central Time-Of-Flight system (CTOF), and Silicon Vertex Tracker (SVT). The SVT will be centered inside of the solenoid, which has 5 T magnetic field.

noise allows setting a 3 σ threshold at 20 keV level.



Channel noise occupancy vs. DAC hit/no-hit threshold (in DAC bins, one DAC bin corresponds to 3.5 mV).

SVT module performance meets physics requirements. Module production at Fermilab has been completed in February 2015. Barrel integration and commissioning is in progress. SVT detector will be installed in Hall B in 2016.

http://clasweb.jlab.org/clas12offline/docs/detectors/html/svt/introduction.html
https://clasweb.jlab.org/wiki/index.php/Clas12_SVT
https://userweb.jlab.org/~gotra/svt/doc/TDR4.pdf
https://userweb.jlab.org/~gotra/svt/doc/commissioning_svt_1.2.pdf

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By Igor Strakovski