STAR Forward Tracker

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RHIC & AGS Annual Users Meeting
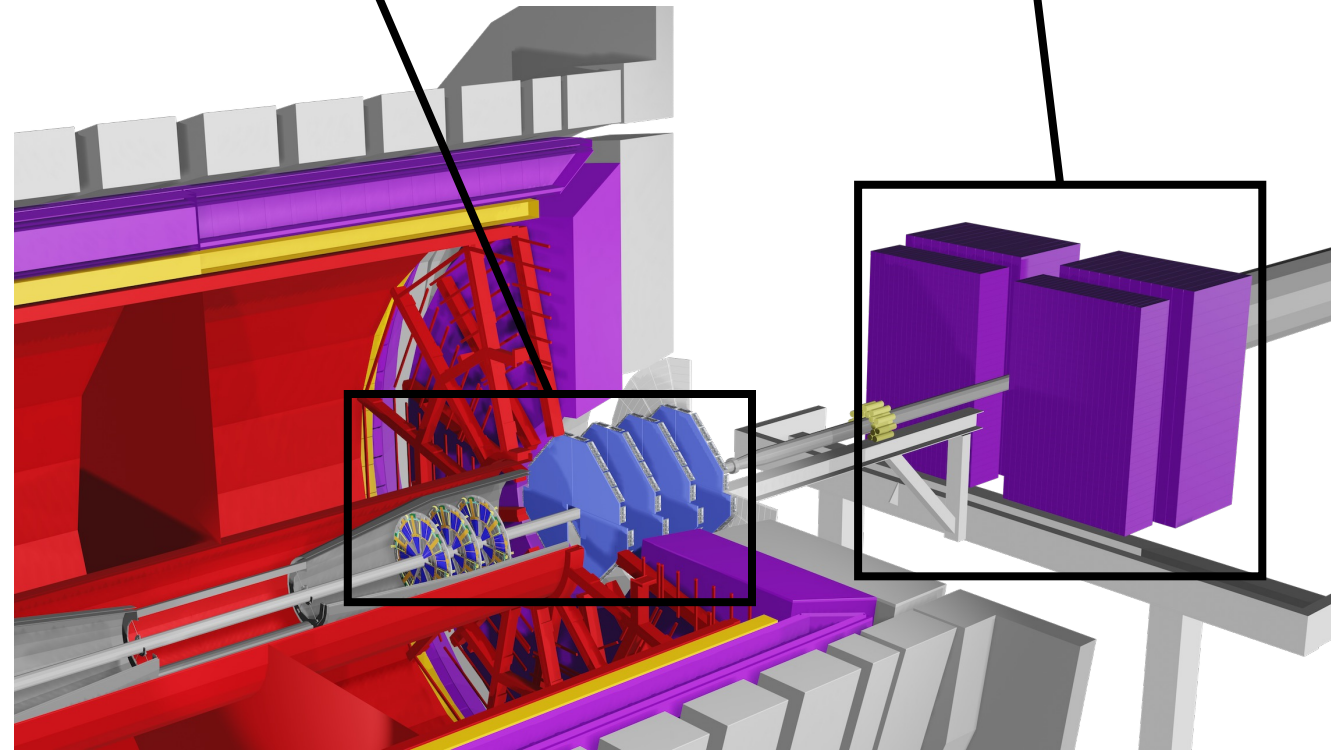
STAR Forward Upgrade: Overview

Forward Tracking System

this talk

Forward Colorimeter System

Xilin's talk

Installed at STAR successfully in 2021, and started taking data in 2022 (Run 22)

Forward Tracking System:

Forward Silicon Tracker (FST)
Forward small-strip Thin Gap Chamber Tracker (FTT)

- ✓ Charge separation
- ✓ $\delta p_T / p_T$ ~ 20-30% for 0.2 < p_T < 2 GeV/c

Forward Calorimeter System:

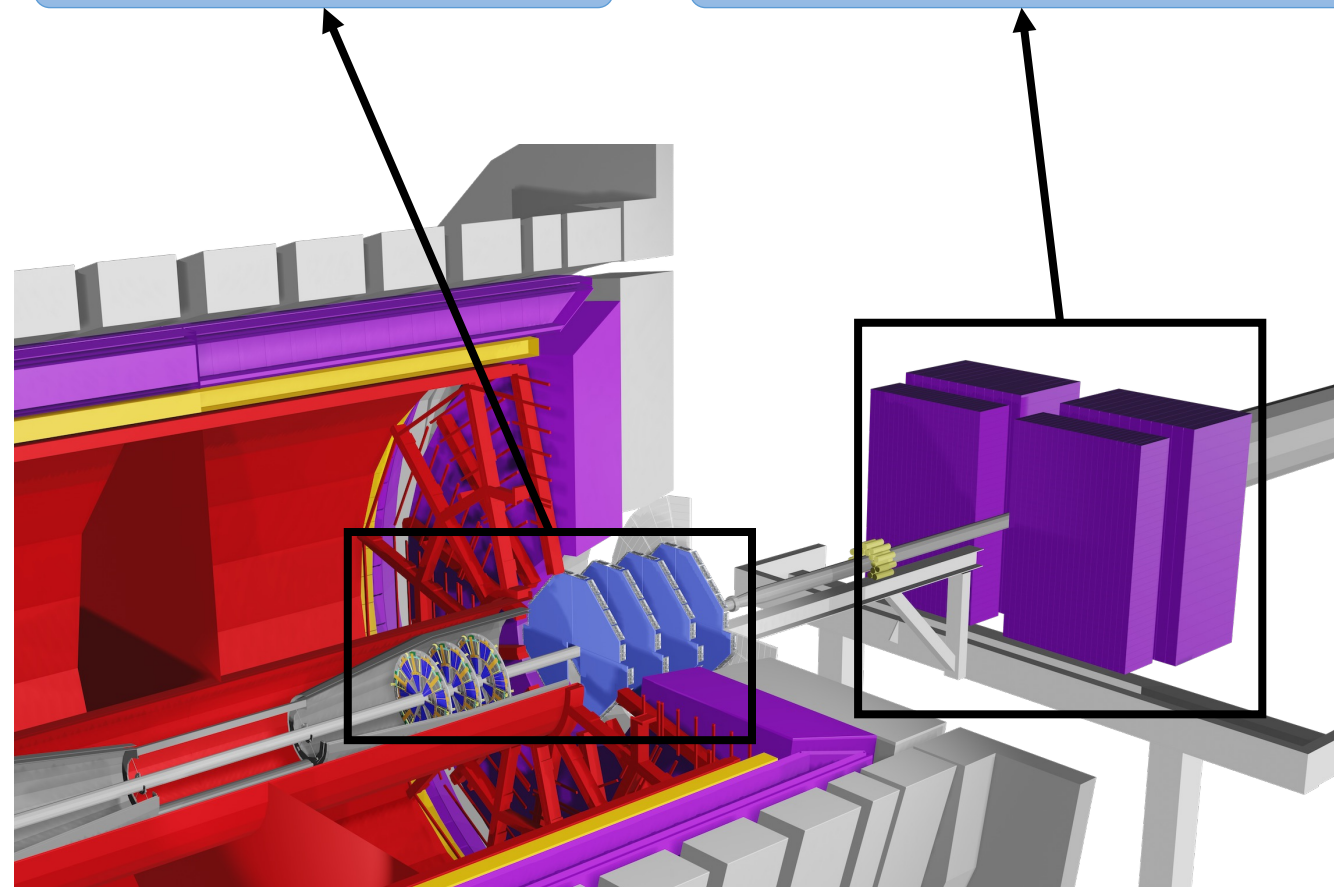Forward Electromagnetic Calorimeter (Ecal)
Forward Hadronic Calorimeter (Hcal)

- ✓ Good e/h separation
- ✓ Photon, π^0 identification

Locate at STAR west side, 2.5 < η < 4
Similar coverage as the EIC detector's hadron endcap

STAR Forward Upgrade: Physics Program

Forward Tracking System

Forward Colorimeter System

Locate at STAR west side, 2.5 < η < 4
Similar coverage as the EIC detector's hadron endcap

Installed at STAR successfully in 2021, and started taking data in 2022 (Run 22)

Cold QCD:

✓ p+p 510 GeV (2022) and p+p & p+Au 200 GeV (2024)
✓ Sivers asymmetries for hadrons, (tagged) jets, and di-jets
✓ Gluon PDFs for nuclei: R_{pA} for direct photons & DY
✓ Tests of Saturation predictions through dihadrons, γ-jets

Hot QCD:

✓ Au+Au 200 GeV (2023 and 2025)
✓ Temperature dependence of viscosity through flow harmonics up to η ~ 4
✓ Longitudinal decorrelation up to η ~ 4
✓ Global Lambda Polarization: test predictions of strong rapidity dependence ...

Observables:

✓ Charged and neutral hadrons
✓ Inclusive jets and di-jets
✓ Photons and electrons
✓ Mid-forward and forward-forward rapidity correlations

Forward Silicon Tracker

Locate at STAR west side, $2.5 < \eta < 4$
Rapidity coverage similar to the EIC hadron endcap
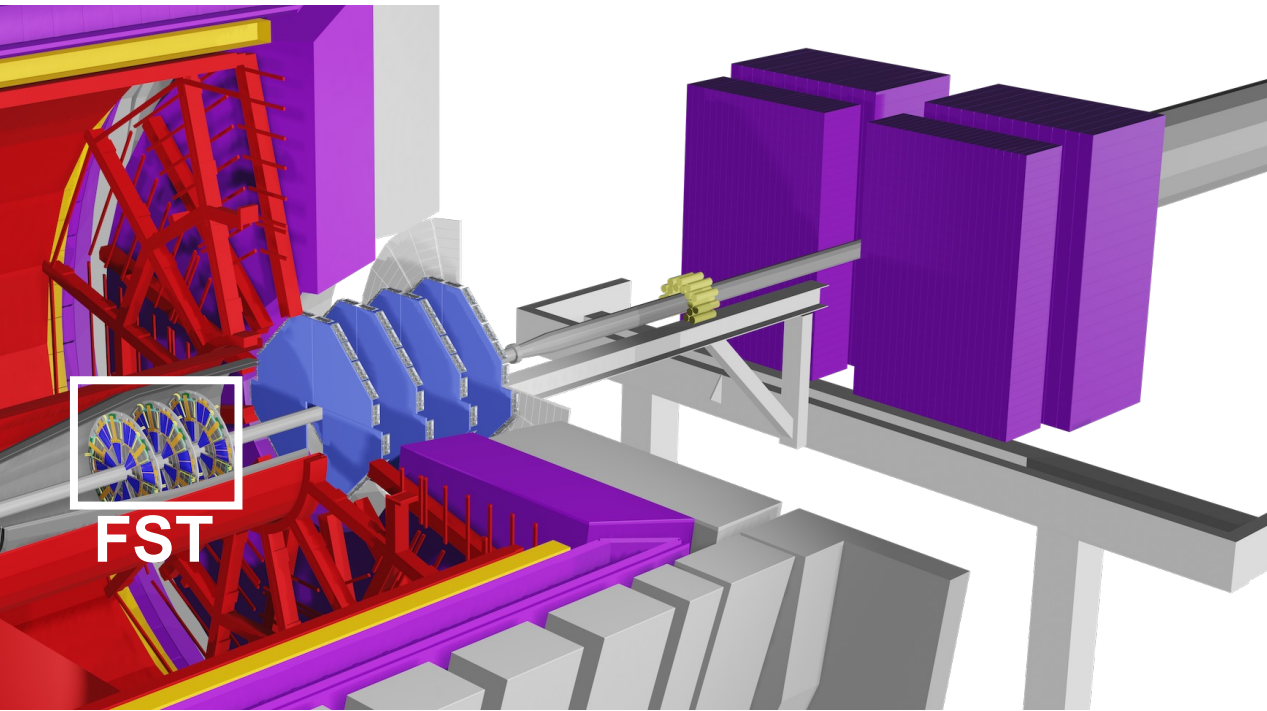
3 Silicon disks:
- ✓ 152, 165, and 179 cm from IP
- ✓ Locate inside STAR TPC cone
- ✓ Single-sided double-metal mini-strip sensors

Granularity:
- ✓ fine in ϕ and coarse in R
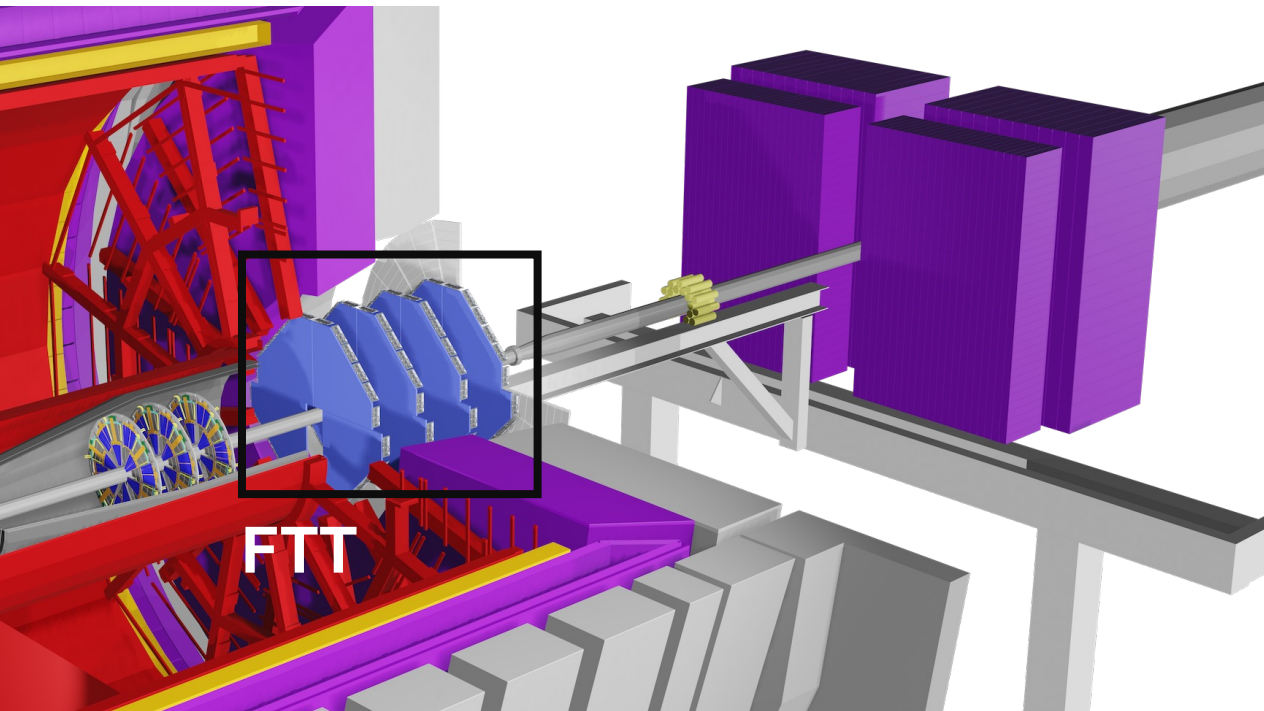- ✓ Si from Hamamatsu

Front-end chips:
- ✓ APV25

Material budget:
- ✓ ~1% per disk

Forward sTGC Tracker

Locate at STAR west side, $2.5 < \eta < 4$
Rapidity coverage similar to the EIC hadron endcap

FTT

4 sTGC disks:
✓ 307, 325, 343 and 361 cm from IP
✓ Locate inside STAR magnet pole tip opening
✓ Inhomogeneous magnetic field

Working gas:
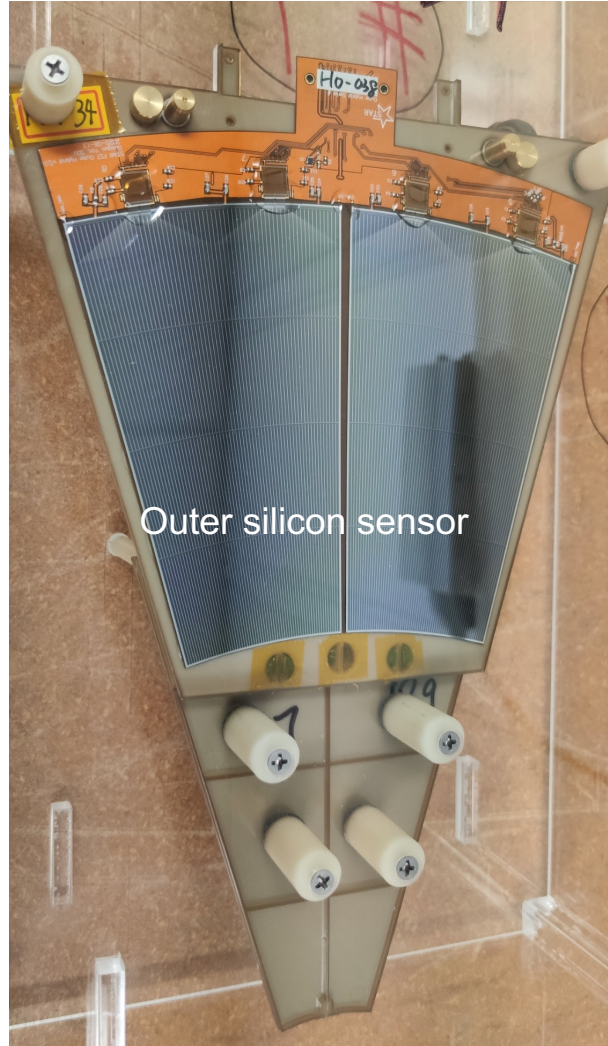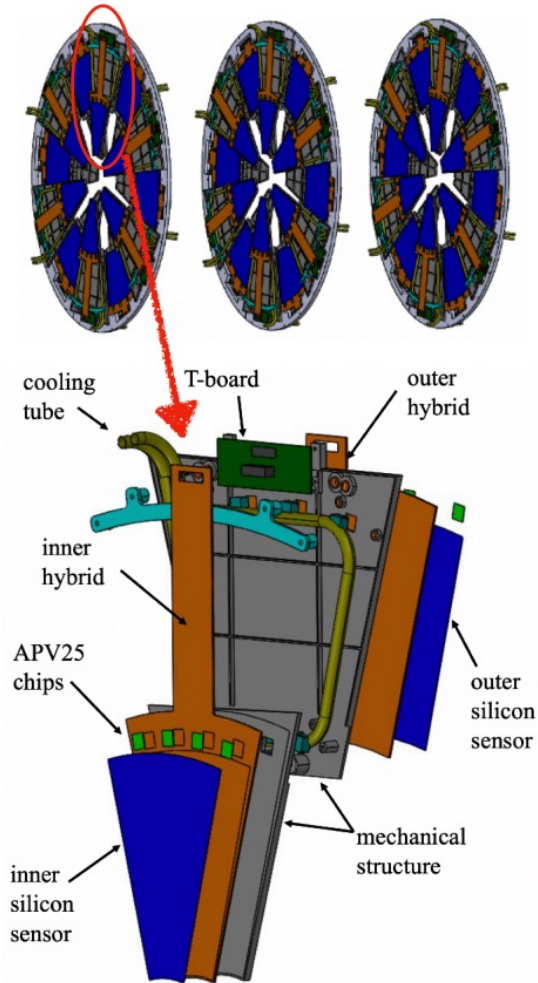✓ n-pentane + CO_2

Position resolution:
✓ < 200 um

Material budget:
✓ ~0.5% per layer

Readout:
✓ based on VMM-chips => Following ATLAS design

Forward Silicon Tracker Module Design

Outer silicon sensor

Each module splits into two regions:

Inner-radius region: 5 < R < 16.5 cm
- ✓ 1 Si sensor 128 × 4 ($\phi \times R$) strips
- ✓ 4 APV chips
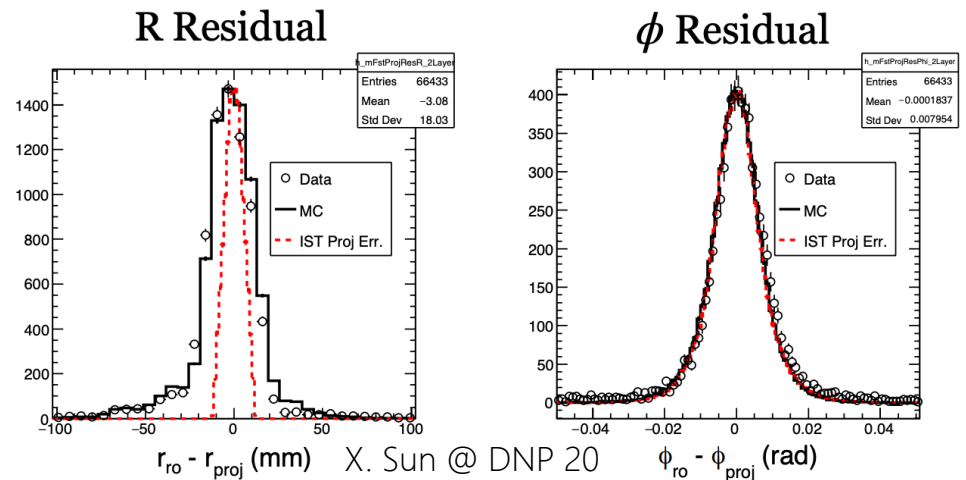
Outer-radius region: 16.5 < R < 28 cm
- ✓ 2 Si sensor 128 × 4 ($\phi \times R$) strips
- ✓ 4 APV chips

Better position resolution in ϕ direction

8/2/2023   X. Sun @ DNP 20

Forward sTGC Tracker Module Design
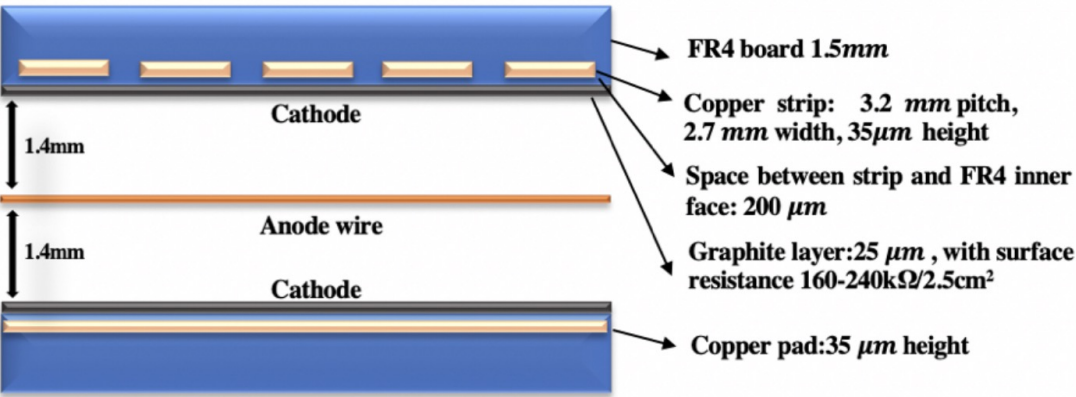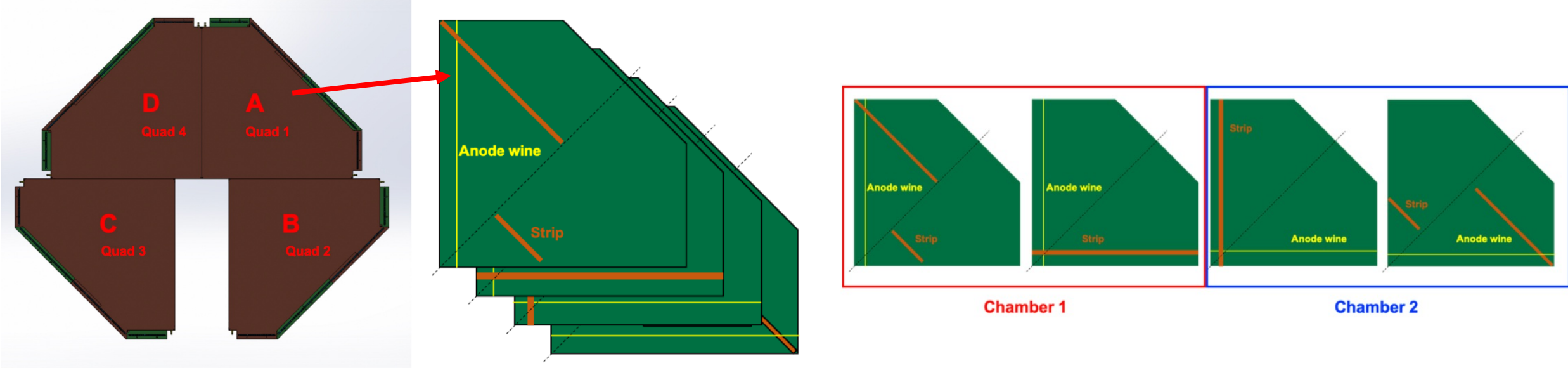
Y. Shi @ INSTR 20

FTT layer combine with 4 pentagon modules:

Center of charge method to get hit position
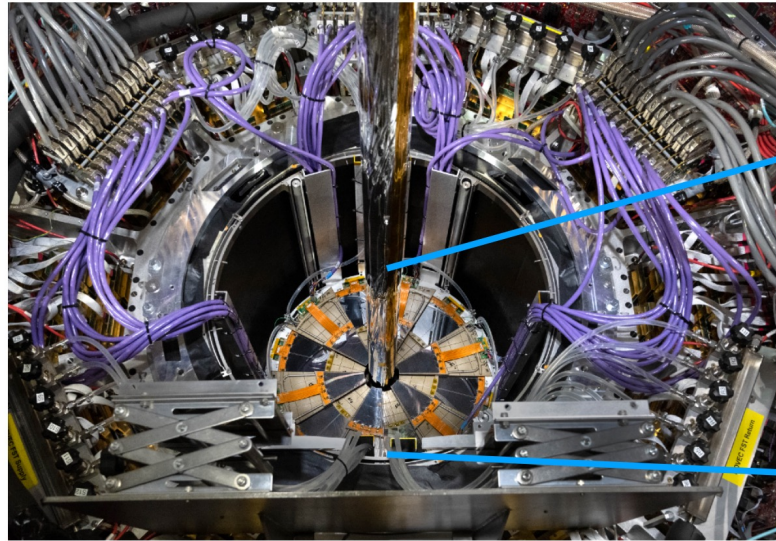- ✓ Perpendicular to strip

2 independence chambers per module
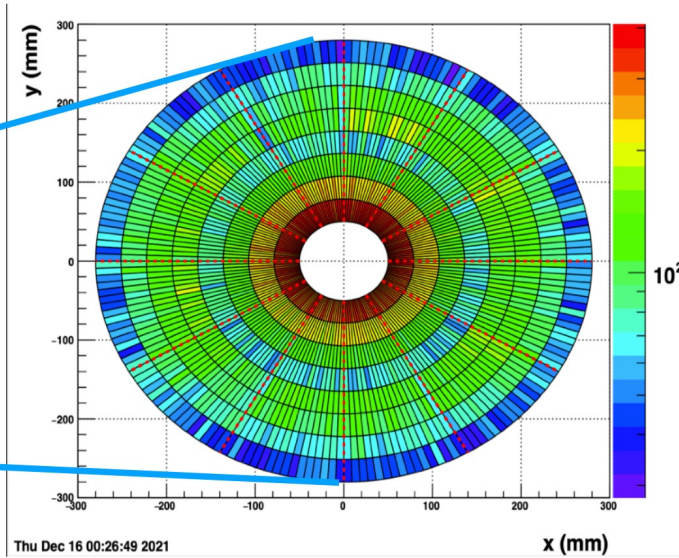- ✓ Read X and Y position separately
- ✓ Diagonal strips to reject ghost hits
- ✓ Same position resolution for each directions
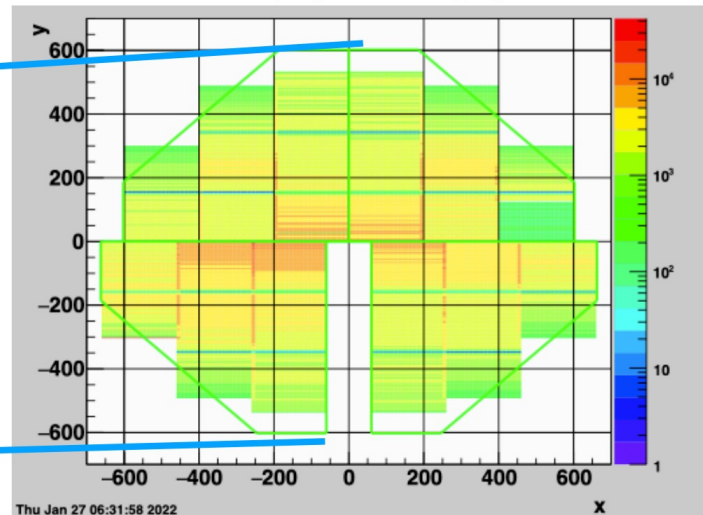
Forward Tracker Performance: Operation

FST event display in run22 p+p 510GeV

Thu Dec 16 00:26:49 2021

FTT event display in run22 p+p 510GeV

Thu Jan 27 06:31:58 2022

FST :
- ✓ HV:
  - o 140V for inner module
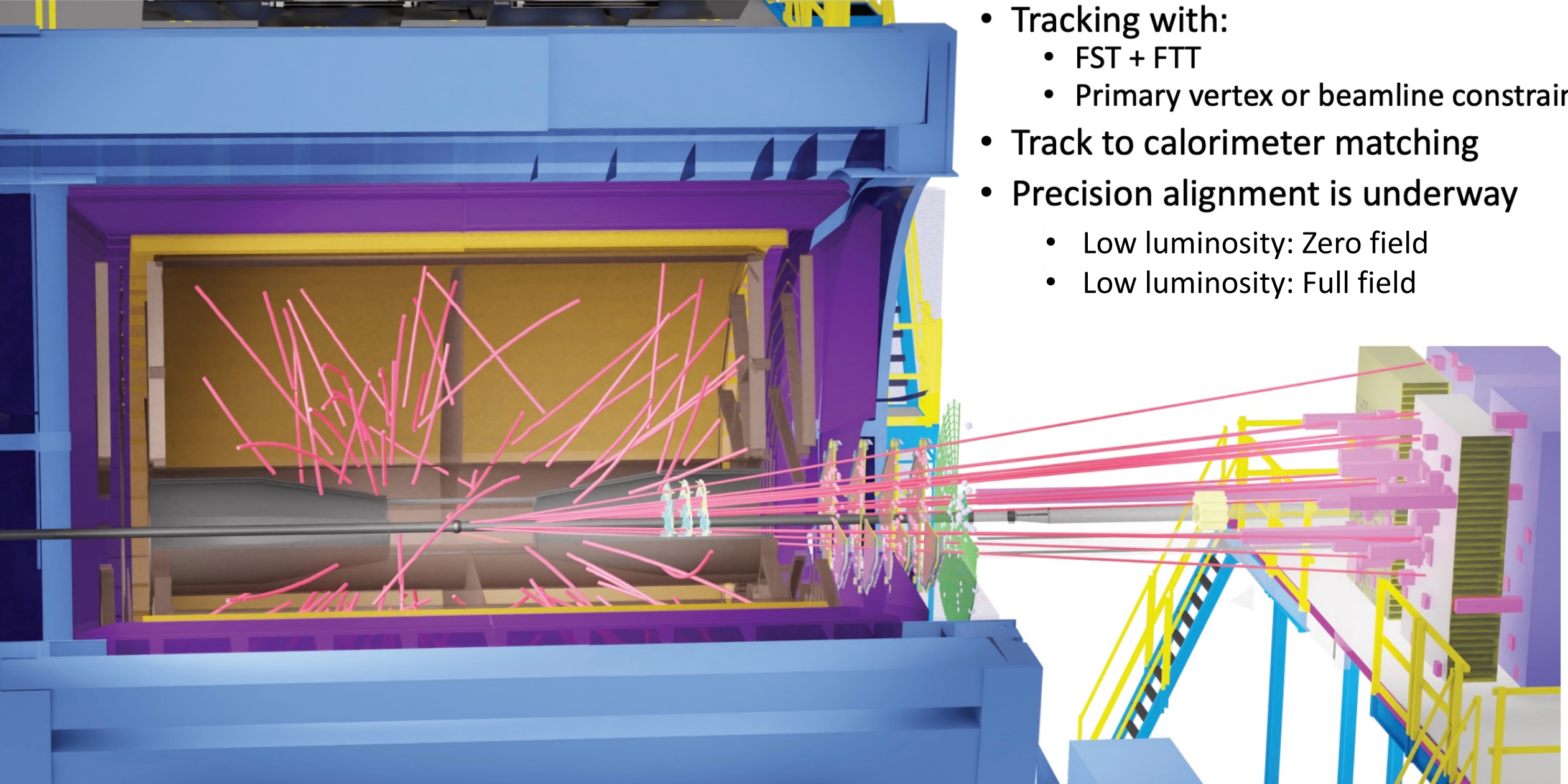 - o 160V for outer module

FTT :
- ✓ HV:
  - o 2900V for data taking
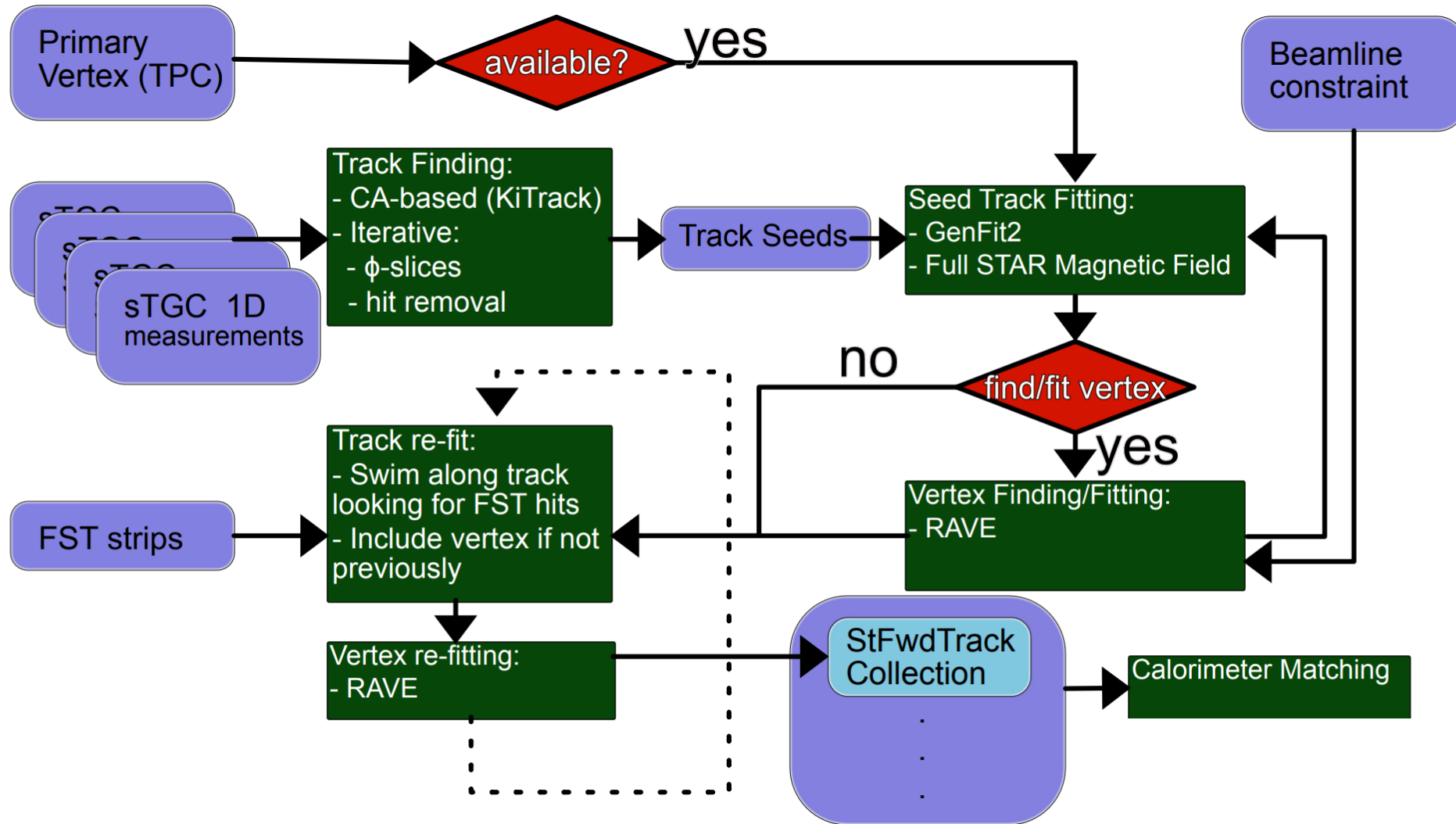 - o 1500V for standby
- ✓ Gas:
  - o Safety and gas mixing is automated through interlock logic
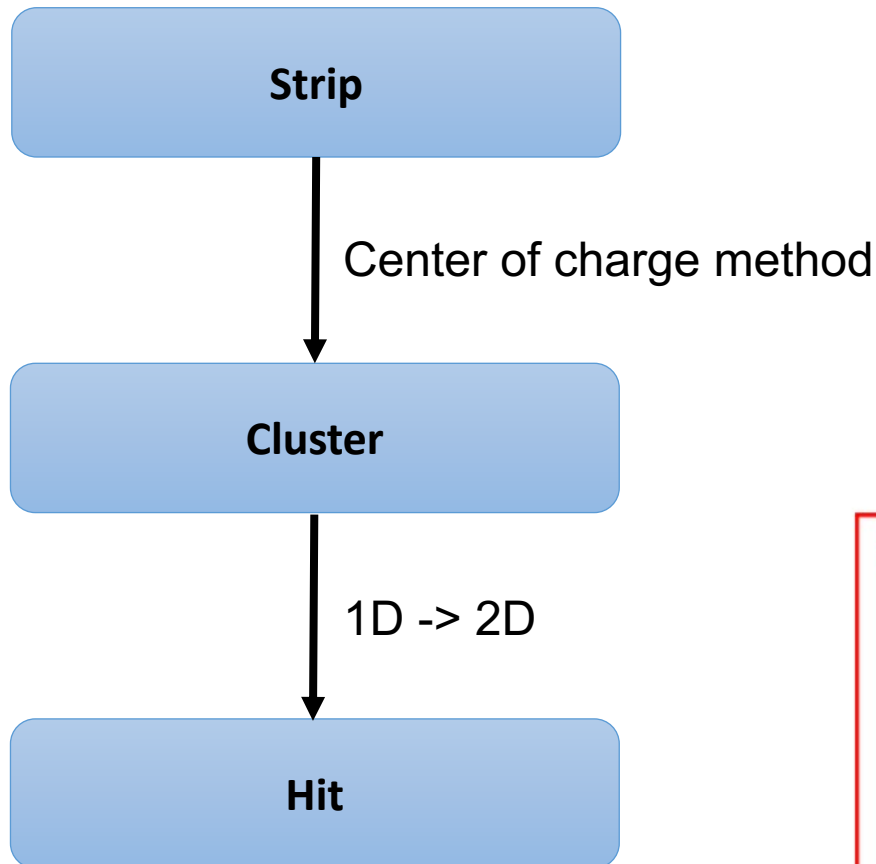
STAR FWD Software Tracking

- Tracking with:
  - FST + FTT
  - Primary vertex or beamline constraint
- Track to calorimeter matching
- Precision alignment is underway
  - Low luminosity: Zero field
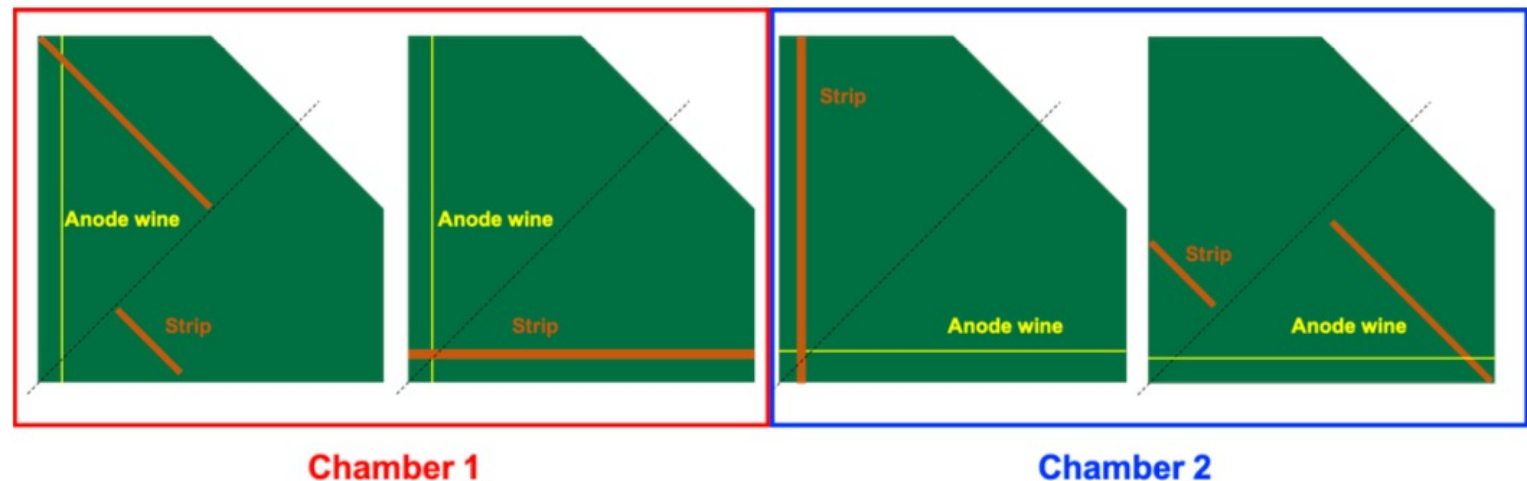 - Low luminosity: Full field

STAR FWD Software Tracking

FTT Hit Reconstruction

Strip

↓ Center of charge method
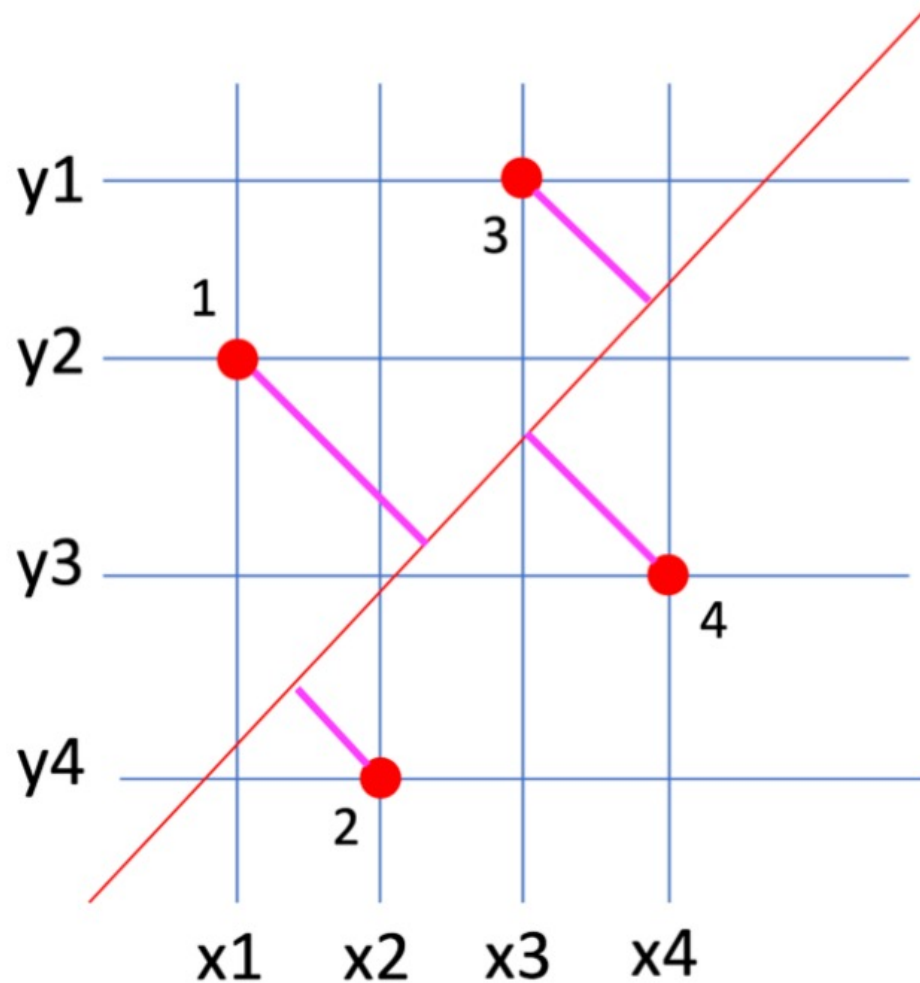
Cluster

↓ 1D -> 2D

Hit

FTT Hit :
- ✓ 1D cluster reconstruction in X, Y and diagonal
- ✓ Combine (X,Y) pairs
  - ○ 2D hits with precise 1D + unprecise 1D information
  - ○ 2D hits with shift in Z direction

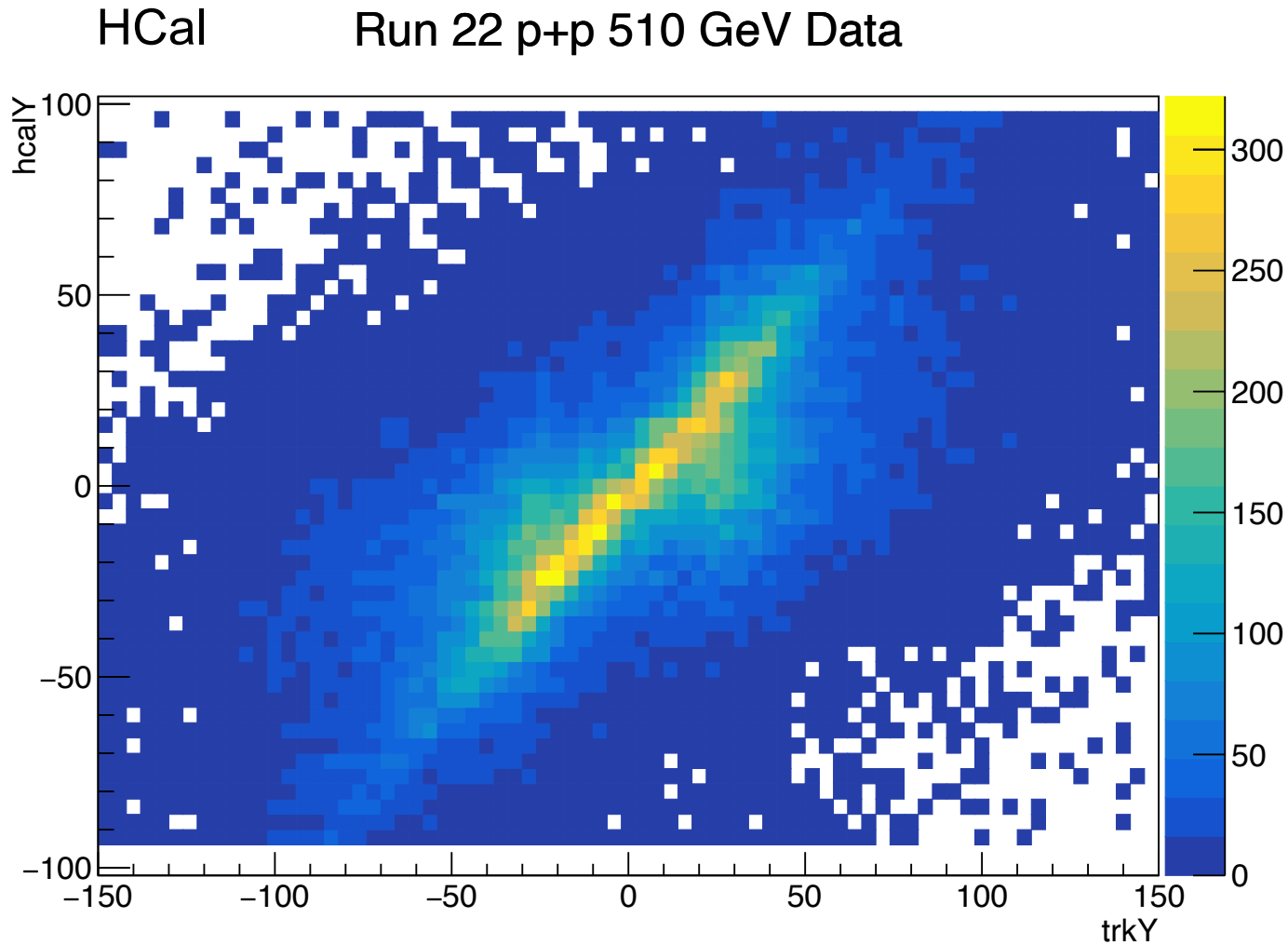Chamber 1   Chamber 2

FTT Hit Reconstruction

FTT Hit :
- ✓ 1D cluster reconstruction in X, Y and diagonal
- ✓ Combine (X,Y) pairs
  - ○ 2D hits with precise 1D + unprecise 1D information
  - ○ 2D hits with shift in Z direction

Ghost(fake) hit :
- ✓ Ghost hits from random pair
  - ○ N real hits will induce $N*(N-1)$ ghost hits
- ✓ Reject ghost hits with diagonal matching

Matching to Calorimeter

HCal   Run 22 p+p 510 GeV Data

Project forward track to calorimeter:

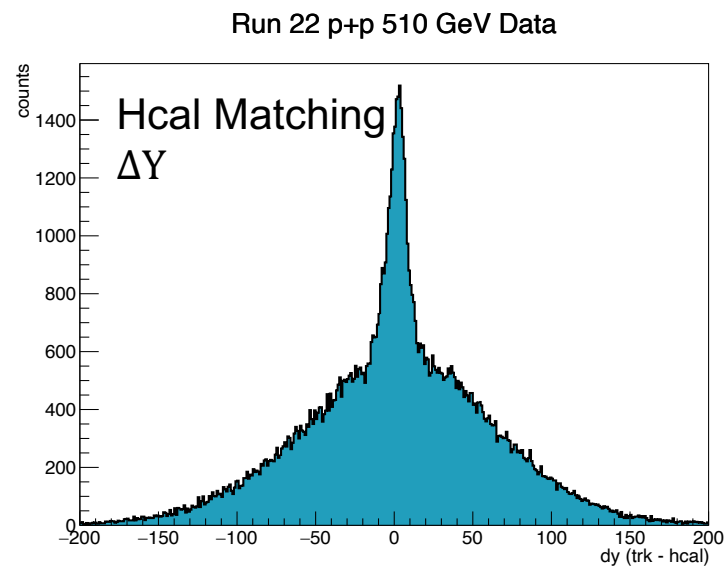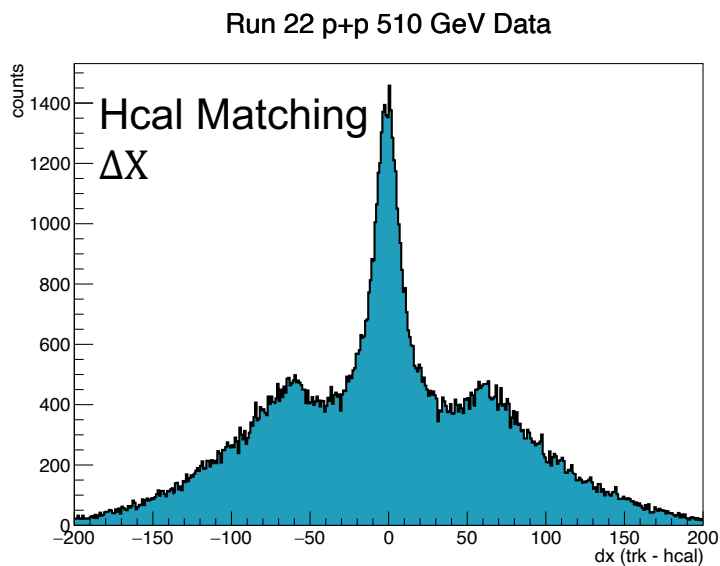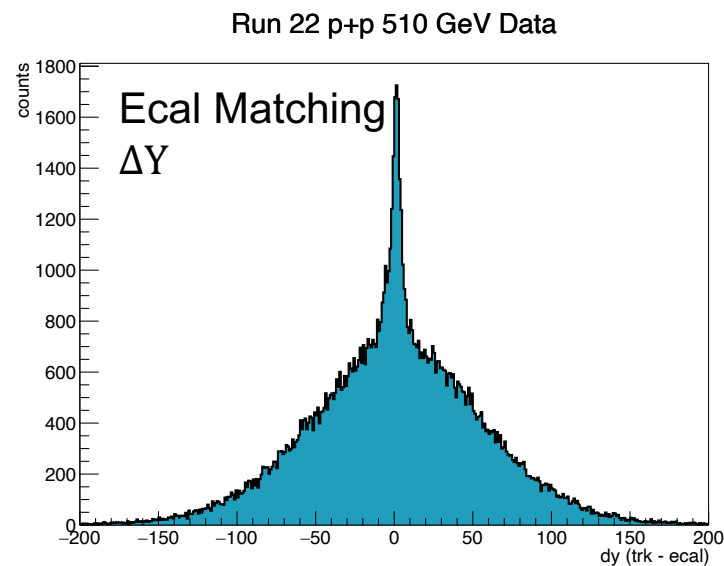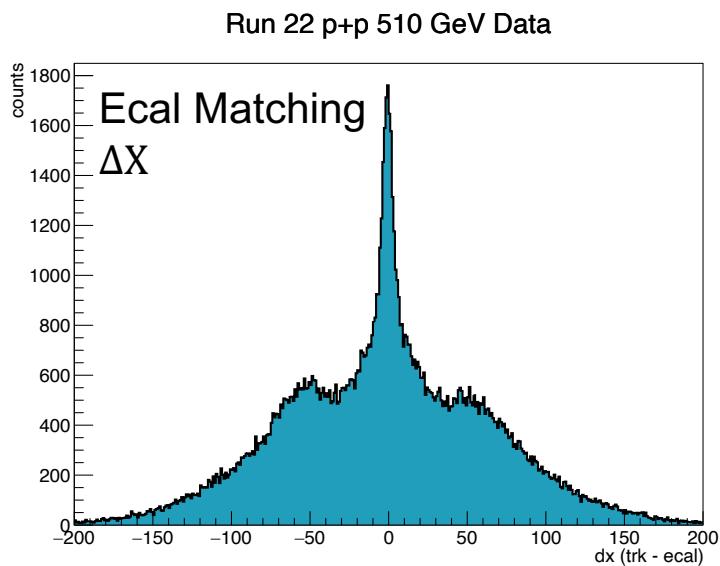- ✓ Good correlation between the forward track and calorimeter hits

Matching to Calorimeter

Project forward track to calorimeter:

- ✓ Good correlation between the forward track and calorimeter hits
- ✓ Non-Zero peak position: alignment needed, working in progress

$$\Delta X = X_{\text{trk}}^{\text{proj}} - X_{E(H)\text{cal}}$$

Summary

- ✓ The STAR Forward Tracker was installed and commissioned successfully. Data taking started since Run 22
- ✓ Hit reconstruction of FTT was done
- ✓ Tracking algorithm has been built
- ✓ Good agreement between the forward tracks and calorimeter hits
- ✓ Alignment is ongoing