STAR Forward Tracker

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RHIC & AGS Annual Users Meeting

SHANDONG UNIVERSITY

STAR

N S F C

STAR Forward Upgrade: Overview

Forward Tracking System

Forward Calorimeter System

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

Forward Tracking System:

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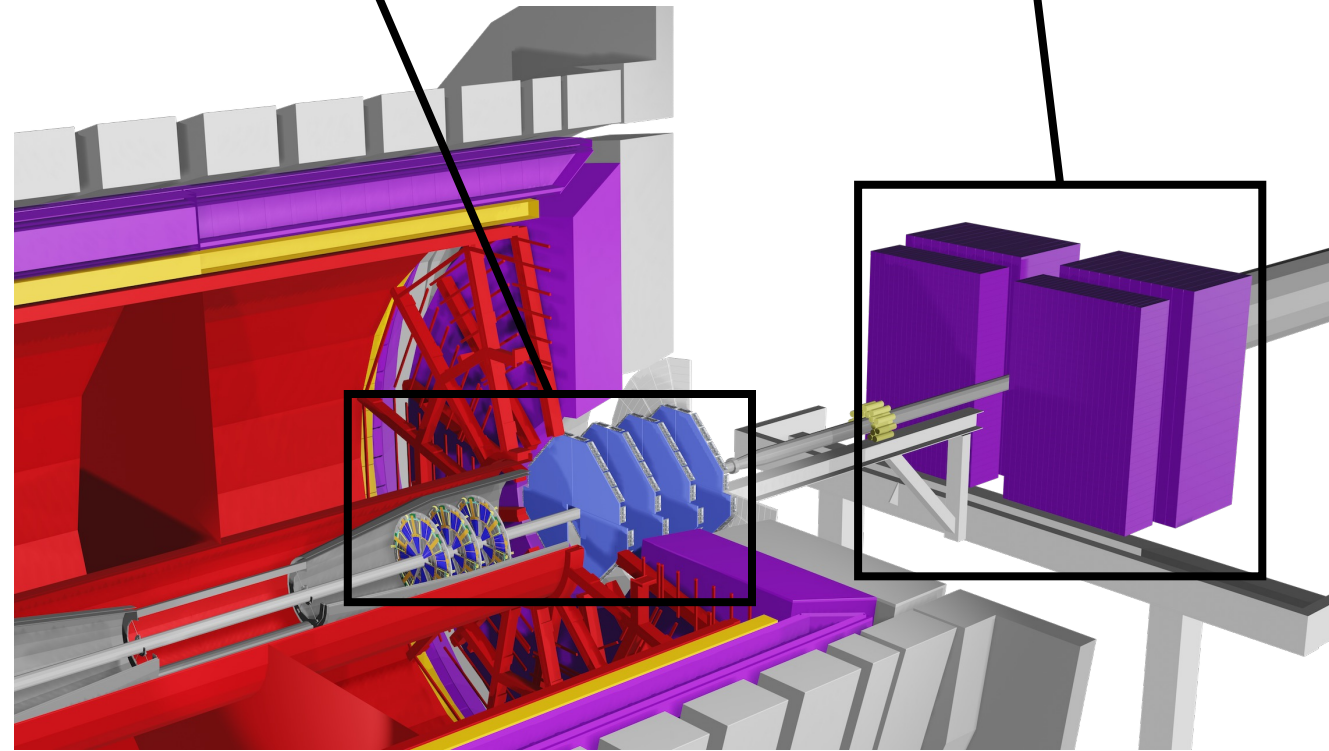Forward small-strip Thin Gap Chamber Tracker (FTT)

- ✓ 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
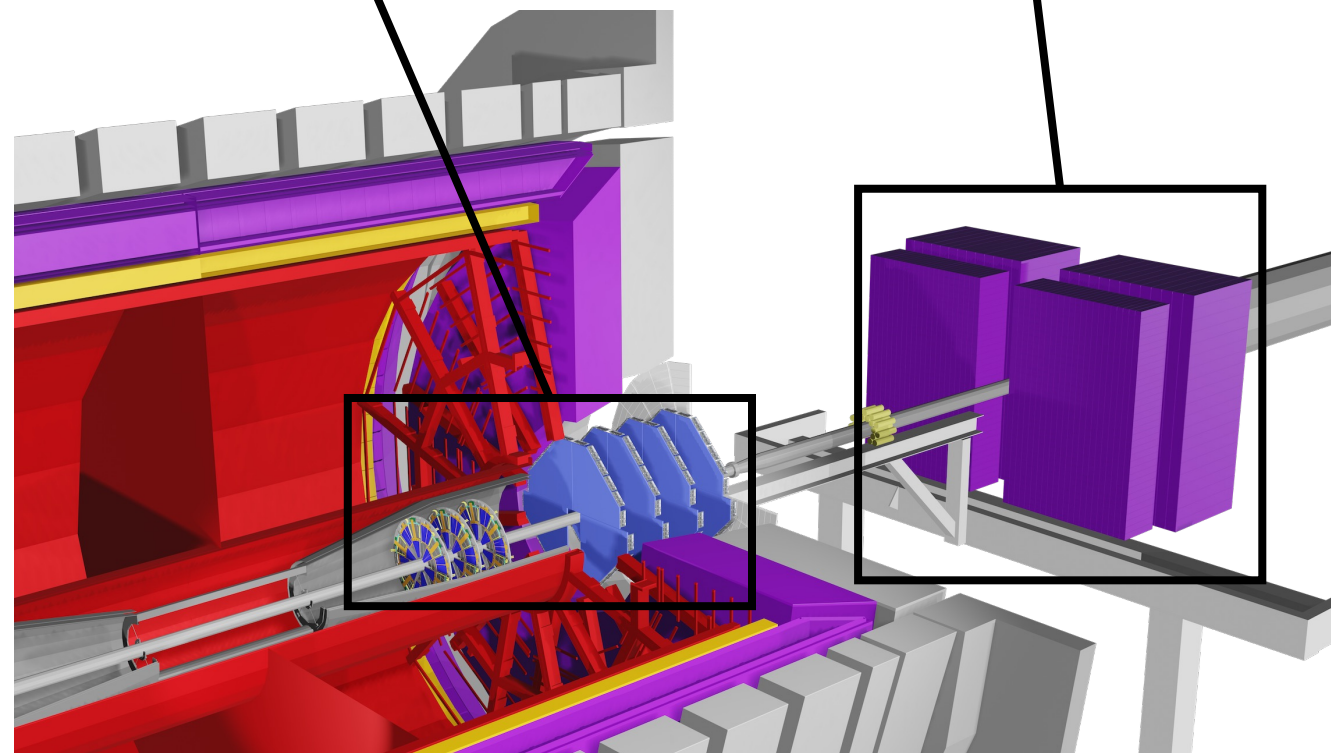Similar coverage as the EIC detector's hadron endcap

STAR Forward Upgrade: Physics Program

Forward Tracking System

this talk

Forward Calorimeter System

Xilin's talk

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

8/2/2023

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

FST
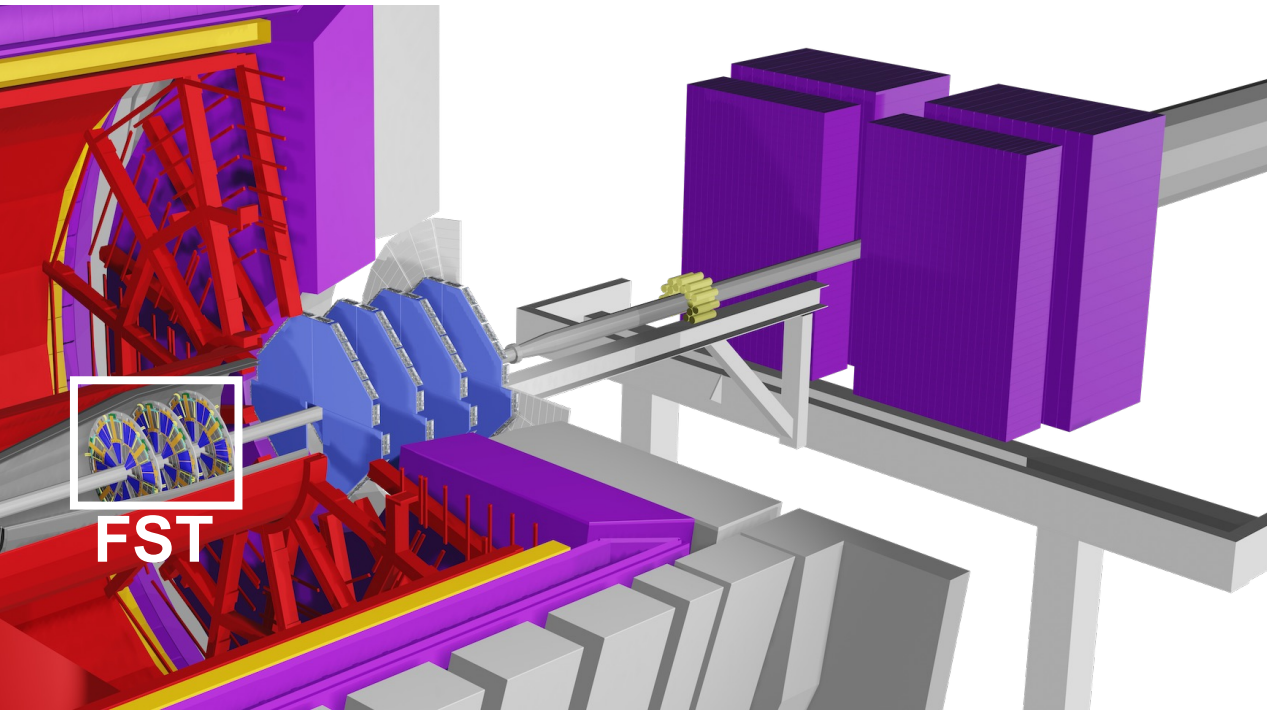
3 Silicon disks:
- ✓ 152, 165, and 179 cm from IP
- ✓ Locate inside STAR TPC cone
- ✓ Single-sided double-metal mini-strip sensors

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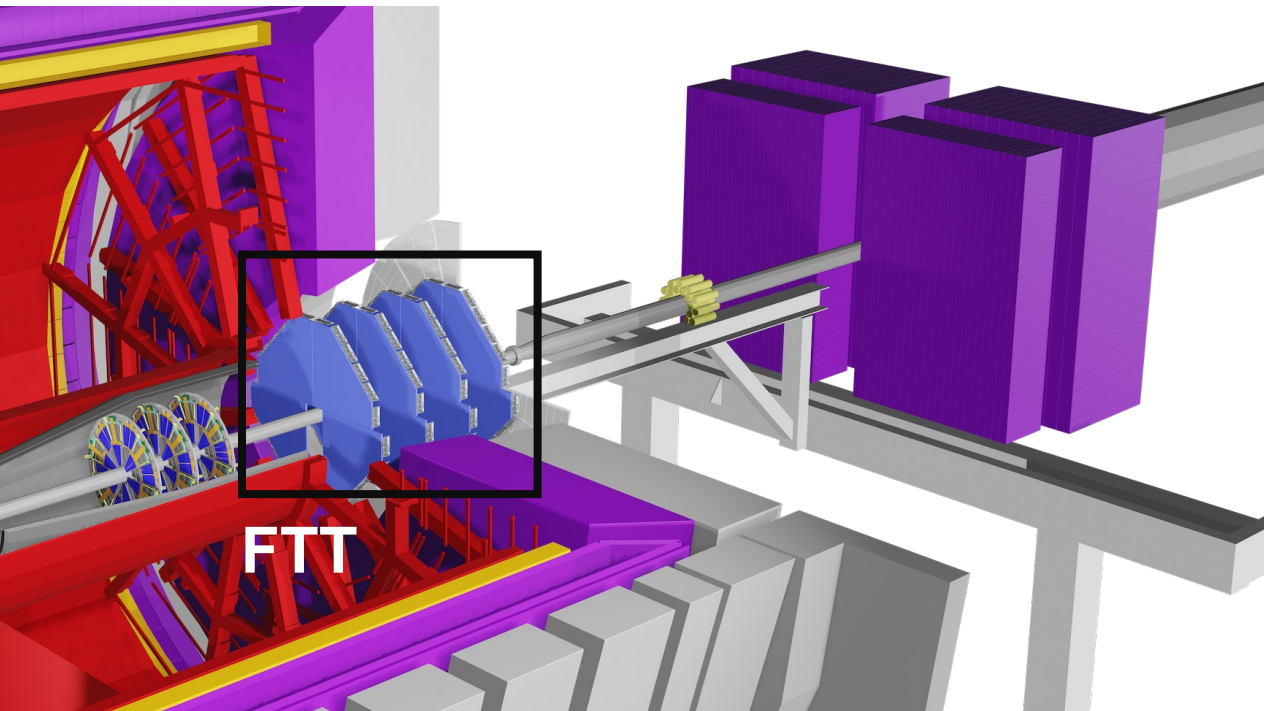- ✓ Si from Hamamatsu

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:
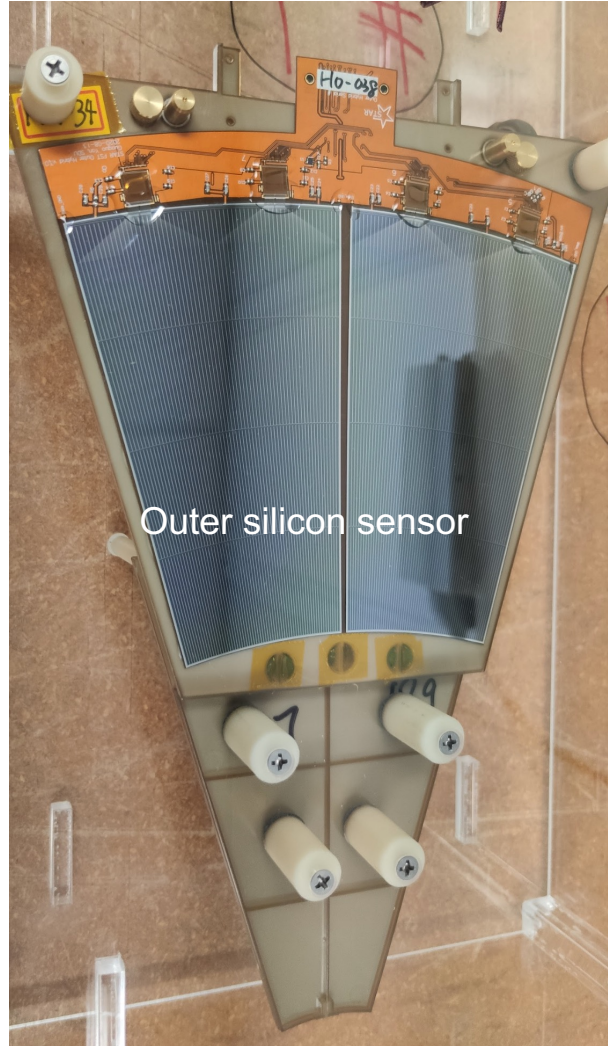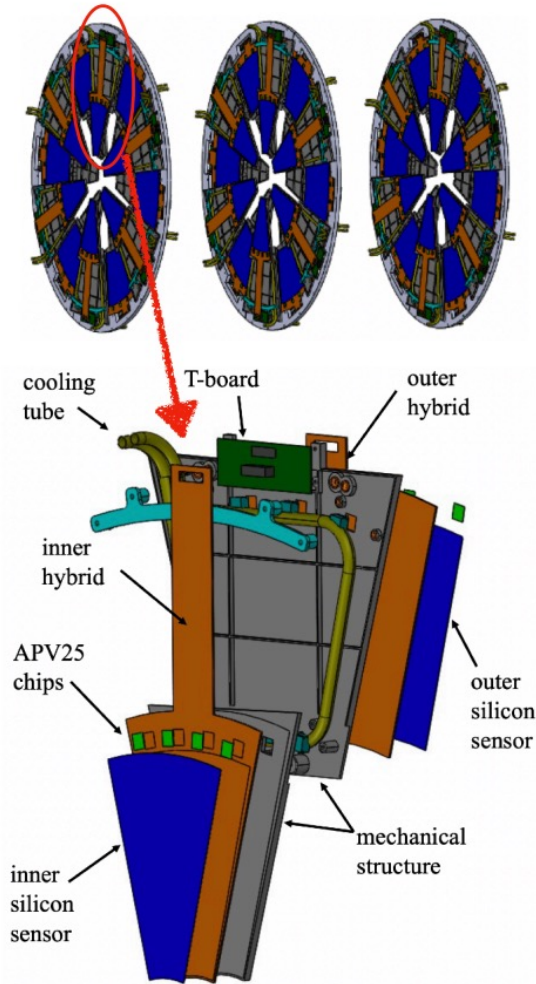- ✓ ~0.5% per layer

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 (ϕ × R) strips
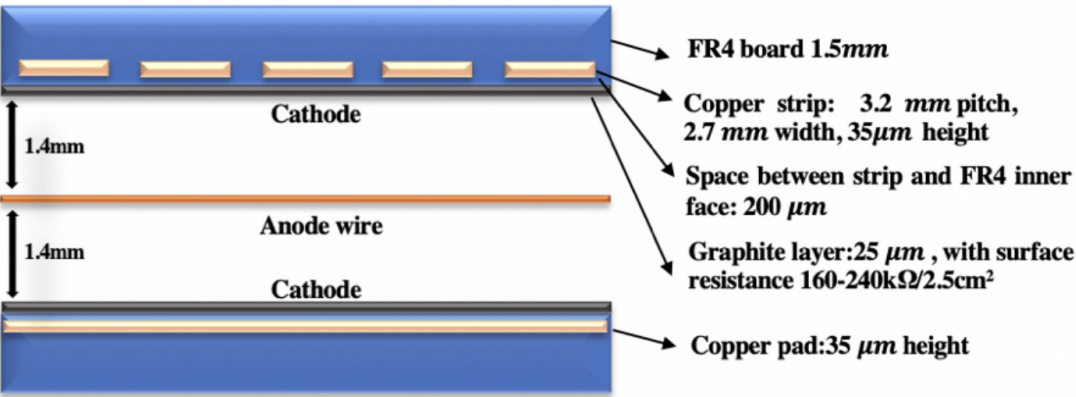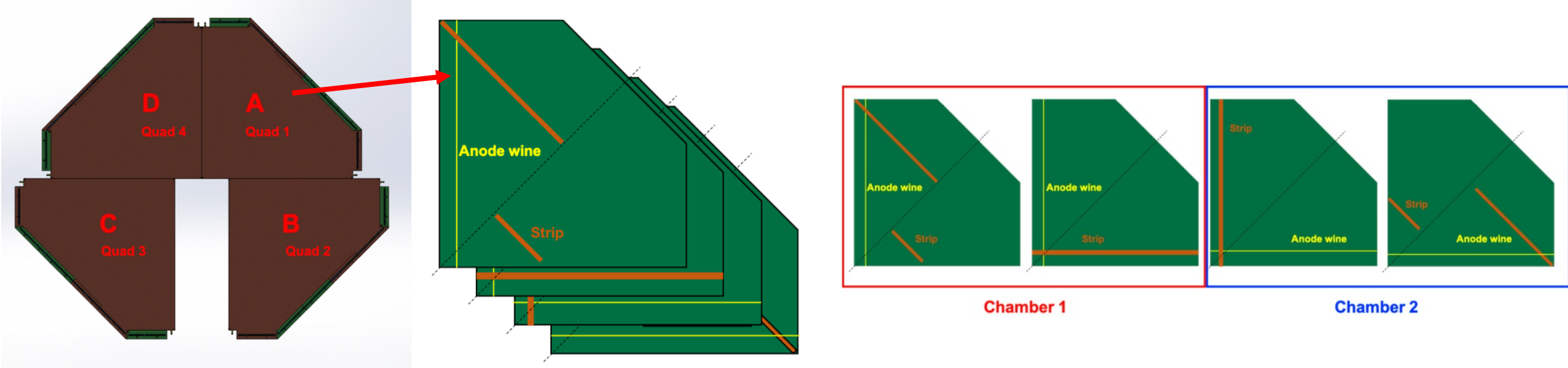- ✓ 4 APV chips

Outer-radius region: 16.5 < R< 28 cm
- ✓ 2 Si sensor 128 × 4 (ϕ × R) strips
- ✓ 4 APV chips

Better position resolution in ϕ direction

X. Sun @ DNP 20
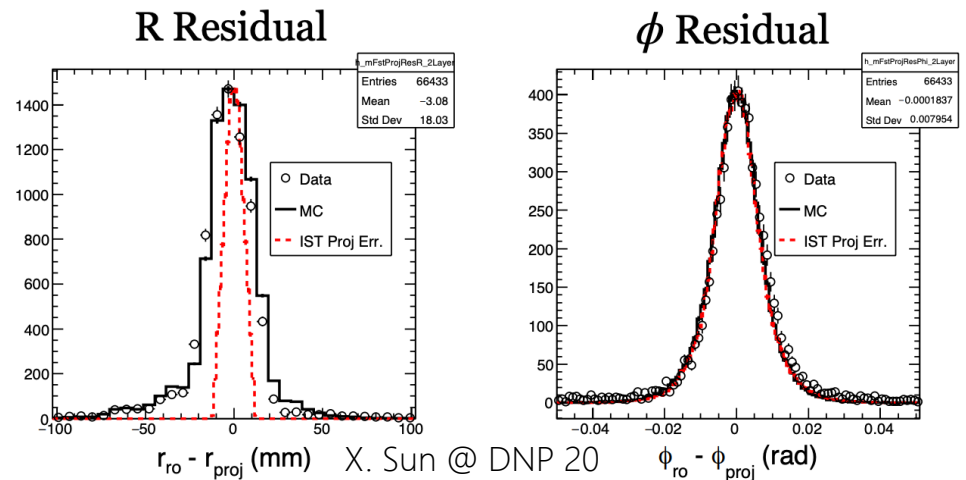
Forward sTGC Tracker Module Design

FR4 board 1.5mm

Copper strip: 3.2 mm pitch, 2.7 mm width, 35μm height

Space between strip and FR4 inner face: 200 μm

Graphite layer:25 μm , with surface resistance 160-240kΩ/2.5cm²

Copper pad:35 μm height

Y. Shi @ INSTR 20

FTT layer combine with 4 pentagon modules:

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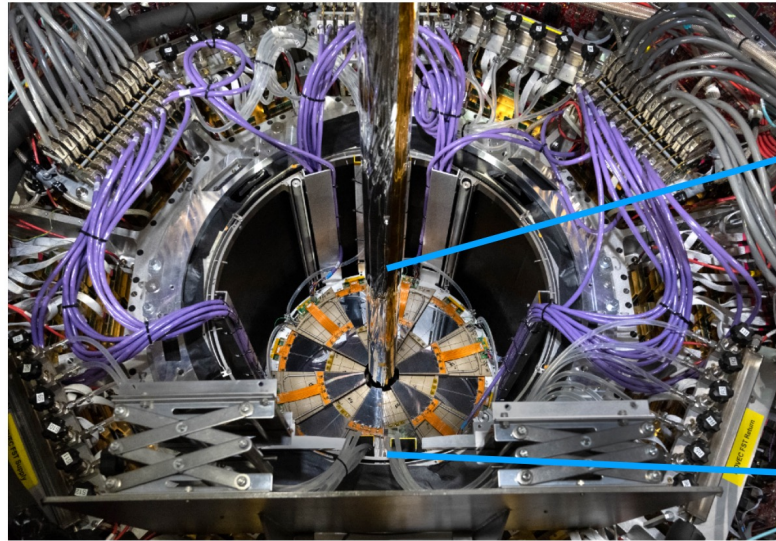- ✓ Perpendicular to strip

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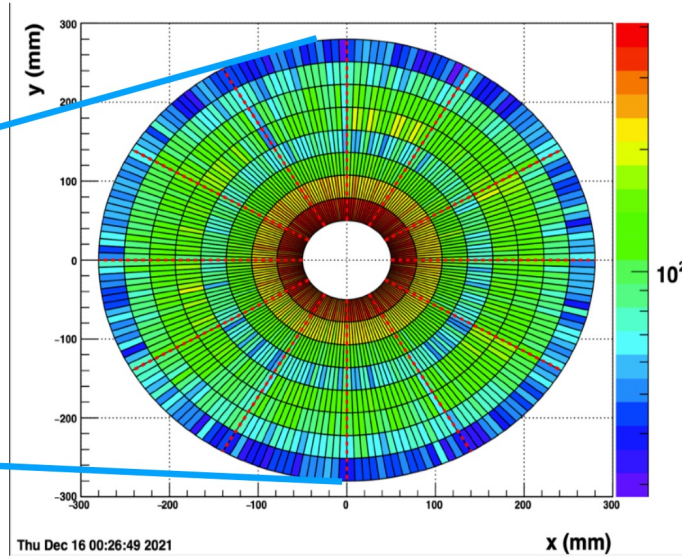- ✓ Read X and Y position separately
- ✓ Diagonal strips to reject ghost hits
- ✓ Same position resolution for each directions

Forward Tracker Performance: Operation

FST event display in run22 p+p 510GeV

FTT event display in run22 p+p 510GeV

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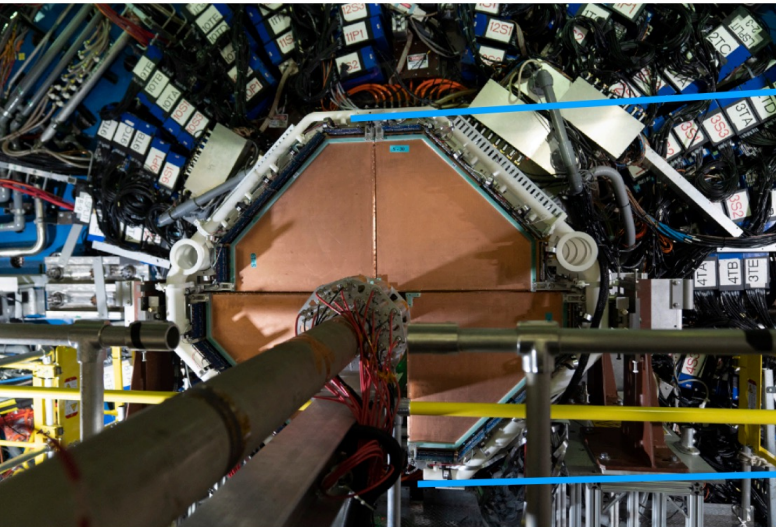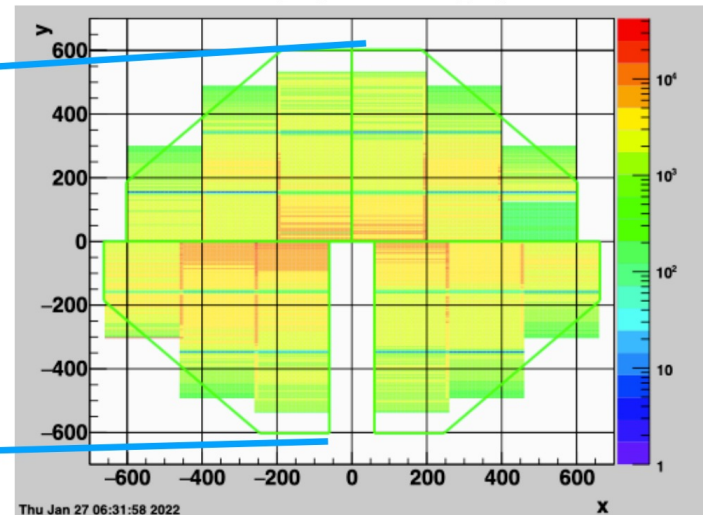 - ○ 140V for inner module
  - ○ 160V for outer module

FTT :
- ✓ HV:
  - ○ 2900V for data taking
  - ○ 1500V for standby
- ✓ Gas:
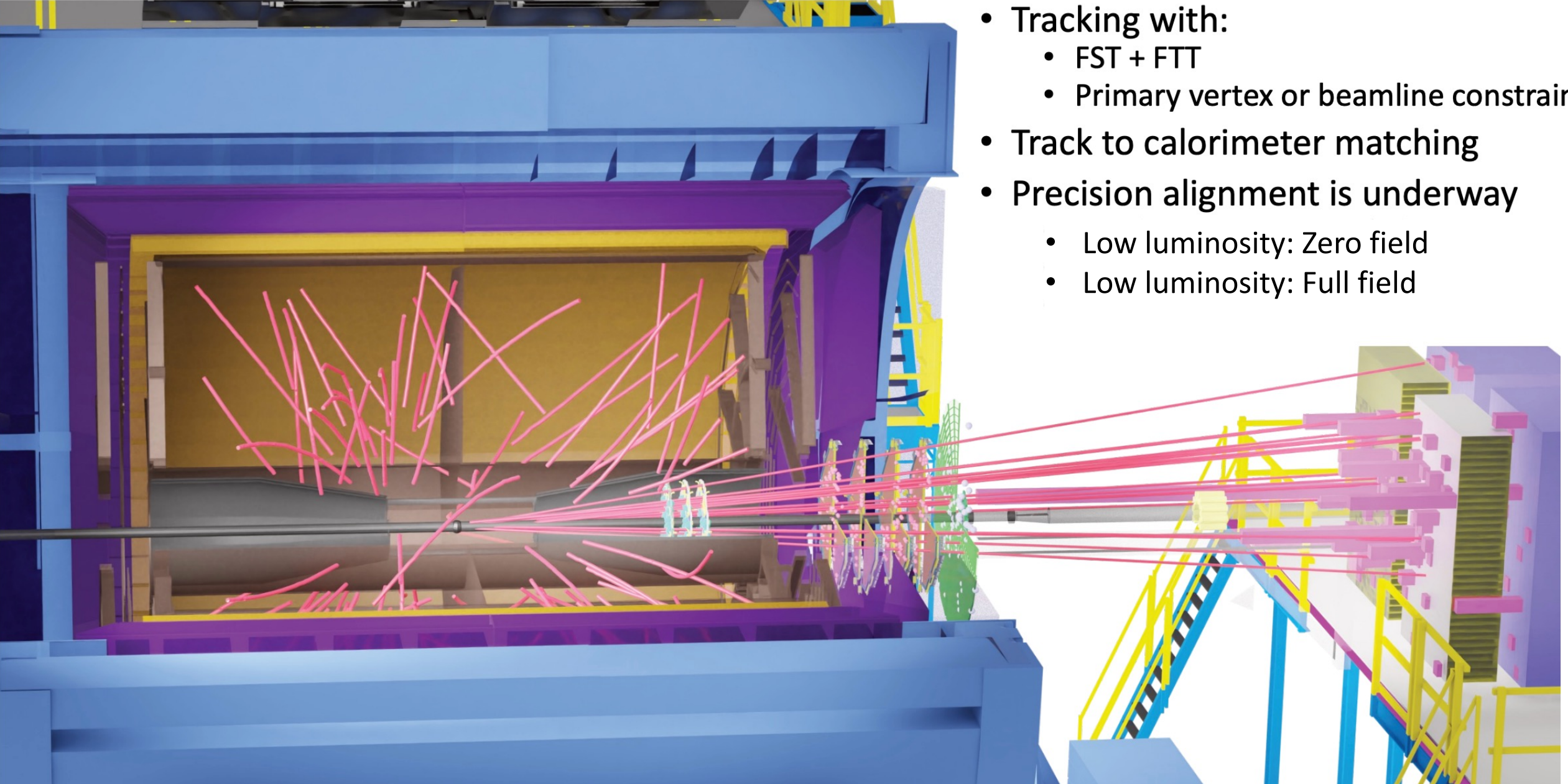 - ○ Safety and gas mixing is automated through interlock logic

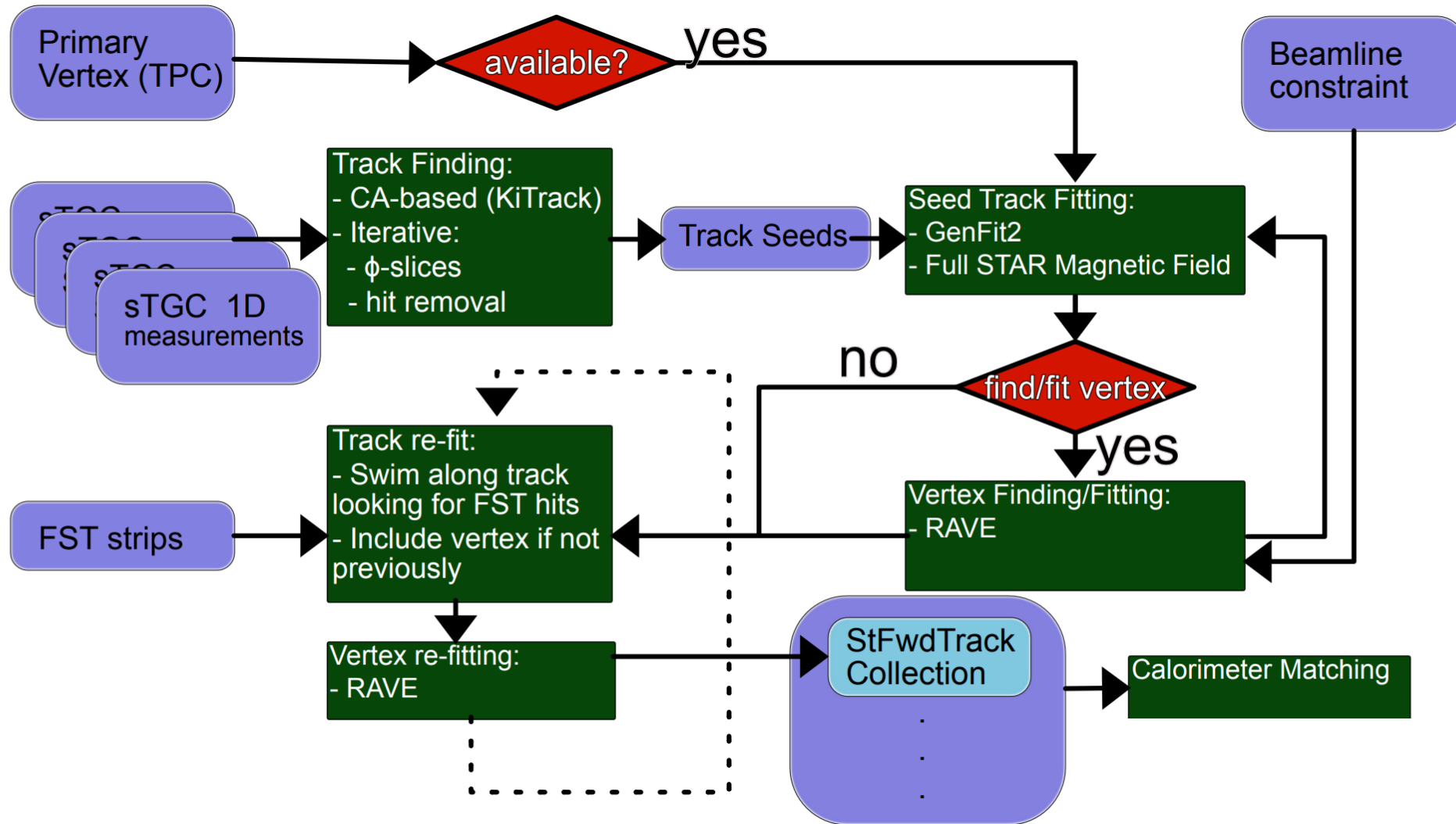Zhen Wang, RHIC & AGS Annual Users' Meeting
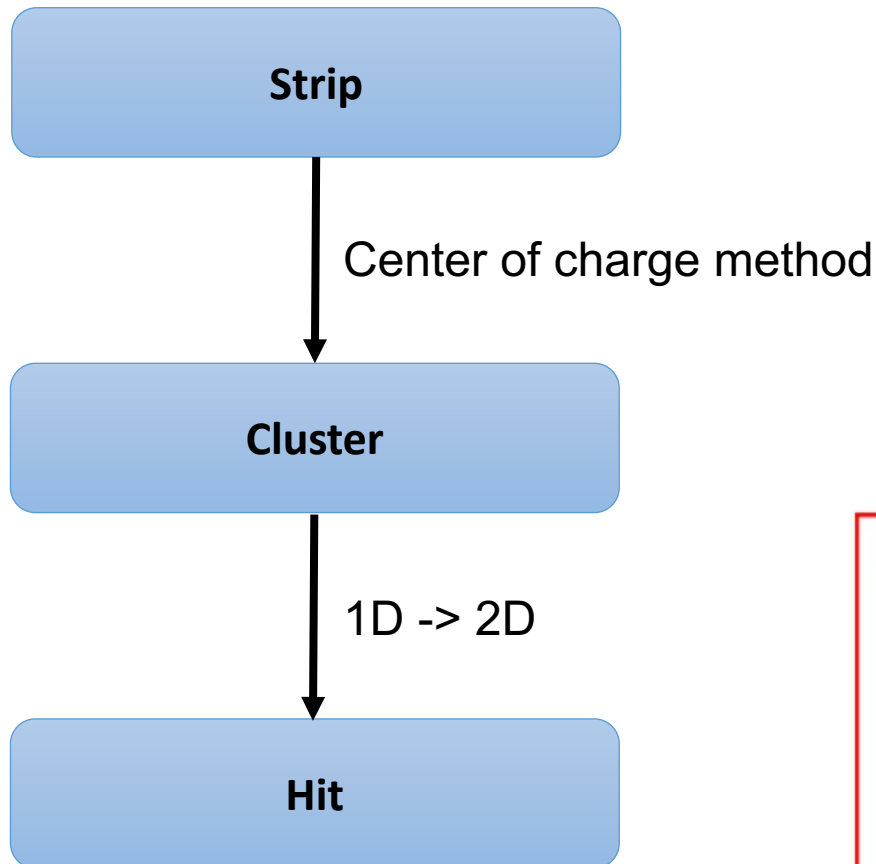
STAR FWD Software Tracking

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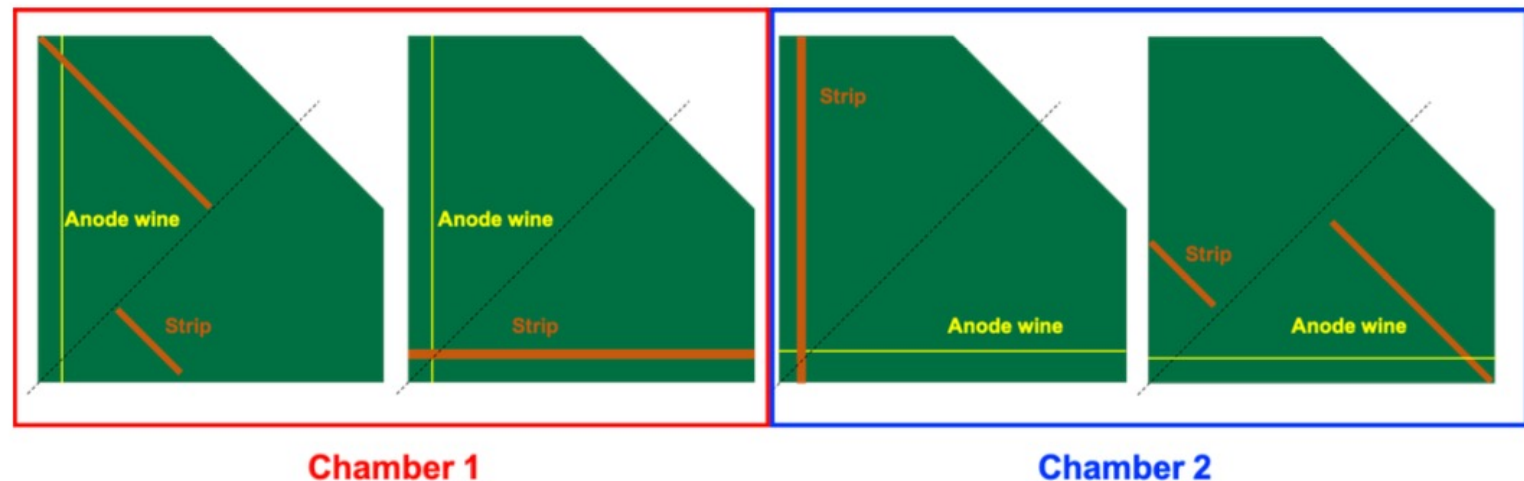 - Low luminosity: Full field

STAR FWD Software Tracking

Zhen Wang, RHIC & AGS Annual Users' Meeting

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

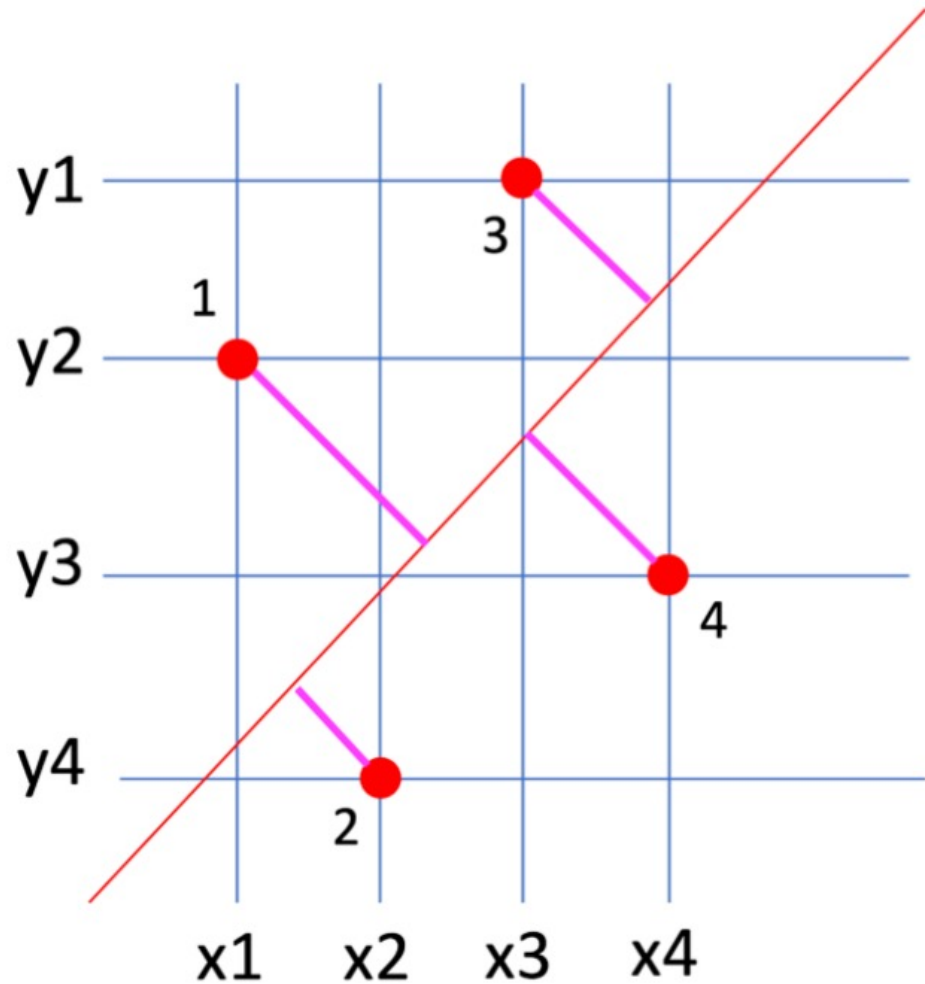Chamber 1   Chamber 2
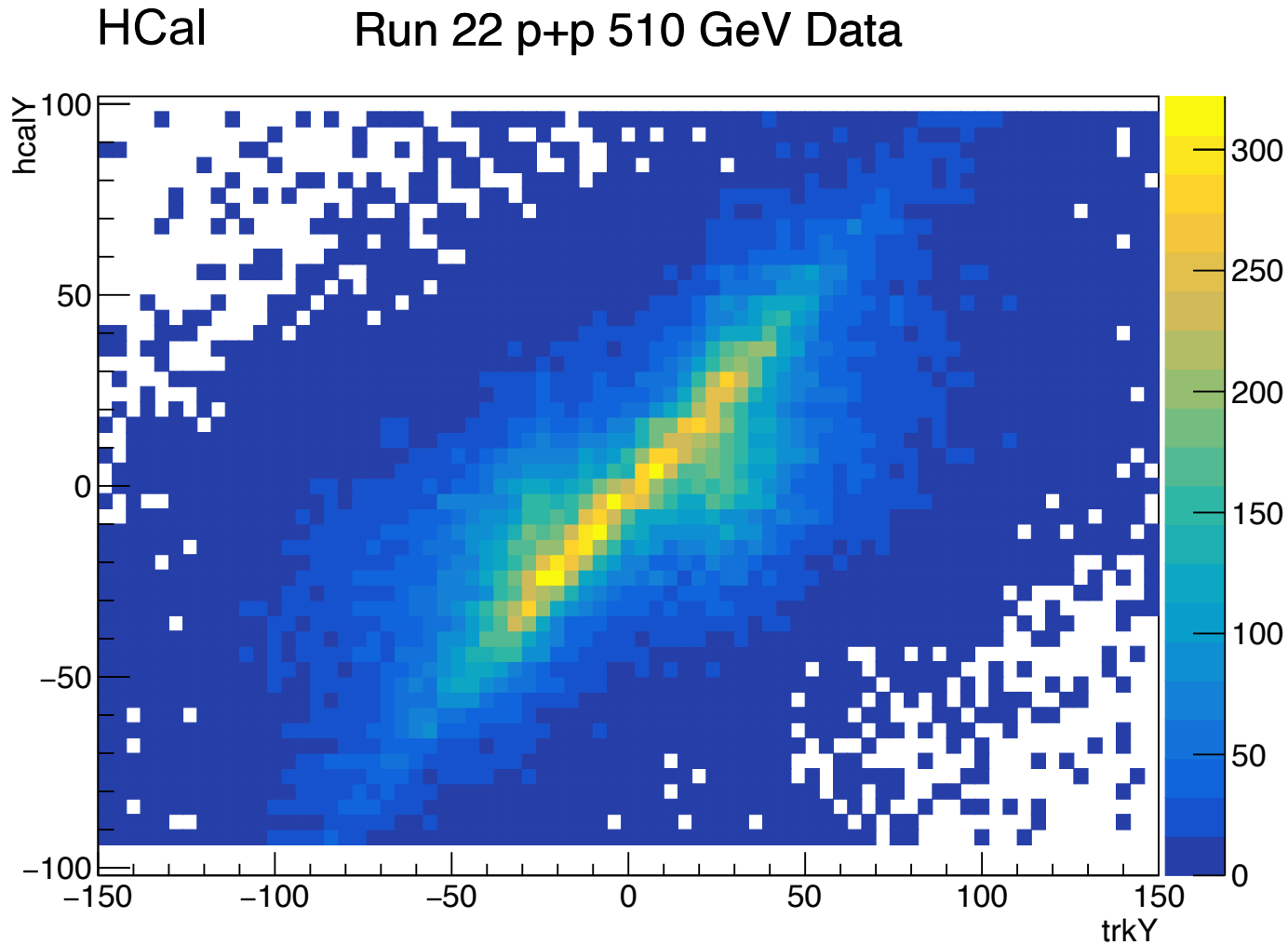
FTT Hit Reconstruction

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

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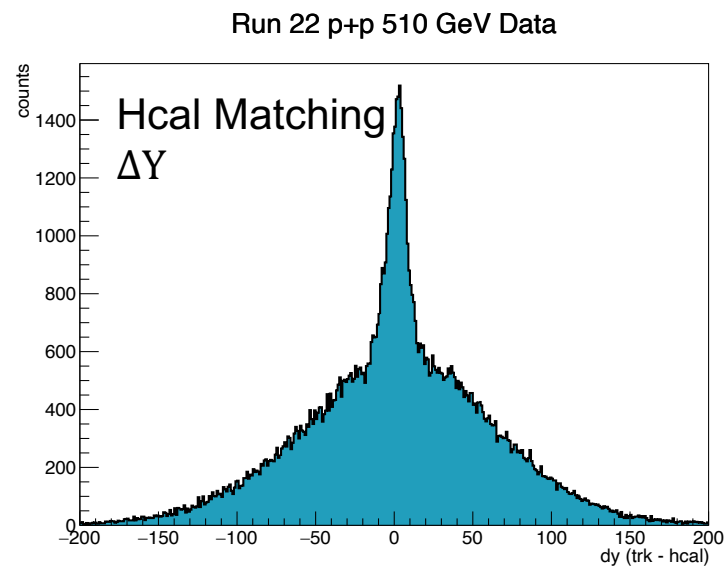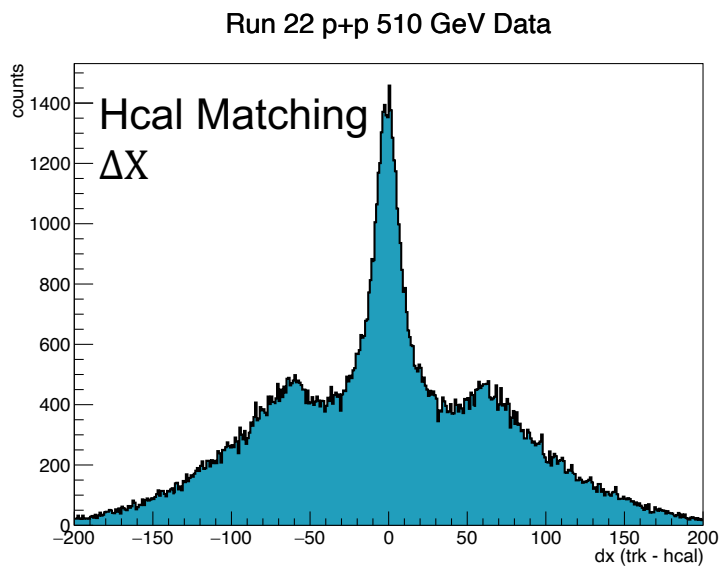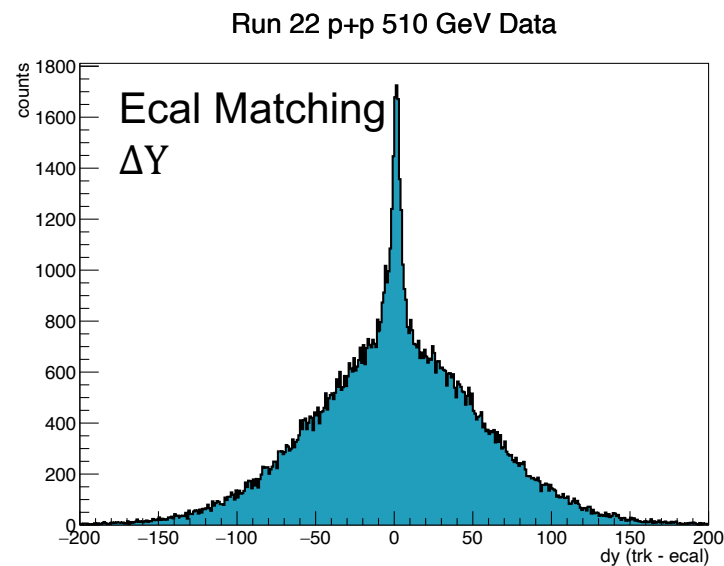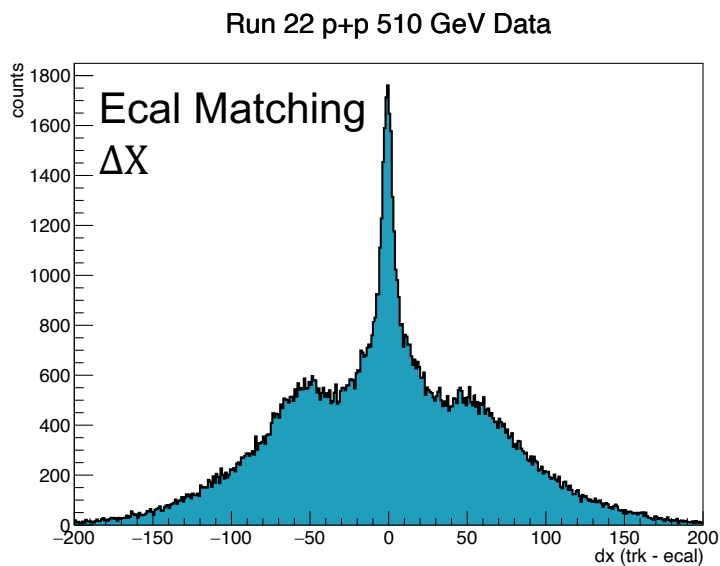- ✓ Reject ghost hits with diagonal matching

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

Run 22 p+p 510 GeV Data — Ecal Matching ΔX — dx (trk - ecal)

Run 22 p+p 510 GeV Data — Ecal Matching ΔY — dy (trk - ecal)

Run 22 p+p 510 GeV Data — Hcal Matching ΔX — dx (trk - hcal)

Run 22 p+p 510 GeV Data — Hcal Matching ΔY — dy (trk - hcal)

Project forward track to calorimeter:

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

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

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