Overview of sPHENIX Tracking Detectors

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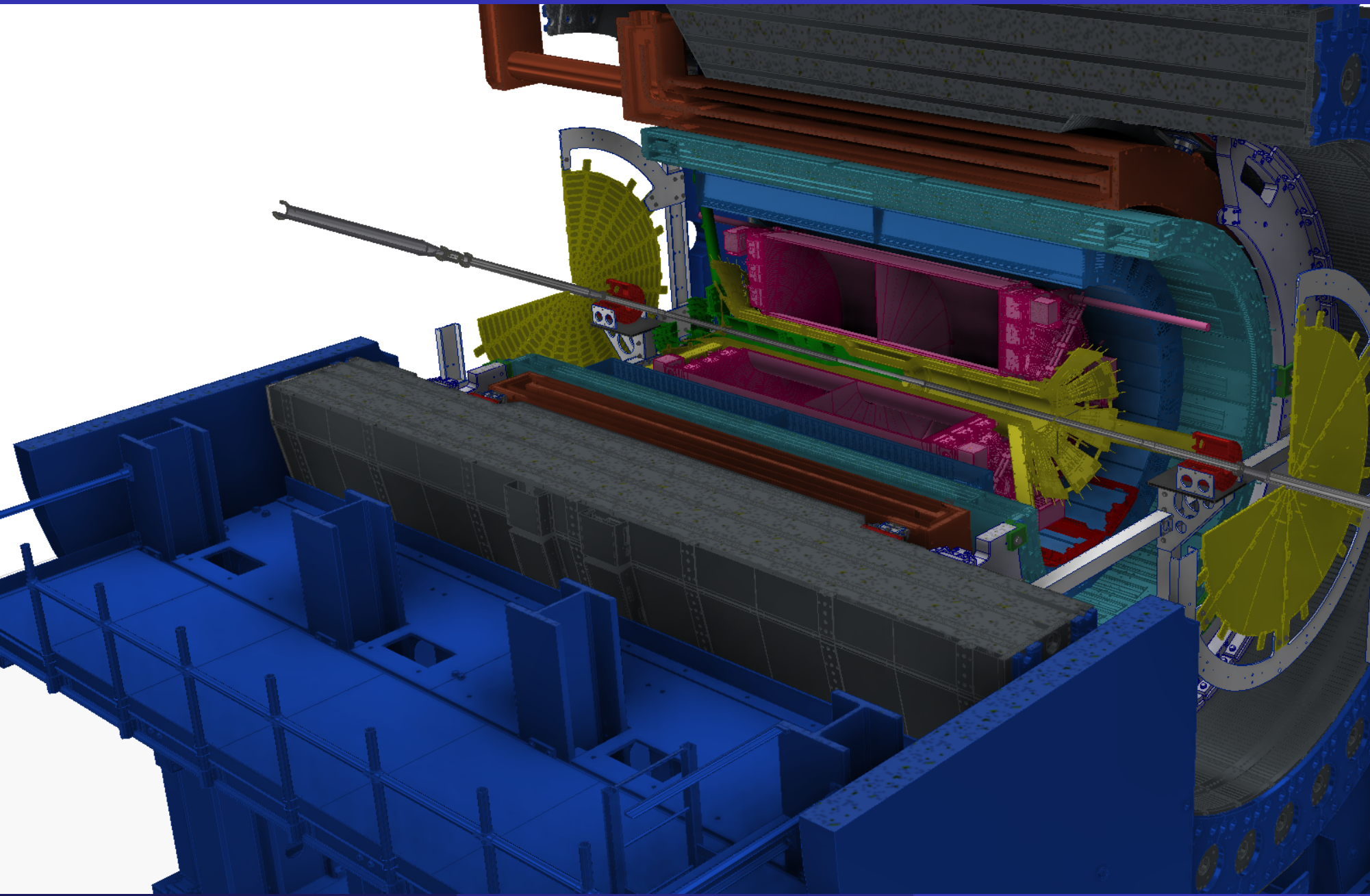
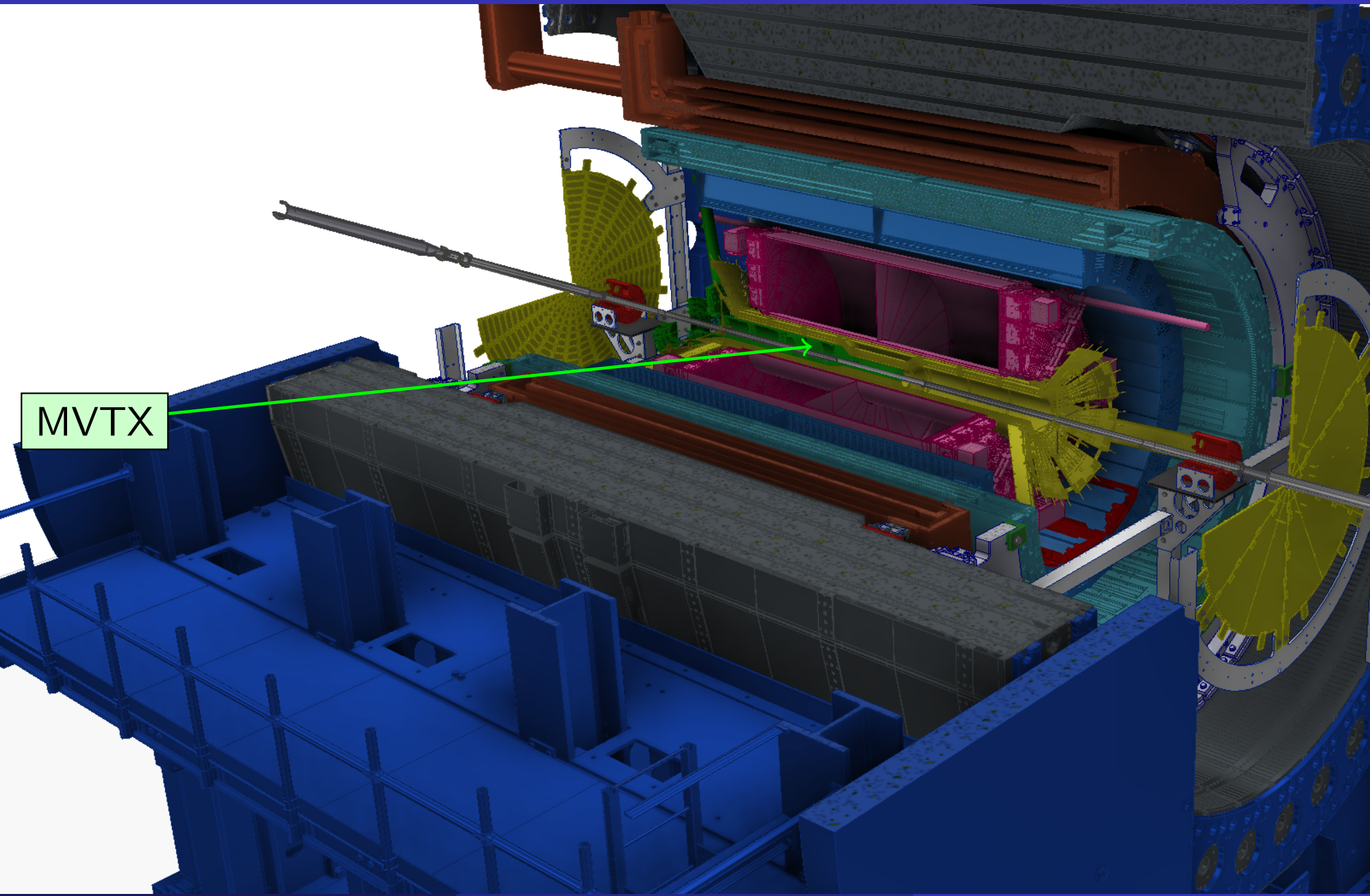
sPHENIX

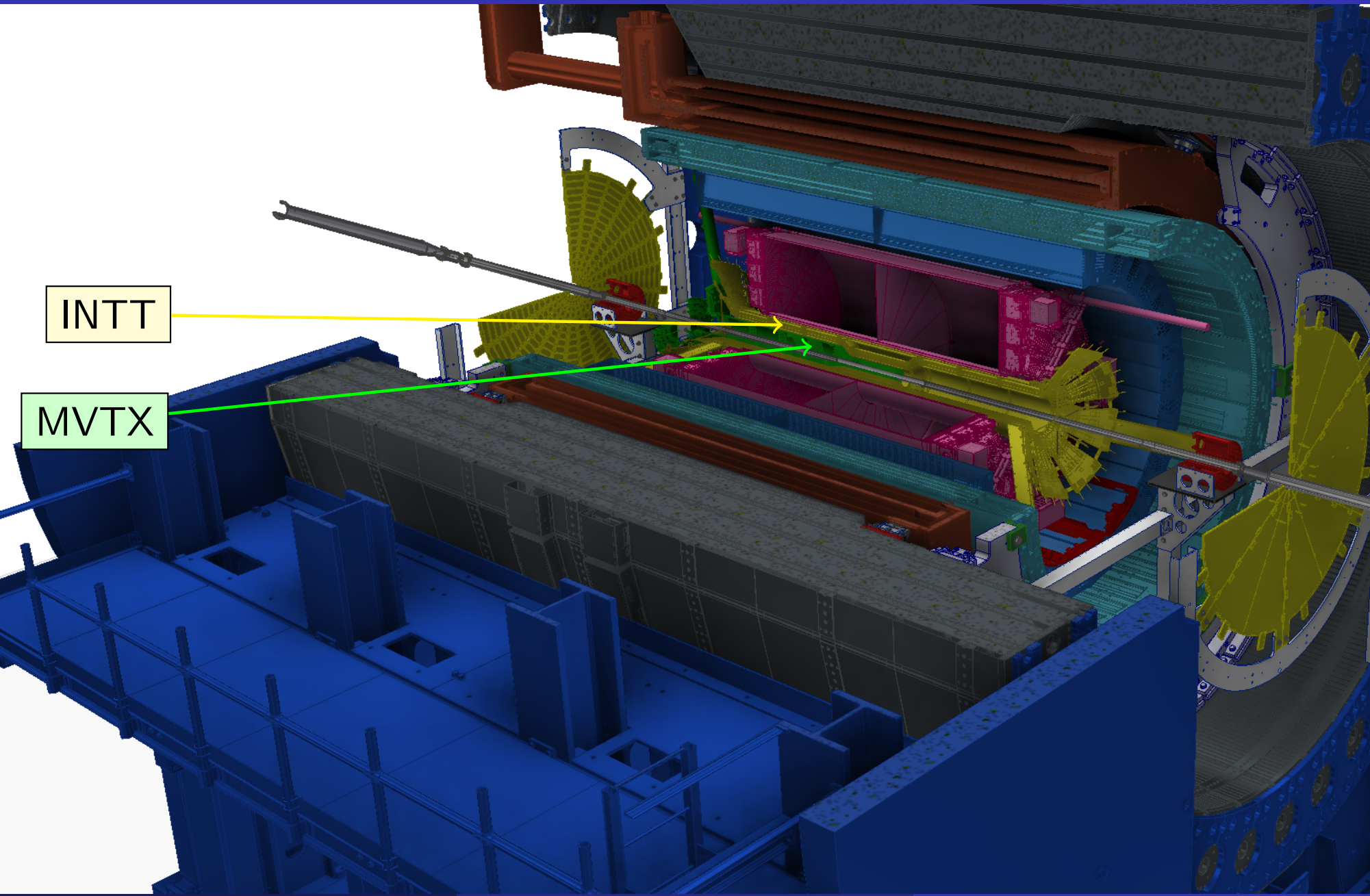
Tracking Subdetectors



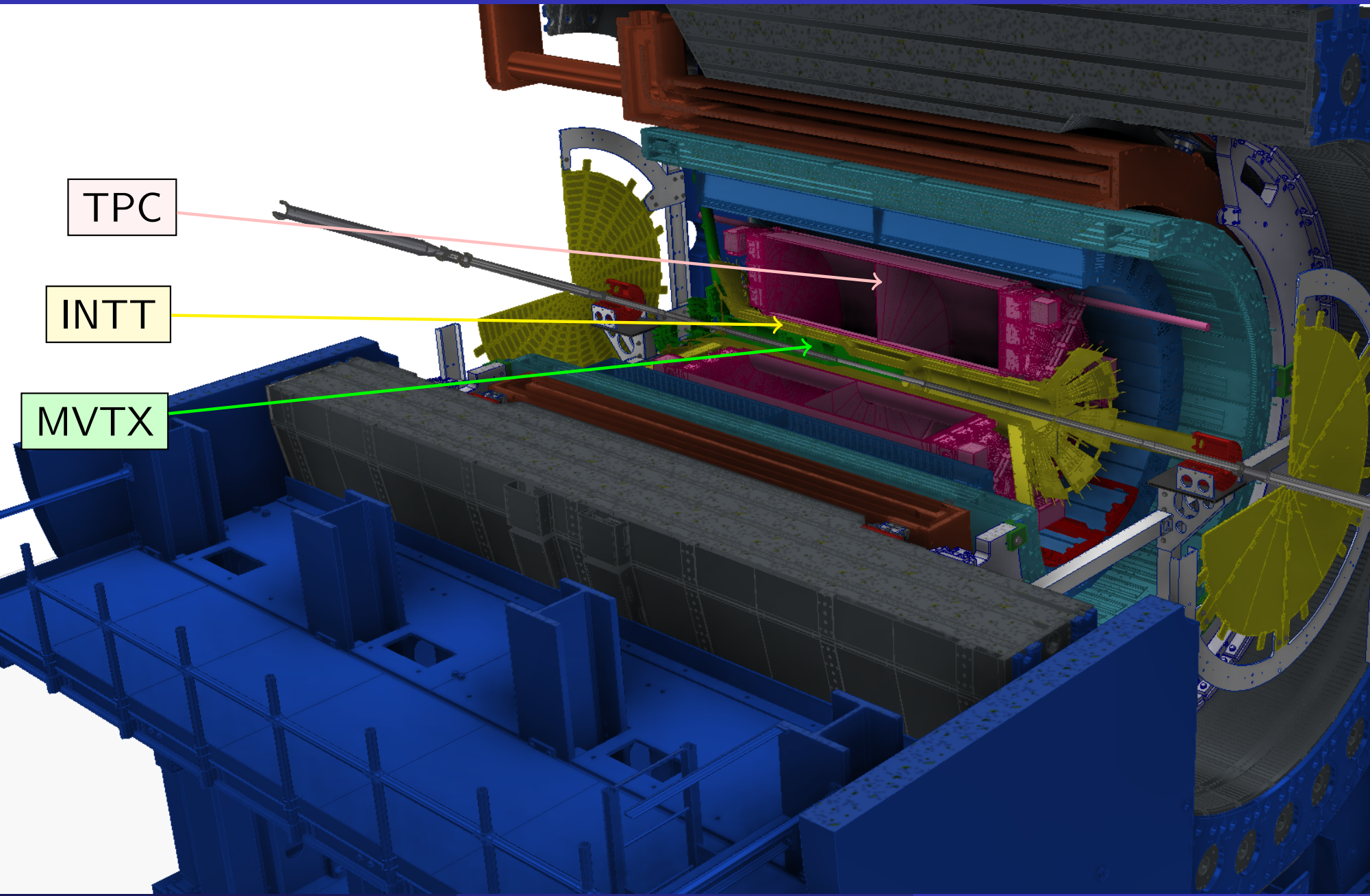
Tracking Subdetectors



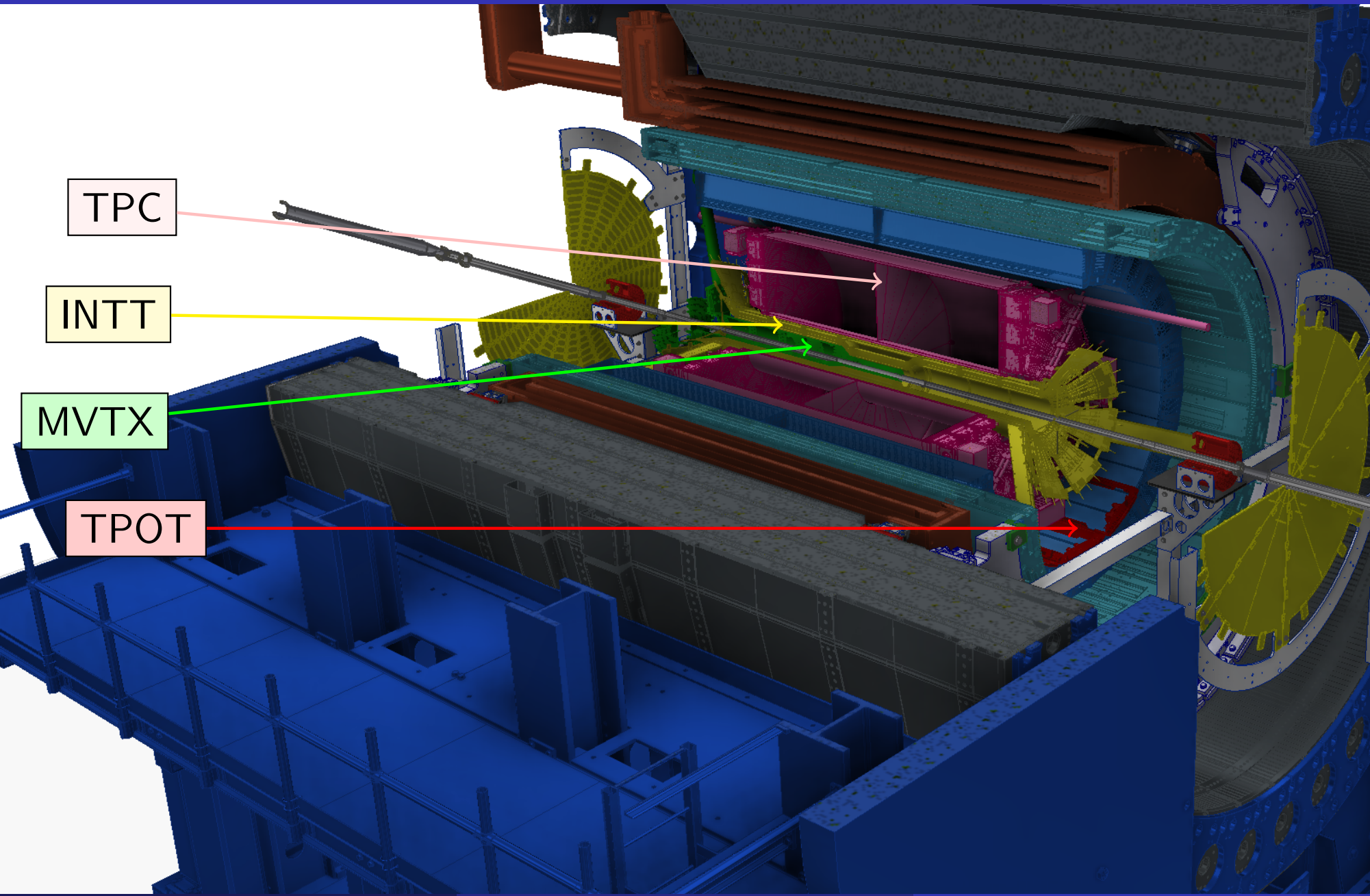
Tracking Subdetectors



Tracking Subdetectors



Tracking Subdetectors



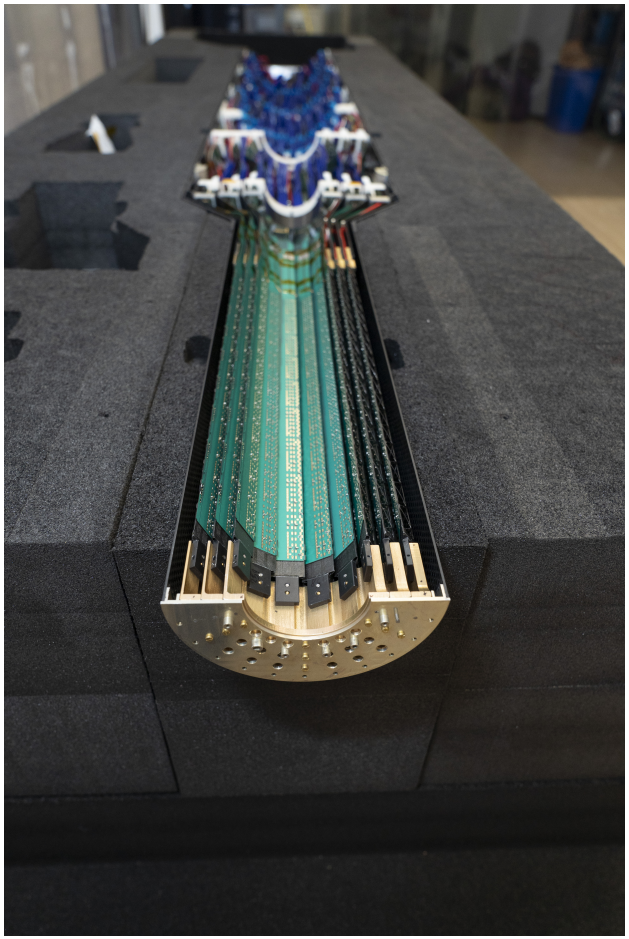
MVTX

"Maps-based VerTeX detector"

MVTX

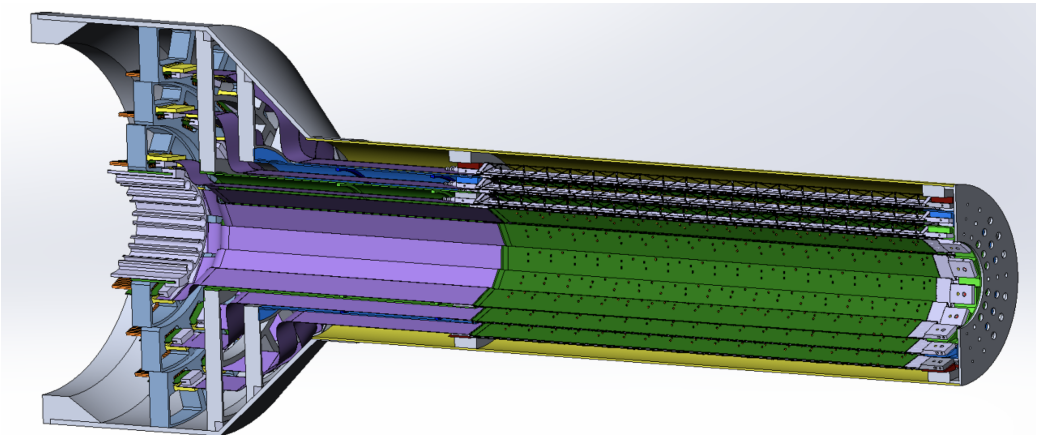
"Maps-based VerTeX detector"

- Silicon pixel detector
  - Pixel size $29 \times 27 \mu$m
  - 48 staves arranged in 3 layers
  - Occupies ~ 3 cm $< r < 5$ cm
- Precision vertexing
  - Position resolution of $\mathcal{O}(1 - 10 \mu\text{m})$
  - Integration time window $\mathcal{O}(\mu\text{s})$
- Based on ITS-2 Inner Barrel (ALICE)



MVTX

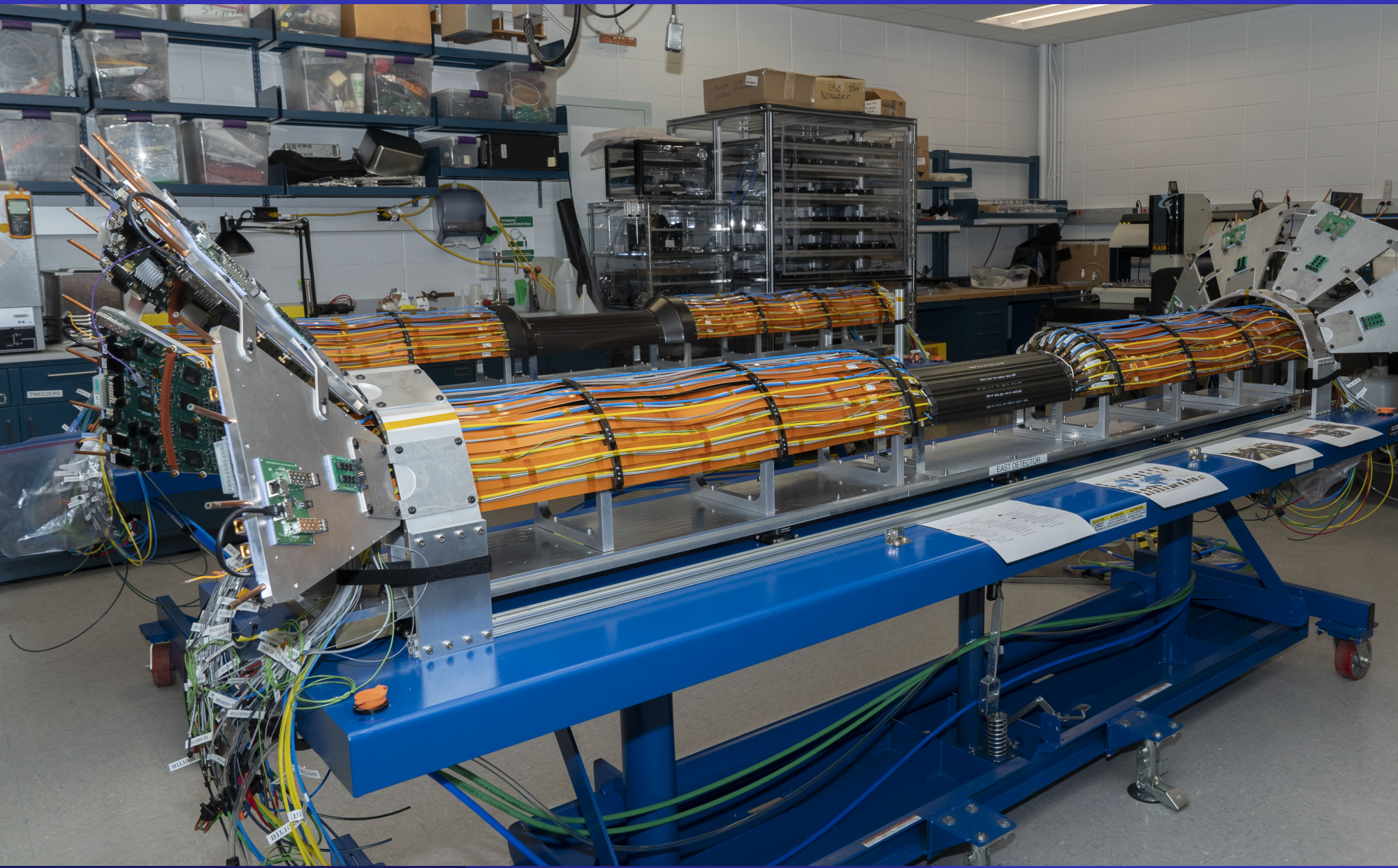
"Maps-based VerTeX detector"



- The vertex resolution of the MVTX is what enables our open heavy flavor program

INTT

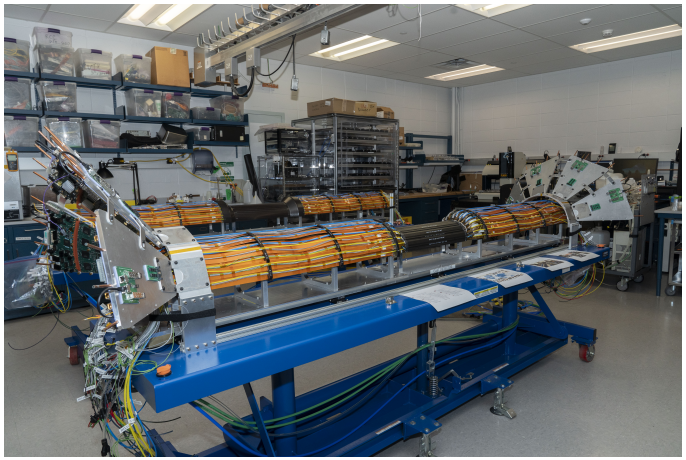
"INTermediate silicon Tracker"

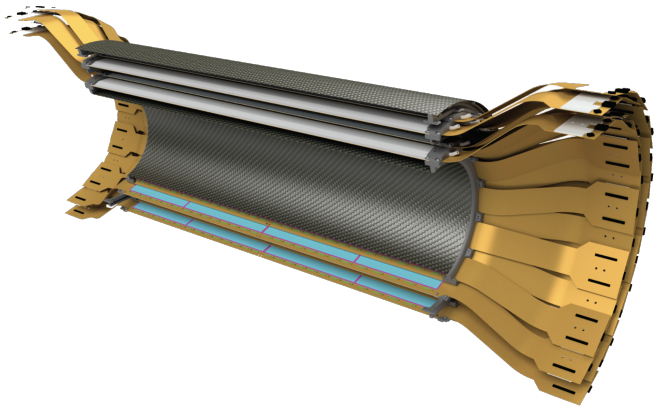


INTT

"INTermediate silicon Tracker"

- Silicon strip detector
  - 56 staves arranged in 2 layers
  - Occupies ~ 7 cm $< r < 11$ cm
- Precision timing
  - Integration time window $\mathcal{O}(100\ \mu\text{m})$
  - Single beam crossing resolution
- Asymmetric spatial resolution
  - $\mathcal{O}(10\ \mu\text{m})$ in $r\phi$
  - $\mathcal{O}(1$ cm$)$ in z

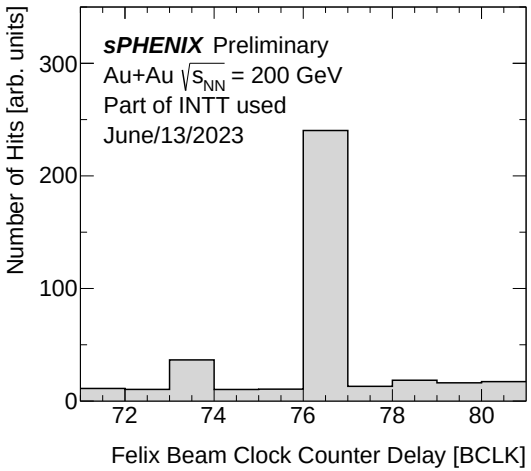




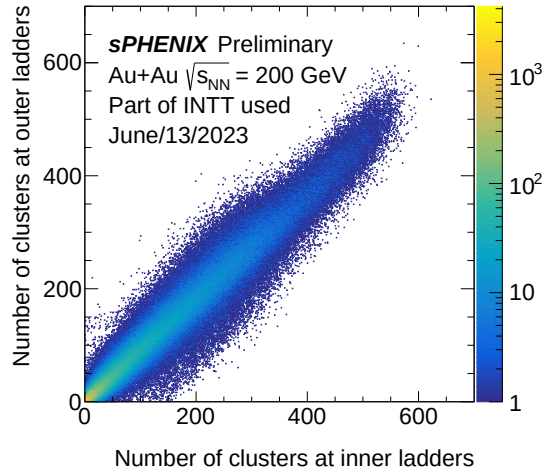
INTT

"INTermediate silicon Tracker"

- Interpolates between MVTX and outer detectors
  - (Hence asymmetric resolution in $r\phi$ compared to z)
- Key timing information in reconstruction
  - Short integration time is what allows vertex disambiguation



Evidence of INTT time in during tuning of firmware parameters

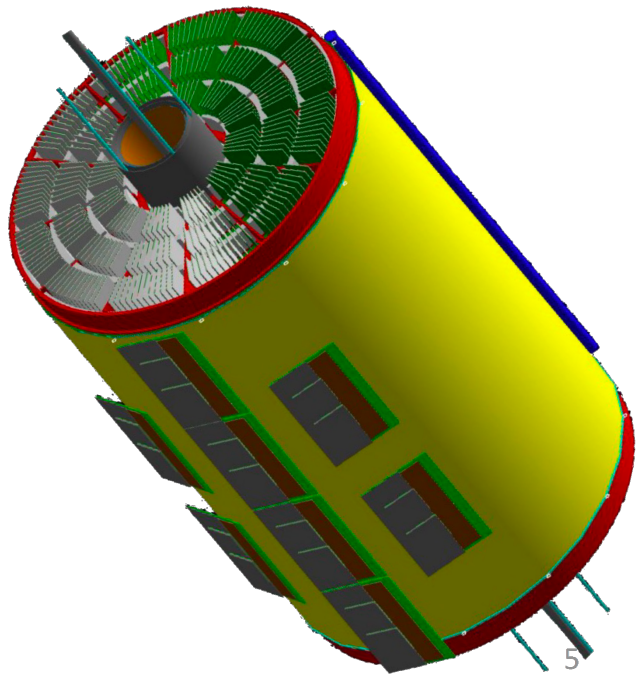


Correlation of INTT hit multiplicity between inner and outer layer

TPC

"Time Projection Chamber"

- Compact, continuous readout GEM (Gas Electron Multiplier)
  - Organized into 48 layers
  - Position resolution of $\mathcal{O}(100\ \mu\text{m})$
  - Occupies $\sim 20\text{ cm} < r < 78\text{ cm}$
- Large number of points provides curvature information
  - Provides momentum information of charged particles
- Long drift time
  - $\mathcal{O}(13\ \mu\text{s})$

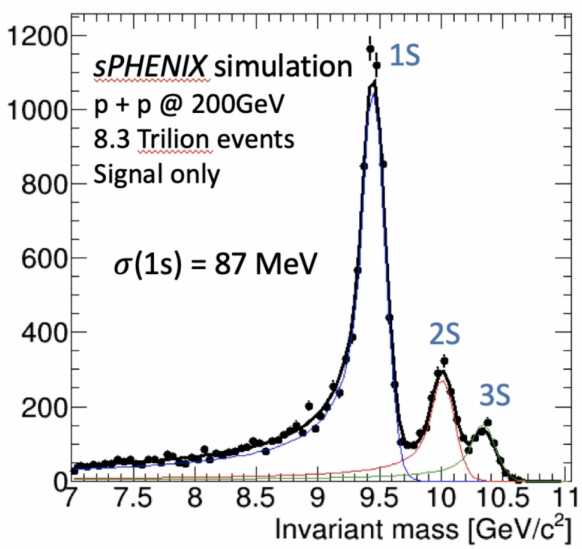


The TPC with the TPOT

TPC

"Time Projection Chamber"

- The motivation for this resolution is to distinguish between $\Upsilon(1s)$, $\Upsilon(2s)$, and $\Upsilon(3s)$ states
  - Center of mass energy for sPHENIX is nominally $\sqrt{s} = 200$ GeV
  - Our target mass resolution is $\lesssim 100$ MeV

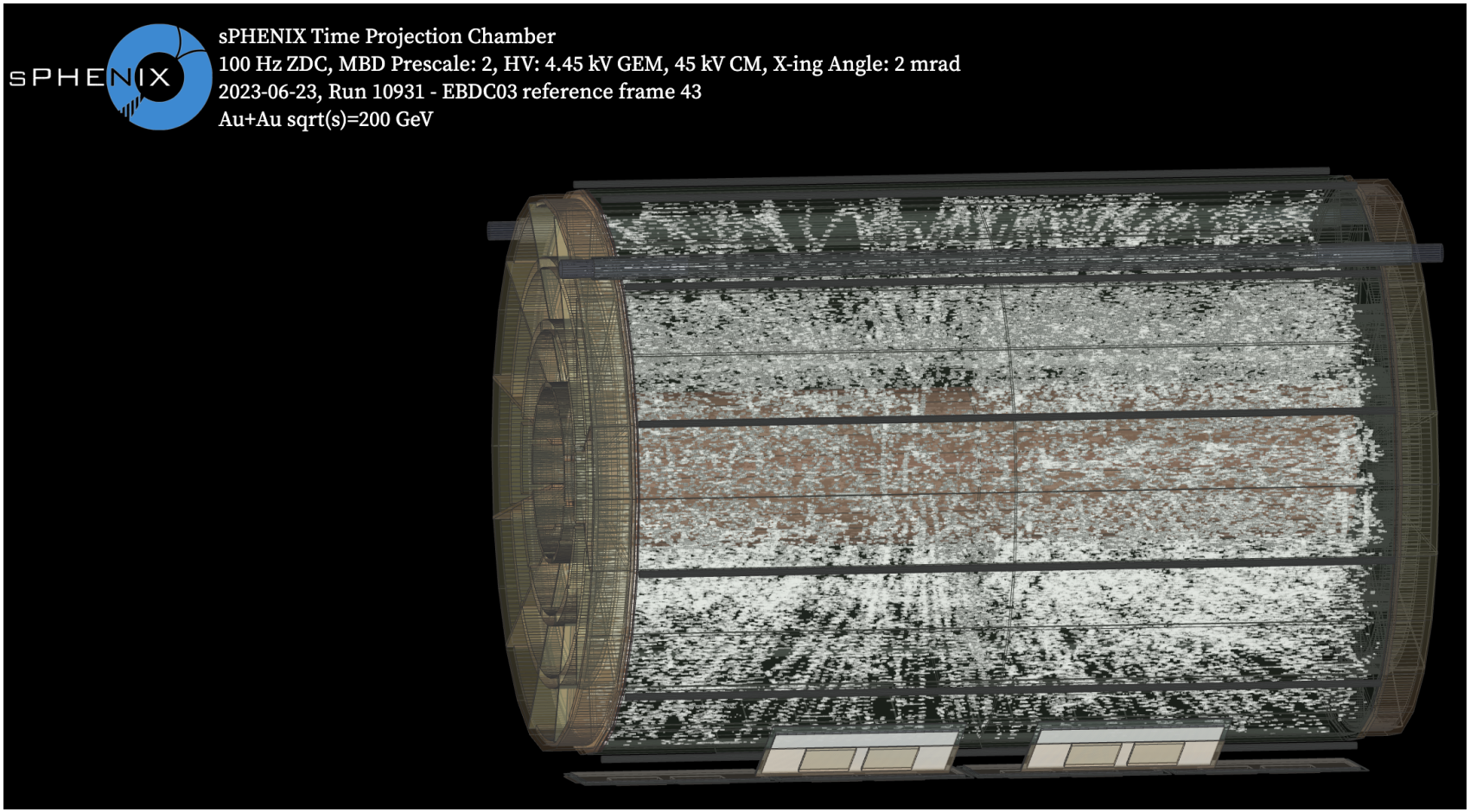


Reconstructed Υ mass from sPHENIX simulation data

- First detector on the RHIC ring with adequate resolution to distinguish Υ states

TPC

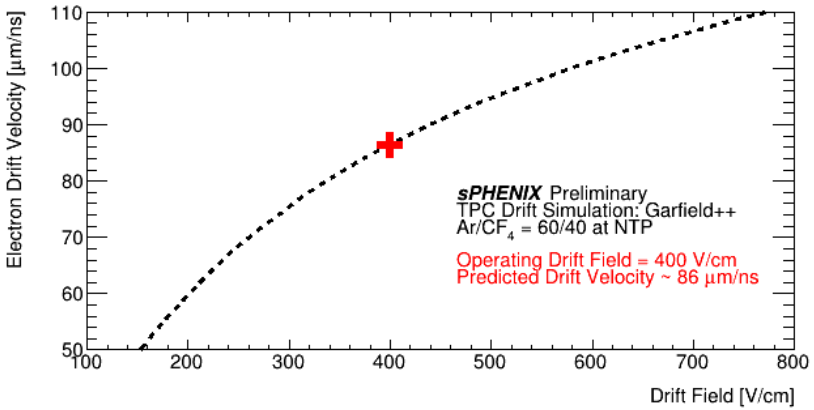
"Time Projection Chamber"

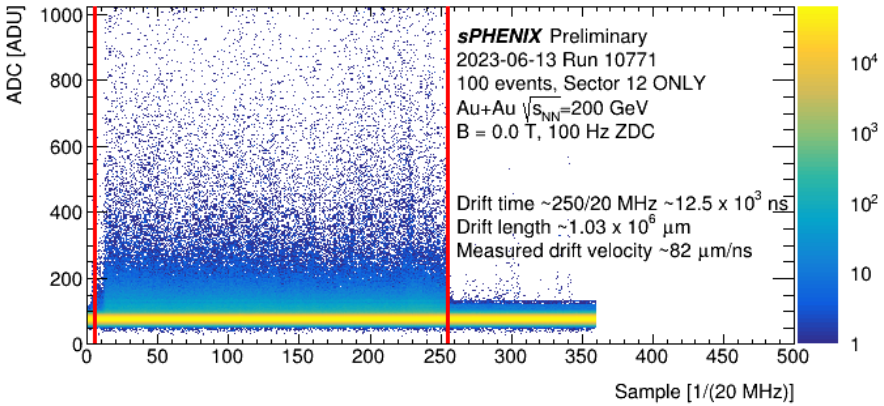


Event display for the TPC

TPC

"Time Projection Chamber"





Top: Simulated curve of drift speed vs electric field. The TPC operates at about 400 V/m, predicting a drift velocity of about 85 μm/ns

Bottom: Measurement of drift velocity. The x-axis is the number of time samples taken to reach the endcap. Red lines show positions of the endcap and central membrane. The position of the central membrane (in time samples), with the length of the TPC (1.03×10^6 μm), give drift velocity (82 μm/ns).

TPC

"Time Projection Chamber"

External links:

- AuAu Cluster Animation
- *pp* Cluster Animation

TPOT

"Time Projection chamber Outer Tracker"

TPOT

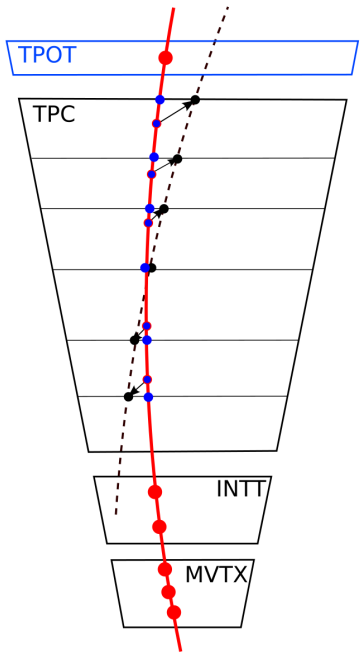
"Time Projection chamber Outer Tracker"

- Primary function is to calibrate TPC
- Consists of 8 micromegas
  - $\mathcal{O}(100\ \mu\text{m})$ resolution
- Only partial coverage
- TPC track reconstruction requires correction of beam-induced distortions, e.g.
  - $\vec{E} \times \vec{B}$ inhomogeneities
  - ion back flow
  - ...

TPOT

"Time Projection chamber Outer Tracker"

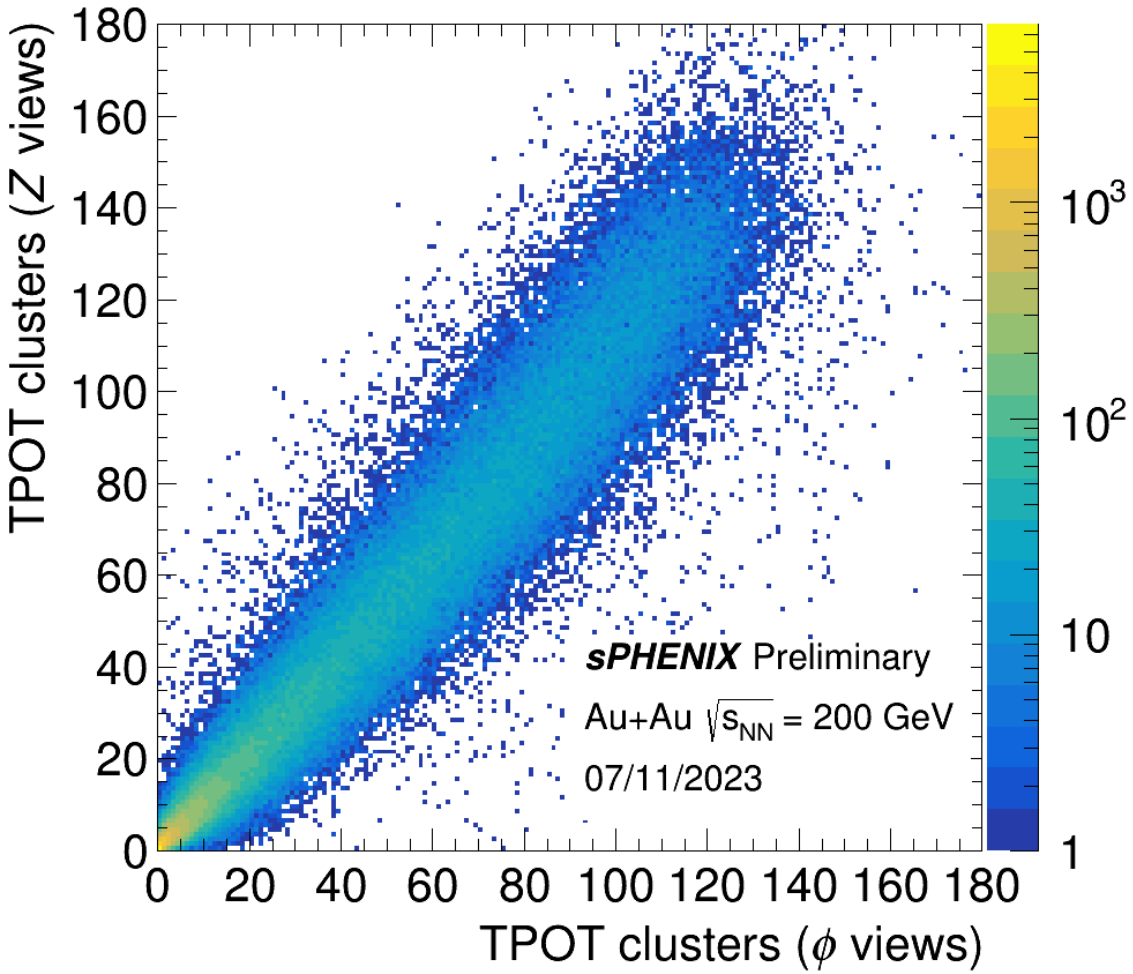
- The GEM readout (black) may suffer from distortions
- Additional spatial measurements from the TPOT provide a reference
- The physical, "truth" track (blue) can be inferred



An idea of distortion correction reconstruction in the tracking workflow

TPOT

"Time Projection chamber Outer Tracker"



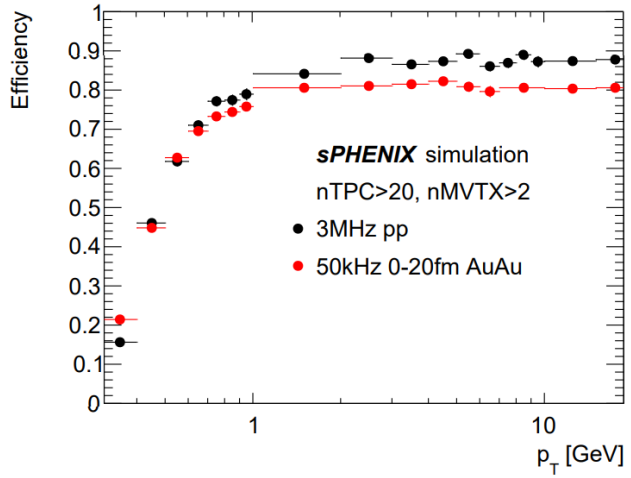
TPOT cluster correlations with itself

- ACTS "A Commmon Tracking Software"
  - Developed by the broader HEP community
  - Experiment-independent track reconstruction tools
  - https://github.com/acts-project/acts

Tracking Workflow

Steps

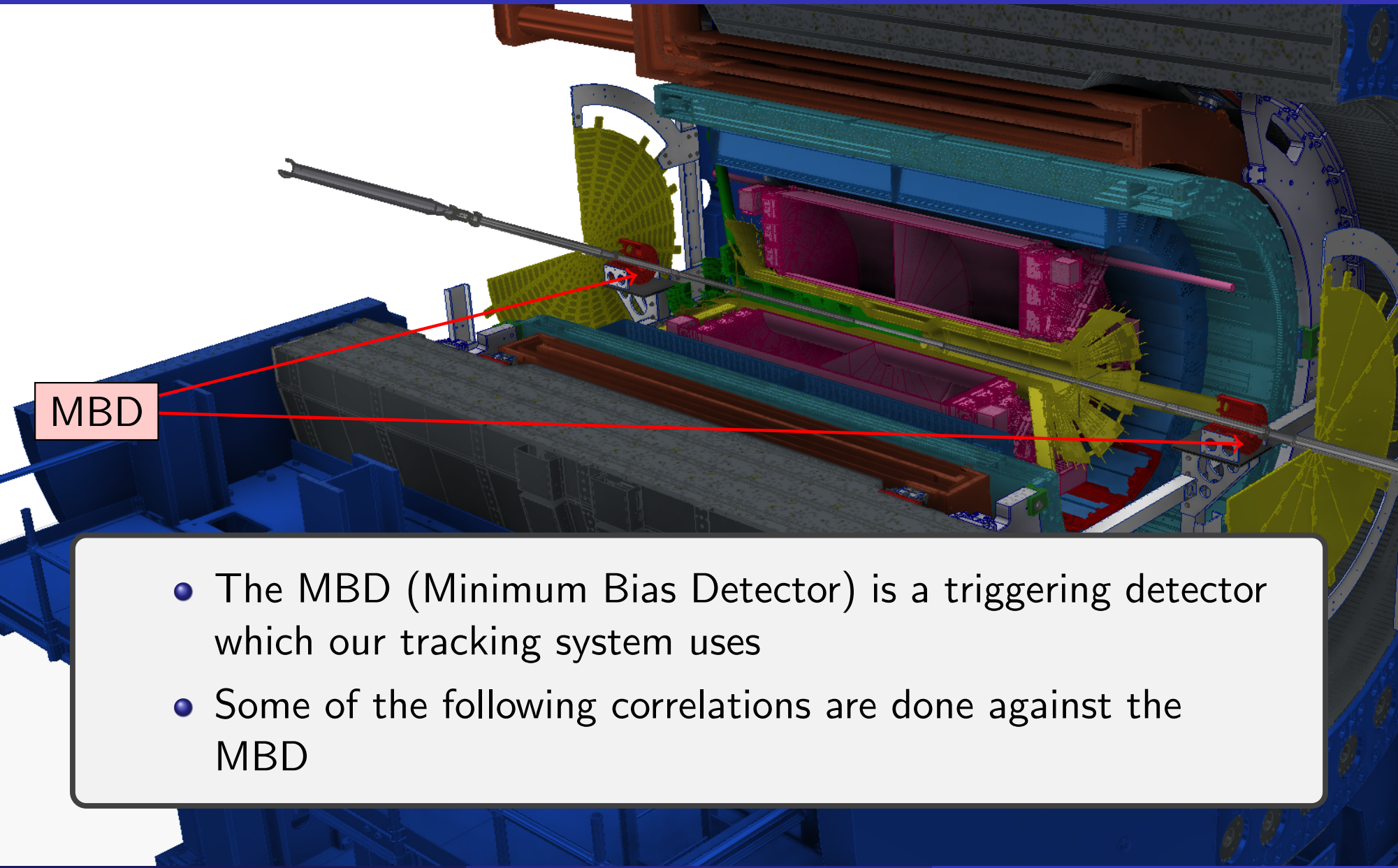
- Strategy:
  - Perform clustering in each detector individually
  - Perform seeding in each detector individually
    - Use Cellular Automaton seeding algorithm (ALICE) in TPC
    - Use ACTS seeder in silicon detectors
  - Combine:
    - Curvature from TPC
    - Timing and vertexing from silicon (MVTX, INTT)
    - TPOT measurements calibrate TPC (where applicable)



Tracking efficiency as a function of transverse momentum p_T for simulated pp and AuAu collisions

Subdetector Correlations

MBD "Minimum Bias Detector"

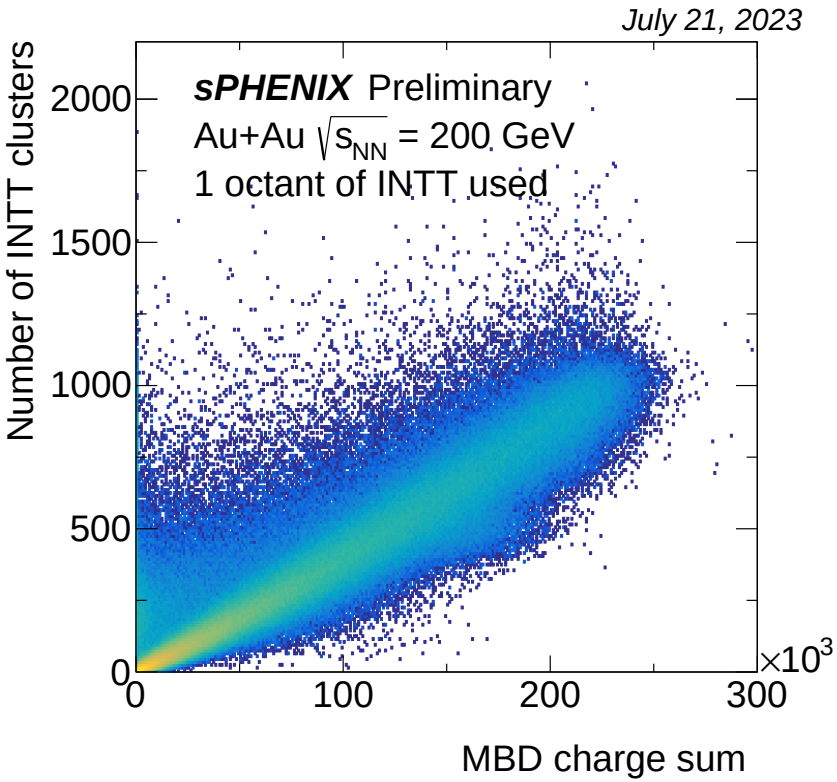


- The MBD (Minimum Bias Detector) is a triggering detector which our tracking system uses
- Some of the following correlations are done against the MBD

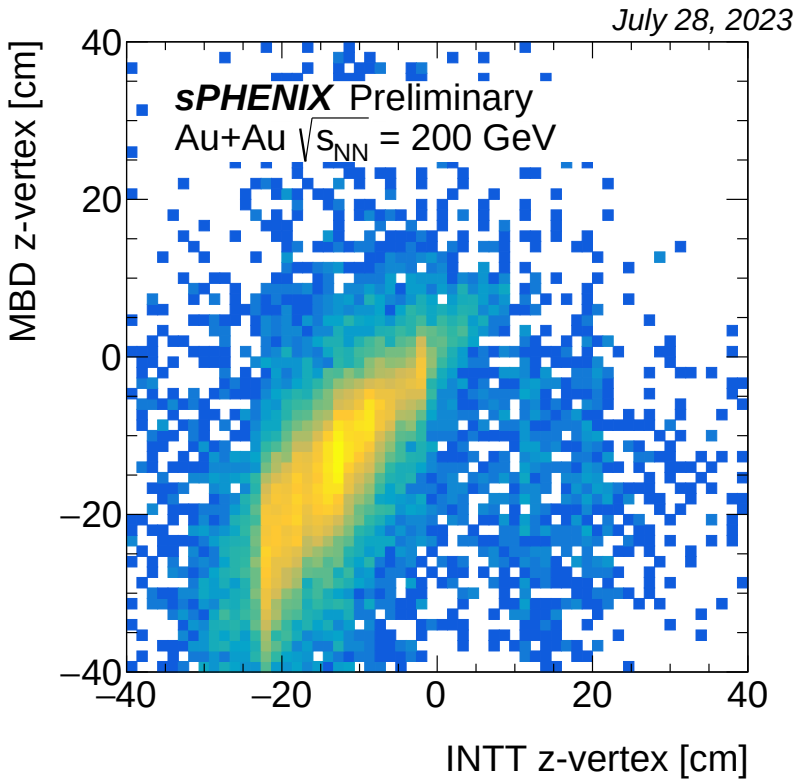
Subdetector Correlations

INTT-MBD

Event correlations between INTT and MBD



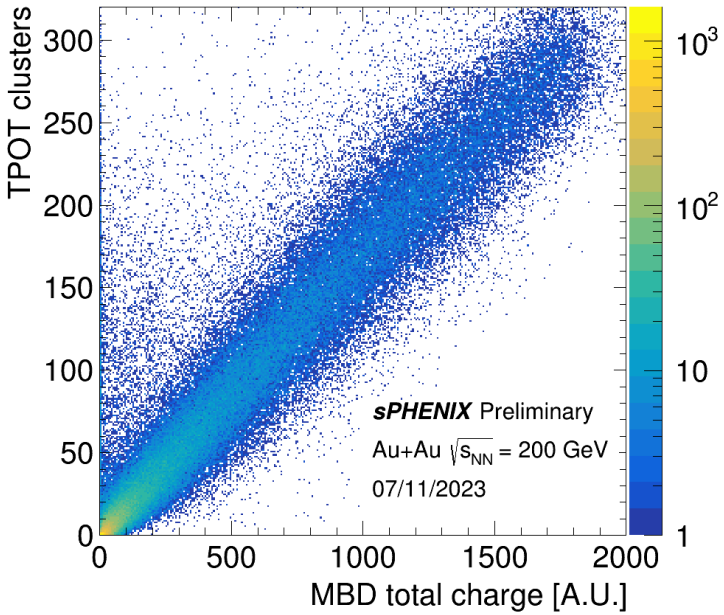
INTT multiplcity correlation with MBD



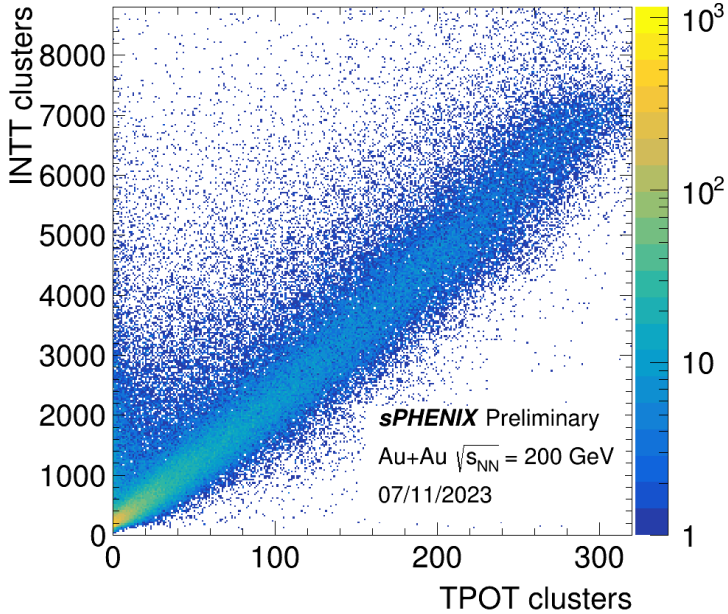
Correlation of z vertex measurement

Subdetector Correlations

TPOT-MBD, TPOT-INTT



Event correlation between TPOT and MBD



Event correlation between TPOT and INTT

Summary

- MVTX
  - Silicon pixel detector
  - Provides position information
- INTT
  - Silicon strip detector
  - Provides interpolation between MVTX and outer detectors
  - Provides timing information
- TPC
  - Layered GEM with continuous readout
  - Provides momentum information
- TPOT
  - Micromegas partially covering TPC
  - Corrects TPC distortions