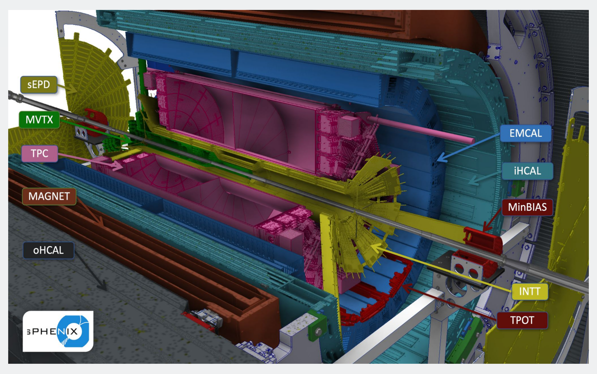
Characterizing Time-Averaged Distortions in the sPHENIX TPC with the TPC Outer Tracker

Bade Saykı for the sPHENIX Collaboration

Abstract

The sPHENIX Time Projection Chamber (TPC) serves as the main tracking detector of the sPHENIX experiment, which began operating at the Relativistic Heavy Ion Collider at Brookhaven National Lab this year. It operates with a quadruple-GEM avalanche stage which provides gain while restricting the flow of ions back into the chamber sufficiently to operate in streaming mode, without any additional gating. However, in order to reach its design performance, the time-varying distortions due to the fields of the remaining ion backflow and primary ionization must be monitored and corrected. The slowly varying component of the distortions is monitored by the TPC Outer Tracker (TPOT), a micromegas-based detector which provides an additional spacepoint for tracks within a limited azimuthal range. This spacepoint enables a data-driven extraction of the distortion vectors within the detector, which can then be extrapolated to the entire chamber. This poster presents the design of the TPOT and methods used to extract the appropriate corrections to these moderate-timescale distortions.

sPHENIX



sPHENIX is the new detector constructed for the RHIC facility at Brookhaven National Laboratory. The sPHENIX collaboration will study the Quark Gluon Plasma through:

- Jet Structure
- Quarkonium Spectroscopy
- Parton Energy Loss
- Cold QCD

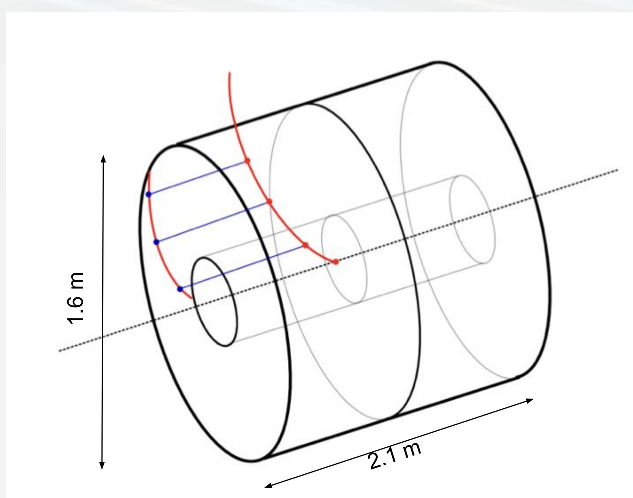
sPHENIX will take data in pp, p-Au and Au-Au collisions at $\sqrt{s_{NN}}$ =200GeV. The experiment started with Au-Au beam in May 2023. sPHENIX Collaboration will take data for three years.

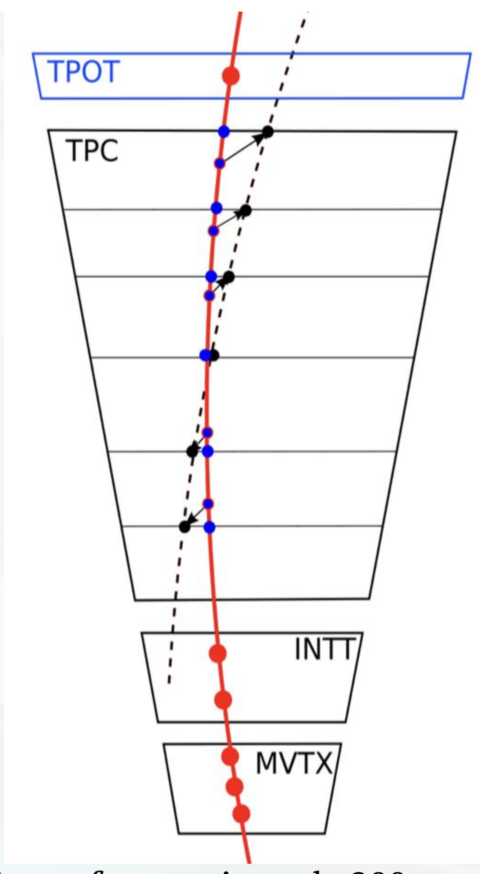
TPC Challenges

The sPHENIX Time Projection Chamber suffers from distortions in the detected trajectory of the particles. To achieve the physics results desired, The trajectory must be measured to an accuracy better than 100µm. This will ensure sufficient momentum and invariant mass resolution.

The main reasons for the distortions are:

- Static distortions: inhomogeneity in the E and B fields and alignment at length scale O(1cm)
  - Directed lasers are used to reconstruct O(1cm) distortions during commissioning. This can potentially interfere with the data taking, which means that it can only be done when the beam is off. Measured during commissioning without beam.
- Beam-induced distortions: Due to charges from primary ionization and ion backflow in drift volume at length scale O(1mm)
  - Tracks are used to reconstruct beam induced O(1mm) space charge distortions.
- Other event-by-event fluctuations: Fluctuations of the beam-induced distortions due to multiplicity/centrality fluctuations at Length scale <100µm and Time Scale O(10ms)
  - Diffuse lasers are used to monitor the O(<100µm) event-by-event fluctuations.





TPOT Purpose

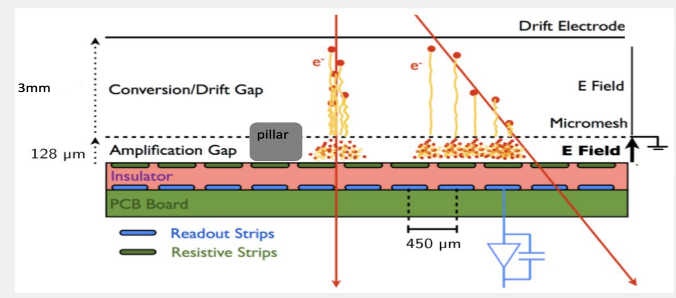
TPOT provides an additional position data point on the outside of the TPC. Together with the inner detectors (MVTX and INTT) it allows to have a more accurate track reference in the TPC, on a fraction of the TPC acceptance.

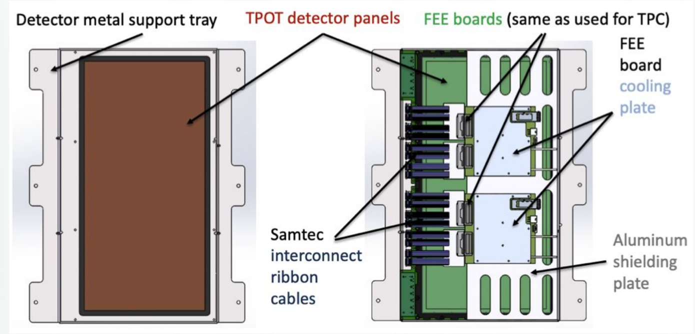
Challenges

- Tight space (< 4 inches)
- > 90% efficiency
- At least two measurements (azimuthal and longitudinal) with resolutions of approximately 200µm, 300µm respectively.
- High occupancy (15% on average) to accommodate the 50kHz collision rate at Au-Au collisions
- Robustness: there is no access to the detectors including electronics once installed
- Tight schedule (~ 1 year between green-light and installation)

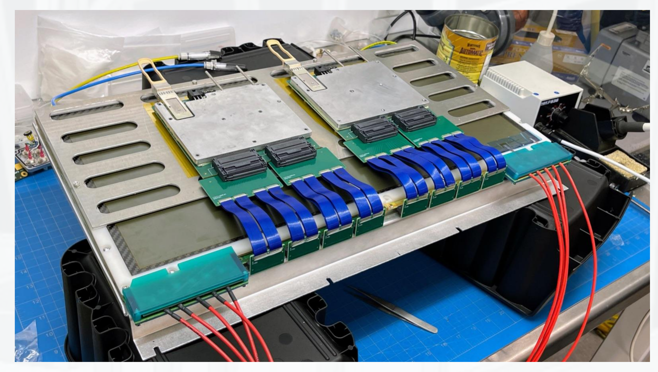
Micromegas & TPOT Structure

Micromegas are thin gas detectors that can fit in the space between the TPC and the EMCal. Each module has two Micromegas detectors, one for longitudinal (z) detection and one for azimuthal (ϕ). The dimensions of each Micromegas are 32cm x 56cm.

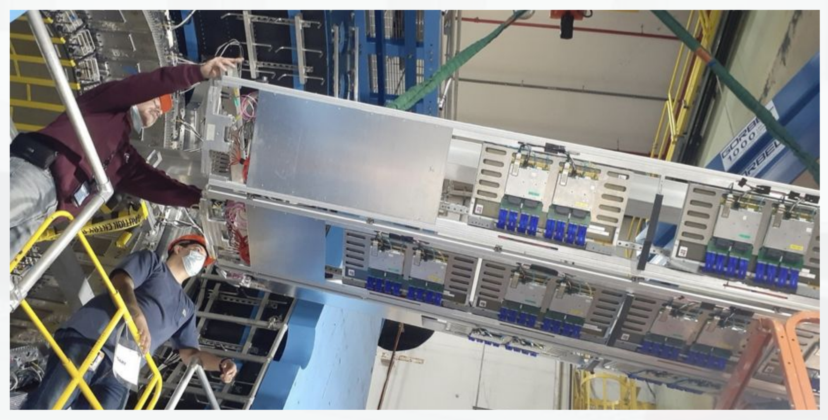




Both z and ϕ detectors sit on an aluminium support tray. FEE boards and cooling plates are installed on an aluminium plate attached to the tray.

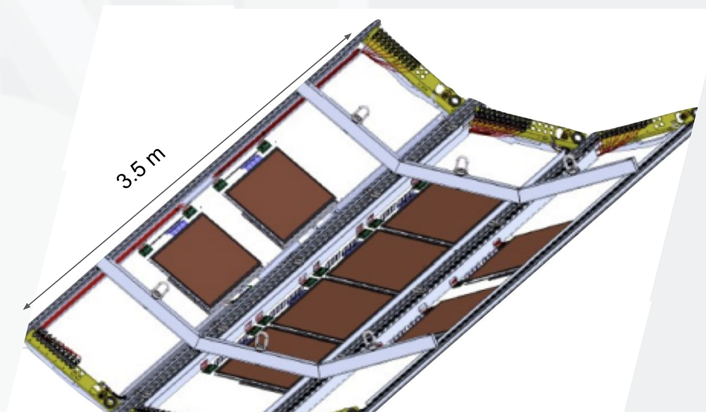


TPOT utilizes the same electronics as the TPC: SAMPA chips 16x256 electronic channels compared to that of the TPC's 624x256 channels.
Gas mixture used is Argon/Isobutane 95/5.



TPOT covers approximately 8% of the TPC acceptance. 4 modules cover the full z extent of the bottommost sector of the TPC (out of 12 sectors total). The other 4 modules are located along the neighbor two sectors (two modules each).

The distortions reconstructed in the region of the TPC that correspond to the TPOT acceptance are extrapolated to the full TPC acceptance using the data provided by the diffuse laser system.
The detectors are supported on a cradle structure. Each module consists of two detectors, a tray, front end electronics and plenty cabling and gas plumbing!



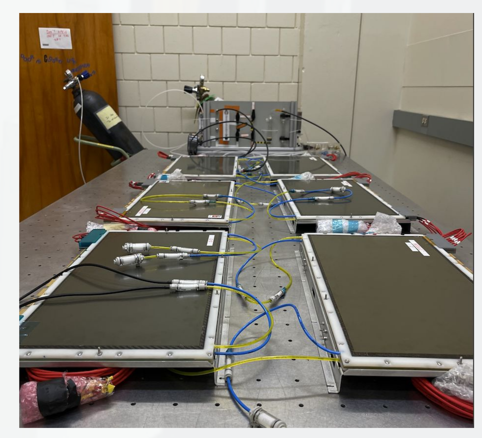
Testing

Pre-Installation

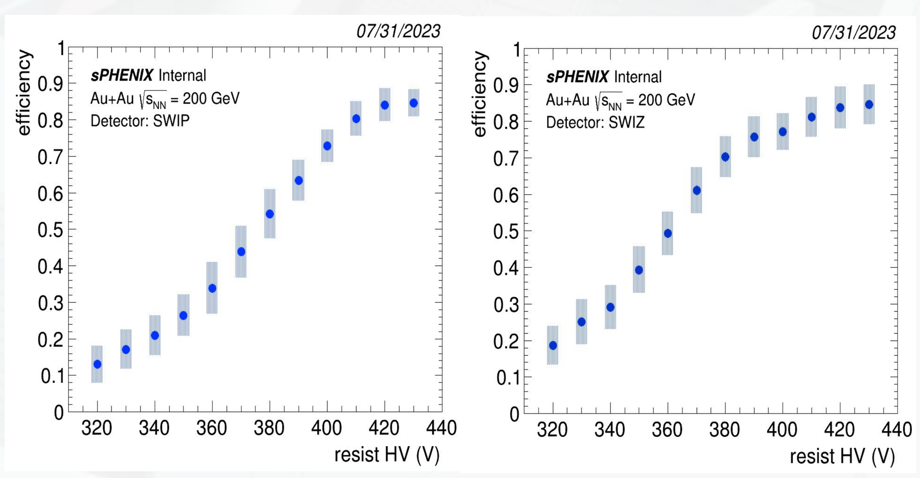
- Each Micromegas
  - Gas tightness
  - Pressure
  - High Voltage and Leak Current testing
- FEEs:
  - Low Voltage bench testing
  - Pulse injection
- Post-Assembly:
  - Gas and Cooling tightness
  - Electronic noise measurements
  - HV test and Cosmic signal
  - Ground connections

Post-Installation

- Gas tightness and pressure measurements
- Cooling tightness
- Temperature
- Electronic noise measurements
- HV test
- LV test



Detector Performance



Detection efficiency estimate for ϕ and z views of one module respectively 1.4T Magnetic Field ON.

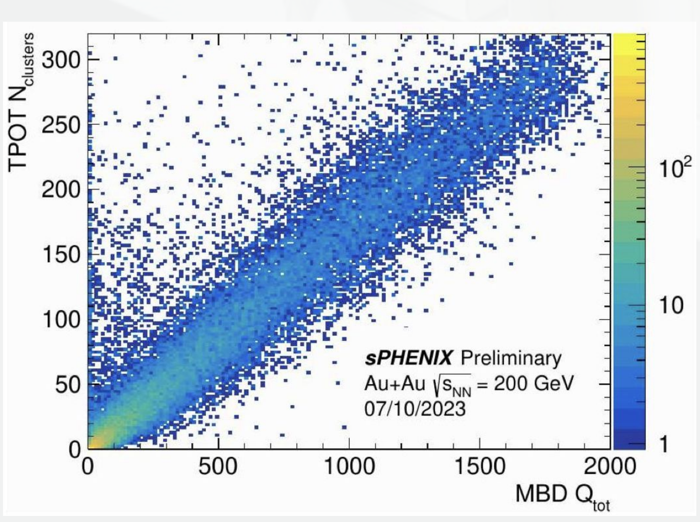
Timeline:

- Installation => December 12th, 2022
- Cabling complete => January 2023
- Gas and full HV system authorization => May 18th, 2023
- TPOT has been operating routinely since May 20th, 2023

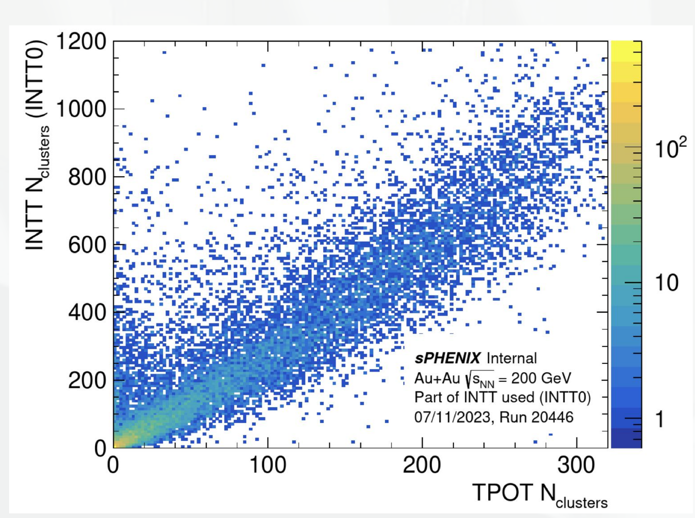
The detector acceptance is 96% due to two low gain channels and one cable that was disconnected during installation.

First detection efficiency estimates are given in this section. For each direction, the measurement on the other detector of the same module is used to define the reference sample. Error bands correspond to varying selection criterion for the reference sample. Differences between the ϕ and z detector efficiencies are due to the orientation of the magnetic field with respect to the strip direction. Deviation from unity at full efficiency is still being investigated, but is likely due to poor definition of the reference sample.

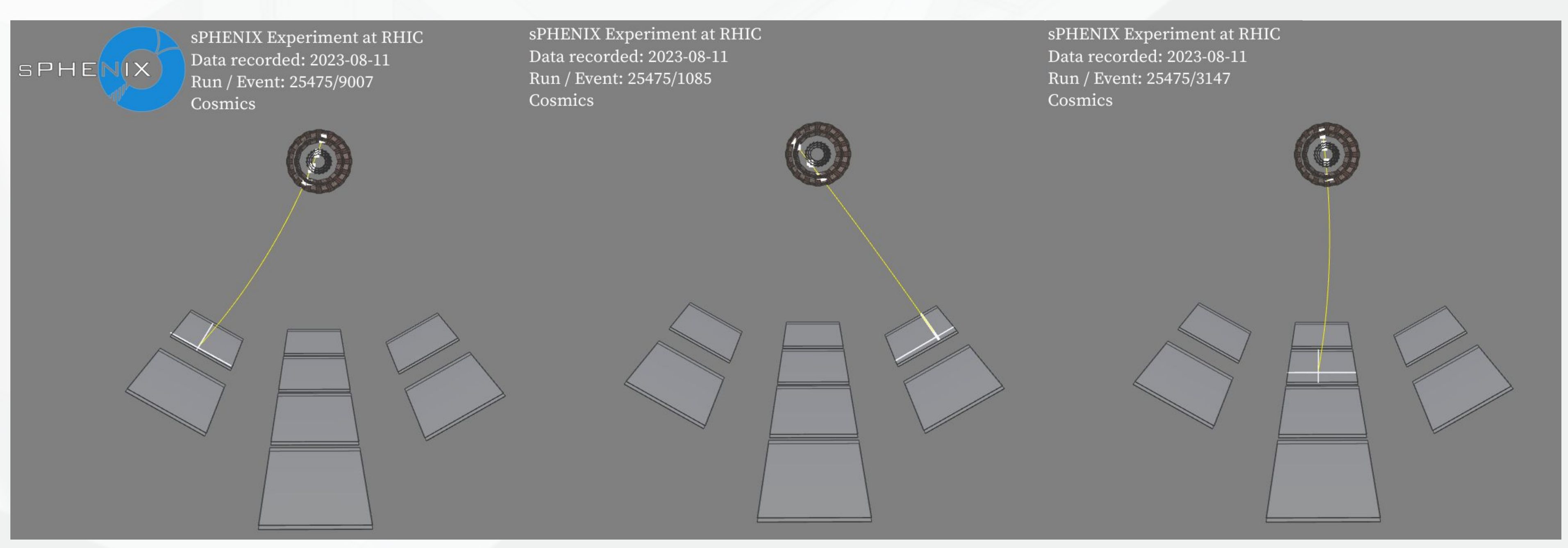
Correlations & Event Display



Correlation between the number of clusters measured in TPOT and the total charge measured in the Minimum Bias Detector (MBD), in Au+Au collisions at $\sqrt{s_{NN}}$ =200GeV



Correlation between the number of clusters measured in TPOT and the total charge measured in the Intermediate Tracker (INTT), in Au+Au collisions at $\sqrt{s_{NN}}$ =200GeV



Event displays for three different cosmic tracks including data from MAPS-based Vertex Detector (MVTX), the Intermediate Tracker (INTT) and TPC Outer Tracker (TPOT.)

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