Vertex reconstruction with MVTX tracklets in the initial Au+Au collision data

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Abstract

sPHENIX, the first detector to be built at the Relativistic Heavy-Ion Collider (RHIC) in over two decades, will bring unprecedented measurement capabilities at RHIC energies. One of the initial physics measurements to be performed by sPHENIX is the charged-particle multiplicity, which utilizes the tracklet analysis method with the cluster information from the Monolithic Active-Pixel-Sensor-based Vertex detector (MVTX). This measurement serves to directly demonstrate, based on real collision data, that the MVTX readout and clustering are operational. Additionally, this analysis technique provides an alternative diagnostic tool for detector alignment and vertex finding, both of which are critical components of the tracking system that will enable the entire physics program of sPHENIX. The status of the commission of the MVTX and the analysis on 2023 Au+Au data is discussed.

Introduction - "Day-1" physics measurement

- The studies of the dependence of the charged particle density on the type of colliding nuclei, on the center-of-mass energy, and on the collision geometry are important for understanding the relative contributions of hard scattering and soft processes to particle production and provide insight into the partonic structure of the nuclei
- The tracklet analysis: A well-established technique, exploited by PHOBOS, PHENIX, ALICE, ATLAS, and CMS.
- We use clusters in the MVTX to form tracklets, two-cluster combinations in different layers that are consistent with a particle originating from the primary vertex

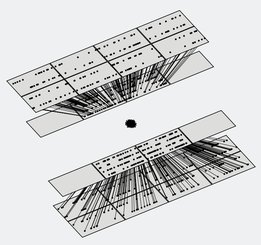
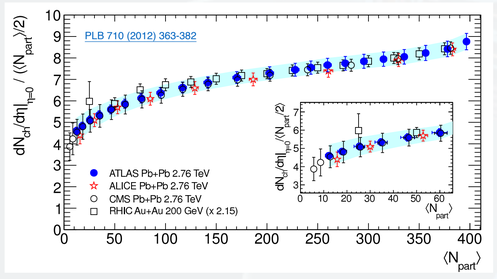
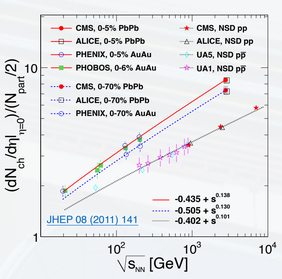


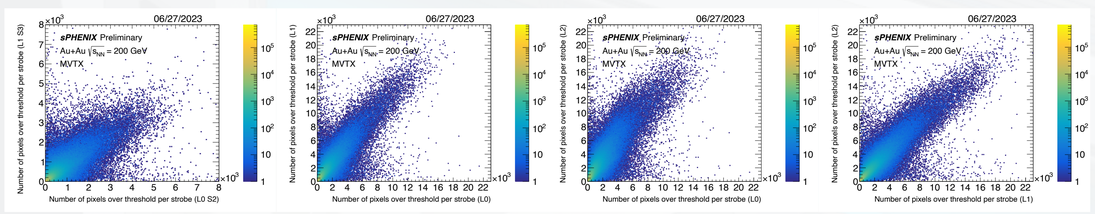
Fig. taken from Phys. Rev. C 83 (2011) 024913



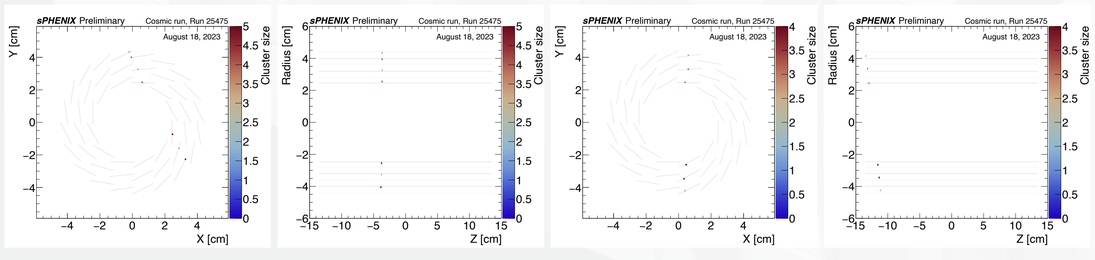


Status of commissioning the MVTX

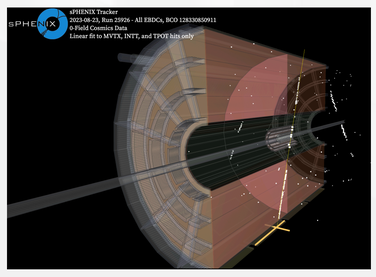
- This analysis is closely related to the commissioning of the MVTX and requires the functioning of key components in the detector and reconstruction chain: triggering, centrality determination, MVTX readout, clustering, and alignment, live channel map and the vertex finding
- Each MVTX stave was tested after installation and found to have more than 99.99% of pixels that could be read out. The calibration was then performed to determine and set the default operating value of the pixel threshold (See Poster Presentation by Yasser Corrales Morales for details of MVTX calibration)
- An initial sample of Au+Au data was taken to confirm synchronization within the MVTX after the pixel threshold was determined and configured



- Cosmic-ray data, triggered by coincidence between top and bottom sectors of outer Hadronic Calorimeter, were taken during periods without beam. A simplified clustering algorithm was developed and applied on the decoded data to obtain the cluster positions. Two cosmic ray candidates found in the MVTX are shown

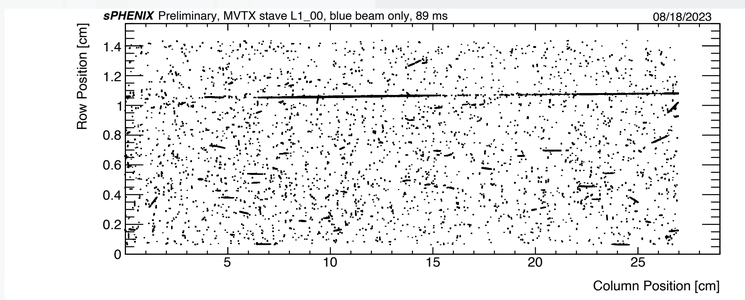


- Shown in the figure to the right is a cosmic candidate passing through all tracking sub-detectors: the MVTX, the intermediate tracker (INTT), the time projection chamber (TPC), and the time projection chamber outer tracker (TPOT). This confirmed the readiness of the MVTX readout system and the external synchronization with other sub-detectors



Initial sample of Au+Au data

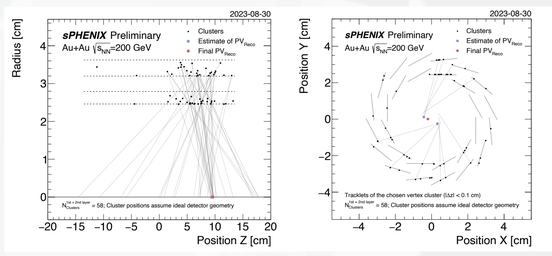
- A large beam background, which overwhelmed the readout and turned off chips and staves, was observed in the MVTX. The hit maps of the MVTX from the initial period of a run showed large "streaks" in the z-direction which was the beam direction.

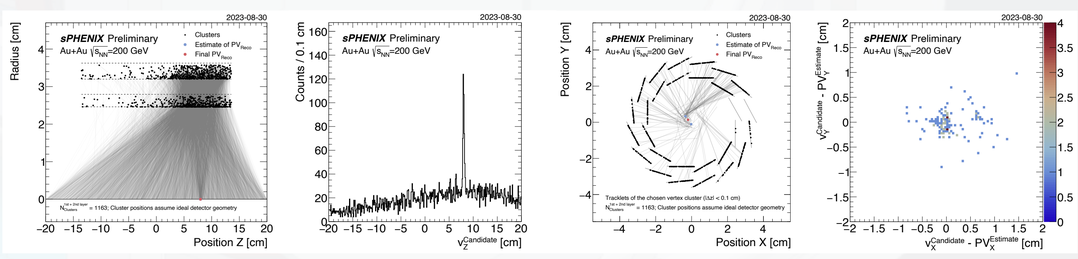


- The beam background significantly reduced the amount of available data to analyze. The MVTX group has been closely working with Collider-Accelerator Department at RHIC to understand and improve the beam conditions
- In an effort to exploit the currently available data, clusters with a number of constituent pixel hits greater than 5 were excluded from the following analysis to reject the beam background

Analysis - Vertex reconstruction

- The event vertex was reconstructed in the following procedures:
  a. Clusters in the first and second MVTX layers with $\Delta\phi < \Delta\phi_{cut}$ are paired to form tracklets. The vertex candidate Z position v_Z is calculated by linearly extrapolating the Z position of the constituent clusters in the tracklet to the beam axis
  b. Each vertex candidate is assigned to a vertex cluster that included all candidates within $|\Delta z| < |\Delta z_{cut}|$. The vertex cluster with the highest number of vertex candidates is chosen, and the median of the vertex candidate v_Z in the chosen vertex cluster defines the primary vertex Z position, PV_Z
  c. Given PV_Z, an additional iteration of linear extrapolation to obtain the X and Y positions of the vertex candidates, v_X and v_Y, in the chosen vertex cluster is performed. The final estimate of the primary vertex X and Y positions, PV_X and PV_Y is defined as the median of the vertex candidate v_X and v_Y in the chosen vertex cluster
- The procedures were repeated for clusters in the east and west half of the MVTX to give two primary vertex estimates. The final primary vertex position is defined as the average of the two primary vertex estimates, weighted by the number of vertex candidates in each chosen vertex cluster
- Two events have been chosen to demonstrate the tracklet vertex reconstruction
  - A low cluster-multiplicity event is shown on the right
  - A high cluster-multiplicity event is shown below





Summary and Outlook

- Various commissioning studies have confirmed that the MVTX is functioning well since its assembly and installation. Calibration has been carried out during no-beam periods.
- The operation and readout of MVTX detector and the event synchronization with other tracking sub-detectors have been tested and verified with the initial Au+Au and cosmic data
- Dedicated analysis strategies have been established and developed to analyze the current available data, as well as results of the tracklet vertex reconstruction with the initial Au+Au data, are outlined in this presentation
- Commissioning efforts, including the alignment and improving the beam quality and condition, are underway to make the MVTX ready for taking data with the expected quality

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