Studies of long-range two-particle correlations in proton-proton collisions with sPHENIX

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Abstract

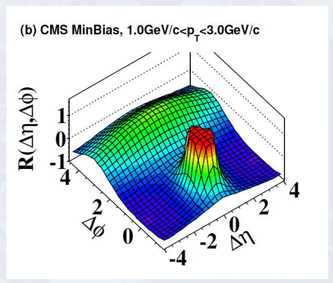
The sPHENIX experiment at RHIC, started operation in 2023, is a next-generation collider detector with broad pseudorapidity coverage and full azimuthal acceptance, enabling detailed studies of jet production, heavy-flavor physics, and collective phenomena in small and large systems. Long-range correlations in small collision systems provide essential information on the early-time dynamics and possible collective behavior in QCD matter. In this poster, we present studies of long-range two-particle correlations in proton-proton collisions at √s = 200 GeV, focusing on silicon seed correlations reconstructed with the Monolithic Active Pixel Vertex Detector (MVTX) and Intermediate Silicon Tracker (INTT) for both the streaming and MBD-triggered data sets.

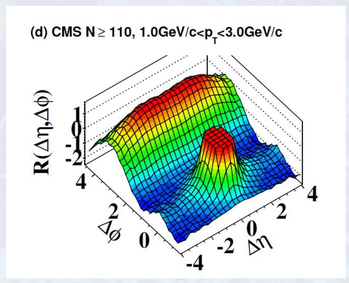
Collectivity in Small System

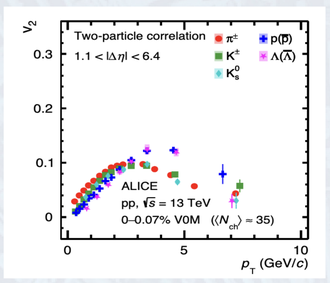
While long-range correlations are formed at the early stages of the collision, they can be modified by the medium and final-state interactions. This provides insight into the interplay between the initial state and the subsequent evolution of the medium created in the collision.

- At the LHC, high-multiplicity p+p events show a near-side long-range ridge (JHEP09(2010)0).
- Identified-hadron v_2 exhibits clearly mass ordering at low p_T and Baryon-meson grouping at intermediate p_T (arXiv:2411.09323).

→At RHIC energies, measuring p+p two-particle correlation as functions of p_T and multiplicity gives an essential insight into the underlying dynamics and onset of collectivity in small systems.

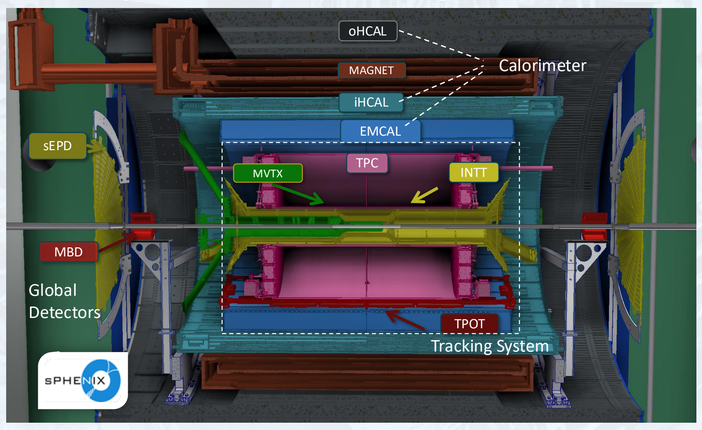


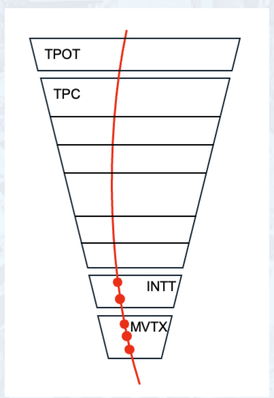




sPHENIX Experiment

sPHENIX features full azimuthal coverage and |η| < 1.1 acceptance with the tracking system and calorimeters, and global detectors located at forward rapidity.





- **MVTX**: 3-layer MAPS sensors
  5um position resolution, provides precise vertexing and heavy-flavor tagging
- **INTT**: 2-layer silicon strip tracker
  Timing resolution < 1 bunch crossing (106 ns)
  → BC tags for hits/ tracks/ events and excellent φ resolution (18μm)
- **TPC**: Gas tracker with GEM readout
  ~150 μm resolution, ~1% pT resolution @ 1 GeV/c, provides dE/dx for PID
- **TPOT:** Micromegas sectors providing extra space points for TPC calibration
- **MBD:** at 3.51 < |η| < 4.61
  Trigger and centrality determination

Silicon Seed

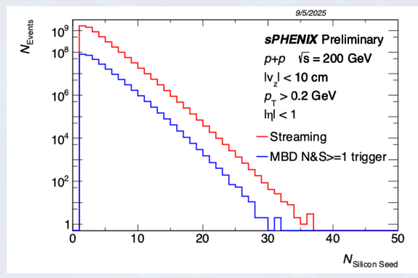
MVTX and INTT clusters are converted to 3D space points and binned in φ–z. The ACTS SeedFinder builds radius-ordered triplets to geometrically estimate helical seeds under beam-spot and minimum-p_t constraints with a margin for multiple scattering. INTT's sub-bunch-crossing timing assigns BC tags so only in-time hits are combined, suppressing out-of-time/duplicate seeds. These silicon-only seeds are then matched to TPC/TPOT and passed to the fitting process. This work uses only MVTX+INTT silicon seeds.

Streaming readout: 20× yield & access to rare high-multiplicity events

During the 2024 p+p run at √s = 200 GeV recorded:

- 13.3 pb^{-1} with all subsystems with MB trigger
- 2.9 pb^{-1} with the tracking system using streaming readout

- The streaming readout allows for the collection of unbiased pp collisions at rates of up to ~200 kHz.
- ≈ 20 × more events than with the minimum-bias trigger
- Reaches the top >0.1% multiplicity tail (≈ Number of silicon seeds ≥ 15), which the trigger under-samples.



Long-range two-particle correlation

In this analysis, two-particle correlations are studied using silicon seeding.
The associated yield per trigger particle as a function of Δη and Δφ is defined as,

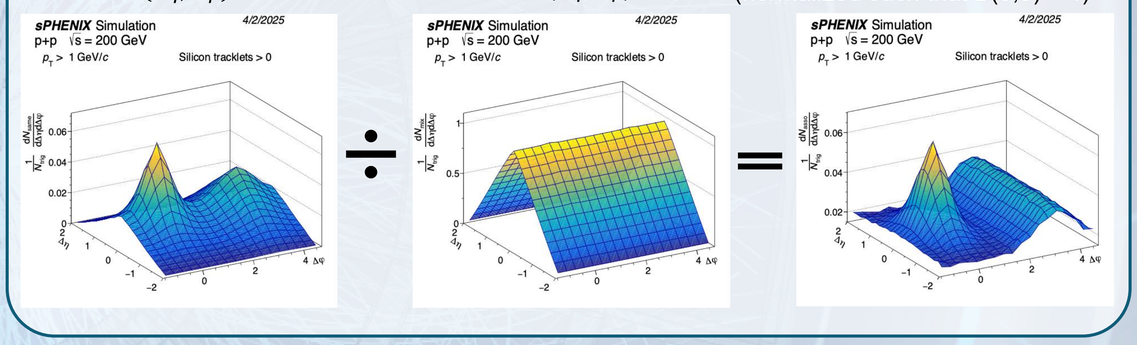
$$\frac{1}{N_{trig}}\frac{d^2N_{associate}}{d\Delta\eta d\Delta\varphi} = \frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}$$

$$S(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}}\frac{d^2N_{same}}{d\Delta\eta d\Delta\varphi}$$

$$B(\Delta\eta,\Delta\varphi) = \alpha\frac{d^2N_{mixed}}{d\Delta\eta d\Delta\varphi}$$

(normalized such that B(0,0) = 1)

$S(\Delta\eta,\Delta\varphi)$ ÷ $B(\Delta\eta,\Delta\varphi)$ =



Current Two-Particle Correlation Results

	$N_{silicon\ seed} > 1$	$N_{silicon\ seed} > 10$ (top 1%)
Trigger		
Streaming		

- Streaming data enables high-statistics measurements of two-particle correlations, even in high-multiplicity events.
- The silicon seeding is still at an early stage of calibration and requires further refinement.

$N_{silicon\ seed} > 15$ (> top 0.1%)

Summary and outlook

- We present the status of long-range two-particle correlations in p+p √s = 200 GeV with sPHENIX, using silicon seeding, for both the streaming and MBD-triggered data sets.
- These preliminary results demonstrate the capability of sPHENIX to explore ridge phenomena in small collision systems. Further analysis will focus on high-multiplicity events to better understand the onset and nature of such correlations using more statistics (~10-20x).
- The silicon seeding is still in its early calibration stage. For the next step, we will improve the precision/purity of the silicon seeding and apply efficiency/acceptance corrections.

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