

OVERVIEW OF RECENT sPHENIX RESULTS*

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*Received 10 April 2026, accepted 13 October 2026,
published online 15 October 2026*

An overview of recent results from the sPHENIX Collaboration spanning the full scientific program is presented. Recent publications on standard-candle measurements are presented in addition to photon and jet cross sections, which demonstrate how sPHENIX can extend to higher momentum measurements than previous RHIC experiments. Transverse Single Spin Asymmetries for neutral mesons and jets are also discussed. The evolution of the dijet-momentum imbalance as a function of centrality in Au+Au collisions is also compared to the imbalance in pp collisions. Finally, invariant mass distributions of several resonances and heavy-flavor hadrons are presented to demonstrate the significant progress made on tracking calibrations and corrections.

DOI:10.5506/APhysPolBSupp.19.5-A16

1. Introduction

sPHENIX [1], the newest experiment at the Relativistic Heavy Ion Collider (RHIC) [2], is designed around a broad science program consisting of cold QCD, jet structure, quarkonium spectroscopy, and parton energy loss. At Cracow Epiphany 2026 Conference, results spanning the full sPHENIX scientific program were presented, including charged-hadron multiplicity, neutral-meson Transverse Single Spin Asymmetry, and dijet-momentum imbalance, among others. Commissioning of the detector was begun in 2023 with Au+Au collisions and was extended into 2024 with $p+p$ collisions to finish commissioning of the tracking subsystem. The measurements shown here are provided by these two data sets; additional physics runs in 2025 and 2026, comprising Au+Au, $p+p$, and O+O collisions, have yet to be fully calibrated and analyzed, but once complete, the statistics and system-size scope of sPHENIX will be improved.

* Presented at the 32nd Cracow Epiphany Conference on the Recent Results from Heavy Ion Physics, Kraków, Poland, 12–16 January, 2026.

2. The sPHENIX detector

sPHENIX is designed to measure heavy-flavor hadrons and jets. In order to accomplish this, measurements of heavy-flavor and jet-substructure observables are enabled by a precision tracking system, while the energy of jets is measured, and direct photons and electrons are identified by the electromagnetic and hadronic calorimeter system. Going outwards starting from the beam line, sPHENIX is comprised of the following subsystems [3]: the MAPS-based Vertex Detector (MVTX); the INTeRmediate Tracker (INTT); the Time Projection Chamber (TPC); the Time Projection Chamber Outer Tracker (TPOT) [4]; the Electromagnetic Calorimeter (EMCAL) [5, 6]; the Inner Hadronic Calorimeter (IHCAL) [6]; the 1.4 T superconducting solenoid magnet [7], and the Outer Hadronic Calorimeter (OHCAL) [6]. Full azimuthal coverage and a pseudorapidity acceptance of $|\eta| < 1.1$ are provided by all detectors except the TPOT. A number of forward detectors are also included in sPHENIX, namely, the Minimum Bias Detectors (MBD), which were previously used as the PHENIX Beam-Beam Counters [8, 9], the sPHENIX Event Plane Detectors (sEPD), and the Zero Degree Calorimeters (ZDC), in which the Shower Maximum Detector (SMD) is included.

3. Global observables and cross sections

Standard-candle observables that have been measured before with high precision should be among the first measurements performed by any new experiment, so that good detector performance and well-understood calibrations are ensured. Two such measurements have recently been published by the sPHENIX Collaboration: the charged-hadron multiplicity [10] and the transverse energy density [11] in Au+Au collisions. The charged-hadron multiplicity using tracklets can be seen in Fig. 1, while the transverse energy density, separated by calorimeter, can be seen in Fig. 2.

Good agreement with previous measurements across all centrality bins is shown by the $dN_{\text{ch}}/d\eta$, while exceptional agreement across both calorimeters individually as well as combined is shown by the $dE_{\text{T}}/d\eta$. Excellent detector performance and a good understanding of the calibrations are shown by these measurements over the full sPHENIX acceptance.

Measurements of the jet [12] and isolated photon [13] cross sections in $p+p$ collisions have also been performed, as shown in Fig. 3. The jet cross-section measurement is the first with mid-rapidity hadronic calorimeters at RHIC, allowing a push to higher p_{T} than has previously been possible. Both of these measurements allow for better constraints of theoretical calculations and Monte-Carlo (MC) models.

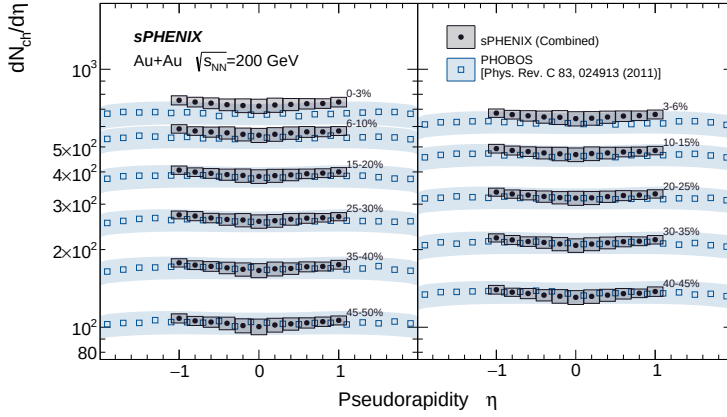


Fig. 1. Charged-hadron multiplicity measured by sPHENIX in Au+Au collisions shown as black circles with the shaded boxes indicating the combined uncertainty. Centrality bins alternate between the left and right panel for readability. Figure from Ref. [10].

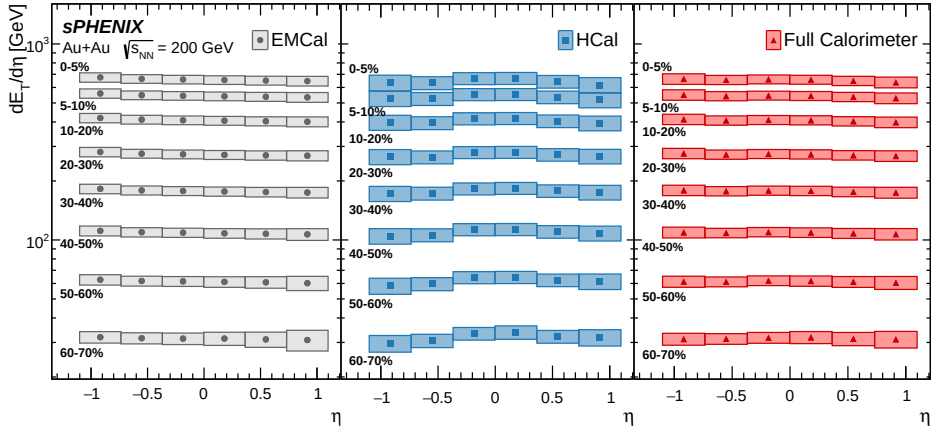


Fig. 2. Transverse energy density measured by sPHENIX in Au+Au collisions in the EMCAL, IHCAL, and OHCAL. Figure from Ref. [11].

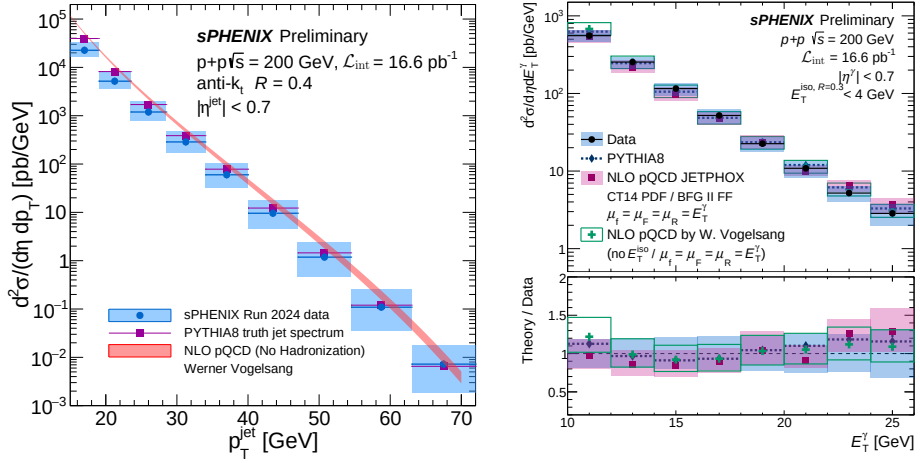


Fig. 3. Left: Unfolded jet cross section for anti- k_t with $R = 0.4$ jets measured using the sPHENIX full calorimeter system (blue circles), NLO pQCD calculation (red band), and a PYTHIA 8 Detroit-tune truth jet spectrum (purple squares). Figure from Ref. [12]. Right: The differential cross-section of isolated prompt photons as a function of E_T^γ is compared with theoretical predictions of PYTHIA 8.307 (Detroit tune), JETPHOX, and NLO pQCD calculations provided by Werner Vogelsang. Figure from Ref. [13].

4. Cold QCD

The inner structure of the proton and the nature of its spin can be probed by collisions of polarized protons. One way in which this is done is by measuring the Transverse Single Spin Asymmetry (TSSA). The TSSA can be probed by measuring the asymmetry of particle production to the left and right of the polarization axis, where a non-zero value is taken to indicate a correlation with the polarization. The TSSA has been measured by sPHENIX in neutral mesons [14] and in jets [15]. The measurement for η -mesons, compared to PHENIX measurements, is shown on the left in Fig. 4, while the measurement for inclusive jets, compared to recent STAR measurement, is shown on the right. In both cases, the TSSA is found to be consistent with zero, and no preferential direction for particle production is indicated.

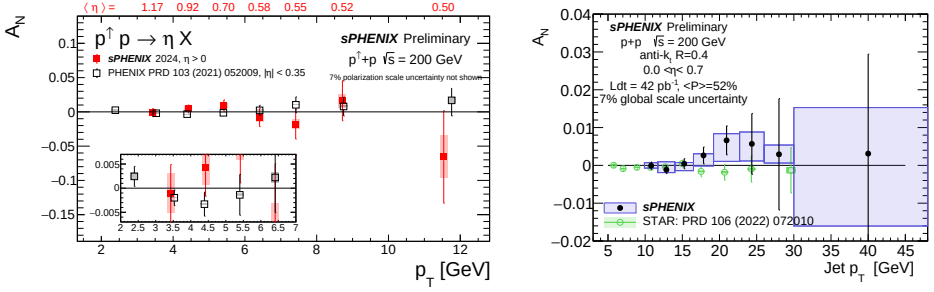


Fig. 4. Left: sPHENIX Run-2024 results compared to PHENIX Run-2015 results in inclusive production of η -mesons in collisions of transversely polarized protons at $\sqrt{s} = 200$ GeV. Figure from Ref. [14]. Right: Transverse single-spin asymmetries as a function of the jet transverse momentum in the forward region (full black symbols), compared to a recent STAR publication of similar observables using charged particles and electromagnetic calorimetry with a radius of 0.6 (dark-green open circles). Figure from Ref. [15].

5. Jet energy loss

One of the primary goals of sPHENIX is to measure jet energy loss in the Quark–Gluon Plasma (QGP). In order to perform such measurements, the underlying event (UE) must be subtracted to obtain the true jet energy. We have performed a set of comprehensive studies in minimum-bias Au+Au collisions to characterize the underlying event using three different background subtraction methods [16], though they are all in agreement within a few percent. The study includes measurements of random cones (accounting for non-stochastic contributions from v_2 and v_3), and the embedding of single high- p_T probes as well as fully simulated MC jets into minimum-bias data to characterize the UE subtraction performance.

Once the UE subtraction was completed, we studied the dijet momentum imbalance ($x_J = p_{T,\text{sub}}/p_{T,\text{lead}}$) in $p+p$ and Au+Au collisions [17]. The results, seen in Fig. 5, show a clear shift from balanced dijets in $p+p$ collisions to imbalanced ones in central Au+Au collisions, with peripheral Au+Au collisions matching closely with the $p+p$ measurement. This shift in the momentum balance indicates that subleading jets lose a significant fraction of their momentum through interactions with the QGP in central and mid-central Au+Au collisions.

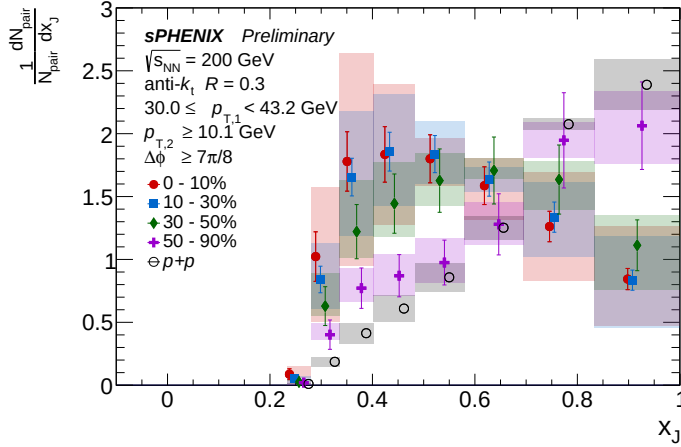


Fig. 5. Fully unfolded x_J distributions of dijet events are shown for different Au+Au collision centrality intervals, 0–10%, 10–30%, 30–50%, and 50–90%, and for $p+p$ collisions with the matching kinematic selections. Statistical uncertainties are shown as vertical lines and systematic uncertainties as filled boxes. The data points are slightly displaced horizontally within their uncertainty boxes for visibility. Figure from Ref. [17].

6. Heavy-flavor prospects

Finally, the tracking system comprised of the MVTX, INTT, TPC, and TPOT allow for reconstruction of resonances and heavy-flavor hadrons via their hadronic decay channels. Preliminary studies [18] from small samples of our $p+p$ data show clear $\Lambda^0 \rightarrow p\pi$ and $D^0 \rightarrow K^-\pi^+$ signals, and even a small peak of the Λ_c^+ from a three-body decay, as seen in Fig. 6. While there has been significant progress with tracking reconstruction, more work is underway to understand tracking calibrations and efficiencies, including space charge distortions in the TPC.

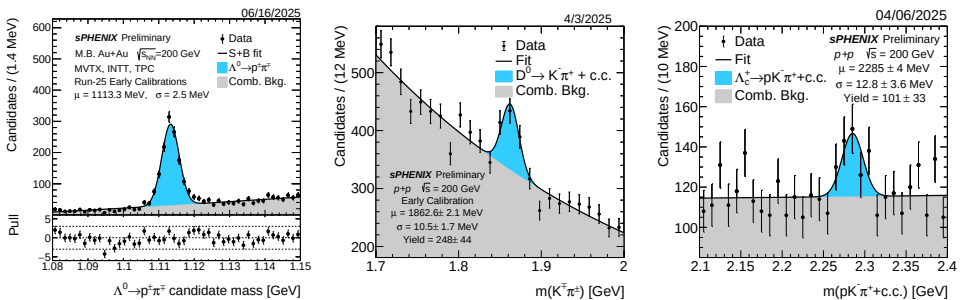


Fig. 6. Invariant mass peaks reconstructed through charged-hadron decays of the Λ^0 (left), D^0 (middle), and Λ_c^+ (right). Figures from Ref. [18].

7. Summary

The sPHENIX experiment has successfully completed its data collection and is transitioning into a full physics analysis mode. Current measurements from early data have already provided high-quality Au+Au and $p+p$ collisions that already validate the detector's design goals and push toward new physics. Numerous jet and photon analyses are already underway, including cold QCD, and significant progress has been made on tracking and heavy-flavor reconstruction. The analysis of our full statistics across $p+p$, Au+Au, and O+O systems will allow for a comprehensive mapping of the QGP properties with unprecedented precision at a variety of scales including system size and probe energy.

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