Medium-energy Nuclear Physics with sPHENIX

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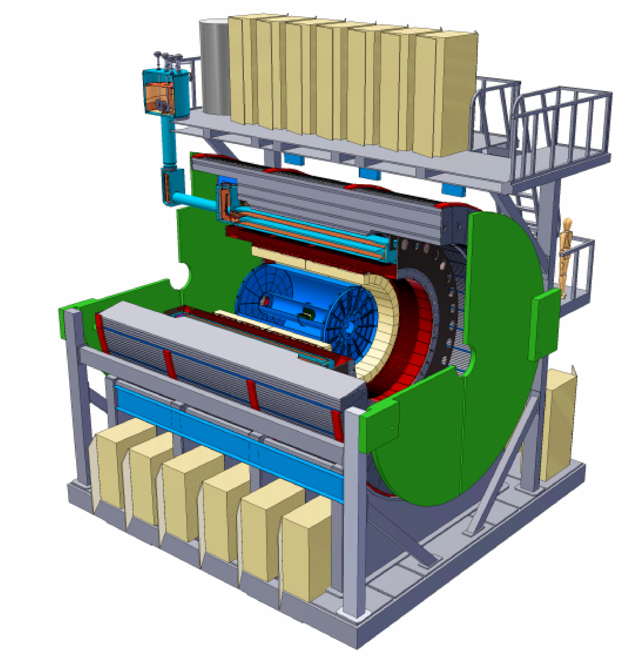
Abstract

A potential upgrade with forward instrumentation of the proposed sPHENIX detector at the Relativistic Heavy Ion Collider (RHIC), together with RHIC's unique capabilities to collide polarized protons and heavy nuclei, will open the door to exciting new measurements to enhance our understanding of quantum chromodynamics (QCD). These measurements will reveal more about how partons behave in a nuclear environment, explore spin-spin and spin-momentum correlations in the nucleon in a new kinematic regime, and investigate high-temperature QCD systems over a range of baryon densities. In addition, they will probe early times in the formation of the strongly coupled quark-gluon plasma. This poster focuses on the measurements enabled by the sPHENIX forward upgrade, as well as the medium-energy nuclear physics program for the sPHENIX mid-rapidity detector itself.

sPHENIX Detector

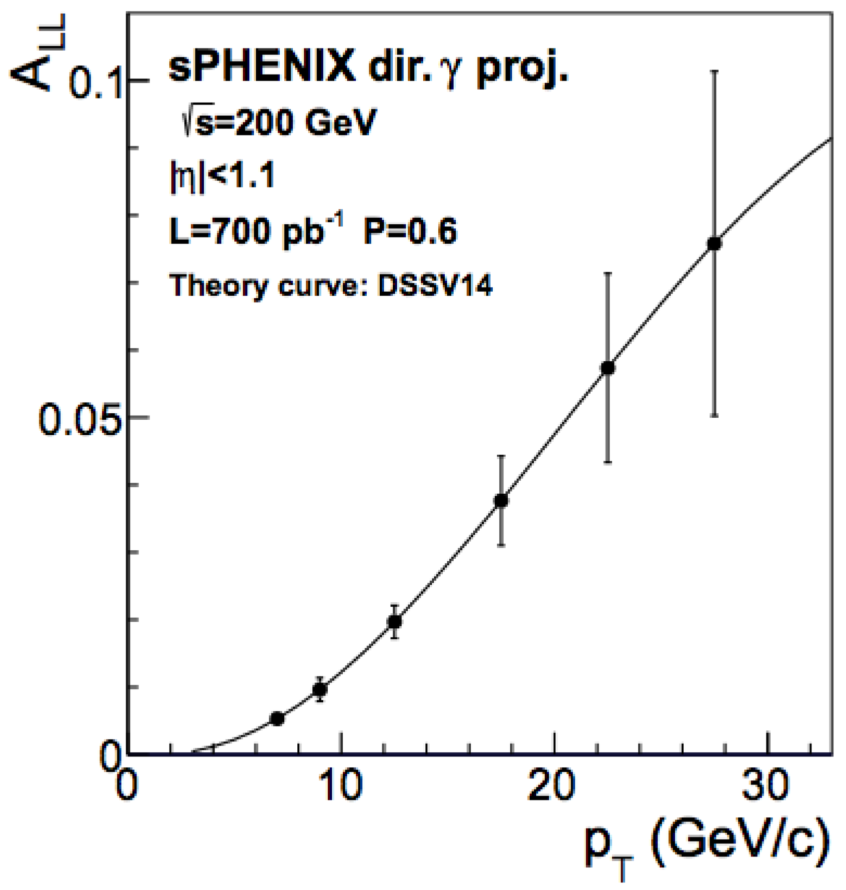
The sPHENIX detector is designed to have full azimuthal coverage and pseudorapidity coverage $|\eta| < 1.1$ around an approximately 1.5 Tesla solenoidal magnet. The detector consists of a central tracking system, an electromagnetic calorimeter, and two hadronic calorimeters situated around the solenoid.



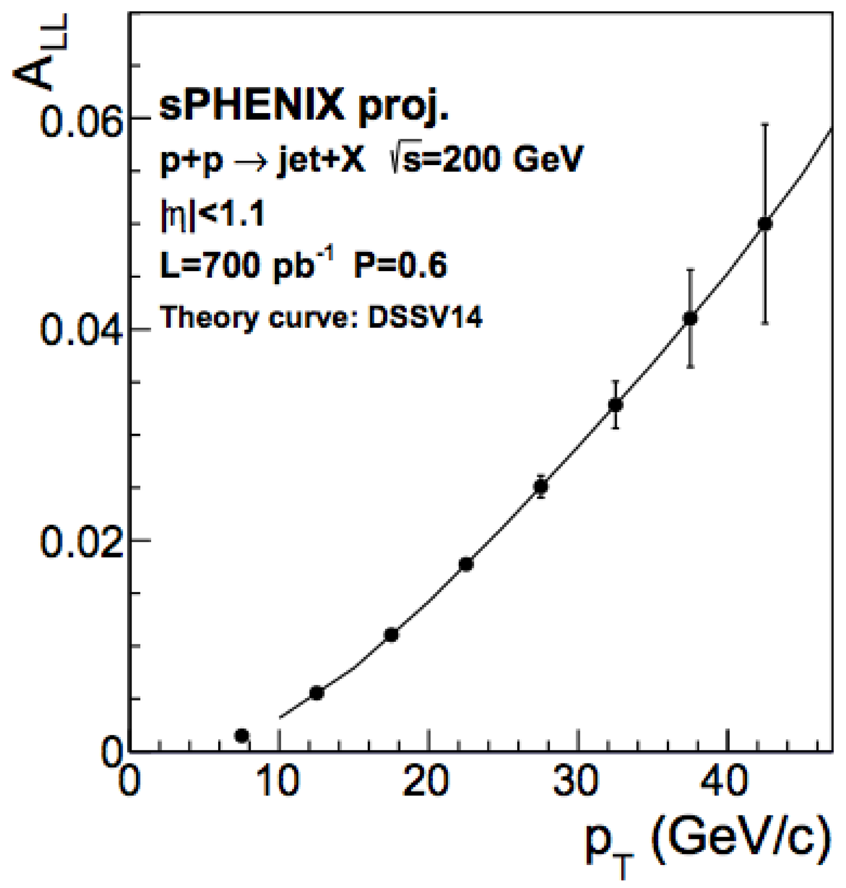
The experiment will rely on a large trigger rate, approximately 15 kHz, to record a large sample of a variety of high p_T processes including but not limited to, jets and γ-jet correlations. sPHENIX is projected to collect p+p, p+Au, and Au+Au data sets between the years 2022 and 2026.

Gluon Spin Contribution

One of the primary goals of the RHIC physics program is to measure the gluon contribution to the total spin of the proton. As RHIC is the only polarized proton-proton collider in the world, sPHENIX will be in a position to make measurements sensitive to the gluon spin contribution.

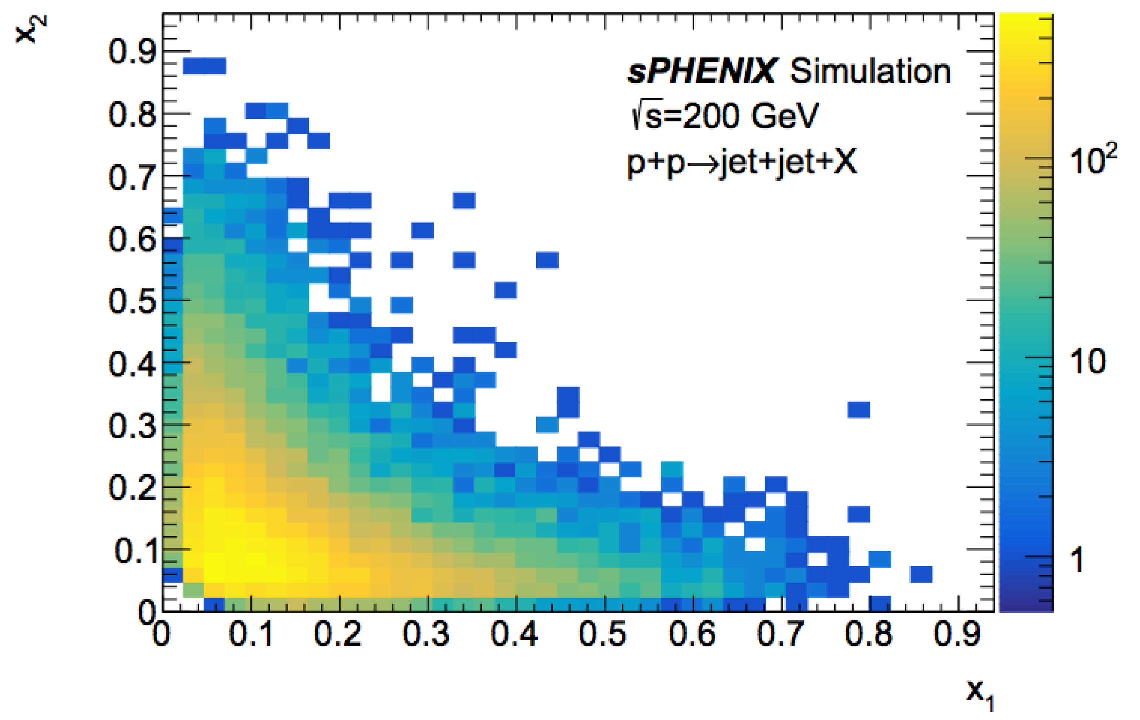


Two of the main physics programs for sPHENIX involve direct photons and jets at large p_T. Projections for the inclusive direct photon (above) and jet (below) double longitudinal asymmetry show that sPHENIX will accumulate significant statistical precision to measure each channel. In particular, these processes provide leading order access to the gluon distributions, which give excellent constraints to the gluon contribution to the proton spin.

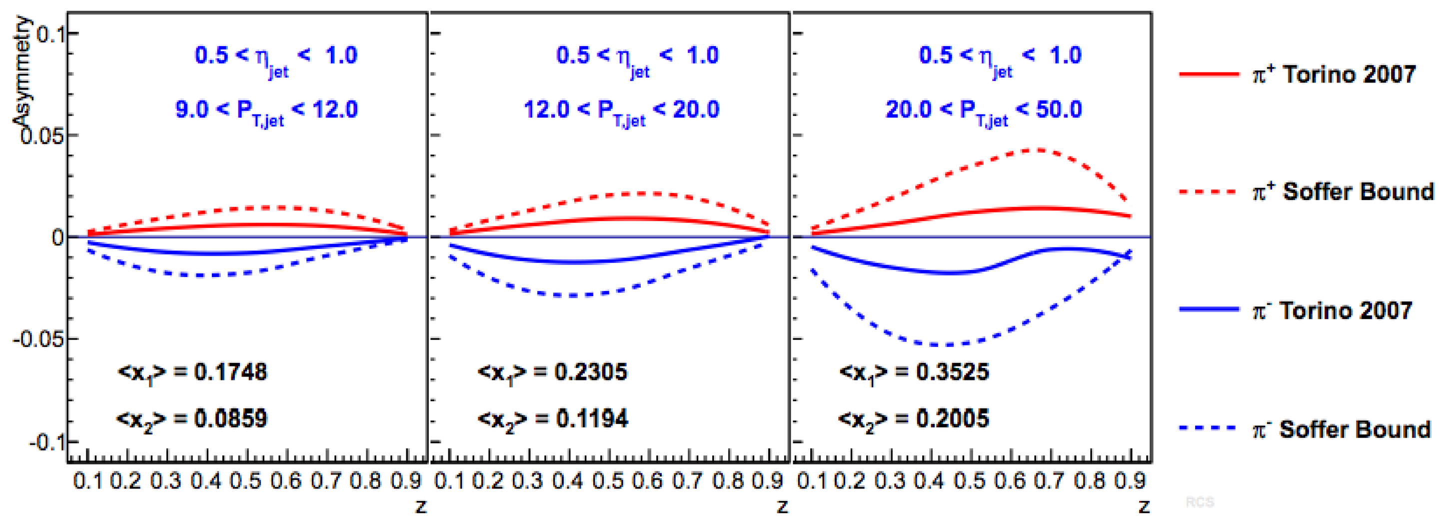


Jet Measurements

As sPHENIX is a dedicated jet detector, inclusive jets and jet correlations can be measured across a wide range of p_T. The partonic momentum fractions x_1 and x_2 probed in dijet simulations within the sPHENIX barrel are shown in the figure below, demonstrating that the experiment will have the opportunity to probe relatively large values of x in each nucleon. This will allow for measurements of the quark transversity distribution to be extended over a larger range of x than current world data allows.

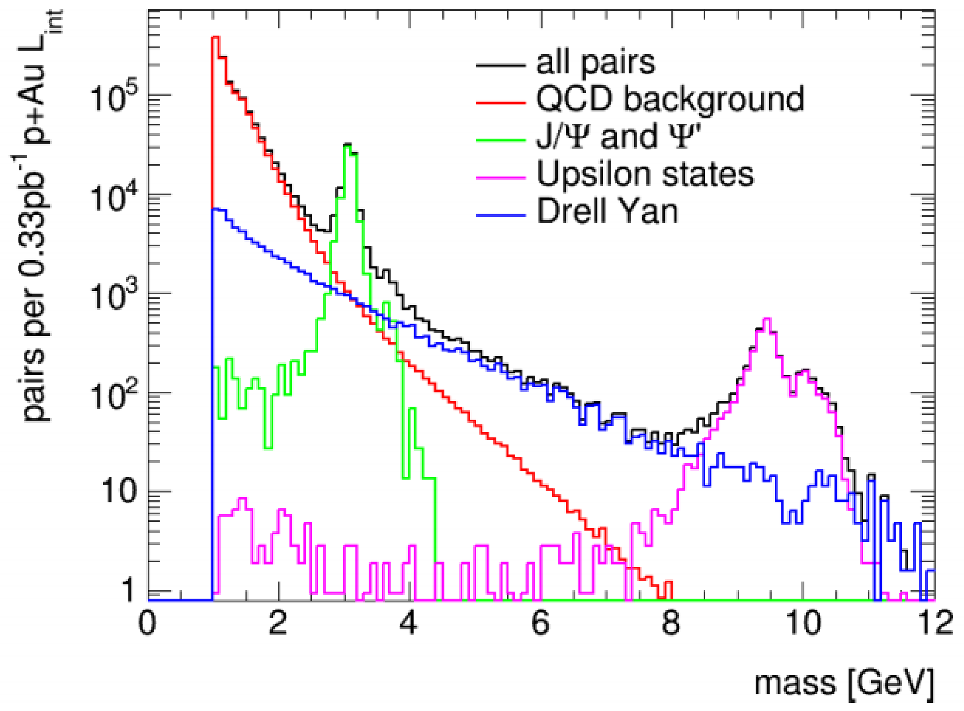


In addition to its calorimetry, the sPHENIX tracking system will allow for robust measurements of hadrons within jets. This will not only allow for nuclear fragmentation function measurements in p+Au collisions, but when transverse spin is also included spin-momentum correlations in the final fragmenting state can be measured. One such correlation, the correlation between a hadron's transverse momentum and parton's spin, will be important for understanding predictions of universality and factorization in certain transverse-momentum-dependent parton-distribution-functions.



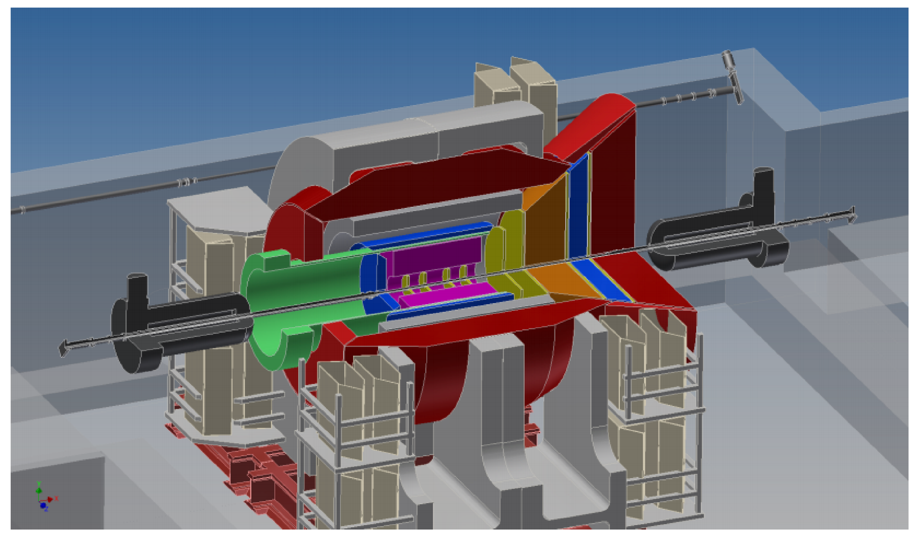
Forward Arm Upgrade

A forward upgrade has been proposed with tracking, electromagnetic, and hadronic calorimetry covering $1.4 < \eta < 4$. This additional coverage would allow for transverse spin phenomena with jets to be studied where inclusive hadron measurements have shown large azimuthal asymmetries. Drell-Yan measurements in p+Au will also be feasible, helping to constrain nuclear parton-distribution-functions. Full detector simulations, shown below, indicate that Drell-Yan measurements will be feasible in the forward arm.



Evolution Towards an EIC Detector

The path of sPHENIX will lead to a capable day-1 Electron Ion Collider (EIC) detector with large coverage of tracking, calorimetry, and particle identification. The EIC will ultimately be the next frontier of proton and nucleus structure studies.



References

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[2] sPHENIX Forward Instrumentation LOI
[3] sPHENIX Proposal, arXiv:1501.06197
[4] Concept for an EIC Detector Around the BaBar Solenoid, arXiv:1402.1209