Cold QCD physics with sPHENIX and potential forward upgrades

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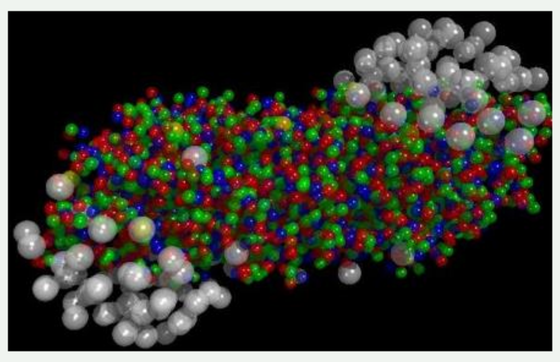
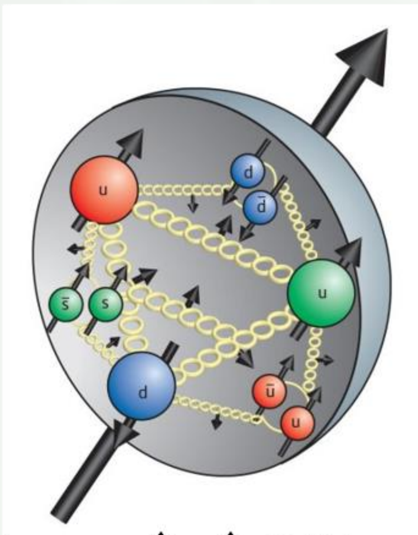
Abstract

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will enable a spectrum of new or improved cold QCD measurements, enhancing our understanding of the initial state for nuclear collisions. sPHENIX measurements in proton-proton and proton-nucleus collisions will reveal more about how partons behave in a nuclear environment, inform our understanding of the initial state in heavy-ion collisions, and provide comparative data to investigate modification of fragmentation functions. Measurements will also take advantage of RHIC's unique capability to collide polarized protons on nuclei, which provides novel opportunities to study nuclear effects with spin observables. A potential upgrade to sPHENIX with forward instrumentation could significantly enhance these physics capabilities. The cold QCD nuclear physics program for the proposed sPHENIX midrapidity detector as well as the enhanced program enabled with forward upgrades will be presented.

How do collective, many-body phenomena arise from first-principles QCD?

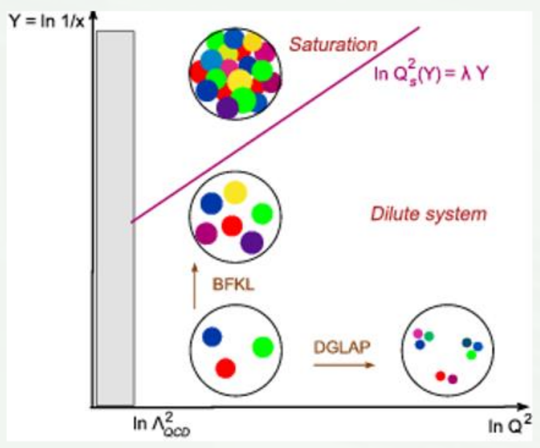
A+A Collisions





$p\uparrow + p\uparrow$ Collisions

p+A Collisions

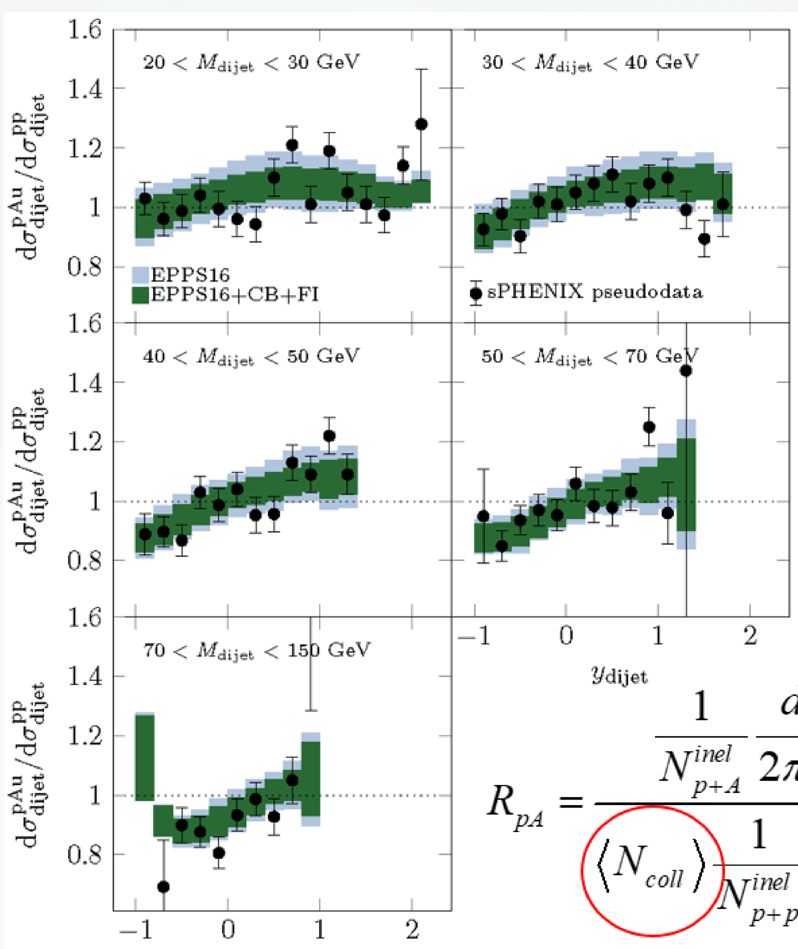


As we transition to the EIC era, we may lose the ability to continue to explore complementary phenomena in p+A and polarized p+p collisions, blocking our ability to address universality in p+A and e+A collisions.

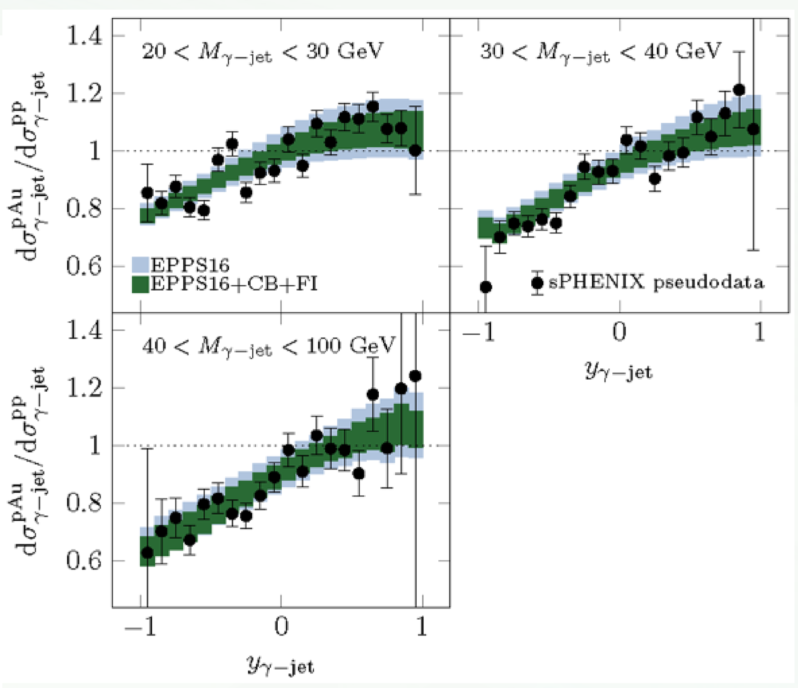
Example: A Multiobservable Approach to nPDF's

Can we use multiple datasets (with similar systematics) to overcome the normalization limitation in R_{pA} measurements?

Central (|η|<1) + Forward dijets (1.6<η<3.6) (used primarily to fix normalization)



Central (|η|<1) gamma+jet



$$R_{pA} = \frac{\frac{1}{N^{inel}_{p+A}} \frac{dN_{p+A\to X}}{2\pi p_T dp_T dy}}{\langle N_{coll} \rangle \frac{1}{N^{inel}_{p+p}} \frac{dN_{p+A\to X}}{2\pi p_T dp_T dy}}$$

CB: central barrel only
CB + FI: central barrel + forward instrumentation

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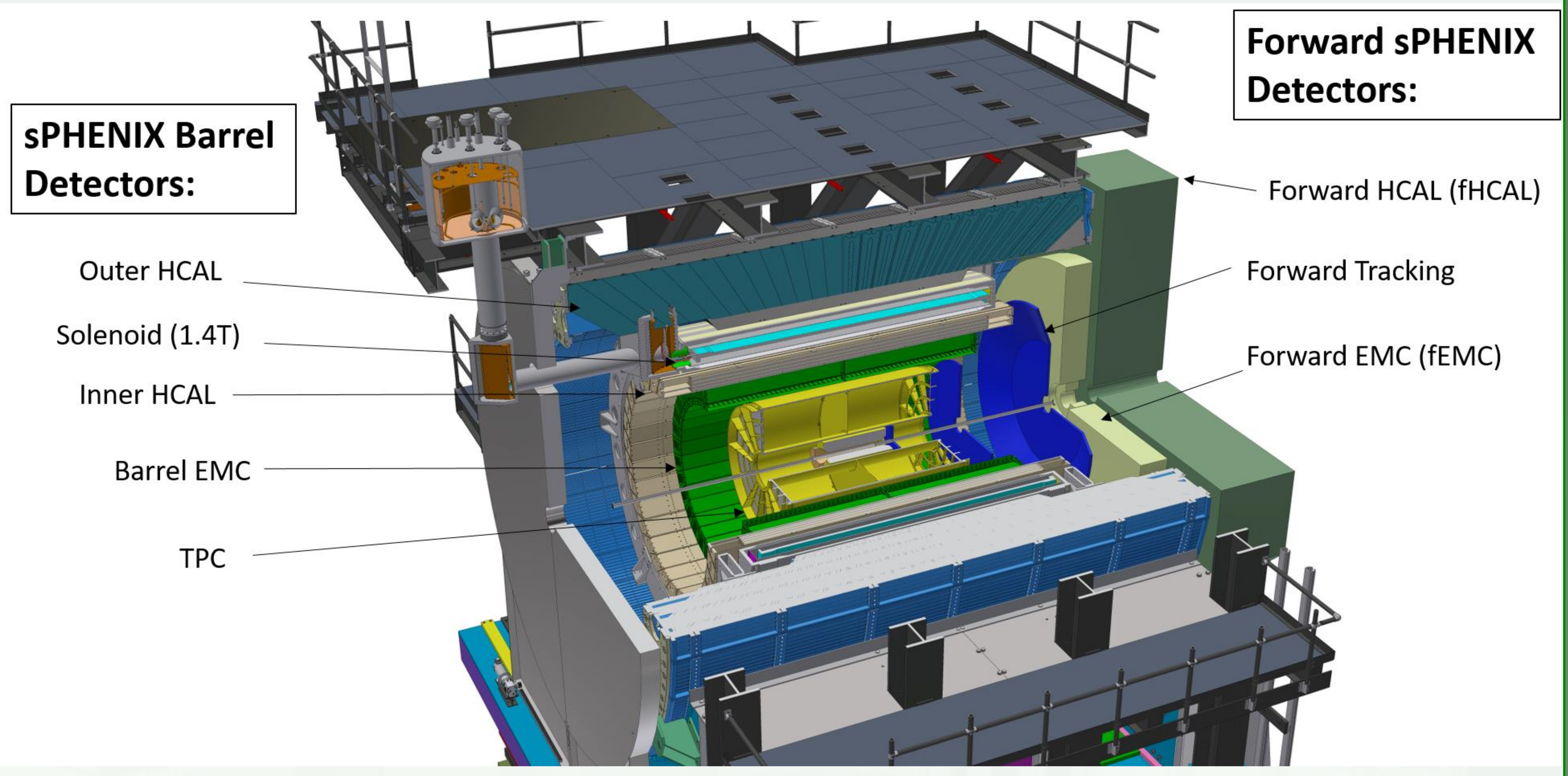
In single measurements of R_{pA} the limiting systematic is often in the determination N_{coll} (or equivalently T_{AB}) in the Glauber model used to scale the p+p measurements. This is an overall systematic error on the level of R_{pA} and often mimics (or hides) an nPDF effect. Therefore, a single R_{pA} measurement is limited in its overall ability to constrain nPDF models, and this is particularly true of measurements in a limited kinematic region.

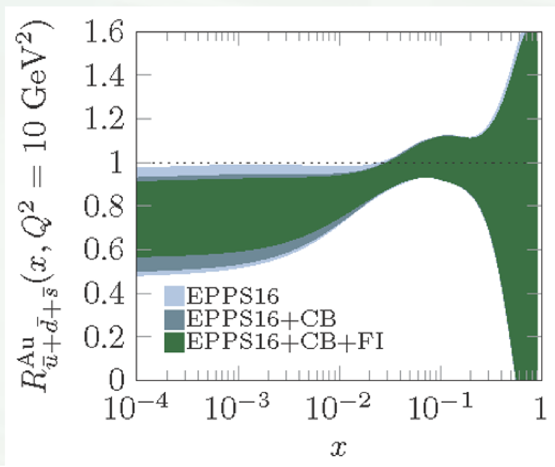
By combining multiple measurements in a multiobservable approach, measurements which share this overall systematic error can be used to reduce the effect of the overall systematic error. For example, measurements of central dijets, which show only a small nPDF effect, can be used to reduce the normalization systematic, making more sensitive measurements of nPDF effects much more powerful.

With the ability to fix the overall R_{pA} normalization in a multiobservable approach, the addition of forward instrumentation is able to provide improved constraints on nPDF models.

sPHENIX with Forward Instrumentation

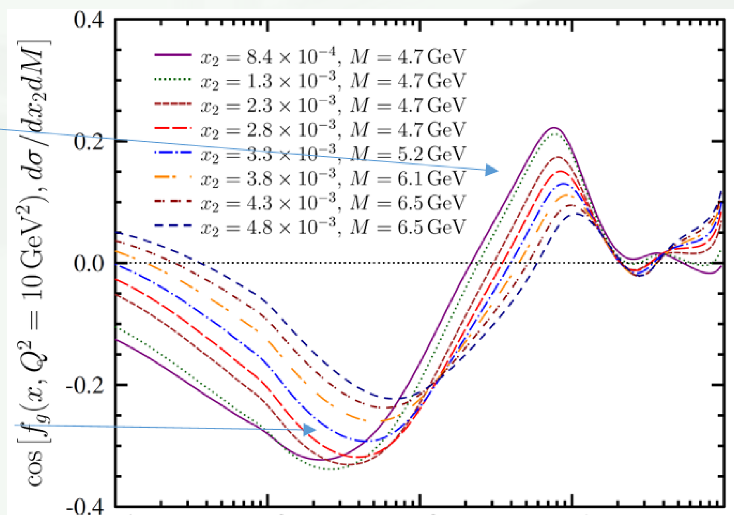


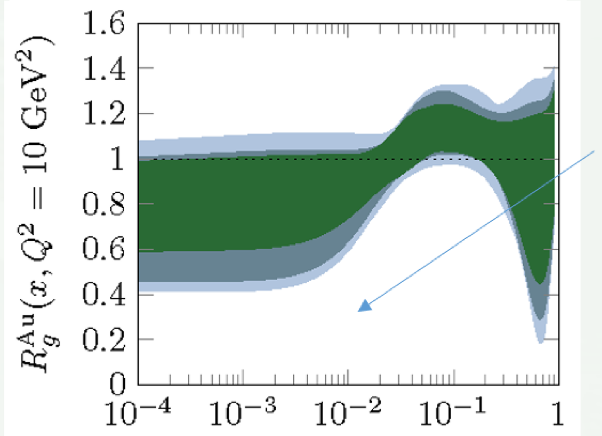
The addition of forward instrumentation (calorimetry and tracking) to the sPHENIX barrel will allow the measurement of forward DY production, which can significantly constrain nPDF's in a multiobservable approach.



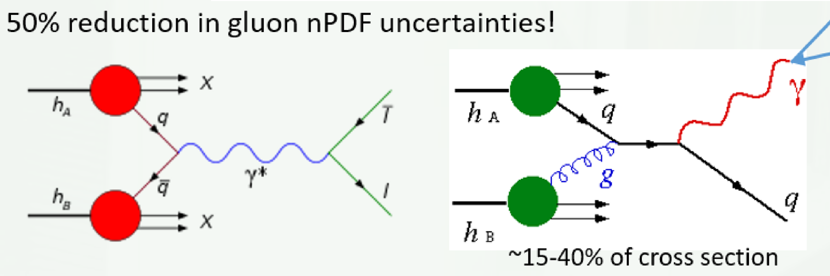
Indirect (LO) by scale evolution

Direct (NLO) contribution





50% reduction in gluon nPDF uncertainties!



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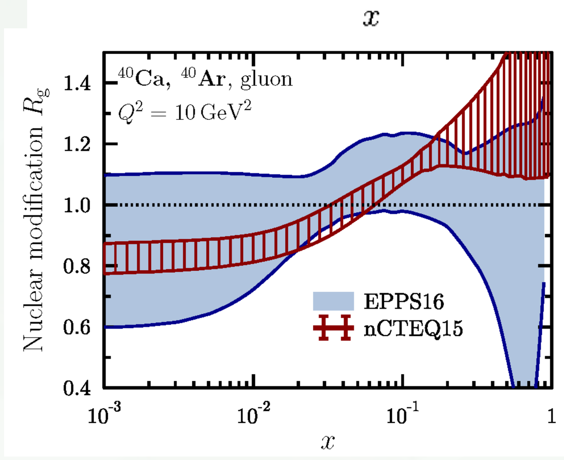
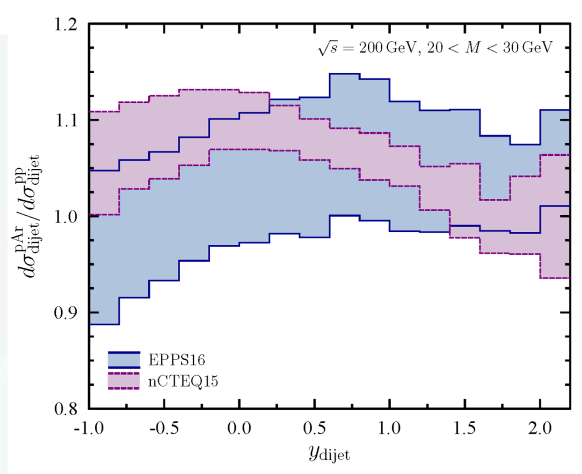
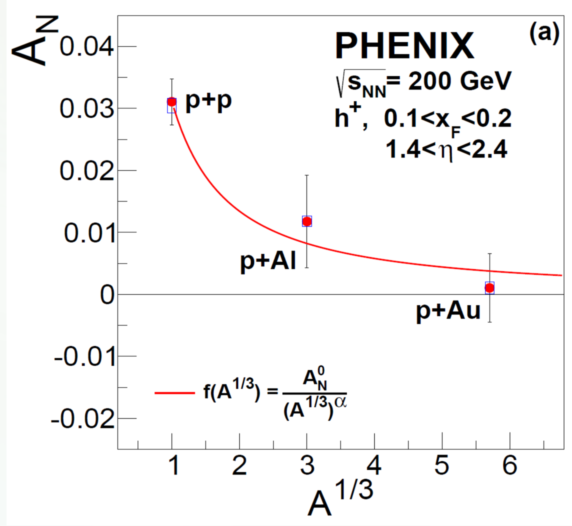


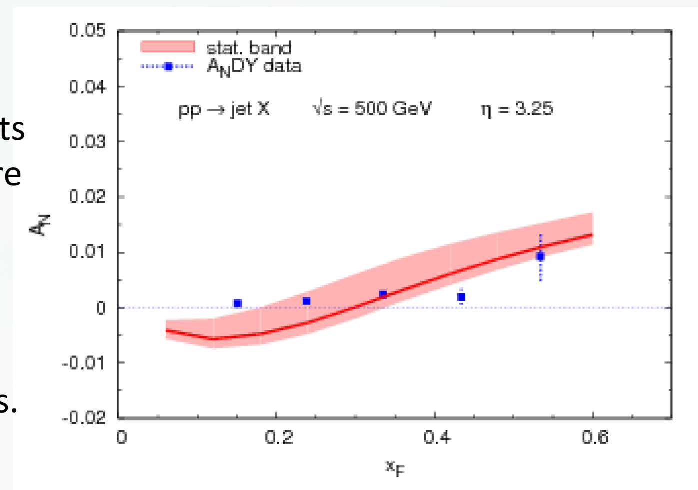


The A-dependence of nPDF's is very poorly constrained; competing models predict very different results that can be easily constrained with a species scan at RHIC.

Unresolved Mysteries



Many transverse spin-dependent measurements from RHIC remain that are not fully explored. Additional forward instrumentation will be required for sPHENIX to elucidate these mysteries.



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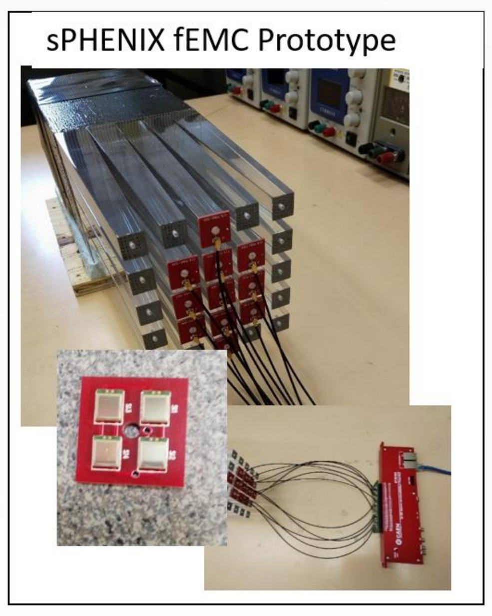
AnDY: Phys. Lett. B750 (2015) 660

Detector Development

R&D for sPHENIX forward detectors leverages existing detectors and technologies combined with EIC R&D for a cost-effective investment that will yield a wealth of physics measurements.

sPHENIX fEMC Prototype



HCAL Prototypes (STAR and sPHENIX)