



Cold QCD Physics with sPHENIX

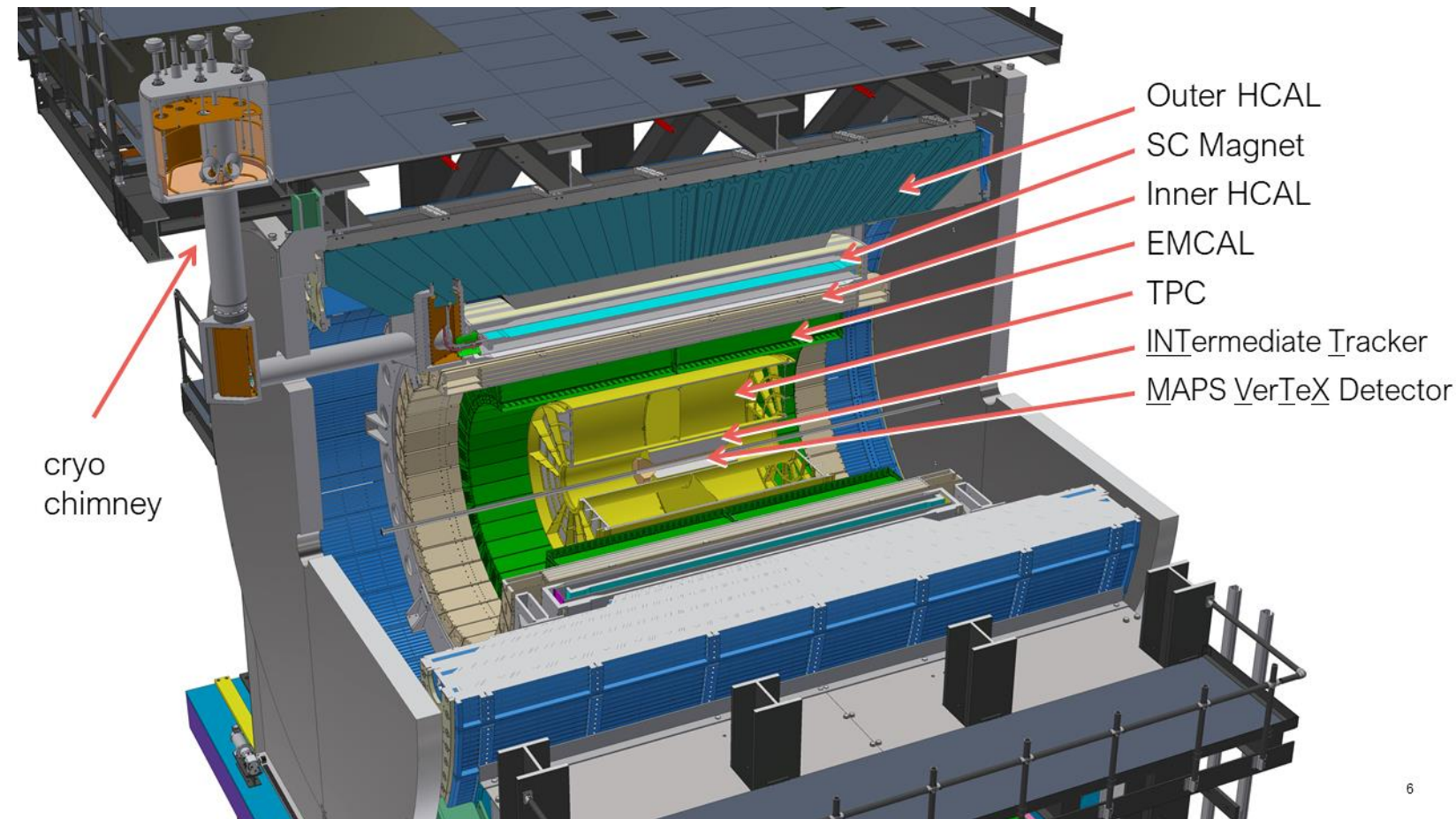
Desmond Shangase (University of Michigan) on behalf of the sPHENIX Collaboration
Hard Probes 2020 - June 5th 2020



U.S. DEPARTMENT OF
ENERGY

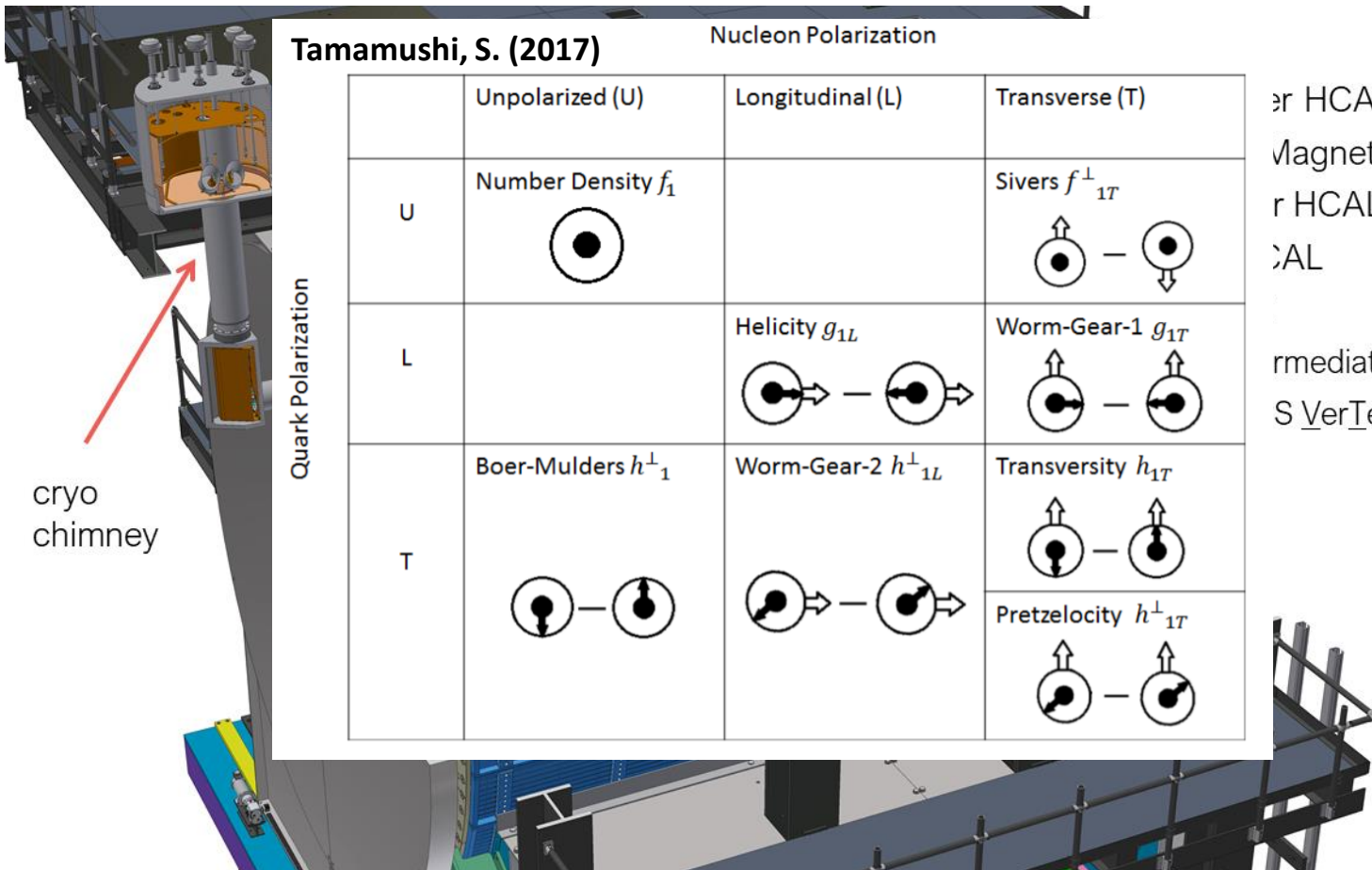
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sPHENIX Detector



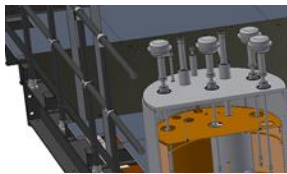
- Full azimuthal detector (Central Barrel)
- To be installed at RHIC
 - Will exploit RHIC capabilities of colliding polarized protons
- Cold QCD Physics Program
 - Proton/Nucleus Structure (PDFs)
 - Parton Dynamics (TMD PDFs)
 - Hadronization (FFs)
- Data collection expected to begin 2023

6



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Tamamushi, S. (2017)

Nucleon Polarization

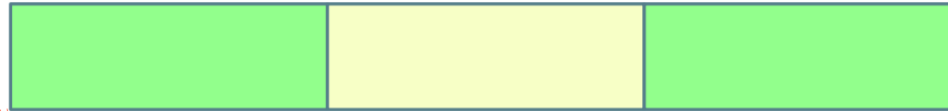
	Unpolarized (U)	Longitudinal (L)	Transverse (T)
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er HCAL
Maanet

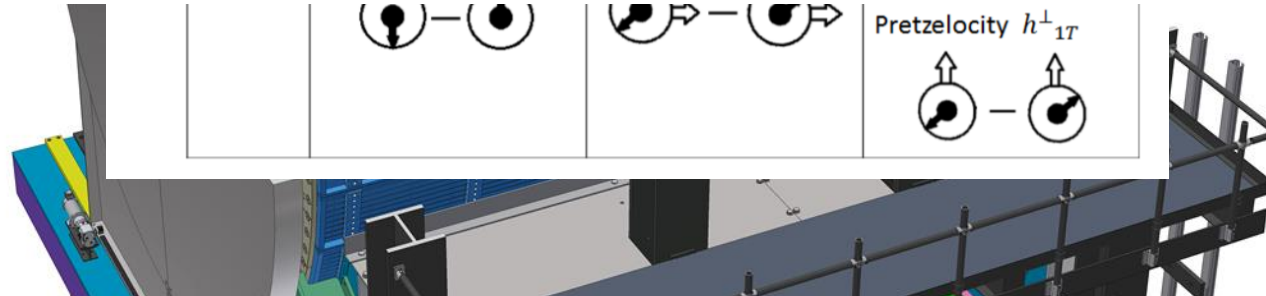
2023

2024

2025



Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb ⁻¹	8.7 nb ⁻¹	34 nb ⁻¹
Year-2	p+p	200	11.5	—	48 pb ⁻¹	267 pb ⁻¹
Year-2	p+Au	200	11.5	—	0.33 pb ⁻¹	1.46 pb ⁻¹
Year-3	Au+Au	200	23.5	14 nb ⁻¹	26 nb ⁻¹	88 nb ⁻¹



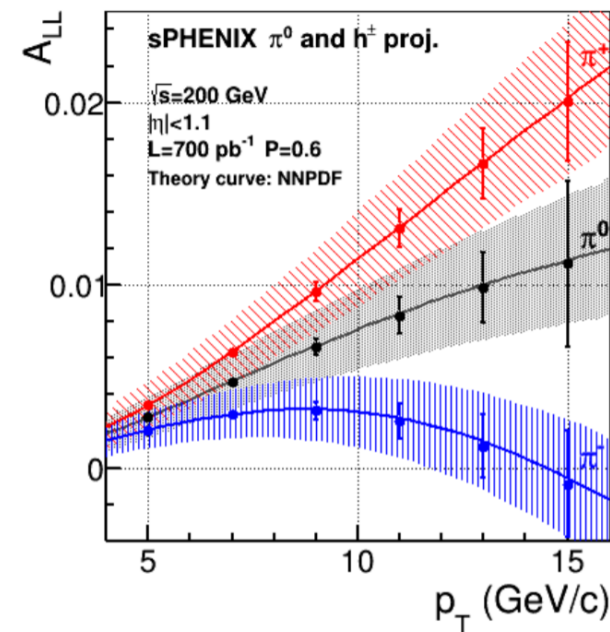
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Probing Proton Structure

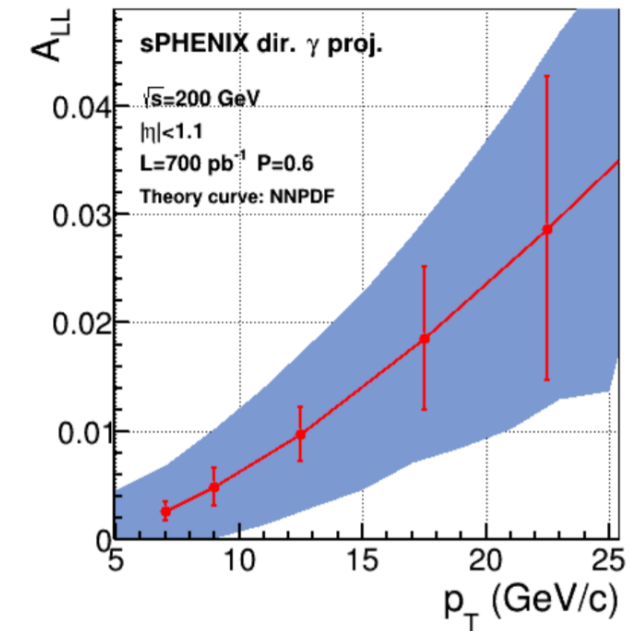
- Exploit polarized proton beam capabilities to access TMD PDFs
- Double-Helicity Asymmetries of hadrons (gg , qg , qq scattering) and photon production (qg , qq -bar) can probe Gluon Helicity Function, ΔG
 - This is because gluonic interactions dominate these cross-sections
- Expected to reduce uncertainty in $0.05 < x < 0.4$ region
 - Luminosity may vary from plots, impacting precision of higher-pt measurements

π^0 and h^\pm



sPH-cQCD-2017-002

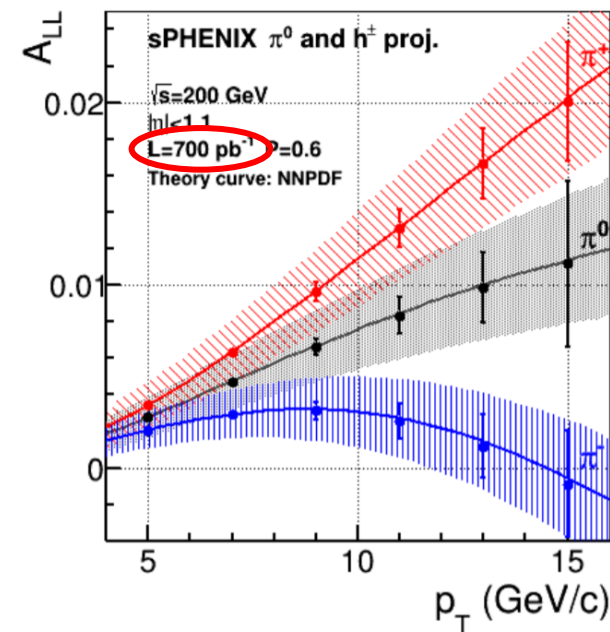
Dir. Photons



Probing Proton Structure

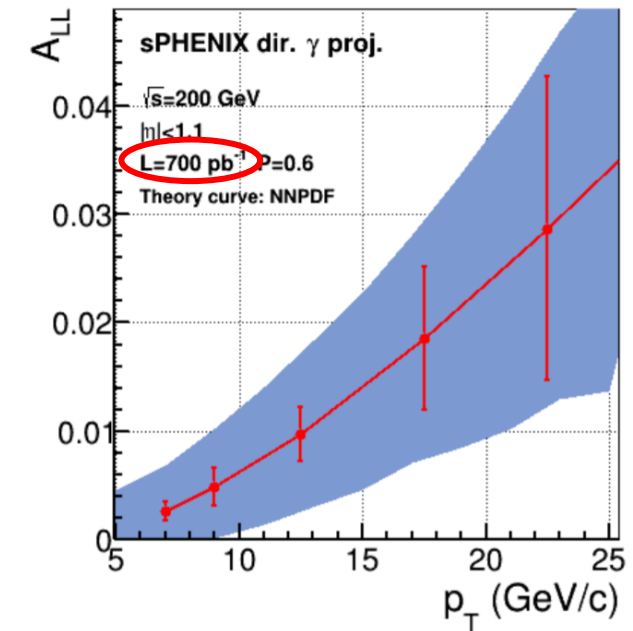
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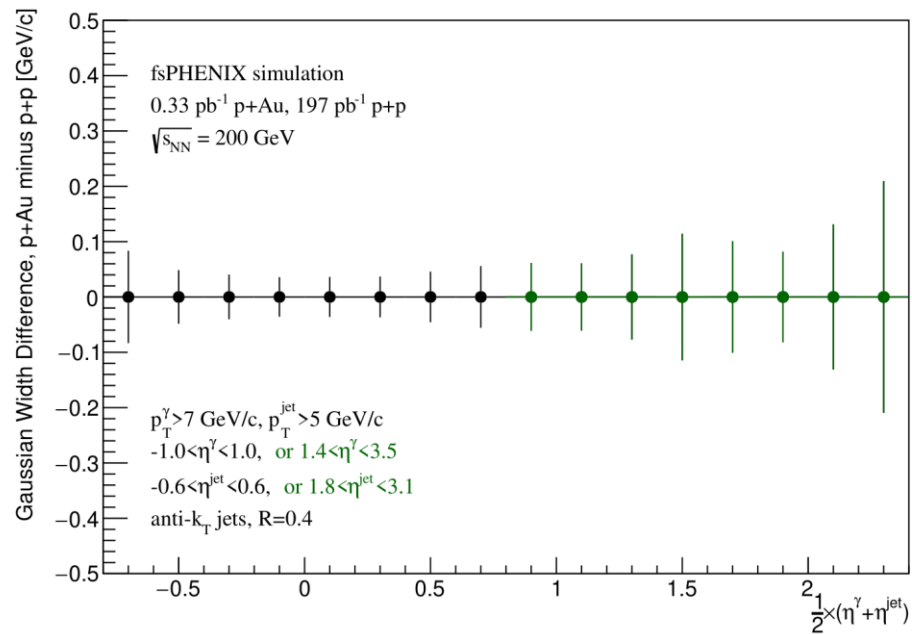
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Dir. Photons

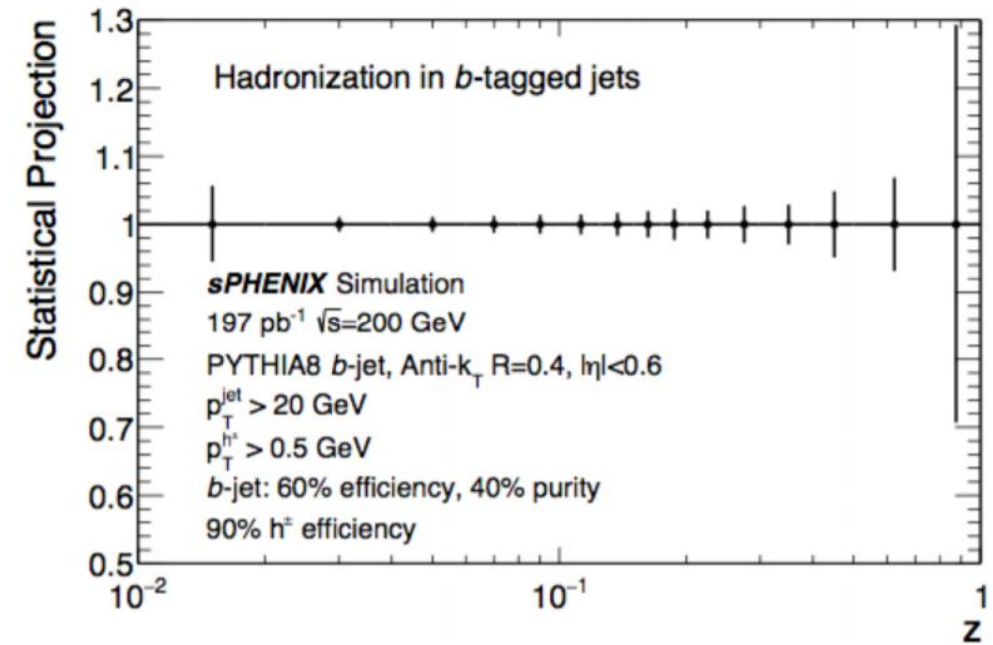


Looks Into Nuclear vs Proton Environment

TRANSPORT COEFFICIENT

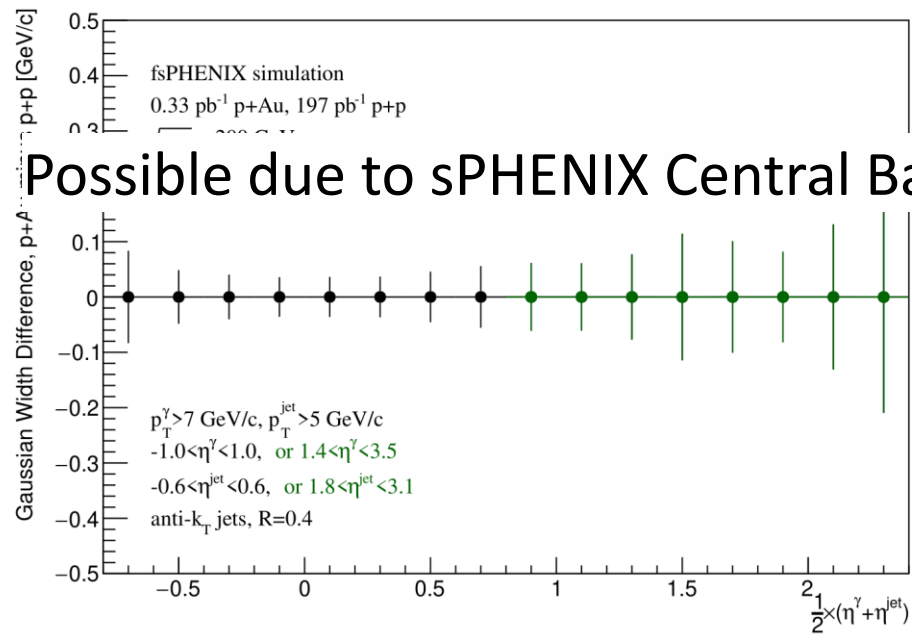


IN-JET HADRONIZATION



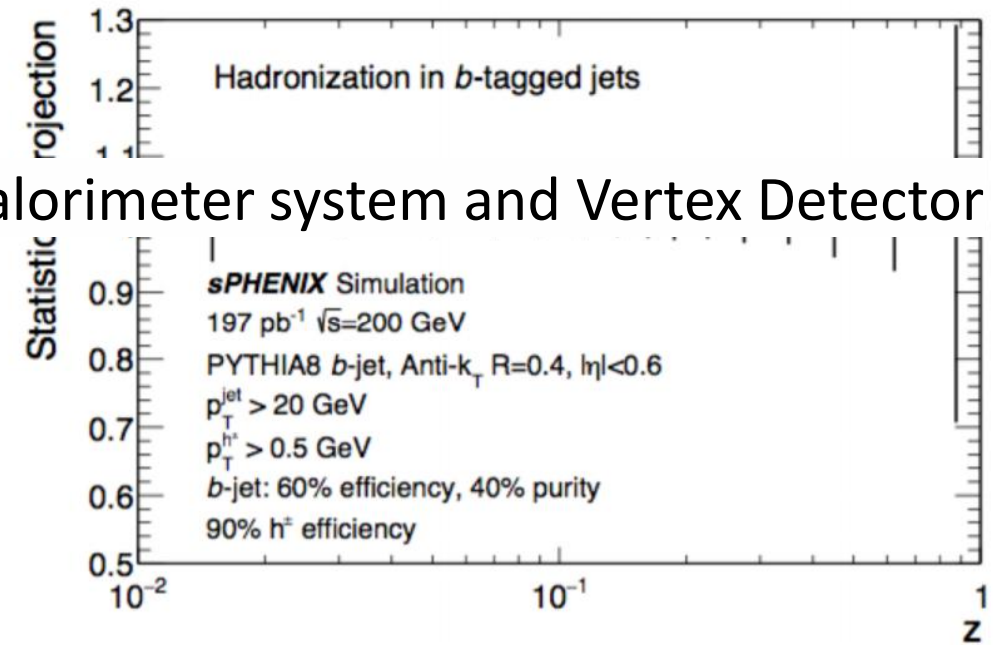
Looks Into Nuclear vs Proton Environment

TRANSPORT COEFFICIENT

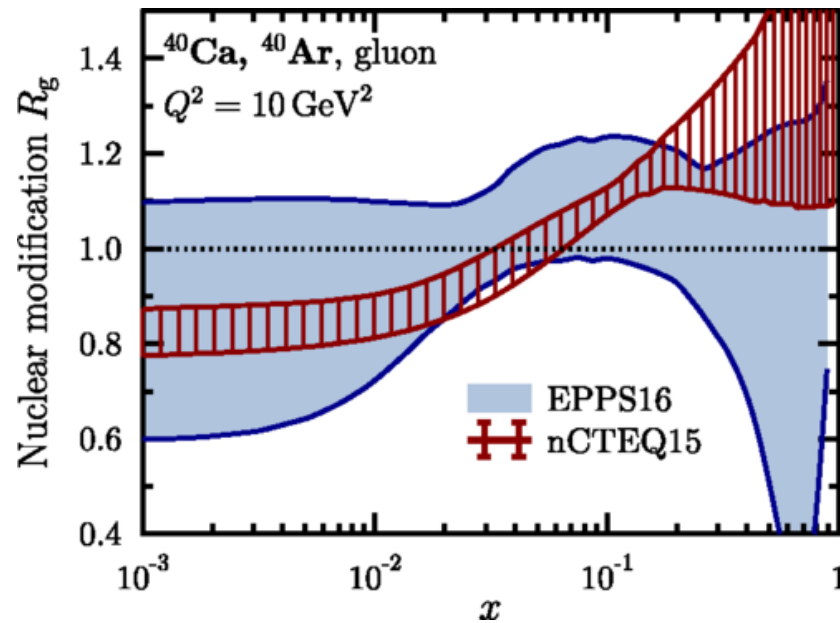


Possible due to sPHENIX Central Barrel Calorimeter system and Vertex Detector

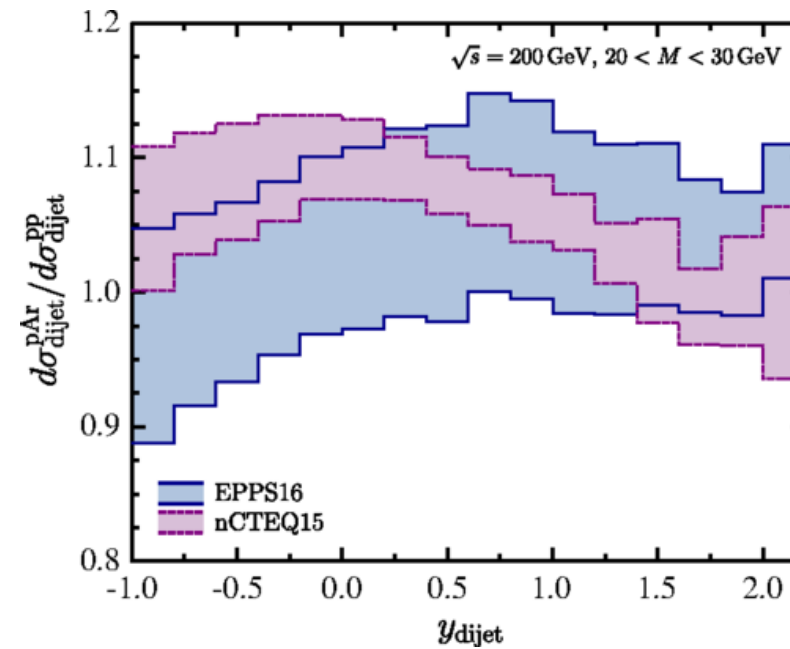
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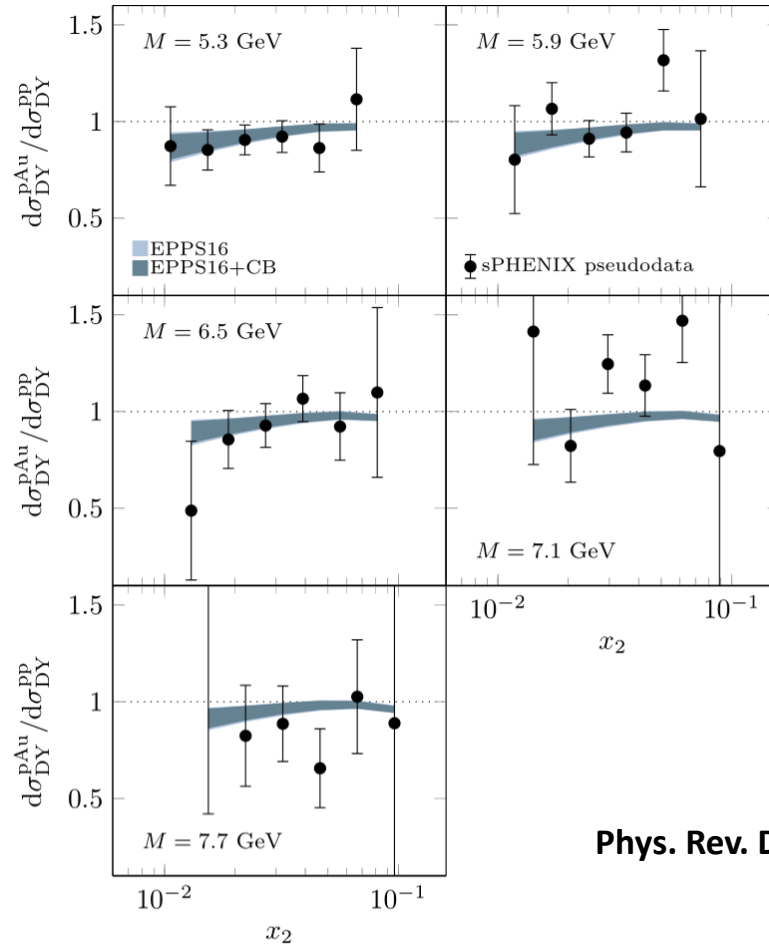
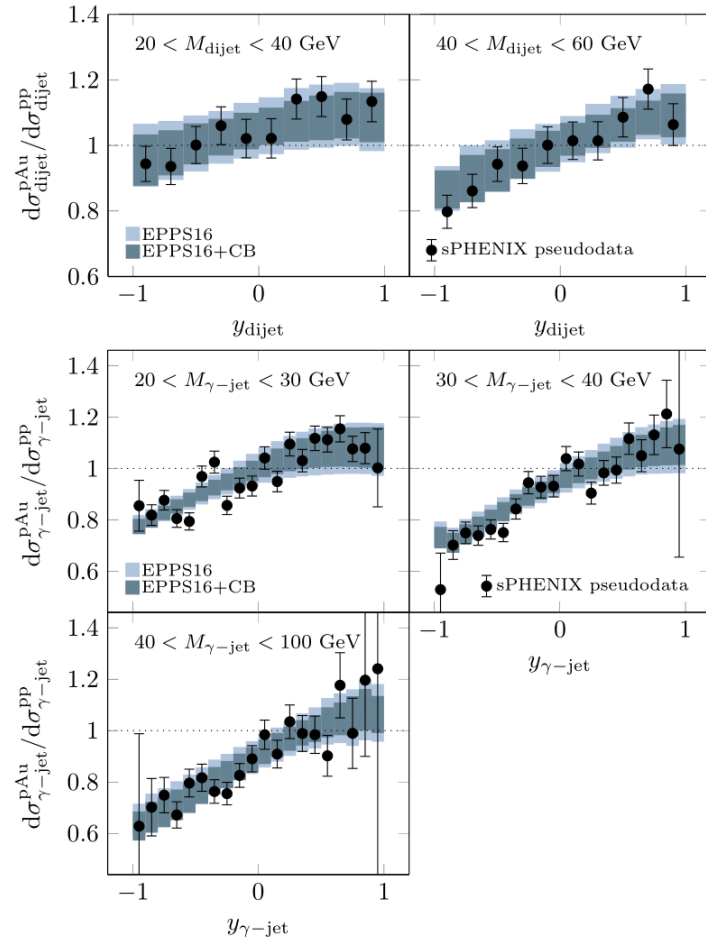
Improving nPDF Confidence



Phys. Rev. D 100, 014004

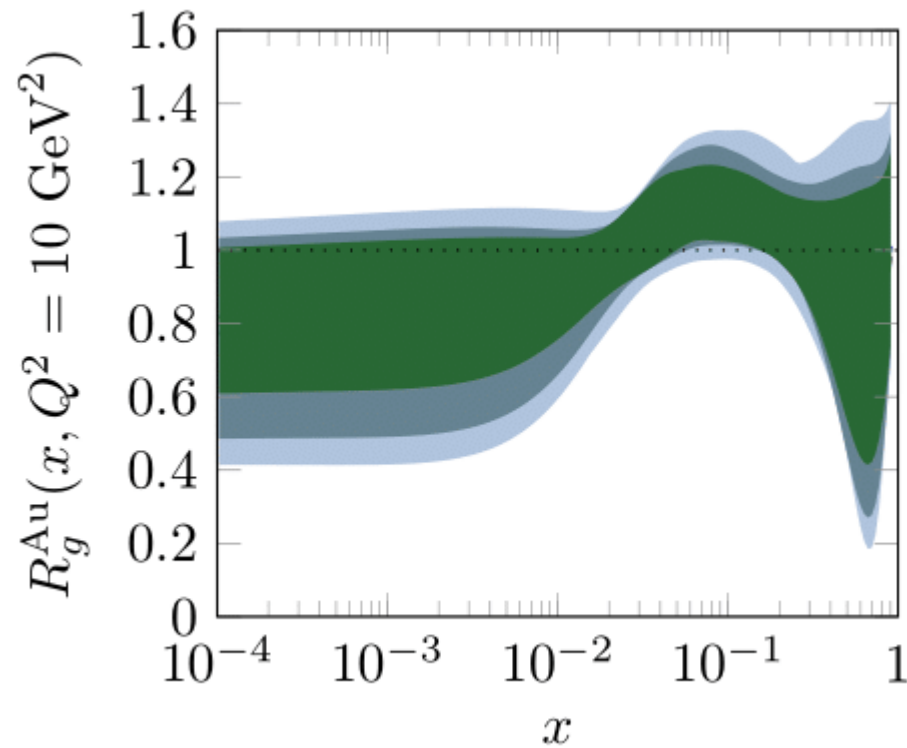


Improving nPDF Confidence

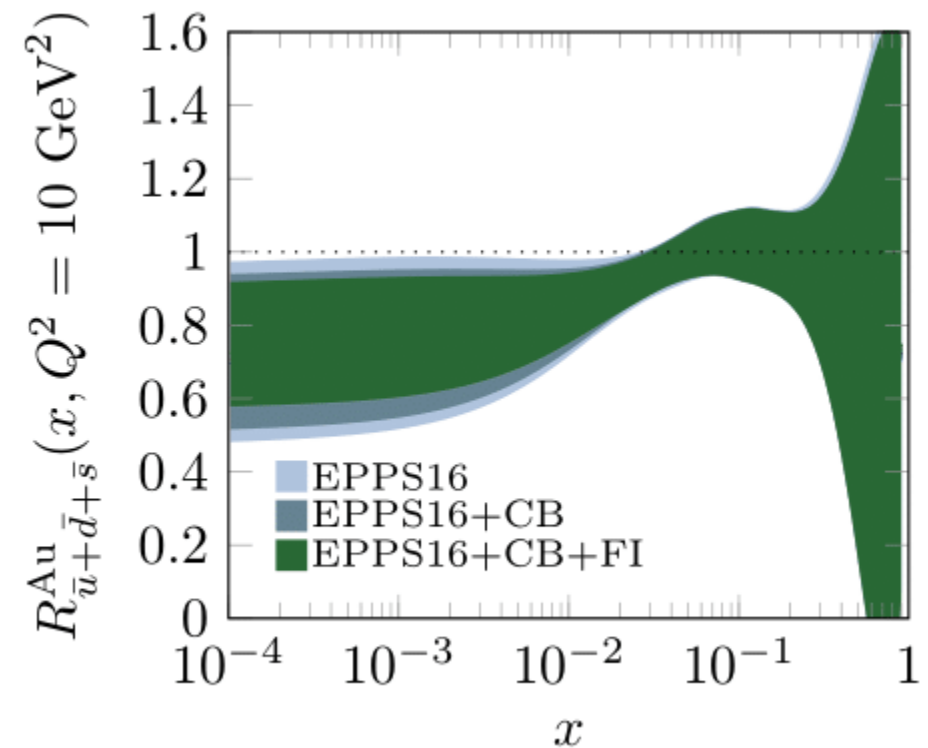


Phys. Rev. D 100, 014004

Improving nPDF Confidence



Phys. Rev. D 100, 014004



Thank You

Cold QCD Physics with sPHENIX

Desmond Shangase
University of Michigan, sPHENIX Collaboration

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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. The cold QCD nuclear physics program for the sPHENIX detector will be presented.

How might collective and many-body behavior arise or evolve from small to large systems?

With the EIC on the horizon, the window for exploring the relationships between (polarized) p+p and p+A collisions can be exploited with the sPHENIX detector. These studies will permit an EIC experiment to address universality between p+p(A) and e+p(A) collisions.

Probing Polarized Proton Structure

Dir. Photons

Expected uncertainties on Double-Helicity Asymmetry (A_{LL}) measurements for (Right) direct photon production ($gg \rightarrow \gamma\gamma$, $q\bar{q} \rightarrow g\gamma$) and (Left) hadron production ($gg, q\bar{q}, q\bar{q}$ scattering) projected onto respective NPDF predictions. Note that each probe contains small contributions from non-gluon sensitive channels. These uncertainties are reduced in comparison to previous measurements and are expected to reduce the gluon helicity PDF (ΔG) uncertainty significantly in the region of $0.05 < x < 0.4$.

Current sPHENIX Design

Improving Precision on Transport Coefficient

Transverse momentum broadening in pA probes transport coefficient \hat{q}

Expected uncertainties for photon pair measurements in p+A vs p+p collisions using the Central Barrel sPHENIX detector (black points). This provides access to the transport coefficient: $((\hat{q}L)/2) \approx ((p_{T^2})_{pA} - (p_{T^2})_{pp})$. Possibility of measuring jet momentum modification in various systems at mid-rapidity is possible with sPHENIX detector.

Studying Hadronization in Jets

Much remains to be learned about hadronization in jets and modification of hadronization in medium. The sPHENIX MVTX will allow heavy flavor tagging of jets. Expected uncertainties are shown for b-tagged hadronization in jet studies in p+p. Modification of jet hadronization in medium will also be studied in p+A and A+A collisions.

Multiobservable Approach to nPDFs

Current nPDF fits including LHC data display significant uncertainties for the nuclear modification (R_A) of PDFs. This is particularly true for gluon nPDFs and the low- x (shadowing) region. In addition, tension between various models further muddles the picture. Simultaneous measurements of Drell-Yan (DY), and photon-jet correlations are expected to refine the R_A of these observables which will translate to improved nPDF fits.

Note the improved modification with the inclusion of sPHENIX Central Barrel measurements (dark blue) compared to the current fits (light blue).

<https://indico.cern.ch/event/751767/contributions/3867324/>