The STAR Forward Upgrade

The Tale of the Initial State: Nucleon to Nuclei

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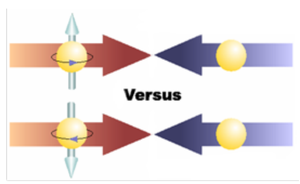
Abstract

The STAR experiment is planning to upgrade the forward rapidity region ($2.5 < \eta < 4.5$) to enable novel measurements in pp, p+A and A+A collisions. The STAR forward upgrade is motivated by exploration of cold QCD physics in the very high and low regions of parton momentum fraction x. But it is specifically noted that the forward upgrade will also provide new detector capabilities at RHIC and STAR to explore the longitudinal structure of the initial state and the temperature dependent transport properties of matter in relativistic heavy ion collisions. The current design of the forward upgrade consists of a Calorimeter System (FCS) integrating the refurbished PHENIX sampling ECal and a hadronic calorimeter made of a sandwich iron scintillator plate sampling type. In addition to the FCS, a Forward Tracking System (FTS) is also proposed. The FTS must be capable of discriminating hadron charge sign in pp and p+A collisions. In heavy ion collisions, it should be able to measure transverse momentum of charged particles in the range of $0.2<p_T<2$ GeV/c with 20-30% momentum resolution. The FTS-system combines 3 Silicon mini-strip disks and 4 Small-Strip Thin Gap Chamber (sTGC) wheels ala ATLAS.

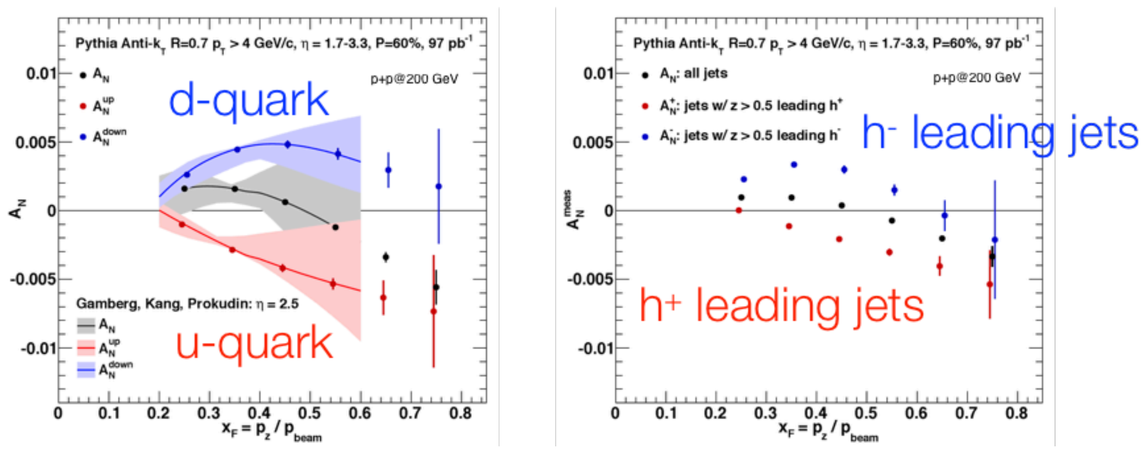
2+1D Imaging of Quarks & Gluons in Proton

- What is the dynamic structure of the proton and nuclei 2D+1 picture in momentum space
- Visualize color interactions in QCD collective phenomena and correlations in fragmentation
- New physics due to confined motion
- u and d quark Sivers functions (spin-orbit correlations) → Accessible via charged hadron tagged in forward rapidity jets

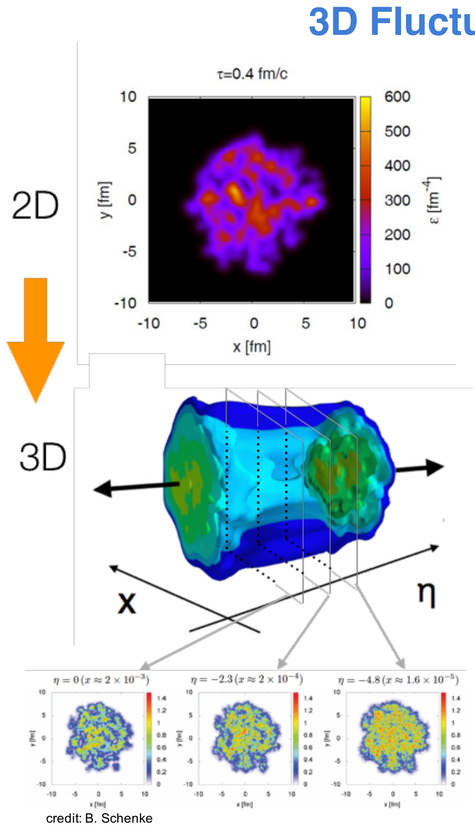


$$A_N = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow}$$

Transverse Single Spin Asymmetries



3D Fluctuations in the Nucleus



Initial fluctuation in the transverse plane has been well studied, but very little is know about the longitudinal direction

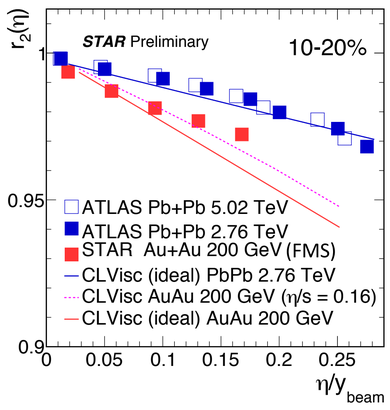
Studying the correlation at **forward rapidity** will constrain the longitudinal structure of initial conditions

Event Plane de-correlation:

$$r_n \equiv \frac{\left\langle \vec{V}_n(-\eta^a)\vec{V}_n^*(\eta^b)\right\rangle}{\left\langle \vec{V}_n(\eta^a)\vec{V}_n^*(\eta^b)\right\rangle} \sim \left\langle \cos n\left[\Psi_n(\eta^a) - \Psi_n(-\eta^a)\right]\right\rangle$$

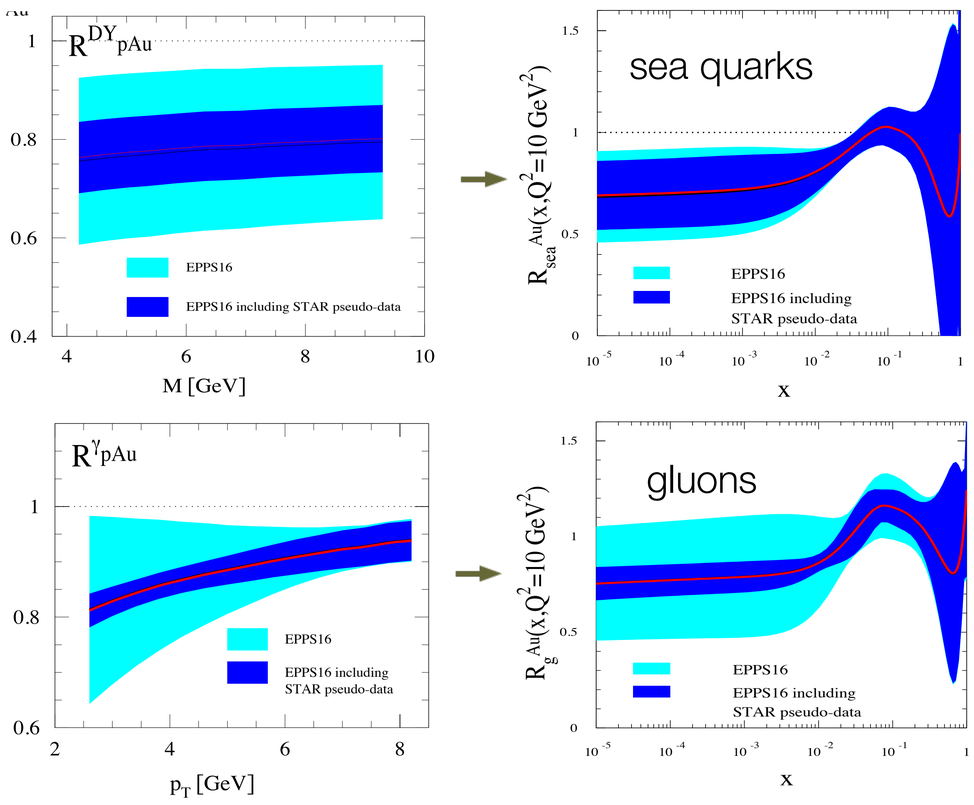
$$Vn = v_n e^{in\Psi_n}$$

ATLAS, EPJC (2018) 78:142
L. Pang et al, EPJA 52 (2016) 97
L. Pang et al, arXiv: 1802.04449



First Look with Forward Meson Spectrometer (FMS) :
Steeper slope at RHIC
Differential measurements needed! fSTAR

Nuclear Parton Distribution Functions

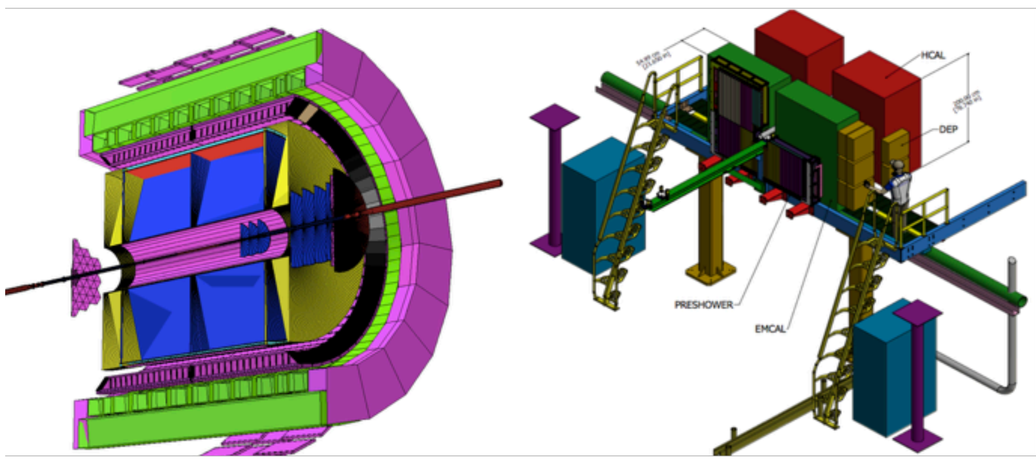


Drell-Yan & direct photon R_{pA} give significant constraints on nPDF alternative observables and kinematics to EIC

p+A@RHIC: **Unique Kinematics** to explore nPDF at low-x, saturation physics, spatial transverse distributions of quarks and gluons in nuclei

Forward Upgrade Detector Proposal

Forward Tracking System — Forward Calorimeter System



Detector	pp and p+A	A+A
ECal	~10%/√E	~20%/√E
HCal	~60%/√E	---
Tracking	charge separation photon suppression	$0.2<p_T<2$ GeV/c with 20-30% $1/p_T$

FTS: 3 Silicon disks + 4 sTGC (Small-strip Thin Gap Chambers)
FCS - Ecal: reuse PHENIX PbSC calorimeter with new readout on front
FCS - Hcal: sandwich iron-scintillator plate sampling calorimeter
→ several beam test and STAR in situ tests
→ system optimized for cost and performance

A broad pp, p+A and A+A physics program starting after the BES-II, built on a forward upgrade at STAR consisting of an ECal and HCal as well as tracking (Si and sTGCs)

References

- "The STAR Forward Upgrade - The Tale of the Initial State: Nucleon to Nucleus", The STAR Collaboration, https://drupal.star.bnl.gov/STAR/starnotes/public/sn0648
- "The RHIC Cold QCD Plan for 2017 to 2023 A Portal to the EIC", The RHIC SPIN Collaboration, arxiv 1602.03922

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