



U.S. DEPARTMENT OF
ENERGY

Office of
Science

STAR Status, Plans, and Upgrades

RHIC & AGS Users Group DNP2019 Open Forum

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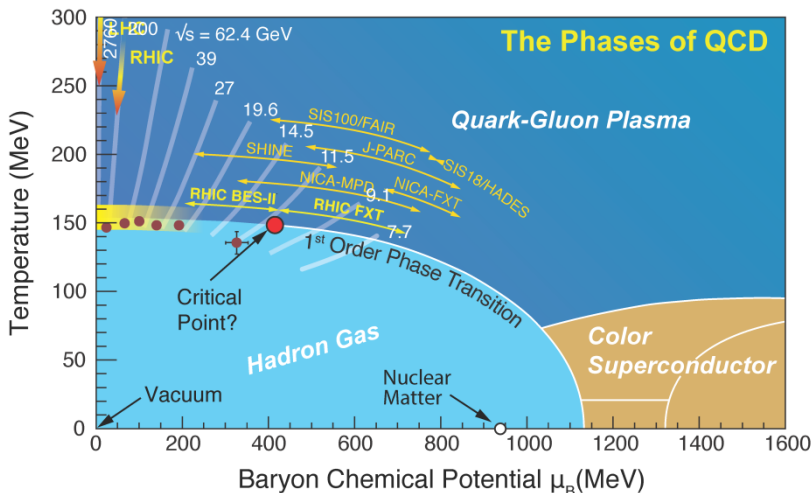
for the

STAR Collaboration

Outline

- Current status: BES II
- Looking forward: Forward Upgrade physics and status

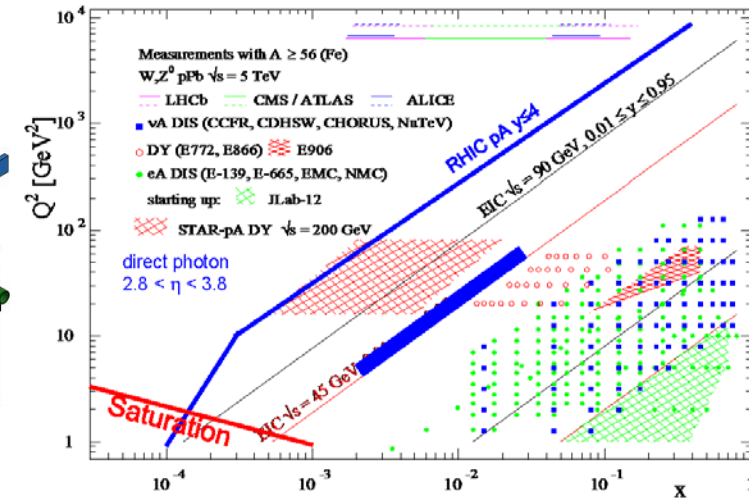
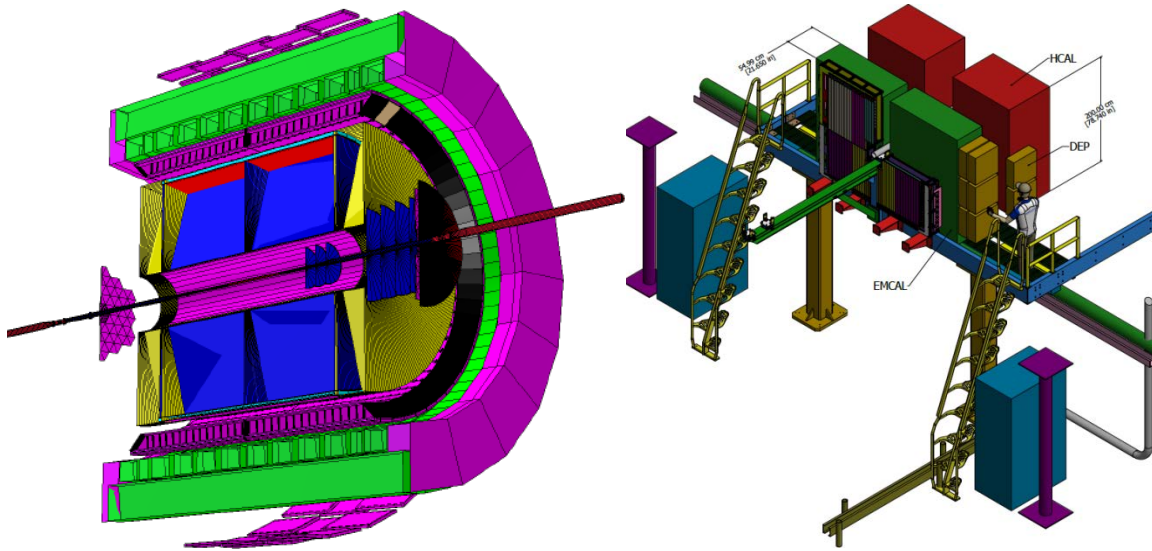
BES II is well underway !



Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Run Time	Number Events
9.8	19.6	205	4.5 weeks	400M
7.3	14.5	260	5.5 weeks	300M
→ 5.75	11.5	315	5 weeks	230M
→ 4.55	9.1	370	9.5 weeks	160M
3.85	7.7	420	12 weeks	100M
→ 31.2	7.7 (FXT)	420	2 days	100M
→ 19.5	6.2 (FXT)	487	2 days	100M
→ 13.5	5.2 (FXT)	541	2 days	100M
→ 9.8	4.5 (FXT)	589	2 days	100M
→ 7.3	3.9 (FXT)	633	2 days	100M
→ 5.75	3.5 (FXT)	666	2 days	100M
4.55	3.2 (FXT)	699	2 days	100M
3.85	3.0 (FXT)	721	2 days	100M

- BES II: search for **critical point** and **1st order phase transitions**
- Run 19 was a big success!
 - Four systems completed; two more half done
- Plan to complete the **eight systems with red arrows** during Run 20
 - 7.7 GeV collider mode will be completed during Run 21

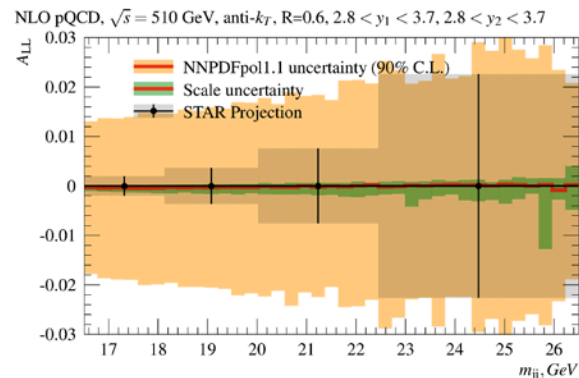
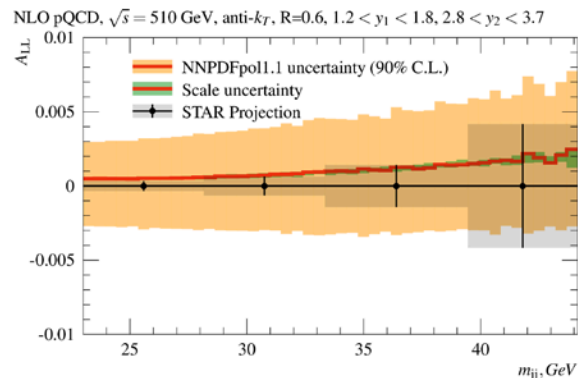
STAR Forward Upgrade for the 2020's



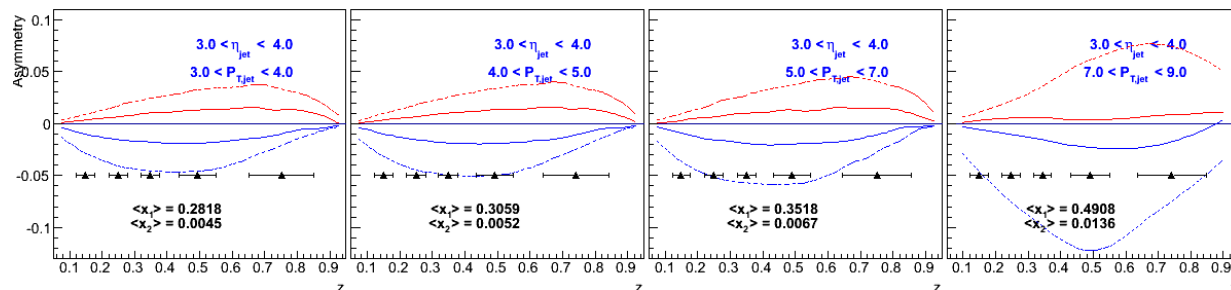
- Complement **STAR's** excellent mid-rapidity detection capability with measurements at **forward pseudorapidity ($2.5 < \eta < 4$)**
 - Cover the EIC x - Q^2 region, and then some
- Will achieve this with:
 - Si disks + small Thin Gap Chambers (sTGCs) for tracking
 - Pre-shower and compact electromagnetic and hadronic calorimeters for e/h discrimination, neutral particles, jets, and triggering

Selected Forward Upgrade science in Run 22

Projected sensitivity of forward di-jet A_{LL} in 510 GeV pp



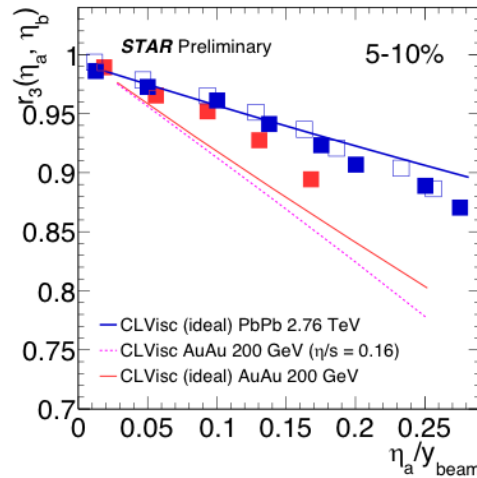
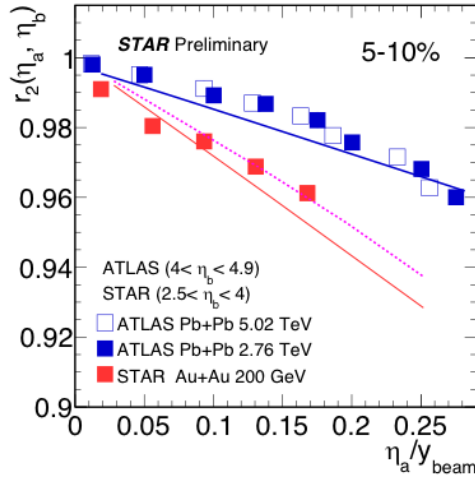
Projected sensitivity to the Collins effect in 510 GeV pp



- Forward di-jets will extend gluon polarization to $x \sim 10^{-3}$
 - Dramatic extension of the lever arm
 - Important to optimize detectors and longitudinal spin running at EIC
- Transverse spin phenomena:
 - Precision TMDs to high and low x through hadrons in jets at forward rapidity
 - $0.3 < x < 0.5$ for Sivers and Collins effects (quark k_T and transversity)
 - x to 0.005 for Collins-like effect (gluon linear polarization)

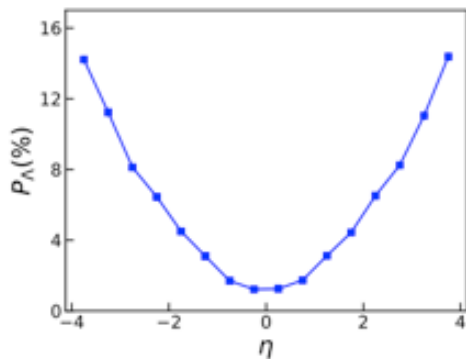
Selected Forward Upgrade science in Run 23

v2 and v3 longitudinal decorrelations
measured at **LHC** and **STAR**

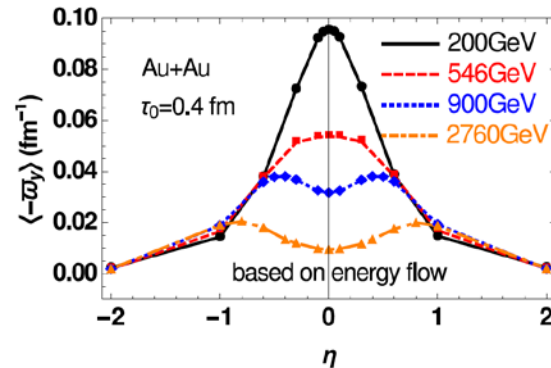


- Longitudinal flow decorrelations
 - Early time correlations are long range in $\Delta\eta$
 - Already a surprise in preliminary **STAR** data

Calculated Lambda global polarization vs. η



Li et al, PRC 96, 054908;
Beccattini et al, EPJ C75, 406

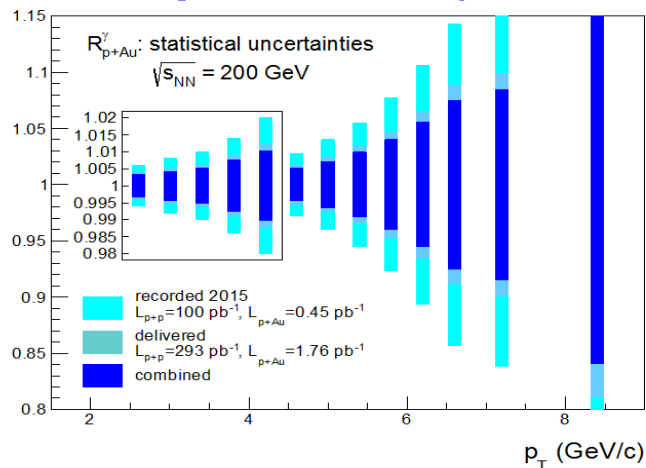


Deng & Huang, PRC 93, 064907

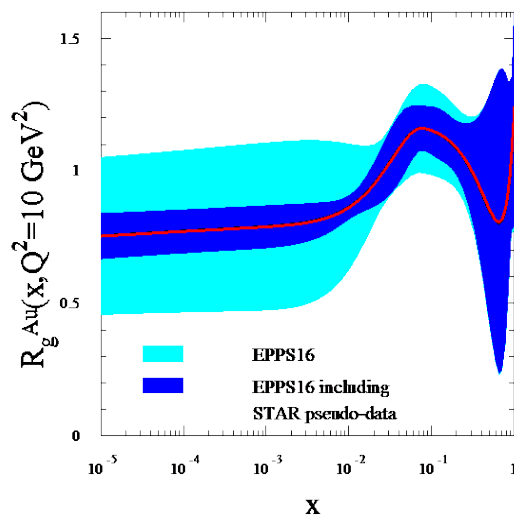
- Rapidity dependence of Lambda global polarization
 - Sensitive to viscosity
 - Different models predict opposite rapidity trends

Selected Forward Upgrade science in Run 24

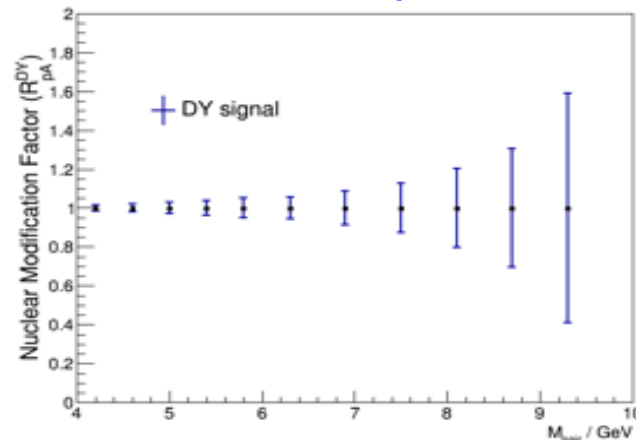
Direct photons in pA at $2.5 < \eta < 4.5$



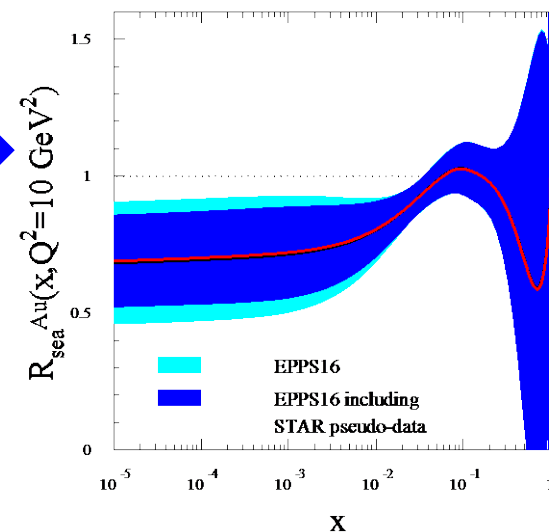
to constrain
gluons



Drell-Yan in pA at $2.5 < \eta < 4.5$



to constrain
sea quarks



- Precision constraints on nuclear gluon and sea quark distributions
 - Essential for a stringent test of nPDF universality at EIC

STAR Forward Upgrade status

- All necessary funding is in place
- ECal and HCal designs finalized, as well as their read-out
 - ECal modules just installed last week
- Silicon design progressing well
 - First full prototype coming together
- sTGC module design close to final
 - Final choice of gas and read-out electronics within next few months
- Full system integration will be complete by the end of this year
- Already well integrated into **STAR** off-line software framework



- **STAR Forward Upgrade project is well on track for first physics data-taking in late 2021 / early 2022**

STAR Forward Upgrade physics program

Forward-rapidity: $2.8 < \eta < 4.2$

A+A

Beam:

Full Energy AuAu

Physics Topics:

- Temperature dependence of viscosity through flow harmonics up to $\eta \sim 4$
- Longitudinal decorrelation up to $\eta \sim 4$
- Global Lambda Polarization
→ strong rapidity dependence

p+p & p+A

Beam:

500 GeV: p+p

200 GeV: p+p and p+A

Physics Topics:

- TMD measurements at high x transversity → tensor charge
- Improve statistical precision for Sivers through DY
- $\Delta g(x, Q^2)$ at low x through Di-jets
- Gluon PDFs for nuclei
➤ R_{pA} for direct photons & DY
- Test of Saturation predictions through di-hadrons, γ -Jets

Observables:

- Inclusive jets and di-jets
- Hadrons in jets
- Photons
- Drell-Yan e^+e^-
- Lambda's
- Mid-forward & forward-forward rapidity correlations

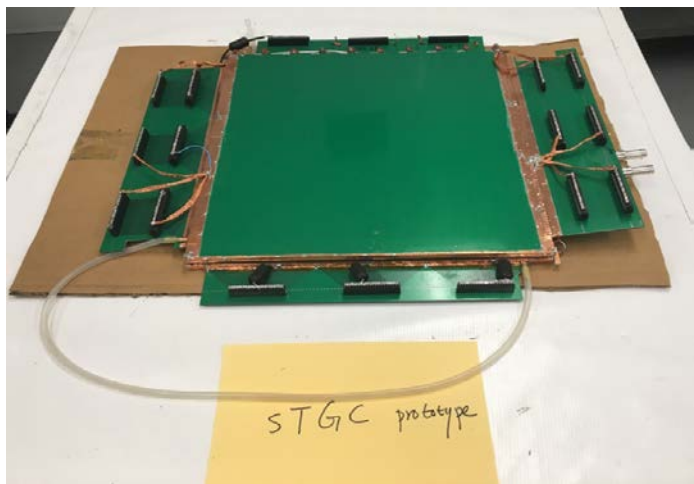
Requirements:

- Good e/h separation
- Hadrons, photons, π^0 identification

2021/22: 500 GeV polarized pp run

Additional pp , pA , and AA data taking in parallel to the sPHENIX campaign

STAR Forward Upgrade full-scale prototype



- Full in-situ system check of sTGC, pre-shower, ECal, HCal, and triggering during Run 19
 - Fully integrated into **STAR** DAQ, on-line and off-line software
 - Slow controls under development