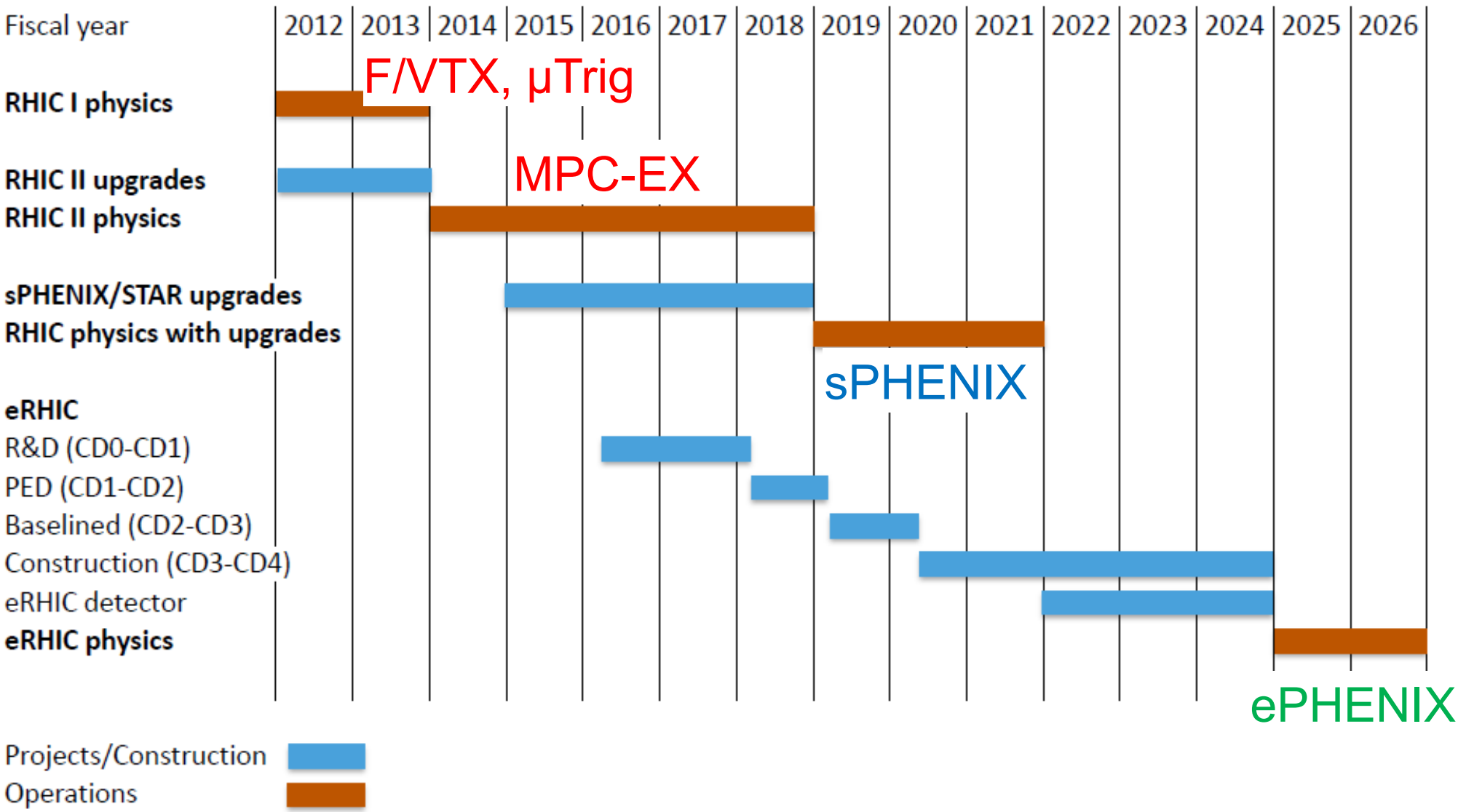
PHENIX upgrade plans and physics outlook

Dave Morrison (BNL)
for the PHENIX Collaboration

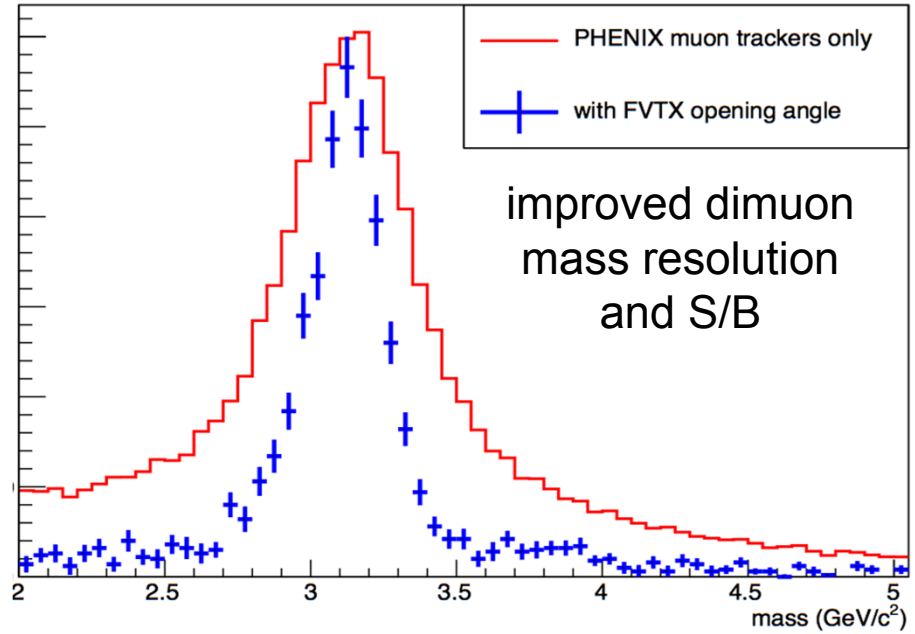
upgrades and physics on many timescales



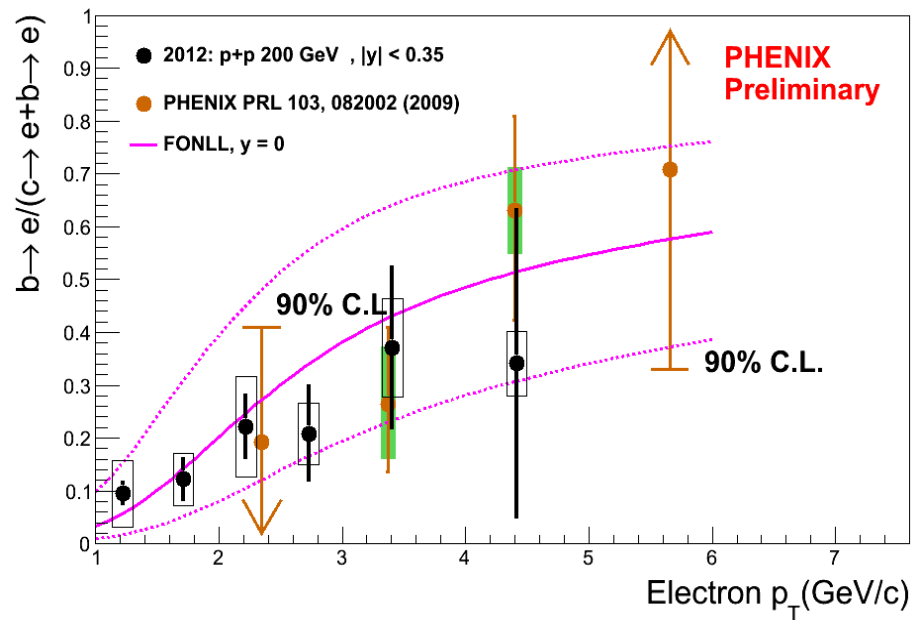
the immediate physics of PHENIX

Run-14/15 Key Detector Upgrades (Silicon Vertex Detectors)

FVTX commissioning run in Run-12
> 96% live active area
Fast analysis results indicate performance exceeding specifications
Displaced vertex results for open heavy flavor from Run-12 Cu+Au expected soon



VTX commissioning run in Run-11
Preliminary p+p charm/beauty results
Repair plans in place for Run-14 readiness



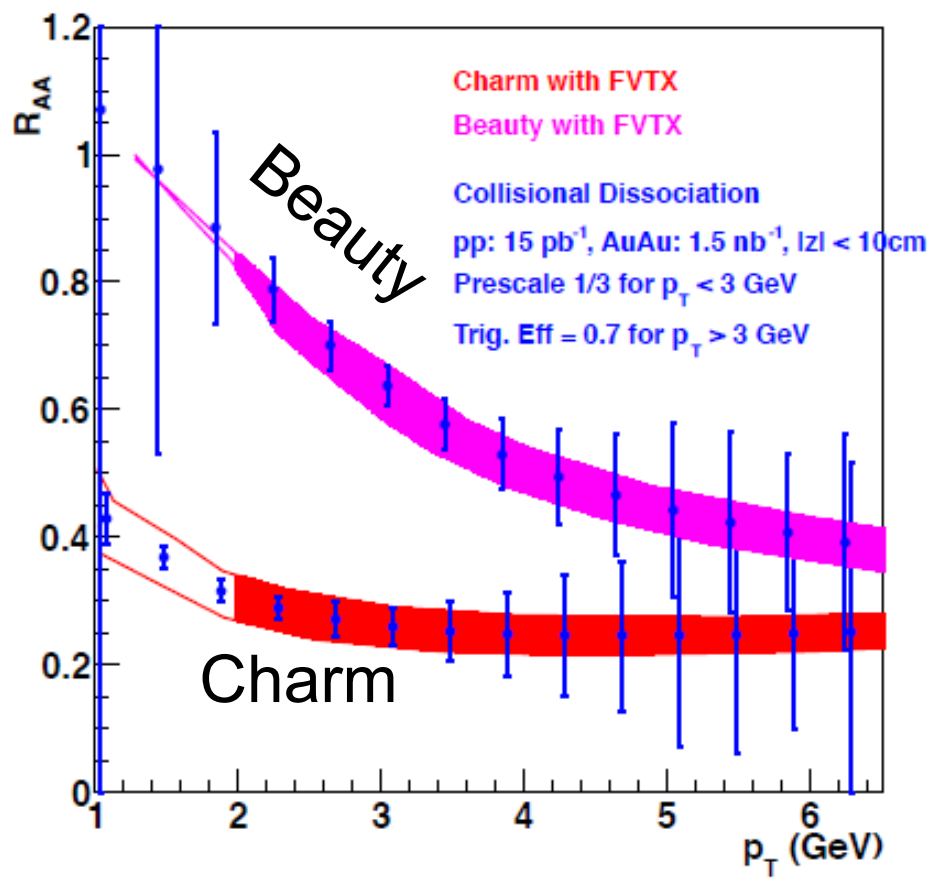
Run-14 Au+Au @ 200 GeV

planning for 1.5/nb – driven by charm and beauty physics

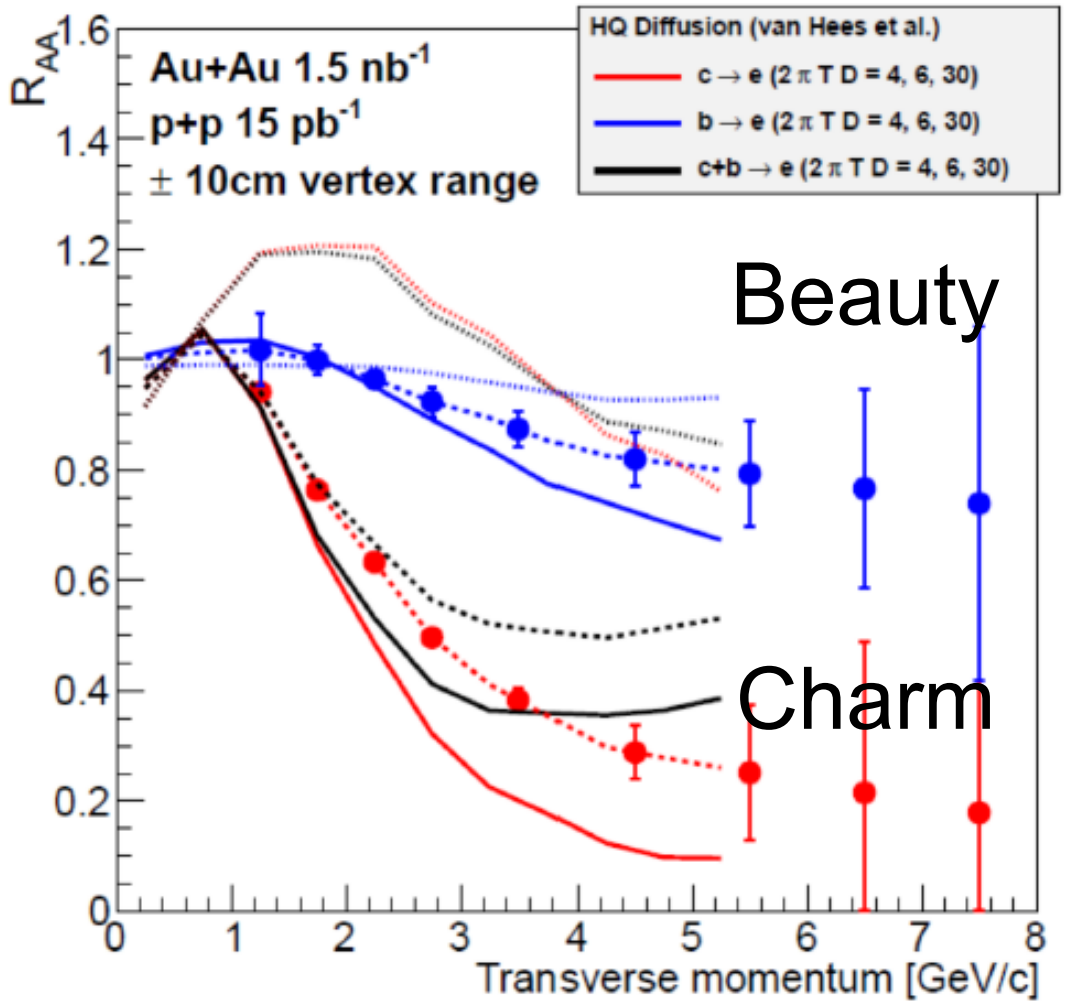
FVTX first Au+Au data set

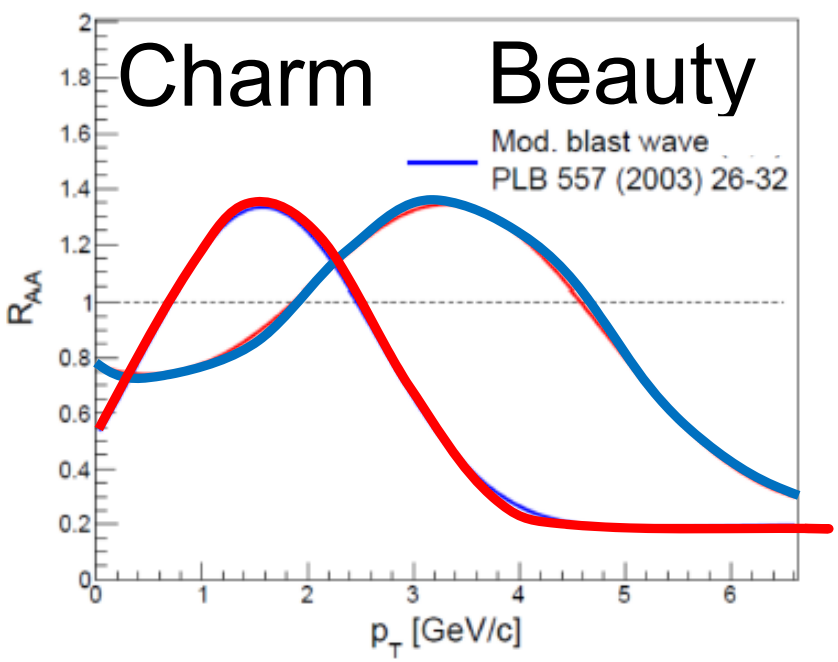
Example projected uncertainties in collisional dissociation model

Bands include unfolding systematic uncertainties



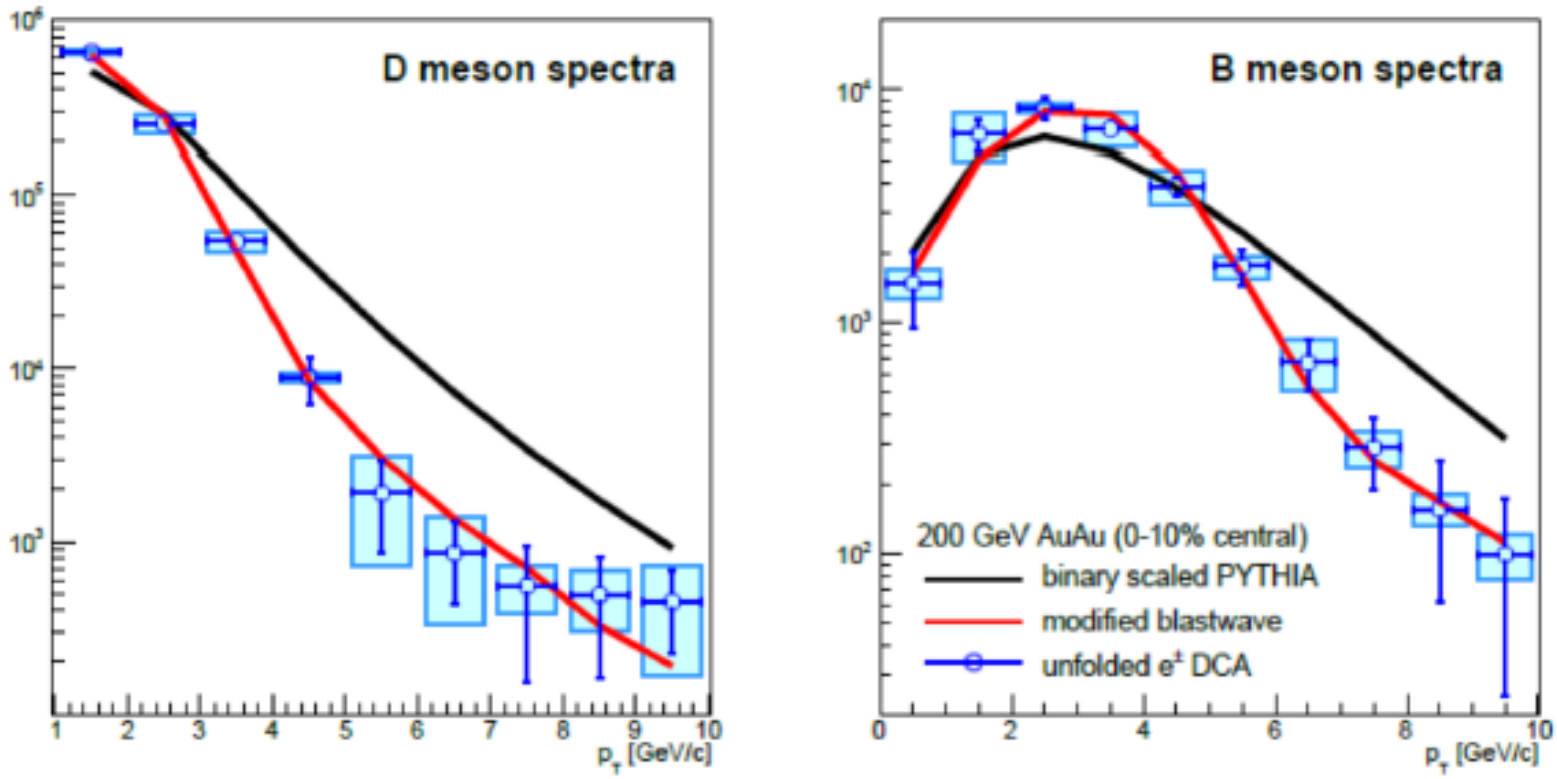
VTX projected uncertainties and sensitivity relative to heavy quark diffusion parameter





In the extreme scenario of beauty quarks following flow field, very different prediction

Example full unfolding from DCA electrons to parent mesons



Au+Au data set will also provide a factor of 2.5 more statistics for all measurements

For J/ψ and ψ', significantly improved mass resolution and background rejection

Definitive Heavy Quark + Quarkonia Au+Au Data Set

planning for Run-15

Run-15 Proposal (22 cryo-weeks)

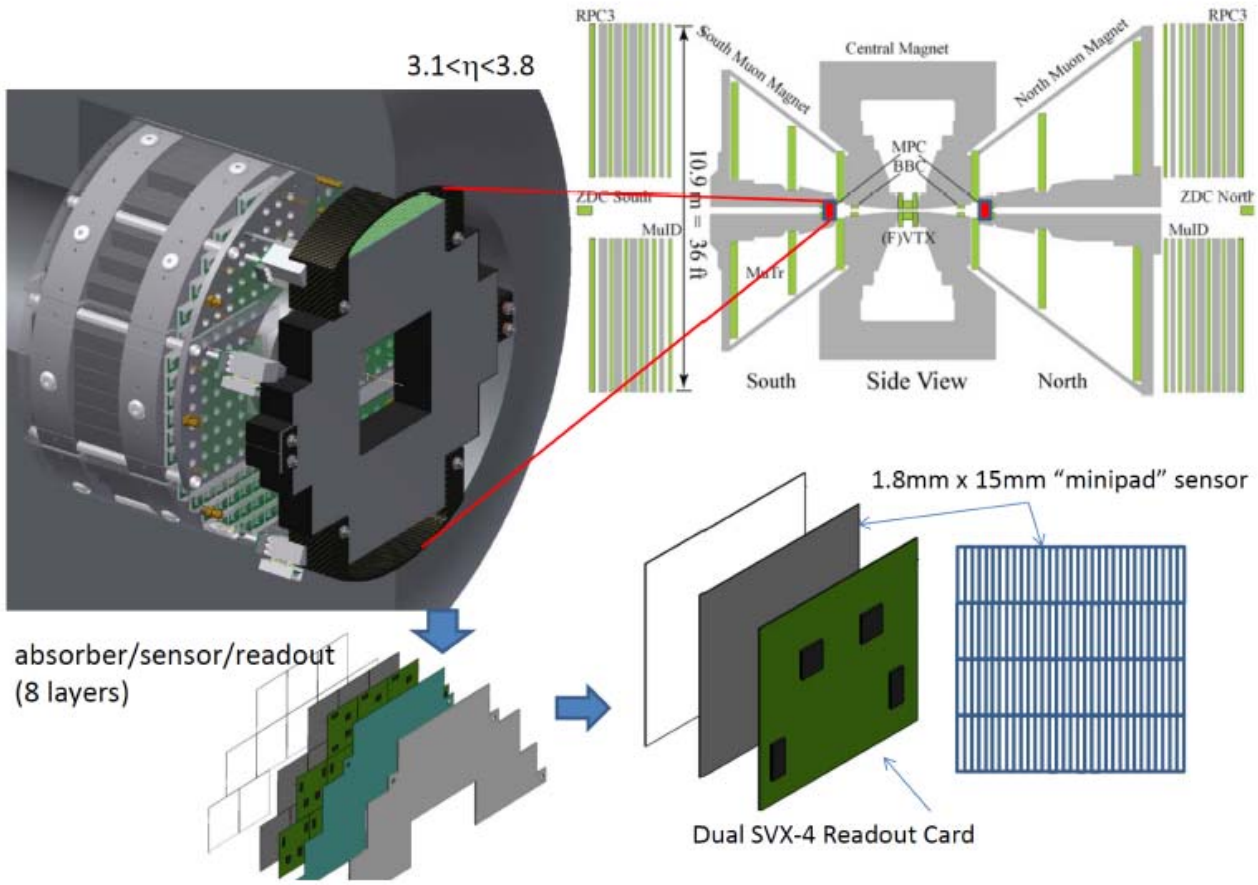
- $p+p$ @ 200 GeV with transverse polarization for 9 weeks [Physics driven goal is 50 pb^{-1} recorded within $|z| < 40$ cm and $\langle \mathcal{P} \rangle = 60\%$]
- $p+\text{Au}$ @ 200 GeV with transverse polarization of the proton for 4 weeks [Physics driven goal is 150 nb^{-1} sampled within $|z| < 40$ cm and $\langle \mathcal{P} \rangle = 60\%$]
- Geometry studies with $d+\text{Au}$ @ 200 GeV and $^3\text{He}+\text{Au}$ @ 200 GeV for 1 week each [Physics driven goal is recording 1 billion minimum bias events for each]
- $p+\text{Si}$, $p+\text{Cu}$ @ 200 GeV for 2 weeks each [Physics driven goal is 450 nb^{-1} and 225 nb^{-1}, respectively, sampled within $|z| < 40$ cm and $\langle \mathcal{P} \rangle = 60\%$]

this plan fully exploits the uniqueness of RHIC

MPC-EX Upgrade

The PHENIX MPC Crystal Calorimeter (|η| = 3.1–3.8) has played a critical role in our forward (low-x) and transverse spin physics program

MPC-EX upgrade adds novel silicon tracking / preshower detector to enable direct photon identification and $\pi^0 \rightarrow \gamma\gamma$ to higher momentum

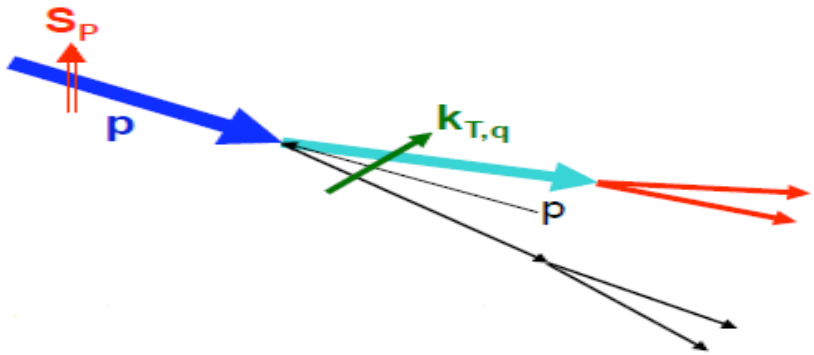


Beam test in fall, and section available for integration tests in Run-14

Full detector available for physics in Run-15

Transverse Spin Physics

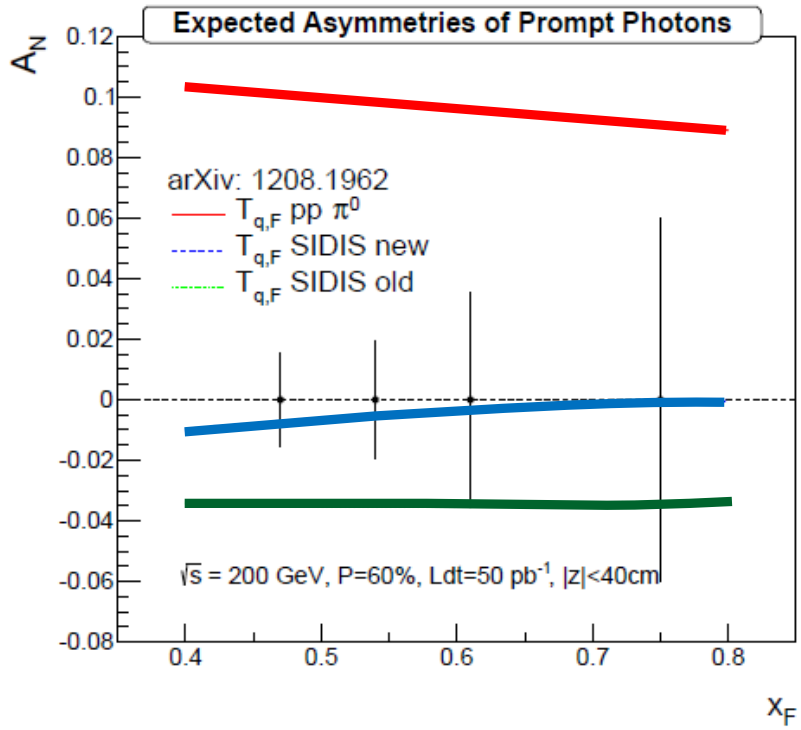
Single spin asymmetries A_N in transversely polarized p+p collisions provide information on the parton's transverse motion in the transversely polarized proton



Approaches: TMDs (correlation between nucleon spin and parton k_T) and colinear twist-3 factorization (quark-gluon correlator $T_{q,F}$)

TMDs include Sivers and Collins functions

Direct photon A_N – *no fragmentation* – almost exclusively sensitive to Sivers



p+p (transverse pol.) @ 200 GeV for 9 weeks (50 pb^{-1} |z|<40cm)

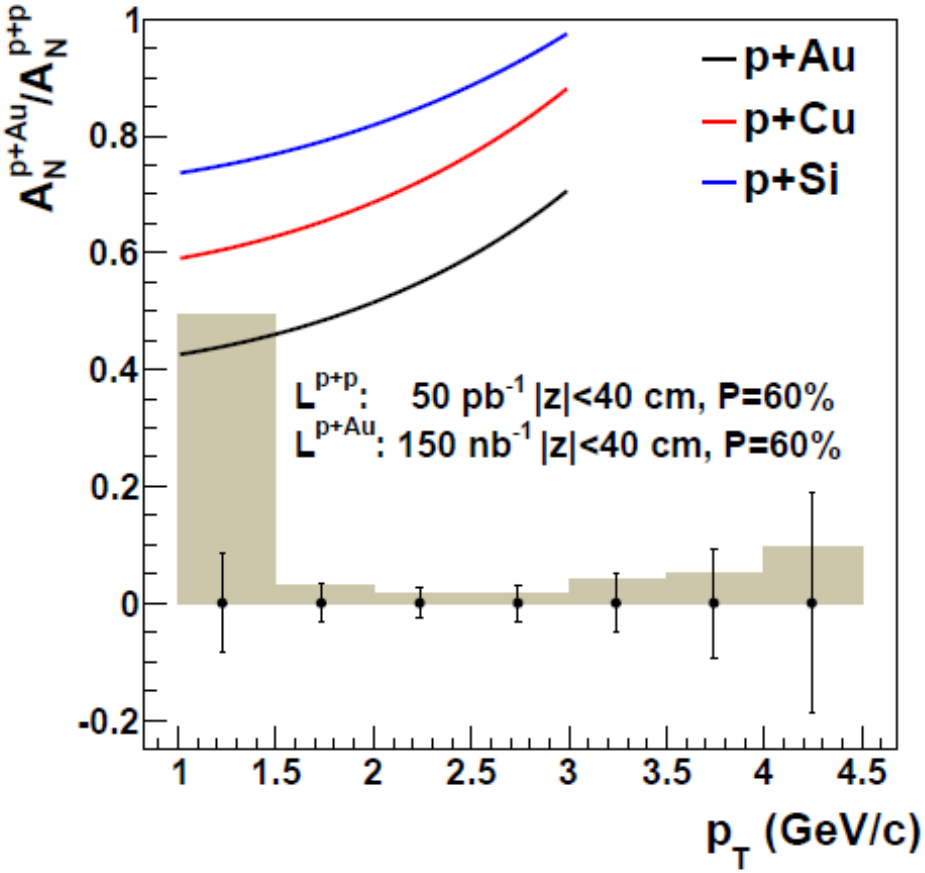
p+Au with transversely polarized protons

New theory developments – transverse polarization A_N in p+A scales with the saturation scale for $p_T < Q_s$

Completely unique RHIC access to saturation physics

p+Au measurement with projected uncertainties in
4 weeks (150/nb |z|<40cm)

Testing geometric scaling with Si, Cu target nuclei
Comparable uncertainties with 2 week runs

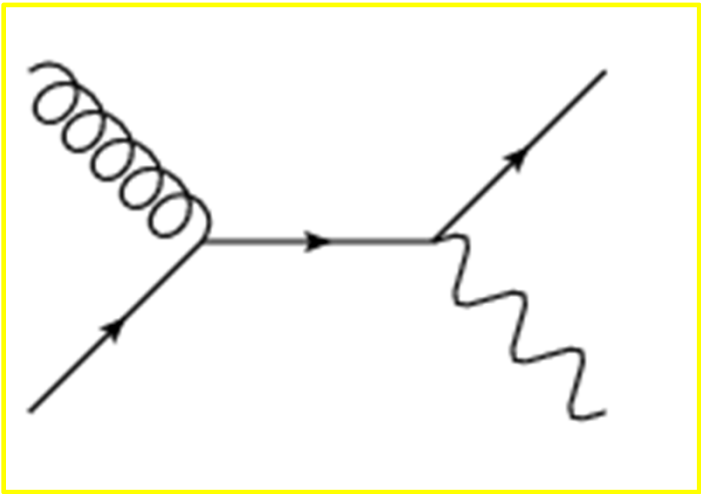


Constraining Gluon nPDFs

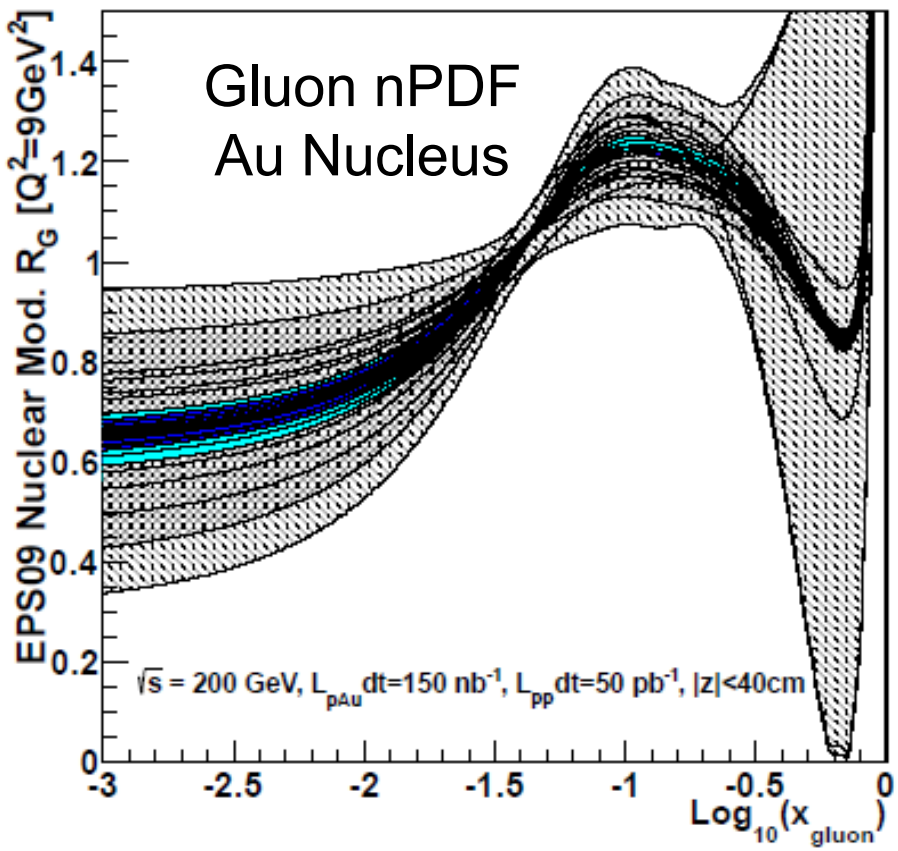
Strong indications of low-x shadowing/saturation physics with d+Au J/ψ, e-μ correlations, h-h correlations, single muons, electrons, …

All have final state interactions.

Golden channel? direct photon!



MPC-EX Direct Photon



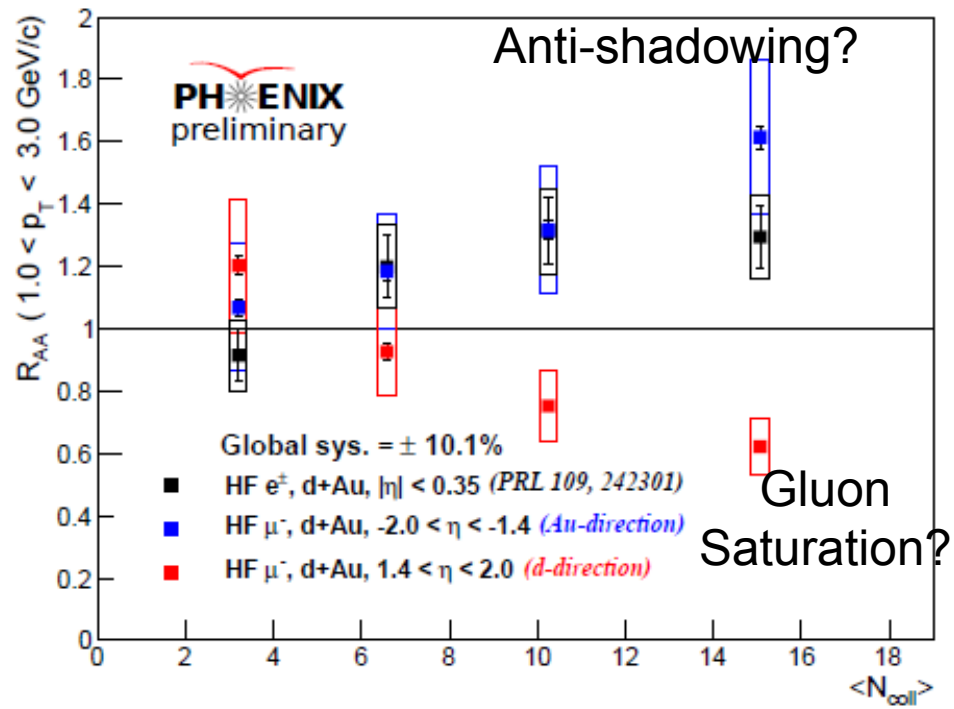
Using full statistical / systematic constraint method on EPS09 nPDFs, blue bands indicate projected measurement (1, 2σ level)

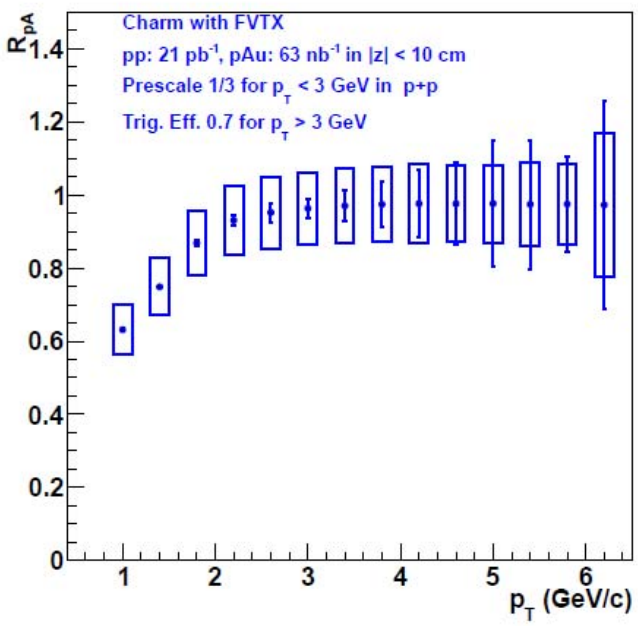
Open Heavy Flavor Probes of nPDFs and More

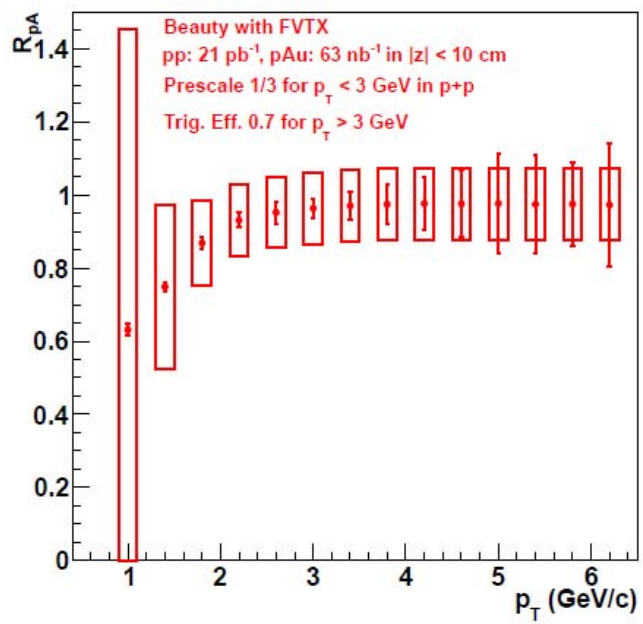
Another handle on gluon nPDF and critical baseline for quarkonia

Measure open charm and beauty at forward/backward rapidity with FVTX

Can we run p+Au and Au+p for systematic checks (a la LHC p+Pb)?



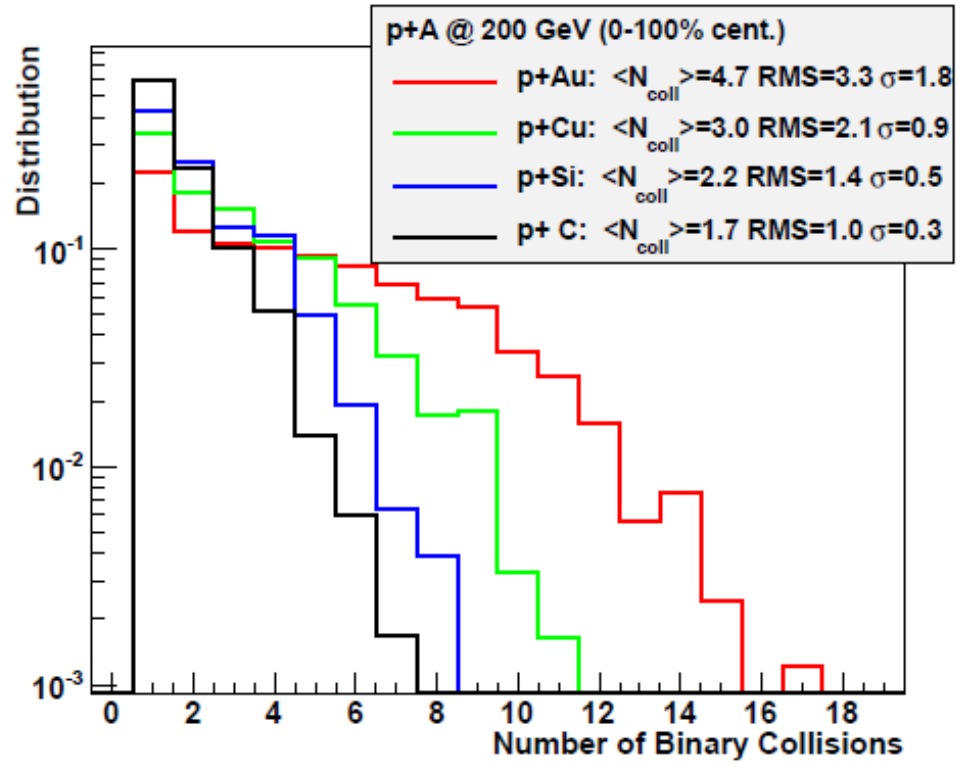


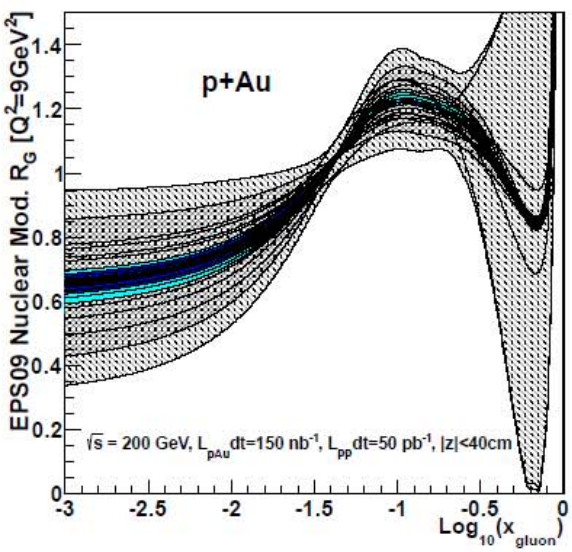


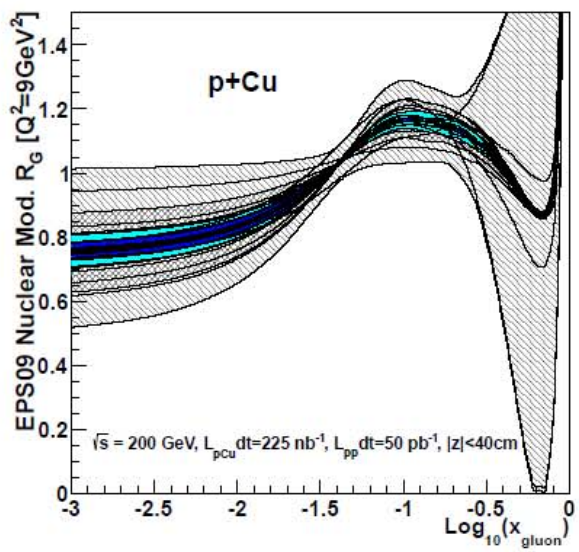
Geometry Test

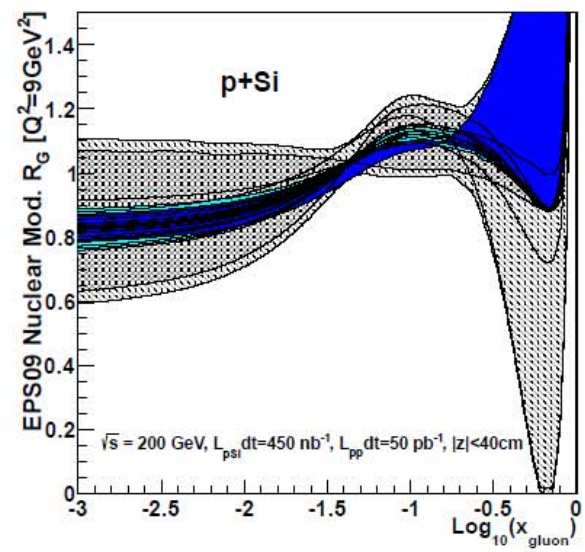
DIS measures give geometry averaged nPDF

Utilized d+Au centrality measures to date…
Excellent opportunity to validate with direct photons nPDF of different nuclei



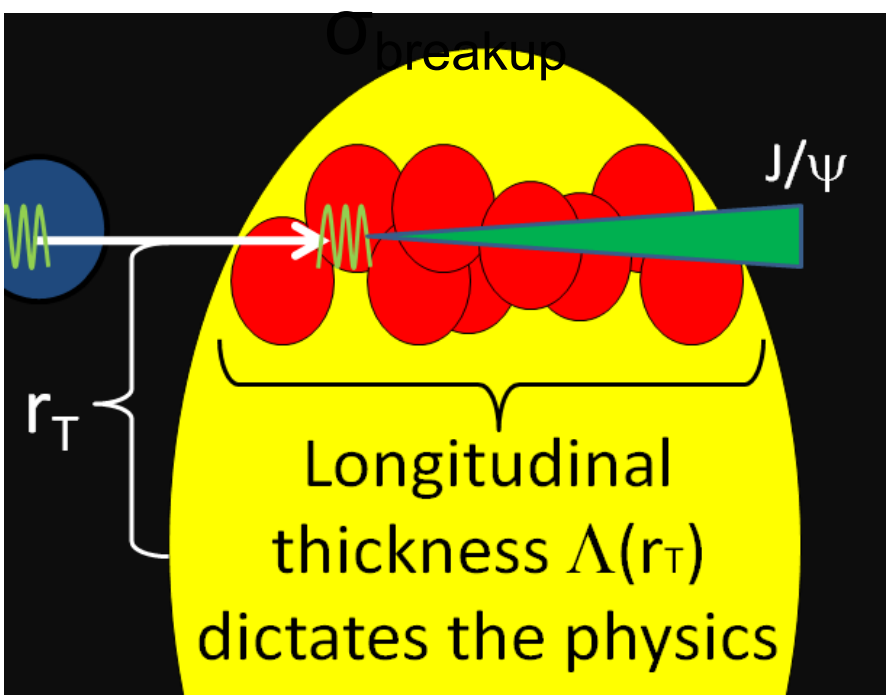


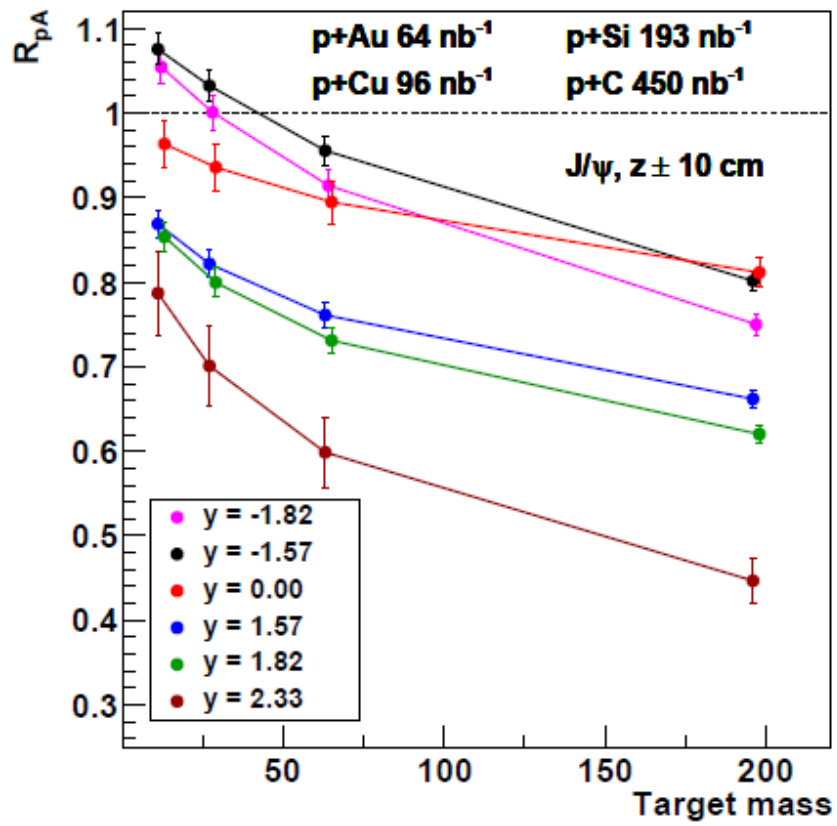




Quarkonia in Medium (Cold or Hot)

J/ψ and ψ' are hard to explain w/ nPDF &

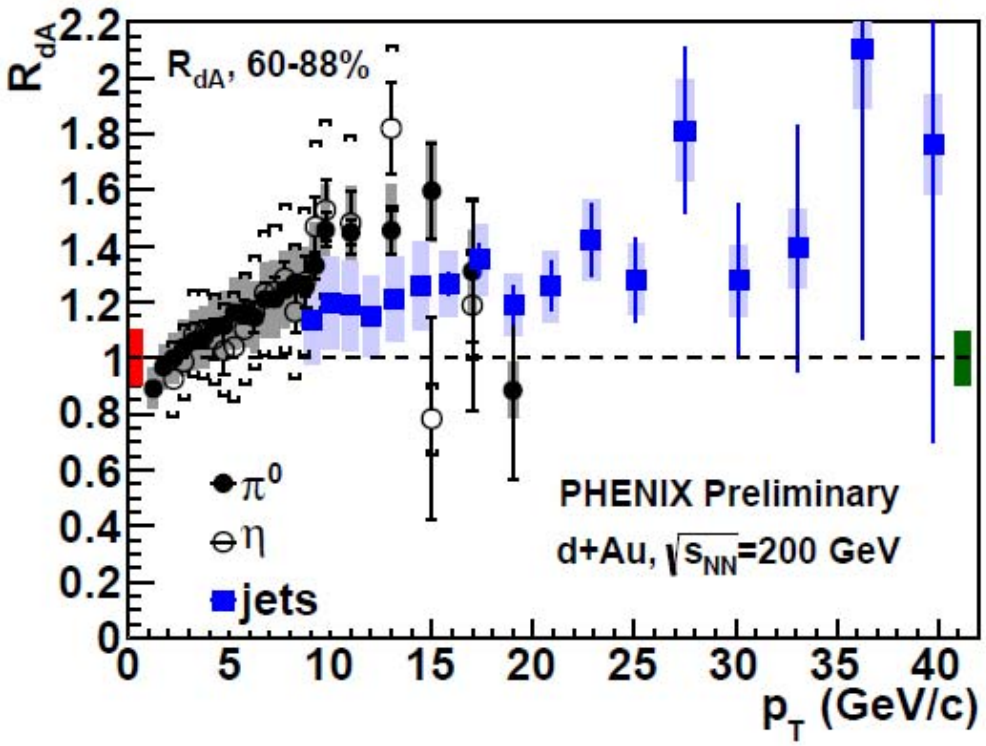


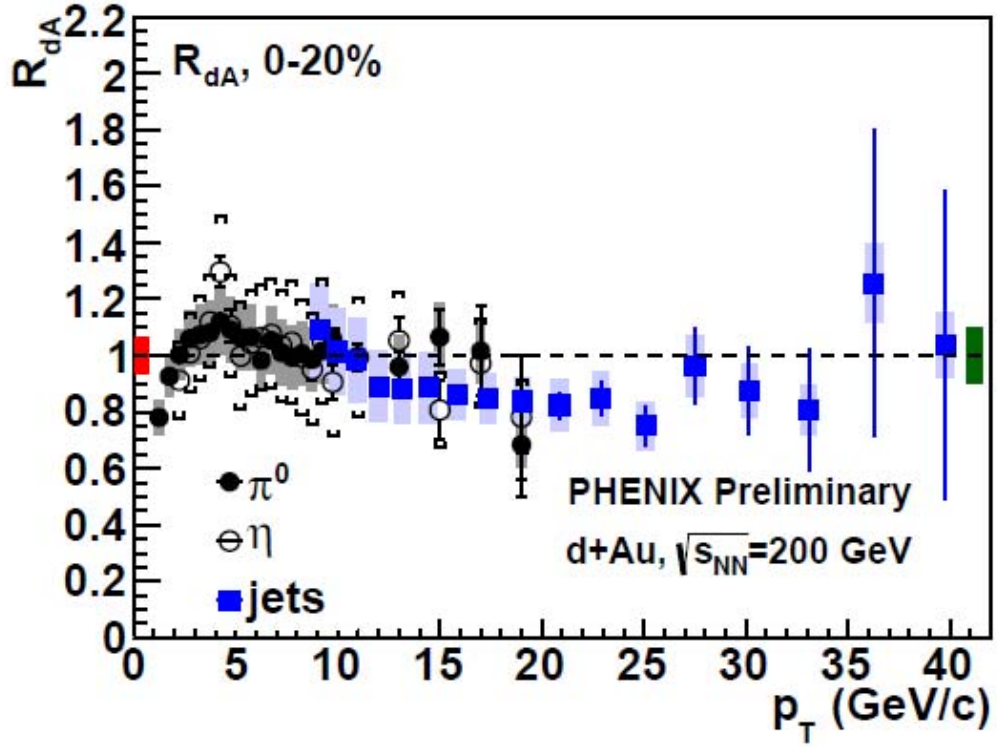


Instead of d+Au centrality selection, another method to change nuclear density is with *different targets*

Also combined with improved S/B and for the first time ψ' at forward and backward rapidity (FVTX)

Geometry selection in p/d+A

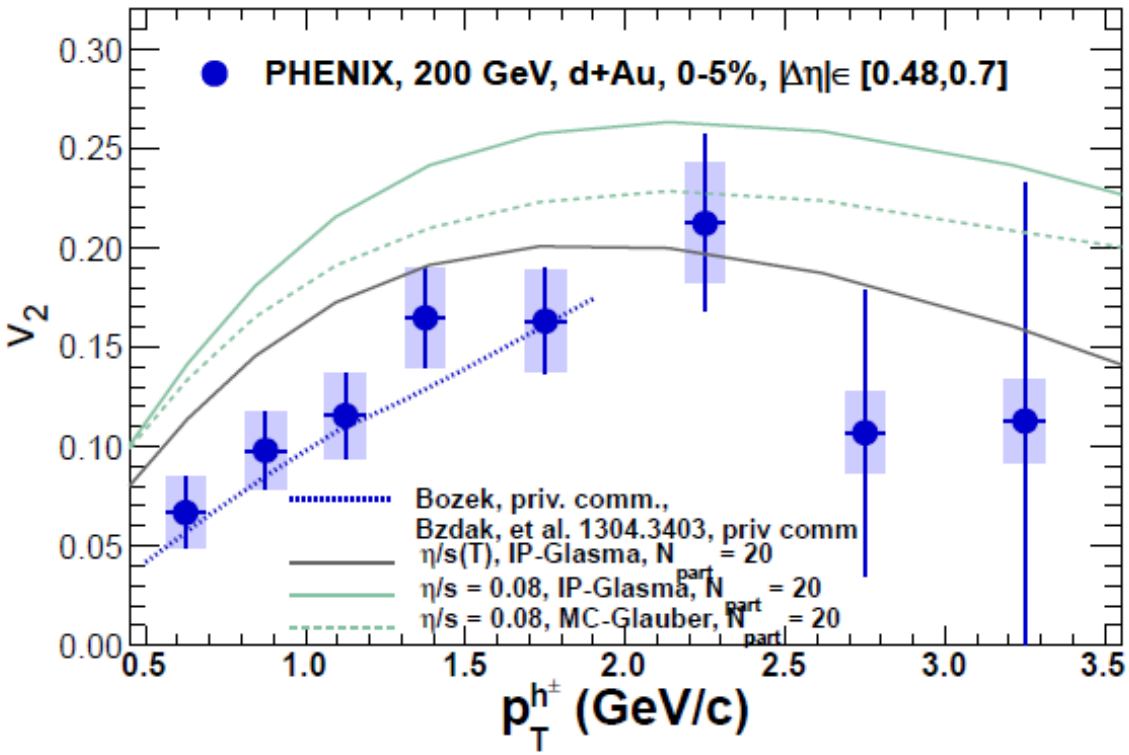


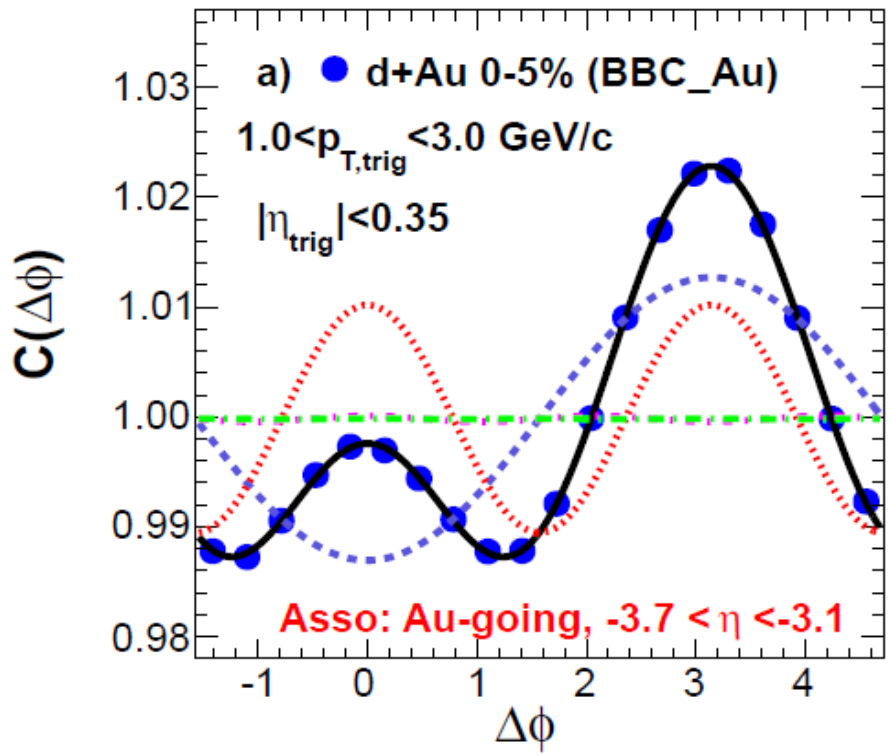


Are there auto-correlations <u>beyond those already accounted for</u> between centrality measure and particle of interest?

Two weeks of p+Si gives $\langle N_{coll} \rangle$ ~ (d+Au 60-88% central), better statistical precision, and no centrality categorization required (i.e. definitive test)

Can a nearly inviscid fluid be created in p/d + A too?

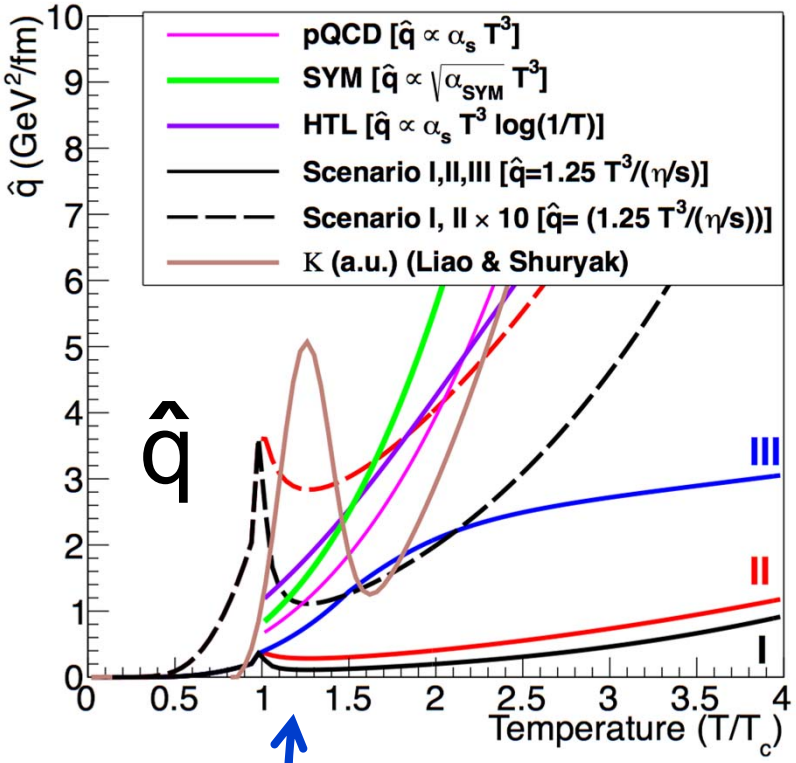




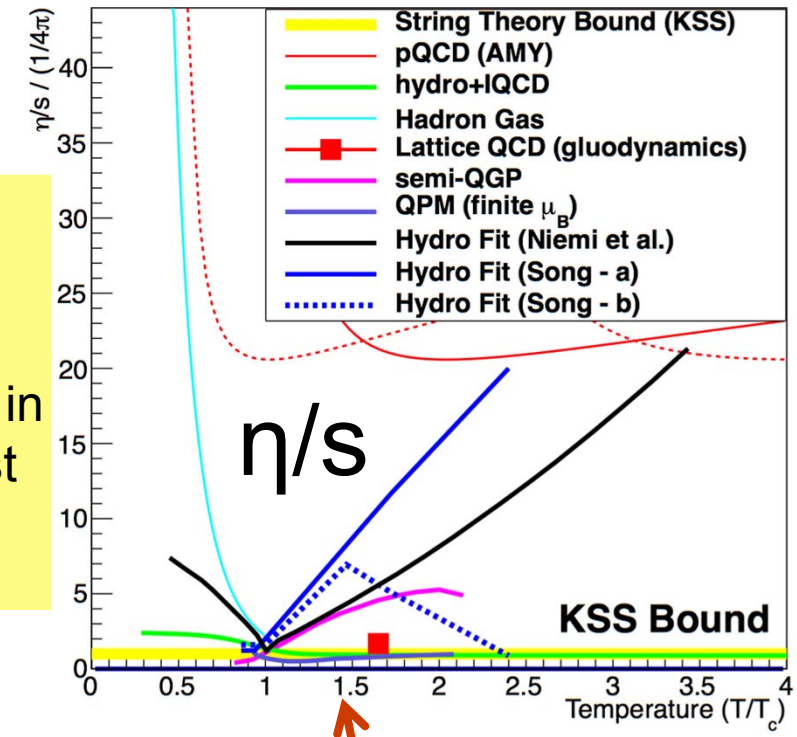
Hydrodynamic flow? Glasma diagrams? Something else?

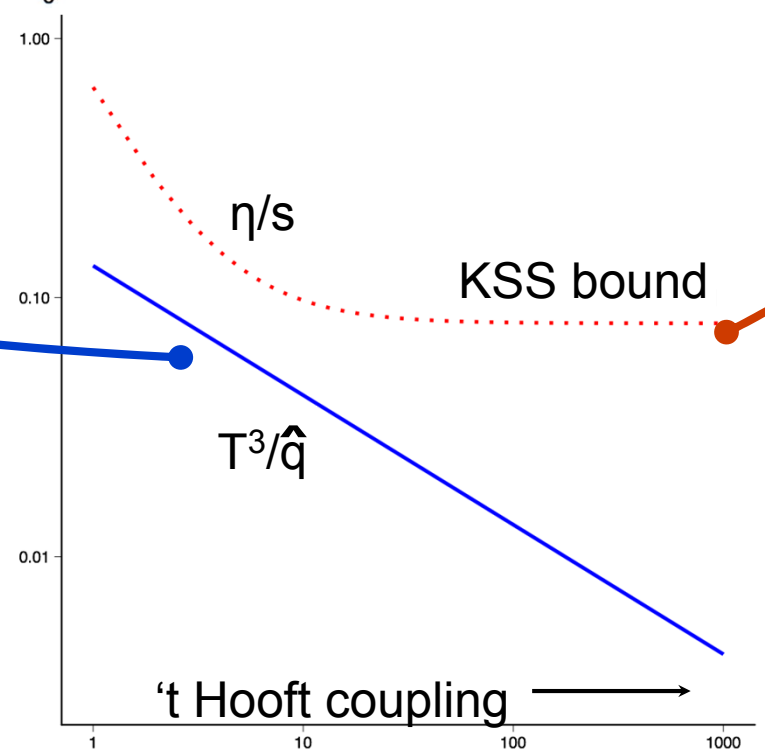
RHIC has unique access to geometric controls:
p+A, d+A, ^{3}He+A

from PHENIX to sPHENIX

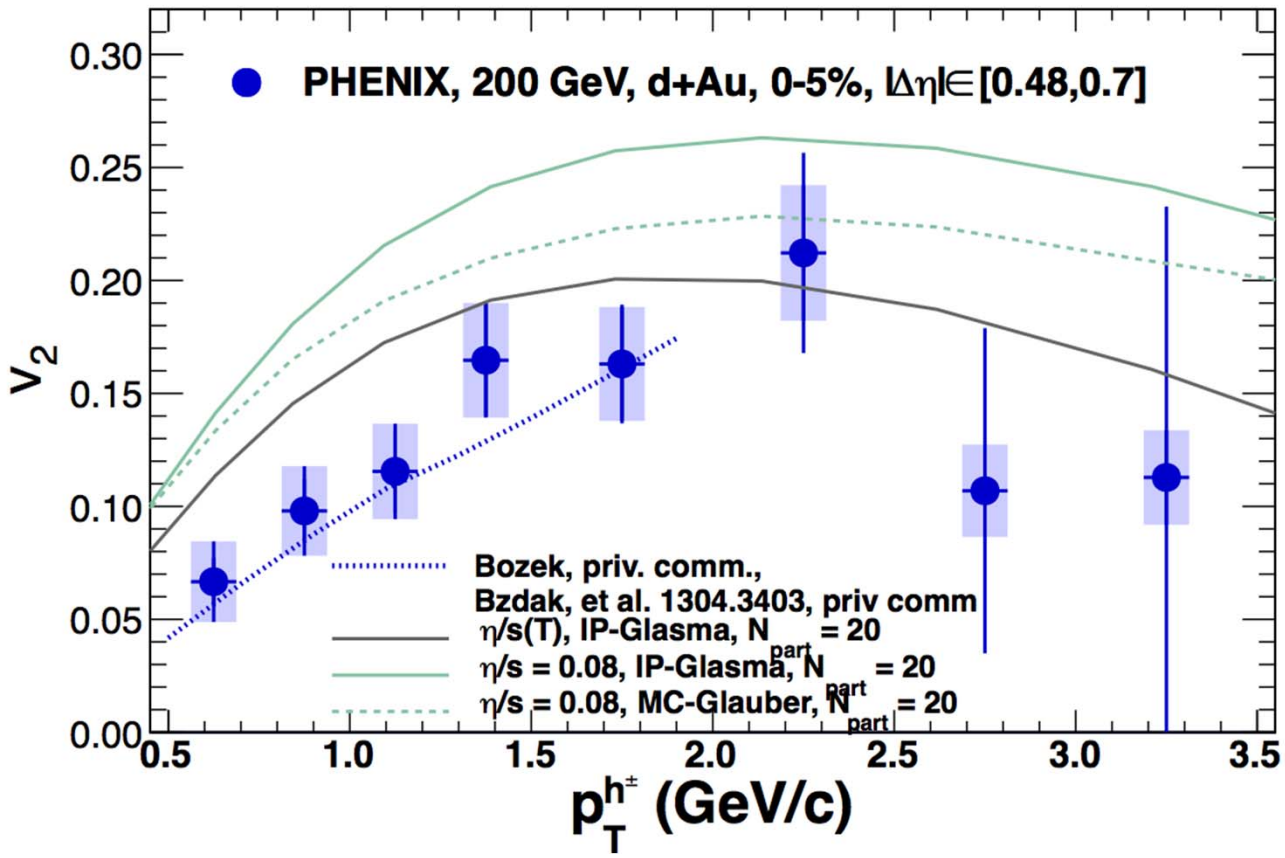


Use jets as a tool to investigate the constituents and dynamics of the sQGP in the region of strongest coupling through its transport coefficients





Back to that plot of v_2 in d+Au for a moment ...

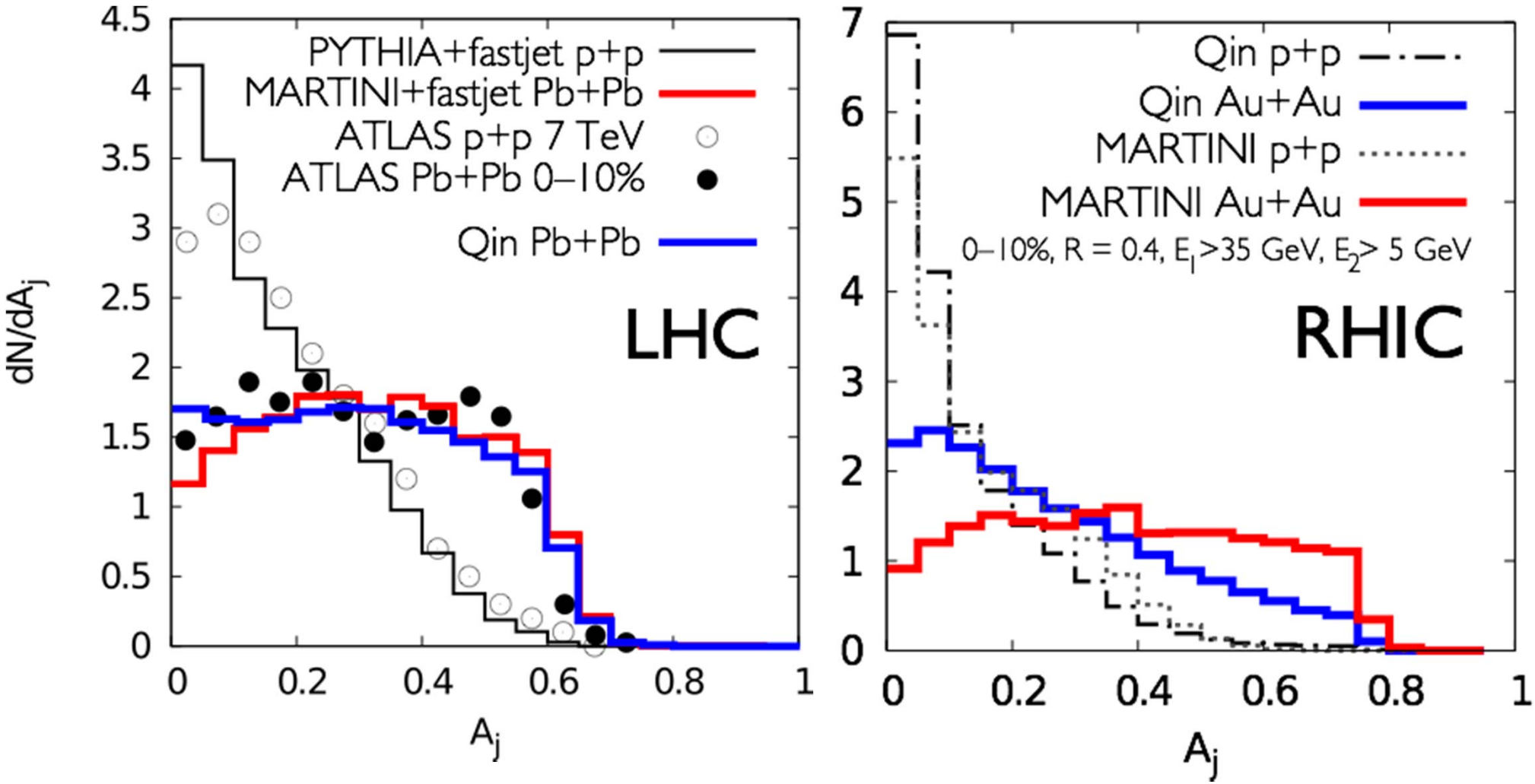


These developments in the past year underscore the need for measurements to address why and how perfect fluidity arises (jet probes).

a broad physics program of the sQGP

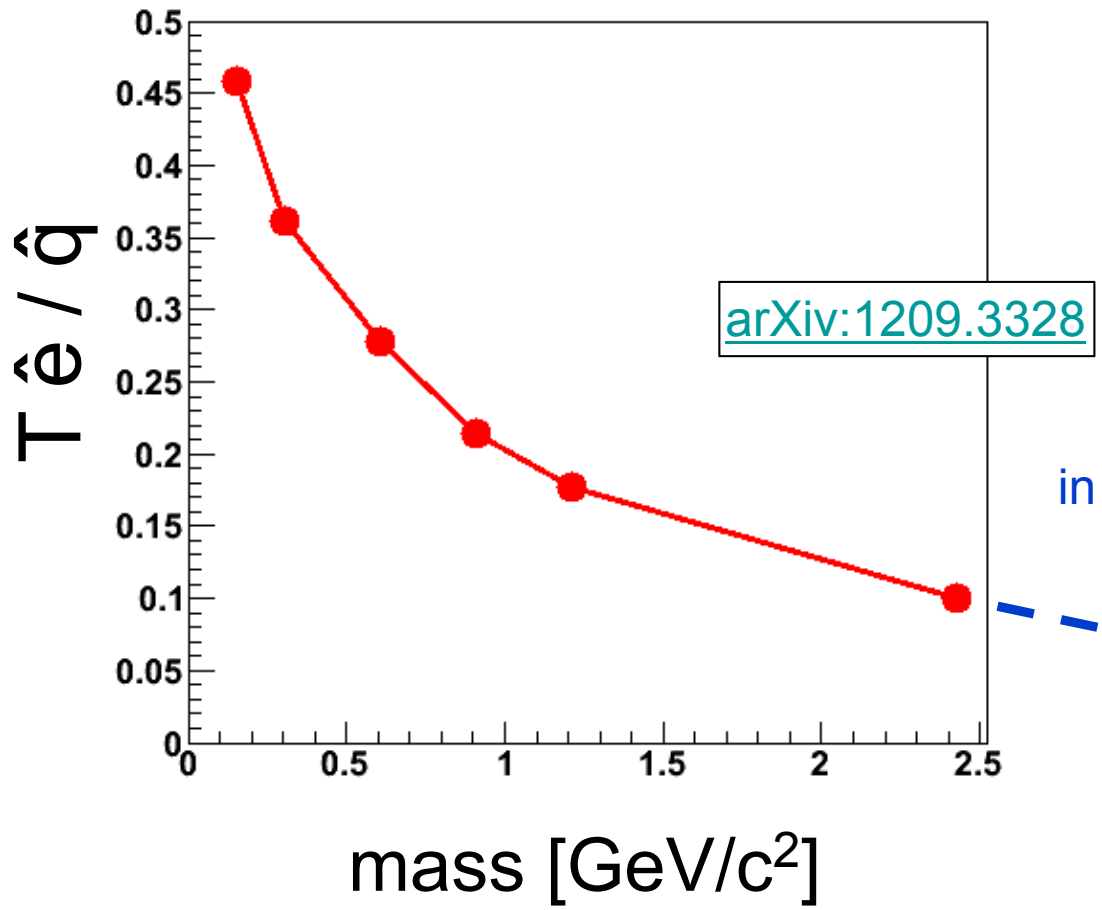
- What are the inner workings of the sQGP?
- Are the key degrees of freedom quasi-particles? excitations? other?
- full jet probes and high statistics dijets
- direct photons
- photon-jet, photon-hadron, jet-hadron correlations
- high statistics upsilons, high statistics open heavy flavor

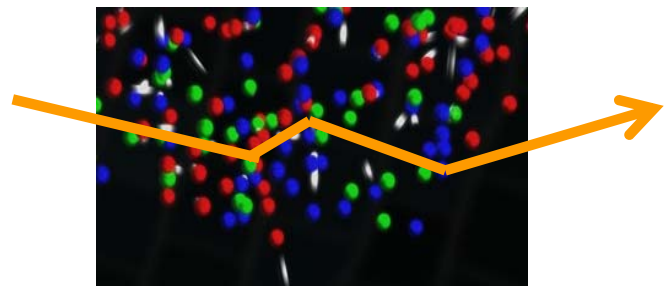
RHIC provides vital discriminating power



C. Young, B. Schenke; G-Y Qin, B. Mueller

what are the jet partons scattering from?

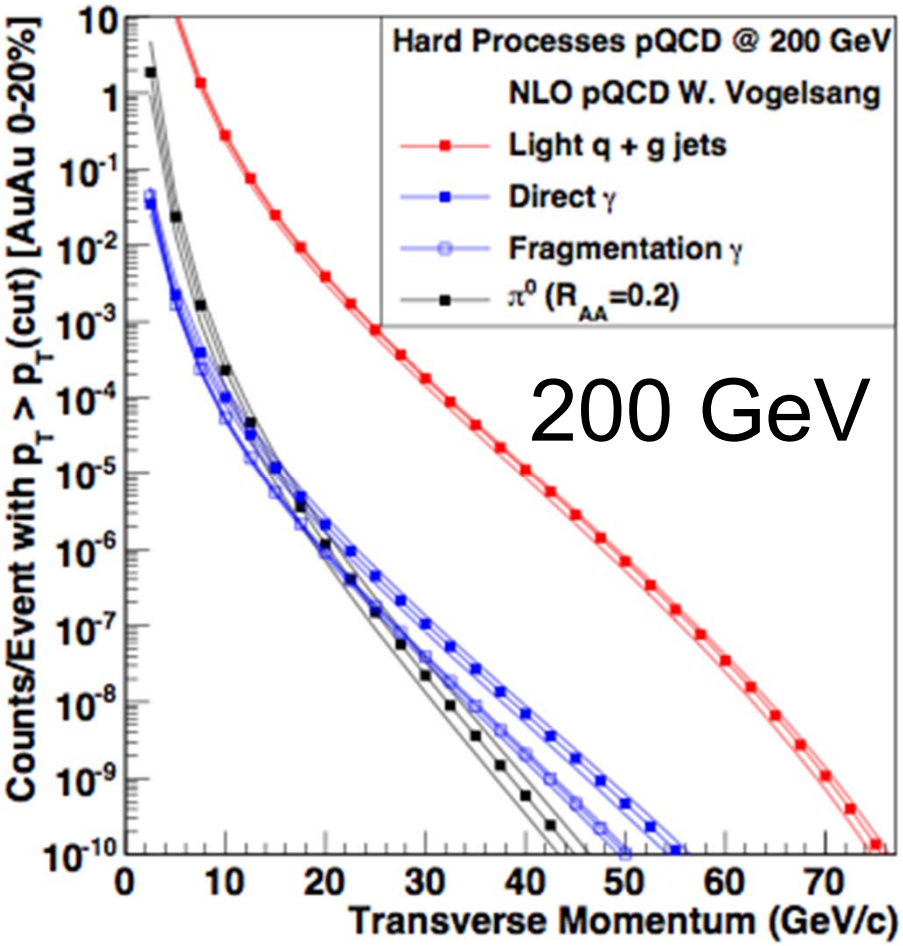


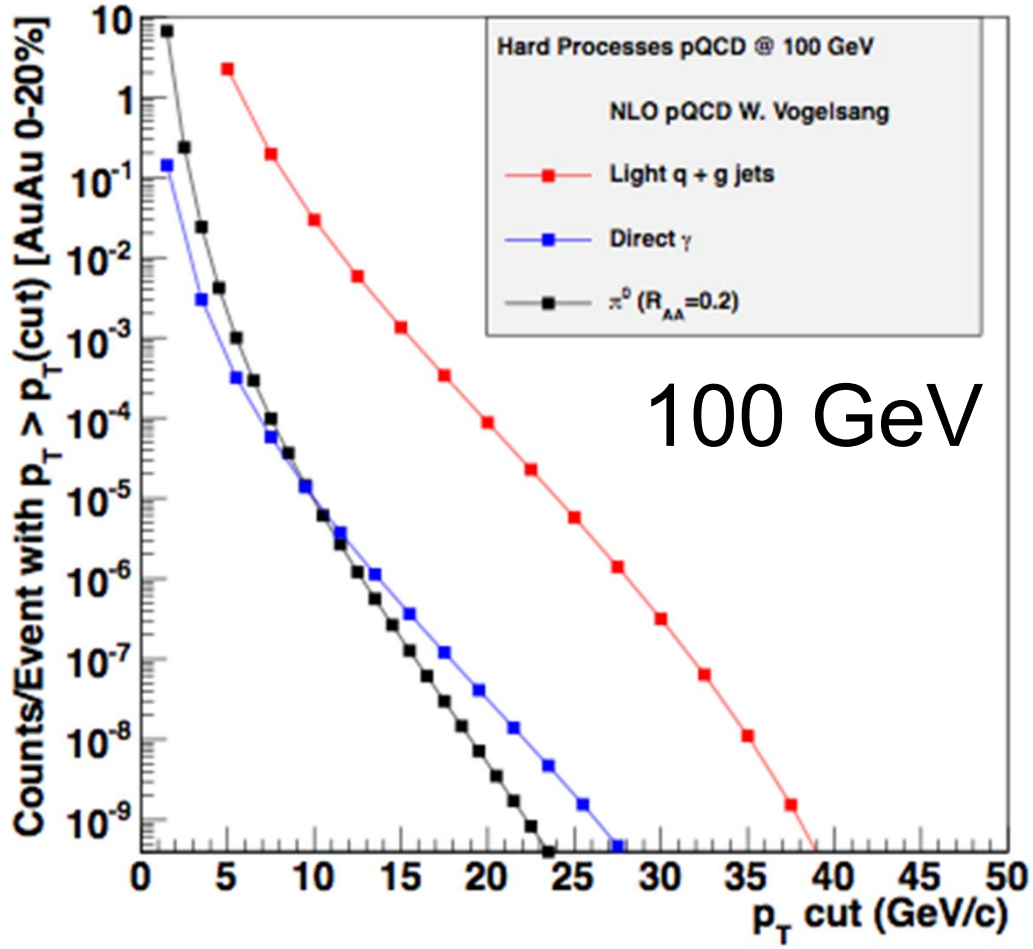


in the limit of infinitely massive scattering centers, all energy loss is radiative

C. Coleman-Smith, B. Mueller

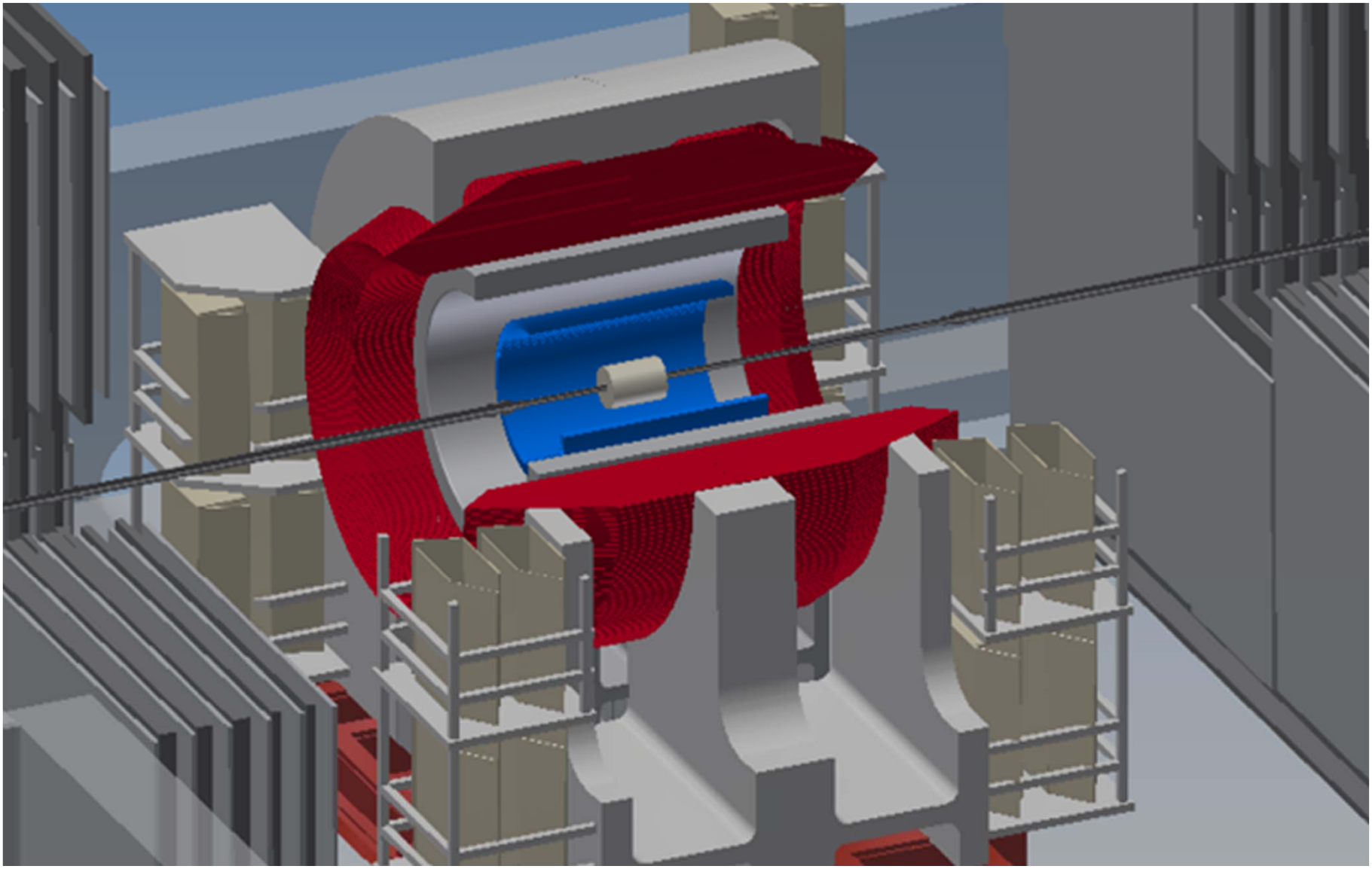
Jets? At RHIC? Absolutely!





central Au+Au @ 200 GeV: 10^6 jets/year with $E_T > 30$ GeV
80% of those jets have dijet partner in $|\eta| < 1$

sPHENIX in the PHENIX IR



the BaBar solenoid is recently available

due to cancelation of the proposed SuperB experiment in Italy

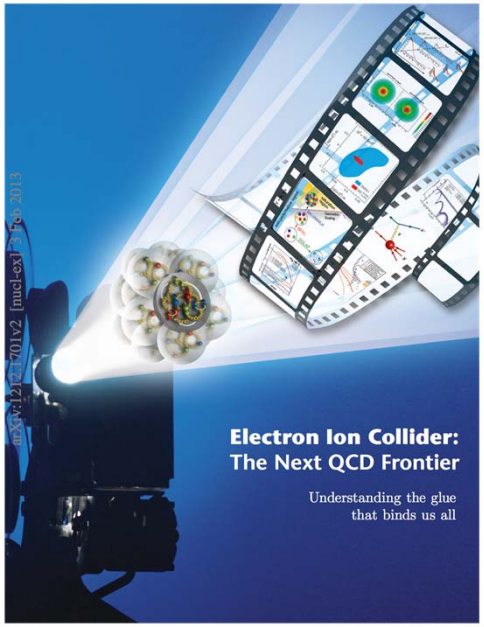
great foundation for sPHENIX: inner radius 140 cm, length 385 cm, field 1.5 T

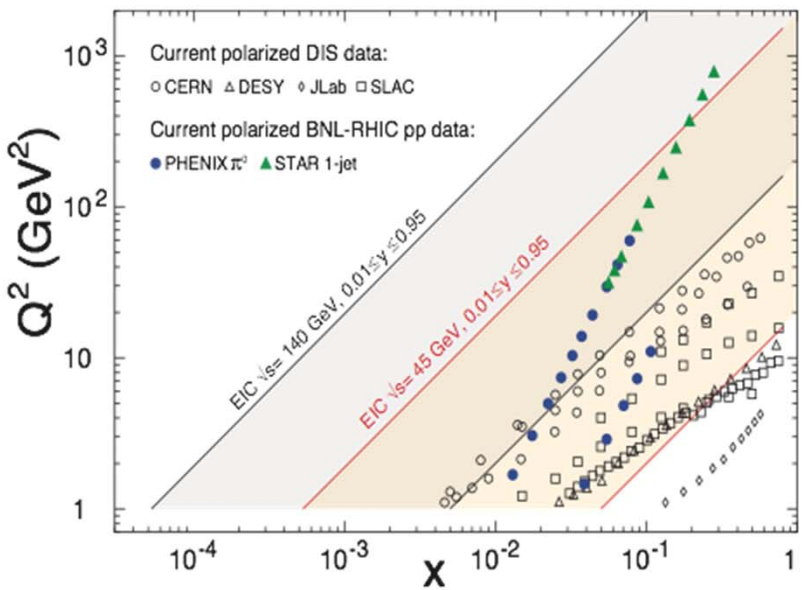
it’s large, but it fits on a truck

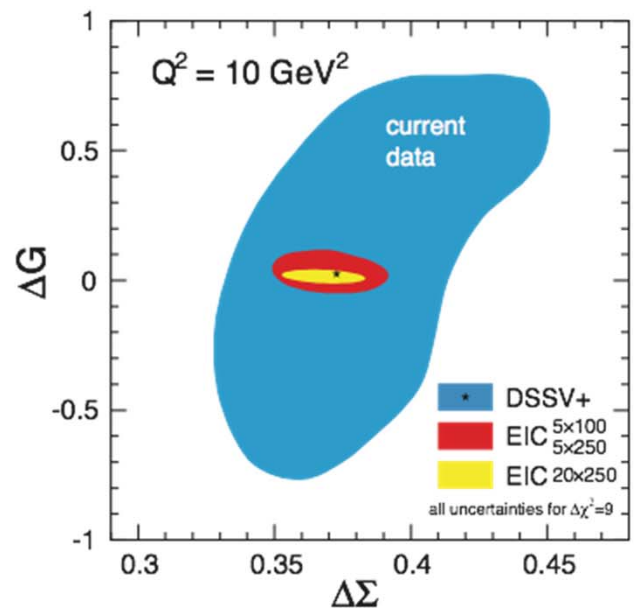
transporting the g–2 magnet was great practice!

from sPHENIX to ePHENIX

ePHENIX takes aim at eRHIC physics!







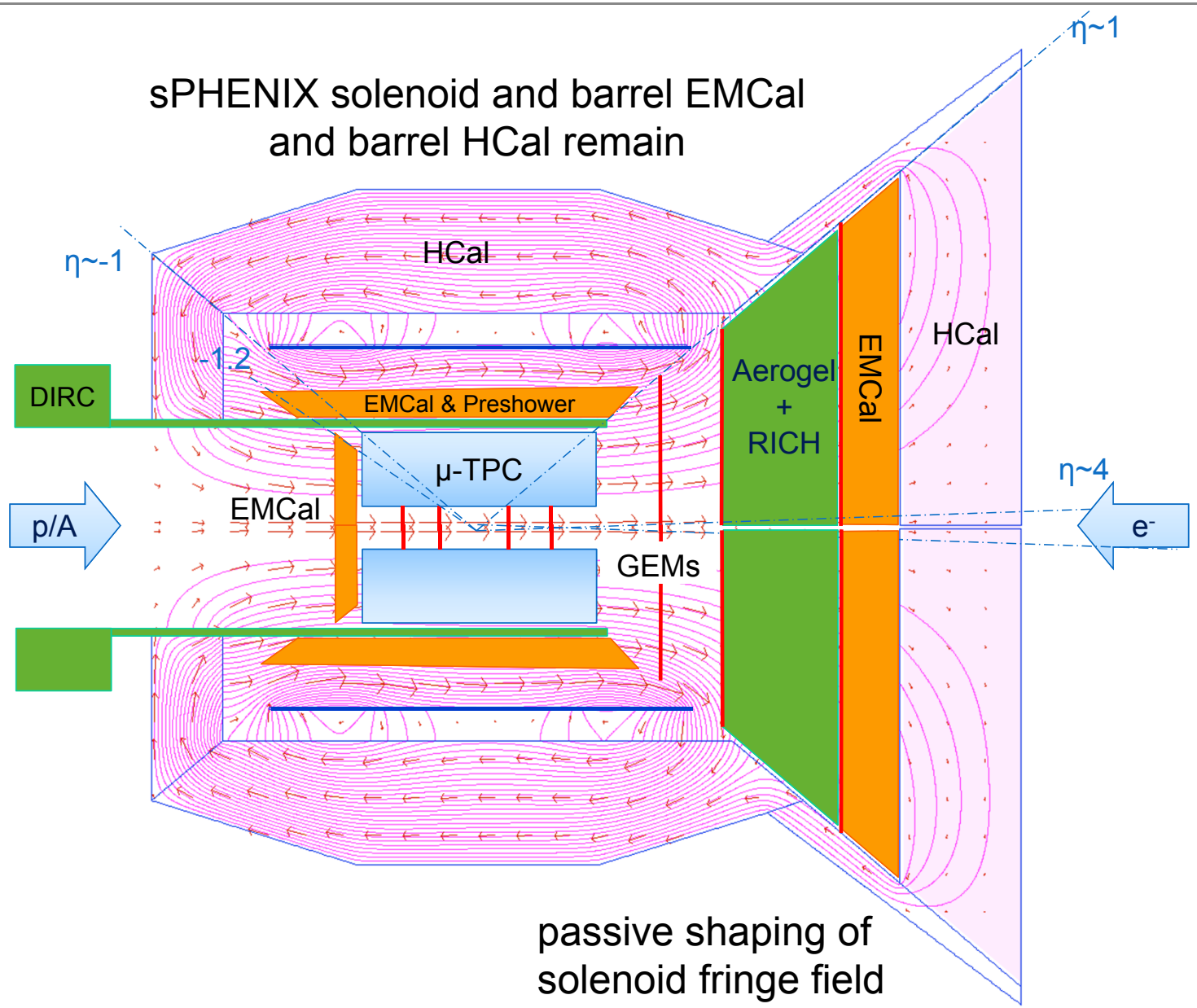
physics case for EIC laid out in detail in white paper

eRHIC: 5–10 GeV electron beam

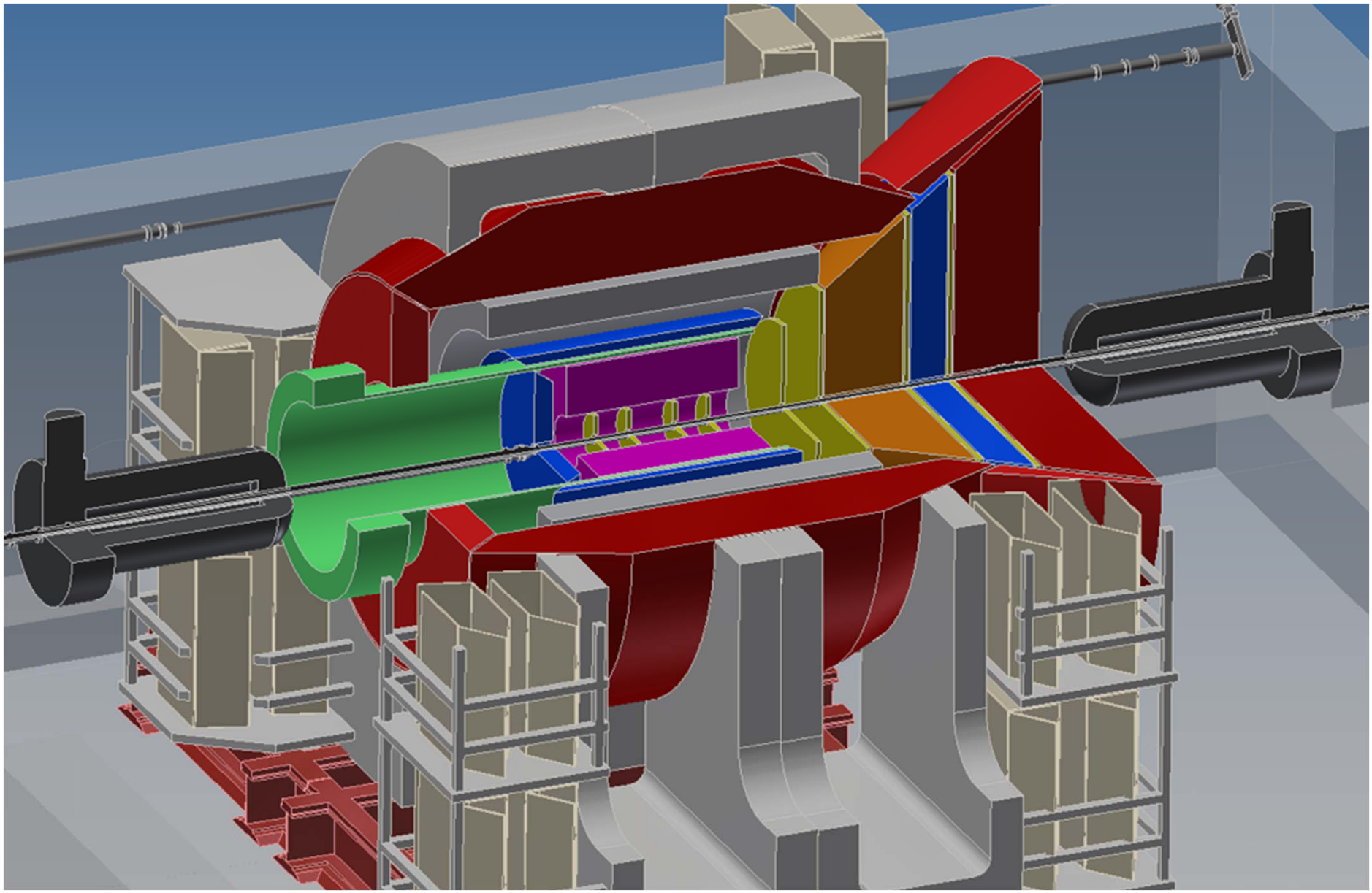
polarized p or ^{3}He, nuclei as with RHIC

L ~ 10^{33}cm^{-2}s^{-1}

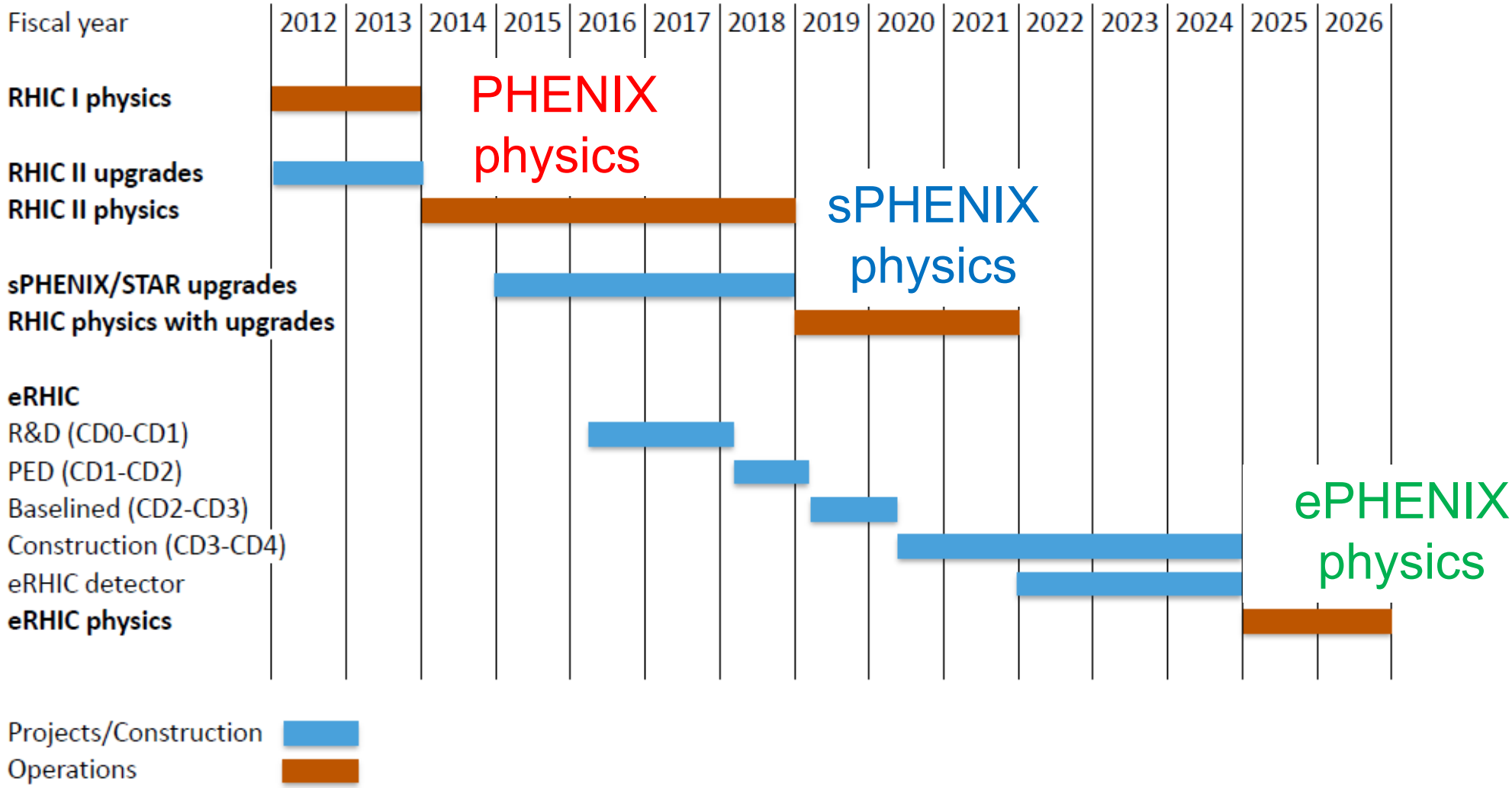
ePHENIX detector concept



ePHENIX in the PHENIX IR



An exciting path forward of upgrades and physics!



plenty of opportunities for students, postdocs: physics, R&D, test beams and detectors!