Physics with the PHENIX Forward Silicon Vertex (FVTX) Upgrade

Mike Leitch LANL – 14 March 2006

Quark Gluon Plasma & AA collisions

- heavy quark dE/dx & flow
- open charm & beauty constraints for quarkonia
- improved reaction plane measurement

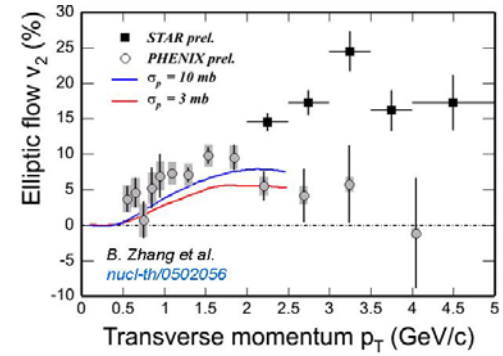
Gluon saturation & dA collisions

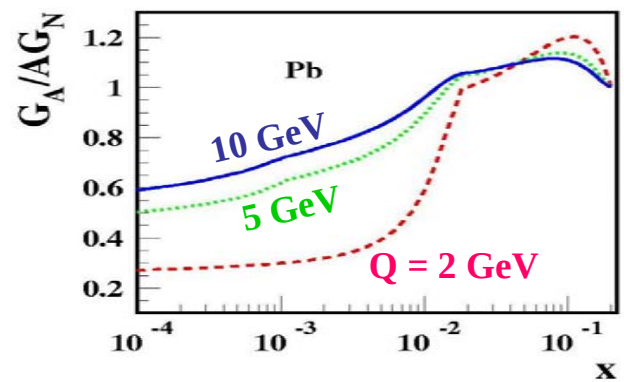
- small-x gluons via heavy quark decays to muons
- cold nuclear matter (CNM) physics for quarkonia
- baseline for AA

Sources of the spin of the nucleon

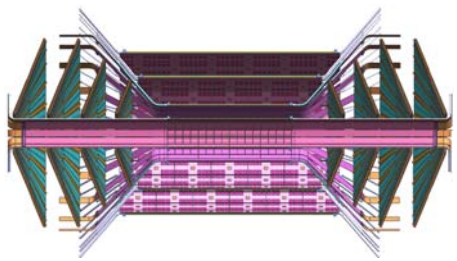
- gluon contribution spin from heavy quarks
- large x range to see shape of asymmetry
- W & Z's with muons

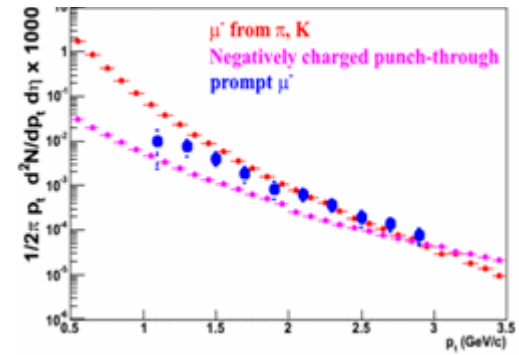
FVTX rates





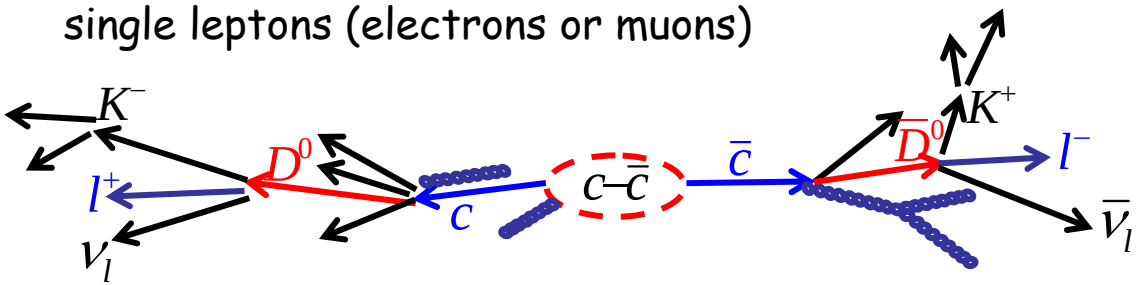
Simulations & Performance in next talk from X-R Wang

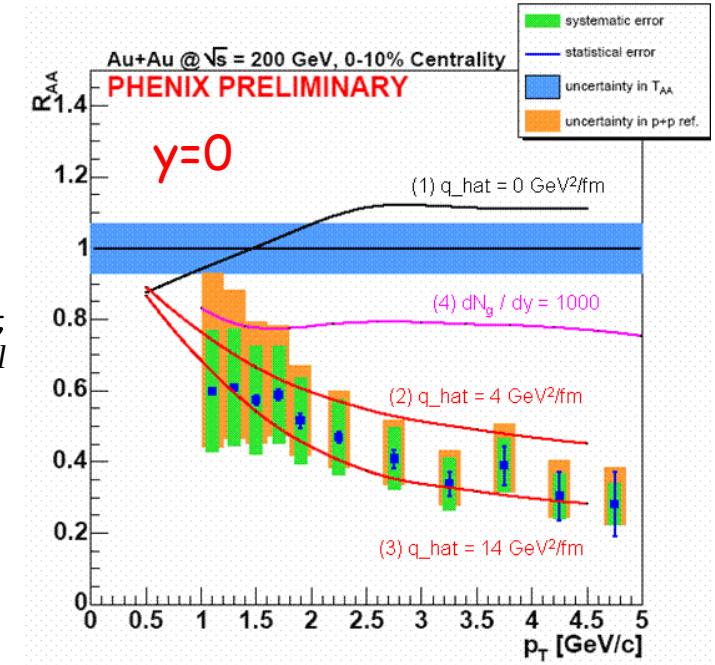




Energy Loss and Flow via Heavy Quarks

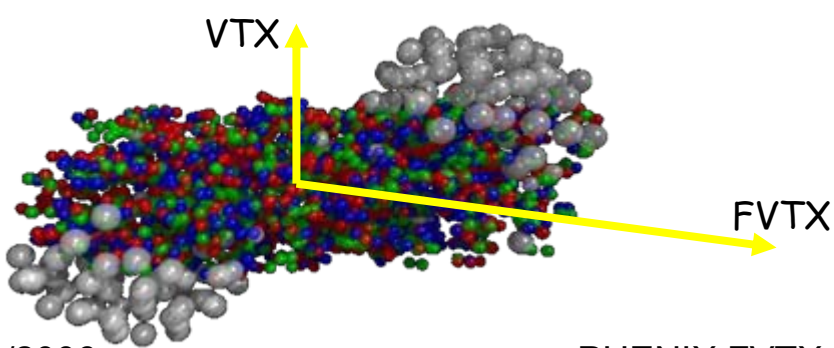
Recently energy loss & flow of heavy quarks have been observed at central rapidity via their decay to single leptons (electrons or muons)

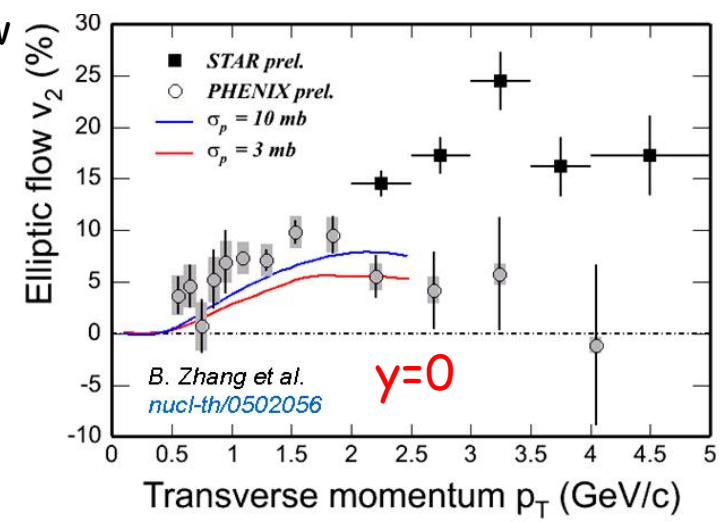




Need to extend these measurements to forward rapidity using muons, with explicit identification of charm and beauty via their downstream secondary vertices

The wide rapidity range with the FVTX should allow characterization of the hot-dense deconfined medium and its evolution





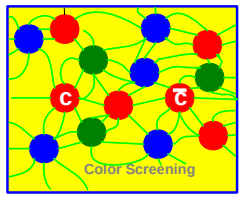
J/ψ Suppression - Sequential Screening vs Regeneration ?

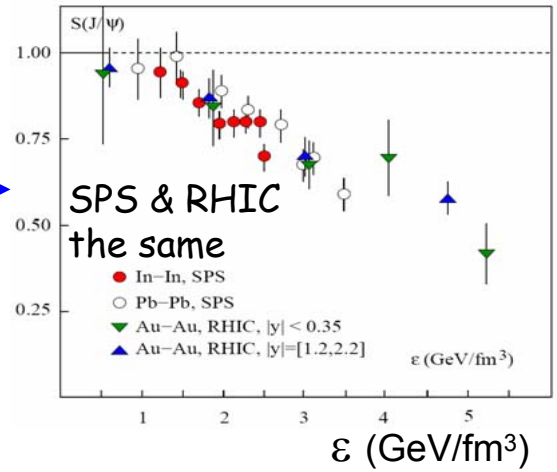
Sequential screening of the higher-mass resonances that feed-down to the J/ψ; with the J/ψ itself still not dissolved?

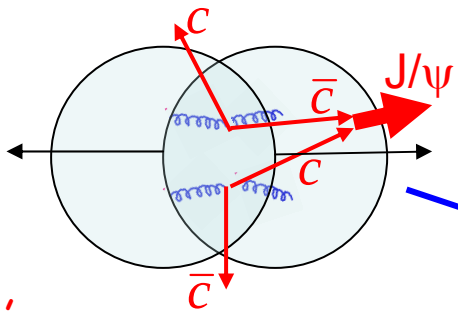
… or

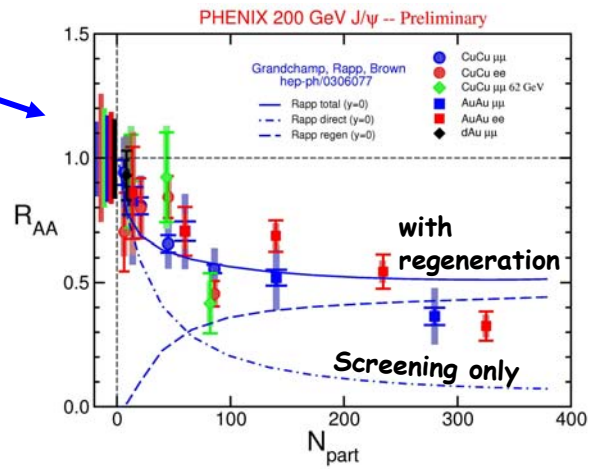
Color screening of $c\bar{c}$ in a deconfined medium + regeneration due to large charm density?

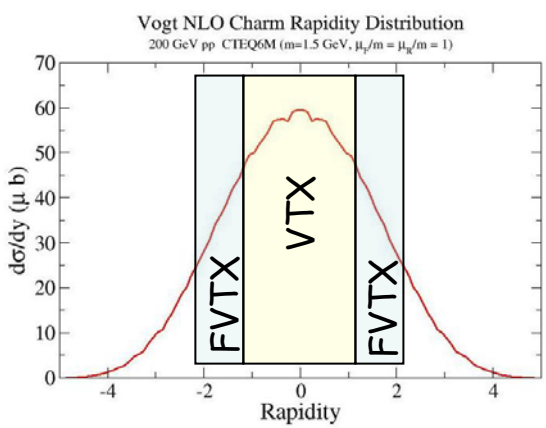
FVTX → better mass resolution, lower backgrounds, & separation of ψ'









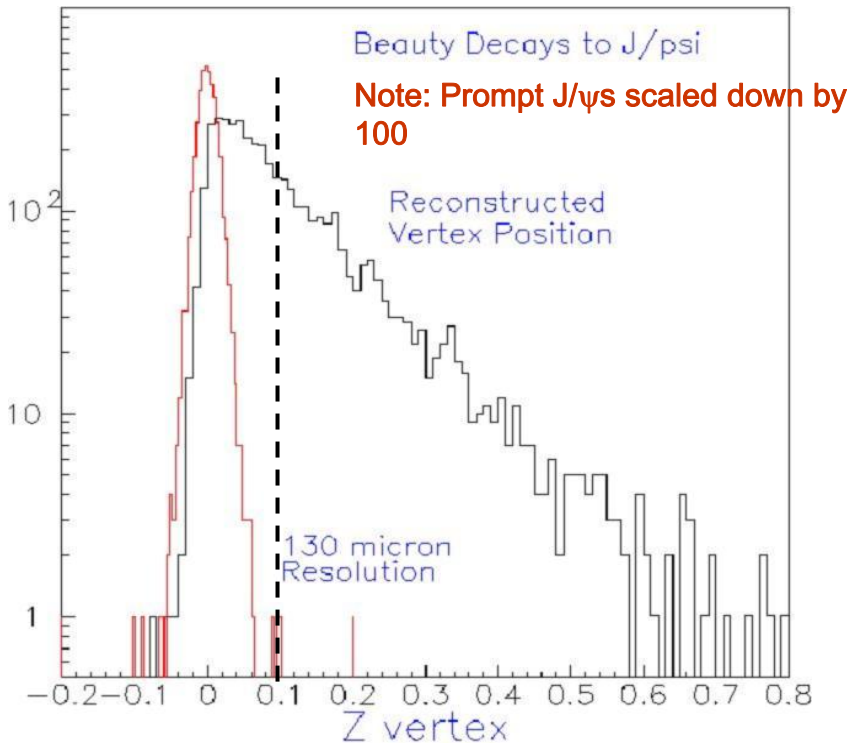


Need robust measurement of the charm and beauty cross sections over a broad rapidity range to constrain regeneration models for J/ψ production

$B \rightarrow J/\psi\ X$ – An Explicit Measurement of Beauty

<u>$B \rightarrow J/\psi\ X$</u>

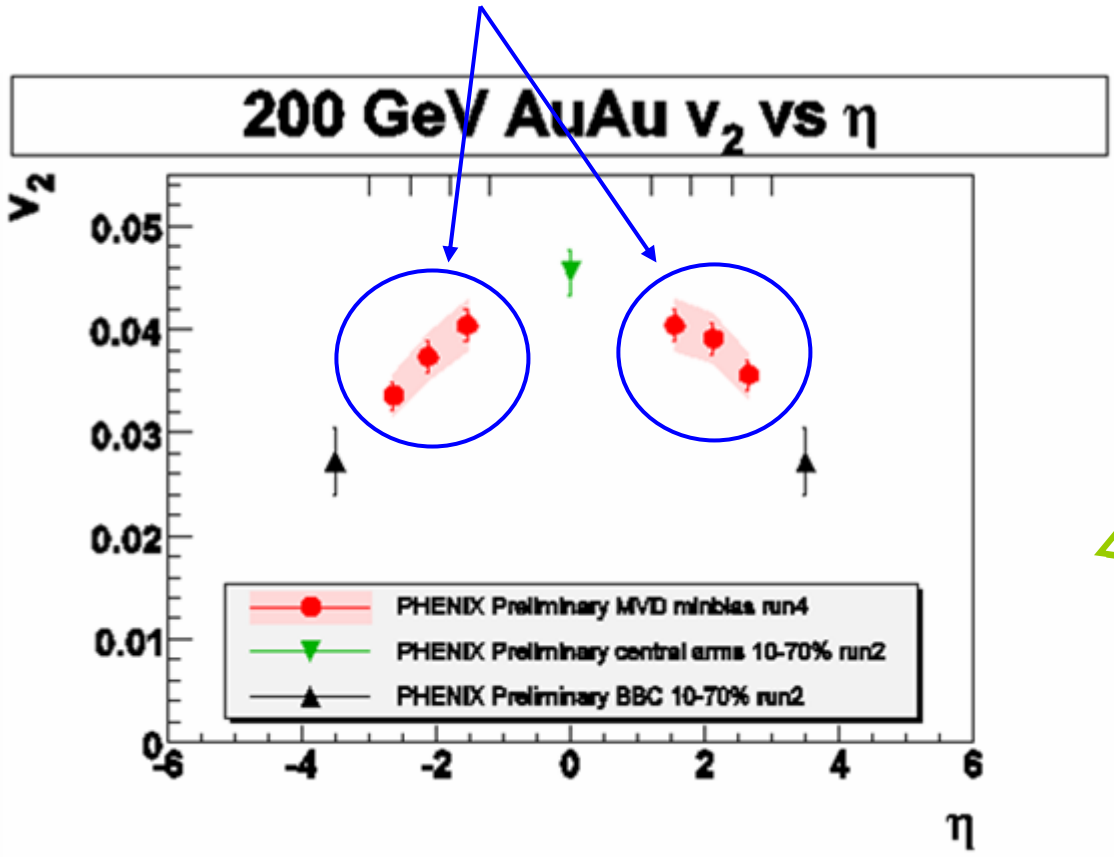
- explicit identification of B's with the FVTX via their downstream vertex
- allows disentangling B's from D's in the single muon spectra by measuring the B cross section independently
- provides direct measurement of contribution of B's to the J/ψ; especially important in strong screening scenarios for the QGP (where direct J/ψ disappear while those from B's remain)

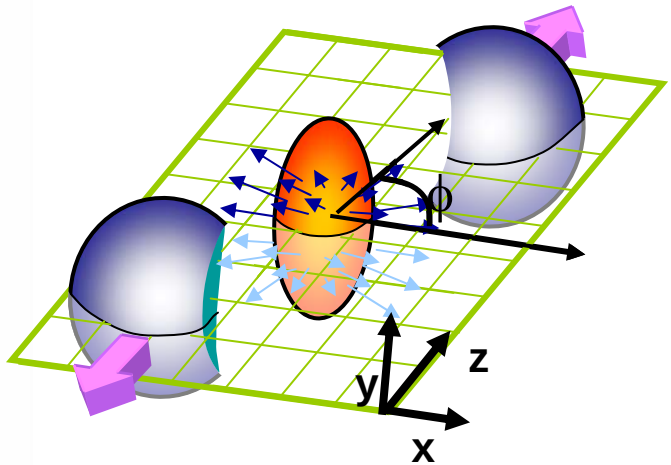


Reaction Plane Measurement with the FVTX

A side-benefit of the FVTX

- reaction plane in a rapidity region where v2, the flow asymmetry, is larger than in the beam-beam counter rapidity range
- also helps with bias issues by adding another rapidity range for the reaction plane measurement

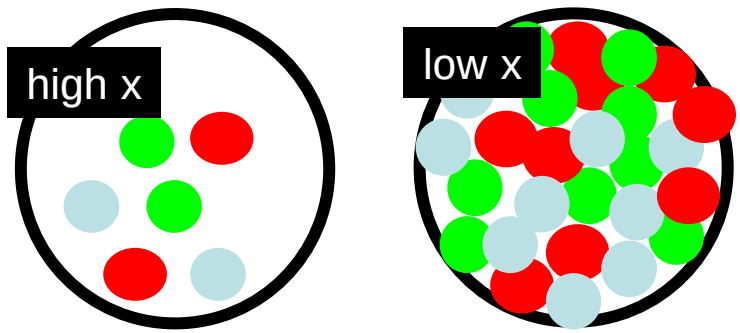


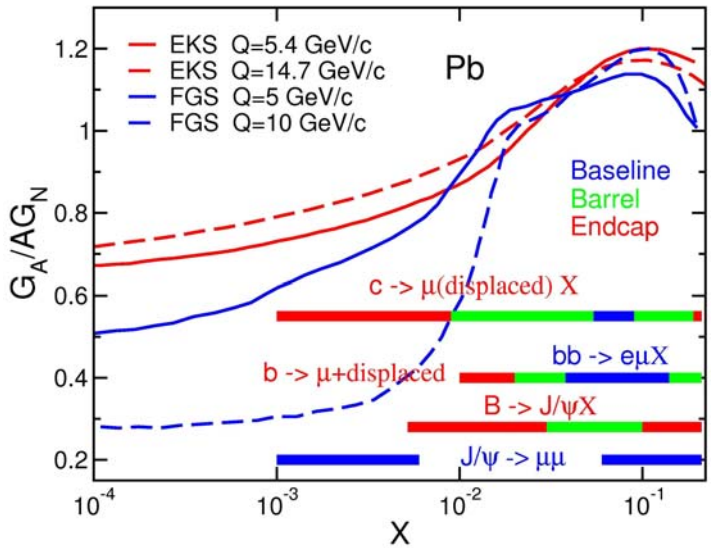


Gluon Saturation or Shadowing in Cold Nuclear Matter (CNM)

Shadowing – depletion of low-momentum partons (gluons) in nuclei:

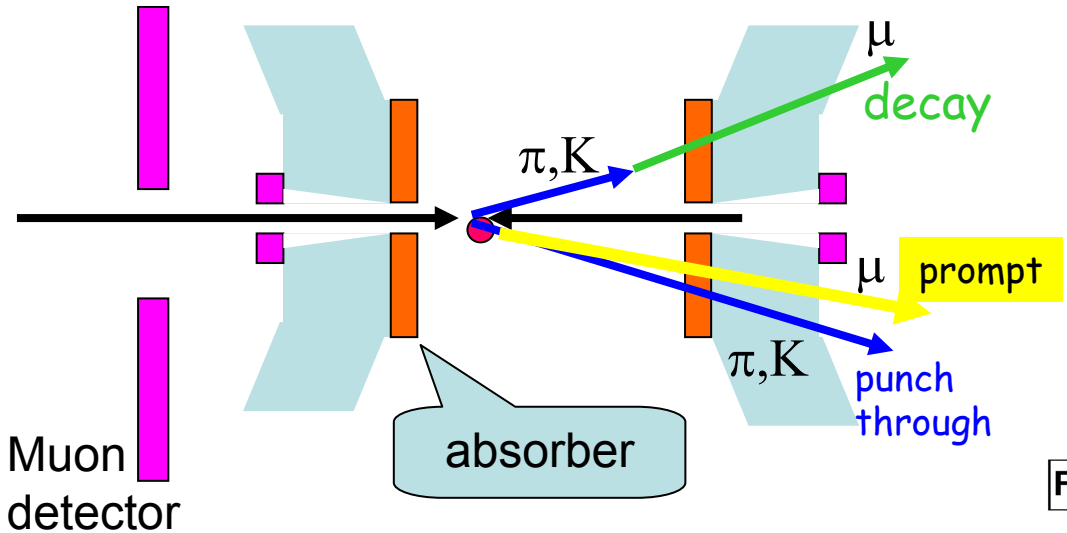
- gluon saturation – large density of small-x gluons crowds some out resulting in depletion at small-x and enhancement (anti-shadowing) at moderate x
- Color Glass Condensate (CGC) - at low-x there are so many gluons that $2 \rightarrow 1$ diagrams become important and deplete the low-x region
- coherent-scattering causing "shadowing"
- Amount of gluon shadowing differs by up to a factor of three between different models!

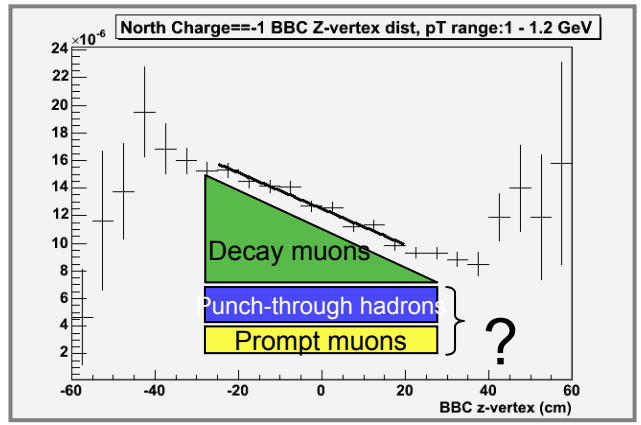


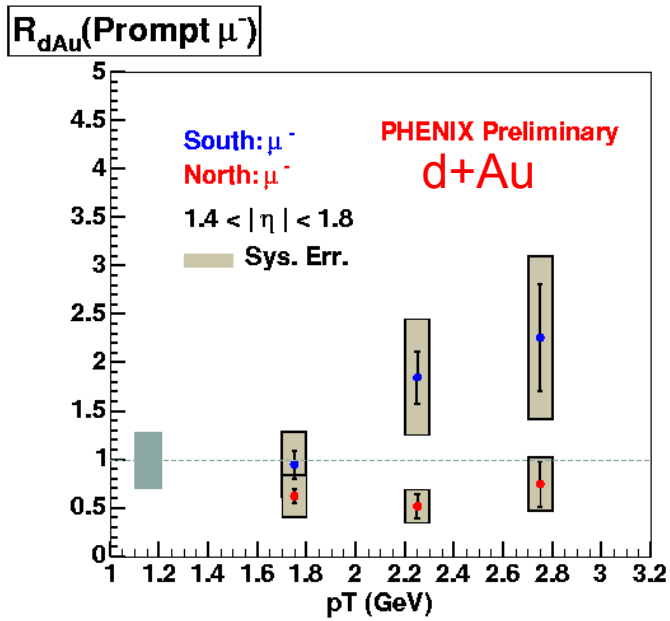


FVTX pushes robust event-by-event coverage with heavy-quarks into the small-x shadowing region

CNM effects on single muons – hadrons, charm and beauty





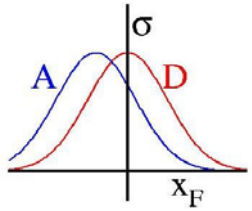


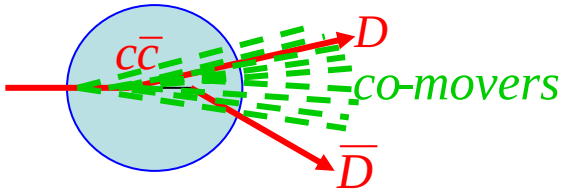
Recent prompt muon (charm & beauty) measurements from statistical subtraction methods suffer from large systematics. Event-by-event FVTX measurements will yield much more accurate measurements and allow separation of charm from beauty

The J/ψ - a Cold Nuclear Matter Puzzle

J/ψ and ψ′ suppression is a puzzle with possible contributions from shadowing & from:

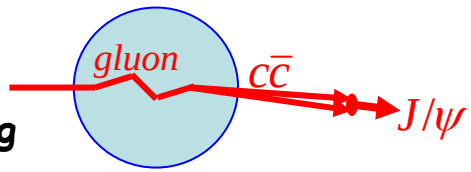
Energy loss of incident gluon shifts effective x_F and produces nuclear suppression which increases with x_F



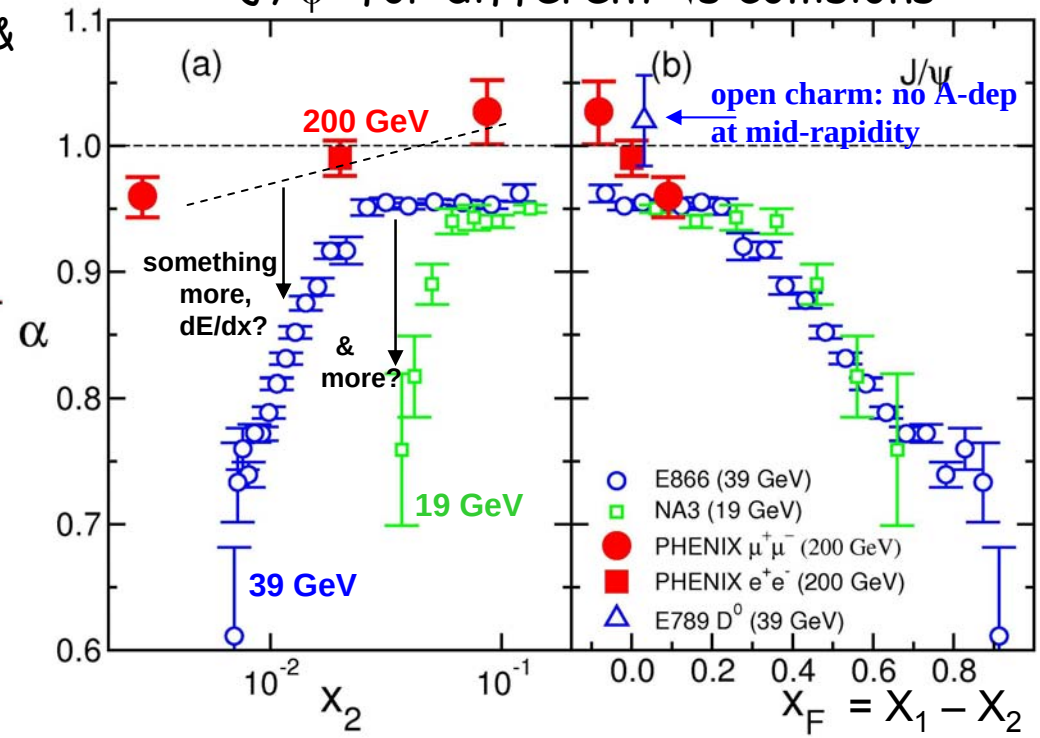


Absorption (or dissociation) of $c\bar{c}$ into two D mesons by nucleus or co-movers (the latter most important in AA collisions where co-movers more copious)

Initial-state gluon multiple scattering causes **p_T broadening** (or Cronin effect)



J/ψ for different √s collisions

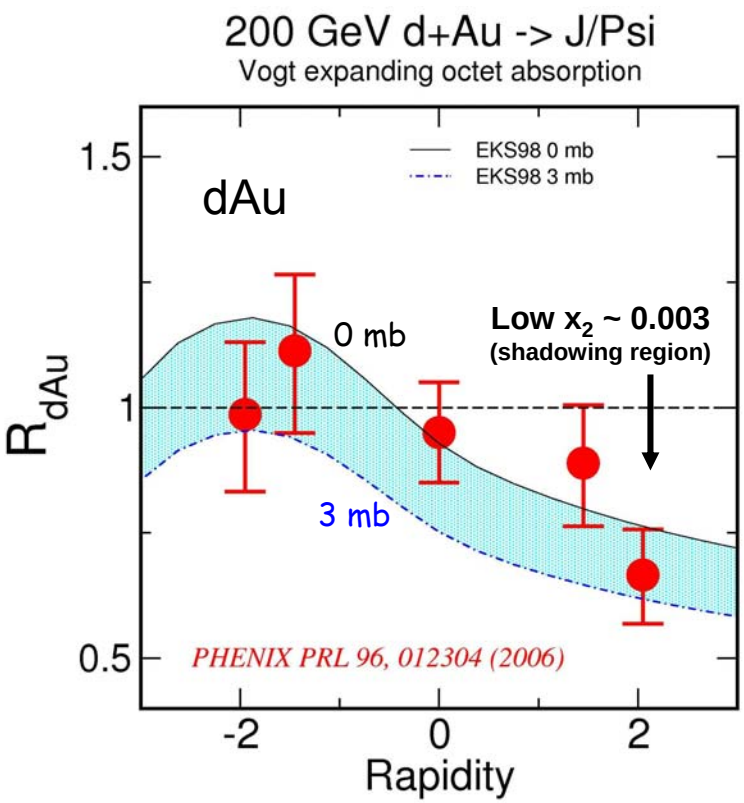


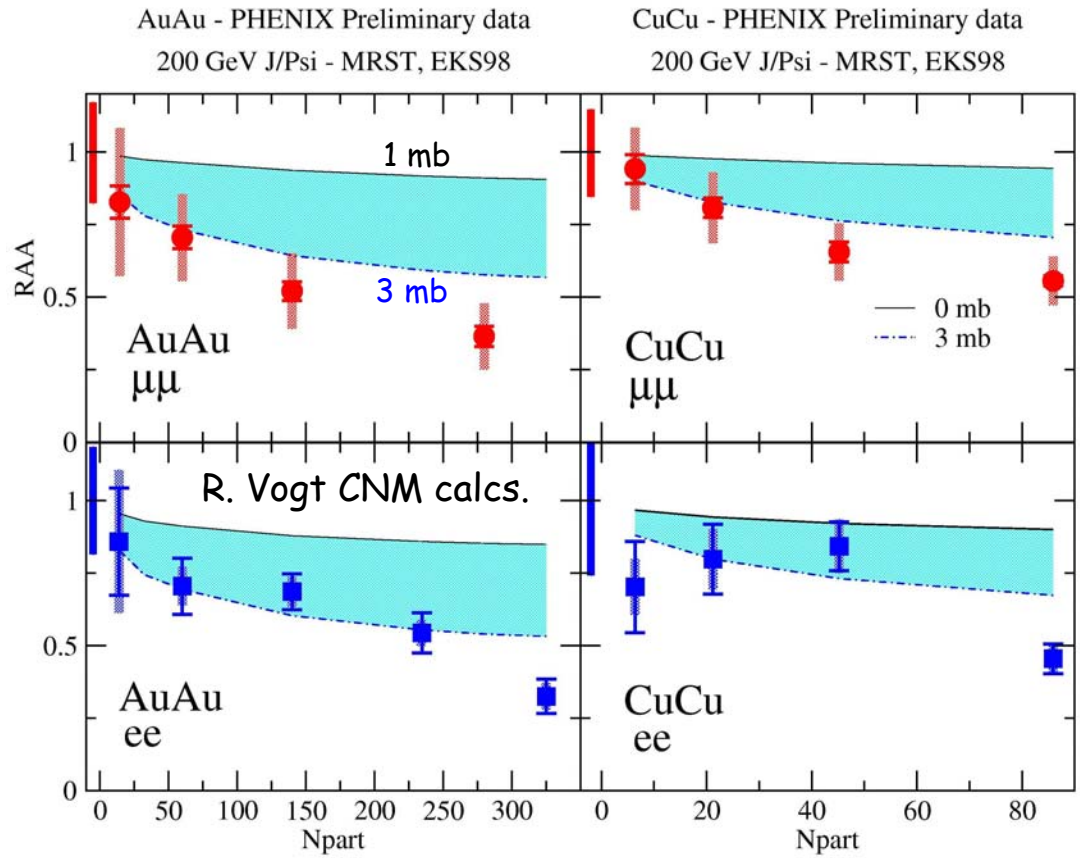
Not universal vs x_2 as expected for shadowing, but does scale with x_F, why?

- initial-state gluon energy loss?
- Sudakov suppression (~energy conservation)?

Need precision data & ψ′ at RHIC + open charm - FVTX background rejection and better mass resolution will be essential as luminosity and statistics increase

J/ψ suppression in AA collisions & CNM baseline



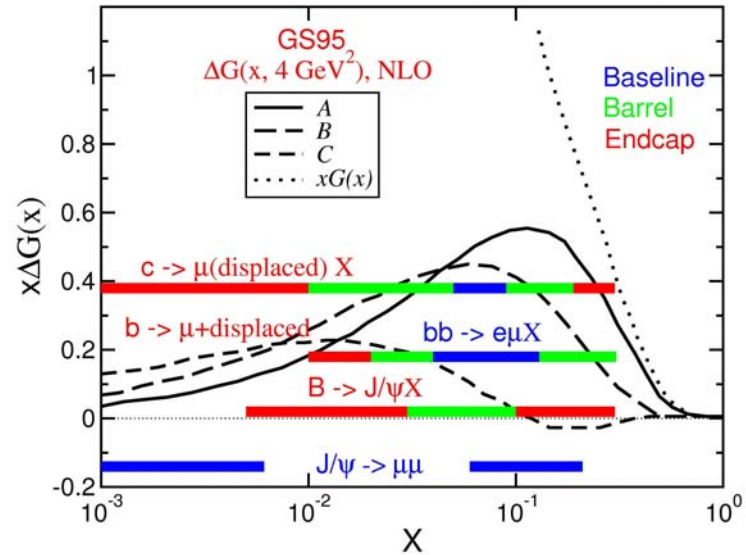


So far dAu J/ψ data gives poor constraint of cold nuclear matter (CNM) effects. FVTX background rejection and better mass resolution will be essential as luminosity and statistics increase

AA suppression is somewhat stronger than poorly constrained CNM calculations predict

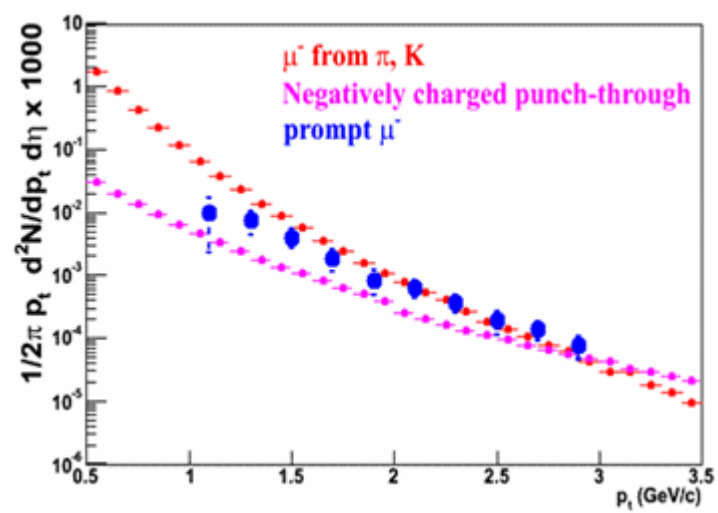
Looking for the Nucleon Spin - are the gluons players?

FVTX adds coverage for charm and beauty that could see the dramatic x variations predicted in the gluon spin asymmetries



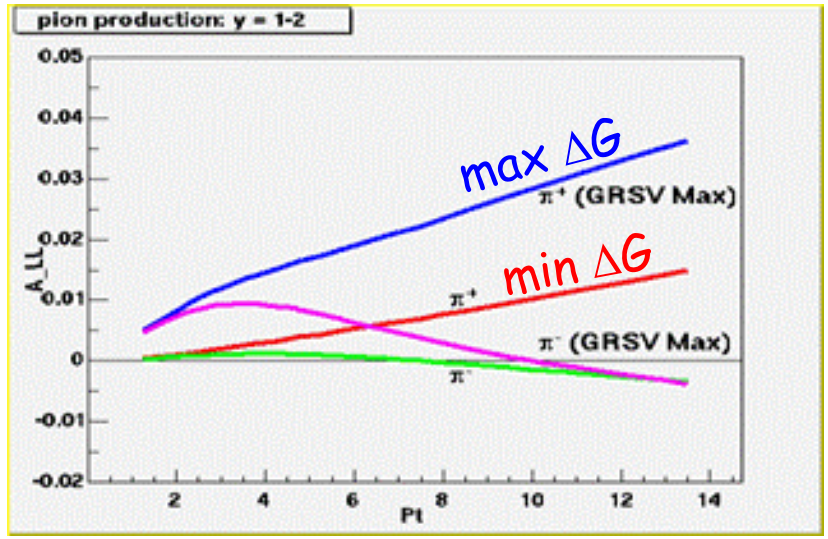
Present single-μ spectra have approximately equal contributions from charm+beauty, light-hadron decays, and punch-through hadrons.

Both of the latter "backgrounds" can be significantly reduced by the FVTX



Other Measurements of Gluon Spin at Forward Rapidity

Predicted spin asymmetries for pions at forward rapidity, also sensitive to gluon spin

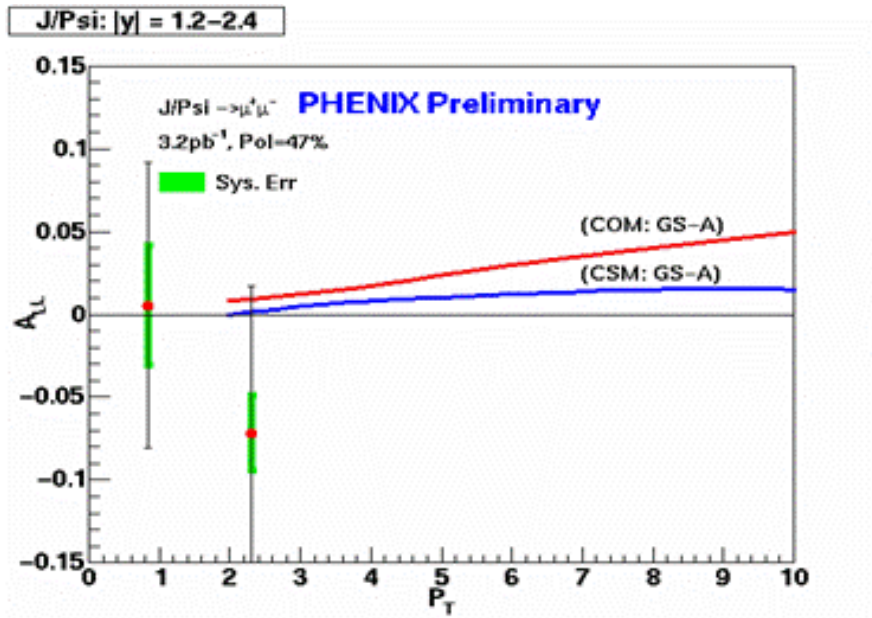


More robust measurements with smaller systematics for forward hadrons with detached vertices from FVTX

1st measurement of the spin asymmetry for J/ψ using dimuons in the forward/backward muon arms

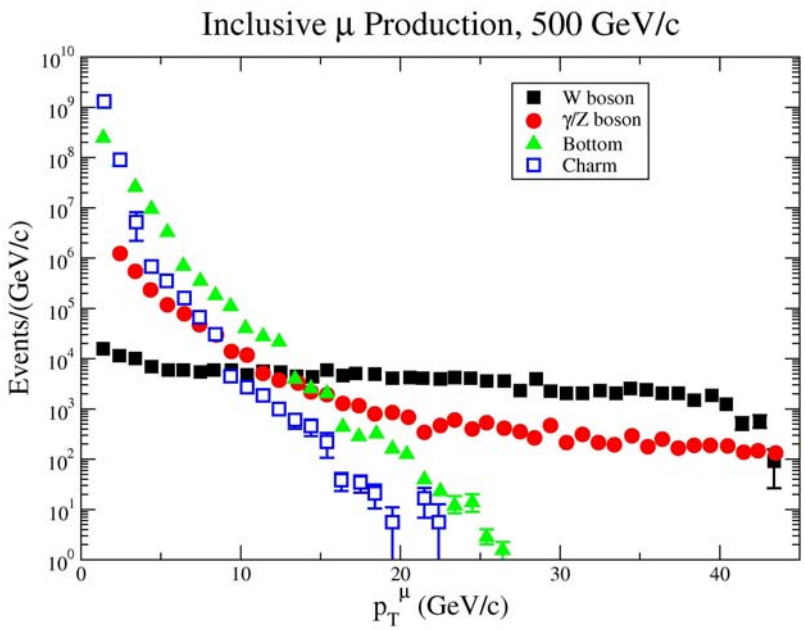
FVTX → better mass resolution, lower backgrounds, & separation of ψ'

ψ' physics cleaner since no feed-down (~420 ψ'/week for RHIC-II pp)



Do the nucleon's anti-quarks also contribute to the nucleon spin?

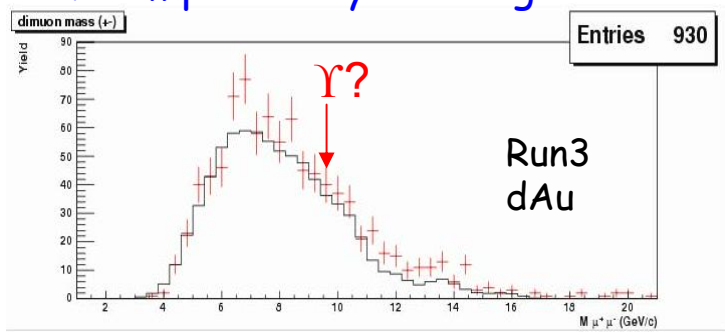
- Reduce jet backgrounds to W's with isolation cut in FVTX
- Also reduce contamination from mis-reconstructed tracks at high-p_T
- Access lower-p_T W's by rejecting b & c with a detached vertex cut



Reducing backgrounds for back-to-back dimuons

- access to mid-rapidity ϒ's and Drell-Yan, which probe large-x gluons and their spin

backgrounds for pairs with one muon in each arm presently are large



Expected Rates and Triggering

Observable	Counts per RHIC-I p+p week	Counts per RHIC-I Au+Au week	Counts per RHIC-II p+p week	Counts per RHIC-II Au+Au week
Luminosity	9.9 pb^{-1}	0.33 nb^{-1}	33 pb^{-1}	2.5 nb^{-1}
$D \rightarrow \mu X$	~ 21M	~24M	~ 71M	~180M
$B \rightarrow \mu X$	~260k	~300k	~880k	~2.3M
$B \rightarrow J/\psi X \rightarrow \mu \mu$	~200	~220	~650	~1.7k

Rates for p+p and Au+Au in one week of running. The semi-leptonic decay rates are before application of a vertex cut

See Appendix C of the proposal for details of the rate calculations & the assumptions underlying them

Physics with the FVTX can be done at highest RHIC-I luminosities with existing triggers + the muon trigger upgrade (RPC's); but for RHIC-II we will need additional trigger rejection from the FVTX

FVTX Physics Summary

Quark Gluon Plasma & AA collisions
- heavy quark dE/dx & flow
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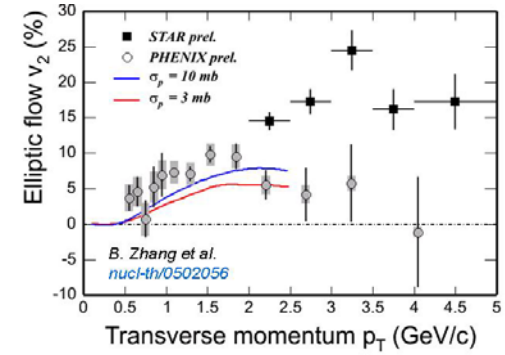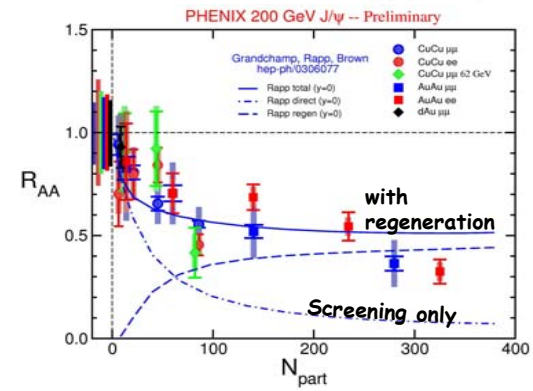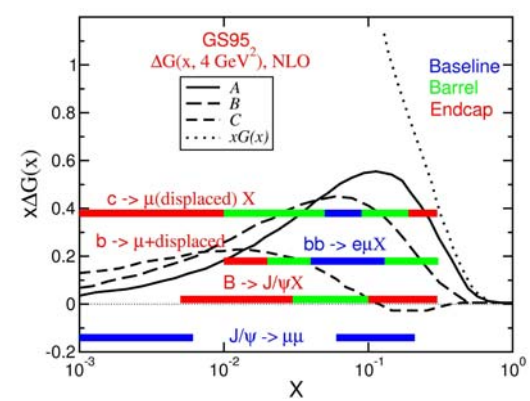
A rich physics program spanning entire range of RHIC collisions and physics – from polarized protons to central AuAu collisions