Upgrade plans for PHENIX

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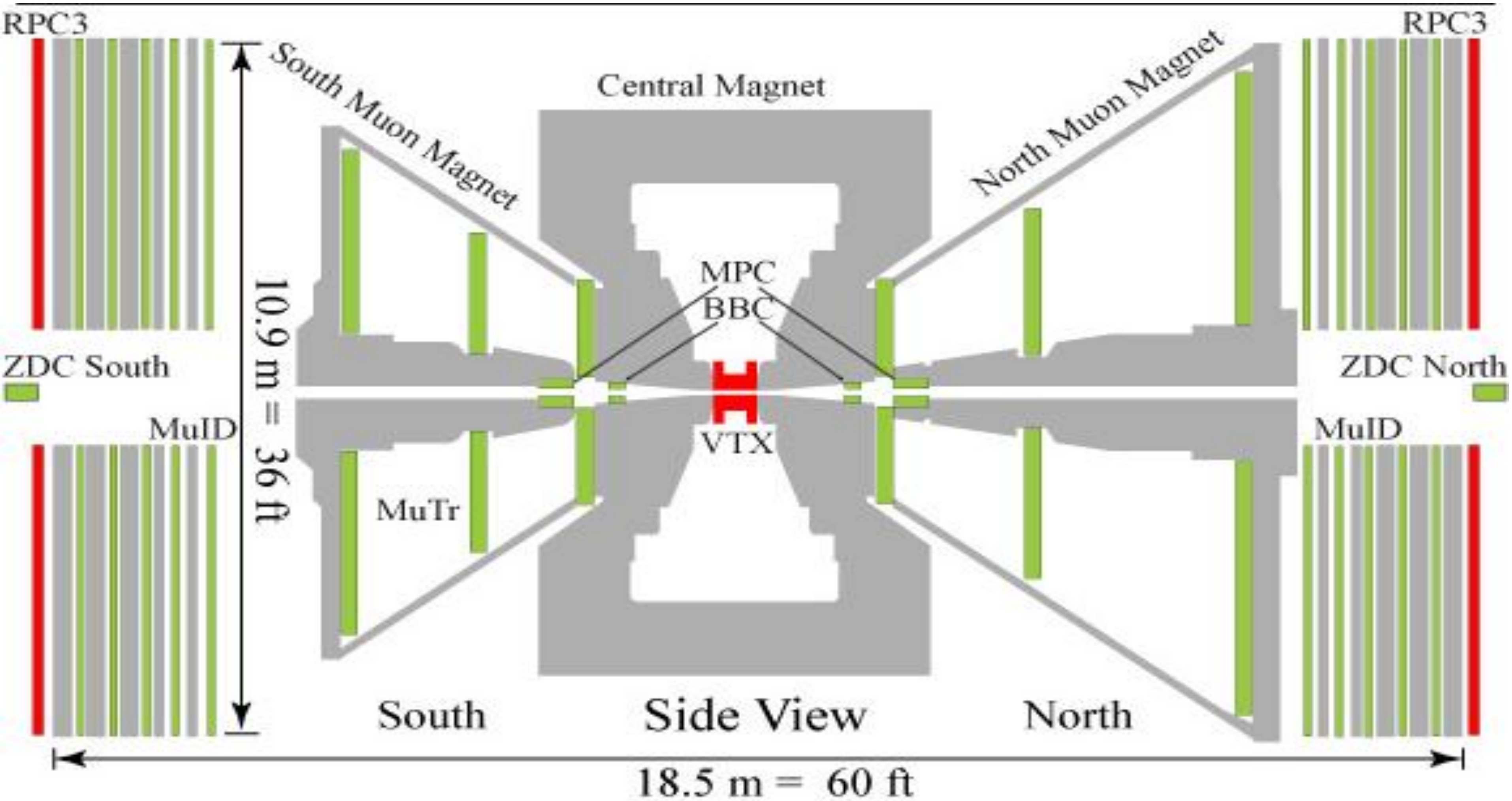
for the

PHENIX Collaboration

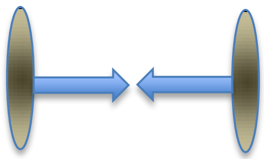
Outline

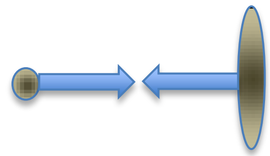
- Brief review of PHENIX Experiment and highlights from the first ~10 years of data taking
  - What we have learned, and what we'd like to learn
- Recent and Near term upgrades
  - MPC-EX
- sPHENIX Conceptual Design
  - Midrapidity detector
    - Jet measurements to probe medium created in Heavy Ion (HI) collisons
  - Forward rapidity detector
    - Understanding large Single Spin Asymmetry (SSA) measurements
    - Studying Cold Nuclear Matter (CNM) and low x gluon in dAu collisions
- Conclusions

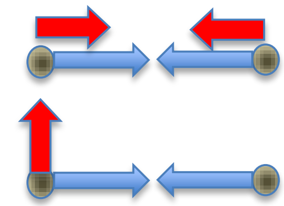
PHENIX Design

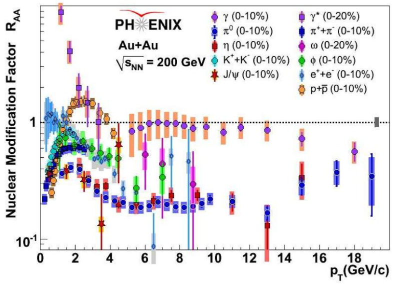


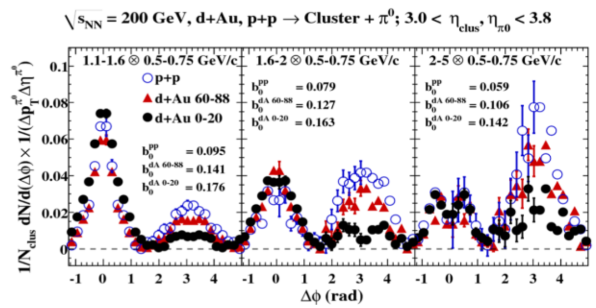
Broad Physics Program

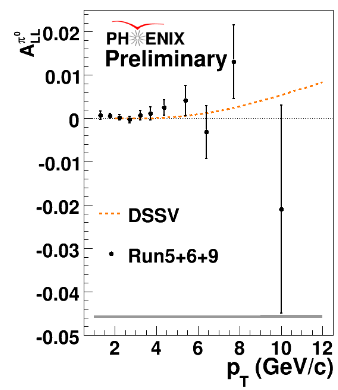


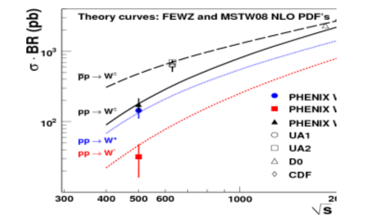


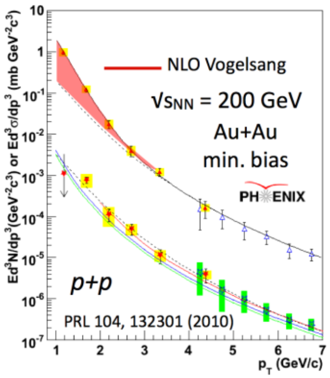


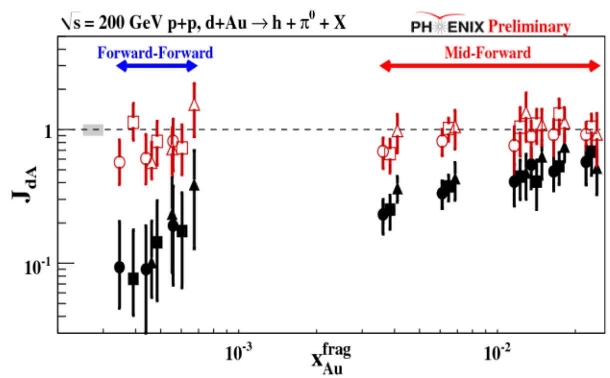


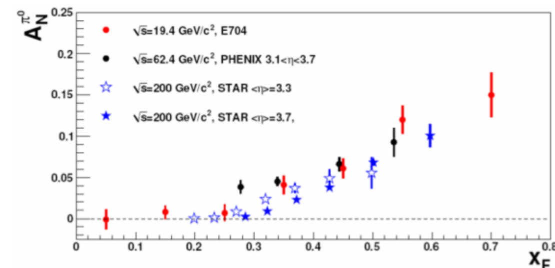








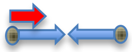




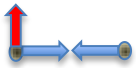
- PHENIX has
  - Probed new matter in HI collisions
  - Studied Cold Nuclear Matter and low x in dAu
  - Explored the nucleon spin structure in polarized pp collisions

Open Questions

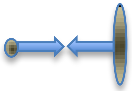
- Many open questions remain:



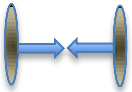
  – What are the helicity dependent sea quark distributions (Y. Kim, Tues.)?



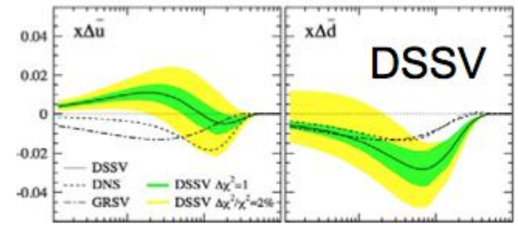
  – Are the large transverse spin asymmetries due to Sivers effect? Collins effect? Some combination?

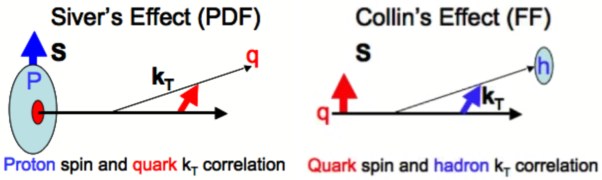


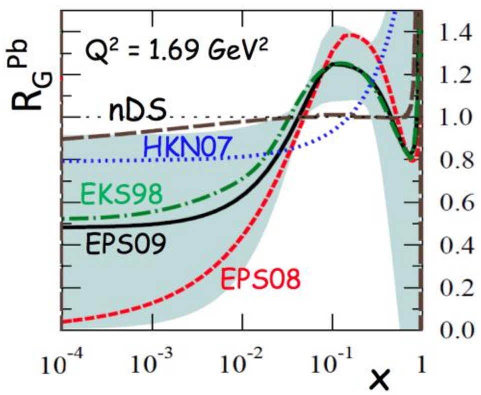
  – How do low x gluons behave? What is the source of the suppression at low x seen in correlated forward π^0s? Is this shadowing, or a gluon condensate?



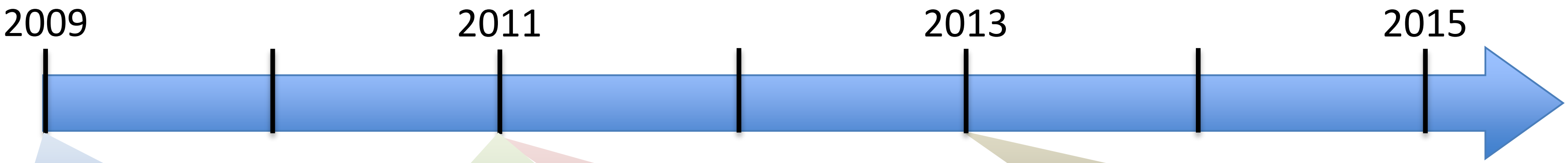
  – What are the properties of the medium created in Heavy Ion collisions? How are quarks traversing the medium effected (jet suppression)? How are heavy quarks (charm and bottom) affected?

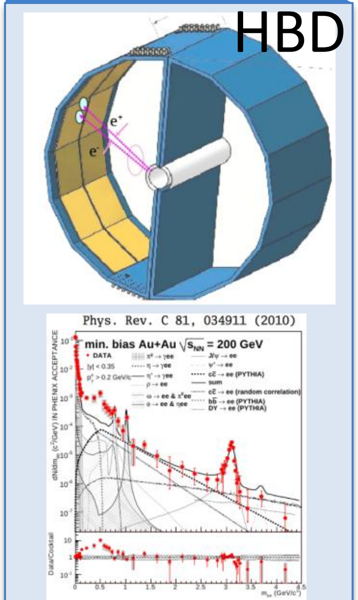




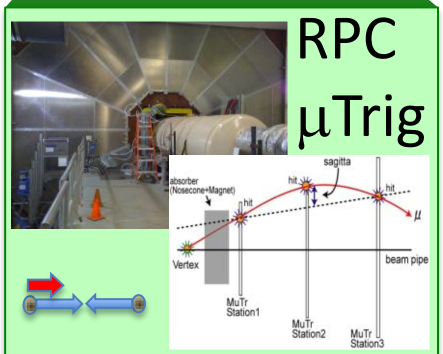


Recent and Near Term Upgrades

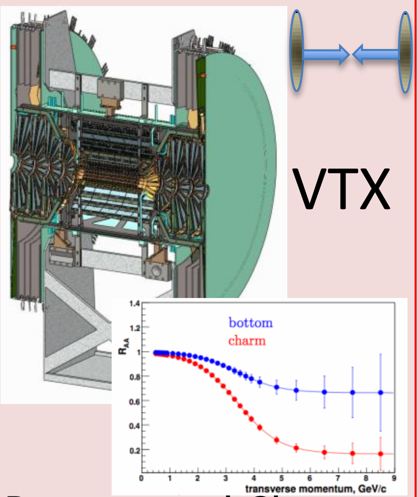




Removing Dalitz decays

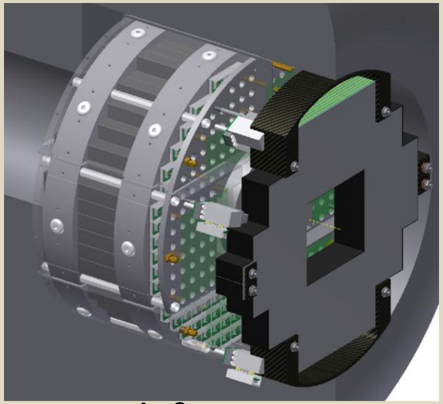


Resistive Plate Chambers (RPC) and sagita based trigger (MuTrig) for W A_L measurement



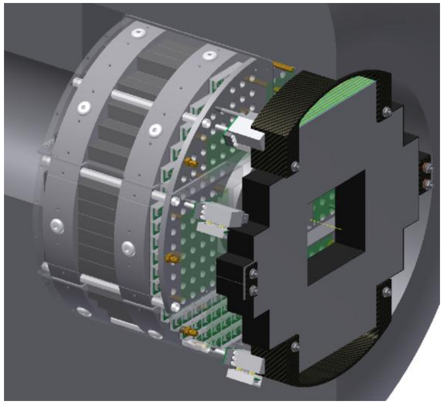
Bottom and Charm separation to study different medium effects in QGP

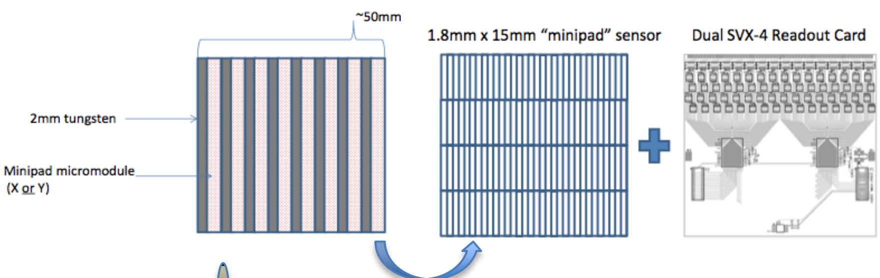
MPC-EX ***Proposed***

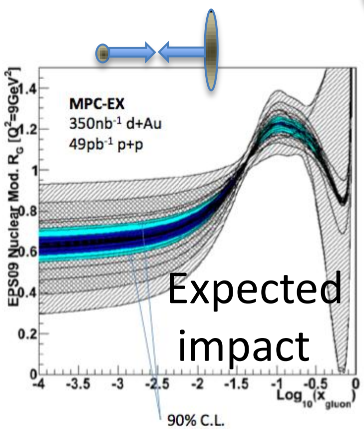


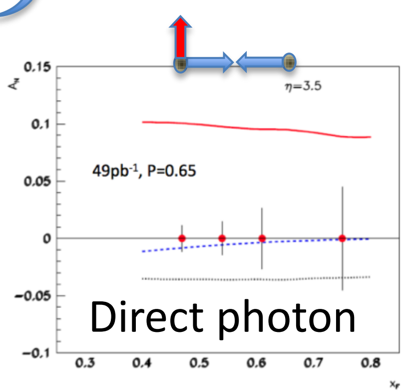
Photon/π^0 separation to probe CNM and transverse spin effects

MPC-EX





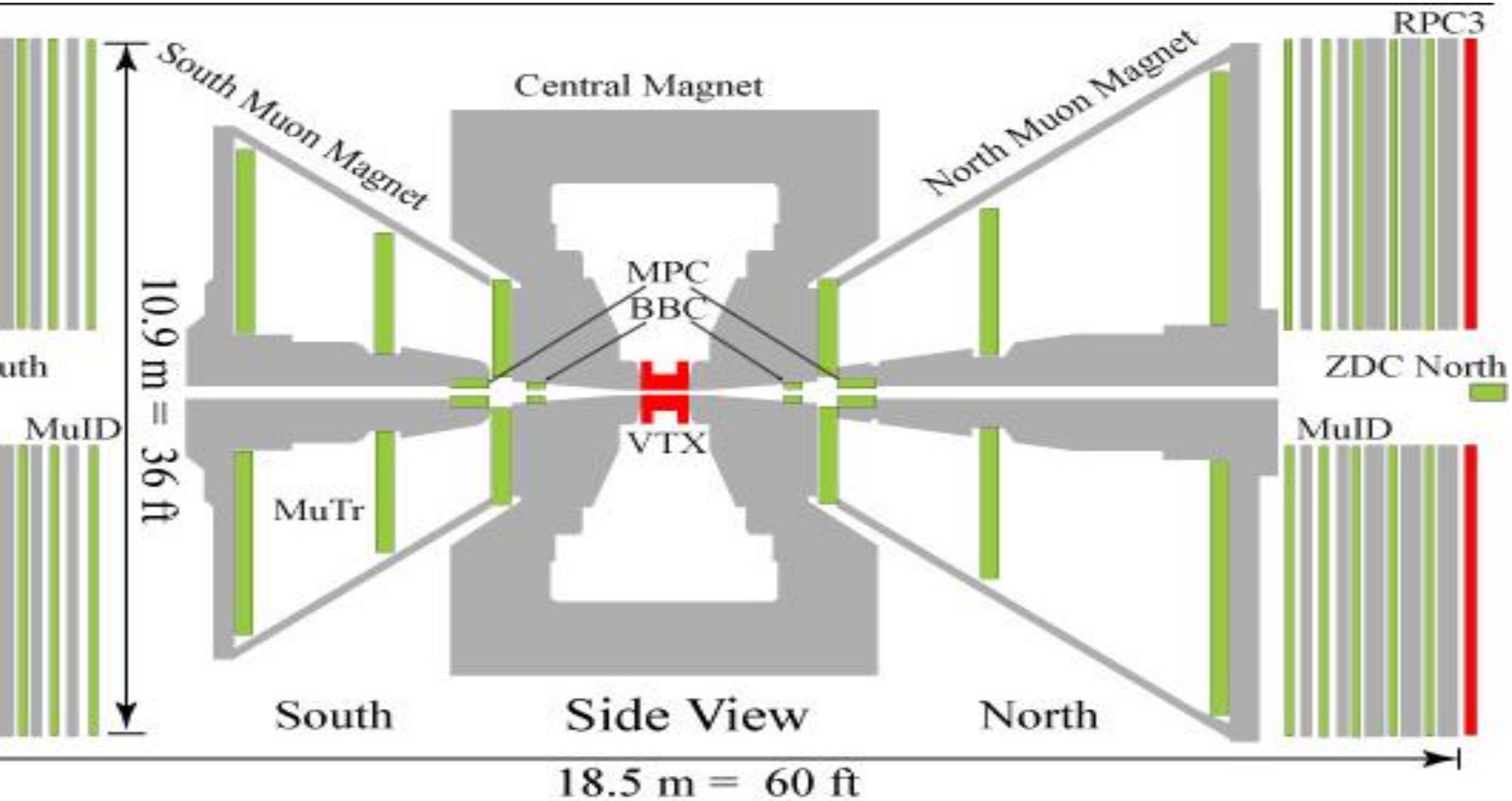




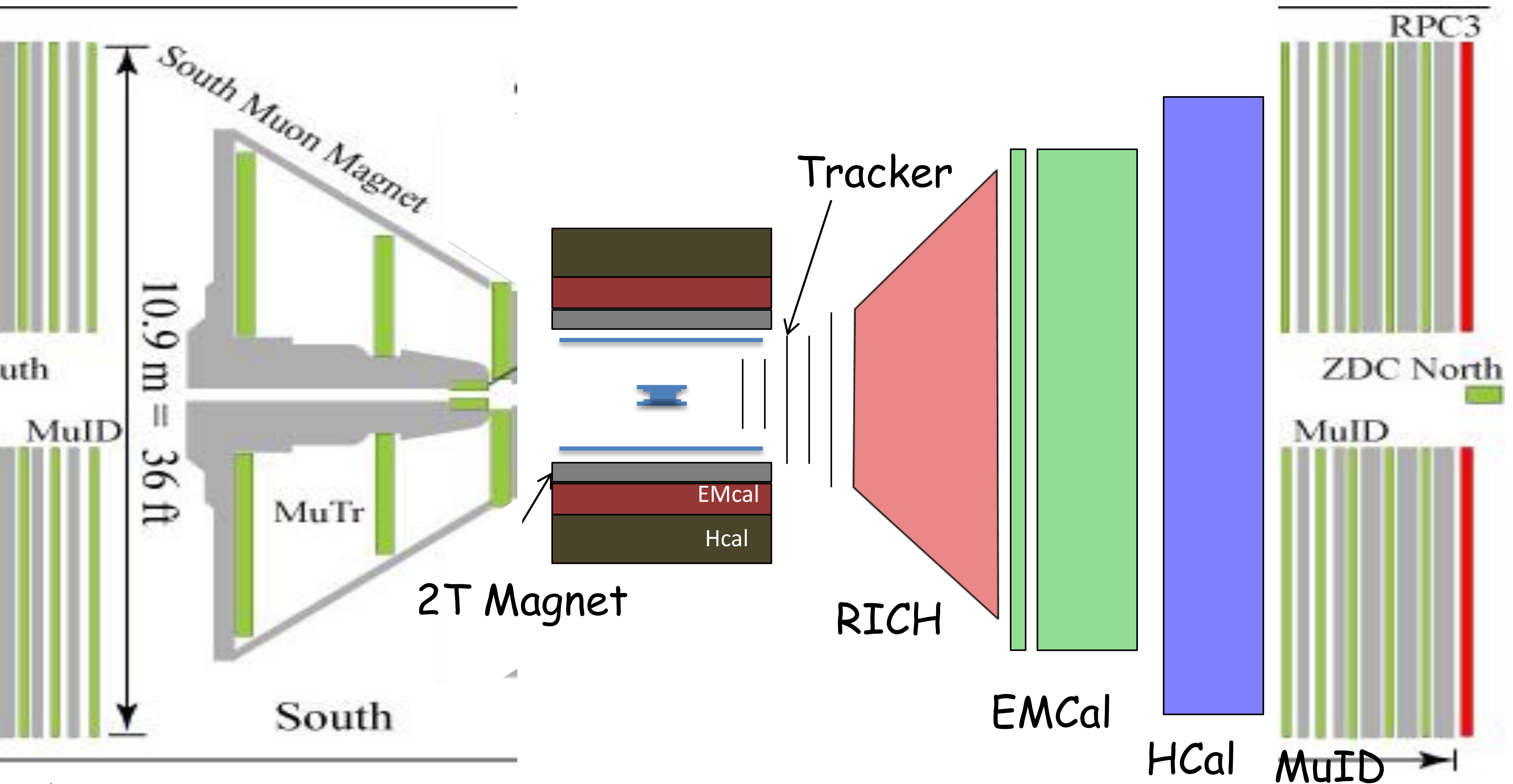
- Large uncertainty in R_G, particularly at low x
- Current MPC ($3.0<|\eta|<3.7$) can reach this low x region (M. Chiu, Tues.)
- Add preshower extension to MPC (MPC-EX)
  - Multilayer Silicon "minipad"/Tungsten sandwich
  - In proposal process
- Allow π^0–γ separation at large p_T.
- Can greatly reduce uncertainties in R_G at low x
- Improve current SSA measurements as well as open new channels (Jet, direct γ)

sPHENIX (CONCEPTUAL DESIGN)

PHENIX Design



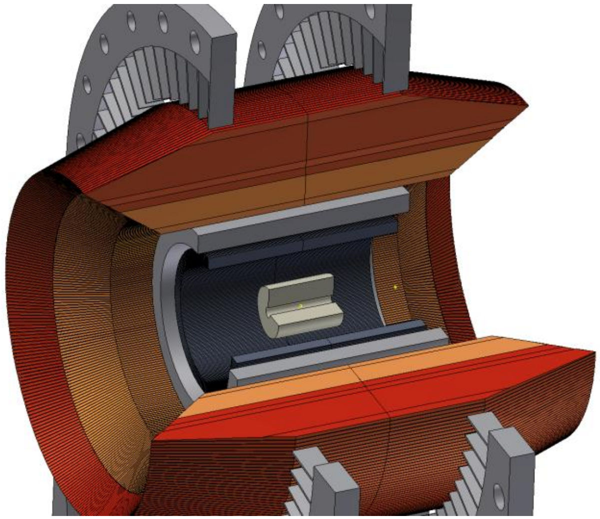
sPHENIX Design



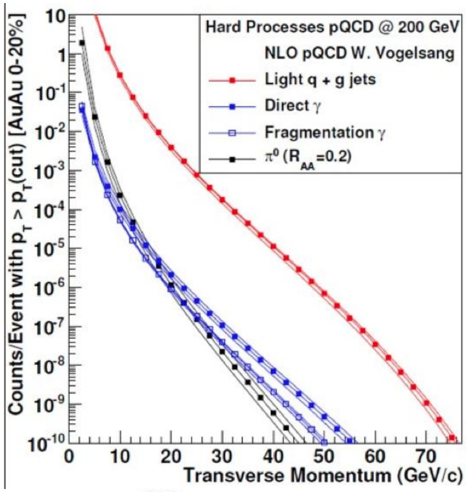
*Not to scale

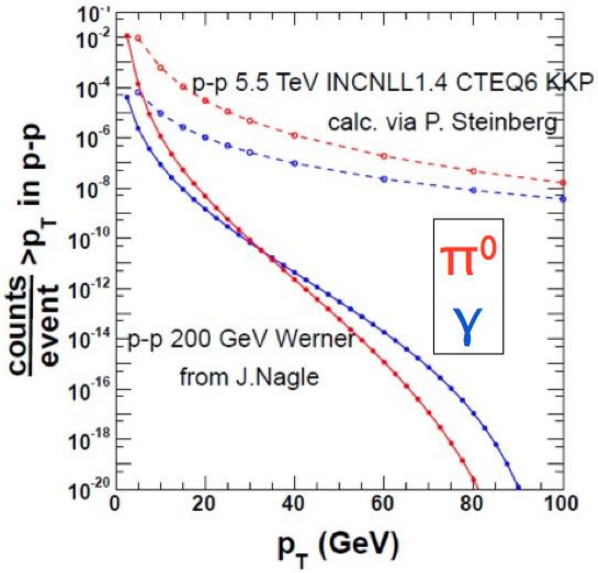
Mid Rapidity Region

- Full 2π coverage, $|\eta|<1$
- Electromagnetic and Hadronic calorimetry
- 2T Solenoidal Field
- Primary (initial) focus is jet and di-jet measurements in HI
- VTX detector for central tracker
  - Also allow heavy quark jets
- Designed to include possible upgrade path: additional tracking, EID, ePHENIX (S. Bazilevsky, Wed.)
- Will take full advantage of RHIC's flexibility: Au+Au, Cu+Au, U+U, etc.

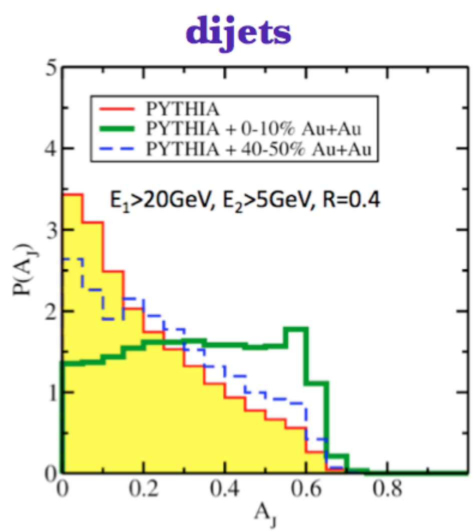


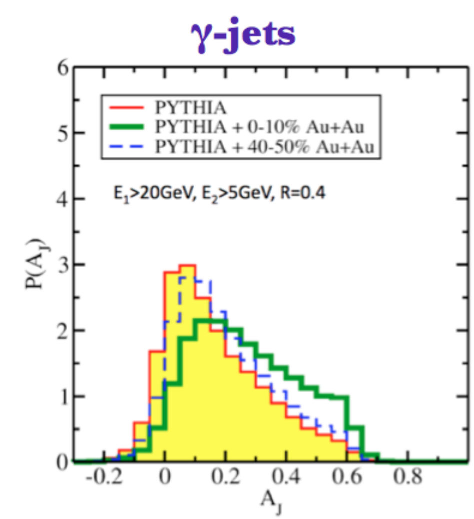
Dijet and γ-jet





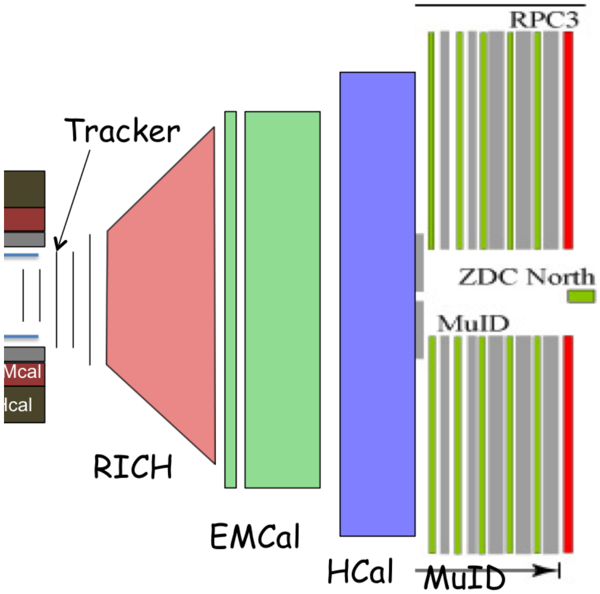
- Expect large jet rate at RHIC
  - Assumes stochastic cooling only
- Direct γ/π^0 ratio at RHIC means better access to γ-jet than at LHC
- Can study medium modification through jet energy asymmetry A_j





Forward Detector at sPHENIX

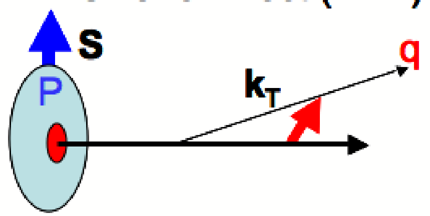
- Primarily interests
  - p+p: Forward transverse asymmetries
    - What is the source of large transverse SSA? Sivers? Collins?
    - Drell Yan (DY) Sivers: test factorization
  - d+A:
    - What are CNM effects relevant for A+A initial conditions?
    - Low x behavior→saturation?
  - A+A:
    - 3D “image” of medium



Separating Collins and Sivers

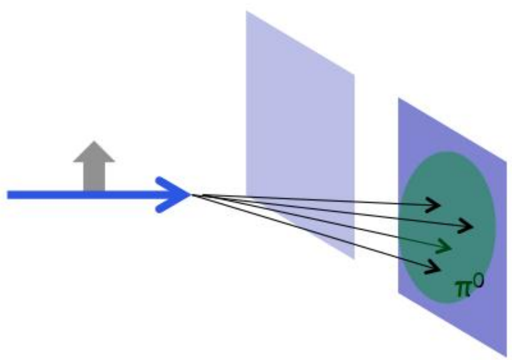
- Source of large SSA seen at RHIC uncertain
- May be Sivers, Collins, or some combination
  - ➜Need to make measurements to separate them

Siver's Effect (PDF)

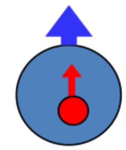


Proton spin and quark k_T correlation

Signature is Jet Asymmetry



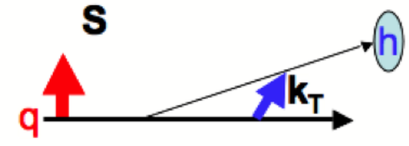
Transversity (PDF)



Proton spin and quark spin correlation

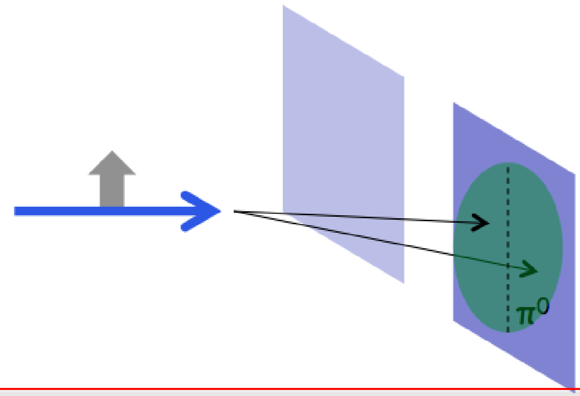
$\otimes$

Collin's Effect (FF)



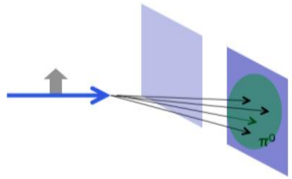
Quark spin and hadron k_T correlation

Signature is Hadron Asymmetry about jet axis

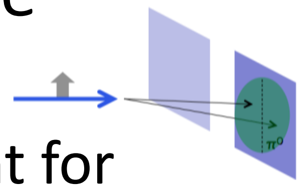


What is Required?

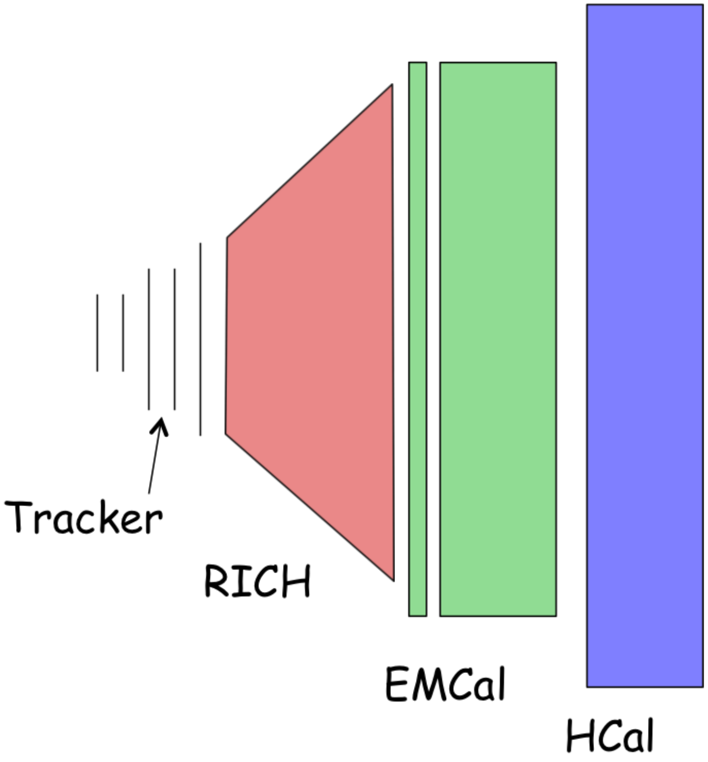
- Good Jet reconstruction to be able to measure Sivers cleanly
  - Electromagnetic and hadronic calorimetry



- Particle ID to measure Collins effect
  - Collins effect different for different hadrons →RICH



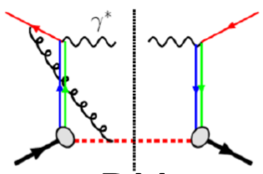
- B Field and tracker to determine charge sign of hadrons



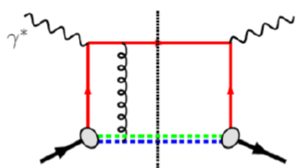
Drell-Yan

Drell Yan production precise probe of our understanding of QCD

- Polarized proton collisions:
- SIDIS and Drell-Yan similar processes



DY



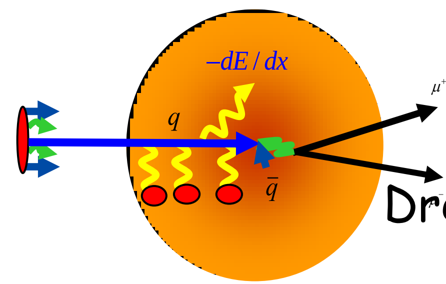
SIDIS

- However, color interaction between the initial or final state quark and the proton remnant cause a specific type of factorization breaking:

  $\text{Sivers}_{\text{SIDIS}} = -\text{Sivers}_{\text{DrellYan}}$

- Therefore, measuring Drell Yan Sivers is a test of our understanding of QCD

- d+A:

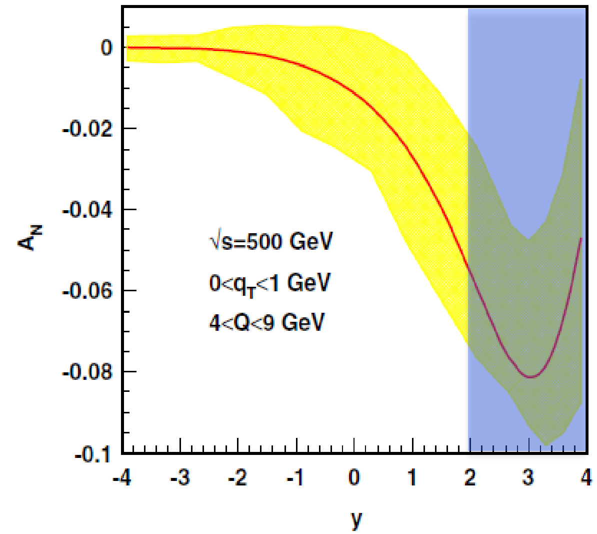


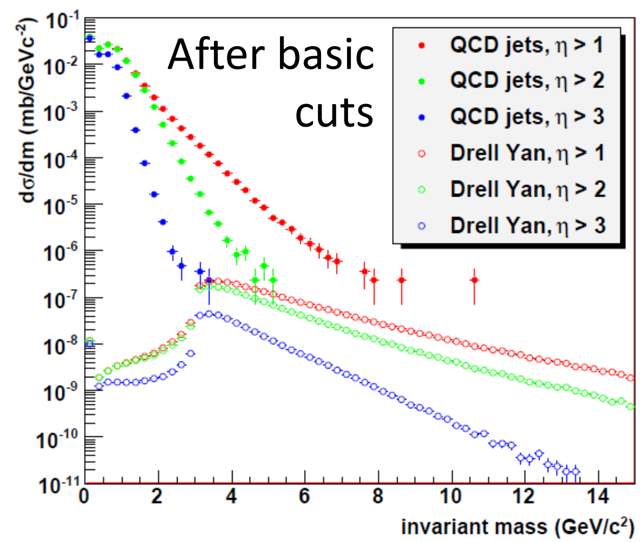
Drell-Yan, J/ψ

- Comparisons of quarkonia and DY production over a broad range in rapidity can help us to disentangle various effects that are expected (initial state, final state, saturation)

What is needed?

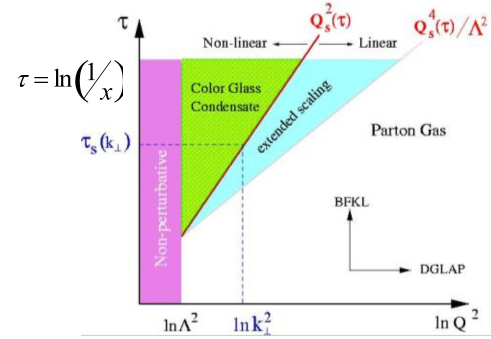
- Measure DY Sivers via $p^{\Uparrow}+p \rightarrow e^+e^-$ above J/ψ mass at $\sqrt{s}$=500 GeV
- Asymmetry expected to peak at y~3
  - Cover $2<\eta<4$
- Charge sign determination
  - Work ongoing to understand how to shape field in large η region
- e/π separation
  - Hadronic calorimetry, preshower

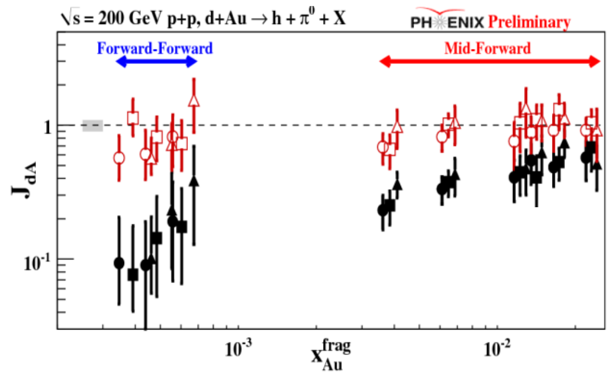


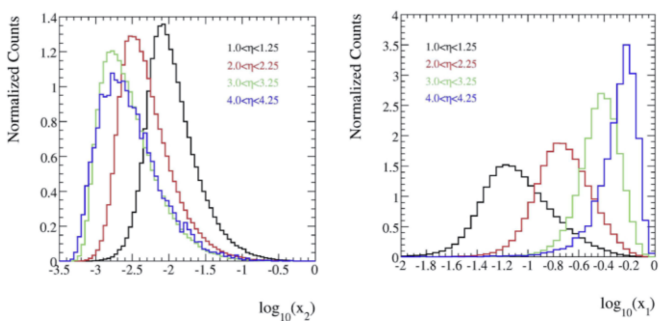


Low-x Structure of Nucleus

- In d+A measurements, can access low x, possibly in saturation region
- Extension of current PHENIX studies at low x
  - Move from single hadrons to jets and di-jets
- By covering large range in η, can access a wide range in the x_2 of the parton in the nuclei to get at shape of R_G
- Need good jet measurement over wide range in forward (dueteron) direction.

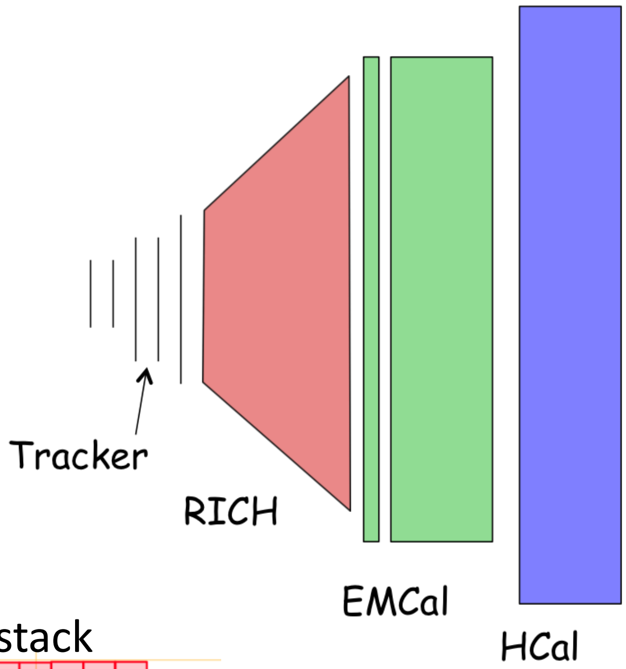


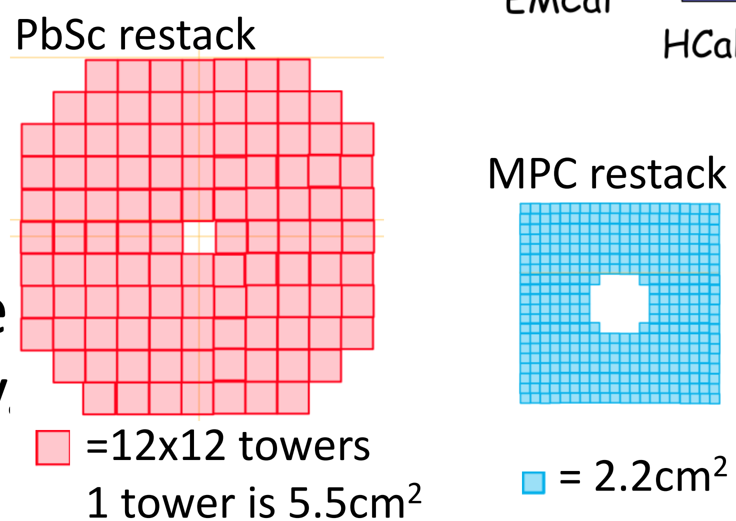




Forward Detector

- Rely on central magnet field
  - Studying other field/magnet possibilities
- EMCal based on restack of current PHENIX calorimetry
  - PbSc from central arm (5.52 cm^2)
  - MPC forward arm (2.2 cm^2)
- For tracker considering GEM technology
- Interest of HI in forward direction may influence choice based on expected multiplicity





Conclusions

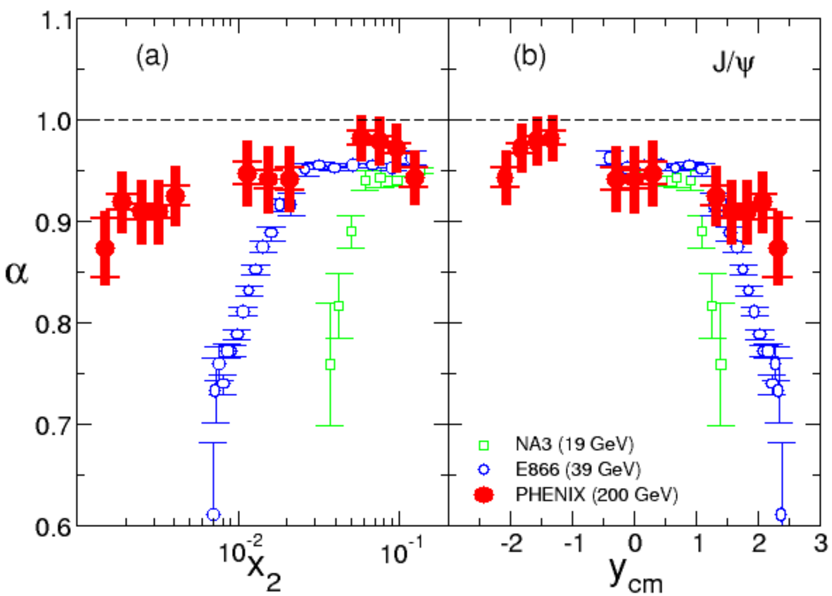
- PHENIX has extended its physics reach through a series of upgrades
  - Many of these near term upgrades are installed
  - Proposed MPC-EX will allow better determination of R_G as well as improve forward SSA measurements
- sPHENIX will significantly extend physics capabilities
  - Currently a conceptual design
  - Jet measurements with hermetic hadronic and electromagnetic calorimetry in midrapidity will probe medium created in A+A collisions
  - With new Forward Detector, will be able to understand large SSA, separating contributions from Sivers and Collins
  - Forward Detector will also probe CNM effects in d+A, as well as explore the low x region

Thank you

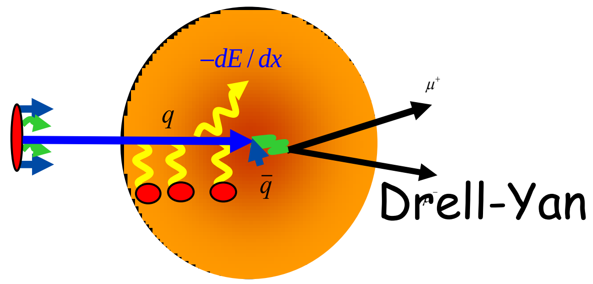
BACKUPS

Hadron Formation in Nucleus

Some portion of the hadron formation during a A+A collision should take place in the cold nuclear environment

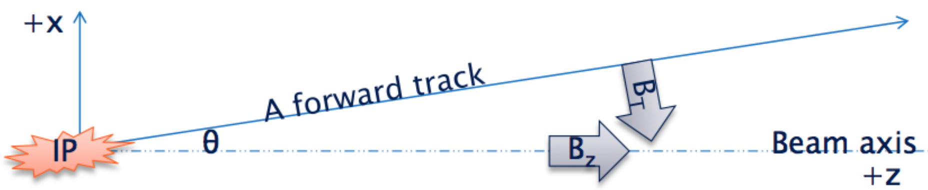


$$\sigma_{pA} = \sigma_{pp} A^{\alpha}$$



- Comparisons of quarkonia and DY production over a broad range in rapidity in d+A can help us to disentangle various effects that are expected (initial state, final state, saturation)
- Requirements

Field considerations



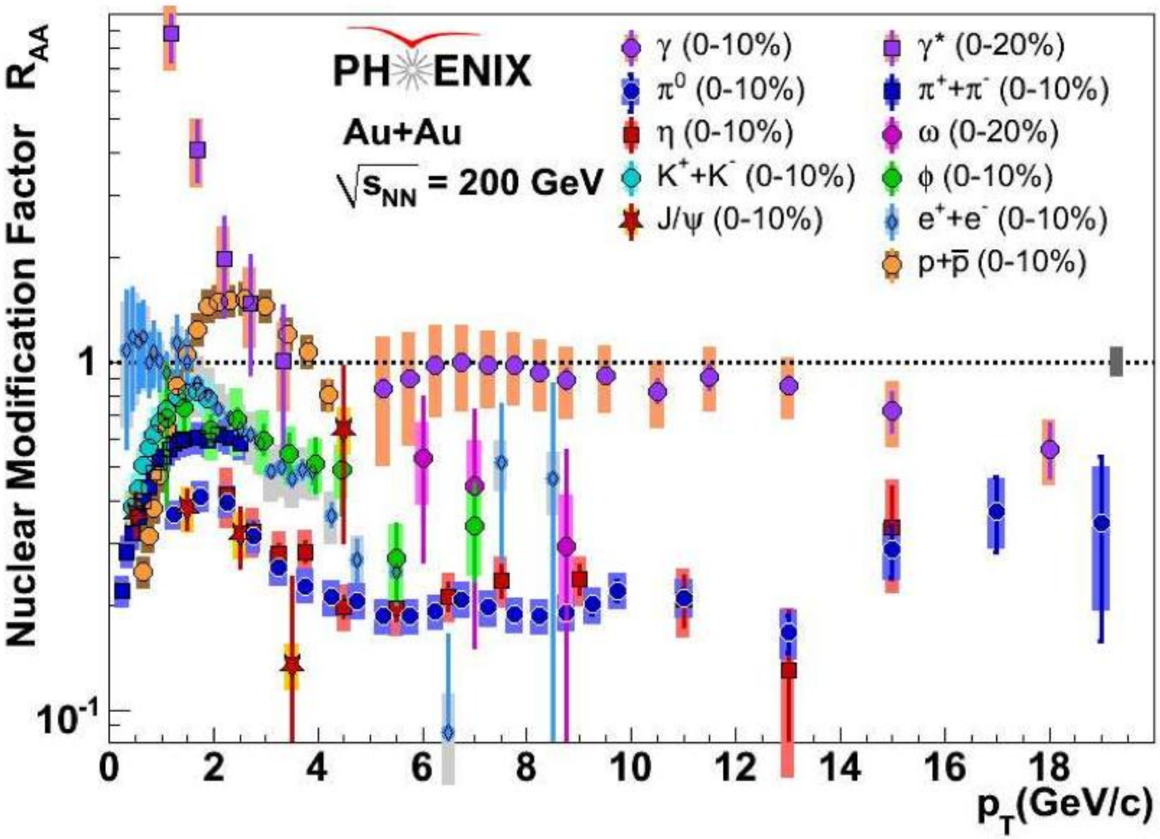
Transverse field is directly related to shape of central longitudinal field:

$$B_T = B_z \tan\theta + \frac{\tan\theta}{2} z \frac{\partial B_z}{\partial z} + O(\theta^2)$$

Geometry Term

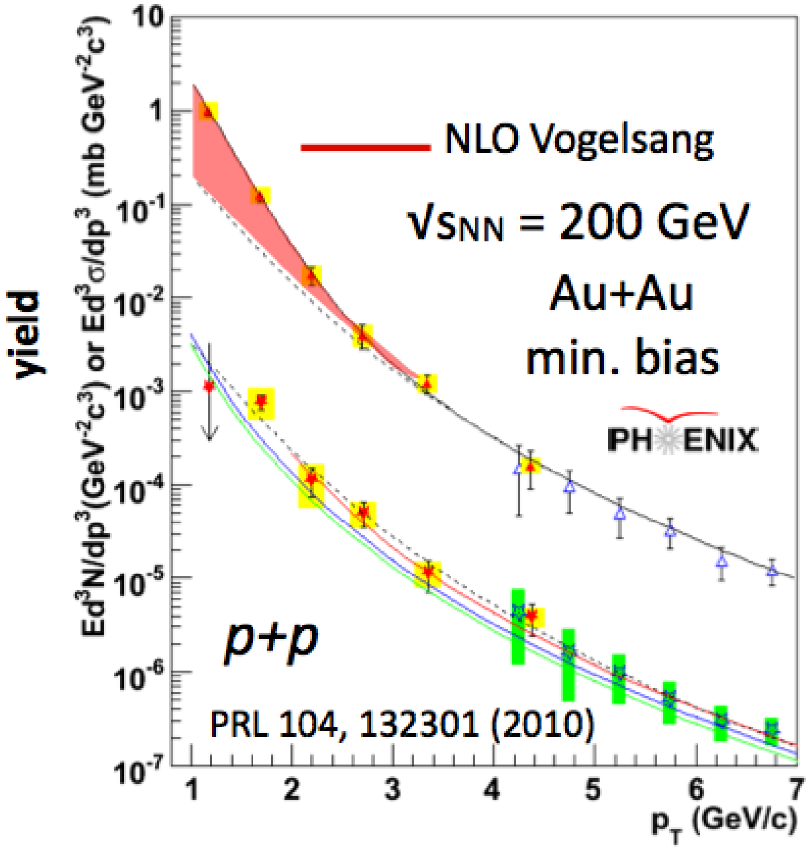
Flux Term

R_{AA}



$R_{AA} = dN_{AA}/(N_{COLL}dN_{pp})$

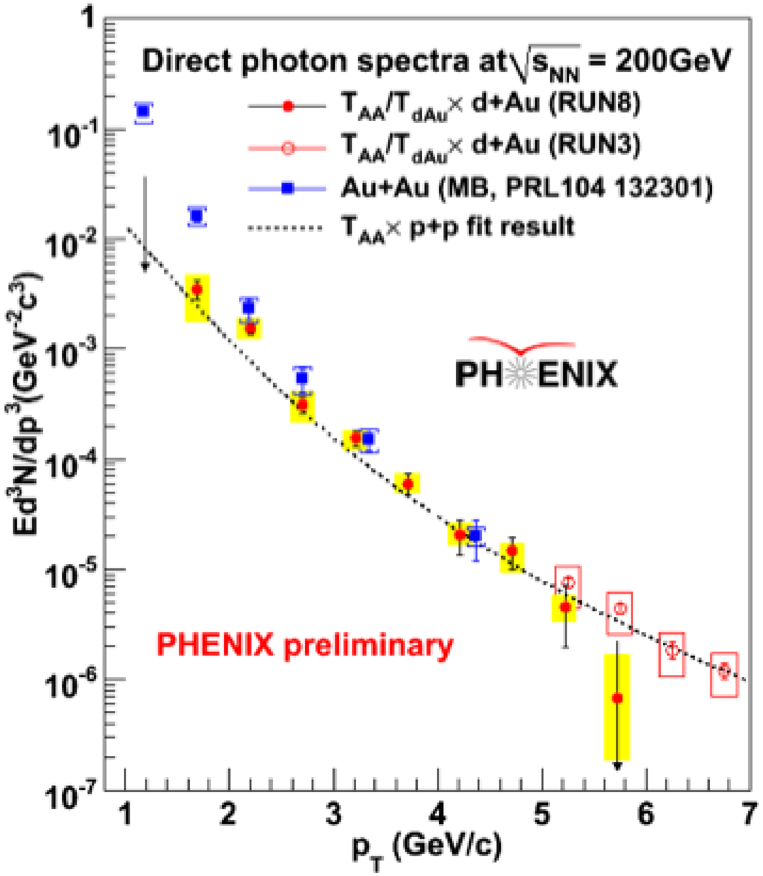
Hadronic final states suppressed. Non hadronic final states (Direct Photon) unsuppressed.



Stefan Bathe for PHENIX, QM2011

- Direct photon excess above *p+p* spectrum
- Exponential (consistent with thermal)
- Inverse slope = 220 ± 20 MeV
- T_i from hydro
  - 300 . . . 600 MeV
  - Depending on thermalization time

No excess in dAu



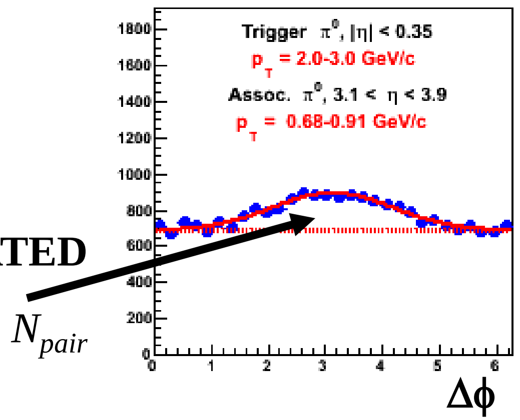
di-Hadron Signal

"Conditional Yield"

$$CY = \frac{N_{pair}}{N_{trig}\varepsilon_{assoc}} = \frac{1}{N_{trig}}\frac{dN^{assoc}}{d\Delta\phi}$$

Number of di-jet particle pairs per trigger particle after corrections for efficiencies, combinatoric background, and subtracting off pedestal

Peripheral d+Au Correlation Function



"Di-Hadron Nuclear Modification factor"

$$J_{dA} = I_{dA}^{trig} \times R_{dA}^{trig}$$

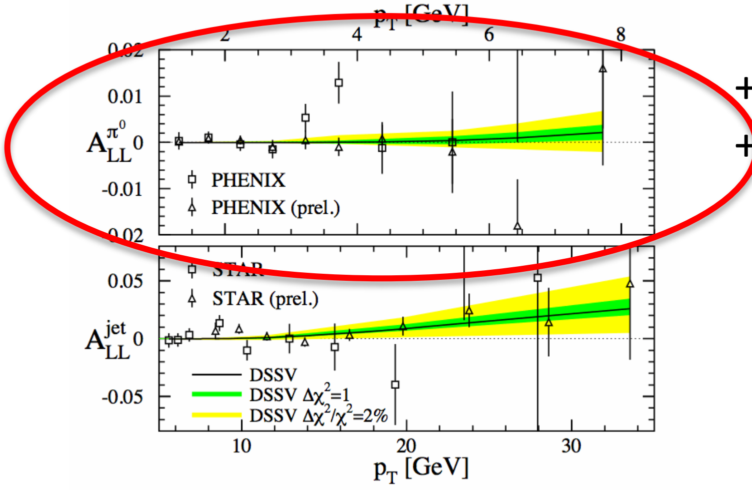
"Sgl-Hadron Nuclear Modification factor"

$$J_{dA} = \frac{1}{\langle N_{coll} \rangle} \frac{\sigma_{dA}^{pair} / \sigma_{dA}}{\sigma_{pp}^{pair} / \sigma_{pp}} \longleftrightarrow R_{dA} = \frac{1}{\langle N_{coll} \rangle} \frac{\sigma_{dA}^{sgl} / \sigma_{dA}}{\sigma_{pp}^{sgl} / \sigma_{pp}}$$

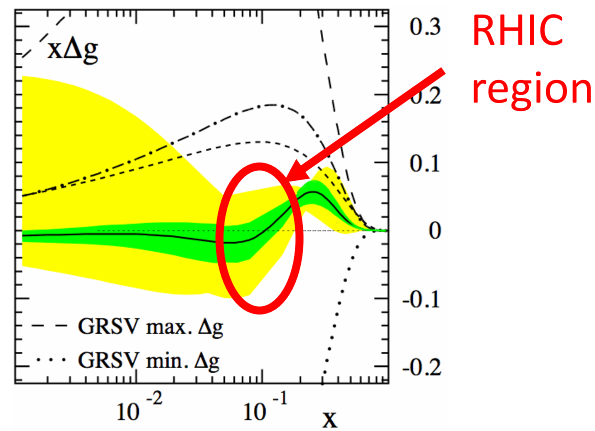
- Possible indicators of nuclear effects
  - $J_{dA} < 1$, $R_{dA} < 1$
  - Angular decorrelation of widths

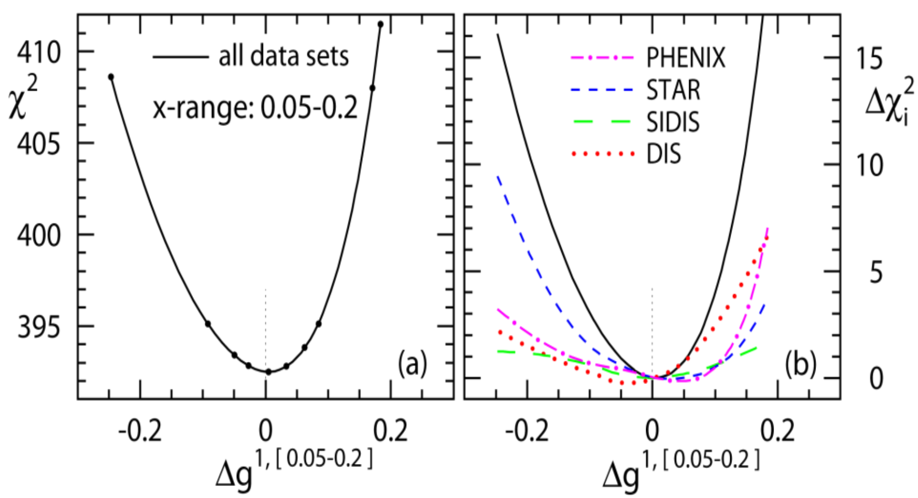
Mickey Chiu

Constraining ΔG



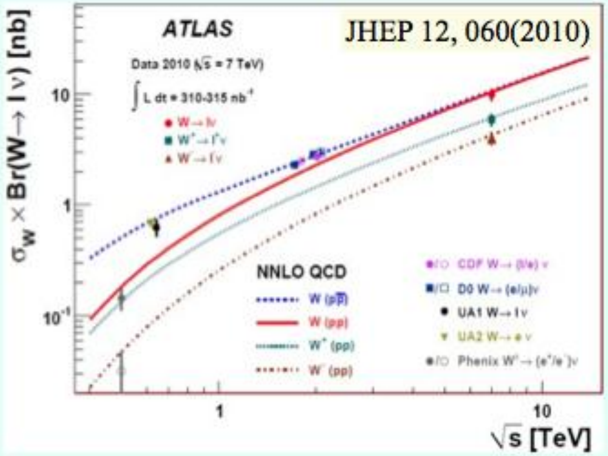
+DIS
+SIDIS

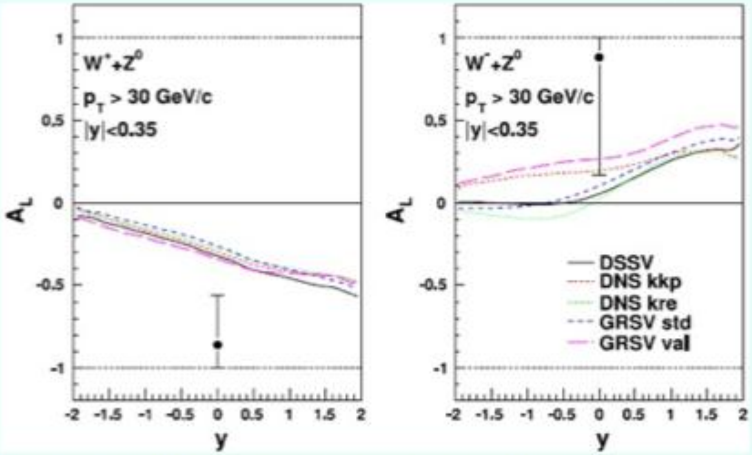




- DSSV fit world date including p+p for first time.
- PRL101:072001, 2008
- PRD 80:034030, 2009
- RHIC data offer significant constraint at 0.05<x<0.2.
- Large uncertainty remains below RHIC x range.

W A_L





PHENIX Collaboration: Phys. Rev. Lett. 106, 062001(2011)