Physics opportunities with Di-muon analysis at PHENIX - Drell-Yan and quarkonia

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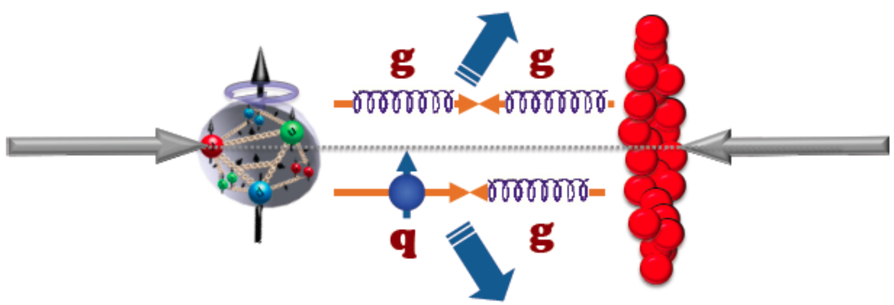
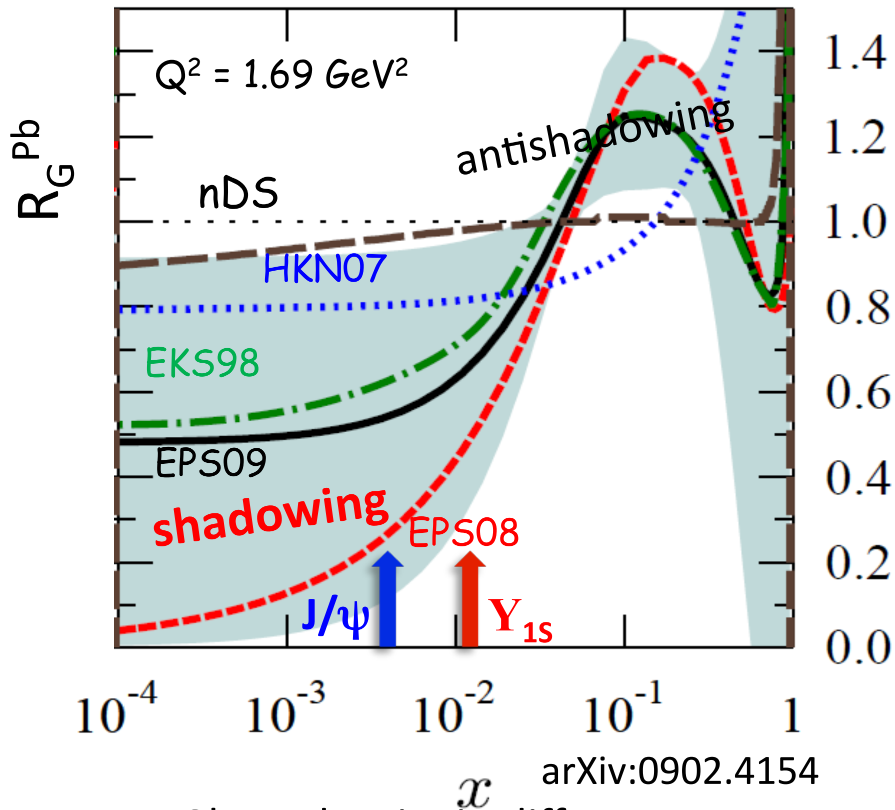
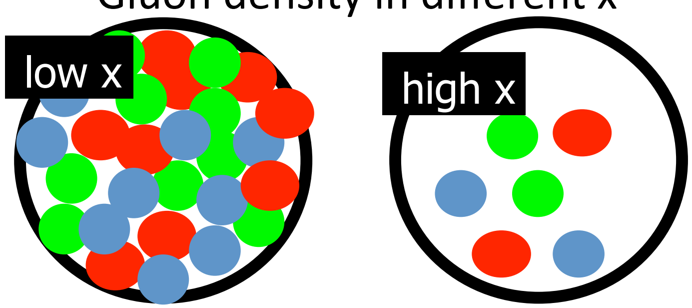


Quarkonia for Heavy Ion phyiscs



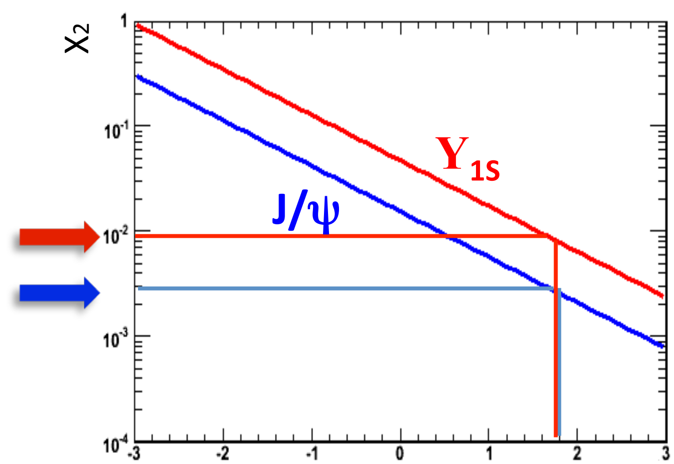
arXiv:0902.4154

Gluon density in different x



- Quarkonia are produced mostly by gluon fusion and good probes to explore gluon distribution in nucleus.
- Nuclear absorption (final)
- Initial state parton energy loss.

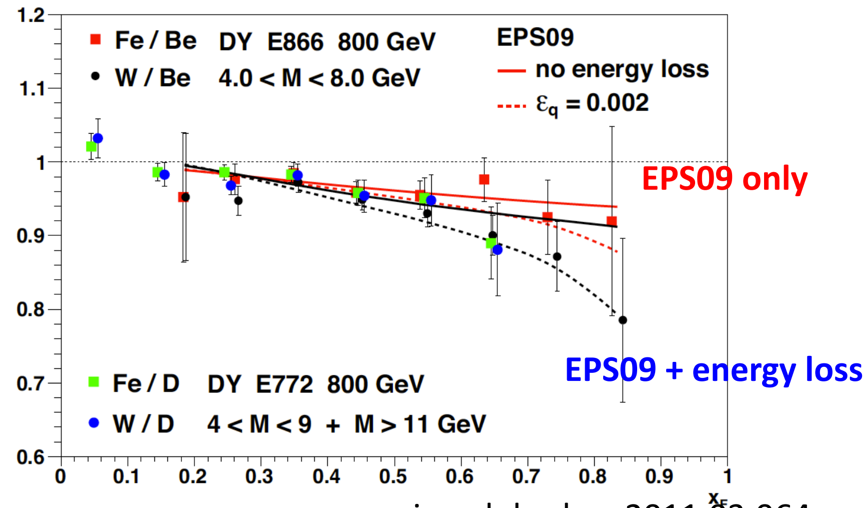
<- disentangle effects seen at hot nuclear collision.



$$x_2 = \frac{m_T e^{-y}}{\sqrt{s}}$$

Drell-Yan for Heavy Ion phyiscs

- Quarkonia measurements are not enough to disentangle the cold nuclear effects.
- The leptons from Drell-Yan process (qq -> γ* -> l^+l^-, *qg->qγ**) does not interact with the nuclear medium.
- Ideally suited to separate the initial-state parton energy loss and parton modification, given the absence of final-state effects.



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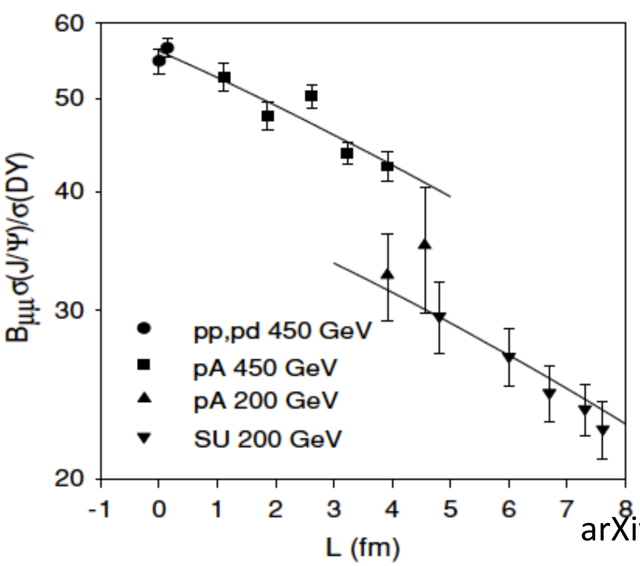
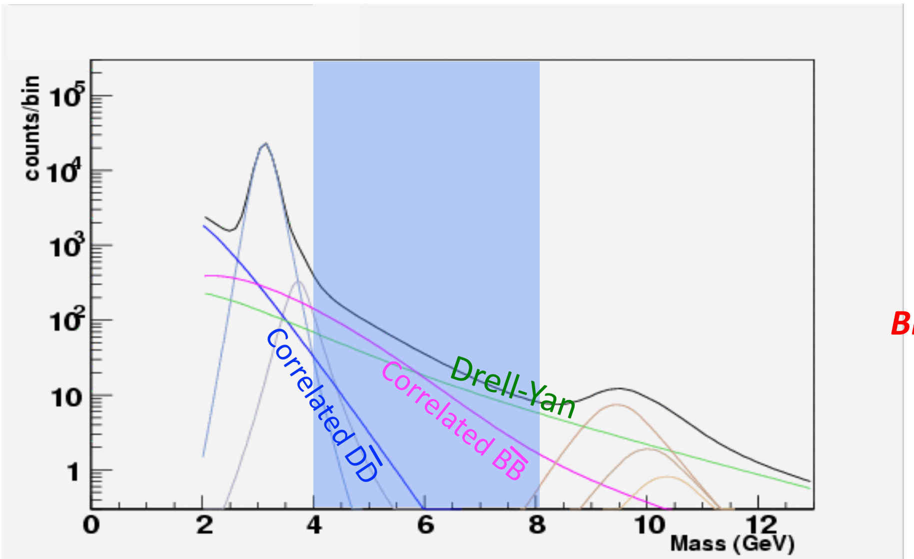


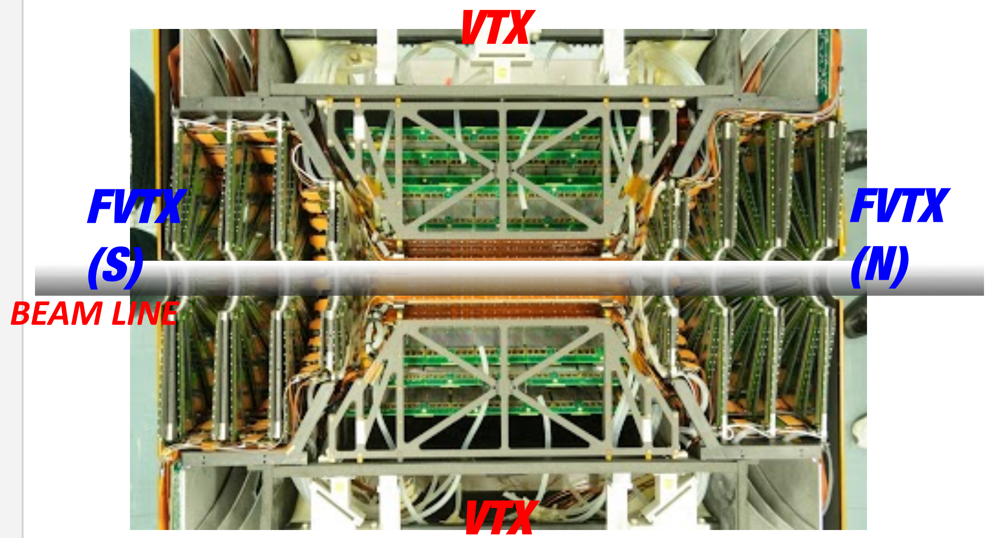
The NA50 experimental ratio of the total J/ψ cross sections and Drell-Yan cross sections as a function of the nuclear length L

arXiv:nucl-th/0212046

Backgrounds under Drell-Yan and control with FVTX/VTX



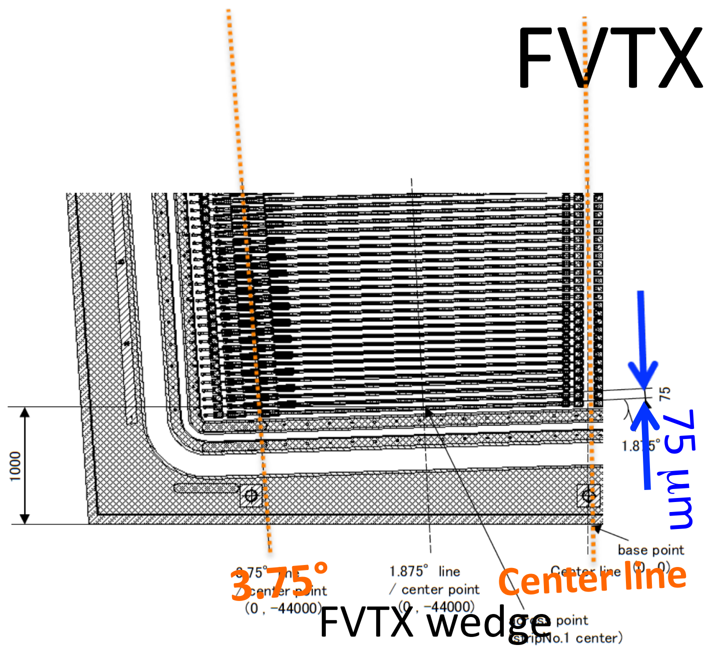
√s = 200 GeV simulation, p+p pythia

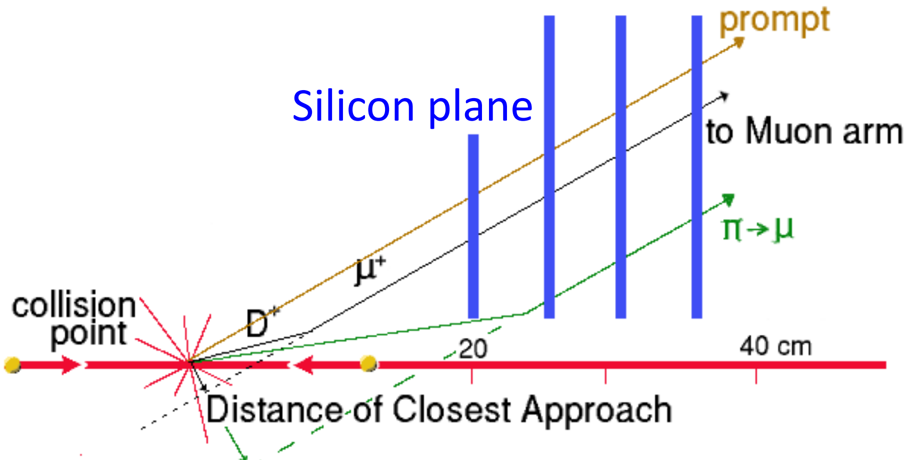


FVTX/VTX have been successfully installed and working since 2012/2011.

- Between 4 GeV/c^2 and 8 GeV/c^2 is thought to be dominated by Drell-Yan process and correlated $B\bar{B}$.
- We would separate Drell-Yan process and correlated $B\bar{B}$ which have different decay lengths, using silicon vertex detector, (F)VTX between 4 and 8 GeV/c^2.
- We would get order of five thousand events for each arm with FVTX with 300 pb^{-1} (p+p equivalent), current muon arm configuration, efficiencies included.

FVTX operation





- Decay length of Drell-Yan : none
- Decay length of B meson : ~ 500 μm

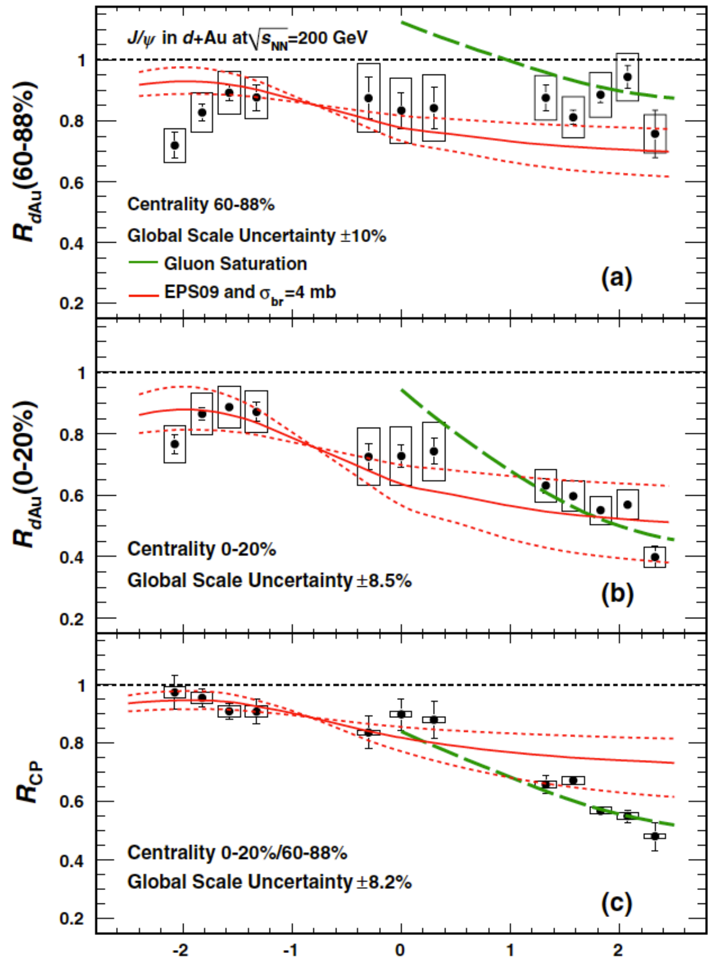
- 75 μm pitch strips in radial directon, r and 3.75° along Φ direction.

- Cover same pseudorapidity, $|\eta|$ of 1.2 to 2.4(2.2) with Muon arm.
  -> Sample momentum fraction, x_2, order of 10^{-3} to 10^{-2} for the Drell-Yan.

- Match track with Muon arm +(F)VTX.
  -> Improve mass resolution.

- Measure the primary vertex and secondary decay.
  -> Extract dimuon vertices, DCAs, to distinguish Drell-Yan and heavy flavor decay background.

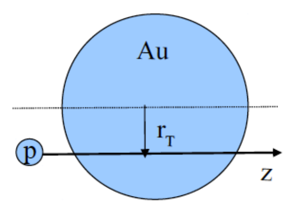
PHENIX J/ψ R_{dAu} measurement



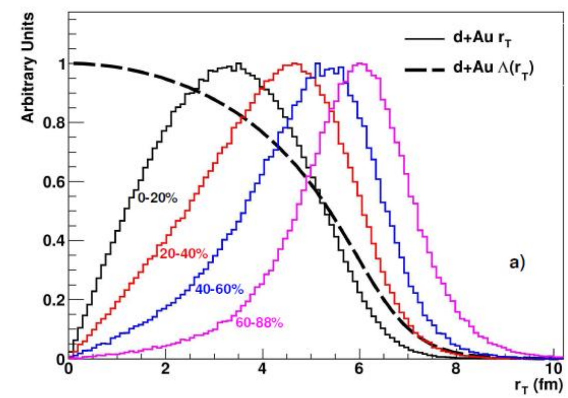
Phys. Rev. Lett. 107, 142301 (2011)

- Tried to fit the data with shadowing model, EPS09 + breakup cross section.

- The centrality dependence of these J/ψ suppression results at forward rapidity is not well described quantitatively by nuclear-shadowing models that include final-state breakup effects.

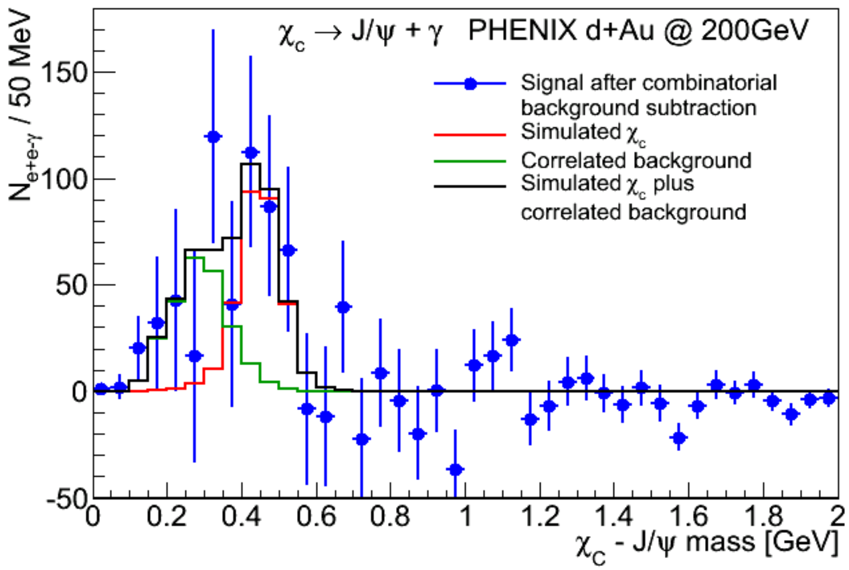


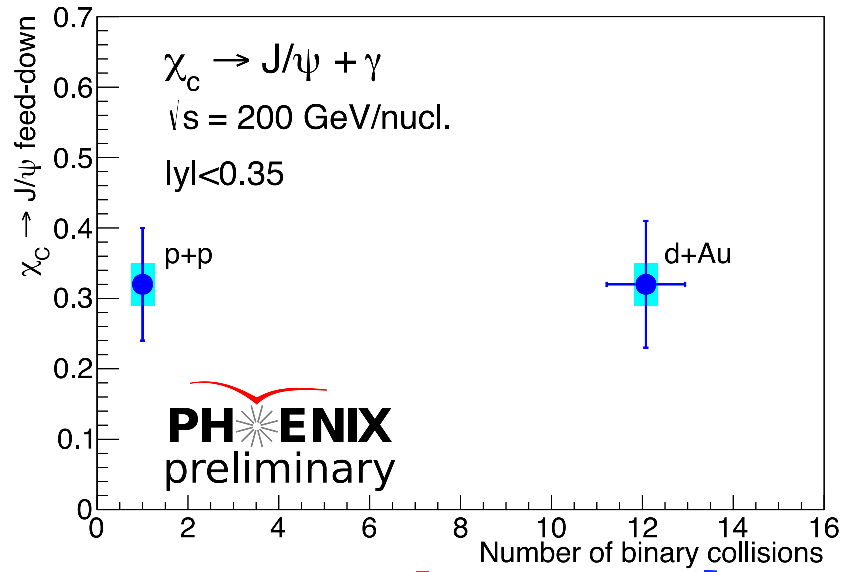
$$\Lambda(r_T) = \frac{1}{\rho_0}\int dz\rho(z,r_T)$$



-> See Cesar's talk for more detail

χ_c at mid rapidity



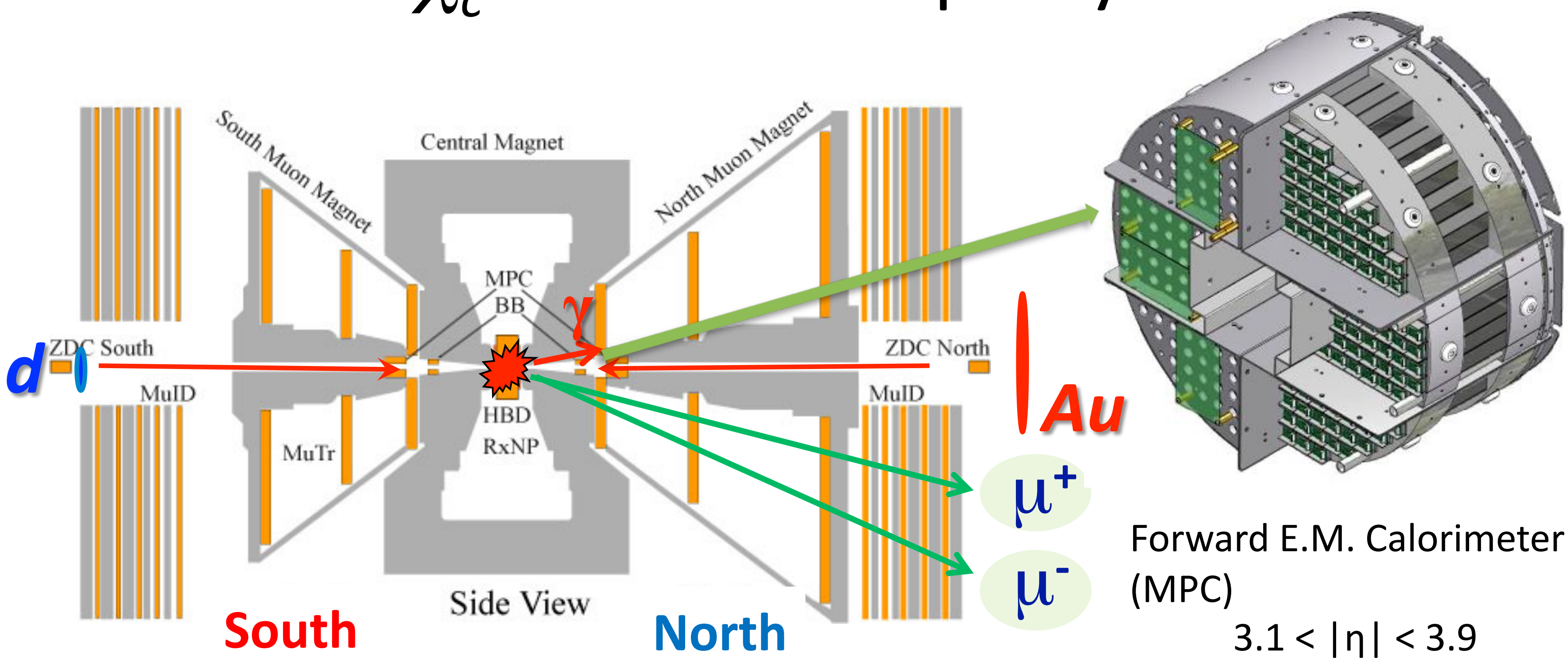


state	J/ψ (1S)	χ_c (1P)	Υ (1S)	Υ (2S)	Υ (3S)
	$c\bar{c}$			$b\bar{b}$	
mass [GeV]	3.10	3.53	9.46	10.02	10.36
radius [fm]	0.25	0.36	0.14	0.28	0.39
T_d/T_c	2.10	1.16	> 4.0	1.60	1.17

hep-ph/0609197v1 H. Satz

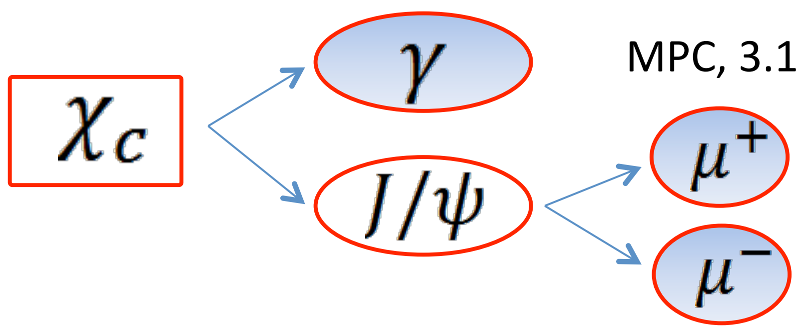
- Higher charmonium state(1P) than J/ψ(1S).
- There are three states of chi_c.
- Radiative decay channel χ_c -> J/ψ + γ -> $\mu^+\mu^-(e^+e^-)$ + γ.
- $R_{\chi c}$ = (χ_c -> J/ψ + γ) / (Inclusive J/ψ).
- Decouple the fraction of decay J/ψ and direct J/ψ and check the production mechanism.
- χ_c has weak binding energy than other quarkonia, rather easily break up.

χ_c at forward rapidity



Forward E.M. Calorimeter (MPC)

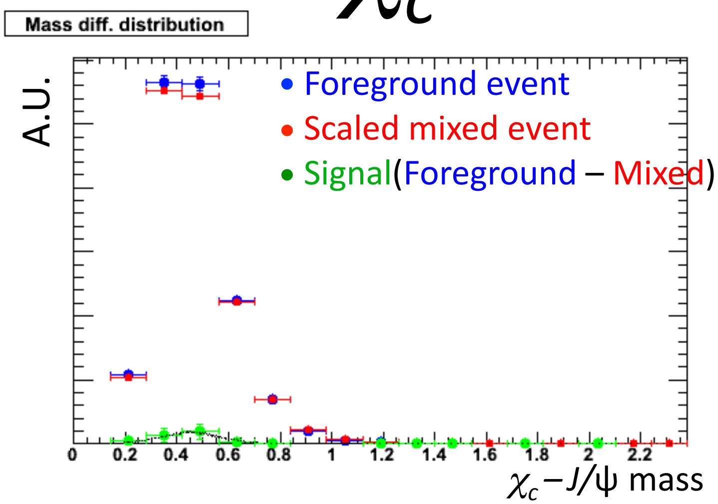
$3.1 < |\eta| < 3.9$

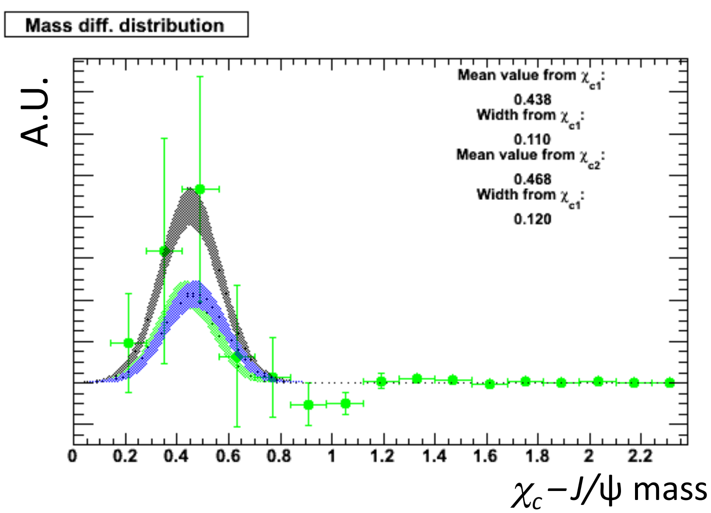


MPC, $3.1 < |\eta| < 3.9$

Muon arm, $1.2 < |\eta| < 2.4$

χ_c at forward rapidity

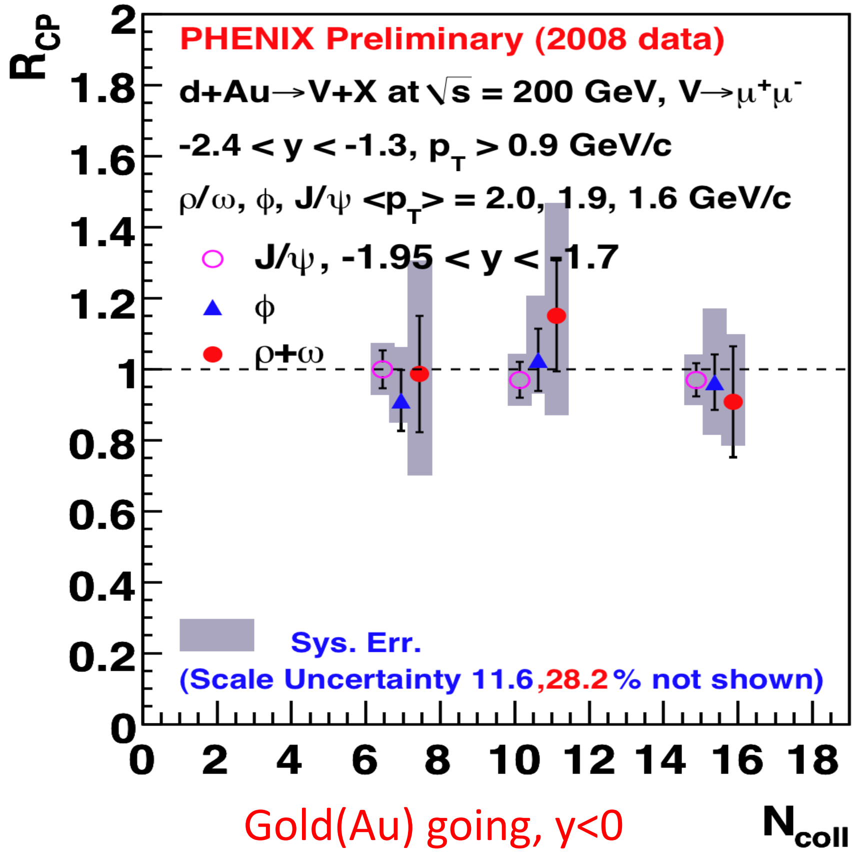


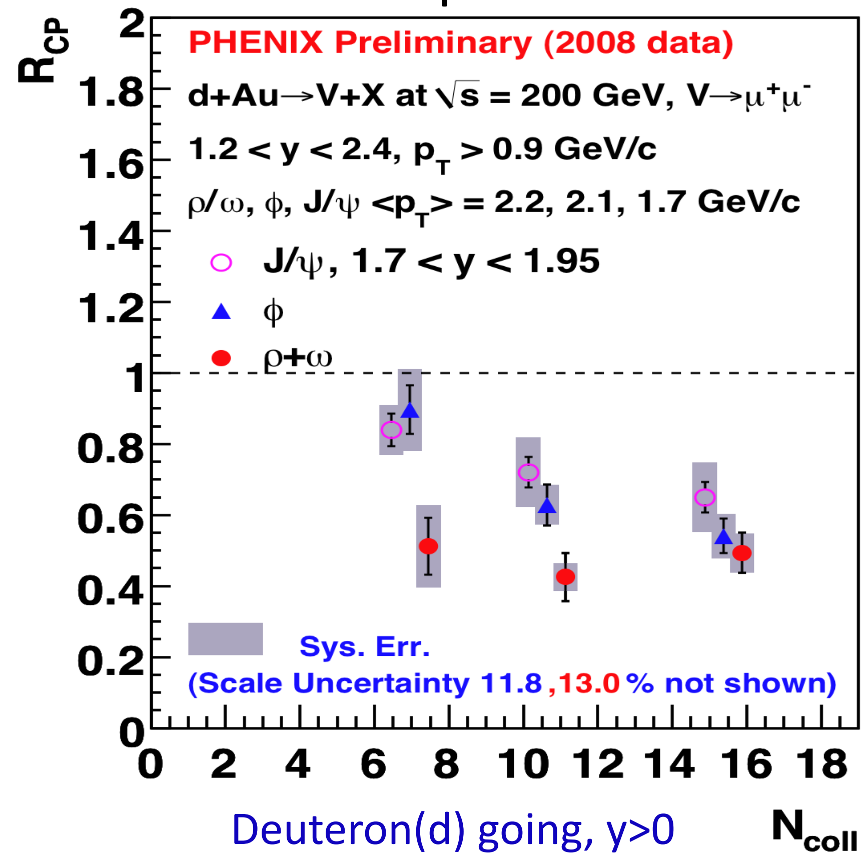


$\sqrt{s_{NN}}$ = 200GeV, dAu North

- We saw the peak, but large uncertainties due to the large backgrounds from low energy photon mess up the χ_c signal.
- Future upgrade with Calorimeter will improve χ_c measurement at forward/mid rapidities.

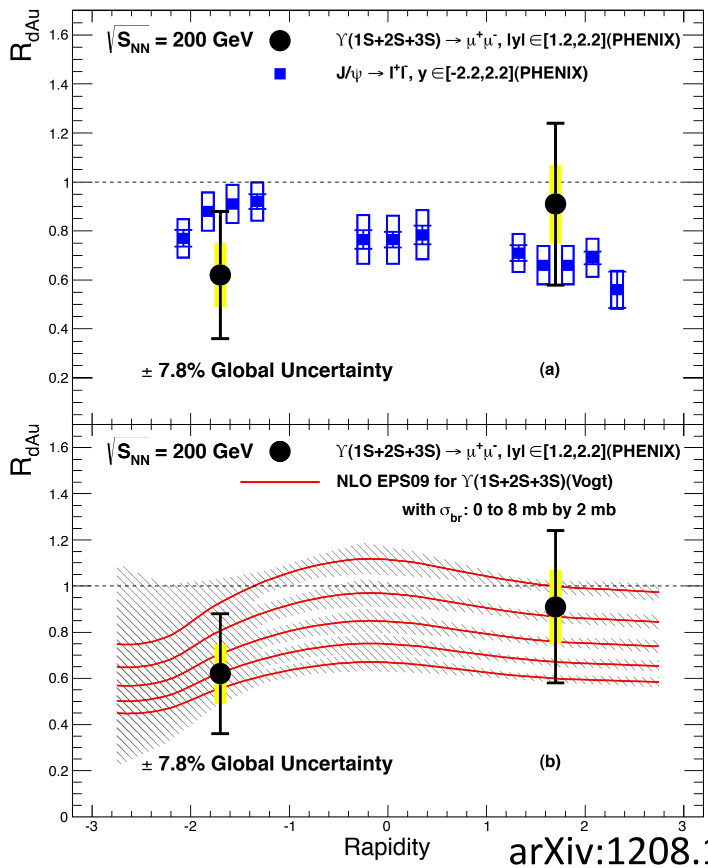
Light Vector Mesons R_{cp}



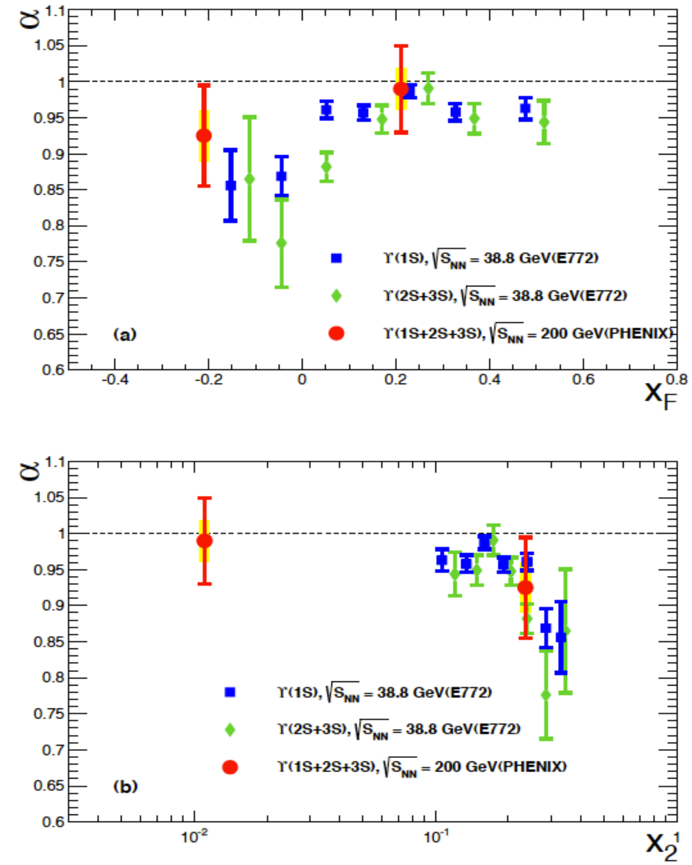


- Nuclear modification factor, R_{CP} measurement for low mass vector mesons
- Significant suppression at deuteron going direction.
- Stronger suppression for ρ/ω than ϕ and J/Ψ.

PHENIX Upsilon R_{dAu} measurement



arXiv:1208.1293



nPDF(EPS09) + breakup σ

Comparison to lower energy pA results(E772)

- The rapidity dependence of the observed suppression at forward and backward rapidities are compatible with lower energy results and a NLO theoretical calculation.
- Expect to separate out ϒ of the ground state and the exited states with the future upgrade.

Summary

- Drell-Yan measurement at pA collision is interesting to test initial-state quark modification and parton energy loss at nucleus.
- Ratio of J/ψ / DY and P_T broadening would be interesting to test nuclear modification/absorption.
- (F)VTX can help to separate open HF correlation from Drell-Yan and quarkonia measurement at dimuon channel.
- Future upgrade and (F)VTX would help to improve mass resolution and separate ψ' and excited states of upsilon as well as χ_c.
- See Cesar, John, Joe more for the upgrade.

Back up

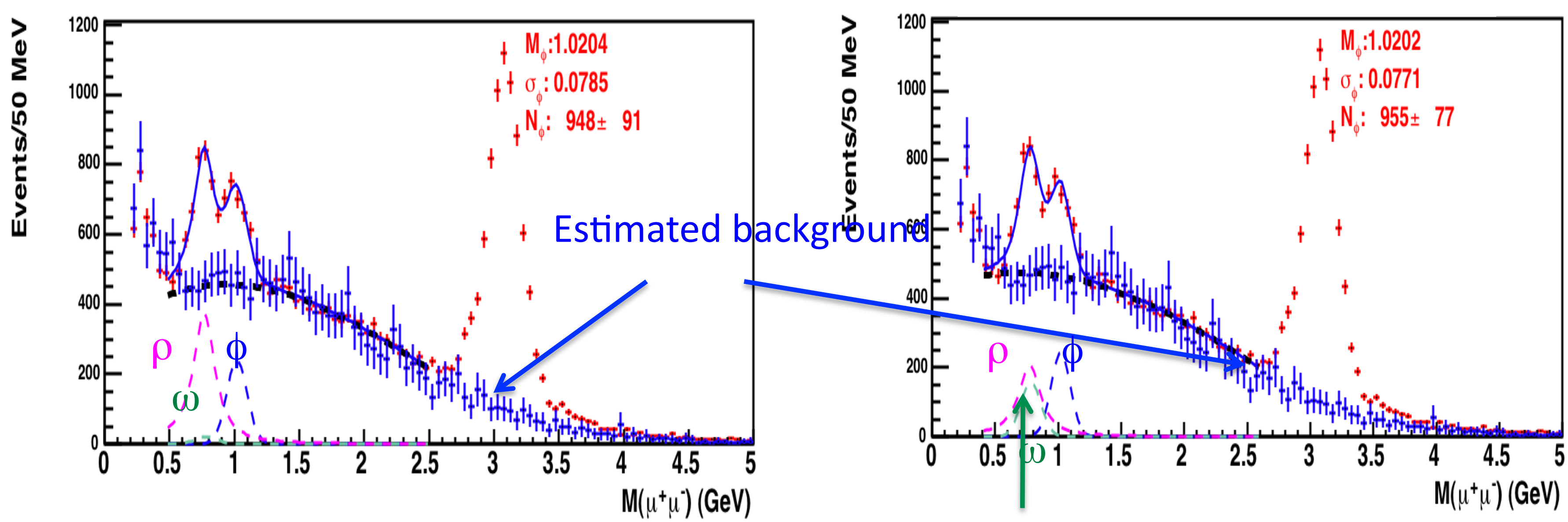
Introduction

- Review the PHENIX dimuon/other previous measurements.
- Check the possible improvements/physics.
- This talk is focused on cold nuclear matter physics, not on the spin measurement.

Yield Extraction Examples

- Fitting function: Two Gaussian (ϕ/ω) + One Relativistc BW (ρ) +Background (Defined by estimated shape)
  - ϕ yields stable when fitting procedure changes
  - ρ+ω yields using background subtraction (large uncertainty)

y>0, Centrality: 40-60 | y>0, Centrality: 40-60

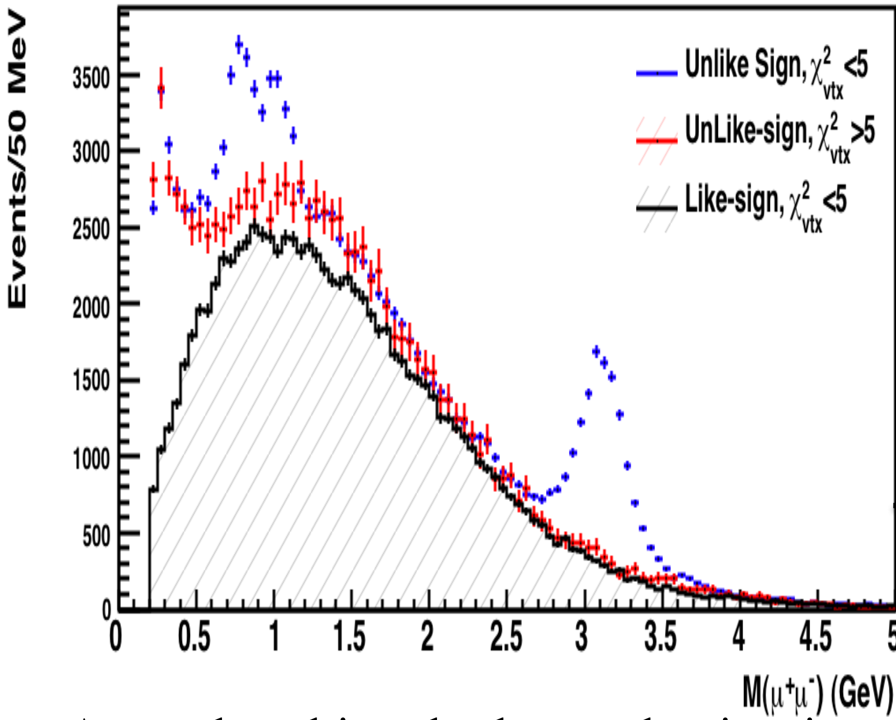


Smaller fitting range:0.5-2.5 GeV
Larger parameter range

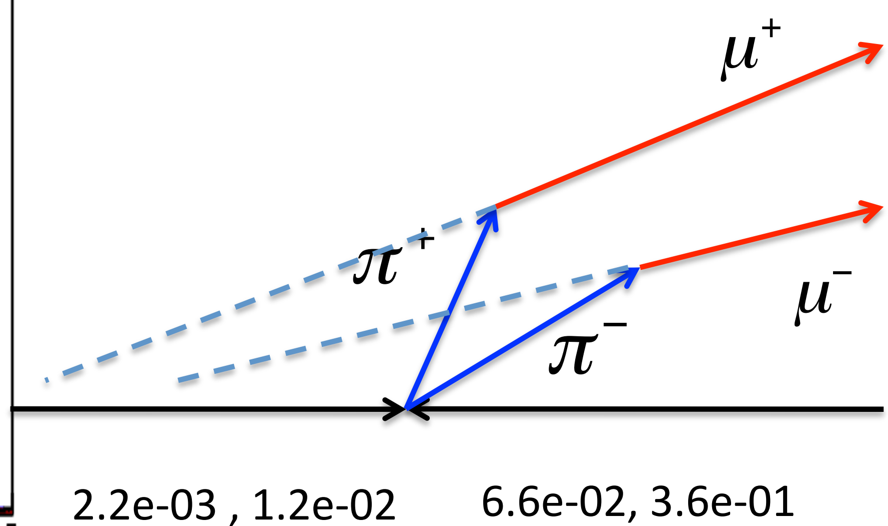
Larger fitting range:0.4-2.6GeV
Smaller parameter range

Background Estimation Challenge

y<0, Centrality: 20-40



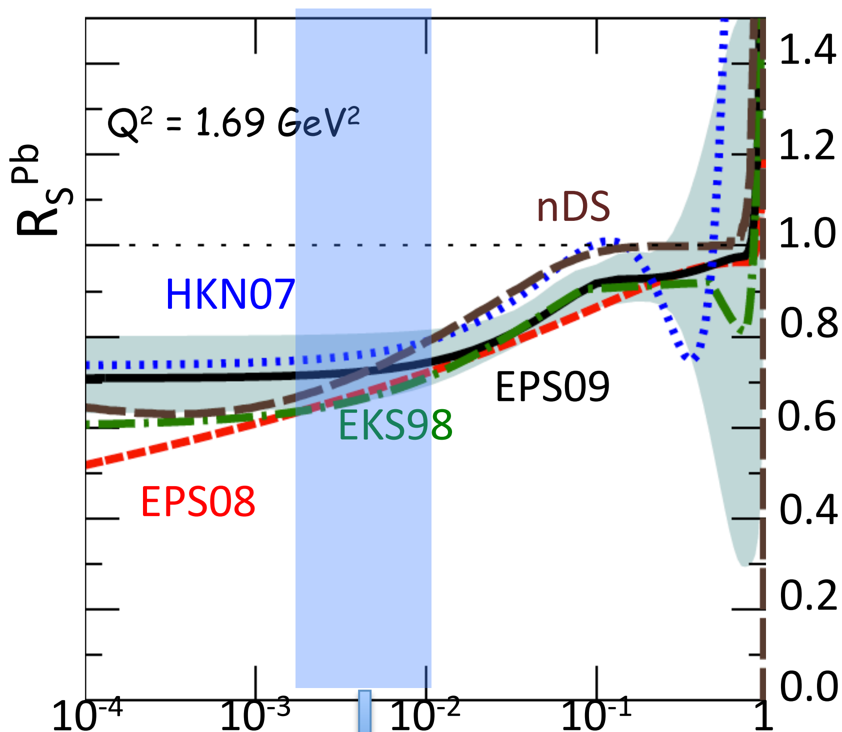
Correlated background



- A new data-driven background estimation method developed
- Use di-muon pairs with large $\chi 2_{vtx}$ to estimate the background
    - Addresses the issue of correlated hadrons that decays to $\mu^{+/-}$
- Achieved good background description at all mass range

Drell-Yan for Heavy Ion phyiscs

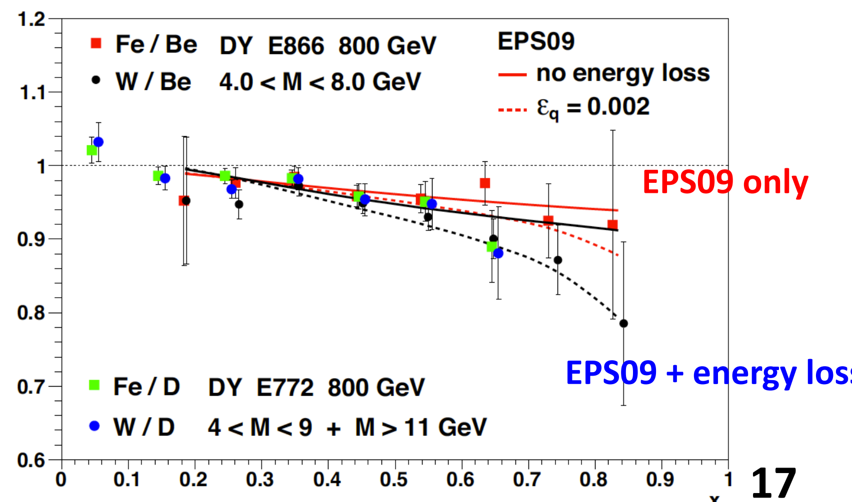
R_S^{Pb}: sea quark modification



arXiv:0902.4154

x coverage of PHENIX Drell-Yan in nucleus at √s = 200 GeV (1.2 < y < 2.2)

- Drell-Yan process ($q\bar{q}$ -> γ* -> l^+l^-) is a good probe to study the quark modification in nucleus and initial-state parton energy loss.
- Ideally suited to isolate the initial-state parton energy loss, given the absence of final-state effects on the produced dimuon.



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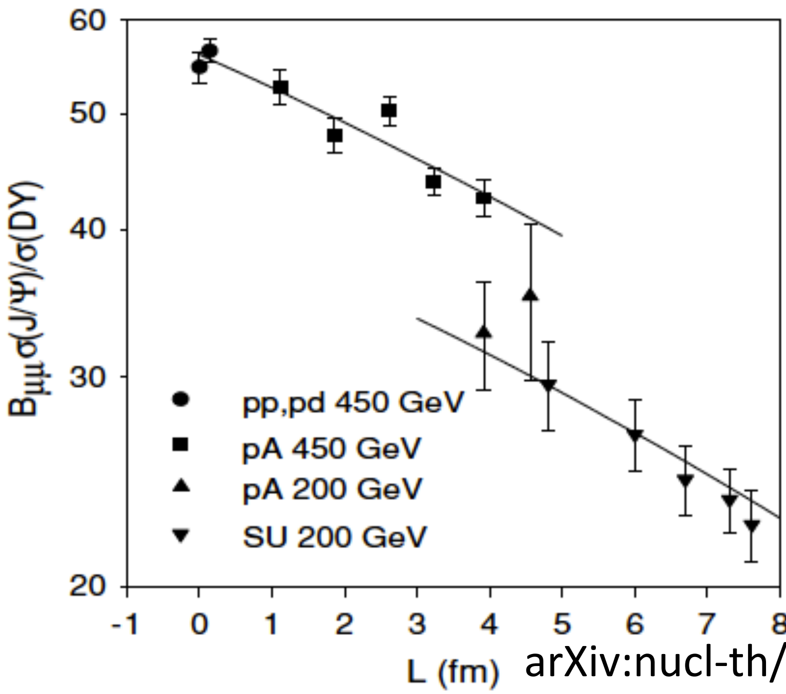
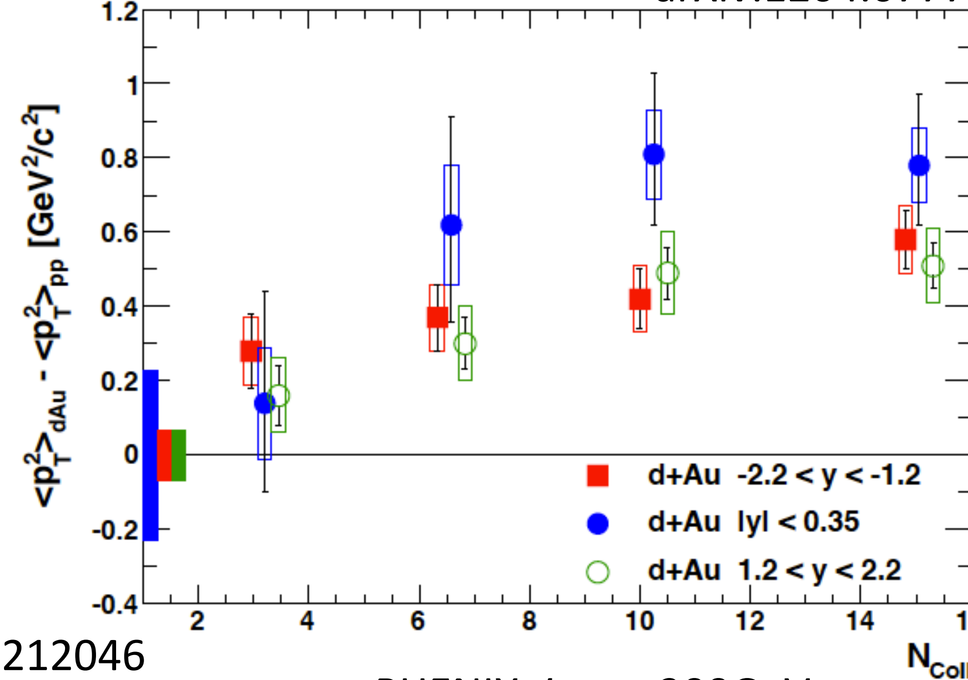
Ratio of J/ψ over DY and P_T broadening



arXiv:nucl-th/0212046

arXiv:1204.0777



PHENIX $\sqrt{s_{NN}}$ = 200GeV

The NA50 experimental ratio of the total J/ψ cross sections and Drell-Yan cross sections as a function of the nuclear length L

- NA50 data are fit with the QCD based nuclear absorption model.
- PHENIX J/ψ data show P_T broadening due to the multiple scattering