J/ψ production in heavy ions collisions Part 1

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January 2007

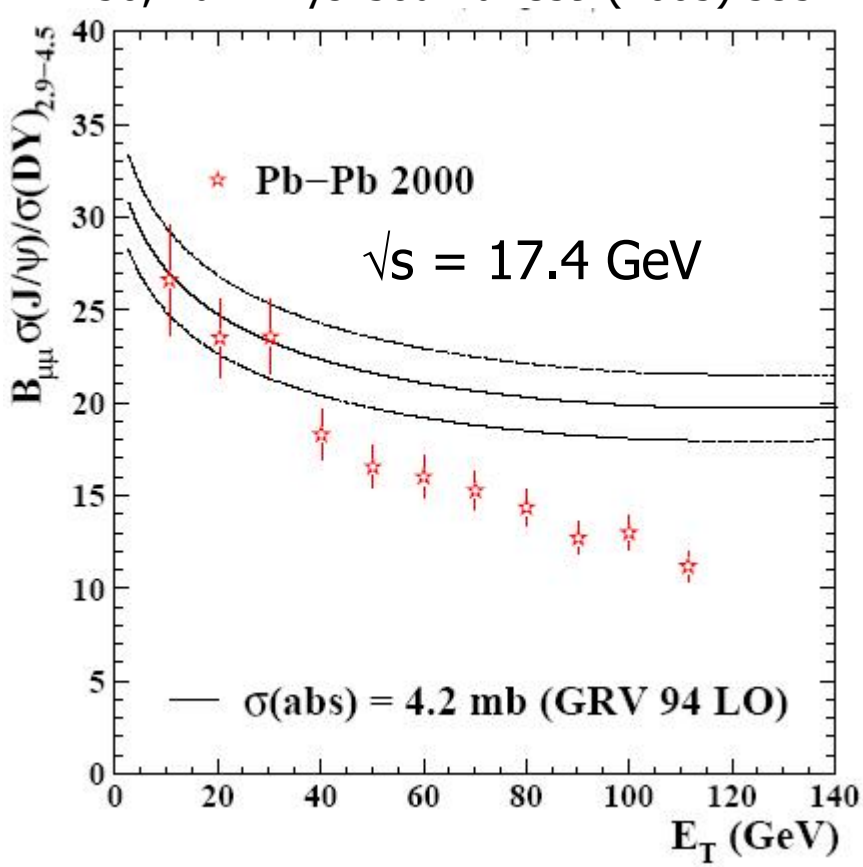
Outline

- Introduction
- Cold nuclear effects
  - Gluon shadowing and nuclear absorption
    - Look at y, centrality, energy dependence
  - Cronin effect

(Initial) Motivation in A+A collisions

- J/Ψ production used as a probe of formed medium
- Anomalous suppression expected in case of QGP formation
- Observed by NA50 at SPS
- Alternative explanation (dense hadronic syst…)

NA50, Eur. Phys. Journal C39 (2005) 335



Look for the effect at higher collision energy

@ RHIC √s =200 GeV

History of J/Ψ measurements by PHENIX

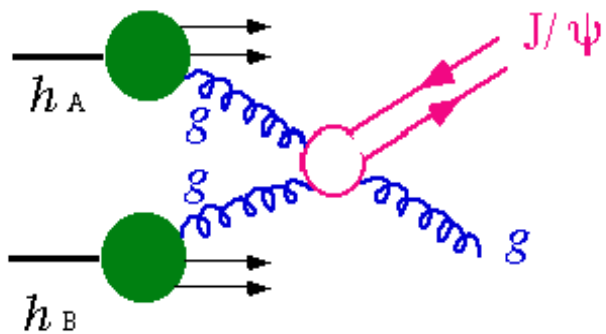
Year	Ions	$\sqrt{s_{NN}}$	Luminosity	Status	J/ψ (ee + μμ)
2001	Au-Au	200 GeV	24 μb^{-1}	Central	13 + 0 [1]
2002	p-p	200 GeV	0.15 pb^{-1}	+ 1 muon arm	46 + 66 [2]
2002	d-Au	200 GeV	2.74 nb^{-1}	Central	360 + 1660 [3]
2003	p-p	200 GeV	0.35 pb^{-1}	+ 2 muon arms	130 + 450 [3]
	Au-Au	200 GeV	240 μb^{-1}	Final	~ 1000 + 4500 [5]
2004	Au-Au	63 GeV	9.1 μb^{-1}	Analysis	~ 13
	p-p	200 GeV	324 nb^{-1}		
	Cu-Cu	200 GeV	4.8 nb^{-1}	Preliminary	~ 2300 + 10000 [4]
2005	Cu-Cu	63 GeV	190 mb^{-1}	Preliminary	~ 60 + 200
	p-p	200 GeV	3.8 pb^{-1}	Final	~ 1500 + 8000 [6]

[1] PRL92 (2004) 051802 [2] PRC69 (2004) 014901 [3] PRL96 (2006) 012304
[4] QM05, nucl-ex/0510051 [5] nucl-ex/0611020 [6] hep-ex/06110202

J/Ψ hadro-production at RHIC

- J/Ψ production dominated by gluon fusion
- Feed-down from higher mass resonances:

  χ_c (~30 %) and Ψ′ (~10 %)



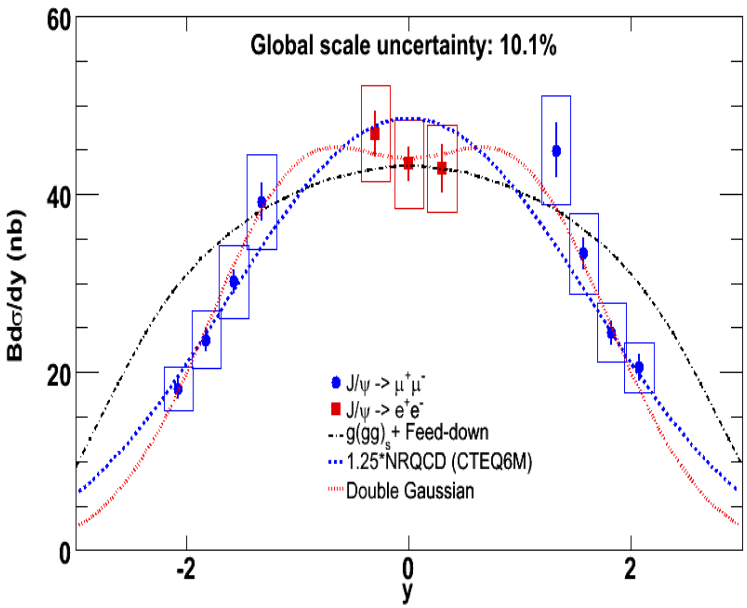
p+p : J/Ψ production used as reference

AB production ~ pp x N_{coll}

* N_{coll} number of binary collisions

$$R_{AB} = \frac{dN^{AB}/dy}{dN^{PP}/dy \times \langle N_{coll} \rangle}$$

Run5 p+p (QM06)

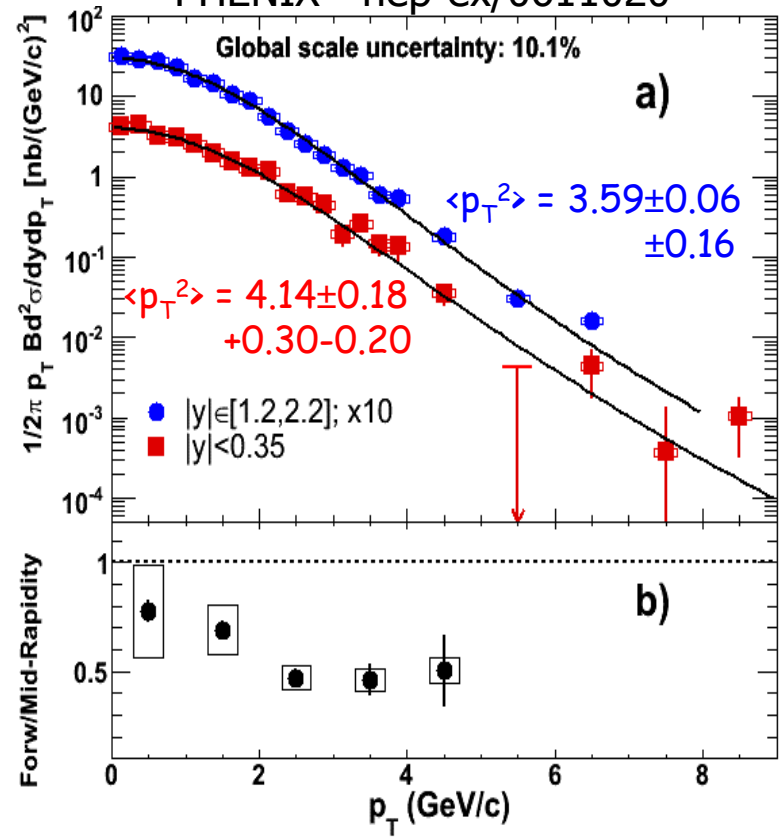


Br x σ = 178 ± 3 ± 53 ± 18 nb
(± stat ± syst ± norm)

Flatter distribution observed

Bar : stat + syst uncorrelated
Box : point 2 point correlated

PHENIX - hep-ex/0611020

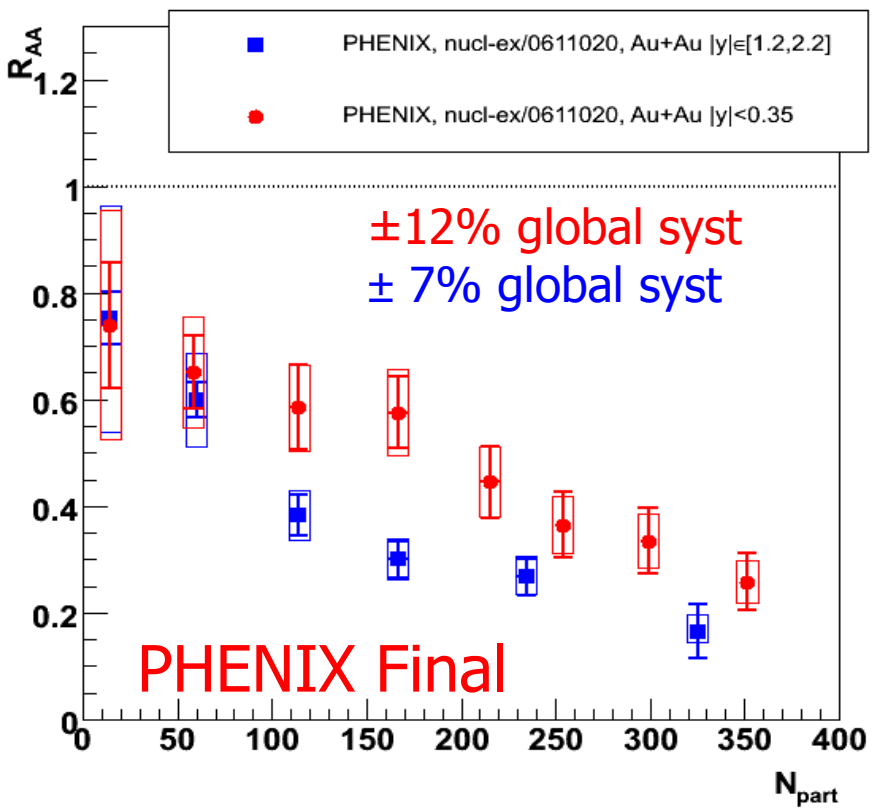


Harder p_T than at lower $\sqrt{s}$
Softer at forward rapidity

Results in Au+Au collisions (QM06)

- Raw result : R_{AuAu}
- Suppression in central collisions :
  - Factor of 3 at mid y
  - Factor of 5 at forward y

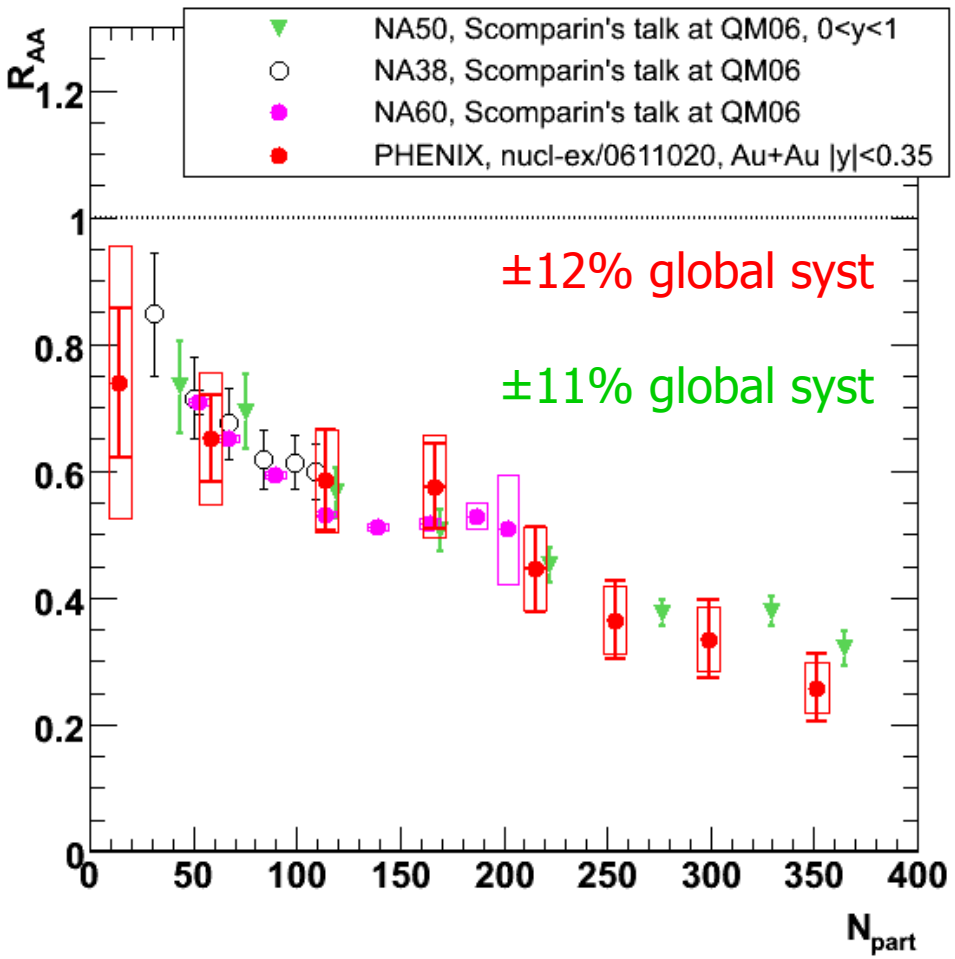
PHENIX, nucl-ex/0611020



Bracket : stat + syst uncorrelated
Box : point 2 point correlated

Comparison with SPS results

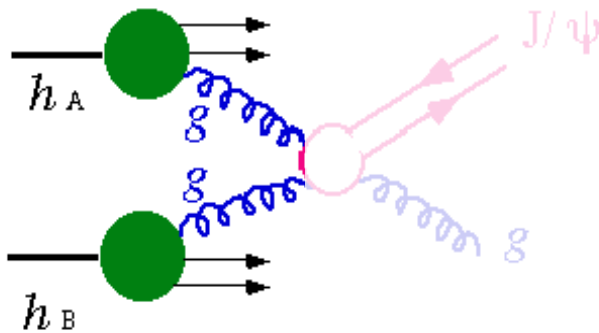
- Kinematic range :
  - SPS : 0 < y < 1
  - RHIC : |y| < 0.35
- Suppression level is similar although $\sqrt{s}$ is 10 times larger
- But cold nuclear effects are supposed to be different at SPS vs RHIC



Cold nuclear effects in J/Ψ production

– Initial state:

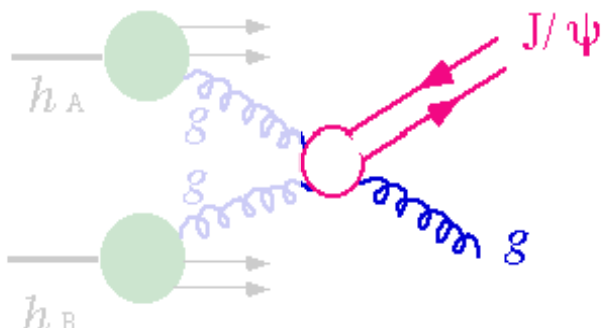
- Gluon (anti)-shadowing,
- p_T broadening (Cronin effect)



– Final state:

- Nuclear absorption

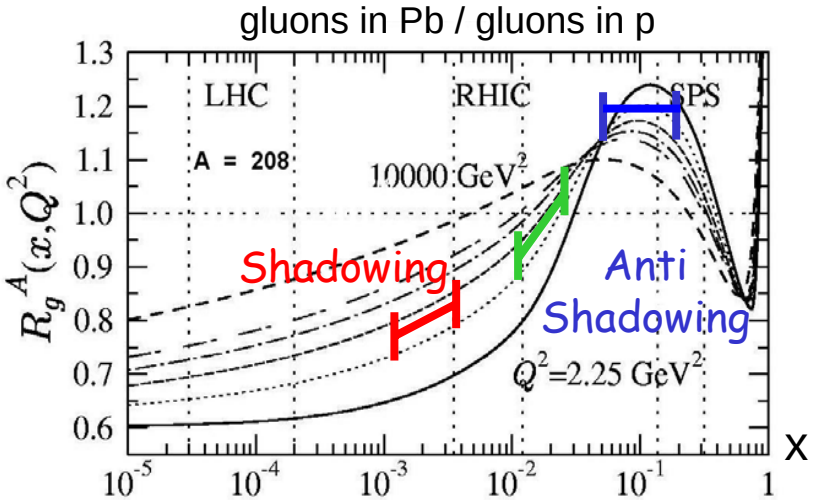
$$c\bar{c} + N \rightarrow open\ \ charm$$



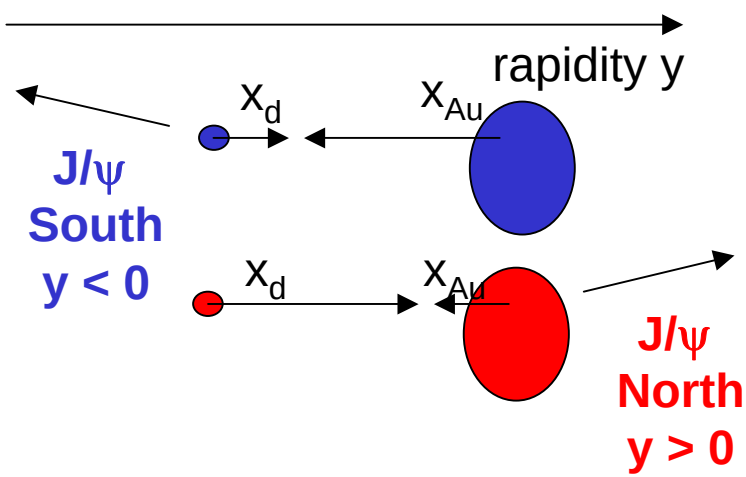
AB production ≠ pp x N_{coll}

d+Au : disentangle cold nuclear effects

Gluon shadowing d+Au data



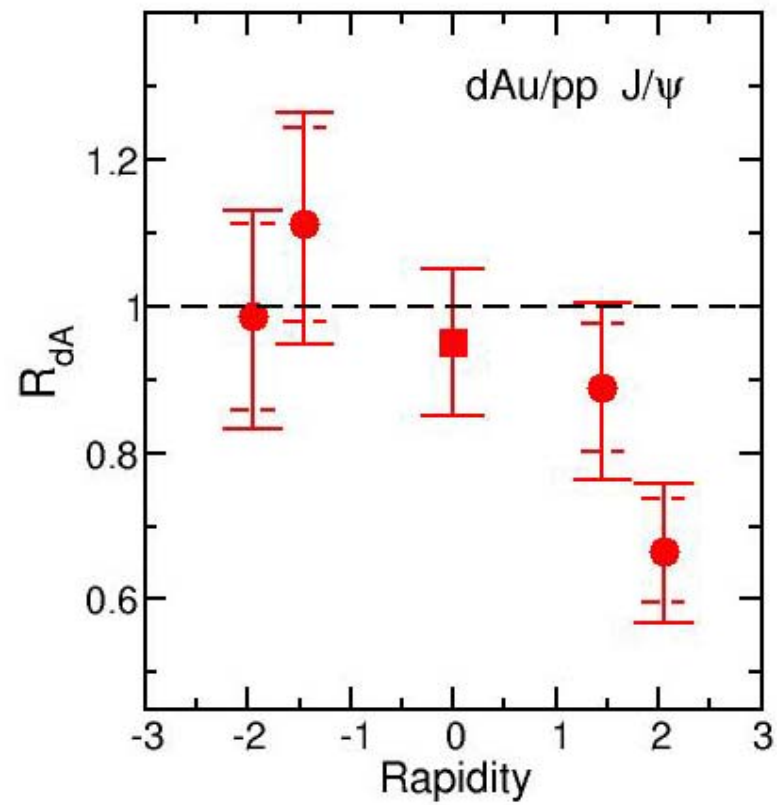
Nucl. Phys. A696 (2001) 729-746



y < -1.2 : large x_{Au} ~ 0.090

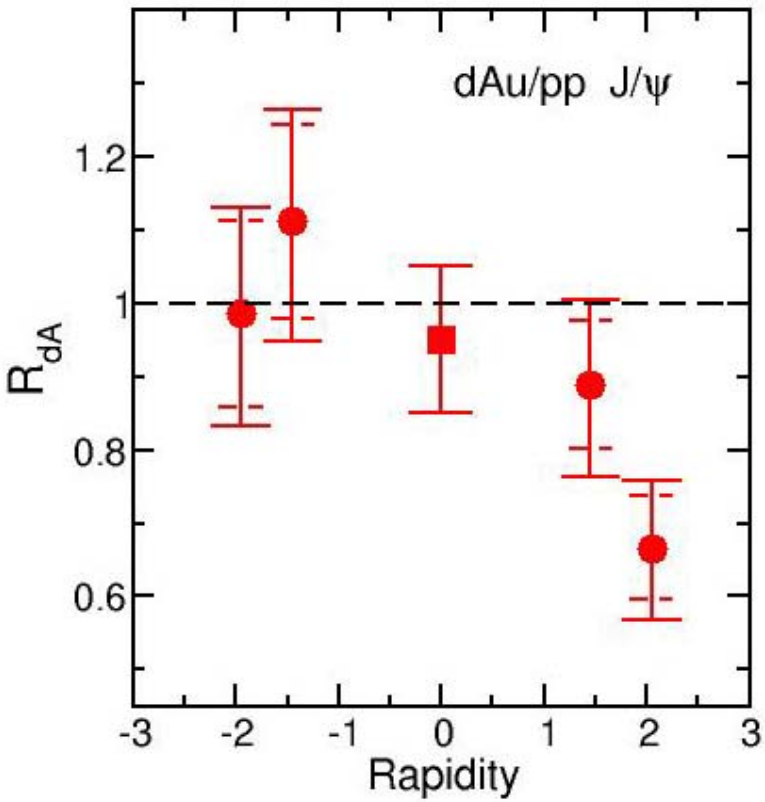
y ~ 0 : intermediate x_{Au} ~ 0.020

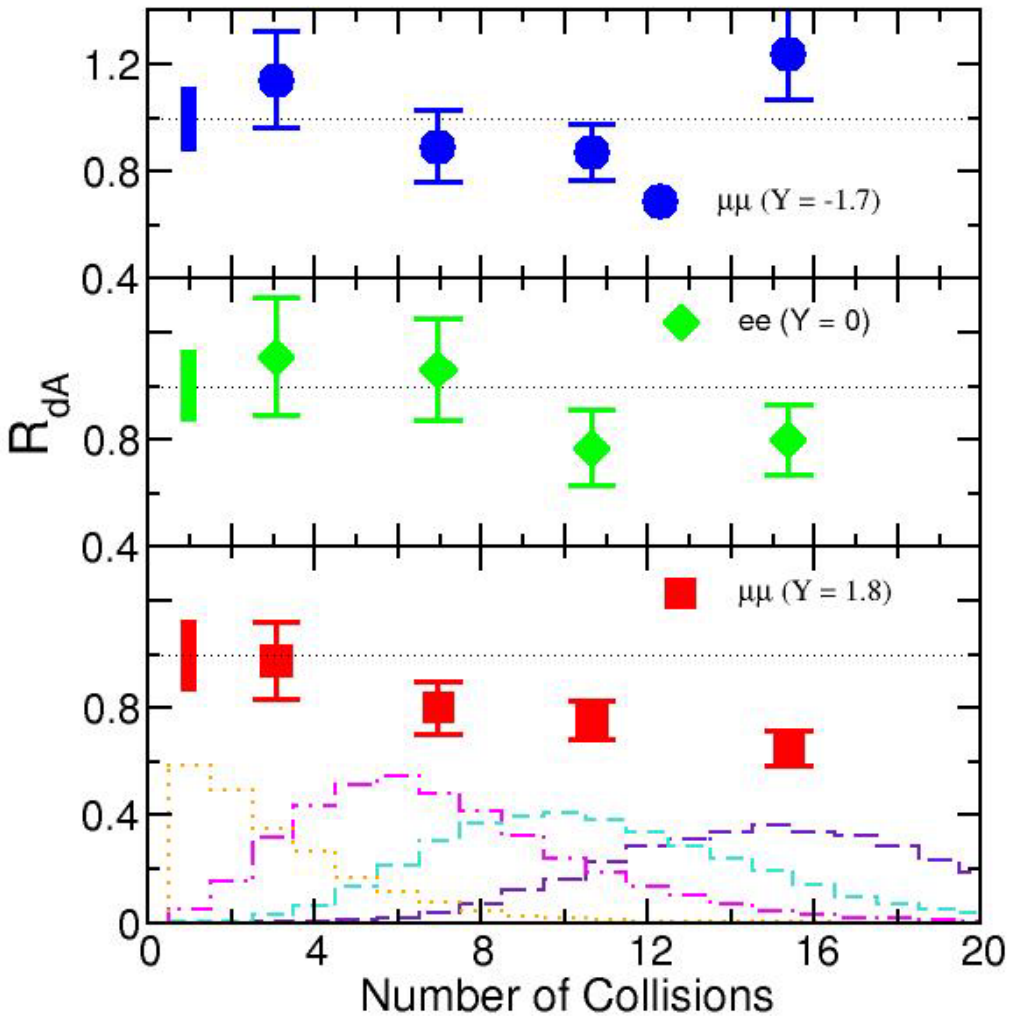
y > 1.2 : low x_{Au} ~ 0.003



$$R_{dA} = \frac{\sigma_{dAu}}{(2 \times 197 \times \sigma_{pp})}$$

Inhomogeneous shadowing ?

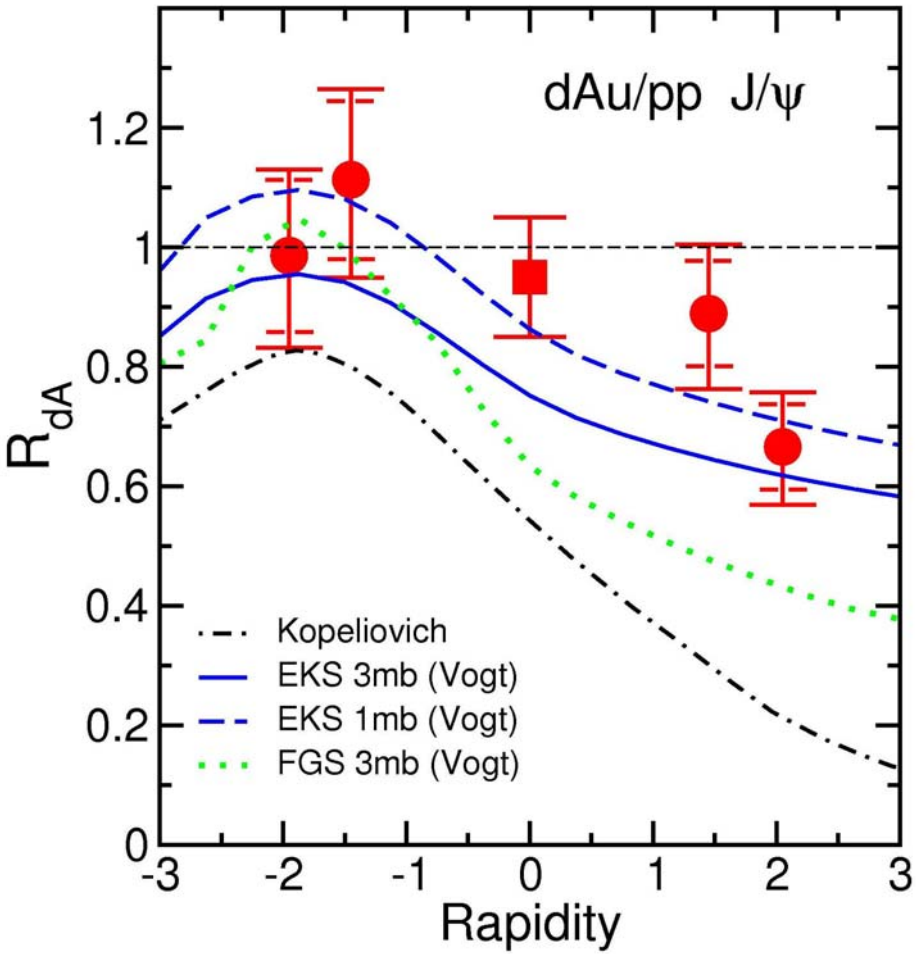


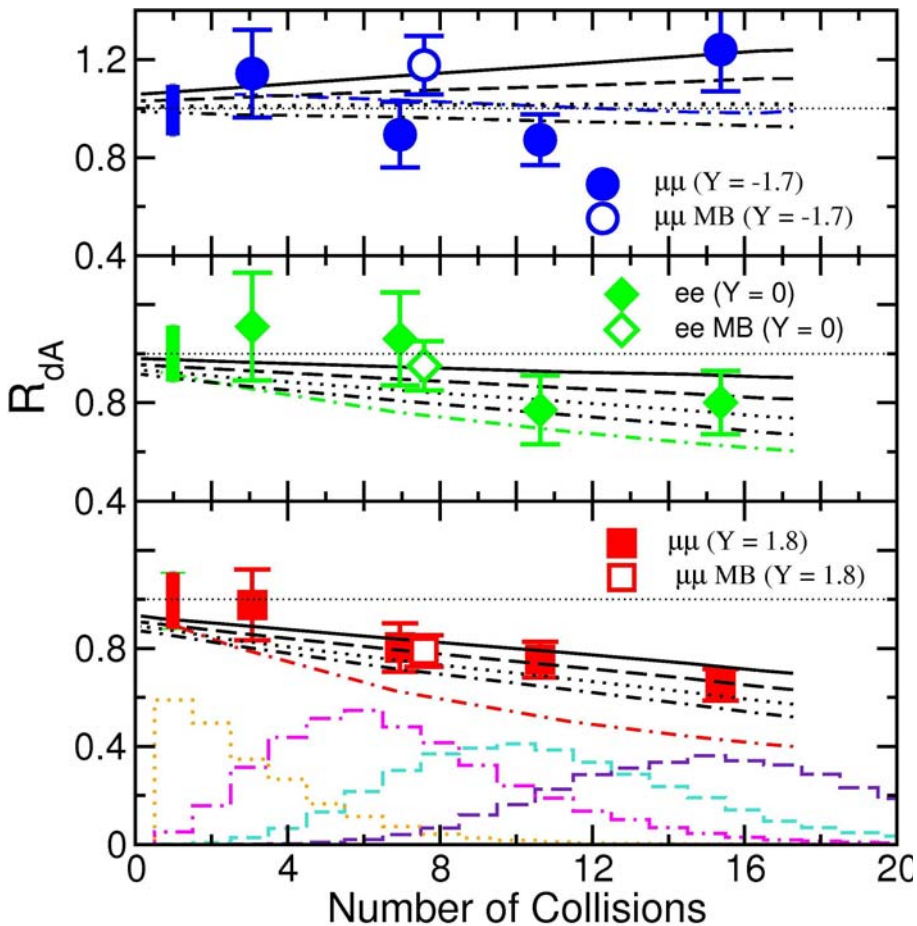


Room for small centrality dependence

WEAK shadowing & WEAK nuclear absorption at RHIC

Models with shadowing + absorption



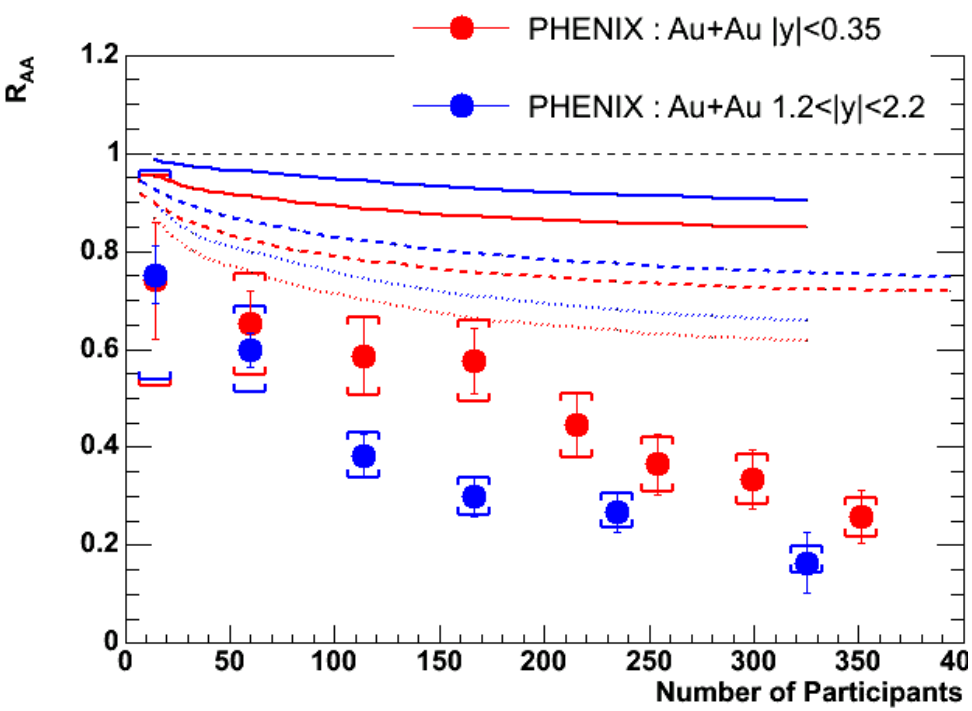


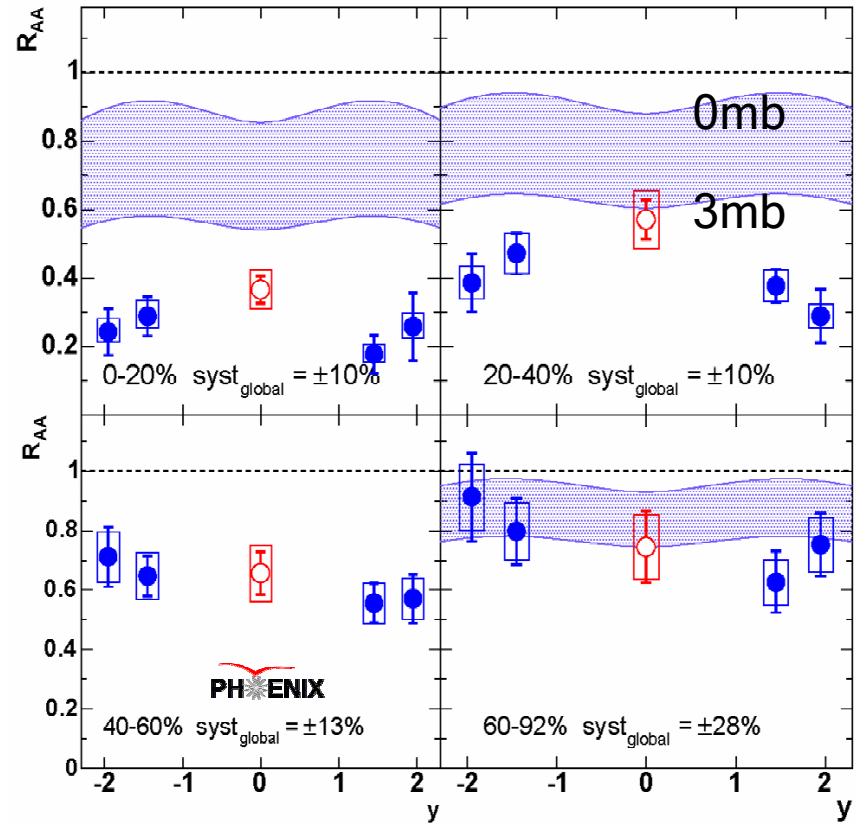
- (Centrality dependent)shadowing EKS98
- σ^{abs} = 0 to 3 mb

PHENIX, PRL96 (2006) 012304
Klein,Vogt, PRL91 (2003) 142301

Predictions for Au+Au systems

R. Vogt et al., nucl-th/0507027





Suppression beyond CNM in central collisions
CNM effects predict larger suppression at mid-rapidity, while data shows larger suppression at forward-rapidity.

Cold nuclear effects RHIC vs SPS

- RHIC : main contributions expected are shadowing and nuclear absorption

- SPS : σ^{abs} = 4,18 mb measured using large range of p-A data, however (anti-) shadowing contribution exists : real σ^{abs} higher…

σ^{abs} decreases with increasing $\sqrt{s}$?

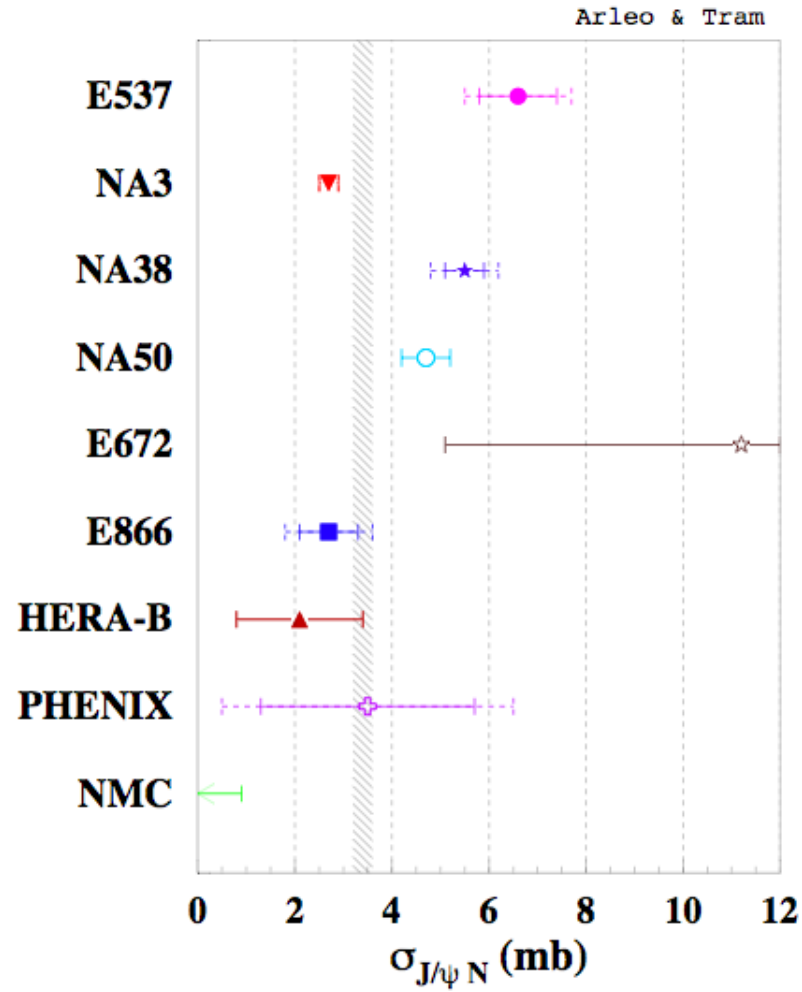
Nuclear absorption

J/Ψ measured in hadroproduction, photoproduction (leptoproduction) at different energy collision at different A

Consistent with no energy dependence

$$\sigma^{abs} = 3.4 +/- 0.2 \text{ mb}$$

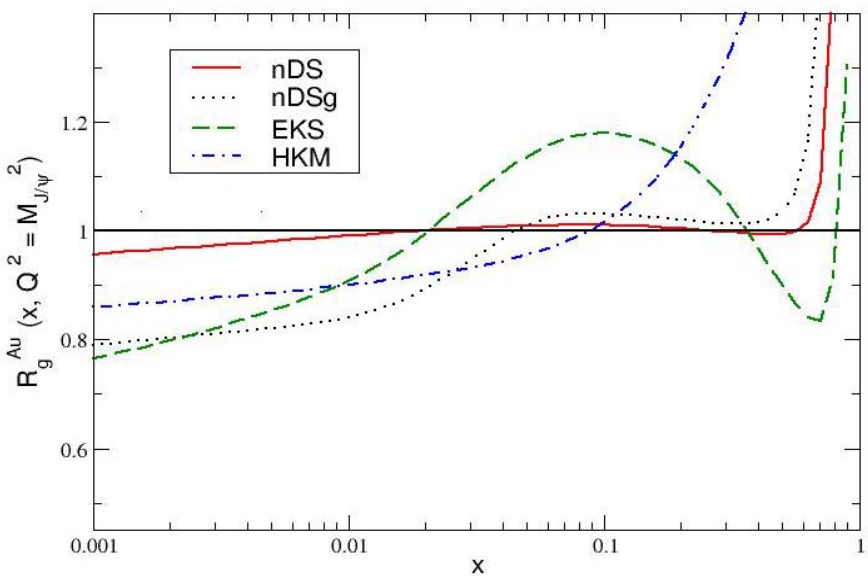
(without shadowing corrections)

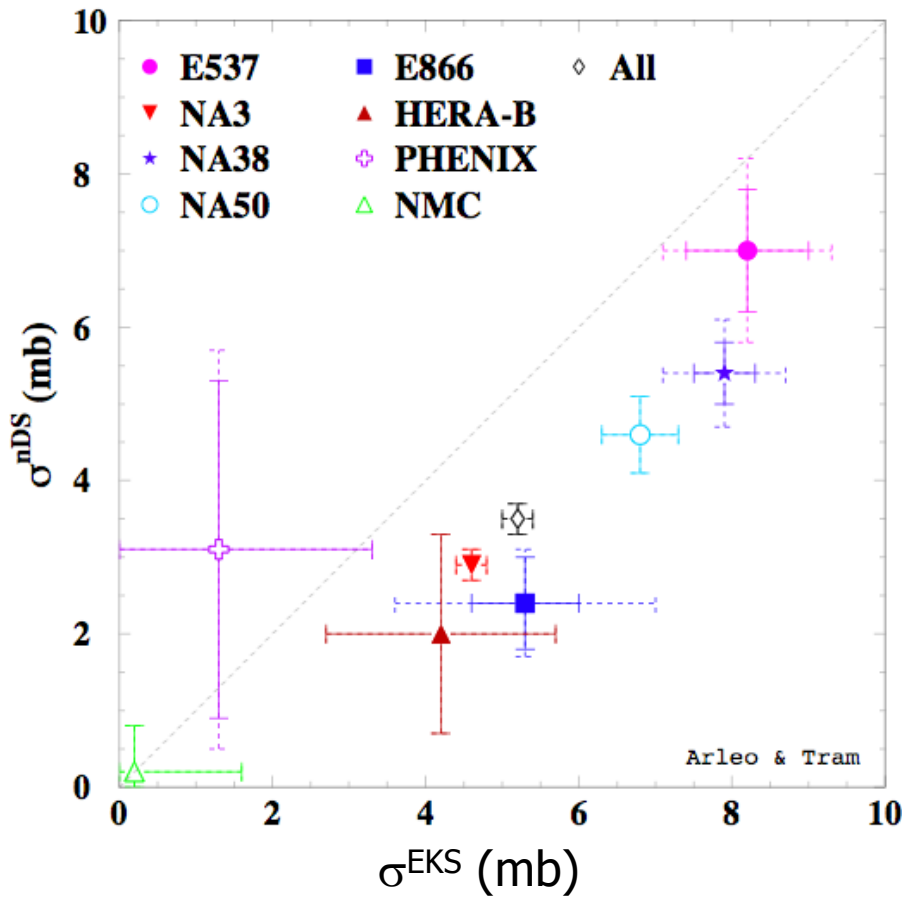


Arleo & Tram, hep-ph/0612043

Gluon shadowing…

Nucl. Phys. A696 (2001) 729-746
Phys.Rev D64,034003
Phys.Rev.D69,074028





σ^{nDS} = 3.5 +/- 0.2 mb
σ^{EKS} = 5.2 +/- 0.2 mb

Gluon shadowing and nuclear absorption not understood/well constrained yet

Data driven analysis

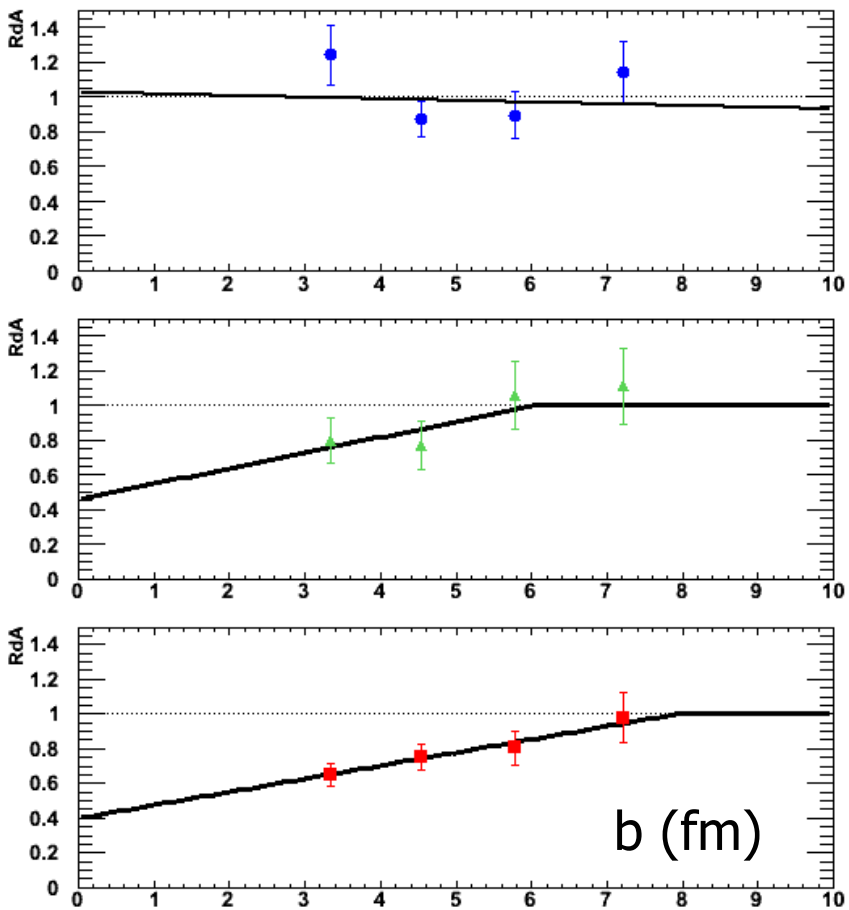
- No shadowing form/nuclear absorption form assumed
- But rapidity factorization assumed:

$\sigma \sim$ pdf1 x pdf2 x S_{abs}

- Centrality dependence:

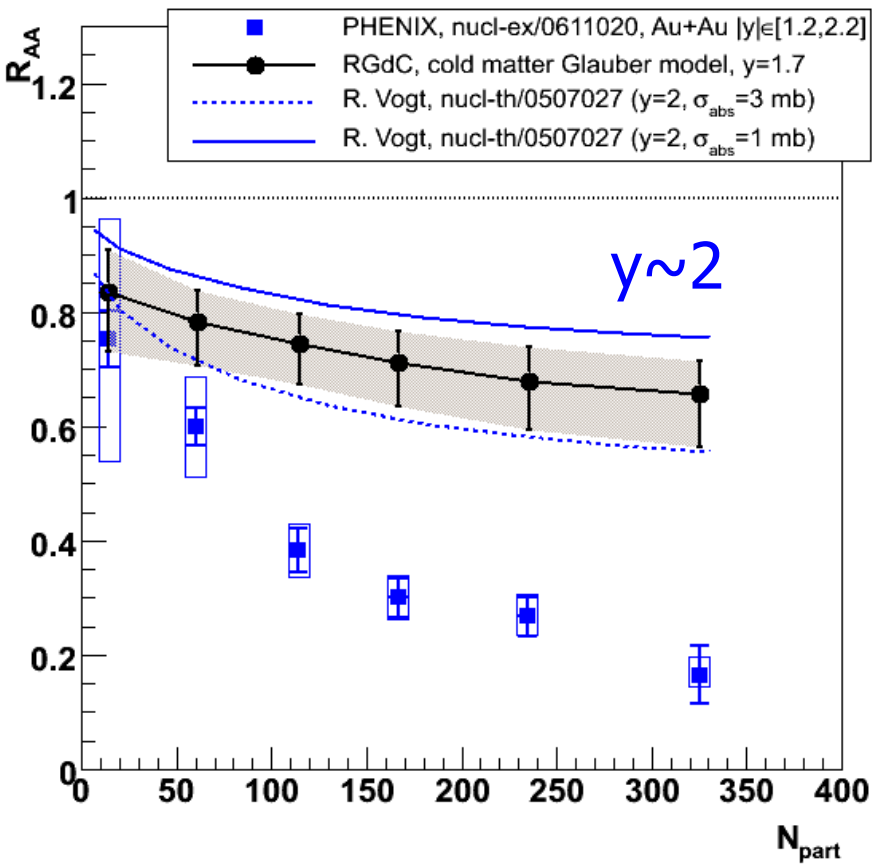
$R_{AA}(|y|,b_{AA}) =$

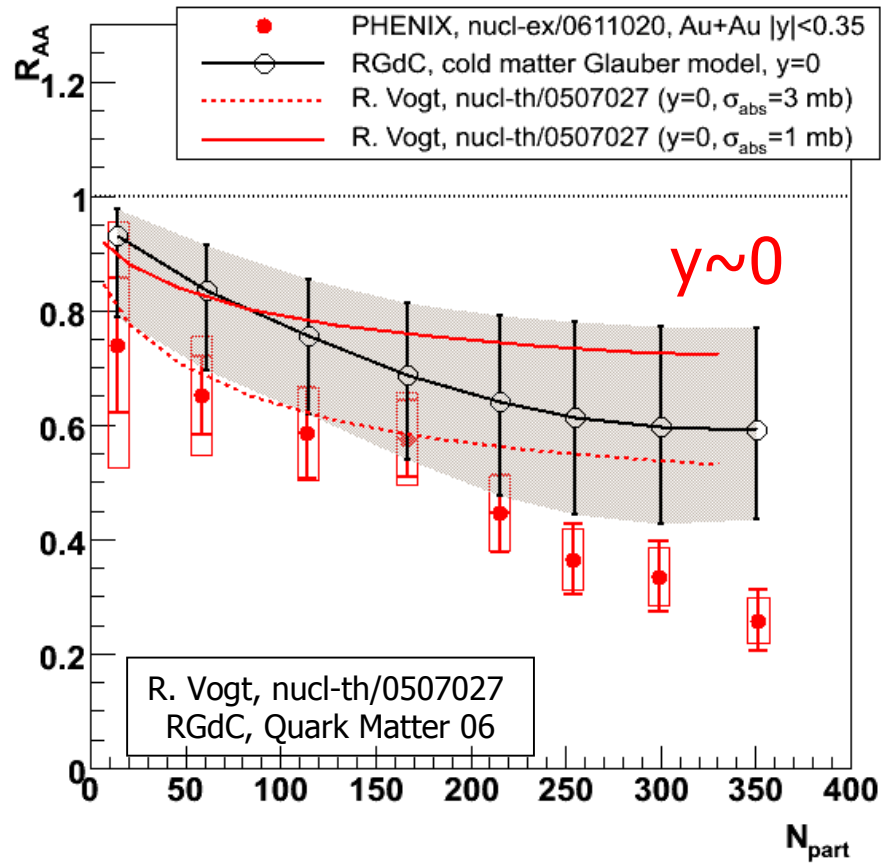
Σ_{coll} [R_{dA} $(-y,b^i_1)$ x R_{dA} $(+y,b^i_2)$] / N_{coll}



R. Granier de Cassagnac, QM06 talk

Cold nuclear effects predictions in AuAu

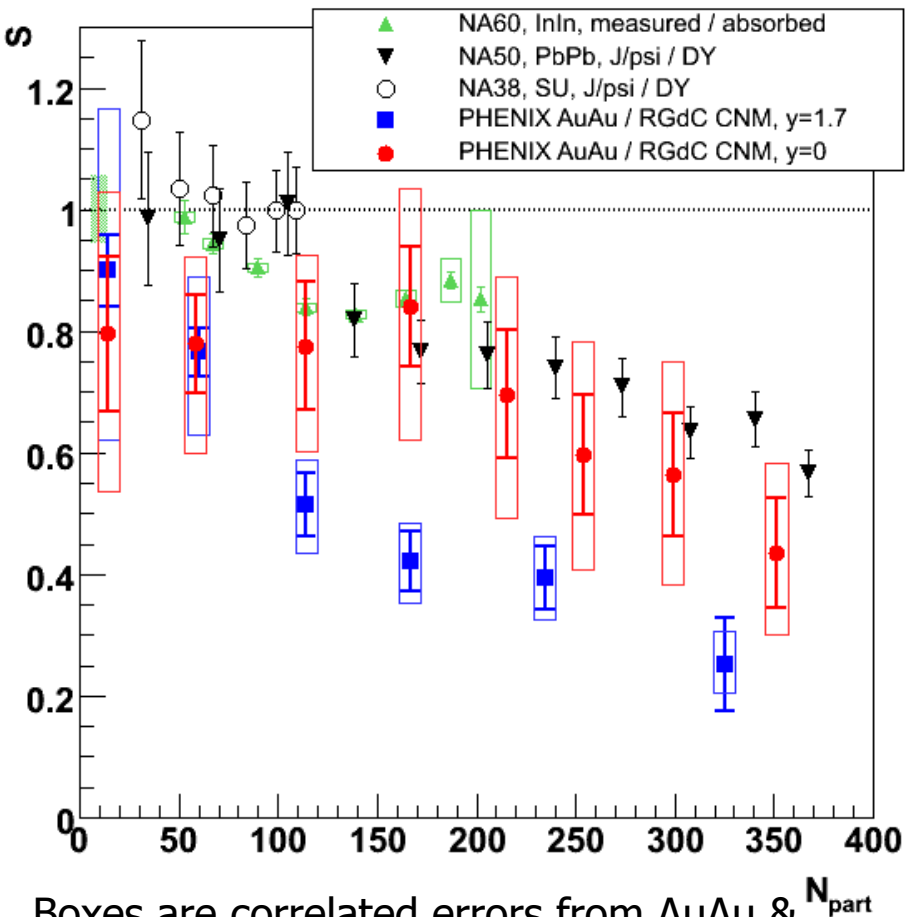




Not very different…

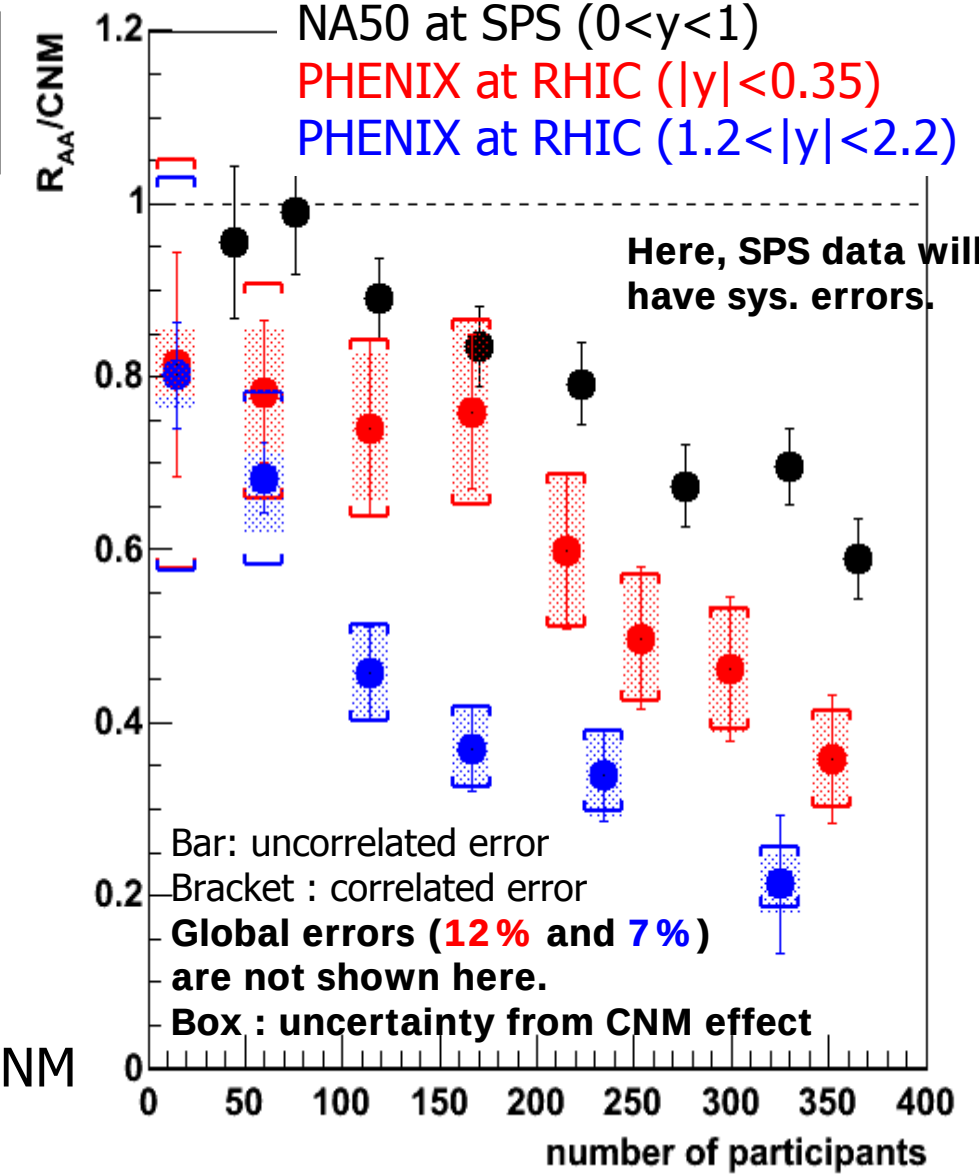
shadowing+absorption by Vogt and dA-driven Glauber by RGdC

Measured/expected @ RHIC

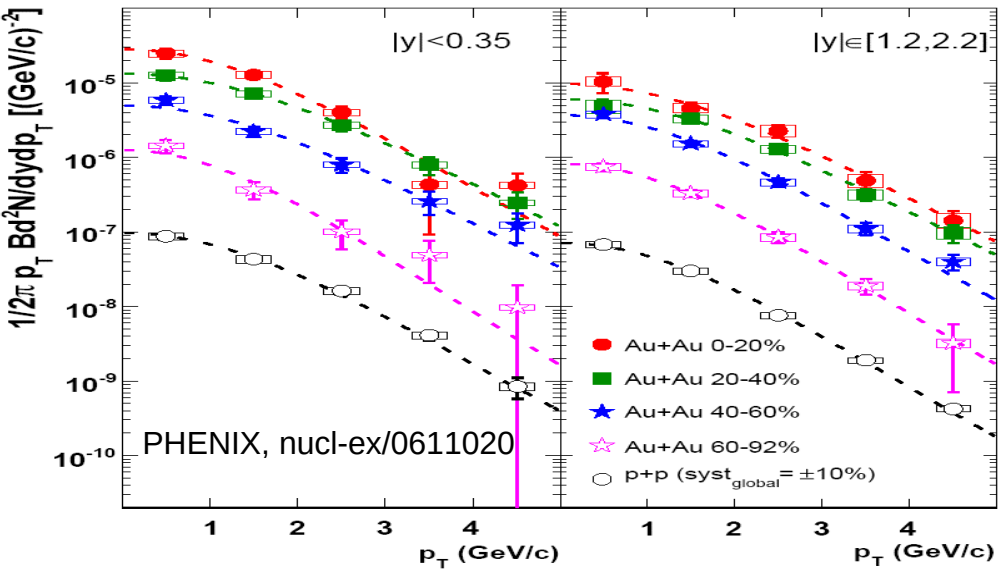


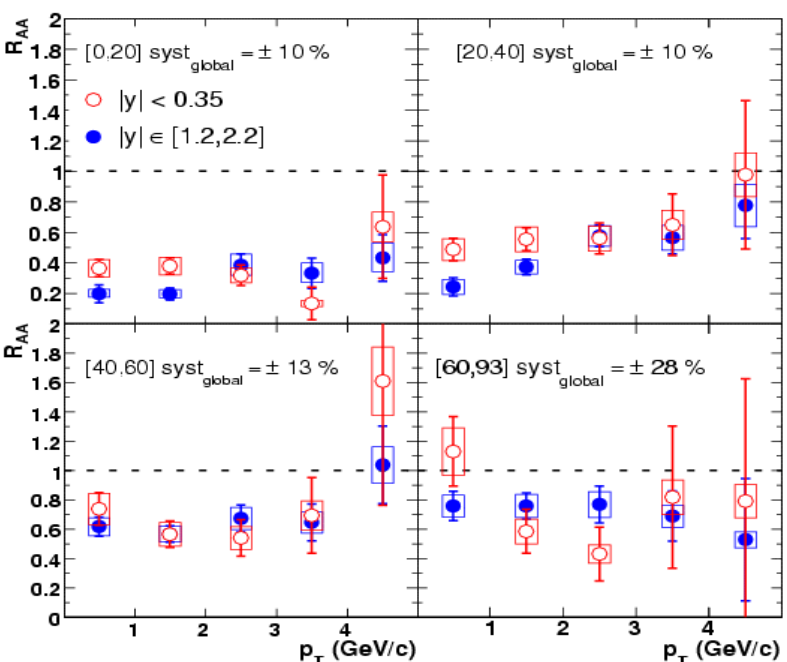
Boxes are correlated errors from AuAu & <u>dominant</u> CNM

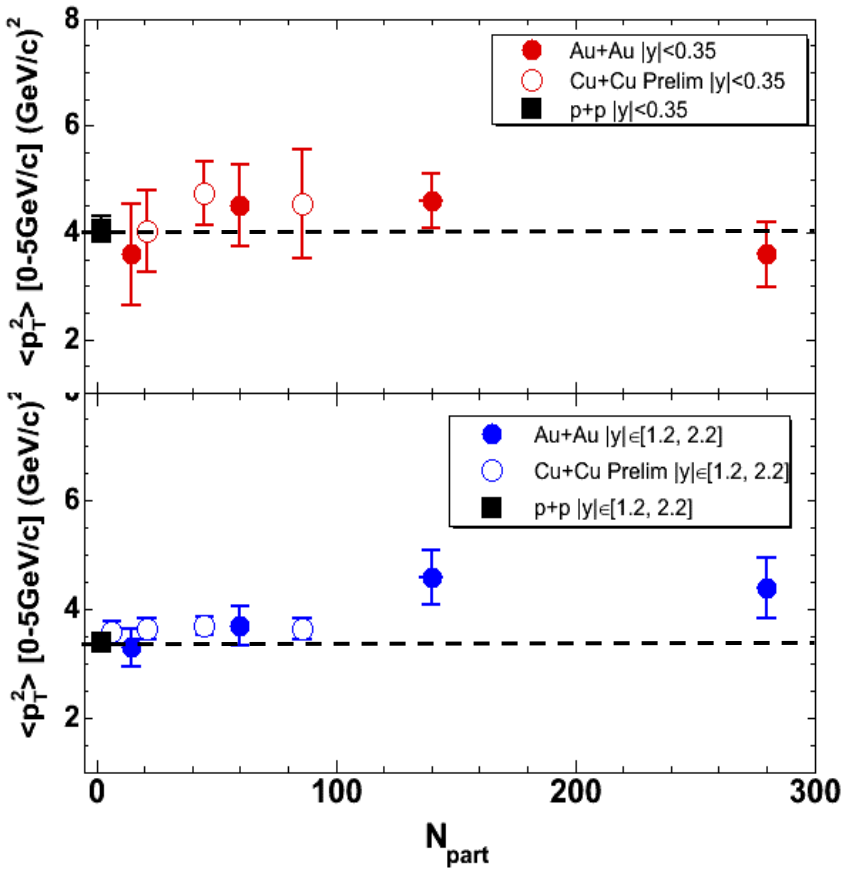
Shaded area : uncertainties from CNM (0-2 mb)



P_t distribution and $<p_T^2>$





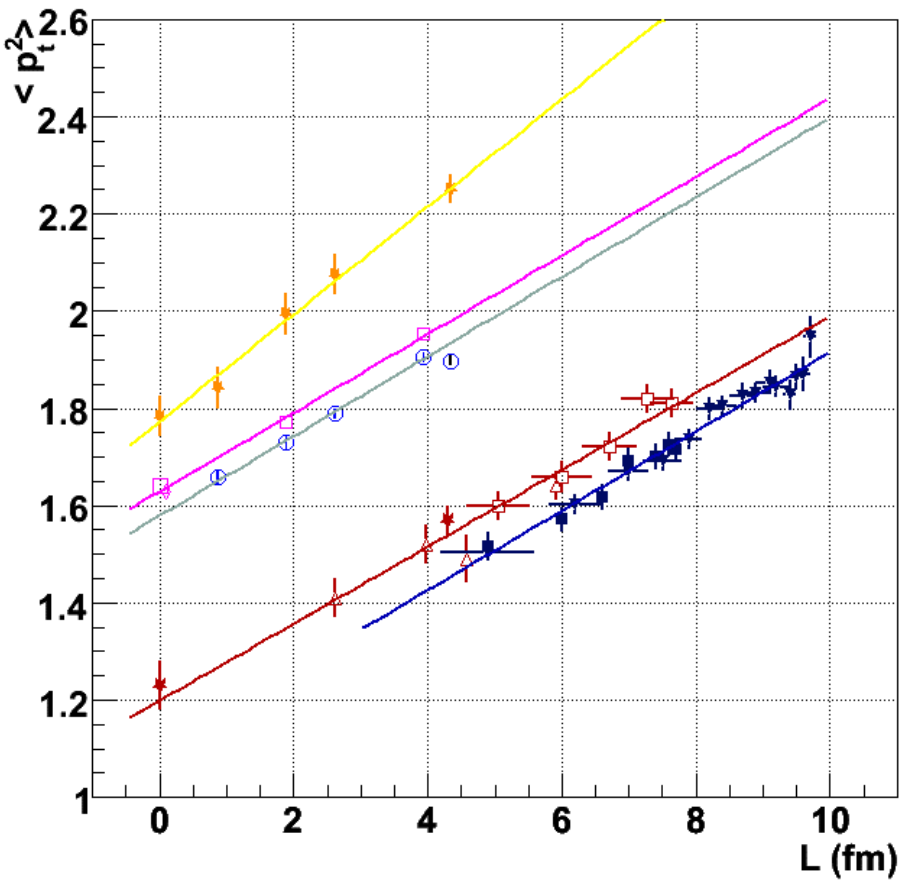


Suppression at low p_T in central collisions

Cronin effect

Scattering of initial gluons on nucleon before ccbar formation

random walk : $\langle p_t^2 \rangle_{AA} = \langle p_t^2 \rangle_{pp} + \rho\sigma\Delta(\langle p_t^2 \rangle)\, L_{AA}$



$\sqrt{s}$ =17,3 GeV : NA50/60 Pb+Pb, In+In

$\sqrt{s}$ = 19,4 GeV : NA3 p+p, NA38 p+Cu, p+U,O+U, S+U

$\sqrt{s}$ = 27,4 GeV : NA50 p+Be, p+Al, p+Cu, p+W

$\sqrt{s}$ = 29,1 GeV :NA51 p+p, p+d, NA50 p+Al, p+W

$\sqrt{s}$ = 38.8 GeV : E866/789/771

ρ nuclear density, σ elastic gluon-nucleon scattering cross section, $\Delta(\langle p_t^2 \rangle)$ kick given by each scattering and L average thickness of nuclear matter

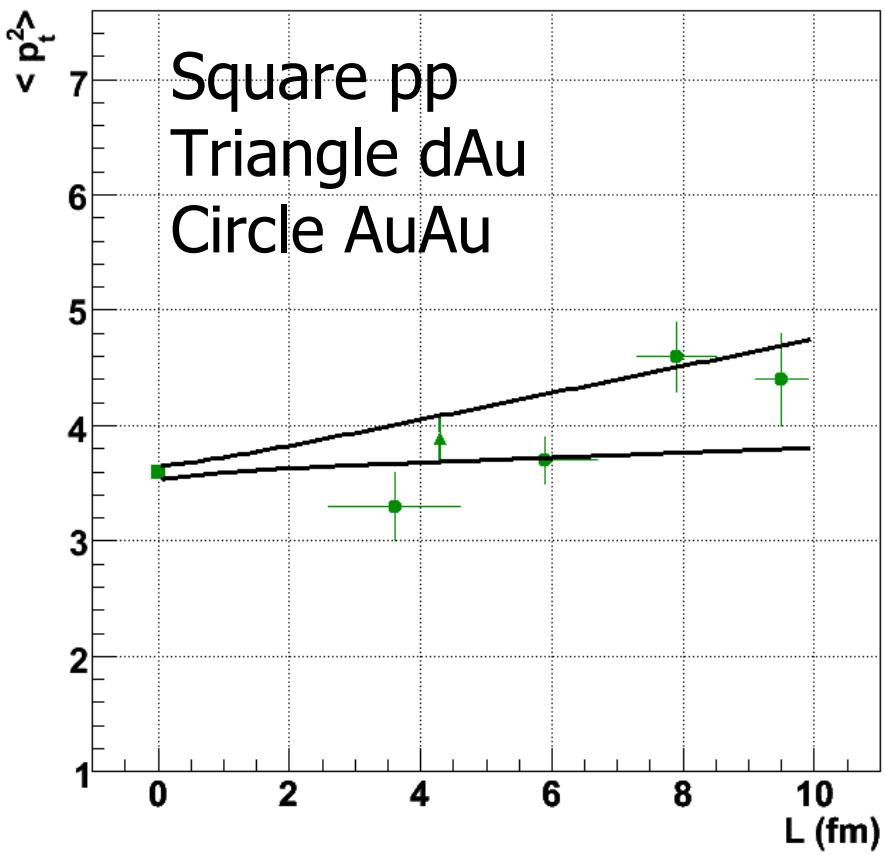
Cronin effect

Cronin : $\langle p_t^2 \rangle_{AA} = \langle p_t^2 \rangle_{pp} + \rho\sigma\Delta(\langle p_t^2 \rangle)\, L_{AA}$

Extrapolation curve from PHENIX J/ψ results in p+p and d+Au

Weak cronin effect observed at forward y

Is AuAu $\langle p_t^2 \rangle$ compatible with Cronin effects ?

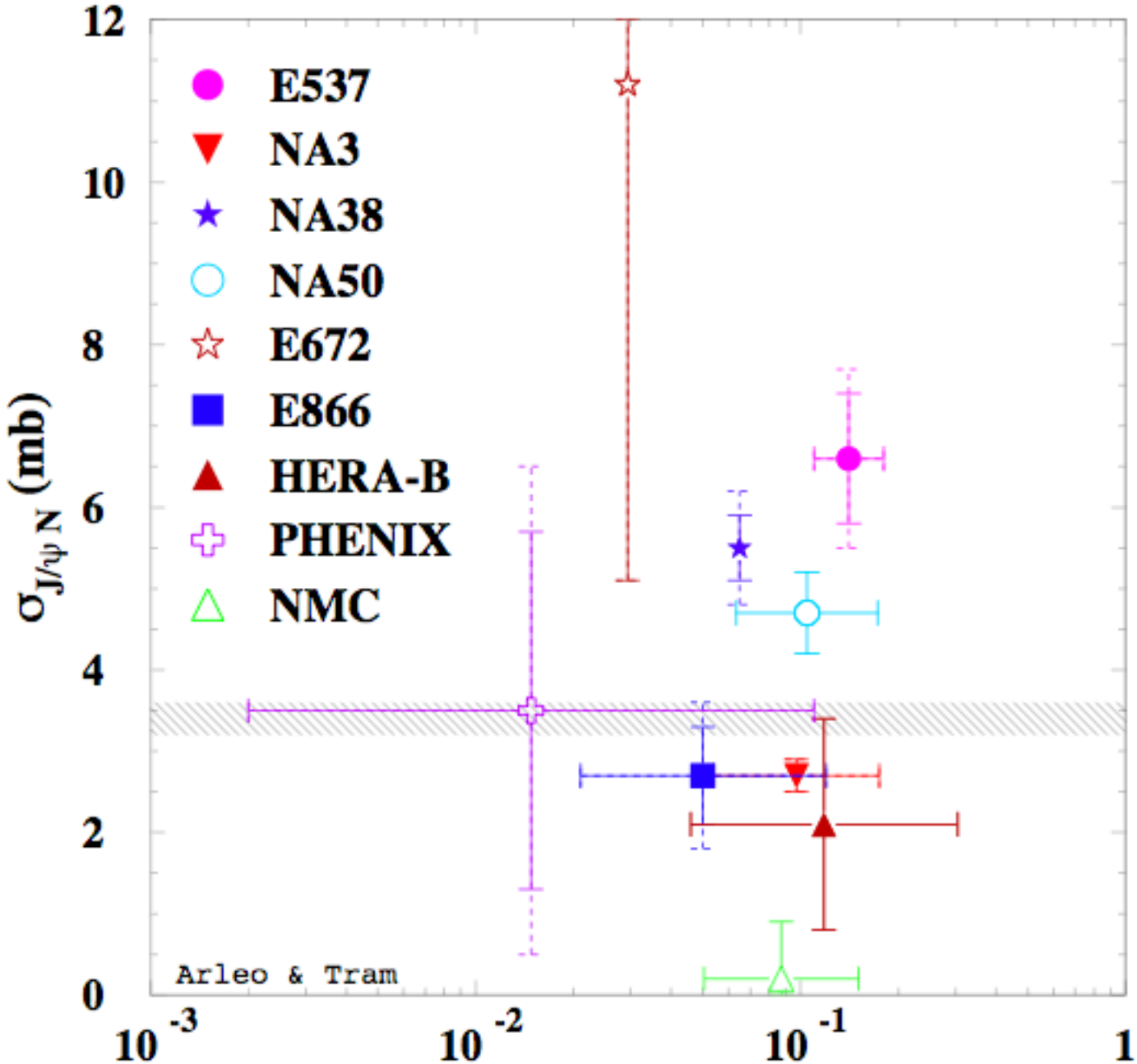


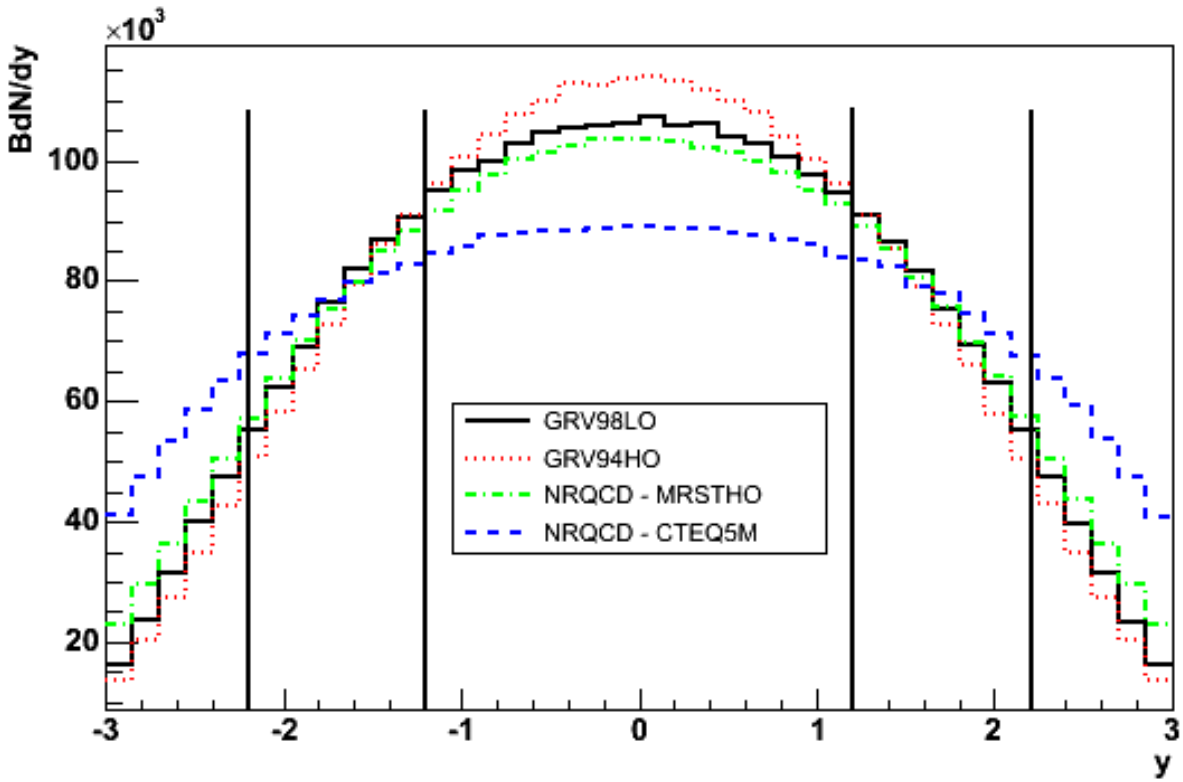
Note that at y =0, measurements show « weaker » Cronin effect

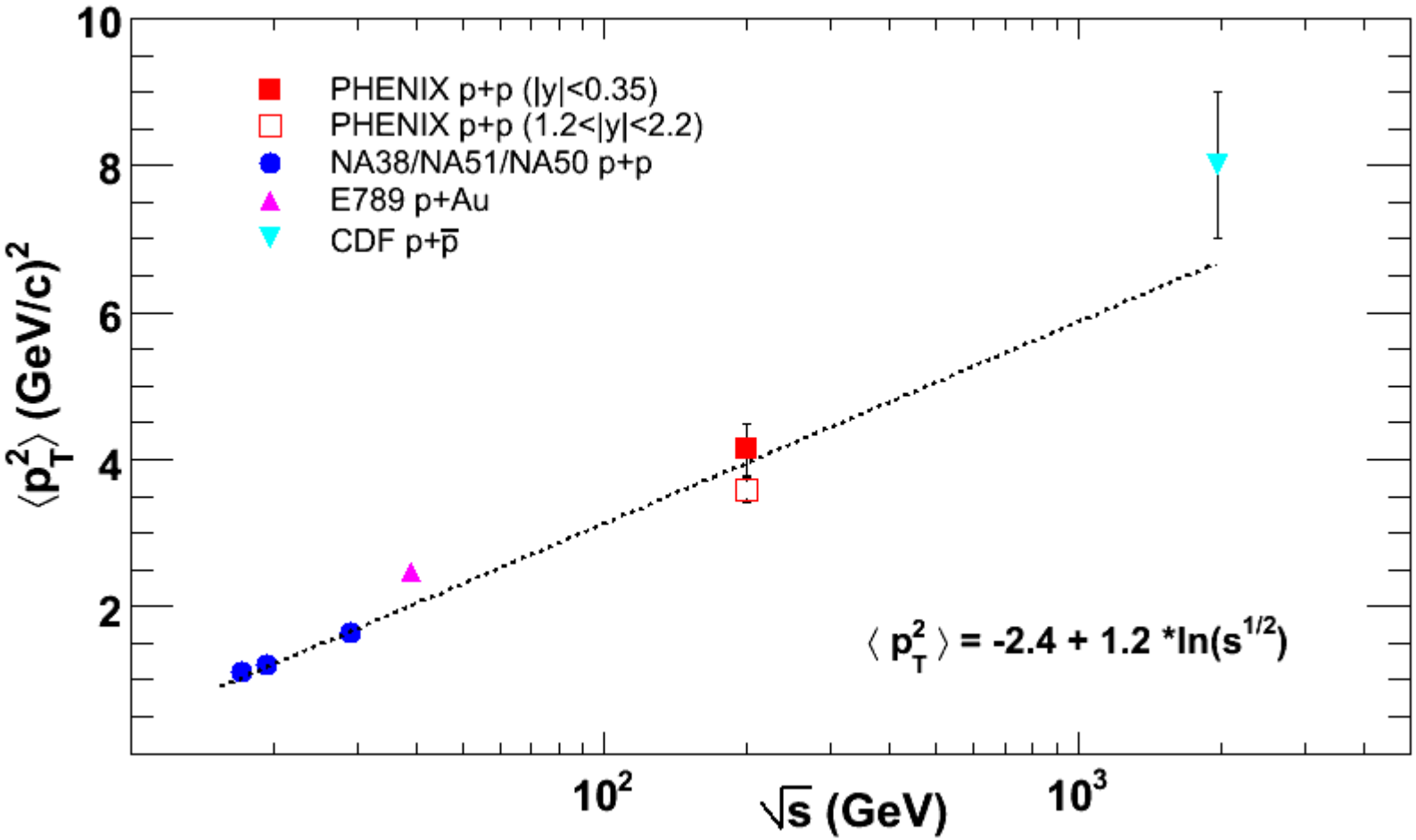
Summary

- Cold nuclear effects have been measured in dAu :
  - weak shadowing
  - weak nuclear absorption
  - weak p_T broadening
- But CNM are not well understood yet
  - Centrality dependence of gluon shadowing ?
  - Nuclear absorption decreases with increasing $\sqrt{s}$?
- … need more (precise) pA data at RHIC !

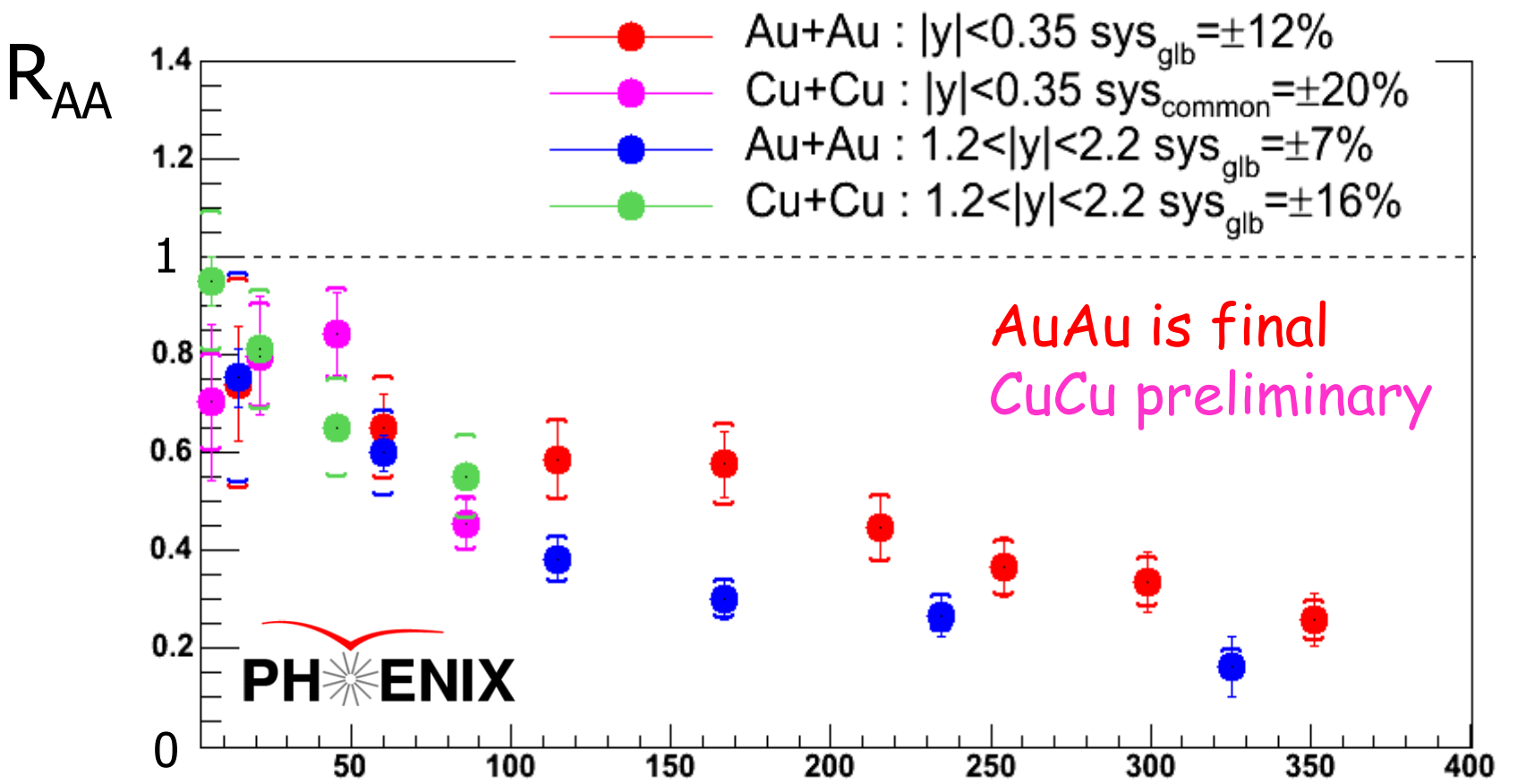
Backup slides


E537
NA3
NA38
NA50
E672
E866
HERA-B
PHENIX
NMC
$\sigma_{J/\psi N}$ (mb)
Arleo & Tram
12
10
8
6
4
2
0
10^{-3}
10^{-2}
10^{-1}
1


×10^3
BdN/dy
100
80
60
40
20
-3
-2
-1
0
1
2
3
y
GRV98LO
GRV94HO
NRQCD - MRSTHO
NRQCD - CTEQ5M


PHENIX p+p (|y|<0.35)
PHENIX p+p (1.2<|y|<2.2)
NA38/NA51/NA50 p+p
E789 p+Au
CDF p+p̄
⟨ p$_T^2$ ⟩ = -2.4 + 1.2 *ln(s$^{1/2}$)
⟨p$_T^2$⟩ (GeV/c)^2
√s (GeV)
10
8
6
4
2
10^2
10^3

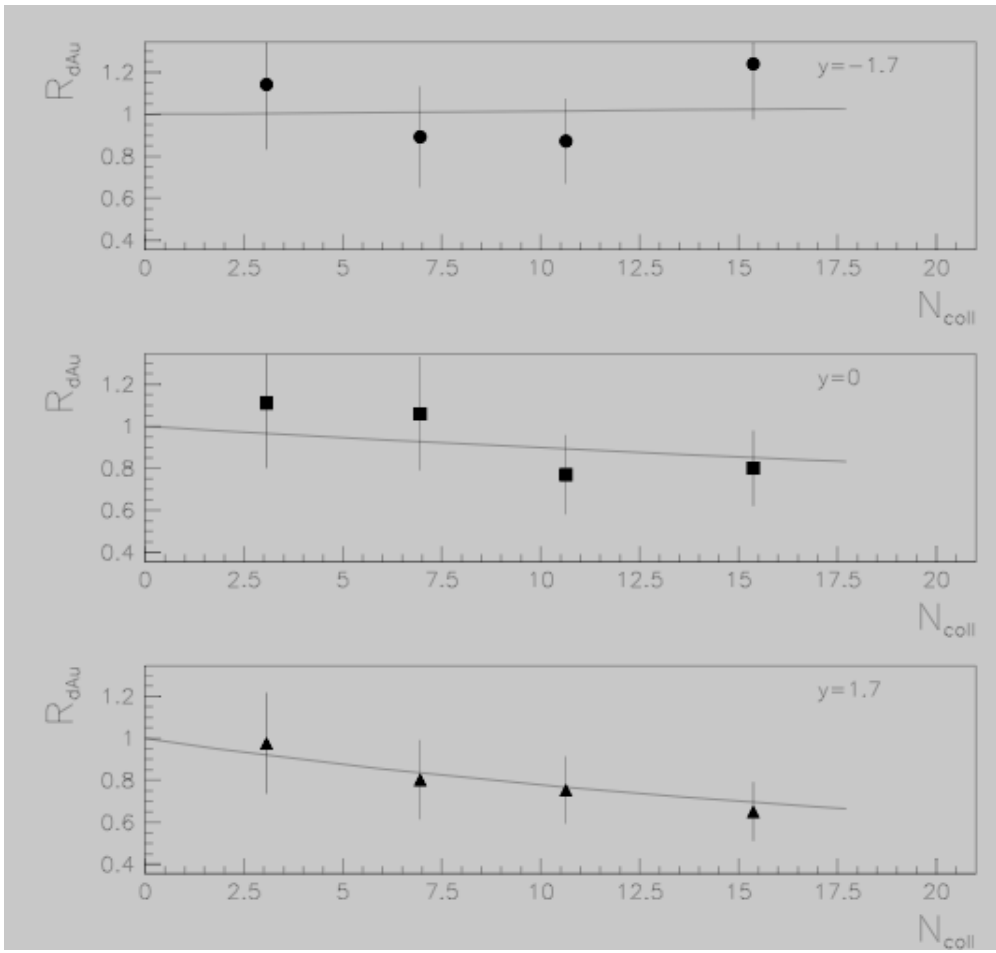
AuAu versus CuCu

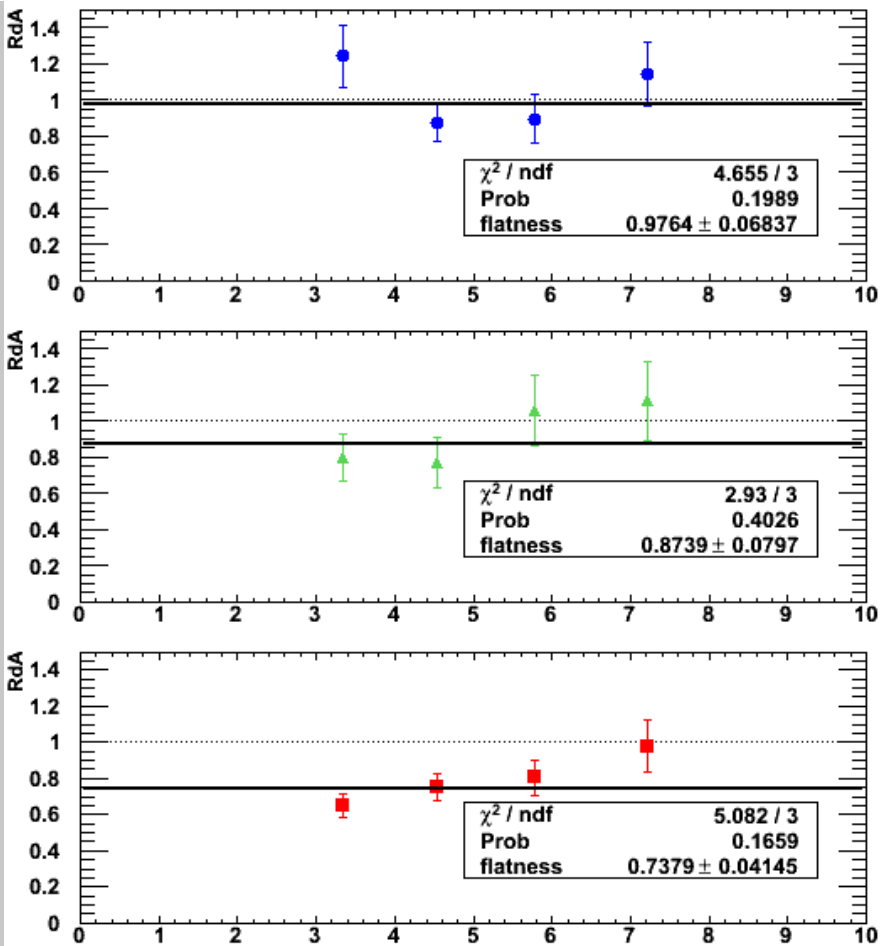


AuAu are normalized with run 5 p+p
Cu+Cu with run 3 p+p, final results soon

Need more precise dAu meas.

Capella & Ferreiro hep-ph/0610313





b (fm)

dAu data described with shadowing only (σ^{abs}=0)

Also…