Cold matter affects quarkonia production

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QM08 satellite meeting
Tata Institute for Fundamental Research
Mumbai, 2008, February 12th

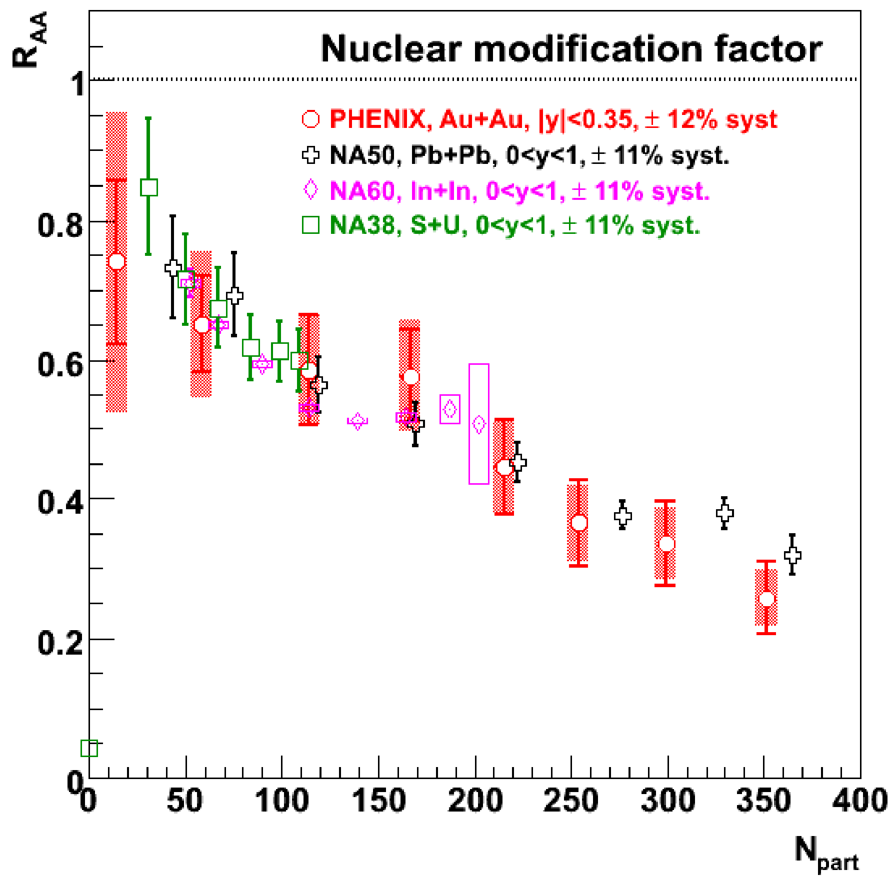
LOGO +
NAME CHECK

Reminder of the two striking behaviors of J/ψ suppression at RHIC energy

1. $R_{AA}(RHIC) \approx R_{AA}(SPS)$
2. $R_{AA}(y \approx 1.7) < R_{AA}(y \approx 0)$

R_{AuAu} (y≈0 in PHENIX) ≈ R_{PbPb} (@ SPS)

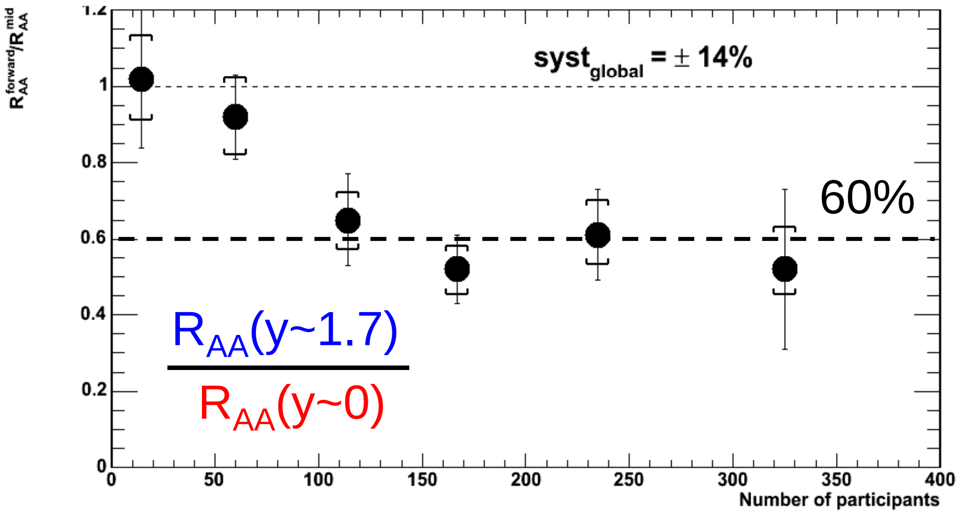
- Midrapidity R_{AA} looks surprisingly similar, while there are obvious differences:
  - At a given N_{part}, different energy densities…
  - Cold nuclear matter effects ($x_{Bjorken}$, σ_{abs}…)
  - …

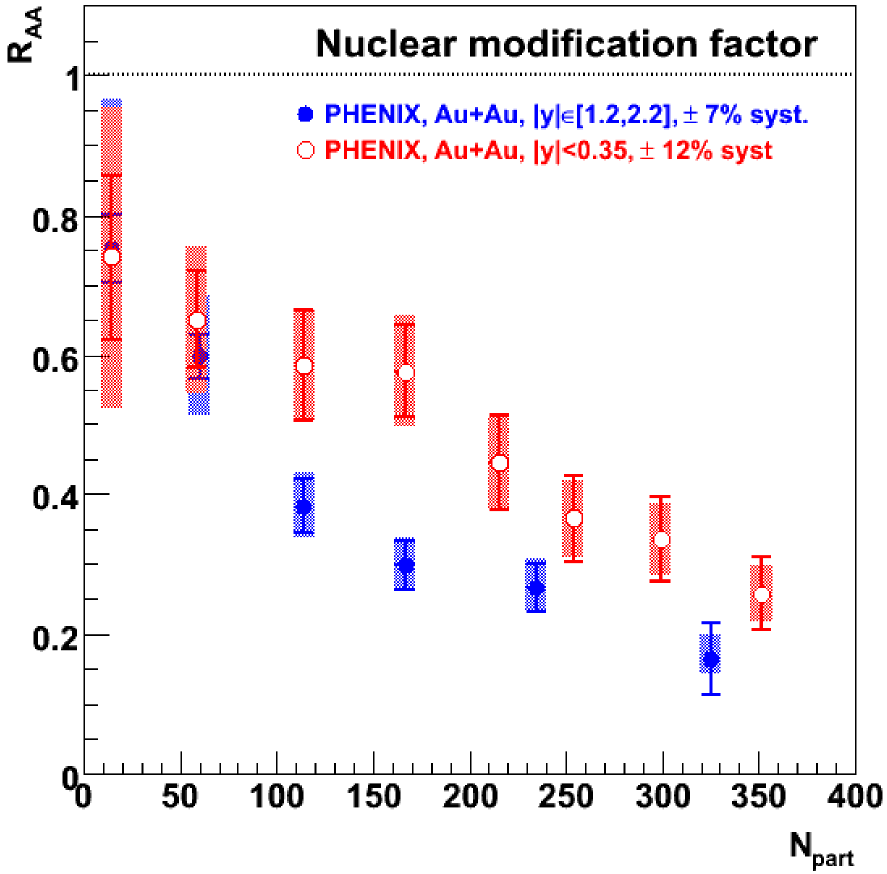


PHENIX, PRL98 (2007) 232301
SPS from Scomparin @ QM06

R_{AuAu} (y≈1.7) < R_{AuAu} (y≈0) in PHENIX

- @ RHIC, more J/ψ suppression at forward rapidity !
- While energy density should be smaller…





PHENIX, PRL98 (2007) 232301

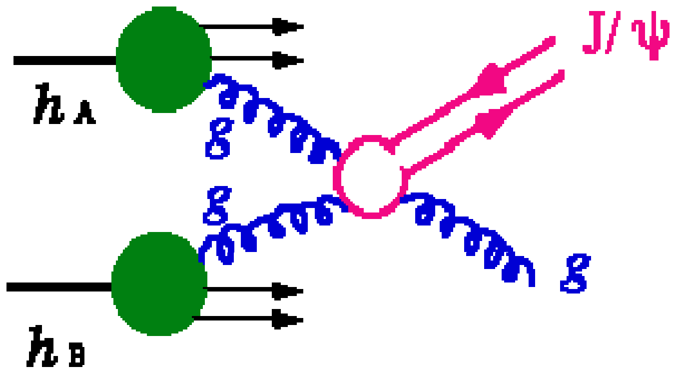
For the hot stuff, see Cesar Luis da Silva's talk on Wednesday

How much of this is due to normal nuclear matter ?

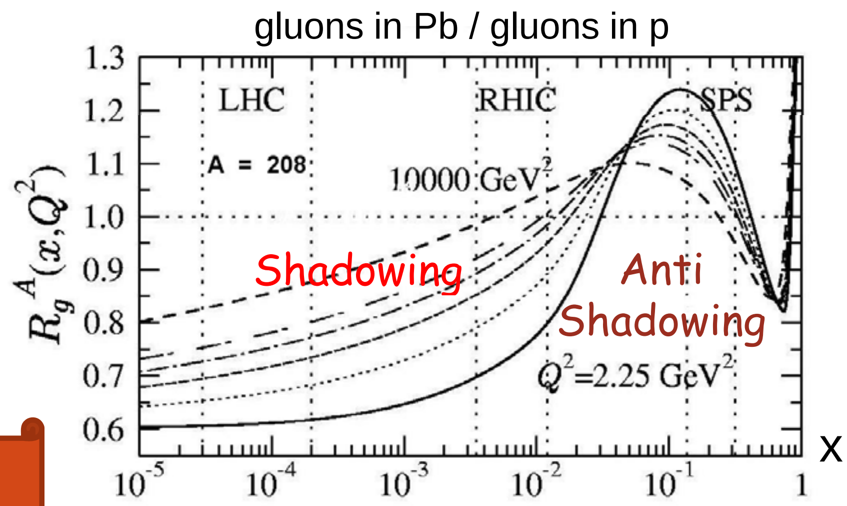
(what cannot claim anything about quark gluon plasma without first answering this question)

Cold nuclear matter effects ?

- Many possible effects:
  - J/ψ (or $c\bar{c}$) absorption/breakup
  - (Anti) shadowing
    (gluon saturation, CGC…)
  - Energy loss of initial parton
  - p_T broadening (Cronin effect)
  - Complications from feed down ψ’ & χ_c ?
  - Intrinsic charm ?
  - Something else ?
- Absolute need for data !



An example of gluon shadowing prediction



Eskola, Kolhinen, Vogt
NPA696 (2001) 729

Nobody is perfect…

- @SPS: many pA ! High statistics ! But small kinematics ($-0.1 < x_F < +0.1$)
  - Nuclear absorption does a splendid job
- @FNAL: less pA… High statistics ! Large rapidity (x_F) coverage… No AA…
  - Many cold nuclear effects needed!
- @HERAB: similar, negative x_F (-0.35 to $+0.15$)
- @RHIC: only dAu, low statistics, but rapidity (-2.2 to $+2.2$) and <u>centrality dependence</u>
  - Absorption + (anti)shadowing

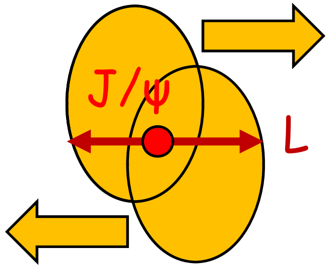
For the real stuff, see Carlos Lourenço's talk hereafter

A snapshot of SPS

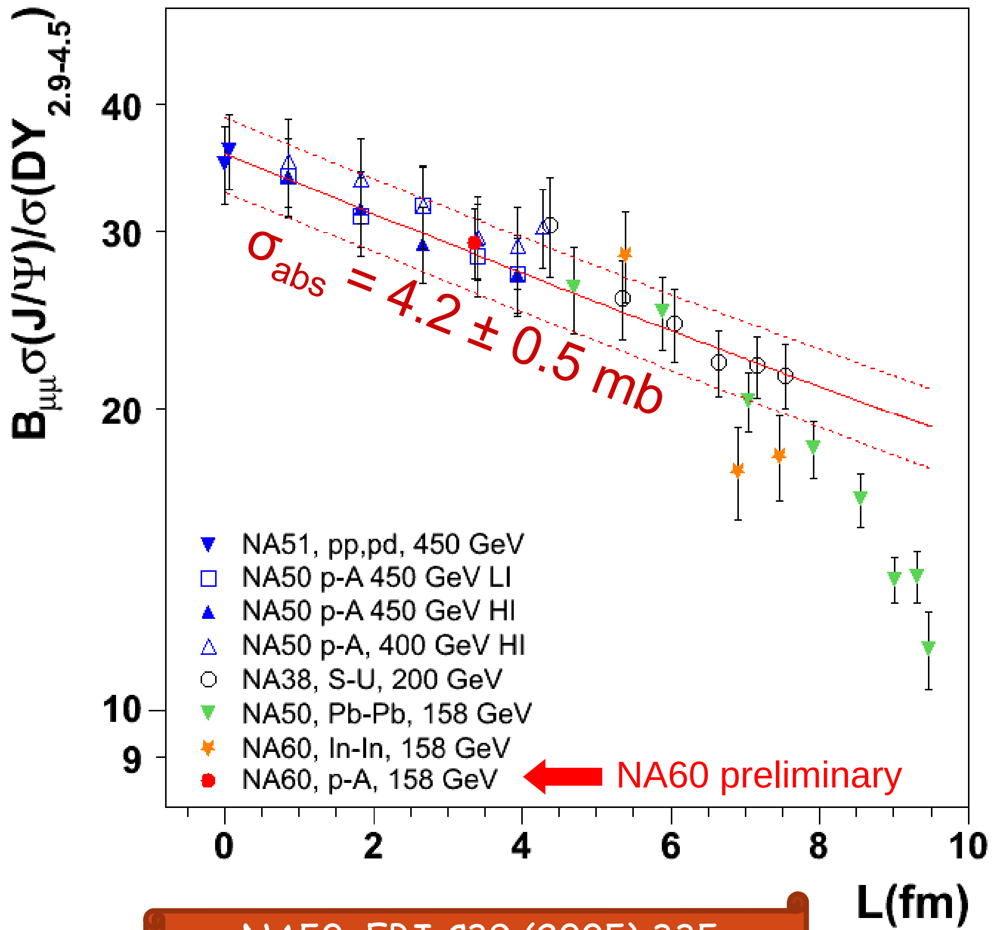
To first order, a simple and elegant description of nuclear matter effects

$\sigma_{abs} = 4.2 \pm 0.5$ **mb**

Cold and hot matters @ SPS



- <u>Normal nuclear absorption alone</u> does a splendid job describing pA, SU and peripheral InIn and PbPb:
  - (including one preliminary pA @ 158 GeV from NA60, final yet to come…)
- exp($-\sigma_{abs}\, \rho_0$ L)
  - L nuclear thickness
  - (or in Glauber model)
  - **σ_{abs} = 4.2 ± 0.5 mb**



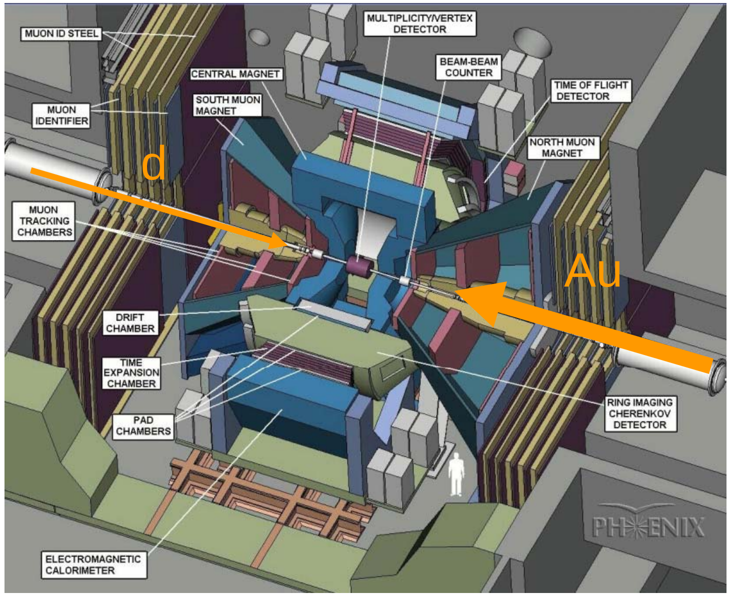
NA50, EPJ C39 (2005) 335
NA60, PRL99 (2007) 132302

R_{dAu} rapidity dependence

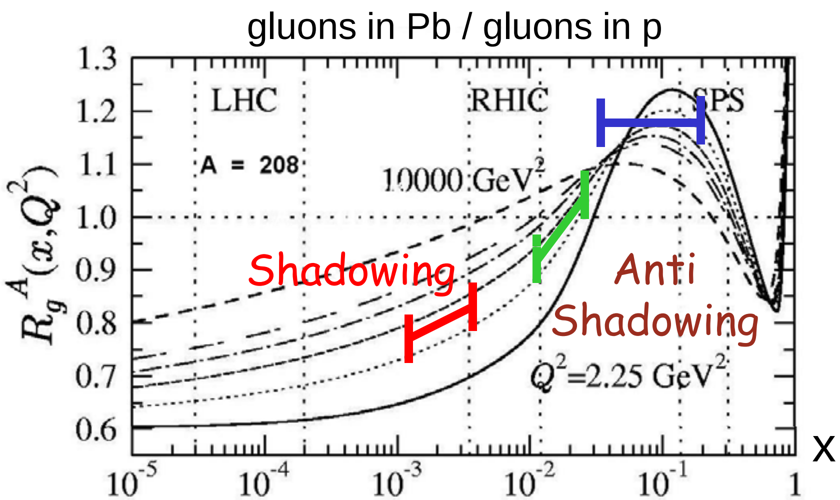
(Capella et al aussi?)

Deuteron → ← Gold

- At RHIC, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon's pdf
- In PHENIX, three rapidity ranges probe different momentum fraction of Au partons
  - South ($y < -1.2$) : large x_2 (in gold) ≈ 0.005 to 0.140
  - Central ($y \approx 0$) : intermediate $x_2 \approx 0.011$ to 0.022
  - North ($y > 1.2$) : small x_2 (in gold) ≈ 0.002 to 0.005



An example of gluon shadowing prediction



Eskola, Kolhinen, Vogt
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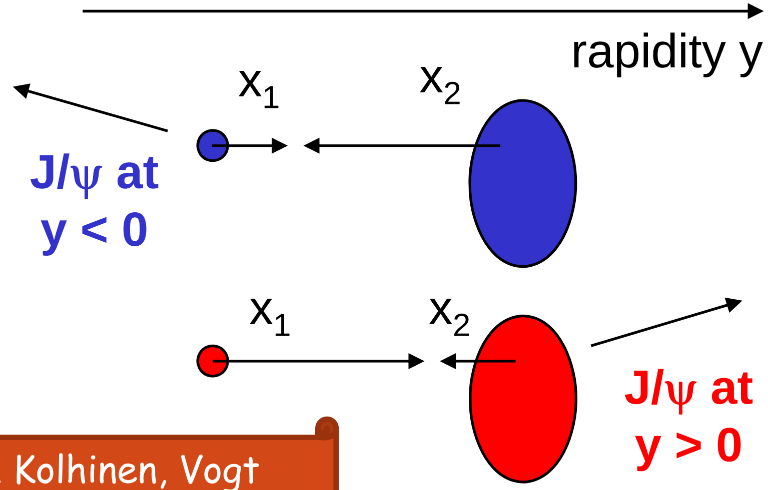
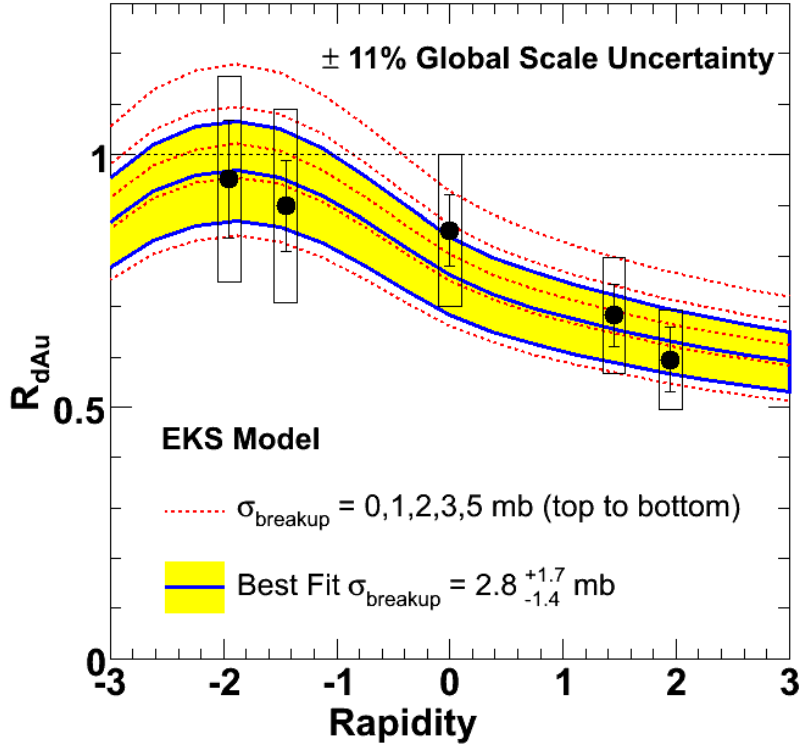


$R_{dAu}(y)$ @ RHIC

- New analysis of run 3 RHIC data
  - Same p+p reference as Au+Au and Cu+Cu
  - Better (cancellation of) systematics
- Suppression at forward rapidity
  - Shadowing
- Assuming a shadowing scheme, adjust an absorption cross-section

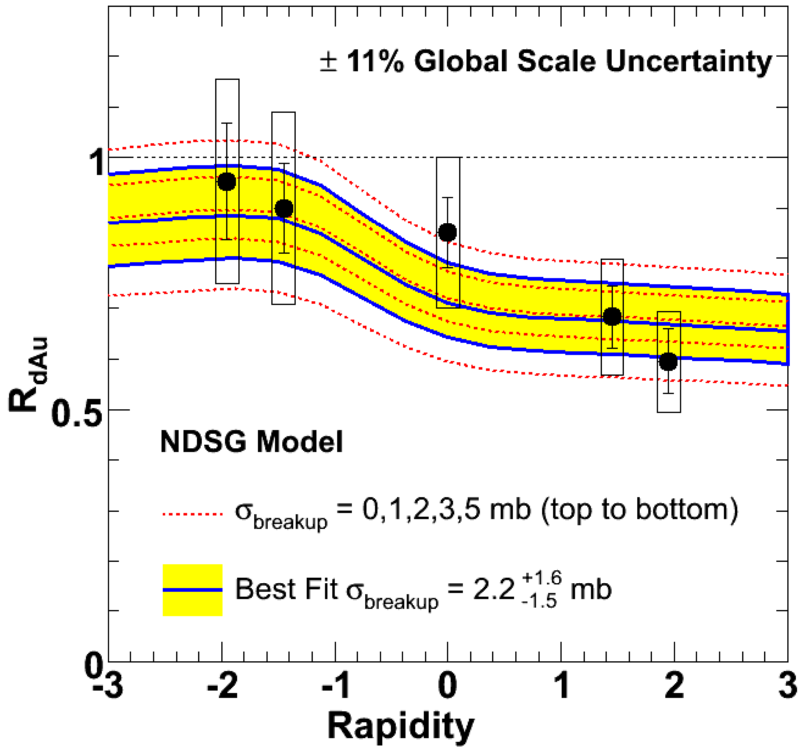


PHENIX, arxiv:0711.3917

$R_{dAu}(y)$

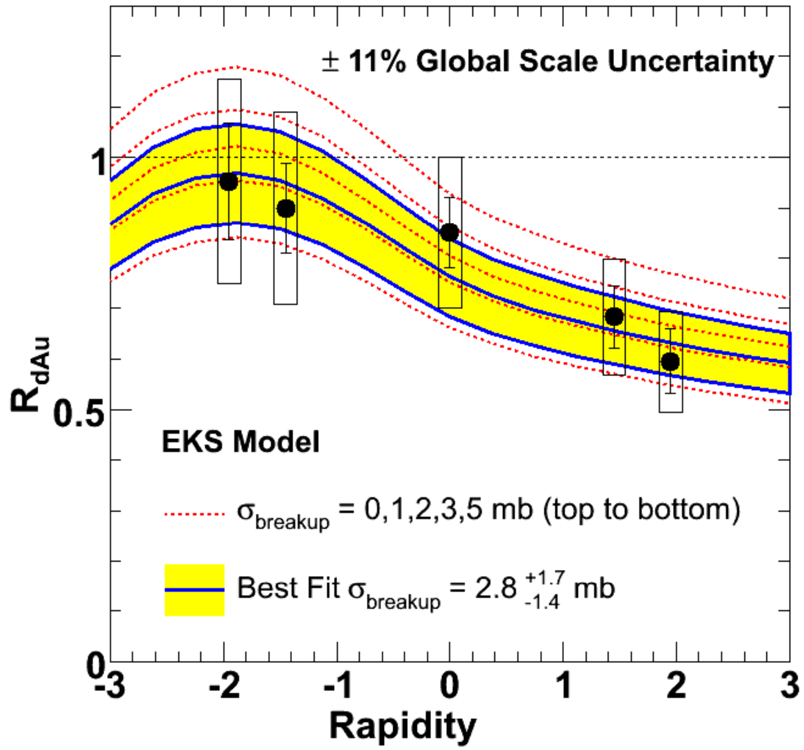
NDSG shadowing

$\sigma_{abs} = 2.2\,^{+1.8}_{-1.5}$ mb

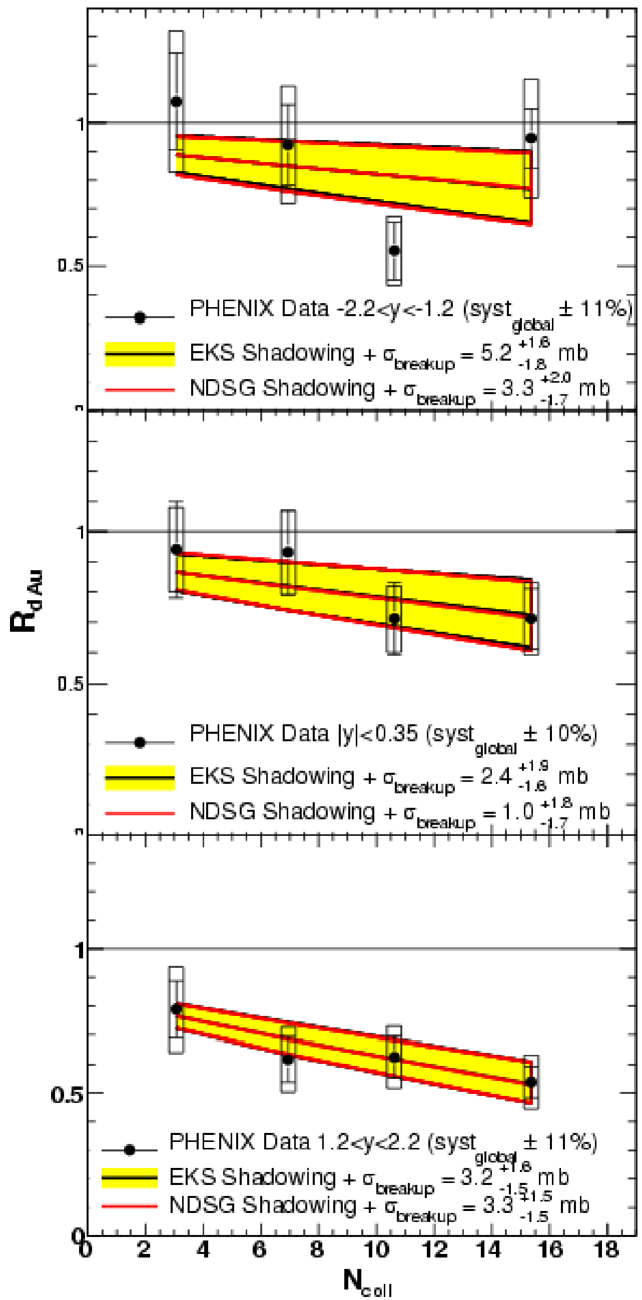


EKS shadowing

$\sigma_{abs} = 2.8\,^{+1.7}_{-1.4}$ mb



PHENIX, arxiv:0711.3917

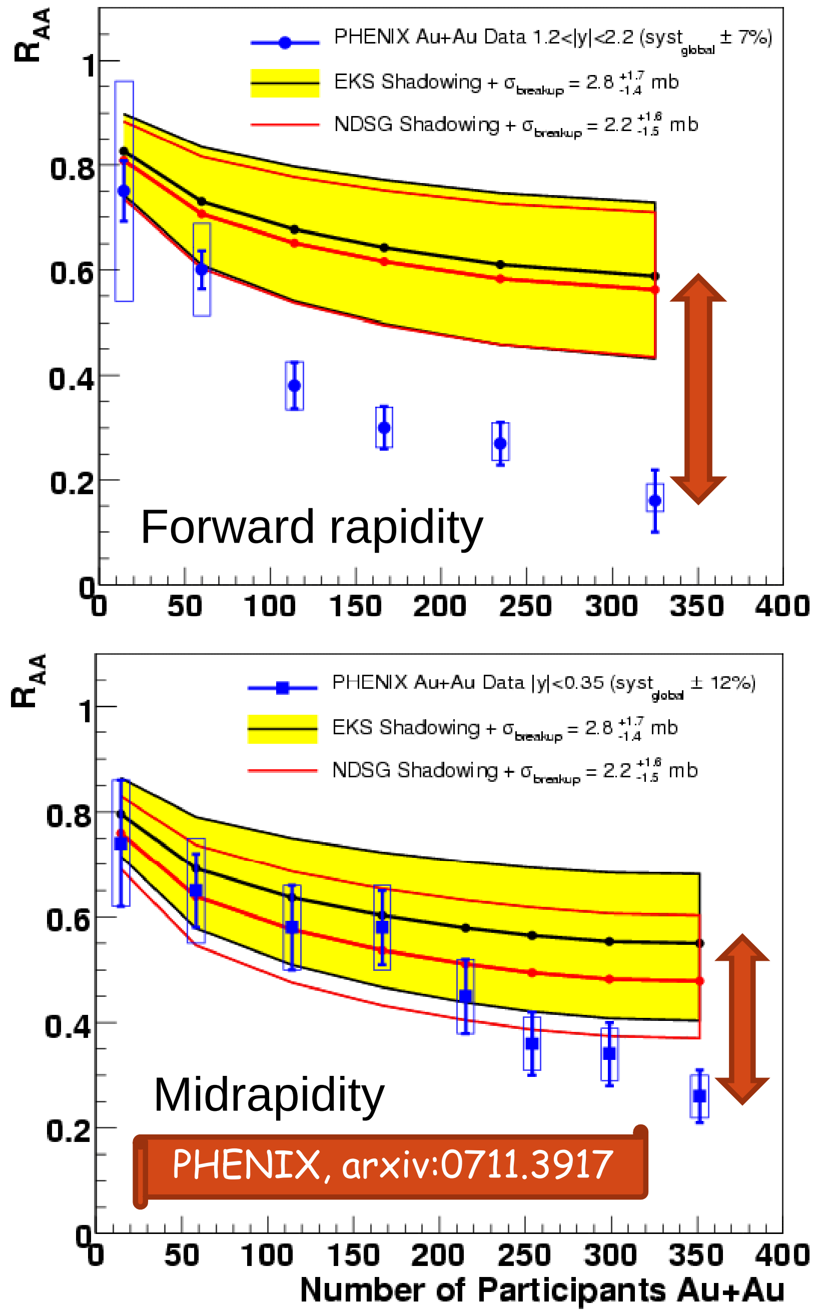


$R_{dAu}(N_{coll},y)$

- Also tried to fit the centrality dependence
  - (assuming a inhomogeneous shadowing scheme)
- Consistent results within (large) uncertainties

R_{AA} (N_{part})

- Now extrapolate to AuAu collisions →
  - (Also available for CuCu)
  - Mid and forward are correlated through shadowing scheme
  - If you believe this shadowing, large anomalous suppression, larger at forward rapidity
- (NDSG midrapidity



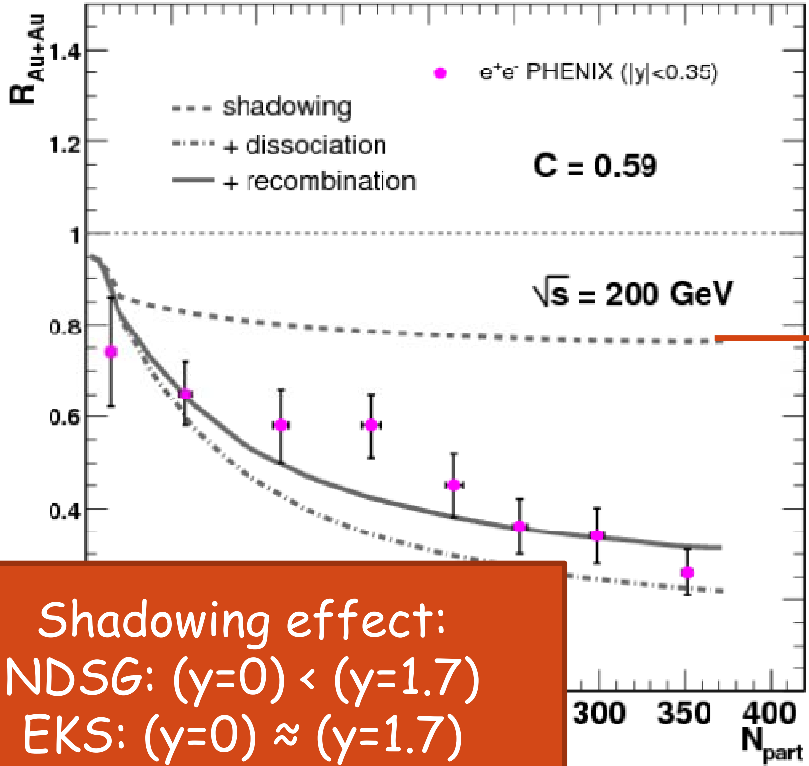
Yet another shadowing scheme?

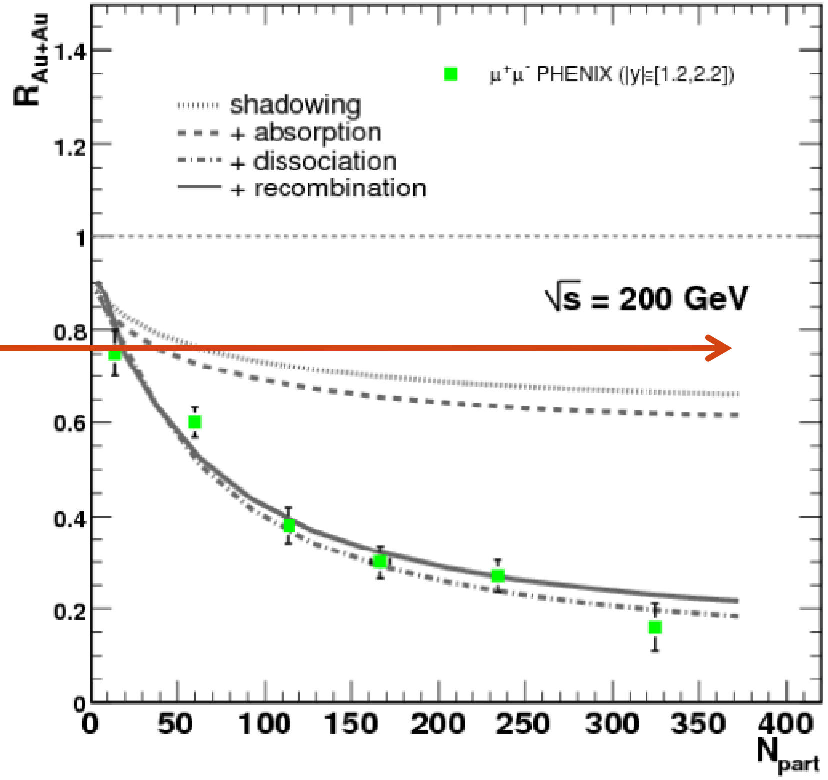
Capella et al, arXiv:0712.4331

Shadowing from Schwimmer multiple scattering :

+ E-p conservation

+ regeneration



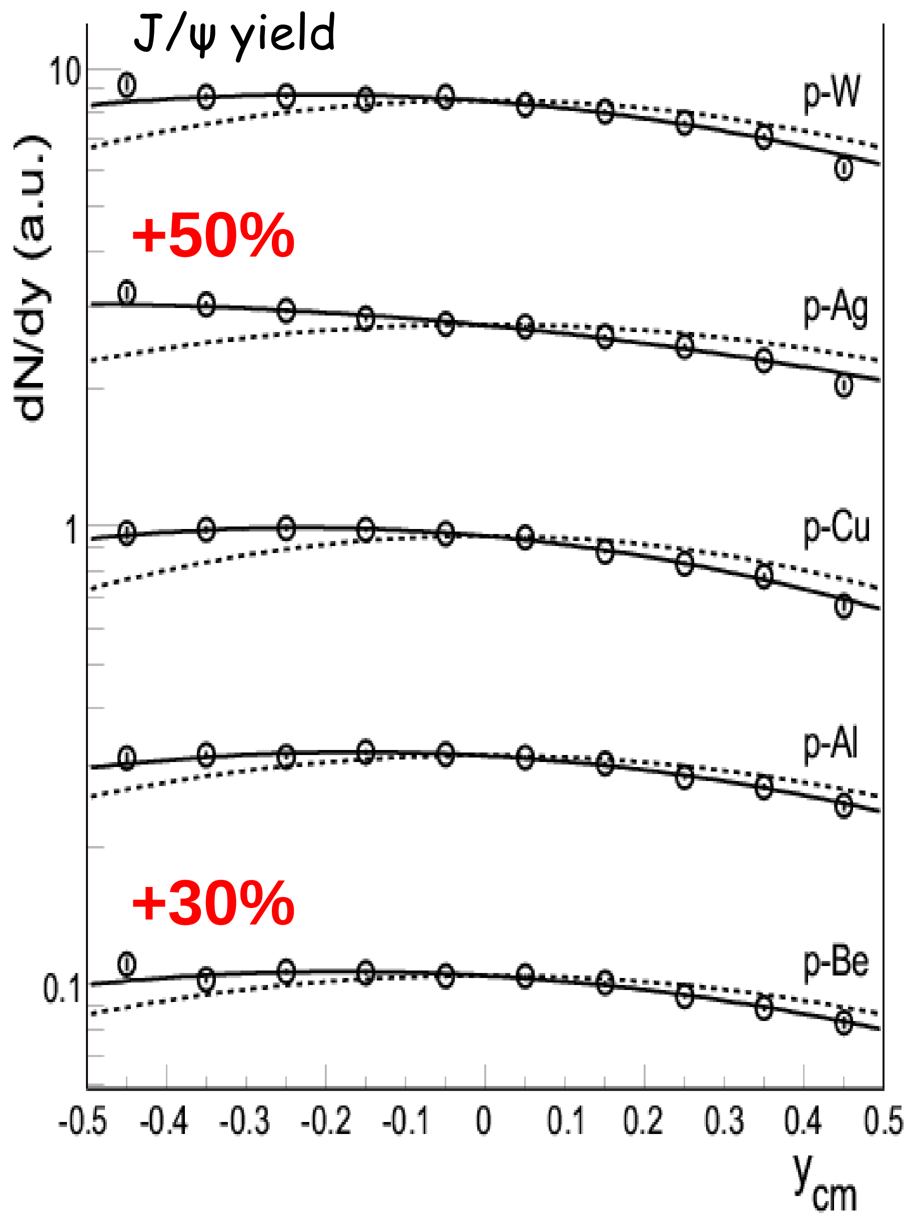


Shadowing effect:
NDSG: (y=0) < (y=1.7)
EKS: (y=0) ≈ (y=1.7)
Schwimmer: (y=0) > (y=1.7)

Something odd @ SPS?

- Do we fully understand CNM @ SPS ?
- Not these surprising rapidity distribution asymmetries →
  - Variation of ~30 to ~50% in one unit of rapidity !
  - Seems large to be (anti)shadowing…
  - Not taken into account in CNM extrapolation…

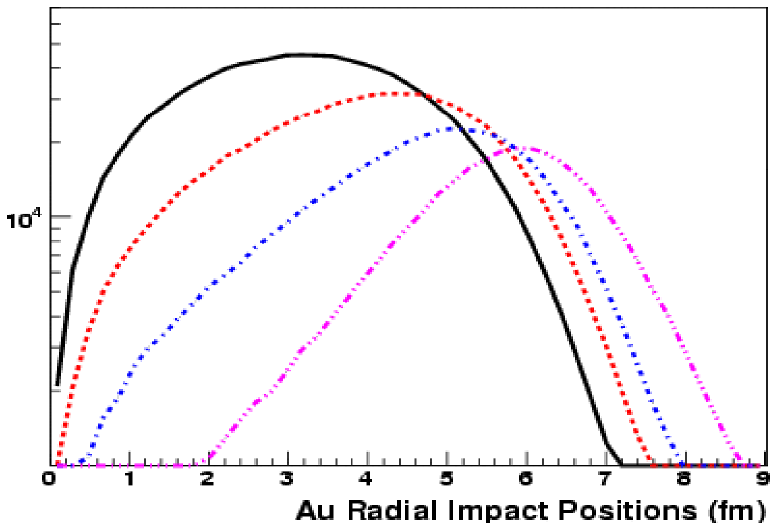
NA50, EPJ. C48 (2006) 329

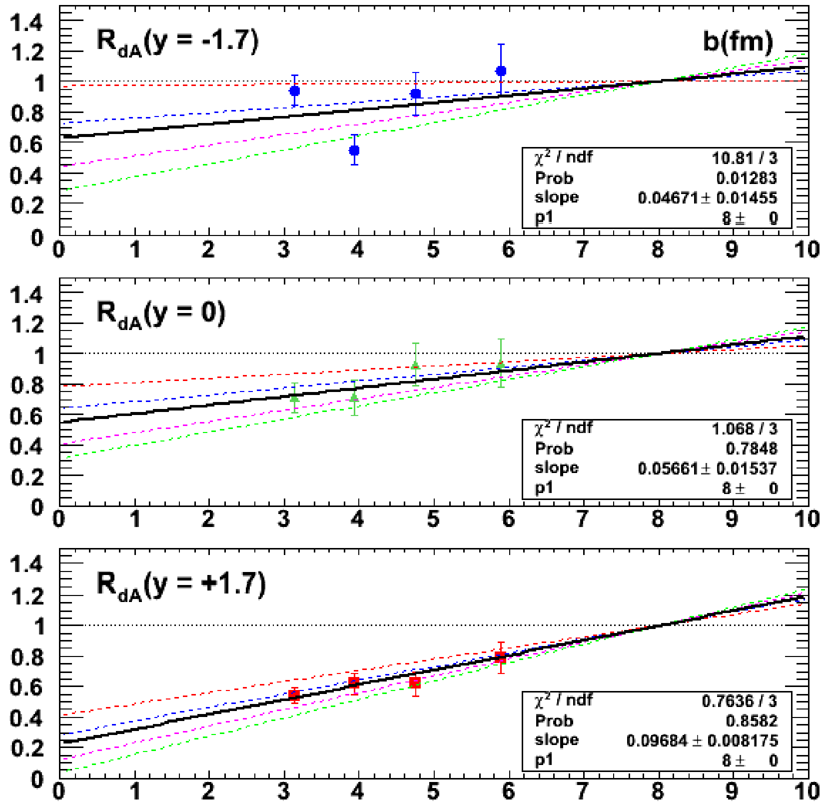


R_{dAu} centrality dependence

R_{dAu} (b)

- Re-plot PHENIX R_{dA} vs local impact parameter b from Glauber model
- Phenomenological fit to R_{dA}(b) →
  - (other shapes tried)





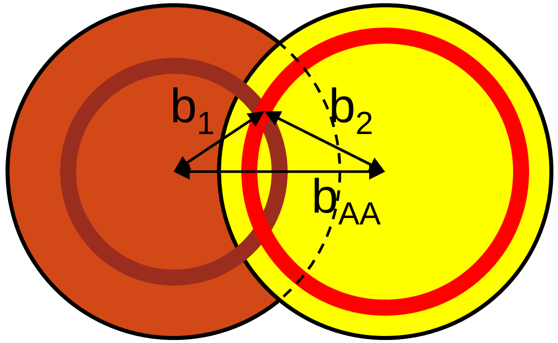
RGdC, Quark Matter 06
PHENIX, arxiv:0711.3917

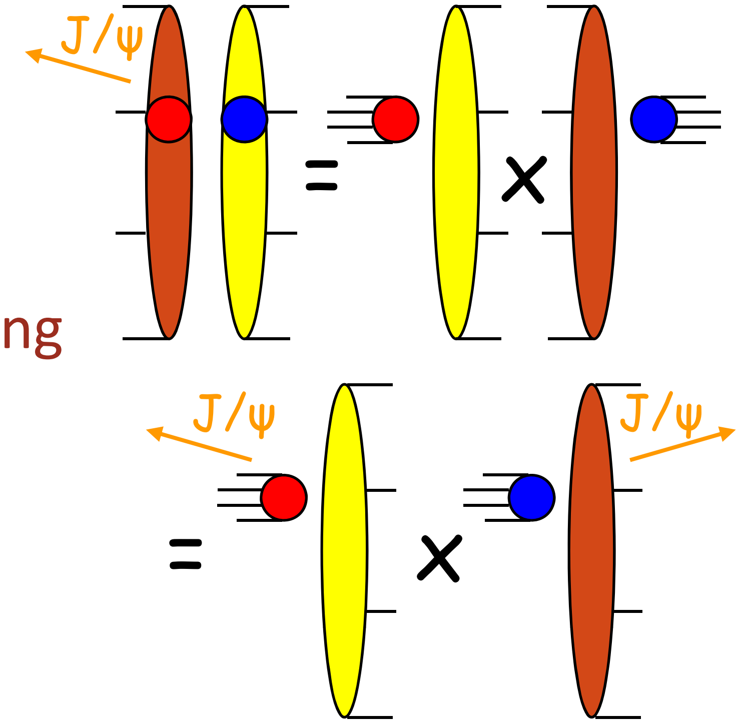
From dA to AA

- For a given A+A collision at b_{AA}, Glauber provides a set of N+N collisions occurring at b_i^1 and b_i^2
- One minimal assumption is rapidity factorization: $R_{AA}(|y|,b_{AA}) = \Sigma_{collisions} [R_{dA}(-y,b_i^1) \times R_{dA}(+y,b_i^2)] / N_{coll}$
- Works (at least) for absorption & shadowing since production

  ~ pdf1 x pdf2 x exp $-\rho\sigma(L_1+L_2)$

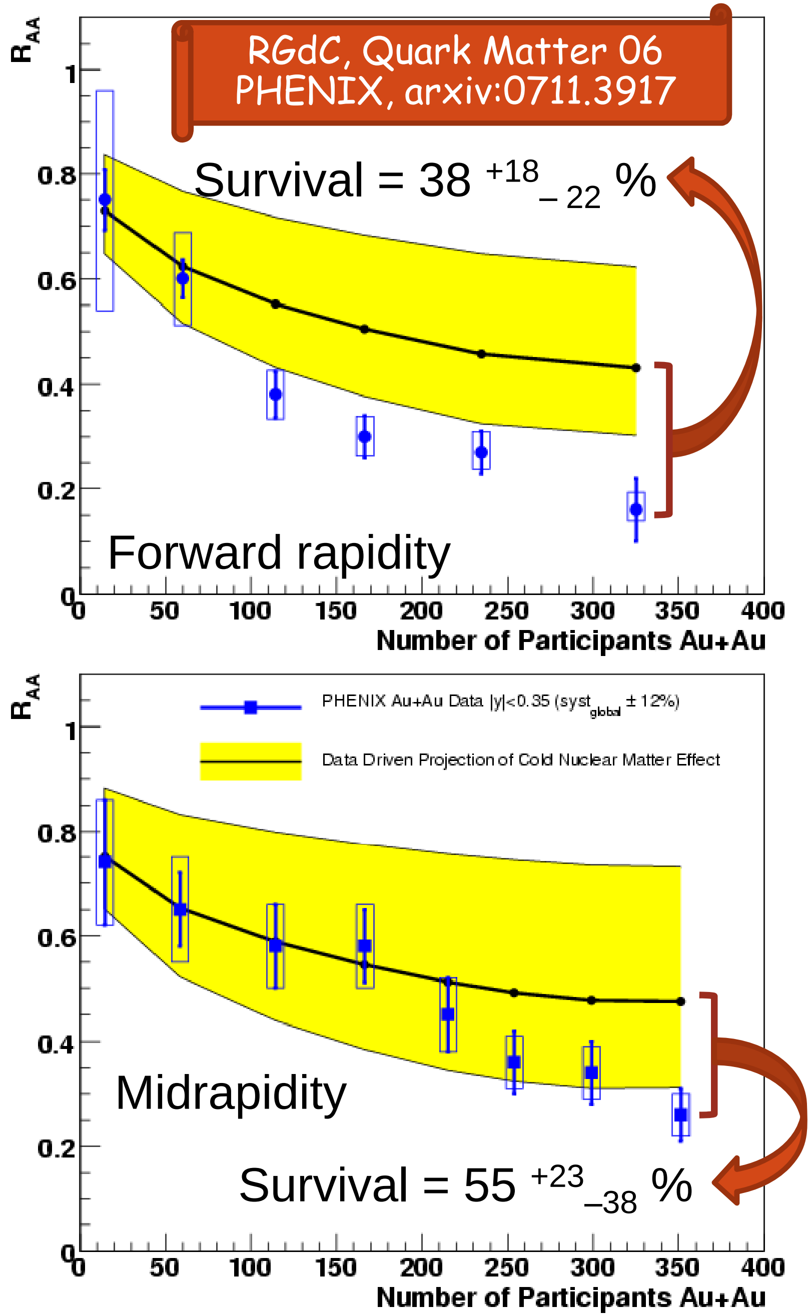
RGdC, QM06, hep-ph/0701222





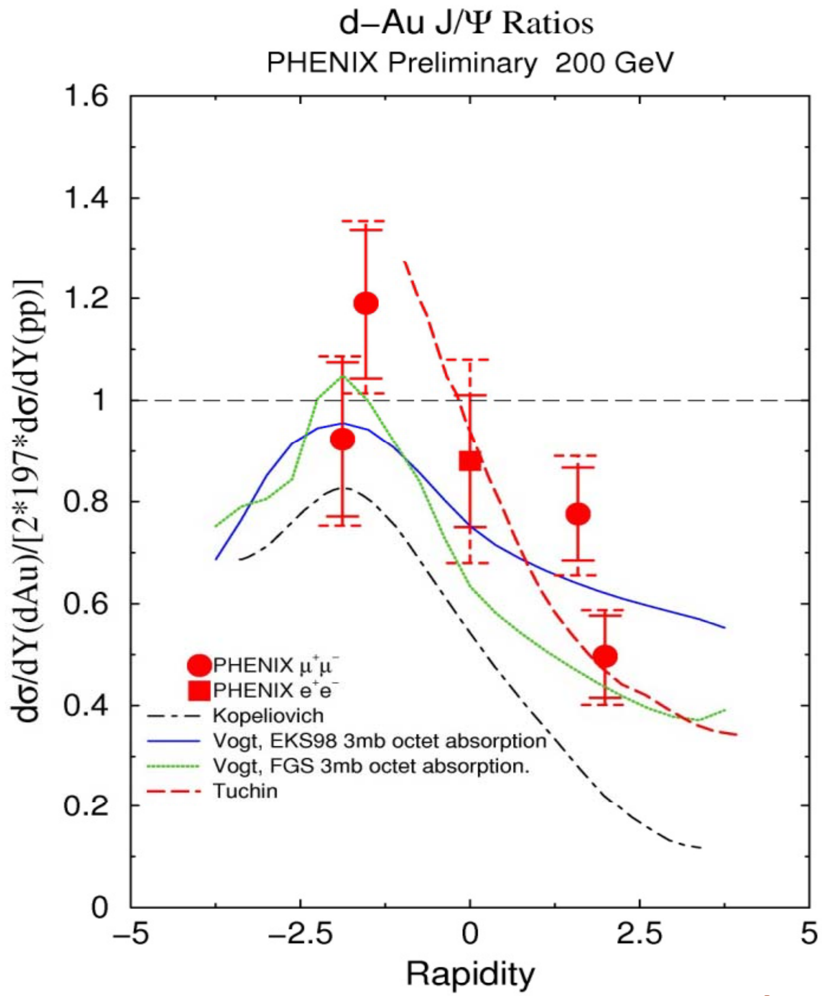
R_{AA} (N_{part})

- Pros and cons:
  - No shadowing scheme nor absorption scheme
  - Mid and forward are not correlated, less model dependent → larger uncertainties (esp. y≈0)
- Anomalous suppression at least at forward rapidity!
- Anomalous suppression could be identical at midrapidity
- (No dCu, so no CuCu)



Unaccounted cold effects ?

- Could $R_{dA}(-y)$ x $R_{dA}(+y)$ factorization be wrong?
- Yes, in case of strong saturation…
- dAu computation →
- AuAu computation underway… But:
  - Is saturation at play beyond traditional shadowing at $x_2 \approx 0.003$?
  - How to describe $x_2 \approx 0.1$?



Tuchin, hep-ph/0504133

Unaccounted cold effects ?

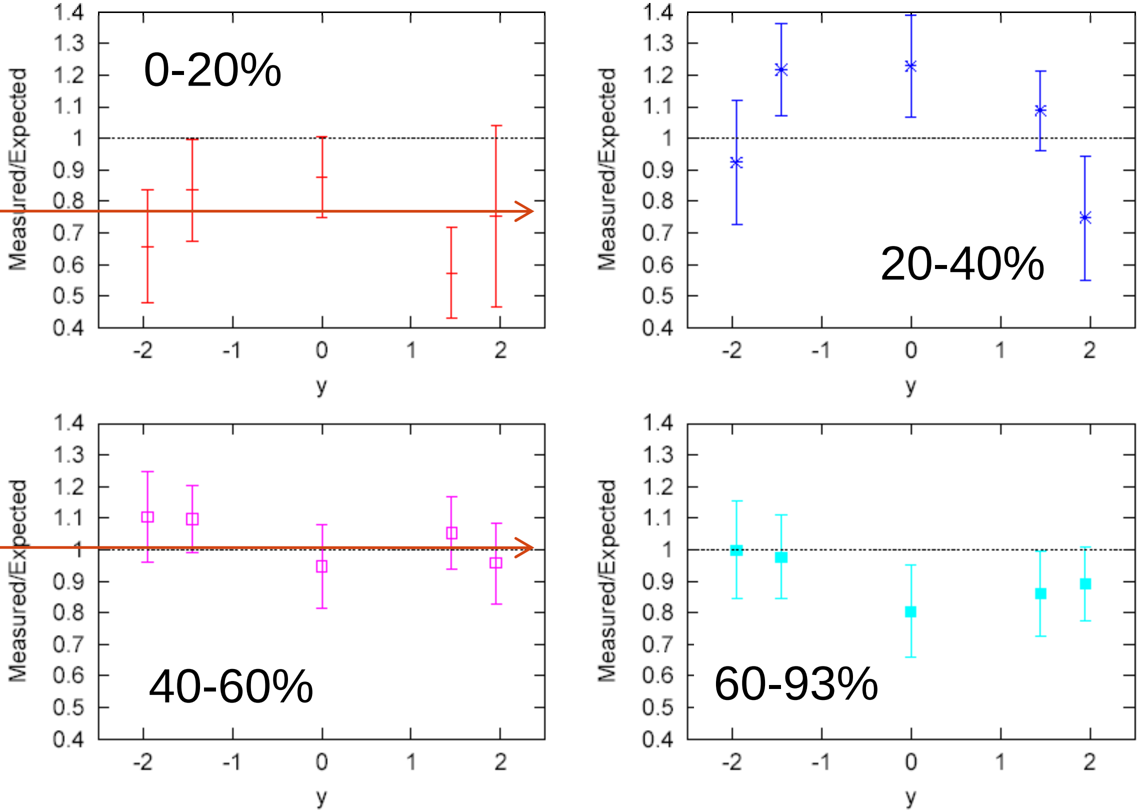
M. Nardi, QM08

- Saturation could suppress forward J/ψ in AuAu
- First numerical estimate, work in progress…

Experiment / Saturation

“Flat anomalous” suppression here ?

Normalisation here ?

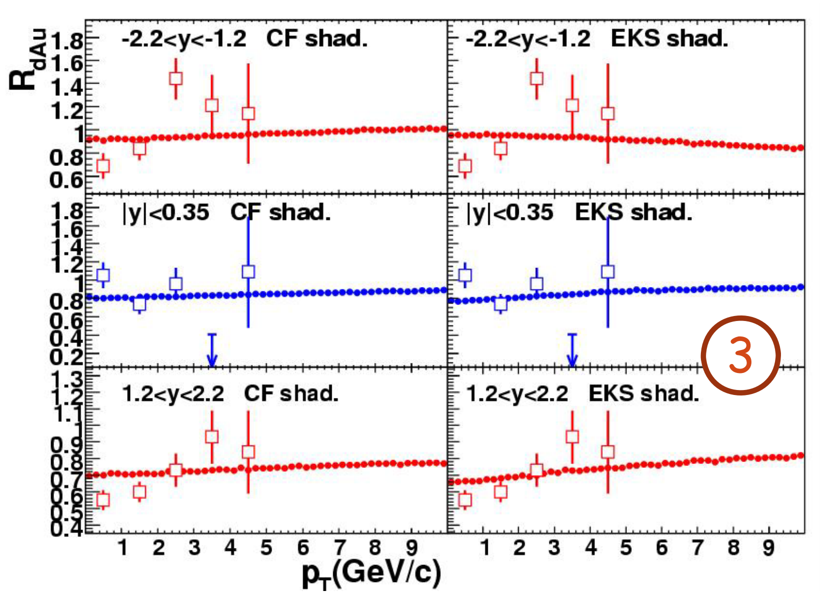


R_{dAu} transverse momentum

(Mettre un plot de Roberta)

Various $R_{XY}(p_T)$

- Several (hints of) raising $R_{AA}(p_T)$
  1. R_{CP} PbPb (NA50)
  2. R_{AuAu} (PHENIX)
  3. R_{dAu} (PHENIX)
- Several potential reasons:
  - Leakage effect, J/ψ escape
    - High p_T J/ψ forming beyond QGP
  - Cronin effect
  - Raising x_{Bj} = less shadowing
    - 0.02 to 0.05 from 0 to 9 GeV/c
    - See discussion in →
- Think about it…



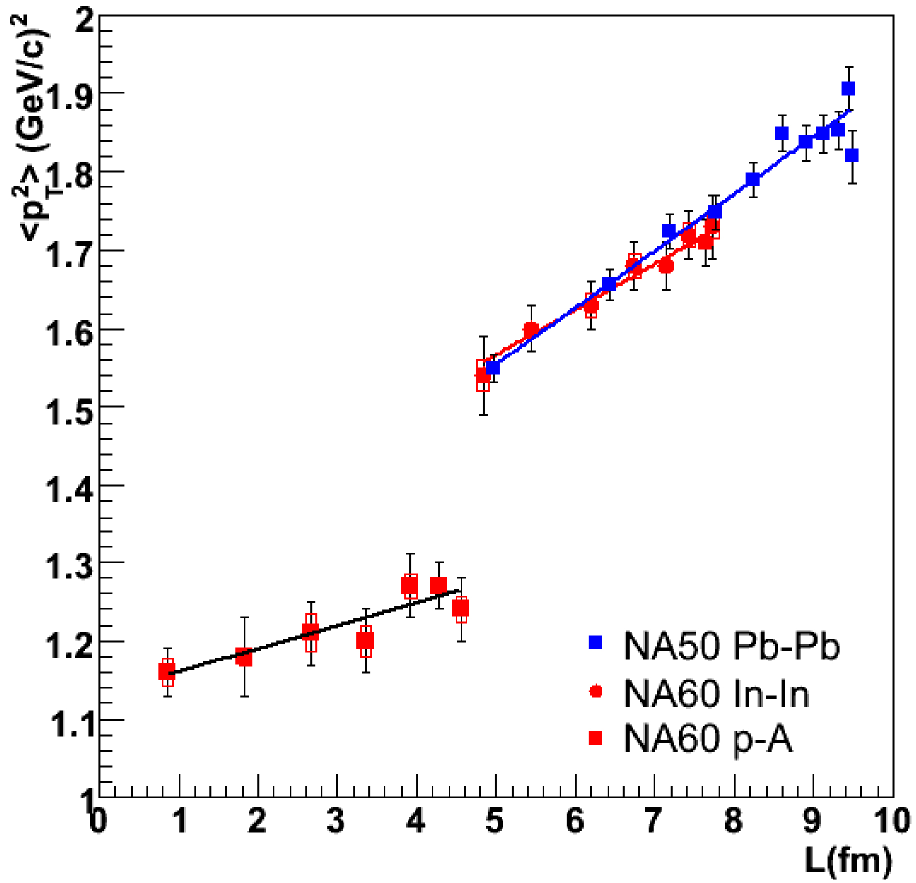
PHENIX, arxiv:0711.3917 compared to Ferreiro, Fleuret, Rakotozafindrabe, arxiv: 0801.4949

3. p_T broadening @ SPS ?

R. Arnaldi, QM08

- Different scaling in pA and AA collisions
- Something else going on in AA?
  - High p_T J/ψ escape?

All data taken at 158 GeV!



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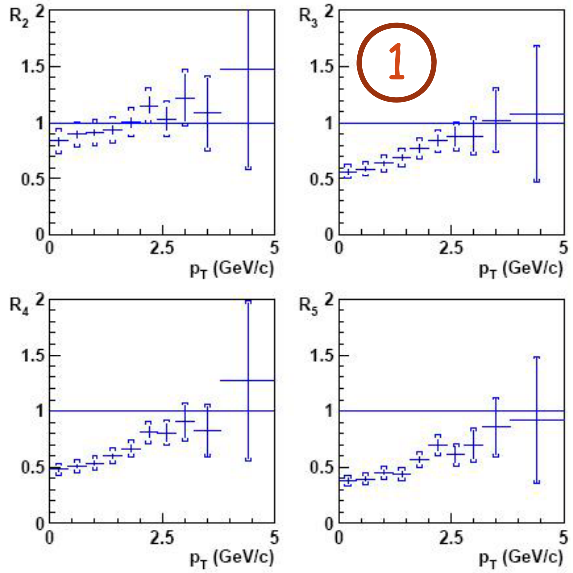
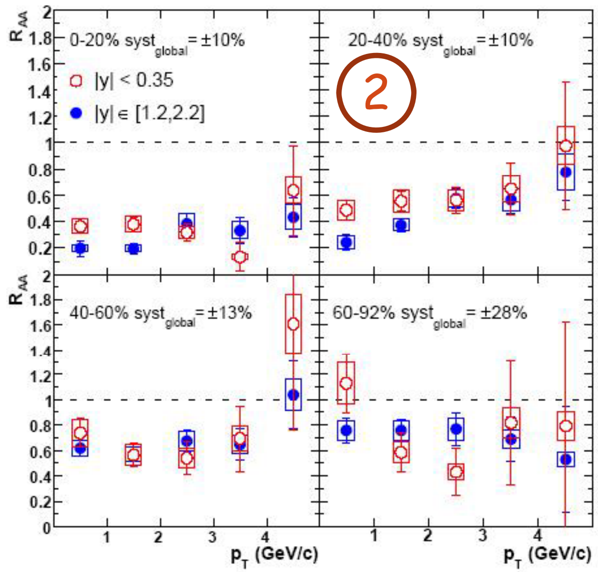
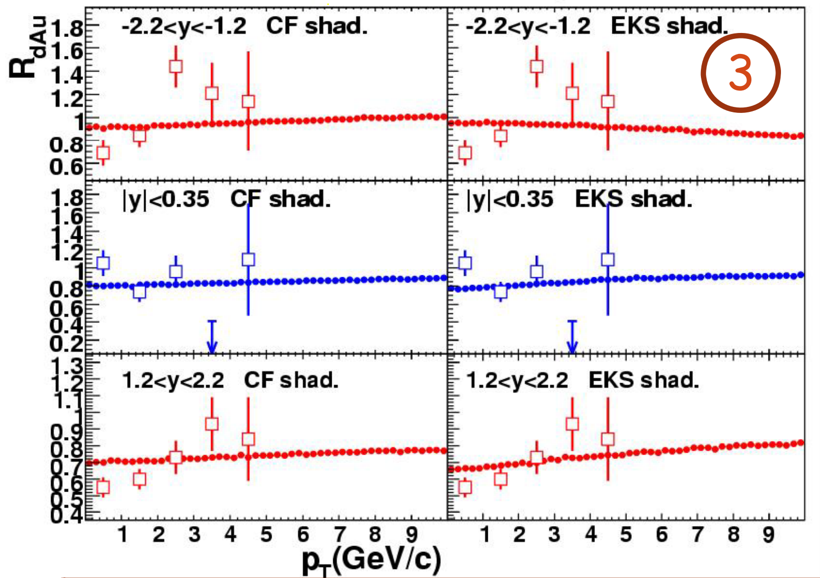






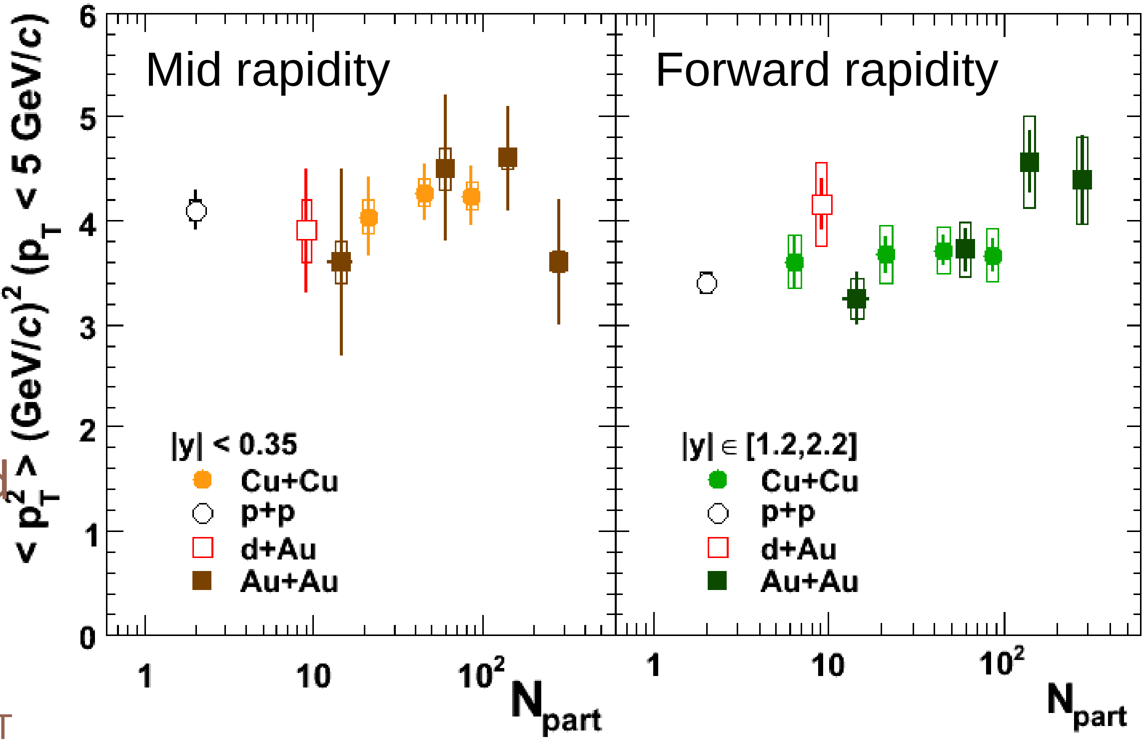
PHENIX, arxiv:0711.3917 compared to Ferreiro, Fleuret, Rakotozafindrabe, arxiv: 0801.4949

Three existing cold scenarios could justify the rapidity anomalous dependence

1. The data itself !
2. A given shadowing scheme
3. Color glass condensate

3. p_T broadening @ RHIC ? vs N_{part} ?

PHENIX, arxiv:0801.0220



- Widely unknown initial charm production:
  - Recombined R_{AA} are poorly constrained…
- Instead look at p_T:
  - Hot: Inherited p_T should be lower than initial
  - Cold: Cronin effect should broaden initial p_T
- Cronin goes like:

$$<p_T^2>_{AB} = <p_T^2>_{pp} + \alpha \times L$$

- No strong $<p_T^2>$ dependence…
- Modest rise at forward rapidity
- Could be broadening
- No need for recombination here

3. p_T broadening @ RHIC ? vs thickness ?

- Widely unknown initial charm production:
  - Recombined R_{AA} are poorly constrained…
- Instead look at p_T:
  - Hot: Inherited p_T should be lower than initial
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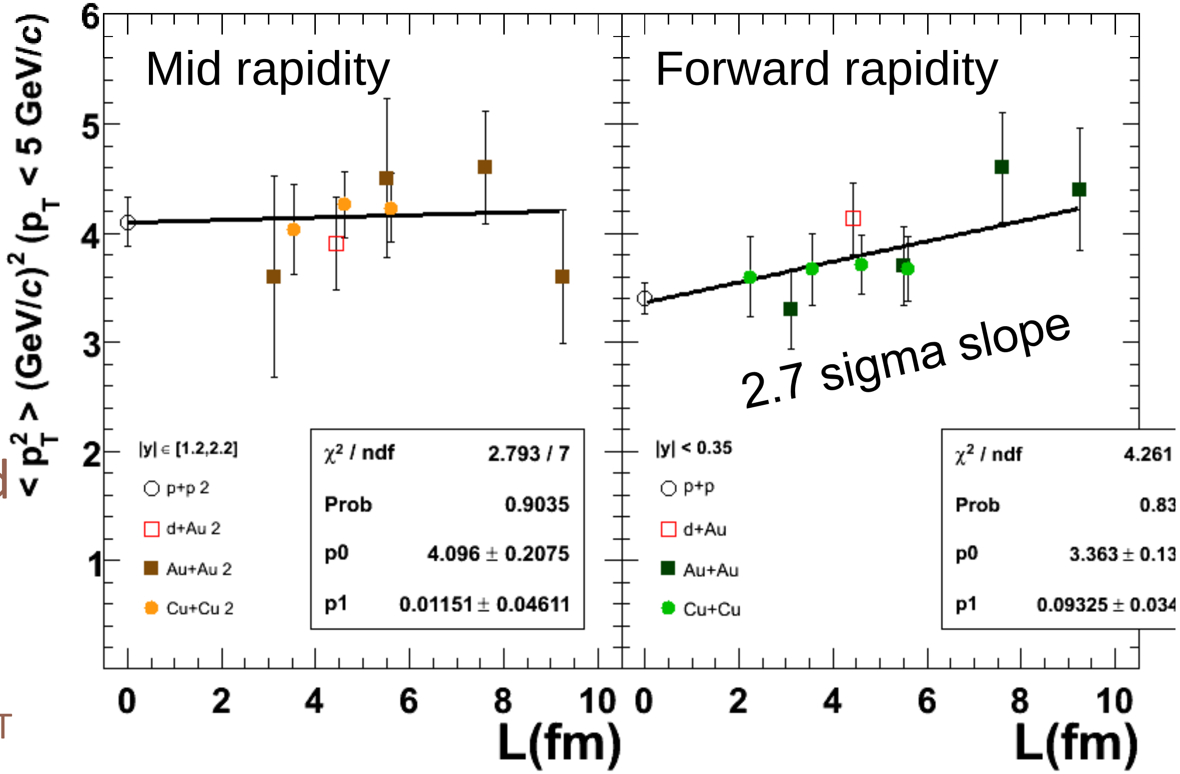
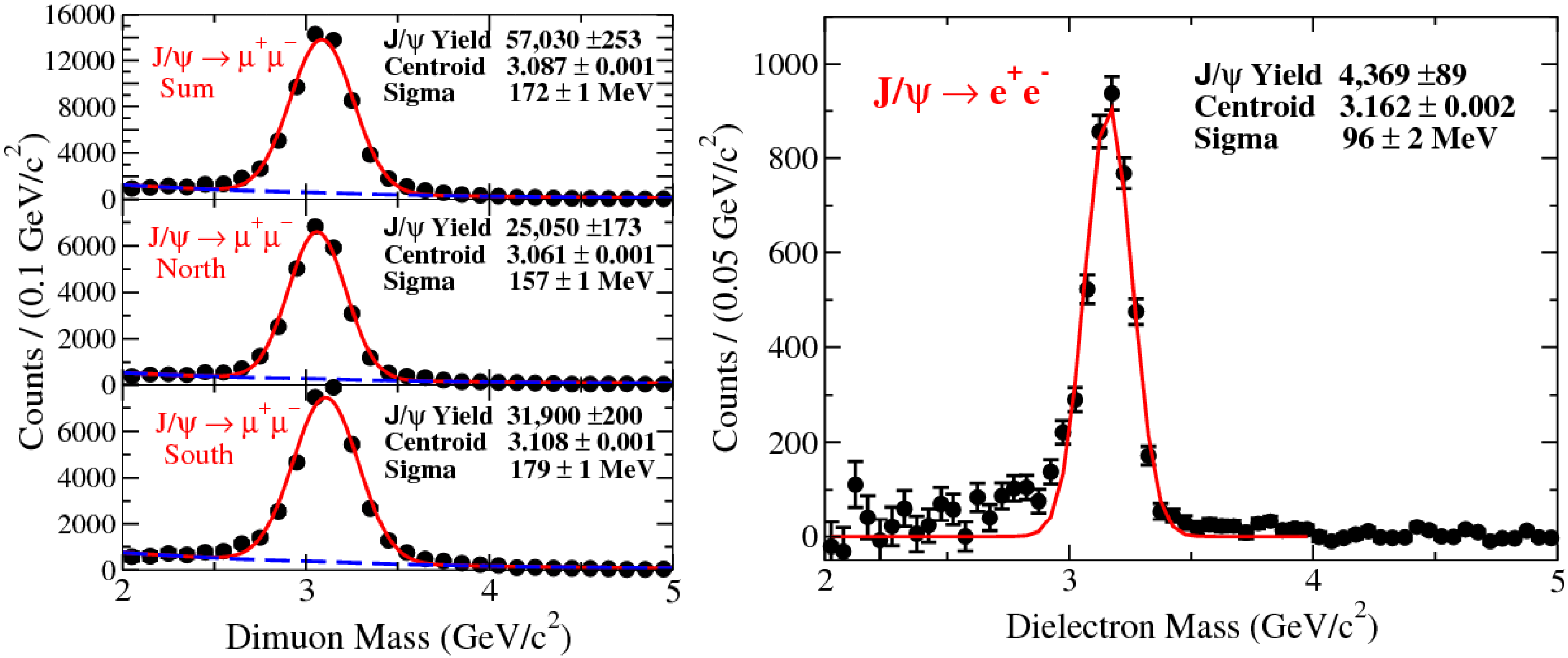
  $\langle p_T^2 \rangle_{AB} = \langle p_T^2 \rangle_{pp} + \alpha \times L$

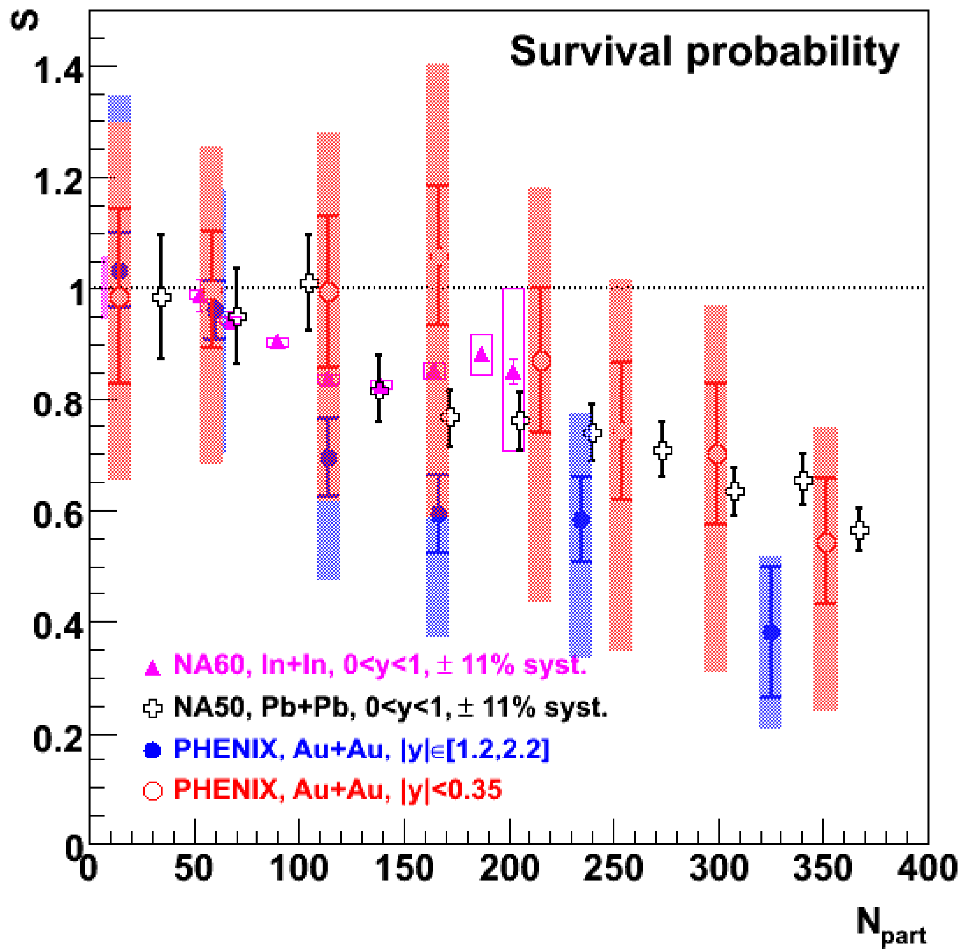


- No strong $\langle p_T^2 \rangle$ dependence…
- Modest rise at forward rapidity
- Could be broadening
- No need for recombination here

RHIC run 8 dAu ≈ 30 x run 3 !



- Let's wait for this run analysis before to say more about cold matter (and derive decent survival probabilities)


Survival probability
S
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
400
N_part
NA60, In+In, 0<y<1, ± 11% syst.
NA50, Pb+Pb, 0<y<1, ± 11% syst.
PHENIX, Au+Au, |y|∈[1.2,2.2]
PHENIX, Au+Au, |y|<0.35

That’s all folks

S. Oda,
Session 18,
Saturday

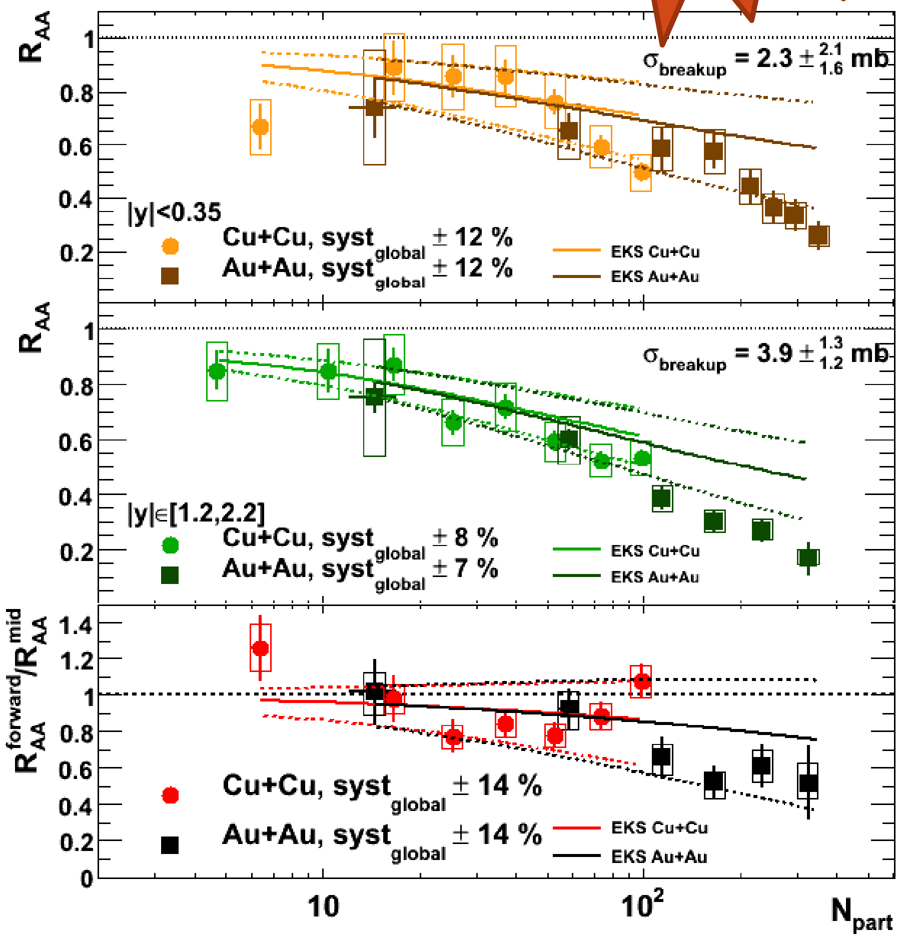
2. Cold matter again ?

PUB

- Fitting an effective break-up cross section (depending on y) and extrapolate to CuCu and AuAu…

STOP

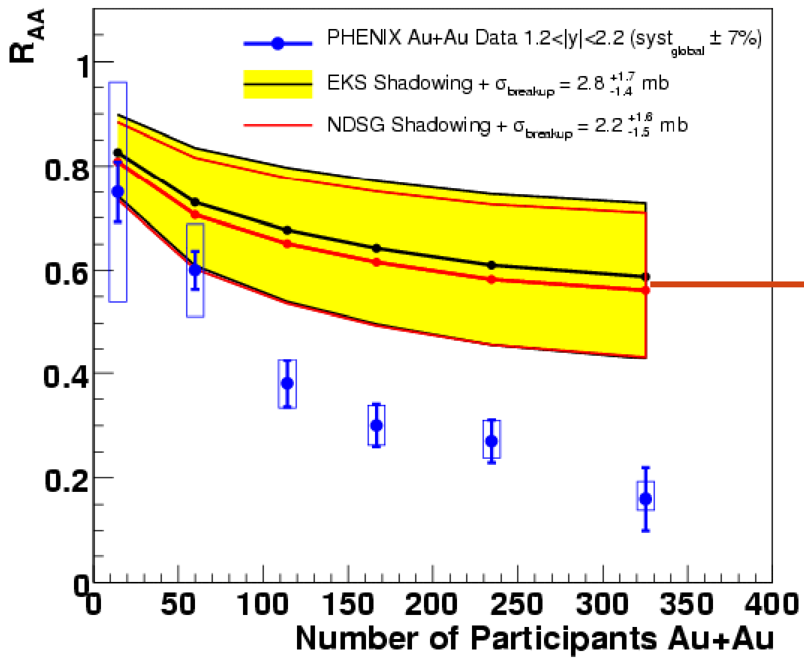
- Do you agree that we have poor handle on the cold nuclear matter effect?



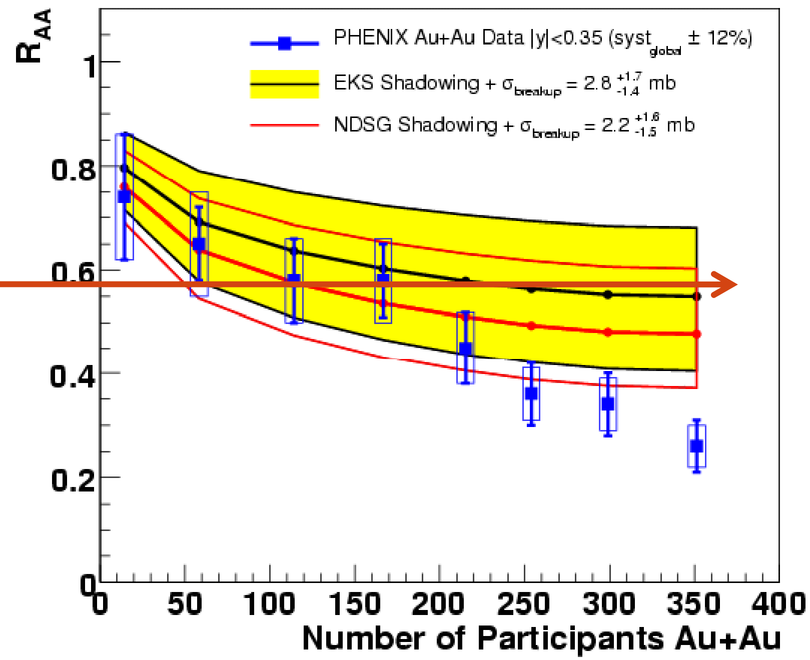
PHENIX, arxiv:0801.0220

Face to face

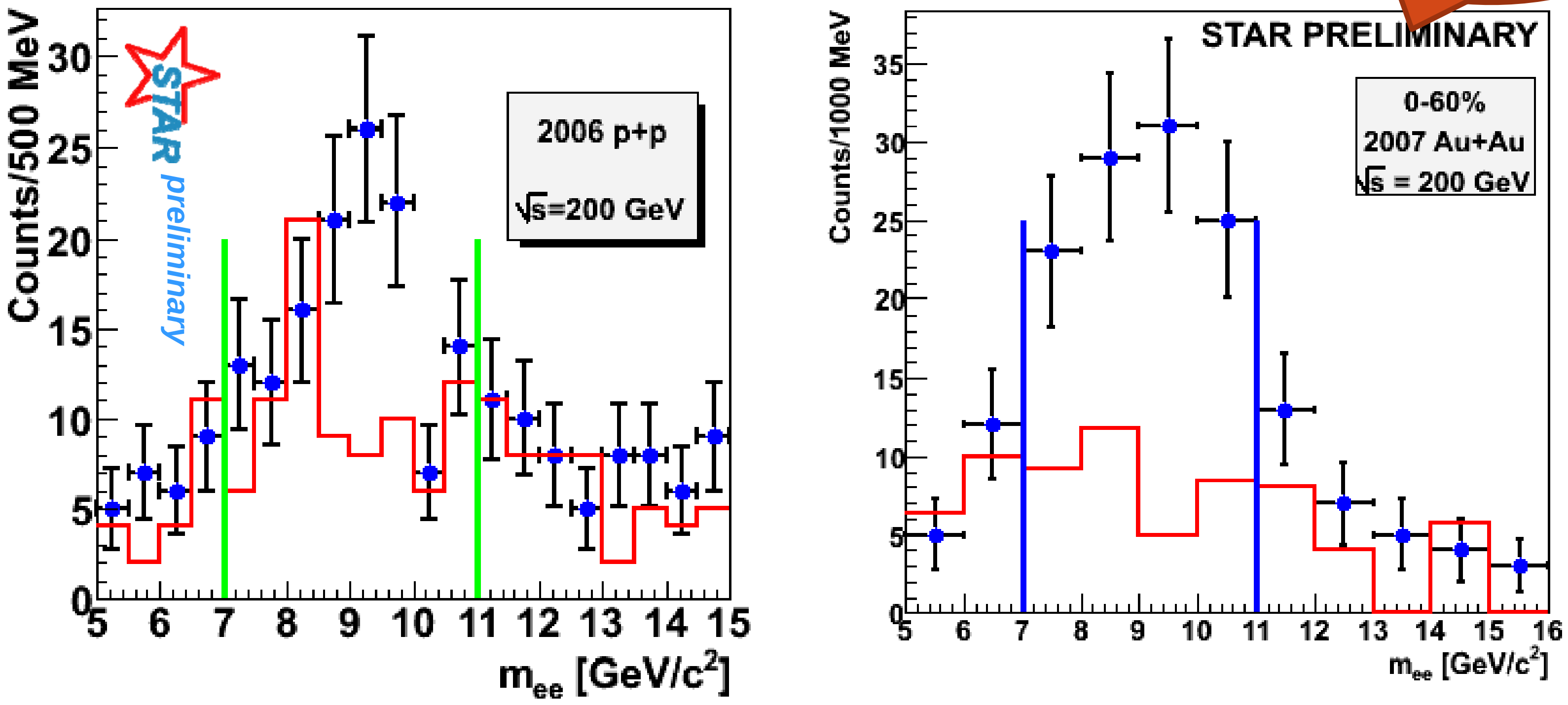
EKS (y=0) ≈ (y=1.7)



NDSG (y=0) < NDSG (y=1.7)



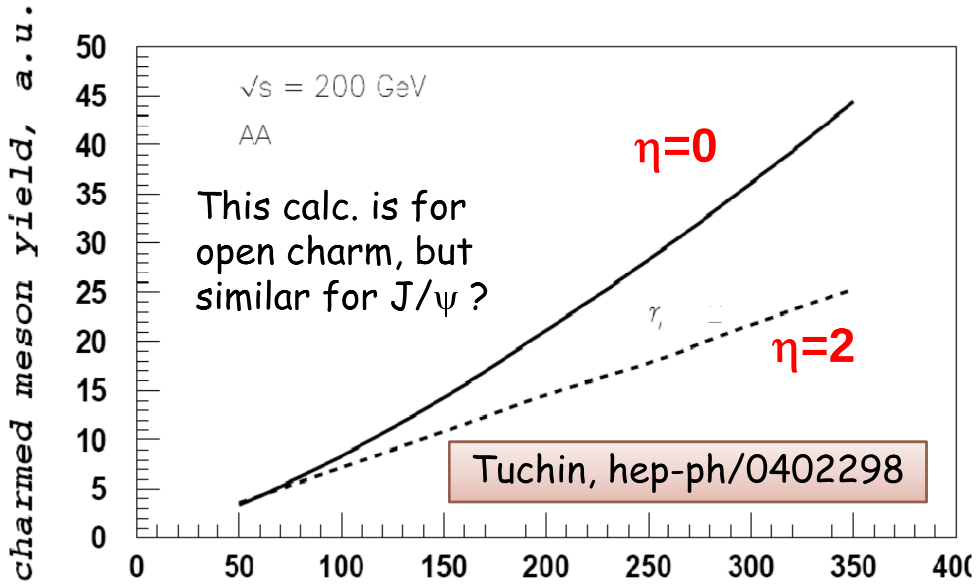
6. STAR upsilon's

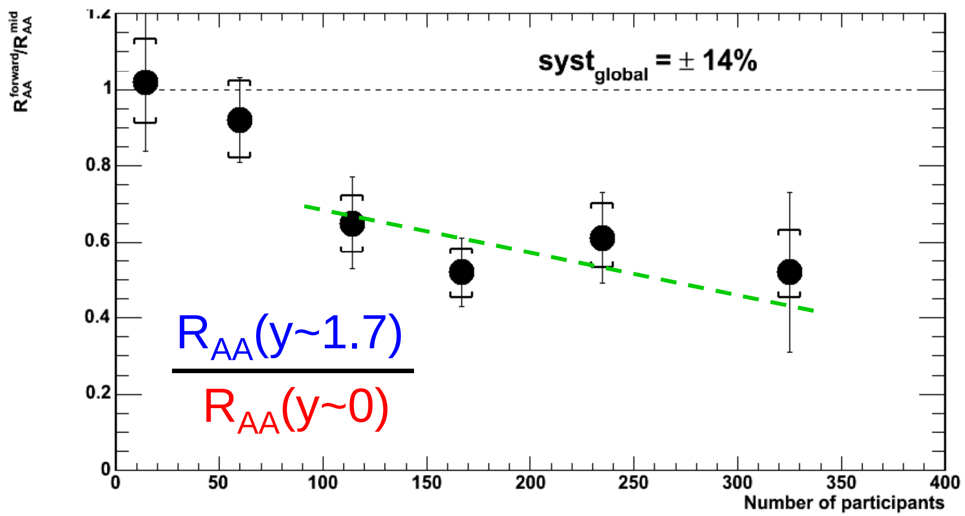


- Proof of principle: dozens of Υ in p+p & A+A!
- Nuclear modification factor to come soon
- Suffers less from cold matter (x=0.02 to 0.1=EKS antishadow)
  - (should be checked with run8 d+Au)
- Should measure (unseparated) excited states melting

Unaccounted CNM ?

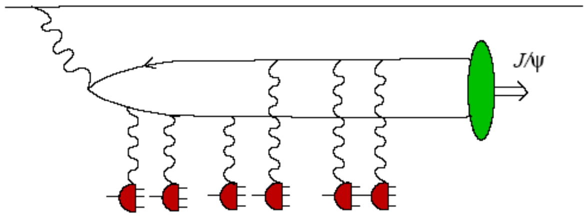
- Strong initial states effect ala color glass condensate ?
  - But they have to violate rapidity symmetrisation $R_{AA}(|y|) = R_{dA}(-y) \times R_{dA}(+y)$
  - (otherwise taken into account in CNM extrapolation)
- Could this + sequential melting produce $R_{AA}(y\sim0)$ and $R_{AA}(y\sim1.7)$?
- Double ratio should drop…
- A possibility…

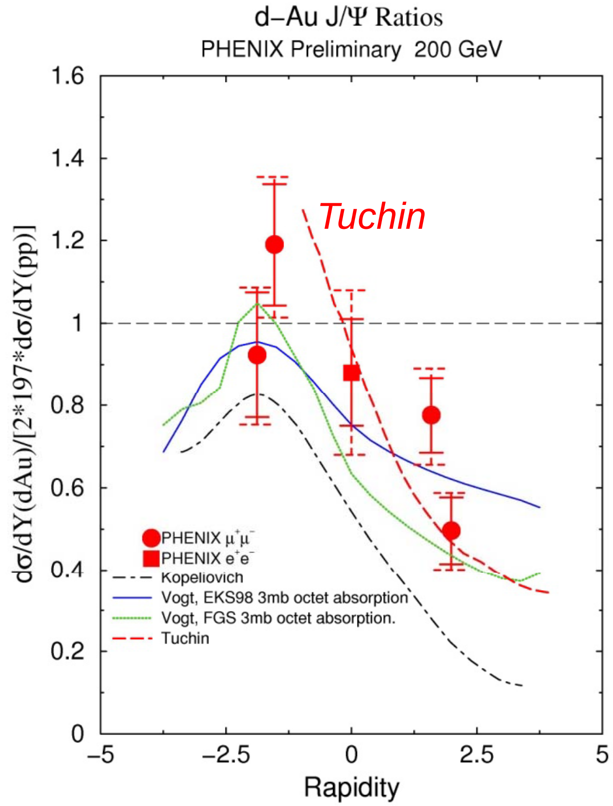




Tuchin & Kharzeev

- Hard probes 2004
  - hep-ph/0504133
- Coherent production of charm (open or closed)
  - (y<0 production time to low to make computation)
  - Shadowing from CGC computation…





Tuchin & Kharzeev...

+ absorption for

SPS & fermilab