Cold matter affects
J/ψ production

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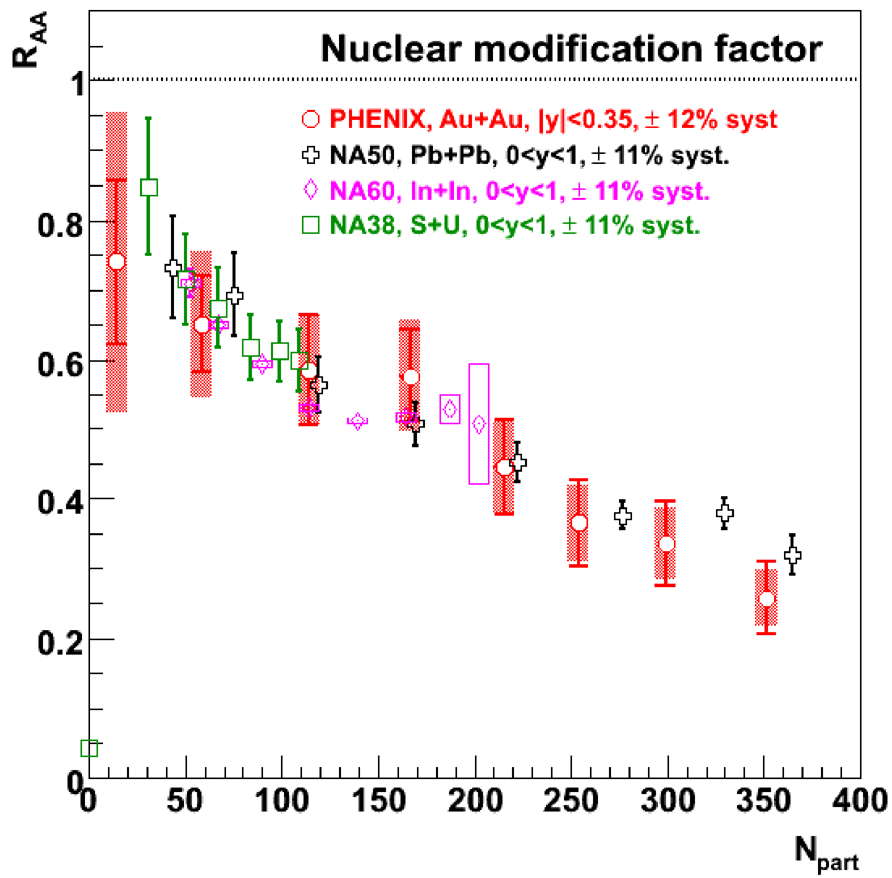
QM08 satellite meeting
Tata Institute for Fundamental Research
Mumbai, 2008, February 12th

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

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

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

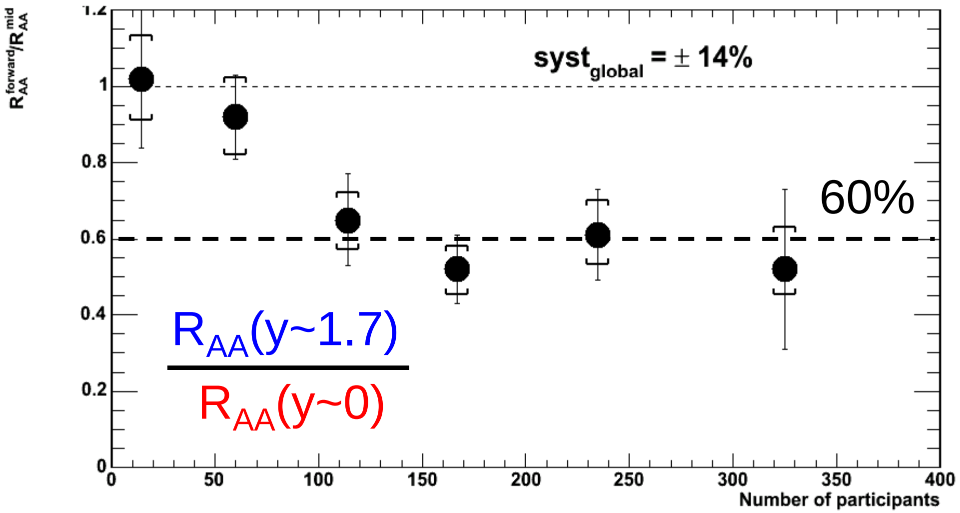
- Midrapidity R_{AA} looks surprisingly similar, while there are obvious differences:
  - At a given N_{part}, different energy densities…
  - Cold nuclear matter effects ($x_{Bjorken}$, σ_{abs}…)
  - …

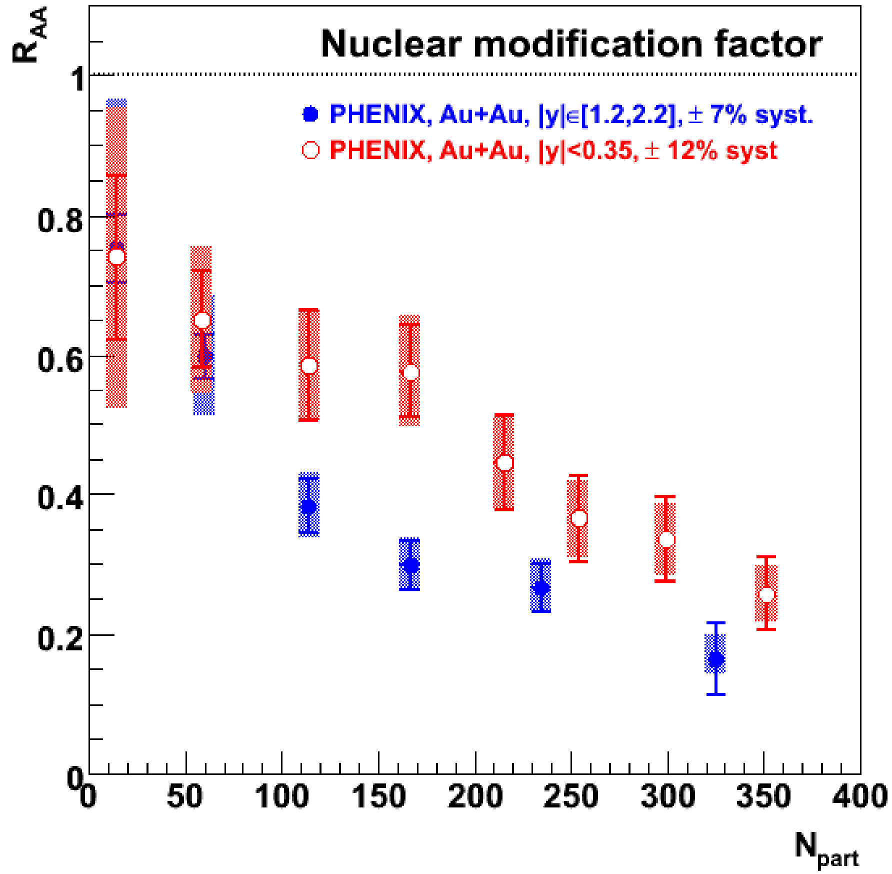


PHENIX, PRL98 (2007) 232301
SPS from Scomparin @ QM06

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…





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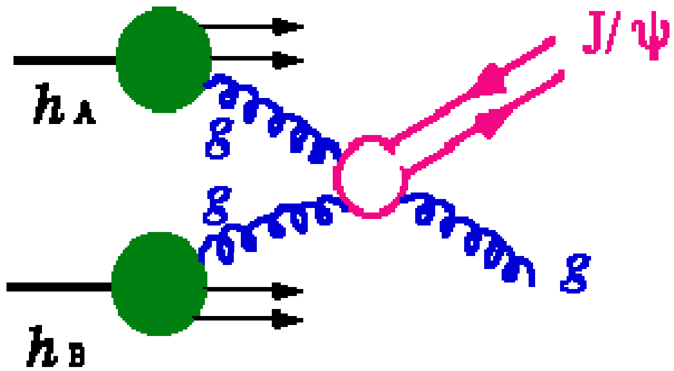
For the hot stuff, see
Cesar Luis da Silva's
talk on Wednesday

How much of this is due to
normal nuclear matter ?

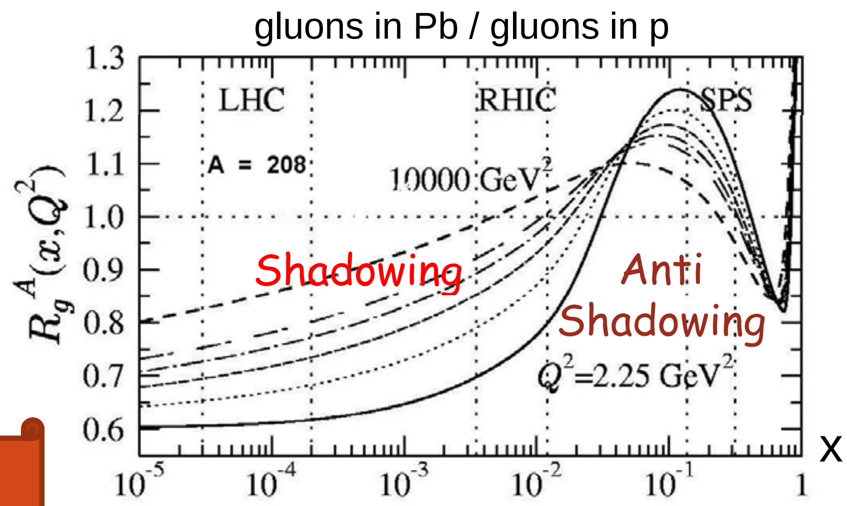
(what cannot claim anything about
quark gluon plasma without first
answering this question)

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

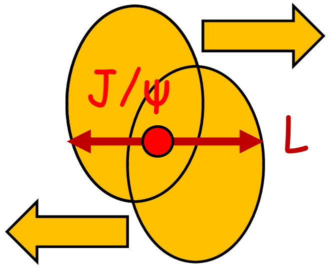
For the real stuff, see Carlos Lourenço's talk hereafter

A snapshot of SPS

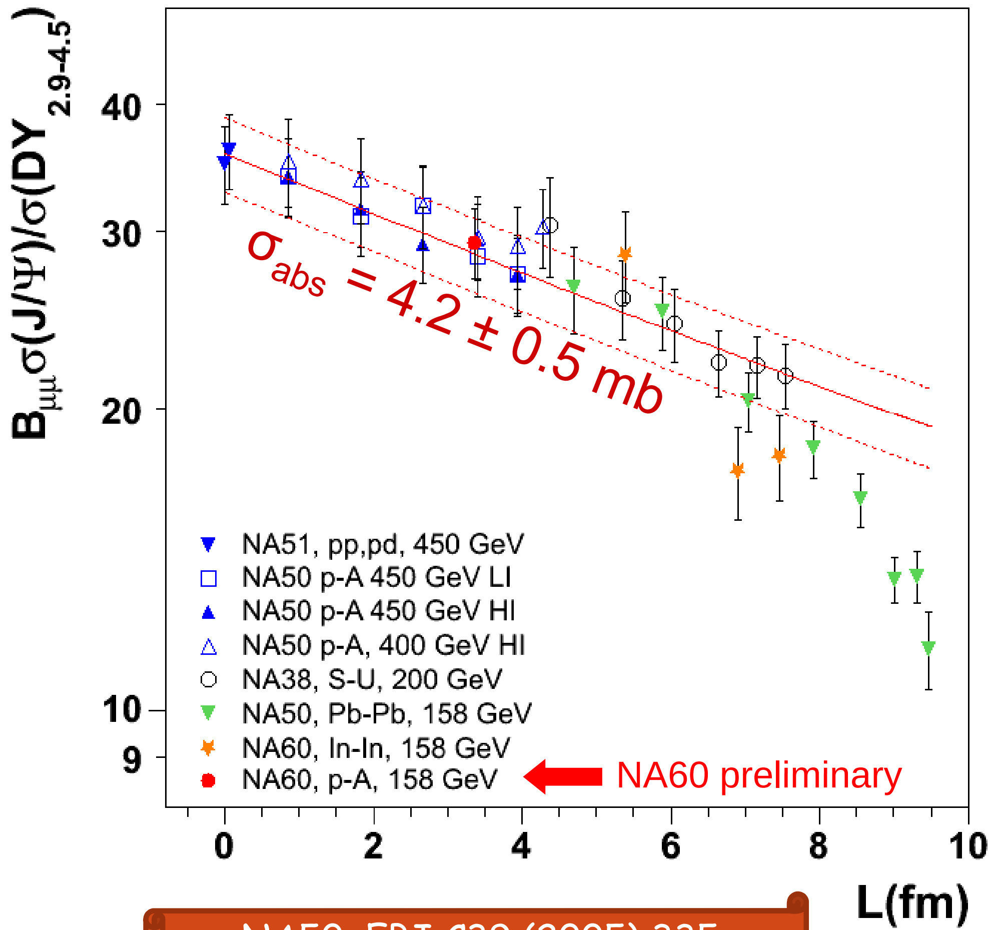
To first order, a simple and efficient description of nuclear matter effects

σ_{abs} = 4.2 ± 0.5 mb

Cold and hot matters @ SPS



- Normal nuclear absorption alone 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

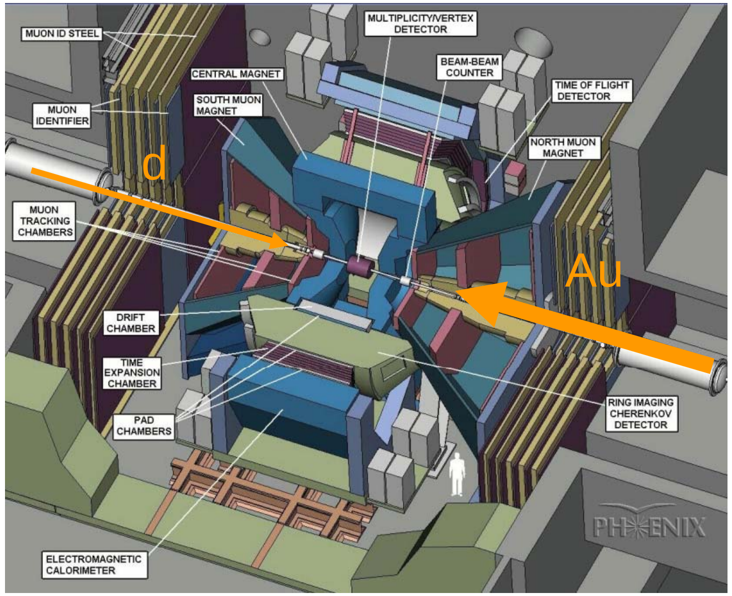
R_{dAu} rapidity dependence @ RHIC

Shading light on shadows

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) ≈ 0.05 to 0.14 *
  - Central ($y \approx 0$) : intermediate x_2 ≈ 0.011 to 0.022 *
  - North ($y > 1.2$) : small x_2 (in gold) ≈ 0.002 to 0.005 *

* Neglecting p_T



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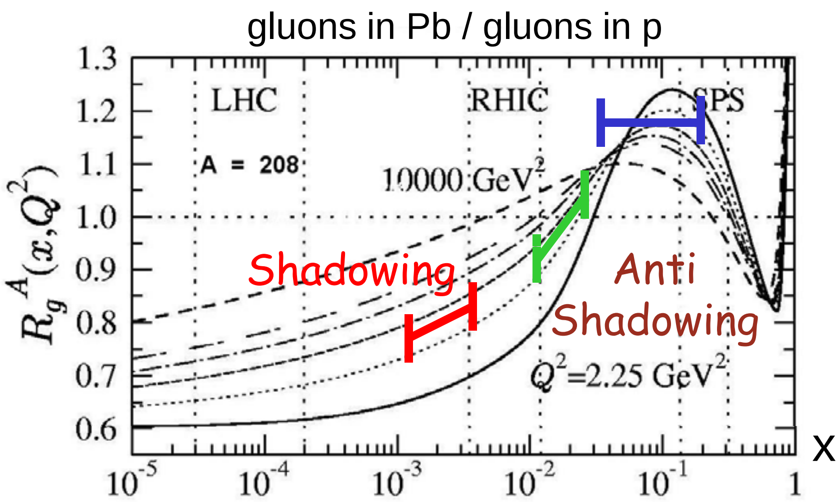
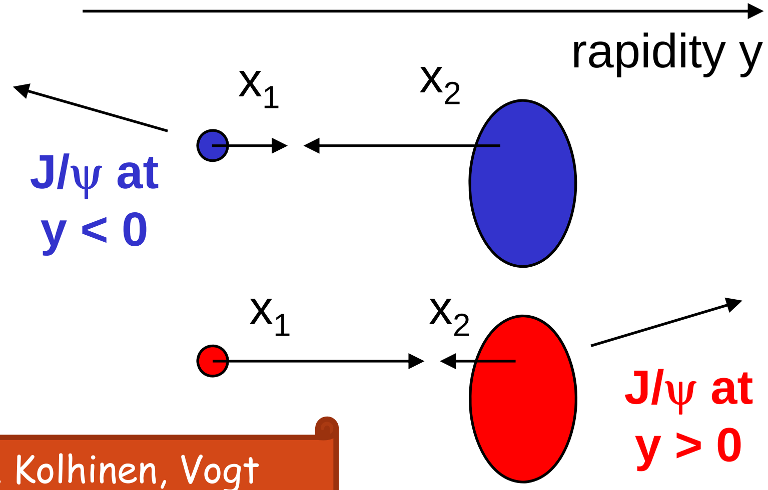




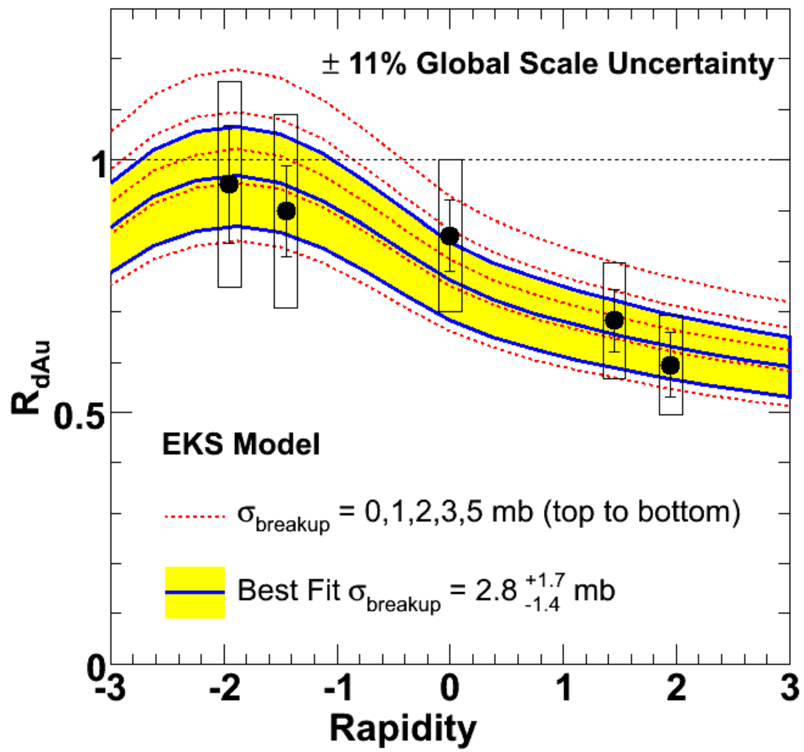
Eskola, Kolhinen, Vogt
NPA696 (2001) 729

$R_{dAu}(y)$ @ 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

EKS shadowing

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

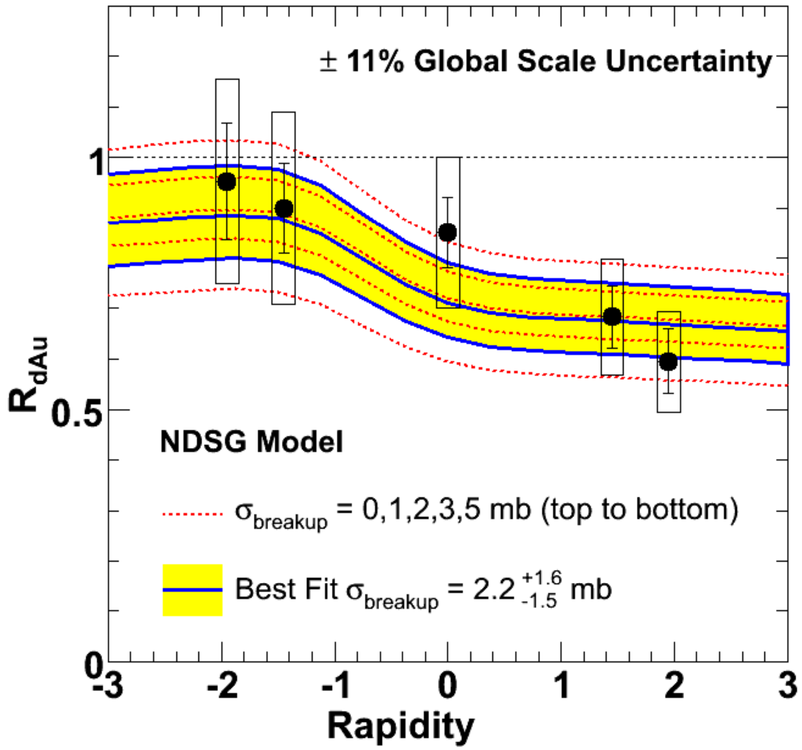


PHENIX, arxiv:0711.3917

$R_{dAu}(y)$

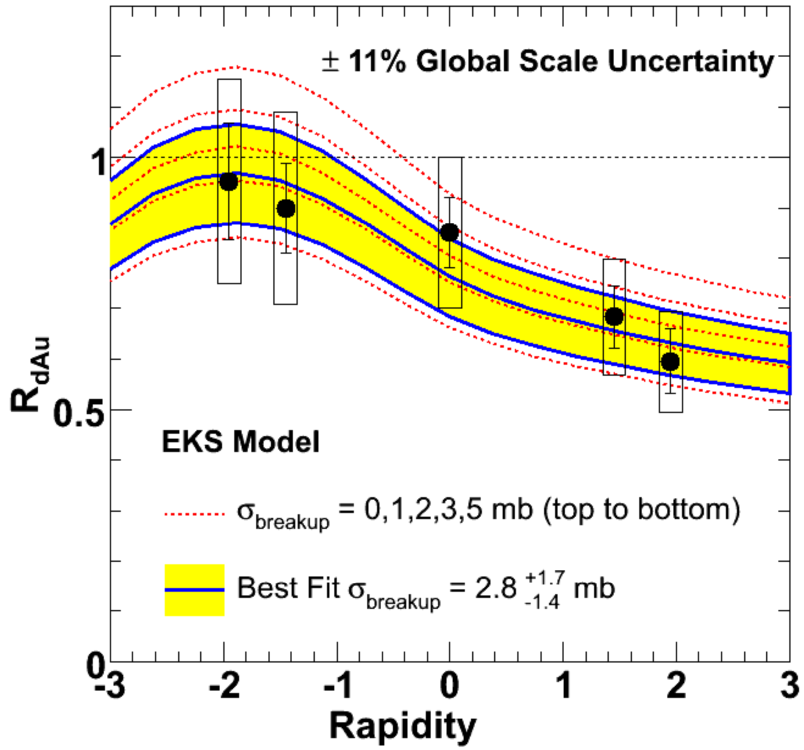
NDSG shadowing

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



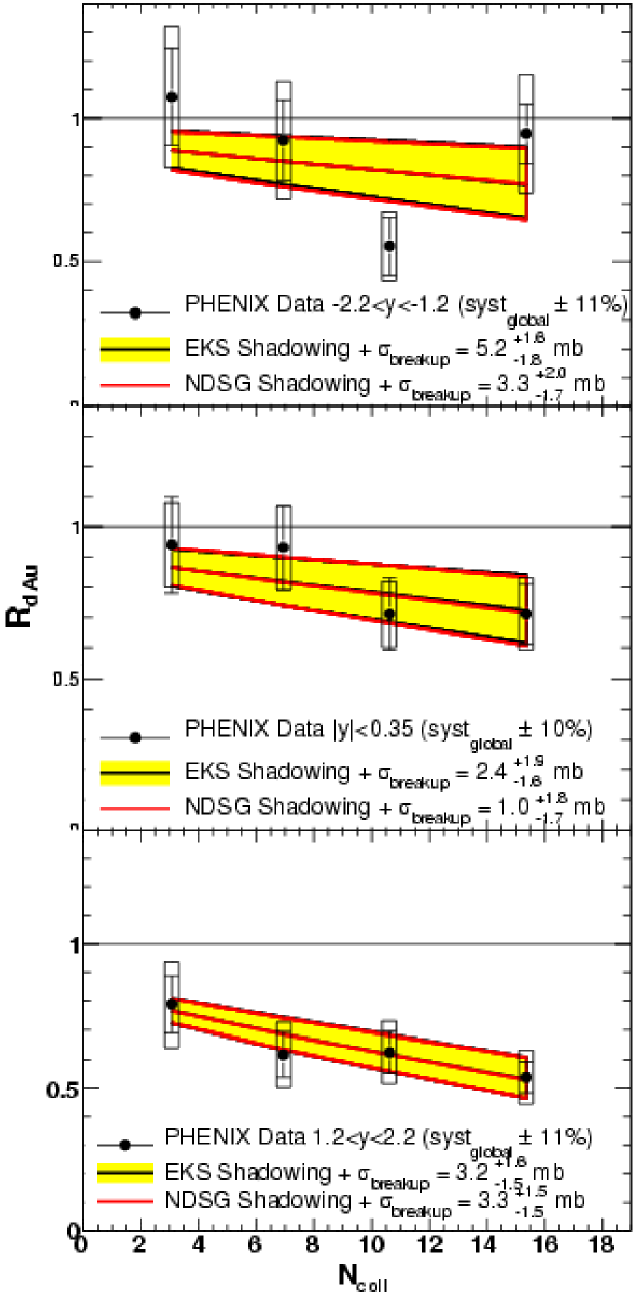
EKS shadowing

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



PHENIX, arxiv:0711.3917

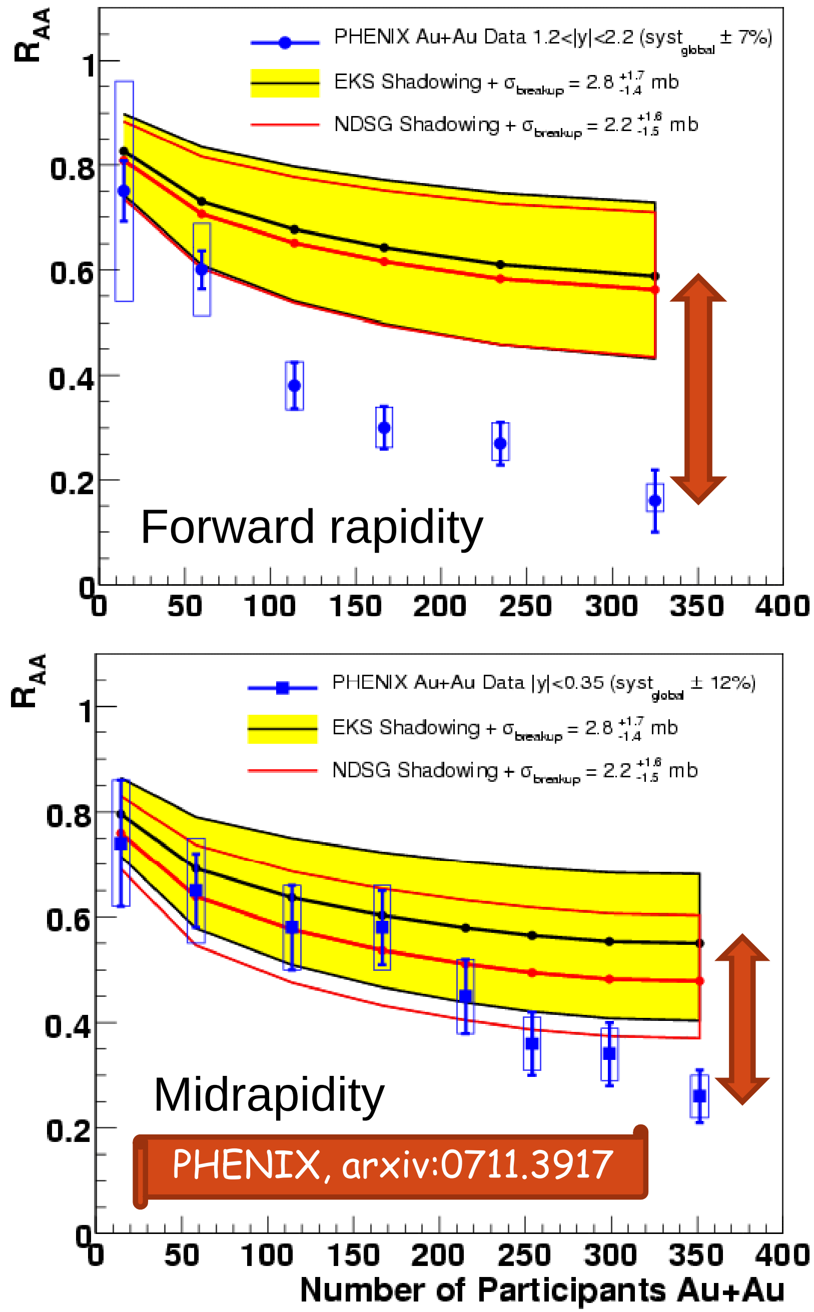
$R_{dAu}(N_{coll},y)$



- 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
- Net shadowing effect
  - EKS: (y=0) ≈ (y=1.7)
  - NDSG: (y=0) < (y=1.7)



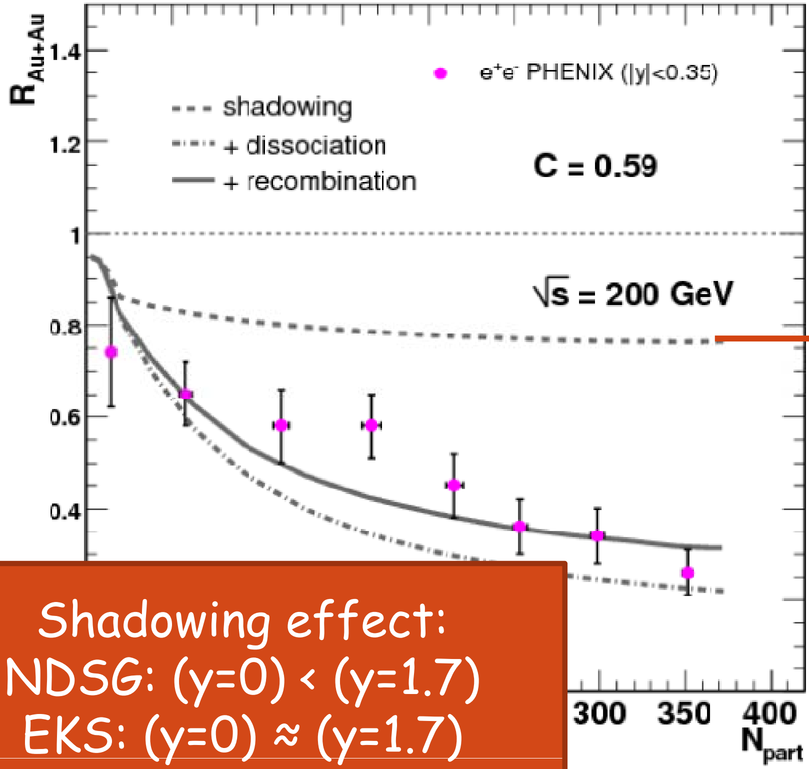
Yet another shadowing scheme?

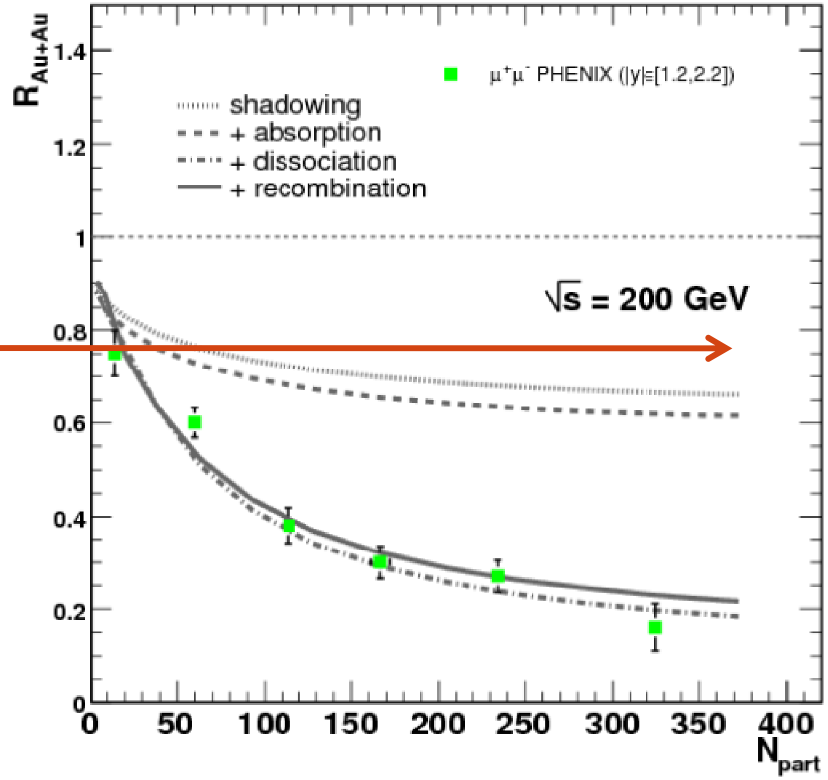
Capella et al, arXiv:0712.4331

Shadowing from Schwimmer multiple scattering :

+ E-p conservation

+ regeneration

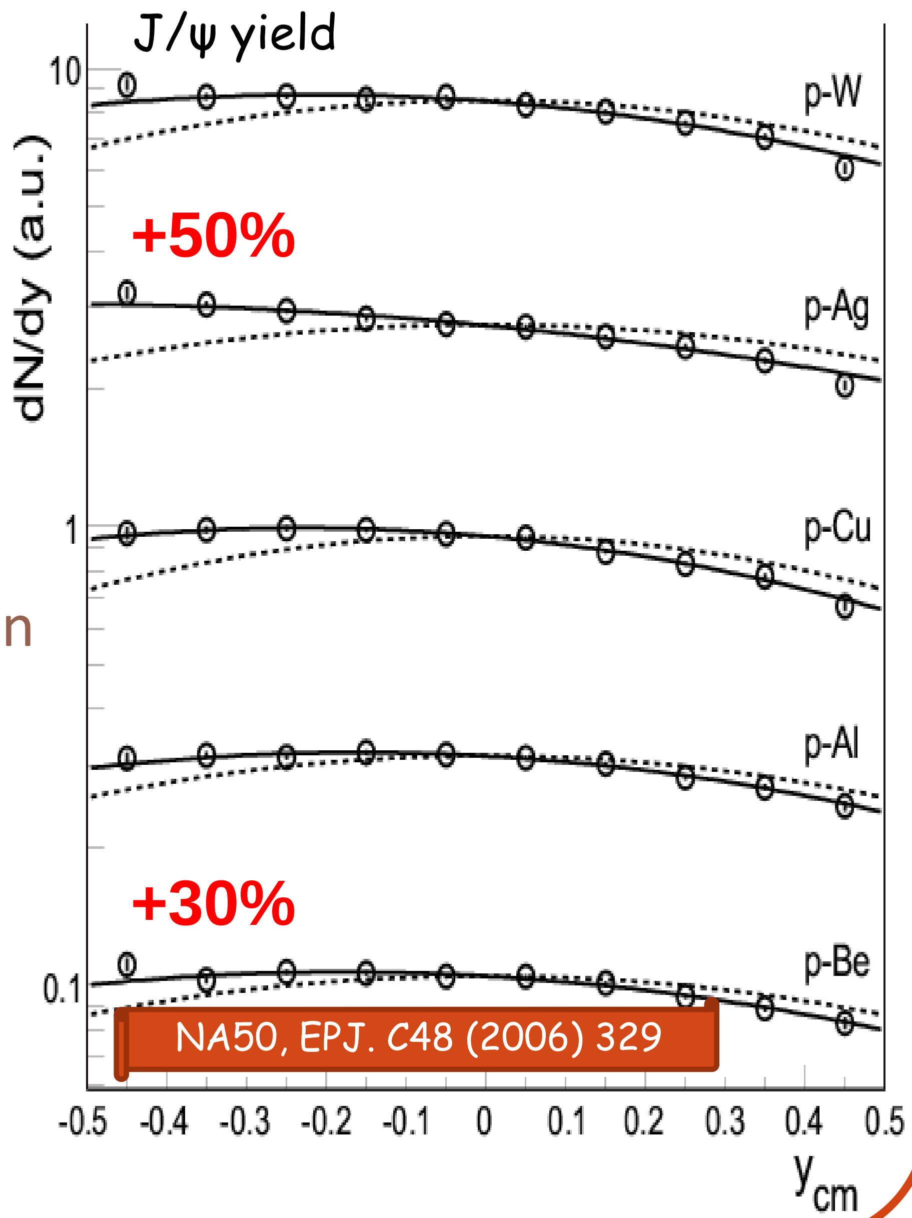




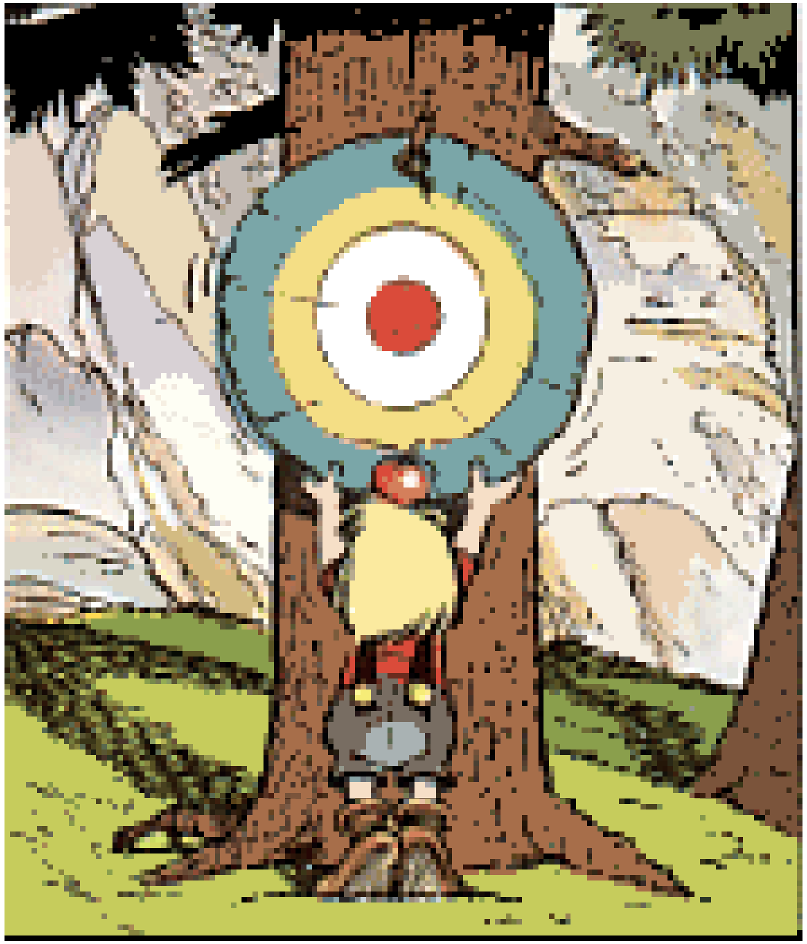
Shadowing effect:
NDSG: (y=0) < (y=1.7)
EKS: (y=0) ≈ (y=1.7)
Schwimmer: (y=0) > (y=1.7)

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…

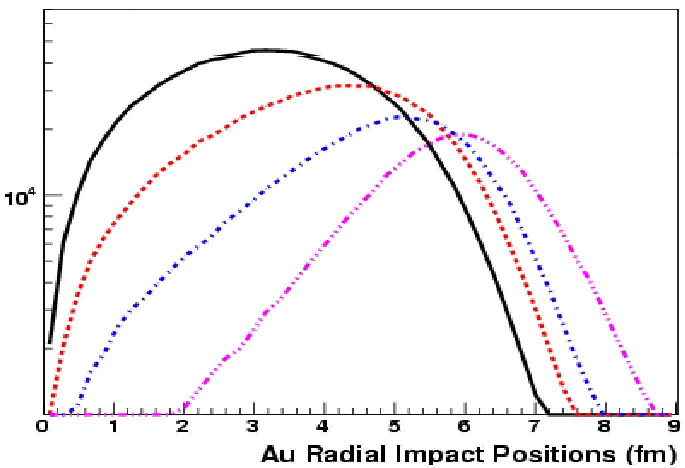


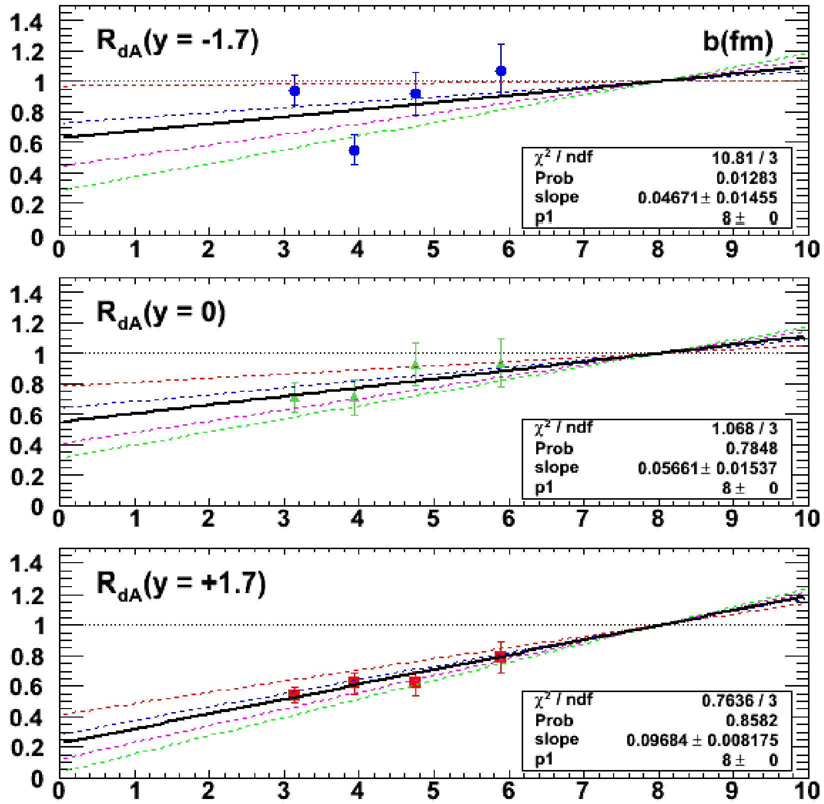
R_{dAu} centrality dependence



R_{dAu} (b)

- Re-plot PHENIX R_{dA} vs local impact parameter b from Glauber model
- Phenomenological fit to R_{dA}(b) →
  - RdA(b) = A*(b-8)+1 & RdA(b>8fm)=1
  - (other shapes were tried)





RGdC, Quark Matter 06
PHENIX, arxiv:0711.3917

From dA to AA

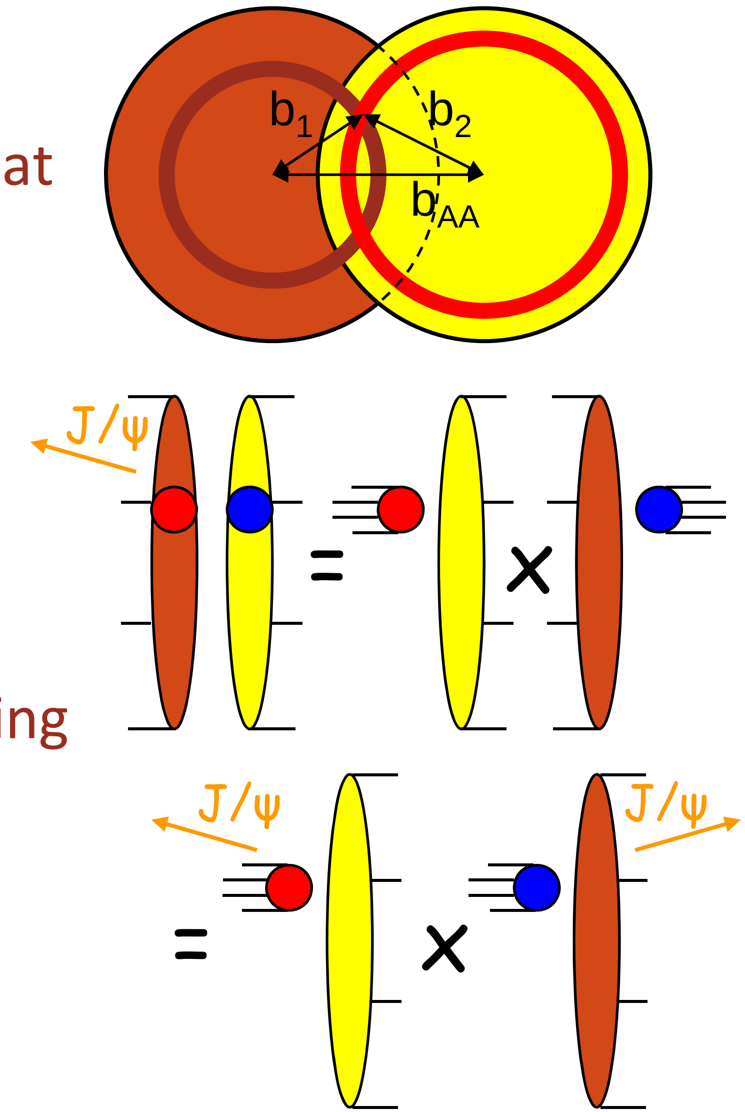
- For a given A+A collision at b_{AA}, Glauber provides a set of N+N collisions occurring at b_i^1 and b_i^2
- One minimal assumption is rapidity factorization: $R_{AA}(|y|,b_{AA}) =$

  $$\Sigma_{collisions}\ [R_{dA}(-y,b_i^1) \times R_{dA}(+y,b_i^2)]\ /\ N_{coll}$$

- Works (at least) for absorption & shadowing since production

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

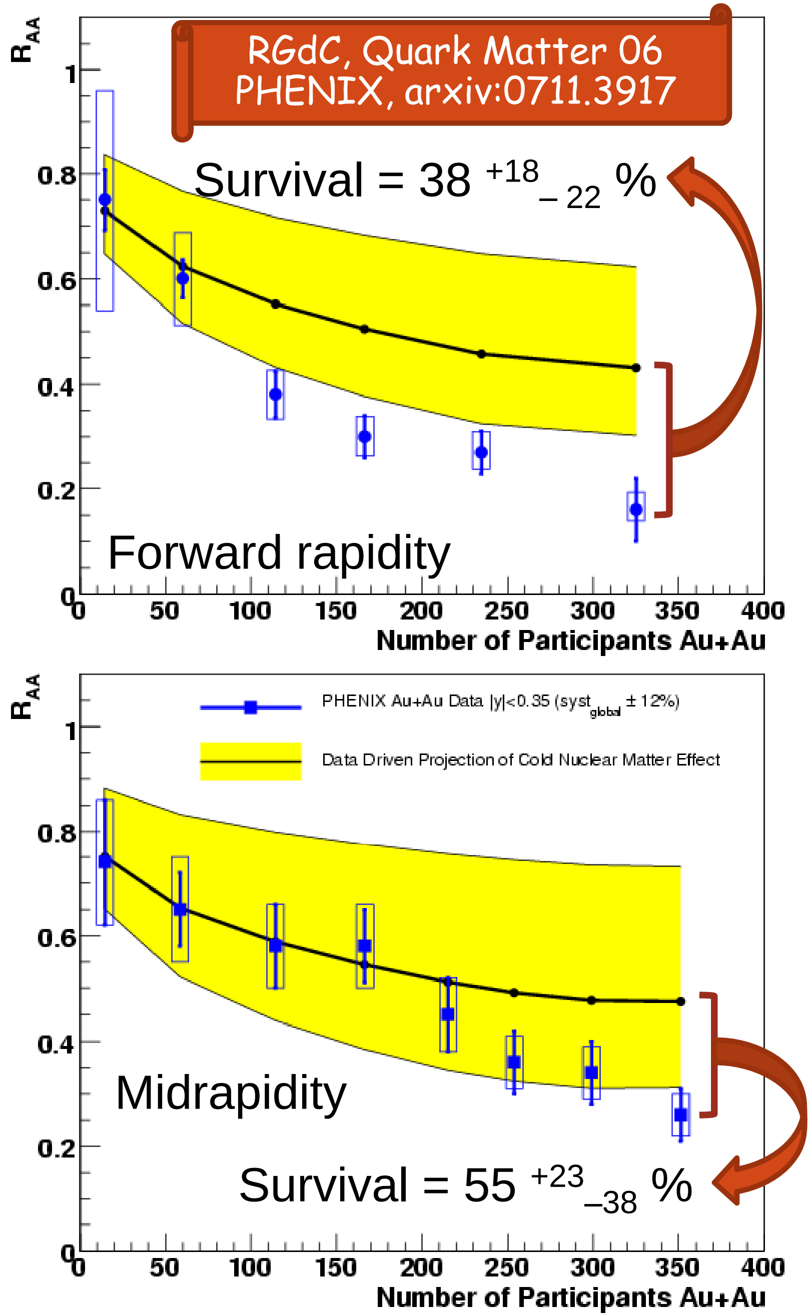
RGdC, QM06, hep-ph/0701222



R_{AA} (N_{part})

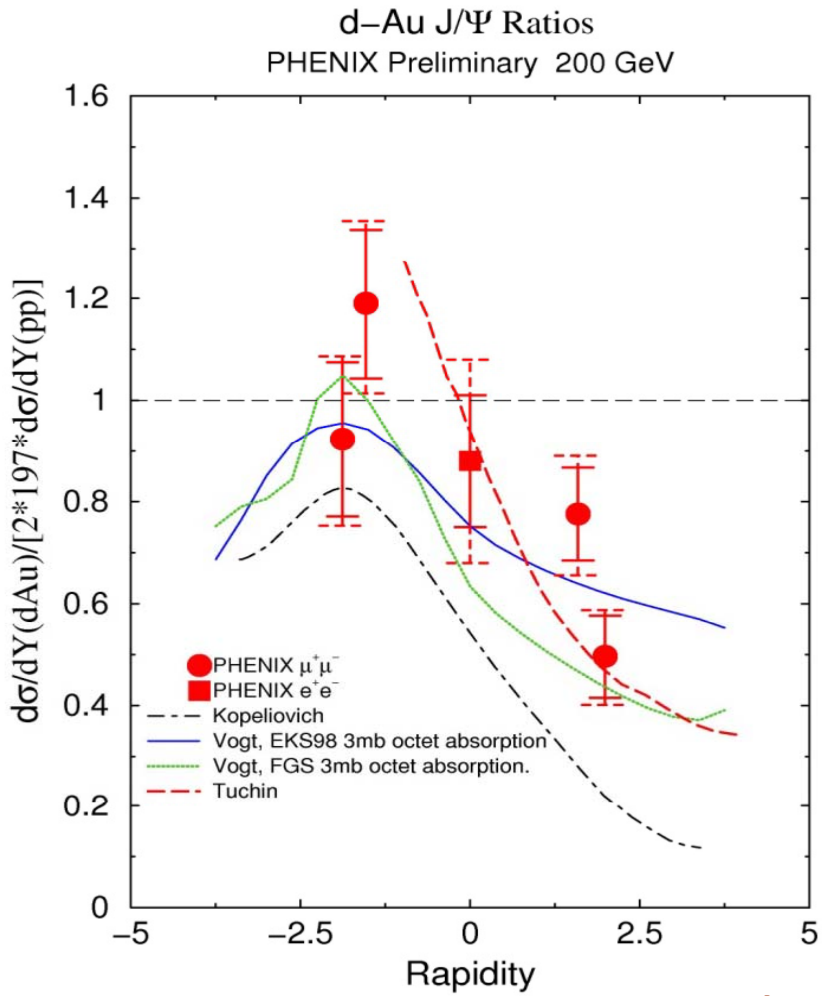
- Pros and cons:
  - No shadowing scheme nor absorption scheme
  - Mid and forward are not correlated, less model dependent

  → Larger uncertainties (esp. y≈0)
  - No dCu, so no CuCu
- Anomalous suppression at least at forward rapidity!
- Anomalous suppression could be identical at midrapidity



Unaccounted cold effects ?

- Could $R_{dA}(-y) \times R_{dA}(+y)$ factorization be wrong?
- Yes, in case of strong saturation…
- dAu computation →
- AuAu computation underway… But:
  - Is saturation at play beyond traditional shadowing at $x_1 \approx 0.003$?
  - How to describe $x_2 \approx 0.1$?



Tuchin, hep-ph/0504133

Unaccounted cold effects ?

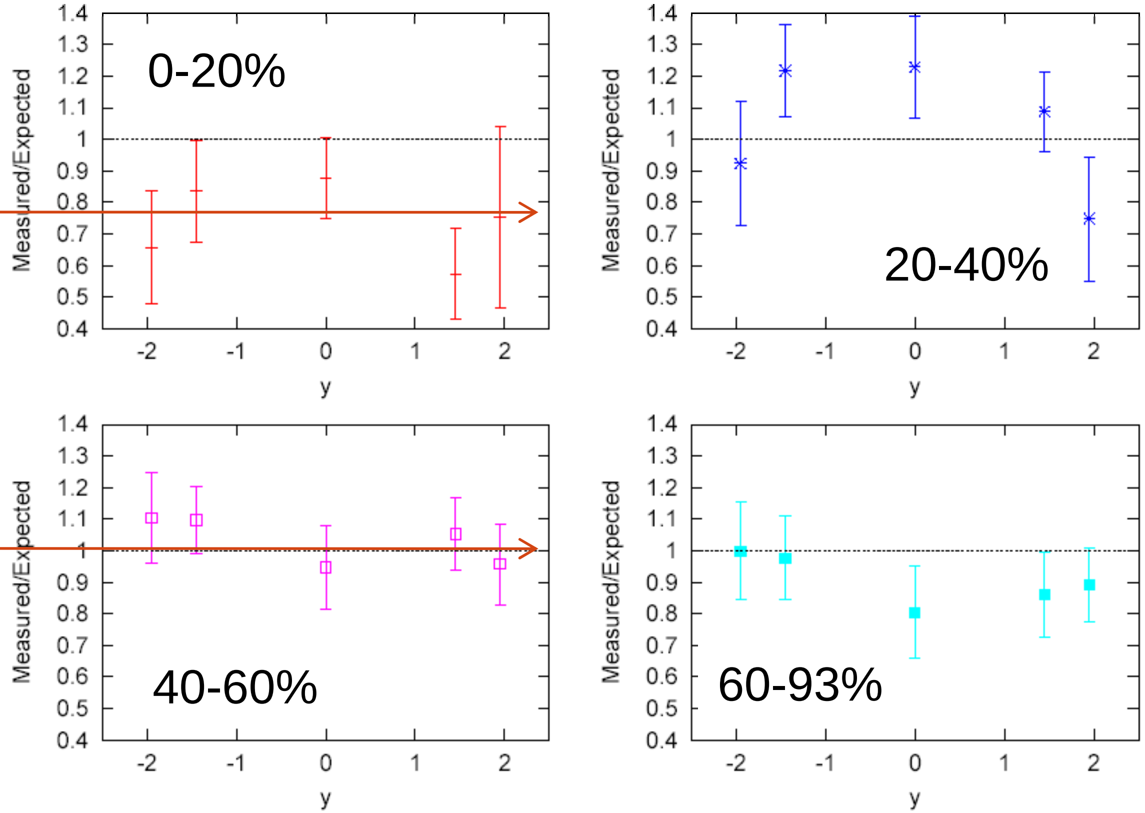
M. Nardi, QM08

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

$\frac{\text{Experiment}}{\text{Saturation}}$

"Flat anomalous" suppression here ?

Normalisation here ?



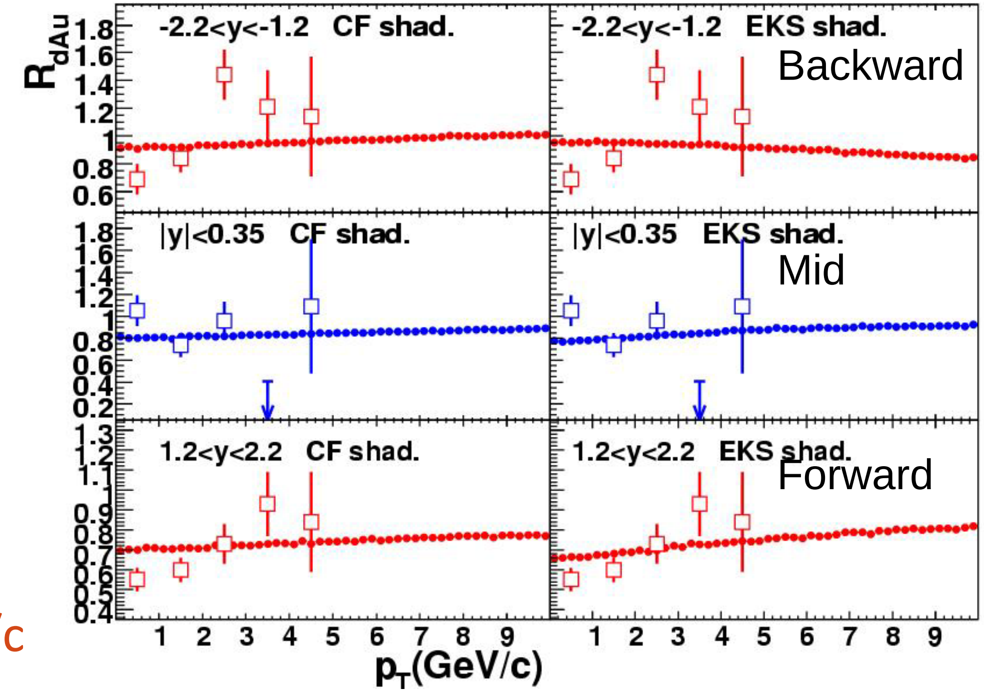
R_{dAu} transverse momentum

$R_{dAu}(p_T)$

- $R_{dAu}(p_T)$ not precise but tendency to raise…
- Potential reasons:

$$x_{1,2} = \frac{m_T}{\sqrt{s}} e^{\pm y}$$

  - Raising x_{Bj} = less shadowing
    - 0.02 to 0.05 from 0 to 9 GeV/c
    - See discussion in →
  - Also Cronin effect? Further pT broadening?

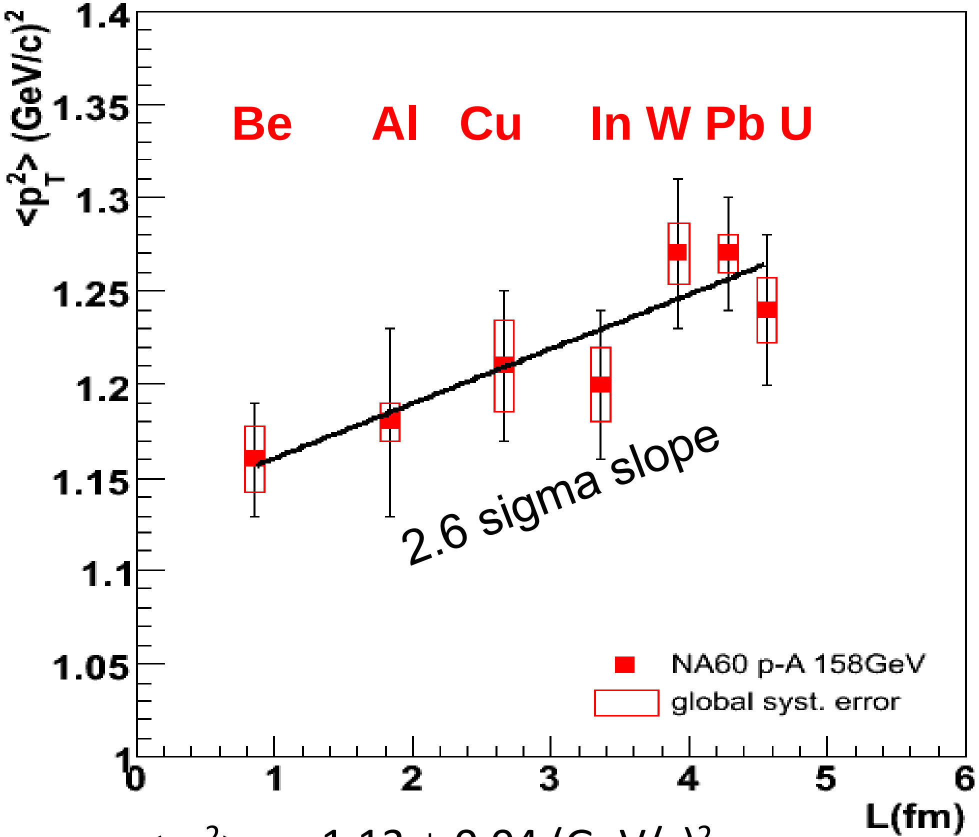


PHENIX, arxiv:0711.3917 compared to Ferreiro, Fleuret, Rakotozafindrabe, arxiv: 0801.4949

$<p_T 2>$ vs L = broadening @ SPS

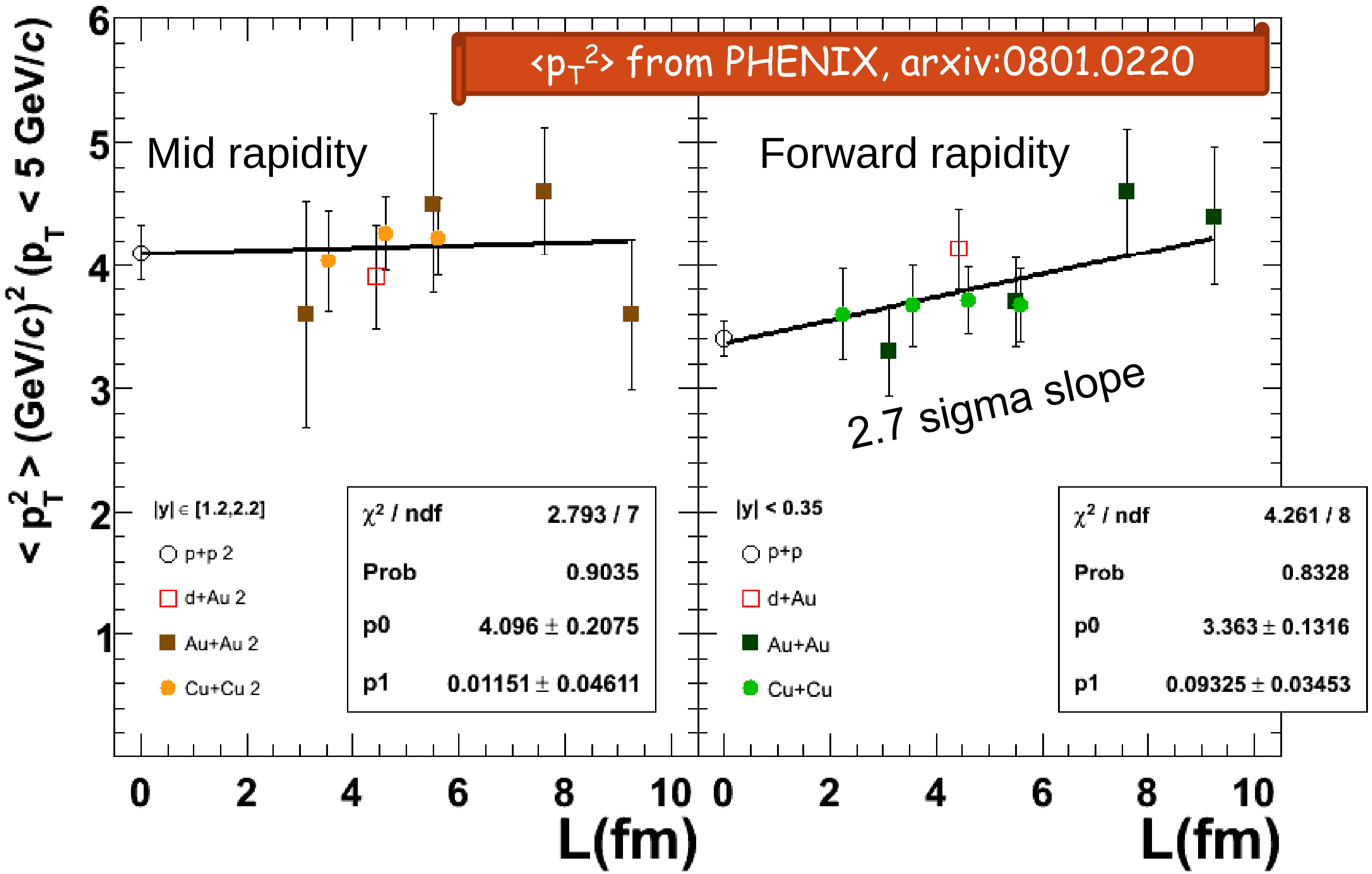
- Cronin should go like:
  - $<p_T^2>_{AB} = <p_T^2>_{pp} + \alpha \times L$
- Different scaling in pA and AA collisions reported at QM08
  - Something else going on in AA?
  - High p_T J/ψ escape?
- Anyway…

R. Arnaldi, QM08



$<p_T^2>_{pp} = 1.13 \pm 0.04$ (GeV/c)^2
$\alpha = 0.029 \pm 0.011$ (GeV/c)^2/fm

p_T broadening @ RHIC ?



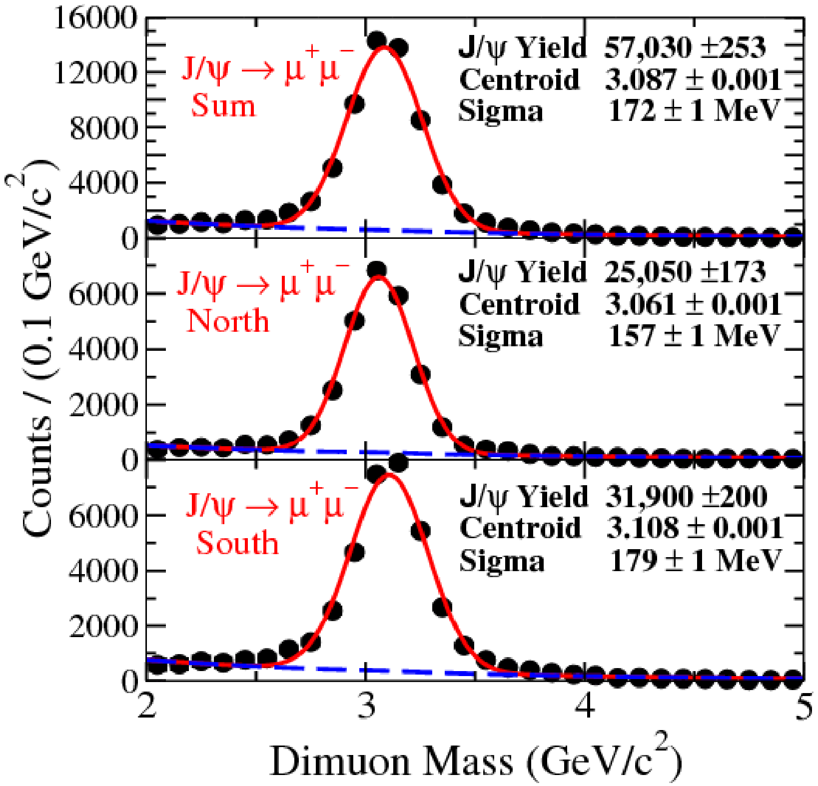
$\alpha = 0.011 \pm 0.046$ (GeV/c)^2/fm ← compatible → $\alpha = 0.093 \pm 0.034$ (GeV/c)^2/fm

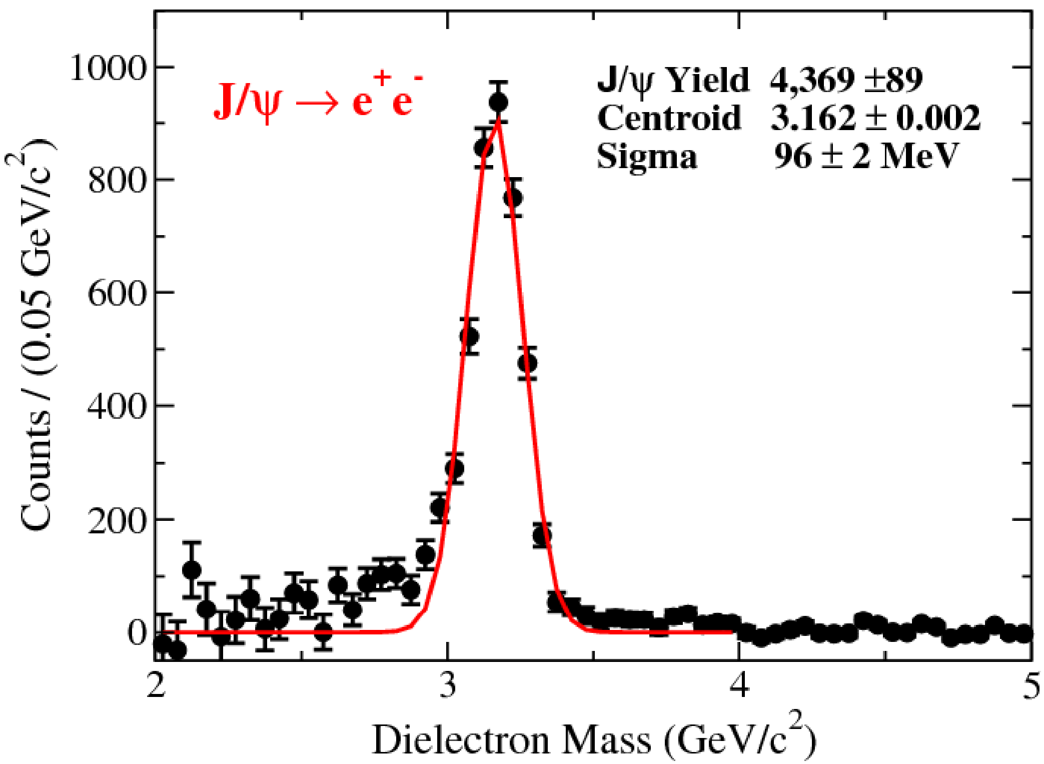
Three existing cold scenarios could justify the rapidity anomalous dependence

1. The data itself (dAu data driven method)
2. A given shadowing scheme (Schwimmer)
3. Color glass condensate (work in progress)

[however very related]

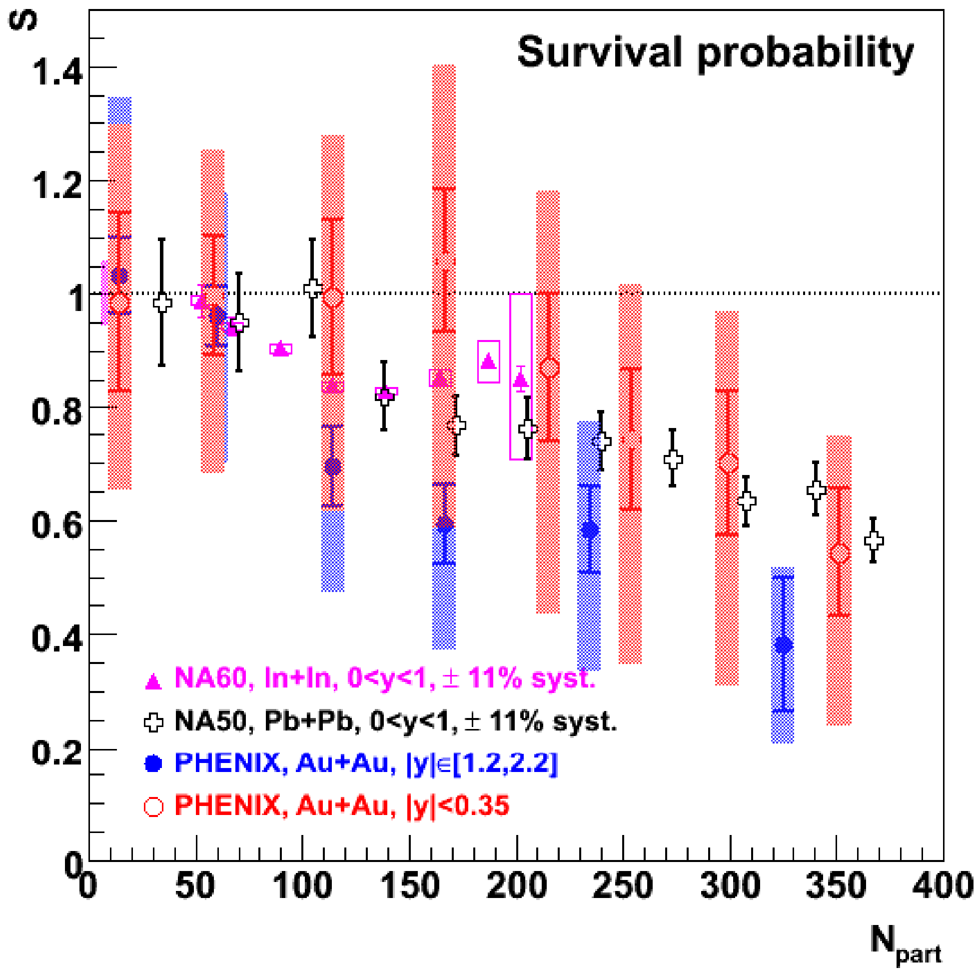
Hopefully, RHIC run 8 dAu ≈ 30 x run 3 !





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

Indecent conclusion…



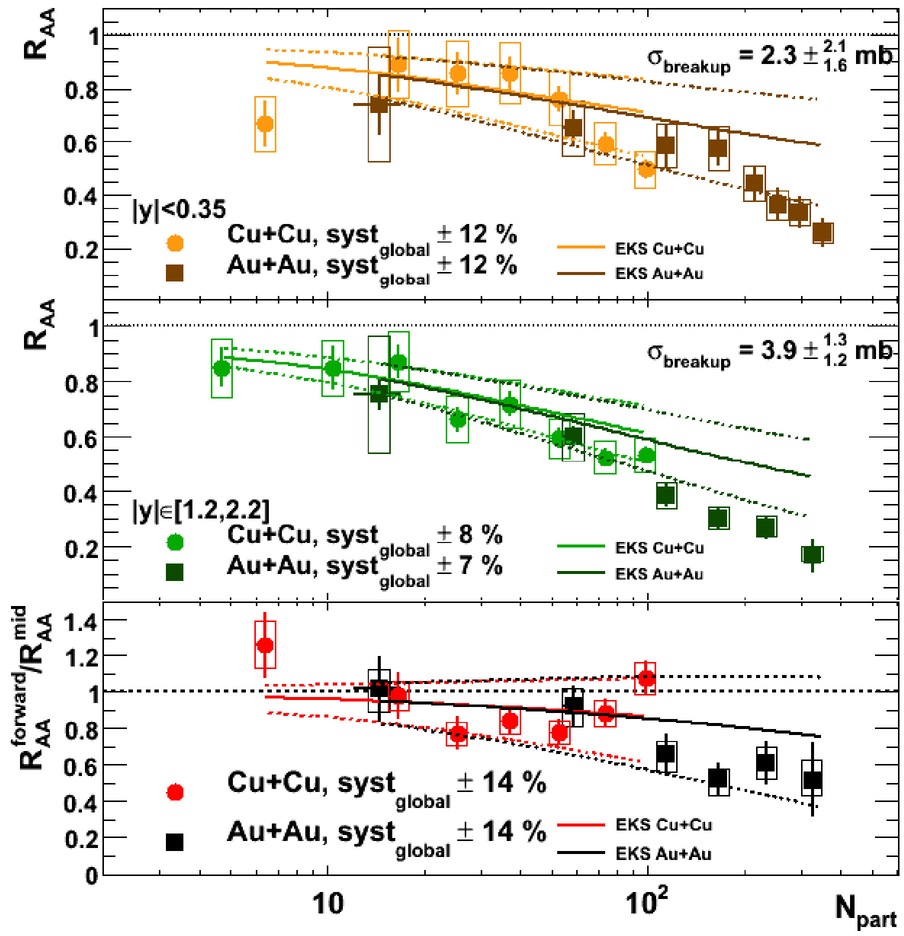
PHENIX, PRL98 (2007) 232301
divided by
PHENIX, arxiv:0711.3917
(data driven method)

- RAA / CNM from data driven method
- Anomalous suppression could :
  - be the same at forward and midrapidity ☺
  - And different between SPS and RHIC ☺

That’s all folks

CuCu data

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



PHENIX, arxiv:0801.0220

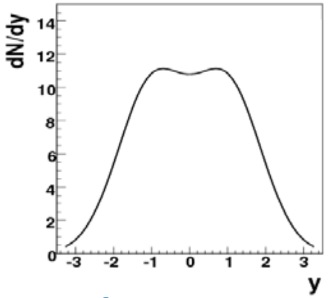
Transverse momentum dependence of J/Ψ shadowing effects

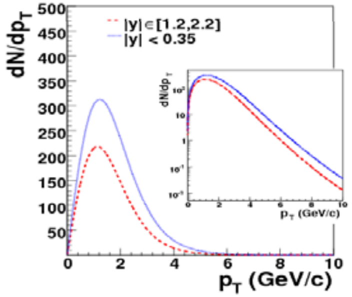
arXiv:0801.4949

Method:

J/Ψ p_T and rapidity extracted from PHENIX 200 GeV proton-proton data

Phys. Rev. Lett.98, 232002 (2007)





$$x_{1,2} = \frac{m_T}{\sqrt{s_{NN}}} e^{\pm y} < 1$$

$$\text{with } m_T = \sqrt{m^2 + p_T^2}$$

Glauber Monte Carlo

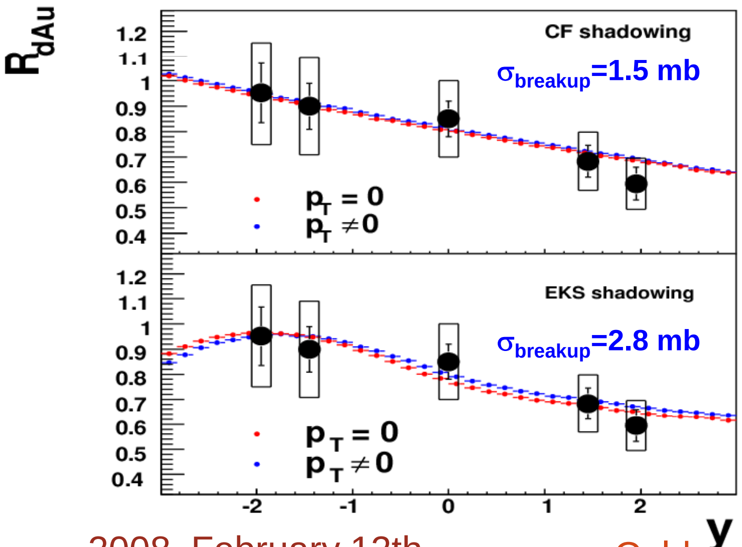
Test 2 shadowing models :

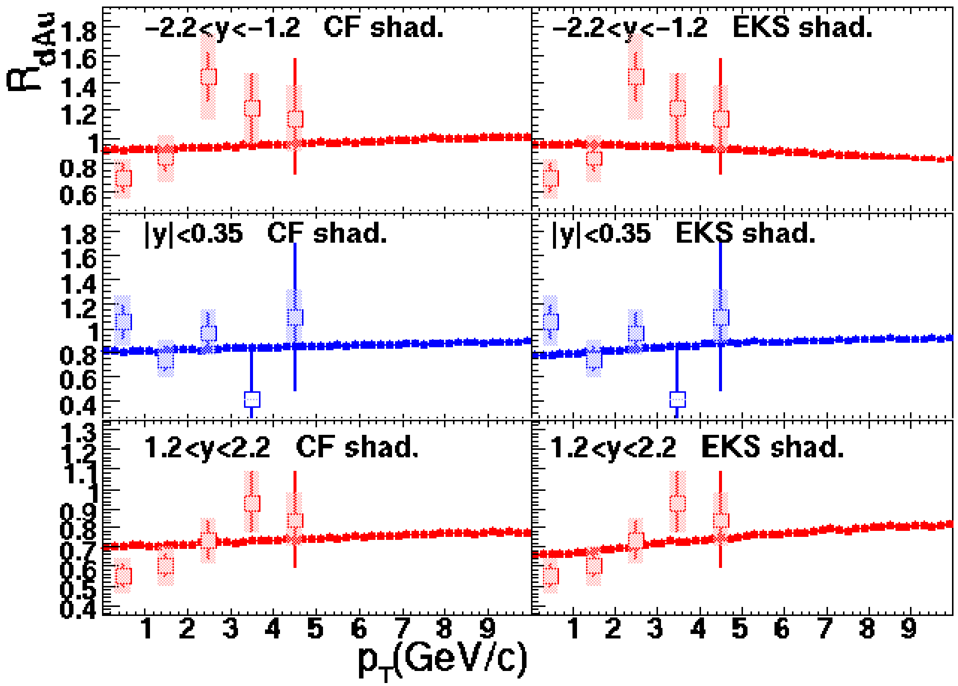
- CF : Eur. Phys. J. C42, 419 (2005)
- EKS : Eur. Phys. J. C9, 61 (1999)

Results:

Expectations for 200 GeV d+Au data

Comparing with PHENIX 200 GeV d+Au data arXiv:0711.3917

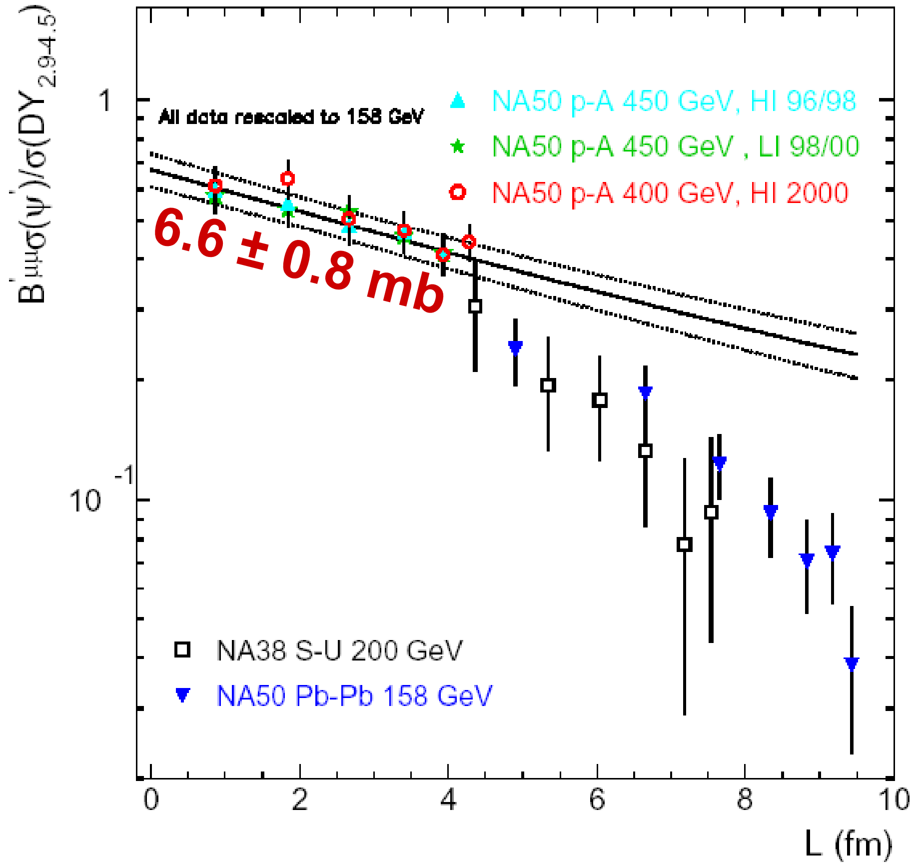




(E.G. Ferreiro, F. Fleuret, A. Rakotozafindrabe)

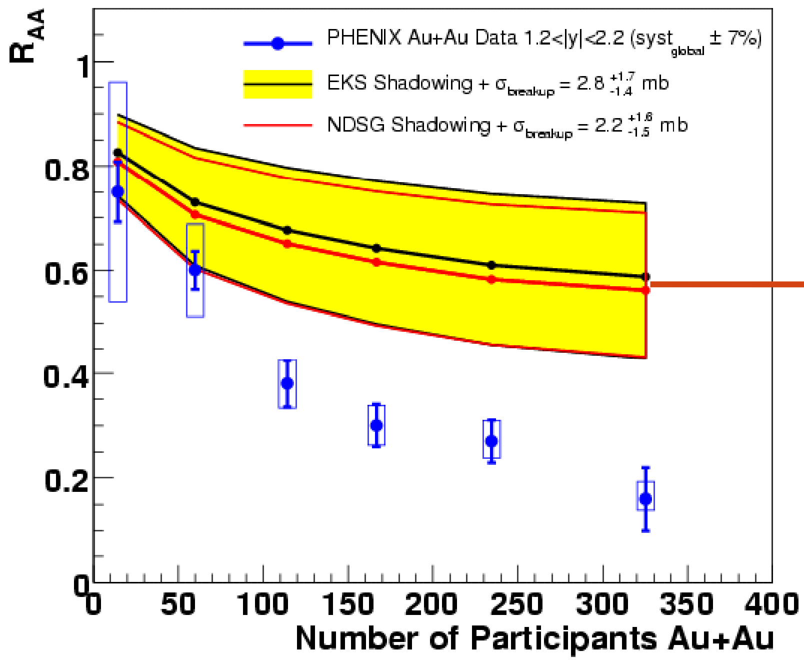
R_{dAu} .vs. p_T gives new constraints on shadowing models

Ψ’ absorption at SPS

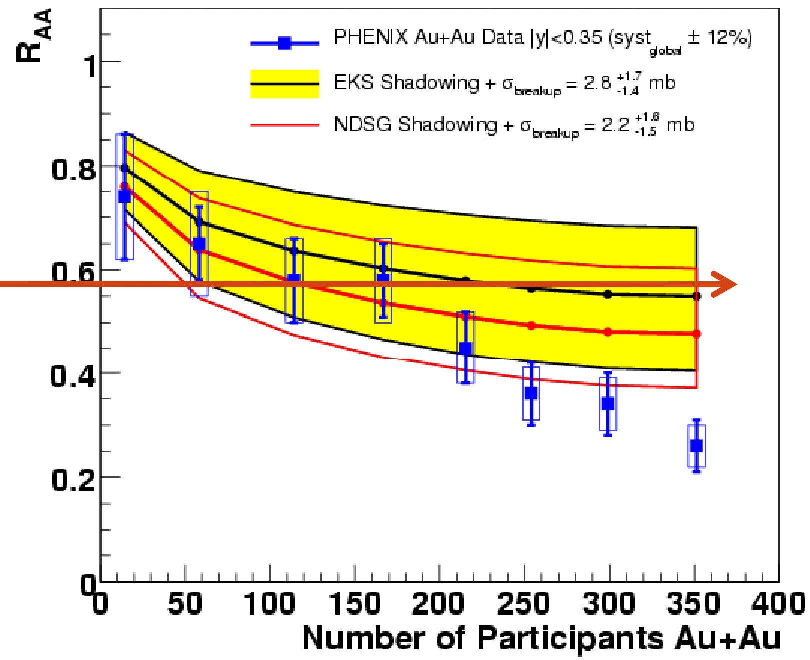


Face to face

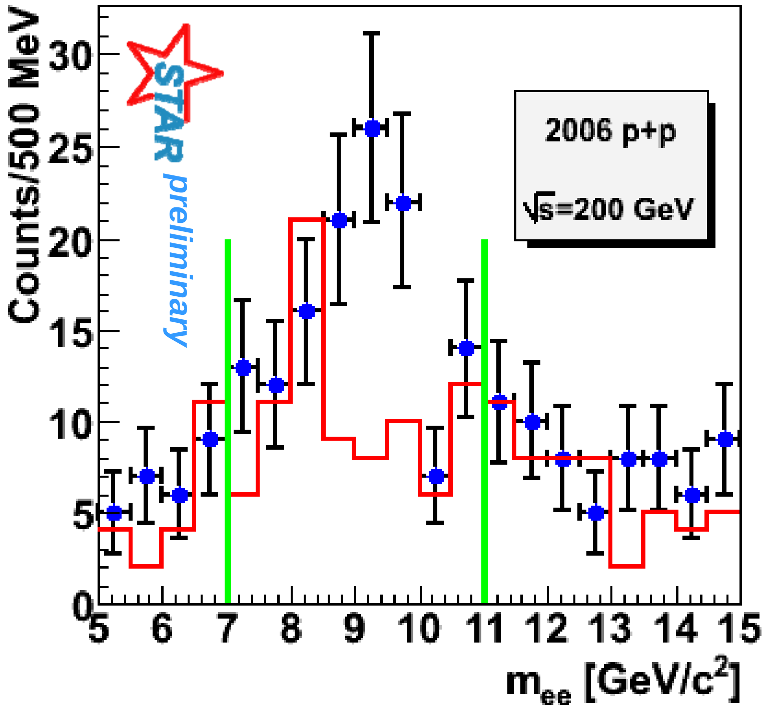
EKS (y=0) ≈ (y=1.7)

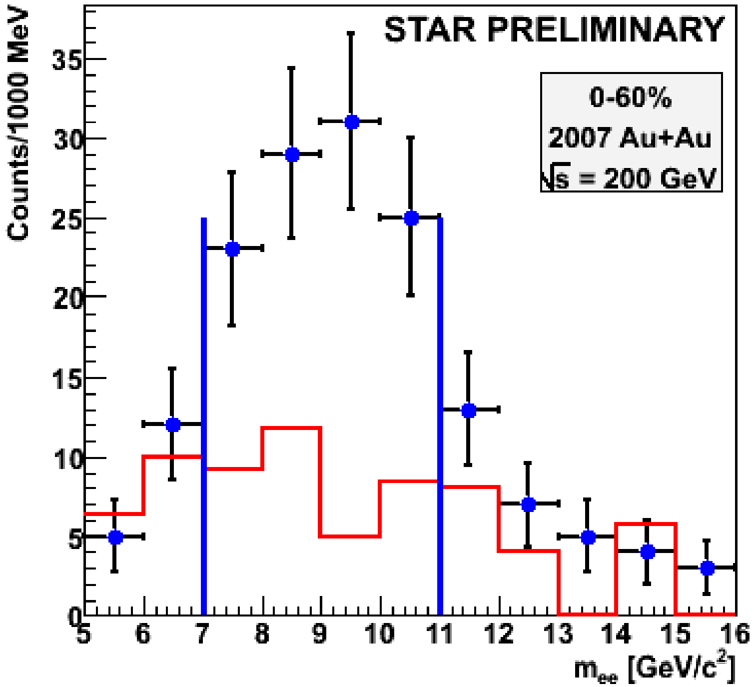


NDSG (y=0) < NDSG (y=1.7)



STAR upsilon's

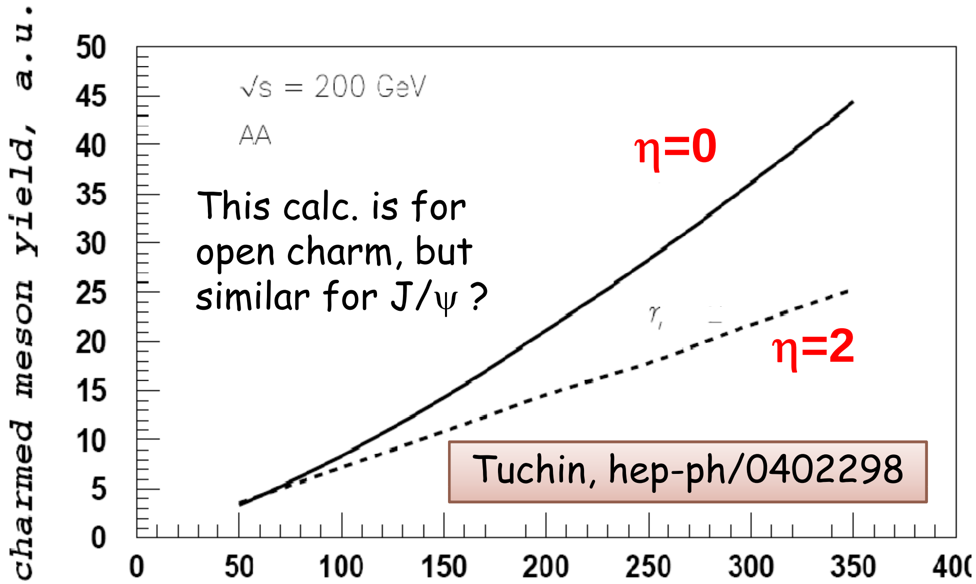


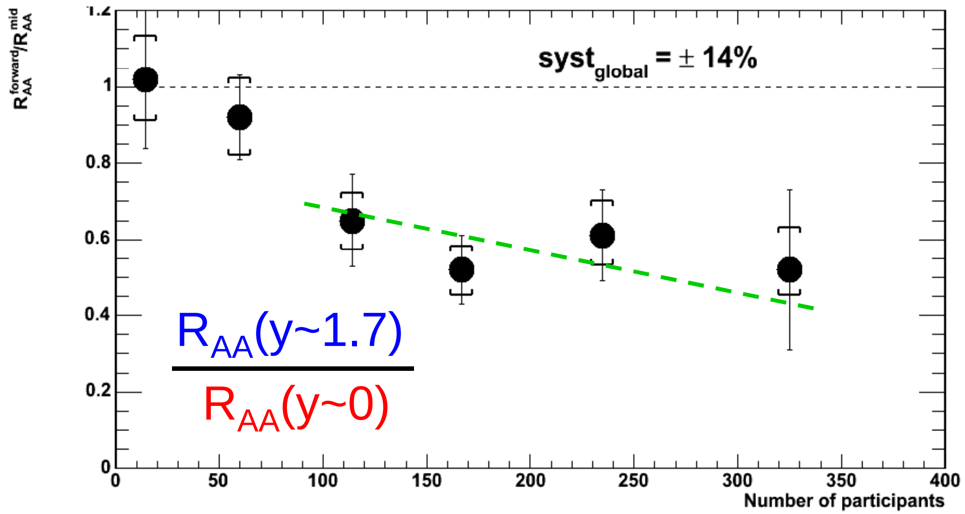


- Proof of principle: dozens of Υ in p+p & A+A!
- Nuclear modification factor to come soon
- Suffers less from cold matter (x=0.02 to 0.1=EKS antishadow)
  - (should be checked with run8 d+Au)
- Should measure (unseparated) excited states melting

Unaccounted CNM ?

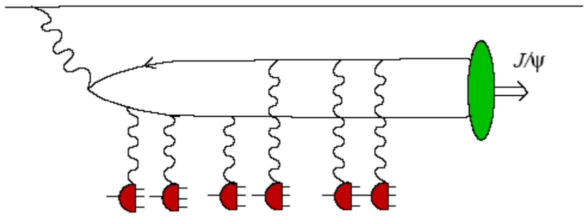
- Strong initial states effect ala color glass condensate ?
  - But they have to violate rapidity symmetrisation $R_{AA}(|y|) = R_{dA}(-y) \times R_{dA}(+y)$
  - (otherwise taken into account in CNM extrapolation)
- Could this + sequential melting produce $R_{AA}(y\sim0)$ and $R_{AA}(y\sim1.7)$?
- Double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

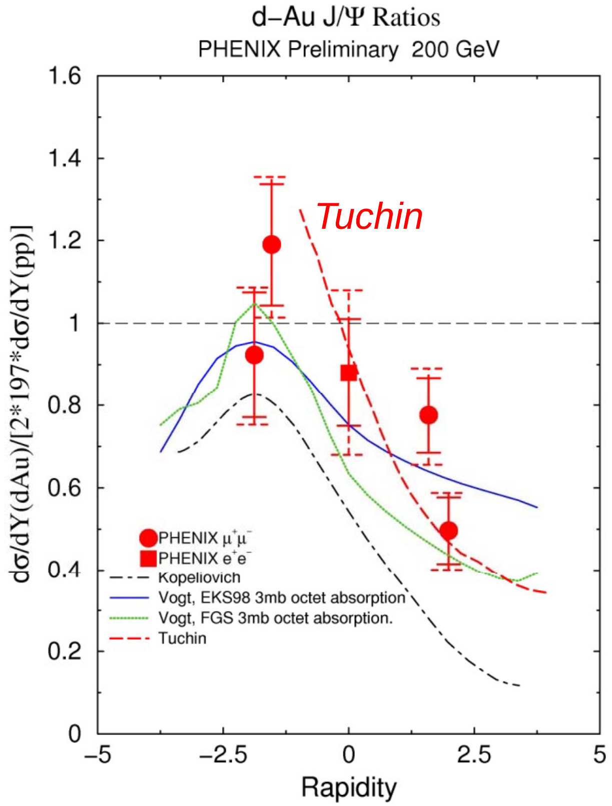




Tuchin & Kharzeev

- 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