Vue d’ensemble quarkonia
Revue des résultats expérimentaux
SPS (FNAL, HERAB) RHIC, de pA à AA

Journées PQG France
Étretat, 5 juillet 2006

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Avertissements

~ Présentation à hard probes 06 (donc en anglais, sorry)

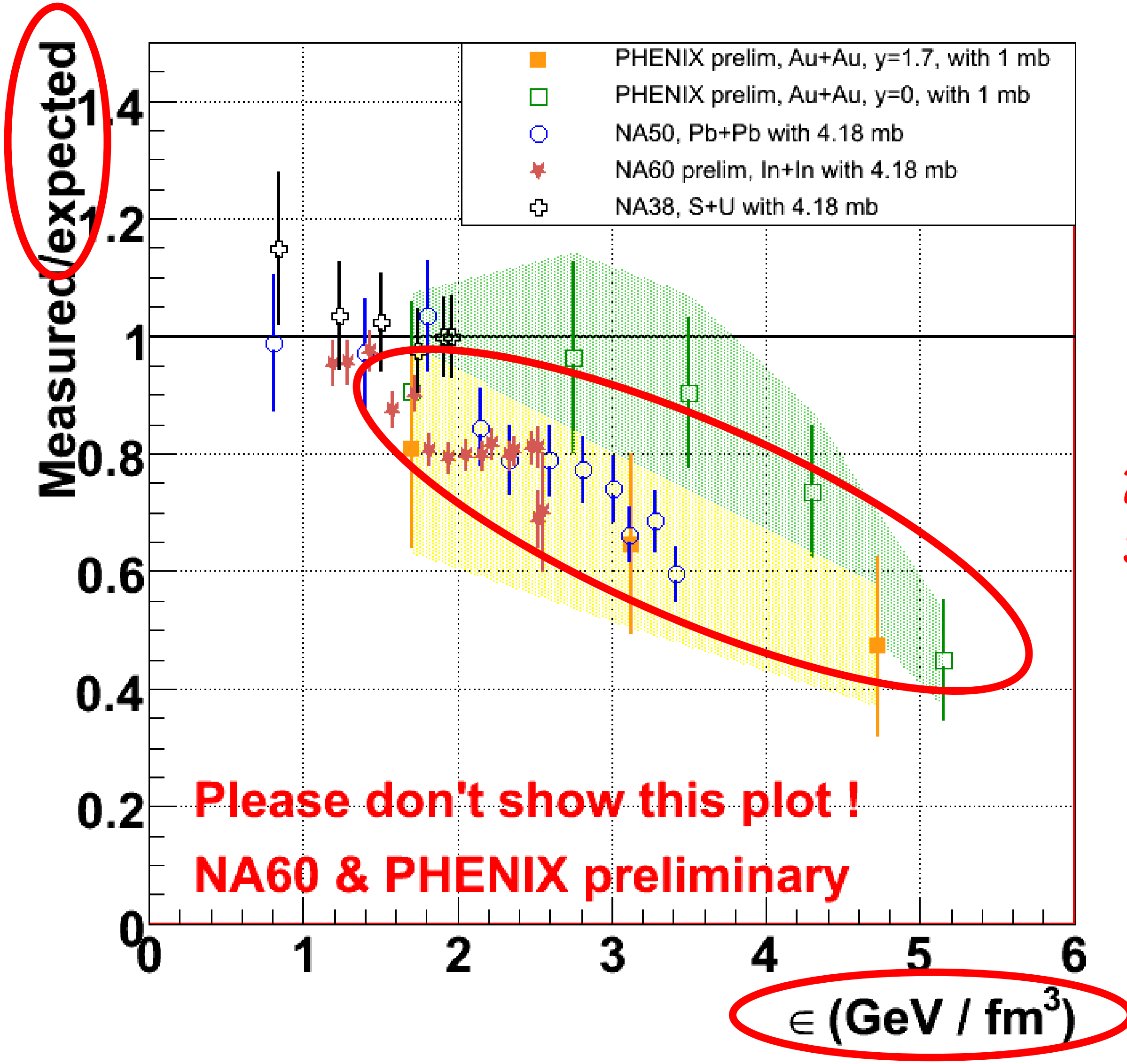
Passer vite sur les points évoqués par Andry, Catherine, Philippe, Ermias, Paul, François,...

Pour Jean & Yves, les nouveautés sont signalées par ce logo

J/ψ survival probability ?

Are we there yet ?

1. Normal suppression



2. Anomalous Suppression ?

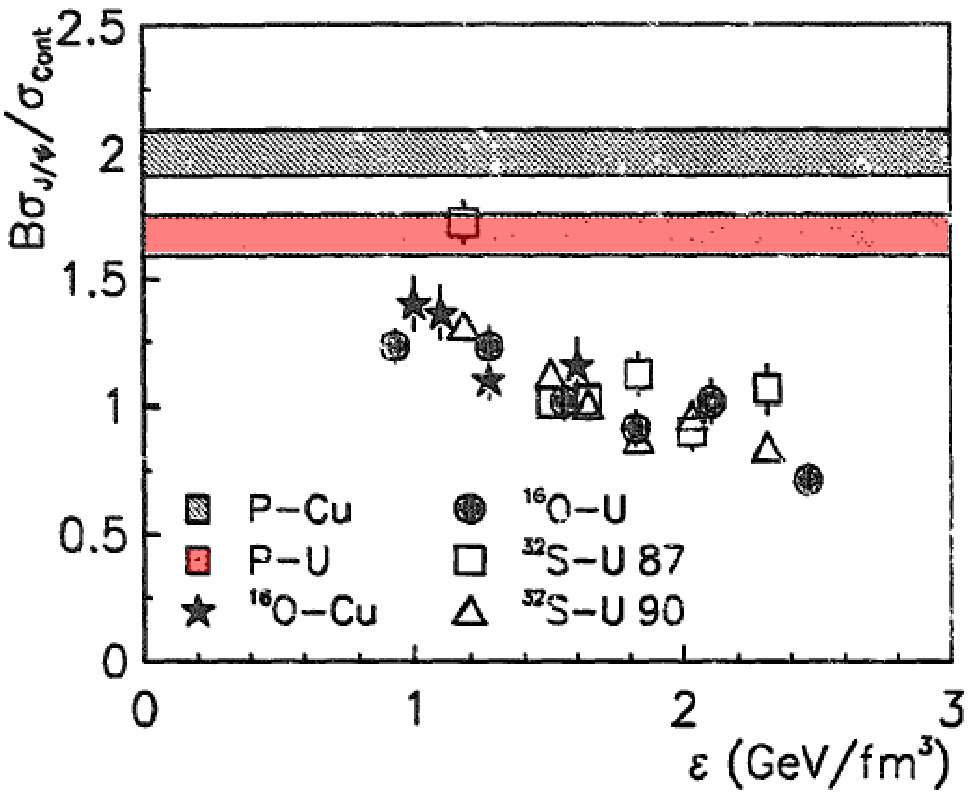
3. Energy density ?

A couple of historical facts

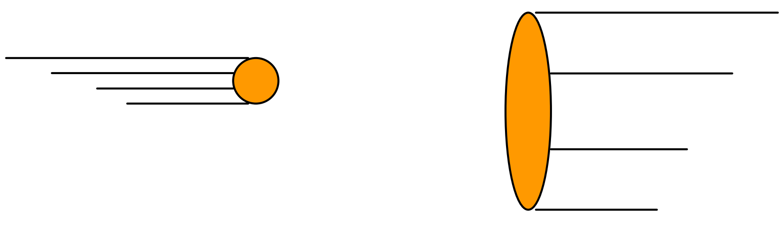
- In 1986, Matsui & Satz predicted an "unambiguous" signature of QGP, that was immediately (~1987) seen by NA38 in SU collisions…

Matsui & Satz, PLB178 (1986) 416

NA38, NPA544 (1992) 209

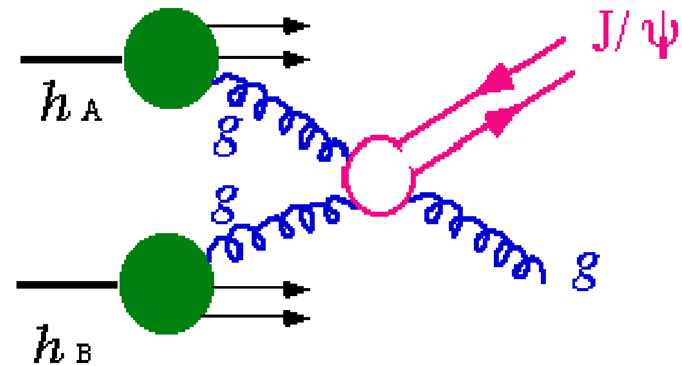


D'abord, faites gaffe aux effets nucléaires froids !

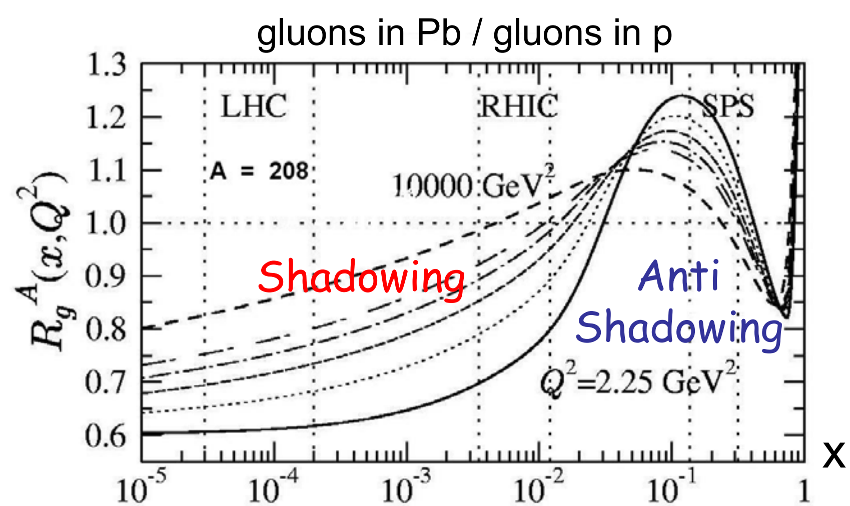


Cold nuclear matter effects ?

- J/ψ (or $c\bar{c}$) absorption
- (Anti) shadowing
  (gluon saturation, CGC…)
- Energy loss of initial parton
- p_T broadening (Cronin effect)
- Intrinsic charm
- Complications from feeddown ψ' & χ_c ?
- Something else ?



An example of gluon shadowing prediction



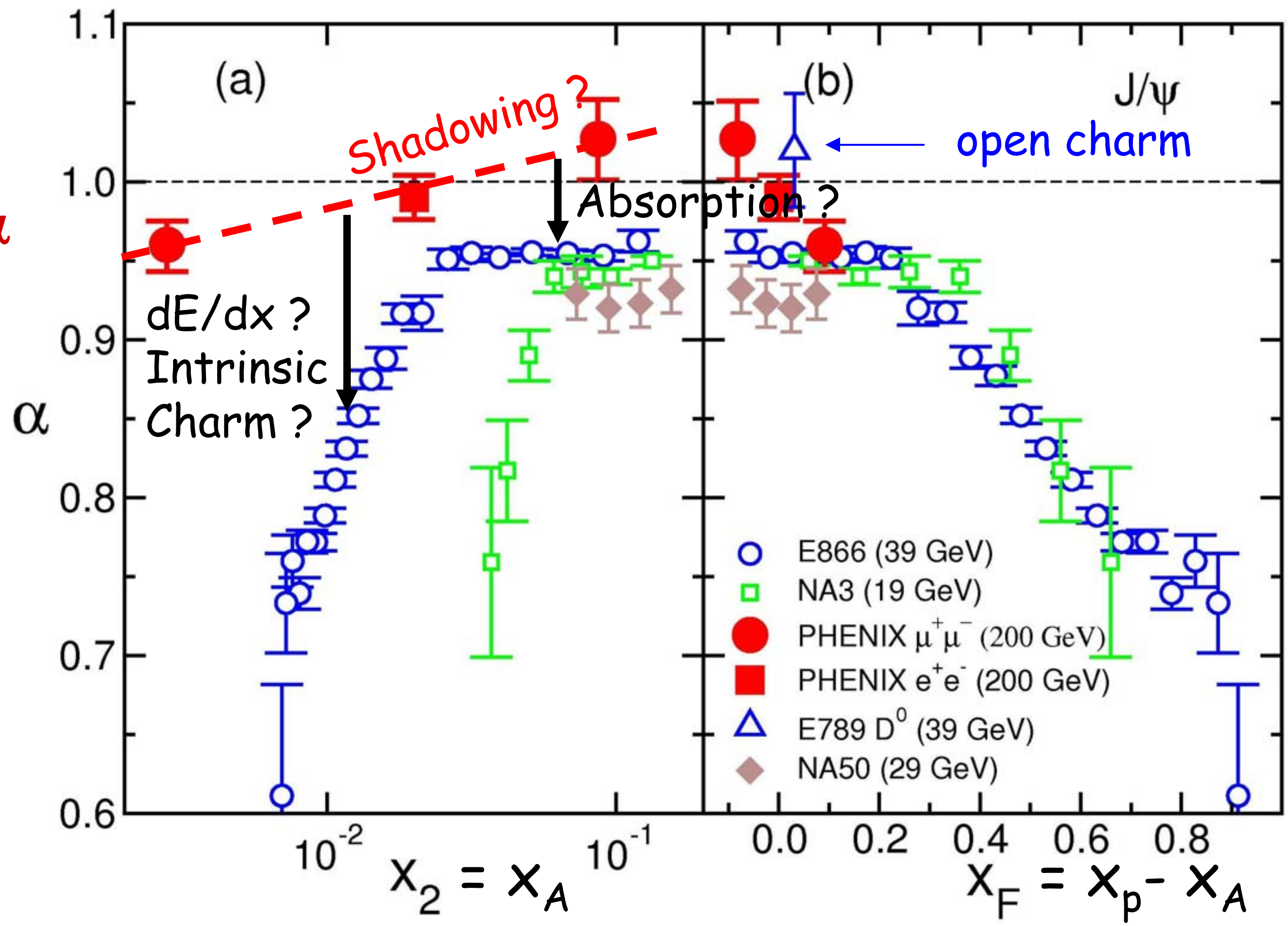
Eskola, Kolhinen, Vogt
NPA696 (2001) 729

Cold nuclear matter effects ?

A real puzzle ! Especially when one goes to low x_2, high x_F...

$\sigma_\psi(pA) = \sigma_\psi(pp) \times A^\alpha$

Voir François



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 centrality dependence
  - Absorption + (anti)shadowing

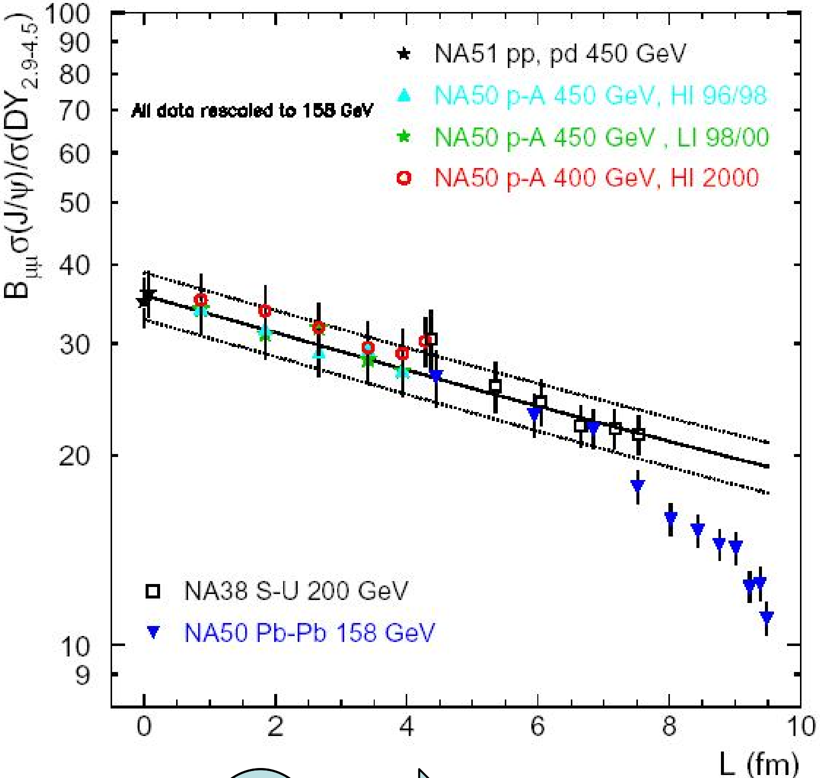
Cold nuclear matter @ SPS

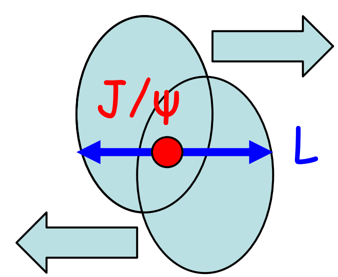
- Normal nuclear absorption does a splendid job in describing pA, SU, peripheral Pb-Pb…
  (S-U suppression was normal)
- $\exp(-\sigma_{abs}\, \rho^{o}\, L)$ with

L nuclear thickness &

σ_{abs} = 4,18 ± 0,35 mb

NA50, EPJ C39 (2005) 335

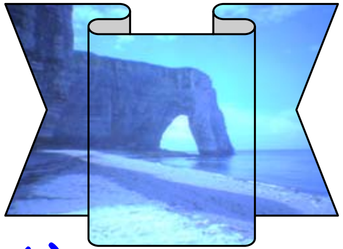




Voir Paul

From pA to AA…

Cold nuclear matter extrapolations always rely on some models and pA data with various balance between the two…



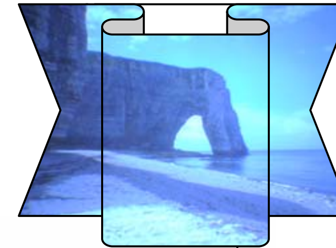
@LHC, will depend strongly on models ?

- Different energies & kinematics (p≠A ≠ AA)…

@SPS, plug measured nuclear absorption either as exp(-ρ σ L) or in Glauber model

- Is there room for (anti)shadowing ?
- Is the pA absorption applicable to AA ?
  (400 vs 158 GeV)

Not taken care of, but again, absorption does a splendid job from pp to peripheral Pb-Pb



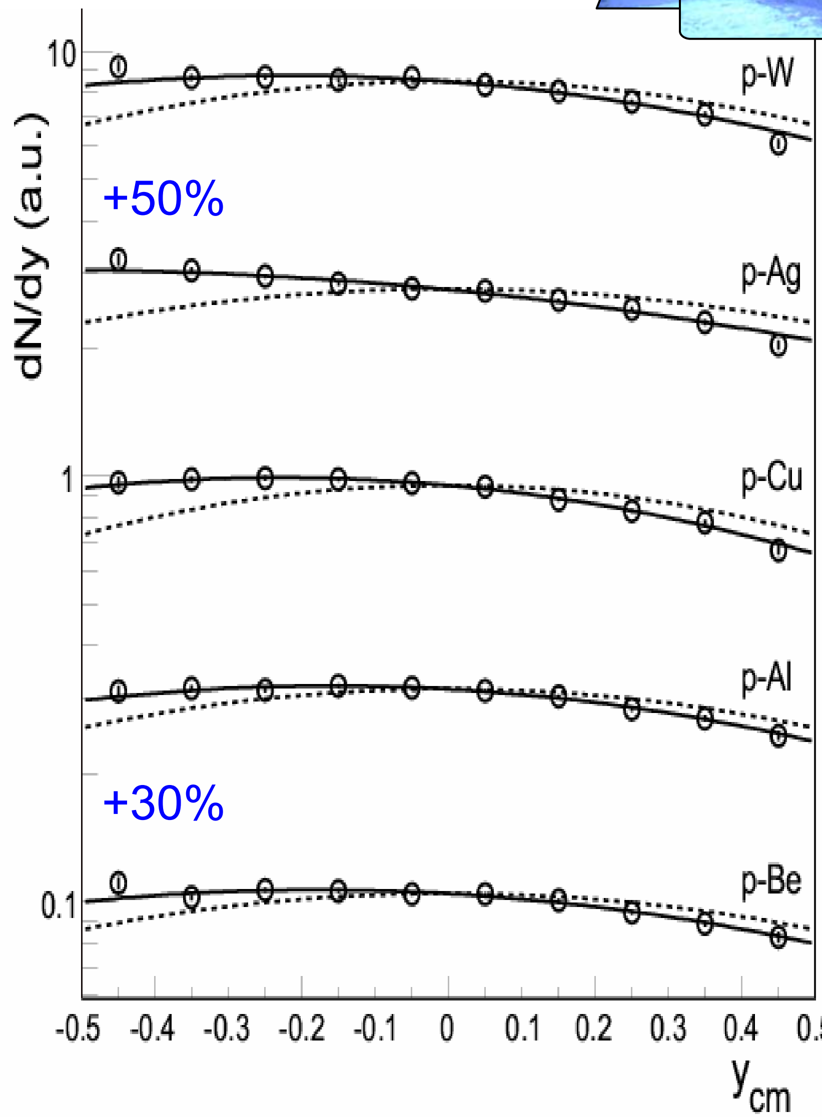
(Anti)shadowing @ SPS ?

Carlos Lourenco, Hard Probes 2006

- NA50 pA (to appear in EPJ)
- Rapidity distribution asymmetry
  - From ~30 to ~50 %

" Why is there a significant change from pp to p-Be but not from p-Be to p-W ? "

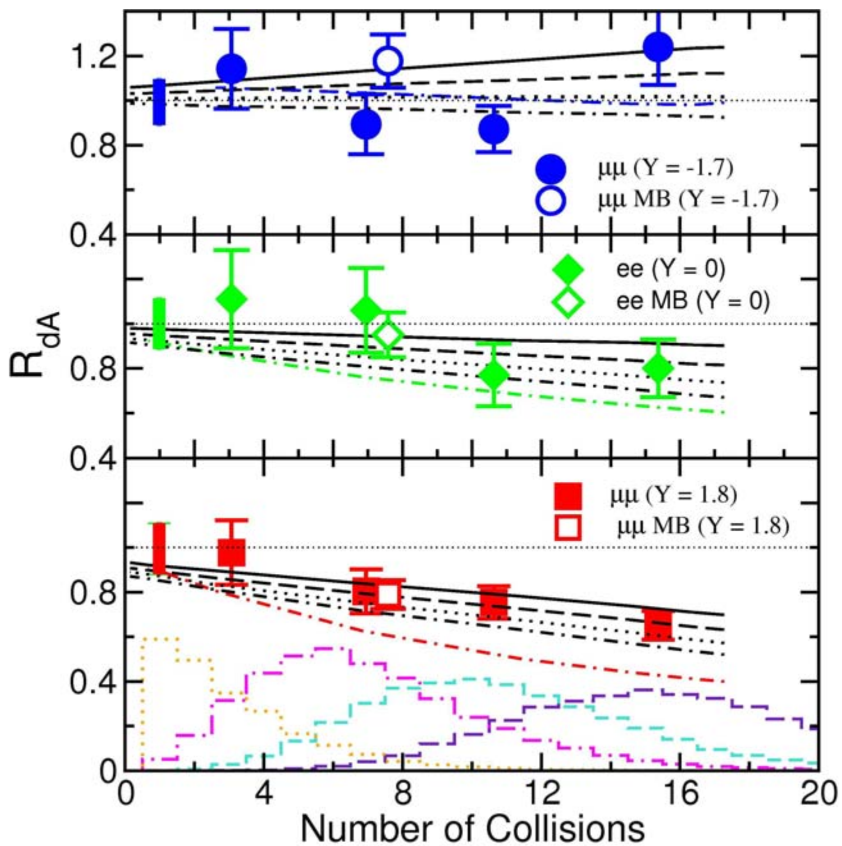
- Not that true !
  - At least by the eye…
- Because of shadowing ?
  - Which should first depend on density, shouldn't it ?



R_{dAu} vs N_{coll} @ RHIC

R_{dA}

High x_2 ~ 0.09



Low x_2 ~ 0.003

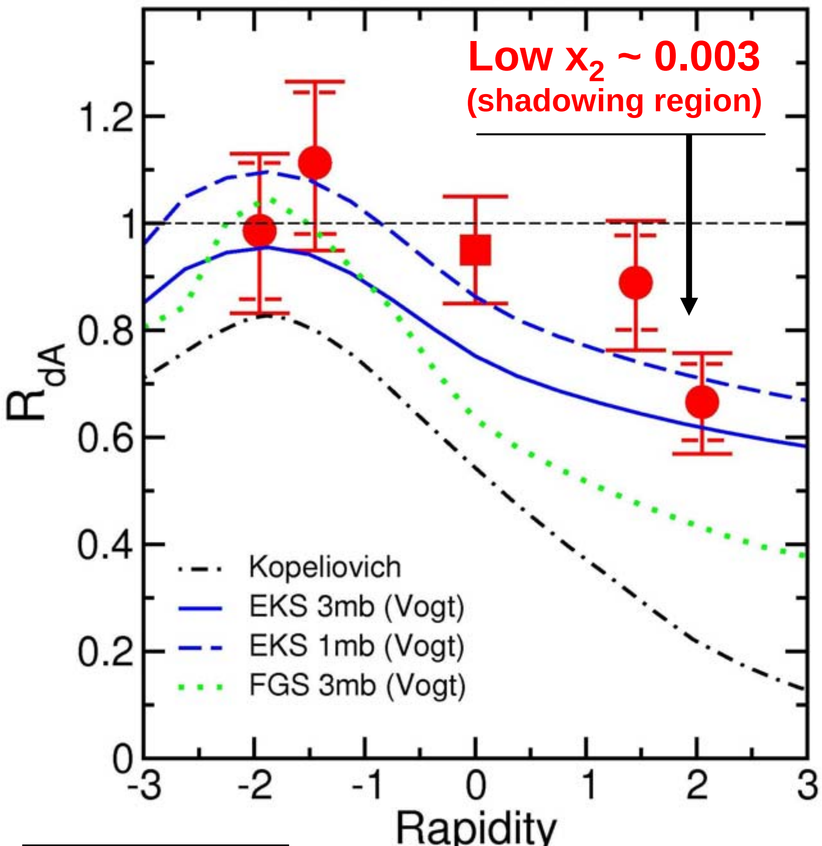
First centrality dependence in dA (or pA) measurement

- Colored lines:
  - FGS shadowing for 3 mb
- Black lines:
  - EKS98 shadowing

  + σ_{abs} = 0 to 3 mb
- Together with rapidity shape, this favours EKS98 + moderate absorption…

R_{dAu} vs rapidity @ RHIC

R_{dA}



Voir Andry

- Data favours
  - (weak) shadowing
    Eskola, Kolhinen, Salgado prescription matches better
  - (weak) absorption
    σ_{abs} ~ 1 to 3 mb !
    (4.18 ± 0.35 mb @SPS)
- But with limited statistics difficult to disentangle nuclear effects !

PHENIX, PRL96 (2006) 012304
Klein,Vogt, PRL91 (2003) 142301
Kopeliovich, NPA696 (2001) 669

From dA to AA @ RHIC

What is on the market ?

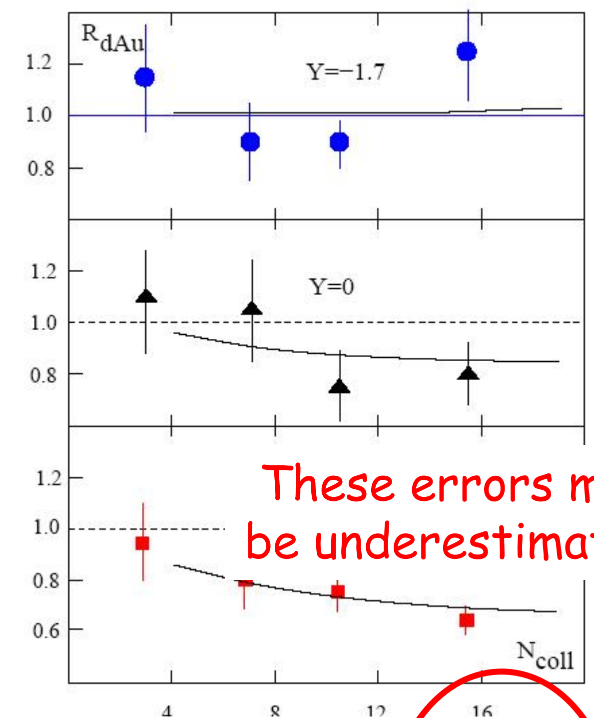
First, the dA data are poor…

1. A model of nuclear absorption + (anti)shadowing

   (Ramona Vogt, nucl-th/0507027)

2. $\exp -(\sigma_{diss}(y)+\sigma_{diss}(-y))n_0L$
   - (Karsch, Kharzeev & Satz PLB637(2006)75)
   - σ_{diss} from fits on dA data →
   - But shadowing doesn't go like L…

3. My own toy model
   - (next 3 slides)



These errors must be underestimated

$$\sigma_{\rm diss}(y=1.8) = 3.1 \pm 0.2 \text{ mb}$$

$$\sigma_{\rm diss}(y=0) = 1.2 \pm 0.4 \text{ mb}$$

$$\sigma_{\rm diss}(y=-1.7) = -0.1 \pm 0.2 \text{ mb}$$

KKS, PLB637(2006)75

My own toy model (1/3)

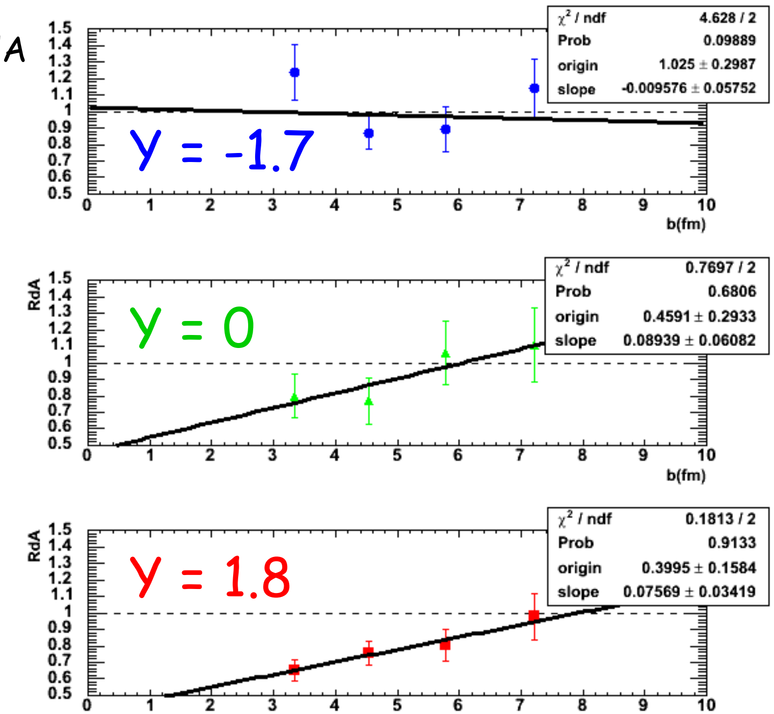
- Data driven, as much as possible…
- Phenomenological fit to RdA(b) →
- Plug this in AuAu Glauber:

$R_{AA}(y, b_{AA}) = \Sigma_{collisions}$

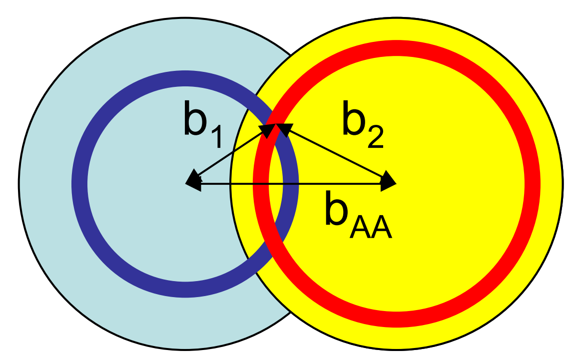
$[\ R_{dA}(-y, b_1) \times R_{dA}\ (y, b_2)\ ]$

- Works for absorption & shadowing since: production ~ pdf1 x pdf2 x exp $-n\sigma(L_1+L_2)$

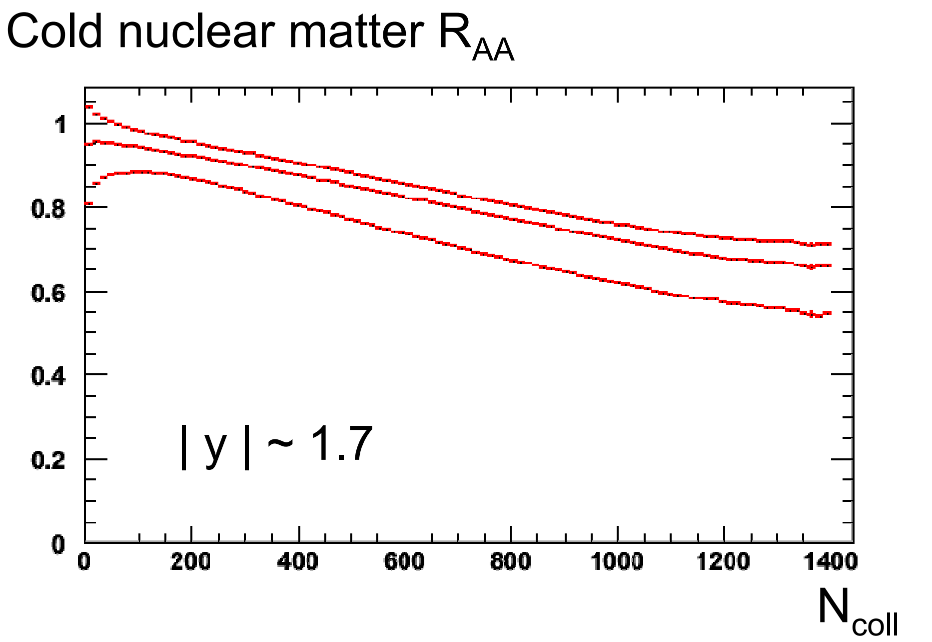
R_{dA}

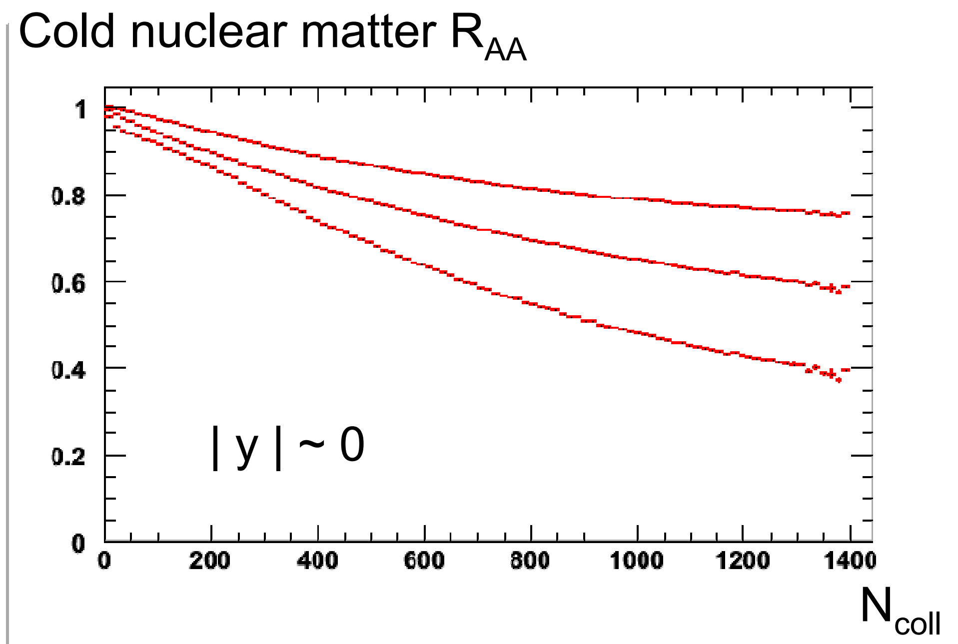


b(fm)



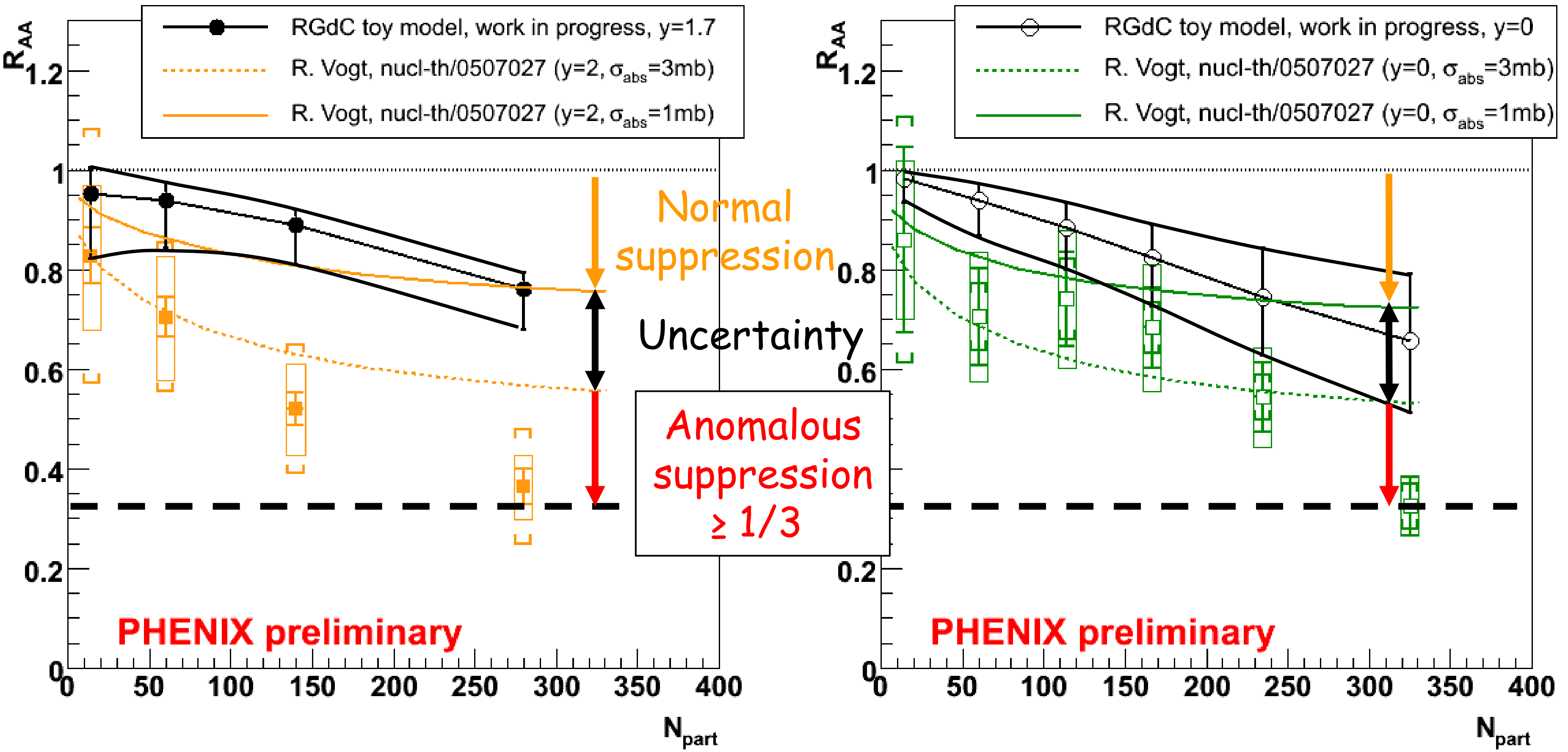
My own toy model (2/3)





- Bands are statistical and systematic errors from dAu
- No systematic from the method itself (work in progress)
- Average on AuAu centrality classes to compare to data…

My own toy model (3/3)



Comparison to AuAu data and Ramona's model…

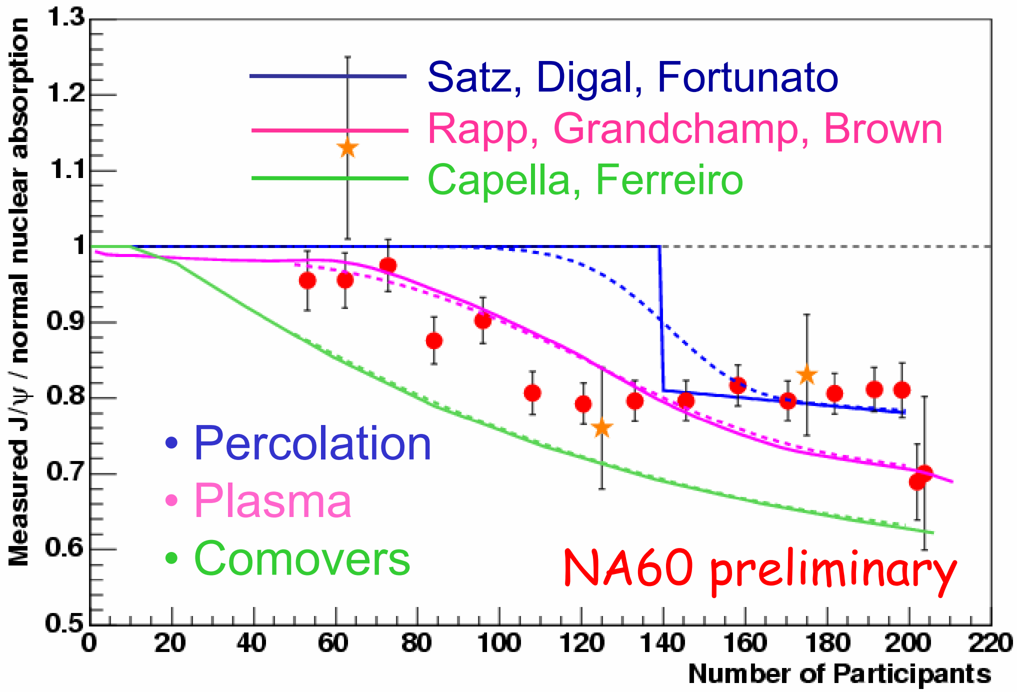
Ensuite… C'est quoi cette foutue suppression ?

What's going on @SPS ?

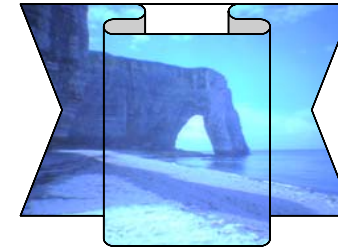
- Several models could fit NA50
  - Plasma (either thermal or percolative)
  - Comovers (hadronic or partonic ?)
- Now NA60…
  - Difficult to reproduce…

Roberta Arnaldi, QM05

Voir Paul et Philippe

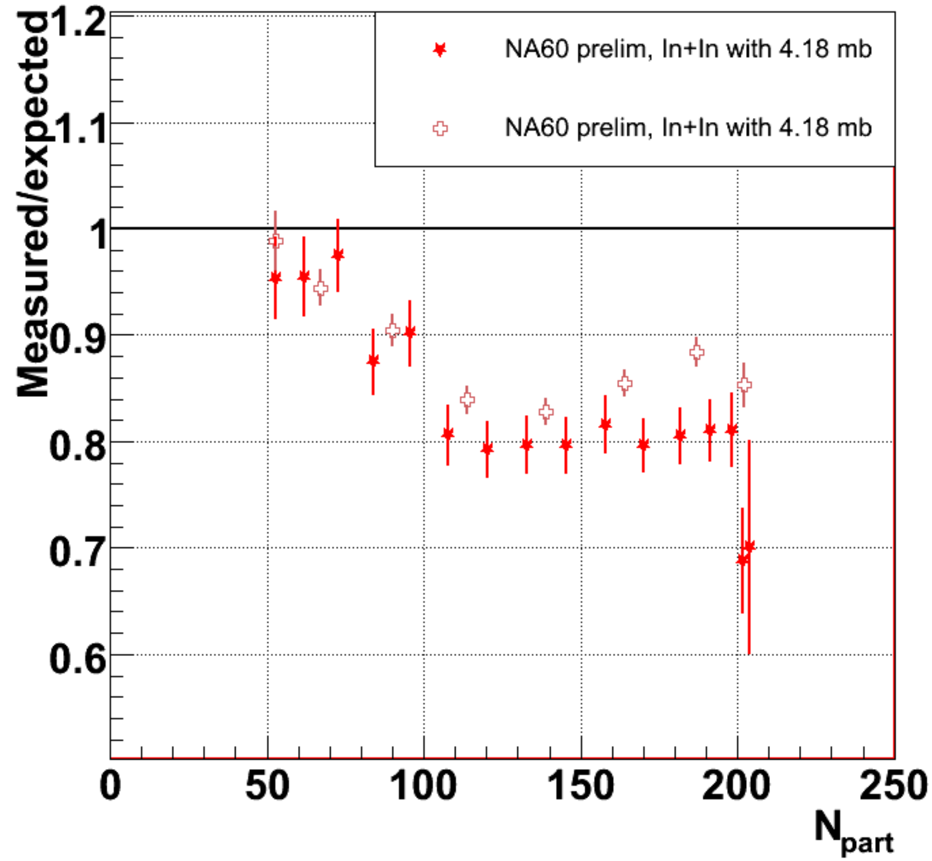


NA60 internal comparison…



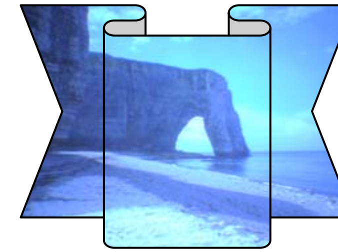
- Very same data !
  - What is the independent systematic uncertainty ?
  - Maybe Jψ / DY ~ 6% ?
- Sequential melting ?
  - Only <20% suppression ?
  - Total global systematic is ~ 11%

    (8% $\sigma^{J/\psi}_{pp}$ 6% DY 4% σ_{abs})
  - J/ψ ~ 0.6 J/ψ + 0.3 χ_c + 0.1 ψ′ ?

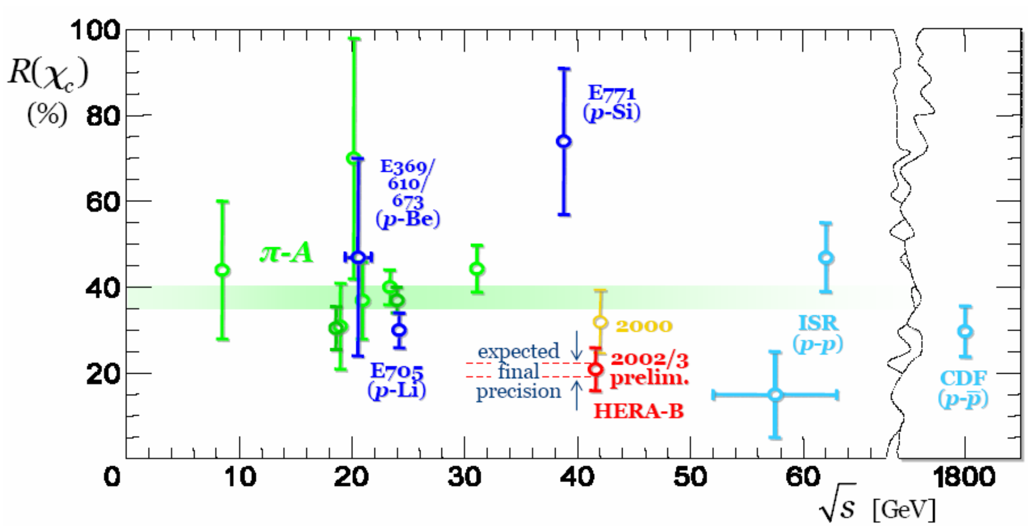


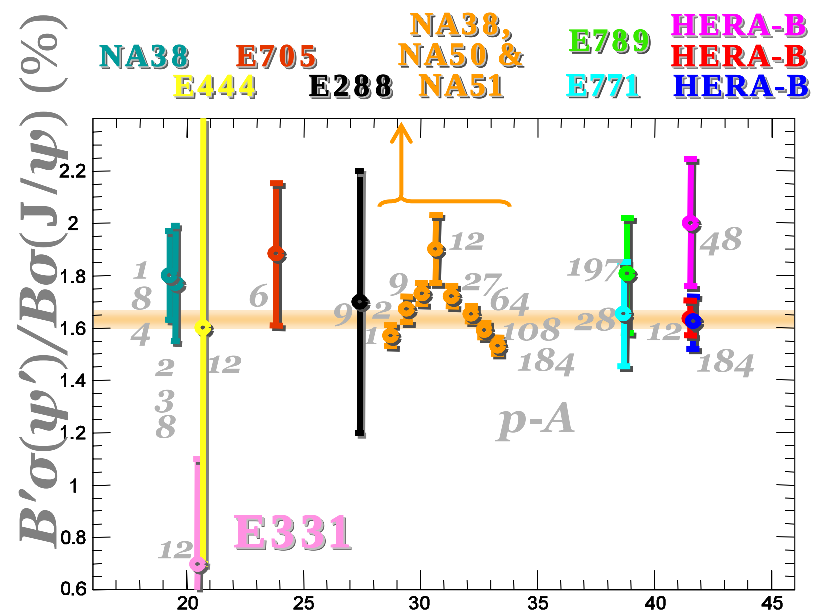
Roberta Arnaldi, HP06

Feed down ratio's ?



- From HERA-B (pA $\sqrt{s}$=41.6 GeV)
  - 7.0 ± 0.4 % from ψ'
  - 21 ± 5 % from χ_c
  - 0.065 ± 0.011 % from B



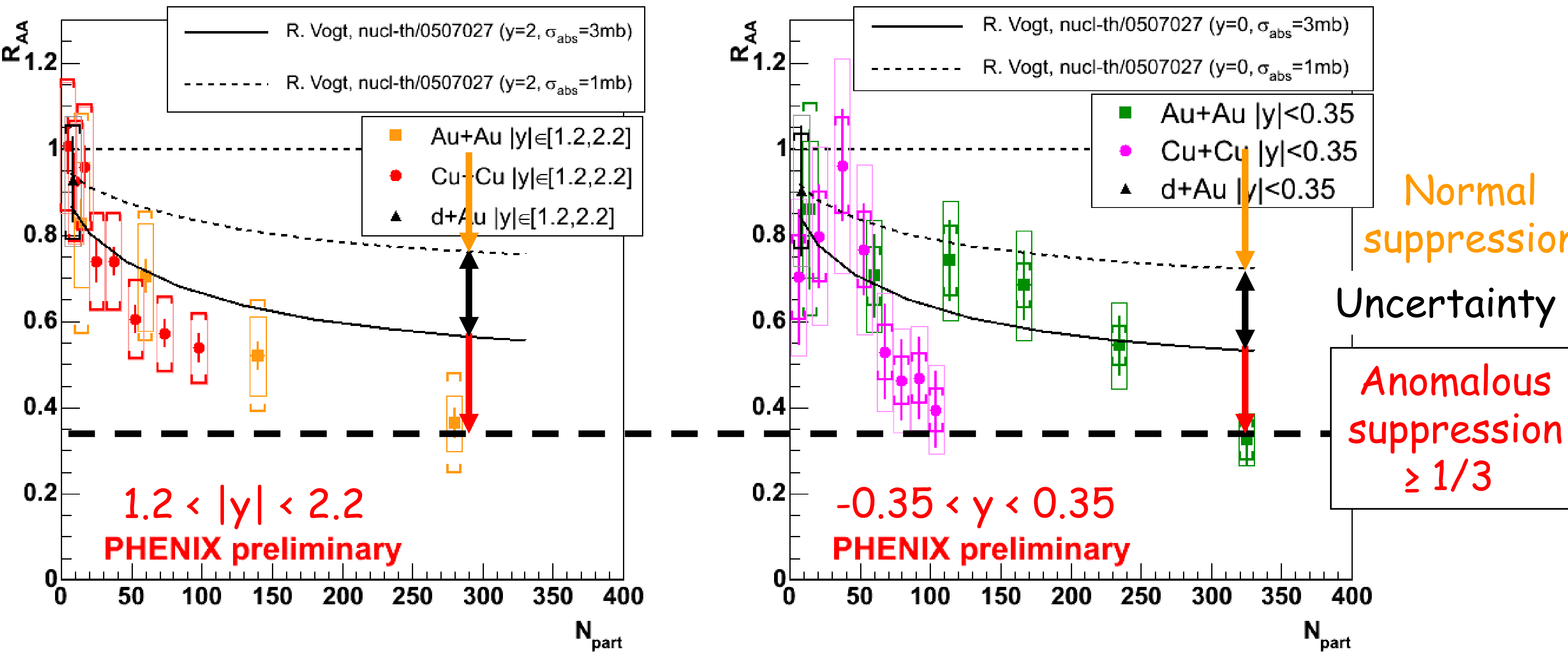


Faccioli, Hard Probes 2006

What's going on @ RHIC ?

voir Andry, Catherine, Ermias

- Shadowing + nuclear absorption (crucial !)



Error bar code : bars = statistical, bracket = systematic, box : global.

PHENIX, QM05, nucl-ex/0510051
Vogt, nucl-th/0507027

"NA50 only" effects

- Cold effects + …

—— Comovers (hadrons or partons?)

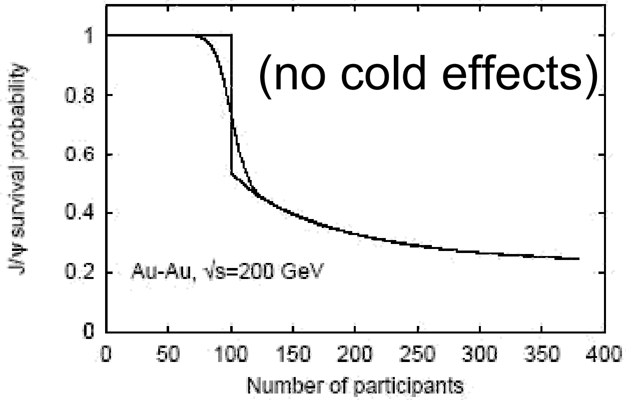
- - - - - Kinetic model ($J/\psi \rightarrow c\,\bar{c}$)

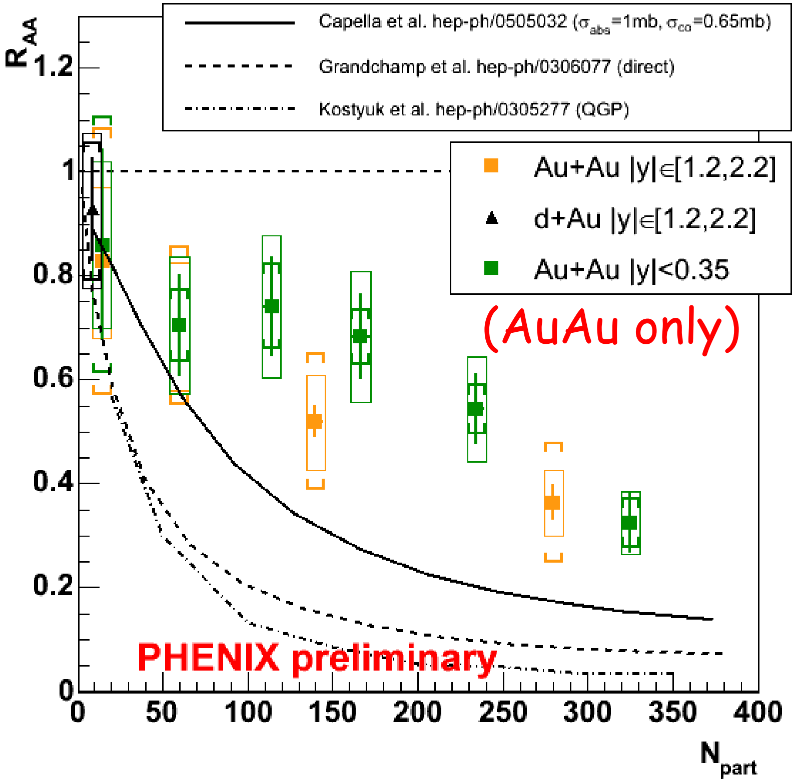
-·-·-·- Thermal plasma

All overestimate suppression !

So does parton percolation

- Onset at $N_{part} \sim 90$
- Simultaneous $J/\psi + \chi_c + \psi'$





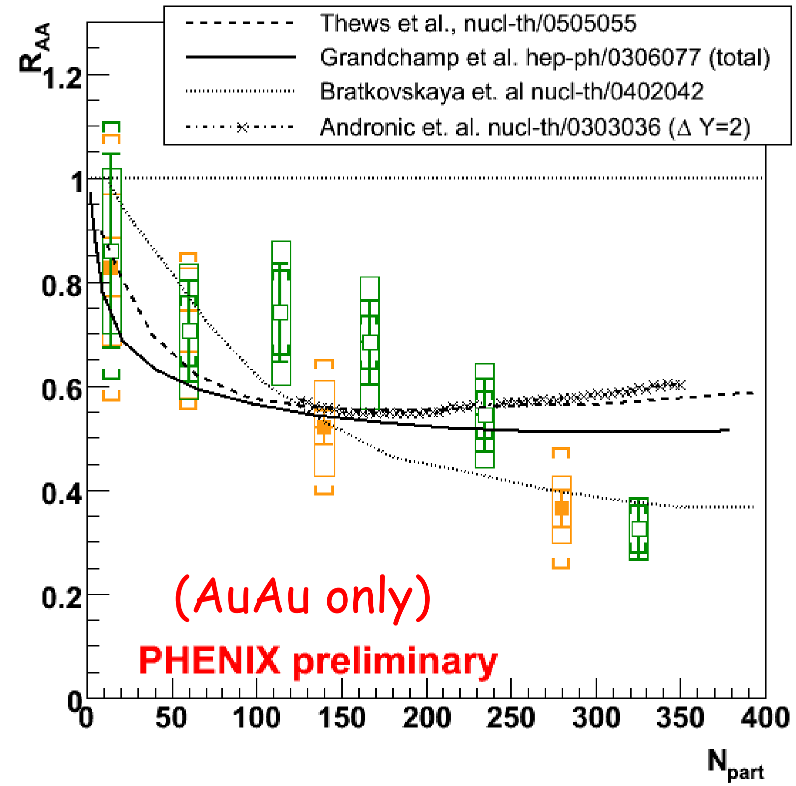
Capella, Ferreiro, EPJC42 (2005) 419
Grandchamp et al, PRL92 (2004) 212301
Kotstyuk et al, PRC68 (2003) 041902
← Digal, Fortuno, Satz, EPJC32 (2004) 547
+ Private communications +

1st. Recombination ?

A variety of recombination & coalescence models can accommodate the suppression…

" But early results suggest some competing mechanism, such as reformation of J/ψ particles, may occur at these densities. " Riordan & Zajc, Scientific American (et Pour la Science)

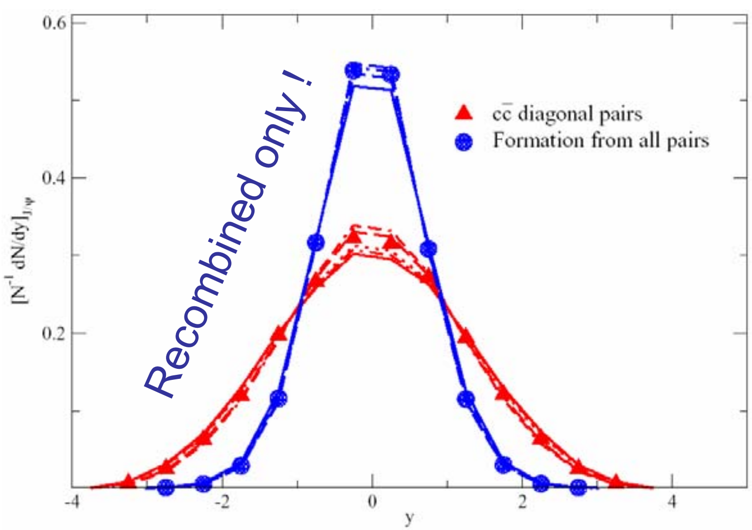
To know more, look at y, p_T…

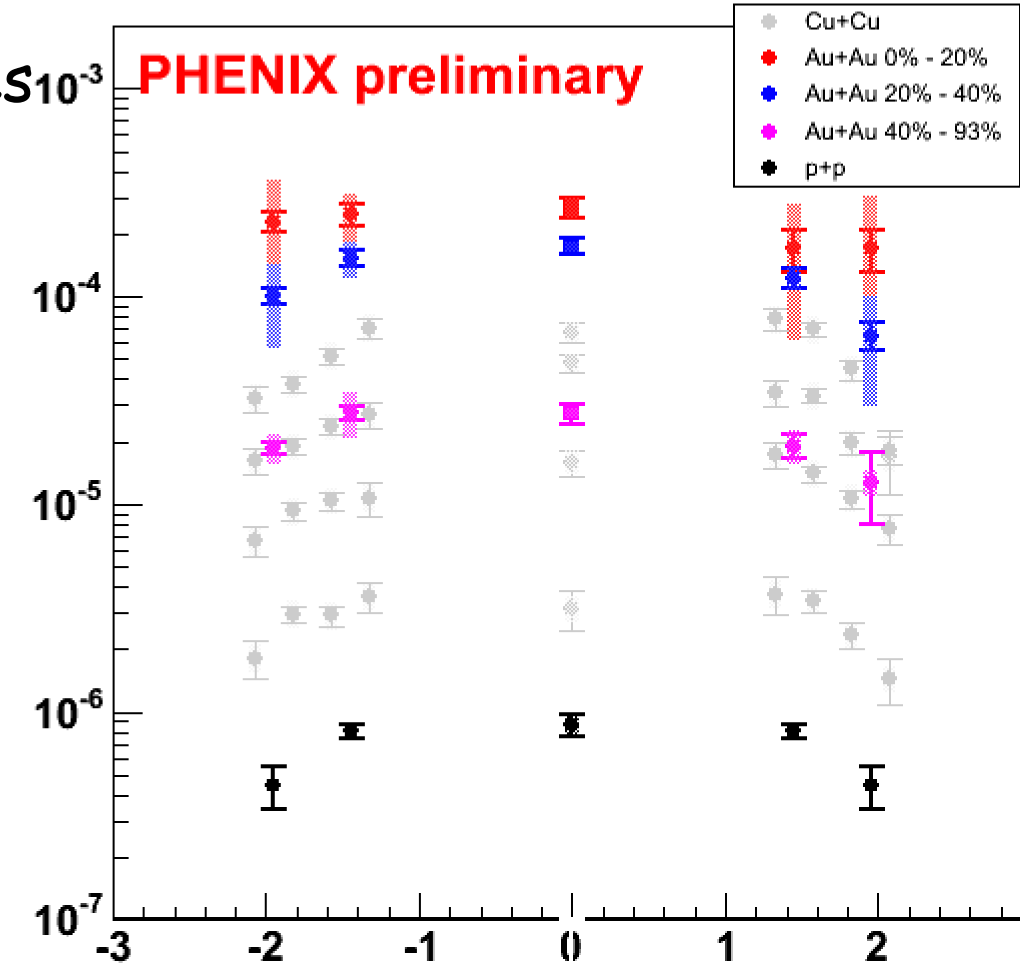


Grandchamp et al, PRL92 (2004) 212301
Bratkoskaya et al, PRC69 (2004) 054903
Andronic et al, PLB571 (2003) 36
Thews & Mangano, PRC73 (2006) 014904c
+ Private communications +

y shape (vs recombination)

- Recombination emphasizes quark y-distribution
- Quark (open charm) y-distribution unknown
- No significant change in rapidity in data…



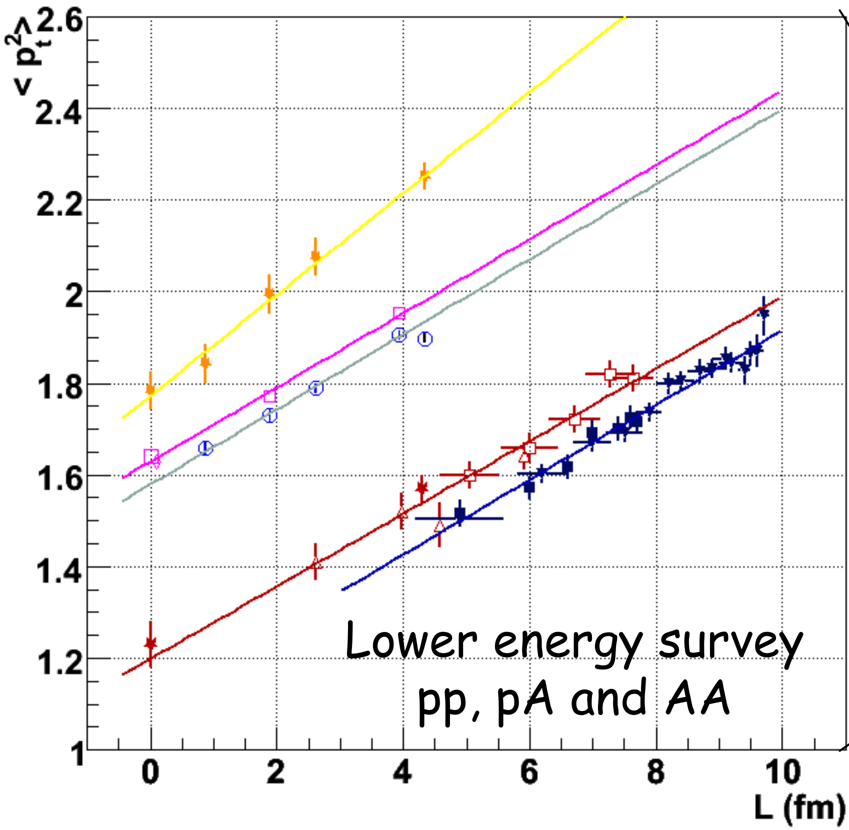


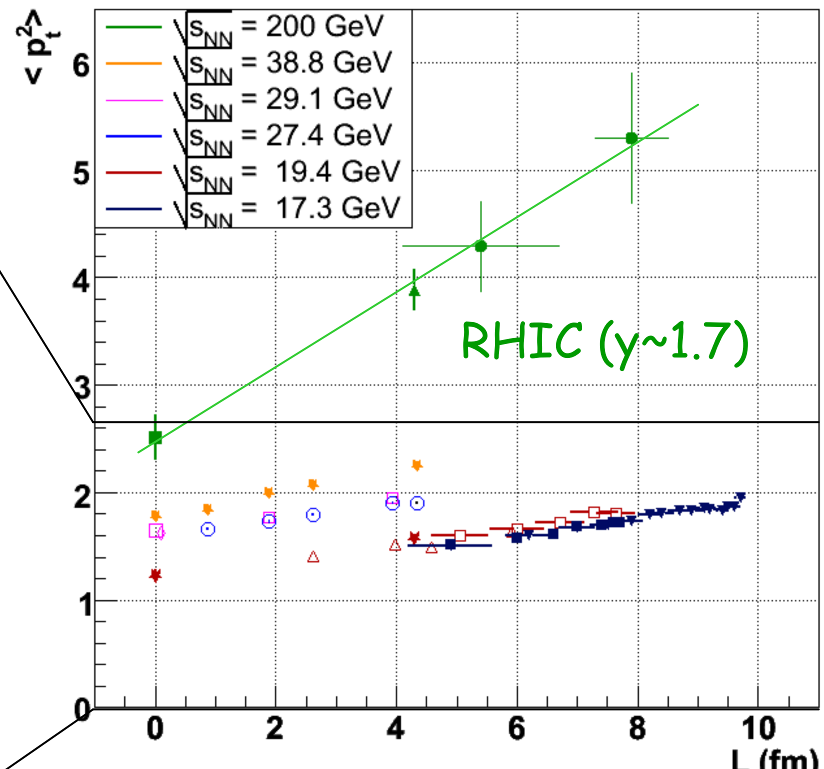
← Thews & Mangano, PRC73 (2006) 014904c

$\langle p_T^2 \rangle$ (vs Cronin effect)

$$\langle p_T^2 \rangle_{AA} = \langle p_T^2 \rangle_{pp} + \rho\, \sigma\, \Delta p_T^2 \times L \text{ [nuclear matter thickness]}$$

(random walk of initial gluons)





VN Tram, Moriond 2006 & PhD thesis

Cronin versus recombination

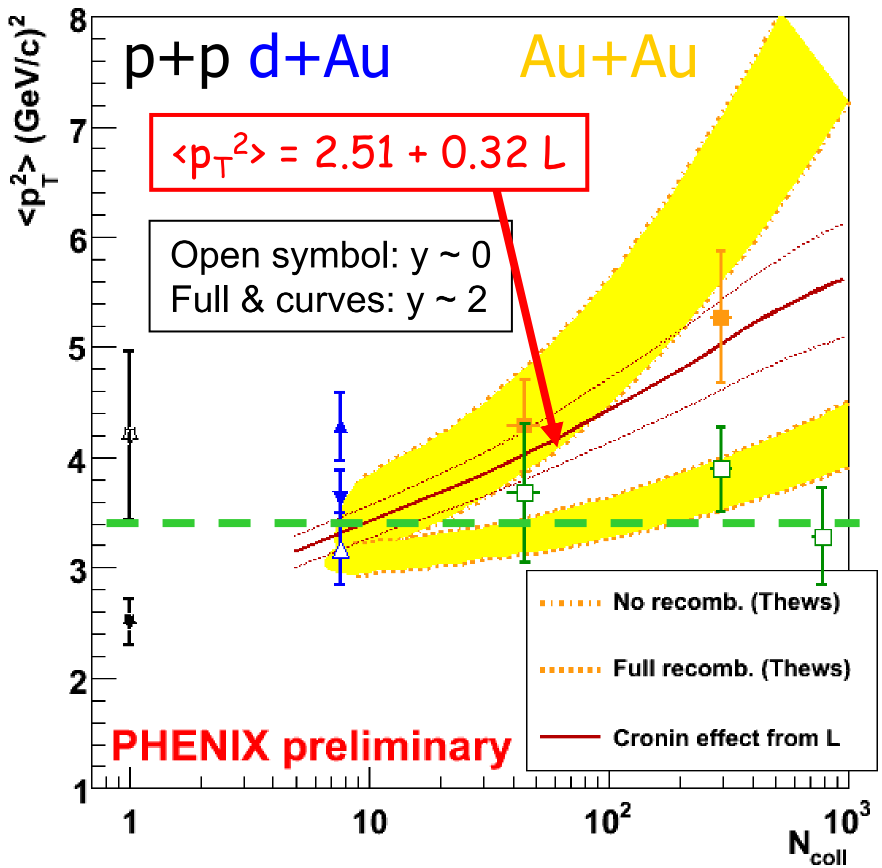
1. At forward rapidity (closed symbols)
   - from pp & dA:

   $\langle p_T^2 \rangle = 2.51 + 0.32\ L$

   (L <-> N_{coll} conversion)

   No sign of recombination !

2. At mid rapidity (open symbols)
   - Negligible Cronin !?...
   - Need better pp !



VN Tram, Moriond 2006 & PhD thesis
Thews & Mangano, PRC73 (2006) 014904c

2nd. Hydro + J/ψ transport

One detailed QGP hydro + J/ψ transport (Zhu et al)

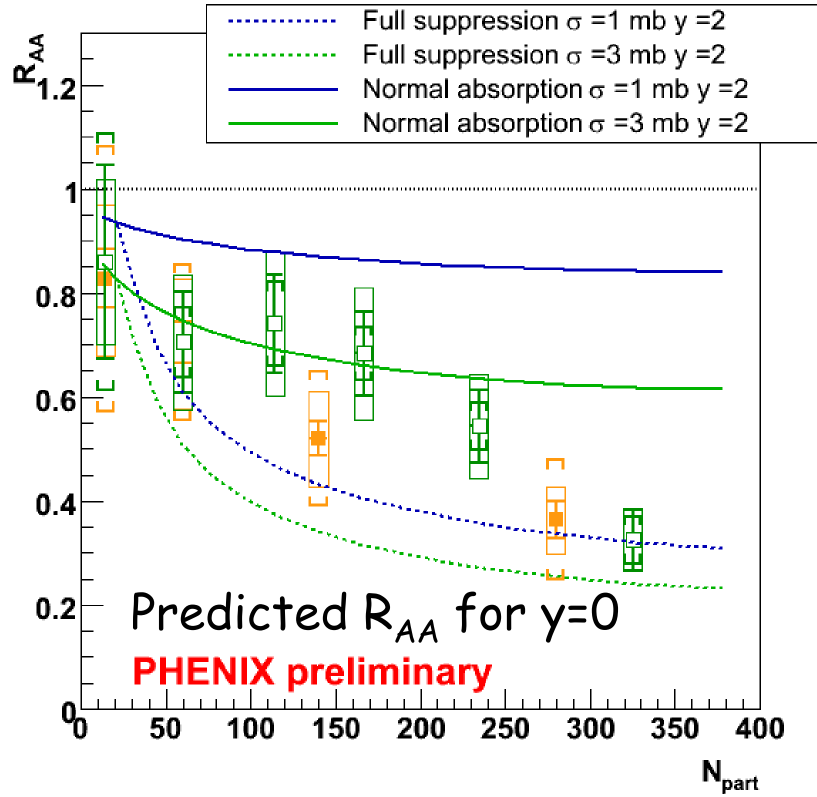
- $g + J/\psi \rightarrow c + \bar{c}$

First published without cold nuclear effects, but here :

+ Nuclear absorption (1 or 3 mb)

+ Cronin effect from dAu

$\langle p_T^2 \rangle$ ok (as on previous slide)

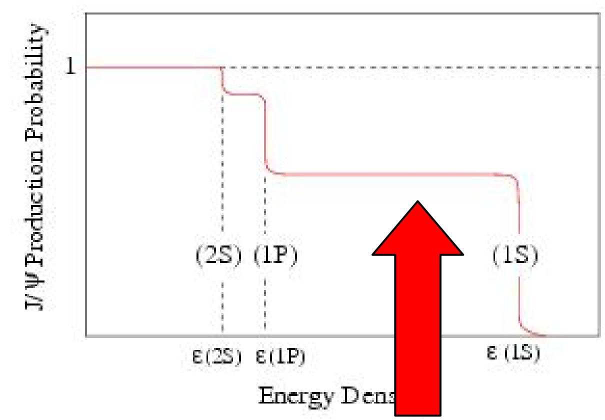


- Model should be valid for y=0
  - But match y=1.7
  - (and central y=0)

Zhu, Zhuang, Xu,
PLB607 (2005) 107
+ private communication

3^{rd} (simple) explanation

- Amount of anomalous suppression depends on cold nuclear effects amplitude
- But could be as low as 30 to 40%
- Compatible to feed-down ratio
  - $J/\psi \sim 0.6\ J/\psi + 0.3\ \chi_c + 0.1\ \psi'$
- Recent lattice $T_d^{\psi} \sim 1.5 - 2.5\ T_c$
  - $\varepsilon \times (T_d^{J/\psi} \sim 2T_c)^4 = 2\ \varepsilon_c \longrightarrow \varepsilon_d^{J/\psi} \sim 32\ \varepsilon_c$!
- Wait for LHC to melt J/ψ ?



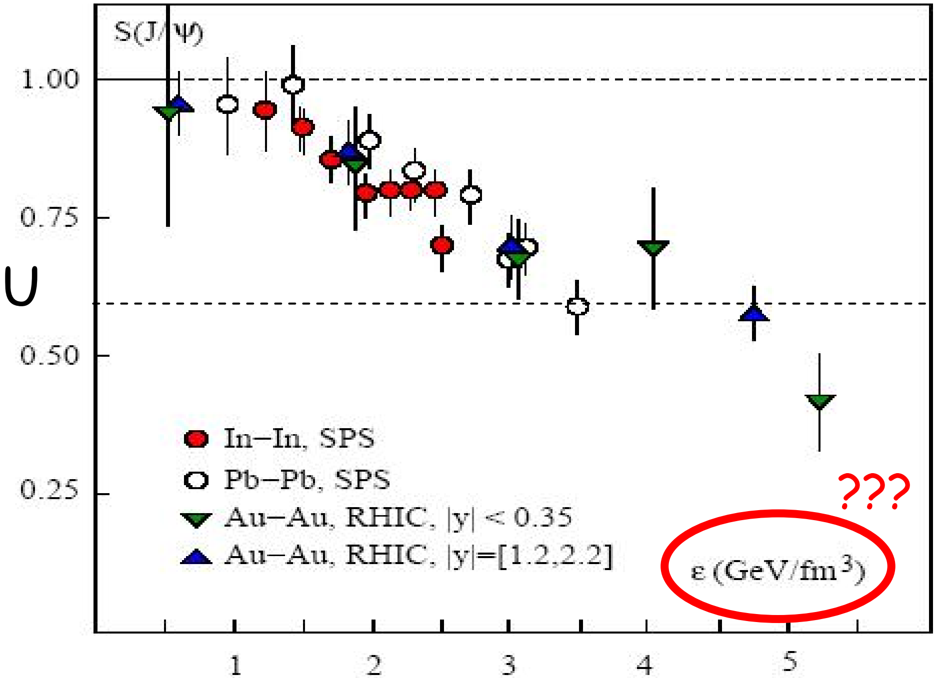
We may still be here

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	>4.0	1.76	1.60	1.19	1.17

Datta & al, hep-lat/0409147
Alberico & al, hep-ph/0507084
Wong, hep-ph/0408020
←Satz, hep-ph/0512217
+ Mocsy, Umeda, Asakawa
@ hard probes 2006

Back to SPS + RHIC

- Sequential melting scenario
  - J/ψ survival only
  - Excited states melting from ψ' suppression pattern @ SPS
  - But J/ψ stay while ψ' leave in S-U
- Be careful when showing this!
  - NA60 and PHENIX are PRELMINARY…
  - No systematic uncertainties on PHENIX (and NA60) points
  - No uncertainties from cold nuclear matter effects !
- However, it does a good job and sequential melting clearly is a possibility !…

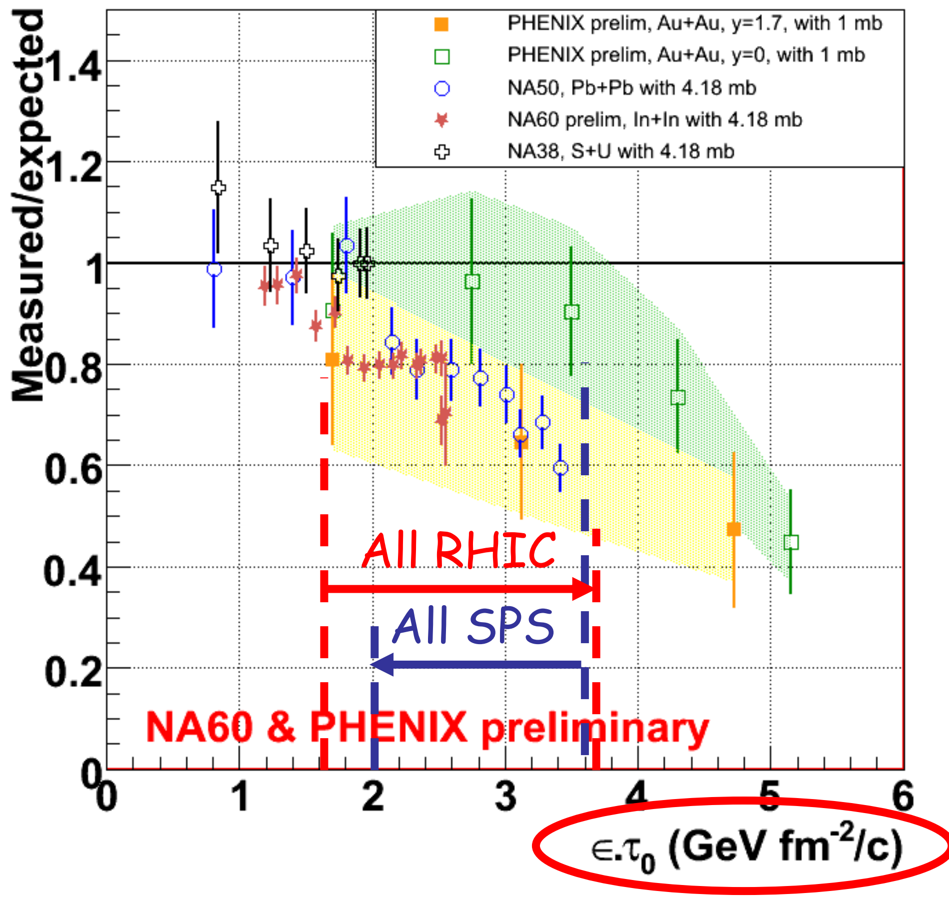


Karsch, Kharzeev & Satz
PLB637(2006)75

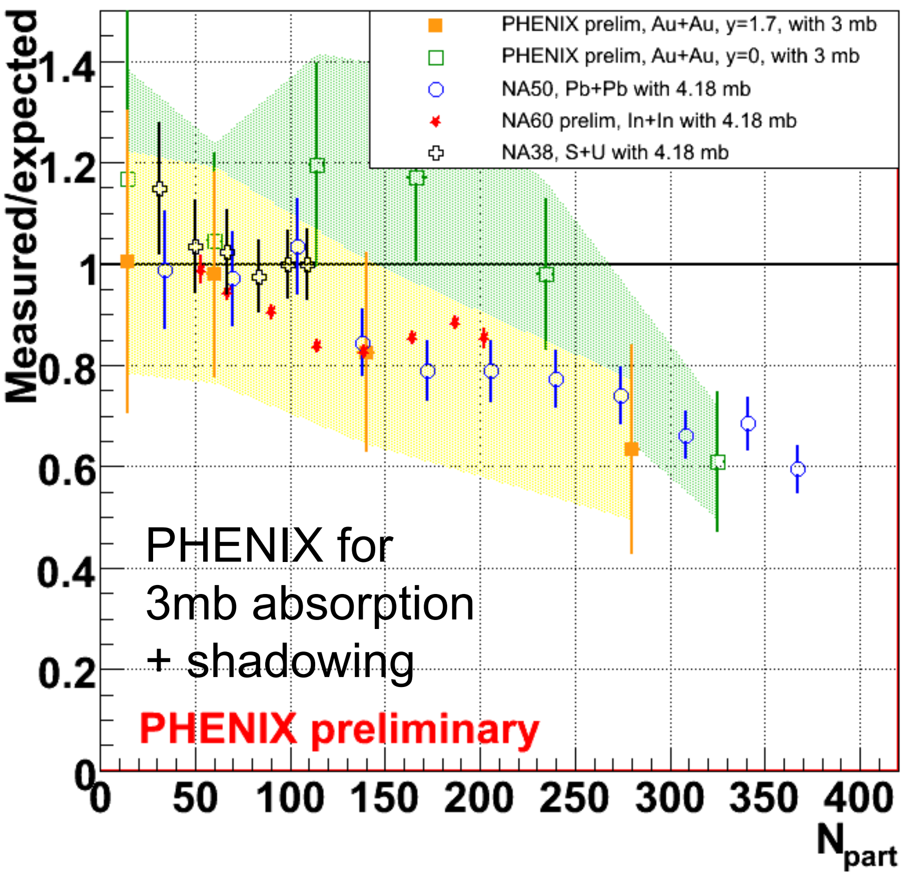
Et maintenant, peut-on se ploter tous ensemble ?

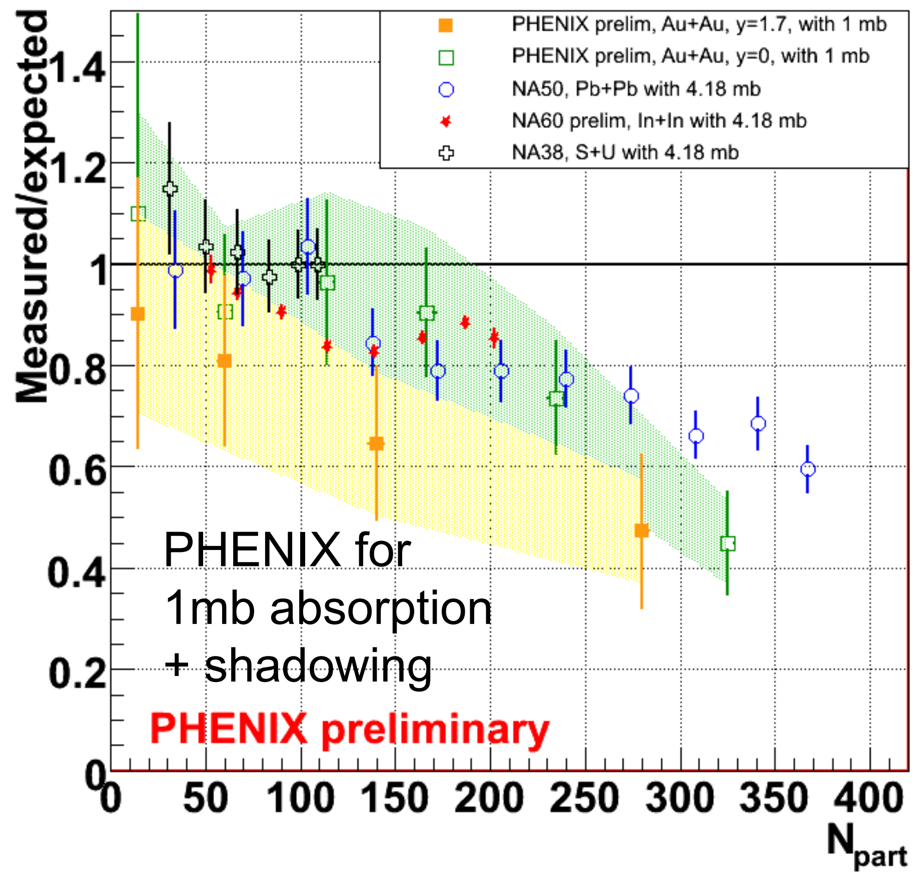
x-axis : energy density ?...

- Should be the right variable...
- But we don't really know how to compare RHIC & SPS!
  - Relevant time should be the J/ψ formation time, SPS = RHIC !
  - But SPS violate the pancake hypothesis (nuclei take 1.6 fm/c to cross each other)
  - τ_0 < 1 fm/c @ RHIC (formation time ~ 0.35 ?)



That's it for today…





(global SPS uncertainty not included)

NA60 new points from Roberta Arnaldi

Anomalous conclusions

For now, no model to "explain" NA60:

- But sequential melting ?

For now, 3 models to "explain" RHIC:

1st Recombination ?

- But no sign of y or p_T^2 modifications…
- $J/\psi \alpha (N_{cc})^2$ (but how much is N_{cc} ?)

2nd J/ψ detailed transport in hydro QGP

3rd Sequential melting ?

- J/ψ may still survive @ RHIC…

(this three models assume a QGP…)

The show must go on…

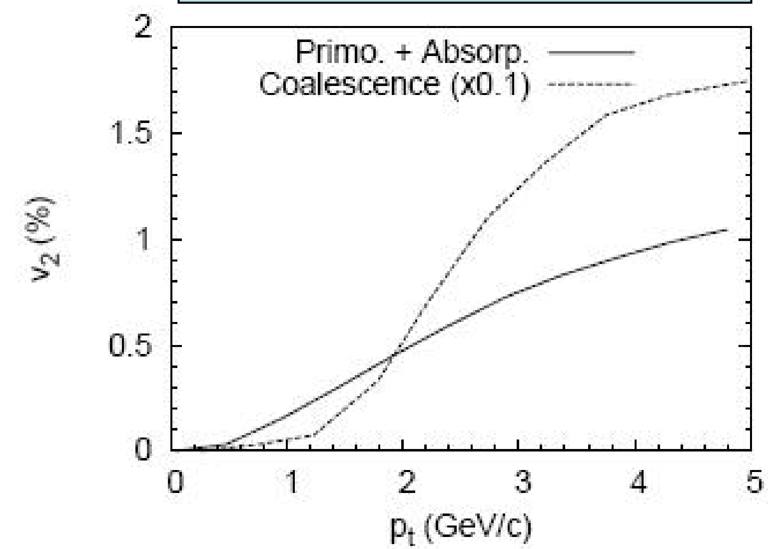
What is coming from SPS ?

- J/ψ flow (Cf. Francesco Prino HP06)
- ψ' from InIn ? X_c from pA ?
- J/ψ pA @ 158 AGeV

What is coming from RHIC ?

- Final AA analysis
  - A bit more data & more bins !
  - With a better pp ref (run 5)
  - With J/ψ elliptic flow ? →
- First look at ψ', χ_c and upsilons
  - Going on with run 5 pp…
- STAR entering the game

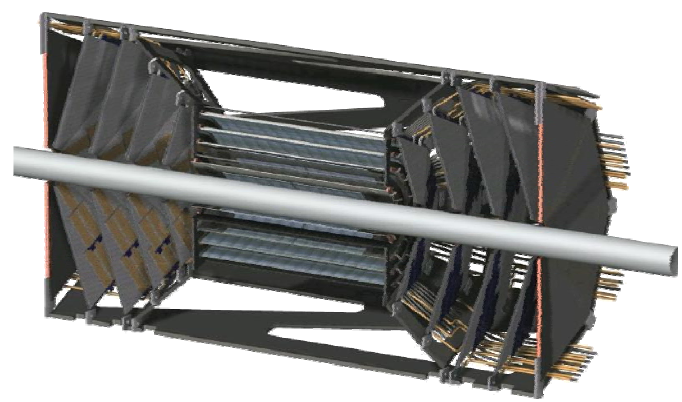
Zhu, Zhuang, Xu, PLB607 (2005) 107



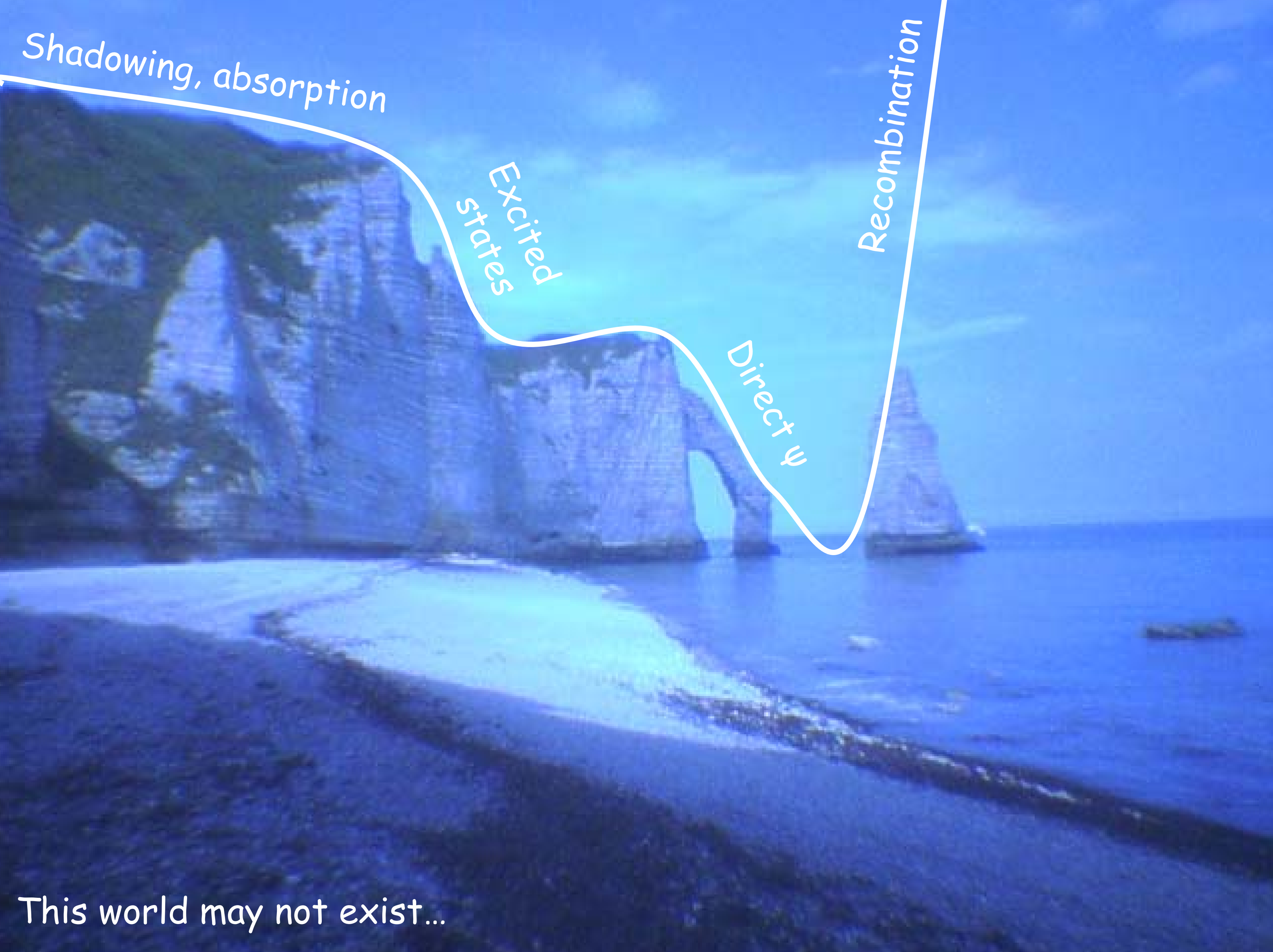
What is needed at RHIC ?

- More dA ! Better handle cold nuclear effects…
- More AA ! With open charm, ψ',…
- Better open charm measurements

(SiVTX upgrades →

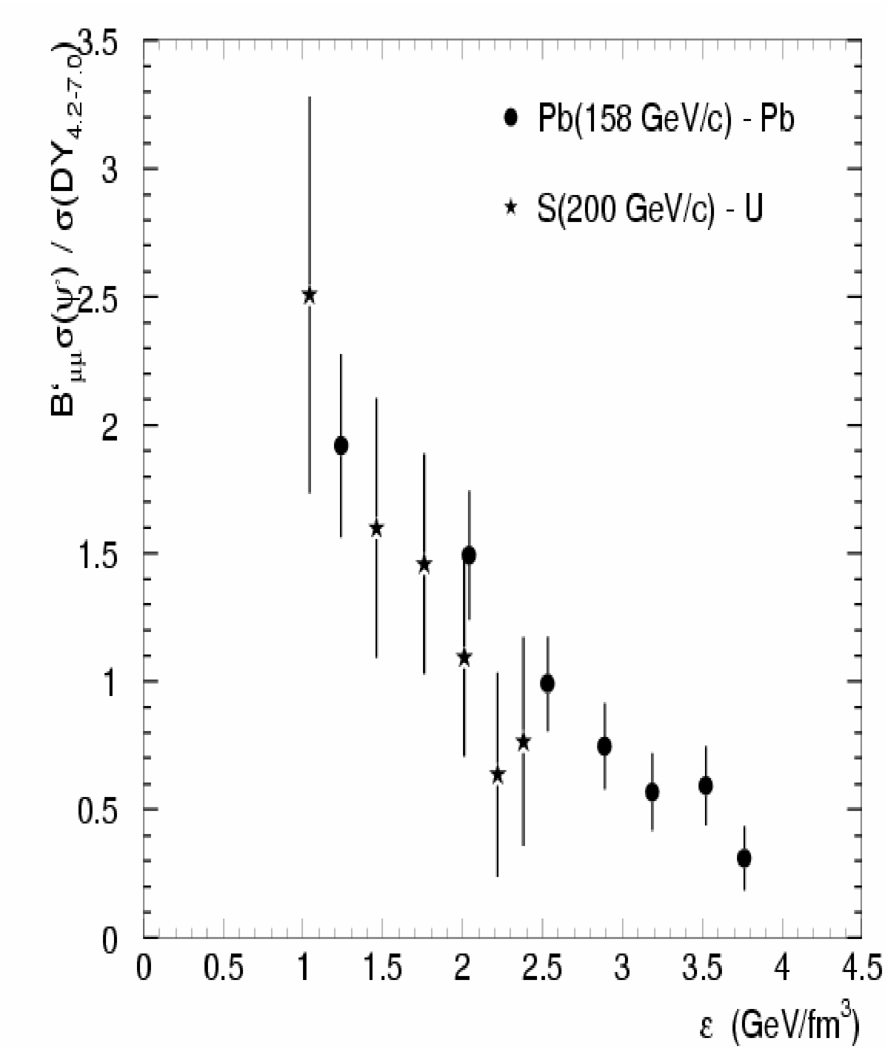


And then, we'll have another story at the LHC !

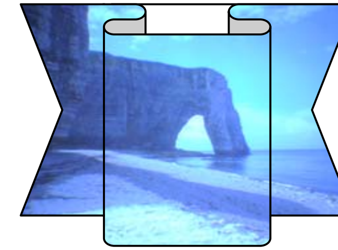

Shadowing, absorption
Excited states
Direct ψ
Recombination
This world may not exist…

Back-up slides

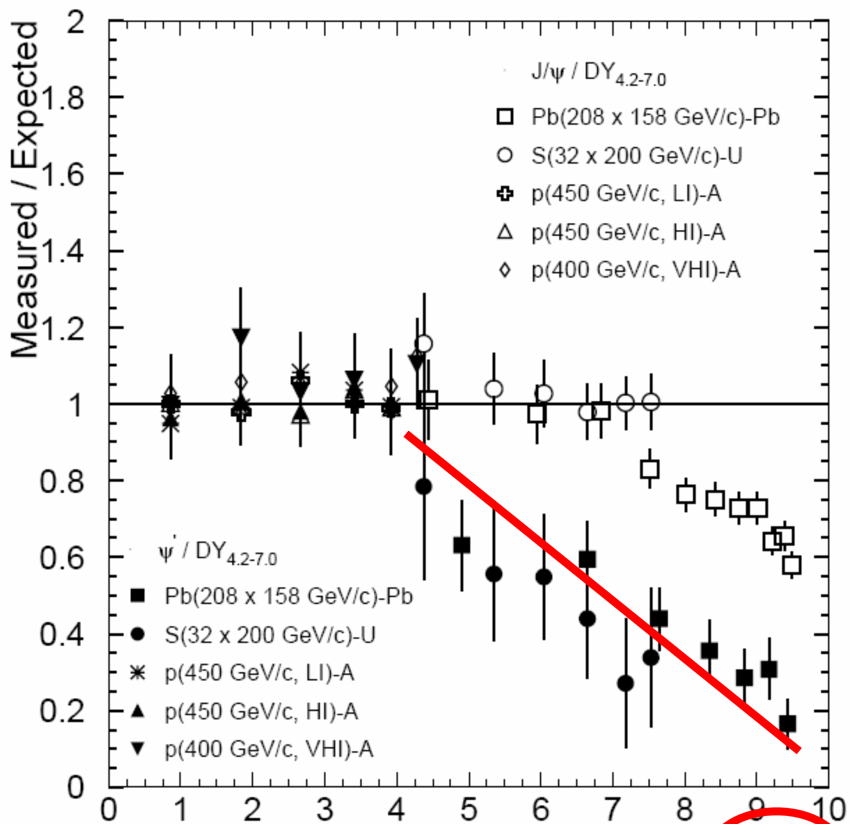
ψ' versus energy density



Louis Kluberg @ Satz fest !



Two words on ψ′



This is not energy density
But it approximately works too
(Louis@Satz anniversary)

To answer Philippe :

ψ': $\varepsilon_d \tau^\circ \sim 0.8$ GeV/fm^2

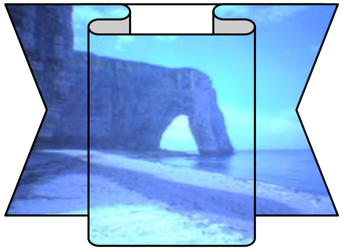
$\psi \sim \chi_c$: $\varepsilon_d \tau^\circ \sim 2$ GeV/fm^2

$T(\chi_c)/T(\psi') = 1.25$!

To answer Louis (KKS) :

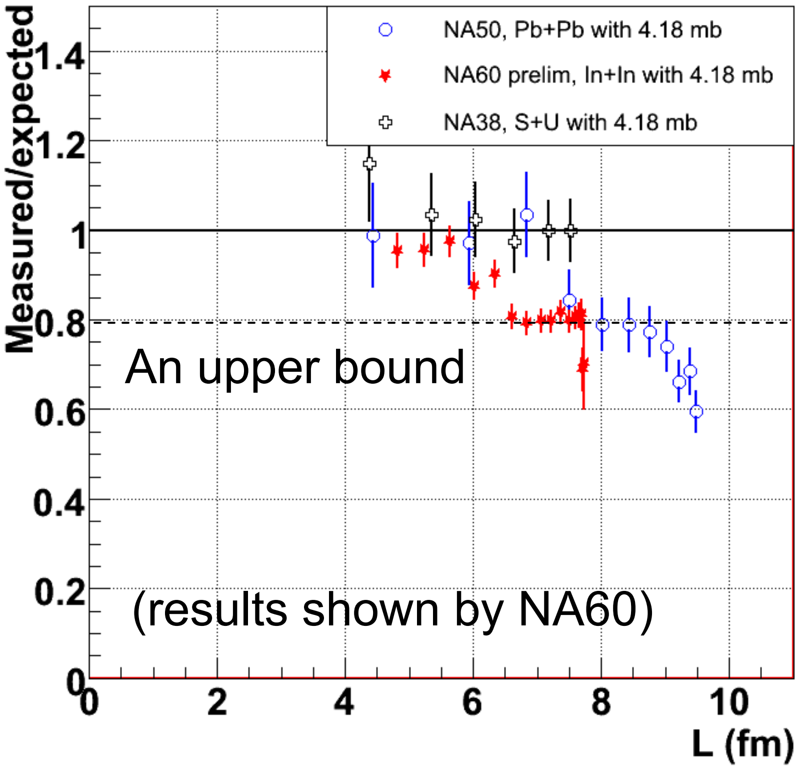
" So far we have considered only symmetric (A–A) collisions. We find, however, that the ψ′ production measured in S–U interactions at the SPS [28] also agrees quite well with the pattern shown […] "

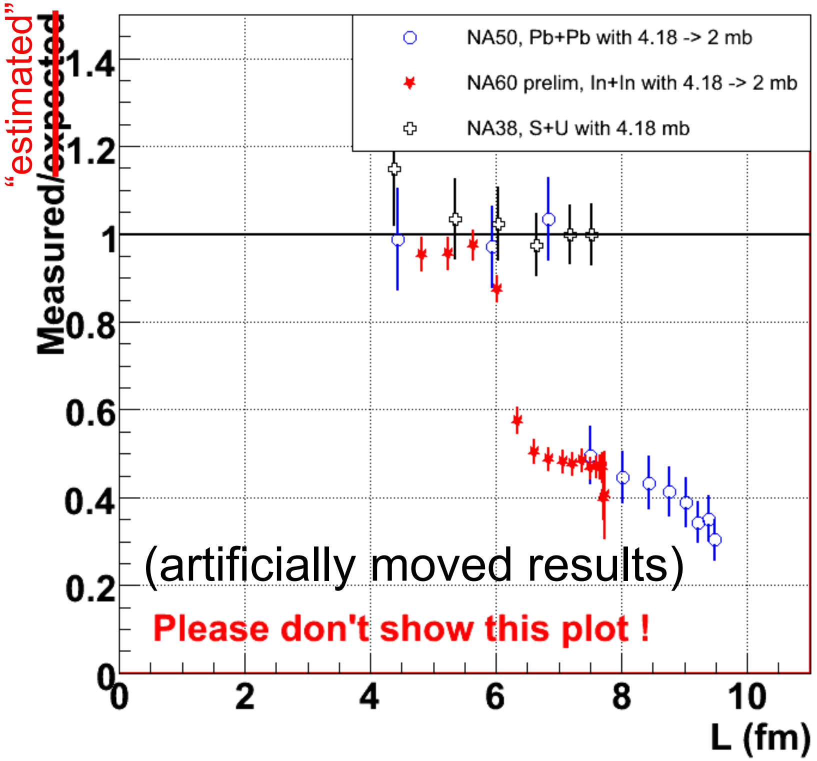
b) Nuclear absorption @ SPS



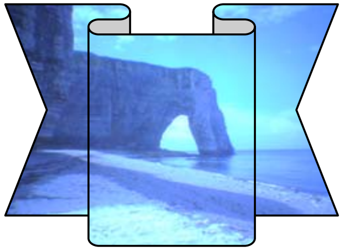
Expected = 4.18 mb absorption
(works from pp to PbPb periph)
while $\psi_{vus} \sim 0.6\ \Psi + 0.3\ \chi_c + 0.1\ \psi'$
and $\sigma_{abs}\ (\psi') = 7.9 \pm 0.6$ mb

Here, I imagine an extreme scenario: instantaneous melting
L=7.0 fm in PbPb L=6.2 fm in InIn
$\sigma_{abs}(\chi_c) \sim \sigma_{abs}(\psi') \rightarrow \sigma_{abs}(\psi) \sim 2$ mb



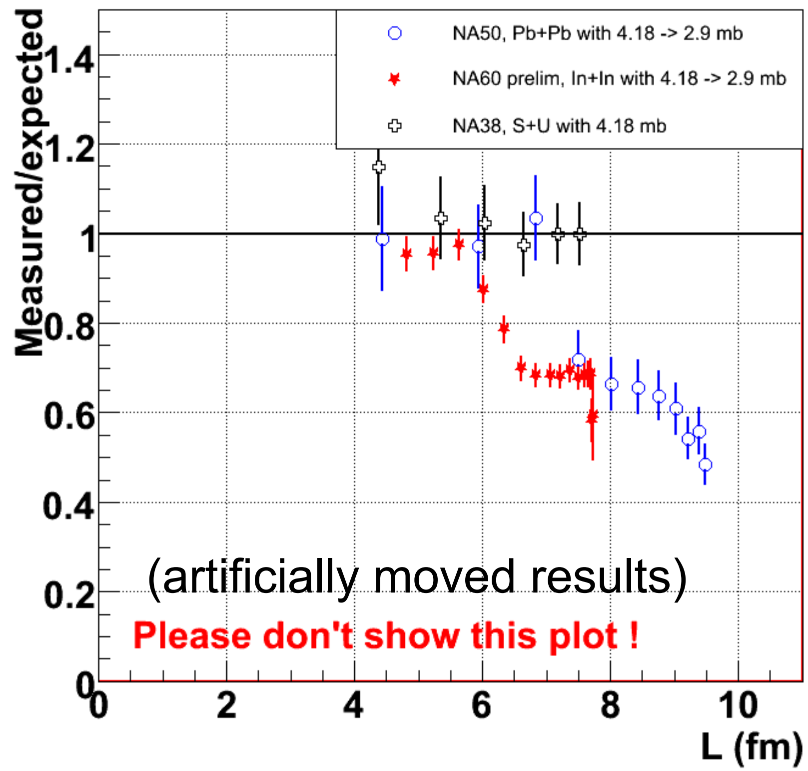


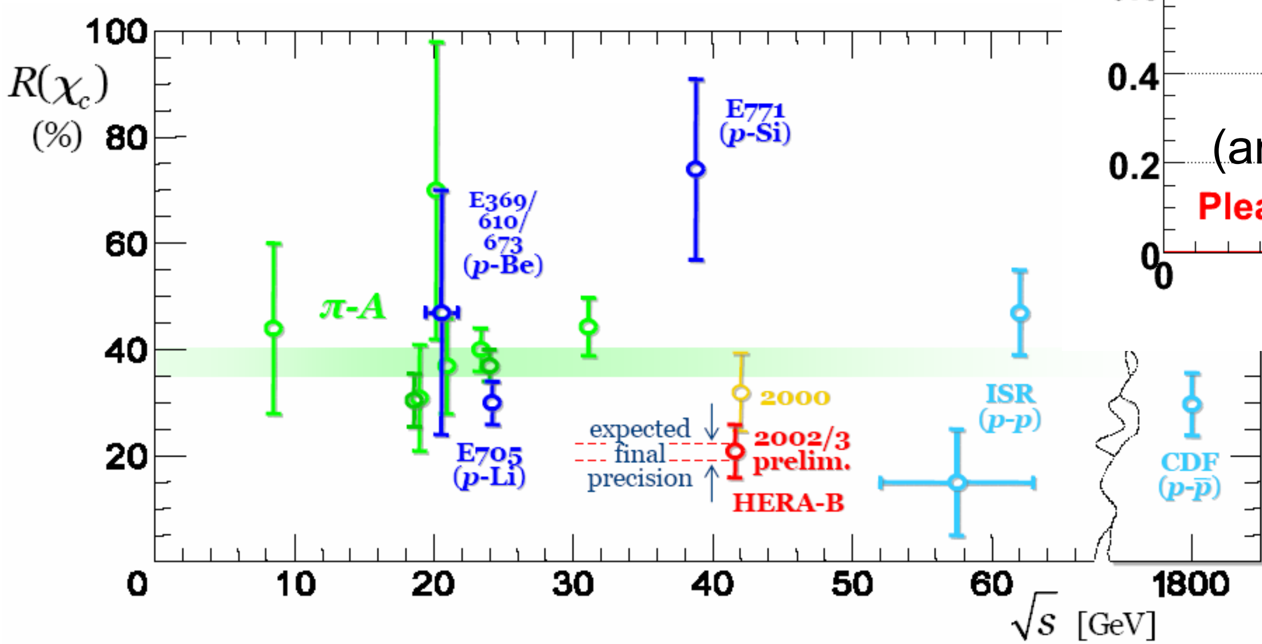
A bit more on excited states



Faccioli, Hard Probes 2006

- Some news from HERA-B
  - 7.0 ± 0.4 % from ψ′
  - 21 ± 5 % from χ_c
  - 0.065 ± 0.011 % from B



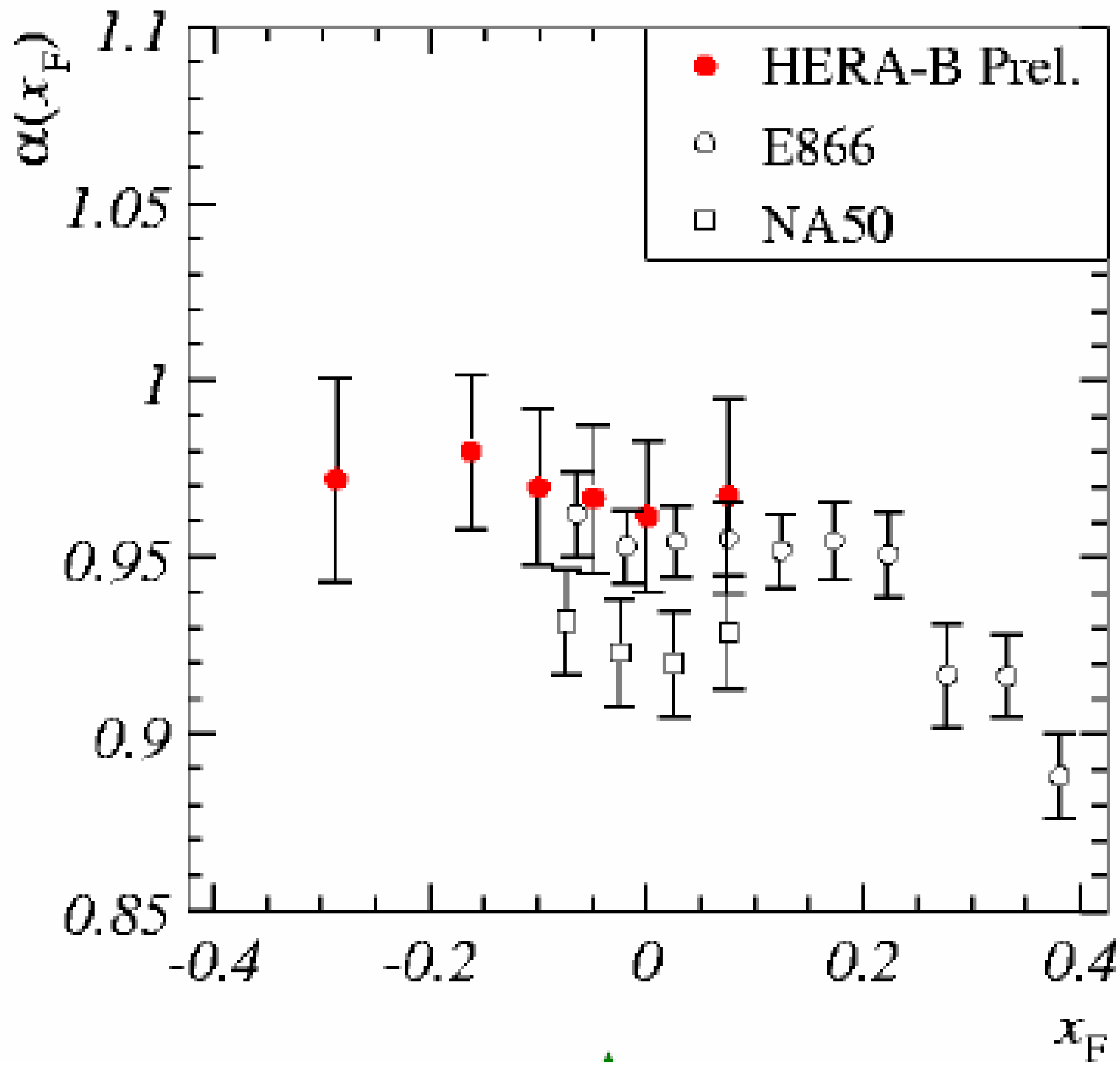


$\sigma_{abs}(\psi) \sim 2.9$ mb

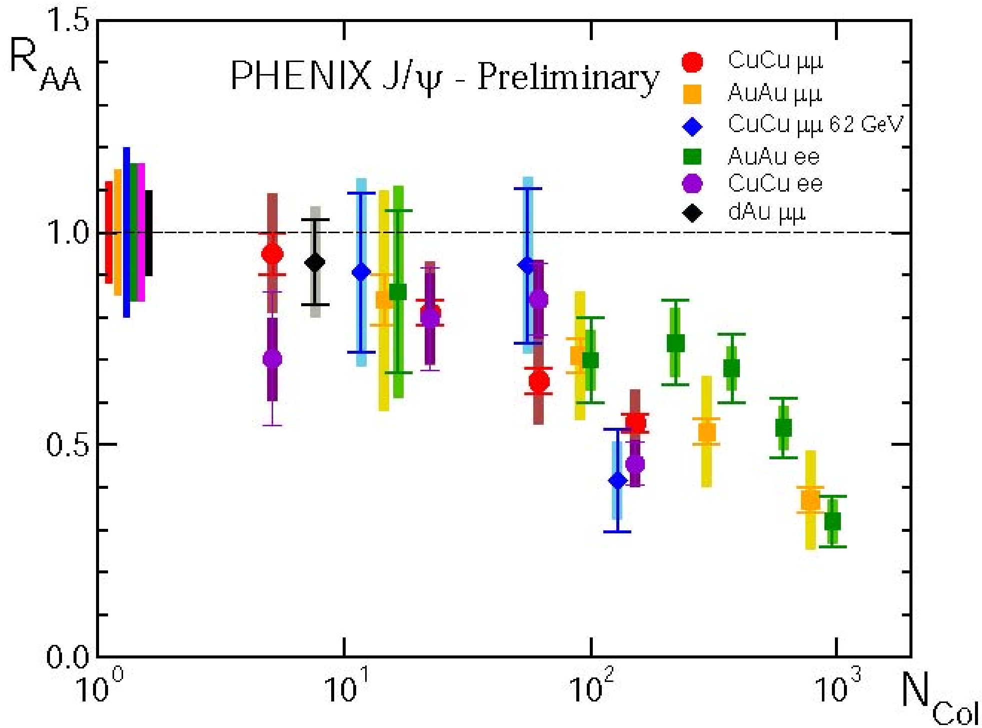
Survival ~ 70%

Consistency…

Some more HERA-B points…



R_{AA} versus N_{coll}



J/ψ → μμ
Muon arm
1.2 < |y| < 2.2

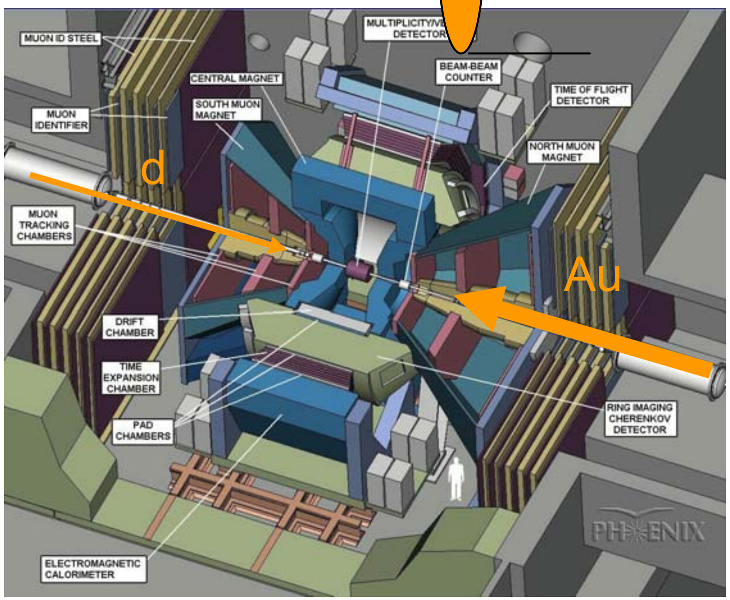
J/ψ → ee
Central arm
-0.35 < y < 0.35

$$R_{AB} = \frac{N_\psi^{AB}}{N_\psi^{PP} \times \langle N_{coll} \rangle}$$

dAu μμ 200 GeV	AuAu μμ 200 GeV	CuCu μμ 200 GeV	AuAu ee 200 GeV	CuCu ee 200 GeV	CuCu μμ 62 GeV

Hugo Pereira da Costa, for PHENIX, QM05, nucl-ex/0510051

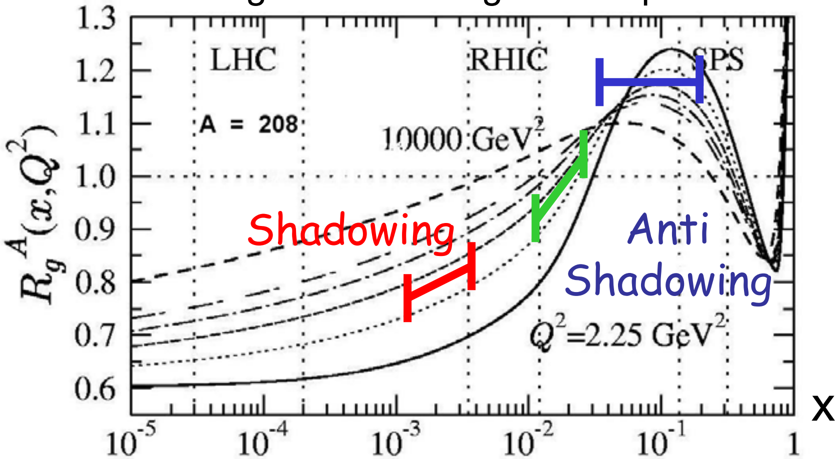
Deuteron → ← Gold

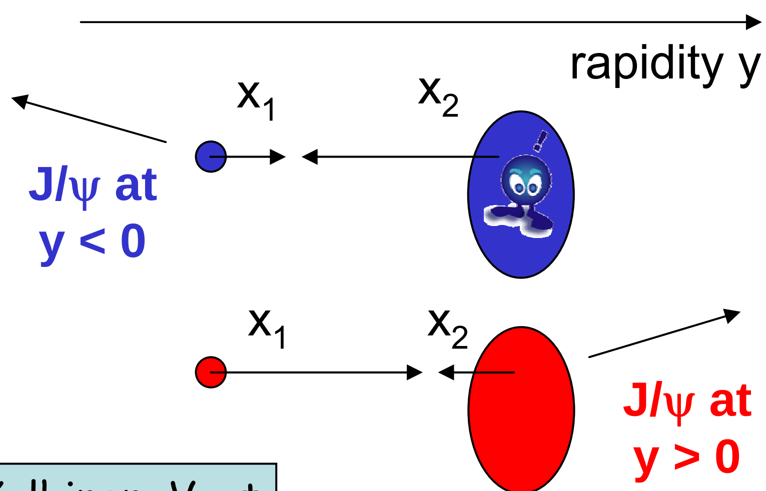


- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf
- Three rapidity ranges probe different momentum fraction of Au partons
  - South ($y < -1.2$) : large x_2 (in gold) ~ 0.090
  - Central ($y \sim 0$) : intermediate x_2 ~ 0.020
  - North ($y > 1.2$) : small x_2 (in gold) ~ 0.003

An example of gluon shadowing prediction

gluons in Pb / gluons in p

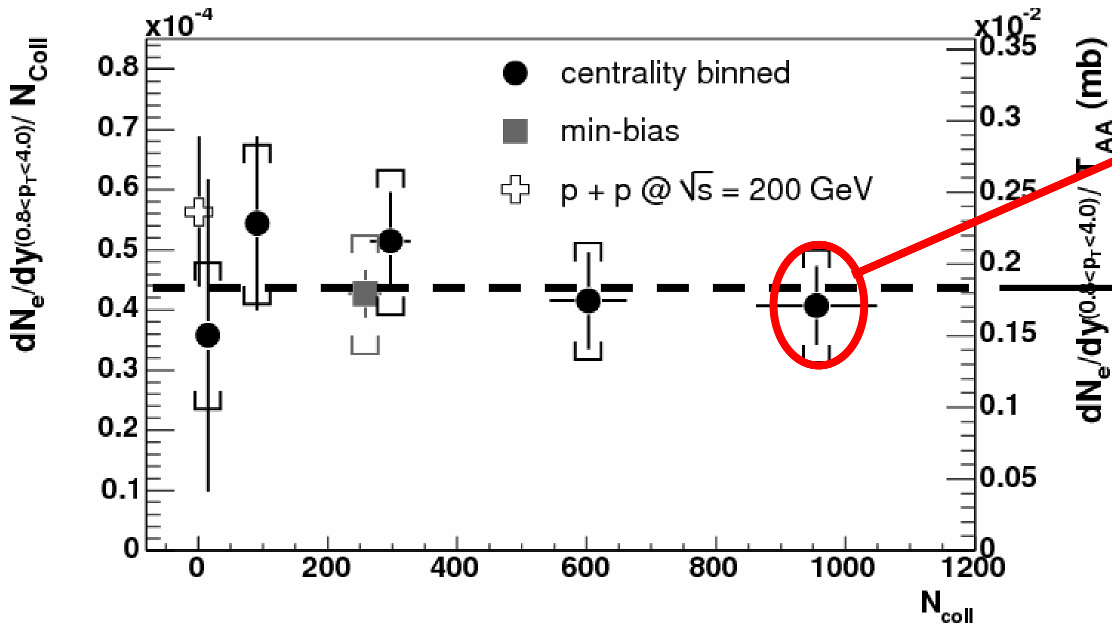




Eskola, Kolhinen, Vogt NPA696 (2001) 729

Quick look to open charm

- Through semileptonic decays ($D \to e$)



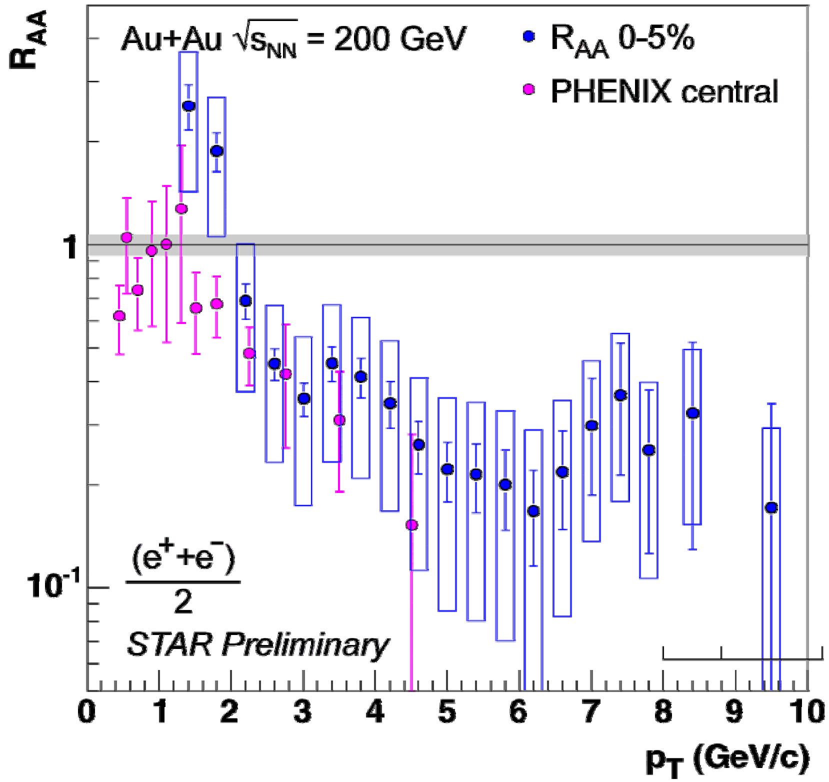
10 to 20 $c\bar{c}$ pairs !
($\to$ 40 acc. STAR)

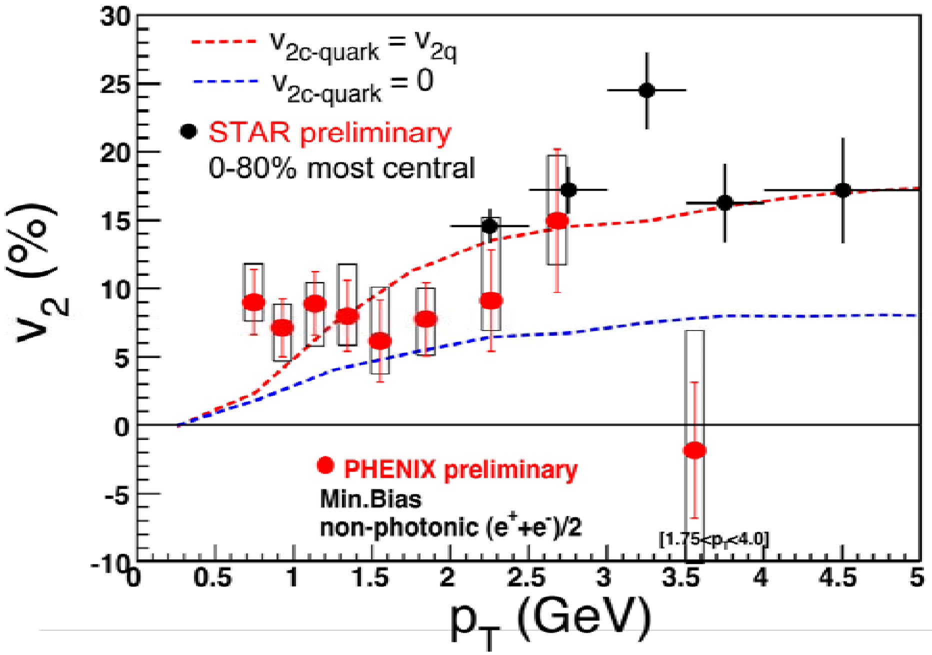
N_{coll} scaling

~25% systematic uncertainties (without Silicon vertex detector upgrade)

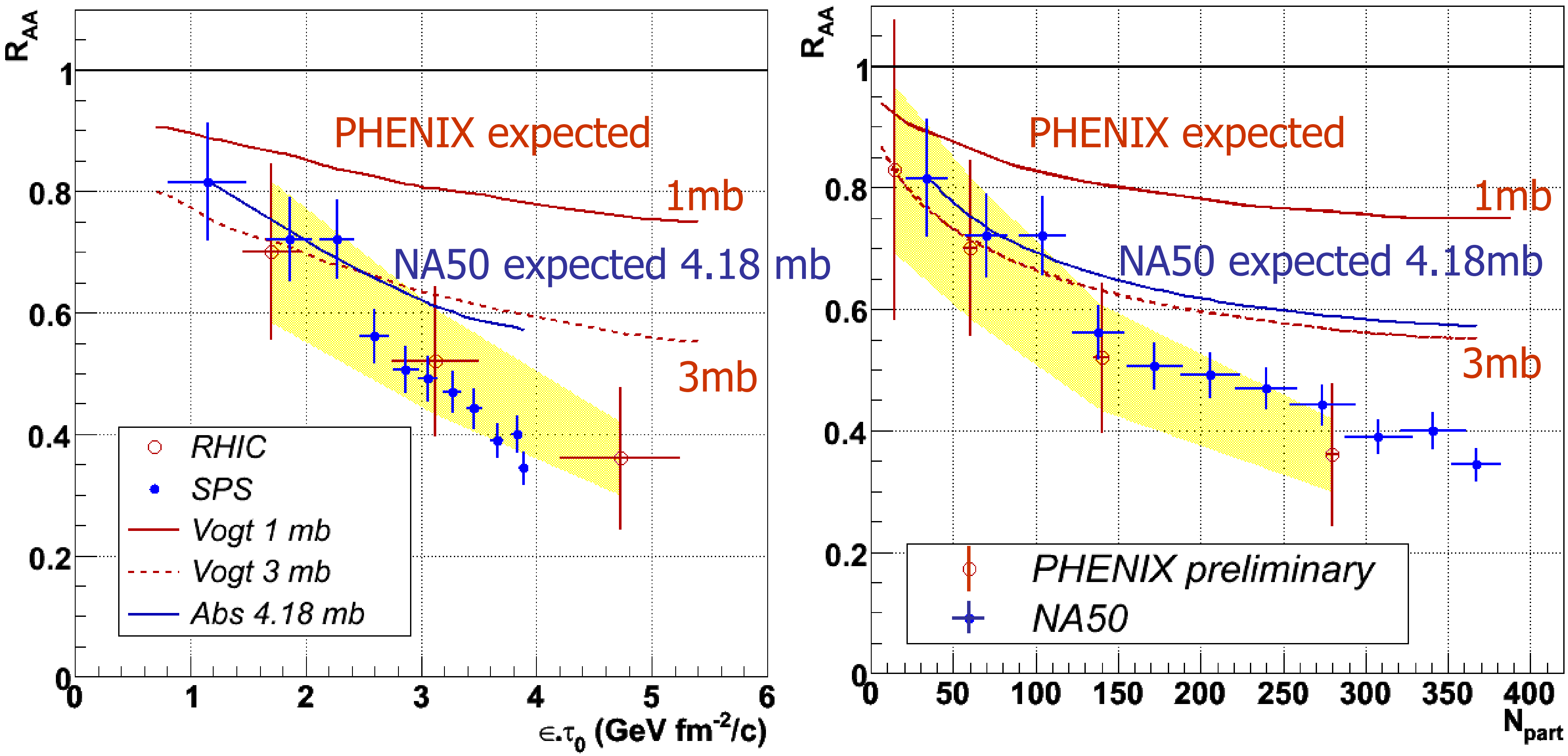
PHENIX, PRL94 (2005) 082301

Charm quench & flow



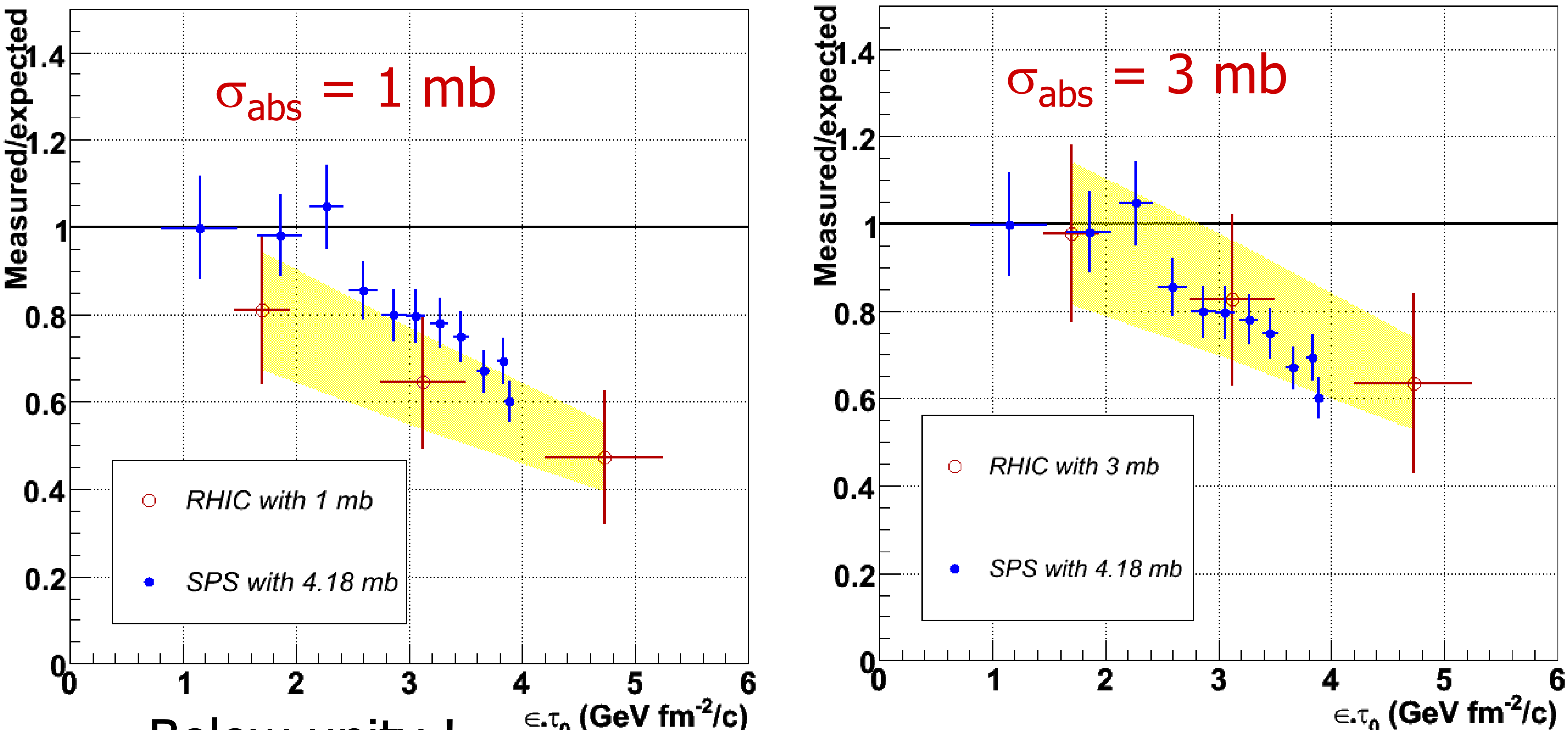


Na50/Phenix comparisons



Consistent suppression amplitude observed
but cold nuclear effects may be different

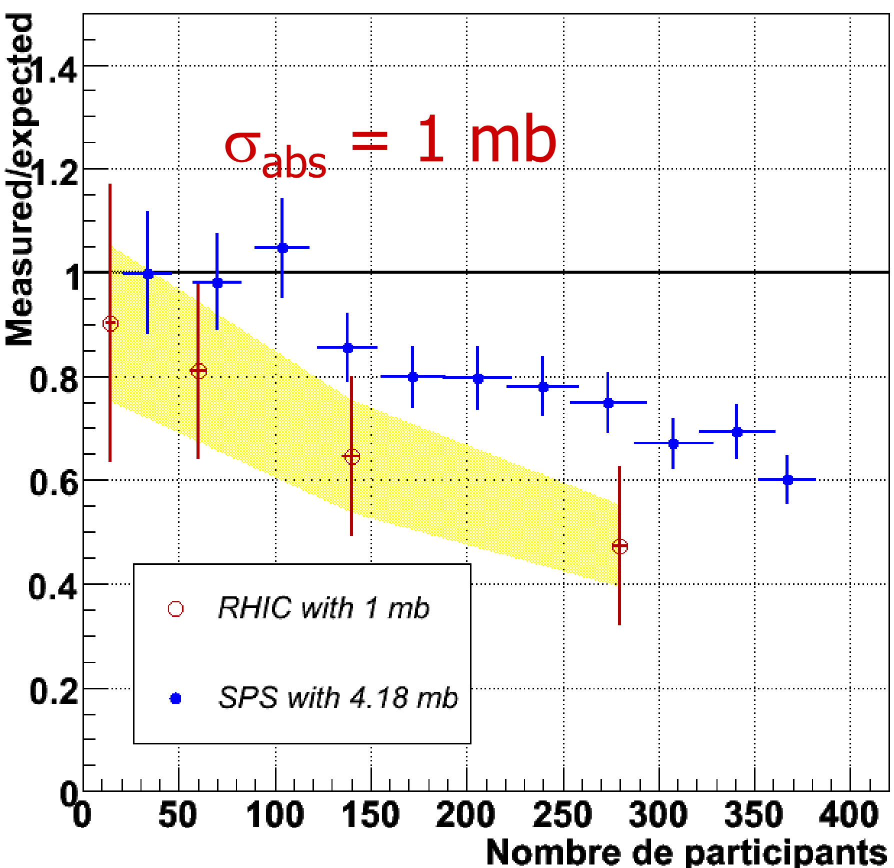
measured/expected vs ε_{Bj} $(\times\ \tau_0)$!

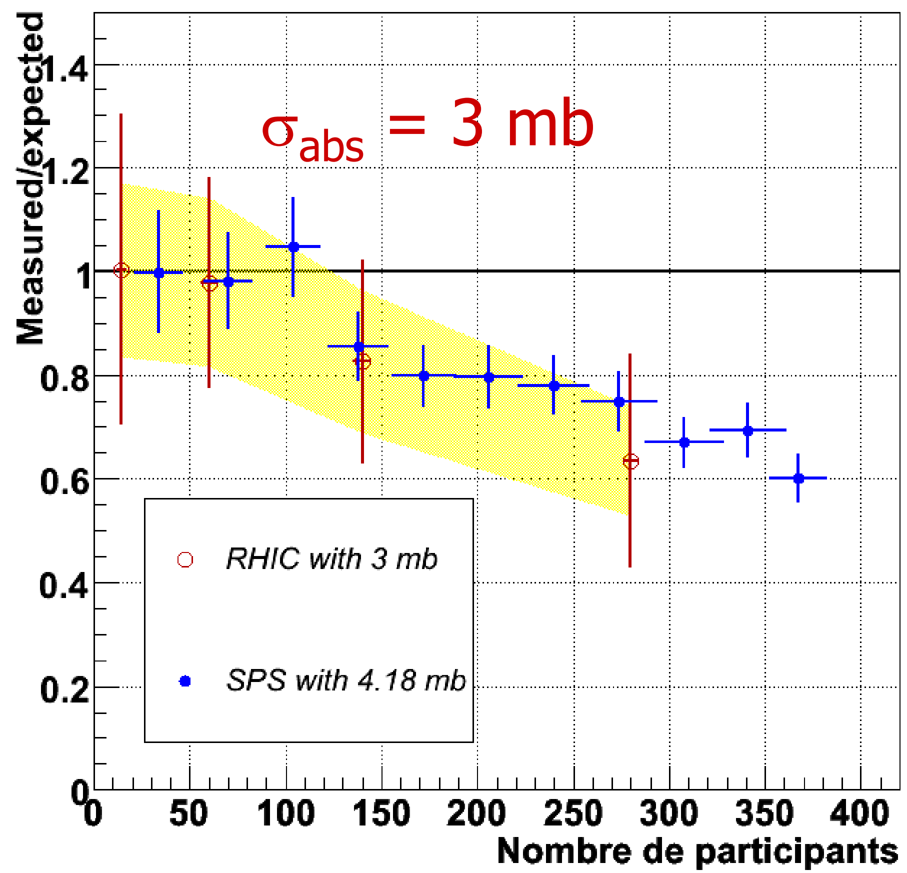


Below unity !

Suppression amplitude consistent within error bars

measured/expected vs N_{part}

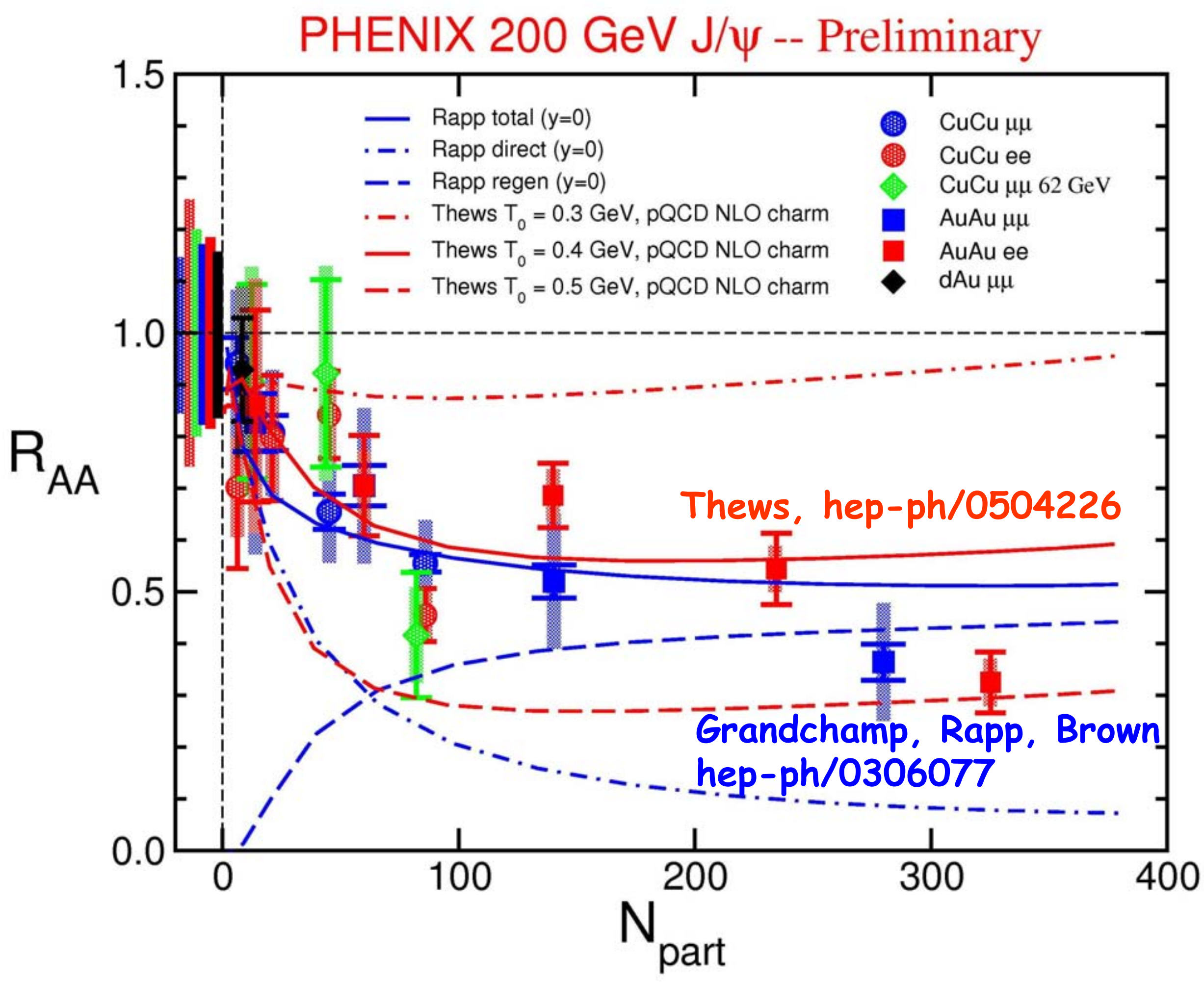




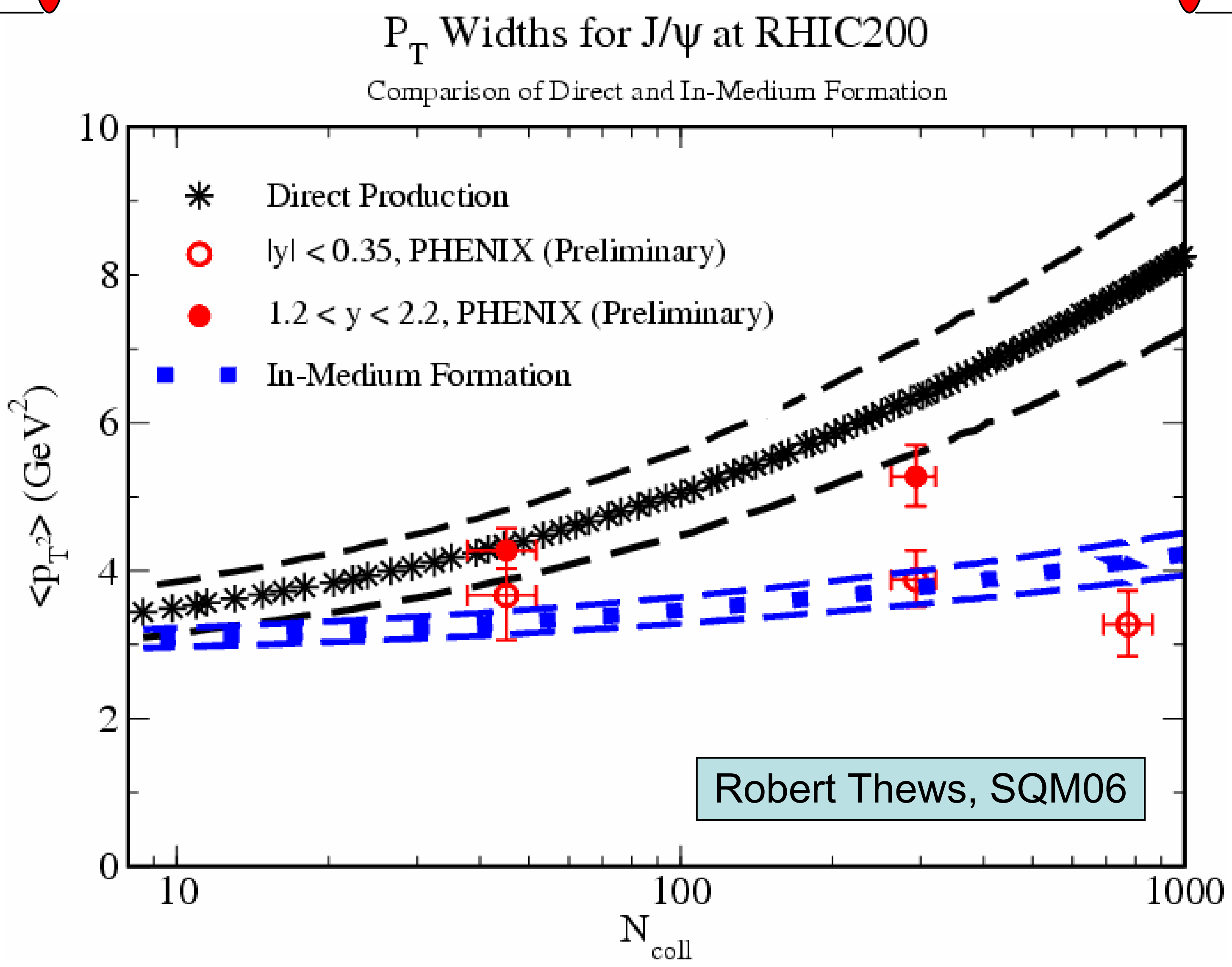
Under unity

Larger difference when 1mb but compatible within error bars

recombination/suppression



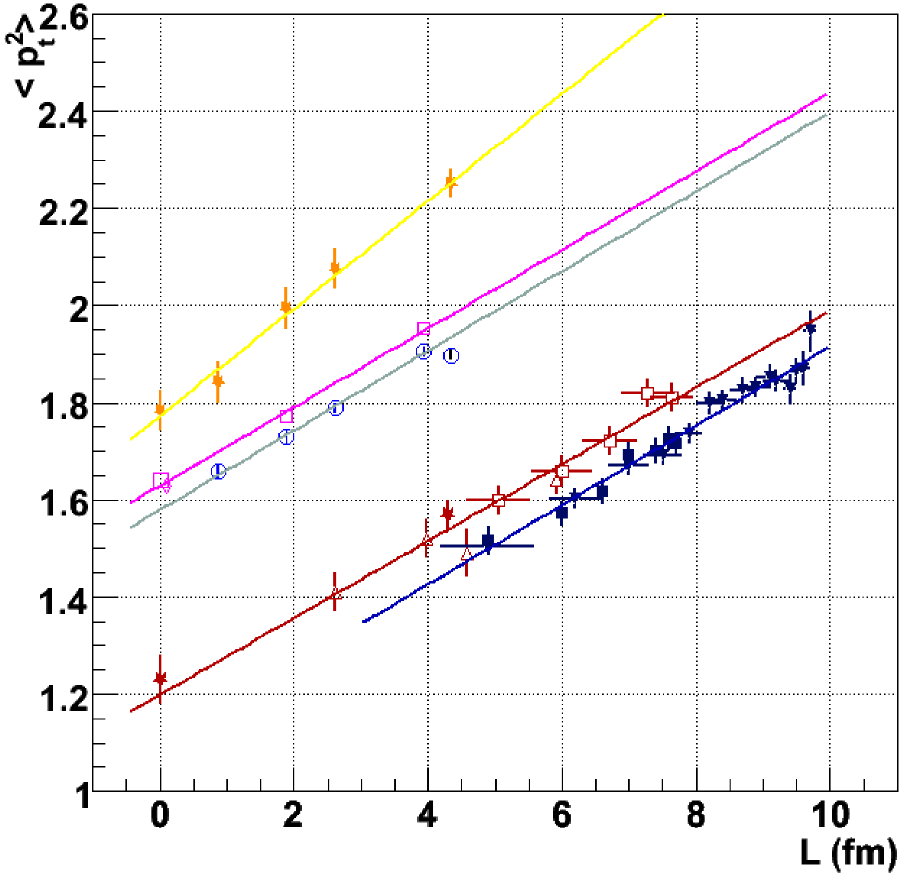
$\langle p_T^2 \rangle$ (vs recombination)



Cronin effect

Scattering of initial gluons of nucleon before ccbar formation

random walk : $<p_t^2>_{AA} = <p_t^2>_{pp} + \rho\sigma\Delta(<p_t^2>)\ L_{AA}$



$\sqrt{s}$ =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

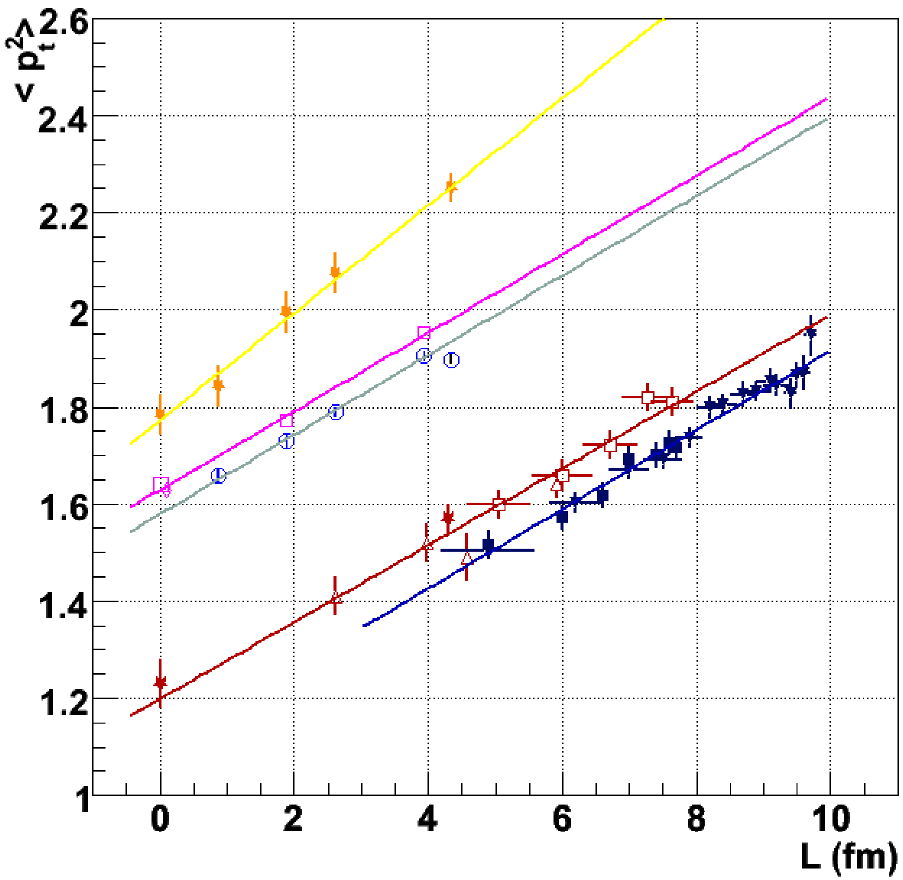
$\sqrt{s}$ = 29.1 GeV :NA51 p+p, p+d, NA50 p+Al, p+W

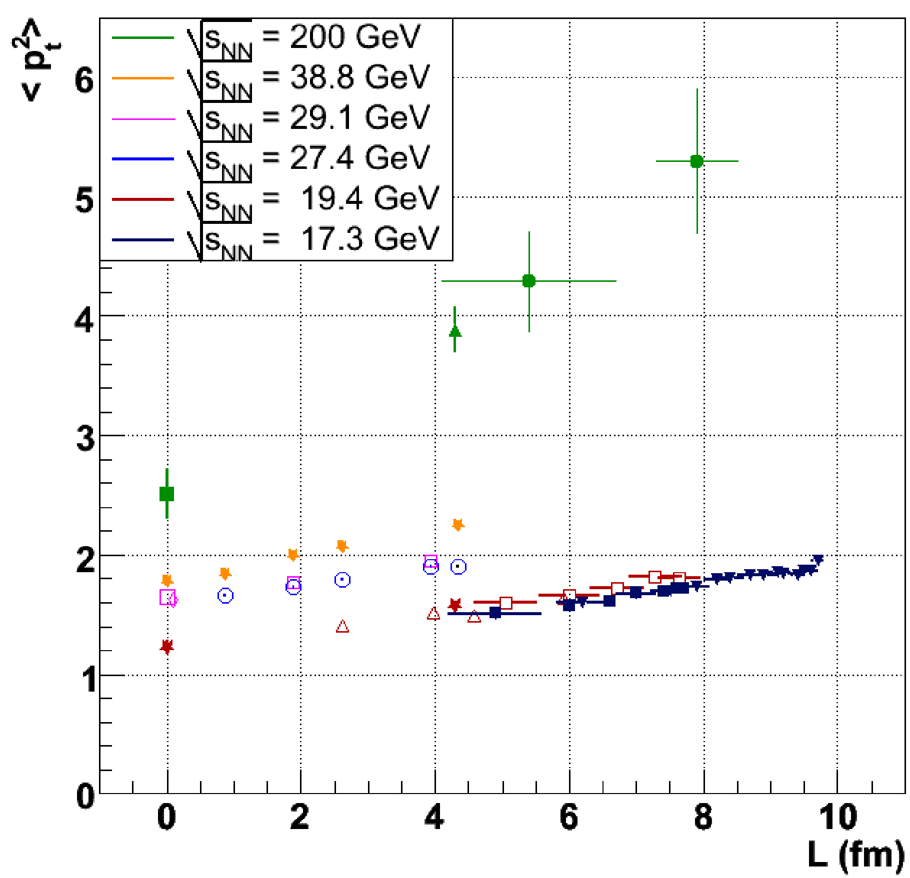
$\sqrt{s}$ = 38.8 GeV : E866/789/771

ρ nuclear density, σ elastic gluon-nucleon scattering cross section, $\Delta(<p_t^2>)$ 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

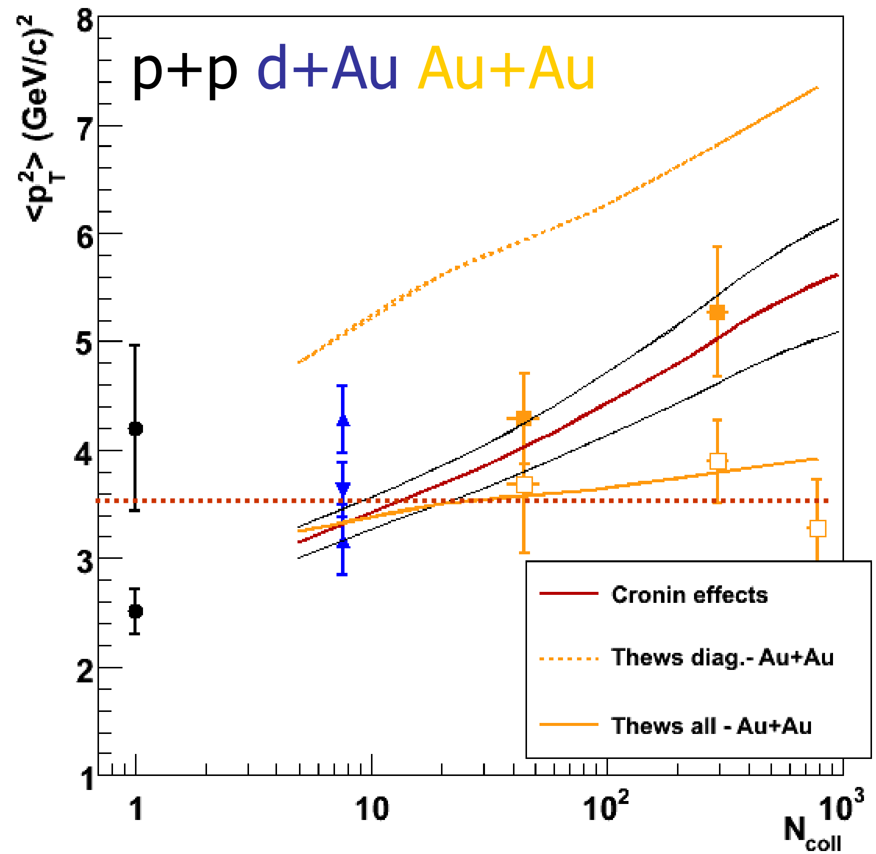
Cronin effect

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

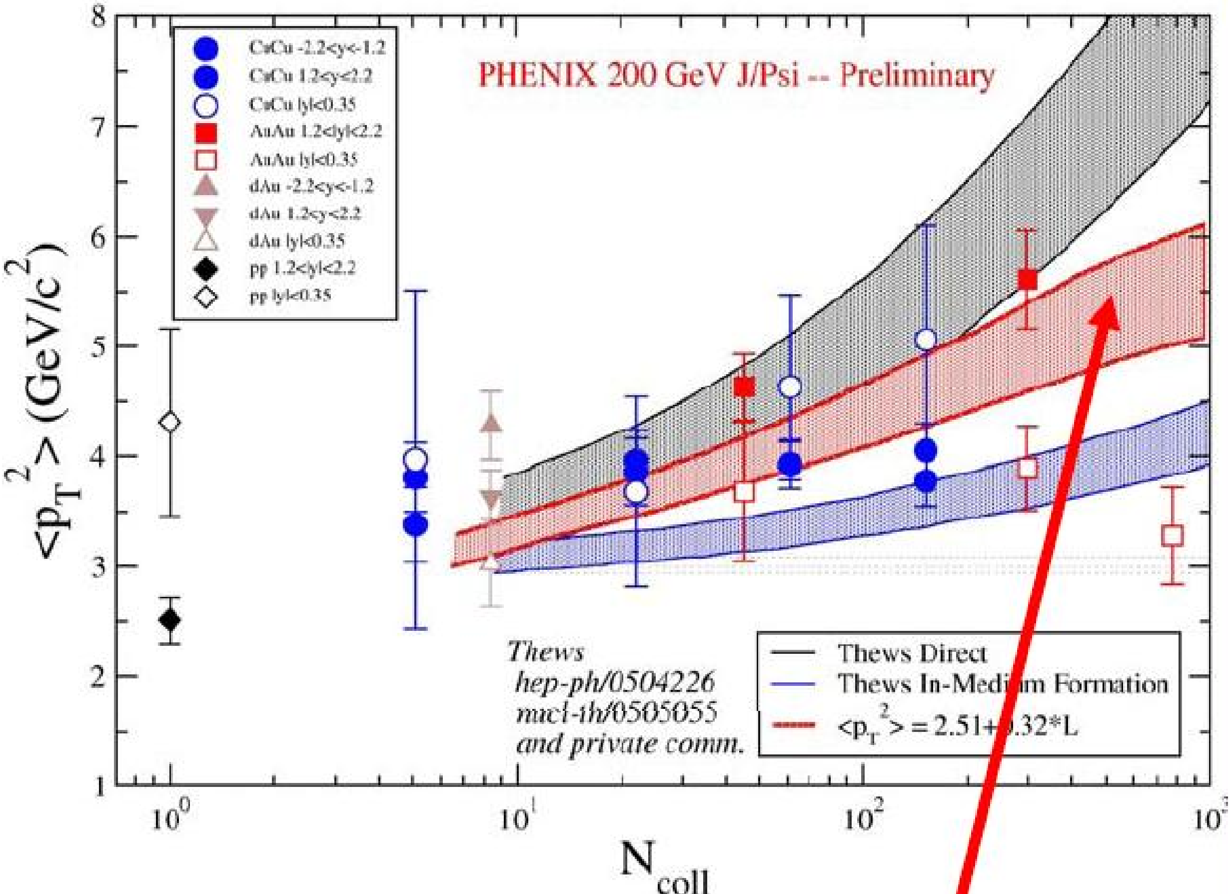
Extrapolation curve from PHENIX J/ψ results in p+p and d+Au

At forward rapidity, $\langle p_t^2 \rangle$ variation compatible with this Cronin extrapolation

At mid rapidity, measurements in p+p and d+Au indicate a weak Cronin effect



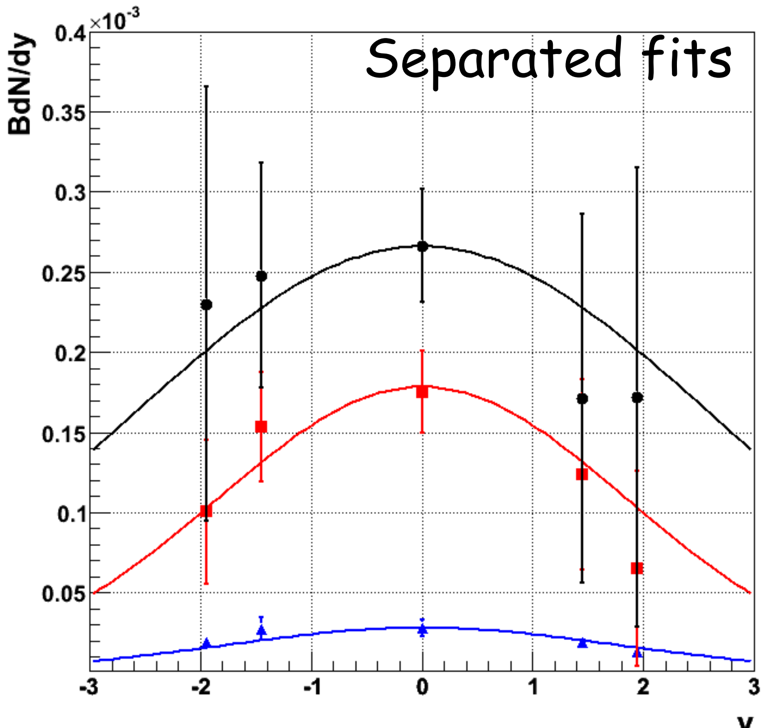
A busy plot about $\langle p_T^2 \rangle$



$\langle p_T^2 \rangle$ = 2.51+0.32*L
from fit to dAu data vs L

(curves to be compared with AA @ 1.2<|y|<2.2)

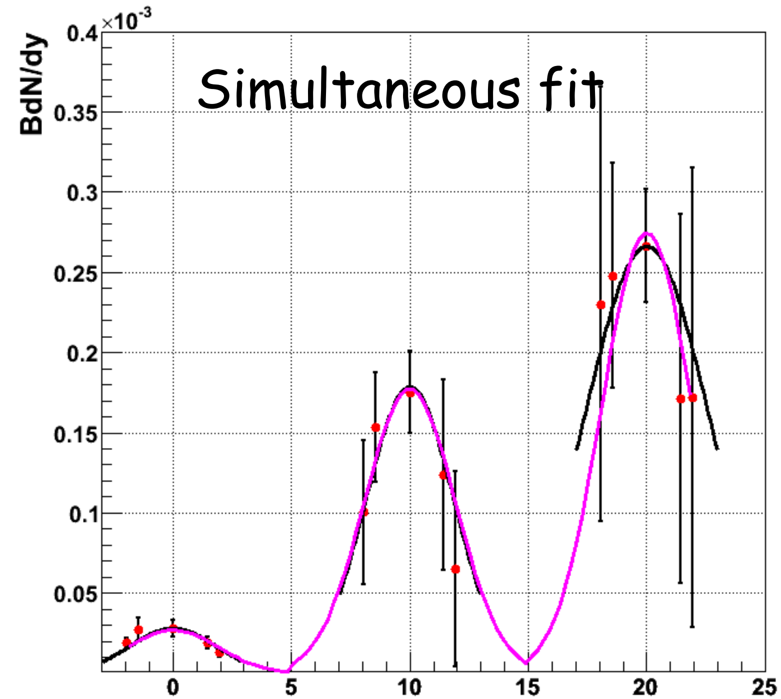
Rapidity width



σ = 2.61 ± 2.54 χ^2/dof = 0.21

σ = 1.85 ± 0.53 χ^2/dof = 0.41

σ = 1.82 ± 1.00 χ^2/dof = 1.39



Width = 1.90 ± 0.32

χ^2/ndl = 0.55

Width pp = 1.75 ± 0.21

No noticeable change in rapidity width

VN Tram thesis

More on transport model…

- 2+1D hydro
- Boltzman-type transport
- Local equilibrium
  - (0.8 & 0.6 fm/c)
  - Normal to anomalous
- T_c = 165 MeV
- T_{fo} = 60 MeV
- $g+\Psi \rightarrow cc$
- 40% feeddown
- No in-medium mod
- No absorption @RHIC (here)

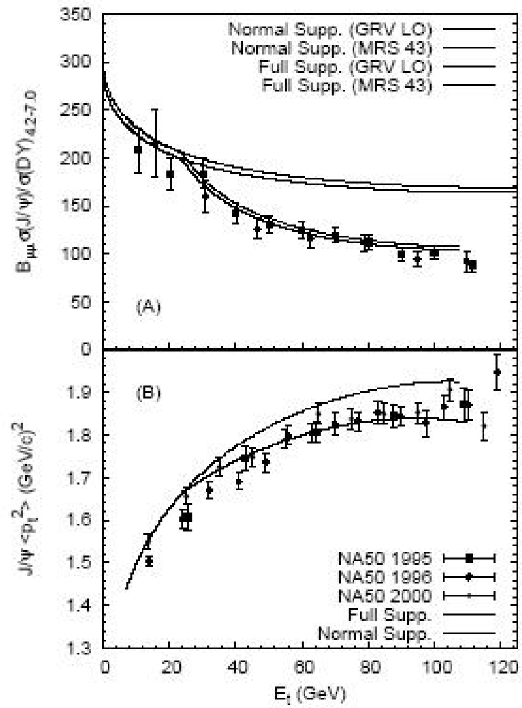


FIG. 1: The J/ψ suppression and $\langle p_t^2 \rangle$ as functions of centrality at SPS energy.

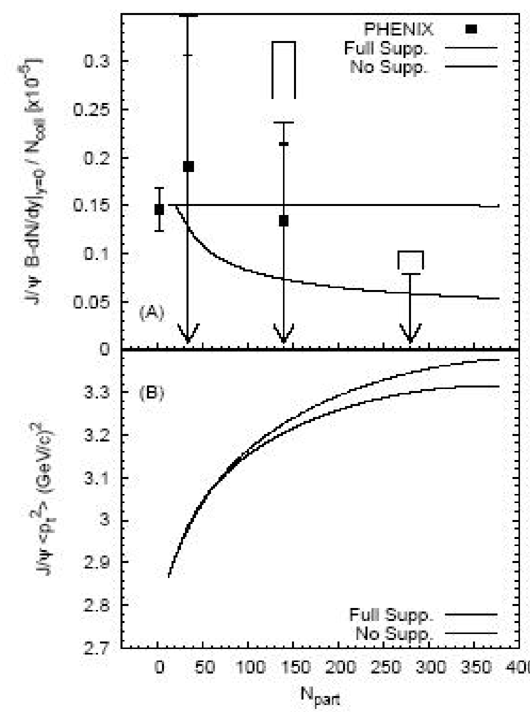
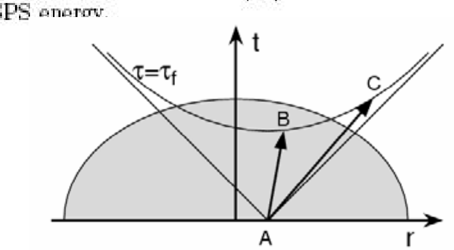
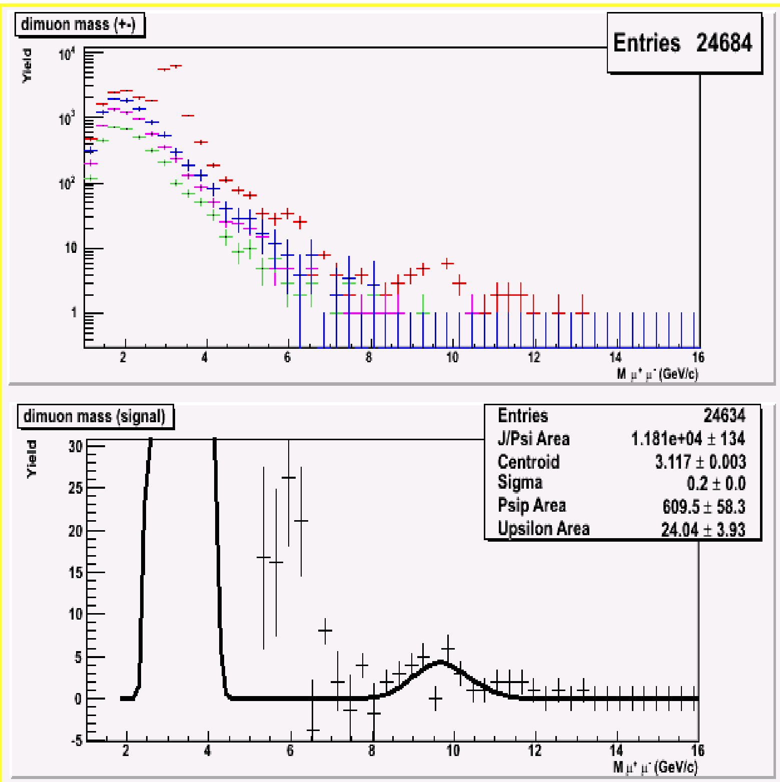


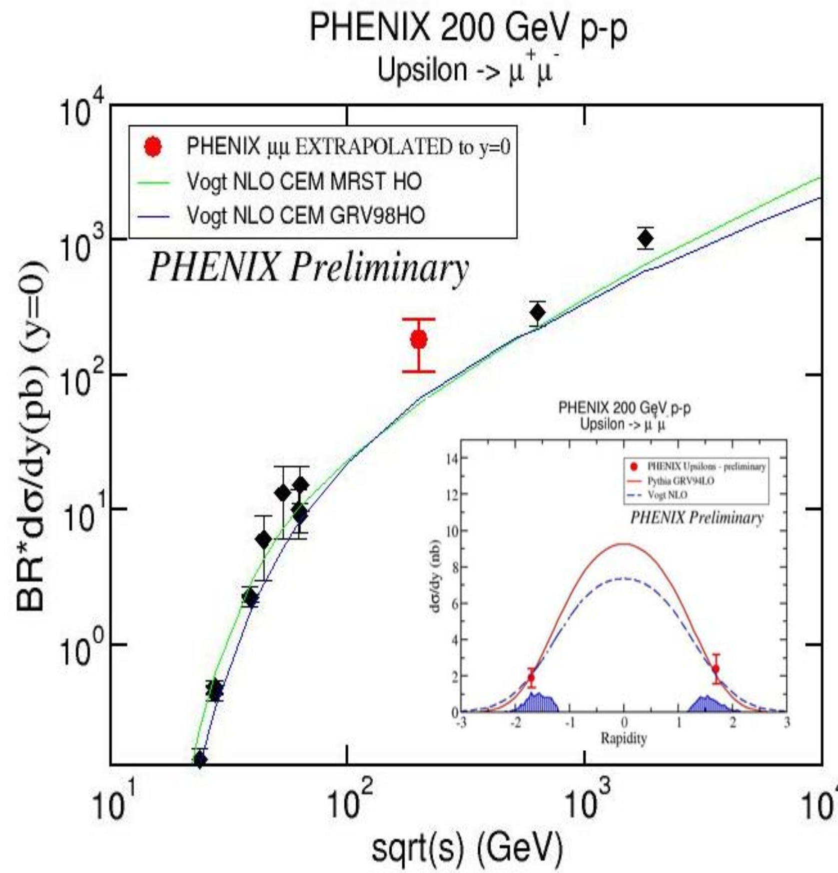
FIG. 2: The J/ψ suppression and $\langle p_t^2 \rangle$ as functions of centrality at RHIC energy.



Zhu, Zhuang, Xu, PLB607 (2005) 107

First upsilons…



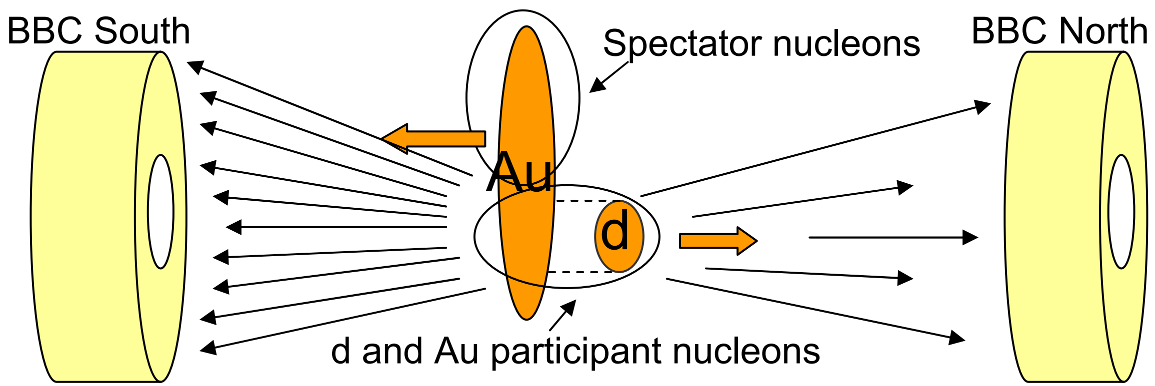


- Run 5 pp (3 pb^{-1})

Hie Wei, Quark Matter 2005

Centrality analysis

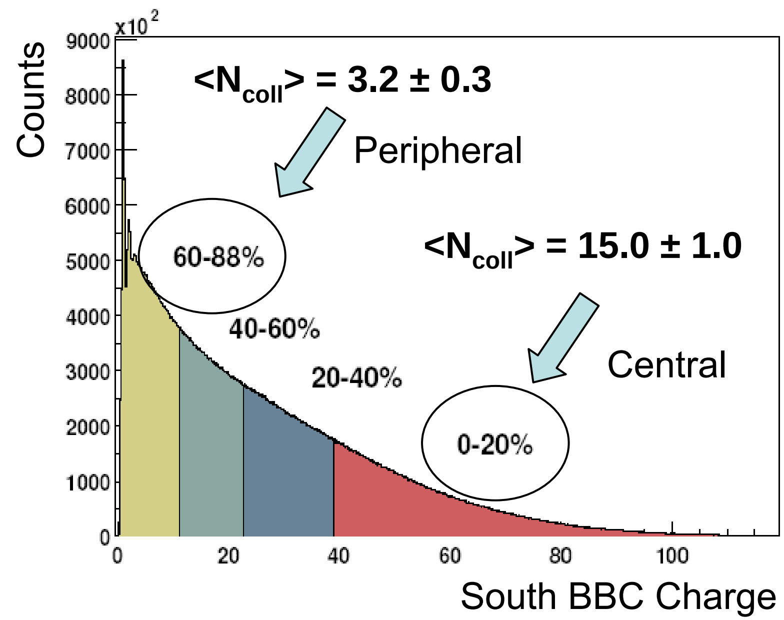
Au breaks up in our south beam counter



- Define 4 centrality classes
- Relate centrality to $\langle N_{coll} \rangle$

through Glauber computation

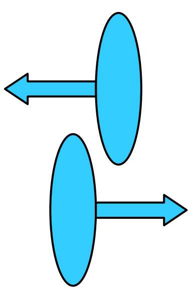
- $\langle N_{coll}^{MB} \rangle = 8.4 \pm 0.7$

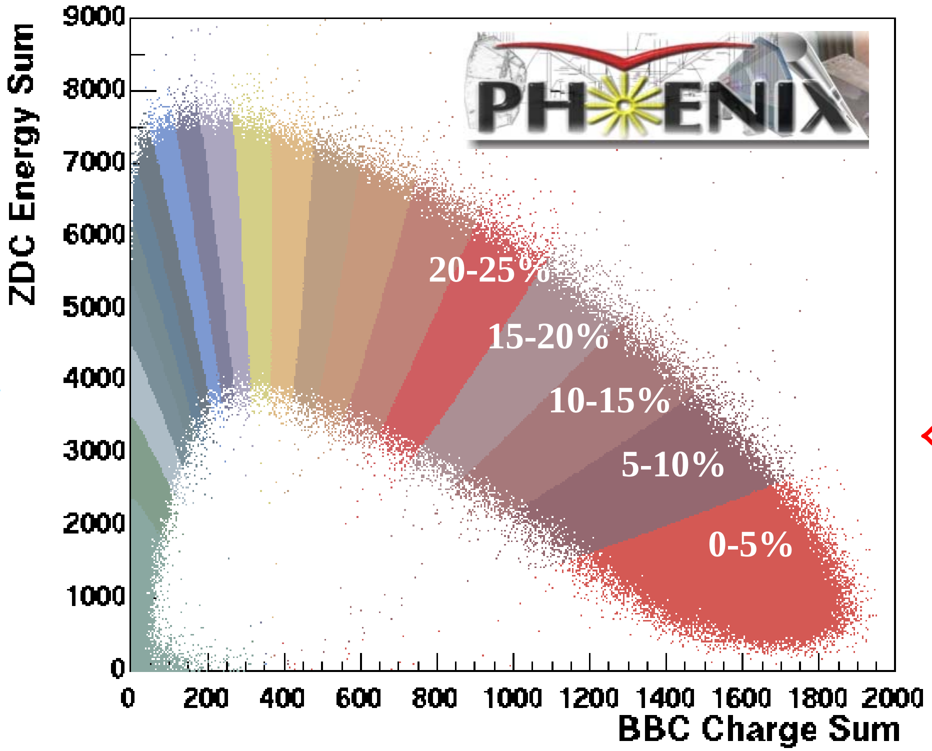


Centrality analysis

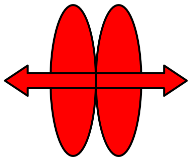
BBC charge versus ZDC energy

Most peripheral
80 - 92.2%
$\langle N_{part} \rangle = 6.3 \pm 1.2$
$\langle N_{coll} \rangle = 4.9 \pm 1.2$

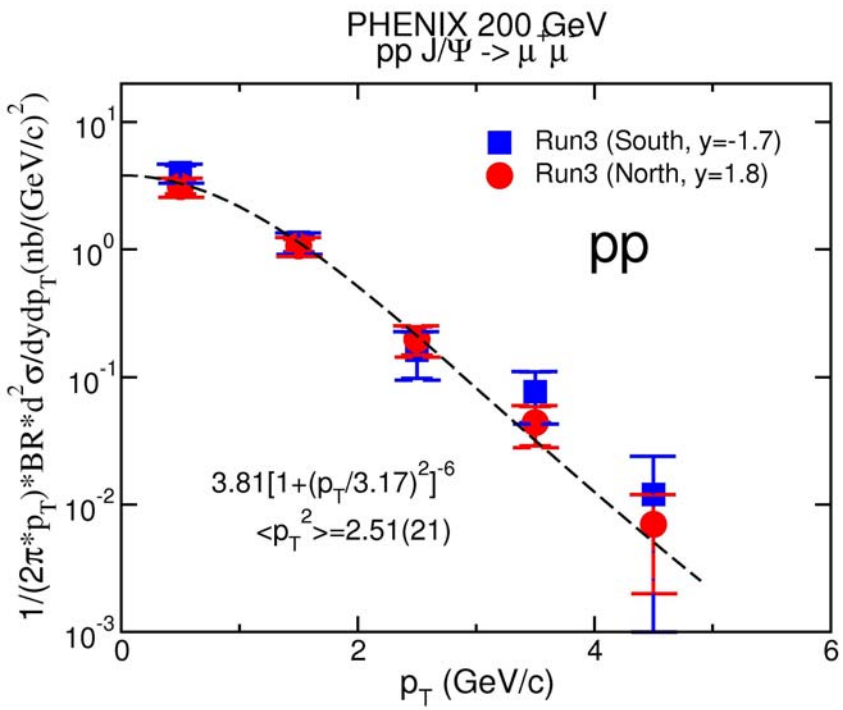


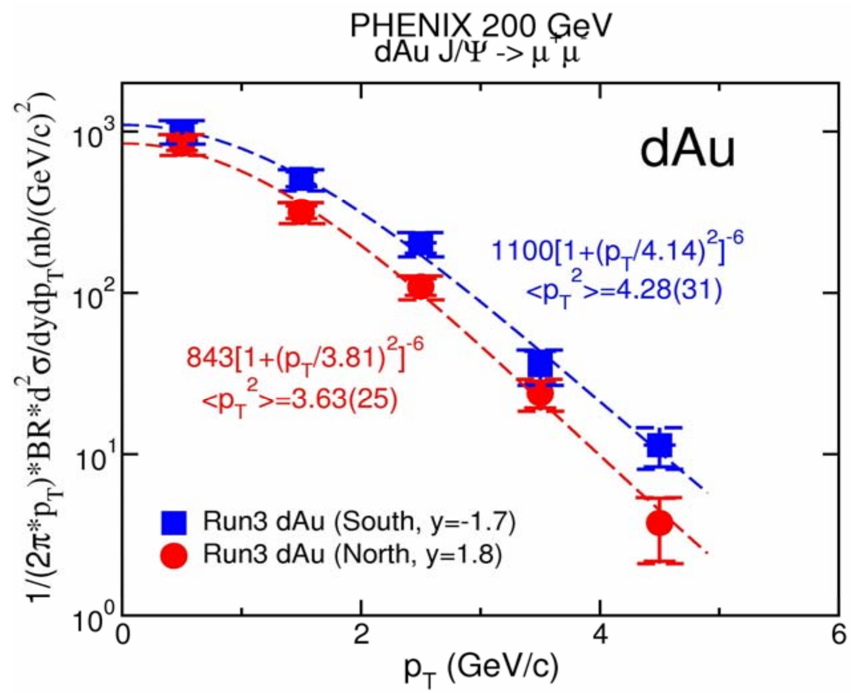


Most central
0 - 5 %
$\langle N_{part} \rangle = 351 \pm 2.9$
$\langle N_{coll} \rangle = 1065 \pm 105$



Cross section versus p_T





$\Delta\langle p_T^2\rangle = \langle p_T^2\rangle_{dAu} - \langle p_T^2\rangle_{pp}$

PHENIX, PRL96 (2006) 012304

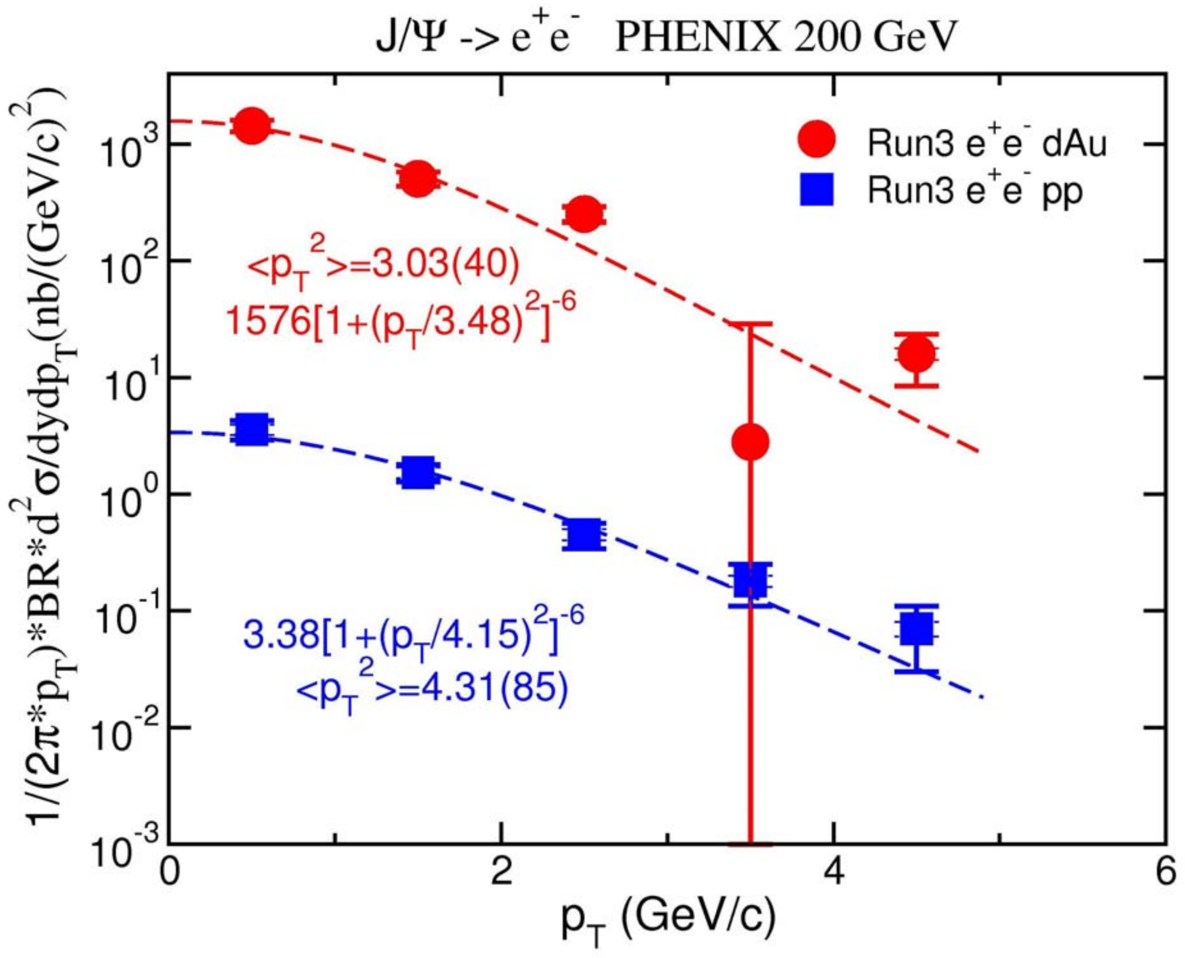
Backward: 1.77 ± 0.37 GeV ^{2}

Mid: (-1.28 ± 0.94 GeV ^{2})

Forward: 1.12 ± 0.35 GeV ^{2}

Some p_T broadening

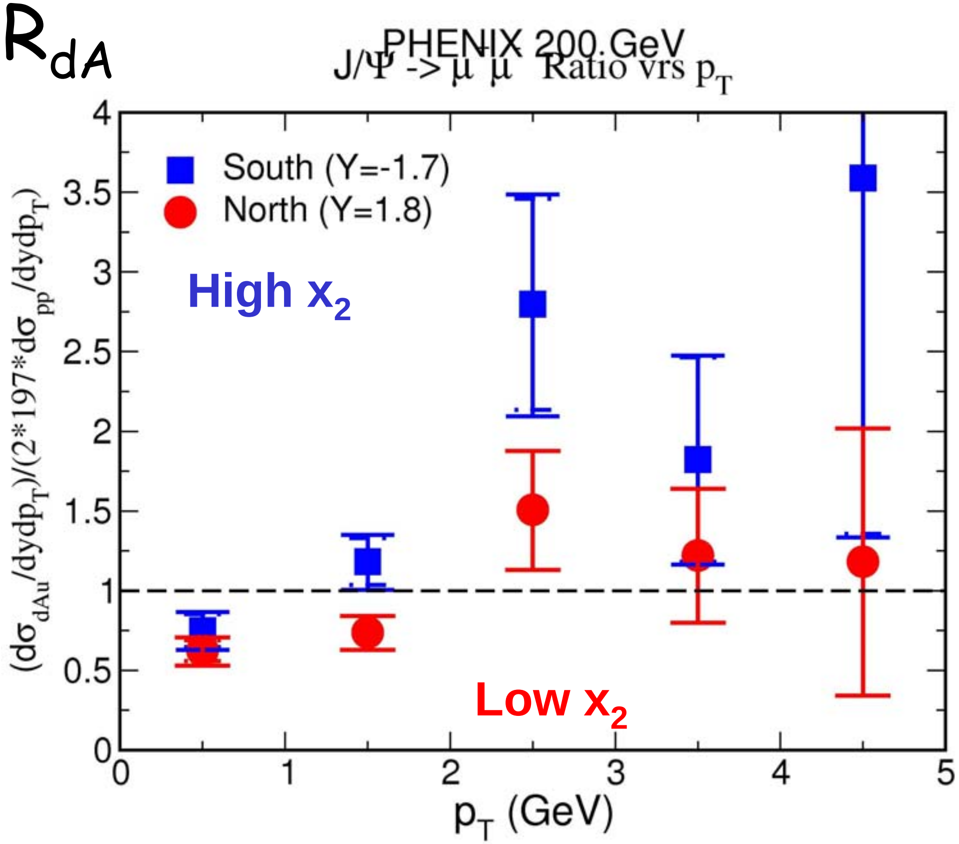
Dielectron pp and dA

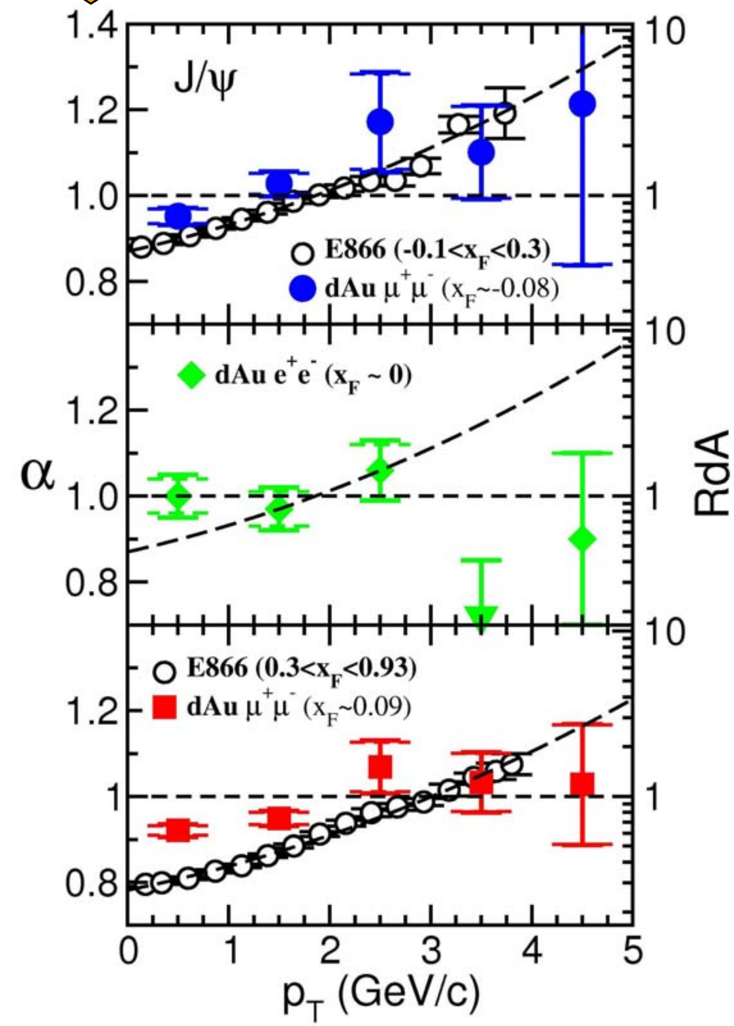


R_{dAu} versus p_T

$$\sigma_{dA} = \sigma_{pp}(2\times197)^{\alpha}$$

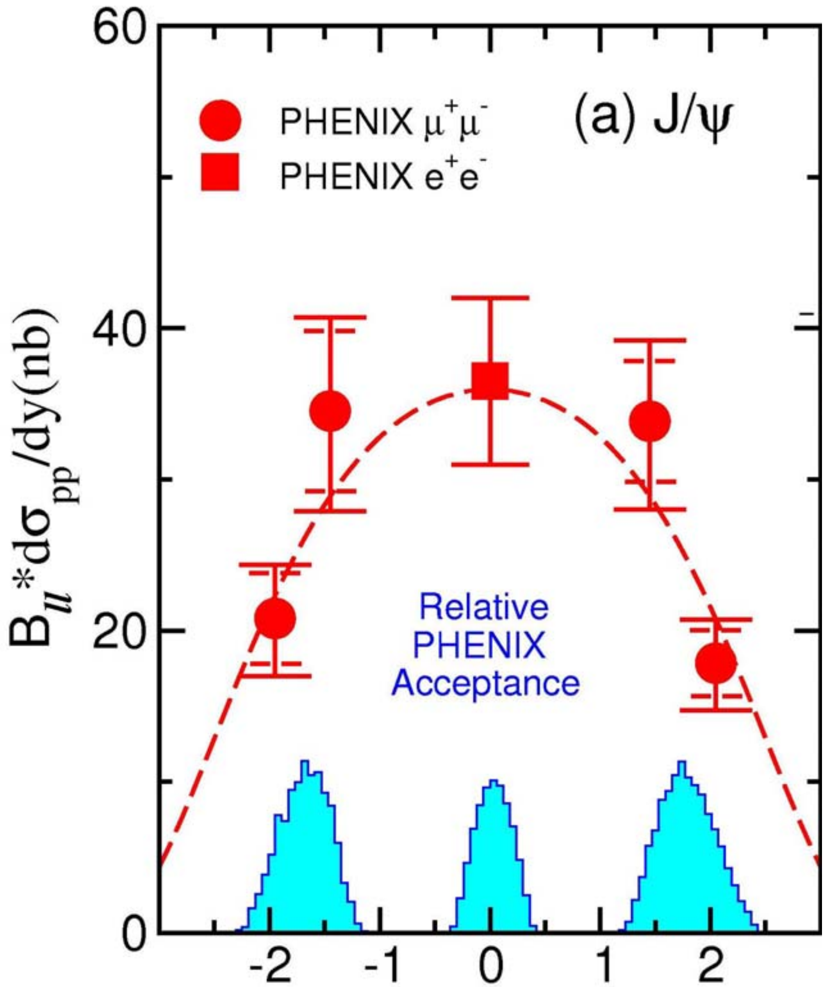
R_{dA}





Broadening comparable to lower energy (√s = 39 GeV in E866)

Cross section vs rapidity



Total cross section

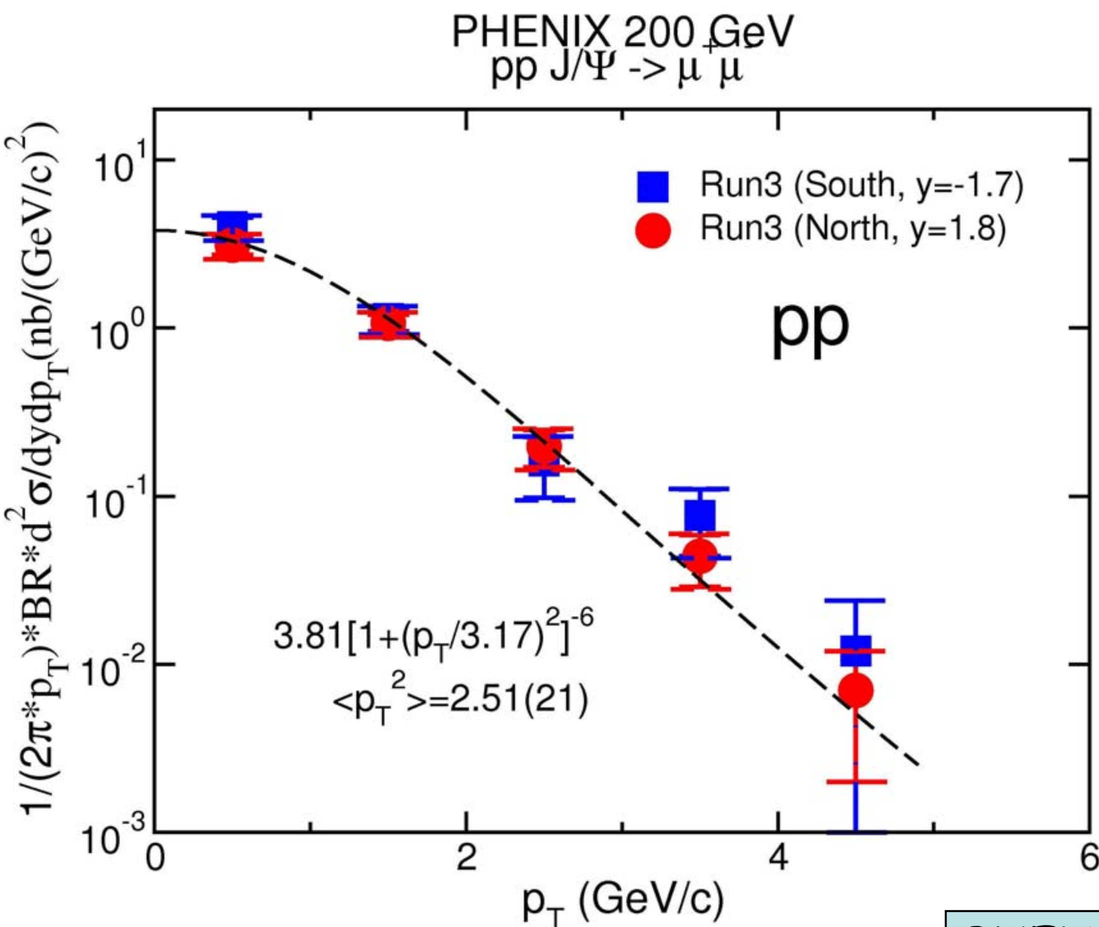
$\sigma\ (pp \rightarrow J/\psi)$

$2.61 \pm 0.20 \pm 0.26\ \mu b$

- Error from fit (incl. syst and stat)
- Error on absolute normalization

PHENIX, PRL96 (2006) 012304

Cross section versus p_T



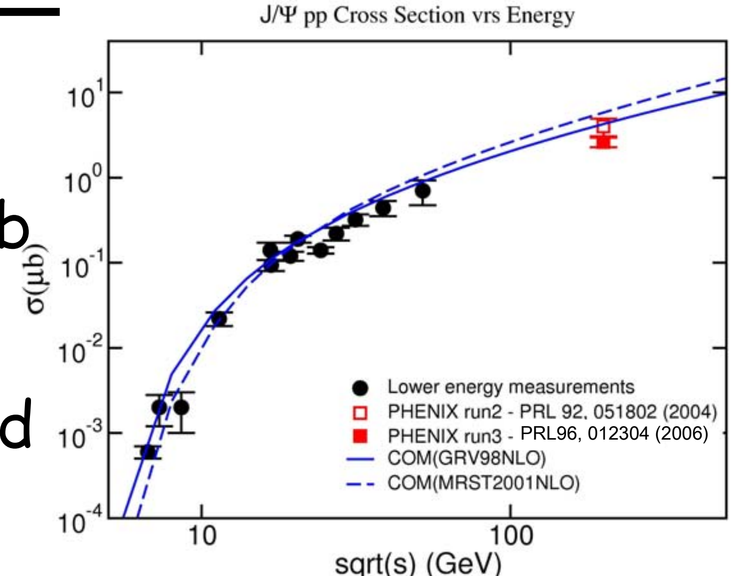
Fit the function

$$\frac{A}{(1+(p_T/B)^2)^6}$$

$\langle p_T^2 \rangle = 2.51 \pm 0.21$ (GeV^2)

PHENIX, PRL96 (2006) 012304

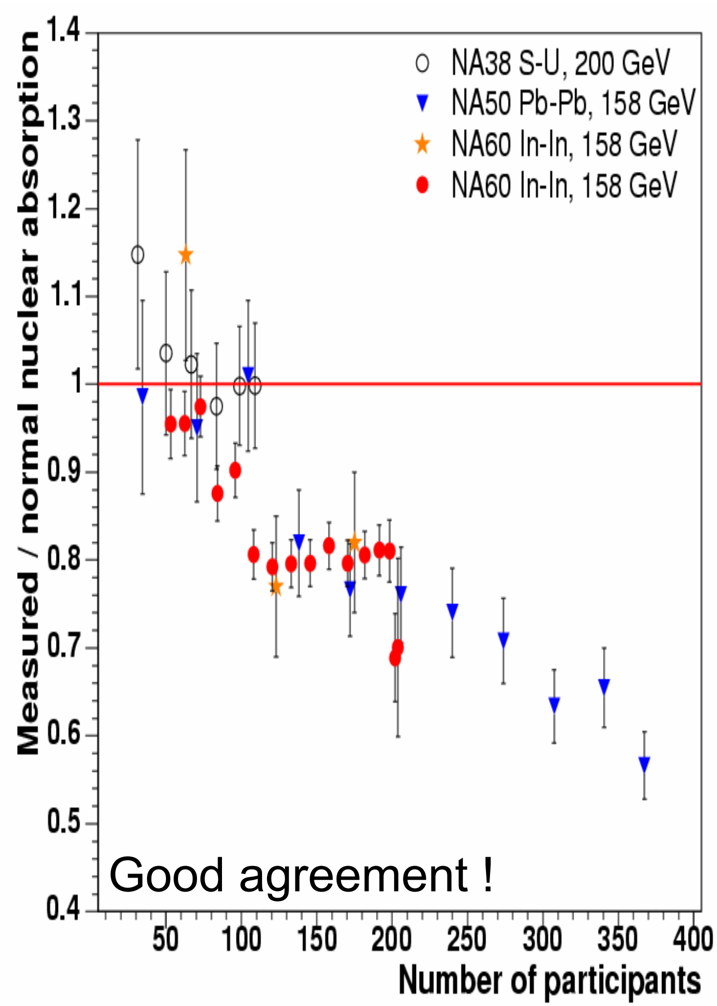
p+p perspectives

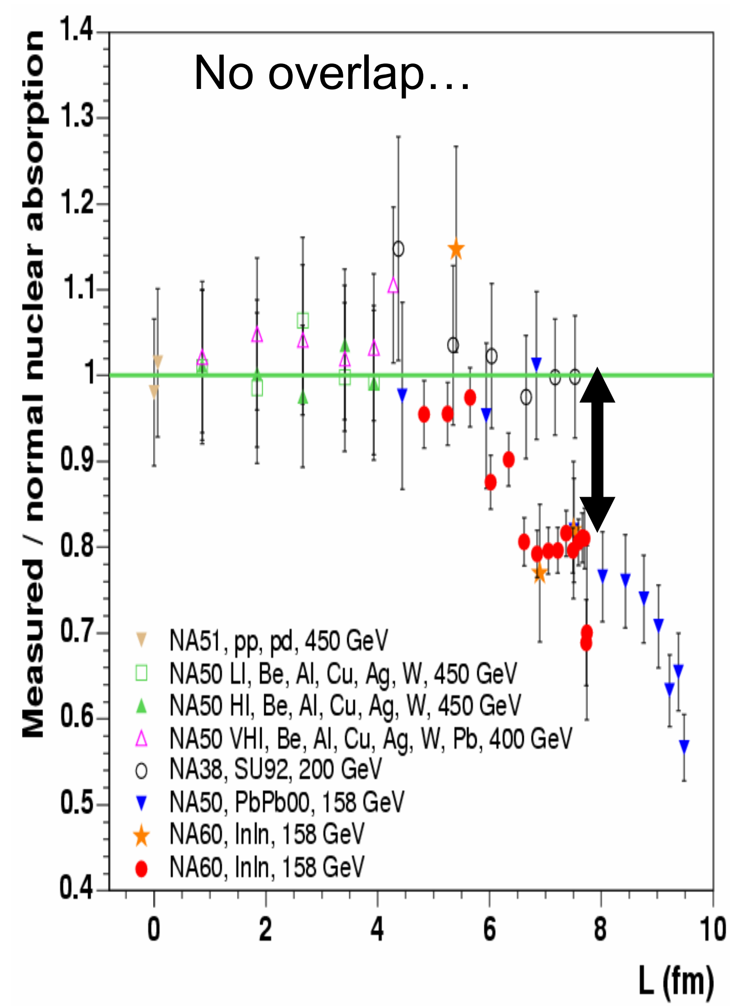


- Production mechanism
  - Color Octet Model does the job
- In AA (or dA)
  - Large combinatorial background
  - Low physics background
    - (Drell-Yan or dileptons from open charm)
- p+p is our baseline
  - Nuclear modification factor
- Run5 pp analysis going on
  - > 10 times statistics

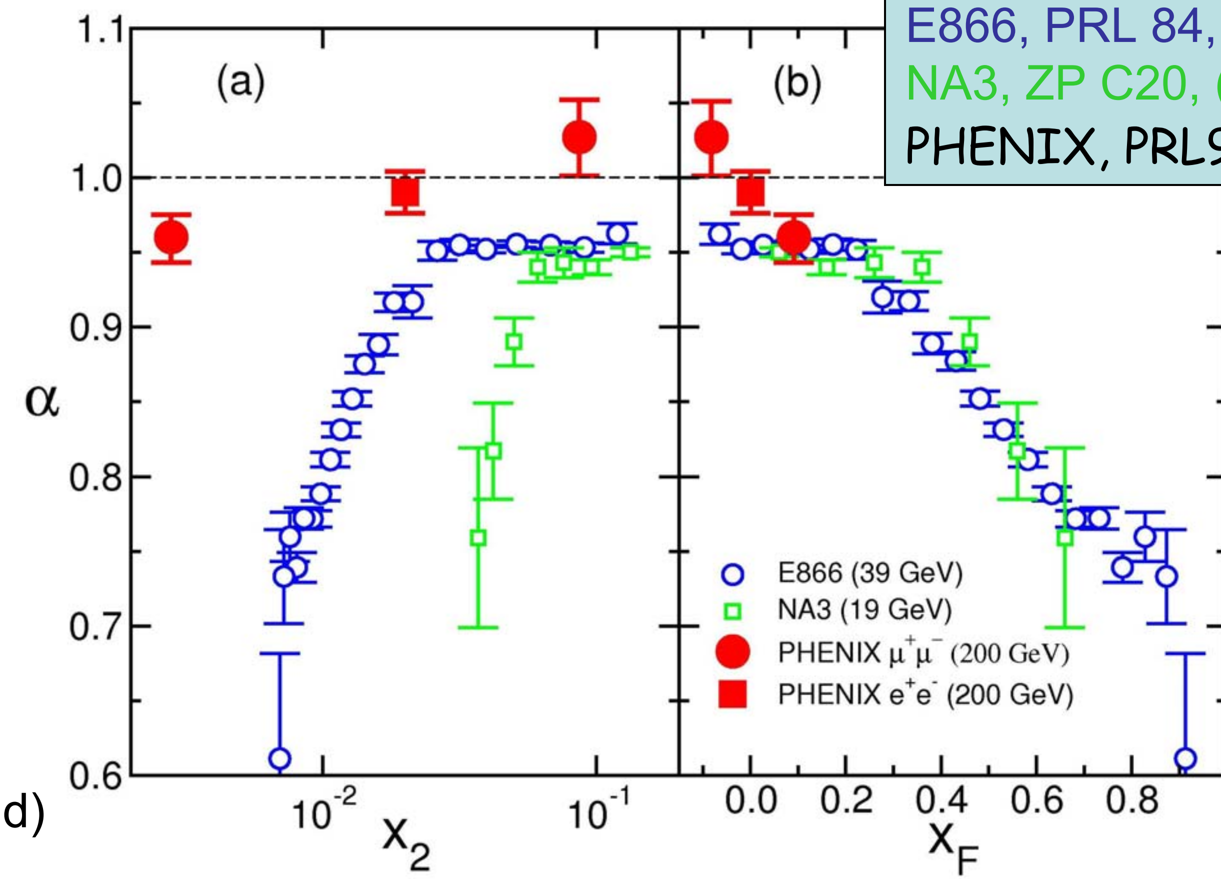
$$R_{AB} = \frac{N_{\psi}^{AB}}{N_{\psi}^{PP} \times \langle N_{coll} \rangle}$$

NA50 versus NA60 (QM05)





α versus X compared to lower $\sqrt{s}$



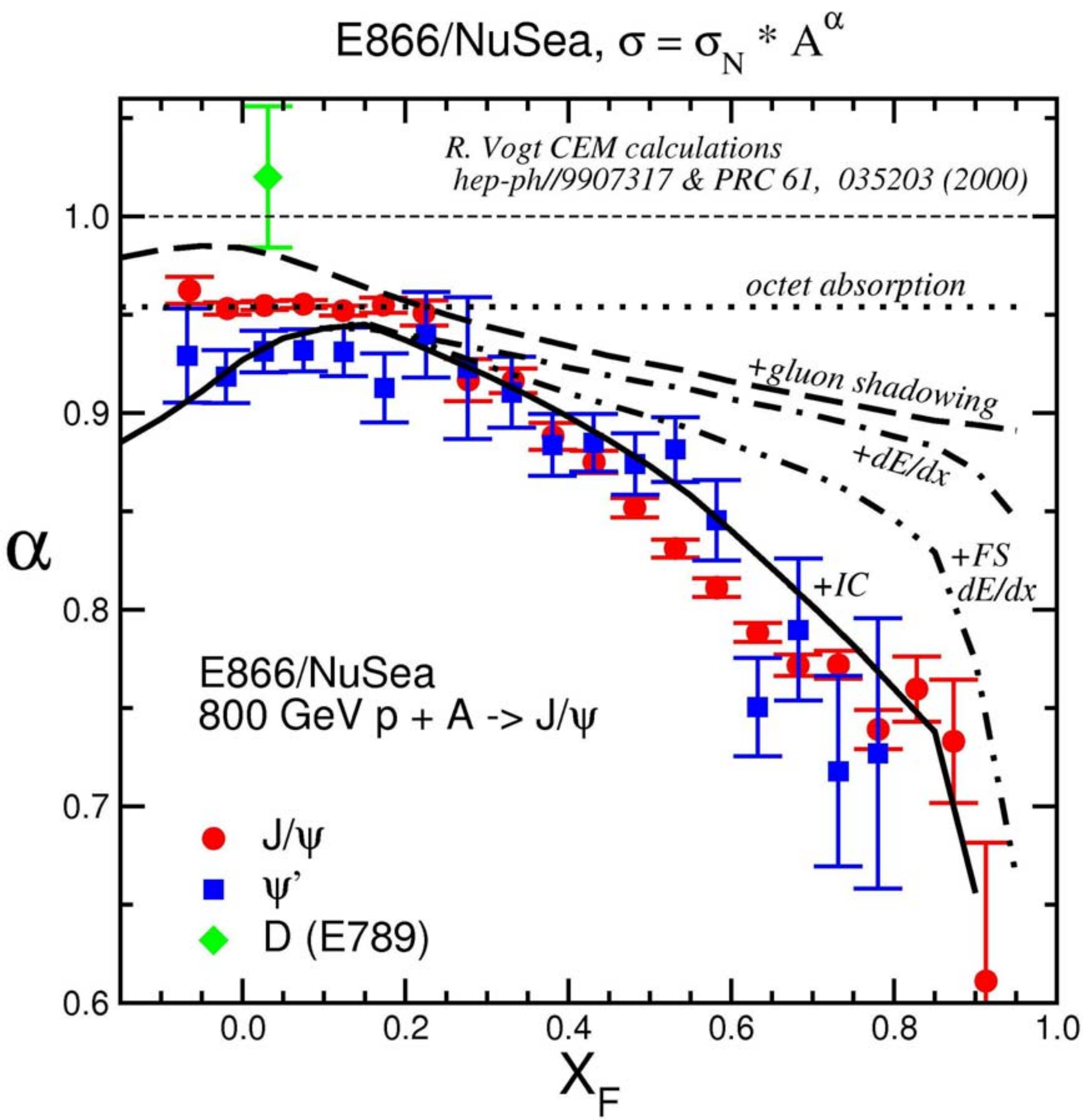
E866, PRL 84, (2000) 3256
NA3, ZP C20, (1983) 101
PHENIX, PRL96 (2006) 012304

X_2 (in gold)

$X_F = X_d - X_{Au}$

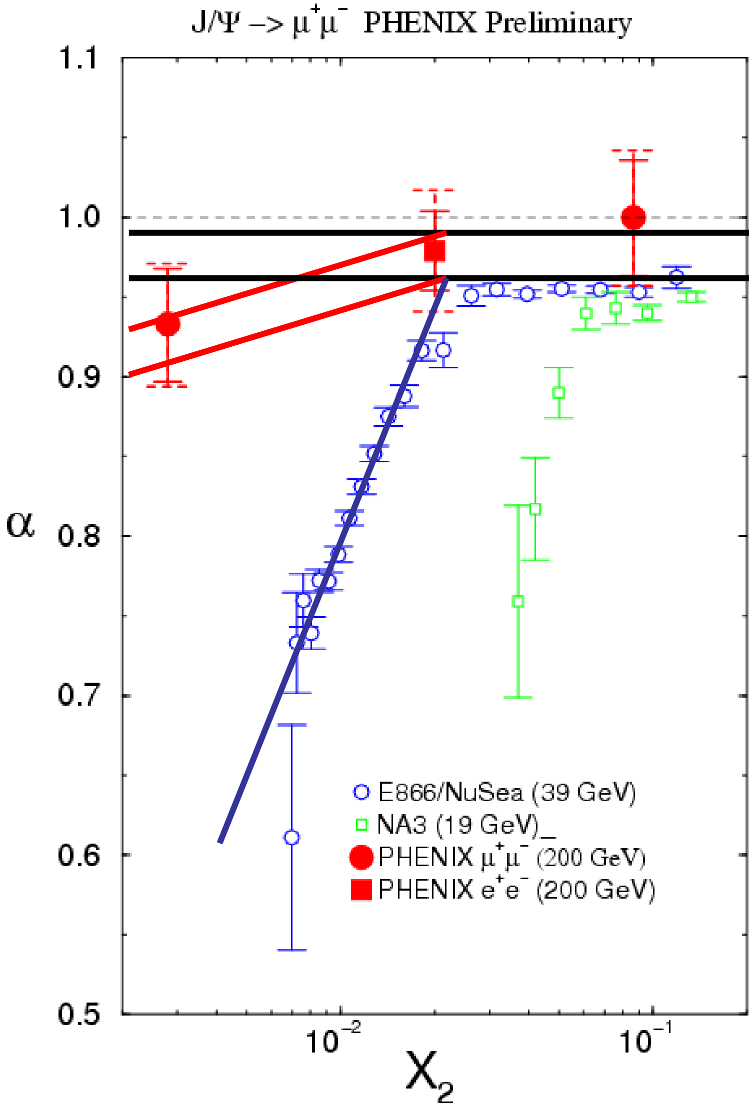
- Not universal versus X_2 : shadowing is not the whole story.
- Same versus X_F for diff $\sqrt{s}$. Incident parton energy loss ? (high X_d = high X_F)
- Energy loss expected to be weak at RHIC energy.

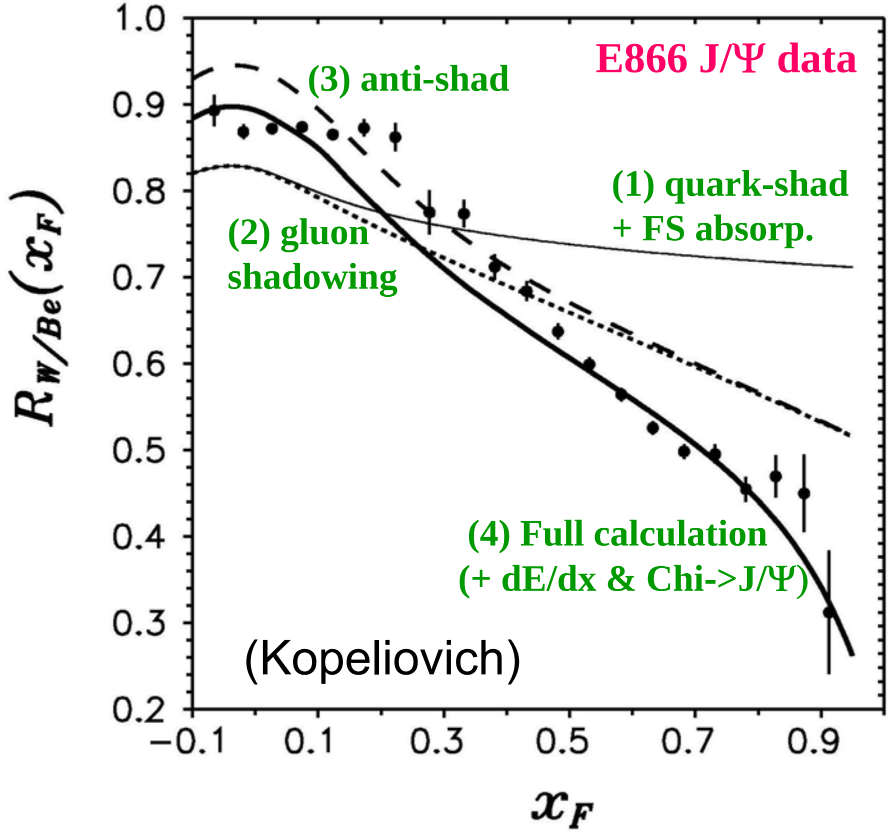
How to get x_F scaling ?



Naive picture

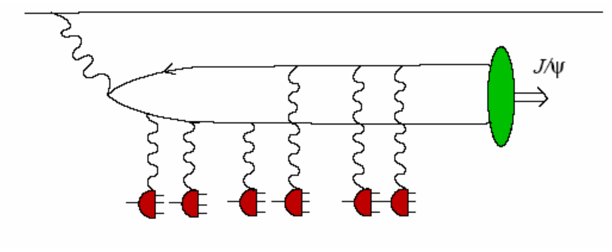
- Less absorption
- Shadowing
- Energy loss

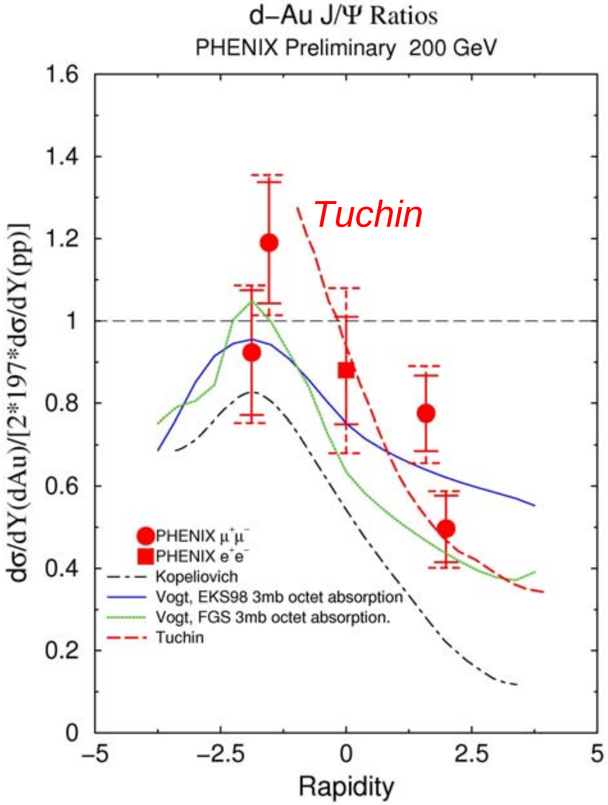




Tuchin & Kharzeev

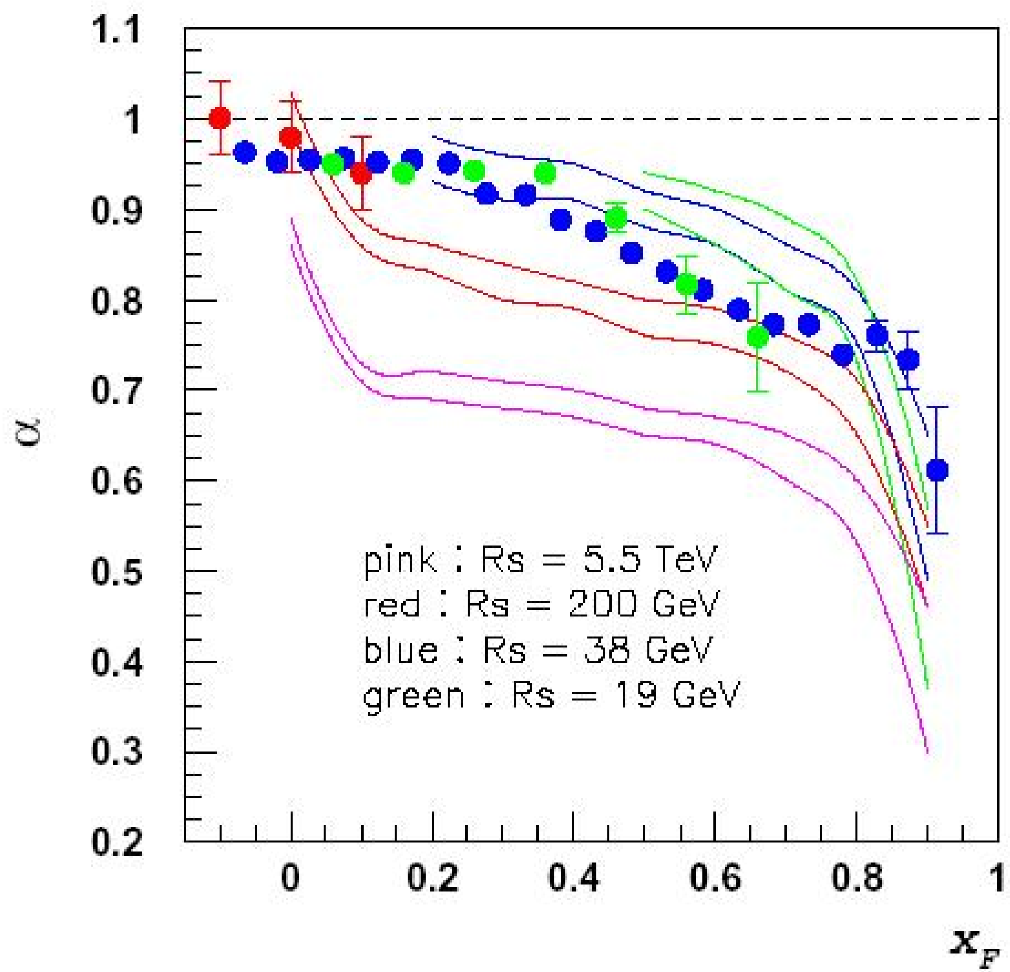
- Hard probes 2004
  - hep-ph/0504133
- Coherent production of charm (open or closed)
  - (y<0 production time to low to make computation)
  - Shadowing from CGC computation…





Tuchin & Kharzeev…

+ absorption for SPS & fermilab



… gold+gold extrapolation …