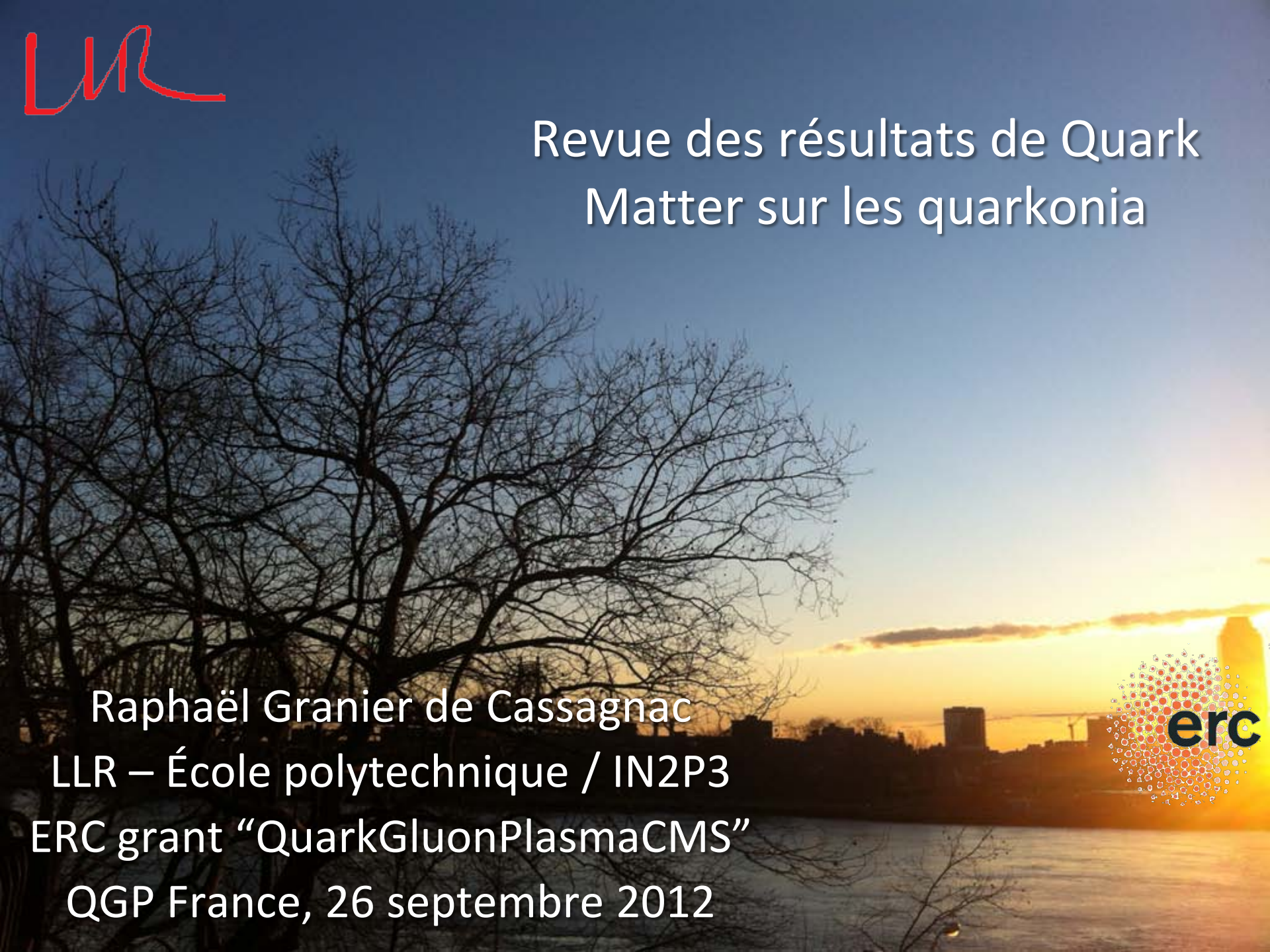


Revue des résultats de Quark Matter sur les quarkonia

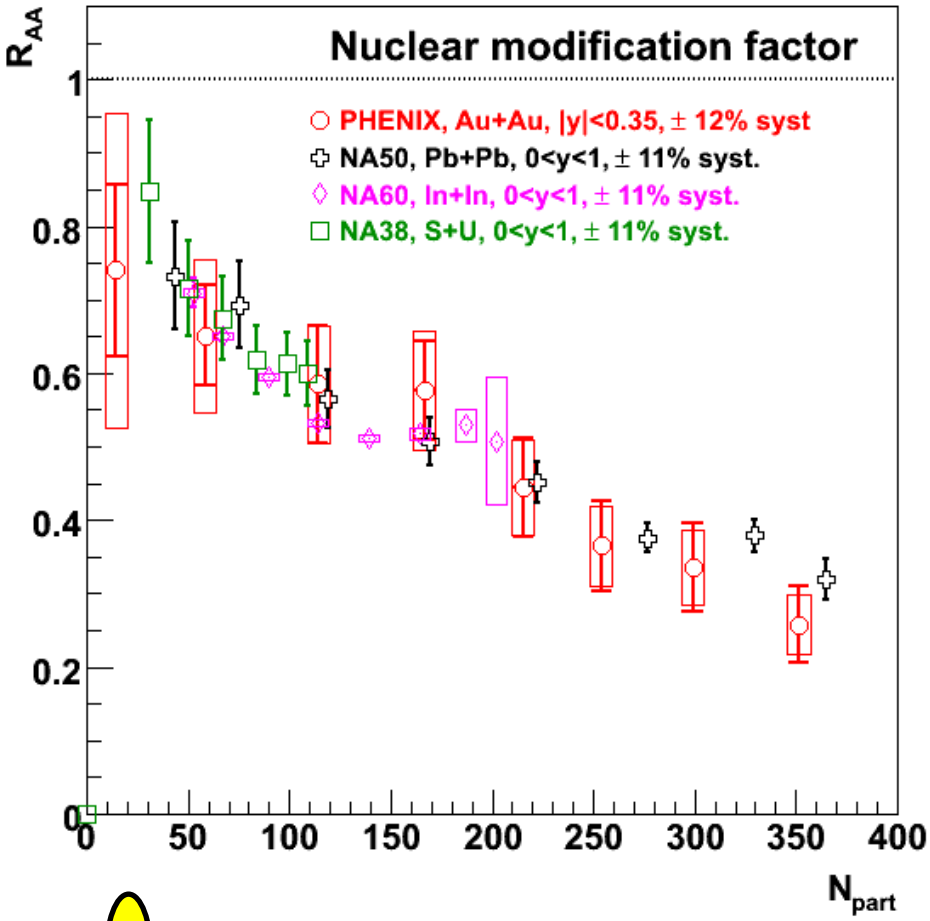
Raphaël Granier de Cassagnac
LLR – École polytechnique / IN2P3
ERC grant “QuarkGluonPlasmaCMS”
QGP France, 26 septembre 2012

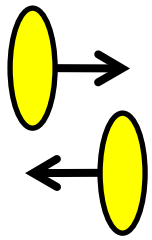
Which Quark Matter?

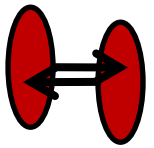
- Lacking instruction, I decided it was 2008!
  - (the quarkonium review speaker is a friend)

J/ψ at RHIC (all p_T)

- Two surprises:
  - At midrapidity, same suppression **at RHIC** and **at SPS**, while density must be higher



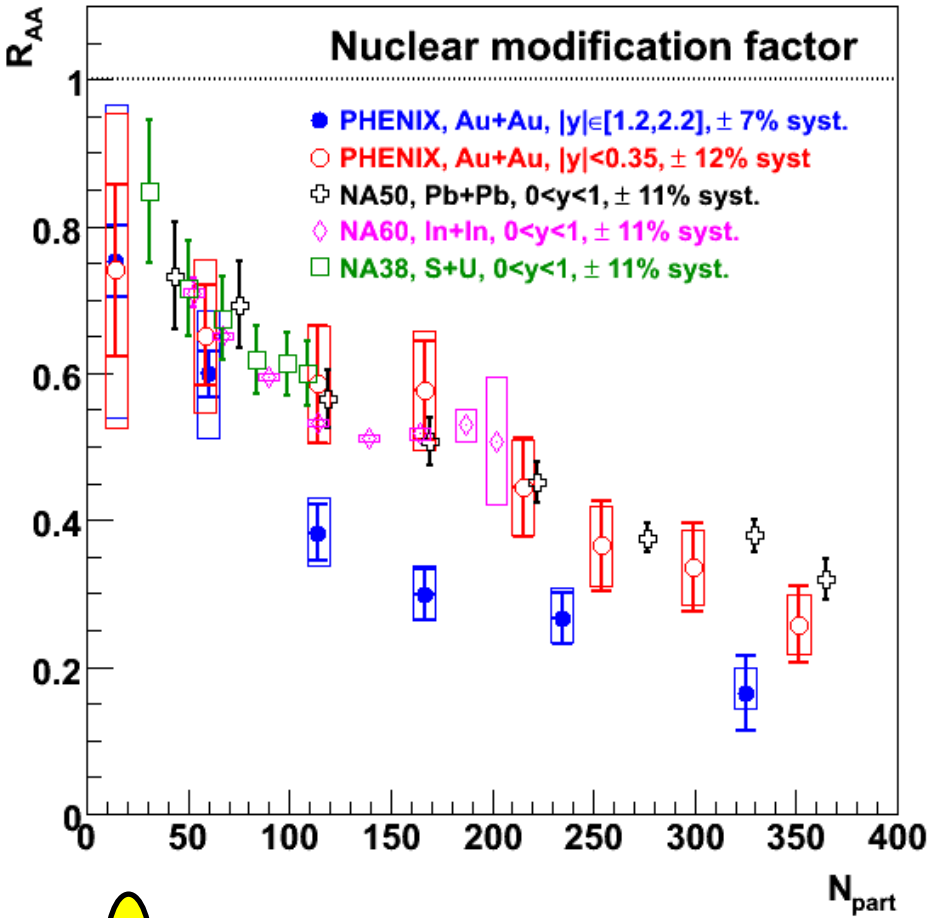


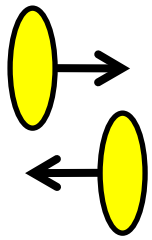


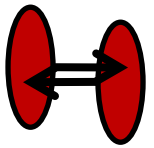
PHENIX, PRL98 (2007) 232301
SPS from Scomparin @ QM06

J/ψ at RHIC (all p_T)

- Two surprises:
  - At midrapidity, same suppression **at RHIC** and **at SPS**, while density must be higher
  - More suppression **at forward rapidity** at RHIC, while density must be lower
- Two popular answers:
  - Cold: shadowing / saturation brings forward yields down
  - Hot: recombination of uncorrelated $c\bar{c}$ brings midrapidity yield up







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

How to move forward experimentally ?

1. Be more open? (Measure cc to constrain regen.)
2. Calm down? (Better pA/dA reference)
3. Broaden interest? (in transverse momentum)
4. Let it flow? (elliptically)
5. Get excited? (ψ', χ_c)
6. Get high? (in mass, looking at upsilons)
7. Be upset? (and search for onset)
8. Give up? And move to the LHC?

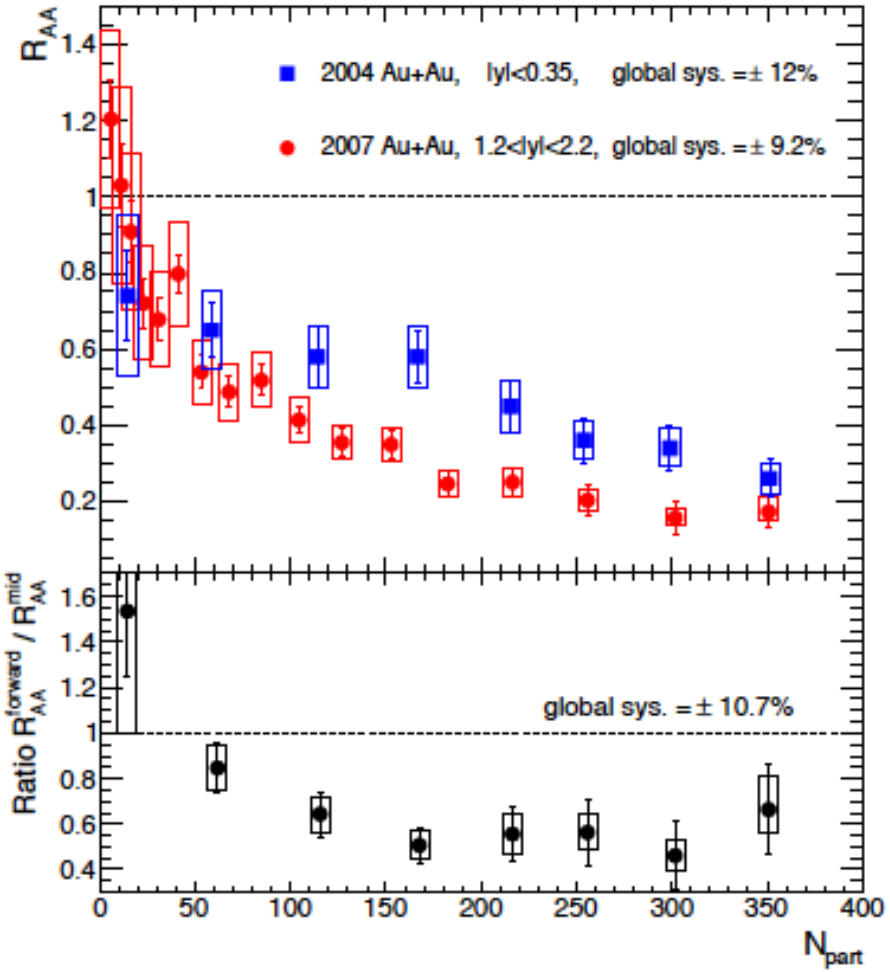
Some progress on all these points at this meeting !

Which Quark Matter?

- Lacking instruction, I decided it was 2008 !
  - (the quarkonium review speaker is a friend)
- Let's see how it has evolved in 2012 !
  - (sorting results according to the 8 points)
  - (trying to focus on RHIC, since 4 next talks are on LHC, but well, you know…)

Modern version of the QM'08 PHENIX plot

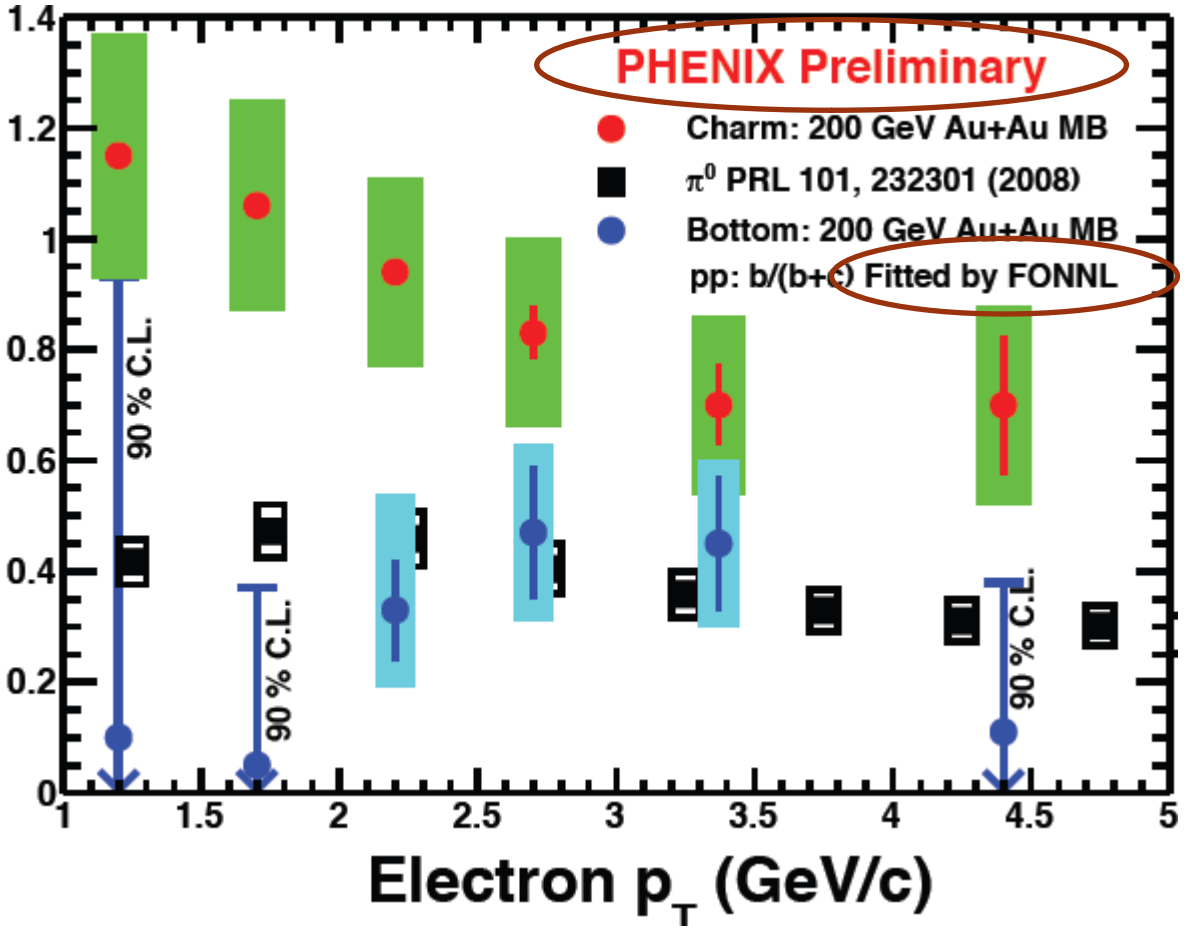
- 40% more suppression in the forward region…

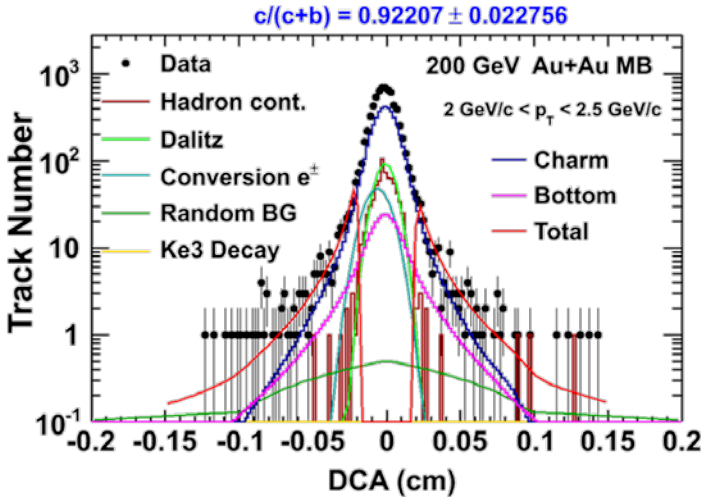


PRC84 (2011) 059412

1. Be more open, very open indeed…

PHENIX pretends that b's are more suppressed than c's
based on displaced electrons measured by the new VTX detector…
We are still far from knowing how many cc pair we have in PbPb…

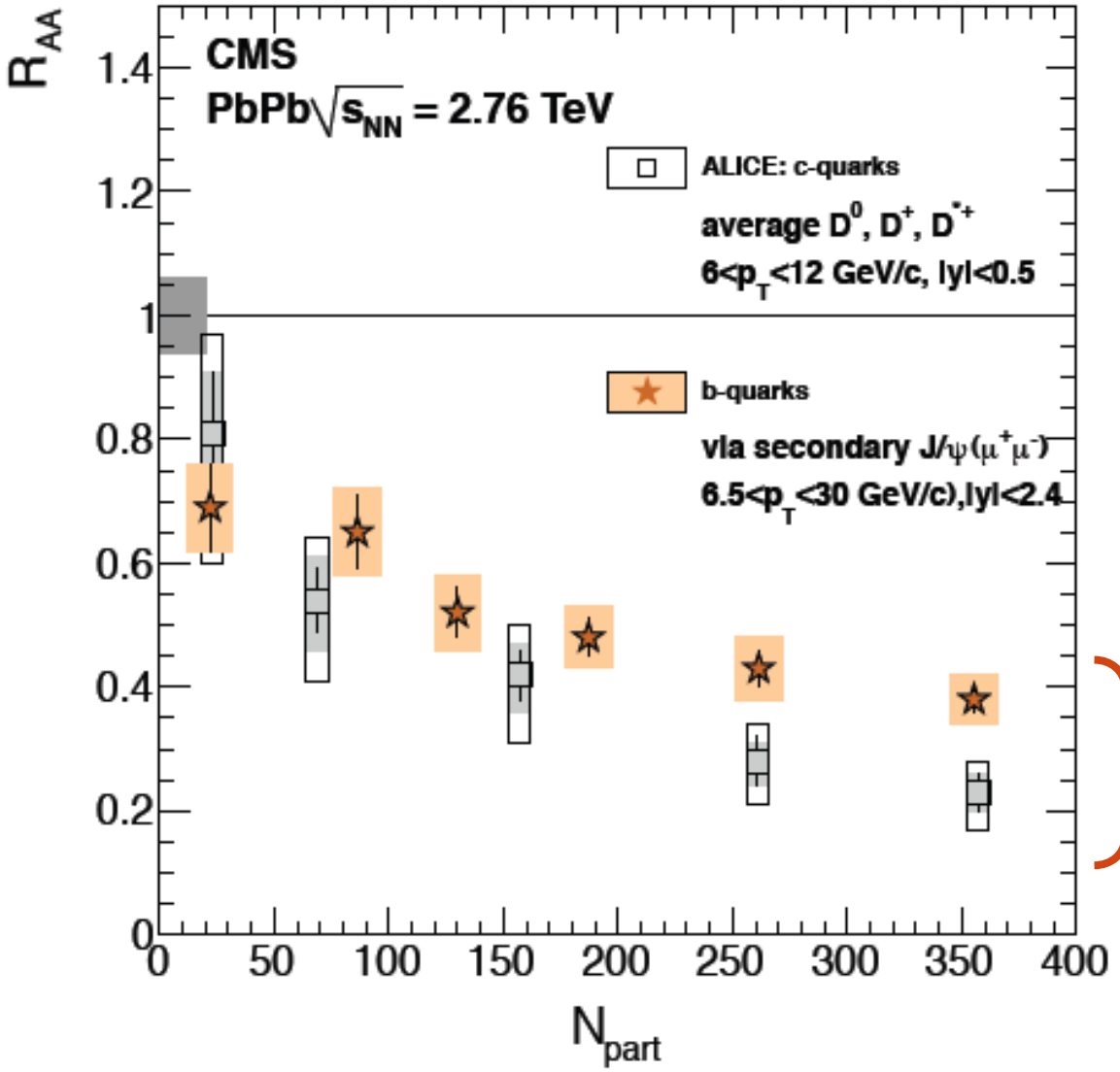




Nouicer @ QM
See Zaida @ Etretat

Still, typical numbers:
σ(cc) ≈ (0.8 ± 0.2) mb in
x 1065 / 42 mb ≈ 20 pairs

… while LHC is kind with us



Plenary talks @ QM
by Zaida (ALICE)
and Camelia (CMS)
See Zaida @ Etretat

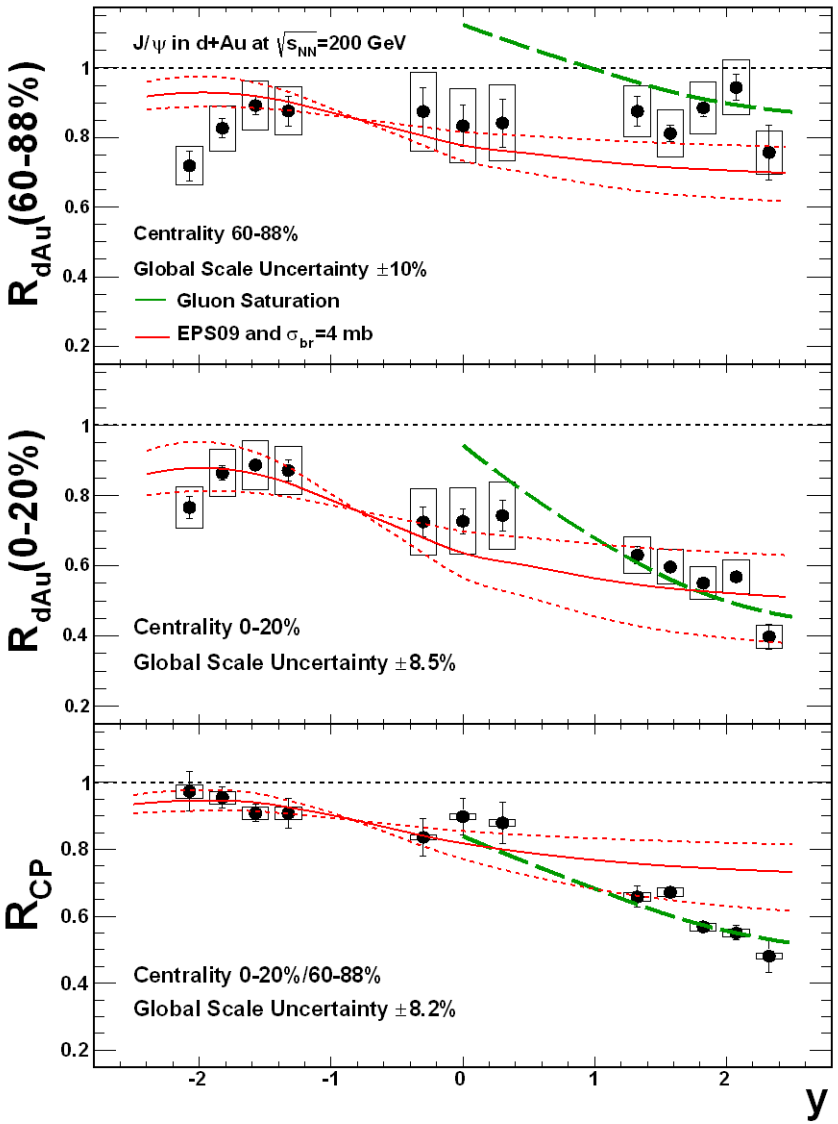
Several D's from Alice
B → J/ψ from CMS

At LHC, we can
forget mixing flavours…

"There is order!"

σ(cc) ≈ 5 mb in pp@2.76 TeV
x 1500 coll / 65 mb ≈ 115 pairs

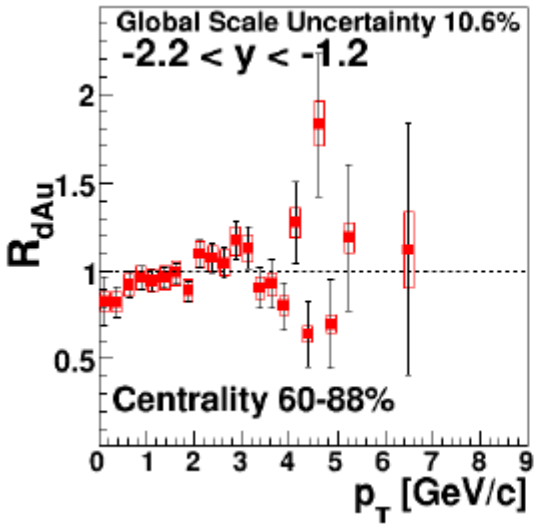
2. Calm down, better dA reference

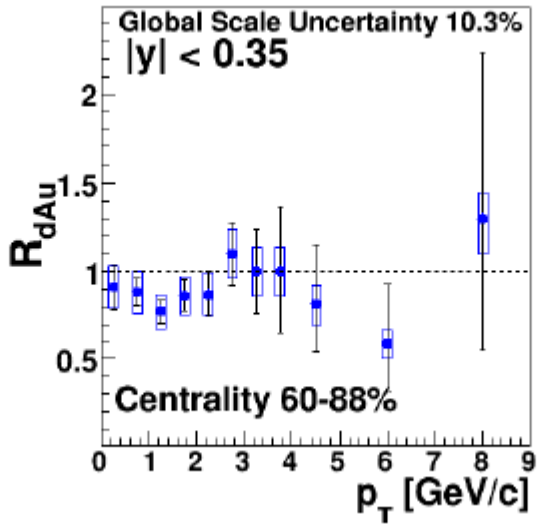


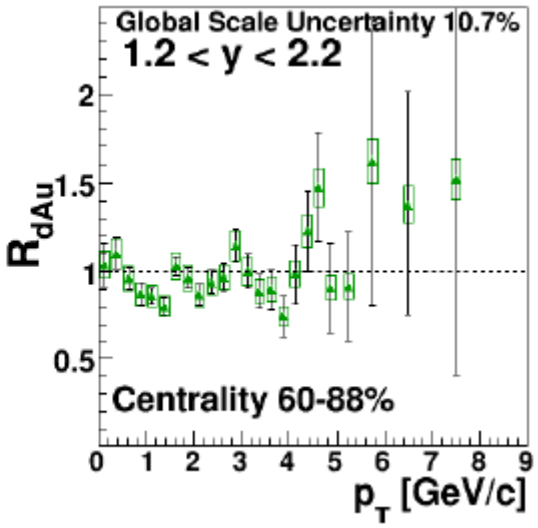
- It came, and is difficult to understand
- nPDF + unique break-up cross section does not work
- Still, the negative/positive rapidity difference goes towards explaining AuAu

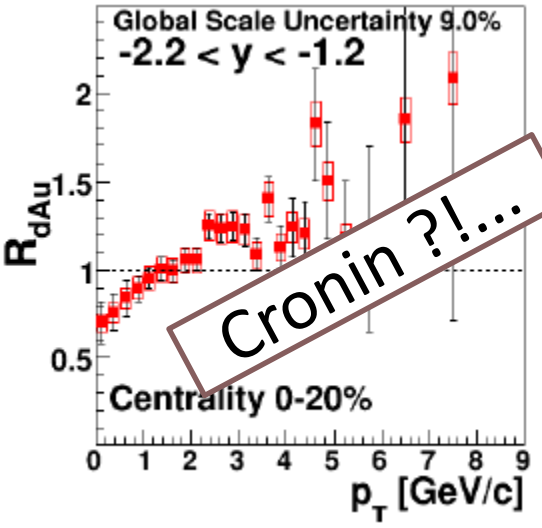
Wysocki, McGlinchey @ QM
PRL 107 (2011) 142301

2.5 Calm down + broaden interest (p_T)

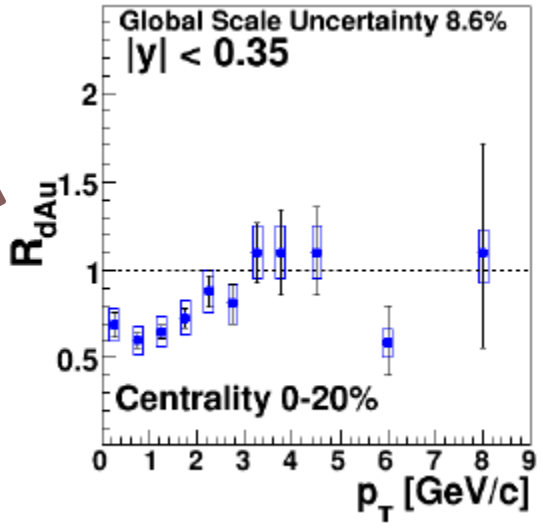


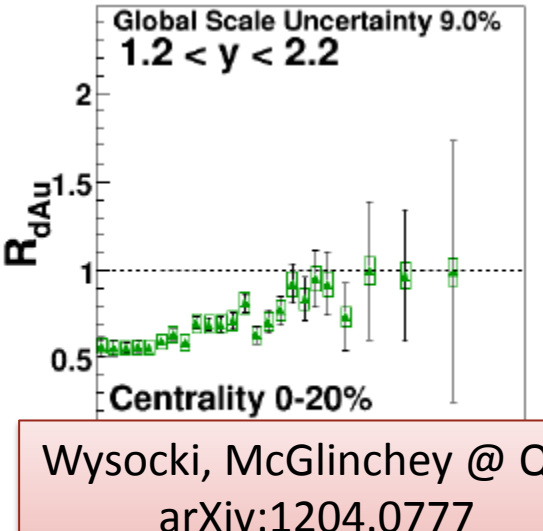






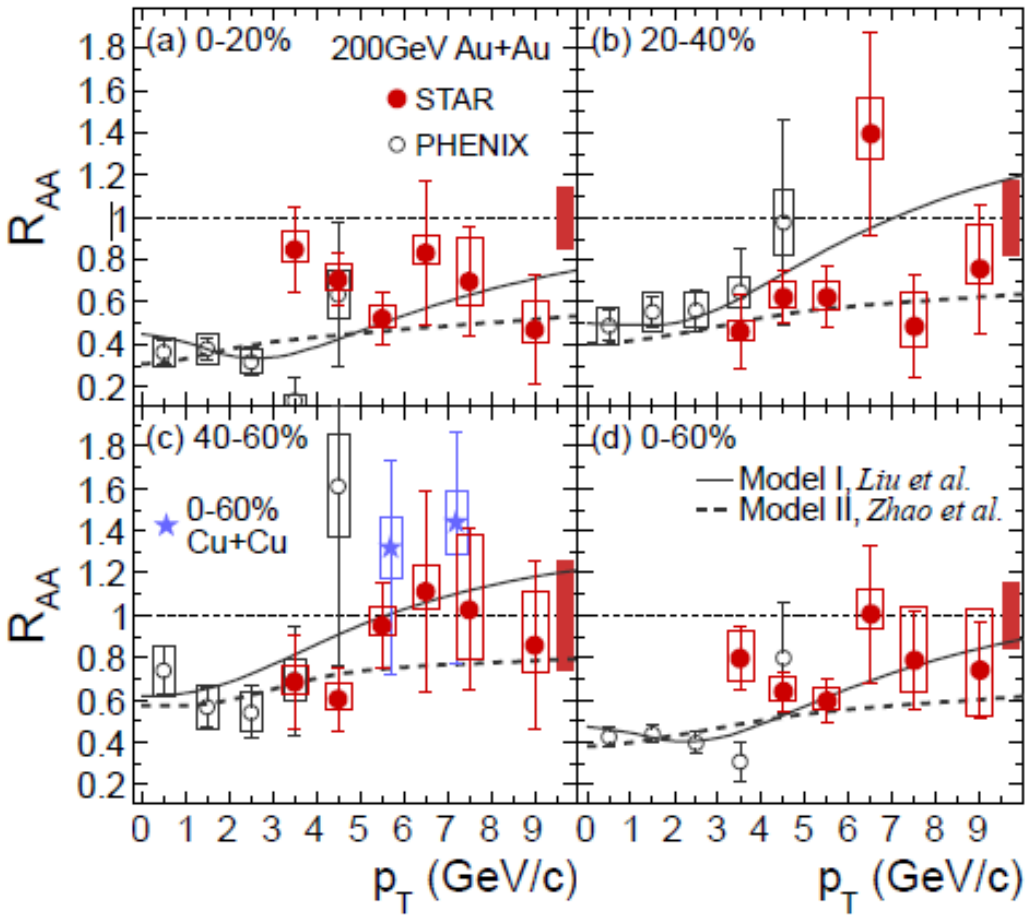
Cronin ?!...





Wysocki, McGlinchey @ QM
arXiv:1204.0777
(also in STAR, less stat)

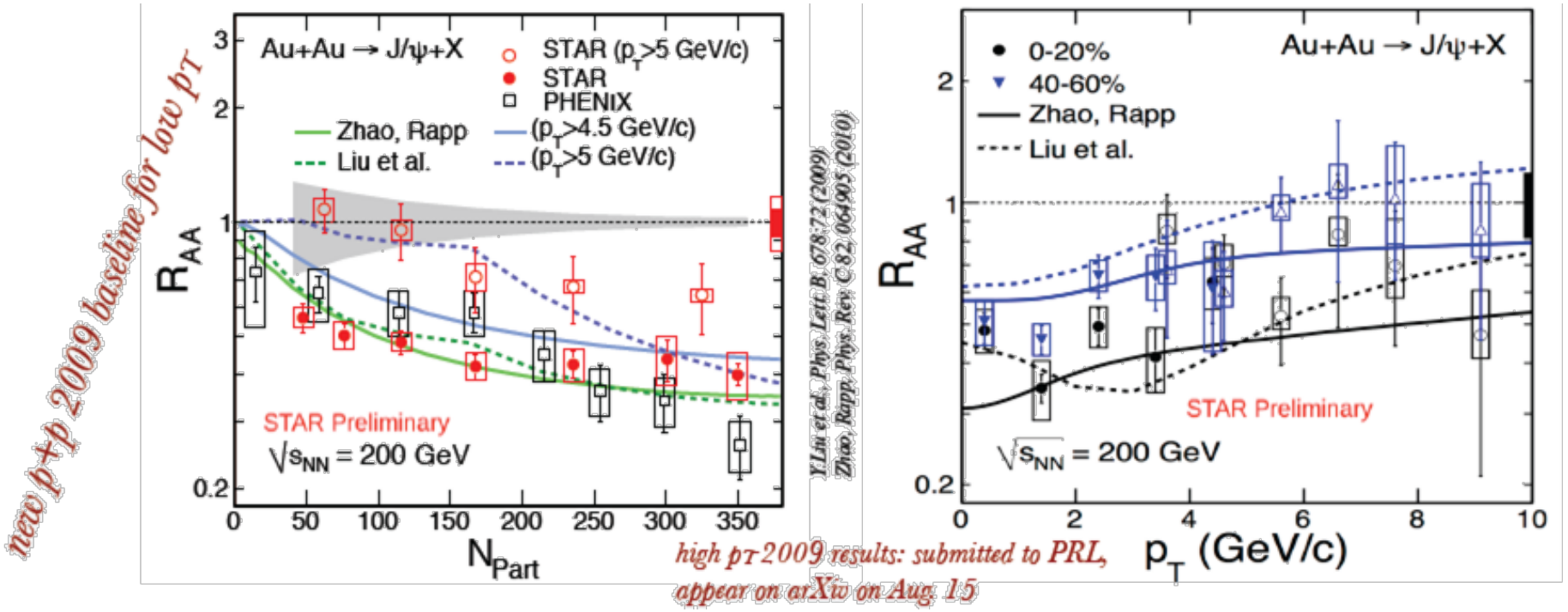
3. Broaden interest (in p_T)



Trzeciak, Xie @ QM
arXiv: 1208.2736

- Less suppression at high p_T @ RHIC
- Not clear why
  - Formation time?
  - Great escape?
  - Cronin?

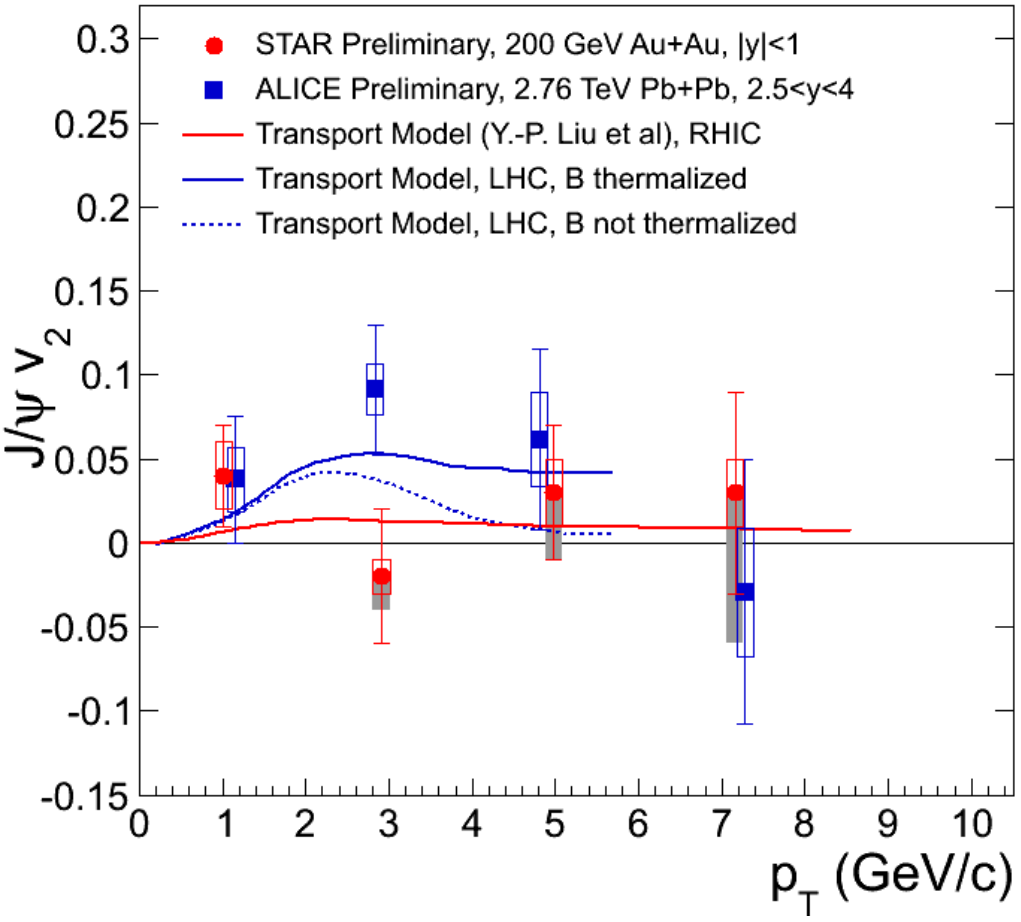
(Side note: BTW, STAR goes to low p_T too)



Trzeciak @ QM
arXiv: 1208.2736

4. Let it flow (elliptically)

- If produced via regeneration, J/ψ should somewhat inherit the (large) flow of charm quarks
  - (though predictions range from 0.05 to 0.15 for RHIC…)
- Agreement between STAR and ALICE
  - But no flow in STAR
  - Hint of flow in ALICE

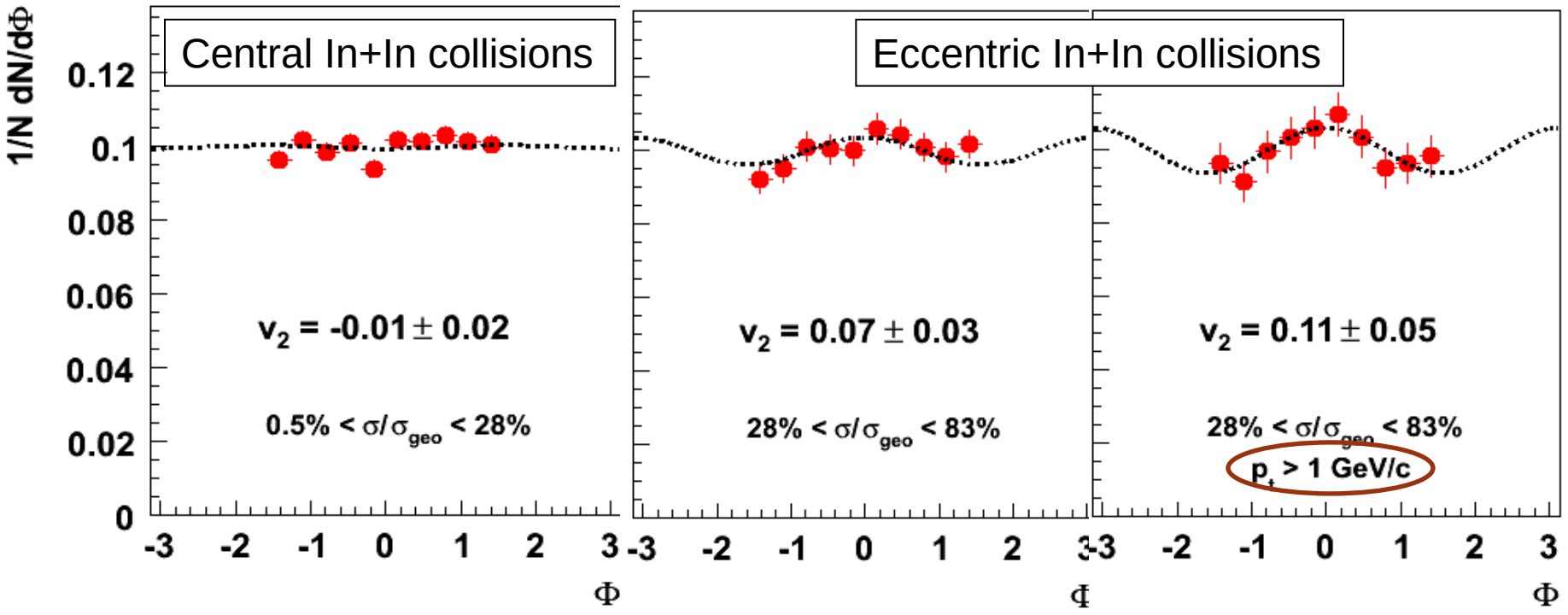


Xie, Scomparin, Ruan @ QM
Hongyan @ QM & Etretat

Let if flow from SPS to LHC

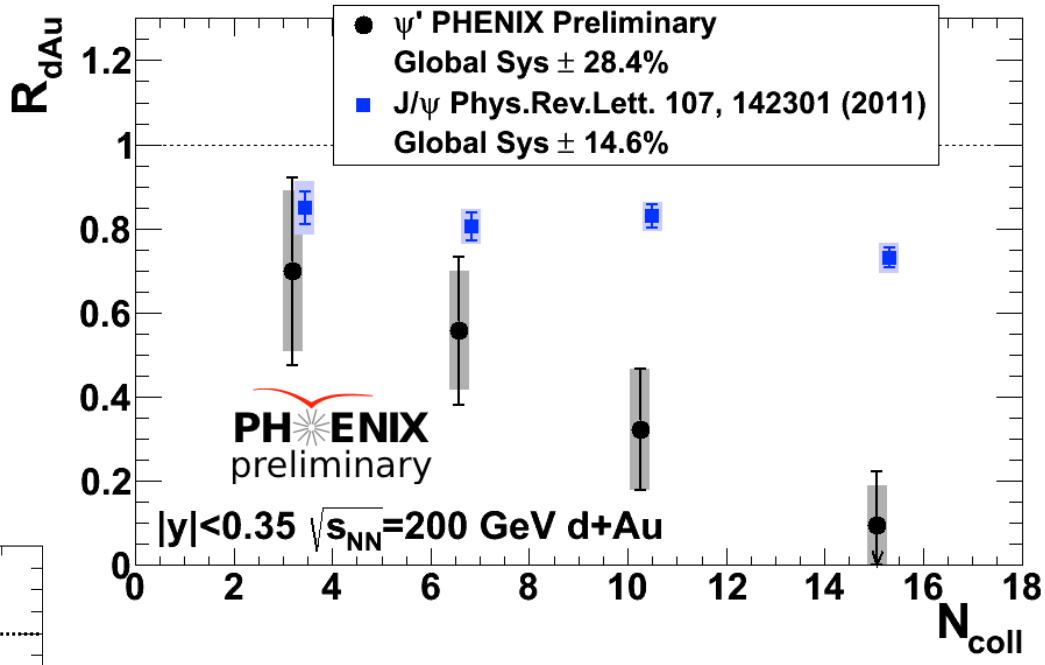
- Hint of flow in ALICE…
- … but also at SPS (2σ level)
- Missing high precision data

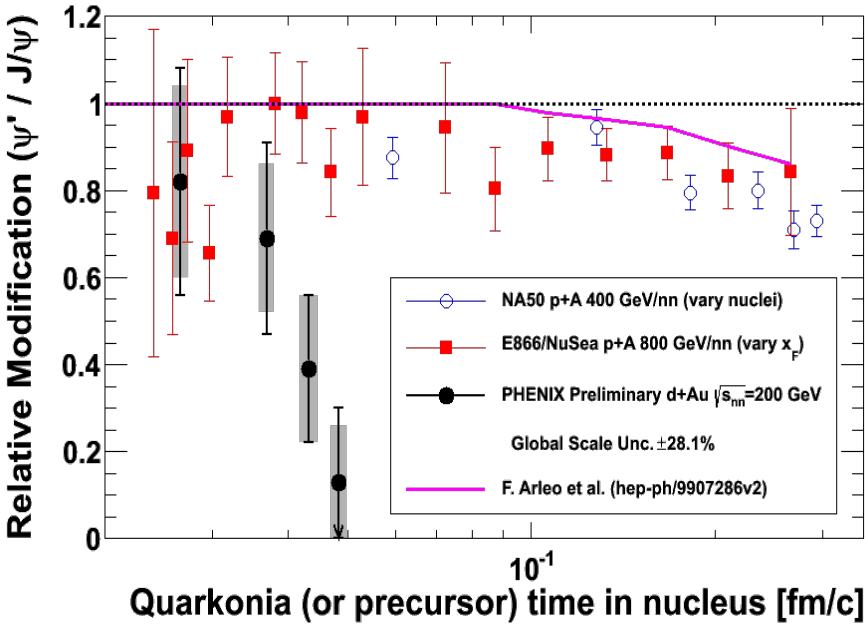
Arnaldi @ QM08



5. Get excited, about ψ' @ RHIC

- No AuAu results…
- But an enormous suppression in dAu
- Such effects already seen at SPS in various pA but much smaller

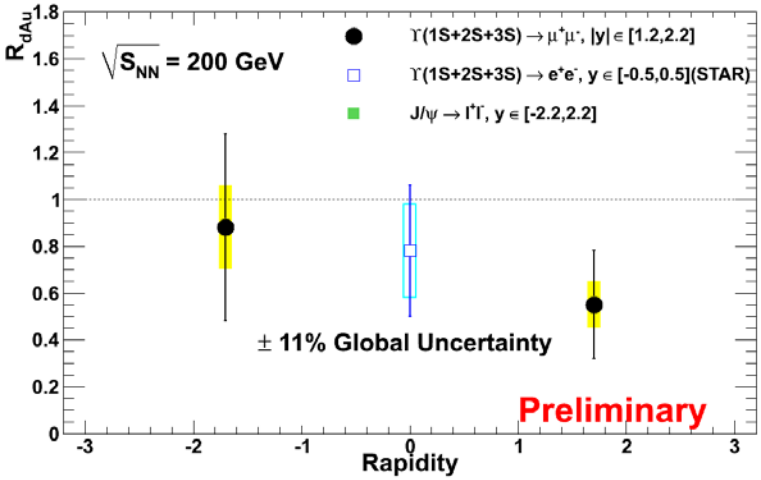


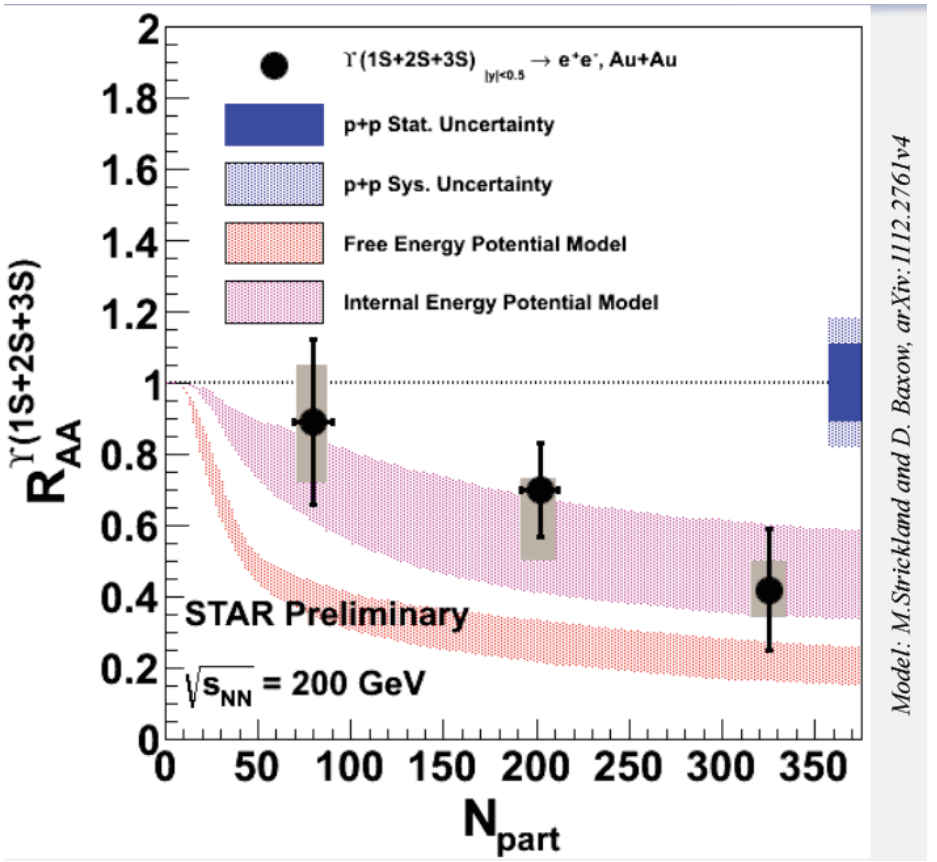


McGlinchey, Wysocki @ QM

6. Get high (in mass, look at Upsilon)

- A few (unseparated) Upsilon @ RHIC, show some suppression



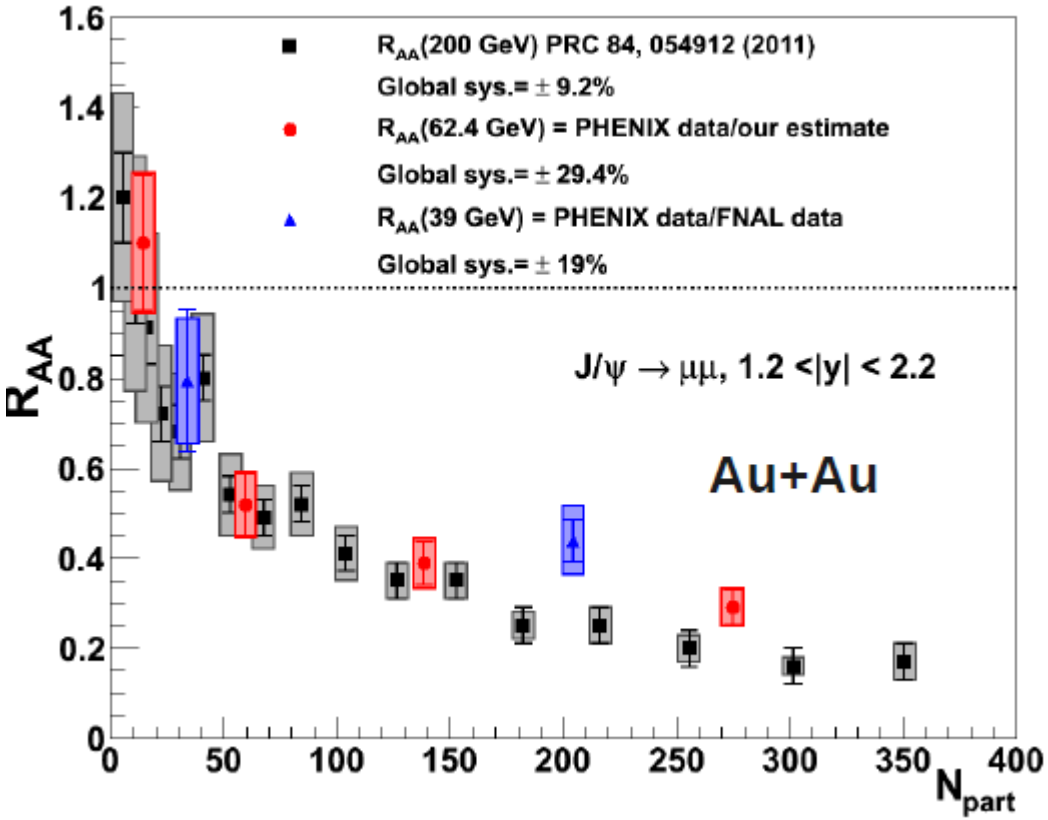


= move to CMS ☺

Xie, Trzeniak, Ruan @ QM

7. Be upset (search for onsets)

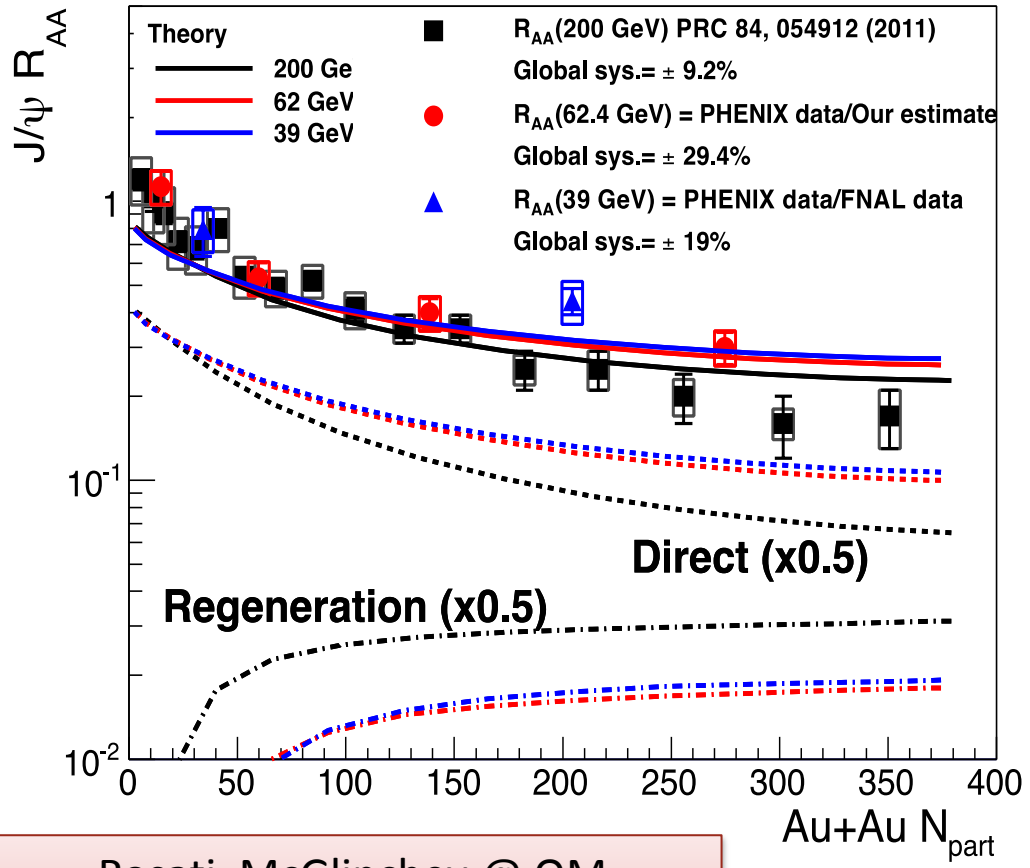
- Energy scan!
- Suppression is similar at 39 and 62.4 GeV…
  - (forward rapidity)



Wysocki, McGlinchey @ QM
PHENIX, arXiv:1208.2251

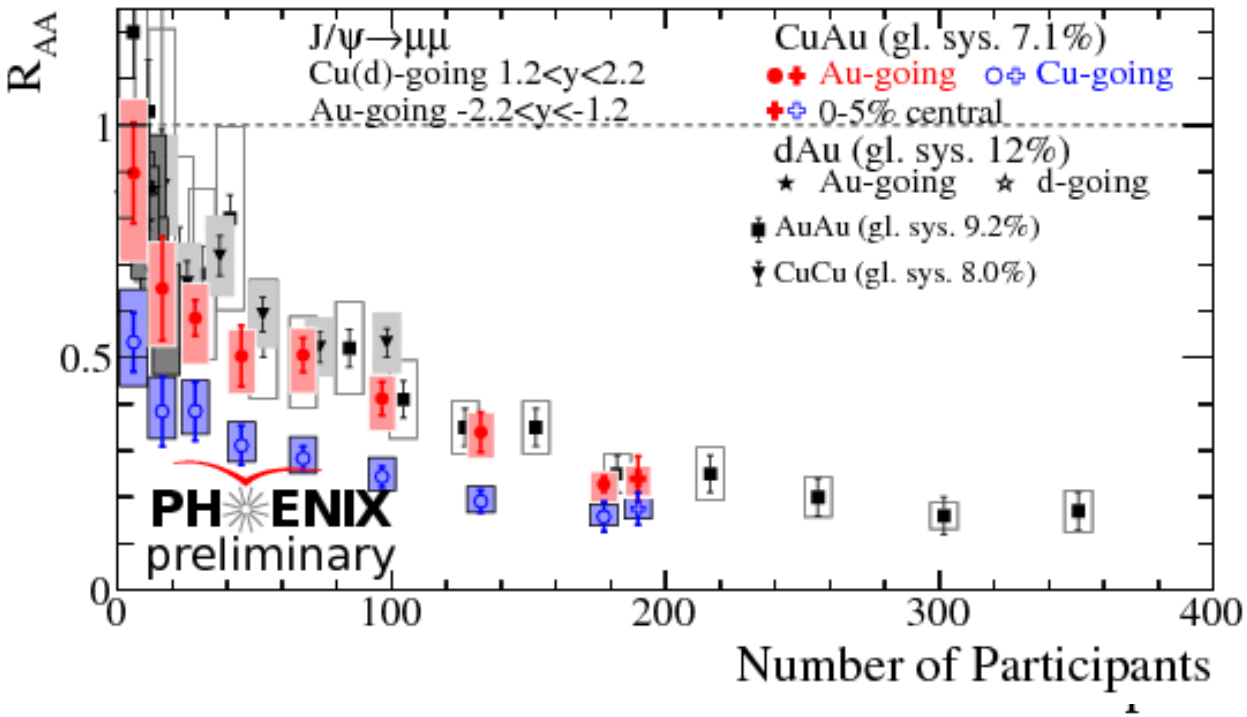
7. Be upset (search for onsets)

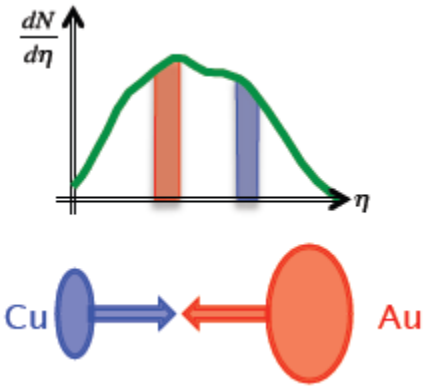
- Energy scan!
- Similar suppression at 39 and 62.4 GeV…
- Could apparently arise from a mix of suppression and regeneration…



Rosati, McGlinchey @ QM
PHENIX, arXiv:1208.2251
Zhao & Rapp, PRC82 (2010) 064905

J/ψ in Cu+Au @ RHIC

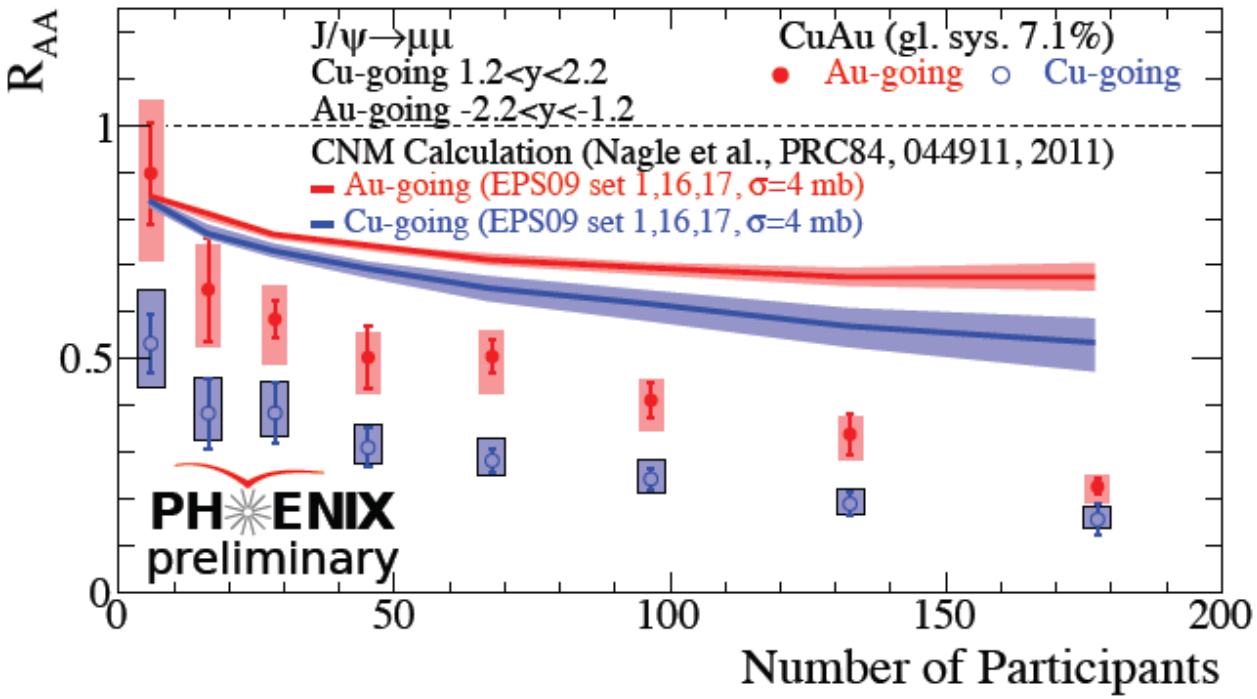


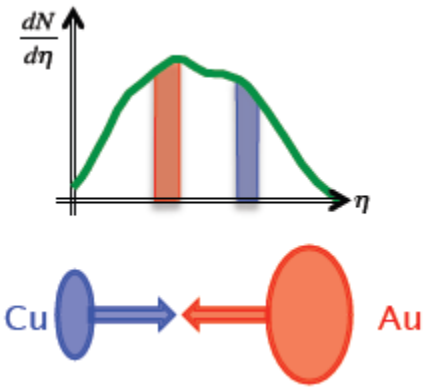


- Same suppression as AuAu or CuCu in the Gold going direction
  - (if plotted vs N_{part})
- More suppression in the Copper going direction

Rosati, Hollis @ QM

J/ψ in Cu+Au @ RHIC





- Same suppression as AuAu or CuCu in the Gold going direction
  - (if plotted vs N_{part})
- More suppression in the Copper going direction
- Qualitatively expected from shadowing (lower x in the Au)
- Quantitatively? Look in the peripheral region…

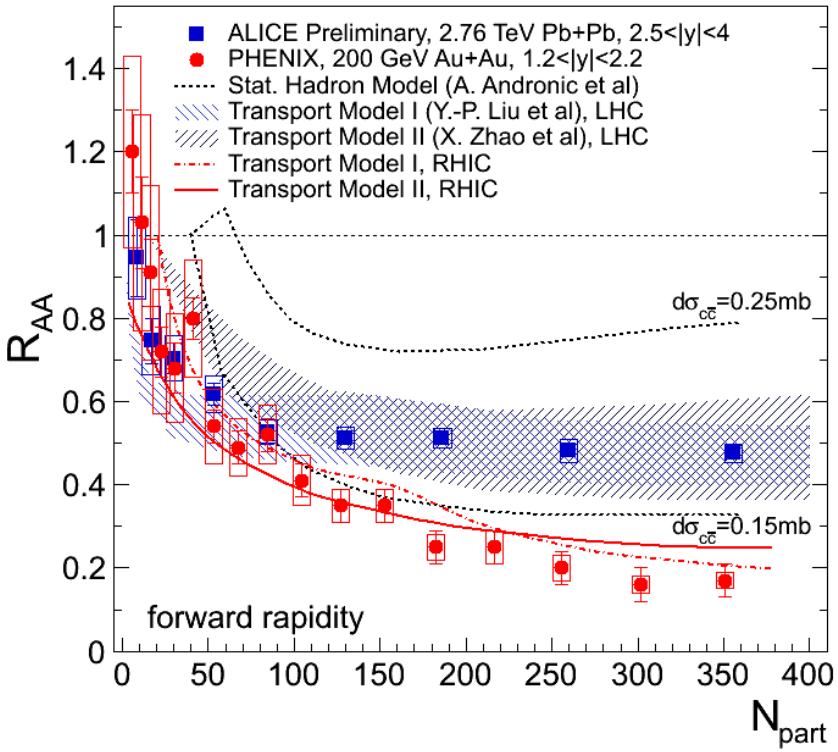
Rosati, Hollis @ QM

8. Give up, and move to the LHC

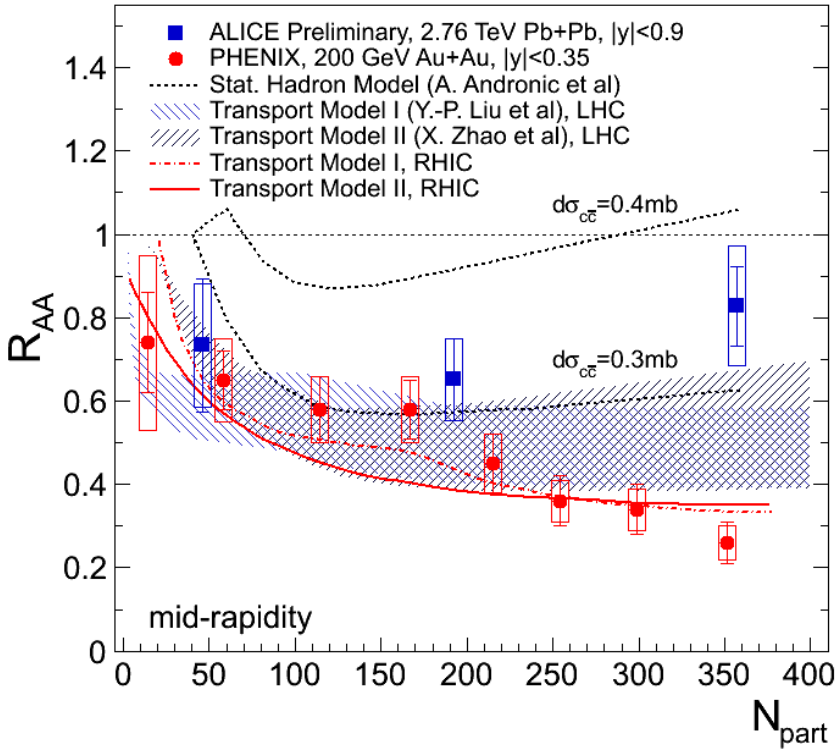
- At RHIC, though it is clear that J/ψ are suppressed beyond cold nuclear matter effects, the detailed (interplay of) mechanisms are not understood
- More luck at the LHC?

Low p_T J/ψ less suppressed @ LHC

Forward rapidity



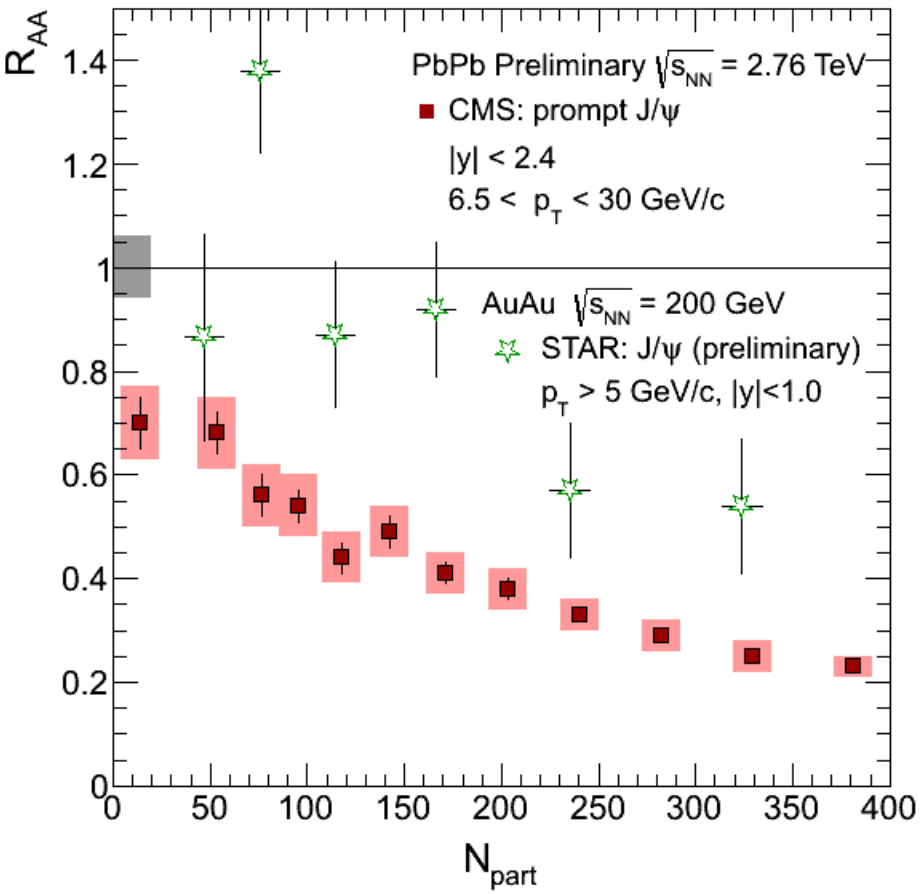
Mid rapidity



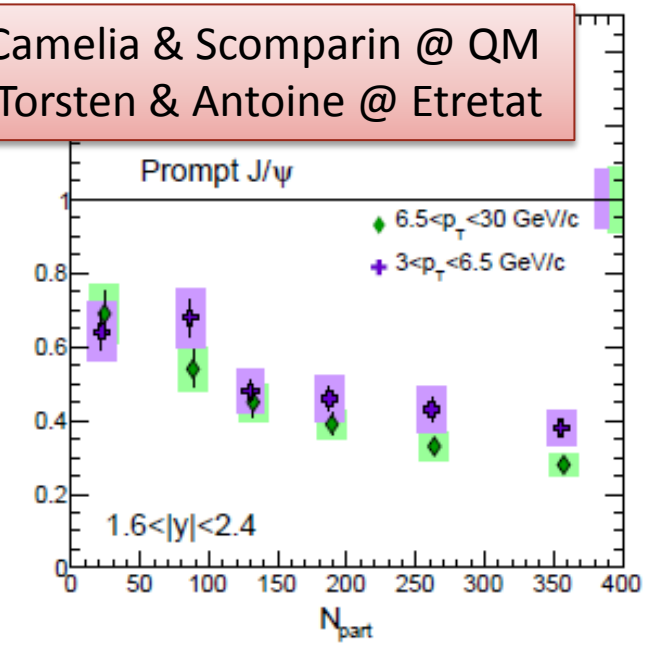
Less suppressed than at RHIC, in particular at mid-rapidity…
Probably due to regeneration !

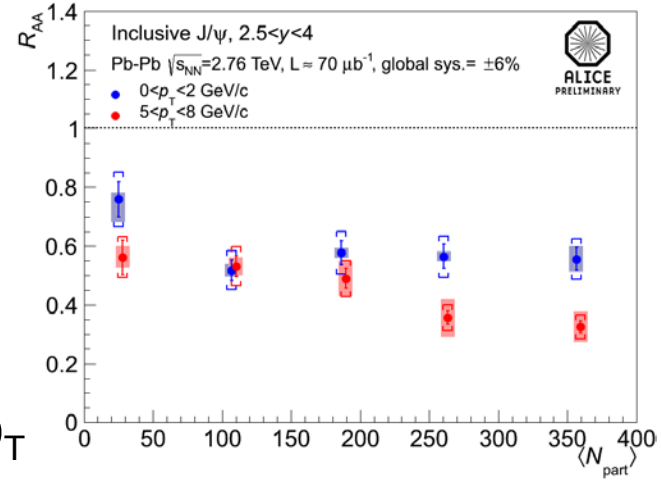
Scomparin, Arnaldi & Arsene @ QM
Lizardo & Antoine @ Etretat

High p_T J/ψ more suppressed than at RHIC



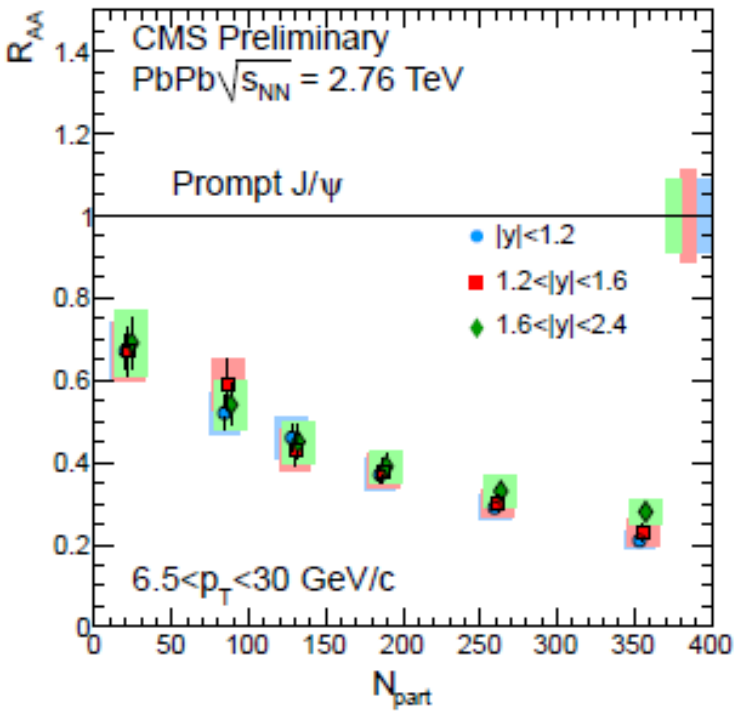
Camelia & Scomparin @ QM
Torsten & Antoine @ Etretat

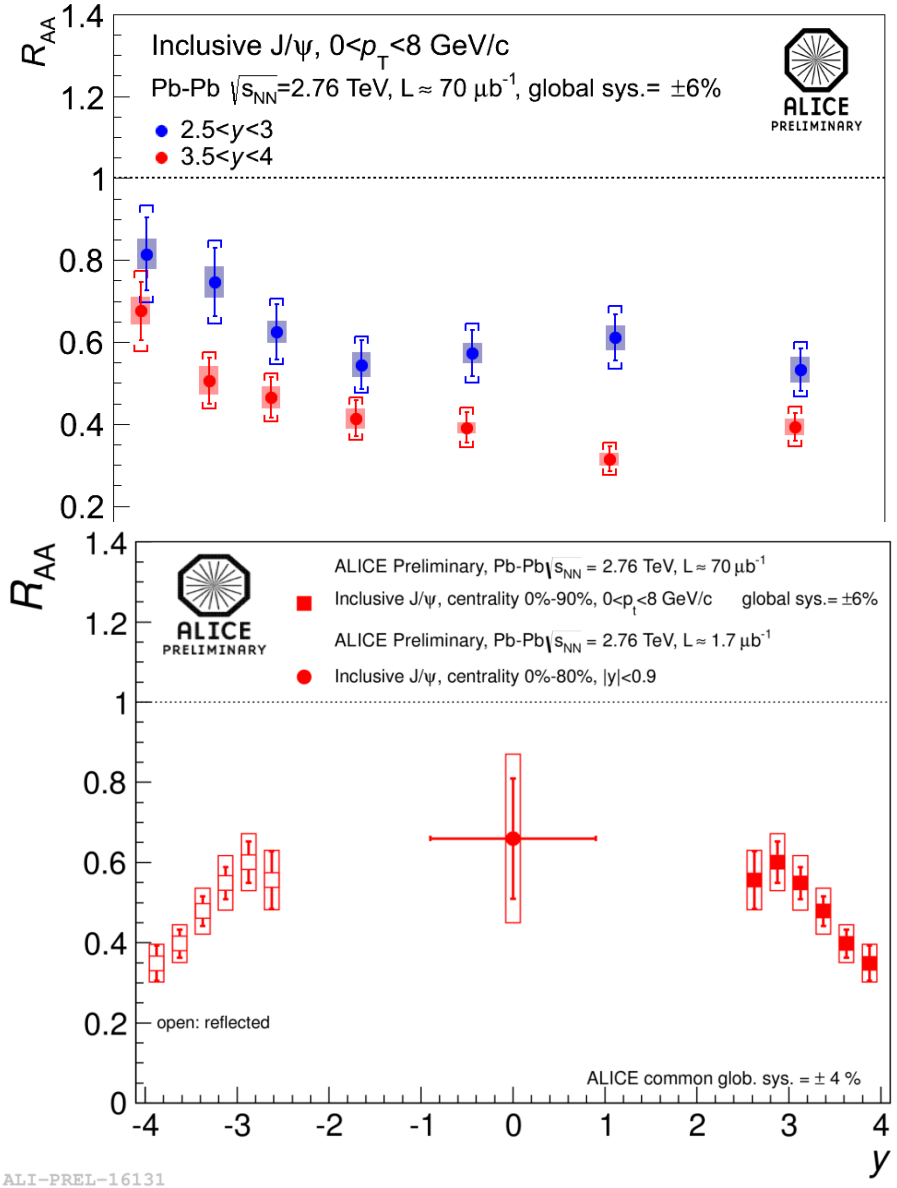




More data, more differential measurement
Alice & CMS seeing more suppression at higher p_T

Rapidity dependence



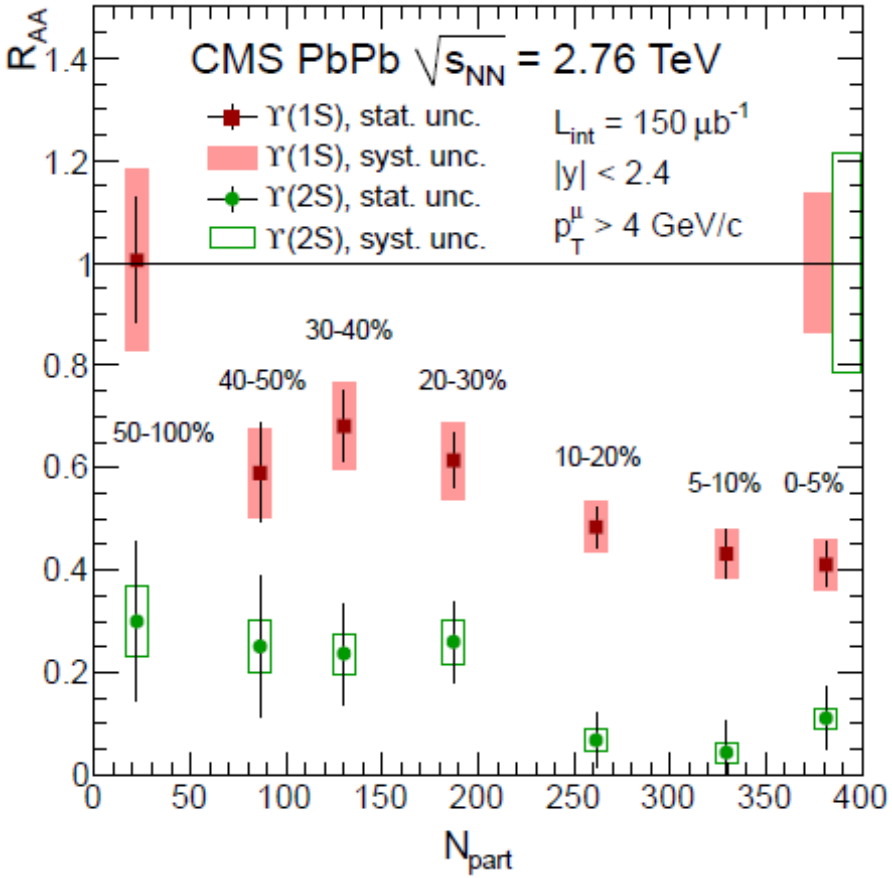


CMS: not much dependence, high p_T
ALICE: more suppression in the most forward (aka the return of the RHIC)

Camelia & Scomparin @ QM
Torsten & Lizardo @ Etretat

Upsilons

Upsilon(1S) and (2S) at LHC



Sequential disappearance of the 3 states

For minimum bias

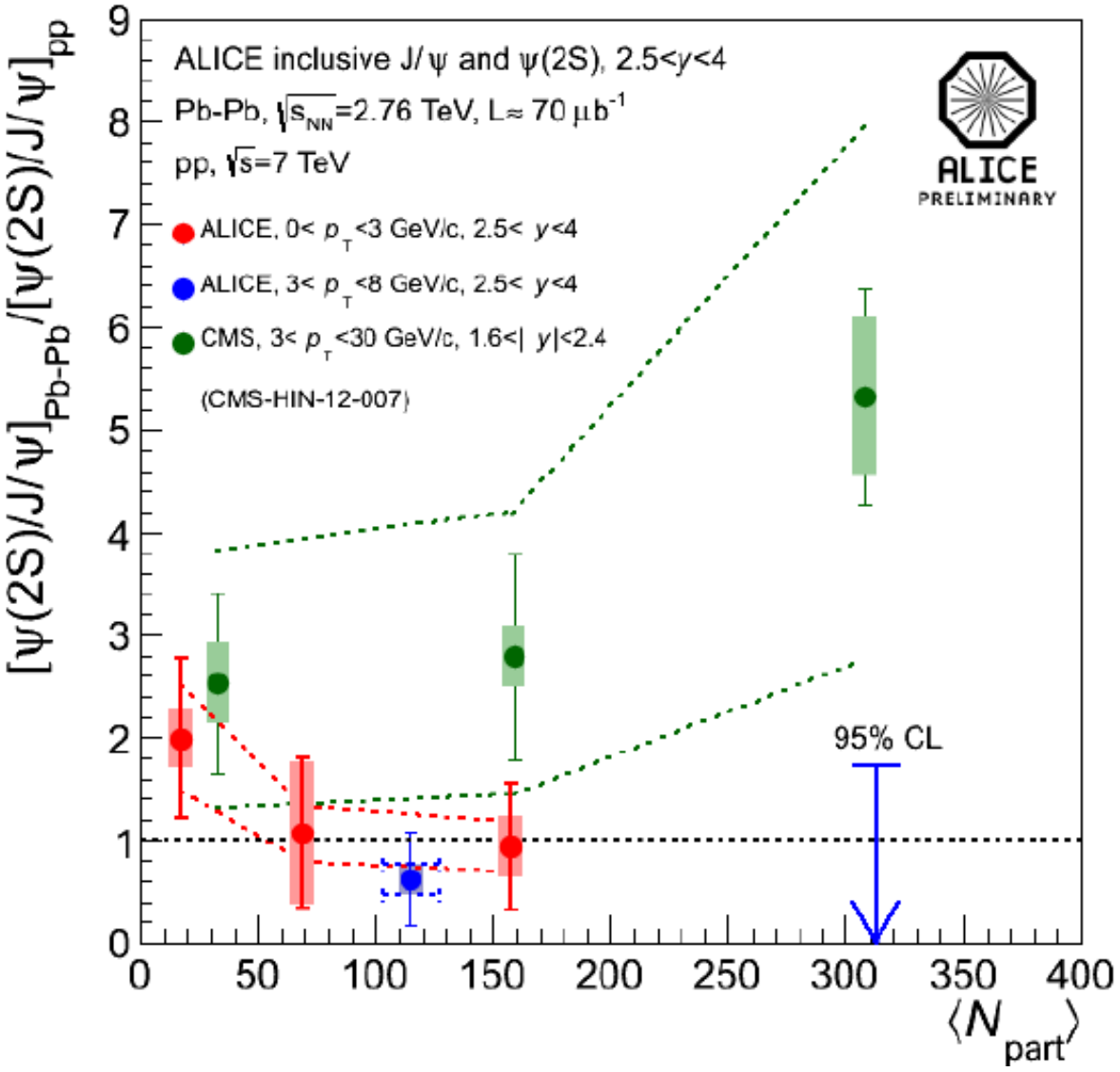
R_{AA} (Y(1S)) = 0.56 ± 0.08 ± 0.07

R_{AA} (Y(2S)) = 0.12 ± 0.04 ± 0.02

R_{AA} (Y(3S)) < 0.10 @ 95% CL

Camelia, Rangel @ QM
Torsten @ Etretat

The surprising quarkonium: ψ' @ LHC



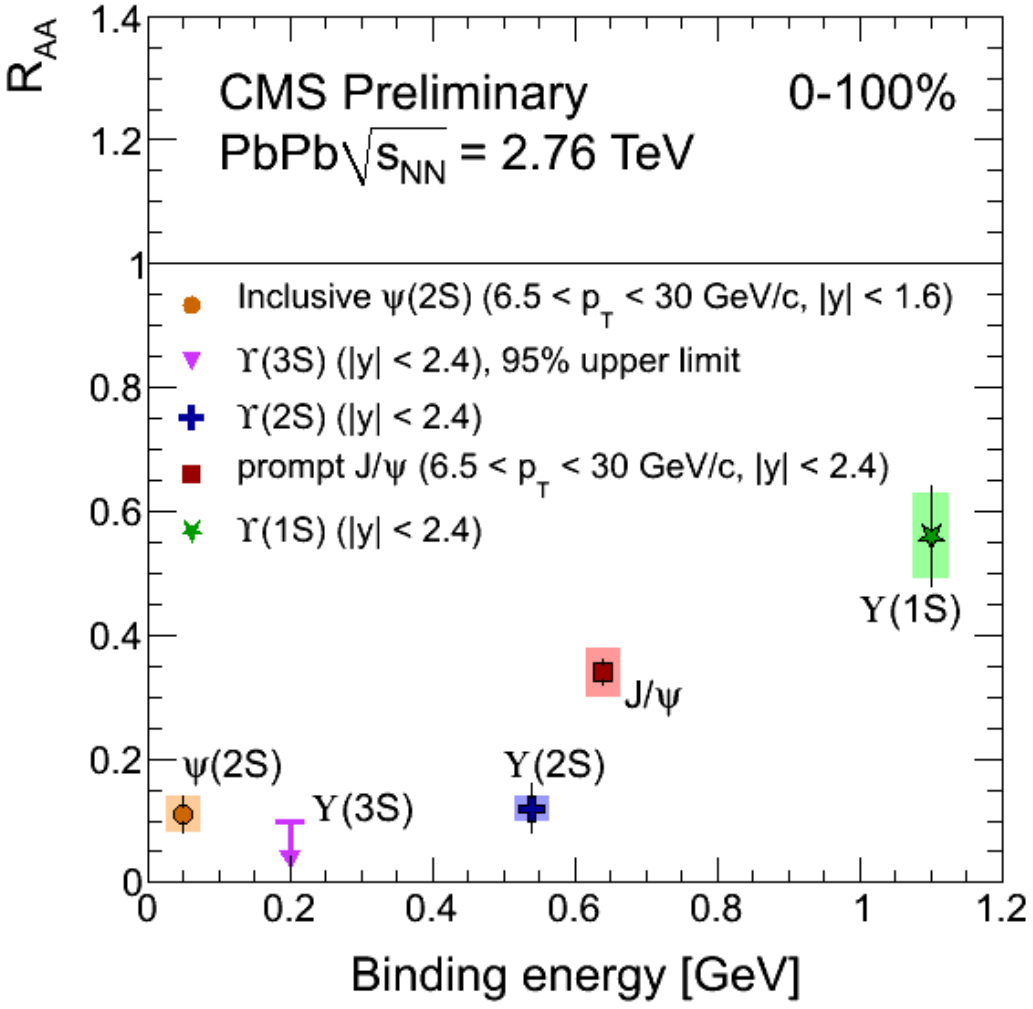
CMS had a hint
(less than 2σ!)
of less suppression
of the ψ' wrt to J/ψ
at lower pt
(pp @ 2.76 TeV)

ALICE looked and
does not see it…
(pp @ 7 TeV)

No discrepancy!

Moon & Camelia @ QM
Scomparin & Arnaldi @ QM
Antoine & Torsten @ Etretat

Five states to bind them all



Forgetting low p_T J/ψ (regeneration) for a while…

R_{AA}(MB) vs binding energy looks ordered

TBD with more data vs centrality and unfolding cold effects and feeddown could start acting as a thermometer?

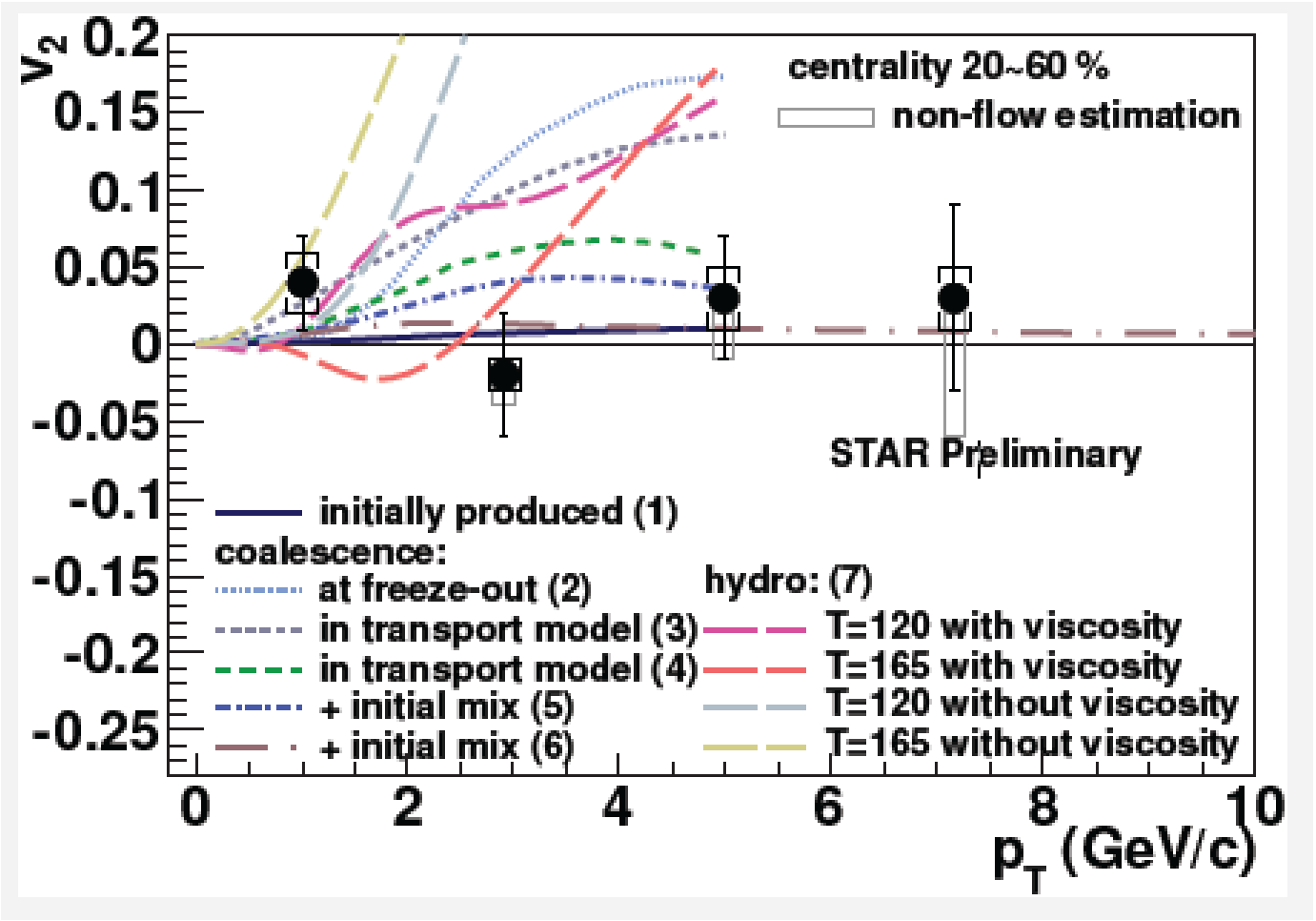
Camelia @ QM
Torsten @ Etretat

Story is not over!

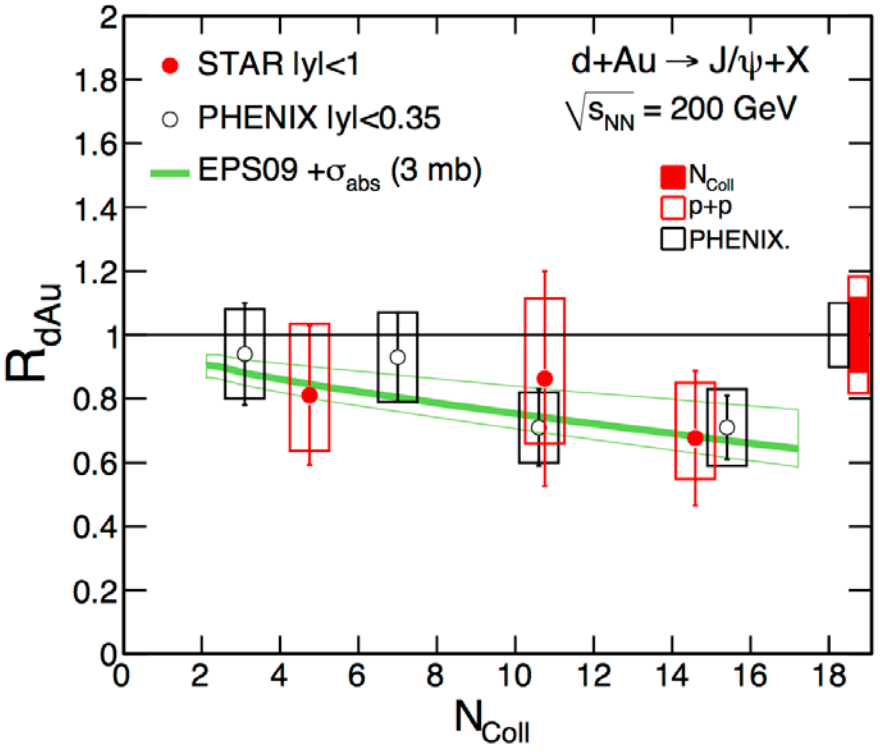
- Optimistic view ☺
  - ALICE data shows consistent hints of regeneration (R_{AA} > RHIC, but also v_2 and p_T…)
  - CMS measures 5 quarkonia → 5 grades of a thermometer
- Pessimistic view ☹
  - Let's look at the quarkonium fate in pA @ LHC (5 TeV)
    - What if suppression Y(3S) > Y(2S) > Y(1S) ?
  - More pp data @ 2.76 TeV could help
    - More differential measurements (p_T, rapidity…)
    - Settle the ψ' story ?
  - pp @ 5 TeV will be missing
  - On the RHIC side, did precision help?

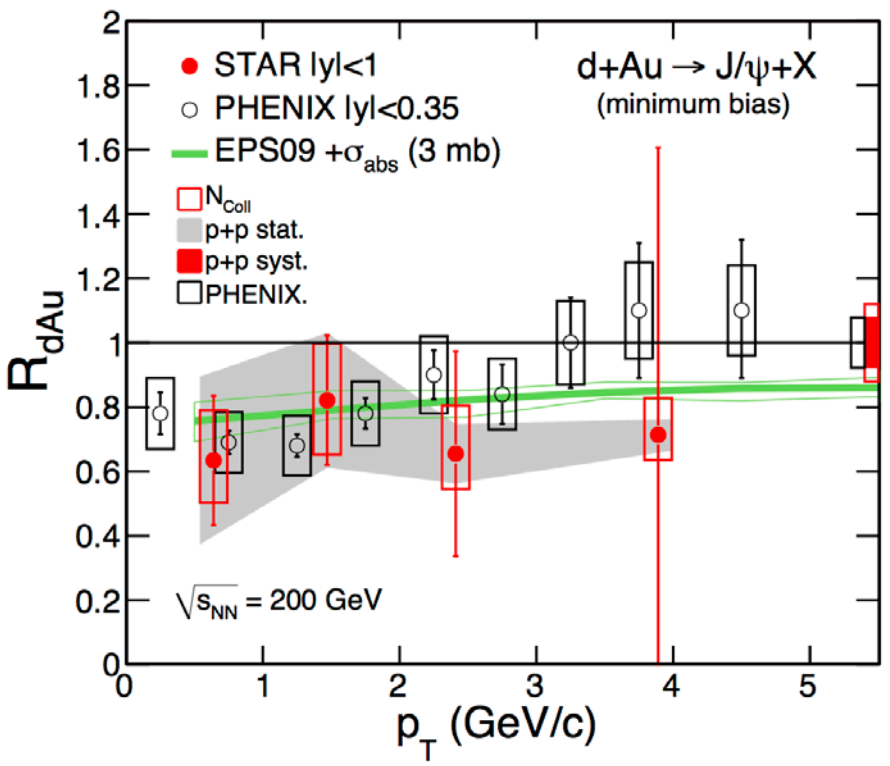
Back up

J/ψ v_2 prediction

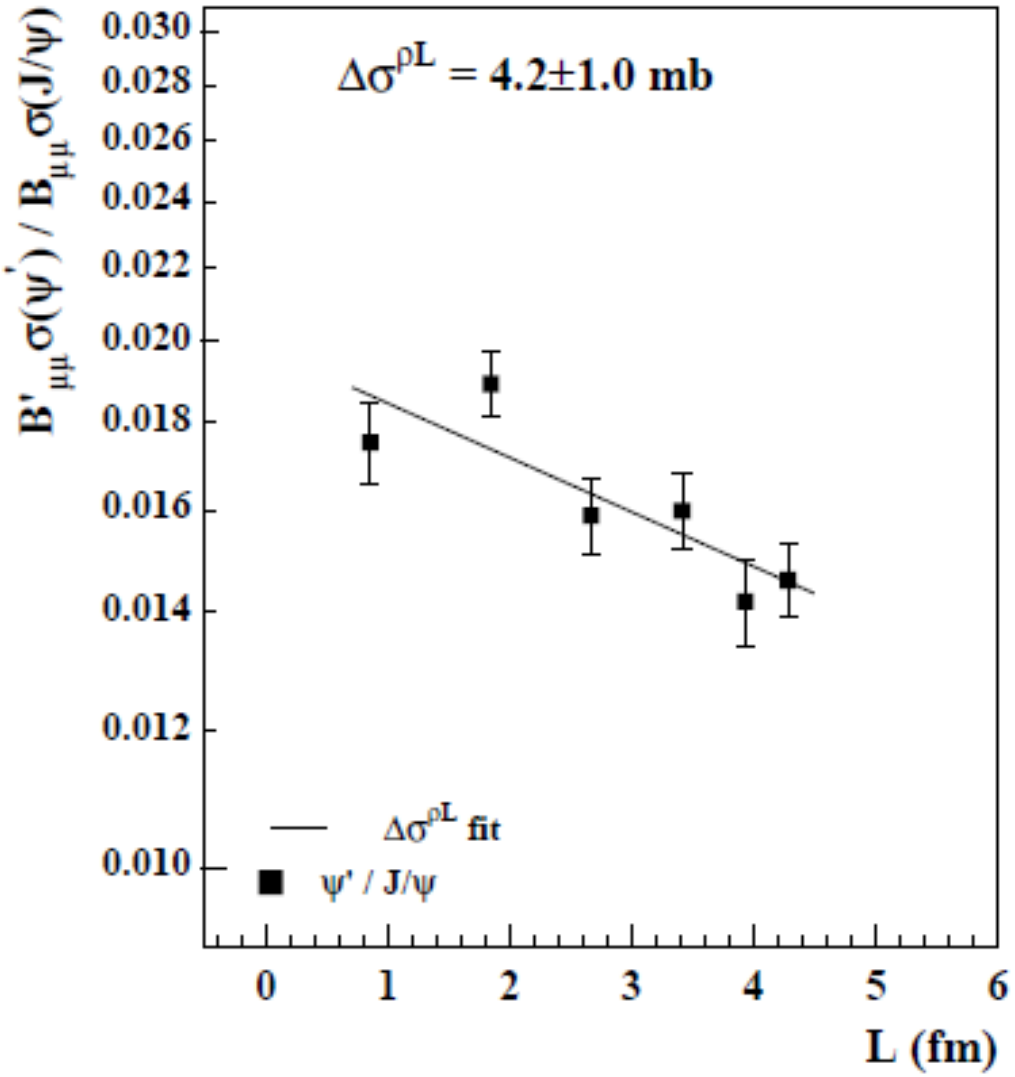


R_{dA} (J/ψ) in STAR too





NA50 ψ’


$\Delta\sigma^{\rho L} = 4.2\pm1.0$ mb
$B'_{\mu\mu}\sigma(\psi') / B_{\mu\mu}\sigma(J/\psi)$
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
$\Delta\sigma^{\rho L}$ fit
ψ' / J/ψ
0
1
2
3
4
5
6
L (fm)