Hard Probes 2013

The 6th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions

November 4 - 8, 2013
Cape Town, South Africa

Open Heavy Flavour, Quarkonia, Thermal and Electroweak Physics

– Torsten Dahms –
Excellence Cluster Universe - TU München

Hard Probes 2013
Cape Town, South Africa
November 8th, 2013

Excellence Cluster Universe

Technische Universität München

Wrapping up:

1. ALICE: R_{AA} and v_2 of muons from HF decays (Gines Martinez Garcia, SUBATECH)
2. STAR: open heavy flavour (Zhenyu Ye, UIC)
3. ALICE: D mesons (Andrea Rossi, CERN)
4. PHENIX: charmonia (Tony Frawley, FSU)
5. ALICE: ϒ (Francesco Bossu, iThemba Labs)
6. CMS: ϒ + J/ψ v_2 (Dongho Moon, UIC)
7. PHENIX: low p_T direct photons (Benjamin Bannier, SBU)
8. ALICE: low mass dimuons (Antonio Uras, Lyon)
9. PHENIX: dielectrons in d+Au (Deepali Sharma, SBU)
10. ALICE: electrons from HF decays (Elienos Pereira de Oliveira Filho, Sao Paulo)
11. ALICE: HF (Davide Caffarri, Padova)
12. STAR: low mass dielectrons (Joey Butterworth, Rice)
13. CMS: quarkonia in pp (Valentin Knünz, HEPHY)
14. Quarkonium production and polarization (Carlos Lourenço, CERN)
15. ATLAS: EWK bosons in PbPb (Thomas Balestri, SBU)
16. CMS: EWK bosons in PbPb (Alice Florent, LLR)
17. PHENIX: Quarkonia (Darren McGlinchey, Colorado)
18. STAR: Quarkonia (Jaroslav Bielcik, FNSPE)
19. LHCb: Quarkonia (R. Jacobsson, CERN)
20. ALICE: Quarkonia (Cynthia Hadjidakis, IPNO)
21. CMS: Quarkonia (Lamia Benhabib, CERN)

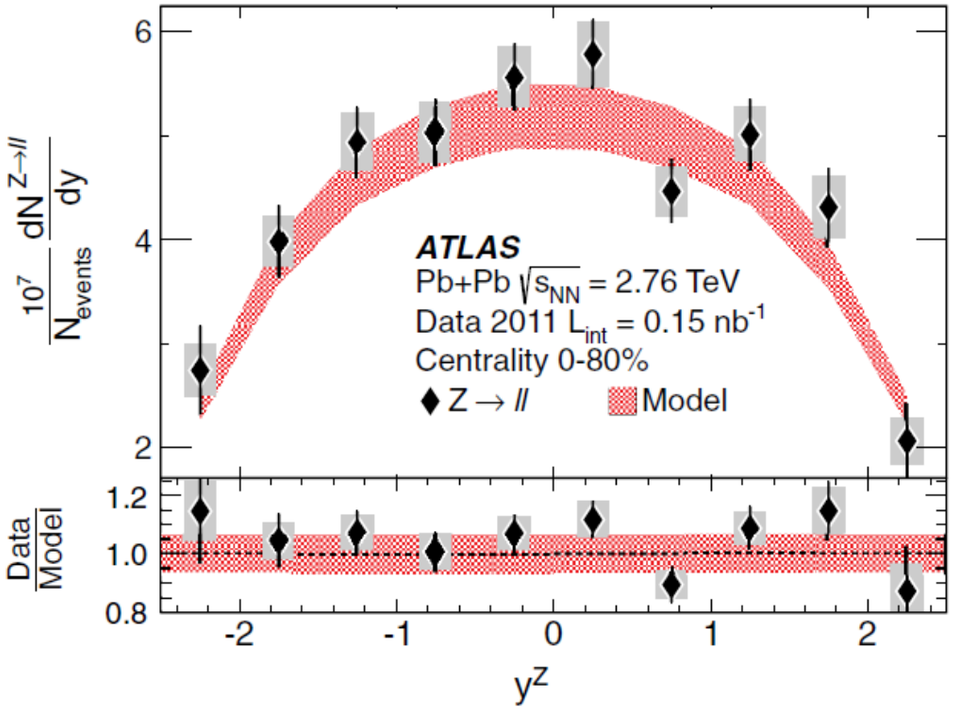
plenary
w/o dedicated plenary
parallel

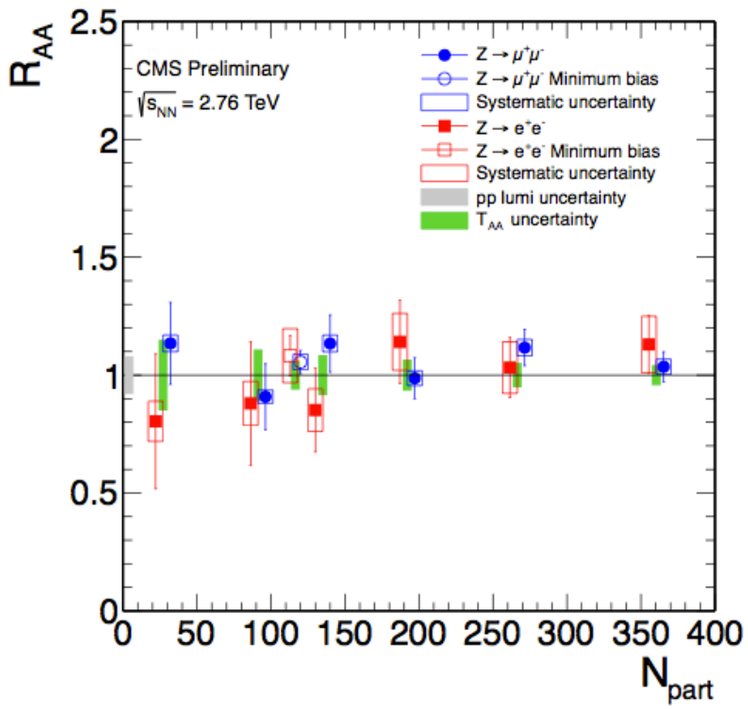
1 minute per talk

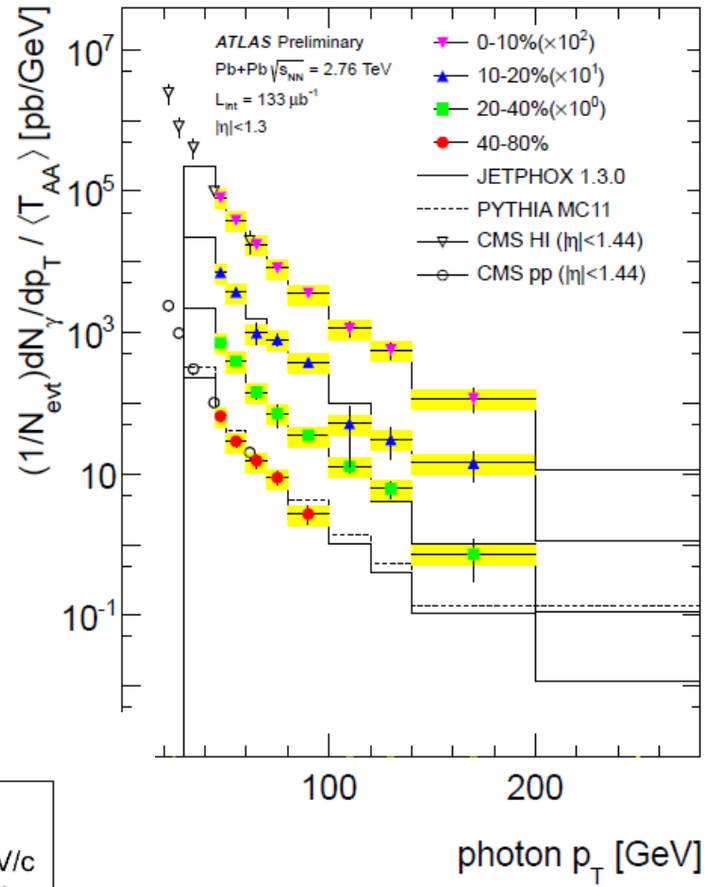
Electroweak bosons

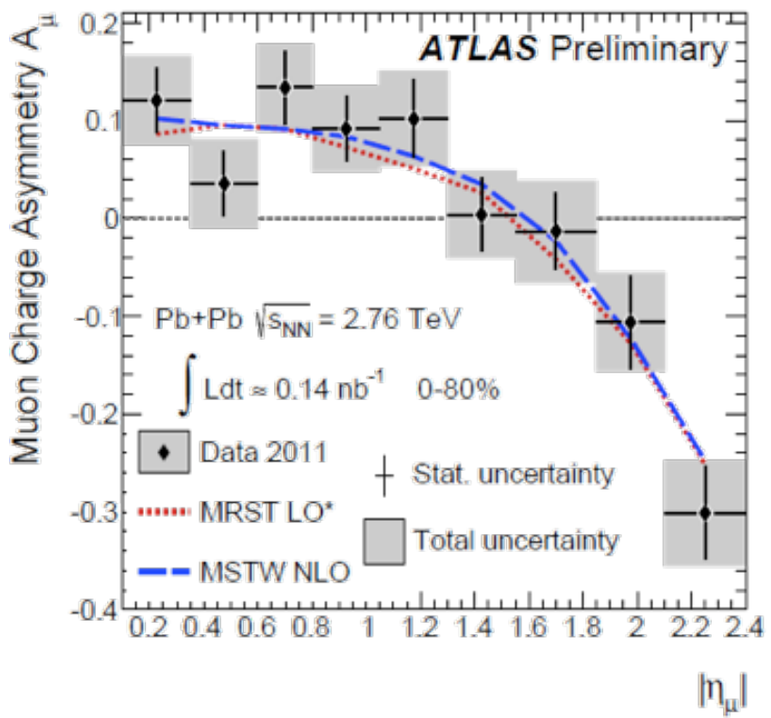
ATLAS: T. Balestri (Thu, 16h20)
CMS: A. Florent (Thu, 16h40)

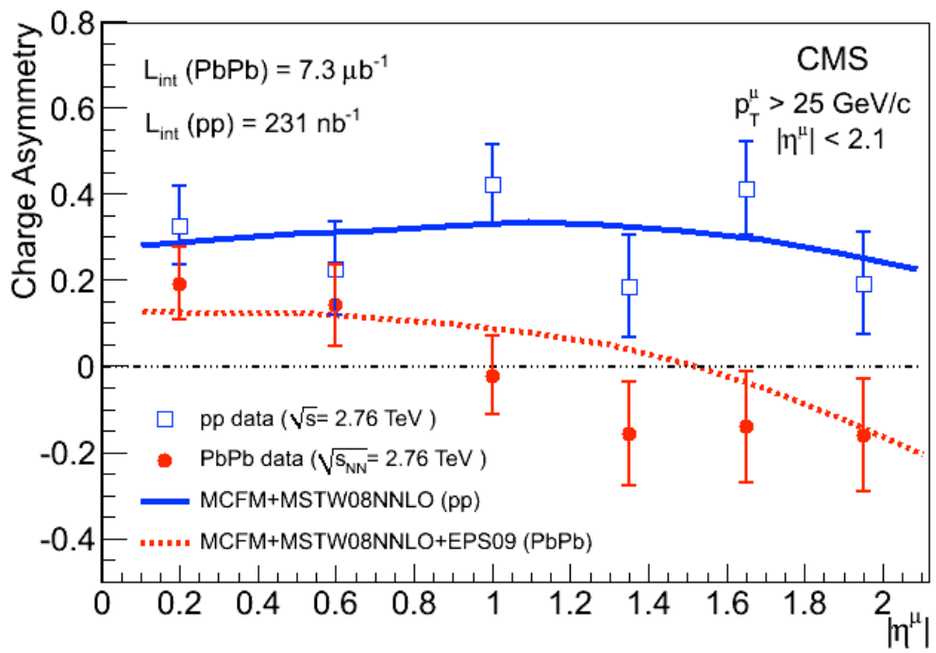
- Confirm binary scaling
- No strong nuclear PDF effects, more sensitivity with pPb data?









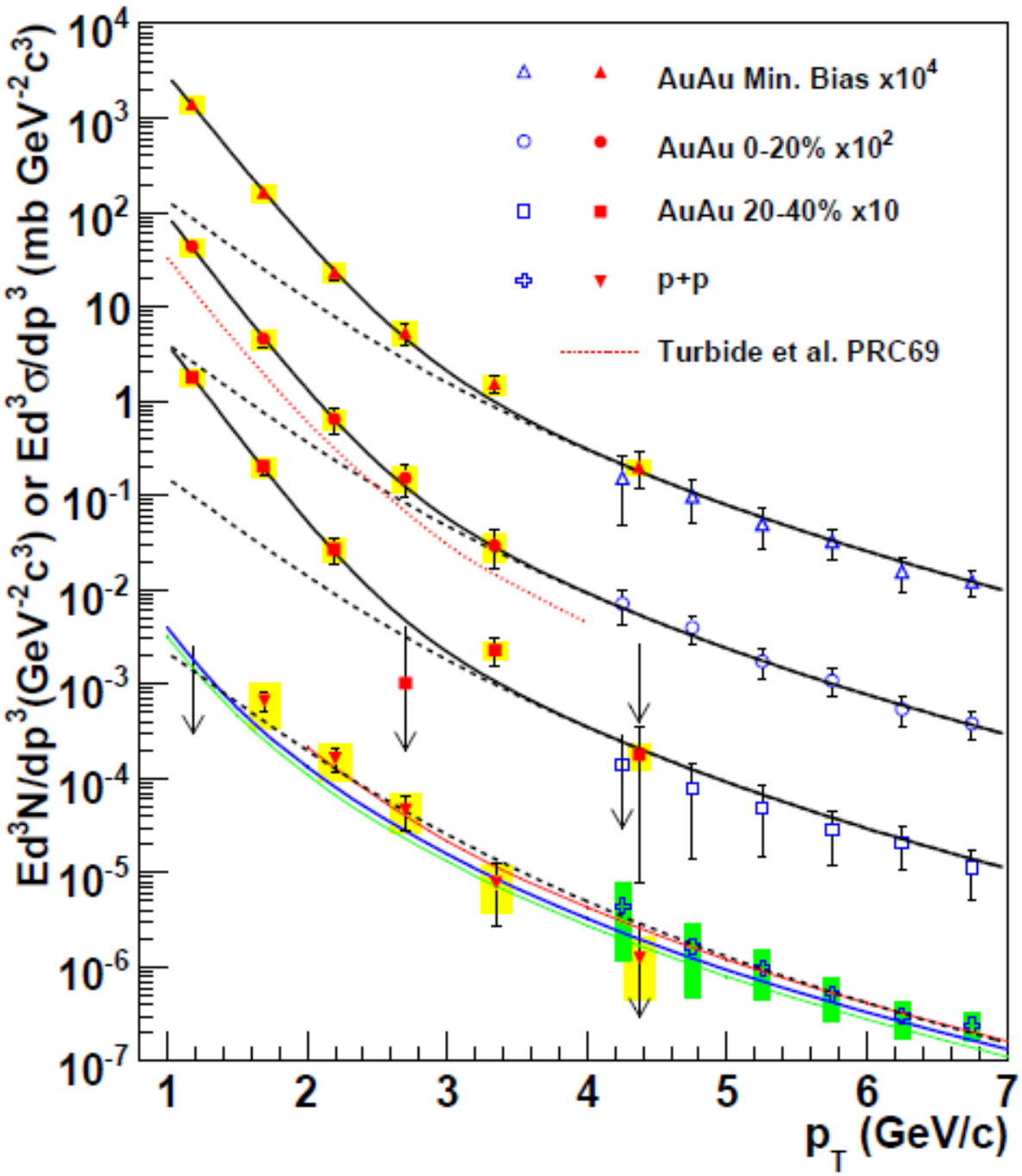


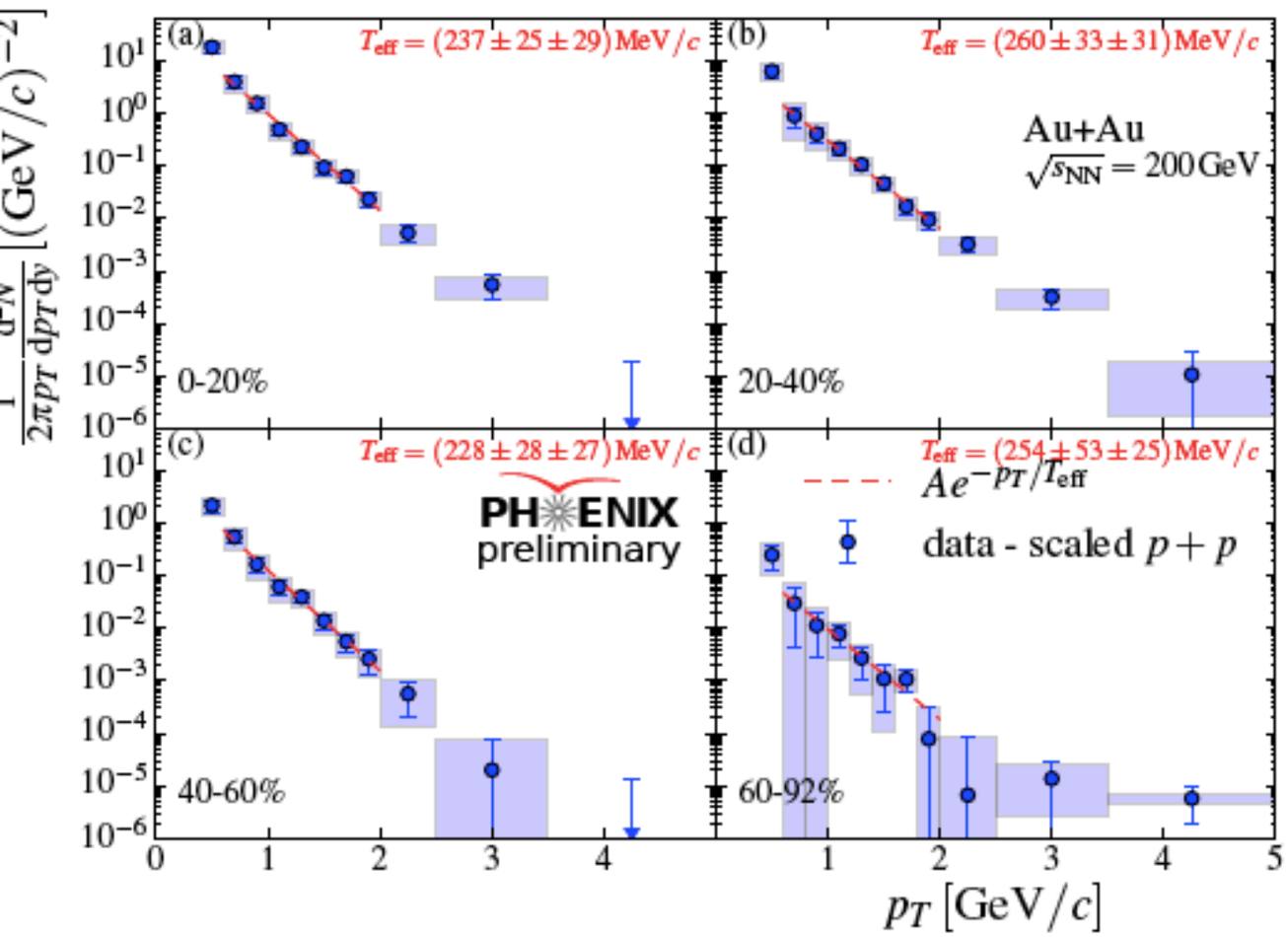
Direct photons at low p_T

- Direct photons at high p_T:
  - prompt QCD photons → scale like N_{coll}
- Direct photons at low p_T:
  - a window for thermal radiation
  - virtual photon "extrapolation" confirmed with measurement of real photons via conversions

excess scales with ~$N_{part}^{1.5}$

PHENIX: B. Bannier (Tue, 13h30)





0-20%	20-40%	40-60%	60-92%	[T_{eff}]
237±25±29	260±33±31	228±28±27	254±53±25	MeV/c

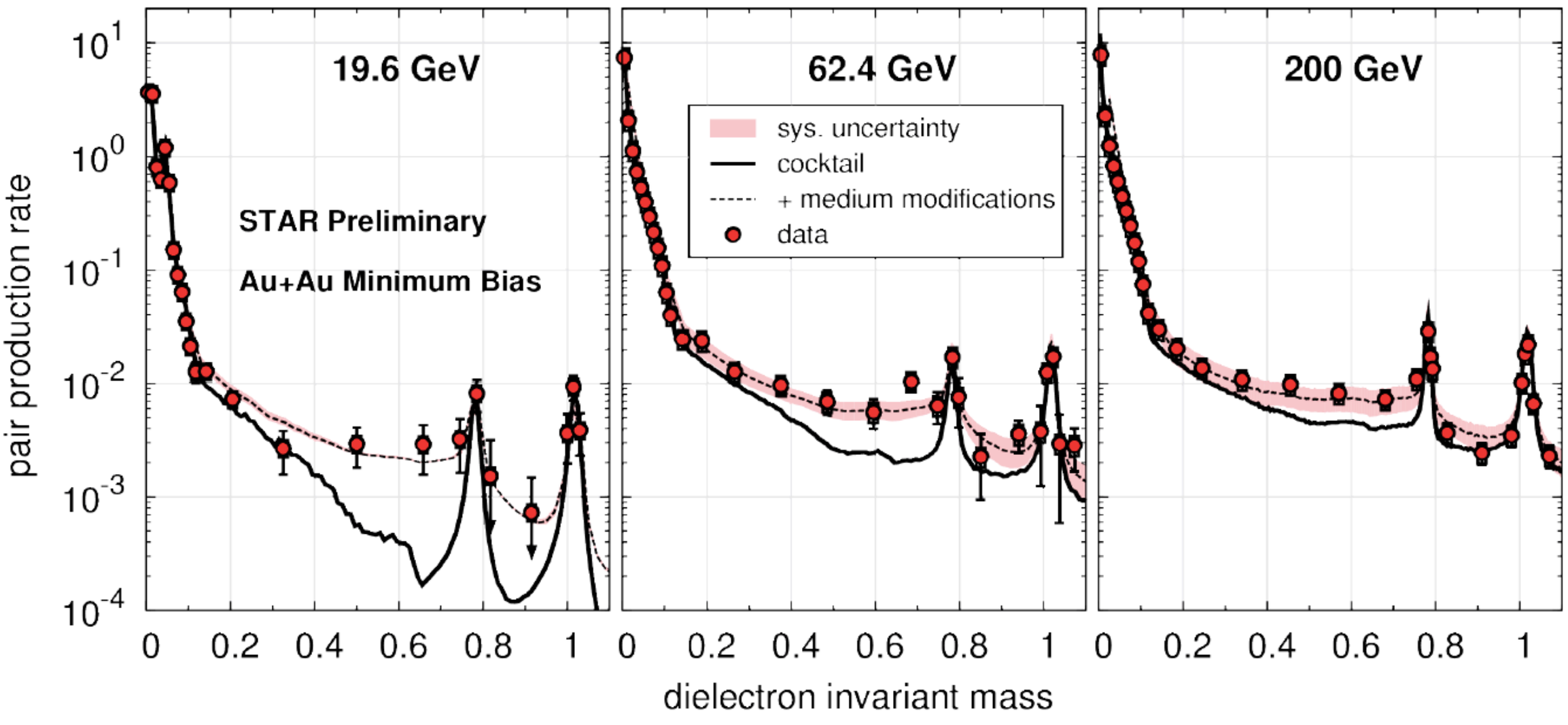
Low mass dileptons

- BES shows low mass enhancement at all $\sqrt{s_{NN}}$

  - ρ melting sensitive to total baryon density not net baryon density
  - model describing data include chirally symmetric phase

STAR: J. Butterworth (Wed, 11h00)

no news on central Au+Au from PHENIX

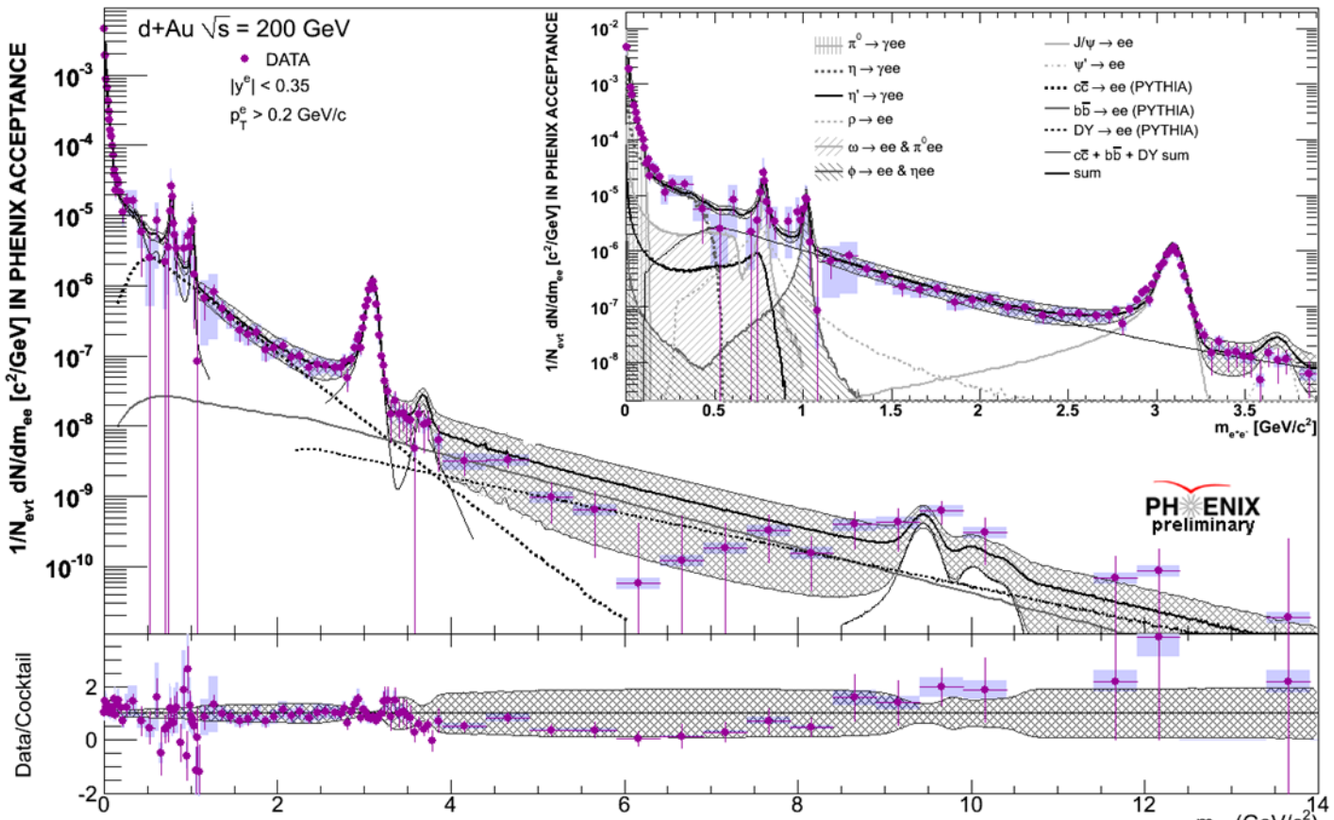


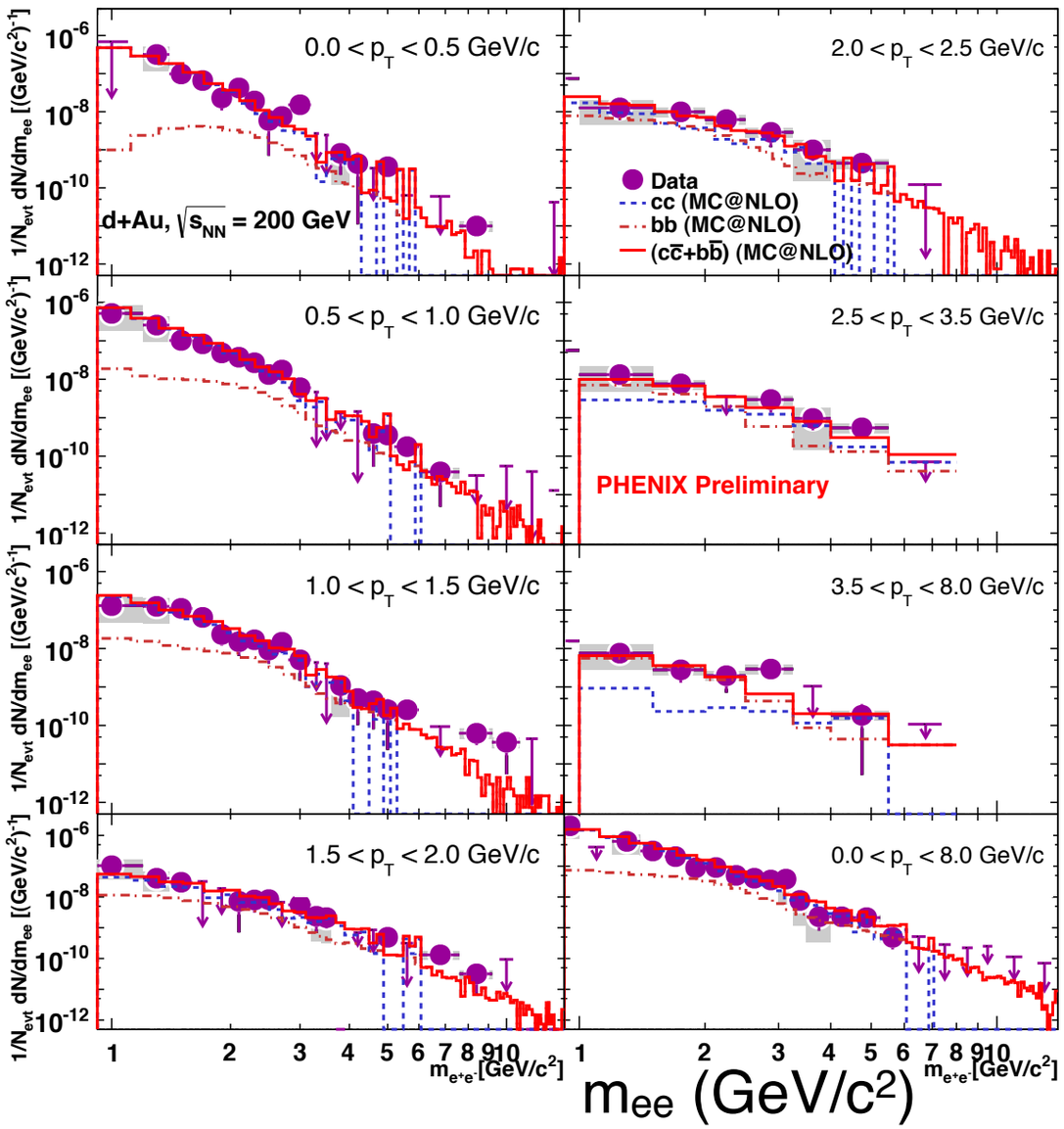
High-mass dileptons

- Dileptons provide a way to measure charm and bottom cross sections
  - and their correlations

PHENIX: D. Sharma (Tue, 14h50)

- pp equivalent HF cross section
  - σ_{cc}^{NN} = 704 ± 47 (stat) ± 183 (syst) ± 40 (model) µb
  - σ_{bb}^{NN} = 4.29 ± 0.39 (stat) ± 1.08 (syst) ± 0.11 (model) µb





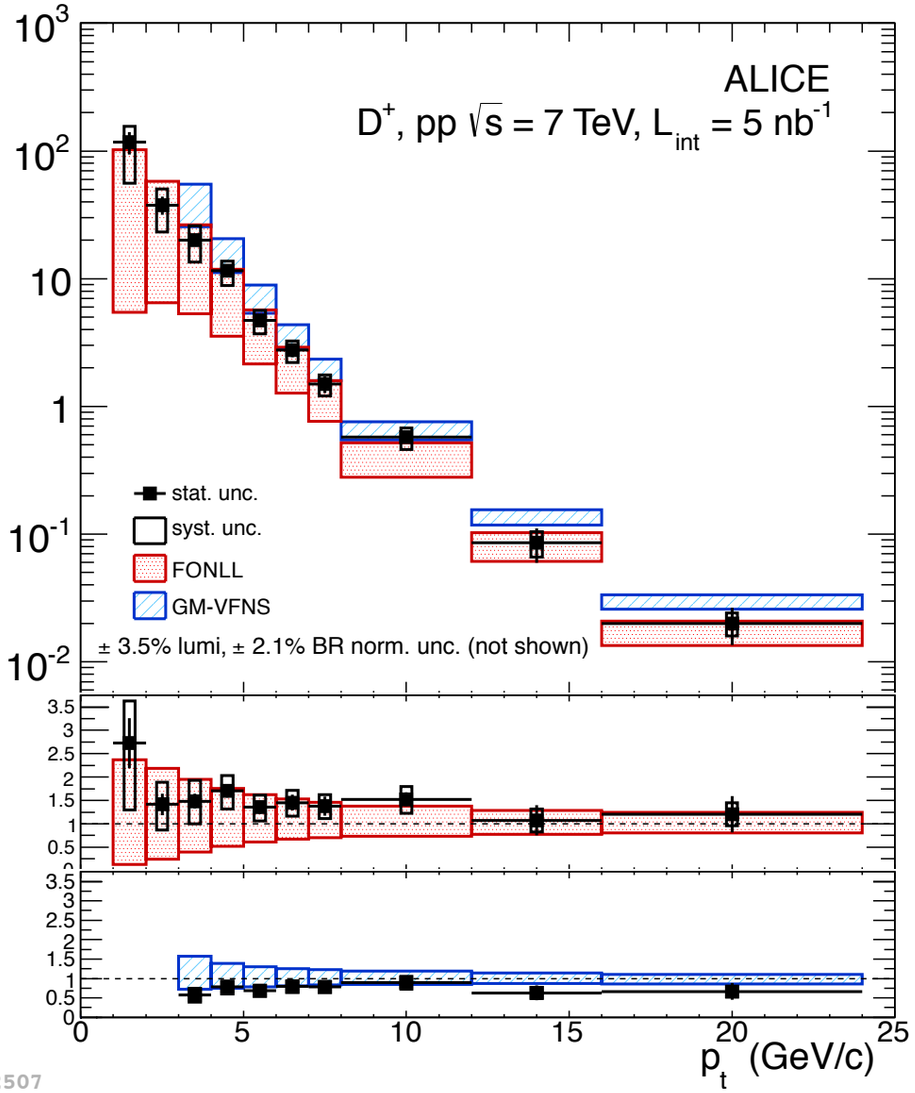
Open HF in pp

ALICE: A. Rossi (Tue, 14h50) and D. Caffarri (Wed, 9h00)

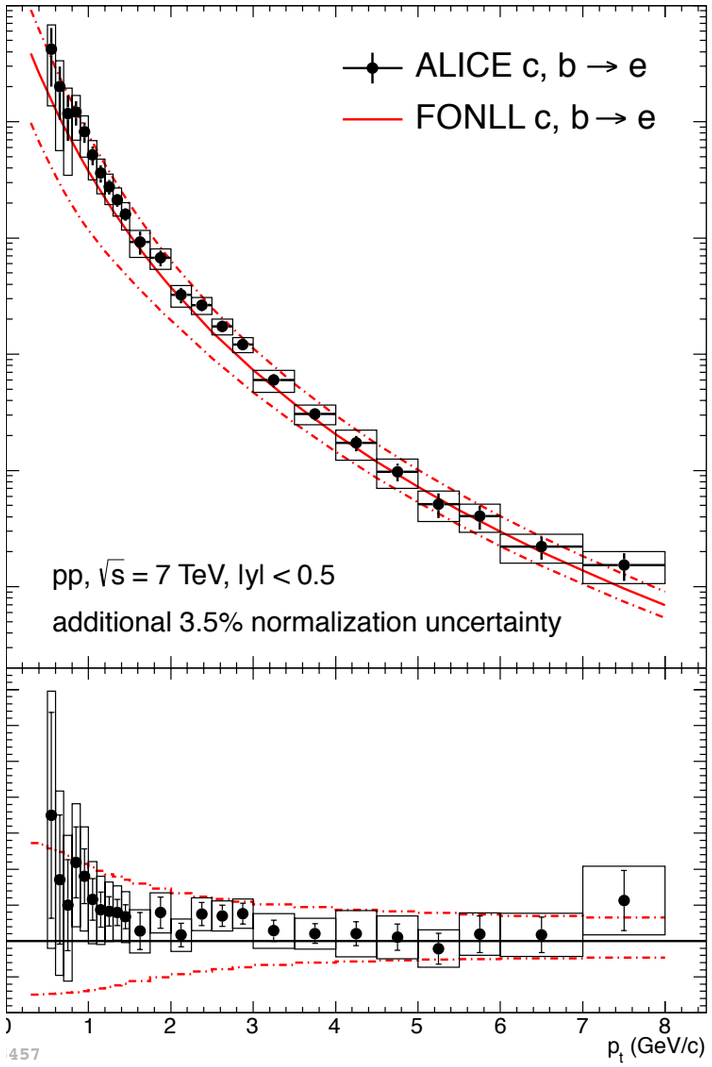
- Total charm cross section and pt spectrum well described by FONLL

JHEP 1201 (2012) 128

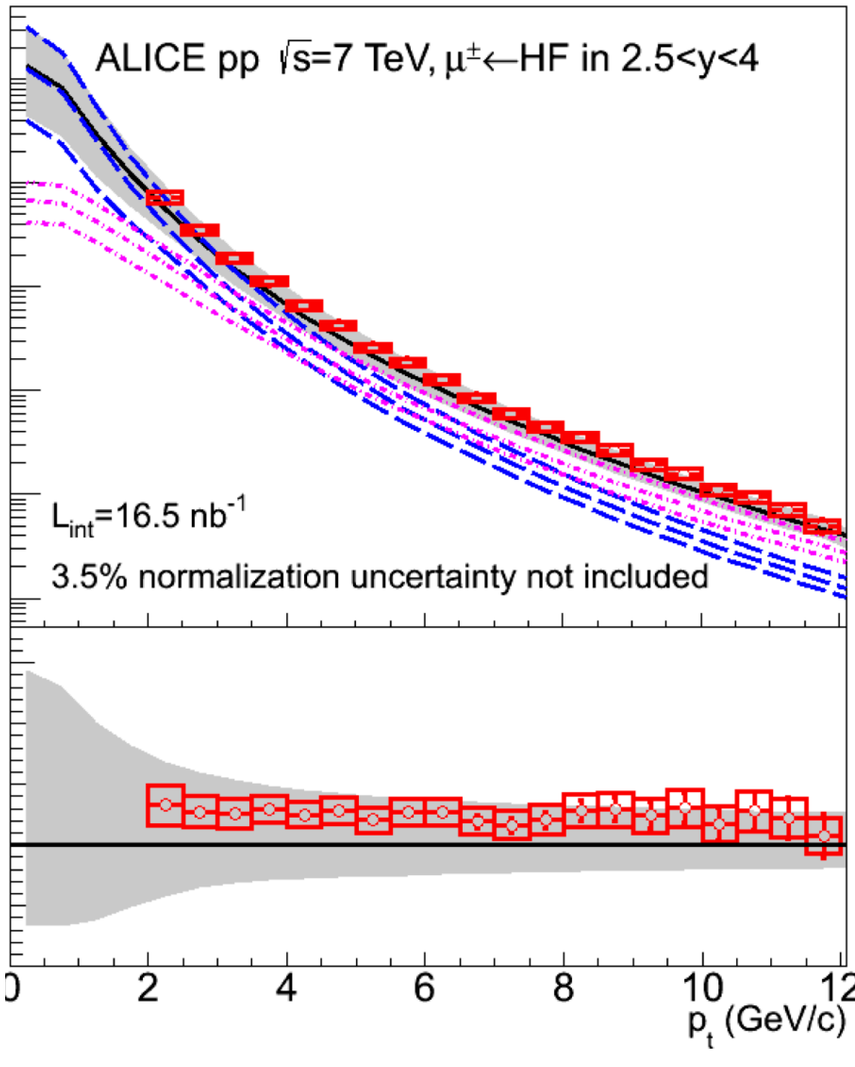
Phys. Lett. B 718 (2012) 279 for D_s^+



Phys. Rev. D 86, 112007 (2012)



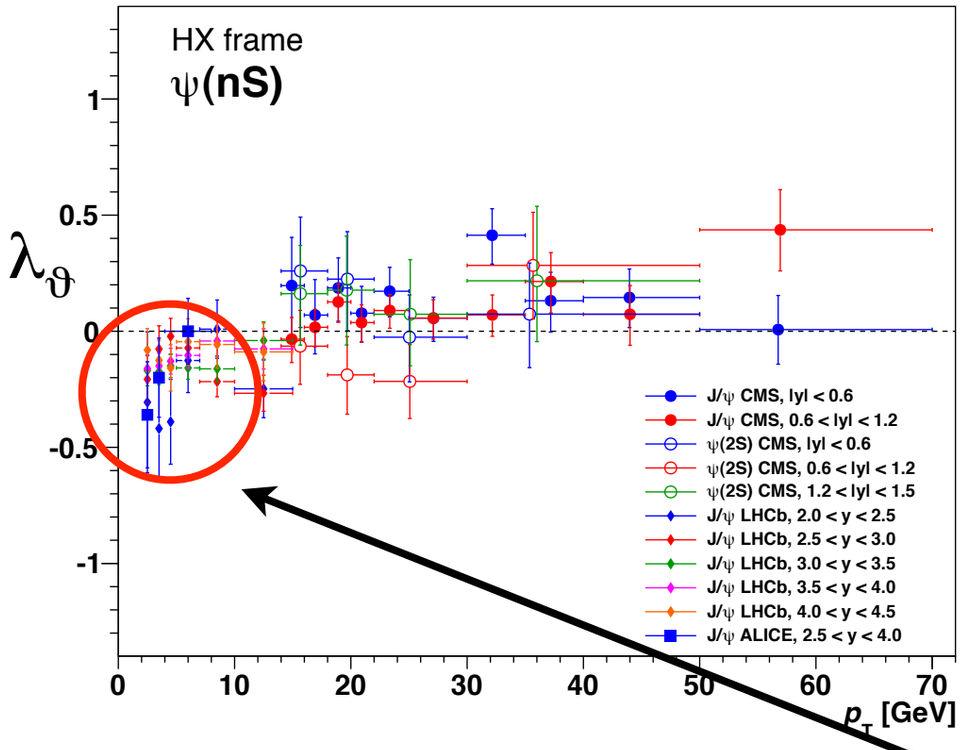
Phys. Lett. B 708 (2012) 265

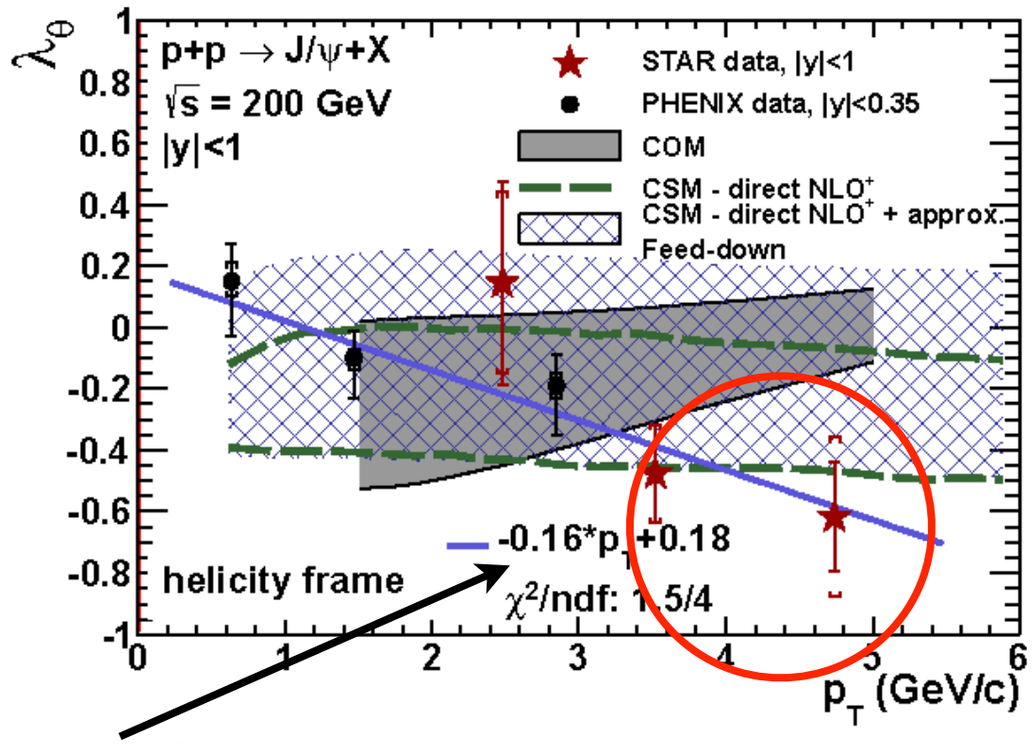


Quarkonia in pp: Polarization

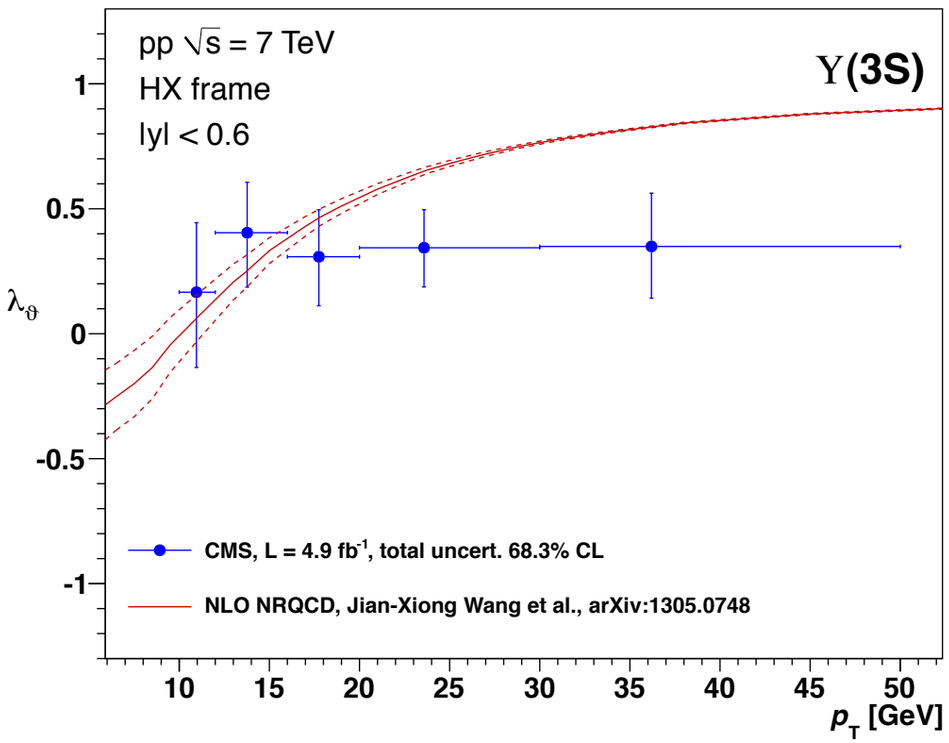
arxiv:1311.1621

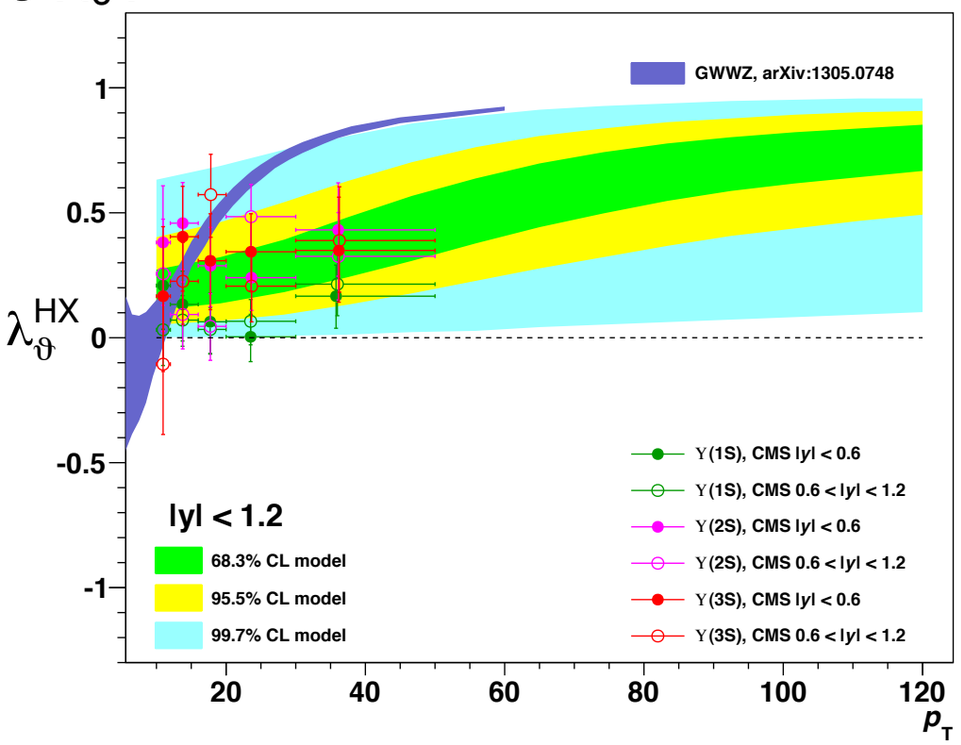
STAR: J. Bielcik (Fri, 9h30)





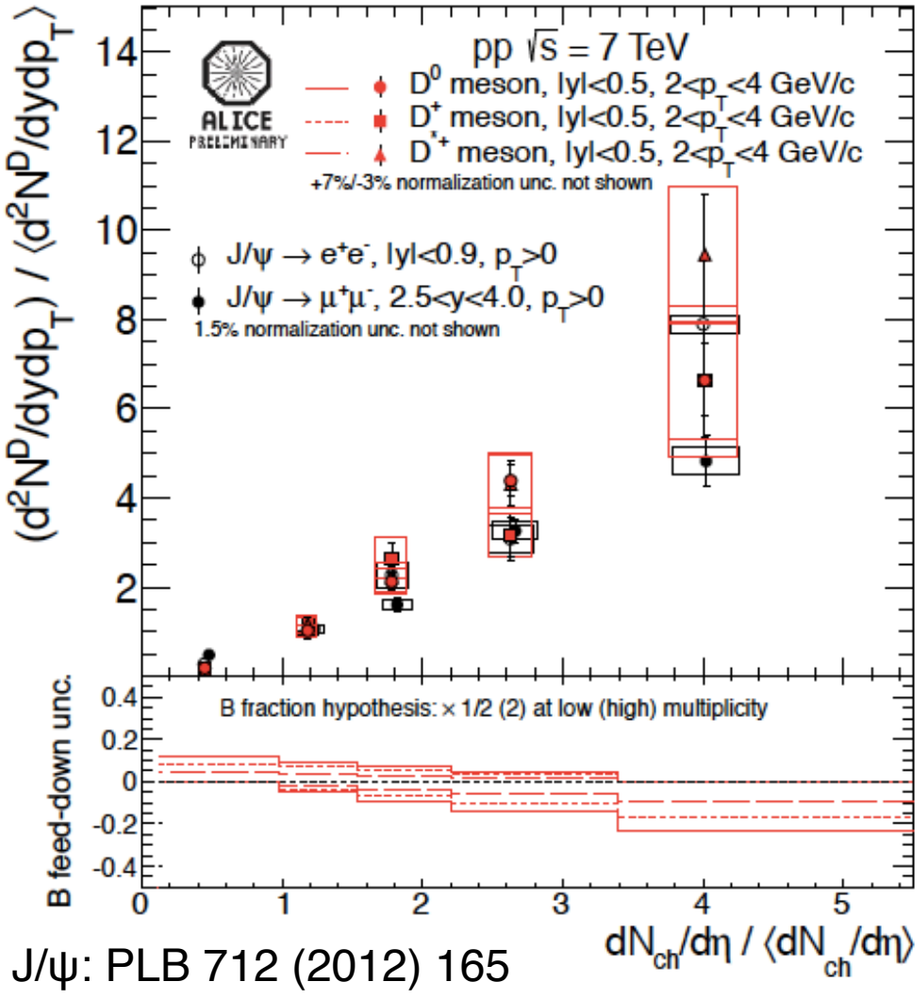
negative λ_θ?



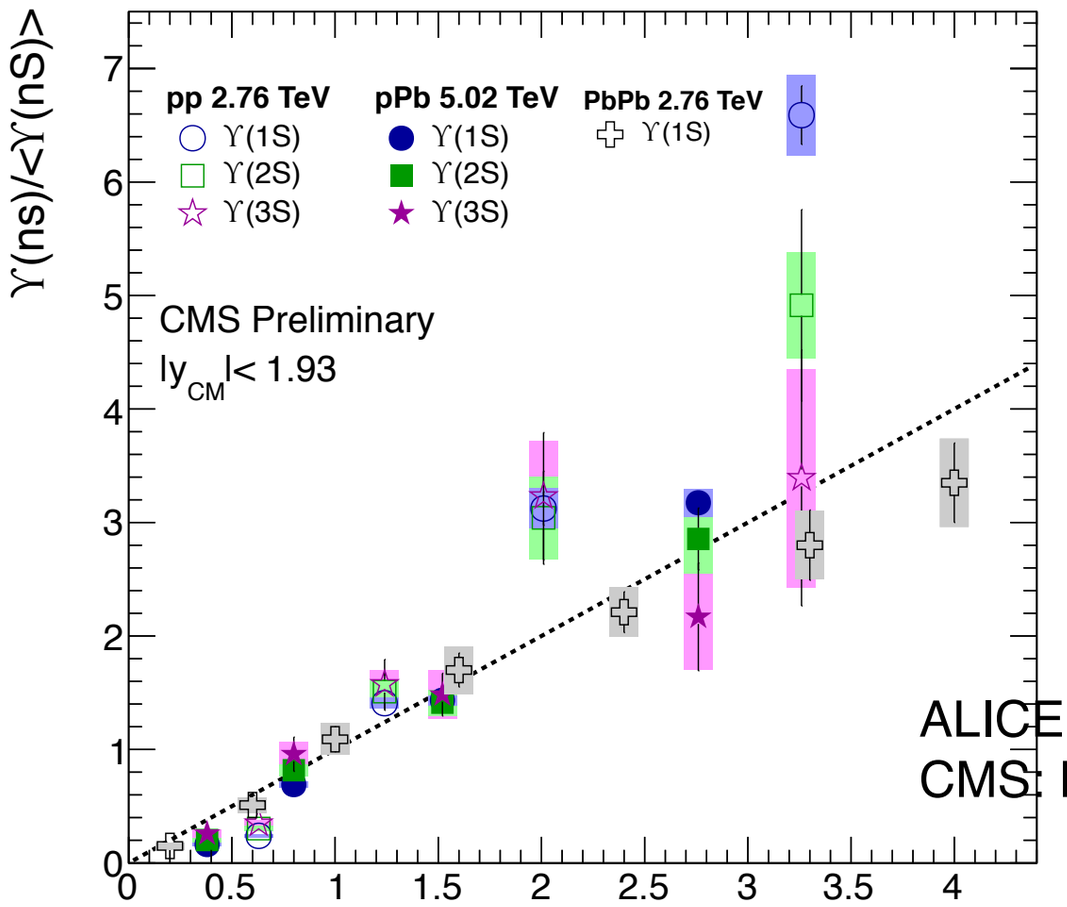


CMS: V. Knünz (Thu, 15h40)
and C. Lourenço (Thu, 16h00)

Do we really understand pp?

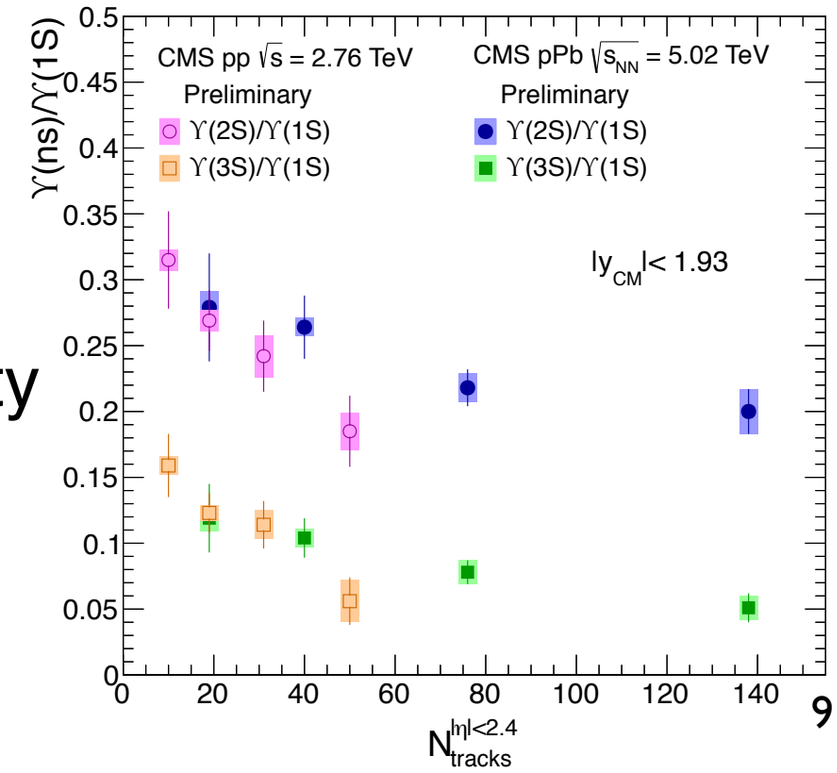


J/ψ: PLB 712 (2012) 165



ALICE: A. Rossi (Tue, 14h50)
CMS: D. Moon (Mon, 16h40)

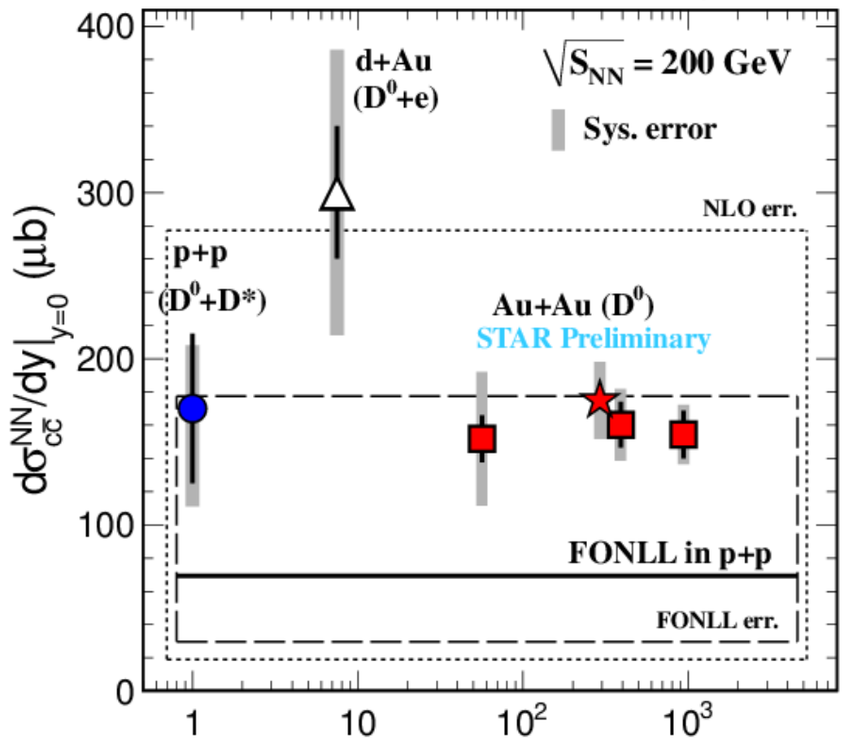
- Increase of hard probes with multiplicity
  - MPI?
- Dropping of excited to ground state with multiplicity
- What's the proper reference then for pA or AA?
  - tail of pp multiplicity vs. "average" pp collision

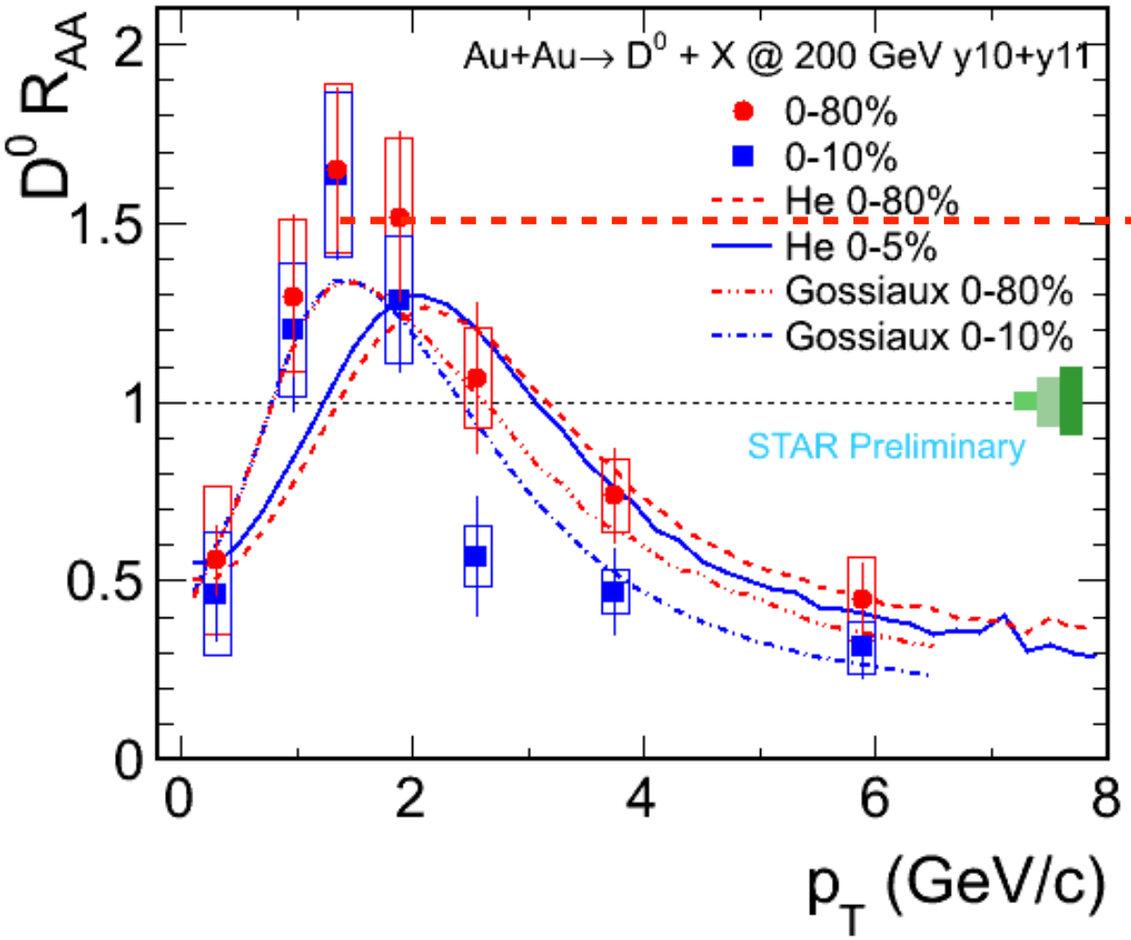


Open HF in AA

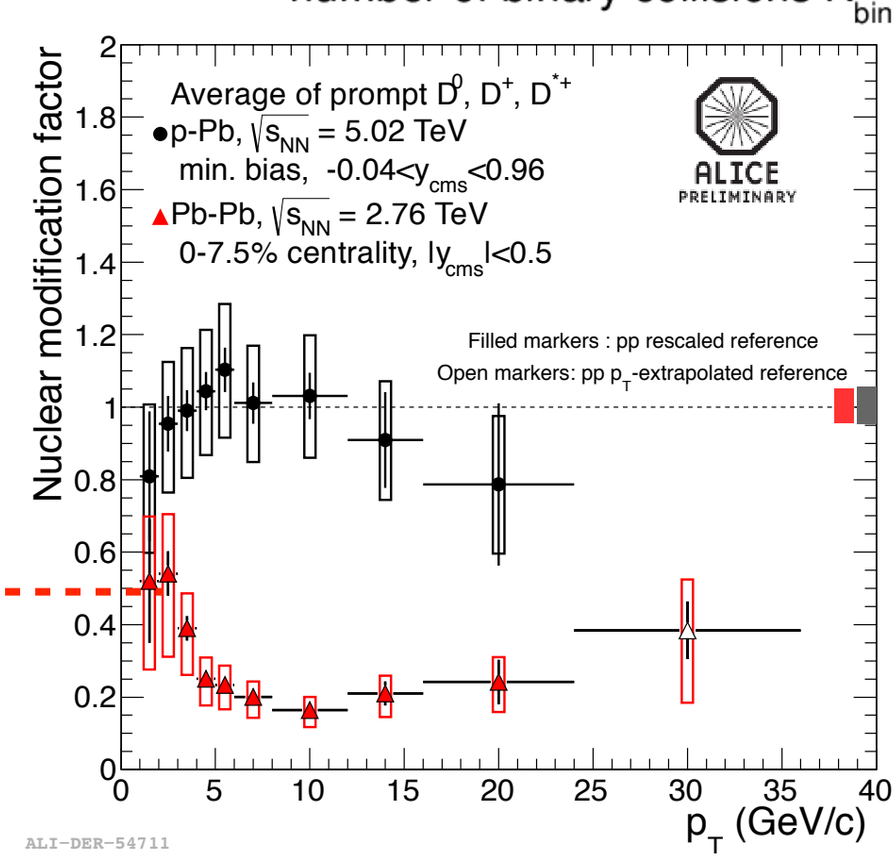
STAR: Z. Ye (Mon, 14h30)
ALICE: A. Rossi (Tue, 14h50)
and D. Caffarri (Wed, 9h00)

- At RHIC: total charm cross section scales with N_{coll}
- At the LHC: need low-p_T D mesons
- Midrapidity at RHIC: anti-shadowing
- Midrapidity at LHC: shadowing





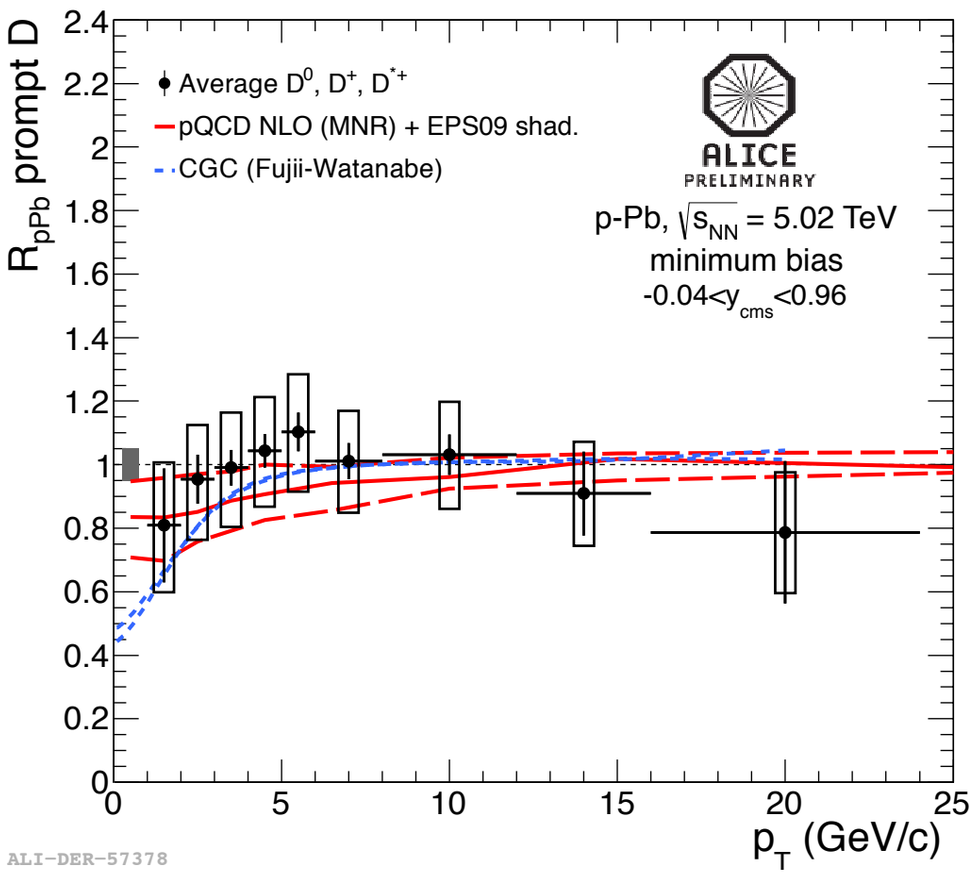
×3



Open HF in pA

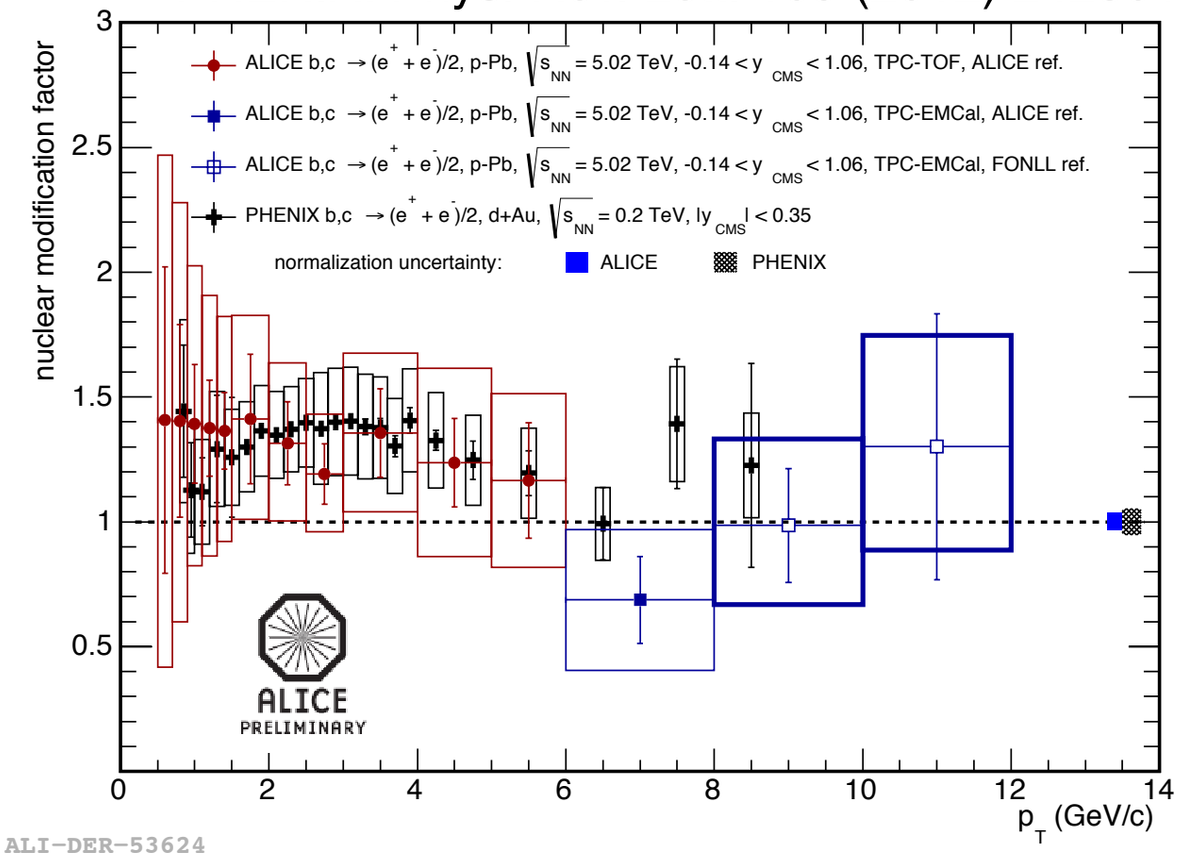
ALICE: A. Rossi (Tue, 14h50)
and D. Caffarri (Wed, 9h00)

- difference between D and e from beauty?
  - or just not enough yield in the hadronic cocktail
  - or something else…?



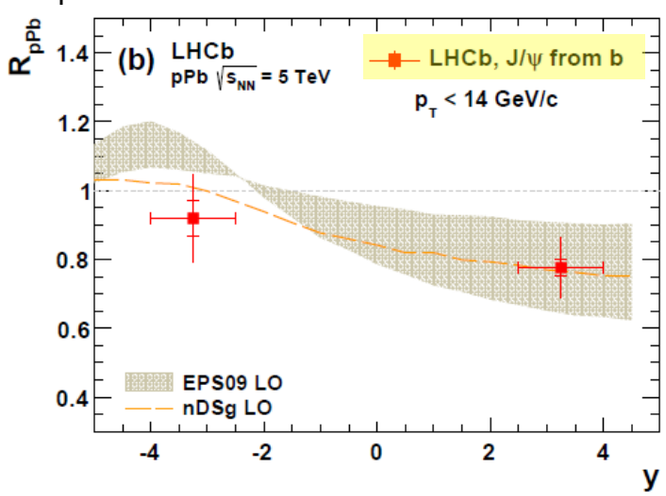
ALI-DER-57378

PHENIX: Phys. Rev. Lett. 109 (2012) 242301



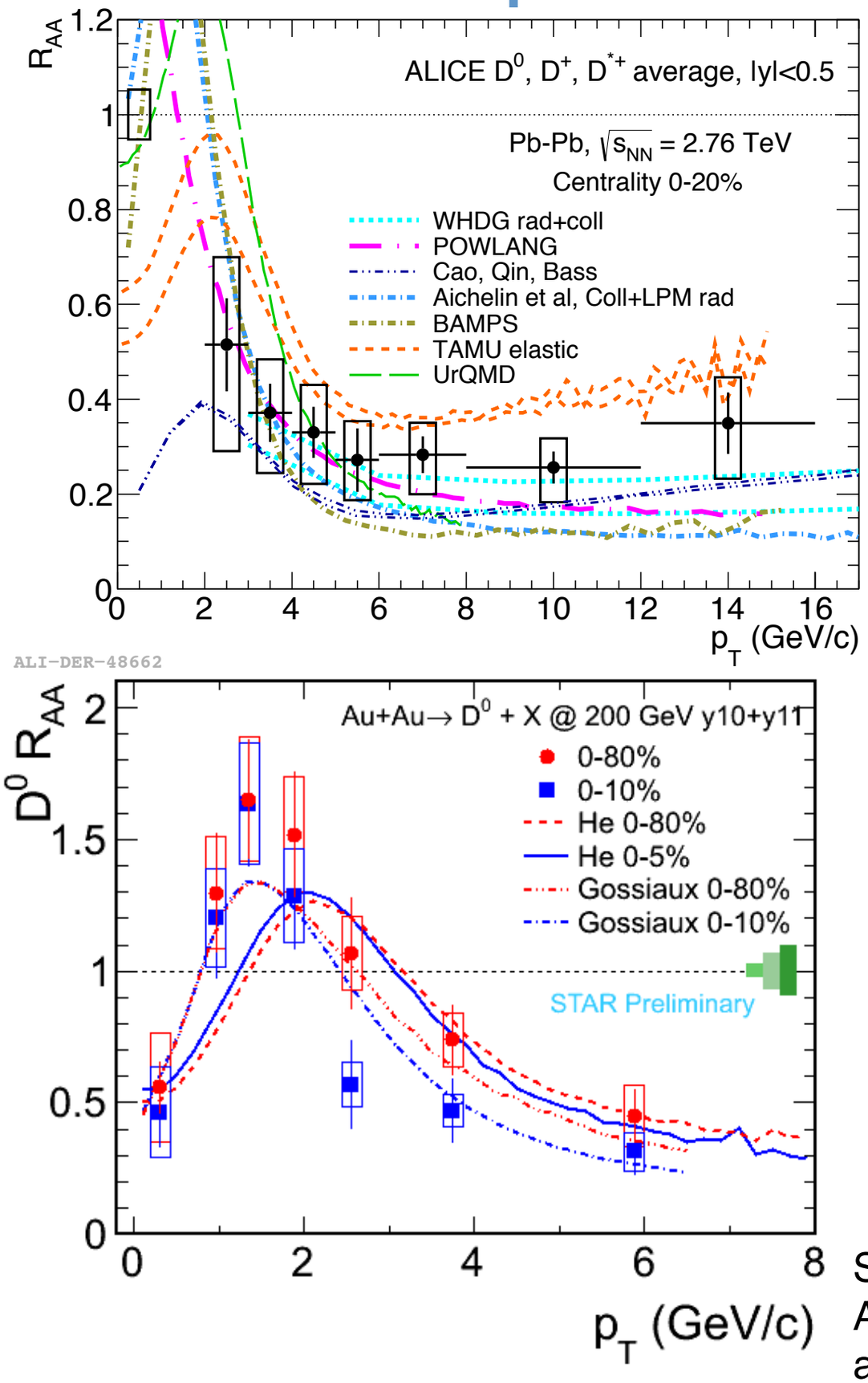
ALI-DER-53624

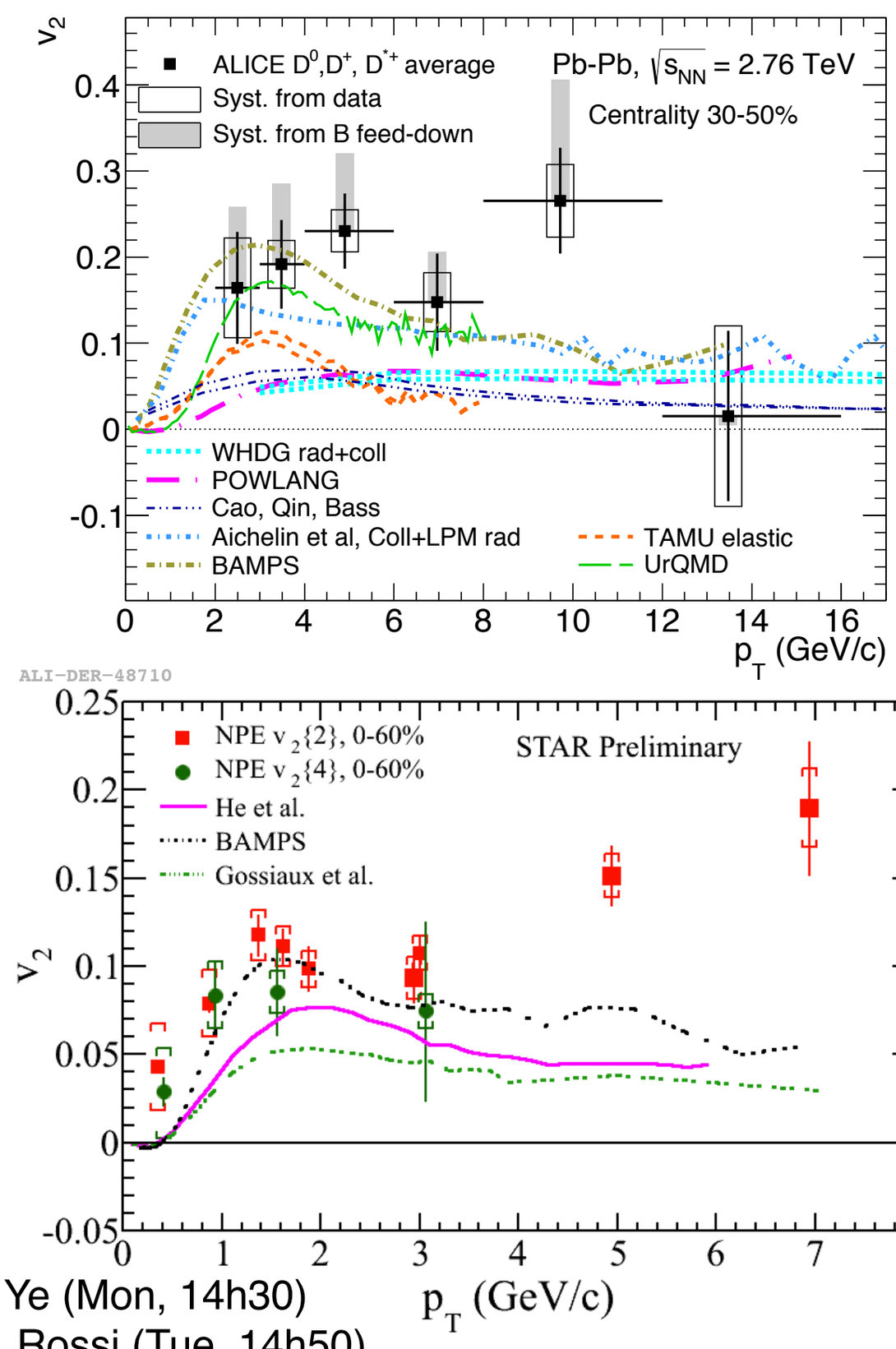
- Speaking of beauty:



LHCb: R. Jacobsson (Fri, 11h00)

Open HF in AA: R_{AA} vs v_2



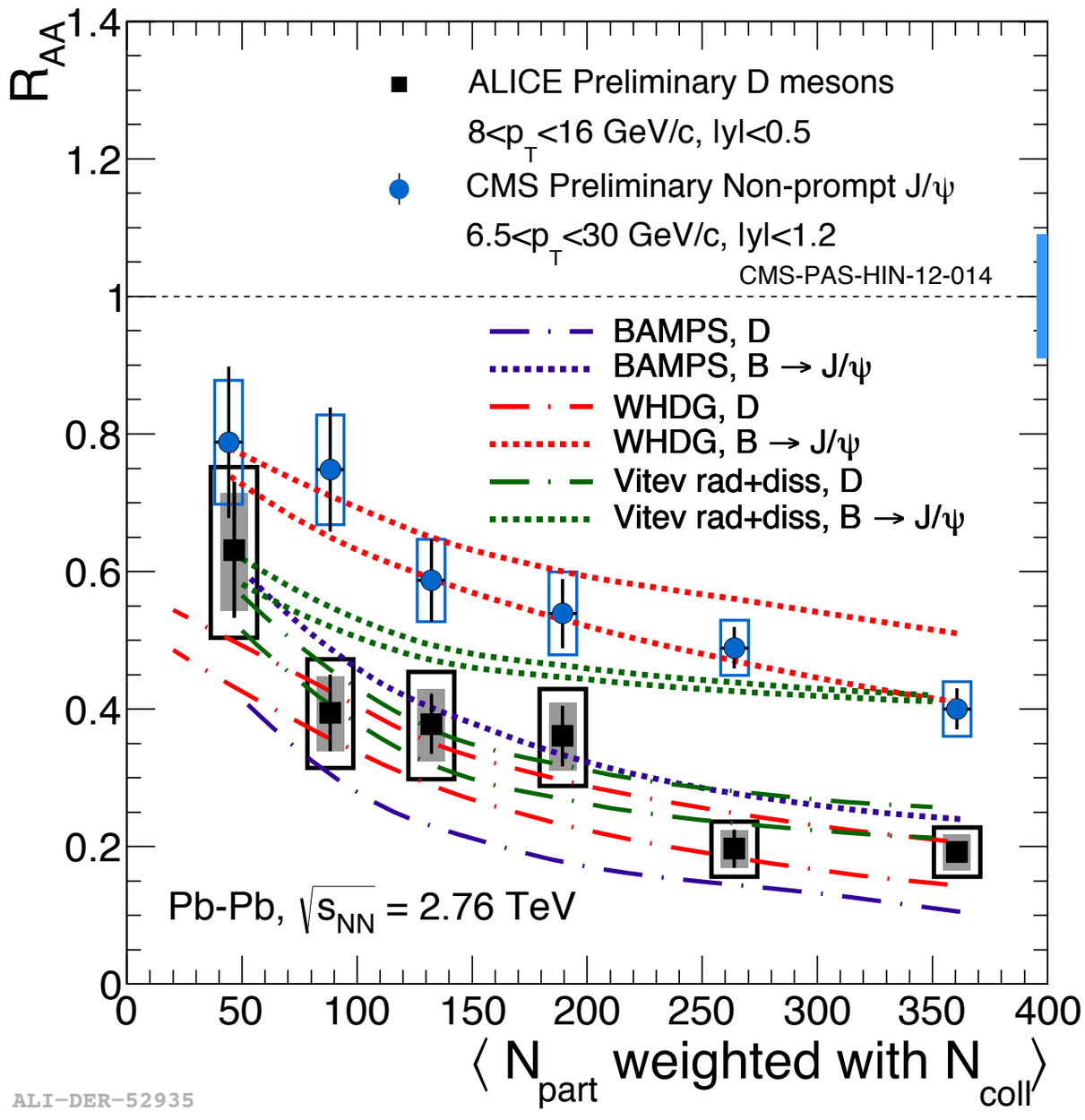


STAR: Z. Ye (Mon, 14h30)
ALICE: A. Rossi (Tue, 14h50)
and D. Caffarri (Wed, 9h00)

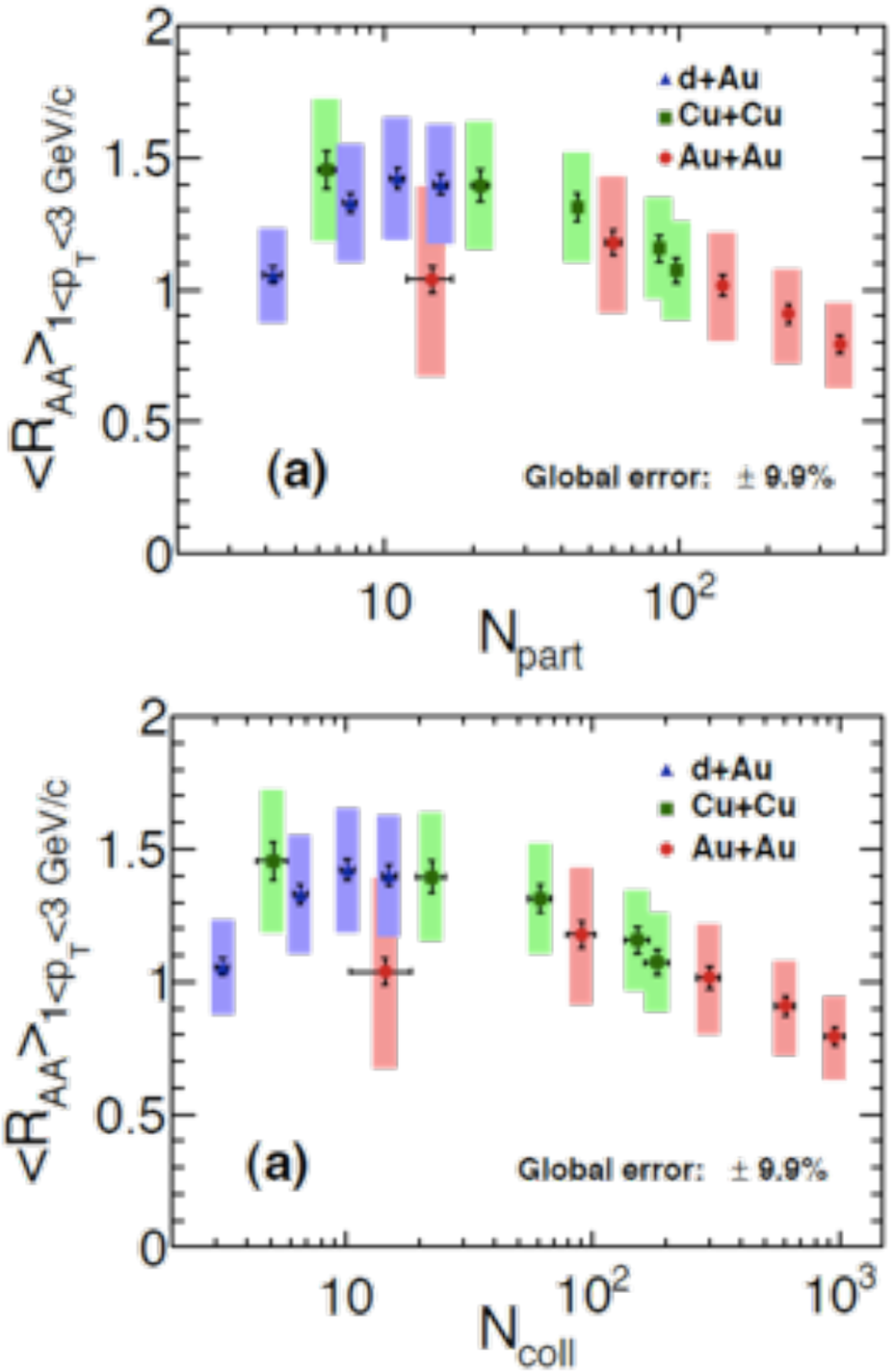
Open HF: charm vs beauty

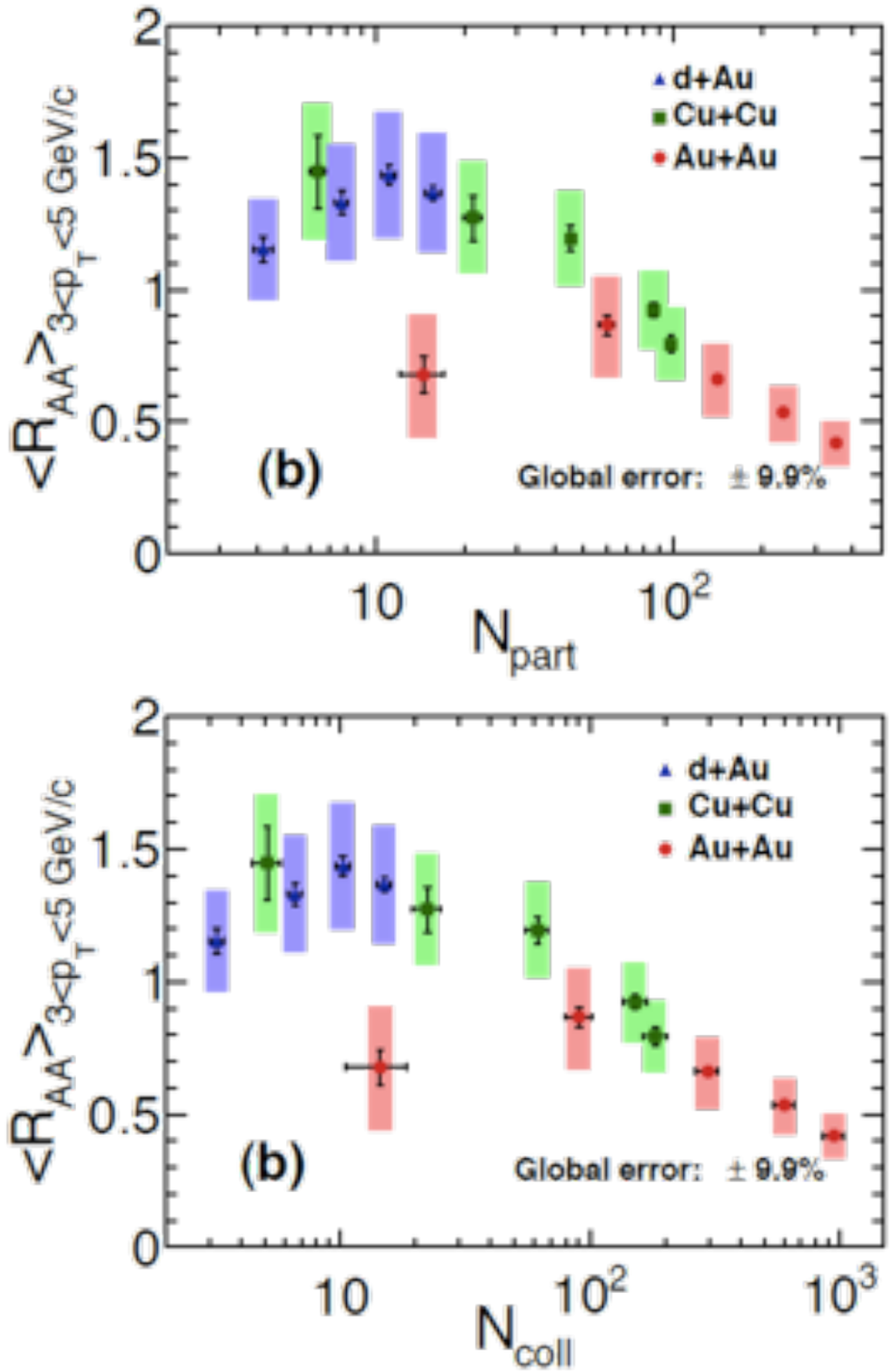
- mass dependent radiative energy loss can explain quantitatively the observed difference

ALICE: A. Rossi (Tue, 14h50)
and D. Caffarri (Wed, 9h00)
CMS data from CMS PAS HIN-12-014



Open HF: one N to rule them all?



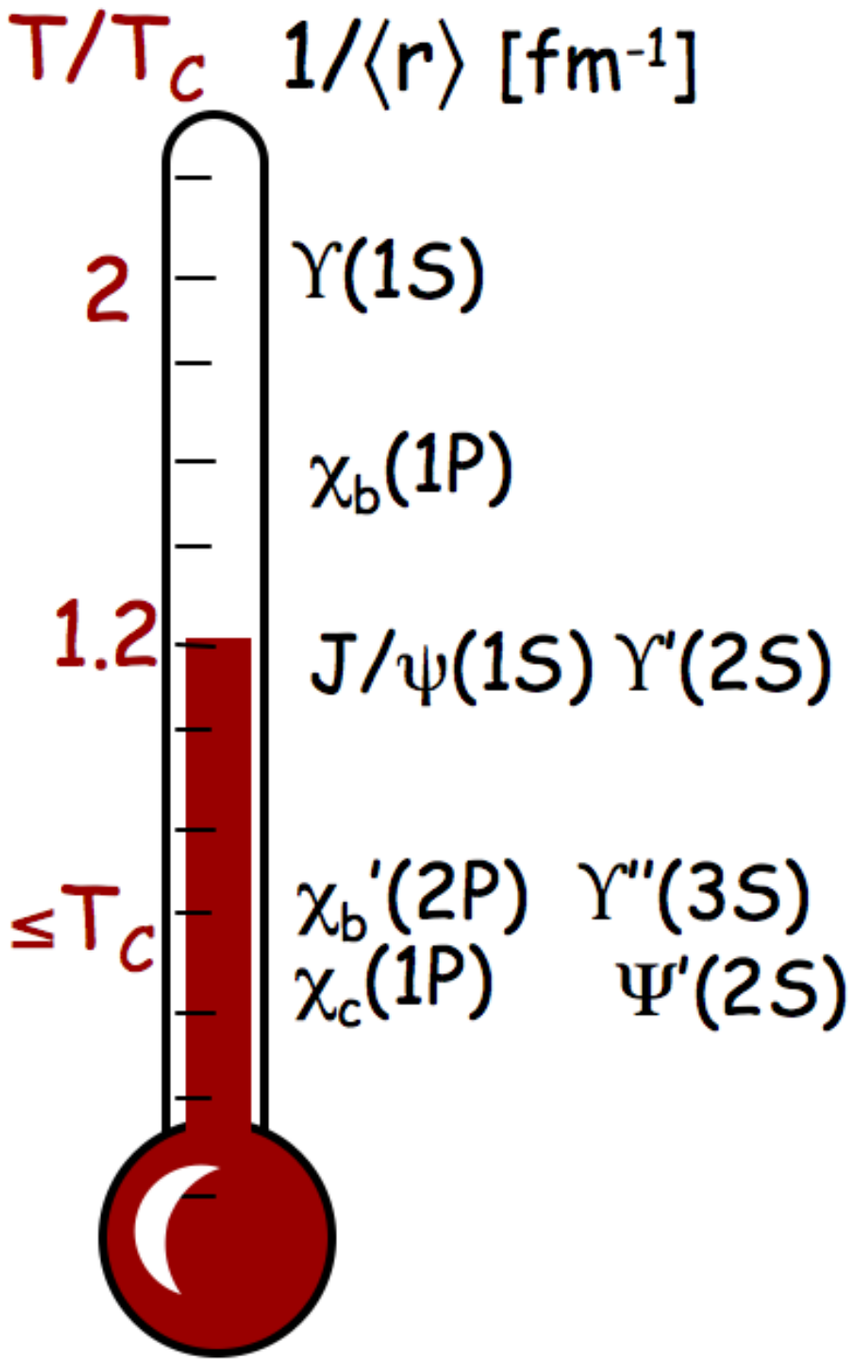


PHENIX: M. Durham (Mon, 15h10)
arxiv:1310.8286

Closed HF a.k.a the Thermometer

Mocsy, EPJ C 61 (2009) 705

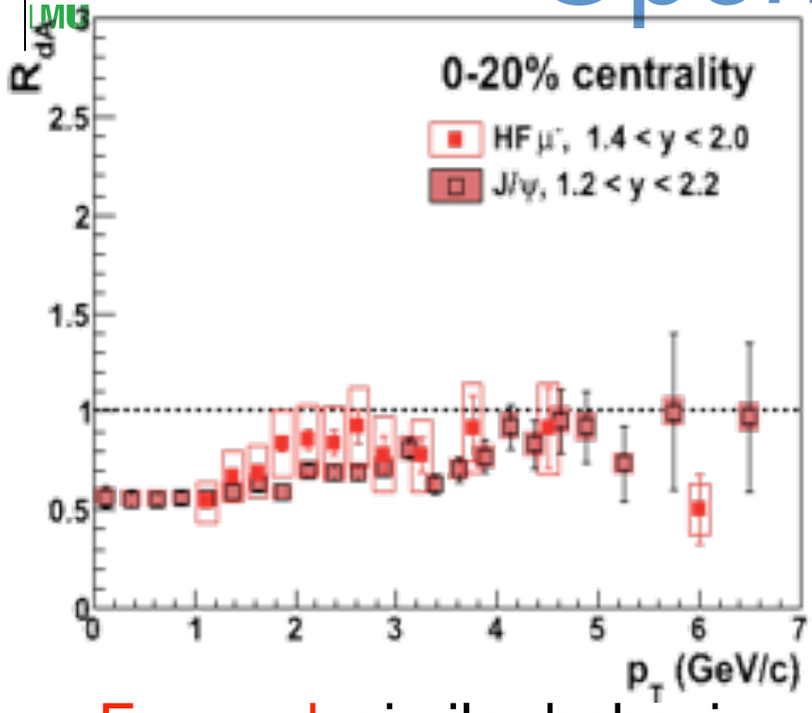
Closed HF a.k.a the Thermometer

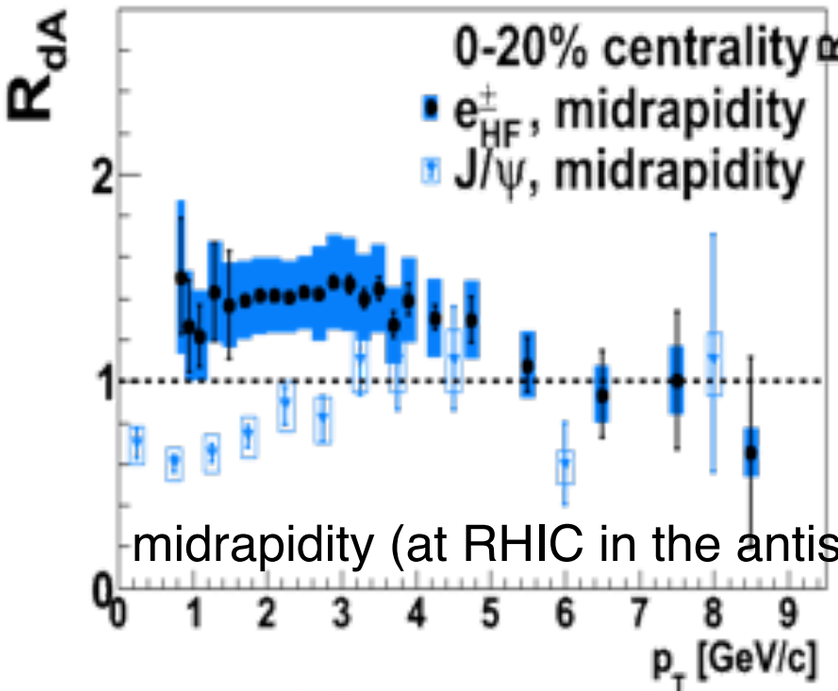


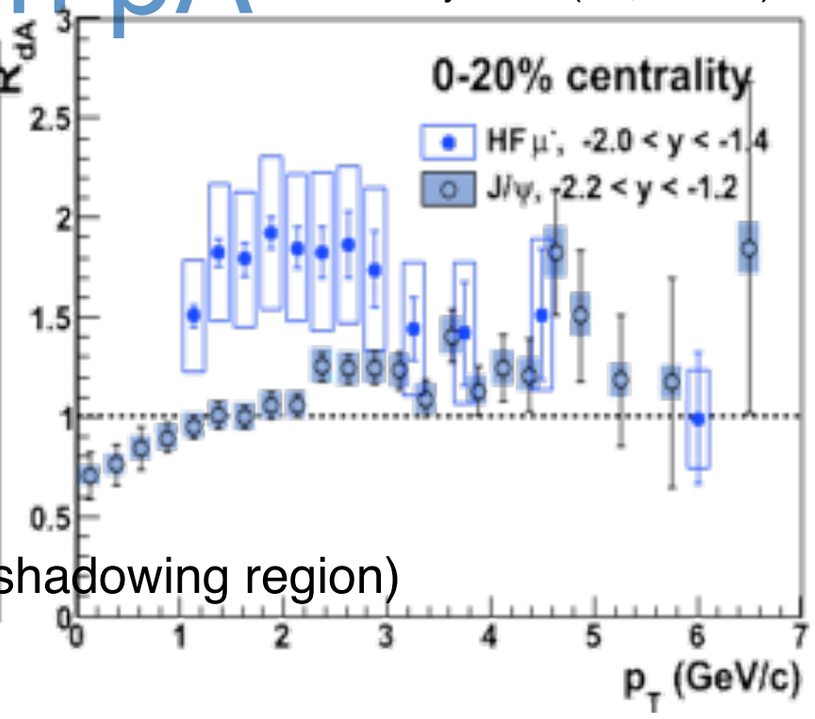
Mocsy, EPJ C 61 (2009) 705

Open vs Closed HF in pA

PHENIX: M. Durham (Mon, 15h10)
ALICE: M. Winn (Thu, 16h20)
and C. Hadjidakis (Fri, 11h30)



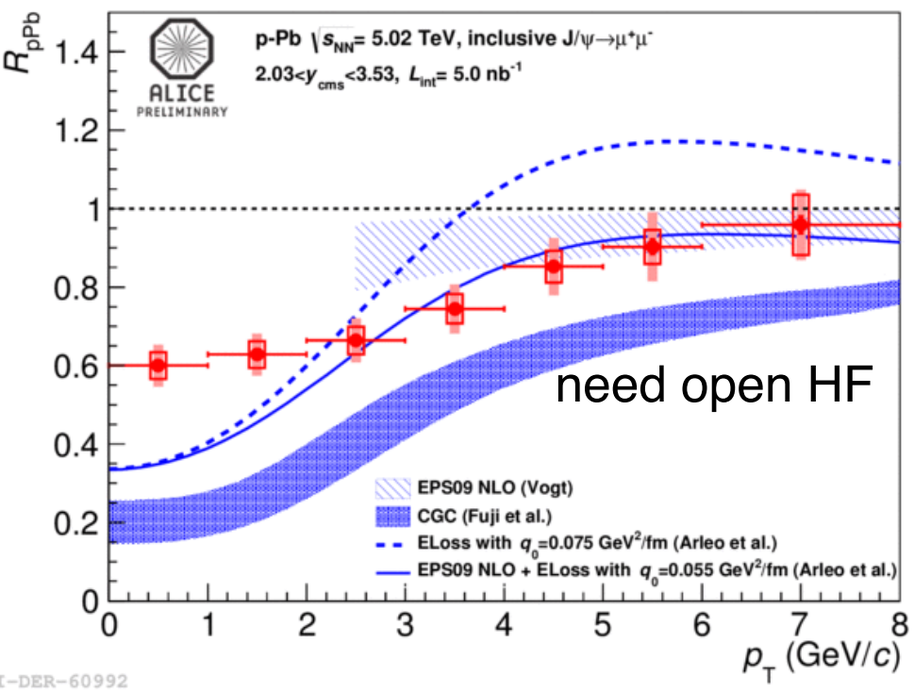


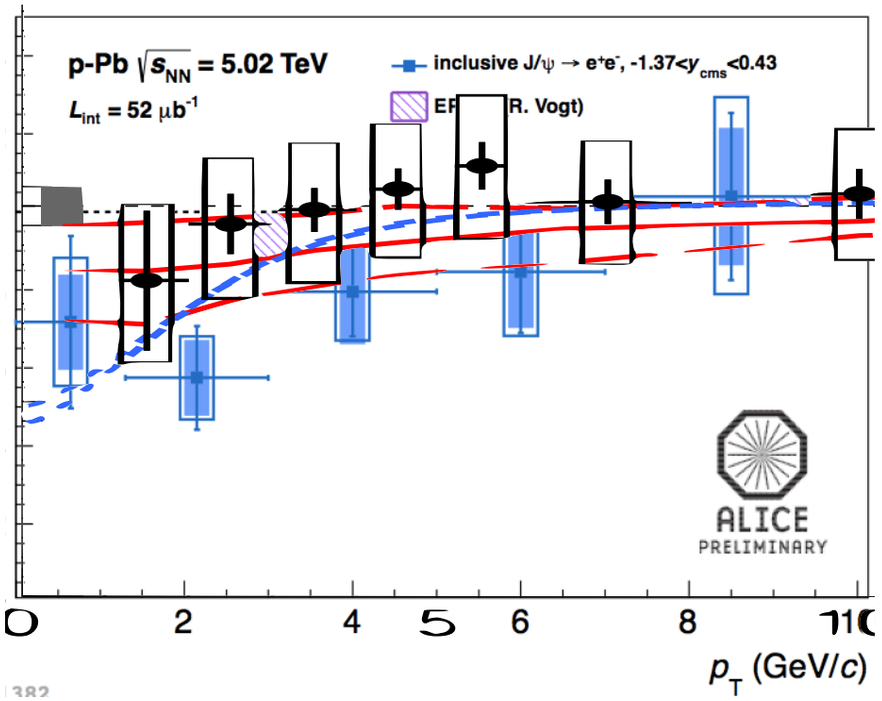


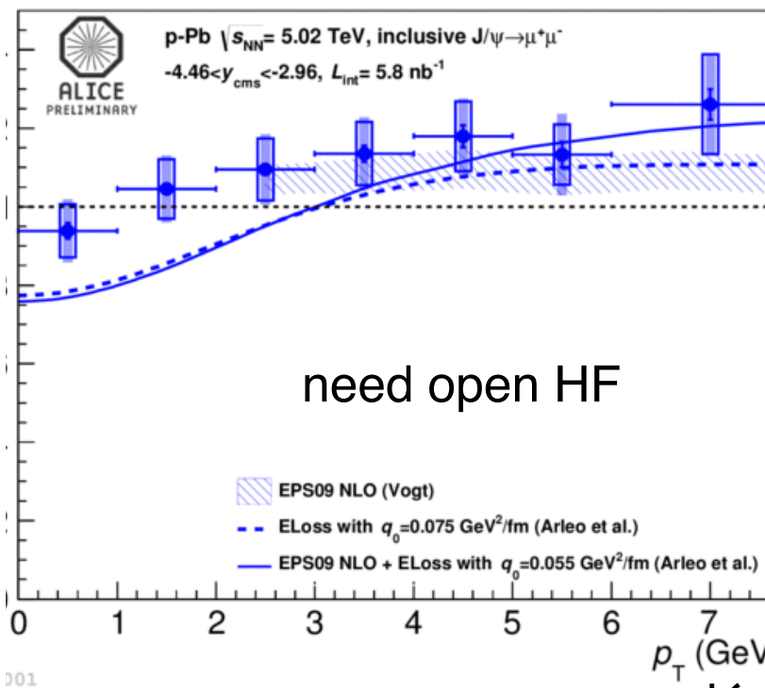
midrapidity (at RHIC in the antishadowing region)

Forward: similar behavior
-Short time in nucleus
-Low comover density

Mid- and backwards rapidity: DIFFERENT behavior
enhanced open HF versus suppressed J/ψ
→ Direct evidence for significant breakup of cc







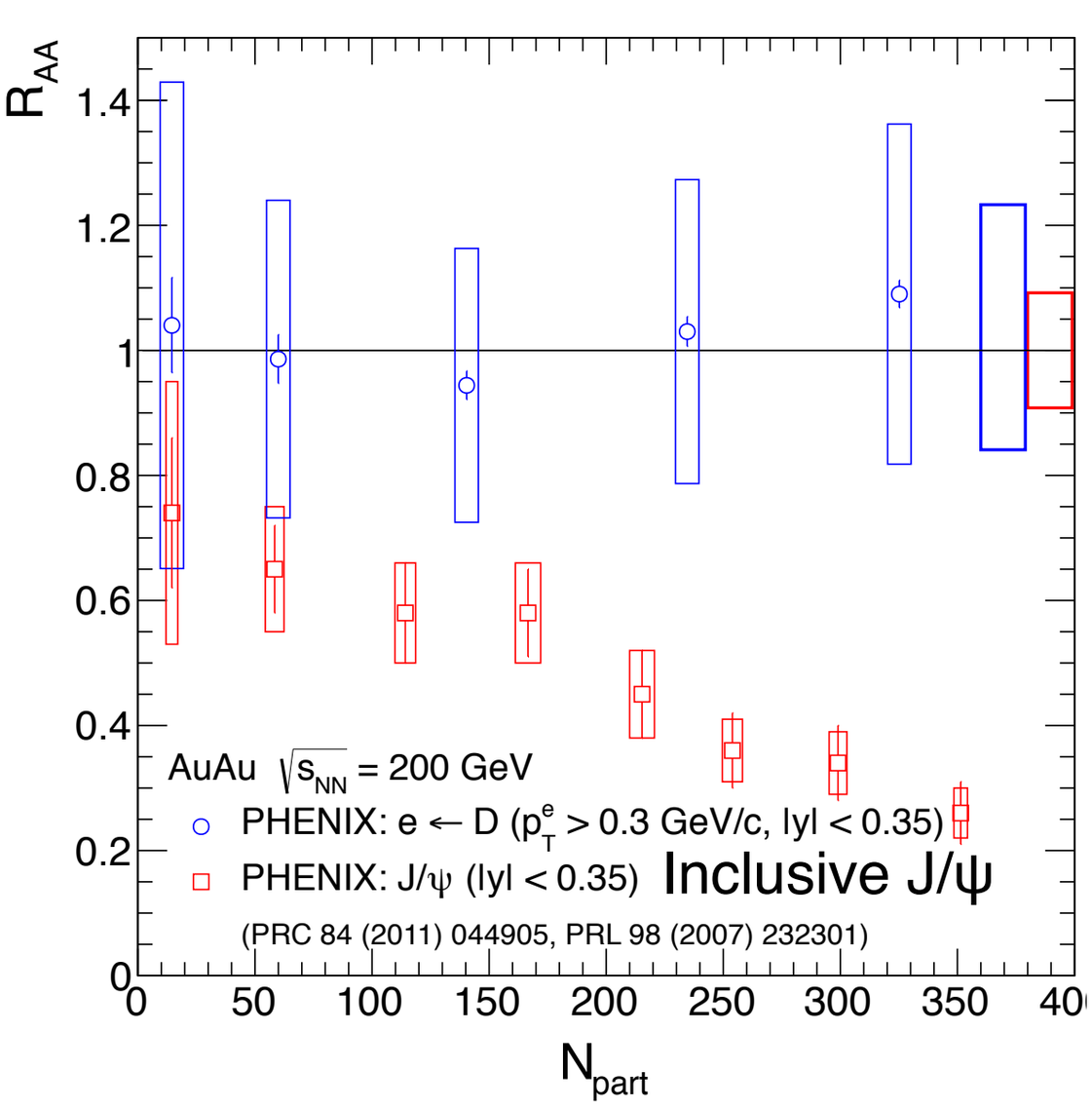
forward

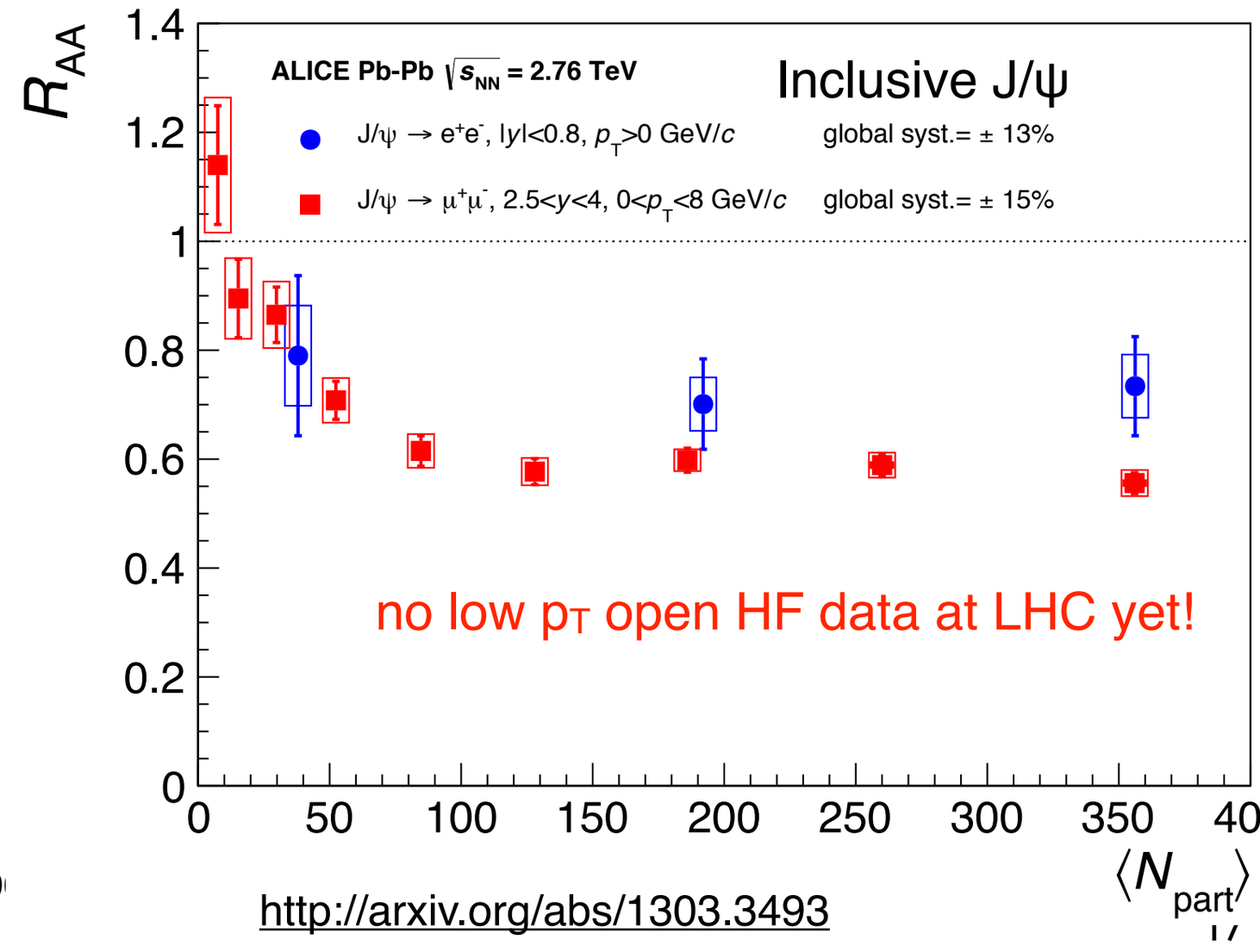
midrapidity (at LHC shadowing region)

backward

Open vs Closed HF in AA

- Sequential melting a la Satz:
  - less closed than open HF
  - not: less closed HF in AA than in pp
- At RHIC: open charm scales with N_{coll} → $R_{AA}(J/\psi)$ = J/ψ / D in PbPb
  - ignoring the large uncertainties on open charm

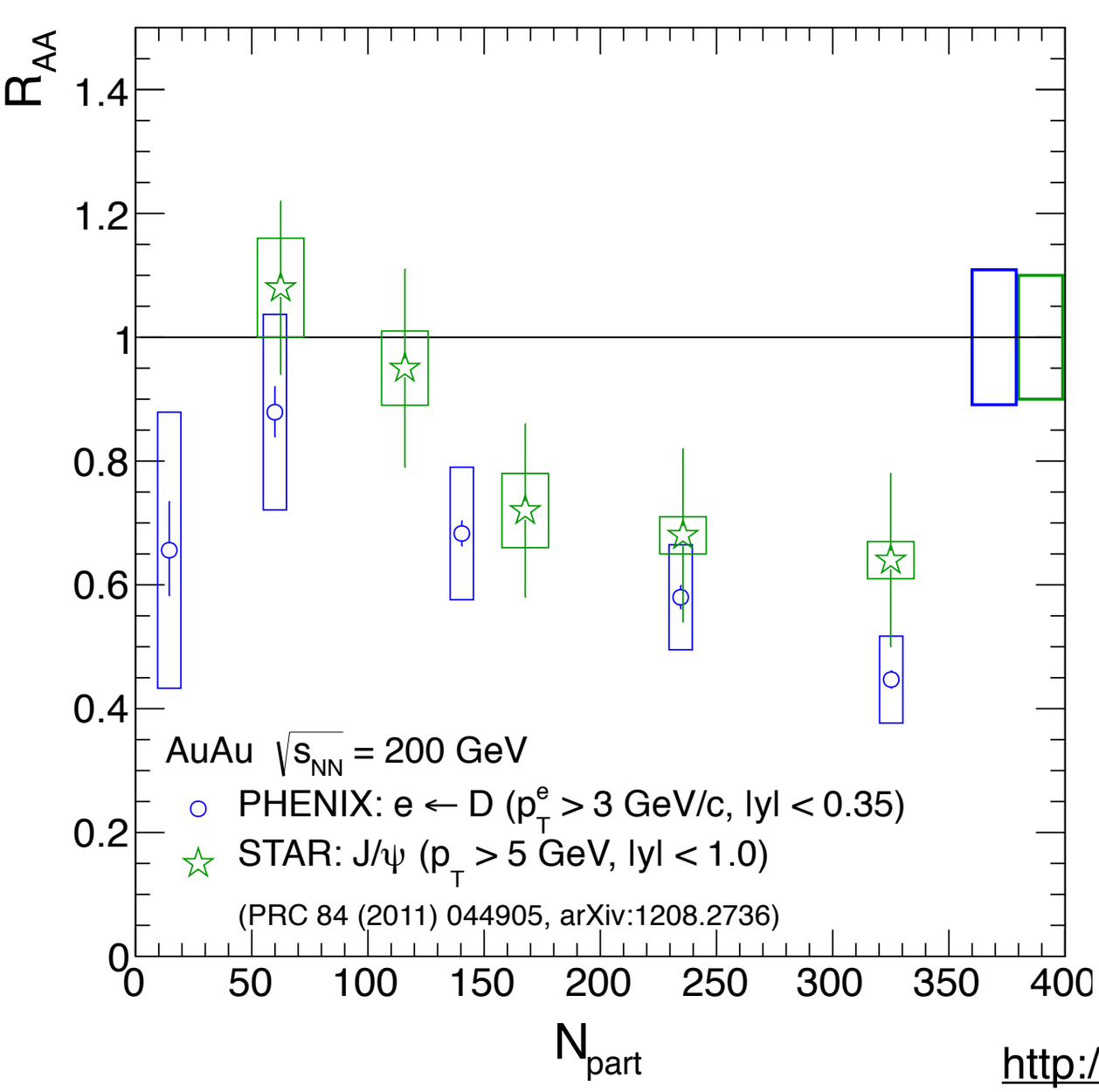


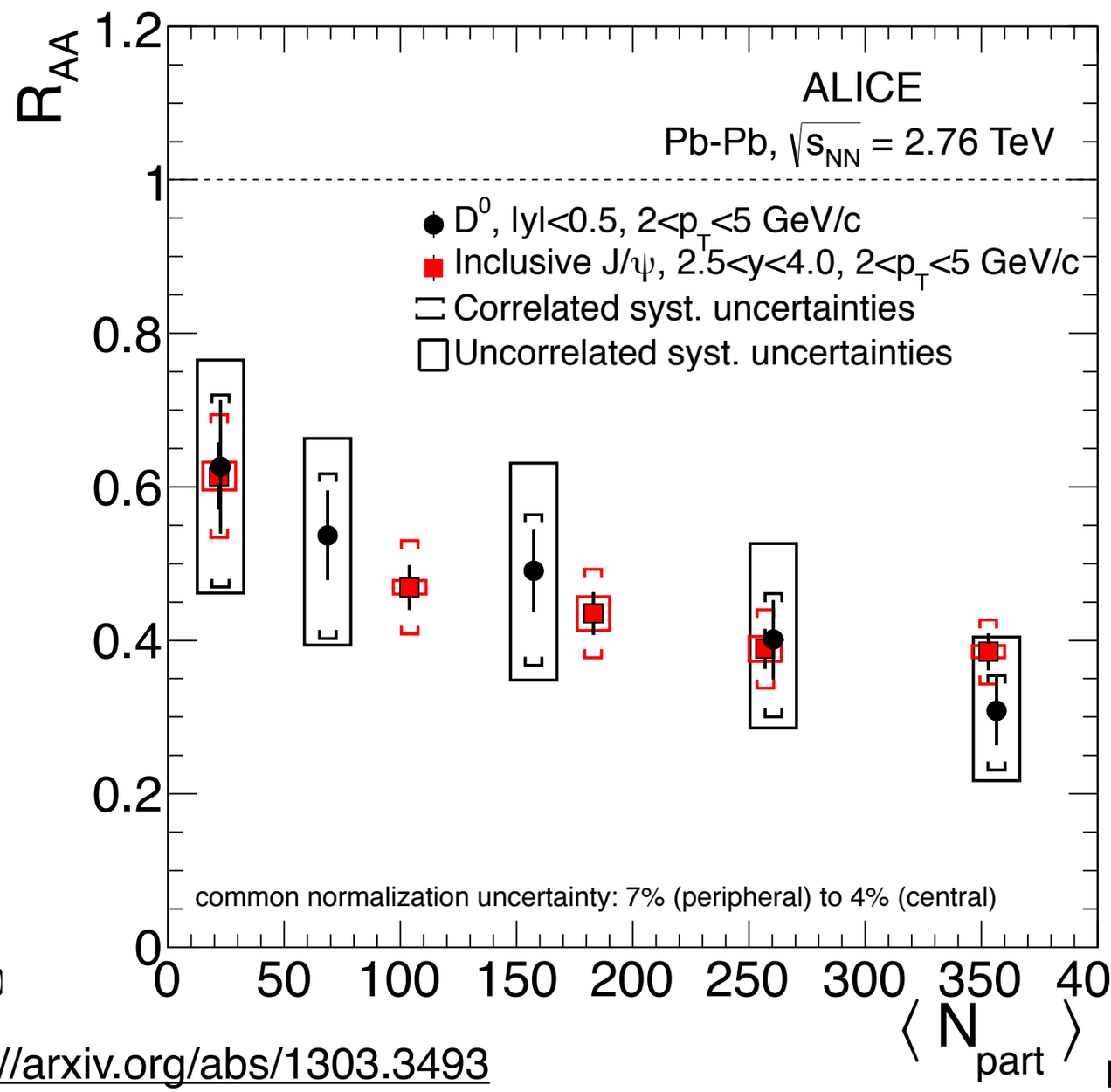


http://arxiv.org/abs/1303.3493

Open vs. Closed HF in AA

- But how to compare open and closed HF with p_T cuts?
  - not trivial to select kinematic region of interest: same quark p_T, same hadron p_T,…?
- Similar suppression for “high p_T” D and J/ψ

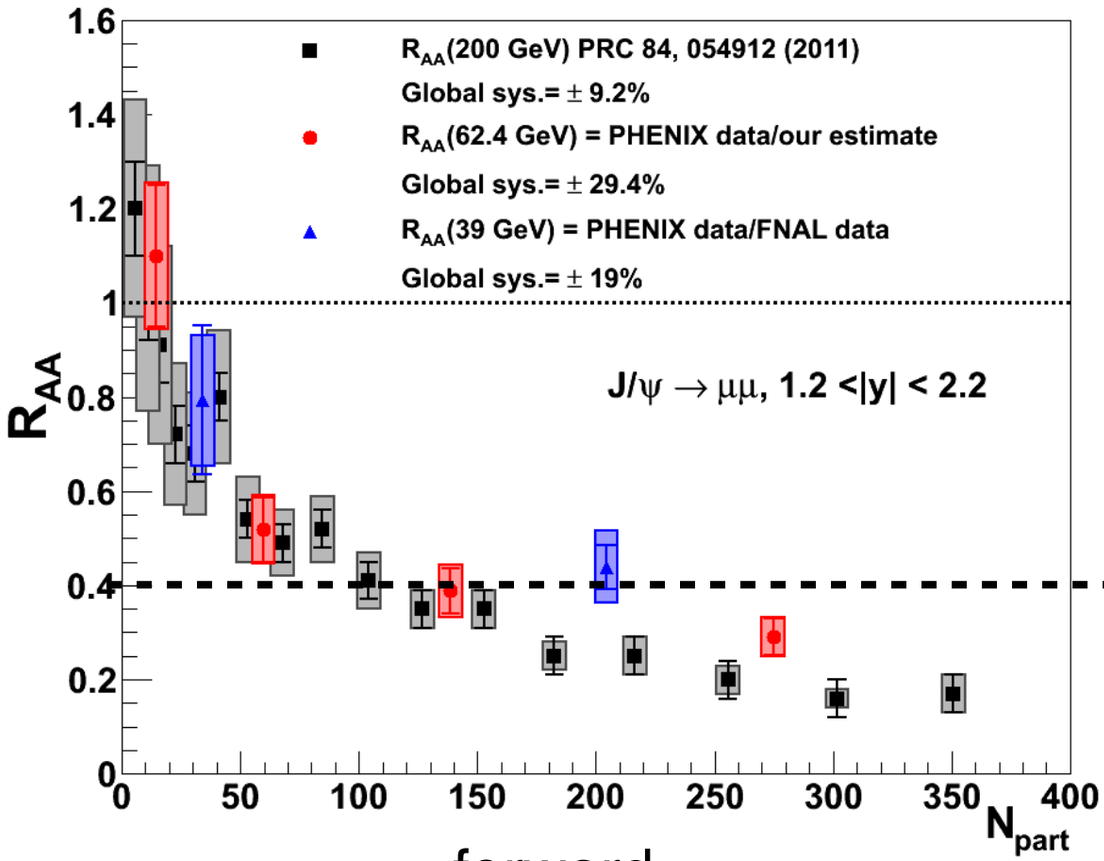




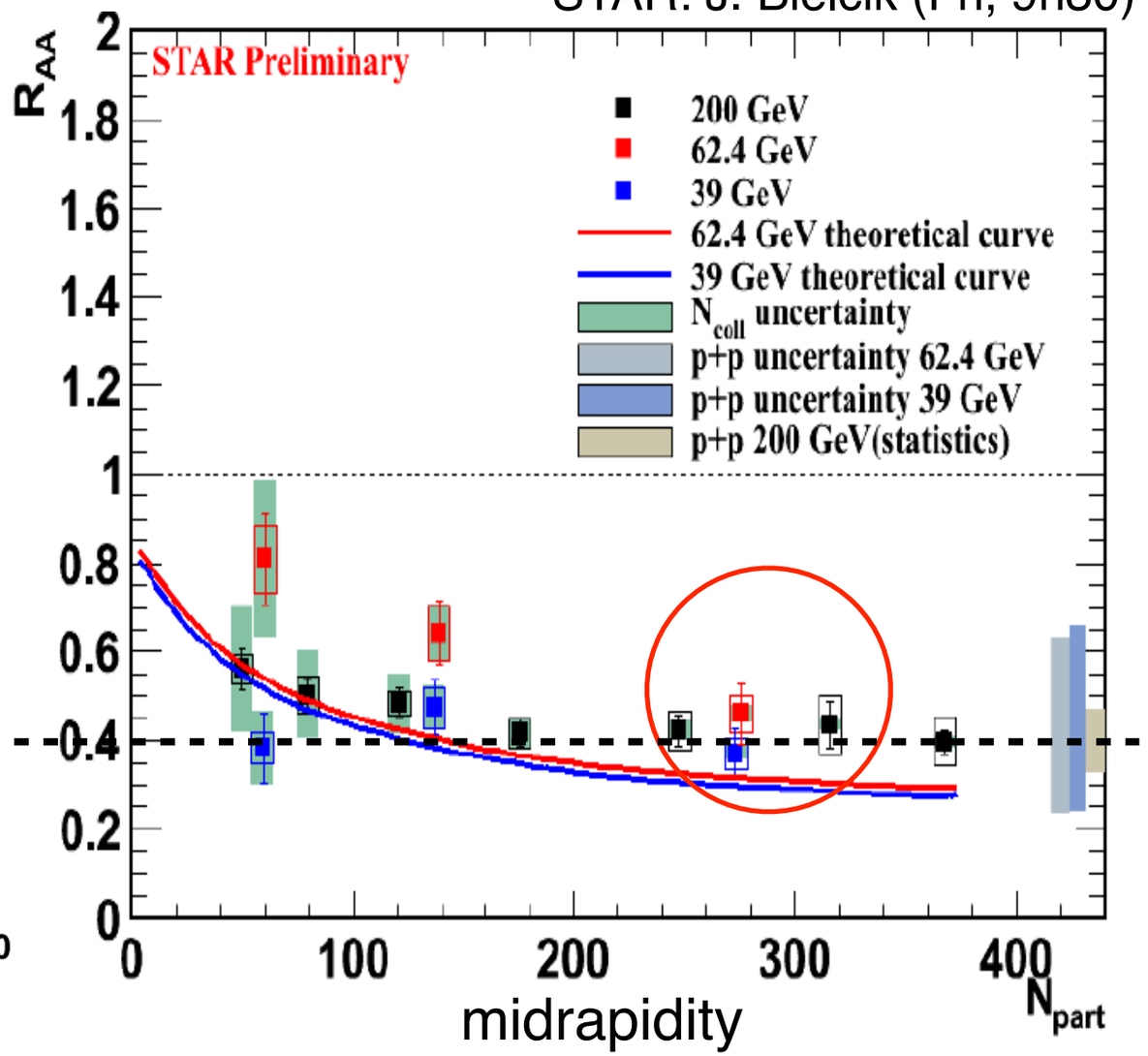
http://arxiv.org/abs/1303.3493

Quarkonia in AA

PHENIX: A. Frawley (Mon, 16h00) and D. McGlinchey (Fri, 9h00)
STAR: J. Bielcik (Fri, 9h30)



forward



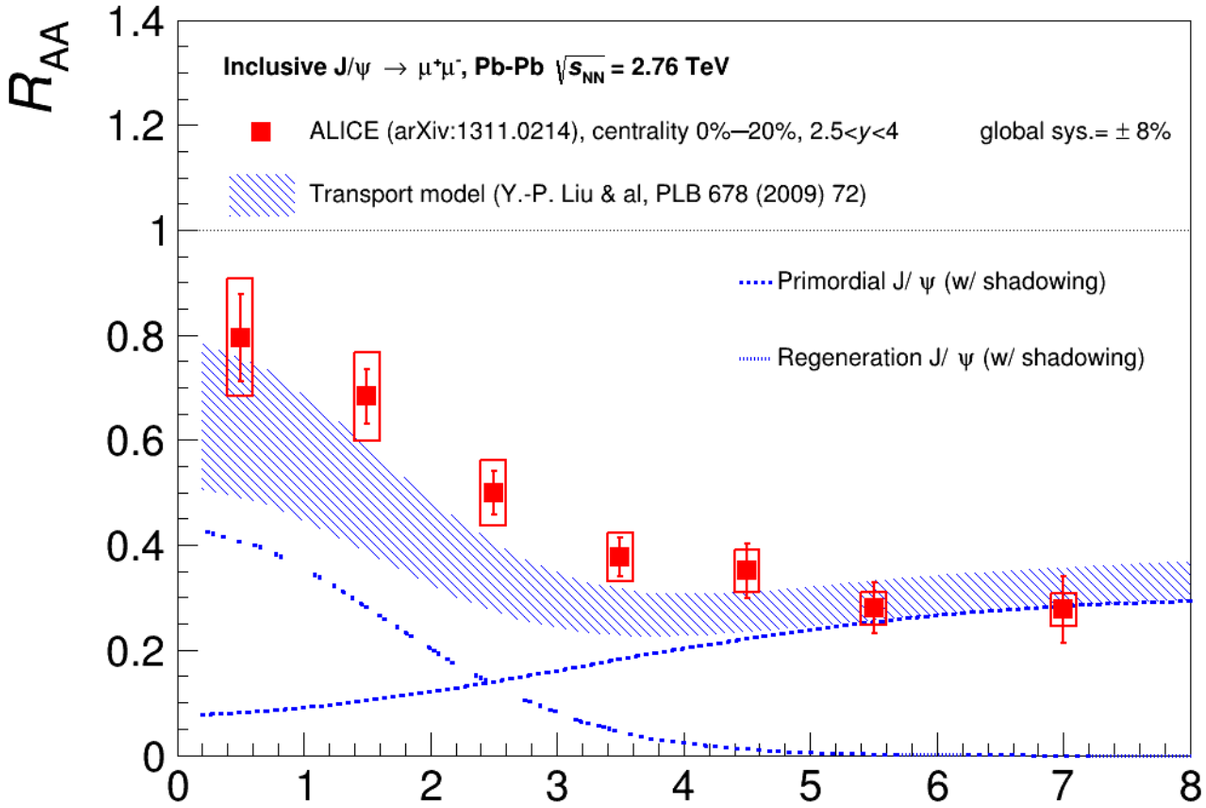
midrapidity

- Midrapidity R_{AA} doesn't change with $\sqrt{s_{NN}}$
  - would have expected recombination to contribute less at lower $\sqrt{s_{NN}}$
  - compensated by lower $\sqrt{s_{NN}}$ moving midrapidity into antishadowing?
- Or: no recombination and difference between forward and midrapidity just shadowing?
  - (at forward rapidity lower $\sqrt{s_{NN}}$ means moving out of the shadowing region)

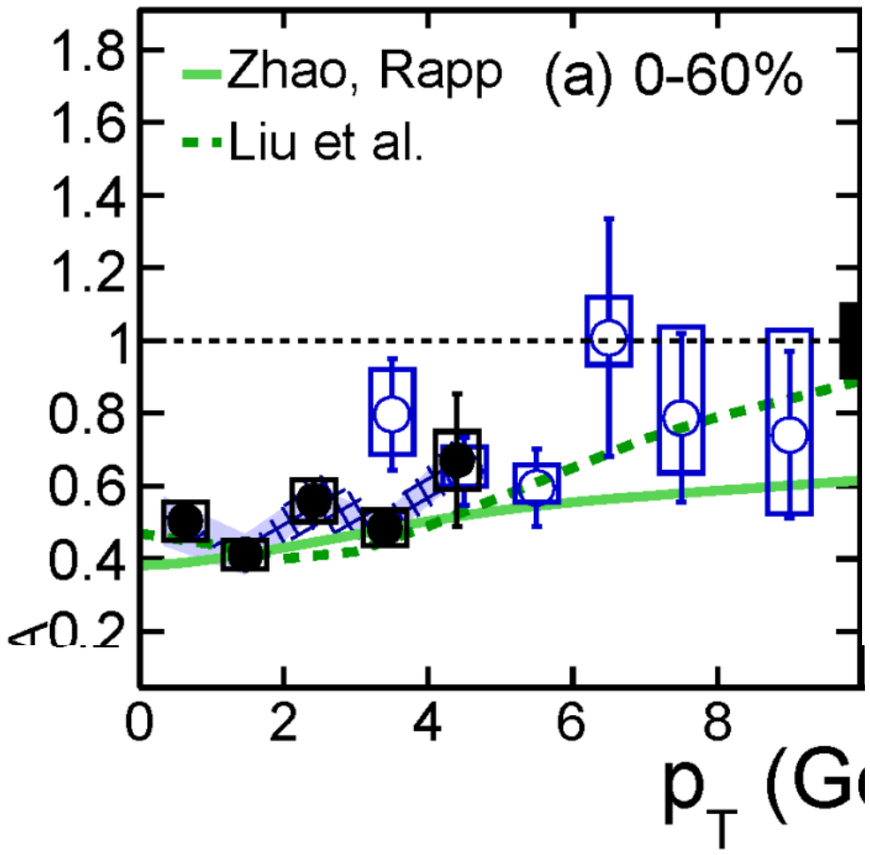
Quarkonia in AA

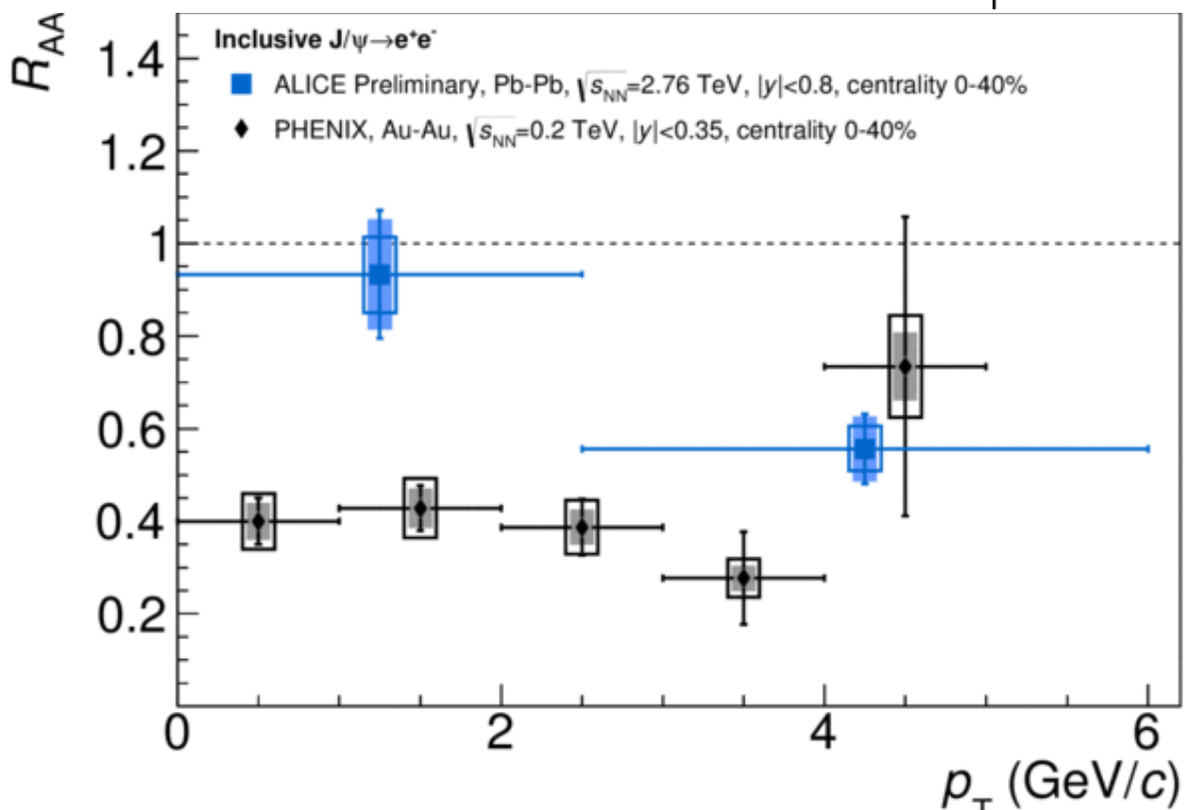
STAR: J. Bielcik (Fri, 9h30)
ALICE: C. Hadjidakis (Fri, 11h30)

- LHC: less suppression at low p_T than at high p_T
  - consistent with screening + recombination
- RHIC: more suppression at low p_T than at high p_T
  - screening w/o significant recombination contribution



ALICE, arXiv:1311.0214

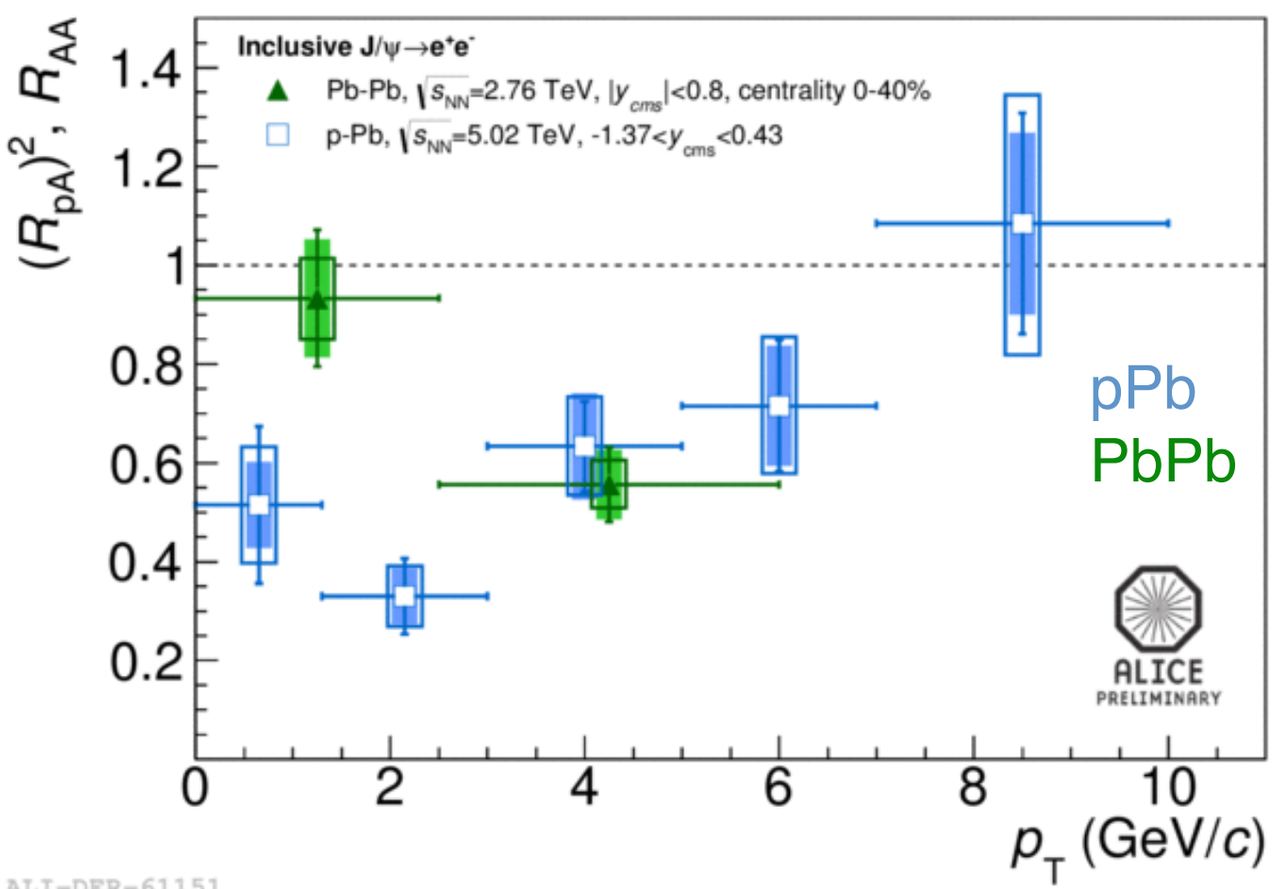




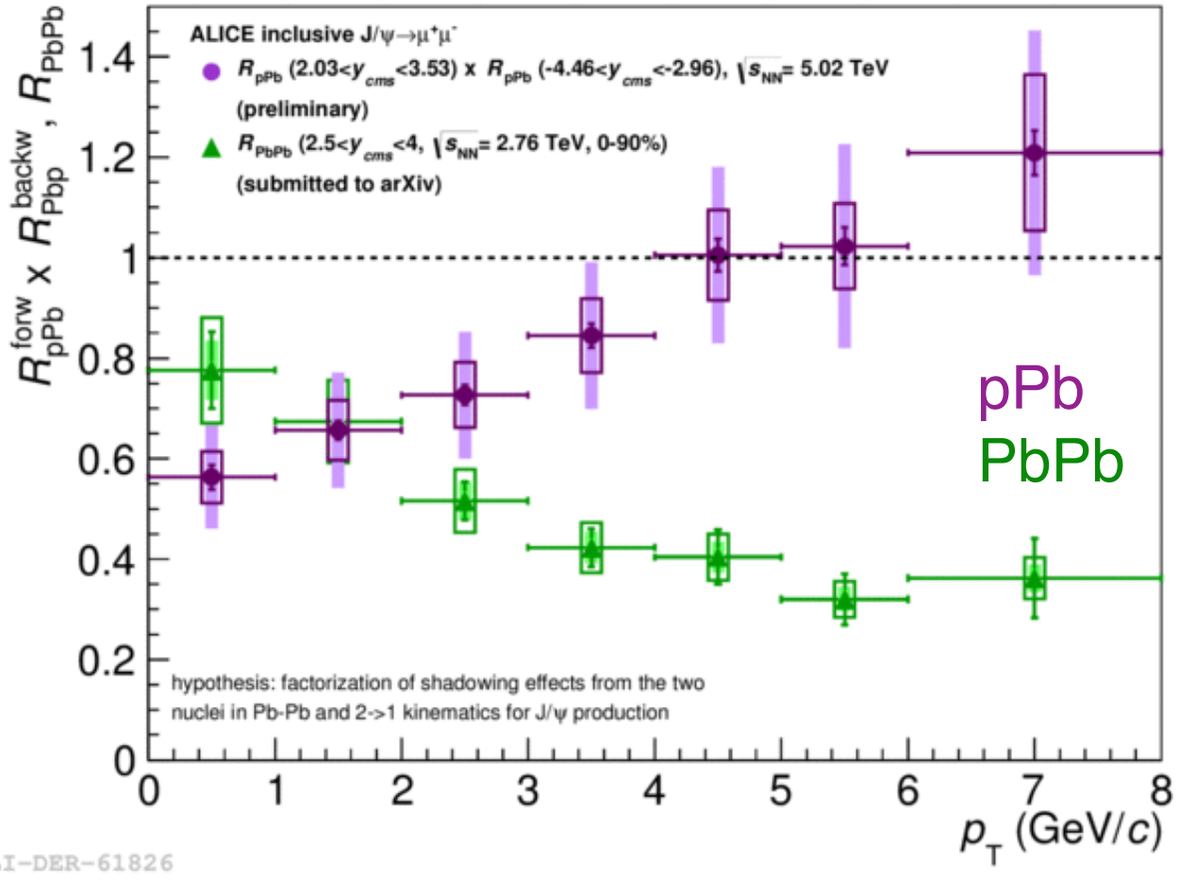
Quarkonia in AA vs. pA

- Attempt to compare R_{AA} with R_{pA}^2
  - assume 2→1 kinematics, comparable x_g, and factorization of shadowing…
  - suppression at high p_T unaffected by CNM
  - CNM correction at low p_T enhances R_{AA}

ALICE: M. Winn (Thu, 16h20) and C. Hadjidakis (Fri, 11h30)



midrapidity

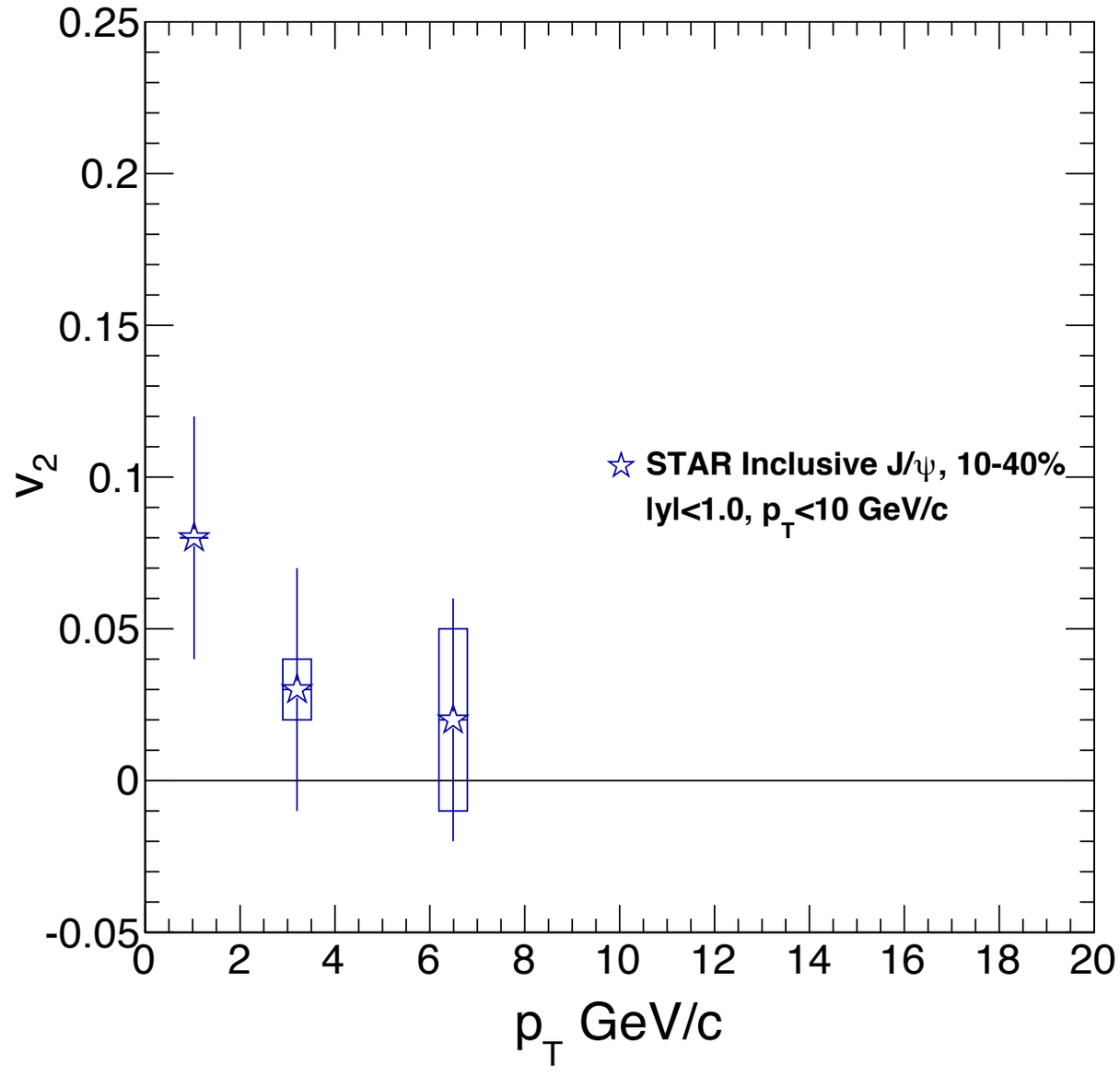


forward

Quarkonia v_2

- STAR found v_2 consistent with 0

STAR: J. Bielcik (Fri, 9h30)
ALICE: C. Hadjidakis (Fri, 11h30)
CMS: D. Moon (Mon, 16h40)
and L. Benhabib (Fri, 12h00)



Quarkonia v_2

- STAR found v_2 consistent with 0
- ALICE found “hint of v_2”
  - as expected for recombination

STAR: J. Bielcik (Fri, 9h30)
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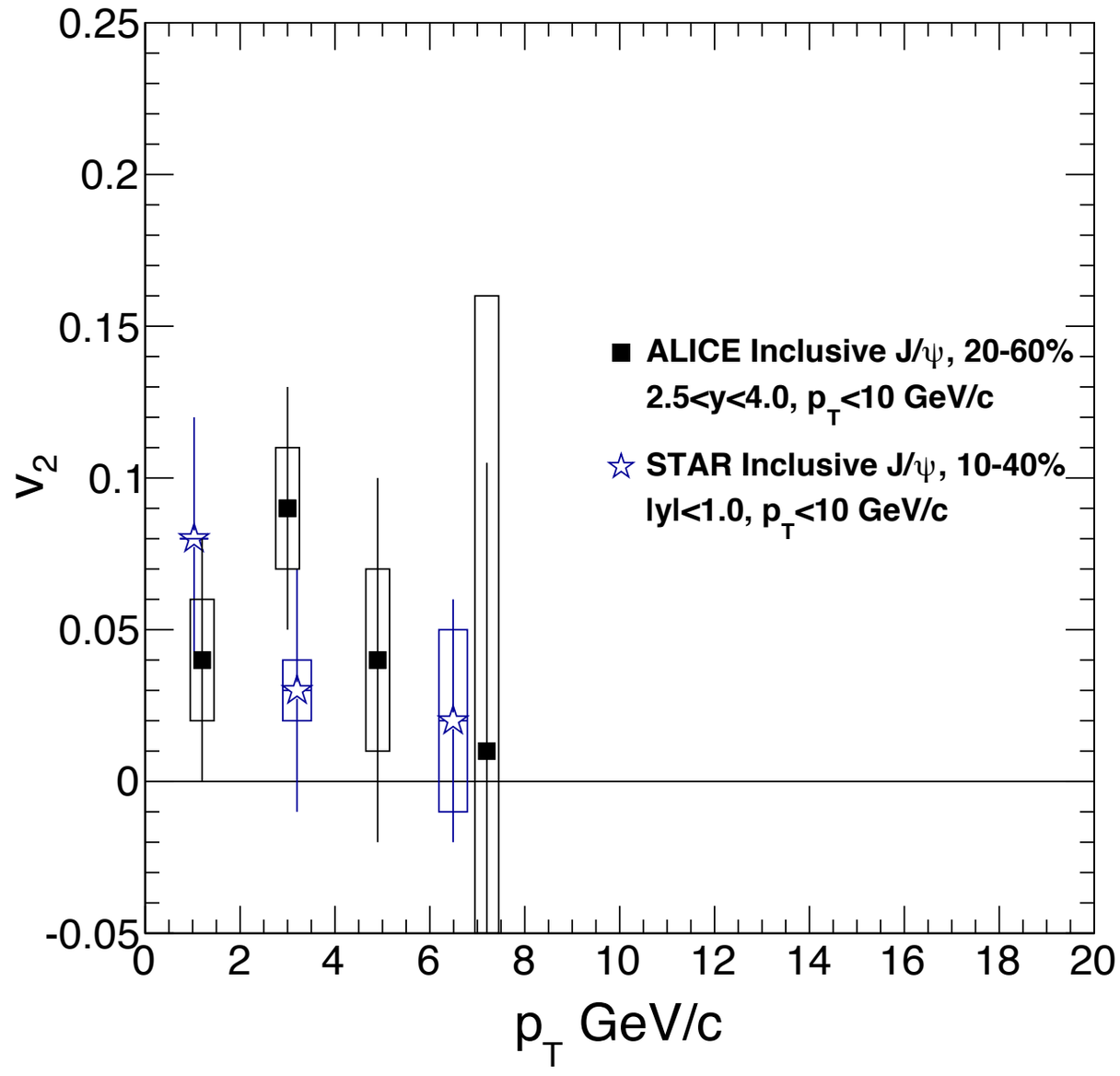

Quarkonia v_2

STAR: J. Bielcik (Fri, 9h30)
ALICE: C. Hadjidakis (Fri, 11h30)
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- STAR found v_2 consistent with 0
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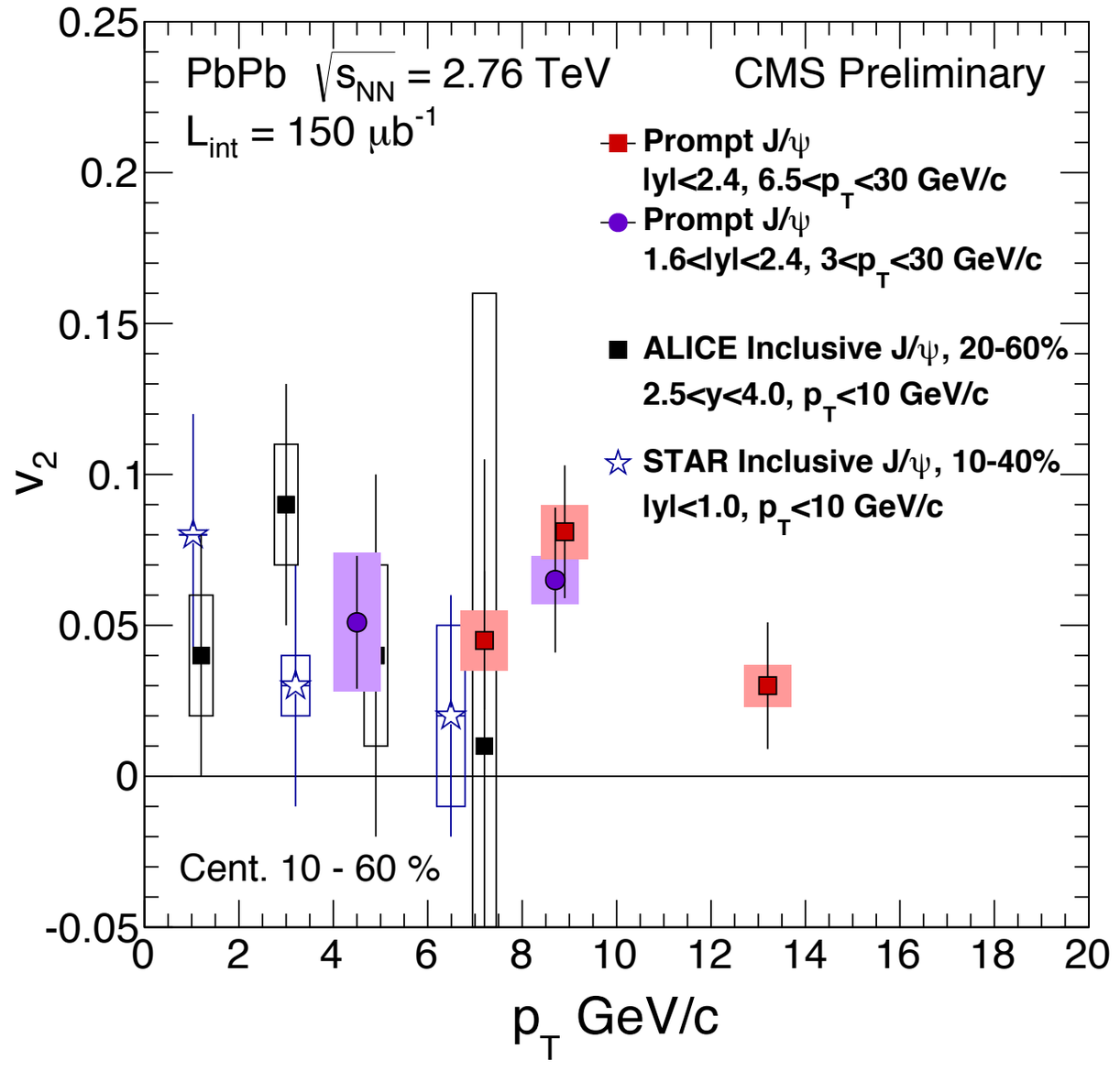
  - as expected for recombination
- CMS measured significant v_2
  - though only above 6.5 GeV/c
  - measurement also for $3<p_T<6.5$ GeV/c
  - high-p_T v_2 → path-length dependent suppression
- Taking all results together
  - J/ψ has non-zero v_2



Quarkonia vs. D v_2

- STAR found v_2 consistent with 0
- ALICE found “hint of v_2”
  - as expected for recombination
- CMS measured significant v_2
  - though only above 6.5 GeV/c
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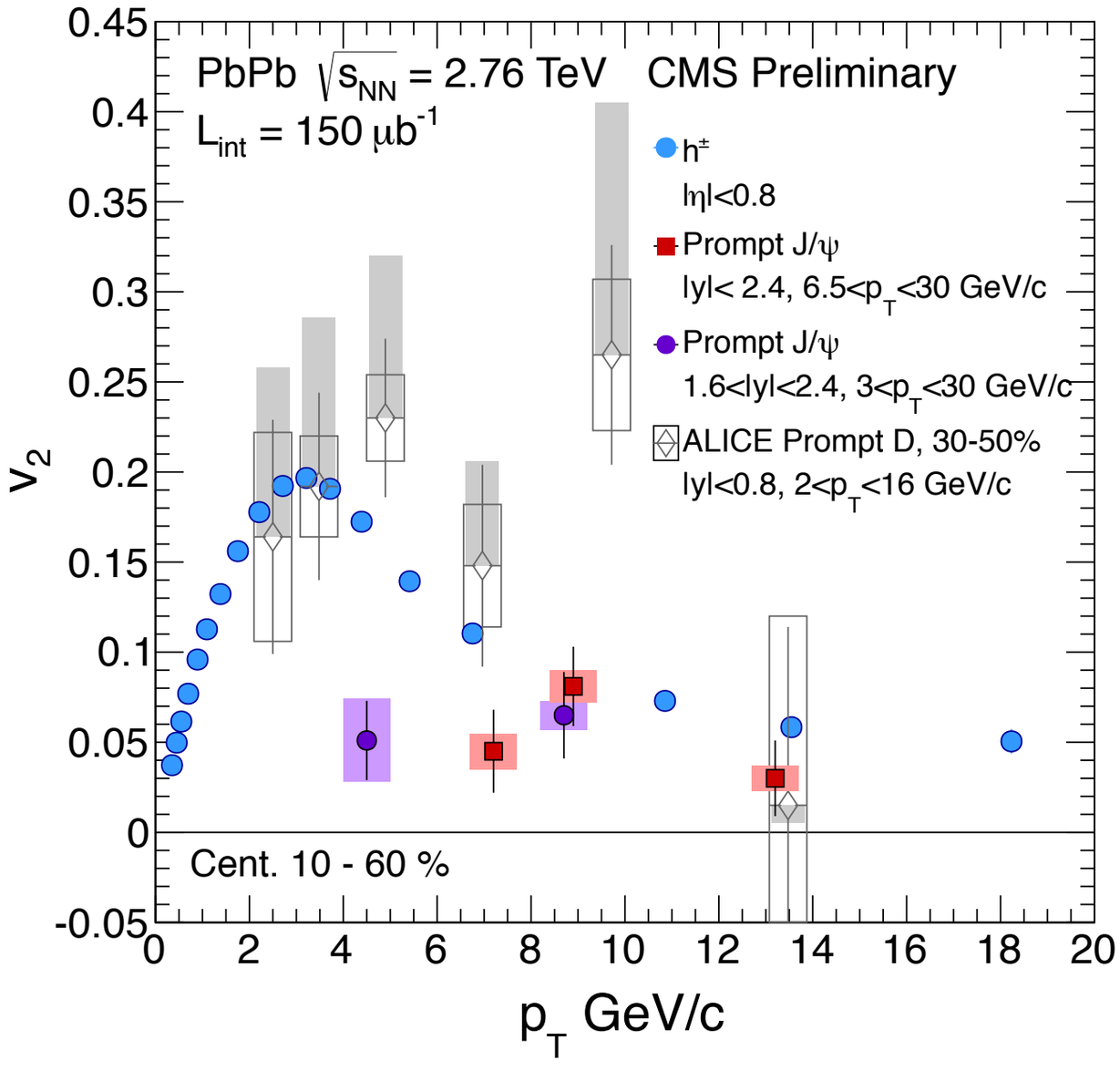
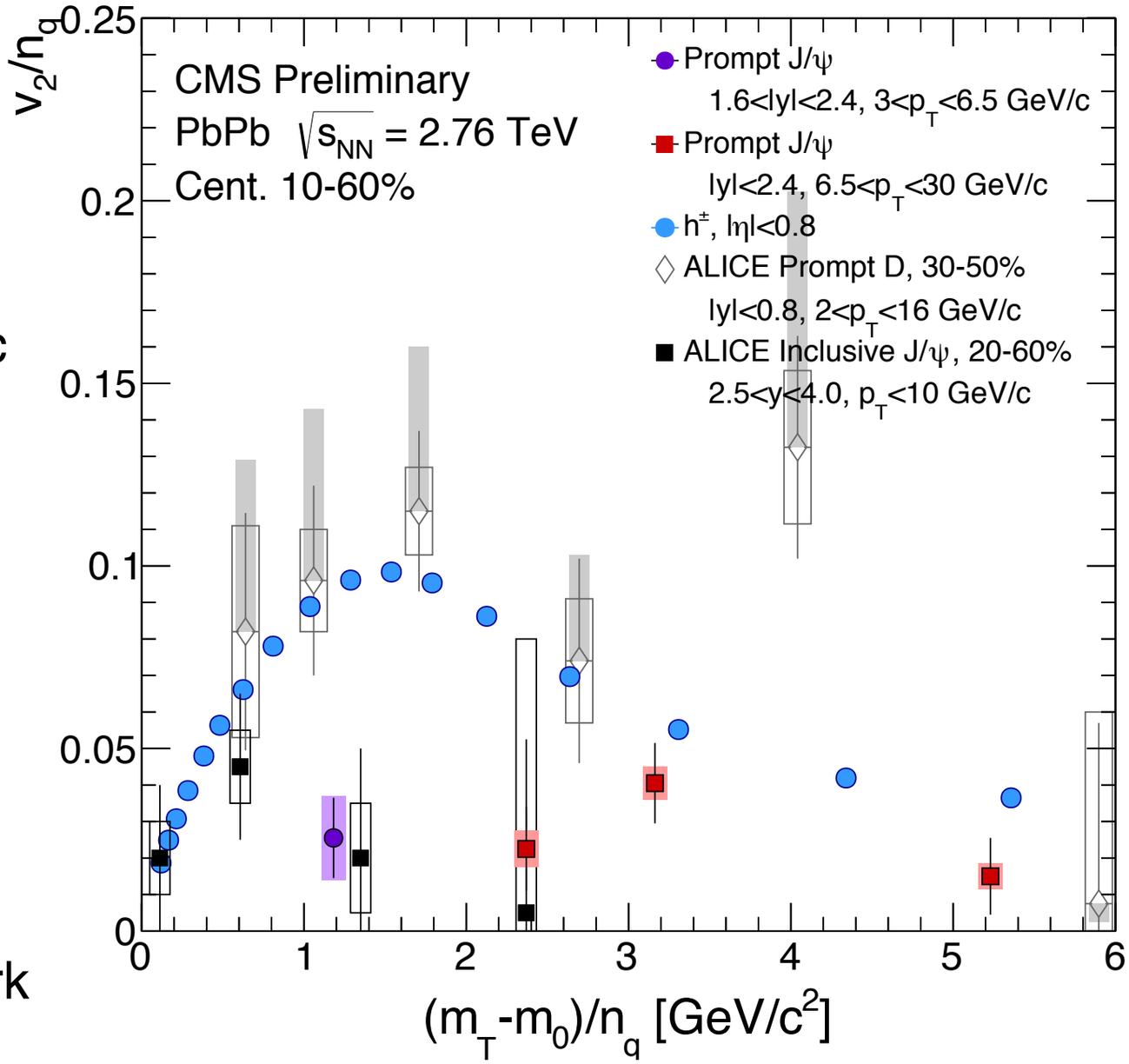
  - high-p_T v_2 → path-length dependent suppression
- Taking all results together
  - J/psi has non-zero v_2
- Comparison to light hadrons and D



Quarkonia vs. D v_2 scaling?

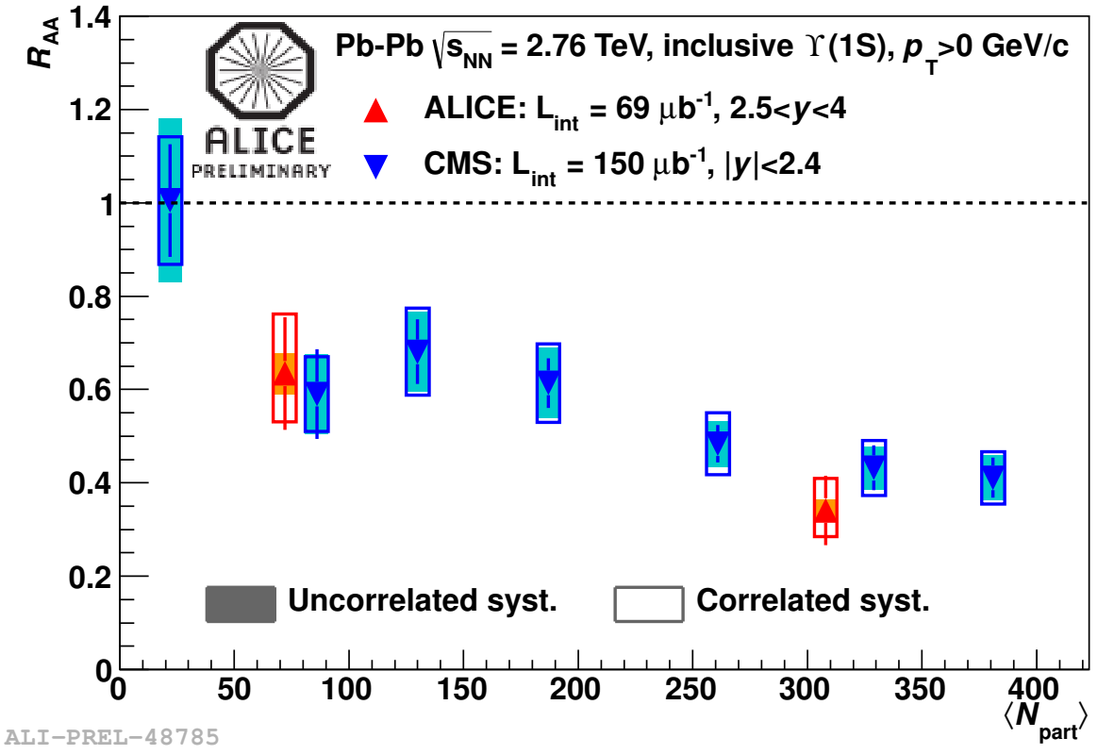
- STAR found v_2 consistent with 0
- ALICE found "hint of v_2"
  - as expected for recombination
- CMS measured significant v_2
  - though only above 6.5 GeV/c
  - measurement also for $3<p_T<6.5$ GeV/c
  - high-p_T v_2 → path-length dependent suppression
- Taking all results together
  - J/psi has non-zero v_2
- Comparison to light hadrons and D
- What about the n_q scaling?
  - approximate scaling for D (charm quark flows as much as the light quark?)
  - no such scaling for J/ψ
  - I am again ignoring uncertainties ☺



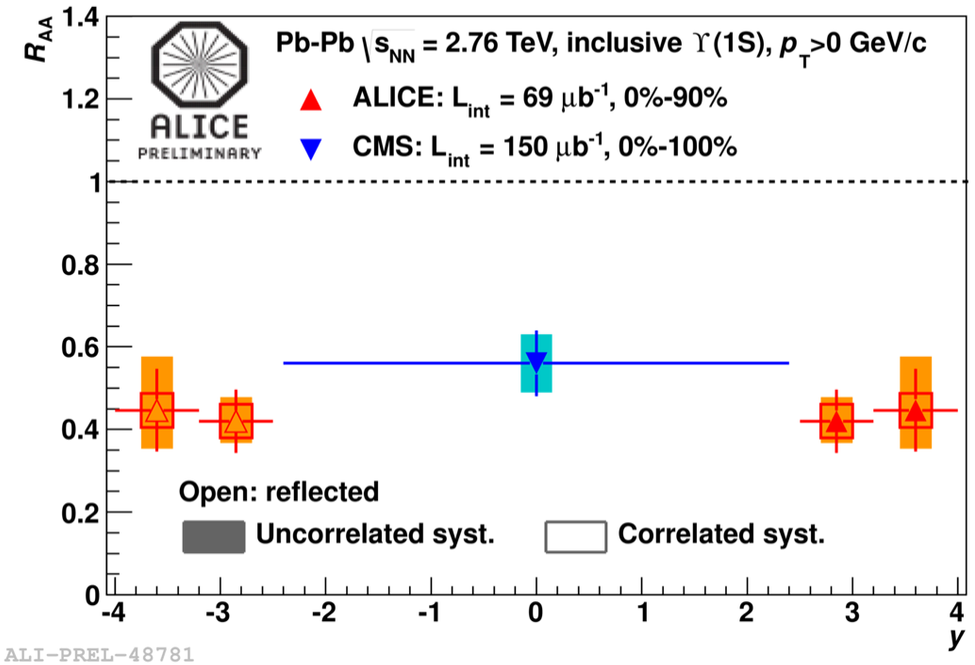
thanks to C. Mironov for making the plot in the middle of the night

Bottomonia

- ALICE extends CMS Υ measurement towards forward rapidity
  - no significant change in suppression with rapidity

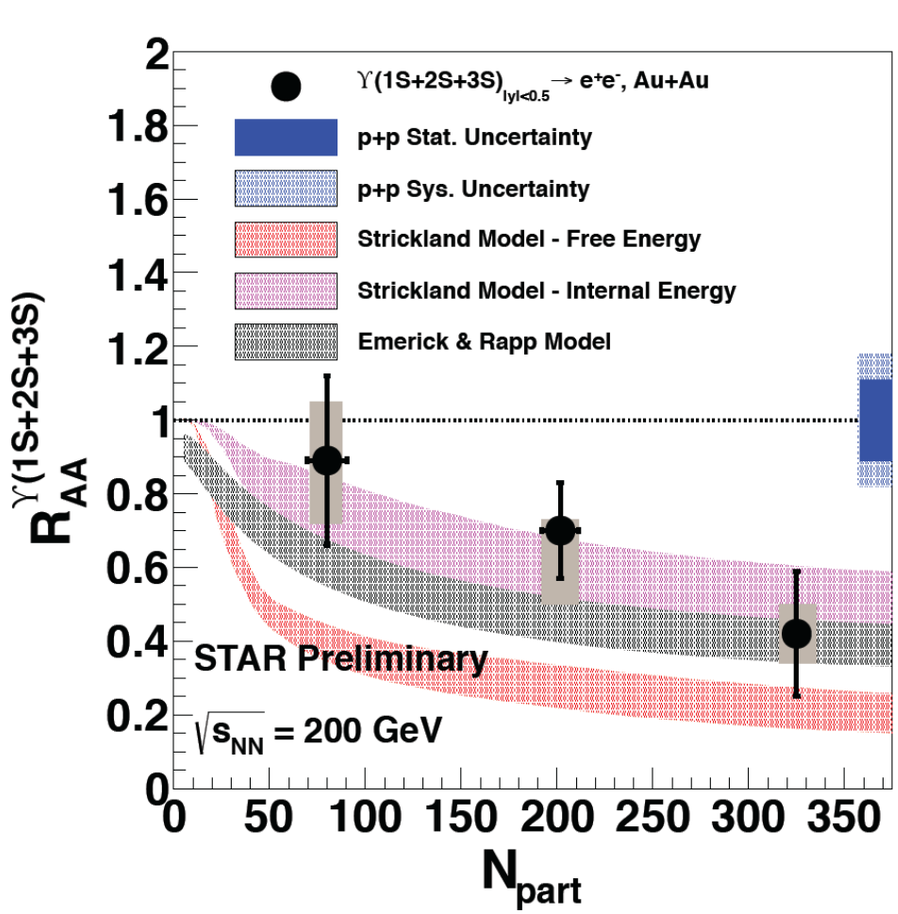


ALI-PREL-48785



ALI-PREL-48781

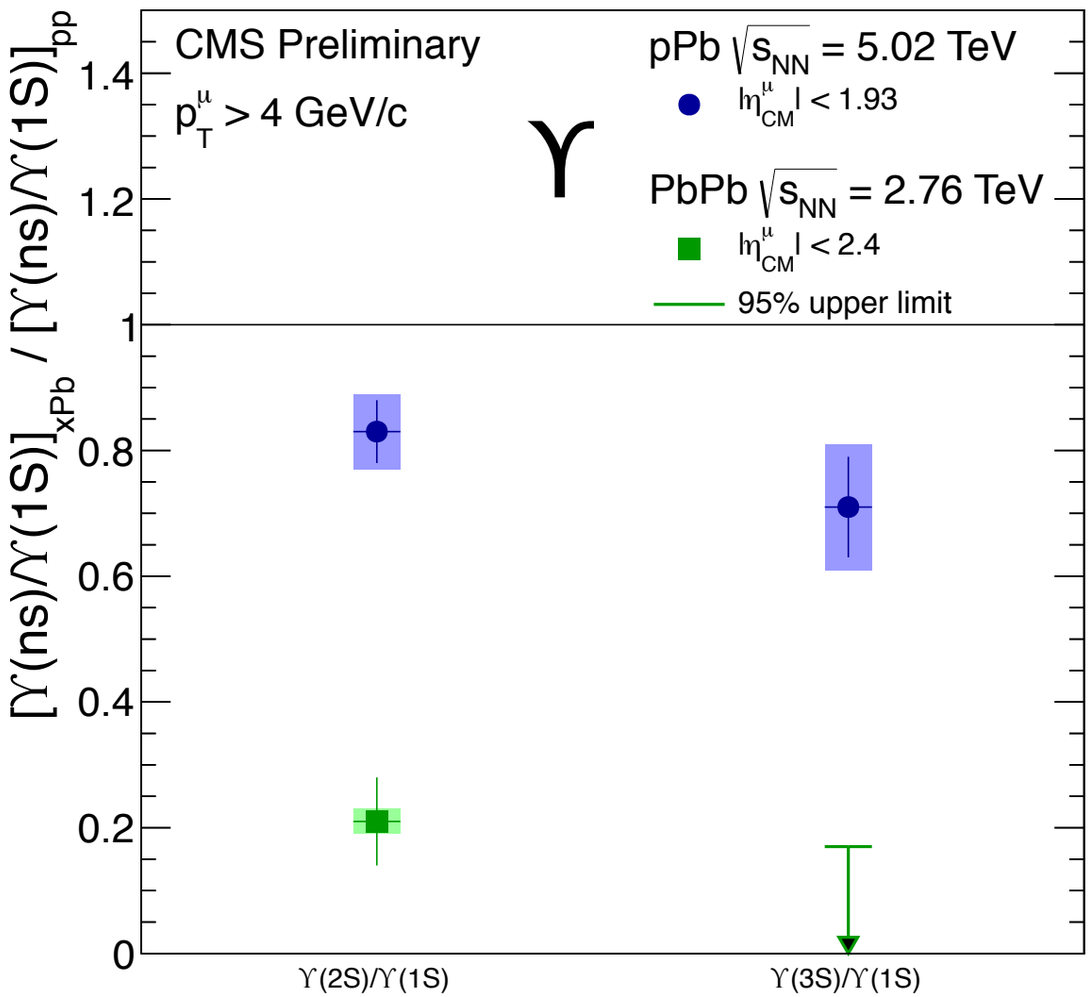
STAR: J. Bielcik (Fri, 9h30)
ALICE: F. Bossu (Mon, 16h20)
and C. Hadjidakis (Fri, 11h30)
CMS: D. Moon (Mon, 16h40)
and L. Benhabib (Fri, 12h00)

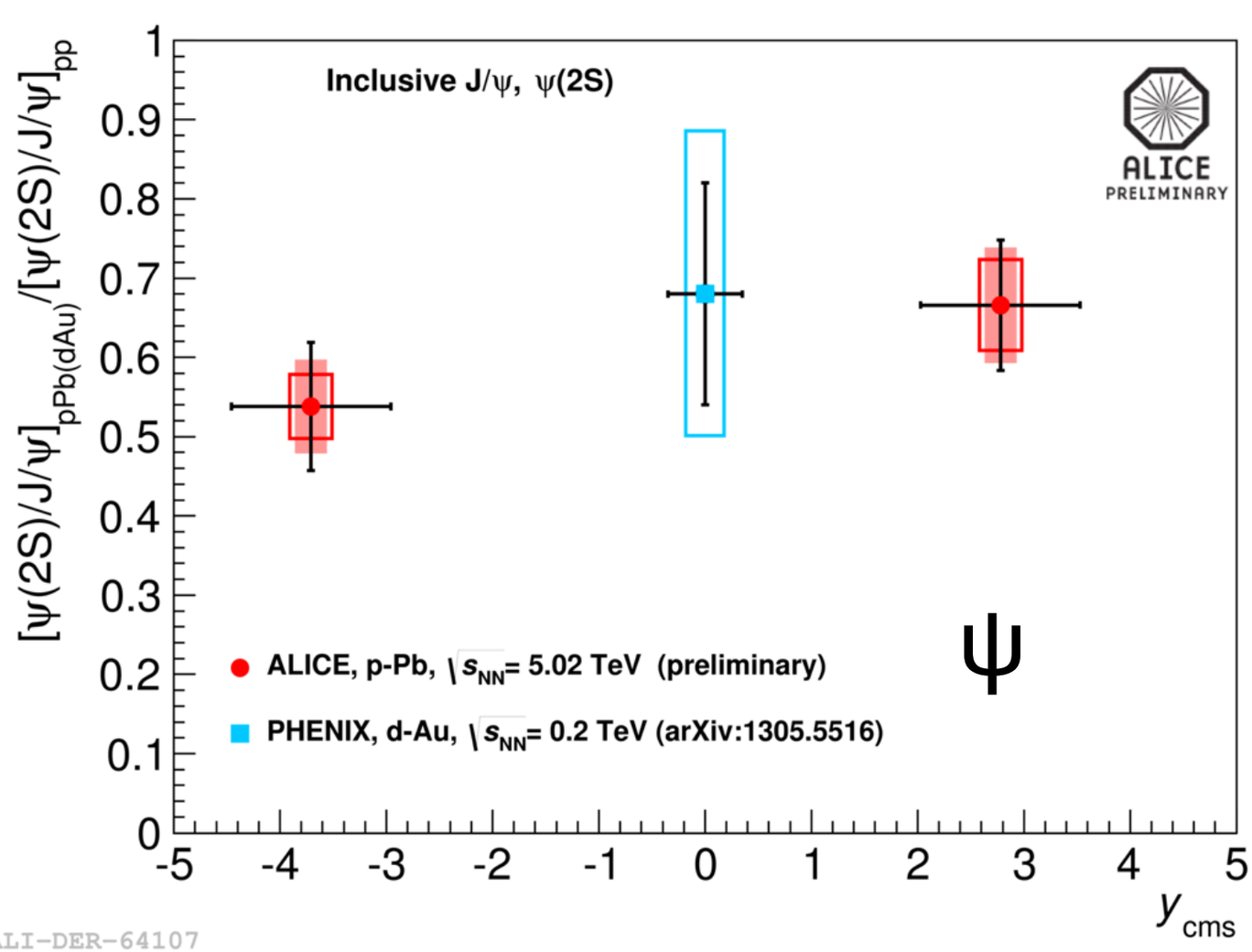


Excited quarkonia states in pA

- In pA excited states suppressed relative to ground state
  - cold effects differ for excited and ground states
- Consequences for AA results?
  - needs modelling, naive squaring for Y would still leave room for extra hot effects
  - but then there is the multiplicity dependence…

PHENIX: A. Frawley (Mon, 16h00) and D. McGlinchey (Fri, 9h00)
ALICE: M. Winn (Thu, 16h20) and C. Hadjidakis (Fri, 11h30)
CMS: D. Moon (Mon, 16h40) and L. Benhabib (Fri, 12h00)





ALI-DER-64107

Summary

- A wealth of new results from all heavy-ion experiments at RHIC and the LHC
- Electroweak probes confirm the binary collision scaling
  - pPb data may give tighter constrains on nuclear PDFs
- Enhancement of low direct photons via virtual photons confirmed by real photon measurement
  - thermal photons, but rates and v2 still challenge to theory
- Open HF with intermediate pT at RHIC show enhancement in d+Au, while no strong modification is observed at the LHC
  - constrain CNM at low x
- Open HF suppression at RHIC and LHC go beyond CNM effects
  - heavy quark energy loss in the QGP
  - c quarks lose more energy than b quarks
- Closed HF at RHIC
  - detailed studies in a variety of collision systems that still need to be understood
- Closed HF at low pT the LHC: more and more indications for recombination
  - if it walks like a duck, …
- Closed HF at intermediate pT at the LHC:
  - it flows, but less than open HF (high pt just like light hadrons: path length dependent suppression)
- But what about pp and pA vs. multiplicity…?
- Many apologies to everybody that I could not include