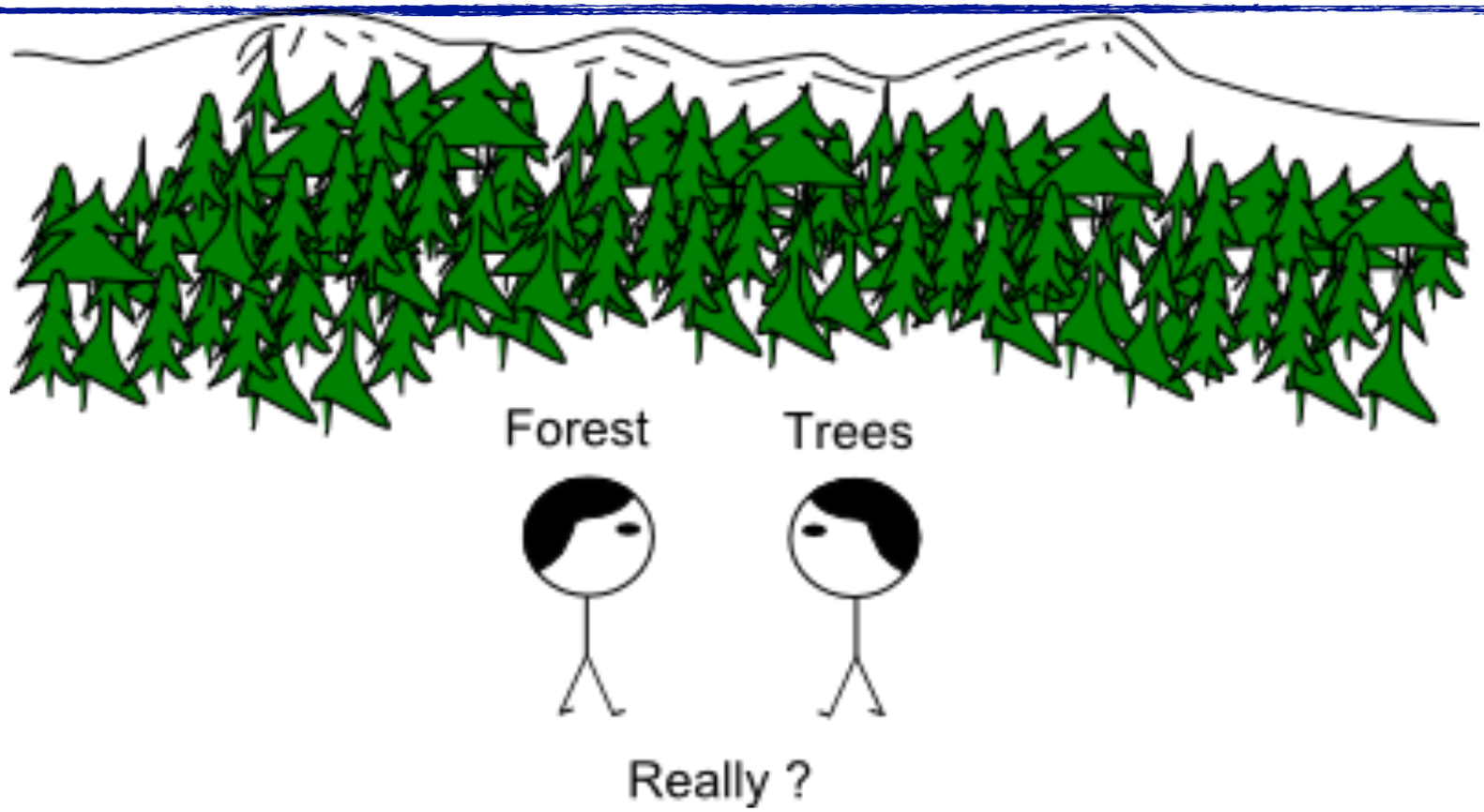
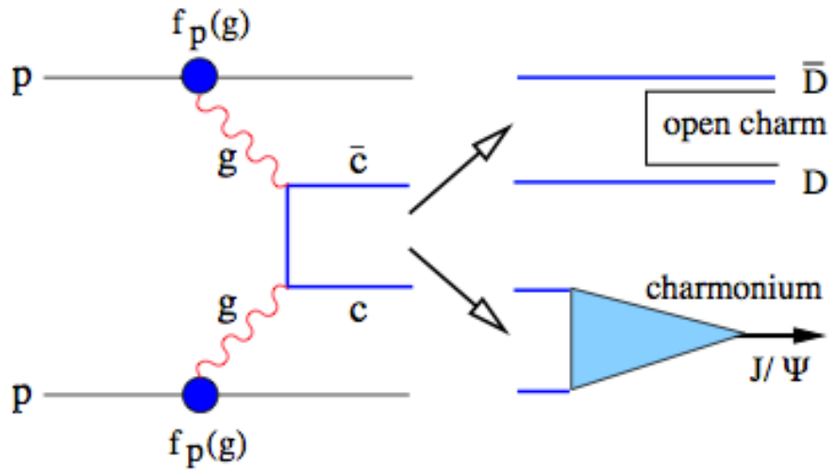
What does the LHC J/ψ v_2 tell us?

Camelia Mironov
LLR/Ecole polytechnique

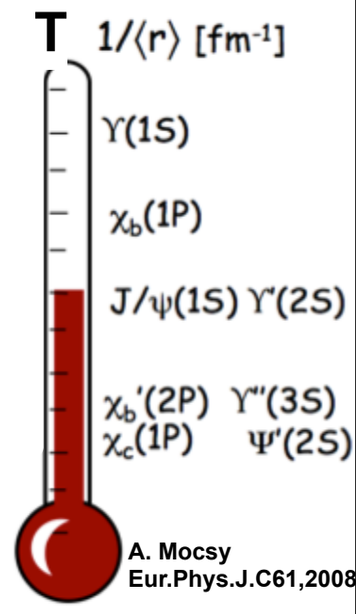
Today



- **Can you study AA J/ψ (production, effects) decoupled from D and cc?**



Onia in AA collisions



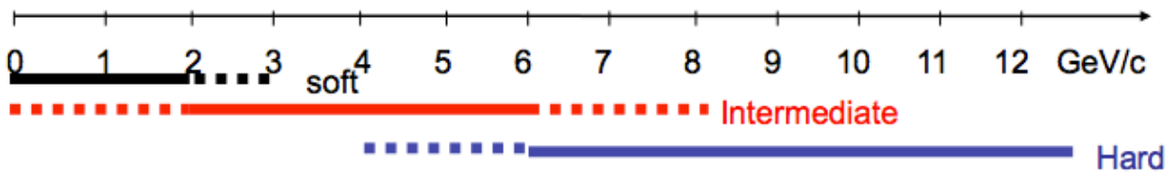
- Tool: in a deconfined, colored charged medium, Debye screening
  - ➡ different T for different onia states → *in situ* thermometer of the QGP

state	J/ψ	χ_c	ψ'	Υ	χ_b	Υ'	χ_b'	Υ''
ΔE [GeV]	0.64	0.20	0.05	1.10	0.67	0.54	0.31	0.20
r_0 [fm]	0.50	0.72	0.90	0.28	0.44	0.56	0.68	0.78

Table 3: Quarkonium Spectroscopy from Non-Relativistic Potential Theory [9]

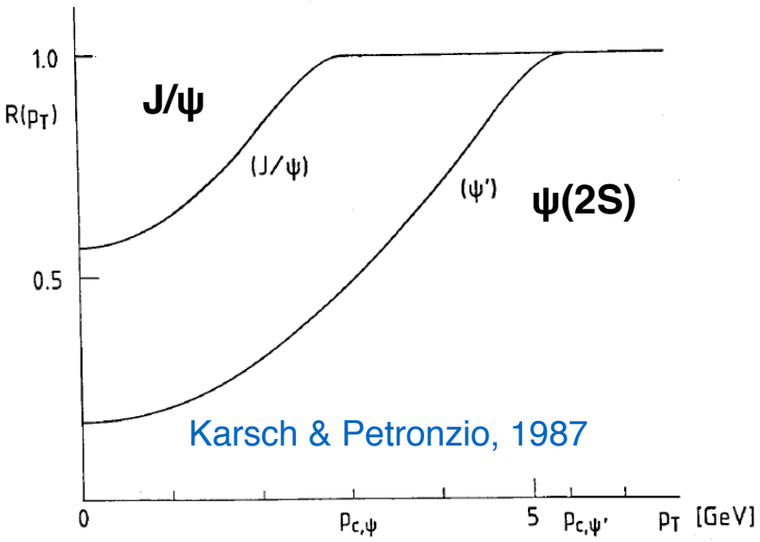
Klubert, Satz, arXiv:0901.3831

- More than a tool: an interesting (and unknown) destiny in the QGP
  - ➡ qq
    - low-p_T :'bulk' — hydrodynamics
    - intermediate-p_T: recombination — recombination
    - high-p_T : fragmentation — en loss



  - ➡ QQ
    - similar as for light ?
    - modified for each different state

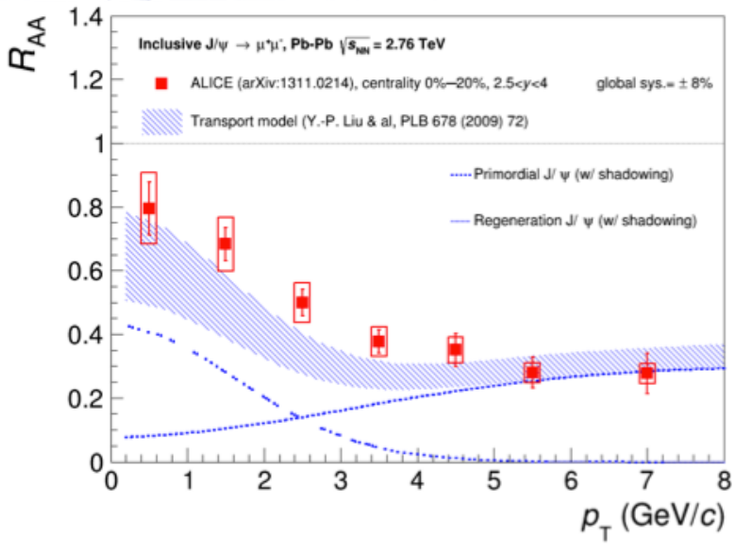
Onia in AA collisions



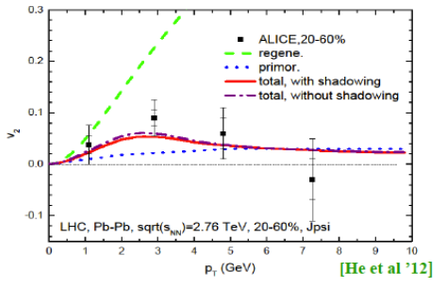
Karsch & Petronzio, 1987

Debye screening vs p_T

- 'Stronger' and 'further' for the excited state
  - ➡ theory update?
- Destroys a state (gone)

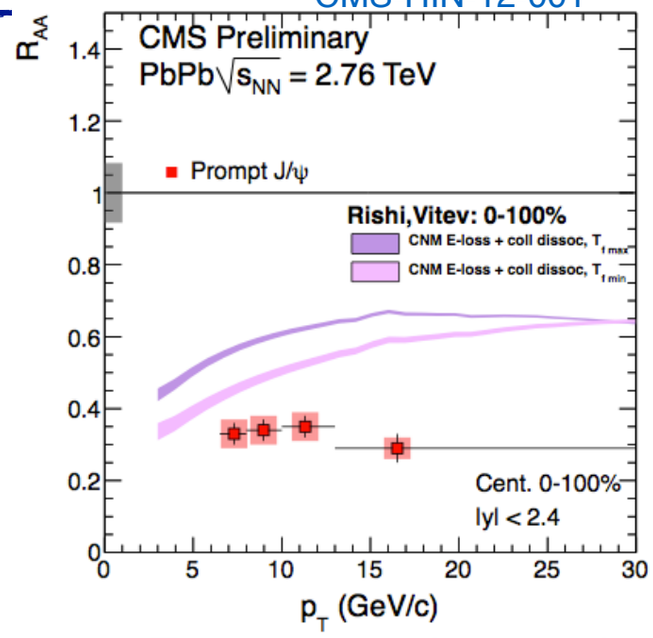


Regeneration and v_2 vs p_T

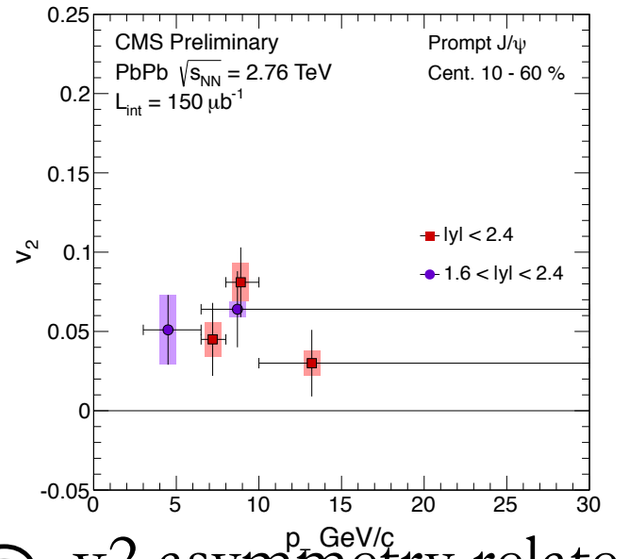


- Excited charmonia states missing theory
  - ➡ from Upsilon (Rapp '10): 2S higher regeneration contribution than 1S
- v2 correlated with the regeneration
- Puts back some yield

CMS-HIN-12-014
CMS-HIN-12-001

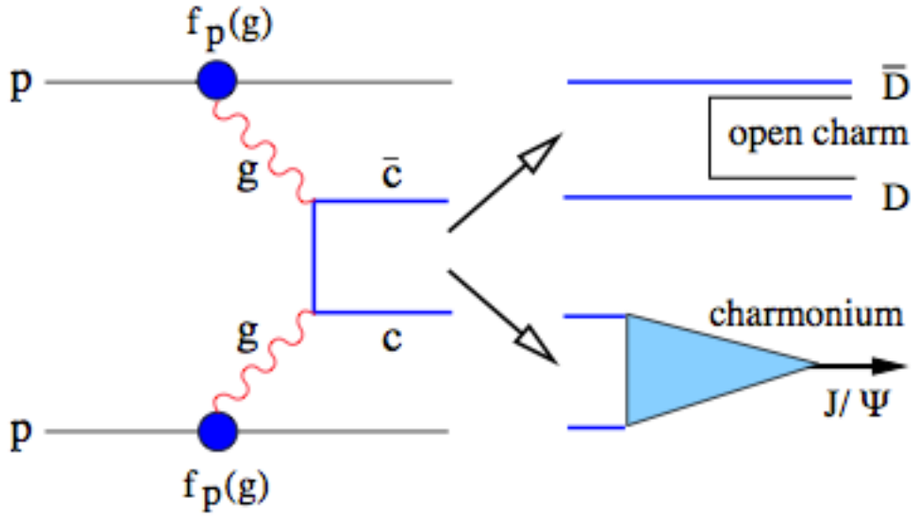


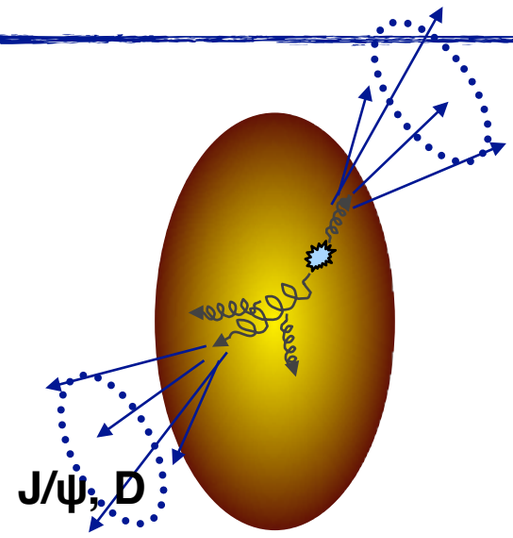
Fragmentation and En loss vs p_T



- v2 asymmetry related to path length dependence of en loss
- Destroys and/or shifts the kinematics

BUT, one should …



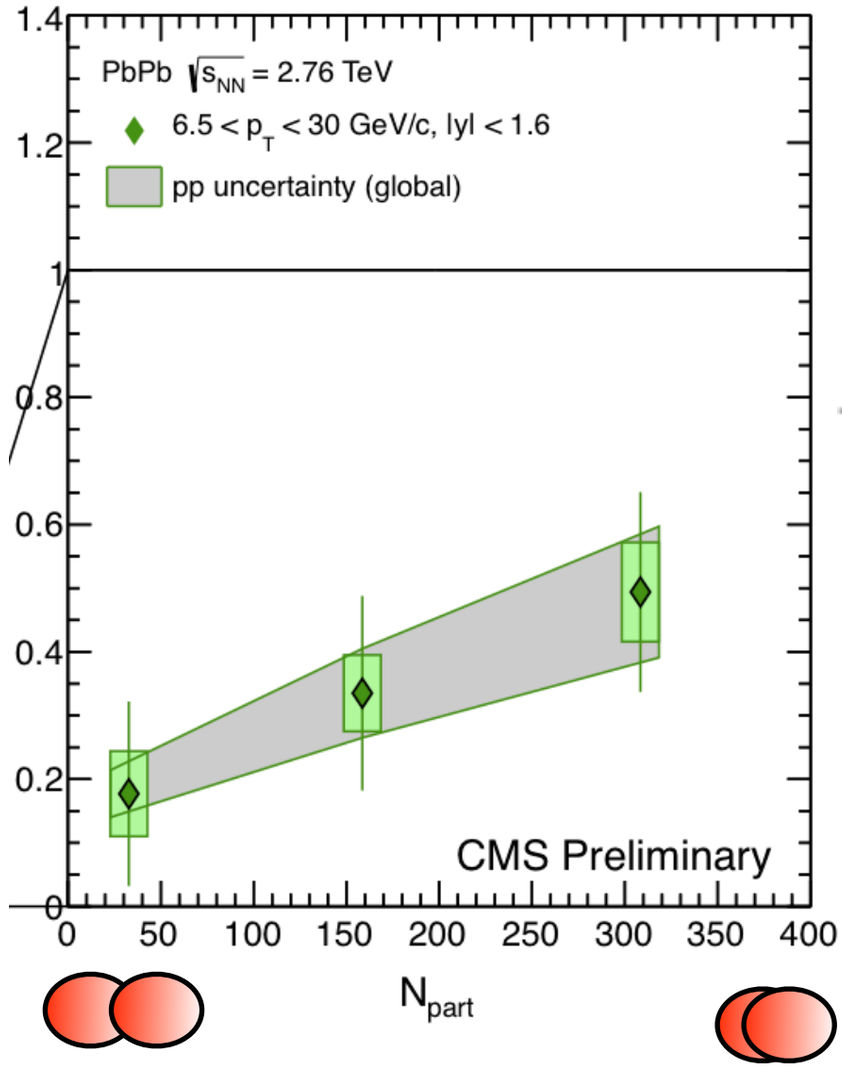


- .. ask:
  - ➡ is the 'pre bound J/ψ' that loses energy or the parent ccbar'
  - ➡ if not, the en loss of 'pre bound J/ψ' different than of the single charm (to form later a D)
  - ➡ at high-p_T: have fragmentation J/ψ — the en loss is of the parent parton?
  - ➡ the destroyed J/ψ feeds the D yield (though 10:90 ratio)

- … consider time/scales …
  - medium time to form, its lifetime and size are important
  - $t^{formation} \sim 1/\Delta E \rightarrow$ excited states:
    - 'larger' (easier to be 'found')
    - weaker bound (easier to break once 'found'),
    - longer time to form → longer in 'proto-state' (more chances to be found and broken)
  - Size and binding energy seems logical to think that matter at all p_T

High-p_T: excited vs ground state

CMS-PAS-HIN-12-007



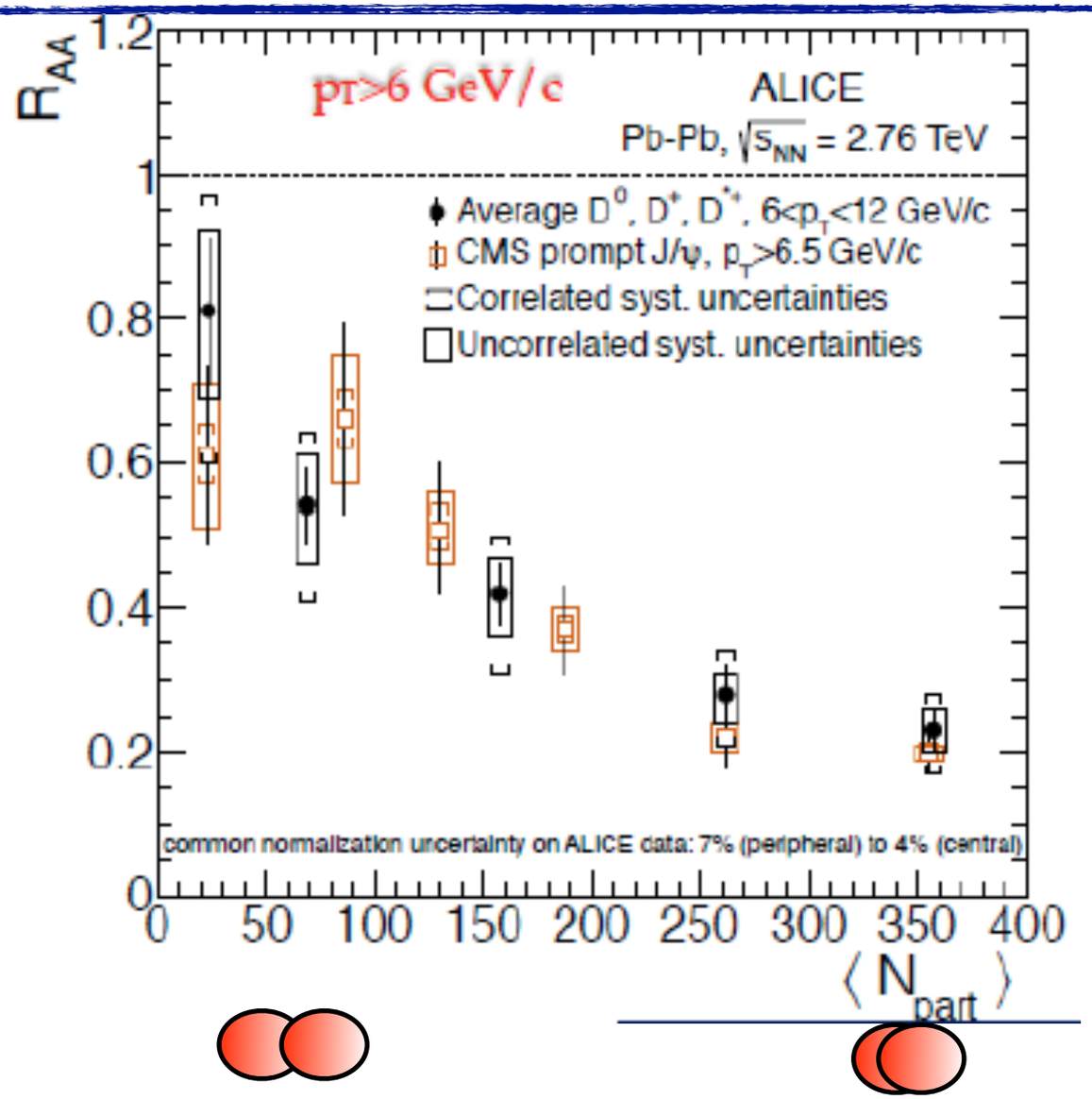
$$\frac{[\frac{\psi(2S)}{J/\psi}]_{PbPb}}{[\frac{\psi(2S)}{J/\psi}]_{pp}} = \frac{R_{AA}(\psi(2S))}{R_{AA}(J/\psi)}$$

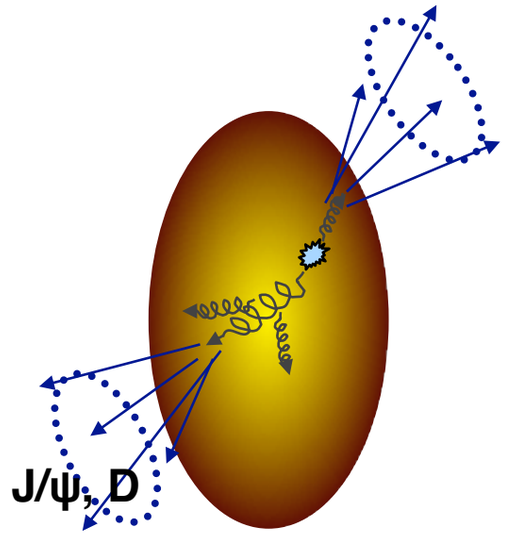
- **$R_{AA}(\psi(2S)) < R_{AA}(J/\psi)$**
  - ordered suppression → size/binding energy/formation time at play
  - if jet-like en loss *only*, the double ratio should've been 1 …

Debye screening
partonic break-up
jet-like en loss?

6.5 pT [GeV/c]

High-p_T: open vs closed

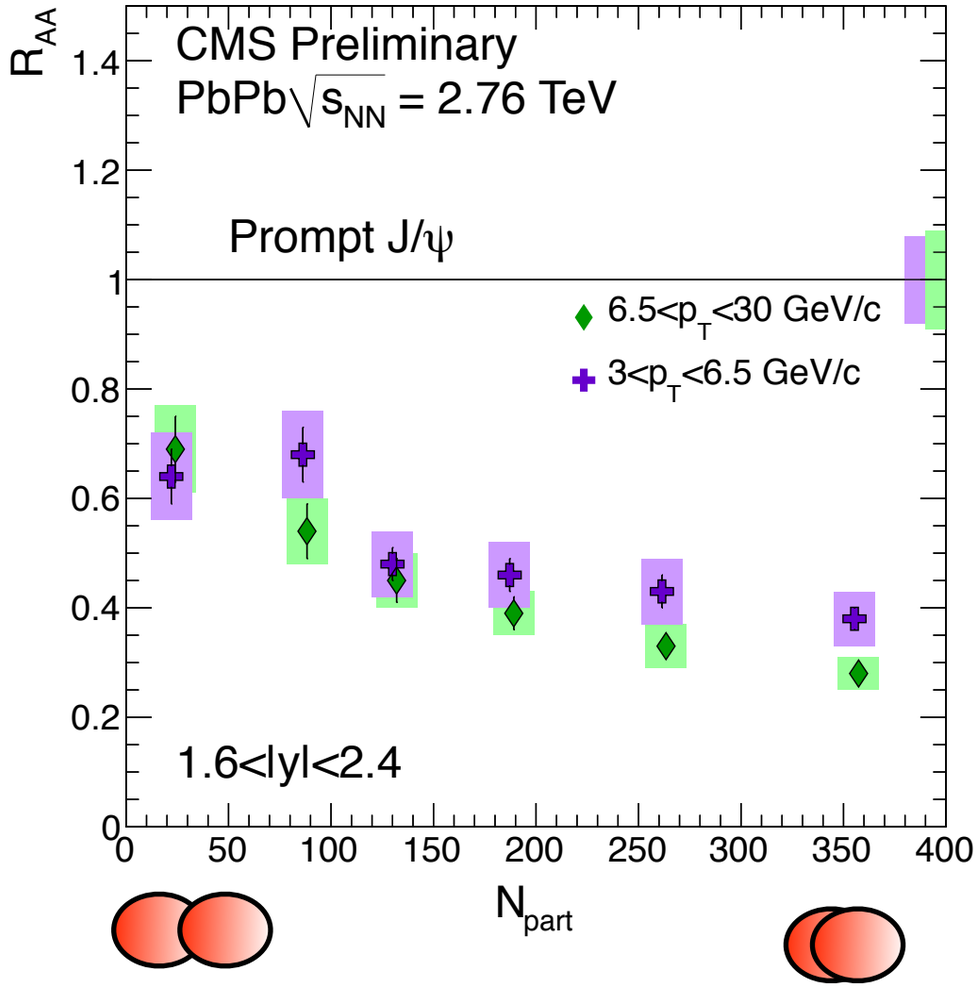




- R_{AA} for D and J/ψ similar
  - ➡ coincidence? (same for intermediate region, 2-5 GeV/c)
  - ➡ it's actually the parent losing an 'universal' energy before the mesons are formed?

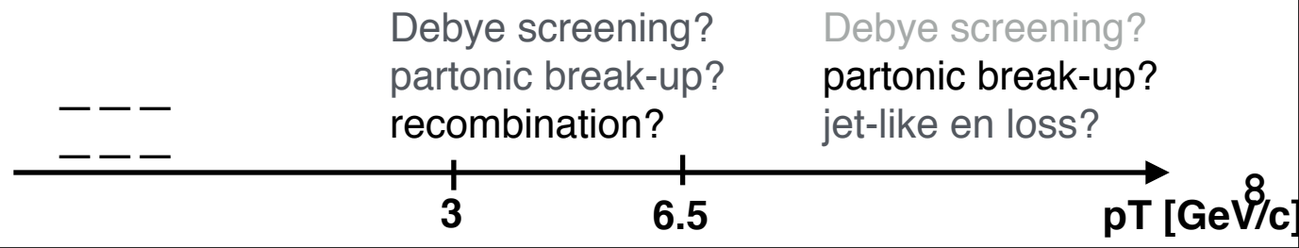
Intermediate-p_T: 3-6 GeV/c

CMS-PAS-HIN-12-014



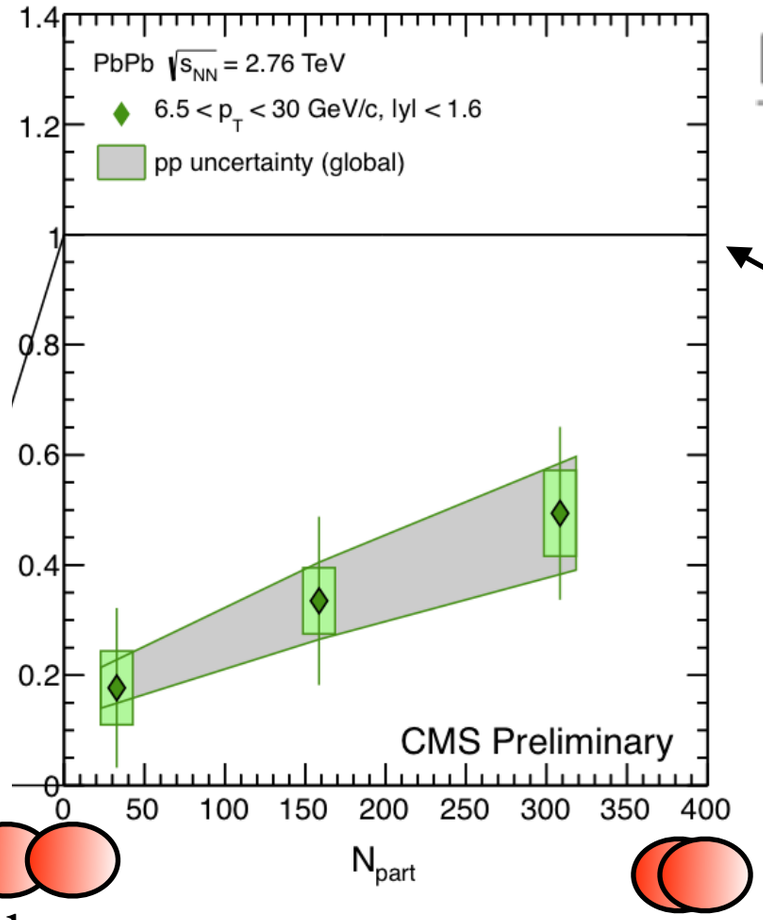
- Slightly higher yield in most central events: recombination kicks in?

➡ does it affect the states with different binding energy differently?

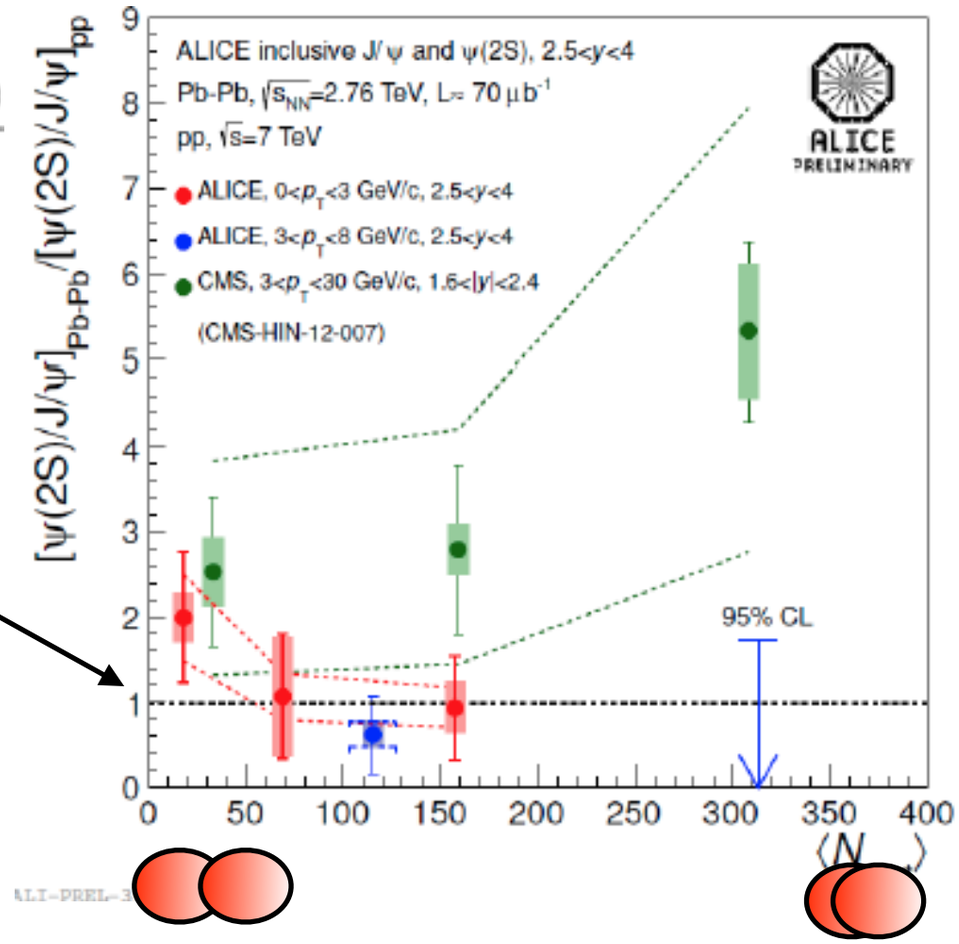


Excited vs ground state

CMS-PAS-HIN-12-007

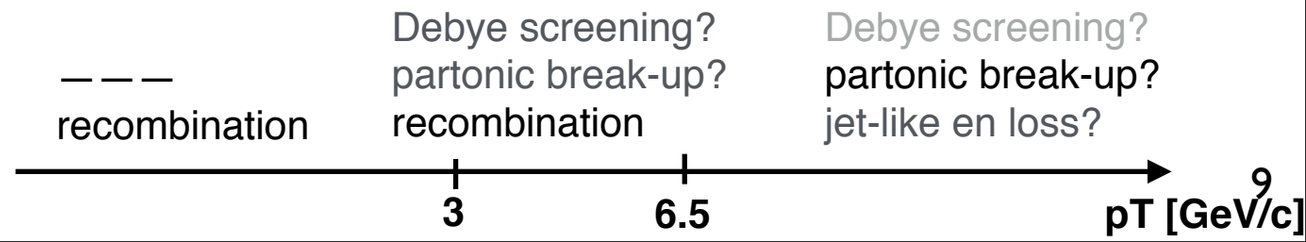


$$\frac{\left[\frac{\psi(2S)}{J/\psi}\right]_{PbPb}}{\left[\frac{\psi(2S)}{J/\psi}\right]_{pp}} = \frac{R_{AA}(\psi(2S))}{R_{AA}(J/\psi)}$$

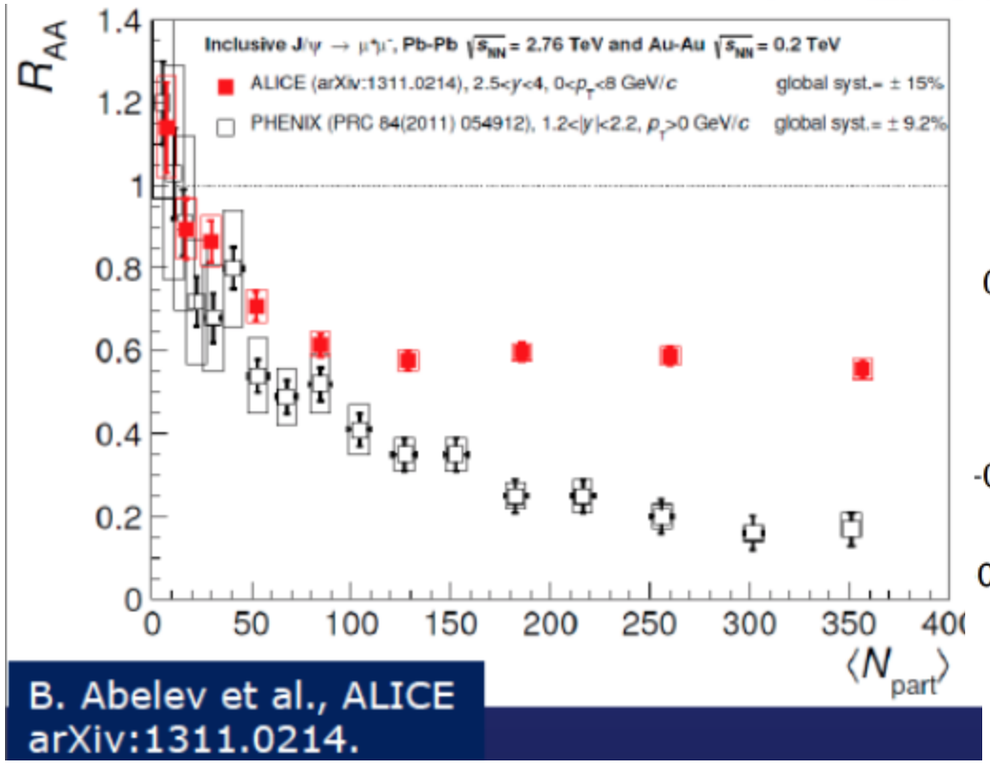


- High-p_T
  - ➡ $R_{AA}(\psi(2S)) < R_{AA}(J/\psi)$
- Low-p_T
  - ➡ $R_{AA}(\psi(2S))$ / $R_{AA}(J/\psi)$ strong increase

- **Ultimate proof for** recombination?
  - ➡ whatever it is, it looks also a process dependent on binding energy/size of the state



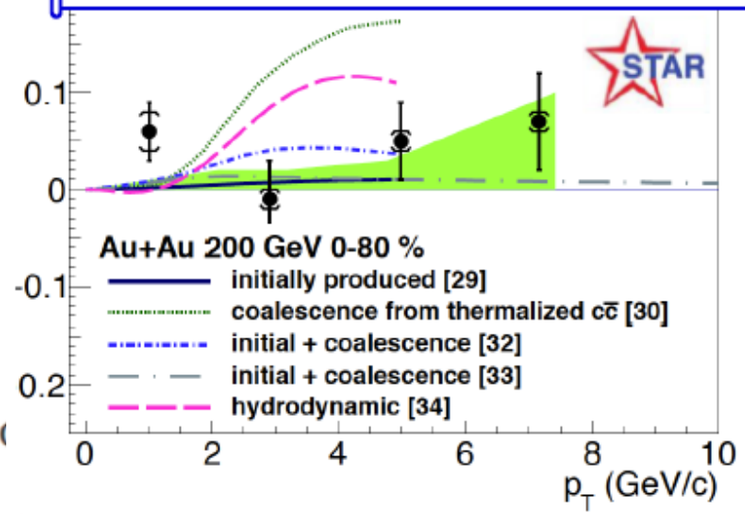
Low-p_T



B. Abelev et al., ALICE arXiv:1311.0214.

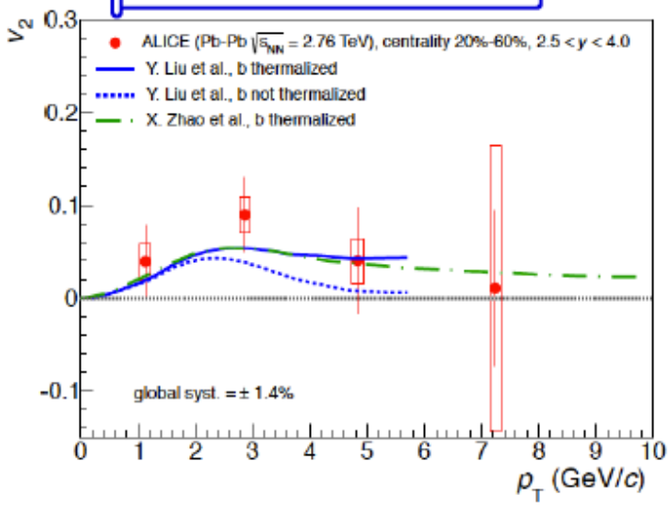
At RHIC
consistent with no flow

STAR Phys. Rev. Lett. 111 52301 (2013)



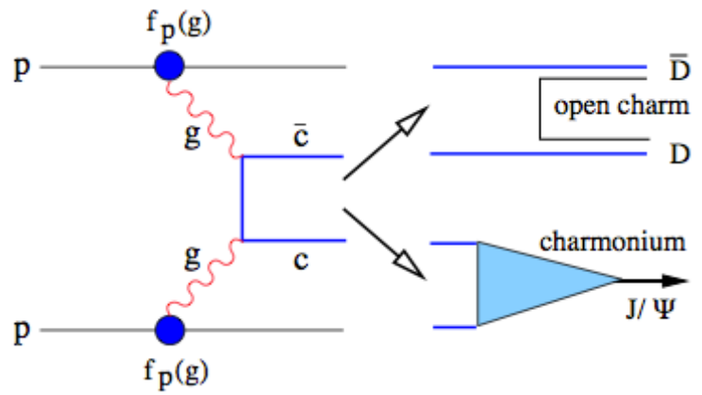
At LHC
Non zero flow at intermediate p_T

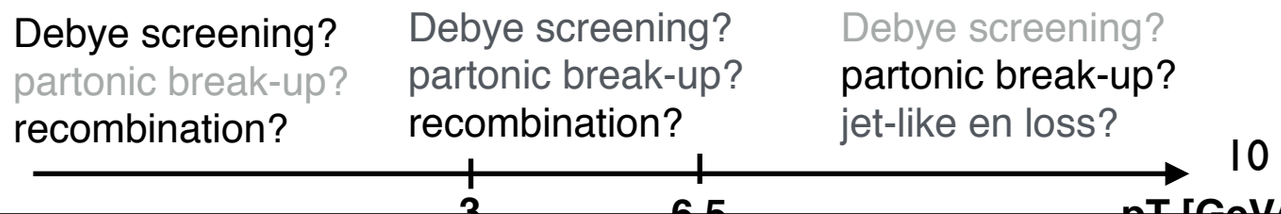
ALICE arXiv:1303.5880



M. Rosati, SaporeGravis201

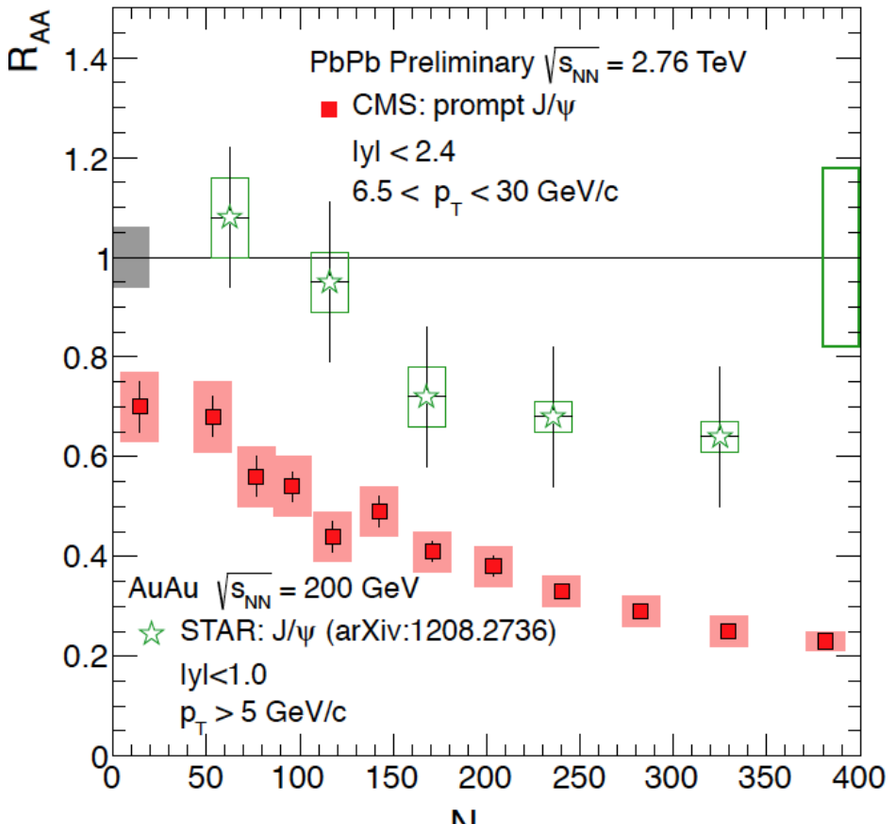
- **R_{AA}(LHC) < R_{AA}(RHIC)**
  - ➡ regeneration compensates for the yield lost via screening
- **v2(LHC) ? v2 (RHIC)**
  - ➡ related to the regeneration
  - ➡ not sure I understand how: parent charm quarks have some v_2
    - is it smaller than that of light, hence the sum (for the bound state) is smaller than of the light OR
    - same as that of light, but when combining, some 'interferences' (different p_T, slowing down each other?)



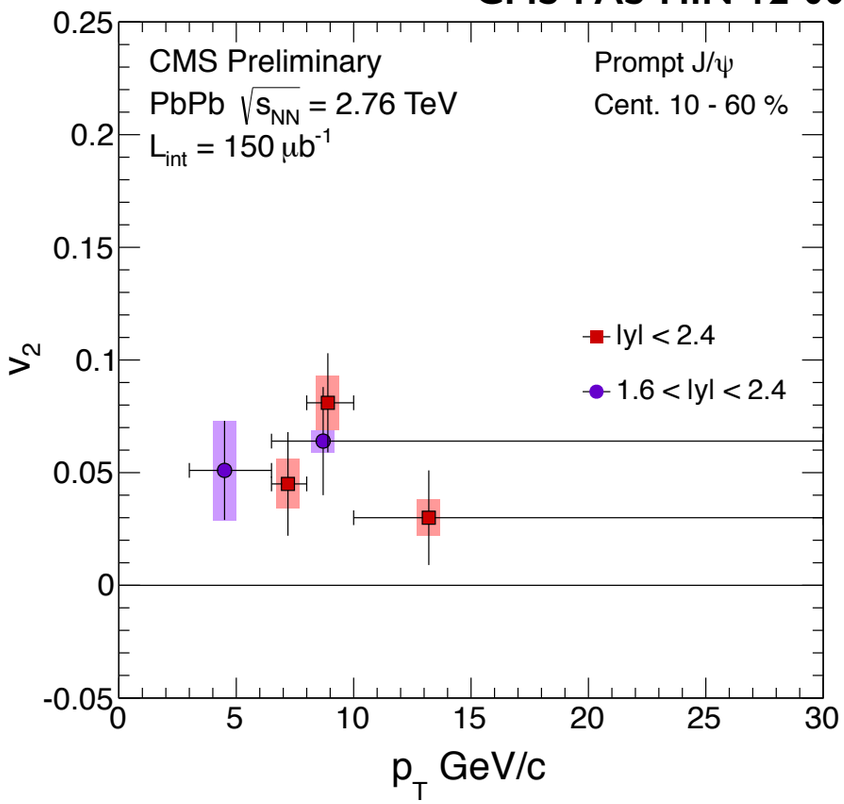


High-p_T

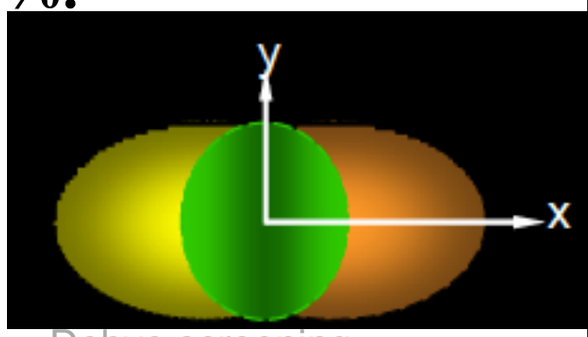
CMS-PAS-HIN-12-014



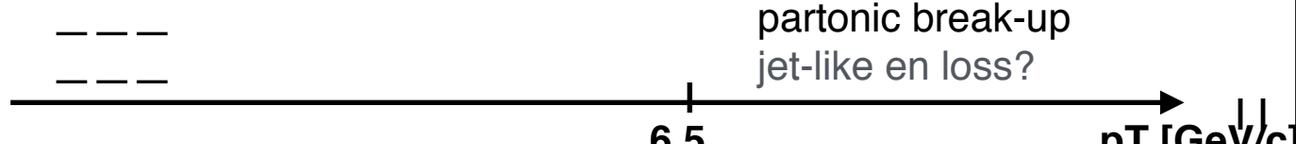
CMS-PAS-HIN-12-001



- **R_{AA}(LHC)< R_{AA}(RHIC)**
  - ➡ stronger (?), longer life plasma —> more time to break the state with partonic dissociation?
- **v_2(LHC) prompt J/ψ, 6.5 < p_T < 30 GeV/c, |y| < 2.4, 10 - 60 %:**
  - 0.054 ± 0.013(stat.) ± 0.006(syst.) (3.8σ)
  - ➡ probing just the path length dependence of the en loss

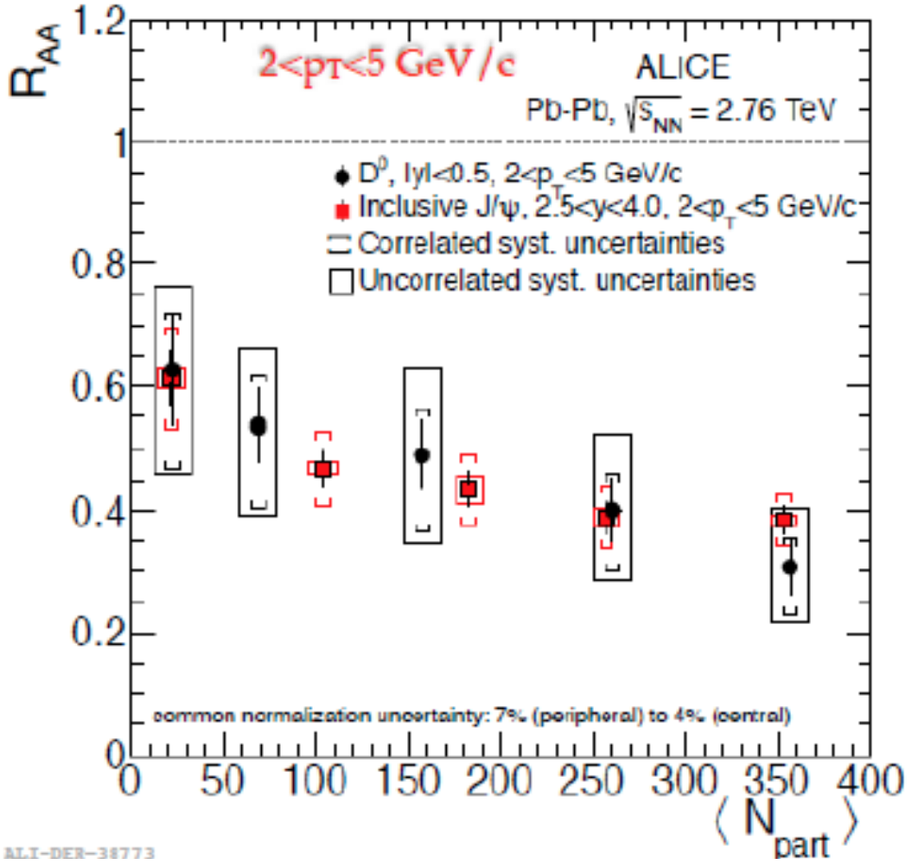


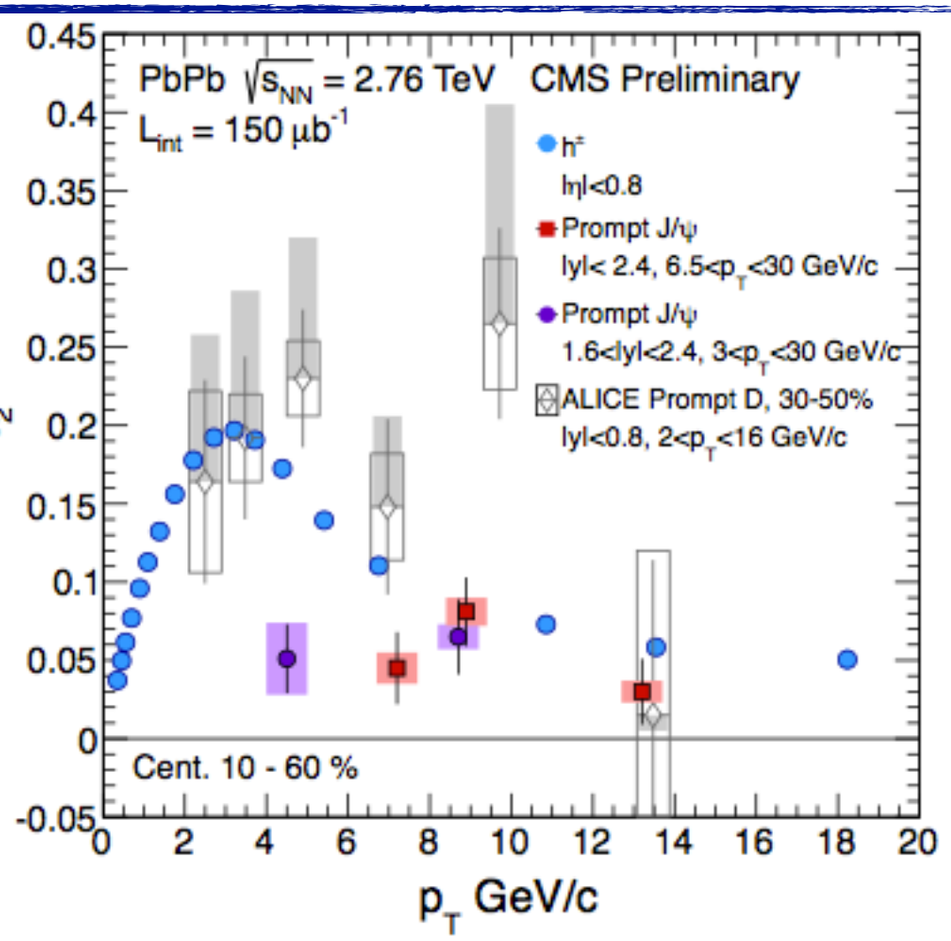
Debye screening
partonic break-up
jet-like en loss?



Open vs closed

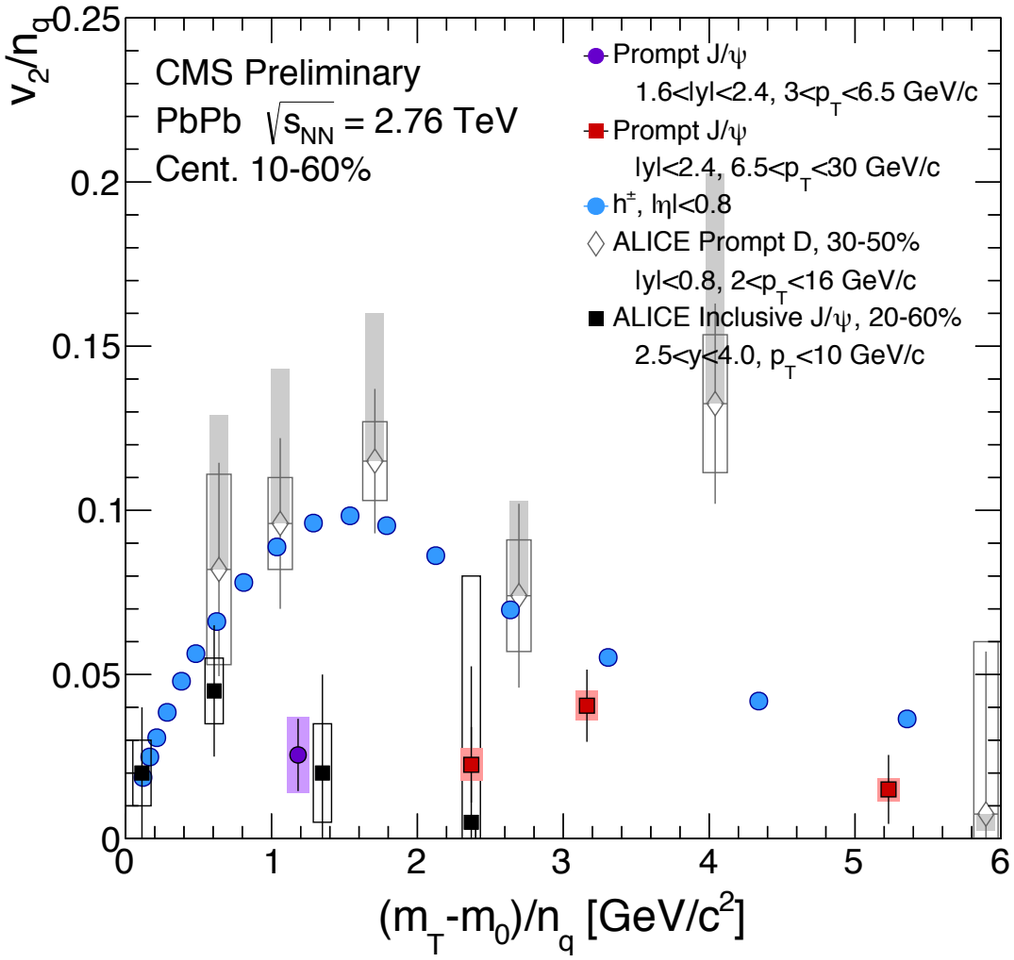
ALICE (2013) arXiv:1303.5880v2
CMS-PAS-HIN-12-001

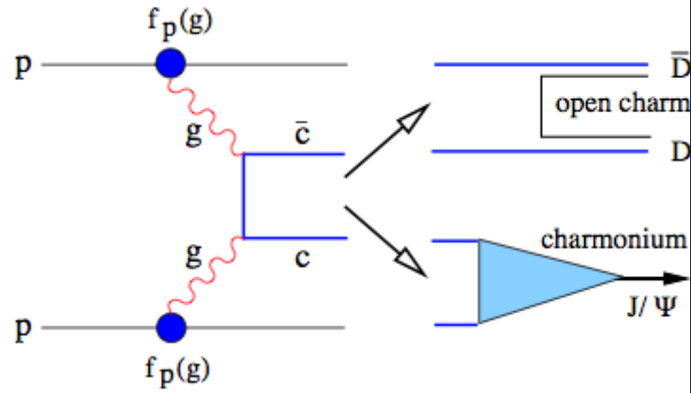




- **While R_{AA} is the same, the asymmetry is different … makes sense?**
  - ➡ R_{AA} shows when things disappeared/got modified (break-up, en loss)
  - ➡ v_2 reflects the real estate of the remaining things (and possibly how they ended as such)

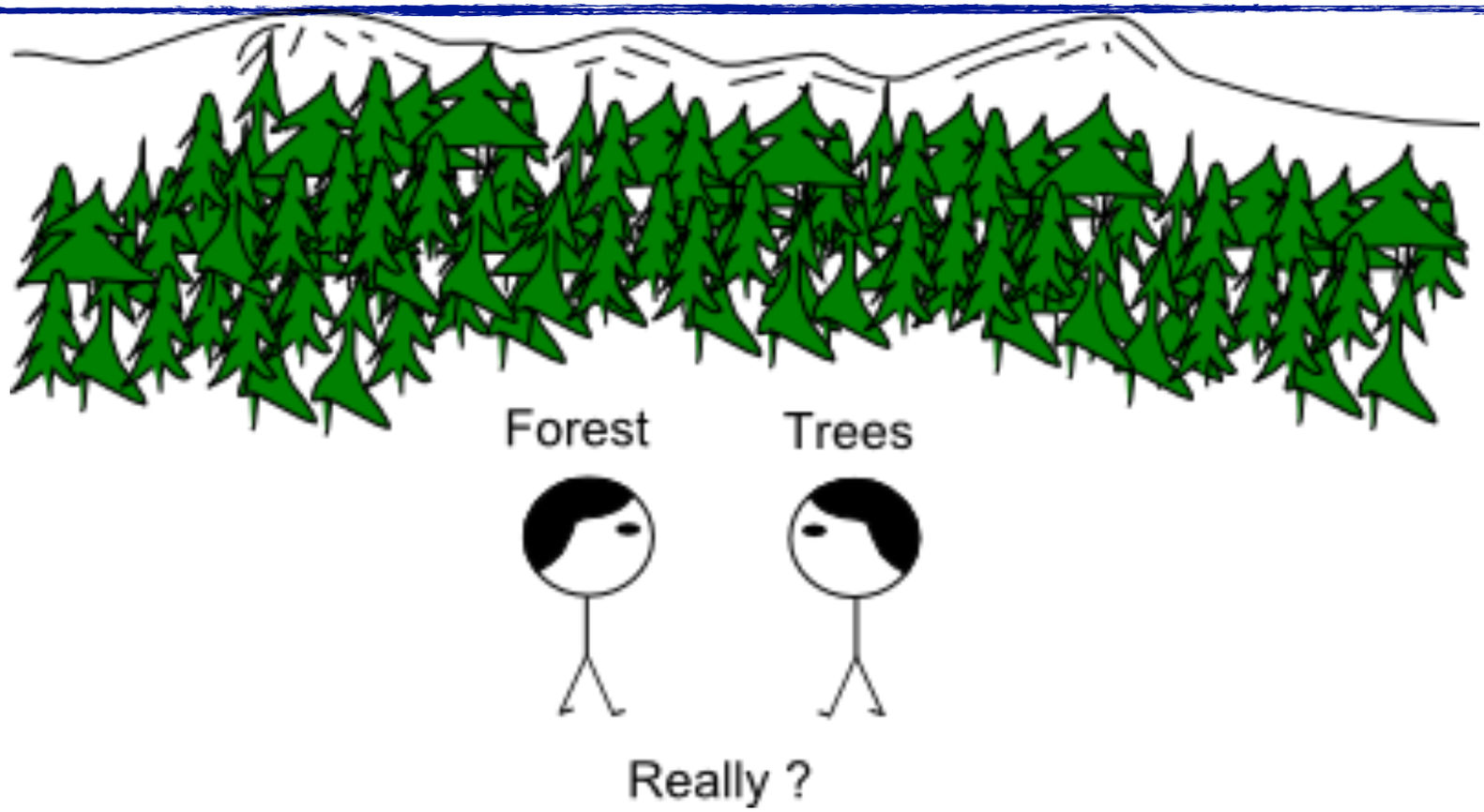
Quark scaling



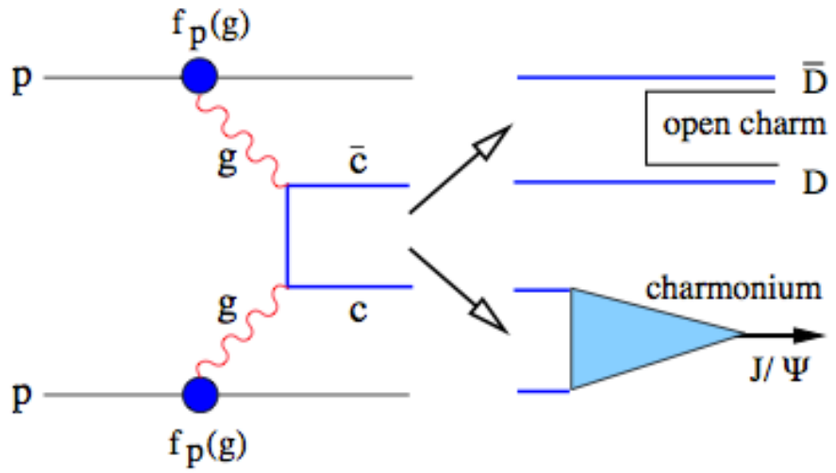


- Approximate scaling for D, J/ψ behaves differently
- D has asymmetry from the 1) thermalized charm OR 2) light quark it combines with OR 3) just probing path lengths dependence
- J/ψ
  - ➡ the 'pre-bound' state has a v2, which with extra contributions from regenerations makes the v2 larger at low-pT?
  - ➡ dominated by the path length dependence of en loss …. <u>whose en loss?</u>
- Need more precision at low-p_T for J/ψ and all over for D

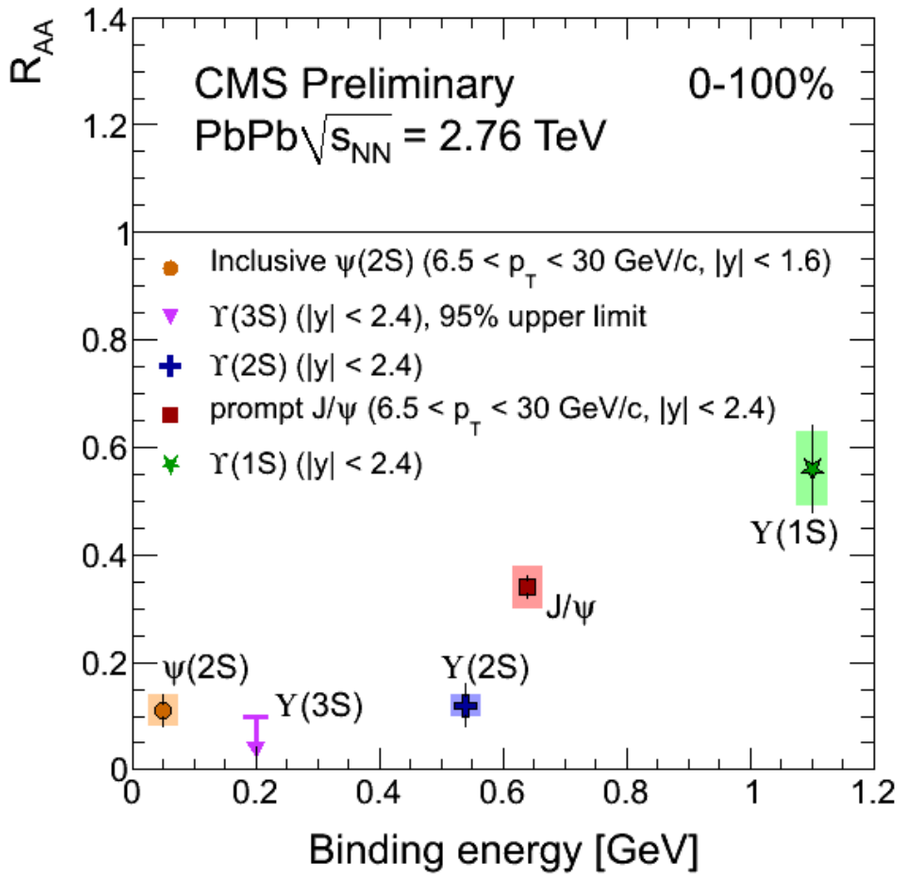
Today

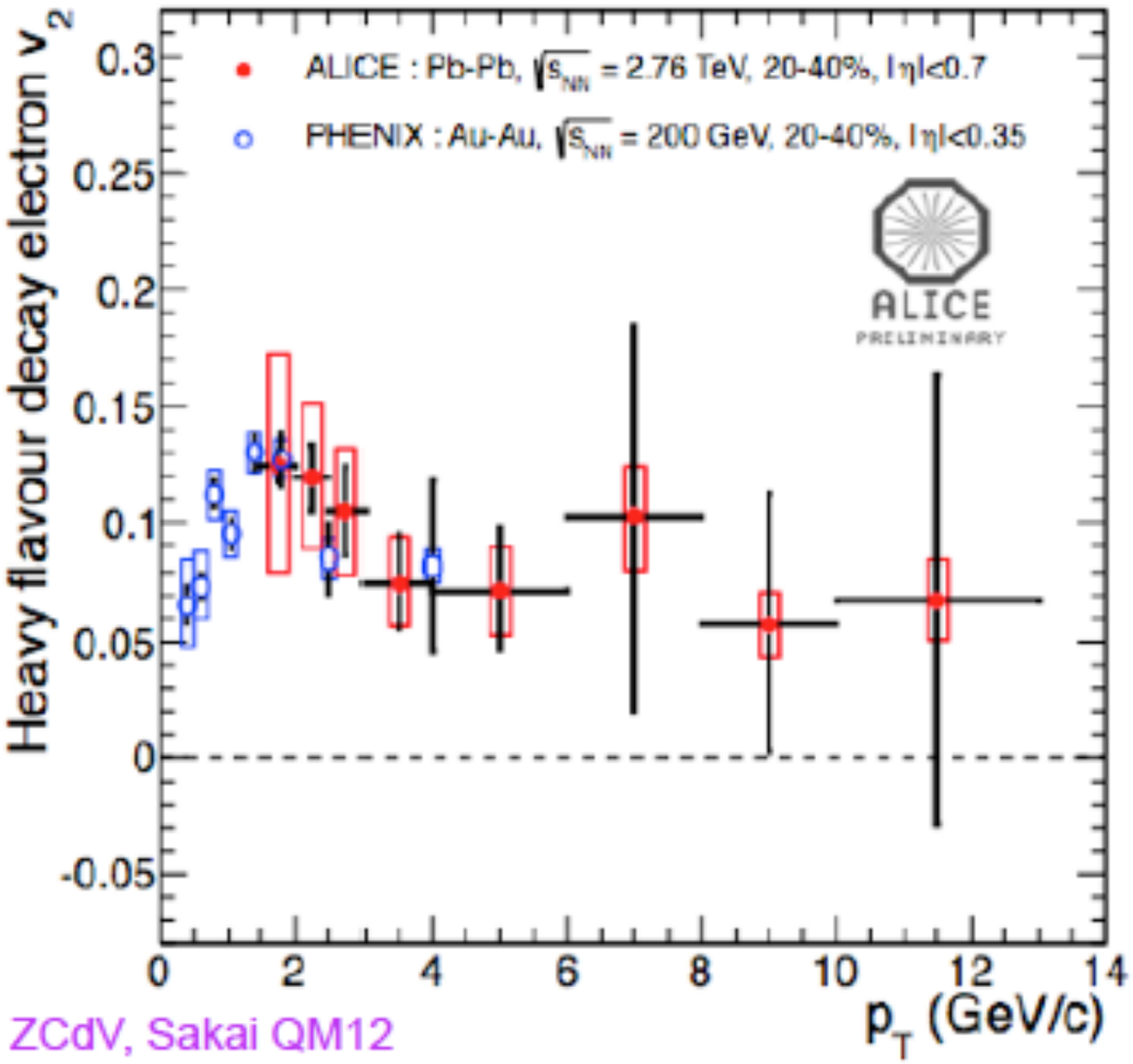


- Can you study AA J/ψ phenomena decoupled from D and cc?



- Yes, you can … but should you?


CMS Preliminary
PbPb$\sqrt{s_{NN}}$ = 2.76 TeV
0-100%
R_{AA}
Inclusive ψ(2S) (6.5 < p_T < 30 GeV/c, |y| < 1.6)
ϒ(3S) (|y| < 2.4), 95% upper limit
ϒ(2S) (|y| < 2.4)
prompt J/ψ (6.5 < p_T < 30 GeV/c, |y| < 2.4)
ϒ(1S) (|y| < 2.4)
ϒ(1S)
J/ψ
ψ(2S)
ϒ(3S)
ϒ(2S)
0
0.2
0.4
0.6
0.8
1
1.2
Binding energy [GeV]

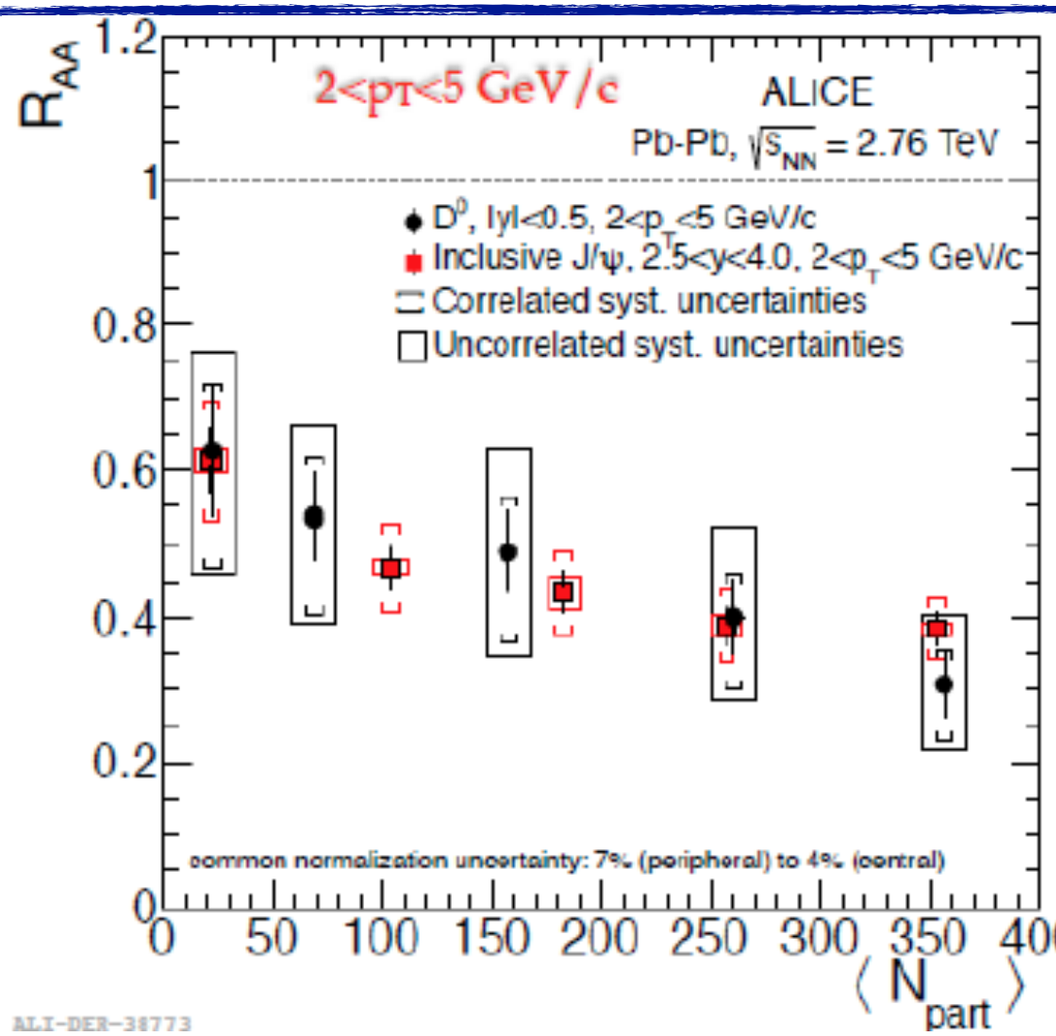


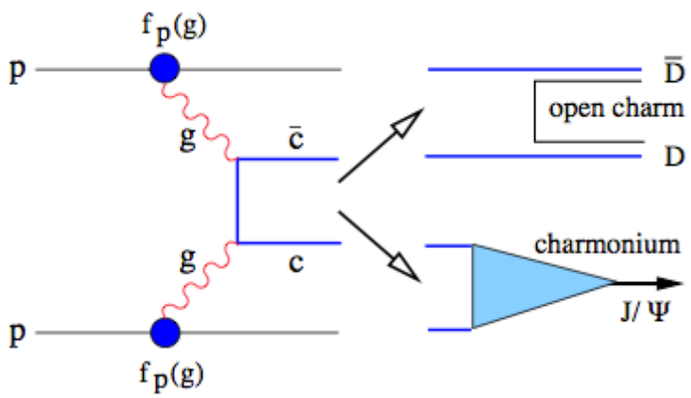
ZCdV, Sakai QM12

Au-Au at 200 GeV

Pb-Pb at 2.76 TeV

Intermediate-p_T: open vs closed





- R_{AA} for D and J/ψ similar
  - ➡ coincidence?
  - ➡ it's actually the parent losing an 'universal' energy before the mesons are formed?