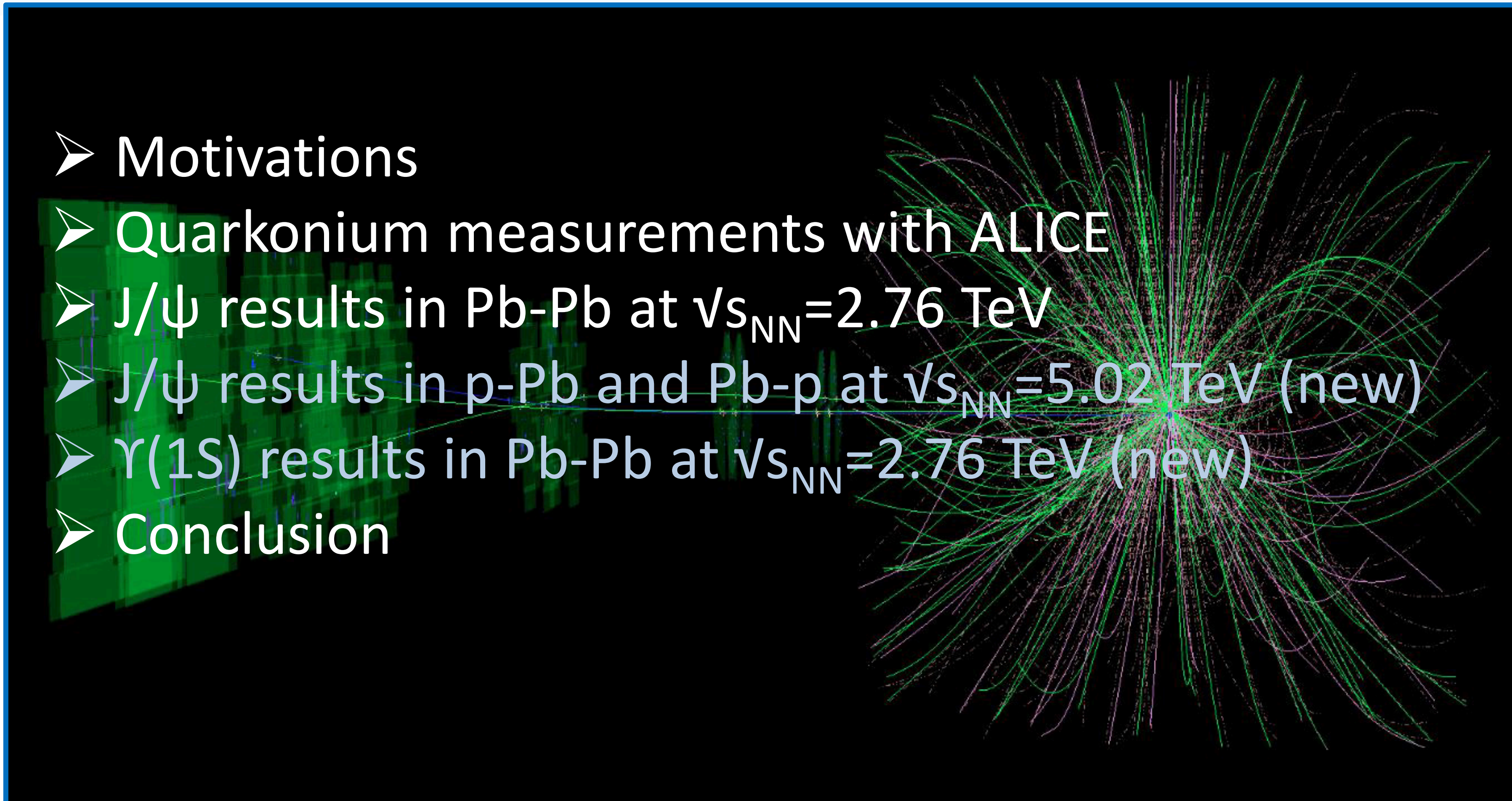
Quarkonium measurement with ALICE at the LHC

Loïc Manceau (INFN sezione di Torino) on behalf of the ALICE Collaboration



- Motivations
- Quarkonium measurements with ALICE
- J/ψ results in Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV
- J/ψ results in p-Pb and Pb-p at $\sqrt{s_{NN}}$=5.02 TeV (new)
- $\Upsilon(1S)$ results in Pb-Pb at $\sqrt{s_{NN}}$=2.76 TeV (new)
- Conclusion

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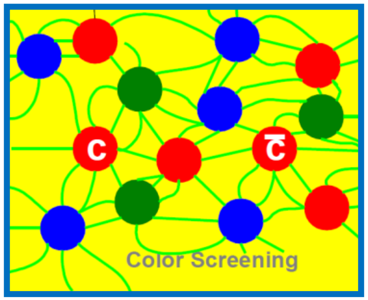
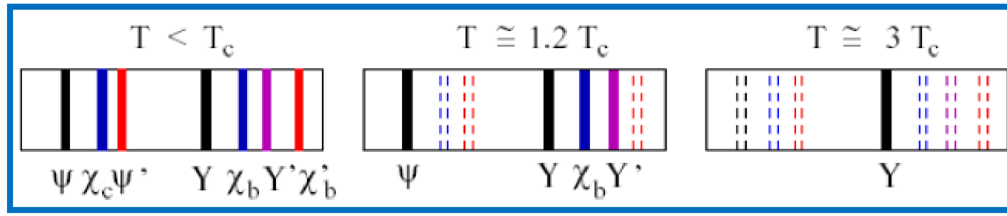
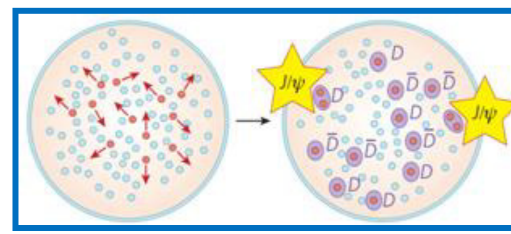
Motivations (Pb-Pb collisions)

- Probe of deconfinement:
  - Quarkonium suppression via colour screening *(Matsui and Satz, PLB 178 (1986) 416)*
  - Sequential suppression of the quarkonium states *(Digal et al. PRD 64 (2001) 0940150)*





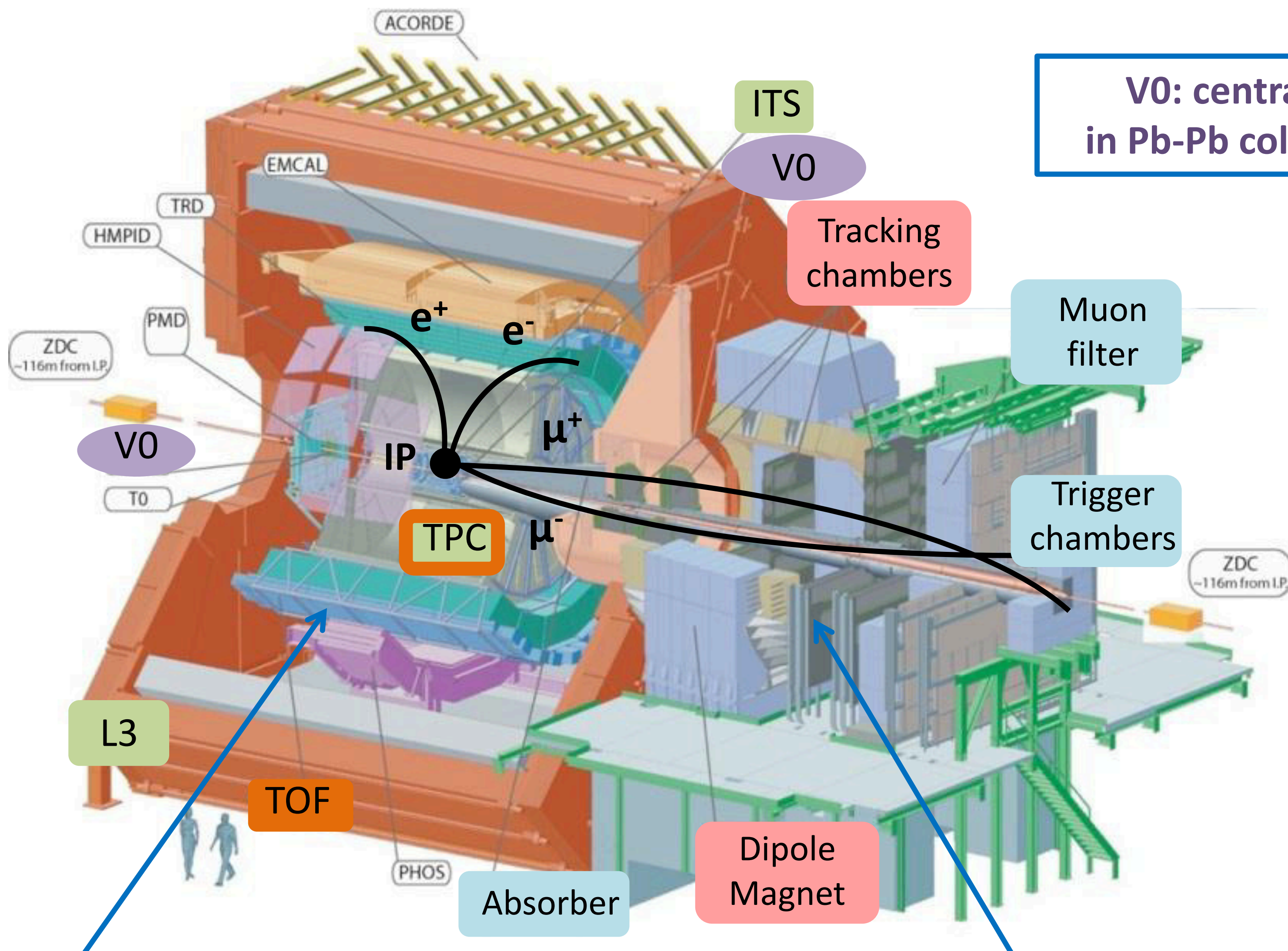
- Enhancement via (re-)generation of quarkonia, due to the large heavy-quark multiplicity
  (Rafelski et al. PRC 63 (2001) 0549057, Andronic et al. PLB 571(2003) 36, Rapp et al. JPG 38 (2011) 124068)



- Key observable → Nuclear Modification Factor:
  - Relative production of quarkonia in AA collisions with respect to that in pp collisions at the same nucleon-nucleon center of mass energy

$$R_{AA}(p_T, y) = \frac{d^2N_{AA}/dydp_T}{\langle N_{coll} \rangle \times d^2N_{pp}/dydp_T}$$

Quarkonium measurements in ALICE



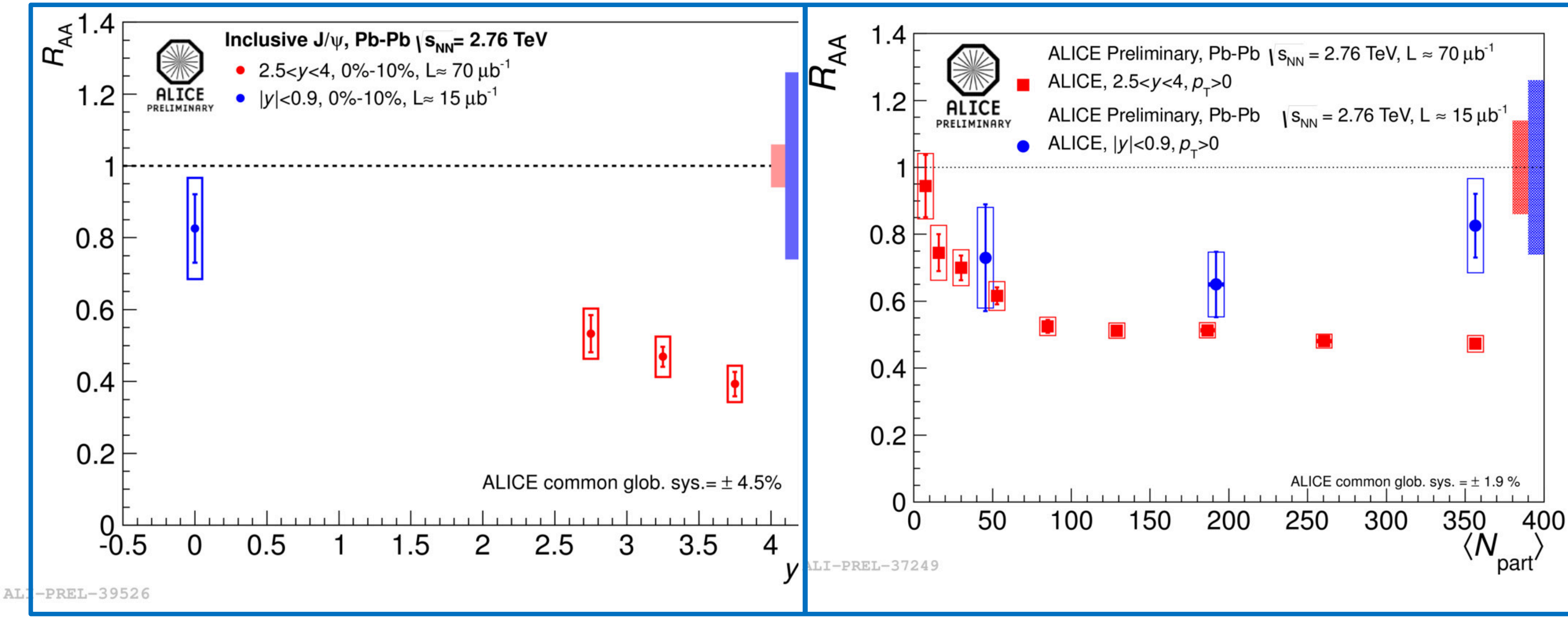
V0: centrality in Pb-Pb collisions

- **Central barrel (|y|<0.9): $J/\psi \rightarrow e^+e^-$**
  - **Tracking: ITS, TPC, L3 Magnet**
  - **Identification: TPC**

- **Muon spectrometer (2.5<y<4): $J/\psi \rightarrow \mu^+\mu^-$, $\Upsilon(1S) \rightarrow \mu^+\mu^-$**
  - **Tracking**
  - **Identification**

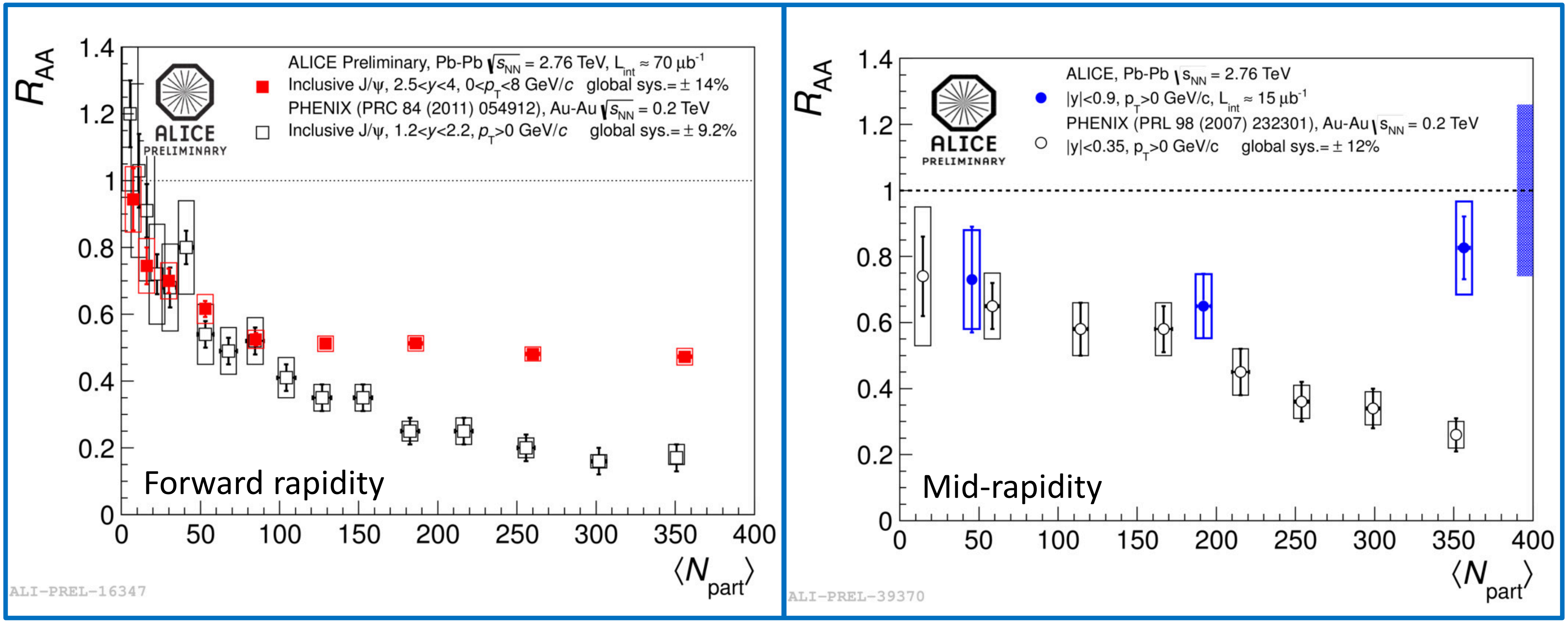
J/ψ results in Pb-Pb at 2.76 TeV

Nuclear modification factor of inclusive J/ψ in Pb-Pb



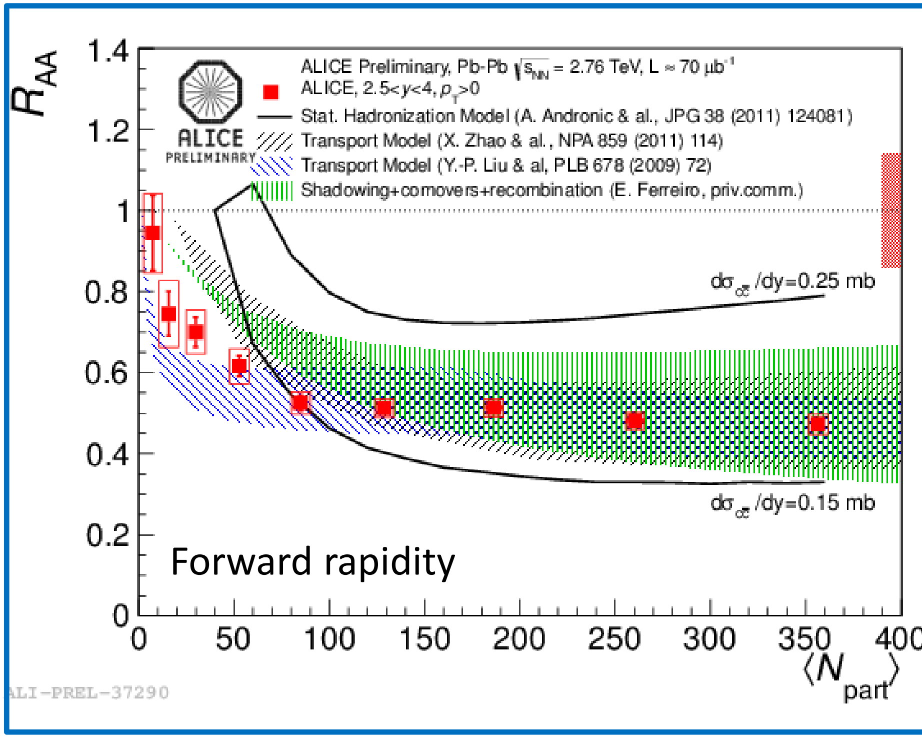
- R_{AA} measured in a large rapidity range and down to zero p_T
- Results:
  - Clear suppression observed
  - Suppression weakly dependent on centrality for N_{part}>100

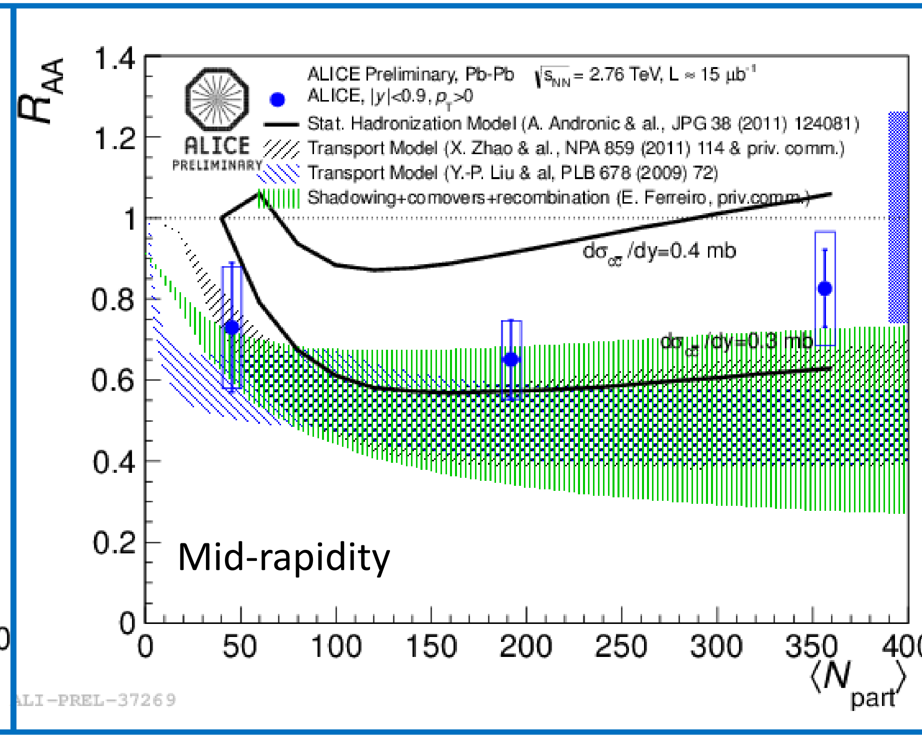
Inclusive J/ψ R_{AA} comparison with RHIC data



- Less suppression observed at LHC energies
- Centrality dependence less important at LHC energies

Inclusive J/ψ R_{AA} comparison with theory



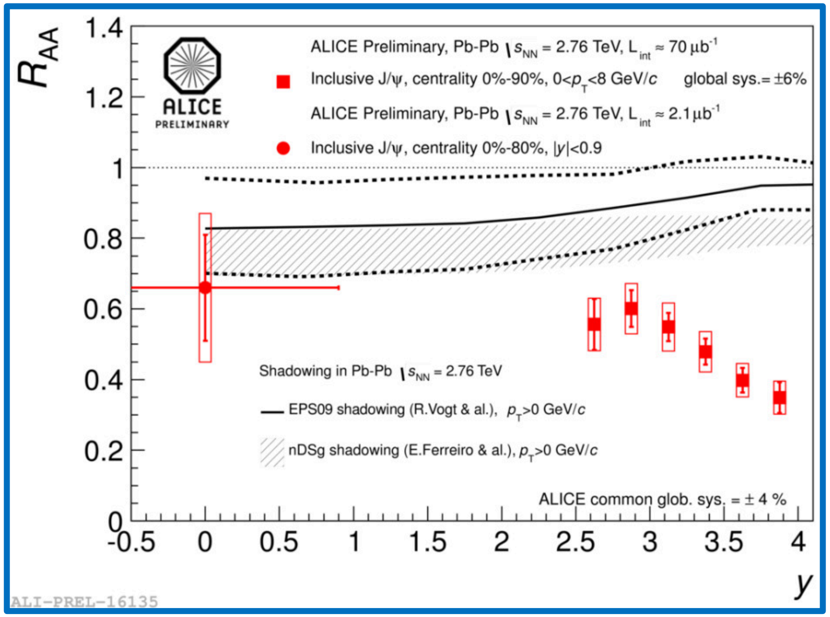


- Transport models and comover model: suppression + large fraction of J/ψ produced by charm quark recombination (>50% in most central collisions)
- Statistical hadronization model: all J/ψ are generated during the hadronization phase by purely statistical mechanisms
- Models describe data for (semi-)central collisions and in the two rapidity ranges → indication of (re-)generation mechanisms in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV

J/ψ results in p-Pb and Pb-p at 5.02 TeV (new)

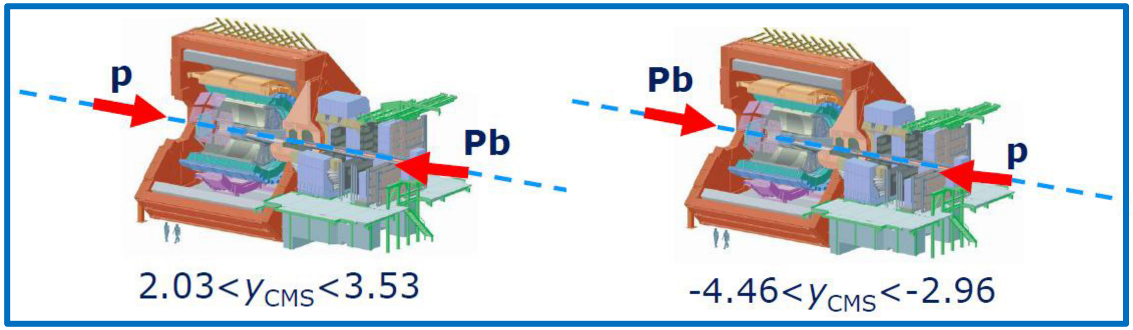
Motivations (p-Pb/Pb-p collisions)

- Study of initial state effects (shadowing, parton energy loss, intrinsic charm) and final state effects (quarkonia in medium dissociation, energy loss)
- Such effects are expected to be sizeable in AA collisions and their measurement in pA is essential to disentangle hot nuclear matter effects (suppression,(re-)generation)



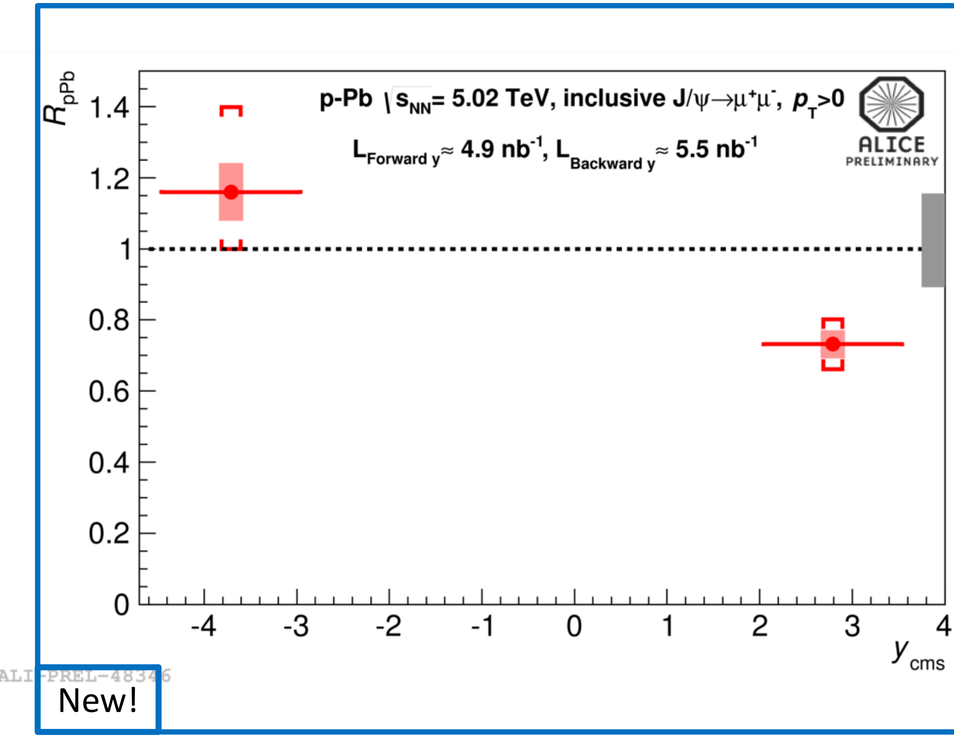
- Key observables:
  - Nuclear modification factor
    → considering p-Pb or Pb-p collisions the factor can be measured at forward or at backward rapidity with the spectrometer
  - The forward-backward ratio of the nuclear modification factors (R_{FB}) is computed

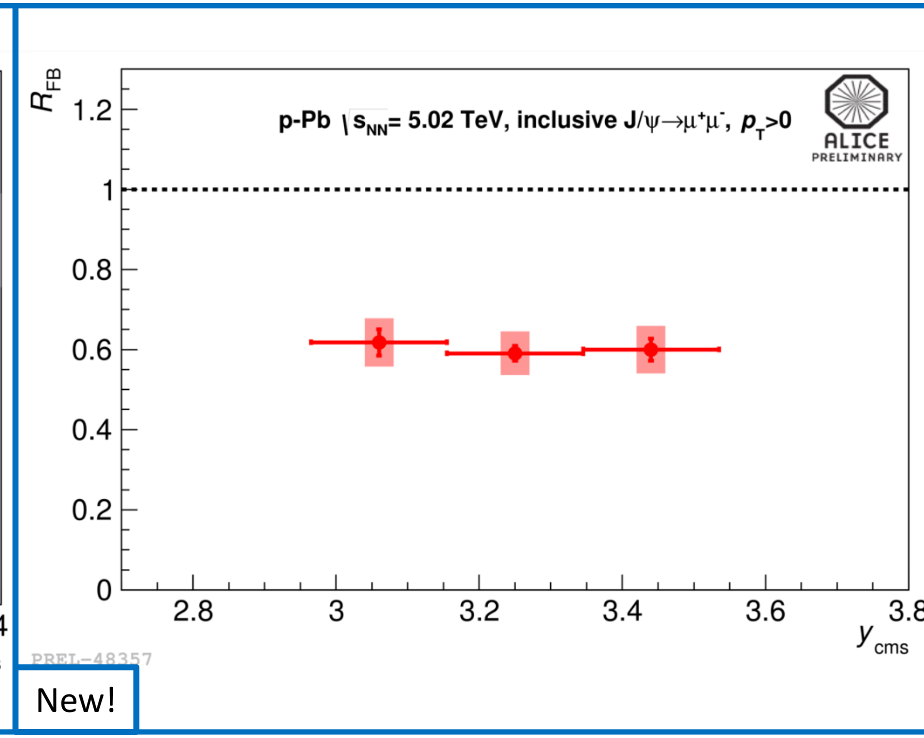
$$R_{pA}(p_T, y) = \frac{d^2N_{pA}/dydp_T}{\langle N_{coll}\rangle \times d^2N_{pp}/dydp_T}$$



$$R_{FB} = \frac{R_{pA}}{R_{Ap}}$$

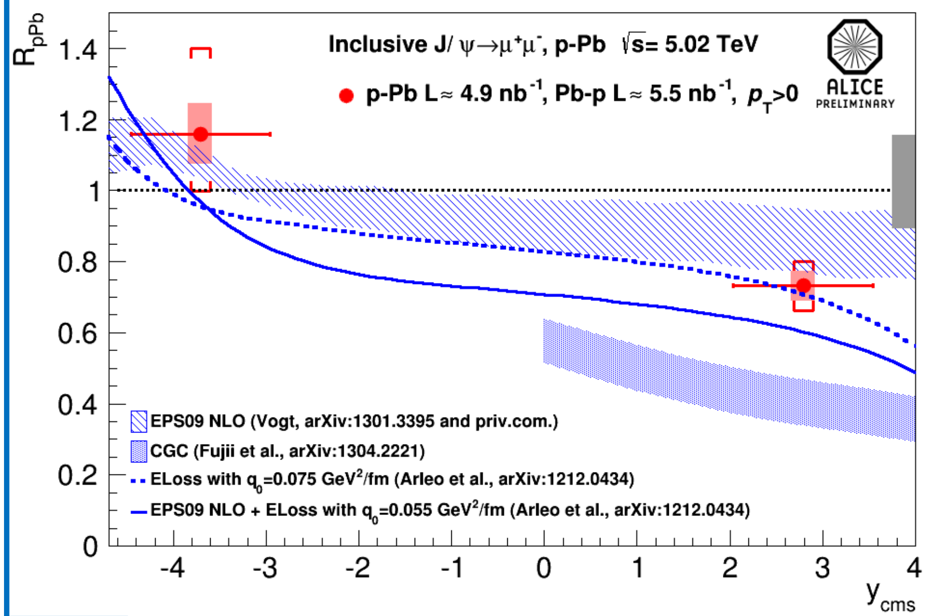
Inclusive J/ψ in p-Pb and Pb-p collisions



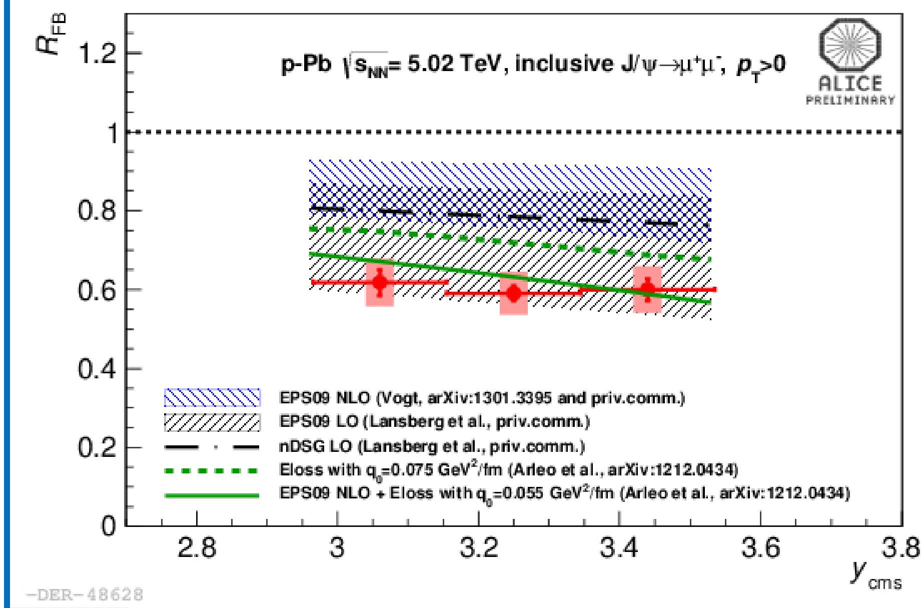


- ➢ The nuclear modification factor and the Forward-Backward ratio were measured in pA collisions at 5.02 TeV and down to zero p_T
- ➢ J/ ψ production decreases from backward to forward rapidity with respect to pp and the Forward-Backward ratio is of the order of 0.6
  → Initial/Final state nuclear effects

Inclusive J/ψ in p-Pb/Pb-p comparison with theory



New!

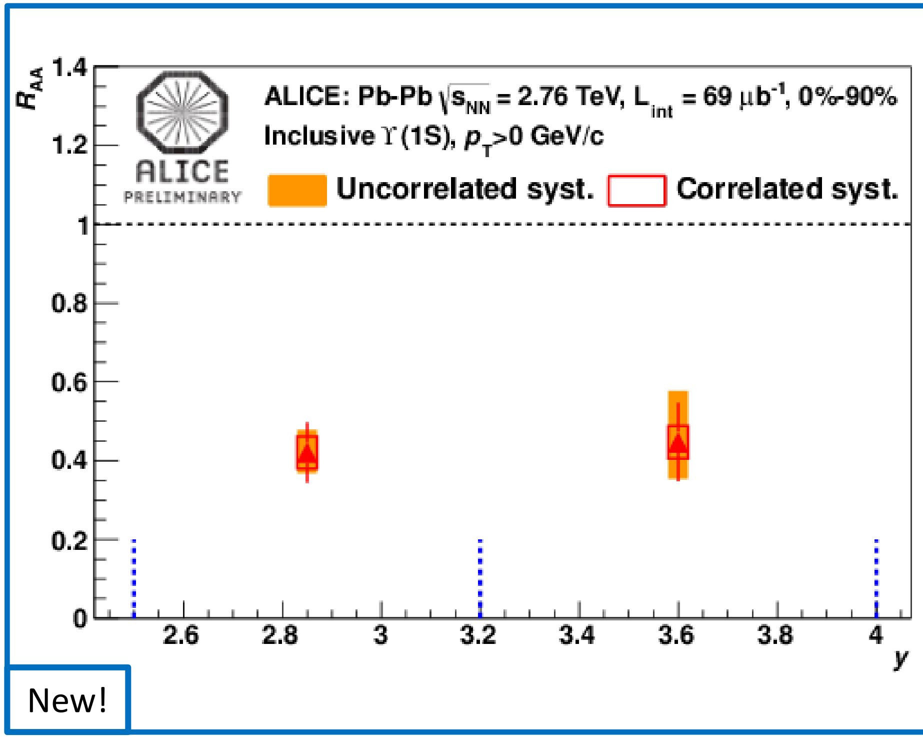


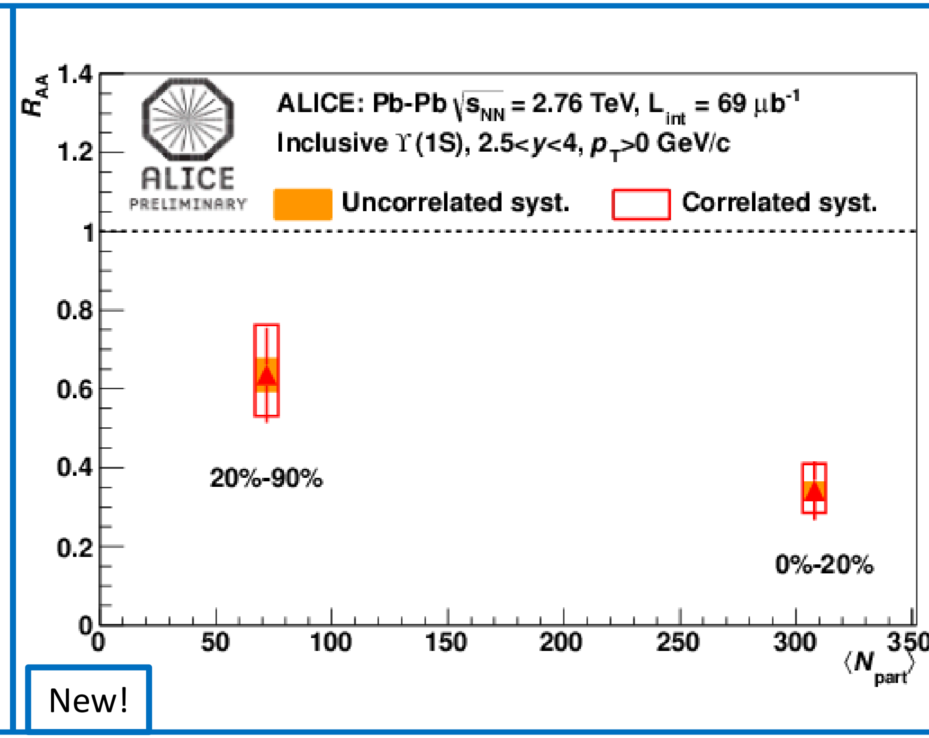
New!

- Nuclear modification factor:
  - The Color Glass Condensate model (forward rapidity only) seems not to be favoured
  - The shadowing EPS09 NLO calculations and models including also coherent parton energy loss reproduce reasonably the data
- Forward-Backward ratio:
  - Shadowing+energy loss model provides a rather good data description

Υ(1S) results in Pb-Pb at 2.76 TeV (new)

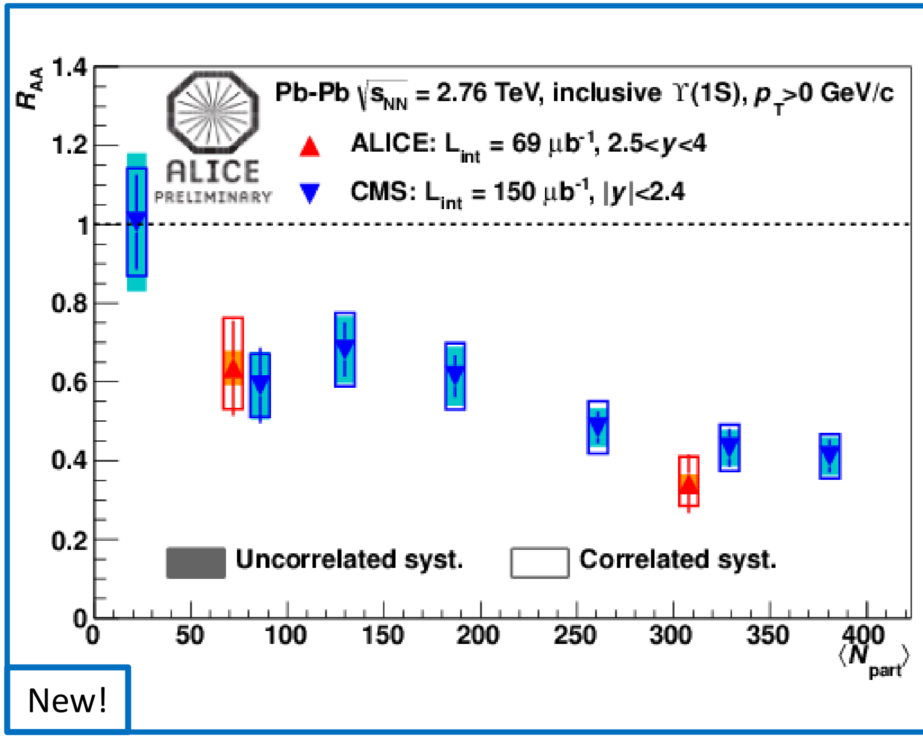
Nuclear modification factor of inclusive ϒ(1S) in Pb-Pb

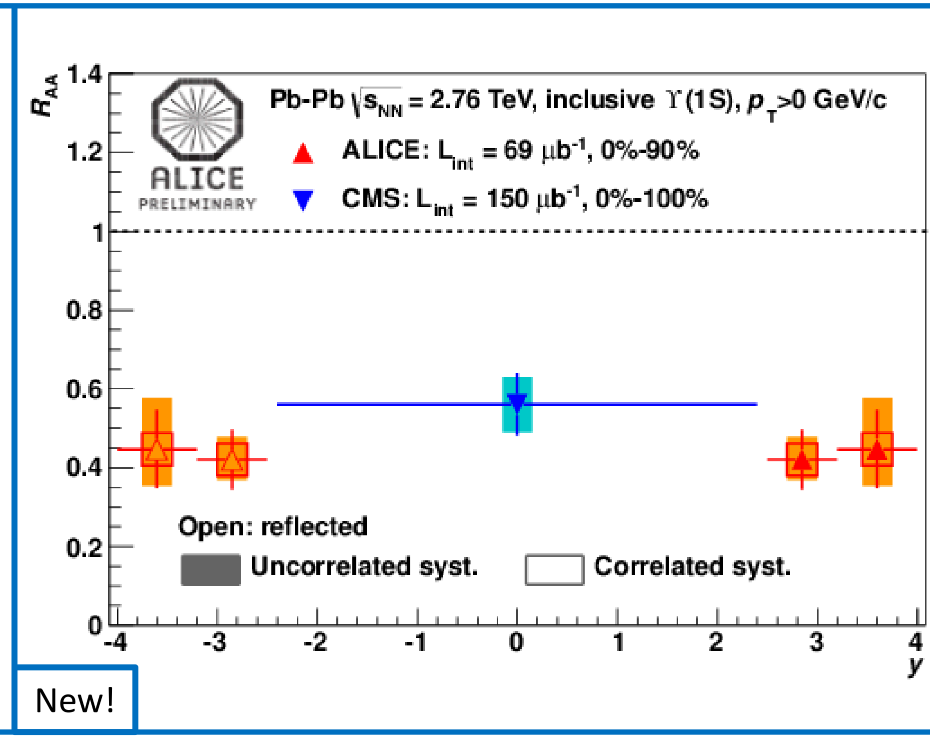




- R_{AA} measured at forward rapidity (2.5<y<4) and down to zero p_T
- Results:
  - Clear suppression observed
  - Weak rapidity dependence in the kinematic range 2.5<y<4
  - Hint for larger suppression in central collisions

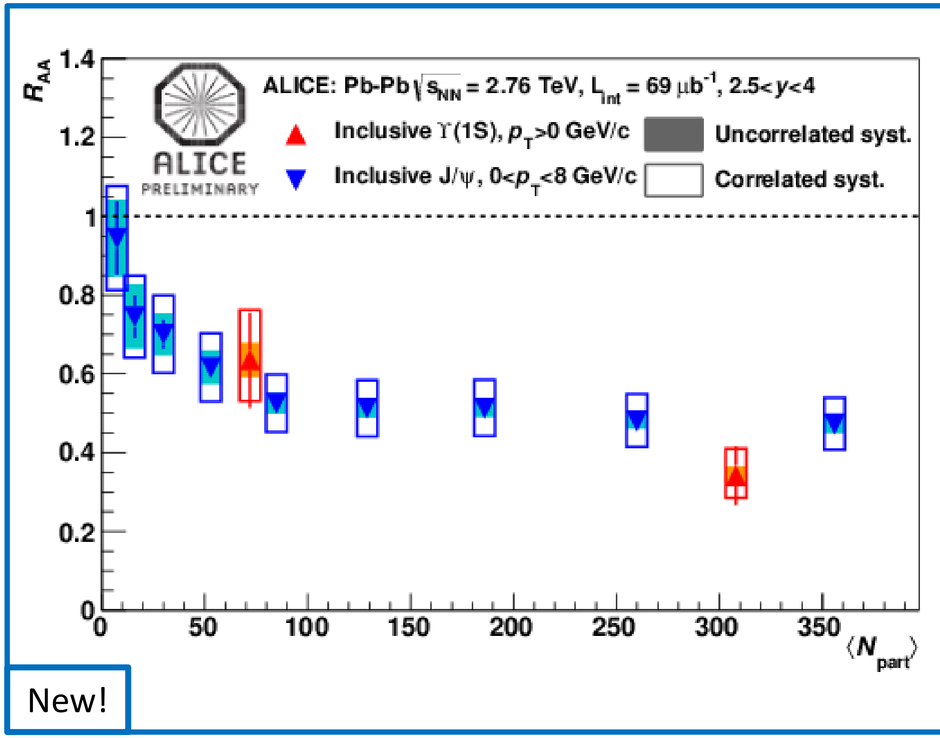
ALICE and CMS data comparison in Pb-Pb

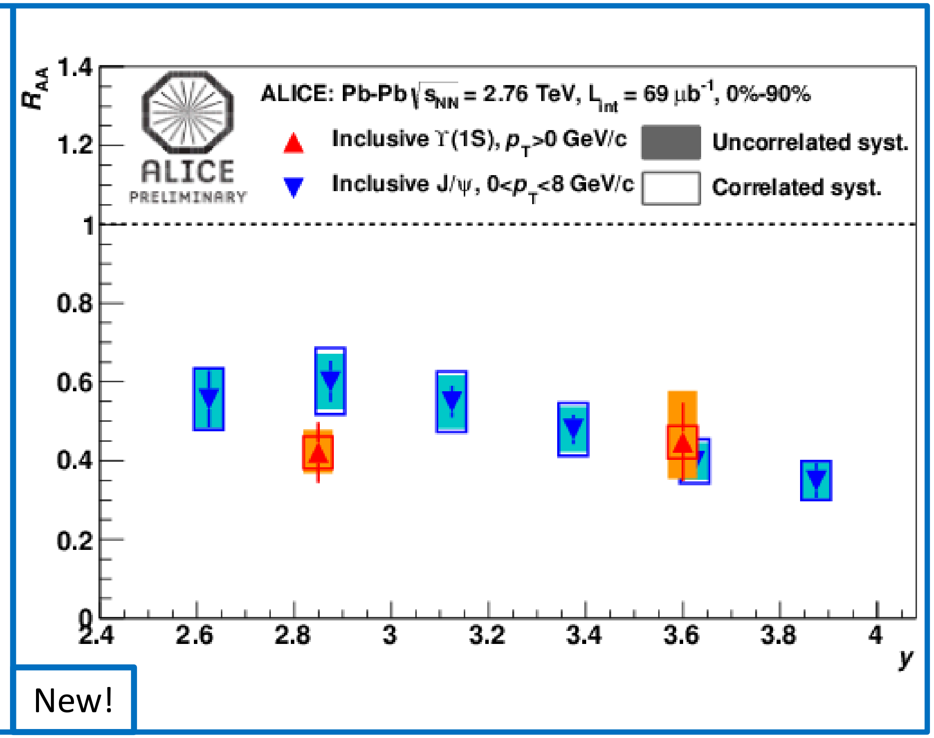




- The centrality dependence of the CMS and ALICE Υ(1S) nuclear modification factors are compatible
- The observed suppression factor (about 2) remains rather constant in the large rapidity range accessed by ALICE and CMS

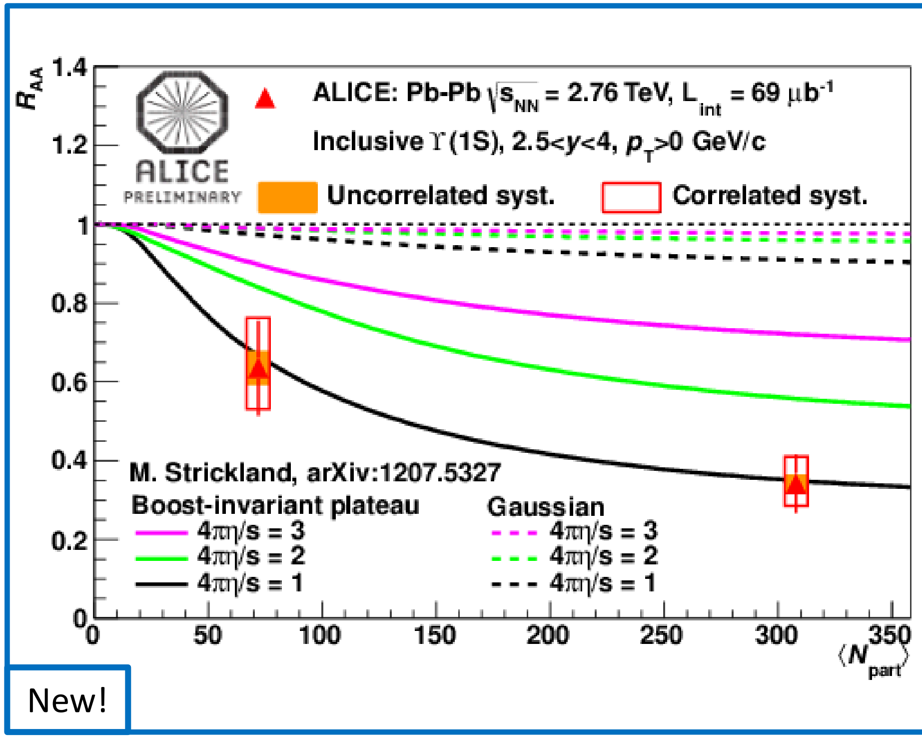
Inclusive Υ(1S) and inclusive J/ψ R_{AA}

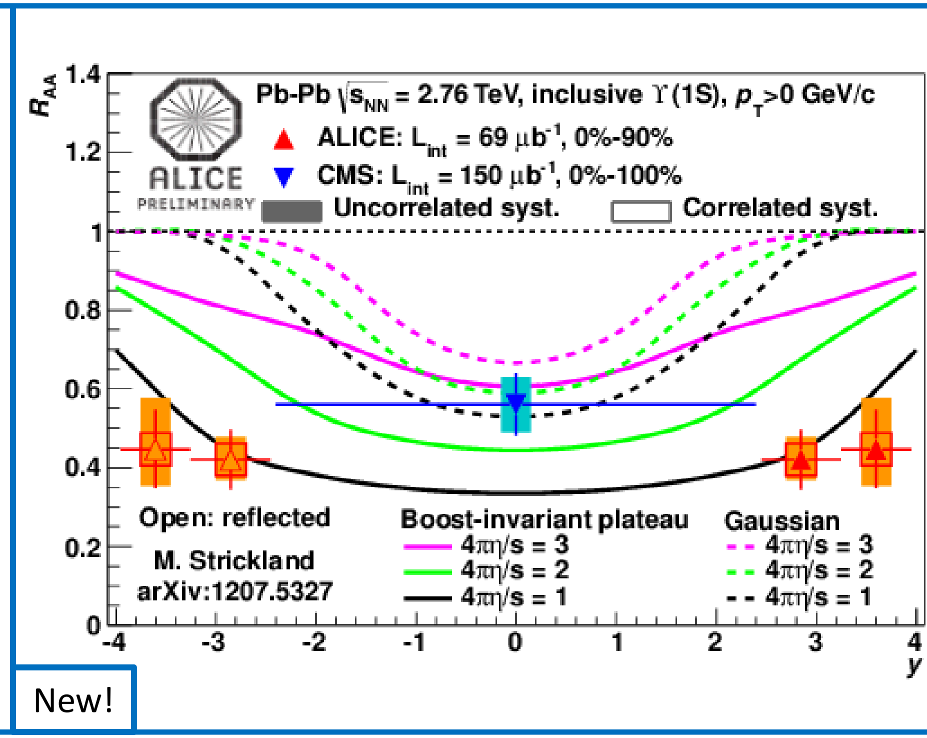




- Similar suppression for J/ψ and Υ(1S) observed as a function of centrality and as a function of rapidity
- CAVEATS: Interplay of various competing mechanisms is to be considered

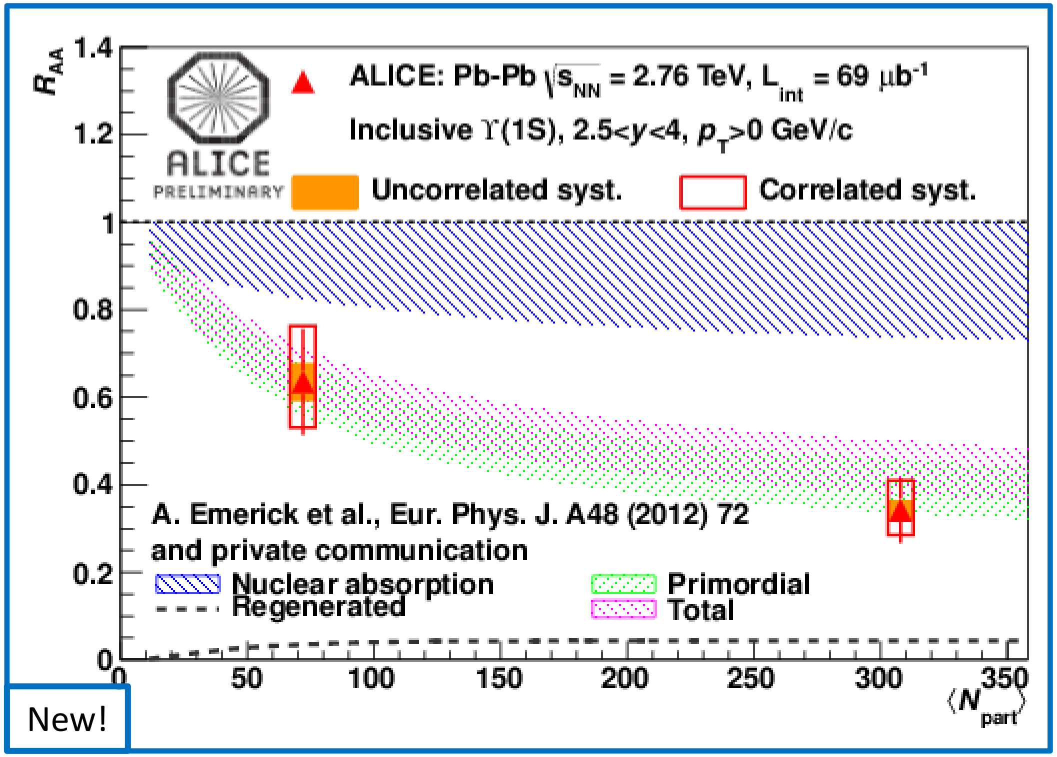
Comparison with models in Pb-Pb





- Hydrodynamic formalism (HYDRO) assuming finite local momentum-space anisotropy due to finite shear viscosity
- The model doesn’t take into account cold nuclear matter effects
- The model reproduces reasonably the data with a boost-invariant plateau as initial temperature profile and a shear viscosity such that 4πη/s=1
- The predicted suppression rapidity dependence is different than that measured

Comparison with models in Pb-Pb



New!

- Rate equation model taking into account an ϒ suppression component and a small (but not negligible) regeneration component
- Cold nuclear matter effects are taken into account by means of an overall absorption cross section including (anti-)shadowing, nuclear absorption and Cronin effect
- Predictions are provided for two absorption cross sections 0 and 2.0 mb

- The model describes reasonably the suppression as a function of the centrality

Conclusion

- J/ψ results in Pb-Pb (2.76 TeV):
  - The inclusive J/ψ R_{AA} has been measured down to zero p_T at mid-rapidity ($|y|<0.9$) and at forward rapidity ($2.5<y<4$)
  - An indication of J/ψ (re-)generation was observed
- J/ψ results in p-Pb/Pb-p (5.02 TeV):
  - The inclusive J/ψ R_{AA} has been measured at forward rapidity ($2.5<y<4$) and at backward rapidity ($-4<y<-2.5$) down to zero p_T as well as their ratio R_{FB}
  - The shadowing EPS09 NLO calculations reproduce reasonably the data
- ϒ(1S) results in Pb-Pb (2.76 TeV): ALICE-PUBLIC-2012-xxx
  - The inclusive ϒ(1S) R_{AA} has been measured down to zero p_T at forward rapidity ($2.5<y<4$)
  - A clear suppression was observed
  - Comparisons with the CMS data show a suppression which weakly depends on rapidity over the large range accessed by both experiments
  - The considered hydrodynamic model describes reasonably well the ALICE data but predicts a different rapidity dependence
  - A rate equation model including suppression and a small regeneration component describes reasonably well the data

ALICE

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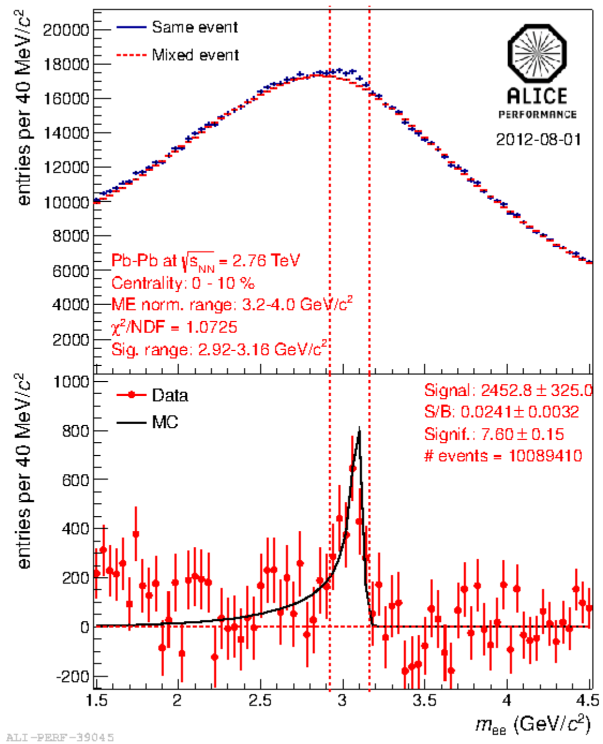
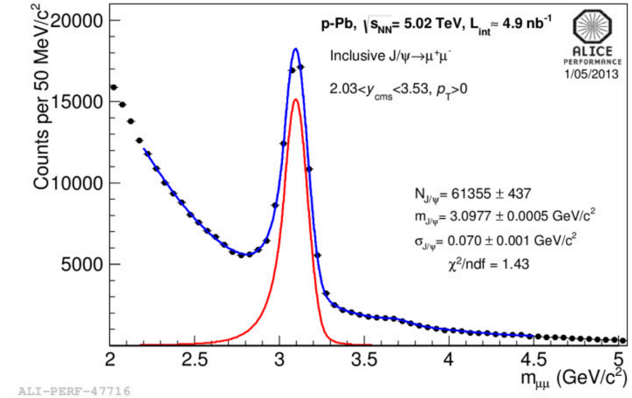
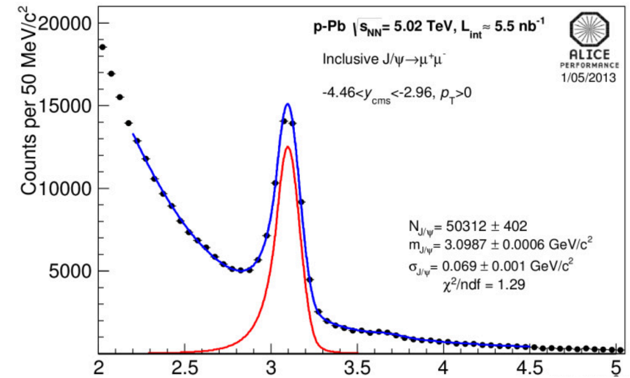
Back up

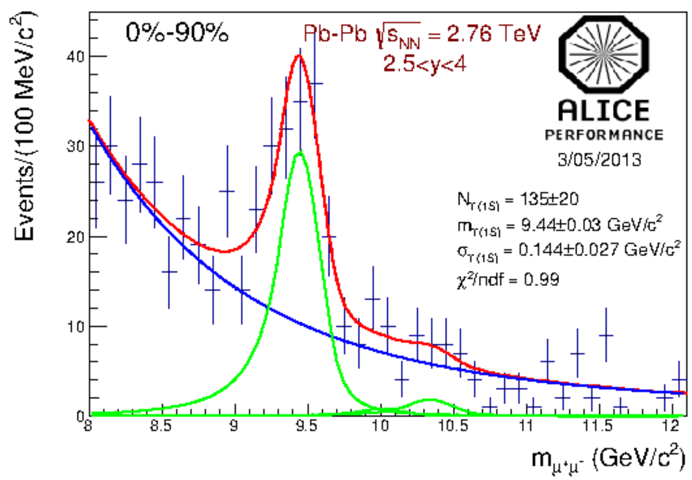
Mid-rapidity

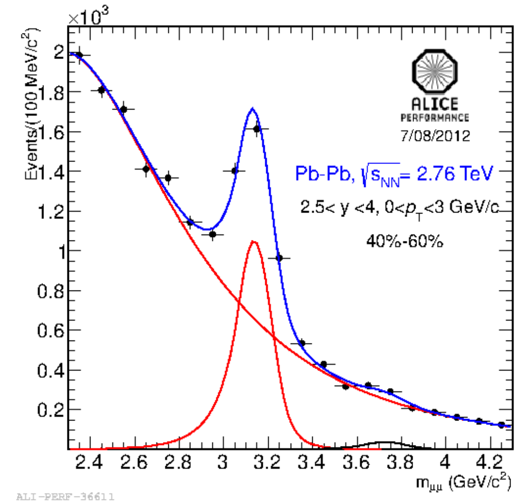


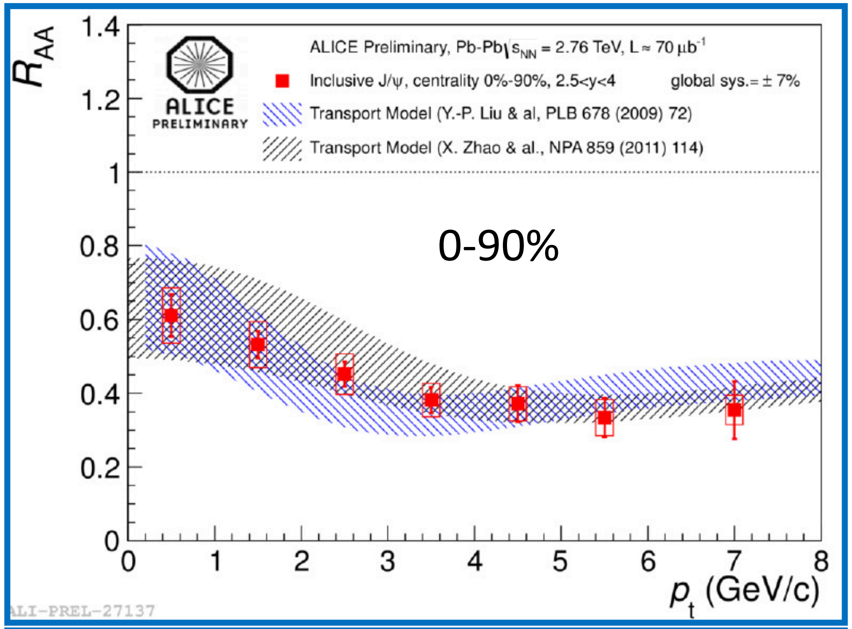
Forward rapidity



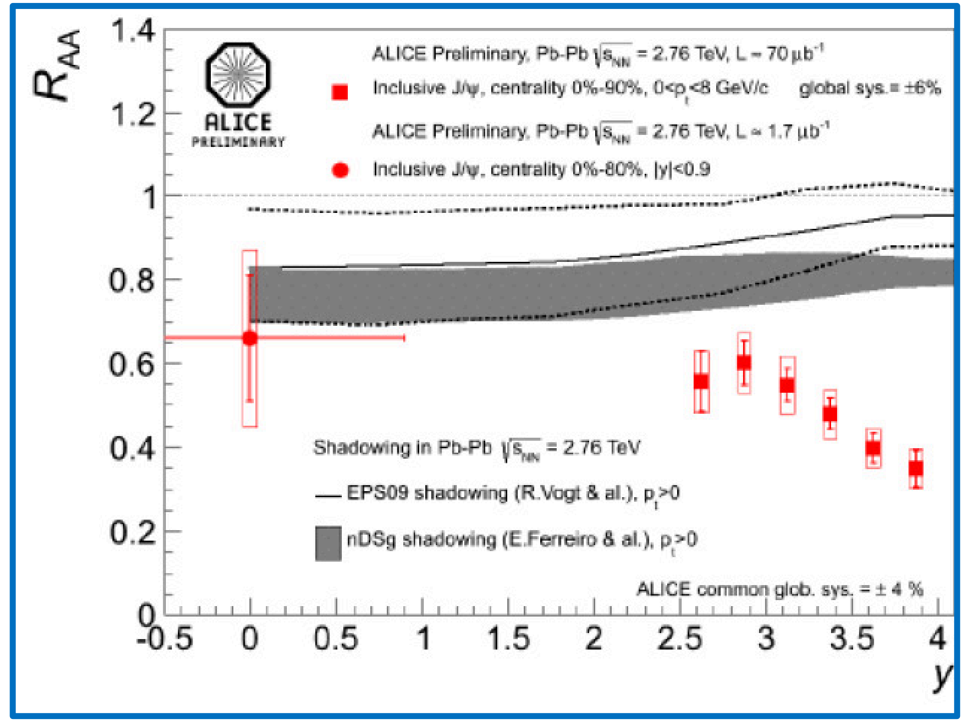




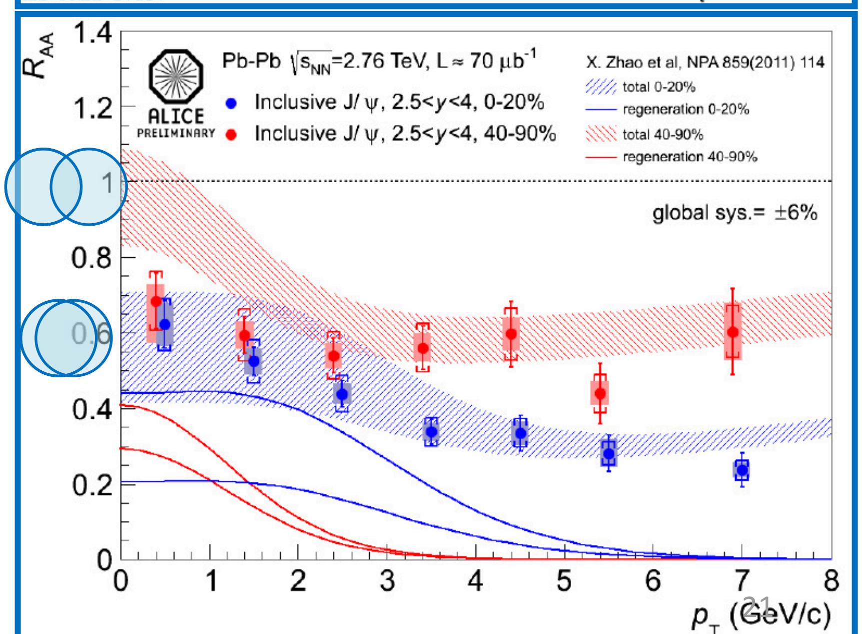




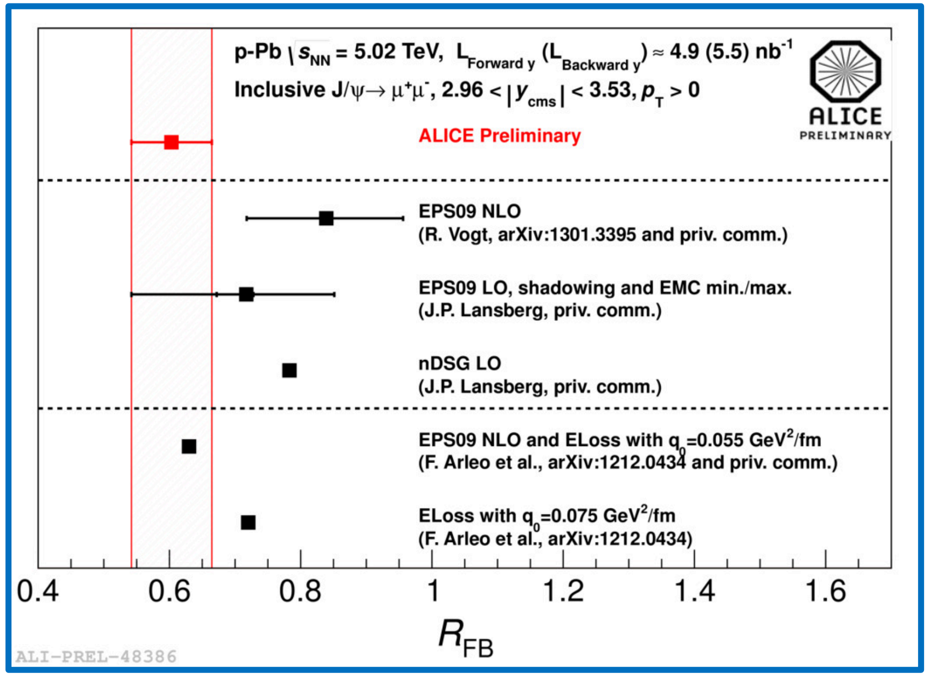
R_{AA}
ALICE PRELIMINARY
ALICE Preliminary, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, L ≈ 70 μb^{-1}
Inclusive J/ψ, centrality 0%-90%, 2.5<y<4
global sys.= ± 7%
Transport Model (Y.-P. Liu & al, PLB 678 (2009) 72)
Transport Model (X. Zhao & al., NPA 859 (2011) 114)
0-90%
p_t (GeV/c)
ALI-PREL-27137

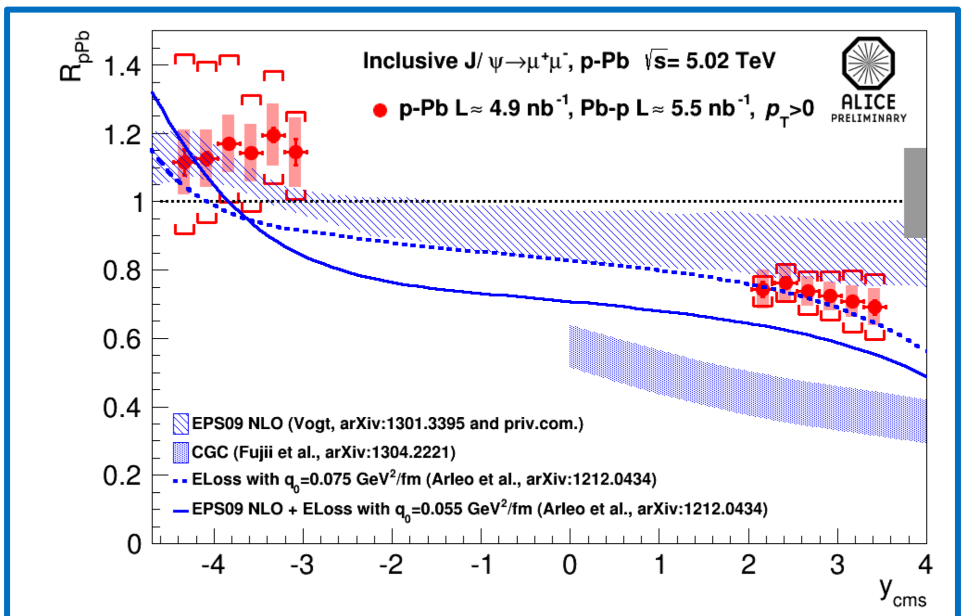


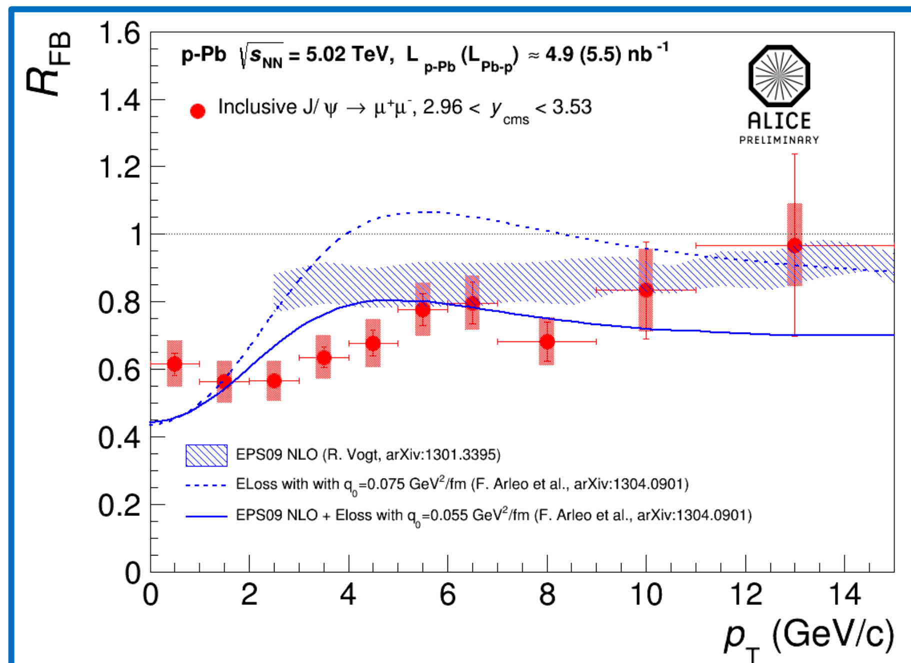
R_{AA}
ALICE PRELIMINARY
ALICE Preliminary, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, L ≈ 70 μb^{-1}
Inclusive J/ψ, centrality 0%-90%, 0<p_t<8 GeV/c
global sys.= ±6%
ALICE Preliminary, Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, L ≈ 1.7 μb^{-1}
Inclusive J/ψ, centrality 0%-80%, |y|<0.9
Shadowing in Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV
EPS09 shadowing (R.Vogt & al.), p_t>0
nDSg shadowing (E.Ferreiro & al.), p_t>0
ALICE common glob. sys. = ± 4 %
y

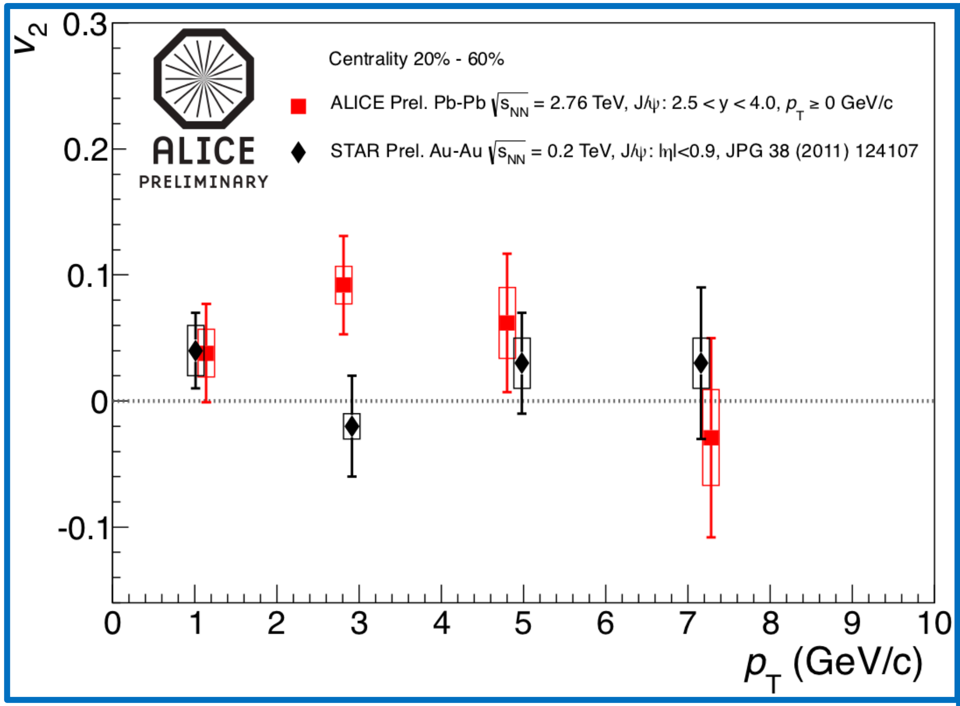


R_{AA}
ALICE PRELIMINARY
Pb-Pb $\sqrt{s_{NN}}$=2.76 TeV, L ≈ 70 μb^{-1}
Inclusive J/ψ, 2.5<y<4, 0-20%
Inclusive J/ψ, 2.5<y<4, 40-90%
X. Zhao et al, NPA 859(2011) 114
total 0-20%
regeneration 0-20%
total 40-90%
regeneration 40-90%
global sys.= ±6%
p_T (GeV/c)

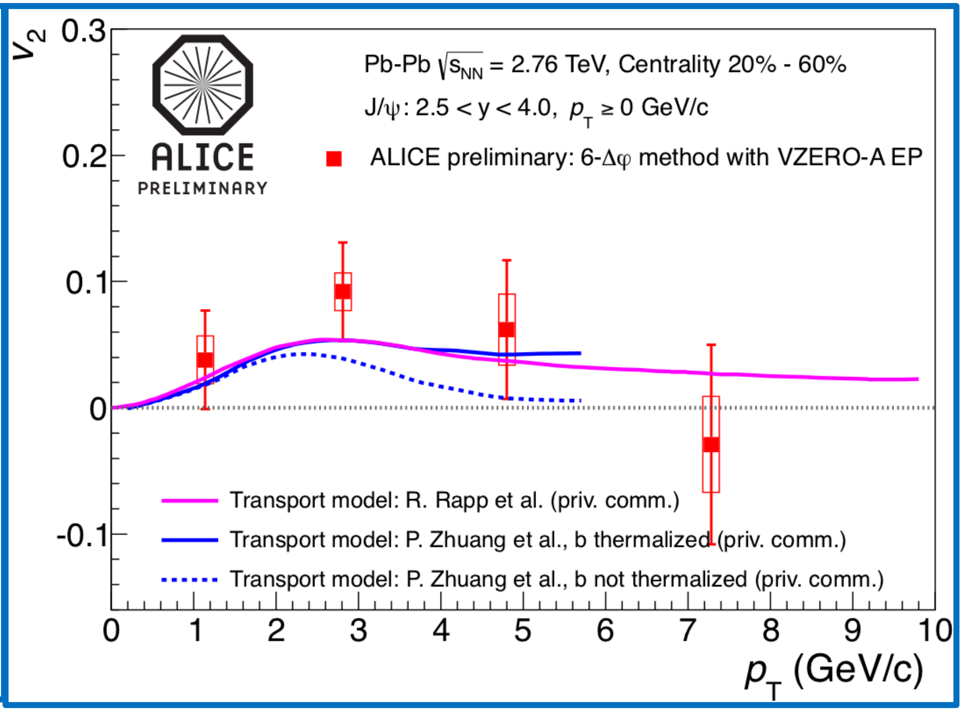

p-Pb $\sqrt{s_{NN}}$ = 5.02 TeV, $L_{Forward\ y}$ ($L_{Backward\ y}$) ≈ 4.9 (5.5) nb^{-1}
Inclusive J/ψ→$\mu^+\mu^-$, 2.96 < |y_{cms}| < 3.53, p_T > 0
ALICE Preliminary
EPS09 NLO
(R. Vogt, arXiv:1301.3395 and priv. comm.)
EPS09 LO, shadowing and EMC min./max.
(J.P. Lansberg, priv. comm.)
nDSG LO
(J.P. Lansberg, priv. comm.)
EPS09 NLO and ELoss with q_0=0.055 GeV^2/fm
(F. Arleo et al., arXiv:1212.0434 and priv. comm.)
ELoss with q_0=0.075 GeV^2/fm
(F. Arleo et al., arXiv:1212.0434)
0.4
0.6
0.8
1
1.2
1.4
1.6
R_{FB}
ALI-PREL-48386
ALICE
PRELIMINARY


R_{pPb}
Inclusive J/ ψ→$\mu^+\mu^-$, p-Pb $\sqrt{s}$= 5.02 TeV
p-Pb L≈ 4.9 nb^{-1}, Pb-p L≈ 5.5 nb^{-1}, p_T>0
ALICE
PRELIMINARY
EPS09 NLO (Vogt, arXiv:1301.3395 and priv.com.)
CGC (Fujii et al., arXiv:1304.2221)
ELoss with q_0=0.075 GeV^2/fm (Arleo et al., arXiv:1212.0434)
EPS09 NLO + ELoss with q_0=0.055 GeV^2/fm (Arleo et al., arXiv:1212.0434)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
-4
-3
-2
-1
0
1
2
3
4
y_{cms}


R_{FB}
p-Pb $\sqrt{s_{NN}}$ = 5.02 TeV, L_{p-Pb} (L_{Pb-p}) ≈ 4.9 (5.5) nb^{-1}
Inclusive J/ ψ → $\mu^+\mu^-$, 2.96 < y_{cms} < 3.53
ALICE
PRELIMINARY
EPS09 NLO (R. Vogt, arXiv:1301.3395)
ELoss with with q_0=0.075 GeV^2/fm (F. Arleo et al., arXiv:1304.0901)
EPS09 NLO + Eloss with q_0=0.055 GeV^2/fm (F. Arleo et al., arXiv:1304.0901)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
2
4
6
8
10
12
14
p_T (GeV/c)



v_2
Centrality 20% - 60%
ALICE Prel. Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, J/ψ: 2.5 < y < 4.0, p_T ≥ 0 GeV/c
STAR Prel. Au-Au $\sqrt{s_{NN}}$ = 0.2 TeV, J/ψ: |η|<0.9, JPG 38 (2011) 124107
ALICE
PRELIMINARY
p_T (GeV/c)



v_2
Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV, Centrality 20% - 60%
J/ψ: 2.5 < y < 4.0, p_T ≥ 0 GeV/c
ALICE preliminary: 6-Δφ method with VZERO-A EP
ALICE
PRELIMINARY
Transport model: R. Rapp et al. (priv. comm.)
Transport model: P. Zhuang et al., b thermalized (priv. comm.)
Transport model: P. Zhuang et al., b not thermalized (priv. comm.)
p_T (GeV/c)