ALICE results on J/ψ production in Pb-Pb collisions at the LHC

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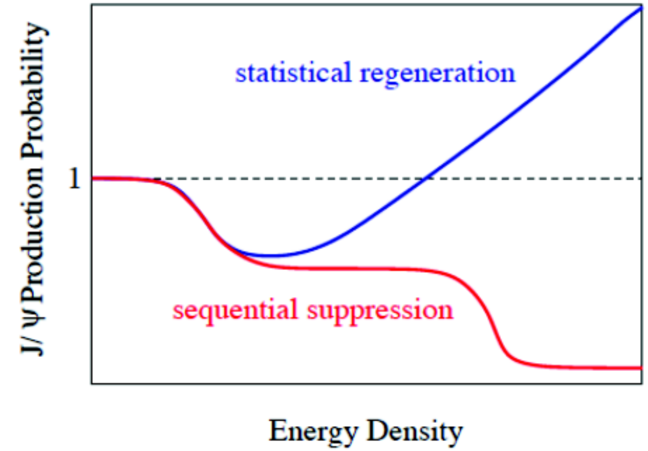
Outline

- Introduction and motivation
- J/ψ nuclear modification factor R_{AA} in Pb-Pb collisions
- J/ψ elliptic flow parameter v_2
- Conclusion and outlook

Motivation

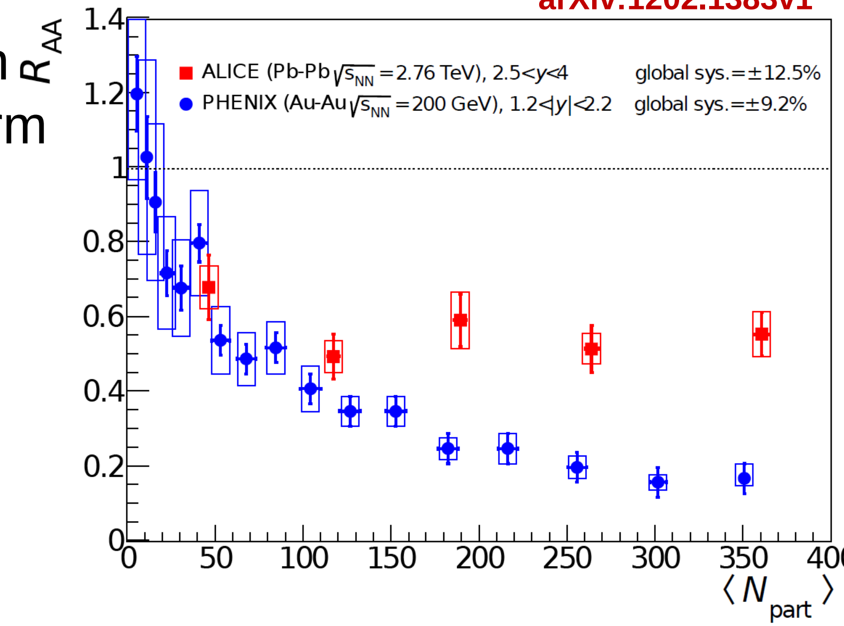
J/ψ mesons can probe the formation of a Quark-Gluon Plasma in heavy-ion collisions: predicted suppression in QGP via Debye-like color screening



Complications due to

- cold nuclear effects (e.g. shadowing)
- possible competing effects in QGP, such as the coalescence of uncorrelated charm quark pairs

arXiv:1202.1383v1



J/ψ suppression already observed at SPS and at RHIC in central HI collisions

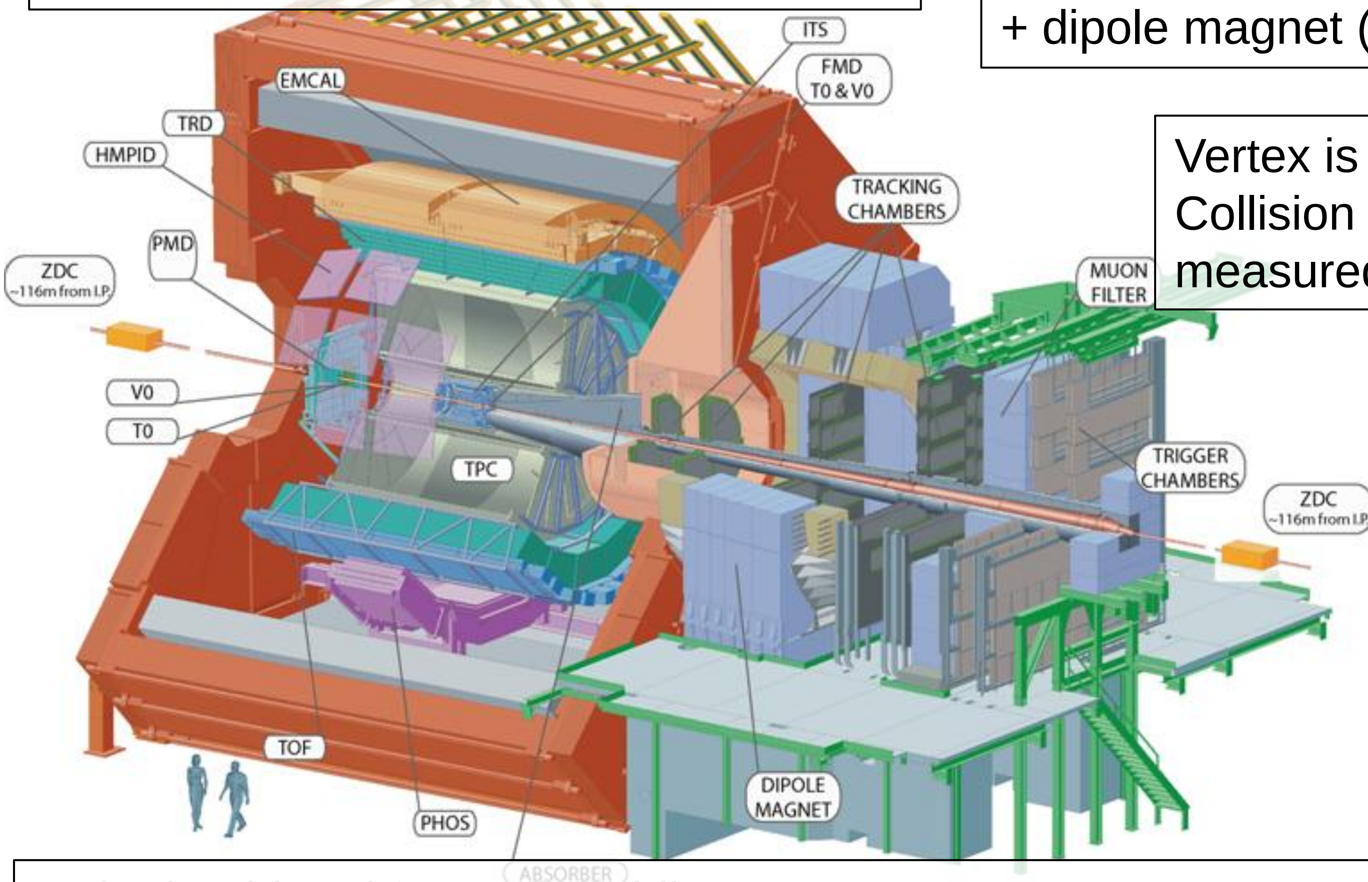
ALICE 2010 result shows less J/ψ suppression than at RHIC, and little dependence on collision's centrality

J/ψ measurements in ALICE

Central Barrel:
J/ψ → e^+e^- @ |y|<0.9
Electrons tracked using ITS and TPC in 0.5 T solenoid field.
Particle Id using TPC and TOF (Pb-Pb)

Forward Spectrometer:
J/ψ → $\mu^+\mu^-$ @ 2.5<y<4.0
Front absorber removes hadrons
Muons identified in trigger chambers
Tracked in 5x2 planes of Pad Chambers
+ dipole magnet (3 T.m)

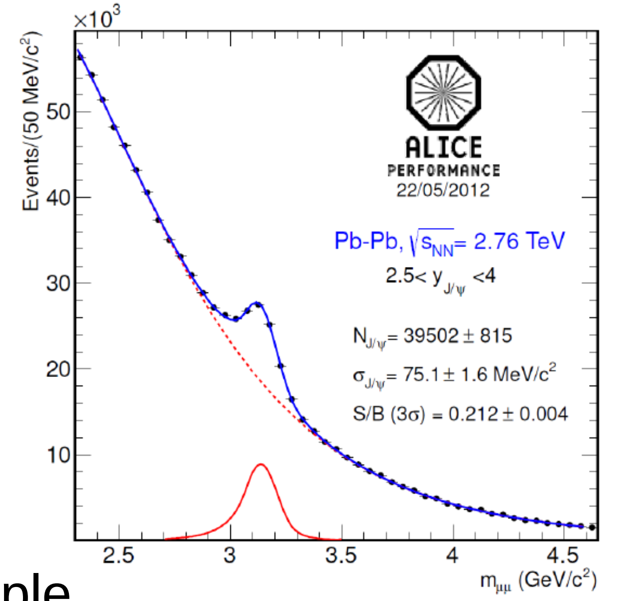
Vertex is reconstructed with ITS
Collision centrality (Pb-Pb) is measured with VZERO



at both mid and forward rapidity, measurements start at p_t = 0 GeV/c

Data set and analysis details (1) 2.5<y<4

Using 2011 data set, di-muon triggered events. Luminosity: ~70 μb^{-1}
(for comparison, 2010 data set was L ~2.9 μb^{-1})



Background estimated using several methods
(fit functions and event mixing)

Signal shape described by extended Crystal Ball function (with non-Gaussian tails on both sides of the peak)

About 40k J/ψ measured in the analyzed data sample

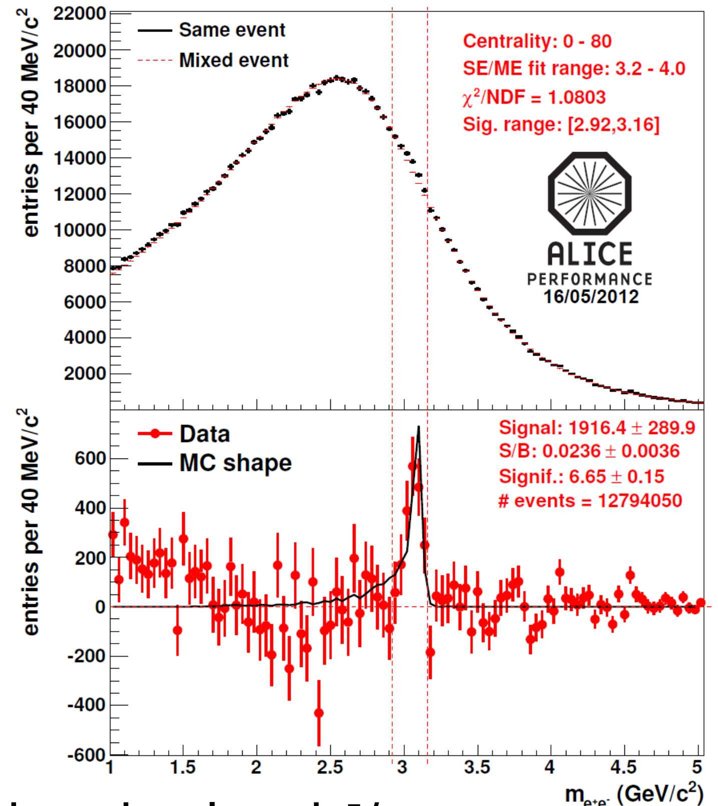
Acceptance x efficiency corrections evaluated using simulated J/ψ embedded into real events. Weak dependence (~10%) upon centrality is observed

Systematic uncertainties dominated by the error on the nuclear overlap function T_{AA} and trigger efficiency

Data set and analysis details (2) $|y|<0.9$

Using 2010 data set and minimum bias trigger. Luminosity: ~1.7 μb^{-1}

Background estimated using event mixing, scaled to same-event spectrum in mass range $3.2<M<4$ GeV/c^2



Signal estimated by counting excess above background in mass range $2.92<M<3.16$ GeV/c^2 and using MC to evaluate the number of J/ψ outside of this range

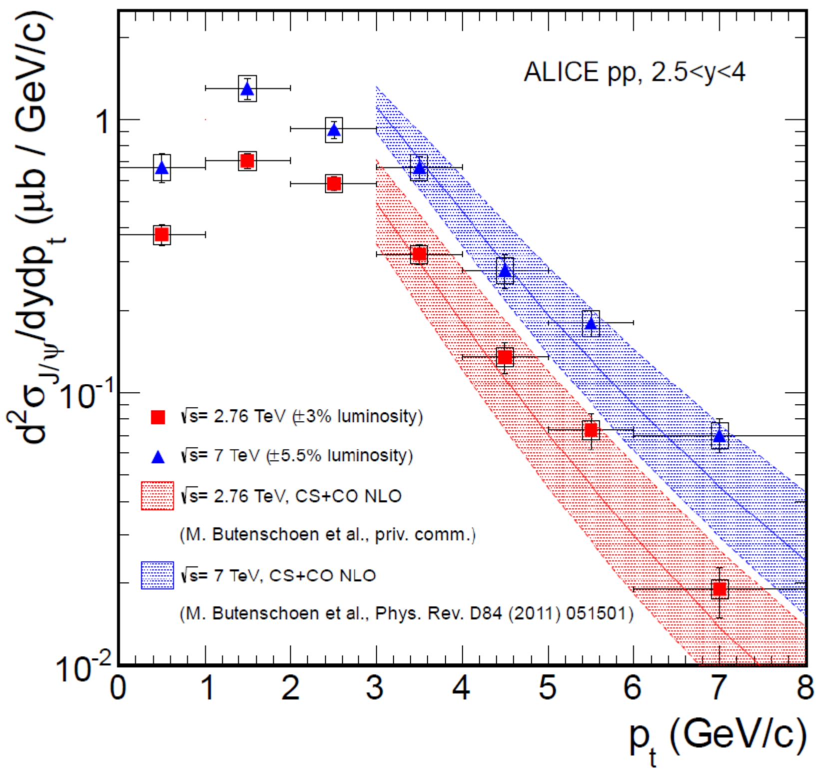
About 2000 J/ψ measured in the analyzed data sample

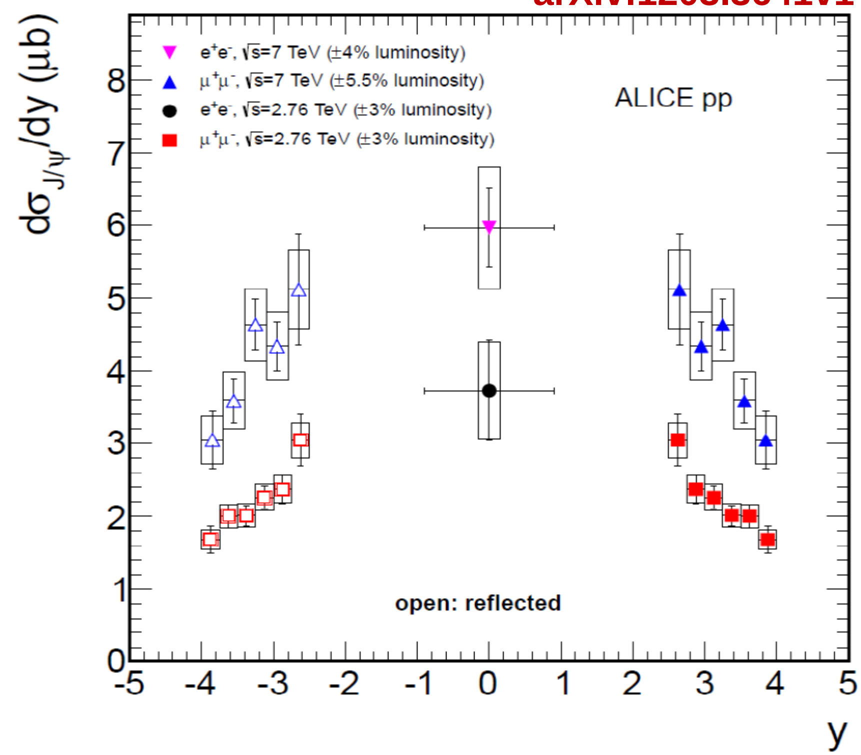
Acceptance x efficiency corrections evaluated using simulated J/ψ embedded into Hijing events. Weak dependence upon centrality is observed

Systematic uncertainties dominated by signal extraction

p-p reference

ALICE has measured J/ψ production vs rapidity and p_t in pp collisions at the same energy (2.76 TeV)





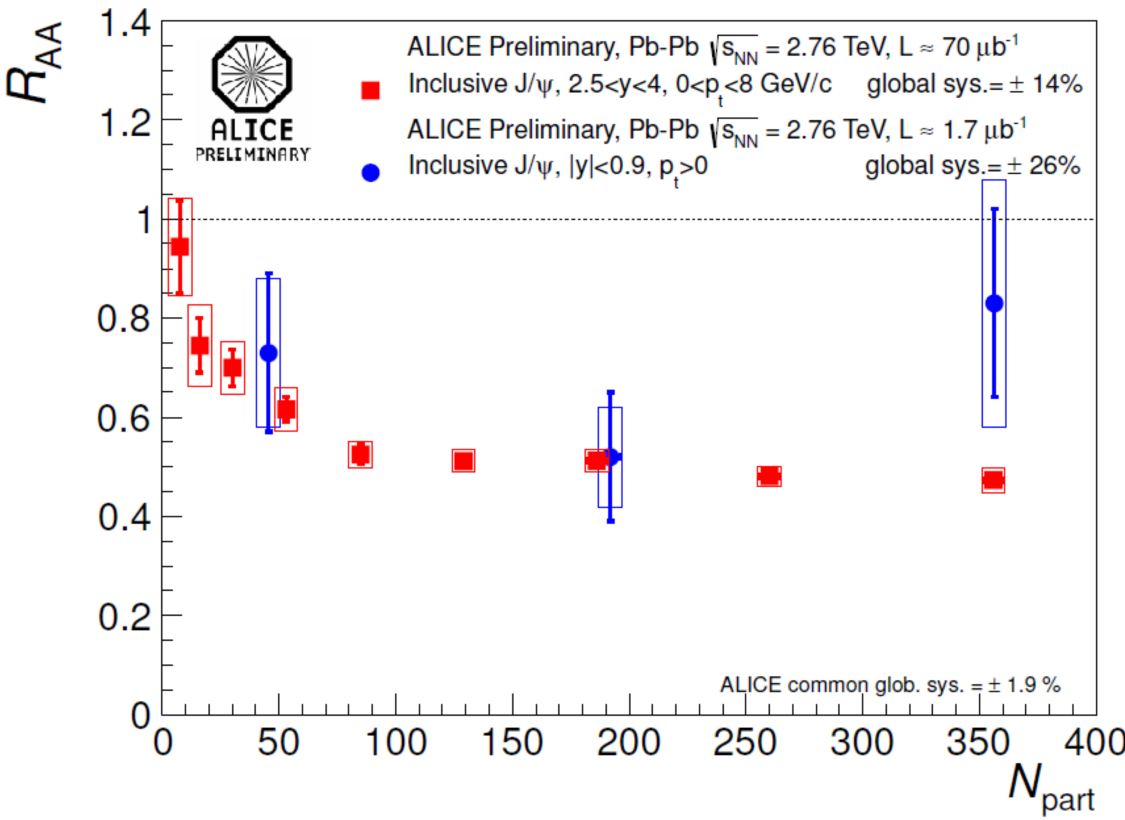
It is used as reference in calculating the nuclear modification factor:

$$R_{AA}^{i} = \frac{Y_{J/\psi}^{\mathrm{PbPb},i}}{T_{AA}^{i} \cdot \sigma_{J/\psi}^{\mathrm{pp}}}$$

(See talk by Livio Bianchi - 2F Tue 17:40)

J/ψ nuclear modification factor

J/ψ R_{AA} as a function of centrality



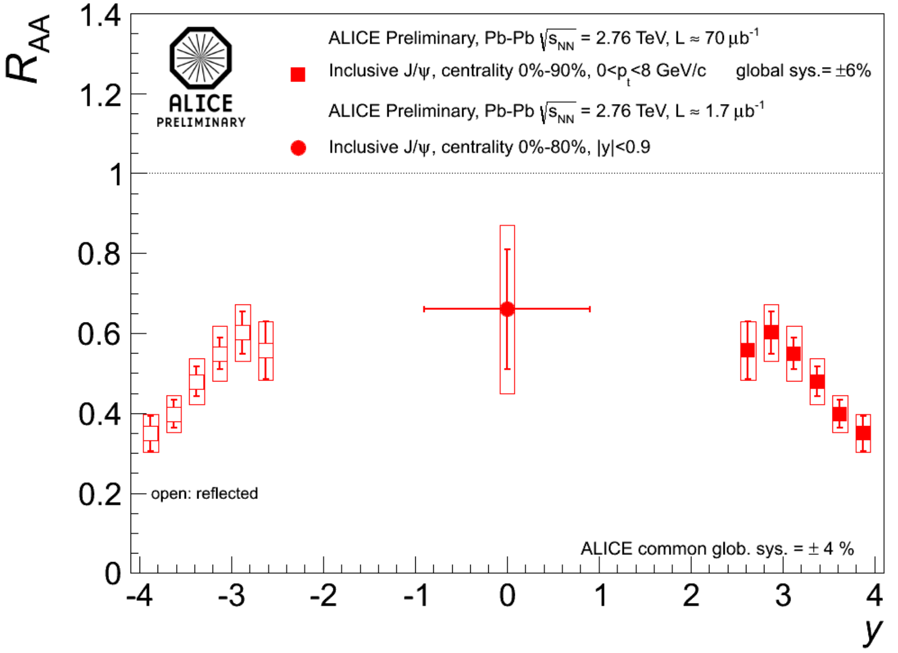
Significant J/ψ suppression observed at forward-rapidity, with little dependence on centrality for N_{part}>100

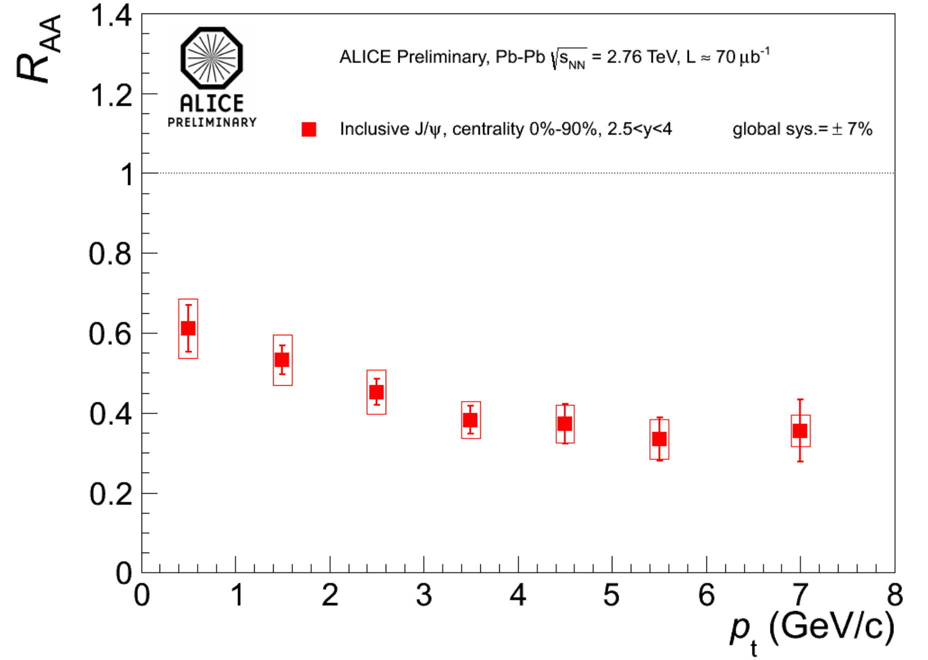
Similar pattern observed at mid-rapidity but large uncertainties prevent firm conclusions.

Inclusive J/ψ → $\mu^+\mu^-$ $\quad R_{AA}^{0-90\%} = 0.497 \pm 0.006\ (stat) \pm 0.078(syst)$

Inclusive J/ψ → e^+e^- $\quad R_{AA}^{0-80\%} = 0.66 \pm 0.10\ (stat) \pm 0.24(syst)$

J/ψ R_{AA} as a function of rapidity and p_t

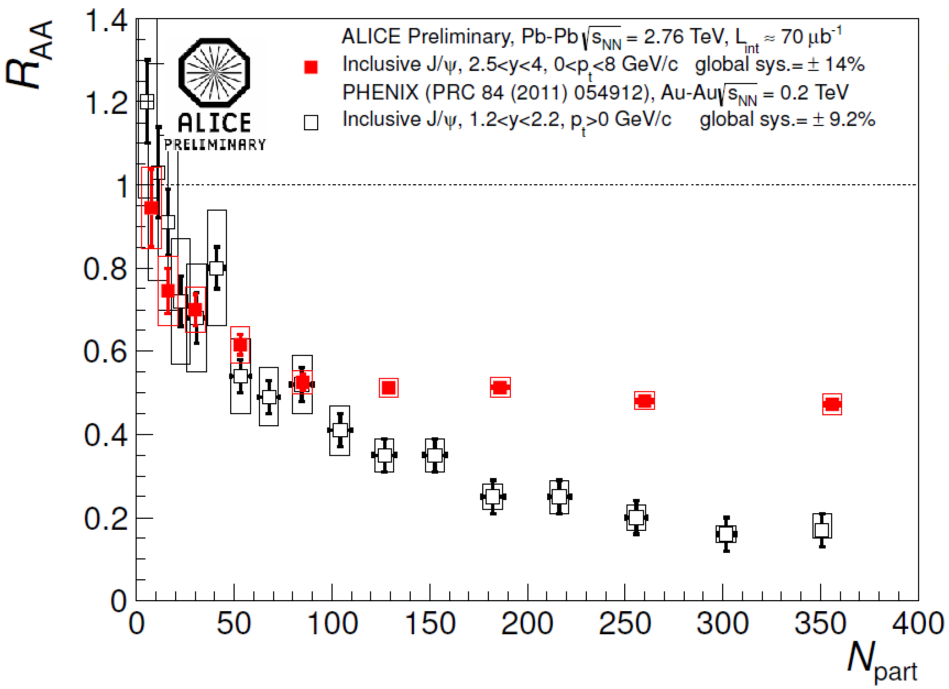


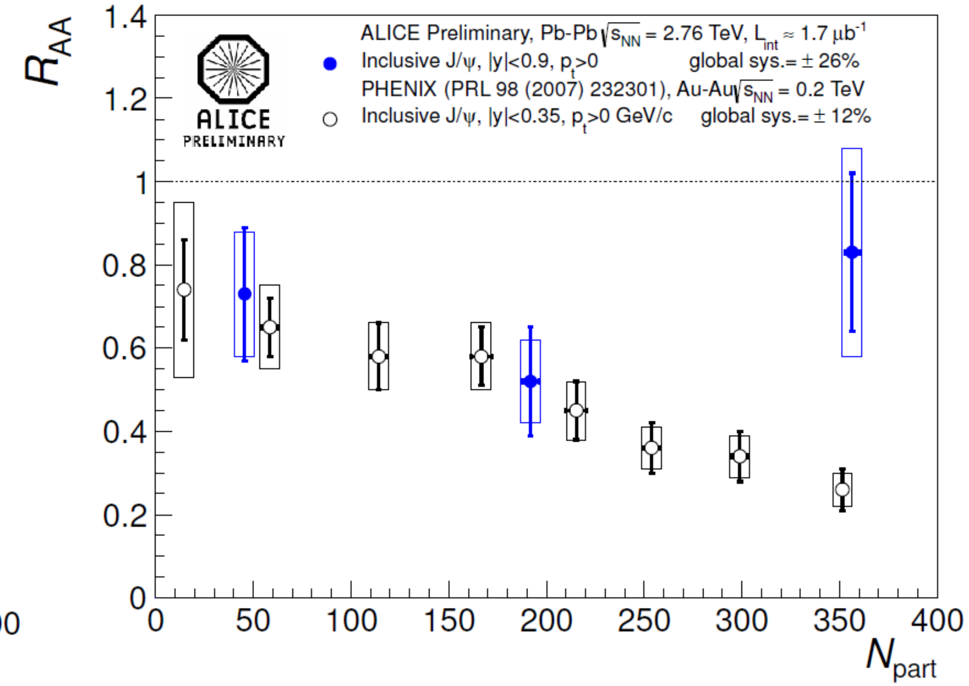


Larger suppression observed at more forward rapidity

Less suppression at low p_t (p_t<3 GeV/c) than at high p_t

Comparison to RHIC



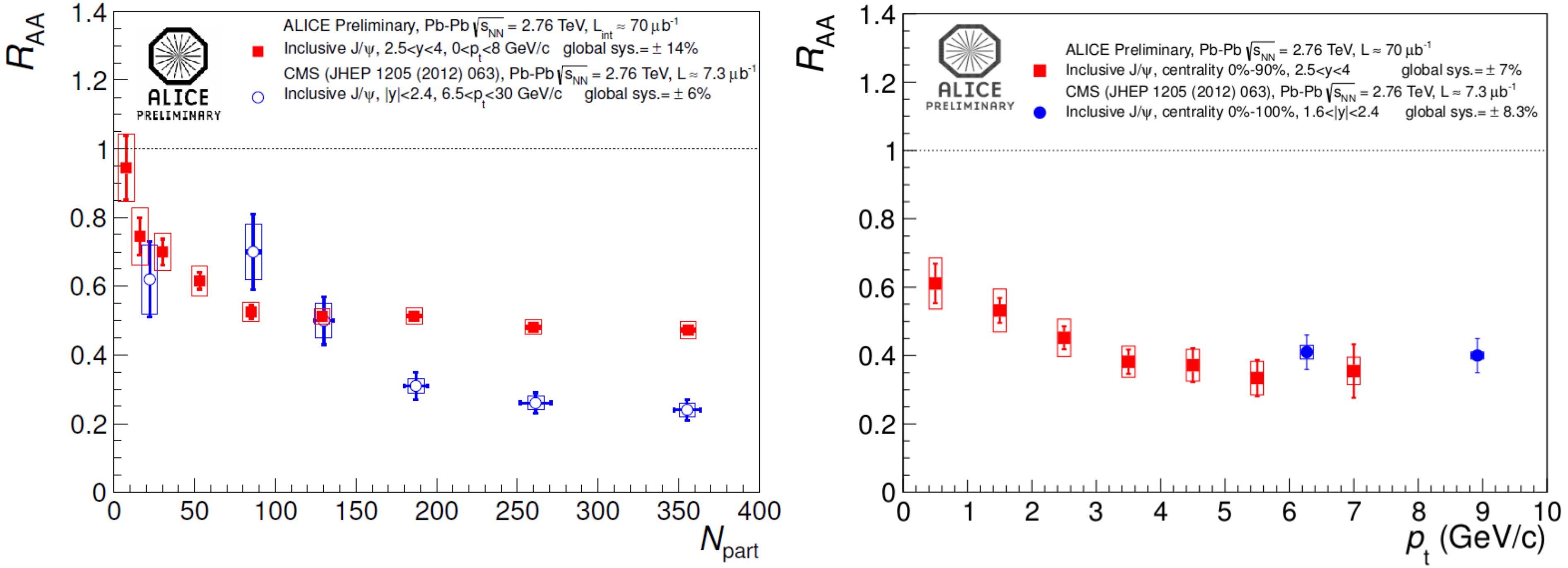


Less suppression at LHC (Pb-Pb@2.76 TeV) than at RHIC (Au-Au@200 GeV)

Notes:

- Energy density is about x2.5 larger at LHC than at RHIC
- Differences between cold nuclear effects at both energies are not accounted for

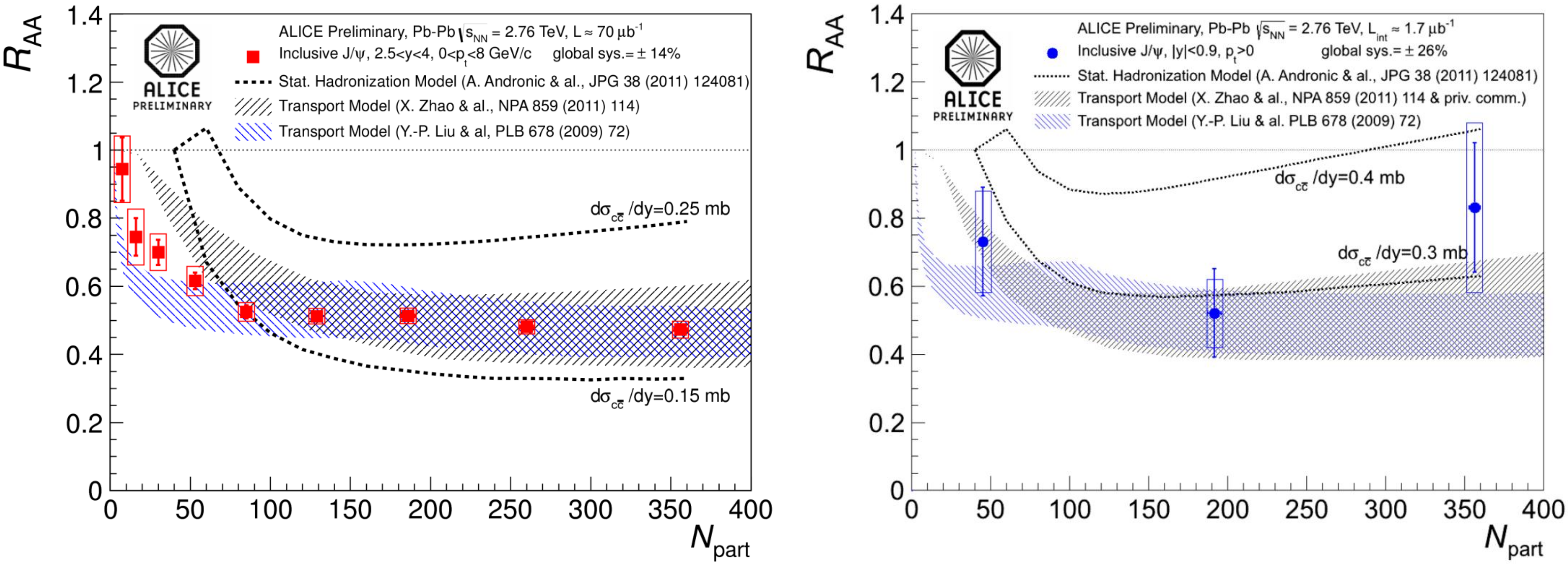
Comparison to CMS



Larger suppression observed in central collisions by CMS for high p_t J/ψ (p_t>6.5 GeV/c)

For minimum bias collisions, R_{AA} vs p_t are consistent between the two experiments even though the rapidity ranges differ

Comparison to models (1) R_{AA} vs centrality

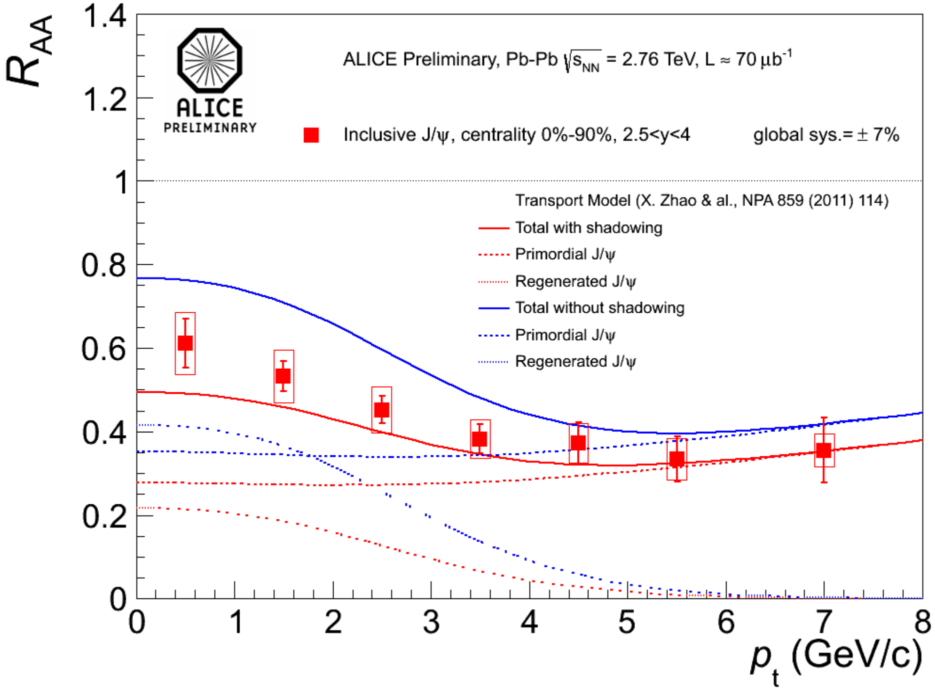


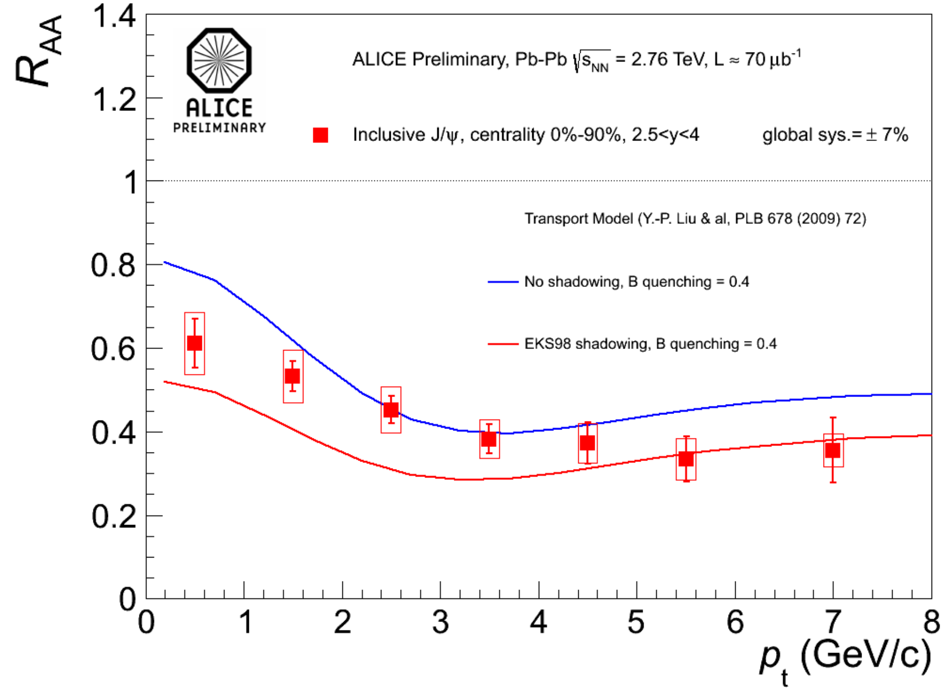
Models ingredients:

- A. Andronic et al: production of c quarks via hard scattering, statistical hadronization into J/ψ at phase boundary
- X. Zhao et al: shadowing on both c quarks and J/ψ, suppression of direct J/ψ by color screening and regeneration in QGP, using transport equation
- Y.-P. Liu et al: similar ingredients but different calculation

Large uncertainties notably from shadowing and charm cross-section

Comparison to models (2) R_{AA} vs p_t



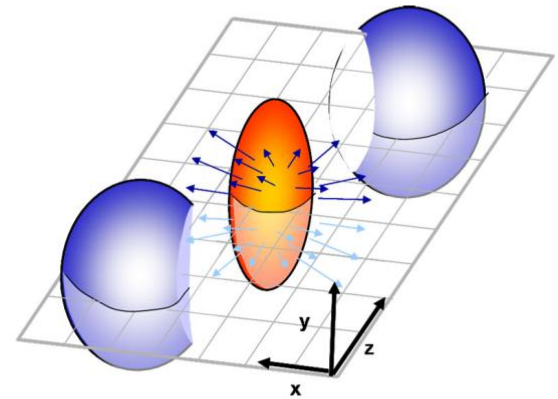


Same transport models as in previous slide

In both models, up to 50% of the low p_t J/ψ's come from regeneration

J/ψ elliptic flow parameter v_2

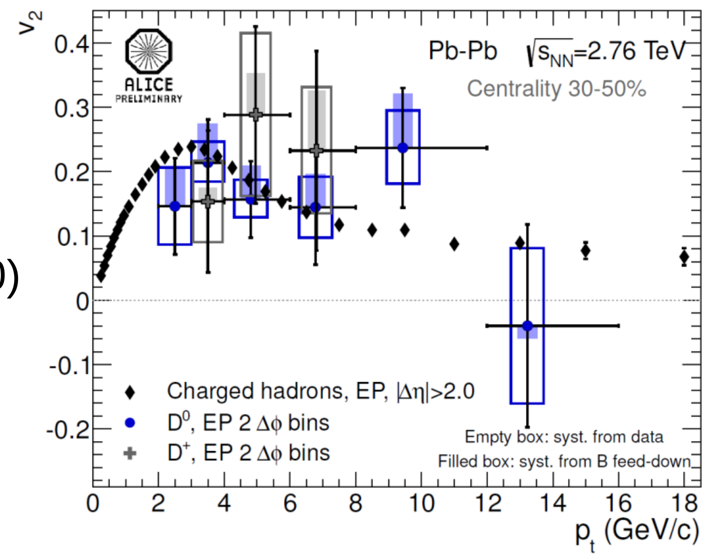
Motivation



The elliptic flow parameter v_2 characterizes the azimuthal anisotropy of particle production measured with respect to the collision reaction plane, related to the initial anisotropy of the nuclei overlapping area

Non-zero v_2 observed for charmed mesons at both RHIC and LHC, attributed to heavy quarks interaction with the medium

(See talk by Yvonne Pachmayer – 2C Tue 15:50)



The observation of a non zero J/ψ v_2 could indicate the existence of J/ψ formed out of such charm quarks, as opposed to *primordial* J/ψ's for which v_2 is expected to be zero

Analysis details

Using 2011 data set, di-muon triggered events, at forward rapidity (2.5<y<4)

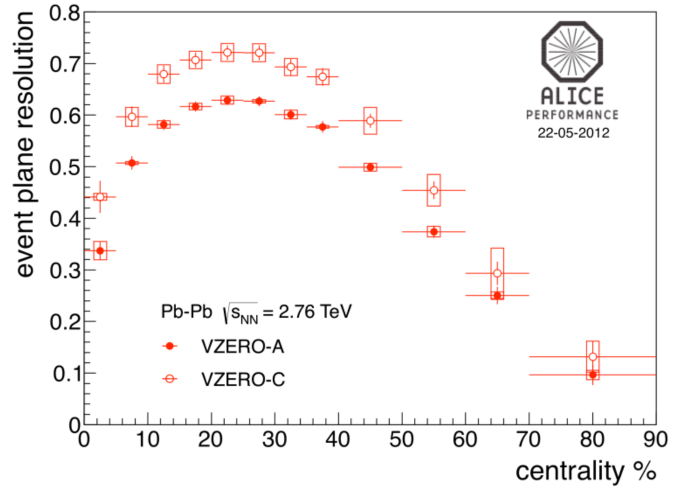
Same selection cuts and signal extraction as those used for R_{AA}

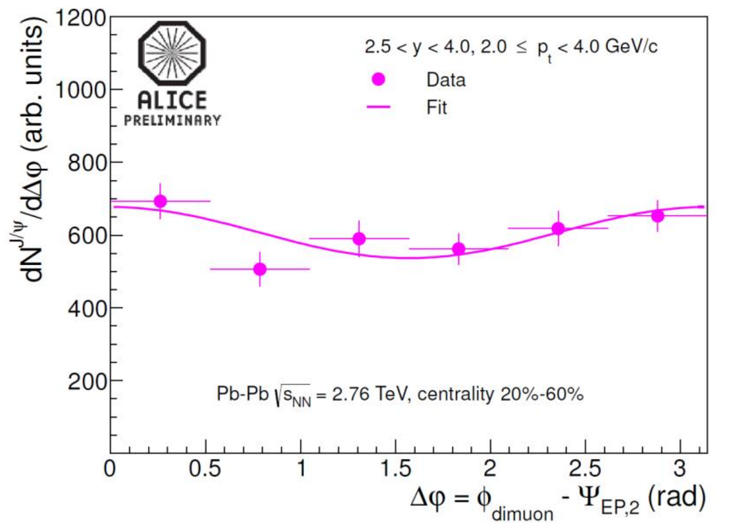
Reaction plane angle measured using VZEROA detector. Resolution evaluated using sub-events method

v_2 evaluated by measuring J/ψ in bins of ΔΦ, and fitting with:

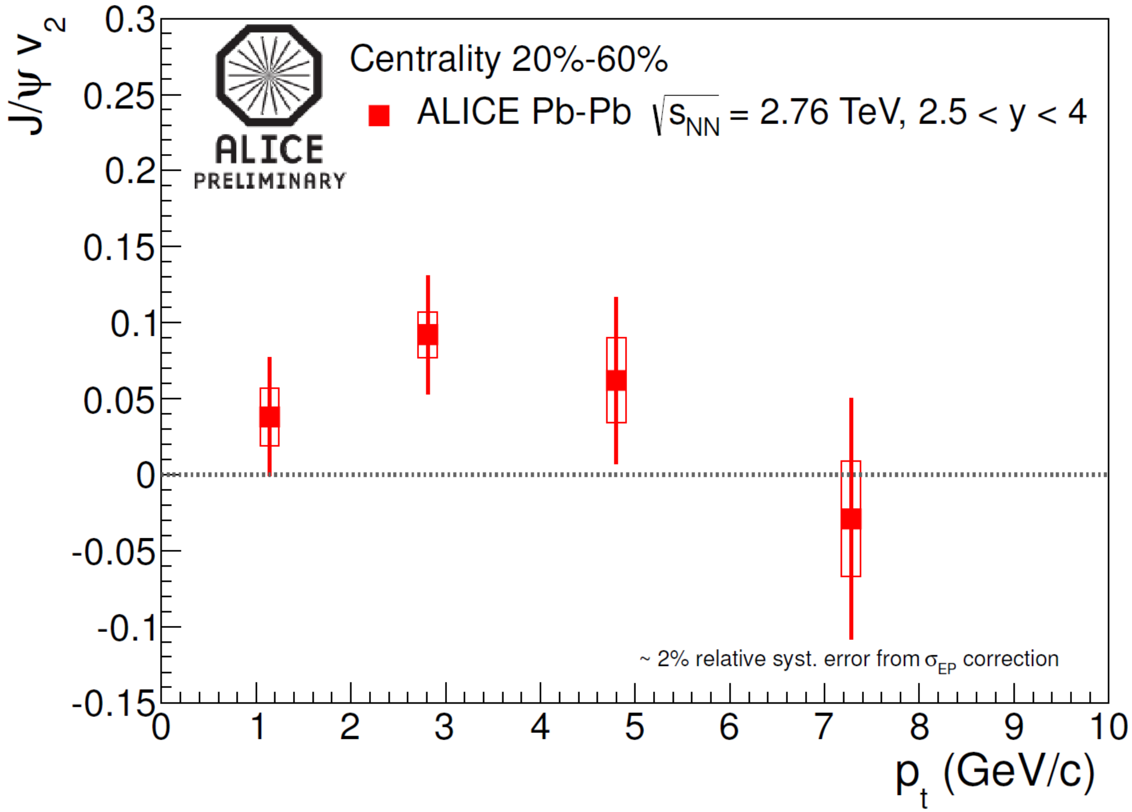
$$\frac{dN^{J/\Psi}}{d\Delta\Phi} = A\left(1 + 2v_2^{obs}\ \cos 2\Delta\Phi\right)$$

Systematic uncertainties dominated by the signal extraction





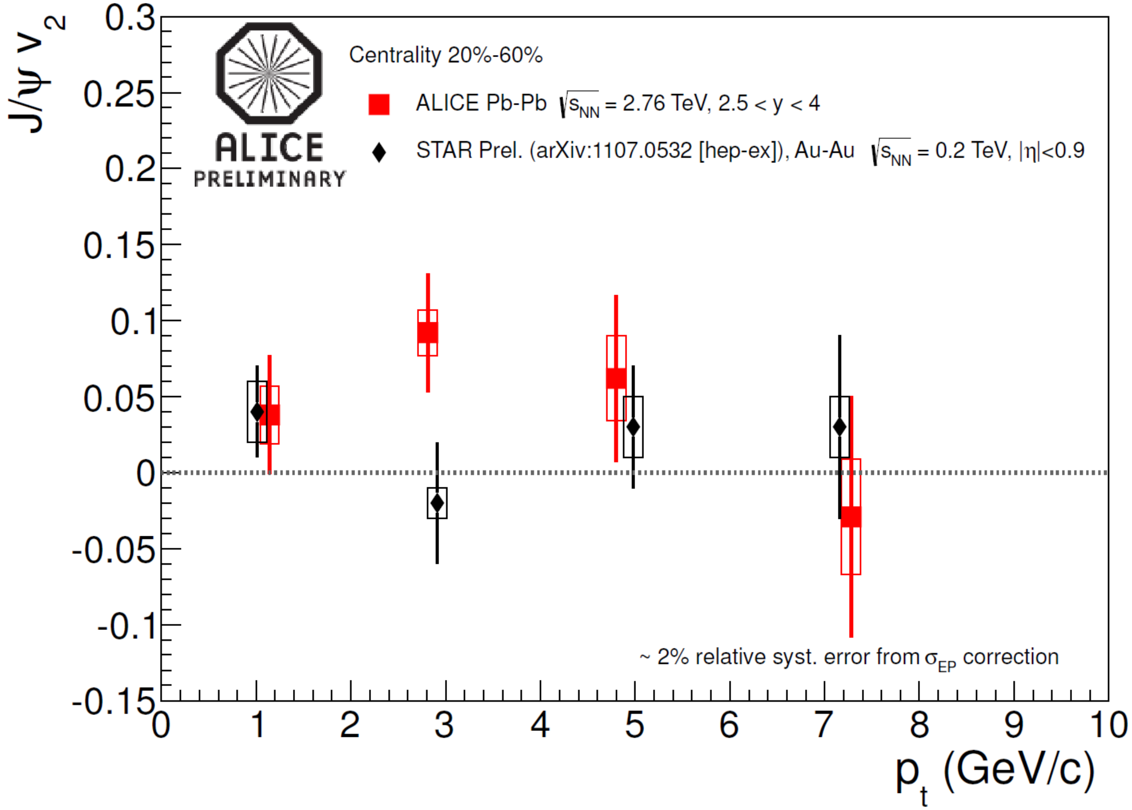
J/ψ elliptic flow parameter v_2



Hint of non-zero v_2 measured for centrality 20-60% and $2<p_t<4$ GeV/c with a significance of 2.2σ

Statistical uncertainties are dominant

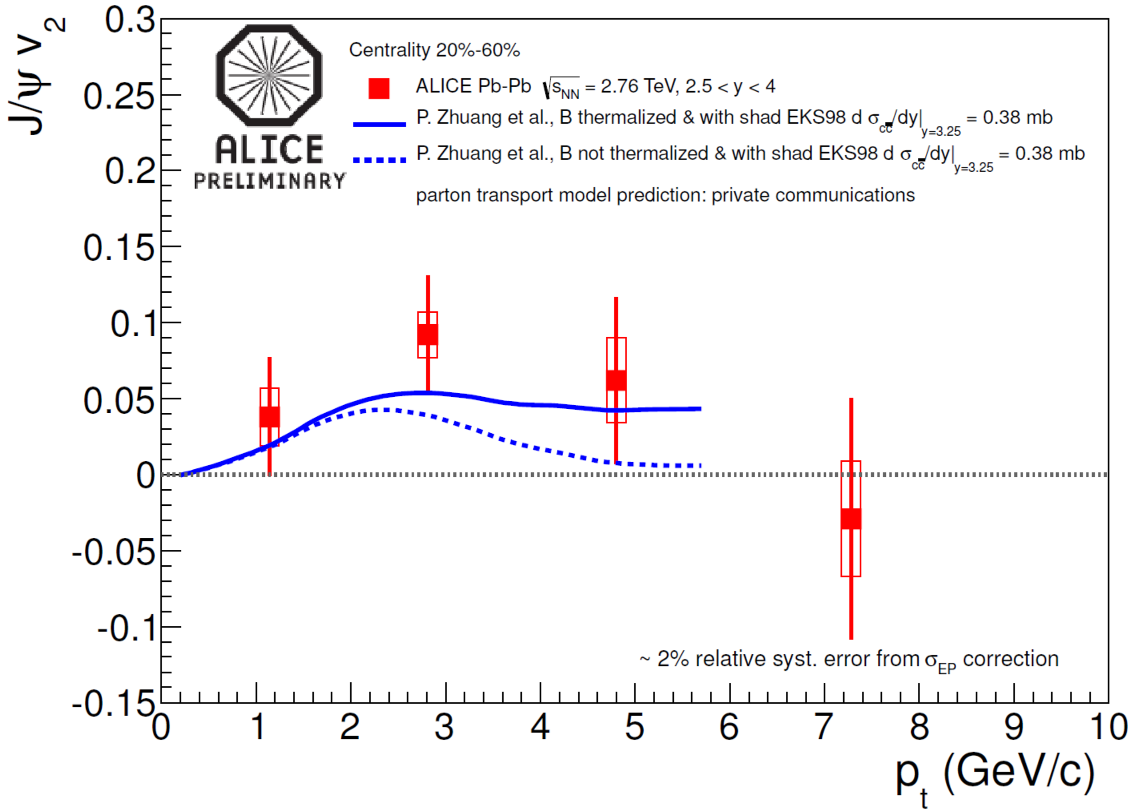
Comparison to RHIC



At RHIC, J/ψ v_2 is consistent with zero over the full p_t range

Different behavior observed between STAR and ALICE for $2<p_t<4$ GeV/c

Comparison to models



Model uses transport equation in QGP on top of shadowing effects

Also describes J/ψ R_{AA} and requires significant contribution from recombination at low p_t

Two assumptions for the contribution from b quarks (via B decay into J/ψ)

Predicts up to 5% azimuthal anisotropy, in good agreement with ALICE measurement

Conclusion and outlook

At forward rapidity, results from 2010 are confirmed with the much larger 2011 data set
The J/ψ meson is less suppressed at LHC than at RHIC
The suppression is larger at high p_t than at low p_t, in contrast to RHIC results
It is larger at more forward rapidity

Models that describe the data fairly well require the existence of J/ψ coming from the coalescence of uncorrelated charm quarks either in the QGP (up to 50% at low p_t) or at phase boundary

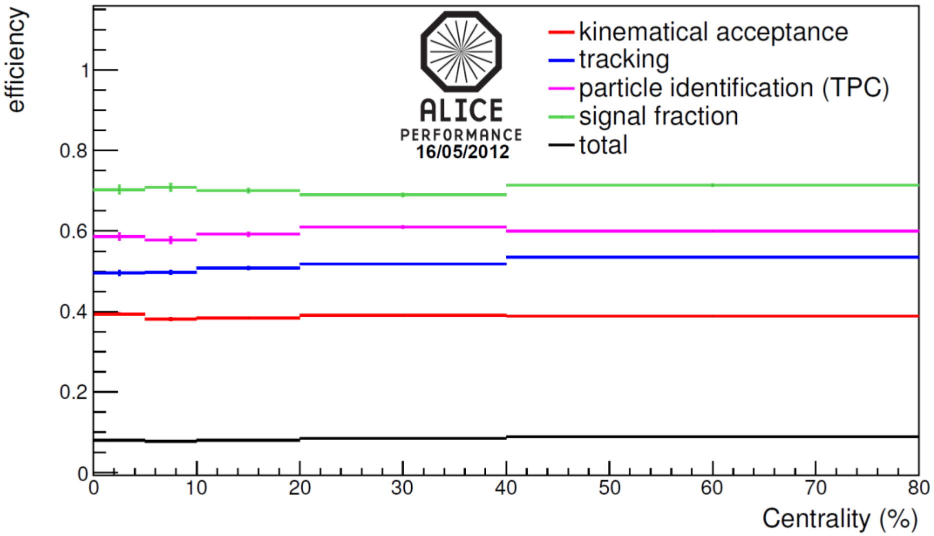
Hint of a non-zero v_2 measured for semi-central collision and $2<p_t<4$ GeV/c (2.2σ significance) is consistent with this picture

2012 p-Pb collisions will be used to assess cold nuclear effects (shadowing, initial state energy loss, etc.), in order to compare to lower energy results more quantitatively and further constrain models

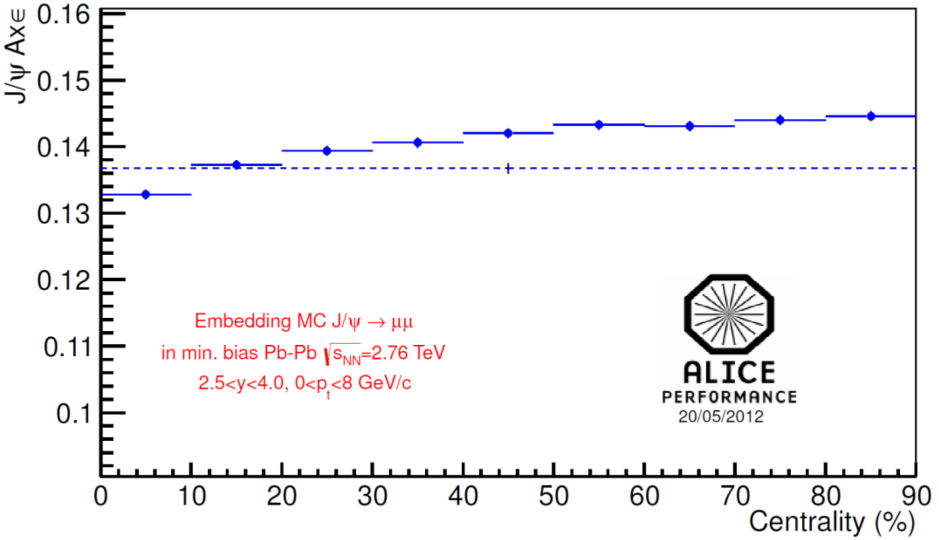
Additional material

Acceptance and efficiency corrections

mid-rapidity

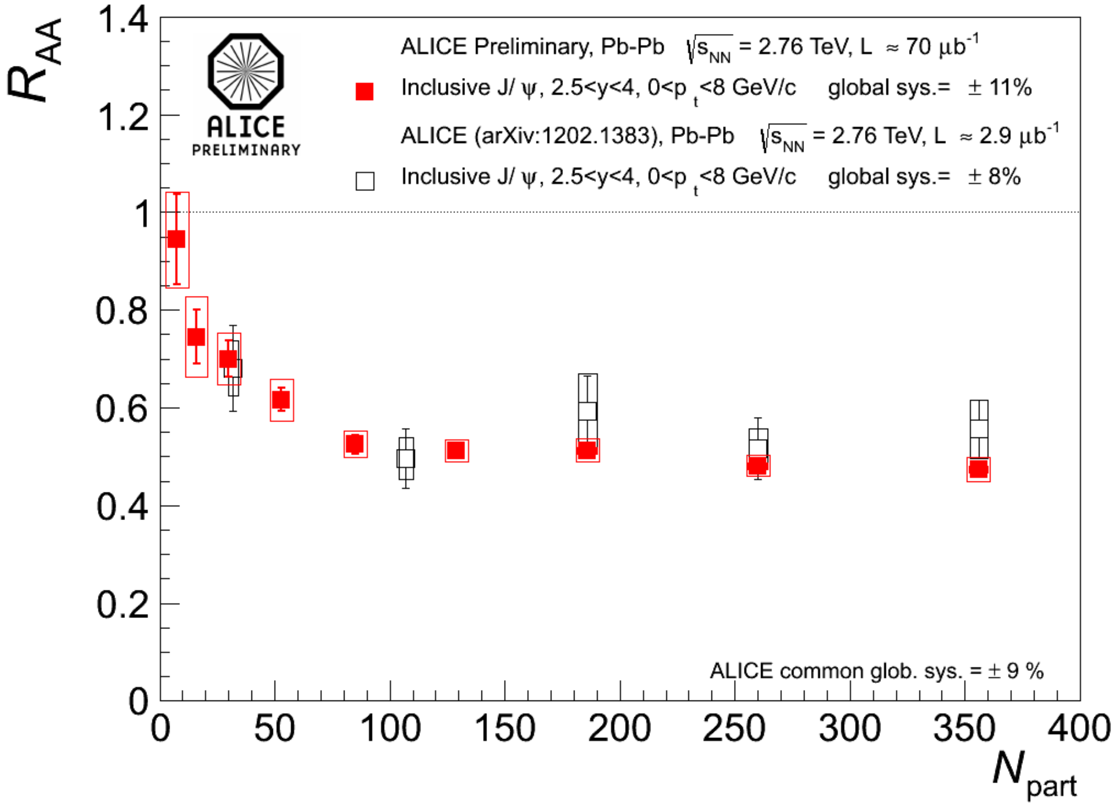


forward-rapidity



For both rapidity ranges, weak dependence of the acceptance x efficiency corrections with respect to collision centrality

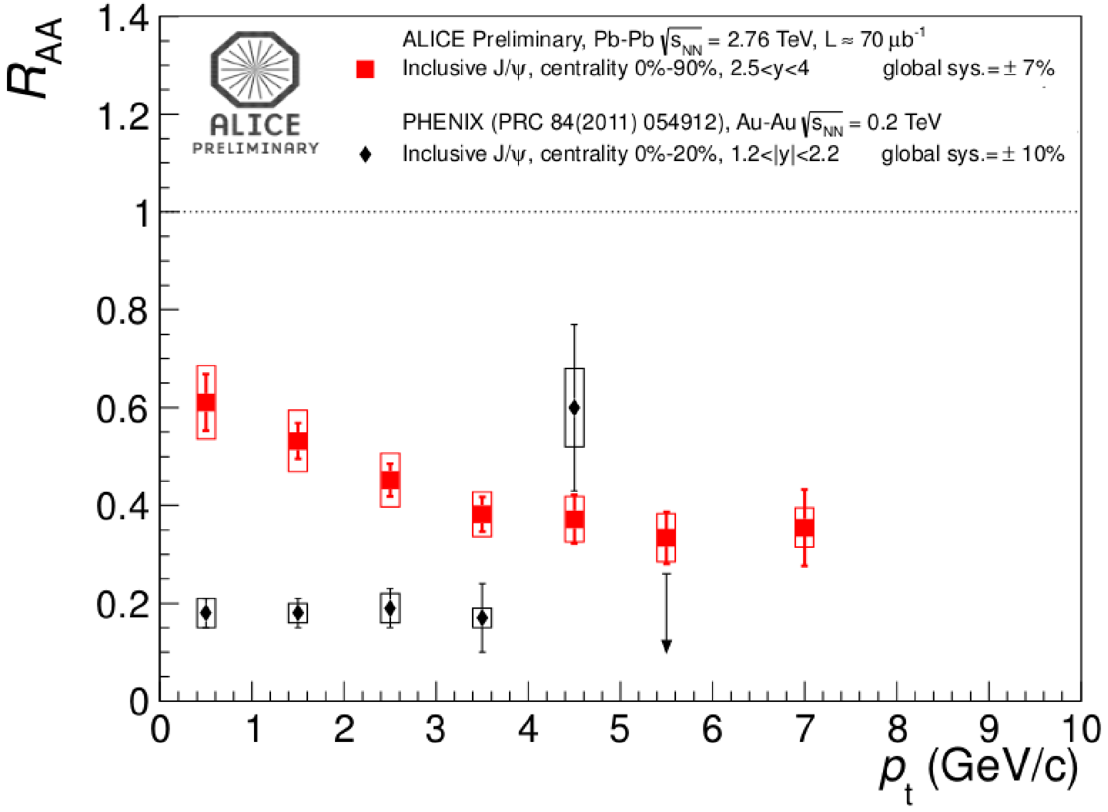
Comparison to 2010 result



Good agreement between the two measurements

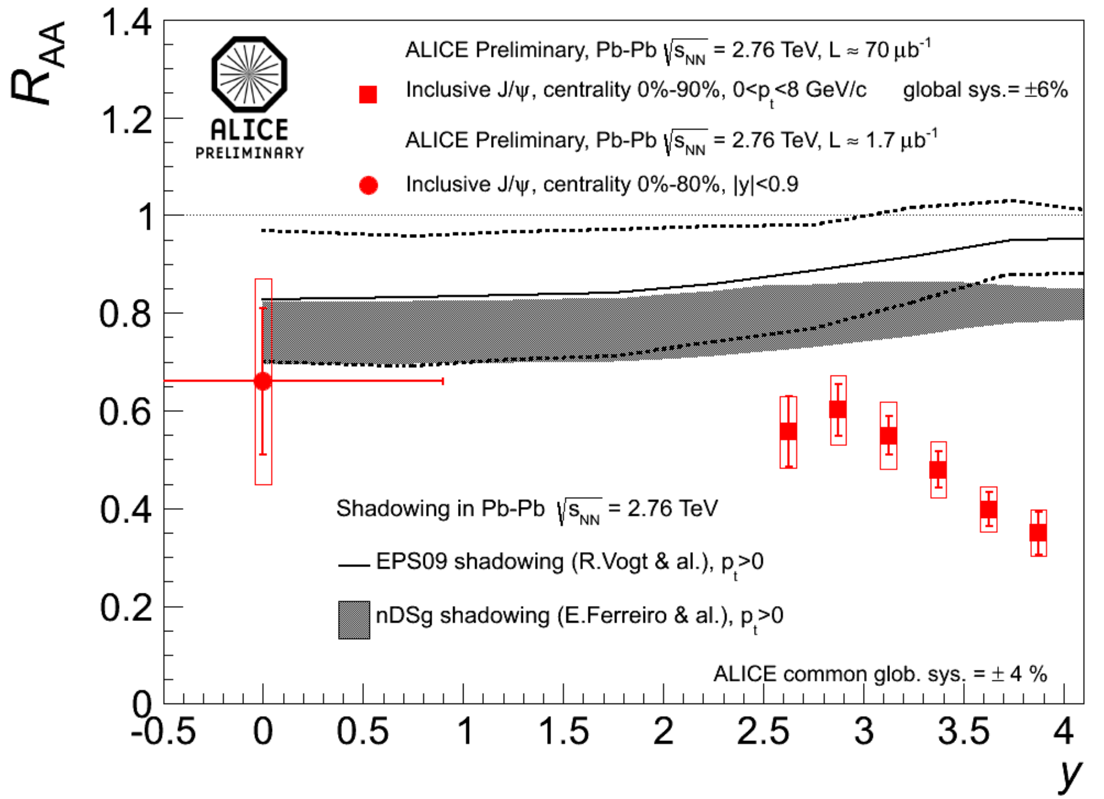
2011 data set has about 25 x more statistics than 2010

Comparison to RHIC (2) R_{AA} vs p_t



At LHC, the J/ψ suppression is larger at high p_t than at low p_t, in contrast to RHIC results

Contribution from shadowing

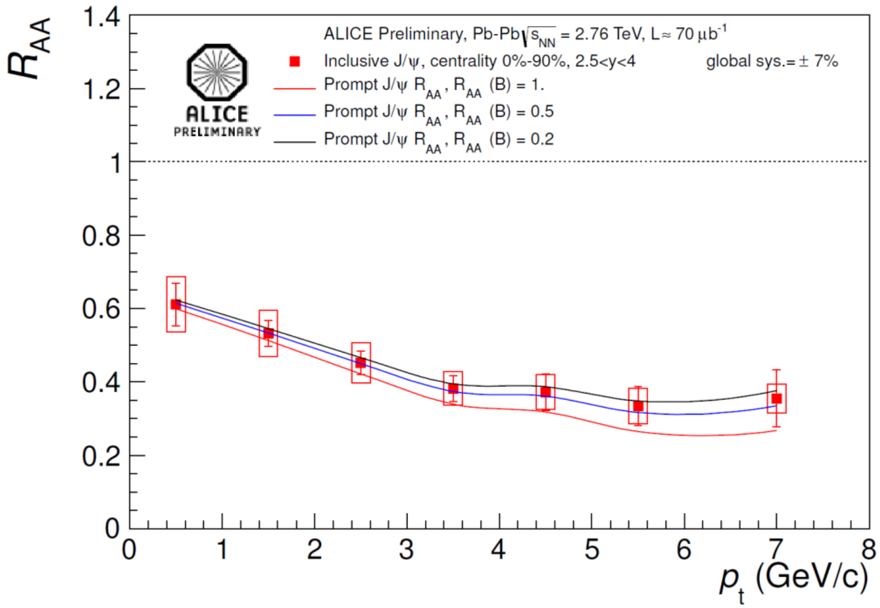


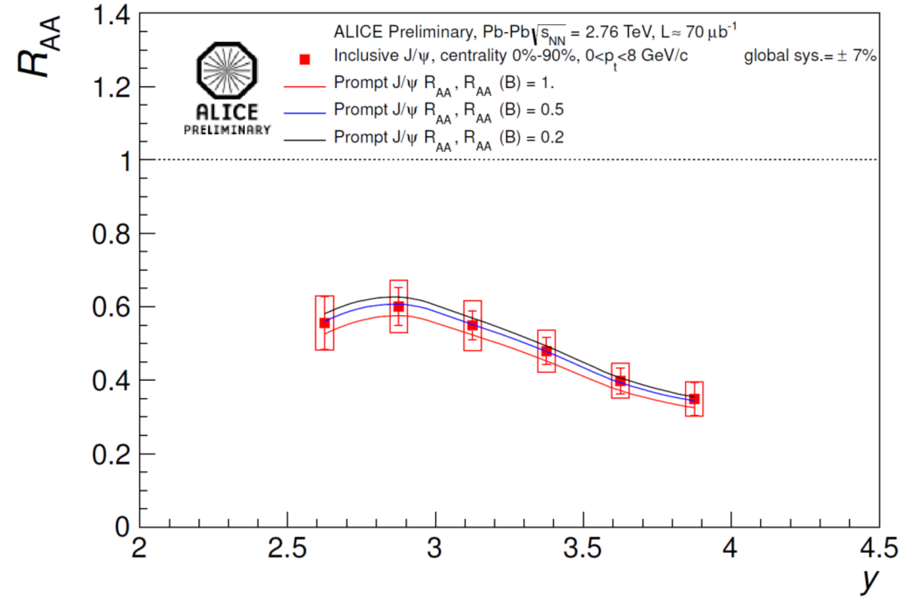
Shadowing effects estimated using 2 different sets of nuclear pdf modification

Both calculations show little dependence on rapidity, in contrast to the data

Clear suppression observed beyond shadowing for forward-rapidity J/ψ's

Contribution from B decays





Alice measures inclusive J/ψ R_{AA}
Contribution from B decay is estimated using:

- b-fraction measured by CDF, CMS and LHCb (in p-p collisions)
- Interpolation at $\sqrt{s}$=2.76 TeV
- Several b-quenching hypothesis from R_{AA}=0.2 to R_{AA}=1

→ contribution from B decay has negligible impact on measured J/ψ R_{AA}