Quarkonia and heavy flavours at forward rapidity in Pb–Pb collisions at ALICE

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on behalf of the ALICE Collaboration

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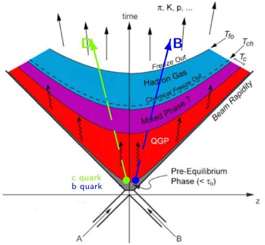
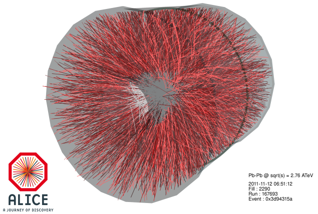
Outline

Physics motivations

Heavy quarks in heavy ion collisions

- Ultrarelativistic heavy ion collisions are the unique tool to study in laboratory the Quark Gluon Plasma, a deconfined partonic phase.
- Heavy quarks (c and b) are sensitive probes of the properties of the QGP and are abundantly produced at the LHC.
- Because of their large masses, they are created in hard scattering processes during the early stage of the collision and subsequently interact with the hot and dense medium.





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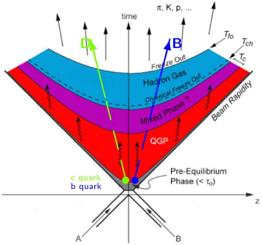
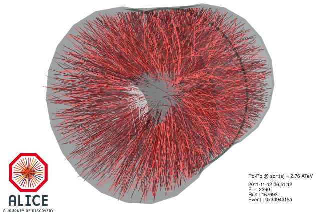
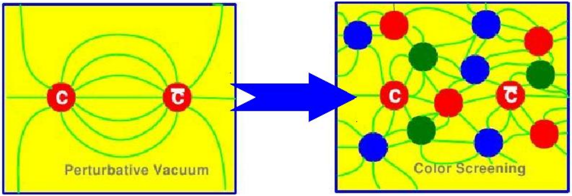




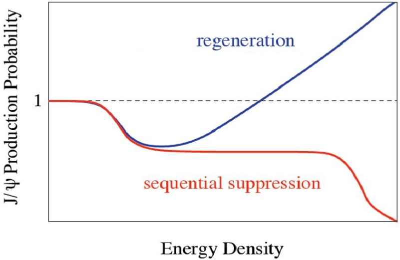
Quarkonia in AA collisions

- Quarkonia play a key role in the study of QGP because:
  - they are created in the early stage of the collision,
  - their production is expected to be modified by the plasma,
  - having different radii ($\rightarrow$ different binding energies) a sequential suppression is expected as a function of the energy density (T. Matsui and H. Satz, Phys. Lett. B 178 (1986)).



Quarkonia in AA collisions

- Two different scenarios at LHC are possible:
  - new energy regime → higher suppression with respect to RHIC,
  - higher $c\bar{c}$ recombination probability → regeneration effects (P.Braun-Munzinger et al., Phys. Lett. B 490 (2000); R.L.Thews et al., Phys. Rev. C 63 (2001) 054905).



Heavy flavours in AA collisions

- As for quarkonia, heavy quarks are produced in the early stage of the collision and can probe the medium evolution.
- The parton energy loss in the medium is due to elastic collisions and gluon radiation.
- The gluon radiation depends on:
  - medium properties and size,
  - parton colour charge (Casimir factor),
  - parton mass (dead cone effect) (Y.L. Dokshitzer et al., Phys. Lett. B 519 (2001)).
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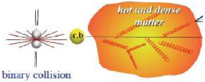

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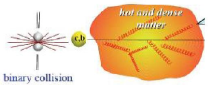

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Nuclear modification factor

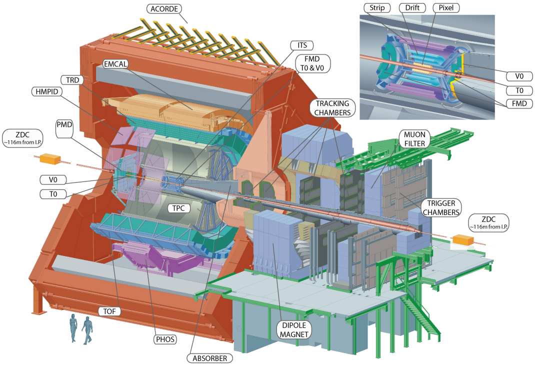
- The nuclear modification factor (R_{AA}) is the observable that allows to estimate the relative production of quarkonia or muons from HF in Pb–Pb collisions with respect to pp.

$$\boxed{R_{\mathrm{AA}} = \frac{1}{\langle T_{\mathrm{AA}} \rangle} \cdot \frac{Y_{\mathrm{AA}}}{\sigma_{\mathrm{pp}}}}$$

- Where:
  - Y_{AA} = yield in AA collisions (i.e. $\mathrm{d}N_{\mathrm{AA}}/\mathrm{d}y$, $\mathrm{d}N_{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}$...),
  - σ_{pp} = corresponding cross section in pp collisions at the same energy,
  - T_{AA} = nuclear overlap function (from Glauber model).

The ALICE experiment

A Large Ion Collider Experiment



- Muon spectrometer:
  - $-4 < \eta < -2.5$,
  - quarkonia and heavy flavours reconstructed in the (di)muon channel,
  - muon trigger based on transverse momentum.
- ITS (mainly SPD):
  - MB trigger,
  - interaction vertex reconstruction.
- VZERO:
  - MB trigger,
  - centrality determination based on Glauber model.

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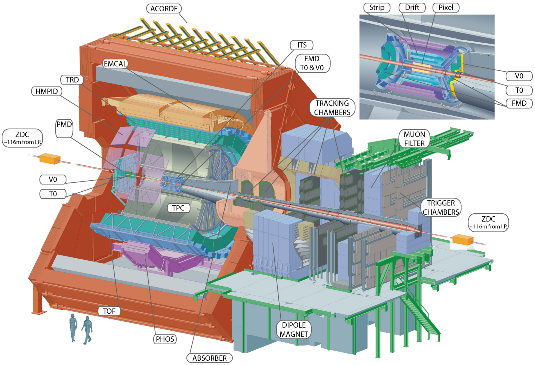

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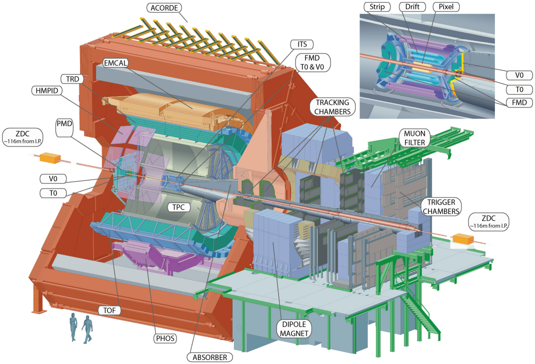

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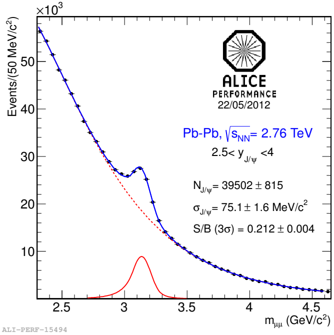
Quarkonia

Experimental data set and pp reference

- J/ψ signal extraction in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV:
  - 17.7×10^7 muon triggered events ($\sim70\ \mu b^{-1}$, $p_{\rm T}^{\mu} > 1$ GeV/c),
  - signal fitted with an extended Crystal Ball function and background subtracted with the event mixing technique,
  - $A \times \varepsilon$ values obtained by embedding MC J/ψ into real events.
- pp reference at $\sqrt{s} = 2.76$ TeV:
  - 8.8×10^6 muon triggered events ($\sim19.9\ \mu b^{-1}$, $p_{\rm T}^{\mu} > 0.5$ GeV/c),
  - at forward rapidity NRQCD describes well the J/ψ differential cross section (ALICE Collaboration, Phys. Lett. B, 718 (2012) 295).



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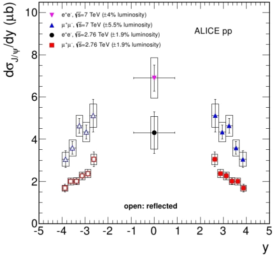
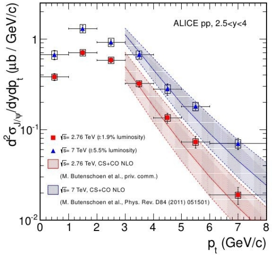
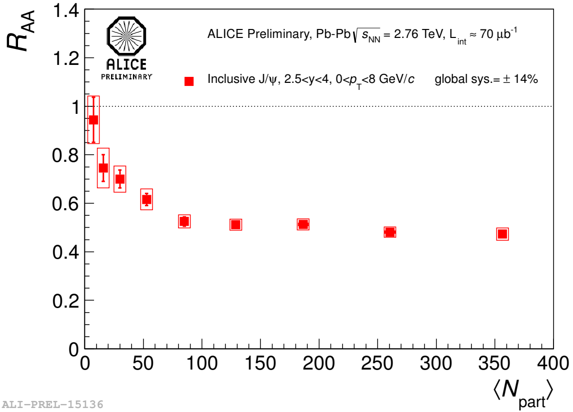




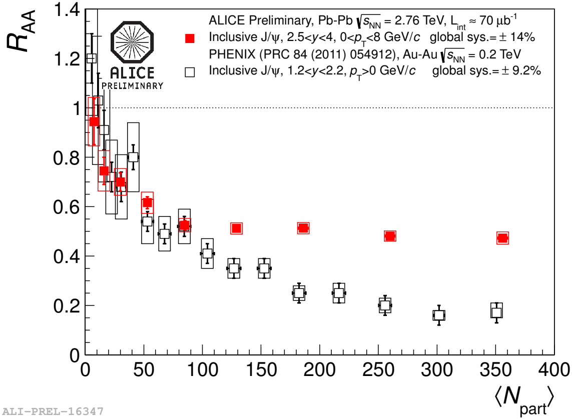
See Lizardo's talk for more details.

J/ψ R_{AA} vs centrality



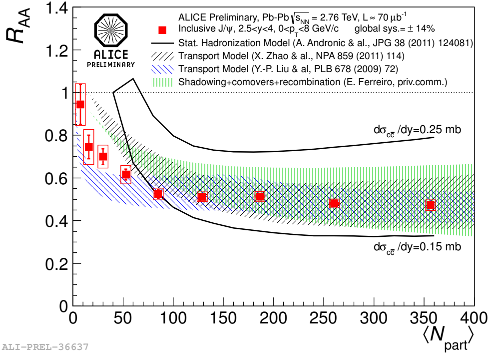
- No centrality dependence for $N_{\mathrm{part}} > 70$.

J/ψ R_{AA} vs centrality



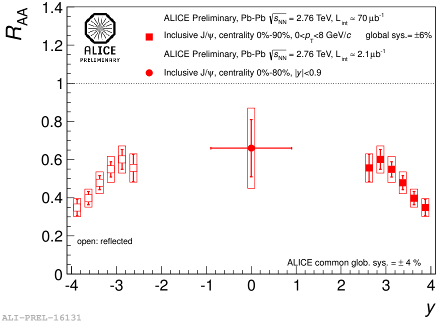
- $R_{AA}^{\mathrm{ALICE}} \sim 3 \times R_{AA}^{\mathrm{PHENIX}}$ for $\mathrm{N_{part}} > 200$.

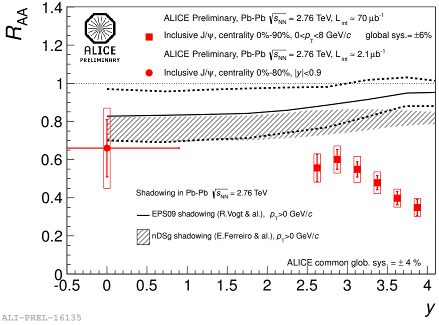
J/ψ R_{AA} vs centrality



- Comparison with different theoretical predictions:
  - Statistical Hadronization Model: prediction for two values of $d\sigma_{c\bar{c}}/dy$,
  - Transport Models: different rates of J/ψ dissociation and regeneration; in both cases more than 50% of measured yield in the most central collisions is due to J/ψ regeneration,
  - green band: includes shadowing, comovers and recombination.

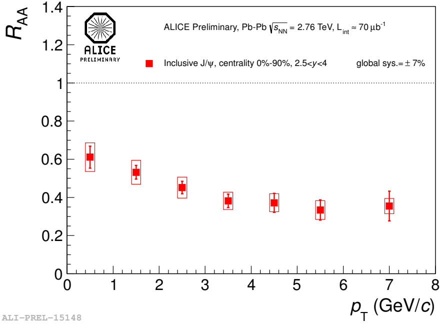
J/ψ R_{AA} vs y

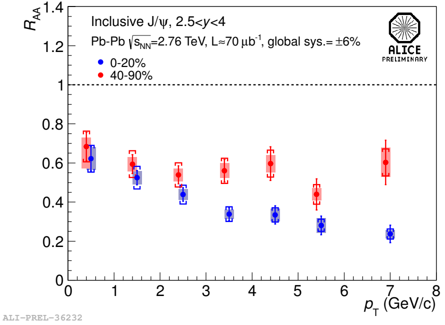




- Data at midrapidity obtained in the dielectron decay channel.
- R_{AA} decreases by 40% from $y = 2.5$ to $y = 4$.
- J/ψ less suppressed if shadowing calculations are considered. Cold nuclear matter effects need to be quantified (possible with pA collisions).

J/ψ R_{AA} vs p_T





- Stronger suppression at high-p_T (mostly for central collisions).
- Good agreement with Transport Models for most central collisions.
- Discrepancy at low-p_T for peripheral collisions.
- Indication of regeneration at low-p_T (at least for central collisions).

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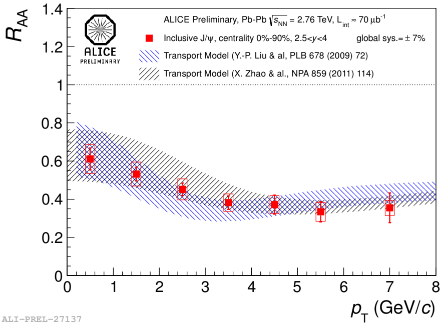

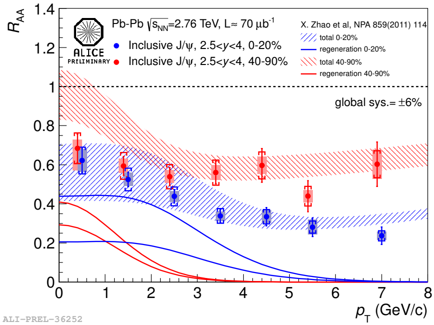

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Muons from heavy-flavour decays

Experimental data set and pp reference

- Signal extraction in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV:
  - 16.6×10^6 MB events ($\sim$2.7 μb^{-1}),
  - background ($\mu \leftarrow \pi, K$) subtracted extrapolating the distribution from midrapidity to forward rapidity (assuming the same suppression).

- pp reference at $\sqrt{s} = 2.76$ TeV:
  - $\mathrm{d}\sigma/\mathrm{d}p_{\rm T}$ well described within uncertainties by FONLL pQCD calculations (ALICE Collaboration, PRL 109, 112301 (2012)),
  - see Lizardo's talk for more details.

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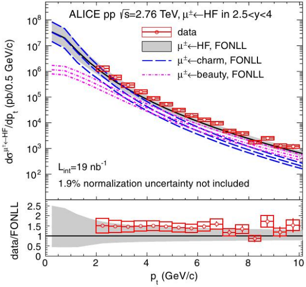
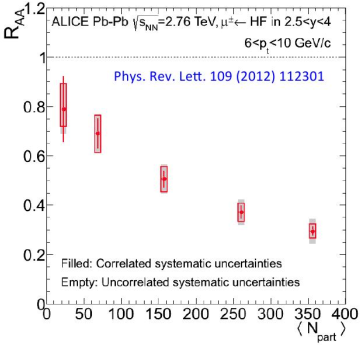


R_{AA} vs centrality



- The R_{AA} of muons from heavy-flavour decays at forward rapidity in high-p_T range (> 6 GeV/c) exhibits a strong suppression with increasing centrality, up to a factor 3÷4 in the most central collisions.
- In this p_T range results are dominated by beauty contribution, according to FONLL calculations in pp collisions.

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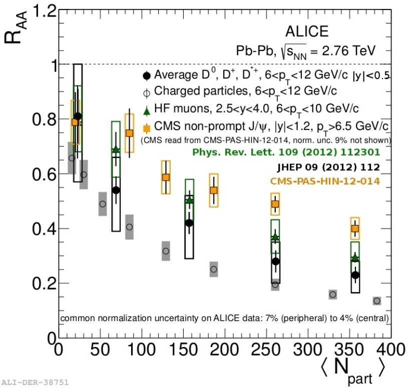
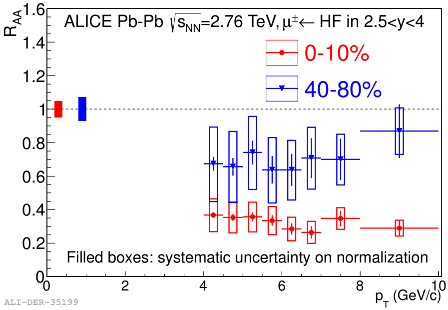


- Prompt D mesons ($|y| < 0.5$), non-prompt J/ψ from beauty decays ($|y| < 1.2$, by CMS) and muons from HF ($2.5 < y < 4$) show a similar centrality trend at high-p_T.
- Hints for $R_{AA}^{u,d} < R_{AA}^{c} < R_{AA}^{b}$. Anyway, due to the large uncertainties and the different y and p_T regions it is difficult to make a clear conclusion.

R_{AA} vs p_{T}



- A larger suppression is observed in central collisions as compared to peripheral ones, with no significant p_{T} dependence within uncertainties ($4 < p_{\mathrm{T}} < 10$ GeV/c).
- Similar R_{AA} for electrons from HF and for D mesons in central collisions ($p_{\mathrm{T}}^{e} \sim 0.5 \cdot p_{\mathrm{T}}^{D}$ at high p_T), though in a different kinematic region.

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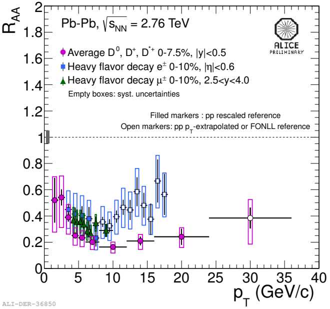

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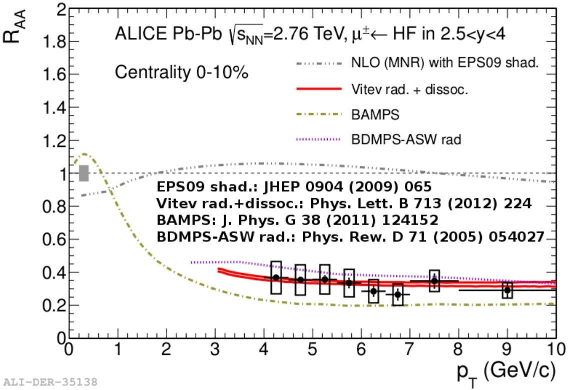

- Models implementing radiative energy loss (BDMPS-ASW) and radiation + dissociation (Vitev) reproduce well the trend.
- The small contribution of shadowing alone (cold nuclear matter effect) cannot explain the suppression. To be checked in 2013 p–Pb data (analysis in progress).

Conclusions

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