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Measurements of quarkonium production in p-Pb and Pb-Pb collisions with ALICE at the LHC

G. G. FRONZÉ(1)(2)(3) for the ALICE COLLABORATION

(1) *INFN, Sezione di Torino - Torino, Italy*
(2) *Dipartimento di Fisica, Università di Torino - Torino, Italy*
(3) *Subatech, IMT-Atlantique - Nantes, France*

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Summary. — ALICE (A Large Ion Collider Experiment) is devoted to the study of heavy-ion collisions at LHC energies. In such collisions, a deconfined state of hadronic matter, the Quark-Gluon Plasma (QGP), is formed. Quarkonium states are important probes to study the QGP evolution since their formation happens early during the collision and their production rate is modified in the interaction with the medium. The latest ALICE results on quarkonium production in Pb-Pb and p-Pb collisions will be presented and discussed.

1. – Motivations to study quarkonium production

Colour screening effects and (re)generation phenomena are mechanisms affecting quarkonium production in ultra-relativistic heavy-ion collisions, where a Quark-Gluon Plasma (QGP) is created [1-3]. While the presence of free colour charges weakens the nuclear potential between quarks (Debye screening) and melts bound states leading to a suppression effect, it is foreseen that the abundance of heavy quarks at LHC energies enhances the statistical (re)generation during the QGP evolution or at the phase boundary. Charmonia and bottomonia (bound states of $c\bar{c}$ and $b\bar{b}$ quarks) are studied in ALICE through their decay into pairs of electrons or muons, at mid and forward rapidities respectively. The study of bottomonium is complementary to the study of charmonium states since a lower production of heavier quarks is expected to limit (re)generation effects. The modification of quarkonium production yields in heavy-ion collisions, with respect to pp collisions, is evaluated through the nuclear modification factor R_{AA}. ALICE is capable of studying qurkonium production in pp and p-Pb collisions too. The pp collisions allow one to measure the reference quarkonium cross section, while p-Pb collisions provide a reference on Cold Nuclear Matter effects (CNM) affecting quarkonia production without the presence of QGP. ALICE is composed of two groups of detectors. The central barrel is placed in a solenoidal magnet and surrounds the interaction point, while the muon spectrometer extends at high rapidities and is optimized for the reconstruction and identification of forward-emitted muons. For a detailed description refer to [4, 5].

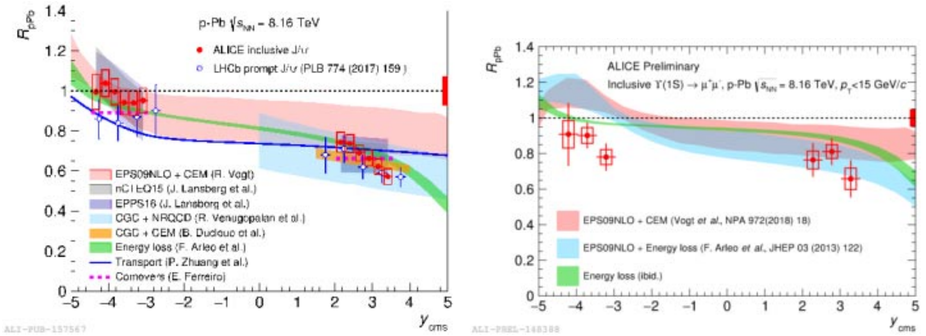

Fig. 1. – Left: J/ψ R_{AA} measured as a function of rapidity in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV compared to theoretical models. Right: Υ R_{AA} measured as a function of rapidity in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV compared to model calculations.

2. – p-Pb collisions

In p-Pb collisions, ALICE is able to study the quarkonium production in the muon decay channel in the ranges $-4.46 < y_{\mathrm{cms}} < -2.96$ and $2.03 < y_{\mathrm{cms}} < 3.53$. Previous results at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV showed a nuclear modification factor compatible with no suppression at negative rapidity for J/ψ [6]. A clear suppression of the J/ψ was observed at forward rapidity. From the differential study over transverse momentum (p_{T}) it is clear that the suppression is focused in the lower p_{T} region. The latest results at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV present a similar trend [7]. Compatibility has been found comparing J/ψ data at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and 8.16 TeV, showing no clear energy dependence (Fig.1). From the comparison of J/ψ measurements at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV with models, a good agreement with predictions including energy loss and nuclear modification of PDFs has been found [7]. Preliminary measurements of $\Upsilon(1S)$ production at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV show a similar modification as for J/ψ. The $\Upsilon(1S)$ production at forward rapidity presents good agreement with models including energy loss and nuclear modification of PDFs, while at backward rapidity some tension is present.

3. – Pb-Pb collisions

From the comparison of ALICE and PHENIX data, collected in Pb-Pb at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV and Au-Au at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV respectively, low-p_{T} J/ψ production is less suppressed at LHC than at RHIC energies at mid and forward rapidities in the most central collisions [8, 9]. The ALICE data at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV show compatibility with data at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV, even if the higher energy measurements are systematically above the lower energy ones. Good agreement can be observed between data and models which include a (re)generation component [10]. Measurements of Υ production at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and $-4.0 < y < -2.5$ are compatible with measurements at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV within uncertainties [11]. At both energies a clear suppression over all centrality classes is observed (Fig.2). As already observed for J/ψ production, the higher energy measurements are systematically above the lower energy ones. A good agreement can be found between data and models both including or not (re)generation, as can be seen in Fig. 2.

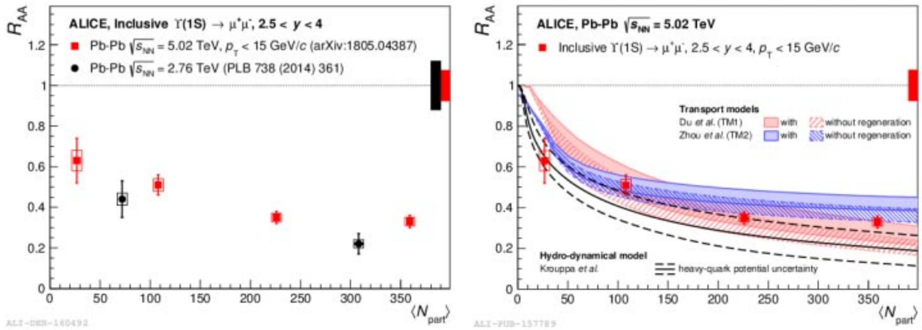

Fig. 2. – Left: Υ $R_{\rm AA}$ measured in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV and 5.02 TeV as a function of the number of participant nucleons ($\langle N_{part}\rangle$), taken as centrality estimation, and compared to theoretical calculations. Right: $R_{\rm AA}$ of inclusive Υ(1S) in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV as a function of $\langle N_{part}\rangle$ compared with transport and hydrodynamic theoretical models.

4. – Conclusions

ALICE measurements of J/ψ and Υ production in p-Pb show agreement with theoretical models based on CNM effects. J/ψ production in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV and 8.16 TeV is in good agreement with theoretical models calculations including (re)generation. Measurement of Υ production at $\sqrt{s_{\rm NN}}$ = 5.02 TeV presents a clear suppression with respect to pp. The Υ measurements can also be used as a cross-check of models including or not (re)generation effects [11], even if the present uncertainties are not small enough to discriminate between proposed models.

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