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Study of J/ψ production at central rapidity with the ALICE experiment at LHC

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We summarize the status of the ongoing analysis on J/ψ production at central rapidity in pp collisions at $\sqrt{s}$=7 TeV. We also give perspectives on the first quarkonium measurements at central rapidity in Pb–Pb collisions.

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1. Introduction

Proton-proton collisions at $\sqrt{s} = 7$ TeV have been recorded by ALICE (A Large Ion Collider Experiment) at the Large Hadron Collider (LHC) at CERN[1]. Hadron collisions at these energies provide an opportunity to probe quantum chromodynamics (QCD) under extreme conditions. In particular, the hadroproduction of heavy quarkonium states is a process where QCD is involved in both perturbative and non-perturbative aspects. Various models [2, 3] have been proposed to describe the results obtained at the Tevatron [4, 5] and RHIC [6] colliders, but they fail to reproduce simultaneously the production cross sections, the transverse momentum distributions and the measured polarization, and their rapidity dependence.

Charmonia and bottomonia production measurements in proton-proton collisions at the LHC energies will also provide the necessary baseline for the study of their production in nucleus-nucleus collisions at similar energies. Heavy quarkonia have been considered as key observables to study the properties of the medium created in ultrarelativistic heavy-ion collisions since the very beginning of this field, when it was suggested [7] that J/ψ suppression is an unambiguous signature for the formation of a deconfined plasma of quarks and gluons (QGP). A suppression of the charmonium yield beyond expectations from a pure nuclear absorption scenario has been indeed observed both at SPS and RHIC energies (see, e.g., references [8, 9, 10]). However, it is now recognized that in order to interpret J/ψ production as a QGP probe one has to consider cold nuclear matter effects such as initial state energy loss [11] and shadowing [12], as well as charm quark energy loss [13], co-mover interactions [14], corrections for feed-down from higher mass charmonium states, and secondary production mechanisms, such as recombination of initially uncorrelated $c\bar{c}$ pairs [15].

Charmonia and bottomonia states are measured in the ALICE experiment at central rapidity and forward rapidity through their e^+e^- and $\mu^+\mu^-$ decays, respectively. In this contribution we focus on the analysis of J/ψ's produced at central rapidity, the ongoing dimuon analysis at forward rapidity being discussed in [16]. We also give the perspectives on the measurements in the first LHC Pb–Pb run.

2. Proton-proton collisions at $\sqrt{s} = 7$ TeV

The ALICE apparatus [1] consists of a central barrel ($|\eta| < 1$), located in a large solenoidal magnet, providing a magnetic field of 0.5 T. The barrel detectors can track particles down to p_{T} of about 100 MeV/c, and provide particle identification over a wide momentum range. The set-up includes a muon spectrometer, covering the pseudo-rapidity interval $2.5 < \eta < 4$, and detecting muons having p >4 GeV/c. The barrel detectors which have been used in this analysis are the Inner Tracking System (ITS) and the Time Projection Chamber (TPC). The main task of the ITS [1], which consists of six cylindrical layers of silicon detectors with radii between 3.9 cm and 43.0 cm and covering the pseudo-rapidity range $|\eta| < 0.9$, is to provide precise track and vertex reconstruction close to the interaction point and to improve the overall momentum resolution. The TPC [17], which is a large cylindrical drift detector with an active volume extending to $85 < r < 247$ cm and $-250 < z < 250$ cm in the radial and longitudinal directions, respectively, is the main tracking detector of the central barrel and it also provides very good particle identification (PID) via spe-

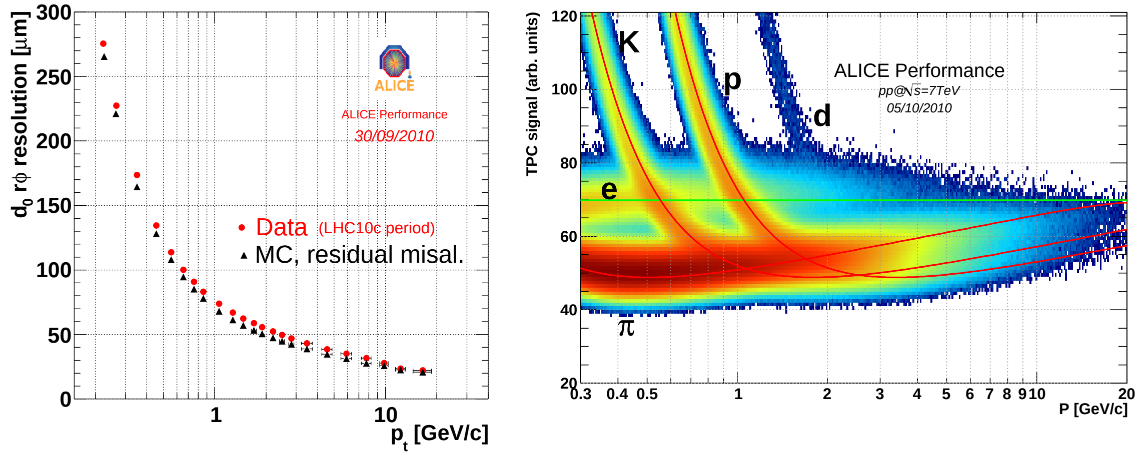

Figure 1: Left panel: transverse impact parameter resolution estimate versus p_{T}, obtained for TPC track which have been refitted in the ITS. Right panel: specific energy loss dE/dx vs. momentum for tracks measured with the ALICE TPC. The solid lines are a parameterisation of the Bethe-Bloch curve.

cific energy loss (dE/dx) measurement with a resolution of $\sigma = 5.5\%$. Both detectors have been calibrated and aligned and the observed performances are very close to the nominal figures. As examples, in the left panel of figure 1 the resolution on the transverse impact parameter (IP) of charged track, i.e. the distance of closest approach of the back-extrapolated track trajectory to the primary vertex, are compared to Monte Carlo simulation as a function of the track p_{T}. Thanks to the excellent IP resolution we will be able to separate the contribution of J/ψ coming from beauty hadron decays. In the right panel, the specific energy loss dE/dx versus the particle momentum measured in the TPC is shown. The PID performance of TPC is the crucial asset for this analysis: we employ a $\pm 3\sigma$ inclusion cut for electrons and a $\pm 3\sigma$ exclusion for pions and protons.

The electron identification capabilities can significantly benefit from the use of the ALICE time of flight (TOF) and transition radiation (TRD) detectors, for rejecting, respectively, the contamination of protons and kaons, and that of pions. In figure 2 the dependence of the particle velocity measured by TOF on the particle momentum is shown (left panel). The distribution of the TPC dE/dx signal (in unit of resolution) relative to the electron Bethe-Bloch line for 2 GeV/c tracks, is shown in the right panel of figure 2 with and without electron tagging in the TRD. The usage of these detectors will be introduced in the analysis soon.

In this preliminary analysis a sample of 105×10^6 events selected with a minimum bias trigger [18] has been used. Besides the TPC PID cuts discussed above, the tracks are required to have a minimum p_{T} of 1.0 GeV/c, a minimum number of TPC clusters per track of 90 and to point back to the interaction vertex within 1 cm in the transverse plane. A hit in the innermost ITS layers is also required in order to reject electrons from γ conversions. The invariant mass distributions for like-sign (LS) and opposite sign (OS) electron pairs are shown in figure 1. The signal, obtained by subtracting the two distributions, is shown in comparison with the signal from Monte Carlo (MC) simulations. We obtain $N_{\mathrm{J}/\psi} = 123 \pm 16$ candidates and a mass resolution of about 50 MeV/c^2.

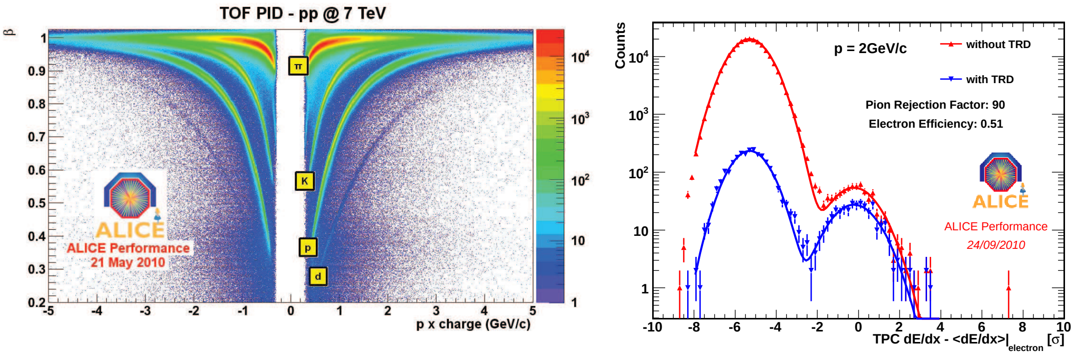

Figure 2: Left panel: dependence of the particle velocity measured by TOF on the particle momentum time particle charge sign. Right panel: distribution of the difference (in unit of resolution) between the TPC dE/dx signal and the electron Bethe-Bloch line for particle with $p = 2$ GeV/c, with and without electron tagging in the TRD.

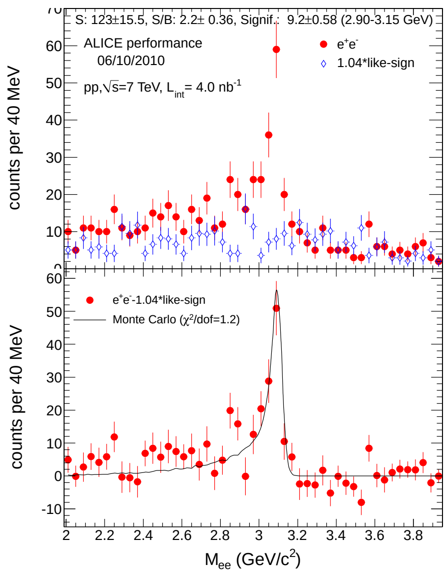

Figure 3: Top panel: invariant mass distributions for like-sign (LS) and opposite sign (OS) electron pairs. Bottom panel: the difference of the two distributions with superimposed Monte Carlo (MC) signal.

2.1 B-hadrons decays

When measuring J/ψ production at the LHC, a significant fraction of the measured yield comes from b-hadron decays. This J/ψ source is a very interesting physics signal for the evaluation of beauty production cross section, nicely complementing measurements performed via single leptons. Complementary, the contribution from b-hadron decays has to be subtracted from the messured J/ψ yeld, to get the prompt J/ψ production cross section. The vertex resolution of the ITS (see figure 1) is good enough to measure the yield of J/ψ produced in secondary vertices. The signed projection of the flight distance of J/ψ on its transverse momentum, $L_{xy} = \vec{L} \cdot \vec{p}_{\mathrm{T}}(J/\psi)/|p_{\mathrm{T}}|$, is a good measurement of the separation from the main vertex. To reduce the dependence on the J/ψ transverse momentum distribution, the variable x is used instead of L_{xy}, $x = L_{xy} \cdot M(J/\psi)/p_{\mathrm{T}}$, where

$M(J/\psi)$ is taken as the known J/ψ mass. Studies based on Monte Carlo simulation have shown that the fractions of secondary J/ψ as a function of p_{T} can be extracted by a likelihood fit to the di-electron invariant mass and the x variable defined above with uncertainties of about 10%. This approach will provide a measurement of the beauty p_{T}-differential cross section down to $p_{\mathrm{T}} \approx 0$.

3. Prospects for the first Pb-Pb run

The first Pb–Pb run at LHC will be performed at a luminosity of about $10^{25}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, i.e. reduced by 2 orders of magnitude below the nominal LHC luminosity for Pb–Pb. Therefore, the expected data sample would amount to few $\mu\mathrm{b}^{-1}$. With such statistics, assuming i) that the J/ψ production scales with the number of binary nucleon-nucleon collisions when going from pp to Pb–Pb, ii) the same reconstruction efficiency as obtained in pp, and iii) a a pseudo-rapidity density of primary charged particles at mid-rapidity of about 1500 for central Pb-Pb collisions, we would have for the most central 10% of the inelastic cross section about 1,000 reconstructed J/ψ with a signal over background ratio $S/B \approx 0.01$. Given these figures, the measurement in the first year would be at the limit of feasibility. However, the introduction in the analysis of the TRD and TOF PID would eventually improve the performances.

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