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J/ψ production at central rapidity in pp collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ with the ALICE experiment

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Summary. — J/ψ production can be measured in the ALICE experiment at central rapidity through the dielectron channel ($J/\psi \to e^+e^-$), reaching $p_{\mathrm{T}} = 0$. In this contribution we report the first results concerning the analysis of the inclusive J/ψ production in pp collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ in the rapidity range $|y| < 0.9$.

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The heavy quarkonium production mechanisms, which are not completely understood yet, involve both perturbative and non-perturbative aspects of Quantum Chromodynamics (QCD). Several models [1, 2] have been proposed to describe quarkonia production in proton-proton collisions, but none succeeds to predict simultaneously cross section, transverse momentum dependence and polarization measured at the Tevatron [3, 4] and RHIC [5] hadron colliders. Furthermore the quarkonium measurements in proton-proton collisions provide a reference for heavy-ion collisions at the same energies.

In relativistic nucleus-nucleus collisions quarkonium states are expected to be sensitive to the initial temperature of the system, through their dissociation due to color screening [1]. Moreover, at LHC energies, uncorrelated charm and anti-charm quarks, abundantly produced in the initial stage of the collision, may recombine and yield an increase in the number of observed charmonium mesons.

Quarkonia measurements in ALICE (A Large Ion Collider Experiment) are performed at central rapidity, in the dielectron channel ($J/\psi \to e^+e^-$) and at forward rapidity, in the dimuon channel ($J/\psi \to \mu^+\mu^-$), reaching in both cases $p_{\mathrm{T}} = 0$. In this contribution we focus on the analysis of "inclusive" J/ψ particles produced at central rapidity ($|y| < 0.9$) in proton-proton collisions at $\sqrt{s} = 7\,\mathrm{TeV}$ [6]. We consider as "inclusive" the superposition of both "prompt" (J/ψ produced directly or coming from the radiative decay of higher-mass charmonium states) and "non-prompt" components (J/ψ coming from b-hadron decays).

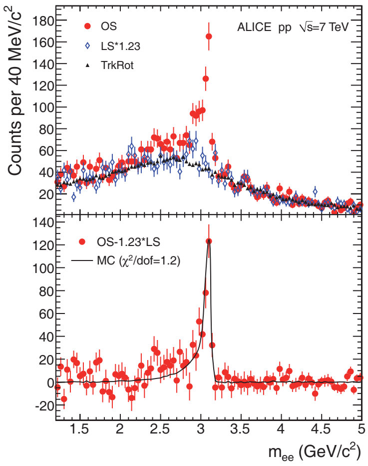

Fig. 1. – Top panel: invariant mass distributions for like-sign (LS), opposite-sign (OS) and rotated (TR) electron pairs. Bottom panel: the difference of the two distributions (OS-LS) with the fit to the Monte Carlo (MC) signal superimposed [6].

The ALICE apparatus [7] is divided into a central part, that covers $|\eta| < 0.9$ region with a magnetic field of 0.5 T, and a forward muon arm that covers the region $-4 < \eta < -2.5$.

The analysis discussed in this document is performed in the central barrel and it relies on the Inner Tracking System (ITS) and the Time Projection Chamber (TPC). The ITS, which is the vertex detector, covers the pseudo-rapidity range $|\eta| < 0.9$ and consists of six cylindrical layers of silicon detectors instrumented using different technologies (pixel, drift, strip). The ITS is designed to provide precise track and vertex reconstruction close to the interaction point and to improve the overall momentum resolution. The TPC, which is the main tracking device of the central barrel, is a large cylindrical drift gaseous detector and gives up to 160 spatial points per track. It also provides an excellent Particle IDentification (PID) by means of specific energy deposition measurements with a resolution of $\sigma = 5.5\%$.

The event sample used for this analysis has been collected using a "minimum-bias" trigger [8]: this analysis is based on a total of $3.5 \cdot 10^8$ minimum bias (MB) events which correspond to an integrated luminosity of about $5.6\,\mathrm{nb}^{-1}$.

Figure 1 (top panel) shows the invariant mass distribution of reconstructed opposite sign (red filled circles), like sign (blue empty circles) and rotated([1]) (black triangles) pairs. The tracks are required to have at least 70 points in the TPC, $p_\mathrm{T} > 1\,\mathrm{GeV}$, the impact parameter in the transverse plane less than 1 cm and a hit in at least one of the two layers of pixels. The PID is provided by the TPC. In particular the used cut is $\pm 3\sigma$ for electron inclusion, $\pm 3.5\sigma$ and $\pm 3\sigma$, respectively for pion and proton exclusion. Furthermore, tracks compatible with being products of γ conversions have been removed, in order to reduce the combinatorial background.

([1]) The method consists in rotating, around the z-axis, one of the tracks of the pair by a random azimuthal angle.

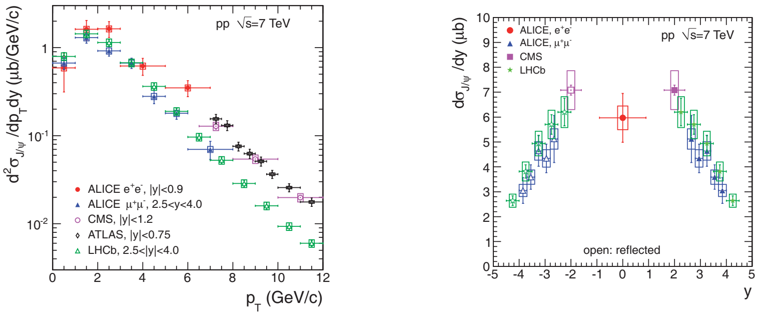

Fig. 2. – Left panel: $\mathrm{d}^2\sigma_{J/\psi}/\mathrm{d}p_\mathrm{T}\mathrm{d}y$ for the midrapidity and forward rapidity ranges, compared with results from the other LHC experiments [6, 10-12] obtained in similar rapidity ranges. The error bars represent the quadratic sum of the statistical and systematic errors (except polarization) while the systematic uncertainties on luminosity (7%) are shown as boxes; systematics due to the unknown polarization is not shown. Right panel: $\mathrm{d}\sigma_{J/\psi}/\mathrm{d}y$ compared with results from the other LHC experiments [6, 10-12]. Error bars: same as left.

The result obtained by subtracting the two distributions (OS-LS) is shown in the bottom panel and it is compared to Monte Carlo signal (black line). The "raw" signal has been extracted by counting the entries in the mass range 2.92–3.16 GeV/c^2 and it amounts to $352 \pm 32(\mathrm{stat.}) \pm 28(\mathrm{syst.})$ counts. In order to extract the J/ψ corrected yield, the number of "raw" signal events has to be corrected, with a simulation procedure, for the acceptance A and efficiency ϵ. The J/ψ production cross section is obtained as

$$(1) \qquad \sigma_{J/\psi}(|y| < 0.9) = \frac{N^{corr}_{J/\psi}(|y| < 0.9)}{BR(J/\psi \to e^+e^-)} \cdot \frac{\sigma_{MB}}{N_{MB}}, \qquad N^{corr}_{J/\psi} = \frac{N^{raw}_{J/\psi}(|y| < 0.9)}{\langle A \cdot \epsilon \rangle},$$

where $BR(J/\psi \to e^+e^-) = 5.94\%$ [9], N_{MB} is the number of minimum bias collisions and σ_{MB} is the measured cross section for such events.

The inclusive J/ψ production cross section at central rapidity is [6]:

$\sigma_{J/\psi}(|y| < 0.9) = 10.7 \pm 1.2(\mathrm{stat}) \pm 1.0(\mathrm{syst})^{+1.6}_{-2.3}(\mathrm{syst.\ pol})\,\mu\mathrm{b}$. The effect of unknown polarization has been treated as a systematic error; it has been quoted separately from other systematics considering two extreme polarization scenarios both in the Collin-Soper (CS) and helicity frame (HF) (the values above are relative to the Helicity reference frame since they are the largest).

Figure 2 shows the p_T-differential cross section $\mathrm{d}^2\sigma_{J/\psi}/\mathrm{d}p_\mathrm{T}\mathrm{d}y$ (left) and $\mathrm{d}\sigma_{J/\psi}/\mathrm{d}y$ ($p_\mathrm{T} > 0$)(right). For the latter the values obtained at forward rapidity have been reflected with respect to $y = 0$. Our results are compared to those obtained by CMS, LHCb and ATLAS Collaborations [10-12]. The p_T differential cross section measured by ALICE at mid rapidity covers a complementary p_T range (extending down to $p_\mathrm{T} = 0$) with respect to the one covered by CMS and ATLAS; at forward rapidity the ALICE and LHCb measurements are in good agreement. Concerning the rapidity distribution, the results from ALICE and LHCb are compatible within the errors at forward rapidity.

With future high-statistics data sample, thanks to the good resolution on impact parameter provided by ITS, the ALICE experiment will identify, at central rapidity, J/ψ from b-decays, via the measurement of the pseudo-proper decay length distributions [13].

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