

# Heavy flavour measurements in pp collisions at 7 TeV with the ALICE experiment at the LHC

C. Zampolli, for the ALICE Collaboration

*CERN, 1211 Geneva 23, Switzerland and CNAF - INFN, v.le Bertì Pichat 6/2 40127, Bologna, Italy*

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## Abstract

The current status of the rich heavy flavour program of ALICE experiment at the LHC will be presented. The results shown cover the 2010  $\sqrt{s} = 7$  TeV pp data.

*Key words:* LHC, ALICE, heavy flavour, proton-proton collisions

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## 1. Introduction

ALICE [1] is the experiment at the Large Hadron Collider (LHC) devoted to the study of ultra-relativistic heavy-ion collisions. The extreme energy density ( $> 10$  GeV/fm<sup>3</sup>) and temperature ( $\geq 3$  GeV) conditions reached in Pb-Pb collisions at LHC energies are expected to lead to a phase transition from ordinary colourless hadronic matter to a deconfined plasma of quarks and gluons (the so-called Quark-Gluon Plasma, QGP [2]). Among the various observables that can allow to shed light on the creation and the properties of the QGP, heavy flavour production is expected to serve as a fundamental tool. Being produced during the early stages of the collisions, heavy quarks (charm and beauty) experience the whole evolution of the system, and are therefore important to probe the characteristics of the medium. On one hand, open charm and beauty are of great interest for the role they play in the study of the in-medium energy loss of heavy quarks [3]. On the other hand, besides depending on the first stages of the collisions for their production mechanism, quarkonium states allow to access information about the medium properties, since their dissociation pattern<sup>1</sup> is sensitive to the initial temperature of the medium [4]. At the same time, a concurrent statistical or quark anti-quark recombination may occur, leading to an enhancement in the  $J/\psi$  production at the LHC.

ALICE started taking pp data in November 2009 at  $\sqrt{s} = 900$  GeV, and continued at 7 TeV from March 2010 until the first Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV took place at the beginning of November 2010 lasting until the LHC winter shutdown. In this paper, the first preliminary results of the ALICE heavy flavour measurements in pp collisions

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<sup>1</sup> Dissociation of quarkonia may occur in a QGP deconfined medium via colour screening.

at 7 TeV will be discussed, with emphasis on those at midrapidity. A brief description of the ALICE experiment will be given in Sec.2, focusing on the detectors involved in the heavy flavour studies, and on their role. In Sec. 2.1 the  $p_t$ -differential cross-sections for open charm mesons in  $|y| < 0.5$ , reconstructed using the decays  $D^0 \rightarrow K^- \pi^+$  and  $D^+ \rightarrow K^- \pi^+ \pi^+$  will be presented (see also [5]). The status of the ongoing analysis of the semi-electronic decays  $D, B \rightarrow e + X$  at midrapidity will be discussed in Sec. 2.2 (more details can be found in [6]). The rapidity-differential cross-section for  $p_t > 0$  of inclusive  $J/\psi$  will be presented in Sec. 2.3 (see [7] for more details). Finally, some conclusive remarks will be given in Sec. 3 in view of the upcoming analyses with Pb–Pb data. The results on the ALICE single muon and  $J/\psi \rightarrow \mu\mu$  analyses can be found in [8].

## 2. The ALICE experiment and its heavy flavour program

The ALICE heavy flavour program relies on the excellent tracking and particle identification capabilities of the experiment. In the ALICE central barrel (covering the pseudorapidity range  $|\eta| < 0.9$ ), in a magnetic field of 0.5 T, the Inner Tracking System (ITS) and the Time Projection Chamber (TPC) are the main tracking devices. The TPC is used in the heavy flavour analyses also in terms of particle identification (PID) of charged hadrons via specific energy deposit  $dE/dx$  measurements at low momenta. Charged hadrons at intermediate momenta are identified by the ALICE Time Of Flight (TOF) detector. Electron PID is carried out at low  $p_t$  ( $< 4$  GeV/ $c$ ) by the TPC and the TOF detectors, while in the range  $p_t > 1$  GeV/ $c$  the Transition Radiation Detector (TRD) is used. The Electromagnetic Calorimeter (EMCal) identifies electrons at high momenta ( $p_t > 5$  GeV/ $c$ ). Finally, the ALICE Muon Spectrometer at  $-4 < \eta < -2.5$  performs both the reconstruction and the identification of muon tracks.

### 2.1. $D$ mesons

The hadronic decay channels  $D^0 \rightarrow K^- \pi^+$  and  $D^+ \rightarrow K^- \pi^+ \pi^+$  are among the most promising for the study of the open charm. The analysis is based on the intrinsic topology of the decay, and exploits the excellent vertex reconstruction and tracking capabilities of the ALICE ITS and TPC detectors. The background is reduced at low transverse momenta combining the TPC and TOF PID information: in order to minimize as much as possible the signal loss due to the usage of the PID, the only rejected candidates are those for which the daughters have been identified by both TPC and TOF, but the two particle type hypotheses differ. Figure 1 shows the preliminary  $D^0$  and  $D^+$   $p_t$ -differential cross sections in  $|y| < 0.5$  obtained with a sample of  $10^8$  minimum-bias<sup>2</sup> pp events. Efficiency and acceptance corrections were applied to the raw data, after the B feed-down correction was performed using FONLL predictions<sup>3</sup> [9]. The measured cross sections are found to be well described within uncertainties by the predictions from the FONLL and GM-VFNS calculations, based on perturbative QCD [9,10].

### 2.2. Electrons from heavy-flavour decays

$c\bar{c}$  and  $b\bar{b}$  production cross sections can be studied through the semileptonic decays of open charm and open beauty. The key tool for this analysis is the excellent electron PID capability of the ALICE experiment. The TPC  $dE/dx$  measurements together with the

<sup>2</sup> The minimum bias trigger is defined as a signal in either one of the two ALICE V0 odoscopes, or in the ITS pixel detector.

<sup>3</sup> A method to correct for feed-down from beauty decays which uses the measured displacement of feed-down D mesons from the primary vertex will be applied for the analysis of the full 2010 data sample.

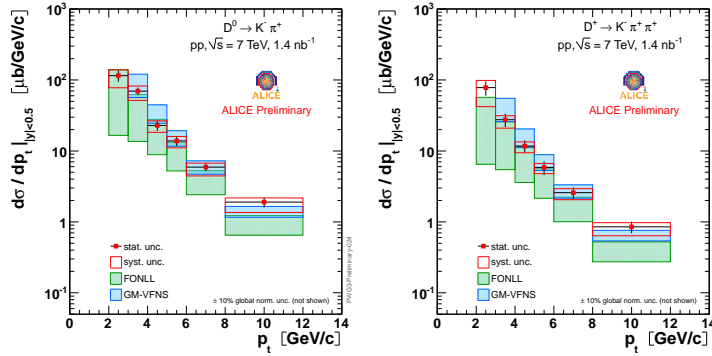


Fig. 1. ALICE  $D^0$  (left) and  $D^+$  (right) cross sections as a function of  $p_t$ .

TOF information allow to identify electrons in the low and intermediate  $p_t$  region (up to  $\sim 4$  GeV/c). The upcoming inclusion in the analysis of the TRD and EMCal detectors (currently being installed and precisely calibrated) will let it cover a broader  $p_t$  range.

The inclusive electron  $p_t$  distribution of heavy-flavour decay electrons presented herein was extracted subtracting from the inclusive electron spectrum a cocktail of the measured background sources of electrons, i.e. electrons from light hadron decays ( $\pi^0$ ,  $\rho$ ,  $\omega$ ,  $\eta$ ), photon conversions in the material, heavy quarkonia ( $J/\psi$  and  $\Upsilon$ ), and direct radiation<sup>4</sup>. The cocktail was based on the measured  $\pi^0$  cross section [11]. The left panel of Figure 2 shows the cocktail spectrum (still excluding the quarkonia and the direct radiation contributions) obtained from the ALICE data compared to the inclusive electron spectrum in the momentum range  $0.4 < p_t < 4$  GeV/c. About  $10^8$  minimum bias pp events were used. The visible excess with respect to one of the ratio (middle panel of Fig. 2) is due to the electrons coming from open charm and open beauty decays.

### 2.3. Quarkonia production

The  $J/\psi$  production cross section can be measured in ALICE in the dielectron decay channel at midrapidity ( $|y| < 0.9$ ), and in the dimuon channel at forward rapidity ( $-4 < y < -2.5$ ) (see [12] for more details). The analysis at central rapidity relies on the PID information provided by the TPC detector, with the plan to add also TRD and TOF. The signal extraction was performed via bin counting in the invariant mass range  $2.90 < M_{inv} < 3.15$  GeV/c, with background removal done subtracting from the opposite-sign electron pairs' invariant mass distribution the corresponding like-sign distribution [7]. Using  $10^8$  minimum bias events, the preliminary  $p_t$ -integrated cross section  $d\sigma/dy = 7.36 \pm 1.22(stat.) \pm 1.32(syst.)^{+0.88}_{-1.84}(pol.) \mu b$  was extracted<sup>5</sup>. The right panel of Figure 2 shows the  $J/\psi$  inclusive  $d\sigma/dy$  for  $p_t > 0$ . The results at forward rapidity are also included so that the rapidity interval  $-4 < y < 0.88$  is covered. The comparison with the other LHC experiments ATLAS, CMS and LHCb is also presented [13]. The CEM [14] and CSM [15] theoretical predictions are superimposed. For a more detailed and exhaustive description of the  $J/\psi$  analysis in ALICE, see [12].

<sup>4</sup> Another way to measure the production cross-section of heavy-flavour decay electrons is to cut on the large displacement of the secondary vertex from the primary one to select electrons coming from B.

<sup>5</sup> In the results presented herein, no B feed-down subtraction was applied.

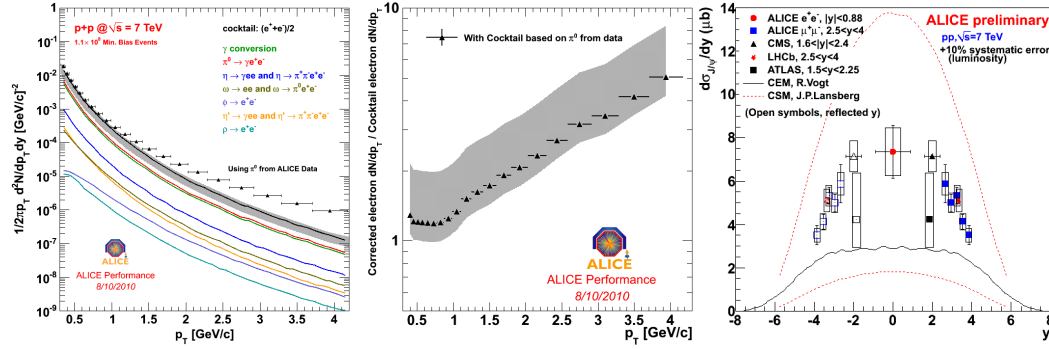


Fig. 2. Left: inclusive electron spectrum  $dN/dp_t dy$  measured with ALICE compared to the electron cocktail (see text). Middle: ratio between the inclusive electron spectrum and the cocktail. Right: ALICE  $p_t$  integrated  $J/\psi$  cross section as a function of rapidity in  $|y| < 0.88$  and  $2.5 < y < 4$ .

### 3. Outlook and conclusions

The first preliminary results from the ALICE central rapidity heavy-flavour analyses have been presented for pp collisions at  $\sqrt{s} = 7$  TeV at the LHC. The open charm analyses in the hadronic and in the semi-electronic channels have been discussed, together with the  $J/\psi$  inclusive cross section. These results will be the baseline for the future heavy ion analyses, such as those concerning the nuclear modification factor, and the study of quarkonia production mechanism. The first Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV recorded at the end of 2010 are the starting point for the QGP quest of ALICE.

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