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Quarkonium and heavy flavour physics with the ALICE Muon Spectrometer at the LHC

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ALICE, the dedicated heavy ion experiment at the LHC, has also an important physics program with proton-proton collisions. The main purpose of the experiment is to investigate the properties of strongly interacting matter at extreme energy density where the formation of the Quark Gluon Plasma is expected. In this regard, quarkonia and heavy flavours are especially relevant. They will be measured in ALICE through the electron channel and the hadron channel in the central barrel as well as through the muon channel in the forward muon spectrometer. In this contribution, the ALICE muon spectrometer is presented and selected heavy flavour physics topics are reviewed. Special attention is given to the capabilities of the apparatus for the first measurements performed with p-p collisions at $\sqrt{s} = 7$ TeV.

1. INTRODUCTION

The LHC (Large Hadron Collider) is designed to collide protons at $\sqrt{s} = 14$ TeV and lead ions at $\sqrt{s_{NN}} = 5.5$ TeV. This energy which exceeds the one reached at RHIC for Au + Au collisions by about a factor 30 will provide new insights for the study of the properties of strongly interacting matter under extreme thermodynamical conditions [1]. One of the most important aspects of this new energy range is the abundant production of heavy quarks (charm and beauty) which will allow to investigate their production mechanisms, propagation and hadronization in the hot and dense nuclear medium. Moreover, the study of quarkonia is of particular interest since their suppression by color screening [2] in nucleus-nucleus collisions was first proposed as one of the manifestations of the Quark Gluon Plasma (QGP) formation. The successful achievement of the heavy ion program requires also the study of proton-proton, proton-nucleus and light nucleus-nucleus systems. Besides providing the necessary baseline for the study of medium effects in Pb-Pb collisions, p-p collisions are of great interest as an important test of QCD in a new kinematic region of unprecedented small Bjorken-x values.

The ALICE (A Large Ion Collider Experiment) experiment [3] designed for and devoted to heavy ion physics at the LHC, also measures p-p collisions. The LHC delivered its first proton beams in November 2009 and will collide Pb ions at $\sqrt{s_{NN}} = 2.75$ TeV at end of 2010. p-p collisions have been measured at $\sqrt{s} = 0.9$ TeV, $\sqrt{s} = 2.36$ TeV and are presently collected at $\sqrt{s} = 7$ TeV.

2. ALICE MUON SPECTROMETER

The ALICE apparatus [3] consists of a central barrel ($|\eta| < 0.9$) placed in the LEP L3 magnet (B $\leq$ 0.5 T), a forward muon spectrometer and other sub-detectors of smaller acceptance.

The main aim of the ALICE muon spectrometer [3] is the study of quarkonium production and heavy flavour production in the (di)muon channel. In addition, the production of weakly interacting probes (Z^0 and $W^{\pm}$ bosons) and low mass resonances (ρ, ω, ϕ) is also investigated. The main design criteria are driven by the requirements that the detector should operate in the high multiplicity environment of central Pb-Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV and should reach a mass resolution of 100 MeV/c^2 in the Υ mass region in order to resolve the $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$ states. The muon spectrometer covers the polar angular range $171^\circ < \theta < 178^\circ$

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($-4.0 < \eta < -2.5$). It is composed of a passive front absorber, a beam shield, a 3 T·m dipole magnet, five stations of high granularity tracking chambers, each based on two planes of Cathod Pad Chambers. Finally, two stations of trigger chambers equipped with two planes of Resistive Plate Chambers each, are located downstream of the tracking system, after a 1.2 m thick iron wall.

3. PERFORMANCE STUDIES

3.1. Heavy flavour production

At the LHC, hard processes contribute significantly to the total cross section. The $c\bar{c}$ and $b\bar{b}$ yields, obtained from perturbative QCD (pQCD) calculations at next-to-leading-order (NLO) and assumed as the baseline for ALICE simulation studies, are 0.16 and 0.007 for *p-p* collisions at $\sqrt{s}$ = 14 TeV, respectively [4] (they are lower by about 40% and 55% at 7 TeV, respectively). The predictions vary within a factor 2-3 [5], depending on free parameters of NLO pQCD calculations. On the other hand, the uncertainty on the ratio of heavy quark cross-section at 14 TeV to that at 5.5 TeV is only about 10% [4]. Therefore a high precision measurement of charm and beauty cross sections at $\sqrt{s}$ = 14 TeV is essential. In addition, the study of beauty production is mandatory to estimate the contribution of secondary J/ψ (from B decay) to the total J/ψ yield. Finally, the large charm and beauty cross sections allow to investigate new observables [6,7] for the study of heavy quark quenching. Indeed, the ratio of the nuclear modification factor of D (B)-hadrons to that of light hadrons allows to probe the color charge (mass) dependence of parton energy loss and the ratio of beauty to charm nuclear modification factor allows to isolate the mass dependence of the energy loss. Furthermore, $W^{\pm}$ can provide a baseline to observe medium-induced effect on heavy quark production [7].

The performance of the ALICE muon spectrometer for the measurement, via single muons, of the B (D)-hadron inclusive production differential cross section has been evaluated in *p-p* collisions at $\sqrt{s}$ = 14 TeV [8,9] by means of full simulations. The principle is first to estimate the muon yield from heavy flavour decay from

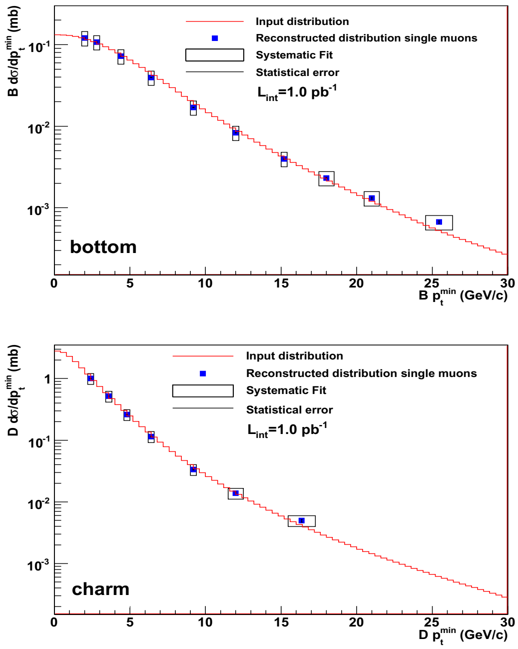

Figure 1. Inclusive differential B-hadron (up) and D-hadron (down) cross sections in *p-p* collisions at $\sqrt{s}$ = 14 TeV. See [8,9] for more details.

the total transverse momentum ($p_{\rm t}$) distribution. Then, beauty and charm muon components are unraveled via a combined fit which includes predicted shapes of the different components[1]. Finally, the B-hadron and D-hadron production cross sections are determined after corrections for efficiency, luminosity, branching ratios and decay kinematics by using the method initially developed by the UA1 collaboration [10]. Figure 1 shows the reconstructed B-hadron (upper panel) and D-hadron (lower panel) cross sections as a function of $p_{\rm t}^{\rm min}$. The statistics corresponds to an integrated luminosity of 1.0 pb^{-1} (t = 10^6 s, $< L > = 10^{30}$ cm^{-2}s^{-1}). The measurement of the B-hadron (D-hadron) cross section can be performed over a large $p_{\rm t}$ range going from about 2 GeV/c to 25 GeV/c (16 GeV/c) with statistical errors lower than 10% at high $p_{\rm t}$. The expected

[1] Note that charm and beauty components have never been disentangled with this method in the past.

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