Open Charm Analysis at Central Rapidity in ALICE using the first year of pp data at $\sqrt{s}$= 7 TeV

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Abstract

ALICE is the dedicated heavy-ion experiment at the LHC. Its main physics goal is to study the properties of the strongly-interacting matter in the conditions of high energy density (>10 GeV/fm^3) and high temperature ($>$ 0.3 GeV) expected to be reached in central Pb–Pb collisions. Charm and beauty quarks are a powerful tool to investigate this high density and strongly interacting state of matter as they are produced in initial hard scatterings, and due to their long life time, they probe all the stages of the system evolution. The detector design was optimized for heavy ions but is also well suited for pp studies. ALICE recorded pp data at $\sqrt{s}$= 7 TeV since march 2010 and the first run with heavy ion collisions took place in November 2010. The measurement of charm production cross section in pp collisions provides interesting insight into QCD processes and is important as a reference for heavy ion studies. The measurement of the D-meson yield in pp collisions can be used to extract the charm cross section. In this contribution, the ongoing study of reconstruction of D-mesons through hadronic decay channels and the first preliminary results obtained with $\sqrt{s}$= 7 TeV pp data will be presented.

Key words: LHC, ALICE, pp collision, D-mesons
PACS:

1. Physics Motivation

Heavy quarks are unique probes to study the Quark-Gluon Plasma produced in heavy ion collisions at the LHC. Due to their large masses, they are produced predominantly in hard scatterings, during the initial phase of the collision. Therefore, they can probe the properties of the nuclear matter created during the entire space time evolution. One of the key methods used to infer the parameters of the matter is the measurement of

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energy loss of the partons traversing it. Heavy quarks are expected to lose less energy in nuclear matter than light quarks and gluons because of the mass dependent suppression of the gluon radiation at small angles (dead-cone effect) [1]. Heavy-quark production measurements in pp collisions at the LHC, besides providing a necessary reference for the study of medium effects in Pb–Pb collisions, are interesting per se, as a test of perturbative QCD (pQCD) in a new domain, up to 7 times above the present energy frontier at the Tevatron. The charm production cross section measured in $p\bar{p}$ collisions at $\sqrt{s}$=1.96 TeV at the Tevatron [2] is on the upper limit of the pQCD caculations, as observed also in pp collisions at RHIC at much lower energy of $\sqrt{s}$= 0.2 TeV [3].

2. ALICE Detector

The ALICE detector [4] consists of two parts: a central barrel at central rapidity and a muon spectrometer at forward rapidity. For the present analysis, we have used the information from a subset of the central barrel detector, namely the Inner Tracking System (ITS), the Time Projection Chamber (TPC), the Time Of Flight detector (TOF), T0 for time zero measurement and V0 scintillator for triggering. The two tracking detectors, the ITS and the TPC, allow the reconstruction of charged particle tracks in the pseudorapidity range $-0.9 < \eta < 0.9$ with a momentum resolution better than 2% for $p_t < 20$ GeV/c and provide particle identification via dE/dx measurement. The ITS, in particular, is a key detector for open heavy flavour studies because it allows to measure the track impact parameter (i.e. the distance of closest approach of the track to the primary vertex) with a resolution better than 75 μm for $p_t > 1$ GeV/c thus providing the capability to detect the secondary vertices originating from heavy-flavour decays. The TOF detector provides particle identification by time of flight measurement. The results that we present are obtained from a sample of 10^8 min. bias events triggered with the V0 scintillator and SPD detector (two innermost layers of ITS detector), which corresponds to 20 % ($1.4\mathrm{nb}^{-1}$) of the total 2010 statistics.

3. Measurement of Charm Production Cross Section

Here we will discuss the strategy for cross section measurement for two hadronic decay channels, i.e $\mathrm{D}^0 \rightarrow \mathrm{K}^-\pi^+$ and $\mathrm{D}^+ \rightarrow \mathrm{K}^-\pi^+\pi^+$. The analysis strategy is based on an invariant mass analysis of fully reconstructed decay topologies originating from displaced vertices. The cross section is calculated from the raw signal yield extracted with invariant mass analysis using the following formula:

$$\left.\frac{d\sigma}{\mathrm{dp_t}}\right|_{|y|<0.5} = \frac{1}{2}\cdot\frac{1}{\Delta\mathrm{y}(\mathrm{p_t})}\cdot\frac{1}{BR}\cdot\frac{1}{\epsilon_c}\cdot f_c(p_t)\cdot\frac{\mathrm{N^D_{Raw}}(\mathrm{p_t})|_{|\mathrm{y}|<\Delta\mathrm{y}(\mathrm{p_t})}}{\mathrm{N^{tot}_{MinBias}}}\cdot\sigma^{tot}_{MinBias} \tag{1}$$

The different terms in the above equation are described in the following steps.

- Raw Signal Extraction ($\mathrm{N^D_{Raw}}(\mathrm{p_t})$). Due to large combinatorial background, the topological cuts have been tuned and applied in order to maximize the statistical significance. In the case of D^0 mesons, the two main cut variables are the product of the impact parameters of the two tracks ($d_0^K \times d_0^\pi$) and the cosine of the pointing angle ($\theta_{pointing}$). For the D^+ meson, the two main selection variables are the distance between the reconstructed primary and secondary vertices and the cosine of the pointing angle. Particle identification, provided by TOF and TPC, helps to further reduce the background at low p_t.

- Correction efficiency (ϵ_c). The measured yield is then corrected for detector acceptance and cut selection efficiency extracted from MC simulation with detailed description of detector response and experimental conditions.
- Correction for feed down from B-mesons (f_c). A relevant fraction of D's comes from B-meson decays and since the tracks coming from secondary D are well displaced from the primary vertex, due to the relatively long life time of B-mesons ($c\tau \approx$ 460-490 μm), the selection further enhances their contribution to the raw yield (upto ≈15 %). This contribution must be subtracted. We have done this estimation using the beauty production cross section predicted by FONLL calculation [6] and the detector simulation. We will check this estimation with the data driven method developed by CDF Collaboration [2] with the full 2010 statistics.
- Cross section normalization: The corrected yield is then divided by the branching ratio, by the acceptance in rapidity ($\Delta \mathrm{y}(\mathrm{p_t})$) of each p_t interval and by a factor 2 (as both particle and antiparticle are measured). Then, the resulting value is divided by the integrated luminosity to obtain the p_t differential cross section.

Each term of the above formula has some systematic uncertainty. The main sources of systematic errors are: raw yield extraction (10 %) which was determined by repeating the fit, in each p_t interval, in a different mass range and also with a different function to describe the background and feed down from B (≈ 15 %). The systematic error for correction factors appplied are also taken into account. Considering all the sources of systematic, we have 20-25% of total systematic uncertainties. Figure 1 shows the first

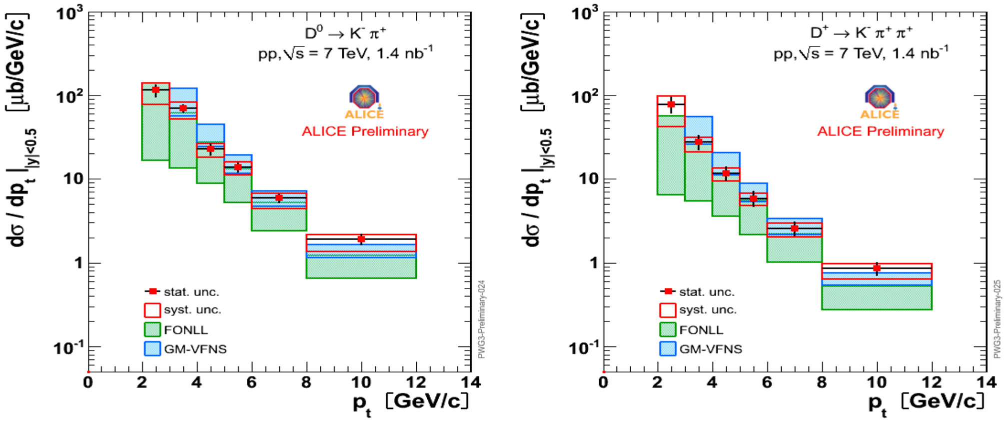

Fig. 1. Preliminary $\mathrm{p_t}$ differential cross section for D^0 (left panel) and D^+ (right panel) compared with FONLL [6] and GM-VFNS [7] theoretical predictions

preliminary p_t differential cross section for D^0 and D^+ mesons, compared with two theoretical predictions, FONLL [6] and GM-VFNS [7]. The measurements are well described by both models within their theoretical uncertainties. With the full statistics of 2010, we expect to increase the p_t coverage.

The $\mathrm{D}^{*+} \rightarrow \mathrm{D}^0\pi^+$ analysis is also well advanced, with the signal extracted in various p_t bins. Figure 2 (right panel) shows the p_t distribution of D^{*+} mesons in the range $3 < p_t <$

12 GeV/c in arbitrary units, with statistical errors only (evaluation of systematic uncertainties is ongoing) and compared to the shape of FONLL theoretical predictions [6]. The p_t shape is well described by the pQCD predictions. For p_t >3 GeV/c, we have derived the D-meson ratios (D^0/D^+ and D^0/D^{*+}) that are found to be in agreement with previous measurements at lower energies [5,2] as shown in the right panel of figure 2. Promising signals have also been observed for the other decay channels $D^0 \to K^-\pi^+\pi^-\pi^+$, $D_s^+ \to K^-K^+\pi^+$ and $\Lambda_c^+ \to pK^-\pi^+$.

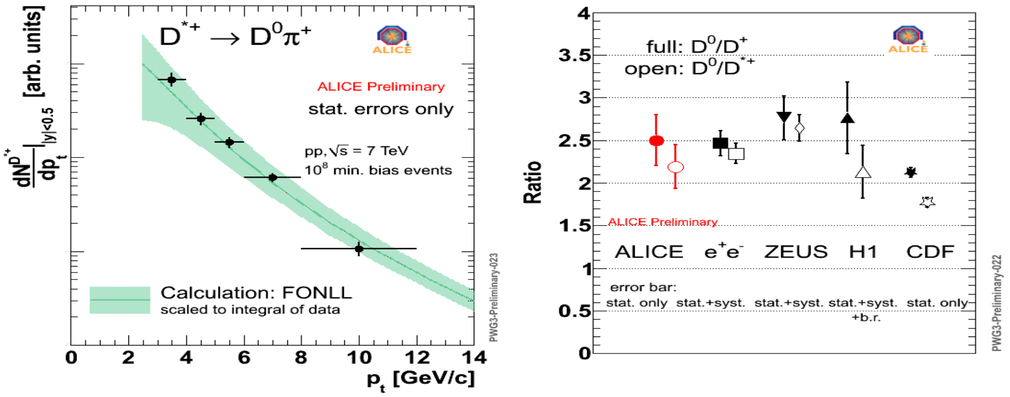

Fig. 2. Left Panel: p_t distribution of D^{*+} meson, shown with statistical errors only. Right Panel: D-mesons ratio for p_t >3 GeV/c compared to previous measurements

4. Conclusions

The ALICE detector provides excellent tracking, vertexing and particle identification capabilities that allow a high precision measurement of the open charm cross section via hadronic decays. We have shown the preliminary results on the measurement of the production cross section of the D^0 and D^+ mesons at central rapidity in pp collisions at $\sqrt{s}$=7 TeV in $2 < p_t < 10$ GeV/c. The measurements are described by the theoretical calculations within their uncertainties. These measurements will provide reference data to measure the energy loss of D-mesons in Pb–Pb collisions at the LHC.

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