OPEN CHARM ANALYSIS ON THE FIRST PP COLLISIONS AT $\sqrt{s} = 7$ TeV WITH ALICE

GIACOMO ORTONA (For the ALICE collaboration)

*Dipartimento di Fisica Sperimentale, Università degli Studi di Torino, via P. Giuria 1
 Torino, Italy
 ortonato@to.infn.it*

A Large Ion Collider Experiment (ALICE) is one of the four large experiments at the Large Hadron Collider (LHC), and the one dedicated to ultra relativistic heavy ion collisions, aiming at investigating the properties of the high-density state of QCD matter produced in such events. ALICE started to collect data in proton-proton collisions at the LHC at CERN in November 2009 (with a centre of mass energy $\sqrt{s} = 900$ GeV). Since March 2010 data are being recorded at an energy of $\sqrt{s} = 7$ TeV while from November 7 to December 6 LHC provided Pb-Pb collisions at an energy of $\sqrt{s} = 2.76$ TeV per nucleon-nucleon pair.

In Pb-Pb collisions heavy quarks are regarded as sensitive probes of the interaction dynamics between the parton and medium produced in the collisions, and the energies available at LHC will allow to study the production of heavy flavours with high statistics. Proton-proton data will be used to measure the heavy flavours production cross section to compare with perturbative QCD calculations in an unexplored energy domain and they will provide the reference for the study of Pb-Pb collisions. After a description of the ALICE experiment focused on its heavy flavour related performance, the status of the first analysis on charm production, measured by reconstructing the decays of D^0 , D^+ , D^{*+} , and D_s into hadronic and semi-leptonic channels will be presented. An outlook of the same measurements for the upcoming Pb-Pb run will also be discussed.

Keywords: LHC; ALICE; Open charm.

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1. Introduction

A Large Ion Collider Experiment (ALICE)¹ is one of the four main experiments at the Large Hadron Collider (LHC). On March 30, 2010 LHC started to deliver proton-proton collisions at a centre of mass energy of $\sqrt{s} = 7$ TeV, and from November 7 to December 6 Pb-Pb collisions at an energy $\sqrt{s} = 2.76$ TeV for nucleon pair. At such unprecedented energies there is a large production of heavy flavour quarks², and the ALICE detector is well suited to study the charm production down to the low p_t region. The preliminary results shown in this report are obtained from ~ 140 million “minimum bias” proton-proton events at $\sqrt{s} = 7$ TeV and ~ 5 million events with at least one muon trigger signal (muon trigger conditions).

2. The ALICE Experiment

The ALICE experiment, described in detail in Reference 1, is designed in order to achieve good performance for heavy flavour measurements².

Experimentally, the two key elements for a rich heavy-flavour program are: good tracking/vertexing capabilities and good particle identification (PID). In ALICE, charged particle tracking at central rapidity relies on the six concentric layers of high resolution silicon detectors of the Inner Tracking System (ITS)^a, a large volume Time Projection Chamber (TPC)^b, and a high granularity Transition-Radiation Detector (TRD). The ALICE detection strategy for charm and beauty hadrons relies on resolving secondary displaced vertices reconstructed from tracks with large impact parameters (d_0)^c and on the identification of single lepton decay modes. The precision on the impact parameter measurement is mainly provided by the two innermost ITS layers (SPD) in the bending plane ($r\phi$) and by the two intermediate ITS layer (SDD) for the z-coordinate. A resolution σ_{d0} better than 60 μm in the bending plane is achieved for tracks with $p_t > 1.5 \text{ GeV}/c$.

"Minimum bias" proton-proton events are defined as events where there is at least a signal in both the V0 scintillators or in the SPD.

3. D Meson Analysis at ALICE

Open charm meson reconstruction is based on the invariant mass analysis of fully reconstructed hadronic decay topologies. The strategy to reduce the large combinatorial background is based on the selection of displaced-vertex topologies, i.e. with impact parameter of the decay tracks of the order of $\sim 100\text{-}500 \mu\text{m}$, large separation between the primary and the secondary vertices, good alignment between the reconstructed D meson momentum and the flight line^d.

The decay channels under study are listed in table 1.

Particle identification is provided by time of flight measurements in the TOF detector and by energy loss in the TPC. It is applied in order to keep all the possible signal, thus only combination of particles that are incompatible with the decay channel are excluded. After the reconstruction, an invariant mass analysis is used to extract the raw signal yield. Then corrections for the detector acceptance, for selection and reconstruction efficiencies are applied.

^aTwo innermost layers equipped with silicon pixel (SPD) plus two middle layers of silicon drift detectors (SDD), and two outermost layers of silicon strip detectors (SSD)

^bA large drift chamber with multiwire proportional chamber (MWPC) endcaps¹

^cthe impact parameter being the distance of closest approach of a particle trajectory to the primary vertex

^dThe flight line is defined as the line passing through both the primary and the secondary vertices. The angle between reconstructed D meson momentum and the flight line is called pointing angle.

Fig. 1. Sketch of the $D^0 \rightarrow K\pi$ decay topology with the definition of the impact parameter d_0 of the daughters and of the pointing angle $\cos \theta_{point}$

Table 1. Decay channels for the reconstruction of open charm mesons

Meson	Decay channel	$c\tau$	BR
D^0	$D^0 \rightarrow K^-\pi^+$	$122.9 \mu\text{m}$	$(3.91 \pm 0.05)\%$
D^0	$D^0 \rightarrow K^-\pi^+\pi^+\pi^-$	$122.9 \mu\text{m}$	$(8.14 \pm 0.20)\%$
D^+	$D^+ \rightarrow K^-\pi^+\pi^+$	$311.8 \mu\text{m}$	$(9.2 \pm 0.25)\%$
D_s^+	$D_s^+ \rightarrow K^+K^-\pi^+$	$149.9 \mu\text{m}$	$(5.50 \pm 0.28)\%$
D^{*+}	$D^{*+} \rightarrow D^0\pi^+$		$(61.9 \pm 2.9)\%$

3.1. D^0 reconstruction

The most promising channel for the study of D^0 meson² is the channel $D^0 \rightarrow K^-\pi^+$, although also the 4-prong decay $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$ is under study. The selection strategy is based on the application of two different cuts: the product of the impact parameter of the two decay tracks ($d_0^K \times d_0^\pi$) and the cosine of the pointing angle^e of the reconstructed D^0 meson. Figure 1 shows a sketch of this decay topology. The invariant mass distribution obtained after the cuts is shown in figure 2 for $p_t > 2$ GeV/c. Figure 3 shows the preliminary $\frac{dN}{dp_t}$ distribution for the D^0 meson in the range $3 < p_t < 12$ GeV/c obtained after the correction for the efficiency and the acceptance. The shape predicted by pQCD calculations (FONLL³) agrees with our data. Contamination from B meson decays is currently estimated to be of $\sim 15\%$ using the beauty production cross section predicted by the FONLL calculation³ and the detector simulation. This contribution is subtracted from the measured raw p_t spectrum before applying the efficiency corrections.

3.2. D^+ reconstruction

The D^+ meson is reconstructed in the channel $D^+ \rightarrow K^-\pi^+\pi^+$. With respect to the decay $D^0 \rightarrow K^-\pi^+$ this topology is affected by higher combinatorial background. On the other hand, as showed in table 1, the branching ratio of this decay is larger and the D^+ has longer life time ($c\tau \sim 310\mu\text{m}$). Thus a cut on the distance between primary and secondary vertices is very effective. Two main cuts⁴ are used to separate the signal from the huge combinatorial background for the D^+ : the distance

^eIf the reconstructed particle is a real D meson, then $\cos \theta_{point} \approx 1$

Fig. 2. D^0 invariant mass distribution for $p_t > 2$ GeV/c

Fig. 3. $D^0 \frac{dN}{dp_t}$, arbitrary unit. Statistical errors only, theory normalized to the integral of data

Fig. 4. D^+ invariant mass distribution for $p_t > 2$ GeV/c.

Fig. 5. $D^+ \frac{dN}{dp_t}$, arbitrary unit. Statistical errors only, theory normalized to the integral of data

between the primary and secondary vertices and the cosine of the pointing angle of the reconstructed meson. To perform this selection, an extremely good vertexing resolution, both on the primary and secondary vertex, must be reached. The identification of the kaon, which in this topology always has opposite sign with respect to the mother meson is also used to reject combinatorial background. The results obtained with this strategy are shown in figures 4 and 5.

Next steps in the analysis of the hadronic decay of the D mesons will be the evaluation of the systematic uncertainties, the correction for the beauty feed-down using the measured impact parameter distribution of the D mesons and the extraction of the p_t differential cross-section using the integrated luminosity. Using the entire 2010 data sample will allow to extend our p_t coverage towards both larger and smaller p_t .

4. Heavy Flavours to Single Leptons

The study of open charm and beauty decays in the semi-leptonic channels is performed in the central rapidity region ($|\eta| < 0.9$) for D and B decays with single electrons and in the muon arm ($-4 < \eta < -2.5$) for the heavy flavour semi-muonic decay channels.

4.1. Heavy flavours to single electrons

The reconstruction of the single electrons provides a different way to assess the charm and beauty production at central rapidity with respect to the study of the hadronic channels and it allows to measure the yield of the open beauty in this rapidity region. To reduce contamination from photon conversions in material, high quality tracks with a hit in the innermost pixel layer (3.8 cm of radius) are requested. A good PID is crucial for this study, as contamination from hadrons is very large. At first, particles compatible with kaons and protons in the TOF detector are rejected. Then the dE/dx deposit in the TPC of the remaining particles is used to identify and reject residual hadrons. The Transition Radiation Detector and the Electromagnetic Calorimeter, whose PID calibration is ongoing at the moment, will allow further improvements in the selection of the electron tracks. Once the single electron p_t distribution is obtained, heavy flavour electrons can be obtained by subtracting a “cocktail” of background electron sources tuned on the basis of the measured $\frac{d\sigma(\pi^0)}{dp_t}$. Any excess of electrons with respect to the cocktail would be given by beauty and charm decay electron signal. Figure 6 shows the electron measured spectra and the “cocktail” of background electron sources, based on the measured π^0 cross section. Next steps in this analysis are the normalization of the electron p_t differential spectra to the proton-proton minimum bias cross section, the selection of displaced electrons to obtain the beauty production cross section and the extension to higher p_t using signals from TRD and EMCAL.

4.2. Heavy flavours to single muons

Production of open charm and beauty in the forward rapidity region is studied using the muon spectrometer. Hadrons and low p_t secondary muons^f are removed requiring the matching between the reconstructed track and a signal in the muon trigger system. Then residual hadrons and muons coming from light hadron decays are subtracted using a PYTHIA MonteCarlo (ATLAS-CSC tuning) normalized to the data at low p_t . In order to obtain the absolute cross section, efficiency and acceptance corrections are applied and cross section is normalized to the pp cross section measured with a Van Der Meer scan. After those steps, the preliminary normalized cross section in the range $2 < p_t < 6.5$ GeV/c and $-4 < \eta < -2.5$ is

^fSecondary muons are muons produced by hadron decays inside the muon arm.

Fig. 6. Inclusive electron spectrum $\frac{dN}{dp_t}$ compared to the “cocktail” of background electrons sources, latter based on data from π^0 .

Fig. 7. cross section for muons coming from B and D decay measured in the ALICE muon arm. 10% systematic error not shown in the figure.

obtained, as shown in figure 7. The corresponding FONLL pQCD calculation, also shown in the figure, agrees with our data within uncertainties.

5. Conclusions

First results obtained from the first proton-proton data at $\sqrt{s} = 7$ TeV with ALICE have been shown. The results obtained from 140 million minimum bias events and 5 million muon events are promising. D mesons (D^0, D^+, D^*, D_s) are exclusively reconstructed in several p_t bins. Single electron p_t distribution has been shown and a preliminary cross section of heavy flavour decay muons has been obtained, while the cross-sections for D mesons and electrons from heavy flavours will be obtained soon.

References

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