Charm content in jets in proton-proton collisions with the ALICE experiment at CERN-LHC

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Abstract.

Charm and bottom quarks have been proposed as probes to study partonic matter produced in high-energy heavy-ion collisions. The detailed understanding of the production mechanisms in proton-proton collisions is of considerable interest as a QCD test tool and as reference calibration for heavy-ion studies. Measurements of the D meson yield in jets probe the production processes in which the observed D mesons are formed primarily from gluon splitting into $c\bar{c}$ or $b\bar{b}$ pairs. The charm content in jets is calculable in perturbative QCD, and the leading non-perturbative correction is expected to be significant at LHC energies. In this contribution we present a performance study of the reconstruction of charged $D^*$ mesons in jets based on the first data collected by the ALICE experiment in minimum bias p+p collisions at $\sqrt{s} = 7$ TeV. $D^*$ mesons are reconstructed through the decay sequence $D^* \rightarrow D^0 \pi^+$ and $D^0 \rightarrow K^- \pi^+$ (and its charge conjugate channel).

1. Introduction

The ratio of gluon splitting in $c\bar{c}$ ($g \rightarrow c\bar{c}$) pairs in gluon jets to that into light quarks pairs is calculable in perturbative QCD (pQCD). This offers not only the possibility to build a baseline for lead-lead collisions studies but even a clear possibility to test the pQCD predictions. At the energies available at Tevatron and RHIC the contribution to the total charm cross-section from this production mechanism is expected to be small [1, 2]. This production mechanism can be investigated studying the $D^*$ content in jets and using the different fragmentation characteristic with respect to pair creation. Several attempts have been made to measure the D content in jets. In proton-proton collisions at $\sqrt{s} = 630$ GeV the UA1 collaboration has observed $D^*$ in jets with transverse momenta over 40 GeV/c [3]. The $D^*$ fractional momenta with respect to the jet energy are consistent with a production mechanism different from pair creation, in which the $D^*$ originate from gluon splitting in $c\bar{c}$. The same result is found by the CDF collaboration at $\sqrt{s} = 1.8$ TeV [4]. The STAR collaboration at RHIC [5] shows that the contribution is about 6% and in agreement within the experimental errors with the pQCD predictions.

2. Experimental apparatus and data sample

The ALICE detector [6] is dedicated to the study of heavy ion collisions at LHC. It is divided into a barrel, that covers a $|\eta| < 0.9$ region with a solenoidal magnetic field of 0.5 T, and a forward muon arm that covers the region -2.5$<|\eta|<$-4 with a 0.7 T dipolar magnetic field. The main tracking detectors used in the present study are placed in the barrel part of ALICE experiment.
and are the Inner tracking System (ITS) and the Time Projection Chamber (TPC). The ITS is made up of 6 layers of silicon detectors built using three different technologies [7] and it is the main vertex detector for heavy flavour physics. The TPC is the main tracking device of ALICE, it gives up to 160 spatial points and has excellent Particle IDentification (PID) capabilities. Besides the TPC, the PID is assured in a wide $p_T$ range and for different particle species, by adding the informations of the Time Of Flight (TOF) and the ITS. The low material budget in the silicon tracker ($\langle X/X_0 \rangle \sim 7\%$) together with the excellent tracking performance of the TPC and the low magnetic field make the ALICE detector competitive even in p+p physics; in particular at low $p_T$. The results presented in this paper are obtained from a sample of $140 \times 10^6$ minimum bias collisions at $\sqrt{s} = 7$ TeV selected using an interaction trigger based on an "or" between two rings of scintillators (VOA and V0C) and the pixel tracker [8].

3. Jet reconstruction

In this analysis jets have been reconstructed using the TPC detector, based on the UA1[9] fixed cone algorithm with an energy threshold of 10 GeV and a cone radius of 0.4. Although ALICE offers the possibility to reconstruct jets with all the main algorithms available (see Fig.1, bottom), most of them are infrared safe, with the first data available we prefer to use the UA1 method with the reported specifications being a very robust and widely tested algorithm. On the top of figure 1 a di-jet event is shown using the ALICE event display. Based on Monte Carlo studies, the chosen cone size in the UA1 algorithm offers a good estimation of the jet axis.

![Figure 1. Top: Di-jet event captured by the ALICE event display. Bottom: Comparison of the uncorrected charged jet spectra for different reconstruction algorithms for $|\eta| < 0.5$ [10].](image-url)
4. **D* reconstruction**

The reconstruction of $D^*$ meson is performed in the channel $D^{*+} \rightarrow D^0 \pi^+$ (BR = $(67.7 \pm 0.5)$%) where the $D^0$ is reconstructed in the hadronic channel $D^0 \rightarrow K^- \pi^+$ (BR = $(3.91 \pm 0.05)$%) and it is based on the invariant mass analysis and the $D^0$ displaced vertex reconstruction. We require as single track selection at least 70 spatial points in the TPC. In addition the tracks must have at least 4 out of six possible clusters in the ITS layers and at least one point in one of the pixel layers. In the case of the $\pi_s$ (soft pion) we use in addition to the ITS+TPC reconstruction the ITS stand alone reconstruction. Once the single track selections are passed then the $D^*$ candidates are built and a set of topological selections are applied to the candidate $D^0$ to suppress the combinatorial background. In the figure 2 a sketch of the $D^0$ decay topology is reported. The main cutting variables are the product of impact parameters ($d_K^0 \times d_\pi^0$) and the cosine of the pointing angle ($\theta_{point}$). The impact parameter is defined as the distance of closest approach in the transverse plane between the back extrapolated trajectory of each of the $D^0$ daughters and the primary vertex. The $\theta_{point}$ is the angle between the $D^0$ momenta and its flight line. To improve the background rejection factor a PID strategy has been implemented. In this analysis the TPC and TOF informations are combined. For the TPC, a $2\sigma$ cut around the kaon (pion) Bethe-Bloch lines ensures good kaon (pion) identification in a $p_T$ region $300 \lesssim p_T \lesssim 800$ MeV/c. The additional information of the TOF allows to identify kaons up to 1.6 GeV/c. Finally the $D^*$ peak is expected to be seen in the mass difference $\Delta M = M(K\pi\pi) - M(K\pi)$ on the edge of combinatorial background as a sharp peak centered at $\Delta M = 145.42$ MeV/c$^2$. In figure 3 the $D^*$ signal is shown, $p_T$ integrated, as extracted using our selections from the first 140M events from the ALICE p+p minimum bias sample at $\sqrt{s} = 7$ TeV. The fit function is a convolution of a power law, used as threshold function, and a gaussian. The applied selections offer the possibility to extract the signal with a very good signal over background ratio ($S/B \sim 2$).

![Figure 2](image1.png)

**Figure 2.** Sketch of the $D^0$ decay topology with the definition of the impact parameters ($d$) of the $D^0$ daughters and the pointing angle $\theta_{point}$ variables.

![Figure 3](image2.png)

**Figure 3.** Invariant mass difference after all the selection cuts. The $D^*$ peak, $p_T$ integrated, is clearly visible. A resolution of $(620 \pm 34)$ keV/c$^2$ is obtained.

5. **D* in jet reconstruction**

In order to investigate the $D^*$ content in jet we have analyzed 1M jet events extracted from the minimum bias sample requiring $E_{jet} \geq 10$ GeV and $|\eta| \leq 0.5$. The search is restricted to
a region of radius 0.4 around the jet axis. Figure 4 shows the signal for the $D^*$ reconstructed inside this sample of jets.

Figure 4. Invariant mass difference computed for candidates inside the jet cone. The $D^*$ peak is visible.

6. Conclusions
The first performance results on jet reconstruction and $D^*$ meson reconstruction with the ALICE detector are reported. A set of selections to extract the $D^*$ signal both in minimum-bias and in the jet sample is found. Since we expect to collect a sample of at least $10^9$ min bias events in 2010 the measurement should not be statistics limited, therefore we tuned the cuts for high purity. The high purity will be an advantage for the correlation and fragmentation studies. In conclusion, we showed the feasibility of the reconstruction of the $D^{*\pm}$ mesons in a jet sample even with limited statistic and early data. This is the first step towards the $D^*$ in jet analysis, the analysis of the correlations and fragmentation function will follow when additional statistics will be available.

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