Heavy flavour measurements in Pb-Pb collisions at $\sqrt{S\_NN}$ = 2.76 TeV whith the ALICE experiment

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Heavy flavour measurements in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ALICE experiment

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The ALICE experiment measured the charm and beauty production in the semi-leptonic decay channels (electrons at mid-rapidity and muons at forward rapidities) and the D meson production in the hadronic decay channels at mid-rapidity in lead-lead collisions at $\sqrt{s_{NN}} = 2.76$ TeV and proton-proton collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 2.76$ TeV. The resulting nuclear modification factors will be presented.

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1. Motivation

The ALICE experiment [1] studies the properties of the QCD matter at extreme energy density, as expected to be produced in heavy-ion collisions at the LHC. Produced on a short time-scale in the initial hard-scattering processes, heavy quarks (charm and beauty) experience the whole collision evolution: measuring the open heavy flavour spectra allows to investigate the mechanisms of energy-loss and hadronization in the hot and dense medium formed in the nucleus-nucleus collision. In particular, due to the large mass and the color charge difference of quarks and gluons, the heavy-flavour energy-loss in the medium is expected to be lower than the one of light hadrons.

The nuclear modification factor is accounted for as a sensitive observable to the effects of the interaction of hard partons with the medium. It is defined as the ratio of the transverse momentum spectrum measured in nucleus-nucleus (AA) collisions to the one measured in pp collisions at the same centre of mass energy, rescaled by the average number of binary nucleon-nucleon collisions ($N_{\rm coll}$) expected in heavy-ion collisions. The ratio can be expressed also in terms of nuclear overlap integral (T_{AA}) estimated within the Glauber-model [2]:

$$R_{AA}(p_{\rm t}) = \frac{1}{\langle N_{\rm coll}\rangle}\frac{{\rm d}N_{AA}/{\rm d}p_{\rm t}}{{\rm d}N_{pp}/{\rm d}p_{\rm t}} = \frac{1}{\langle T_{AA}\rangle}\frac{{\rm d}N_{AA}/{\rm d}p_{\rm t}}{{\rm d}\sigma_{pp}/{\rm d}p_{\rm t}} \tag{1.1}$$

The measurements of the nuclear modification factors of heavy flavours with the ALICE experiment will be discussed in this paper.

2. Data taking

The ALICE experiment is designed to detect heavy flavours in a wide phase space range and in different decay channels: in the following, only the detectors used in the analysis will be described. Its central barrel ($|\eta| < 0.9$) is equipped with an Inner Tracking System (ITS) and a large Time Projection Chamber (TPC) positioned inside a solenoidal magnet that provides a field of 0.5 T, allowing for charged particle reconstruction down to low momenta (100 MeV/c). The TPC provides also charged particle identification, together with the Transition Radiation Detector (TRD) for electron identification and the Time Of Flight (TOF) detector for electron, pion, proton and kaon separation. A forward muon spectrometer ($-4 < \eta - 2.5$), consisting of a passive front absorber, a beam shield, five tracking stations (the central one positioned in a 3 T·m dipole magnet) and two trigger stations placed downstream a muon filter, allows to detect and identify muons with $p > 4$ GeV/c. The experiment is completed by several detectors for triggering and event characterization in the forward and backward pseudo-rapidity region. Among these, the VZERO detector, consisting of two arrays of scintillator hodoscopes covering the range $2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$, is involved in the fast triggering and centrality determination.

The analysis is based on proton-proton collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 2.76$ TeV and Pb–Pb collisions at $\sqrt{s} = 2.76$ TeV. The proton-proton data sample consists of Minimum Bias (MB) and muon triggers. The former is defined by the presence of a signal in the Silicon Pixel Detector (two innermost layers of the ITS) or in either of the two VZERO arrays, in coincidence with the beam-beam counters placed at both sides of the interaction point. The latter requires, in addition to a MB event, that a muon with transverse momentum above about 0.5 GeV/c reaches the muon trigger stations. In Pb–Pb collisions, the MB trigger requires the coincidence of signals in the two arrays of the VZERO and in the SPD. The centrality classes are estimated with a Glauber-model analysis of the amplitudes of the VZERO scintillator arrays [2].

3. Analysis and results

Open charm mesons are measured in the rapidity range $|y| < 0.5$ via the invariant mass analysis of the fully reconstructed hadronic channels $D^0 \rightarrow K^-\pi^+$, $D^+ \rightarrow K^-\pi^+\pi^+$, $D^{*+} \rightarrow D^0\pi^+$ (ongoing study) and their charge conjugate. The combinatorial background is reduced by topological constraints on the kinematics of the decay products, in particular by requiring a good separation of the candidate tracks from the primary vertex, a large decay length (compared to the estimated uncertainties) and a small angle between the reconstruction momentum direction and the D meson flight line. At low transverse momenta, the background is further reduced by the identification of charged kaons and pions in the TPC ($p_t \lesssim 1.1$ GeV/c) and TOF ($p_t \lesssim 1.5$ GeV/c).

Electrons are reconstructed in the range $|\eta| < 0.8$ by the ITS and the TPC, and identified through their energy deposit in the TPC, the time of flight in TOF, and, for pp collisions only (for the moment), through the transition radiation in the TRD. The contribution of electrons from the decay of heavy flavours was extracted from the inclusive electron spectrum by subtracting a cocktail simulation of the non heavy flavour electron sources (see [3] for details). The simulation is based on the measured distributions of π^0 in pp collisions and of $\pi^\pm$ in Pb–Pb collisions. The contribution of the decay of resonances was obtained through m_t scaling, while the direct γ contribution was derived from Next-to-Leading Order (NLO) perturbative QCD (pQCD) calculations.

Muons are measured in the muon spectrometer and identified by requiring that the reconstructed track matches a tracklet in the trigger system, placed behind an iron wall. This condition allows to efficiently remove the background contribution of hadrons punching through the frontal absorber. The main source of background consists of muons from the decay-in-flight of pions and kaons produced in the interaction point. In pp collisions, such contribution is subtracted through simulations, while in Pb–Pb a harder cut on the transverse momentum (up to 6 GeV/c) allows to select a region of the spectrum where the contribution is estimated to be at the level of few percent.

The raw heavy-flavour yields obtained from the different analyses were finally corrected for the respective acceptances and efficiencies.

The pp data collected at $\sqrt{s} = 7$ TeV were rescaled to the centre of mass energy of Pb–Pb collisions (2.76 TeV) by means of the FONLL pQCD calculation, which was proven to well describe proton data (see [4] and references therein). The scaled results for the D^0 and D^+ mesons were further cross-checked with the available measurements in pp collisions at $\sqrt{s} = 2.76$ TeV (such sample was collected in a 3-days run and could not be directly used in the R_{AA} due to the low statistics). The systematic uncertainties were obtained by taking into account the full theoretical uncertainties, and assuming no dependence of the quark mass and scales with $\sqrt{s}$.

The transverse momentum dependence of the nuclear modification factor for charmed mesons and heavy-flavour electrons is shown in the left panel of Fig. 1: the statistical (systematic) uncertainties are shown as bars (boxes). A large suppression of prompt D mesons ($R_{AA} \sim 0.25$) is observed in the region of $p_t \gtrsim 5$ GeV/c, where the nuclear shadowing effects are expected to be smaller than 10%. The value is in agreement with the one of the inclusive heavy-flavour electrons

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at intermediate p_{t}. The right panel of the same figure shows the central to peripheral nuclear modification factor (R_{CP}) for inclusive muons, defined as the ratio of the p_{t} distributions measured in different centrality classes, to the one measured in peripheral collisions (in this case 60-80%), both rescaled by the respective averaged nuclear overlap function $\langle T_{AA} \rangle$. Statistical (bars) and systematic (open boxes) uncertainties are shown, as well as the systematic uncertainty on the normalization (grey box). The figure evidences a suppression which increases with centrality. It is worth noting that, according to FONLL, the muon spectrum with $p_{\mathrm{t}} > 6$ GeV/c is dominated by beauty decay.

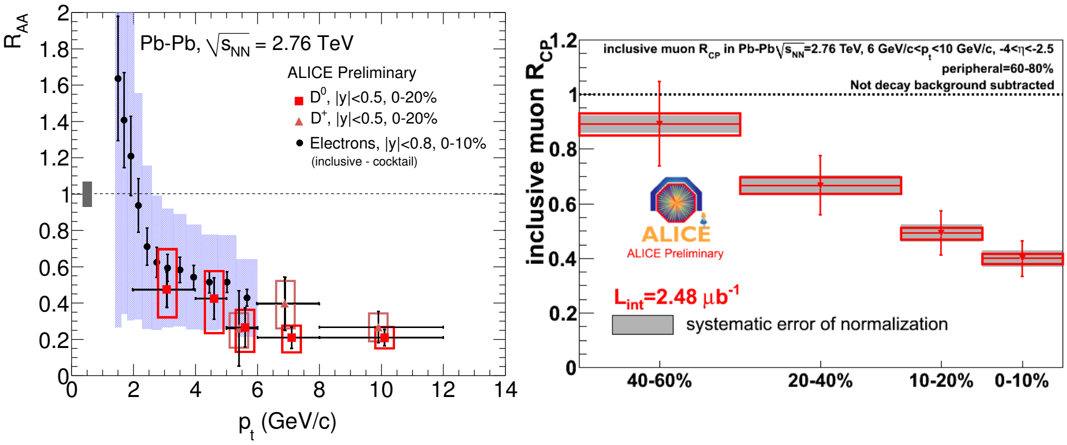

Figure 1: Left panel: nuclear modification factor (R_{AA}) of D^0 and D^+ mesons measured in the hadronic decay channels and of the inclusive heavy flavours measured in the semi-electronic decay channel. The bars (boxes) are the statistical (systematic) uncertainties. The grey band is the systematic uncertainty on the normalization. Right panel: central to peripheral nuclear modification factor for inclusive muons with $p_t > 6$ GeV/c and $-4 < \eta < -2.5$. The high transverse momentum cut ensures a contamination of the background at the level of few percent. Statistical (bars) and systematics (open boxes) are shown, together with the systematic uncertainty on the normalization (grey boxes).

4. Conclusions

Heavy flavour production was measured by the ALICE experiment in the hadronic and semi-leptonic decay channels in proton-proton and Pb–Pb collisions. The nuclear modification factor for prompt D^0 and D^+ mesons at central rapidities shows a large suppression (by a factor of 4-5) for transverse momenta higher than 5 GeV/c. The results are in agreement with the inclusive heavy-flavour electron suppression at mid-rapidities. A strong centrality dependence is also evidenced in the inclusive single muon analysis at forward rapidities, in a transverse momentum region which is expected to be dominated by beauty production.

References

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