Strange and non-strange D-meson production in pp, p–Pb, and Pb–Pb collisions with ALICE at the LHC

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The ALICE experiment at the CERN LHC was designed to study the colour-deconfined state of the nuclear matter created in heavy-ion collisions, called Quark-Gluon Plasma (QGP). Heavy flavours (i.e. charm and beauty quarks) represents an ideal probe of the QGP, since they are produced via hard-scattering processes in short time scales and hence experience the full system evolution, loosing energy via elastic and inelastic scatterings with the medium constituents. The measurement of open-heavy flavour hadrons represents also an important test for the understanding of the hadronisation mechanism in the hot environment created in heavy-ion collisions. In fact, if a fraction of heavy quarks hadronises via recombination with the medium constituents, the relative abundance of open heavy-flavour hadrons containing strange quarks with respect to those without strange-quark content is expected to be larger in heavy-ion collisions compared to proton–proton (pp) collisions, due to the enhanced production of strange quarks in the QGP.

The aim of the studies presented in this Thesis is the precise measurement of charmed mesons with and without strange-quark content, reconstructed in the three-body decay channels $\mathrm{D_s^+} \to \phi\pi^+ \to \mathrm{K^-K^+}\pi^+$ and $\mathrm{D^+} \to \mathrm{K^-}\pi^+\pi^+$.

The measurement of the $\mathrm{D_s^+}$-meson production in pp collisions at a centre-of-mass energy of $\sqrt{s} = 5.02$ TeV is described by perturbative QCD calculations. The abundance of $\mathrm{D_s^+}$ mesons relative to that of non-strange D mesons is found to be compatible with that measured in e^+e^- collisions, indicating that the charm-quark hadronisation mechanism is not significantly modified in pp collisions.

The multiplicity-dependent nuclear modification factor of $\mathrm{D^+}$ mesons measured in p–Pb collisions Q_{pA} measured at a centre-of-mass-energy per nucleon pair of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV was found compatible with unity, with a hint of enhancement for the transverse-momentum interval $2 < p_{\mathrm{T}} < 10$ GeV/c. A strong suppression of the p_{T}-differential yields of D^+ and $\mathrm{D}_{\mathrm{s}}^+$ mesons, increasing with the collision centrality, is observed in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The nuclear modification factor R_{AA} of D^+ mesons is found to be higher than that of charged particles for $p_{\mathrm{T}} < 8$ GeV/c. The central values of the $\mathrm{D}_{\mathrm{s}}^+$-meson R_{AA} are found to be higher than those of non-strange D mesons, as expected in case of hadronisation via recombination in a strangeness-rich medium, but still compatible within uncertainties.

The measurement of the azimuthal anisotropies in the momentum distribution of D^+ mesons in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, quantified by the second-harmonic coefficient of the Fourier decomposition, denoted elliptic flow v_2, indicates that the charm quarks participate in the collective motions of the system. The comparison with the v_2 of charged pions and J/ψ mesons suggests a contribution to the D^+-meson v_2 originated by the hadronisation of the charm quark via recombination with flowing light-quarks in the medium. A positive correlation between the v_2 of D^+ mesons and that of light-flavour hadrons is observed thanks to the first application of the event-shape engineering (ESE) technique to the measurement of the D-meson azimuthal anisotropies.

The perspectives of improved measurements with the application of machine-learning techniques for the selection of the D-meson signal and with the upgrade of the ALICE Inner Tracking System (ITS), planned for the LHC Run3 in 2020, are discussed.

The results presented in this Thesis were approved by the ALICE Collaboration and presented in various conferences. The measurement of the $\mathrm{D}_{\mathrm{s}}^+$-meson production in pp collisions was published in Ref. [1], the measurement of the D^+-meson nuclear modification factors in p–Pb and Pb–Pb collisions in Refs. [2, 3], and the measurement of the D^+-meson azimuthal anisotropies in Refs. [4, 5]. The perspectives for the ESE measurements with the upgraded ITS were included in Ref. [6]. The measurement of the $\mathrm{D}_{\mathrm{s}}^+$-meson R_{AA} and the improved measurements of the D^+-meson azimuthal anisotropies were approved as preliminary results and will be published soon.

References

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[3] **ALICE** Collaboration, S. Acharya *et al.*, "Measurement of D^0, D^+, D^{*+} and D_s^+ production in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV," *JHEP* **10** (2018) 174, arXiv:1804.09083 [nucl-ex].

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