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Measurement of heavy-flavour azimuthal correlations in pp, p-Pb and Pb-Pb collisions with ALICE

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Abstract

Heavy-flavour azimuthal correlations with charged particles are measured with the ALICE detector at central rapidity in pp collisions at $\sqrt{s}$ = 7 TeV, p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV at the Large Hadron Collider. Azimuthal correlations are constructed using D mesons or heavy-flavour decay electrons as trigger particles and associated charged particles. The near-side correlation yield is studied as a function of the transverse momentum of the trigger particle. In p-Pb collisions, the azimuthal correlation is studied as a function of the event multiplicity.

Keywords: LHC, QGP, heavy flavour, D meson, heavy-flavour decay electron, two-particle azimuthal correlations

1. Introduction

In heavy-ion collisions a state of matter consisting of deconfined quarks and gluons, the Quark-Gluon Plasma (QGP), is formed. Due to their large masses, heavy quarks (charm and beauty) are predominantly produced in hard scattering processes during the early stages of the collision, before the formation of the QGP. As their masses are much larger than Λ_{QCD}, their production is governed by perturbative QCD. Through interactions with the medium, they lose energy via both collisional and radiative processes. This is supported by several measurements, for instance, the strong suppression of D-meson production at $p_T > 4$ GeV/c in central Pb-Pb collisions relative to pp collisions [1]. Further insight into the energy loss mechanism of charm and beauty quarks can be obtained by measuring the azimuthal correlation between heavy-flavour particles (or their decay products) and charged particles.

The difference between the azimuthal correlation distributions in pp and Pb-Pb collisions is quantified by evaluating the ratio of the near-side or away-side yields, defined as $I_{AA} = \frac{Y_{AA}}{Y_{pp}}$. I_{AA} provides information about the processes by which heavy quarks lose energy in the QGP and could identify possible modifications to the charm parton shower and hadronisation in the presence of the medium. The measurement of azimuthal correlations in pp collisions, besides providing a reference for p-Pb and Pb-Pb collisions, may also provide information on the production mechanisms and hadronisation of heavy quarks. In addition, the study of the azimuthal correlation between heavy-flavour (HF) decay electrons and charged particles in pp collisions facilitates a statistical separation of the contribution from charm and beauty [2]. Finally, the study of long-range heavy-flavour angular correlations may shed light on the underlying production mechanism that gives rise to the double-ridge structure observed in high multiplicity p-Pb collisions with light-flavour di-hadron correlations [3]. It has been suggested that this structure may be due to collectivity or gluon saturation effects [4], [5]. Its observation in heavy-flavour correlations may help to distinguish between these two scenarios.

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2. Analysis strategy

Two-dimensional (2D) angular correlations are constructed by calculating the difference in azimuthal angle, $\Delta\varphi$ and pseudorapidity, $\Delta\eta$, between the trigger particle which in this study is either a D meson or a HF-decay electron (in a certain range of p_T^{trig}) and associated charged particles with different p_T thresholds ($p_T > p_T^{assoc}$).

Trigger particle: D mesons and their charge conjugates are reconstructed via their hadronic decay channels $D^0 \rightarrow K^+\pi^-$ (Branching Ratio (BR) of 3.88 ± 0.05 %), $D^+ \rightarrow K^-\pi^+\pi^+$ (BR of 9.14 ± 0.19 %) and $D^{*+} \rightarrow D^0\pi^+$ (BR of 67.7 ± 0.5 %). The extraction of the D-meson signal is based on the reconstruction of decay vertices displaced from the primary vertex by a few hundred microns, which is achieved by the Inner Tracking System (ITS) and the Time Projection Chamber (TPC) over a pseudorapidity region $|\eta| < 0.8$. The identification of the decay particle species is based on the measurement of specific energy loss (dE/dx) in the TPC. The Time Of Flight (TOF) detector is used in conjunction with the TPC to separate pions (kaons) up to p_T = 1.5 (2) GeV/c, which reduces combinatorial background. D mesons are selected according to their invariant mass. Candidates lying between $\mu \pm 2\sigma$ (where μ and σ are the mean and the width of the Gaussian fit to the invariant mass peak) are used to build the azimuthal correlations. The remaining combinatorial background is estimated from the sidebands (4-8σ region) of the invariant mass distribution and is removed from the azimuthal correlations. The contribution of B-hadron decays to D mesons is also subtracted from the azimuthal correlations using PYTHIA simulation [6].

Electrons are identified using the TPC and the TOF detectors and by measuring the E/p ratio with the Electromagnetic Calorimeter (EMCal). Heavy-flavour decay electrons are found by subtracting the contribution of various background sources, the dominant being electrons from Dalitz decays of light mesons (in particular π^0 and η) and electrons from photon conversion, that are identified by an invariant mass study of electron-positron pairs.

Azimuthal correlation: D meson and HF-decay electron correlation distributions are corrected for the reconstruction efficiency of associated tracks and trigger particles. The azimuthal correlation distributions are further corrected for the limited acceptance and spatial inhomogeneities of the detector using a mixed-event method. The fully corrected correlation distribution is normalised by the number of trigger particles and studied differentially as a function of the transverse momentum of the trigger particle and the associated tracks. In the case of HF-decay electrons, where the available statistics allow for differential studies, the distribution is studied as a function of the event multiplicity (p-Pb collisions) and centrality (Pb-Pb collisions).

3. Results

The azimuthal correlation distributions of average D (D^0, D^+, D^{*+}) mesons and charged particles was studied in pp and p-Pb minimum-bias (MB) data. The correlation is measured for D meson in the p_T intervals: 3 < p_T^D < 5 GeV/c, 5 < p_T^D < 8 GeV/c and 8 < p_T^D < 16 GeV/c in pp collisions; and in the p_T intervals 5 < p_T^D < 8 GeV/c and 8 < p_T^D < 16 GeV/c in p-Pb collisions.

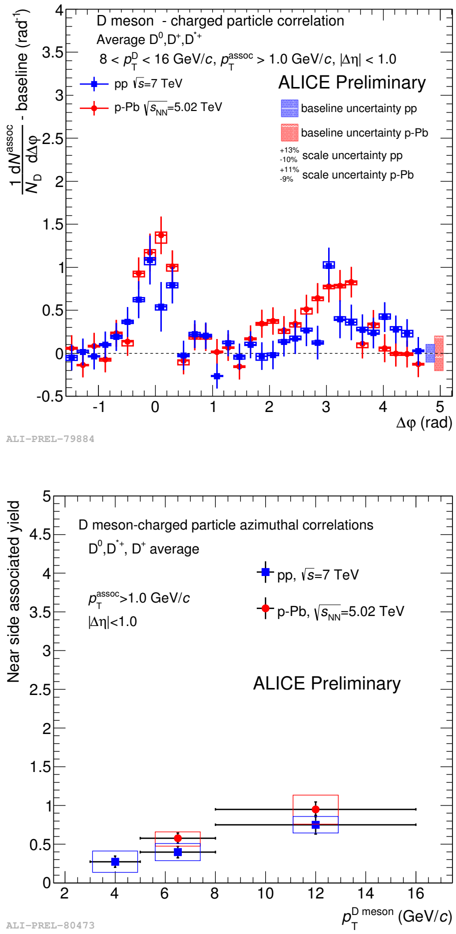

Figure 1: (top) D meson - charged particles $\Delta\varphi$ correlations and (bottom) near-side correlation yield as a function of D-meson transverse momentum in pp (blue points) and p-Pb collisions (red points).