PROCEEDINGS OF SCIENCE

Study of heavy-flavour hadron decay electrons as a function of charged-particle multiplicity in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE

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The study of the multiplicity dependence of heavy-flavour hadron production in pp collisions provides insight into heavy quark production mechanisms and into the interplay between hard and soft processes in particle production. Further, multiple parton interactions may also play a significative role in the heavy-flavour production at LHC energies. In this proceeding, we present the measurement of the heavy-flavour hadron decay electron yield as a function of transverse momentum and charged particle multiplicity at mid-rapidity ($|\eta| < 0.8$) in pp collisions at $\sqrt{s} = 13$ TeV. Electron identification is done within $0.5 < p_{\mathrm{T}} < 4.5$ GeV/c with the Time Projection Chamber (TPC) and the Time-of-Flight (TOF) detectors of the ALICE apparatus. The measurement of electrons from heavy-flavour hadron decay is expressed in terms of the ratio of the yield in a particular multiplicity interval to the multiplicity integrated yield (self-normalized yield). The result is given as a function of the relative charged particle pseudorapidity density within $|\eta| < 1$.

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1. Introduction

Heavy quarks (charm and beauty), produced in proton-proton (pp) collisions dominantly via gluon–gluon scatterings at the LHC energies, provide an essential testing ground for perturbative QCD calculations[1],[2]. The study of the multiplicity dependence of heavy-flavour production in pp collisions can be crucial in understanding their production mechanism and the role of hard and soft processes for particle production[3]. At the LHC energies, multiple parton interactions could play a significant role in heavy-flavour production [4]. High-multiplicity pp collisions at the LHC exhibit features resembling those seen in relativistic heavy-ion collisions[5],[6] and pointing to the possible need of revisiting the particle-production models.

2. ALICE detector

The ALICE detector is described in detail in reference [7]. In this analysis the Time Projection Chamber (TPC) and Time of Flight (TOF) detectors are used for electron identification at low and intermediate p_{T} ($0.5 < p_{\mathrm{T}} < 4$ GeV/c). The Inner Tracking System (ITS) is used for vertex determination and, together with the TPC for tracking and particle identification (PID) in $|\eta| < 0.8$. The number of tracklets obtained from the Silicon Pixel Detector (SPD) is used for the multiplicity measurement (see Section 3.2). A layout of the ALICE detector system is shown in figure 1.

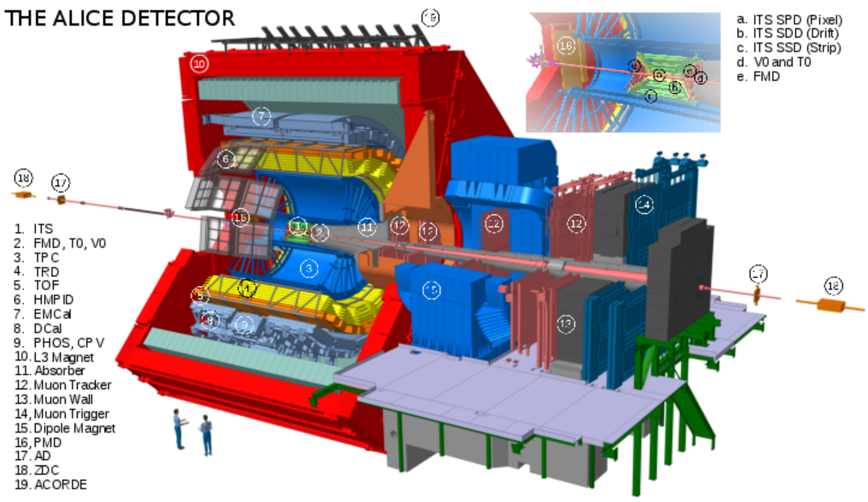

Figure 1: ALICE Detector layout

3. Analysis Methodology

3.1 Inclusive electron identification and photonic background subtraction

The charged-particle identification (PID) in the TPC is based on the specific energy loss measurement, dE/dx, of a particle in the gas while the time-of-flight measurement is exploited with the TOF detector, as shown in figure 2. The electron sample is selected within $|n_{\sigma^{TOF}}| < 3$ and -1$< n_{\sigma^{TPC}} < 3$ where n_{σ} is the difference of the measured signal in the detector from the expected value for electrons normalised to the detector resolution. This selection was optimized to remove the hadron contamination from the sample.

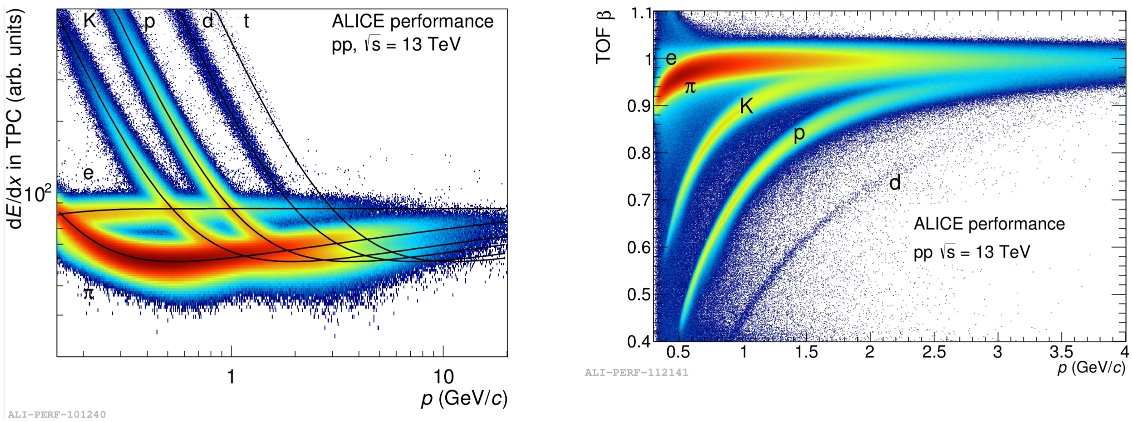

Figure 2: *Left Panel* : TPC dE/dx (in arbitrary units) vs. momentum *Right Panel* : TOF β vs. momentum

To select electrons from heavy-flavour hadron decays, the non-heavy flavour background sources are subtracted from the inclusive electron spectrum. The photonic background electrons which mainly come from the Dalitz decay of light neutral mesons (π^0 and η) and γ conversions in the detector material, are subtracted from the inclusive electron sample using the photonic-electron tagging method. To identify electrons from photonic sources (N_{photonic}), the invariant-mass distributions of pairs of electrons with unlike sign (ULS) and same (LS) charge sign are considered (left panel of figure 3). The LS pairs are used to estimate and subtract the random combinatorial background from the ULS:

$$N_{\mathrm{photonic}} = \frac{N_{\mathrm{ULS}} - N_{\mathrm{LS}}}{\varepsilon_{\mathrm{tagging}}}$$

where $\varepsilon_{\mathrm{tagging}}$ is the photonic electron tagging efficiency obtained from MC simulations.

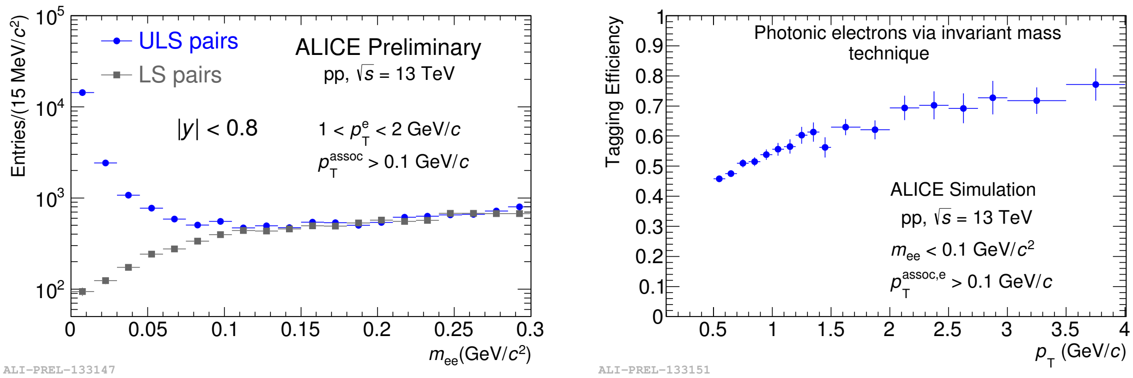

Figure 3: *Left Panel* : Invariant mass distribution of unlike-sign and like-sign pairs *Right Panel* : Tagging Efficiency

3.2 Multiplicity estimation

Silicon Pixel Detector (SPD) tracklets within $|\eta| < 1$ (N_{tr}) are used as the multiplicity estimator. A tracklet is reconstructed by joining clusters of both the SPD layers which point back to the primary vertex. As seen from the left panel of figure 4, the number of SPD tracklets ($|\eta| < 1$) depends on the position of the interaction point along the beam axis (z_{vtx}). This observed dependence is due to inhomogeneous acceptance, dead modules of SPD and changes in the number of active modules in the SPD during data taking. In order to correct for the z_{vtx} dependence of the tracklet reconstruction efficiency, each event is weighted in such a way that the distribution of the corrected tracklet ($N^{\text{corr}}_{\text{tracklet}}$) vs. z_{vtx} is flat. However, the $N^{\text{corr}}_{\text{tracklet}}$is not corrected for the z_{vtx}-integrated

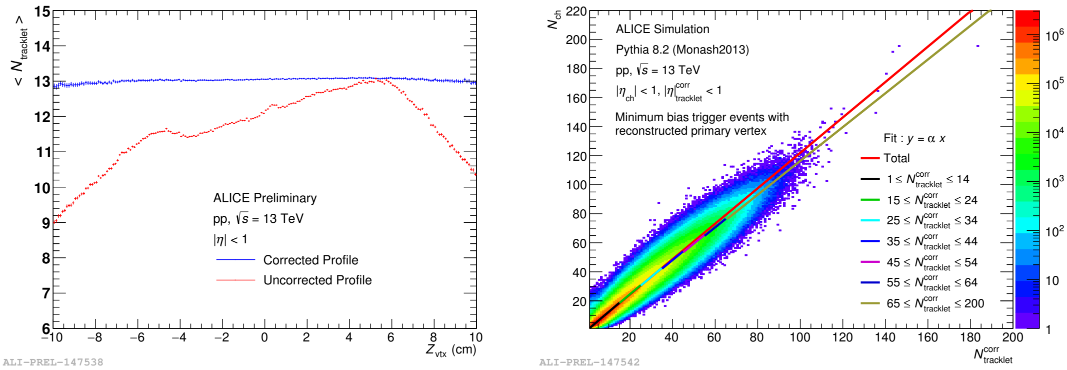

Figure 4: *Left Panel* : Average number of SPD tracklets vs. z_{vtx} before (red) and after the correction (blue) *Right Panel* : Number of charged particles within $|\eta| < 1$ (N_{ch}) vs. number of corrected SPD tracklets ($N^{\text{corr}}_{\text{tracklet}}$) along with the linear fit for the total distribution and in multiplicity bins

tracklet reconstruction efficiency. For this purpose, linear fits ($y = \alpha\ x$) to the 2D-distribution representing the correlation between the number of charged primary particles (N_{ch}) and $N^{\text{corr}}_{\text{tracklet}}$, are performed in several multiplicity intervals. The correlation distribution is obtained by means of a Monte Carlo simulation with PYTHIA 8.2 (Monash 2013 tune), as shown in the right panel of figure 4. The value $(\mathrm{d}N_{\text{ch}}/\mathrm{d}\eta)/ < \mathrm{d}N_{\text{ch}}/\mathrm{d}\eta >$ (x-axis) is calculated as :

$$\frac{(\mathrm{d}N_{\text{ch}}/\mathrm{d}\eta)}{< \mathrm{d}N_{\text{ch}}/\mathrm{d}\eta >} = \frac{< N^{\text{corr}}_{\text{tracklet}} >_{\text{i}} .\alpha_{\text{i}}}{< N^{\text{corr}}_{\text{tracklet}} > . < \alpha >} \qquad \text{where "i" denotes the multiplicity class}$$

4. Results

The self-normalized yield of electrons from heavy-flavour hadron decays is calculated using the following equation:

$$y = \frac{N^{\text{i}}_{\text{counts}}/(\varepsilon^{\text{i}} \times n^{\text{i}}_{\text{events}})}{(N^{\text{min.bias}}_{\text{counts}})/(\varepsilon^{\text{min.bias}} \times n^{\text{min.bias}}_{\text{events}}/\varepsilon_{\text{trigger}})}$$

where, "i" denotes the multiplicity class; $\varepsilon_{\text{trigger}}$ is the minimum-bias trigger efficiency estimated for INEL > 0 events, defined as inelastic events with at least one charged particle within $|\eta| < 1$, N_{counts} is the number of electrons from heavy-flavour hadron decays, n_{events} is the number of events and ε is the heavy-flavour electron reconstruction efficiency.
The self-normalized yield shows a faster than linearly increasing trend and higher p_{T} intervals tend to show a steeper increase, as seen in figure 5. In figure 6, the open heavy-flavour decay

electron yield is plotted with J/ψ ($p_{\mathrm{T}} > 0$) result at mid-rapidity to compare open and hidden charm production (left panel). A similar increasing trend is observed for both open and hidden heavy-flavour production indicating that this behaviour is most likely related to the c$\bar{\mathrm{c}}$ and b$\bar{\mathrm{b}}$ production processes and is not significantly influenced by hadronisation. The centre panel of figure 6, shows the comparison of heavy-flavour decay electron measurement with PYTHIA8.2[8], a multi-parton-interaction (MPI) based model. The data is well described by PYTHIA8.2 expectations, suggesting the importance of the MPI in the heavy-flavour production mechanism. In the right panel of figure 6, the comparison with measurement for muons from heavy-flavour hadron decays at forward rapidity in pp collisions at $\sqrt{s}$ = 8 TeV [9] points to slightly different trends. This difference at mid and forward rapidity may possibly arise from the overlap of the η window used for measuring the electron yield ("autocorrelation" + "jet bias") and the event multiplicity, which is absent in the muon case.

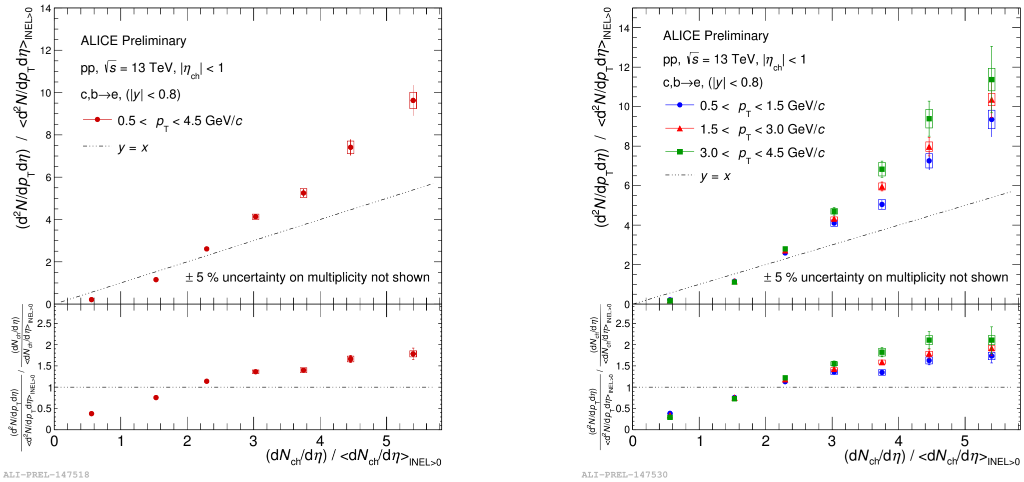

Figure 5: Multiplicity dependent self-normalized yields of electrons from heavy-flavour hadron decays in different p_{T} intervals

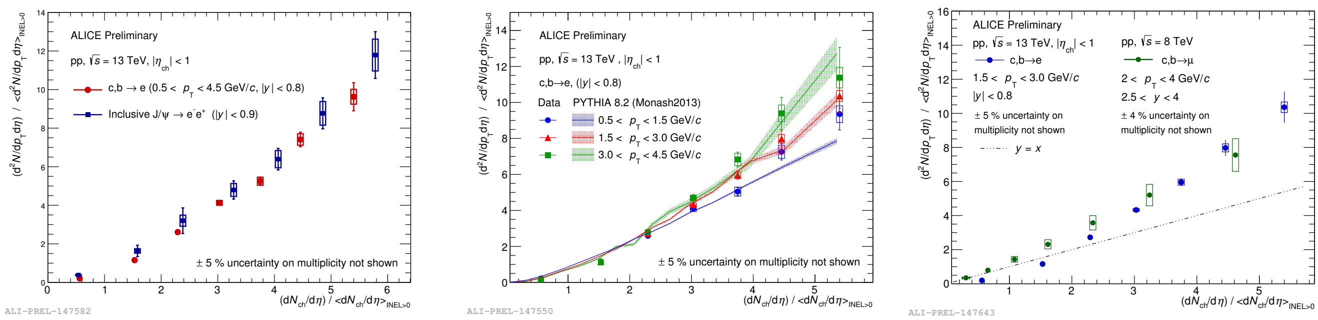

Figure 6: Comparisons of the result with J/ψ ($p_{\mathrm{T}} > 0$) at mid-rapidity (*left panel*), PYTHIA8.2 model expectations (*centre panel*) and muons from heavy-flavour hadron decays at forward rapidity in pp at $\sqrt{s}$ = 8 TeV[8] (*right panel*)

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