PROCEEDINGS OF SCIENCE

Nuclear modification factor of electrons from open beauty-hadron decays in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV with ALICE

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The ALICE Collaboration at the LHC aims at investigating the properties of hot and dense QCD matter, the quark-gluon plasma (QGP), created in ultra-relativistic heavy-ion collisions. Heavy quarks are created in initial hard scattering process, therefore they are effective probes of the evolution of the QGP. Since beauty quarks are four times heavier than charm quarks, we can get an insight into the in-medium mass dependent energy loss by comparing beauty with charm.

In ALICE, beauty production can be studied via semi-electronic decays of beauty hadrons. The yield of electrons coming from open beauty-hadron decays is obtained by fitting the impact parameter distribution with templates of different electron sources. In this contribution, the measurements of electrons from beauty-hadron decays in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV are presented.

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1. Introduction

The LHC heavy-ion physics program aims at investigating the properties of strongly-interacting matter in extreme conditions of temperature and energy density, where the formation of the quark-gluon plasma (QGP) in which quarks and gluons are de-confined, is expected. Heavy quarks (charm and beauty) are regarded as unique probes of the properties of the QGP as they are created on a very short time scale in initial hard scattering processes [1, 2] and subsequently interact with the medium. The partons (quarks and gluons) lose their energy in the medium, the in-medium energy loss is expected to depend on color charge and mass. The in-medium energy loss of quarks is smaller than that of gluons due to weaker color coupling to the medium [3]. Among quarks, the heavier the mass, the less energy it loses via collisional and radiative processes [4]. The presence of the medium can be quantified by the nuclear modification factor ($R_{\rm AA}$) defined as

$$R_{\rm AA} = \frac{1}{\langle N_{\rm coll} \rangle} \frac{{\rm d}N_{\rm AA}/{\rm d}p_{\rm T}}{{\rm d}N_{\rm pp}/{\rm d}p_{\rm T}} \tag{1}$$

where ${\rm d}N_{\rm AA}/{\rm d}p_{\rm T}$ and ${\rm d}N_{\rm pp}/{\rm d}p_{\rm T}$ are the $p_{\rm T}$-differential yield in AA and pp collisions, respectively, and $\langle N_{\rm coll} \rangle$ is the average number of binary nucleon-nucleon collisions. Beauty quarks, being four times heavier than charm quarks, can be used to study the in-medium mass dependent energy loss by comparing with inclusive heavy flavor decay electron $R_{\rm AA}$.

The ALICE detector has excellent capabilities for particle identification (PID) down to very low $p_{\rm T}$, and momentum and track impact parameter resolution at mid-rapidity region ($|\eta| < 0.9$). In ALICE, beauty quark production can be studied via electrons from semi-electronic decay channel of beauty hadrons.

2. Analysis

In this analysis, we use the data set of Pb–Pb collisions recorded in 2015. The electrons are identified using Time Projection Chamber (TPC) that the TPC PID is based on the specific energy loss of charged particles in its gas volume. Additionally, up to 8 GeV/c, we use Time-Of-Flight (TOF) that measures time of flight of particles between two scintillators, and an electromagnetic calorimeter that uses energy deposited in the cluster per track momentum above 8 GeV/c.

For the signal extraction, the typical large decay length of beauty hadrons ($c\tau \approx 500\ \mu$m) can be used to separate the beauty decay electrons from background electrons. The large decay length leads to a large impact parameter (d_0) defined as distance closest approach (DCA) to the primary vertex in the plane perpendicular to the beam direction. Most of the background electrons at low $p_{\rm T}$ come from Dalitz decays of light mesons and photon conversions created on beam pipe and in the detector materials. At high $p_{\rm T}$, the dominant background source is charm hadron decay electrons. Due to this reason, four templates (d_0 distributions of electrons from charm and beauty hadrons, Dalitz decays of light mesons and conversion) are used up to 8 GeV/c, and two templates (d_0 distribution of electrons from charm and beauty hadrons) are used above 8 GeV/c. The templates are obtained from Monte Carlo simulation (PYTHIA 6 generators) which was designed to reproduce the detector response of the particle transport with GEANT 3. To extract the beauty decay electrons, we perform the fit to the inclusive electrons d_0 distribution in data using such templates (Fig. 1). The template

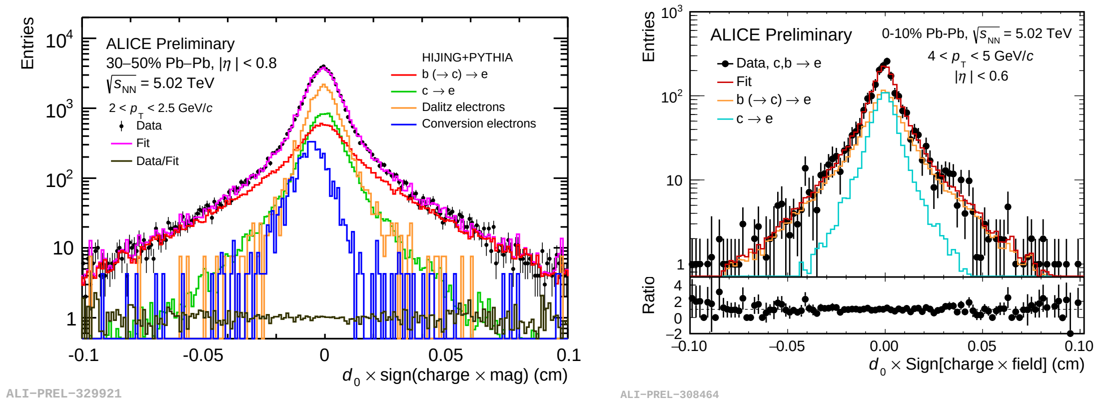

Figure 1: Examples of the template fit to measure beauty decay electrons using TPC+TOF (left) and TPC+EMCal (right).

fit is based on maximum likelihood approach which takes into account finite statistics of data used in templates [5].

3. Results

The R_{AA} of electrons from beauty-hadron decays in Pb–Pb collisions, measured as a function of p_T, is shown in Figure 2. For both centrality intervals 0-10% and 30-50%, R_{AA} values are below unity for $p_T > 2$ GeV/c, indicating that the spectra shapes of the beauty decay electrons are modified by the medium. In case of 0–10%, the result is well-described by theoretical model calculations including particle transport in the medium (Fig. 2 (left)). The R_{AA} is observed to be greater for semi-central collisions than for central collisions, as can be seen from in the panel on the right in Fig. 2, in spite of the large uncertainties.

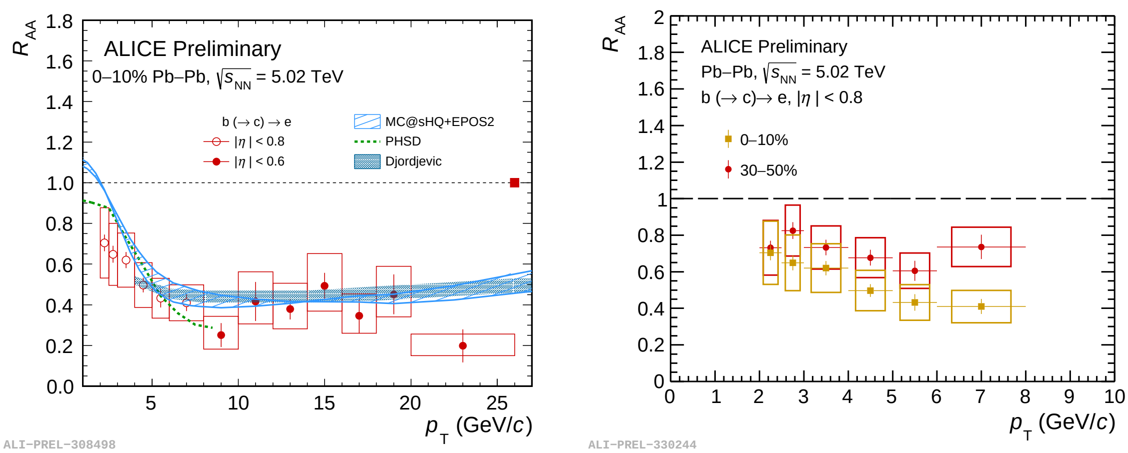

Figure 2: Nuclear modification factor of beauty decay electrons in Pb–Pb collisions at 5.02 TeV.

The R_{AA} of beauty decay electrons is compared to the R_{AA} of inclusive heavy–flavor decay electrons [6] measured at the same center-of-mass energy and the same centrality classes as shown in Figure 3. For both centrality classes, at low p_T, the R_{AA} of beauty decay-electrons tend to be higher than that of heavy flavor decay-electrons. This indicates that more beauty quarks survive the passage through the dense medium than charm quarks, presumably due to their lower energy loss because of heavier mass. At high p_T, the R_{AA} for beauty quarks and heavy quarks are comparable in the centrality interval 0-10% since the beauty quarks are dominant at high p_T [7].

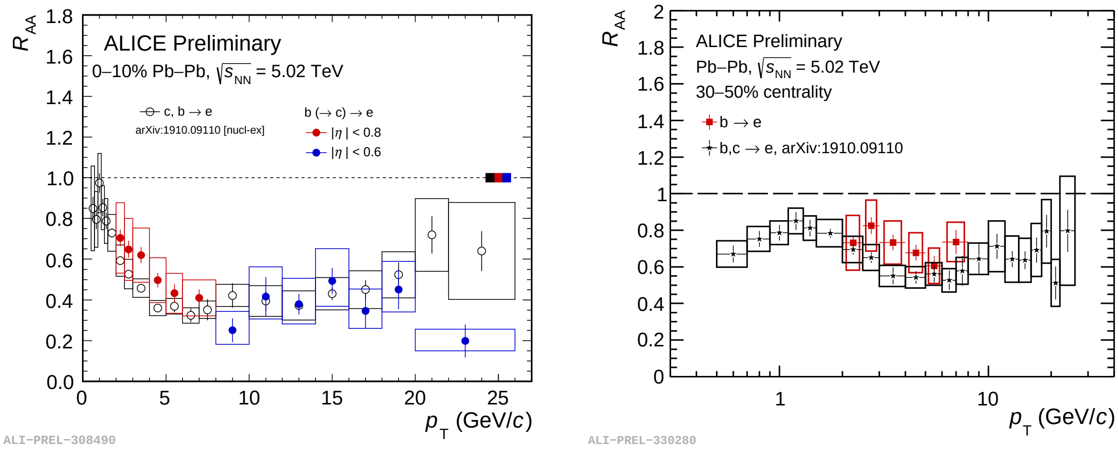

Figure 3: Comparison of R_{AA} between beauty decay electrons and heavy flavor decay electrons in 0–10% (left) and 30–50% (right) Pb–Pb collisions at 5.02 TeV

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