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Analysis of b-jet production in p–Pb and pp collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV with ALICE

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In these proceedings preliminary measurements of the charged-particle b-jet production in p–Pb pp collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV performed with the ALICE experiment are reported. The presented analysis utilizes secondary vertex of b-hadron decays to identify b-jet candidates. The resulting fully corrected b-jet spectrum obtained in p–Pb collisions is compatible with the result of a simulation based on POWHEG HVQ and PYTHIA event generators. The nuclear modification factor of charged-particle b jets is found to be consistent with unity within uncertainties, suggesting that the production of b jets in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV is not affected by large cold nuclear-matter effects.

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Measurements of heavy-flavour production in high-energy proton-proton (pp) collisions provide important tests for Quantum Chromodynamics (QCD) calculations. In addition to single-particle measurements, reconstruction of a jet containing a heavy-flavour hadron provides further constraints on the initial parton kinematics. The ALICE Collaboration [1] measured the production of b-tagged jets in minimum bias pp and p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV [2]. Jets were reconstructed from charged particles with transverse momentum $p_{\rm T} > 0.15$ GeV/c and pseudorapidity $|\eta| < 0.9$ using the anti-$k_{\rm T}$ algorithm [3] with jet cone radius $R = 0.4$ and the $p_{\rm T}$ recombination scheme. The pseudorapidity of the reconstructed jets was limited by the ALICE centra-barrel acceptance to $|\eta_{\rm jet}| < 0.5$. The jet $p_{\rm T}$ was corrected for the mean underlying event $p_{\rm T}$ density, which was calculated on an event-by-event basis using the estimator introduced by CMS [4].

A b-jet candidate was identified by imposing topological constraints on the most displaced secondary vertex (SV), which was reconstructed from all possible triplet combinations of jet-constituent tracks. The topological selections applied are:

- The minimal value of the significance of the SV displacement from the primary vertex, $SL_{xy} = L_{xy}/\sigma_{L_{xy}}$, which was by default required to be larger than 7. Here L_{xy} is the distance between the primary vertex and the SV and $\sigma_{L_{xy}}$ is the corresponding uncertainty.
- The maximal value of the SV dispersion, $\sigma_{\rm SV} = \sqrt{\sum_{i=1}^{3} d_i^2}$, which was by default required to be less than 0.03 cm. Here d_i denotes the distance of closest approach of each SV constituent to the SV itself.

The obtained spectrum of b-jet candidates is corrected to account for the purity and the efficiency of the b-jet tagging selections, according to the equation

$$\frac{{\rm d}N_{\rm b-jet}}{{\rm d}p^{\rm ch}_{\rm T,jet}} = \frac{{\rm d}N_{\rm b-jet\,candidates}}{{\rm d}p^{\rm ch}_{\rm T,jet}} \times \frac{P_{\rm b}}{\varepsilon_{\rm b}}, \tag{1}$$

where $P_{\rm b}$ is the b-jet sample purity, defined as the fraction of true b jets among all tagged b-jet candidates, and $\varepsilon_{\rm b}$ is the tagging efficiency, which represents the probability that a true b jet passes the SV tagging selections. In case of p–Pb collisions, the b-jet tagging efficiency was estimated from a MC simulation based on the EPOS event generator [5] with embedded PYTHIA 6 [6] events containing a $b\bar{b}$ pair, propagated through a simulation of the ALICE detector with the GEANT 3 transport code [7]. For pp collisions a Monte Carlo simulation based on PYTHIA 8 [8] was used.

The purity of the b-jet candidate sample was estimated by means of a hybrid method that combines data-driven template fitting strategies and simulations. The data-driven template fit method parameterizes the measured invariant mass distribution of the selected secondary vertices as a linear combination of templates corresponding to b jets, c jets, and light-flavor jets, see Fig. 1. The invariant mass was calculated from the three prongs that were used to reconstruct the secondary vertex assuming that all tracks have the mass of a charged pion. The templates were obtained from the simulations discussed above. However, the limited statistic of the measured data prevented the use of the template fitting method for jets with momenta larger than 30–40 GeV/c. Therefore, the purity was also estimated based on POWHEG HVQ simulations [9]. In this approach, the POWHEG generator was used to calculate $p_{\rm T}$ spectra of b and c jets at the particle level. The spectra were then folded with a response matrix that accounted for the jet $p_{\rm T}$ smearing due to local background fluctuations and instrumental effects. The corresponding spectrum of light-flavor jets was assessed by subtracting the smeared b-jet and c-jet spectra from the raw inclusive jet spectrum. The resulting purity of the selected b-jet sample then equals:

$$P_{\rm b} = \frac{N_{\rm b} \cdot \varepsilon_{\rm b}}{N_{\rm b} \cdot \varepsilon_{\rm b} + N_{\rm c} \cdot \varepsilon_{\rm c} + N_{\rm LF} \cdot \varepsilon_{\rm LF}}, \tag{2}$$

where $N_{\rm b}$, $N_{\rm c}$, $N_{\rm LF}$ denote the raw inclusive $p_{\rm T}$ spectra of different jet flavors and $\varepsilon_{\rm b}$, $\varepsilon_{\rm c}$, $\varepsilon_{\rm LF}$ are the associated SV tagging efficiencies. This purity estimate relies on model parameters that cannot be directly validated as the quark masses and the renormalization and factorization scales used in the computation of the beauty and the charm production cross sections. Hence, an analysis was carried out comparing the simulated purities with the purities obtained by the data-driven invariant-mass template fit method to determine configurations of the simulations that are consistent with the results of the data-driven method, see the right panel of Fig. 1.

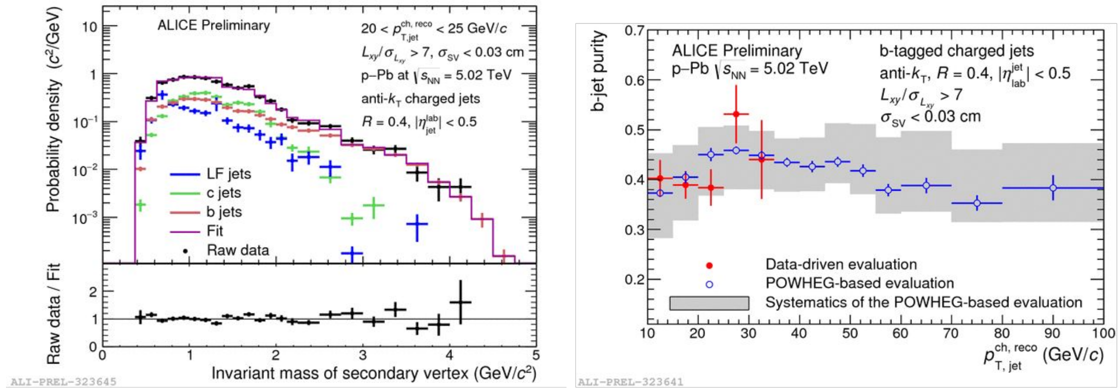

Figure 1: Left: invariant mass distribution of the most displaced secondary vertex in jets with $20 < p_{\rm T,jet}^{\rm ch,reco} < 30$ GeV/c for the default topological selections. The measured data (black points) are fitted by the sum of Monte Carlo invariant-mass templates for different jet flavours. Right: comparison of b-jet purities obtained with the data-driven method and POWHEG based estimate (Eq. 2) for the optimal choice of POWHEG settings. The gray band represents the spread of purities obtained for the POWHEG settings that provide purity values compatible with the data-driven estimator.

The raw spectrum of b jets given by Eq. 1 was then corrected for momentum smearing due to local background fluctuations and detector effects by means of a SVD unfolding [10]. The fully corrected $p_{\rm T}$ differential inclusive production cross-section of charged-particle b jets in p–Pb collisions is shown in the left panel of Fig. 2.

The spectrum is compatible with a simulation performed with the POWHEG HVQ programme [9], used to generate the hard-scattering kinematics with NLO accuracy in perturbative QCD, with the PYTHIA6 event generator [11] used for parton shower and hadronization. The EPS09NLO parametrization of nuclear Parton Distribution Functions was used [12]. The nuclear modification factor for charged-particle b jets was calculated as:

$$R_{\rm pPb}^{\rm bjets} = \frac{1}{A} \frac{{\rm d}\sigma_{\rm pPb}^{\rm bjets}/{\rm d}p_{\rm T,chjet}}{{\rm d}\sigma_{\rm pp}^{\rm bjets}/{\rm d}p_{\rm T,chjet}} \tag{3}$$

where A is the Pb mass number. The result is compared to the analogous measurement for full-jets from CMS [13] and shows good agreement. The $R_{\rm pPb}$ measurement is consistent with unity within uncertainties, signalizing that the ALICE measurement does not show to be affected by cold nuclear matter effects for the current resolution.

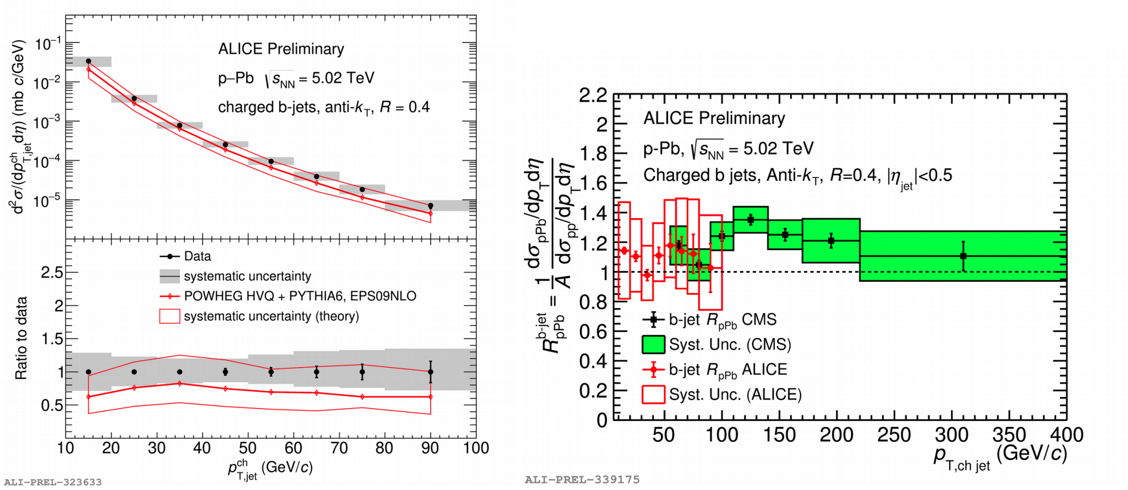

Figure 2: Left: Fully corrected p_{T}-differential spectrum of charged b jets with $R = 0.4$ obtained with the SV tagging method in minimum bias p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The data are compared to the POWHEG HVQ tune with the PYTHIA 6 parton shower and the EPS09NLO nuclear modification of the parton distribution functions. Right: The nuclear modification factor R_{pPb} for charged-particle b jets measured by ALICE compared to the b-jet measurement from the CMS experiment.

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