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

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Due to their large mass, b quarks are produced in initial hard scatterings and their production rate is calculable from perturbative quantum chromodynamics. In heavy-ion collisions, the production of b jets is affected by jet quenching and cold nuclear matter (CNM) effects. The size of the CNM effects can be assessed from the measurement of b-jet production in p–Pb collisions.

b jets can be efficiently tagged through displaced decay vertices of b hadrons ($c\tau \approx 500$ μm). The ALICE experiment at the LHC [*] reconstructs such vertices with help of excellent tracking capabilities of the Inner Tracking System detector.

Reconstruction of b-jet candidates

- **Charged-particle** based jets were reconstructed using the anti-$k_T$ algorithm with $R = 0.4$, where $R$ – is the radius of the jet cone.

- Jet constituents have $p_T > 150$ MeV/c and pseudorapidity $|\eta| < 0.9$.

- Pseudorapidity of jets was constrained to $|\eta_{jet}| < 0.5$.

- Two independent methods were used for b-jet tagging
  1) **Impact parameter** method - distance of closest approach of jet constituents to primary vertex.
  2) **Secondary vertex** (SV) method - properties of most displaced 3-prong secondary vertex.

Discrimination variables to tag b-jet candidates and suppress the admixture of light-flavor and c-quark jets used in the SV method:

- **Minimal significance of the SV displacement:** $SL_{xy} = L_{xy}/\sigma_{L_{xy}}$
  
  - $L_{xy}$ – distance between primary and secondary vertices
  - $\sigma_{L_{xy}}$ – uncertainty of $L_{xy}$ measurement

- **Upper limit on the SV resolution:** $\sigma_{sv} = \sqrt{\sum_{i=1}^{3} d_i^2}$
  
  - $d_i$ – distance of closest approach (DCA) of the i-th prong to the SV

Default cut: $\sigma_{sv} < 0.03$ cm, $L_{xy}/\sigma_{L_{xy}} > 7$
Correction of b-jet spectra

Measured spectrum of b-jet candidates needs to be corrected for SV tagging purity and efficiency:

\[
\frac{dN_{b\text{-}jet}^{\text{primary}}}{dp_{T, jet ch}} = \frac{dN_{b\text{-}jet candidates}^{\text{raw}}}{dp_{T, jet ch}} \times \frac{P_b}{\varepsilon_b}
\]

\( \varepsilon_b \) – probability that true b jet will pass SV tagging selections.
\( P_b \) – fraction of true b-jets among all tagged b-jet candidates.

Purity of b-jet candidates is estimated from:

a) data-driven SV invariant mass template fit method
b) POWHEG simulation based approach, where

\[
P_b = \frac{N_b \varepsilon_b}{N_b \varepsilon_b + N_c \varepsilon_c + N_{LF} \varepsilon_{LF}}
\]

\( N_b, N_c \) – POWHEG \( p_T \) spectrum of b and c-jets folded with the response matrix
\( N_{LF} \) – \( p_T \) spectrum of light flavour-jets (LF): \( N_{LF} = N_{\text{raw}} - N_b - N_c \)
\( \varepsilon_b, \varepsilon_c, \varepsilon_{LF} \) – efficiency of SV tagging for b, c and LF jets

POWHEG variations were required to provide purity compatible with the data-driven method.

Figure 3: b-jet tagging efficiency and mistagging efficiency for c jets and light-flavor jets

Figure 4: b-jet purities from the data-driven template fit method and the POWHEG for the optimal MC settings
Figure 5: The differential cross-section of charged-particle anti-$k_T$ b jets with $R = 0.4$ measured in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with systematic uncertainties represented by grey rectrangles.

Figure 6: The nuclear modification factor $R_{pPb}$ for charged-particle b jets measured by the ALICE experiment, compared with the b-jet measurement from the CMS experiment [*].

\[ R_{pPb}^{b \text{ jet}} = \frac{1}{A} \frac{d \sigma_{pPb}^{b \text{ jet}}/dp_{T, ch \text{ jet}}}{d \sigma_{pp}^{b \text{ jet}}/dp_{T, ch \text{ jet}}} \]

- Fully corrected $p_T$-differential inclusive production cross section of charged-particle b jets in p-Pb is compatible with calculation by POWHEG HVQ simulation with EPS09NLO pdfs.
- The ALICE measurement of charged b-jet $R_{pPb}$ is compatible with the analogous CMS measurements for full-jets. No strong CNM effects present in p–Pb.