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

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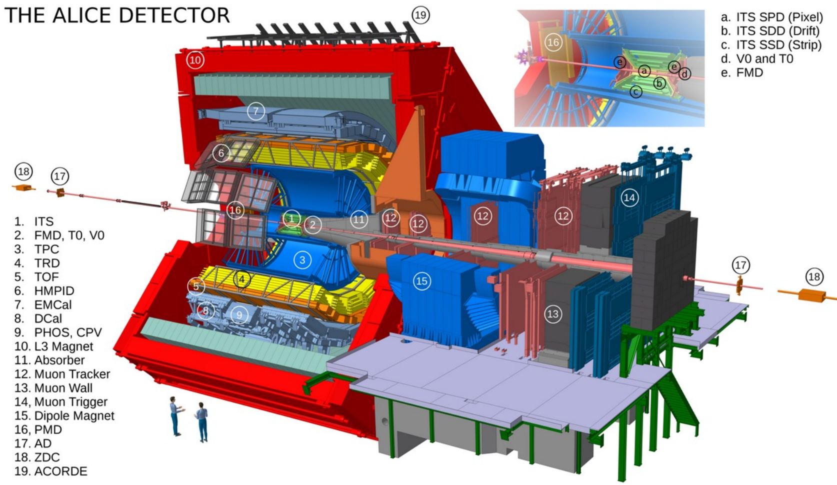
Jet production in heavy-ion collisions is affected by jet quenching and cold nuclear matter (CNM) effects. The size of these effects can be assessed by comparing results from AA collisions with reference systems such as p−Pb and pp collisions. Ideal probes for such studies are b quarks: due to their large mass, b quarks are produced in initial hard scatterings and their production rate are calculable from perturbative QCD.

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

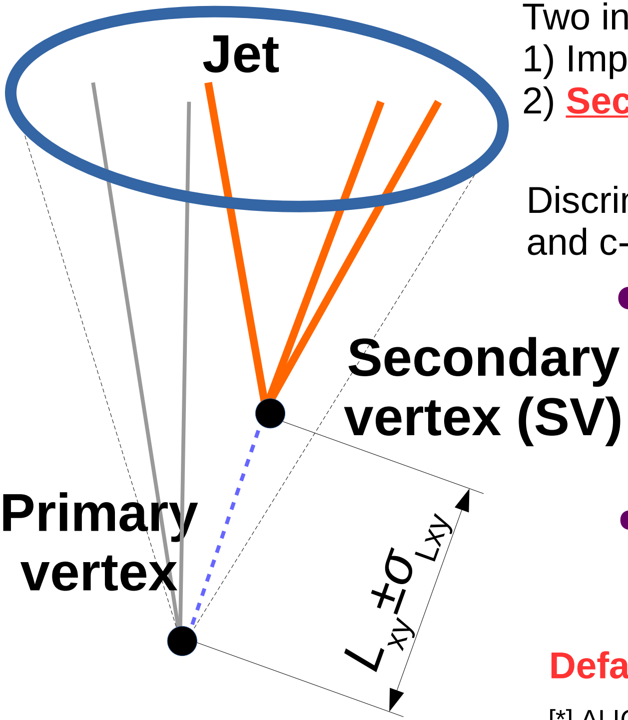


Results were recently published in ALICE Collaboration, JHEP 01 (2022) 178 (link)

[*] ALICE Collaboration, Int.J.Mod.Phys. A 29, 1430044 (2014)

Reconstruction of b-jet candidates

- **Charged-particle** jets were reconstructed with the **anti-k_T** algorithm with the radius of the jet cone of $\boldsymbol{R = 0.4}$.
- Jet constituents have $\boldsymbol{p_T > 150}$ **MeV/*c*** and pseudorapidity $\boldsymbol{|\eta| < 0.9}$.
- Pseudorapidity of jets was constrained to $\boldsymbol{|\eta_{jet}| < 0.5}$.



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

Discriminating 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:** $SL_{xy} = L_{xy}/\sigma_{Lxy}$

  L_{xy} – distance between primary and secondary vertices
  σ_{Lxy} – 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 i-th prong to the SV

Default SV selection: $\sigma_{SV} < 0.03$ cm, $L_{xy}/\sigma_{Lxy} > 7$

[*] ALICE Collaboration, JHEP 01 (2022) 178

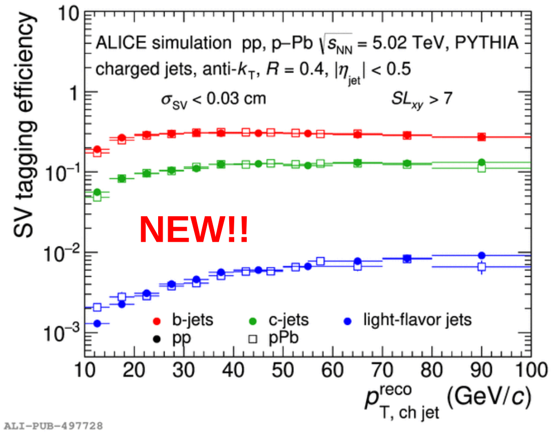
Correction of the b-jet spectra

The obtained spectrum of b-jet candidates needs to be corrected to account for purity and efficiency of b-jet tagging:

$$\frac{d N^{\text{primary}}_{\text{b-jet}}}{d p_{\text{T, ch jet}}} = \frac{d N^{\text{raw}}_{\text{b-jet candidates}}}{d p_{\text{T, ch jet}}} \times \frac{P_{\text{b}}}{\varepsilon_{\text{b}}}$$

ε_{b} – the probability that true b jet will pass SV tagging selections (efficiency)

P_{b} – the fraction of true b jets among all tagged b-jet candidates (purity)



b-jet tagging efficiency and mistagging efficiency for c jets and light-flavor jets obtained with PYTHIA detector-level simulation

Purity of b-jet candidates was estimated using two methods:

- data-driven SV invariant mass template fit method (fails for $p_{\text{T,ch jet}}$ > 30–40 GeV/c)
- POWHEG simulation-based approach (wider $p_{\text{T,ch jet}}$ range, but depends on model settings):

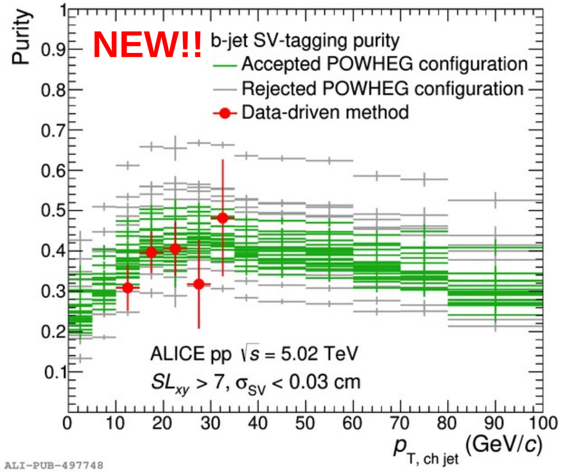
$$P_{\text{b}} = \frac{N_{\text{b}}\varepsilon_{\text{b}}}{N_{\text{b}}\varepsilon_{\text{b}} + N_{\text{c}}\varepsilon_{\text{c}} + N_{\text{LF}}\varepsilon_{\text{LF}}}$$

$N_{\text{b}}, N_{\text{c}}$ – POWHEG p_{T} spectrum of b and c-jets folded with the response matrix

N_{LF} – p_{T} spectrum of light flavour jets (LF): $N_{\text{LF}} = N_{\text{raw}} - N_{\text{b}} - N_{\text{c}}$

N_{raw} – raw p_{T} spectrum of inclusive jets

$\varepsilon_{\text{b}}, \varepsilon_{\text{c}}, \varepsilon_{\text{LF}}$ – efficiency of SV tagging for b, c and LF jets

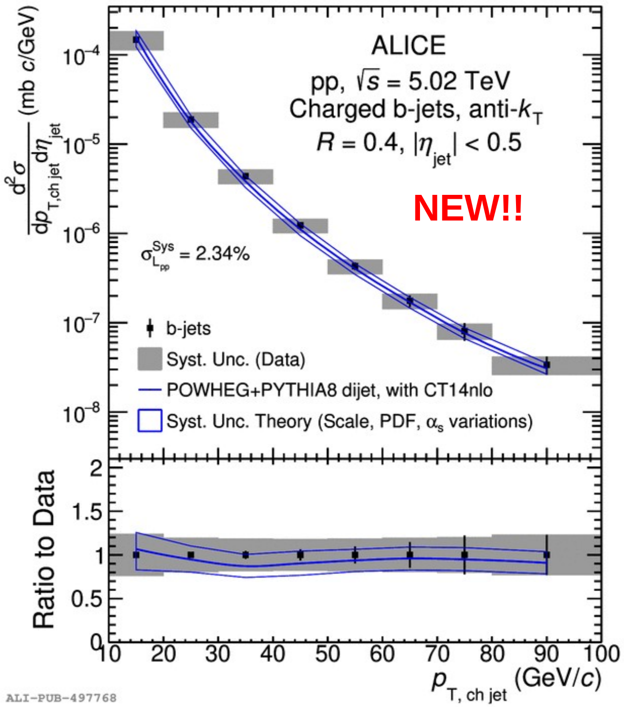


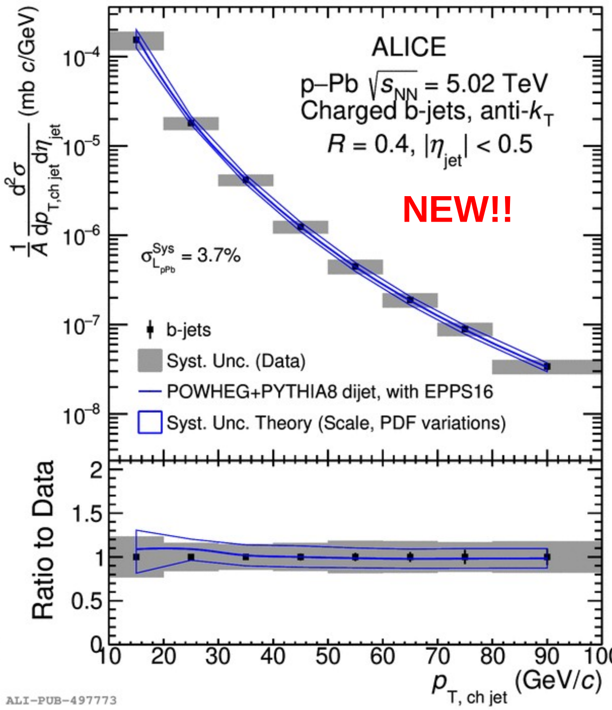
b-jet purities from the data-driven template fit method and the POWHEG for the optimal MC settings

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

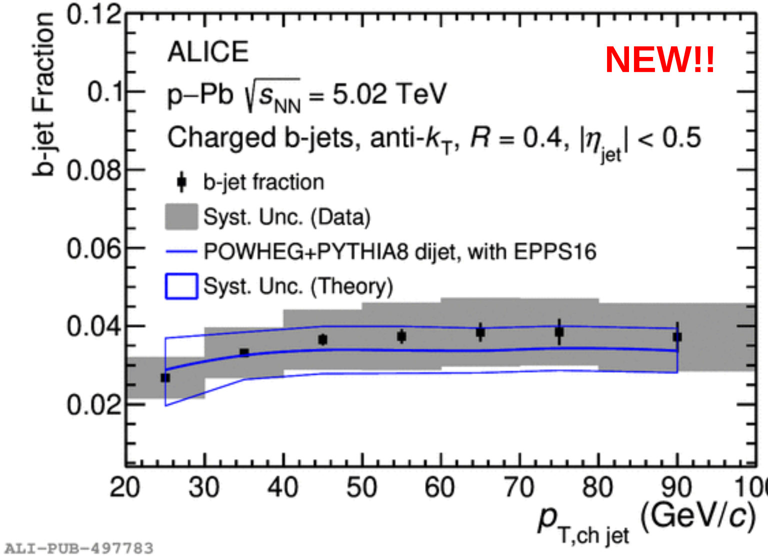
The differential production cross-section

The Best Linear Unbiased Estimator (BLUE)[*] method was used for merging the results of the SV and IP methods.





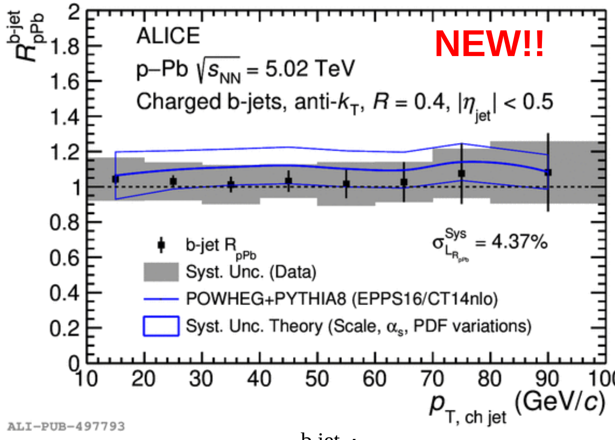
The differential cross-section for pp (left) and p−Pb (right) minimum bias collisions with systematic uncertainties represented by grey boxes. The measurements are consistent with calculations by POWHEG with PYTHIA fragmentation.



The b-jet fraction is defined as a ratio of spectra of b jets and inclusive untagged charged-particle b jets. The obtained value is consistent with the POWHEG predictions within the uncertainties. b jets amount about 4% of all jets.

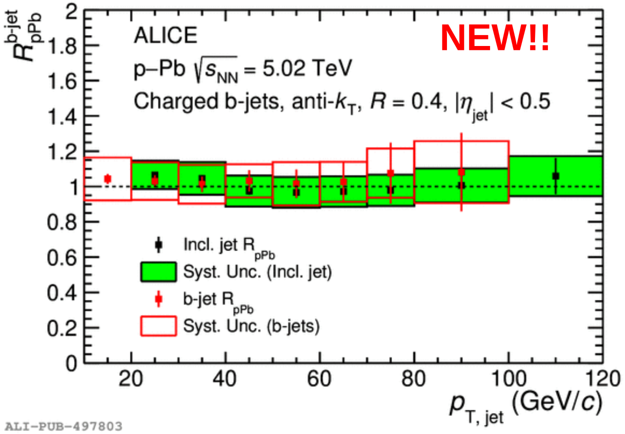
[*] L. Lyons, D. Gibaut and P. Clifford, Nucl. Instrum. Meth. A 270 (1988) 110

Nuclear modification factor

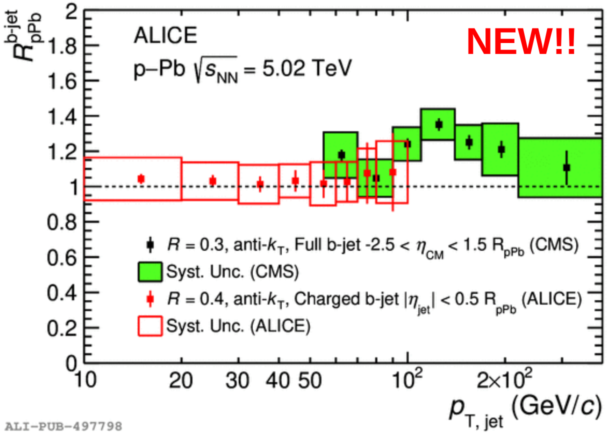


$$R^{\text{b jet}}_{\text{pPb}} = \frac{1}{A} \frac{\mathrm{d}\sigma^{\text{b jet}}_{\text{pPb}} / \mathrm{d}p_{\text{T,ch jet}}}{\mathrm{d}\sigma^{\text{b jet}}_{\text{pp}} / \mathrm{d}p_{\text{T,ch jet}}}$$

The measurement is compatible with POWHEG calculations, including a mild anti-shadowing modification predicted by EPPS16 nuclear PDF.



The nuclear modification factor R_{pPb} for charged-particle b jets measured by the ALICE experiment is compatible with the R_{pPb} of inclusive charged-particle jets measured by ALICE[*].



The ALICE measurement of charged-particle b-jet R_{pPb} is compatible with the analogous CMS measurement for full-jets[**]. The R_{pPb} does not show to be affected by CNM effects within uncertainties.

The authors acknowledge support by the grant LTT17018

[*] ALICE collaboration, Phys. Lett. B 749 (2015) 68.
[**] CMS Collaboration, Phys. Lett. B 754 (2016).