Analysis of b-jet production in p–Pb and pp collisions at $\sqrt{s_{NN}} = 5$ TeV with ALICE

Artem Isakov, NPI CAS
for the ALICE Collaboration

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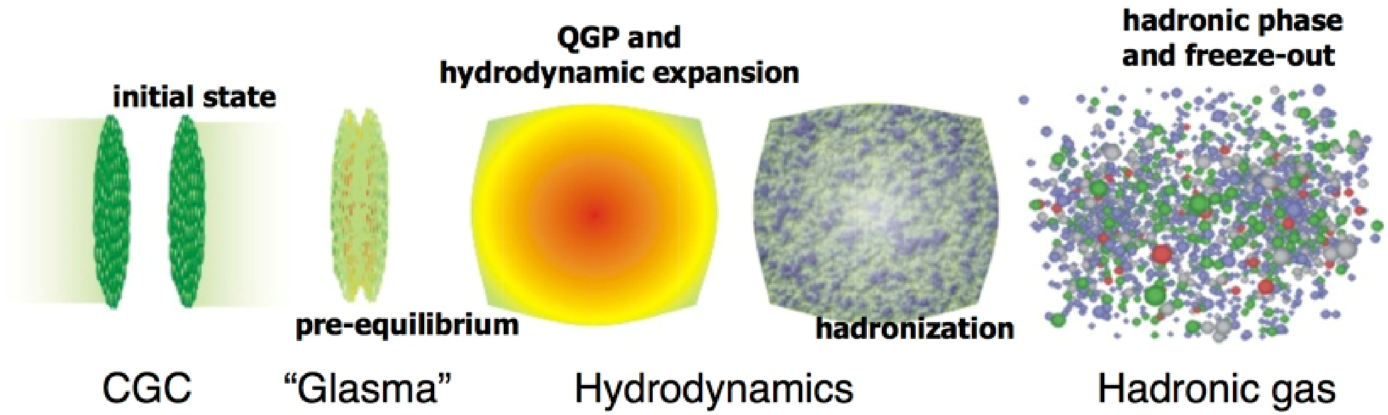
Nuclear modification factor

Quark-gluon plasma (QGP) is created in heavy-ion (HI) collisions:



Signatures of QGP:

- **Collective flow** → QGP acts like nearly-perfect liquid
- ***Jet quenching*** → QGP slows penetrating patrons

Nuclear modification factor compares particle yields in HI and in pp collisions scaled by the number of binary NN collisions (N_{coll}):

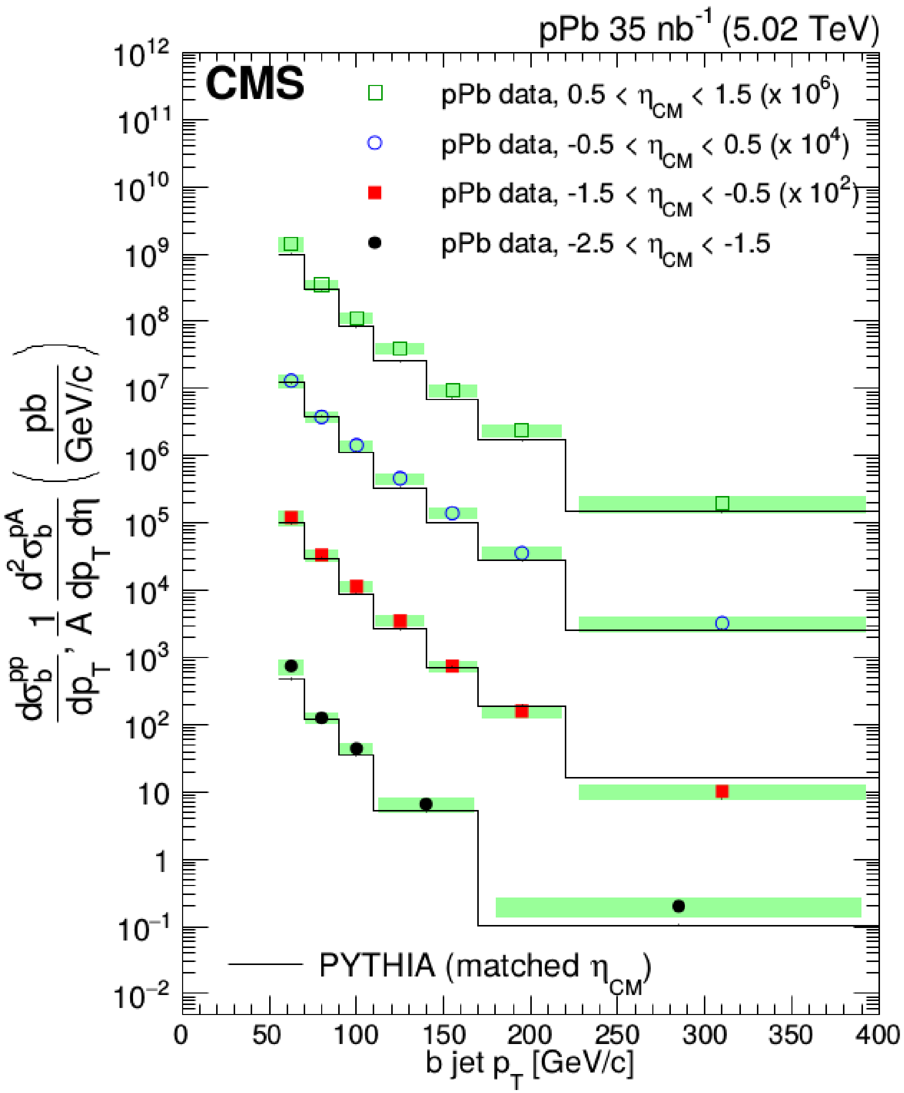
$$R_{AA} = \frac{\frac{dN_{AA}}{dp_T}}{\langle N_{\text{coll}} \rangle \frac{dN_{pp}}{dp_T}}$$

Different collision systems:

- $R_{pA} \neq 1$ → presence of cold nuclear matter (CNM) effects
- $R_{AA} < 1$ → indication of final state effects (medium energy loss)

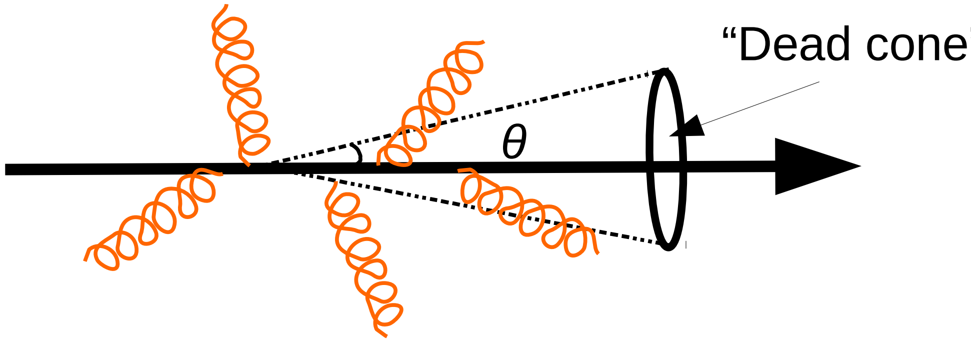
b jets

Inclusive b jets in p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV, full jets[*]



Properties of b-quark:

- large mass (4.62 GeV/c^2) → it can be created only in initial hard scatterings. Its production rate can be calculated from pQCD
- long lifetime → it survives through the whole evolution of QGP

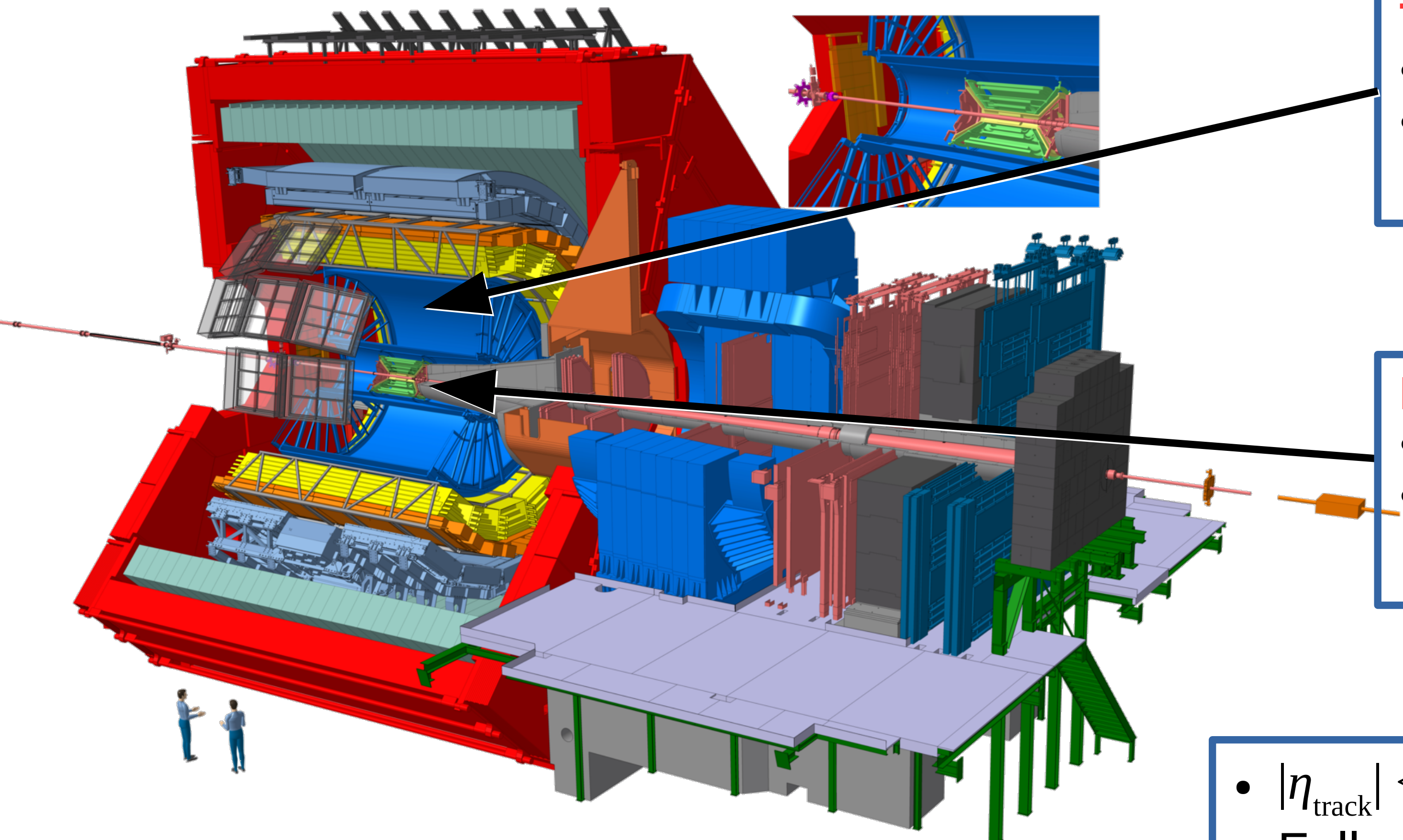


dead cone effect – gluon radiation from massive quarks is suppressed at angles $\theta < m/E$

ALICE has excellent capabilities at **low-p_T**

[*] CMS, CERN-PH-EP/2013-037

ALICE experiment



Time Projection Chamber
- Track reconstruction
- Particle identification via specific energy loss

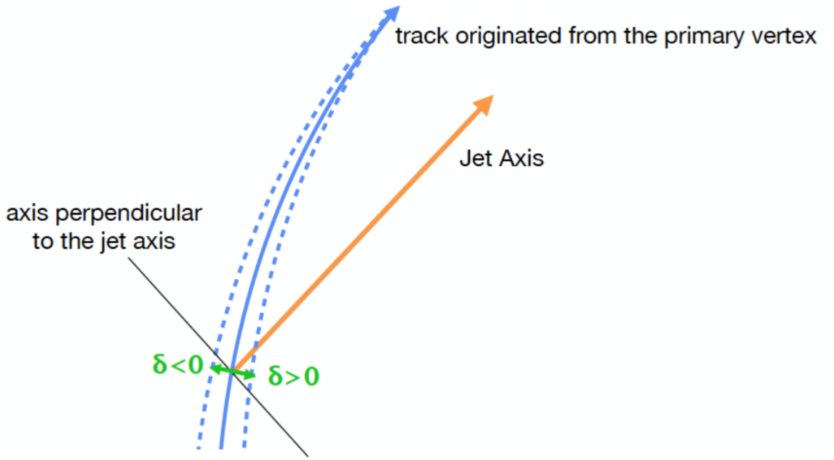
Inner Tracking System
- Track reconstruction
- Primary and secondary vertex reconstruction

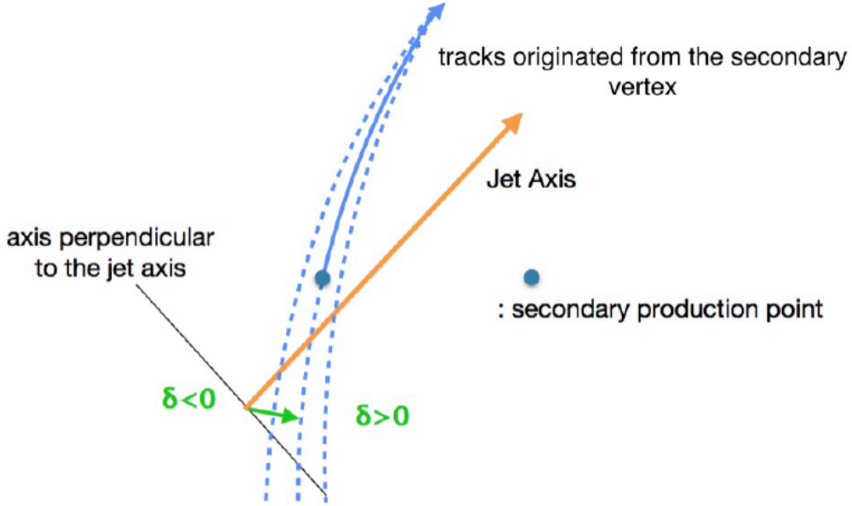
- $|\eta_{\mathrm{track}}| < 0.9$
- Full azimuth
- 0.5 T solenoid
- $p_{\mathrm{T,\,track}} > 0.15$ GeV/c

V0 - scintillator arrays located at forward and backward pseudorapidity for triggering and centrality determination

b-jet tagging via impact parameter

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.





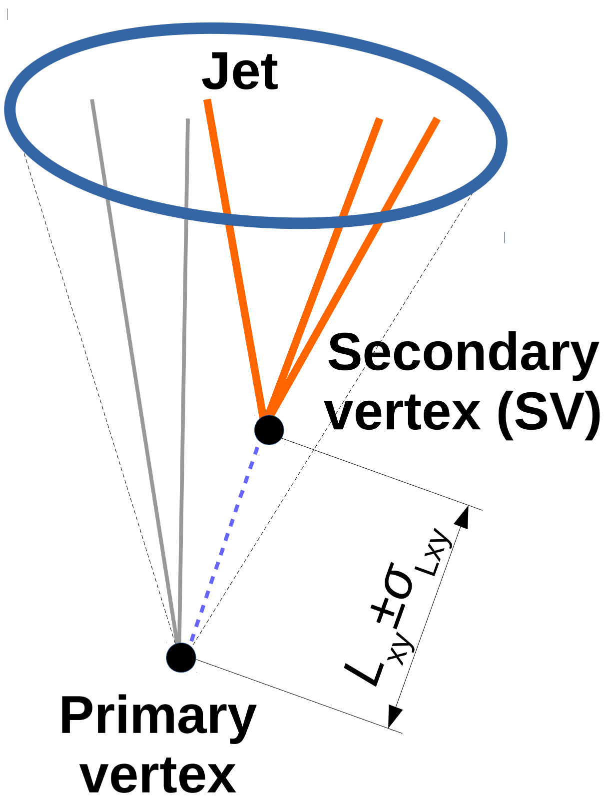
b-jet candidate selection with IP method:

- Impact parameter significance, $sd_{xy} = \delta \cdot d_{xy} / \sigma_{dxy}$, is calculated for each track in the jet:
  - $\boldsymbol{\delta}$ – impact parameter sign
  - $\boldsymbol{d_{xy}}$ – 2D impact parameter
  - $\boldsymbol{\sigma_{dxy}}$ – uncertainty of d_{XY} measurement
- sd_{xy} of the tracks are sorted in descending order
- b jets are tagged by imposing the criteria:

*2*th most displaced track,
$d_{xy} > d_{xy}^{treshold}$, threshold parameter varied:

b-jet tagging via secondary vertex

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



b-jet candidate selection with SV method:

- 3 prong SV is made out of jet constituents
- In each event we consider the most displaced SV

- **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 cut: σ_{SV} < 0.03 cm, L_{XY}/σ_{Lxy} > 7

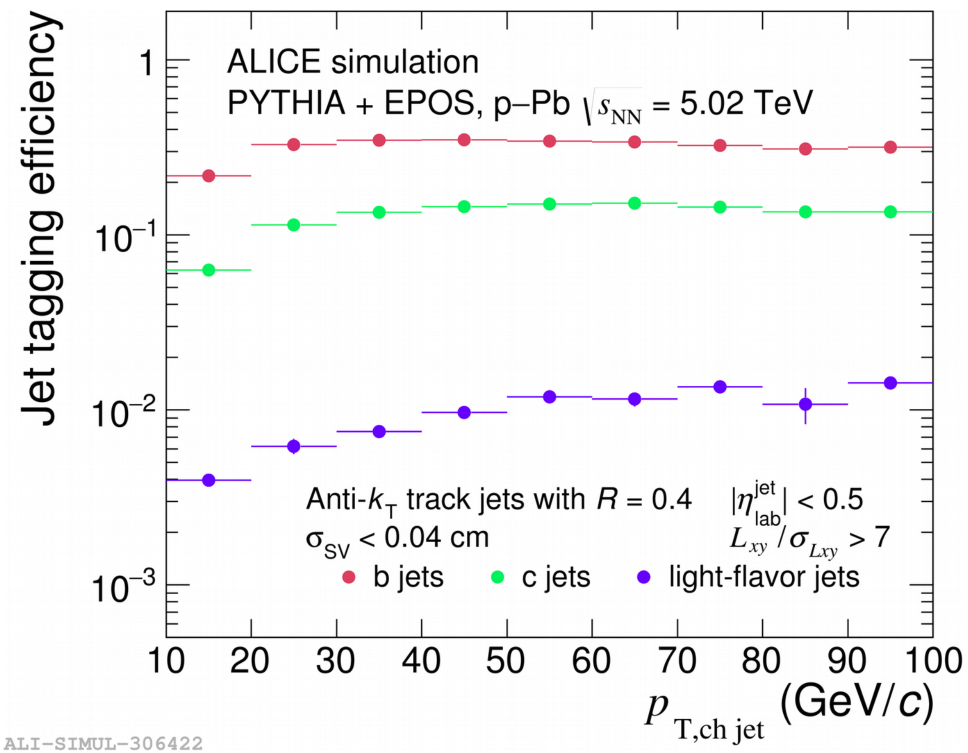
Corrections of b-jet spectra

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

$$\frac{dN^{primary}_{b\text{-}jet}}{dp_{T,\,jet\,ch}} = \frac{dN^{raw}_{b\text{-}jet\,candidates}}{dp_{T,\,jet\,ch}} \times \frac{P_b}{\varepsilon_b}$$

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 is estimated from EPOS+PYTHIA detector-level simulation:

$$\varepsilon_b = \frac{N^{selected}_{b\text{-}jets}}{N^{all}_{b\text{-}jets}}$$

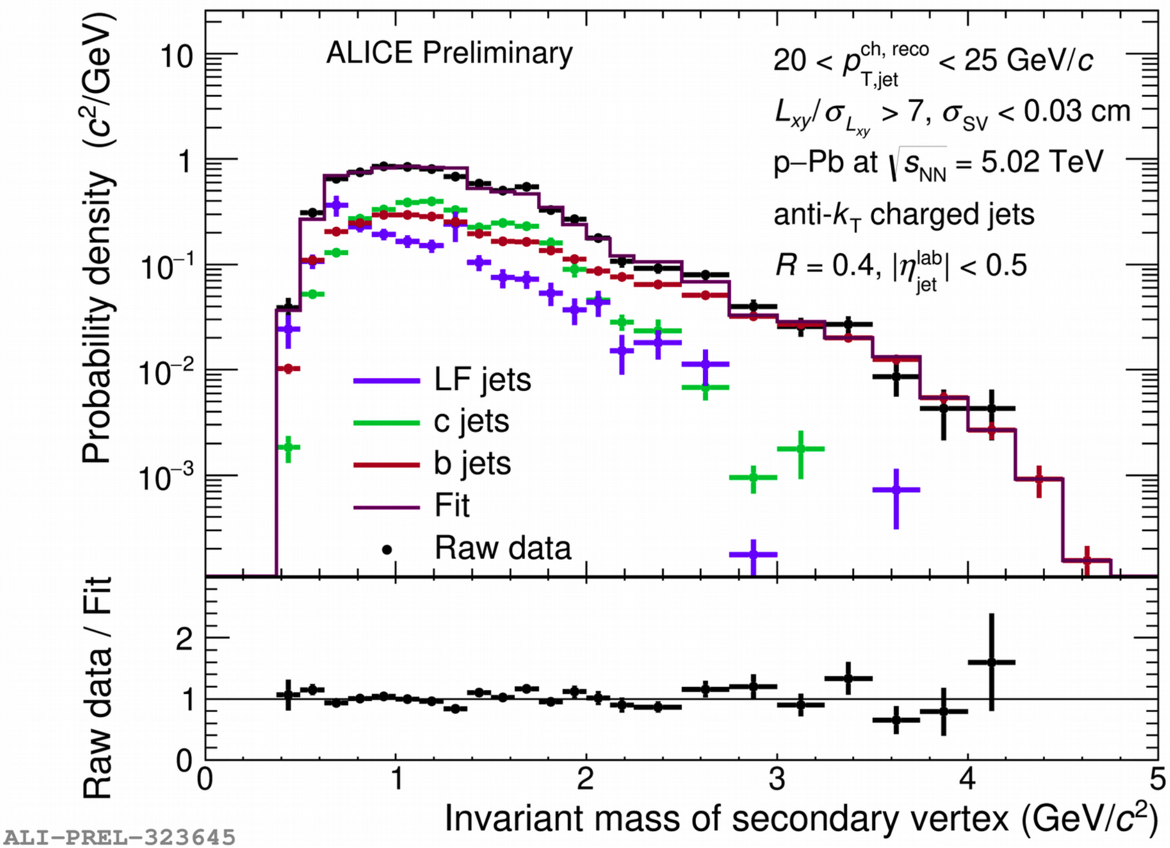
$N^{all}_{b\text{-}jets}$ – the number of b-jets without any constraint on parameters of the SV

$N^{selected}_{b\text{-}jets}$ – the number of b-jets that were reconstructed after the SV cuts

b-jet tagging efficiency in p-Pb for the default SV cuts: $\boldsymbol{\varepsilon_b \approx 35\ \%}$, $\varepsilon_c \approx 11\ \%$, $\varepsilon_{LF} \approx 1\ \%$

Data driven method for b-jet purity

The purity of the b-jet candidate was estimated by hybrid method that utilizes data-driven template fitting and POWHEG simulations:



The data driven method describes the measured distribution of invariant mass of SV as a linear combination of MC templates:

$$\begin{cases} n_{SV} = P_b \cdot T_b + P_c \cdot T_c + P_{LF} \cdot T_{LF} \\ 1 = P_b + P_c + P_{LF} \end{cases}$$

n_{SV} – measured SV invariant mass
T_b, T_c, T_{LF} – MC template for each jet flavor
P_b, P_c, P_{LF} – purity for each jet flavor

The template fitting method fails for jets with momenta larger than 30–40 GeV/c

POWHEG based method for b-jet purity

POWHEG method - based on *b* and *c*-jets spectra calculated by Next-to-Leading Order (NLO) POWHEG generator:

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

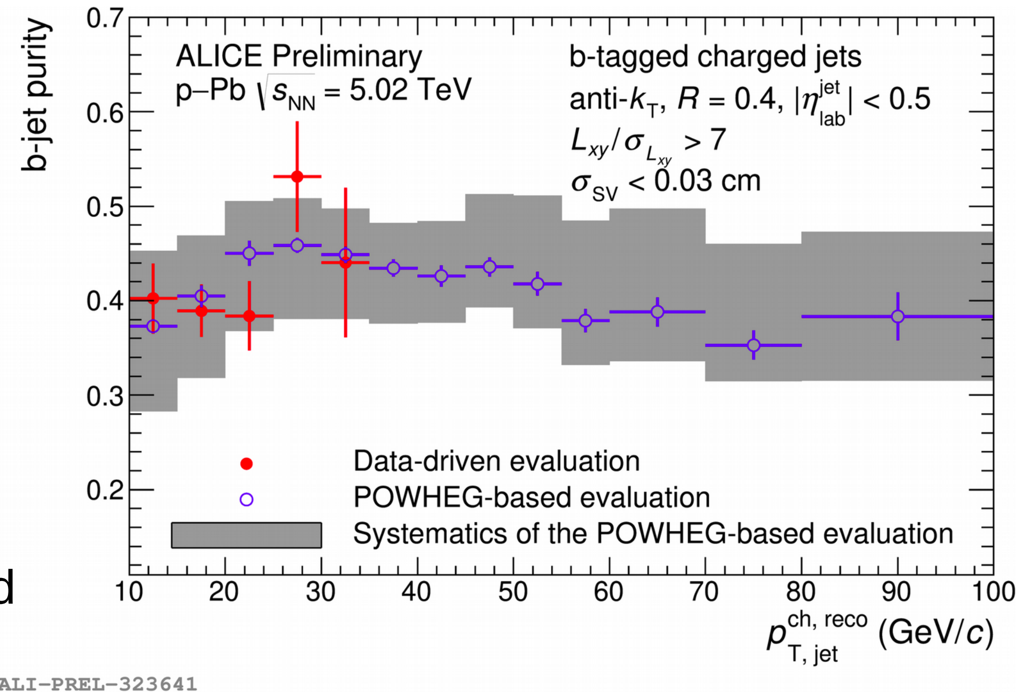
$\boldsymbol{N_b, N_c}$ – POWHEG p_T spectrum of b and c-jets folded with the response matrix

$\boldsymbol{N_{LF}}$ – p_T spectrum of light flavour-jets (LF):

$$N_{LF} = N_{raw} - N_b - N_c$$

$\boldsymbol{N_{raw}}$ – raw p_T spectrum of inclusive jets

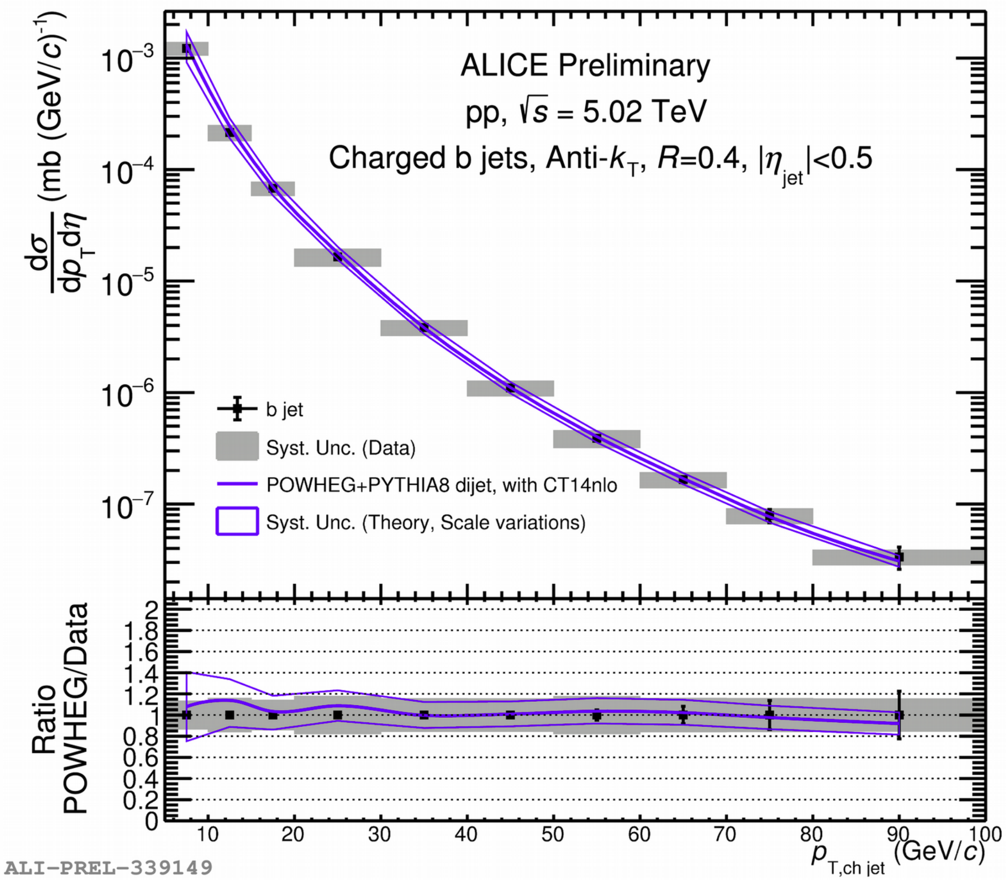
$\boldsymbol{\varepsilon_b, \varepsilon_c, \varepsilon_{LF}}$ – efficiency of SV tagging for b, c and LF jets



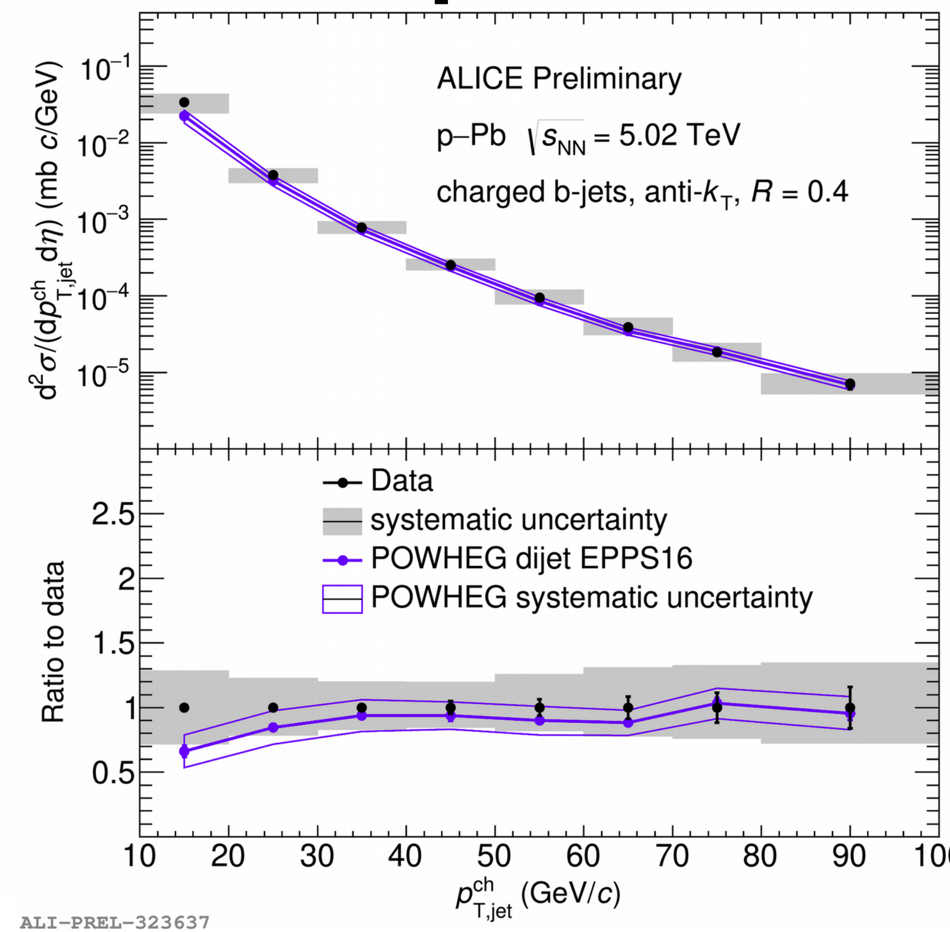
Different POWHEG settings were tested against the template fit results to find plausible POWHEG settings (regularization and renormalization scale)

The differential production cross section

pp

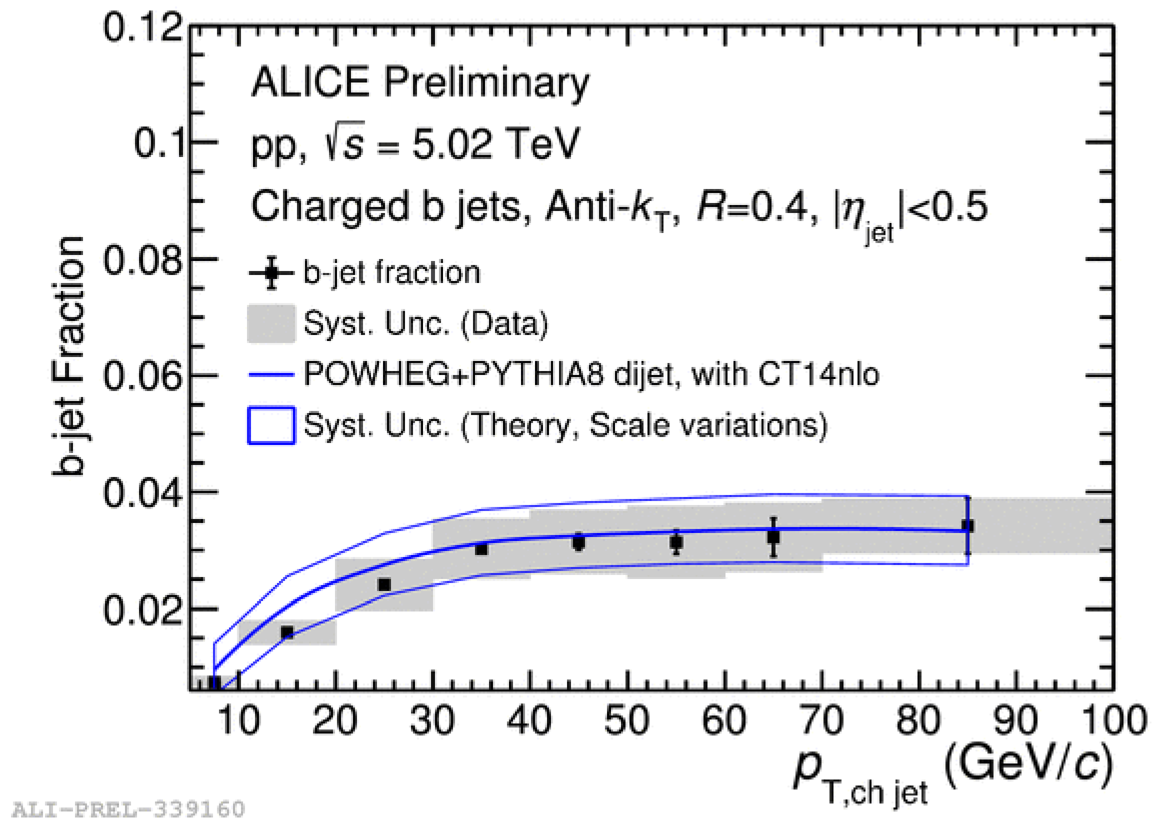


p-Pb

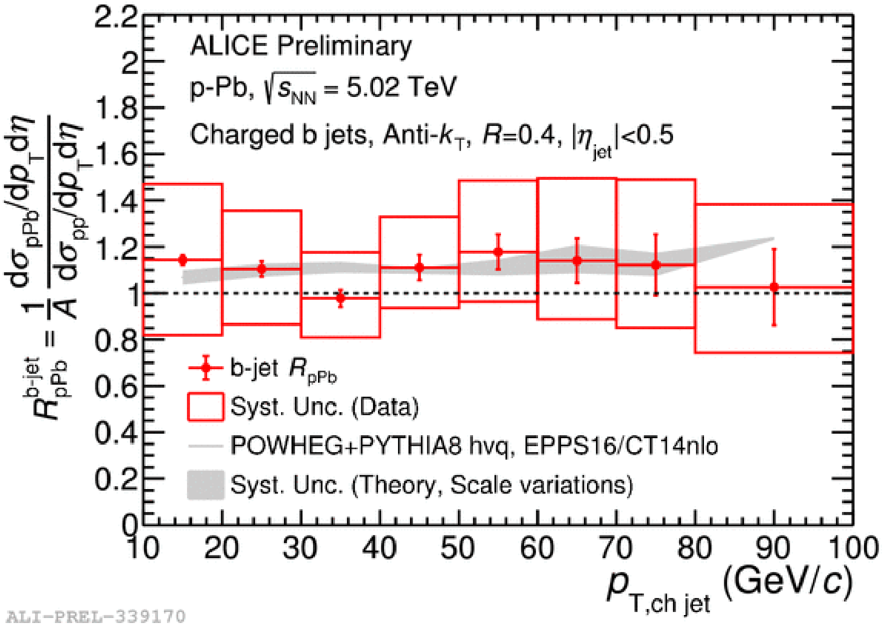


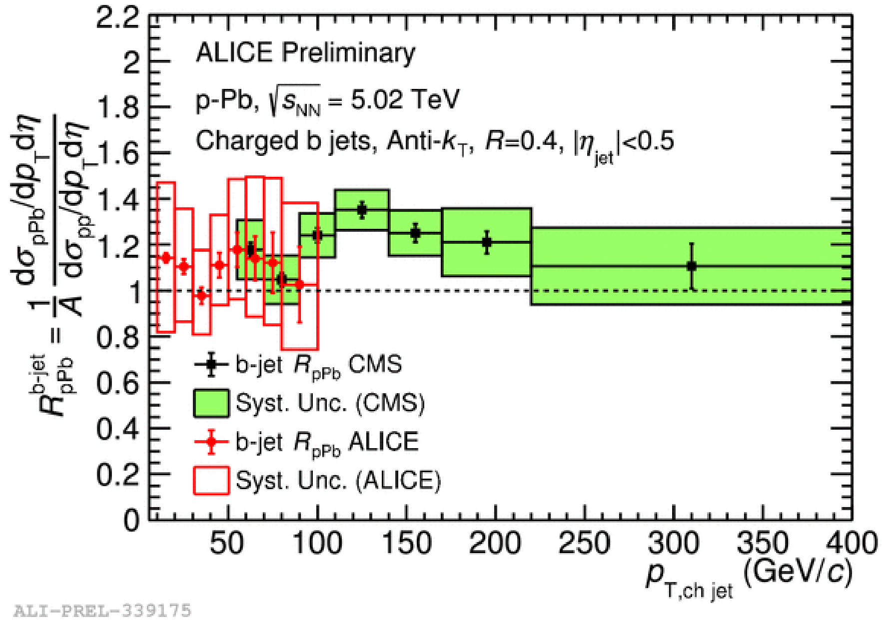
The measurement of b-jet the production cross section agrees with POWHEG calculations

The measurement of b-jet fraction in pp collisions



The measured b-jet fraction is consistent with the POWHEG predictions within the uncertainties.





No strong CNM effects present in p–Pb.

CMS measured full anti-k_T R=0.3 b-jets within $-2.5 < \eta_{jet} < 1.5$.

Summary

- Results of differential production cross-section and b-jet fraction in pp collisions are compatible with POWHEG simulations
- Within the current precision the ALICE measurement of charged b-jet R_{pPb} does not show to be affected by cold nuclear matter effects.
- The ALICE measurement of charged b-jet R_{pPb} is compatible with the analogous CMS measurements for full-jets.

Backup

Bjet Analysis settings

Event selection

- Minimum bias trigger (V0 scintillator arrays)
- $|z_{vtx}| < 10$ cm
- Pileup rejection

After event selection we have **$6 \cdot 10^8$** minimum bias events (**pPb**)
$9.2 \cdot 10^8$ minimum bias events (**pp**)

Track selection

- $|\eta_{track}| < 0.9$

Jet selection:

- Charged-particle anti-k_T, R=0.4
- p_T recombination scheme
- $p_{T,\text{ constituent}} > 0.15$ GeV/c
- $|\eta_{jet}| < 0.5$

Background density correction:

Two leading k_T jets are excluded

$$p_{T,charged\ jet}^{corrected} = p_{T,charged\ jet}^{RAW} - \rho \cdot A_{jet}$$

$$\rho = \frac{A_{physical\ jets}}{A_{all\ jets}} \times median_{k_{T\ physical\ jet}} \left\{ \frac{p_{T,jet}^{ch,raw}}{A_{jet}} \right\}$$