Prospects for beauty-jet measurements with ALICE

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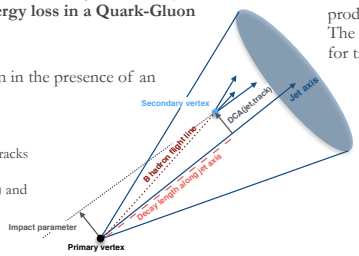
Introduction

Determine beauty quark production rate via the measurement of beauty-flavoured jets. Quantify mass and colour charge dependence of parton energy loss in a Quark-Gluon Plasma (QGP).

Tag jets coming from fragmentation of beauty quarks
- unbiased selection on the kinematics of the hard scattering, even in the presence of an (underlying) heavy-ion collision

Three main analysis steps:
1. Jet-finding algorithms - reconstruct full jet starting from charged tracks and neutral energy
2. Beauty(b)-tagging algorithms - exploit long lifetime ($c\tau \sim 500$ μm) and large mass (~ 5 GeV/c^2) of B mesons
3. Corrections - unfold jet energy resolution and correct for b-tagging efficiency and charm/light flavour contamination

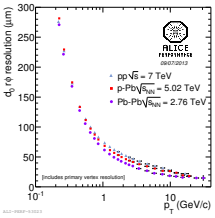


Tracking performance

ALICE ia a general purpose experiment optimized for the study of the **QGP** produced in heavy-ion collisions.
The **Inner Tracking System** (ITS) and **Time Projection Chamber** (TPC) are used for tracking and secondary vertex reconstruction.

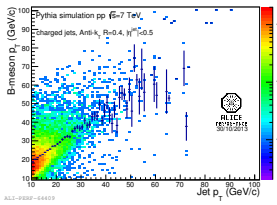
The **track impact parameter** (d_0) is the charged track's distance of closest approach (DCA) to the primary vertex, projected on the transverse plane, perpendicular to the beamline.

High precision tracking
For all collision systems ALICE measures d_0 with a resolution better than 70 μm for $p_T > 1$ GeV/c.



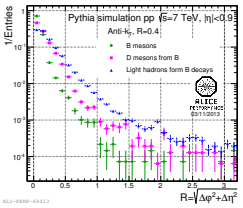
MC studies of b-jet properties

Correlation of B-meson p_T and jet p_T



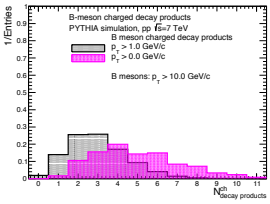
Above 15-20 GeV/c
$p_{T,\,B} \sim p_{T,\,\text{charged jet}} \times 1.5$
(neutral energy not used in the jet reconstruction)

Distribution of particles in jet cone



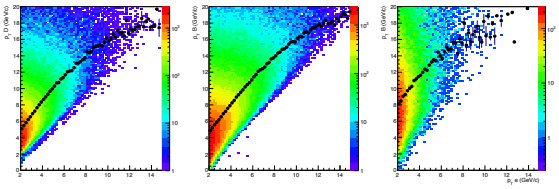
***R*<0.4** {
- B mesons: 99% in jet cone
- D mesons from B: 96%
- light hadrons from B decays: 90%

Charged particles in B decays



Number of charged particles in B decays
~ 5 for $p_{T,\text{daug}} > 0$ GeV/c
2-3 for $p_{T,\text{daug}} > 1$ GeV/c

Semi-electronic decays of D-/B-mesons



- $B \to e^+\nu_e$ anything B.R. ~ 10%, $D^{0(+)} \to e^+\nu_e$ anything B.R. ~ 6(16)%,
- A high-p_T electron carries roughly **half of B meson momentum**
- **Electron identification** with the TPC, the Electromagnetic Calorimeter (EMCal) and the Transition Radiation Detector
- Exploit high-p_T EMCal triggered events

Beauty-jet tagging algorithms

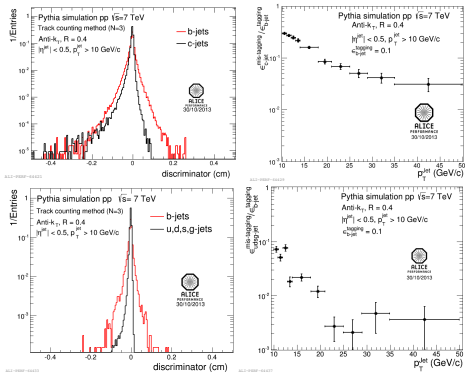
Track counting method

Benefit from the relatively long **lifetime** of B mesons. Calculate the **impact parameter** (d_0) in rφ for each track within the reconstructed charged jet and project along the jet axis. [CMS NOTE-2006/019].

$$d_{0,\text{jet}} = \mathbf{d_0} \cdot \mathbf{p_{T,jet}}$$

The **third most displaced** ($d_{0,\text{jet}}$) value used as **discriminator** (N=3)

✦ Jet flavour defined via the leading (highest p_T) parton in the jet cone.
✦ The $p_{T,\text{jet}}$ is taken from the MC truth to account for neutral particles



Selection criteria:
FastJet Anti-k_T, R=0.4
$p_{T,\text{track}} > 1$ GeV/c
$p_{T,\text{jet}} > 10$ GeV/c
$d_0 < 0.2$ cm
decay length < 10 cm
DCA(jet,track) < 7 μm
ΔR(jet,track) < 0.3

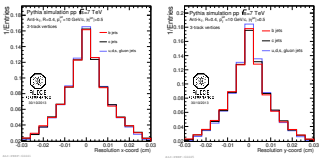
Typical values of the d_0 requirement on the third most displaced track are ~ **100 μm** when $\varepsilon_b = 0.1$

Secondary vertexing method

Benefit from the relatively long **lifetime** and large **mass** of B mesons.
High multiplicity of charged particles produced in the decay.

3-prong vertices selected using tracks from the jet

Select jet flavour using leading parton in the jet

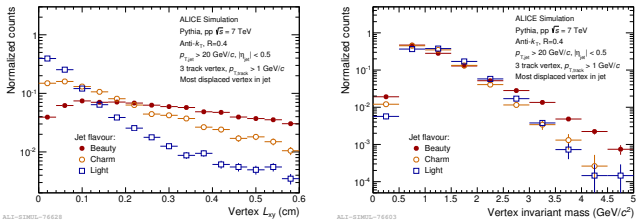


Selection criteria:
FastJet Anti-k_T, R=0.4
$p_{T,\text{track}} > 150$ GeV/c
$p_{T,\text{Reco jet}} > 20$ MeV/c

3-prong vertex
$p_{T,\text{prong}} > 1$ GeV/c
$p_{T,\text{MC jet}} > 20$ GeV/c

Vertex selections:
- $L_{xy} = L_{xy} \times \text{sign}(L_{xy} \cdot p_{T,\text{jet}})$
- 3-track invariant mass
  *input pion mass for track mass hypothesis

What's next?
Cut optimization studies
✦ strong criteria → favouring a pure sample
✦ loose criteria → favouring more statistics, b-jet yield extraction via MC mass template fits



Ongoing studies

- Estimation of the **purity** of the b-tagged sample with current detector setup and with ALICE ITS upgrade
- Correction for b-tagging **efficiency** and **unfolding** of the jet spectrum for the jet energy scale and background fluctuations
- **Electron identification** to enhance the purity, take advantage of the highly efficient EMCal event trigger

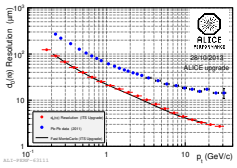
- Tagging algorithm based on the probability of in-jet tracks to be secondary
- Vertex finding algorithm based on vertex clustering and/or N-track vertices
- Comparison of the results obtained using the different algorithms

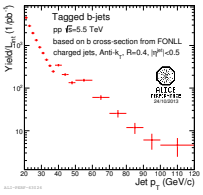
GOALS:
b-jet p_T differential cross section in pp, p-Pb, and Pb-Pb collisions down to low p_T (~20 GeV/c), to complement high-p_T measurements from CMS

Prospects with LHC/ALICE upgrades

ALICE read-out and LHC upgrades (2018)
Higher integrated luminosities: ~10 pb^{-1} in pp and ~10 nb^{-1} in Pb-Pb collisions at $\sqrt{s_{NN}}$=5.5 TeV required by the ALICE upgrade program
High-precision heavy-flavour results, possibility to study **on-line b-jet tagging**

Upgrade of the Inner Tracking System (2018)
x3 (x6) **improvement of the track impact parameter resolution** in the transverse (longitudinal) direction → **improved light-flavour rejection** in b-tagging analyses
[CERN-LHCC-2012-012, CERN-LHCC-2012-013]





Expected yield of raw b-jets per pb^{-1} in minimum bias pp collisions at $\sqrt{s}$=5.5 TeV assuming a constant b-tagging efficiency of 10% for jet $p_T > 20$ GeV/c

Reduced statistical uncertainty on the raw b-jet yield allows measurements over a large momentum range

Achievable purity with improved light-flavour rejection being studied

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