Jet Reconstruction in LHCb

Albert Bursche[1] on behalf of the LHCb Collaboration

[1] Universität Zürich – Physik-Institut Winterthurerstrasse 190, CH 8057 Zürich, Switzerland

DOI: `http://dx.doi.org/10.3204/DESY-PROC-2012-02/146`

We report on the jet reconstruction in LHCb. An overview of the LHCb jet reconstruction is presented and the performance of the jet reconstruction is evaluated.

1 Introduction

The LHCb detector [1] was designed and built to study the properties of charmed and beauty hadrons but it is also used to perform a rich programme of electroweak physics and QCD. In order to reach the LHCb acceptance the produced particles must be moving in the forward direction. This leads to an constraint on the interacting partons, which have to have a large difference in BJÖRKEN–x. LHCb is able to probe partons in the proton BJÖRKEN–x as low as 8×10^{-6} at $Q^2 = 25$ GeV [2]. Most of the studies have been carried out using lepton final states. Reconstruction of jets enables LHCb to extend this programme to include studies like Z production in association with jets [3].

2 LHCb detector

The LHCb detector is a single-arm forward spectrometer covering the pseudo-rapidity range $2 < \eta < 5$, designed for the study of particles containing b or c quarks. The detector includes a high precision tracking system consisting of a silicon-strip vertex detector (VELO) surrounding the pp interaction region, a large-area silicon-strip detector (TT) located upstream of a dipole magnet with a bending power of about 4 Tm, and three stations of silicon-strip detectors (IT) and straw drift-tubes (OT) placed downstream. The combined tracking system has a momentum resolution $\Delta p/p$ that varies from 0.4% at 5 GeV to 0.6% at 100 GeV, and an impact parameter resolution of 20μm for tracks with high transverse momentum. Charged hadrons are identified using two ring-imaging Cerenkov detectors (RICH). Photon, electron and hadron candidates are identified by a calorimeter system consisting of scintillating-pad and pre-shower detectors, an electromagnetic calorimeter (ECAL) and a hadronic calorimeter (HCAL). Muons are identified by a muon system composed of alternating layers of iron and multiwire proportional chambers.

3 Jet Reconstruction

Jets are clustered using the anti–k_T algorithm [4, 5] in the energy recombination mode with an R–parameter of one half. The jets on truth level are defined for *stable particles*[1].

[1] Stable particles in this sense are $p, n, \pi^{\pm}, K^0, K^{\pm}, e^{\pm}, \mu^{\pm}$ and γ.

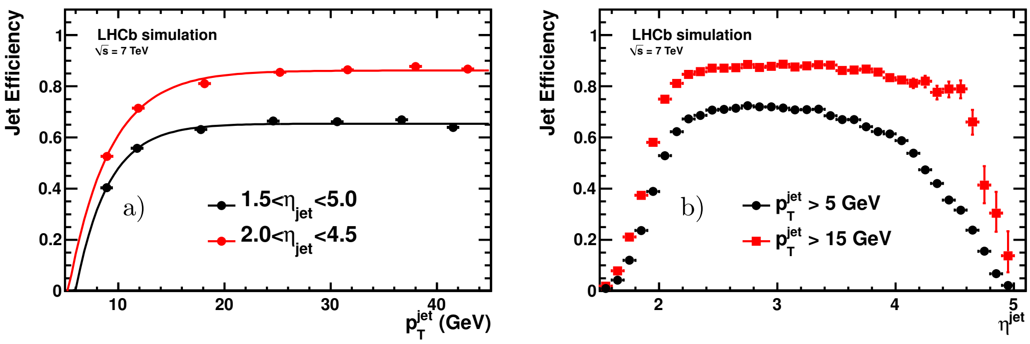

Figure 1: Efficiency of the jet reconstruction and identification as function of the transverse momentum and of η.

The jet reconstruction is optimised to use the precise tracking information wherever possible, since the energy recorded in the individual calorimeter cells saturates at transverse energies about 10 GeV. Therefore the measured jets are reconstructed from charged particle candidates from tracks; reconstructed Λ^0 and K^0_S candidates as two track combinations; π^0 and photon candidates from the ECAL and neutral hadron candidates from the HCAL. No track in the jet is allowed to carry more than 80% of the jet momentum. Otherwise the jet candidate is rejected. In order to minimise the dependence on pileup the jets are reconstructed for each primary vertex separately and are required to contain at least four particles reconstructed from tracks containing VELO segments that are associated to a primary vertex.

4 Performance of the Jet Reconstruction

The efficiency of the jet reconstruction and identification in simulation(Pythia) is shown in Figures 1a as function of transverse momentum p_T and in Figure 1b as function of η. The efficiency for 15 GeV is well above 80% in the central η region: $2 < \eta < 4.5$. Most of the inefficiency originates from the jet identification selection.

Figure 2 shows the fraction of the jet energy measured by the tracking system, the ECAL and the HCAL respectively. About 70% of the jet energy is carried by stable charged particles and thus can be measured precisely by the tracking system. The second largest component of about 20% of the jets energy is carried by photons and measured in the ECAL. Only a small fraction of about 10% of the jet energy is measured with the HCAL.

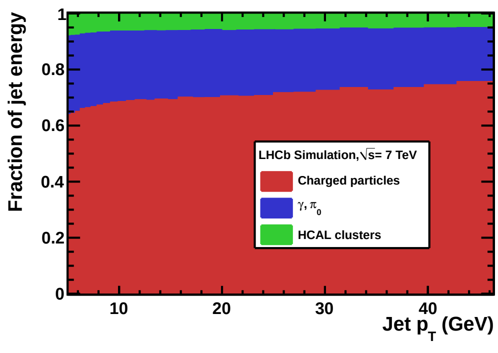

Figure 2: Measured particle content of the jets.

$Z \to \mu\mu$ production in association with jets is used to study the jet reconstruction in data.[2] A candidate event is shown in Figure 3.

Z candidates are selected using the selection defined in [6]. This selection requires two identified muons with opposite charge, a $p_T > 20$ GeV, and pseudorapidity $2 < \eta < 4.5$, that have an invariant mass between 60 and 120 GeV. Additionally, one jet originating from the Z vertex with $p_T > 10$ GeV is required and the Z p_T should exceed 10 GeV as well. Events with a second jet satisfying $\frac{p_{T,\text{Next to leading Jet}}}{p_{T,\text{Leading Jet}}} > 0.25$ are rejected.

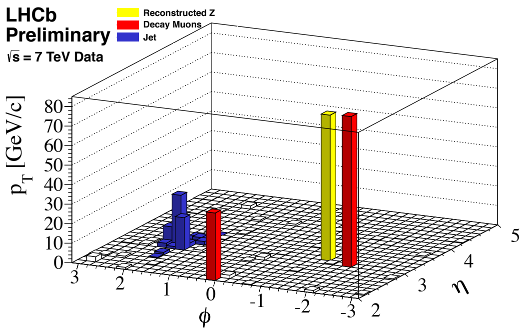

Figure 3: Candidate event of associated production of a Z boson and a jet. ($p_{T,\text{jet}} = 75$ GeV, $p_{T,\mu^+} = 35$ GeV, $p_{T,\mu^-} = 77$ GeV and $m_{\mu^+\mu^-} = 97.1$ GeV)

Figure 4a shows the angle $\Delta\phi$ of to Z and the jet in the transverse plane. There is a clear peak of events being back–to–back. In those events any transverse momentum from the Z boson must be roughly balanced by the jet. Thus the p_T measurement contains information about the jet p_T.

For further studies we require the Z boson to recoil collinearly ($|\Delta\phi(Z, \text{Leading Jet})| < \frac{7\pi}{8}$) against the jet. Figure 4b shows the Z–jet p_T balance. This provides a control sample to study the jet energy scale. Both the mean value and the shape of the distribution are nicely described by the simulation. This means the jet energy correction factors can be extracted from simulation with a small uncertainty.

5 Conclusion and Outlook

LHCb is able to reconstruct jets and to correct their energy to the level of stable particles. This jet reconstruction has extended the LHCb electroweak and QCD programme. A full Z plus jet measurement is now available [3].

References

[1] A. A. Alves, Jr. *et al.* [LHCb Collaboration], JINST **3** (2008) S08005.

[2] R. Aaij *et al.* [LHCb Collaboration] LHCb-CONF-2012-013.

[3] R. Aaij *et al.* [LHCb Collaboration] LHCb-CONF-2012-016.

[4] M. Cacciari, G. P. Salam and G. Soyez, Eur. Phys. J. C **72** (2012) 1896 [arXiv:1111.6097 [hep-ph]].

[5] M. Cacciari, G. P. Salam and G. Soyez, JHEP **0804** (2008) 063 [arXiv:0802.1189 [hep-ph]].

[6] R. Aaij *et al.* [LHCb Collaboration], arXiv:1204.1620 [hep-ex].

[2] With $Z \to \mu\mu$ the contribution of the virtual photon is included in this notation.

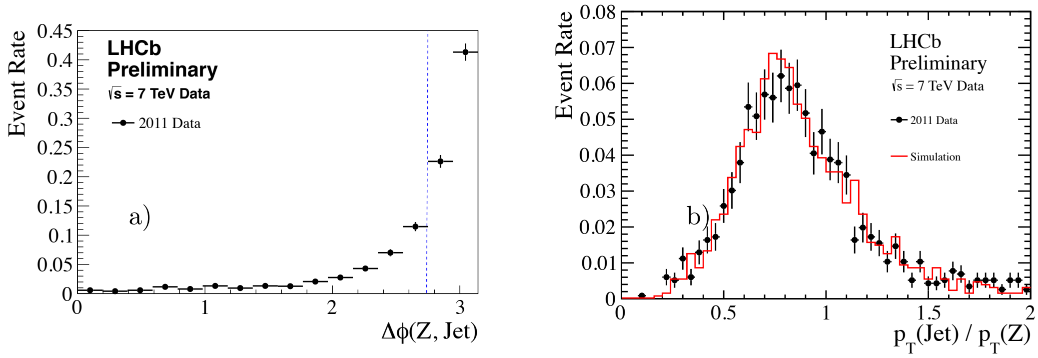

Figure 4: Angle $\Delta\phi$ of the Z and the jet in the transverse plane (a). Events above the dashed line at $7\pi/8$ are considered back to back in this analysis and shown in the Z–jet p_T balance plot (b).