**Scientific Note**

**Tau jet reconstruction and tagging with CMS**

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**Abstract.** The \(\tau\) identification and reconstruction algorithms developed for the CMS experiment at LHC are presented. The algorithms are aimed to an efficient selection of hadronic decays of the \(\tau\) lepton. Reconstruction methods suitable for use at the High Level Trigger and off-line are described in detail.

1 Introduction

The searches for the Higgs boson and SUSY signatures at the LHC relay very much on the identification of \(\tau\) leptons in the final state. A number of methods to identify \(\tau\) jets, i.e. hadronic decays of the \(\tau\) lepton, used in CMS are described. The methods are based on \(\tau\) properties such as its long lifetime, its mass and the small number of charged decay products. Usage of these methods in different combinations depends on the physics channel considered. The \(\tau\)-jet identification requires an isolated and collimated jet made of charged particles reconstructed with the tracker; the \(\tau\) identification can be improved combining this isolation criterium with other algorithms.

In the following, the basic properties of a \(\tau\) jet are presented in Sect. 2. In Sect. 3 the off-line isolation and the other tagging methods are discussed. The impact parameter, flight-path and mass tagging are intended to be applied after isolation and so their performances have been computed over a preselected sample of isolated jets. In Sect. 4 the High Level Trigger chain is presented and discussed. In Sect. 5 the calibration of the energy of the \(\tau\) jet is discussed and the basic ideas on how to estimate the tagging algorithms performances are presented.

2 Tau properties relevant to \(\tau\) jet reconstruction and identification

The \(\tau\) lepton decays hadronically 65% of the time, producing a \(\tau\) jet, which is a jet-like cluster in the calorimeter containing a relatively small number of charged and neutral hadrons. When the \(p_T\) of the \(\tau\) jet is large compared to the \(\tau\) mass, these hadrons have relatively small momentum in the plane transverse to the \(\tau\) jet axis. In 77% of hadronic \(\tau\) decays, the \(\tau\) jet consists of only one charged hadron and a number of \(\pi^0\)s (one-prong decays). Because of these features hadronic \(\tau\) decays produce narrow jets in the calorimeter.

Figure 1 shows the ratio \(r = E_{\text{reco}}^{\text{T}}/E_{\text{MC}}^{\text{T}}\) as a function of the reconstruction cone size for three bins of \(E_{\text{MC}}^{\T}\). The \(E_{\text{reco}}^{\T}\) is the transverse energy reconstructed in the calorimeter with an iterative cone algorithm, while the \(E_{\text{MC}}^{\T}\) is the Monte Carlo (MC) generated transverse energy. The thresholds on calorimeter towers, input to the jet finder, were set as \(E_{\text{T}}^{\T} = 0.5 \text{ GeV} \) and \(E = 0.8 \text{ GeV}\). The values of \(r\) in Fig. 1 were normalized to the value obtained with a cone size of 0.6. Figure 2 shows the transverse energy resolution of the \(\tau\) jet as a function of the reconstruction cone size for the three different bins of \(E_{\text{MC}}^{\T}\). From Fig. 1 a cone size of 0.4 for \(\tau\) jet reconstruction with the calorimeter was chosen since it contains a large fraction of the \(\tau\)-jet energy (more that 98%) and the cone size smaller than 0.4 leads to a degradation of the \(\tau\)-jet energy resolution as can be seen from Fig. 2. A larger cone size can lead to a con-
3 Methods for \( \tau \) tagging and performance

All the efficiencies shown in these sections are relative to events in which the calorimeter reconstructed jet matches contamination from other jets in multi-jet events. Figure 3 shows the difference in \( \phi \) (left plot) and in \( \eta \) (right plot) between the jet-direction of the true \( \tau \) jet and the \( \tau \) jet reconstructed with the calorimeter, for the three intervals of the true \( \tau \)-jet energy. The charge of the \( \tau \) lepton is positive in these event samples. The 4 Tesla magnetic field leads to a systematic shift of \( \approx 0.02 \) rad in the reconstructed \( \tau \) jet direction in \( \phi \) for \( \tau \) jets with \( E_T \) between 40 and 60 GeV. The shift is reduced for the jets with larger \( E_T \). The resolution in \( \eta \) is slightly worse than in \( \phi \) and does not depend on \( E_T \) between 40 and 250 GeV.

The \( \tau \) jet-identification requires a matching between the calorimeter jet axis and the charged particles from the hadronic \( \tau \) decays measured with the tracker. Figure 4 shows the distance \( \Delta R \) in \( \eta-\phi \) space between the direction of the leading \( p_T \) track at the origin, reconstructed with the tracker, and the direction of the \( \tau \) jet reconstructed with the calorimeter for three bins of the true \( \tau \)-jet transverse energy \( E_{T}^{MC} \). A cut of 3 GeV/c was applied on the \( p_T \) of the leading track. Both, the one and the three-prong (three charged particles in the decay product) \( \tau \) decays are included. The value of \( \Delta R \) does not exceed 0.1 for the range of \( E_{T}^{MC} \) considered.

In the case of hadronic \( \tau \) decays with three charged particles in the final state, the three particles are produced within a narrow cone. Figure 5 shows the maximal distance \( \Delta R \) in \( \eta-\phi \) space between the leading \( p_T \) charged particle and other two charged particles in the three-prong \( \tau \) decays for three bins of the true \( \tau \)-jet transverse energy \( E_{T}^{MC} \).

The \( \tau \)-lepton lifetime (\( c\tau = 87.11 \) \( \mu \)m) and the mass (\( m_{\tau} = 1.78 \) GeV/c\(^2\) were used for the \( \tau \) jet tagging with the track impact parameter measurement, vertex reconstruction (for three-prong decays) and constraining the effective mass of track(s) and calorimeter clusters.

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**Fig. 1.** Distribution of the ratio \( r = \frac{E_{T}^{reco}}{E_{T}^{MC}} \) as a function of the reconstruction cone size for the three bins of \( E_{T}^{MC} \). The values of \( r \) were normalized to the \( r \) for a cone size of 0.6.

**Fig. 2.** Transverse energy resolution of \( \tau \) jet as a function of the reconstruction cone size for the three bins of \( E_{T}^{MC} \).

**Fig. 3.** Distribution of the difference in \( \phi \) (left plot) and in \( \eta \) (right plot) between the true \( \tau \) jet direction and the jet direction reconstructed with the calorimeter for the three different intervals of the true \( \tau \)-jet energy. The \( \tau \) lepton has a positive charge in these event samples.