PROCEEDINGS OF SCIENCE

Reconstruction and identification of τ hadronic decays in the CMS Experiment

L. Lusito* **on behalf of the CMS Collaboration**
Università and Istituto Nazionale di Fisica Nucleare Bari, Italy
E-mail: letizia.lusito@cern.ch

New reconstruction and identification strategies for τ lepton hadronic decays in the CMS experiment are described in details. The improvements achieved using Particle Flow based techniques are also presented.

Prospects for Charged Higgs Discovery at Colliders
September 16-19 2008
Uppsala, Sweden

*Speaker.

 http://pos.sissa.it/

PoS(CHARGED2008)029

1. Introduction

In the LHC era τ leptons are expected in final states of many interesting physics channels such as Higgs-bosons decays (h, H, A $\rightarrow \tau\tau$, H$^{\pm} \rightarrow \tau\nu$), SUSY and decays from other exotic-particles. The main difficulties in these analyses arise from the fact that hadronic τ-jets closely resemble QCD jets but the cross-section for QCD multijet production is many order of magnitude larger than even electroweak τ channels. Moreover a significant fraction of the τ momentum escapes undetected with the associated ν_{τ}. For these reasons an efficient and accurate τ reconstruction and identification is an important part of the CMS physics programme and early results about the feasibility of these studies can be found in Ref. [1] and [2]

The τ lepton decays hadronically in 64% of the time, producing a collimated and well isolated jet containing charged and neutral pions (which deposit energy in both electromagnetic and hadronic calorimeters) and characterized by low charged particle multiplicity. In the rest of time it decays in leptons (e or μ) and neutrinos. In this last case the τ decay can be retrieved through standard lepton identification methods, as explained in Ref. [3] and [4].

2. Tau identification methods

The performances of the latest τ identification methods have been evaluated using a sample of simulated $Z \rightarrow \tau\tau$ in which both taus decay hadronically as the signal and a sample of simulated QCD multijet events with a generated $\hat{p_T}$ in the range from 5 to 120 GeV/c as a background. Both samples have been produced with PYTHIA.

2.1 The Particle Flow technique

The Particle Flow (PF) technique allows to improve the τ identification efficiency. In a first step all tracks and energy clusters are indipendently reconstructed in each subdetector. Then all PF Candidates (muons, electrons, charged and neutral hadrons and photons) are associated in an optimal combination to one or more of these subdetector signals (of course if they are compatible with the physics properties of each particle) and reconstructed in the event. The list of particles found in the event is then used to derive composite physics objects such as jets which are clusterized using standard jets algorithms. In the Particle Flow framework the Cone algorithm is mainly used with a cone size of 0.5 in the (η-ϕ) space, as explained in Ref. [5].

2.2 Tau reconstruction: preselection

Tau reconstruction relies mainly on a set of simple and robust methods to reduce the amount of huge QCD background still keeping a large efficiency for all decay modes and preserving the selection from any possible bias. A first step is the application of an isolation algorithm to a PF jet reconstructed as explained in Section. 2.1. A cut of 15 GeV/c is further applied to the jet p_T.

Then at least one charged hadron with a $p_T > 5$ GeV/c located at a distance less than 0.1 in the (η-ϕ) space from jet direction is required. The highest- momentum charged hadron that satisfies this condition is called the 'leading track' of the jet. Around the leading track a signal cone, which is expected to contain all τ decay products, and an isolation annulus, in which little activity (in particular no charged hadron or photon candidates above the p_T threshold of respectively 1 and 1.5

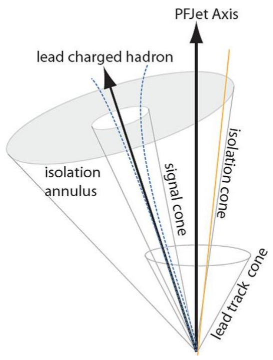

Figure 1: Signal cone and isolation annulus definition for the Cone Isolation algorithm.

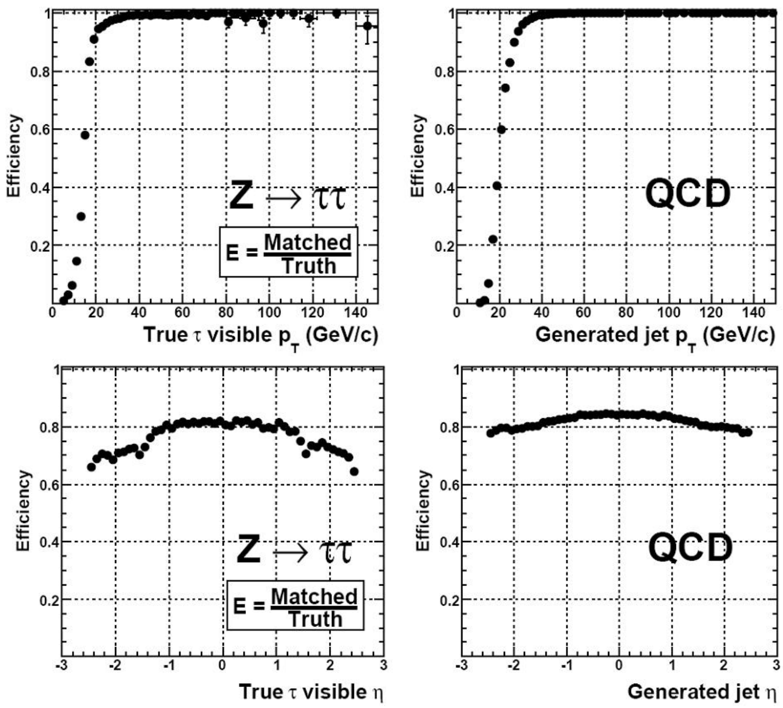

Figure 2: Efficiencies as a function of the generated visible p_T for finding a jet with $p_T > 15$ GeV/c around a true τ-jet (top right) or a generated QCD jet (top left) with respect to those with $p_T > 5$ GeV/c and $|\eta| < 2.5$ and the same but as a function of the generated visible η for a true τ-jet (bottom left) and a generated QCD jet (bottom right).

GeV/c) is expected due to the isolation characteristics of τ-jets, are defined as indicated in Fig. 1. The signal cone has a typical size of 0.07 while the isolation annulus has a typical size of 0.45.

In Fig. 2 the efficiency for reconstructing a jet with $p_T > 15$ GeV/c matched to a true τ-jet or a generated QCD jet is reported as a function of the jet p_T and η. The turn-on of the curves in the upper plots is indicative of the jet energy measurement resolution while the absolute efficiency value in lower plots distributions depends only on the energy spectrum of the data sample: it reflects simply the fact that QCD jets have an harder spectrum respect to $Z \rightarrow \tau\tau$.

The leading track finding marginal efficiency (determined with respect to the τ candidate sat-

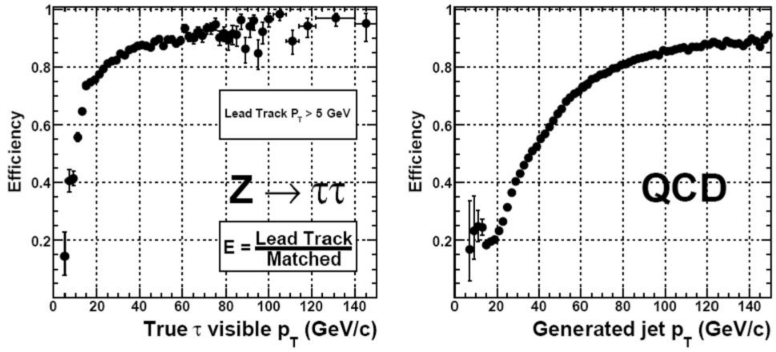

Figure 3: Efficiency for finding a leading track in τ-jet for signal (left) and background (right) events as a function of the generated visible p_T.

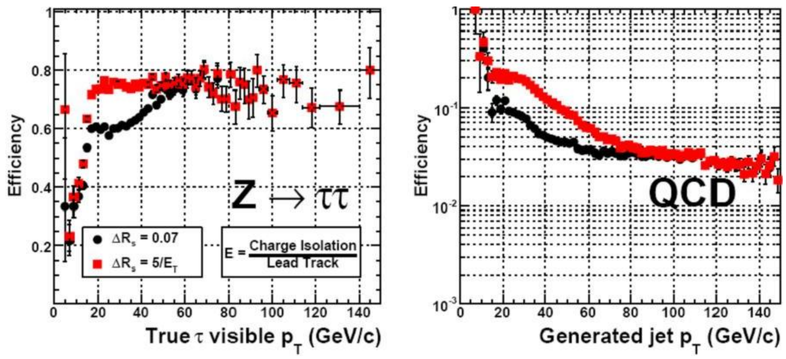

Figure 4: Marginal efficiencies for the charged-hadron isolation requirement as a function of the generated visible p_T for τ's (left) and QCD background (right) with the fixed (Δ R$_{sig}$ =0.07) and shrinking (Δ R$_{sig}$ $<$ $5/E_T$) signal-cone definitions.

isfying the previous requirement) is reported in Fig. 3; it shows the probability for a PF jet to contain a charged particle with $p_T > 5$ GeV/c. It is larger for signal events because of the larged charged particles multiplicity in QCD jets vastly dominated by low p_T jets. For this reason this discriminator is very powerful for QCD rejection.

An alternative approach respect to the use of signal cone with fixed size is the shrinking cone approach, in which the size scales as $5/E_T$ with minimum and maximum values set respectively to 0.07 and 0.15. It relies on the fact that τ-jets become more collimated at higher energies. A comparison of the marginal efficiencies as obtained using the fixed and the shrinking cone size is reported in Fig. 4. An increase of approximately 20% is observed in the signal efficiency for the low p_T region using this new method. Unfortunately also an approximate doubling of the background rate is also observed but a better background rejection can be obtained in a subsequently phaseas explained in Section. 2.3. The main advantage of the shrinking cone definition is the better acceptance of the three prong τ decays because of the larger signal cone in which all tracks can fit. The recovery of the three prong decays is essential to make these preselection criteria indipendent from the decay type thus avoiding any possible bias. In Fig. 5 the number of charged signal occupants is reported and the recovery of the three prong decays is clearly observable.

The global efficiencies of the preselection cuts as a function of the p_T and η for the shrinking

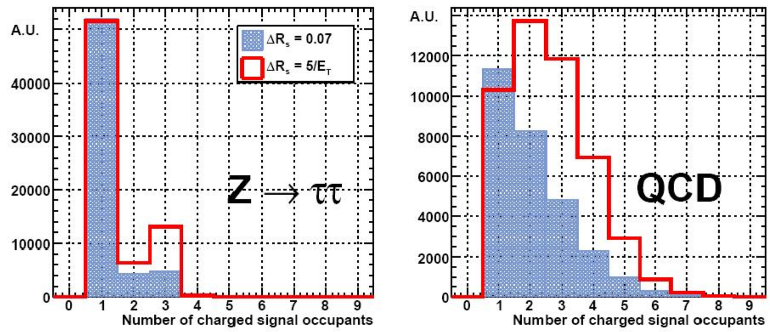

Figure 5: Charged-hadron multiplicity distributions in the signal cone for taus (left) and QCD jets (right) with the fixed (ΔR_{sig} =0.07) and shrinking ($\Delta R_{sig} < 5/E_T$) signal-cone definitions. The histograms are normalized to unit area.

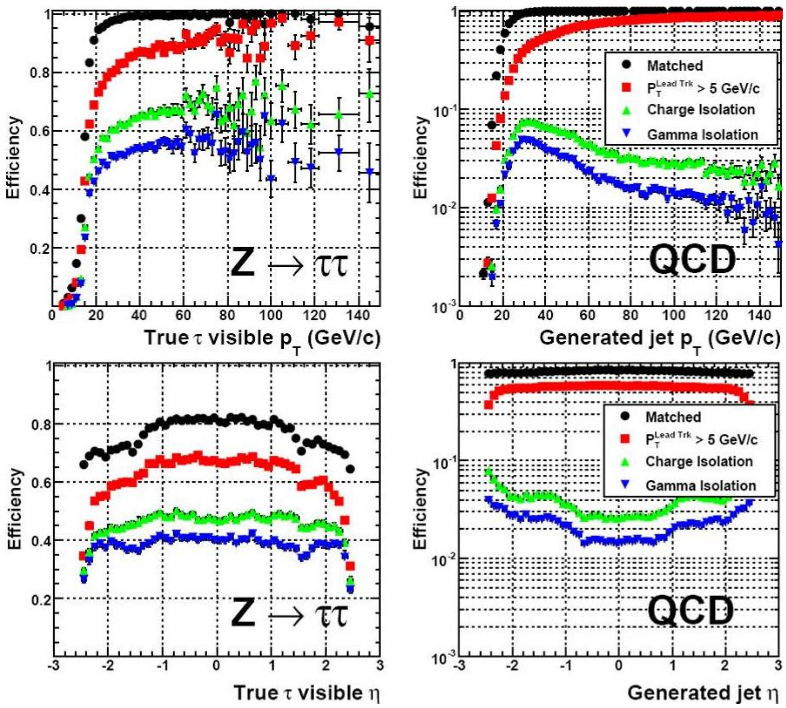

Figure 6: Global efficiencies of the successive pre-selection cuts as a function of the true p_T for signal (top left) and QCD jets (top right) events and as a function of the true η for signal (bottom left) and QCD jets (bottom right) using the $5/E_T$ shrinking signal cone definition.

cone size definition are displayed in Fig. 6 both for signals and QCD background. The efficiences are respect to candidates with $p_T > 5$ GeV/c and $|\eta| < 2.5$.

2.3 Tau high-level identification

After the preselection, a sophisticated high-level identification is applied. It allows the tunability of efficiency and purity levels and it is aimed mainly at the suppression of isolated electrons and muons coming from electroweak processes which can easily fake τ-jets.

The μ rejection is based on the standard reconstruction criteria which allow a τ selection

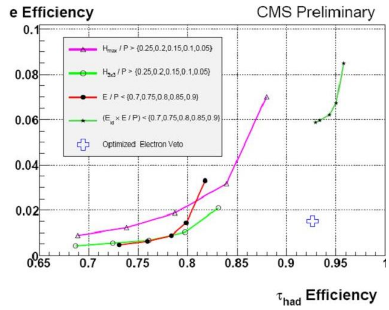

Figure 7: Efficiencies for selecting taus and electrons for several electron rejection approaches including the Optimized Electron Veto (displayed as a blue cross).

efficiency and a muon rejection efficiency of >99%.

The e rejection is achieved through a fast MVA (multivariate) analysis of tracker and calorimeters informations which allows an efficiency of 95% for electrons and 5% for pions. These values can be further improved to efficiencies of 92.5% for τ's and 1.5% for electrons with an ad-hoc optimized electron veto which takes into account the ratios E/P and $H_{3\times3}$/P where E is the summed energy of all ECAL clusters in $|\eta|<0.04$ respect to the extrapolated impact point of the leading track on the ECAL surface, $H_{3\times3}$ is the summed energy of all HCAL cluster within $\Delta R<0.184$ with respect to the extrapolated impact point of the leading track on the ECAL surface and P is the momentum of the leading charged hadron. The selection is different if the τ candidate is pre-identified as an electron or not. In the first case the cut values are E/P$<$ 0.95 and $H_{3\times3}$/P$>$ 0.05 while in the second case the cut values are E/P$<$ 0.8 and $H_{3\times3}$/P$>$ 0.15. In Fig. 7 the efficiencies for typical electron rejection criteria are compared to the optimized electron veto indicated as a blue cross. The electron pre-identification cut is labeled E_{id}.

3. Conclusion

The performance of the new methods based on Particle Flow algorithm for τ identification and reconstruction from its hadronic decay mode are reported. These new techniques demonstrate good efficiency of selection with high background rejection power. It is also described how these selections can be tuned to achieve the desired level of efficiency/purity and so can be utilized in every analysis with τ's in final states in the CMS experiment.

References

[1] CMS Physics TDR, Volume 1, CERN-LHCC-2006-001

[2] CMS Physics TDR, Volume 2, CERN-LHCC-2006-021

[3] The CMS Collaboration, "Towards a measurement of the inclusive $W \to e\nu$ and $Z \to ee$ cross section in pp collisions at $\sqrt{s}$=14 TeV", CMS PAS EWK-07-001

[4] The CMS Collaboration, "Towards a measurement of the inclusive $W \to \mu\nu$ and $Z \to \mu^+\mu^-$ cross section in pp collisions at $\sqrt{s}$=14 TeV", CMS PAS EWK-07-002

[5] The CMS Collaboration, "Tau reconstruction using the Particle Flow technique", PFT-08-001.