$Z \rightarrow \tau^+\tau^-$ Production in 7 TeV proton-proton Collisions at CMS

Letizia Lusito (University & INFN Bari, CERN)
On behalf of the CMS Collaboration

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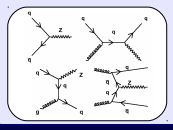
The reconstruction of tau leptons in a hadronic environment can be challenging, yet it is important for many searches for new particles as well as studies of Standard Model procsses. The production of Z bosons decaying into tau pairs serves as a "standard candle" for the commissioning of the tau reconstruction as well as test bench for analogous $H \rightarrow \tau^+\tau^-$ decays. Tau reconstruction in CMS is described and one Z boson candidate decaying to a pair of taus in the $\mu+\tau_{had}$ channel is presented.

Z and τ production

Z production @ LHC occurs by $q\bar{q} \rightarrow Z$ qg or gg subdominant



Tau: mass 1.777 GeV/c^2, lifetime 290 ps heaviest of the three leptons

Decay Products	Branching Ratio
$e^-+\bar{\nu}_e+\nu_\tau$	(17.84±0.05)%
$\mu^-+\bar{\nu}_\mu+\nu_\tau$	(17.36±0.05)%
$1\pi+n\pi^0+\nu_\tau$	49.2%
$3\pi+n\pi^0+\nu_\tau$	14.6%

Significant fraction of τ momentum escapes undetected with ν_τ

Leptonic decays

Hadronic decays (τ_{had})

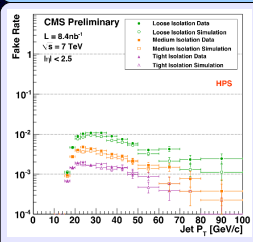
- Collimation, isolation
- Low charged tracks multiplicity
- ECAL & HCAL energy deposits

Hadron Plus Strips τ algorithm

Aimed at the individual reconstruction of hadronic decay modes

- It starts by clusterizing gamma candidates reconstructed by the Particle Flow[1] (PF) algorithm to Strips
  - —Account for photon conversions
  - —Threshold of 1 GeV applied to Strips
- Strips and charged hadrons reconstructed with the PF combined to τ
  - —Single hadron: aims for one prong decays (π^+, π^-, K^+, K^-)
  - —Hadron + Strip: aims for decays to single prong + π^0 via ρ(770) resonance
  - —Three hadrons: aims for three prongs decays via the a_1 resonance
- Mass compatibility and collimation of jet
  - —Mass compatible with ρ/a_1
  - —All decay products within cone of size $\Delta R = 2.8/p_T$
- Energy within jet not attributed to τ decay products < 1 GeV

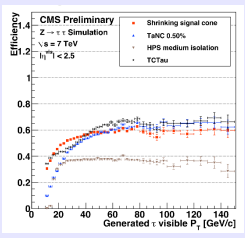
Performances: fake rates



HPS fake rates

Probabilities for q/g jets to pass the HPS tau identification criteria as a function of jet p_T for data and MC predictions (left)

Probabilities of q/g jets to pass the selection criteria for the four τ ID algorithms used in CMS as a function of jet p_T (MC predictions) (right) [2]



τ algorithms efficiencies

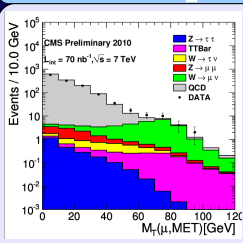
μ & τ selections for EWK analyses

- Muons are identified by using both tracker and muon chambers [3]
- Single muon trigger, $p_T > 15$ GeV/c, $|\eta| < 2.1$
- Tracker hits > 10 (at least 1 in the pixels), muon hits > 1
- Muon track with at least two chambers in different muon stations with matching segments
- Muon fit quality $\chi^2/ndof < 10$
- Impact parameter d_{xy} respect to the Beam Spot < 2 mm
- Mass of the muon and any other OS track in the event not in the mass window 80-100 GeV/c^2
- Combined relative isolation < 0.1 with isolation cone size $\Delta R = 0.4$

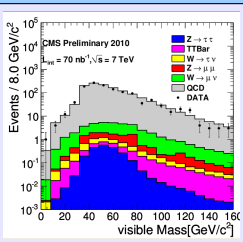
- Taus are identified by the HPS algorithm
- $p_T > 20$ GeV/c, $|\eta| < 2.4$
- Loose HPS Isolation: no PF charged candidates with $p_T > 1$ GeV/c and no PF Gamma with $E_T > 1.5$ GeV, Isolation cone size $\Delta R = 0.5$ (Efficiency 50%, Fake Rate 0.9%)
- Tau muon veto

- $\Delta R(\mu, \tau_{had}) > 0.2$ (overlap cleaning)
- $M_T(\mu, MET) < 40$ GeV/c^2
- Candidates with Opposite Sign charges

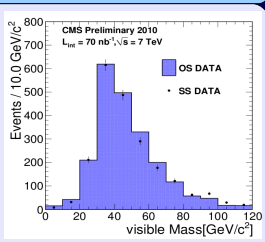
Control plots (loose selections)



Transverse mass of μ+MET



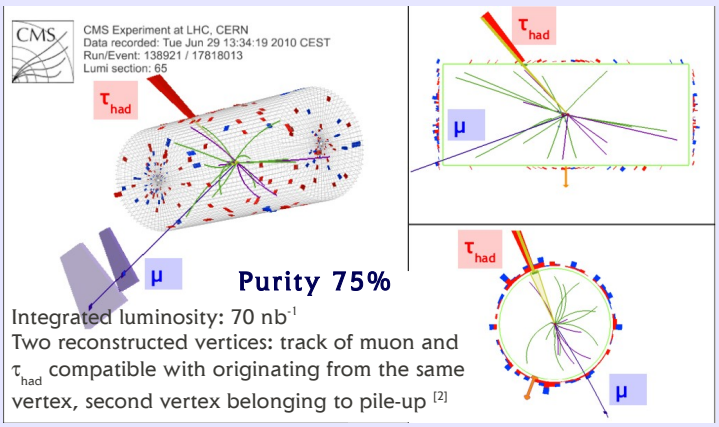
Visible mass of $\mu+\tau_{had}$



OS/LS visible mass of $\mu+\tau_{had}$

Transverse mass of muon plus MET (left) and visible mass of $\mu+\tau_{had}$ (middle) distributions in background-enriched data events compared to those expected for signal and background after applying EWK selections except lepton isolation. Comparison of $\mu+\tau_{had}$ visible mass distributions for background-enriched data events containing a pair of muon and tau of like-sign (LS) versus opposite-sign (OS) charge: they match within statistical uncertainties , in agreement with the expectation for a background dominated sample (right) [2].

Event Display of the Candidate



Purity 75%

Integrated luminosity: 70 nb^{-1}

Two reconstructed vertices: track of muon and τ_{had} compatible with originating from the same vertex, second vertex belonging to pile-up [2]

μ p_T = 22.8 GeV/c	τ_{had} E_T = 32.9 GeV	Vis. Mass = 60.8 GeV/c^2 $M_T(\mu, MET)$ = 10.1 GeV/c^2

Conclusions

The performances of the tau identification algorithm fully satisfy the requirements of CMS analyses of processes which include tau lepton hadronic decays in the final state as demonstrated by the successful identification of the first $Z \rightarrow \tau\tau \rightarrow \mu + \tau_{had}$ candidate event in CMS

References:

[1] CMS Collaboration, "Particle-Flow Event Reconstruction in CMS and Performance for Jet, Taus, and Missing E_T", CMS PAS **PFT-09-001** (2009).

[2] CMS Collaboration, "Study of tau reconstruction algorithms using pp collisions data collected at √s = 7 TeV", CMS PAS **PFT-10-004** (2010).

[3] CMS Collaboration, "Performance of muon identification in pp collisions at √s = 7 TeV", CMS PAS **MUO-10-002** (2010).