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Reconstruction and identification of hadronic Tau decays with the CMS detector

Outline

- Tau properties
- Motivation
- Taus@CMS: the PF approach
- Tau base reconstruction
- High-level τ identification
- Conclusions
- Future work

Tau Properties

- Mass 1.78 GeV/c^2, lifetime 0.29 ps
- Decay modes:

	Decay	Final state	BR(%)
	Leptonic 35.2	$e+\nu_e+\nu_\tau$	17.8
		$\mu+\nu_\mu+\nu_\tau$	17.4
Hadronic decays	1-Prong	$\pi+\nu_\tau$	10.9
		$\pi+\nu_\tau+\geq 1\pi^0$	35.8
	3-Prong	$\pi\pi\pi+\geq 0\pi^0+\nu_\tau$	13.9

τ-jets characteristics

- Very collimated and isolated
- Low multiplicity
- Electromagnetic and hadronic energy deposits

Why tau physics is so interesting?

- New Physics could show up at LHC with taus in final states:
  - light SM Higgs boson (m_H <130-140 GeV/c^2)
  - charged Higgs boson decays in $\tau\nu$
  - Susy decays at large value of tanβ(~10)
  - new heavy gauge bosons or doubly-charged Higgs bosons in many extensions of the SM

BUT

- hadronic τ closely resemble QCD jets
- a significant fraction of the τ momentum escapes undetected with the ν_τ

⇓

- **τ reconstruction and identification is an important part of the CMS physics programme**

Tau@CMS:the PF approach

Indipendent reconstruction of tracks and energy clusters in each subdetector →

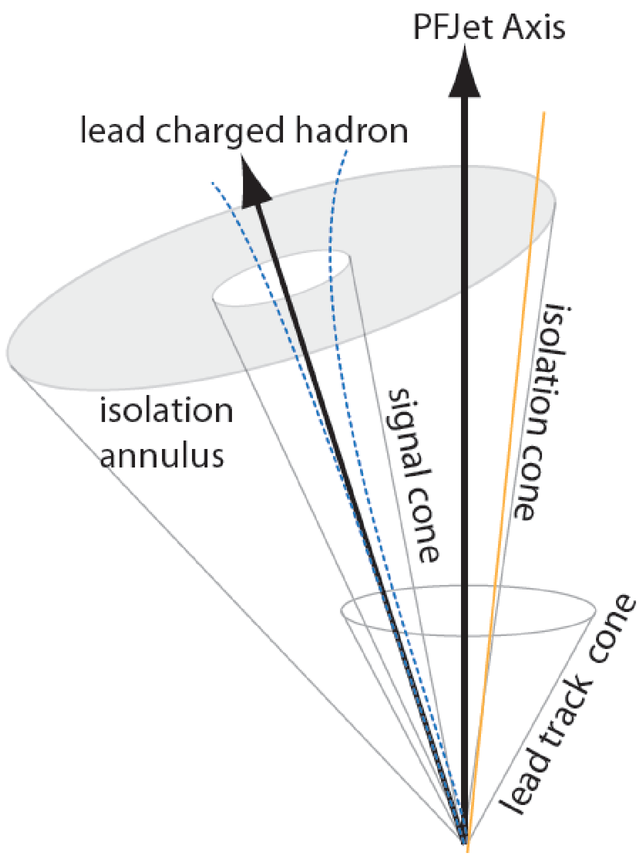
- Muons
- Electrons
- Charged hadrons
- Neutral hadrons
- Photons

← Clustering into jets with standard jet algorithms (Cone algorithm with radius of 0.5)

Tau Reconstruction

- Two distinct stages:
  - Common preselection: simple and robust methods to reduce backgrounds still keeping a large efficiency for all decay modes without biases, used to define CMS tau secondary datasets ("skims")
  - Sophisticated τ identification tunable for each physical analysis

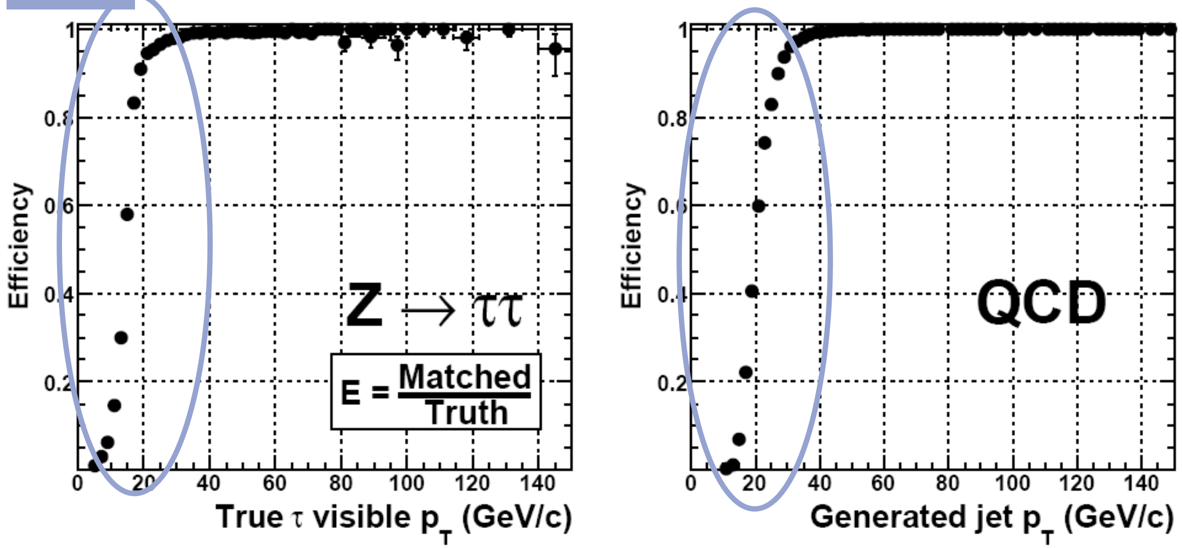
Tau base reconstruction: the isolation algorithm



(courtesy of E. Friis)

- PF-based Jet reconstruction (p_T>15 GeV/c)
- At least one charged hadron with p_T > 5 GeV/c at a ΔR<0.1 from jet direction in the (η,ϕ) plane
- Signal cone and isolation annulus definition around the leading track, typical values are for the signal cone ΔR=0.07 and for the isolation annulus ΔR=0.45
- No charged hadron or photon candidates above a p_T threshold (1 GeV/c for the charged, 1.5 GeV/c for the gamma cand) in the isolation annulus

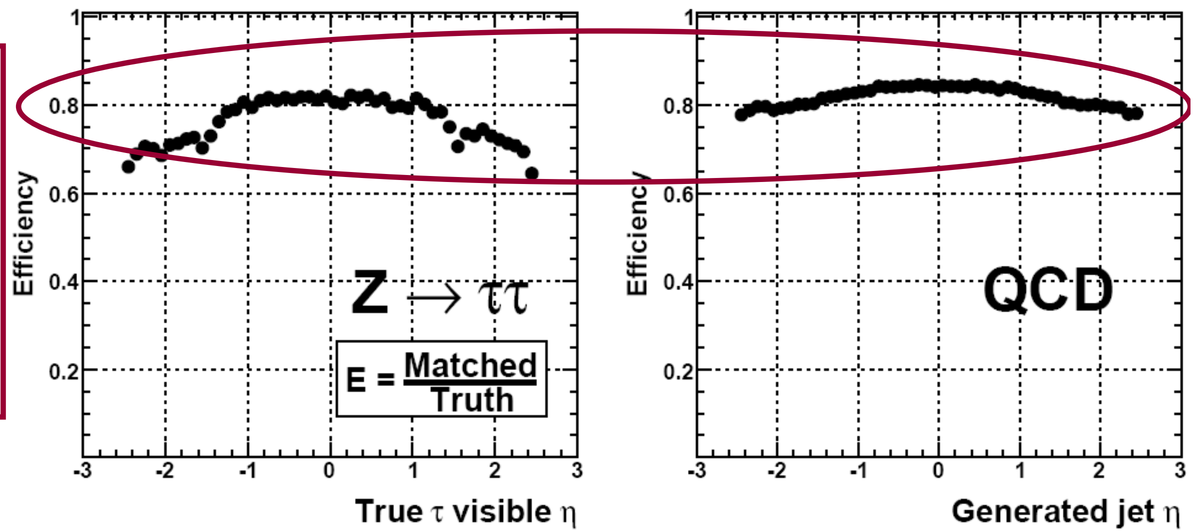
Jet reconstruction



Efficiency for reconstructing a jet with p_T>15 GeV/c matched to a true τ-jet or generated QCD jet

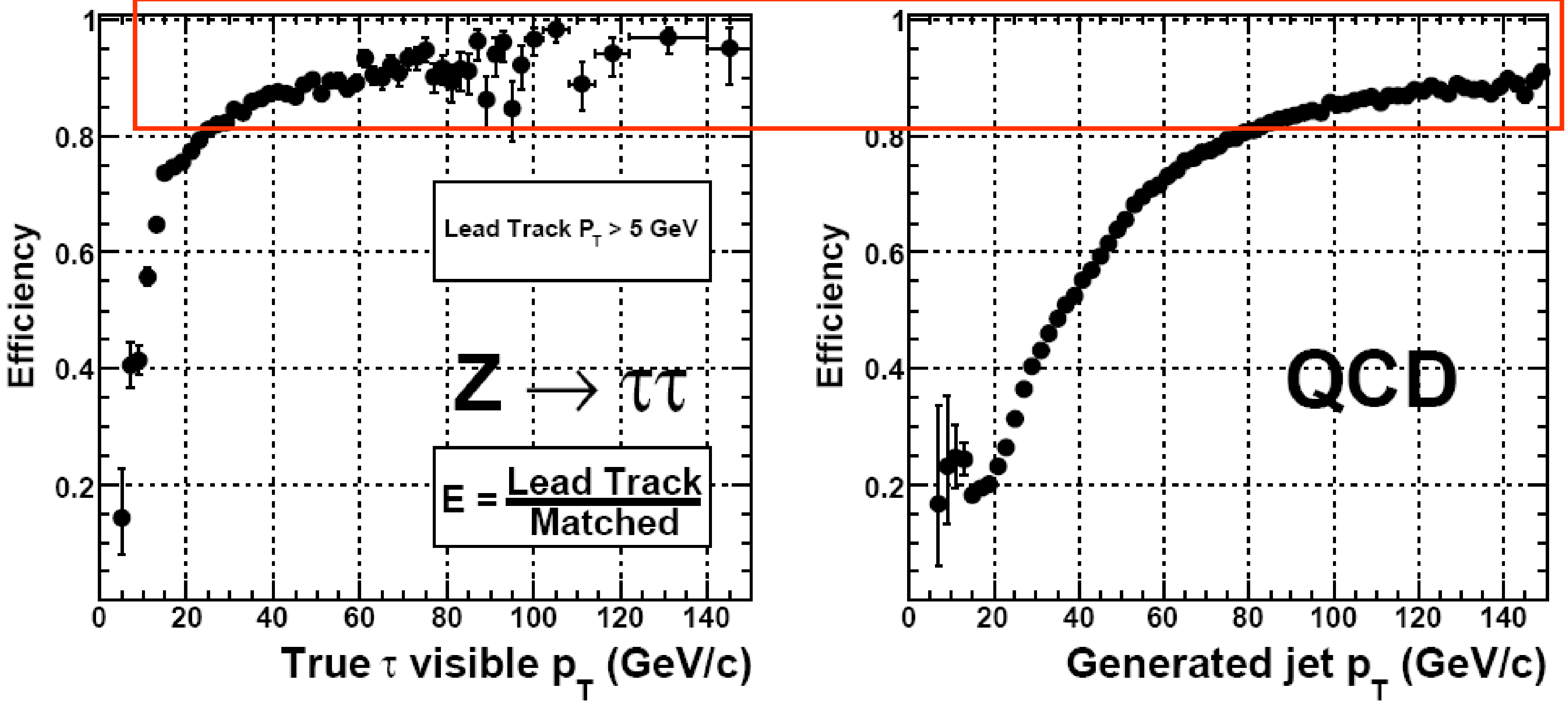
indicative of the jet energy measurement resolution

The absolute value depends on the energy spectrum of the data sample (QCD jets have an harder spectrum than taus of Z→ττ sample



Leading track finding efficiency

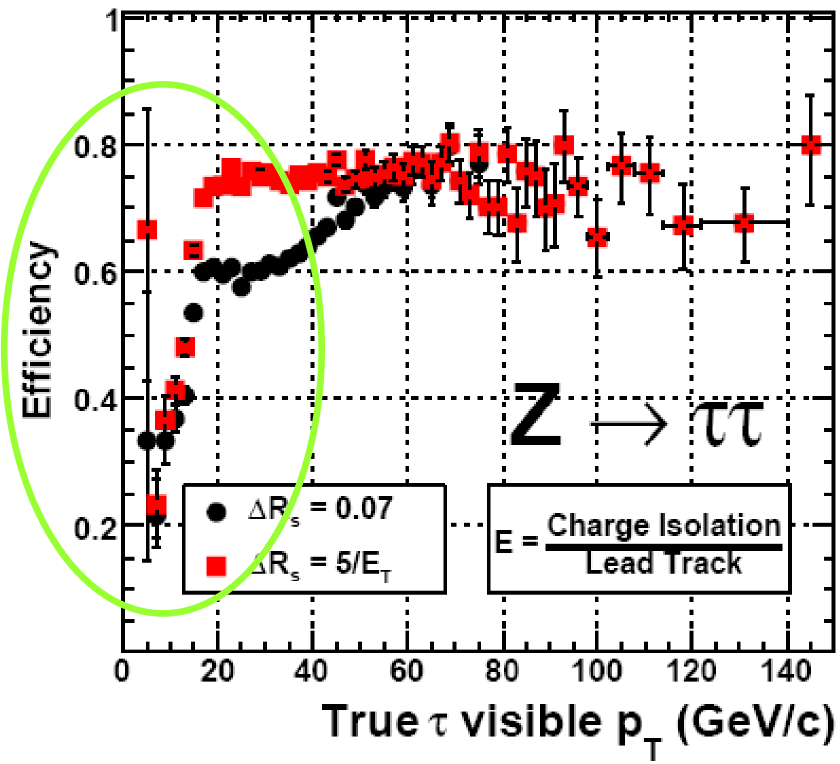
- Leading track finding marginal efficiency: probability for the jet to contain a charged particle with p_T>5 GeV/c

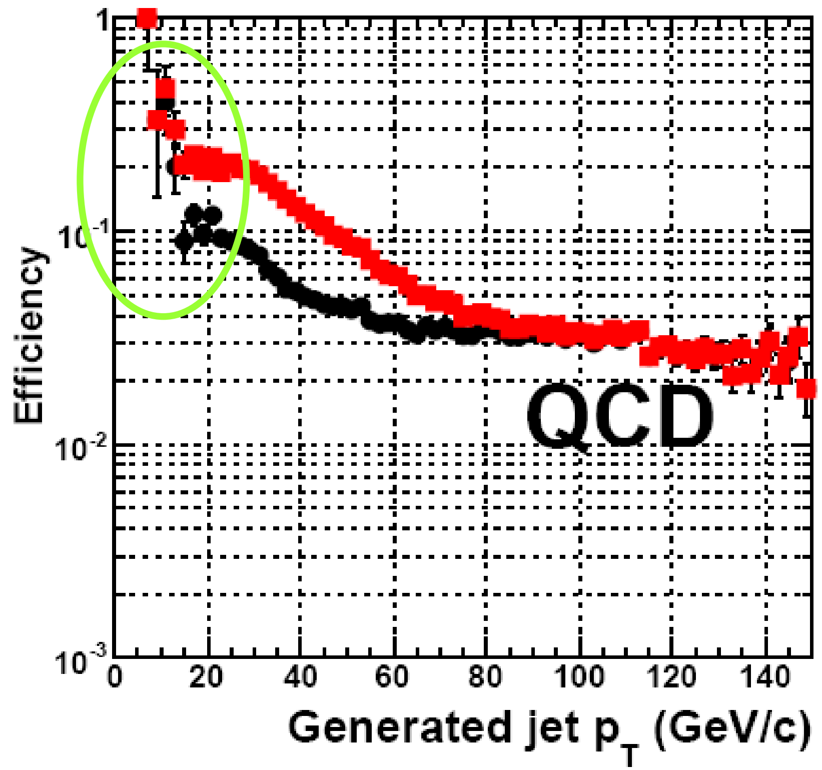


For signal larger efficiency because of the larger average particle multiplicity in QCD jets→efficient discrimination variable for QCD suppression

Tau base reconstruction: the shrinking cone

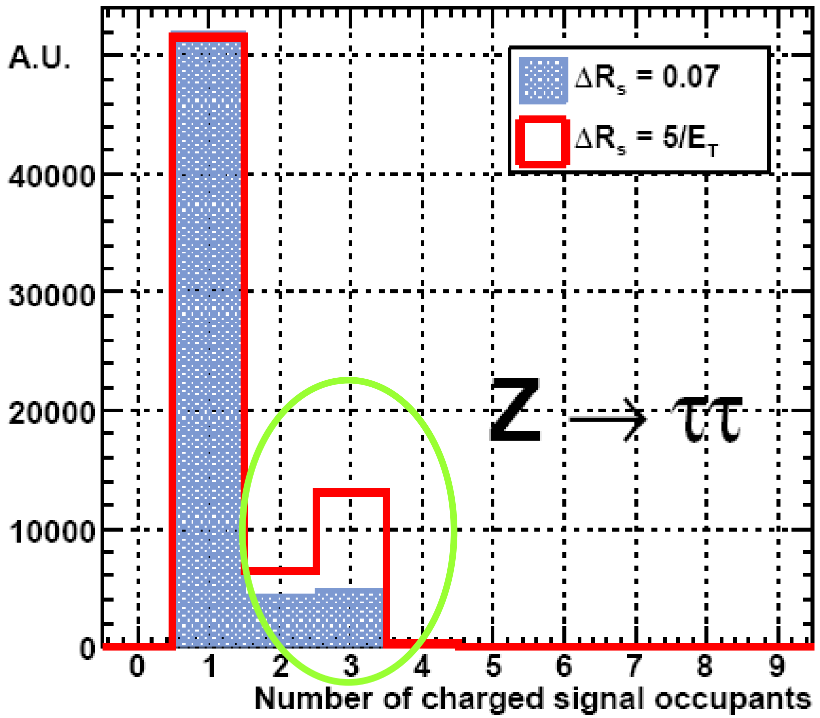
- τ-jets become more collimated at higher energies
- better reconstruction performances achieved with a signal cone size which scales as $5/E_T$ with a min and a max set to 0.07 and 0.15 respectively (marginal efficiencies)

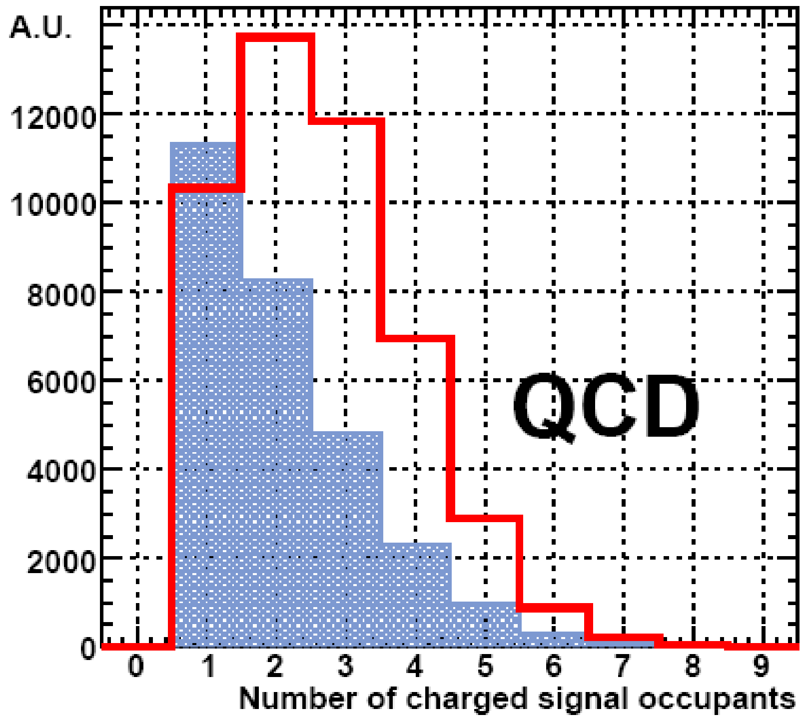




Tau base reconstruction: the shrinking cone

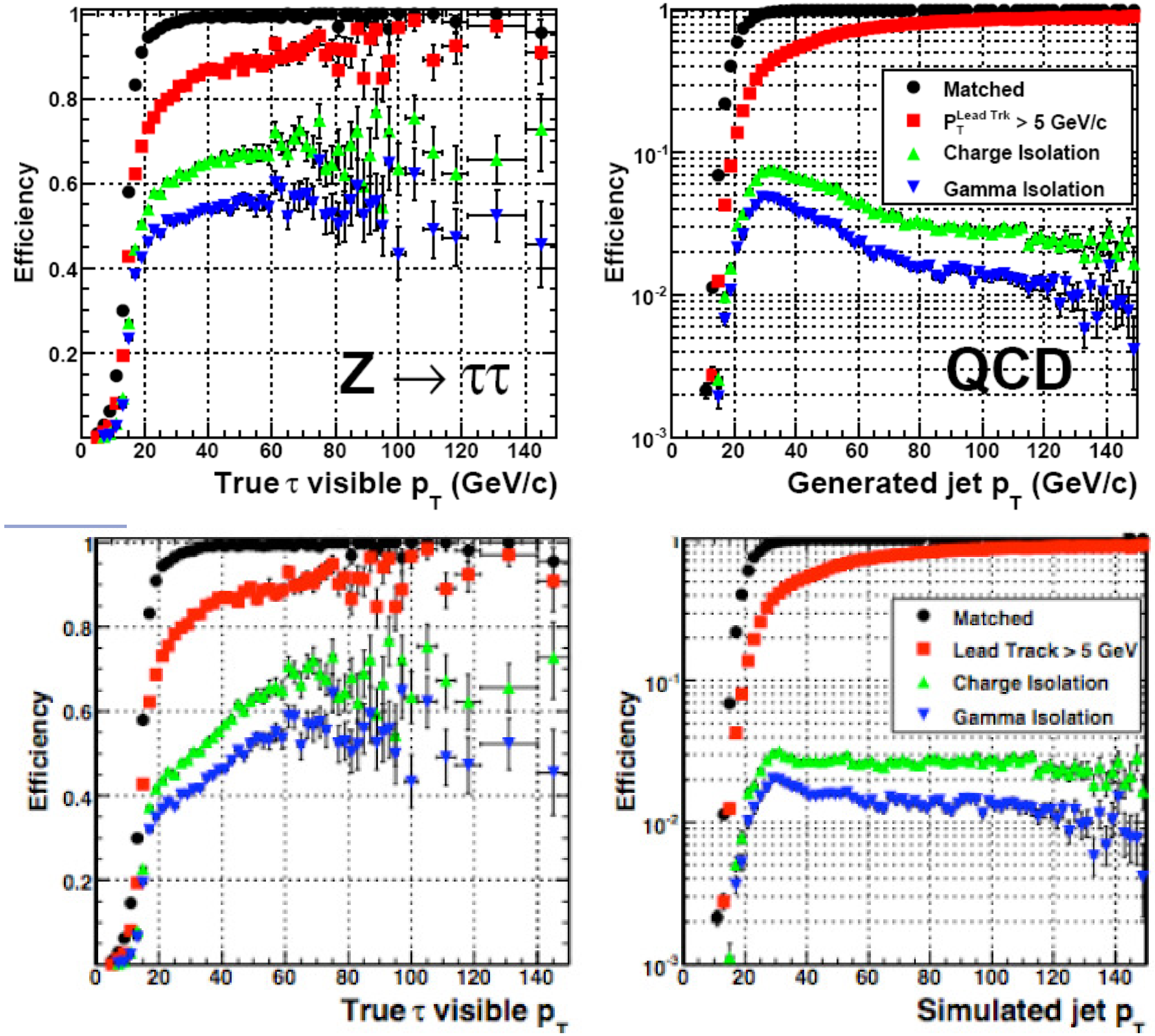
- Better signal efficiency in the low-p_T region due to a better acceptance for the three-prong τ because of the larger signal cone in which all tracks can fit





Tau base reconstruction: global efficiencies

- Global efficiencies of the preselection cuts as a function of p_T for the (new) shrinking and the (old) fixed cone



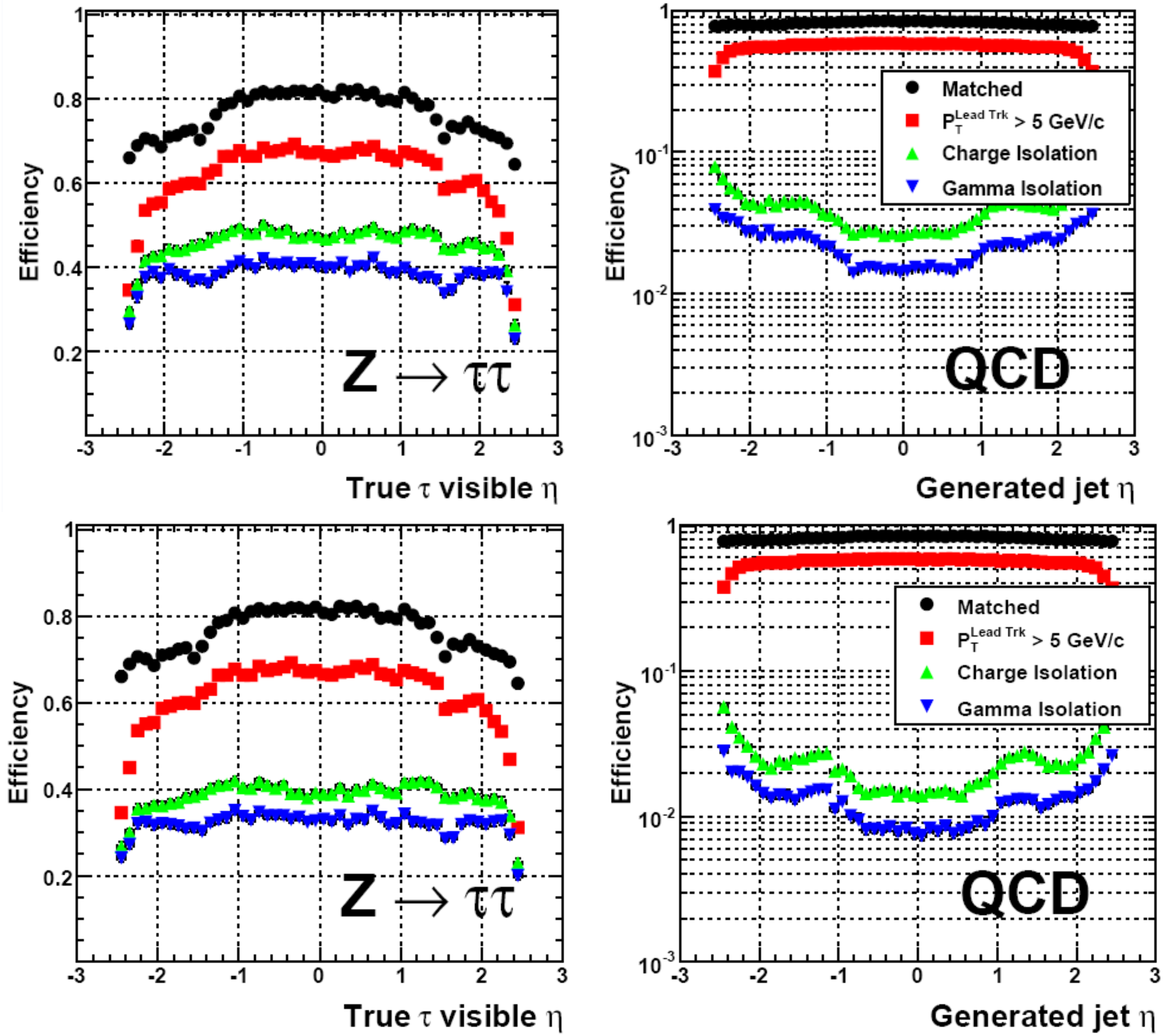
shrinking cone

Efficiencies respect to τ or QCD jets with a true visible p_T>5 GeV/c and true $|\eta|$<2.5

fixed cone

Tau base reconstruction: global efficiencies

- Global efficiencies of the preselection cuts as a function of η for the (new) shrinking and the (old) fixed cone



shrinking cone

Efficiencies respect to τ or QCD jets with a true visible p_T>5 GeV/c and true $|\eta|$<2.5

fixed cone

High-level identification criteria

- Aimed at suppression of e and μ from EWK processes

MUON REJECTION

- Standard muon reconstruction (τ efficiency >99%, μ rejection efficiency 99%)

ELECTRON REJECTION

- Electron algorithm based on fast multivariate analysis of tracker and calorimeter informations (efficiency 95% for electrons, 5% for pions)
- Optimized electron veto (τ efficiency 92.5%, e efficiency 1.5%)

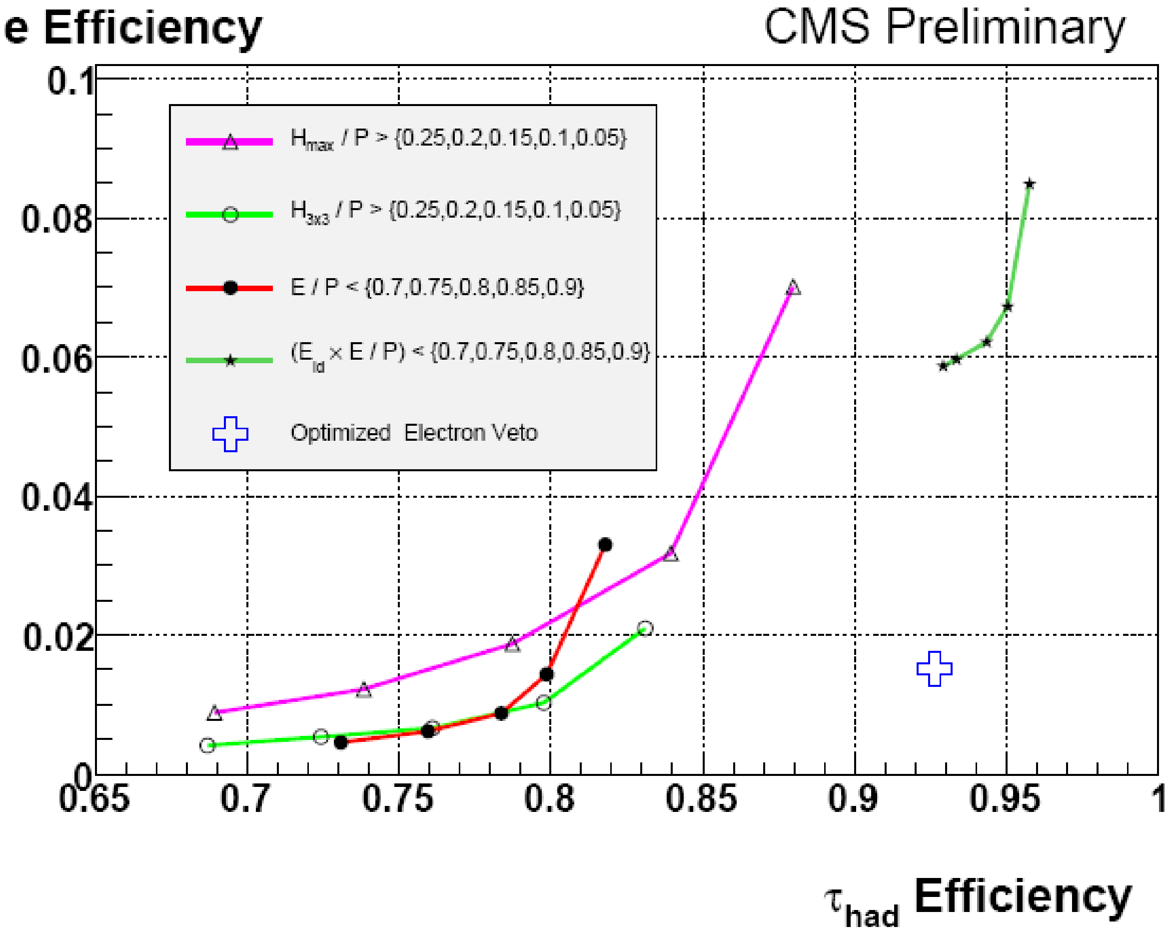
High-level identification criteria

- **Optimization of electron veto**
  - E/P → summed energy of all ECAL clusters in $|\eta|<0.04$ with respect to the extrapolated impact point of the leading track on the ECAL surface divided by the momentum of the leading charged hadron
  - H_{3x3}/P →summed energy of all HCAL cluster within $\Delta R<0.184$ around the extrapolated impact point of the leading track on the ECAL surface divided by the momentum of the leading charged hadron

$E/P<0.8$ or $H_{3x3}/P>0.15$ for τ cand not pre-id. as e
$E/P<0.95$ or $H_{3x3}/P>0.05$ for τ cand pre-id. as e

High-level identification criteria

- Efficiency plot for several variables defined for the e rejection and the optimized electron veto



Conclusions

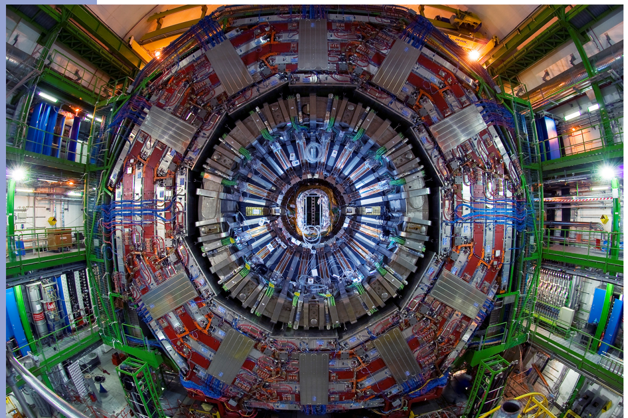
- Leading track requirement provides a significant suppression of QCD backgrounds (dominated by low-p_T QCD jets)
- The shrinking cone diminishes the effectiveness of isolation requirement but it allows a better selection of three-prongs decays at low energy, not selected with the fixed cone approach because of the smaller size of the signal cone

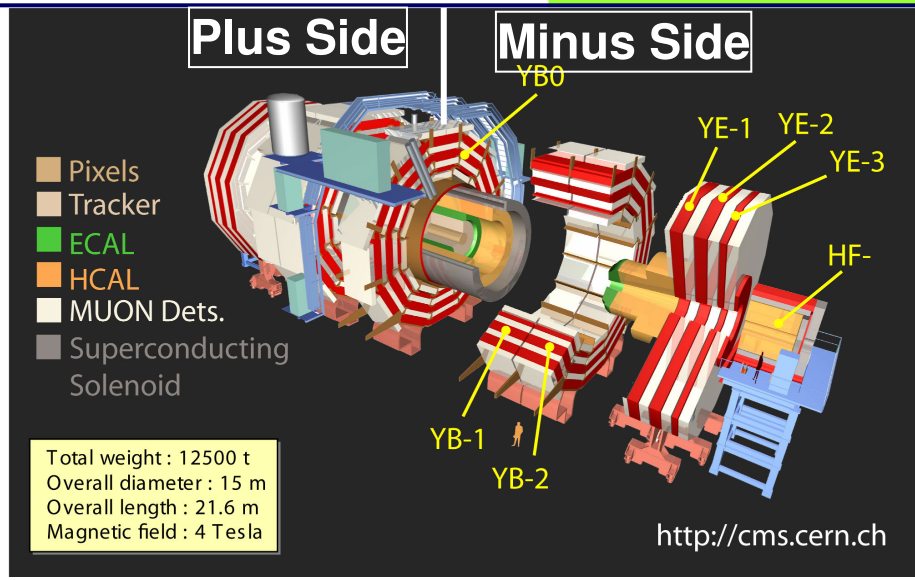
Future work

- Integration of the photon conversion reconstruction into the particle-flow framework is under development: its inclusion in the high-level analysis tools will allow a better tuning of photon isolation
- Multivariate discrimination techniques
- Data-driven techniques for the estimation of tau efficiency and fake rate from the first data

BACKUP

CMS overview





SubDetector	Resolution	Coverage
Tracker	σ_{pT}/pT = 1-5% pT	$\|\eta\|<2.5$
ECAL	$\sigma_E/E=(3\%/\sqrt{E})+0.5\%$	$\|\eta\|<3$
HCAL	$\sigma_E/E = (65\%/\sqrt{E})+0.05\%$	$\|\eta\|<3$ B, 5 F
Muon system	$\sigma_{pT}/pT=5\%$ @1TeV	$\|\eta\|<2.4$

Samples and efficiencies

- Signal 75000 Z->tau tau (both decaying hadronically); QCD background 720000 events with p_T_hat from 5 to 120 GeV/c
- Efficiencies are defined per tau candidate with respect to those with p_T>5GeV/c and |n|<2.5; the reconstructed jet axis within $\Delta R<0.15$ respect to the simulated tau or within $\Delta R<0.3$ respect to the simulated QCD jets
- Marginal efficiencies: measured with respect to the tau candidates that satisfy the previous cuts
- All efficiencies are offline efficiencies: they don't include trigger efficiency

Other electron rejection variables

- H/P: the summed energy of all HCAL clusters divided by the momentum of the leading charged hadron inside the jet
- H_{max}/P: the energy of the leading HCAL cluster divided by the momentum of the leading charged hadron inside the jet

Calo Tau (from CMS Physics TDR)

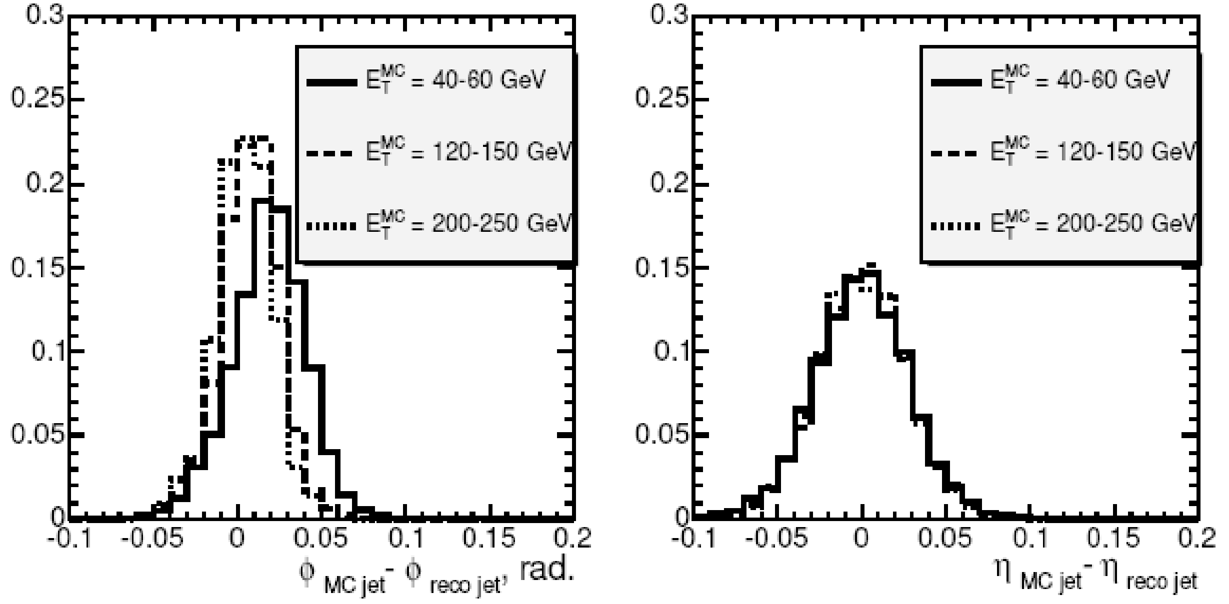


Figure 12.3: The difference between the true and reconstructed values of the τ-jet direction components, ϕ (left plot) and η (right plot), where the reconstructed jet direction is determined using calorimeter information. Three τ-jet energy ranges are shown which have been determined using Monte Carlo truth information. All τ leptons used to make these plots were positively charged.

Calo Tau (from CMS Physics TDR)

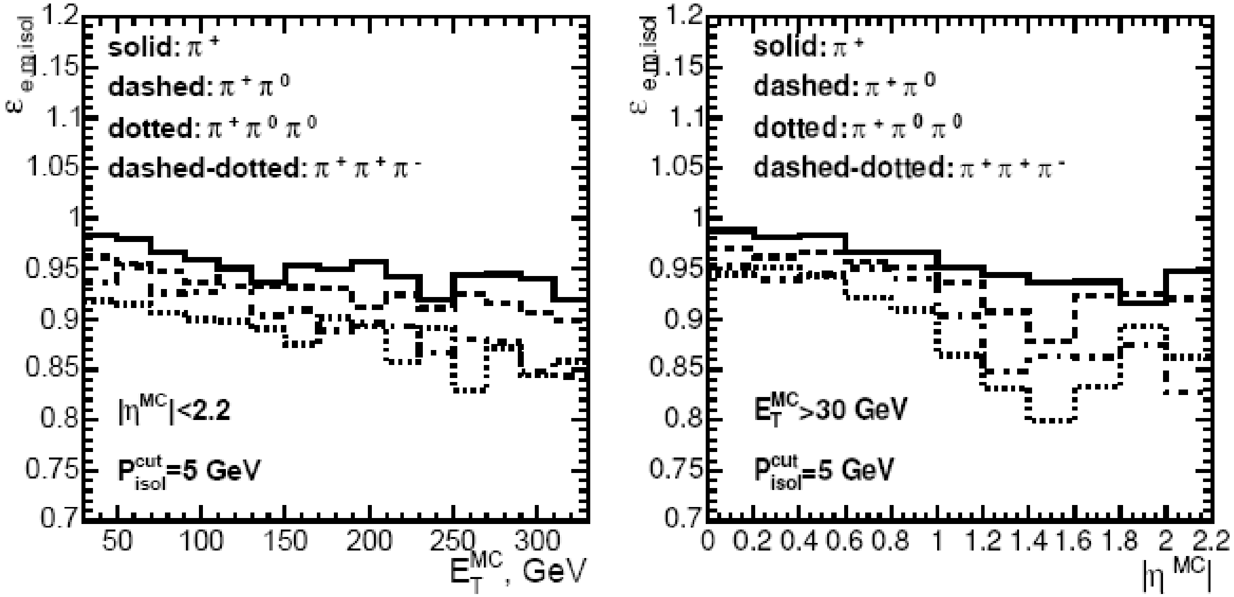


Figure 12.6: The efficiency of the ECAL isolation for τ jets as a function of E_T^{MC} (left plot) and $|\eta^{MC}|$ (right plot) for $P_{isol}^{cut} = 5$ GeV/c. The efficiency is shown separately for different final states of hadronic decays of τ lepton.

Calo Tau (from CMS Physics TDR)

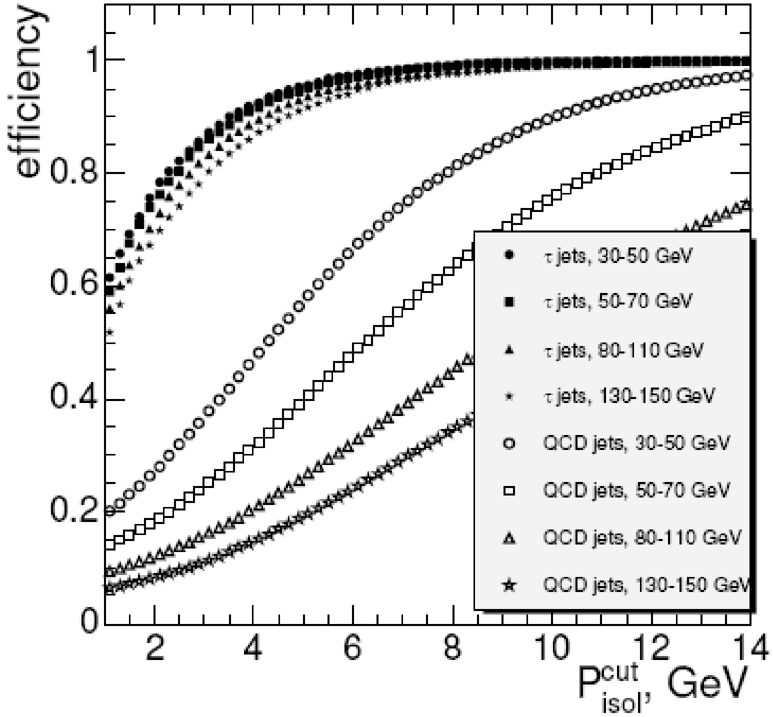


Figure 12.7: The efficiency of the electromagnetic isolation criterion, for τ jets and QCD jets in the different bins of the true transverse energy when the value of P^{cut}_{isol} is varied.

Calo Tau (from CMS Physics TDR)

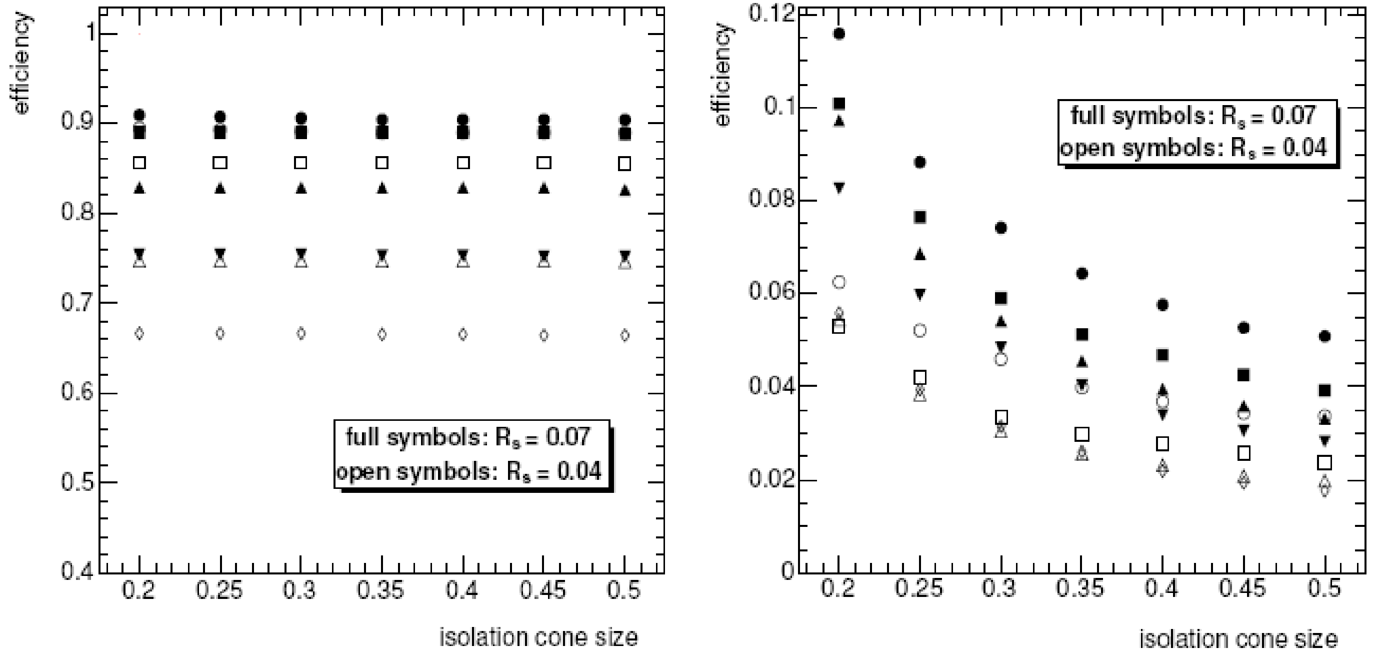


Figure 12.9: The tracker isolation efficiency for τ jets (left plot) and QCD jets (right plot) as a function of the isolation cone R_i for 2 values of the signal cone R_S=0.07 (full symbols) and R_S=0.04 (open symbols). In order of decreasing efficiency the symbols correspond to E_T^{MC} bins of 130–150, 80–110, 50–70 and 30–50 GeV. The remaining tracker isolation parameters are: R_m=0.1, p_T^i=1 GeV/c, Δz_{tr}=2 mm and the leading track $p_T > 6$ GeV/c.

Calo Tau (from CMS Physics TDR)

Table 12.2: The efficiency of the track counting requirement for τ and QCD jets in different bins of E_T^{MC}.

QCD jets; E_T^{MC} (GeV)	30–50	50–70	80–110	130–150
1 track	63 %	72 %	69 %	60 %
3 tracks	7 %	9 %	9 %	13 %
1 or 3 tracks	70 %	81 %	78 %	73 %
τ jets; E_T^{MC} (GeV)	30–50	50–70	80–110	130–150
1 track	81 %	77 %	71 %	70 %
3 tracks	10 %	16 %	16 %	20 %
1 or 3 tracks	91 %	93 %	87 %	90 %