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Reconstruction of Z->$\tau\tau$->e+τ jet events with early data in CMS

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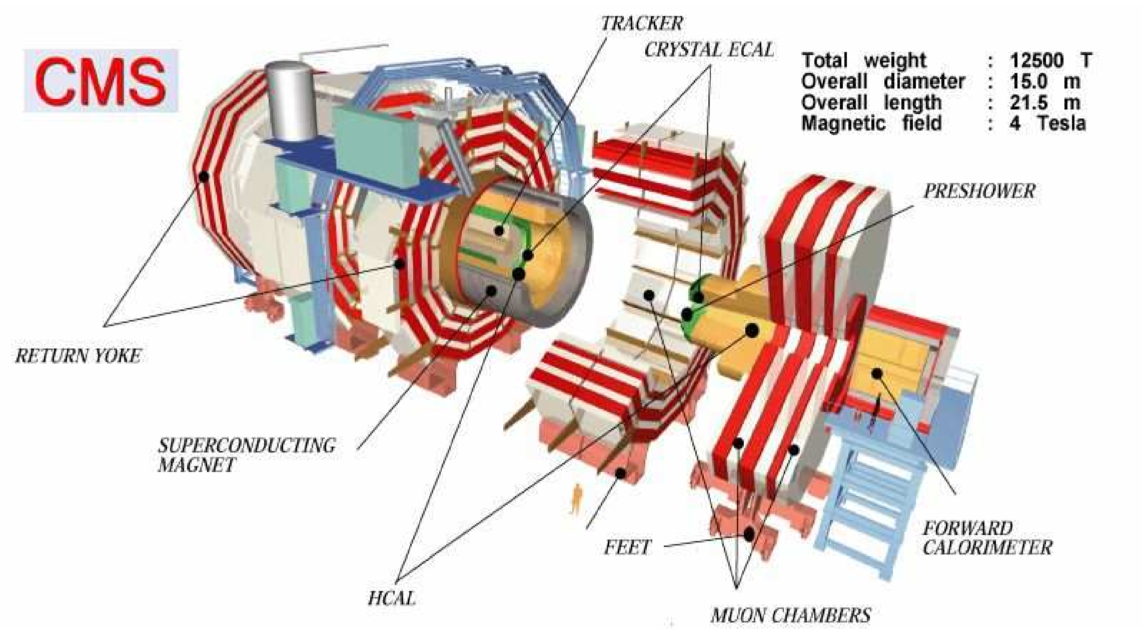
Overview

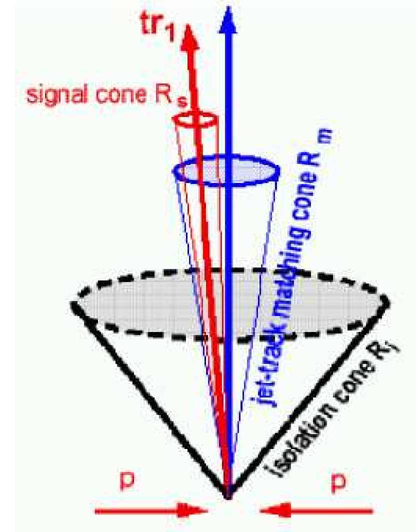
- Motivation
- Detector and algorithm description
- Aspects of τ jet reconstruction
- Results
- Background estimation
- Conclusions

Introduction

- Motivation for reconstructing and selecting $Z \to \tau\tau \to e+\tau$ jet events
  - Benchmark for light SM/SUSY $H \to \tau\tau \to e+\tau$ jet discoveries
  - Main channel to measure τ jet tagging efficiency
    - Vital ingredients for the measurement of x-section of events involving τ jets
    - Input to measurements of SUSY studies
- Description of Reconstruction and Selection strategy
  - Trigger on events using the Single Electron Trigger
  - Offline electrons matched to HLT and pass offline Id with E_T>16GeV
  - Offline Calo τ jet E_T>20GeV passing e rejection and isolated in the tracker with using $\eta-\phi$ cone with constant R_s and 1 or 3 signal tracks
  - $M_{e\text{-}MET}<60\text{GeV}/c^2$, $\Delta\phi_{e\text{-}MET}<2.4$, $N_{other\ jets}<2$
  - Require e, τ jet candidates to have opposite charge

The CMS Detector





Electron L1+HLT: Calorimeter isolation at L1. At HLT build Ecal clusters out of "L1 accepted" objects. Build pixel seeded tracks and require E/P, HCal and Tracker isolation cuts.

Offline Electron Id: Based on H/E, E/P, cluster shape, brem fraction, track-cluster matching …cuts.

Tau Jet L1+HLT: Calorimeter isolation at L1. At HLT build calo-jets out of "L1 accepted objects". Build pixel seeded tracks and require Ecal and Pixel/Track isolation

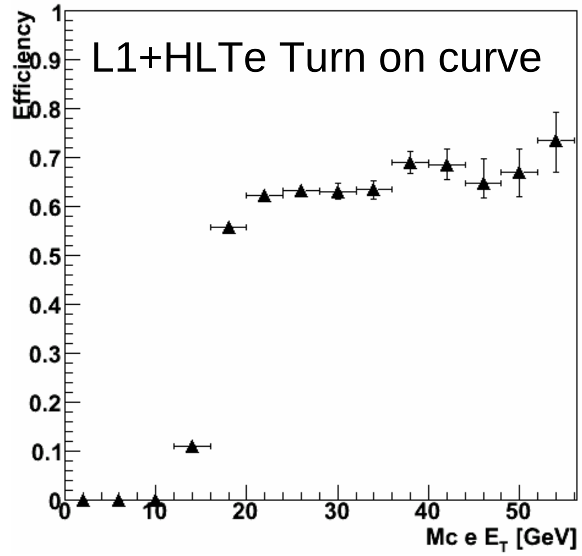
Tau Jet Offline: Calo/PF jet with isolated tracks. Variations of isolation (varying $R_{S,}$ $\eta-\phi$, $\theta-\phi$ cone definitions….)

Triggering on Z->ττ->e+τ jet

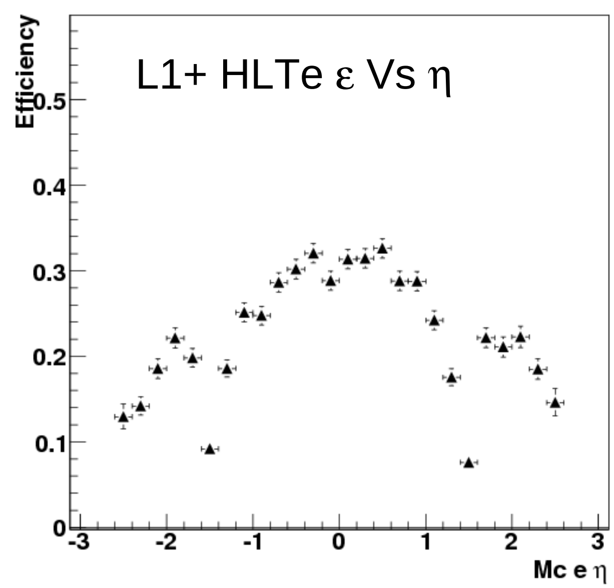
- Ideally trigger using HLT e+eτ jet trigger
- At $10^{32}cm^{-2}s^{-1}$: HLTe E_T^e>15GeV

HLTe+τjet E_T^e>12GeV $E_T^{\tau\ jet}$>20GeV

- No gain of HLTe+τ jet on top of HLTe at $10^{32}cm^{-2}s^{-1}$
- HLTe+τ jet becomes important at higher L scenario when HLTe E_T threshold increases



Trigger/Samples	$Z \to e + \tau$-jet	QCD $\hat{p}_T$ 15-170 GeV/c
Level-1 $e+\tau$	$(43.9 \pm 0.4)\%$	(1.92 ± 0.05) kHz
HLT $e+\tau$	$(16.2 \pm 0.6)\%$	(0.37 ± 0.37) Hz
Level-1 + HLT $e+\tau$	$(7.2 \pm 0.3)\%$	(0.04 ± 0.04) Hz
Level-1 $e+e\tau$	$(55.8 \pm 0.4)\%$	(3.15 ± 0.07) kHz
Level-1+HLT $e+e\tau$	$(22.9 \pm 0.4)\%$	(12.41 ± 3.96) Hz
Level-1+HLT *e*	**(22.4+/-0.4)%**	**~(12+/-4)Hz**

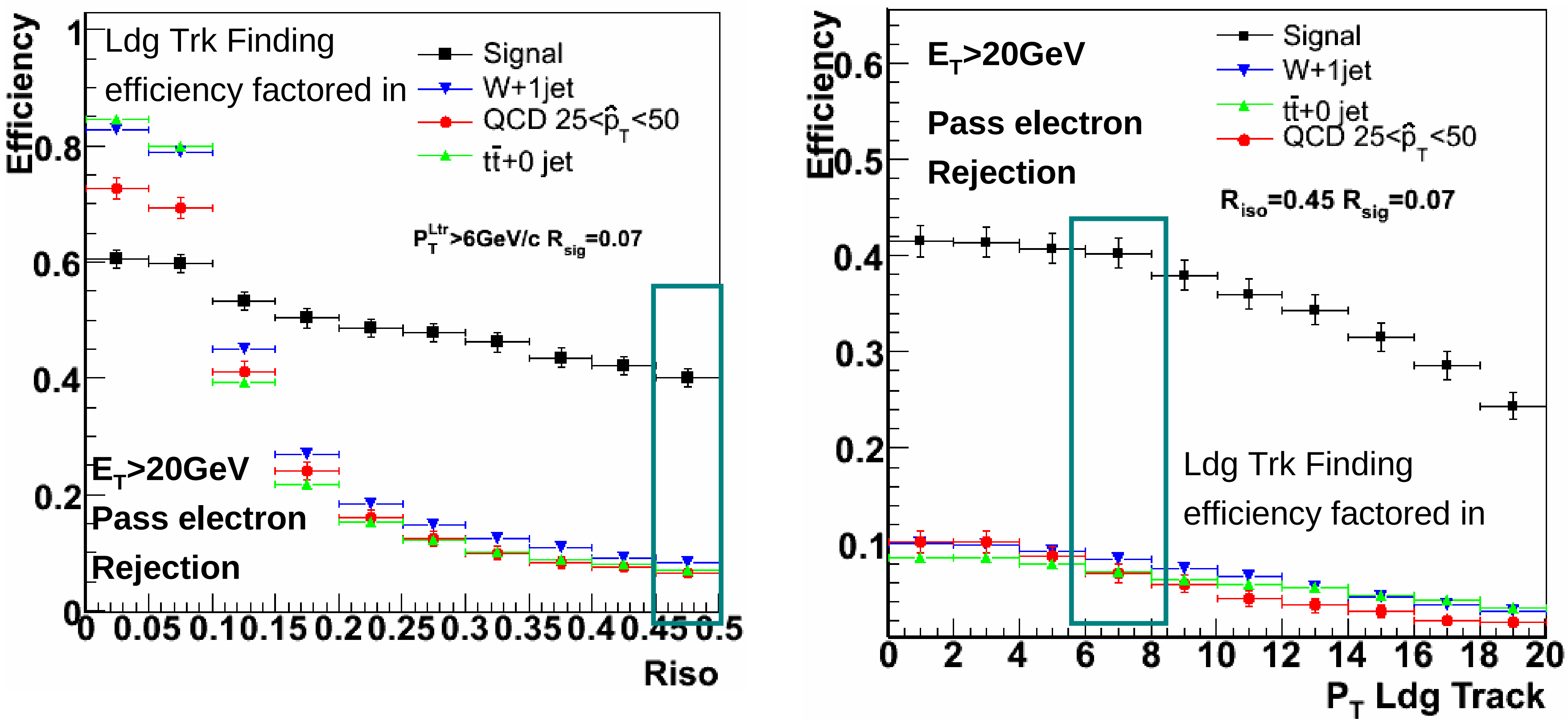


HLTe = Single electron HLT

HLTe+τ jet = Single electron AND τ jet HLT

HLT e+eτ jet = HLTe OR HLTe+τjet

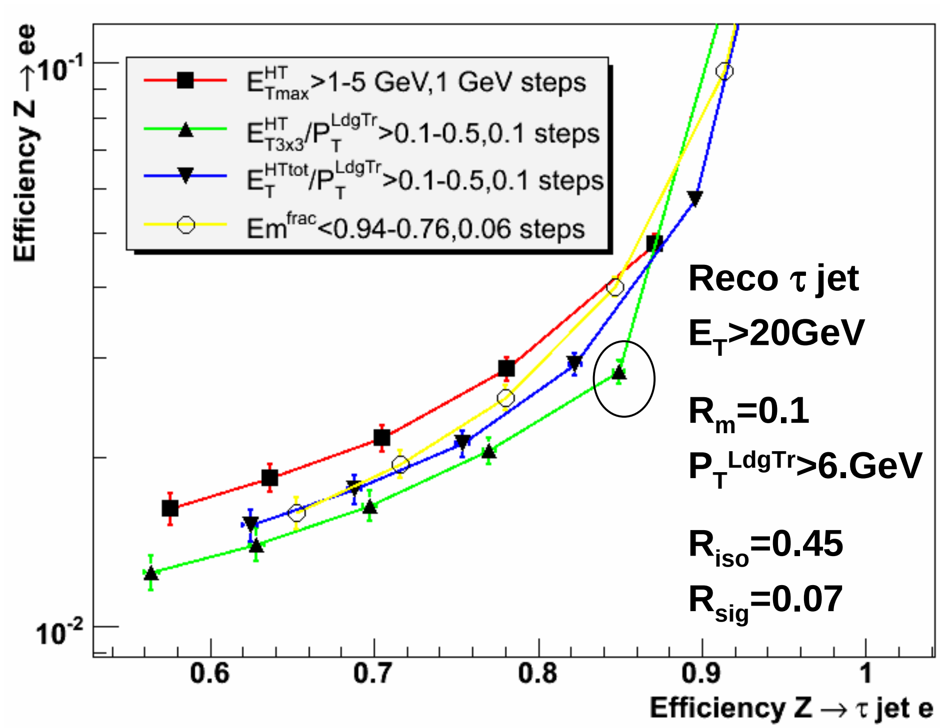
Offline τ jet tracker isolation performance



e-τ jet misidentification

- Electrons are ideal candidates to pass τ jet identification criteria since they are single isolated tracks. Need to be able to reject them.

- Consider $E_{T3x3}^{HT}/P_T^{LdgTr}$ = Sum of 3x3 HCal Tower E_T around ldg track impact point on Calo Surface divided by Ldg Trk P_T



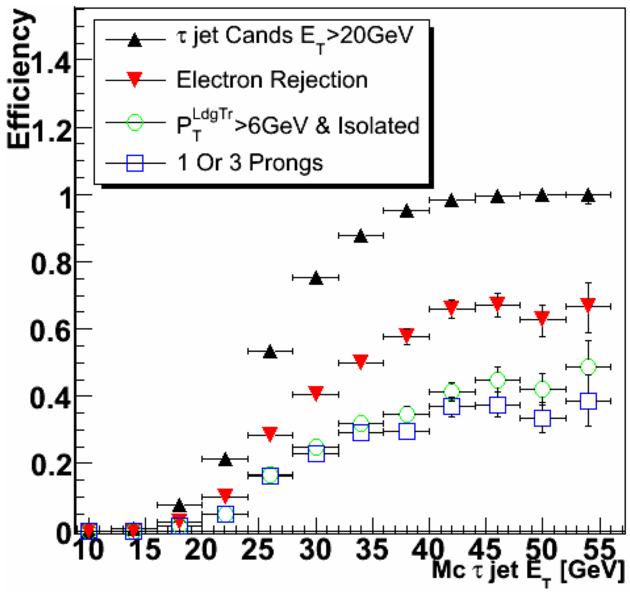
- For (85+/-0.2)% τ jet efficiency mark, $E_{T3x3}^{HT}/P_T^{LdgTr}$>0.1 gives lowest e efficiency (2.7+/-0.2)% out of all selections

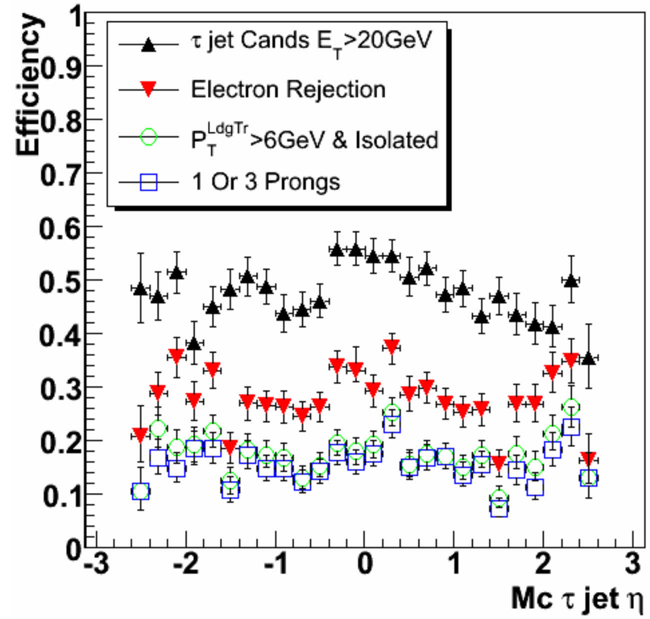
- Further apply veto for candidates with LdgTr @ Ecal pointing to η cracks giving a total

τ jet eff ~80%

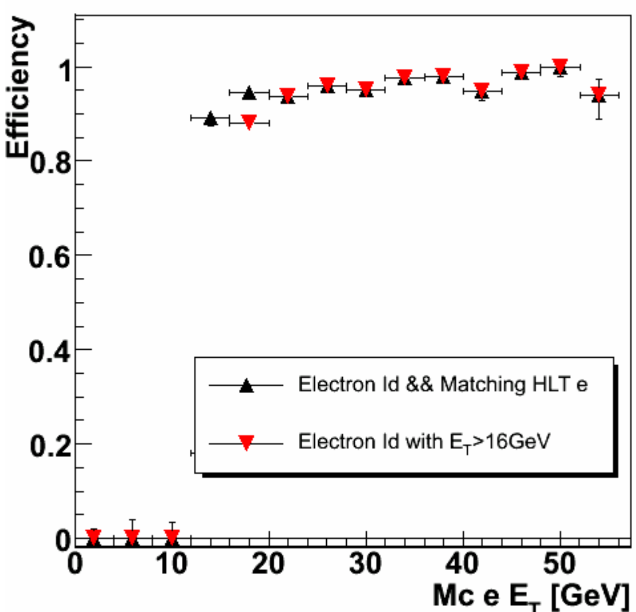
e eff ~1%

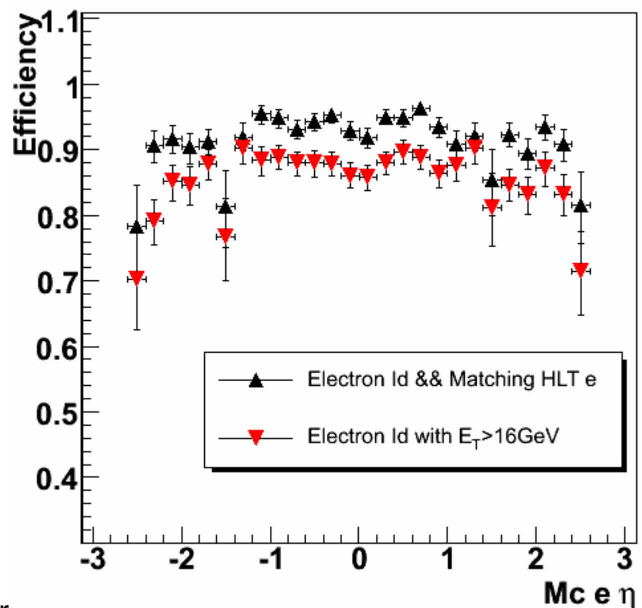
Offline Signal Performance





τ jet id eff

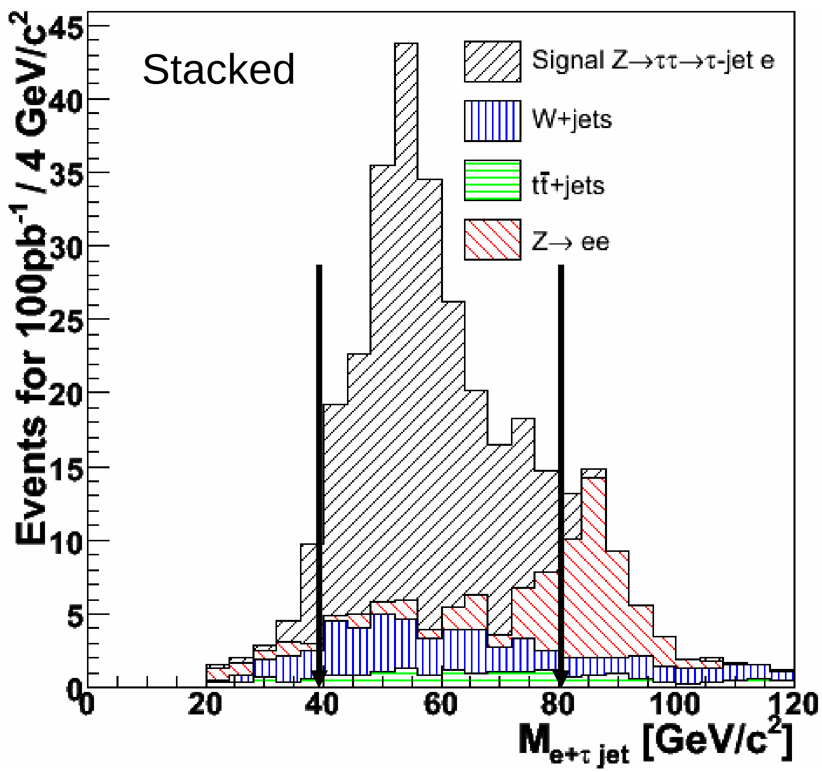




e id eff

Mass Plot

Look at invariant mass between Opposite Sign (OS) reconstructed visible Z products $M_{e+\tau\ jet}$ since want to minimise the use of Missing E_T at startup



Signal: 195.8

W+jets: 27.5

ttbar+jets: 10.4

Zà ee: 17

S/√(S+B) ~26

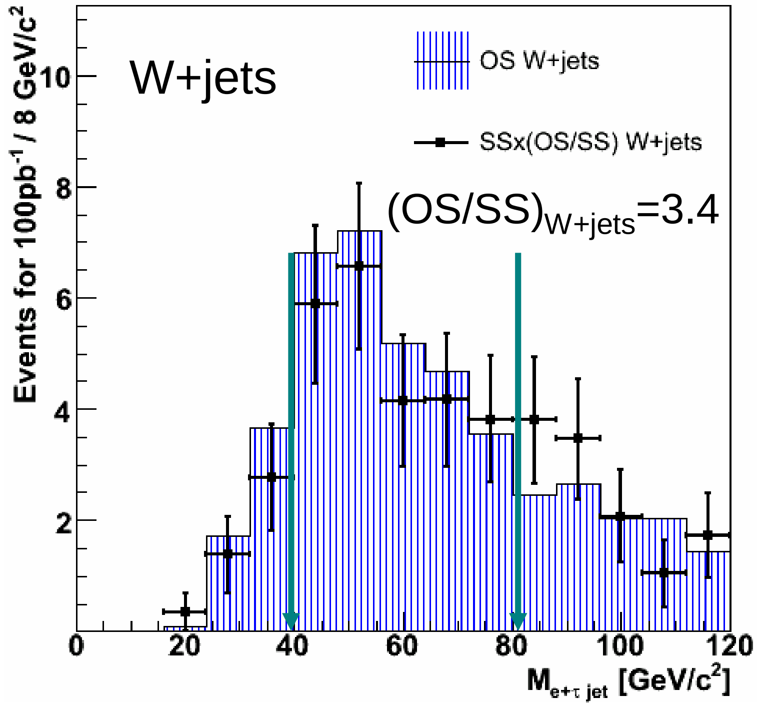
Contribution of QCD is currently being evaluated

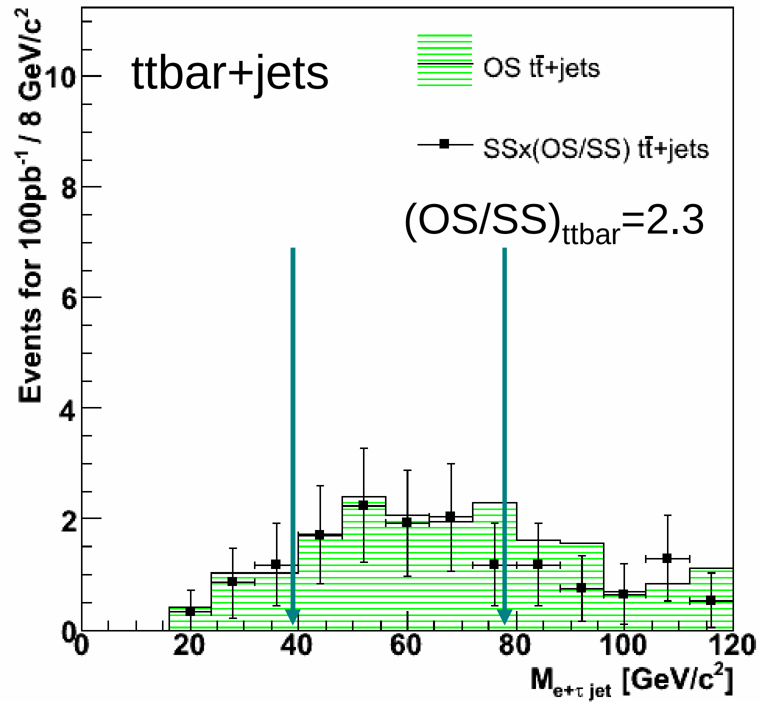
Background Estimation

- The charges of the electron and τ jet in Signal events are opposite
  - This gives a good handle for selecting a Signal-Free mass window by looking at Same Sign (SS) $M_{e+\tau\ jet}$
  - Background contribution in the Opposite Sign (OS) mass window can be extracted by looking at the number of events and shape of the SS mass window
- Charge correlations between QCD and EWK processes are different so treat separately
  - For W+jets, ttbar ,Z+jets->ee, we use dedicated analyses to get the number of events for the corresponding luminosity and apply the selections efficiencies obtained from MC simulations to extract N_{W+jets}^{SS}, N_{ttbar}^{SS}, $N_{Z+jets\text{->}ee}^{SS}$
  - The $(OS/SS)_{EWK}$ ratios are obtained from MC simulations and verified with data
  - For QCD: $N_{QCD}^{SS} = N_{data}^{SS} - N_{W+jets}^{SS} - N_{t\bar{t}}^{SS} - N_{Z+jets}^{SS}$
  - And $(OS/SS)_{QCD}$ can be obtained by looking at events passing a Non-Isolated electron trigger. This trigger has just been approved by CMS so this study is ongoing

W+jets and ttbar Background Estimation

Extracting OS mass dist'n from SS $N^{OS}=N^{SS}x(OS/SS)_{MC}$





$N^{OS}=27.5$

$N^{SS}x(OS/SS)_{MC} = 25$

$N^{OS}=10.4$

$N^{SS}x(OS/SS)_{MC} = 9$

Z->ee Background Estimation

- Extract OS Z->ee contribution by looking at events with reverse electron rejection criteria $E_{T3x3}^{HT}/P_{T}^{LdgTr}<0.1$ (τ-veto)
- Hence $N_{Z\text{->}OS}^{e\text{-}veto}=N_{Z\text{->}eeOS}^{\tau\text{-}veto} \times \varepsilon_{Z\text{->}ee}^{e\text{-}veto}/\varepsilon_{Z\text{->}ee}^{\tau\text{-}veto}$
- This requires knowledge of $\varepsilon_{Z\text{->}ee}^{e\text{-}veto}/\varepsilon_{Z\text{->}ee}^{\tau\text{-}veto}$ which can be extracted using “Tag and Probe” methods (See Backup)
- Can also extract mass shape however there are still some discrepancies that need to be understood

Conclusions

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- Presented a brief description of some of the aspects of selecting and reconstructing Z->ττ->e+τ jet events
- Performance of the algorithms was discussed
- For 100pb^{-1} we have ~200 Signal with ~ 55 Bkg events (QCD omitted)
  - Effect of QCD is currently been studied. Recently produced 10pb^{-1} and results out shortly
- Methods for extracting the number and shape of background events from data were discussed
- Finally a data driven method for measuring the “per event” τ tagging efficiency is presented in the backup. Studies are ongoing to use a more powerful method (System D of D0) to measure the “per jet” efficiency as a function of kinematic variables

Backup

Samples used

- Data Sets used
  - Signal: Pythia Zà ττà e+τ jet with $|\eta|_{e,\tau\ jet}$<2.5 70GeV/c^2<m_Z<110GeV/c^2
  - Pythia Zà ee $|\eta|_e$<2.5 m_Z>40GeV/c^2
  - Alpgen W+0,1,2 jets
  - Alpgen ttbar+0,1,2 jets
  - Pythia QCD p_T^{hat} 25-170GeV

Triggering on Z->ττ->e+τ jet events

- Ideally a logical OR between Single Isolated e HLT (e HLT) and the X-channel eτ HLT should be used
  - However current trigger table designed for $L=10^{32}cm^{-2}s^{-1}$ has low E_T threshold for eHLT
  - For startup L use only Single e HLT which is ideal for τ tagging efficiency measurement

Selection criteria	eτ+e HLT selections
Level-1 τ, isolated electron E_T [GeV]	20, 10
HLT e E_T [GeV]	12
L25 regional pixel seeding region $\delta\eta$, $\delta\phi$	0.1, 0.1
L25 cone isolation ΔR_{iso}, ΔR_{sig}, p_T^{LdgTr}	0.45, 0.07, 6 GeV/c
L3 regional pixel seeding region $\delta\eta$, $\delta\phi$	0.5 , 0.5
L3 cone isolation ΔR_{iso}, ΔR_{sig}, p_T^{LdgTr}	0.45, 0.07 , 6 GeV/c
Level 1 single isolated electron E_T [GeV]	12
HLT single electron E_T [GeV]	15

"CMS HLT exercise" Table

Very similar thresholds

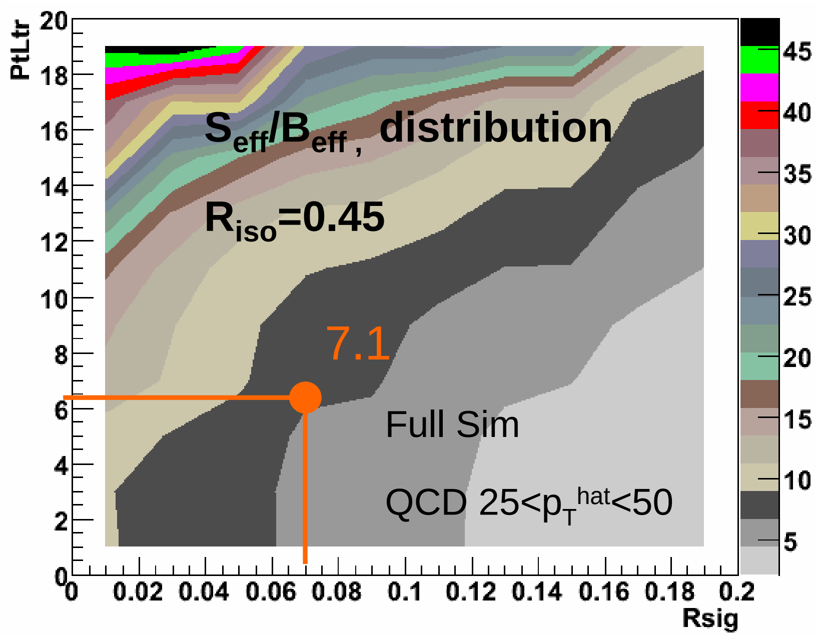
$Z \to \tau\tau \to e\ \tau-$jet Selection	Efficiency
L1+HLT e	$(23.7 \pm 0.2)\%$
L1+HLT e OR eτ	$(25.1 \pm 0.2)\%$
L1+HLT e + Offline	$(0.81 \pm 0.04)\%$
L1+HLT e OR eτ + Offline	$(0.83 \pm 0.04)\%$

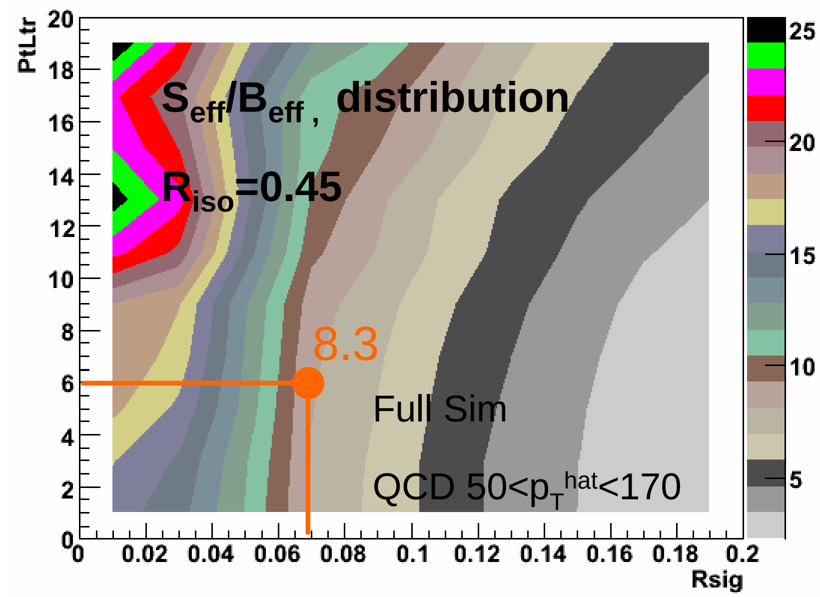
Gain of using eτ HLT on top of e HLT is minimal both at HLT and offline

- However as L increases, e HLT E_T threshold will need to increase accordingly
  - Gain of eτ HLT on top of e HLT will be more evident

τ id tightening

- Look at isolation + leading track finding efficiency in Signal QCD $25<p_T^{hat}<50$ and QCD $50<p_T^{hat}<170$





"Per jet" efficiency w.r.t jets that pass:

$E_T^{\tau\ cand}$>20GeV,

E_{T3x3}^{HT}/P_T^{Ldg}>0.1,

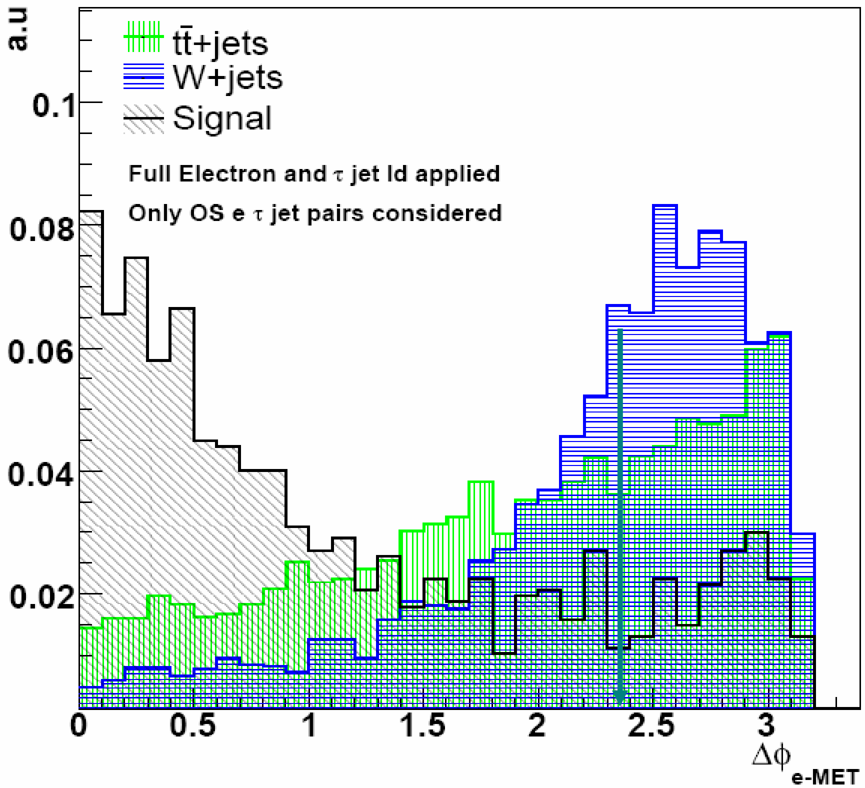
$\Delta\eta_{LdgTr-HTmax}$<0.1,

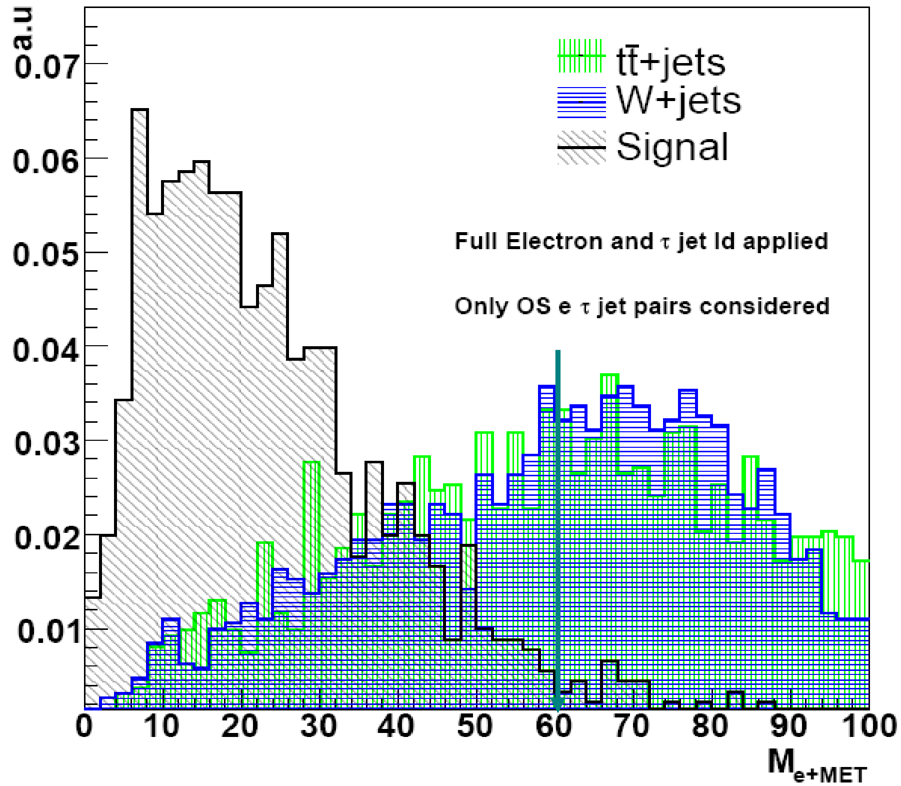
Tighten cuts: R_{sig}=0.05, P_T^{LdgTr}>16GeV

QCD_25_50 per jet S/B~22

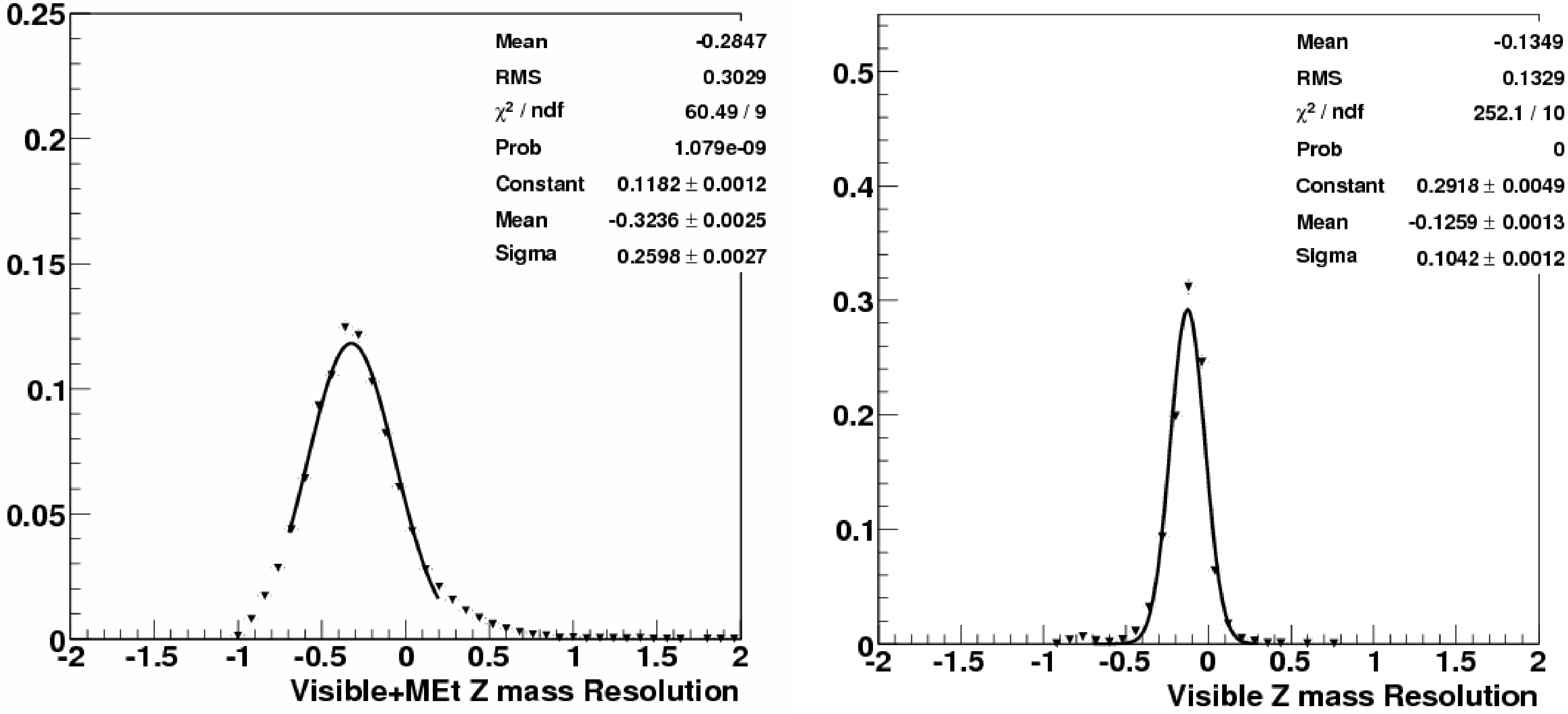
QCD_50_170 per jet S/B~15

Kinematic Variables





Mass Resolutions



Measuring Electron Rejection Efficiency on Electrons using Z->ee

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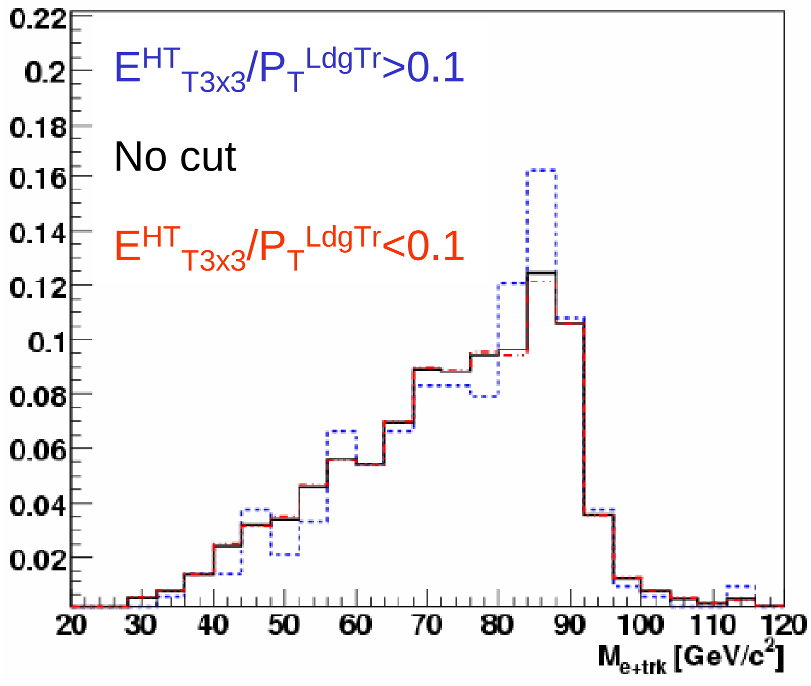
- Based on tag-probe method used by Egamma people
  - Use events triggered by Single Iso elec HLT
  - Tag: electron passing offline and HLT Id – Require only 1 per event
  - Probe: τ candidate passing isolation but without applying e-rej criteria AND not collinear to Tag electron
  - Then plot $M_{(tag-probe)}$ for:
    - a) No e-rejection criteria applied. Events in window=N_{tot}
    - b) With reversed e-rejection (τ-veto) criteria applied . Events in window=$N_{\tau\ veto}$
  - Contrary to tag-probe method of Egamma we define $M_{(tag-probe)}$ energy and direction of τ candidate and not track information.
  - $\varepsilon_{\tau\ veto}=N_{\tau\ veto}/N_{tot}$ and hence can get the e-rej efficiency $\varepsilon_{e\ veto}=1-\varepsilon_{\tau\ veto}$

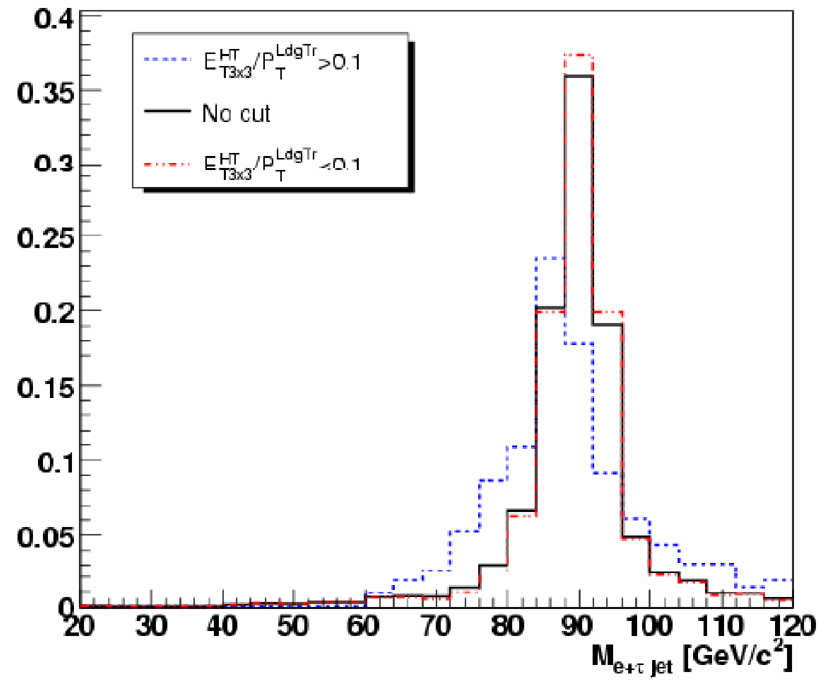
View of $M_{(tag+probe)}$

Probe = Ctf Track of 1-prong τ candidate



Large lower tail since combining "good" electron with CTF track of calo τ matching 2nd MCe from Z that does not appear in elec cand list (Bad elec)

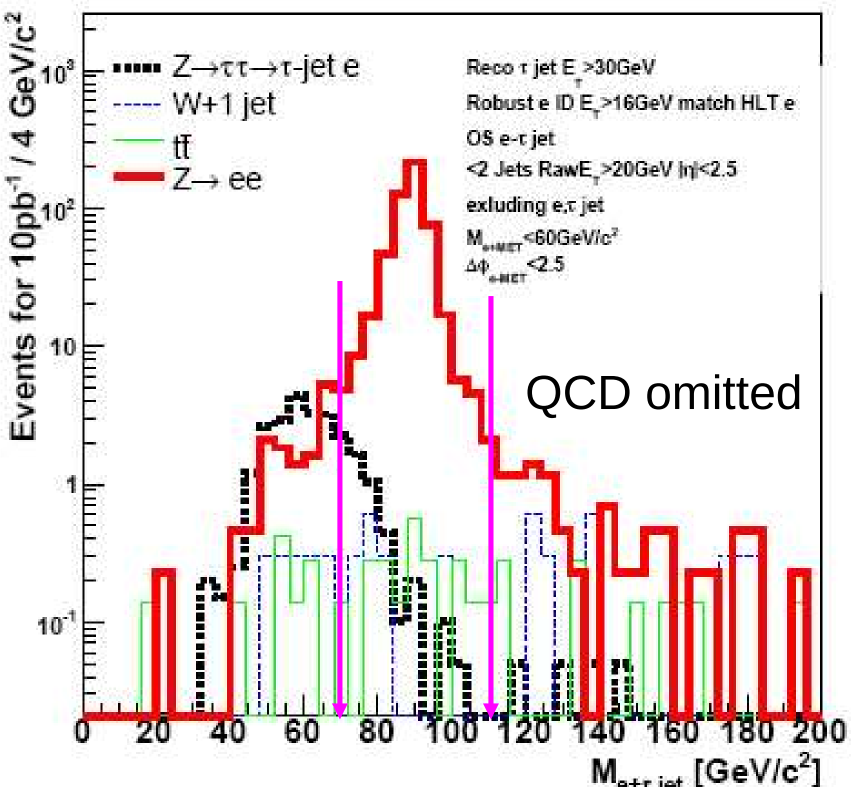
Probe = Calo Jet of τ candidate



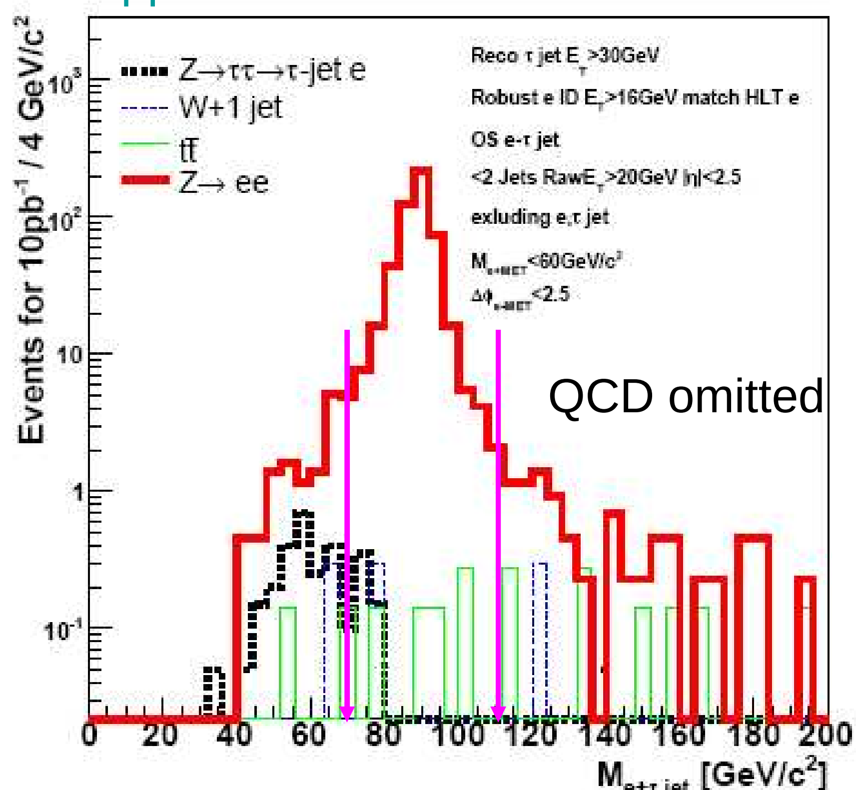
Combining good electron with calo τ matching 2nd MCe from Z. Mass is recovered. Mass shape discrepancy due to HCAL. (extent of difference under investigation)

Feasibility of measurement

$M_{e+\tau\ jet}$ for Z->ee and backgrounds with no e-rej criteria applied



$M_{e+\tau\ jet}$ for Z->ee and backgrounds with reverse e-rej (τ veto) criteria applied



>100 times more Z->ee than backgrounds within window. Can easily extract N_{tot} and $N_{\tau\ veto}$ and hence $\varepsilon_{e\ veto}=1-N_{\tau\ veto}/N_{tot}$ and $N_{e\ veto}=N_{\tau\ veto}x(1-\varepsilon_{\tau\ veto})/\varepsilon_{\tau\ veto}$

Effect of QCD is under estimation

Tau tagging efficiency measurement method (I)

- Method based on CMS Note 2006/074 (see backup)
  (A. Nikitenko, A. Kalinowski). **ORCA based, 30fb^{-1}**
  - **Ratio of x-sections of $Z\rightarrow ll$ /** $Z\rightarrow\tau\tau\rightarrow l+\tau$-jet using events (l = e in this study) **which fire single-lepton trigger**

$$\varepsilon_{\tau\ \mathrm{tag}} = \frac{N^{\mathrm{meas}}_{e\tau\ \mathrm{jet}} - N^{\mathrm{bkg}}_{e\tau\ \mathrm{jet}}}{N^{\mathrm{meas}}_{ee} - N^{\mathrm{bkg}}_{ee}} \times \frac{BR(Z\rightarrow ee)}{BR(Z\rightarrow\tau\tau\rightarrow e\,\tau\!-\!\mathrm{jet})} \times \frac{\varepsilon_{HLT^{ee}_{1e}}}{\varepsilon_{HLT^{e\tau\ \mathrm{jet}}_{1e}}} \times \frac{\varepsilon^{ee}_{\mathrm{mass\ reco}}}{\varepsilon^{e\tau\ \mathrm{jet}}_{\mathrm{mass\ reco}}}$$

- **Parameters which can be extracted from data:**
  - $N^{meas}_{e+tau\text{-}jet}$, N^{meas}_{ee},
  - $Br(Z\rightarrow ee)$, $Br(Z\rightarrow e+\tau)$ from e.g LEP
- **Parameters known from MC or data:**
  - $N^{bkg}_{e+tau\text{-}jet,ee}$, eff_{HLT}, $eff_{mass\ reco}$

Tau tagging efficiency measurement method (II)

- Definition of efficiencies
  - Want to measure τ tagging efficiency on as a pure sample of τ jets as possible, so apply electron rejection selections with efficiency $\varepsilon_{\tau q}$ before τ Id is applied

$$\varepsilon^{e\tau\ \mathrm{jet}}_{\mathrm{mass\ reco}} = \varepsilon_{\mathrm{e\,E_T}} \times \varepsilon_{\tau\,\mathrm{E_T}} \times \varepsilon_{\tau\,\mathrm{q}} \times \varepsilon_{\mathrm{m_T^{e-MET}}} \times \varepsilon_{\mathrm{nJets}} \times \varepsilon_{\Delta\phi_{e\tau}} \times \varepsilon_{E_\nu} \times \varepsilon_{\mathrm{m\,sel}}$$

- Definition of efficiency measured in note
  - For purpose of note Ldg Track finding efficiency was factored in efficiency

$$\varepsilon_{\tau\,\mathrm{tag}} = \varepsilon_{\mathrm{Ldg\,Tr}} \times \varepsilon_{\mathrm{iso}} \times \varepsilon_{1\,||\,3}$$

- This is a global efficiency given that electron rejection criteria are satisfied
  - Efficiency as a function of t jet E_T is underway, results by end of week

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Tau tagging efficiency measurement result

Summary of Zà ee selection efficiencies (cumulative)

$\sigma \times BR$[pb]	1700
single e HLT (E_T >15 GeV)	58%
pixel match gsf e (E_T >16 GeV)	57%
gsf e^+e^- pairs with m_{ee} >70 GeV/c^2	30%
Events for 100 pb^{-1}	51,000

- Assumptions made
  - Statistical errors in Zà ee events assumed negligible
  - Background events passing the Zà ee events assumed negligible
  - Systematic errors were not considered

- tau-id efficiency:
  - (40.5+/-6.3)% (Global and error only statistical). But topology & selection dependent
  - Errors and systematics are under estimation
  - Similarly we can calculate τ HLT efficiency given that offline τ ID criteria are satisfied