Tau Dilepton Analysis: $t\bar{t} \rightarrow \tau_h e j j$

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- Motivation
- Tau ID Cuts
- Fake Rates (electron and jet)
- Acceptance using ttbar MC
- Backgrounds
- Status

Motivation

- The decay chain:

$$t \rightarrow W + b \rightarrow \tau + \nu_\tau + b$$

- exclusively third generation quarks and leptons
- a light, charged Higgs ($t \rightarrow H + b \rightarrow \tau + \nu_\tau + b$) has the same final state

- This analysis concerns the decay chain:

$$t\bar{t} \rightarrow W, W, b, b \rightarrow e, \tau_{had}, \nu_\tau, \nu_e, b, b$$

- at the least:
  - increase acceptance of dilepton channels
  - cross section measurement
- you never know 'til you look:
  - could point to new physics

Tau Cuts

- We begin with a Cdf Tau Candidate, found with TauFinderModule (Fedor, Anton et alia)

Tau Variable	Cut
Cluster E_T	> 15 GeV
z_0	< 60 cm
Cal Mass	< 4.0 GeV/c^2
(Track + π^0) Mass	< 1.8 GeV/c^2
Cal Iso: ΔR=0.4/$E_T^{cluster}$	< 0.06
# tracks in Iso Annulus	0
# π^0's in Iso Annulus	0
# tracks in Tau Cone	< 4
$\mid \Sigma$(track charge) in Tau Cone$\mid$	1
μ veto	no stubs in 15 degree cone
e veto: E_{HAD}/SUM (P)	> 0.15

Table 1: Tau Cuts

- Tau Cone (and iso annulus) depend on Tau Energy
- Tau Group defaults include CES cuts and seed track quality cuts, which we're still missing

Electron Fakes

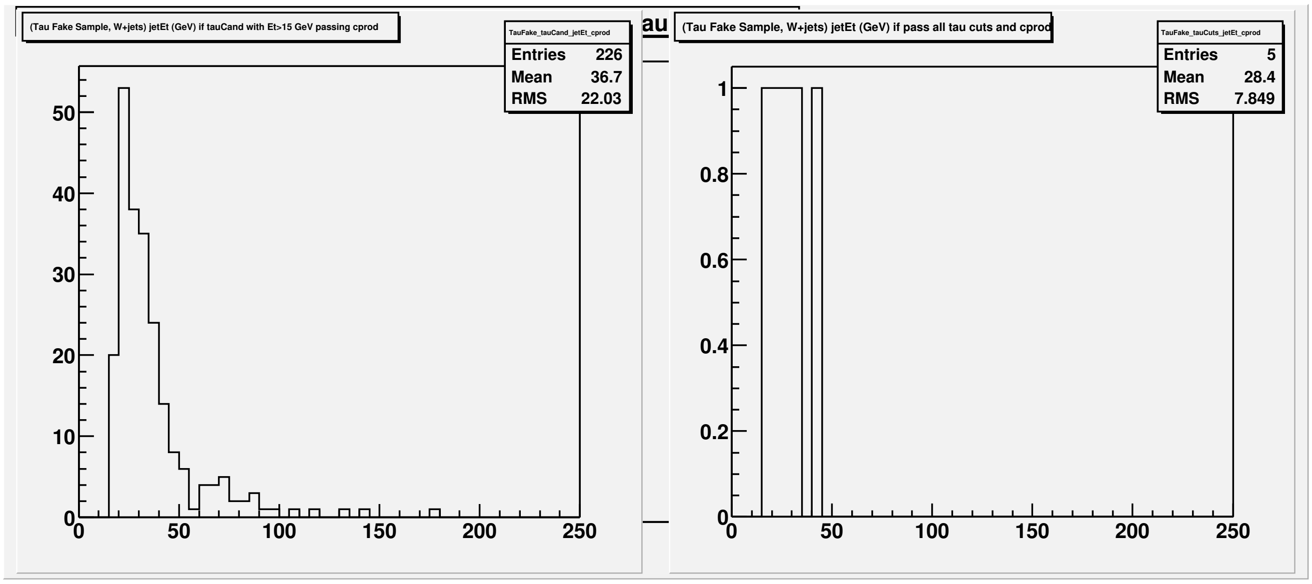
$E_{had}/\Sigma P$ value	# Events Passing cut	Electron Fake Rate
no cut	990	100%
0.05	98	10.1 ±1.0%
0.075	54	5.5 ±0.7%
0.10	36	3.6 ±0.6%
0.125	21	2.1 ±0.5%
0.15	12	1.2 ±0.4%

Table 2: From CDF Note 6408: Electron Fake Rates for different vales of the $E_{had}/\sum P$ cut measured from Z→ ee events in data.

- Measure Electron to Tau relative fake rates as a function of our electron veto variable using $Z \to ee$ events in the Data (CDF Note 6408)
- $E_{had}/\Sigma P$ is demonstrated to be independent of $\not{E}_T$
- Fake rate is relative because denominator includes all other tau cuts

Jet Fakes: W+jets

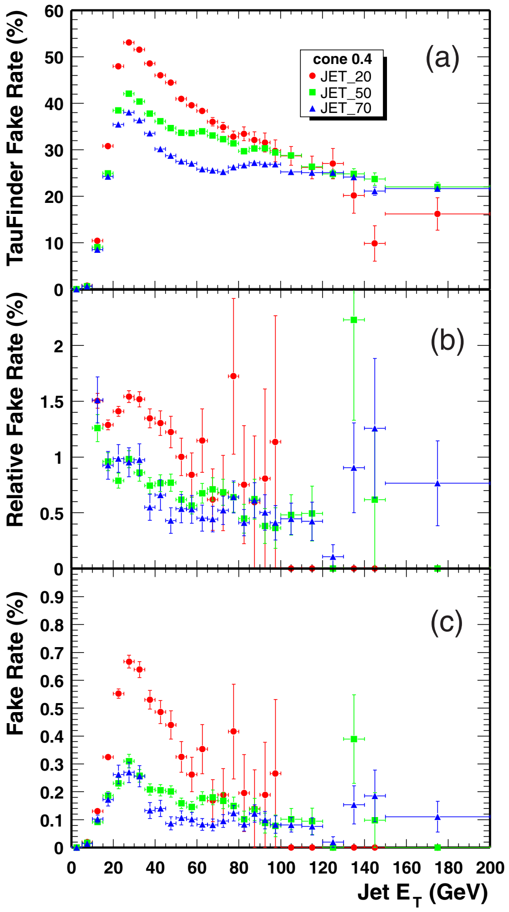
- Measure relative fake rate using the W+Jet data (correct heavy flavor content)
- Denominator Selection:
  - Electron $E_T > 25$GeV and $\not{E}_T > 25$GeV
  - Central Jet with $E_T > 10$GeV matching to a tau candidate with $E_T > 15$GeV (tau candidate must pass ele veto)
  - Ele and Jet are not back to back: $\Delta\phi < (\pi - 0.5)$
- Numerator Selection:
  - Denominator cuts plus Tau ID cuts



- 5 / 226 = 2$\pm$1$\%$
- there may be real taus in sample

Jet Fakes: Dijets

- Can also use Jet20, Jet50, Jet70 data
- Done by Rutgers members of the tau group (CDF Note 6308)
- Trigger Bias may not yet be completely understood (different fake rates for different data samples)
- The Rutgers group does not apply a Tau Et cut at 15GeV so we cannot use their results directly



- Tony V. is doing this analysis with the tau E_T cut

Analysis Cuts

- Goal: To use cuts similar to e, μ Dilepton Analysis cuts to allow for combining the analysis
  - Some Cut thresholds are lowered to achieve similar efficiencies as in the e, μ Dilepton Analysis
- Central tight electron candidate with $E_T > 20$ GeV
- Central tau candidate ($|\eta| < 1.1$) with $E_T > 15$ GeV that passes tau ID cuts
- electron and tau must have opposite charge
- Minimum of two jets (cone 0.4) separated by ΔR of 0.4 from tau and electron.
  - jet $|\eta| < 2.0$
  - jet $E_T > 10$GeV
- $\not{E}_{\rm T} > 20$GeV
  - similar efficiency as e, μ Dilepton cut at 25 GeV
- $H_T > 180$GeV (same as in Run1)
  - H_T is defined as the sum of the $\not{E}_{\rm T}$, E_T of the electron, E_T of the tau, and E_T of the two jets.
  - similar efficiency as e, μ Dilepton cut at 200 GeV

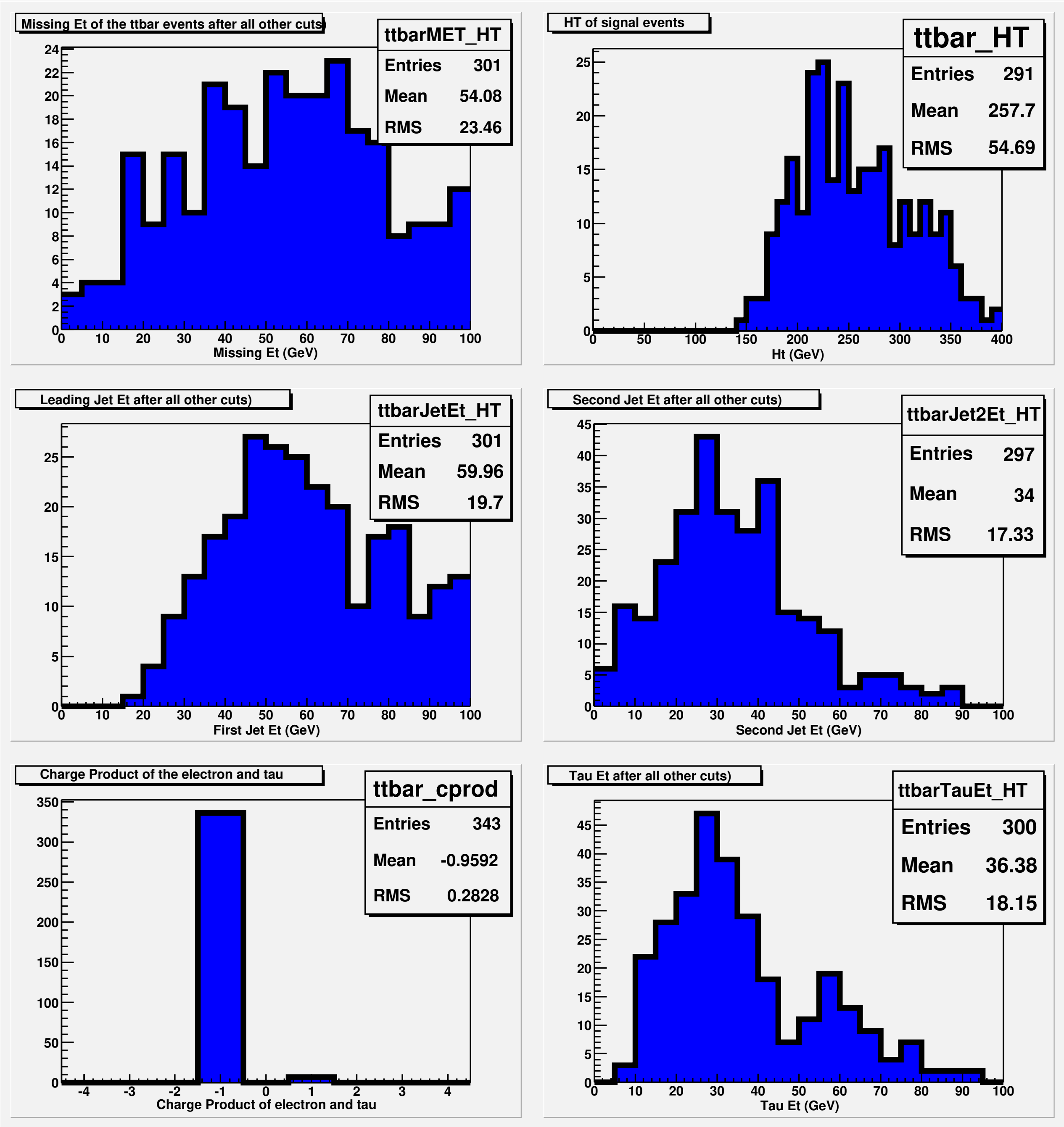
Acceptance

- We begin with the familiar MC dataset, ttop2i, which is 390,000 inclusive events generated with Herwig 6.4 and version 4.9.1 of the CDF Software.

Cut	#Events	sequential eff.	cumulative eff.
ttop2i dataset	390000		
e, τ_h final state	6427	1.6%	1.6%
tight, central ele	2504	39.0%	0.64%
cent tau ID	473	18.9%	0.12%
tau passes E_T cut	426	90%	0.11%
tau passes ele veto	386	91%	0.10%
opp sign tau, e	378	98%	0.097%
>2 jets	328	87%	0.084%
$\not\!E_{\mathrm{T}}$	291	89%	0.075%
H_T	275	95%	0.071%
$Z \to \tau\tau$ removal	266	97%	0.068±0.004%

Table 3: Acceptance numbers. Sequential efficiency refers to the number of events remaining after the cut divided by the number of events remaining just before the cut. Cumulative efficiency in the last column is the number of events surviving the cut divided by the total number of events in the dataset (390,000).

Acceptance - Plots from $t\bar{t}$ MC



- N-1 plots (with the exception of the ”first jet Et” plot, which is made with no requirement on the second jet.)

Background Summary

- Run1 Result (CDF Note 4280, M. Hohlmann, p156)
- 109±7 pb^{-1} using both e, τ and μ, τ channels

	Run1 # of Events	tools
$Z/\gamma^* \rightarrow \tau^+\tau^- + jets$	1.48±0.38	Mass Reco
τ fakes	0.78±0.04	jet fake rate
WW, WZ	0.24±0.09	Monte Carlo
$b\bar{b}$	< 0.10	jet, ele f.r.
$Z \rightarrow e^+e^-$	< 0.09	ele ID
$Z \rightarrow \mu^+\mu^-$	< 0.09	
Total Background	2.50±0.43	
expected from top	1.1±0.4	

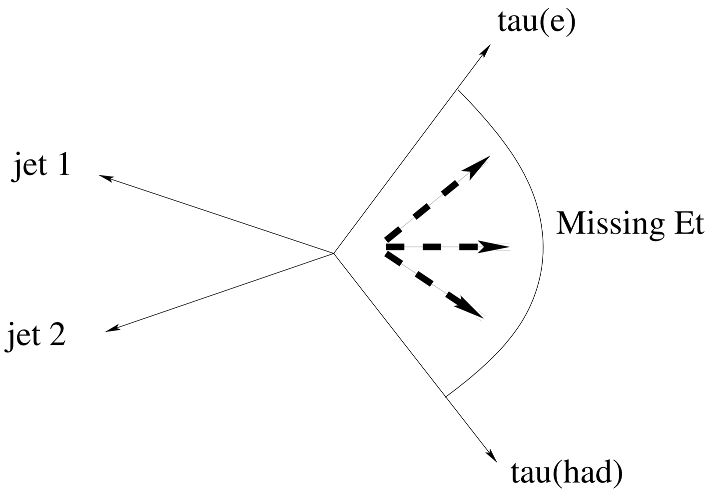
Table 4: Run1 Results

- over 85% of the background comes from two sources

$\mathbf{Z} \rightarrow \tau^+\tau^- + jets$

- In Run1 this background contribution was larger than the expected signal
- Lowering this background has been our top priority
- Use Z Mass reconstruction
  - We only do the reconstruction on a certain class of events so only a fraction of our signal events are candidates for this cut
- MC dataset: atop2b (Herwig + Alpgen)
- We look at 90k events from the inclusive $Z \rightarrow \tau\tau + 2$ particle dataset
- Cross Section times Branching Ratio: 23.3±0.1pb (from top MC web page)
- 34 events pass all cuts before the $Z \rightarrow \tau\tau$ removal
  - With $72pb^{-1}$ that corresponds to 0.63±0.11 background events

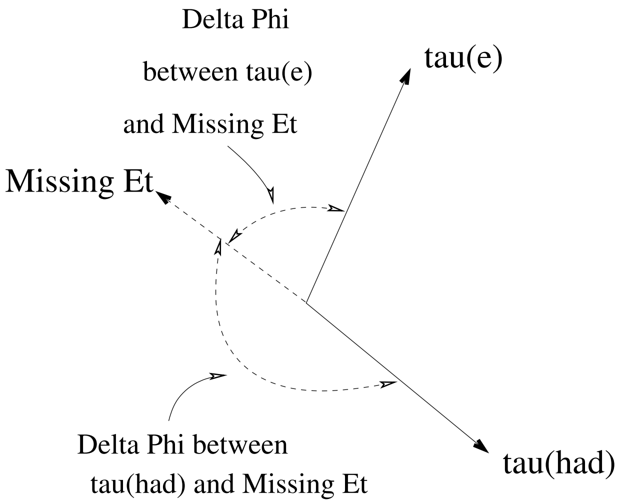
$\mathbf{Z} \rightarrow \tau^+\tau^- + jets$



- Assume the decay products of the tau go along the original tau direction
- Use $\not\!\!E_{\mathrm{T}}$ magnitude and direction to assign lost energy to the electron and hadronic tau jet
  - Very similar to technique used by Amy Connolly (CDF Note 5953)
  - This method derived by UR's Jon Petruccelli
- The Mass window we exclude is 65 - 115 GeV
  - The cut is so wide because resolution is poor and mean is slightly low

$\mathbf{Z} \rightarrow \tau^+\tau^- + jets$

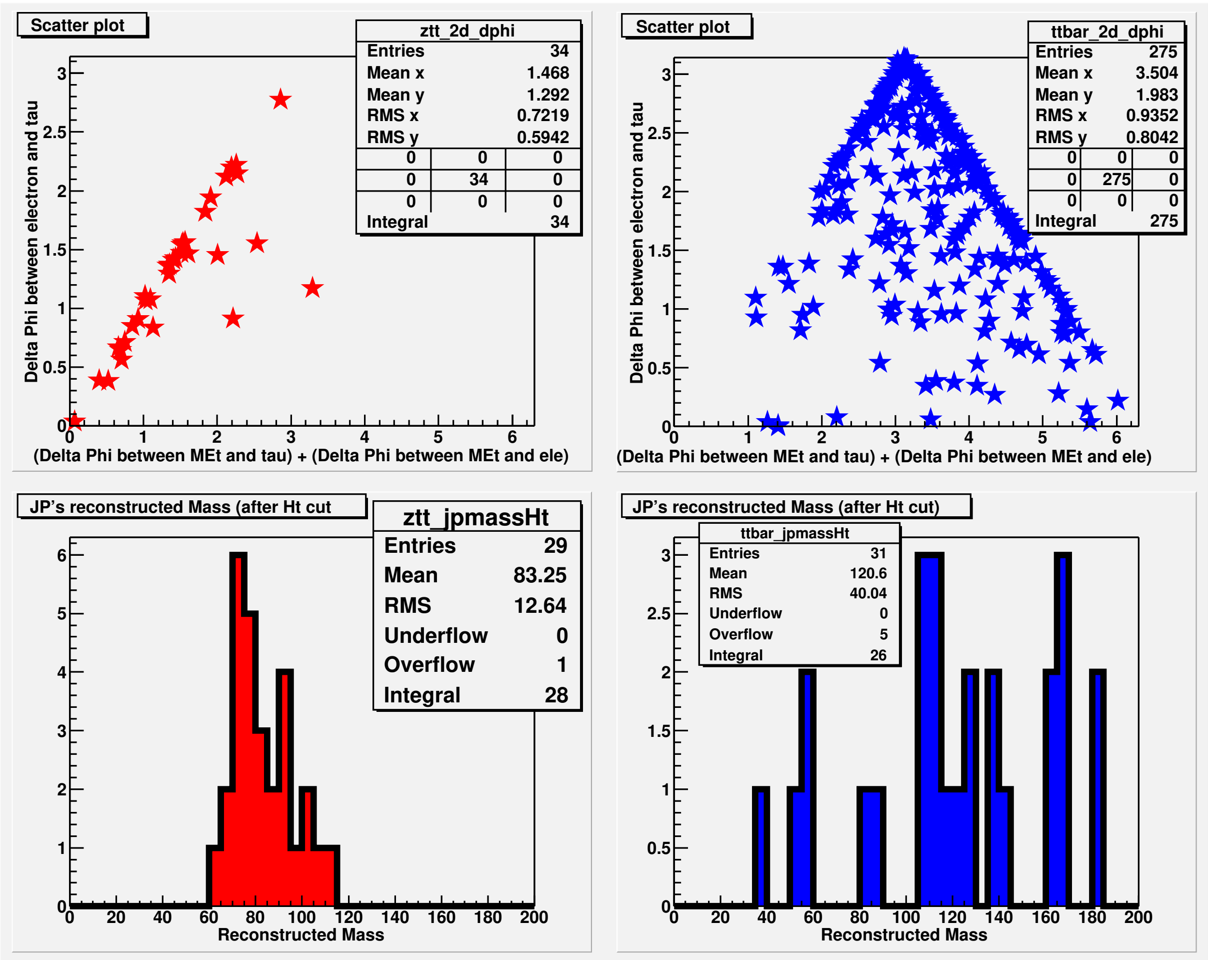
- We can only reconstruct the Mass in events with taus that are not back to back ($\Delta\phi_{\tau_e,\tau_h}$ < (π - 0.5))
- We also require the $\not{E}_T$ to be between the taus (in phi) or close to one of the taus (see cut below)



- This event would not have its mass reconstructed because
  - the $\not{E}_T$ is not between the taus or close enough to the them to pass the cut
    - $((\Delta\phi_{\tau_e,\not{E}_T} + \Delta\phi_{\tau_h,\not{E}_T}) - \Delta\phi_{\tau_e,\tau_h}) < 0.4$

$\mathbf{Z} \rightarrow \tau^{+}\tau^{-} + jets$

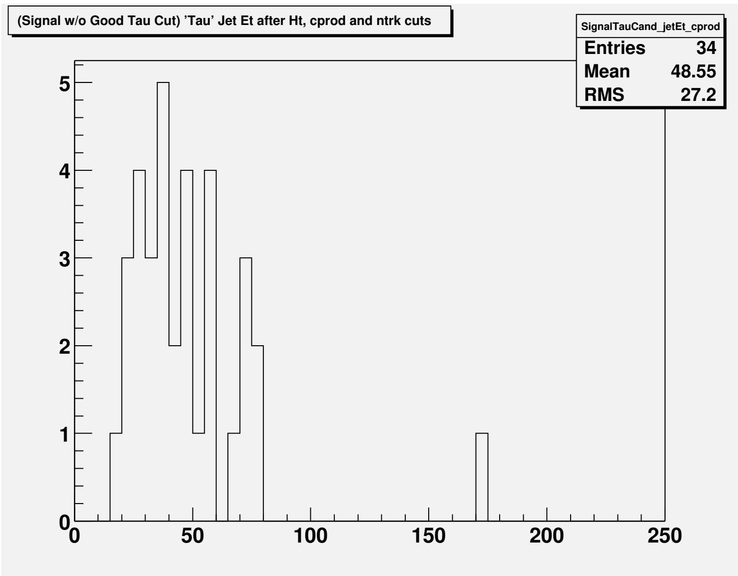
- After all other cuts, we can reconstruct the mass of:
  - 29 of 34 $Z \rightarrow \tau\tau + jets$ events (85%)
  - 31 of 275 $t\bar{t}$ events (11%)



- 9 of the $t\bar{t}$ events fail the Mass reco cut
- 28 $Z \rightarrow \tau\tau + jets$ events fail the Mass reco cut
- We're left with 6 $Z \rightarrow \tau\tau + jets$ events, giving us a background of 0.11±0.05 events

W+jets

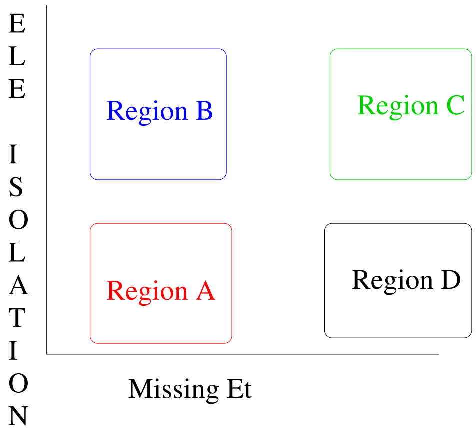
- a W+ $\geq$ 3 jet event can fake our signal if one of the jets is central and passes our tau cuts.
- we find the number of events with an electron passing our cuts, a central jet ($|\eta| < 1.1$) with $E_T > 10$GeV and two other jets ($|\eta| < 2.0$) with $E_T > 10$GeV
  - central jet must be a tau candidate with opposite charge of the electron
  - there can be more than one possible combination per event
- we find 723 jets, 34 of which are tau candidates



- This gives a background of 0.75±0.3 events
- A sanity check: CDF Note 6308 relative fake rate would give us a background of 0.37±0.07 events

QCD - CDF Note 6400

- A QCD process can produce an event that passes our signal cuts:
  - a jet fakes an electron
  - a jet fakes a tau
  - two other jets in the event pass our jet cuts
  - $\not{E}_{\mathrm{T}}$ and H_T cuts are passed
- This is very rare (and will be a tiny background) but the dominance of QCD processes makes it worth exploring
- This method is often done using regions in Iso vs $\not{E}_{\mathrm{T}}$, but we use all of the electron ID variables, not just Iso, to get the best ratio of events in region B to A



QCD

- Make 4 "regions" from the data, always requiring
  - a tau candidate passing tau cuts
  - a minimum of two extra jets
- Region A :
  - low $\not{E}_T$ (0< $\not{E}_T$ < 10GeV)
  - electron passes tight cuts
  - cut on the mass of the electron and tau candidates to remove Z→ee events (events with 80GeV < $Mass_{e,\tau}$ < 100GeV are excluded)
- Region B :
  - low $\not{E}_T$ (0< $\not{E}_T$ <10GeV)
  - electron passes trigger cuts but fails tight cuts
  - cut on the mass of the electron and tau candidates to removeZ→ee events (events with 80GeV < $Mass_{e,\tau}$ < 100GeV are excluded)
- Region C :
  - high $\not{E}_T$ ($\not{E}_T$ > 20GeV)
  - electron passes trigger cuts but fails tight cuts
- Region D: Signal Region (currently blind)
  - high $\not{E}_T$ ($\not{E}_T$>20GeV)
  - electron passes tight cuts

QCD

$$N_D = N_e \epsilon_e + N_Q f_j \quad (1)$$
$$N_C = N_e(1-\epsilon_e) + N_Q(1-f_j) \quad (2)$$

$$N_D = \# \; of \; events \; in \; Region \; D$$

$$N_C = \# \; of \; events \; in \; Region \; C$$

$$N_e = \# \; of \; events \; with \; real \; electrons$$

$$N_Q = \# \; of \; events \; with \; dijets$$

$$\epsilon_e = efficiency \; of \; tight \; electron \; cuts \; after \; trigger \; cuts$$

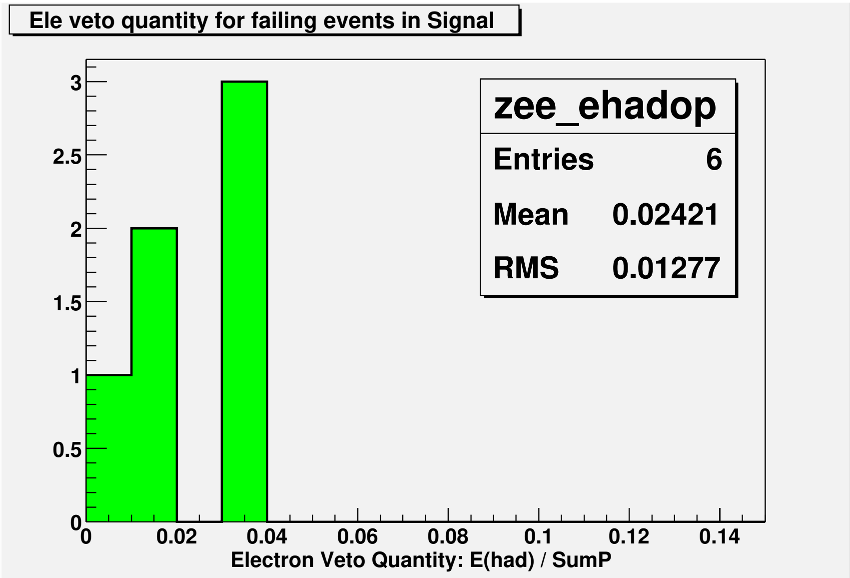
$$f_j = N_A/(N_A + N_B), \; probability \; of \; jets \; which \; pass \; trigger \; cuts \; also \; passing \; tight \; cuts$$
$$with \;\; N_A = \# \; of \; events \; in \; Region \; A$$
$$and \;\; N_B = \# \; of \; events \; in \; Region \; B$$

QCD

- Results of measurements with 72±4.3 pb^{-1} of Data
  - 5 events in Region A
  - 49 events in Region B
  - 7 events in Region C
  - We are currently blinded to Region D
- We therefore measure a f_j of 0.09 $\pm$ 0.04
- 4 of the events in Region C pass the H_T cut and none pass the Charge Product cut so our QCD background is 0.0 $\pm$ 0.1 events

$Z \rightarrow ee + jets$

- Multiply events that pass all signal cuts except for the electron veto cut by the electron fake rate
  - Electron Veto cut is $E_{had}/\Sigma P > 0.15$
- We have 4 events that pass all cuts other than the Electron Veto (6 events before the H_T cut)



- The electron fake rate at our cut is $1.2 \pm 0.4\%$
- This gives us a background of 0.05 ± 0.02 events

Summary of Status

- We haven't yet looked at our signal region in the Data
- With our $72pb^{-1}$ of Winter Conference Data, here is the current status

	Run2 # of Events
$Z/\gamma^* \rightarrow \tau^+\tau^- + jets$	0.11±0.05
τ fakes	0.75±0.3
QCD	0.0±0.1
$Z \rightarrow e^+e^-$ + jets	0.05±0.02
WW, WZ	-
Current Background Total	0.91±0.1
expected from top	0.33

Table 5: Current Status

Backup Slides

Corrections

- Jet Energies are corrected for
  - η dependence (relative corrections)
  - Energy Scale
- $\not{E}_{\mathrm{T}}$ is corrected for
  - Beam constrained tight muons
  - Jet corrections (raw Jet Et added in, corrected Jet Et subtracted out) of two b-jet candidates (unless noted)
- H_T is calculated with
  - corrected Jets as described
  - corrected $\not{E}_{\mathrm{T}}$ as described
- Corrections are applied before analysis, at the level of event selection

Electron Fake Rate Details

- Require one tight central, isolated electron with $E_T >$ 20GeV
- For 2nd electron:
  - must be back-to-back with first electron ($\Delta\phi < (\pi - 0.5)$)
  - must match to CdfTau Object that passes tau cuts
- no other jets in event >8GeV
- invariant mass of the two EM Objects > 75GeV ($\not{E}_T$ is added to the second ele if it is less than $\Delta\phi$ of 0.7 away)

W+jets

- Distributions from the W+jet events
- no tau cuts or tau candidate requirements