$Z \rightarrow \tau\tau$ with Safe Cuts

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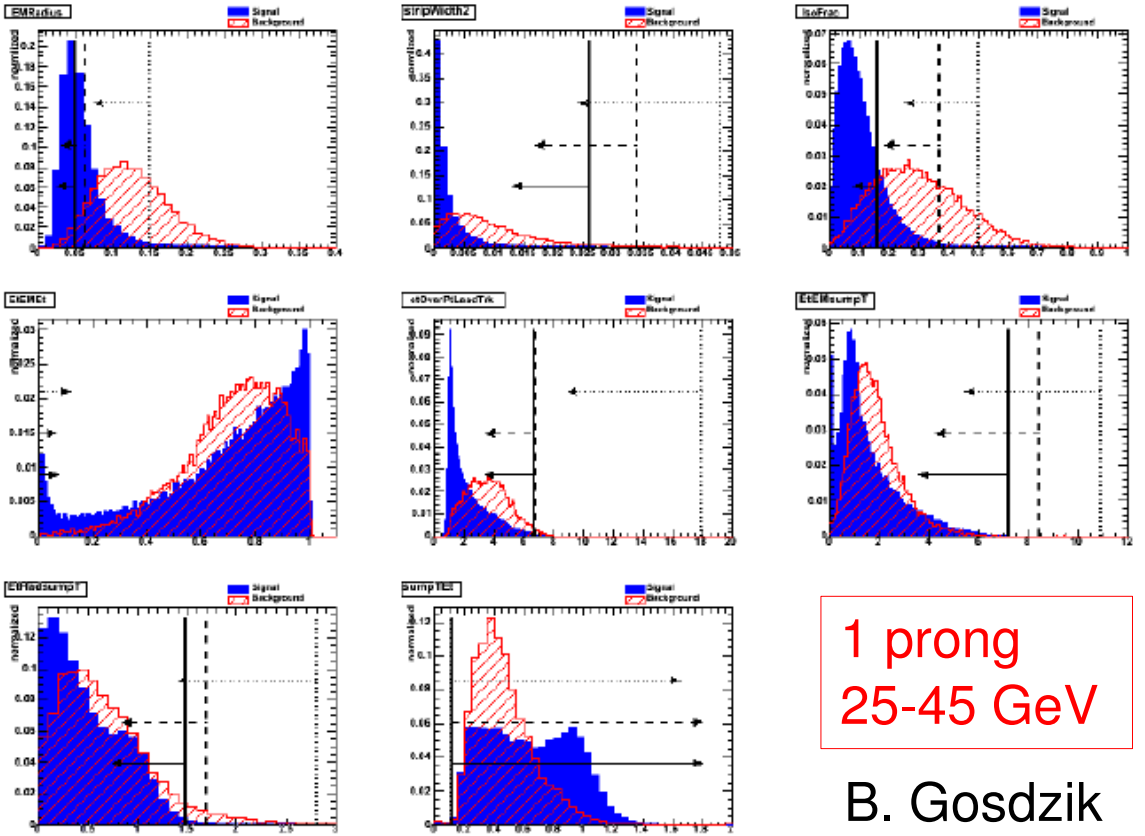
“Safe” Tau ID

- The full tau ID uses many variables from both the calorimeter and the tracker.
  - Some of these are likely to be less well understood at the beginning.
- Consequently, there has been an effort (B. Gosdzik et al.) to define a set of well understood variables for use in first data.
  - http://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=43438
- This uses a cut-based method with a limited set of robust variables. Two approaches:
  - Calorimeter only or calorimeter + tracking
- Will compare the performance of these on $Z \rightarrow \tau\tau$
  - Use official variables by running v15 and redo TauCommonSetIsTau

“Safe” Tau ID: Variables

- Calo variables:
  - R_{EM}
  - Isolation Fraction
  - $(\Delta\eta)^2$,
  - $E_t(EM)/E_t(EM+Had)$
- Tracking variables:
  - $E_t/P_t(lead\text{-}track)$
  - $E_t(EM)/\Sigma P_t(track)$
  - $E_t(Had)/\Sigma P_t(track)$
  - $\Sigma p_t(track)/E_t(EM+Had)$
  - 2-track width

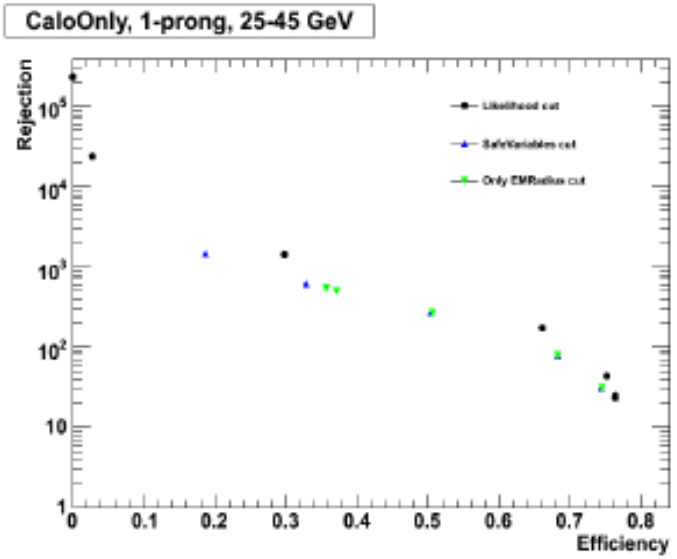
- Cuts values are dependent on both the P_t and multiplicity of the tau

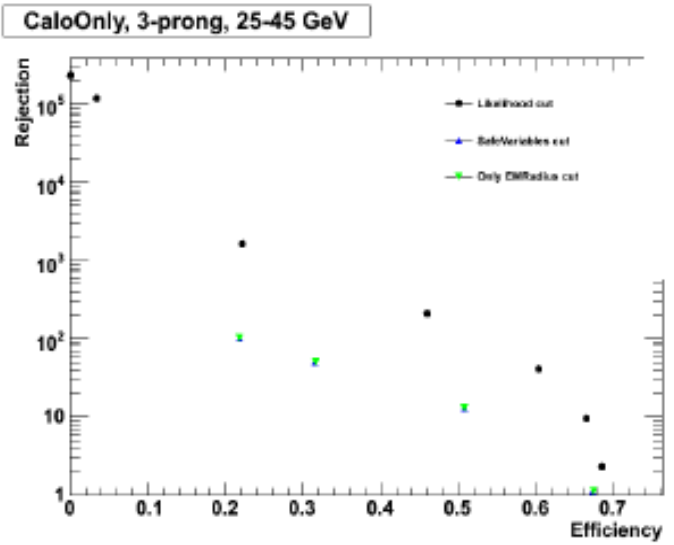


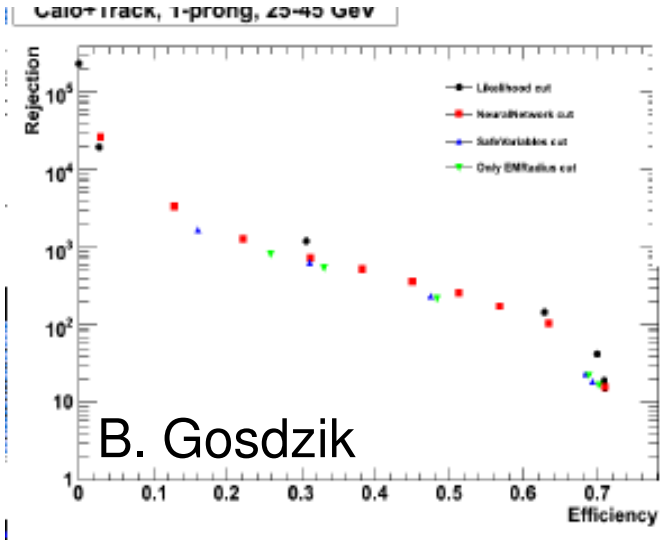
1 prong
25-45 GeV

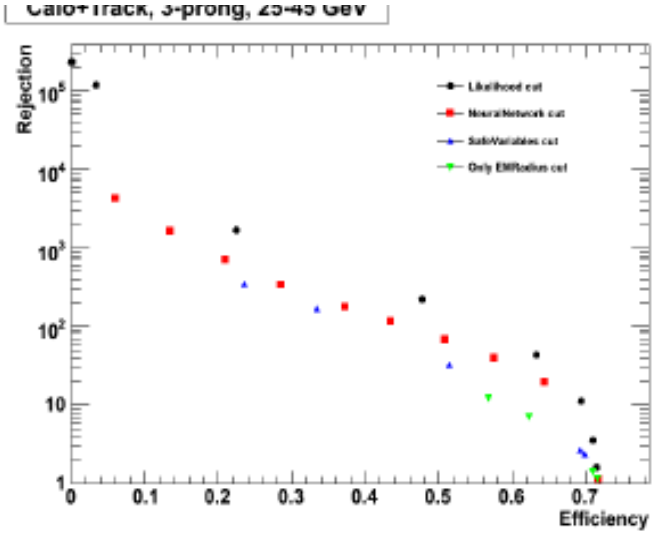
B. Gosdzik

“Safe” Tau ID: Performance





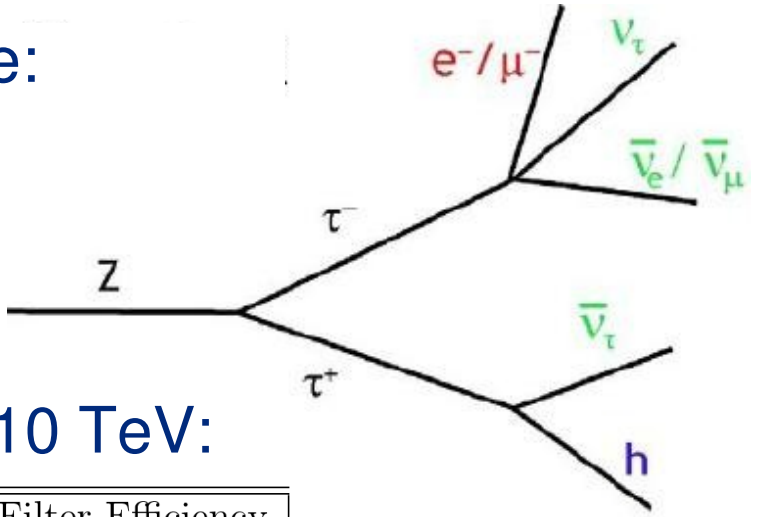




- R_{EM} provides the strongest separation
- Significantly worse than LH in 3-prong case
- Define 3 cut levels:
  - Loose (70%)
  - Medium (50%)
  - Tight (30%)

Signal and Backgrounds

- We consider only lepton-hadron mode:
  - Isolated lepton for triggering
  - Narrow tau-jet
  - Missing E_t (MET)



- Signal & (non-QCD) backgrounds @ 10 TeV:

Process	Dataset	NLO Cross section (pb)	Filter Efficiency
$Z \rightarrow \tau\tau$	106052	1357	-
$Z \rightarrow ee$	106050	1357	0.96
$Z \rightarrow \mu\mu$	106051	1357	0.96
$W \rightarrow e\nu$	106020	13814	0.87
$W \rightarrow \mu\nu$	106021	13814	0.87
$W \rightarrow \tau_l\nu$	106022	13814 × 0.352	0.87
$W \rightarrow \tau_h\nu$	106023	13814 × (1-0.352)	-
$t\bar{t}$ (ll, lh)	105200	401.60 × 0.543	-

New

Cross section significantly lower at 10 TeV

- QCD di-jet background not yet been considered.
- All results that shown are normalised to 100 pb^{-1}

Selection

Based on post-CSC note ATL-COM-PHYS-2008-127

- Trigger
  - e10_medium || mu_10
- 1 isolated lepton
  - $P_t^l > 15$ GeV and $|\eta^l| < 2.5$
  - Track+calo isolation:
    - P_t^{trk} & E_t^{calo} ($\Delta R=0.2$) < 5 GeV
  - Electron: medium isEM and author != softe
  - Muon: High P_t combined
- Missing E_t
  - MET > 20 GeV
  - M_t (lep,MET) < 30 GeV
  - $\Sigma E_t < 400$ GeV
- Make all lepton-τ pairs with:
  - $P_t^\tau > 15$ GeV and $|\eta^\tau| < 2.5$
  - $1 < \Delta\varphi_{l,\tau\text{-jet}} < 3.1$ rad.
  - Tau ID:
    - Tight calo, calo+track, LH
    - 1 or 3 tracks
    - Remove overlaps with e/μ
- Separate OS (signal) and SS (background) events
- Reconstruct visible mass
  - $37 < M_{l,\tau\text{-jet}} < 77$ GeV
- Generally, there is only 1 combination remaining

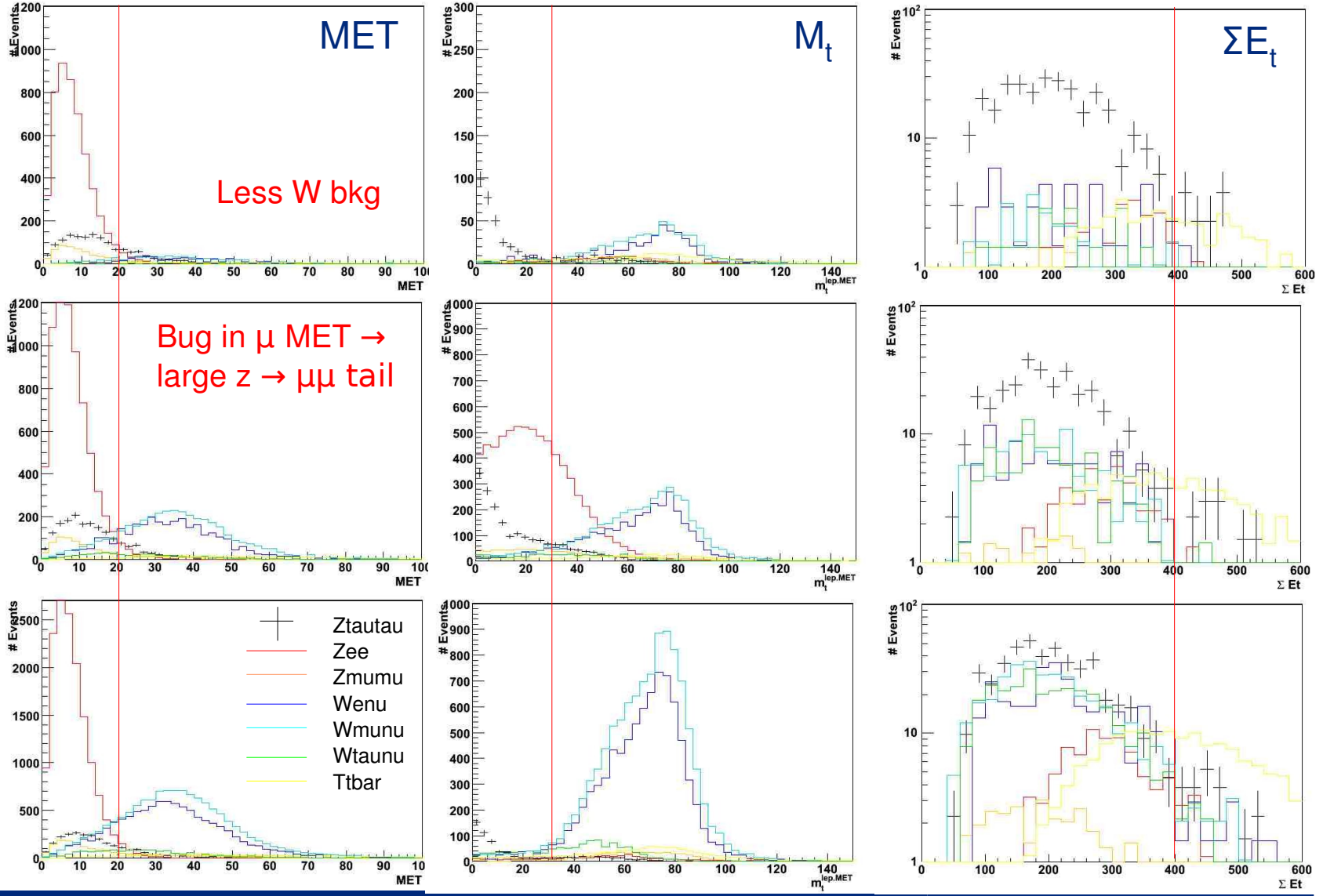
Missing E_t

1 lepton + Tau ID

LH

Calo + track

Calo (different scale)

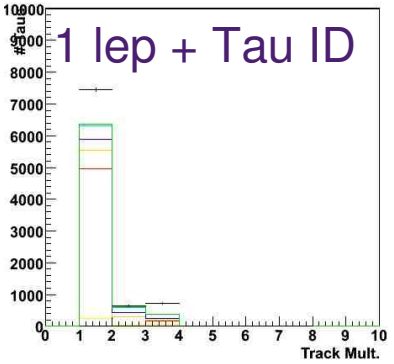


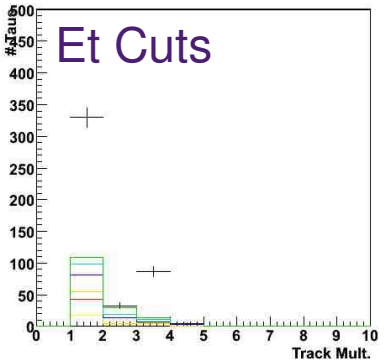
Track Multiplicity

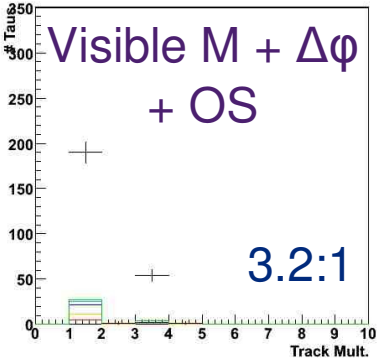
LH

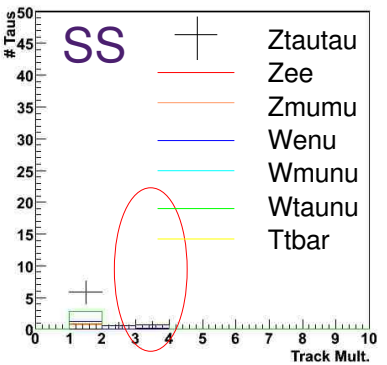
Calo + track

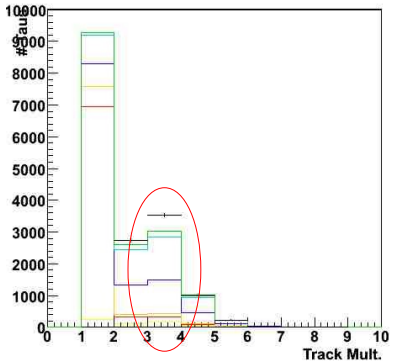
Calo (different scale)

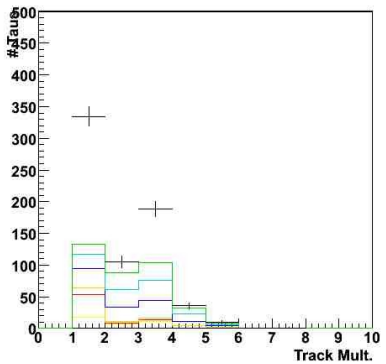


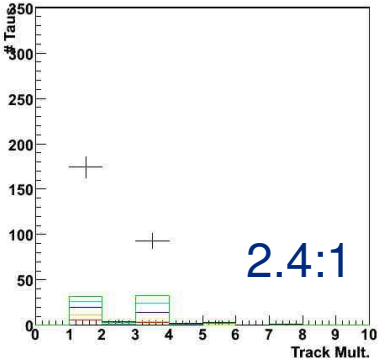


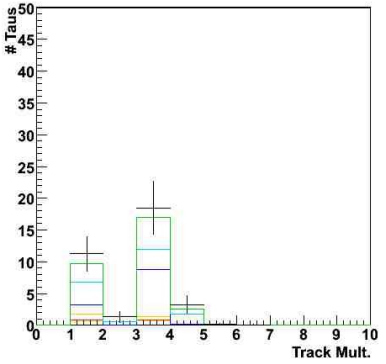


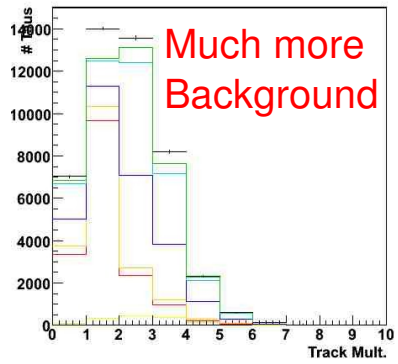


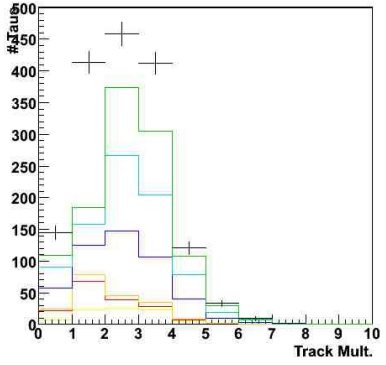


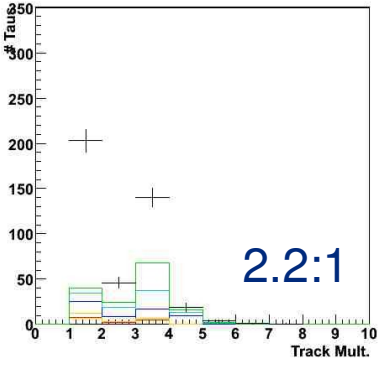


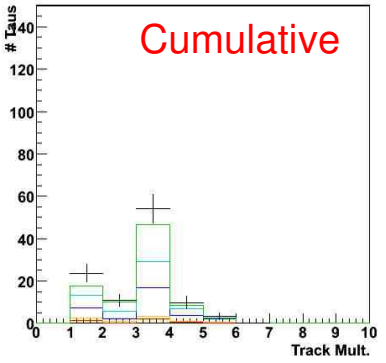








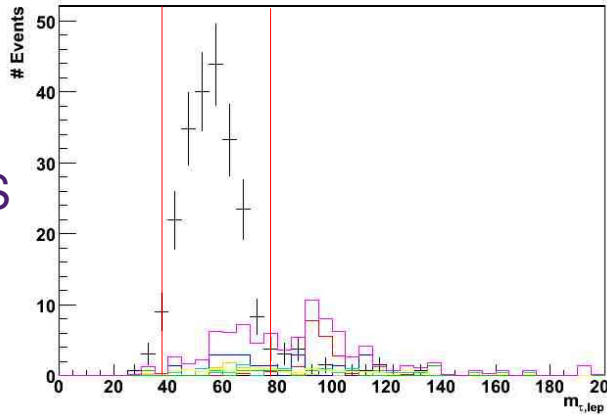


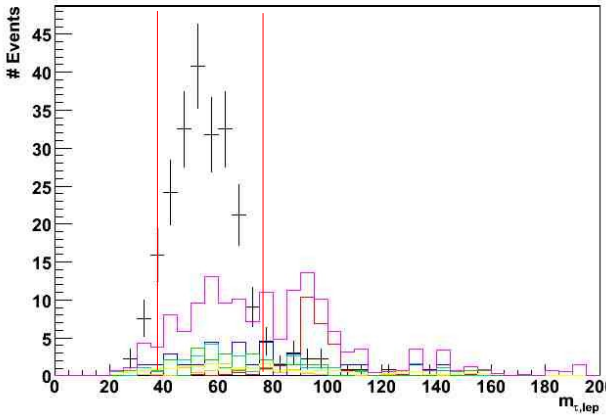


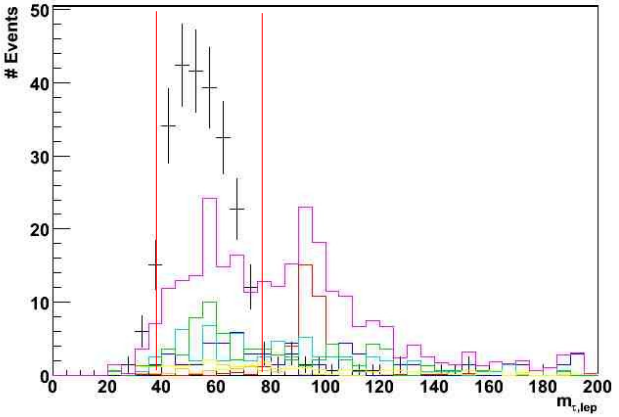
Results

LH | Calo+Track | Calo

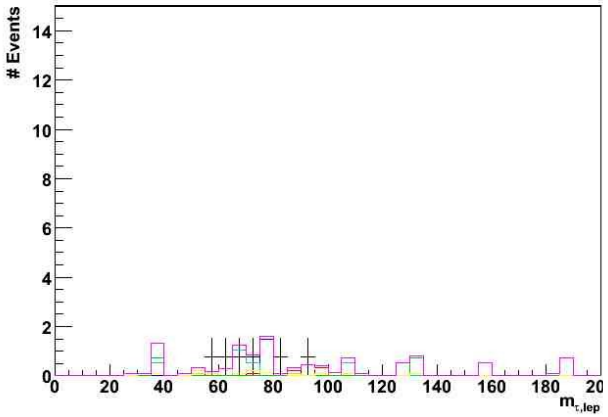
OS

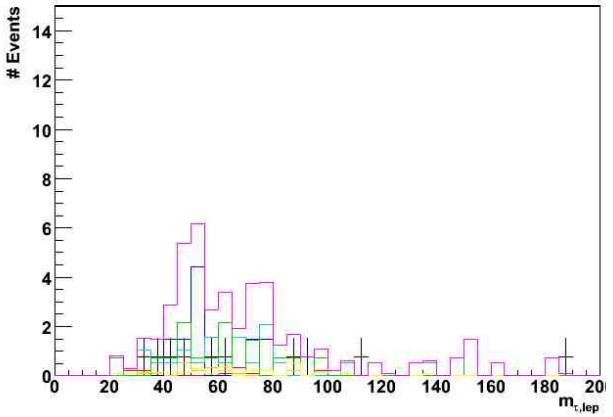


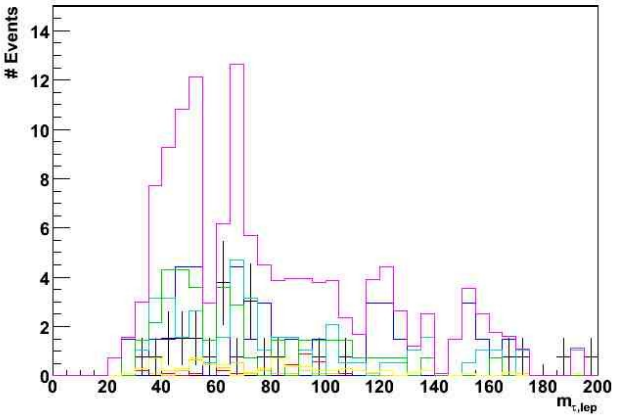




SS







Results (2)

- Event-level cut flow:

Cut	$Z \to \tau\tau$	$Z \to ee$	$Z \to \mu\mu$	$W \to e\nu$	$W \to \mu\nu$	$W \to \tau_l\nu$	$W \to \tau_h\nu$	$t\bar{t}$
Total # events	135700 ± 320	130285 ± 120	130332 ± 119	1210962 ± 1334	1210525 ± 796	425106 ± 553	895147 ± 2068	21807 ± 47
Trigger	24342 ± 136	97497 ± 104	103864 ± 106	716716 ± 1026	742887 ± 623	128240 ± 304	4290 ± 143	12826 ± 36
1 isol. lepton	15026 ± 107	51417 ± 75	44587 ± 69	568003 ± 914	692746 ± 602	82629 ± 244	817 ± 62	9338 ± 31
$MET > 20$	4551 ± 59	1663 ± 14	25593 ± 53	493619 ± 852	538171 ± 531	49685 ± 189	568 ± 52	8527 ± 29
$M_t^{l,MET} < 30$	2275 ± 41	320 ± 6	433 ± 7	4937 ± 85	5924 ± 56	5153 ± 61	48 ± 15	1238 ± 11
$\sum E_t < 400$	2182 ± 41	285 ± 6	420 ± 7	4626 ± 82	5710 ± 55	4930 ± 60	38 ± 14	516 ± 7
At least 1 cand.	1955 ± 38	164 ± 4	328 ± 6	3929 ± 76	4948 ± 51	4341 ± 56	38 ± 14	515 ± 7

- At this stage W is the largest (non -QCD) background.

- Efficiency of safe cuts for $Z \to \tau\tau$
  - $P_t^{\tau} > 15$ GeV and $|\eta^{\tau}| < 2.5$
  - Truth-matched ($\Delta R<0.1$)

Cut	Level	Efficiency
Safe Calo	Loose	53.1%
	Medium	39.1%
	Tight	25.5%
Safe Calo + Track	Loose	41.2%
	Medium	30.6%
	Tight	18.5%

- What is the effect of the various tau IDs on $Z \to \tau\tau$ cut flow ...

Results (3)

LH

Cut	$Z \to \tau\tau$	$Z \to ee$	$Z \to \mu\mu$	$W \to e\nu$	$W \to \mu\nu$	$W \to \tau_l\nu$	$W \to \tau_h\nu$	$t\bar{t}$
# candidates	3027 ± 48	244 ± 5	459 ± 7	5650 ± 91	7226 ± 61	6224 ± 67	48 ± 15	1817 ± 13
$1 < \Delta\phi < 3.1$	2685 ± 45	189 ± 5	398 ± 7	5070 ± 86	6457 ± 58	5614 ± 64	43 ± 14	1534 ± 12
Tau ID	240 ± 13	22 ± 2	10 ± 1	25 ± 6	20 ± 3	11 ± 3	0 ± 0	18 ± 1
OS	236 ± 13	21 ± 2	10 ± 1	22 ± 6	16 ± 3	9 ± 3	0 ± 0	16 ± 1
$M_{l,\tau-jet}$	213 ± 13	0 ± 0	7 ± 1	12 ± 4	4 ± 1	2 ± 1	0 ± 0	5 ± 1
SS	5 ± 2	1 ± 0	0 ± 0	3 ± 2	4 ± 1	2 ± 1	0 ± 0	2 ± 0
$M_{l,\tau-jet}$	3 ± 2	0 ± 0	0 ± 0	0 ± 0	2 ± 1	0 ± 0	0 ± 0	1 ± 0

$$\frac{S}{\sqrt{B}} = 39$$

Calo + track

Cut	$Z \to \tau\tau$	$Z \to ee$	$Z \to \mu\mu$	$W \to e\nu$	$W \to \mu\nu$	$W \to \tau_l\nu$	$W \to \tau_h\nu$	$t\bar{t}$
# candidates	3027 ± 48	244 ± 5	459 ± 7	5650 ± 91	7226 ± 61	6224 ± 67	48 ± 15	1817 ± 13
$1 < \Delta\phi < 3.1$	2685 ± 45	189 ± 5	398 ± 7	5070 ± 86	6457 ± 58	5614 ± 64	43 ± 14	1534 ± 12
Tau ID	242 ± 14	32 ± 2	11 ± 1	50 ± 9	48 ± 5	41 ± 5	0 ± 0	23 ± 2
OS	234 ± 13	30 ± 2	9 ± 1	38 ± 7	32 ± 4	28 ± 4	0 ± 0	20 ± 1
$M_{l,\tau-jet}$	203 ± 12	1 ± 0	6 ± 1	19 ± 5	16 ± 3	14 ± 3	0 ± 0	9 ± 1
SS	8 ± 2	2 ± 0	2 ± 0	12 ± 4	15 ± 3	13 ± 3	0 ± 0	3 ± 1
$M_{l,\tau-jet}$	3 ± 2	1 ± 0	1 ± 0	9 ± 4	7 ± 2	8 ± 2	0 ± 0	1 ± 0

$$\frac{S}{\sqrt{B}} = 25$$

Calo

Cut	$Z \to \tau\tau$	$Z \to ee$	$Z \to \mu\mu$	$W \to e\nu$	$W \to \mu\nu$	$W \to \tau_l\nu$	$W \to \tau_h\nu$	$t\bar{t}$
# candidates	3027 ± 48	244 ± 5	459 ± 7	5650 ± 91	7226 ± 61	6224 ± 67	48 ± 15	1817 ± 13
$1 < \Delta\phi < 3.1$	2685 ± 45	189 ± 5	398 ± 7	5070 ± 86	6457 ± 58	5614 ± 64	43 ± 14	1534 ± 12
Tau ID	286 ± 15	45 ± 2	14 ± 1	97 ± 12	117 ± 8	114 ± 9	0 ± 0	35 ± 2
OS	265 ± 14	42 ± 2	10 ± 1	57 ± 9	74 ± 6	76 ± 7	0 ± 0	28 ± 2
$M_{l,\tau-jet}$	235 ± 13	1 ± 0	6 ± 1	24 ± 6	30 ± 4	36 ± 5	0 ± 0	11 ± 1
SS	20 ± 4	3 ± 1	4 ± 1	40 ± 8	43 ± 5	38 ± 5	0 ± 0	7 ± 1
$M_{l,\tau-jet}$	14 ± 3	1 ± 0	2 ± 1	18 ± 5	19 ± 3	22 ± 4	0 ± 0	3 ± 1

Similar to v14 results

$$\frac{S}{\sqrt{B}} = 23$$

Conclusion and Plans

- Prospects for $Z \rightarrow \tau\tau$ in 100 pb^{-1} look promising and robust
  - Depends on the being able to control the QCD backgrounds
- Safe tau ID performs reasonably well compared to full ID
  - Some reduction in $S/\sqrt{B}$, but still a clear signal
  - Calo only cuts let in significantly more background (but also more signal)
  - Need to see the effects on the QCD background!
  - Safe likelihood/NN?
- Future plans:
  - Add in QCD backgrounds.
  - Study and optimise selection criteria for first data.
  - Investigate data-driven techniques for background estimation.

Back-up Slides