Trilepton SUSY signatures

Outline:

- Introduction: presentation of signal and backgrounds

- Particle selection

- Efficiencies and fake rates

- Trigger

- Event selection

- Eventselection and cut flow

Constrained parameter space

There are still some areas which give a neutralino relic density which is consistent with the WMAP observations.

▷ Bulk region - relatively low value of the SUSY mass scale.

▷ Coanihilation region - $m_{\tilde{\tau}_1} \sim m_{\chi_1^0}$ such that $\tilde{\tau}\tilde{\chi}$ annihilation in the early universe reduces the relic density.

▷ Funnel region - (for large values of $\tan\beta$) $2m_{\tilde{\chi}_1^0 \approx M_H^0, A^0}$ giving an enhances $\tilde{\chi}\tilde{\chi}$ annihilation cross section.

▷ Focus-point region - $m_{1/2} \ll m_0$ - the lightest neutralino has a significant Higgsino component, enhancing the $\tilde{\chi}\tilde{\chi}$ annihilation cross section

ATLAS has chosen benchmark points in all these regions.

There are also scans through the parameter space.

Other constraints
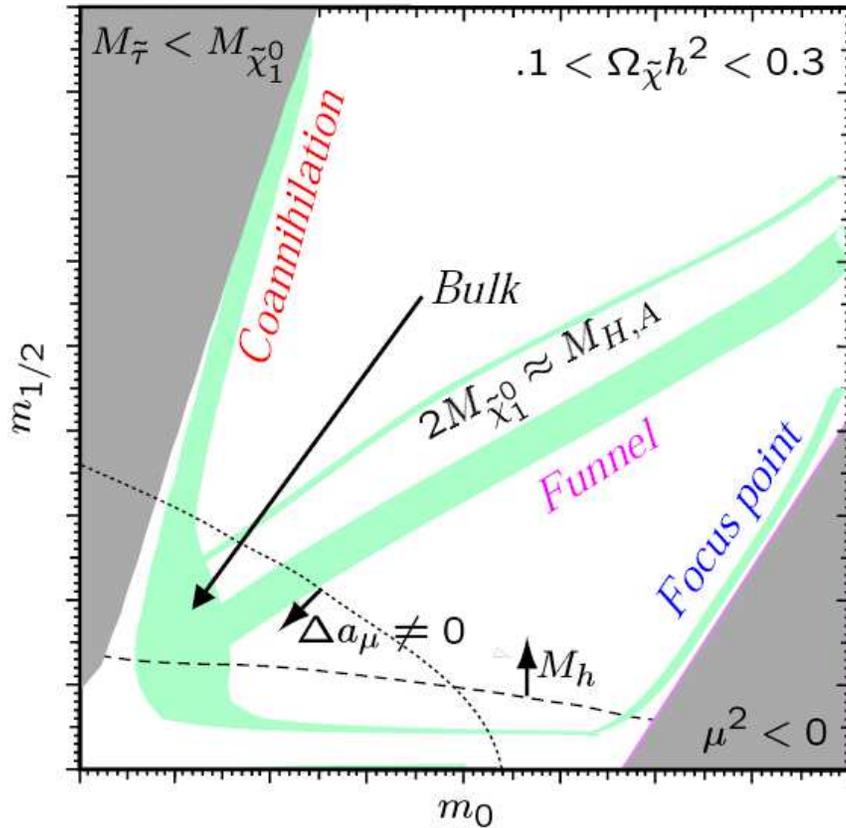
$m_{\tau_1} > m_{\chi_1^0}$ - otherwise we get a charged LSP. If that was the case, it would have been observed.

Electro-weak symmetry breaking.

The limit of on the Higgs mass.

SUSY particle can can contribute to higher order corrections. The decay $b \to s\gamma$ and the anomalous magnetic momentum of the muon $g_\mu - 2$ are sensitive to these effects.

This analysis: Focus Point Region - SU2

Focus point - SU2

Sparticle	Mass [GeV]
χ^0	103, 160, 180, 294
$\chi^\pm$	149, 287
$\tilde{g}$	857
$\tilde{q}$	2131, 2935, 2925, 3501, 3563, 3574
$\tilde{l}_{L,R}$	3547, 3547

Parameters:
$m_0 = 3550\text{GeV}$
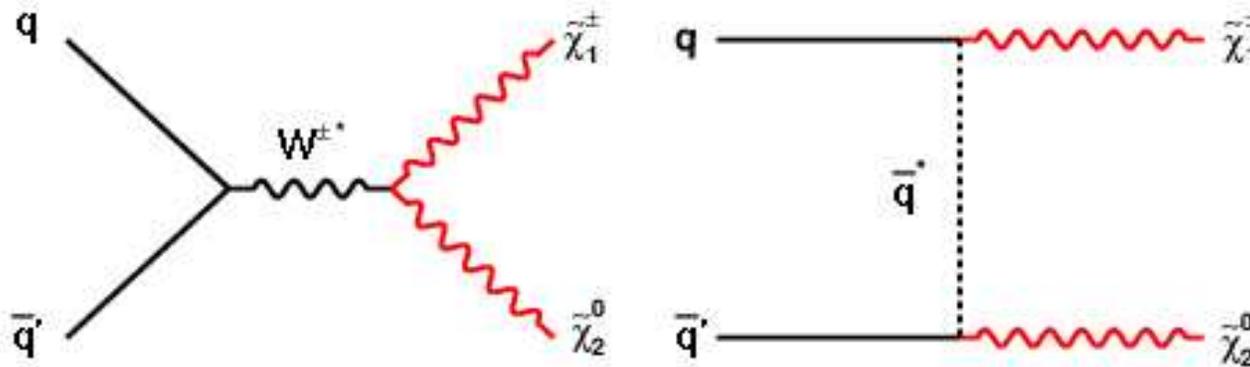$m_{1/2} = 300\text{GeV}$
$A_0 = 0$
$\tan\beta = 10$
$\mu > 0$

Mass spectrum of sparticles at the SU2 point
m_0=3550, $m_{1/2}$=300, A_0=0, tanβ=10, μ>0
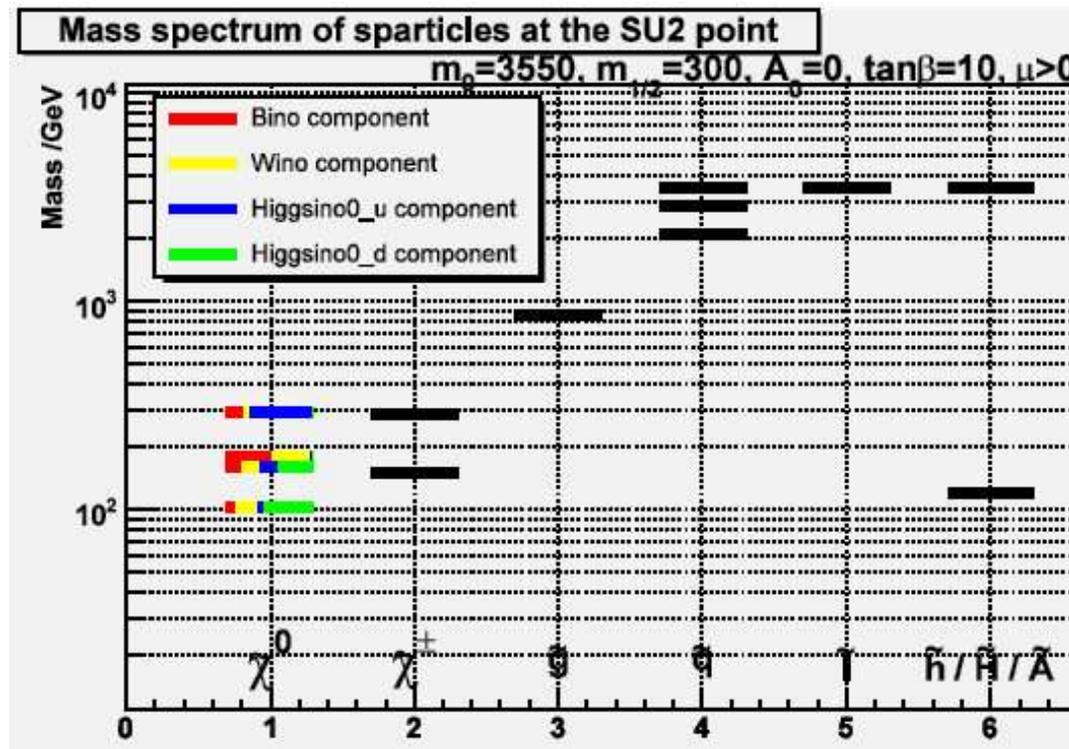
Total cross section (LO): $\sigma = 4.9\text{pb}$

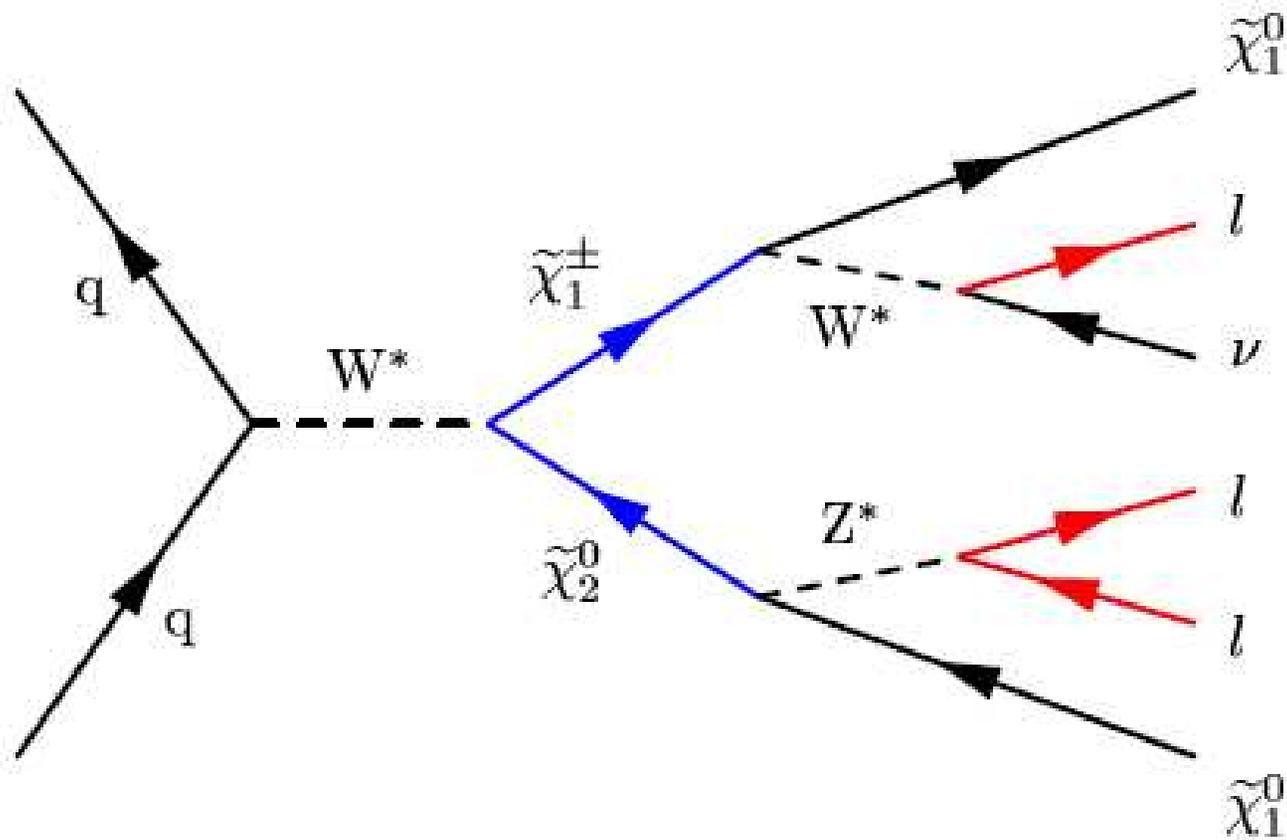| Production	$\sigma[\text{pb}]$
$\tilde{\chi}^0 \tilde{\chi}^\pm$	3.06
$\tilde{\chi}^\pm \tilde{\chi}^\pm$	1.14
$\tilde{\chi}^0 \tilde{\chi}^0$	0.22
$\tilde{g} \tilde{g}$	0.58

Gluon decay:
$\tilde{g} \to \chi^0 q\bar{q}$ 29% , $\tilde{g} \to \chi^0 g$ 6.4% , $\tilde{g} \to \chi^\pm q\bar{q}'$ 53%
75% of the quarks are from the third generation giving quite a number of b-jets.
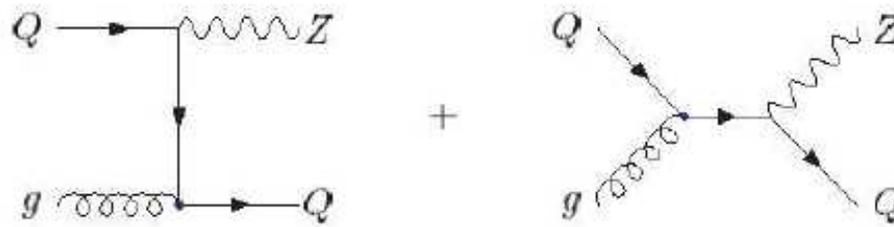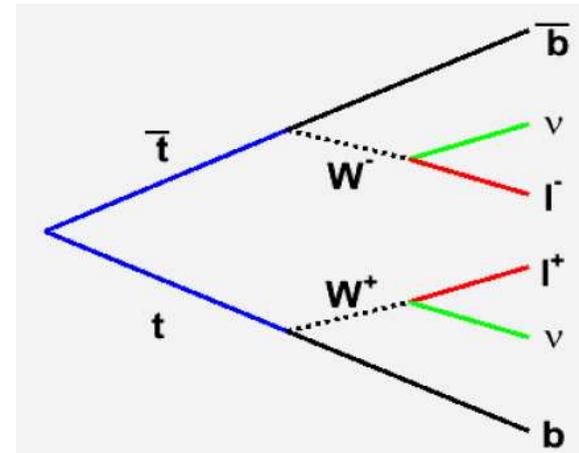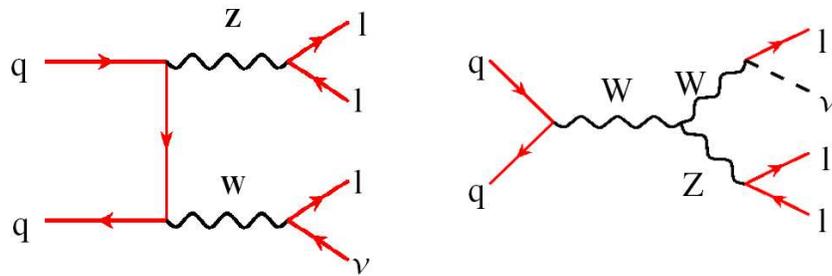
Tri-lepton signal

Direct chargino and neutralino production gives a jet-free tri-lepton signal.
Discovery channel at Tevatron

SM Backgrounds

▷ SM counterpart: dibozon production, WZ, ZZ, WW, $Z\gamma$

▷ Top pair production (high cross section), Wt (single top)

▷ Zb (high cross section)

Datasets

Set	Dataset name	σ[pp]
SU2	trig1_misal1_csc11.005402.SU2_jimmy_susy.recon.AOD.v12000601_tid005862	4.46
T1	trig1_misal1_mc12.005200.T1_McAtNlo_Jimmy.recon.AOD.v12000604_tid008037	461
Zb	trig1_misal1_mc12.005178.Zb_acer_pythia.recon.AOD.v12000601_tid006708	102
WW	trig1_misal1_csc11.005985.WW_Herwig.recon.AOD.v12000601_tid006070	24.5
WZ	trig1_misal1_csc11.005987.WZ_Herwig.recon.AOD.v12000601_tid006069	7.8
ZZ	trig1_misal1_csc11.005986.ZZ_Herwig.recon.AOD.v12000601_tid006068	2.1
$Z\gamma$	trig1_misal1_csc11.005900.PythiaZPhoton25.recon.AOD.v12000601_tid006248	2.58
Wt	trig1_misal1_mc12.005500.AcerMC_Wt.recon.AOD.v12000601	25.5

Analysis tools:

- TopView as basis, top analysis removed
- HighPtView with some additional configurations
- Added track based isolation cuts in the ElectronInserter and MuonInserter
- Own code - add track info, MC truth mothers of particles, MC physics process info (MSUB) - Ganga for making ntuples on NorduGrid

Particle Selection

For efficiency calculations:

etCut for leptons: Asymmetric cuts to avoid resolution effects.

-`"etCut":5*GeV` -Reco,`"etCut":10*GeV` -Truth, when matching Truth→Reco, efficiency calculation

-`"etCut":10*GeV` -Reco `"etCut":5*GeV` -Truth, when matching Reco→Truth, fake rate calculation

For analysis:

- `"etCut":10*GeV` - Reco and Truth

Electron selection, track based isolation cuts:

- `"onlyEgamma":True` - no soft electrons
- `"isEMMasks":[0x3FF]` - medium electron
- `"isolationCone":0.20`
- `"UseTrackIsol":True`, - `"UseptTrackMax":True`
- `"ptTrackMin":0*GeV`
- `"absoluteTrackCut":2*GeV`
- `"relativeTrackCut":0`
- `"TrackContainerKey":"TrackParticleCandidate"`
- $|\eta| < 2.5$

Particle Selection

Muon selection, track based isolation cuts:

- `"ContainerKey"` : `"MuidMuonCollection"` - changed from Staco Muons
- `"onlyHighPt"` : `True`
- `"chi2NdofCut"`:5 - track fit chi2/ndf
- `"chi2MatchCut"`:20 - track match chi2
- `"isolationCone"`:0.20
- `"UseTrackIsol"`:True, - `"UseptTrackMax"`:True
- `"ptTrackMin"`:0*GeV
- `"absoluteTrackCut"`:1*GeV
- `"relativeTrackCut"`:0
- `"TrackContainerKey"`:"TrackParticleCandidate"
- $|\eta| < 2.5$

Jet selection:

- `"ContainerKey"` : `"Cone4TowerParticleJets"`/`"Cone4TruthParticleJets"`
- `"etCut"`:15/5*GeV input for matcing with leptons, when calculating fake rate same p_T cut as for leptons
- `"etCut"`:10*GeV analysis
- `"deltaRCut"`:0.3
- `"RemoveOverlapWithMuon"`:False - following the example of TopView. - $|\eta| < 2.5$

Truth lepton definitions

Definition - 1 Generator level leptons from SUSY, W, Z, τ.

Definition - 2 All generator level leptons, also those coming from b-jets, hadrons etc.

*Definition 2 corresponds to what is obtained by applying the truth thinning job options which remove the Geant4 particles.

*Definition 2 is used in current analysis as input for Reco $\rightarrow$ Truth matching.

Efficiency and fake rate

$$Efficiency = \frac{\#Truth(1/2)matchedtoReco}{\#Truth(1,2)} \tag{1}$$

Three fake rate definitions are used:

Fake-1 Number of reconstructed leptons not matched to true leptons (two definitions) within a 0.02 cone divided by the total number of MD jets.

Fake-2 Number of reconstructed leptons not matched to true leptons (two definitions) within a 0.02 cone, but matched to a MC truth jets within a 0.4 cone.

Fake-3 Number of reconstructed leptons neither matched to true leptons nor to MC truth jets divided by total number of MC truth jets.

Example:
Fake-1, truth definition 1: leptons not matched to anything or matched to non def-1 truth lepton (leptons from b, c etc.)

Fake-1, truth definition 2: leptons not matched to truth which in is a def-2 truth (lepton from signal and from jets etc.)

Efficiencies Electrons
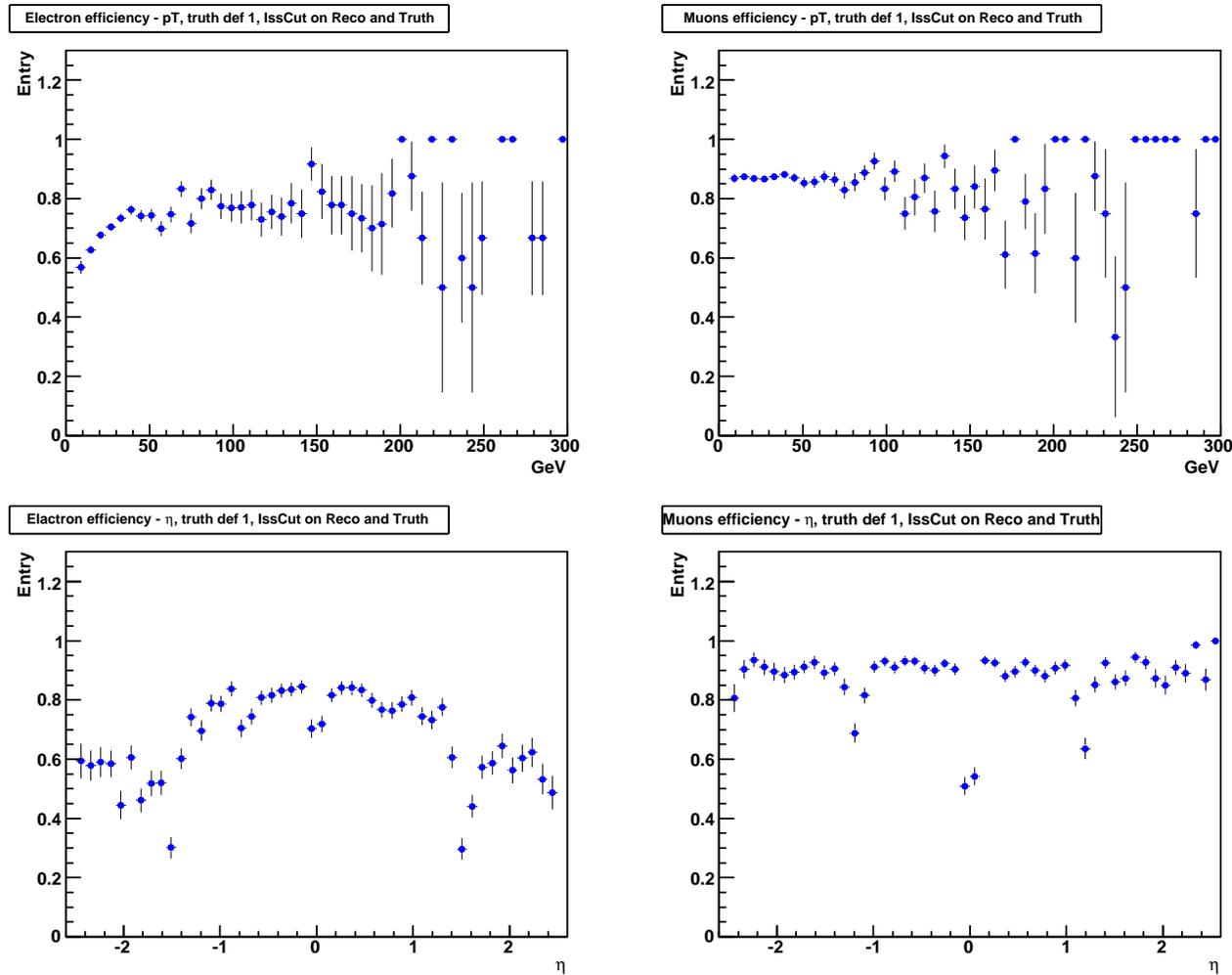
Figure 1: SU2 efficiencies, isolation cut on both reco and truth. Truth Definition 1

Efficiencies

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	72.3 ± 0.5	55.3 ± 0.5	71.0 ± 0.4	62.6 ± 0.4	70.0 ± 0.6	61.4 ± 0.6
Eff (isol reco/tr)	75.9 ± 0.5	75.8 ± 0.5	73.3 ± 0.4	73.2 ± 0.4	73.5 ± 0.6	73.4 ± 0.6
Tokyo	75.6 ∓ 0.5	75.6 ± 0.5	73.4 ± 0.3	73.3 ± 0.3		
Milano	72.8 ∓ xx	58.9 ± xx	71.5 ± xx	63.8 ± xx		
Winconsin	75.6 ∓ 0.5	75.6 ± 0.5	73.4 ± 0.3	73.6 ± 0.3		

Table 1: Electron efficiency $p_T > 20$ GeV, calorimeter based isolation etcone20 $< 10\ GeV$. The Milano group is using isolation cuts only on reconstructed leptons.

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	69.5 ± 0.4	48.4 ± 0.4	69.6 ± 0.3	55.1 ± 0.3	66.5 ± 0.5	55.4 ± 0.5
Eff (isol reco/tr)	73.3 ± 0.4	73.0 ± 0.4	71.6 ± 0.3	70.9 ± 0.3	70.2 ± 0.5	69.9 ± 0.5

Table 2: Electron efficiency $p_T > 10$ GeV, calorimeter based isolation etcone20 $< 10\ GeV$.

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	66.3 ± 0.4	45.8 ± 0.4	65.6 ± 0.3	50.1 ± 0.3	63.2 ± 0.5	51.9 ± 0.5
Diff. calo. isol.	-3.2	-2.5	-4,0	-5,0	-3.3	-3.5

Table 3: Electron efficiency $p_T > 10$ GeV, track based isolation, on reco only.

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	64.4 ± 1.0	42.5 ± 0.8	64.0 ± 1.0	49.3 ± 0.9	64.6 ± 1.5	54.1 ± 1.5
Diff. no pile up	-1.9	-3.3	-1.6	-0.8	+1.4	+ 2.2

Table 4: Electron efficiency $p_T > 10$ GeV, track based isolation, on reco only, pile up

Efficiencies Muons

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	82.1 ± 0.4	64.8 ± 0.5	84.1 ± 0.2	74.6 ± 0.2	83.1 ± 0.5	72.6 ± 0.5
Eff (isol reco/tr)	85.3 ± 0.4	85.3 ± 0.4	86.5 ± 0.2	86.5 ± 0.2	86.3 ± 0.4	86.3 ± 0.4
Tokyo	82.3 ∓ 0.6	65.3 ± 0.7	83.5 ± 0.3	74.2 ± 0.3		

Table 5: Muon efficiency $p_T > 20$ GeV

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	82.0 ± 0.4	61.7 ± 0.4	84.0 ± 0.3	68.1 ± 0.3	82.8 ± 0.4	70.4 ± 0.4
Eff (isol reco/tr)	85.3 ± 0.3	85.2 ± 0.3	86.5 ± 0.2	86.3 ± 0.2	86.6 ± 0.4	86.6 ± 0.4

Table 6: Muon efficiency $p_T > 10$ GeV, calorimeter based isolation etcone20 $< 10\ GeV$.

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	75.1 ± 0.4	55.2 ± 0.4	77.4 ± 0.3	59.1 ± 0.3	76.1 ± 0.4	63.1 ± 0.5
Diff. calo. isol.	-4.9	-6.5	-6.6	-9.0	-6.7	-7.3

Table 7: Muon efficiency $p_T > 10$ GeV, track based isolation on reco only.

	SU3	SU3	T1	T1	SU2	SU2
	Truth def 1	Truth def 2	Truth def 1	Truth def 2	Truth def 1	Truth def 2
Eff (isol reco)	67.0 ± 0.9	48.3 ± 0.8	67.7 ± 1.0	51.2 ± 0.9	67.5 ± 1.6	55.7 ± 1.5
Diff. no pile up.	-8.1	-6.9	-9.7	-7.9	-8.6	-7.4

Table 8: Muon efficiency $p_T > 10$ GeV, track based isolation on reco only, pile up

Fakerates

	SU3 Truth def 1	SU3 Truth def 2	T1 Truth def 1	T1 Truth def 2	SU2 Truth def 1	SU2 Truth def 2
Electrons						
Fake 1	3.3 ± 0.1	2.7 ± 0.1	5.3 ± 0.1	2.6 ± 0.1	3.0 ± 0.1	2.3 ± 0.1
Fake 2	1.5 ± 0.1	1.4 ± 0.1	2.3 ± 0.1	2.0 ± 0.1	2.2 ± 0.1	2.1 ± 0.1
Fake 3	1.8 ± 0.1	1.3 ± 0.1	3.0 ± 0.1	0.6 ± 0.1	0.8 ± 0.1	0.2 ± 0.1
Muons						
Fake 1	1.06 ± 0.06	0.10 ± 0.02	4.68 ± 0.14	0.06 ± 0.02	1.36 ± 0.08	0.09 ± 0.02
Fake 2	0.98 ± 0.06	0.07 ± 0.02	4.53 ± 0.13	0.04 ± 0.01	1.29 ± 0.08	0.07 ± 0.02
Fake 3	0.07 ± 0.02	0.03 ± 0.01	0.15 ± 0.02	0.02 ± 0.01	0.07 ± 0.02	0.02 ± 0.01

Table 9:   Electron and muon fake rates $p_T > 10$ GeV, calorimeter based isolation etcone20 $< 10 \; GeV$. All numbers $\times 10^{-3}$.

	SU3 Truth def 1	SU3 Truth def 2	T1 Truth def 1	T1 Truth def 2	SU2 Truth def 1	SU2 Truth def 2
Electrons						
Fake 1	1.3 ± 0.1	1.2 ± 0.1	0.9 ± 0.1	0.8 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
Fake 2	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0
Fake 3	1.0 ± 0.1	1.0 ± 0.1	0.6 ± 0.1	0.5 ± 0.1	0.2 ± 0.0	0.1 ± 0.0
Muons						
Fake 1	0.02 ± 0.01	0.01 ± 0.01	0.10 ± 0.02	0.0 ± 0.0	0.06 ± 0.02	0.01 ± 0.01
Fake 2	0.02 ± 0.01	0.0 ± 0.0	0.09 ± 0.02	0.0 ± 0.0	0.06 ± 0.02	0.01 ± 0.01
Fake 3	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Table 10:   Electron and muon fake rates $p_T > 10$ GeV, track based isolation. All numbers $\times 10^{-3}$.

Trigger

Standard trigger menus are stored in the ntuple
Trigger Menu : CSC=06 - low luminosity $(10^{33}cm^{-2}s^{-1})$

- Level one: just ask it to be passed: Reco.PassedL1 $== 1$ (efficiency $sim100\%$)

- Level 2 (L2) and Event Filter (EF):

- Electron: (Reco.PassedL2_e10), Reco.PassedL2_e15iL2_e15i, Reco.PassedL2_e25i

- Muon: Reco.PassedL2_mu6I, Reco.PassedL2_mu6, Reco.PassedL2_mu20i

- Jet: Reco.PassedEF_jet20kt, Reco.PassedEF_jet160

OR   between the different triggers at one level
AND   between the different levels

Trigger efficiency as in the $\eta - \phi$ plane - SU2

L1 L2 EF Electron Trigger
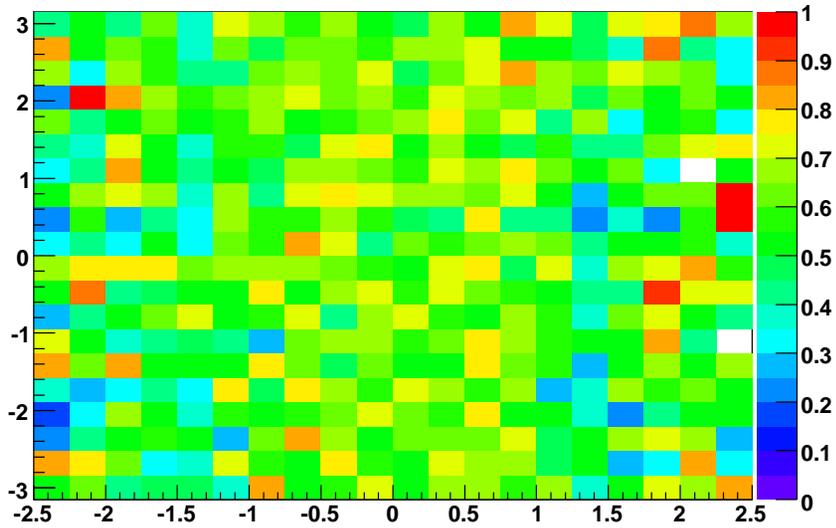
L1 L2 EF Muon Trigger
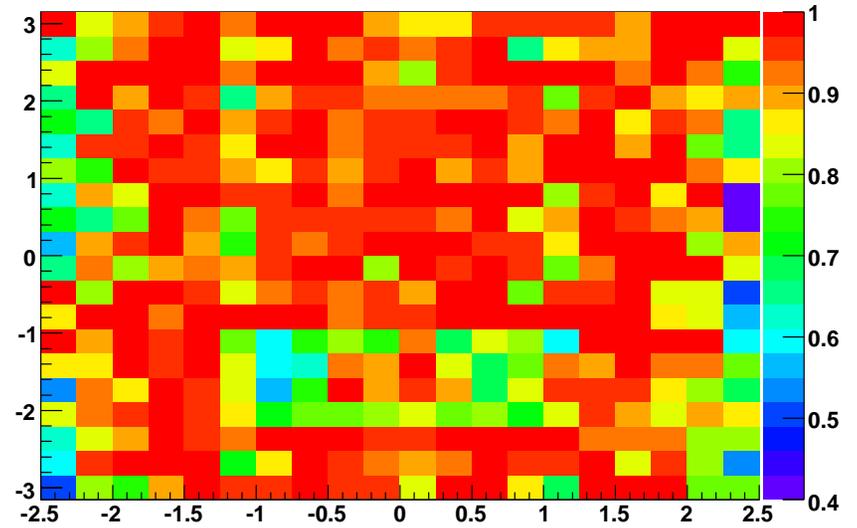
L2 Trigger
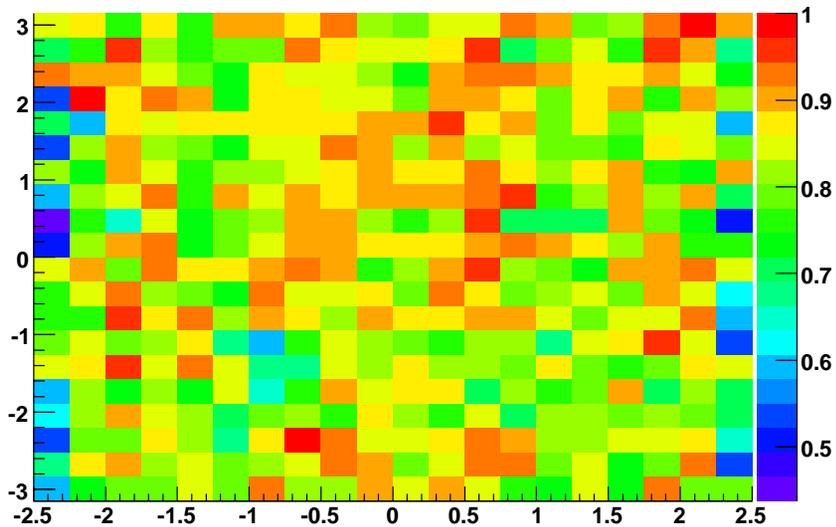
All Trigger Levenls
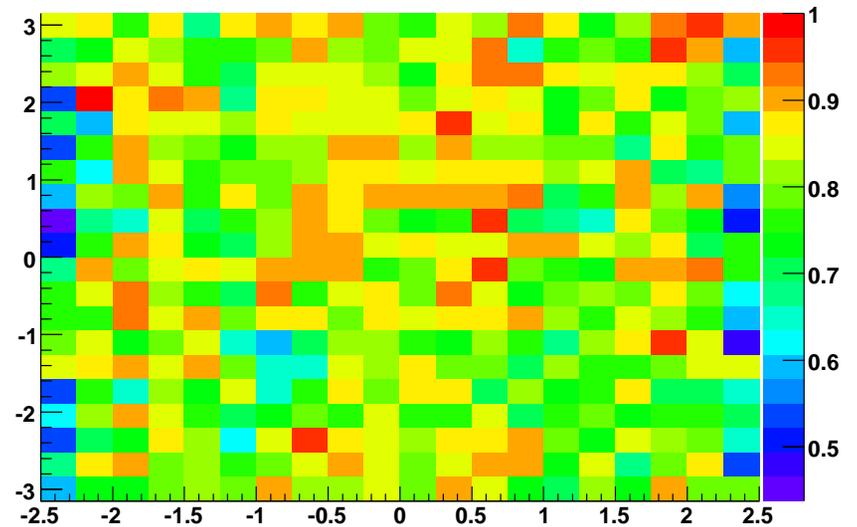
Trigger efficiency electron, muons - SU2
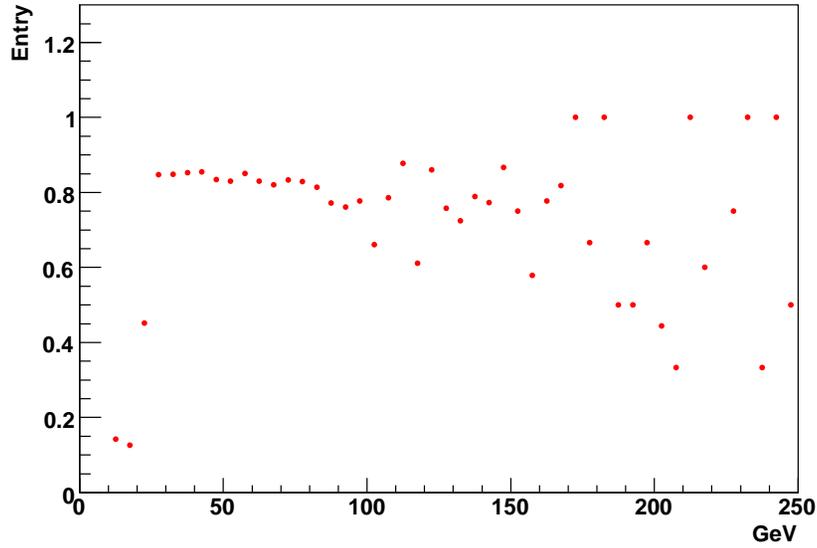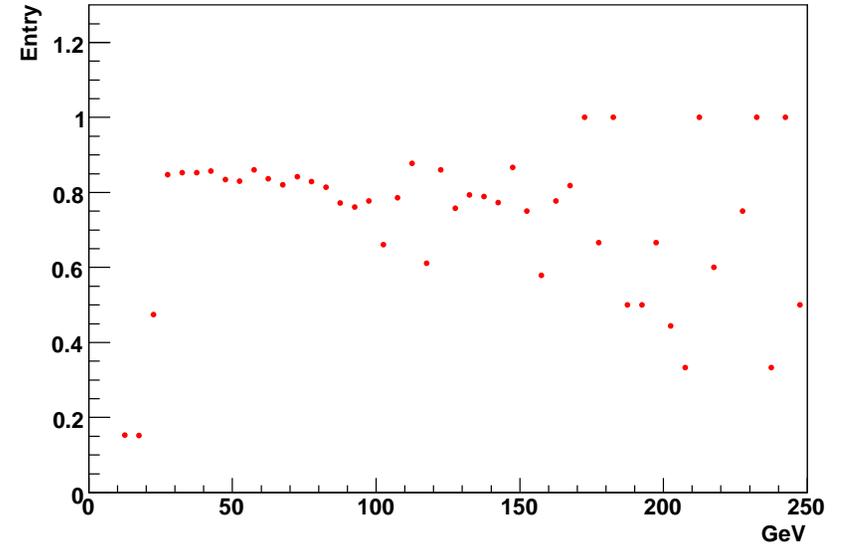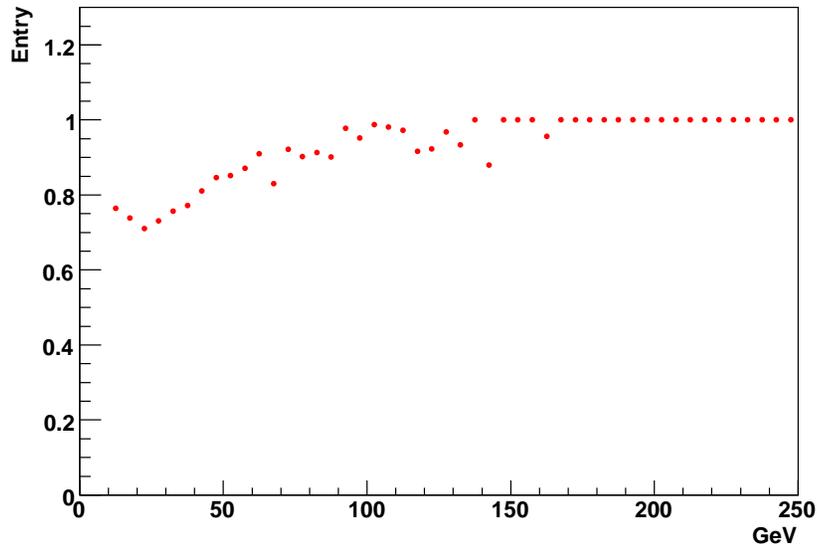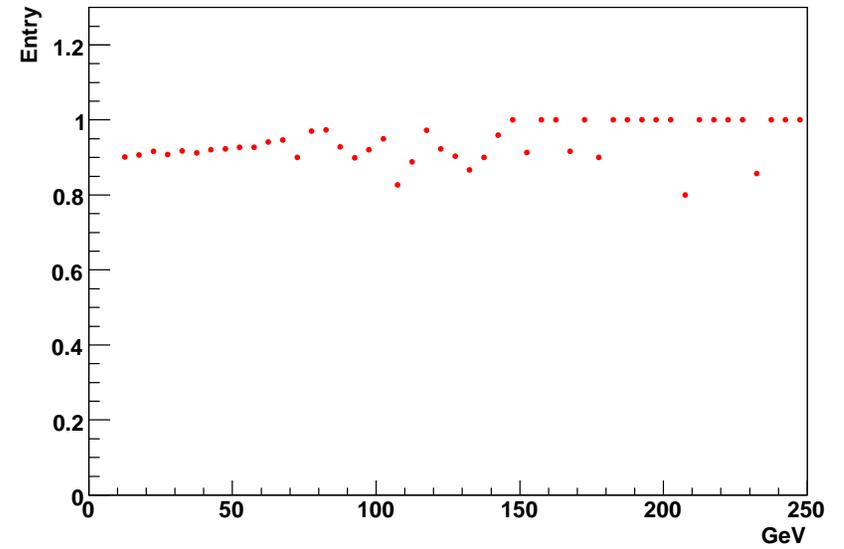
Event Selection

- Pass trigger: L1 AND L2 (any lepton trigger) AND EF (any lepton trigger)

- Number of leptons > 3

- Require Same Flavor Opposite Signs pair (SFOS)

- Track based isolation: Max track p_T in a cone with $\Delta R = 0.2$ around the lepton track.
  Electron: $p_{T\ max} < 2$
  Muon: $p_{T\ max} < 1$

	no cuts	L1	L2	EF	3lep	Isol
SU2 S	19735	19708	5031	4661	138	115
SU2 B	28865	28745	8114	7516	508	234
Sum SMB	6226495	6225563	4218609	3949575	62294	16782
Sig 2	7.88	7.87	2.45	2.34	0.55	0.88

$$Sig = Significance = \frac{S}{\sqrt{S+B}}$$

Isolation Maximum p_T of tracks in a cone around the lepton
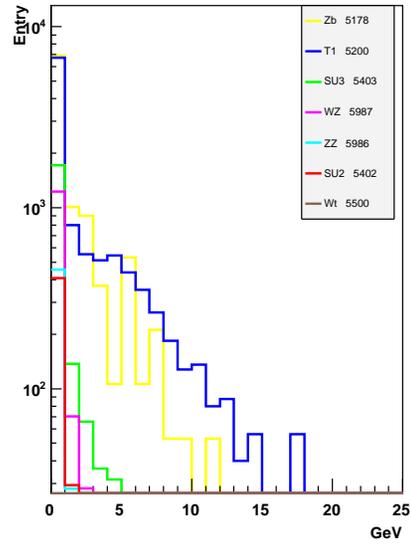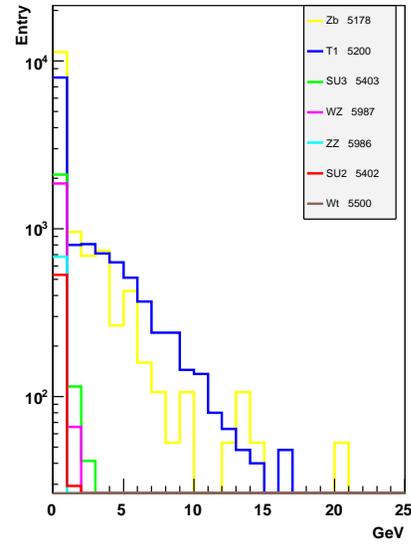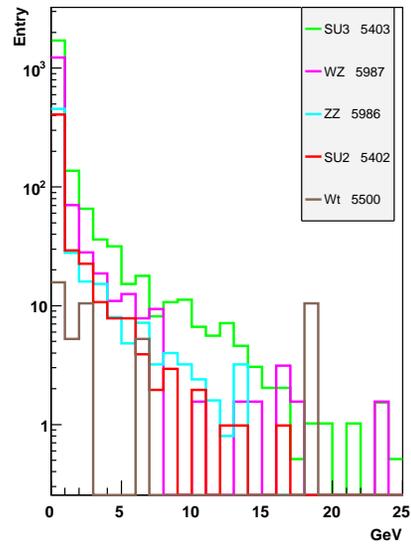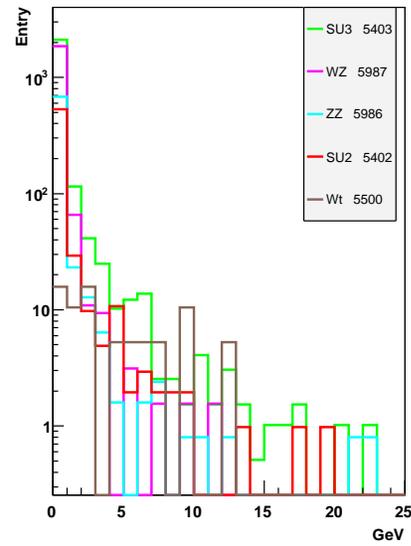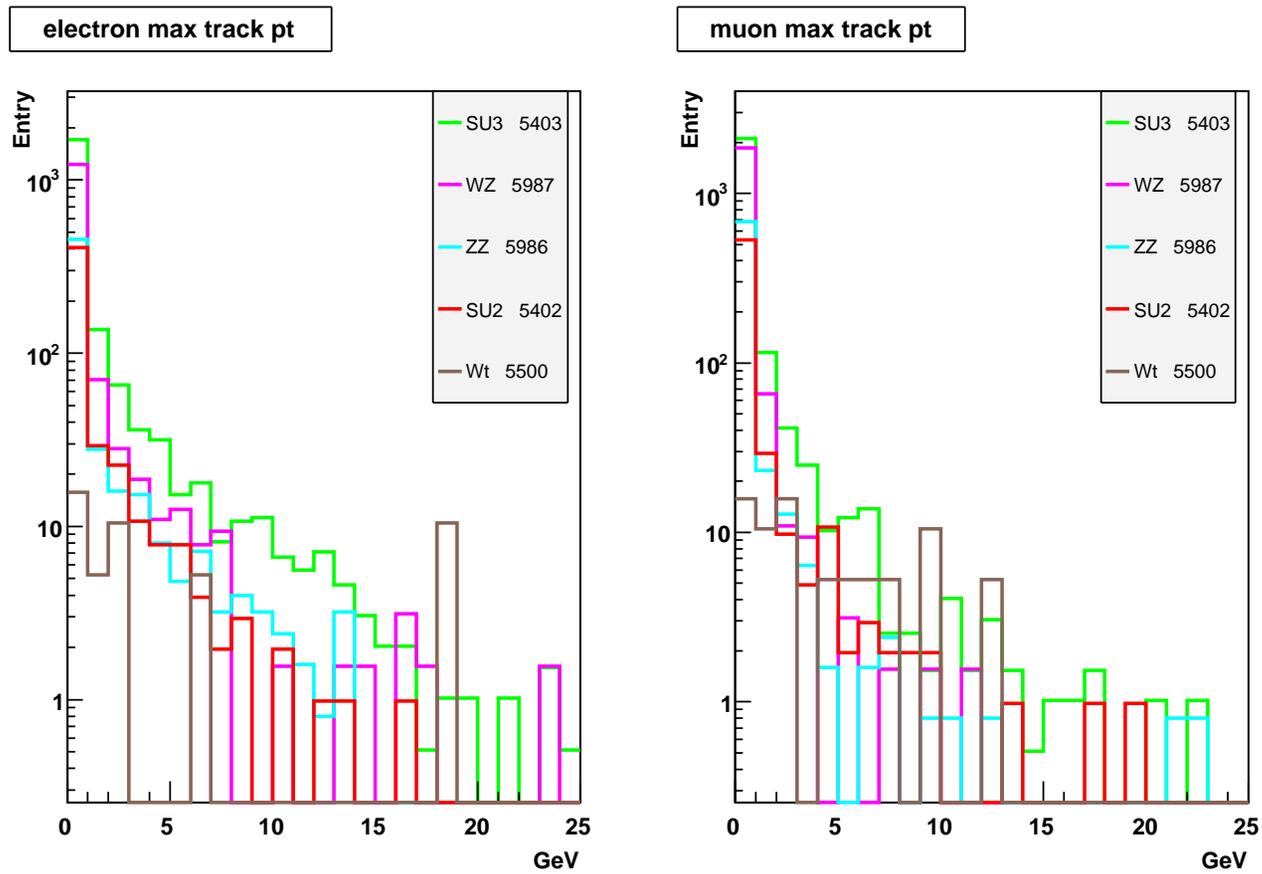
Figure 2: Maximum p_T of tracks in a cone around the lepton. Selection of samples

Isolation Maximum p_T of tracks in a cone around the lepton
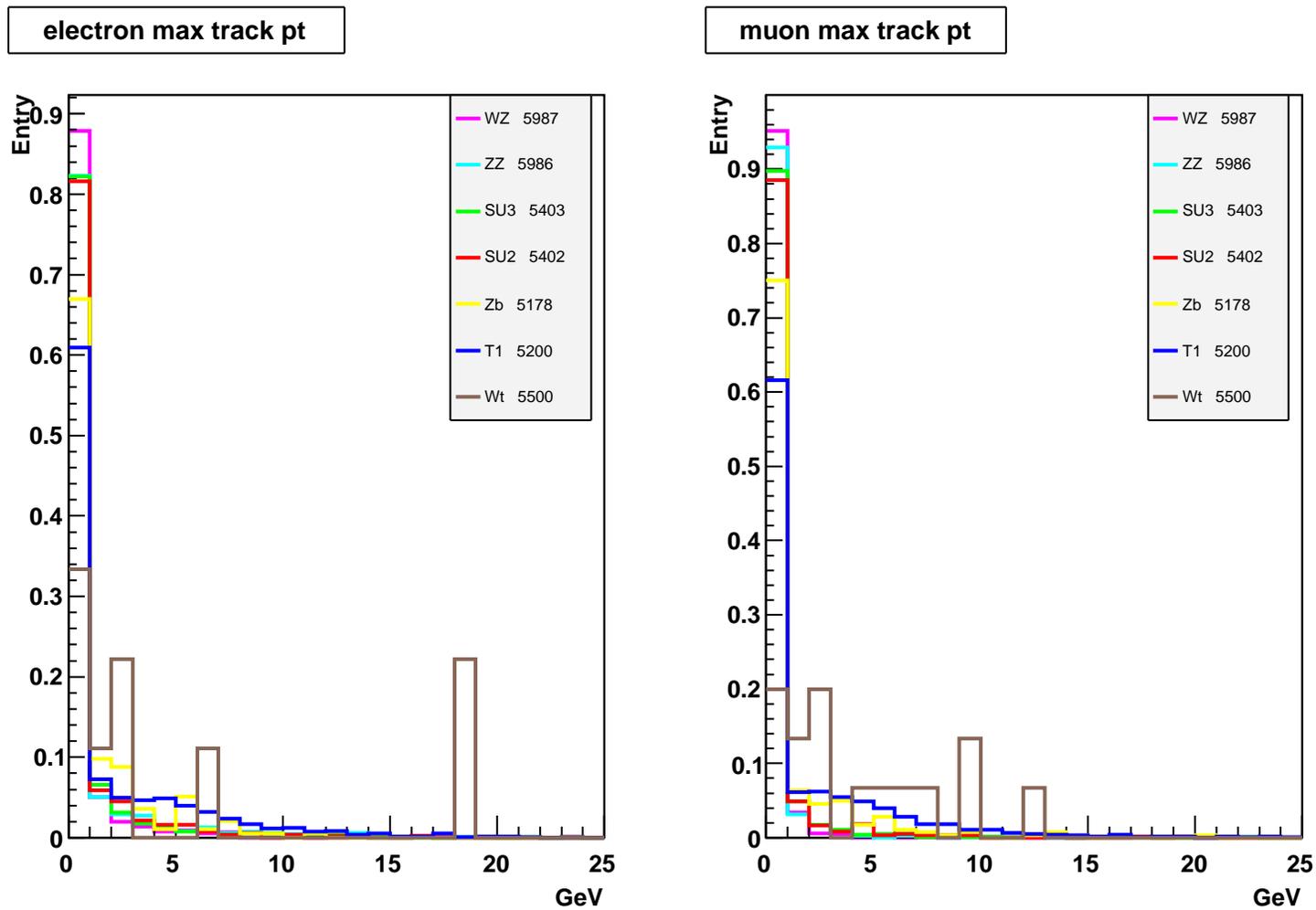
Maximum p_T of tracks in a cone around the lepton. NB! Normalized to 1.

Why background? - Fake electrons
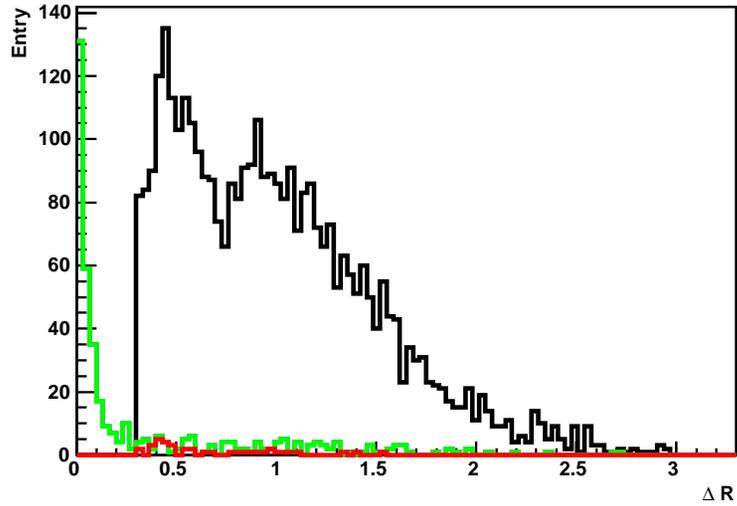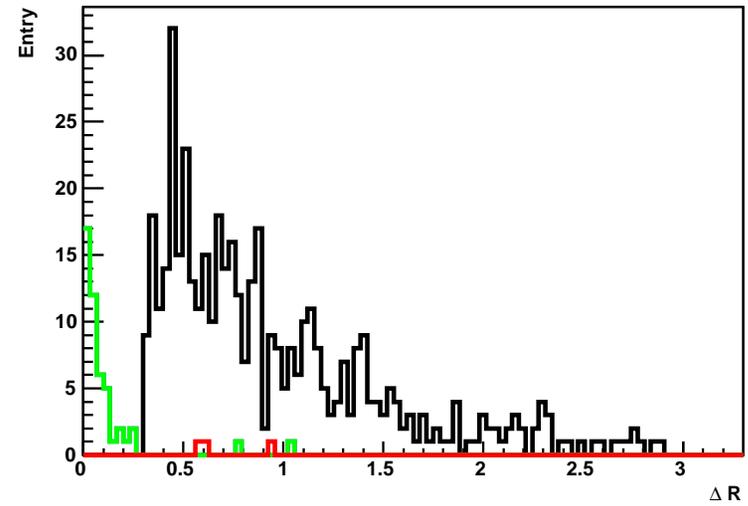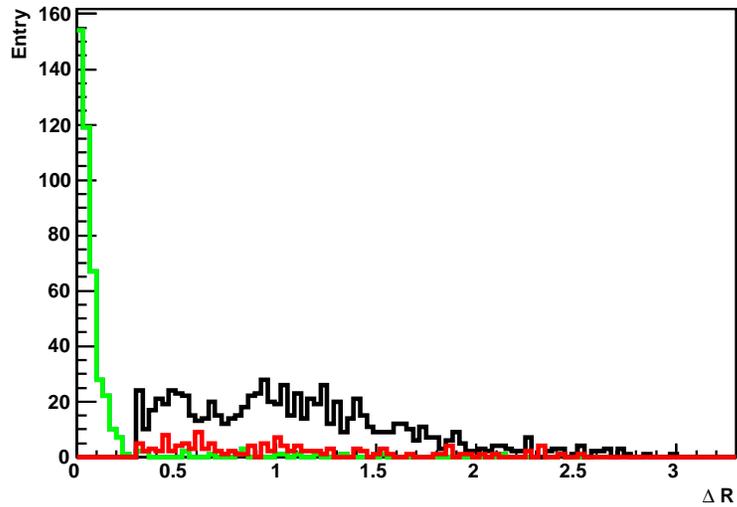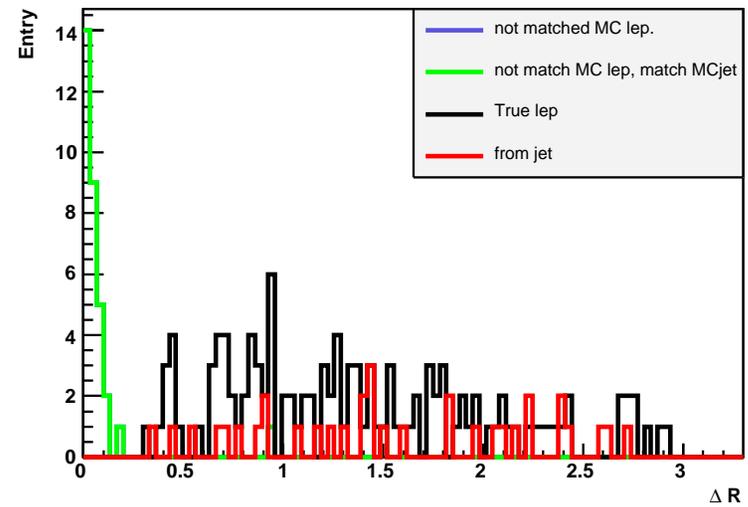
Why background? - Fake muons
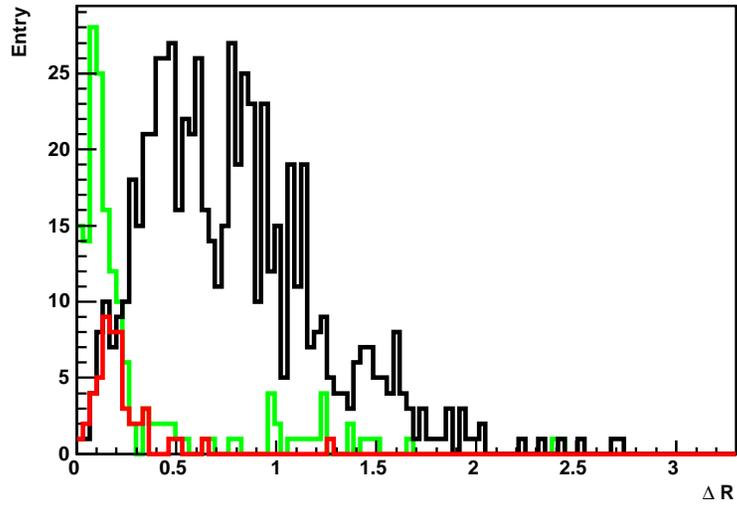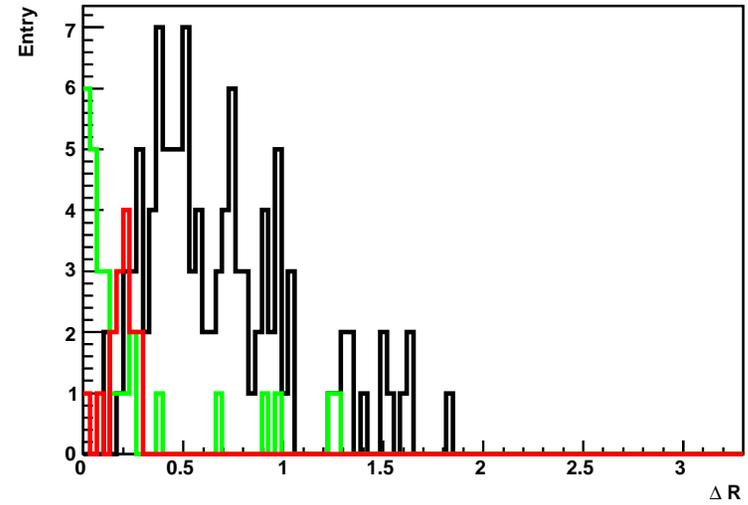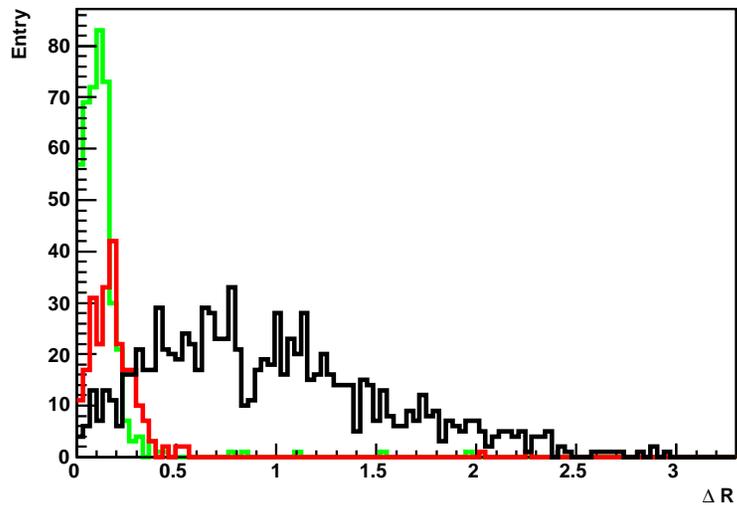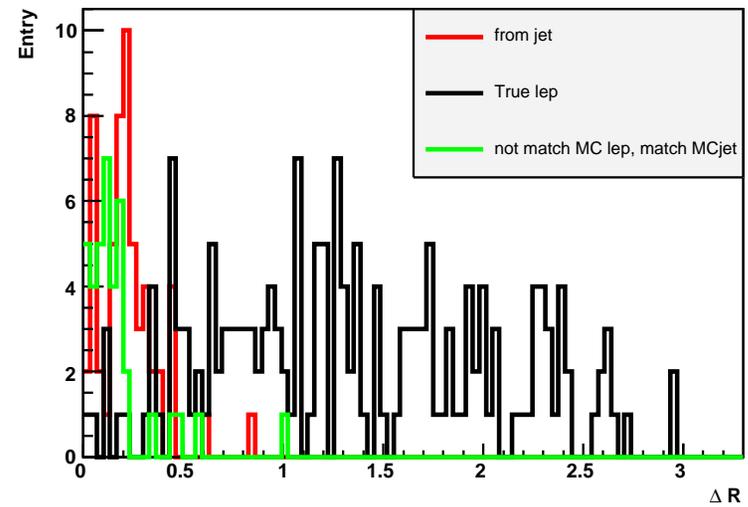
Cuts: B jets , Missing E_T
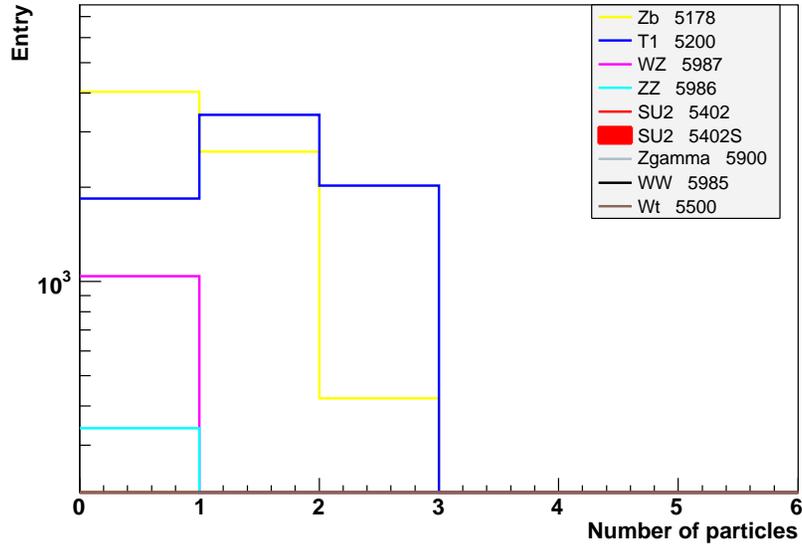
Number of B-jets
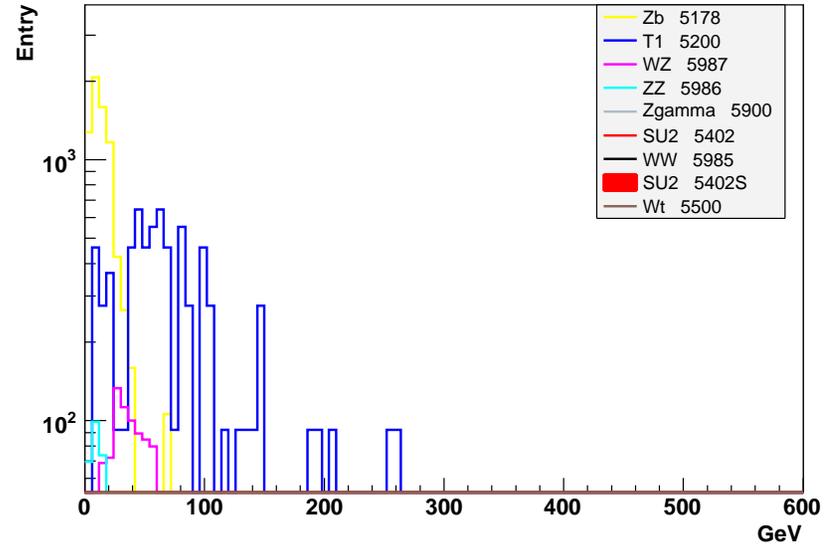
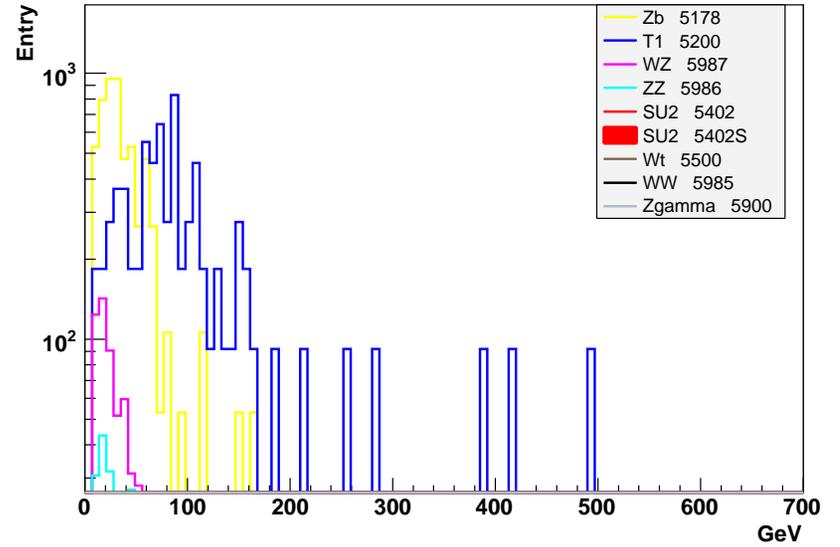**Missing Et**
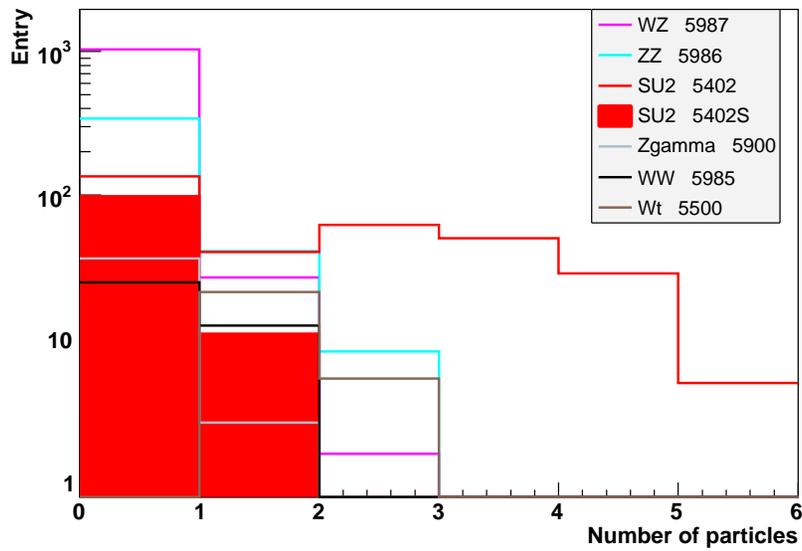
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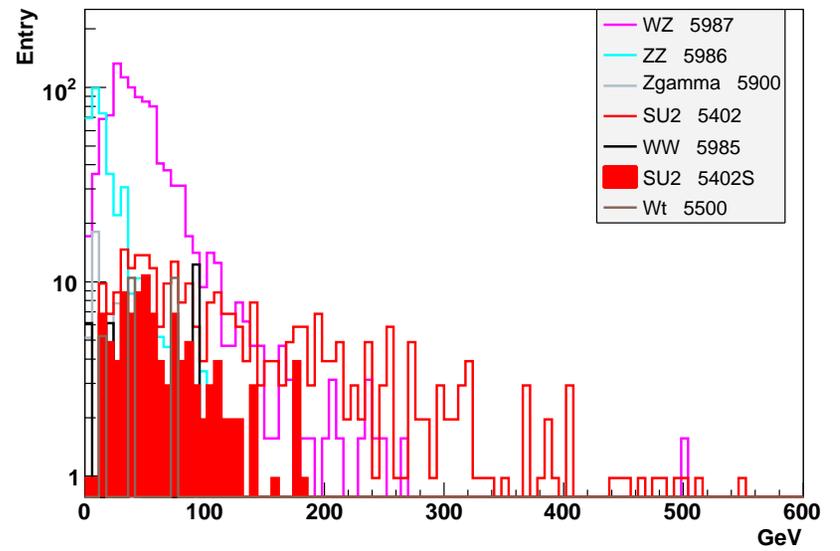
Missing Et

Cuts: Number of jet , p_T leading jet
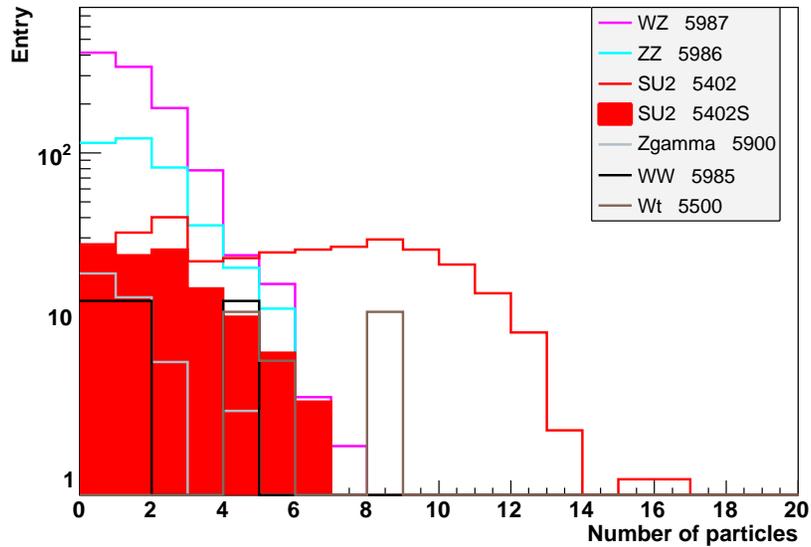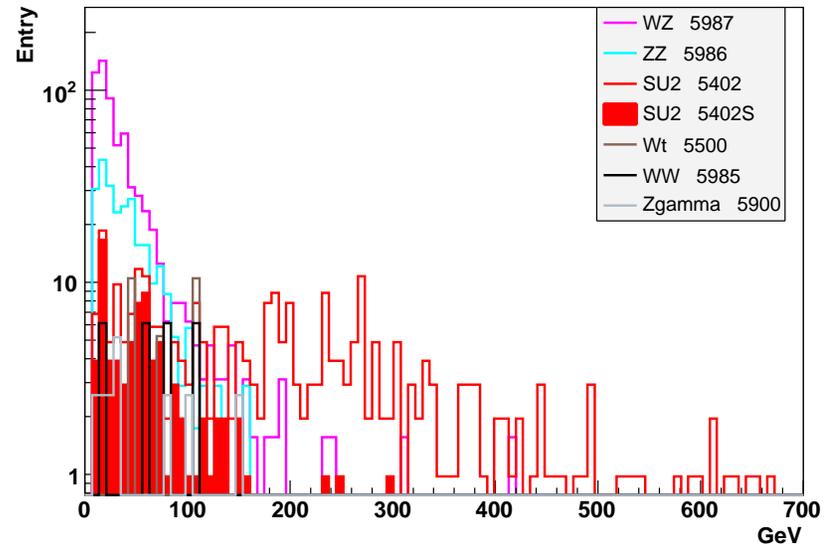
Number of jets
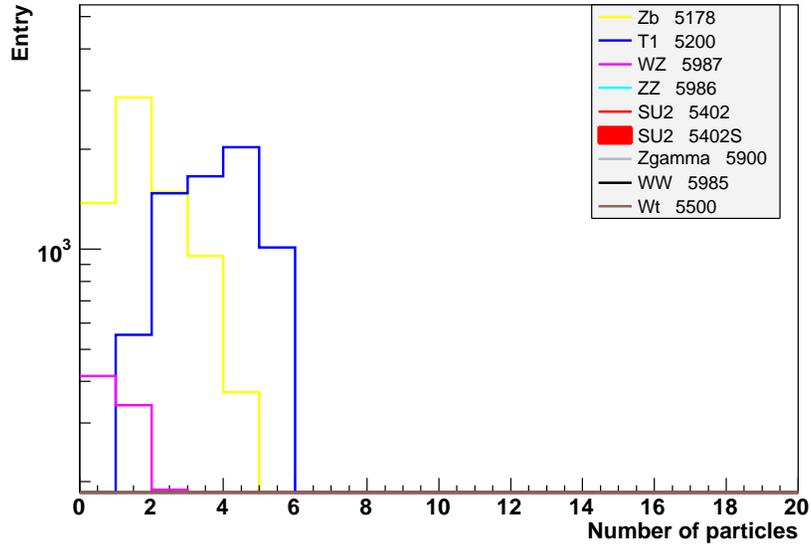
p_T leading jet

Number of jets

p_T leading jet

Further event selection

- Number of B jets $= 0$

- Missing $E_T > 14 GeV$

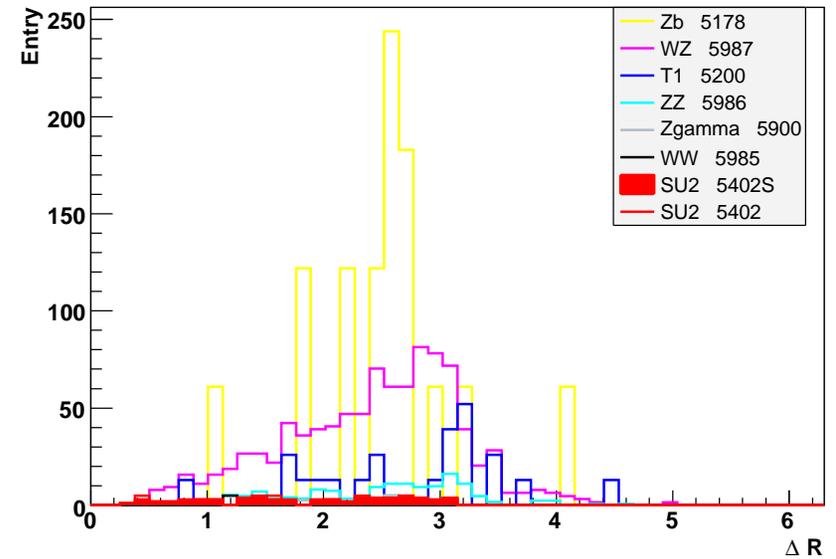- p_T leading jet < 20 GeV - Jet veto for exclusive analysis

	no cuts	L1	L2	EF	Isol	SFOS	N Bjet=0	EtMiss >14	Pt_J1
SU2 S	144	144	140	138	115	109	98	93	
SU2 B	510	510	508	508	234	212	37	35	
SMB	59139	59139	58330	57971	16565	15844	6899	4133	
Sig 2	0.59	0.59	0.58	0.57	0.89	0.85	1.42	1.17	

Dilepton SFOS Invariant mass, ΔR_{SFOS}
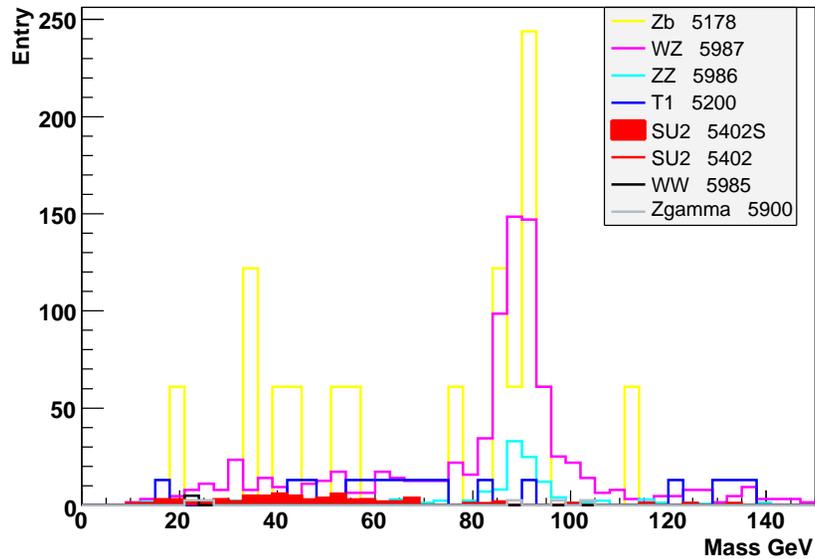
- $\Delta R < 2.6$

- Invariant mass on SFOS pair not between 80 GeV and 100 GeV

Dummy