Production cross section Measurement of tqZ using CMS 2012 data

Outline

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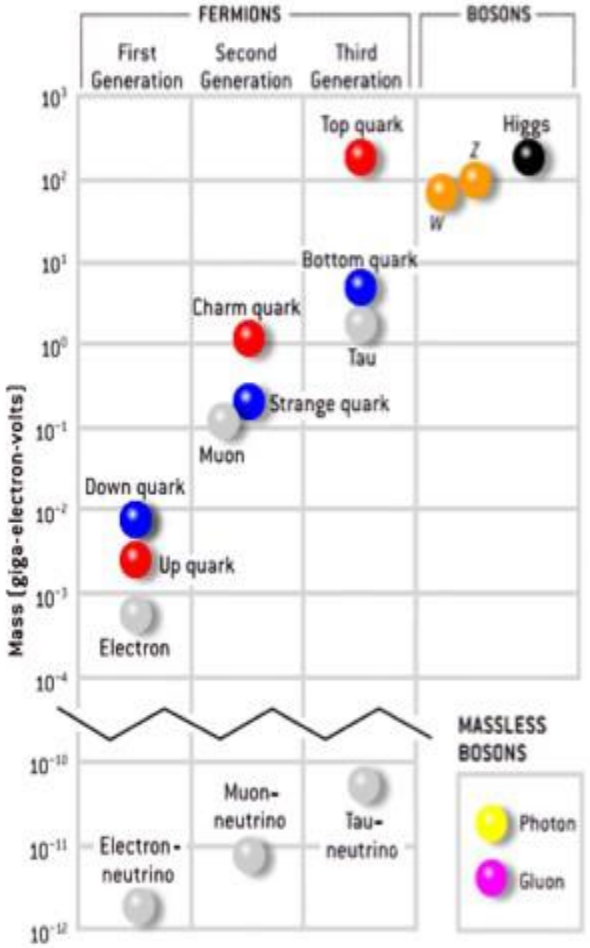
- Top Quark
- Analysis Introduction
- Analysis Cut Flow
- Pileup
- Basic Plots
- Background Estimation
- PAT vs AOD
- Analysis Documentation
- Summary and Conclusion

Motivations

- Plan to measure tqZ cross-section using 8 TeV, CMS data with 19.6 fb-1 Integrated Luminosity.
- tqZ is rare standard model process and it is irreducible background for ttbar and ttbar +Z, FCNC.
  - Measuring will confirm a predicted feature of the standard model and allow other analyses to include tqZ as a background.
  - In LHC run-II, with more top statistic, we will also be able to study vector boson association with top.
- Analysis techniques are similar to SUSY multi-lepton analysis

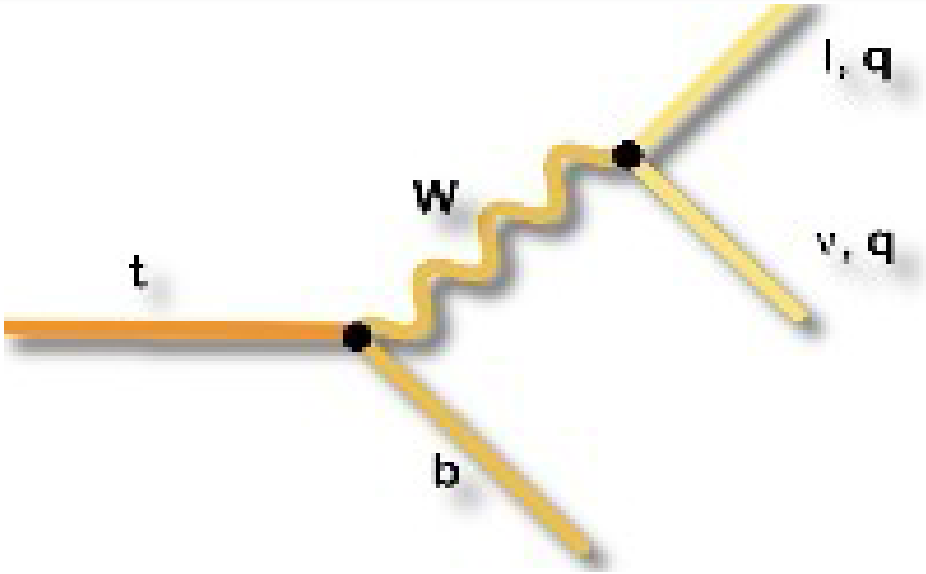
What is top quark

- The heaviest quark in the SM M ~ 172.4 GeV
- Mass near the electroweak symmetry breaking scale, has "natural" Yukawa coupling.
- Discovered in 1995.
- Charge of +2/3 and weak isospin of +1/2
- Lifetime 5×10−25 s:
- ~20 times shorter then time scale of strong int.
- decays before hadronization
- the spin information is kept by its decay products
- Gives opportunity to study "bare" quark

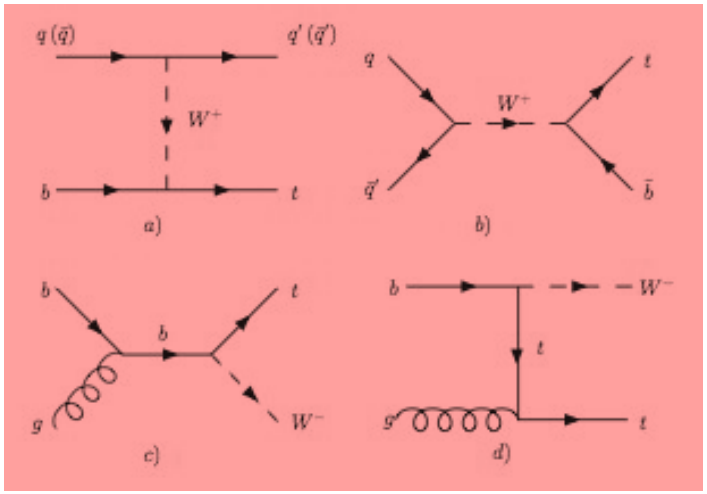


Top quark

$$\begin{cases} Br(t \to bW^+) \simeq 0.998 \\ Br(t \to sW^+) \simeq 0.0019 \\ Br(t \to dW^+) \simeq 0.0001 \end{cases}$$



Single top production:

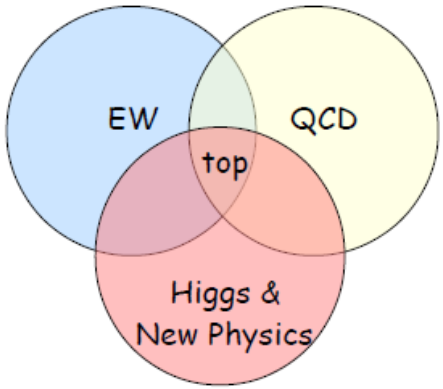


Life Time: 5 * 10 -25 sec

Proceeds via weak interactions:

- exchange of virtual W in s and t channel

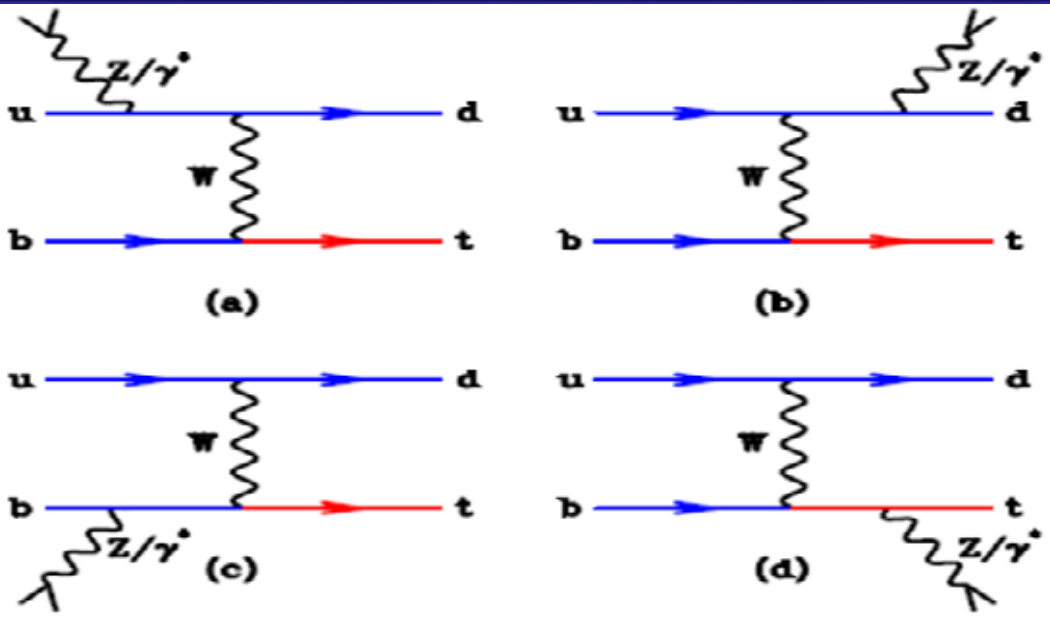
- associated production with real W



Analysis Introduction

The single top + Z cross section is about the same size as the $t\bar{t}Z$ one

Cross section for ttbar+Z is ~ 0.2057



tbZ Cross-section mentioned on single top page ~ 0.0114 pb

$\sigma . L = N$

Total events with this cross section and 19600 pb-1 integrated luminosity ~ 223

$$u + b \rightarrow t + Z + d$$
$$\mu^- + \mu^+$$
$$\nu + e^+ + b$$

tqZ cross-section ~ 0.02450 pb

Total events with this cross section and 19600 pb-1 integrated luminosity ~ 480

Analysis Framework

- Developed AOD based analysis framework
  - Run under CMSSW_5_3_21
  - Have producers for all basic objects
  - Cut flow about Muons and Electron implemented
  - Plus analyzers for various tasks like final cut flow, top reconstruction
  - Adapted some existing tools such as Pz calculation for MET (using W constrain)
- Recommended MET filter incorporated.
- Jet Energy Corrections(JEC) Type-I applied.
- Now migrated to PAT formate

Event Selection

- Tri-lepton final state.
  - eee
  - eeu
  - euu
  - uuu
- Two leptons should be same flavor and opposite charge.
- Third lepton should be from top decay with neutrino (MET).
- One b-tag.
- Light Jets should be more than 1 .

Datasets

- **Data used:**
  - **CMS 2012 (ReReco 8 TeV) data: 19.7 fb-1 Lumi**
    - **Double Electron**
    - **Double Mu**
    - **MuEG**
  - **JSON file:**
    - Cert_190456-208686_8TeV_22Jan2013ReReco_Collisions12_JSON.txt

Trigger

Trigger Applied
DoubleElectron
HLT_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL
DoubleMu
HLT_Mu17_Mu8
HLT_Mu17_TkMu8
MuEG
HLT_Mu17_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL
HLT_Mu8_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL

MC Samples Used

SignalMC	/TZJetsTo3LNuB_8TeV_TuneZ2Star_madgraph_tauola/ [1]
ttbarMC	/TTJets_MassiveBinDECAY_TuneZ2star_8TeV-madgraph-tauola/ [1]
ttbarW	/TTWJets_8TeV-madgraph/ [1]
ttbarZ	/TTZJets_8TeV-madgraph_v2/ [1]
WZ (3l + Nu)	/WZJetsTo3LNu_TuneZ2_8TeV-madgraph-tauola/ [1]
ZGamma	/ZGToLLG_8TeV-madgraph/ [1]
Z + Jets	/DYJetsToLL_M-10To50filter_8TeV-madgraph/ [1]
	/DYJetsToLL_M-50_TuneZ2Star_8TeV-madgraph-tarball/ [1]
	/ZbbToLL_massive_M-50_TuneZ2star_8TeV-madgraph-pythia6_tauola/[1]
WV	/WW_TuneZ2star_8TeV_pythia6_tauola/ [1]
	/WGstarToLNu2E_TuneZ2star_8TeV-madgraph-tauola/ [1]
	/WGstarToLNu2Mu_TuneZ2star_7TeV-madgraph-tauola/ [1]
ZZ	/ZZTo4e_8TeV-powheg-pythia6/ [1]
	/ZZTo4mu_8TeV-powheg-pythia6/ [1]
	/ZZTo2e2mu_8TeV-powheg-pythia6/ [1]

[1]= Summer12_DR53X-PU_S10_START53_V19-v1/AODSIM

Object Selection

- **Selection of objects** (TOP-PAG recommendations):

- **Exactly three `tight' leptons, two of which must be oppositely charged, same flavour and invariant mass within the z mass window (78-102 GeV).**

- **Events with good vertex cuts:**
  - **Ndof>5, Z<24.0, rho()<2.0**

- **Muon selection**
- **Electron Selection**
- **Jet & MET Selection**

Muons Selection

Selection of tight Muons

- Global AND tracker muon
- Is also a PF Muon
- pt >= 20, |eta| <= 2.4
- chi2/ndf <10 && chi2/ndf > 0
- track()->hitPattern().trackerLayersWithMeasurement() > 5
- recoMu.globalTrack()->hitPattern().numberOfValidMuonHits() > 0
- Transverse IP of the muon wrt primary vertex (cm) < 0.02,
- fabs(muon.vertex.z() - pv.z()) < 0.5
- muon.innerTrack()->hitPattern().numberOfValidPixelHits() > 0
- numberOfMatchedStations() > 1
- RelIso(dBeta) <= 0.20, cone of 0.4

Selection of loose Muons

- Global OR tracker muon
- pt >= 10, |eta| <= 2.4
- RelIso(dBeta) <= 0.20, cone of 0.4

Electron Selection

Selection of tight Electrons

- Gsf pt >= 20, Gsf |eta| <= 2.5 (Gsf == ecalDrivenMomentum)
- is both a PF and a GsF electron
- dxy(vertex) <=0.04 (fabs(electron.gsfTrack()->dxy(vertex_->position())))
- passes photon conversion veto electron.passConversionVeto()
- MVA ID >= 0.5 (mvaTrigV0)
- electron.gsfTrack()->trackerExpectedHitsInner().numberOfHits() <=0
- relIso (r=0.3) with Rho corrections < 0.15

Selection of loose Electrons

- Gsf pt >= 10, Gsf |eta| <= 2.5 (Gsf == ecalDrivenMomentum),
- MVA ID > 0,
- relIso (r=0.3) with Rho corrections < 0.15.

Jet and MET Selection

- **Jet selection: Official jet ID implemented**
  - PFJets with Jet pt> 20 GeV, eta< 3. and CVS disc < 0.679
  - neutralHadronEnergyFraction > 0.99
  - chargedHadronEnergyFraction > 0
  - neutralEmEnergyFraction > 0.99
  - chargedEmEnergyFraction > 0.99
  - JetIso (j, l) < 0.3
- **Tag jet: CSV (Combined Secondary Vertex) disc > 0.679**
  - Eta<2.4, pt > 25 GeV, It's a Medium working point
- **MET: pFMET with 25 GeV MET Cut.**

Cut Flow Table

	Dmu	DE	MuEG	tData	tMC	Signal	ttbar	ttbarW	ttbarZ	WZ	WW	Zgamma	ZZ (2e2mu)	ZZ (4e)	ZZ (4mu)	Z Jets (Less 50)	Z Jets (Grtr 50)	Zbb	WGstarToLNu2Mu	WGstarToLNu2E
All events	1.00E+08	9.15E+07	5.64E+07	2.48E+08	9.33E+07	485.075	510876	4593.37	3445.03	20947.3	1.13E+06	2.63E+06	3498.48	1522.74	1522.74	1.70E+07	6.99E+07	1.86E+06	37895.3	116280
Dilepton Trigger	5.20E+07	2.14E+07	3.51E+07	1.08E+08	9.33E+07	485.075	510876	4593.37	3445.03	20947.3	1.13E+06	2.63E+06	3498.48	1522.74	1522.74	1.70E+07	6.99E+07	1.86E+06	37895.3	116280
Primary vertx cut	5.20E+07	2.14E+07	3.51E+07	1.08E+08	9.26E+07	484.665	510642	4591.82	3443.9	20859.6	1.13E+06	2.61E+06	3484.95	1516	1517.4	1.69E+07	6.94E+07	1.86E+06	37717.2	115610
tight leptons 3	316	297	7	620	803	20	1	4	9	464	0	18	56	30	23	0	30	4	7	136
elec 3 +Z + W(MET)	0	57	0	57	69	3	0	0	1	57	0	1	0	4	0	0	2	0	0	1
Muon 3 + Z + W(MET)	75	0	0	75	79	3	0	0	1	70	0	0	0	0	5	0	0	0	1	0
muons 2 + elec 1 + Z + W(MET)	54	0	2	56	68	2	0	0	1	58	0	0	5	0	0	0	2	0	0	0
muons 1+ elec 2 + Z + W(MET)	1	54	0	55	68	2	0	0	1	60	0	0	4	0	0	0	0	0	0	0
Elec 3 + Z + MET + 1b	0	2	0	2	4	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Muon 3 + Z + MET +1b	3	0	0	3	3	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Muon 2 + elec 1 + Z + MET +1b	3	0	0	3	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Muon 1 + elec 2 +Z + MET +1b	0	4	0	4	4	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0

Pileup

- the additional interactions that occur in each beam crossing because the instantaneous bunch-by-bunch collision luminosity is very high.

- "additional" implies that there is a hard-scatter interaction that has caused the event to fire the trigger.
  - end of 2011: ~15 interactions per crossing
  - End of 2012: as high as 40 interactions per crossing

- **"In-time pileup":**
  - **the interactions that occur in the bunch crossing that fires the trigger**

Pileup

- **"Out-of-time pileup":**
  - the interactions that occur in bunch crossings earlier or later than the in-time interaction
  - depending on the integration time of the different CMS detector elements, these interactions can leave energy or tracks in the detector

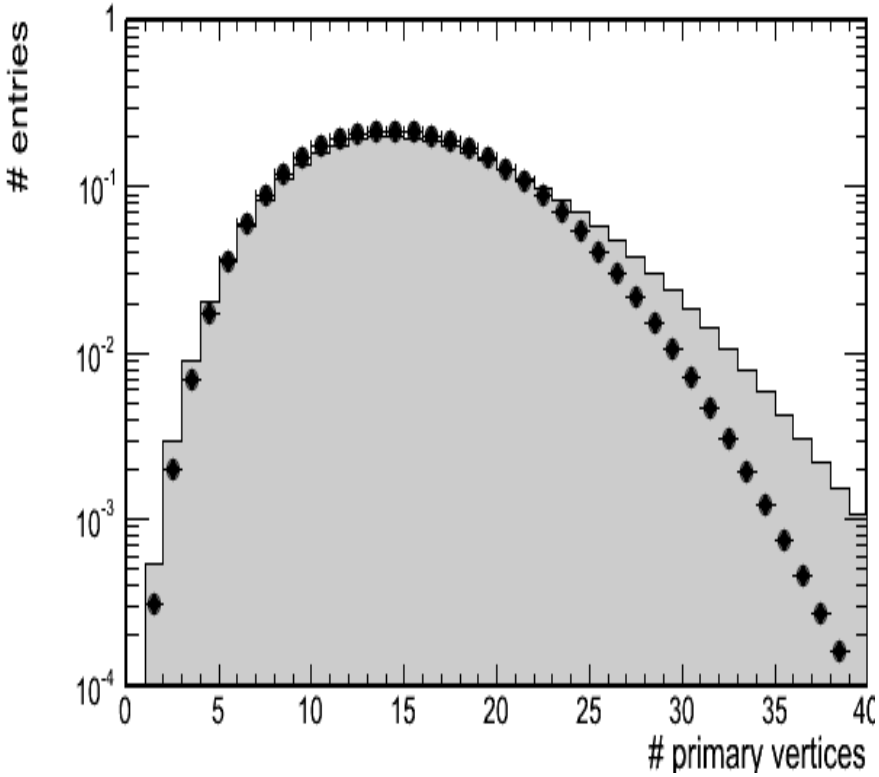
  - Tracker: only sensitive to in-time pileup
  - – Calorimeters: sensitive to out-of-time pileup
  - – Muons: sensitive to out-of-time pileup

Pileup Reweighting

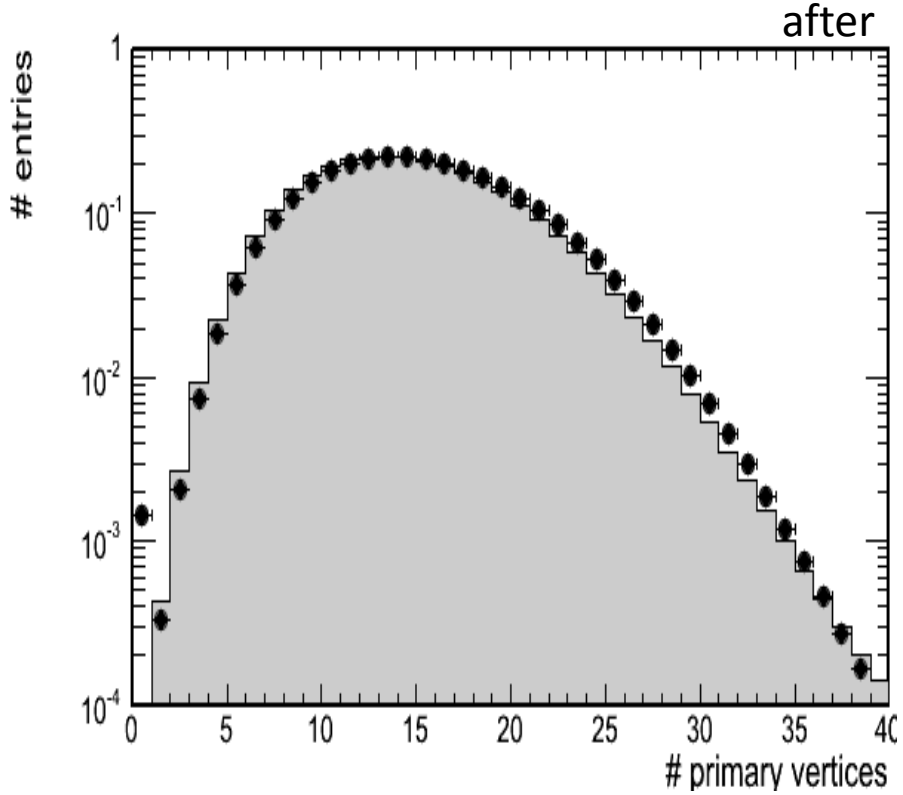
All used MC Samples produced using same scheme PU_S10

Weight for Pileup reweighting calculated using WZ MC sample

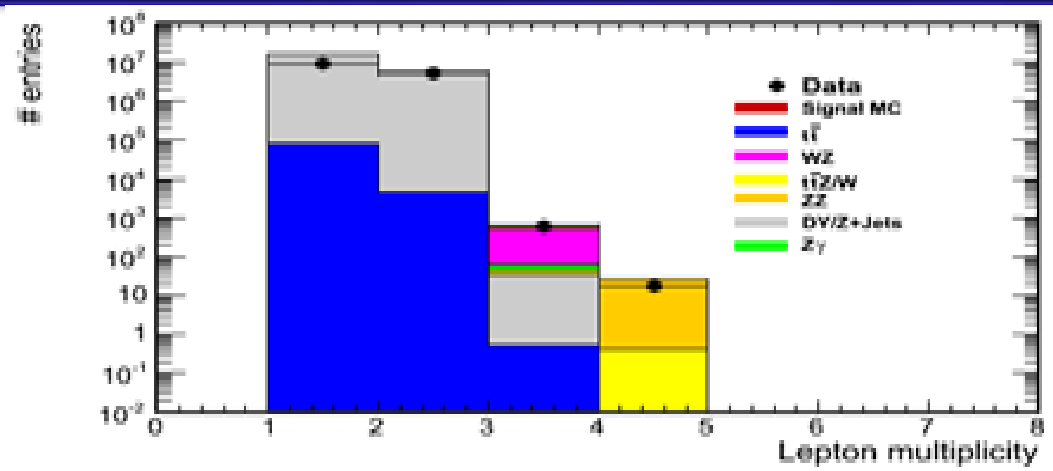
before

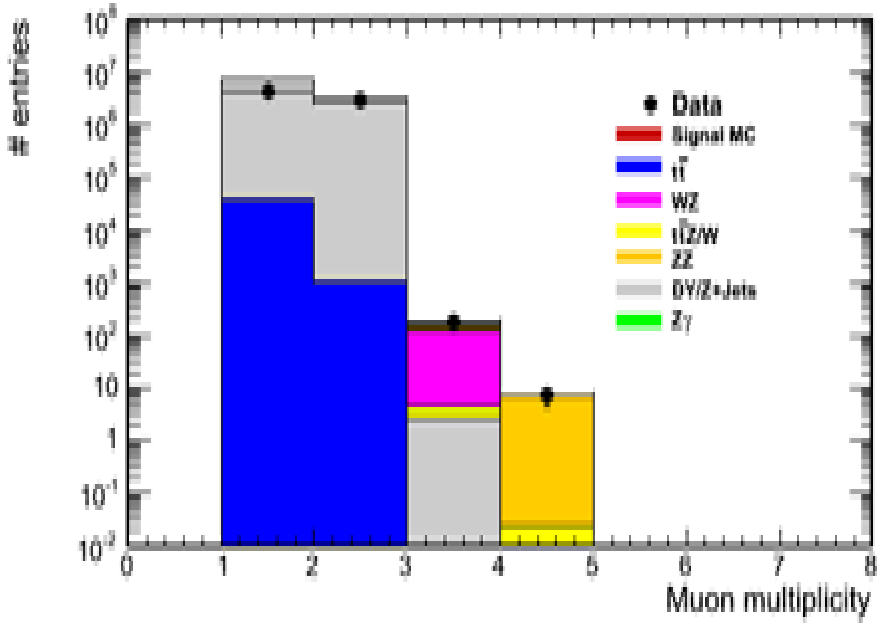


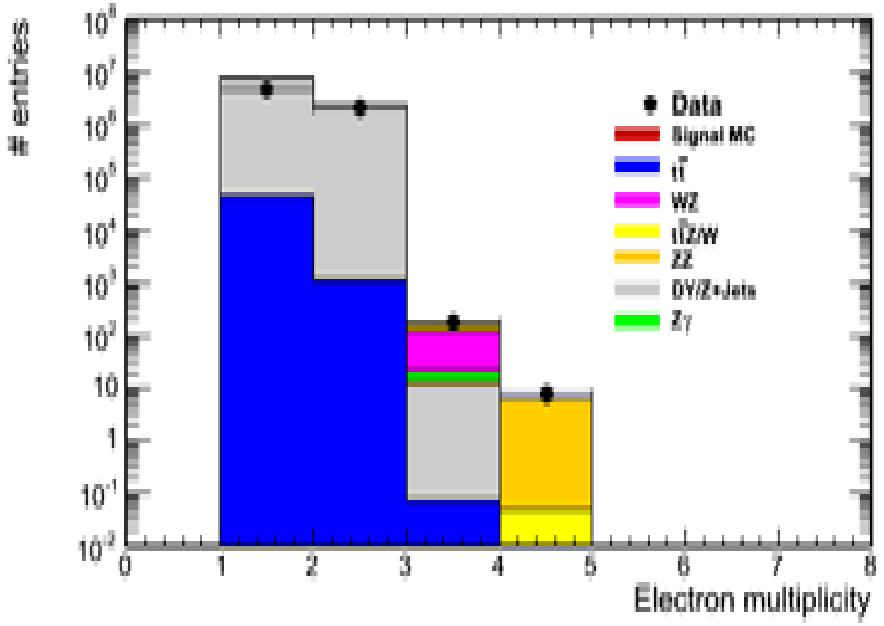
after



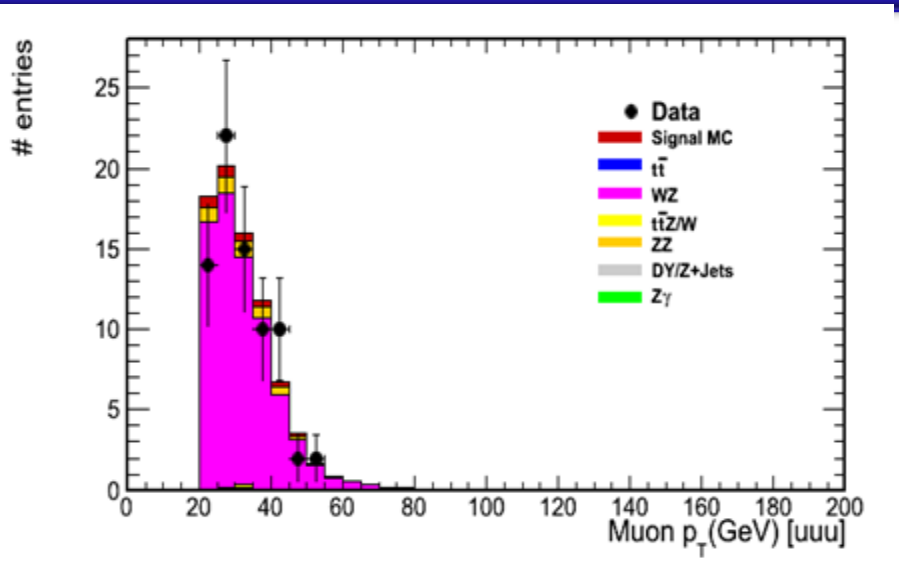
Leptons Multi

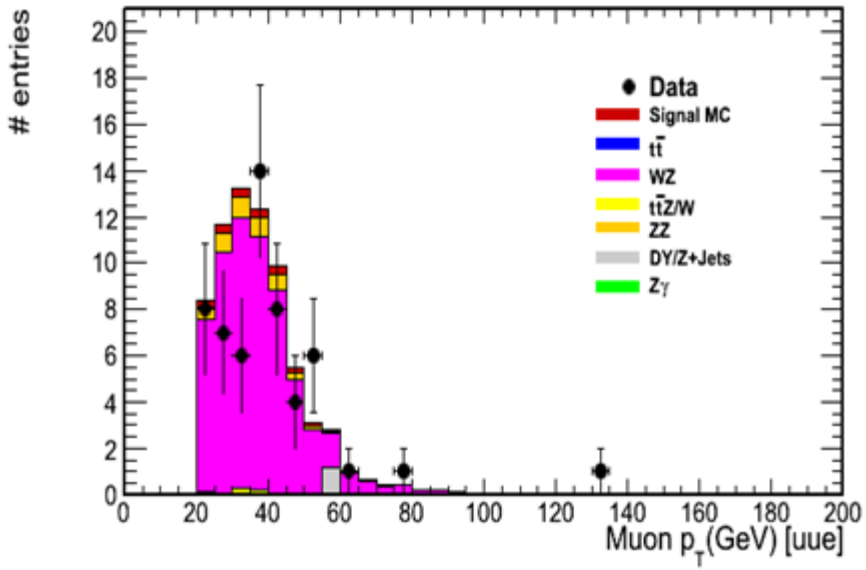


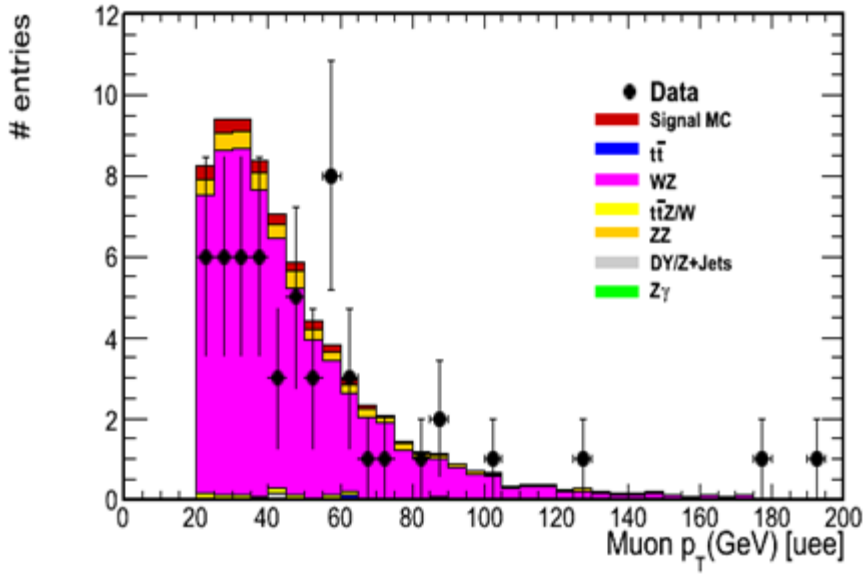




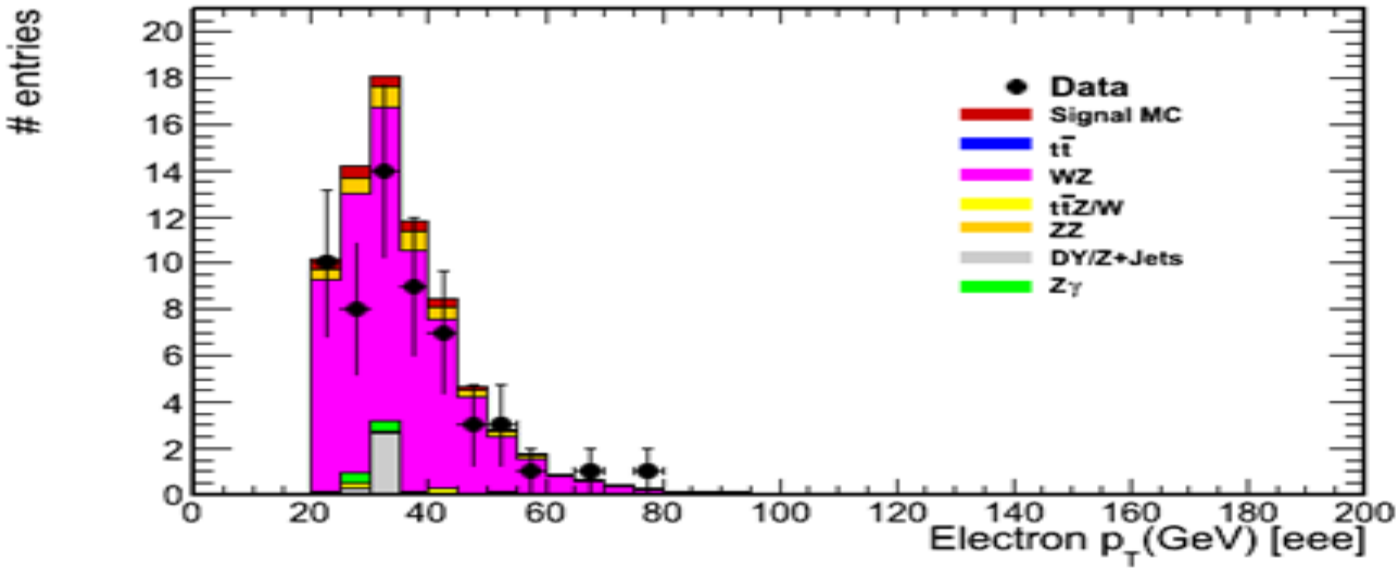
Muons Pt after Pre-selection

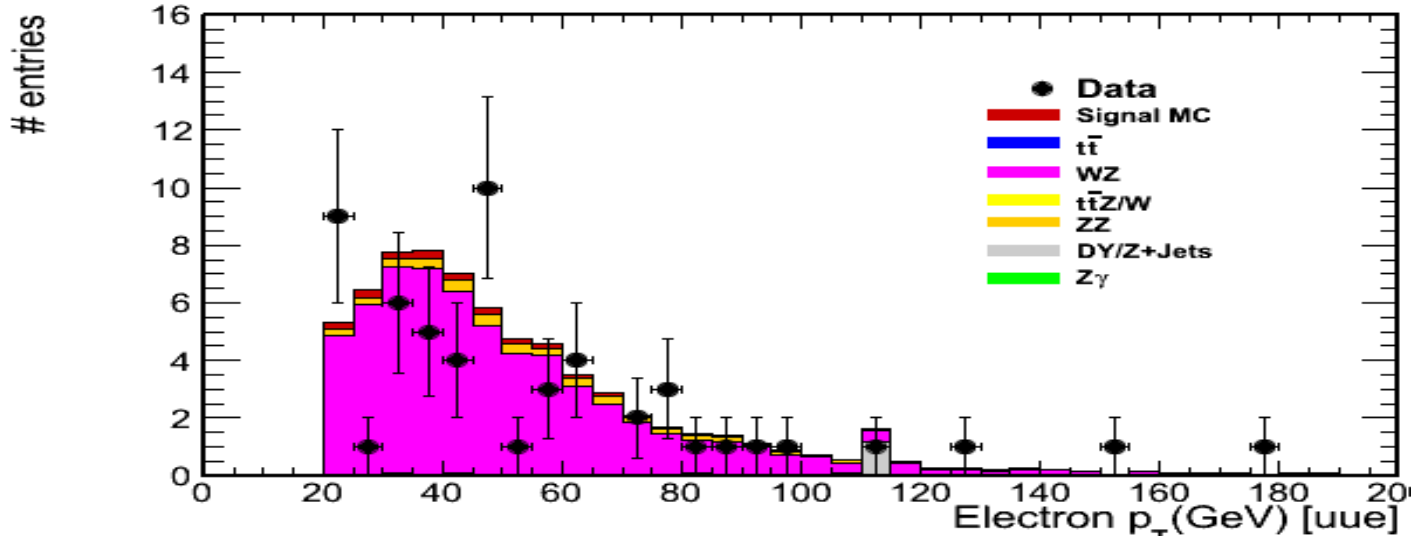




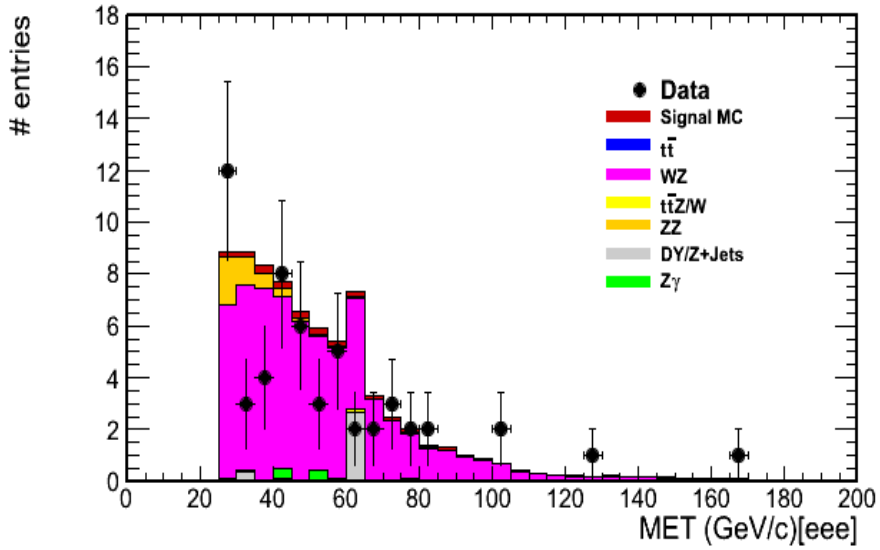


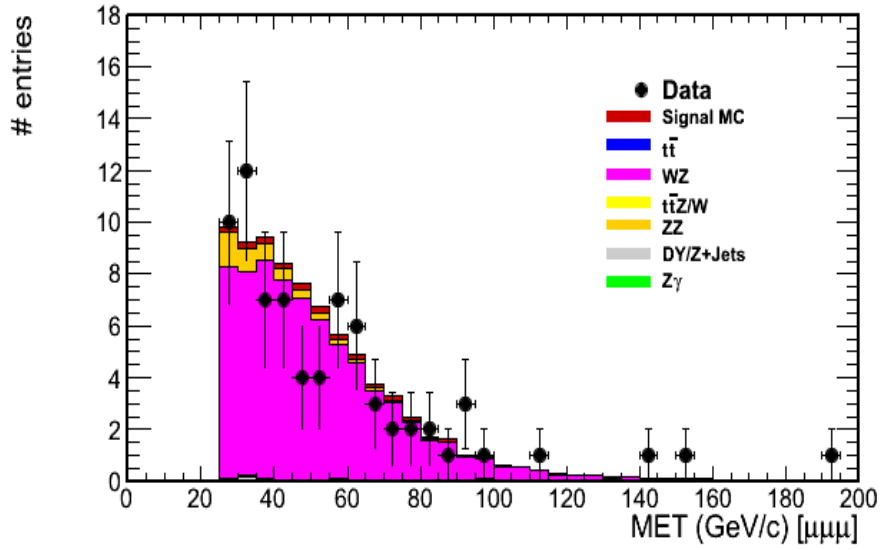
Electrons Pt after Pre-selection

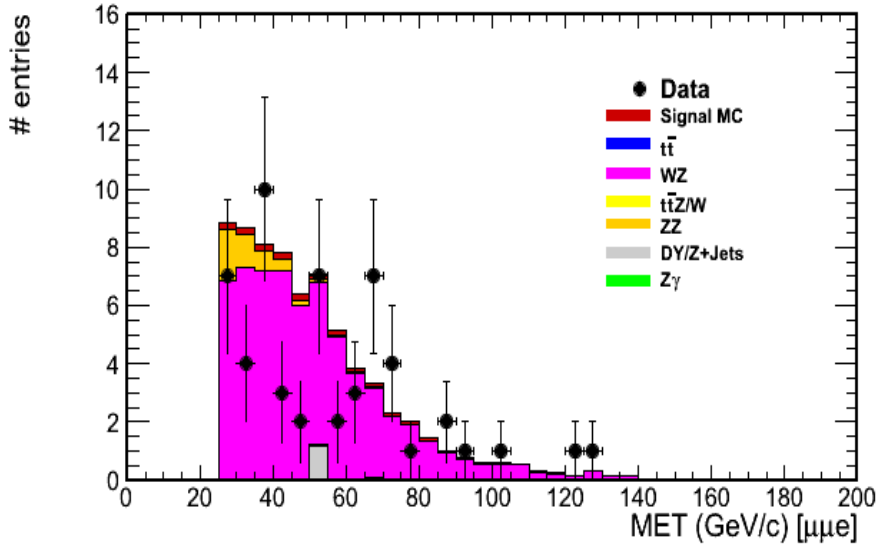


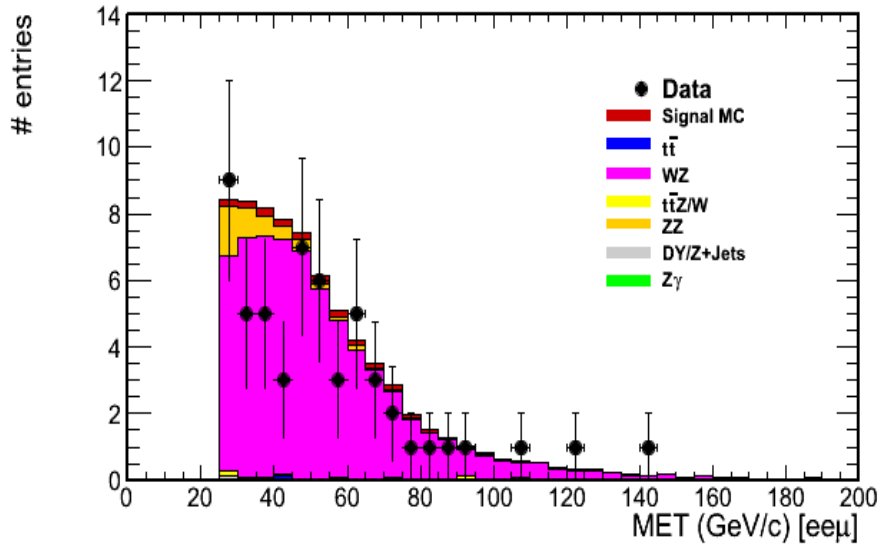


MET after pre-selection

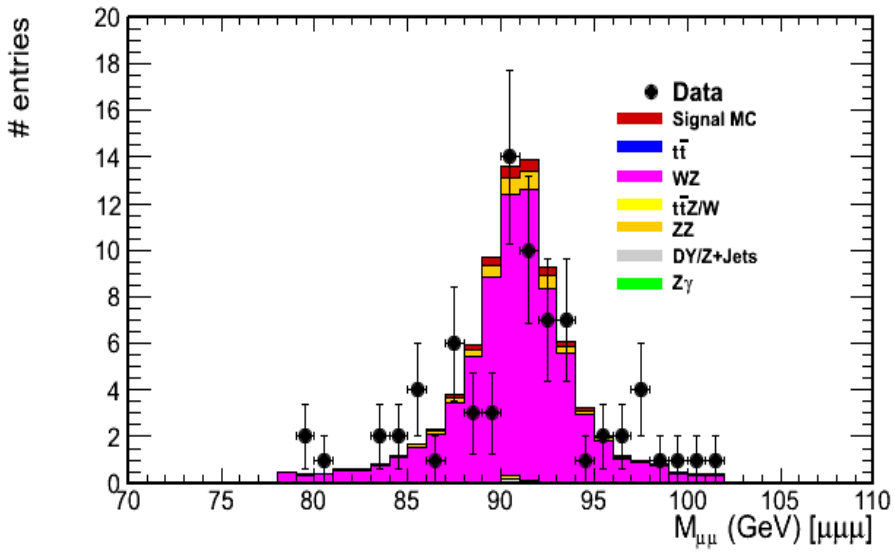


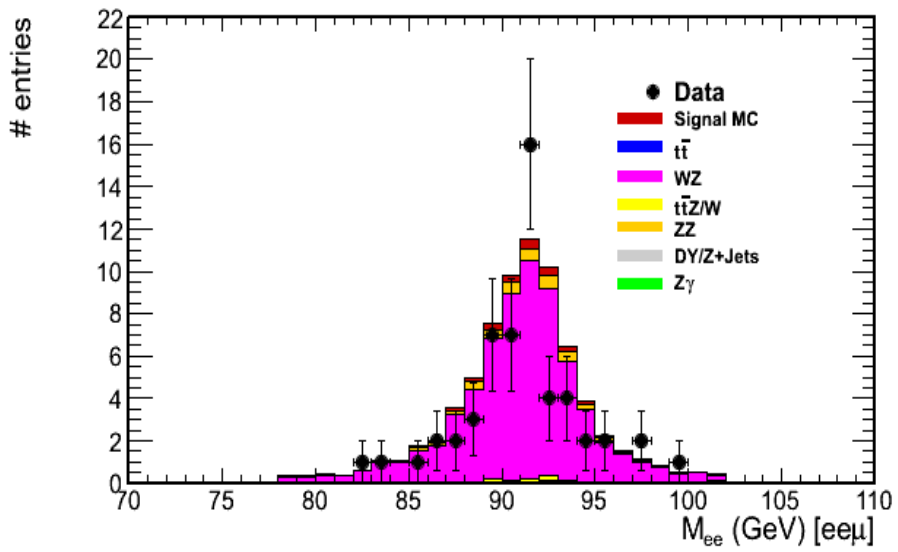


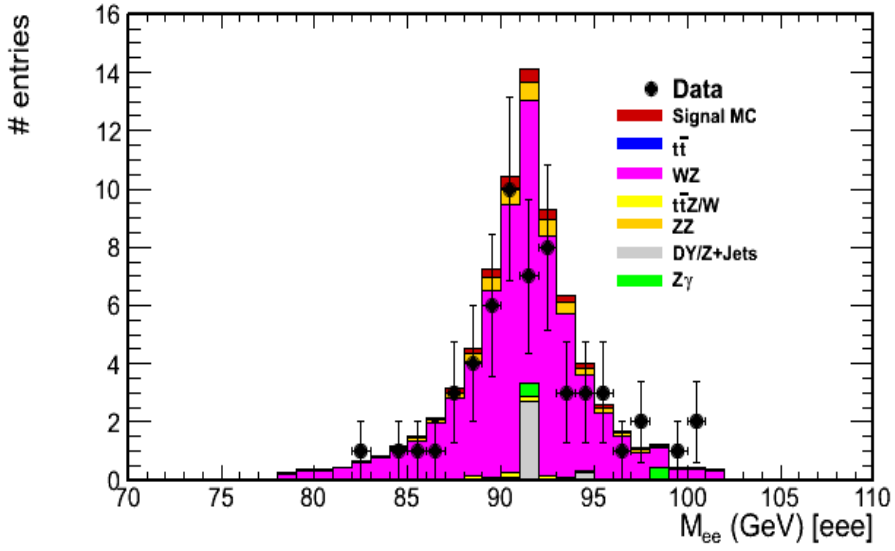


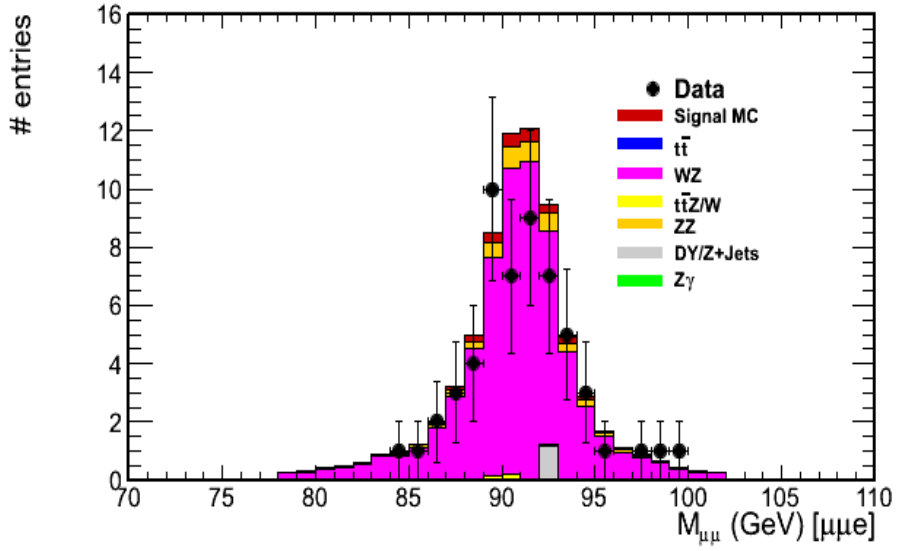


Z mass after pre-selection

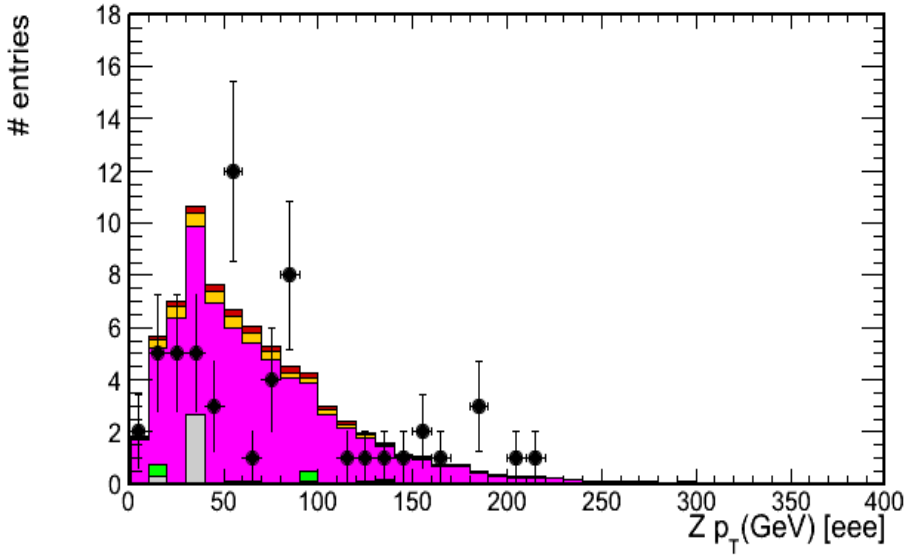


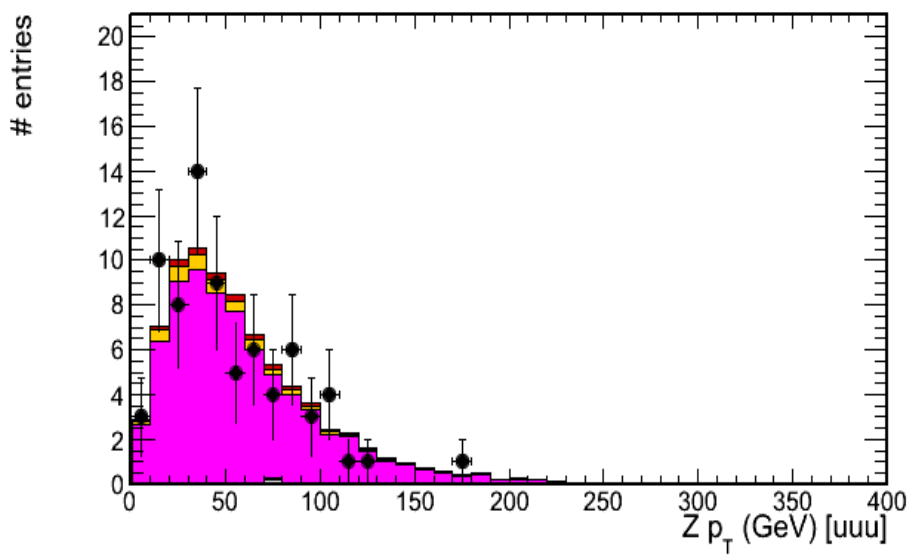


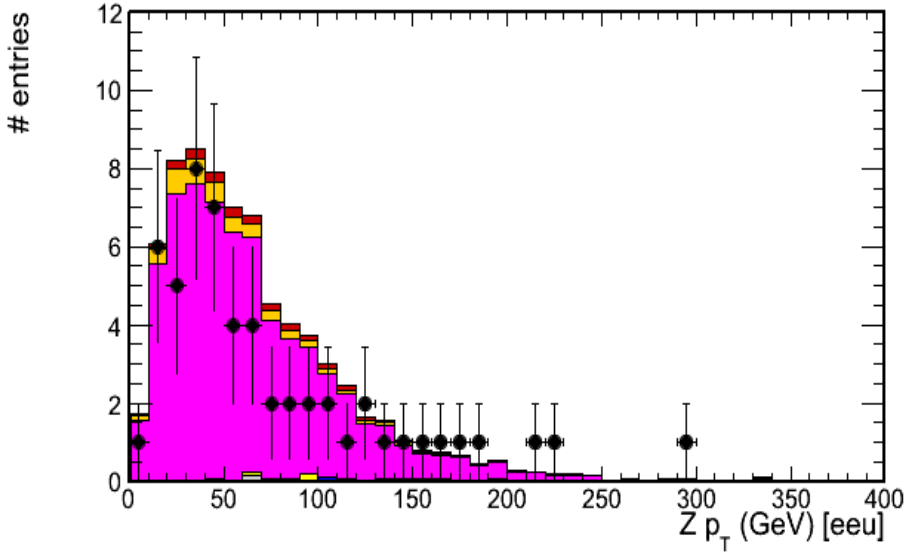


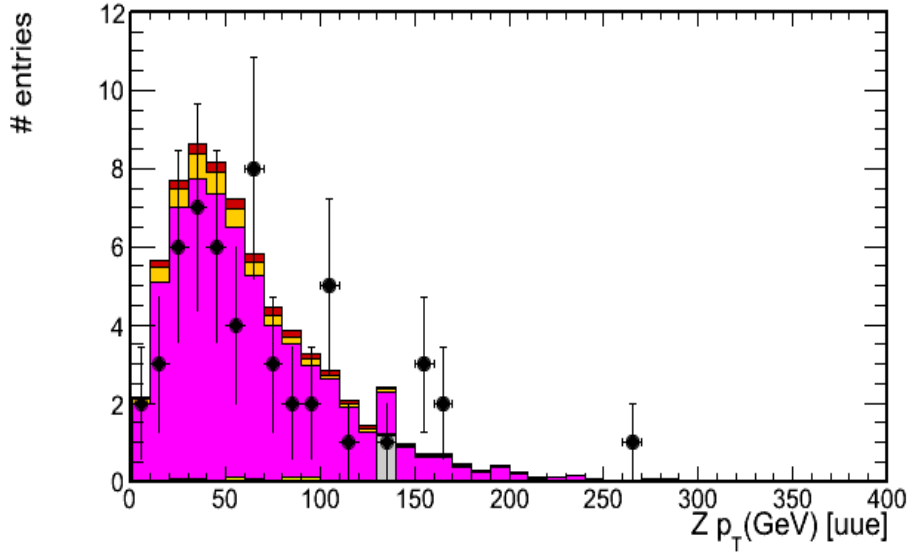


Z Pt after pre-selection

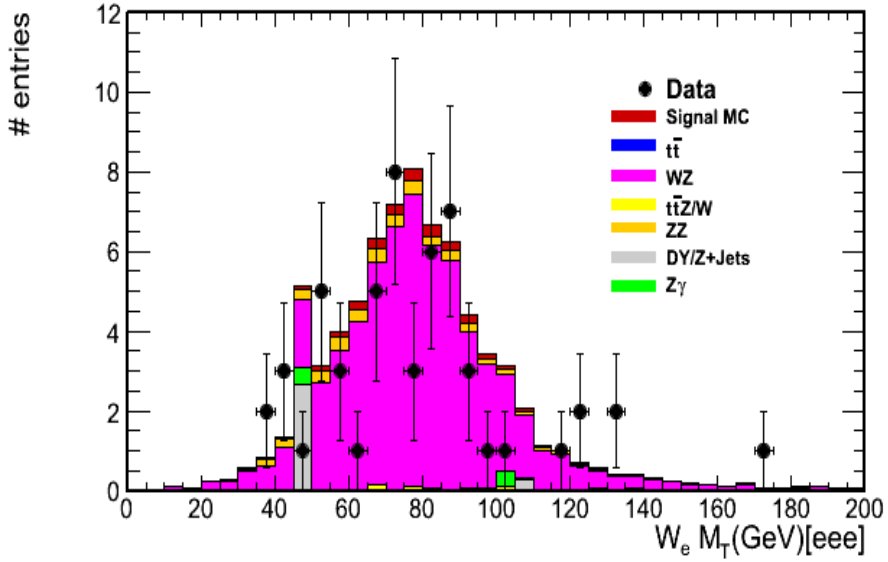


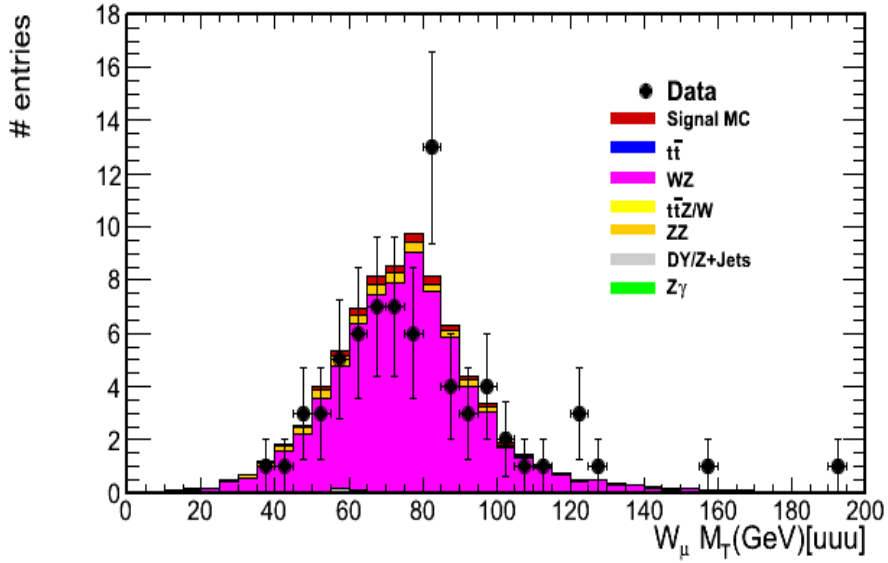


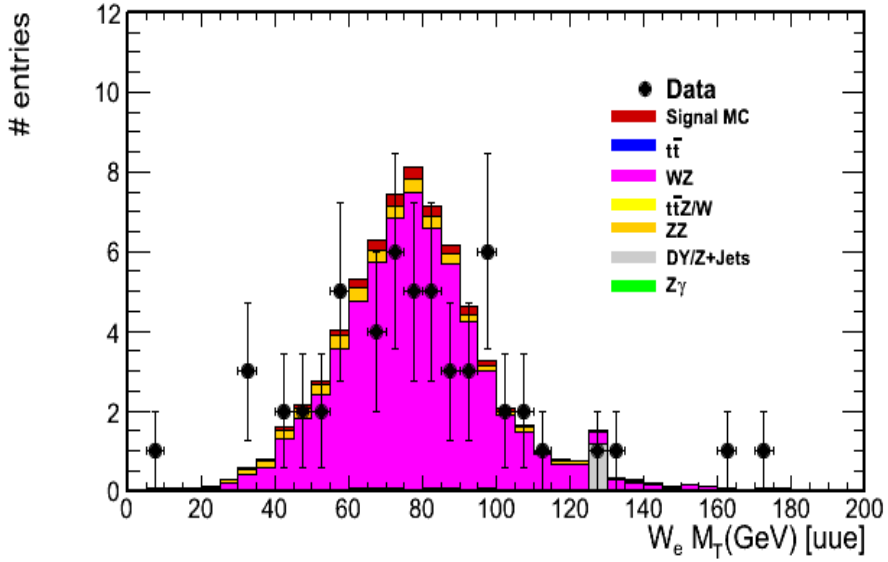


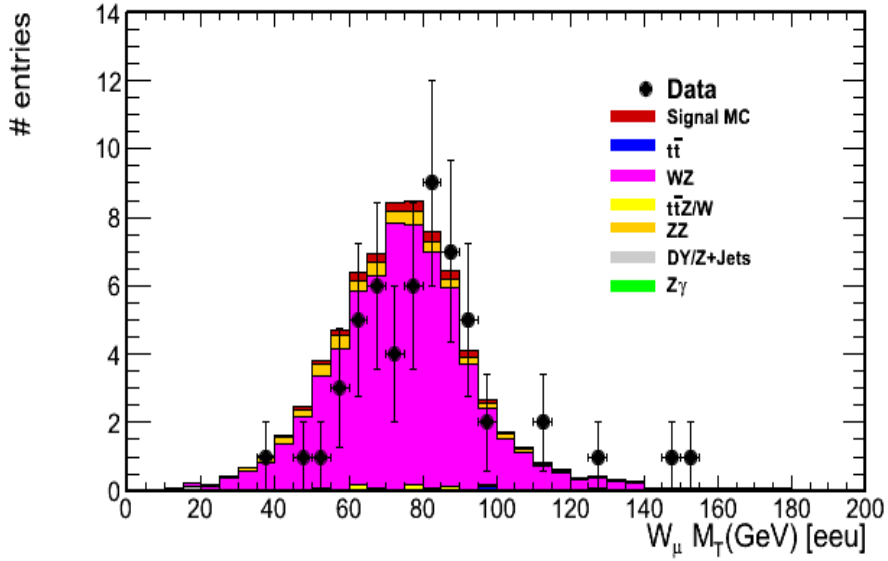


W transverse Mass in combinations

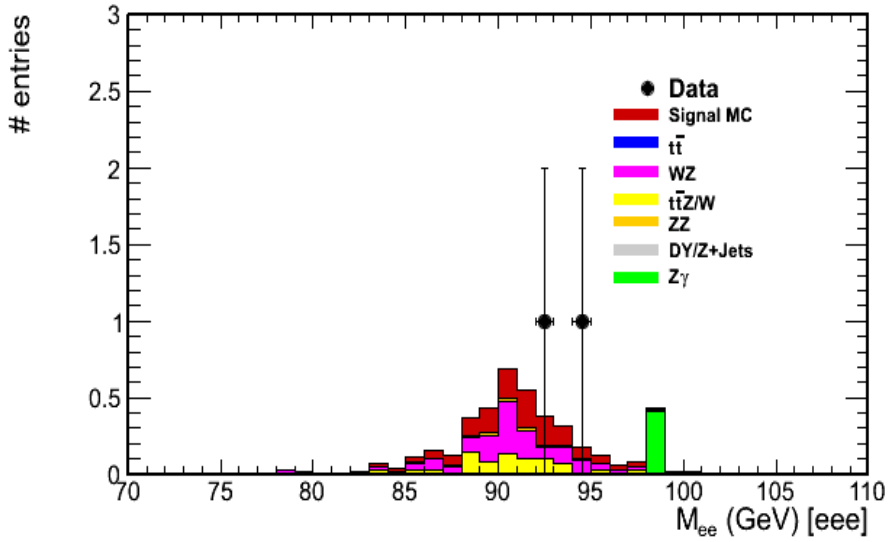


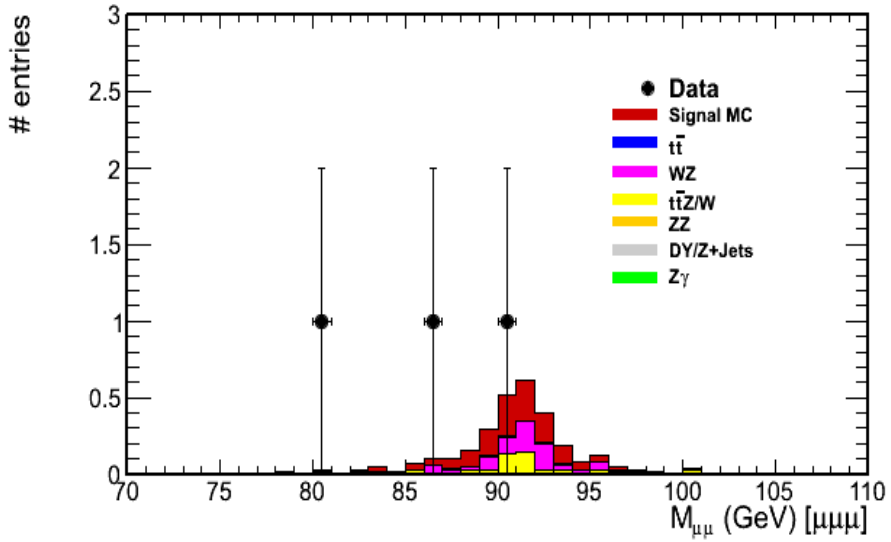


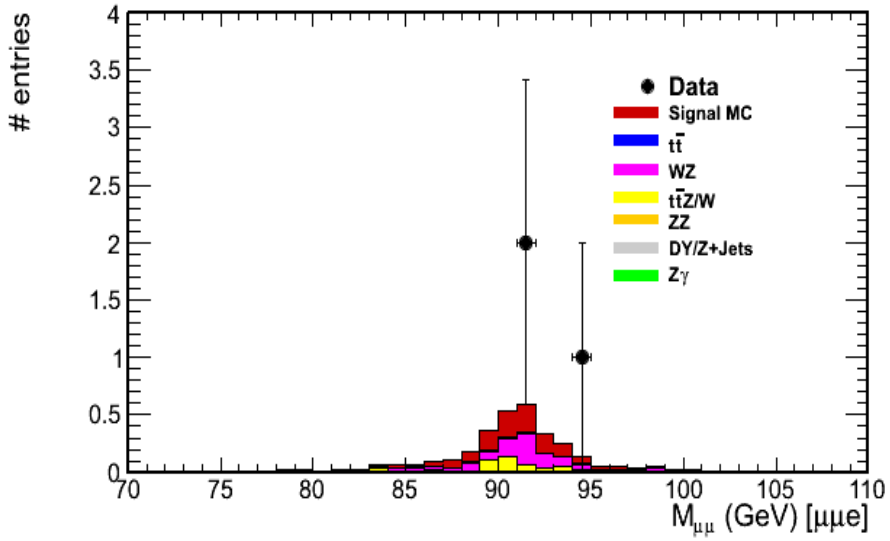


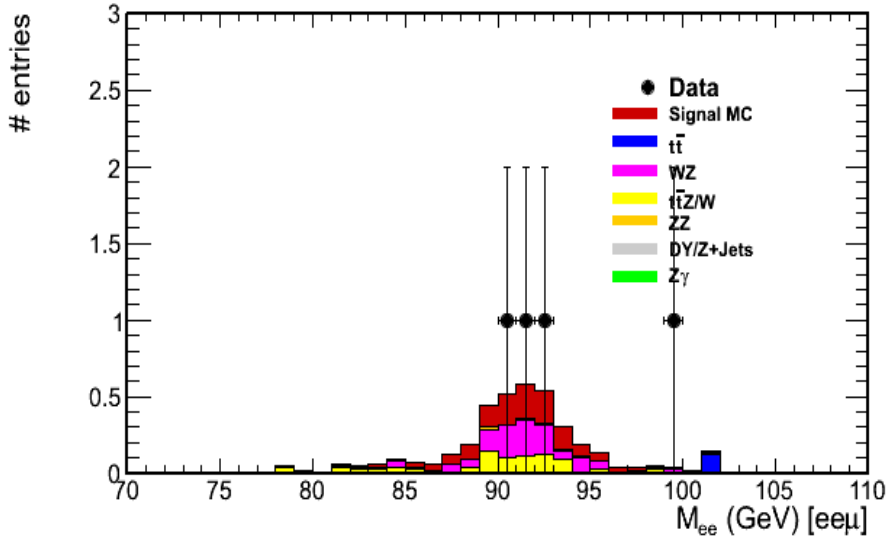


Di-Lepton Mass in Final Combinations









Background SF

- **Main backgrounds:** WZ, ttbar, ttarW, Z+Jets
- Plot Z mass for events with 0 bjets
- calculate ratio of data and MC in Z mass window [78,101]
- Apply these scale factors to reweight dominant WZ MC in final plots/cutflow
- Can do the above bin-by-bin but that would over correct MC

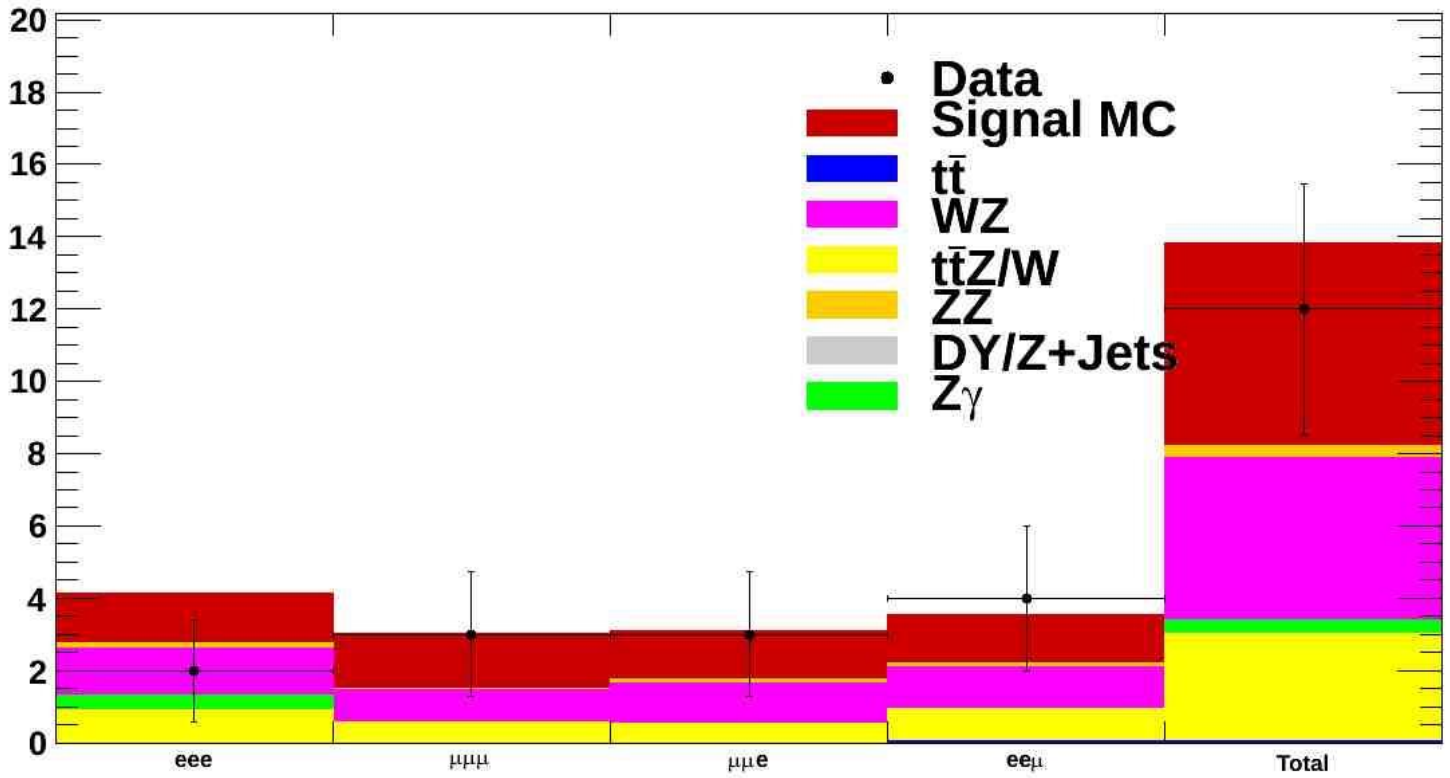
uue SF = 0. 788539

eeu SF = 0. 736197

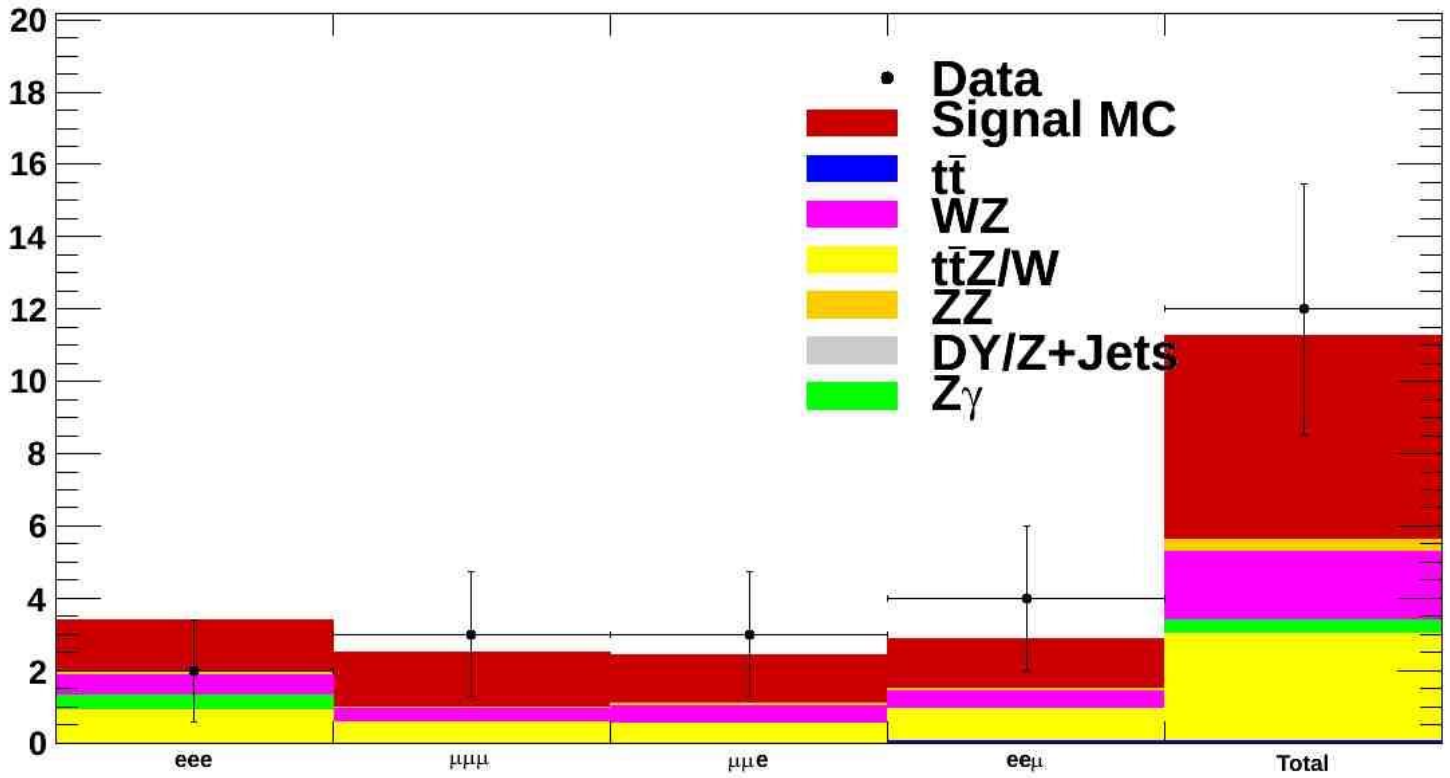
ee e SF = 0. 780372

uuu SF = 0. 92914

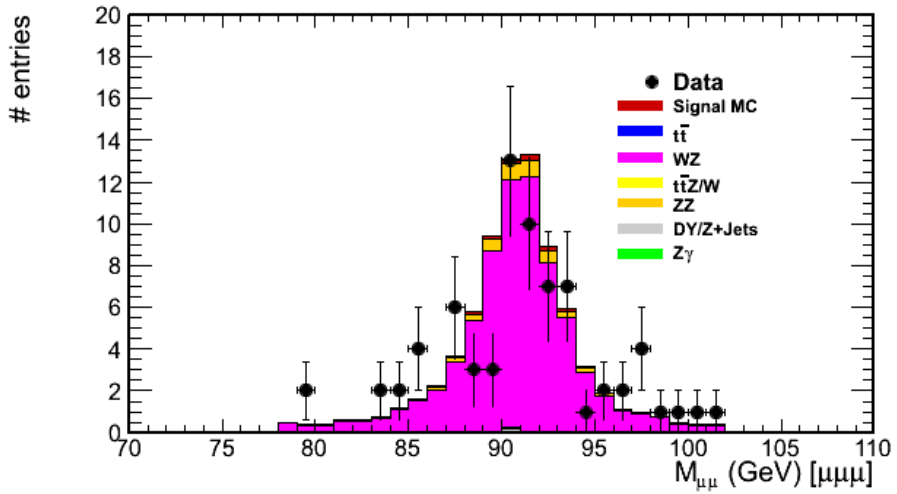
Without SF

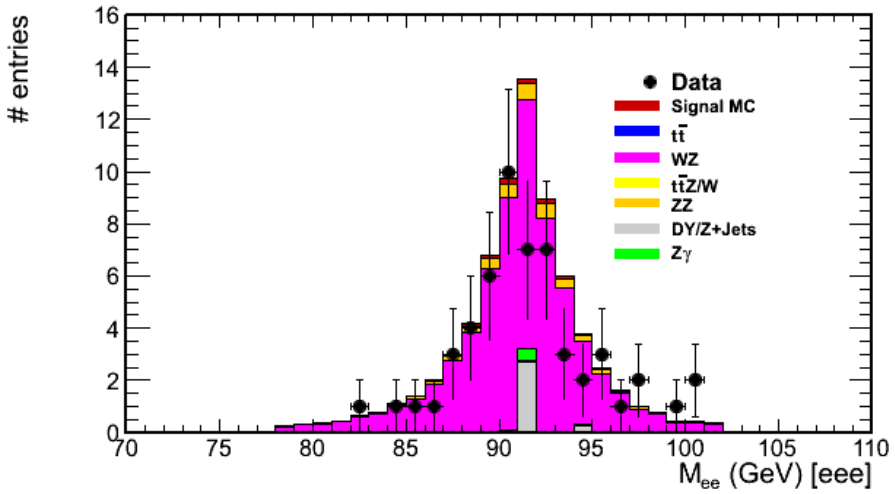

20
18
16
14
12
10
8
6
4
2
0
Data
Signal MC
tt̄
WZ
tt̄Z/W
ZZ
DY/Z+Jets
Zγ
eee
μμμ
μμe
eeμ
Total

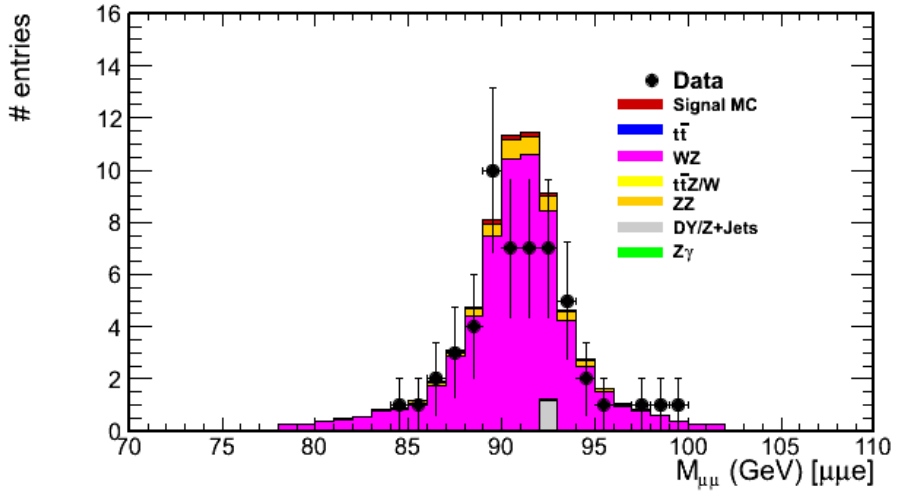
With Background Scale (WZ)

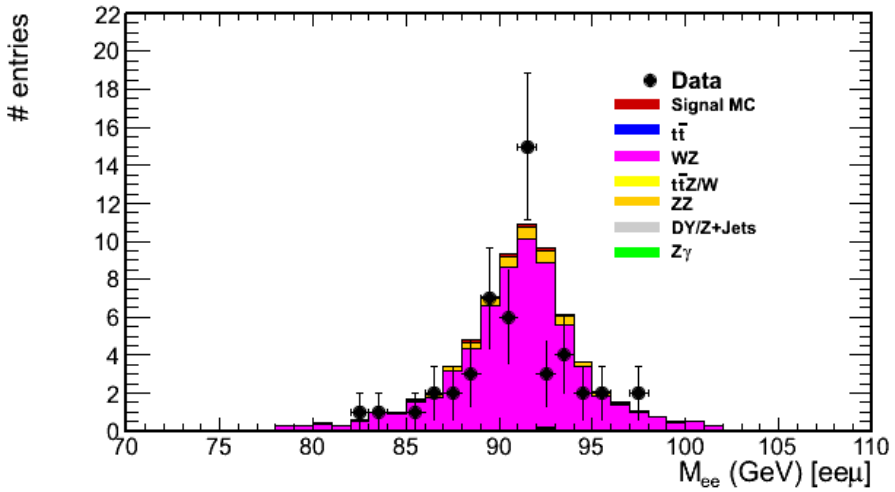


Background Scale Factors (Plotting Z mass with 0 bjets)

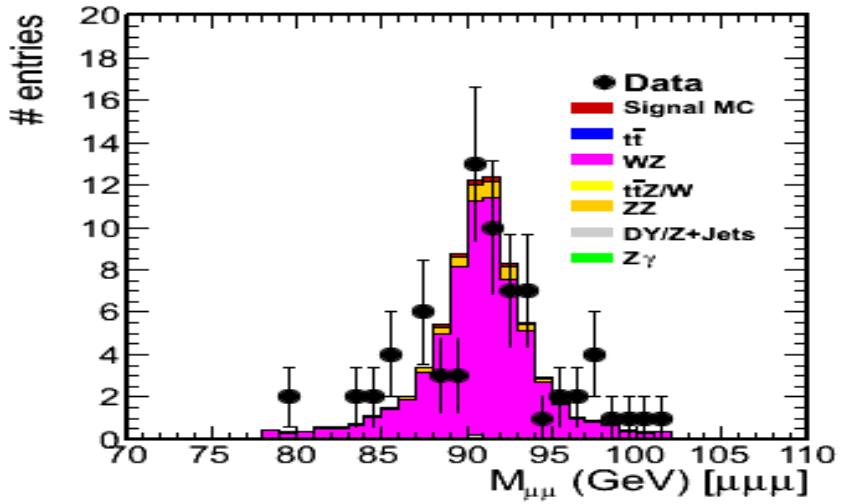


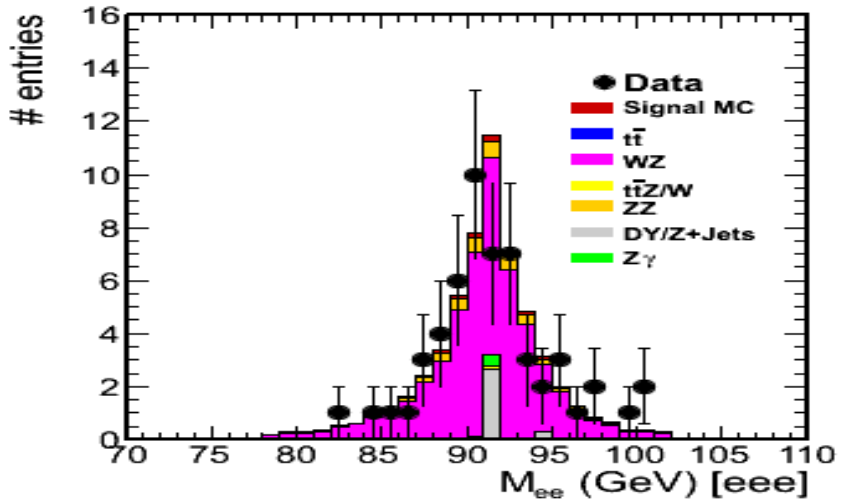


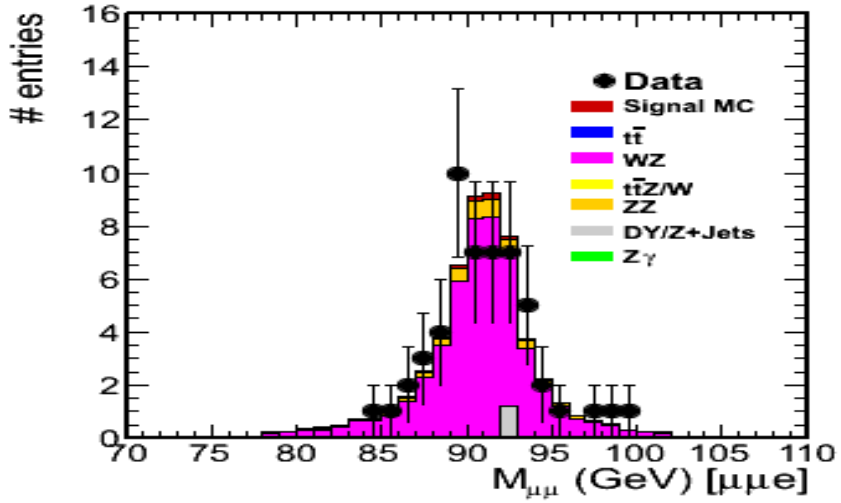


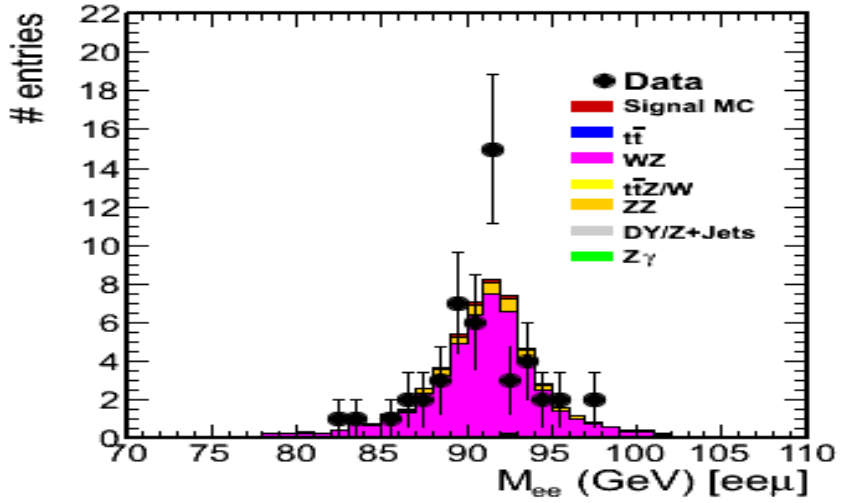


Applying Scale Factors to WZ MC in background enriched mass plots

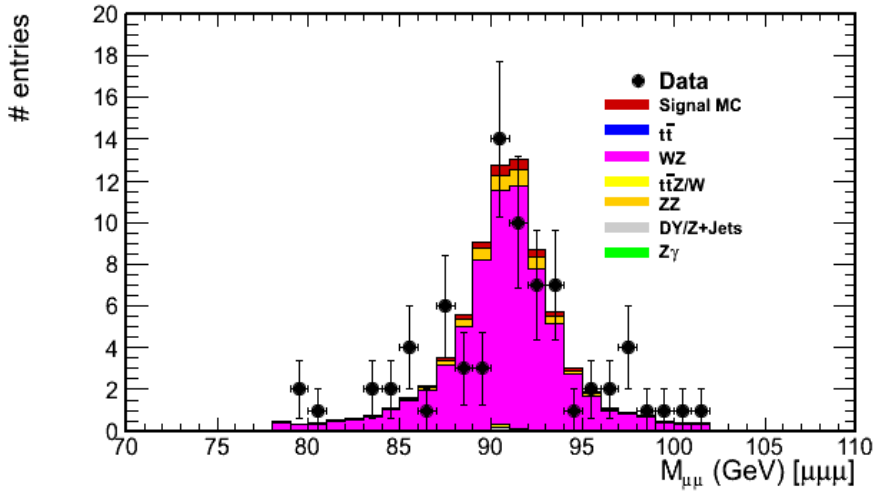


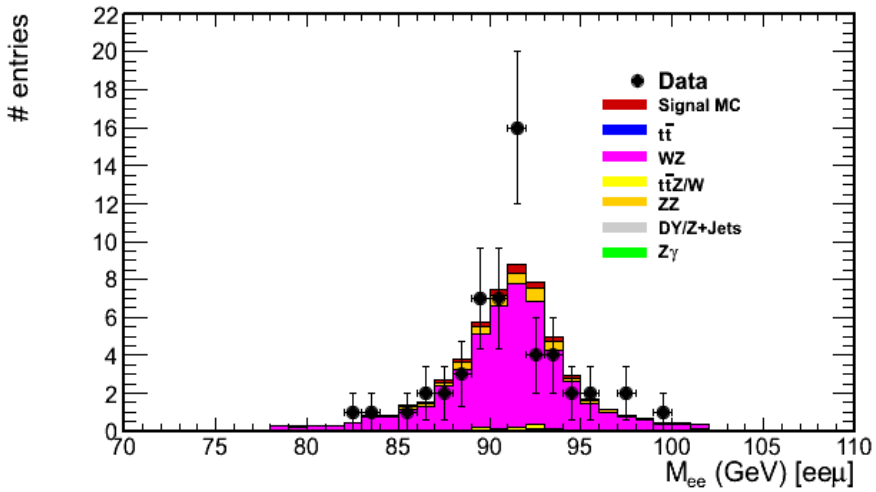


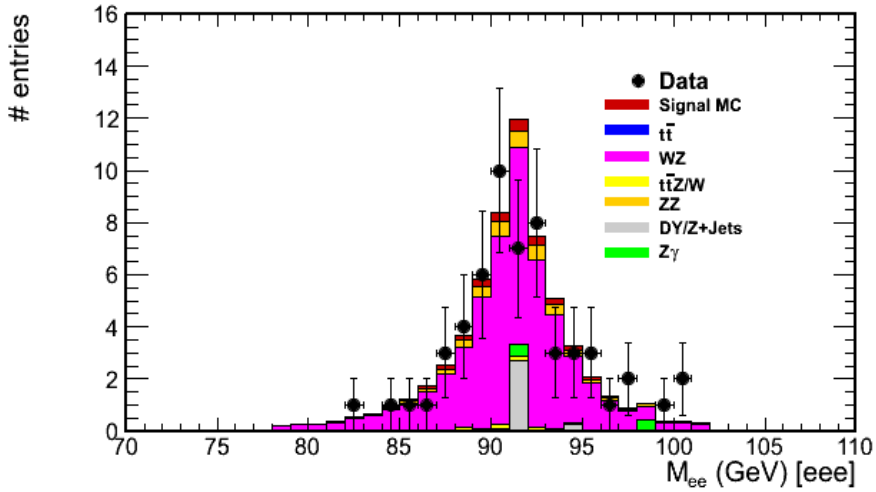


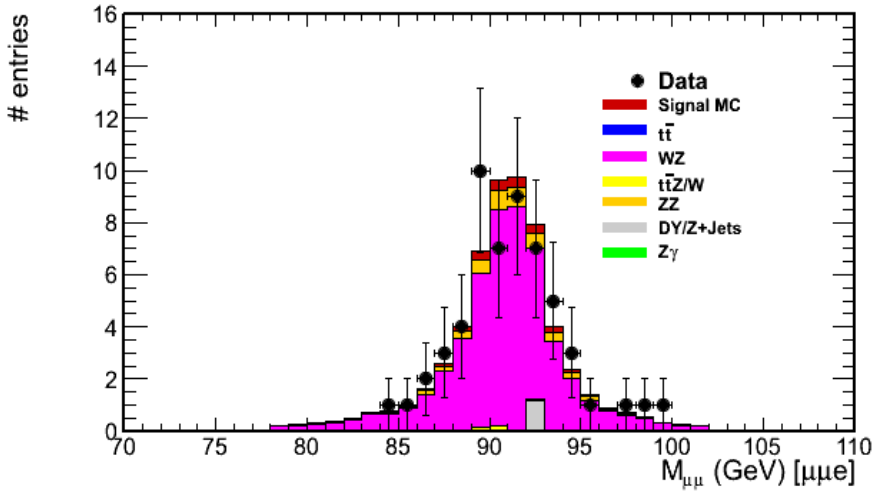


Applying Scale Factors to WZ MC in preselected mass plots



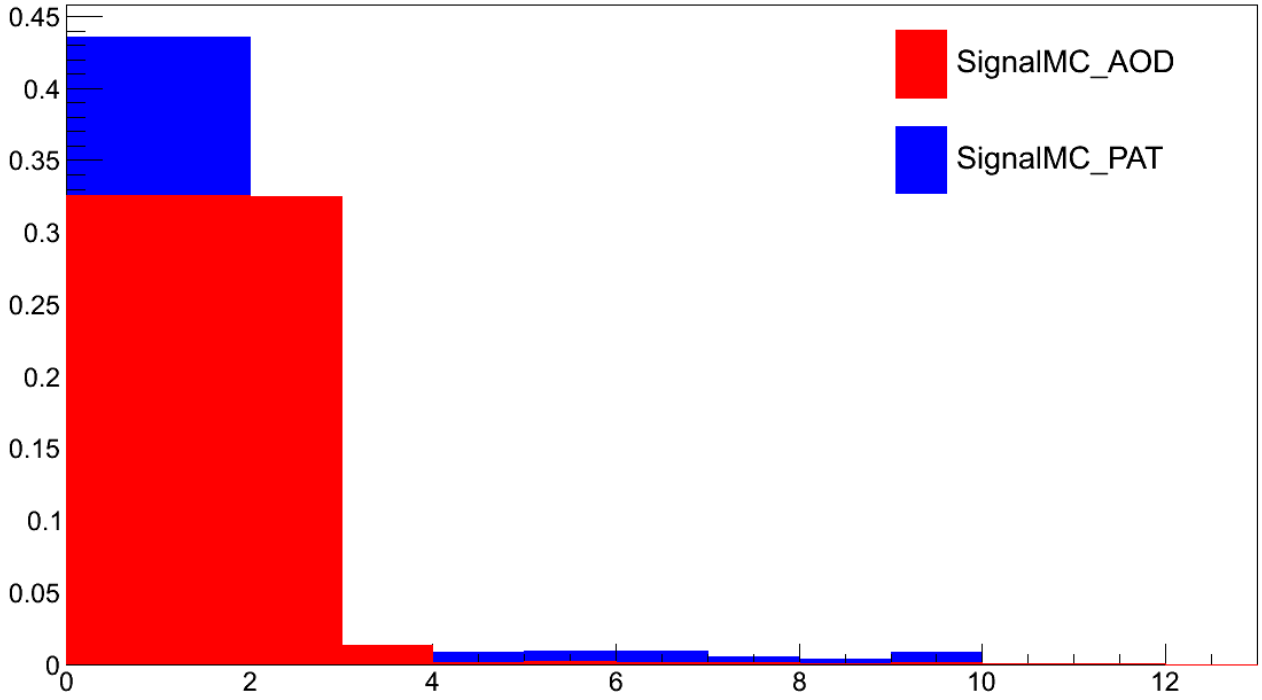




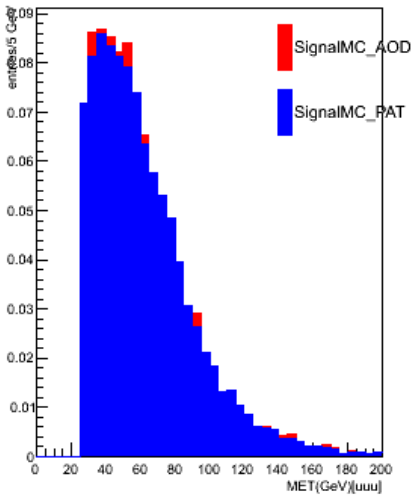


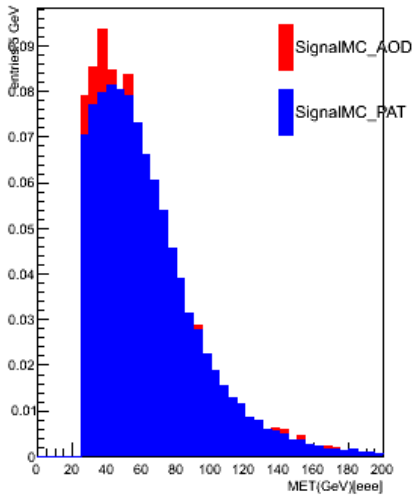
Basic Plots with PAT

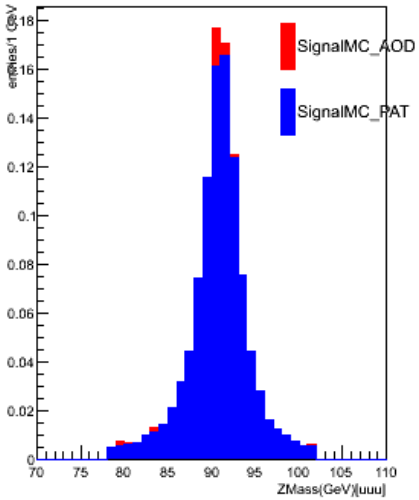
- Pat Tuple Produced using single top file
  - At least one tight lepton
  - Light jet quarks >= 2

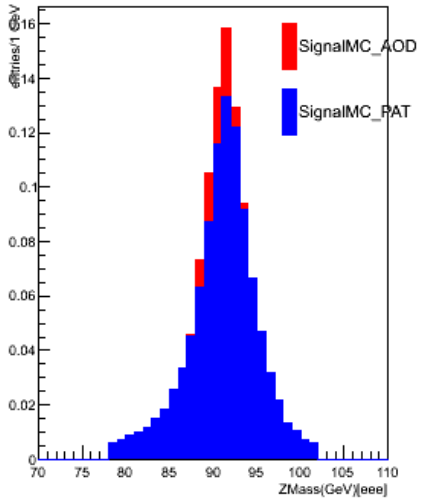


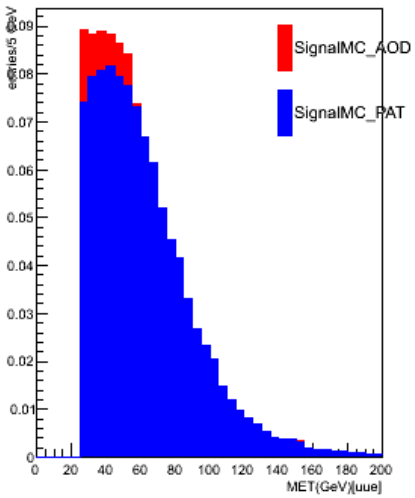
Basic Plots with PAT

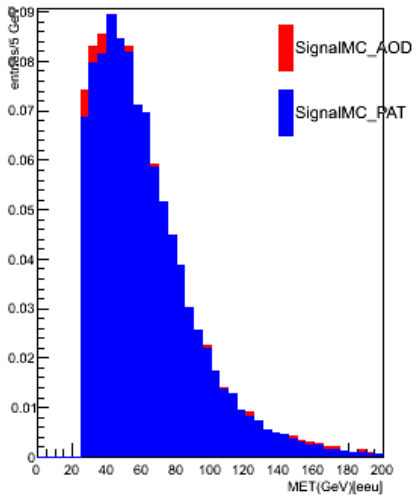


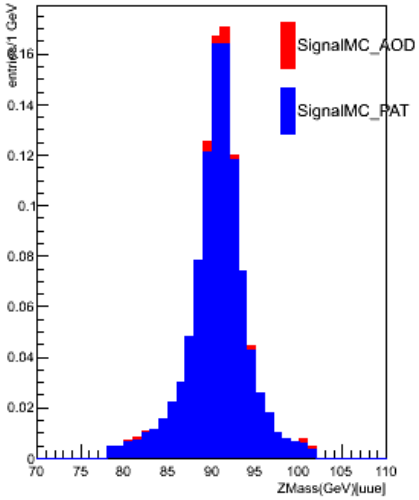


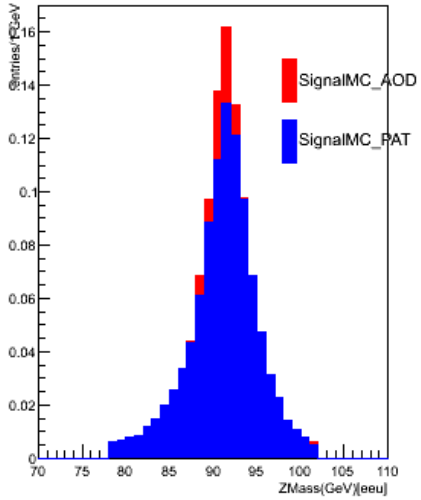












Analysis Documentaion

- Twiki page: all analysis strategy and updates

https://twiki.cern.ch/twiki/bin/view/Sandbox/SingleTopinAssociationofZboson

- CMS Analysis Note:
  - AN2014_182

Summary and Plan

- **Validation plots after pre-selection shows reasonable agreement between data and MC**
- **pileup reweighting applied**
- **Background SF have been calculated and Applied**
- **Pat tuple produced with single top file and basic plots with signal MC.**

- **Future plans**

- AN2014-182 completion up to end of year
- Work on systematic
- Fake Rate Estimation


That's all Folks!