Determination of Invisible Z Boson+Jets Background to Hadronic SUSY Searches using Z->μμ+Jets

"On behalf of the CMS collaboration"
Huseyin Topakli
Çukurova University/FermiLab

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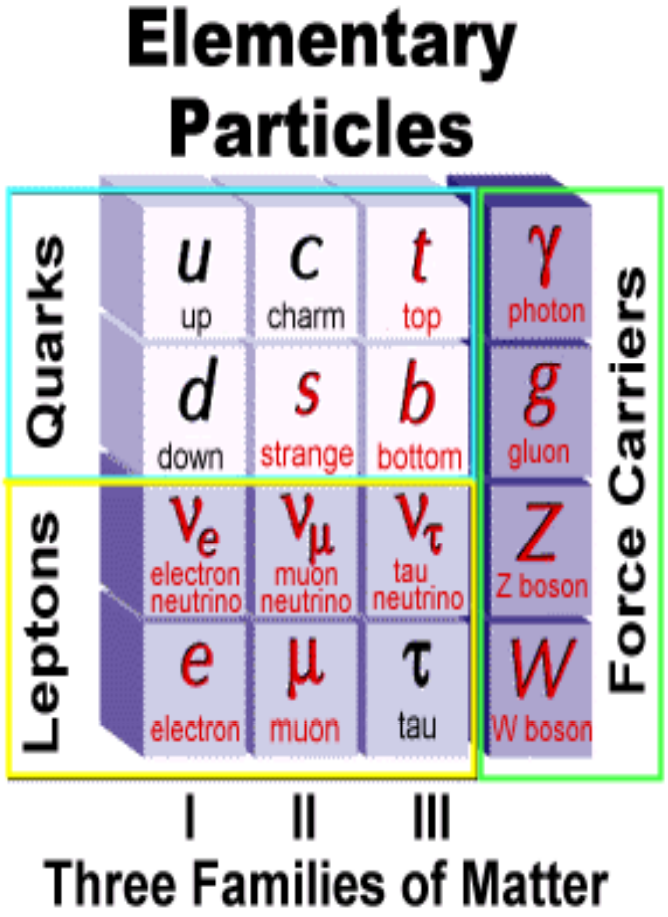
Outline

- Standard Model
- SUSY
- LHC&CMS
- Event Selection
- Muon Selection
- Estimation of background
- Conclusion

Standard Model

- What are fundamental constituents of the world?
- What holds these constituents together?
- Standard Model is one of the most robust theory to find out answers to the questions. In the Standard Model
  - 6 quarks
  - 6 leptons
  - 4 force carriers
- Quarks, leptons and intermediate weak bosons are massless but W and Z are massive particles in the SM.

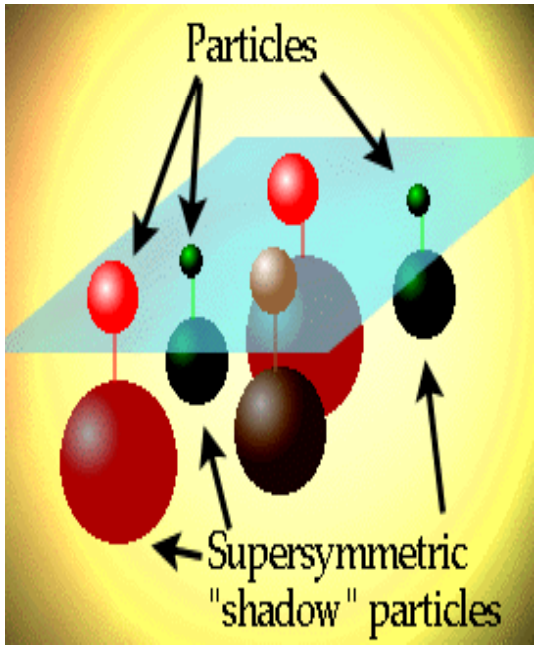


SUSY

- **SUSY (Supersymmetry) is basically a symmetry which relates fermionic fields to bosonic fields. Anticommuting spin=1/2 supersymmetry operator Q which operates on fermions and bosons as;**

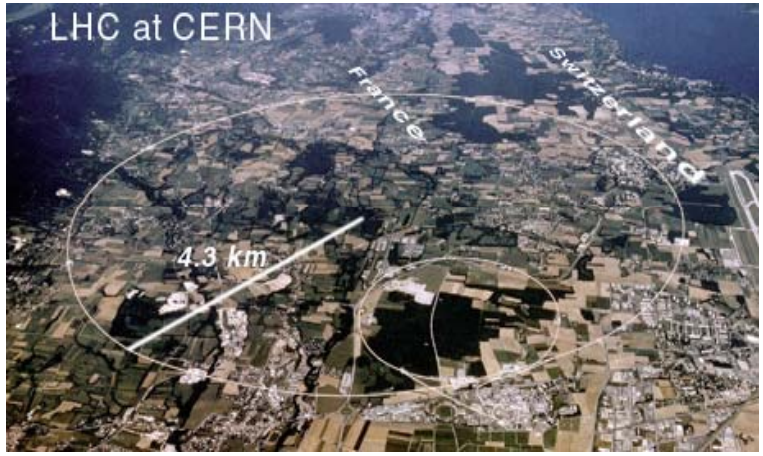
  $Q|Fermion\rangle = |Boson\rangle \ , \ Q|Boson\rangle = |Fermion\rangle$

- **mSUGRA model is a version of SUSY model with universal scalar, gaugino masses and trilinear parameters at some high mass scale. Model is specified by 5 parameters,**
  - **$m_0, m_{1/2}, \tan\beta, A_0, \text{sign}(\mu)$**
- **Supersymmetric partners of SM particles have not been observed, SUSY must be broken.**

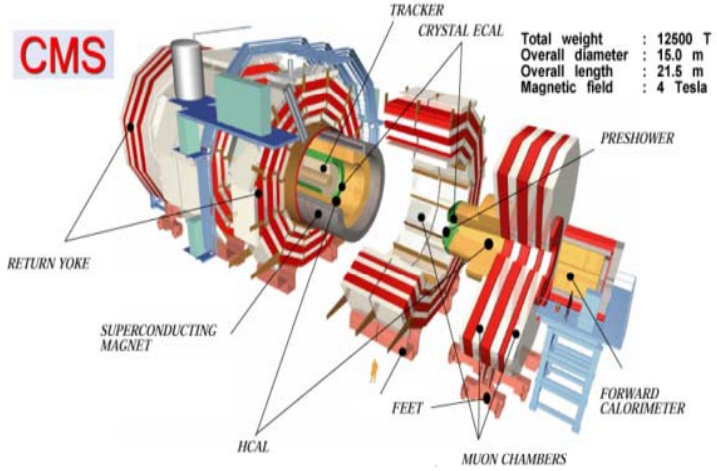


LHC and CMS.

- LHC
  - Proton-proton : 2835 bunch/beam
  - Protons/bunch :10^{11}
  - Beam Energy :7 TeV
  - Luminosity :10^{34} $cm^{-2}s^{-1}$
  - Crossing rate :40 MHz

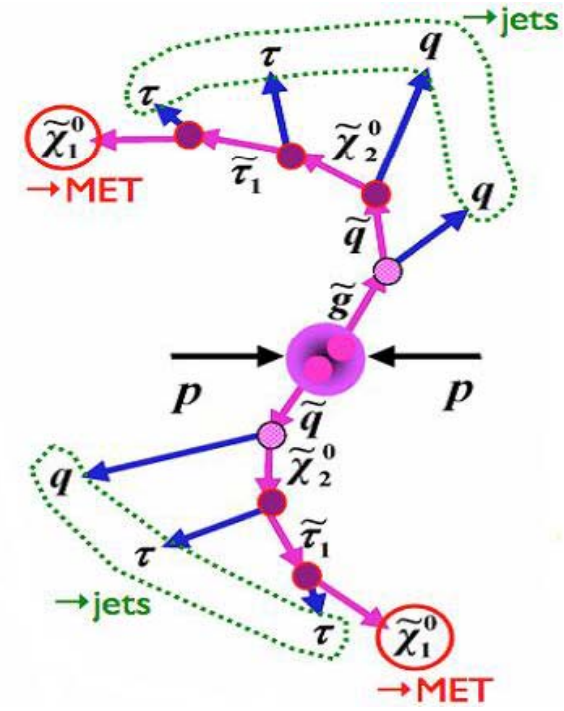


- CMS
  - Inner Tracker:Si(pixels and strips)
  - EM Calorimeter:PbWO4 Crystals
  - HAD Calorimeter:Brass+scintillator.
  - Muon:Drift tube/cathode-strip/resistive plate.



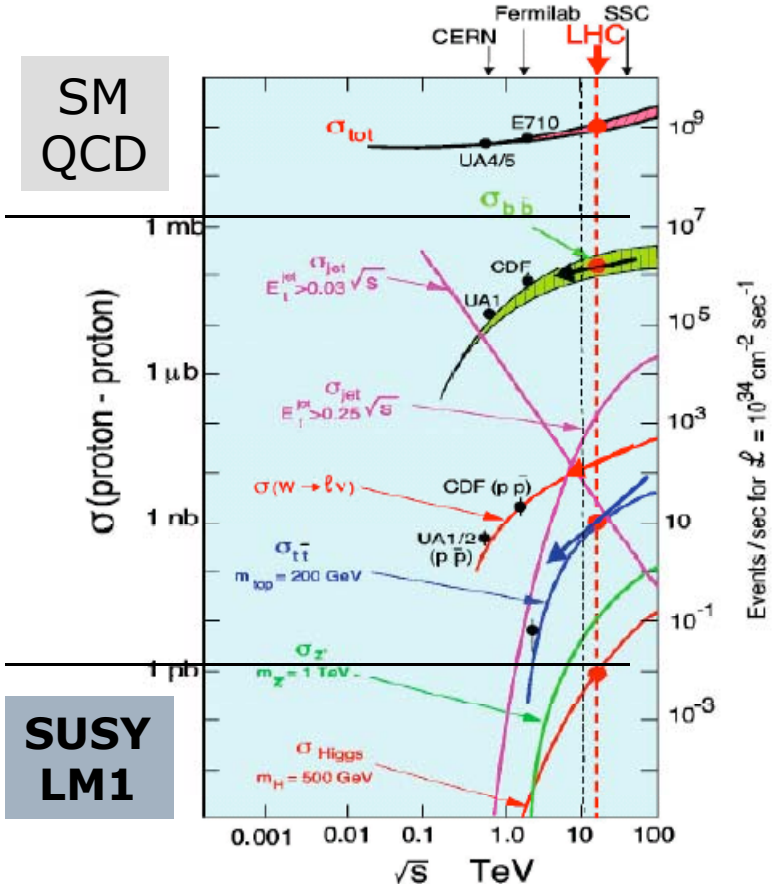
SUSY Particles and Test Points at CMS

- The mSUGRA model is constructed by assuming R-parity is conserved and sparticles can only be pair produced by collisions of SM particles. Lightest supersymmetric particle (LSP) produced in the decays of sparticles in SUSY events.
  - R-parity=$(-1)^{2S+3B+L}$
- In order to test mSUGRA selected LM1 test point,
  - m_{gluino}~600GeV, m_{squark}~550GeV
  - $m(\tilde{g}) \geq m(\tilde{q})$ hence,
  - $\tilde{g} \rightarrow \tilde{q}q$ is dominant decay channel
- In the final state Missing Energy and multi-jets are a canonical signature for SUSY search.
- 3jet+MET is promising channel to search for SUSY.
- Main backgrounds to hadronic SUSY are QCD multi-jet production, ttbar and Z->vv+jets.



SM Backgrounds

- SM process are dominant
  - QCD cross-section~ 5.6×10^{10}pb
  - SUSY LM1 cross-section~ 42pb
- Develop data-driven methods to estimate the backgrounds.
  - Minimizes systematic errors from differences between data and MC.



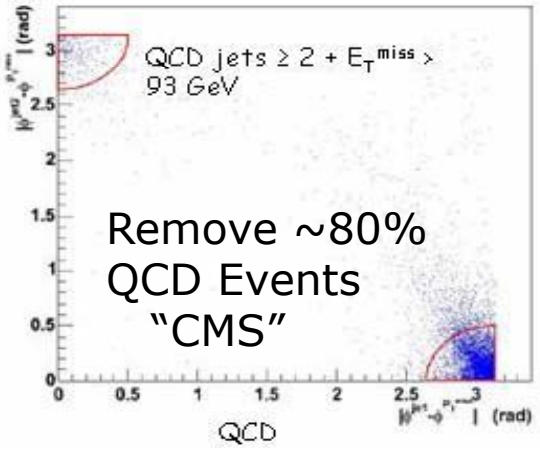
SUSY Event Selection and MET clean-up

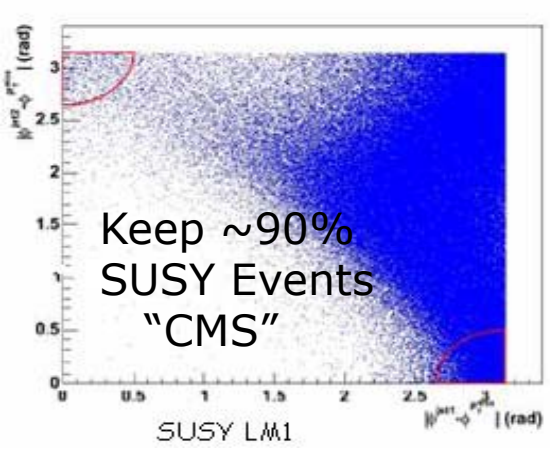
- Event selection in the CMS analysis
  - $N_{jet} \geq 3$, $E_T^{miss} > 200$GeV
  - $E_T^{J1} > 180$, $E_T^{j2} > 110$ and $E_T^{j3} > 30$GeV
  - $|\eta_{jet}| < 3.0$ & $|\eta^{1st}_{jet}| < 1.7$
- True MET comes from LSP and neutrinos. Large MET is also observed in detector due to mis measurements of QCD jets. These events can be removed by angular cuts between jet and MET.

$$R1 = \sqrt{\delta\phi_1^2 + (\pi - \delta\phi_2)^2}$$

$$R2 = \sqrt{\delta\phi_2^2 + (\pi - \delta\phi_1)^2}$$

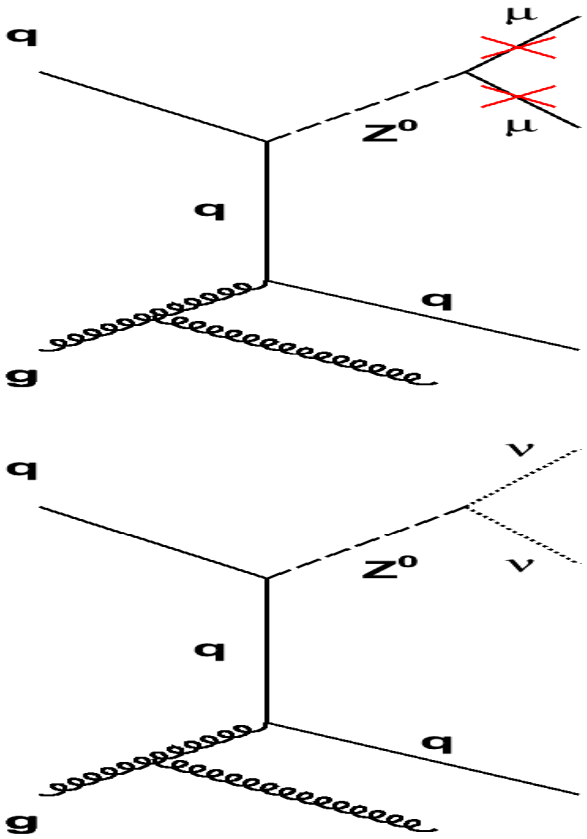
$$\delta\phi_{1,2} = |\phi_{1,2}^{jet} - \phi^{met}|$$





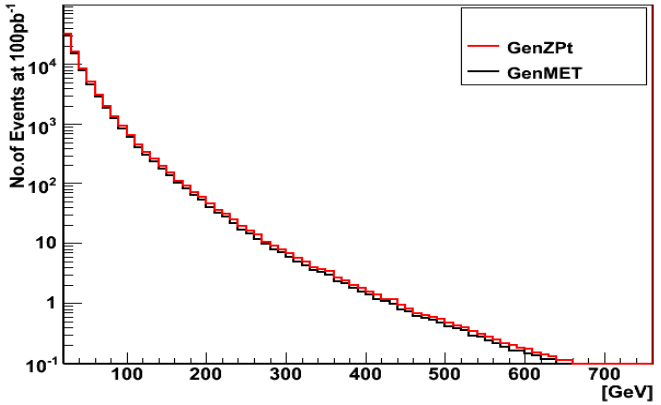
Estimation process of Z->νν bkg using Z->μμ

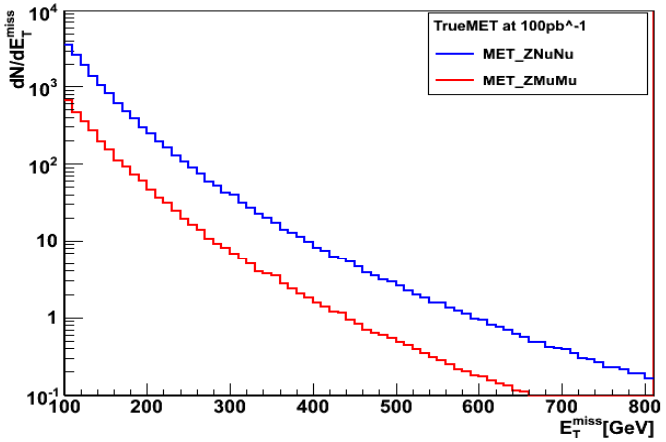
- Z->νν+jets events have the same kinematic characteristic as the Z->μμ+jets events. Therefore, number of Z->νν+jets can be estimated using number of Z->μμ+jets events observed in data.
- Z boson decays into any pair of neutrinos ~6 times more often than into a pair of muons.
- This background can also be estimated using Photon+Jets and W+Jets events. (see PAS-SUS-08-002).



True MET and Pt of Z

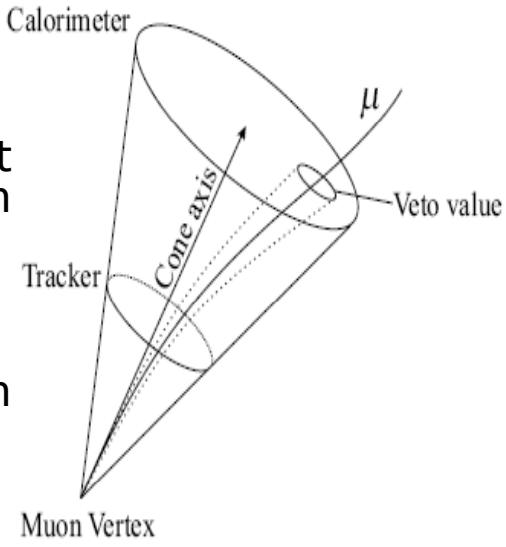
- Since muons deposit very little energy in calorimeter they lead to observed MET. Generated MET and Pt of generated Z distributions are consistent with each other in Z->μμ sample.
- True MET in Z->μμ and Z->νν is shown in bottom plots. Correlation between two curve is pT independent ratio.





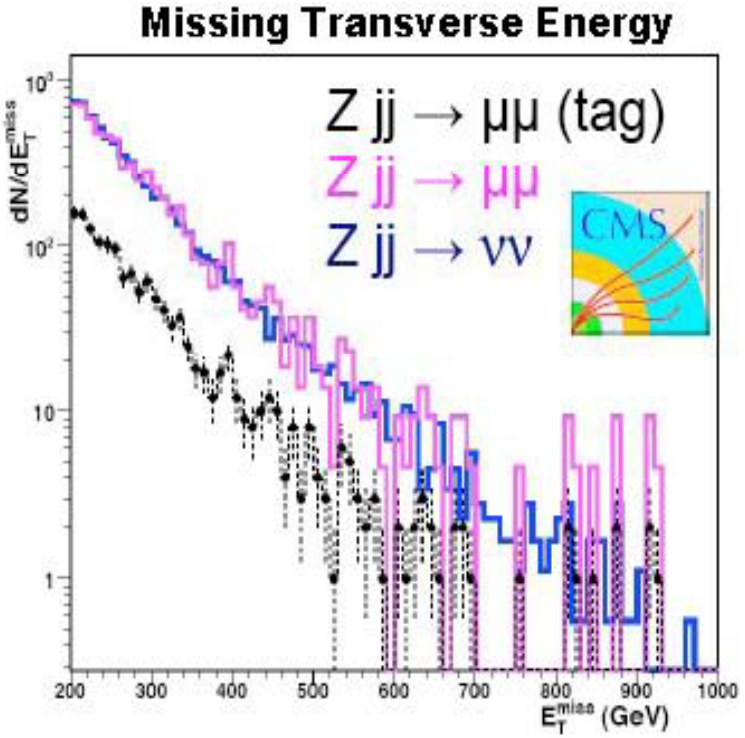
Muon Selection

- QCD jets may have b/c quarks. These can decay into muons. These muons have energy from other particles from the jet and thus can be removed by requiring that muon is isolated from other energy deposition in the calorimeter or away from any other track.
- The cone axis is chosen according to muon direction.
- The size of the cone is given by $\Delta R=\sqrt{(\Delta\eta)^2+(\Delta\varphi)^2}$
- The muon contributes to the detector measurement inside the cone. ***Veto value*** is used to subtract muon contribution to the detector measurement.
- **Selection of good muons;**
  - **For Tracker,**
    - Fit quality parameters (Chi^2/ndof) ,#of muon hits, ∑Pt of tracks in a cone.
  - **For Calorimeter isolation,**
    - $\sum E_T^{ECAL} + \sum E_T^{HCAL}$



Z->νν background

- The rate and event kinematics of the invisible Z->νν+≥3jet events process can be estimated using the Z->μμ+≥3jet events in the data.
- Z->μμ+≥2jets with Z_{pT}>200GeV is the "candle" data sample. The shape of the E_T^{miss} distribution of the measured the Z->μμ+≥2jet events very close to the shape of the invisible Z->νν+≥2jet events.
- Lepton ID efficiency determined in data.
- Small cross section.
- Little background, low systematics.
- 5% accuracy with 1.5 fb^{-1}.



Conclusion

- It has been shown that Z->μμ+jets events can be used to estimate the "invisible Z" background to the search for new physics in the MET plus jets channel.

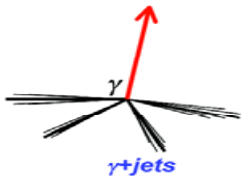
Backup Slide.

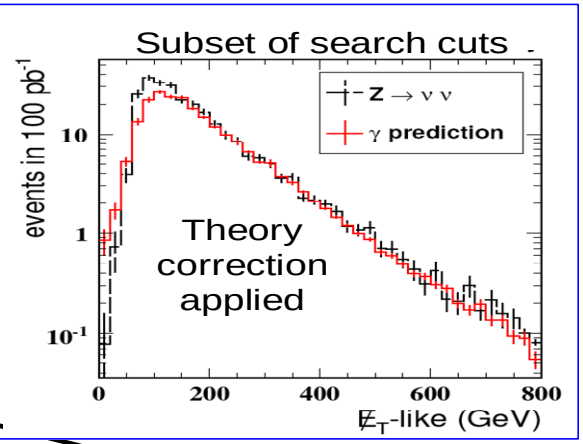
γ and W+Jets to predict Z->νν (∫L=100pb^{-1})

γ and W + Jets to predict Z→νν (∫L=100pb^{-1})

γ + jets: 124 events

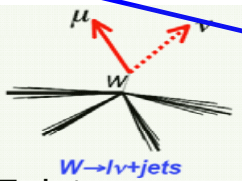
- Backgrounds estimated from data
  - QCD, electrons
- Dynamics is different from Z production.
  - Applying a QFT correction manages to reproduce the Z spectrum
  - Correction must be parametrized as a function of the event selection
  - Still, out-of-the-box agreement is already quite good

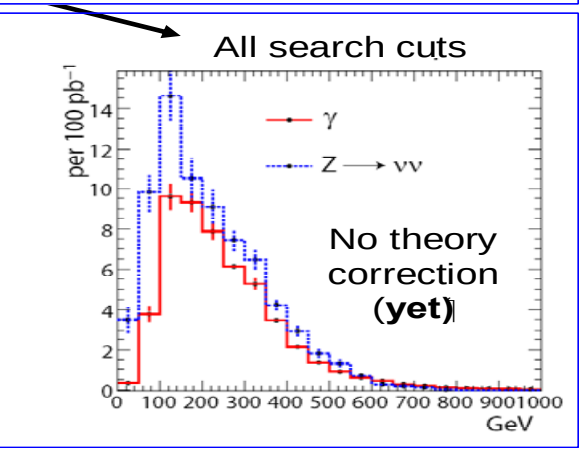


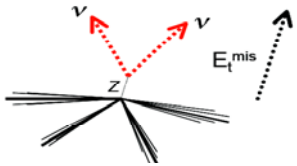


W + jets: 24 events from W->munu

- Backgrounds estimated from data
  - QCD, tt, Z
- Well known theory correspondence to Z+jets







$Z \rightarrow \nu\nu$ background estimate (100 pb^{-1})	
MC-truth	35
From γ+jets	29 ± 3 (stat) ± 5 (sys)
From W+jets	35 ± 10 (stat) ± 8 (sys) ± 3 (theory)