SUSY Physics and Missing Energy in ATLAS

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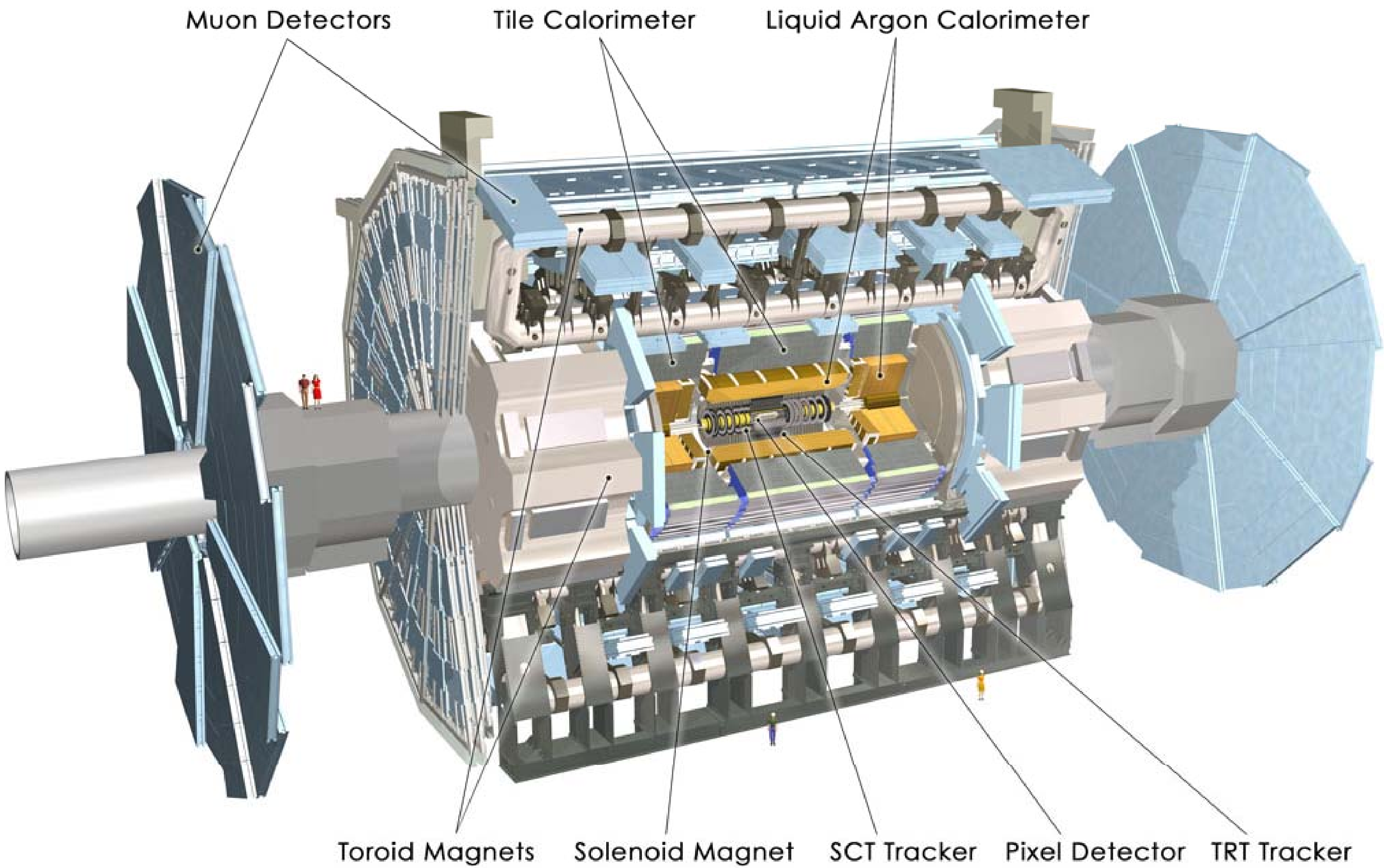
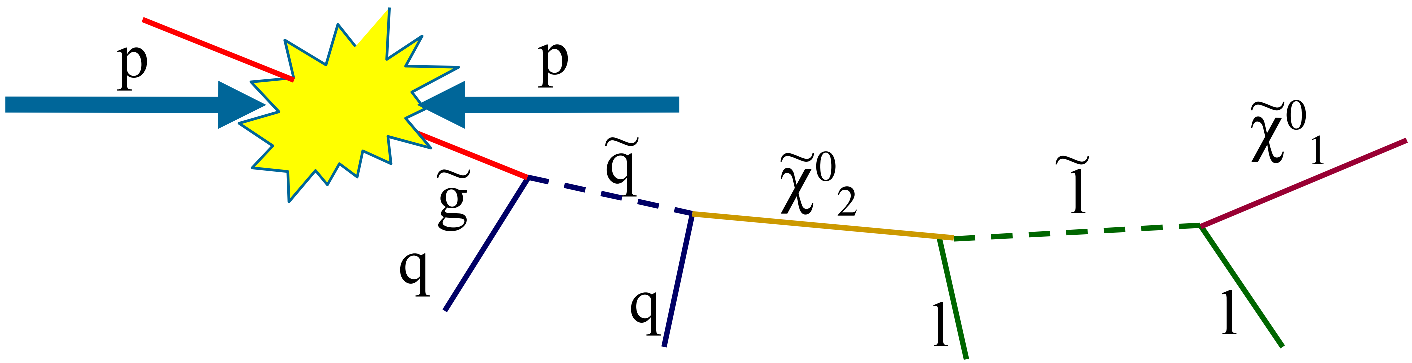
The ATLAS Detector



* See A. Parker's talk, monday

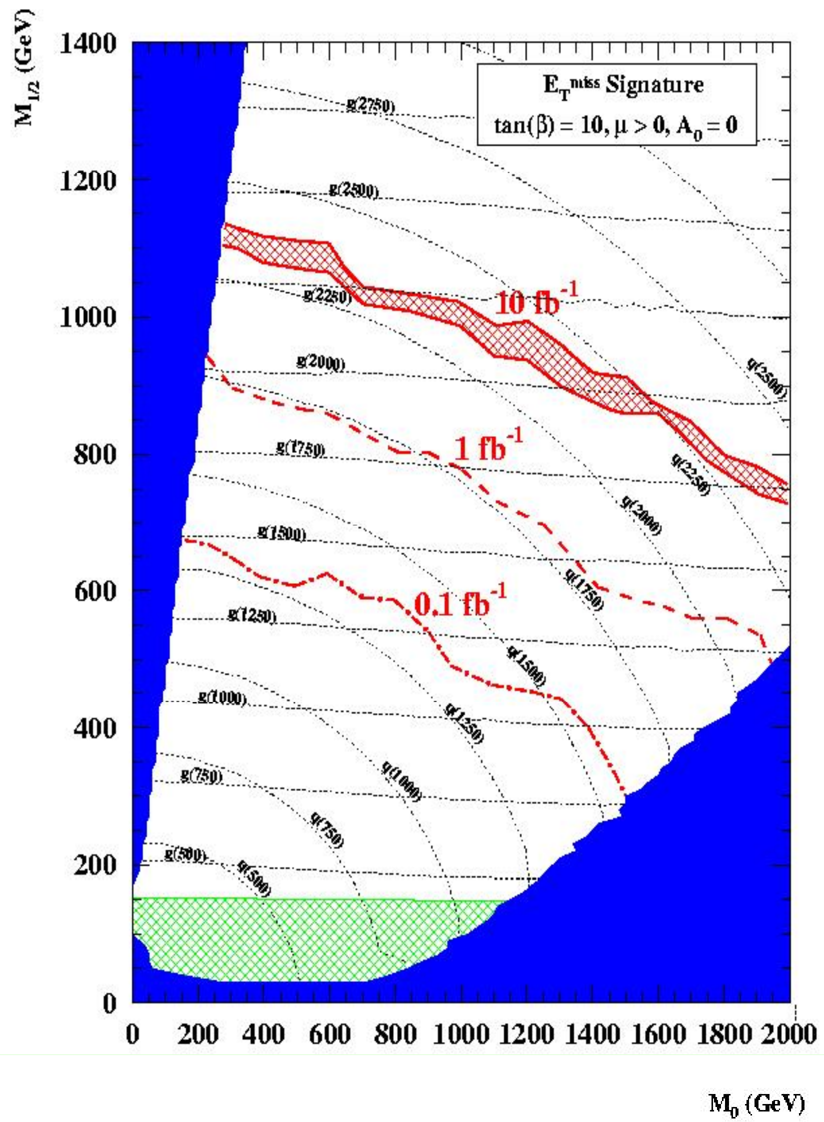
Supersymmetry

- Most well motivated extension to the Standard Model.
- Usually consider R-Parity conserving models (gives stable proton) :
  - Multiplicative quantum number: R(SM) = +1, R(SUSY) = -1.
  - Sparticles are produced in pairs and lightest SUSY particle (LSP) is stable.
- LSP must be only weakly interacting on cosmological grounds.
  - ➔ final state characterised by observed imbalance in momentum.
- Dominated by production of strongly interacting sparticles → lots of jets.



SUSY at the LHC

- The Large Hadron Collider Provides pp collisions with √s = 14TeV.
- With M_{SUSY} ~ 1TeV and well controlled systematics, can achieve 5♦ discovery with first 100pb^{-1} of data using the Missing Transverse Energy signature.
  - Limiting factor is control of systematics rather than statistics
  - Need to quickly understand detector and SM backgrounds.

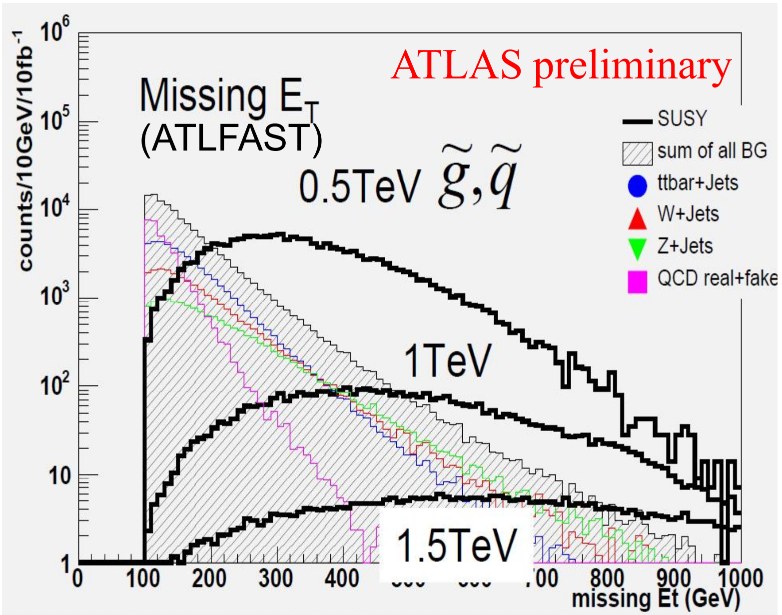


The Missing Transverse Energy Variable

- Can only apply momentum conservation in the plane transverse to the beam.
- Measure apparent imbalance in final state using calorimetry (+ muons)
  - ➔ '$E_T$miss'.
- SUSY selection: high-p_T jets, large $E_T$miss and (possibly) isolated leptons.
- $E_T$miss gives excellent discrimination against most SM processes.
- Remaining background from events with neutrinos – W/Z + jets, tt, bb.
- QCD: from ■ in bb and cc events. Also huge event rate means rare effects due to imperfections in detector can be significant.

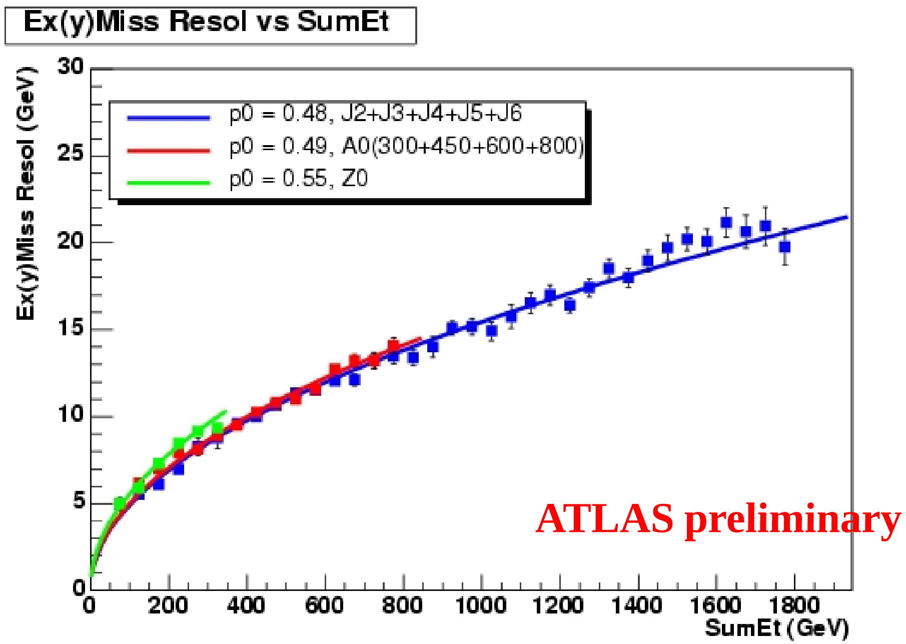
Typical SUSY cuts:

- NJets >= 4
- p_T(j1) > 100GeV, p_T(j4) > 50GeV
- $E_T$miss > 100GeV
- Transverse Sphericity S_T > 0.2
- 0 leptons



Reconstructing $E_T$miss

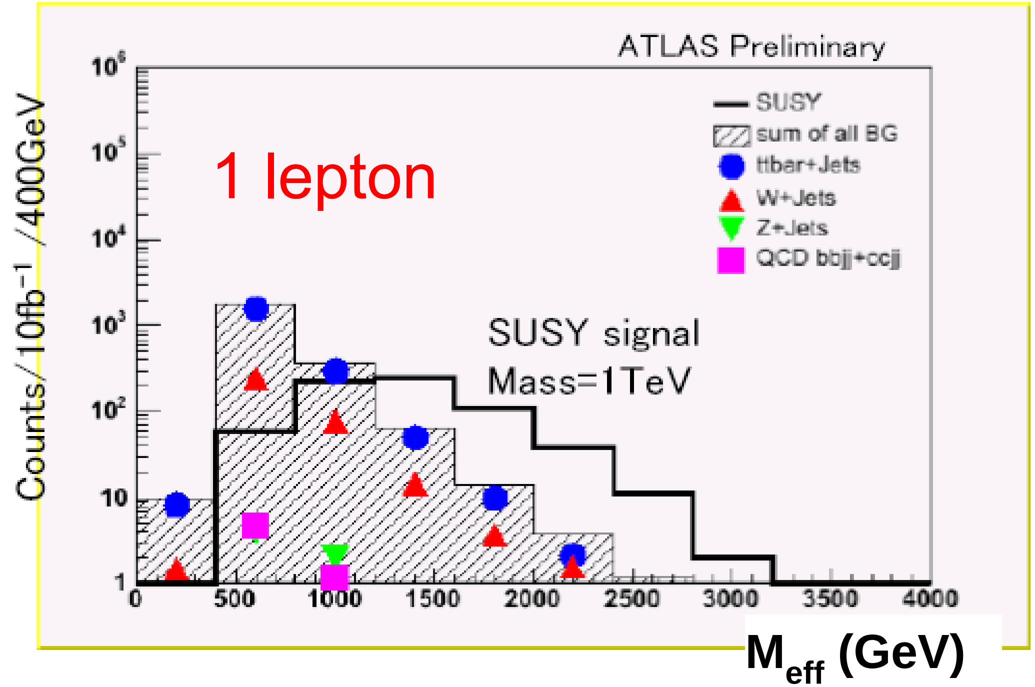
- $E_T$miss calculated from vector sum over calorimeter cells plus contribution from muons corrected for energy loss in calorimeter.
- Noise cells removed with topological clustering algorithm.
- Cells calibrated with H1 style weights (low energy density cells up-weighted to compensate for invisible processes in hadronic showers).



- Resolution scales with square root of scalar sum E_T :
  - ♦ $(E_T\text{miss}) \sim 0.5\ \sqrt{E_T\text{sum}}$

Dealing With Backgrounds

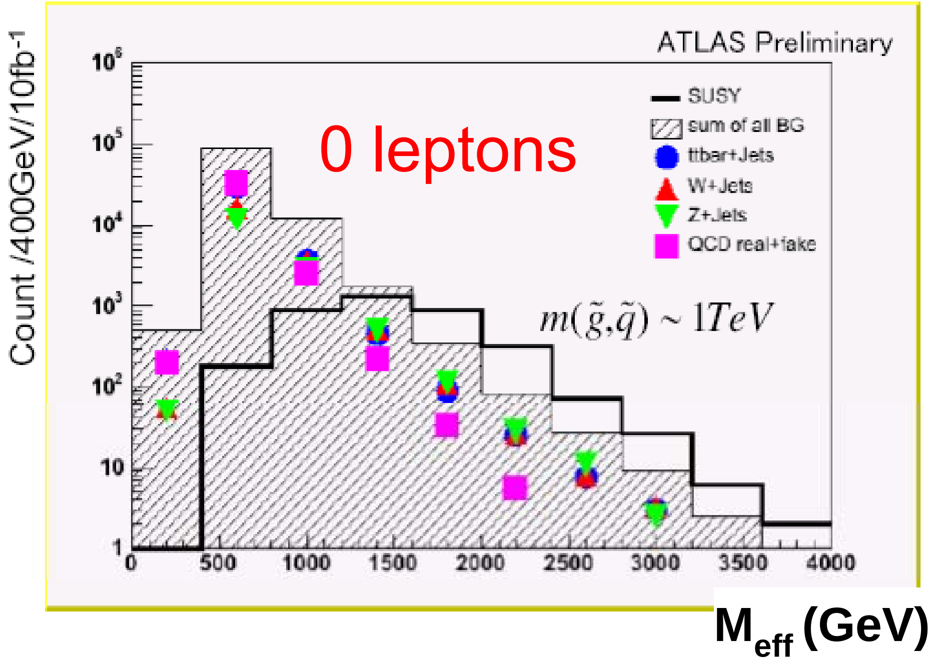
- In addition to jet and $E_T$miss cuts, apply additional cuts to reduce certain backgrounds
  - number of isolated leptons
  - $M_{eff} = E_T miss + \sum p_T^{jets}$

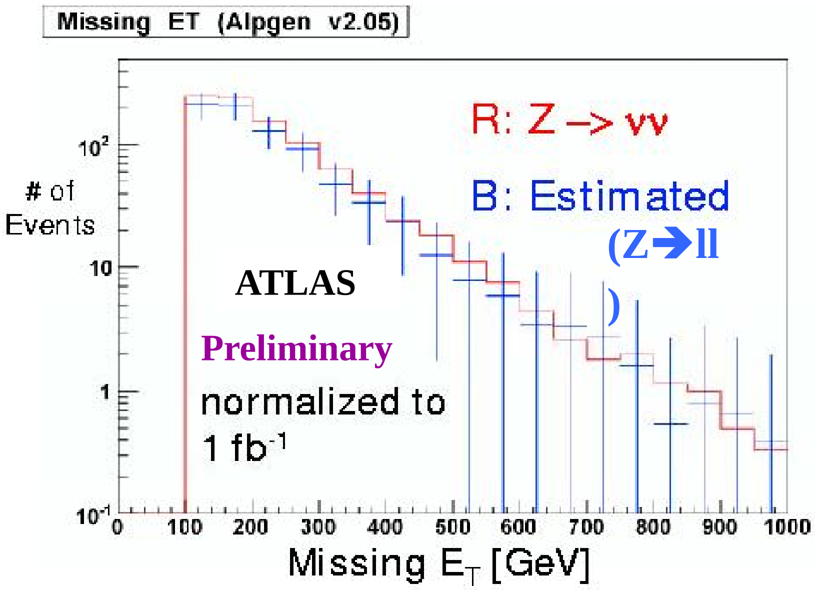


- Ability to reliably estimate backgrounds is vital to demonstrate excess in signal region.
- Systematics from Monte Carlo likely to be large, so try to estimate from data wherever possible
  - particularly important with early data.

W/Z + jets

- Significantly reduce Z → ■■ and W backgrounds with 1 lepton requirement and $m_T(l, E_T miss) > m_W$ cut at expense of statistics.
- Background now dominated by tops.

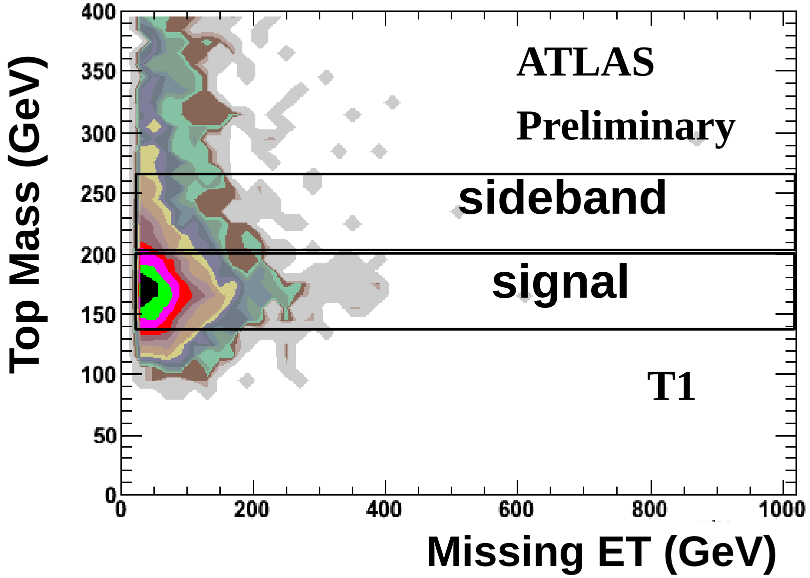


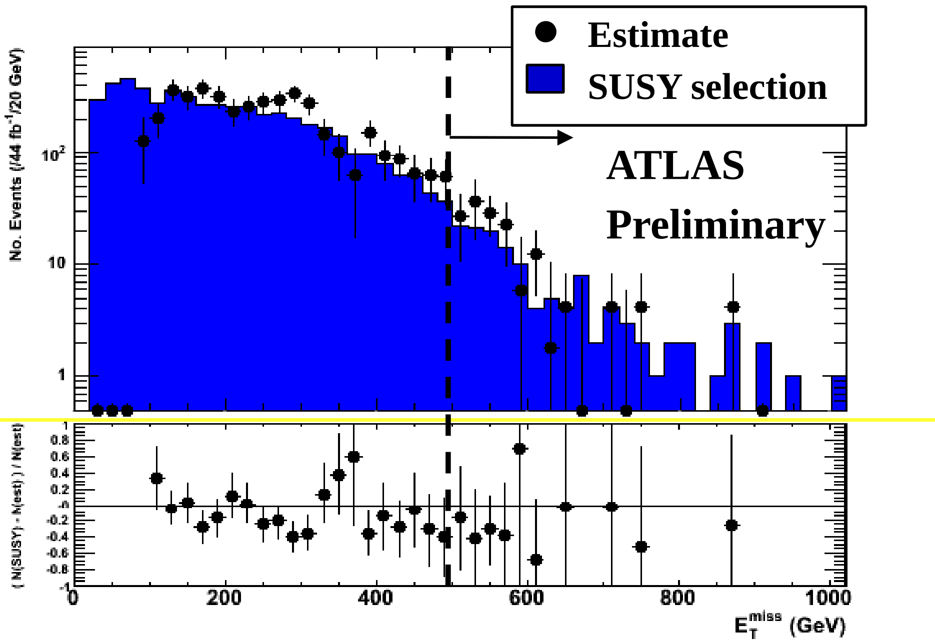


- Estimate Z ❼ ■■ in 0 leptons case by using Z → ll data, replacing lepton p_T with $E_T$miss.
- Can use same channel to obtain estimate for W → l■.

top

- For tt → bbl■qq, can reduce background with transverse mass cut. Then tt → bbl■l■qq becomes the dominant background in the 1 lepton channel.
- To obtain estimate: select semi-leptonic top events from a mass window around the top mass (m_t = 140 – 200GeV).
- Subtract combinatorial background using sideband (m_t = 200 – 260GeV).

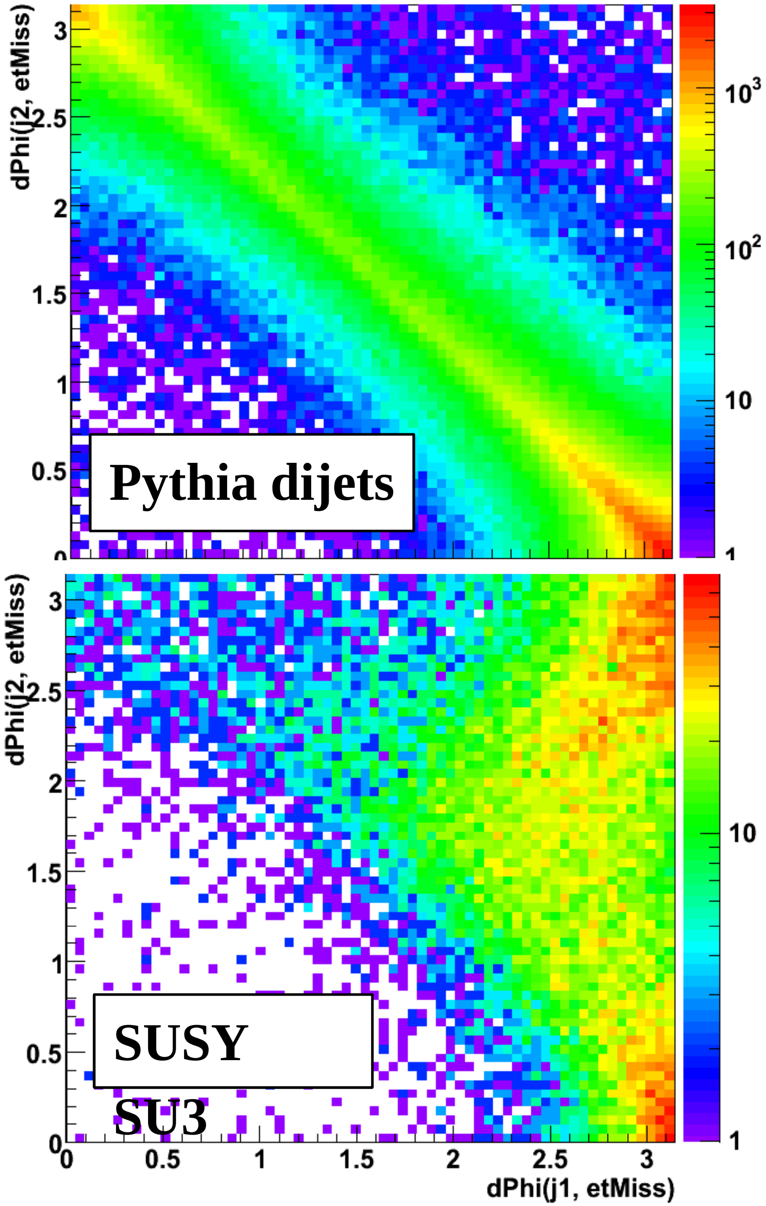




- Get estimate for semi-leptonic top $E_T$miss distribution.

QCD (1)

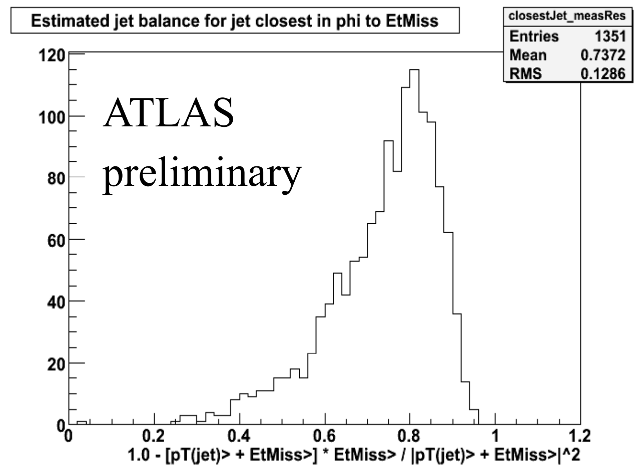
- Two main sources:
  - fake $E_T$miss (gaps in acceptance, dead/hot cells, non-gaussian tails etc.)
  - real $E_T$miss (neutrinos from b/c quark decays)
- Hard to estimate with Monte Carlo
  - depends on details of detector response
  - need large statistics to get into tails
- 1 lepton requirement minimises contribution
  - may be best until detector is well understood (real/fake?)
- Can reduce contribution by cutting on correlations in φ between the leading jets and $E_T$miss, jets pointing at poorly instrumented regions of the detector etc...

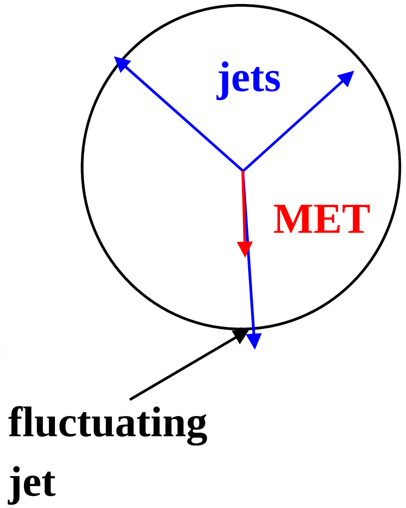


QCD (2)

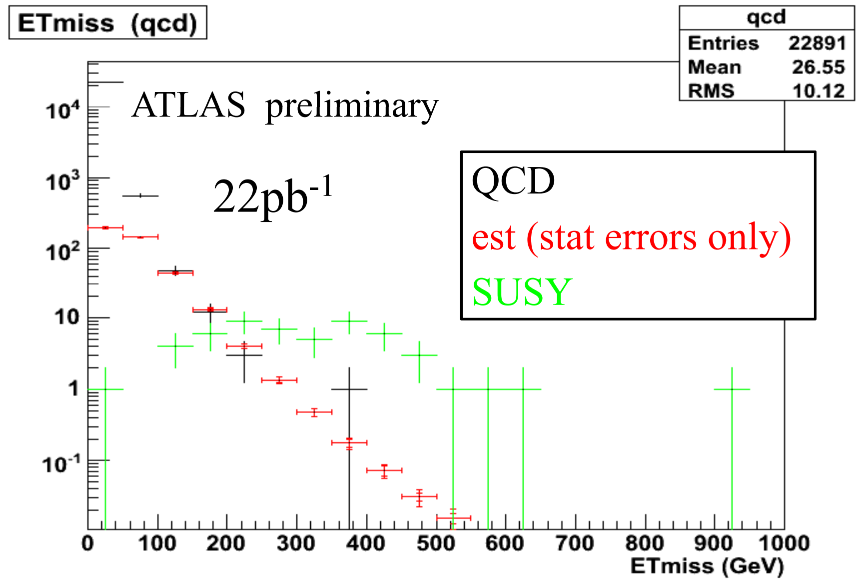
- To obtain estimate :
- <u>Step 1:</u> Measure jet smearing function from data
  - Select events: $E_T$miss > 60 GeV, $\Delta\phi(E_T\text{miss, jet}) < 0.1$
  - Estimate p_T of jet closest to $E_T$miss as

$$p_T^{\text{true-est}} = p_T^{\text{jet}} + E_T\text{miss}$$





- <u>Step 2:</u> Smear low E_T^{miss} multijet events with measured smearing function.
- Technique does not work in low $E_T$miss region (gaussian jet response), but gives good agreement in tails (SUSY signal region!)



Summary

- Potential for discovery of 1TeV scale SUSY with first data at ATLAS, but...
- Must understand detector and backgrounds.
- Data driven approaches most likely to give robust background estimates with first data – ongoing work!