Measurement of Missing ET in ATLAS

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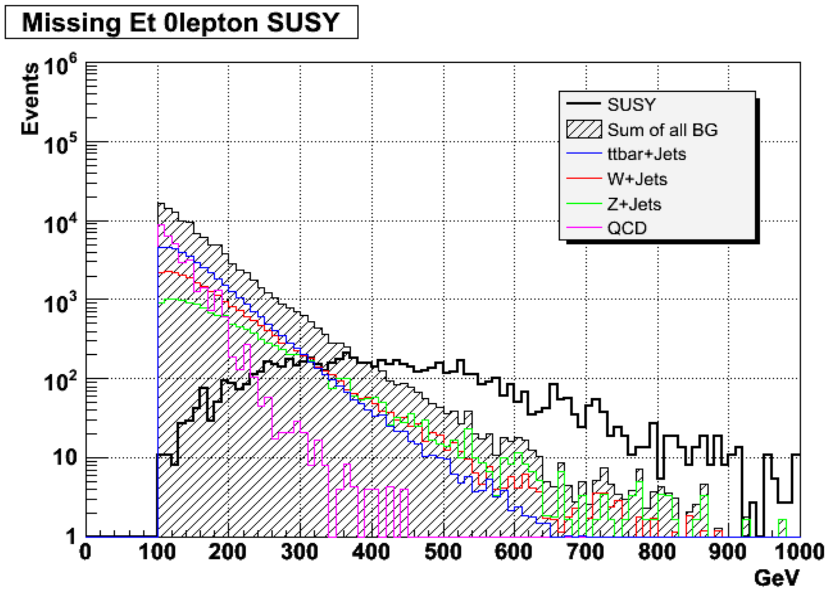
Introduction

- Good measurement of Missing ET characterized by non-interactiong particles is the key to search new physics. These particle cannot be caught by detector.
  - SM W, Z, Higgs
  - SUSY lightest super-symmetric particle (LSP)
- It is important to understand the following
  - Resolution
  - Scale
  - Non-gaussian tail

Right figure shows Missing ET dist. SUSY vs BG. Missing ET is good probe to new physics.

Important to reconstruct, calibrate and evaluate Missing ET



M_{SUSY}~1TeV @1fb^{-1}

Outline

- Measurement of Missing ET
- Atlas Calorimetry
- Reconstruction
  - Calibration
  - Noise suppression
- Performance
  - Scale
  - Resolution
  - Tail
- Estimation from early data

Measurement of Missing ET

- There are two strategy to measure Missing ET
  - Cell base
  - Object base
- Origins of Missing ET is neutrino, LSP, and gravitino etc (real Missing ET). But badly measurement of Jet, electron etc. becomes miss-measurement of Missing ET (fake Missing ET)
- Default Missing ET calculation is based on cell-based method

Cell-Base

- PtMiss = ΣPT (cell) + ΣPT (muon) + ΣPT (loss in cryostat (dead material))

- Dead/hot/noisy cell
- Noise/pile-up suppression
- Energy calibration (nonlineality, resolution)
- Losses in dead materials/cracks

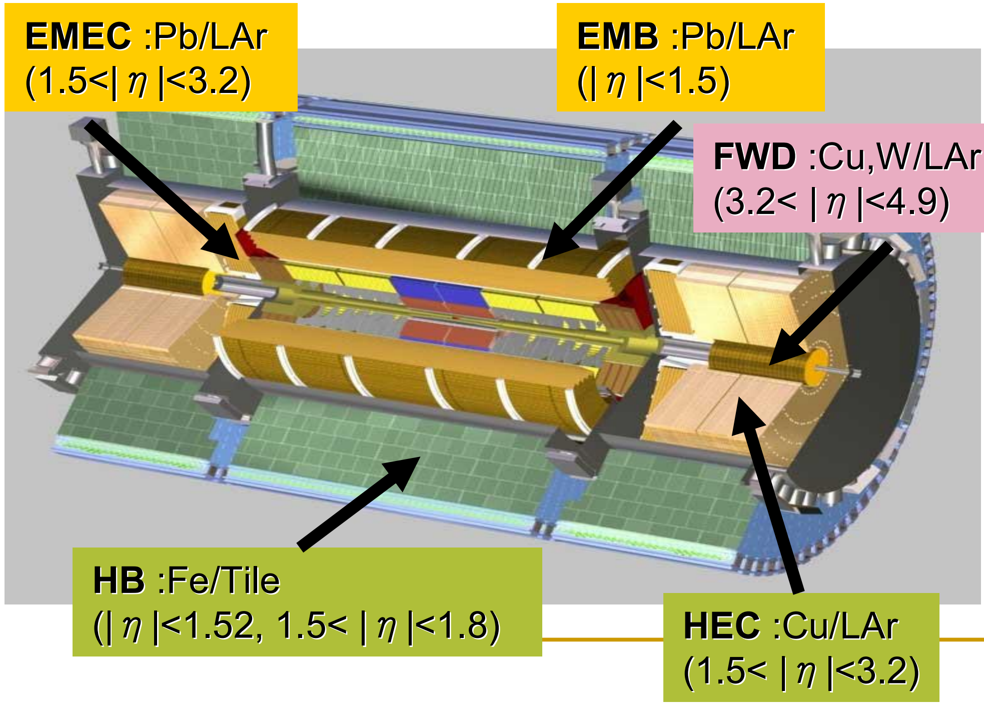
Object-Base

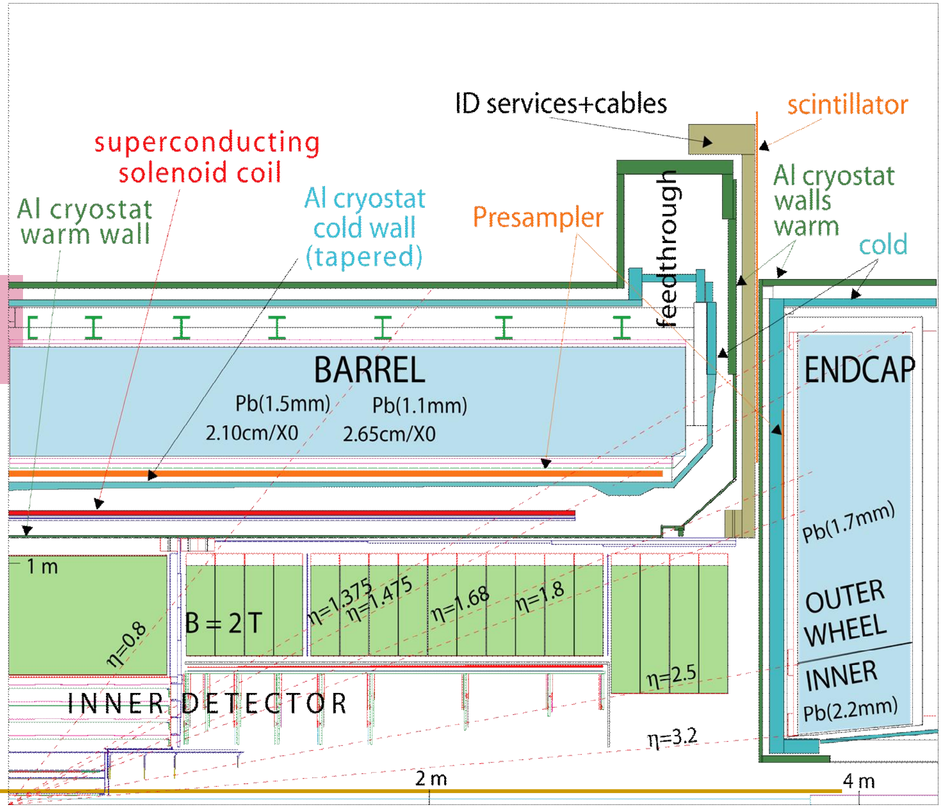
- PtMiss = ΣPT (high Et objects, e/γ, μ, τ, jet)
+ ΣPT (low Et object, pion, unclustered cells)

- Individual calibrations applied to each object
- Now development

Atlas Calorimetry

- Full coverage | η |<5
- **EM calorimeter** : 22-26X (radiation length), high granularity
- **Hadron calorimeter** : ~8.8 λ (interaction length)
- **e/h** : ~1.4
- σ **/E for jets in barrel**: 0.67/sqrt(E)+0.02+4.3/E





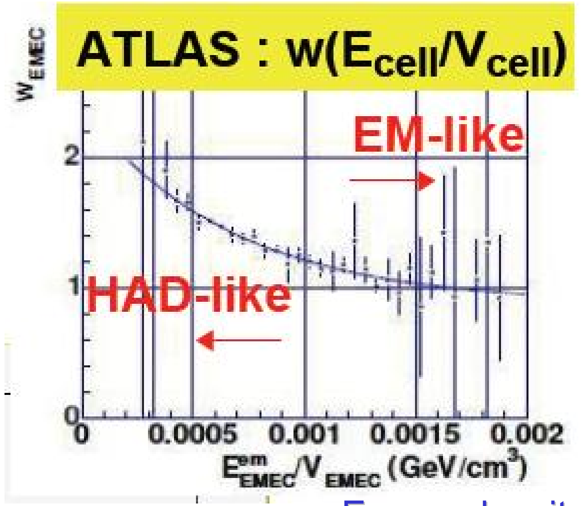
Missing ET Reconstruction

- Atlas calorimeter cover nearly full solid angle and have good granularity, but EtMiss is degraded by several reasons
  - Limited coverage (| η |<5)
  - Presence of minimum bias
  - Swept-out charged particles by magnetic fields
  - Calorimeter response (non-compensation, non-linearity)
  - Noise (electronics/pile-up)
  - Energy loss in inactive materials and leak at cracks
- The large fraction of energy is measured by calorimeter. Calorimeter energy calibration, energy correction and noise suppression are crucial for the best EtMiss reconstruction

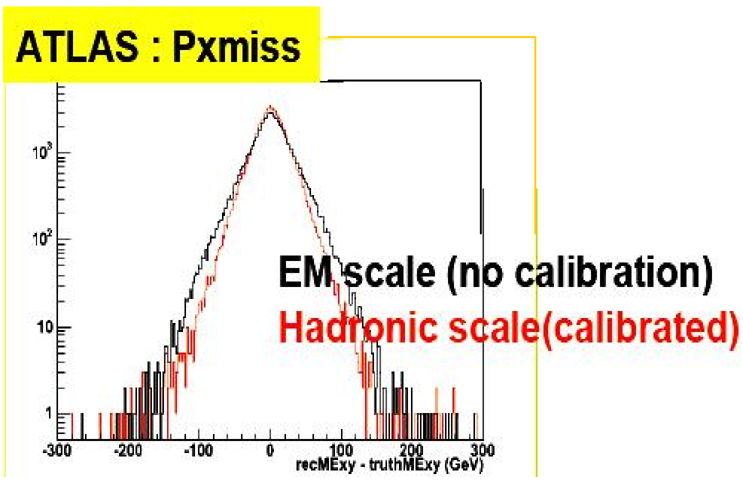
Energy calibration

- Since the calorimeter is not compensated and has non-linear/non-uniform response, then need several corrections for better performance
- A hadronic shower consists of
  - EM energy (e.g. $\pi \rightarrow \gamma\gamma$)
  - Visible non-EM energy (e.g. dE/dx from π)
  - Invisible energy (e.g. break up of nuclei)
  - Escaped energy (e.g. ν)
- difference of energy density
  - High energy density denotes high EM activity
  - Low energy density correspond to hadronic activity
- Apply weight function

  $E'_{cell} = E_{cell} \times w(E_{cell}/V_{cell}, \eta, \text{calorimeter})$
- The refined approach is now used, which improves performance: Apply cell calibration weights according to the reconstructed objects (e/γ, μ, τ, jets) to which the cell belongs



Energy density

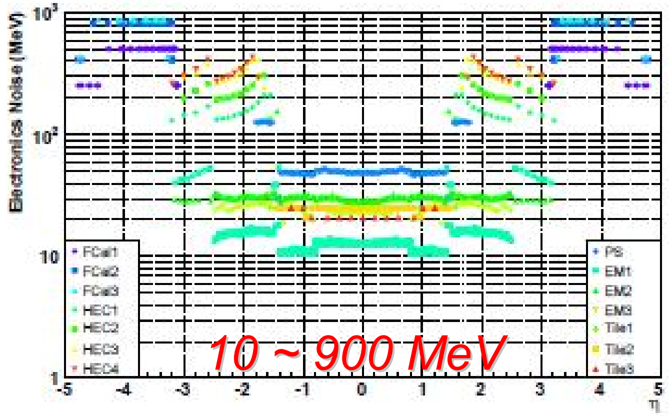


di-jets event (560-1120 GeV)

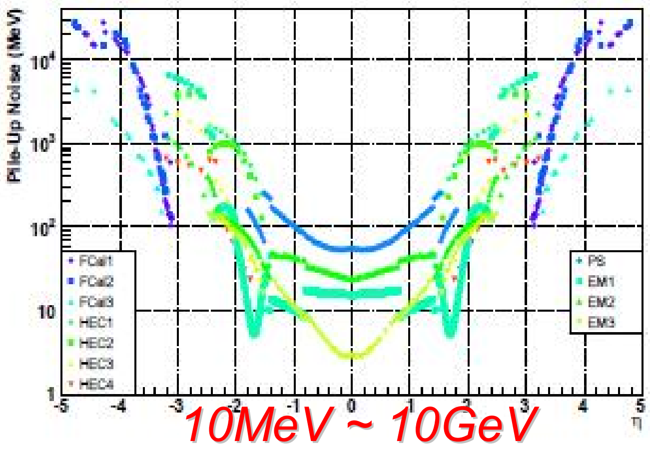
Noise Suppression

- Origins of noise are
  - Electronics noise
  - Pile-up noise
- To suppress these noise
  - Apply 2 sigma cut on expected noise level
  - Build topological clustering from calorimeter cells and use cells inside (default)

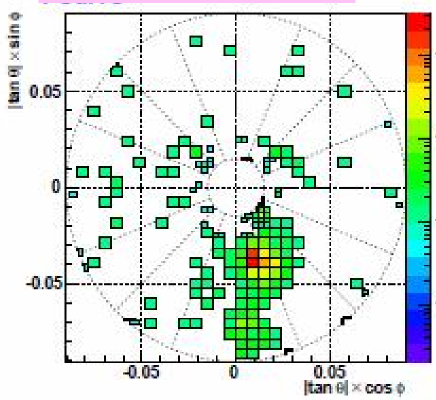
Electronics noise



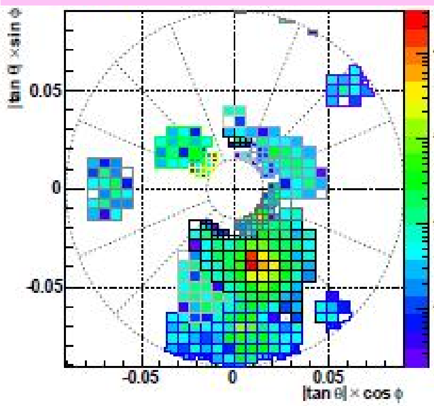
Pile-up noise



$|E_{cell}|>2\sigma$

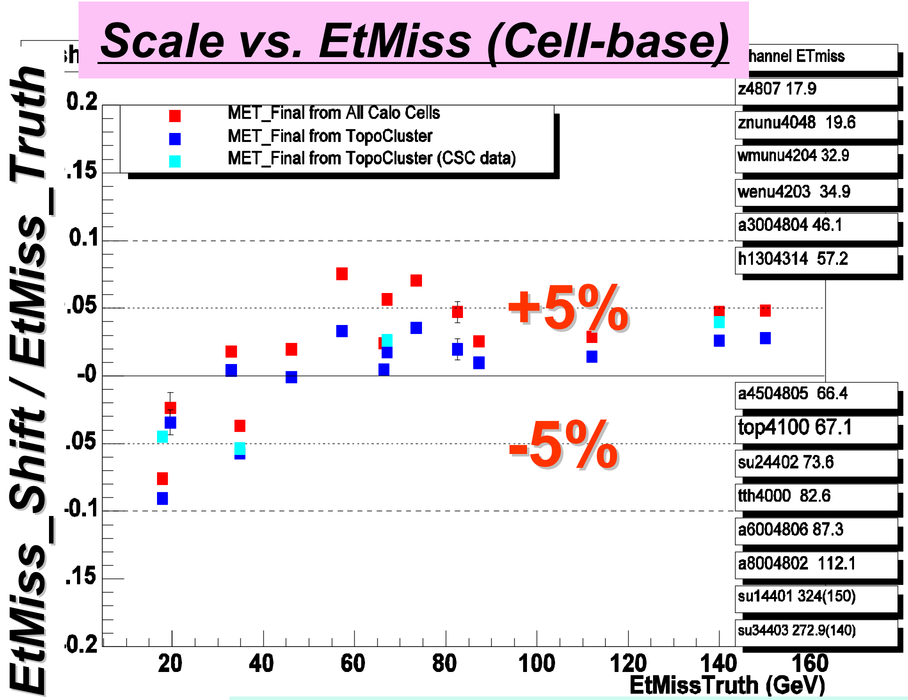


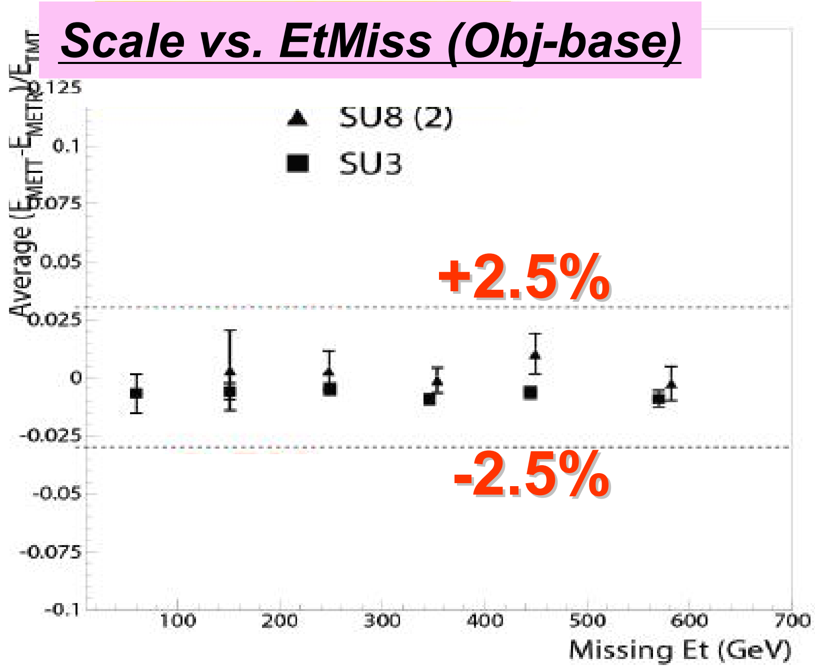
Topo cluster 4/2/0 σ



Missing ET Scale

- Correct scale is important for Inv Mass, edge etc.
- Missing ET Shift = True Missing ET – Reconstructed Missing ET
- Shift is within 5%, it is reduced applying refined calibration
- Good scale is achieved in Object-base method in high Missing ET samples





Red : 2 sigma cut
Blue : Topological Clustering

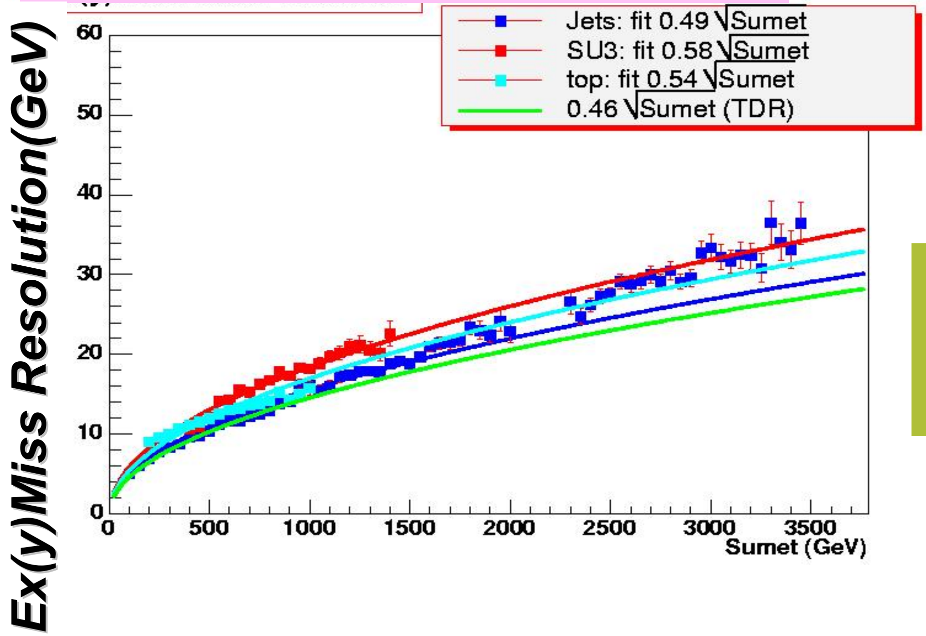
Missing ET Resolution

- Ex(y)Miss Resolution is well represented by the following equation.

  *Final Ex(y)miss Resol = p0 * √SumET*

- Different resolution for different event topology. Different corrections should be applied for different objects (jets, e/γ …), but not considered.

Ex(y)Miss Resolution vs. SumEt

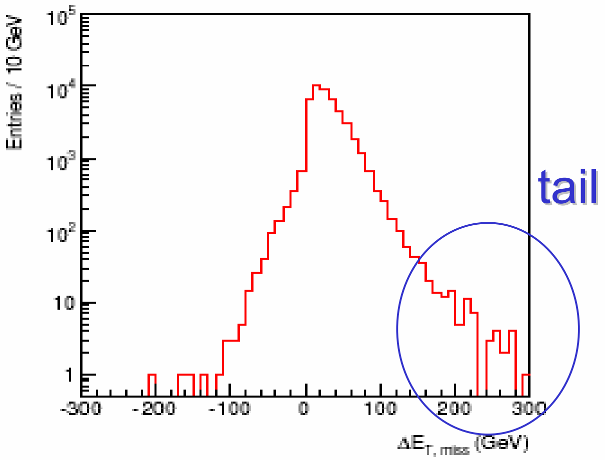


SUSY(SU3)	(0.58)
di-jet	(0.49)
Top	(0.54)

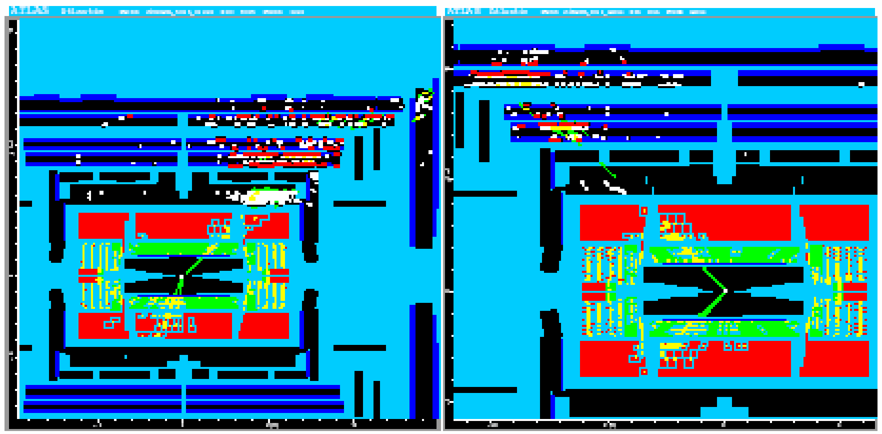
Non-Gaussian Tails

- Detection of large EtMiss is important signature in many physics channels
- Badly measured EtMiss (fake EtMiss) is dangerous. Understanding of tail is important since they affects background uncertainty (ex. QCD multi-jet)
- *Origins of tail are*
  - *Shower leakage (shown in fig)*
  - *Fake muons*
  - *instrumental effects as hot/noisy/dead cells, cavern background, beam halo, etc*

Δ Ex(y)Miss(GeV)



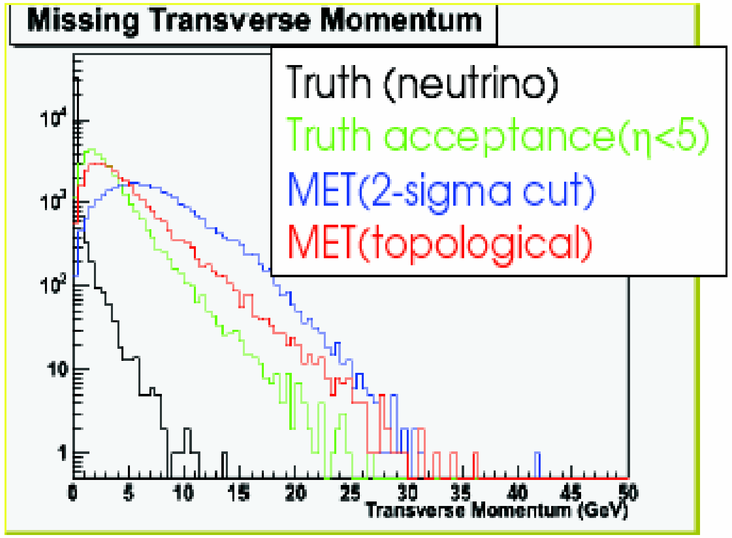
Jet leakage from Tile/ExtTile crack, shower in muon system



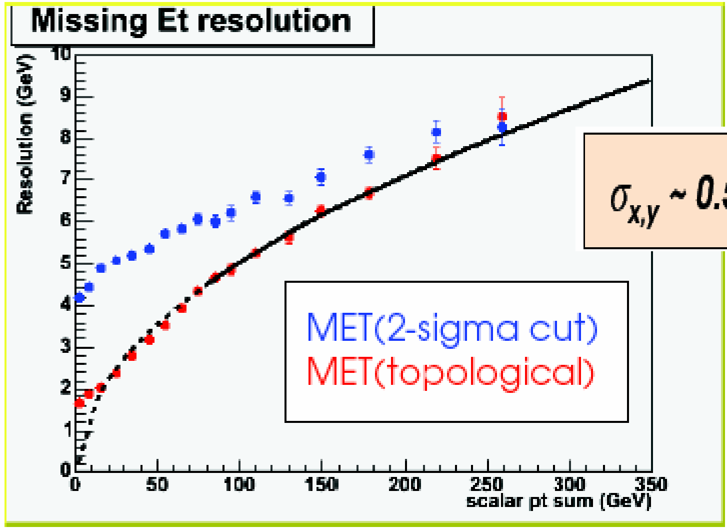
Validation of resolution using Minimum Bias

- By using Minimum Bias(~300GeV) resolution can be estimated in the early stage.
- Minimum bias contain no real Missing ET. It can be useful probe to estimate resolution.
- “Out of coverage” is main resource of non-zero EtMiss in Minimum Bias event
- With topological clustering estimated resolution is consistent with truth

Missing ET

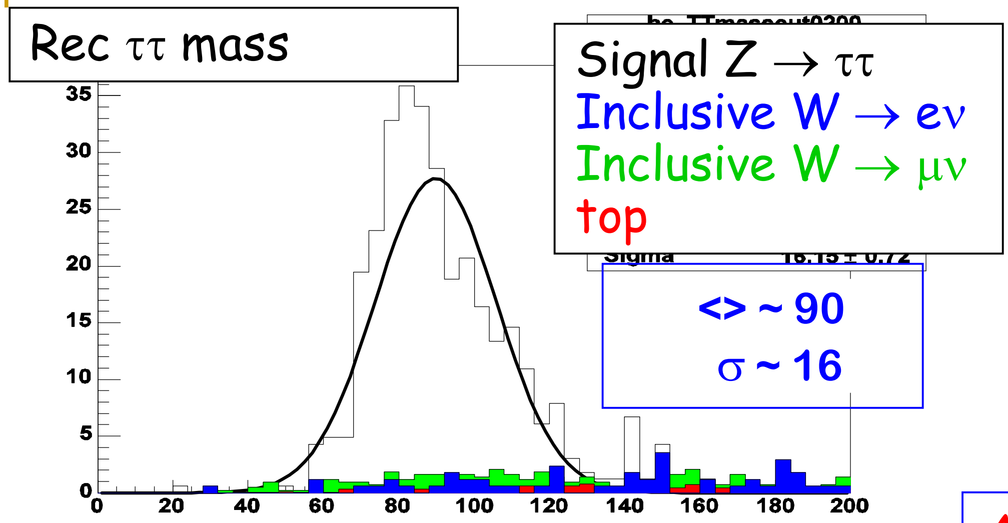


Ex(y)Miss resolution vs SumET

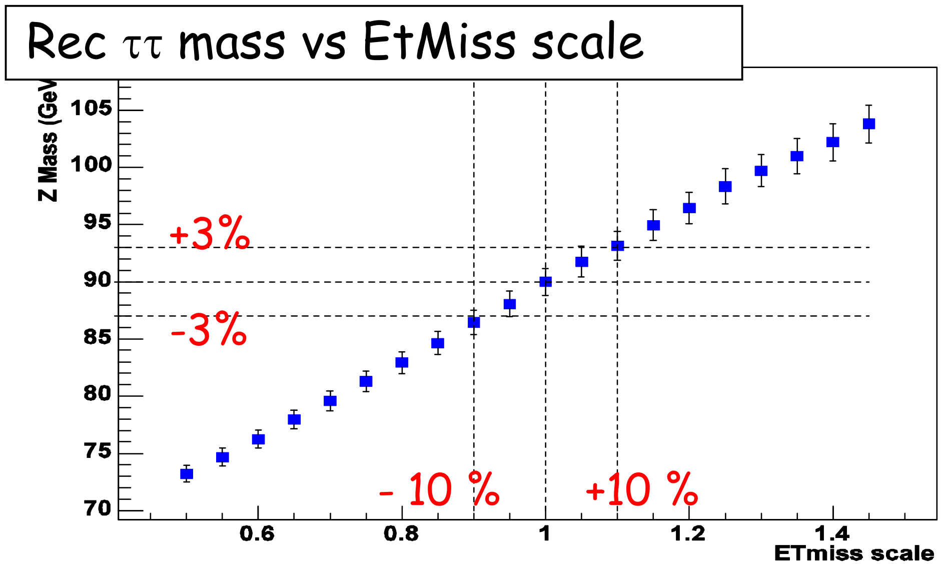


$\sigma_{x,y} \sim 0.5 \times \mathrm{sqrt}(\Sigma E_T)$

Validation of using Z-> τ τ ->lept-had



- τ τ invariant mass reconstruction
- Sensitive to EtMiss scale
- Z mass measured to 3% will result in an error of 10% on Missing ET absolute scale
- QCD/bb background is still included



Applied cuts :

pt(lep) > 15 GeV, $|\eta|$<2.5

pt(jet) > 15 GeV, $|\eta|$<2.5

1.<$\Delta\phi$ < 2.7 or 3.6<$\Delta\phi$ <5.3

m_T(lept-EtMiss)<50GeV

τ-likelihood > 8 (τ-eff ~ 30%)

66<rec $m_{\tau\tau}$<116 GeV

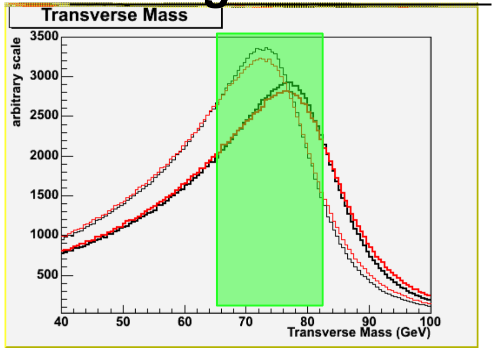
Expected in 100pb-1

~ 300 evts with ~ 20% backgd

Estimation using W+jets

- Using Transverse mass distribution of W+jets (~1TeV) at 1fb^{-1}
- simple selection exactly 1 muon with pT>20GeV and |η|<2.5

fit range 64-84GeV



- a(reso)=7GeV, α(scale)=1
- a(reso)=8GeV, α(scale)=1
- a(reso)=7GeV, α(scale)=0.9
- a(reso)=8GeV, α(scale)=0.9

Express reconstructed MET(x) distribution by

$$MEX_{reco} = \alpha \times Gaus(MEX_{truth}, a)$$

MEX : MissingEx (reco or truth)

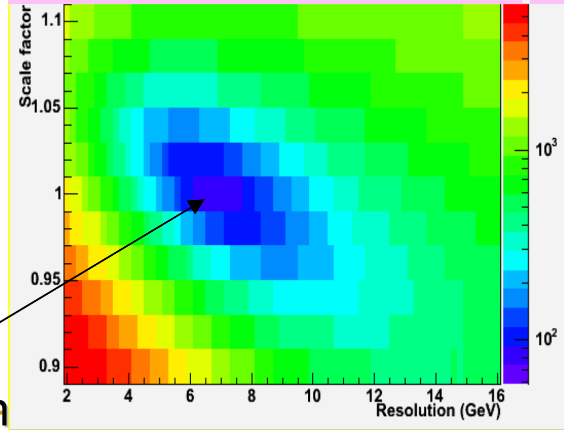
α : scale factor

a : MEX resolution (in GeV)

→ Determine these parameters with "template method".

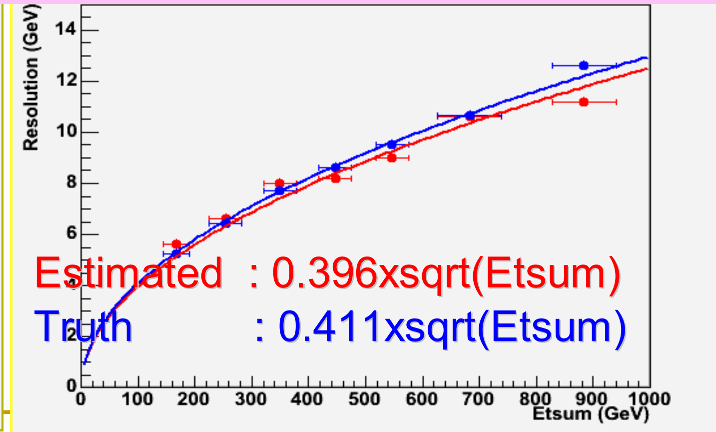
- Generate pseudo-data histogram using reconstructed information
- Fit pseudo-data to series of template histograms and obtain the best estimated variables minimizing χ^2

Scale vs. Resolution



χ^2 minimum

Ex(y)Miss resolution vs SumET



Summary

- Good measurement of Missing ET is very important for new physics (both Higgs and SUSY)
- Missing ET performance is dominated by calorimeter resolution and energy reconstruction
- Resolution and Scale are improved by correcting nonlinearity response, eta dependency and energy lost in cryostat. These can still be improved with refined calibration
- Non gaussian tails can be reduced cleaning for instrumental effects, fake muons and correcting for shower leakage, jets in cracks...
- Important to validate/improve Missing ET performance with early data

Backup slides

ATHENA MissingET : EtMiss Reconstruction and Calibration

MET_Final = MET_Calib + MET_Cryo + MET_ Muon

All Calorimeter cells in
|η|<5

|Ecell | > 2σ(noise)

H1-like weights from jets

OR

Calorimeter cells in Topoclusters 4/2/0

H1-like weights from jets

Estimated energy loss in cryostat between LAr and Tile

from reco jets (cone07)
w*sqrt(EM3*TILE1)

OR

from reco jets (kT)

from MOORE mu |η|<2.7

pT from external Spectrometer

BestMatch /good quality

OR

from MuonBoy muons in |η| < 2.7

Calorimeter cells in Topoclusters 4/2/0

LocalHadronCalibration (under test)

Topoclusters 4/2/0

LocalHadronCalibration (under test)

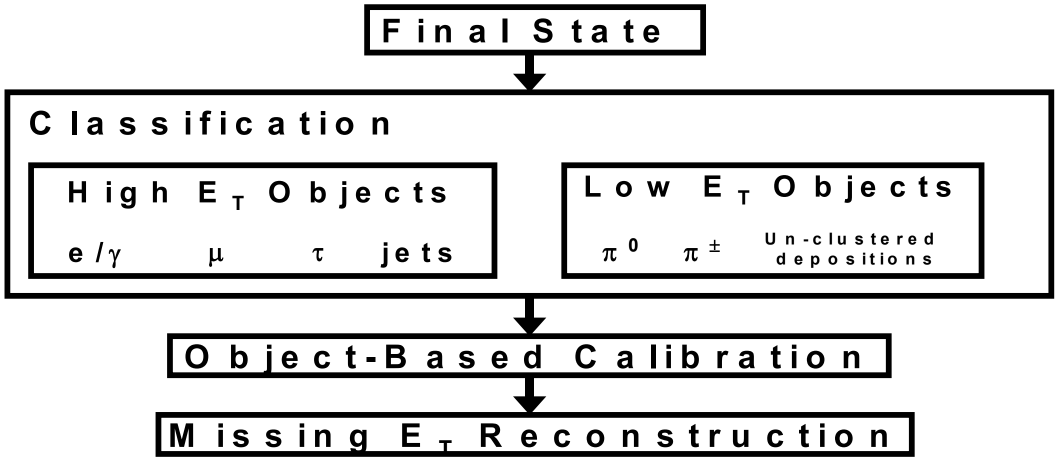
Refinement of Calibration for cells in different objects (e/γ, τ, μ ,jets...) a la TDR

(implementation in 12.0.2)

: Present defaul in MissingET

ObMET: a different approach for EtMiss

Object-Based Missing E_T



Calibration

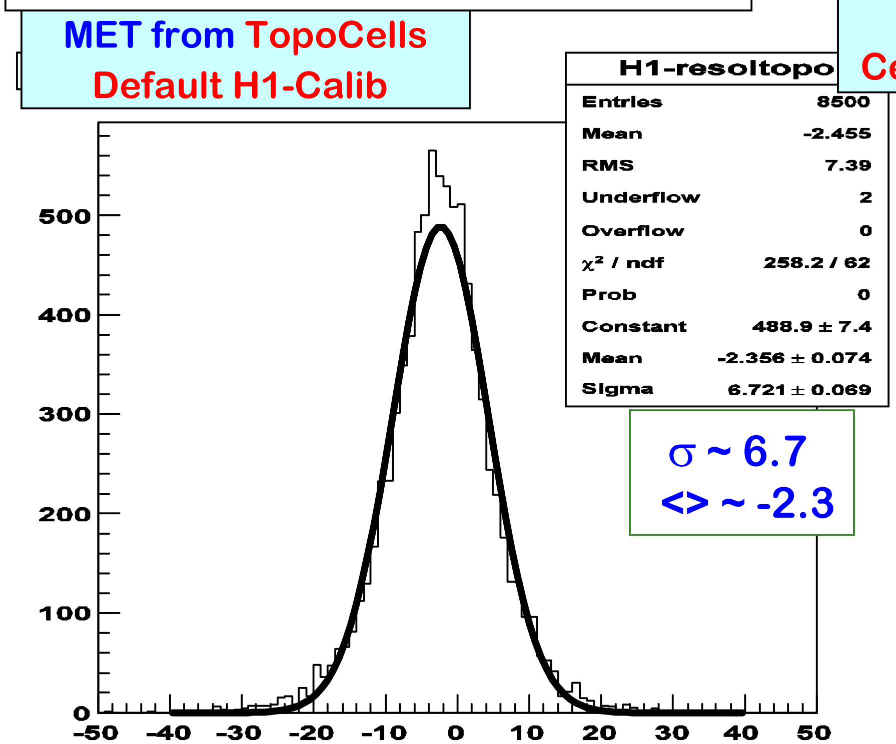
Electrons from Egamma collection IsEm=0 L.Flores sampling based calibration	**Track** from TrackParticles E>2Gev, good quality, isolation. Remove overlap with e, muons, jets
Muons from StacoCombined collection Emuon-Eloss. Eloss in calo is standard parametrisation based	**Mini Topo-jets** from low pT Topoclusters separated in π^0 (sampling based calib) and charged π (cell based calib)
Cone 0.7 **Jets** from Topoclusters & pseudo-H1 S.Padhi calibration. Jet clusterisation correction	**remaining cells** with a scale factor depending on 3 regions

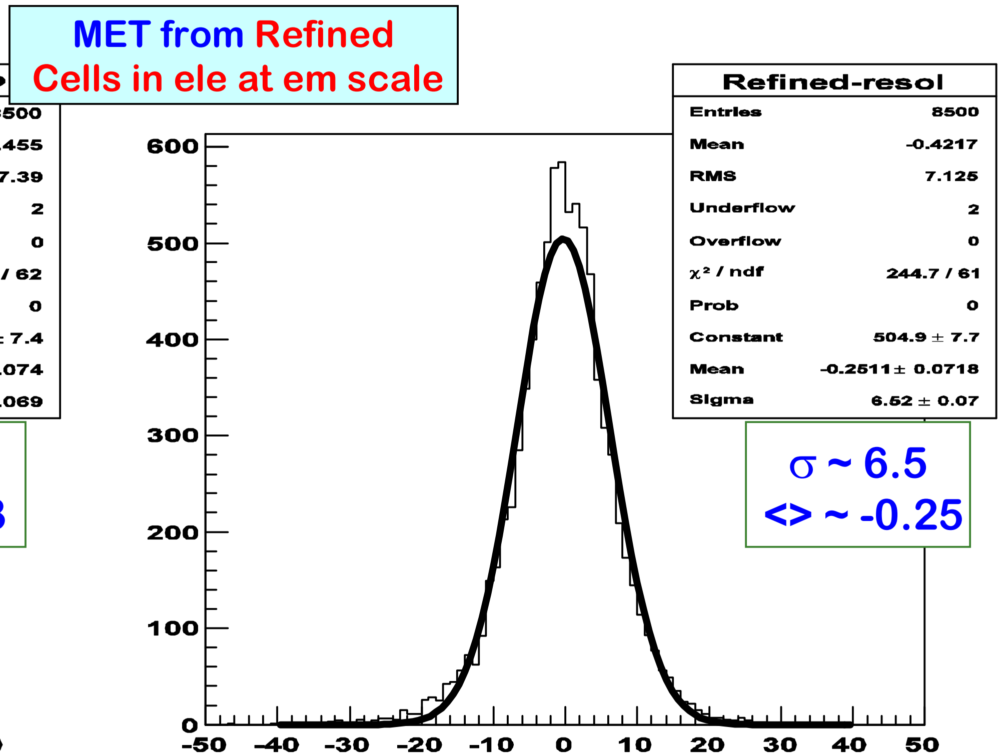
Refined MissingET: First tests

Expect improvement in samples with electrons

In W $\rightarrow$ eν EtMiss_Truth-EtMiss is better centered and resolution also improves leaving the cells in electrons at the em scale

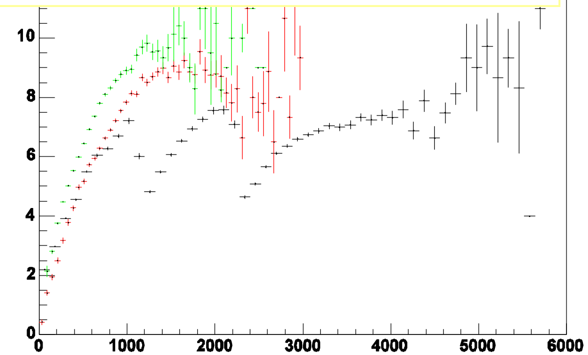
EtMiss resolution in W$\rightarrow$ eν



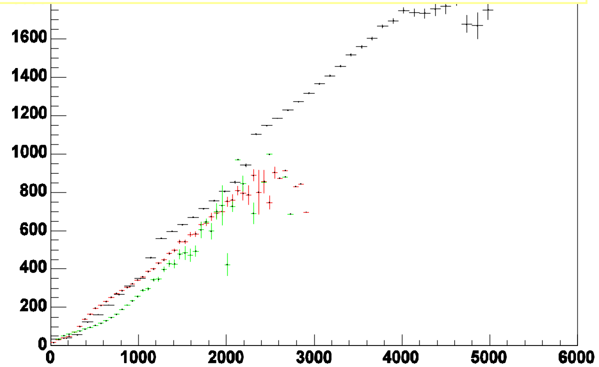


EtMiss: dependence on Event Topology
Compare different data samples Top, SU3, Jets from CSC

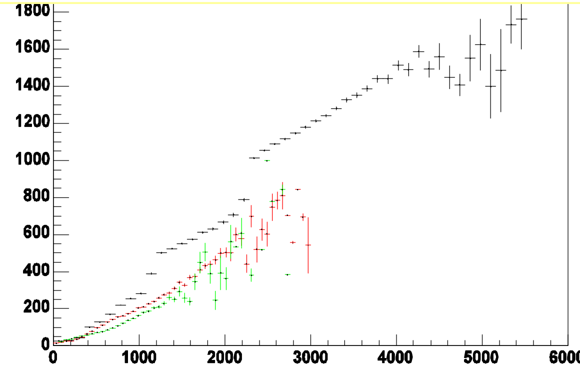
Njets vs SumET



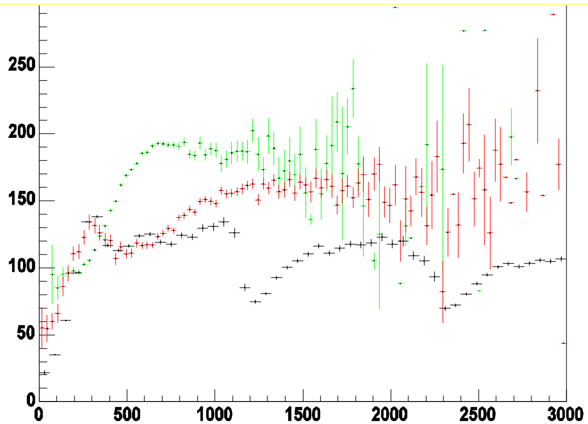
pT leading jet



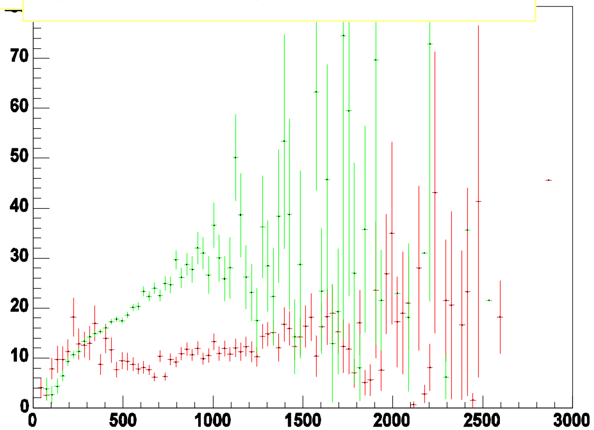
pT next-to-leading jet



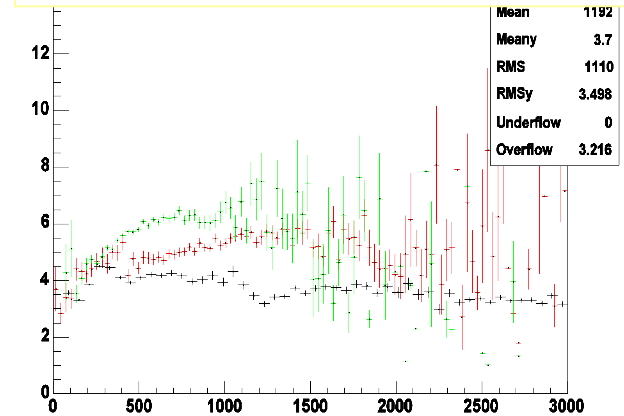
SumET-SumETjets-SumETele



SumET electrons

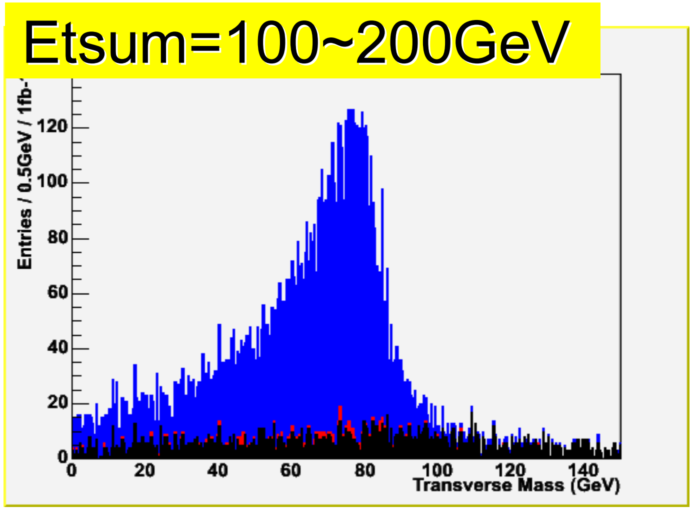


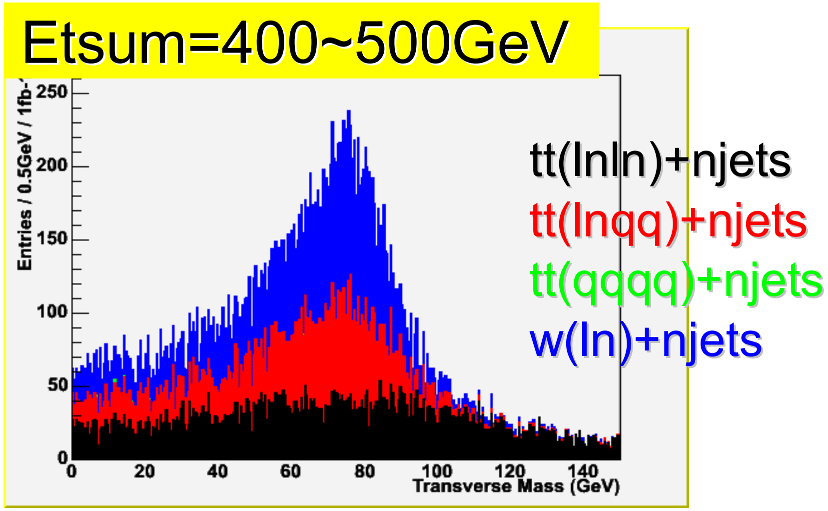
EtMissout

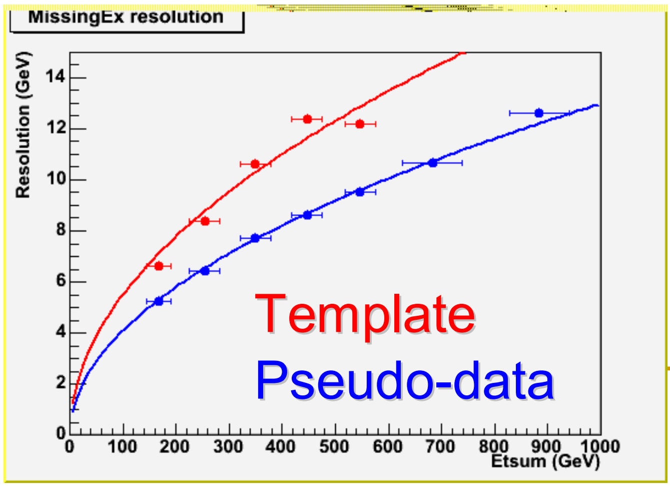


tt+njet background

Dominant background is tt+njets(lnln and lnqq), especially in high Etsum region.





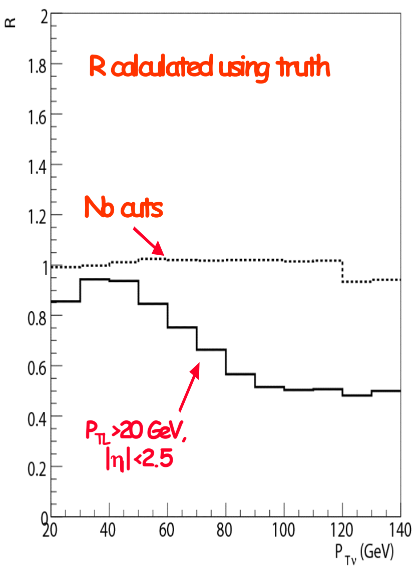


Need to suppress or subtract bkg.

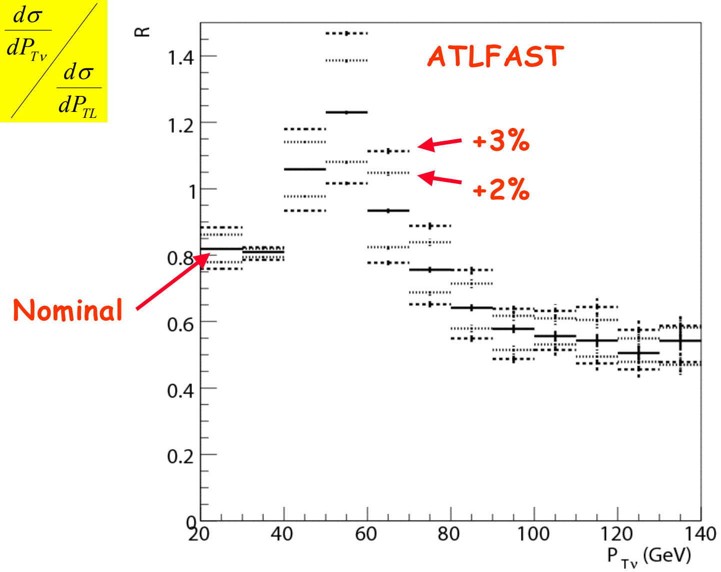
Scale estimation using W->ln

- Ex(y)Miss Scale can be estimated by W(->lnu) event with 100 pb-1 of data
- Use ratio R = Pt(ν)/Pt(l) calculated with MC. It depends on experimental cuts
- R is sensitive to scale but less to resolution
- Need to address top background

$$R = \frac{d\sigma}{dP_{T\nu}} \Big/ \frac{d\sigma}{dP_{TL}}$$



$$R = \frac{d\sigma}{dP_{T\nu}} \Big/ \frac{d\sigma}{dP_{TL}}$$



P_{TL}>20 GeV, $|\eta_l|$<2.5

$100pb^{-1}$