Missing Tranverse Energy in first ATLAS data

Donatella Cavalli, Caterina Pizio, Silvia Resconi, Rosa Simoniello

On behalf of ATLAS Collaboration

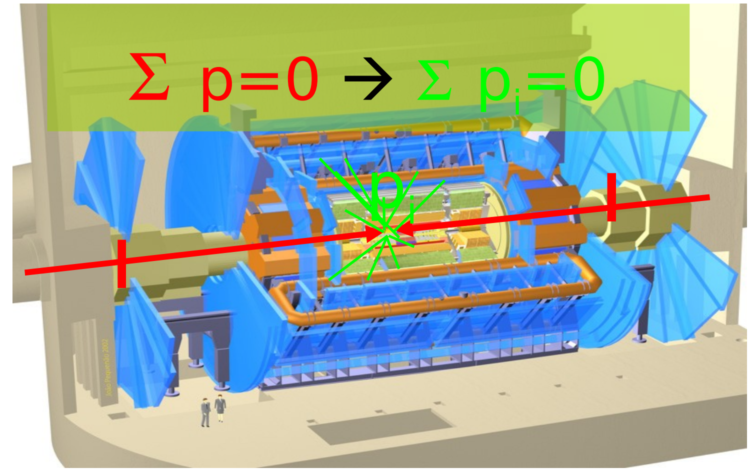
07.04.2010

E_T^{miss} Reconstruction in ATLAS

Transverse Missing Energy:

$$E_T^{miss} = \sqrt{E_x miss^2 + E_y miss^2}$$

$$\left.\begin{aligned} E_x miss &= -\Sigma\ Ex \\ E_y miss &= -\Sigma\ Ey \\ SumE_T &= \Sigma\ E_T \end{aligned}\right\}$$ Sum of energy of all particles seen in the detector



E_T^{miss} is a complex event quantity:

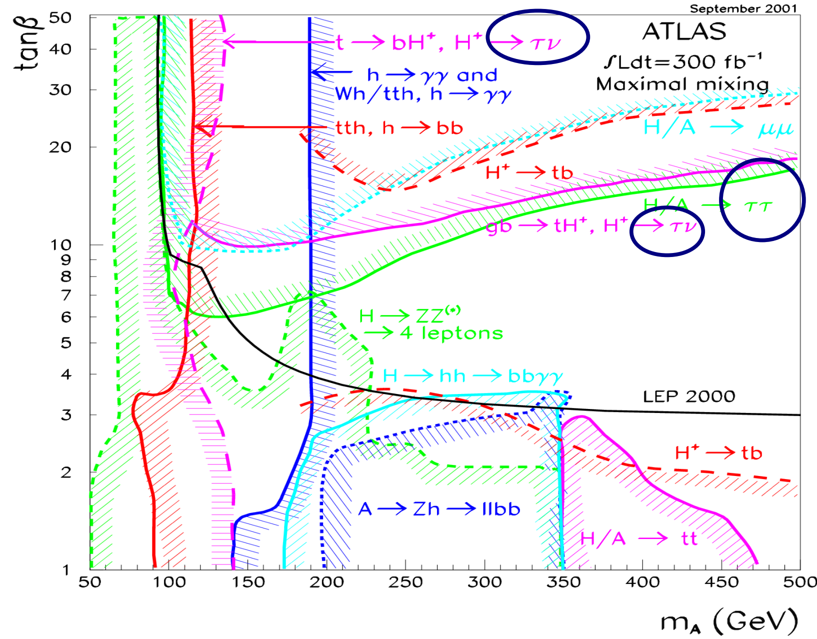
- It is calculated adding all significant signals from all detectors:
    - Calorimeter input signals (Cells, TopoClusters):
        - used for physics objects
        - not used for physics objects
    - Muon signals
    - Tracks in regions where Calorimeter/Muon Spectrometer are inefficient
    - Correction for energy lost in dead material

E_T^{miss} importance in ATLAS physics

E_T^{miss} is the signature for many physics channels

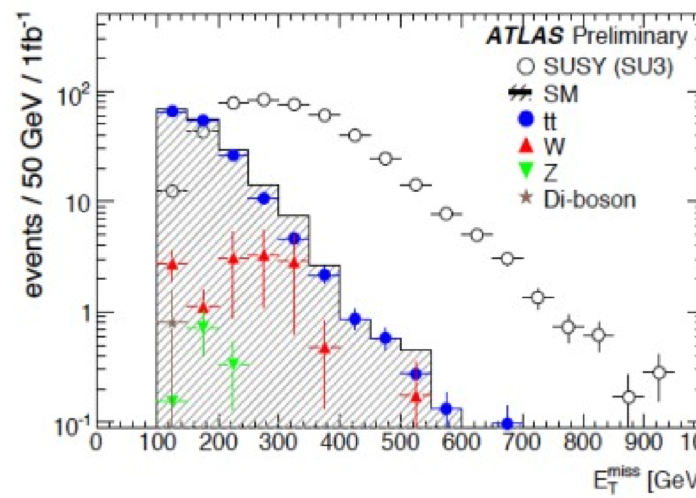
A very good E_T^{miss} measurement is a crucial requirement for the study of many physics channels in ATLAS:

- $W \rightarrow l\nu$, $Z \rightarrow \tau\tau$, Top decays...
- SM Higgs (VBFh $\rightarrow \tau\tau$, tth $\rightarrow \tau\tau$)
- MSSM Higgs ($A/H \rightarrow \tau\tau$, $H^{\pm} \rightarrow \tau\nu$)
  - reconstruct the invariant $\tau\tau$ mass from the two E_T^{miss} components
- SUSY → Large E_T^{miss} signature (lsp)



A bad measurement of E_T^{miss} could fake a non-zero reconstructed E_T^{miss} in events with no physical E_T^{miss}

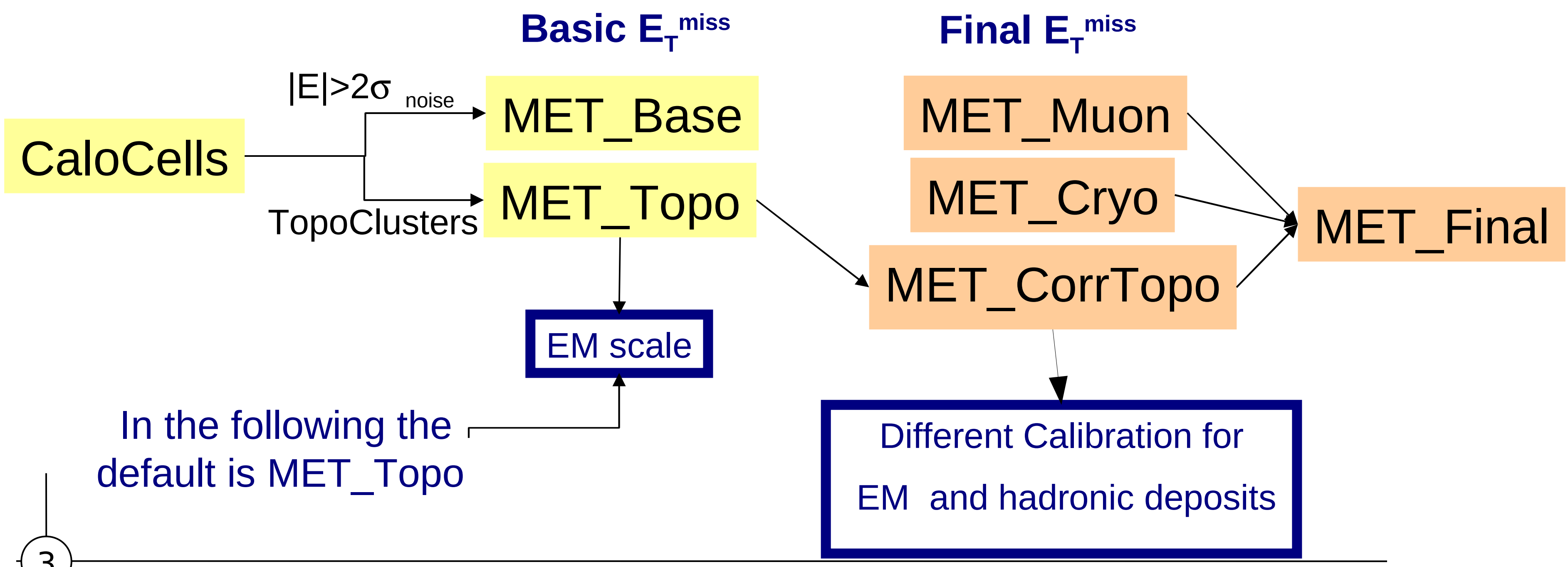
- QCD with fake E_t^{miss} background for inclusive no-lepton SUSY events
- Z+jets with fake E_T^{miss} background for $H \rightarrow ll\nu\nu$



From Basic to Calibrated E_T^{miss}

- **Basic E_T^{miss}** from all Calorimeter cells with two possible noise suppression approaches (see below)

- **Final E_T^{miss}** :
  - Different calibrations approaches
  - Correction for energy lost in cryostat between EM and Had calorimeters
  - Contribution from muons



Basic E_T^{miss}

- First data → E_T^{miss} is calculated only from the calorimeters (few muons)

- **All cells in Topo-Clusters are used**
  Topo-Clusters are groups of calorimeter cells topologically connected

  Noise suppression via noise-driven clustering thresholds:
  Seed, Neighbour, Perimeter cells $(S,N,P) = (4,2,0)$
    - seed cells with $|E_{cell}| > S\sigma_{noise}$ $(S = 4)$
    - expand in 3D; add neighbours with $|E_{cell}| > N\sigma_{noise}$ $(N = 2)$
      - merge clusters with common neighbours
    - add perimeter cells with $|E_{cell}| > P\sigma_{noise}$ $(P = 0)$

$$E_x^{miss} = -\sum_{i=1}^{N_{cell}} E_i \sin\theta_i \cos\phi_i,$$
$$E_y^{miss} = -\sum_{i=1}^{N_{cell}} E_i \sin\theta_i \sin\phi_i,$$
$$E_T^{miss} = \sqrt{(E_x^{miss})^2 + (E_y^{miss})^2},$$

→ The sum is done on all cells in TopoClusters

- EM scale calculation, no calibration applied

Data samples and event selection

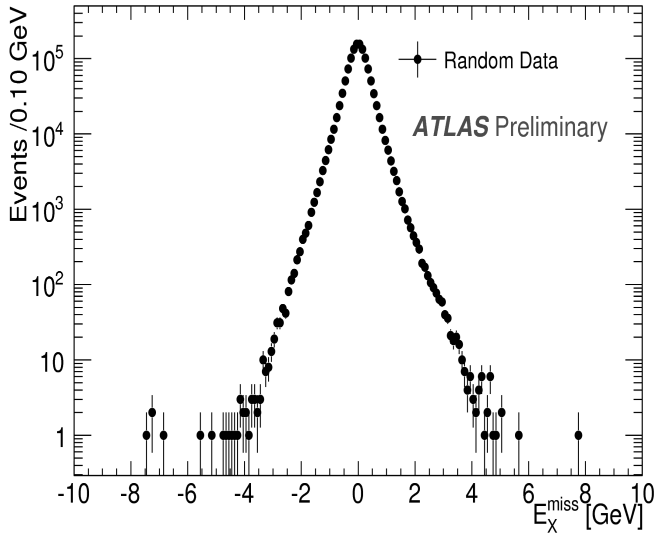
- **Data (stable beam, nominal magnetic field, good calorimeters)**:
  - 900 GeV data and 2.3 TeV data

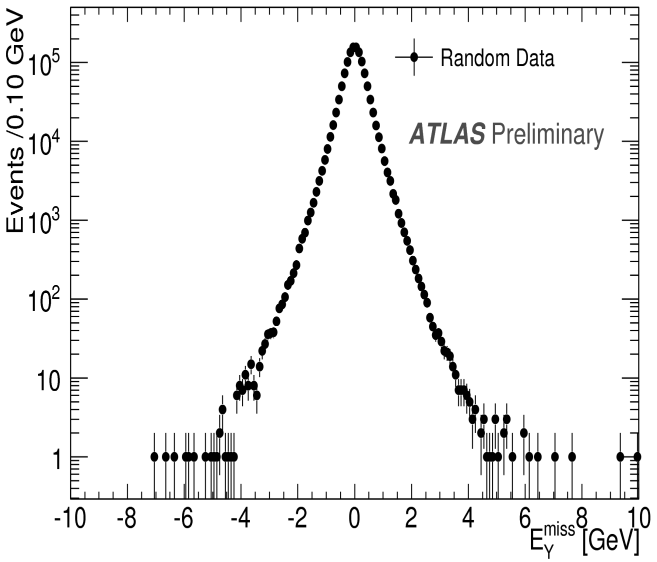
- **MonteCarlo**:
  - PYTHIA/Geant4 Minbias events: 1 Mevts at 900 GeV (200 Kevts at 2TeV)
    - Non diffractive(ND) + Single/Double diffractive(SD/DD)
      DD/SD/ND = 6.4 / 11.7 / 34.4 mb

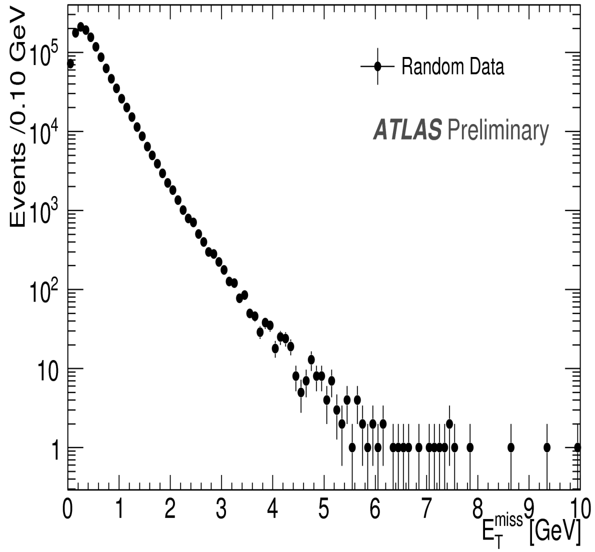
- **Collision Candidates selection (on data and MC):**
  - Evts triggered by at least 1 hit per side in Minimum Bias Trigger Scintillators (MBTS_1_1)
  - Signals coincident in a time window observed in both sides of end-cap calo or MBTS (MBTS timing ($\Delta\ t_{A\text{-}C}$<10 ns) .OR. LAr timing ($\Delta\ t_{A\text{-}C}$<5 ns))
  - Event Cleaning vs fake jets (Antikt R=0.6 jets (EM scale) p_T>7GeV):
    - Known problematic cells, energy estimated from neighbours jet energy coming from such cells must be <20%
    - Jet energy not concentrated in less than 3 cells (noisy cells)
      - Few per mill events rejected

→ data ~600kevts at 900 GeV (20kevts at 2TeV)

Random trigger events

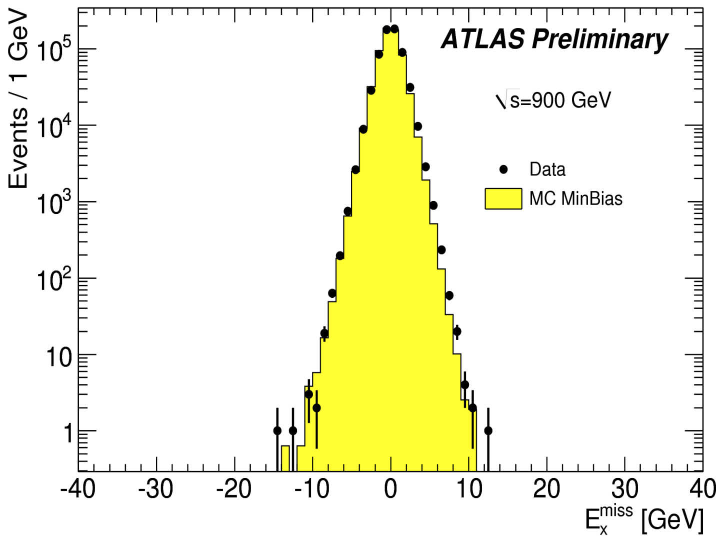


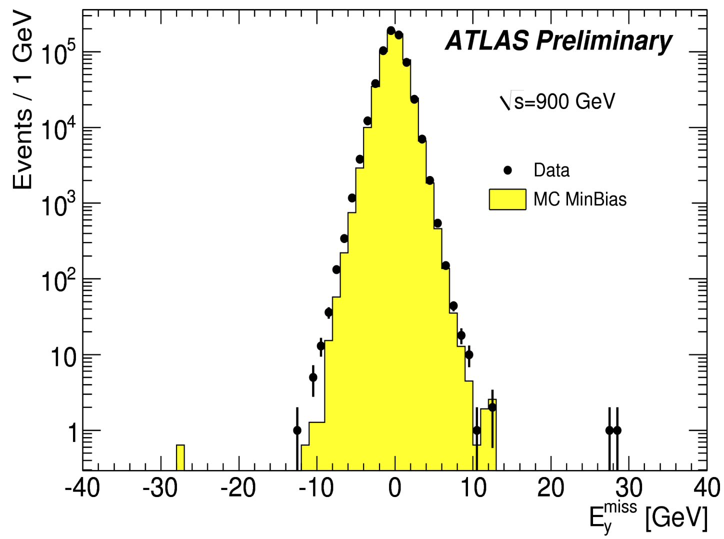


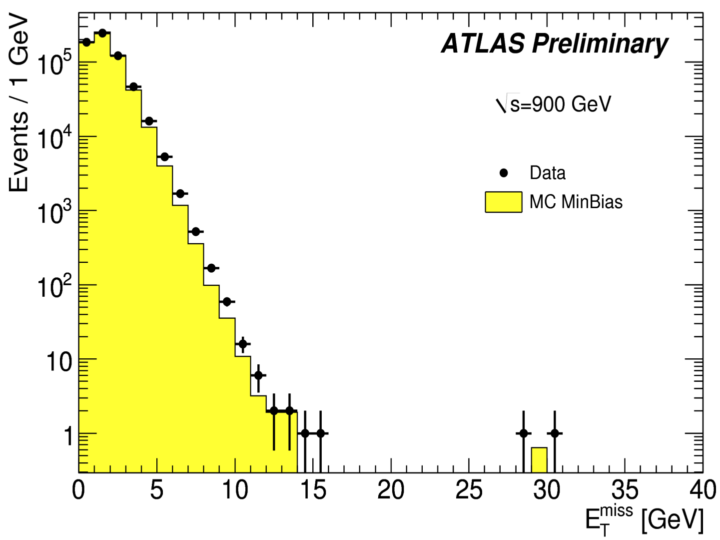


- Useful to understand the noise contribution
- Distribution centered on zero with RMS 0.43 GeV
- No tails in E_T^{miss} distribution as expected

pp collision events $\sqrt{s}$ = 900 GeV

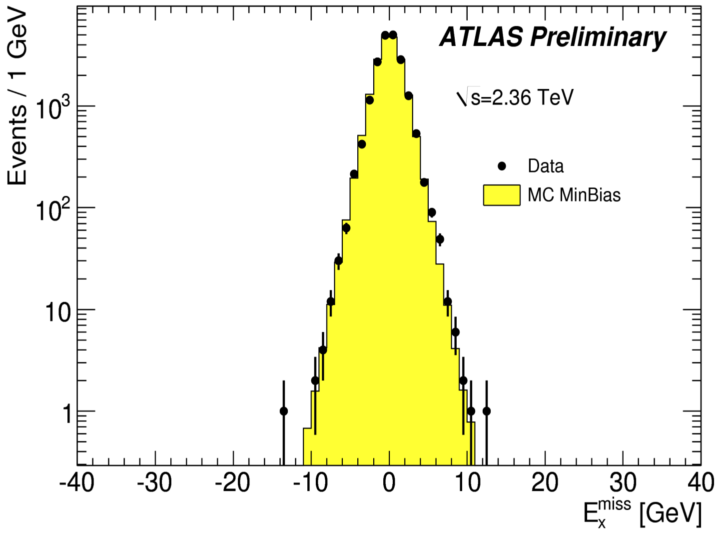


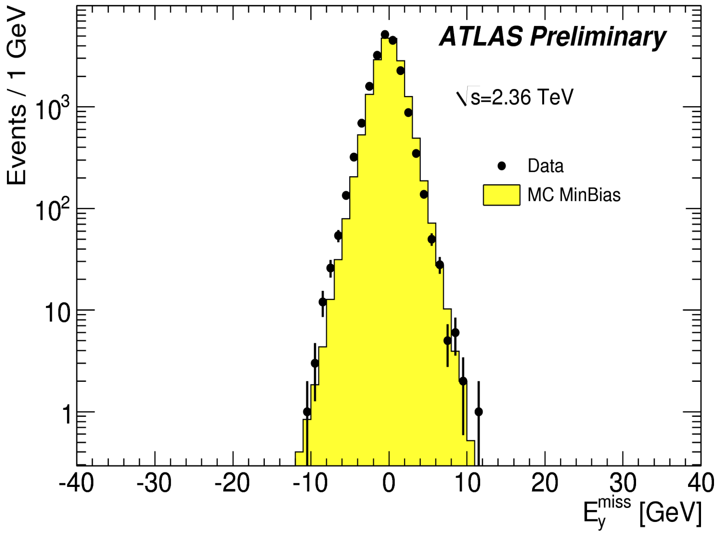


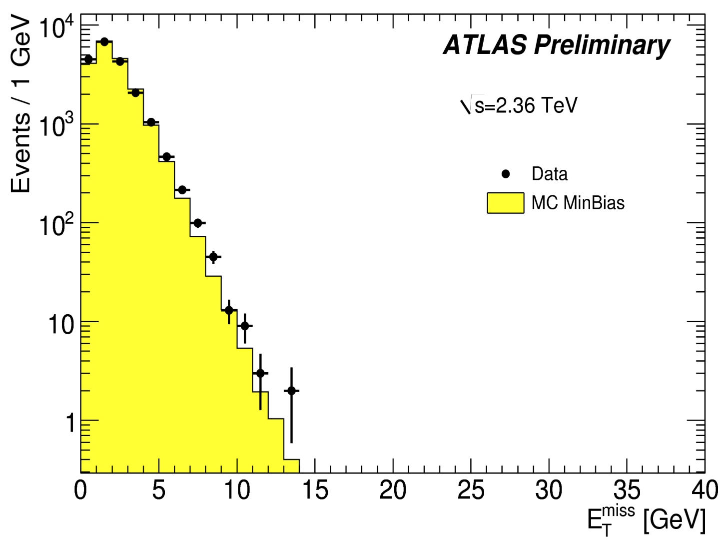


- In minbias events → no true E_T^{miss}
  → $E_{x/y}$ distributions peaked at 0
- RMS 1.4 GeV → higher than in randomly trigger evts because of
  - real ΣE_T
  - finite calorimeter resolution
- **Very few events in tails**
- **Good agreement DATA-MC**

pp collision events √s = 2.36 TeV







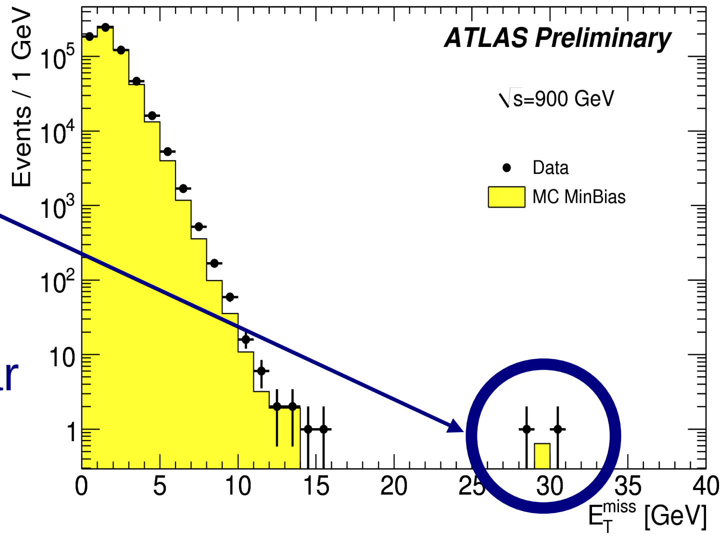
- In minbias events → no true E_T^{miss} → $E_{x/y}$ distributions peaked at 0
- RMS 1.8 GeV
- **No events in tails!**
- **Very good agreement DATA-MC**

E_T^{miss} Tails

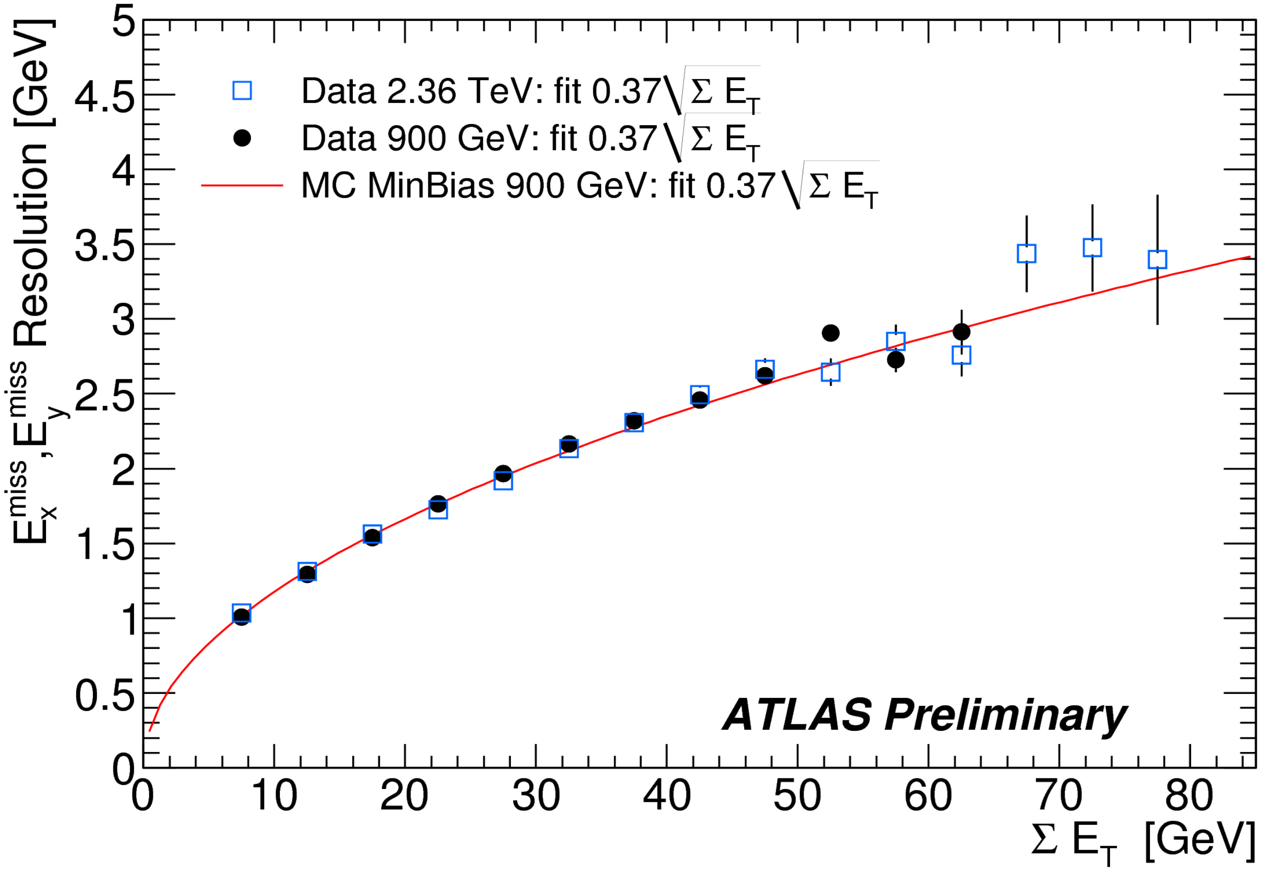
- New physics may produce E_T^{miss} Tails
  - Need to control fake Etmiss at a very high level
- Main sources of Fake E_t^{miss}
  - Hardware (noisy cells, problems linked to DAQ, …)
  - Software (corrections for “bad” calorimeter regions)
  - Physics (Cosmic background, beam halo, beam gas...)

- Strategy up to now: remove ANY noisy jet events
- Work started on alternative solutions:
  - Detect fake Tile TopoCluster, use cluster timing

- After cleaning (with detector/jets)
  - 2 events in data
    - Due to out of time signal superposed to the event (use timing cuts)
  - 1 event in MC
    - One jet lost because in crack (use angular correlation cut between E_T^{miss} and jets)



E_T^{miss} Resolution



- E_x^{miss} and E_y^{miss} as a function of ΣE_T
- Plot done in ΣE_T bins
- Good agreement data-MC

Refined E_T^{miss}

- **Separate contributions of reconstructed physics objects** (e/γ, τ, b-jet, jet, μ, ...)
- Most **complex schema** to apply after validation of reconstructed objects:
  - After particle identification, decomposition of each object into constituent Calorimeter Cells

Electrons | Photons | Taus | Jets | Muons | Unused TopoClusters

Go back to constituent Calorimeter Cells → apply overlap removal at Cell level →
Cell calibration weights dependent on the object → add them to calculate partial terms

MET_RefEle + MET_Refγ + MET_RefTau + MET_RefJet + MET_RefMuo + MET_CellOut

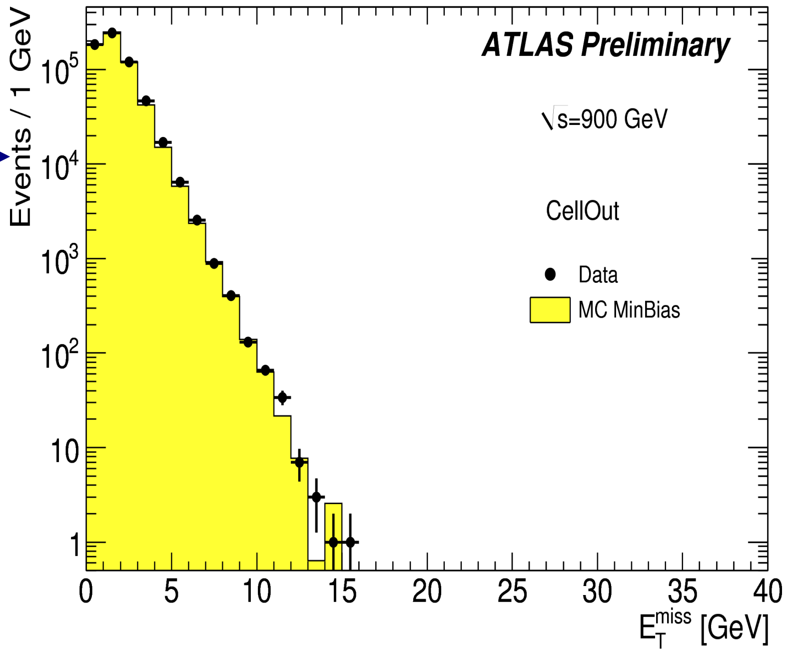
+ MET_Cryo + MET_Muon = MET_RefFinal

In minbias events only those contributions are significant

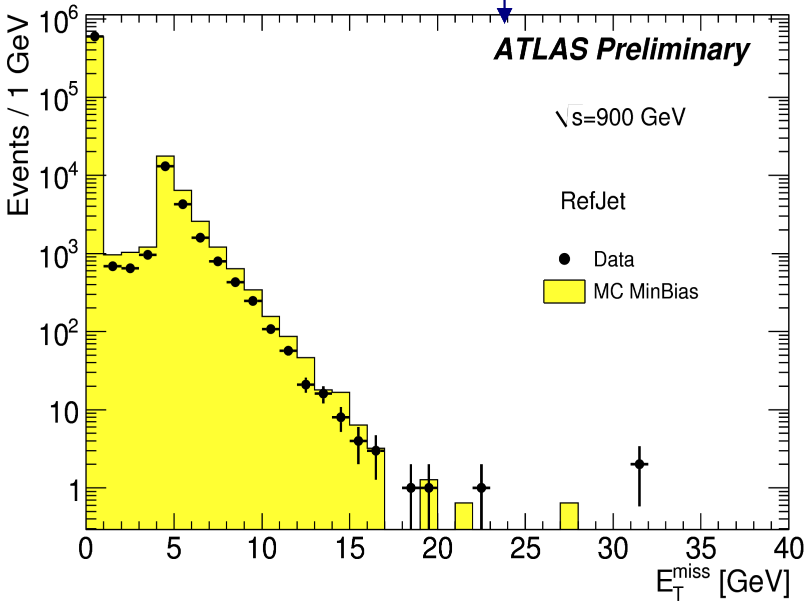
CellOut & RefJet Contributions

In minimum bias events E_T^{miss} is due to :

- cells in topoclusters not associated to any reconstructed object (**CellOut**)



- cells belonging to jets (**RefJet**) → Jet Energy measured at EM Scale, jet p_T>4GeV



Data in very good agreement with MC
→ **E_T^{miss} is well understood in ATLAS!**

Conclusions and Outlook

- **Minbias evts at 0.9 (2.36) TeV provide a first test of E_T^{miss}**

→ The algorithms in MET package work well and are robust.

- Work at **EMscale** with cells from **TopoClusters** : MET_Topo
  - Missing transverse energy (E_x^{miss}, E_y^{miss}, E_T^{miss}):
    - Good agreement data-MC for distribution and performance
    - With good calorimeter + event cleaning, E_T^{miss} tails compatible with MC
- A look at different terms entering final E_T^{miss} → Encouraging results

- **Plans for 7 TeV**
  - ~10 pb^{-1}: QCD di-jets → E_T^{miss} calibration
  - 10-100pb^{-1}: W production → set E_T^{miss} scale with $W \rightarrow e\nu/\mu\nu$
  - 100-200pb^{-1}: Z production
    - diagnostic plot in $Z \rightarrow ll$ (sensible to CellOut)
    - E_T^{miss} scale with $Z \rightarrow \tau\tau$

Backup

Time stability