Missing Tranverse Energy in first ATLAS data

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07.04.2010

Transverse Missing Energy:

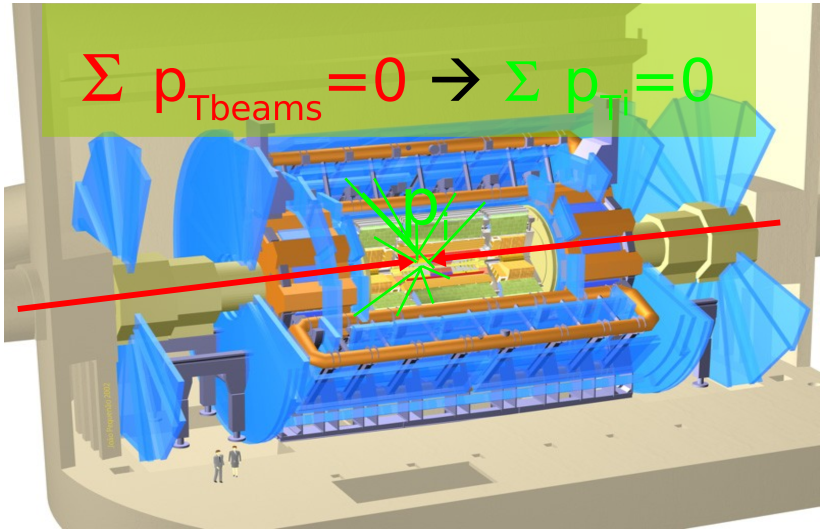
$$E_T^{miss} = \sqrt{E_x miss^2 + E_y miss^2}$$

$E_x miss = -\Sigma\ Ex$

$E_y miss = -\Sigma\ Ey$

$SumE_T = \Sigma\ E_T$

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 signals (input: 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

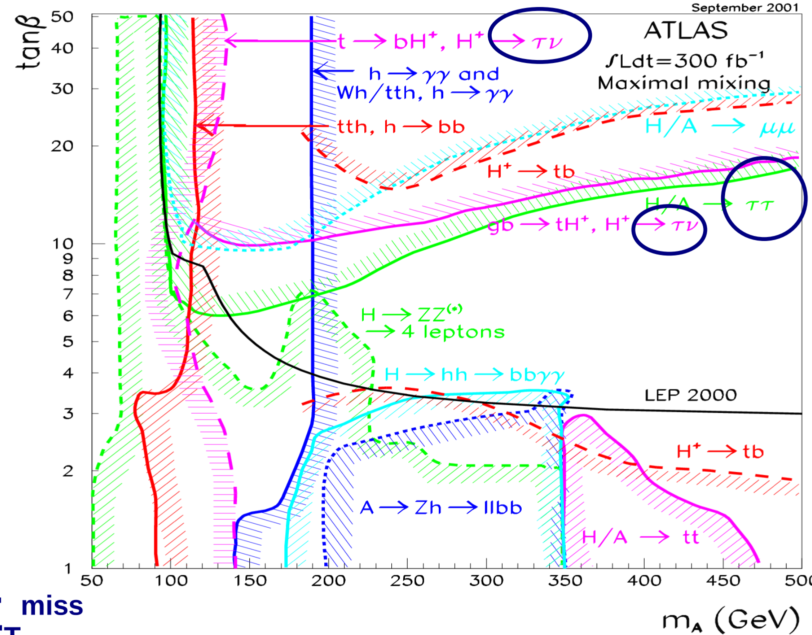
E_T^{miss} importance in ATLAS physics

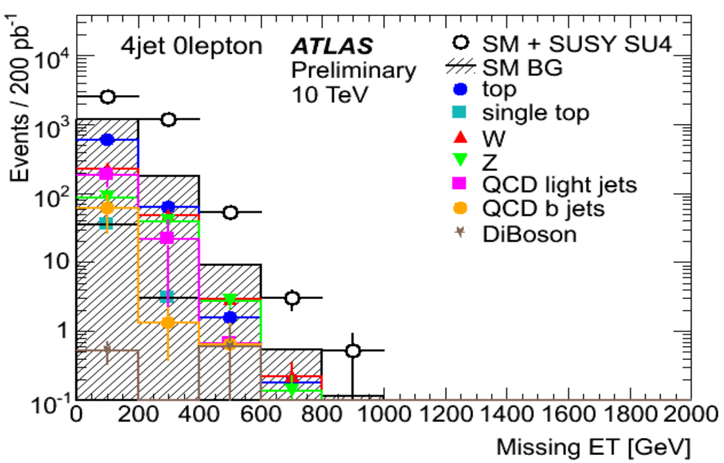
TRUE E_T^{miss}

E_T^{miss} is due to non interacting particles in detector (ν , lsp)

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 (VBF$h \rightarrow \tau\tau$, $tth \rightarrow \tau\tau$)
- 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 $\rightarrow$ Large E_T^{miss} signature (lsp)





FAKE E_T^{miss}

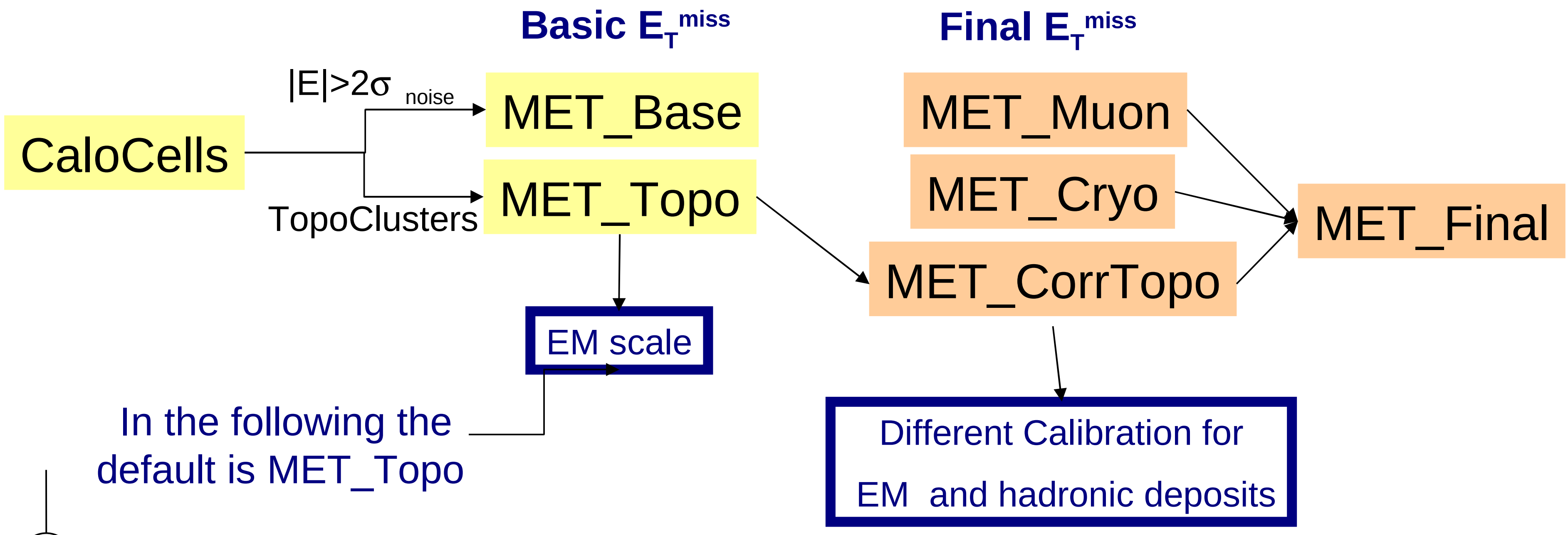
- Particles outside the detector acceptance
- Other particles arriving at the detector
- Energy lost in dead materials
- Problems in detector, pileup, electronic noise
- Many other effects...

A bad measurement of E_T^{miss} could fake a non-zero reconstructed E_T^{miss} in events with no physical E_T^{miss} $\rightarrow$ QCD with fake E_T^{miss} background for inclusive no-lepton SUSY evts

E_T^{miss} reconstruction in ATLAS: 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}** :
  - Calibration (different calibration approaches)
  - Correction for energy lost in cryostat between EM and Had calorimeters
  - Contribution from muons



E_t^{miss} reconstruction in ATLAS: Basic E_T^{miss}

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

- **All cells in Topo-Clusters are used (MET_Topo)**
  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

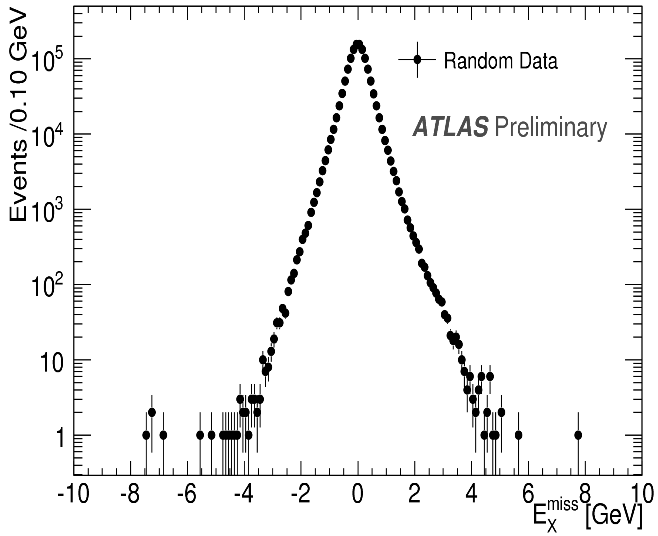
First ATLAS data: samples and event selection

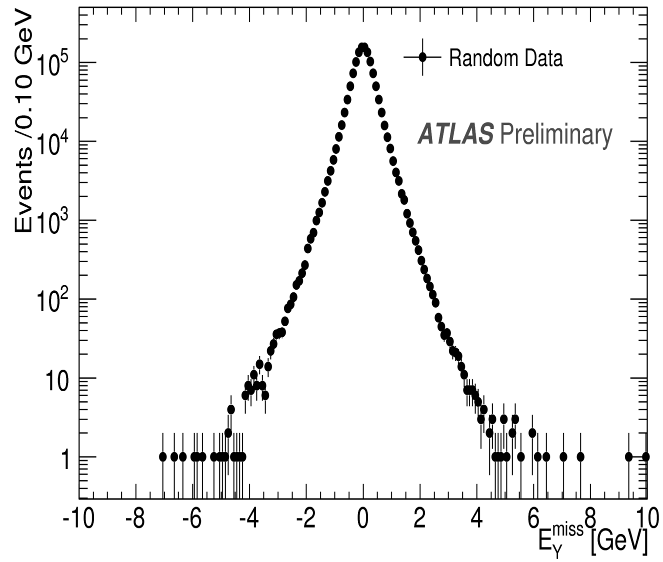
- **Data at 900 GeV and 2.3 TeV taken at the end of 2009**
(stable beam, nominal magnetic field, good calorimeters)

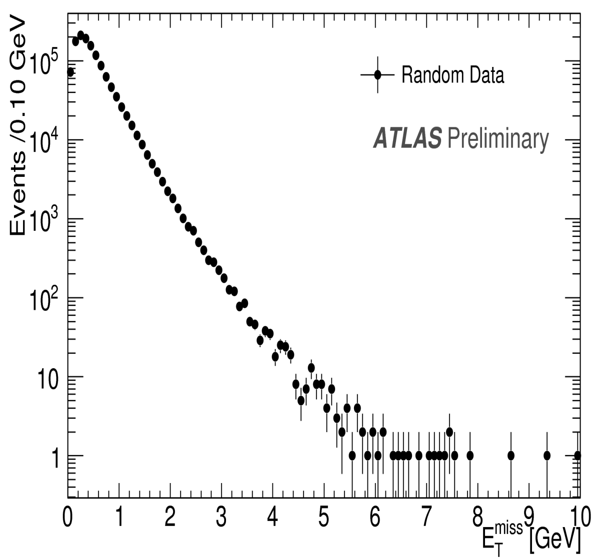
- **MonteCarlo**:
  - PYTHIA/Geant4 Minbias events: 1 Mevts at 900 GeV (200 Kevts at 2TeV)
    - Non diffractive(ND) + Single/Double diffractive(SD/DD)
      DD/SD/ND = 6.4 / 11.7 / 34.4 mb
- **Collision Candidates selection (on data and MC):**
  - Evts triggered in Minimum Bias Trigger Scintillators
  - Signals observed in both sides of end-cap calorimeter or MBTS coincident in a time window(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):
    - Jet energy coming from known problematic cells (energy estimated from neighbours) 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)

E_T^{miss} in random trigger events

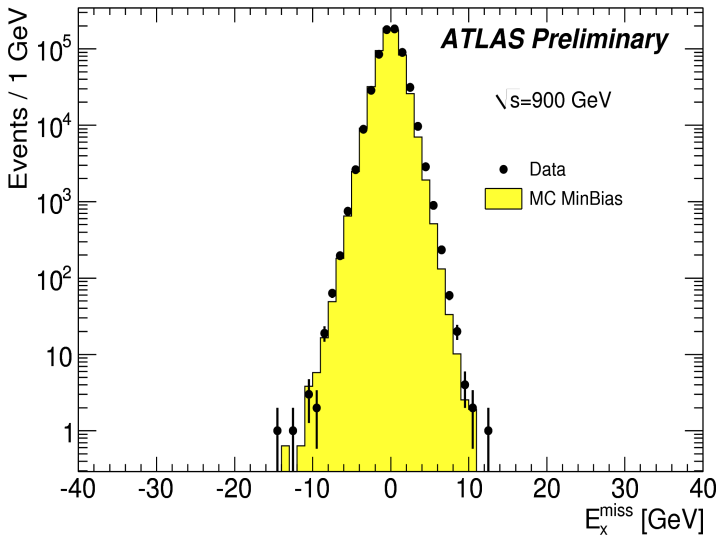


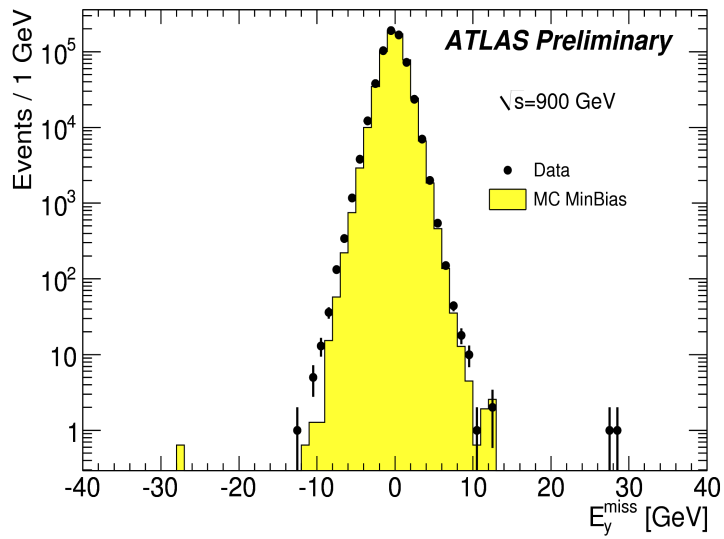


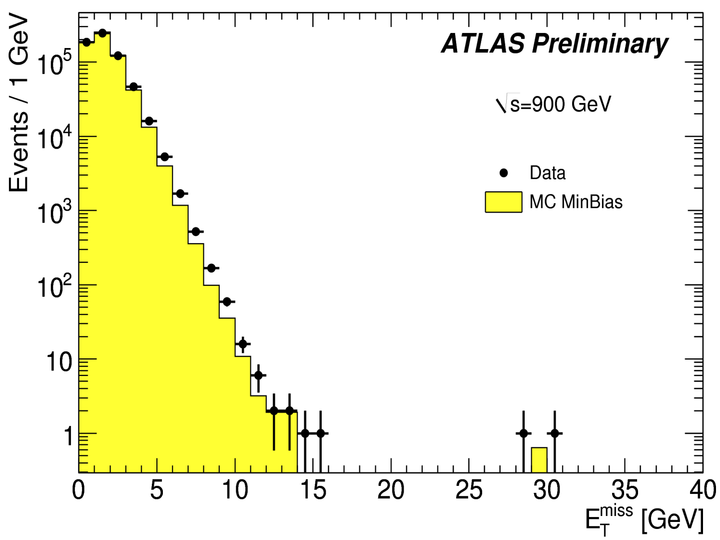


- Events not containing physics signals
- Useful to understand the noise contribution
- Distribution centered on zero with RMS 0.43 GeV
- No tails in E_T^{miss} distribution as expected

E_T^{miss} in pp collision events √s = 900 GeV

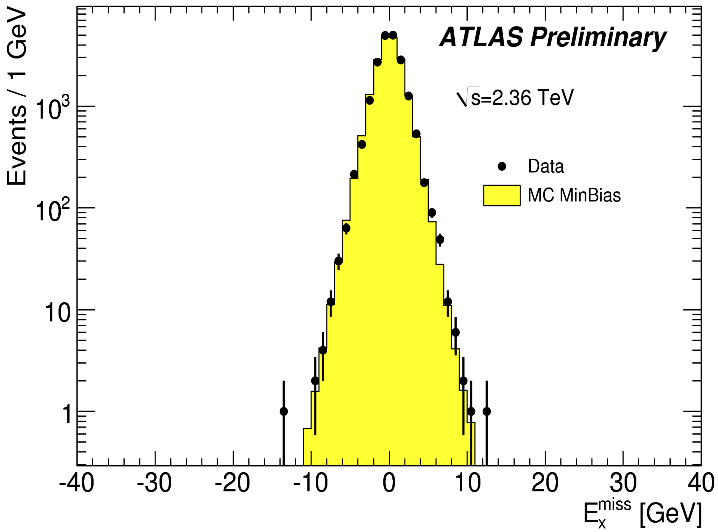


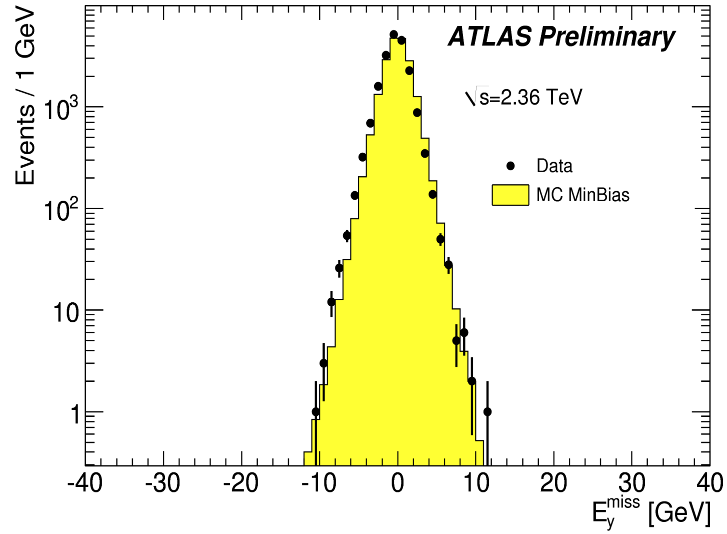


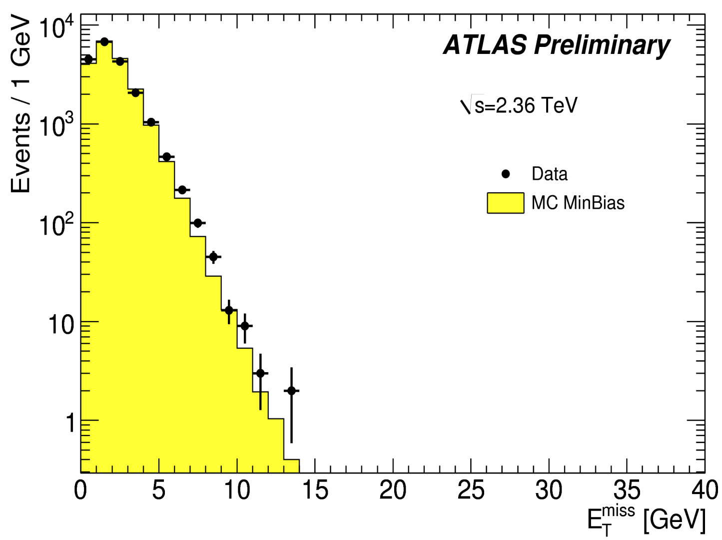


- In minbias events → no true E_T^{miss}
  → $E_{x/y}^{miss}$ distributions peaked at 0
- RMS 1.4 GeV → higher than in random trigger evts because of
  - real ΣE_T
  - finite calorimeter resolution
- **Very few events in tails**
- **Good agreement DATA-MC**

E_T^{miss} in pp collision events √s = 2.36 TeV







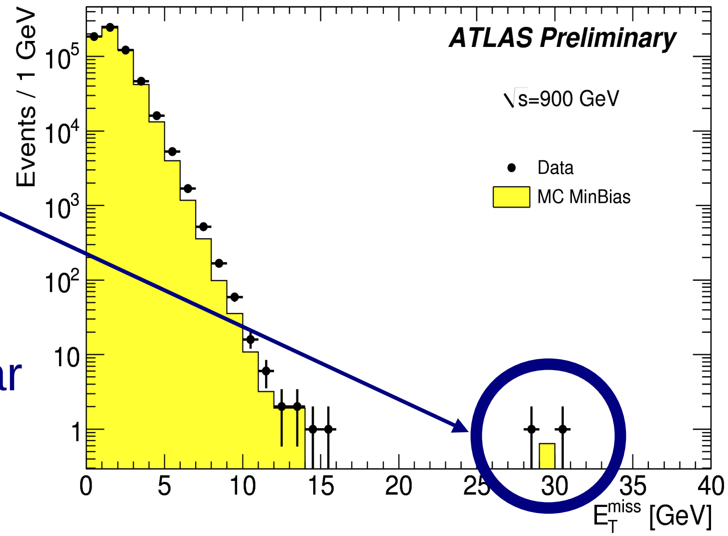
- In minbias events → no true E_T^{miss} → $E_{x/y}^{miss}$ distributions peaked at 0
- RMS 1.8 GeV
- **No events in tails!**
- **Good agreement DATA-MC**

E_T^{miss} tails in pp collision events $\sqrt{s}$ = 900 GeV

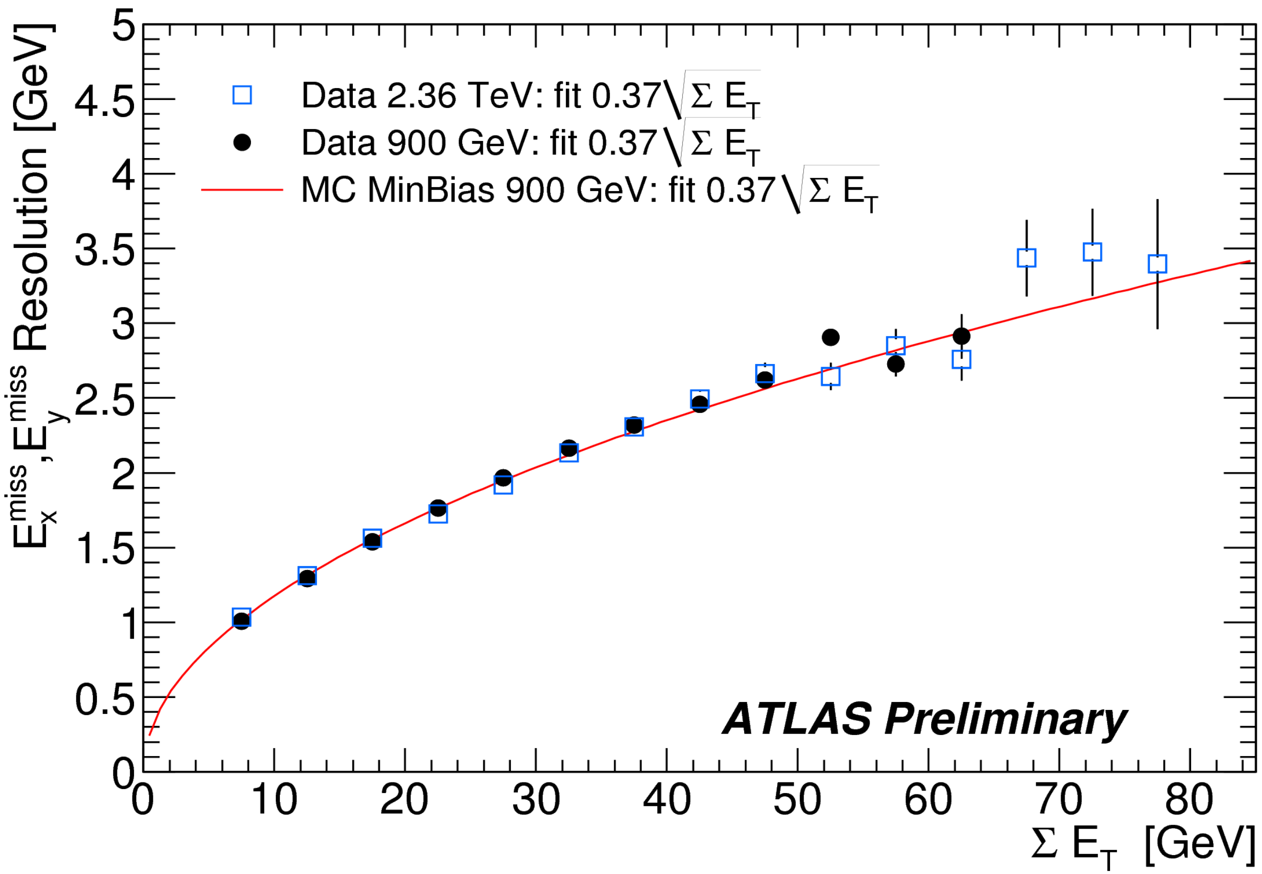
- New physics may produce E_T^{miss} Tails
  - Need to control fake Etmiss at a very high level
- Main sources of Fake E_t^{miss}
  - Hardware (noisy cells, problems linked to DAQ, …)
  - Software (corrections for “bad” calorimeter regions)
  - Physics (Cosmic background, beam halo, beam gas...)

- 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)



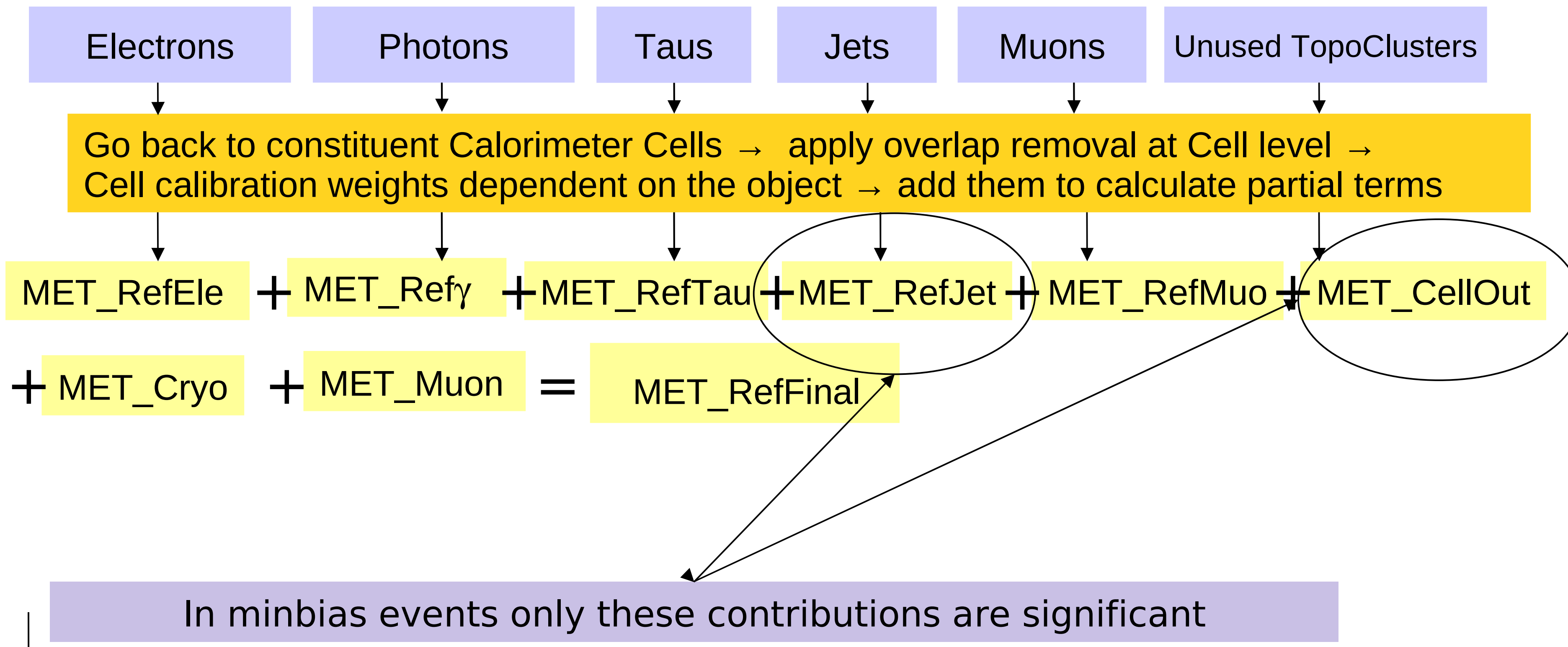
E_T^{miss} Resolution



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

E_T^{miss} reconstruction in ATLAS: Refined E_T^{miss}

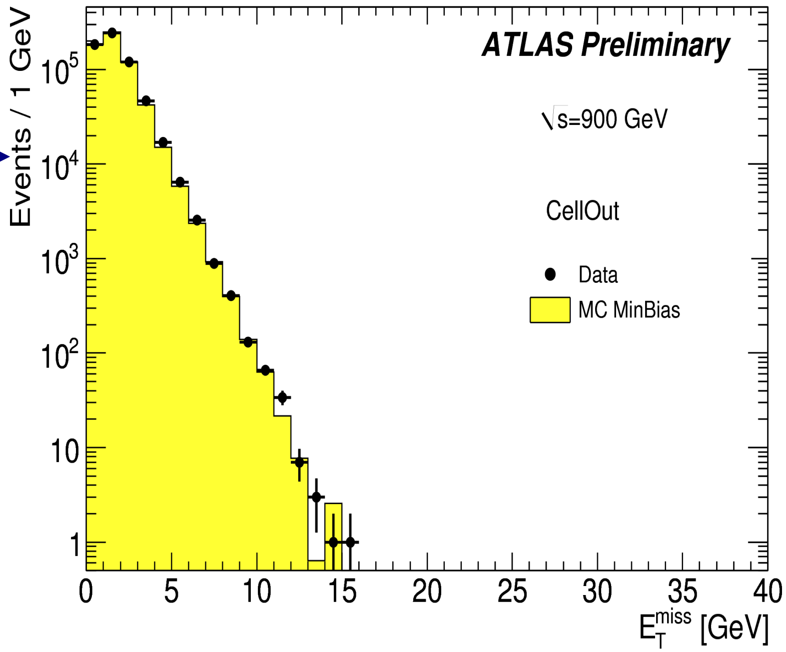
- **Separate contributions of reconstructed physics objects** (e/γ , τ , b-jet, jet, μ , ...)
- Most **complex schema** to be used after validation of reconstructed objects:
  - After particle identification, decomposition of each object into constituent Calorimeter Cells



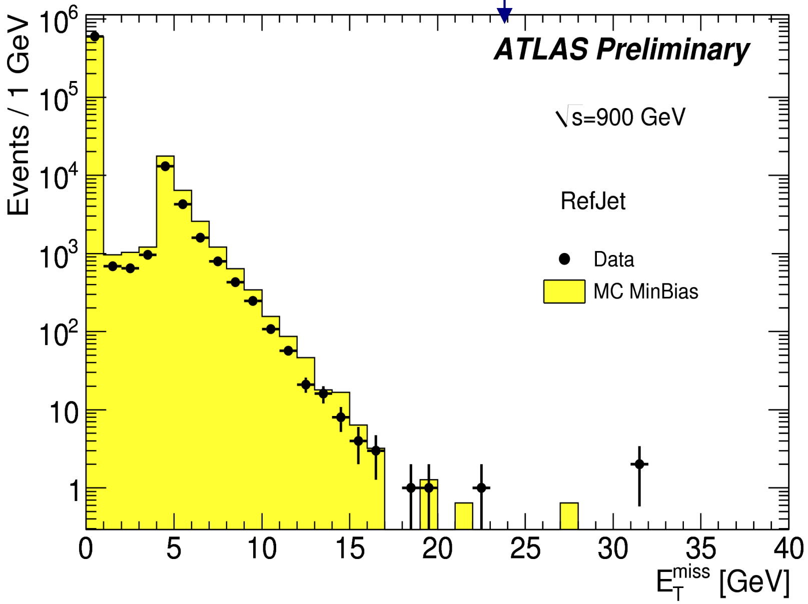
Contributions to E_T^{miss} in pp collision events √s = 900 GeV

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 900 GeV and 2.36 TeV provided 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 → E_T^{miss} scale with $W \rightarrow e\nu$ / $\mu\nu$
  - 100-200pb^{-1}: Z production
    - diagnostic plot in Z → ll (sensible to CellOut)
    - E_T^{miss} scale with $Z \rightarrow \tau\tau$

No surprises in minbias at 7 TeV... still few tails... agreement data-MC

Backup

Time stability