Missing Tranverse Energy in first ATLAS data

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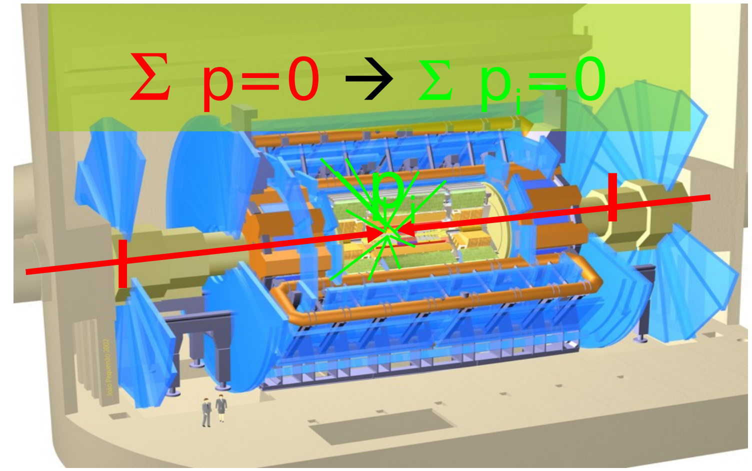
E_T^{miss} Reconstruction in ATLAS

Transverse Missing Energy:

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

$$\left.\begin{array}{l} E_x miss = -\Sigma\ Ex \\ E_y miss = -\Sigma\ Ey \\ SumE_T = \Sigma\ E_T \end{array}\right\}$$

Sum of energy of all particles seen in the detector



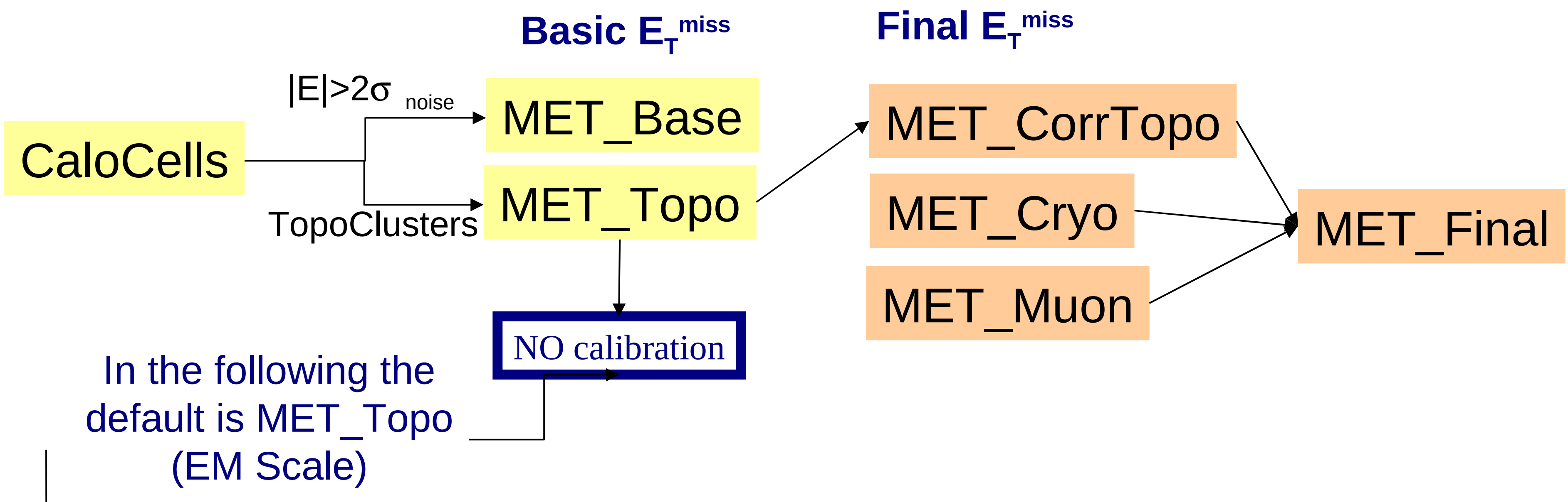
E_T^{miss} is a complex event quantity:

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

From Basic to Calibrated E_T^{miss}

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

- **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 (N < S)
  - 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

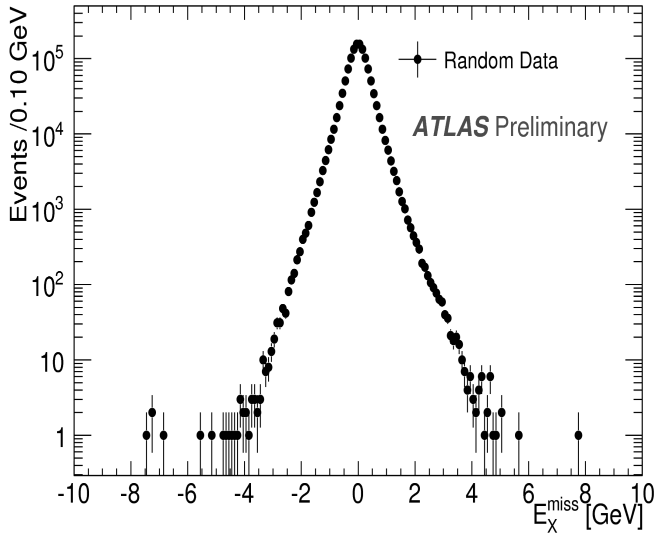
Data samples and event selection

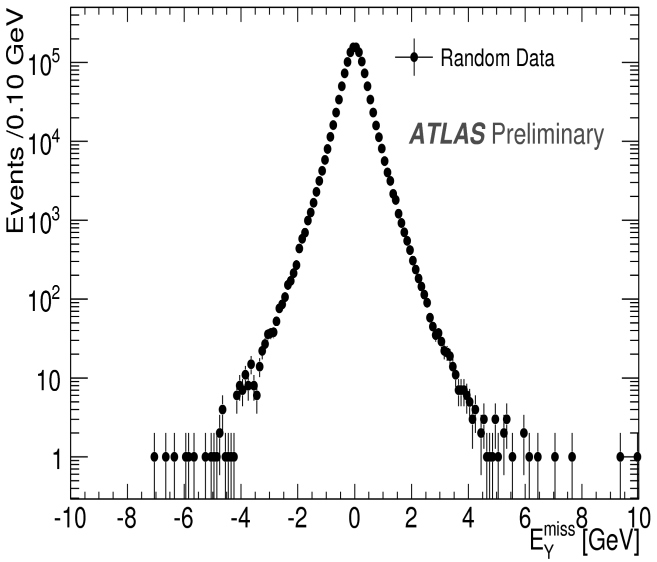
- **Data (stable beam, nominal field condition, good calorimeters)**:
  - 900 GeV data and 2.3 TeV data
- **MonteCarlo**:
  - PYTHIA/Geant4 Minbias events: 1 Mevts at 900 GeV (200 Kevts at 2TeV)
    - Non diffractive(ND) + Single/Double diffractive(SD/DD)
      DD/SD/ND = 6.4 / 11.7 / 34.4 mb

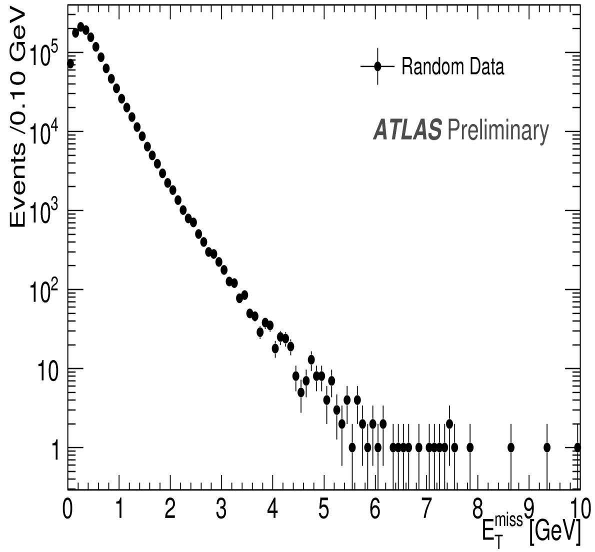
- **Collision Candidates selection (on data and MC):**
  - Evts triggered by at least 1 Minimum Bias Trigger Scintillator (MBTS_1_1)
  - Signals coinciding in a time window observed in both sides of end-cap calo or MBTS (MBTS timing ($\Delta t_{A\text{-}C}$<10 ns) .OR. LAr timing ($\Delta t_{A\text{-}C}$<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
      - Few per mill events rejected

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

Randomly trigger events

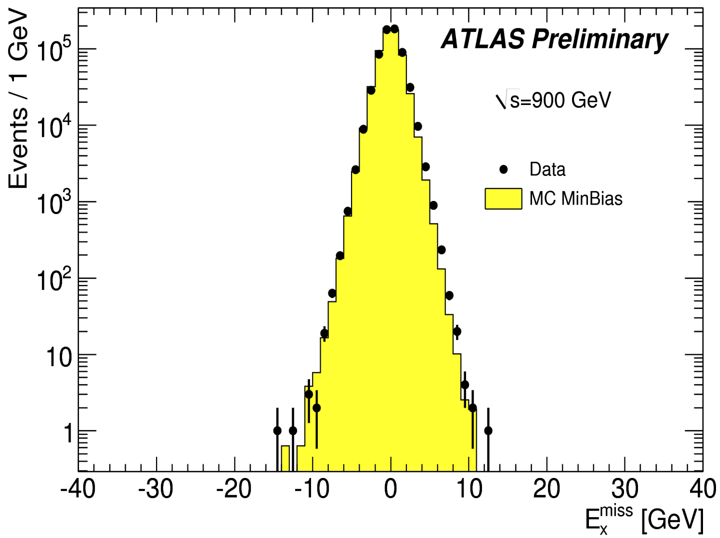


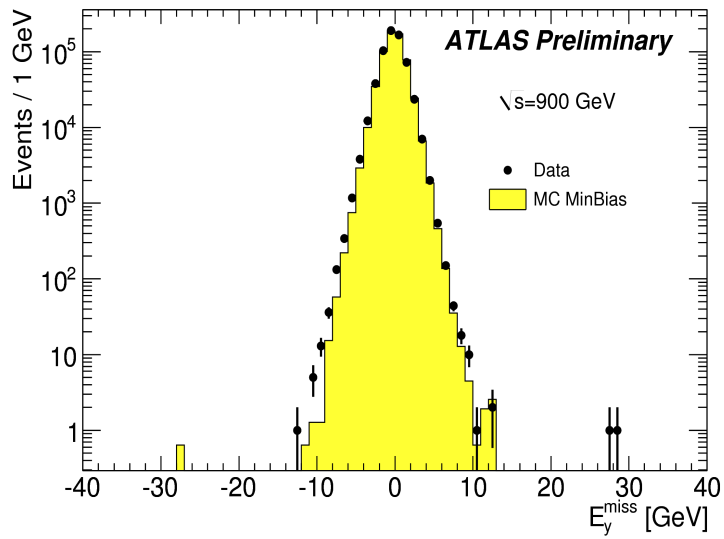


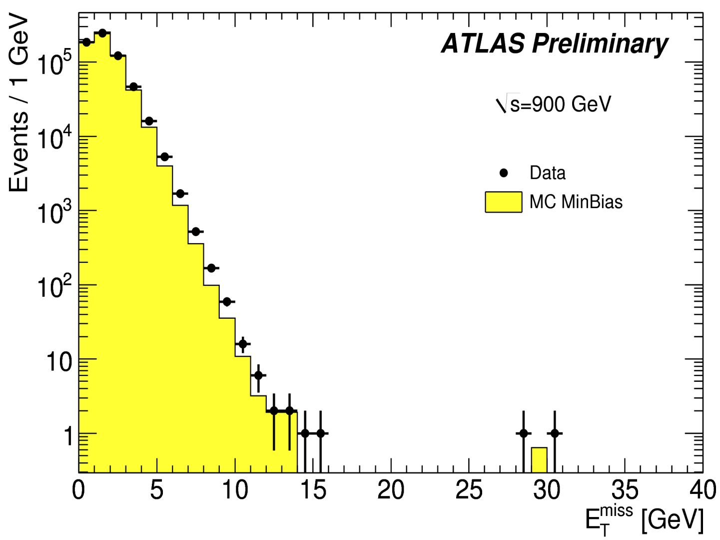


- Useful to understand the noise contribution
- Gaussian distribution centred on zero with RMS 0.43 GeV
- No tails in E_T^{miss} distribution as expected

pp collision events √s = 900 GeV



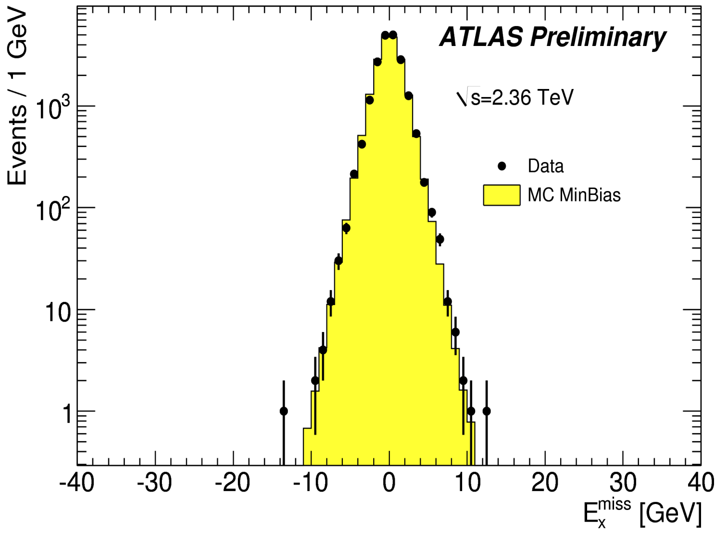


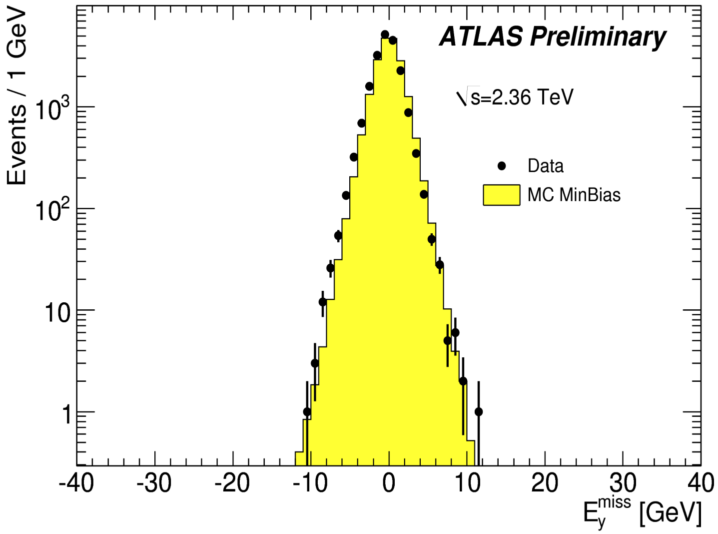


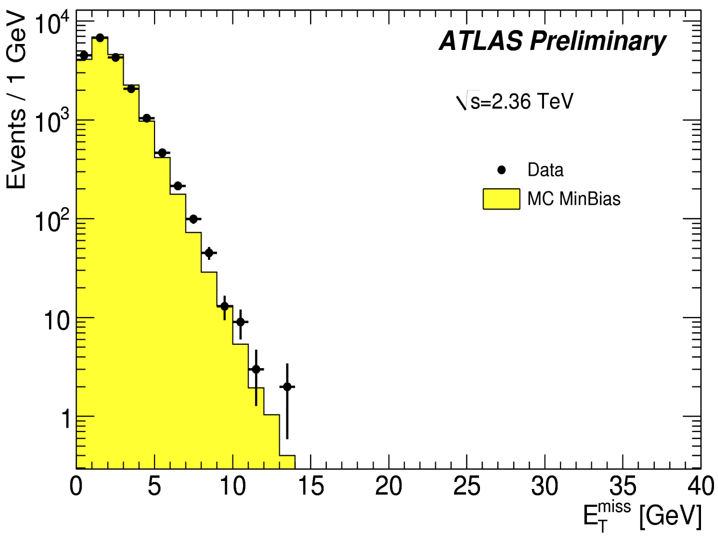
- In minbias events → no true MET → $E_{x/y}$ distributions peaked at 0
- RMS 1.4 GeV → higher than in randomly trigger evts because of
  - real ΣE_T
  - finite calorimeter resolution

- **Very few tails**
- Good agreement DATA-MC

pp collision events √s = 2.36 TeV



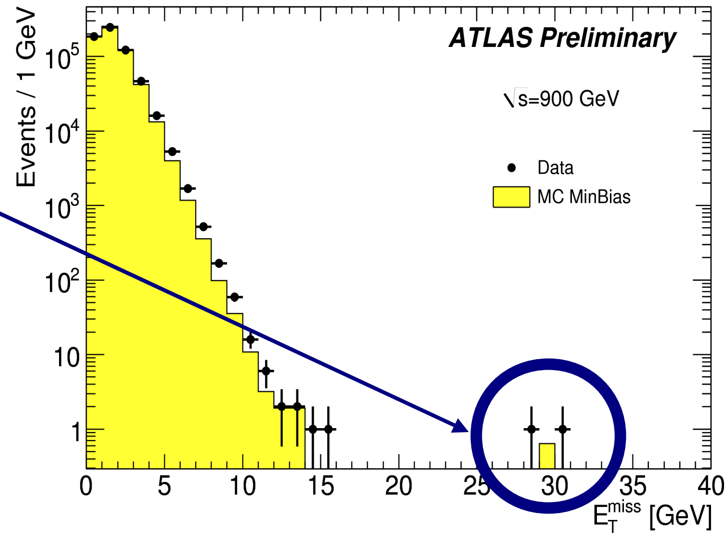




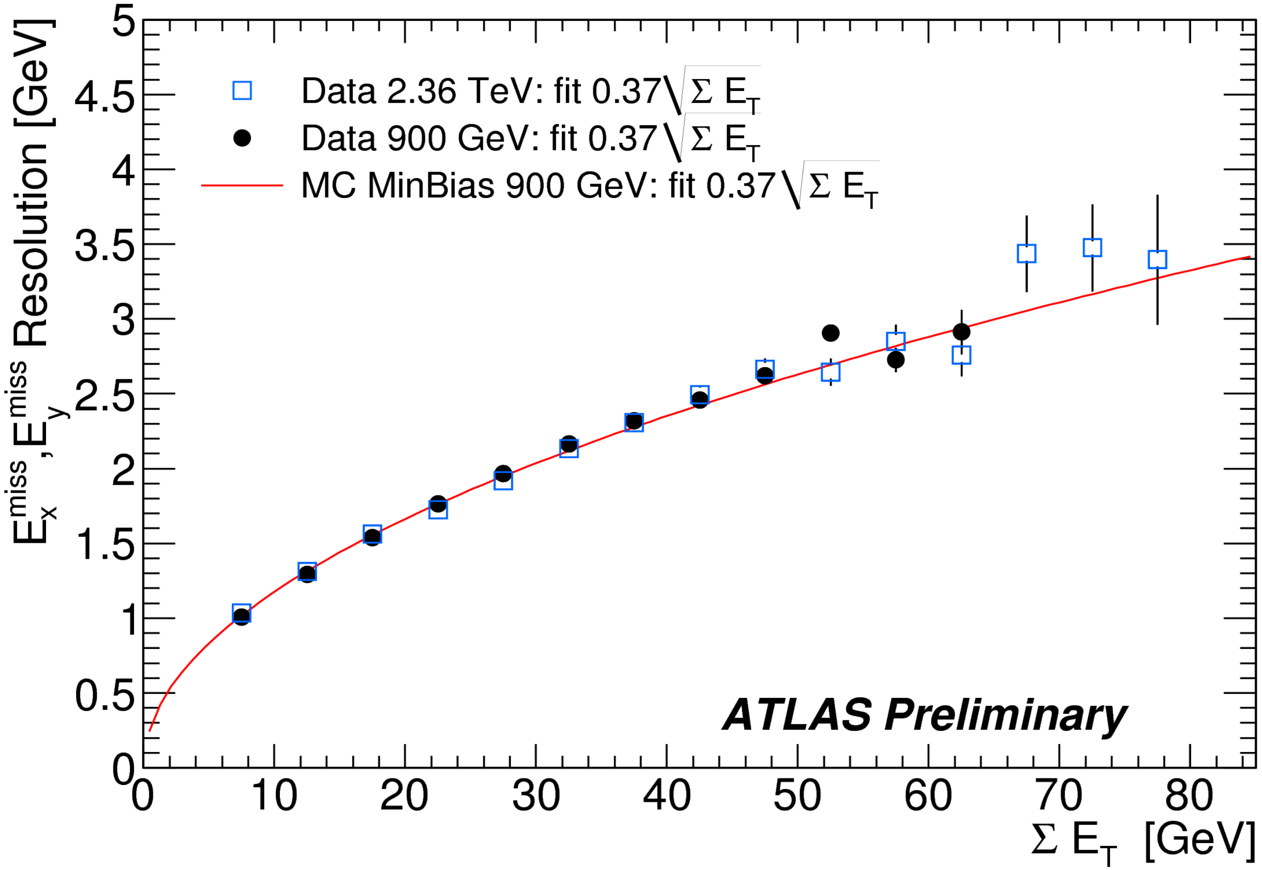
- In minbias events → no true E_T^{miss} → $E_{x/y}$ distributions peaked at 0
- RMS 1.8 GeV
- No events in tails!
- **Very good agreement DATA-MC**

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 during DAQ, …)
  - Software (corrections for "bad" calorimeter regions)
  - Physics (Cosmic background)
- 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
  - 1 event in MC
    - One jet lost because in crack



Missing ET 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

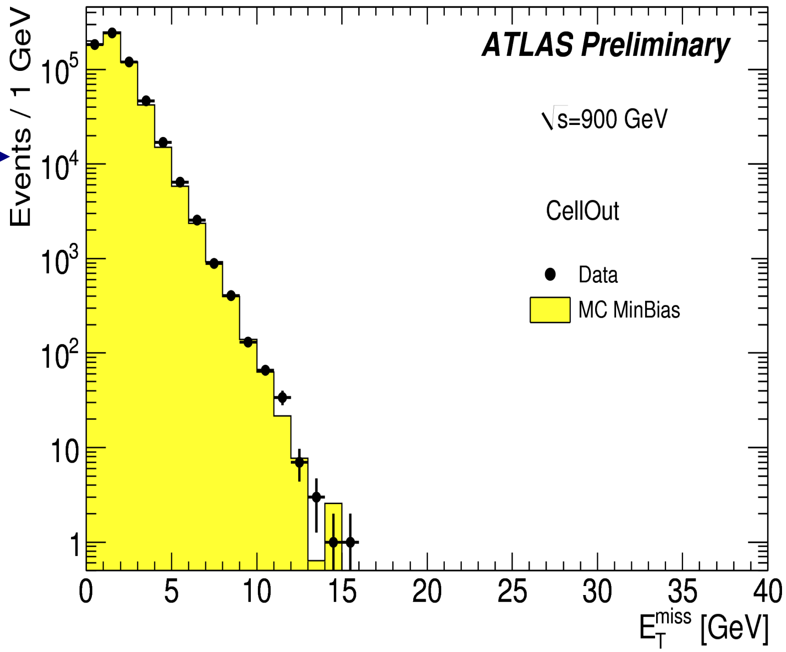
+ MET_Cryo + MET_Muon = MET_RefFinal

Here used to separate the different contribution in the event E_T^{miss}

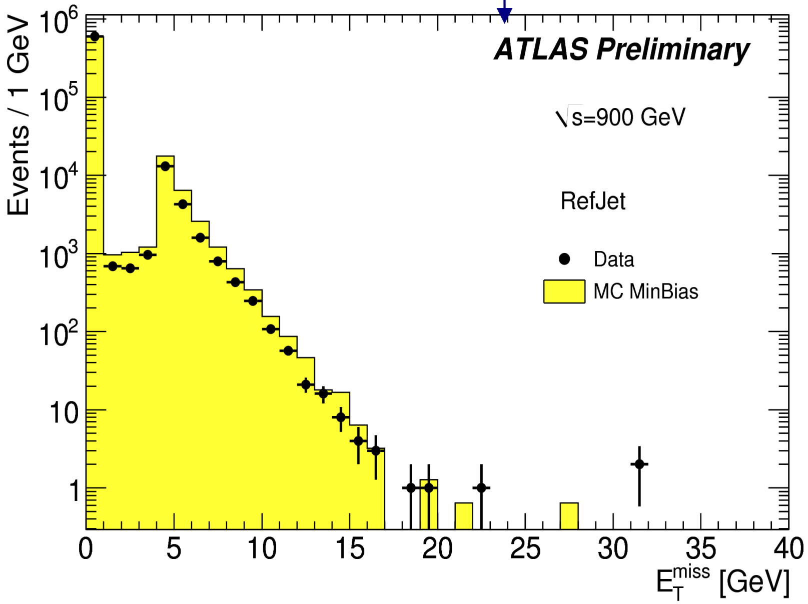
CellOut & RefJet Contributions

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}**

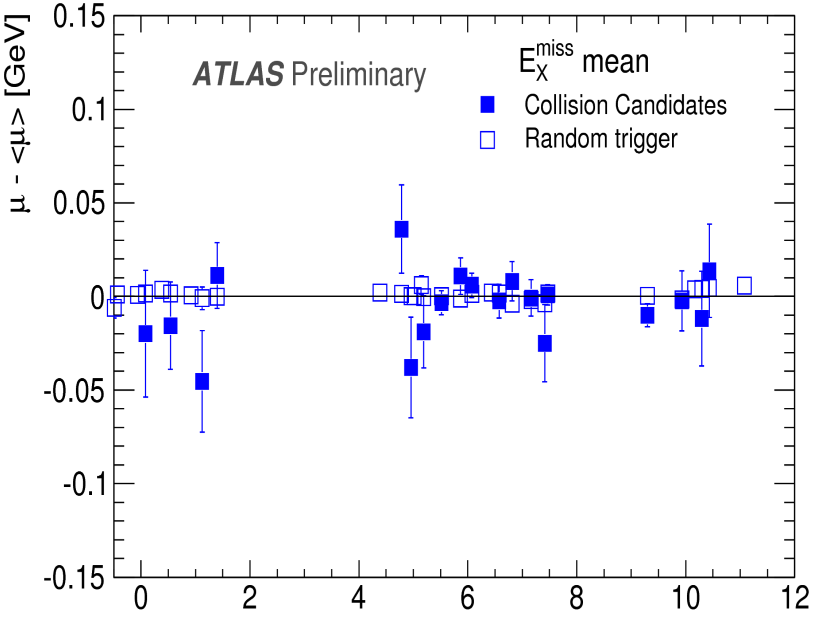
→ The algorithms in MET package work well and are robust.

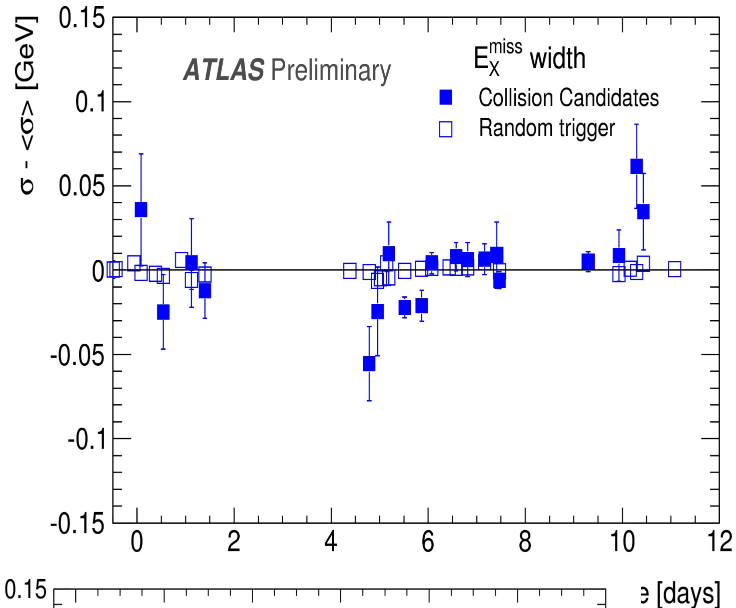
- Work at **EMscale** with cells from **TopoClusters** : MET_Topo
  - Missing transverse energy (E_x^{miss}, E_y^{miss}, E_T^{miss}):
    - Good agreement data-MC for distribution and performance
    - With good calorimeter + event cleaning, E_T^{miss} tails compatible with MC
- A look at different terms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

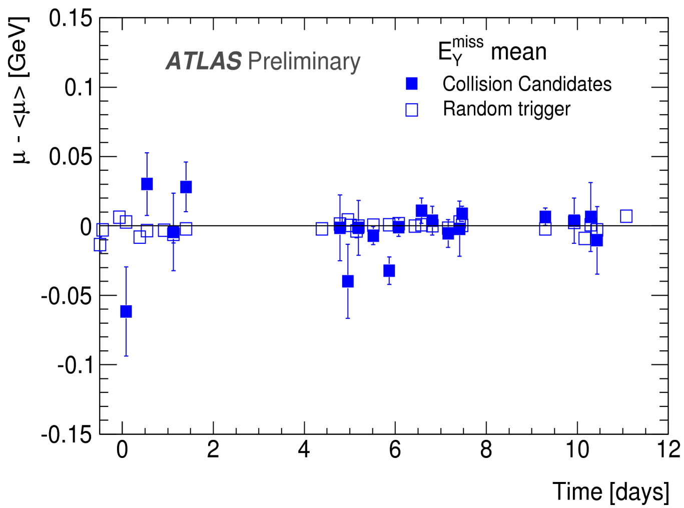
- **Plans for 7 TeV**
  - ~10 pb^{-1}: QCD di-jets → E_T^{miss} calibration
  - 10-100pb^{-1}: W production → set E_T^{miss} scale with W→lnu
  - 100-200pb^{-1}: Z production
    - diagnostic plot in Z → ll (sensible to CellOut)
    - E_T^{miss} scale with Z →τ τ

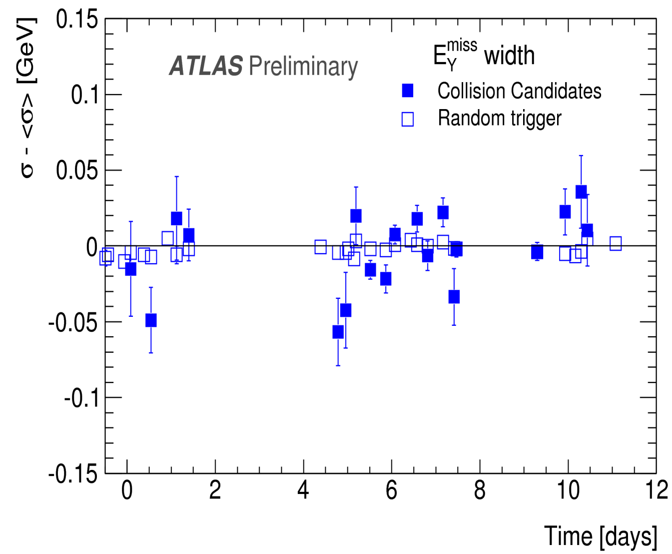
Backup

Time stability









Toward Final MET calculation

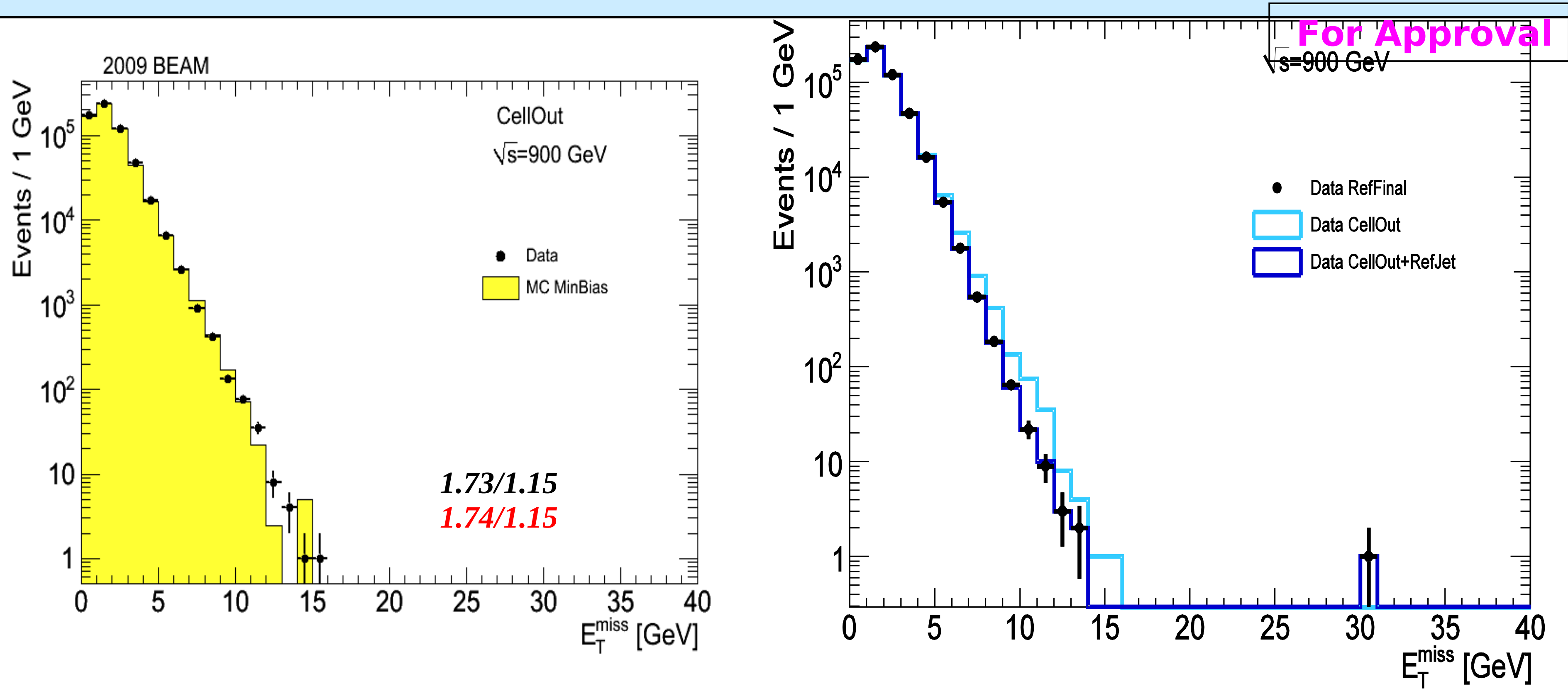
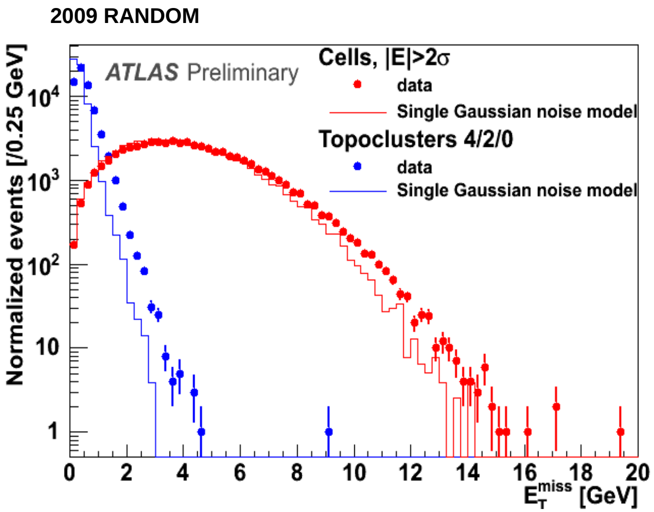


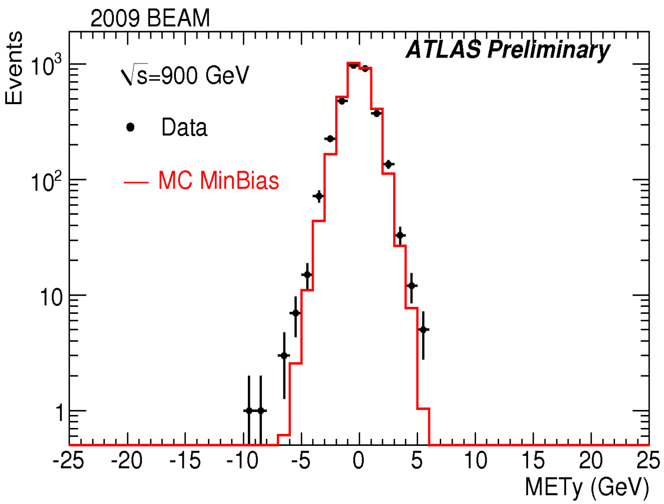
Figure 7: ***Left: Distribution of E_T^{miss} computed with cells from topoclusters not in reconstructed objects (CellOut) for data and Monte Carlo at 900 GeV center of mass energy. Right: Distribution of ETmiss (RefFinal) for data with superimposed distributions of CellOut and CellOut+RefJet for data. In both case, cell energies are at EM scale.***

Here jets reconstructed with Antikt D=0.6 algorithm (EM scale) with pT>4 GeV are used. Only 4% of events in data and 5 % in MC have jets (RefJet #0)

First results from LHC data

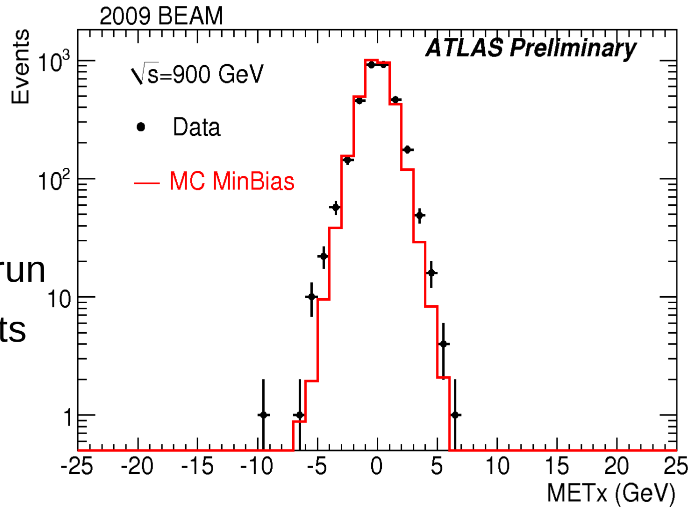
➔ 4 plots approved in December with low statistics





1 “good” run

~4000 evts



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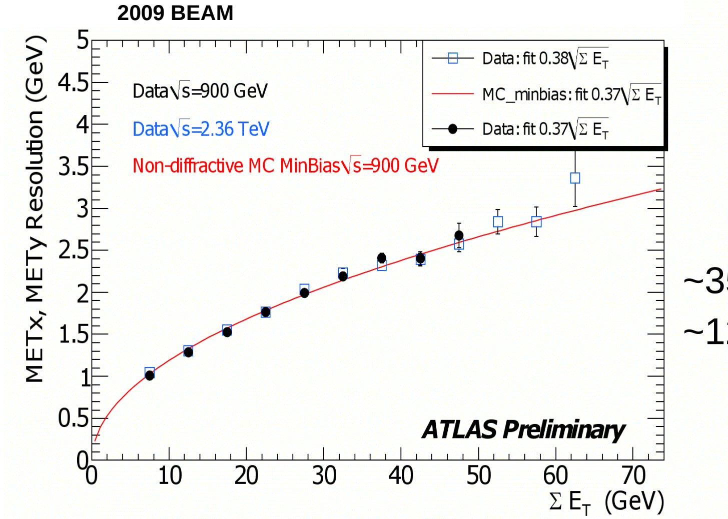
~4000 evts



~35Kevts 900Gev

~12Kevts 2.36TeV

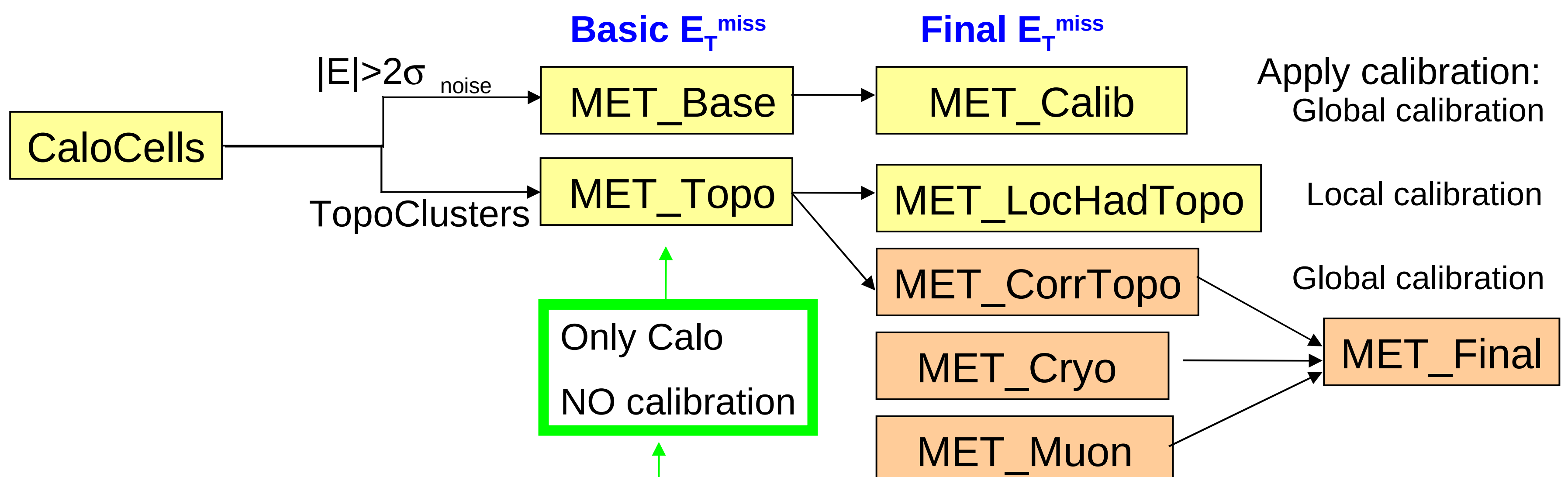
After Xmas reprocessing: update the plots with all 2009 statistics+new plots → CONF Note

From Basic to calibrated MET

⇒ **Basic E_T^{miss}** from all Calorimeter cells with two possible noise suppression approaches (MET_Base, MET_Topo)

⇒ **Final E_T^{miss}** adding calibration step plus contribution from muons and for dead material (MET_Final):

- Different calibrations approaches:
  - Global cell energy density calib (GC) and local hadron calib (LC)
- Correction for energy lost in cryostat between EM and Had calos (MET_Cryo)
- Contribution from muons (MET_Muon)



➔ In the following default is MET_Topo (EM Scale) – calorimeters only

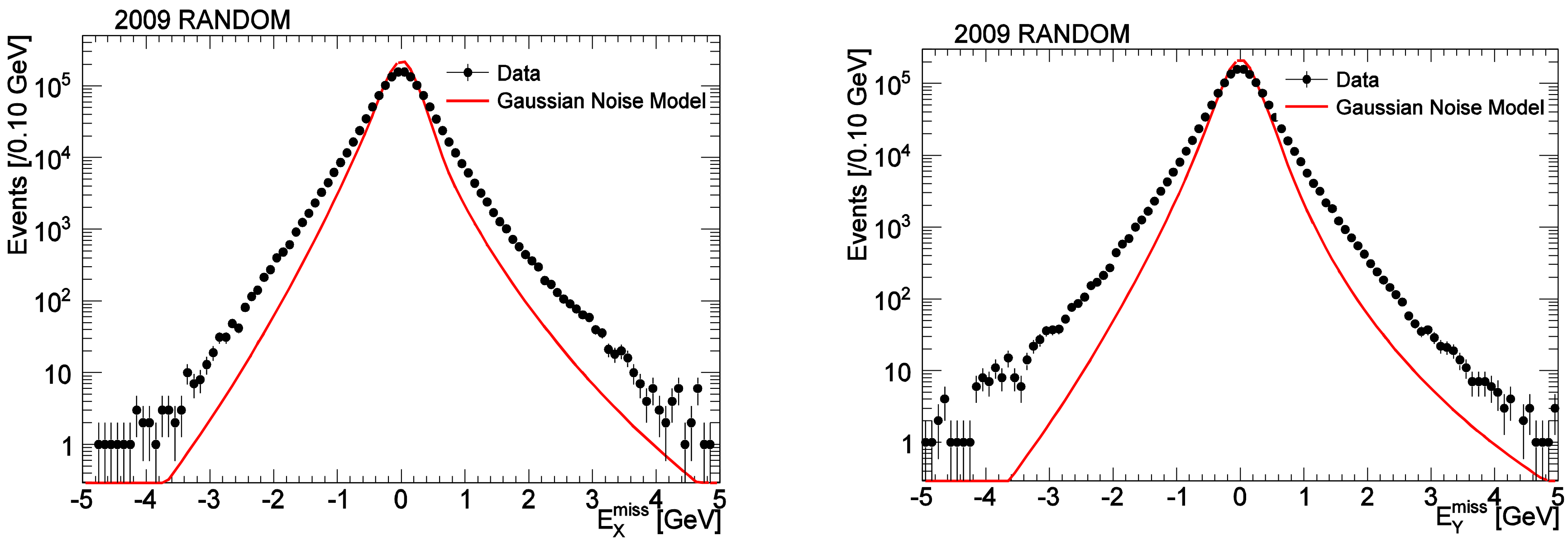
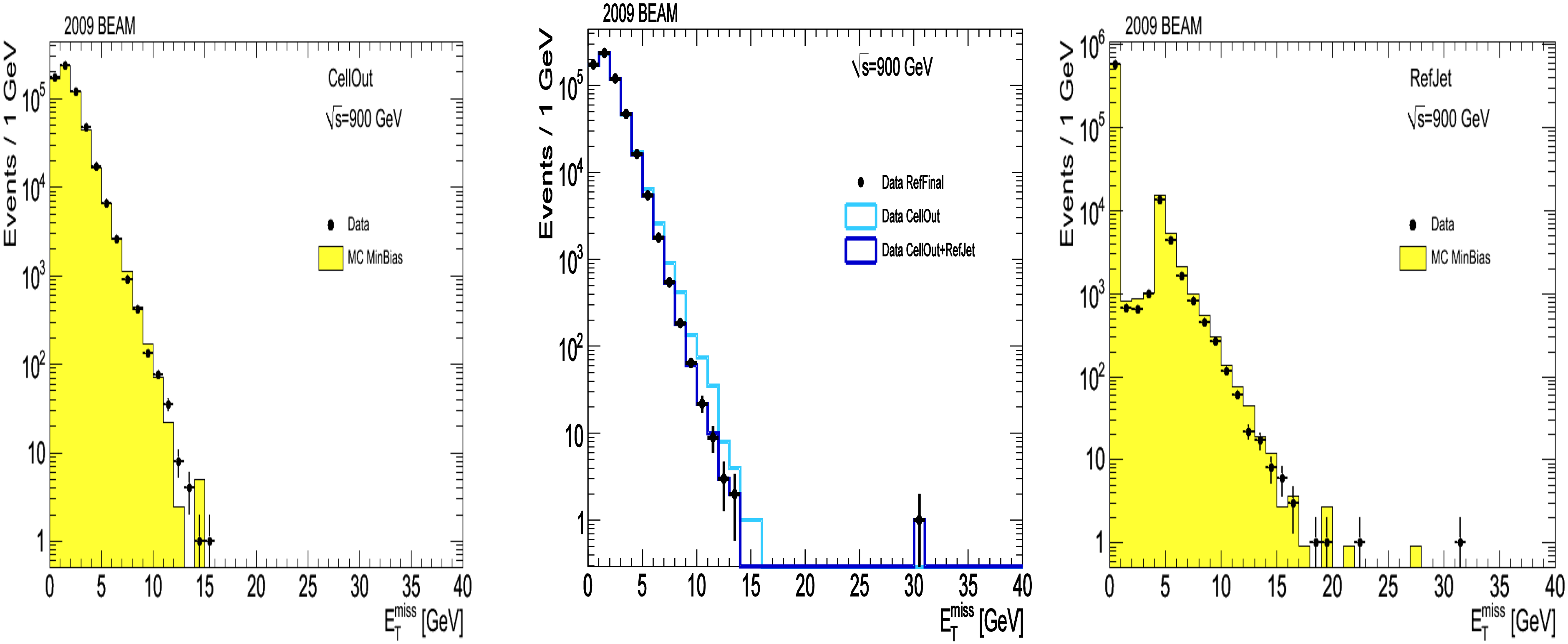


Figure 1: ***E_x^{miss} (left) and E_y^{miss} (right) distributions obtained from randomly triggered events. E_x^{miss} and E_y^{miss} are computed with topocluster cells at EM scale.***

Toward Final MET calculation

Fig.7

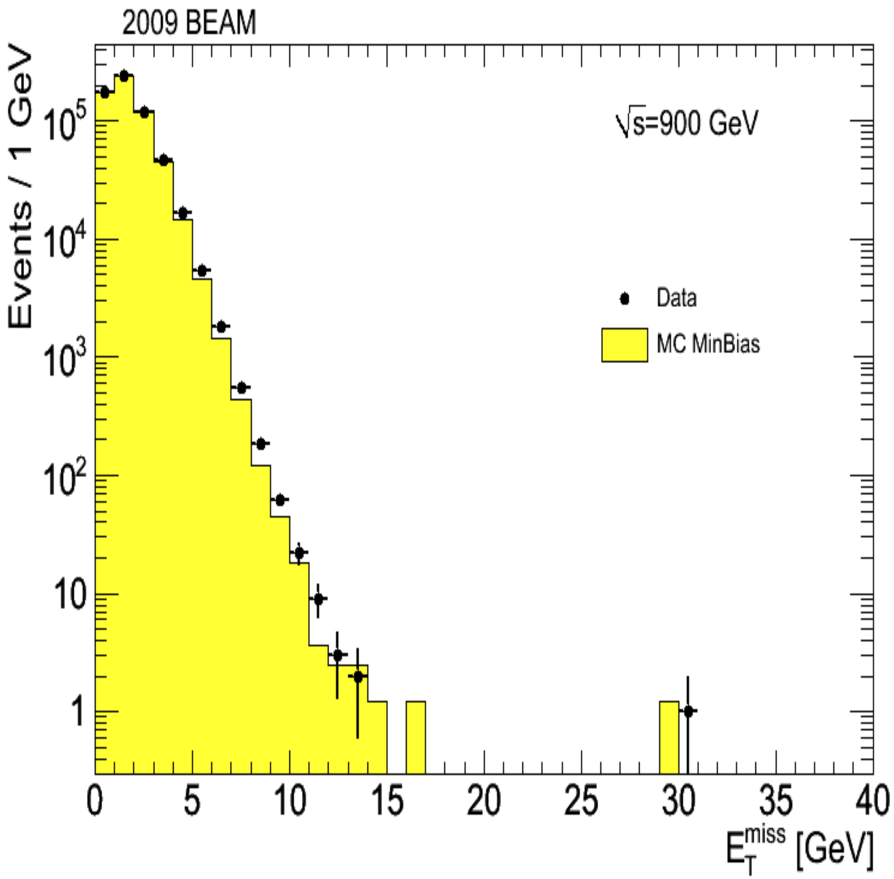


Here jets reconstructed with Antikt D=0.6 algo (EM scale) with pT>4 GeV are used. Only 4% of events in data and 5 % in MC have jets (RefJet #0)

Look at RefJet distribution

event in the tail at high MET

Fig.4



Event in data with MET around 30 GeV:
- 1 jet Antikt06

pt ~ 40.6 GeV

eta = 1.1952710 phi = -1.125769

emfraction = 0.94

n90 = 61

fcor = 0.0063 (cell-level energy corrections for missing calorimeter cells)

MET is back-to-back with the jet

Event in MC with MET around 30 GeV:
- 1 jet Antikt06

pt ~66.3 GeV

eta =0.6583793, phi= 0.9532663

emfraction = 0.8438582

n90 = 125

fcor=0

dphi_met-jet= 2.9082090