Missing Transverse Energy Scale Validation in ATLAS

Peter Loch
INFN Pisa & University of Arizona

Overview

Introduction

- ATLAS detector
- Detector signal contributions to missing ET for physics

Brief look: validating missing ET reconstruction in ATLAS with early data

- $Z \rightarrow \tau\tau$ in the first $100 pb^{-1}$
- Fake missing ET
- Missing ET resolution

Closing remarks

Warning!

All results discussed in this talk are expectations from generators and detector simulations!

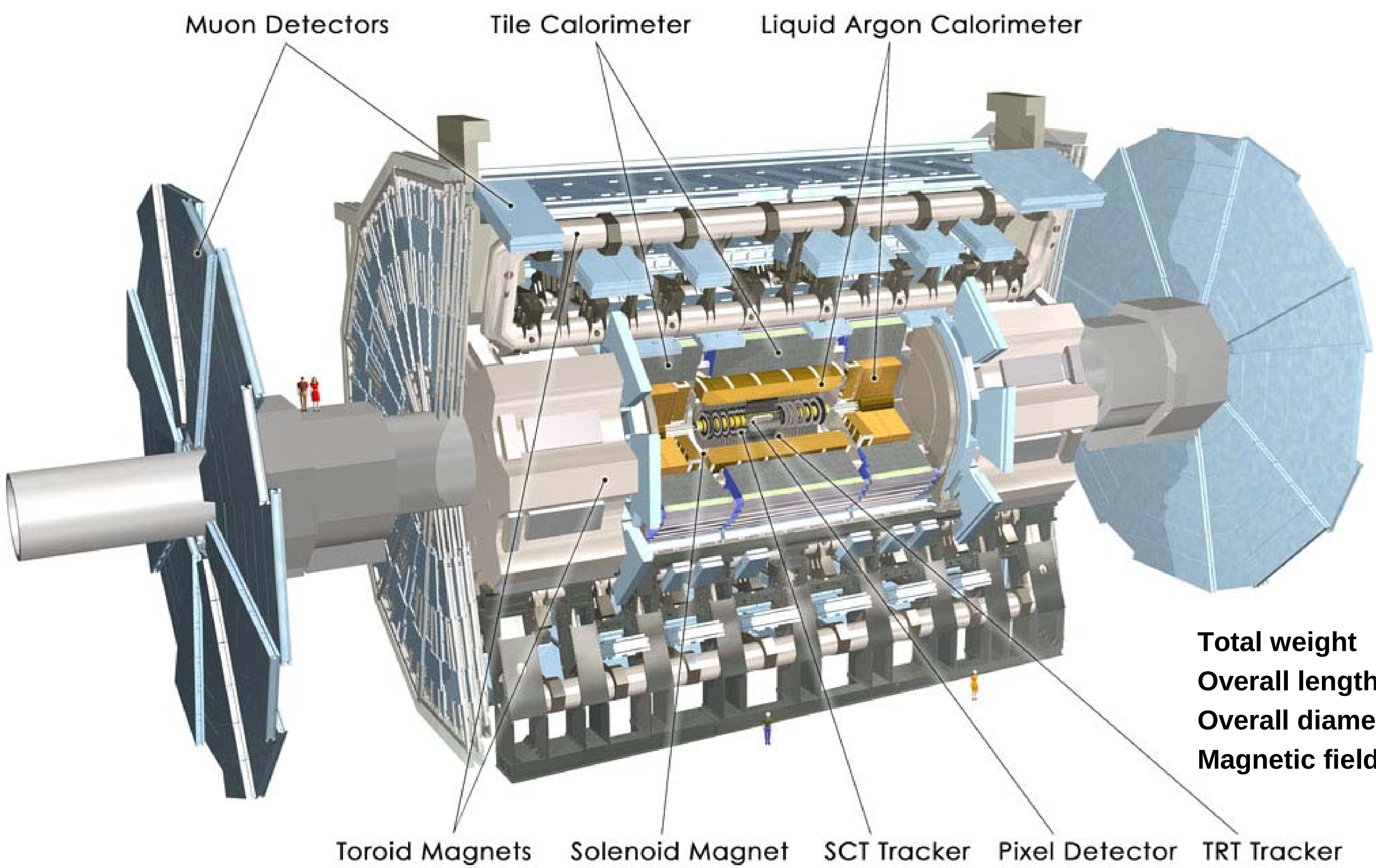
- Everything is at $\sqrt{s} = 14$ TeV!
- This is very likely **not** the initial center of mass energy!

One of the larger experimental issues, the pile-up at LHC, is not included in most studies!

- Except if noted otherwise!

Introduction

ATLAS: A General Purpose Detector For LHC



Total weight : 7000 t
Overall length: 46 m
Overall diameter: 23 m
Magnetic field: 2T solenoid + toroid

Typical Detector Features

Hermetic coverage over a wide angular range

- Efficient missing transverse energy reconstruction due to large coverage in pseudo-rapidity

$$|\eta| = \left|\frac{1}{2}\ln\left(\frac{p+p_z}{p-p_z}\right)\right| = \left|\ln\left(\tan\frac{\theta}{2}\right)\right| \leq 5$$

- Very forward detection of particles and jets produced in pp collisions

High particle reconstruction efficiency

- Important for final state reconstruction and classification

Particles	Efficiency	Jet Rejection
muon	~90%	10^5
$e^\pm$	~80%	10^5
photon	~80%	10^3
b-jet	~60%	100
tau	~50%	100

Relative energy resolution for electrons, photons and muons is 2-4%

Detector Signal Contributions To MET

Hard signal in calorimeters

- Fully reconstructed & calibrated particles and jets
  - Not always from hard interaction!

Hard signal in muon spectrometer

- Fully reconstructed & calibrated muons
  - May generate isolated or embedded soft calorimeter signals
  - Care needed to avoid double counting

Soft signals in calorimeters

- Signals not used in reconstructed physics objects
  - I.e., below reco threshold(s)
- Needs to be included in MET to reduce scale biases and improve resolution

Need to avoid double counting

- Common object use strategy in ATLAS
  - Find smallest available calorimeter signal base for physics objects (cells or cell clusters)
- Check for exclusive bases
  - Same signal can only be used in one physics object
- Veto MET contribution from already used signals
  - Track with selected base
- Priority of association is defined by reconstruction uncertainties
  - Electrons (highest quality) → photons → muons* → taus → jets (lowest quality)

Validation Of MET Scale

Remark: MET calibration

- **MET is determined by hard signals in event**
  - Reconstructed particles and jets above threshold
    - All objects on well defined energy scale, e.g. best reconstruction for individual object type
  - Really no freedom to change scales for any of these objects
    - Little calibration to be done for MET
    - Note that detector inefficiencies are corrected for physics objects
- **Some freedom for soft MET contribution…**
  - Signals not used in physics objects often lack corresponding context to constrain calibration
    - ATLAS has developed a low bias "local" calibration for the calorimeters based on signal shapes inside calorimeters
  - Some degree of freedom here
    - But contribution is small and mostly balanced in Et anyway
      - Source here often UE/pile-up!
- **…and overall acceptance limitations**
  - Detector "loses" particles in non-instrumented areas or due to magnetic field in inner cavity
    - Same remarks as above, very small and likely balanced signals
  - Event topology dependent adjustments to MET are imaginable to recover these losses
- **I prefer "validation" rather than "calibration"**
  - Discrepancies in MET need to be isolated for systematic control

Z Mass Constraint

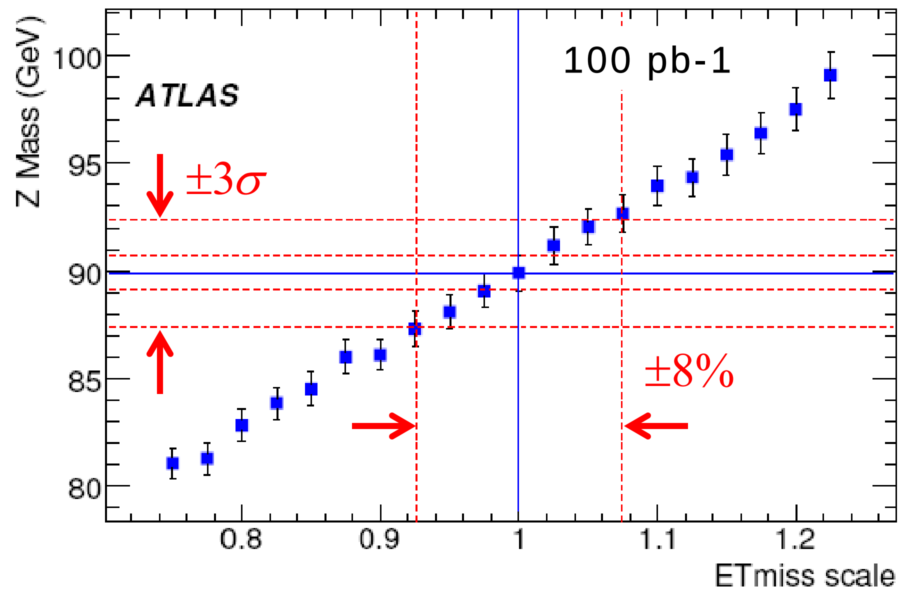
MET scale can be checked with physics

- Look for one hadronic and one leptonic tau from Z decays
  - Can be triggered nicely with lepton + MET requirement
- Use collinear approximation to reconstruct invariant mass
  - Massless taus
  - Neutrinos assumed to be collinear to observable tau decay products

Check dependence of invariant mass on MET scale variations

- Expect correlation!

CERN-OPEN-2008-020



$$m_{\tau\tau} = \sqrt{2(E_{had} + E_{\nu_1})(E_\ell + E_{\nu_2})(1 - \cos\theta)}$$

Determined from two reconstructed MET components and directions of detectable decay products

Fake Missing ET

What is that?

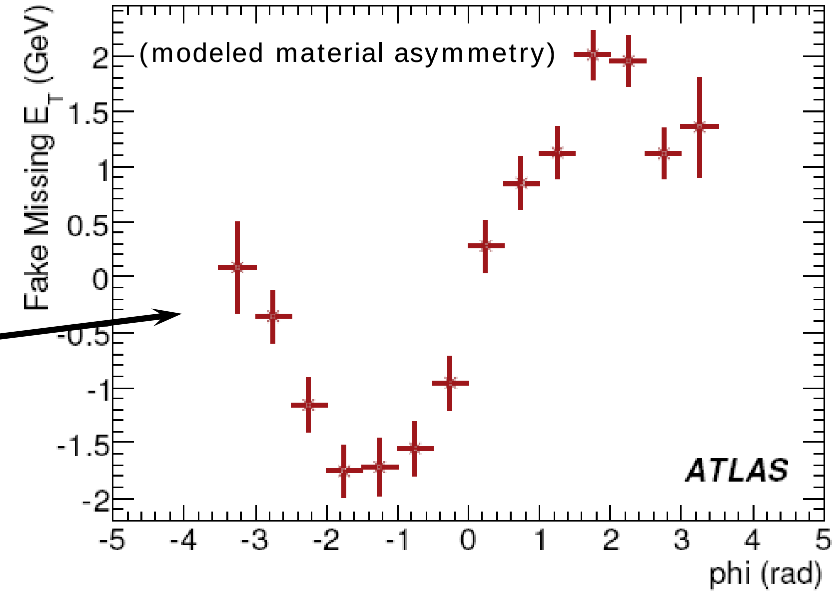
- MET contribution from response variations
  - Cracks, azimuthal response variations…
  - Never/slowly changing
  - Particle dependent
- MET contribution from mis-calibration
  - E.g., QCD di-jet with one jet under-calibrated
  - Relative effect generates MET pointing to this jet

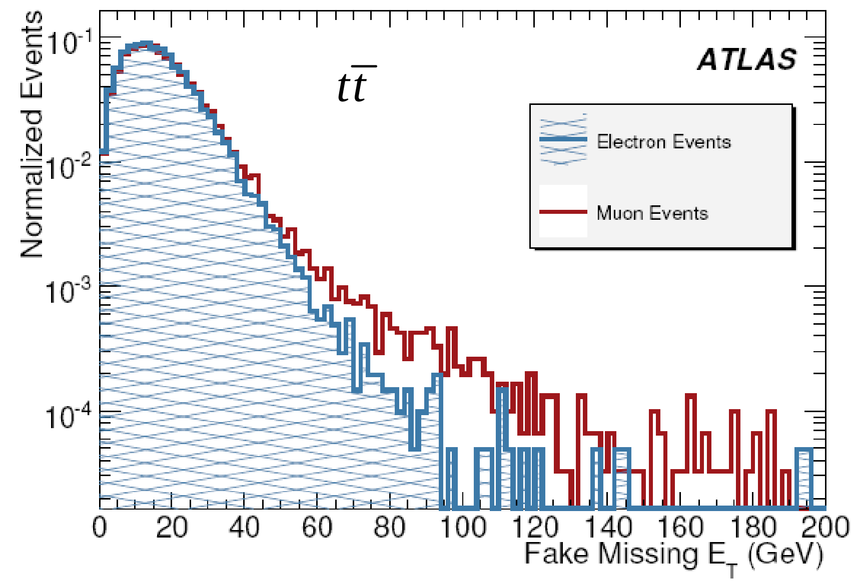
Dangerous source of MET

- Disturbs many final states in a different way
- Can fake new physics

Suppression strategies

- Track jets
- Energy sharing between calorimeters
- Event topology analysis

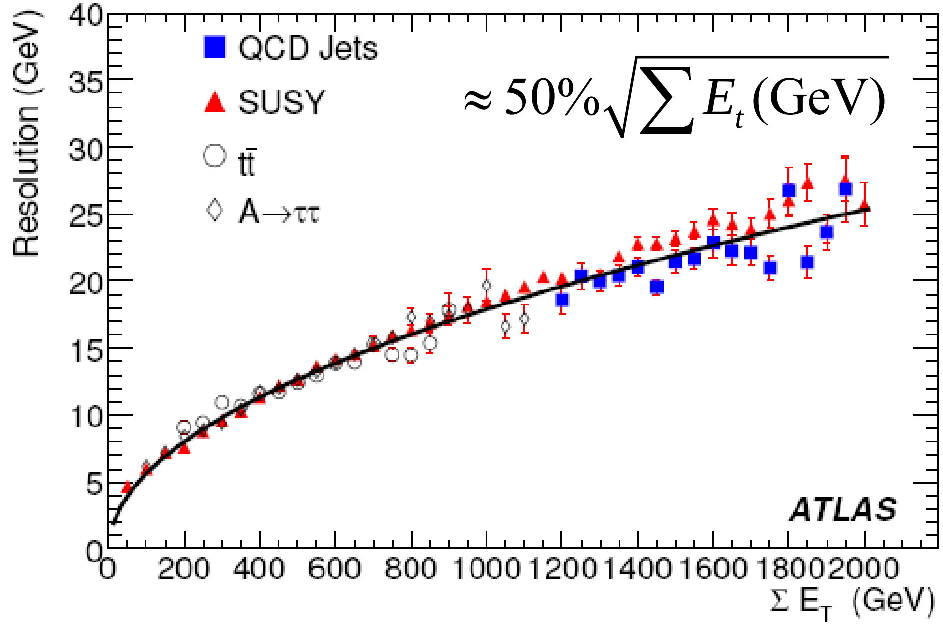




CERN-OPEN-2008-020

MET Resolution From MC

- **Came up earlier in this workshop**
  - MET resolution in each component as function of scalar Et sum for various final states
    - Systematically evaluated with MC in ATLAS
  - No direct experimental access
    - Minimum bias with limited reach/precision?
    - Concern is pile-up effect on scalar Et
- **Will discuss experimental access on next slide(s)**



CERN-OPEN-2008-020

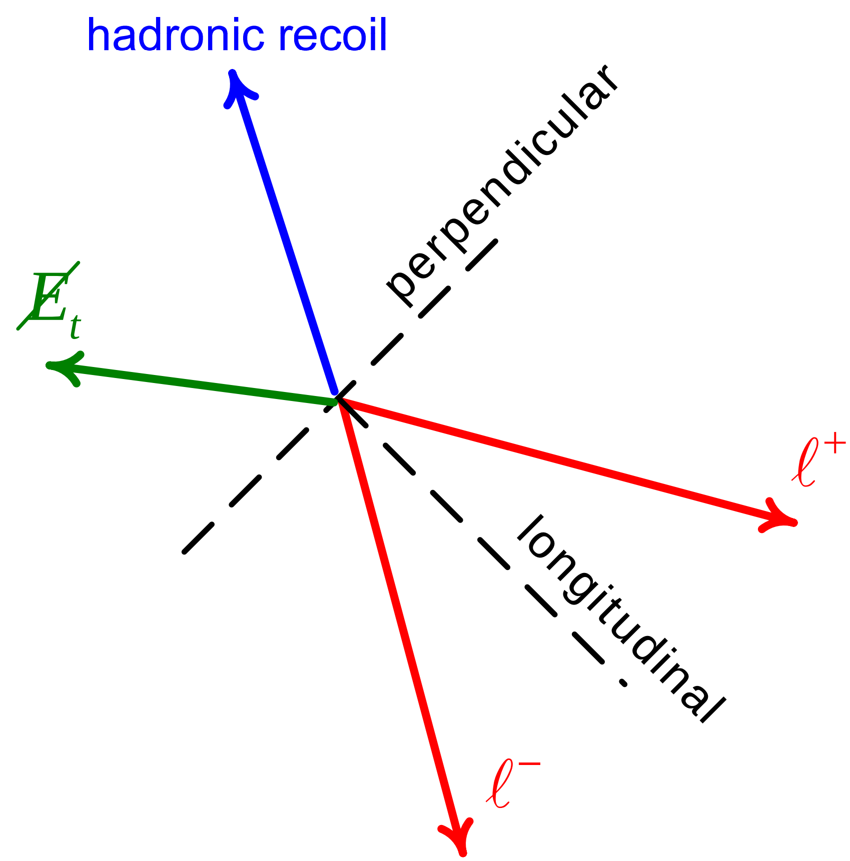
MET Scale & Resolution

Experimental access

- Use bi-sector signal projections in Z decays
- Longitudinal projection sensitive to scale
  - Calibration of hadronic recoil
- Perpendicular projection sensitive to angular resolution

Neutrinofication

- Assumed to be very similar in Z and W
  - One lepton in Z decay can be "neutrinofied"
- Access to MET resolution



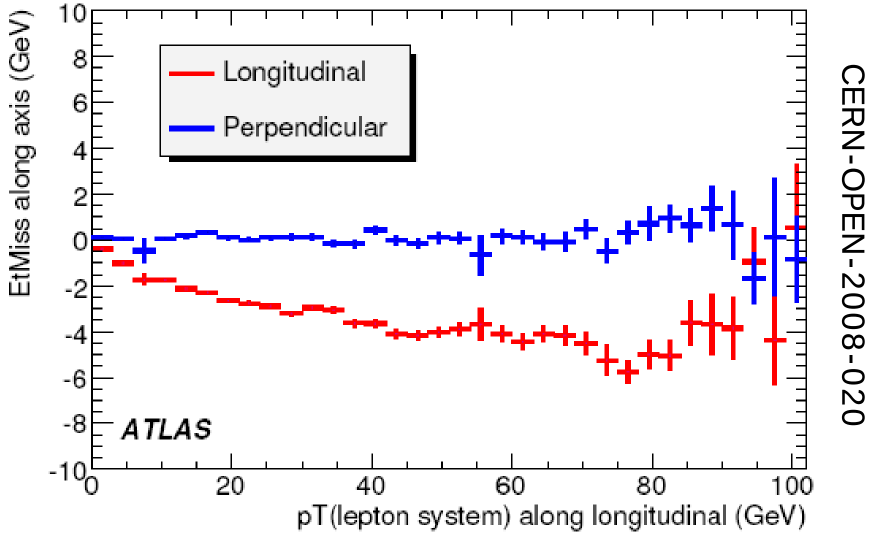
MET Scale & Resolution

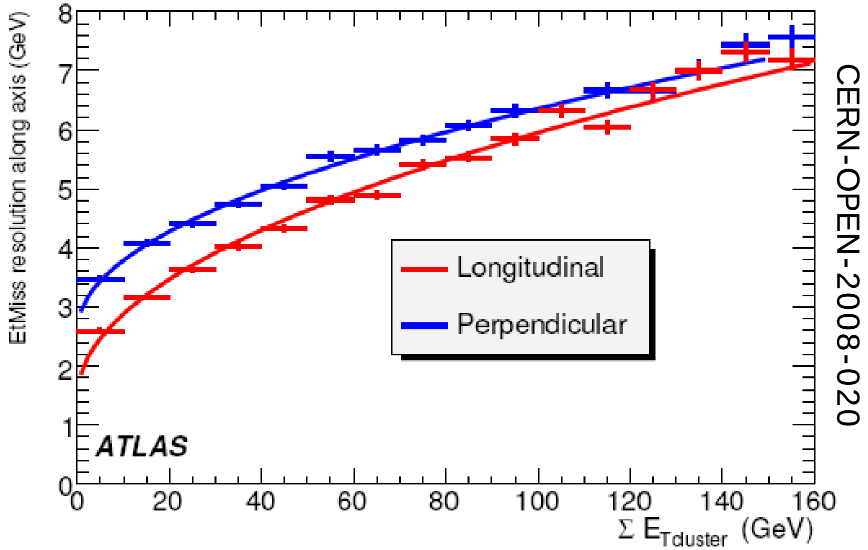
MET scale

- Folds hadronic scale with acceptance
  - Note: no jets needed!
- Experimental tool to validate calibration of "unused" calorimeter signal
  - Hard objects can be removed from recoil
  - One possible degree of freedom in MET "calibration"
- Relevance for other final states to be evaluated
  - Otherwise purely experimental handle!

MET resolution

- Can be measured along perpendicular and longitudinal axis
  - Resolution scale is scalar Et sum of hadronic calorimeter signal
  - Biased by UE and pile-up (MC needed here)
- Qualitatively follows calorimeter energy resolution





Closing Remarks

Closing Remarks

- **Missing ET is a complex experimental quantity**
  - Sensitive to precision and resolution of hard object reconstruction
    - MET is calibrated by everything
  - Easily affected by detector problems and inefficiencies
    - Careful analysis of full event topology
    - Signal shapes in physics and detector
- **Known unknown (1): effect of underlying event**
  - Some correlation with hard scattering
  - Insignificant contribution??
    - To be confirmed early with di-jets
- **Known unknown (2): effect of pile-up**
  - Level of activity not so clear
    - Minimum bias first and urgent experimental task
  - Expectation is cancellation on average (at least)
    - Detector signal thresholds/acceptance potentially introduce asymmetries
    - Need to know the "real" detector
  - Considerable contribution to MET fluctuations
    - Severe limitation in sensitivity for discovery