The ATLAS $E_{\mathrm{T}}^{\mathrm{miss}}$ trigger

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HEFTI Workshop on Missing Energy Signals at LHC
1–2 Apr 2009
University of California Davis

Outline

Introduction

The ATLAS detector at LHC

Event selection with $E_{\mathrm{T}}^{\mathrm{miss}}$

Commissioning of $E_{\mathrm{T}}^{\mathrm{miss}}$ in ATLAS

Performance

Summary

[All plots are taken from the ATLAS "CSC book", CERN-OPEN-2008-020.]

Outline

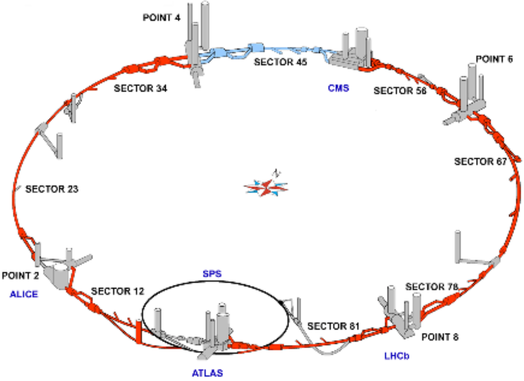
Introduction

- Missing energy in high-energy collision is a general signature of most models beyond SM
- Example: if SUSY is to provide the DM particle
  - R-parity is conserved
  - the LSP is neutral
- Hence
  - SUSY particles produced in pairs in collisions
  - they decay into LSP and SM particles
  - LSPs leave the detector without loosing energy

Outline

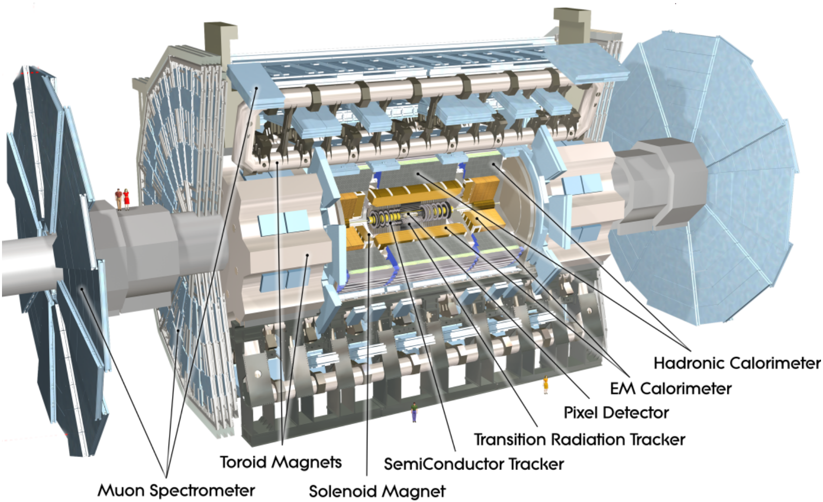
The LHC startup

- Design: $\sqrt{s} = 14$ TeV, $\mathcal{L} = 10^{34}$ cm^{-2} s^{-1}, 23 interactions per bunch crossing, 40 MHz bunch crossing
- LHC startup: ~ 11 months with $\sqrt{s} = 10$ TeV (much time at 20 MHz) for a total of $O(200)$ pb^{-1}. Pile-up may be present



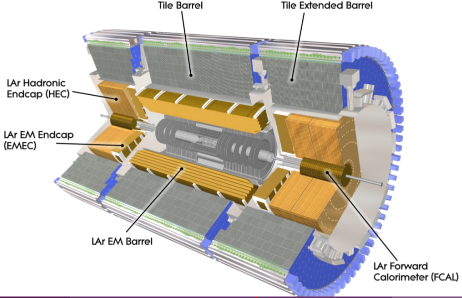
The ATLAS detector

- 25 m diameter, 46 m length



The ATLAS calorimeters

- Liquid Argon EM calorimeter over $|\eta| < 3.2$
  - Barrel ($|\eta| < 1.475$) and end-caps ($1.375 < |\eta| < 3.2$)
  - Lead absorbers in LAr with accordion-shaped Kapton electrodes
- Hadronic calorimeter over $|\eta| < 4.9$
  - Fe scintillating-tile for barrel and extended-barrel ($|\eta| < 1.7$)
  - LAr Hadronic End-Cap ($|\eta| < 3.2$)
  - High-density Forward Calorimeter ($3.1 < |\eta| < 4.9$)
- Calorimeters are longitudinally segmented



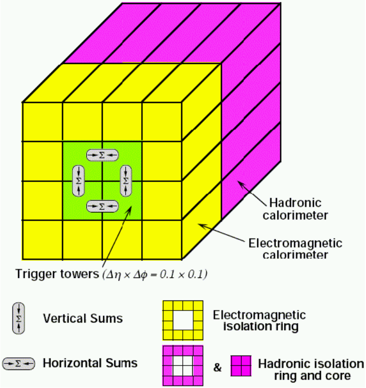
The ATLAS TDAQ system

The challenge is to achieve sensitivity to new physics while keeping an acceptable event rate.

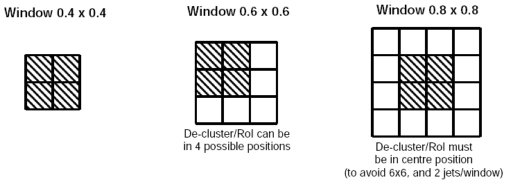
- LHC bunch crossing rate: $\leq$ 40 MHz
- L1 is hardware based
  - can access full calorimeters (no tracking)
  - must reduce the rate to 75 kHz
- L2 is software based
  - can access only channels inside Regions of Interest
  - must reduce the rate to $\sim$ 2 kHz
- Event filter (EF)
  - can access all channels (same granularity as offline)
  - must reduce the rate to 200 Hz ($\approx$ 1.5 MB/event)
- L2 and EF constitute the high-level trigger (HLT) system

The ATLAS L1 calorimeter trigger

- e/γ & τ/had trigger ($|\eta| < 2.5$): 0.1×0.1 trigger towers in (η, ϕ) space



- Jet trigger ($|\eta| < 3.2$): 2×2 jet RoI as seed, windows to measure Et



- JEM also computes Ex, Ey and SumEt from jet elements: XE, TE and JE RoIs ($|\eta| < 4.9$)

The ATLAS HLT trigger

- The HLT makes use of the Athena environment and tools
- At each level, there are two phases:
  - Feature extraction (Fex): physics objects are built (possibly in multiple steps)
  - Hypothesis testing (Hypo): verify conditions (early reject)
- L2 can access full granularity data from the seed RoI to refine the L1 decision
- EF can access data from the full detector

Outline

The E_T^{miss} trigger

- L1 E_T^{miss} (and ΣE_T) from all calorimeters ($|\eta| < 4.9$)
  - Hardware based
  - Computed using trigger towers
  - ~ 1 GeV granularity (LUT of $\not{E}_x$, $\not{E}_y$)
- L2 refines the L1 result with muons
- EF recomputes calorimeter and muon contributions
  - Cell-based E_T^{miss},ΣE_T by default (with or without noise suppression)
  - May also use FEB header summary info (much quicker)
- The EF E_T^{miss} Fex does not replicate the offline algorithm
  - It accesses the same channels as the offline reconstruction
  - but it is kept simple and robust

The mHT trigger

- mHT and SumHT can also be used to select events
  - At present, mHT is used at L1 and L2 only
- mHT and SumHT computed using jets only
  - mHT uses localized energy: very effective noise suppression
- E_T^{miss} is computed using the full calorimeters
  - E_T^{miss} accounts for unclustered energy: less model dependent
- Work in progress to combine mHT with E_T^{miss}

Trigger menus

- Trigger menus will evolve with LHC luminosity
- Menus contain inclusive E_T^{miss} chains and combined signatures like electron+E_T^{miss}, muon+E_T^{miss}, τ+E_T^{miss}, jet+E_T^{miss}, etc.

Trigger Item	XE15	XE20	XE25	XE30	XE40	XE50	XE70	XE80
Prescale	30000	7000	1500	200	20	2	1	1
Rate (Hz)	2.5	3	4	7.5	7.5	14	2	1

Table 7: L1 trigger items and estimated rates at 10^{31} cm^{-2} s^{-1} for Missing E_T objects.

Trigger Item	EM13_XE20	EM7_MU6	MU11_XE15	MU10_J18
Rate (Hz)	225	10	13	33
Trigger Item	2J42_XE30	4J23_EM13I	4J23_MU11	EM13I_J42_XE30
Rate (Hz)	13	6.5	1	6.5

Table 9: A representative list of L1 trigger items and estimated rates at 10^{31} cm^{-2} s^{-1} for triggers combining several object types. The "_" notation is used to show the AND between two object types.

[From the ATLAS "CSC book", CERN-OPEN-2008-020]

Offline E_T^{miss} reconstruction

- MET_CaloCalib
  - All calo cells with $|E_{cell}| > 2\sigma_{noise}$ and "H1 style" calibration
  - TopoClusters (4/2/0) with "H1 style" calibration
  - TopoClusters (4/2/0) with local hadronic calibration
  - Cells in reconstructed objects (e, γ, τ, jet) and unused TopoClusters with object-based calibration
- MET_Cryo
  - Cryostat losses EMB/Tile using cone tower jets with $\Delta R < 0.7$
  - Cryostat losses EMB/Tile using cone TopoCluster jets with $\Delta R < 0.7$
- MET_Muon
  - Momentum measured with muon spectrometer only
  - Momentum measured with muon spectrometer, inner detector and and calorimeter
- MET_Final = MET_CaloCalib + MET_Cryo + MET_Muon

[See the ATLAS "CSC book", CERN-OPEN-2008-020, for more details]

Outline

Commissioning of $E_{\mathrm{T}}^{\mathrm{miss}}$ trigger

- With first collisions:
  - (large) subset of L1 signatures will be enabled
  - HLT will be in pass-through
- Introduce new signatures as soon as their behavior is understood
- Trigger slices have different commission strategies for HLT
- The $E_{\mathrm{T}}^{\mathrm{miss}}$ slice approach is the following:
  1. Tune the 8 L1 thresholds to get almost the same rate for each signature
  2. While HLT is in pass-through, decide final configuration of EF
  3. Refine trigger menus in order to have many chains in common for different luminosities
  4. Enable HLT as soon as rates are under control

Commissioning of full reconstruction

- First, calo-based methods not relying on other components will be validated step by step
  1. All cells with 2-sigma noise suppression
  2. All 4/2/0 TopoClusters [see Peter's talk]
- Next, the following improvements will be applied, as soon as other things get commissioned:
  - H1-like and local hadronic calibration [see Peter's talk]
  - Cryostat correction (needs jets)
  - Muon correction (needs muons)
  - Object-based calibration piece by piece (as soon as e, τ, etc. are ready)
- To validate each step, the performance will be compared with the previous one and with expected results [see Peter's talk]
  - Min.bias/QCD events: assume $E_T^{miss} \approx 0$ and plot $\not{E}_x$,$\not{E}_y$ vs. ΣE_T
  - Tag-probe: use W/Z and $t\bar{t}$ events with single lepton trigger

Outline

Trigger performance

- Showing figures from the ATLAS "CSC book", CERN-OPEN-2008-020
- The plots are obsolete: many improvements since CSC book

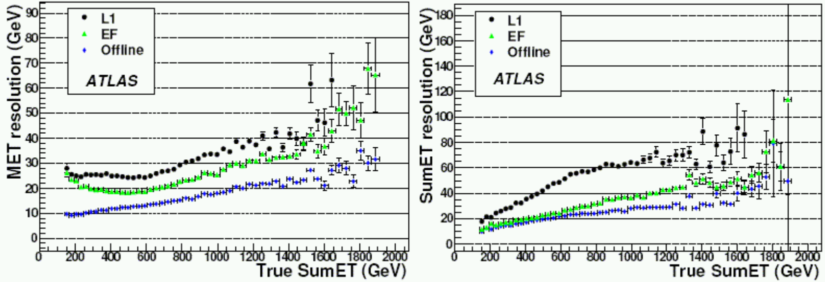


Figure 17: L1, EF and offline results for the $\not\!E_T$ (left) and the $\Sigma\not\!E_T$ (right) resolution as a function of the true $\Sigma\not\!E_T$ in $t\bar{t}$ events.

Full reconstruction performance (1/2)

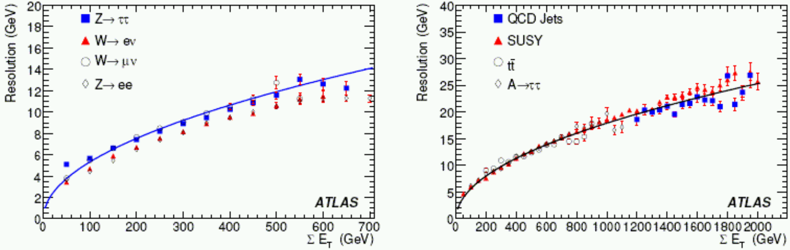


Figure 4: Resolution of the two $\not{E}_T$ components with refined calibration as a function of the total transverse energy, ΣE_T for low to medium values (left) and for higher values (right). The curves correspond to the best fits of $\sigma = 0.53\sqrt{\Sigma E_T}$ through the points from $Z \to \tau\tau$ events (left) and $\sigma = 0.57\sqrt{\Sigma E_T}$ through the points from $A \to \tau\tau$ events (right). The points from $A \to \tau\tau$ events are for masses m_A ranging from 150 to 800 GeV and the points from QCD jets correspond to dijet events with $560 < p_T < 1120$ GeV.

Full reconstruction performance (2/2)

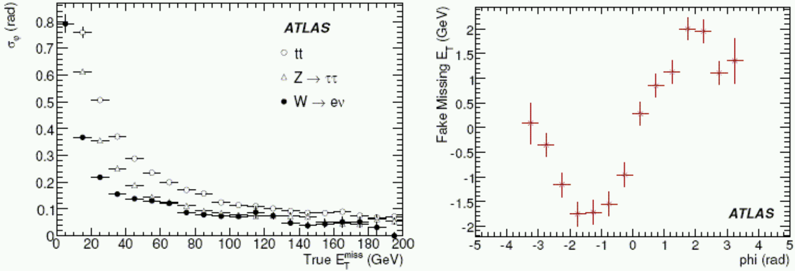


Figure 9: (left) Accuracy of the measurement of the azimuth of the $\not{E}_T$ vector as a function of the true $\not{E}_T$ for three different physics processes: semi-leptonic $t\bar{t}$ events, $Z \to \tau\tau$ and $W \to e\nu$ events. (right) $\not{E}_T^{Fake}$ as a function of the reconstructed $\phi(\not{E}_T)$ in $t\bar{t}$ events, simulated with extra material in ϕ.

Fake E_T^{miss}

- Fakes are one of the most important problems
- Fake E_T^{miss} may come from hardware problems and physical environment
- Hardware problems
  - Dead or noisy channels
  - Dead read-out units
- Physical environment
  - Cosmic rays and cavern background
  - Pile-up
  - Beam-gas, beam-halo, beam-pipe collisions
- Offline, many fake events can be found and discarded (see next page)
- Work is in progress to flag them in trigger

Example of offline clean-up

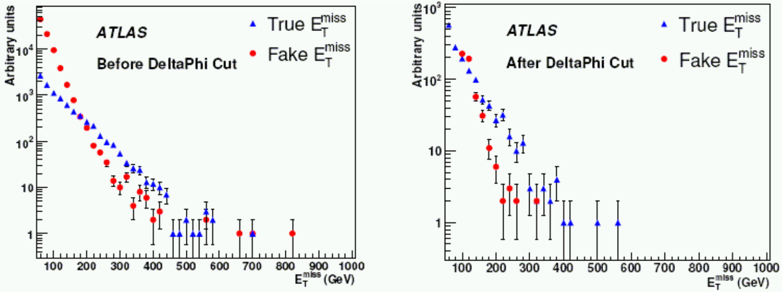


Figure 10: The rates of $\not{E}_T^{Fake}$ and $\not{E}_T^{True}$ in the QCD sample with $560 < p_T < 1120$ GeV: (left) overall rates, (right) requiring a $\Delta\phi$ separation between $\not{E}_T$ and the leading high-p_T jet in the event. The $\not{E}_T^{Fake}$ rates can be strongly reduced. It should be noted though that such cuts are very analysis dependent.

Outline

Summary

- $E_{\mathrm{T}}^{\mathrm{miss}}$ is important signature for new physics
- ATLAS will try to commission $E_{\mathrm{T}}^{\mathrm{miss}}$ trigger and full $E_{\mathrm{T}}^{\mathrm{miss}}$ reconstruction as early as possible
- Expected $E_{\mathrm{T}}^{\mathrm{miss}}$ performance good enough to be sensitive to large portions of the SUSY parameter space
- LHC startup going to be very exciting!