New ATLAS Triggers Based on the Missing $E_T$ Significance

The prospects of an increasing amount of pile-up in 2011 will make it difficult to maintain trigger thresholds for Missing $E_T$ at the same levels that were successfully used in 2010. However, in order to extend the range of many physics analyses, including SUSY and beyond the standard model searches, it will be necessary to trigger on missing momentum while minimizing the background contamination from QCD fakes.

To address this issue, ATLAS has developed a family of triggers which accept events based on Missing $E_T$ Significance (XS), a quantity which approximates the level of Missing $E_T$ in units of standard deviations of the background Missing $E_T$ distribution. This quantity is parameterized as:

$$\text{Missing } E_T \text{ Significance (XS)} = \frac{\text{Missing } E_T}{\sigma(\sqrt{\text{Sum } E_T} - c)}$$

### Missing $E_T$ Resolution

- Fake Missing $E_T$ predominantly comes from the effects of finite calorimeter resolution.
- The scale of fake Missing $E_T$ in background events is linear in $\sqrt{\text{Sum } E_T}$, where Sum $E_T$ is the scalar sum of transverse energy.

### Level-1 Implementation

Implementation of the new Missing $E_T$ Significance triggers required a re-formulation of the Missing $E_T$ and Sum $E_T$ logic at the firmware level, as well as corresponding changes to the online and offline simulations, the interaction with the L1 Central Trigger Processor (L1CTP), and the output to the Level 2.

The design of the Missing $E_T$ logic is based on four look-up tables (LUTs) which receive digitalized sums of the $E_T$ and $E_y$ deposited in the calorimeter and calculate the Missing $E_T$ and Significance logic in parallel. The first LUT receives $E_x$ and $E_y$ and performs the Missing $E_T$ calculation according to Missing $E_T = \sqrt{E_x^2 + E_y^2}$. The second LUT receives the Sum $E_T$ and finds the square root. These two values form the input to the Missing $E_T$ Significance LUT, which calculates Significance according to the above equation, where $a$ and $c$ are adjustable parameters. A set of 8 thresholds are then applied to the Missing $E_T$ Significance results. All threshold bits, including the new $X_S$ bits, are sent to the L1CTP. In the event of an L1Accept from the L1CTP, all energy values including the Missing $E_T$ Significance itself are sent to Level 2.

### Physical Motivation

![Real Missing $E_T$ ($W \to e\nu$) vs. Fake Missing $E_T$ ($QCD$)]

- One expects a Missing $E_T$ distribution for real events bounded by an approximate parabola in the plots to the left.
- QCD events have a Missing $E_T$ distribution which tends to populate a different region which is linear in $\sqrt{\text{Sum } E_T}$.
- Contours of Significance are straight lines in the Missing $E_T$, $\sqrt{\text{Sum } E_T}$ plane.
- Triggers based on Missing $E_T$ Significance can accept events with an reasonable rate by eliminating background QCD while maintaining a high signal efficiency.

### Separation between Signal and QCD Background

Growing levels of pile-up will lead to large calorimeter activity and will increase the rate of fake Missing $E_T$. Events with more primary vertices have high rates of standard Missing $E_T$ triggers. However, fake Missing $E_T$ comes from calorimeter resolution effects, scales as a known function of Sum $E_T$, and hence, to the extent that pile-up simply overlaps non-interesting events, our model for the Missing $E_T$ resolution still holds.

Therefore, Level 1 significance triggers, whose rate are dominated by QCD background, will remain steady even as pile-up increases.

### Robustness against Pile-Up

Distributions of Missing $E_T$ and Significance with varying number of primary vertices.

Rate estimates for Level 1 Missing $E_T$ and Significance triggers as a function of pile-up.