An Analysis of Missing Transverse Momentum Triggers for Improving Efficiency at the ATLAS Experiment at CERN

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Table of Contents

The LHC

- Circumference $27\mathrm{km}$
- Design energy of 7TeV per electron
- Expected number of proton-proton collisions is $10^9\mathrm{s}^{-1}$

ATLAS

- $1\mathrm{Gbs}^{-1}$ is collected
- Trigger system is designed to run at about 1kHz (retain this number of events per second)
- Many events need to be rejected

The Trigger System

- A trigger is a system that uses simple criteria in order to rapidly decide which events to keep when only a small fraction are acceptable
- The triggers are divided into levels so that each level selects data that becomes and input for the next level which has more time and information to make better decisions
- There is the **L1** level, which relies on custom electronics, and the **High Level Trigger** (HLT) system that relies on commercial processors.

Missing Transverse Momentum

- Momentum in the plane transverse to the beam pipe.
- Transverse momentum is conserved (protons collided approximately head on)
- Therefore, we use missing transverse momentum as a measure to see if interesting particles escaped the detector

Efficiency

- Efficiency is a measure of the classification accuracy of one algorithm, relative to another algorithm
- We usually consider the efficiency of cutting on one of the algorithms, as a function of the value given by another algorithm
- A perfect efficiency curve looks like a step function, centered on the value of the cut

Reconstructing the Unbiased CELL Distribution as function of μ

- Determine CELL MET Distribution as a function of μ
- Zerobias events run out of statistics above about 80 GeV
- Use `HLTnoalg_L1XExx` triggered events to extend to higher MET.
- Correct the HLTnoalg Data Using Efficiency determined from lower threshold triggers.
- Determine errors including statistical and those due to determination of efficiency.

Method

For each bin of actual number of interactions per bunch crossing (actint/InTimePileup):

1. Compute the Efficiency of L1XE 30 for `HLTzb_L1ZB` events as a function of cell met
2. Obtain an unbiased (with respect to L1) CELL MET distribution from the `HLTnoalg_L1XE30` data by multiplying by the prescale and dividing by efficiency computed previously
3. Compute efficiency of L1XE50 for `HLTnoalg_L1XE30` data as a function of cell met
4. Obtain an unbiased (with respect to L1) CELL MET distribution from the `HLTnoalg_L1XE50` data by multiplying by the prescale and dividing by both of the previously computed efficiencies.

Data Used

- Used 2015, 2016 and 2017 combined `HLTnoalg_L1ZB`, `HLTnoalg_L1XE30`, and `HLTnoalg_L1XE50` data produced by Jonathan Burr dated 2017-11-17 from ZB and JETM10 trees
- Removed events from Runs 330203, 331975 and 334487. These had large MET events without jets and logbook says there were calorimeter noise problems in these runs

Efficiency Fits

- Assume the distribution of L1 MET, given the value of CELL MET, is gaussian.
- Fitted an error function to the efficiency to evaluate a continuous function when correcting the distribution of `HLTnoalg` data.
- Fit function we used has 4 parameters: a, b, σ, and L1XE.
- $f(x) = \frac{1}{2}\left(1 + \mathrm{Erf}\left(\frac{ax+b-\mathrm{L1XE}}{\sigma\sqrt{2}}\right)\right)$.
- Fit in actint bins of $0-10, \ldots, 60-70$.

../../Mu_Analysis/plots/L1XE30Efficiency_Curves.png

../../Mu_Analysis/plots/l1xe30_efficiencies/L1XE30Efficiency_

../../Mu_Analysis/plots/L1XE30Efficiency_Fits.png

../../Mu_Analysis/plots/L1XE50Efficiency_Curves.png

../../Mu_Analysis/plots/l1xe50_efficiencies/L1XE50Efficiency

../../Mu_Analysis/plots/L1XE50Efficiency_Fits.png

Correcting the HLTnoalg Distribution

- After computing the efficiency curves for the cuts on L1, the curves were used to correct the HLTnoalg distributions that are biased with respect to L1 so that they replicate the unbiased distribution
- In order to do this, it was necessary to multiply by the recorded prescale, and divide by the efficiency used to correct the data
  - For the `HLTnoalg_L1XE30` data, we used the `L1XE30` efficiency curve to correct the distribution
  - For the `HLTnoalg_L1XE50` data we used the `L1XE30` efficiency of the zerobias data, as well as the L1XE50 efficiency of `HLTnoalg_L1XE30` data to correct the distribution

Error Propagation

- The error in each efficiency value is determined by propagating the errors on the parameters of the respective fit function.
- The reconstructed MET distribution includes both the error determined above, and the statistical error.
- Since prescales vary for each bin, must keep track of errors event by event, rather than using ROOTs built-in errors.
- Kept track of the errors on the `L1XE30` corrected curves, as well as the `L1XE50` corrected curves, for each of the mu bins
- There is no error included to reflect the fact that the error function may not be a perfect model. Therefore, in final distribution, zerobias data is kept to as high an MET as possible and similarly for keeping `HLTnoalg_L1XE30` versus `HLTnoalg_L1XE50`

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1X

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1XE

Relative Normalization

- Because the error bars are larger at low values of MET, it is not sufficient to normalize the entire curve to one. Instead, it was necessary to perform a relative overall normalization between the original zerobias distribution and the corrected curves in order to be able to compare the shapes more easily.
- The relative normalization factor was computed by taking a weighted average of ratios computed in the region where the slopes look most parallel.
- The following slides show all 3 sets of data points after all corrections and the relative normalization (from the corrected HLTnoalg data to the unbiased distribution) have been done.
- The vertical black lines on the bottom efficiency curve plots show where I've stopped using the zerobias data and started using the `HLTnoalg_L1XE30` and `HLTnoalg_L1XE50` data, respectively.

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Appendix

L1XE30 Efficiencies with respect to HLTnoalg_L1ZB Data

../../Mu_Analysis/plots/L1XE30Efficiency_Curves.png

L1XE50 Efficiencies with respect to HLTnoalg_L1XE30 Data

../../Mu_Analysis/plots/L1XE50Efficiency_Curves.png

HLTnoalg_L1XE30 Plot for $0 < \mu < 10$

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1XE

HLTnoalg_L1XE30 Plot for $10 < \mu < 20$

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1X

HLTnoalg_L1XE30 Plot for $20 < \mu < 30$

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1X

HLTnoalg_L1XE30 Plot for $30 < \mu < 40$

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1X

HLTnoalg_L1XE30 Plot for $40 < \mu < 50$

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1XE

HLTnoalg_L1XE30 Plot for $50 < \mu < 60$

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HLTnoalg_L1XE30 Plot for $60 < \mu < 70$

../../Mu_Analysis/plots/hlt_noalg_l1xe30_plots/hlt_noalg_L1XE

HLTnoalg_L1XE50 Plot for $0 < \mu < 10$

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1X

HLTnoalg_L1XE50 Plot for $10 < \mu < 20$

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1X

HLTnoalg_L1XE50 Plot for $20 < \mu < 30$

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1X

HLTnoalg_L1XE50 Plot for $30 < \mu < 40$

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HLTnoalg_L1XE50 Plot for $40 < \mu < 50$

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1XE

HLTnoalg_L1XE50 Plot for $50 < \mu < 60$

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1X

HLTnoalg_L1XE50 Plot for $60 < \mu < 70$

../../Mu_Analysis/plots/hlt_noalg_l1xe50_plots/hlt_noalg_L1X

L1XE30 Efficiency Curve Plot for $0 < \mu < 10$

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L1XE30 Efficiency Curve Plot for $10 < \mu < 20$

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L1XE50 Efficiency Curve Plot for $0 < \mu < 10$

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L1XE50 Efficiency Curve Plot for $60 < \mu < 70$

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Unbiased Distributions for $0 < \mu < 10$

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Unbiased Distributions for $10 < \mu < 20$

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Unbiased Distributions for $20 < \mu < 30$

../../Mu_Analysis/plots/zerobias_distributions_corrected/zb_r

Unbiased Distributions for $30 < \mu < 40$

../../Mu_Analysis/plots/zerobias_distributions_corrected/zb_r

Unbiased Distributions for $40 < \mu < 50$

../../Mu_Analysis/plots/zerobias_distributions_corrected/zb_r

Unbiased Distributions for $50 < \mu < 60$

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Unbiased Distributions for $60 < \mu < 70$

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Reconstructed Unbiased CELL MET Distribution for $0 < \mu < 10$

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Reconstructed Unbiased CELL MET Distribution for $10 < \mu < 20$

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Reconstructed Unbiased CELL MET Distribution for $20 < \mu < 30$

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Reconstructed Unbiased CELL MET Distribution for $60 < \mu < 70$

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Efficiency Fit Functional Form

$$f(x) = \frac{1}{2}\left(1 + \mathrm{Erf}\left(\frac{ax + b - \mathrm{L1XE}}{\sigma\sqrt{2}}\right)\right)$$

L1XE30 Efficiency Fits with respect to HLTnoalg_L1ZB Data

../../Mu_Analysis/plots/L1XE30Efficiency_Fits.png

L1XE50 Efficiency Fits with respect to HLTnoalg_L1XE30 Data

../../Mu_Analysis/plots/L1XE50Efficiency_Fits.png

Table: Fit Parameter Table

a	b	σ	L1XE	μ bin
0.536043	-4.88401	7.63437	30	0
0.449818	18.4754	10.3507	50	0
0.40883	-3.87341	8.13195	30	1
0.505088	16.3944	10.3677	50	1
0.336915	-2.90115	8.63962	30	2
0.345437	22.3296	9.83129	50	2
0.29943	-2.17211	9.01473	30	3
0.277972	24.32	9.94887	50	3
0.281092	-1.63701	9.27598	30	4
0.289215	22.6488	10.6932	50	4
0.2487	-0.58147	9.68806	30	5
0.230607	24.8226	9.95501	50	5
0.231716	0.541431	9.99171	30	6
0.183126	26.0774	10.0148	50	6