

# Trigger Software Validation and DQM Development in SUSY and Exotica Analysis at CMS

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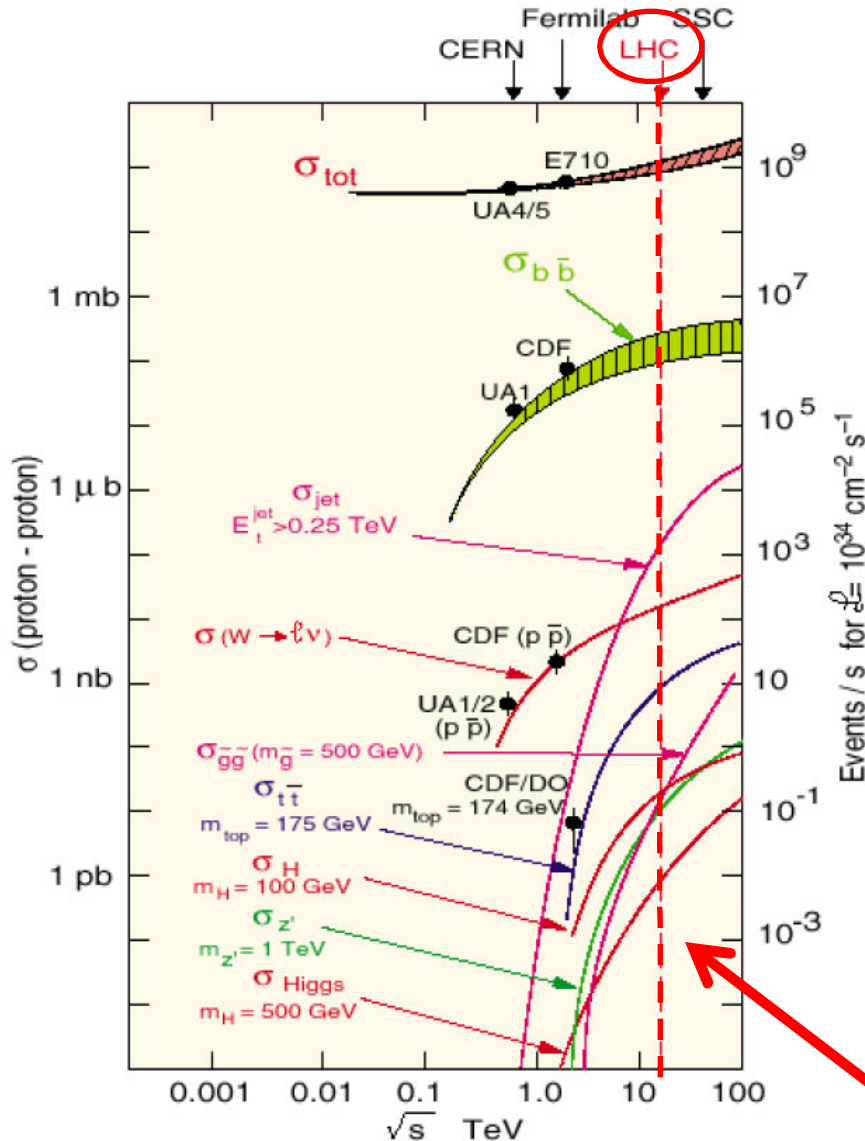
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# Project Overview

- Three activities within the SUSY group of the CMS collaboration:
  - Trigger software validation
  - Evaluation of trigger tables for SUSY/Exotica needs
  - Development of a trigger DQM (with detector data) dedicated to SUSY needs

# The Trigger Challenge

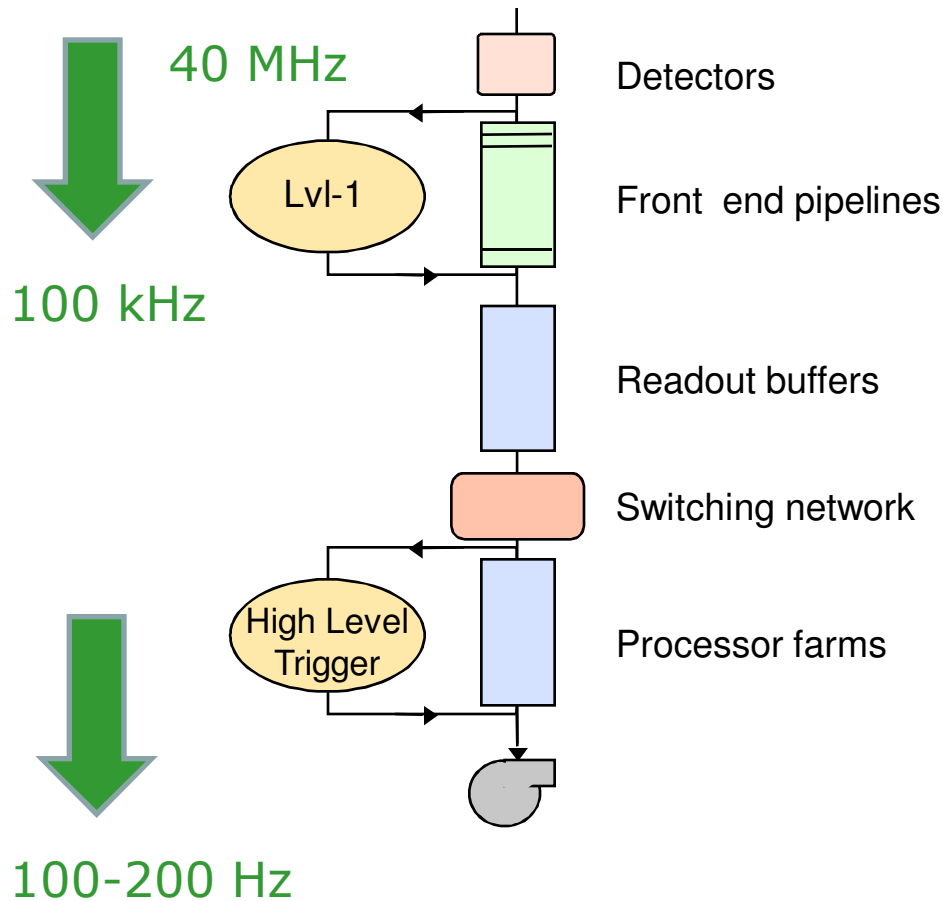
$$\mathcal{L} = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$



Process	$\sigma$ (nb)	Production rates (Hz)
<b>Inelastic</b>	$10^8$	$10^9$
$b\bar{b}$	$5 \times 10^5$	$5 \times 10^6$
$W \rightarrow \ell\nu$	15	100
$Z \rightarrow \ell\ell$	2	20
$t\bar{t}$	1	10
$H(100 \text{ GeV})$	0.05	0.1
$Z'(1 \text{ TeV})$	0.05	0.1
$\tilde{g}\tilde{g}(1 \text{ TeV})$	0.05	0.1
$H(500 \text{ GeV})$	$10^{-3}$	$10^{-2}$

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# Overview of Trigger Systems



- L2, L3: merged into HLT
- L1: hardware, firmware
- HLT: high-level software

# Trigger Software Validation

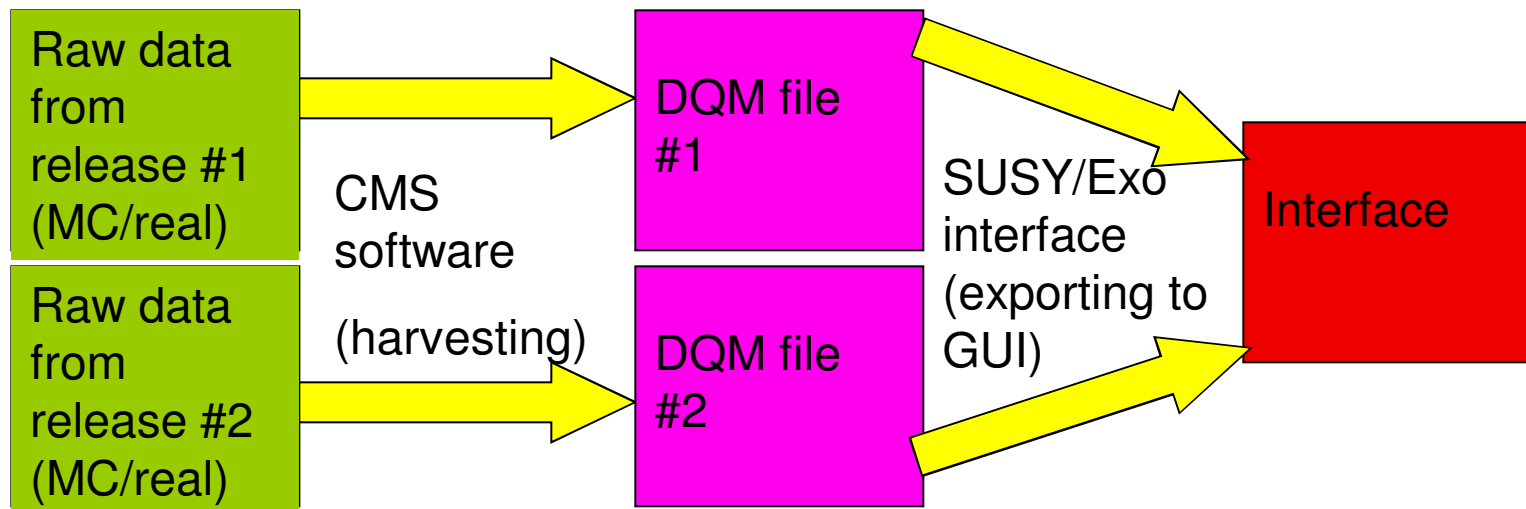
- CMSSW is the entire collection of software that processes event data
  - Same software for Monte Carlo and detector data
- As new releases of the software are made available, the behavior of the triggers may change, even if the trigger code remained the same
  - HLTriggerOffline/SUSYBSM package is used
- The new software is validated by:
  - Checking if the efficiencies for the trigger paths in both samples are within a certain tolerance
    - Many trigger to check in SUSY/Exotica analysis (~150)
  - Comparing the distributions of reconstructed objects path by path

# Package Description

- HL Trigger software is sensitive to release changes in CMSSW
  - Check efficiencies individually for discrepancies (i.e. path by path)
  - SUSY or Exotica samples must be used due to their unique signatures
    - e.g. high MET, high Pt objects
    - Test uses two SUSY samples and one Exotica sample
    - Example of SUSY sample: LM1 (Jets+MET+leptons)
    - Example of Exotica sample: RSGrav (high pt di-leptons and di-jets)

# Validation Process

- Two steps in the validation process
  - An analyzer runs over two samples separately and produces histograms for each sample in a ROOT file
  - A script uses a ROOT macro to compare efficiencies for trigger paths between the two files and produces comparison plots
- Comparison plots are displayed in a GUI
  - Official CMS interface and the preferred SUSY/Exo interface



# Changes to the Package

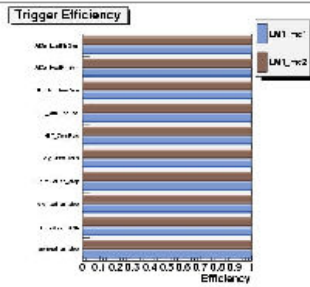
- The CMS interface is set up such that all desired features must be implemented at the harvesting stage
- Changes to the harvesting stage have resulted in:
  - Plots grouped by trigger-type
  - Selection on the final states
  - Implementation of muon turn-on and efficiency plots (as a function of muon pt and eta, respectively)
- Changes to the SUSY/Exo interface have resulted in:
  - Plots ordered with respect to discrepancy
    - The discrepancy can only be calculated at the interface level





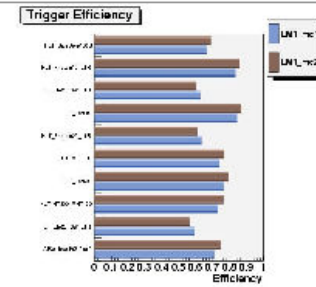
# After Changes

## HLT Efficiency Comparison



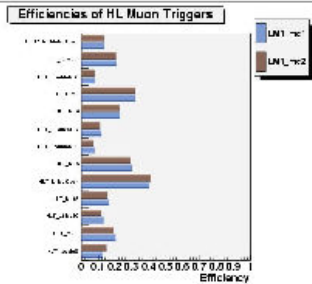
Plot of highest efficiencies for L1 paths

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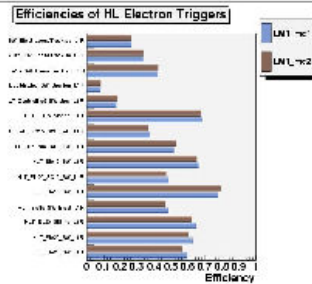


Plot of highest efficiency differences for L1 paths

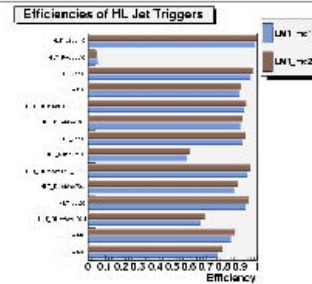
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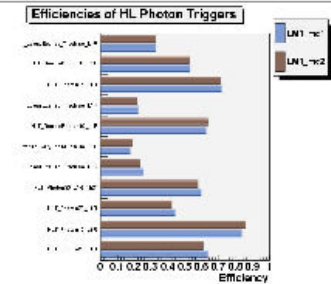
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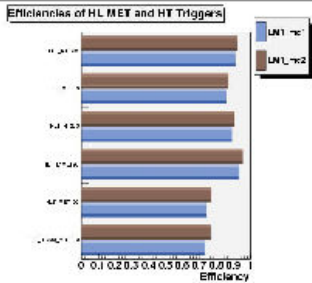
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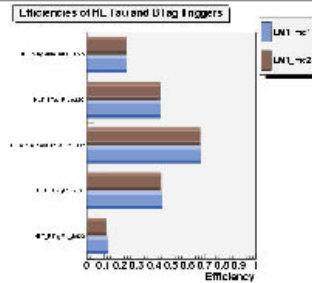
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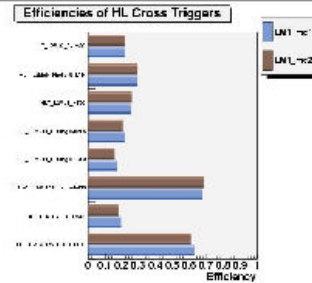
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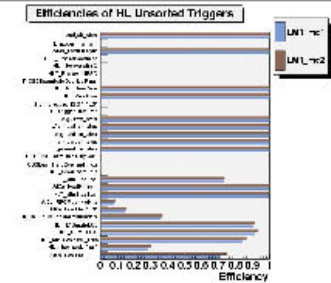
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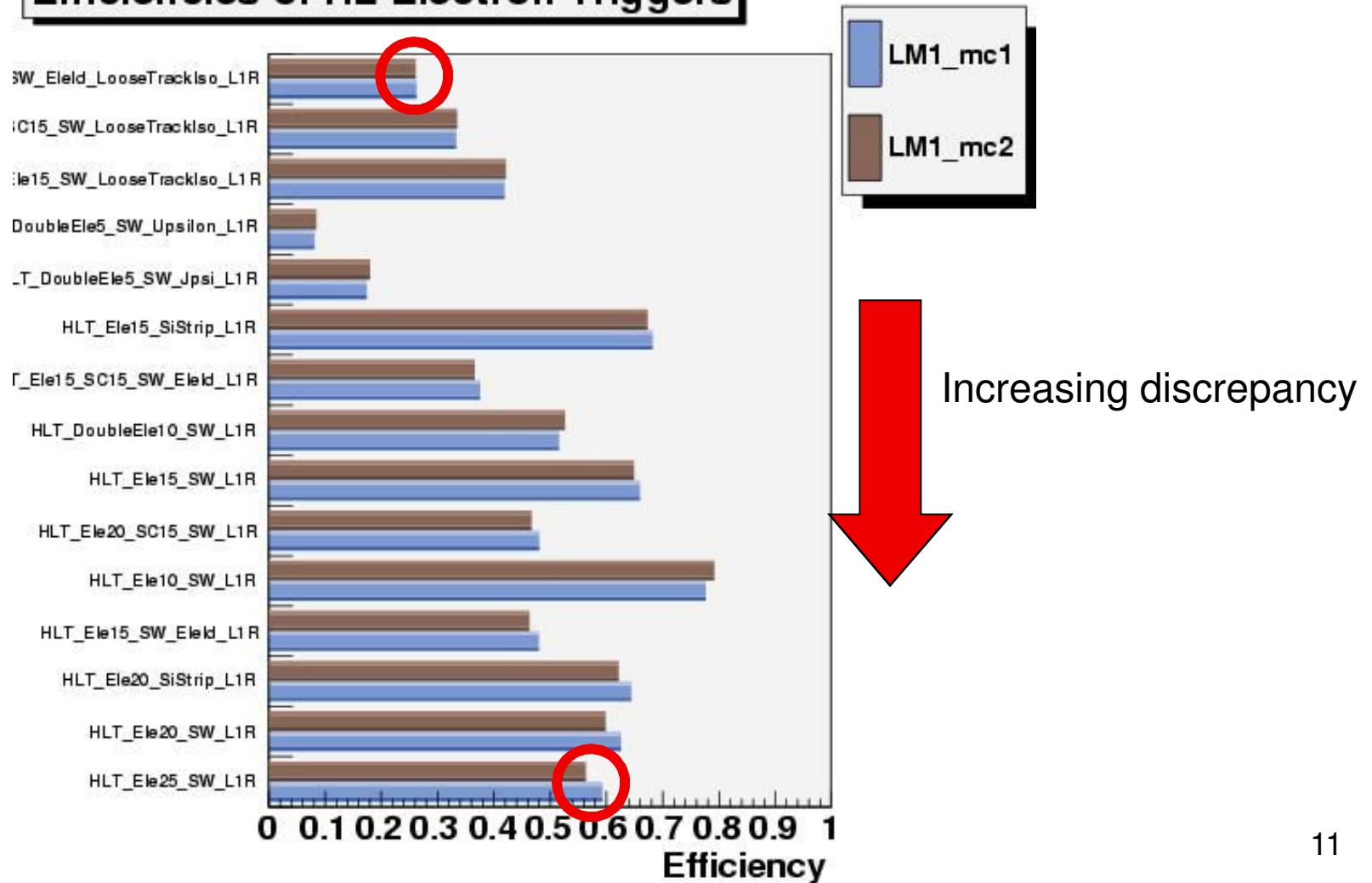
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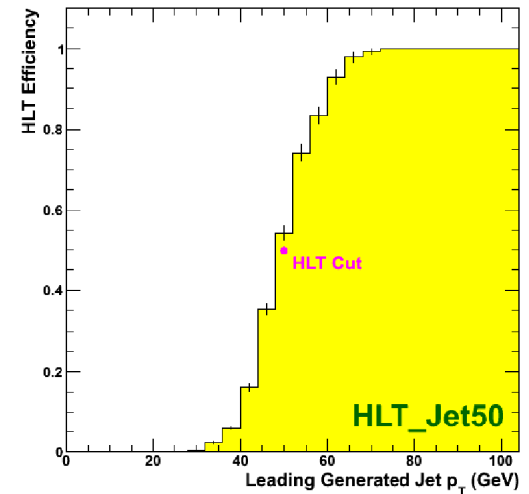
# HL Electron Triggers

**Efficiencies of HL Electron Triggers**

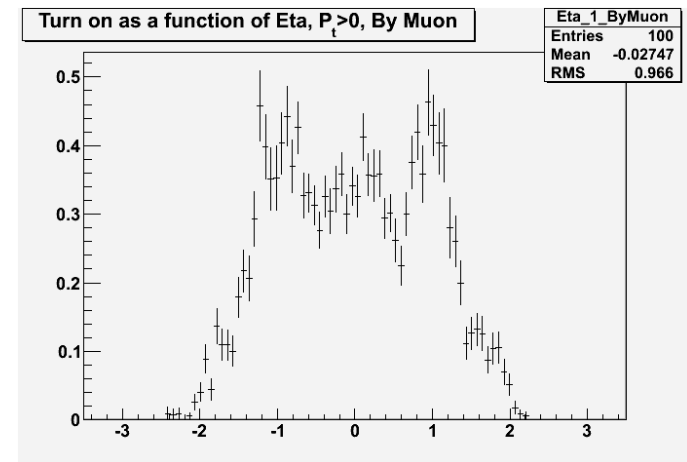
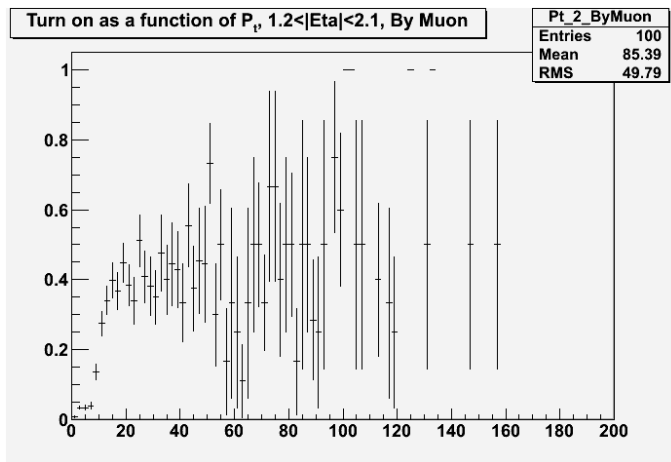
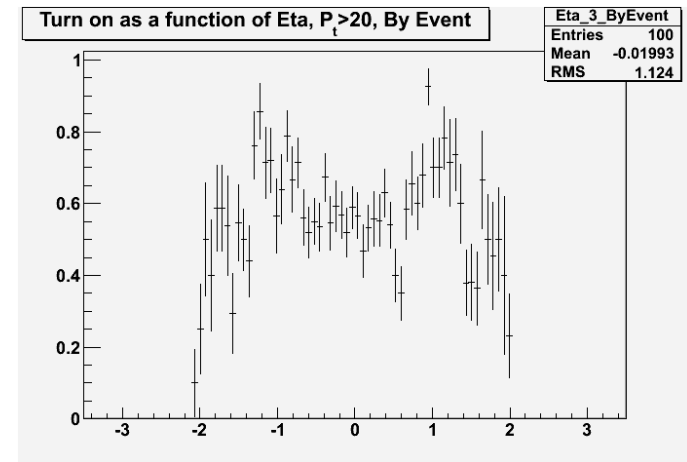
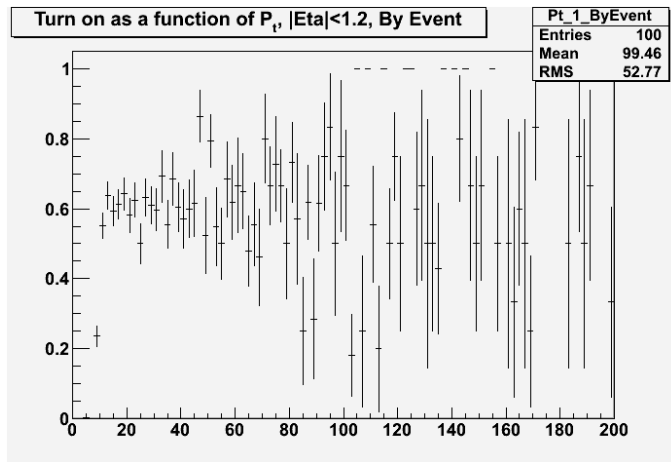


# Returning to the Physics

- Turn-on curves and efficiency curves of reco muons associated to a L3 muon by  $\Delta R < 0.5$ , where  $\Delta R = (\Delta\eta^2 + \Delta\phi^2)^{1/2}$ 
  - Function of  $p_t$  or  $\eta$
  - Analyzed in two ways
    - Event by event (taking the lead reco muon)
    - Muon by muon (accounting for all reco muons)
  - Three regions
    - For turn-on curves:  $|\eta| < 1.2$ ,  $1.2 < |\eta| < 2.1$ , and  $|\eta| > 2.1$
    - For efficiency curves:  $p_t > 0$ ,  $p_t > 10$ , and  $p_t > 20$
- Turn-on curves
  - Numerator: number of muons with  $p_t$  corresponding to bin associated to L3 muon
  - Denominator: number of muons with  $p_t$  corresponding to bin
- Efficiency curves
  - Numerator: number of muons with  $\eta$  corresponding to bin associated to L3 muon
  - Denominator: number of muons with  $\eta$  corresponding to bin



# Selected Plots from LM1 Sample



# Transition to Detector Data

- We would like to use the package developed for software validation to monitor detector data with respect to the performance of triggers interesting for SUSY analysis
- Changes must be made in the selection of final states, the calculation of efficiencies, and turn-on and efficiency plots

# Focus on Signatures

- SUSY has many possible manifestations, even in a five-dimensional parameter space (mSUGRA)
  - We are unsure which, if any, hypothesis best describes reality
- There are many scenarios of interest
- We focus on signatures rather than scenarios
  - Cuts are placed on signal and background (i.e. standard model) events
    - Using detector data, the cuts must be optimized to be as close as possible to the offline analysis cuts while keeping enough background events

# Global Efficiency

- For MC data, the calculation is simple because the total number of events is known
  - $\text{Eff} = (\text{events passed by trigger}) / (\text{total events})$
- For real data, the total number of events is not known, so a reference point is needed
  - Temporarily, Hlt\_ZeroBias trigger is used
  - Investigation is needed into using a reference point based on trigger-type



# Turn-on Curves with Data

- Future changes to be implemented
- Turn-on curves
  - Numerator: number of muons with  $p_t$  corresponding to bin associated to L3 muon from HLT\_L1MuOpen (or an orthogonal path such as HLT\_Jet30, HLT\_MET60, or HLT\_HT200)
  - Denominator: number of muons with  $p_t$  corresponding to bin from HLT\_L1MuOpen (or an orthogonal path such as HLT\_Jet30, HLT\_MET60, or HLT\_HT200)
- Efficiency curves
  - Numerator: number of muons with  $\eta$  corresponding to bin associated to L3 muon from HLT\_L1MuOpen (or an orthogonal path such as HLT\_Jet30, HLT\_MET60, or HLT\_HT200)
  - Denominator: number of muons with  $\eta$  corresponding to bin from HLT\_L1MuOpen (or an orthogonal path such as HLT\_Jet30, HLT\_MET60, or HLT\_HT200)
- We have to test with QCD or TTbar samples

# Acknowledgements

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- Maria Spiropulu
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