Optimization and Performance of the ATLAS Tau Trigger with Cosmics Data

Mansoor Shamim
University of Oregon
On behalf of the ATLAS Collaboration
Oct 6, 2009

11th ICATPP Conference
Como, Italy
5-9 October 2009

Outline

- Motivation
- ATLAS detector and trigger system
- Tau trigger at ATLAS experiment
- Performance and optimization of tau trigger
- Cosmics data taking
- Summary

Motivation

- What is so special about tau
 - the heaviest of the known leptons ($m_\tau = 1776.84 \pm 0.17 \text{ MeV}$)
 - large number of decay modes
 - local, isolated deposition of energy
- A pure sample of taus will
 - provide understanding of the detector using standard model processes ($W \rightarrow \tau \nu$ and $Z \rightarrow \tau \tau$)
 - help search for Higgs boson and Supersymmetry

Decay modes of tau

- leptonic
 - $\tau^\pm \rightarrow e^\pm + \nu + \nu$ (17.8%)
 - $\tau^\pm \rightarrow \mu^\pm + \nu + \nu$ (17.4%)
- hadronic
 - 1-prong
 - $\tau^\pm \rightarrow \pi^\pm + \nu$ (11%)
 - $\tau^\pm \rightarrow \pi^\pm + \nu + n\pi^0$ (35%), $n \geq 1$
 - 3-prong
 - $\tau^\pm \rightarrow 3\pi^\pm + \nu$ (9%)
 - $\tau^\pm \rightarrow 3\pi^\pm + \nu + n\pi^0$ (4.5%), $n \geq 1$
 - other $\sim 5\%$

ATLAS Detector

- A general purpose detector
- Trackers
 - Pixel
 - Silicon microstrip tracker (SCT)
 - Transition radiation tracker (TRT)
- Solenoid
 - 2T magnetic field
- Calorimeter
 - Electromagnetic (EM)-Liquid Argon (LAr)
 - Hadronic (HAD)
 - scintillating tiles in the central barrel, LAr in end caps (EC)
- Muon Spectrometer
 - excellent momentum resolution
 - independent momentum measurement at high transverse momentum
- Three large superconducting toroids
 - one barrel and two EC
 - eight-fold azimuthal symmetry around calorimeter
 - 1.2 T magnetic field

25 m

$\eta \equiv -\ln \tan(\theta/2)$; polar angle θ is the angle from the beam axis

Detector component	η coverage	
	Measurement	Trigger
Tracking	± 2.5	
EM calorimetry	± 3.2	± 2.5
Hadronic calorimetry (jets)		
barrel and end-cap	± 3.2	± 3.2
forward	$3.1 < \eta < 4.9$	$3.1 < \eta < 4.9$
Muon spectrometer	± 2.7	± 2.4

ATLAS Trigger System

- Three level trigger system
 - Level 1 (L1)
 - Hardware-based
 - reduced granularity from subset of detectors
 - calorimeter and muon
 - identifies Regions-of-Interest (Rols)
 - decision time $\sim 2.5 \mu\text{s}$
 - Level 2 (L2)
 - Software-based, seeded by Rols
 - full granularity-includes inner detectors
 - decision time $\sim 40 \text{ ms}$
 - Event Filter (EF)
 - uses offline analysis procedure
 - fully built events
 - processing time $\sim 4\text{s}$

L2 and EF together form the High-Level Trigger (HLT)

Tau Trigger at Level 1

- Dedicated tau trigger
 - designed to select hadronic decays of taus
 - common features with electron/photon trigger
 - hardware-based, only information from calorimeter
 - uses trigger tower of size 0.1×0.1 in $\eta \times \phi$ space (one of the four green boxes)
 - a 2×2 tower EM cluster and 2×2 tower HAD cluster are used to identify regions of interest

Tau trigger at LVL1

Tau High Level Trigger

- Level 2 (L2)
 - seeded by RoI at Level 1
 - information from both calorimeter and tracking is used
- L2 and EF make use of track multiplicity, narrowness and isolation criteria to increase the purity
- Event Filter
 - seeded by RoI from L2
 - algorithms similar to offline tau reconstruction are used to find good tau candidates

Tau Trigger Menu

- Menu

- A table which specifies the threshold and selection criteria at each trigger level

- Separate menus designed to deal with different luminosities

- motivated by physics requirements
- control background rates while keeping the signal efficiency high

- At $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$

- tau trigger will be used in combination with missing transverse energy (MET), electron and muon triggers
 - enriched sample of $W \rightarrow \tau \nu$
 - understanding of detector and tau reconstruction and identification software

- Tau Trigger menu for $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$ at 10 TeV

- errors are statistical only- rates calculated using multi-jet samples
- ATL-DAQ-CONF-2008-002

Menu	Goal	Trigger	Unprescaled Rate [Hz]
Single Tau	Searches at high P_T	tau50_loose	0.9 ± 0.5
tau+lepton	$Z \rightarrow \tau \tau$	tau12_loose_e10_loose	2.0 ± 0.7
tau+MET	$W \rightarrow \tau \nu, t\bar{t}, Z \rightarrow \tau \tau$	tau16_loose+xe25	6.9 ± 1.2
tau+jets	$t\bar{t}$	tau16i_loose+3j40	2.2 ± 0.7

- At $\sim 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

- tight identification requirements, increased E_T threshold or tau trigger combined with lepton, jet, MET triggers
 - sample used to search for new physics
 - $H^\pm \rightarrow \tau \nu, H \rightarrow \tau \tau, Z',$ decay chains of SUSY particles

Tau Trigger Performance

- Efficiency measured using $Z \rightarrow \tau\tau$ sample

$$\text{Efficiency} = \frac{\text{\# of truth matched reconstructed taus that fired a trigger}}{\text{\# of truth matched reconstructed taus}}$$

ATL-DAQ-PROC-2009-027

Plans to Measure Tau Trigger Efficiency in Early Data

- Single tau trigger efficiency can be measured using $Z \rightarrow \tau(e/\mu)\tau(\text{had})$
 - tag and probe method
 - require tag electron to pass e/μ trigger
 - what fraction of probes pass single tau trigger
 - direct measurement but low statistics
- QCD events (fake taus)
 - higher statistics
 - tight offline selections are applied to select good taus
- Top events
 - events triggered by 3jet trigger
 - one of the W decays into tau
 - how often this tau fires a tau trigger

arXiv:0810.0465v4 [hep-ex]

Cosmics-ray Data at ATLAS

Cosmics Data Taking

- ATLAS was ready for LHC data taking in Aug 2008
- Since then global cosmic runs
 - 500 M events collected: Aug-Oct 2008
 - alignment studies
- Single beam events in Sep 2008
 - used for timing studies
- Detector maintenance and repair work: Oct 2008 – Jun 2009
- Global cosmic runs in June 2009
 - 100 M events collected
- Combined global cosmic runs to start again in Oct 2009

ATLAS beam splash event (Sep 10, 2008)

Triggered by L1TAU, L1 Min. Bias and L1JET

Cosmic-ray Event Display

- energy deposition in the calorimeter
- a track reconstructed by tau trigger algorithms
- helpful in commissioning of tau trigger

Cosmics Data and Tau Trigger

Energy Correlation at Level 1(L1)

- L1 calorimeter energy correlation plot showing the energy measured in
 - trigger towers used to apply threshold
 - calorimeters cells
- Different electronics and subject to different calibrations
- Sharp cut-off due to trigger threshold of 5 GeV

Tau Trigger Data Quality (DQ) Monitoring

- Online DQ plots
 - grey: reference
 - green & red: data being taken online
 - issues with the total energy deposition
 - EM energy distribution looks fine
 - problem in HAD energy deposition
 - solution: trigger configured properly to cure the problem

Summary

- A dedicated tau trigger at ATLAS
 - designed and its performance evaluated using simulated events
 - commissioned during 2008 cosmics data taking
 - has provided valuable tool to understand the detector
 - MIP studies
 - DQ monitoring
- Ready to collect data with colliding beams
 - further understanding of SM processes
 - unveil the mysteries through searches for new physics using taus
 - effect of improvements implemented in algorithms
 - based on the studies of 2008 cosmics data

General Information

- Talk will be on Tuesday Oct 6, 2009
- Parallel session IX on high energy physics II 14:30-16:00
- Does not explicitly say how long the talk should be
 - 90 minutes and 4 talks scheduled
 - ~ 20 + 2 minutes
- Slide 17 is tentative-plot needs to be approved
- Another ATLAS talk in the same session on trigger monitoring

MIP Cluster at Event Filter

- Typical MIP energy deposit
 - ~ 200 MeV in LAr (EM)
 - 4 GeV in Tile (HAD)
- Uncorrelated behavior seen in EM and HAD energy deposition at L1 in cosmic events
 - Helpful to extract properties of MIP
- Large EM energy deposition- by energetic photon via Bremsstrahlung
 - small HAD energy deposition- muon as MIP
- Large HAD energy deposition
 - MIP cluster firing the trigger above 5GeV threshold

Tentative slide: Plot needs to approval

L1 EM seeded ($L1\text{ Em } E_T \geq 5\text{ GeV}$ and $L1\text{ Had } E_T = 0\text{ GeV}$),

L1 HAD seeded ($L1\text{ Em } E_T = 0\text{ GeV}$ and $L1\text{ Had } E_T \geq 5\text{ GeV}$),