The ATLAS tau trigger

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***Abstract*—The ATLAS tau trigger consists of three trigger levels: the first one (L1) is hardware based and uses FPGAs, while the second (L2) and third levels (EF -Event Filter-) are software based and use commodity computers. In this contribution, we discuss both the physics characteristics of tau leptons and the technical solutions to quick data access and fast algorithms. We show that L1 selects narrow jets in the calorimeter with an overall rejection against QCD jets of 300, whilst L2 and EF (referred together as High Level Trigger -HLT-) use all the detectors with full granularity and apply a typical rejection of 15 within the stringent timing requirements of the LHC. In the HLT there are two complementary approaches: specialized, fast algorithms are used at L2, while more refined and sophisticated algorithms, imported from the offline, are utilized in the EF.**

I. Introduction

THE ATLAS trigger system consists of three level trigger systems: the first one (L1) is hardware based and uses FPGAs, while the second (L2) and third levels (EF -Event Filter-) are software based and use commodity computers[1]. The L1 is designed to accept events up to 75 kHz, while the L2 and EF acceptances are 3 kHz and 200 Hz, respectively. Our challenge of the tau triggering is to suppress the QCD jets events on the order of 10^6. This can be archived by using an unique feature of the hadronically decaying tau leptons measured in the detector. The hadronic tau produces a collimated energy deposition in the calorimeters in a narrower region than QCD jets, relatively larger energy deposition in the electromagnetic (e.m.) calorimeter than the hadronic one and high p_T tracks in the narrow region assocated with the position found in the calorimeters. We use the shower shape and track information to identify the hadronic tau. The tau trigger does not have as strong a suppression of jets as the electron and muon triggers. The thresholds for single taus are therefore higher than the single electron and muon trigger thresholds. In addition, the selection criteria can be tightened. An alternative approach to controlling the rate that is also used is the combination of tau trigger items with electron, muon, or missing E_T triggers. The combined menu is expected to be used in the high rate environment of LHC operation at $\mathcal{L} = 10^{33-34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, where the main focus of tau triggers will be on the search for the Higgs boson or new physics beyond the Standard Model. In the early data taking period, the tau trigger will be also well tested and validated by the standard candle processes of the $W \to \tau\nu$, $Z \to \tau\tau$ and $t\bar{t}$ events.

[1]Currently, 2 x Intel Harpertown quad-core 2.5 GHz running on scientific linux 5 is used.

II. Description and performance of the ATLAS tau trigger

The L1 tau trigger selection is fully documented in [1]. It is a hardware trigger based on e.m. and hadronic calorimeter information, with 0.1×0.1 granularity in $\eta \times \phi$.

The selection at the HLT [2] makes use of the tracking and the full granularity calorimeter information. Whilst fast and specialized algorithms are used in the L2, more sophisticated and precise determinations can be performed in the EF. In

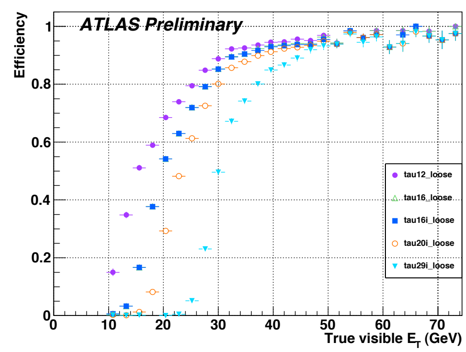

Fig. 1. Overall trigger efficiency (L1 + L2 + EF) for different tau triggers.

the ATLAS trigger menu, different single tau triggers are implemented, corresponding to different threshold requirements in the basic tau trigger variables: `tau12`, `tau16`, `tau16i`, `tau20i`, `tau29i`, where the first symbol of the signature represents the particle type, the following number is the E_T threshold and the "i" indicates that an isolation requirement is applied. The last argument "loose" is the adjustable configuration parameter which depends on the physics analysis and luminosity requirements. The other arguments are "medium" and "tight", which apply tighter selection against QCD jets background. Fig. 1 presents the overall trigger efficiency (L1 + L2 + EF) for different tau triggers. The efficiency is normalized with respect to those tau leptons that decay hadronically with visible tau momentum ($p^{\alpha}_{\mathrm{vis}} = p^{\alpha}_{\tau} - p^{\alpha}_{\nu}$) in the sensitive region of the detector ($|\eta| \leq 2.5$) and greater than the nominal E_T threshold requirement for a given signature. Furthermore, the efficiency is optimized to select those tau leptons which are likely to be selected by the tau identification algorithms of the offline reconstruction software [2]. The final rates are within the ATLAS bandwidth assigned to the tau trigger. The typical QCD rejections apply by the L1 and HLT tau triggers are 300 and 10 or more, depending on p_T range and tightness, respectively.

Table I gives the trigger menu proposed for initial data taking, including expected prescale factors and corresponding trigger rates. The un-prescaled single tau menu will be available above threshold $E_T \geq$50 GeV, while the combined menu can achieve the necessary rate suppression with lower thresholds.

TABLE I
TAU TRIGGER MENU FOR $\mathcal{L} = 10^{31}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ AT 10 TEV. TAU TRIGGERS (TAUXX) APPEAR IN COMBINATION WITH ELECTRON TRIGGERS (EXX), MUON TRIGGERS (MXX) AND MISSING E_T TRIGGERS (XEXX).

Trigger	Prescale	Rate (Hz)
tau50	1	0.89±0.44
tau16i_EFxe30	1	5.8±0.70
2tau20i	1	1.1±0.5
tau12_e10	1	0.89±0.45
tau16i_mu6	1	0.11±0.03

III. TRIGGER TIMING STUDIES

The L1 latency, which has been determined on the final hardware, is typically $2.5\mu s$, dominated by cable delays and including all stages of the signal processing. The actual L1 tau algorithm that identifies the L1 tau RoI takes $< 40ns$.

Prior to LHC data taking, the HLT system on 2008 (composed of Intel(R) XEON(TM) CPU 2.20 GHz machines) has to be assessed in simulated conditions, resembling real data taking. Simulated L1 trigger signals are produced using QCD background events with hard parton $35 < p_T < 70\,\mathrm{GeV/c}$. One exercise is the test of individual triggers to gauge the impact of increasing threshold levels on the total execution time of the trigger, presented in Table II. Although the average execution time of each algorithm remains roughly equal between triggers, the average total time per event decreases as a result of the lower number of RoIs per event for high energy triggers. The results shown in Table II indicate that the time performance of the tau trigger should be well within the constraint for total execution time at L2 and EF.

TABLE II
MEAN ALGORITHM EXECUTION TIME FOR EACH OF THE TAU TRIGGERS. ALL TIMES ARE GIVEN IN MS AND PER ROI, EXCEPT THE L2 AND EF TOTAL TIMES ARE GIVEN PER EVENT, IN MS. THE MEASUREMENTS ARE PERFORMED ON A SIMULATED SAMPLE OF LIMITED STATISTICS, 950 QCD BACKGROUND EVENTS WITH HARD PARTON $35 < p_T < 70$ GEV/C.

	Threshold Signature		
Algorithm	tau10i	tau20i	tau35i
L2 Calo	8.1	8.0	8.1
L2 Tracking	15.4	15.0	14.7
L2 Combined	1.9	2.0	2.2
L2 TotalTime	41.6	19.7	7.9
EF Calo	12.3	13.4	14.0
EF Tracking	289.7	269.5	247.8
EF Combined	77.0	80.7	78.9
EF TotalTime	149.1	67.5	24.6

IV. COMMISSIONING OF THE TAU TRIGGER

The tau trigger is tested with the ATLAS commissioning run in cosmic ray events. Although there is no real tau signature in the cosmic muon events, it is extremely worth to test the trigger chain and all detector systems, since the tau trigger uses the track and e.m. and Hadronic calorimeter information. As shown in Fig. 2, the triggered events are compared with

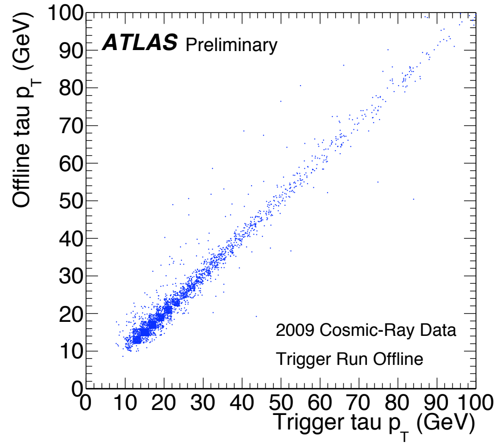

Fig. 2. Comparison of the EF and offline taus with respect to the reconstructed p_T spectrum, where the EF and offline taus are matched within $\Delta R \leq 0.2$.

the offline reconstructed events. Since the arrival time of the cosmic ray is in principle a random process, the measured pulse in the calorimeters synchronized with the beam clock is not precise in the trigger reconstruction, while in the offline reconstruction, a more sophisticated procedure is used to determine the best optimal timing. This means that the offline energy reconstruction has better performance than the trigger reconstruction. Regardless of the different energy measurement scheme between trigger and offline reconstructions, we can see a reasonable agreement between the EF and offline taus. This is an expected feature in that we observed small difference in each channel in the calorimeters between trigger and offline reconstructions.

V. CONCLUSION

We present an overview performance of the ATLAS tau trigger at $\mathcal{L} = 10^{31}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for 10 TeV collisions. The typical tau trigger efficiency is expected to be around 90% for a wide range of physics channels, resulting in a total tau trigger rate of about 15 Hz including triggers for monitoring and calibration. The trigger menu is well tested by the cosmic data and demonstrated its performance with respect to the offline reconstruction. The main focus of tau triggers will be on the selection of the standard candle processes $W \to \tau\nu$, $Z \to \tau\tau$ and $t\bar{t}$ in the early phase of the experiment, but it will also turn to the search for the Higgs boson or new physics beyond the Standard Model in long term of the experiment.

REFERENCES

[1] J.Garvey *et al.*, Nucl. Inst. and Meth. **A** 512, no. 3 (2003), 506-516.
[2] ATLAS Collaboration, Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics, CERN-OPEN-2008-020,arXiv:0901.0512.