UPGRADE OF THE TRIGGER READOUT SYSTEM OF THE ATLAS LIQUID ARGON CALORIMETERS

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ATLAS EXPERIMENT

44m



ATLAS LAr calorimeter uses different technologies and comprises more than 180k cells:

- Electromagnetic (EM) calorimeter is composed of lead and liquid argon.
- LAr Hadronic end-cap and forward calorimeters use copper, iron, tungsten and liquid argon.

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ATLAS TRIGGER SYSTEM



Level-1 calorimeter trigger system:

Uses a coarse granularity, grouping together as many as 60 calorimeter cells into Trigger Towers. There is no longitudinal information available the Level-1 trigger and the digitization precision is only 1 GeV.

LHC UPGRADES AND PLANS

Performance has been good to this point (see talk by Walter Lampl)

But LHC running conditions will become more challenging: actual instantaneous luminosity could be even higher than the nominal plan

To study the LAr Upgrade performance a Run-3 luminosity of 3 x 10^{34} cm⁻²s⁻¹ and <µ> = 80 interactions per bunch crossing (pileup)



LAR UPGRADE MOTIVATION

- The ATLAS Level-1 trigger rate will be limited to 100 kHz in Run-3 for all triggers
- Current Electron and photon (EM) trigger selections alone would be 270 kHz under Run-3 luminosity and pileup conditions !
- Reducing the EM trigger rate to the desired bandwidth of 20 kHz will require a significant increase of transverse energy thresholds
- Even with strong isolation requirements this increase will lead to important acceptance losses

LAR UPGRADE CONCEPT

- Design, build, and install new trigger readout electronics during the second long shutdown (LS2) of the Large Hadron Collider (LHC) in 2018
- Provide more information from the calorimeter to the Level-1 trigger processors
 - \rightarrow Higher granularity and resolution
 - \rightarrow Longitudinal shower information
 - \rightarrow Take advantage of feature extraction
- Apply rejection criteria similar to those used offline in order to reject the dominant background of QCD jets

CURRENT SYSTEM



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ELECTRONICS TO BE UPGRADED



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INCREASE OF GRANULARITY



A "SuperCell" is the name given to the new grouping of calorimeter cells provided to the trigger with finer granularity in eta, phi and longitudinally



UPGRADE IMPACT

The proposed LAr upgrade would impact resolution and trigger efficiency for:

- Electrons and photons
- > Tau leptons
- Jets
- Missing transverse energy

While maintaining or even increasing efficiency, reduced transverse energy (E_T) thresholds will increase acceptance for measuring Higgs properties and looking for new physics including supersymmetry (SUSY) and extra dimensions



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SHOWER SHAPE VARIABLES

- R_η variable uses the ratio of E_T in 3x2
 SuperCells to that in 3x7 SuperCells around an energetic seed (middle layer only)
- f_3 is the ratio of the E_T measured in the back EM layer in an area of size $\Delta \eta x \Delta \phi = 0.2x0.2$ to that deposited in all three layers for an EM cluster
- A third variable (w_n^2) can also be used
- These variables are more robust than current Level-1 electron identification to changes in pileup level



EM TRIGGER PERFORMANCE



For an electron efficiency of 95% the EM E_T threshold can be lowered by 7 GeV with respect to Run-2 keeping the 20 kHz rate budget

- Photon efficiency will be maintained at 96-98%
- Single and di-object EM triggers will be very important for many analyses in the ATLAS physics program

TAU TRIGGER PERFORMANCE

- A shower shape variable similar to the EM R_η can reject jet backgrounds which dominate the single hadronic tau triggers
- Nearly 50% rejection can be achieved with a 90% efficiency for 20-25 GeV hadronically decaying tau leptons
- Other variables under study show promise for further reduction
- Lower rates will allow the E_T threshold to be reduced



JET TRIGGER PERFORMANCE

- Increased pileup leads to greatly enhanced event activity
- Jet triggers will suffer from very large jet multiplicity at <µ> = 80 and beyond!
- Smaller quantization of SuperCells gives a sharper turn-on curve and higher efficiency for true jets while reducing backup from pileup
- Pileup subtraction similar to E_T density (ρ) correction used in offline software reduces the number of fake jets



MISSING ENERGY TRIGGER

- Two different methods to decrease pile-up contribution to missing E_T
 - η slice-based pileup subtraction
 - Layer-based pileup suppression
- With the same bandwidth as the Level-1 missing E_T expected for Run 2, the threshold could be lowered from 90 to 70 GeV using layer-based method only



CURRENT SYSTEM



- A partial sum of pulses within each Front-end board (FEB) is performed by the Layer Sum board

-Partial sums are sent to a Tower Builder Board which makes the final sum for a Trigger Tower

-The results go to the L1 Trigger



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UPGRADED SYSTEM





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UPGRADE COMPONENTS

- The Layer Summing Boards will be changed to produce sums consistent with the finer SuperCell granularity.
- A new board, LAr Trigger Digitizer Board (LTDB) will be added to the electronics
- New base plane will allow the transmission of an increased number of signals between the Front end boards and the new LTDBs
- A new LAr Digital Processing System (LDPS) will receive the digital signals from the 124 LTDBs and transmit the data to the Level-1 calorimeter trigger system and Feature extractor (LDPS is also responsible for E_T/time computation at 40MHz)

LAR TRIGGER DIGITIZER BOARD

- Each LTDB will process up to 320 Super Cell signals.
- High performance ADC in development (40MHz, low power consumption)
 - 1 commercial option under test
 - 2 application specific cicuits being designed
- High speed Serializer
- The LTDB design will allow a digital precision of 32 MeV in the front layer and 125 in the middle layer



Demonstrator board (not final)



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LAR DIGITAL PROCESSING SYSTEM



- Receives data from the LTDBs and transmits the computed SuperCell energy to L1Calo
- Distributes the ATLAS Trigger, Timing and Control signals back to the LTDBs
- Enables the Feature extractor Upgrade to use global calorimeter information in Level-1 trigger decision
- Addvanced Telecom Computer Architecture standard chosen
- On-going algorithm optimization: high frequency(40 MHz), high speed (within 6 bunch crossings) computation of variables very challenging

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CONCLUSIONS

- An upgrade of the trigger readout for the ATLAS LAr Calorimeters is essential for running in high luminosity and pileup conditions
- The proposed upgrade will provide :
 - Higher granularity and resolution
 - Longitudinal shower information
 - Global feature extraction
- Reduced transverse energy (E_T) thresholds for electrons, taus, jets and missing energy will increase acceptance for many ATLAS measurements and searches
- Demonstrator phase will validate the upgrade design starting in one crate in 2014