A program to drive the ATLAS Local Trigger Interface (ALTI) at the ATLAS experiment

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Introduction
Subatomic particles are accelerated close to the speed of light along a circular tunnel (circumference of 27 km) near the Swiss-French Border.

Collisions at LHC: counter rotating, high intensity bunches of protons or heavy ions - center of mass energy $\sqrt{s} = 13$ TeV (Run II)

Beam structure:
3564 bunches of which 2808 full bunches with $1.15 \times 10^{11}$ protons per bunch and spacing of 25 ns (40 MHz, distance: 7.5 m)
The ATLAS experiment – Phase I upgrade

General-purpose experiment operating at the Large Hadron Collider (LHC)
Currently in shutdown mode (LS2) and Phase-I experiment upgrade on the path to
High Luminosity – LHC:  \( L = 5 \times 7 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \)

Affected regions: New Small Wheel
will replace Small Wheel, the current inner station of the ATLAS muon end-cap system

Goals:
• Improve tracking efficiency in the high rate environment (up to 15 kHz/cm² )
• Reduce end-cap fake triggers from background hits (currently at 90%)
• Provide spatial resolution at 100 μm and angular resolution < 1 mrad at Level-1 Trigger

ATLAS detector [3]
The ATLAS New Small Wheel

NSW will utilize two different gas detector technologies:

- **Micromegas (MM)** detectors optimized for precision tracking
- **small-strip Thin Gap Chambers (sTGC)** optimized for triggering

![NSW layout](image)

- 16 sectors (8 small, 8 large)
- **Two** sTGC wedges / sector and **two** MM wedges / sector
- **Four** layers / wedge of each detector technology

Layout [4]
NSW Trigger and Readout Electronics

Central Trigger Processor (CTP)

sTGC and MicroMegas trigger data from Trigger Processor are combined at Sector Logic and sent to the Central Trigger Processor (CTP).

CTP: responsible for making the initial trigger decision (Level 1 trigger accept signal) by identifying interesting particle candidates coming from the Level-1 calorimeter and Level-1 muon trigger systems.
ATLAS Local Trigger Interface (ALTI)
ATLAS Local Trigger Interface (ALTI)

Interface between the Level-1 Central Trigger Processor (CTP) and the timing, trigger and control (TTC) optical broadcasting network to the front-end electronics of each of the ATLAS sub-detectors.
ATLAS Local Trigger Interface (ALTI)

Currently:
ALTI provides an artificially generated pulse pattern and the Bunch Crossing clock at 40 MHz for data synchronization.

Pattern contains the TTC information (FORWARD and BACKWARD signals)
ALTI pattern and parameters

Important **FORWARD** type of signals:

- **ORB**
  Periodic signal representing one full LHC turn.
  LHC orbit period is \( \sim 89 \, \mu s \) (3564 BC’s)

- **BGO [0-3]**
  Signals for sending TTC trigger commands

- **L1A**
  Pulse representing the Level 1 trigger accept signal
  \( \rightarrow \) Produced by identifying interesting particle candidates, combined by the Level-1 calorimeter and Level-1 muon trigger systems
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BACKWARD type of signals:

- **BUSY**
  Informs CTP to postpone L1A signals e.g. when the readout buffers are overwhelmed

- **CREQ [0-2]**
  Signals to generate calibration requests
ALTI pattern generator

Program containing the tools to generate configurable ALTI pattern files at different trigger rates

Motivation: Simulate real-time conditions and study the response of the trigger electronics

Important parameters:
- content of ALTI output file
  - test pulses, L1As or both
- trigger type
  - clocked (fixed distance between consecutive test pulses)
  - random
- test pulse – L1A latency
- LHC beam structure

3 files are generated:
- ALTI configuration file (.dat)
- txt file
- pdf of histograms (random operation)

Trigger mechanisms:
- sliding window
- complex deadtime
Trigger mechanisms

Mechanisms implemented in the CTP to minimize BUSY from sub-systems:

➢ **Simple deadtime:** TP- L1A latency
  • Prevents overlapping of readout time-frames

➢ **Complex deadtime:** “Leaky” bucket algorithm
  • Prevents de-randomisers of front-end systems to fill-up

➢ **Sliding window:** Maximum 15 L1As in 3600 BCs
  • Prevents Pixel front-end to suffer from data de-synchronization due to single very large background event

" Leaky” bucket algorithm [6]

Additional trigger rules: limits on frequency, duration and number of orbits
Generation of ALTI pattern file

Contains all generated data sorted in the required ALTI format
(example at 100 kHz – 44 BCs TP-L1A latency)

Test pulse signal arrives every 400 BCs in each LHC orbit - L1A signal arrives 44 BCs later
LHC beam structure (random)

Histograms for test pulse/L1A signals after implementing LHC beam structure (example at 200kHz – 70BCs TP-L1A latency)

ATLAS work in progress
Sent ALTI patterns at various frequencies to the trigger path

Used `netio_cat` to readout data from the pFEBs and the Pad Trigger

Test pulse and L1A signals are assigned a specific Bunch Crossing ID (BCID) in each orbit

**Goal**: Observe matching consecutive test pulse BCIDs between ALTI pattern files and data
Decoded and analyzed netio packages obtained for frequencies up to ~15 kHz

First observations (example at 10 kHz -clocked)
Pad Trigger readout - Analysis

VMMs receive test pulse signal from ALTI → Generate a test pulse signal at the next BC → Pad Trigger receives test pulse data 3 BCs later

BCIDs and time differences:
- pFEB BCID - txt BCID
- pad BCID – pFEB BCID

10 kHz clocked

1 kHz random

ATLAS work in progress
Summary and plans

• A program has been created in order to configure the ATLAS Local Trigger Interface and test how the New Small Wheel trigger electronics respond under the generated conditions

• Results are promising for clocked and random triggers, produced by this program

• Further analysis and readout tests at higher rates are planned

Thank you for your attention
References


