ATLAS ITk-Pixel DAQ System
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ITk-Pixel Read-out System

Following Run 3 of the Large Hadron Collider (LHC), the ATLAS experiment is undergoing significant enhancements as part of the High-Luminosity LHC (HL-LHC) upgrade for Run 4.

The goal of the HL-LHC is to achieve high-energy collisions with a luminosity $\simeq 7 \times 10^{34} cm^{-2}s^{-1}$, trigger rate $\simeq 1$ MHz and pile up events up to 200 @40 MHz.

The existing ATLAS inner detector system will be replaced by a new all-silicon tracking system called ITk (Inner Tracker).
ITk is composed of 4 strip and 5 pixel layers in barrels and end-caps. Pixel system covers an area of ~13 m².

ITk-Pixel[1] properties:
- Higher range cover ($|\eta| < 4$)
- Higher resolution (50µm x 50µm pixel size and 25µm x 100µm for the inner-most layer)

Target: Provide read-out of the whole ITk-Pixel (~9700 Modules).

Intermediate step:
ITk Outer Barrel consists of loaded local supports (LLS):
- Longeron (36 Quad modules (QM)).
- Inclined Half Rings (from 16 QMs up to 28 QMs).

Read out ITkPix Front-end with the final chain.

Goal: Need to prepare, debug, validate read-out chain through scaling up the number of modules under test.

Starting point: Read out 1 FE to few QMs.

ITk Read-out Data AcQuisition (DAQ)

Challenges:
- O(10k) modules of operated front-ends:
  - O(5 billion) pixels to deal with.
    - Send commands to them.
    - Receive data from them.

DAQ read-out chain consists of:
- ITkPix QMs(each QM has 4 FEs)
- Electric connections to optobox
- Optobox with up to 7 optoboards:
  Data aggregation, Command and triggers spreading, electrical/optical conversion
- Optical connections: Fiber cables to off-detector DAQ system
- DAQ PC:
  - FELIX[2] Card (PCIe FPGA board): Interface between FEs and ITk DAQ SW (YARR)
  - YARR[3]: Commands FEs, through FELIX, receives and processes event data and stores them in database

Optical link **command transmission** at 2.56 Gb/s

Optical link **data reception** at 10.24 Gb/s

Experimental Results

The lab setup consists of:
- 3 ITkPix Quad modules
- Electrical connections
- Optobox with optoboard
- Optical connections
- FELIX server hosting a FELIX Card with installed optoboard software, FELIX software and YARR software.

Procedure:
- Start doing YARR digital scan with one front-end.
- Scaling up by adding more front-ends.

Achieved result:
- Validation of DAQ read-out for 10 ITkPix front-ends with no data transmission errors in 3 ITkPix QMs.

Achieved Performance

Tracking the digital scan results and execution times with the increasing number of FE operated at the same time to assess the DAQ system functionality.

Hit map of 1st module sequentially enabling:

| 1 FE | 2FE | 3 FE | 4 FE |

The scans run in parallel with 3 threads each

YARR configures the front-ends one by one

→

Configuration time increases linearly.
Scan time increases slightly

→ Reasonable performance

YARR processes consumed time

Current status & Outlook

The ITk DAQ readout is validated to read out 10 front-ends simultaneously with increase in scan time as the number of front-ends increases.

- Scaling up the number of front-ends once extra QMs are available.
- Optimizing (decreasing) the time consumed by YARR scans → for better DAQ performance.

References:
1-Technical Design Report for the ATLAS Inner Tracker Pixel Detector, tech. rep.,Geneva: CERN, 2017
2-https://atlas-project-felix.web.cern.ch/atlas-project-felix/
3-https://yarr.web.cern.ch/yarr/

Inner Detector => All-silicon Inner Tracker

Inner Tracker (ITk)

Quad Module (QM)