SWEDISH INSTITUTES' CONTRIBUTIONS TO THE ATLAS UPGRADES

Partikeldagarna - Uppsala University - 23-25 November 2020

Eleni Myrto Asimakopoulou on behalf of the Swedish ATLAS Institutes

Uppsala Universitet

UPPSALA UNIVERSITET

LUND UNIVERSITY

Stockholms universitet

KTH VETENSKAP OCH KONST

Run-3 & High-Luminosity LHC (HL-LHC)

Good physics studies rely on:

- reproduction of a process of interest (collision)
- enough statistics

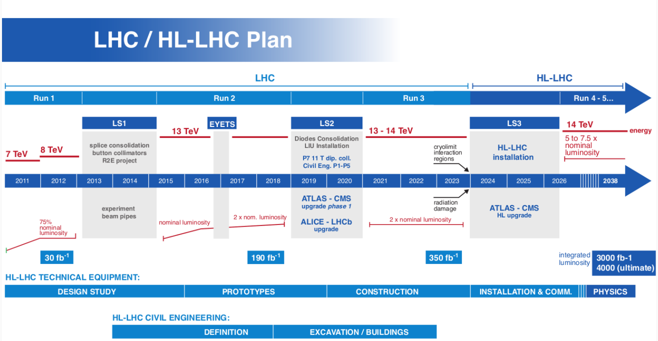
$$\mathrm{N}_{\mathrm{events}} \longleftrightarrow \mathrm{L}\, \sigma_{\mathrm{event}},$$

↪ $\mathrm{N}_{\mathrm{events}}$: # times process occurs
↪ σ_{event}: probability of process to occur
↪ L: luminosity

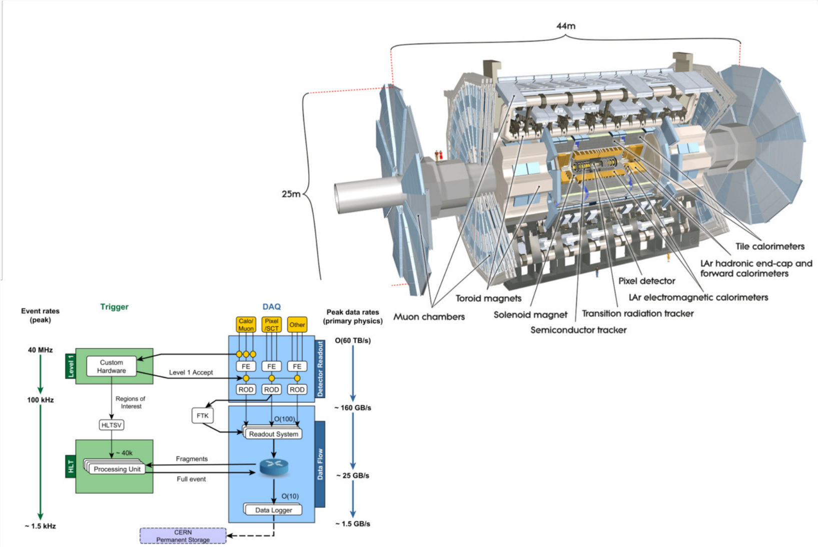
Upgrades:

Higher beam energies
↪ Run-3: 13 — 14 TeV
↪ HL-LHC: 14 TeV

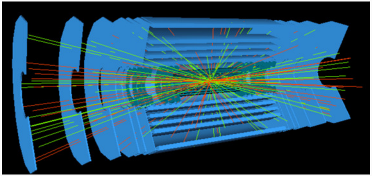
Higher Luminosity
↪ HL-LHC: $L_{\mathrm{peak}} \sim$ 5-7.5 × 10^{34} $cm^{-2}s^{-1}$
↪ HL-LHC: $L_{int} \sim 3000(4000)\ fb^{-1}$

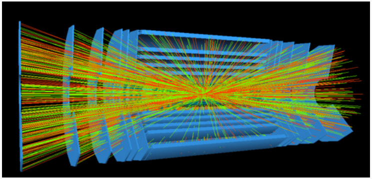


ATLAS Detector & Data acquisition



ATLAS Upgrades - HL-LHC





- **Higher Radiation levels**
  ↪ detectors will be damaged
  ↪ electronics will not cope with these conditions
- **Higher Pile-Up**
  ↪ bandwidth saturation
  ↪ detectors will not be able to cope

Upgrade

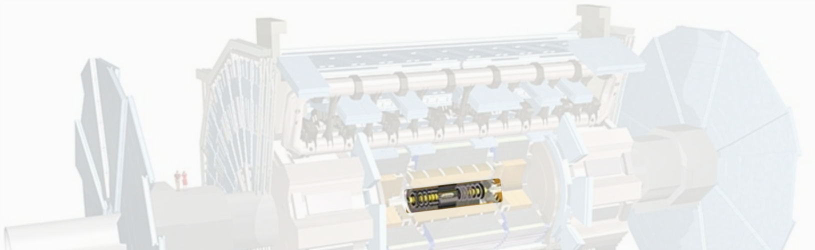
↪ Detector materials

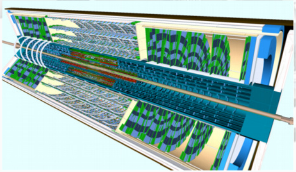
↪ Electronics

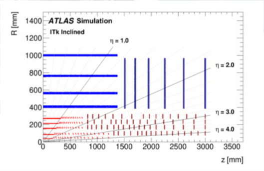
↪ Trigger & Data acquisition system

Inner Tracker (ITk)

pixel TDR: CERN-LHCC-2017-021
strip TDR: CERN-LHCC-2017-005





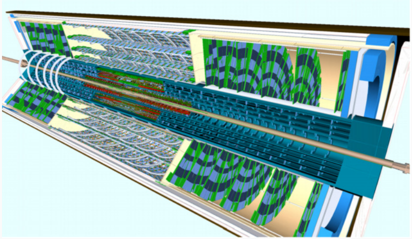


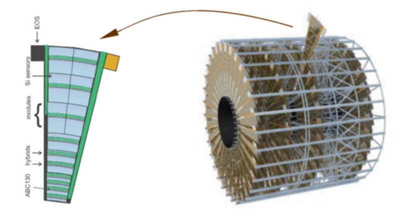
Purpose & Design

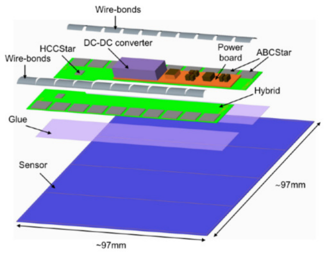
- Identify and track charged particles
  Reconstruct primary vertices $\Rightarrow$ identify hard scattering
  $\hookrightarrow$ jet energy measurements, particle isolation, missing transverse momentum

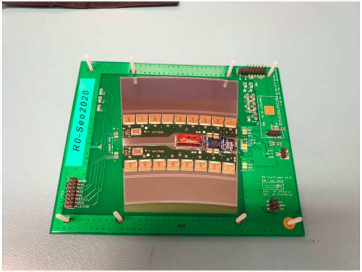
- Radiation tolerant!
  $\hookrightarrow$ 10 *yrs* operation under
  $1.3 \times 10^{16}\ n_{eq}/cm^2$ (pixel)/
  $1.6 \times 10^{15}\ n_{eq}/cm^2$ (strips)

- All silicon detector (n-type implants on p bulk)
  $\hookrightarrow$ 6 *m* long, 2 *m* in diameter,
  $|\eta| = 4$ coverage.









Scandinavian Cluster:

- Four participating institutes in Scandinavia:
  ↪ Uppsala University (UU)
  ↪ Lund University (LU)
  ↪ ~~Niels Bohr Institute (NBI)~~
  ↪ University of Oslo (UiO)

Activities

- Pledged for ∼10% of the whole end-caps production (R1, R3 module types)
- Module production in industry (NOTE)
  ↪ UU: responsible for Quality Assurance and some Quality Control procedures during module production
- Module testing in institutes
  ↪ LU: responsible for Quality Control of modules

\+ Readout ASIC irradiation campaign
\+ Assembly Tool preparation
\+ Thermal Testing ("ColdBox") jig preparation

\+ Readout Scheme

Hardware Track Trigger (HTT)

Motivation

- Higher luminosities ⇒ more events
- Resource limitations for data recording
- Need same trigger efficiency

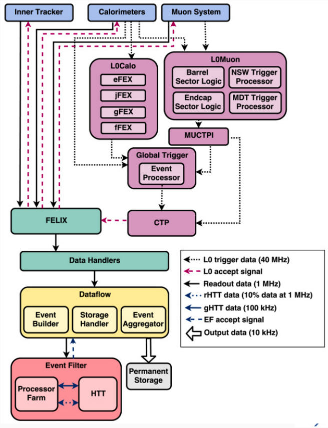
Single Hardware Trigger senario: (baseline)

- Provide good quality tracks to the software trigger
- Acts as a co-processor for the software trigger, lightening the load
- Software trigger is in charge of requesting tracking from HTT
  Regional (rHTT) and Global (gHTT) tracking:
  ↪ rHTT: tracking on regions of interest (10% of full ITk data) at 1 *MHz* → reconstruct tracks with $p_T > 2$ *GeV*
  ↪ gHTT: tracking on full ITk data at 100 *kHz* → reconstruct tracks with $p_T > 1$ *GeV*

! Can evolve for use in the hardware-based Level-1 trigger
↪ dual-level hardware trigger → reconfiguration of HTT

Plan

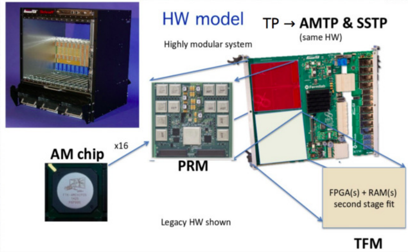
- Improve trigger level reconstruction
  ↪ currently software-based tracking,
  ↪ addition of hardware-based trigger to reduce the load
  (**HTT**): based on the existing hardware tracking input to the software trigger



HTT

Design

- custom Associative Memory ASICs for for pattern recognition and FPGAs for track reconstruction and fitting
- Flexible, modular
- Presently preparing a system demonstrator (v0)
- Optimizations with respect to the original Technical Design Review ↪ cost reduction!

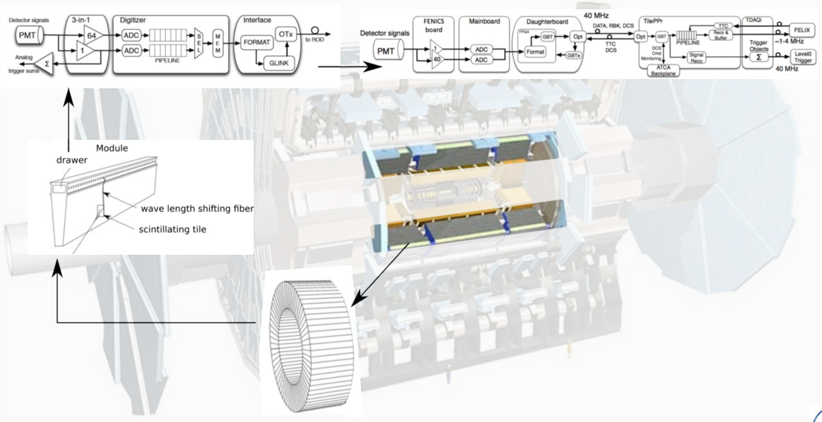


UU Involvement

- Development of alternative pattern recognition to AM based (requires custom made ASICs) on Hough transform (implemented in firmware)
- Data format definition and test-vector preparation
  ↪ uniform format across all boards & simulation
- Offline simulation studies
  ↪ investigation of benefits to the HTT simulation from including minimalisic extrapolation of charged tracks through the ITk
  ↪ prospect studies of using HTT to trigger on Long Lived Particles
- Online control & monitoring of the pattern recognition Menzanine cards

Tile Calorimeter (TileCal)

TileCal TDR: CERN-LHCC-2017-019

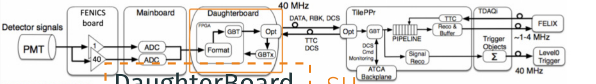


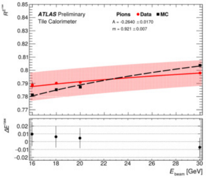
Overview

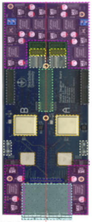
- scintillating plastic tiles and steel absorbers hadron calorimeter
  ↪ readout with photomultipliers and wavelength shifting fibers
- hadronic jet energies & missing transverse momentum
- input to the trigger system

Upgrade SU

- replace most exposed photomultipliers
- replace and redesign read out electronics
  ↪ fully digital, using full granularity
  ⇒ higher precision
  ↪ Readout at 40MHz (1.7 ms) → LHC timing.
  ↪ Higher radiation tolerance







COTS

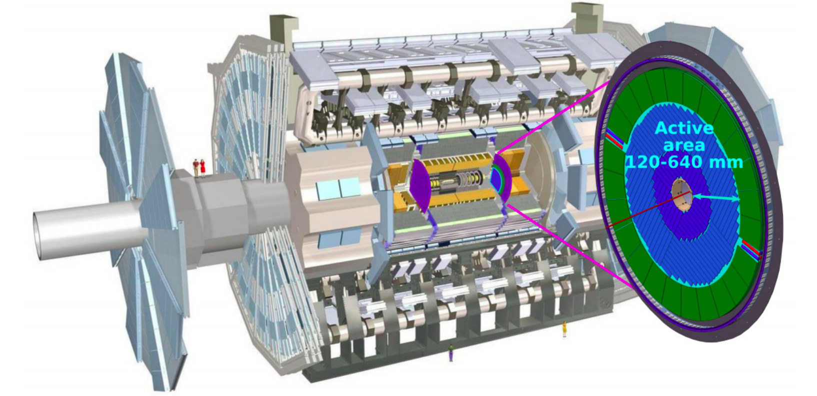
DaughterBoard SU

- high speed communication with off-detector electronics
- receives & distributes LHC clock,
- distribute configuration commands and control signals to the front-end,

Expected doses for $L_{\text{int}} = 4000\ fb^{-1}$ (Geant4):
↪ Total Ionizing Dose: 24 Gy
↪ Non-Ionizing Energy Loss: $1.1 \times 10^{12}\ n/cm^2$
↪ Single Event Errors: $1.4 \times 10^{11}\ p/cm^2$
No tolerance for Single-Event Latch-up → DB6

High-Granularity Timing Detector (HGTD)

HGTD TDR: CERN-LHCC-2020-007

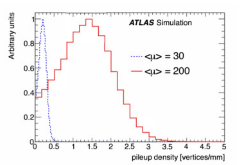


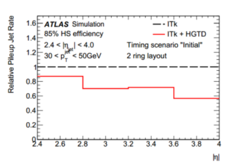
HGTD

B. Lund-Jensen: Institute Board Chair, co-coordinator for the Electronics group
J. Strandberg: co-coordinator for the Luminosity & DAQ group
C. Ohm: co-coordinator for the Sim/Perf/Physics group (up-to mid. 2020)

Scope & Design

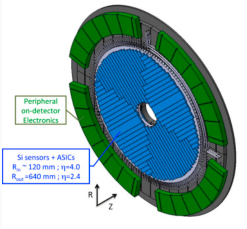
- More collisions at close distances
  ↪ Difficult to distinguish tracks (! forward region)
  ↪ Assign high-precision time information to tracks
- Enhance performance of physics object reconstruction
  ↪ Augment ITk capabilities in the forward region
- Precise luminosity determination KTH
- Design based on silicon pixels
  ↪ Low Gain Avalanche Diode technology, $1.3 \times 1.3\ mm^2$
- $2.4 < |\eta| < 4.0, \quad 120\ mm < R < 640\ mm$
- <time resolution> per track: 30 ps (start)





Luminometer capabilities

- Fast & high granularity ⇒ low occupancy ⇒ good linearity of hits to the interaction rate ⇒ per bunch crossing readout at 40MHz rate (no trigger bias, “online”) and offline
- $2.4 < |\eta| < 2.8$
- Lower systematic uncertainties in luminosity measurements

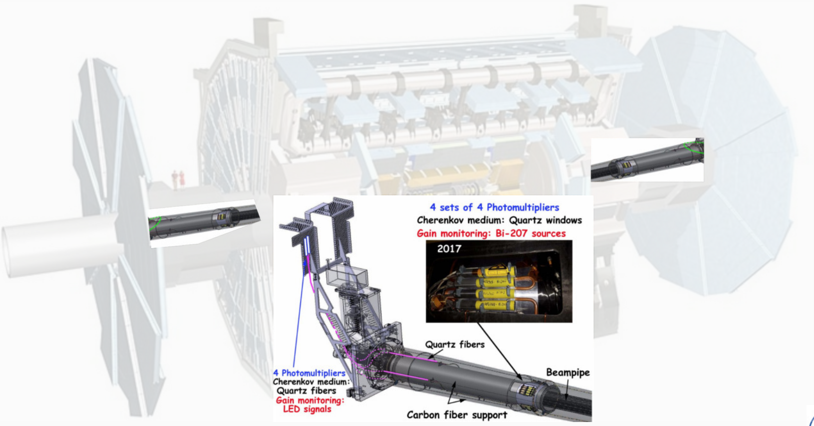


KTH Involvement

- luminosity processing system
- produced overall design and performed TDR simulations studies

LUMINOSITY CHERENKOV INTEGRATING DETECTOR (LUCID)

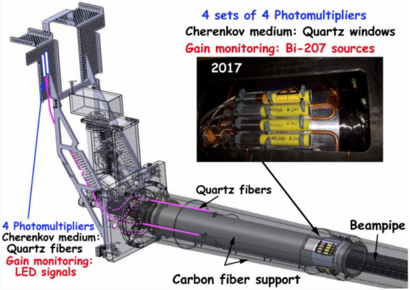
LUCID Upgrade Doc: 2018 JINST 13 P07017



LUCID

Scope & Overview

- Luminosity measurements
  ↪ average number of detector hits recorded per bunch crossing & charge integration
  ↪ Run2,3: main online and offline luminometer for ATLAS.
- 2 modules, placed symmetrically from the interaction point
  Each module:
  ↪ 4 groups of 4 (16) photomultipliers with quartz windows
  ↪ 4 bundles of quartz fibers



Upgrade LU

- **LUCID-2** (Run3): Prototype detectors under development with photomultipliers in new locations and new quartz fiber detectors.
  ↪ detector gain measured with Bi-207
  ↪ fiber degradation monitoring with LEDs and PIN diodes
- **LUCID-3** (HL-LHC): New photomultipliers and new fiber detectors
  ↪ final design depends on Run3 result with prototype detectors

Summary

- High Luminosity LHC
  ↪ Motivated by physics searches.
  ↪ Upgrades in the ATLAS detector.
- Inner Tracker
  ↪ New all-silicon design, with larger η range.
  ↪ UU & LU involved in the production of detector modules and the ITk readout scheme.
- Hardware Track Trigger
  ↪ Employment of a Hardware track trigger to allow better trigger capabilities for physics.
  ↪ UU heavily involved in the project management and contributes in data format compatibility, offline simulation software and online monitoring & control of Menzanine cards.
- Tile Calorimeter
  ↪ Replacement of current components.
  ↪ New electronics readout system.
  ↪ SU involved in the upgrade and in charge of preparing the DaughterBoard.
- High Granularity Timing Detector
  ↪ Time stamping of charged particles' tracks.
  ↪ Luminometer capabilities.
  ↪ KTH involved in management of project and in charge of the luminosity processing system.
- Luminosity Cherenkov Integrating Detector
  ↪ Upgrades for Run-3 and HL-LHC.
  ↪ LU leads the project and is in charge of preparing detector prototypes.

Questions?

Individual Contributions

ITk	UU	Richard Brenner	Scandinavian cluster activities coordinator, Industry contact, QA/QC procedures Assembly jig preparation, ASIC irradiation studies
	LU	Torsten Akesson	Scandinavian cluster activities coordinator
	LU	Geoffrey Mullier	Scandinavian cluster activities coordinator, QC procedure, Thermal jig studies ASIC irradiation studies
	LU	Else Lytken	Scandinavian cluster activities coordinator
	UU	Eleni Myrto Asimakopoulou	QA/QC procedures (industry & inhouse)
	UU	Jonas Steentoft	QA/QC procedures (industry & inhouse)
	LU	Alexander Ekman	Thermal jig studies
	UU	Thomas Mathisen	Trigger test procedures and Readout scheme studies
	LU	Lennart Osterman	Electrical Engineer
	UU	Nils Bingefors	Electrical Engineer
	UU	Lars Erik Lundqvist	Workshop
HTT	UU	Richard Brenner	Project Officer
	UU	Rebeca Gonzalez Suarez	Data format definition and test-vector preparation
	UU	Olga Sunneborn Gudnadottir	Offline simulation studies (optimization and prospect studies)
	UU	Jonas Steentoft	Online control & monitoring of the pattern recognition Menzanine cards
TileCal	SU	Sam Silverstein	DaughterBoard hw and fw development
	SU	Christian Bohm	DaughterBoard development
	SU	Eduardo Valdes Santuro	DaughterBoard hw development, lead fw developer
	SU	Katie Dunne	Developer for ProAsic3 design on daughterboard
	SU	Suhyun Lee	Developer for power system design on daughterboard
	SU	Christophe Clement	Upgrade project leader (2018-20), work with testbeam, demonstrator and radiation tests
HGTD	KTH	Bengt Lund-Jensen	Institute Board Chair, co-coordinator for the Electronics group, Lumi processing system development
	KTH	Jonas Strandberg	co-coordinator for the Luminosity & DAQ group, Lumi processing system development
	KTH	Christian Ohm	co-coordinator for the Sim/Perf/Physics group (up-to mid. 2020) Lumi processing system development
	KTH	David Shope	Lumi processing system development
	KTH	Olle Lundberg	Lumi processing system development
LUCID	LU	Vincent Hedberg	Project leader, Detector prototype preparation