General overview of ATLAS Upgrades projects for HL-HC

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On behalf of the ATLAS collaboration

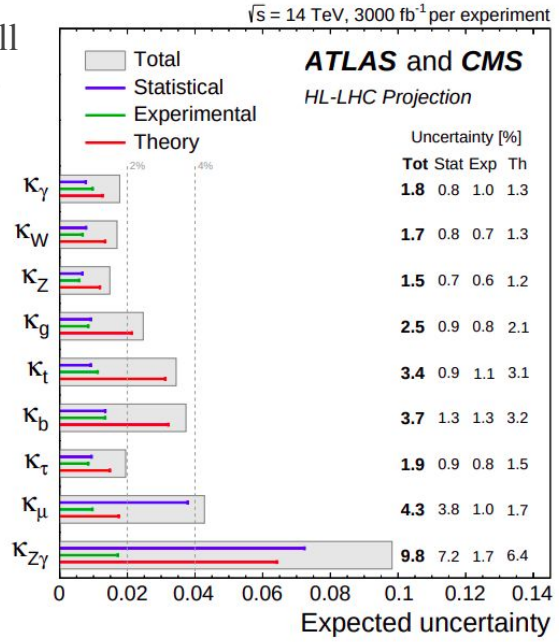
HL-LHC physics program

- HL-LHC will provide 10-fold increase in integrated luminosity

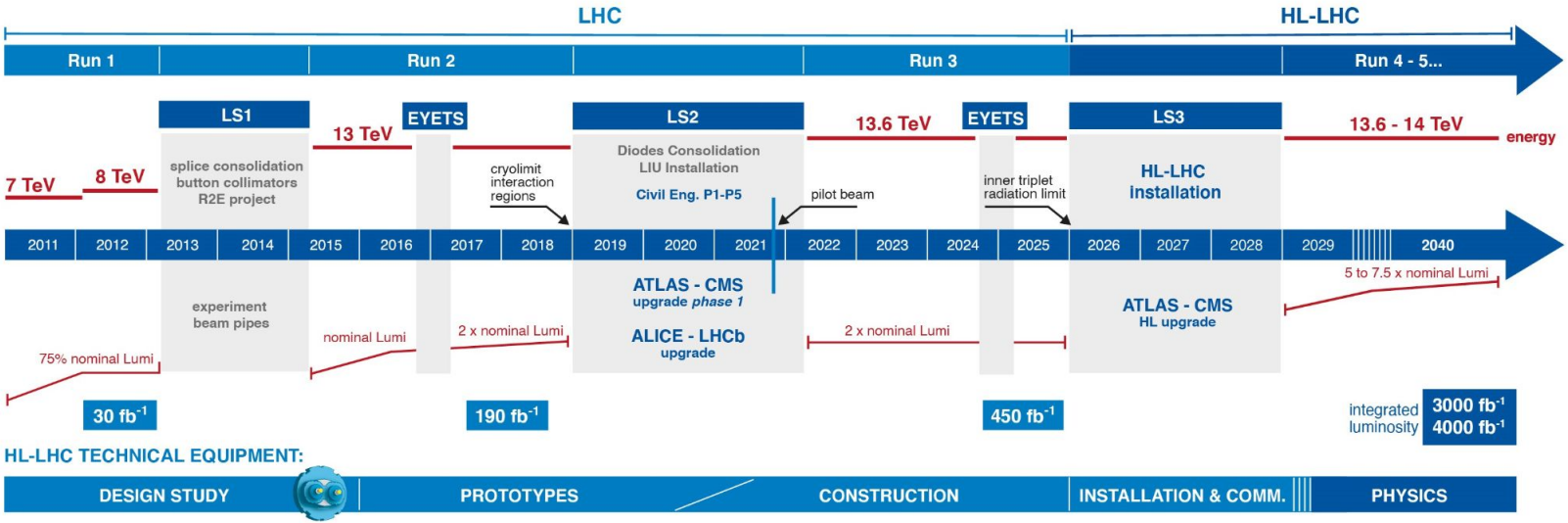
- Highlights of envisioned physics program
  - **Measurement of Higgs boson properties**: couplings, mass, width, self-coupling
  - **Precision electroweak measurements**: vector boson scattering, triboson couplings, rare processes
  - **Searches for Beyond Standard Model physics**: SUSY, dark matter, new resonances, long-lived particles
  - **Flavor physics studies**: rare bottom and top decays, constraints on CKM

CERN-LPCC-2018-04

Uncertainty will be improved to ~2-4%



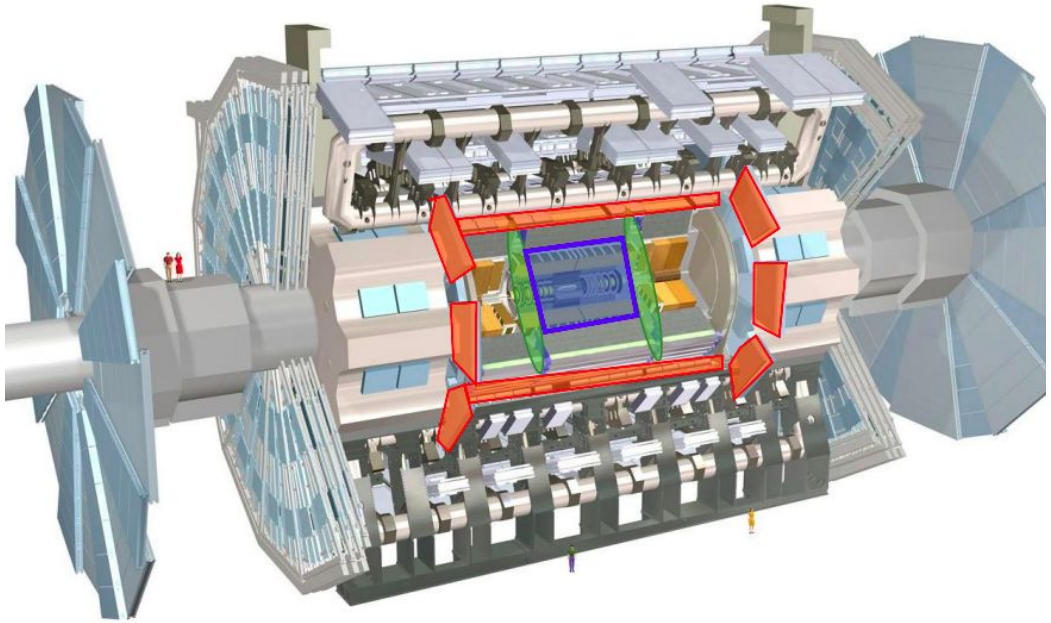
LHC upgrade timeline



- HL-LHC phase currently scheduled to start in 2029.
- About 10 years of data taking with following conditions foreseen:
  - **Instantaneous luminosity** to increase from 2.0 to 7.5 $\times$ $10^{34}s^{-1}cm^{-2}$
  - **Pile-up** to increase from currently 55 to 200.

- **Major upgrades of all experiments** needed to cope with these requirements!

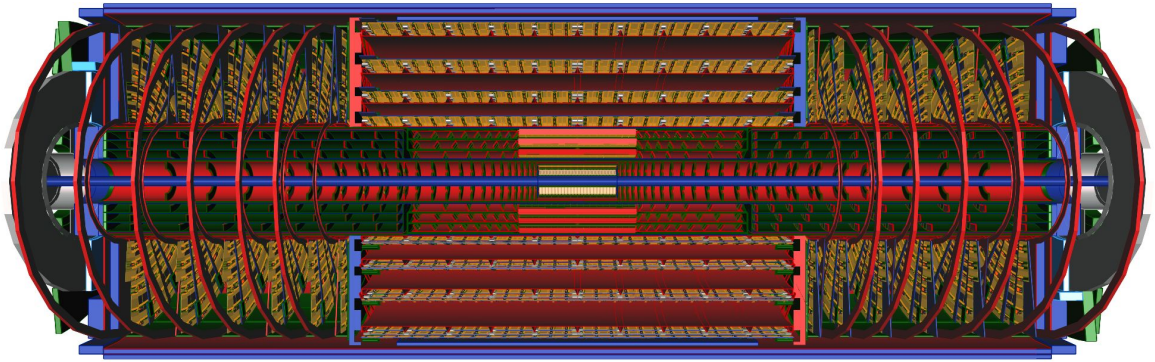
ATLAS upgrades for HL-LHC

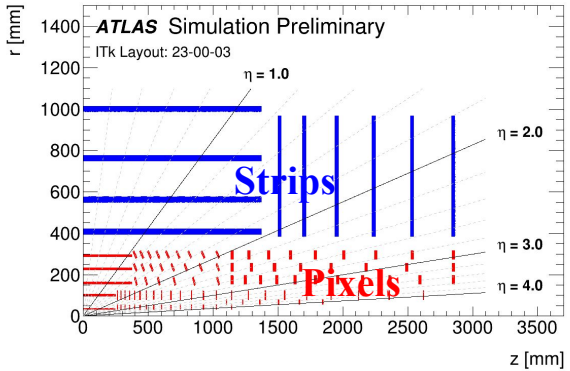


- **New muon chambers**
  - Improved trigger efficiency/momentum resolution, reduced fake rate
- **New tracker (ITk)**
  - Less material & finer segmentation
- **High Granularity Timing Detector (HGTD)**
  - Improved pile-up separation and bunch-by-bunch luminosity
- **EM calorimeter (LAr), hadronic calorimeter (Tile), and Muon detectors** will have on- and off-detector electronics upgrade
- **Upgraded TDAQ system**
  - Single Level Trigger with 1 MHz output
- **Upgraded luminosity detectors**
  - 1% precision

Inner Tracker (ITk) upgrade

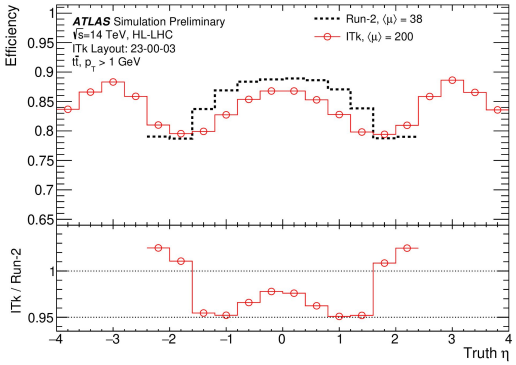
More details in Thomas Strebler's talk

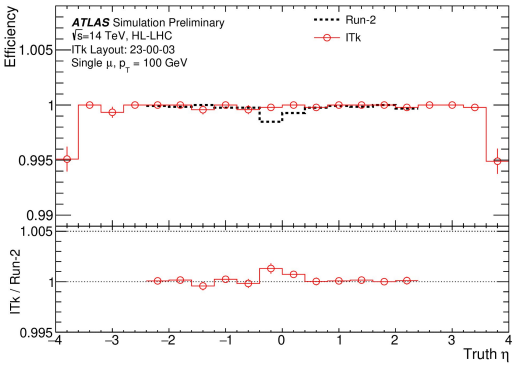




ATLAS-PHYS-PUB-2021-024

- **New all-silicon inner tracker** with increased acceptance from $|\eta|<2.5$ (ID) to $|\eta|<4$ (ITk) and increased pile-up rejection
- **Tracking performance comparable or better** than before at much higher pile-up conditions

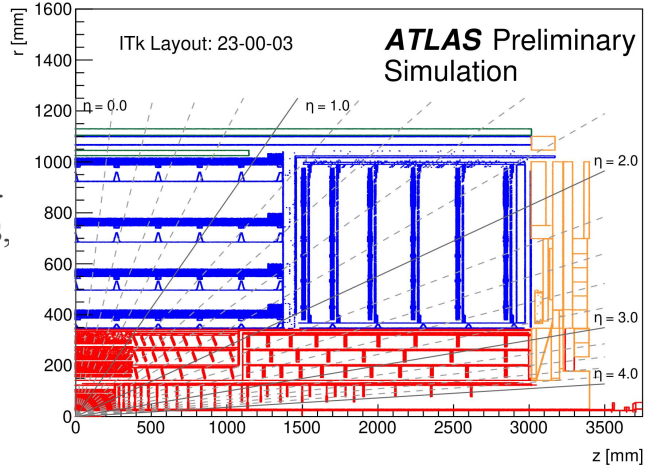


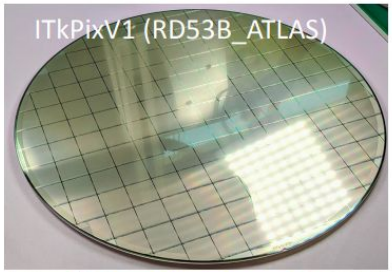


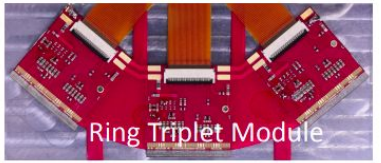
ITk Pixel upgrade

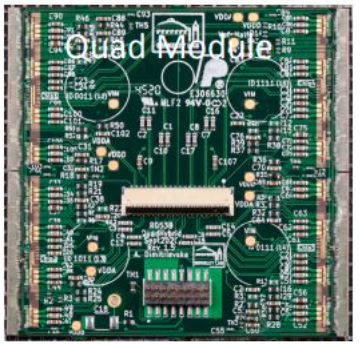
More details in Saverio D'Auria's talk

- 9164 modules, covering surface of 12.8 m^2, 12.8 million channels
- 1 MHz readout rate
- **Sensors**:
  - Pixel sizes 25 × 100 μm^2 in the L0 barrel. 50 × 100 μm^2 everywhere else.
  - 3D sensors in innermost barrel & disks, planar sensors everywhere else
- **Production status**
  - All sensors are in pre-production and hybridization started
  - Production readout chip (ITkPixV2 from RD53) being finalised for submission









ATLAS-TDR-030

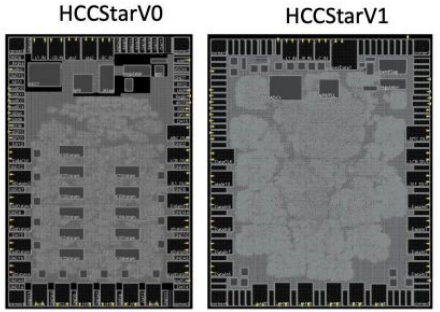
ITk strip upgrade

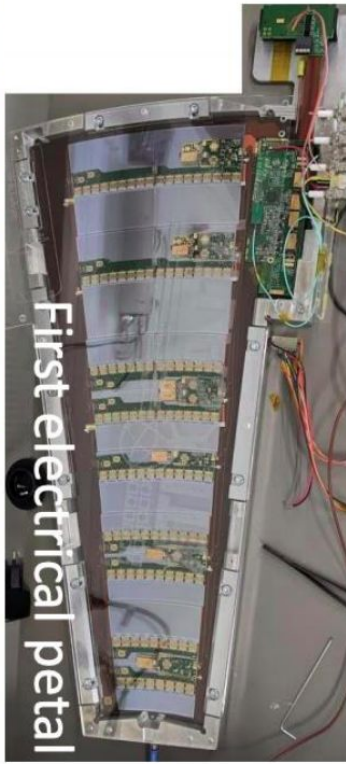
More details in Sergio Diez Cornell's talk

- 17888 modules, covering surface of 165 m^2, 60 million channels

- **Sensors/ASICs**
  - Strip width 75 μm
  - Three dedicated ASICs
    - ABCStar (FE)
    - HCCStar (hybrid controller)
    - AMACStar (analog monitor/ctrl)

- **Production status**
  - Sensors in production
  - Hybrids and modules in pre-production
  - ABCStar in production
  - HCCStar and AMACStar pre-production done and testing ongoing



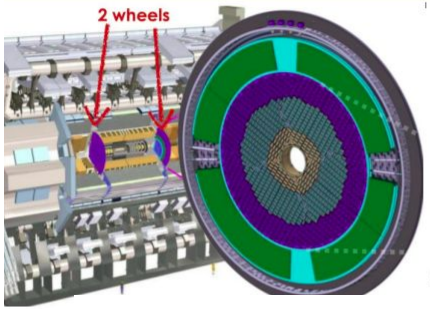


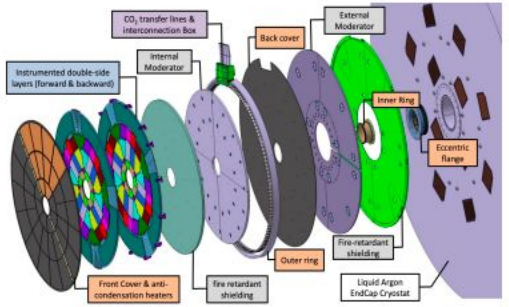
HGTD

More details in Zhijun Liang's talk

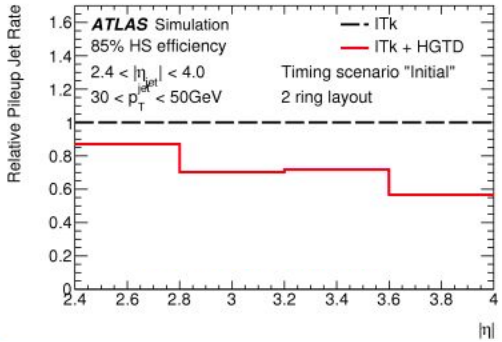
- Fine timing (<70ps/hit) to **disentangle events in large pile-up conditions**, pixel size 1.3✕1.3 mm^2
- **Precision luminosity measurement** bunch-by-bunch
- Four layers of silicon detector modules, covering 2.4<|η|<4.0, ~3.6 million channels
- **Low gain avalanche detector (LGAD)** technology sensors will be bump-bonded to read-out ASIC and have been demonstrated to work.
- First hybrids with ALTIROC2 FE chip and FE-chip functionality demonstrated
- **Carbon infused sensors** more robust against Single Event Burn-out (SEB) with stable operation at lower voltages

ATLAS-TDR-031



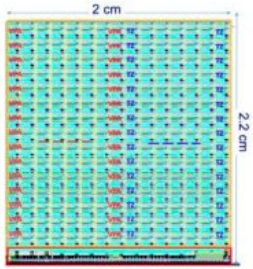


Pile-up jet rejection with and without HGTD



15x15 LGAD

Charge [fC]



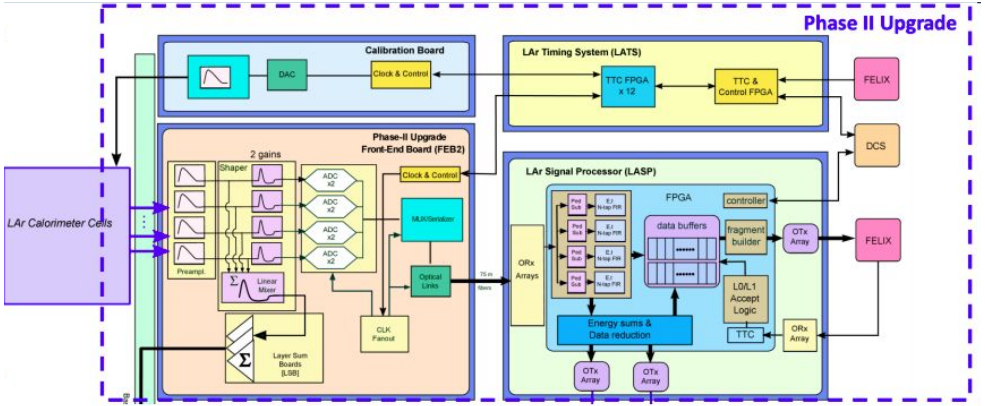
ALTIROC2

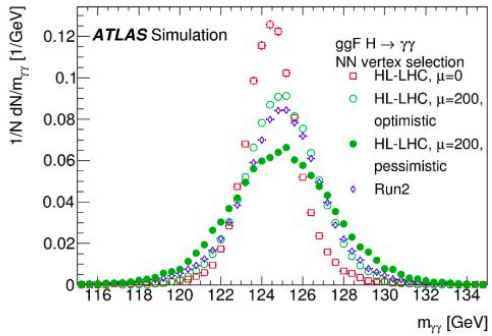
CERN-LHCC-2020-007

Electromagnetic calorimeter upgrade

More details in Allison Deiana's talk

- **New on-detector and off-detector electronics**
  - 40 MHz continuous readout and FE electronics with following features
    - Pre-amp/shaper: 16-bit dynamic range (from 50 MeV to 3 TeV) with 11-bit precision
    - ADC: 2 overlapping 14-bit gains (12-bits SAR + DRE)
  - Improved radiation hardness
- New **LV power supplies** in radiation zone for on-detector electronics
- Major technical progress in all areas
  - Last on-detector ASIC prototypes in hand and testing well
  - Prototype off-detector elements proceeding



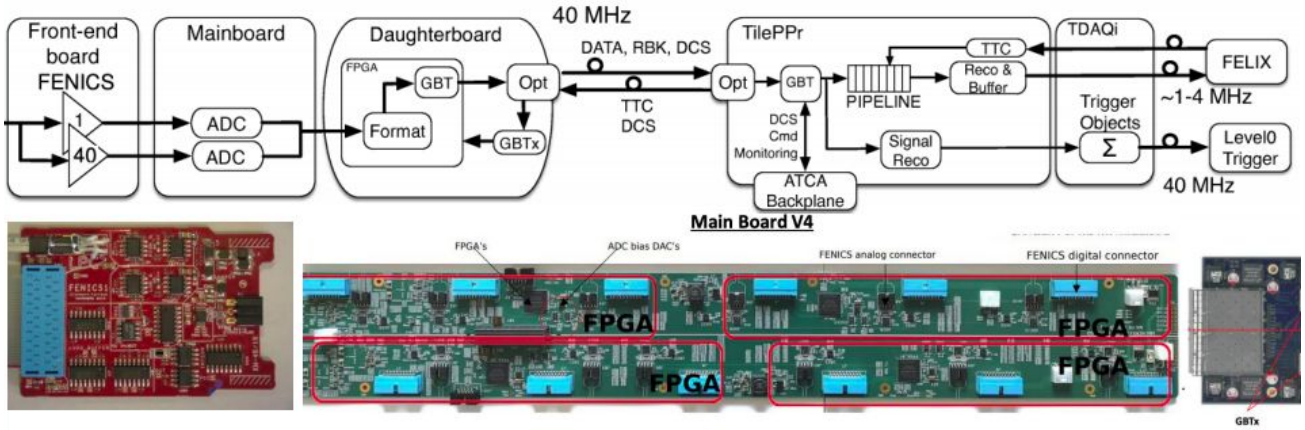


LHCC-2017-018

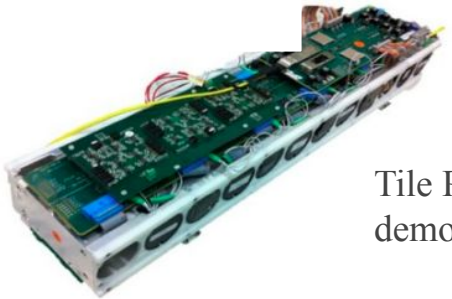
Hadronic calorimeter upgrade

More details in Ilya Korolkov's talk

- Full replacement of **front-end and back-end electronics**
  - Modified mechanics for easier access and maintainability
  - Fully digital readout data and input to trigger system



- Most on-detector items are in **pre-production**
- Pre-production electronics performance as expected
- Off-detector electronics prototype under evaluation

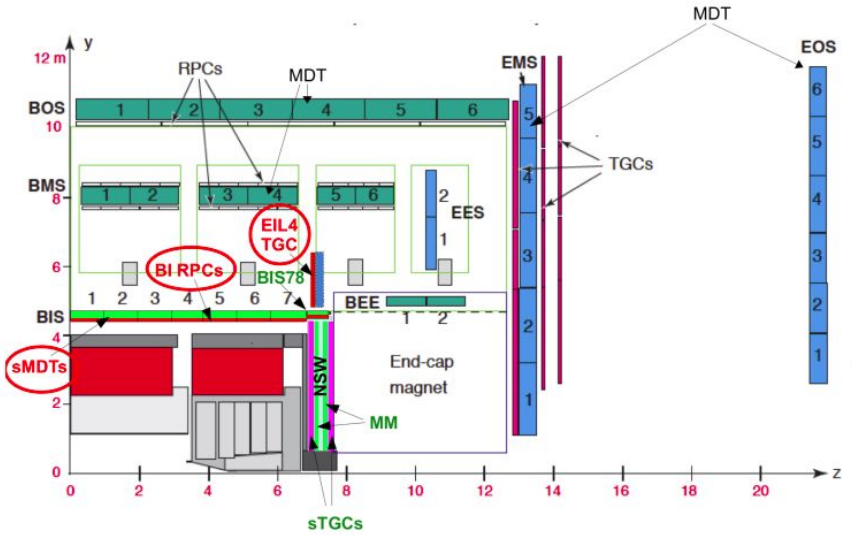


Tile Phase-II demonstrator

Muon detector upgrade

More details in Allison Deiana's talk

- Updated readout and trigger electronics to 40 MHz
- **Addition layers of sMDT, RPC, and TGC** to improve coverage, trigger uniformity & momentum resolution, fake rates
- Current status
  - **sMDT**: chambers in production, electronics near pre-production
  - **RPC**: FE prototypes submitted, prototype chamber nearly complete
  - **TGC**: Triplet prototype completed, FE ASIC production complete production



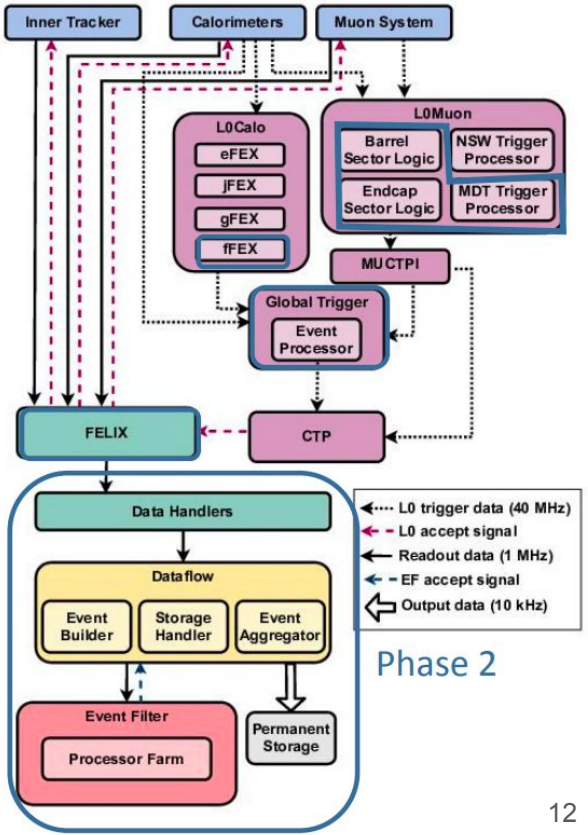
TDAQ upgrade

More details in C. A. Gottardo's talk

- Move to **1 MHz single-level HW trigger** for all systems
  - Level 0: 1 MHz, ~5.2 TB/s, 10 μs latency
  - Event Farm: 10 kHz, ~52 GB/s
- **Exploit full detector granularity** and extended tracking range, improve muon trigger efficiency
- FE electronics linked via FELIX readout to DAQ
- **Prototypes of FELIX, jFEX, L0 Muon Trigger, & Global Trigger** under evaluation

L0 muon trigger board prototype

FELIX Phase-II test-board

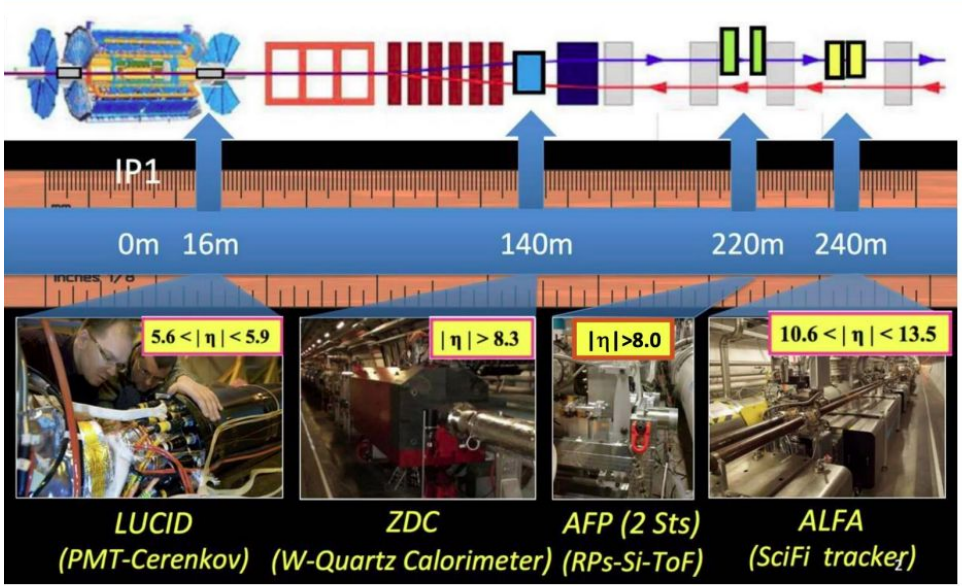


Forward detectors upgrade

More details in Paula Erland's talk

- Stable and precise luminosity measurement in forward direction
  - **BCM'**: bunch-by-bunch luminosity measurement (inside ITk)
  - **HGTD:** bunch-by-bunch luminosity measurement
  - **PLR**: Pixel luminosity rings base on silicon pixel detector (inside ITk)
  - **New LUCID3**: Cherenkov integrating luminosity monitor

- Heavy Ion Physics programme
  - **New Zero-Degree-Calorimeter (ZDC)** in development.



Summary

- ATLAS currently develops and **constructs major upgrades to its detector system** to optimise the experiment for HL-LHC data taking
- An **all-new silicon tracker (ITk)** improves tracking up to $|\eta|<4$
- The HGTD based on LGADs will help to **resolve pile-up through timing measurements**
- Additional **muon detector upgrade** will follow the LS2 New Small Wheel installation
- Most detector electronics, DAQ and trigger systems will be upgraded to cope with the increased luminosity and increased trigger readout rate

Backup