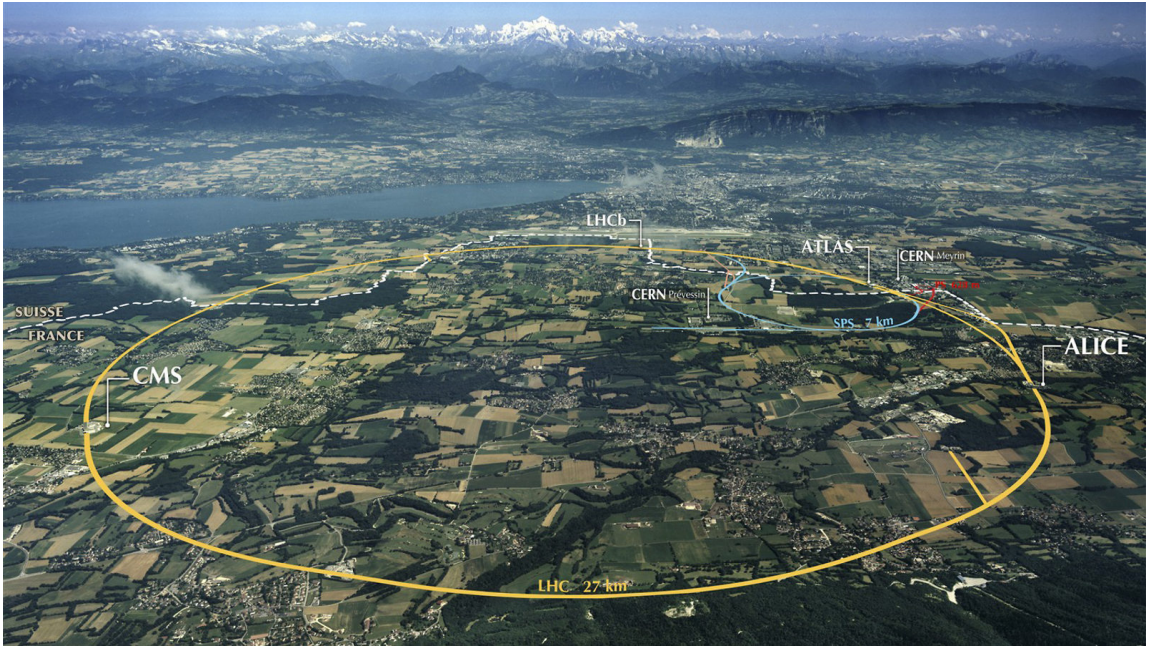
Science & Technology Facilities Council
Rutherford Appleton Laboratory

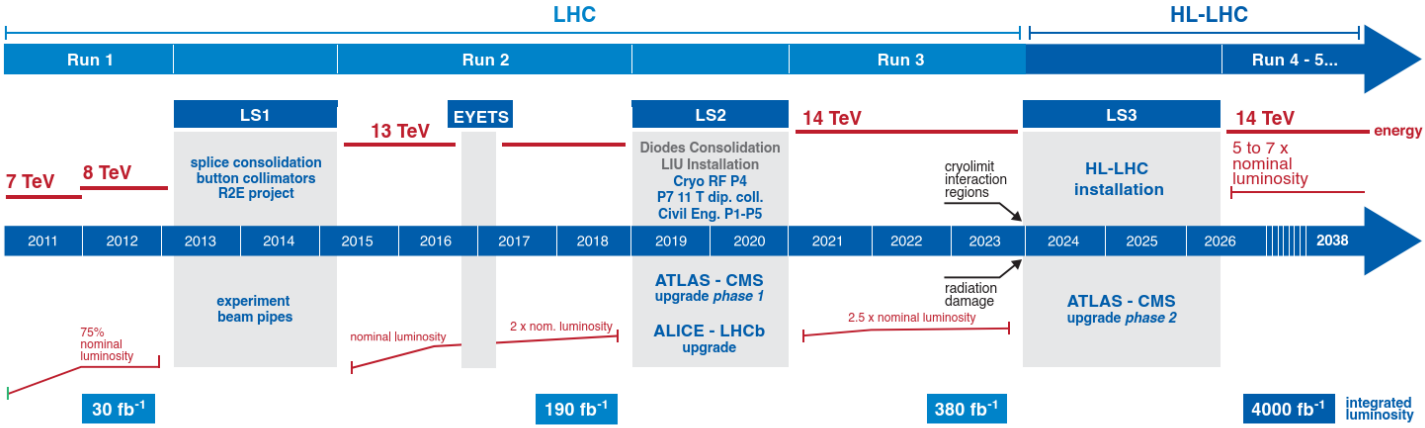
Particle Physics

ATLAS studentship at RAL

Particular emphasis on preparation of upgraded ATLAS Calorimeter Trigger for LHC Run 3



LHC timeline



LHC first started serious data taking in 2011

Run 1, ran at up to 75% nominal luminosity, culminated in discovery of Higgs boson

LHC Run 2 has just finished

Reached 2 times nominal luminosity, delivered over 5 times data of Run 1

Now in Long Shutdown 2 for upgrade for Run 3

Machine consolidation, Phase-I upgrades to ATLAS

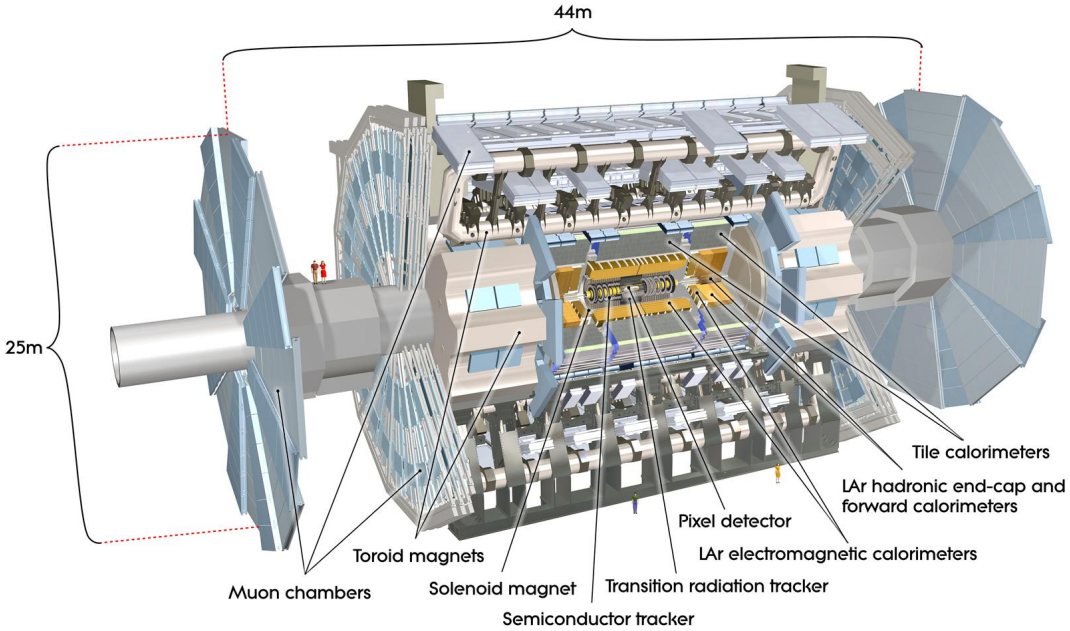
Further Long Shutdown 3 starting in 2024 for upgrade to HL-LHC

Phase-II upgrades to ATLAS for 5 to 7 times nominal luminosity

ATLAS Experiment

ATLAS one of two general purpose detectors at the Large Hadron Collider

25 m high, 44 m in length, consisting of different subsystems wrapped concentrically in layers around collision point to record trajectory, momentum and energy of particles



ATLAS Collaboration ~5000 scientists and engineers, 182 institutions, 38 countries

In UK 14 universities and Rutherford Appleton Laboratory (RAL group 22 people)

RAL ATLAS group

Group Leader

Stephen Haywood

Tracker

Steve McMahon

- Jens Dopke, Bruce Gallop, John Matheson, Peter Phillips, Craig Sawyer, Ben Smart, Weimin Song (RIF), Giulio Villani, Monika Wielers, Gary Zhang

L1Calo

Robin Middleton

- Bruce Barnett, Norman Gee, Dave Sankey, Weiming Qian (TD)

HLT

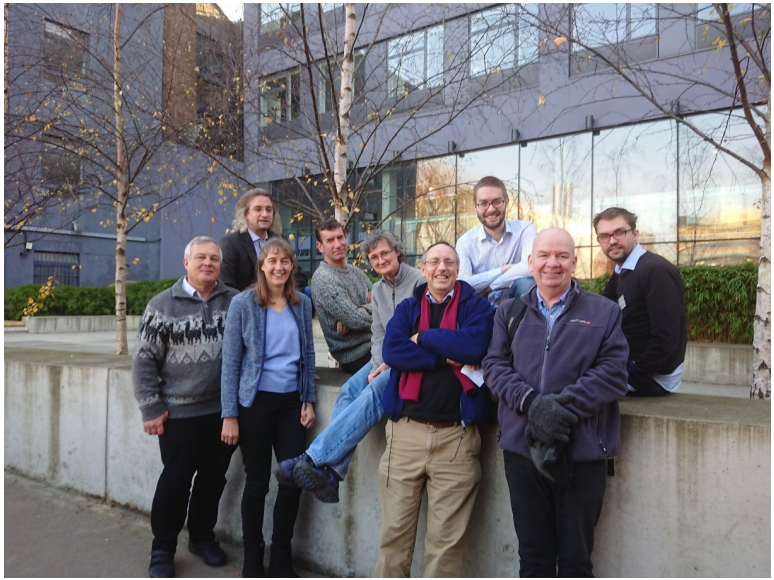
John Baines

- Dmitry Emeliyanov, Julie Kirk, Stewart Martin-Haugh

Physics & Computing

Monika Wielers

- Tim Adye (Tier 1), Bill Murray



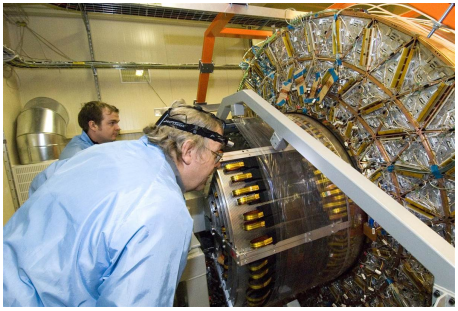
RAL involvement in ATLAS

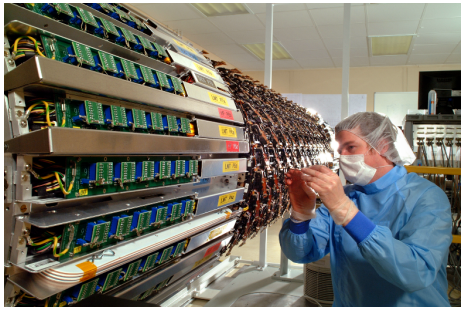
RAL group had responsibility for original construction

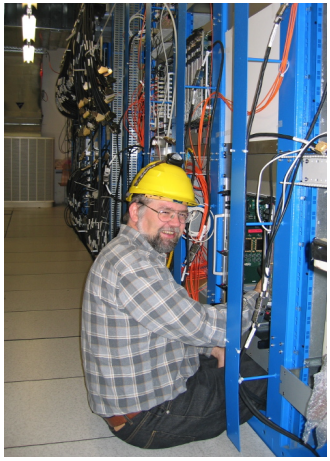
Level-1 Calorimeter Trigger

High Level Trigger

Semi-Conductor Tracker (SCT)







Since then operating the detector and contributing to the physics analysis

Including B physics, Higgs measurements and searches for heavy bosons

Now preparing for upgrades

Phase-I upgrades for installation this Long Shutdown

- Level-1 Calorimeter Trigger and High Level Trigger

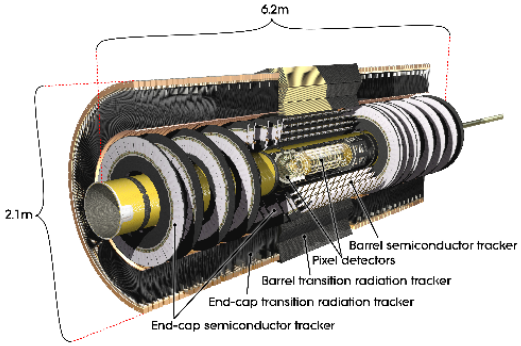
Phase-II upgrades for installation in next Long Shutdown starting in 2024

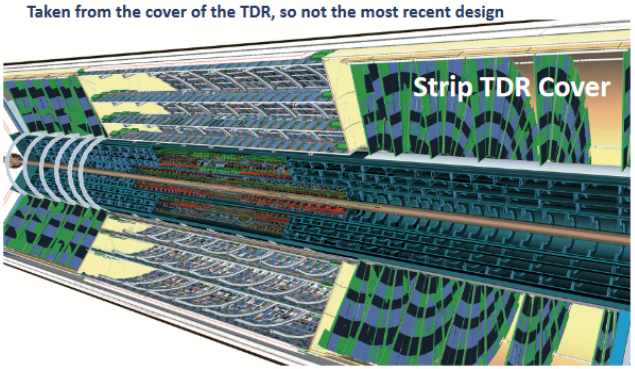
- Level-0 Global Trigger, Event Filter and new Inner Tracker (ITk)

ITk

Original Inner Detector reaches its end of life in 2024

Will be replaced with new all silicon detector





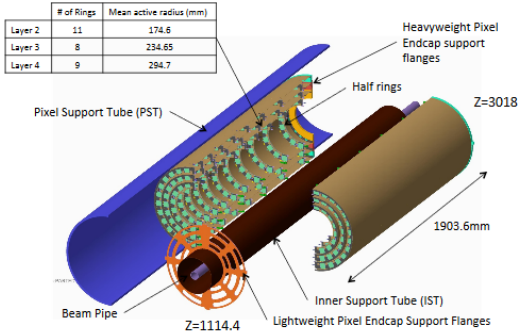
RAL involved in barrel strips and endcap pixels

Strip R&D, including testing ASICs, leading into module production

- mounting modules onto staves

Pixel R&D wafer probing, development of HV multiplexing, DAQ and control systems

- production mounting onto half-rings in construction of endcap



	# of Rings	Mean active radius (mm)
Layer 2	11	174.6
Layer 3	8	234.65
Layer 4	9	294.7

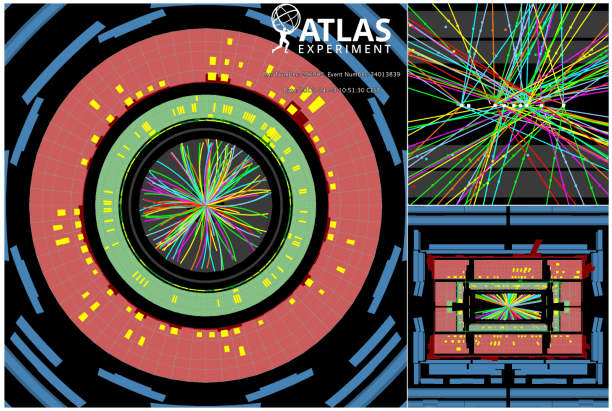
Triggering at the LHC

LHC collides bunched beams of protons 40 million times per second

Every time the bunches cross multiple protons collide

Real example from 2016 with 10 collisions

- *at end of Run 2 LHC delivering ~1 billion proton-proton collisions per second*



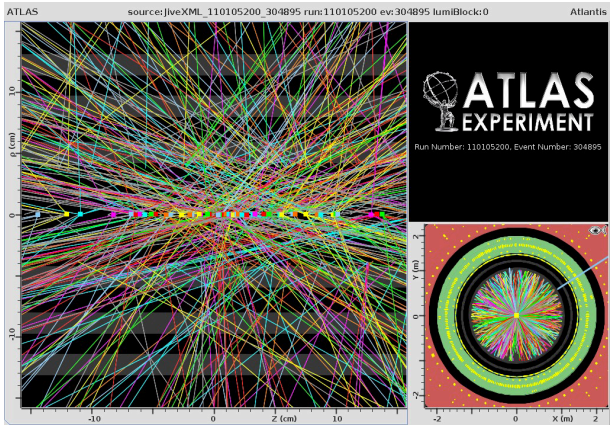
In Run 4 expect an average of 200 collisions each time bunches cross

This a simulated example with 200 collisions

- *up to 10 billion collisions per second*

Interesting collisions at much much lower rate

- 1 Higgs boson per 10 billion collisions, some analyses a handful of collisions per year



We want just the interesting collisions

Sitting in a sea of 'pileup' collisions

Triggering in ATLAS

The trigger system decides instantaneously which of these collisions are interesting

As a multi-stage decision to select which are kept

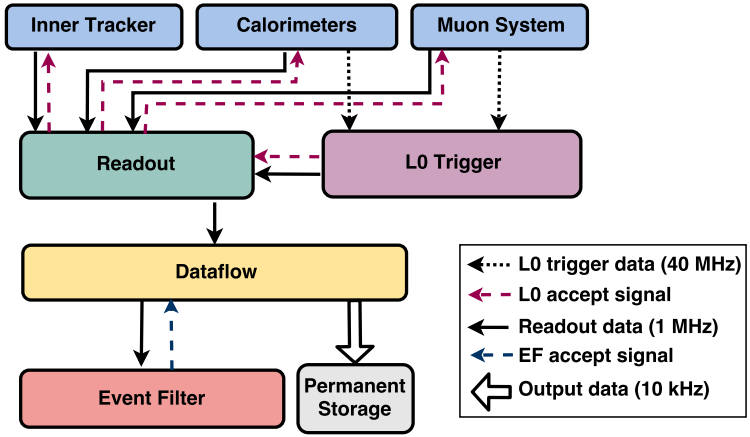
Baseline trigger system for ATLAS in Run 4

Level-0

- custom hardware using subset of information from detector
- 40 million decisions per second
- up to 6 μs for each decision (10 μs buffer for detector)

Event Filter

- based on heterogeneous computer farm
- 1 million decisions per second



10 thousand events per second output to storage for physics analysis

Original and Run 3 systems conceptually similar

Level-1 40 million decisions per second, up to 2 μs for decision, 2.5 μs buffer on detector

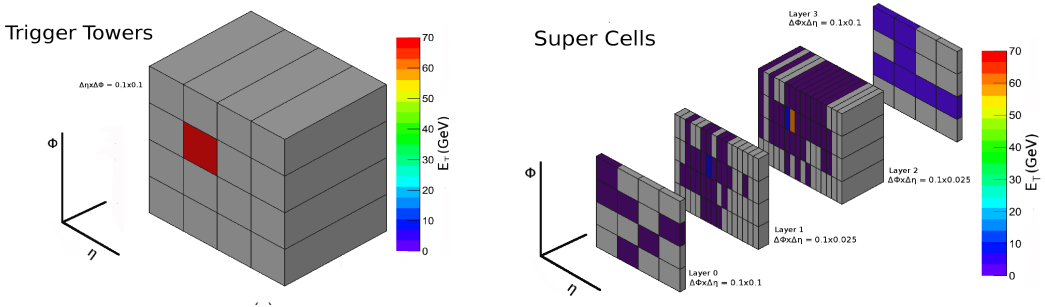
HLT CPU farm 100 thousand decisions, 1 thousand events to storage per second

Level-1 Calorimeter Trigger upgrade for Run 3

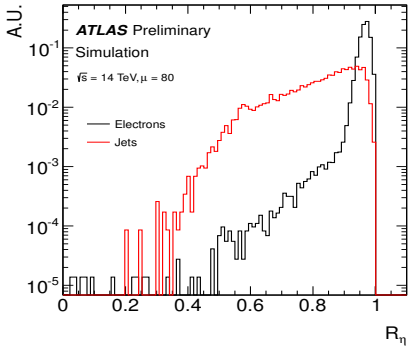
Need to improve sensitivity to electroweak physics in face of increased pileup

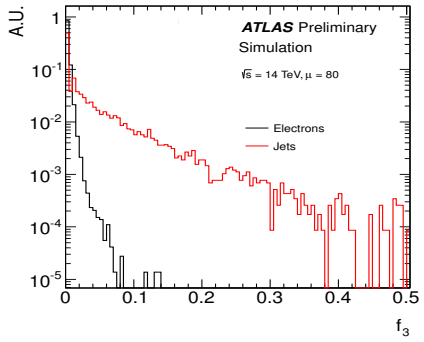
Maintain thresholds close to original system by increasing data into trigger by factor 10

- LAr SuperCells with finer azimuthal and depth segmentation



Lateral R_η and depth f_3 shower shape discriminants between electrons and jets in eFEX

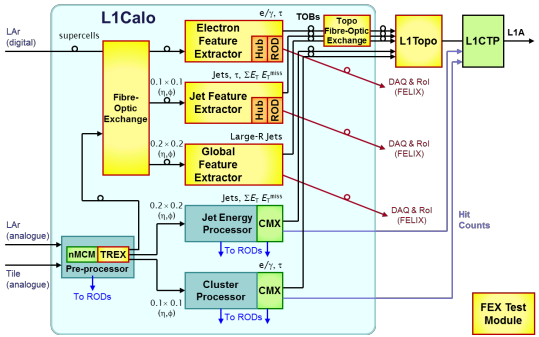




Trigger modules for Run 3

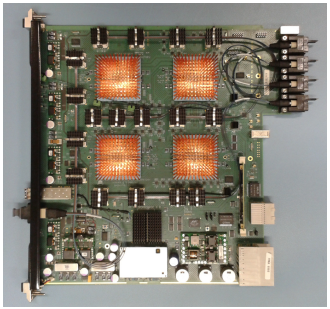
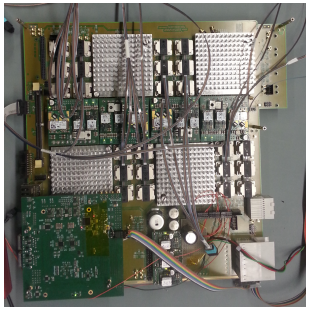
Factor 10 increase in data rate to 30 Tb/s requires very many high-speed optical links

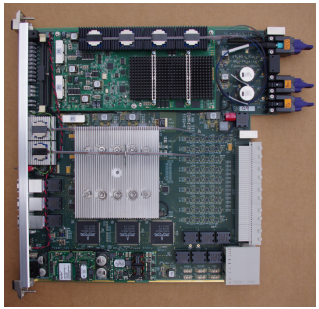
- fibre-optic switchyard to map ~3000 fibres from calorimeter to trigger processors



eFEX, jFEX and gFEX boards with up to 240 inputs each running at 11.2 Gb/s

- up to 120 high-speed serial transceivers per FPGA, high density mid-board optics



Studentship project

Start at Birmingham

Academic and computing courses

Year to 18 months at CERN

Hands-on experimental experience commissioning eFEX system at start of Run 3

- including control room shifts and providing first-line expert support

Join physics analysis group, foundation for physics analysis component of thesis

Return to RAL

Work on eFEX calibration and performance during Run 3

Space in USA15 cavern already being prepared, test lab on surface already in use