OPERATIONS & PERFORMANCE OF
THE ATLAS DETECTOR IN LHC RUN II

CANADIAN ASSOCIATION OF PHYSICISTS
CONGRESS

MAY 2017

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OVERVIEW


- Large Hadron Collider
  - Outline, schedule and performance
- ATLAS Detector Run II performance
  - Detector operation and challenges
- Looking ahead to 2017 operation
  - Work during technical stop
    - Detector upgrades, software development
- Current picture with first beam from the LHC
THE LARGE HADRON COLLIDER

$E_{cm} = 13$ TeV
We are here

Currently ~36 fb\(^{-1}\) proton-proton data to analyse at 13 TeV

Ramping up for another 13 TeV data-taking campaign
THE LARGE HADRON COLLIDER & EXPERIMENTS
THE LARGE HADRON COLLIDER & EXPERIMENTS
THE ATLAS DETECTOR

25m

44m

Muon chambers

Solenoid magnet

Semiconductor tracker

Toroid magnets

Transition radiation tracker

Pixel detector

LAr electromagnetic calorimeters

LAr hadronic end-cap and forward calorimeters

Tile calorimeters
THE MOVE FROM 8 TEV TO 13 TEV

- Large gains to be had in terms of new physics discovery potential moving from 8 to 13 TeV
  - Significant increase in squark & gluino production cross-section

Potentially gaining up to a factor 30 in rate for large particle masses!
THE MOVE FROM RUN I TO RUN II

Increase in collision energy during 2015+2016

→ 13 TeV for the remainder of LHC Run II

Increase in collision rate (20 MHz → 40 MHz)

→ 40 million proton bunch crossings per second!

Excellent LHC performance during 2016!

LHC availability ~ 75 %, with ~ 50% stable beam time.
Large 2016 dataset delivered to ATLAS

- 38 fb\(^{-1}\) delivered
- 35 fb\(^{-1}\) recorded
- 33 fb\(^{-1}\) “good quality” data

36.1 fb\(^{-1}\) data from 2015+2016 for physics analysis

92.4% data-taking efficiency
93-95% data quality selection efficiency
Average recording rate of 1 kHz during 2016
- Increased interactions per bunch crossing ("pile-up")
- Increased occupancy
- Dead-time during data-taking

Steady increase in peak instantaneous luminosity during 2016
- Peak instantaneous luminosity up to $1.4 \times 10^{34}$ cm$^{-2}$ s$^{-1}$
- Peak interactions per bunch-crossing up to 52
- Writing out 3 GB/s at peak instantaneous luminosity
- Very challenging in terms trigger and detector operations!
**INNER DETECTOR PERFORMANCE**

**PIXEL DETECTOR**
- 98.9% data-quality efficiency during 2016
  - Dynamic alignment as pixels turned on at the start of every fill.
  - Mass in cooling pipes changes as temperature stabilises.
  - Insertable B-layer (IBL) inserted for Run II also suffers from temperature variations (“IBL bowing”)
  - New alignment scheme to account for this.

**TRANSITION RADIATION TRACKER (TRT)**
- 99.7% data-quality efficiency during 2016
  - Increasing occupancy and trigger rates.
  - Operating close to read out saturation in 2016.
  - Work to overcome this during EYETS and beyond.

**SEMI-CONDUCTOR TRACKER (SCT)**
- 99.9% data-quality efficiency during 2016
  - Relatively trouble-free operation during 2016.
  - Firmware development resulted in dead time reduction from 0.4% to 0.05%.
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LIQUID ARGON CALORIMETER

- 99.3% data-quality efficiency during 2016
  - HW problems
    - Cooling leak in May 2016
    - HEC LV power supply issues affected 1/4 of the HEC A-side
      - Fixed during winter shutdown 2016/2017
  - Number of HV trips vastly reduced in 2016 due to new current control HV modules
  - New treatment of detector noise implemented to reduce impact on data quality

TILE CALORIMETER

- 98.9% data-quality efficiency during 2016
  - Cooling leak in August 2016 - isolated to single module
  - Fewer noisy channels with respect to previous year operation.
  - Good stability of scintillator and PMT.
MUON PERFORMANCE

CATHODE STRIP CHAMBERS (CSC)
- 99.9% data-quality efficiency
- 3 dead layers due to broken wires

MONITOR DRIFT TUBES (MDT)
- 99.8% data-quality efficiency
- Smooth operation

RESISTIVE PLATE CHAMBERS (RPC)
- 99.8% data-quality efficiency
- New trigger chambers in “feet” region fully operational

THIN GAP CHAMBERS (TGC)
- 99.9% data-quality efficiency
- “Noise burst” veto activated in October to reject noise in TGCs.

ATLAS Preliminary $\sqrt{s}=13$ TeV

$Z \rightarrow \mu\mu$, $p_T^\mu > 25$ GeV, $|\eta^\mu| < 1.05$

L1_MU20, Data 2015, 3.2 fb$^{-1}$
L1_MU20, Data 2016, 127 pb$^{-1}$
PILING UP THE TRIGGER

- Extensive work in preparation for new data-taking campaign:
  - Code optimisation (e.g. reduction in HLT processing time of ~20%)
  - Increased/revised thresholds
  - New ideas for triggers
  - Exponential pile-up dependence of $E_T^{\text{miss}}$ trigger rate
    - Forced to raise $E_T^{\text{miss}}$ trigger thresholds in 2016
    - Current trend not sustainable for 2017

NEW PUFIT ALGORITHM FOR $E_T^{\text{miss}}$ TRIGGERS INTRODUCED FOR 2017 OPERATION

- Calorimeter clusters grouped into “towers”, which are deemed to come from pile-up if their $E_T$ falls below a pile-up dependent threshold.
- The fitted $E_T$ values of these pile-up contributions are used to correct the $E_T$ of the calorimeter topological clusters.
Tier0 cluster size increased over the year - continue to exploit all available resources, including clouds.

CAP Congress 2017
DETECTOR READINESS FOR 2017 DATA

Inner detectors

- Improvements to readout systems (20% gain for TRT, factor 2 pixel).
- Updates to data compression.
- Updates to HV systems.
- Work to tackle problems with high occupancy at high pile-up.

Reduce data volume
Increase bandwidth
DETECTOR READINESS FOR 2017 DATA

Calorimeters

- Hardware repairs (including Tile cooling leak).
- Increase Tile Calorimeter readout by factor of two.
- HV system maintenance.

Software updates and noise rejection algorithm development.
DETECTOR READINESS FOR 2017 DATA

Muon system

- Repair broken wires in two muon chambers.
- Installation of 12 new sMDT chambers in the “feet” of ATLAS.
- Noise reduction and mitigation.
- Gas leak repairs and flow rate meter integration in RPCs/MDTs.
- Power supply replacements.
- TGC chamber replacements.
### DETECTOR READINESS FOR 2017 DATA

**ATLAS Run-2 Detector Status (from May 2017)**

<table>
<thead>
<tr>
<th>Subdetector</th>
<th>Number of Channels</th>
<th>Approximate Operational Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>92 M</td>
<td>97.8%</td>
</tr>
<tr>
<td>SCT Silicon Strips</td>
<td>6.3 M</td>
<td>98.7%</td>
</tr>
<tr>
<td>TRT Transition Radiation Tracker</td>
<td>350 k</td>
<td>97.2%</td>
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<tr>
<td>LAr EM Calorimeter</td>
<td>170 k</td>
<td>100%</td>
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<tr>
<td>Tile Calorimeter</td>
<td>5200</td>
<td>99.9%</td>
</tr>
<tr>
<td>Hadronic End-Cap LAr Calorimeter</td>
<td>5600</td>
<td>99.5%</td>
</tr>
<tr>
<td>Forward LAr Calorimeter</td>
<td>3500</td>
<td>99.7%</td>
</tr>
<tr>
<td>LVL1 Calo Trigger</td>
<td>7160</td>
<td>99.9%</td>
</tr>
<tr>
<td>LVL1 Muon RPC Trigger</td>
<td>383 k</td>
<td>99.8%</td>
</tr>
<tr>
<td>LVL1 Muon TGC Trigger</td>
<td>320 k</td>
<td>99.9%</td>
</tr>
<tr>
<td>MDT Muon Drift Tubes</td>
<td>357 k</td>
<td>99.7%</td>
</tr>
<tr>
<td>CSC Cathode Strip Chambers</td>
<td>31 k</td>
<td>96.1%</td>
</tr>
<tr>
<td>RPC Barrel Muon Chambers</td>
<td>383 k</td>
<td>94.4%</td>
</tr>
<tr>
<td>TGC End-Cap Muon Chambers</td>
<td>320 k</td>
<td>99.5%</td>
</tr>
<tr>
<td>ALFA</td>
<td>10 k</td>
<td>99.9%</td>
</tr>
<tr>
<td>AFP</td>
<td>430 k</td>
<td>93.8%</td>
</tr>
</tbody>
</table>
FIRST BEAM OF 2017!

Beams return to ATLAS in the first “splash” events of 2017.

Splashes are generated when protons circulating the collider ring strike collimators downstream from ATLAS.

The resulting spray of particles strike the detector, causing it to light up all the sub-detectors.

BEAM SPLASH EVENT

29 APRIL 2017
One of the early collision events with stable beams recorded by ATLAS on 23 May 2017, with a reconstructed muon candidate.

Eta-phi view of the energy deposits in the cells of the ATLAS calorimeters and a transverse view of the inner tracking detectors.

ATLAS in longitudinal cross-section and a transverse view of the whole detector.
SUMMARY

- Excellent LHC availability and performance last year
  - 38 fb$^{-1}$ delivered to ATLAS during 2016

- Increased luminosity and pile-up posed challenges for detector, trigger and computing systems
  - Lessons help to prepare for what’s to come in 2017

- Extensive work during EYETS to ready ALTAS for 13 TeV data-taking this year
  - Already starting the 2017 ramp-up
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BEAM SPLASH EVENT
29 APRIL 2017

READY FOR SOME NEW PP DATA AT 13 TEV
Large gains to be had in terms of new physics discovery potential moving from 8 to 13 TeV

Potential gains of > factor 10 for large particle masses.
**FORWARD/LUMINOSITY**

**LUCID**
- Cerenkov detector
- Upgraded LUCID detector installed end of 2015
- New electronics to cope with 25 ns bunch-spacing.
- Smaller acceptance to avoid saturation.
- Preferred source of luminosity measurement for 2016 operations - also used to monitor non-collision background.

**ALFA**
- Total cross-section and luminosity measurement
  - Mainly active for high beta* 2.5km runs ($330 \mu b^{-1}$).
  - Increase in radiation in 2016 by factor ~10 (AFP)
  - Increase shielding to reduce impact from radiation during EYETS.

**TIMEPIX**
- Not “forward”, but also offers handle on luminosity
  - Two silicon Timepix detectors interleaved with neutron converters.
  - Active area $2\text{cm}^2$

**AFP**
- First AFP arm commissioned during 2016
  - Restricted usage due to concerns over ALFA radiation exposure.
  - Second arm and time-of-flight detector installed during EYETS.
  - Continuous operation planned for 2017 running.