ATLAS Status Report
Operations, Physics & Upgrade Planning

P. Krieger, University of Toronto
(on behalf of the ATLAS Canada Collaboration)
# ATLAS Canada Collaboration

<table>
<thead>
<tr>
<th>Founded in 1992:</th>
<th>M. Lefebvre, UVic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R. McPherson, IPP/UVic 2007-2015</td>
</tr>
</tbody>
</table>

## Current Management

| Spokesperson, PI (2015 –): | P. Krieger, U of T |
| Deputy:                    | M. Vincter, Carleton |
| Physics Coord:             | A. Warburton, McGill |
| Computing Coord:           | R. Tafirout, TRIUMF |

- 38 University/Lab faculty (34.7 FTE) [details in backup slides]
- 27 Postdocs, 68 GS (Feb 2016), ≈ 25 UG students/year
- Plus engineers and technicians (some MRS funded)
- Group includes 5 IPP Research Scientists (4 FTE)
Canadian ATLAS Leadership

• Canadians are present in all levels of ATLAS management and coordination:
  – Some prominent examples below
  – Also many roles in detector operations, data quality, upgrade and physics and performance sub-group coordination (not shown here):
    • Including two ATLAS Run Managers

Major (recent and present) ATLAS management / coordination roles

ATLAS Management
  • McPherson (deputy spokesperson 2015-2017)

Executive Board
  • Vetterli (pubcom chair), McPherson (at-large)

Physics coordination
  • Lister (top), Savard (Higgs), Canepa (Upgrade physics), Gingrich (MC)

Speakers Committee Advisory Board
  • Krieger, Vachon, Taylor

Publications Committee Chair
  • Vetterli

Speakers Committee Chair
  • Lefebvre

Authorship Committee Chair
  • Trigger

Publications Committee members
  • Krieger, Trigger

Computing resources management Chair
  • Vetterli
ATLAS Canada HQP Training

• ATLAS Canada has an excellent history of HQP training:
  – Current graduate student and postdoc numbers shown on previous slide
  – 67 PhDs awarded (Jan 2016), 42 with collisions (distribution below)
  – About 100 postdocs have been trained on ATLAS Canada
  – Of completed degrees / training in last 5 years*:
    • ~70% of MSc students continued to a PhD (usually in the same field)
    • ~40% PhD remained in research, ~30% went to industry, 20% became teachers
    • ~70% of postdocs remained in research, ~20% to industry

A Canadian student won one of the four 2015 ATLAS PhD Thesis Awards
The Large Hadron Collider at CERN

- The world’s highest-energy particle collider.
  - Likely to remain at the energy-frontier for at least another two decades
- Over 500 scientific ATLAS publications (see next slide)
- Higgs Boson discovery in 2012 led to 2013 Nobel Prize to Higgs and Englert (with ATLAS and CMS mentioned in the citation)
  - Investigations of Higgs properties still important and on-going
  - This will remain true to the end of the LHC/HL-LHC experimental program
- Increased energy, decreased bunch spacing for Run-2 (2015-2018):
  - Bunch spacing of 25ns (instead of 50 ns) for reduced pileup
  - 13 TeV up from 8 TeV in Run-1
    - opens a new window for searches for BSM physics
    - May increase to 14 TeV later in Run-2
    - 2016 run will be at 13 TeV
- Maximum LHC energy is 14 TeV. After that, planned improvements associated with an increase of the collision rate (luminosity):
  - The is the goal of both the Phase-I and Phase-II ATLAS Upgrades
• Most papers based on analysis of Run-1 data (2011,2012)
• A few Run-1 papers still in progress: SUSY and Exotics searches complete
• Some results from Run-2 (13 TeV) have also already been published / submitted
Cross-section Ratios 13TeV / 8TeV

At $10^{34}$ cm$^{-2}$ s$^{-1}$ @ 13 TeV pp the LHC produces:
- 200 Hz $W \rightarrow lv$
- 19 Hz $Z \rightarrow ll$
- 8 Hz top pair
- 0.5 Hz Higgs
Cross-section Measurements at 13 TeV

- Small 2015 data sample, but numerous results (preliminary or published)
- Cross sections: good agreement with Standard Model, but also “hints” to be explored with 2016 data
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- Cross sections: good agreement with Standard Model, but also “hints” to be explored with 2016 data

**ATLAS Preliminary**

- **pp → W**
  - 7 TeV, 36 pb\(^{-1}\), PRD 85, 072004 (2012)
  - 13 TeV, 85 pb\(^{-1}\), ATLAS-CONF-2015-039

- **pp → Z / γ\(^{*}\)**
  - 7 TeV, 36 pb\(^{-1}\), PRD 85, 072004 (2012)
  - 13 TeV, 85 pb\(^{-1}\), ATLAS-CONF-2015-039

- **pp → t\(\bar{t}\)**
  - 13 TeV, 78 pb\(^{-1}\), ATLAS-CONF-2015-049

- **pp → tq**
  - 7 TeV, 4.6 fb\(^{-1}\), PRD 90, 012006 (2014)
  - 8 TeV, 20.3 fb\(^{-1}\), ATLAS-CONF-2014-007
  - ATLAS-CONF-2015-079

- **pp → H**
  - 7 TeV, 4.5 fb\(^{-1}\), arXiv:1507.04548
  - 8 TeV, 20.3 fb\(^{-1}\), arXiv:1507.04548
  - 13 TeV, 3.2 fb\(^{-1}\), ATLAS-CONF-2015-069

- **pp → ZZ**
  - 7 TeV, 4.6 fb\(^{-1}\), JHEP 03, 128 (2013)
  - 8 TeV, 20.3 fb\(^{-1}\), ATLAS-CONF-2013-020
  - 13 TeV, 3.2 fb\(^{-1}\), arXiv:1512.05314

**HINT OF NEW BOSON SPARKS FLOOD OF PAPERS**

In just 21 days, physicists have posted 150 papers on the arXiv preprint server about tantalizing results at the Large Hadron Collider.

P.Krieger, U of T
Institute of Particle Physics, AGM, June 12, 2016 Ottawa
Canadian Hardware Contributions to ATLAS

Main contributions to the original detector

• Hadronic Endcap calorimeter
  – Two of four wheels
• Hadronic Forward calorimeter
  – All four modules
• Liquid argon front-end electronics
  – Switched capacitor array controller chips
• Liquid argon calorimeter endcap signal feedthroughs

Other contributions to the existing detector (up to LS1)

• Beam Conditions Monitor (also used for luminosity)
• High-level trigger (HLT) processors
• MediPix / TimePix for cavern background monitoring, luminosity
• LUCID luminosity monitor and upgrade in LS1
• Diamond Beam Monitor (telescope) installed in LS1
• Inner Detector readout
LHC/ATLAS Operations 2016

- Both LHC and ATLAS operating well: fastest luminosity ramp-up in LHC history
- New peak $L_{\text{inst}}$ record of $8.2 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$ last week
- All this in spite of the “weasel”

ATLAS Run-2 Detector Status (from May. 2016)

<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>98.2%</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>
</tr>
<tr>
<td>LAr EM Calorimeter</td>
<td>170 k</td>
<td>100%</td>
</tr>
<tr>
<td>Tile calorimeter</td>
<td>5200</td>
<td>100%</td>
</tr>
<tr>
<td>Hadronic endcap LAr calorimeter</td>
<td>5600</td>
<td>99.6%</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>100%</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>100%</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>98.4%</td>
</tr>
<tr>
<td>RPC Barrel Muon Chambers</td>
<td>383 k</td>
<td>96.6%</td>
</tr>
<tr>
<td>TGC Endcap Muon Chambers</td>
<td>320 k</td>
<td>99.6%</td>
</tr>
<tr>
<td>ALFA</td>
<td>10 k</td>
<td>99.9%</td>
</tr>
<tr>
<td>AFP</td>
<td>188 k</td>
<td>98.8%</td>
</tr>
</tbody>
</table>

Dataset for ICHEP: up to ~ end of July
LHC/HL-LHC Schedule / ATLAS upgrade planning

Main ATLAS Canada shutdown / upgrade activities

- New Pixel insertable b-layer (IBL): DBM
- Consolidation of LAr calorimeter LVPS
- LUCID upgrade
- Forward protons (AFP)

- sTGC for Muon New Small Wheel
- Liquid Argon Calorimeter electronics

- New ATLAS Inner Tracker (ITk)
- Liquid Argon Calorimeter electronics
- Liquid Argon Forward Calorimeter replacement (if needed – decision June 2016)
Phase-1 Upgrades: Muon New Small Wheel

- NSW key component of ATLAS trigger strategy for Run-3
- sTGC construction / testing infrastructure in place at TRIUMF, Carleton and McGill.
- Module-0 sTGC completed by Canadian group in May 2016
- Production Readiness Review (PRR) passed last week at CERN
- Production of sTGC quadruplet production to begin this summer
  - Canadian NSW work on schedule
  - Overall, critical schedule issue is electronics

- Leading coordination roles in NSW project:
  - Overall project management, schedule, finances
  - Cathode board procurement
  - Wedge assembly at CERN
  - Software / simulation
  - Electronics / software for cosmic-ray test station
  - Production test pulser board for sTGCs
Phase-1 Upgrades: LAr Calorimeter Electronics

- Another key component of ATLAS trigger strategy for Run-3
- Improve granularity of information supplied to the L1 trigger
  - Provide additional background suppression at trigger level

Amongst other things, implementation requires new Front-End Crate baseplanes
- For the HEC, the are being developed and produced by Victoria / TRIUMF
  - Design approved in 2015
  - Pre-production board have been produced and are being tested
  - Environmental testing
  - Electrical testing: TDR test illustrated for one trace -- displays proper 50Ω impedance)

PRR planned for Fall 2016: production to follow approval
Phase-1 Upgrades: LAr Calorimeter Electronics

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**Phase-1 trigger granularity**

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  - Pre-production board have been produced and are being tested
    - Environmental testing
    - Electrical testing: TDR test illustrated for one trace -- displays proper 50Ω impedance)

PRR planned for Fall 2016: production to follow approval
Phase-II Upgrades: Physics Motivations

- Primary goals: discovery of BSM and more detailed studies of the Higgs boson:
  - Higgs studies, in particular couplings:
    - Improvements over results with 300 fb\(^{-1}\)
    - Access to second-generation fermion couplings via \(H \rightarrow \mu\mu\)
    - Investigations of Higgs self coupling (via \(HH\) production)
    - Vector boson scattering: is this Higgs alone responsible for unitarizing \(\sigma(LV_L \rightarrow LV_L)\)
    - Sensitivity to VBF/VBS drives performance requirements in forward region
  
- Searches: increased sensitivity to rare SM/BSM processes
  - Exploration of Run-3 hints observations or discoveries.
  - Or (better?) the unexpected

![Physics processes for Phase-II performance studies](LHCC-G-166: physics processes for Phase-II performance studies)
ATLAS at the High Luminosity LHC

• Proposed instantaneous luminosity of $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ ($\mu \approx 200$)
  – Needed for the desired ($\times 10$) increase in integrated luminosity
  – Rate and accumulated dose causes problems for some detector subsystems

• Proposed L0/L1 trigger scheme with rates of $1\text{MHz}/400\text{KHz}$ is incompatible with both tracker and calorimeter readout electronics:
  – Calorimeters modules can operate (except maybe the FCal – see later) but:
    • Calorimeter front- and back-end electronics must be entirely replaced
    • FE electronics also need replacing due to increased expected dose

• Radiation dose and occupancy also an issue for the tracker
  – This will be entirely replaced by a new all-silicon tracker, the ITk
    • Pixels at low radius, strips at higher radius.
      – Possible extension to $|\eta| = 4.0$ (from 2.5 for current inner tracker)
    • About 200 m$^2$ of silicon. Half the cost / effort of Phase-II upgrades
    • Will require involvement of large fraction of the collaboration

• Anticipate some coverage improvements for Muon System

• ATLAS investigating dedicated timing detector in the forward region
Phase-II Tracker Upgrade (ITk)

- Excellent tracking needed for the HL-LHC physics program
- Need precision vertexing to identify the primary vertex to which hard-scatter products are associated (pileup suppression)
- Canadian group proposing to contribute to construction of the Endcap Strips detector:
  - About 20k Si strip modules needed: plan for 1500 in Canada
  - Additional planned contributions:
    - Industrialize production of “hybrid boards”
    - Module placement on support structure for Endcap “petals”
Past/Current ITk Activities

Canadian group already well established in the ITk collaboration:

- Detector layout studies
- Electronics coordination
- Radiation testing of Strip ASICs
- Adhesive studies (modules to support structure)
- Module construction preparations:
  - Two sites: both have produced good quality prototypes
  - Moving towards “site qualification” process
- DAQ development (using prototype built in Canada):
  - Includes contributions to firmware development:
    • single / multiple module
  - Module test stands available at both sites
- Development of QA/QC procedures:
  - Si sensor testing
  - Modules: measurements of per channel noise, gain, signal-to-noise ratio

NSERC-funded R&D in progress
Phase-II LAr Calorimeter Upgrade Work

- Integration into Phase-II electronics effort:
  - This would follow on naturally from our current Phase-I work
  - Focus initially on FE electronics for the HEC (also plan to contribute to BE)
    - HEC was built in part in Canada
    - Different from other LAr subsystems, due to cold preamplifiers in the cryostat
      - Exploit particular Canadian expertise in the HEC readout
    - Some work already beginning.

- Forward Calorimeter upgrade
  - Pulse degradation due to ion buildup and HV sagging due to high current draws over the HV resistors
  - Replacing FCal involves risk to other ATLAS endcap calorimeter systems: need to balance risk & reward
  - New “sFCal” would fix above problems and increase readout granularity by factor of ~ 4. Increase helpful for
    - PU suppression in forward region
    - VBF production, Vector boson scattering etc.

Decision on whether to replace the FCal expected in ~ month following June 22 review
Summary

- LHC/ATLAS operations starting the year very well

- Canadian group has long and successful involvement with ATLAS
  - Important and visible roles in the Collaboration
  - Physics output (including Physics Group Coordinators, subgroup conveners etc.)
  - Detector construction
  - Detector operations
  - Strong participation in current detector upgrade activities (Phase-I)
  - Strong participation in preparing for Phase-II Tracker and Calorimeter upgrades:
    - Canadian LAr Phase-II Upgrade Coordinator
    - Active preparations for Phase-II contributions:
      - Funding request in preparation for current CFI IF competition

- Canadian group planning to extend their historical and present level of commitment to ATLAS into the HL-LHC era

ATLAS @ CAP Congress 2016: 4 invited talks, 6 contributed talks, 1 poster
LHC Schedule 2016 Q2-Q4

<table>
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<tr>
<th>Week</th>
<th>April</th>
<th>May</th>
<th>June</th>
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<td>Mon</td>
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<td>17</td>
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</tr>
<tr>
<td>Tue</td>
<td>11</td>
<td>19</td>
<td>VdM</td>
</tr>
<tr>
<td>Wed</td>
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<tr>
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<tr>
<td>Sat</td>
<td></td>
<td></td>
<td>beta* 2.5 km dev.</td>
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<tr>
<td>Sun</td>
<td>15</td>
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<table>
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<tr>
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<tr>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
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<td>Lab closed</td>
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<td>End of run [06:00]</td>
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<tr>
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<td>49</td>
<td>Ion run (p-Pb)</td>
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<tr>
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</tr>
<tr>
<td>Sun</td>
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<td>51</td>
<td>Pb MD</td>
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P.Krieger, U of T
Institute of Particle Physics, AGM, June 12, 2016 Ottawa