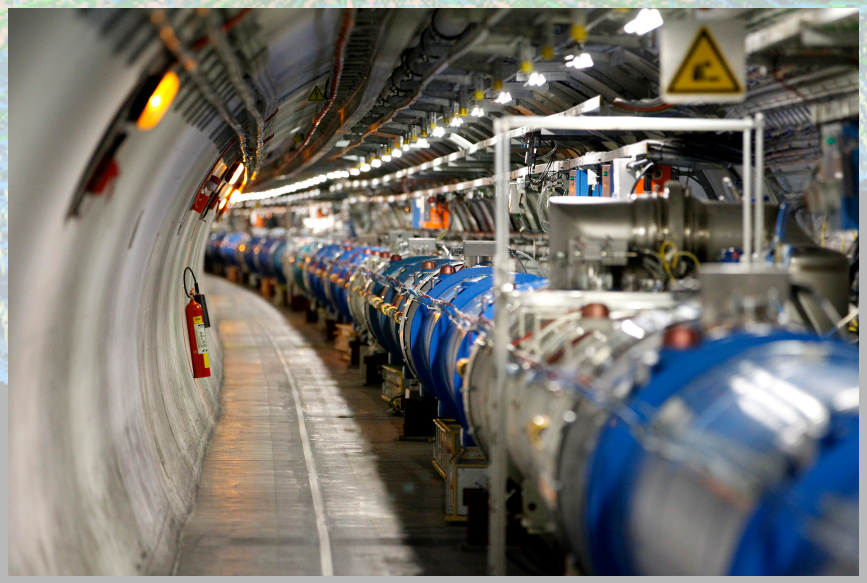
ATLAS Status Report
Operations, Physics & Upgrade Planning

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



ATLAS Canada Collaboration

Founded in 1992: M. Lefebvre, UVic
Spokespersons: R.S. Orr U of T 1994–2007
R. McPherson, IPP/UVic 2007-2015

Alberta
Carleton
McGill
Montréal
SFU
Toronto
TRIUMF
UBC
Victoria
York

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

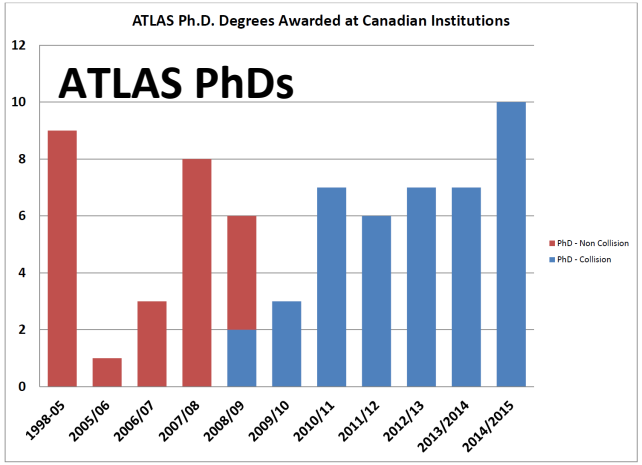
Authorship Committee Chair
- Trigger

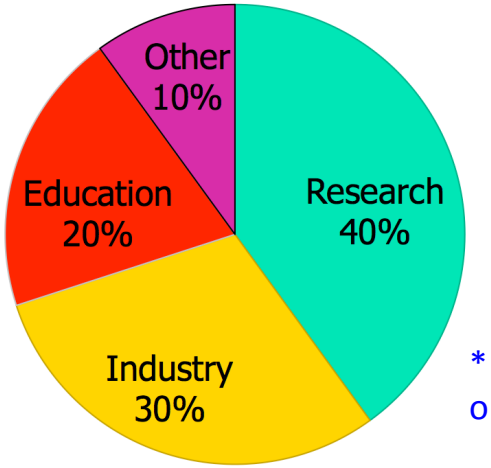
Publications Committee members
- Krieger, Trigger

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





Post PhD careers (2010-2015)

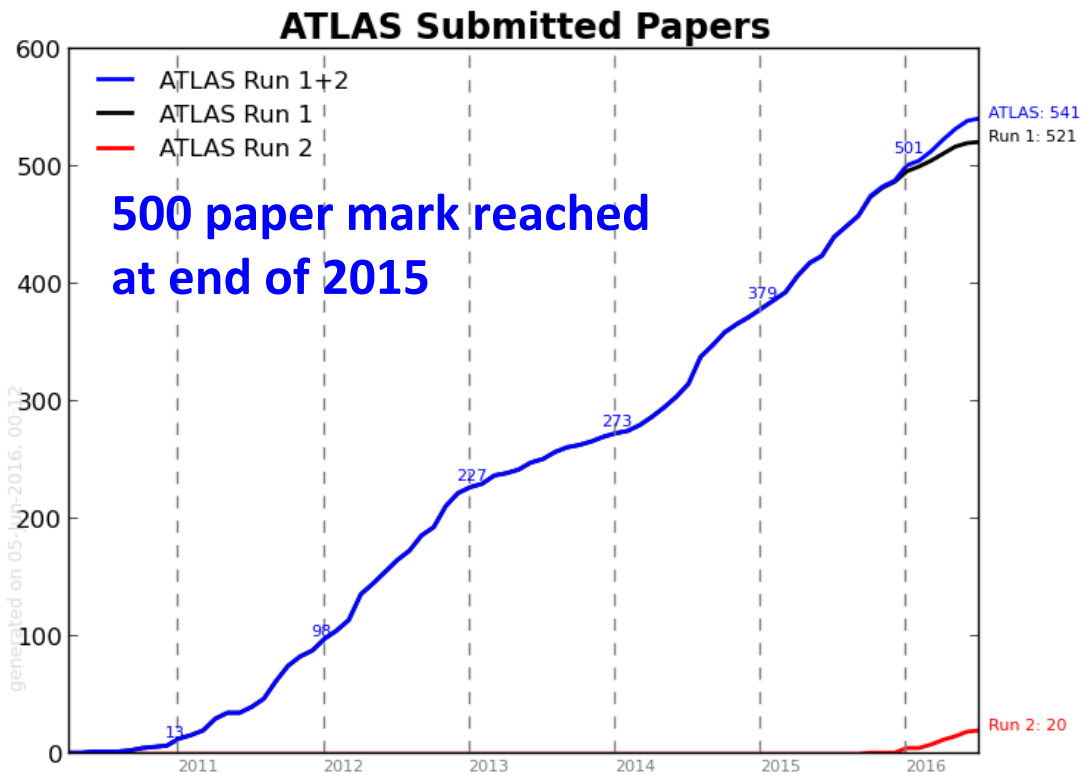
* Career numbers based on incomplete information

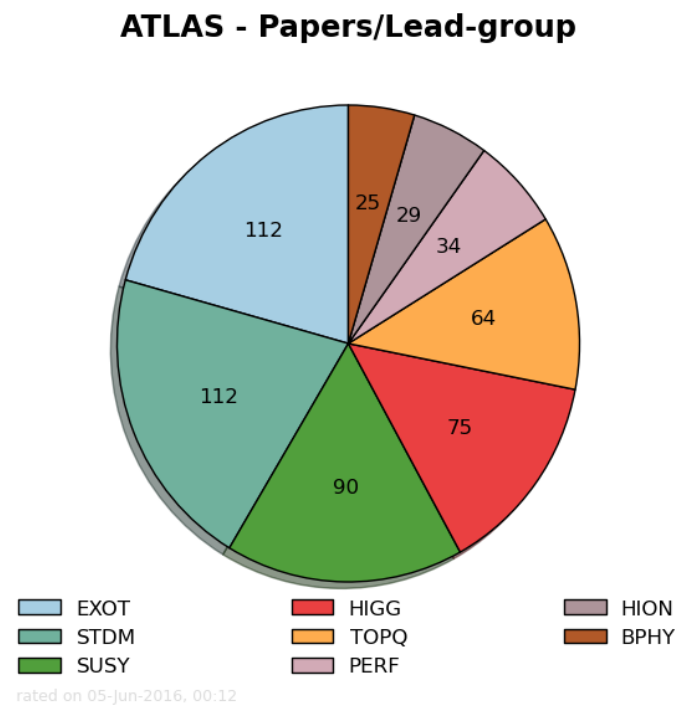
A Canadian student won one of the four 2015 ATLAS PhD Thesis Awards

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

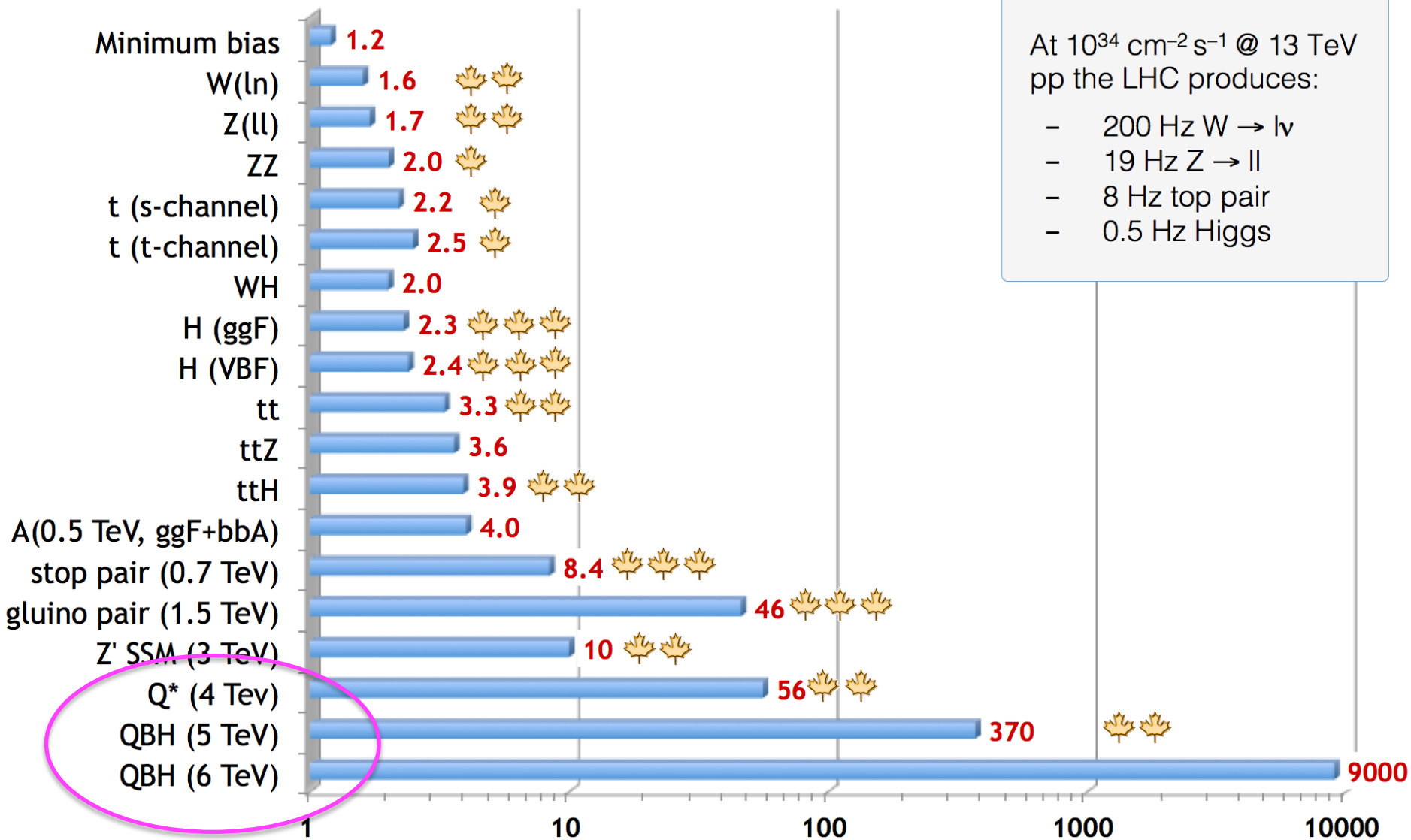
ATLAS Scientific Results





- 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

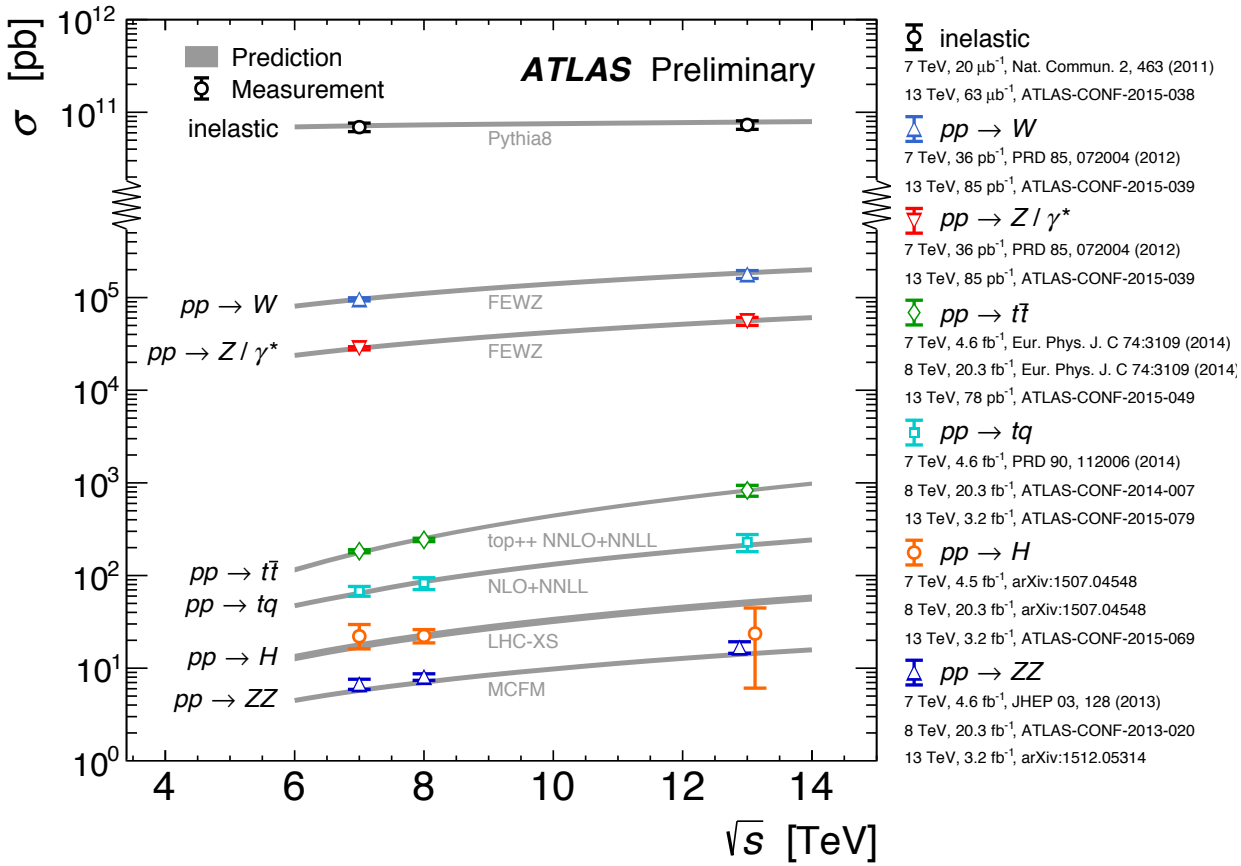


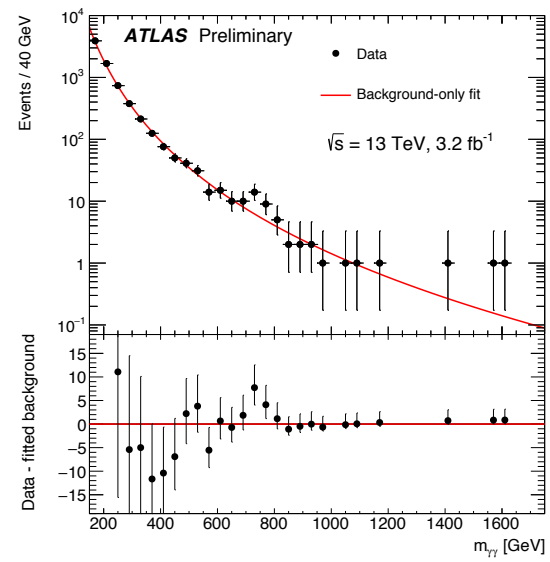
At 10^{34} cm^{-2} s^{-1} @ 13 TeV pp the LHC produces:

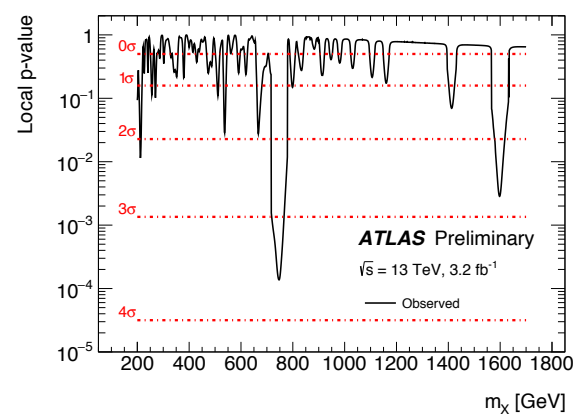
- 200 Hz W → lν
- 19 Hz Z → ll
- 8 Hz top pair
- 0.5 Hz Higgs

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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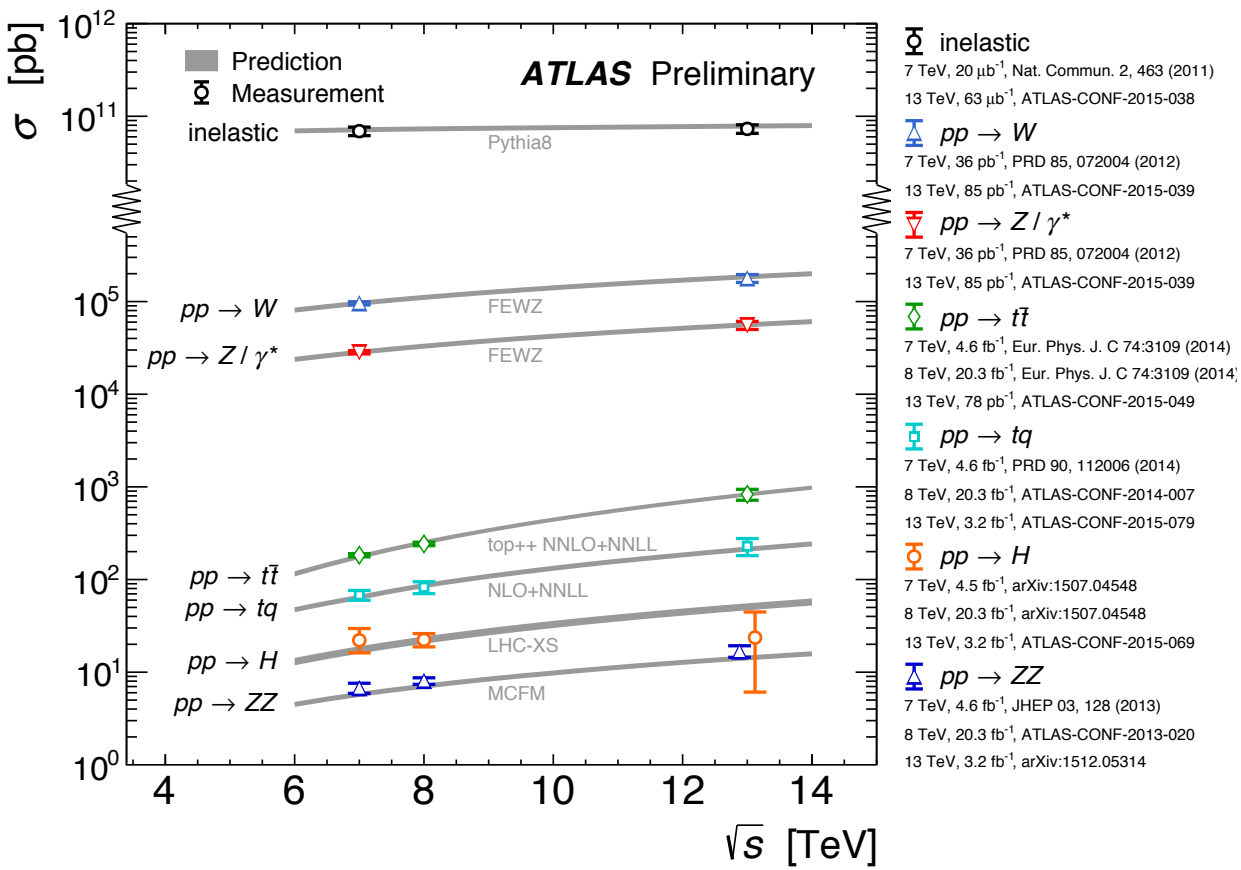
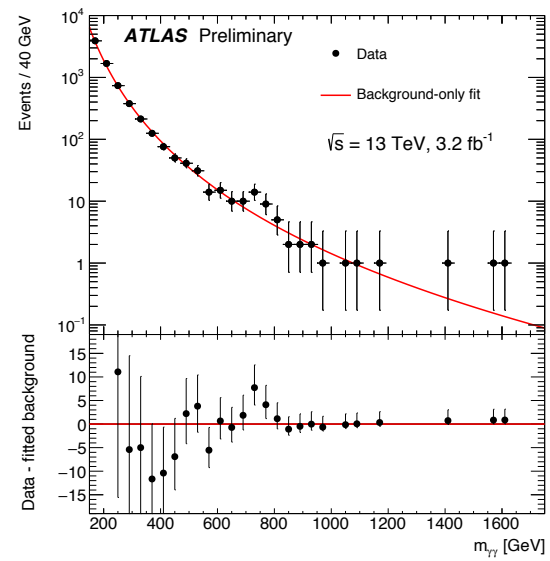
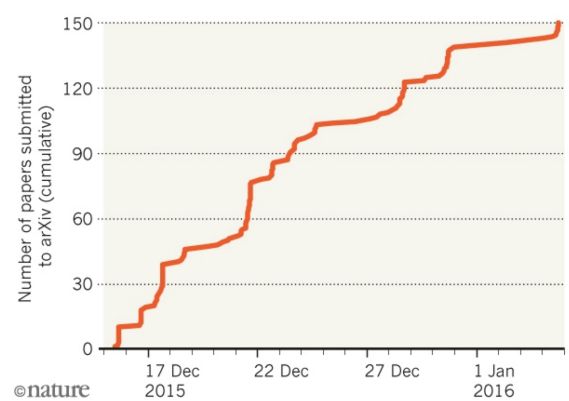




HINT OF NEW BOSON SPARKS FLOOD OF PAPERS

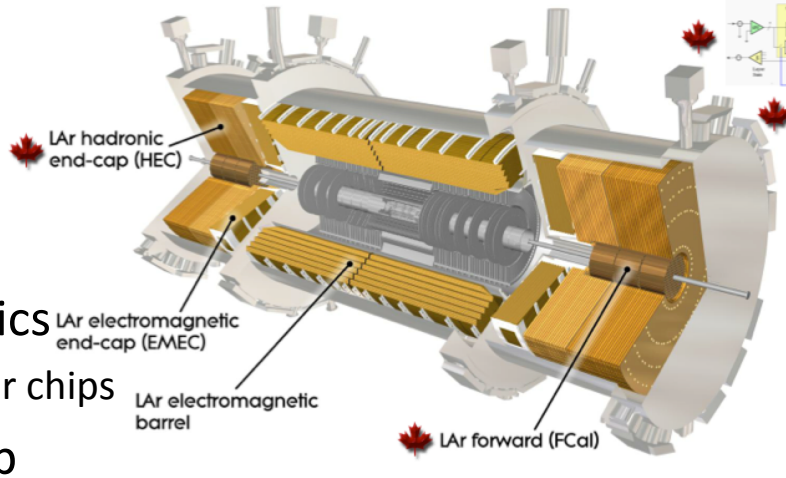
In just 21 days, physicists have posted 150 papers on the arXiv preprint server about tantalizing results at the Large Hadron Collider.

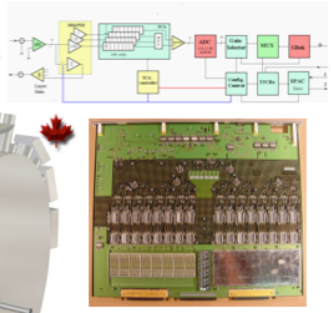


Canadian Hardware Contributions to ATLAS

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



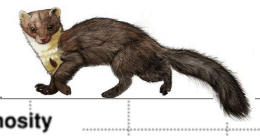


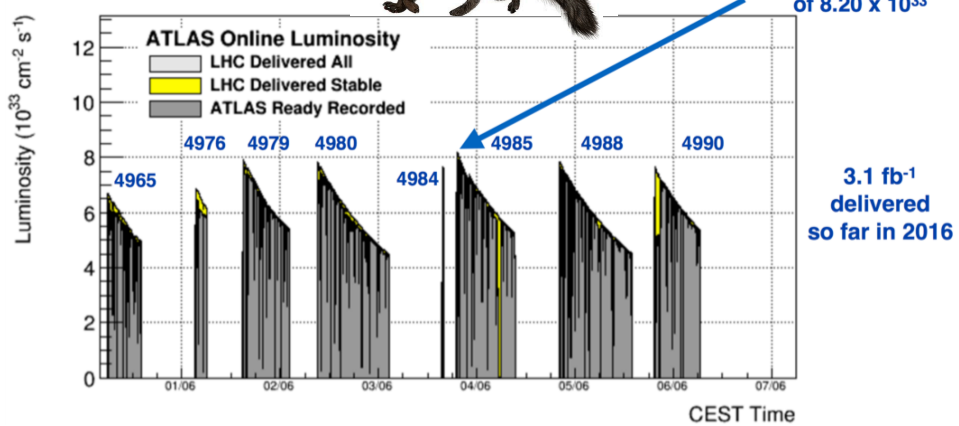
Other contributions to the existing detector (up to LS1)

- 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

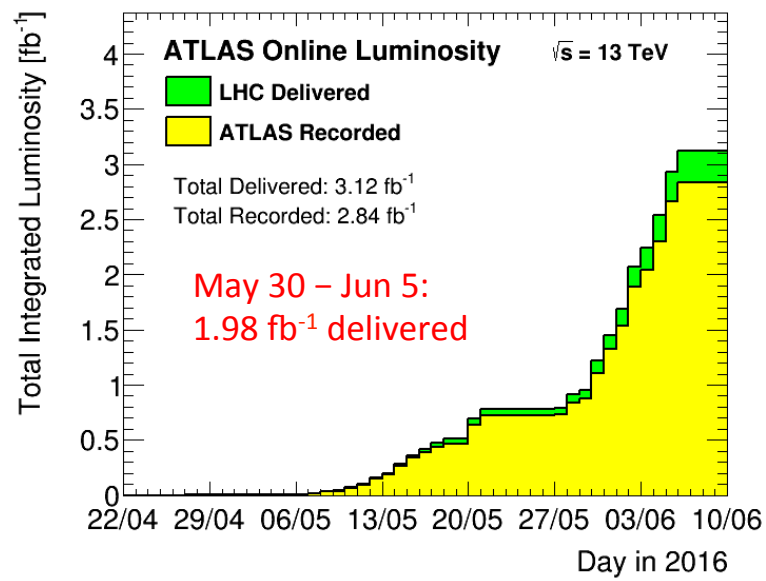
- Both LHC and ATLAS operating well: fastest luminosity ramp-up in LHC history
- New peak $\mathcal{L}_{inst}$ record of 8.2 $\times 10^{33} cm^{-2} s^{-1}$ last week
- All this in spite of the "weasel"





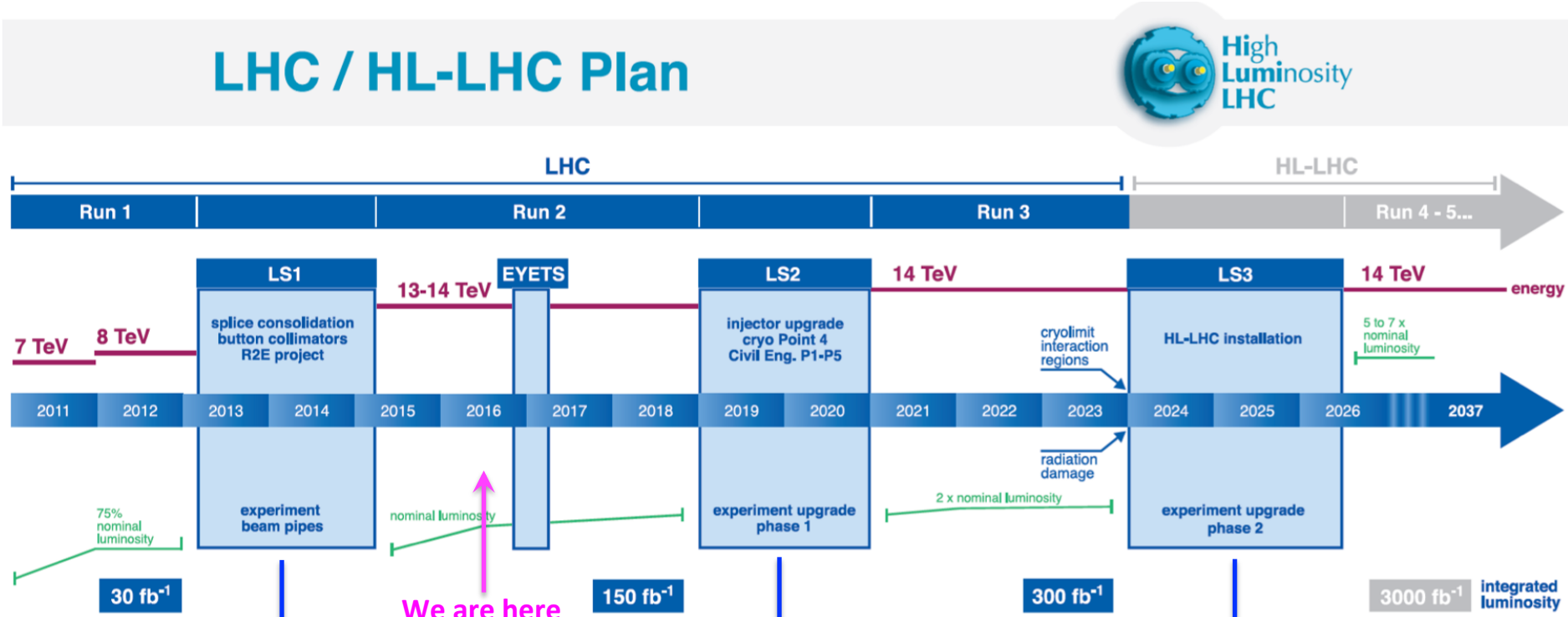
ATLAS Run-2 Detector Status (from May. 2016)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	98.2%
SCT Silicon Strips	6.3 M	98.7%
TRT Transition Radiation Tracker	350 k	97.2%
LAr EM Calorimeter	170 k	100%
Tile calorimeter	5200	100%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.7%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	383 k	99.8%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	357 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Chambers	383 k	96.6%
TGC Endcap Muon Chambers	320 k	99.6%
ALFA	10 k	99.9 %
AFP	188 k	98.8 %



Dataset for ICHEP: up to ~ end of July

LHC/HL-LHC Schedule / ATLAS upgrade planning



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

Completed

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

In progress

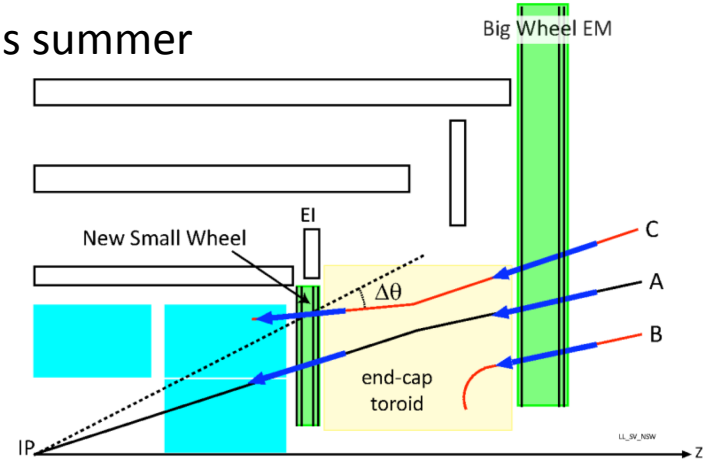
- New ATLAS Inner Tracker (ITk)
- Liquid Argon Calorimeter electronics
- Liquid Argon Forward Calorimeter replacement (if needed – decision June 2016)

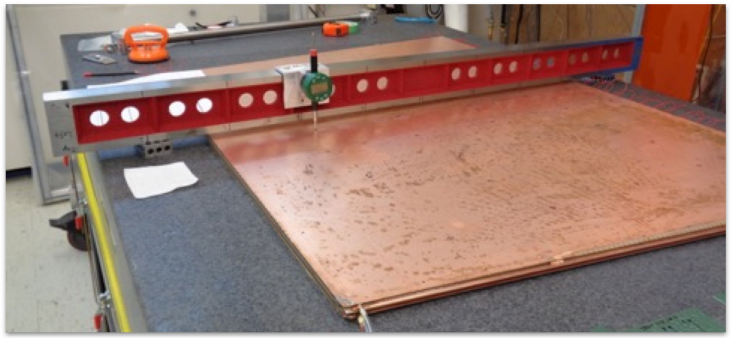
Proposed

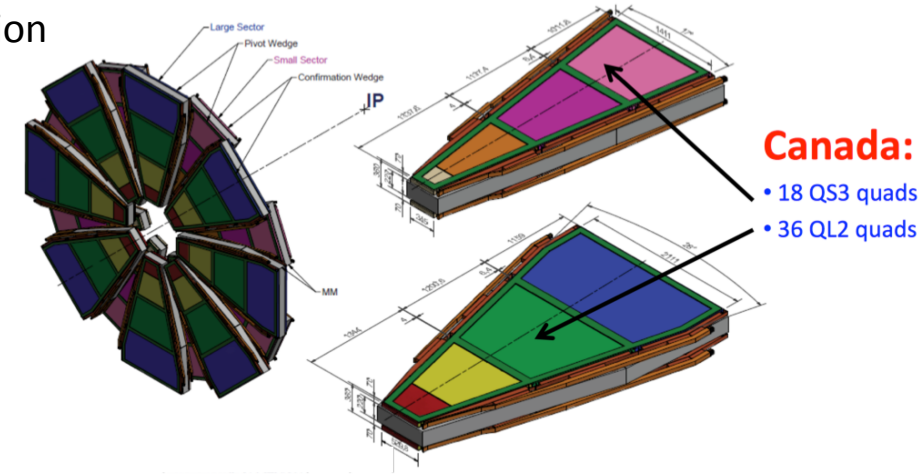
Main ATLAS Canada shutdown / upgrade activities

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



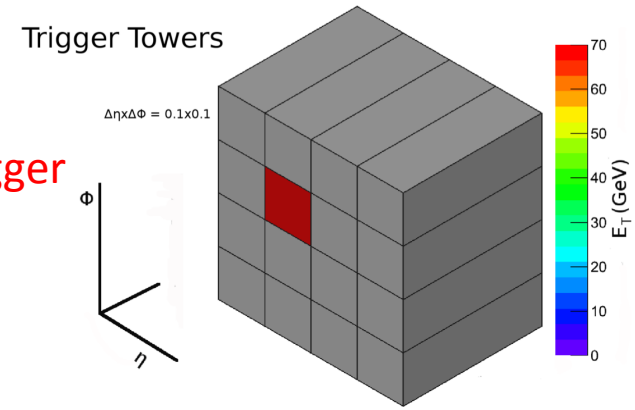




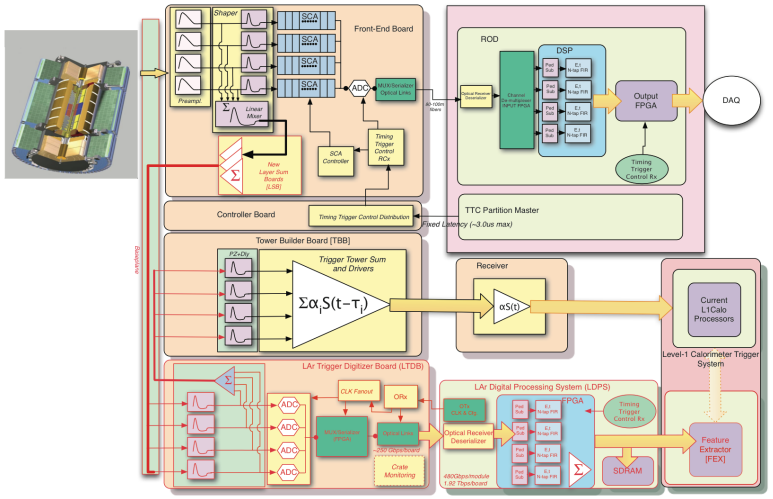
Phase-1 Upgrades: LAr Calorimeter Electronics

- 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

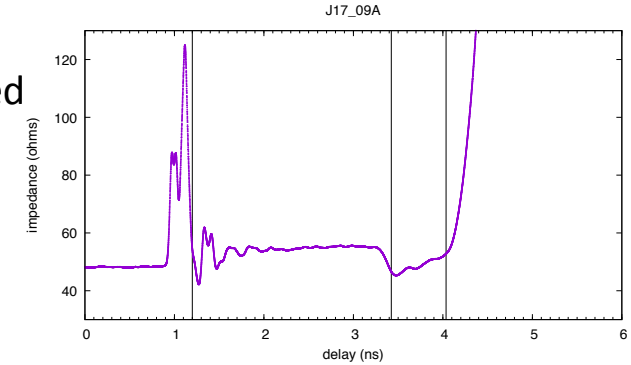
Current trigger granularity



(a)



- 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

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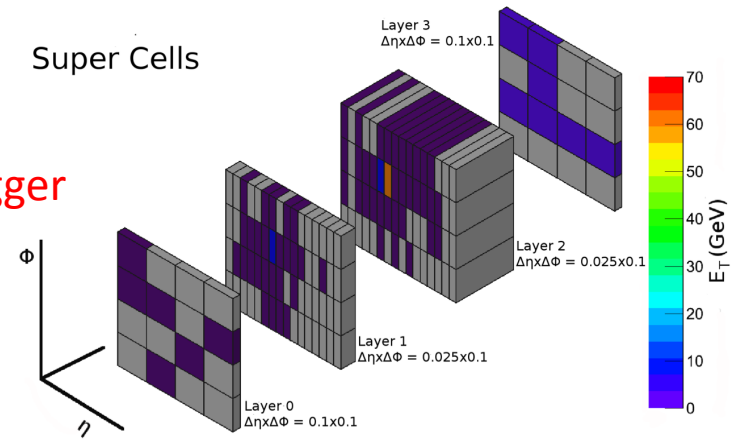
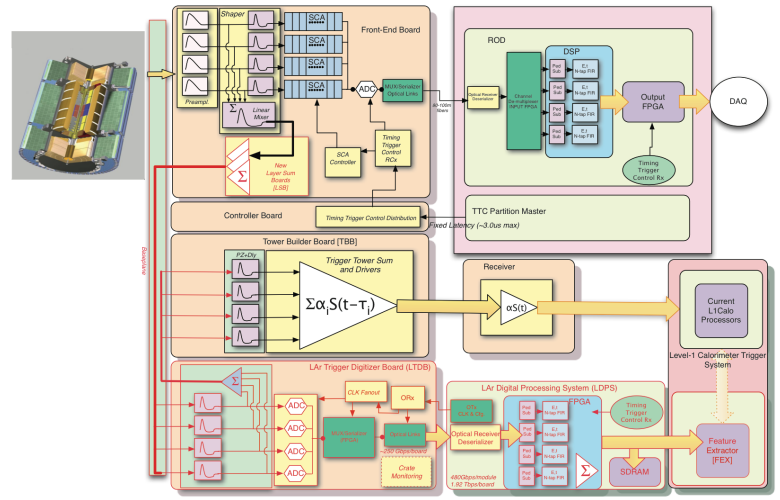
Phase-1 trigger granularity



(b)



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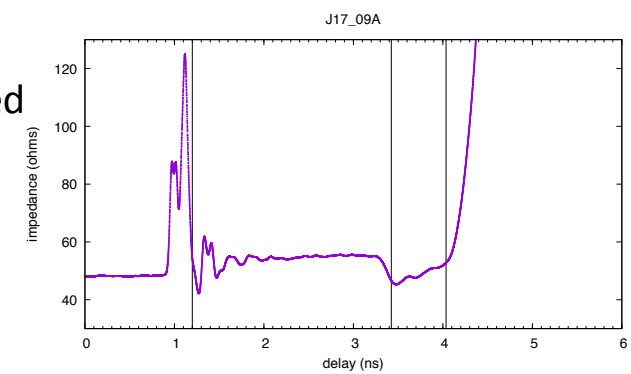
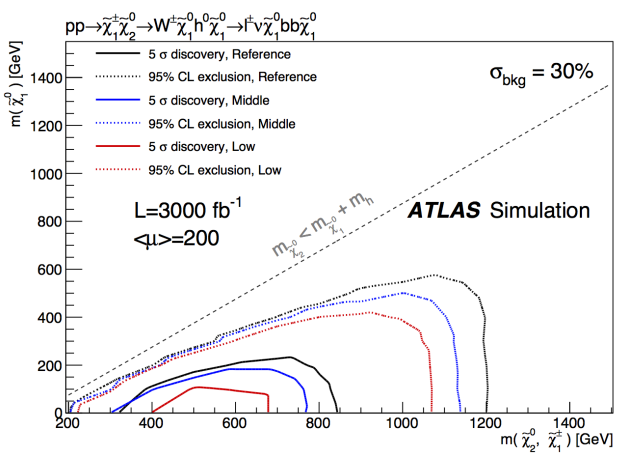


PRR planned for Fall 2016: production to follow approval

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 $\sigma\left(V_L V_L \rightarrow V_L V_L\right)$
    - 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



Detector system	Trigger–DAQ		Inner Tracker	Inner Tracker + Muon Spectrometer	Inner Tracker + Calorimeter		
Object Performance / Physics Process	Efficiency/ Thresholds $\mu^{\pm}$	Efficiency/ Thresholds $e^{\pm}$	b-tagging	$\mu^{\pm}$ Identification/ Resolution	Pile-up rejection	Jets	E_T^{miss}
$H \longrightarrow 4\mu$	✓			✓			
VBF $H \rightarrow ZZ^{(*)} \rightarrow \ell\ell\ell\ell$	✓	✓		✓	✓	✓	
VBF $H \rightarrow WW^{(*)} \rightarrow \ell\nu\ell\nu$	✓	✓	✓	✓	✓	✓	✓
SM VBS ssWW	✓	✓		✓	✓	✓	✓
SUSY, $\chi_1^{\pm}\chi_2^o \rightarrow \ell b\bar{b} + X$	✓	✓	✓	✓	✓	✓	✓
BSM $HH \rightarrow b\bar{b}b\bar{b}$			✓			✓	

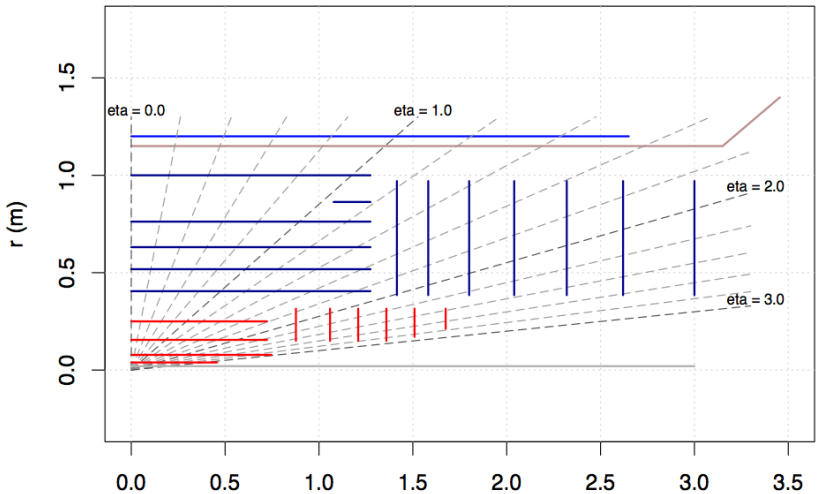
[LHCC-G-166: physics processes for Phase-II performance studies]

ATLAS at the High Luminosity LHC

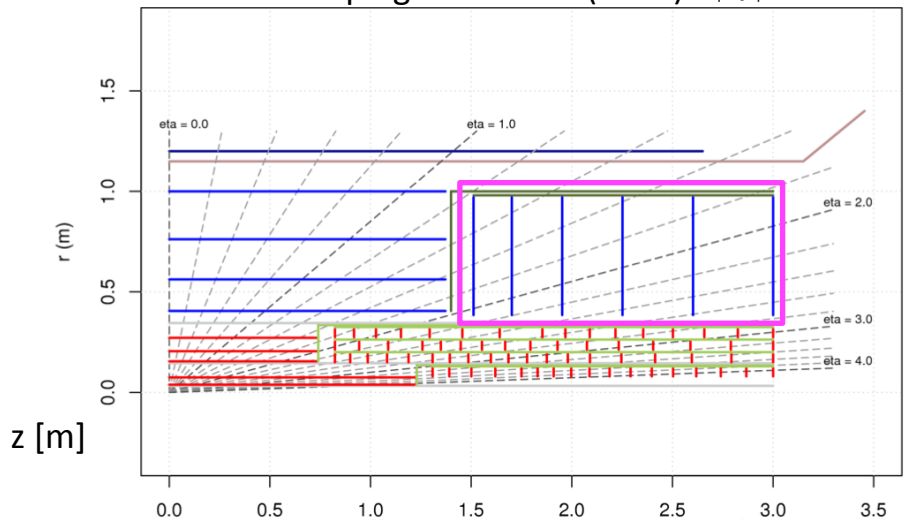
- Proposed instantaneous luminosity of 7.5×10^{34} $cm^{-2}s^{-1}$ ($\mu \approx 200$)
  - Needed for the desired (×10) increase in integrated luminosity
  - Rate and accumulated dose causes problems for some detector subsystems
- Proposed L0/L1 trigger scheme with rates of 1MHz/400KHz is incompatible 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)

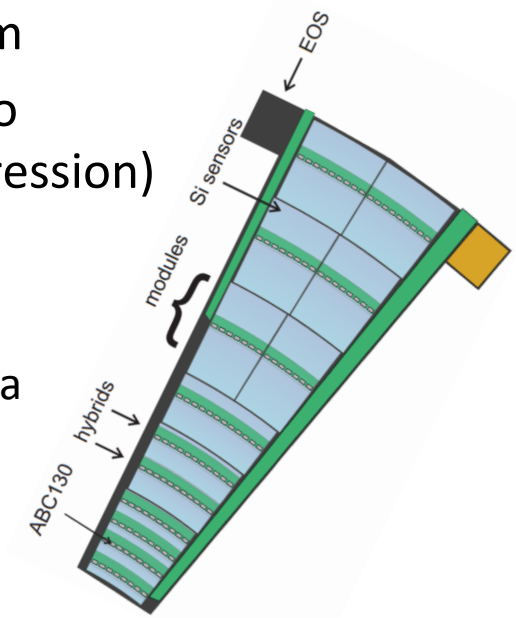
ATLAS Phase-II Letter of Intent (2012) $|\eta| < 2.7$



ATLAS Scoping Document (2015) $|\eta| < 4.0$

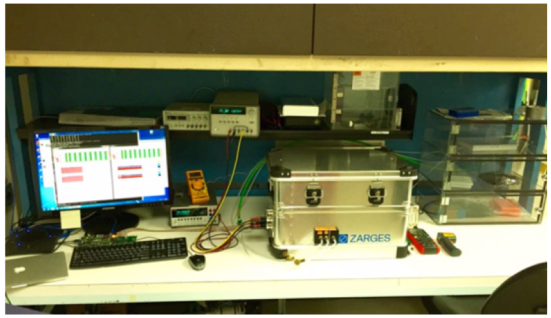


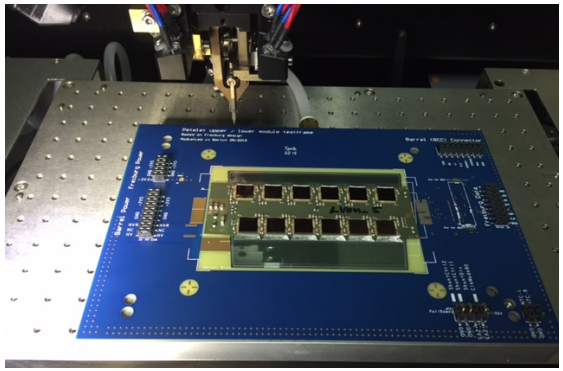
- Excellent tracking needed for the HL-LHC physics program
- Need precision vertexing to identify the primary vertex to which hard-scatter products are associated (pileup suppression)
- Canadian group proposing to contribute to construction of the Endcap Strips detector:
  - About 20k Si strip modules 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

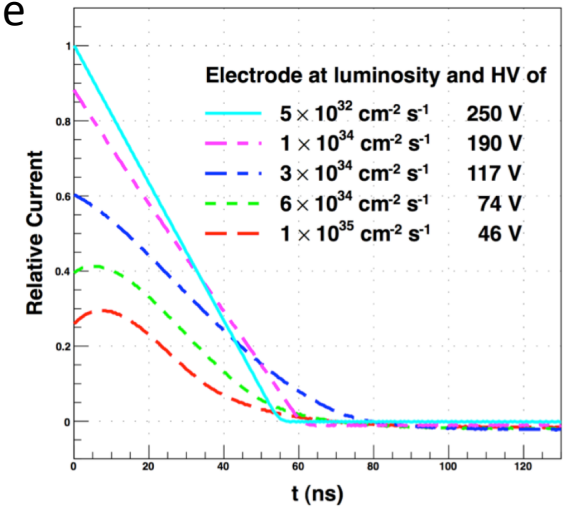
NSERC-funded R&D in progress

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.

NSERC-funded R&D in progress

- 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