Rob McPherson IPP RS Report

1) Rob McPherson: mini CV

2) ATLAS Running and Operations

3) ATLAS Upgrades
   - overview
   - current Canadian projects

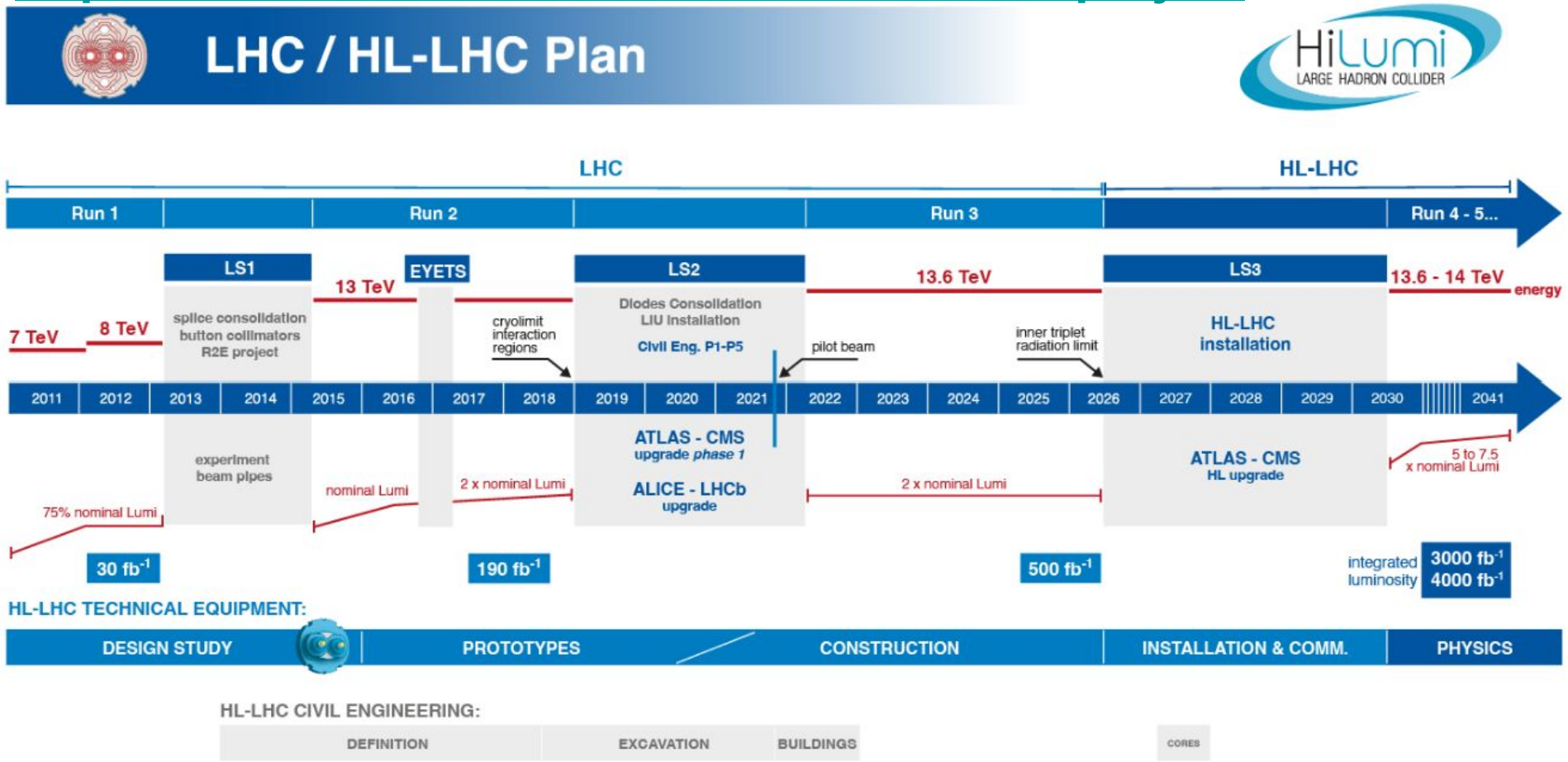
4) Summary

Rob McPherson

- **Education/Employment History**
  - PhD 1995, Princeton, BNL E787: $K^+ \to \pi^+ \nu\nu$
  - CERN Fellow 1996-1997, OPAL at the Large Electron Positron Collider (LEP)
  - IPP Research Scientist & Prof at Victoria since October 1997, TRIUMF Affiliated Scientist since 2005. CERN 2015-2017: OPAL and ATLAS
- **Research History**
  - 1989-1995 low energy e^+e^- resonances at Princeton, $K^+ \to \pi^+ \nu\nu$ at BNL
    - Straw tube and strip chamber design/construction/readout electronics, fast trigger electronics, cyclotron operation, computing, software, data analysis
  - OPAL, 1996 – 2008 (still on long-term editorial board)
    - "Zed-chamber" front-end electronics operation and maintenance
    - Searches group convener, a number of new particle search publications
    - 3 PhD students completed, a number of masters and undergrads, supervised many Canadian students @ CERN
    - Physics coordinator 2000 – 2001
  - ATLAS
    - Hadronic Endcap calorimeter construction/commissioning, LAr Data Quality coordinator
    - ATLAS offline commissioning and overall Data Quality Coordinator
    - SUSY, Exotics, Higgs analysis & publications
    - 8 PhD students, a number of masters and undergrads, supervised many Canadian students @ CERN
    - Principal Investigator of Victoria ATLAS group (7 faculty, ≈20 people)
    - NSERC ATLAS-Canada PI & National Contact Physicist to CERN for ATLAS 2007—2015 2023-present
    - ATLAS Deputy Spokesperson 2015—2017
    - ATLAS sTGC upgrade project coordinator (largest Phase-I upgrade) 2017—Present
  - Other
    - IPP Council 2x, TRIUMF U.G. exec, TRIUMF 2010 5YP co-author, NSERC 2008 SAP LRP Committee, PLHC 2012 Chair, referee for PRL, PRD, NIM
    - Senior Canadian@CERN 1997-2005 & 2015-2017, supervised/assisted students from all Canadian institutes
    - History of outreach: The National, Maclean's, many TV, radio and newspaper interviews, recent "Open Science" with Krieger/Vincter
  - This updated: mostly on ATLAS activities at the LHC

LHC / HL-LHC Schedule

- Continue collision operations ~ 1.5 decades, analysis ongoing for years
  - https://hilumilhc.web.cern.ch/content/hl-lhc-project



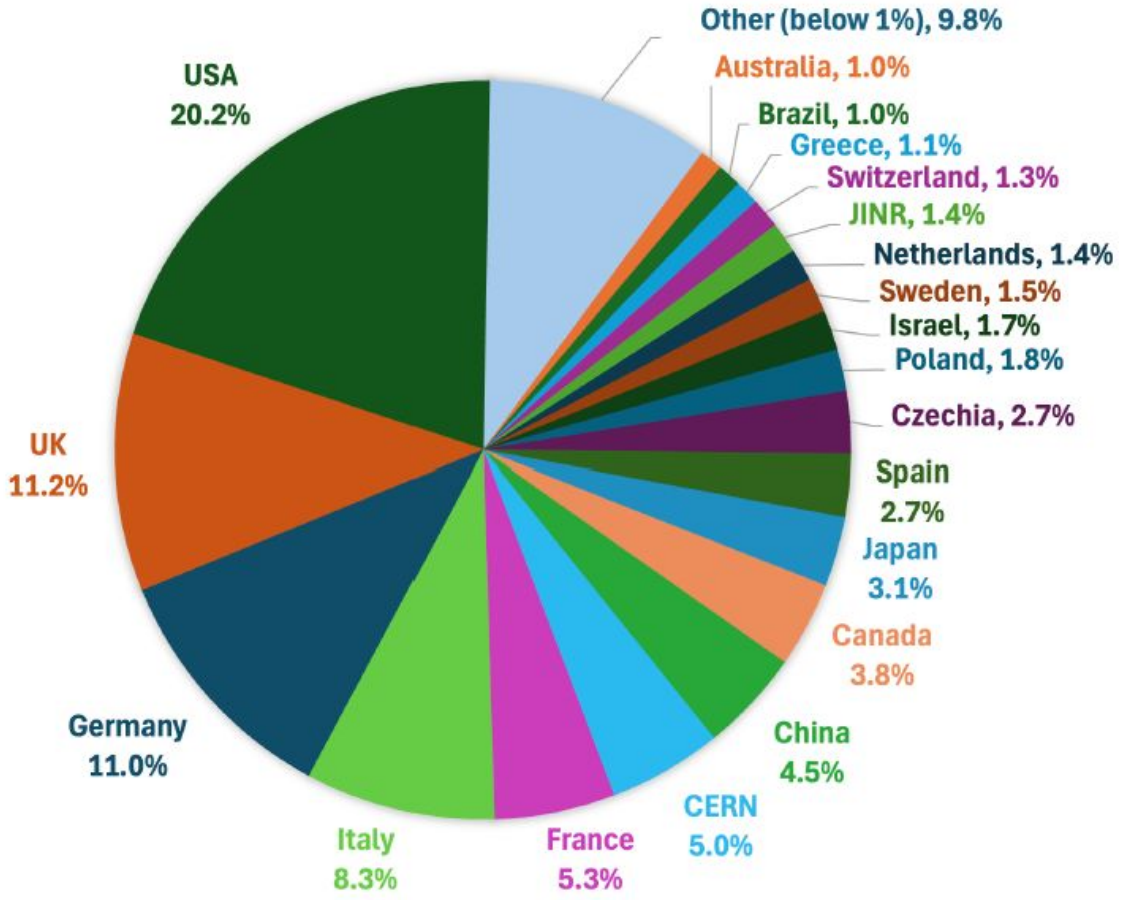
- Run 3 finishes end June 2026, moving into Long Shutdown 3 (LS3)
- Need *increased* CERN-presence for upgrade integration&integration (I&I)
- Also significant maintenance on existing detector systems

ATLAS at the LHC

- LHC: world's highest-energy particle collider
  - Energy frontier for another 2 decades
- Leading new particle searches, SM precision measurements, heavy flavour, heavy ion
- 176 institutions (246 institutes)
  - 17 Technical Associate institutes
- 40 countries

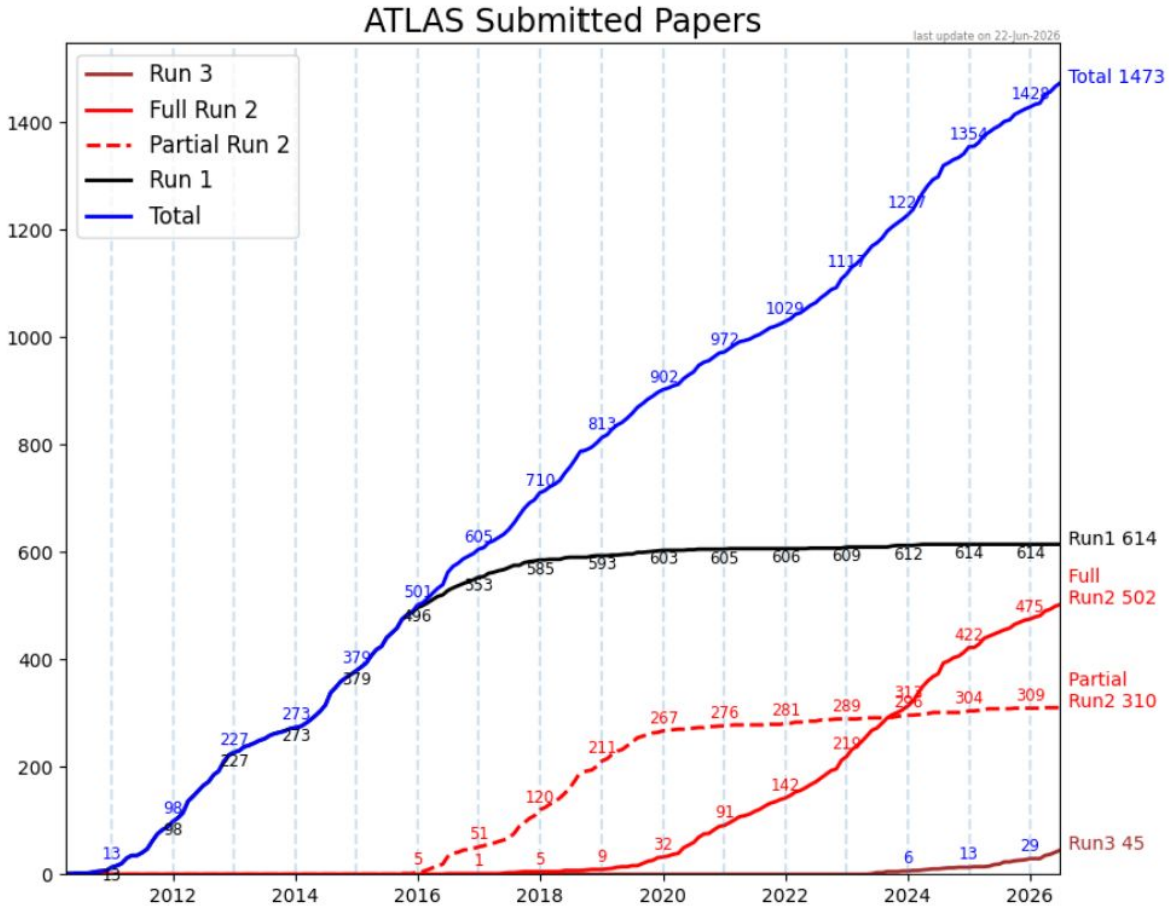
- 2600 Scientific authors (April 20th 2026)
  - 347 qualifying, 264 signing-only
  - students: 1161 physics PhD, 115 Engineering, 433 Masters/Diploma
  - 6014 active members

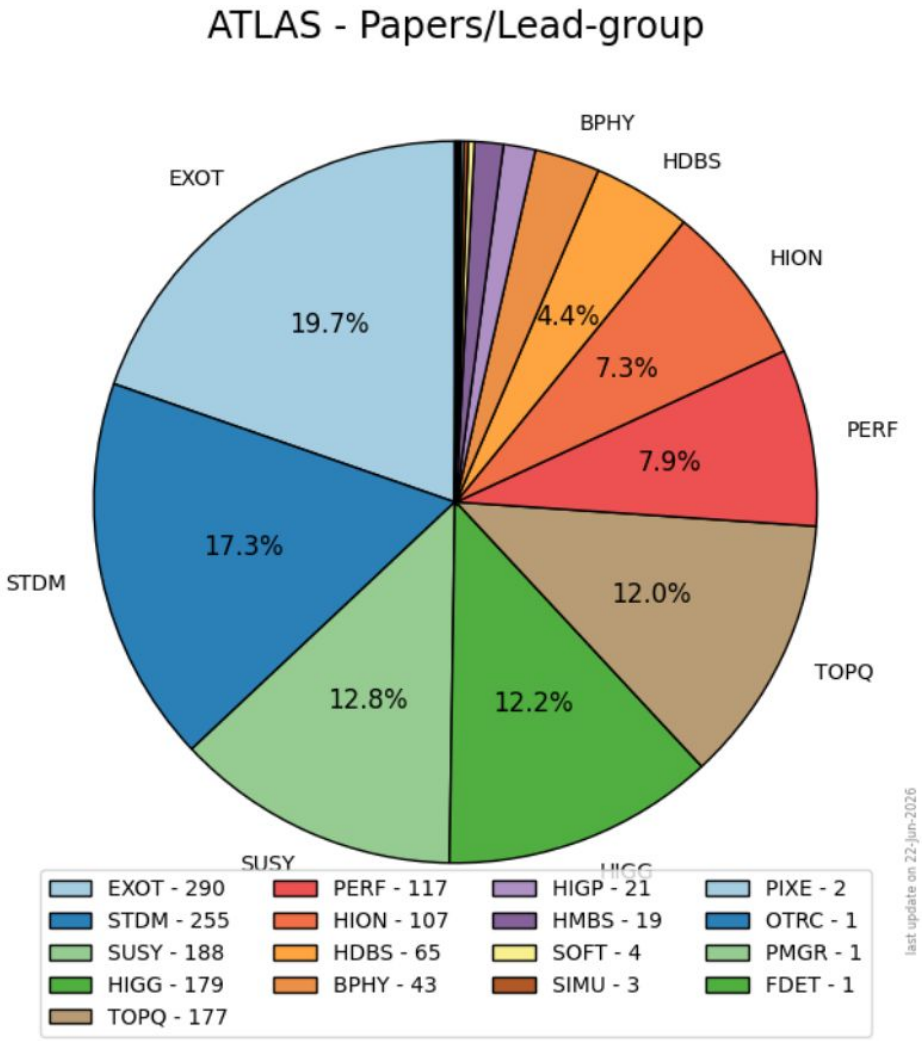
- ATLAS Active authors per country



Producing Physics: ATLAS Publications

- **Using collision data:**
  - **1473 papers submitted**

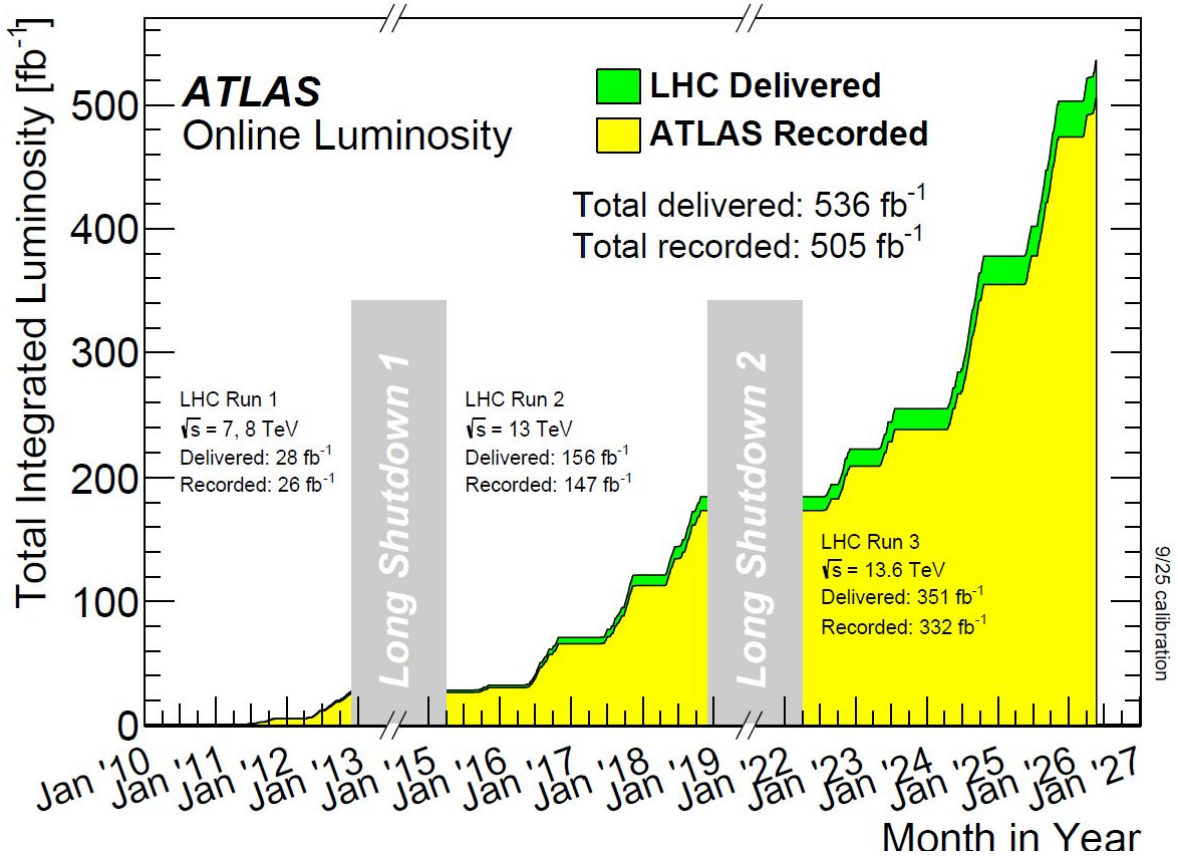




- **Postdocs and senior students often drive physics analyses**
- **Precision measurements are often statistics limited (STDM, HIGG)**

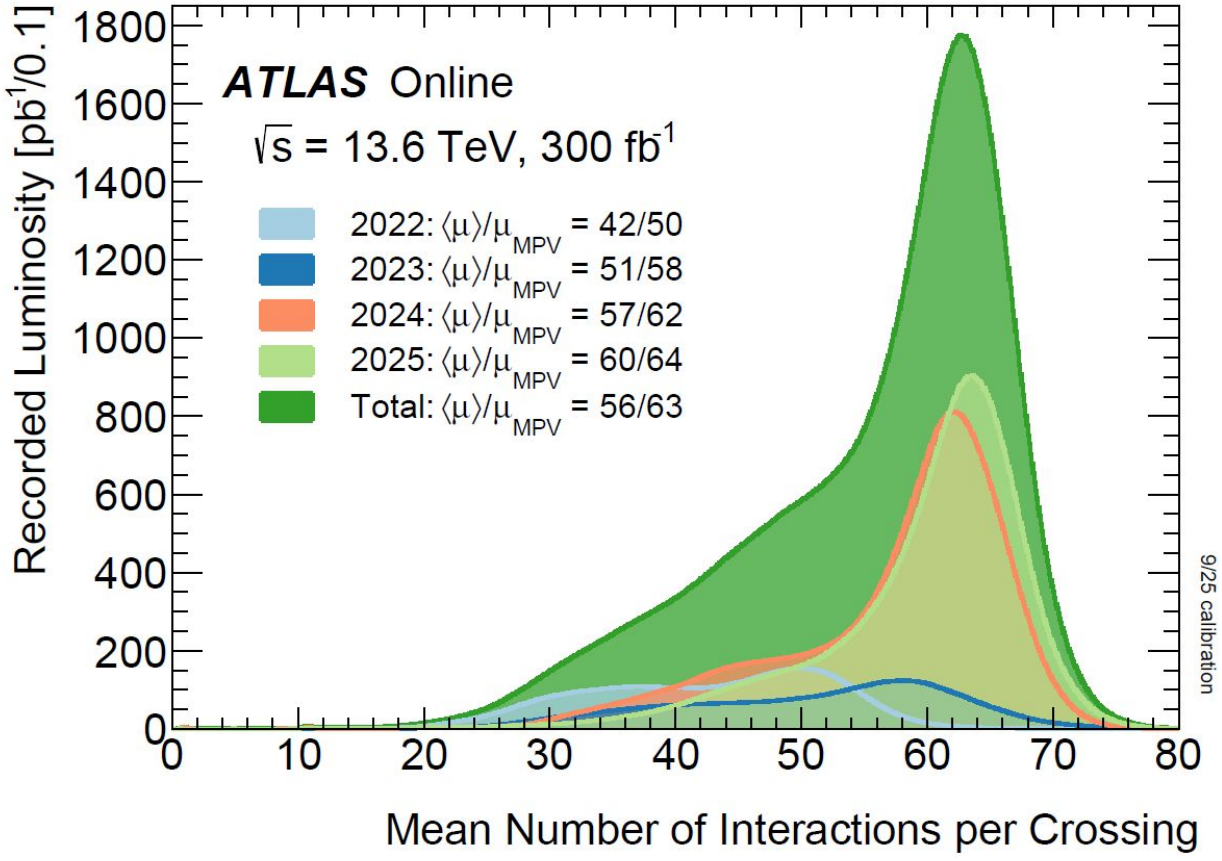
Integrated Luminosities / Pileup

- **Run-3 Integrated Luminosity Achieved**
  - Run 3: 351 (332) fb^{-1} delivered (recorded)
  - Run 2: 156 (147) fb^{-1} delivered (recorded)
- **Outstanding recording efficiency > 95%**
  - Despite pileup μ = 64 with mostly ~1.6 x1011 protons / bunch
  - enabled by Phase-I upgrades Muon NSW and LAr digital trigger



- **Integrated Luminosity expected**: HL-LHC: 3-4000 fb^{-1} delivered

- **2022-2025 Pileup**
- **Run-3 Pileup**
  - Leveling at μ > 60 interactions per crossing



- **Future**: HL-LHC: 140 – 200 interactions per crossing

ATLAS-Canada

Founded in 1992: Michel Lefebvre, Victoria
Spokesperson (94-07): Bob Orr, Toronto
Spokesperson (07-15): Rob McPherson UVic/IPP
Spokesperson (15-23): Peter Krieger, Toronto

Alberta
Carleton
McGill
Montréal
SFU
Toronto
TRIUMF
UBC
Victoria
York

Current ATLAS-Canada Management

Spokesperson,PI (07-15, 23--): Rob McPherson, Victoria/IPP
Deputy: Alain Bellerive, Carleton
Physics coord: Max Swiatlowski, TRIUMF
Computing coord: Isabel Trigger, TRIUMF
EDI coord: Heather Russell, Victoria

39 University/Lab. Faculty (33–34 FTE),

32 postdocs, 71 graduate students, ~ 25 undergrads/yr

Plus Engineers, Technicians

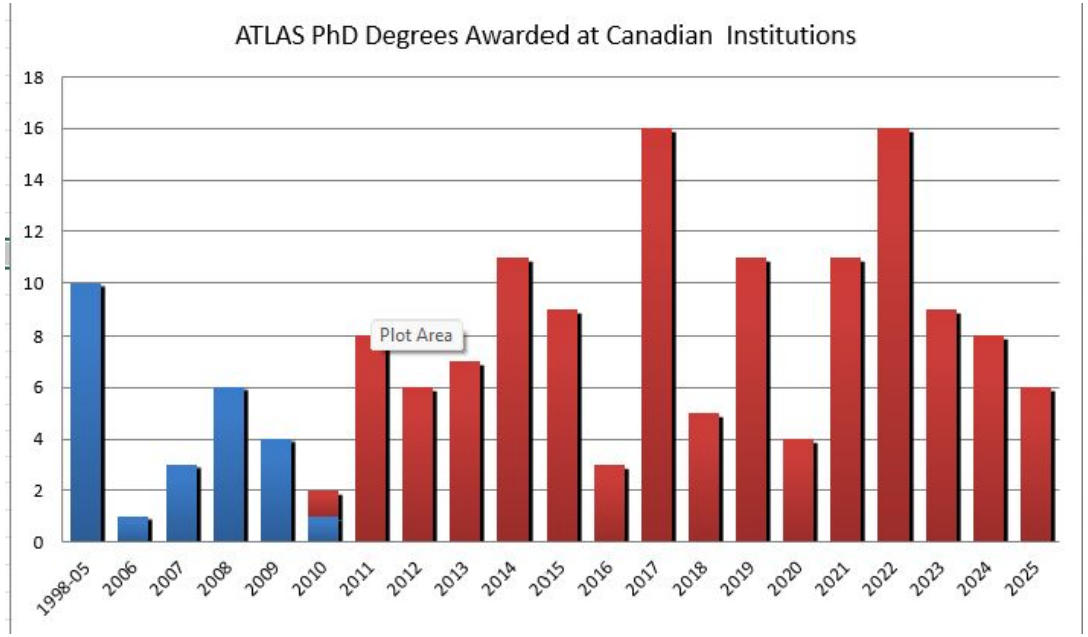
Includes 4 / 7 IPP Research Scientists, 6 CRC (4 former, 2 new)

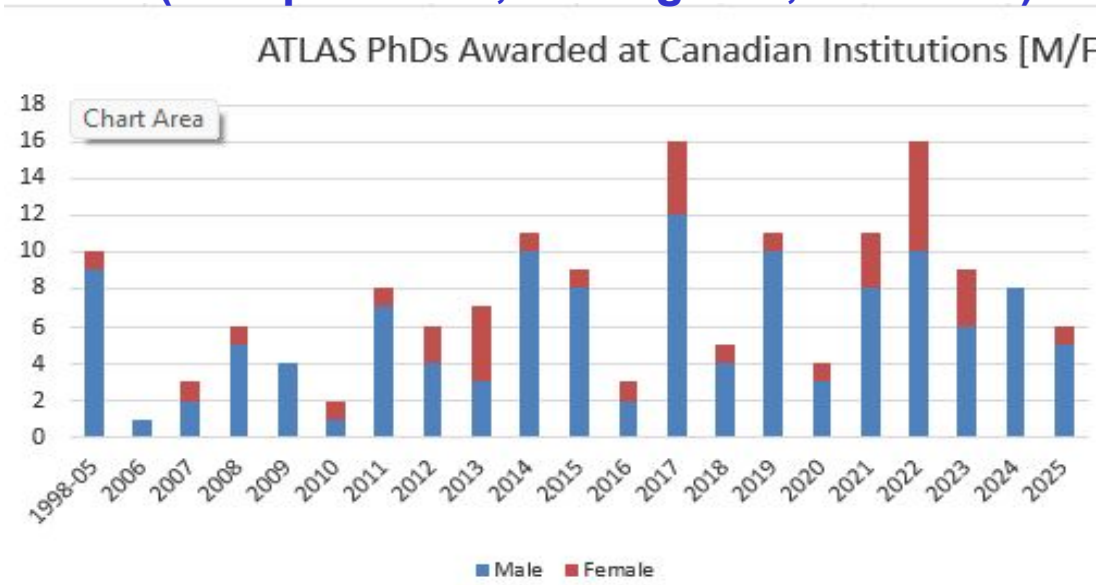
Leading detector roles, physics program, strong educational & training role

Many leadership roles in ATLAS: 2x Deputy Spokesperson, Management committee chairs, Upgrade/construction/subsytem coordinators, Physics Coordinator, …

ATLAS-Canada Grad Students

- **ATLAS-Canada has a strong record of training grad students (also postdocs, undergrads, technical)**





  - **Have 71 enrolled now (Capacity is > 100 total)**
  - **Typically accept 10—15 new GS/year if we can afford it**

- **Grad student salary flagged as issue**
  - **ATLAS-Canada EDI survey,**
    - **+personal communication with GS candidates**
  - **2024 Federal budget: average single person poverty line is $27,500 (worse in Vancouver, Toronto, Victoria, Ottawa, …)**
  - **Eg: TRIUMF requires minimum $32,000/year PhD and $27,000/year MSc (all-in)**
  - **Request, and try to allocate, funds keeping students above poverty line with TA, other support**

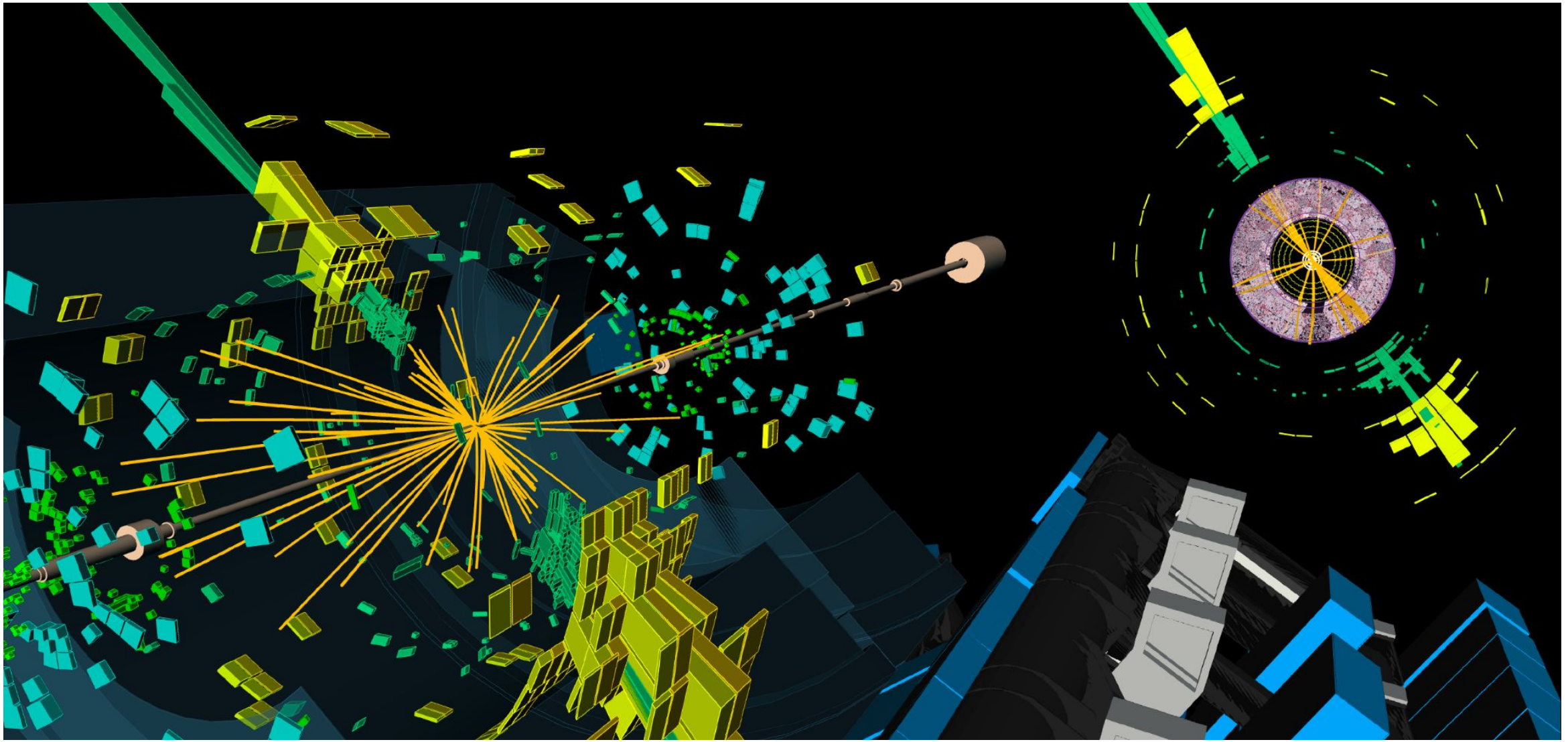
- **2024 Federal Budget: Welcome large increase**

Enhanced Scholarships and Fellowships

	Current Programs Annual Award		New Talent Program Annual Award
Canada Graduate Scholarships – Master's	$17,500	Master's →	$27,000
SSHRC Doctoral Fellowships	$20,000	Doctoral →	$40,000
NSERC Postgraduate Scholarships	$21,000		
CIHR Doctoral Foreign Study Award	$35,000		
Canada Graduate Scholarships – Doctoral	$35,000		
Vanier Canada Graduate Scholarships	$50,000		

ATLAS: Recent physics results

total of 502 papers on full Run-2 dataset, growing total of 45 papers including Run-3 data

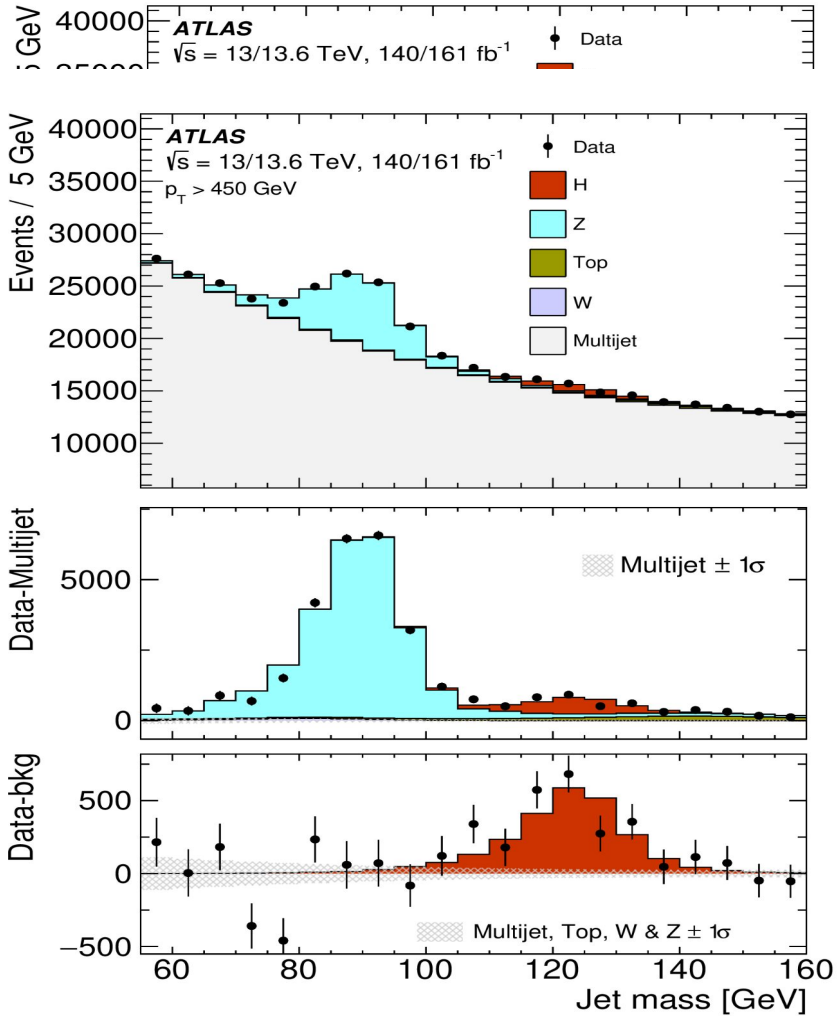


Candidate high-pT event $H \rightarrow b\bar{b}$: arXiv:2603.19369

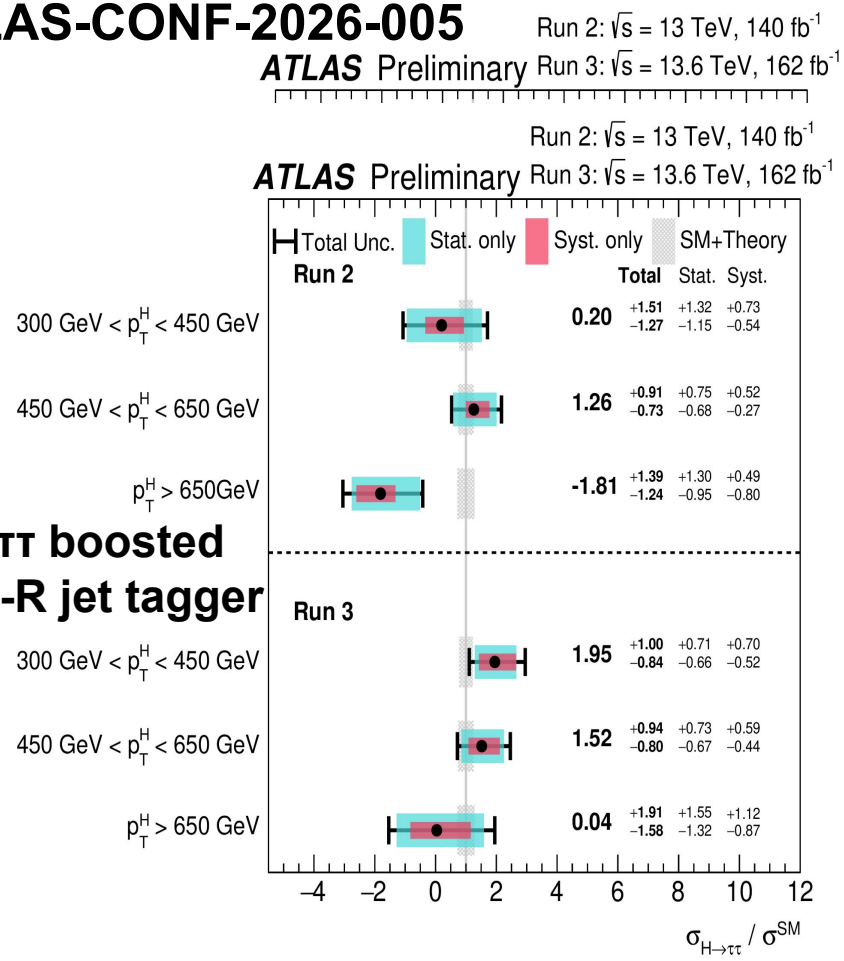
ATLAS: too many (esp. Canadian!) results to summarize

LHC: Higgs factory!

Evidence for inclusive high-pT H—>bb prod. arXiv:2603.19369



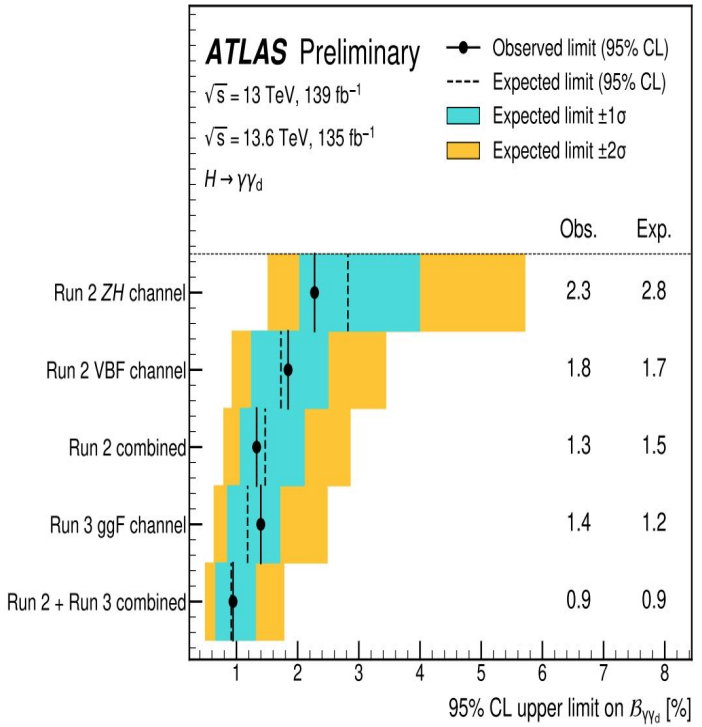
Evidence for high-pT H—>ττ prod. ATLAS-CONF-2026-005



H—>ττ boosted large-R jet tagger

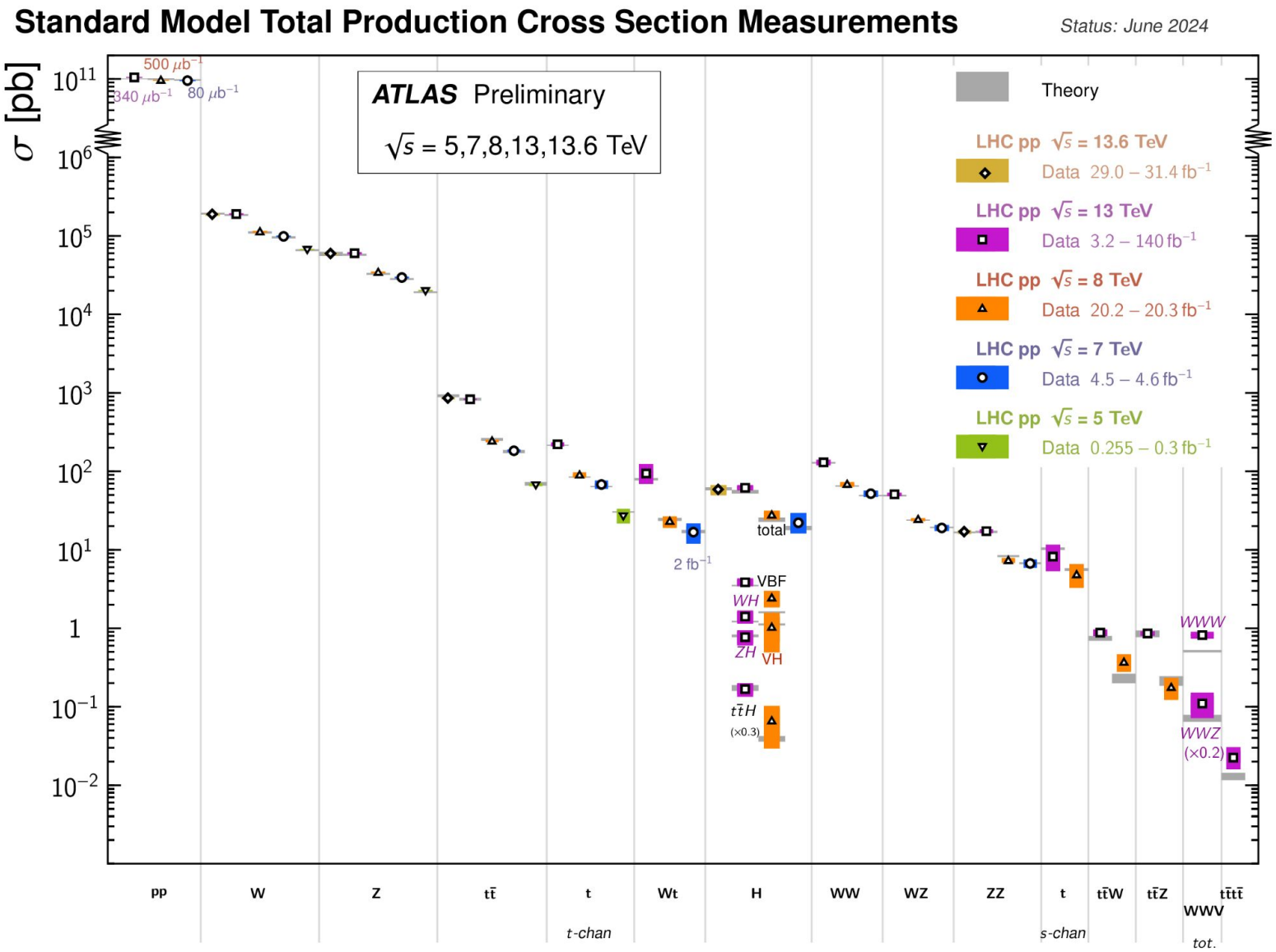
Many (many) N.P. Searches

Dark photon search in H → γγd arXiv:2606.14362

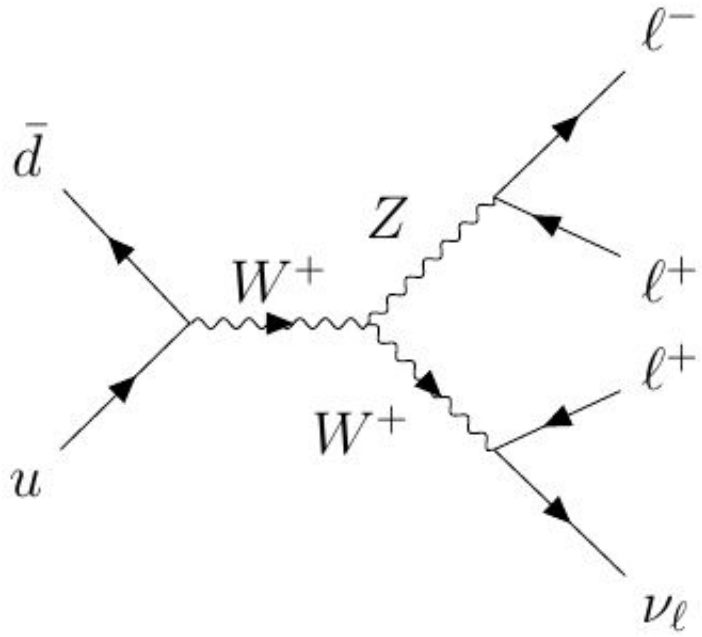


Standard Model: precision measurements

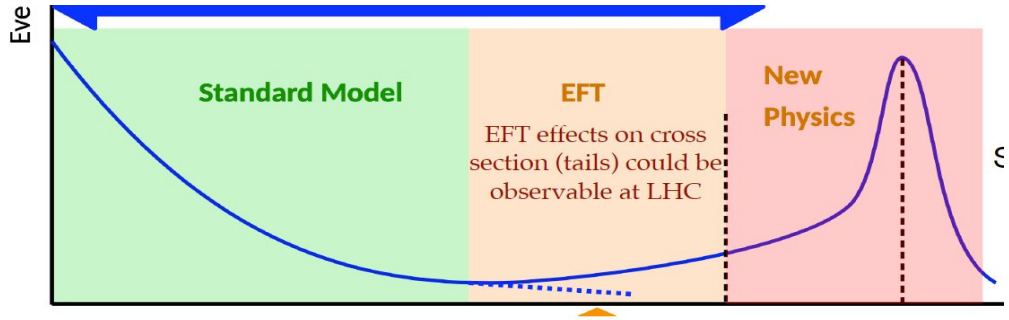
- **ATLAS will continue with**
  - SUSY and Exotic searches
  - Top and flavour physics
  - Precision Higgs measurement
  - Other Standard Model precision measurements
- **Many results benefit from lower e/μ trigger thresholds**
  - Upgrades led by Canadians
    - sTGC/NSW
    - L1 digital e trigger
- **Personally (RMcP)**
  - become more interested in pinning down the Electroweak sector to characterise possible new physics

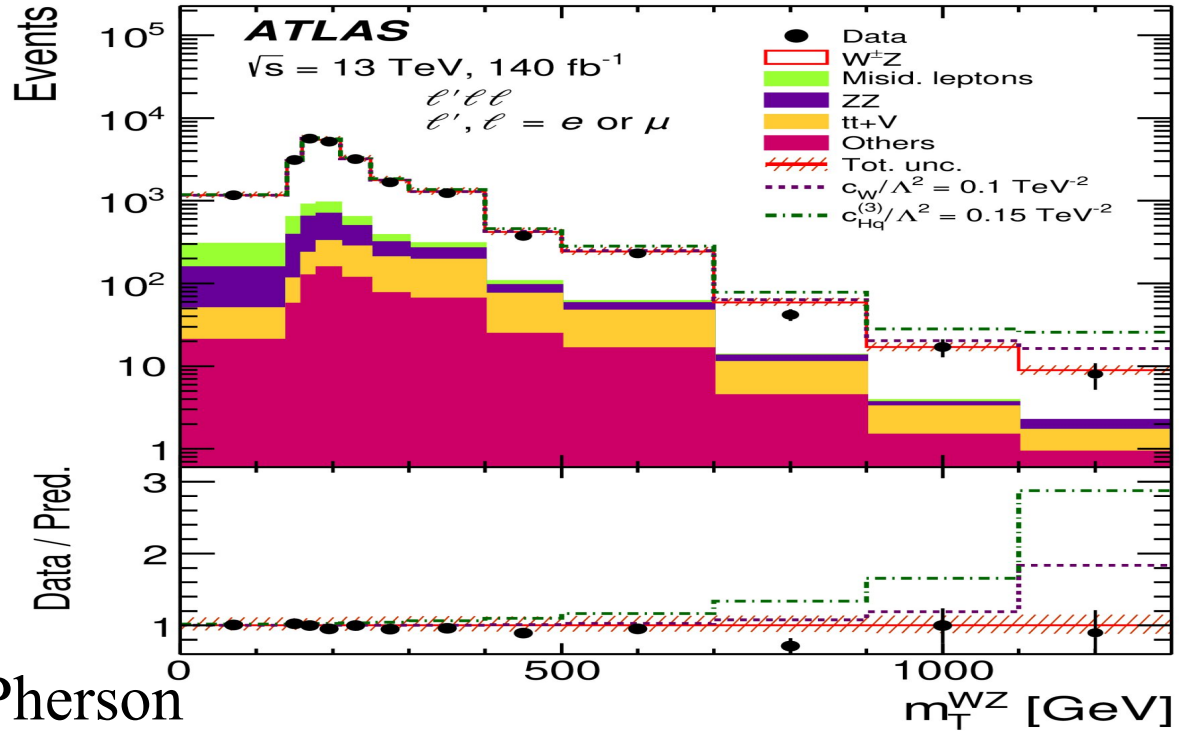


Leptonic WZ: Effective Field Theory (EFT)



$$\mathscr{L}_{SMEFT} = \mathscr{L}_{SM} + \sum_i \frac{c_i^{(5)}}{\Lambda}\mathcal{O}_i^{(5)} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \ldots$$





- **Full Run-2 WZ analysis: JHEP 11 (2025) 006**
  - **Analysis team includes RMcP + UVic PDF Joseph Lamber, José Pretel, and PhD students Juan Cristobal Rivera and Maheyer Shroff, + Isabel Trigger**
- **Working now on full Run-3, combined with updated Run-2**
  - **Including UVic PhD student Leesa Brown**

INSTITUTE OF PARTICLE PHYSICS
INSTITUT DE PHYSIQUE DES PARTICULES

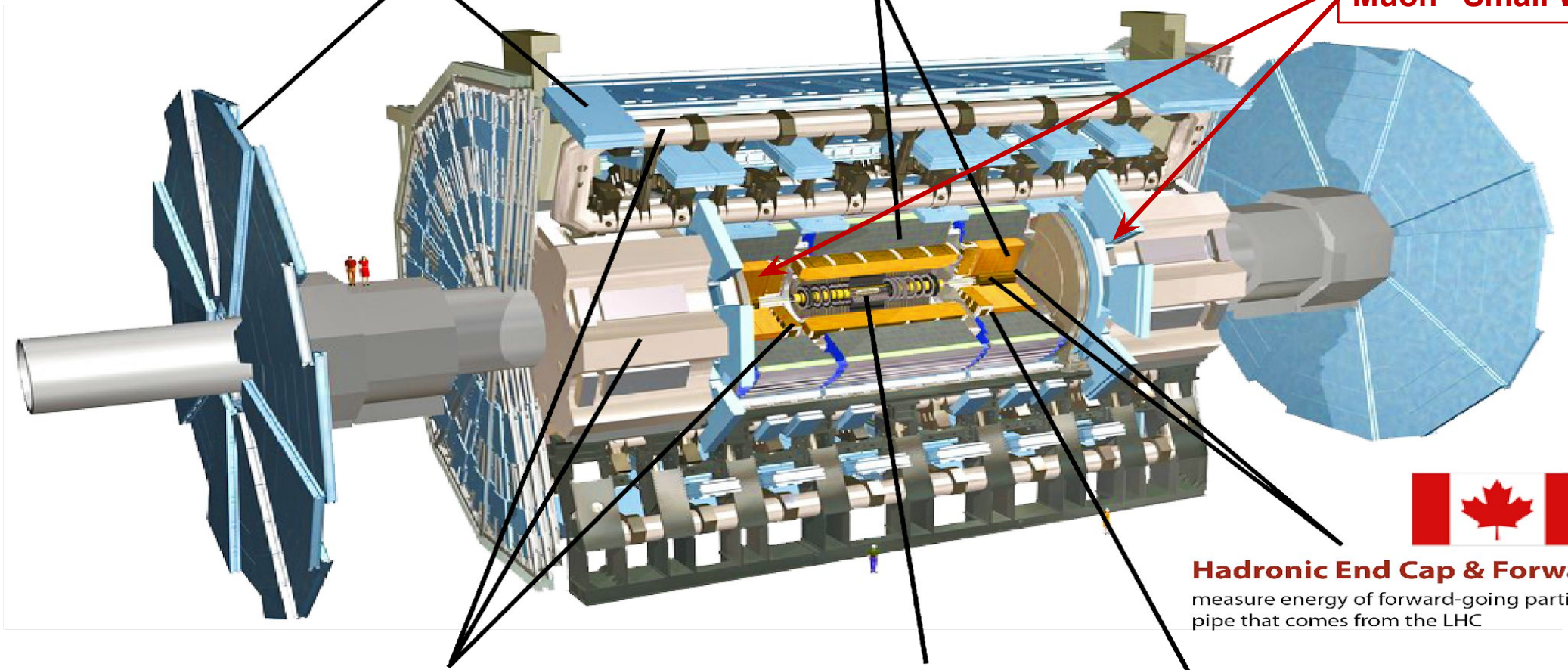
The ATLAS Detector

ATLAS EXPERIMENT

Muon Detectors
detect escaping charged particles

Electromagnetic and Hadronic Calorimeters
measure energy of particles from the collision by absorbing them

Muon "Small Wheels"



Hadronic End Cap & Forward Calorimeters
measure energy of forward-going particles near the beam pipe that comes from the LHC

Total Detector Width: 44 metres
Diameter: 22 metres
Weight: 7000 tonnes

Solenoid & Toroid Magnets
bend the charged particles so that they can be measured by the detectors

Inner Detector
tracks charged particles and measures momentum & charge

Cryostat Feedthroughs
manage data signals from inside the hyper-cold liquid argon calorimeters to room temperature external computers

ATLAS Upgrade Timelines

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026-2030

Phase 0 upgrade:

Consolidation, $\sqrt{s}$=13 TeV, 25nsec bunch spacing, $L \approx 1 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 30$—50)

$\int L \approx 150$ fb^{-1}

- New insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation (calorimeter power supplies)
- Neutron Shielding
- Finish EE muons installation
- Upgrade magnet cryo

Phase I upgrade:

- Likely $\sqrt{s}$=14 TeV
- $L \approx 2 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 60$)
- $\int L \approx 300$ fb^{-1}

- New Muon Small Wheel (NSW)
- High Precision Calorimeter Level-1 Trigger
- Fast Track Trigger (FTK)
- Topological Level-1 Trigger Processor
- New forward diffractive physics detectors AFP
- Trigger-DAQ

Phase II upgrade:

$L \approx 7 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 150$)

$\int L \approx 3000$ fb^{-1}

- All new Tracking Inner Detector
- Calorimeter Electronics Upgrades
- Muon system upgrades
- Level-1 track trigger
- Trigger-DAQ
- High Granularity Timing Detector (R&D)

ATLAS Upgrade Timelines

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026–2030

Phase 0 upgrade:

Consolidation, $\sqrt{s}$=13 TeV, 25nsec bunch spacing, $L \approx 1 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 30$—50)

$\int L \approx 150$ fb^{-1}

- New insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation (calorimeter power supplies)
- Neutron Shielding
- Finish EE muons installation
- Upgrade magnet cryo

Phase I upgrade:

- Likely $\sqrt{s}$=14 TeV
- $L \approx 2 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 60$)
- $\int L \approx 300$ fb^{-1}

- New Muon Small Wheel (NSW)
- High Precision Calorimeter Level-1 Trigger
- Fast Track Trigger (FTK)
- Topological Level-1 Trigger Processor
- New forward diffractive physics detectors AFP
- Trigger-DAQ

Phase II upgrade:

$L \approx 7 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 200$)

$\int L \approx 3000$ fb^{-1}

- All new Tracking Inner Detector
- Calorimeter Electronics Upgrades
- Muon system upgrades
- Level-1 track trigger
- Trigger-DAQ
- High Granularity Timing Detector (R&D)

ATLAS Upgrade Timelines

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026–2030

Phase 0 upgrade:

Consolidation, $\sqrt{s}$=13 TeV, 25nsec bunch spacing, $L \approx 1 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 30$—50)

$\int L \approx 150$ fb^{-1}

- New insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation (calorimeter power supplies)
- Neutron Shielding
- Finish EE muons installat
- Upgrade magnet cryo

Phase I upgrade:

- Likely $\sqrt{s}$=14 TeV
- $L \approx 2 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 60$)
- $\int L \approx 300$ fb^{-1}

- New Muon Small Wheel (NSW)
- High Precision Calorimeter Level-1 Trigger
- Fast Track Trigger (FTK)
- Topological Level-1 Trigger Processor
- New forward diffractive physics detectors AFP
- Trigger-DAQ

Phase II upgrade:

$L \approx 7 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 200$)

$\int L \approx 3000$ fb^{-1}

- All new Tracking Inner Detector
- Calorimeter Electronics Upgrades
- Muon system upgrades
- Level-1 track trigger
- Trigger-DAQ
- High Granularity Timing Detector (R&D)

ATLAS Upgrade Timelines

22010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026–2030

Phase 0 upgrade:

Consolidation, $\sqrt{s}$=13 TeV, 25nsec bunch spacing, $L \approx 1 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 30$—50)

$\int L \approx 150$ fb^{-1}

- New insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation (calorimeter power supplies)
- Neutron Shielding
- Finish EE muons installat
- Upgrade magnet cryo

Phase I upgrade:

- Likely $\sqrt{s}$=14 TeV
- $L \approx 2 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 60$)
- $\int L \approx 300$ fb^{-1}

- New Muon Small Wheel (NSW)
- High Precision Calorimeter Level-1 Trigger
- Fast Track Trigger (FTK)
- Topological Level-1 Trigger Processor
- New forward diffractive physics detectors AFP
- Trigger-DAQ

Phase II upgrade:

$L \approx 7 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 200$)

$\int L \approx 3000$ fb^{-1}

- All new Tracking Inner Detector
- Calorimeter Electronics Upgrades
- Muon system upgrades
- Level-1 track trigger
- Trigger-DAQ
- High Granularity Timing Detector (R&D)

ATLAS Upgrade Timelines

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026–2030

Phase 0 upgrade:

Consolidation, $\sqrt{s}$=13 TeV, 25nsec bunch spacing, $L \approx 1 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 30$—50)

$\int L \approx 150$ fb^{-1}

- New insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation (calorimeter power supplies)
- Neutron Shielding
- Finish EE muons installat
- Upgrade magnet cryo

Phase I upgrade:

- Likely $\sqrt{s}$=14 TeV
- $L \approx 2 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 60$)
- $\int L \approx 300$ fb^{-1}

- New Muon Small Wheel (NSW)
- High Precision Calorimeter Level-1 Trigger
- Fast Track Trigger (FTK)
- Topological Level-1 Trigger Processor
- New forward diffractive physics detectors AFP
- Trigger-DAQ

Phase II upgrade:

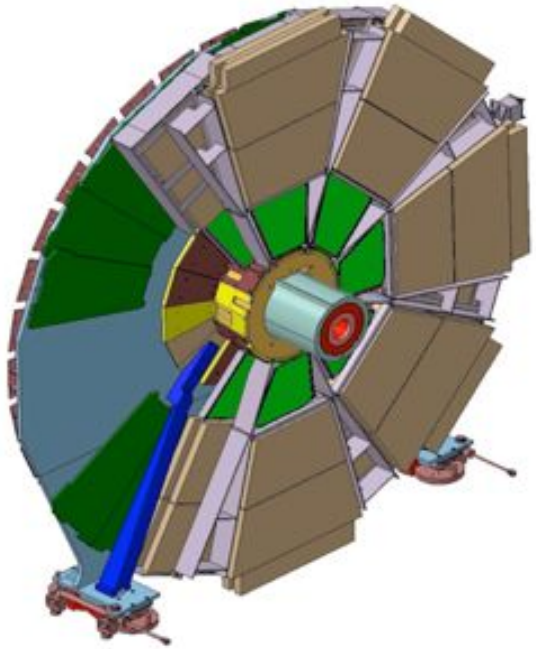
$L \approx 7 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 200$)

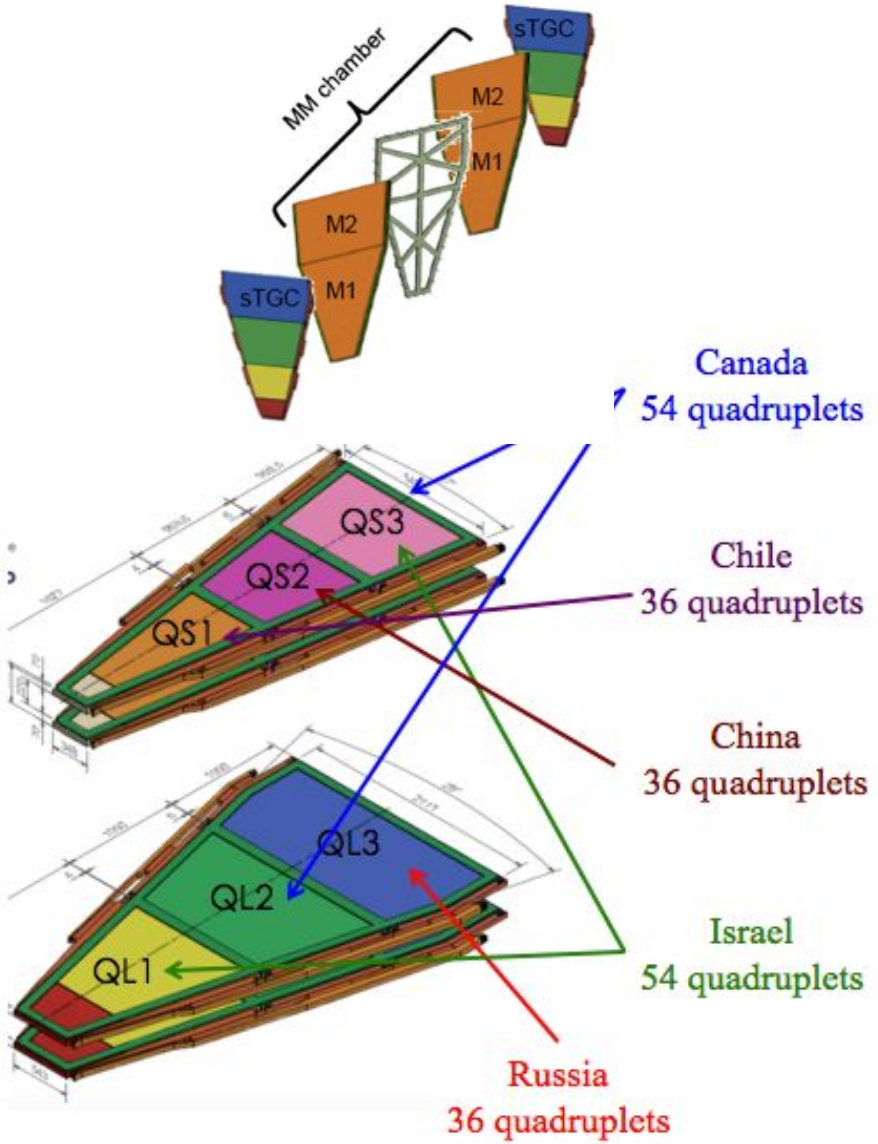
$\int L \approx 3000$ fb^{-1}

- All new Tracking Inner Detector
- Calorimeter Electronics Upgrades
- Muon system upgrades
- Level-1 track trigger
- Trigger-DAQ
- High Granularity Timing Detector (R&D)

sTGC (in NSW) : RMcP Coordinated Overall Project Construction

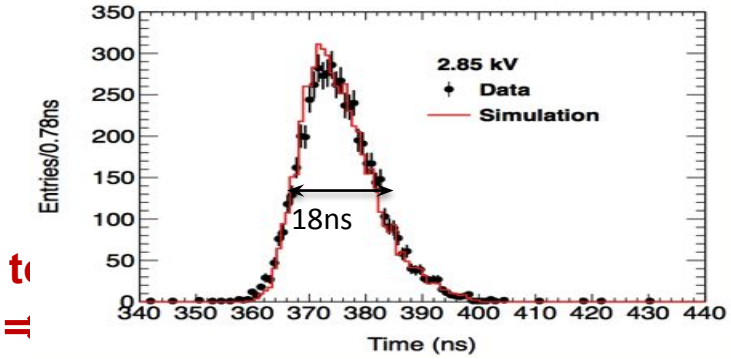
- Largest ATLAS Phase-1 upgrade
- Essential for HL-LHC
- Two detector types
  - sTGC: small-strip thin gap chambers
  - MM: Micro-megas
- Canada:
  - ¼ of all sTGC chambers
  - Integration @ CERN coordination

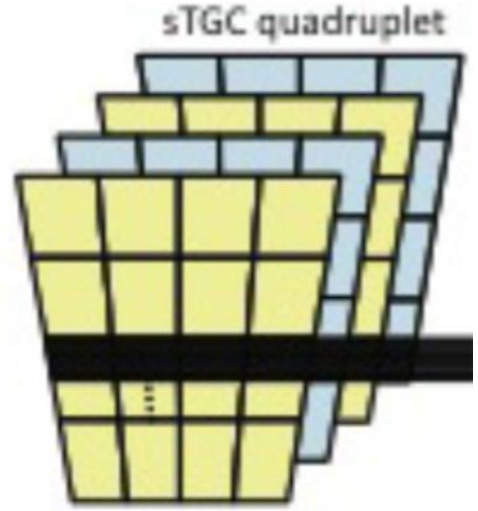




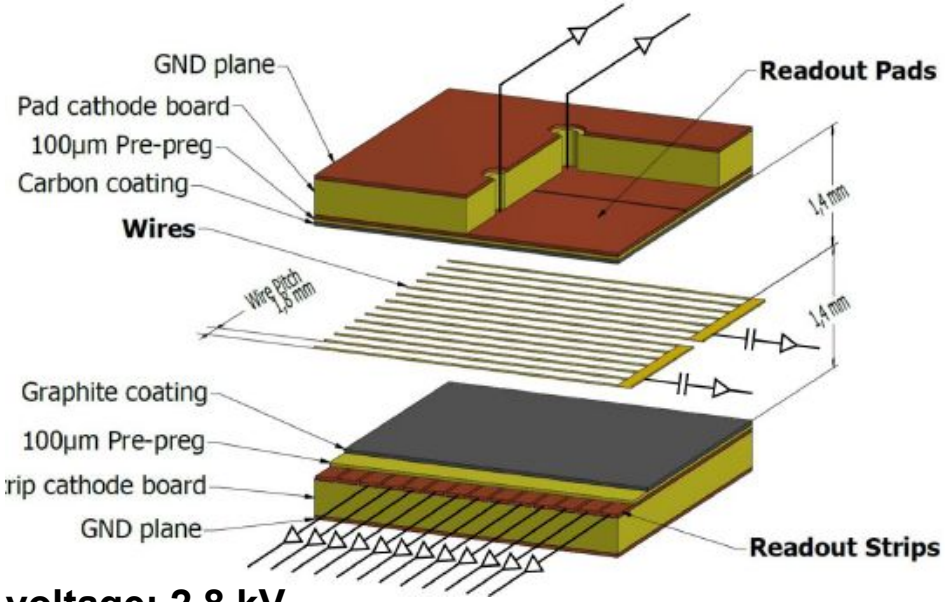
sTGC Technology

- **Based on TGC technology**
  - ATLAS trigger, OPAL
- **sTGC specifications**
  - Low cathode resistance – high rate
  - Pads for trigger – online trigger t
  - Strip charge readout – 3.2 mm pitch =
  - Wire readout – coarse φ coordinate

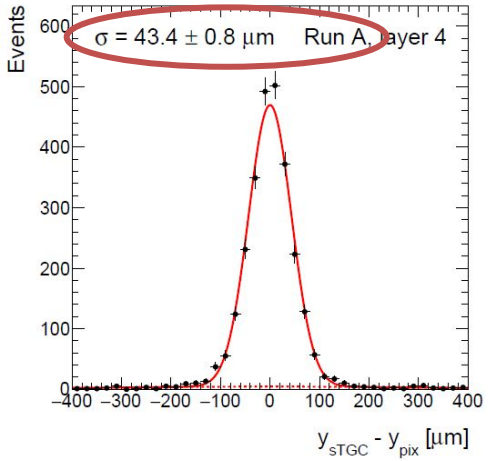




Pad coincidence (3 out of 4) defines trigger region



Beam tests @ FNAL + CERN



Operating voltage: 2.8 kV

Self-quenching limited streamer mode, 55% CO2, 45%n-pentane

- **Caution: Fukui H et al. Studies on ageing effects and rate dependence of Thin Gap Chambers. NIM A419 (1998) 497-502**

⇨Graphite coatings in chambers with n-pentane: susceptible to breaking organic molecules and coating cathodes

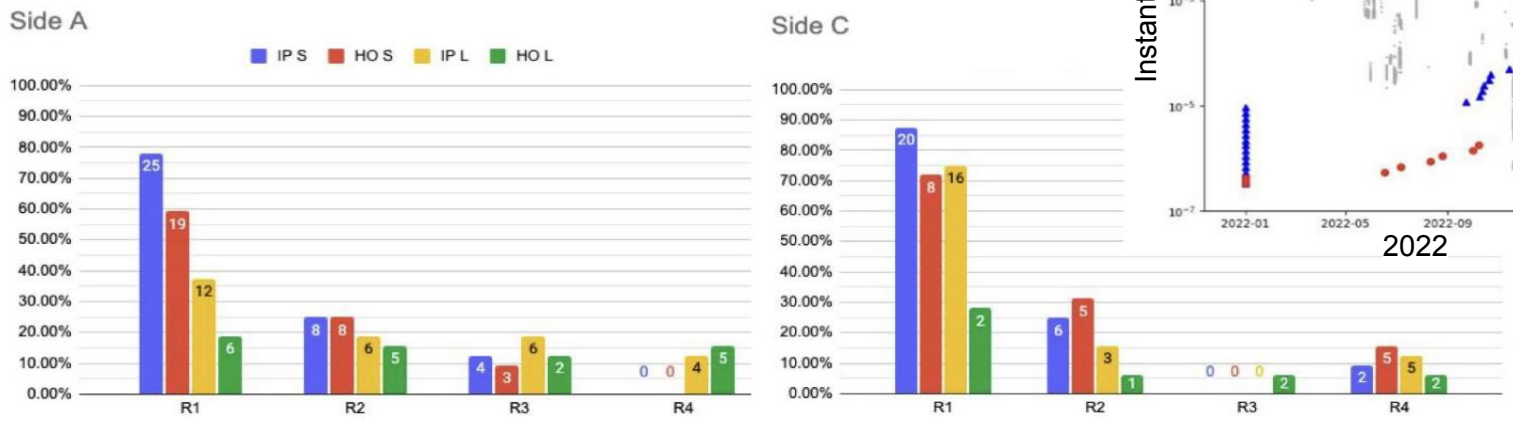
sTGC: operation overview during Run-3

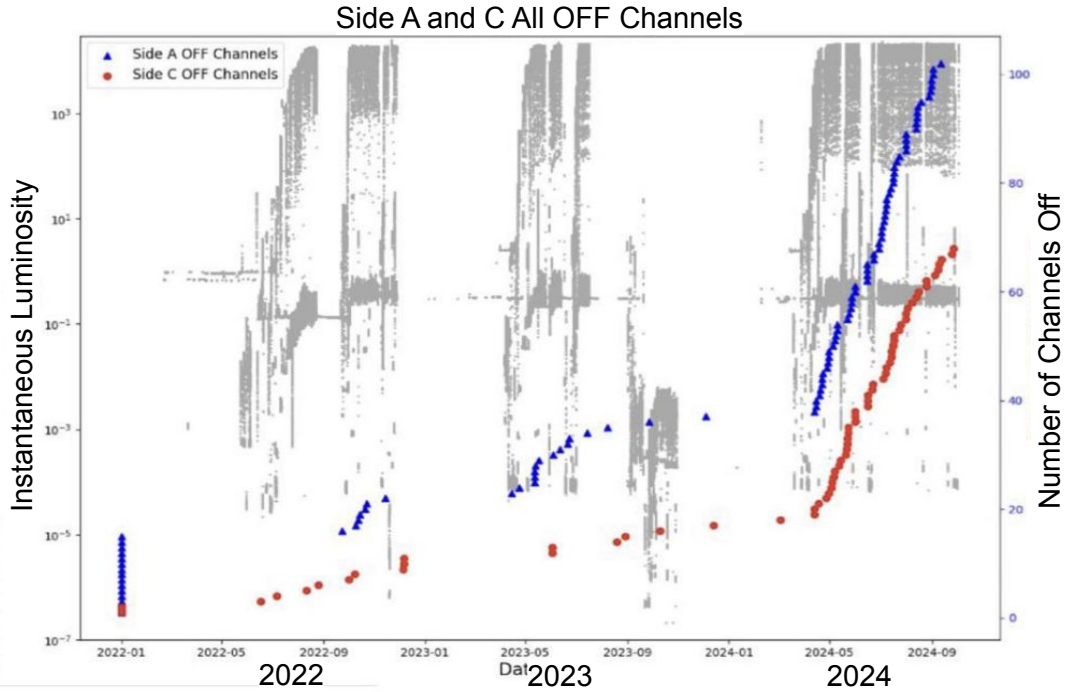
sTGC operation overview during Run3

A sizable number of HV failures observed since operations of the NSW sTGC detectors in ATLAS since 2022

→ **Drastic increase on 2024 and 2025 *pp* data-taking**

Studies at GIF++ aim to assess possible sources of this degradation on sTGC detectors





Status on 11.05.2026
[L. Brown]

UVIC UNIVERSITY OF VICTORIA CANADA

José Pretel – June 16, 2026

ATLAS EXPERIMENT 3

José Pretel (UVic PDF), Leesa Brown(UVic PhD student), Isabel Trigger (TRIUMF) and RMcP

- **Note: damage (so far) largely in innermost parts of chambers – "R1"(which we DON'T TRIGGER ON)**
  - **sTGC are primarily trigger chambers. Not critical so far, but further losses would be bad**
- **Of course: HL-LHC will have larger radiation doses – working actively to limit damage**

Summary

- LHC and ATLAS completing Run-3 and moving towards Phase II upgrades completion and installation
- Producing a huge amount of diverse physics
  - 1473 papers submitted to journals
    - Significant Canadian involvement
    - Many Physics topics
      - Many new and interesting avenues to explore, especially with more data
      - Find new topics, exploring them, publishing results
- Significant HQP training environment
  - More interest from Canadian HQP than we can afford $$
- ATLAS detector, and the LHC, is largely running well
  - Investigating, and hopefully solving, problems that do occur
- LHC is moving to high-luminosity era (HL-LHC)
  - Canadians leading several upgrade areas/projects (see, eg, Richard Teuscher's talk)
- IPP RS leading ATLAS-Canada, ATLAS management, ATLAS Physics, and ATLAS Upgrades
  - ATLAS/LHC in collision operations for ~15 more years, and the physics output will continue even beyond that time