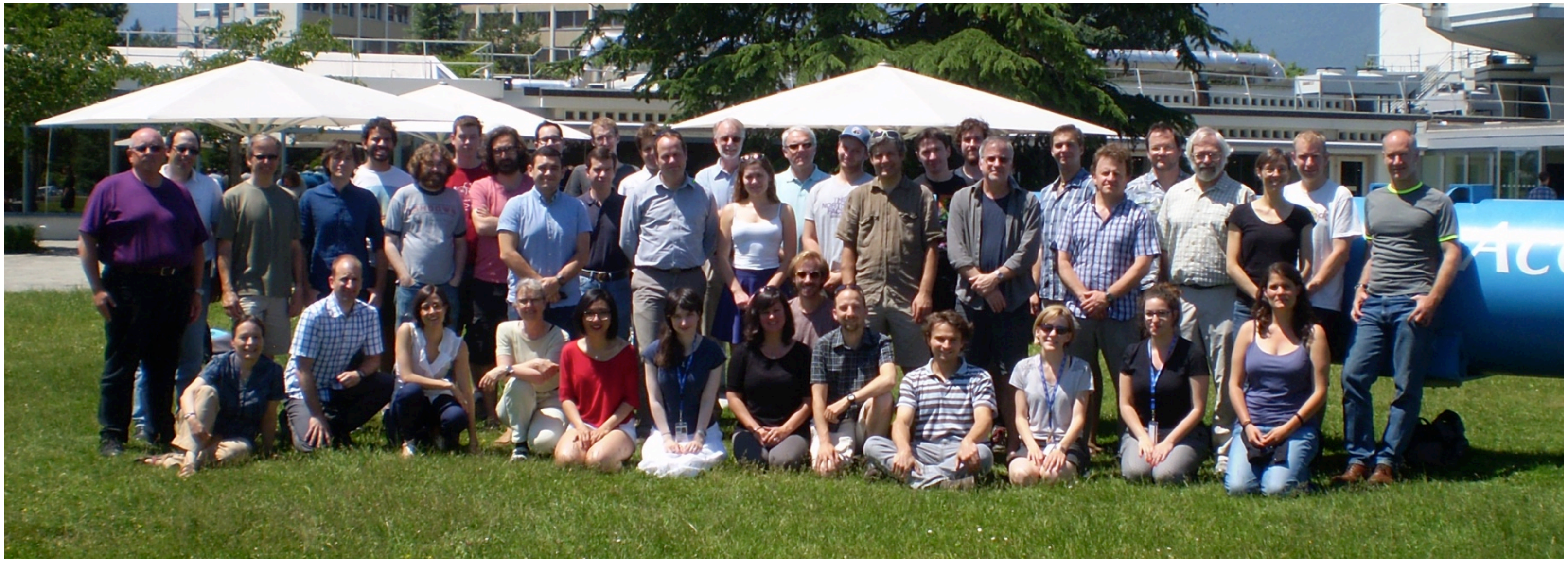
Status and plans of ATLAS-Canada

Presentation to the June 2015 IPP Town-hall meeting

Alison Lister (UBC)
On behalf of the ATLAS-Canada group

Outline

- Who we are
- What we have done (in 2 slides): hardware and analysis
  - See CAP week talks for further details
- Computing: status and prospects
- LHC in the next 10 years
- ATLAS-Canada upgrade projects and plans



Some of the people at CERN during first 13 TeV collisions

ATLAS-Canada (founded in 1992)

University of Alberta, Edmonton, Alberta
University of British Columbia, Vancouver, British Columbia
Carleton University, Ottawa, Ontario
McGill University, Montreal, Quebec
Université de Montréal, Montréal, Québec
Simon Fraser University, Burnaby, British Columbia
University of Toronto, Toronto, Ontario
TRIUMF, Vancouver, British Columbia
University of Victoria, Victoria, British Columbia
York University, Toronto, Ontario

Composition

- 10 Universities/Lab
- 38 faculty members
  - ~34 ½ FTE/year for next 3 years
  - 5 IPP RS + 5 CRC (incl. past)
  - Prospects for growth in FTE in next ~3 years: 2-3?
- ~130 people total
  - ~5% of ATLAS
  - 26 postdocs, 47 PhD, 18 MSc
  - Typically 25 undergrads/year
  - Plus engineers, technical staff

Current management

- Spokesperson/PI
  - Peter Krieger (UofT) [2015-]
  - Rob McPherson (UVic/IPP) [2007-2015]
- Deputy
  - Manuella Vincter (Carleton)
- Physics coordinator
  - Andreas Warburton (McGill)
- Computing coordinator
  - Reda Tafirout (TRIUMF)

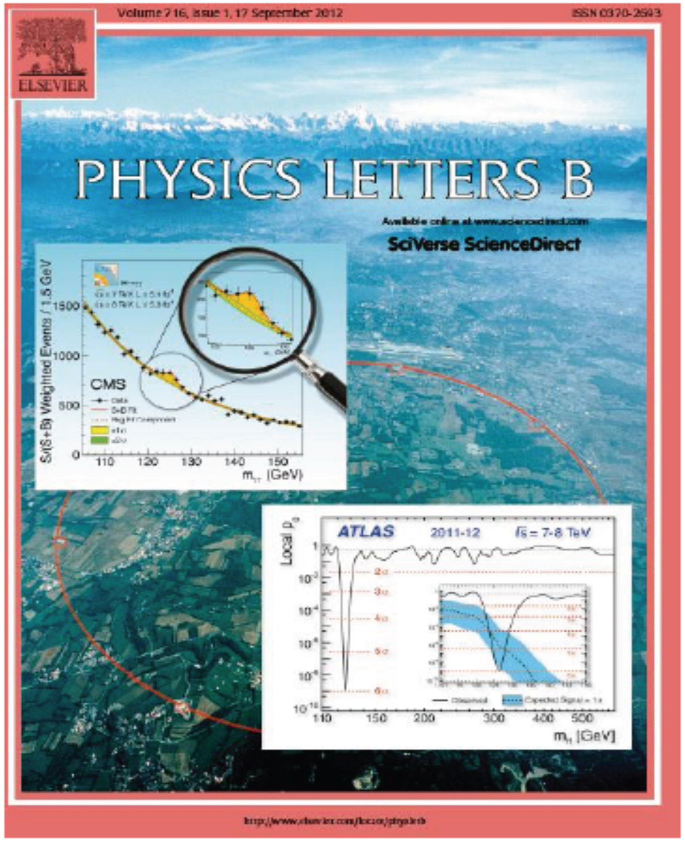
ATLAS detector/operations: Canadian Contributions

- Major construction projects
  - Hadronic Endcap and Forward Calorimeters
  - Endcap Calorimeter signal feedthroughs and calorimeter readout electronics
- High Level Trigger
  - Significant hardware contribution to farms
- Other systems
  - Beam Conditions Monitors, Tracking (TRT), luminosity (LUCID), Radiation mon. (MPX)
- Computing at TRIUMF (Tier-1) and universities (Tier-2)
  - Continual use of Compute Canada resources at universities that act as Tier-2
- Operations
  - Firmly engaged in LAr, TRT, Muons, BCM, TDAQ, LUCID, Data Preparation, Data Quality
- Operations model
  - Some postdocs and students based at CERN with key roles in operations
  - Also commuters and activities in Canada including remote monitoring
- Numerous management roles across ATLAS and subsystem management

Physics analyses: Canadian Contributions

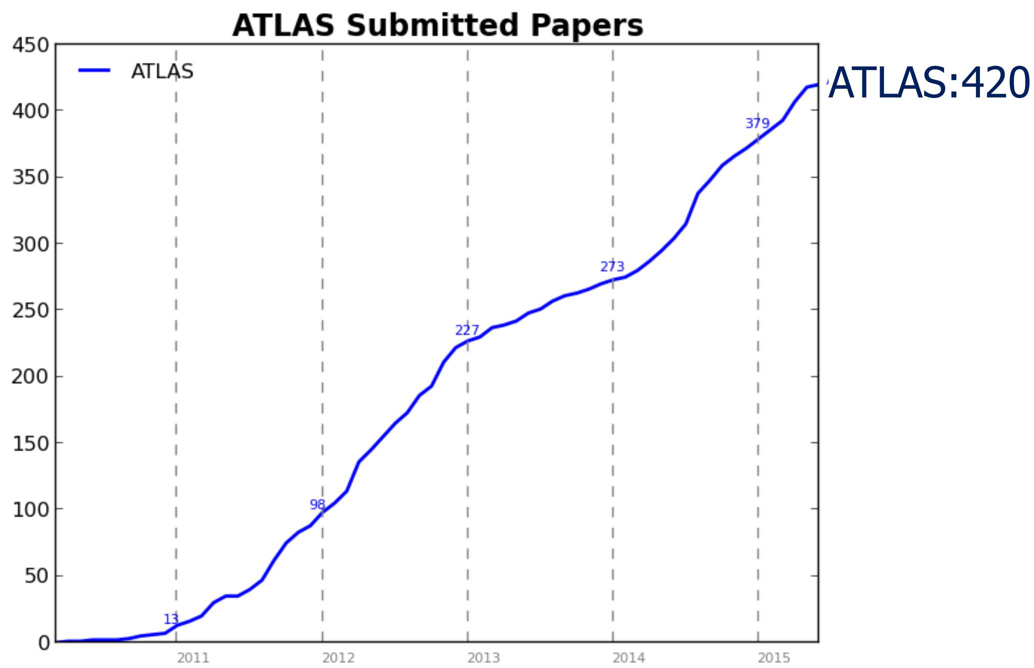
- "Higgs-like particle" discovery announced July 4/12
- March 2013: two key ATLAS papers: new particle declared "a Higgs boson"
- Citation for 2013 Nobel Prize in Physics
- Canadians played central roles in the discovery and subsequent papers / studies in all of the discovery analysis channels
  - In past 5 years, ~20 on-going & completed PhD theses related to Higgs physics
- Balanced contributions to all areas of ATLAS physics
  - In past 5 years, on-going & completed PhD:
    - ~20 SM+top, ~30 Exotics, ~10 SUSY
- Strong contributors to all the infrastructure required to make these measurements successful
  - Quantifying and improving performance of physics objects, developing core software for object reconstruction, improving simulation …

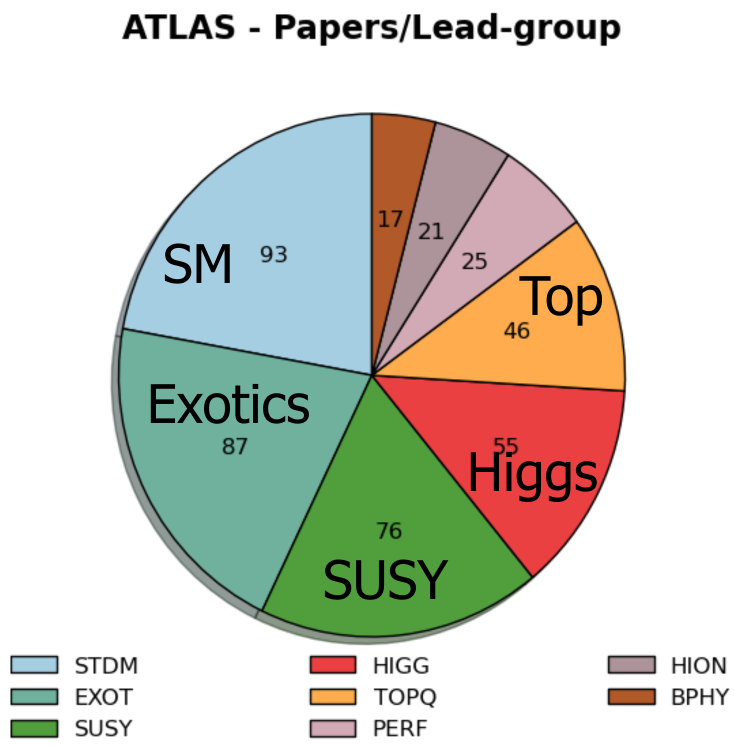
Phys. Lett. B 716 (2012) 1-29



ATLAS: Publications, conference notes, conferences*

- ATLAS has submitted to date 420 papers for publication, and produced 625 conference notes
  - Papers: ~50% are searches, 45% are measurements, and 5% are performance
  - Estimated that there are still ~100 run-1 physics papers still to be completed
- In 2014, ATLAS speakers gave 742 talks, plus 142 posters for international conferences
  - ~5% of the talks were given by Canadians



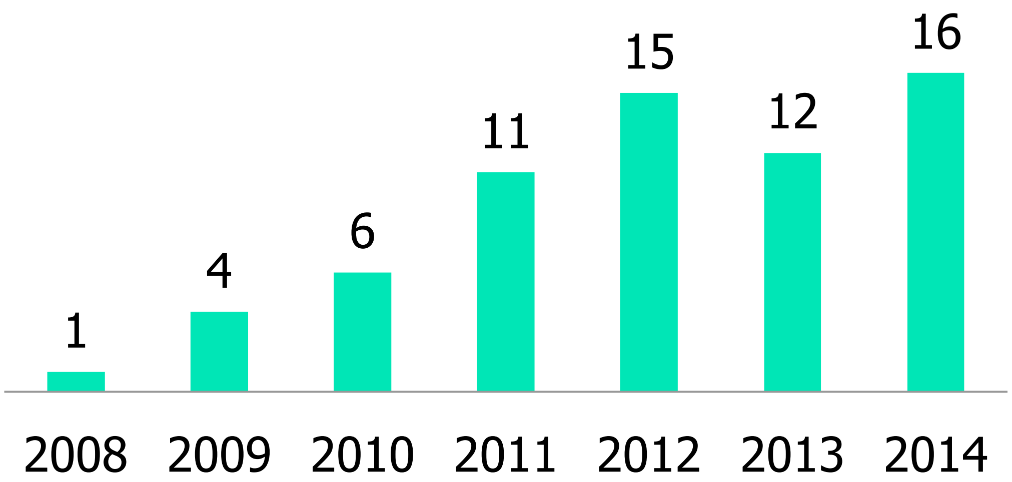


*Statistics as of May 20, 2015

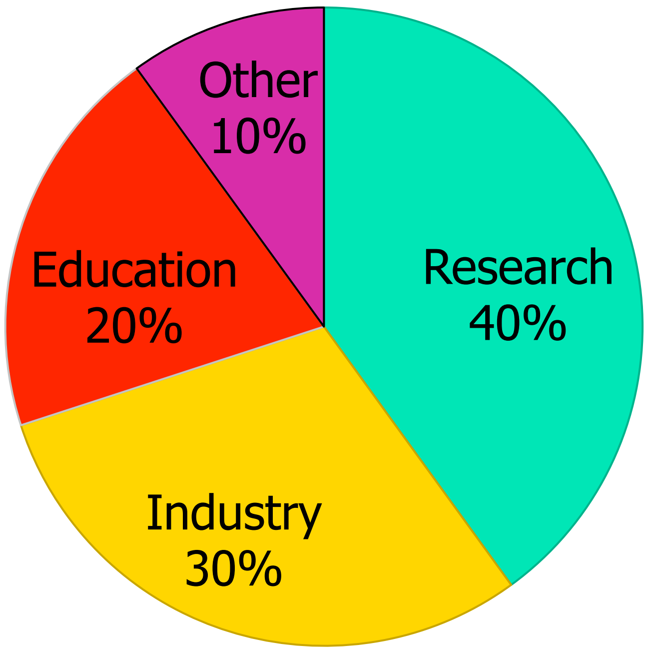
What we do is not just science: Training

- Since the start of ATLAS-Canada (approximate numbers*):
  - Total past and present: 95 MSc, 102 PhD, 95 postdocs
- Current numbers: 18 MSc, 47 PhD, 26 postdocs
- Of the completed degrees/postdocs in the past ~5 years:
  - ~70% of MSc continued to PhD (mainly remaining in the same field, but not always)
  - ~40% of PhD remained in research, ~30% went to industry, ~20% became teachers
  - ~70% of postdocs remained in research, ~20% went to industry

Current students start year (MSc+PhD)



Post-PhD careers in past 5 years



*Numbers as of Sept. 2014. Some post-graduate info is missing.

ATLAS-Canada funding successes in past 5 years

NSERC project grant

- Flat to ~10% from 2010-2017 (includes new faculty funding)
  - Significant increase in student population
    - Have had to cap student intake
  - Have had to reduce the number of postdocs employed in Run 2 compared to Run 1

CFI for Tier-1 computing

- Award for renewal of hardware
- Award for operation and personnel
  - Rolled into TRIUMF 5 year plan

NSERC Major Resources Support

- At some universities, provide essential support engineers/technicians for Phase-1&2 R&D

NSERC Research Tools and Instruments

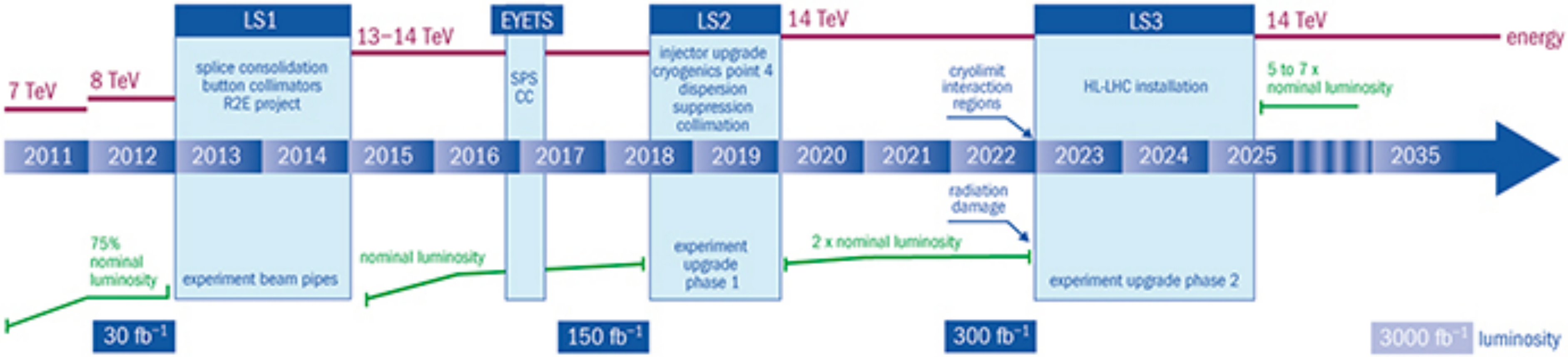
- Critical contributions in 2013/4 provided seed funding to develop successful Phase-1 proposal to CFI

CFI for Phase-1

- March 2015: ~$6M for Phase-1 LAr electronics and New Small Wheel

LHC IN THE NEXT 10 YEARS: PLANS AND PROSPECTS

Run 2,3,4++ LHC Targets



Run 2: 2015-2018

- 13 to 14TeV, 1.3x10^{34} cm^{-2}s^{-1} at 25ns, with estimated pileup of 40-50 events/bc
    - Accumulate ~100 fb^{-1} by end of 2018

Run 3: 2021-2023

- Run near or at 14TeV, 2x10^{34} cm^{-2}s^{-1} at 25ns.
    - Accumulate ~300 fb^{-1} before LS3

Run 4++ (HL-LHC): 2026 and beyond

- 14TeV, 5-7x10^{34} cm^{-2}s^{-1}, achieved with lumi levelling, keep pile-up tolerable, challenges of up to 200 pileup events/bc
    - Accumulate ~250-300 fb^{-1} per year, Reach ~3000 fb^{-1} by ~2036
    - Would need to increase run time and number of days operational

Run 2 Motivations & Plans

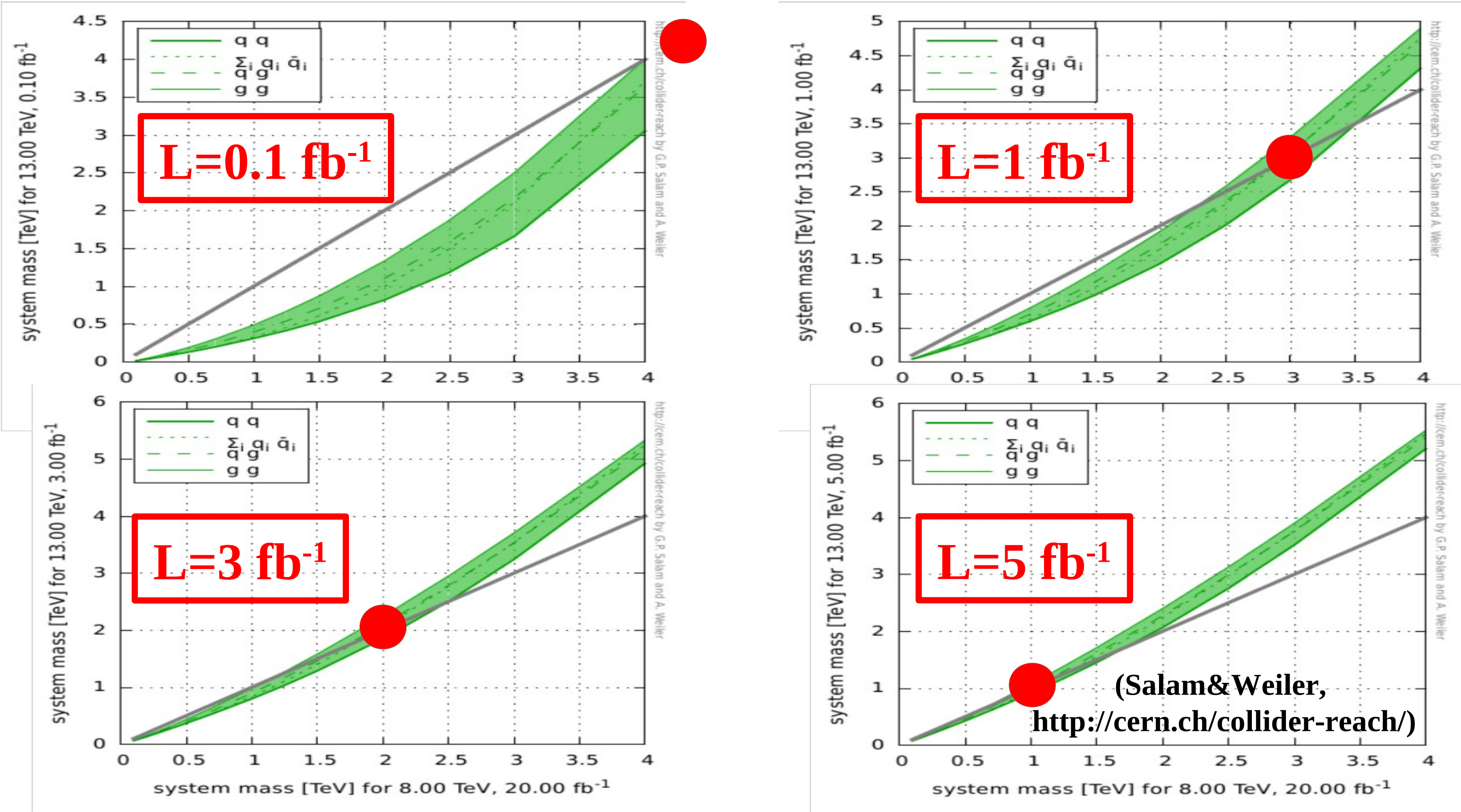
ATLAS Run 2 physics goals

- Discover physics beyond the Standard Model
  - Nearly double energy we had before, higher luminosity
  - Huge increase in cross section for heavy particles
- Precision characterisation of Higgs boson
  - Most of its decay modes can be measured
  - Coupling to heavy quarks, gauge bosons
- Continue top, SM precision studies in a new energy regime
  - To identify origin of “new physics”
  - New physics could be hiding in corners!

LHC-2015

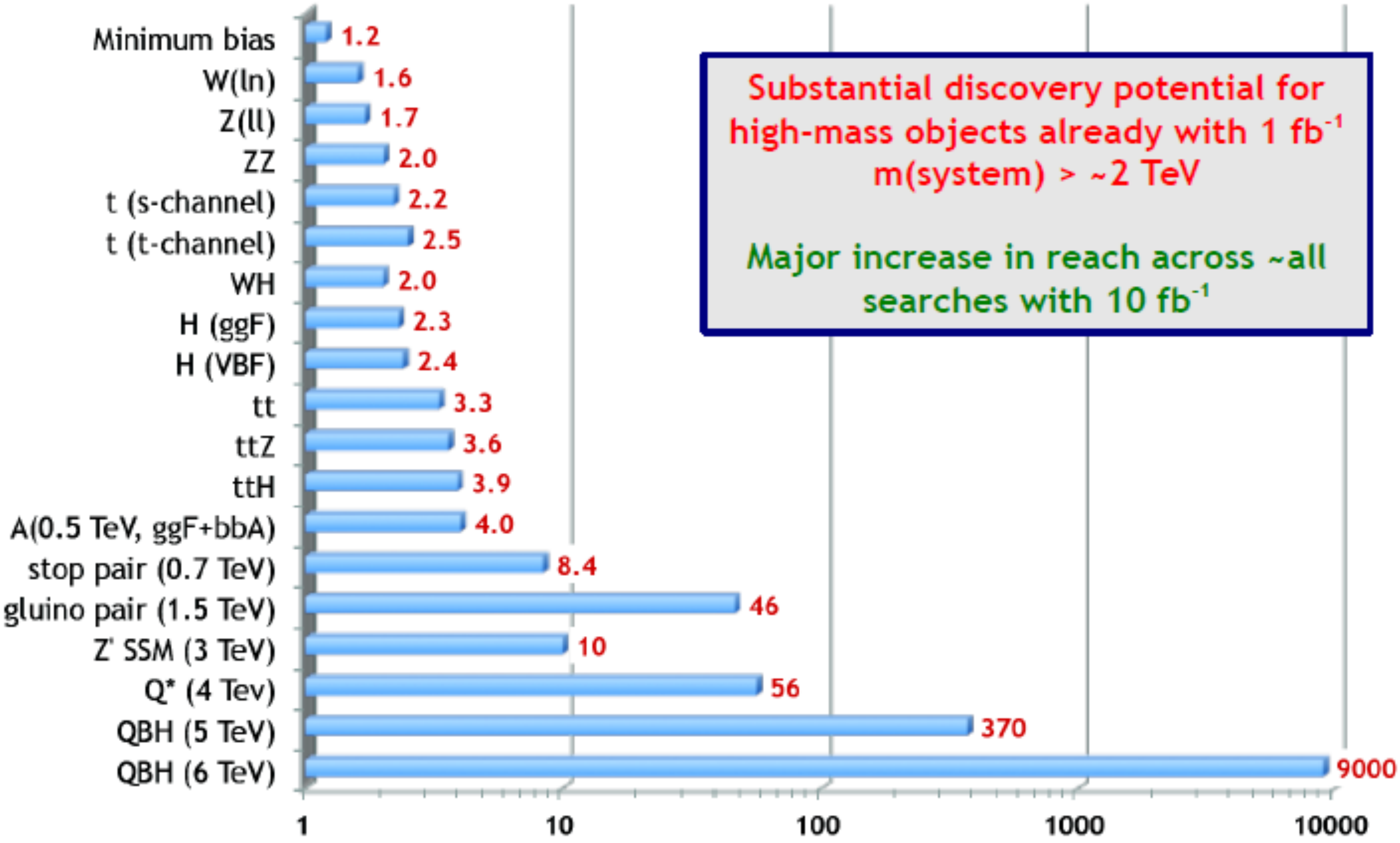
- p-p collisions at 13TeV with 50ns then 25ns bunch spacing
  - First stable beam 3rd June 2015
  - Priority is on machine commissioning and understanding
  - Expect 5-10 fb^{-1} in 2015
  - Energy could increase after 2015
- One month of heavy-ion running at the end of the year

√s = 13 TeV: parton luminosities



Red dots indicate where we expect to do better than Run 1 for different Run 2 integrated luminosities

Cross-section ratio: 13 TeV / 8 TeV



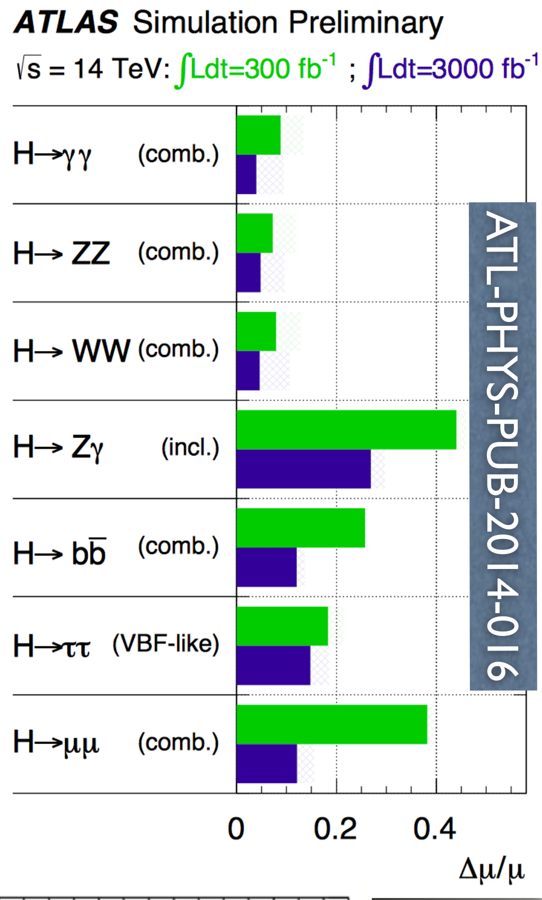
Run 3 and HL-LHC Motivations

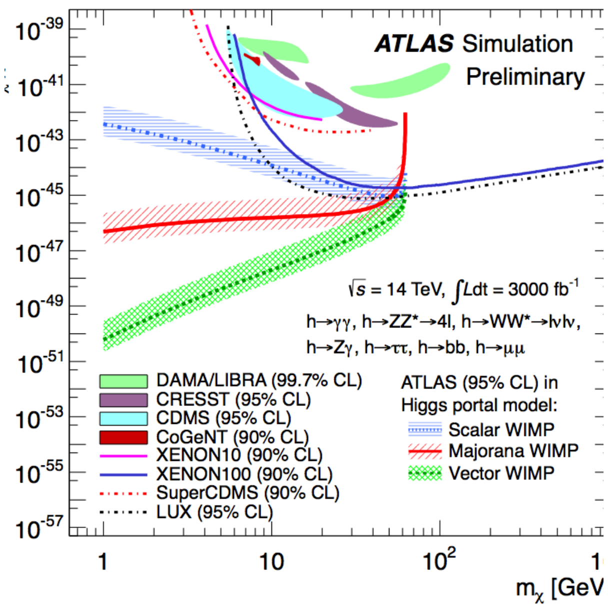
Extend the reach of many searches e.g.

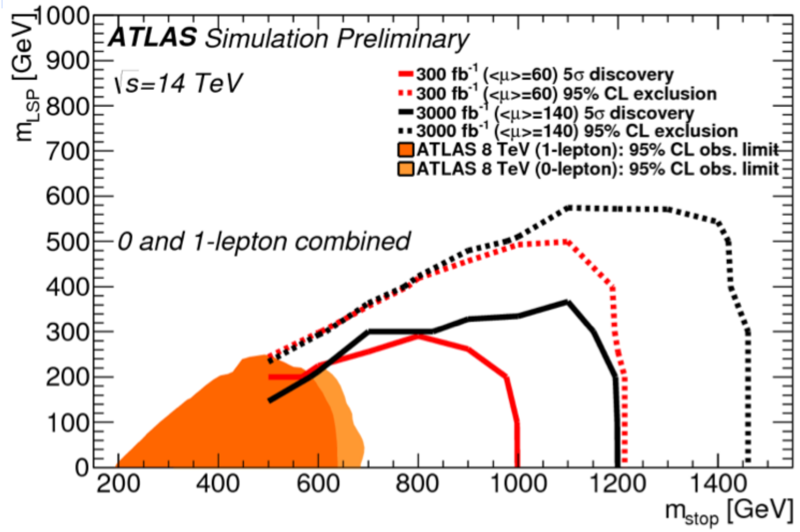
- Dark Matter
- Many SUSY models

Increased precision

- Precision measurements of the Higgs cross sections and couplings
- Probe Higgs pair production with 3000 fb^{-1}
- Sensitivity to very rare processes (e.g. FCNC)







ATLAS-CANADA
IN THE NEXT 10 YEARS

ATLAS-Canada priorities: next 10 years - I

Exploitation of Run 2 and Run 3 ATLAS data

- Perform world-class physics via
  - Sustained contributions to the operations of the detector
    - Requires CERN presence for postdocs and students
  - Further build and maintain the understanding of the performance of the detector
    - This is the only way to get high-quality physics out of ATLAS
  - Leadership in physics analyses
    - Build clear links between Canada and key physics measurements and discoveries
  - ➧ The latter two require a balance of CERN and home institute-based presence
  - ➧ All require continued support from NSERC through our project grant
- To achieve this success, it is critical to maintain excellent computing and networks
  - The entire analysis model is based on distributed data

ATLAS-Canada priorities: next 10 years - II

Upgrades for Phase-1 (2019-2020) and Phase-2 (2024-2025)

- **Phase-1**
  - Our CFI application for construction costs of the New Small Wheel and LAr electronics upgrades was granted
  - We must carry out this research programme to successful completion
    - Important component to ATLAS for Run 3 and also important step to any further application to CFI for construction capital
  - After construction, we need also the resources to participate in the installation, benchmarking of performance and subsequent exploitation of what we built
- **Phase-2**
  - Interest in Canada for contributions, particularly in the areas of calorimetry and tracking
  - Seed NSERC RTI over the next ~2 years critical for R&D and to develop a coherent Canadian plan to submit for a CFI capital request
    - Scope of project will be ≥ 2 x larger than our Phase-1 request
- Require continued support from our national laboratory (TRIUMF) and critical contributions from NSERC and CFI via our project grant (to support students and postdocs), RTI (R&D for Phase-2), CFI (Phase-2 construction) and MRS to support our core team of technicians, engineers, and designers to complete Phase-1, and to participate in the R&D and ultimately the construction of Phase-2 projects

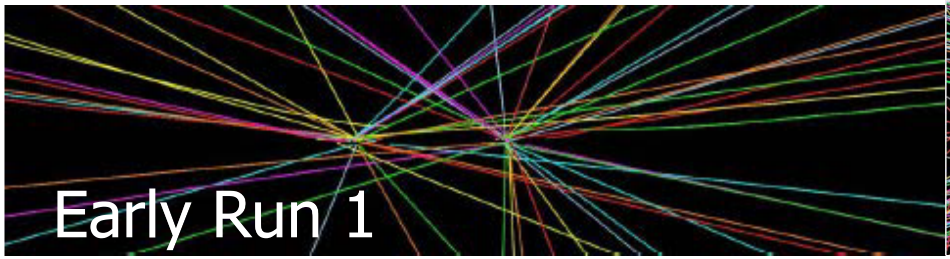
Phase-1 upgrades: motivations

- **The LHC luminosity will roughly double after every long shutdown**
  - Collision environment will become harsher, detectors have to cope
- A key aspect of the ATLAS trigger is to select energetic electrons, photons and muons
  - The Level–1 trigger rate will be limited to ~100 kHz in Run–3 for all triggers
- To reduce event stream to a manageable rate, need improved real time filter or trigger

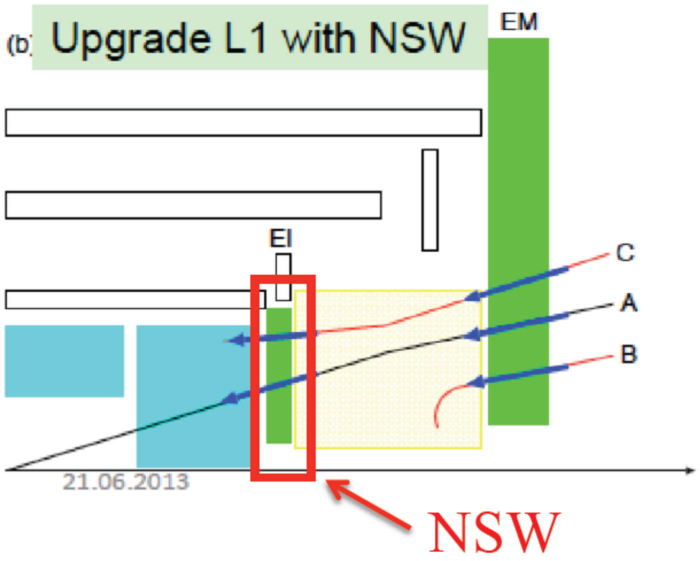
Phase-1 upgrades: keep Level-1 triggers usable with as low E threshold as possible

- Current e and γ (EM) trigger selections would be 270 kHz under Run-3 conditions
  - Without upgrade would need to reduce EM trigger rate to the desired bandwidth would require a significant increase of transverse energy thresholds, leading to important acceptance losses
    - Improved trigger decisions: get more info from calo to Level-1 trigger processors
- Reduce the fake rates in the muon trigger by improved muon origin determination
- Improve degraded muon track reconstruction in endcap: maintain precision measurements

While maintaining or even increasing efficiency, reduced transverse energy/momentum thresholds will increase acceptance for measuring Higgs properties, looking for new physics

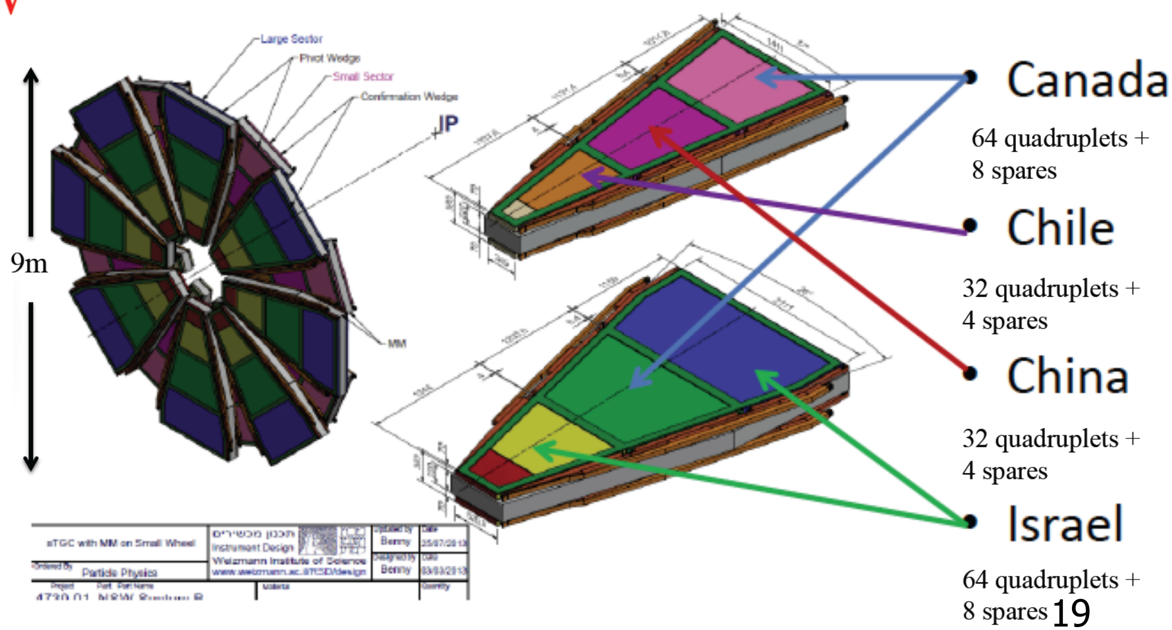


ATLAS Phase 1 upgrade New Small Wheel (NSW)



- Provides track segments to level 1 trigger processors
- In conjunction with Big Wheel (EM) keeps single muon triggers at an acceptable level for luminosities up to those expected at the HL-LHC
- Rejects background tracks from beam shielding(B) and halo tracks (C).
- CFI funding for project was announced in April 2015

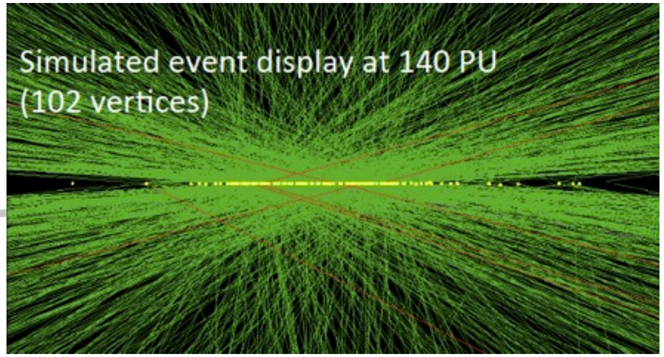
- Each NSW is 9m in diameter and contains wedges of sTGC and MM
- Canada will build 64 sTGC quadruplets for NSWs
- Construction at TRIUMF and Carleton; testing at McGill.
- Wedge assembly at CERN starting in 2018.
- Installation in Phase 1 shutdown 2019-2020



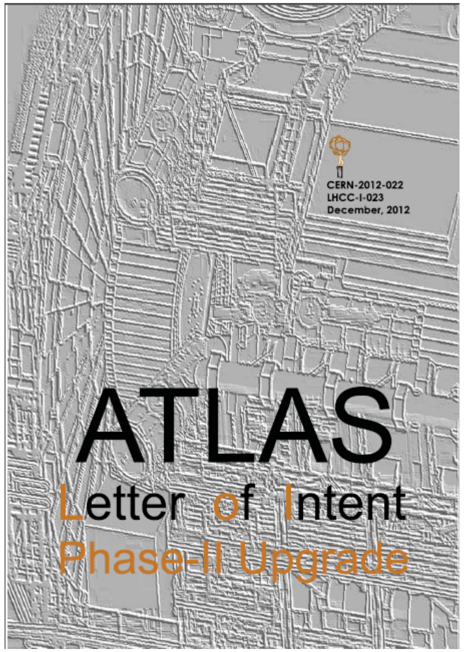
Phase-1 and 2 LAr Electronics Upgrade

- Need a better level 1 trigger based on more information being made available to the trigger from the calorimeters
  - Possible because of improvements in electronics that allow higher density signals and on-detector fast digitization with better resolution
- **The Phase-1 upgrade will provide**
  - Finer granularity, better energy resolution, more exclusive triggers based on a new topological processor
  - Technical Design Report (TDR) for Trigger (TDAQ) and LAr
    - Endorsed by ATLAS Collaboration board and LHCC
  - Demonstrator boards installed in a special crate
    - Review passed in May 2014
    - A Saclay and a BNL version of LTDB installed in a crate with a new base-plane on the barrel calorimeter is running now
  - Funding:
    - Two NSERC RTI awards
    - Recent CFI award
- **Future Phase-2 upgrade**
  - An enhanced all digital version of the LAr electronics is being discussed
  - Our phase-1 work positions ATLAS Canada to be part of the phase-2 upgrade

Phase-2 upgrades overview



- **Letter-of-intent** Dec 2012 outlines main Phase-2 upgrades
  - Entirely new inner tracker ITk (Si strips + pixels)
    - HL-LHC luminosity/pileup, replace aging components
  - Trigger/DAQ
    - New trigger architecture, with split L0 and L1
  - Muon electronics/detector/trigger upgrades
  - EM + hadron calorimeters:
    - New digital calorimeter frontend readout (LAr, Tile)
    - Replacement/add new forward calo ($3<|\eta|<5$)
  - All but ITK: Initial Design Reviews 2016 / TDR 2017
- CORE (equipment) cost estimate at that time was 230-275 MCHF
- Since then, basics unchanged but details are being refined
- Full re-costing of the Phase-2 upgrades this summer
- Consider value-for-money Scoping Document (SD)
  - Three indicative scenarios with different total CORE costs
    - 200 MCHF, 235 MCHF and 275 MCHF
  - Draft SD to LHCC in early summer, final by September 2015



From Apr 2015: CERN-RRB-2015-024
LOI: LHCC-I-023

Phase-2 Scoping Document

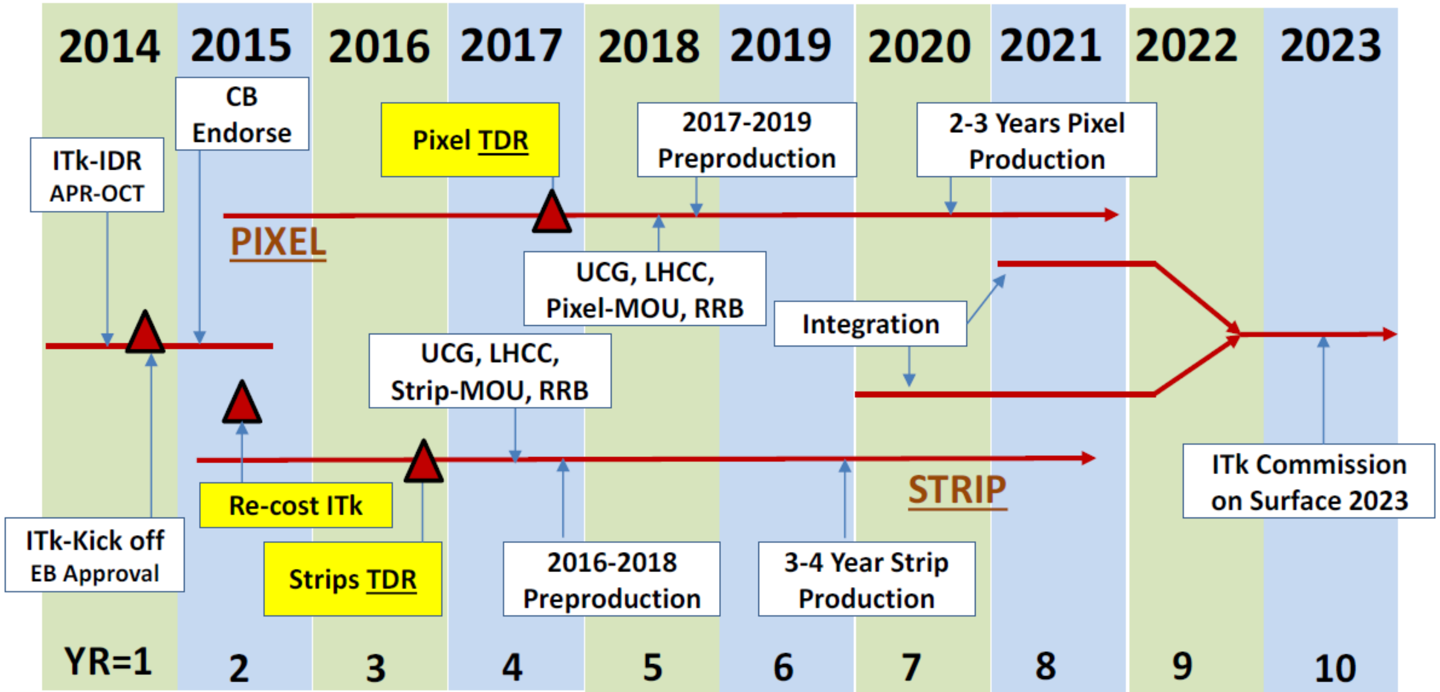
Scoping Document scenarios

- Options for the tracker
  - Three layout variants with different $|\eta|$ coverages and total surface area of silicon
- Options for the FCal region $3.1 < |\eta| < 4.9$
  - sFCal replacing the current FCal
  - MiniFCal in front of the current FCal
  - New Si/W 4D detector layer in $2.4 < |\eta| < 4$ with precision timing
- Options for the muon system
  - Replacement of inner barrel chambers, all or in part
  - Adding a new segment tagger in the region $2.6 < |\eta| < 4$
  - Scaling TDAQ system to cope with these changes and different L1Track/FTK+ options; varying L1 rate between 200 and 400 kHz
- Also considering option of not extending $|\eta|$ reach in any sub-system
- Several large cost items in Phase-2 in all scenarios, as in Dec 2012 LoI
  - ITk, new electronics for all systems, and TDAQ changes for higher rates

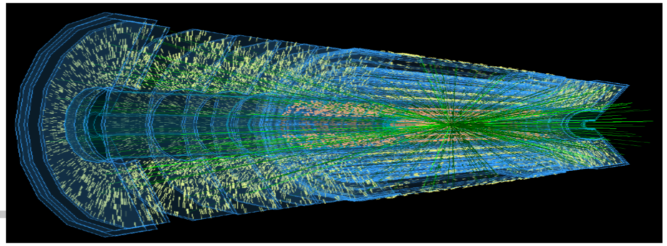
From Apr 2015: CERN-RRB-2015-024

Phase-2: ITK

- ITK: largest component of the ATLAS Phase-2 upgrades
- October 2014: Initial Design Review (IDR)
- February 2015 : Approved as ATLAS upgrade project
- Next formal steps are the TDRs, proposed for strips in 2016 and pixel in 2017
- MoU-addenda for details sharing of responsibilities, follow TDRs

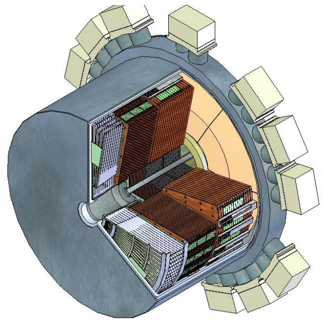


Phase-2: ITK



- The present ATLAS Inner Tracking Detector (ID) won't survive the HL-LHC
  - Radiation damage, bandwidth saturation, Transition Radiation Tracker (TRT) would be at 100% occupancy
- ID will be replaced with an all-silicon Inner Tracker (ITk) for the Phase-2 Upgrade
  - Pixels + silicon microstrips, total area 200 m^2
- 20,000 silicon strip modules to be produced from 2017-20
  - Estimated 50 bonder years required. Even with 10+ sites, schedule tight!
  - Preproduction: 2017-2018. Full production 2019-202
- 8/100 institutes who have expressed interest in ITK are Canadian
  - A possible role for Canada would be to provide 2 production sites (1 west, 1 east). Strong support for Canada from ATLAS ITk/Upgrade management
    - Canadians starting to learn elements of building up production sites-> Leverage experience in previous projects, re-use clean rooms, …
- Engagement with leading Canadian industry started (microelectronics, manufacturing)

Forward region calorimeter upgrades



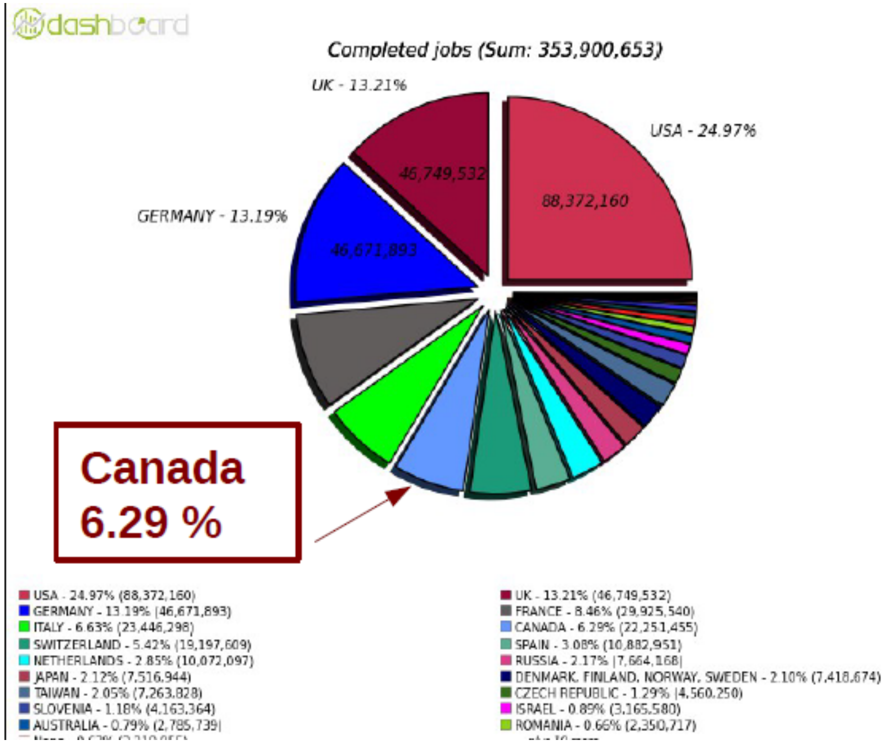
- Existing liquid argon forward calorimeter (FCal) will not operate normally at HL-LHC instantaneous luminosities (in high-|η| region)
  - FCal with slightly modified design (sFCal) can solve the problems
  - Recent proposal to build this with ×4 granularity increase relative to FCal
  - Decision to be based on performance studies: may also depend on decision for coverage of upgraded tracker, ITK (which may be up to |η| = 4.0)
  - Best solution in terms of performance (but also most expensive and risky)
  - ATLAS review (decision) planned for Nov/Dec 2015
- If the decision is to NOT build an sFCal, remaining options are
  - Do nothing: need to understand performance losses and ensure that LAr will not boil (simulations, mockup measurements in progress to address this)
  - If LAr will boil (or we cannot prove that it will not) build a "MiniFCal" that sits in front of the high-|η| region of the existing FCal to absorb enough of the particle flux in this region that the FCal can operate normally
  - MiniFCal design exists (LAr/Cu): simulations are in progress. Some technical challenges to be addressed (services, cooling). Requires less time than sFCal
- Canadian involvement / leadership in both upgrade options

COMPUTING: PRESENT STATUS & PLANS

ATLAS-Canada Computing

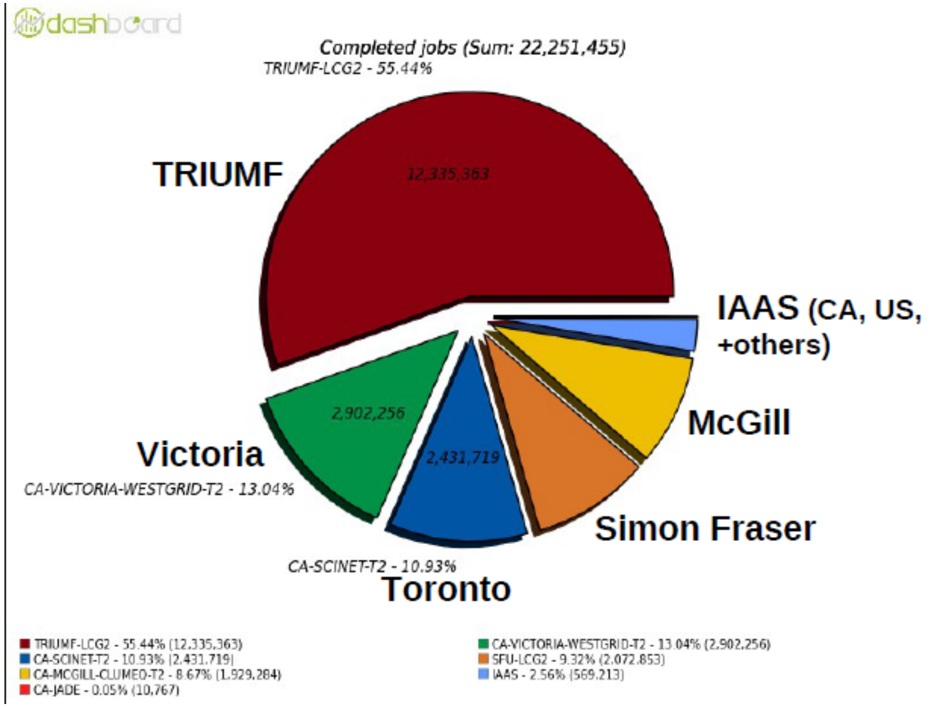
- Providing 10% of Tier-1 and 5% of Tier-2 required resources
- Key contributions to data processing, simulation and analysis tasks

Completed Grid jobs worldwide 2014



- TRIUMF Tier-1 & four Tier-2s at Compute Canada
- Excellent performance, reliability & availability

Relative contributions within Canada



Evolution of ATLAS-Canada computing (I)

- Operations of ATLAS computing in Canada supported from outside NSERC envelope
- CFI, provinces: hardware & personnel at TRIUMF and Compute Canada centres
- Continued support from Canarie for our network infrastructure
- Historical leverage from NSERC SAPES MRS critical to successful situation we are in today at University centres
- Changing landscape: new CFI cyber infrastructure, increased national role for Compute Canada, and sites consolidation (from ~27 to 4-6) for more effective operations and support
- Compute Canada Phase 1 expansion / hardware refresh: 4 initial sites selected based on Universities proposals (UVIC, SFU, UoT, Waterloo)
- Compute Canada Phase 2: more sites (proposals) are expected

Evolution of ATLAS-Canada computing (II)

- Future of ATLAS computing in Canada
  - TRIUMF assuming Tier-1 operations support in its new 5YP
  - Working today with TRIUMF and Compute Canada to understand our future evolution for both hardware and ops (personnel & infrastructure)
    - Tier-1 is primary focus of the current discussion within the CFI cyber infrastructure framework
  - TRIUMF, Tier-1 and ATLAS-Canada management responded positively to Compute Canada's proposal to transition the Tier-1 to SFU
    - Detailed transition plan in the works
  - Compute Canada is restructuring the location of ATLAS Tier-2
    - Likely moving from 4 to 2 Tier-2 & centralized model of ops
- Expecting flat funding for computing in next 5 years, many changes implemented
  - Life-time models for data, cloud computing for opportunistic use (with strong Canadian contributions), improvements in reconstruction time

➡ Need to ensure reliably maintained capability

Summary and Outlook

- LHC Run 1 was a huge success
  - Higgs discovery completed the SM
  - Significantly constraining many models for physics beyond the SM
  - Some difficult / precision analyses still ongoing
- ATLAS-Canada is playing a leading role in many aspects
  - Analysis, detector, performance, leadership
- To continue to maintain our high performance in the next 10 years we must
  - Make the most of the 13 TeV data
    - Significant presence of postdocs and students at CERN
  - Prepare and carry out detector upgrades for both Phase-1 and Phase-2
    - RTI (for R&D) then CFI grants (for construction) is the expected model
  - Continue to be at the forefront of computing
    - Need to invest in, develop and consolidate our infrastructures
- Will continue our track record of training and promoting our young scientists

ADDITIONAL MATERIAL

CERN Relations

http://international-relations.web.cern.ch/International-Relations/office/participation.html
http://international-relations.web.cern.ch/International-Relations/office/CERN2918Rev.pdf

- Institutional participation is via Membership and Associate Membership
  - open to states only, irrespective of their geographical location
- Membership: access to scientific & technical programmes, staff employment, industrial return Participate in the governance through their representation in the Council with full voting rights.
  - CERN has 21 Member States, which contribute to the budget of the Organization in proportion to their Net National Income (NNI)
- Associate membership: pay reduced contribution to the CERN budget, benefits are reduced accordingly. Represented at the CERN Council, except at closed sessions. No voting rights.
  - Annual contributions subject to agreements: ≥10% of state's contribution as member
  - Eligible to apply for CERN positions, with caps and limitations
  - Firms entitled to bid for CERN contracts, with ceilings
- What about Associate membership for Canada?
  - Scope of discussion beyond ATLAS or IPP Town Hall
  - Obvious benefits for the Canadian particle physics community and to Canadian industry
  - Some dialogue in the past between CERN DG and Ottawa

- Need a mechanism for signing international Memorandum of Understanding (MOU)
  - Needs clarification

NSW

L1 Trigger Rate

L1 rate is very high in the endcap

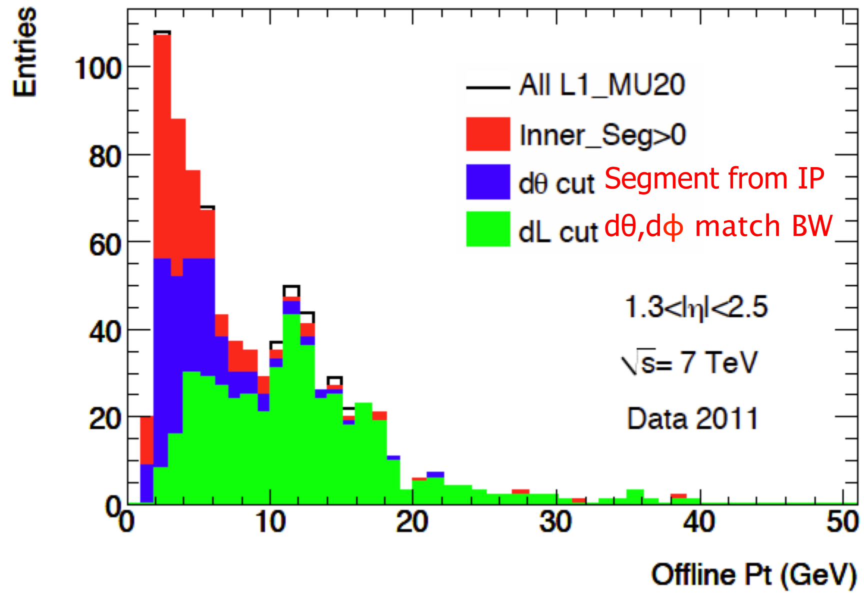
Total L1 bandwidth = 100 kHz (single muon ~ 20 kHz)

L1 rate estimate at 14 TeV, L = $3x10^{34}$

Single muon rate (kHz)

	Mu20	Mu40
Without NSW	60	29
With NSW	22	10
NSW + phase-0	17	8

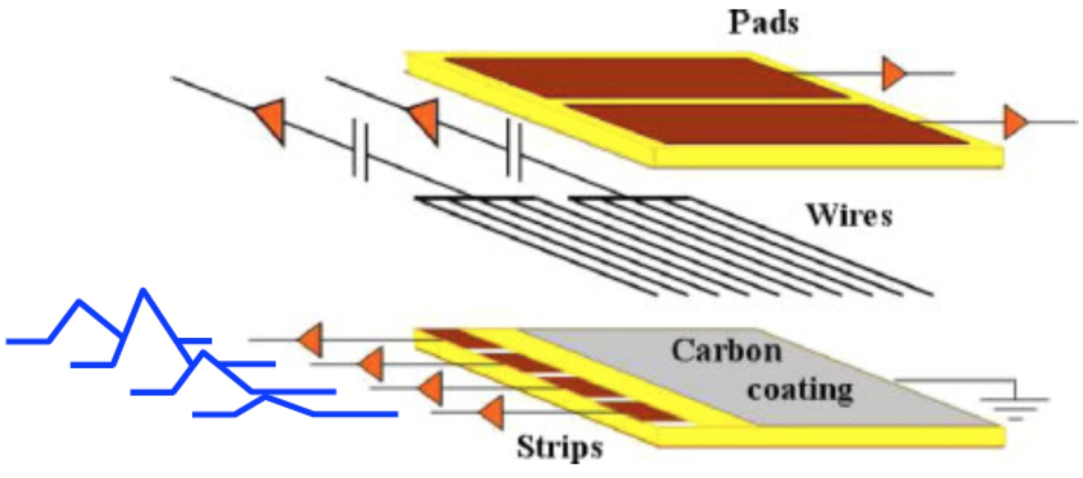
Offline study, relative rate



Release ~40 kHz of L1 bandwidth for other useful L1 inputs while maintaining low p_T threshold

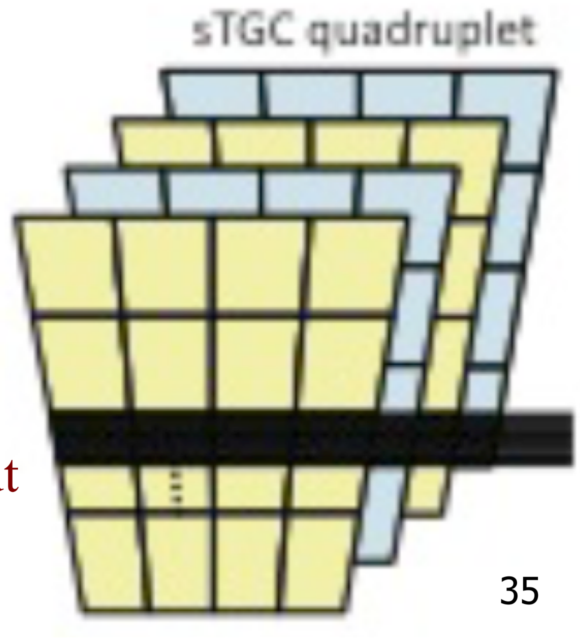
small Thin Gap Chamber (sTGC)

- Thin gap wire chamber with resistive cathode
- Used for the forward region trigger



(a) a

Pad coincidence defines the region of interest (RoI) to look at and selects strips to send to the sTGC trigger processor, where precision positions are calculated



sTGC incorporates:-

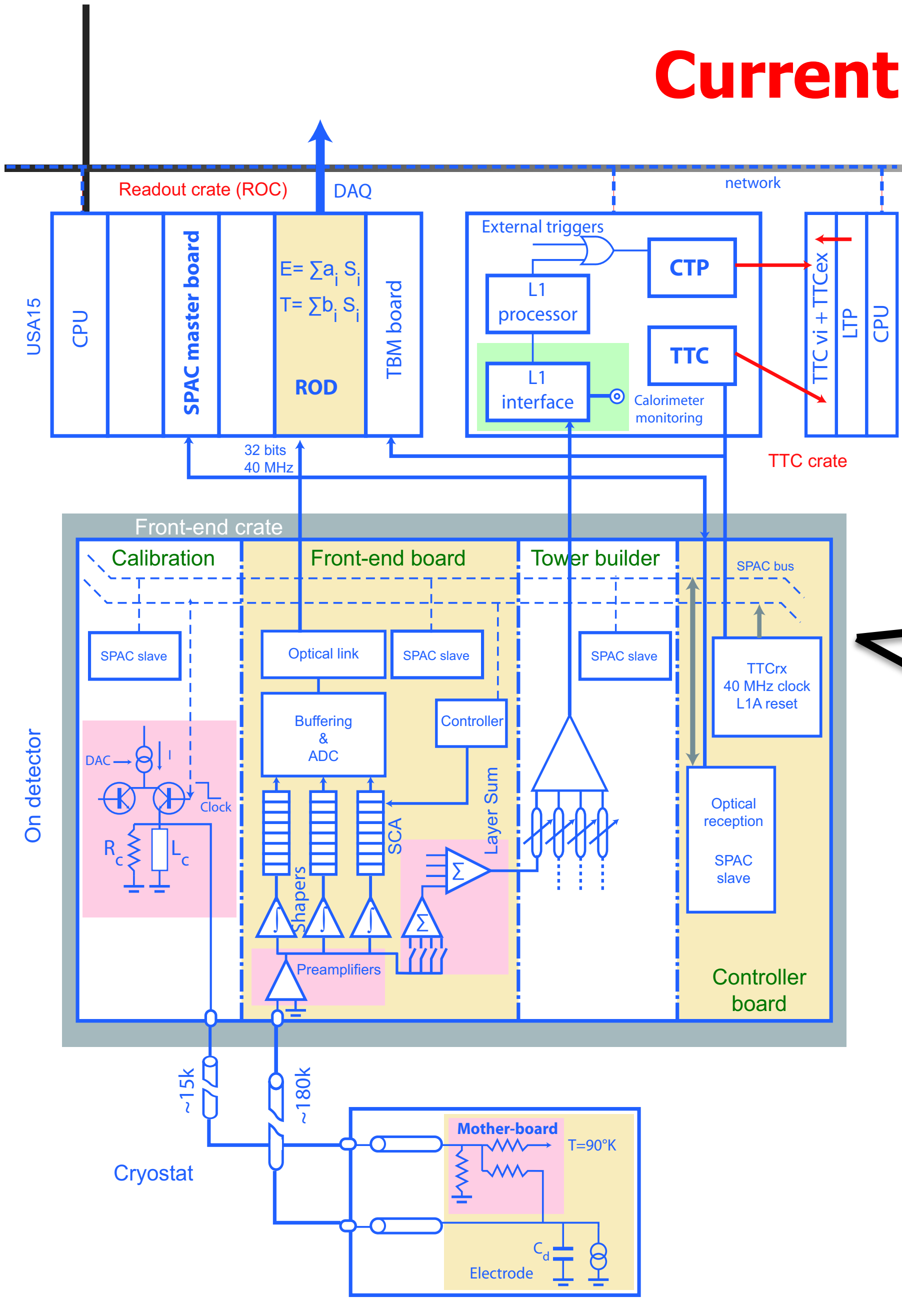
- Lower cathode resistance - for high rate
- Pads - online trigger tower
- Strip charge readout - precision coord. readout
- Wire readout - coarse φ coordinate

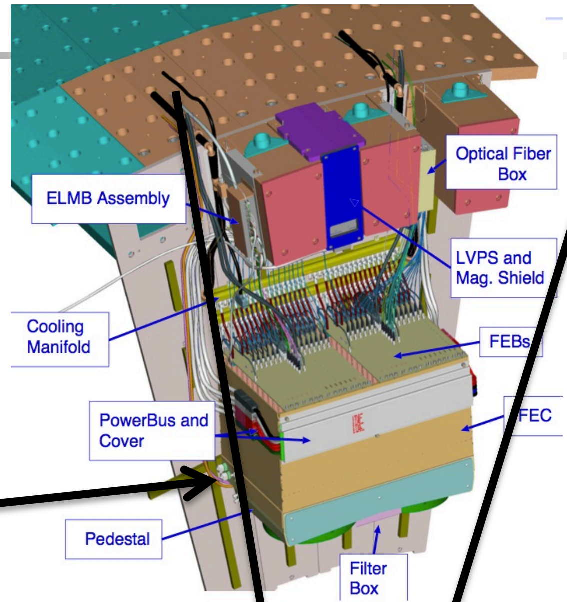
Canadian sTGC construction

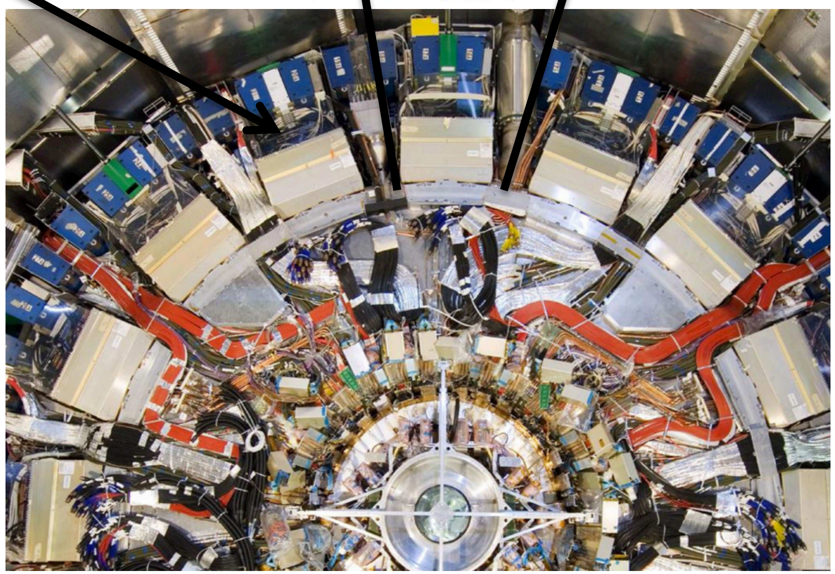
- TRIUMF cluster(Vancouver)
  - Receipt of parts - spray/polish carbon coating – glue frames and wire supports
  - Ship boards Vancouver to Ottawa
- Carleton cluster (Ottawa)
  - Wire stringing, gap and quadruplet assembly, adapter boards and chamber sealing
  - Ship Quadruplets Ottawa to Montreal
- McGill cluster (Montreal)
  - Cosmic ray testing, preparation for shipping to Geneva
  - Ship batches of chambers to CERN
- Note shipping is all under climate controlled conditions by land/sea

LAr electronics

Current system

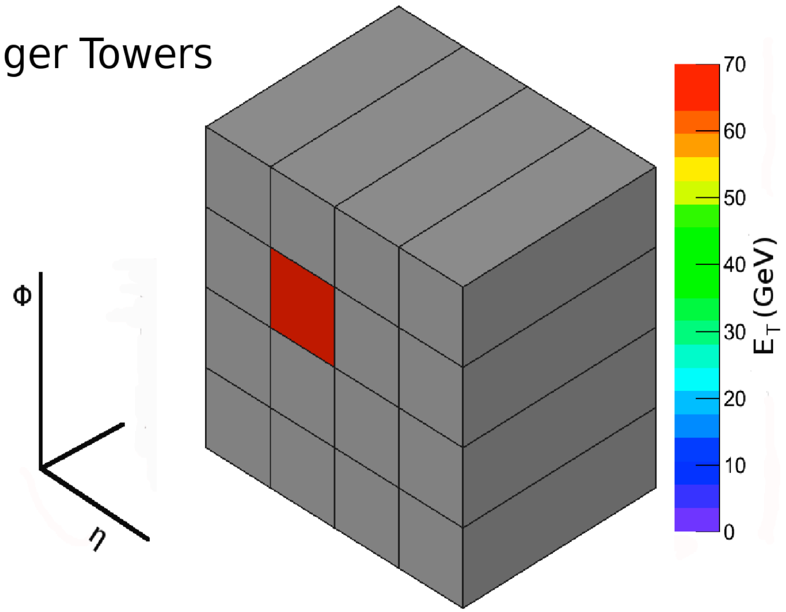






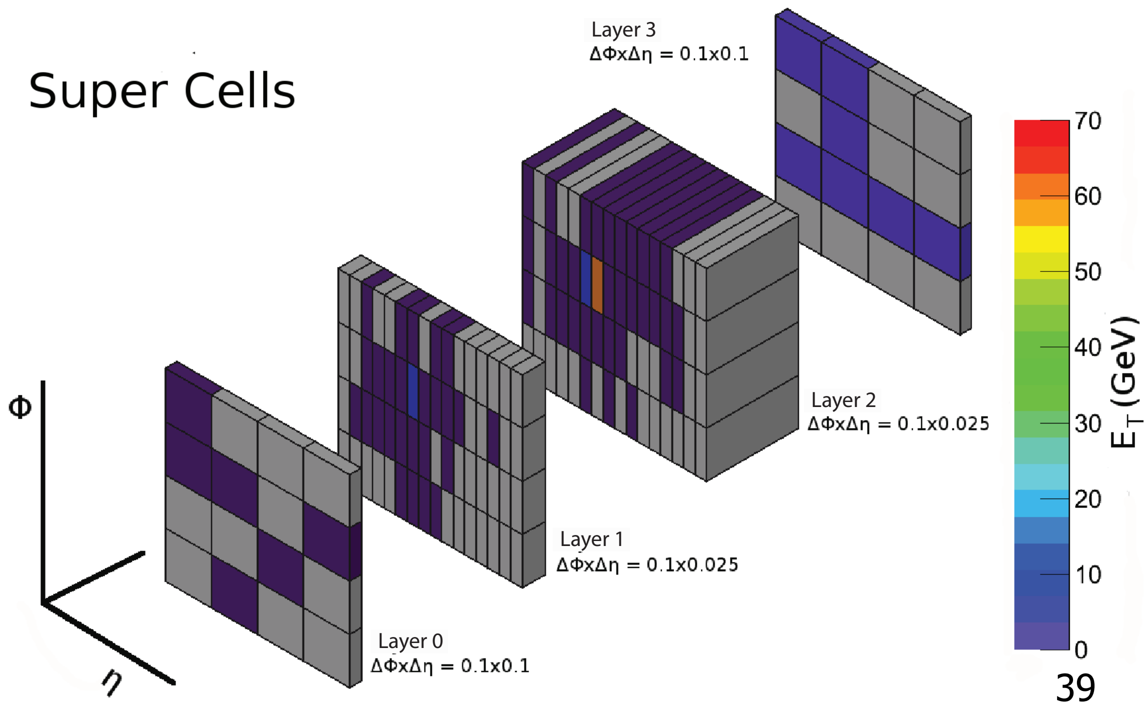
Existing Trigger Tower compared to a new Supercell for a 70 GeV electron

Trigger Towers

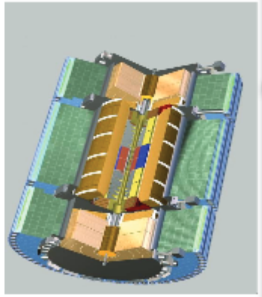


Super Cells

The newer finer granularity cells are called supercells



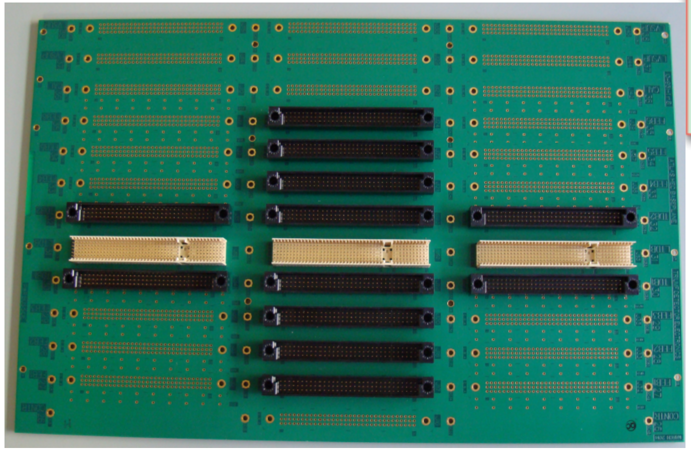
Upgraded system

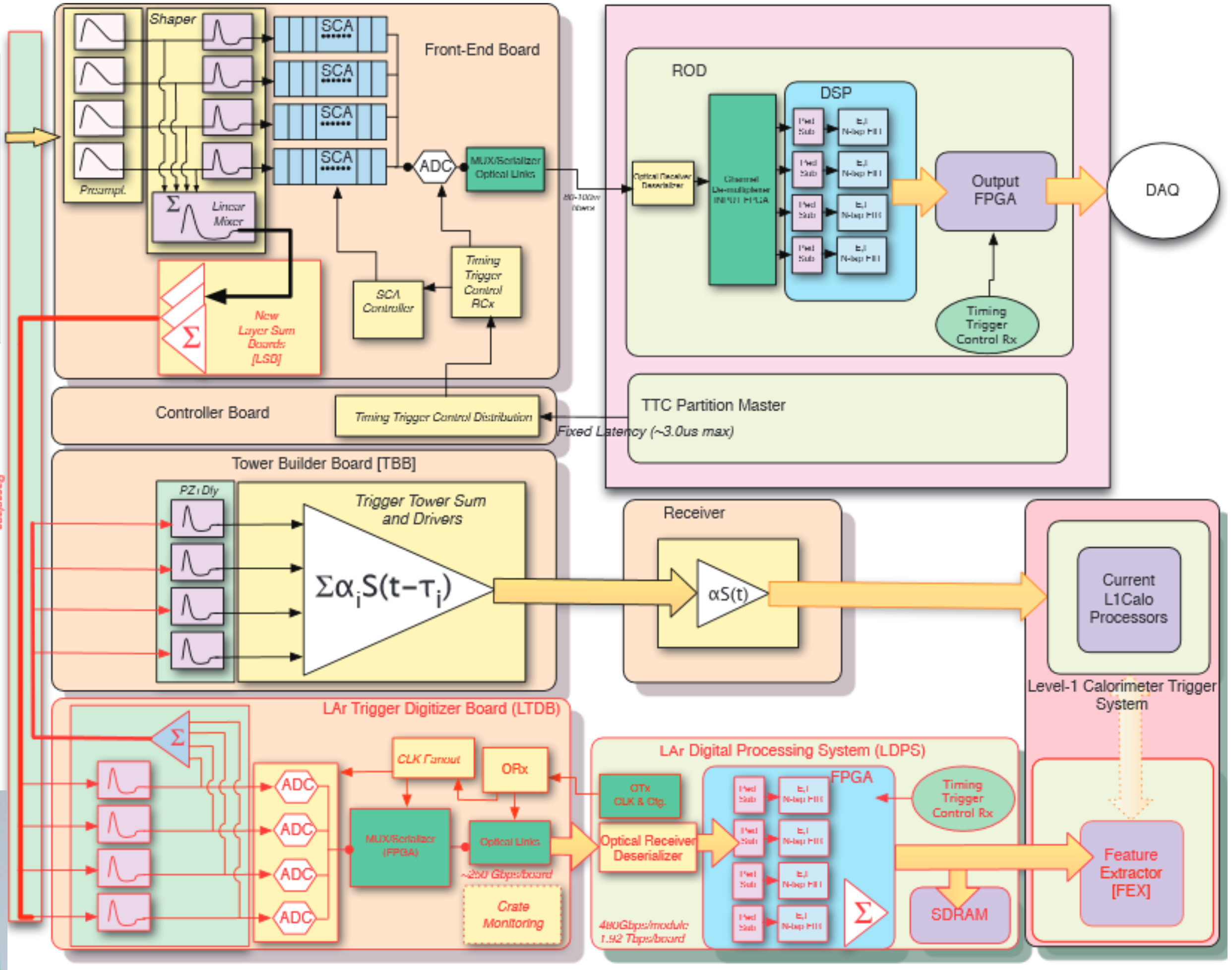


Prototype Baseplane (seen below) has been tested.

It is the component shown as the red line on the side of the diagram

→





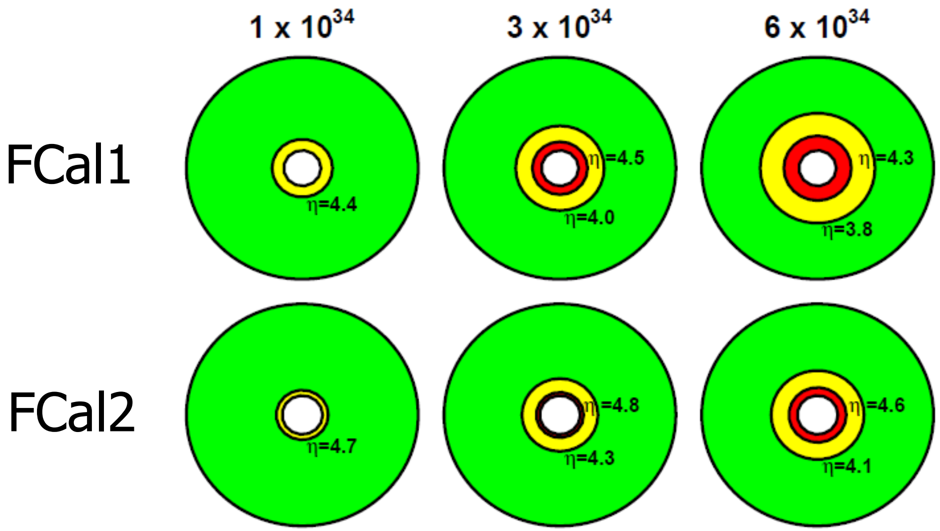
FCal

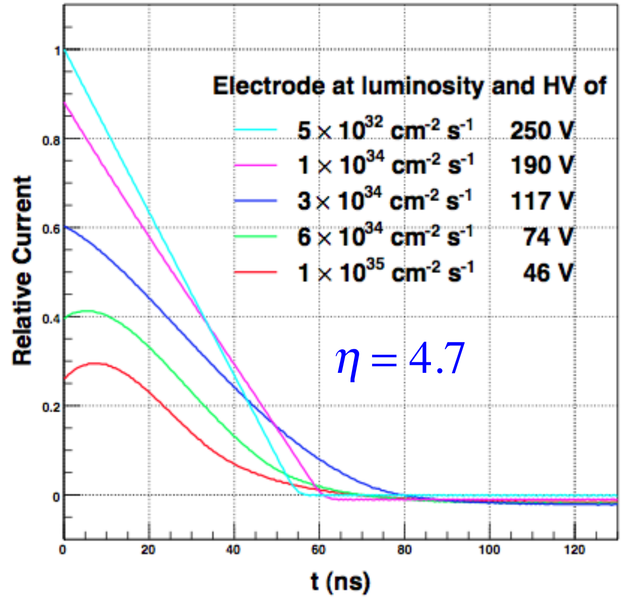
FCal problems at HL-LHC Luminosities

- Issues for the liquid argon forward calorimeter at the HL-LHC:
  - Existing FCal designed for $\mathcal{L}_{inst}$ = 10^{34} $cm^{-2}s^{-1}$, $\mathcal{L}_{int}$ = 1000 fb^{-1}.
  - HL-LHC proposal $\mathcal{L}_{inst}$ = 5-7x10^{34} $cm^{-2}s^{-1}$, $\mathcal{L}_{int}$ = 3000 fb^{-1}.
  - Consequences for the Forward Calorimeter (FCal)
    - Ion buildup affecting the electric field in the gap: depends on L and *r* : the narrow LAr gaps are no longer narrow enough.
    - Higher current draw → significant voltage drop across HV protection resistors: these are located **inside** the endcap cryostat.
    - High ionization load → potential for boiling of liquid argon.
- FCal (with existing LAr gaps) shows degraded response at HL-LHC luminosities (next slide); narrow gap electrodes (~100μm) proposed for sFCal and LAr MiniFCal shown to work well at HL-LHC intensities.
- Ion-buildup / HV-sagging / boiling issues all addressed by both the sFCal and MiniFCal solutions.
- Maintain / improve upon current performance only in sFCal case.

FCal problems at HL-LHC Luminosities

- Plots illustrate combined effects of decreased field (HV sag) and ion-buildup, on FCal performance (at high η)

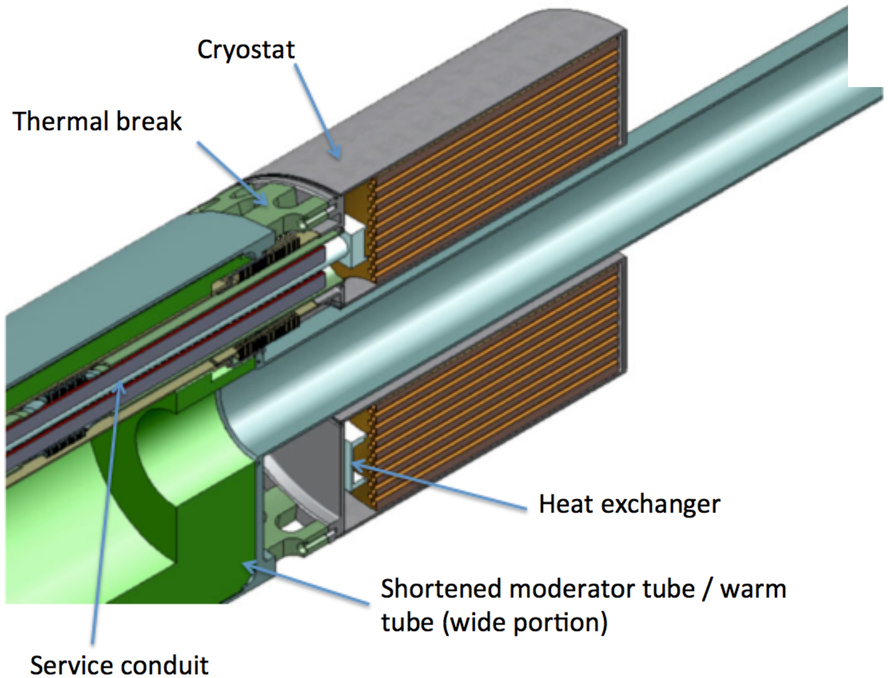


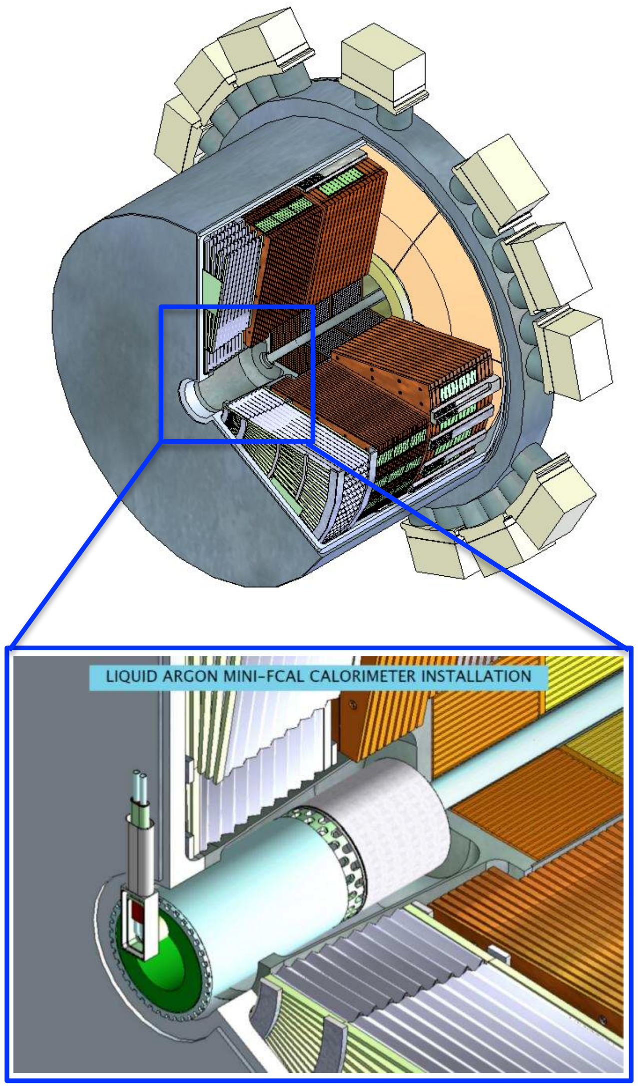


- Two approaches considered for addressing these problems:
  1. Replace FCal with sFCal - smaller gaps, new summing boards (lower resistances, to resolve HV-sagging issue) and cooling loops (to avoid LAr boiling).
     - Requires opening of cryostat and a long shutdown: addressed all issues.
  2. Small calorimeter in front of FCal (absorb particle flux at high η):
     - Referred to as the Mini-FCal: addresses all issues.

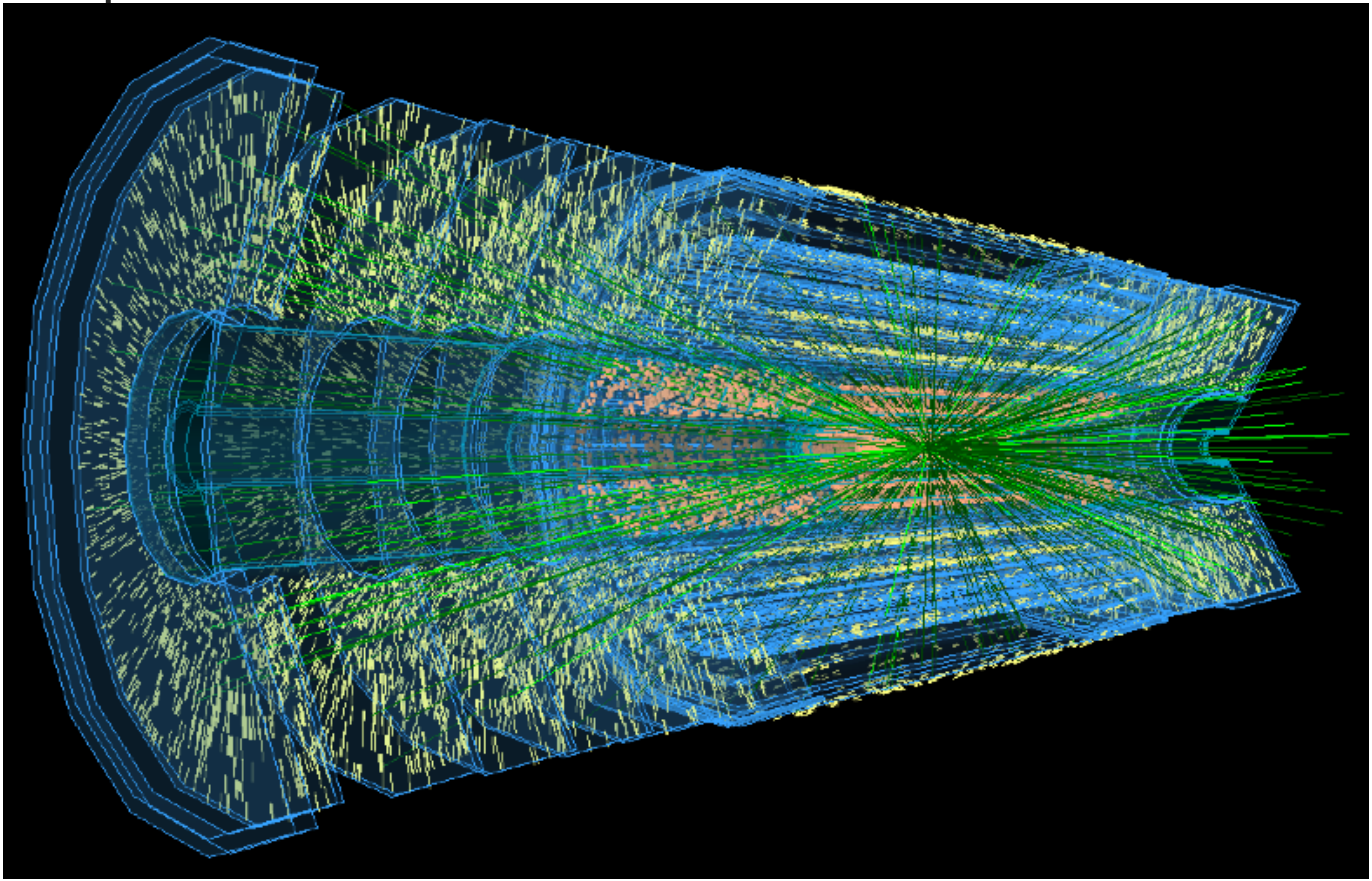
The Liquid Argon MiniFCal

- MiniFCal concept developed & led by Canadians from the start.
- LAr/Cu version is intrinsically radiation hard; challenges are technical: need to get services in (cooling, LAr, cabling) and need to sufficiency cooling power.

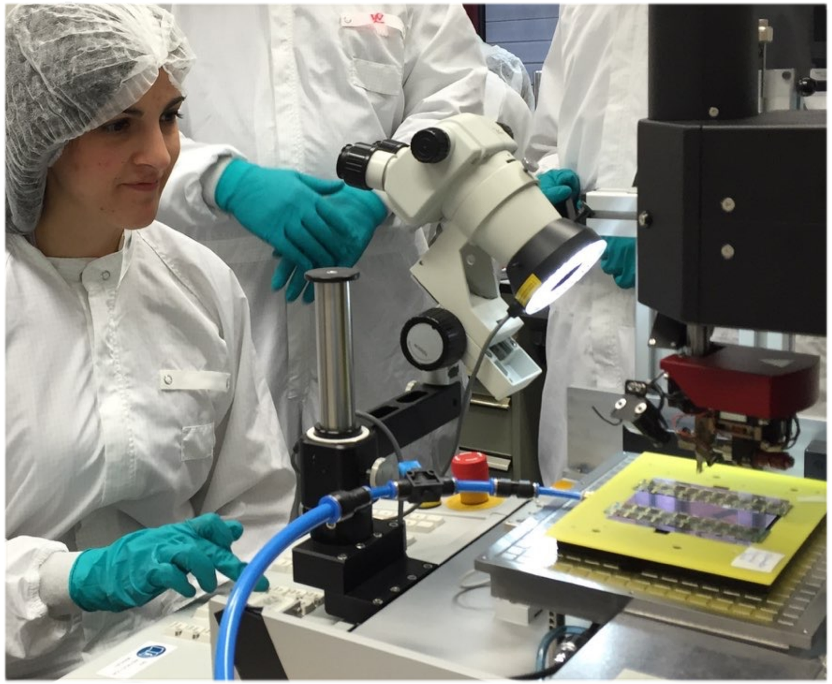




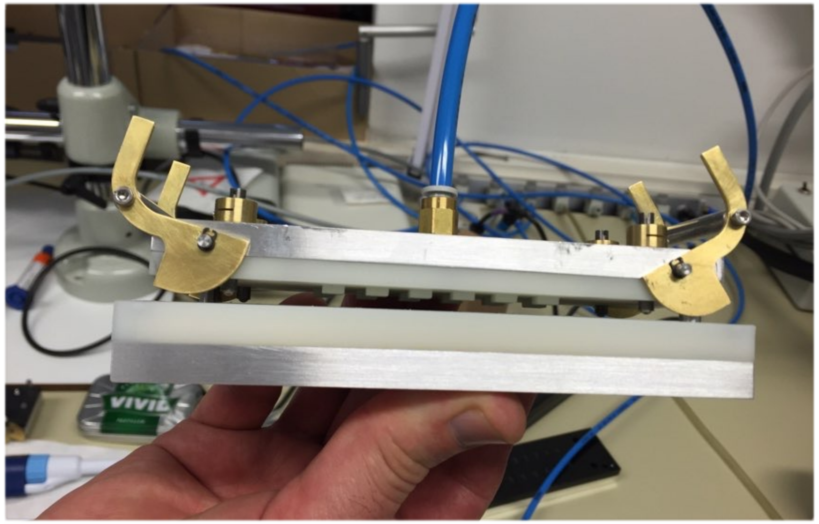
ITK: 2015-2021



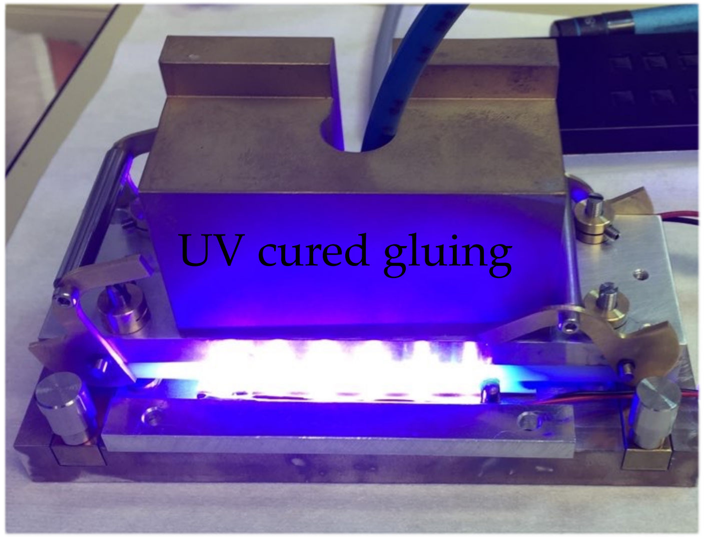
HQP Training: Canada @ DESY Zeuthen, Berlin, in April 2015

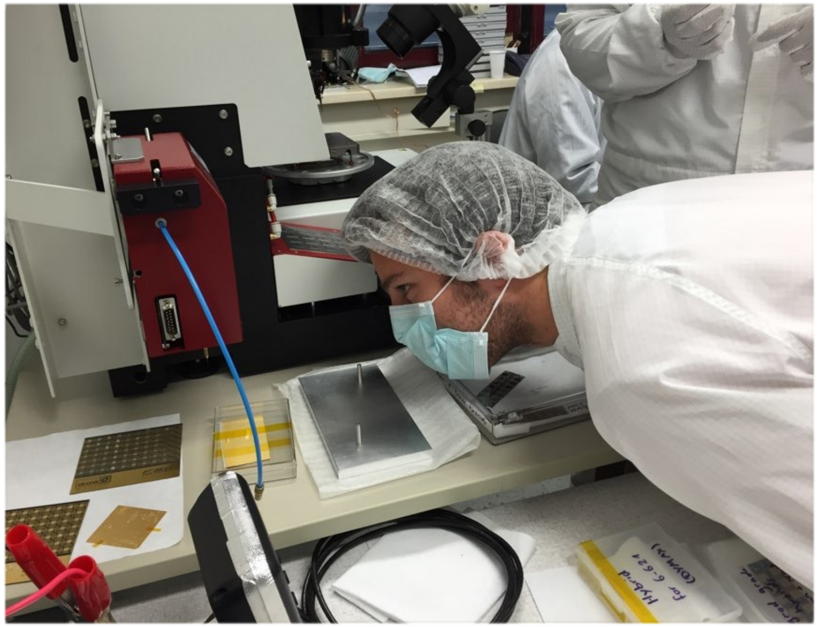


Canadian grad student wire bonding



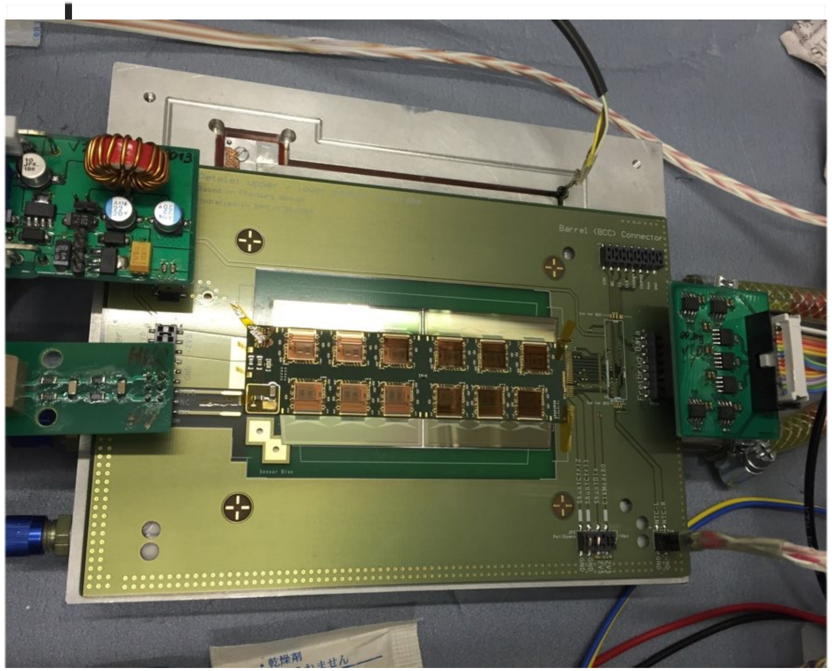
Canadian engineer's precision tooling.

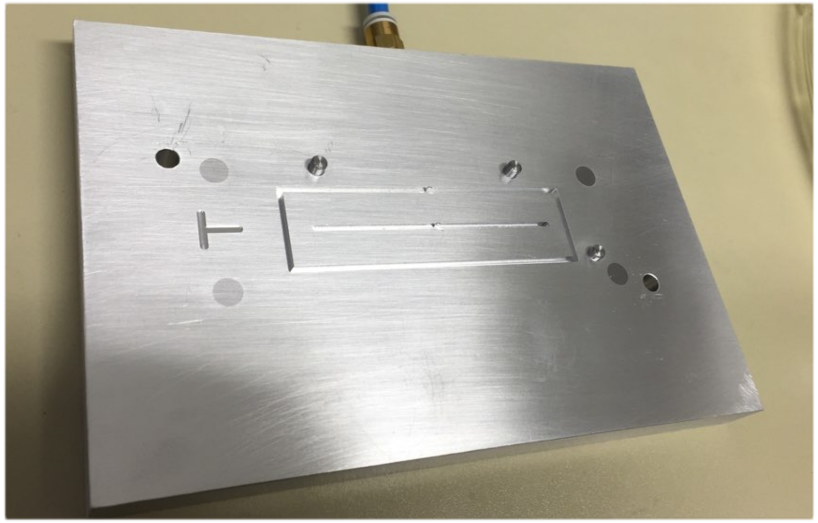


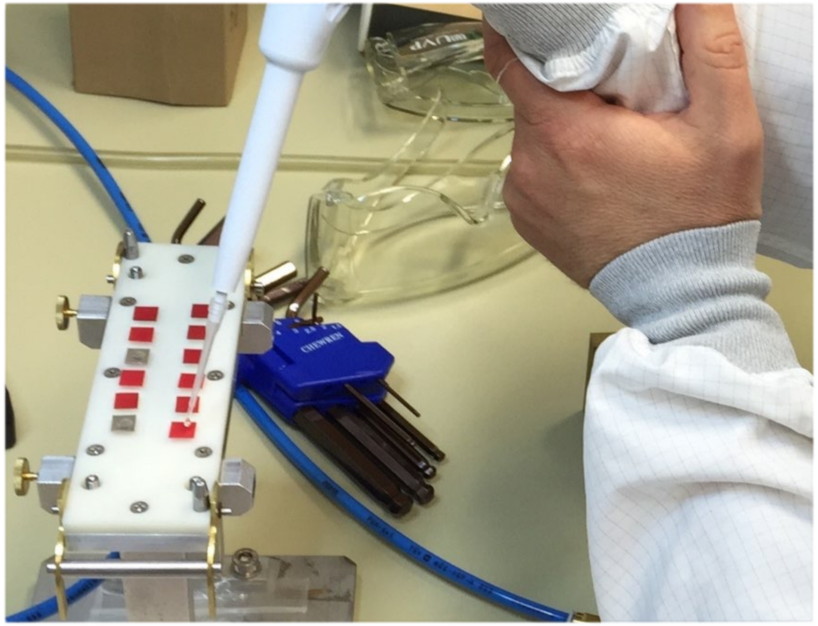


Canadian grad student & wire bond tester

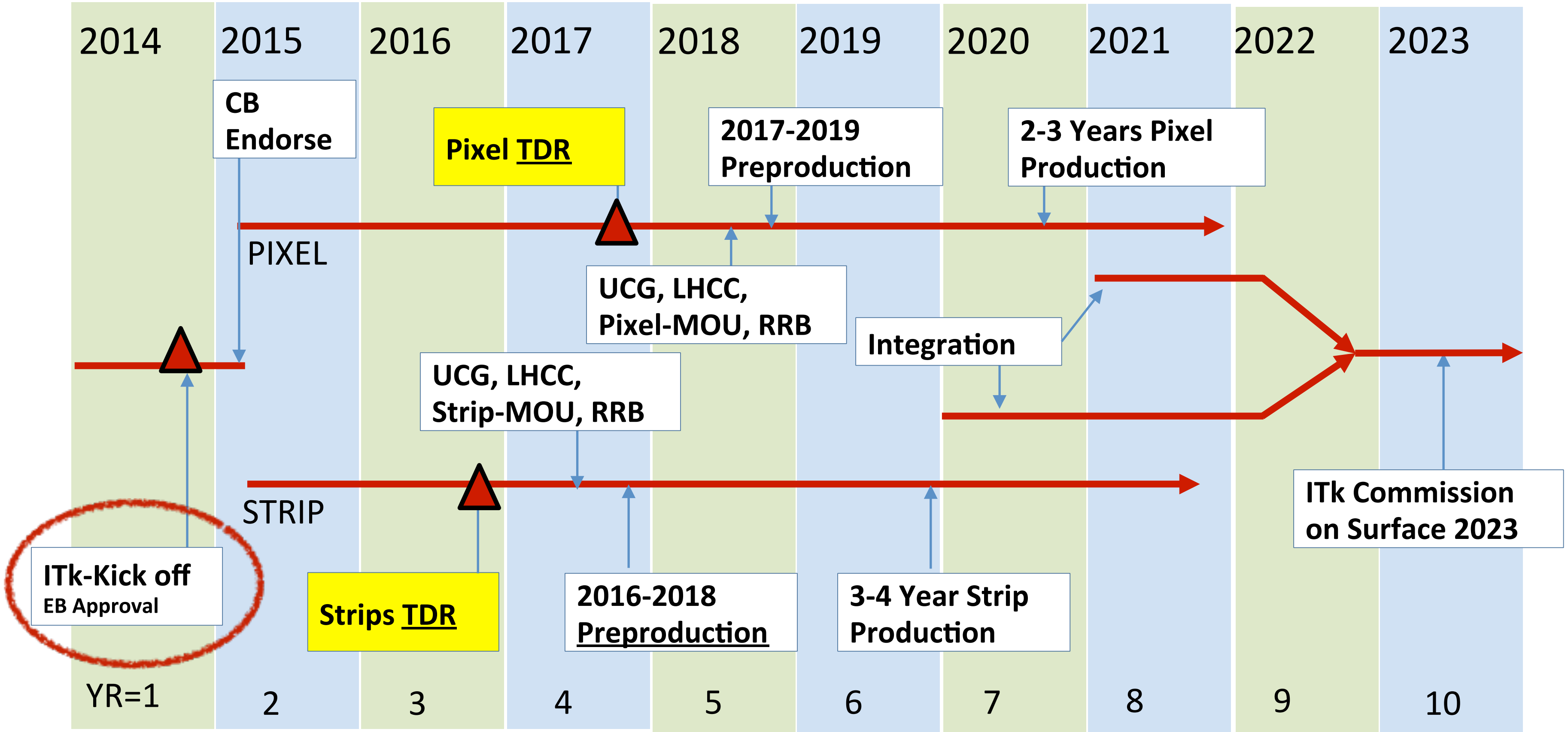
HQP Training: Canada @ DESY Zeuthen, Berlin, in April 2015


Learning about module tests


Canadian engineer's precision test jig

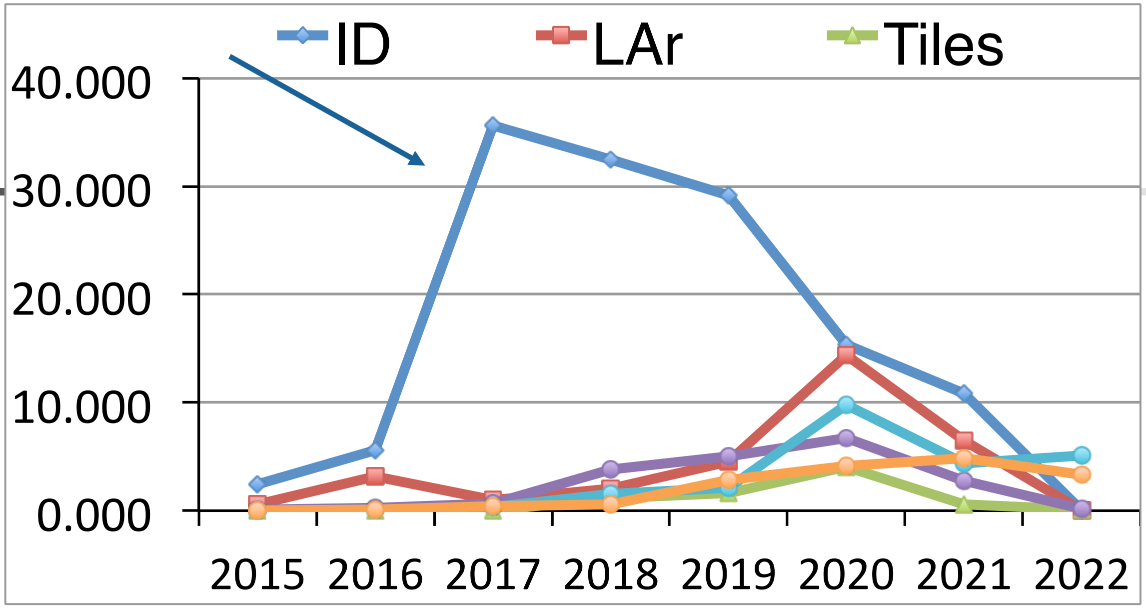

ASIC test uv gluing on Canadian tool

ITk in next 10 years : The BIG picture



CB= collaboration board, EB=executive board, IMOU=interim memorandum of understanding, UCG=upgrade cost group, RRB= Resources review board, IDR=initial design review (internal), TDR=technical design report (external)

Overall Phase-II Upgrade

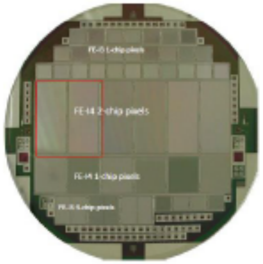


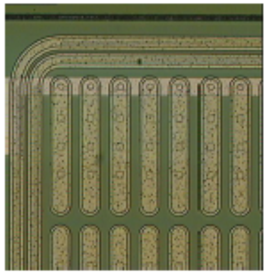
	ATLAS PHASE II upgrade (LS3)		
		it will happen	it might happen
		[MCHF]	[MCHF]
1	***New Inner Detector***	***131.500***	***26.000***
2	LAr upgrades	*32.124*	*15.096*
3	Tiles upgrades	*7.483*	*2.517*
4	Muon spectrometer upgrades	*19.632*	*0.500*
5	TDAQ upgrades	*23.315*	*0.900*
6	Infrastructure items	*16.280*	*0.000*
	TOTAL	*230.334*	*45.013*

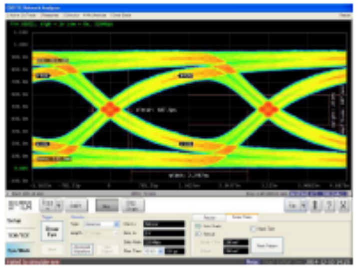
Phase-2: ITK R&D details

Main R&D for TDRs - prototyping & technology qualification (including radiation hardness)

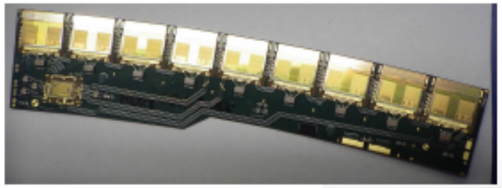
- Pixel
  - Front-end chip in 65nm technology (w/RD53)
  - Planar and 3D sensors
  - Large-scale bump-bonding → modules
  - Data transmission
  - Power distribution
  - CMOS sensor option

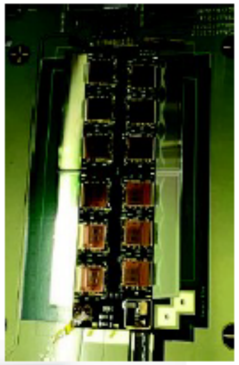


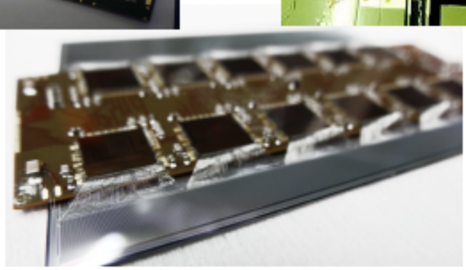




- Strip
  - Planar n-in-p sensor design & characterisation
  - Front-end chip in 130nm technology
  - Hybrid controller chip
  - Power distribution and supply
  - Hybrids
  - CMOS sensor option



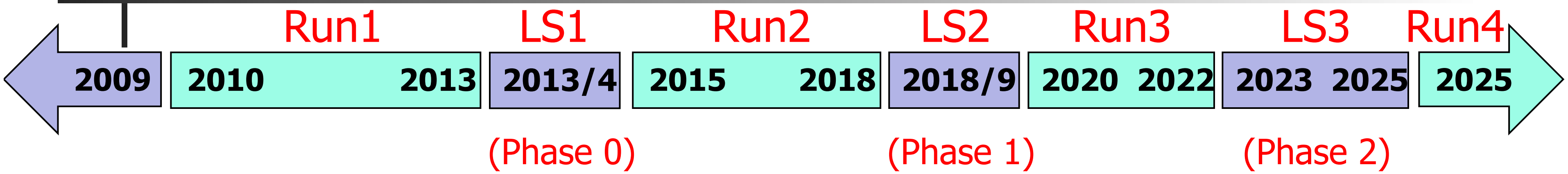




For pixel and strip sensors, electronics & modules:
R&D is covered by existing & foreseen effort & funding

Other material

Run 2,3,4++ LHC Targets



Run 2 luminosity goals:

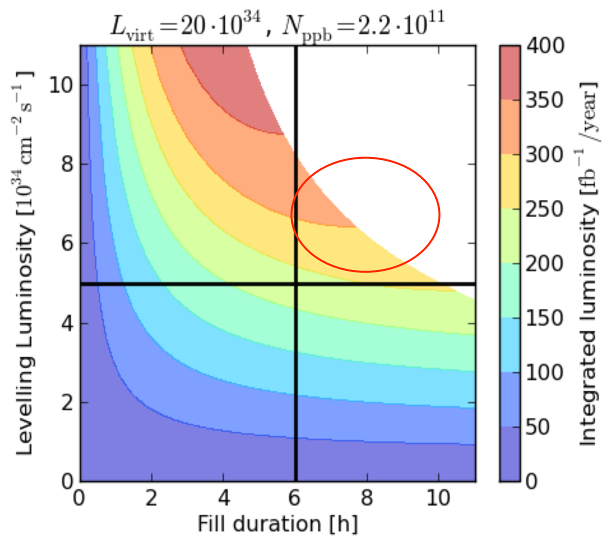
- 13 to 14TeV, $1.3 \times 10^{34}\ cm^{-2}s^{-1}$ at 25ns, with estimated pileup of 40-50 events/bc
  - Accumulate 100-120 fb^{-1} by mid 2018

Run 3 luminosity goals:

- Run near or at 14TeV, $2 \times 10^{34}\ cm^{-2}s^{-1}$ at 25ns.
  - Accumulate 300 fb^{-1} before LS3

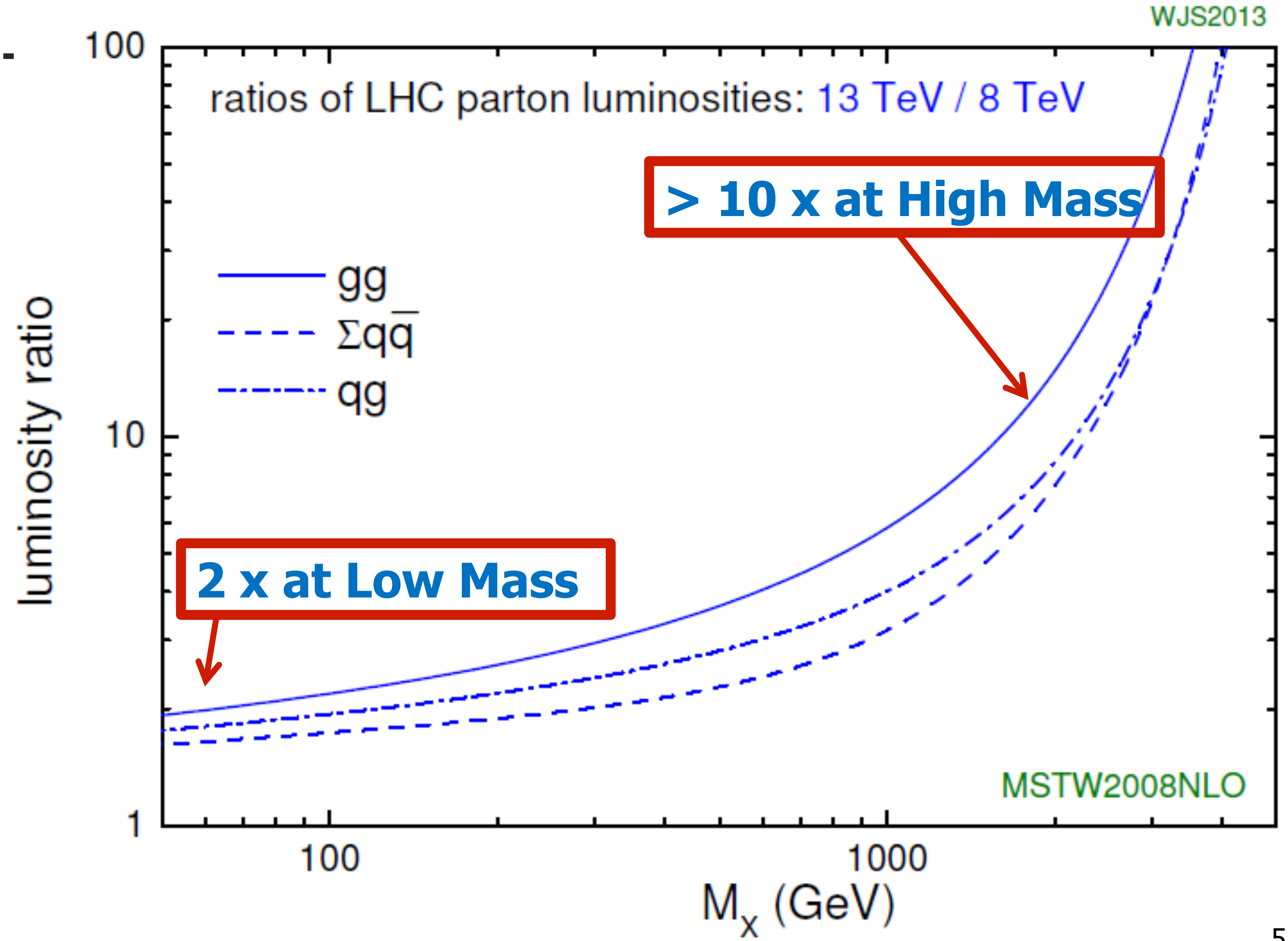
Run 4++ (HL-LHC) luminosity goals:

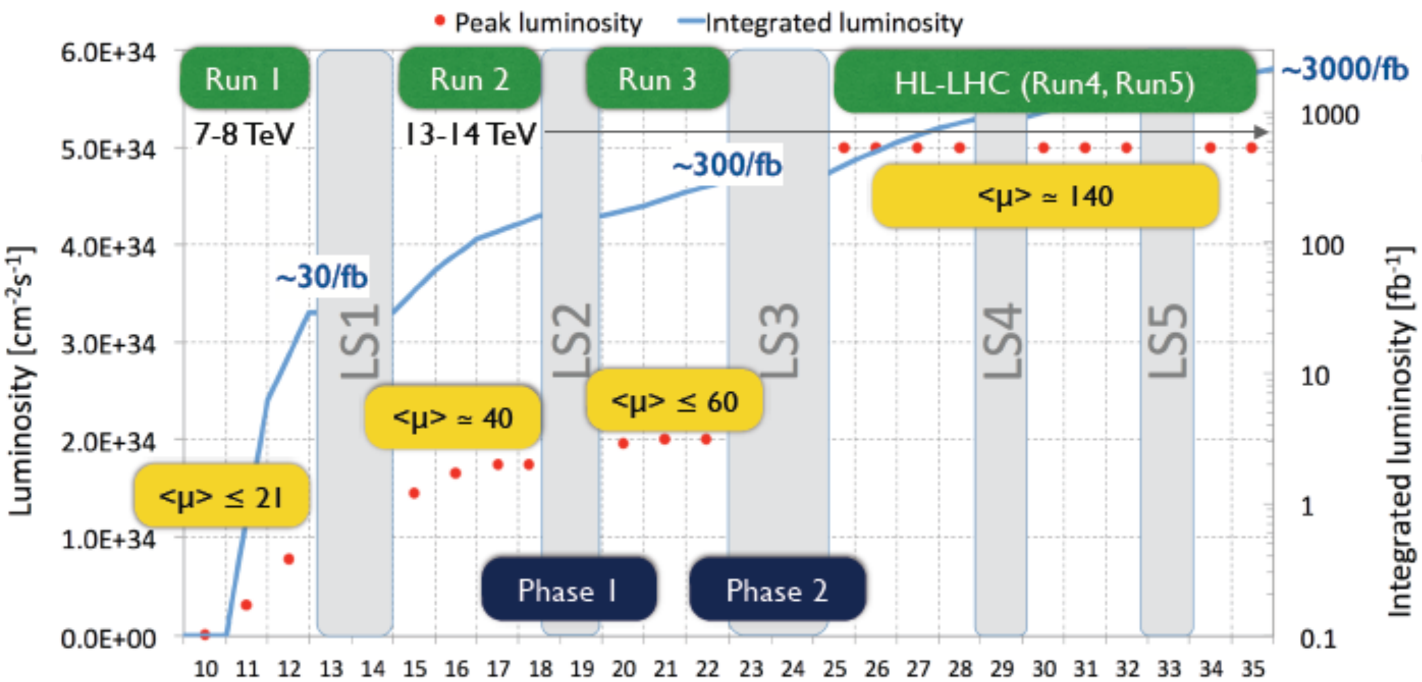
- 14TeV, $5\text{-}7 \times 10^{34}\ cm^{-2}s^{-1}$
  - Achieved with lumi levelling, keep pile-up tolerable
    - Challenges of up to 200 pileup events/bc
  - Accumulate 250-300 fb^{-1} per year
    - Reach 3000 fb^{-1} by ~2036
  - Would need to increase run time and number of days operational



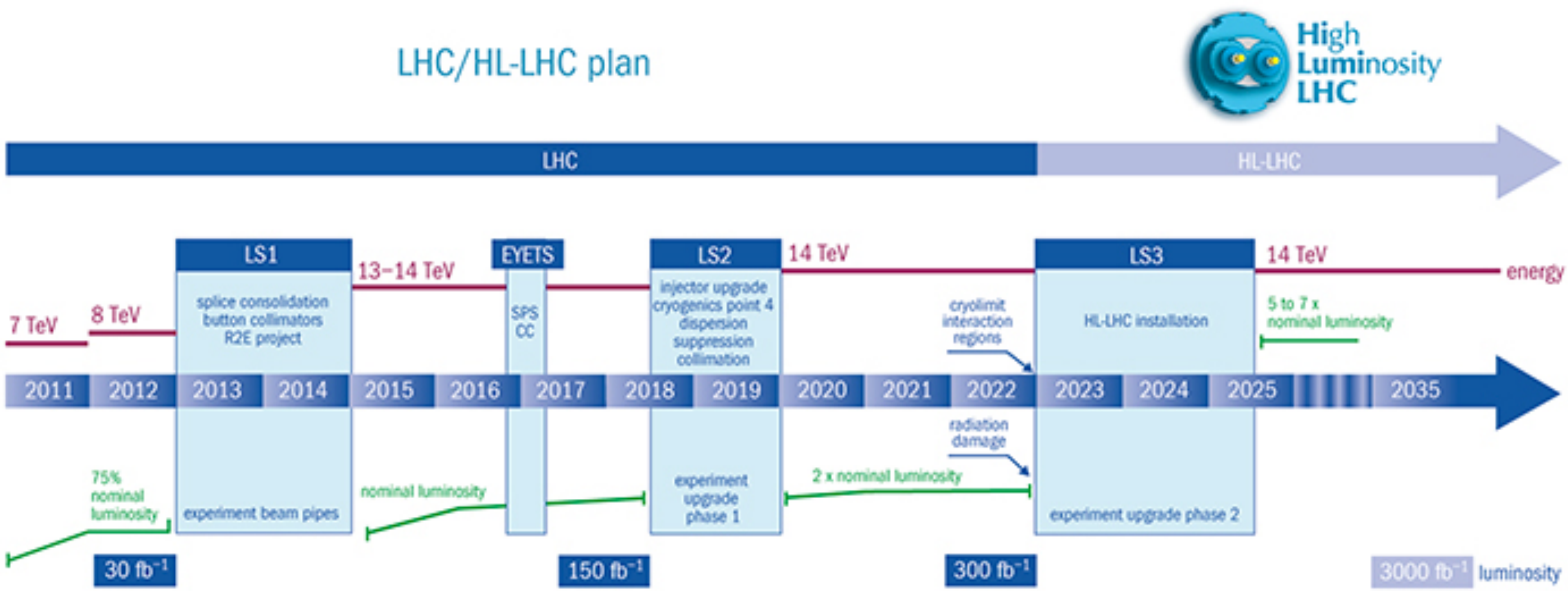
√s = 13 TeV: parton luminosities

-





Peak luminosity
Integrated luminosity
Run 1
Run 2
Run 3
HL-LHC (Run4, Run5)
7-8 TeV
13-14 TeV
~30/fb
~300/fb
~3000/fb
LS1
LS2
LS3
LS4
LS5
<μ> ≤ 21
<μ> ≃ 40
<μ> ≤ 60
<μ> ≃ 140
Phase 1
Phase 2
Luminosity [cm⁻²s⁻¹]
Integrated luminosity [fb⁻¹]
6.0E+34
5.0E+34
4.0E+34
3.0E+34
2.0E+34
1.0E+34
0.0E+00
1000
100
10
1
0.1
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35



LHC/HL-LHC plan
High Luminosity LHC
LHC
HL-LHC
LS1
splice consolidation
button collimators
R2E project
experiment beam pipes
EYETS
SPS
CC
LS2
injector upgrade
cryogenics point 4
dispersion
suppression
collimation
experiment
upgrade
phase 1
LS3
HL-LHC installation
experiment upgrade phase 2
7 TeV
8 TeV
13–14 TeV
14 TeV
14 TeV
energy
cryolimit
interaction
regions
radiation
damage
75%
nominal
luminosity
nominal luminosity
2 x nominal luminosity
5 to 7 x
nominal luminosity
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2035
30 fb⁻¹
150 fb⁻¹
300 fb⁻¹
3000 fb⁻¹
luminosity

ATLAS Upgrade Timelines

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

Phase 0 upgrade:	Phase 1 upgrade:	Phase 2 upgrade:
Consolidation, $\sqrt{s}$=13-14 TeV, 25nsec bunch spacing, $\mathcal{L}\approx 1\times10^{34}$ $cm^{-2}s^{-1}$ ($\mu\approx30$) $\int\mathcal{L}\approx 50$ fb^{-1}	Ultimate luminosity $\mathcal{L}\approx 2\times10^{34}$ $cm^{-2}s^{-1}$ ($\mu\approx60$) $\int\mathcal{L} > 350$ fb^{-1}	$\mathcal{L}\approx 5\times10^{34}$ $cm^{-2}s^{-1}$ ($\mu\approx150$) $\int\mathcal{L}\approx 3000$ 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	• 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)	• All new Tracking Inner Detector • Calorimeter Electronics Upgrades • Muon system upgrades (big wheels) • Level-1 track trigger • New forward calorimeters