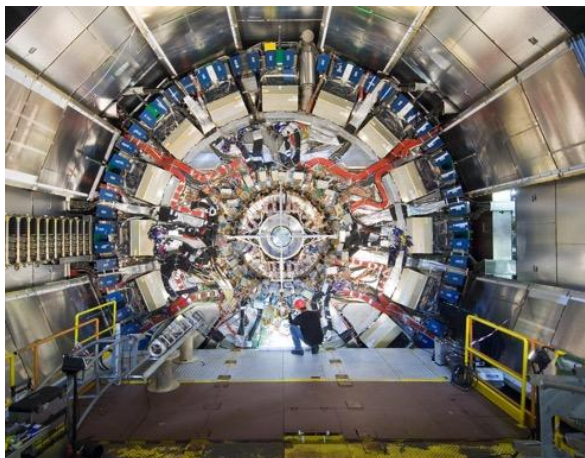


From the ATLAS ITk towards future trackers



Current ATLAS Inner Tracker

Luise Poley (TRIUMF, SFU)

TRIUMF Science Week

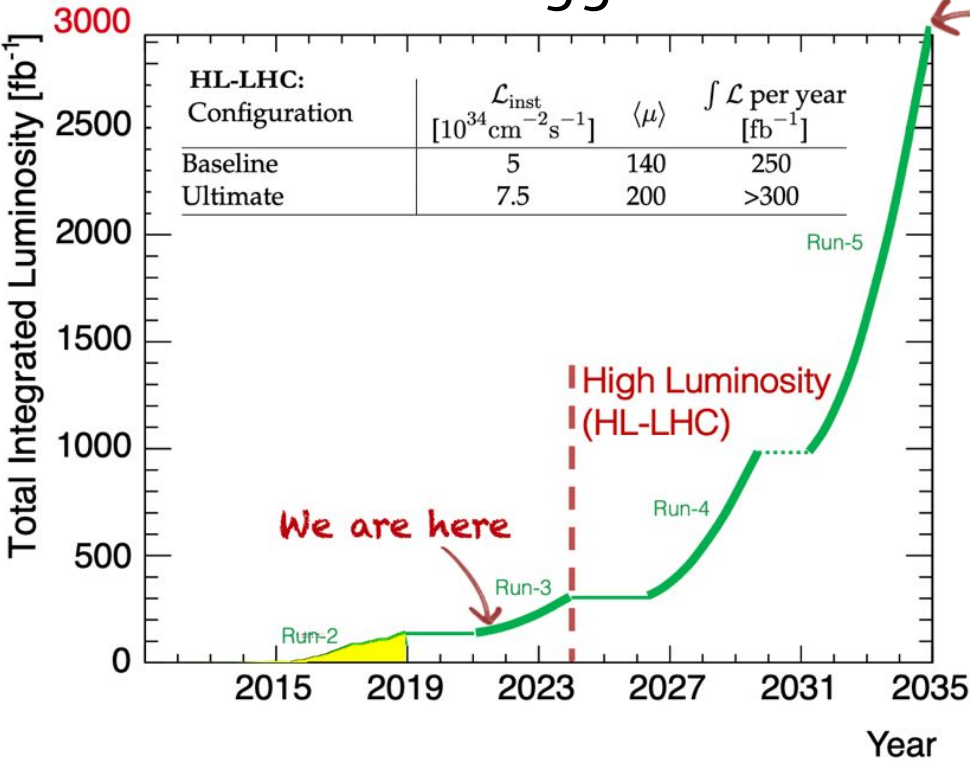


Alexander von Humboldt
Stiftung/Foundation



“Petal” of New Inner Tracker

ATLAS Experiment and the Higgs



Expected from High-Luminosity LHC

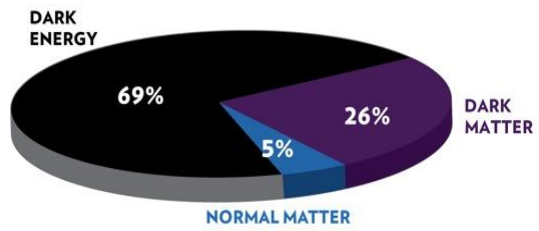
190 million Higgs bosons
 120 thousand Di-Higgs boson (see Max's talk)

Important questions to be addressed

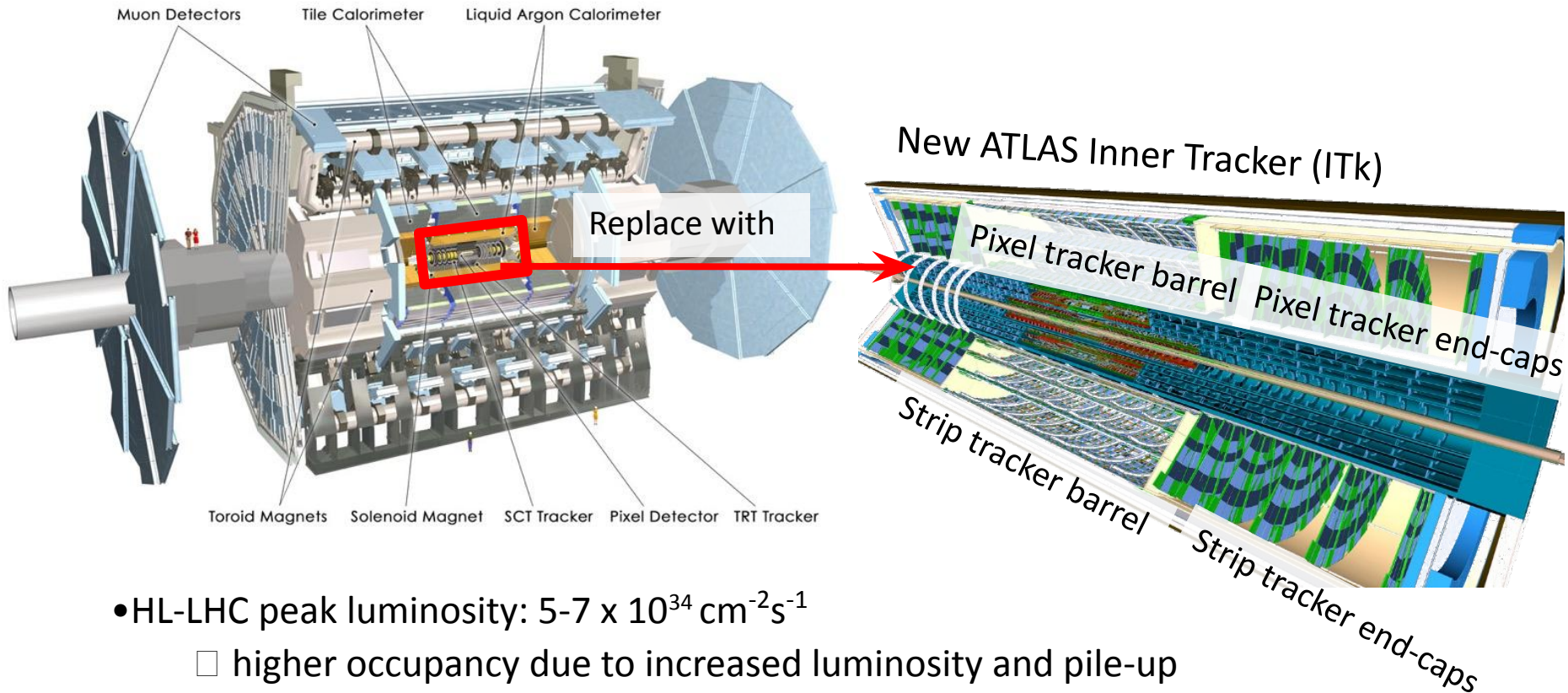
- Is this the Standard Model Higgs boson?
- Are there more Higgs-like bosons?
- What is the Higgs field potential?
- Compelling evidence for "dark matter"
- **Higgs as a portal to the "dark sector"?**



BUT:
 ATLAS Inner Detector needs to be replaced

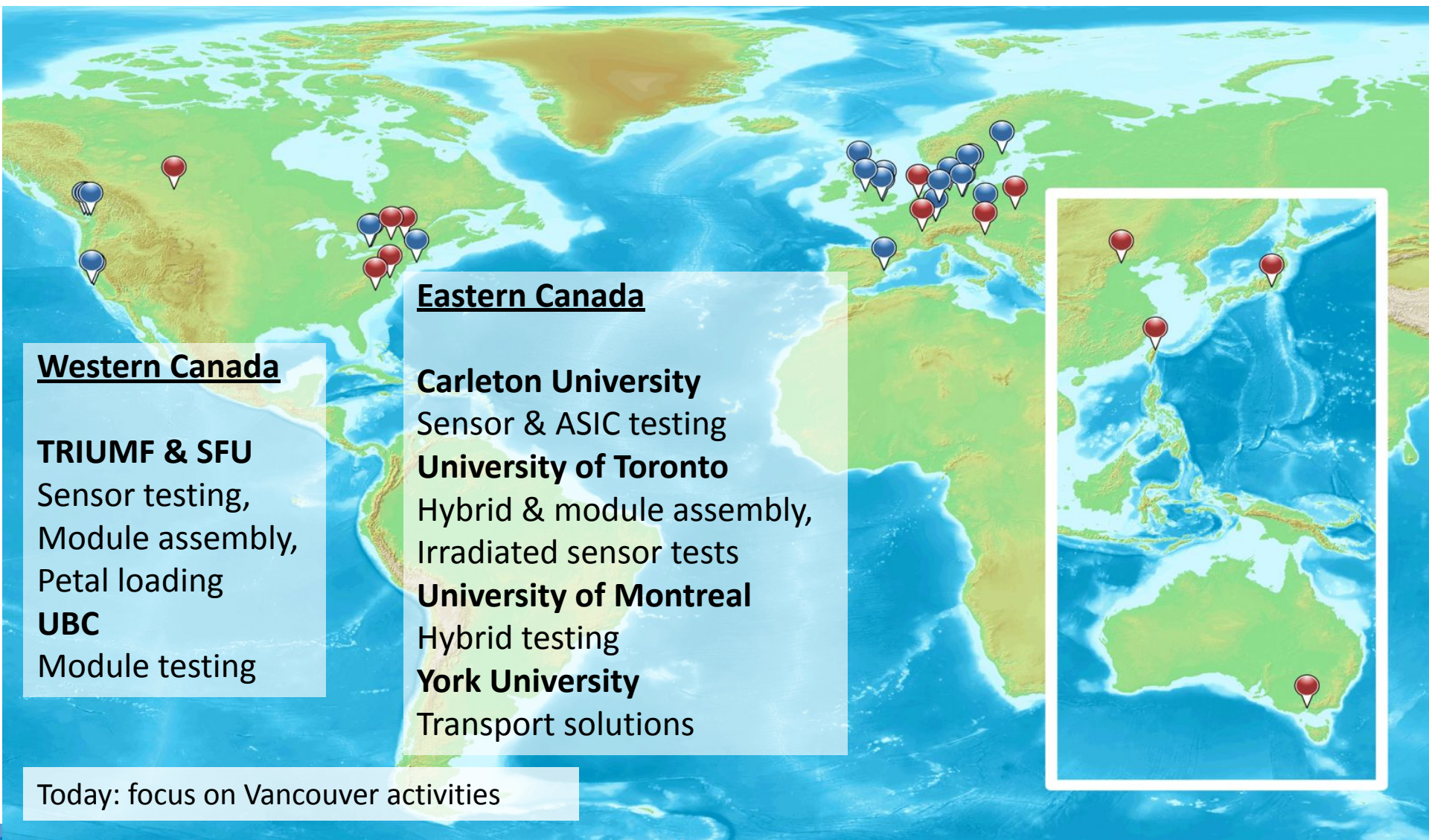


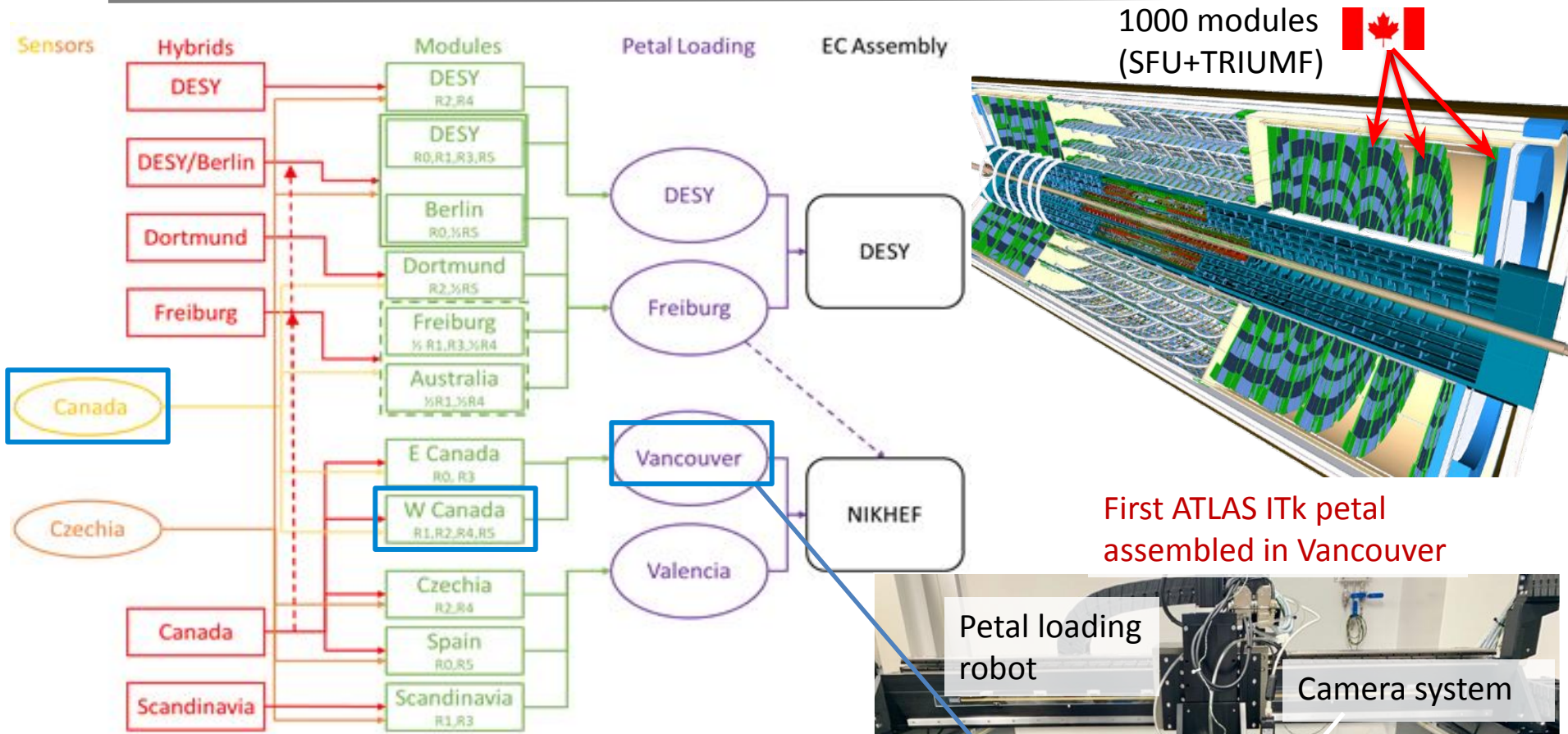
ATLAS New Inner Tracker (ITk)



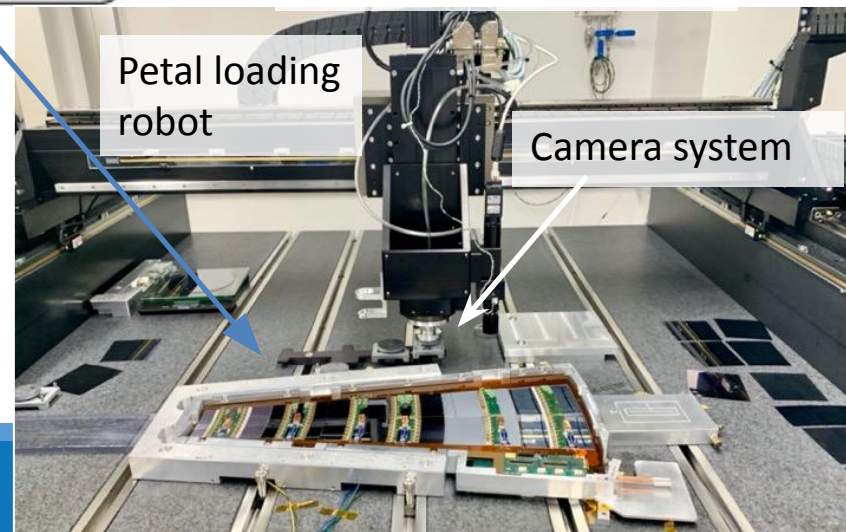
- HL-LHC peak luminosity: $5-7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
 - higher occupancy due to increased luminosity and pile-up
- Required radiation tolerance: factor 20 increase
- Higher granularity: 5000 million channels (ID: 100 million)
- Larger solid angle coverage: 180 m^2 area of silicon
- Minimised multiple scattering: require $< 1\% X/X_0$

Today:
focus on strip tracker





1000 modules (SFU+TRIUMF)
 First ATLAS ITk petal assembled in Vancouver



INTERNATIONAL MANAGEMENT

ITk Production management (deputy)
Luise Poley (TRIUMF/SFU)

ITk Activity coordination (petal loading)
Bernd Stelzer (SFU/TRIUMF)

The immediate future

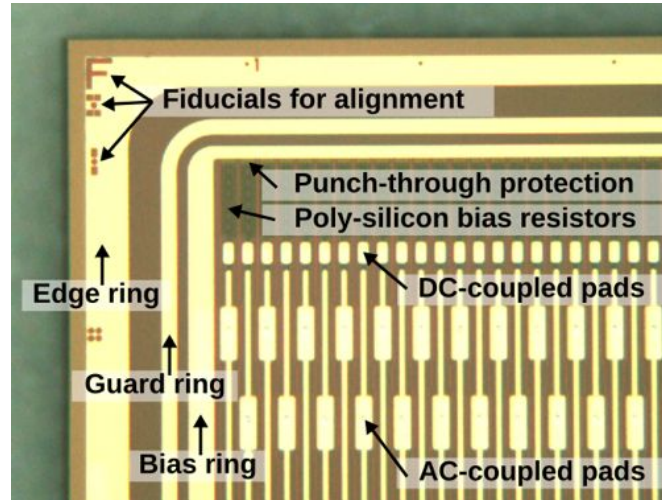
- ITk site qualification, Pre-Production (5%)
- Full ATLAS ITk Production (by 2025)

- Total of 2000 sensors to be tested at SFU + TRIUMF
- Site qualification for sensor testing completed, first 100 sensors tested successfully

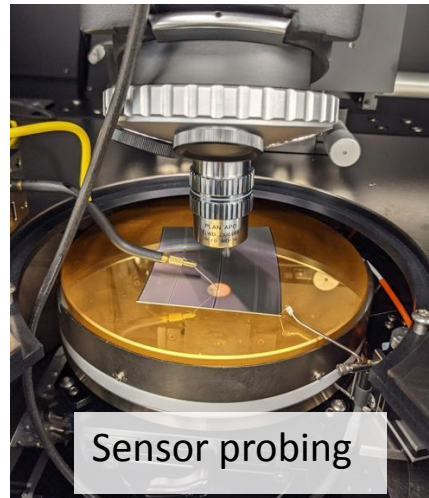
Development of additional sensor testing infrastructure

- Edge-TCT (Transient Current Technique) setup
- Sensor defect detection through thermal emission

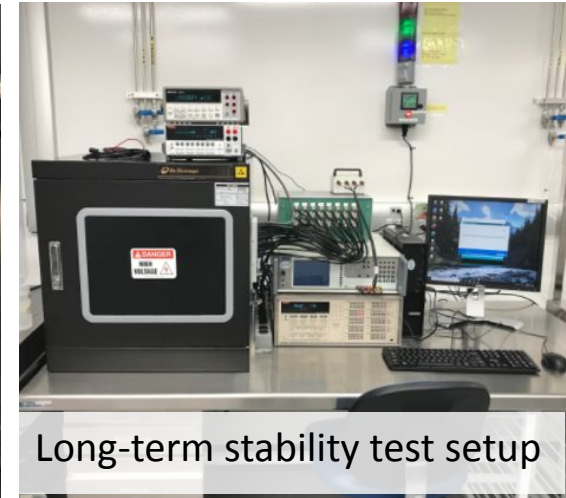
Currently leading investigations into humidity sensitivity* of sensors



*The ABC130 barrel module prototyping programme for the ATLAS strip tracker, L. Poley *et al* 2020 *JINST* 15 P09004



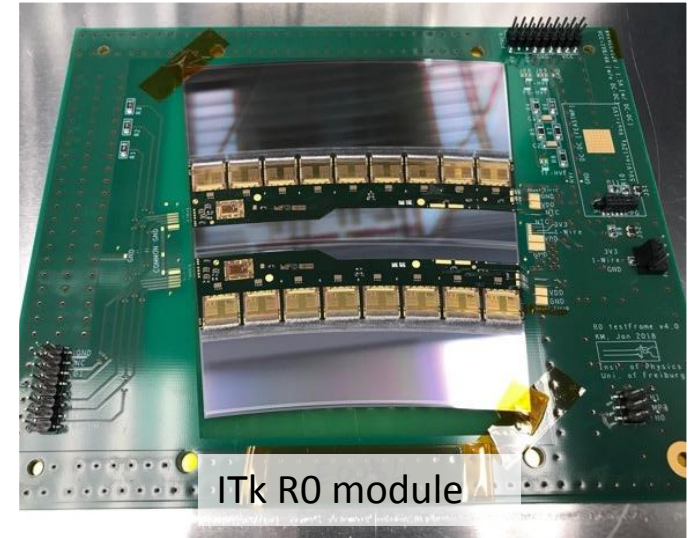
Sensor probing



Long-term stability test setup

ITk Module assembly

- Complete infrastructure for module assembly and testing (current and future)
- Cleanrooms equipped with high performance wire-bonders, metrology, electrical testing and inspection equipment
- Production of high-precision assembly tools for collaboration in Vancouver
- Site-qualification for modules in progress
- **Canadian sites among the first sites to build electrical modules for the end-cap**



INNOVATION.CA
 CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION



- Loading ITk modules on support structures: precision placement of large, delicate objects
- SFU+TRIUMF leading robotic placement effort
 - Developed fully automated module placement (and inspection) using robotic gantry
 - Development of associated Production Database structures
 - Design of handling and placement tools and frames
 - First petal for Final Design Review at CERN was loaded at TRIUMF ([60s video](#))
- Upcoming:
 - Cold testing at -40 °C
 - Assembly of the first electrical petal with production components



The immediate future

- ITk site qualification, Pre-Production (5%)
- Full ATLAS ITk Production (by 2025)

The near future

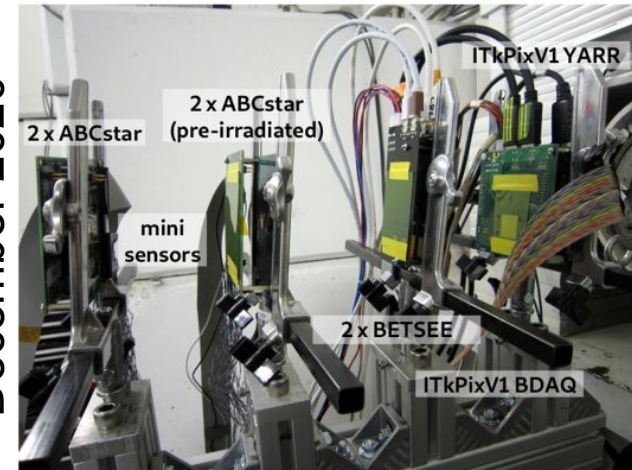
- Beam-test experiments
 - ASIC SEU tests at PIF (TRIUMF)
 - New temporal + spatial precision telescope (UBC/TRIUMF/SFU/Carleton)

- In 2020: the ABCStar V1 production chip became available
- SEU (proton beam) tests were needed for design verification, but travel restrictions and unavailabilities made usual testbeams impossible
- Within 6 months, irradiations organised and conducted at TRIUMF to qualify ASICs for collaboration* (thanks to PIF!)
“After the testbeam is before the testbeam”
- December 2020: pixel chip design verification needed
- Combined pixel + strips SEU testbeam, set up and conducted at TRIUMF
- First official ITk pixel + strips testbeam
→ Future opportunities for ASIC tests

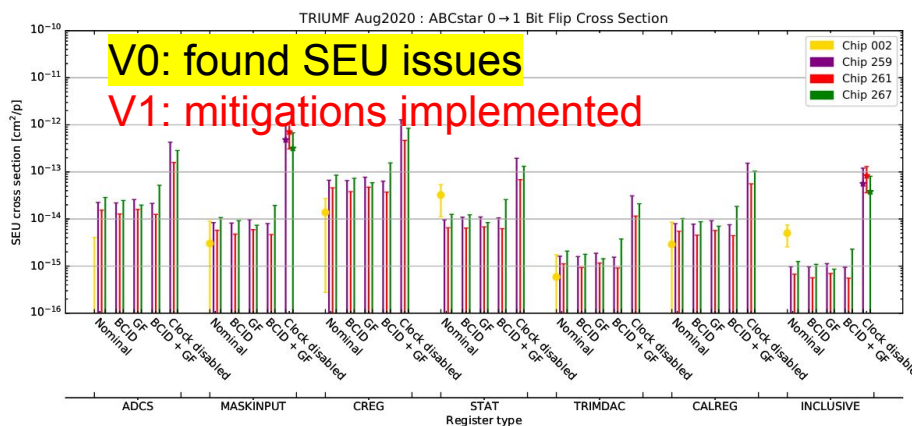
August 2020



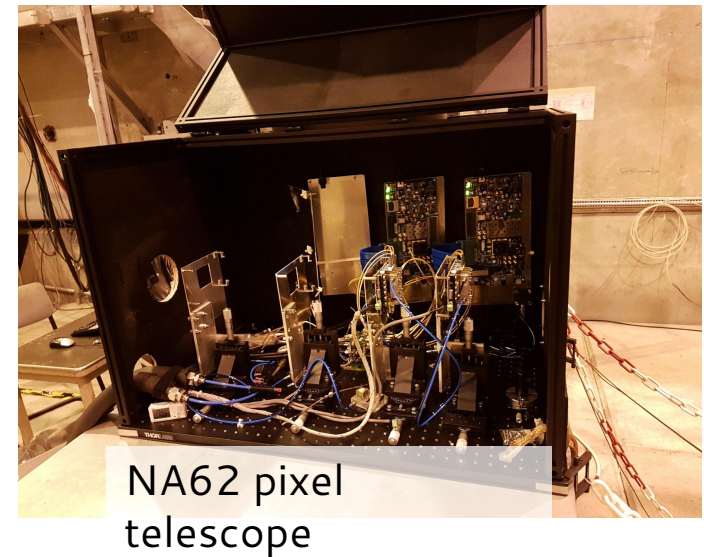
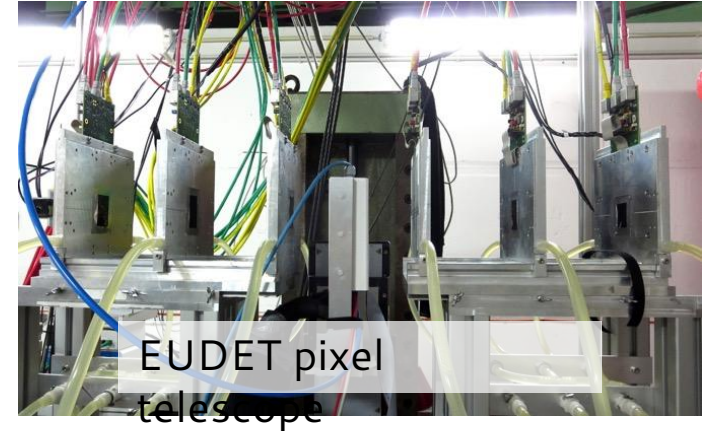
December 2020



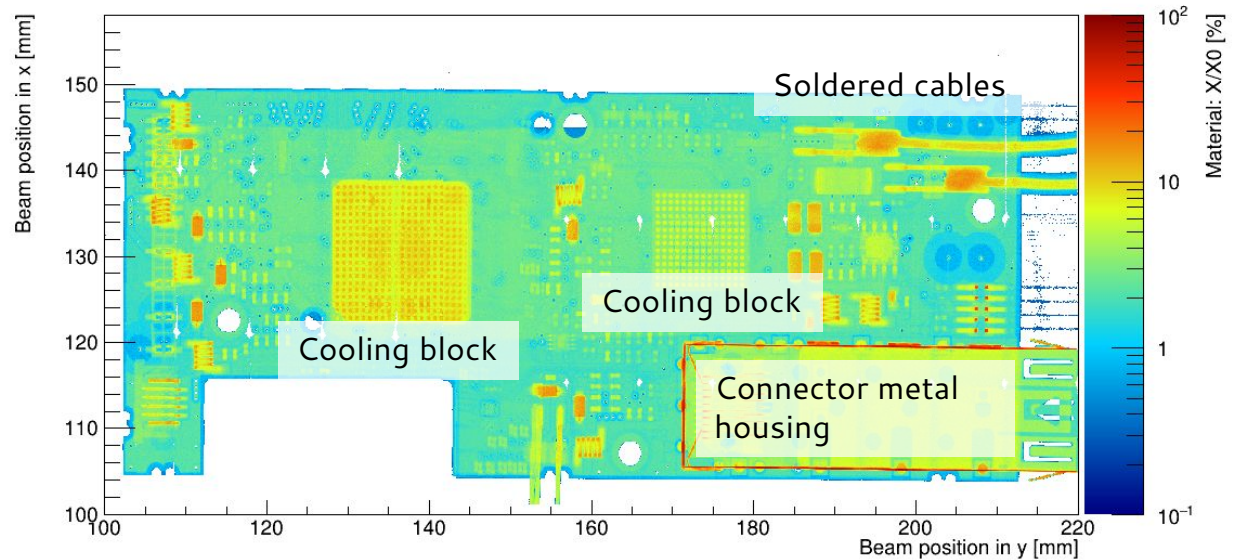
* paper in preparation



- Electron beam tests frequently performed as reliable test for sensor/module performance for ATLAS ITk
- Collaboration between TRIUMF and Carleton to bring EUDET pixel telescope to TRIUMF for future beam test preparation
- Combined effort to investigate synergies between NA62 pixel telescope (see next talk) and EUDET pixel telescope at TRIUMF

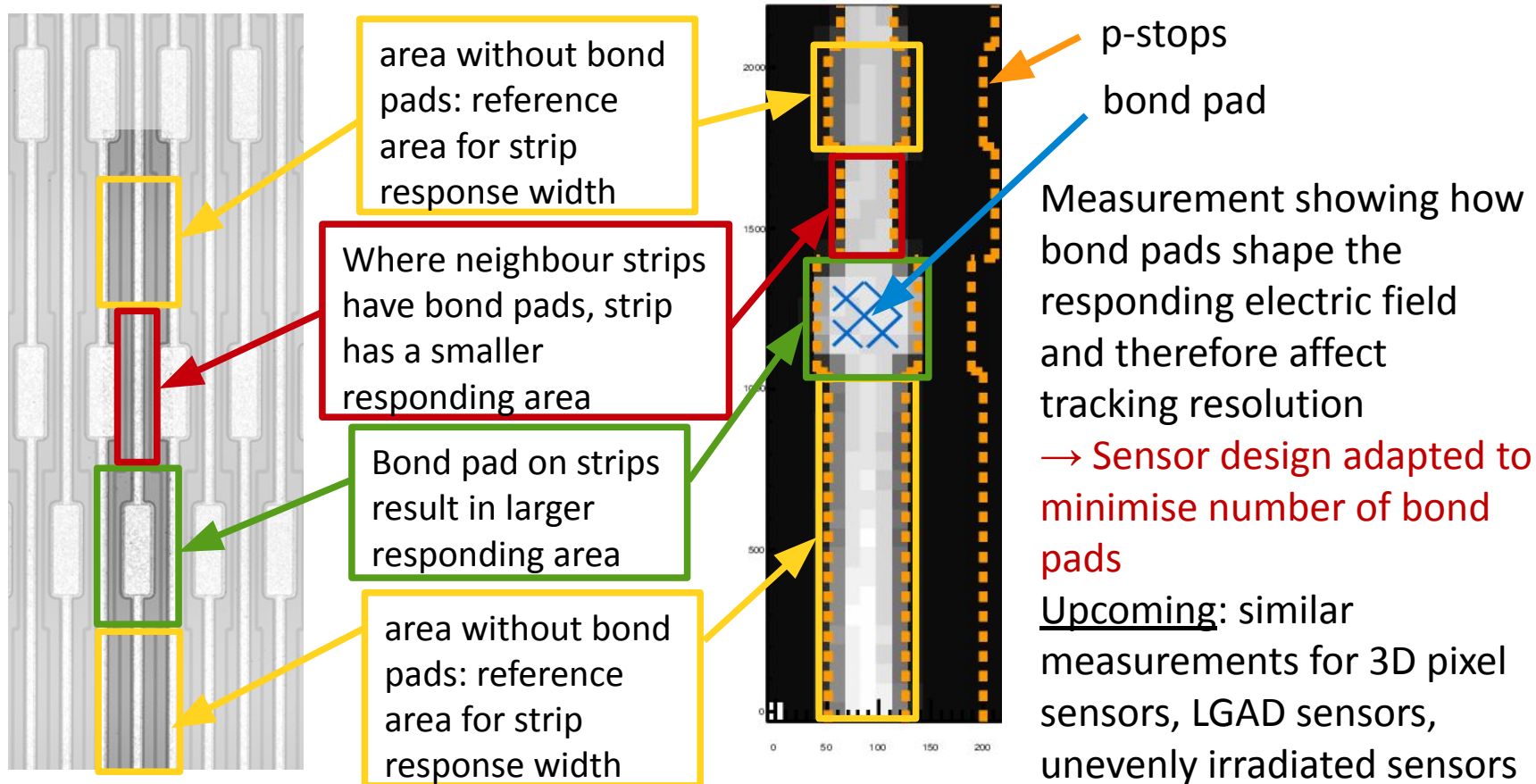


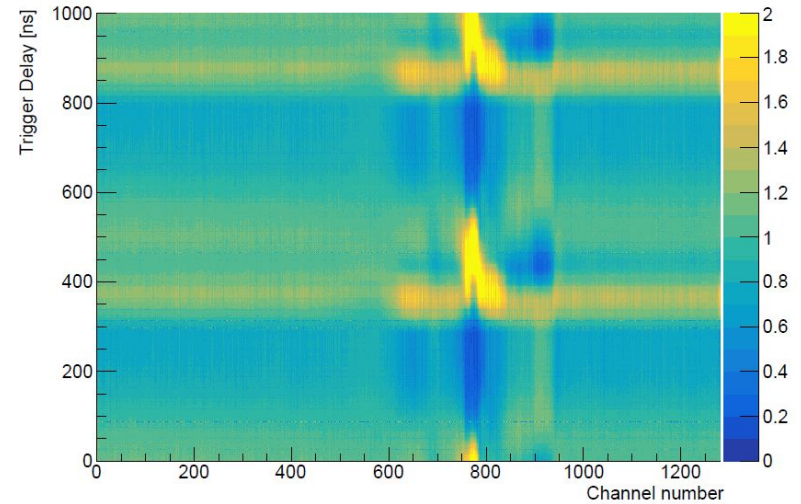
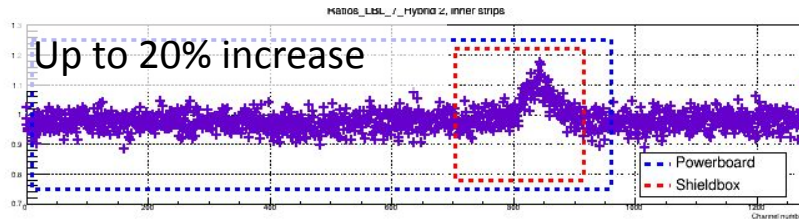
- More applications of electron beam measurements at DESY: mapping of material distribution in complex structures
- Better material description in simulation for material $> 1 \text{ X0}$



L. Poley et al 2021 JINST 16 P01010

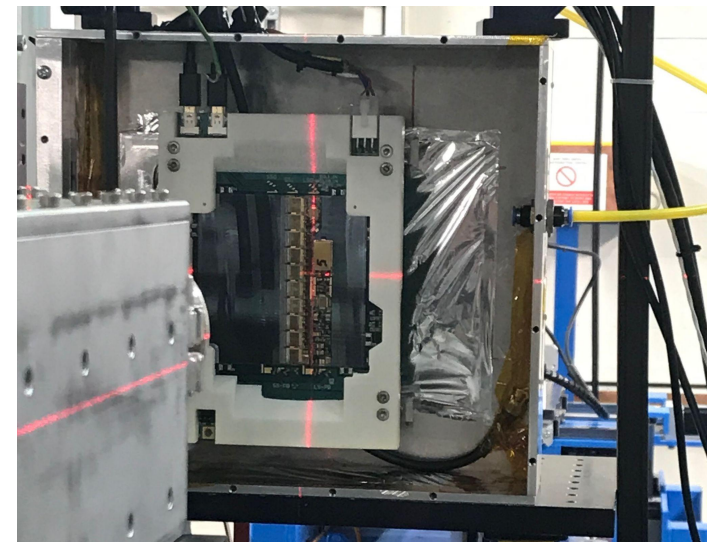
- Extensive experience with X-ray beam tests at the Diamond Light Source in the UK (*investigating options at Canadian Light Source*)





- Crucial measurement for ITk strip modules: need Signal-to-noise ratio > 10:1 end-of-life performance
- 1) general module QC showed that modules have high noise in presence of DCDC-switching circuit,
- 2) Dedicated follow-up measurement showed concern over time dependence: noise increase not always 20%, up to 100% depending on phase shift
- 3) Time-resolved signal-to-noise ratio measurement at the Diamond Light Source showing that Signal-to-noise ratio variations are safe for ITk*
- → Measurement only possible at photon beam

* published in Magnetic triggering — time-resolved characterisation of silicon strip modules in the presence of switching DC-DC converters
<https://iopscience.iop.org/article/10.1088/1748-0221/16/06/P06012>



The immediate future

- ITk site qualification, Pre-Production (5%)
- Full ATLAS ITk Production (by 2025)

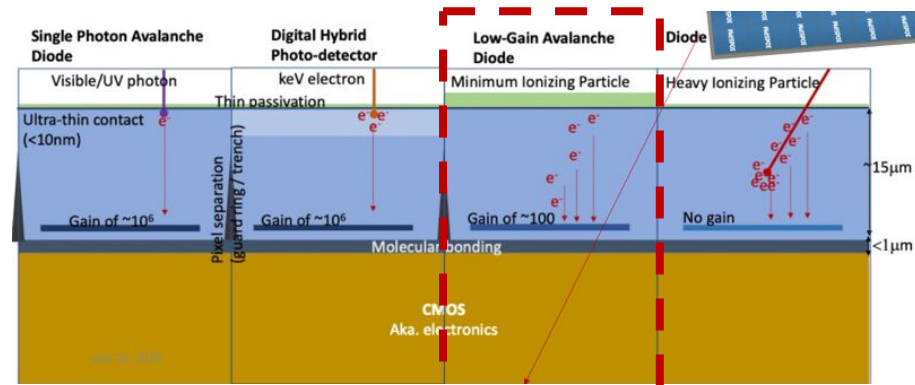
The near future

- Beam-test experiments
 - ASIC SEU tests at PIF (TRIUMF)
 - New temporal + spatial precision telescope (UBC/TRIUMF/SFU/Carleton)

Future tracking detectors

Silicon for future trackers

- Synergies between several directions of sensor developments and testing (SPAD/LGAD/SiPM)
- Establishing collaborations with local/global LGAD/SiPM effort*
- Participation via sensor testing and simulation for future R&D
- Investigation of options for LGAD collaboration with ITk colleagues (Carleton, SCIPP, CNM Barcelona) and within RD50
- Investigating silicon prototype fabrication at 4DLabs (SFU)



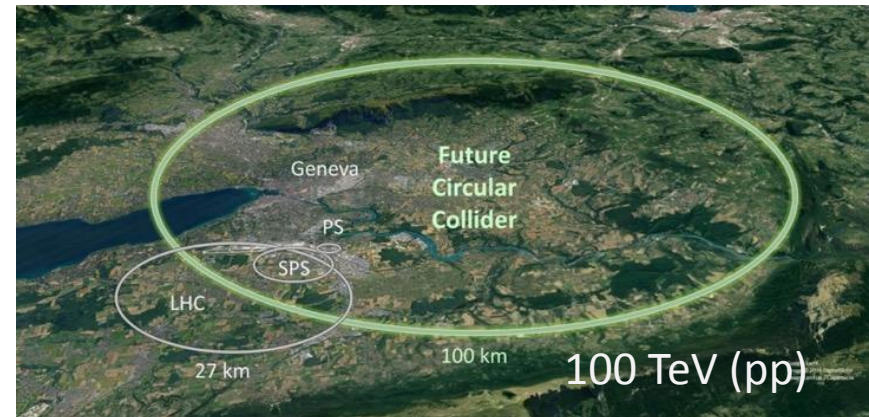
from Fabrice's PDC talk 2020

*See Thomas Koffas' talk at TRIUMF Science Week 2020: <https://meetings.triumf.ca/event/116/contributions/406/>

- Large infrastructure for silicon detector development and production exists now in Vancouver & across Canada
 - This positions us well for earlier involvement in future silicon-based trackers (R&D and production)
- Several proposals for future collider experiments on the time scale when the ITk is completed
 - International Linear Collider (ILC in Japan)
Strips + Pixel tracker
 - Circular Electron Positron Collider (China)
Pixel tracker
 - Future Circular Collider (FCC at CERN)
Pixel tracker
- New generation of trackers to be developed!

Future Circular Collider - FCC hh/ee

Another x10 increase in fluence!



The immediate future

- ITk site qualification, Pre-Production (5%)
- Full ATLAS ITk Production (by 2025)

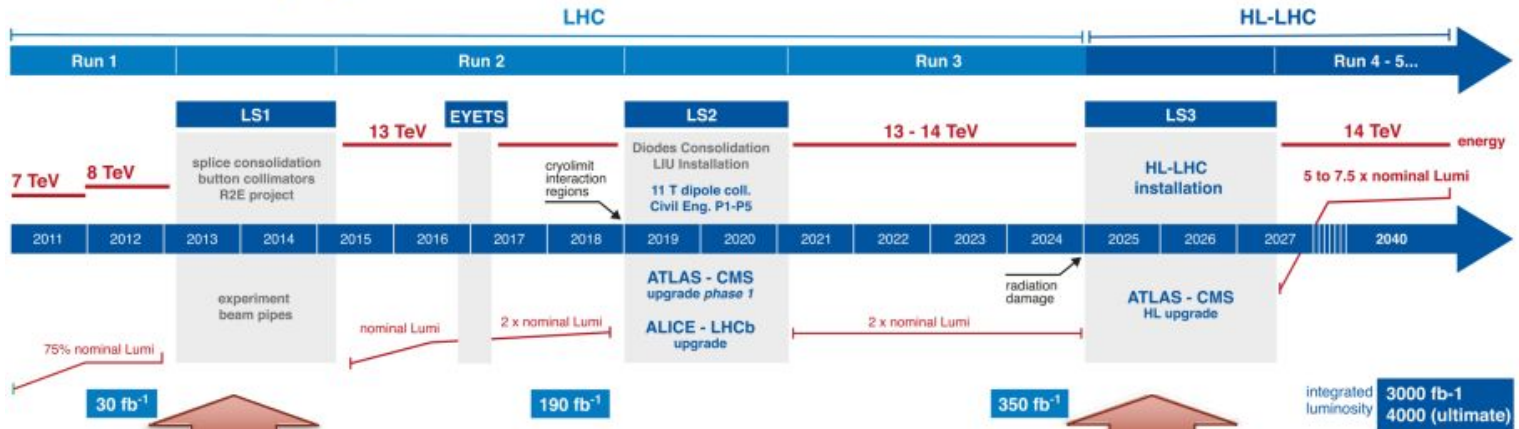
The near future

- Beam-test experiments
 - ASIC SEU tests at PIF (TRIUMF)
 - New temporal + spatial precision telescope (UBC/TRIUMF/SFU/Carleton)
- Next silicon R&D project (LGADs/SiPM)
- Investigate local silicon manufacturing
- Expand collaboration

Future tracking detectors

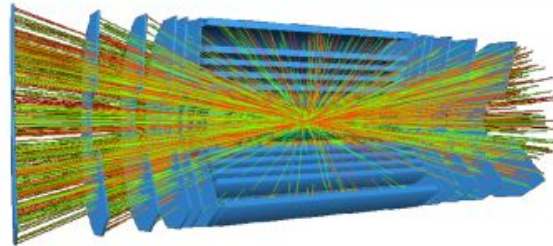
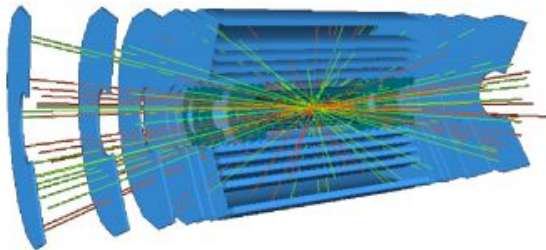
- ILC? FCC? CEPC?
- Join tracking detector effort matching our expertise:
 - ASICs, sensors, modules, loading, testbeam ...
 - Build the next tracker!

LHC Upgrade



Inner Detector (ID): Pixel+Strip+TRT upgraded by IBL

“Phase II”: full inner detector replacement (Pixel+Strip)



LHC
19 - 55 Pile-up events

High Luminosity LHC (HL-LHC)
140-200 Pile-up events

