

# ATLAS experiment - status and overview

TRIUMF Science Week, Jul 31st - Aug 4th 2023

Marco Valente

Particle Physics department

TRIUMF, Canada's particle accelerator centre

[marco.valente@cern.ch](mailto:marco.valente@cern.ch)



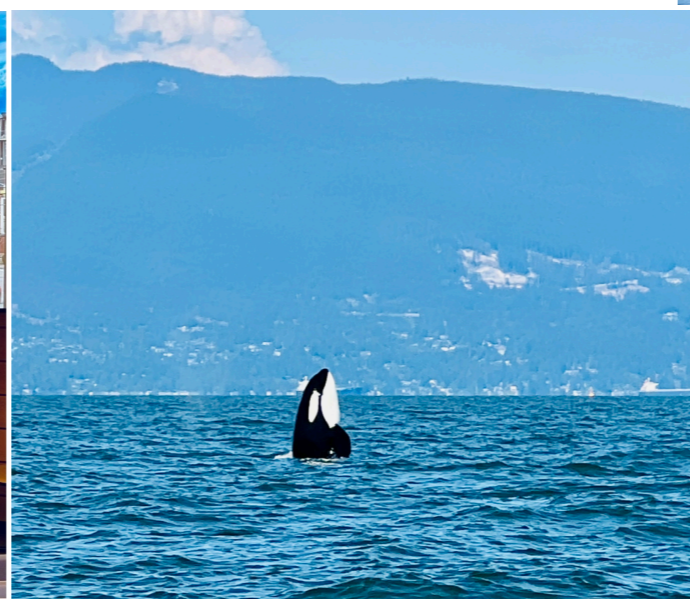
# Just had a very successful ATLAS week in Vancouver!

June 26th - 30th 2023

ATLAS experiment - status and overview



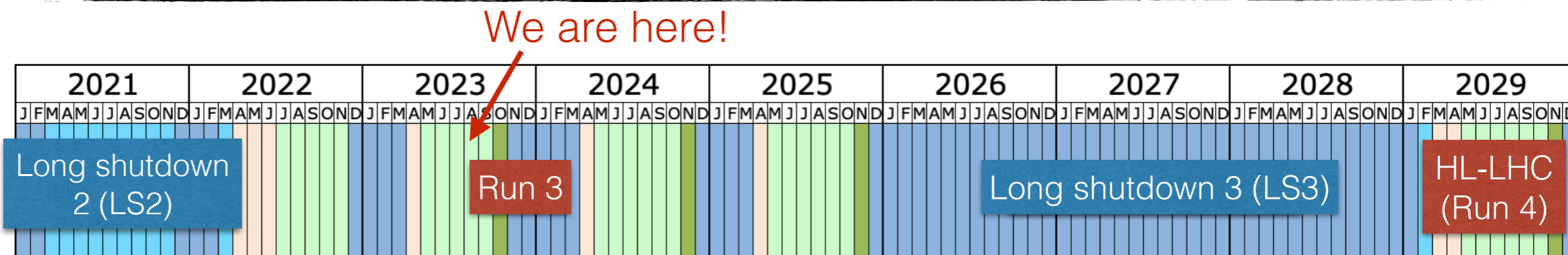
**ATLAS**  
WEEK 2023



Marco Valente  
Particle Physics department  
TRIUMF, Canada's particle accelerator  
Centre



# Where are we and what is happening



- Currently **restarted second year of the LHC Run 3 data-taking**. This will bring us:
  - More luminosity: currently considering 65 simultaneous pp collisions (aka pileup). Total expected collected Run 2+ 3 luminosity:  $\mathcal{L}_{\text{int}}^{\text{Run 2+3}} \sim 450 \text{ fb}^{-1}$
  - More energy:  $\sqrt{s}$  from 13.0 to 13.6 TeV (more interesting data expected!)
  - More detectors: New Small Wheels, better triggers (Phase-I L1Calo, HLT upgrades), and more!
- **HL-LHC (Run 4) also quickly approaching (2029)!**
  - More simultaneous pp collisions (200!) will require detector upgrades, such as the new Inner Tracker (ITk).

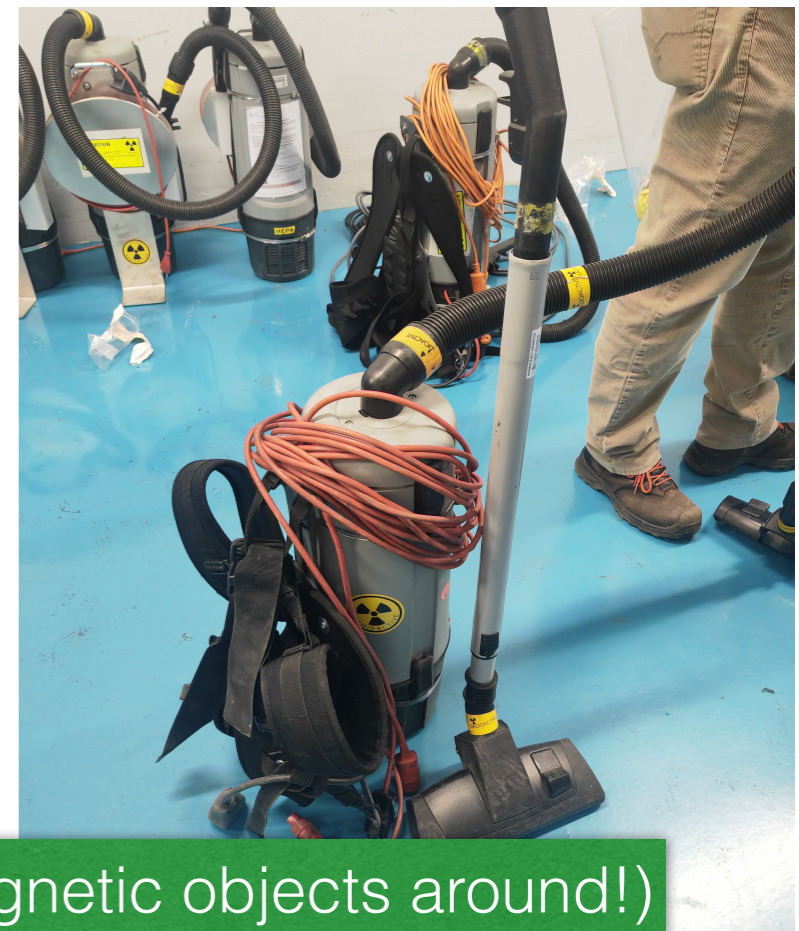
Will provide an overview of these activities and our involvement here (can't cover everything!)



# Our team has restarted and operated ATLAS!



Russell Bate (UBC graduate student) in the ATLAS Control Room as shift leader



ATLAS Cavern cleaning (no radioactive dust or magnetic objects around!)



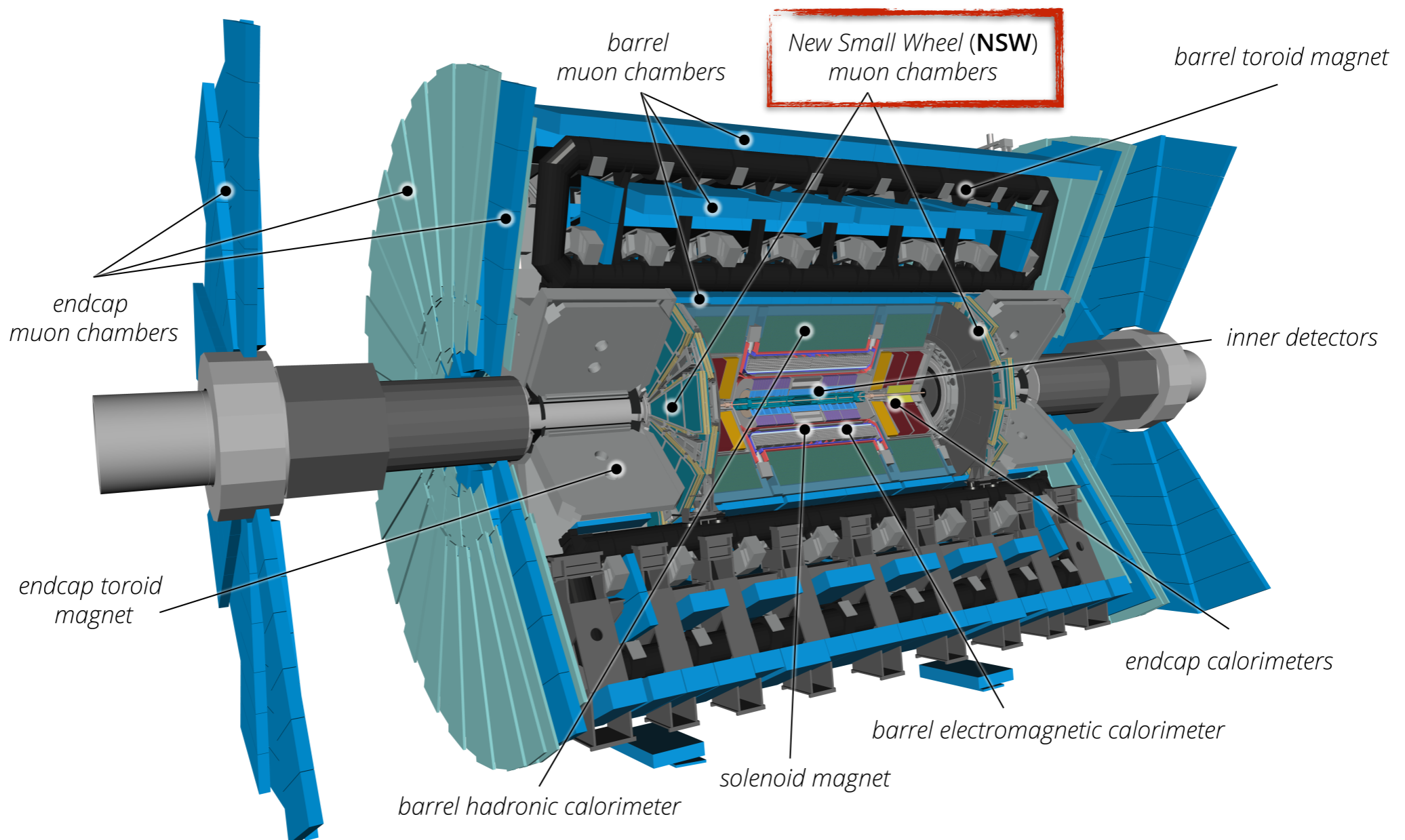
Dilia Portillo (TRIUMF postdoc)



# New Small Wheels (NSWs)

## Overview

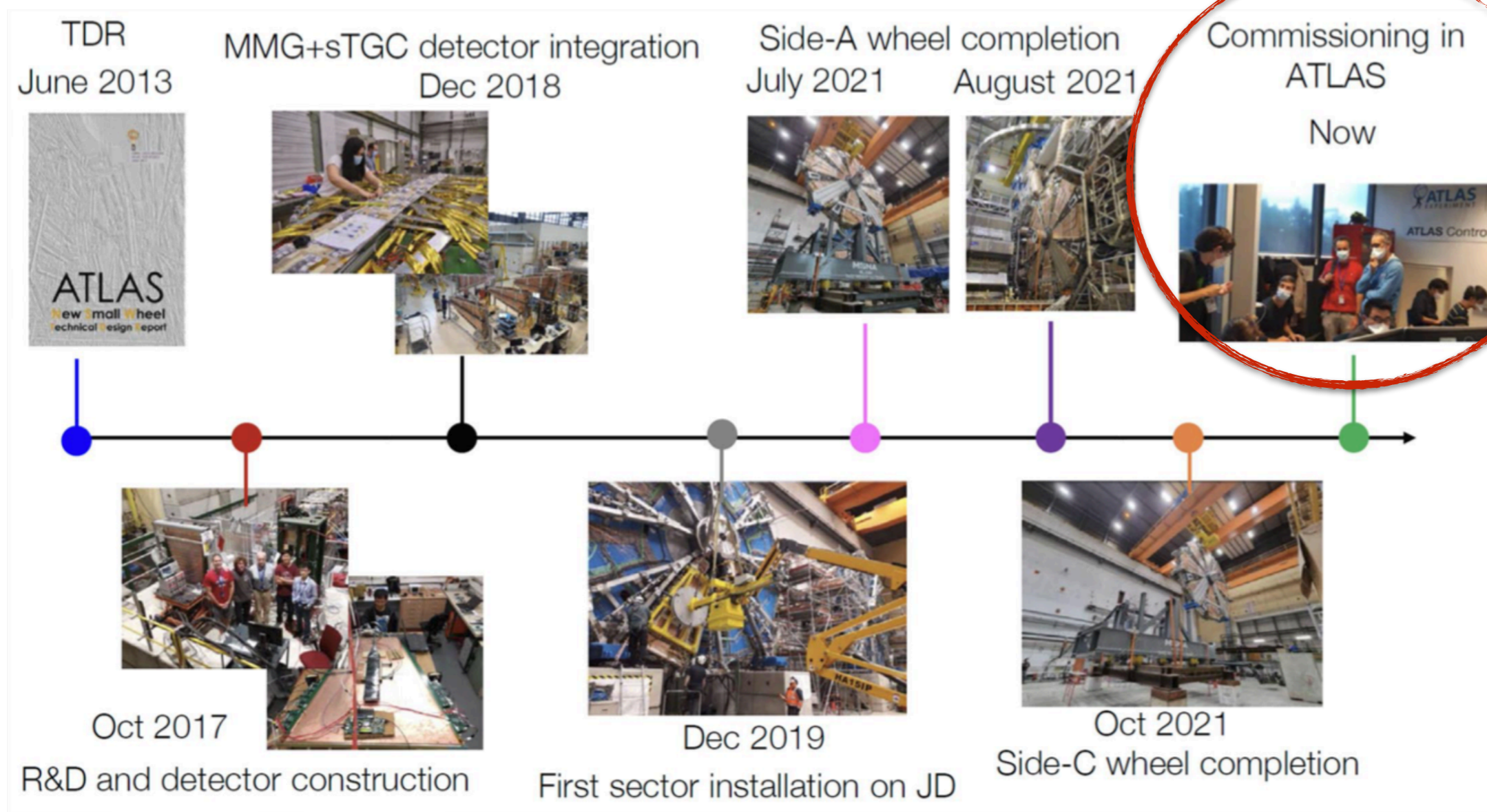
- New detectors for Run 3! Allow for **improved muon  $p_T$  resolution** and high-efficiency triggering with lower output rates
  - Two technologies: **small-strip Thin Gas Chambers (sTGCs)** and **micro-mesh gaseous structure detectors (Micromegas)**



# New Small Wheels (NSWs)

Recap and status

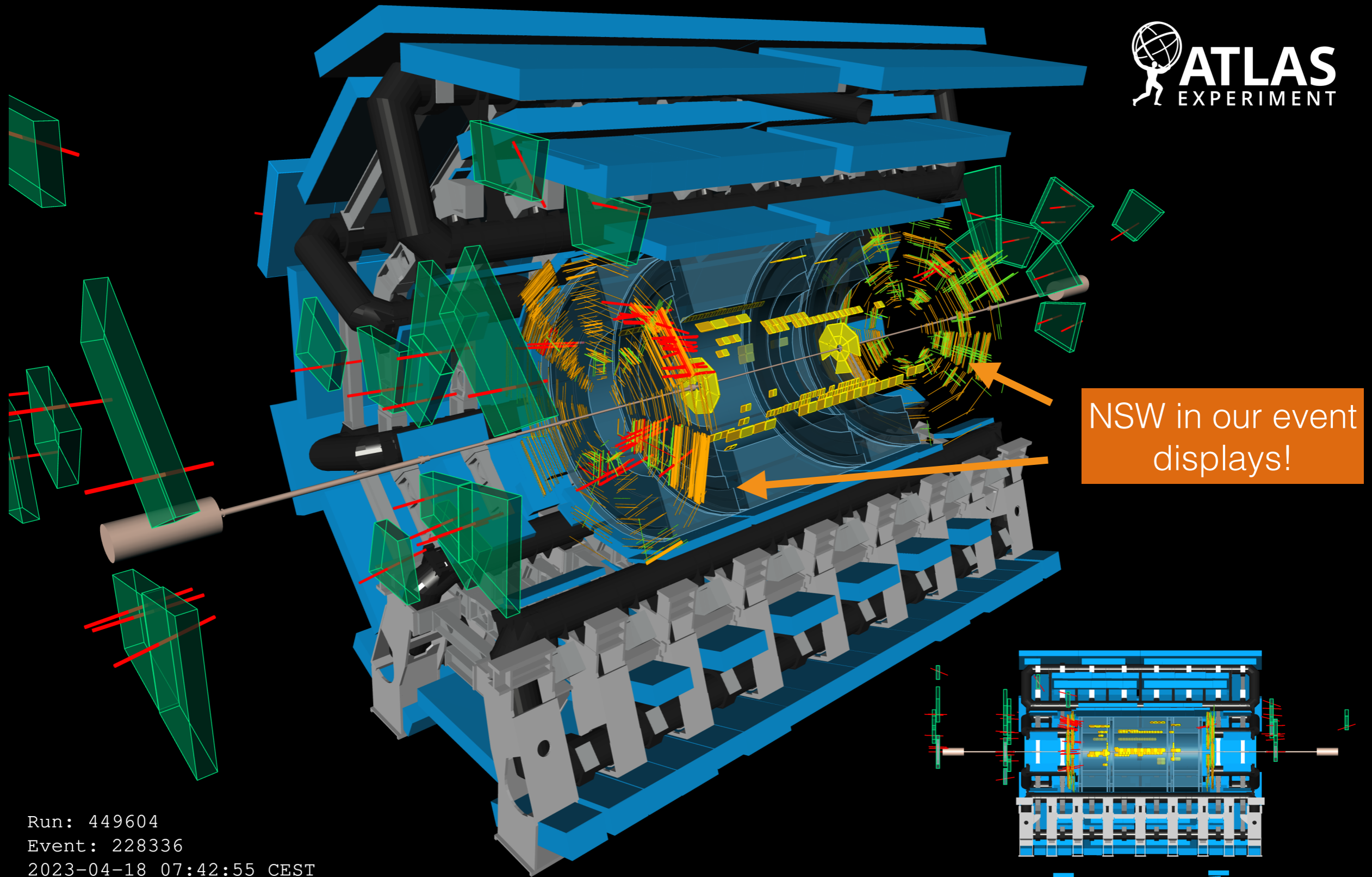
- **Both wheels completely installed in 2021** during LHC shutdown. Now in commissioning for Run 3!
- Last year focus: implement wheels readout in **software reconstruction and trigger.**



Adapted from [T. Xu](#)



NSWs now fully implemented in muon reconstruction software!



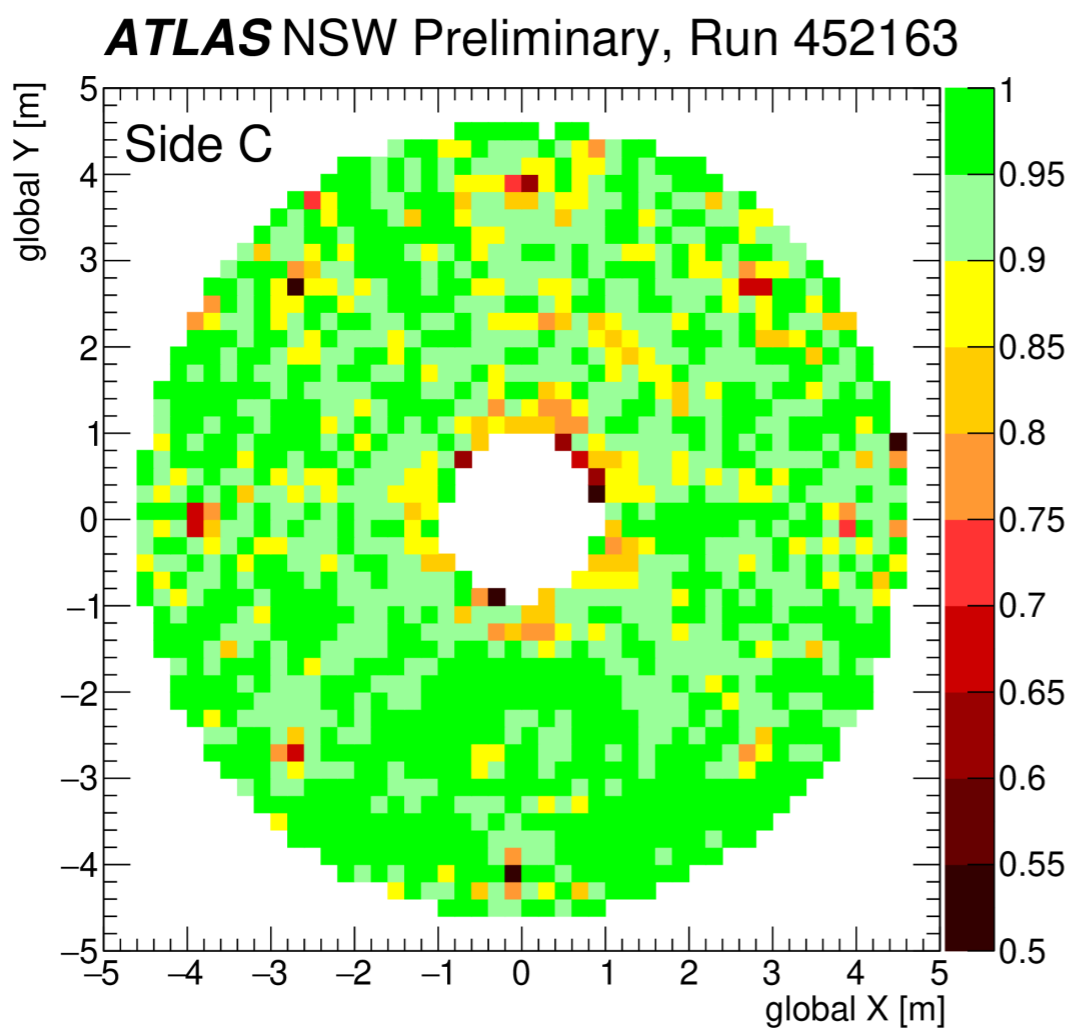
NSW in our event displays!

Run: 449604  
Event: 228336  
2023-04-18 07:42:55 CEST

# New Small Wheels (NSWs)

Performance and triggers

- Recently **assessed reconstruction performance** and **implementation inside L1 trigger**:
  - Performance: **efficiency** for at least 4 hits in MMs and sTGCs **above 95% for muon tracks**
  - L1 trigger: full trigger chain successfully integrated very recently to release the rate pressure from high pileup conditions
- Huge work from TRIUMF team** at CERN to make certain NSW operations can run smoothly
  - Lots of work and resolution of issues to make certain detector could achieve this successful performance



Marco Valente  
Particle Physics department  
TRIUMF, Canada's particle accelerator  
Centre

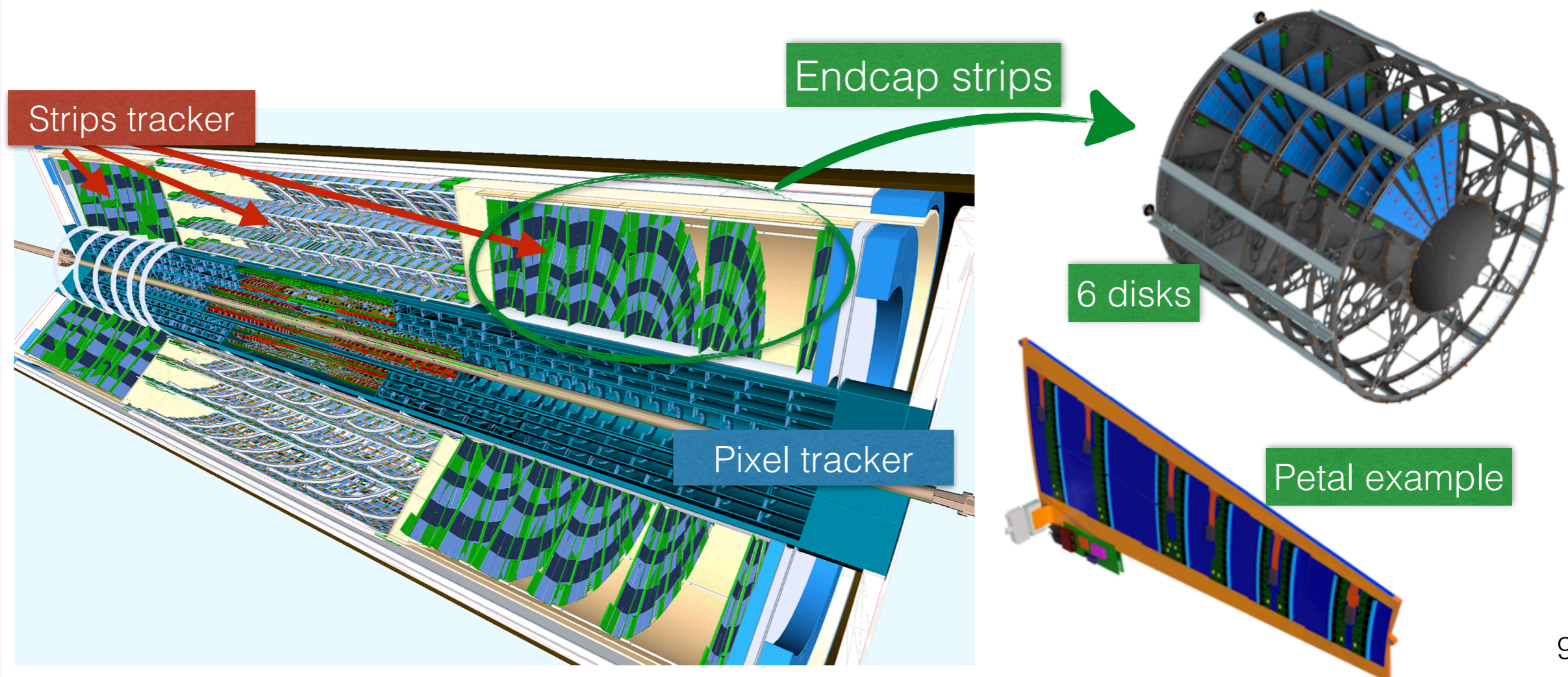




# Inner Tracker (ITk)

## Overview

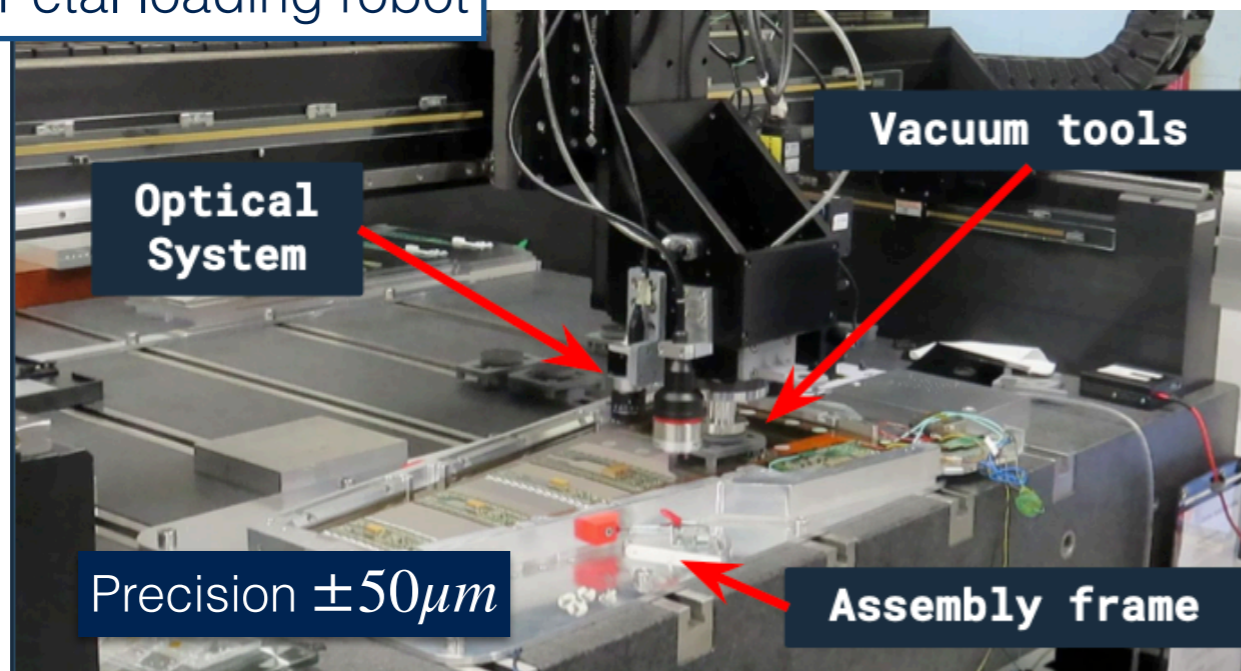
- **Fundamental new piece** of ATLAS to **cope with the 200 simultaneous pp collisions** of the HL-LHC, expected to start in 2029.
  - Detector composed of silicon **pixels** (inner part) and **strips** trackers (outer part) and aiming at **detecting charged particle tracks**.
- **TRIUMF/SFU/UBC** (and Canada) largely involved in the **construction of endcap strip detectors**.
  - **Endcap strips** composed of **6 disks** made of **32 identical petals**.



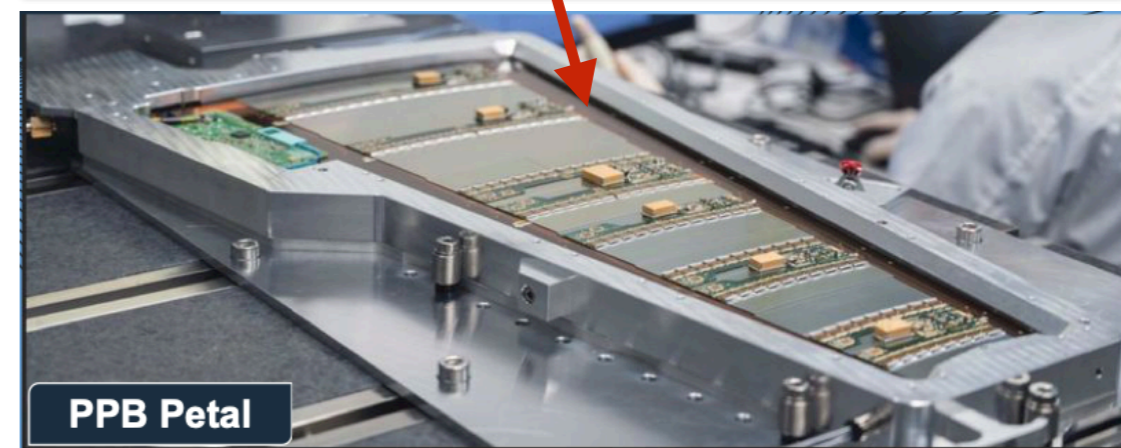
# End-cap strip tracker status

- TRIUMF/SFU/UBC involved in: modules **assembly**, sensor/module **testing**, petal **loading**, petal **testing** as well as **testbeams**.
  - Cleanrooms equipped with high performance wire-bonders, metrology, electrical testing and inspection equipment.
- For successful ITk installation (~2027-2029) **critical to have small pre-productions of modules** to catch possible issues as early as possible.
  - **Second phase of pre-production B (PPB) recently finished.**
  - Currently **moving from pre-productions to full detector productions**. Soon receiving more modules to assemble/test and petals to load for the final detector!

Petal loading robot



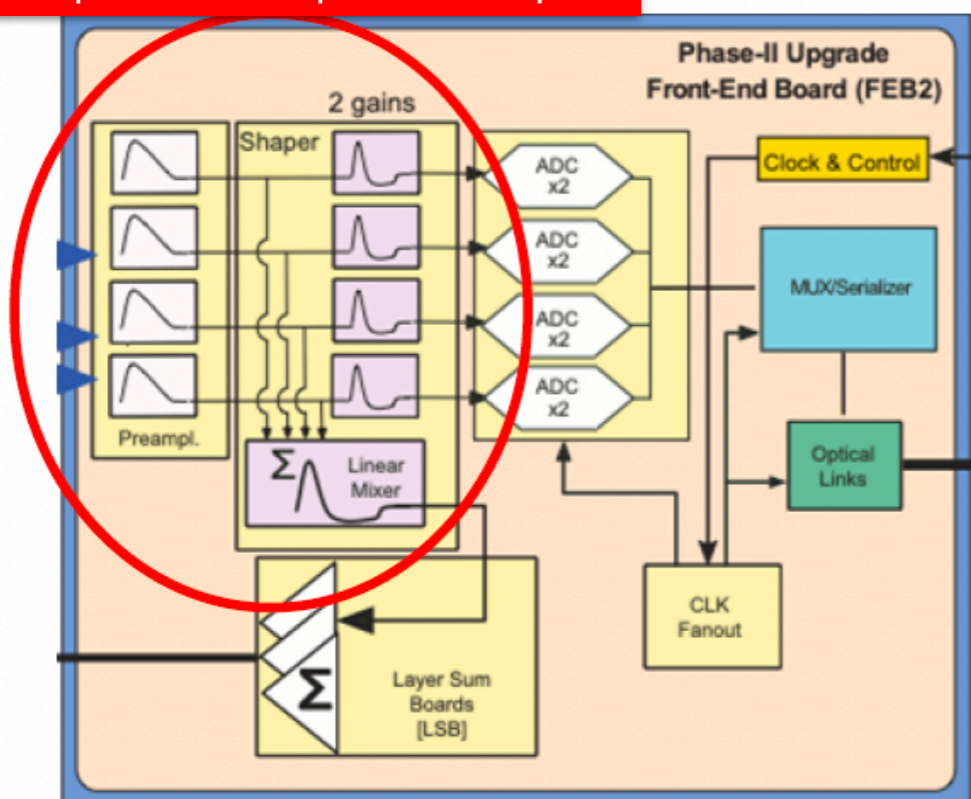
We assembled the first pre-production petals in ATLAS and we were the first endcap site to go through qualification. 🚀



# LAr calorimeter Front End

- Another important HL-LHC upgrade is the new Liquid Argon (LAr) Calorimeter **Front End Boards electronics (FEB2)**
  - Allow for **lower noises**, **improved read-out** and **high-granularity input** for new HL-LHC L0 trigger.
- **TRIUMF contributing to ASICs of shaper and pre-shaper** for Hadronic End-cap calorimeter (HEC)
  - Current measurements show **good agreement with specs**. **Only few % degradation with 20x** the required **irradiation** dose (63 MeV protons at PIF).
- Status: 300 pre-production ASICs manufactured and packaged now. Co-op student will test prototype ASICs with HEC preamplifiers and cables.

## Shaper and pre-shaper



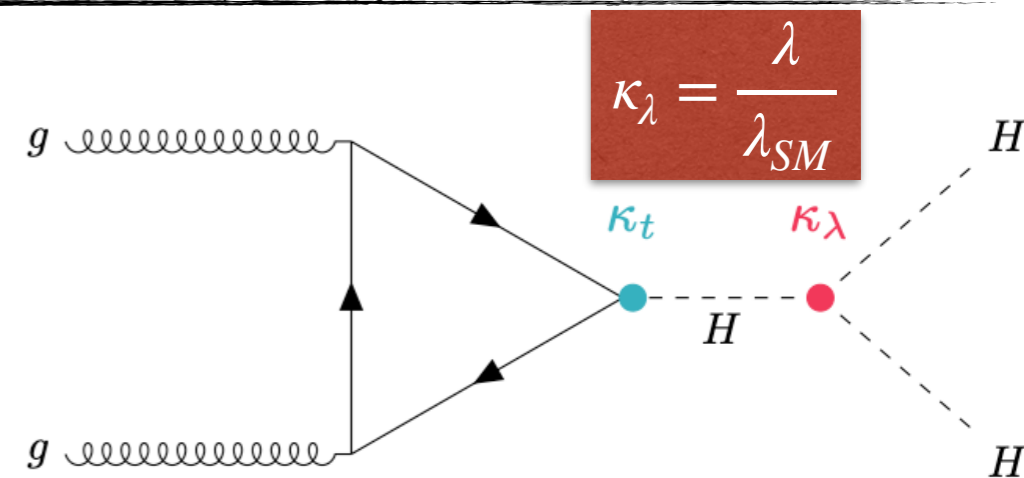
## HEC pre-shaper (HPS2) specs

Parameter	Requirement	HPS2A	Comment
Input impedance	50±5 Ω	50±3 Ω	Acceptable
Output DC Out-P	300 mV	Doable	Might be small asymmetry
Out-N	900 mV	Doable	
PS G2/G1 ratio	2.00±0.05	1.9±0.1	Acceptable
HG/LG ratio	22±5	22.5±2.5	Acceptable
Rise time	45±1 ns	Doable	Acceptable
Linearity	<±0.5%	0.3%	Acceptable
Noise (ENV)	<20 mV	18 mV	Acceptable
Xtalk LG-LG	<0.5%	0.4%	Acceptable
HG-HG	<0.5%	0.3%	Acceptable
LG-HG	<11%	2%	Acceptable
Saturation recovery	< 450 ns	140 ns	Acceptable
TS rise time	35±1 ns	Doable	Acceptable
TS uniformity	<5%	4%	Acceptable
TS g3/g1 ratio	3±0.45	3.1±0.1	Acceptable
TS linearity	<2%	0.4%	Acceptable
Consumption	<650 mW	305±15	Acceptable
PSRR for 1.2V	>10 db at <1 MHz	13 db	Acceptable
2.5V		18 db	Acceptable

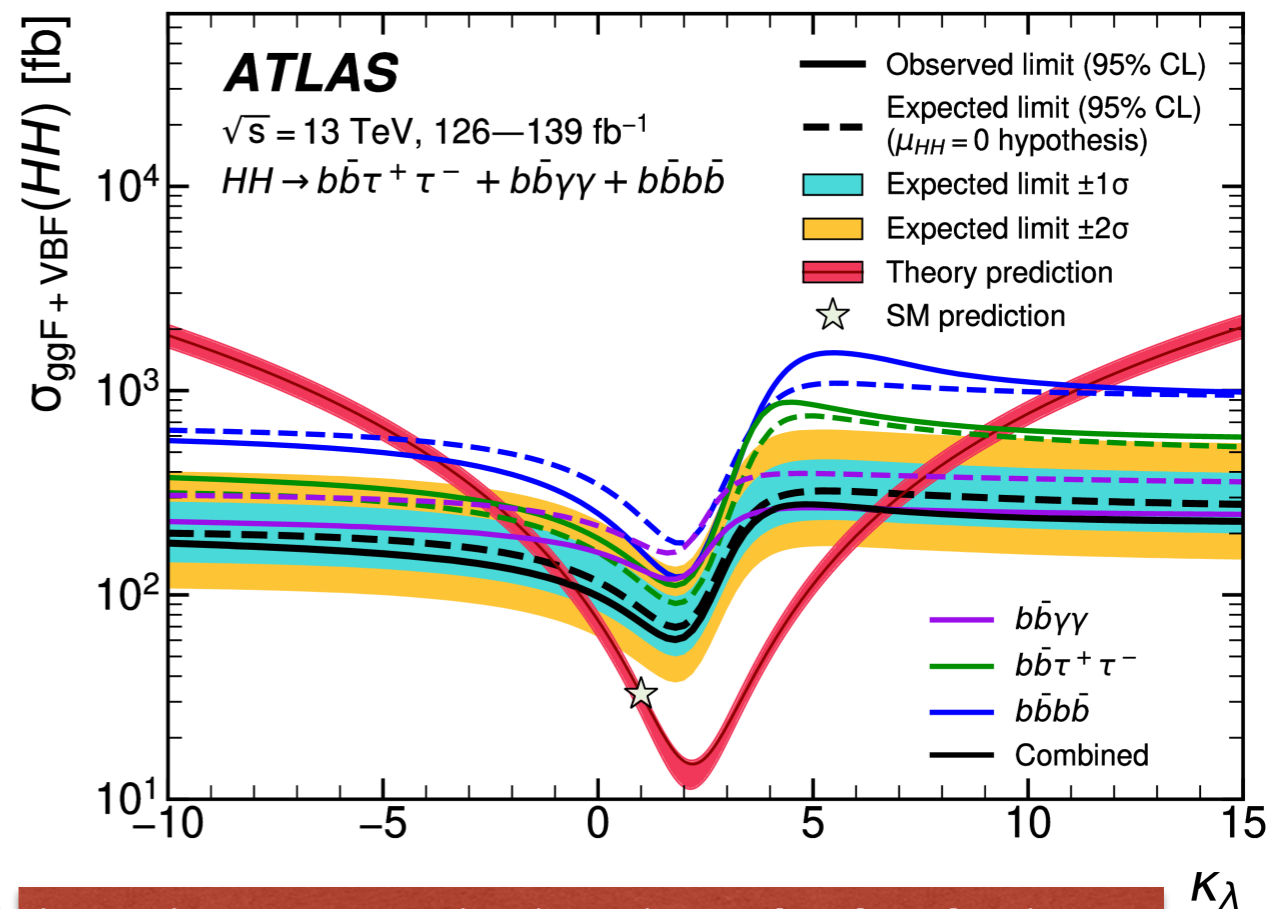
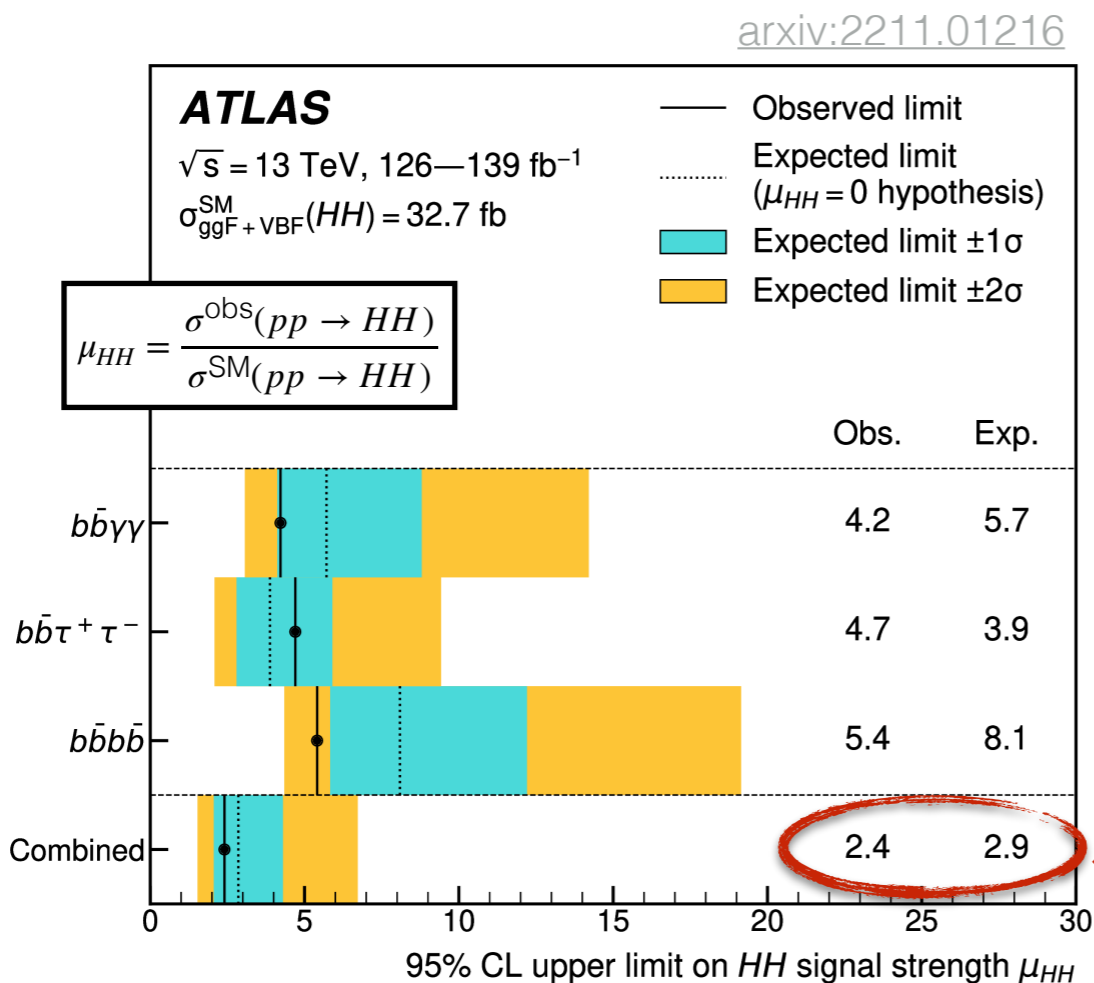
Recent physics results  
with Run 2 dataset  
(140 fb<sup>-1</sup>)

# Di-Higgs searches and combination

- The **Higgs self-interaction** ( $\kappa_\lambda$ ) is an extremely interesting process as it provides access to the shape of the Higgs potential.
- Recently published non-resonant Run 2  $HH \rightarrow b\bar{b}b\bar{b}$  search ([arXiv:2301.03212](https://arxiv.org/abs/2301.03212)) and combination ([Phys.Lett.B 843 \(2023\) 137745](https://arxiv.org/abs/2301.137745)) with **complete Run 2 dataset**.



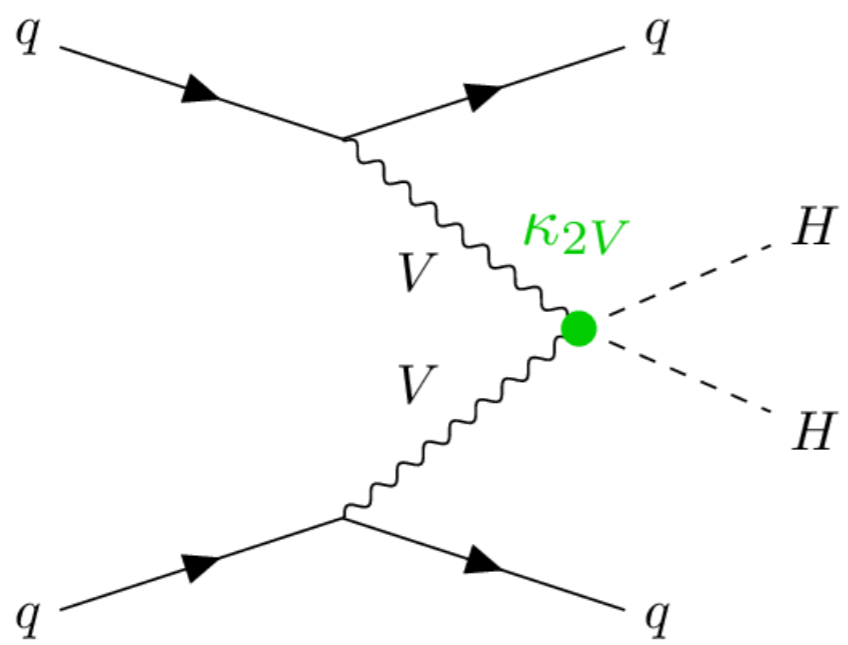
Observed  $\kappa_\lambda$  range (95% CL) [-0.6,6.6]!  
 Expecting to exclude  $\kappa_\lambda = 0$  with Run 3 dataset



Large improvement thanks to larger **luminosity**, better **reconstruction** (b-jet) and **analysis improvements**

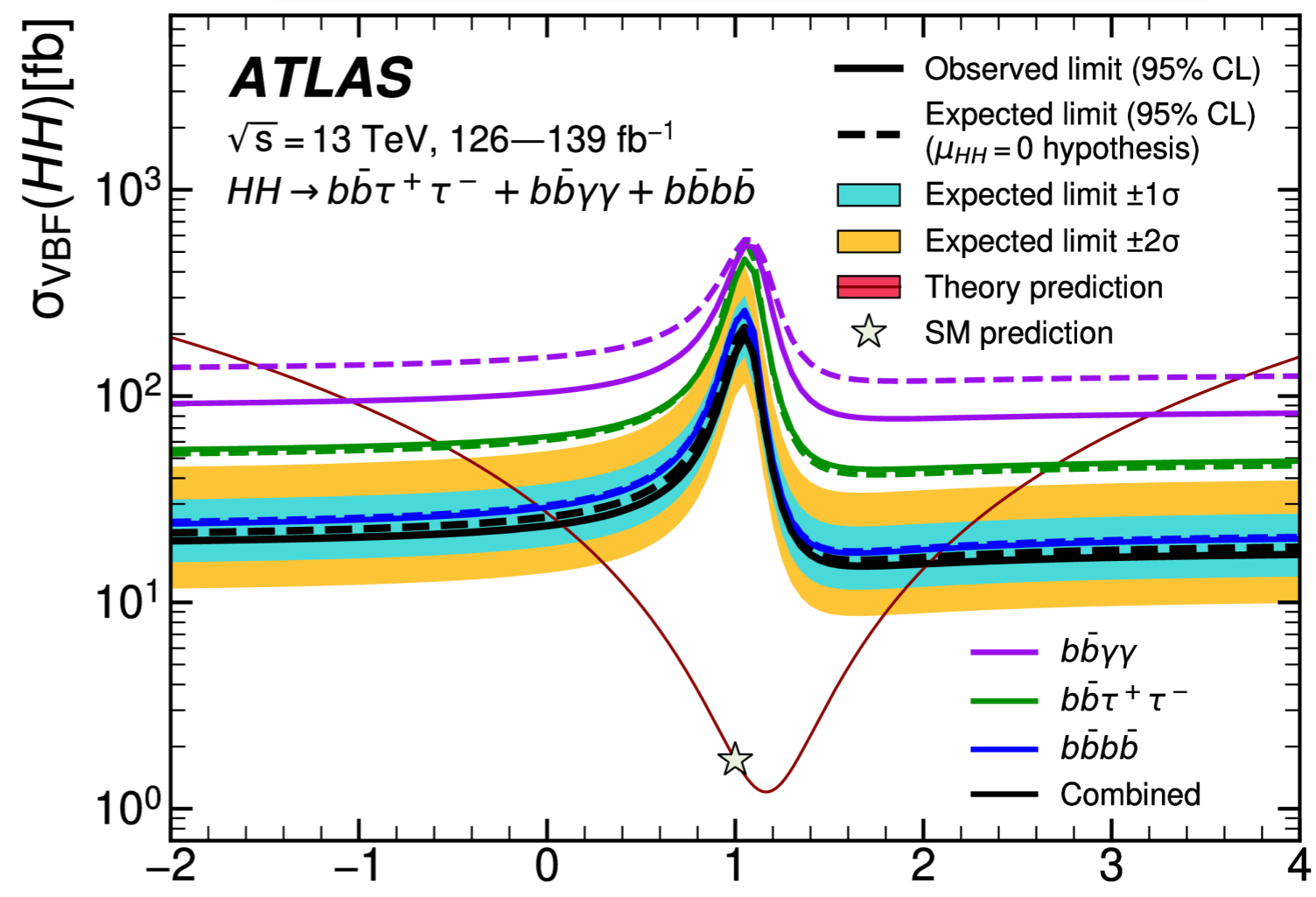
# New constraints on VBF $HH$ production

- Extracted also **constraints on VVHH Higgs coupling** through scan of  $\kappa_{2V}$ .
  - $b\bar{b}b\bar{b}$  has the **best sensitivity** overall due to dedicated  $\kappa_{2V}$  categories and high BR(HH) and acceptance in VBF regime.



$\kappa_{2V} = 0$  excluded at 95% CL with complete Run 2 statistic ( $139 \text{ fb}^{-1}$ )

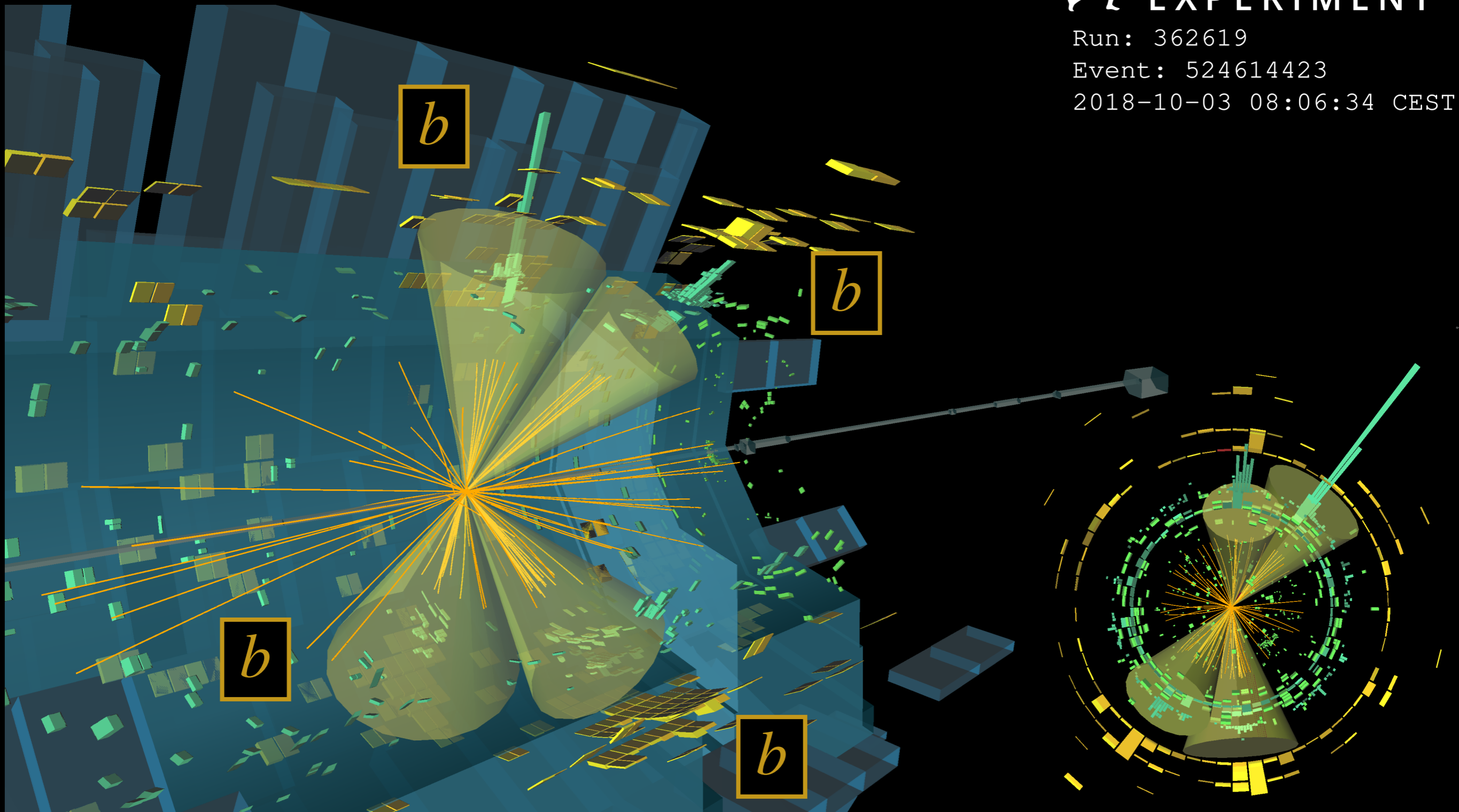
Allowed observed  $\kappa_{2V}$  range:  $0.1 < \kappa_{2V} < 2.0$



Run: 362619

Event: 524614423

2018-10-03 08:06:34 CEST

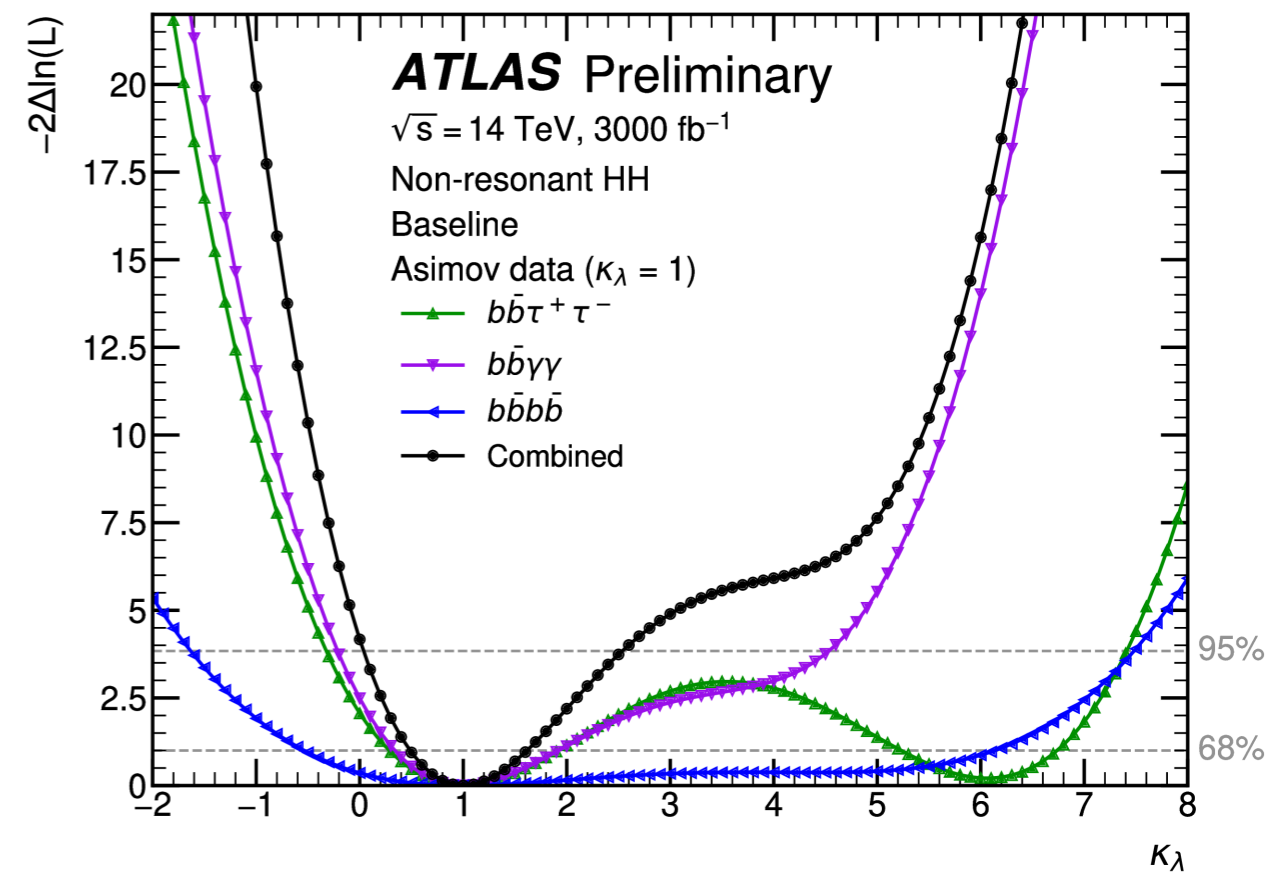
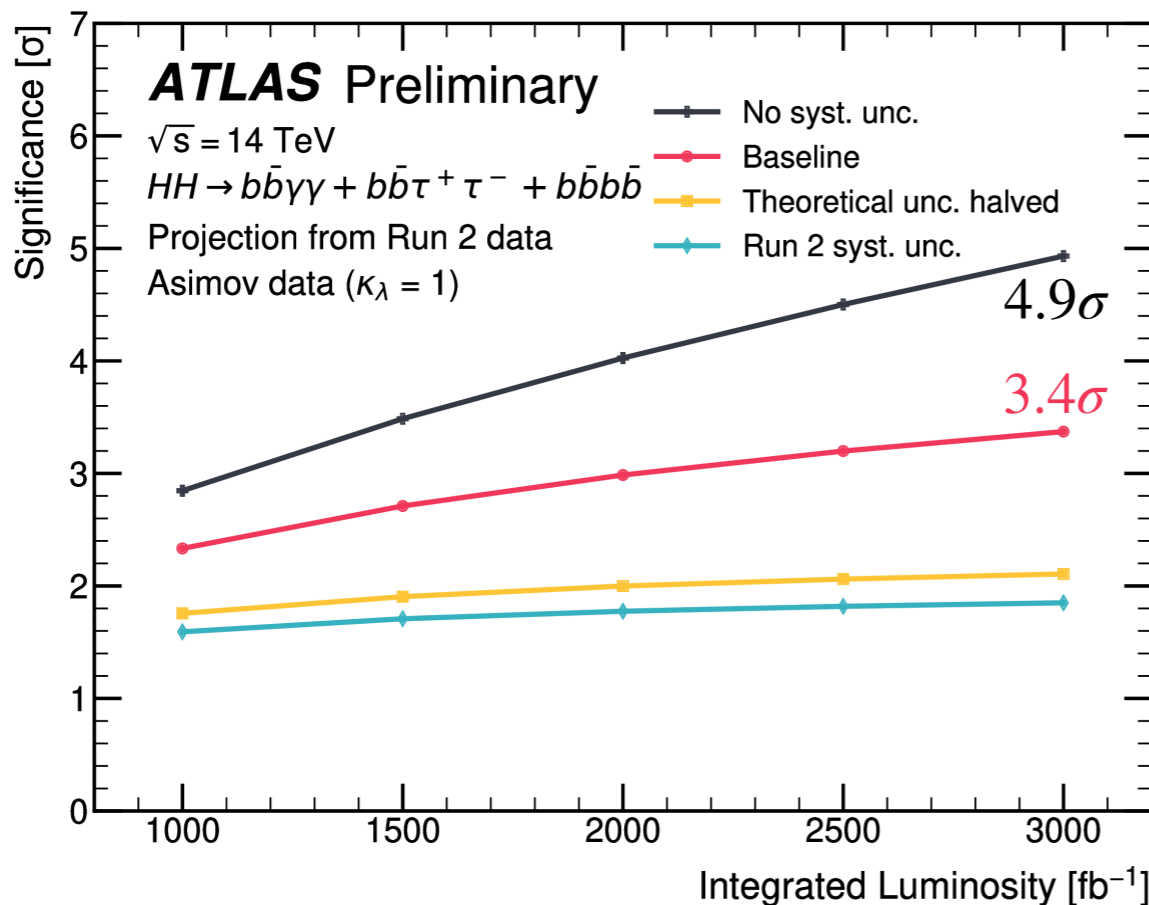


$HH \rightarrow b\bar{b}b\bar{b}$  event display by Colm Sam (UBC)

# Updated HL-LHC projections for HH

[ATLAS-PHYS-PUB-2022-053](#)

- Assuming Run 2 detector performance and expected reduction of systematics, **statistical evidence ( $3.4\sigma$ ) is expected for SM HH ( $\kappa_\lambda = 1$ )** with  $3000 \text{ fb}^{-1}$ .
  - SM signal strength  $\mu_{HH}^{\text{SM}}$  measured with 30% precision.**
  - $\kappa_\lambda$  constrained to  $[0.5, 1.6]$  at 68% CL.**
- Reduction of systematic uncertainties could bring us close to discovery ( $4.9\sigma$  with stat. only).** And we still have to combine with CMS! 😊





# Summary and outlook

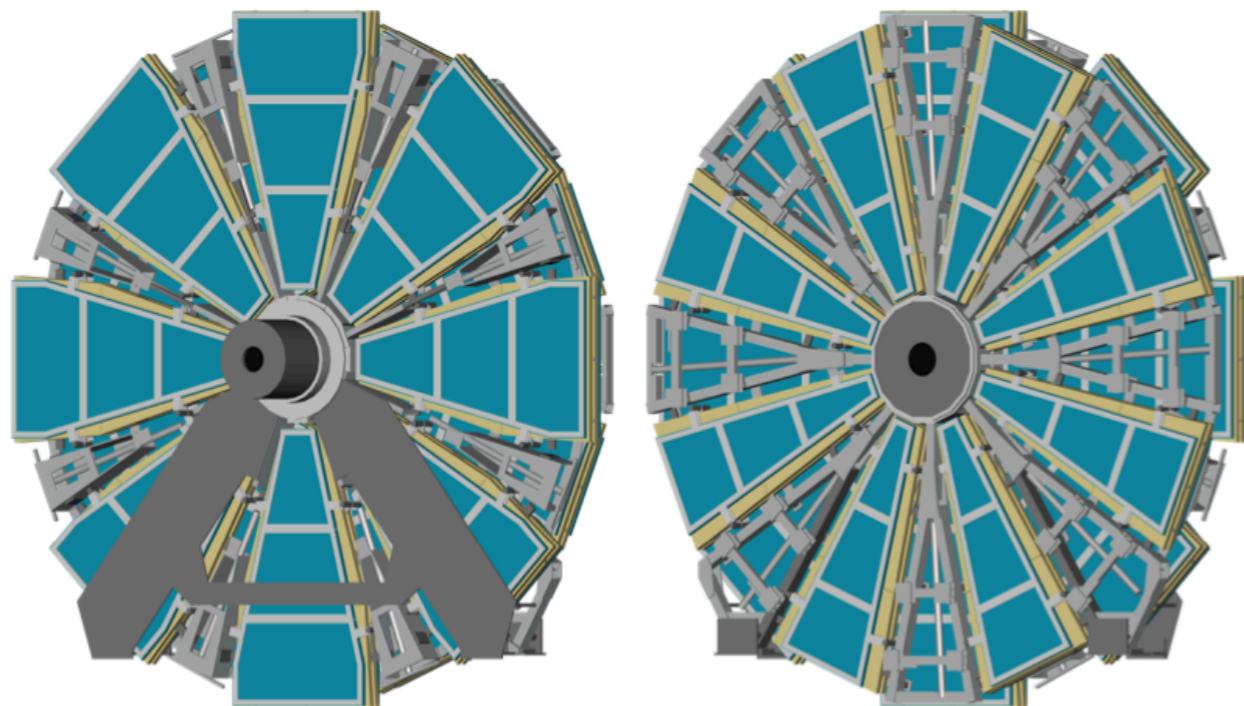
---

- New Small Wheels approaching standard operation. Readout **already included in reconstruction and L1 trigger**.
- **ITk pre-production finished** and **first ATLAS endcap petals built by our team!**
  - **First site to qualify for module production!** Full transition to production ongoing.
- Phase-2 LAr Front-End boards upgrades continues and current ASIC measurements found to be in agreement with specs.
- Many **new Run 2 physics results published:**
  - **Huge improvements achieved for HH** and **Run 3 will bring us even more** (more luminosity, better triggers, etc.). If something is really unexpected in the Higgs potential, we could start to see it with the Run 2+3 dataset!
- **Many topics not covered today:** ML4Pions, displaced SUSY searches, VBF single-Higgs measurements, dark jet searches, HLT muon performance, jet triggers, and more.



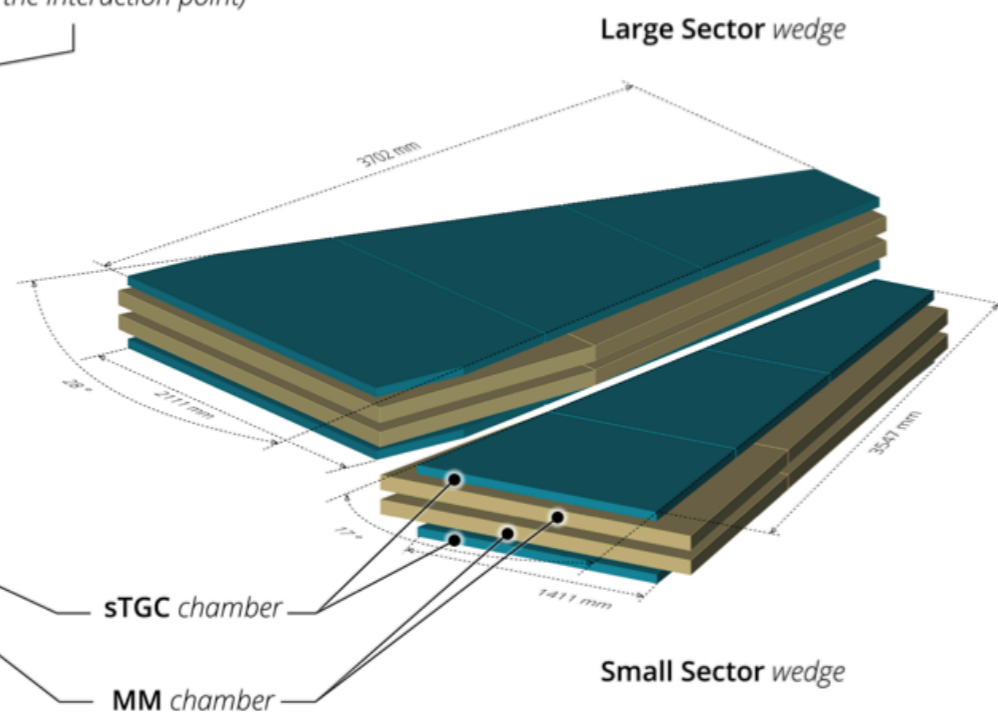
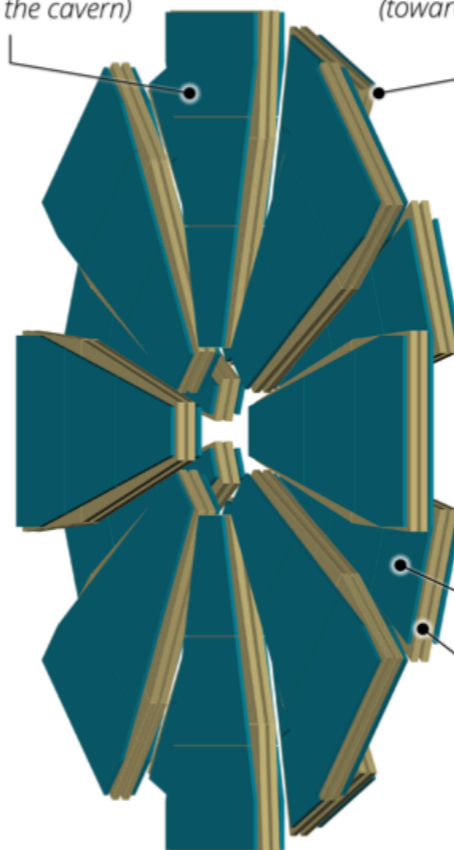
**Backup**

# New Small Wheels



Large Sector  
(toward the cavern)

Small Sector  
(toward the interaction point)



Large Sector wedge

Small Sector wedge

STGC chamber

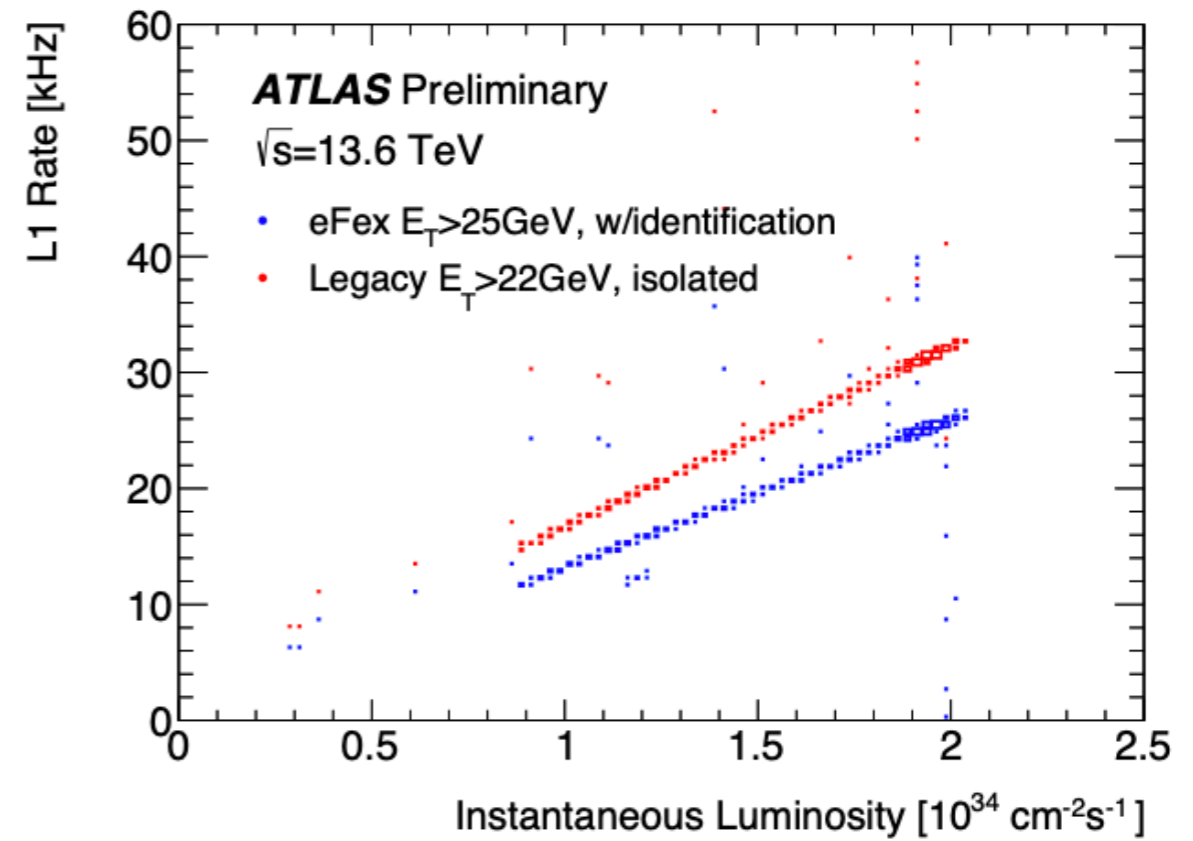
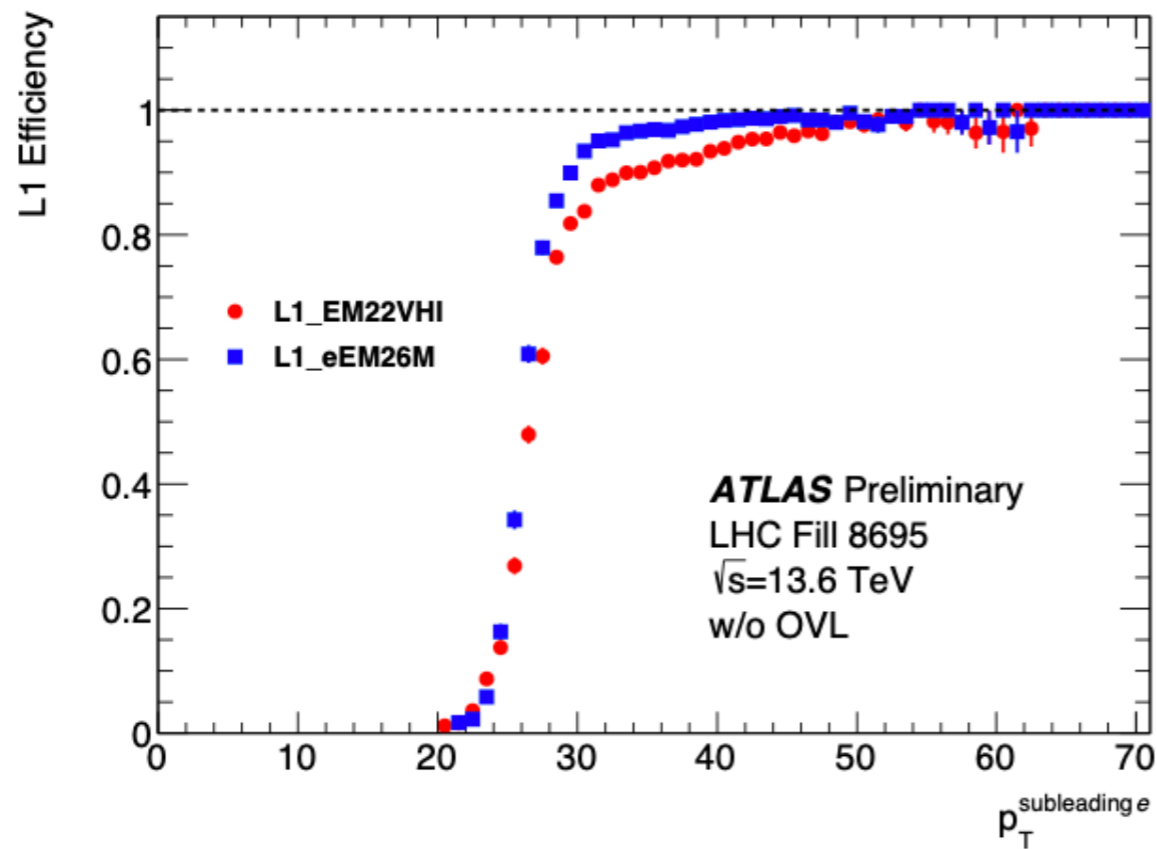
MM chamber

# Run 3 new cross-sections

Channel	13.6 / 13 TeV
H (ggF)	7%
HH	11%
tt	11%
ttH	13%
tttt	19%
SUSY stop (1.2–1.5 TeV)	20–30%
Z' (5–6 TeV)	50–70%
QBH (9.5 TeV)	250%



# Other trigger upgrades and improvements



# Inner Tracker (ITk) strip detectors

## Overview

---

- Modules are received and assembled here
- Further tests are also performed before
- Currently finished pre-production and production is ongoing.
- Cold noise: large noise spikes when running modules in cold conditions (typically starting at -10 deg)
  - Found during pre-production.
  - Evidence of a mechanical origin (vibrations from power-board)
  - Affecting all strip modules, even though less severe for end-cap modules.
  - Alternative glue modules (TrueBlue, thicker glue layers) also tested for possible noise reduction.
- Planning also tests in magnetic field.
- Pre-production full of fun and interesting challenges. Transition to full production started and it continues with tremendous effort from the.
- Full production to be started as soon as problems observed to be solved.



# Petal loading

## Overview

- Assembly of 3 petals recently in Vancouver.
  - First pre-production A and B petals in ATLAS and first endcap site to go through site qualification. 🚀
  - Automated loading using robotic gantry
  - All placement within specification  $\pm 50 \mu m$

