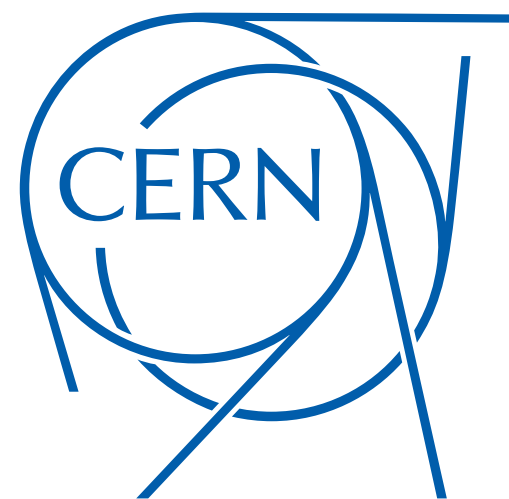


# Status of LHC Experiments, including Phase II upgrades

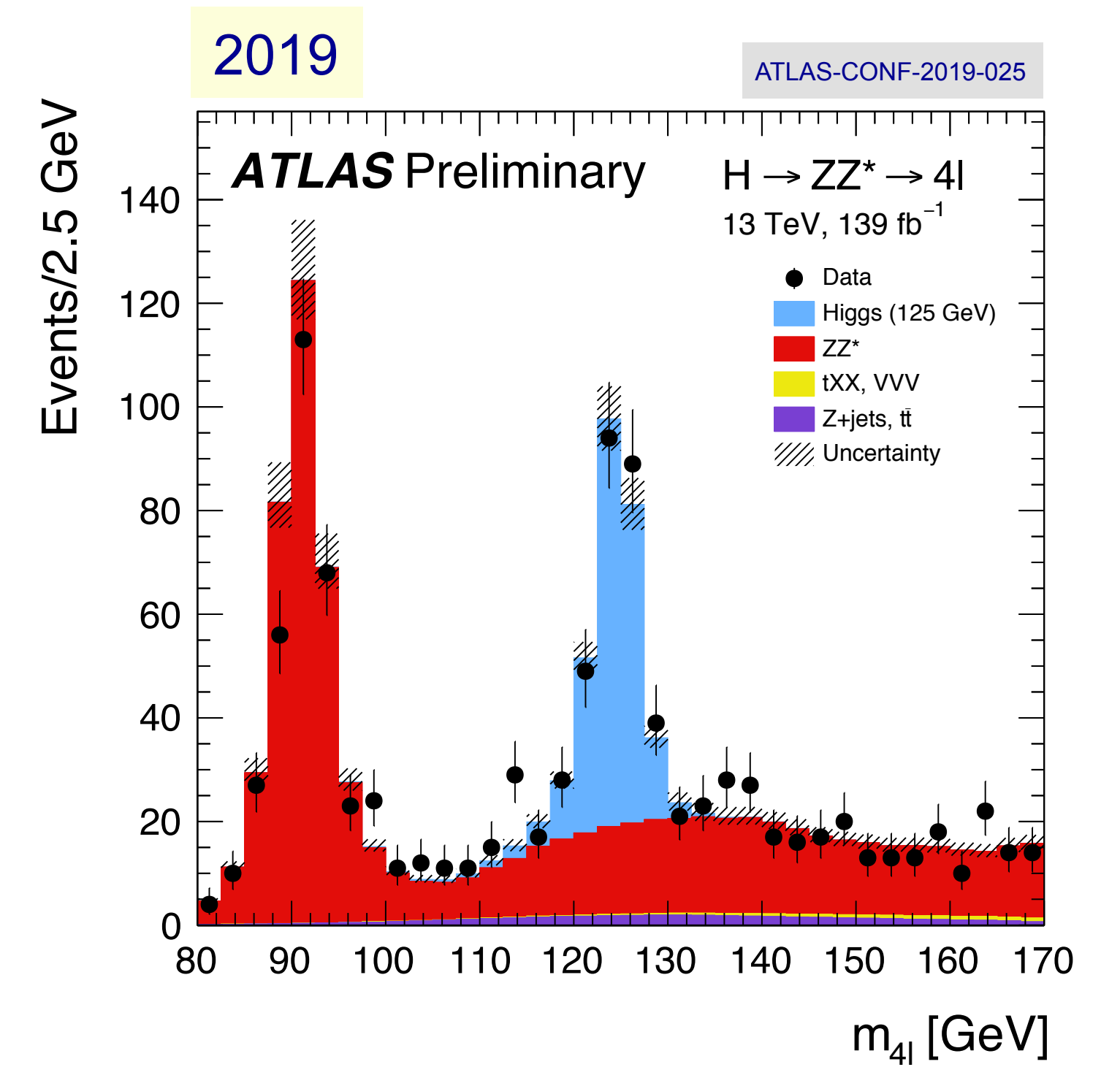
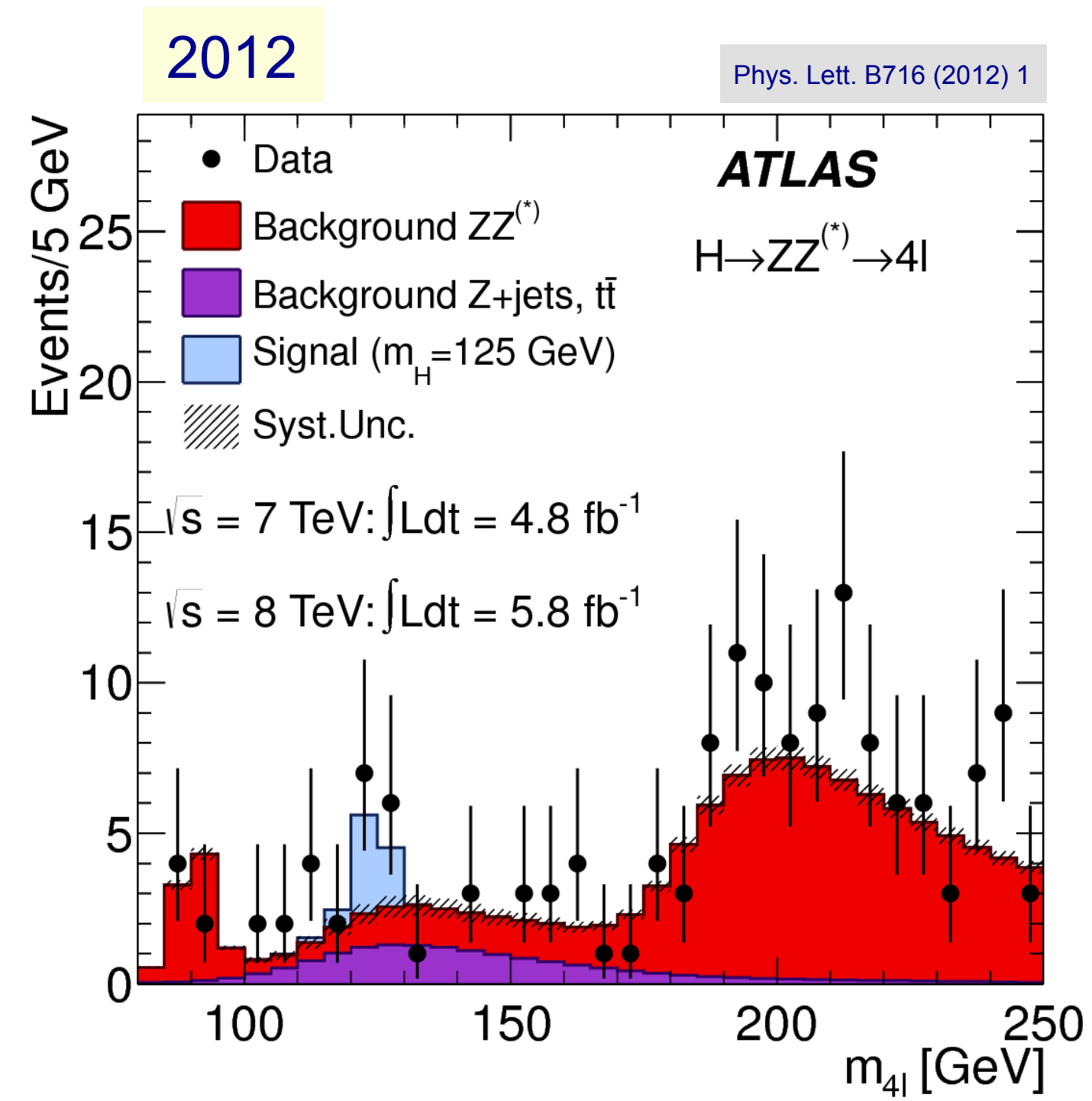
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Eckhard Elsen

Director Research and Computing



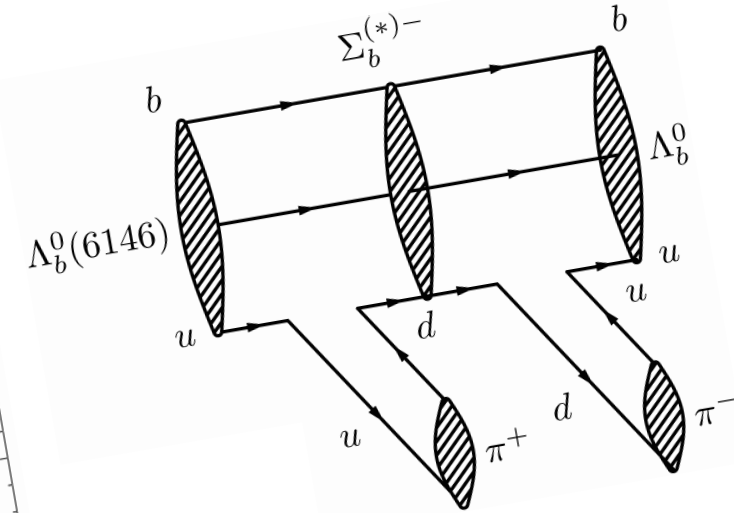
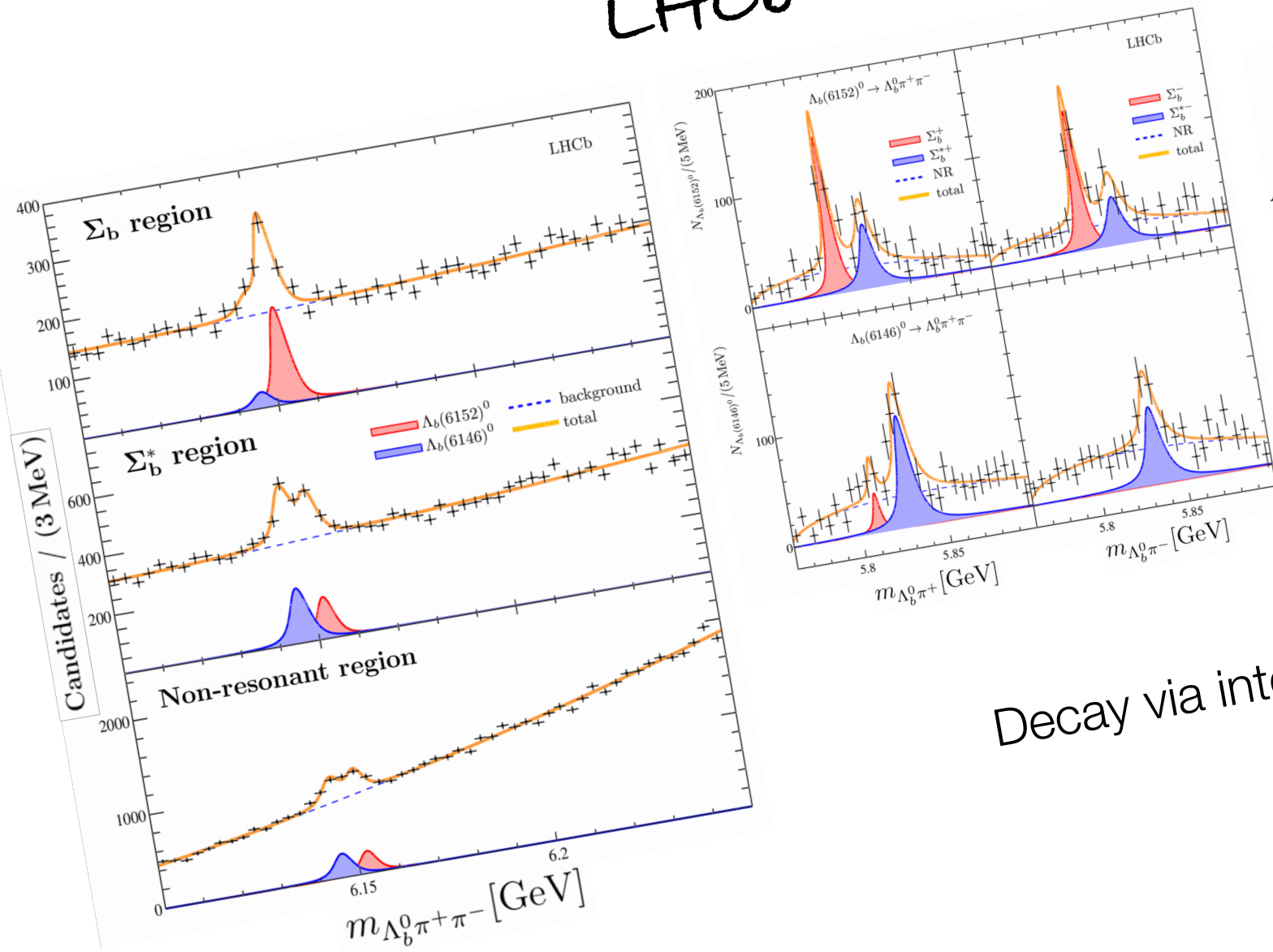
# Some physics results



Huge progress illustrated by comparison of  $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$  signals



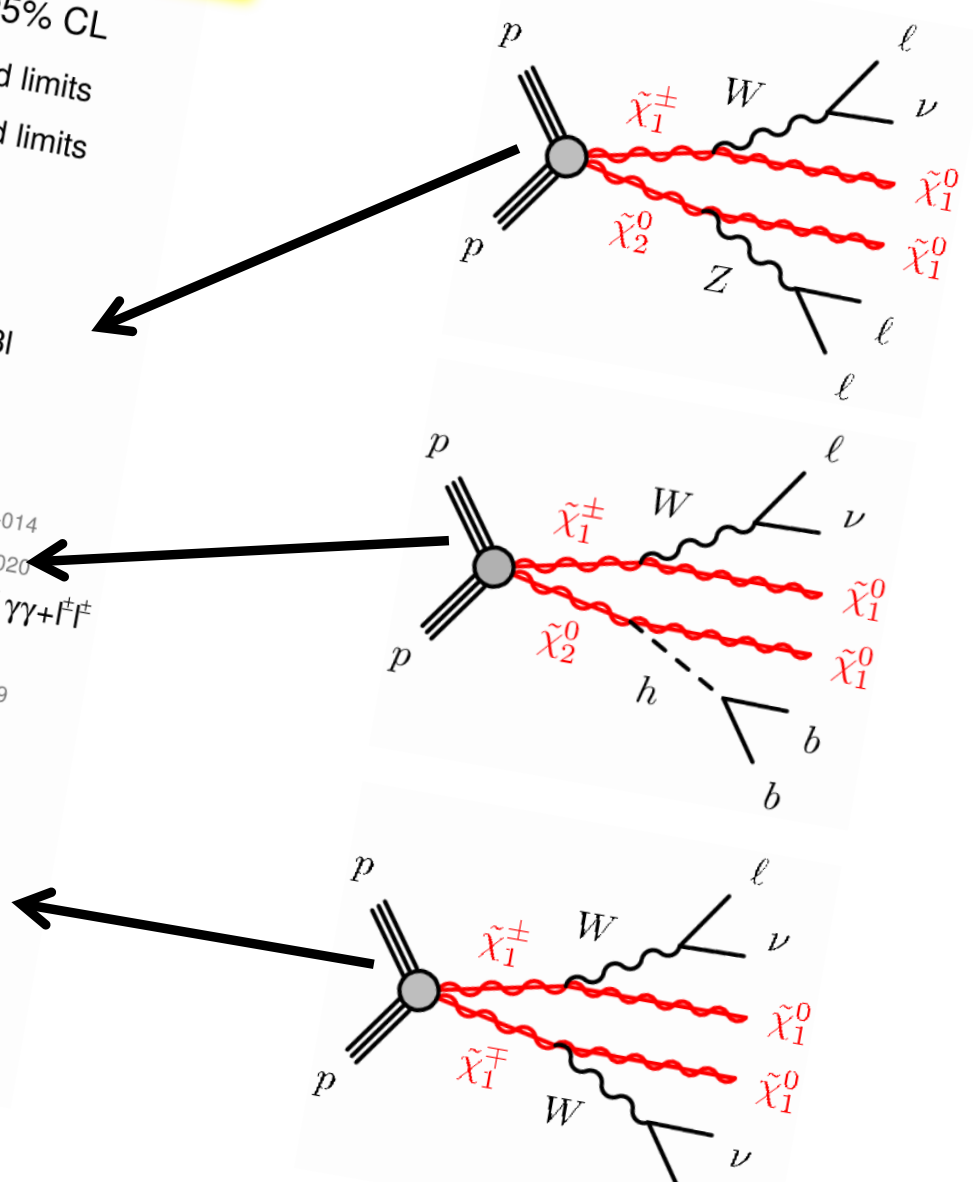
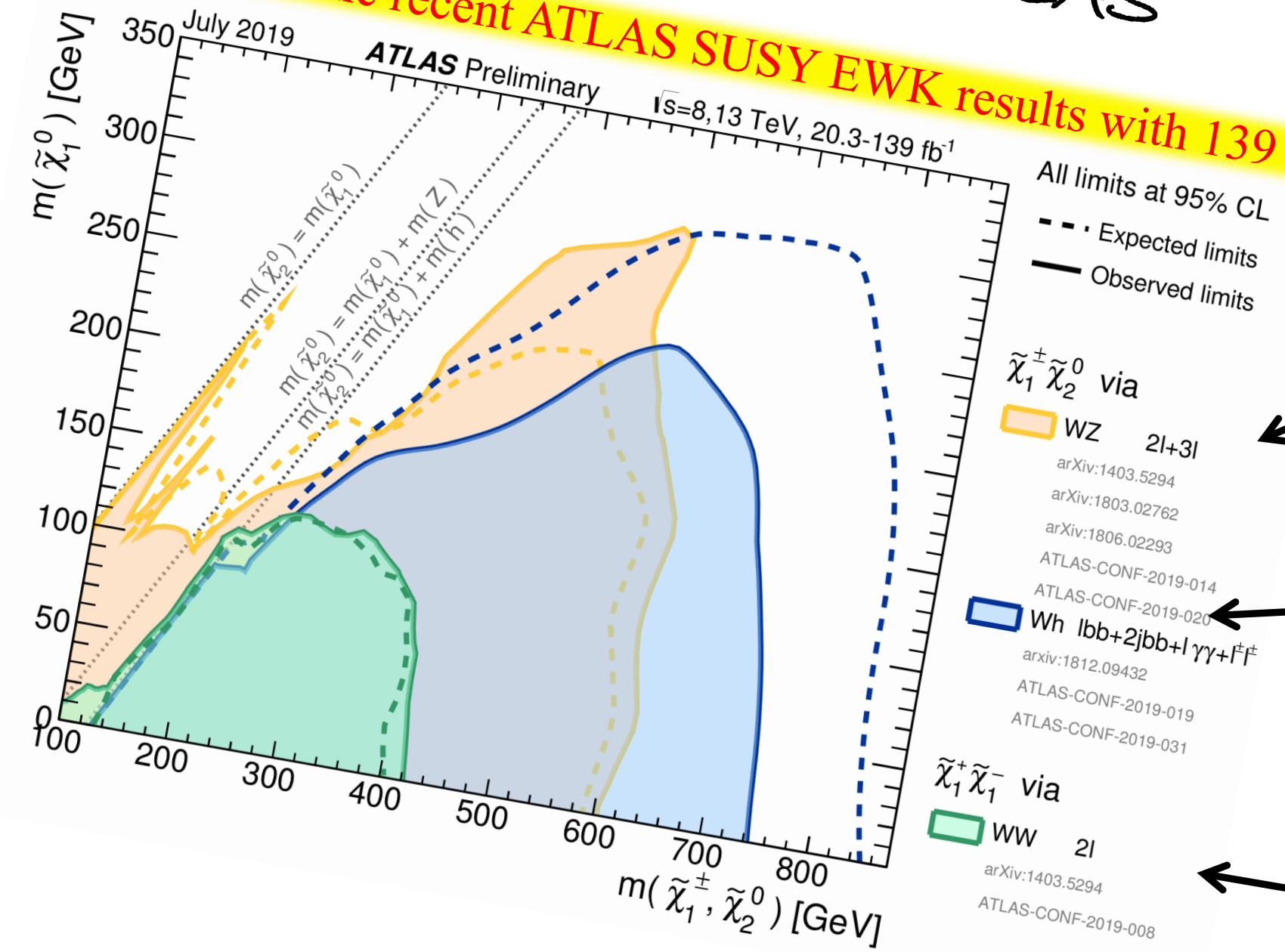
LHCb



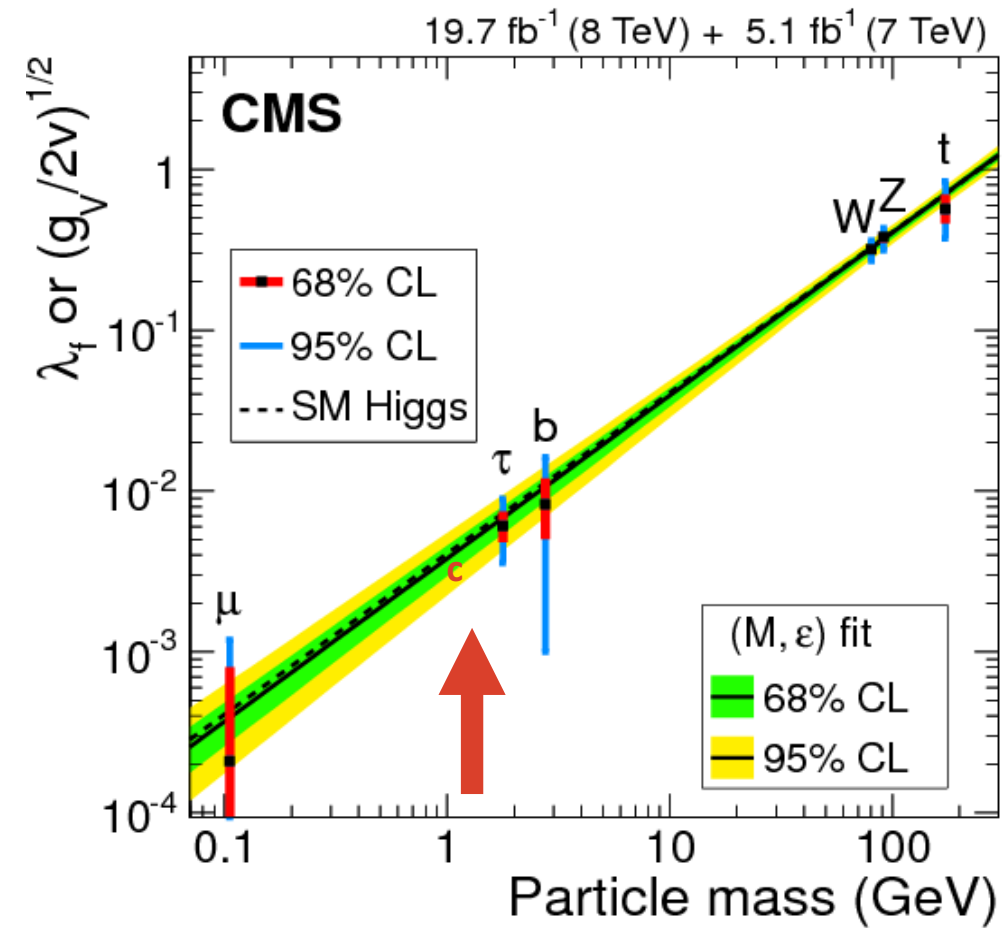
Decay via intermediate  $\Sigma_b$  states

Summary of some recent ATLAS SUSY EWK results with 139 fb<sup>-1</sup>

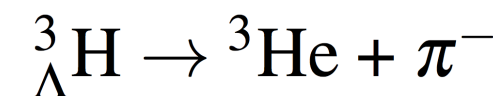
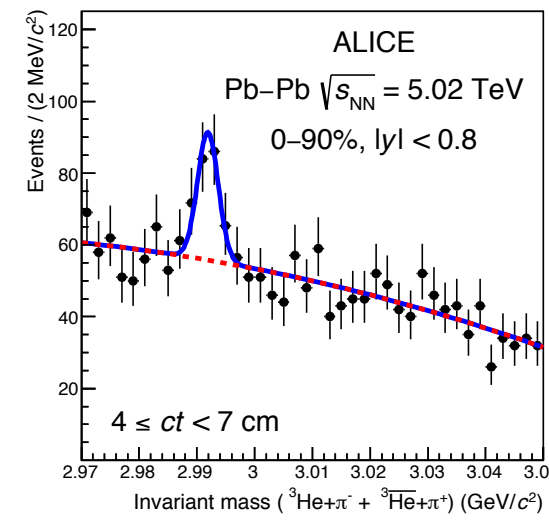
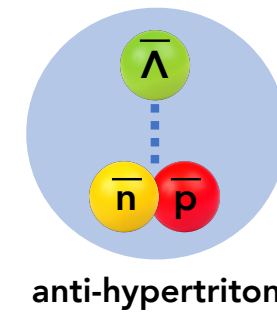
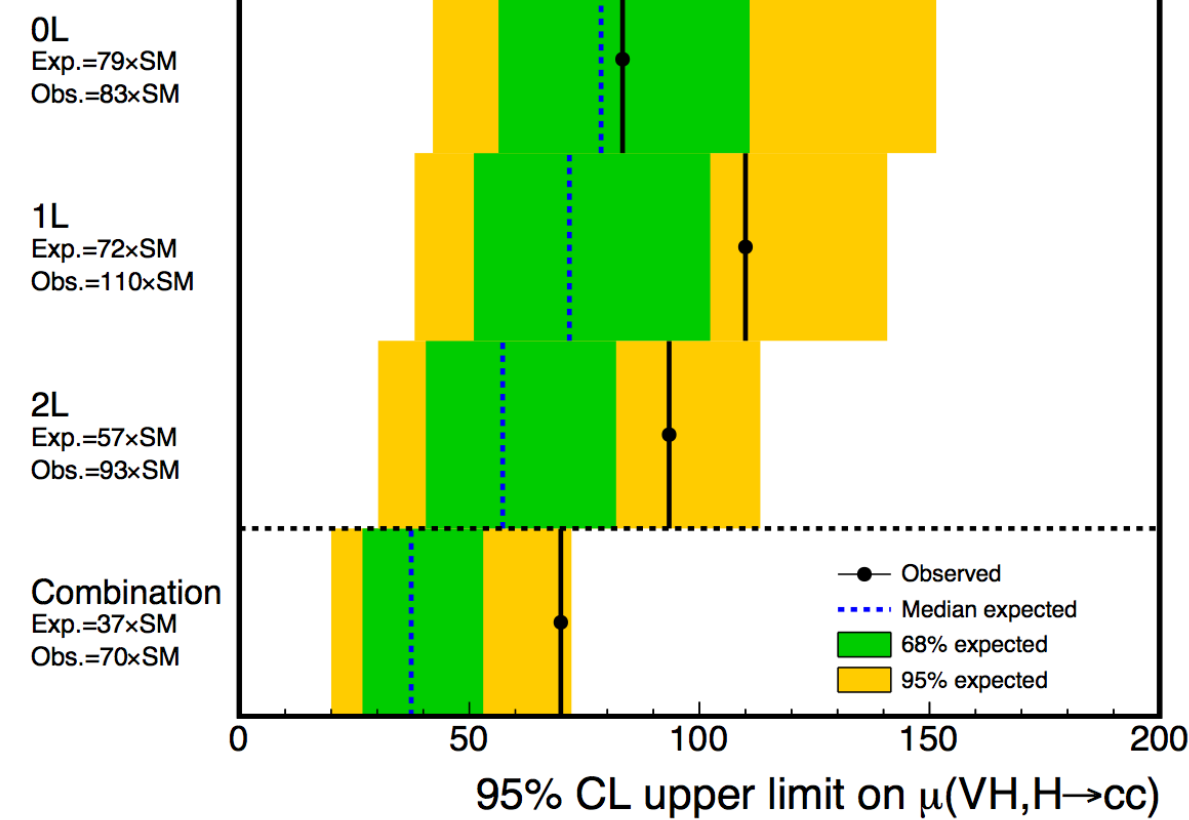
ATLAS



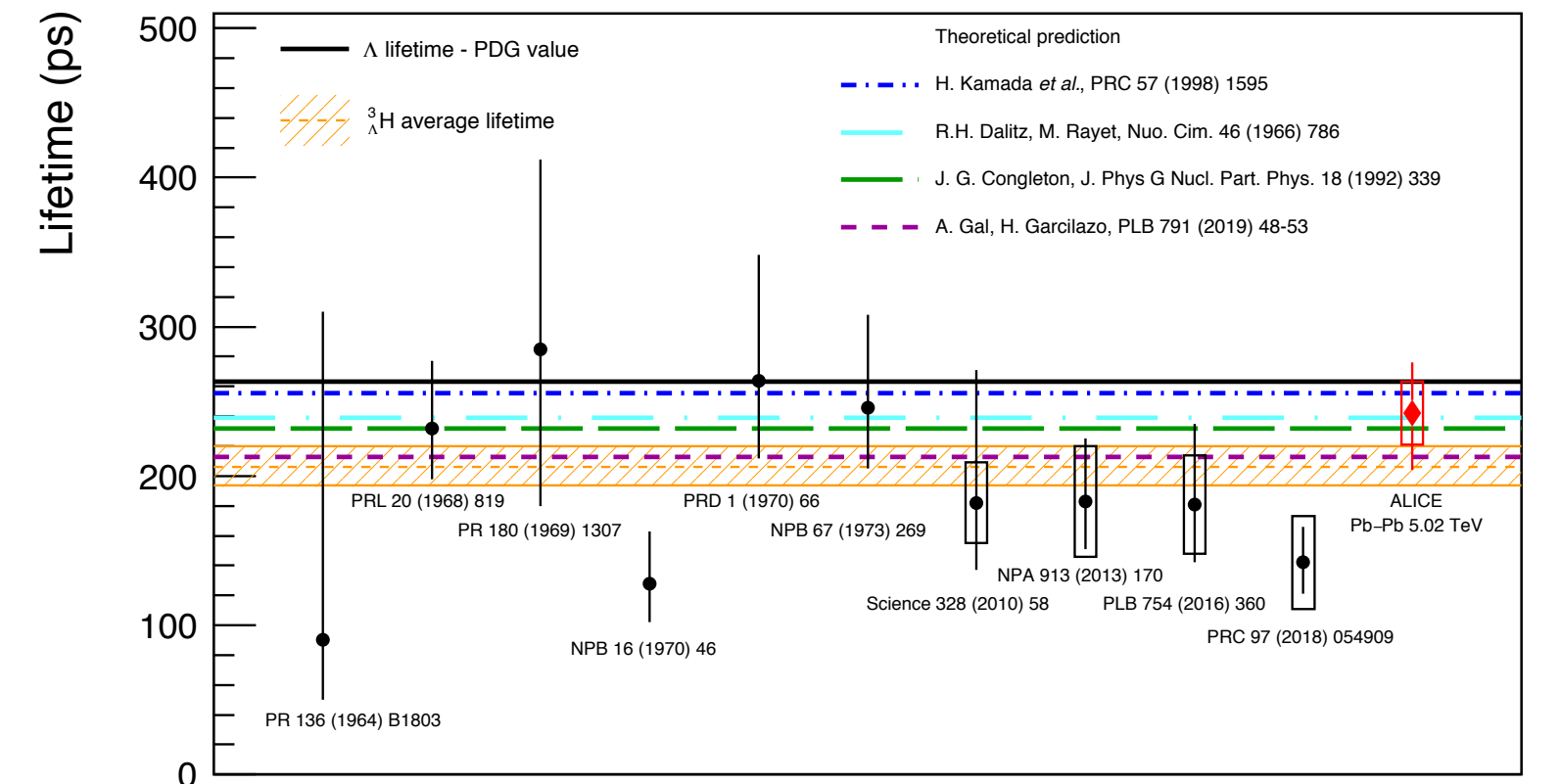
CMS



CMS Preliminary 35.9 fb<sup>-1</sup> (13 TeV)



ALICE



LS2 Activities

*Overall very good progress*

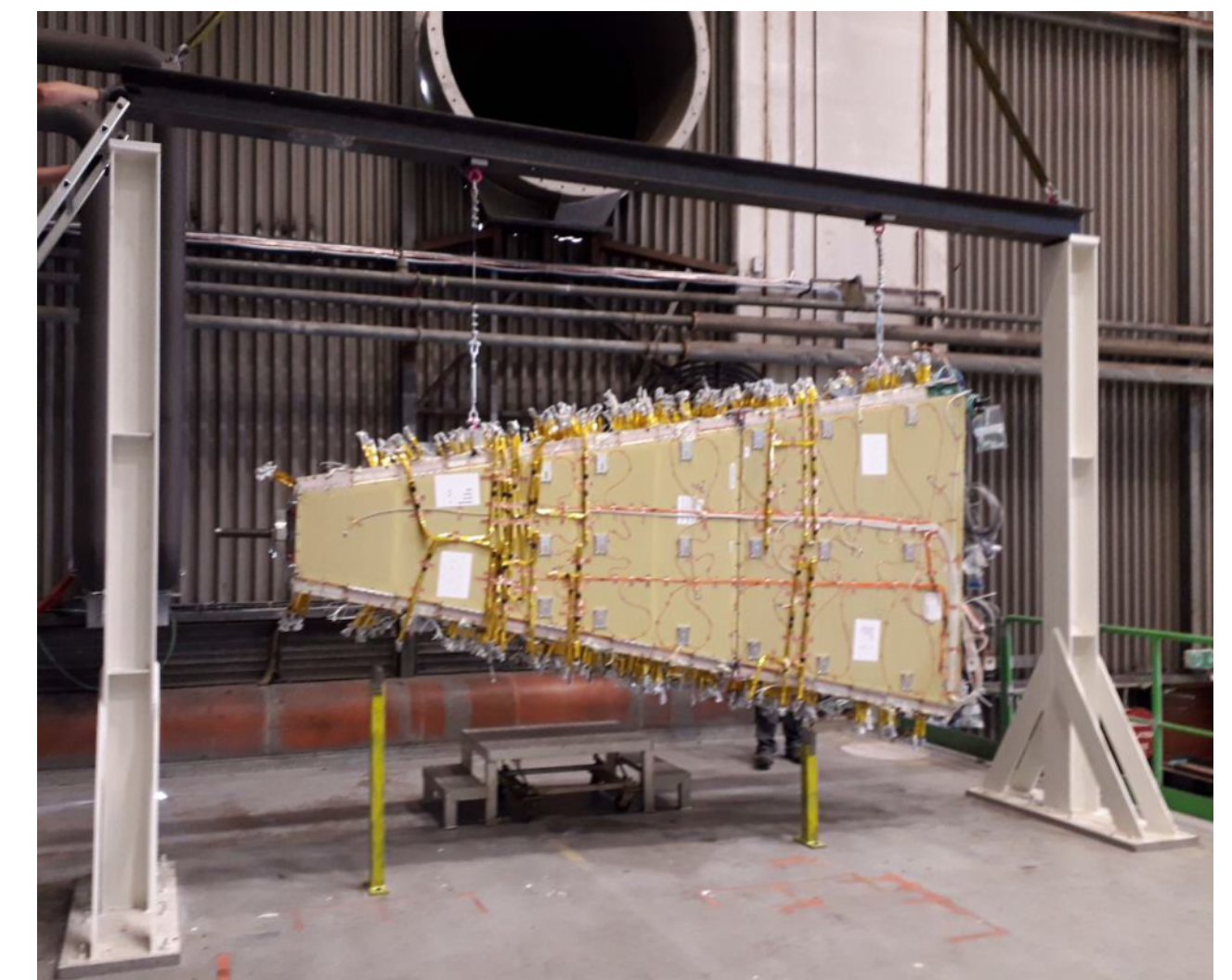
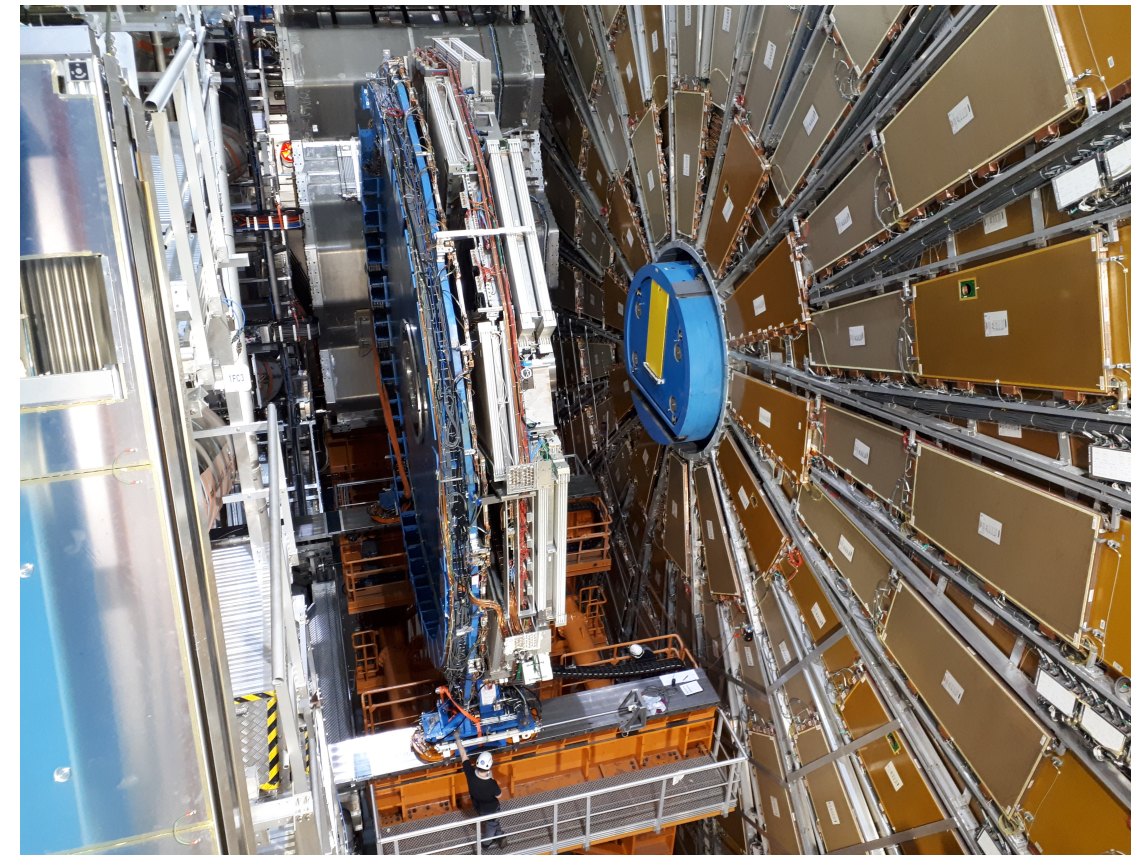
ATLAS



ATLAS

# New Small Wheel (NSW)

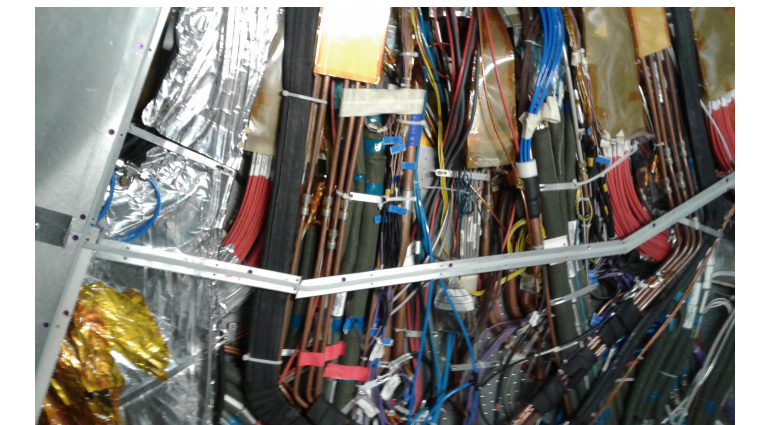
- sTGC
  - on track : 51 / (96x2) chambers ready
  - 9 / (32x2) wedges completed
- Micromegas
  - edge passivation leads to better production yield
  - good / slow rate for small / large sector chambers
  - 4 / 16x2 double wedges fully integrated with electronics
- Electronics
  - 100% VMM (ASIC) received; 50% packaged
- First sector test coming forward; decisive input for installation decision in November



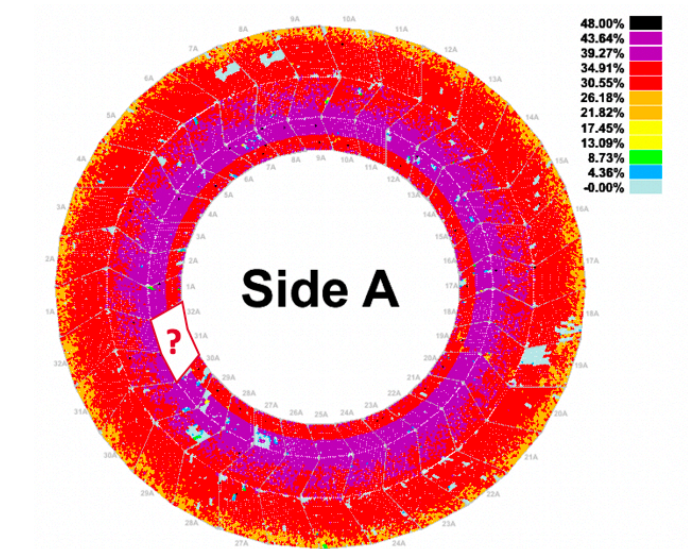


# Major LS2 Detector Maintenance Activities

- **Pixel Detector** Installation of 272 new optoboards
- **SCT (Si strips)** Installation of a new 48 V powering scheme for LV and HV power supplies
- **TRT** Consolidation of the cooling system (opening of Inner Detector endplates required)
- **Liquid Argon** Consolidation of power supplies (lost redundancy) and of the front-end cooling system
- **Tile Calorimeters** Consolidation of the cooling system (connectors); Consolidation of the Cs source calibration system; Replacement of trigger scintillators (MBTS) and scintillators in the barrel-endcap crack region
- **Muon system** Replacement of several TGC chambers RPC: leak search and repair in gas system
- **Forward** Refurbishment of LUCID (photomultipliers)



View of the Inner Detector, after opening of end plate (March 2019)



TRT occupancy map, two sectors in inner layer switched off

## Transition Radiation Tracker

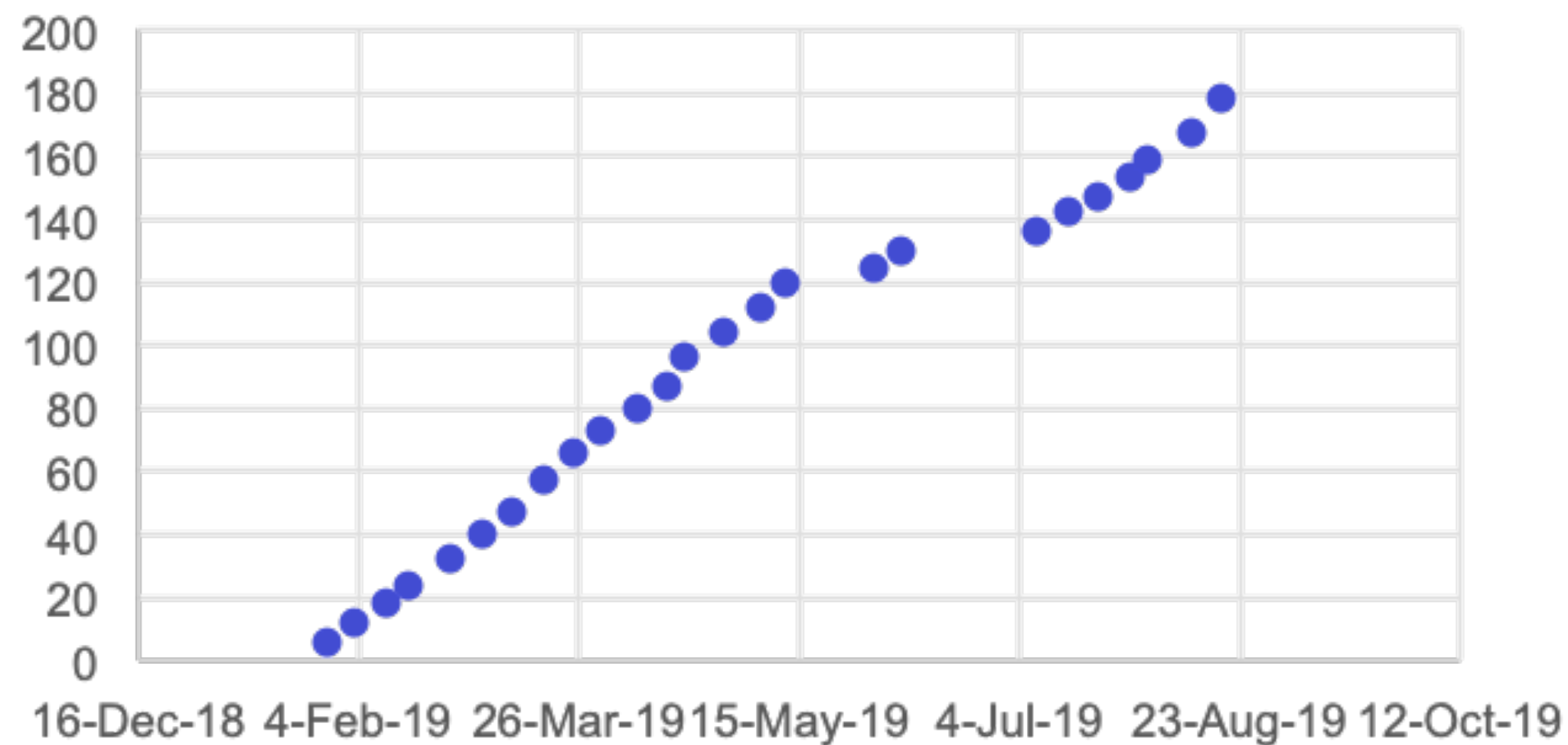
- Leak in the front-end cooling system not found after opening of the Inner Detector end plate;
- Consolidated with regulation of flow (now at the level of 1.2 l/day C<sub>6</sub>F<sub>14</sub>), however, two sectors in the inner ring (side A) need to be switched off in Run 3
- Due to gas loss (200 l /day) the barrel part will be operated with Ar instead of Xe gas in Run 3



# Upgrade of Muon system

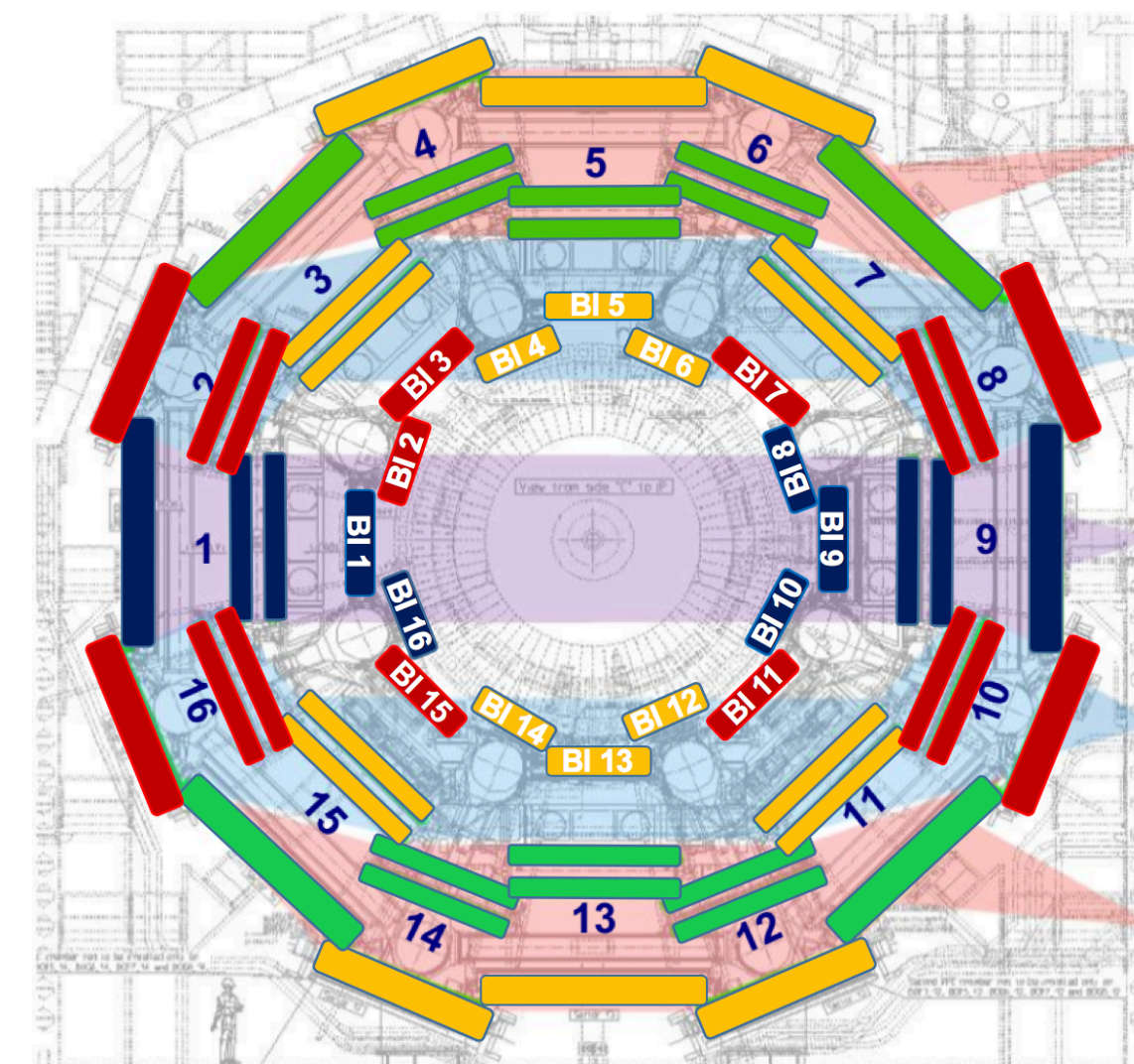
- Fixed one leaky sector for Cathode Strip Chambers Front-End cooling
- Resistive Plate Chambers (RPC) gas leak fixes: ongoing (see plot)
- Installation of new RPC gas racks to minimise the pressure difference between sectors: should hopefully reduce the development of new leaks in the future

Number of fixed RPC gas leaks in LS2



Present system

- Rack65
- Rack64
- Rack63
- Rack62
- Rack61



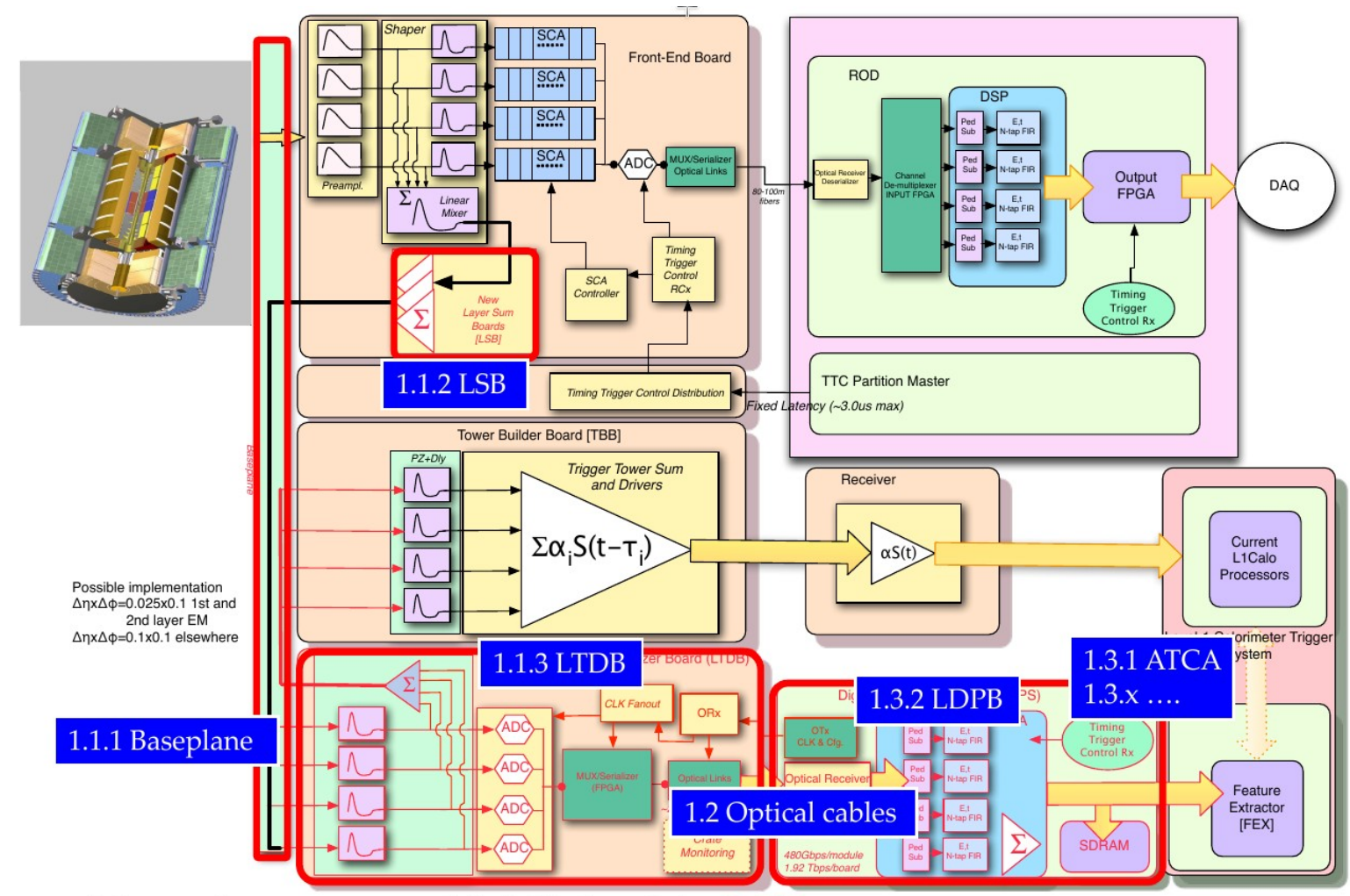
Future upgrade

- New Rack 69
- New Rack 68
- New Rack 67
- New Rack 66
- Rack65
- Rack64
- Rack63
- Rack62
- Rack61

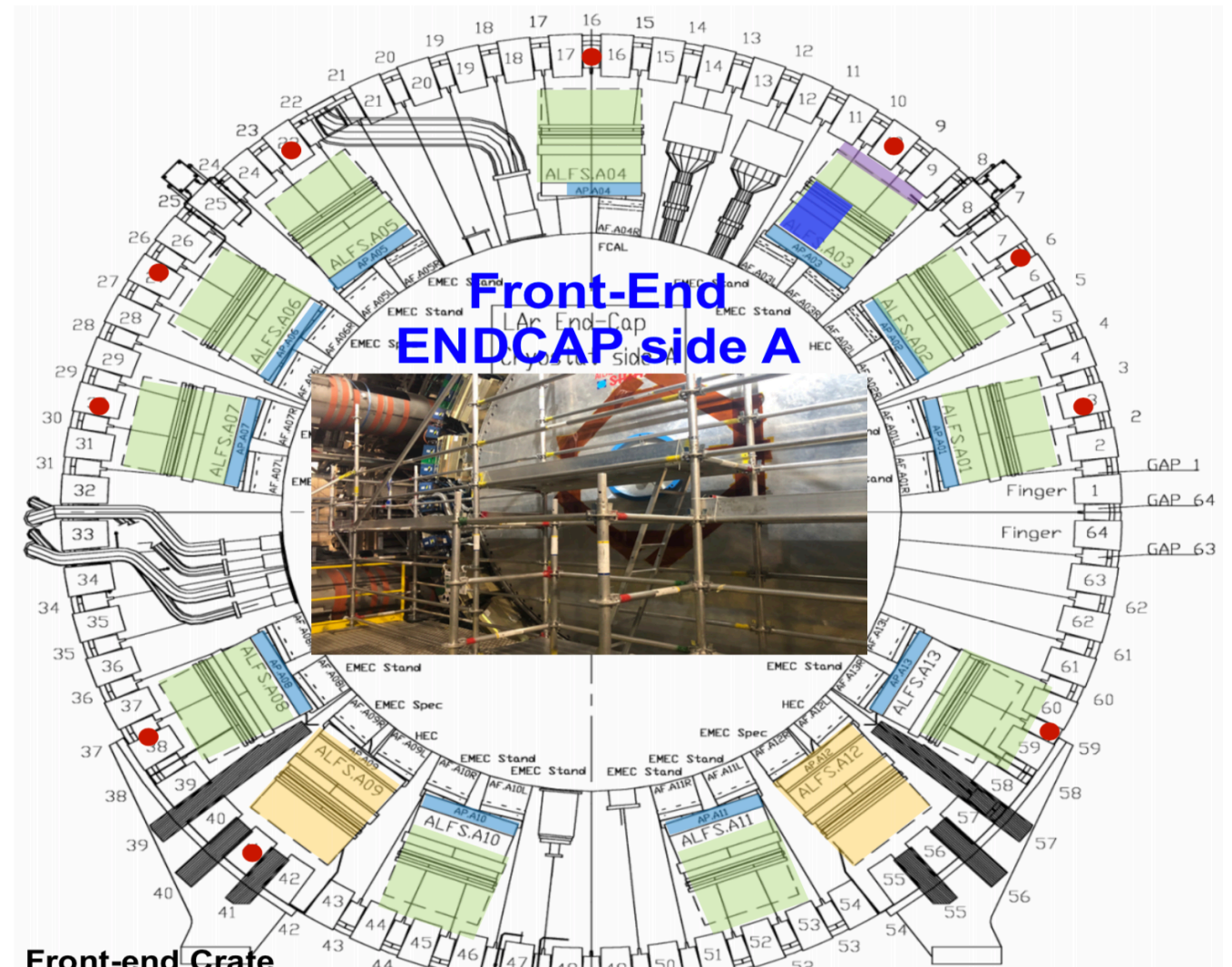


# Maintenance and Upgrade of LAr Calorimeter

- Upgrade of Front-End and Back-end electronics
- including trigger

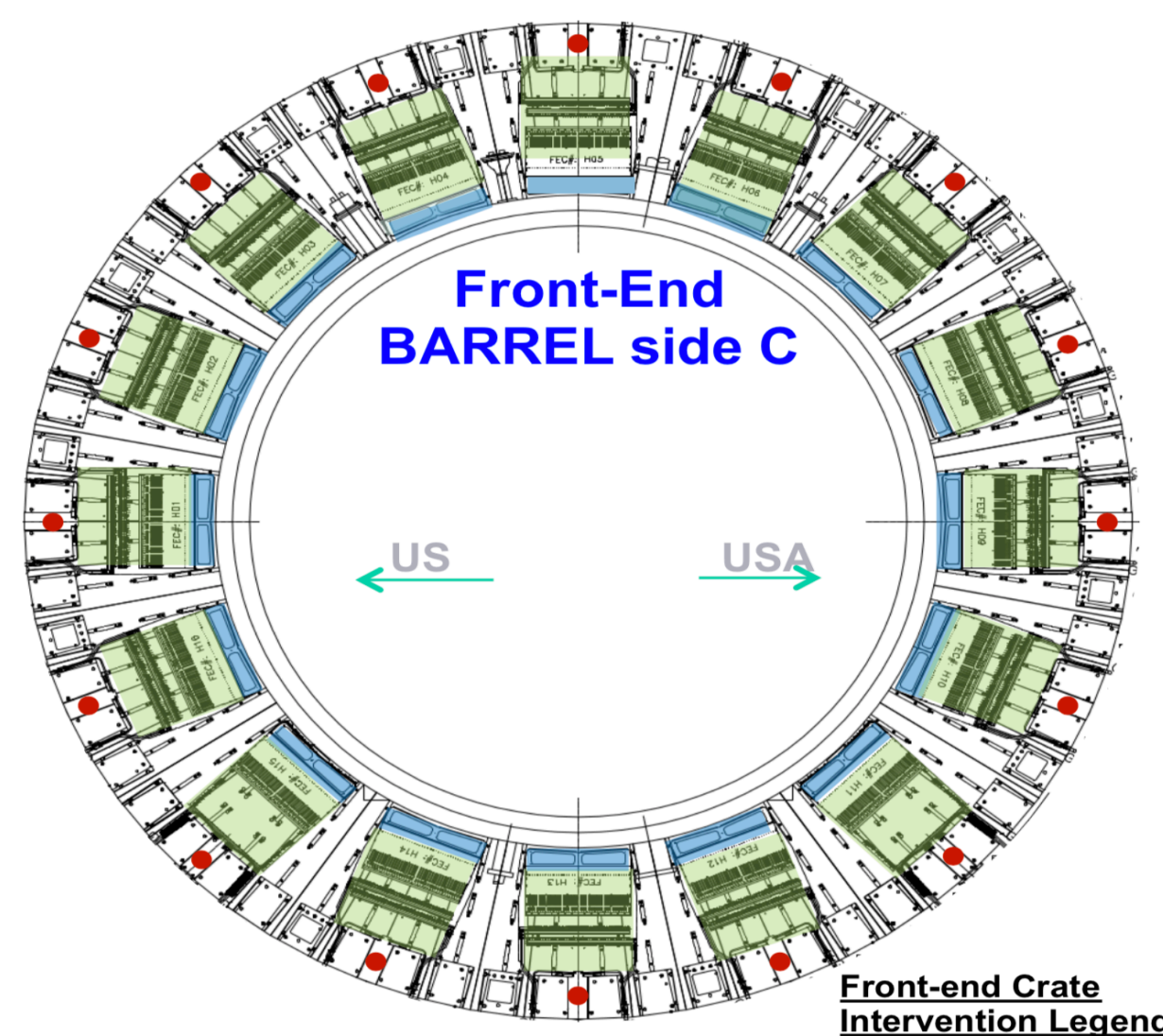


▪ New elements are highlighted in **RED**



**Front-end Crate Intervention Legend**

11 crates	Baseplane exchanged	0.5 crate	LTDB installed, in commissioning
1 crate	Re-cabled for commissioning	10 crates	LVPS cooling hose replaced
11 crates	Boards reinserted	2 crates	Boards Removed



**Front-end Crate Intervention Legend**

16 crates	Baseplane exchanged
16 crates	Boards reinserted
16 crates	LVPS cooling hose replaced



# ATLAS FTK project stopped

---

- A Fast Tracker TDR introduced in 2013 for Run 2 and 3
  - relying on use of ambitious Associative Memory AM, which did not exist at the time
    - AM chip has been successfully developed
- ...but project got severely delayed, which was noted early on (LHCC etc.)
  - slice test was finally successfully performed in 2018
- Considerable effort would remain to introduce full operation
  - descoping proposal (35 kHz) was attempted; however, such a solution cannot compete with the more flexible software solution provided by today's HLT
- ATLAS decided to close the project after extensive discussion in the collaboration





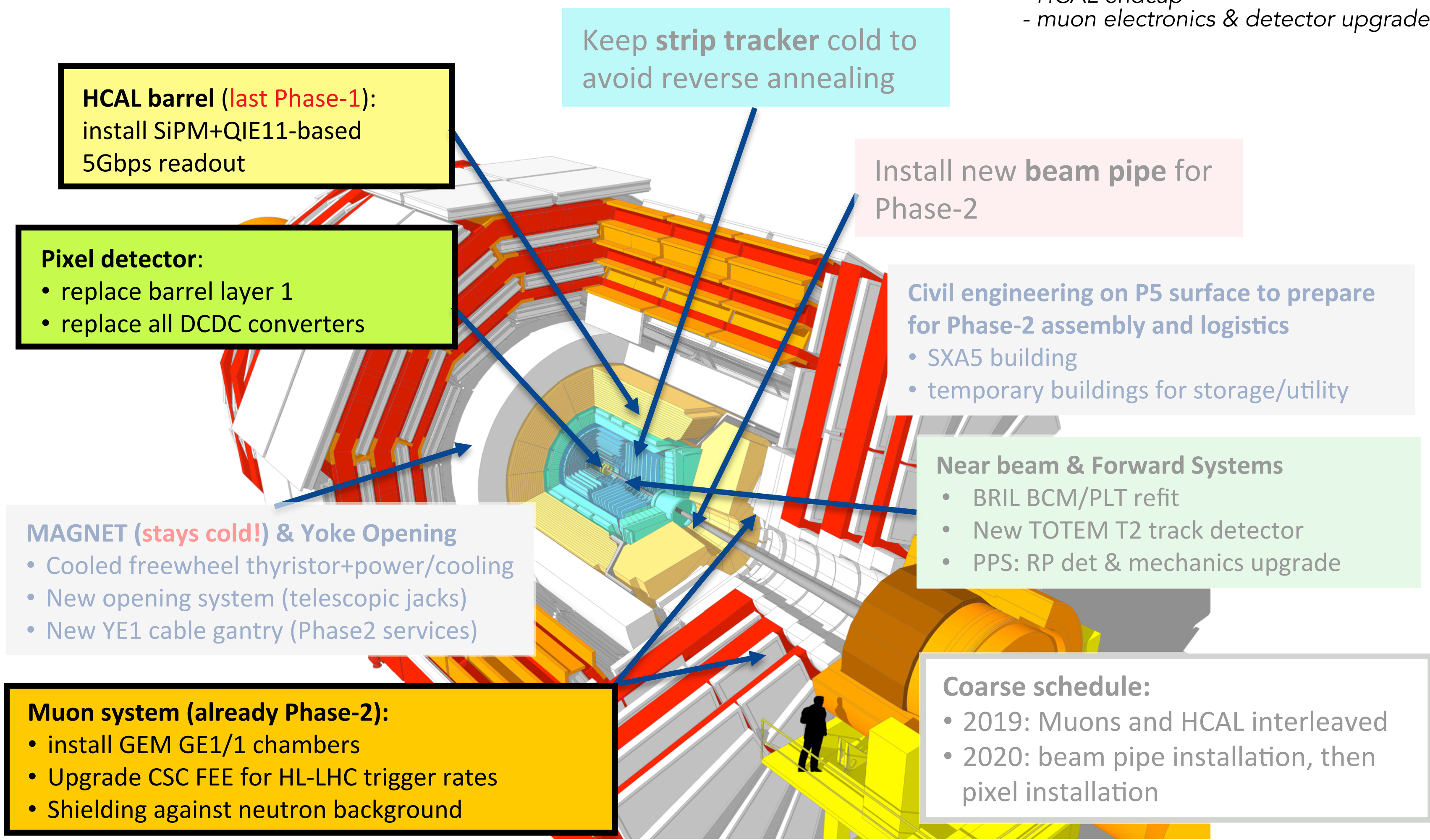
CMS

# Overview of CMS activities during LS2

Good progress on planned work @ P5

**Completed Phase-1 upgrades**

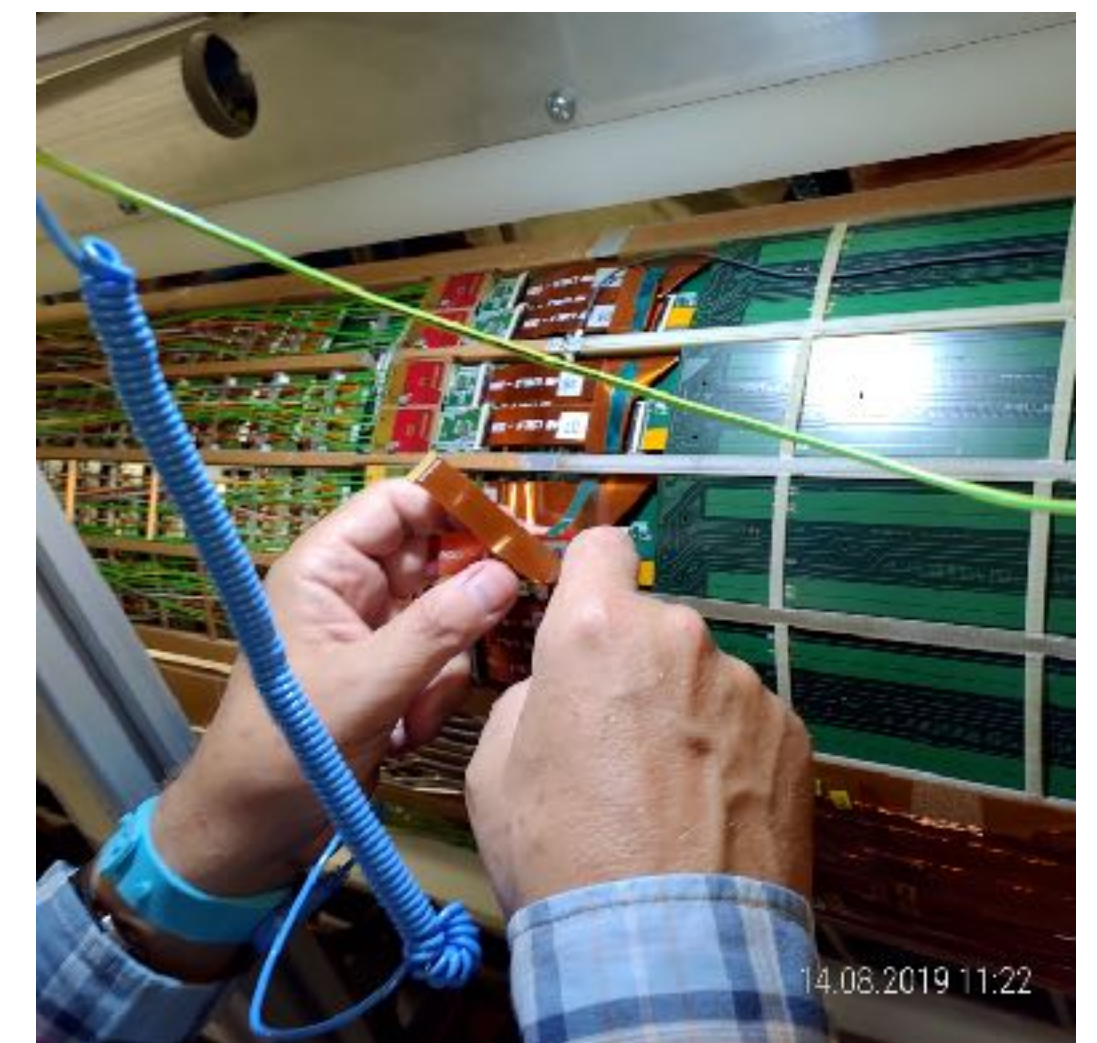
- new L1 trigger
- new pixel detector
- HCAL endcap
- muon electronics & detector upgrades



# Pixel and Silicon Strip Tracker

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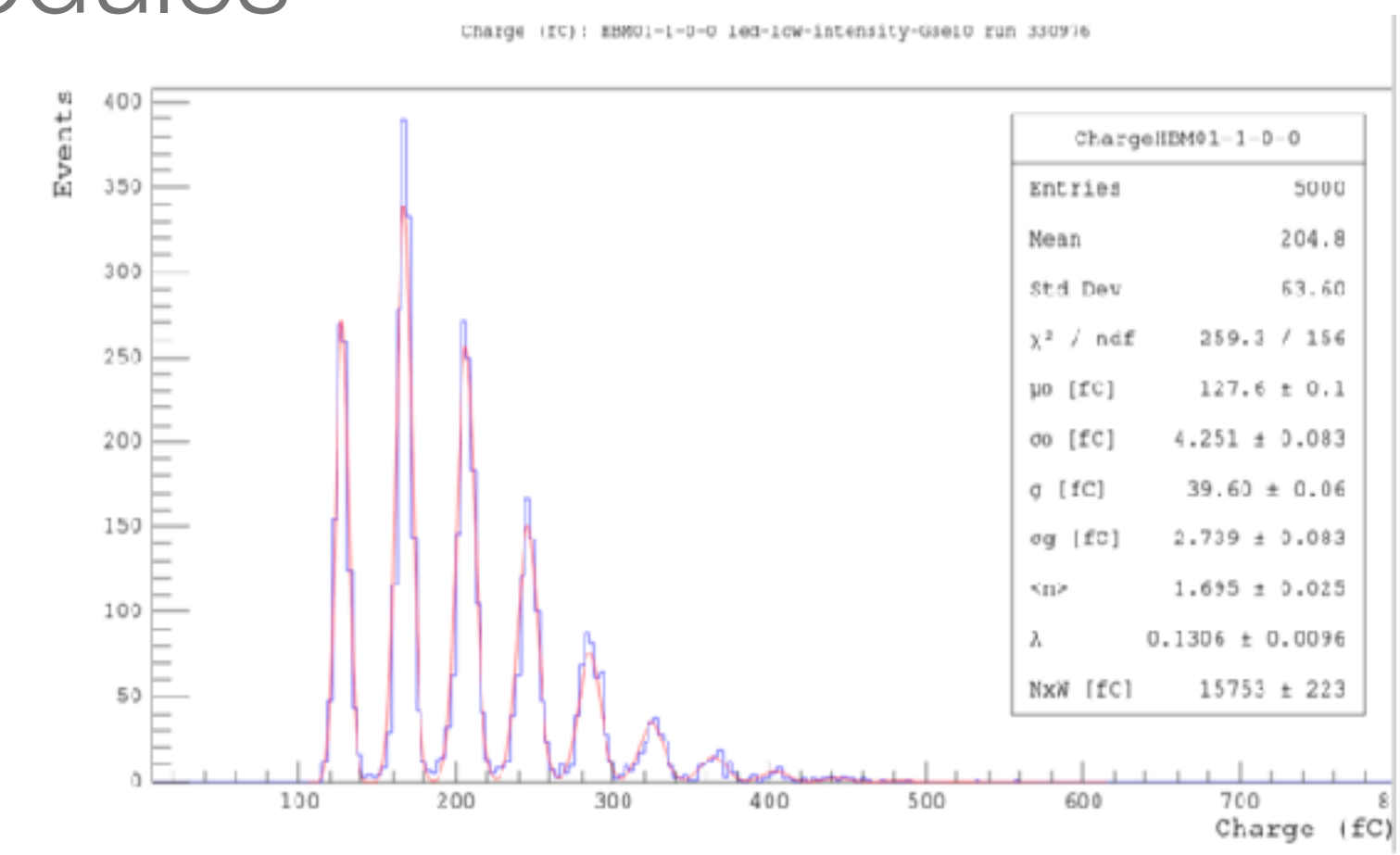
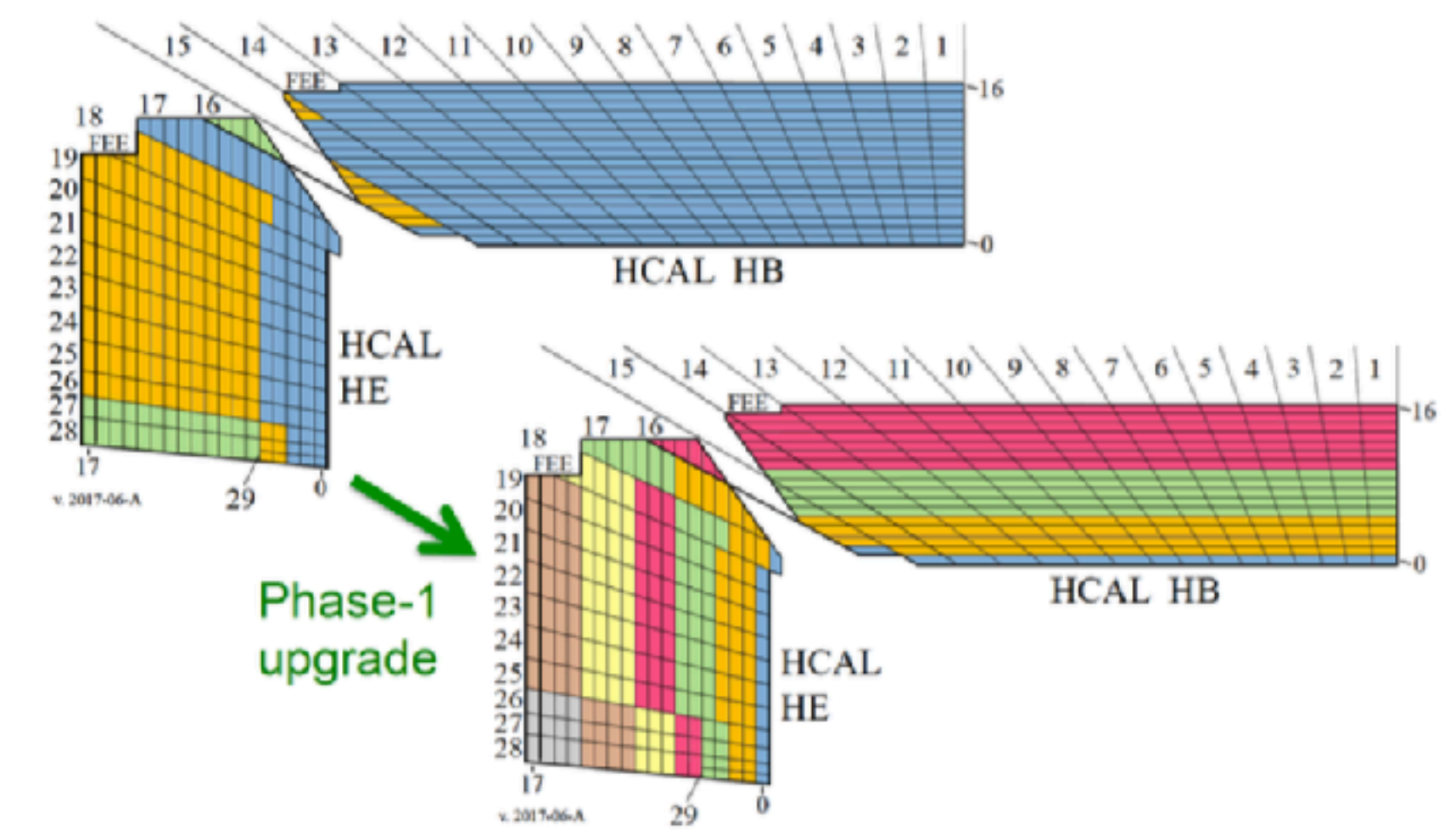
- Silicon Strip detector
  - System is kept dormant at 0°C with all non-essential electronics off
- Pixel Detector : extracted in January
  - DCDC converters issue faced during run2 has been solved and the DCDC converters will be fully replaced with a working version
  - Ensure detector longevity for Run 3 despite radiation effects:
    - Replacement of Barrel Layer 1
    - Ensure the detector can be operated with a larger HV bias 600-800V
    - Improved version of the readout chip (PROC600)
  - Module production expected to be finished in early 2020





# HCAL Barrel Phase 1 upgrade

- replacement of HPDs with SiPM
  - better noise levels, light yield and radiation tolerance. Provides longitudinal segmentation
- Status
  - All 144 Readout Modules, 72 Clock-and-Control Modules and 36 Calibration Units have been installed on the HCAL Barrel (HB) detector.
  - Undergoing  $\text{Co}^{60}$  calibration scheduled for completion by mid-October

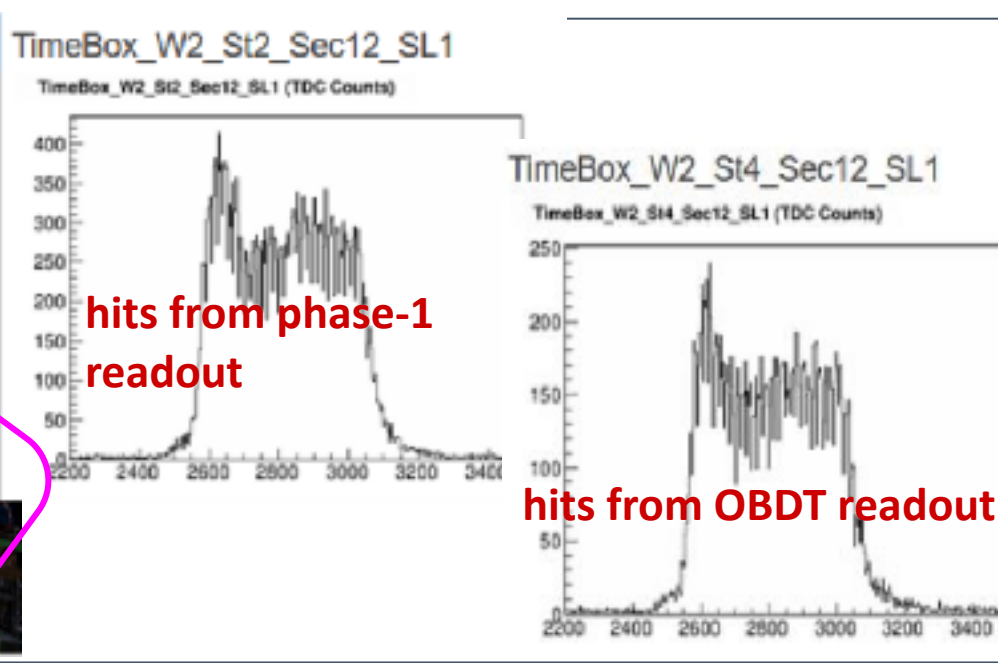
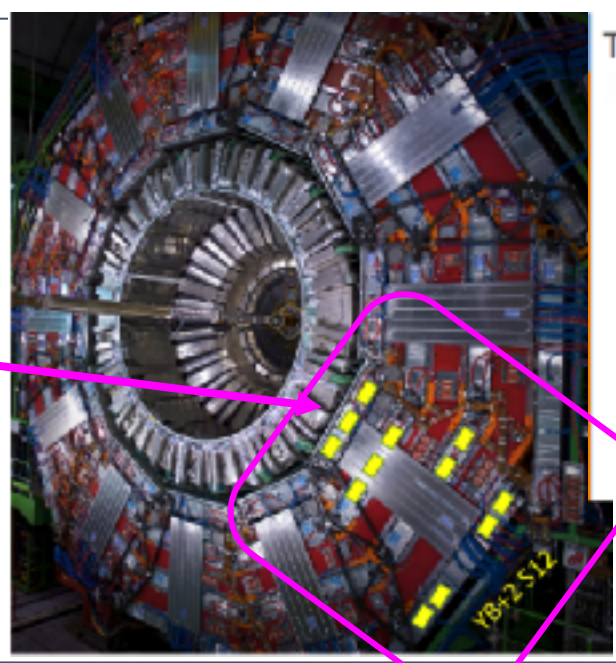


# Muon Chambers

## DT Slice Test

New phase-2 electronic (OBDT) readout and trigger. To be tested in Wh+2 S12 during LS2 and Run3

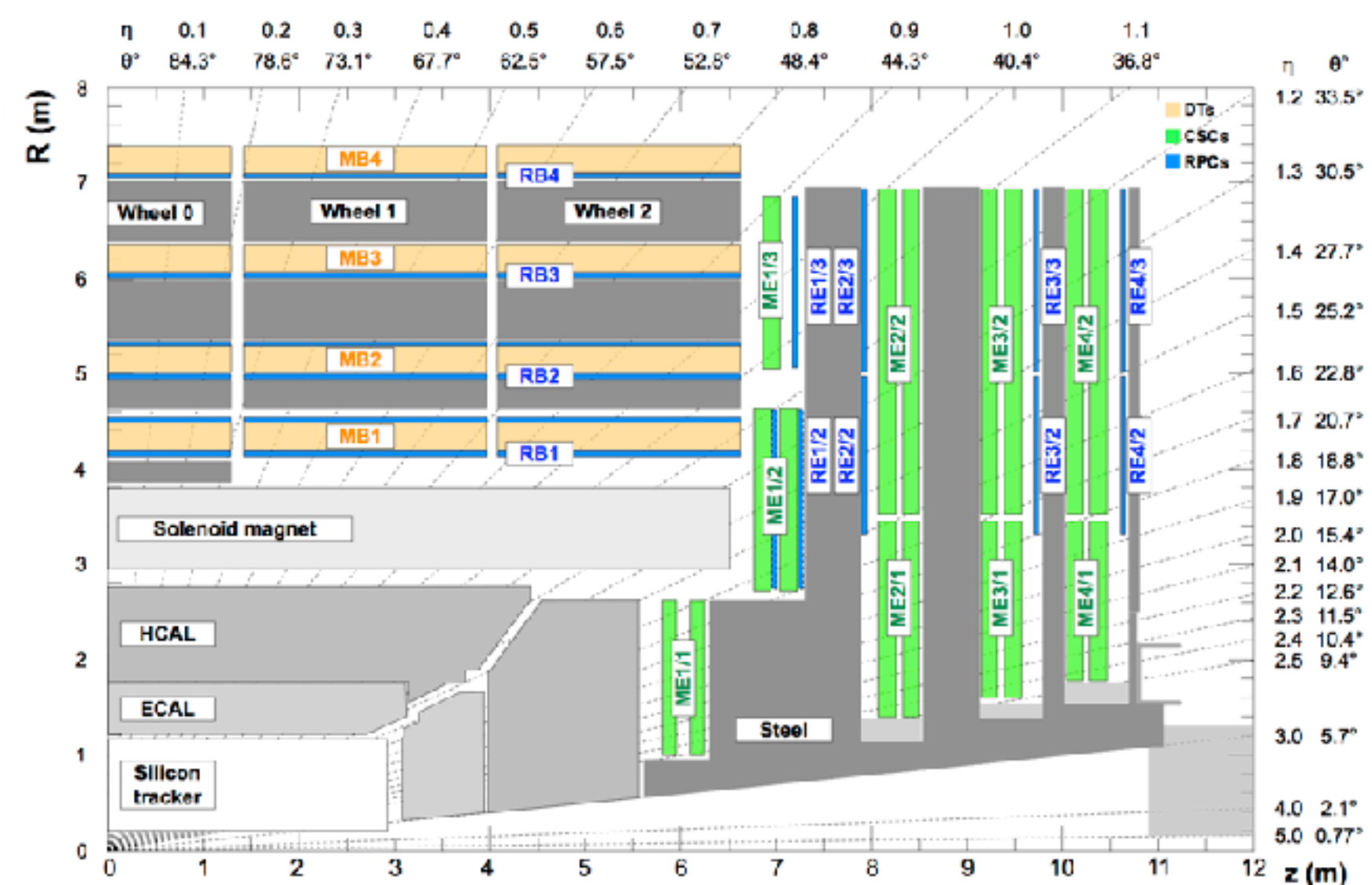
- OBDTs already installed in MB2, MB3, MB4
- Data and analysis are just starting



## RPC Barrel leak repair on W-2/-1:

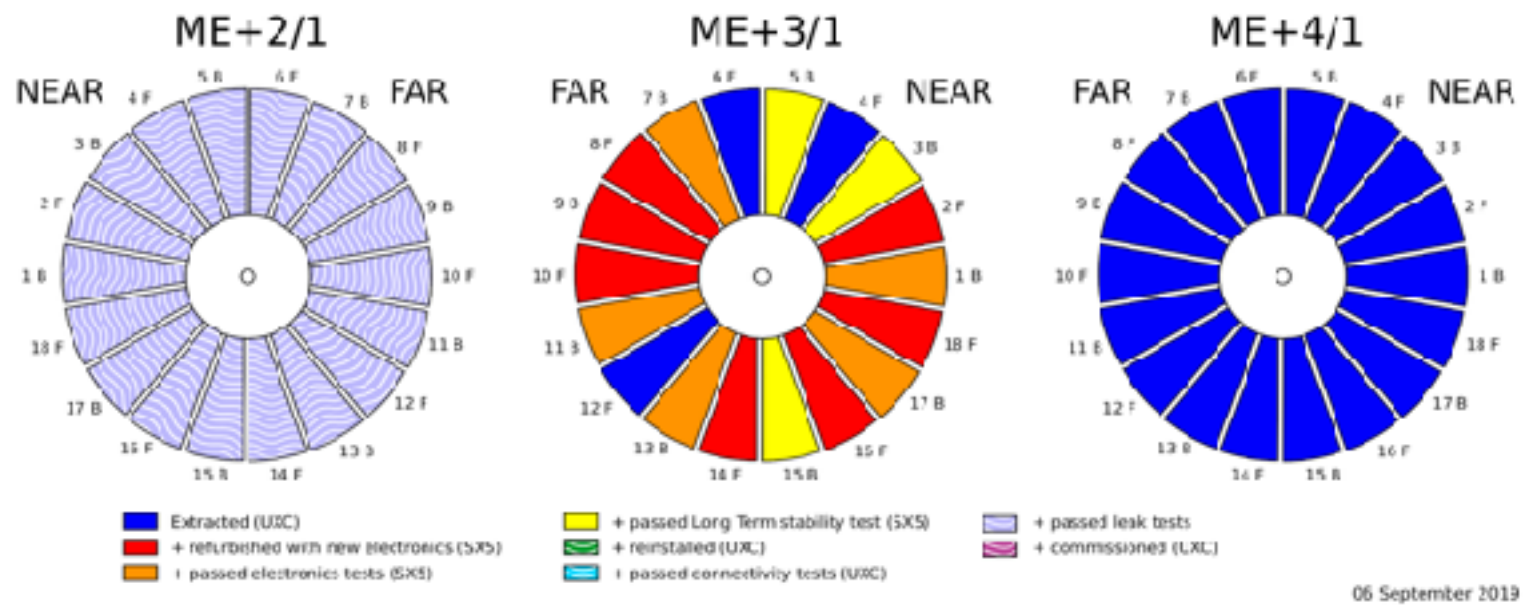
In the context of our strategy for GHG emission reduction, a massive leak repair campaign started in March 2019.

40% of leaking chambers has been already fixed



## CSC electronics refurbishing

- ME-1/1: Reinstalled. Running under cosmic
- ME+2/1: Reinstalled. Commissioning ongoing
- ME+3/1: Electronics installation and tests ongoing
- ME+4/1: All extracted from the wheel



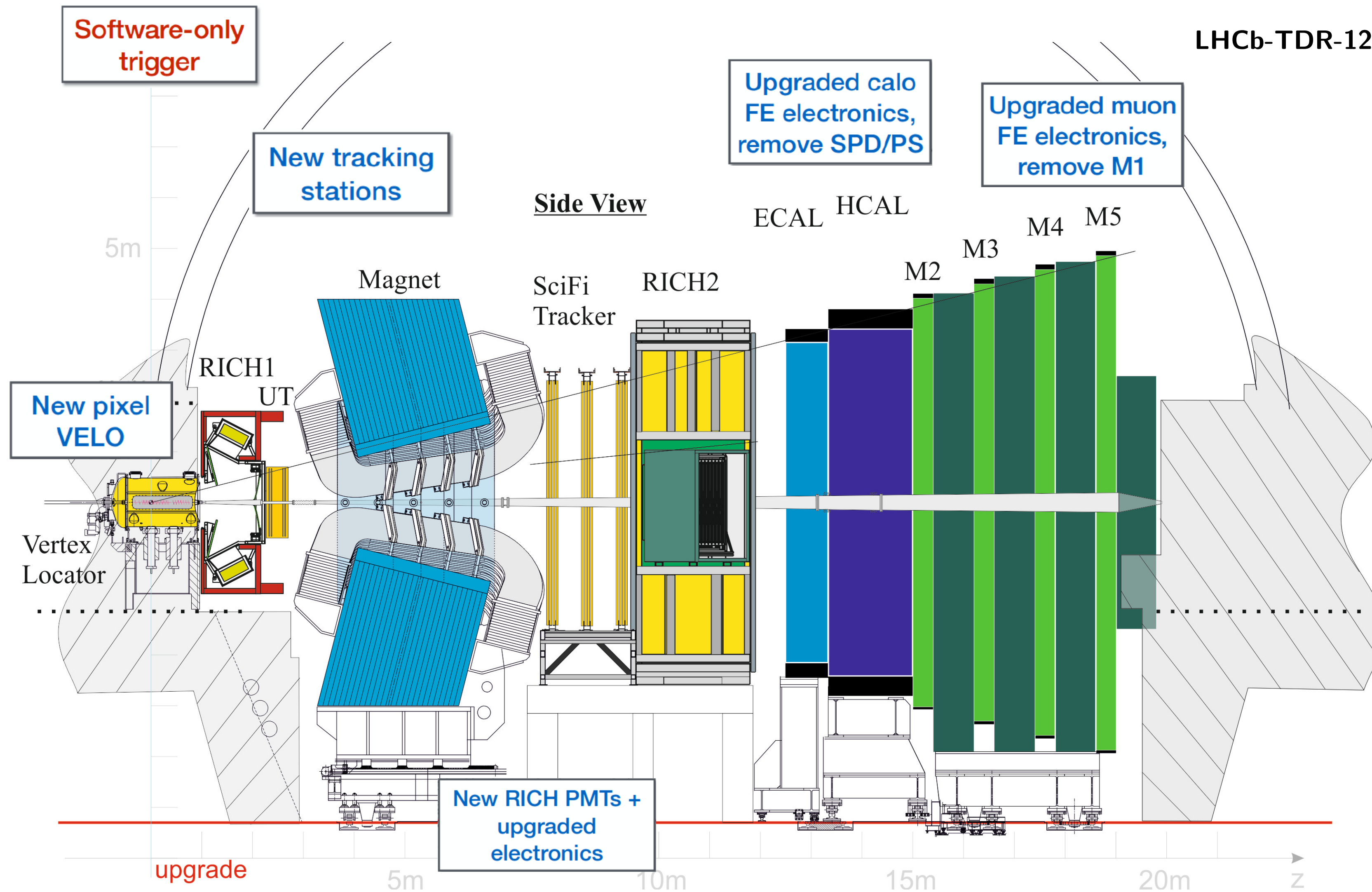
- DT : Drift Tubes
- CSC : Cathode Strip Chambers
- RPC : Resistive Plate Chambers

LHCb



# LHCb Phase I upgrades

LHCb



Assembly hall fully prepared





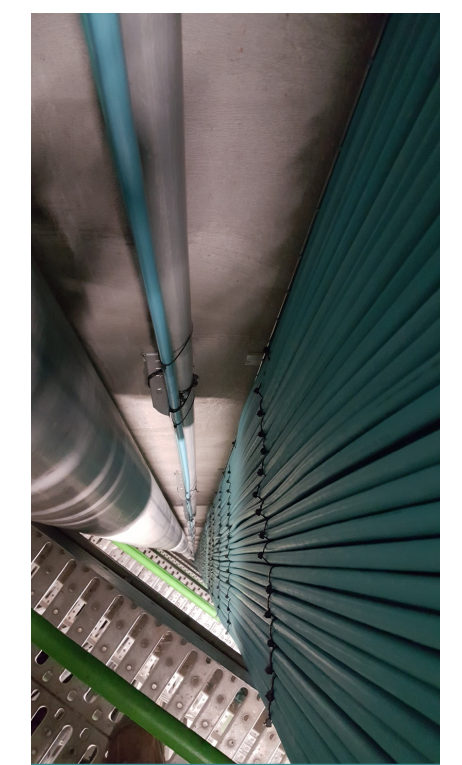
LHCb

# Upgrade progressing well

- All old detectors and obsolete equipment removed
- All new cooling systems installed
- All optical fibers in place
- New computing center containers in place



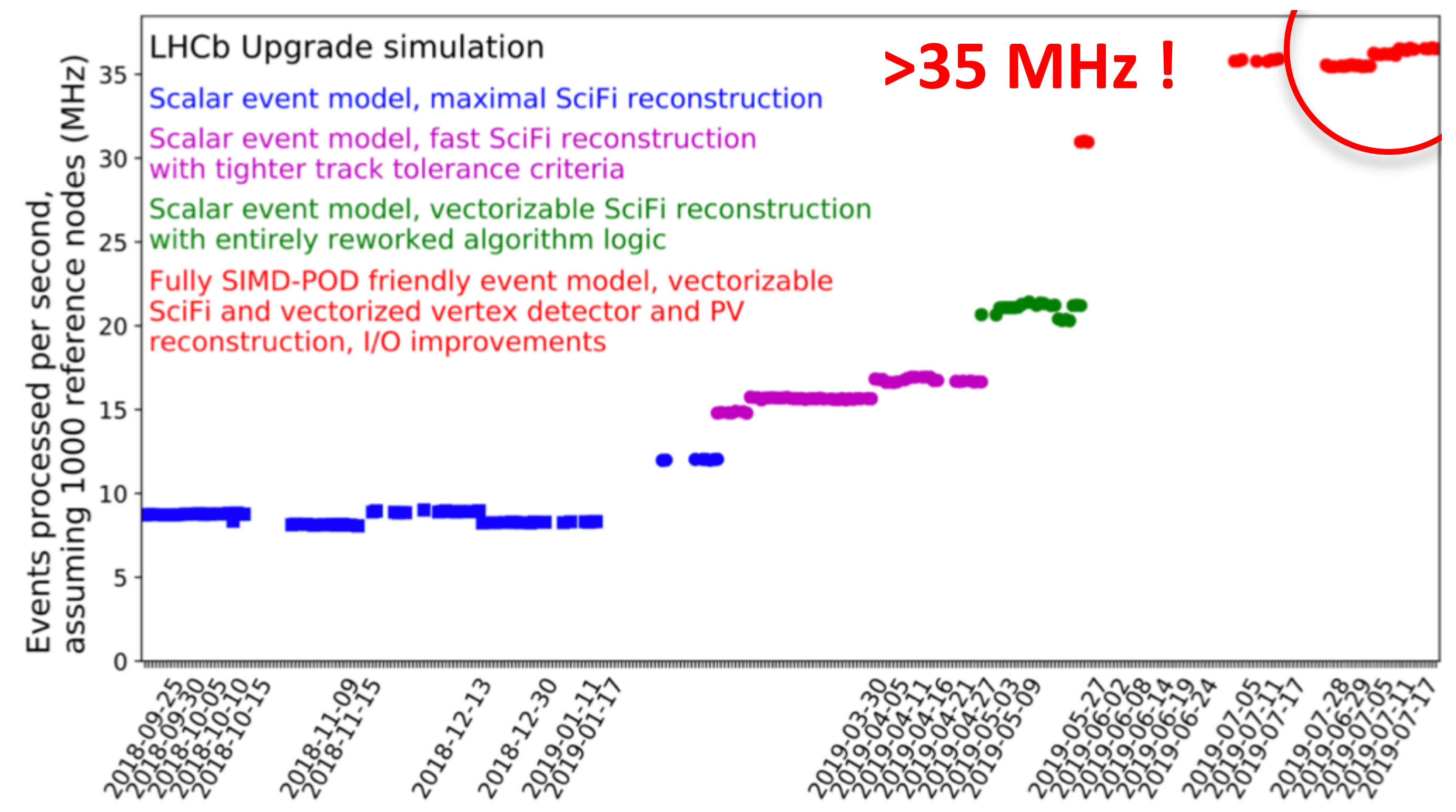
19000 fibres





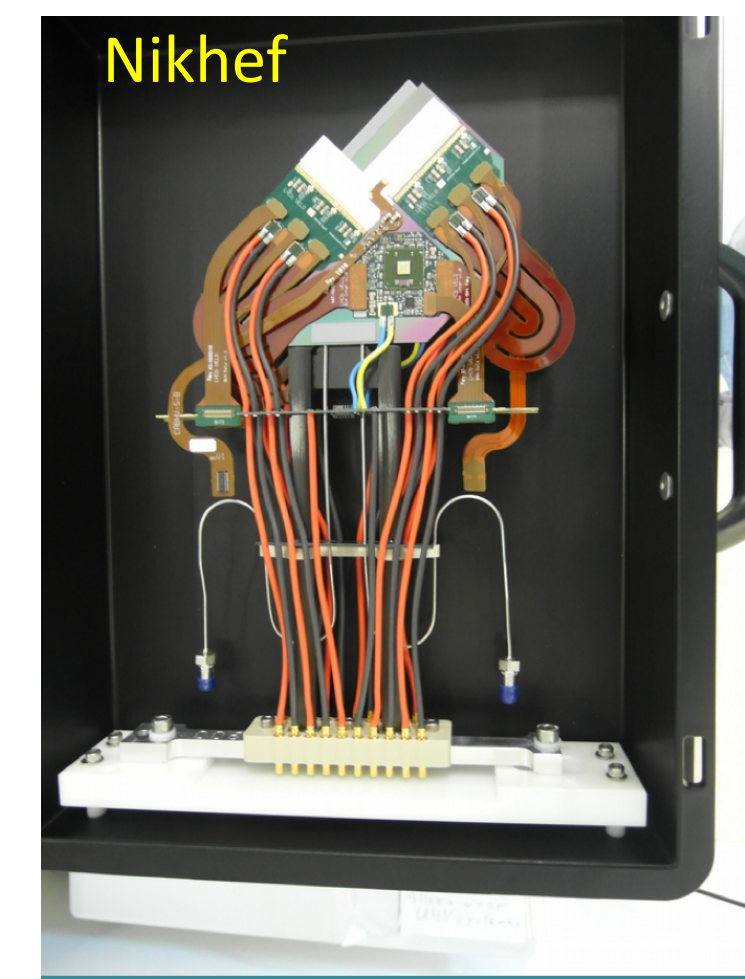
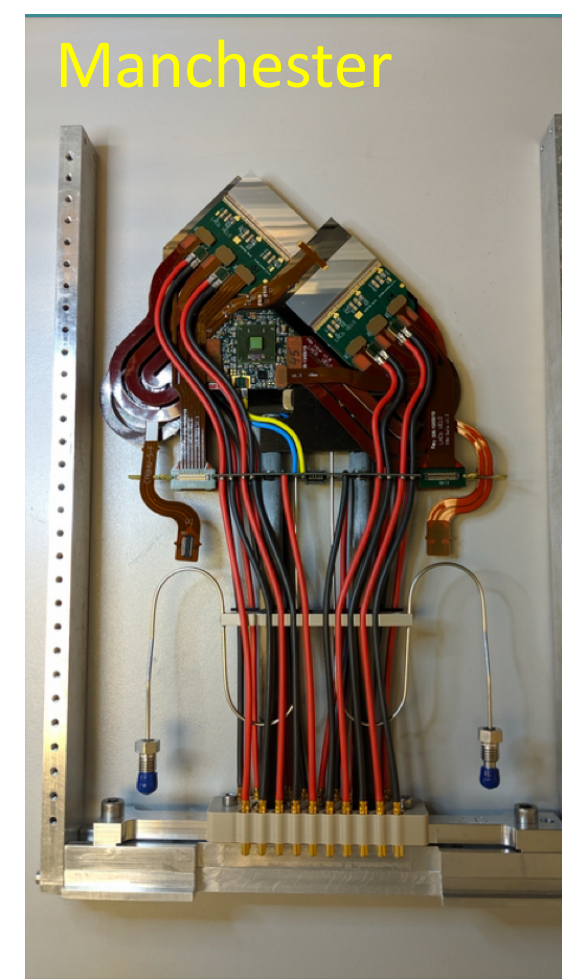
LHCb

# Some Upgrade Highlights



Breakthrough in introducing an all-software trigger

Velo production

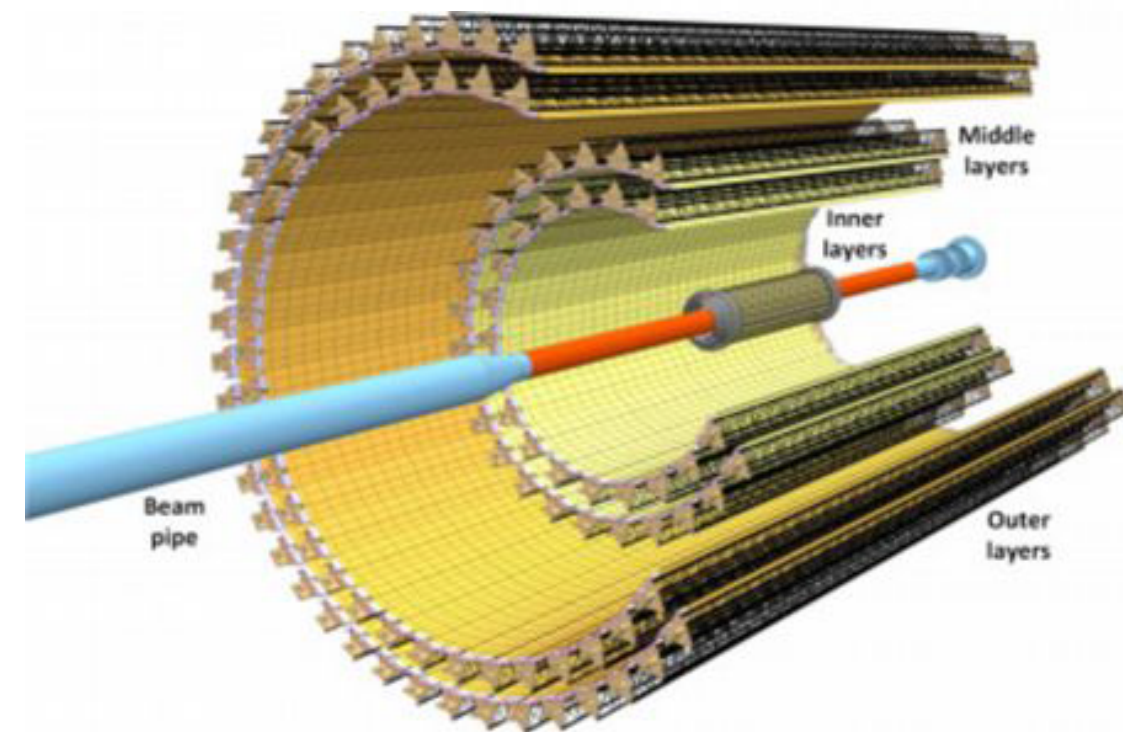


ALICE



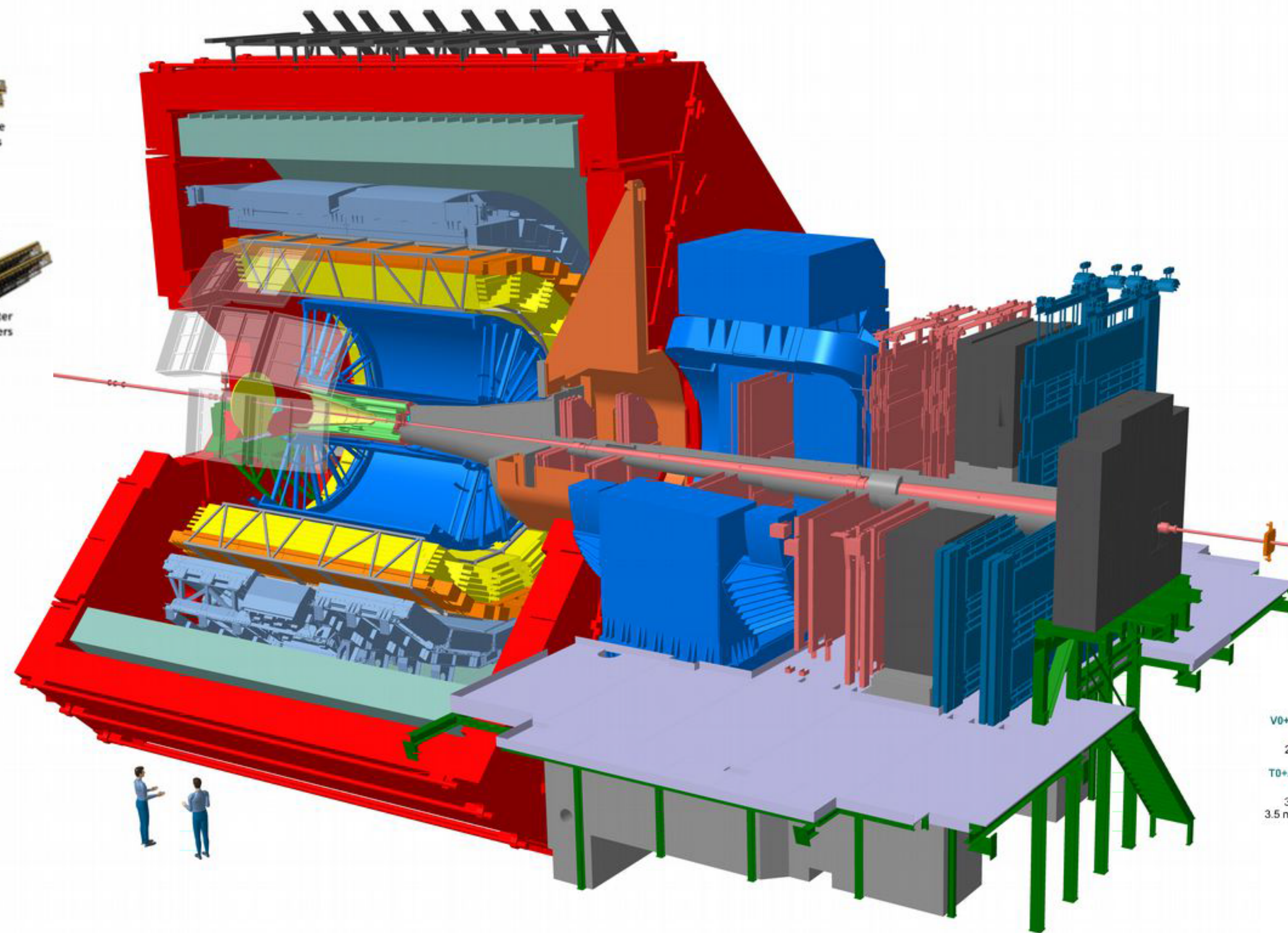
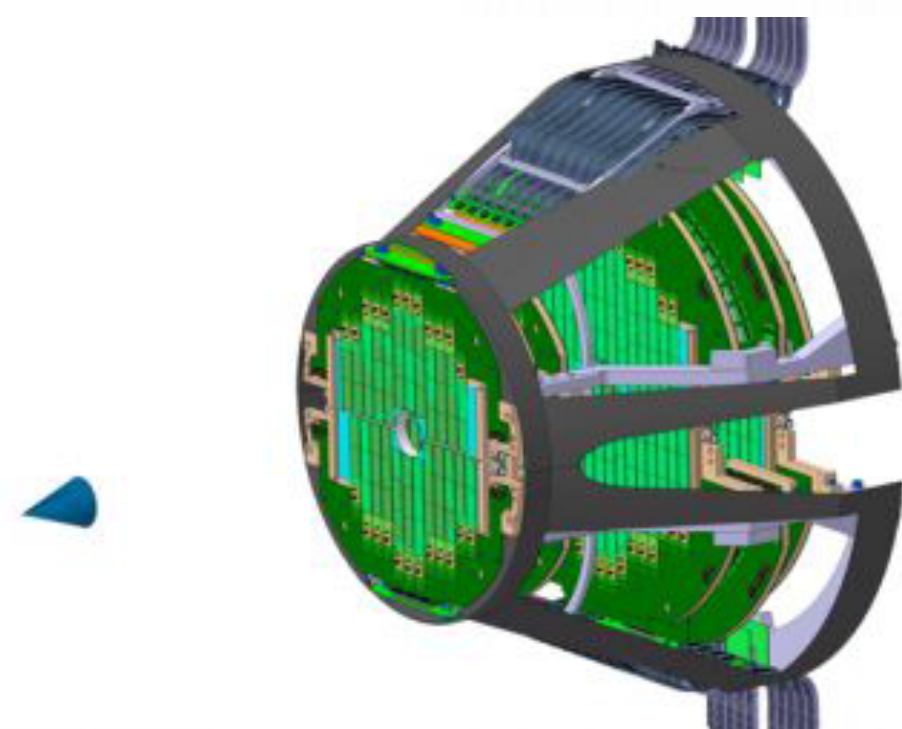
# ALICE LS2 Upgrade

## Inner Tracking System

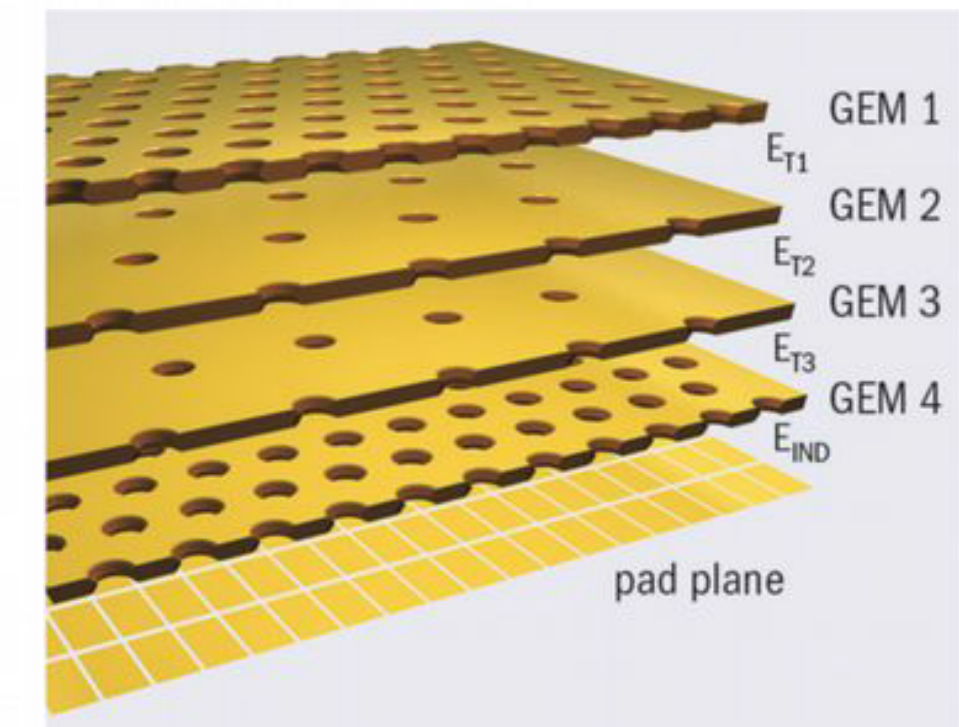


Both based on Monolithic Active Pixel Sensors

## Muon Forward Tracker

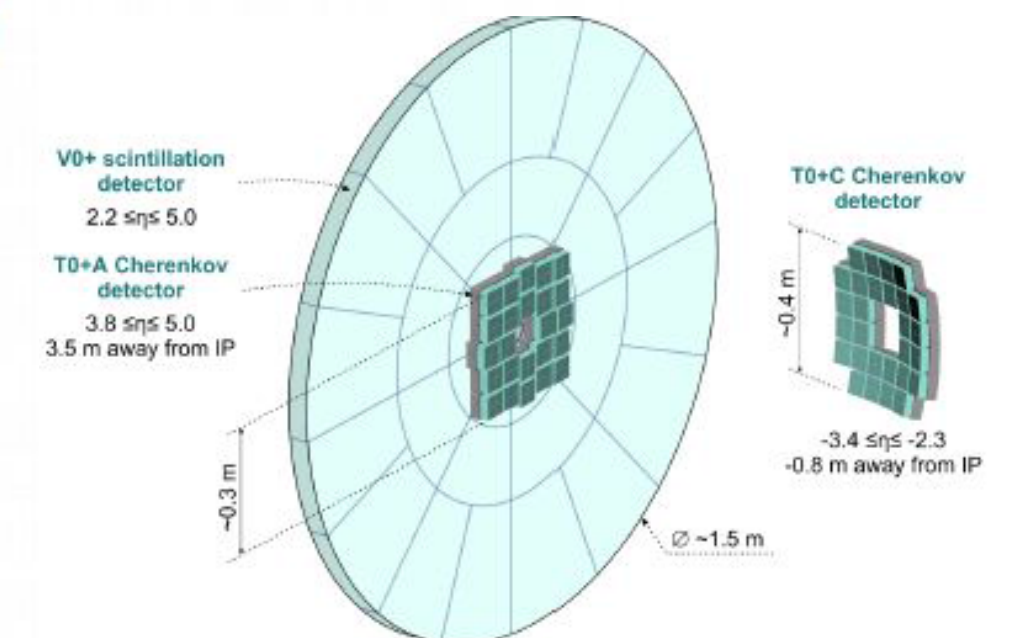


## Time Projection Chamber



GEM readout chambers

## Forward Interaction Trigger



To replace the V0 and T0 detector

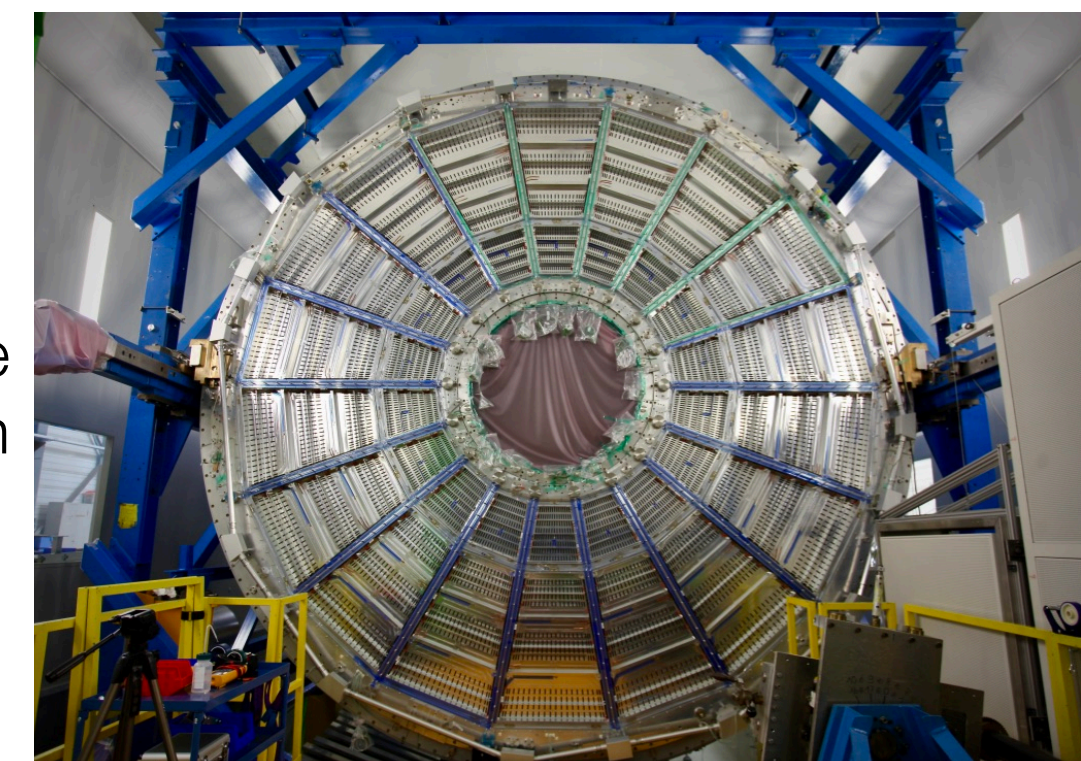
- + improved readout for calorimeters, TOF, TRD, Muon arm, ZDC
- + new Central trigger Processor
- + new DAQ and Online-Offline System (O<sup>2</sup>)



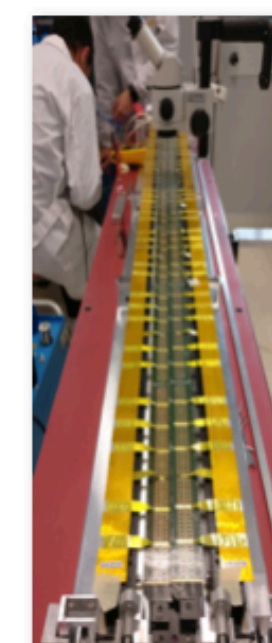
# Some Highlights

- Excellent progress on TPC installation
- Issues over CRU for TPC need resolving
- ITS and MFT proceeding well
- Containers for Online/Offline Readout system (O<sup>2</sup>) in place

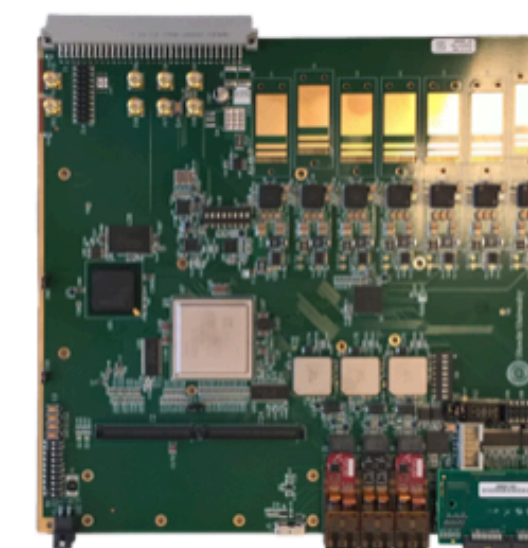
GEM installation on A-side complete; C-side following soon



ITS production and assembly proceeding well



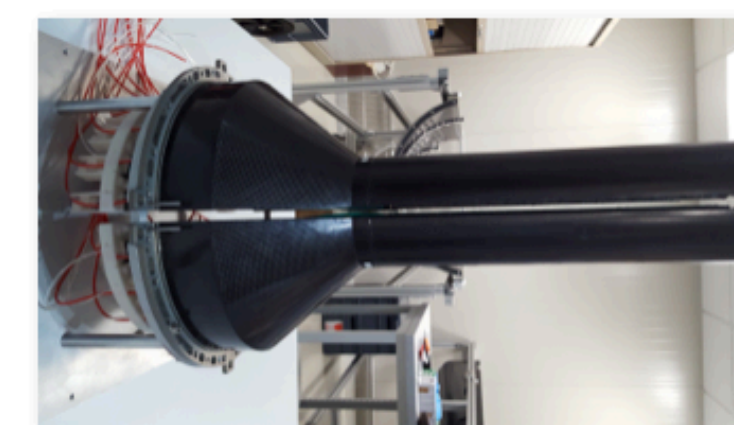
Stave



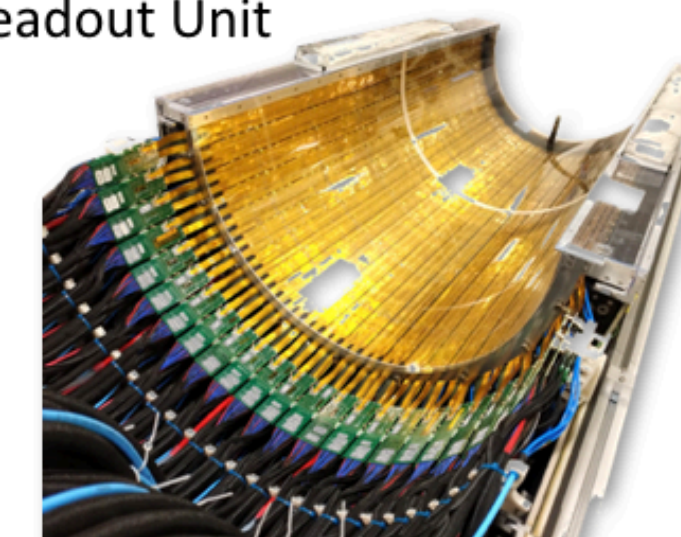
Readout Unit



Containers for O<sup>2</sup> system



Inner Barrel Assembly



Outer Barrel Assembly

# Delay in Order of Common Readout Units for ALICE TPC

---

- Joint and successful design effort for CRU with vital contributions from Indian Institutes, Hungary, CERN and LHCb
  - Production line in Europe consequently well established and proven
- Mass production of **390 CRUs** for **TPC** was repeatedly attempted with Indian companies; full qualification could never be assured – largely because of difficulties of administrative nature
  - Deadline for latest possible delivery for production in India was missed
  - To ascertain TPC operation at startup ALICE issued order for production with established company week of Oct. 14, backed by CERN management
  - Continue to negotiate to have Indian commitment fulfilled
- More details in ALICE session



# LS2 Brief Summary

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- ATLAS

*Excellent Progress everywhere, but...*

- NSW: progress in understanding Micromega production; installation of one wheel likely in LS2

- CMS

- biggest concern is over timely completion of preparatory work for LS3

- LHCb

- UT installation remains on critical path

- ALICE

- CRU electronics have to be delivered in time to allow for critical tests of the TPC

News on Phase II Upgrades

# Phase II Upgrade

- Contract for silicon sensors for
  - ATLAS ITK
  - CMS Tracker
  - CMS HGCal
- have been signed
- Commitment for many institutes



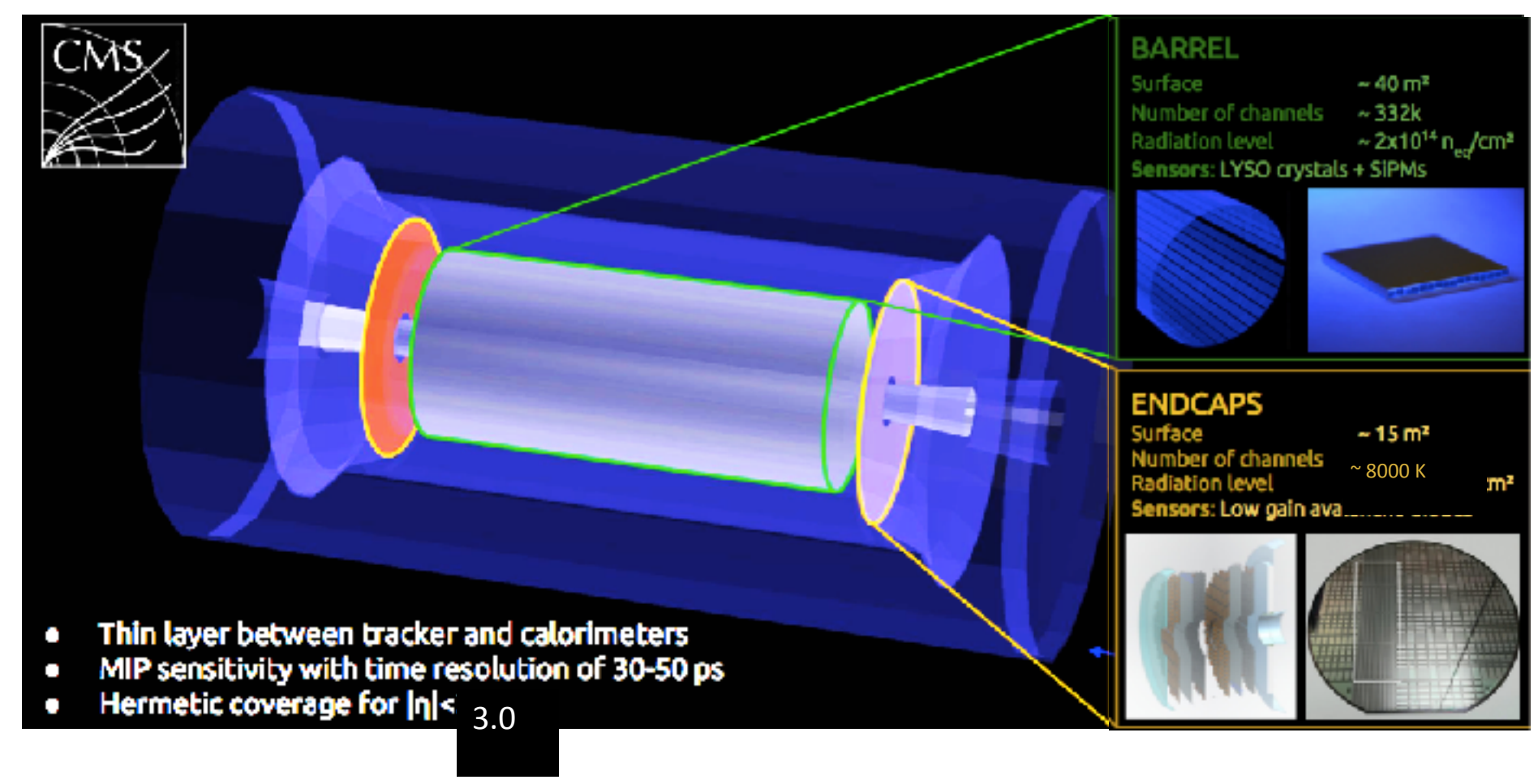
Signature of Contract with Hamamatsu 23.8.2019



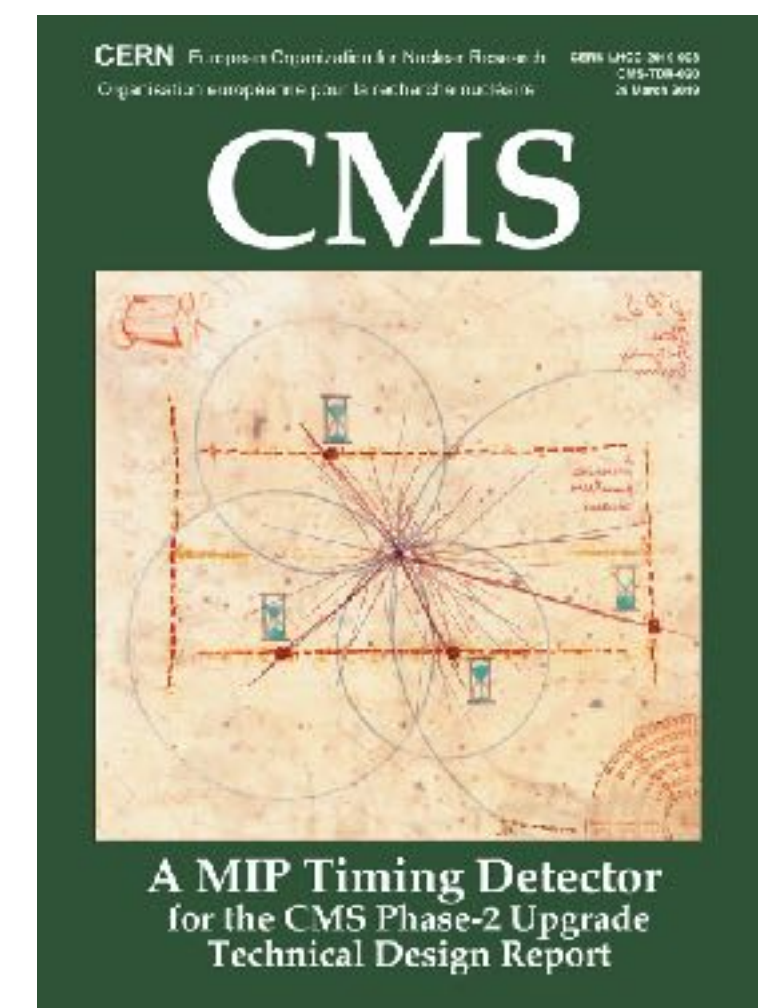
CMS

# CMS Phase 2 MIP Timing Detector

- TDR submitted in March 2019
- Scientific review successfully completed in June
- Cost and Schedule review process completed
- MTD UCG final review September
- LHCC and UCG review panels recommend the CMS MTD project for approval



Research Board approved  
CMS MTD in September



# Collaborations

---

- Phase I and II upgrade projects have been prepared and scrutinised in extensive TDRs before approval
  - generally the most challenging aspects are properly identified and followed up
  - the often complex ancillary components or the administrative hurdles are sometimes underestimated
- In the end we rely on the collaboration as a whole to deliver and commission components
  - Typically a stringent set of project reviews are carried out inside the collaborations
- For Phase II we introduced P2UG for efficient external monitoring

# Reminder – Full mandate of P2UG

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- The ATLAS and CMS P2UG chairs and regular members are nominated by the CERN DRC, also using the broad expertise available among the members of the Phase II TDRs review panels. The P2UGs report to the DRC and to the LHCC through their chairs. The LHCC and UCG chairs are ex-officio members of the two P2UGs, although they are not expected to participate in every meeting.
- The P2UGs will monitor the execution of the Phase II upgrade projects, verifying the technical progress, tracking the milestones, and ensuring the level of effort and managerial organisation are adequate. They will regularly report to the LHCC about their findings, promptly identifying areas that might require further in-depth investigation, in particular significant deviations from the TDR plans. The P2UGs is also expected to report on the final reviews convened by the experiments before major spending, providing advice to the LHCC and the CERN management on the approval for construction of the projects, described as Step 3 in CERN-LHCC-2015-007. It is expected that each P2UG will meet twice a year with the respective experiment, scheduling the meeting to maximize synergies with the experiment internal review process. CERN will provide centralised support for collecting and maintaining milestones and schedule information uniformly for the two experiments, as well as secretarial support to run the meetings
- The initial mandate for the P2UGs members will be two years, although the P2UGs should remain in place until the installation of the upgrades, currently foreseen during LS3 (Q1/2024-Q2/2026).

# Phase II Upgrade Group (P2UG)

---

- Progress Tracking of the Phase II upgrade
  - ATLAS and CMS progress reviewed every 6 months, interleaved
  - Milestone tracking
  - Chairs
    - Marcel Demarteau
    - Mauro Morandin
- Each team is consists of ~10 experts including those familiar with the TDR approval process



## P2UGs of both experiments have met

---

- P2UG analysed the resource allocation at the start of the Phase II upgrade projects
  - noted very ambitious aspects of the projects in particular
    - the large area Silicon detectors, the CMS high granularity calorimeter
- warned that the current schedule may not be tenable

*Reminder: a Run 3 scheduling meeting with the machine and experiments has been called for on  
27 Nov 2019*



# Conclusions

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- Physics data evaluation continuing successfully
- Long Shutdown 2 has proceeded well so far
  - some earlier critical items are getting settled
- Phase II Upgrade has now started in earnest
  - The two collaborations are mounting a  $\sim 1/4$  bnCHF upgrade effort each that has to be ready when the machine is

Success relies on the all partners honouring their commitments