



# Status of the Experiments

RRB Plenary  
Joachim Mnich 26.04.2021

# LHCb Recent Results – Lepton Flavour Universality



Standard Model predicts identical electroweak couplings of  $e, \mu$

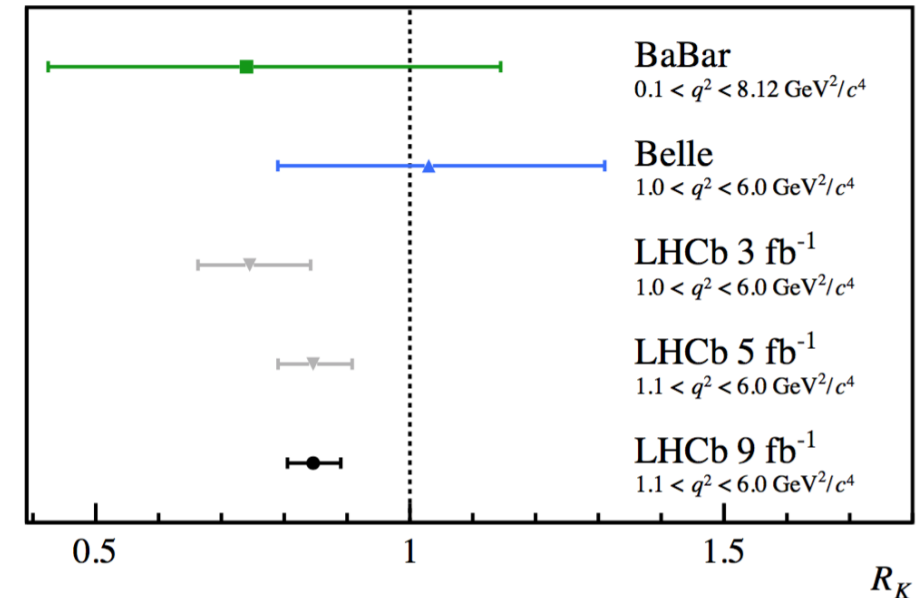
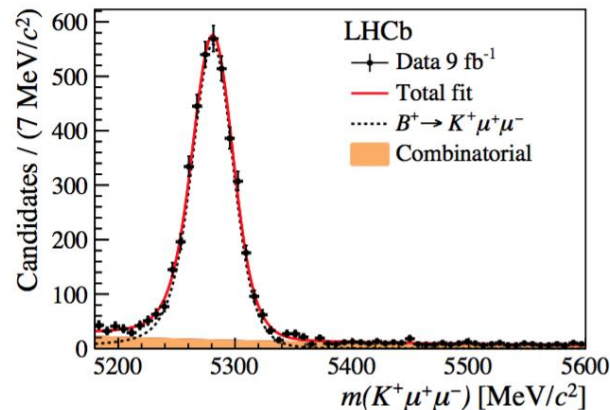
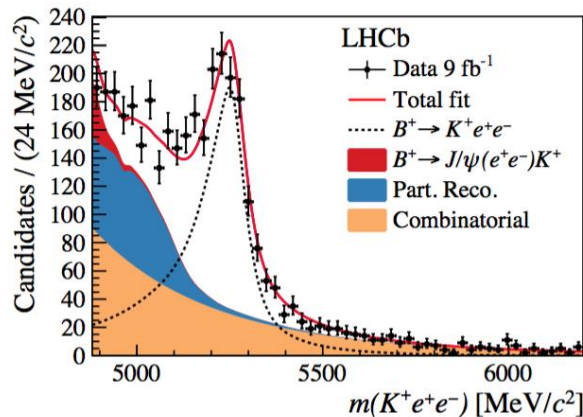
- Intriguing hints from LHCb in recent years at  $2.1\text{-}2.5\sigma$  level of deviations from SM in  $b \rightarrow s l^+ l^-$  ratios, also in angular distributions and branching fractions.

LHCb-PAPER-2021-004  
Shown for first time at Moriond EW & CERN Seminar, 23<sup>rd</sup> March 2021

$$R_K(1.1 < q^2 < 6.0 \text{ GeV}^2/c^4) = 0.846^{+0.042}_{-0.039} {}^{+0.013}_{-0.012}$$

$$R_K = N(B \rightarrow K \mu^+ \mu^-) / N(B K e^+ e^-)$$

- 3.1 $\sigma$  deviation from SM
  - Additional measurements with existing data set will provide further information, then data from the current major LHCb Upgrade for Run 3



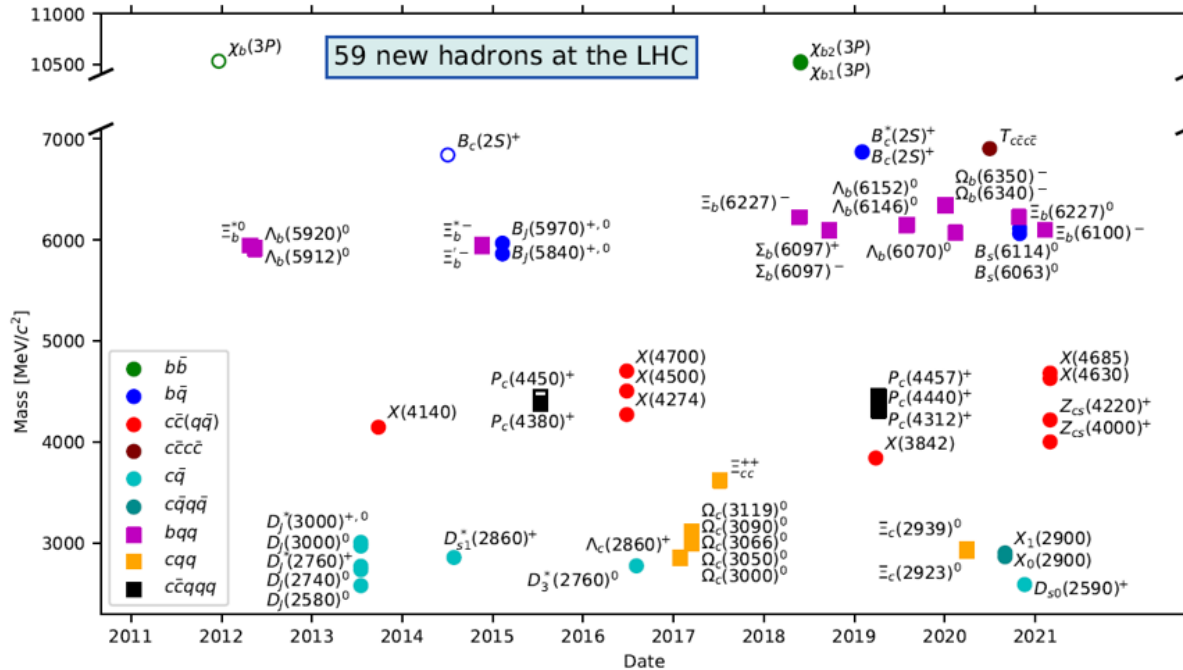
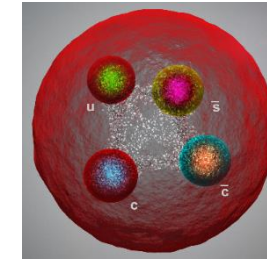
# Tetraquark Discovery and 59 New Hadrons @LHC

Observation of two  $c\bar{c}u\bar{s}$  tetraquarks and two  $c\bar{c}s\bar{s}$  tetraquarks

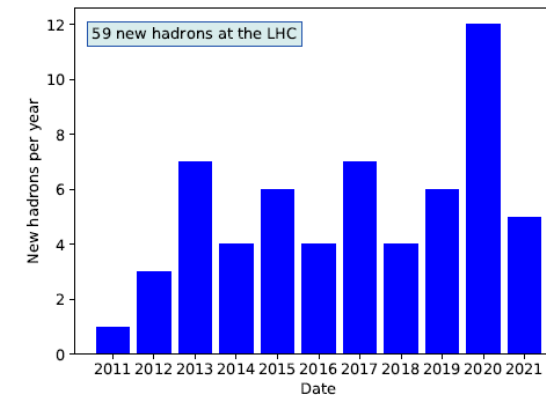
- $Z_{CS}(4000)^+$ ,  $Z_{CS}(4220)^+$ ,  $X(4630)$ ,  $X(4685)$
- For the 50<sup>th</sup> anniversary of hadron colliders the LHC has now discovered more than 50 new hadrons! (LHCb, ATLAS, CMS)



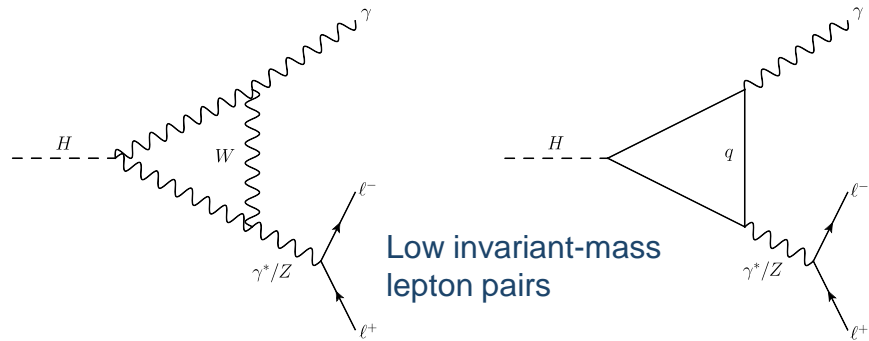
LHCb-PAPER-2020-044  
Shown for first time at La Thuile 2021,  
10<sup>th</sup> March 2021



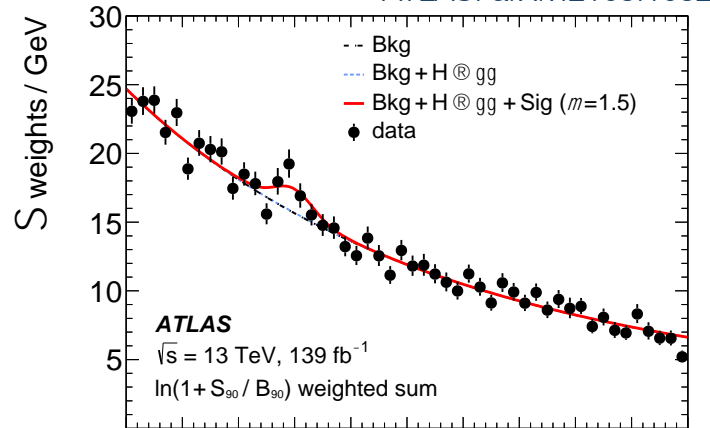
- 2020 was a very productive year despite COVID



# Evidence for a new Higgs decay mode

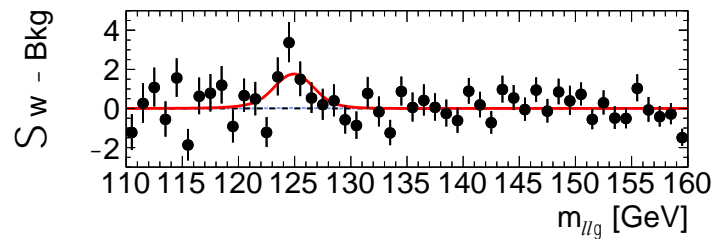


ATLAS: arXiv:2103.10322



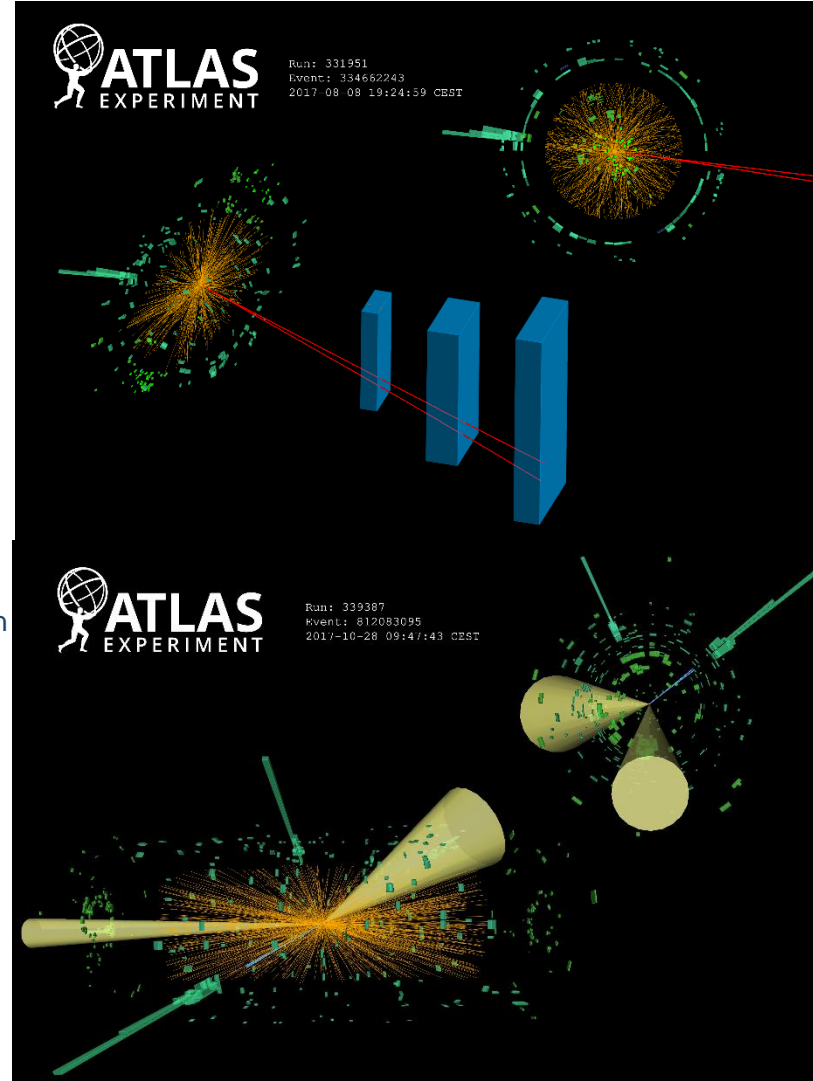
**First  $3.2\sigma$  evidence for the Dalitz decays of the Higgs boson**

Relies on novel reconstruction of near-by electrons in calorimeter



$H \rightarrow \mu\mu + \gamma$  candidate (top)

$H \rightarrow ee + \gamma$  candidate (bottom)



Process is about 5 – 10 times more rare than the Higgs discovery mode  $H \rightarrow \gamma\gamma$

# LS2 and Mitigation of Covid

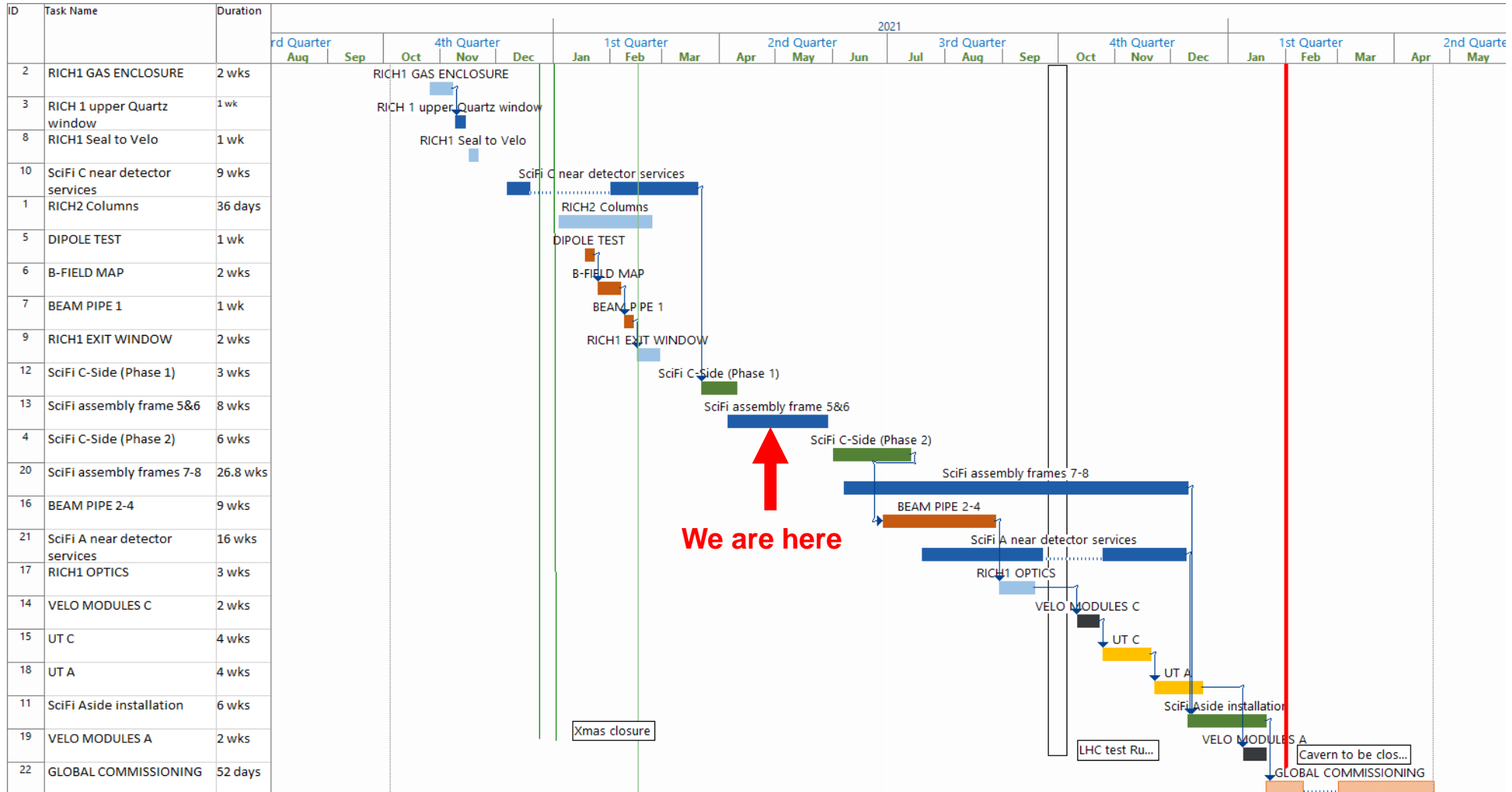
CERN support for users required for important and urgent work on site

- Provide safe environment at CERN
- CERN works closely with the Host States to respect travel and quarantine rules
- We can ask for quarantine exceptions in well justified cases
- We can facilitate access to the necessary COVID tests
- We are working closely with institutes to make sure they have all the information they need to arrange transport, places to stay, and to be sure they know of the services available in case of symptoms.....

Among others this helped LHCb to get experts from Germany and the Netherlands to CERN to resume the work on the SciFi installation

# LHCb LS2 Schedule

LHCb remains on the critical path:





# LHCb Scintillating Fibre Tracker



LHCb SciFi is a major new tracking system and one of the critical path projects for LS2

CERN is assisting in facilitating travel and local arrangements for high priority projects such as this

We thank all the participating institutes and agencies for their support in these difficult circumstances

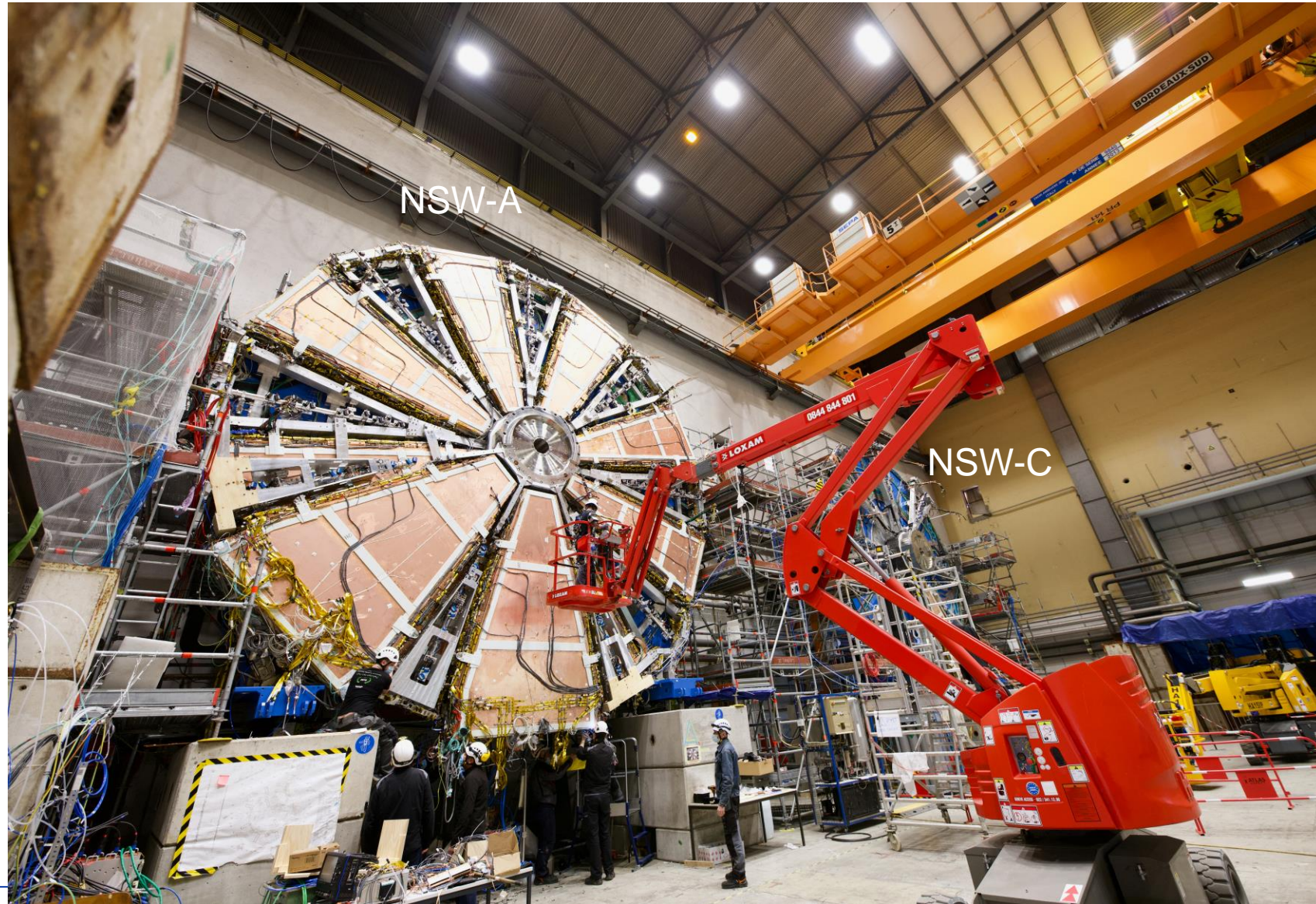


Installation work on the LHCb SciFi Tracker at LHCb



# LS2 Progress

Work on ATLAS  
New Small Wheel  
April 22, 2021



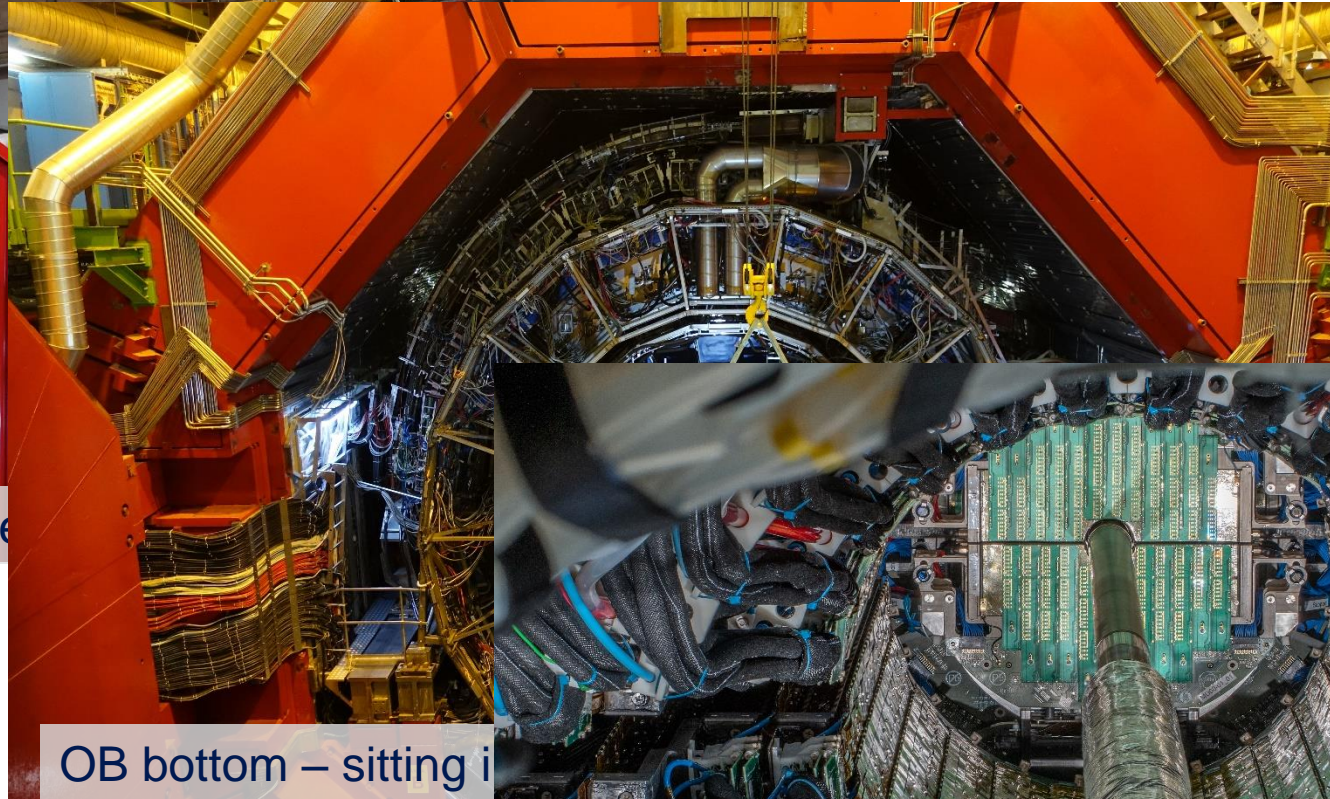


# ALICE ITS Barrel Installation

Outer Barrel (OB)

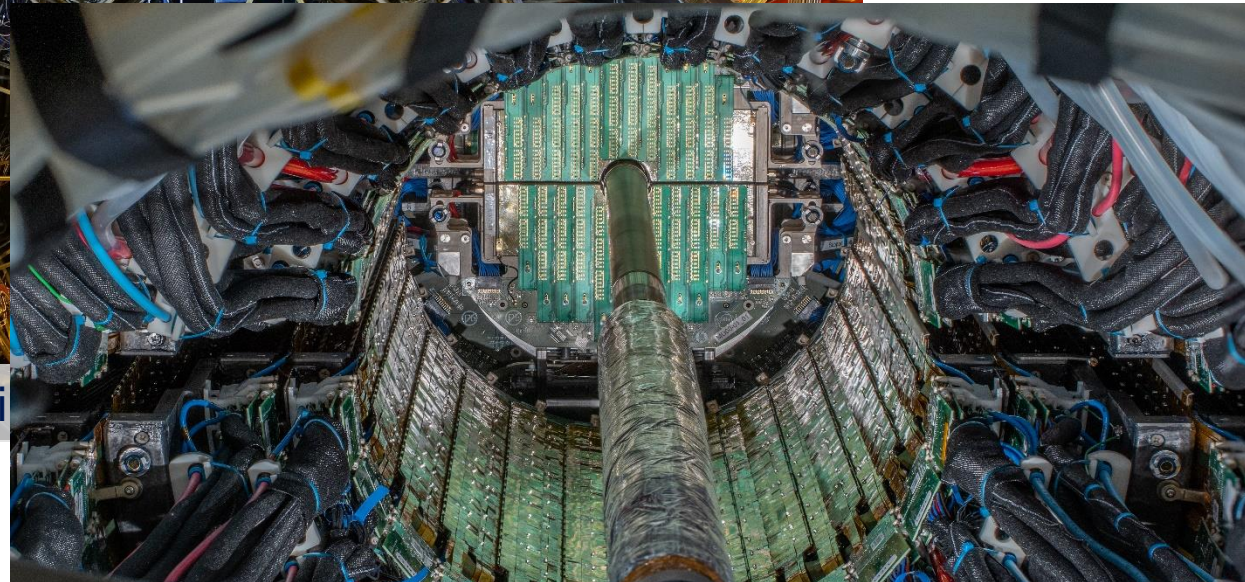


OB bottom – desc



OB bottom – sitting i

**Installation of ITS inner barrel scheduled for this week**



The whole ITS Outer Barrel installed in its final position



# CMS Central Beampipe Installation



# Common Issue: VTRx Module

Radiation tolerant optical link designed for LS2 upgrade (and non-LHC experiments)

- Since end 2020 failures of module as they went into long-term operation
- Used in different subsystems of all LHC experiments

Experiment	Sub-System	Update	# VTRx installed	Unstable* RSSI	Communication failure
ALICE	ITS (MM)	15 Dec 2020	192	~40%	~2.5%
	ITS (SM)	15 Dec 2020	192	~20%	~18% <sup>†</sup>
	TPC	4 Feb 2021	3276	~50%	0.3%
ATLAS	NSW	8 Feb 2021	1408	<i>not measured</i>	0.0%
	LArg	8 Feb 2021	620(MTRx)	<i>not measured</i>	0.0%
CMS	HCAL	4 Feb 2021	72	37.5%	2.8%
	GEM	11 Jan 2021	432	<i>not measured</i>	0.7%
LHCb	RICH	12 Jan 2021	450	<i>not measured</i>	3.3%

RSSI: Received Signal Strength Indicator

Two different failure modes suspected

- cracks in flex cable
- temperature investigations on-going

Problem is under study  
potential impact not clear yet, cooling seems to mitigate the problem

More info available end May



# Status LS2: Summary Experiments

- Schedule has become tighter:  
COVID, travel restrictions, some technical problems

**But still possible**

(pilot beam 2 weeks Sep/Oct 2021, closure of cavern Feb. 1st, 2022)

- Potential problems with VTRx module are a threat
- Revisit schedule in June
- Experiments show enthusiasm for dipole training and hope to get to 14 TeV
- Pilot beams are very helpful for experiments if there could be collisions in stable-beam condition, even at injection energy



# ATLAS Phase II

## ATLAS Phase II Upgrades



### Inner Tracker (ITk)

New All-Silicon inner Tracker

### Muon Chambers

Chamber replacement in the inner barrel

### Electronics Upgrades

LAr, Tile, Muons

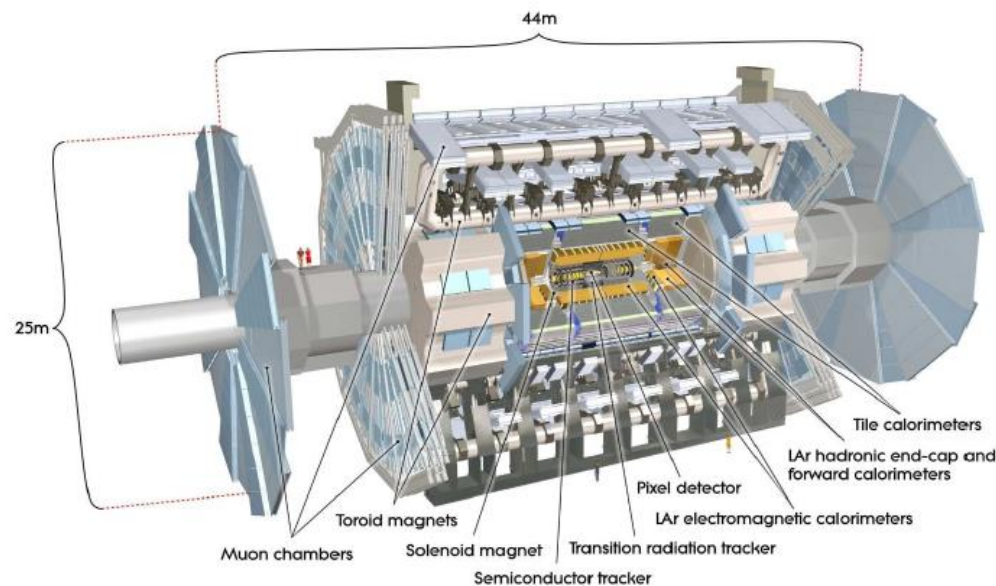
### Trigger/DAQ

Upgrade to LO-based system at 1 MHz

### HGTD

High Granularity Timing Detector

Forward timing coverage from LGADs, 30-50 ps resolution for MIPs



### Goal:

- Best possible performance in tracking, b-tagging,  $E_T^{\text{miss}}$ , ...
- Low  $p_T$  threshold for trigger.
- Extension of tracking coverage up to large  $\eta$ .

### Challenge:

- High radiation
- High Pile-up

# CMS Phase II

## L1-Trigger HLT/DAQ

<https://cds.cern.ch/record/2714892>

<https://cds.cern.ch/record/2283193>

- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz
- 40 MHz data scouting

## Barrel Calorimeters

<https://cds.cern.ch/record/2283187>

- ECAL crystal granularity readout at 40 MHz with precise timing for  $e/\gamma$  at 30 GeV
- ECAL and HCAL new Back-End boards

## Muon systems

<https://cds.cern.ch/record/2283189>

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC  $1.6 < \eta < 2.4$
- Extended coverage to  $\eta \approx 3$

## Calorimeter Endcap

<https://cds.cern.ch/record/2293646>

- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

## Beam Radiation Instr. and Luminosity

<http://cds.cern.ch/record/002706512>

- Bunch-by-bunch luminosity measurement: 1% offline, 2% online

## Tracker <https://cds.cern.ch/record/2272264>

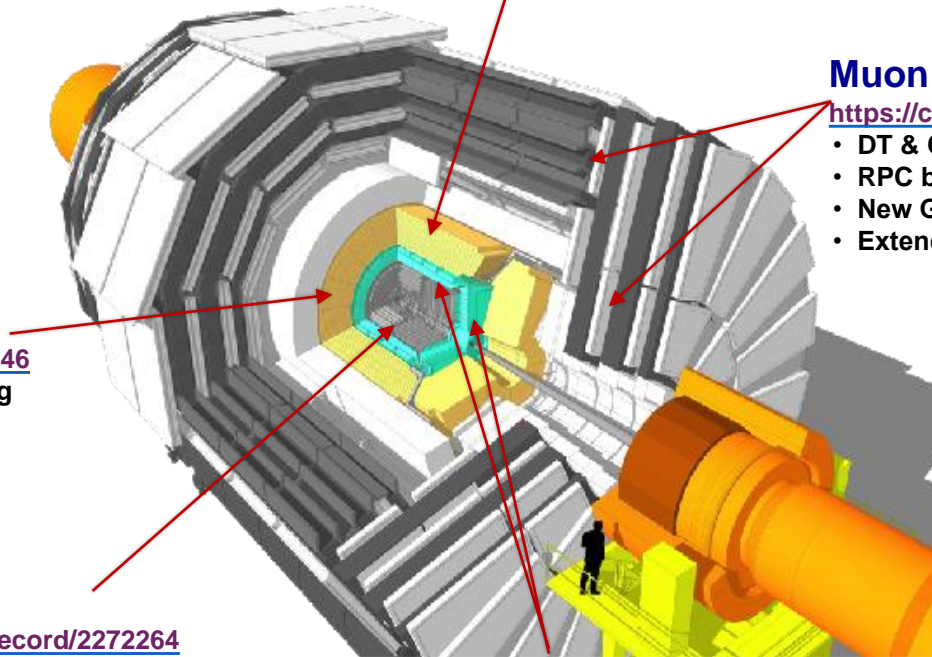
- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to  $\eta \approx 3.8$

## MIP Timing Detector

<https://cds.cern.ch/record/2667167>

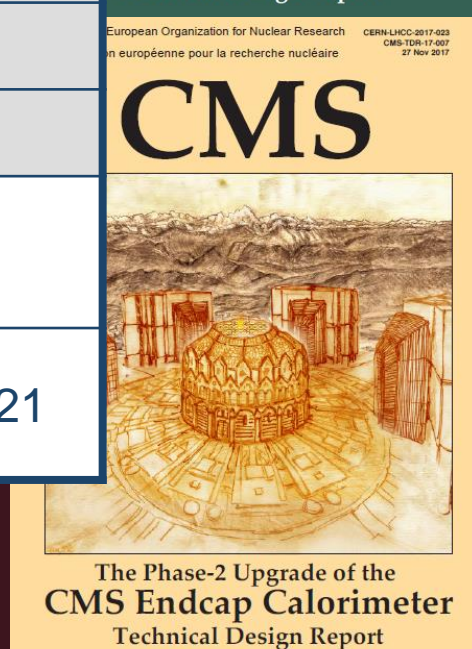
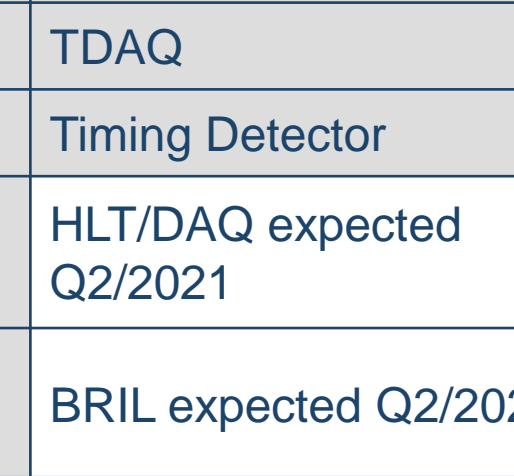
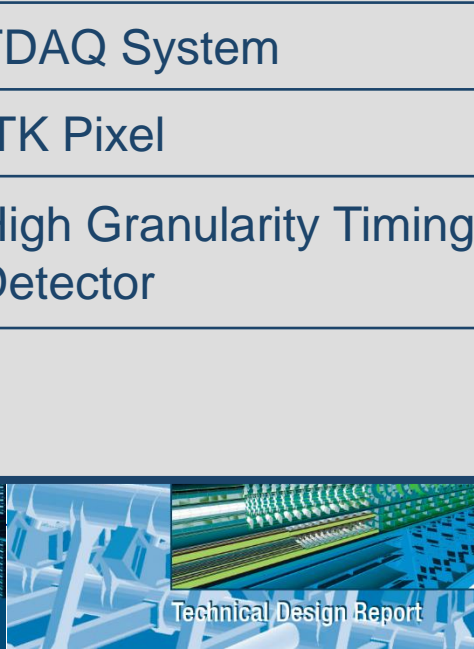
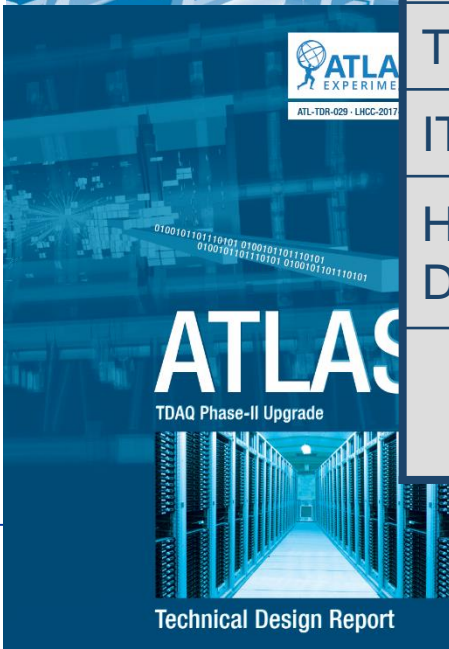
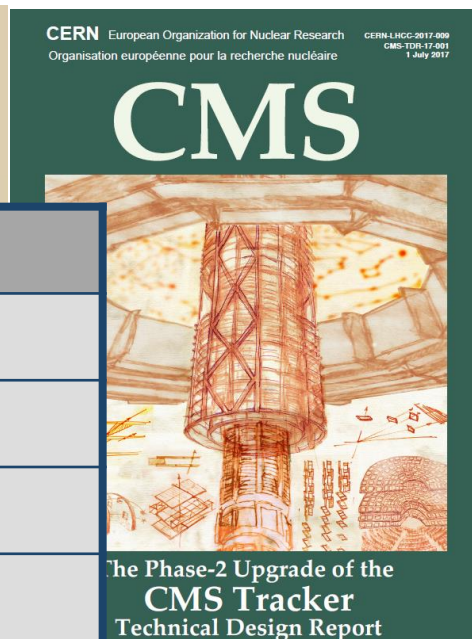
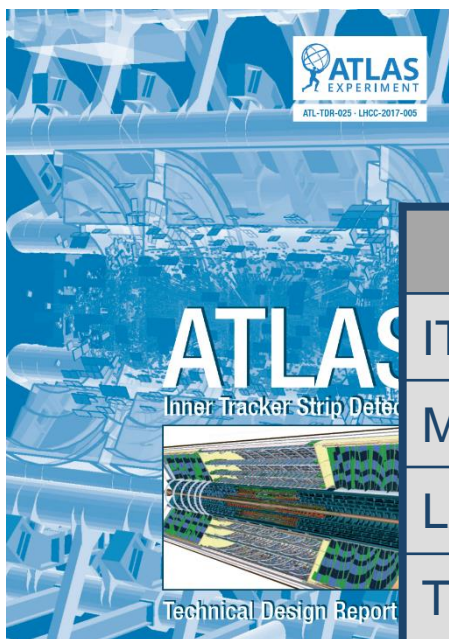
Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes



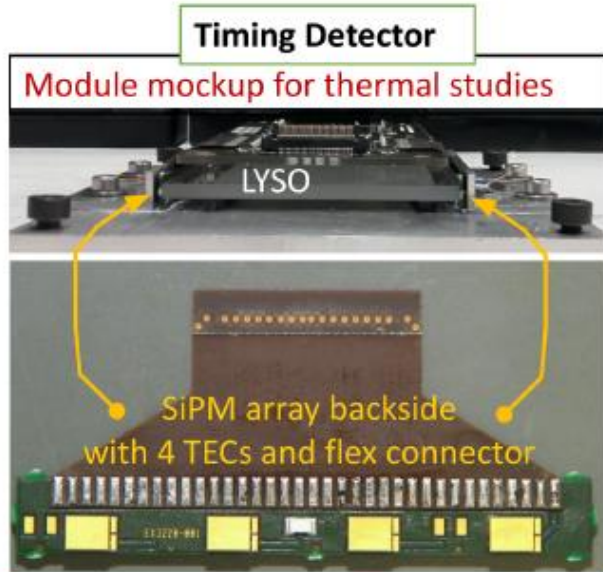
# Status TDRs

ATLAS	CMS
ITK Strip	Tracker
Muon Spectrometer	Barrel Calorimeter
LAr Calorimeter	Muon System
Tile Calorimeter	Endcap Calorimeter
TDAQ System	TDAQ
ITK Pixel	Timing Detector
High Granularity Timing Detector	HLT/DAQ expected Q2/2021
	BRIL expected Q2/2021

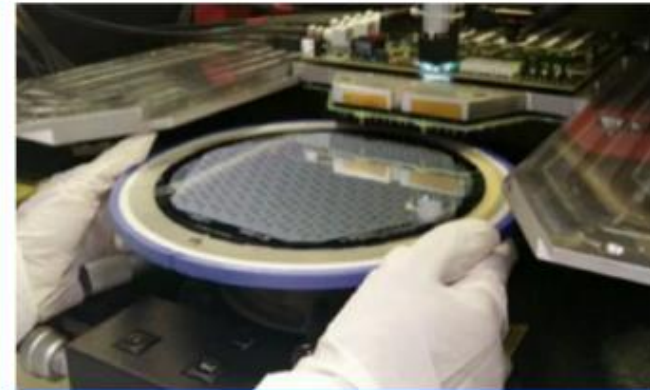




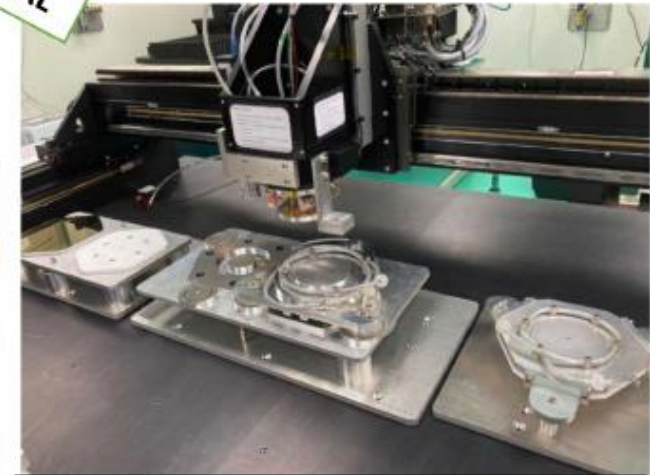
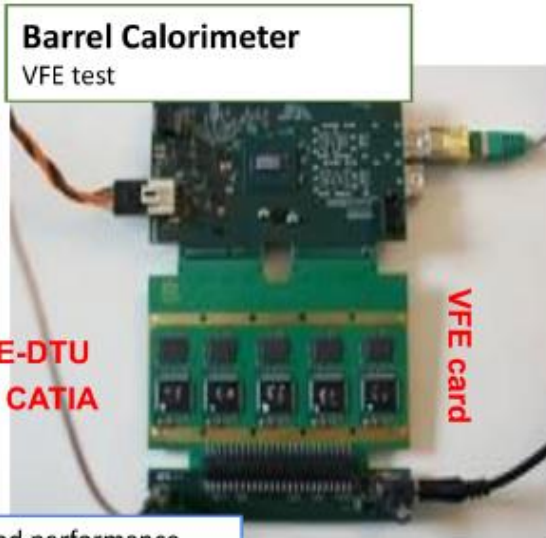
# CMS Phase II Progress



Barrel Timing Layer testing implementation of Thermo Electric Coolers (TECs) to reduce temperature locally thereby decreasing dark current rate (DCR)



HGCAL



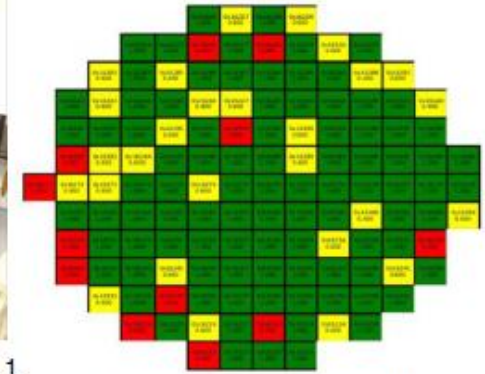
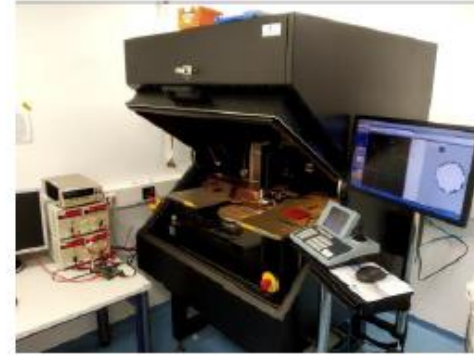


# Status ATLAS Phase II Upgrades

## ITk

### ➤ Pixel

- Transition from R&D to (pre-)production.
- Sensors already going into pre-production.
- 4 wafers from ITkPixV1.1 received end of November, first tests with the patched frontend chip ongoing.
  - Power consumption on power up as expected.
  - Output is binary with ToT=7, no hit loss observed.



ITkPixV1.1  
Preliminary results indicate good yields.

### ➤ Strips

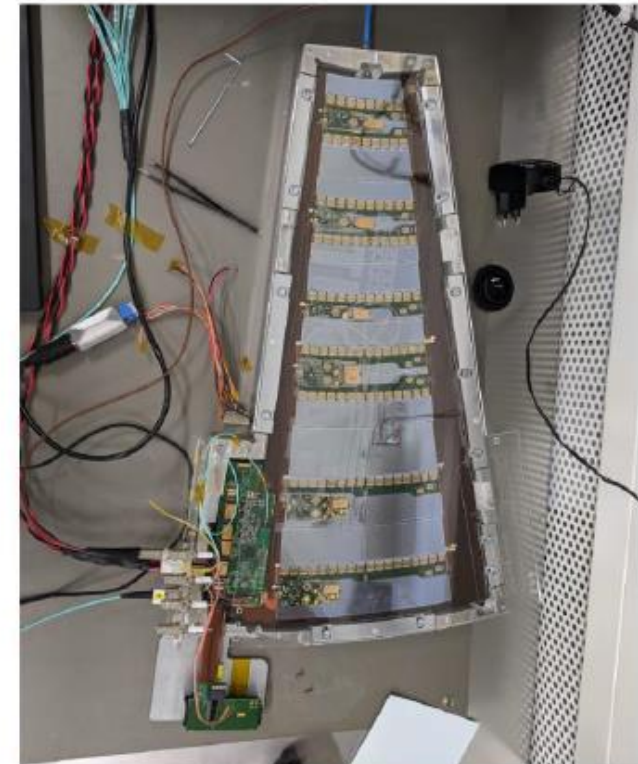
- Sensors: PRR to start production, passed last month.
- HCCstar is delayed, solving the issue (SEE weaknesses in v0).

### ➤ Main concern: schedule slipping.

- Now both systems with negative float. 7 months for Pixel, ~1 month for Strips.

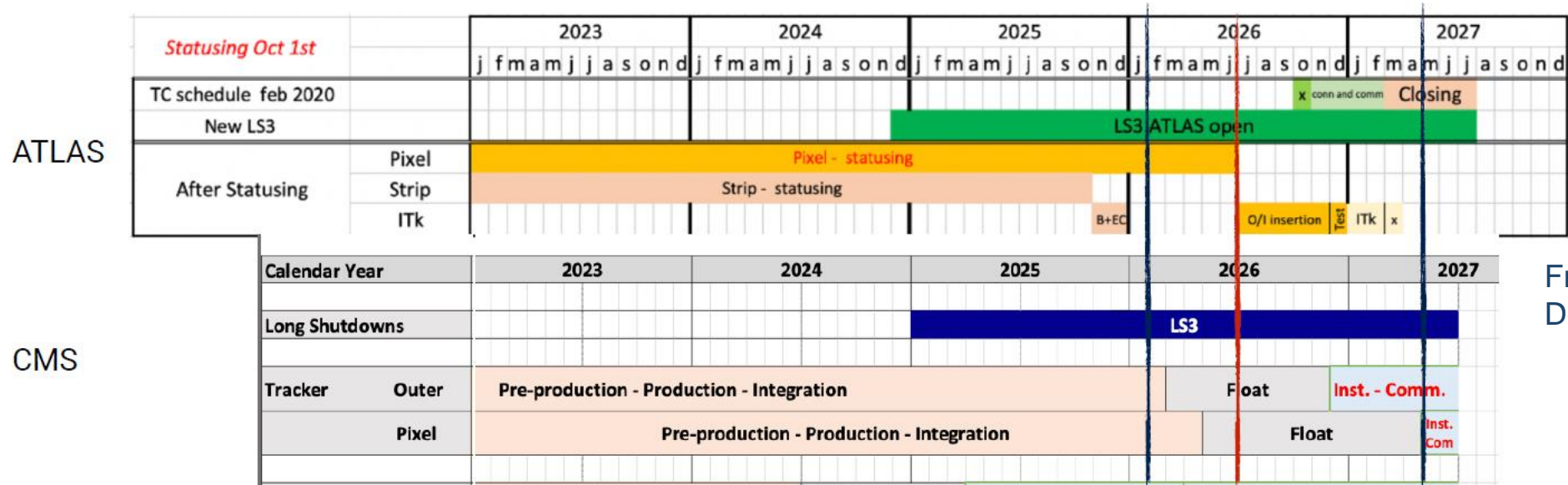
## Trigger architecture

- ATLAS needs to converge on a baseline on the implementation of tracking at the Event Filter Level. To be reviewed by LHCC.
  - Previous baseline: full custom hardware system based on associative memory ASIC.
  - Studies indicating significant potential cost reductions both for HTT and commodity (SW and “heterogeneous”) options.



ITk Strips: First fully electrical petal

# Schedule Phase 2 Tracking Inner Detectors



Frank Simon,  
December 2020

ATLAS pixel ready for installation

ATLAS pixel current plan

CMS ready for pixel installation

Concerns about schedule persist

- COVID slows down activities in many labs around the world
- New potential threat: world-wide shortage of silicon wafers
- ASIC design in general remains a challenge

Note: some of these concerns apply to other sub-detectors as well

SPC asks for a review of the LS3 schedule end 2021 / beginning 2022

# Working Group for Long Term Support of the LHC Experiments

Results of the WG presented in December

- Here: follow up and implementation of the recommendations

Technical group is working on a proposal of the modalities of „Experimental Project Associate“ (PJAS):

- Duration (max. 8 years?)
- Modalities of extension (within the 8 years)
- Conditions
- etc.

This technical group will include administration and representatives of EP and LHC experiments

The proposal will then go into the concertation process with Staff Association, Comite de Concertation Permanent (CCP), Tripartite Employment Conditions Forum (TREF)

Goal is to complete in the second half of 2021

# General Support for CERN Users

On the initiative of the CERN directorate a new

## Working Group on Strengthening the support for Users at CERN

has been established to assess the present status and to propose possible improvements.

The Working Group's work shall be complementary to ACCU

Chair: EP Department Head Manfred Krammer

Among the areas the WG will look into:

- Housing (CERN Hostel, St. Genis Foyer, CERN apartments, private market, booking rules and procedure)
- Catering (restaurants, cafeterias, vending machines, food pick-up)
- Mobility (shuttle service, car and bike rental, parking and bike shelters, public transport, road safety, charging of e-cars/bikes, support to mobility-impaired people)
- Installation and Integration (welcome of newcomers, green plates)
- Computing (accounts, network, telephony including mobile phones, licensed S/W)
- Office space, conference rooms, laboratories
- Administration (registration procedure, Host State regulations and documents)
- Access (access to CERN site, including family members)
- Health and Safety (medical service, dedicated health insurance for MPAs, social security)
- Kindergarten
- Diversity, inclusion, with emphasis on support to people with disability
- Education, Communication, Outreach (academic training, bulletin and communication, visits)

Other topics might be added as a result of the work



## Preparation Run 3:

- WLCG services are operationally ready: they never stopped during LS2 and the activity continuously increased
- Resource needs for the start of Run 3 are manageable with flat funding, with some margin

## To be noted:

- ALICE and LHCb have many new detectors and a completely new computing model. Resource needs might exceed above flat funding in future
- Run conditions after 2022 (e.g. pileup – event complexity) could be challenging
- COVID is impacting economy and the trend of hardware cost is harder to predict



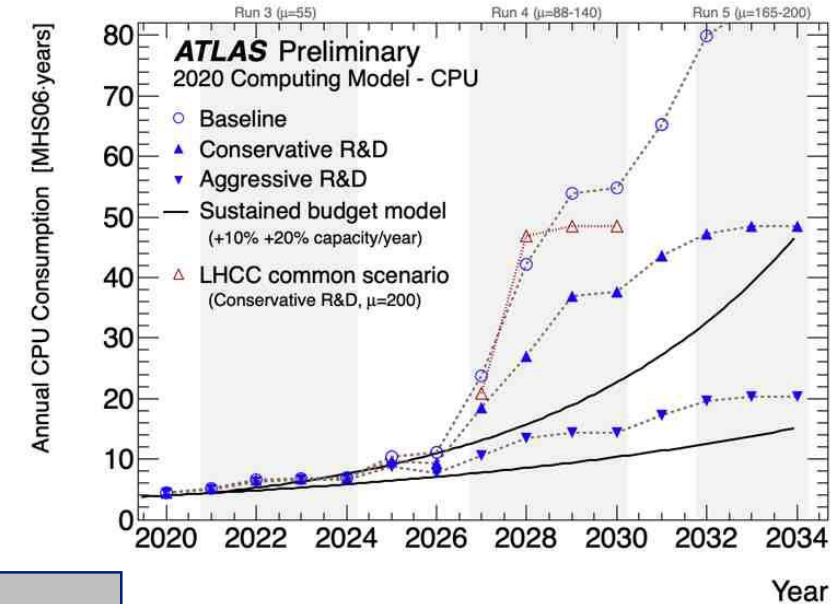
# Preparing for the HL-LHC computing challenge

Aggressive investment in R&D is needed to address the computing challenge

- in terms of resources, if we foresee no more than constant investment in hardware
- in terms of long term sustainability for infrastructure and software

The ongoing R&D is focusing on:

- Improvements in software performance.
- Software portability to heterogeneous architectures (CPUs and accelerators)
- New data models and new data management services
- Integration of non Grid resources in WLCG (Clouds, HPCs)
- Modernization of the infrastructure and services



**CERN Council approved the Prévessin Computing Centre**



# CERN Quantum Technology Initiative

New CERN activity in place

Communication channels (web site) being set up

Most Scientific Advisory Board members have been nominated

Invitation letters being prepared

Collaborations being established in the Member States, US (Fermilab, Oak Ridge) and Japan (Tokyo – ICEPP)

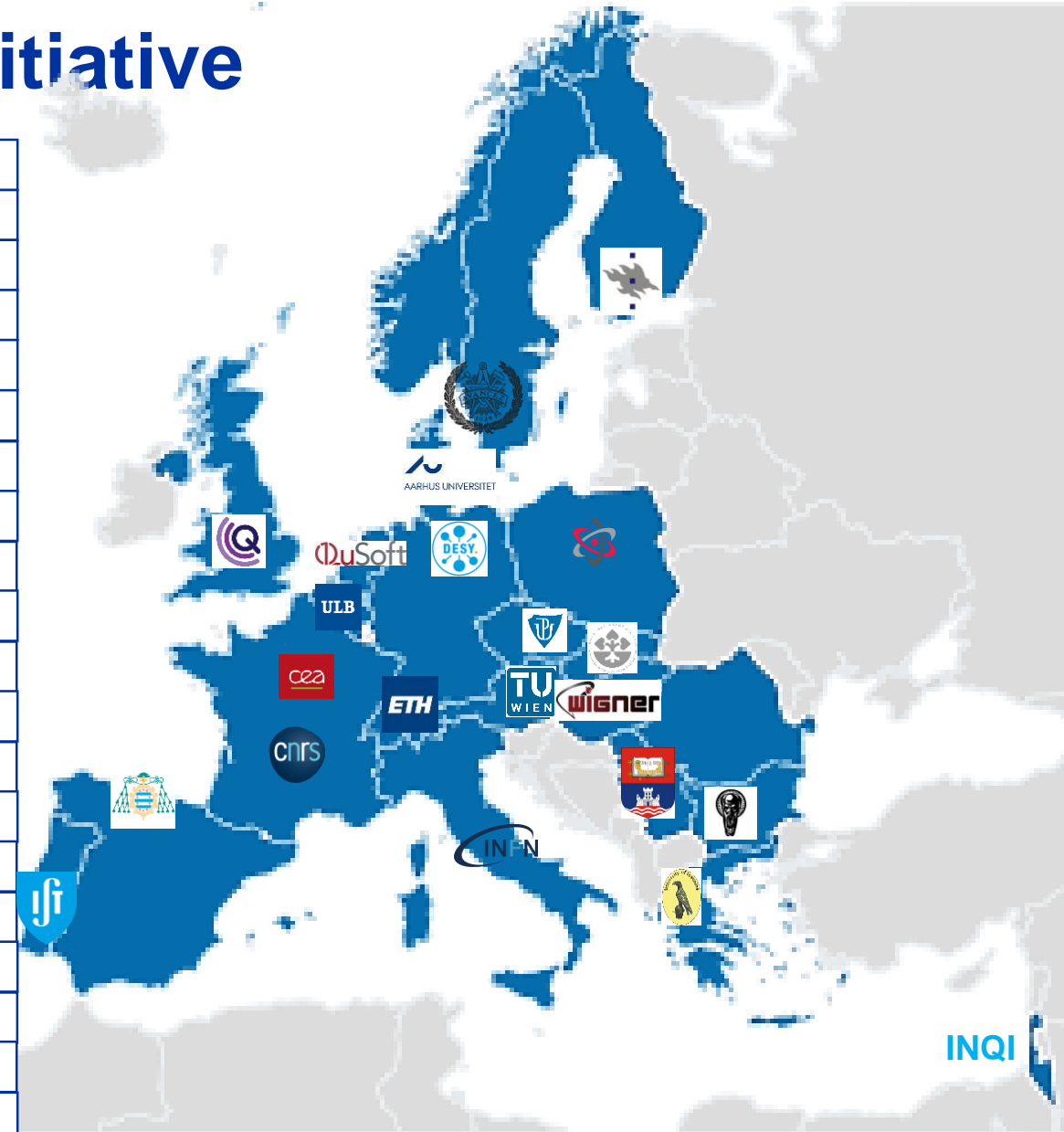
Signed Quantum Hub Agreement with IBM

Working on roadmap white paper

A workshop on Quantum Technologies for HEP being organised tentatively in June

- Kick-off of the Advisory Board
- Presentation of the draft Roadmap
- First projects, activities, results

Austria: Vienna University of Technology
Belgium: Université Libre de Bruxelles
Bulgaria: Sofia University
Czech Republic: Palacký University
Denmark: Aarhus University
Finland: University of Helsinki
France: CEA, CNRS
Germany: DESY
Greece: University of Ioannina
Hungary: Wigner Research Centre
Israel: Israel National Quantum Initiative
Italy: INFN
Netherlands: QuSoft
Norway: under discussion
Poland: National Centre for Nuclear Research
Portugal: IST Lisbon
Romania: under discussion
Serbia: University of Belgrade
Slovakia: Slovak Academy of Science
Spain: Universidad de Oviedo
Sweden: Chalmers University
Switzerland: ETHZ
United Kingdom: Quantum Sensing Hub



# Summary

Despite the pandemic

- Scientific output of experiments and theory stays at a high level
- LS2 upgrade work continues  
schedule is tight but still possible

Computing for run 3 in place

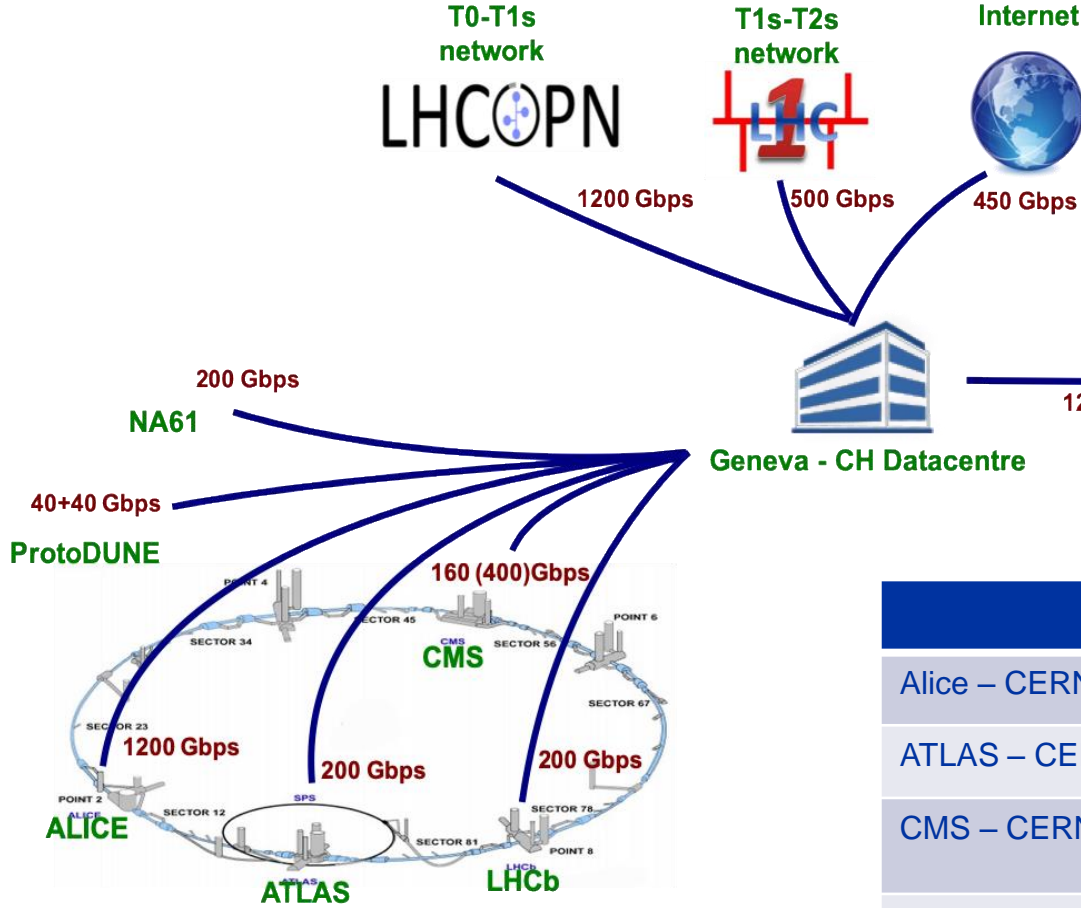
- Growing demands, in particular for HL-LHC, remain a challenge

LS3 schedule and impact of Covid to be reassessed later in 2021/22



# Backup

# Network upgrade in preparation for Run-3



Wide Area Network connectivity (LHCOPN/LHCONE and Internet) increased between x2 and x3 since 2017

	2017 (Gb/s)	2021 (Gb/s)
Alice – CERN data center	80	1200
ATLAS – CERN data center	80	200
CMS – CERN data center	160	160 (400 in summer)
LHCb – CERN data center	20	200