CERN-RRB-2022-107 (slides)

Status of LHCb: Start of Upgrade I & Run 3

RRB, 26th October 2022

- Collaboration Matters
- Selected Physics Results
- LHCb Upgrade I Status
- Summary

Start of Run 3 13.6 TeV collisions 5th July 2022

Chris Parkes
on behalf of the LHCb Collaboration

Collaboration News

Welcome to

- **CONARE, Costa Rica.** Consortium of five universities joined as a single full member group. Interests include GPUs and SiPMs, long-lived particle searches.

- **Eric Thomas** (CERN) took over as Technical Coordinator from 1st July
- **Yasmine Amhis** (IJC Lab, Paris) took over as Physics Coordinator from 1st August
- **Francisco Polci** (LPNHE, Paris) took over as Operations Coordinator from 1st September

The three eras of LHCb

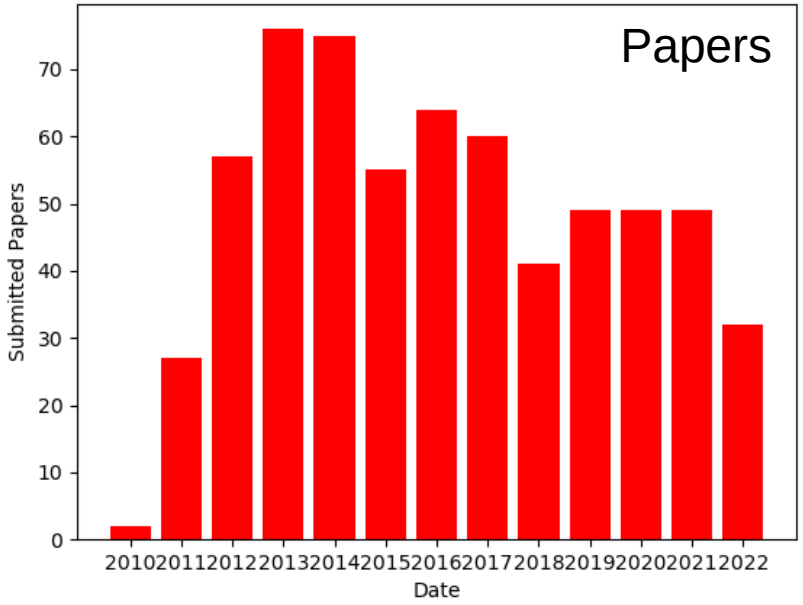
Original	*2009-2018*
Upgrade I	*2022-2033*
Upgrade II	*2035-*

- Physics results
- Commissioning
- R&D underway

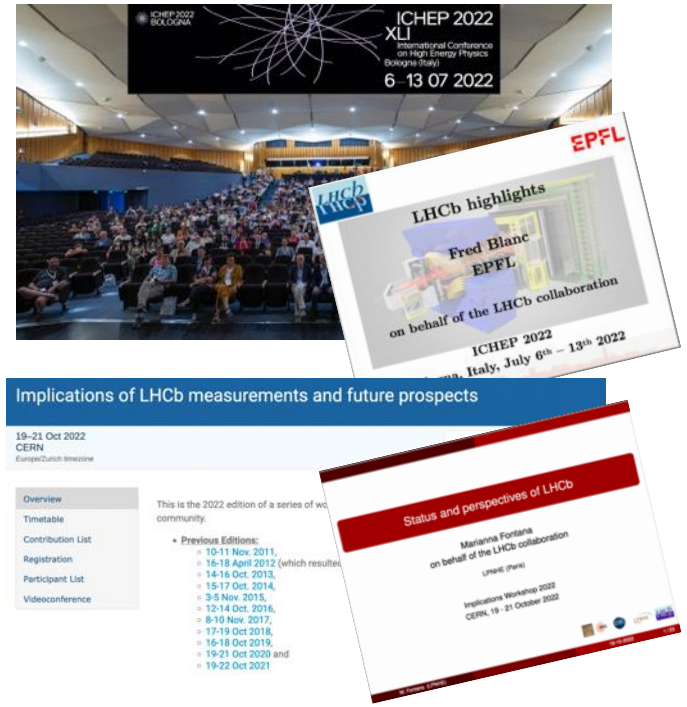
Collaboration week, CERN, June 2022

Collaboration week, Dortmund, September 2022

Physics Results: Publications



Year of submission



- 636 Submitted papers
- 32 submitted papers 2022

In addition:

- 22 with the Editorial Board
- 54 in collaboration review

- Following Russian invasion of Ukraine discussions on authorship continue
- Paper submission to preprint server with collaboration name only given
- Collaboration reviews & approval unaffected

Selected Physics Results

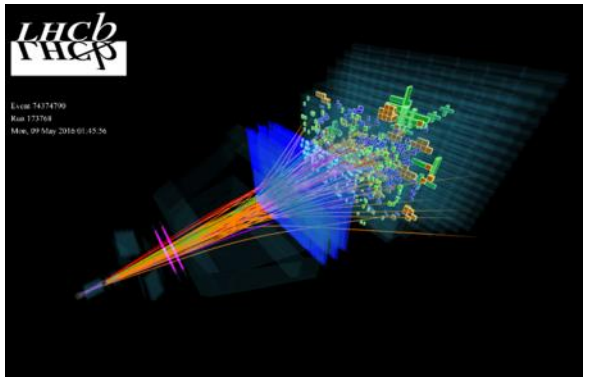
- LHCb was originally designed for matter antimatter asymmetry measurements (CP Violation) and studying rare decays
  - of course it is achieving much more
- Report on recent highlights from the core programme and beyond.

Tetraquarks & Pentaquark — ICHEP 2022

Charm matter-antimatter difference — ICHEP 2022

Rare Charm: D→μμ — ICHEP 2022

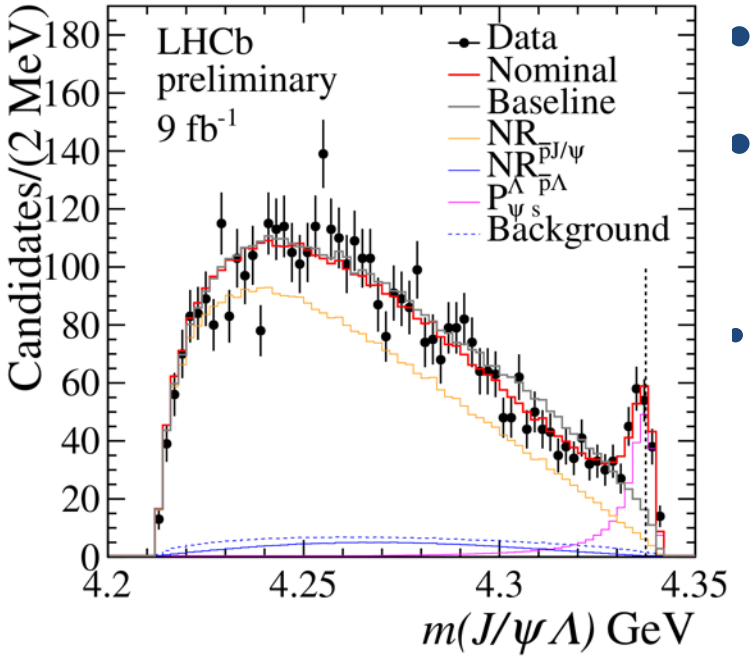
Lepton Flavour Universality: R(D,D*) — IW 2022



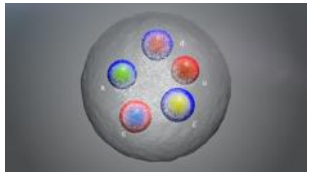
Pentaquark & Tetraquarks

LHCb-PAPER-2022-031
LHCb-PAPER-2022-026

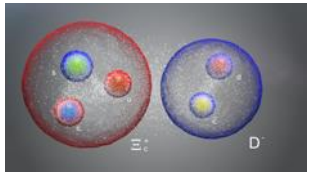
ICHEP 2022



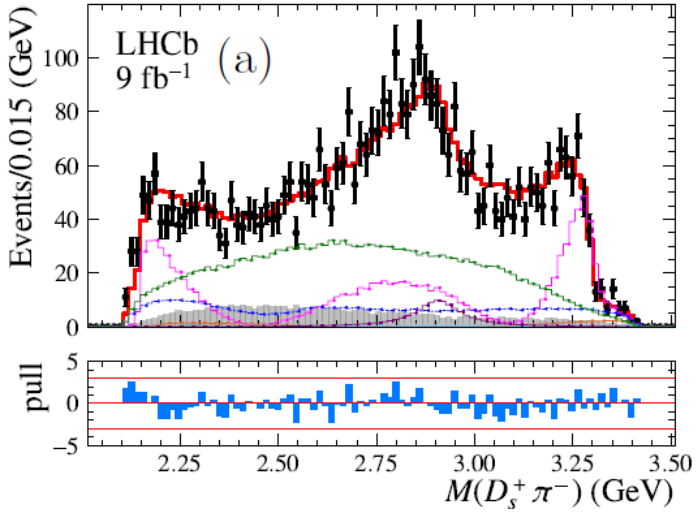
- Discovery of new states continues
- First strange pentaquark $P^{\Lambda}_{\psi s}(4338)^0$ $c\bar{c}sud$
  - Confirms pentaquarks in different decay to LHCb 2015 discovery
- Tetraquark isospin partners $T^a_{c\bar{s}0}(2900)^{++}$ $c\bar{s}u\bar{d}$ $T^a_{c\bar{s}0}(2900)^0$ $c\bar{s}\bar{u}d$
  - First doubly charged tetraquark
  - Start to build up **multiplets**

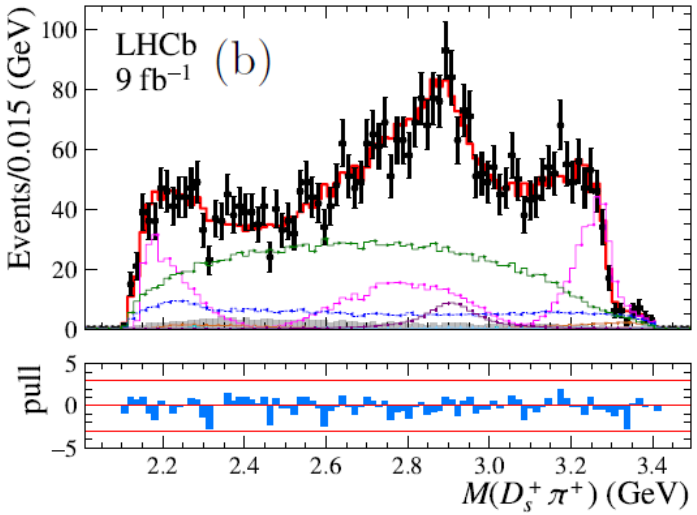


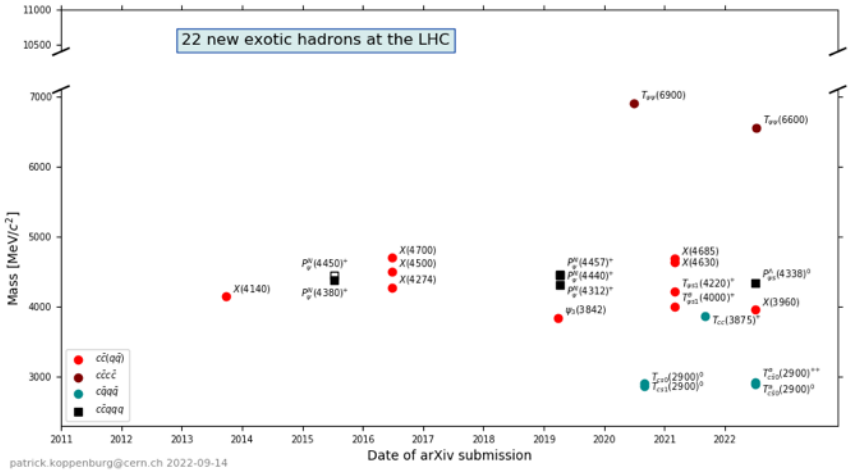
or



or…. understand nature of states



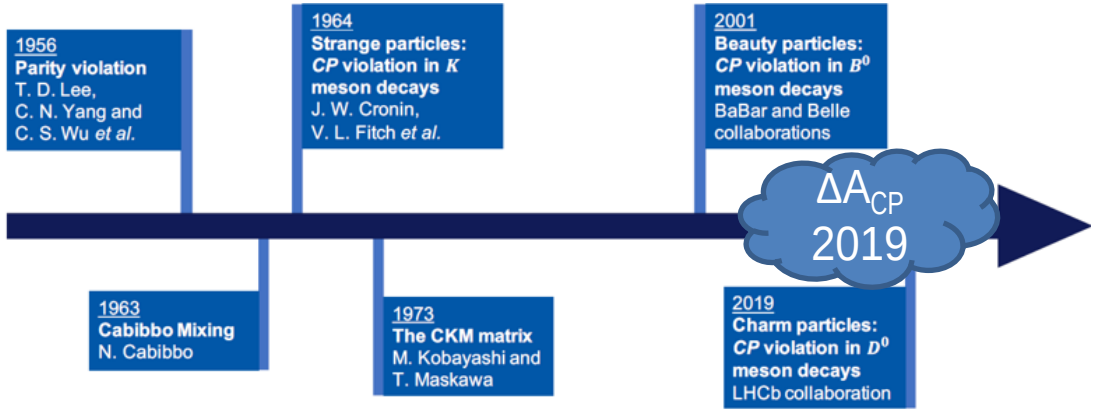


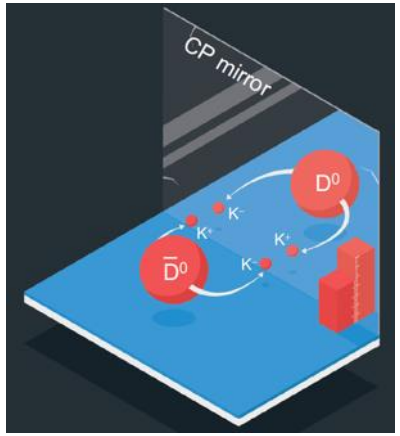


First evidence Charm CP Violation in specific decay

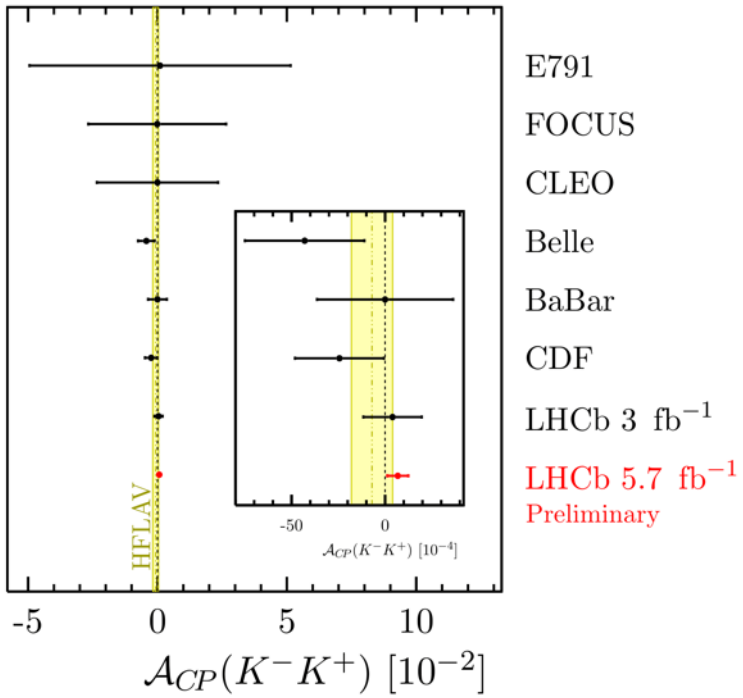
ICHEP 2022

LHCb-PAPER-2022-024

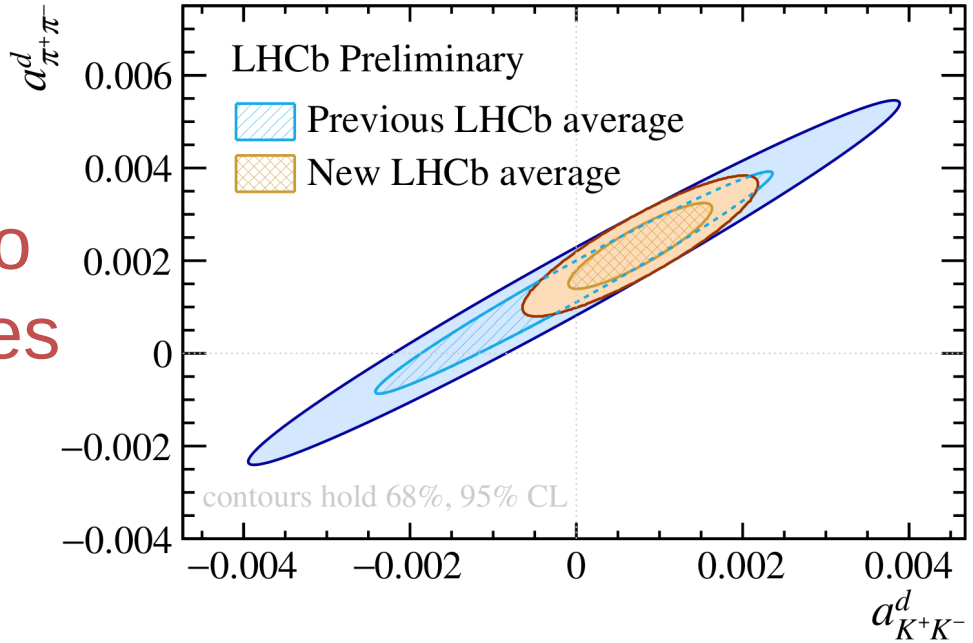




- Direct CP Discovery 2019
- ΔA_{CP} difference KK,ππ
- Cancel systematics
  - Production, detection asymmetries



- Upper end of SM prediction – separate into individual symmetries
  - Control channels to correct asymmetries
  - 3.8σ asymmetry evidence in KK



Rare Charm: D→μμ

LHCb-PAPER-2022-029

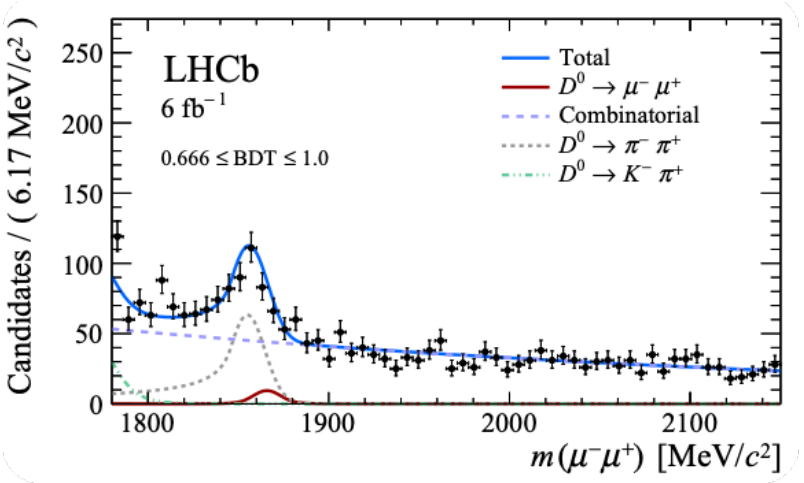
ICHEP 2022

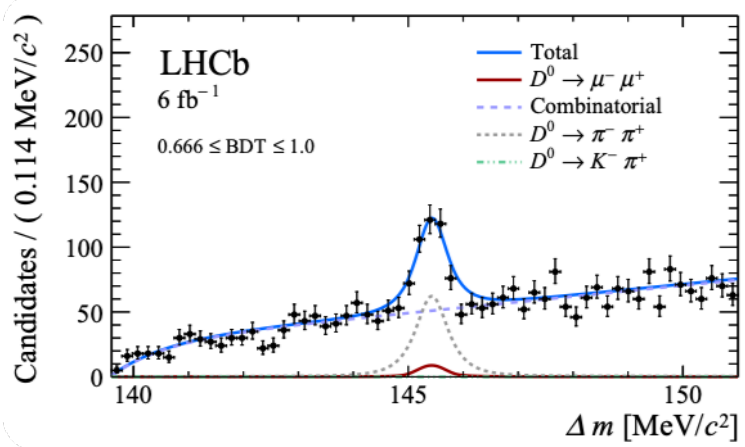
$B_s^0 \to \mu^+\mu^-$ [Phys. Rev. Lett. 128, (2022) 041801]	$B^0 \to \mu^+\mu^-$ [Phys. Rev. Lett. 128, (2022) 041801]	$D^0 \to \mu^+\mu^-$ [Phys. Lett. B 725 (2013) 15-24]	$K_S^0 \to \mu^+\mu^-$ [Phys. Rev. Lett. 125, (2020) 231801]

- Rare decays to two muons are important measurements to search for new physics
  - Experimentally clean and rare in SM
    - Flavour changing neutral currents
  - look for difference in observed rate from prediction
- Full Run1&2 analysis of D→μμ

$$\mathcal{B}(D^0 \to \mu^+\mu^-) < 2.94\,(3.25) \times 10^{-9} \text{ at } 90\ (95)\%\ \text{CL}$$

  - World's most stringent limit

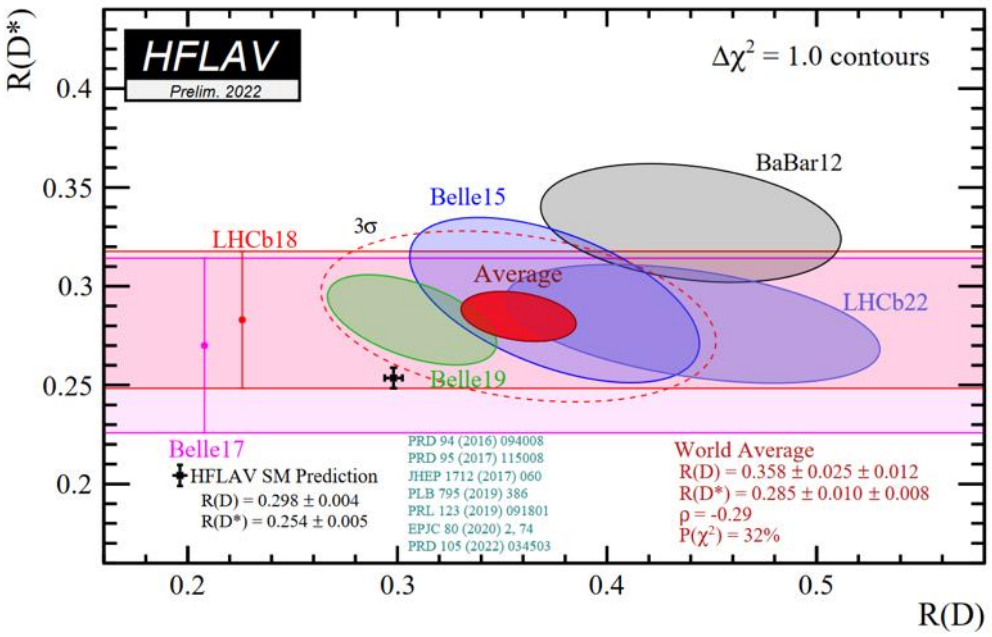




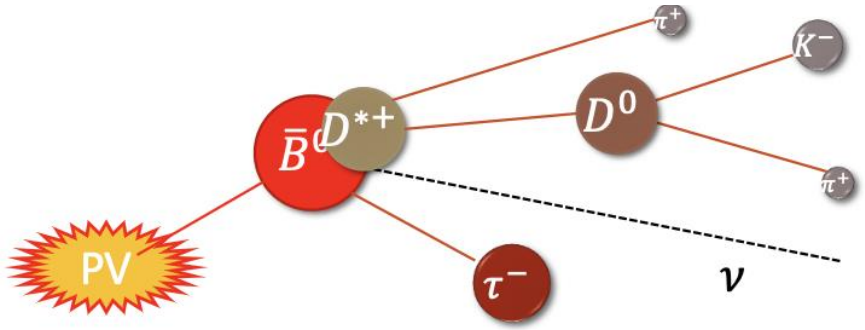
Lepton Flavour Universality: R(D,D*)

LHCb-PAPER-2022-039

IW 2022



$$R(D^{(*)}) \equiv \frac{\mathcal{B}(\bar{B}^0 \to D^{(*)}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B}^0 \to D^{(*)}\mu^-\bar{\nu}_\mu)}$$

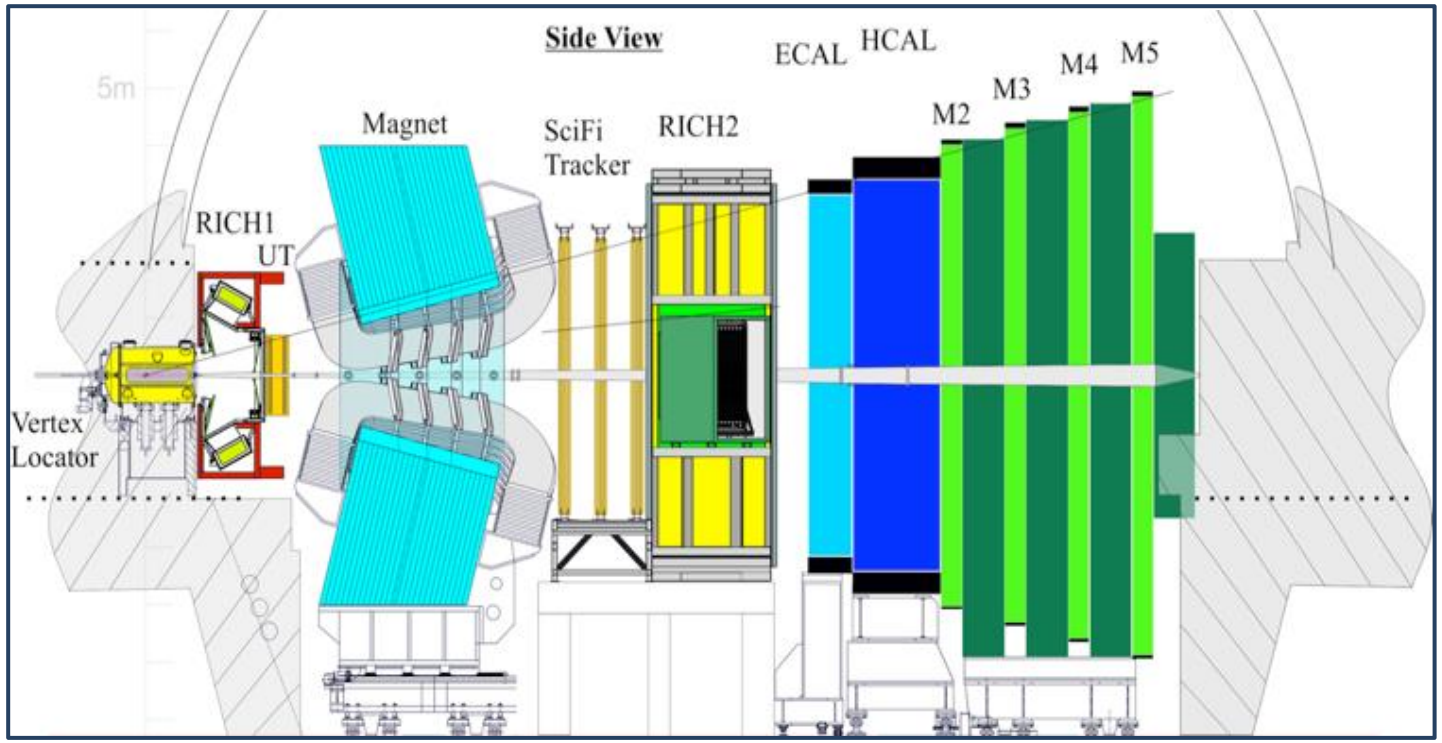


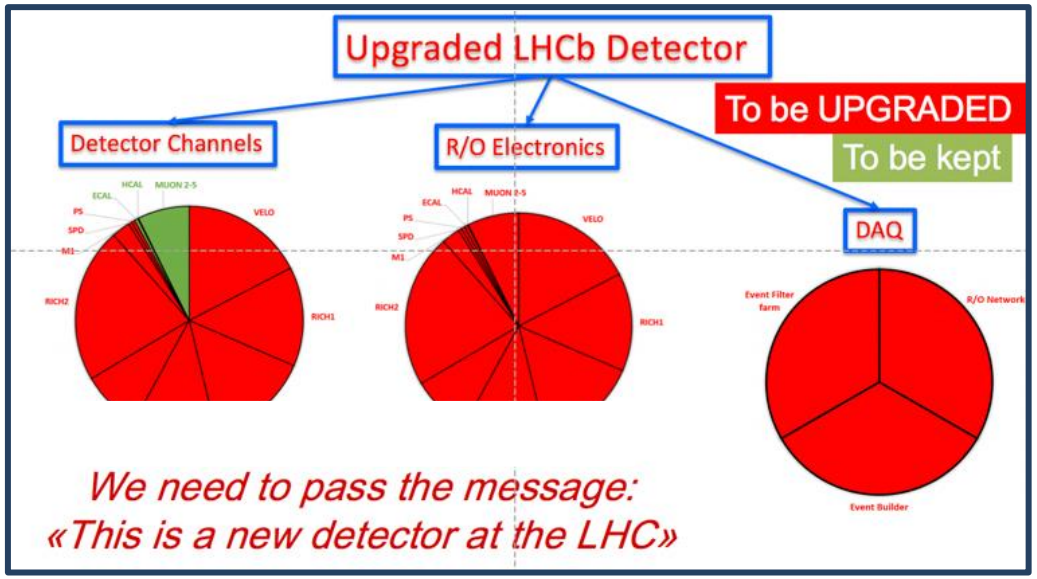
$\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$
"signal"

- Tension with theory in b→clv decays, mainly from Babar/Belle
- Challenging analysis: missing neutrinos, large backgrounds
- First combined R(D),R(D*) at hadron collider
  - Much anticipated result, pathfinder result with Run 1 data
- Excellent agreement with world average, 1.9σ from standard model

Upgrade I: Reminder

- All sub-detectors read out at 40 MHz for a **fully software trigger** with new data centre



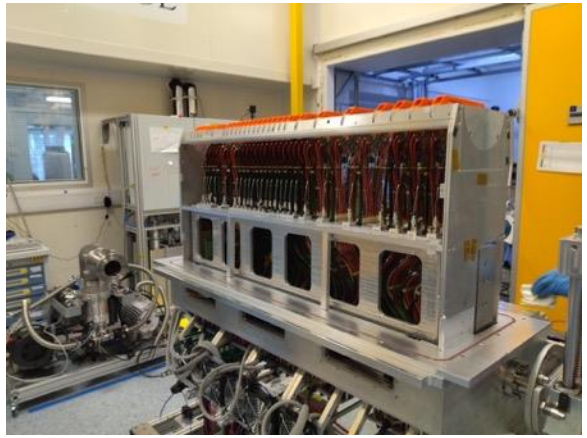


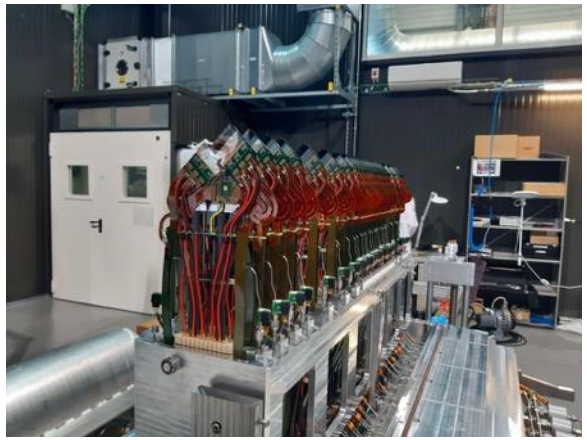
- Pixel detector VELO with silicon microchannel cooling 5mm from LHC beam
- New RICH mechanics, optics and photodetectors
- New silicon strip upstream tracker UT detector
- New SciFi tracker with 11,000 km of scintillating fibres
- New electronics for muon and calorimeter systems

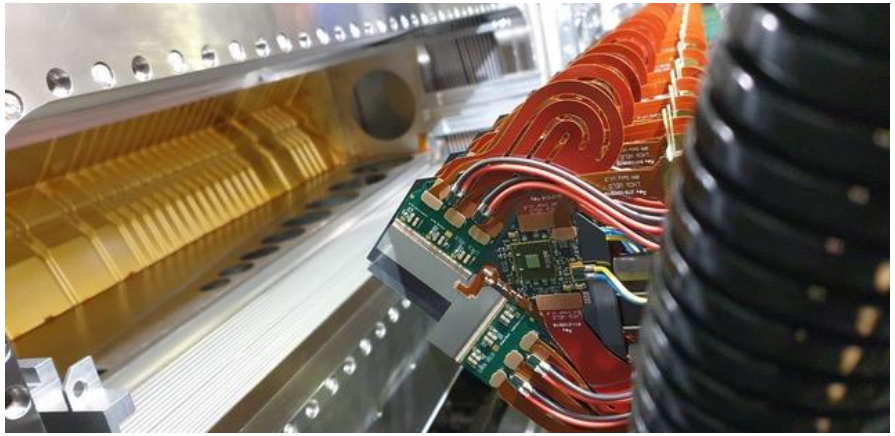
Major project installed for operation in Run 3

Upgrade I Completion: VELO

- Installation completed shortly after last meeting as expected
  - In shadow of LHC machine RF issue



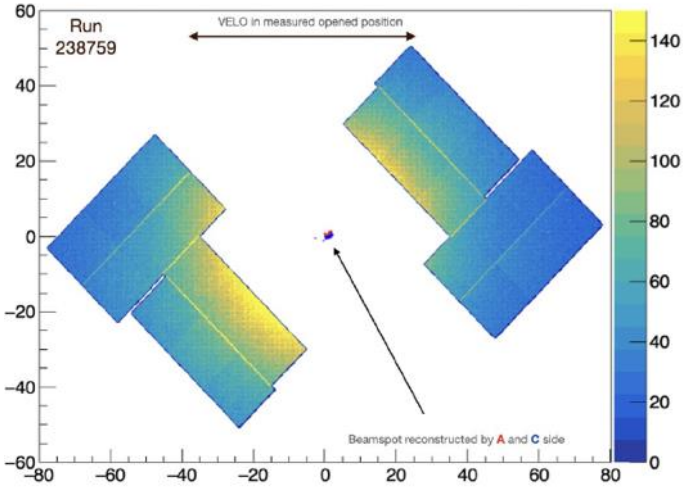


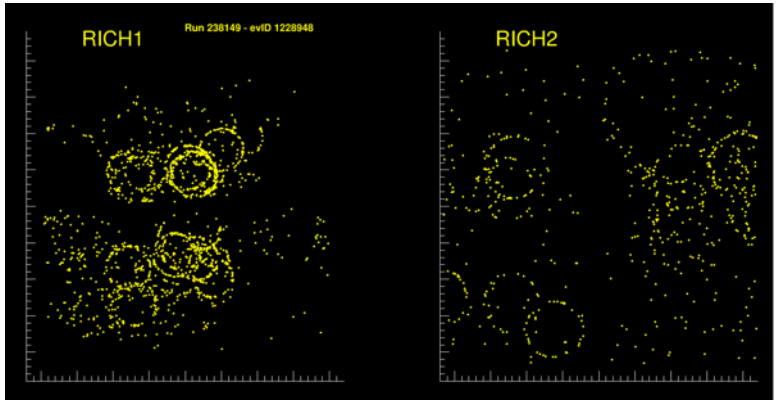


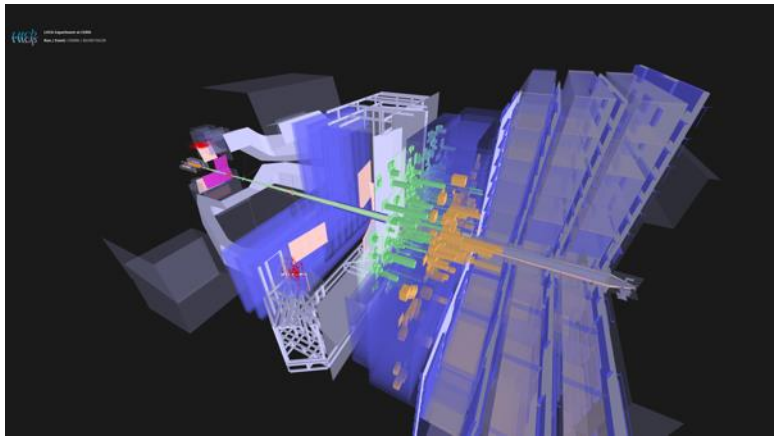
Upgrade I Completion: Upstream Tracker

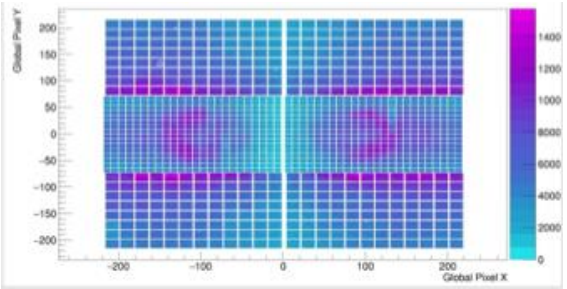
- Silicon planes before magnet (UT), not essential for early physics operation
- First half fully assembled
- Second side assembly underway
- On schedule for installation in year end technical stop

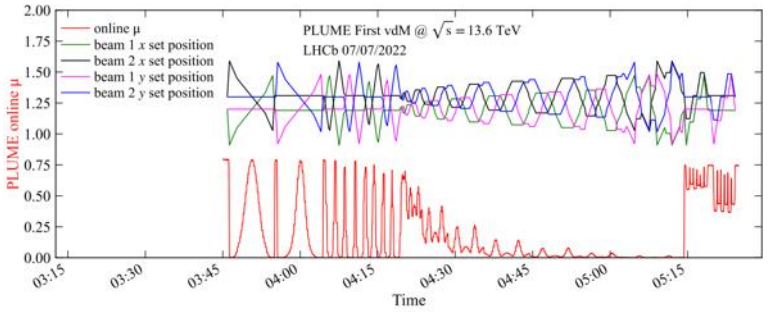
Commissioning

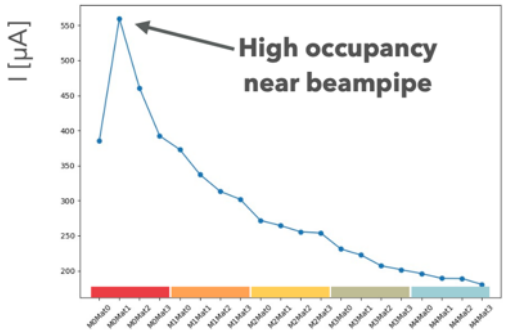




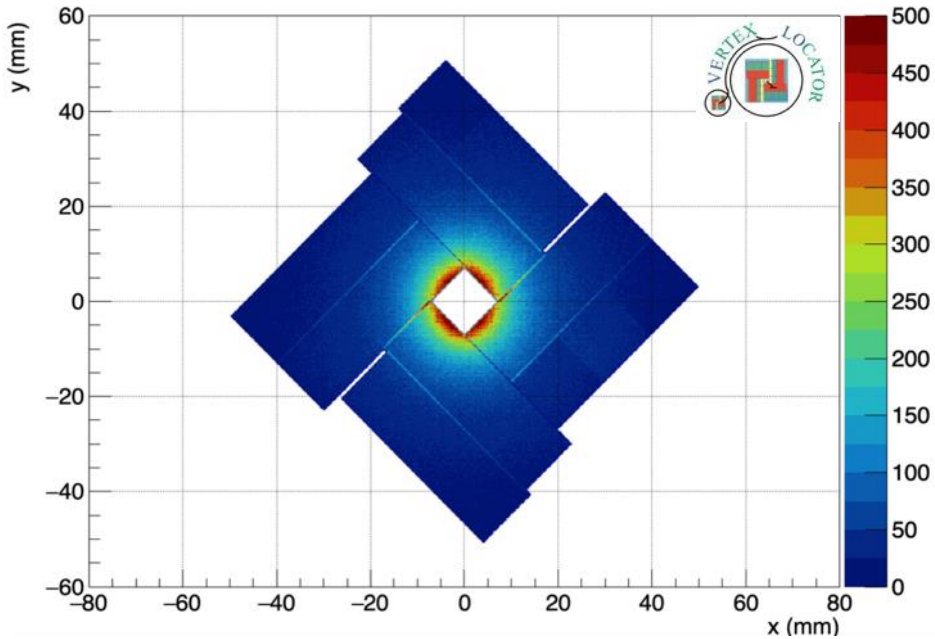




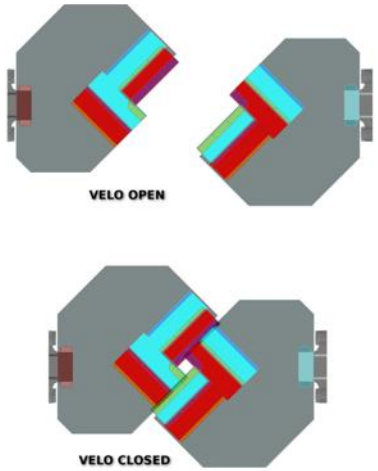


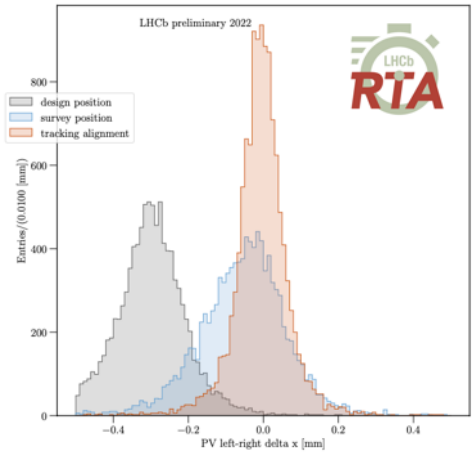


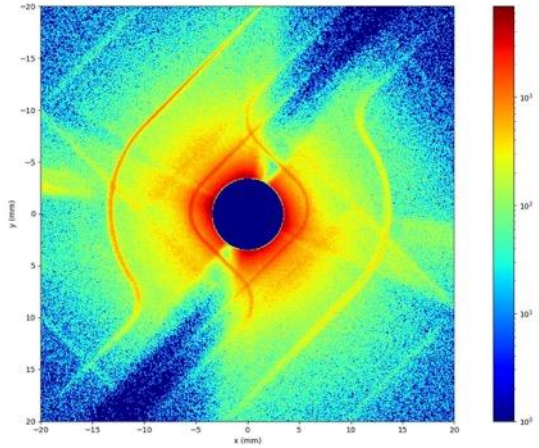
Commissioning – VELO Closing



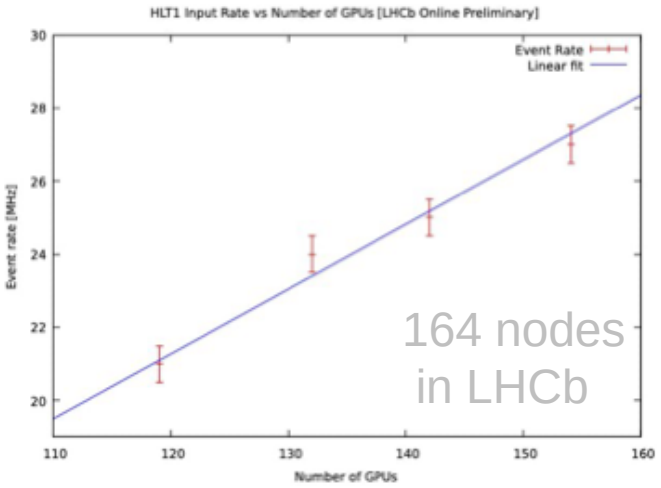
- Detector retracted by 3cm while LHC injecting beams
- VELO approaches LHC beam to 3mm
  - LHC beam with energy of TGV train passes through pencil sized hole !
- For the safety of LHC & VELO detailed closing procedure required
- **Fully closed Friday 21st October**



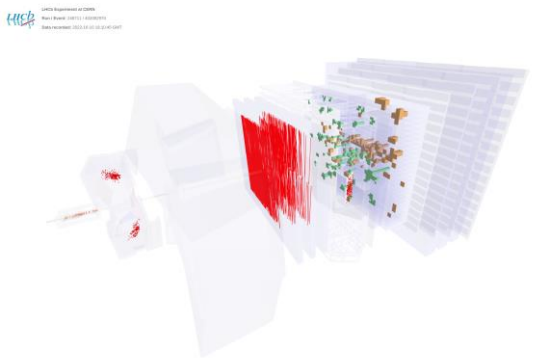


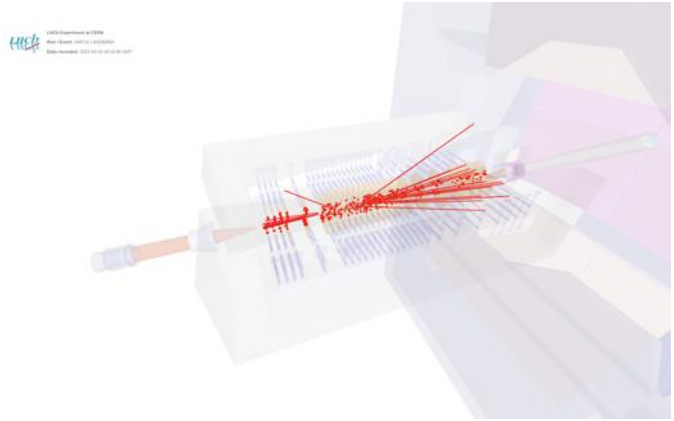


Commissioning – Status & Next steps



- All subsystems of all detectors in excellent state
  - Sensors, Cooling, HV, LV, DAQ, monitoring, safety systems….
- Fully software trigger with GPU first level
  - 25MHz stable operation, trigger on CALO activity
- Strong progress despite reduced LHC beam time this year



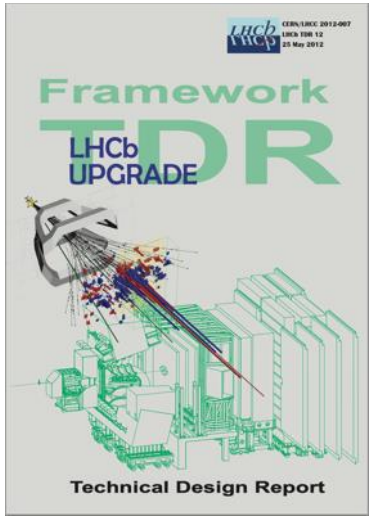


Upgrade I: A new Era

Upgrade I

2022-2033

10 years from Framework TDR



MoU & TDRs

Reality

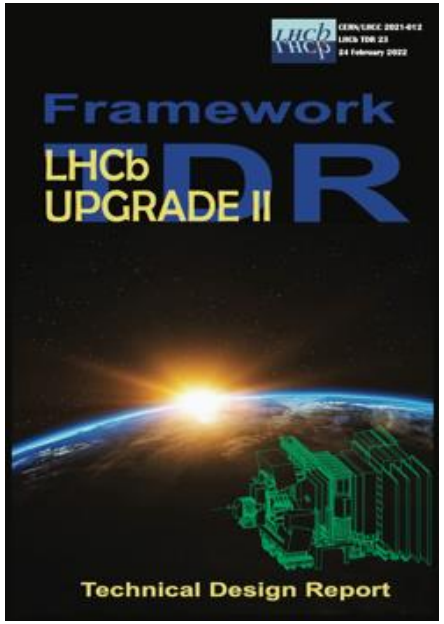
- Collisions have begun, and we start to understand the performance of what we have built
- Innovative 40MHz readout detectors with **first-of-kind real-time analysis trigger**, pathfinder for other large science projects
- **Huge thanks to all of you for your support**

Upgrade II: Ultimate Flavour Physics

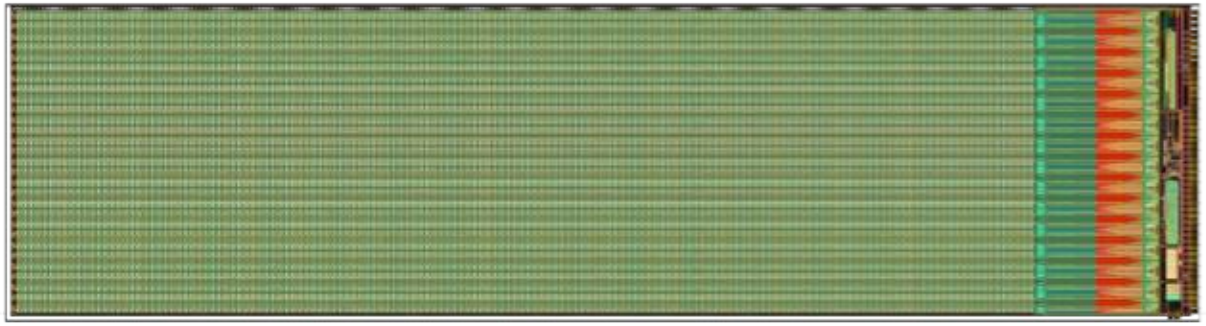
Upgrade II

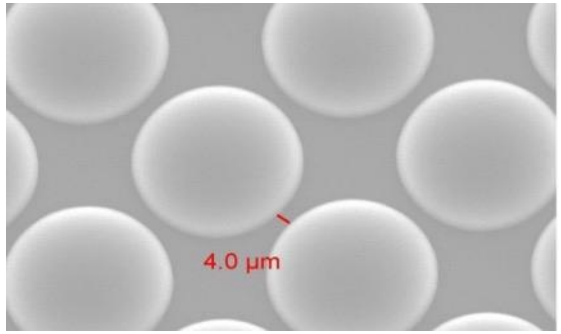
2035-

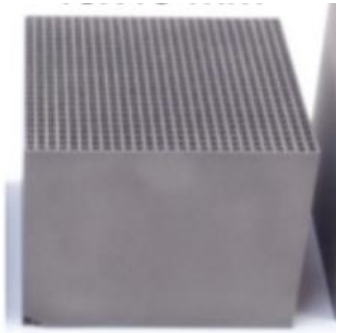
Framework TDR

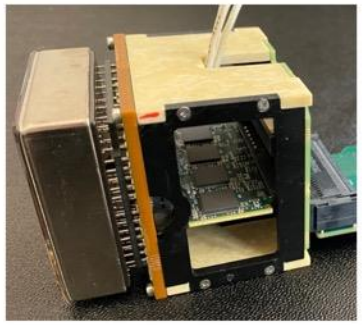


- **Full exploitation in HL-LHC era for flavour physics and *beyond***









- R&D underway
- Dedicated session tomorrow

Summary

- Largest CERN particle physics detector project since LHC completion
  - Despite pandemic being completed on-budget and in time for Run 3
  - Commissioning proceeding well
    - All subsystems working
    - VELO Closing milestone

- Significant physics results
  - Pentaquark & Tetraquark discoveries
  - Lepton Flavour Universality R(D,D*)