Istituto Nazionale di Fisica Nucleare
SEZIONE DI CAGLIARI

LHCb Muon Detector

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ICHEP 2024 - Prague, Czech Republic

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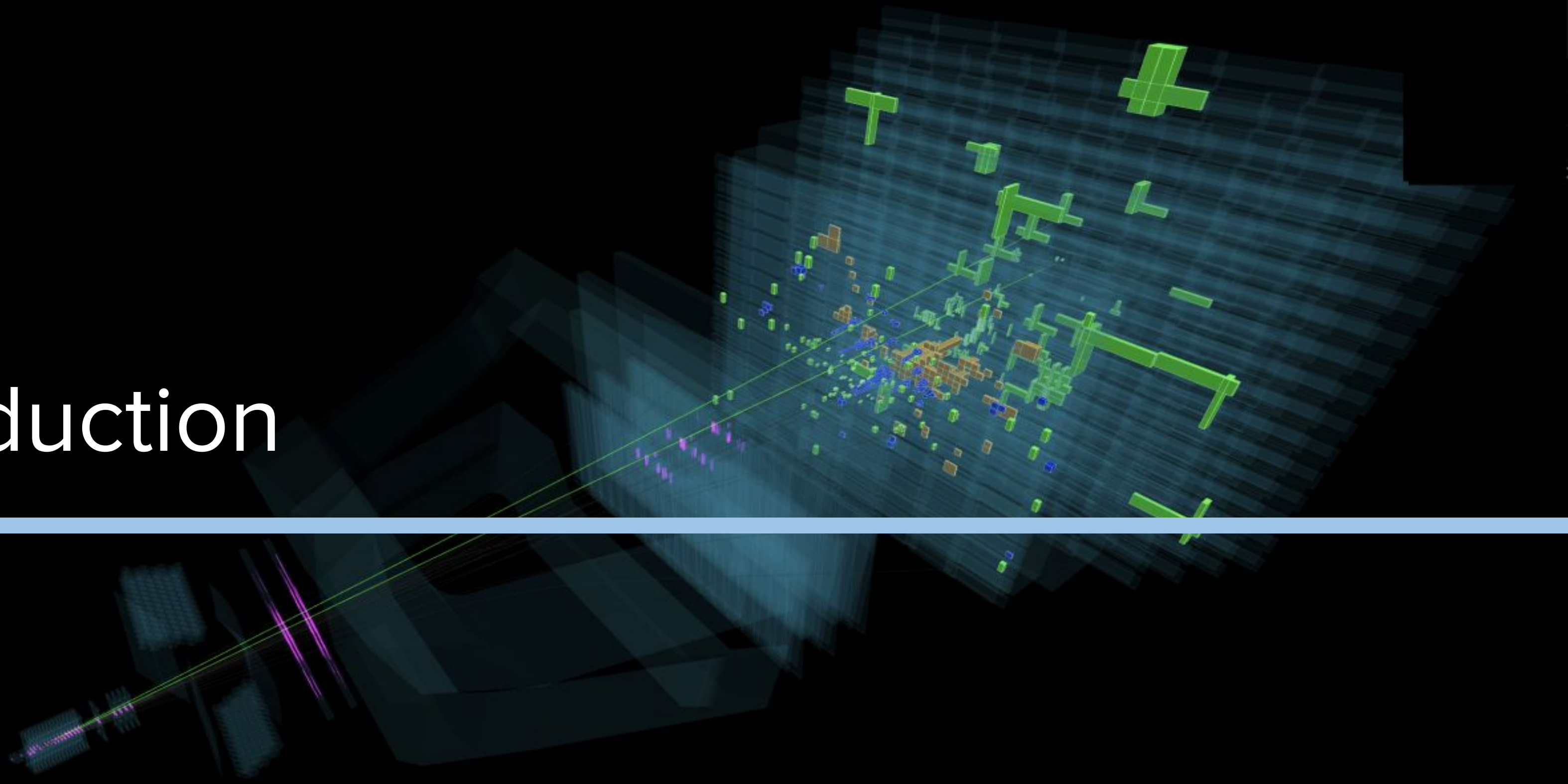
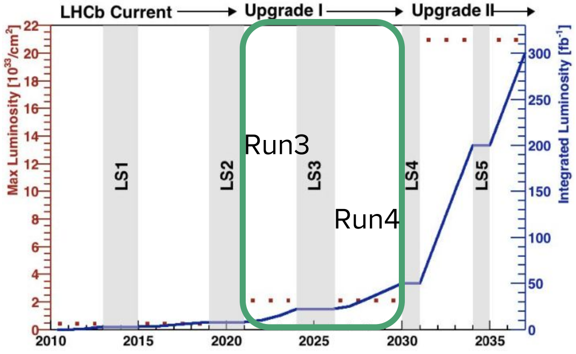
Outline

- The current muon detector
- New off-detector electronics
- Commissioning
- Status and Performance
- Conclusions

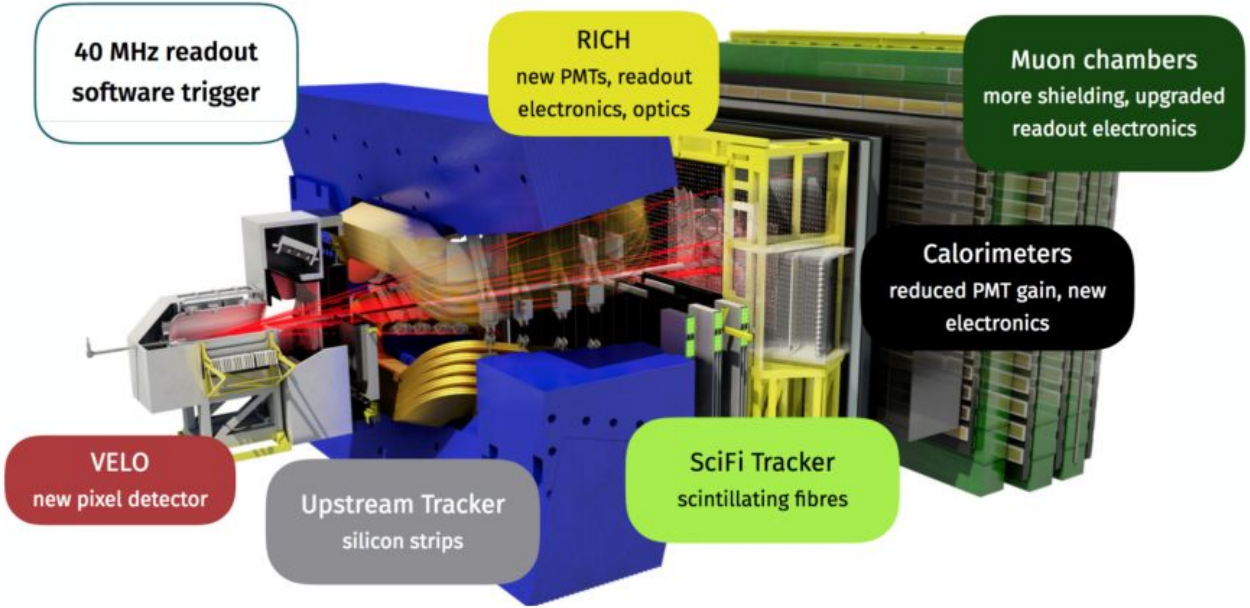
Introduction



The current LHCb detector



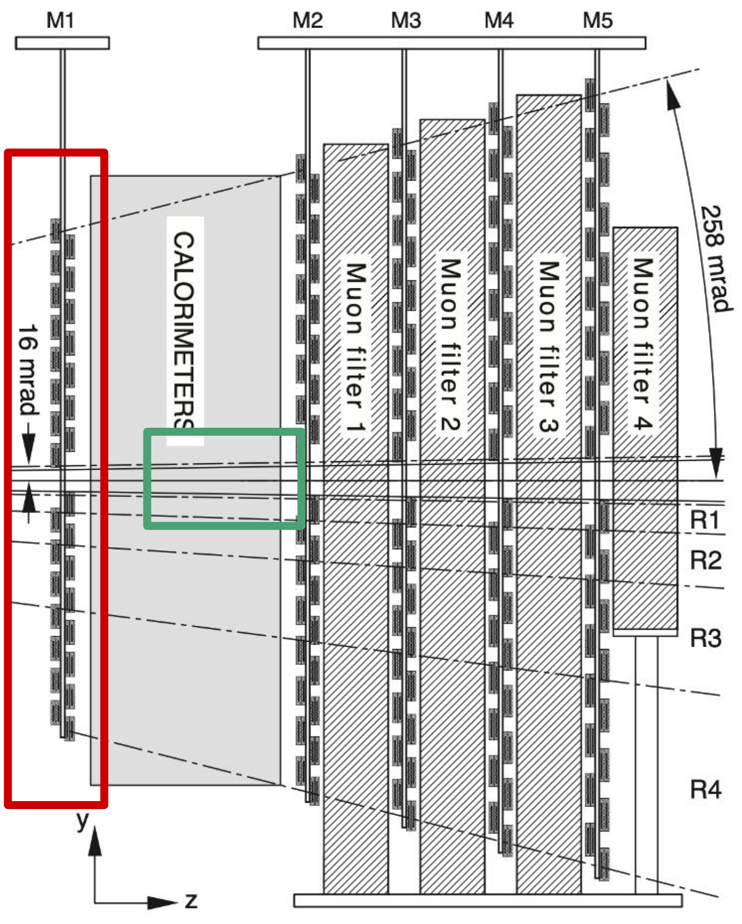
- Aim to collect ~50 fb^{-1} at roughly $\mathcal{L} = 2 \times 10^{33}$ cm^{-2}s^{-1}
- Keeping at least the same performance on Run 1&2



Overview and performance in early Run3

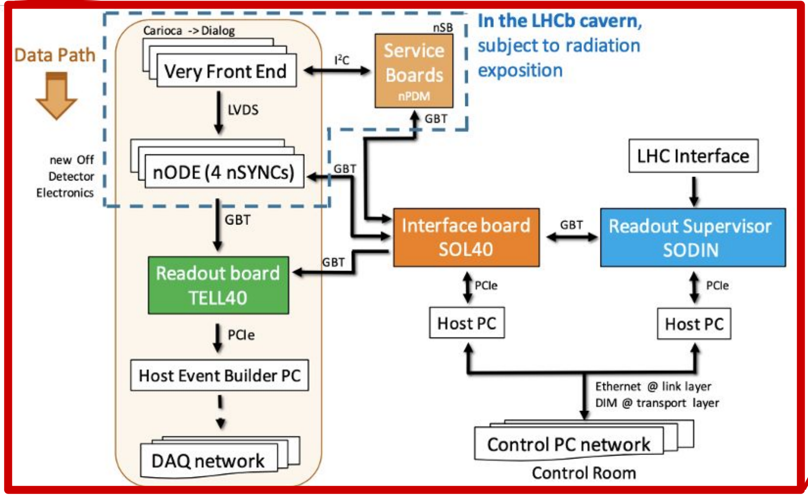
The muon detector

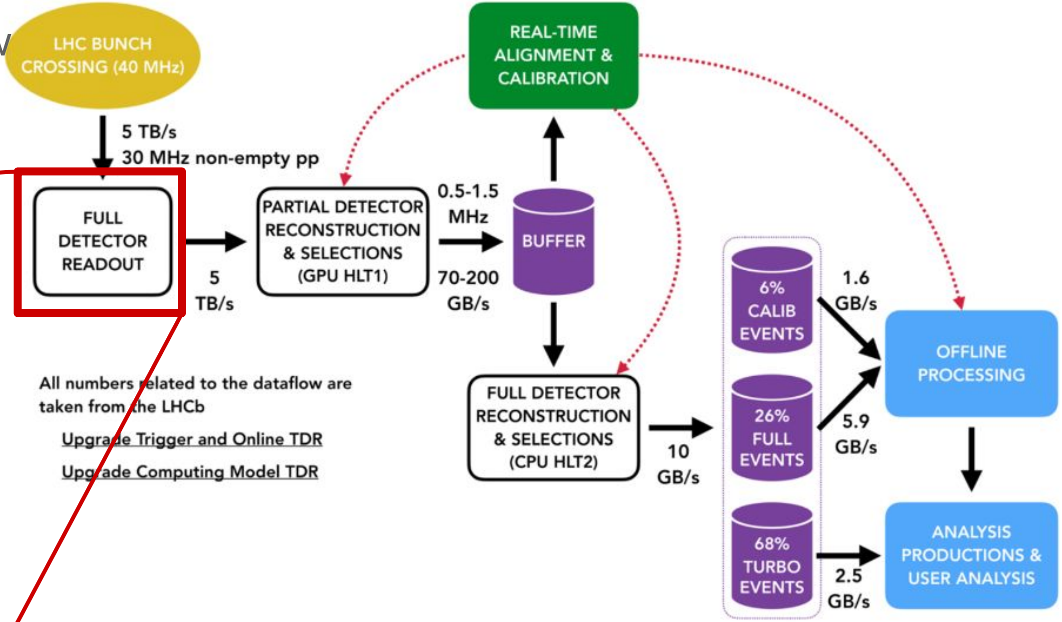
- Originally in Run1&2: 5 stations of MWPC + GEM in internal region of first station
- Exceptional performance in Run 1&2 of the LHC:
  - Trigger input
  - Particle Identification
- **Main changes for Run 3**:
  - **M1 removal**
  - **New shielding in front of M2**
  - **New electronics**
- Detectors (MWPC) will stay until the end of Run 4, 12 new high granularity MWPC in preparation for M2R1, to be installed at LS3



LHCb upgraded DAQ and Trigger

- Moving to a higher luminosity and a fully software trigger required new off-detector electronics (ODE)

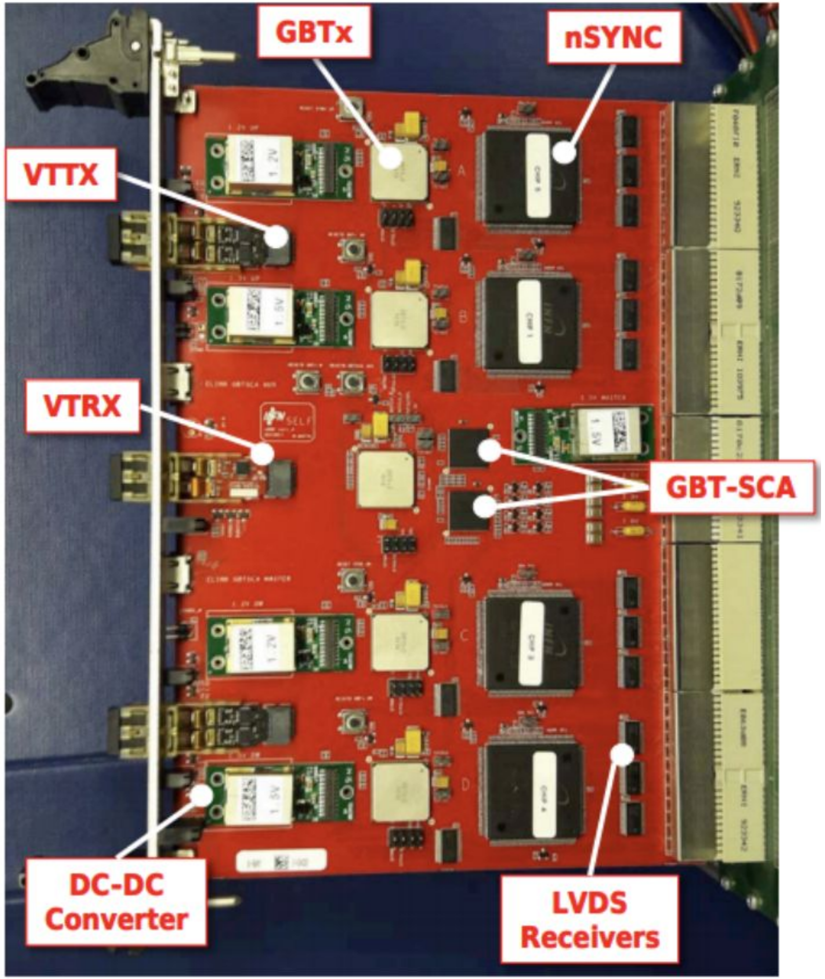




ODEs and nSync

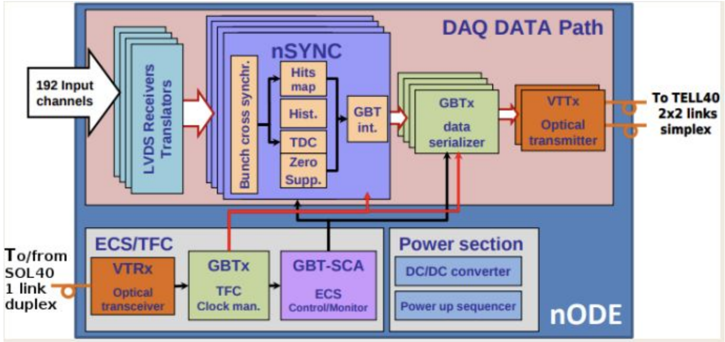
- Each ODEs (144 in total) are equipped with 4 nSYNC ASICs to
  - transmit digital signals from Front End Electronics
  - measure hit arrival times
  - tunable delays to provide coarse time alignment (steps of 25ns)

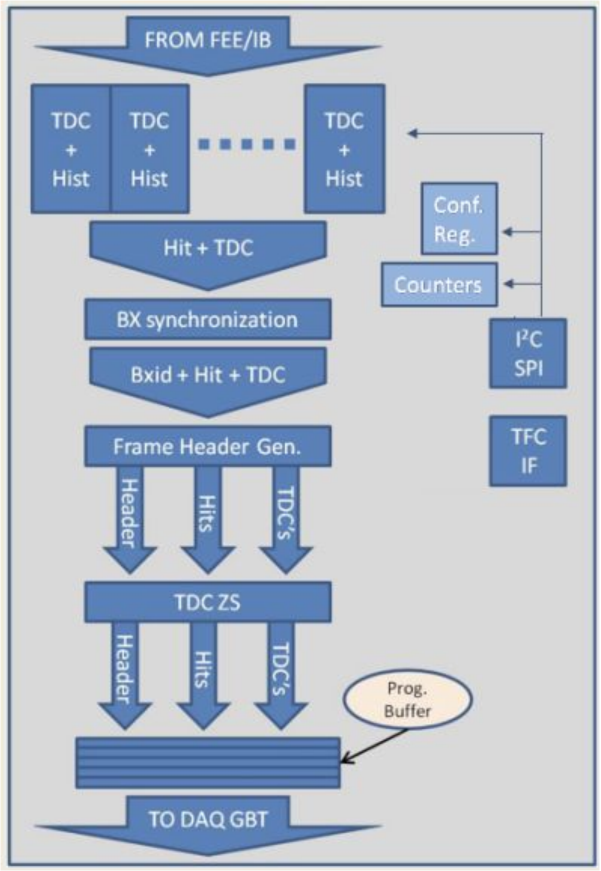
NIM A 936 (2019) 378-379



Off-detector electronics

- Each nSYNC receives 48 digital signals from FEs
- Time-to-Digital Converters (TDC) to measure time of arrival (phase difference wrt master clock)
- nODEs handle and distribute the master clock, and transfer data processed by nSYNCs to the DAQ
- They also handle chip configuration and power.





Commissioning the muon detector

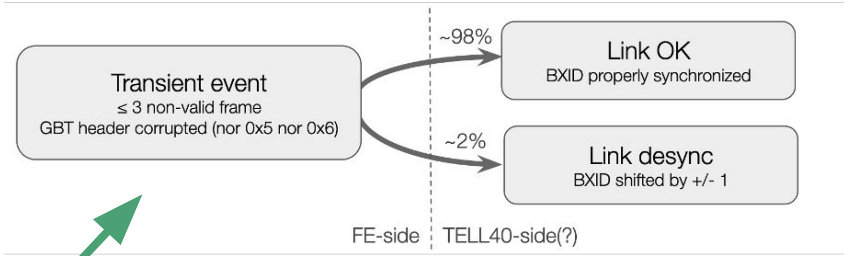
Commissioning (2022-beginning of 2024)

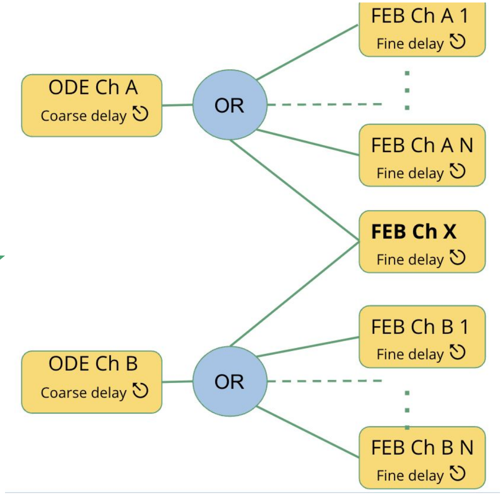
- Changing the off-detector electronics required an almost complete overhaul of the control and calibration system
- Moreover the removal of some Intermediate Boards* to cope with the increased lumi changed a bit the cabling scheme
- A full realignment, calibration (of time delays, thresholds, etc.) and monitoring was necessary (and time consuming)
- Issues with the LHC, particularly in 2023 did not help in having enough (and suitable) calibration data to reach our goals

*used in Run1 and Run2 to reduce the number of ODE channels by merging several front-ends

Commissioning issues

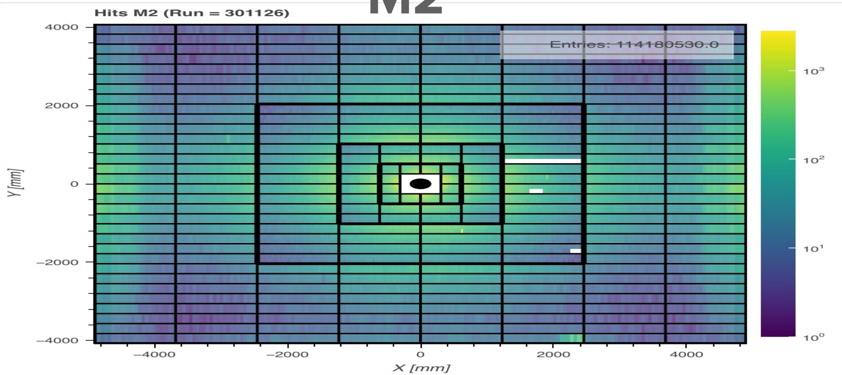
- **Commissioning is now fully complete**, most important issues encountered and fixed were
  - **De-synchronisation of data links** (not just for muons), seems due to the GBTx scrambler. Needs to be fully understood but effect now negligible thanks to a combination of intervention on the ODEs and readout boards
  - **Time alignment**, mostly driven by the complex cabling scheme (some channels are correlated) the lack of sufficient collision data to align all the regions



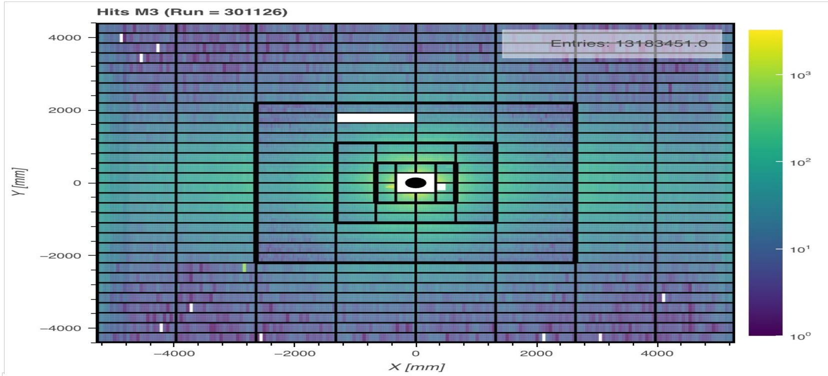


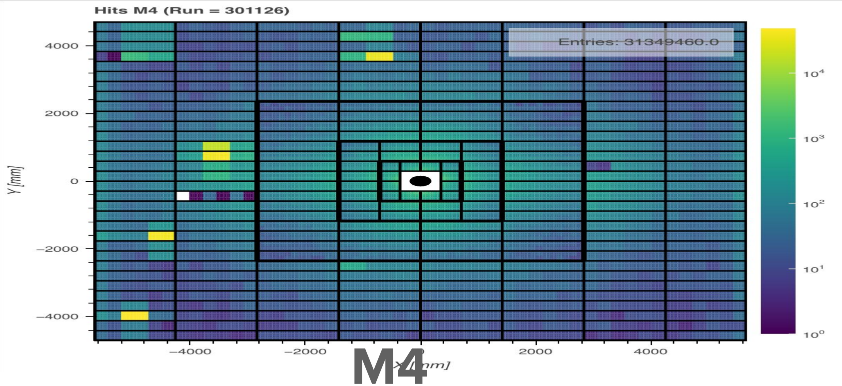
Commissioning - Hitmaps

M2

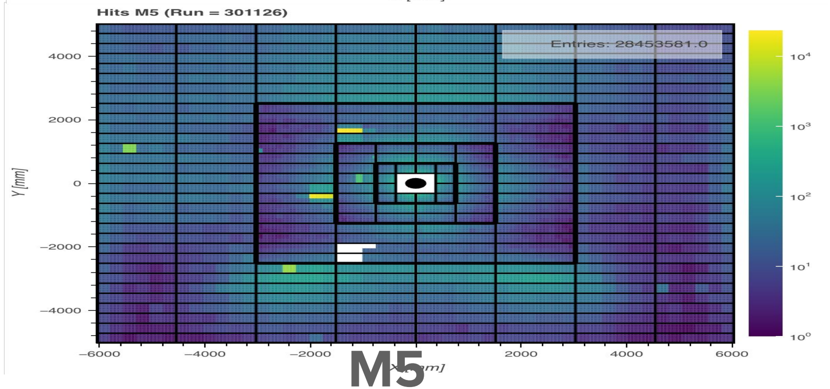


M3



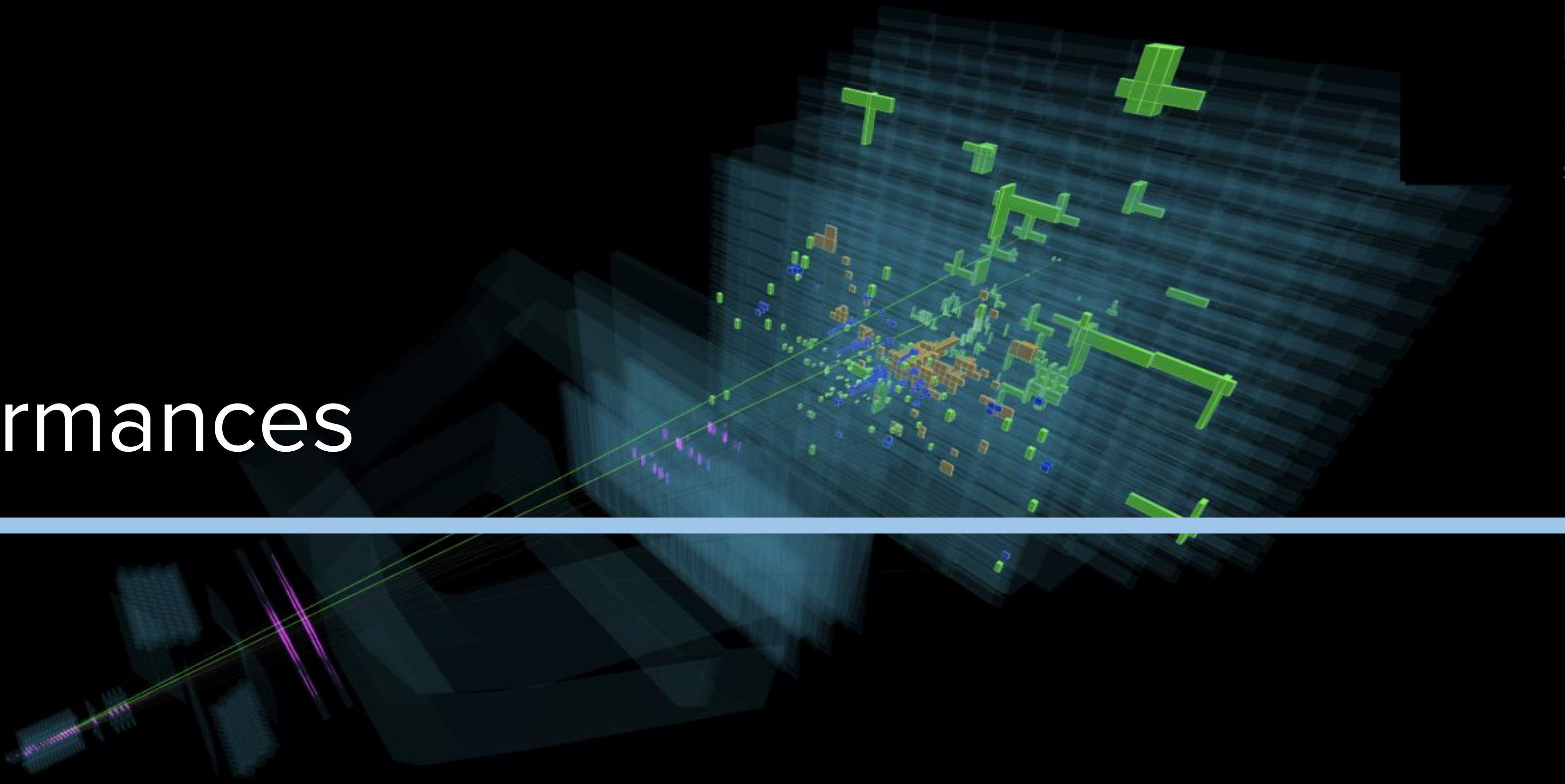


M4

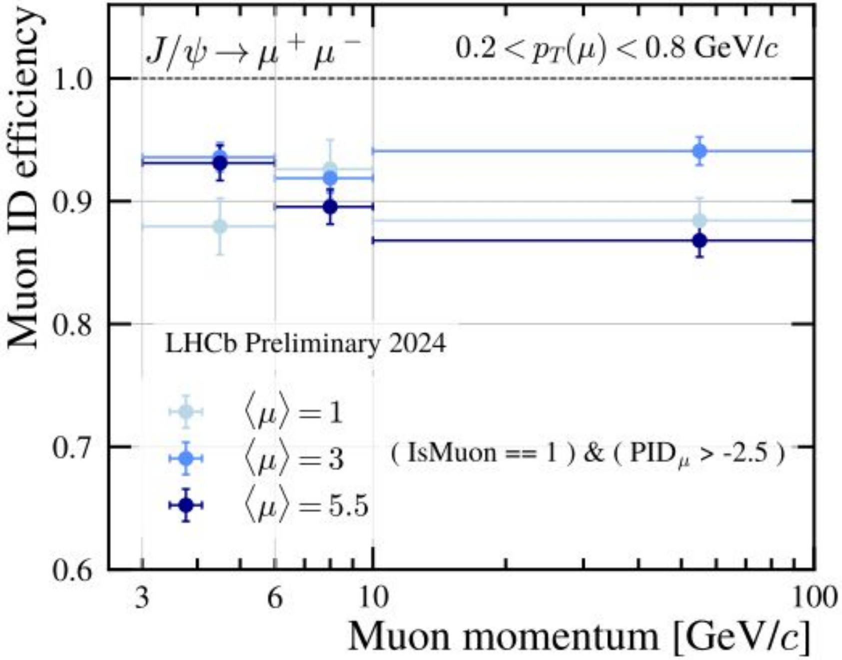


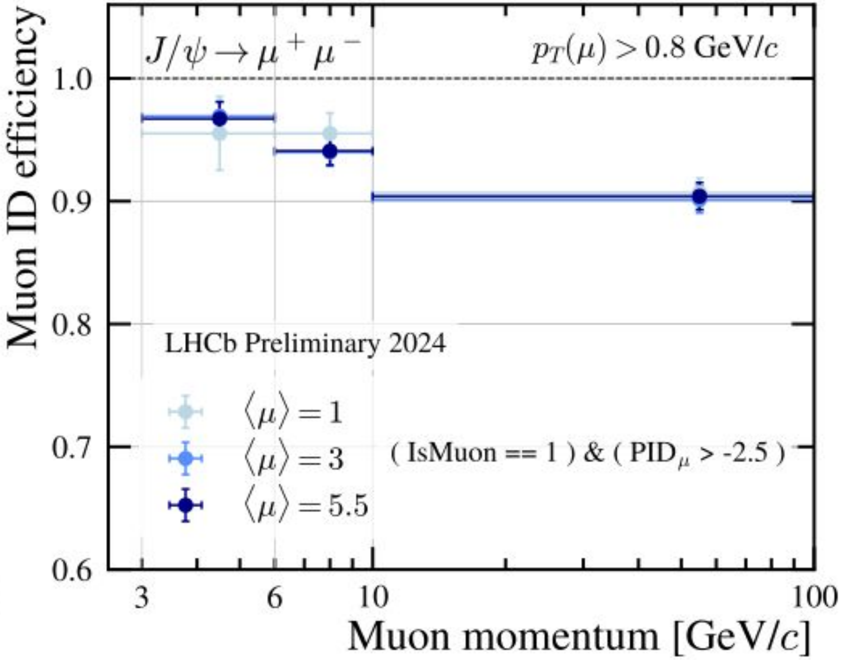
M5

Performances

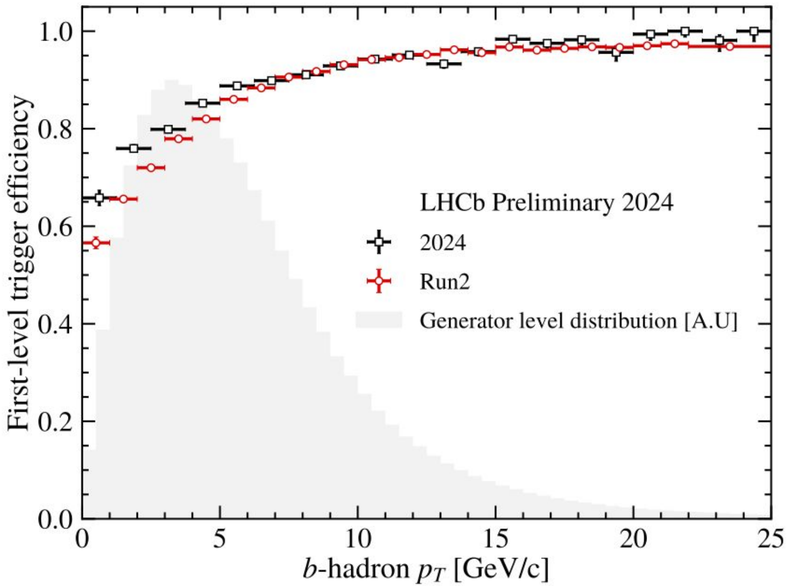


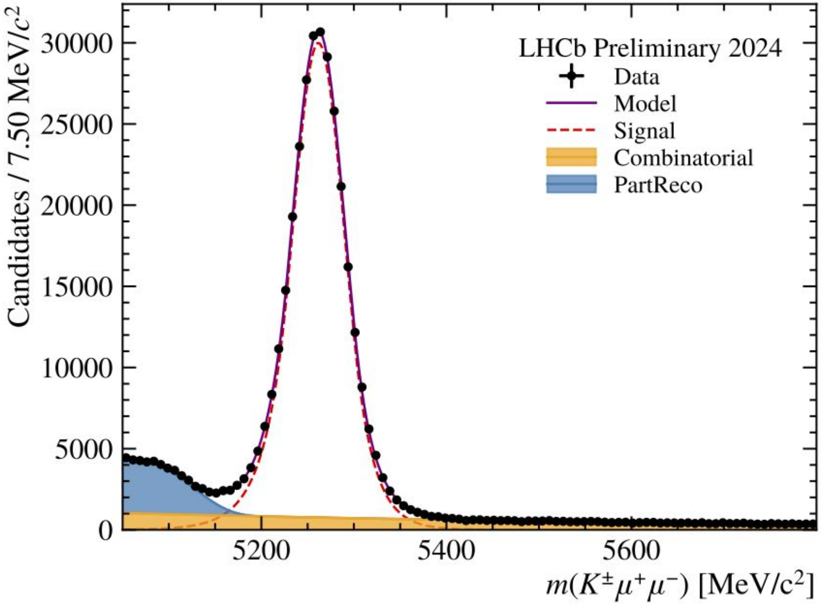
Performance 2024 (LHCb-FIGURE-2024-20)





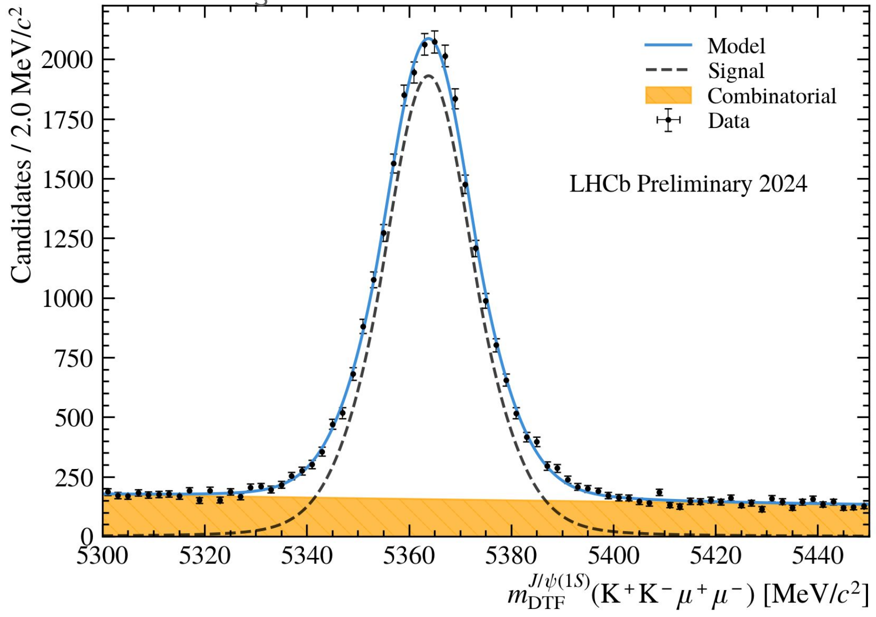
Performance 2024 on $B^{\pm} \to K^{\pm}J/\psi(\mu\mu)$ LHCb-FIGURE-2024-07





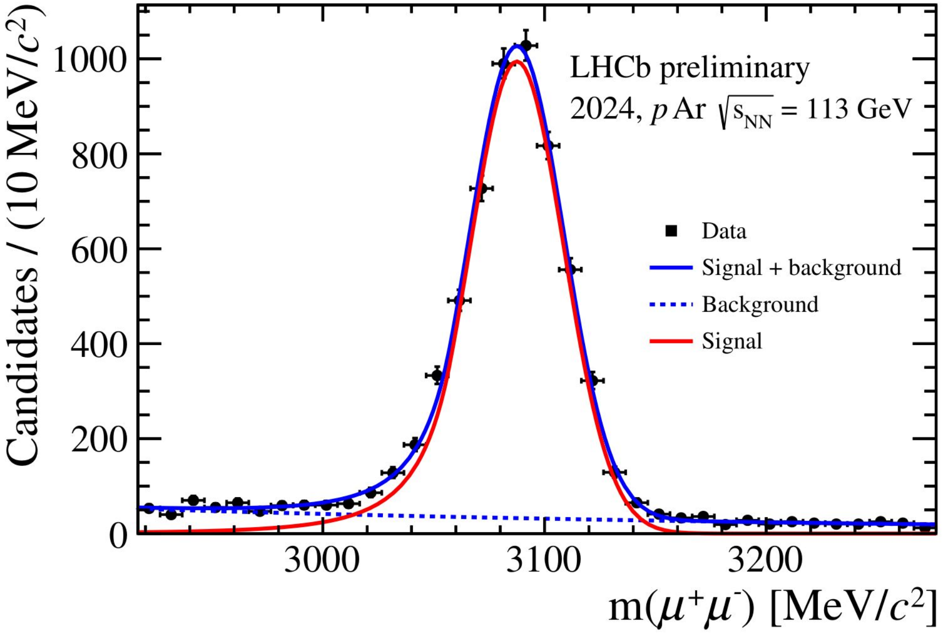
Performance in 2024

$B^0_s \rightarrow \varphi\,(K^+K^-)J/\psi(\mu^+\mu^-)$.



LHCb-FIGURE-2024-07

J/ψ collected using SMOG

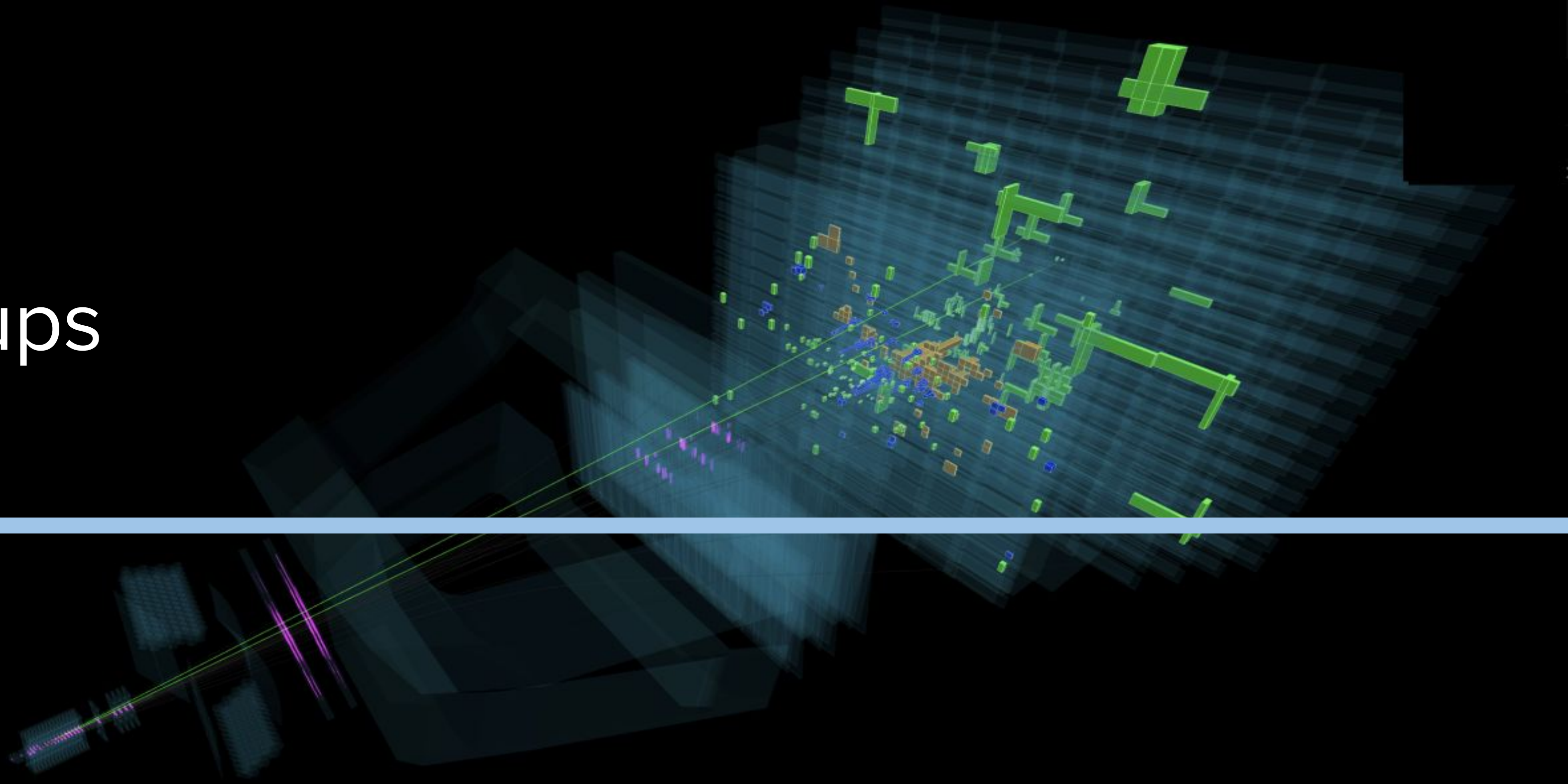


LHCb-FIGURE-2024-05

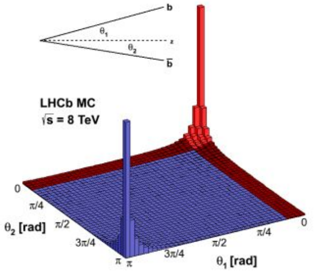
Conclusions

- **The LHCb Muon Detector is working close to its peak performance, at a similar level as in Run 1 and 2**
- **Main issues encountered during commissioning have been overcome**
- **Now focused on incremental minor improvements and maintenance**
- **Despite being an old detector it is still working beautifully!**
- **For future upgrades see M. Poli Lerner's talk**

Backups

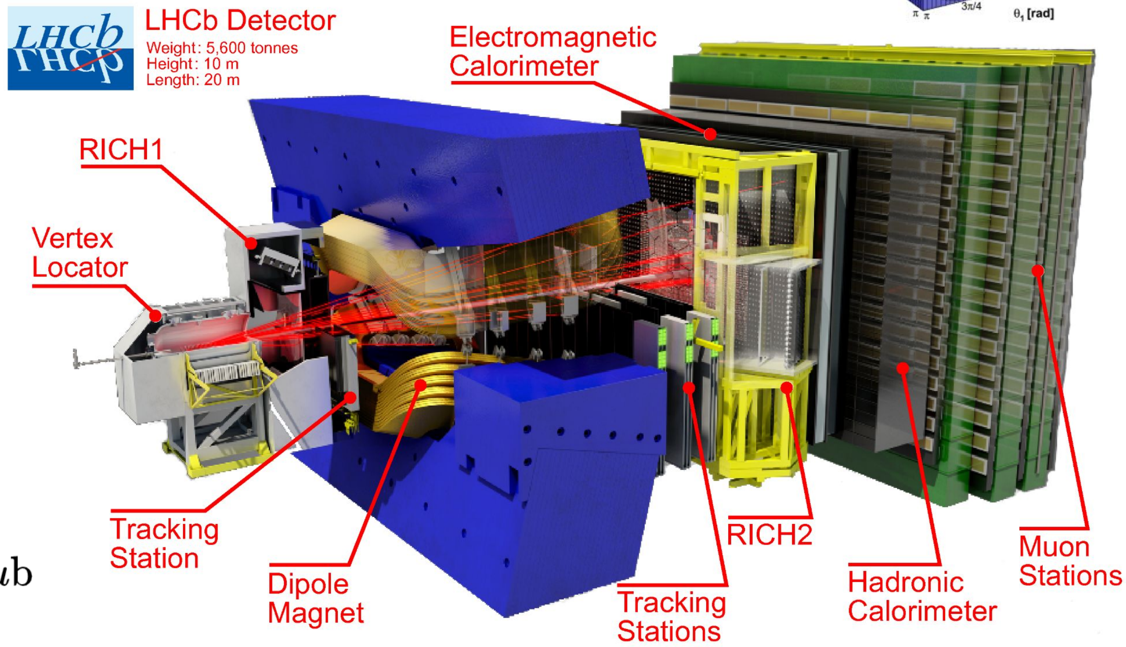


The LHCb detector in Run 1 and Run 2 (2011-2018)



- Excellent particle identification, IP and momentum resolution (~13 µm on the transverse plane and Δp/p ~ 0.5% – 0.8%, respectively.)
- Huge beauty and charm production

JINST 3 S08005 (2008)
IJMP A 30, No. 07, 1530022 (2015)



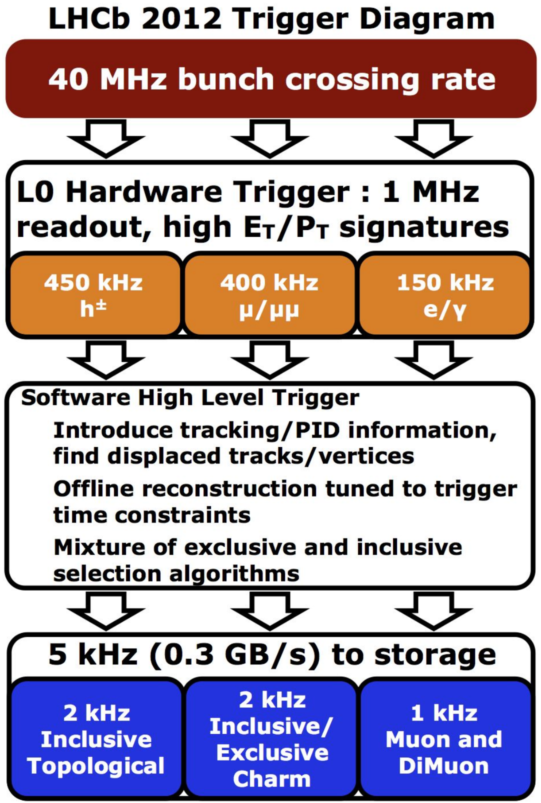
$$\sigma(pp \to b\bar{b}X)_{2<\eta<5} = 144 \pm 1 \pm 21 \mu b$$

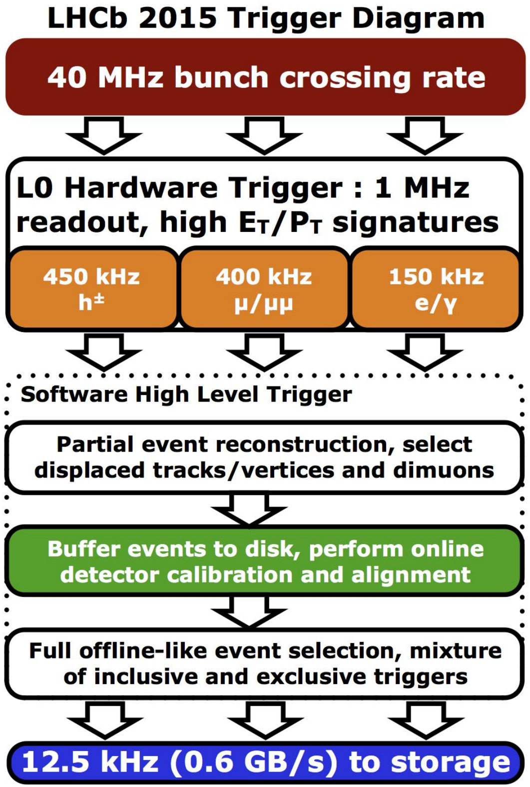
[PRL 119, 169901 (2017)]

$$\sigma(pp \to c\bar{c}X)_{p_T < 8\ \mathrm{GeV}/c,\ 2.0 < y < 4.5} = 2369 \pm 3 \pm 152 \pm 118\ \mu b.$$

[JHEP 05 (2017) 074]

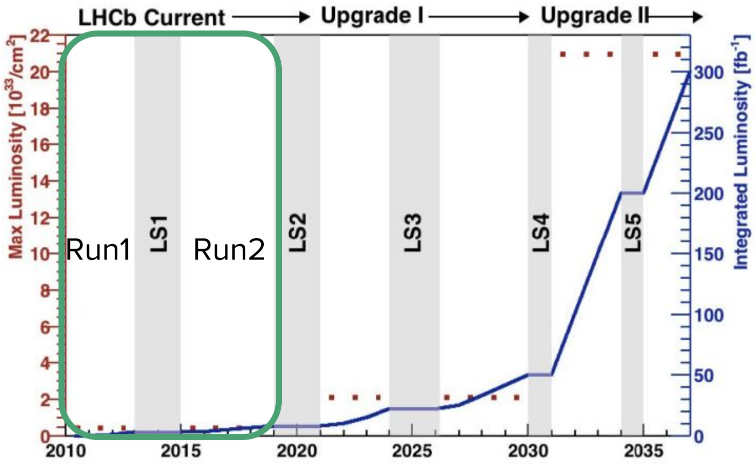
LHCb Trigger System

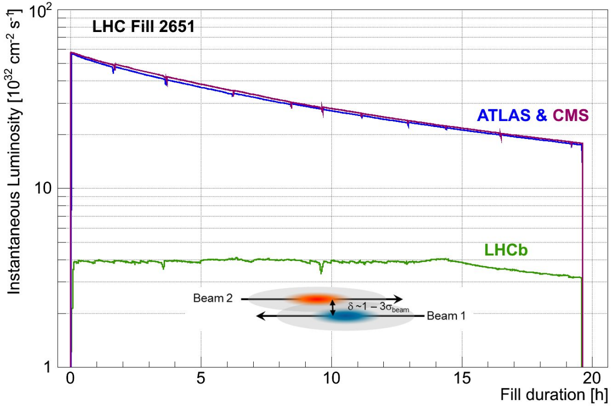


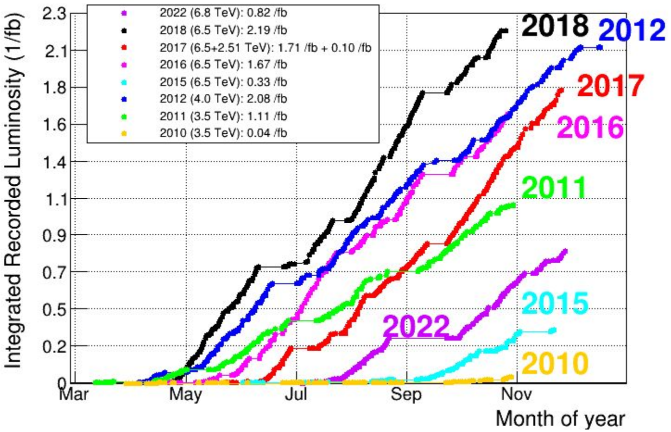


Run1 and Run2 data takings

- Running with luminosity levelling at $\mathcal{L} = 4 \times 10^{32} cm^{-2} s^{-1}$, **2x design luminosity!**
- Roughly 1.5 interactions per bunch crossing
- Total of 9 fb^{-1} collected







Trigger yield vs lumi in Run 1&2