Performance of LHCb Upgrade I in Run 3

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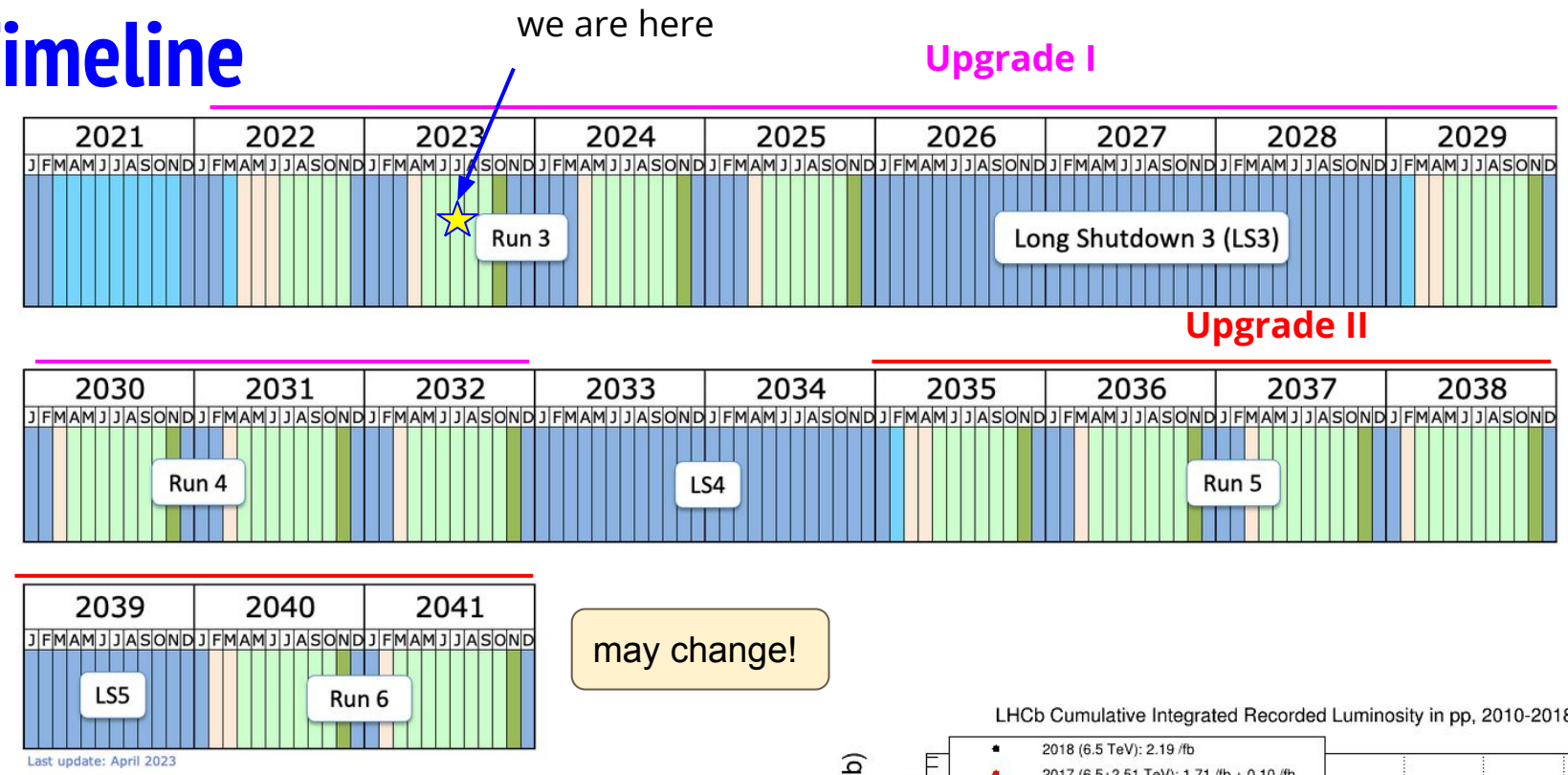
Introduction

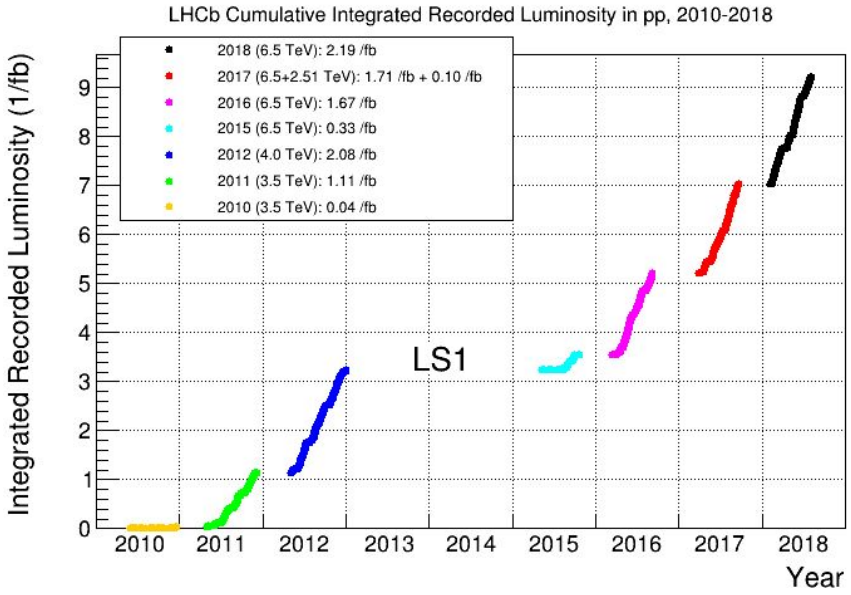
- LHCb Run 1 and Run 2: huge success!
- Non-exhaustive selection of charm highlights:
  - First observation of CPV in charm decays PRL 122 (2019) 211803
  - Observation of the mass difference between neutral charm-meson eigenstates PRL 127(2021)111801
  - Evidence of CPV in a single channel arXiv:2209.03179
- The majority of measurements is statistically limited

  → LHCb Upgrade I: 5x instantaneous luminosity
- Improve physics performance, despite the more challenging environment
  - Completely new tracking and trigger system

Timeline



- Run 1+2
  - Integrated luminosity 9 fb^{-1}
- Upgrade I
  - Integrated luminosity ~41 fb^{-1}
- Upgrade II
  - Integrated luminosity ~250 fb^{-1}



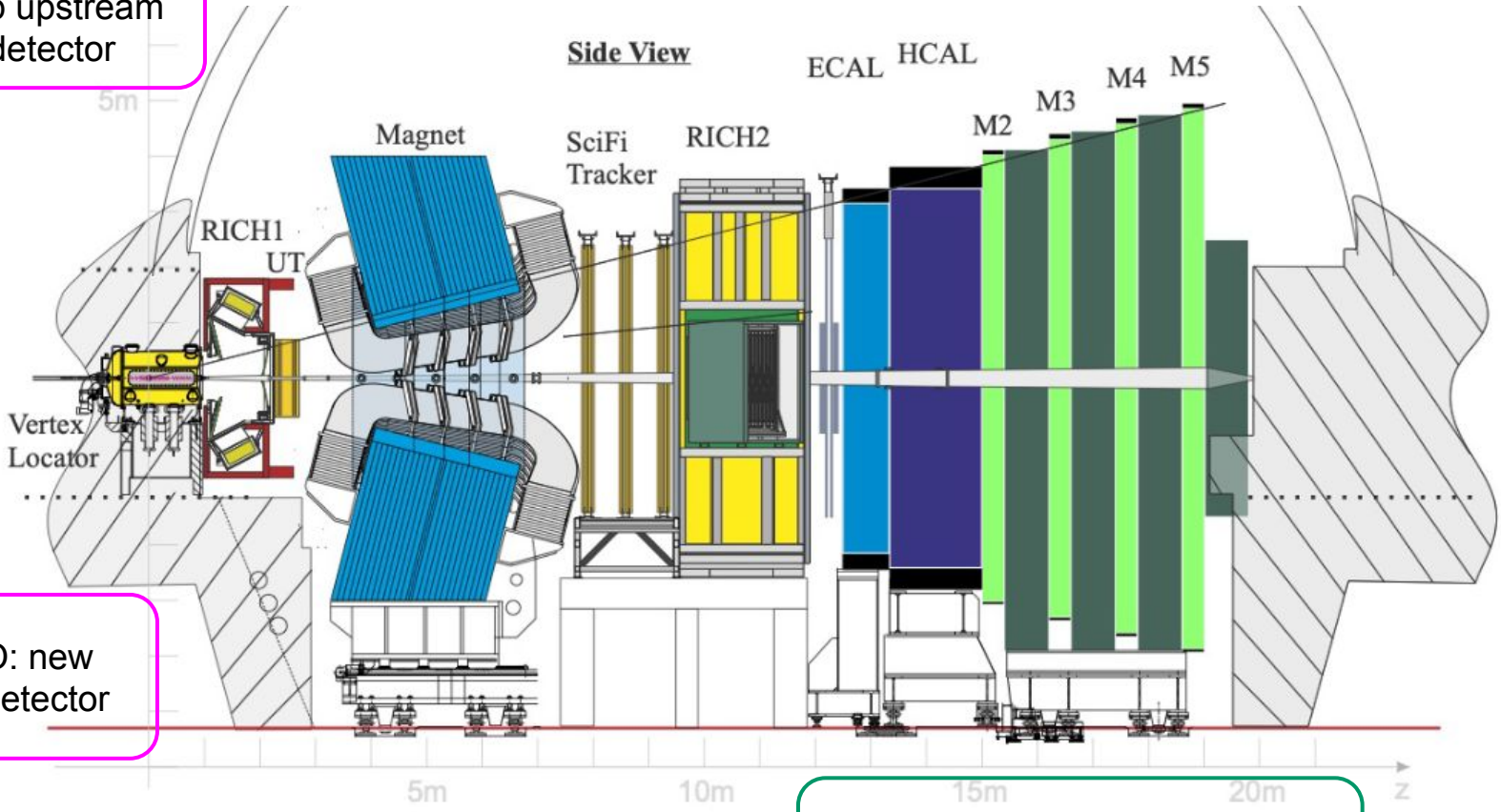
LHCb Upgrade I detector

arXiv:2305.10515

SciFi: new scintillating fibres downstream detector

RICH: new mechanics, optics, photodetectors

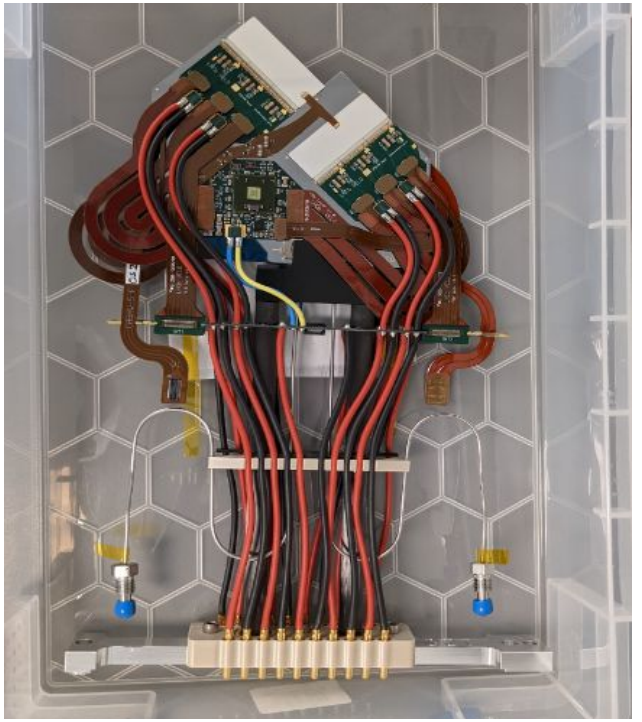
UT: new silicon strip upstream detector



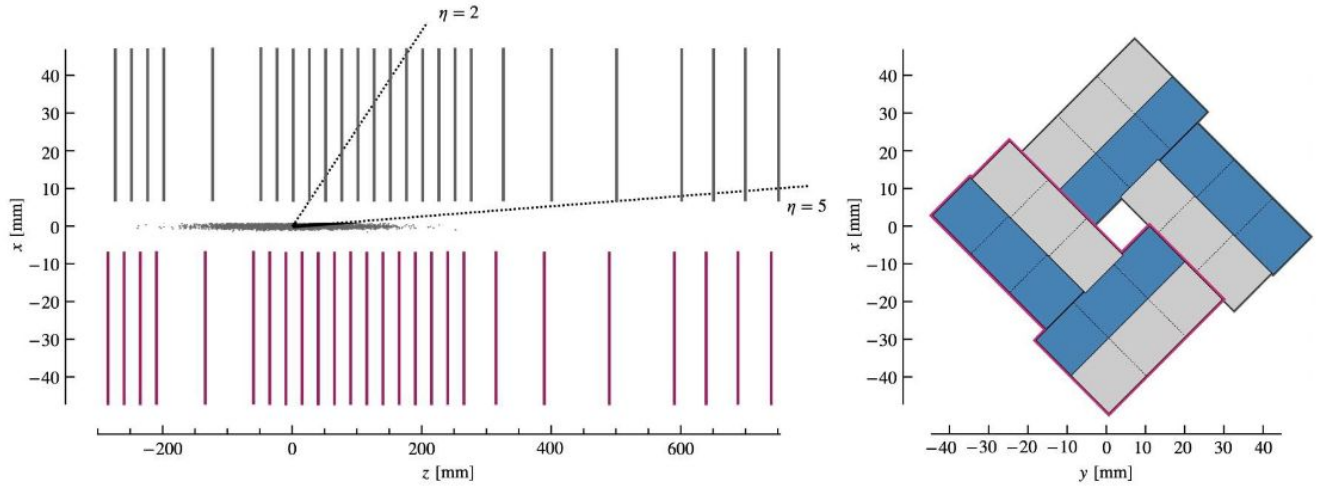
VELO: new pixel detector

New frontend electronics and new DAQ for all sub-detectors!

Tracking detectors: VELO

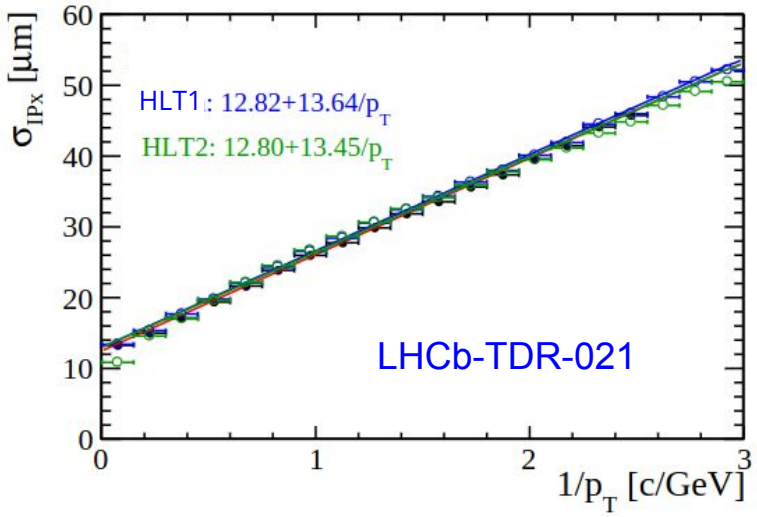


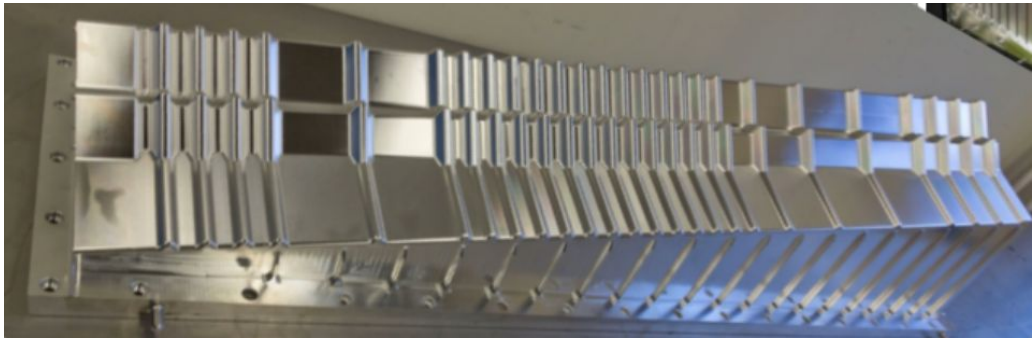
- Charm and beauty hadrons:
  - $\tau \sim O(0.1\text{-}1\ ps)$
  - Can flight several mm before decaying: distinctive feature to select them
- High resolution vertex detector
  - Silicon pixels → single hit resolution 12-15 μm



Tracking detectors: VELO (2)

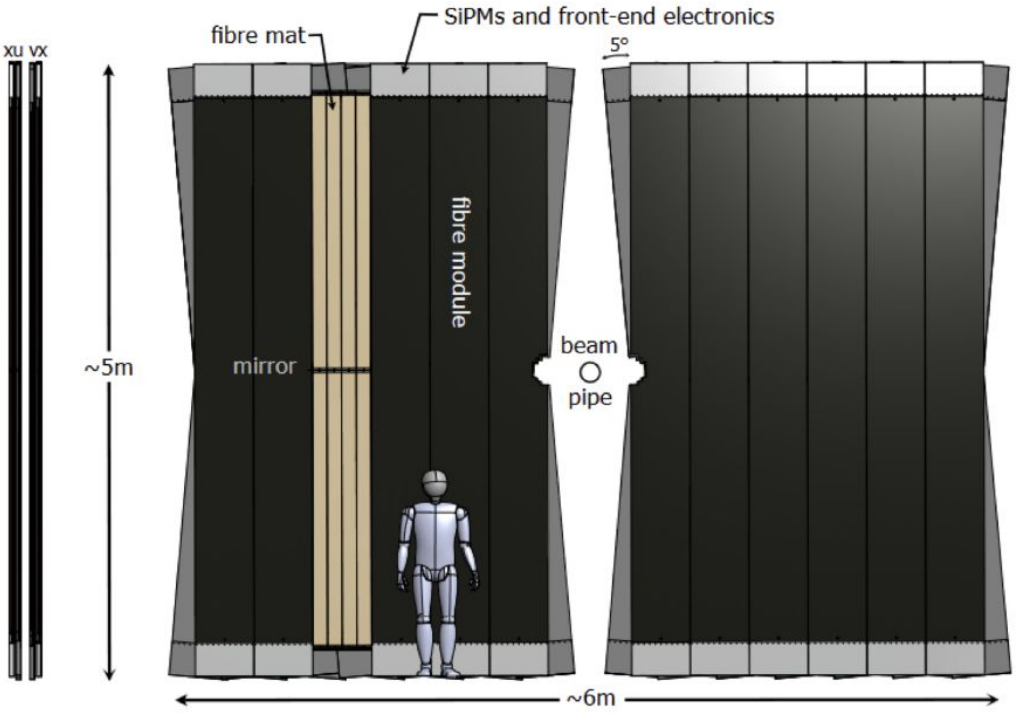
- VELO is separated from the primary vacuum by the 1.1m long thin walled “RF box”
- 3.5 mm clearance from the beam and 900 μm clearance from the sensors
- → aperture is so small that during LHC injection the VELO halves and boxes must be retracted





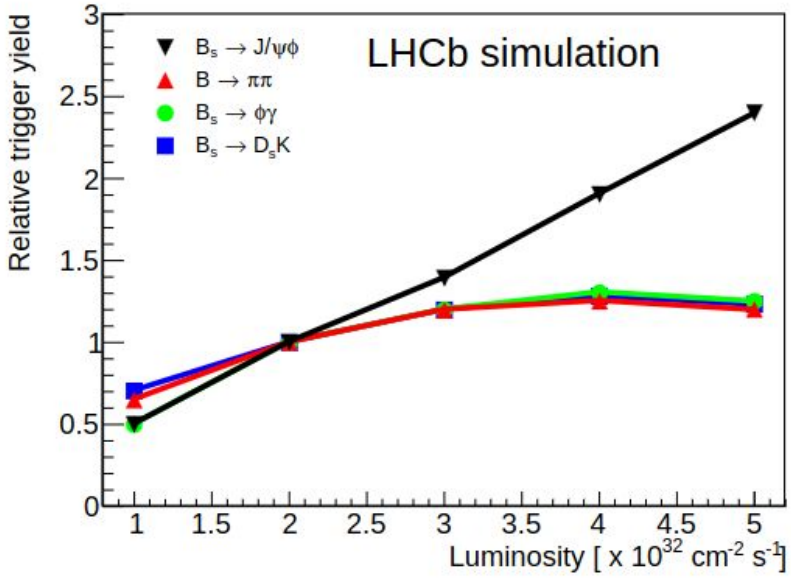
Tracking detectors: SciFi

- Single hit resolution better than 100 μm
- Single hit efficiency of 99%
- Light detector, to limit multiple scattering
- Radiation hardness: the tracker should operate at the desired performance over the lifetime of the experiment
- → Scintillating Fibre Tracker!



Trigger system

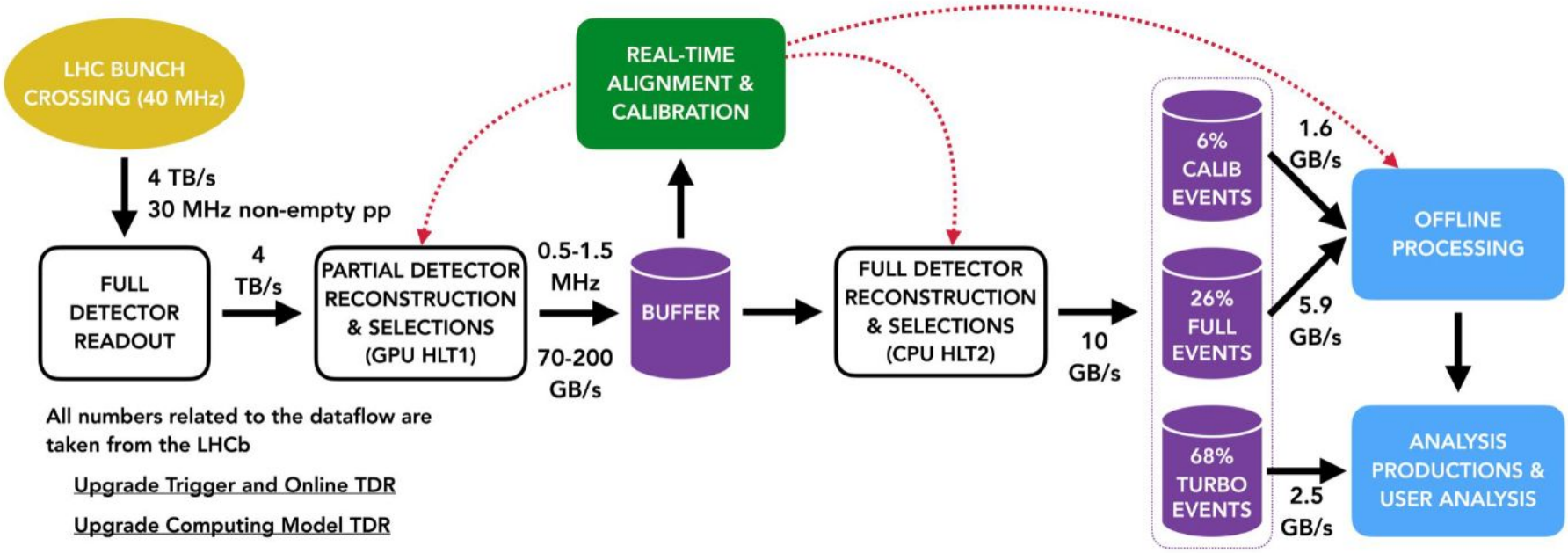
- Trigger strategy in Run 1 + Run 2:
  - Hardware trigger (L0), followed by a software trigger
- Instantaneous luminosity will reach 2 x 10^{33} $cm^{-2}s^{-1}$
  - Tight p_T and E_T cuts saturate hadronic channels → L0 trigger removed
  - Software trigger process events at the full LHC collision rate



arXiv:2305.10515

Data flow

LHCb-FIGURE-2020-016



All numbers related to the dataflow are taken from the LHCb

Upgrade Trigger and Online TDR

Upgrade Computing Model TDR

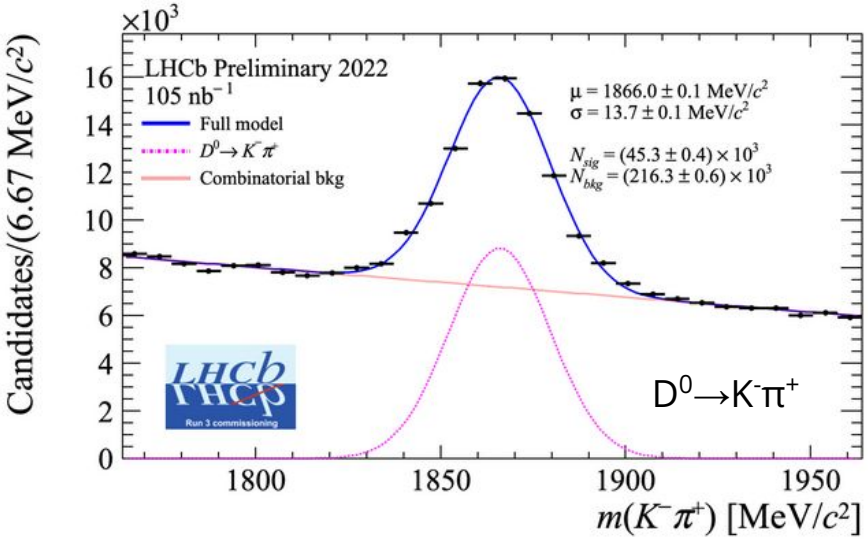
New trigger system: implications for charm decays

- 1) Charge asymmetries
  - L0 trigger for hadrons in Run 2: information from the calorimeter
  - Calorimeter is quite coarse: many particles fall in the same cell
  - Cannot combine efficiencies for single tracks to determine efficiency of a decay
  - Difficult to evaluate trigger induced asymmetries in CPV measurements
  - Not a problem anymore in Run 3: L0 trigger removed

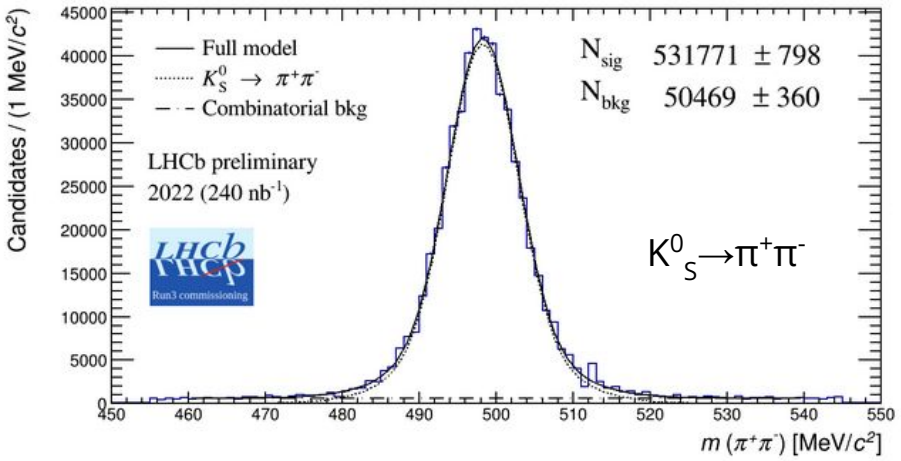
New trigger system: implications for charm decays

- 2) Greater flexibility in design of selections
  - D^0 and K_S^0 candidates reconstructed directly at the first level of the trigger!
  - → room for improving trigger efficiency w.r.t. Run 2

LHCb-FIGURE-2023-009

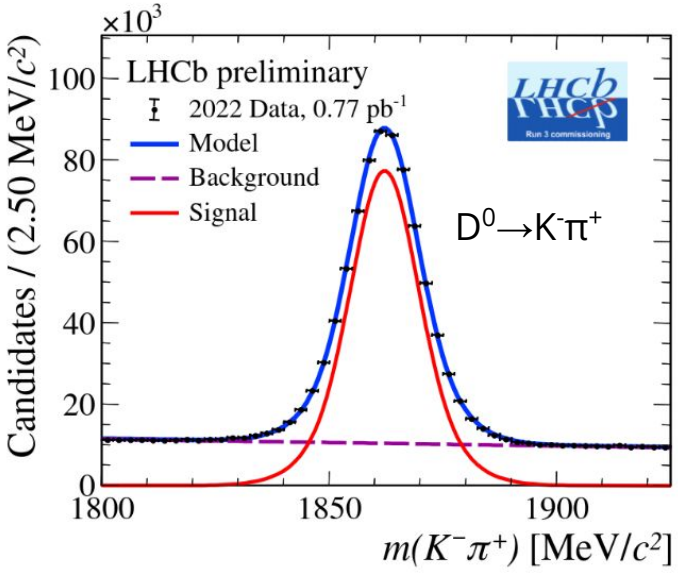


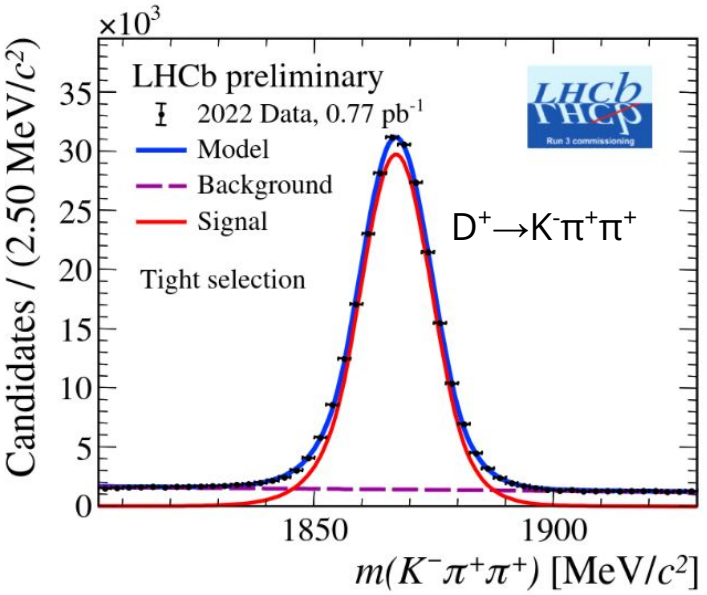
LHCb-FIGURE-2023-005

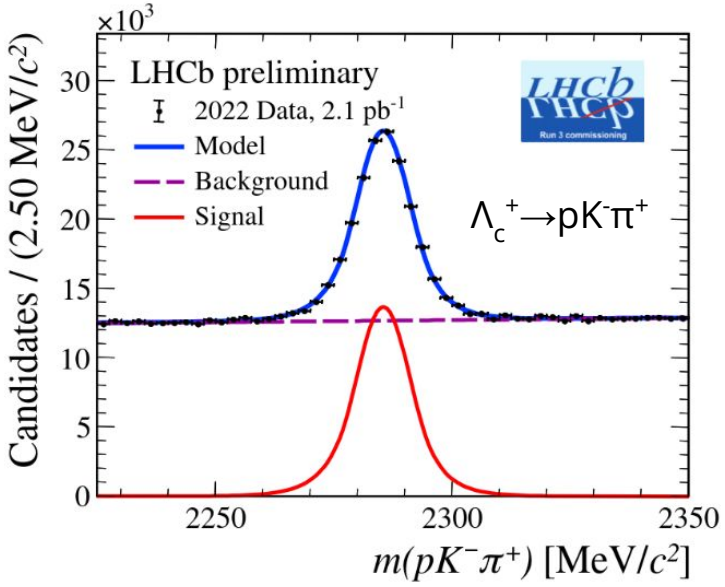


Mass peaks in 2022 data

LHCb-FIGURE-2023-011



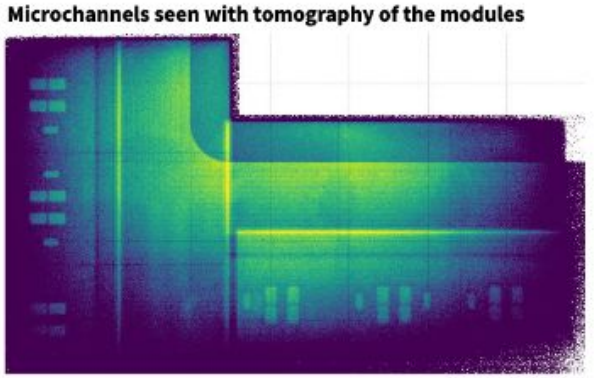


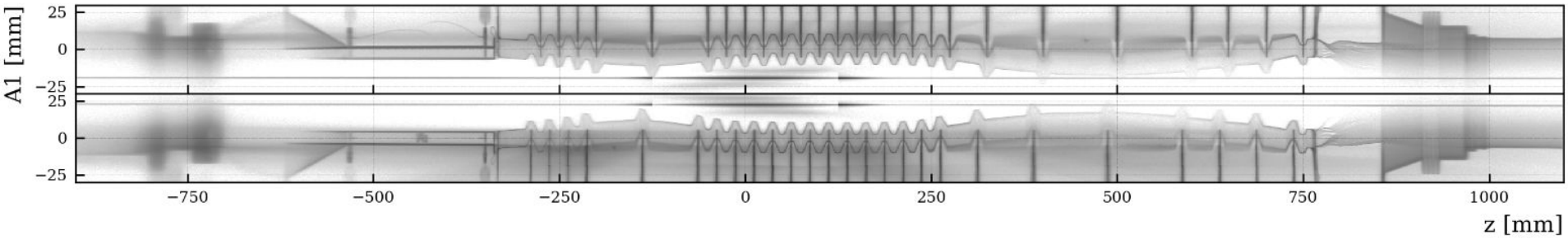


Mass resolution compatible with MC expectations within 1 MeV

2023 - Vacuum incident

- 10 Jan 2023: loss of the protection system
  - pressure differential of 200 mbar between the secondary VELO vacuum and the LHC one (max design pressure 10mbar)
- Tomography to check the sensor status and the shape of RF box
  - No damage to VELO sensors
  - But VELO cannot be fully closed to the nominal 3 mm position around the beam due to a plastic deformation of the boxes of about 17mm
  - RF box will be replaced during YETS 2023/2024



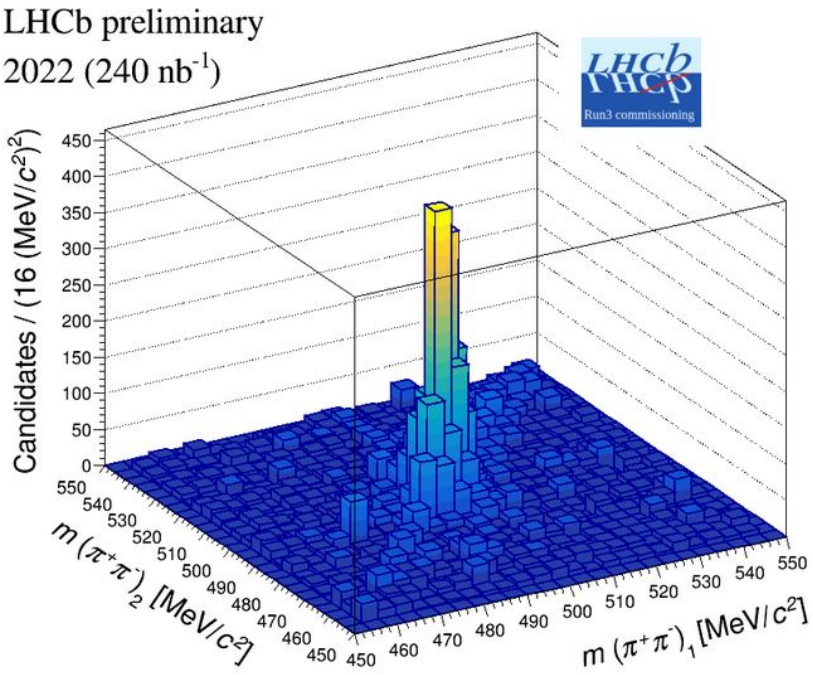


Physics opportunities in 2023 (before 17.07.23)

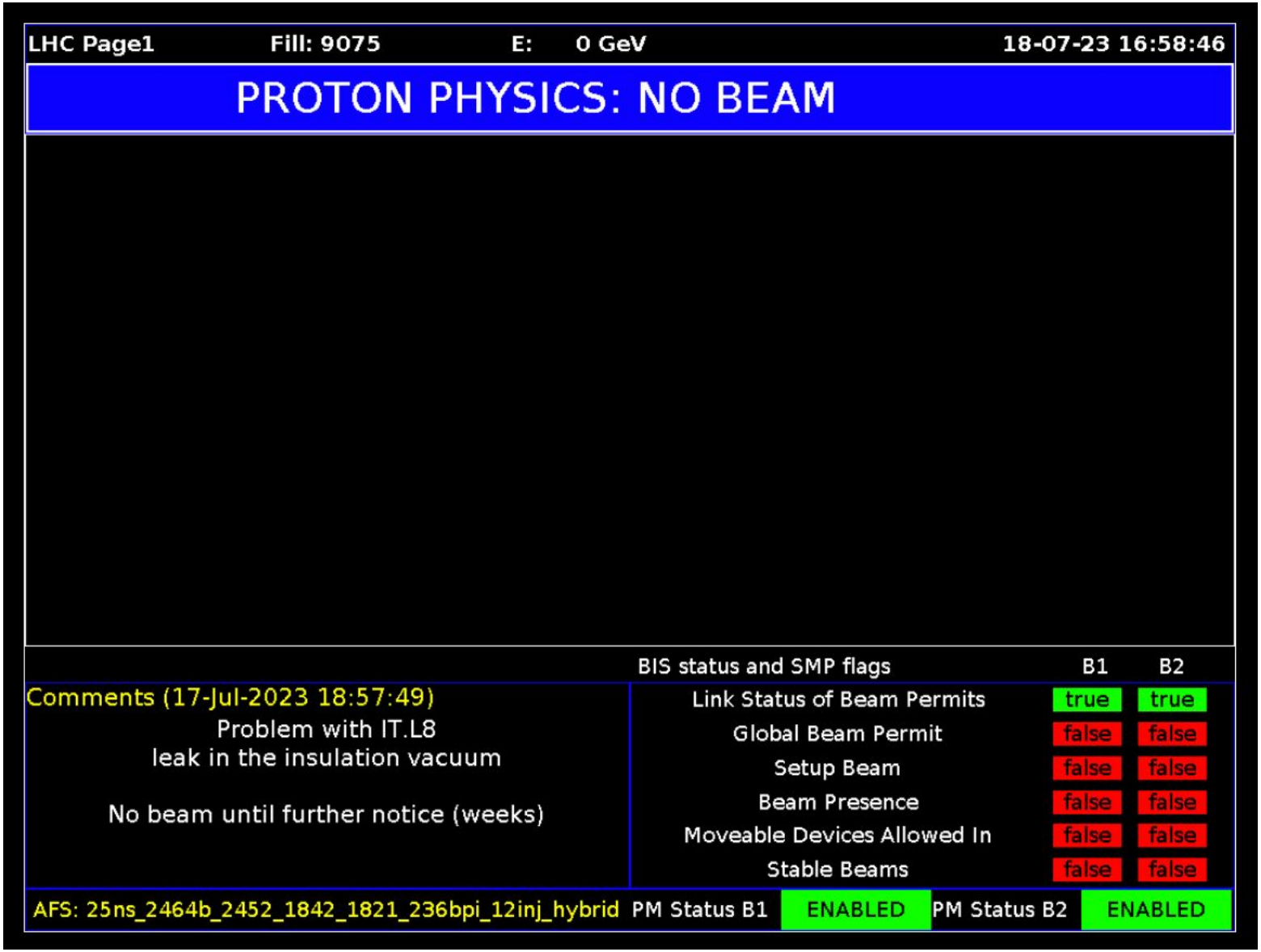
- VELO partially open during 2023 data taking (24.5 mm per side)
- LHCb physics program affected, but still many opportunities

- Reconstruction of K_S^0 and Λ^0 not affected by open VELO
- Dedicated HLT1 selections to collect single K_S^0 and pairs of K_S^0
  - ➢ x2.6 efficiency on $D^0 \to K_S^0 K_S^0$ decays (see LLP workshop 2022)

LHCb-FIGURE-2023-005



Current status



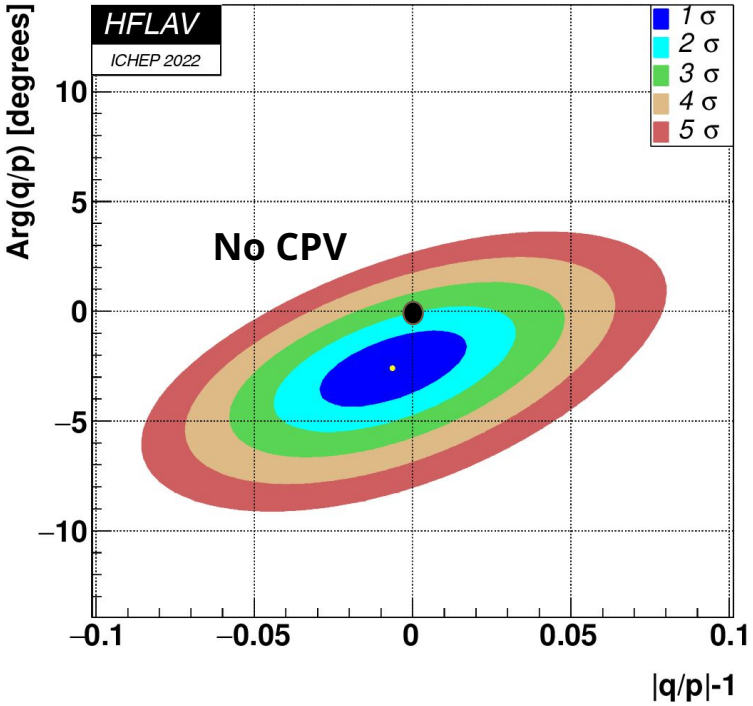
Conclusions

- A huge amount of work has been done to finalize the commissioning of our brand new detector
- Cannot promise anything today for 2023 data-taking, but we are making our best in the conditions which are given

Backup slides

Prospects

Current status
(average on all available measurements)



Future prospects (only $D^0 \to K_S^0 \pi^+ \pi^-$)

Sample (lumi $\mathcal{L}$)	Tag	$\sigma(\lvert q/p \rvert)$	$\sigma(\phi)$
Run 1–3 (23 fb^{-1})	SL	0.036	2.5°
	Prompt	0.017	0.77°
Run 1–4 (50 fb^{-1})	SL	0.024	1.7°
	Prompt	0.011	0.48°
Run 1–5 (300 fb^{-1})	SL	0.009	0.69°
	Prompt	0.004	0.18°

Physics case for an LHCb Upgrade II