Status and perspectives of LHCb

Marianna Fontana
on behalf of the LHCb collaboration

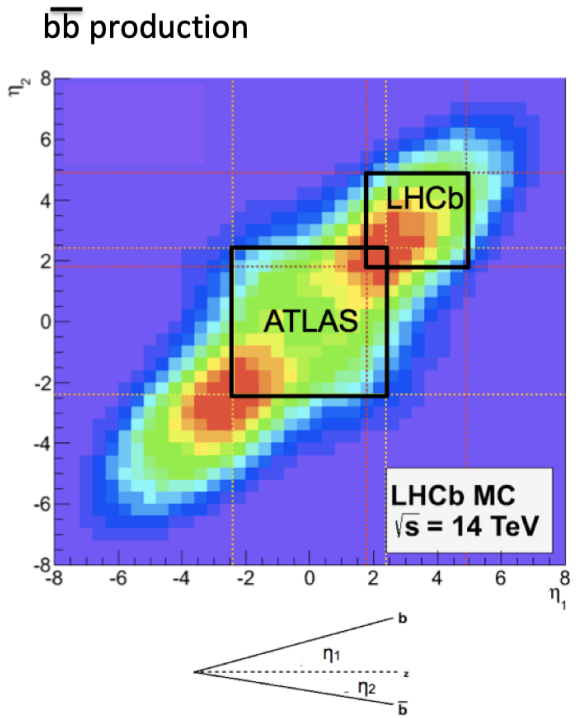
LPNHE (Paris)

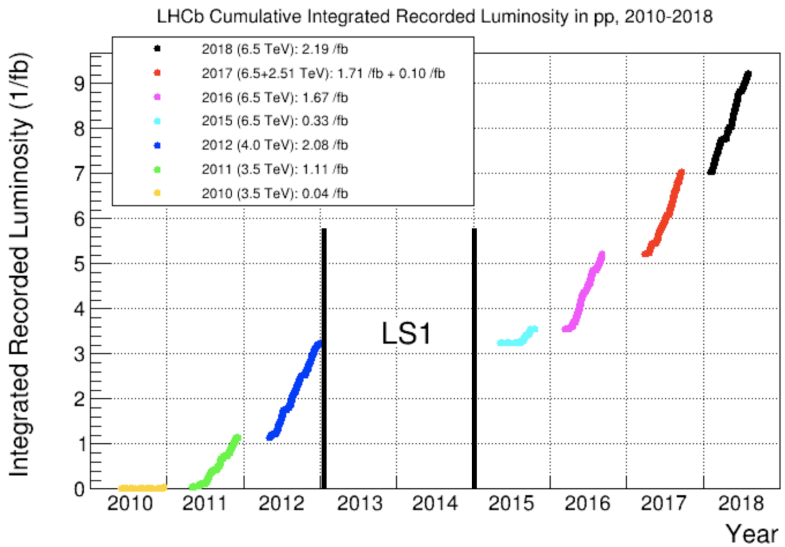
Implications Workshop 2022

CERN, 19 - 21 October 2022

LHCb in a nutshell

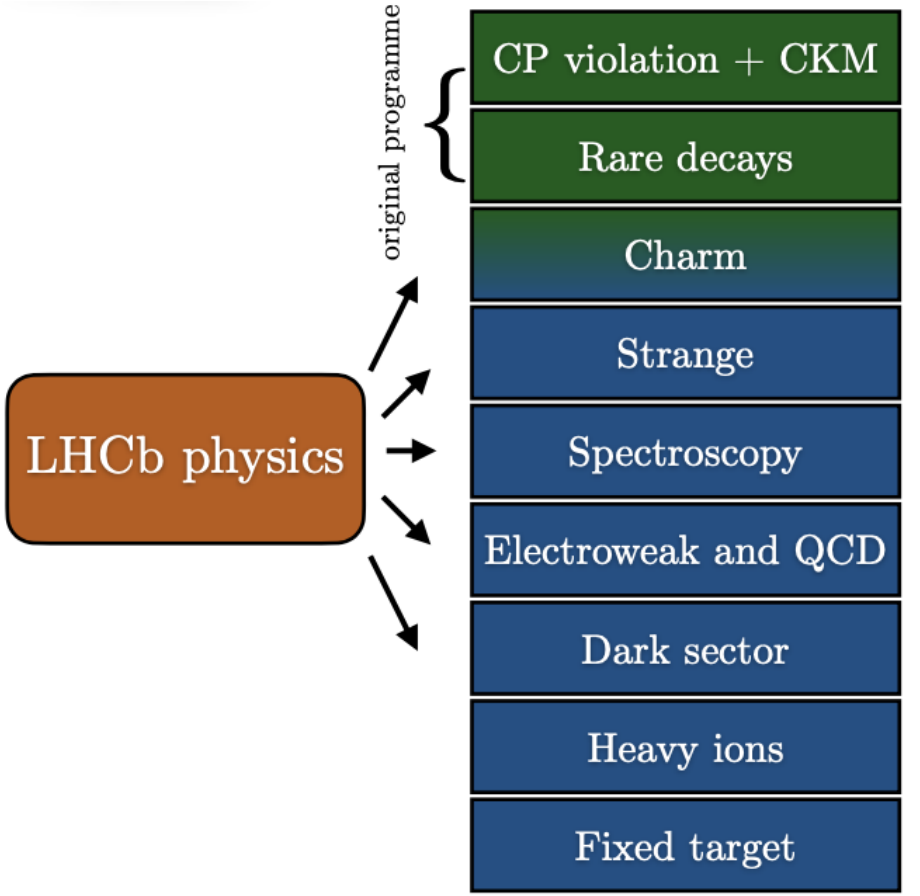
- LHCb originally designed for CP violation and rare decays measurements $\rightarrow$ nowdays a **general purpose detector**!
- $\bar{b}b$ production in pp collisions mostly in the forward direction
- Run 1+2: 9 fb^{-1} of pp collisions (+ heavy ions, fixed target mode)
- Forward spectrometer ($2 < \eta < 5$) with excellent vertexing, tracking and particle identification [JINST 3 (2008) S08005]



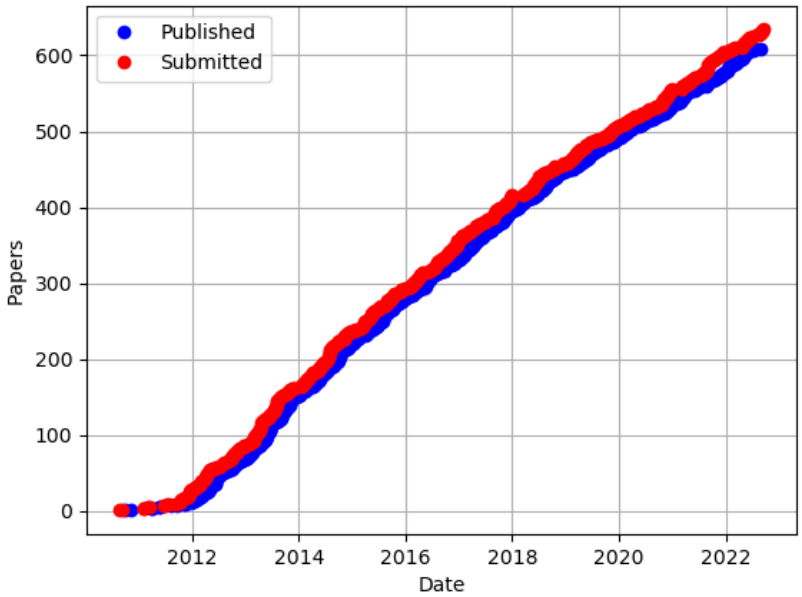


Run 1, 3fb^{-1} Run 2, 6fb^{-1}

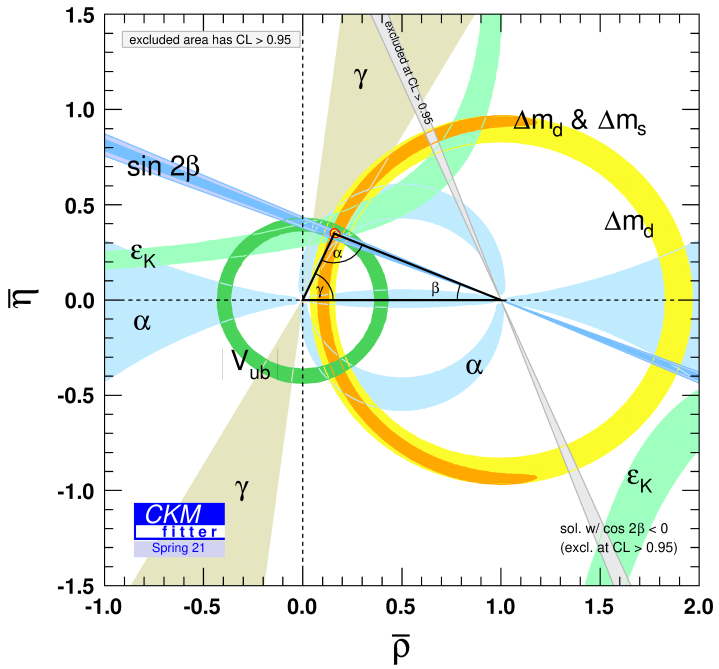
The LHCb physics programme



More than 630 papers submitted!

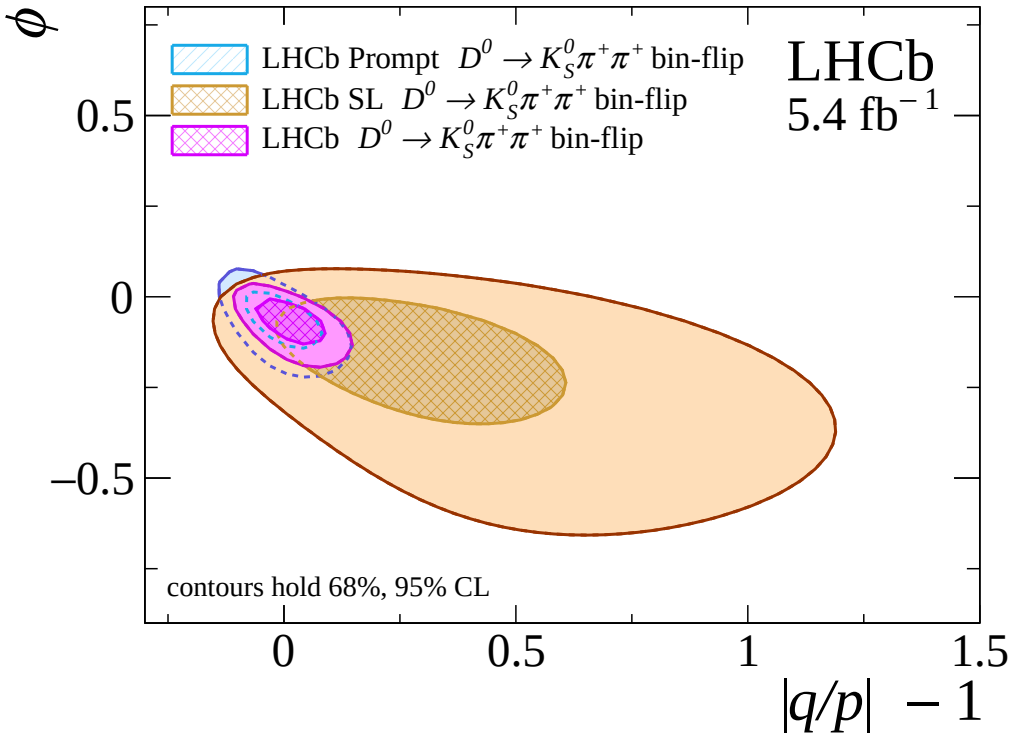


The CKM picture



- Great success of the Standard Model CKM picture
- All measurements agree coherently
- How does that relate to other information which tells us that NP must exist?
- Approaching the 4% uncertainty level on $\gamma \rightarrow$ new combination being shown!

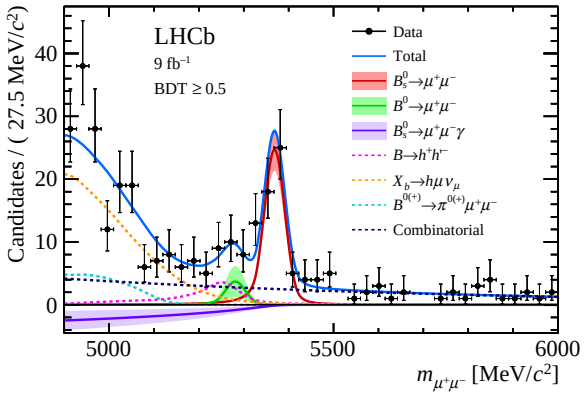
The *up* sector



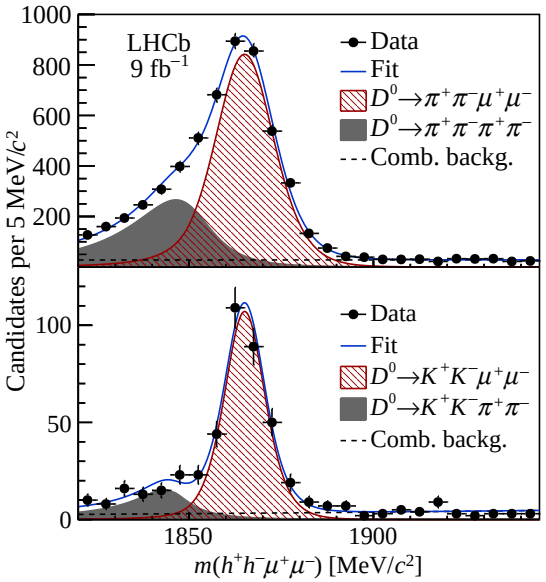
[arXiv:2208.06512]

- CPV in charm observed by LHCb in the difference of CP asymmetries for $D^0 \to \pi\pi$ and $D^0 \to KK$
- Now beginning to characterise the individual asymmetries!
- Charm mixing well-established since more than a decade! Keeping improving the precision on the mixing parameters

Rare and semileptonic decays

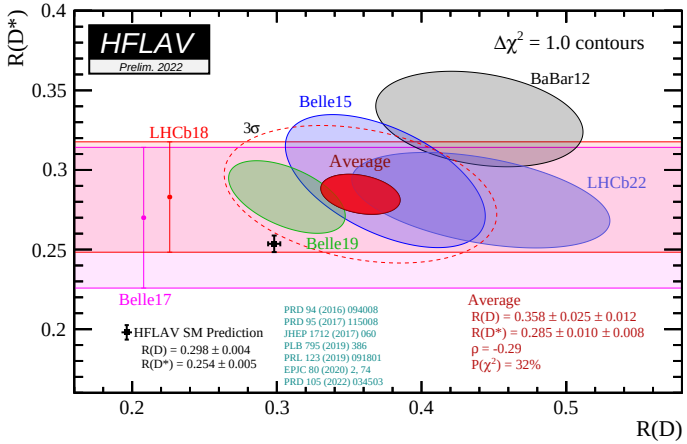


[PRL 128 (2022) 041801]



[PRL 128 (2022) 221801]

- Rich laboratory for SM tests
- Many progress towards the legacy Run 1+2

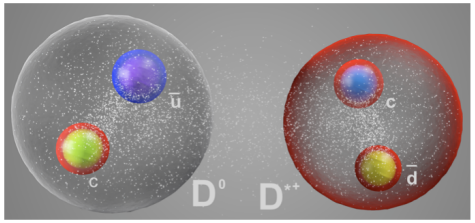


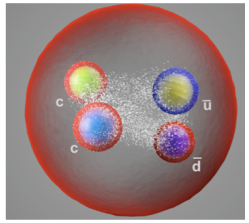
[LHCb-PAPER-2022-039]

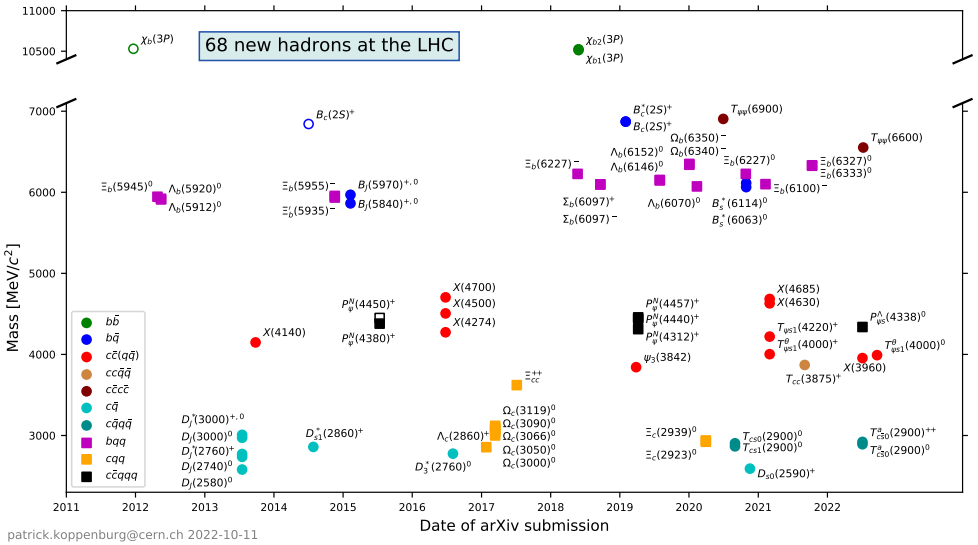
Have a look at our latest results presented at the CERN seminar yesterday!!

Search for hadronic states

- Conventional and exotic hadronic states are key to study non-perturbative QCD
- Many of them discovered by LHCb
- Nature of exotic states still unclear: hadronic molecule or tightly bound states?



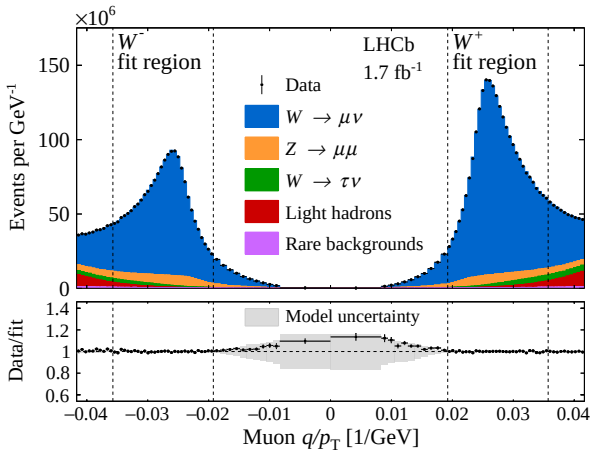




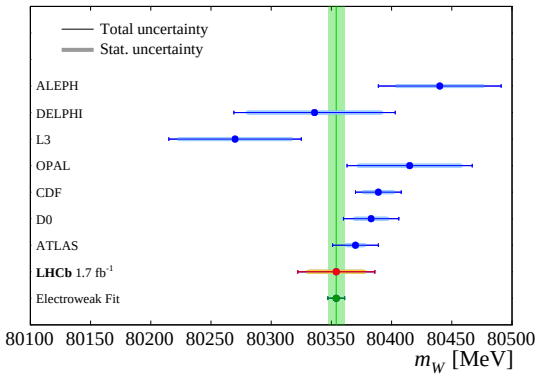
[https://www.nikhef.nl/ pkoppenb/particles.html]

- Workshop on exotic hadrons held yesterday at CERN
- New naming convention proposed by LHCb [arXiv:2206.15233]

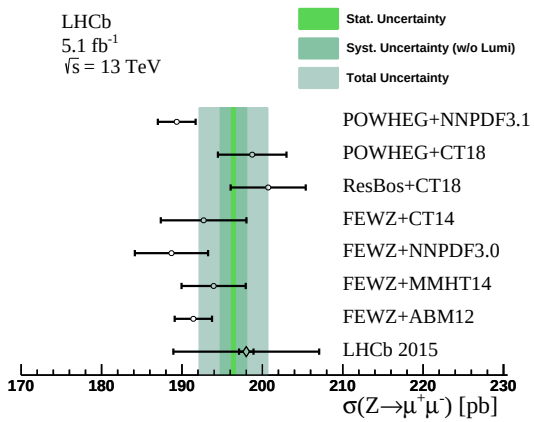
Electroweak



$$m_W = 80354 \pm 23_{\text{stat}} \pm 10_{\text{exp}} \pm 17_{\text{theory}} \pm 9_{\text{PDF}}\ \text{MeV}$$



[JHEP 01 (2022) 036]



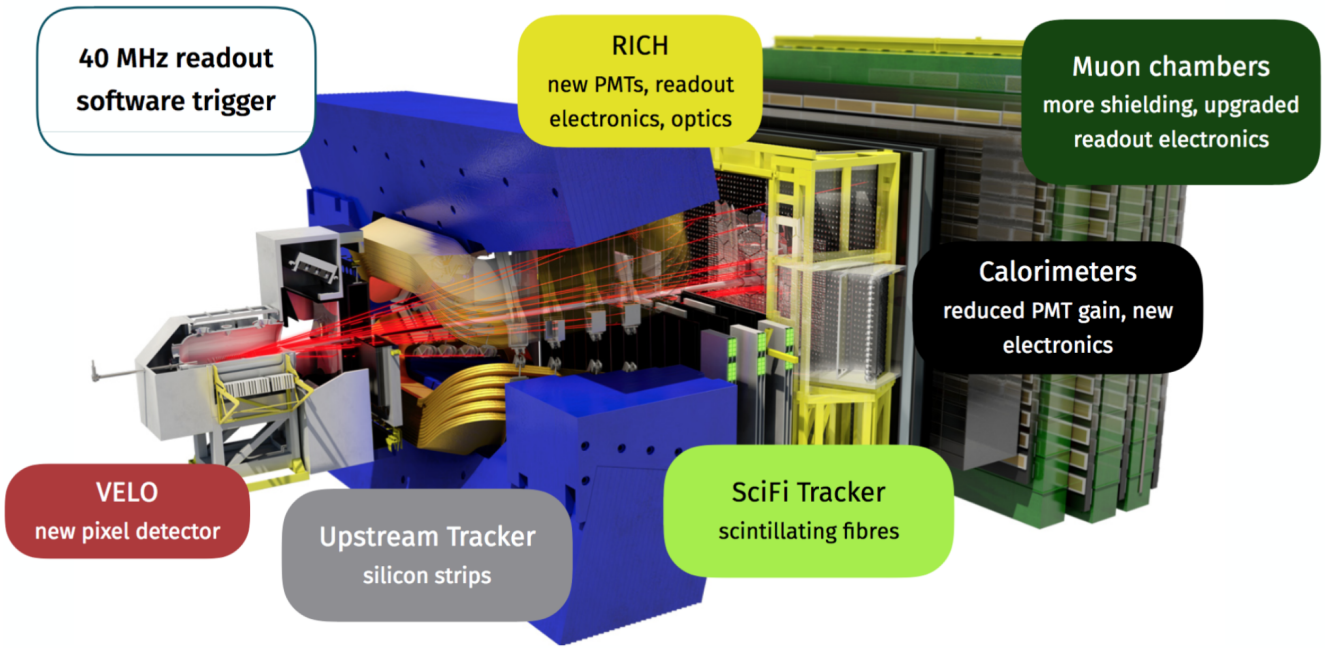
[JHEP 07 (2022) 026]

- LHCb characteristics allow to perform unique observable measurements
- Precision measurement of EW observables allows to search for NP effects
- The W measurement agrees well with the prediction of the global electroweak fit and with previous measurements

The upgraded LHCb

Major upgrade of all sub-detectors

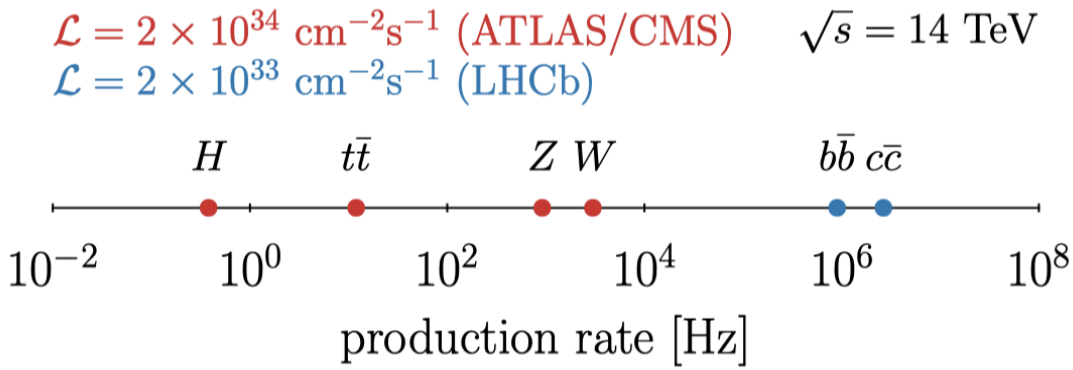
- $\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$, pile-up ≈ 5



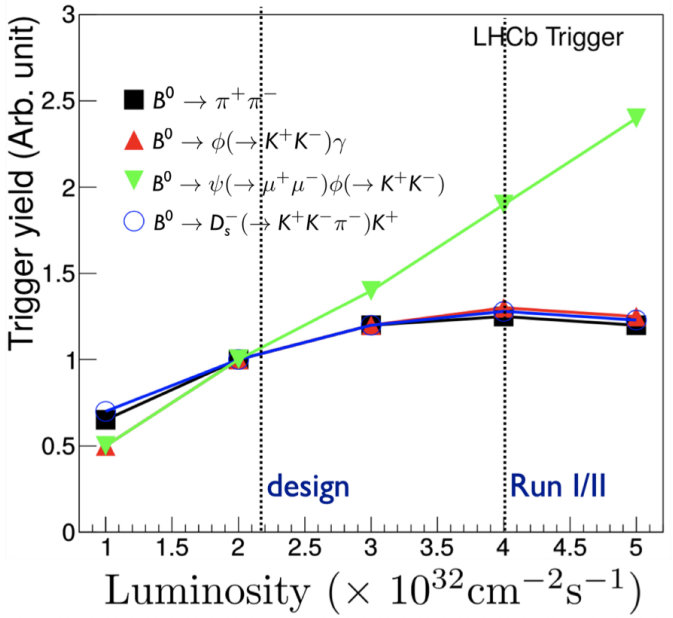
- New pixel-detector **VELO**
- New **RICH** mechanics, optics, photodetector
- New Silicon strip upstream tracker **UT**
- New **SciFi** tracker
- New electronics for **MUON** and **CALO**
- New luminometer **PLUME**

- 100% of the readout electronics replaced
- New data acquisition system and data center
- Very challenging installation and commissioning!

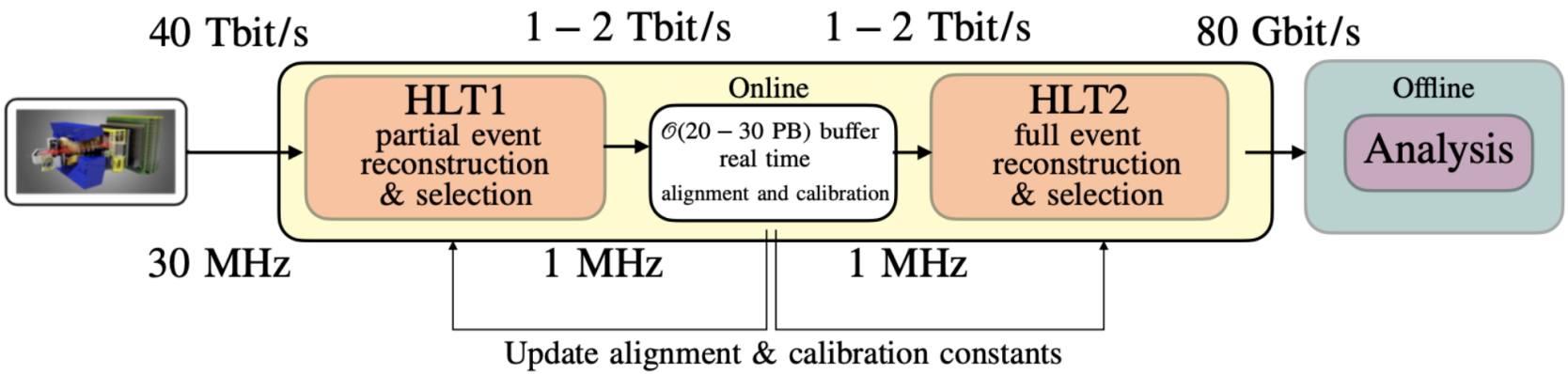
Upgrade the trigger strategy



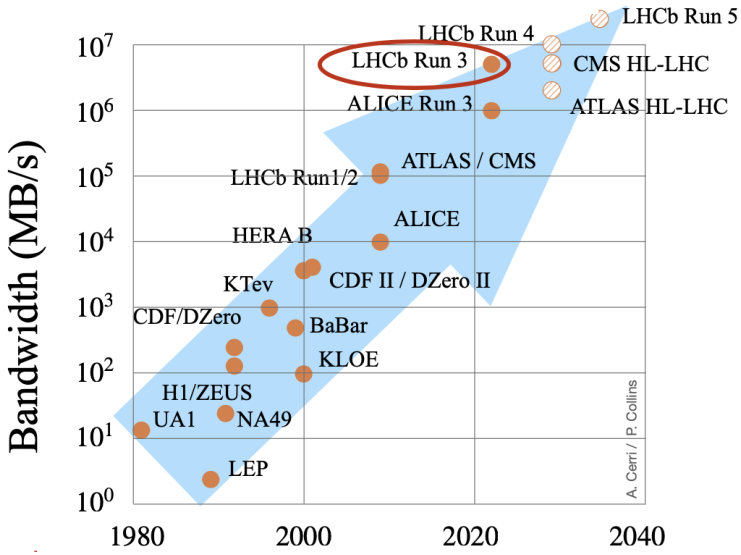
- Heavy flavour hadrons decay to final-state particles with momenta similar to those of particles from the underlying event
- LHCb has to distinguish between signal and signal-like background
- Cannot effectively trigger on heavy flavour using hardware signatures
- Trigger for many hadronic channels saturated already at Run 1–2 luminosity



Upgrade the trigger strategy



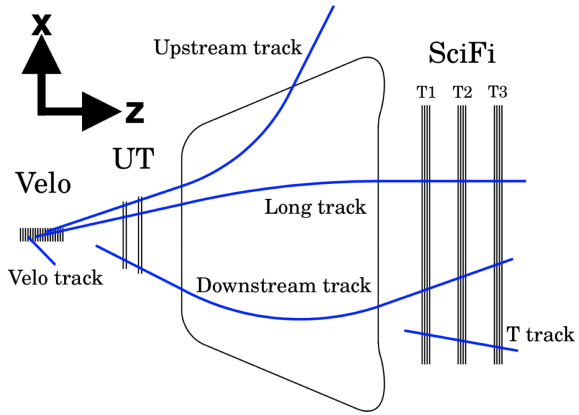
- **Solution**: fully software trigger
- Online reconstruction at 40 MHz
- 30 MHz of inelastic collisions reduced to 1 MHz in Hlt1 (running on GPUs)
- Offline-quality reconstruction in “real-time”
- Increase of hadronic trigger efficiency by 2–4 wrt. Run 2



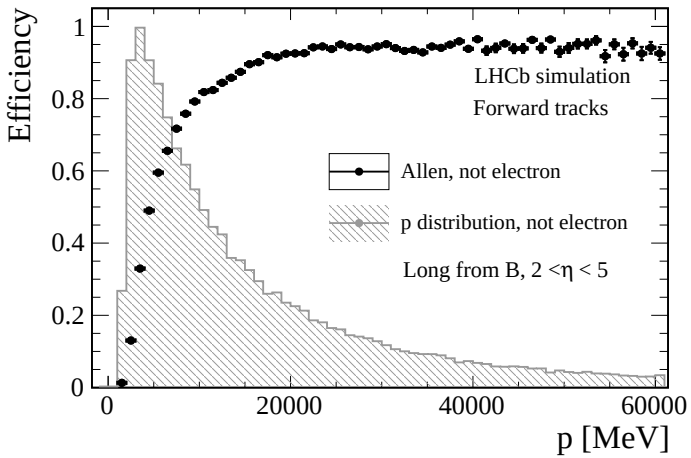
Highest data processing rate of any HEP experiment!

Tracking

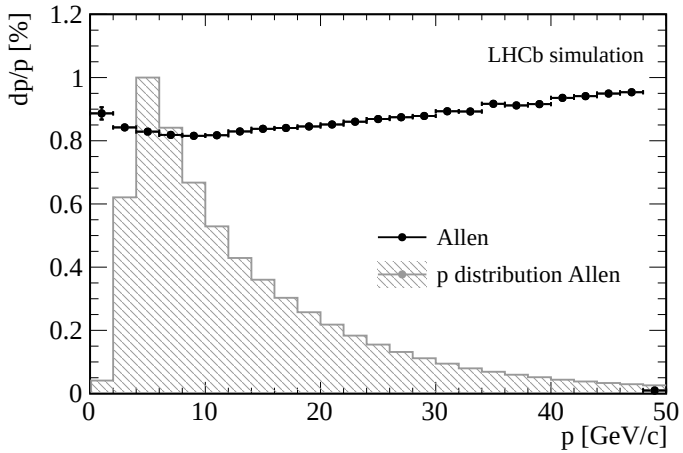
- Various type of tracks in LHCb
- *Long tracks* used for most analyses ($B_s^0 \to \mu^+\mu^-$, ...)
- *Downstream tracks* can be used by analyses like for example $D^0 \to K_S^0 K_S^0$
- Run 2 performance maintained at x5 instantaneous luminosity



[LHCb-FIGURE-2020-014]



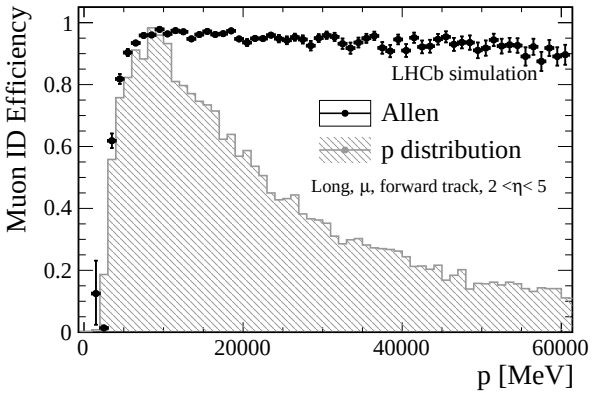
[LHCb-FIGURE-2020-014]



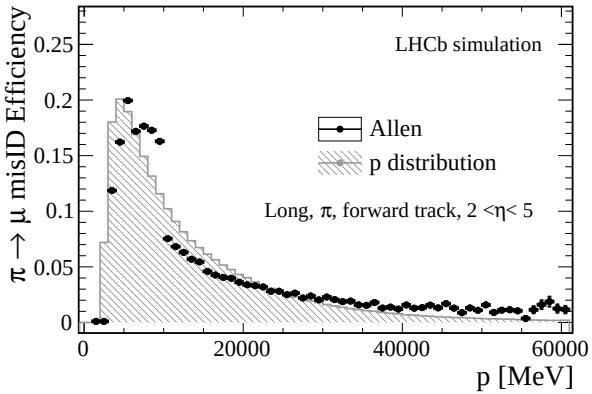
Particle identification

- Fundamental ingredient for LHCb analyses ($B_s^0 \to \mu^+\mu^-$, $B^0 \to h^+h^-$)
- PID combines information from RICH, calorimeters and muon system
- Used extensively in the trigger
- Expect to keep the same performance in Run 3

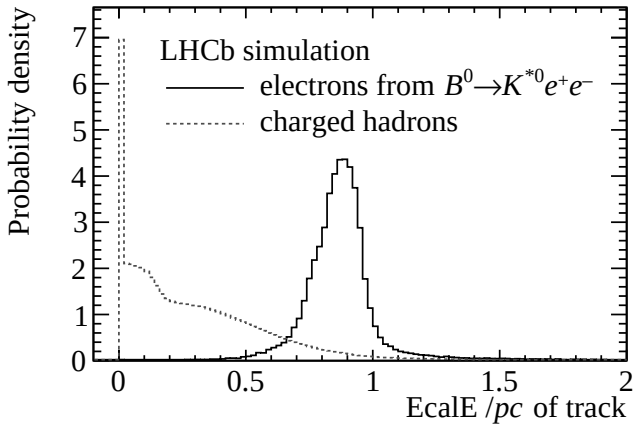
[LHCb-FIGURE-2020-014]



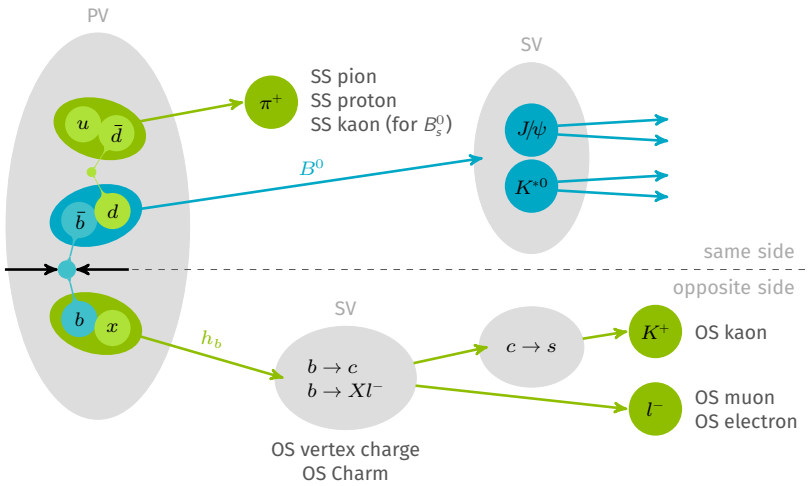
[LHCb-FIGURE-2020-014]



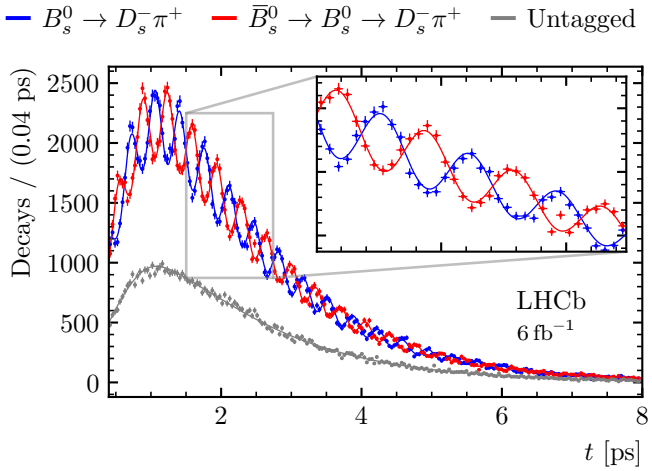
[LHCb-FIGURE-2021-003]



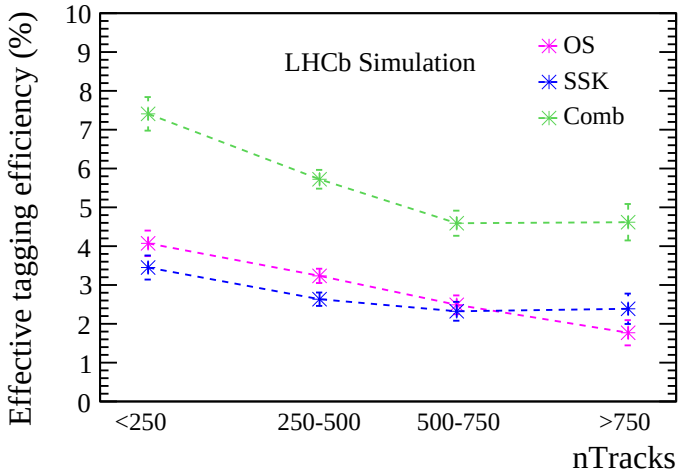
Flavour tagging



- Various algorithms to determine whether a neutral B meson is a particle or anti-particle at production
- Essential for time-dependendent analyses like ϕ_s, $\sin 2\beta$
- Effective tagging power ε is determined: asymmetry uncertainty $\sim 1/\sqrt{\varepsilon N}$

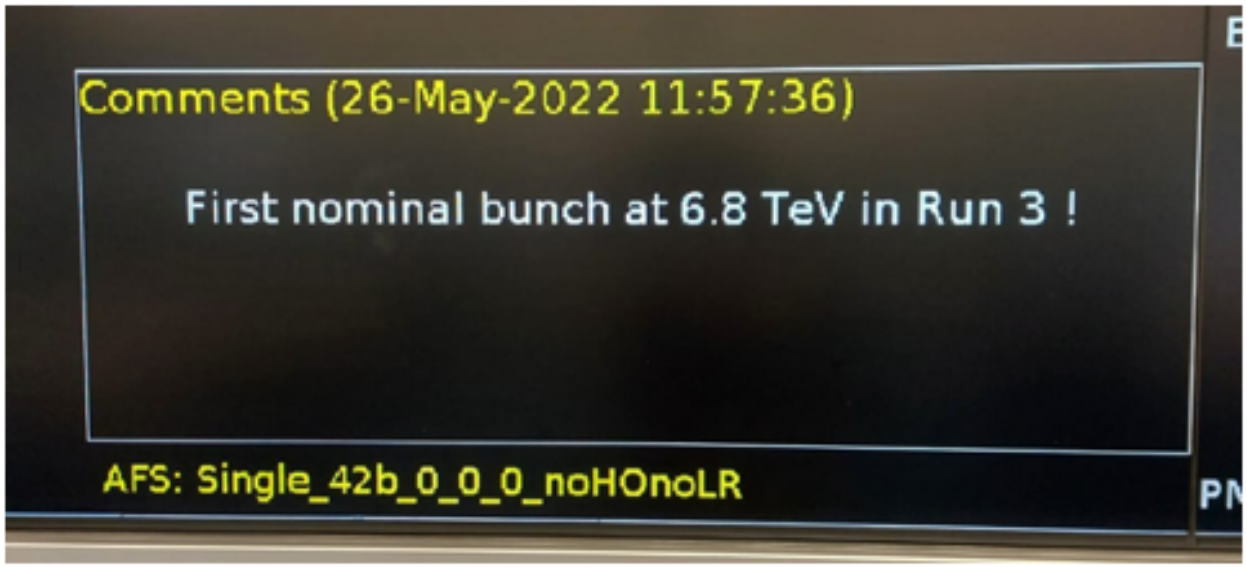


[Nature Physics 18, (2022) 1-5]



[LHCB-PUB-2018-009]

The commissioning trip



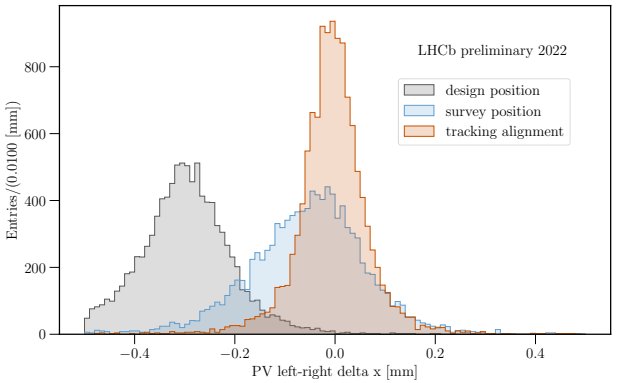
5th July 2022: first data at 13.6 TeV

5th July 2022: first data at 13.6 TeV

Trackers commissioning

VELO

- Tracks and vertices are reconstructed
- Accurate reconstruction of the beam position achieved
- Closure procedure in progressive steps: partially closed to 2 mm from nominal
- Good alignment reached

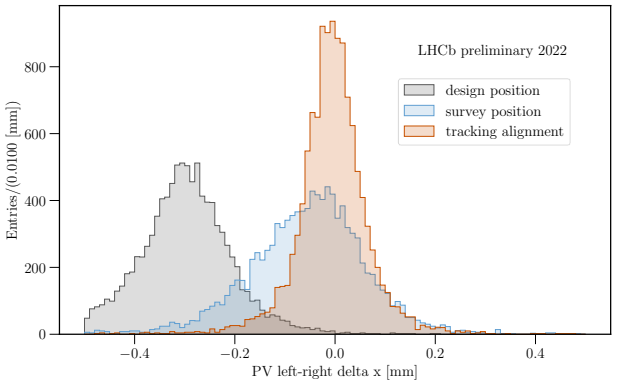


[LHCb-FIGURE-2022-029]

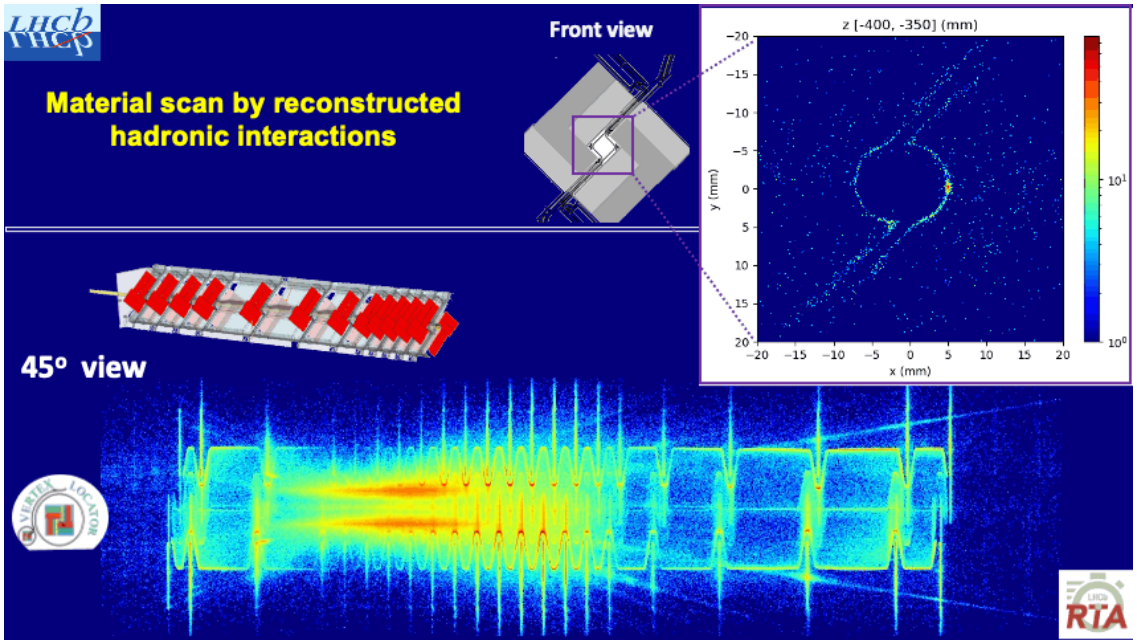
Trackers commissioning

VELO

- Tracks and vertices are reconstructed
- Accurate reconstruction of the beam position achieved
- Closure procedure in progressive steps: partially closed to 2 mm from nominal
- Good alignment reached



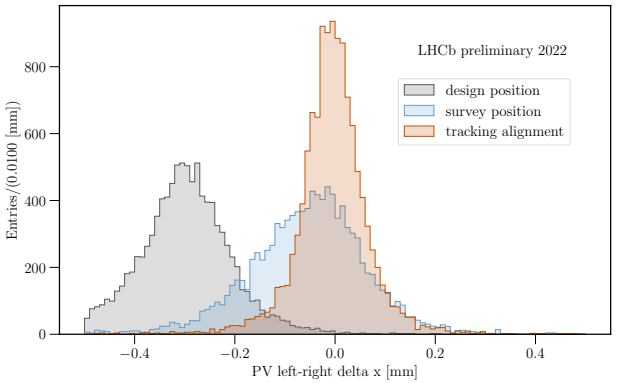
[LHCb-FIGURE-2022-029]



Trackers commissioning

VELO

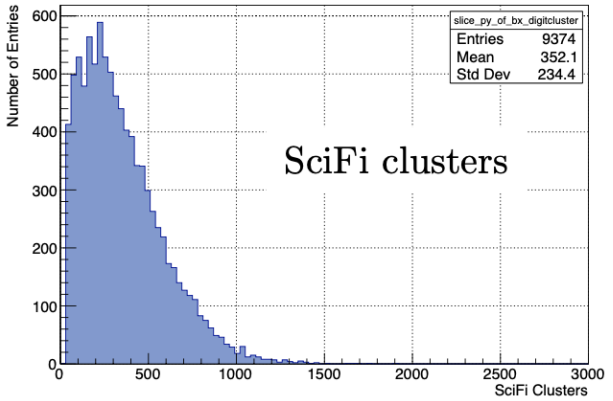
- Tracks and vertices are reconstructed
- Accurate reconstruction of the beam position achieved
- Closure procedure in progressive steps: partially closed to 2 mm from nominal
- Good alignment reached



[LHCb-FIGURE-2022-029]

SciFi

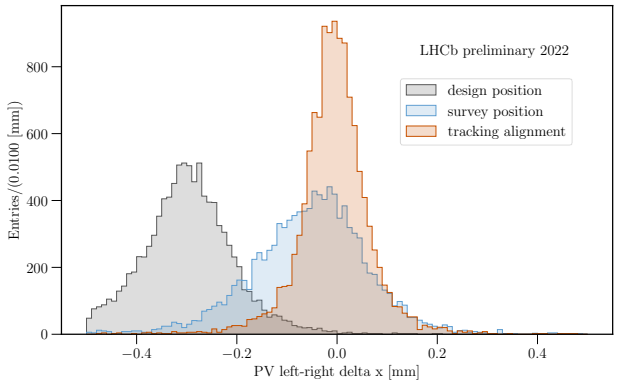
- Time alignment performed to maximise efficiency
- First tracks recorded



Trackers commissioning

VELO

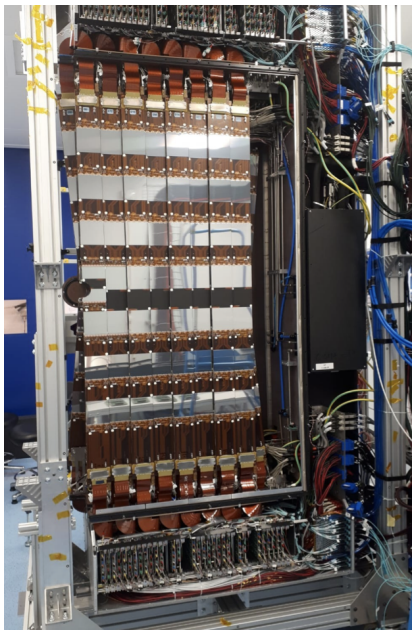
- Tracks and vertices are reconstructed
- Accurate reconstruction of the beam position achieved
- Closure procedure in progressive steps: partially closed to 2 mm from nominal
- Good alignment reached



[LHCb-FIGURE-2022-029]

SciFi

- Time alignment performed to maximise efficiency
- First tracks recorded



Upstream tracker

- Good progress towards the full installation at the end of the year

PID detectors commissioning

RICH

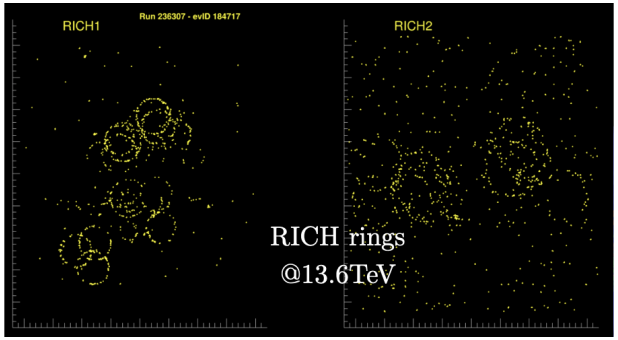
- RICH took part to stable beams runs since the first injection
- Time alignment performed
- Ready to be included in runs with track reconstruction

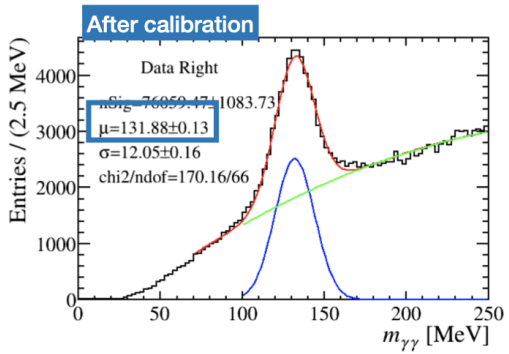
CALO

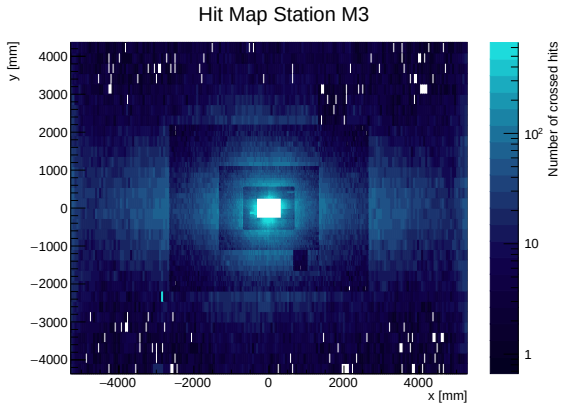
- The first collisions allowed individual time alignments of the calorimeter channels
- Thanks to the energy calibration, π^0s have been reconstructed

Muon system

- Work ongoing to complete fine time alignment
- Standalone muon reconstruction being tested soon

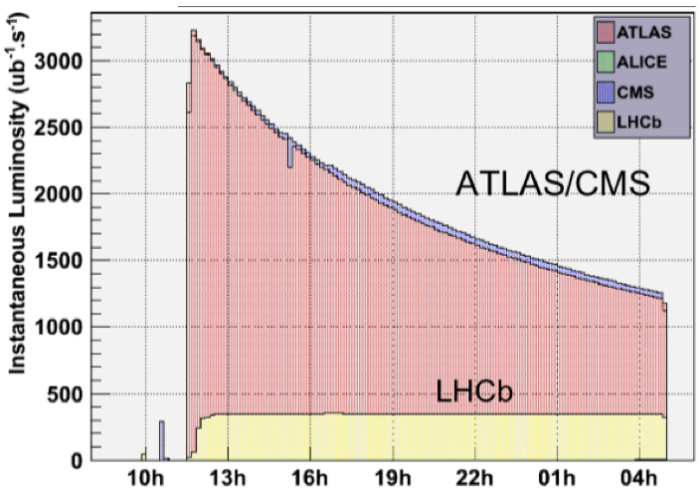


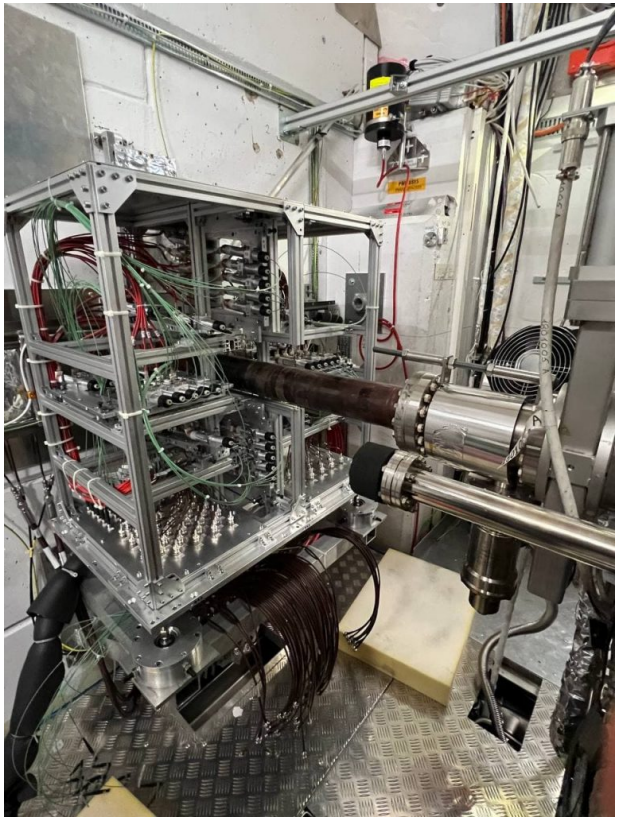




Luminosity

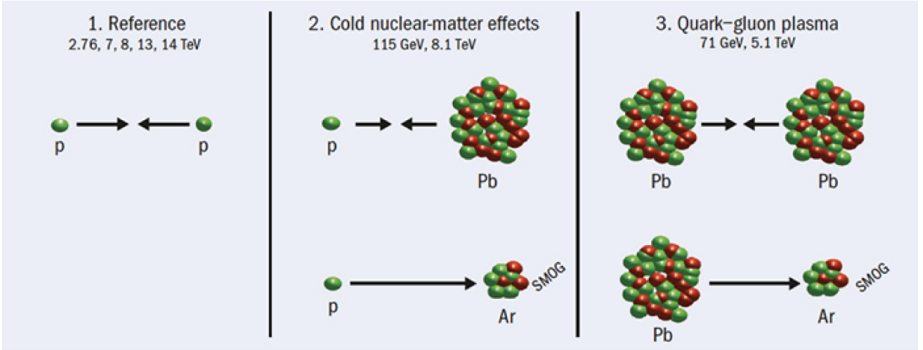
- Time-integrated luminosity necessary to calculate x-secs
- Instantenuos luminosity at LHCb: continuous luminosity levelling
- New dedicated detector PLUME (Probe for LUminosity MEasurements)
- Preliminary calibration of absolute luminosity at 13.6 TeV performed

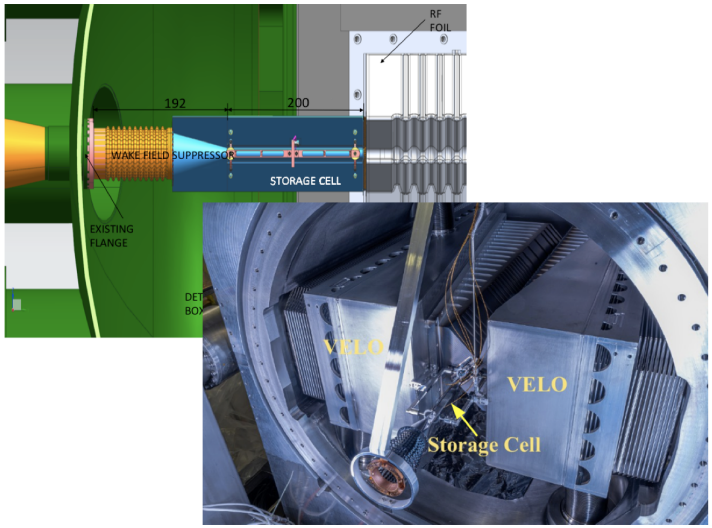


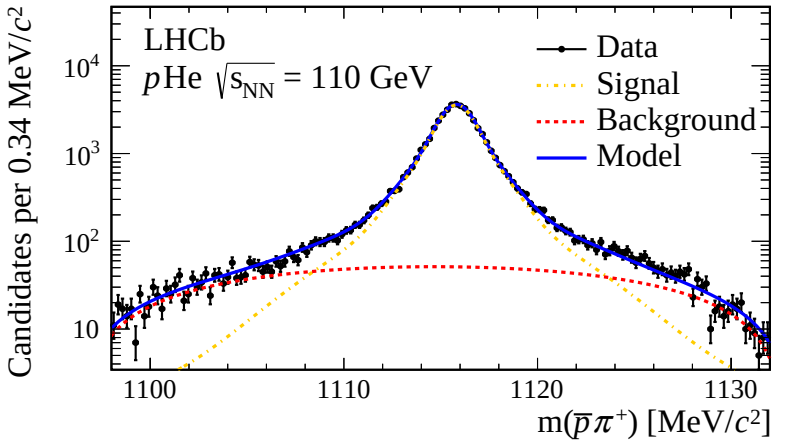


Heavy ions and fixed target

- Different kind of environments enrich the LHCb physics programme
- Several results from heavy-ion collisions
- New fixed target device (SMOG2): gas injection system

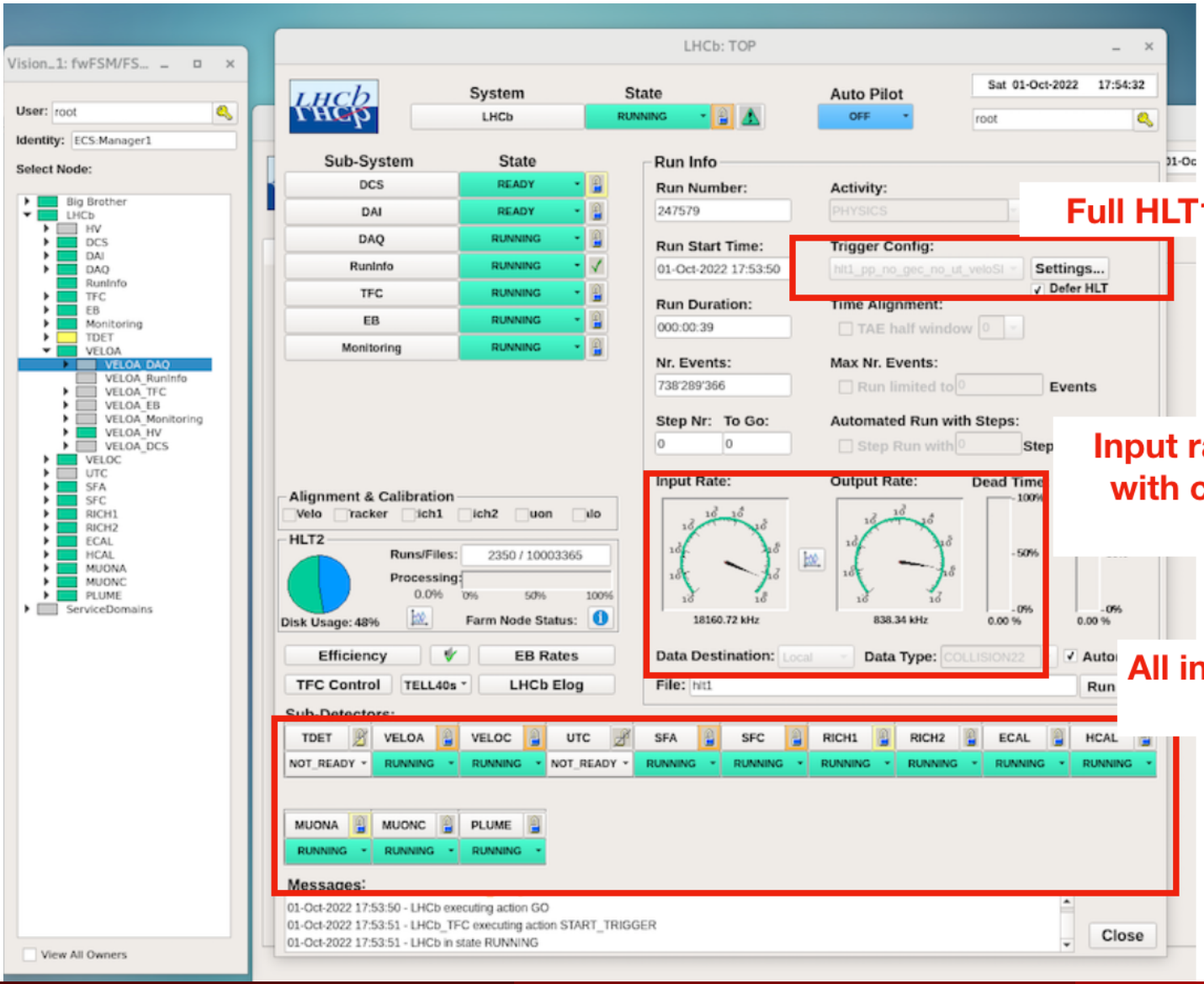






[arXiv:2205.09009]

1st October 2022: all the pieces together!

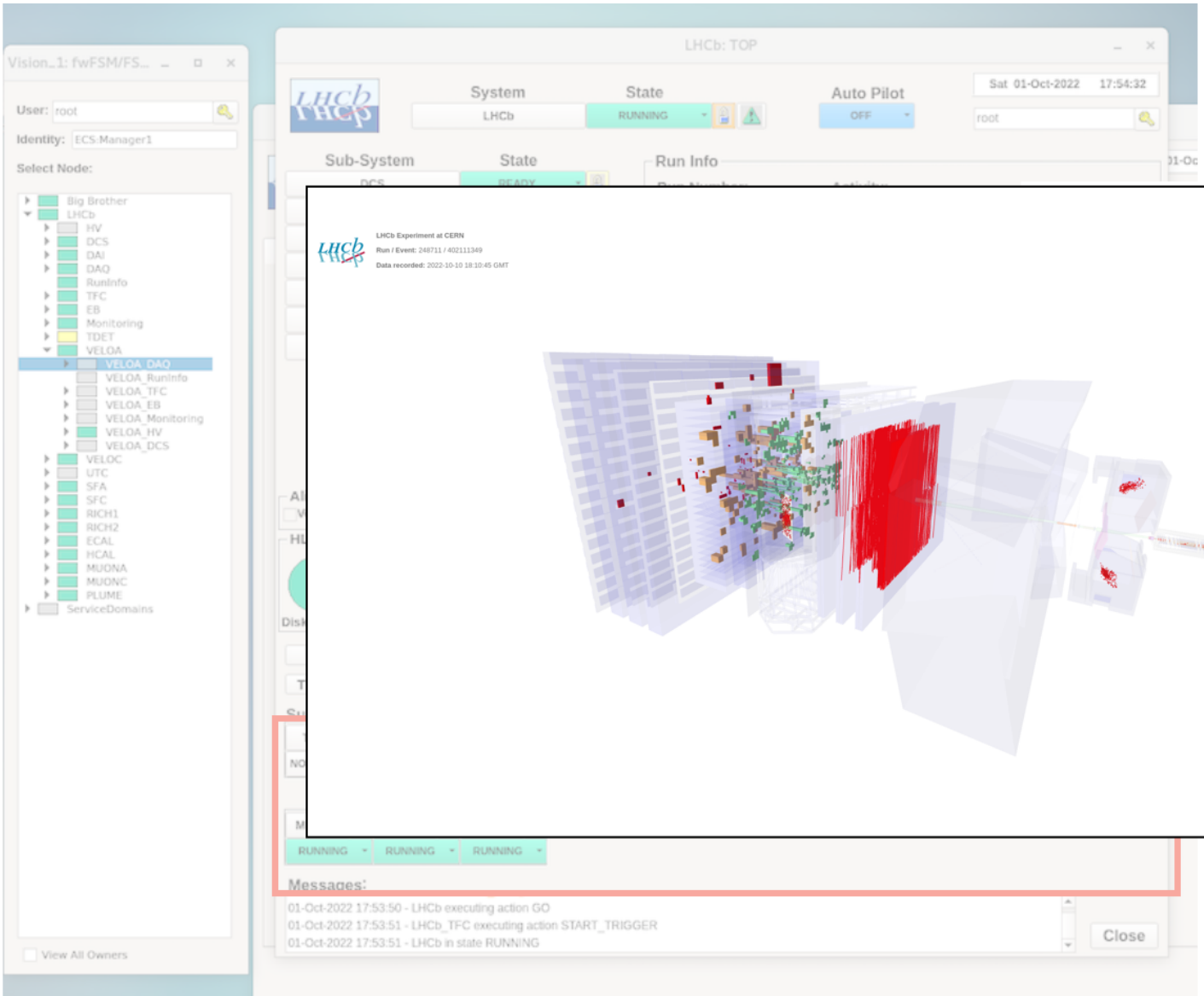


Full HLT1 tracking sequence

Input rate ~20 MHz (max. with current LHC filling scheme)

All installed sub-detectors included

1st October 2022: all the pieces together!



g sequence

MHz (max.
HC filling
e)

ub-detectors
ded

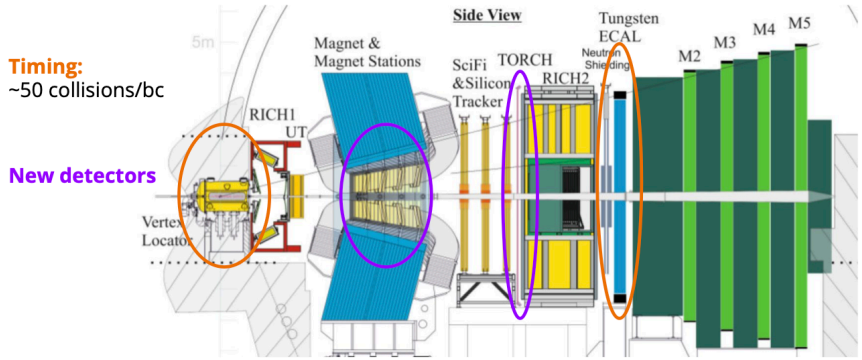
Towards the ultimate precision: LHCb Upgrade II

Run 5+6: $\mathcal{L}_{int} = 300$ fb^{-1}, Pile-up ~ 40

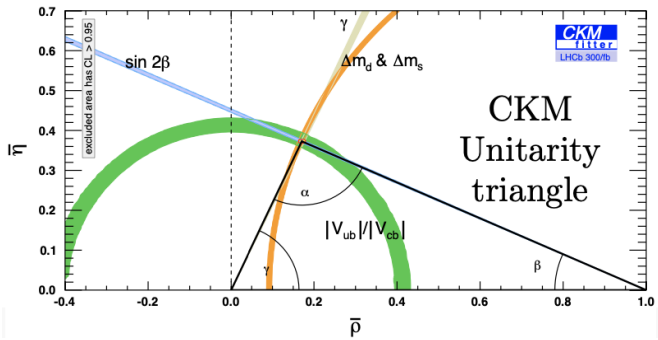
[LHCC-2021-012]

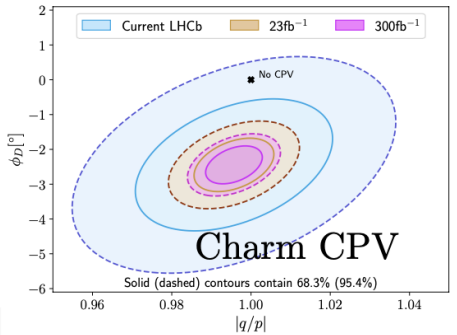
Starting R&D of new technologies

- precision timing for tracking and PID
- extreme radiation hardness



- Unprecedented sensitivity expected for flavour physics





Conclusion

- Broad physics programme at LHCb
  - Flavour physics, spectroscopy, EW, heavy ions, long lived particles, fixed target
- Upgrade I detector under commissioning
  - The installed detectors are promptly releasing their nominal capabilities
  - First mass peaks appearing
  - Full power of the fully-software trigger being exploited soon
- Already planning for the future
  - FTDR for the Upgrade II detector approved
  - R&D towards new generation subdetectors ongoing

Backup