The LHCb Upstream Tracker: Operations and Performance in Run3

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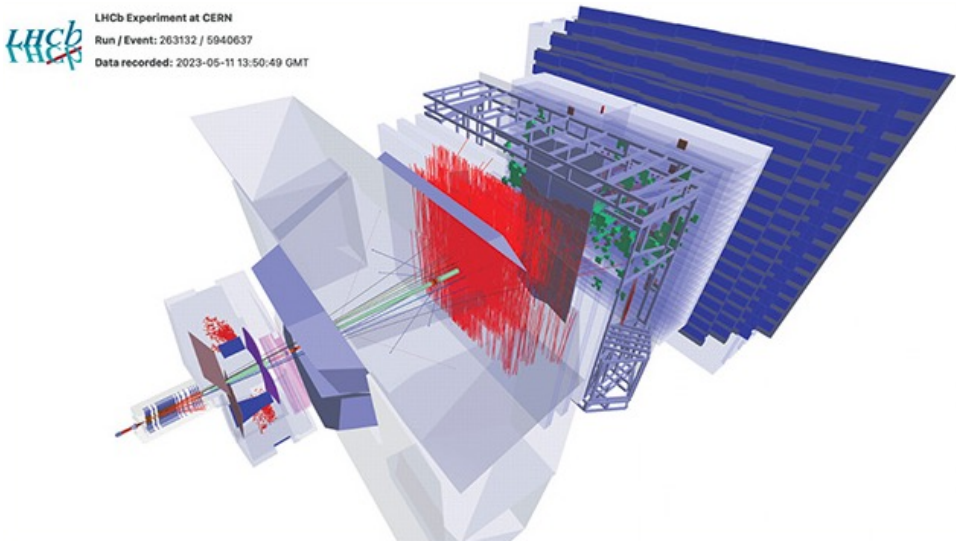
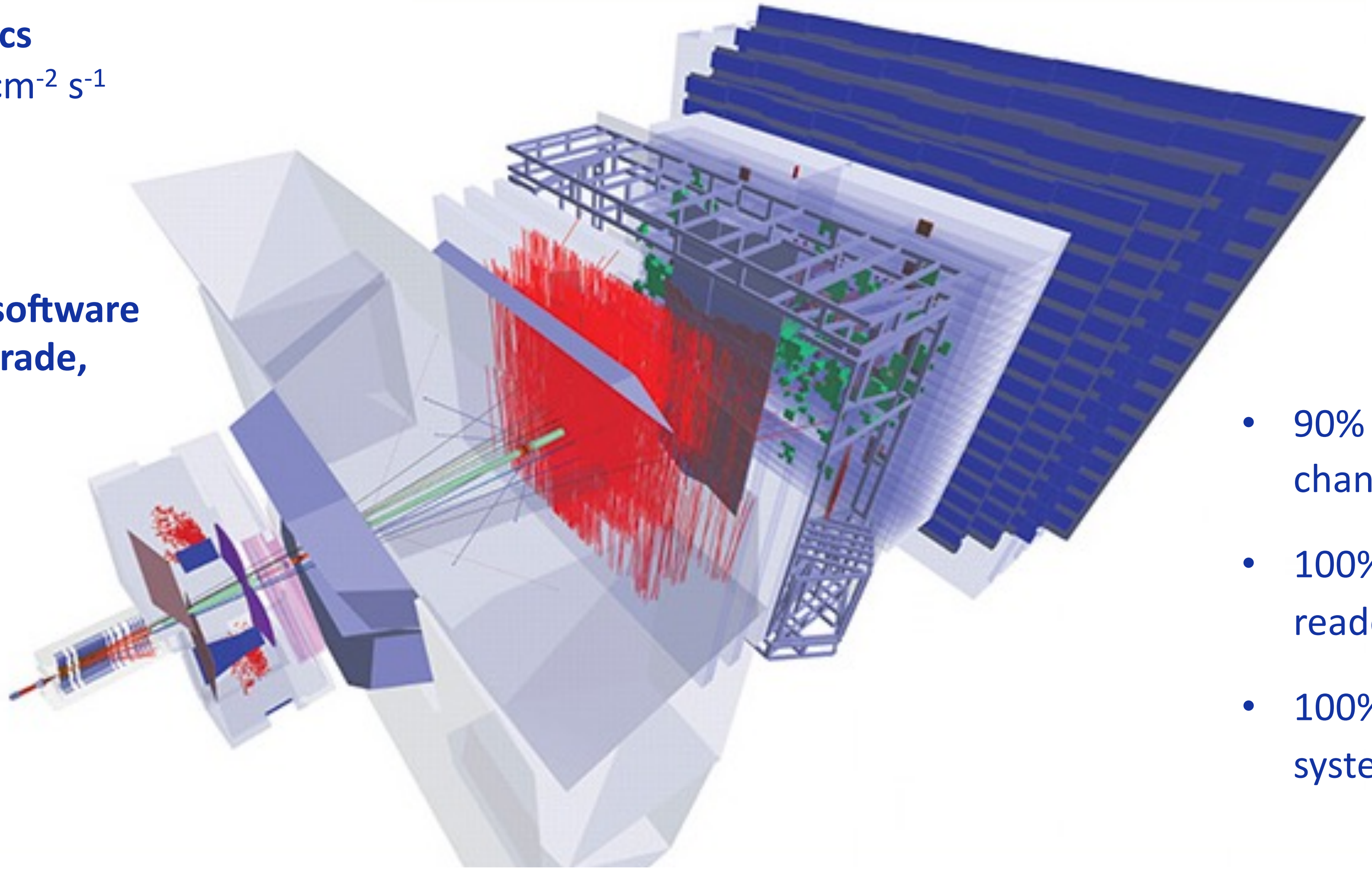


The LHCb experiment

Run 3 goal: collect **more data** to improve the **physics results** → L = 2 10^{33} cm^{-2} s^{-1}

Main limitation:
L0 hardware trigger

BRAND NEW LHCB: **software trigger, detector upgrade, change of readout electronics**



- 90% of the detector channels upgraded
- 100% replacement of readout electronics
- 100% new DAQ & online system @ collision rate

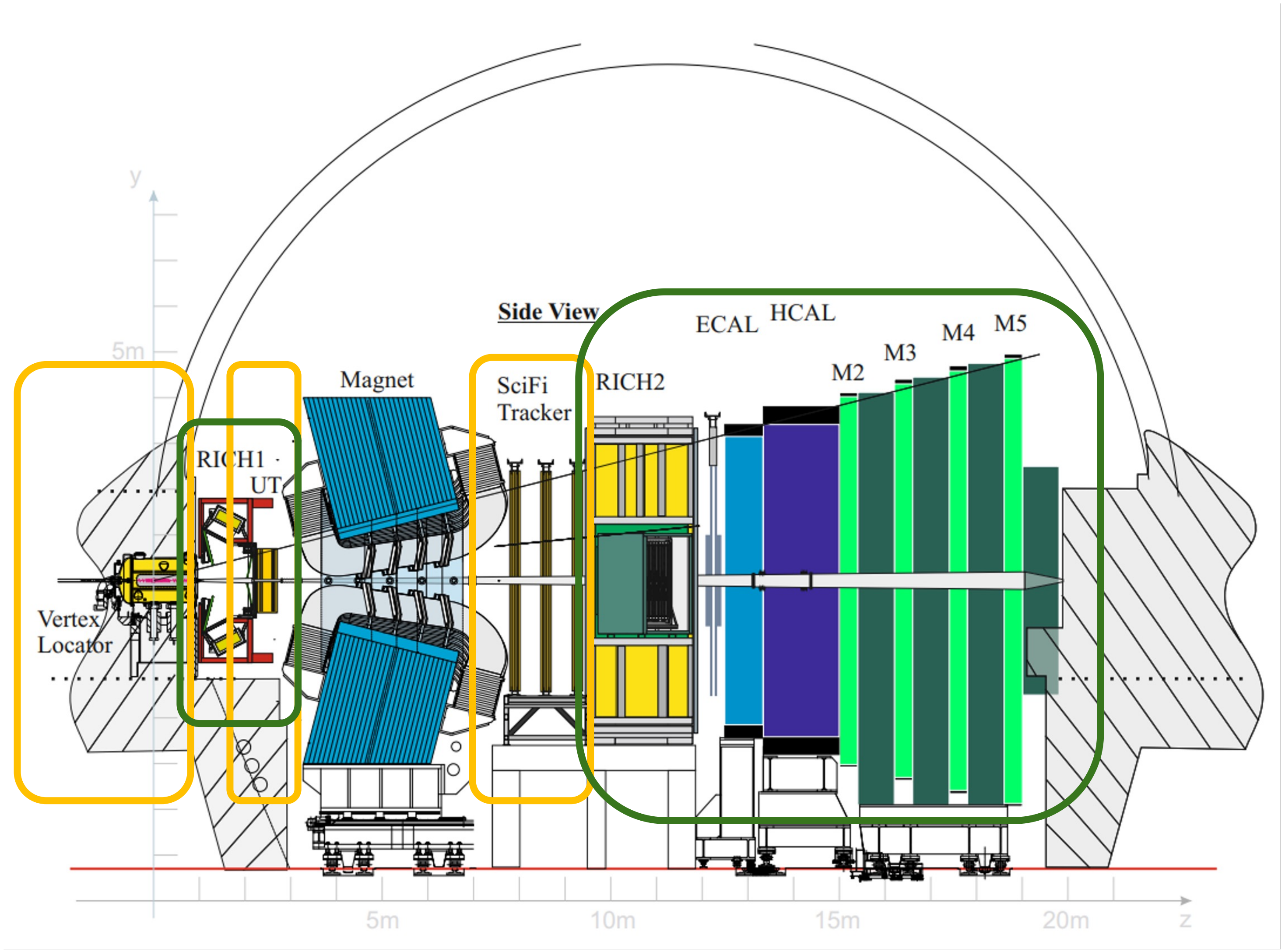
The LHCb experiment

Single-arm forward spectrometer

Pseudorapidity range: $2 < \eta < 5$

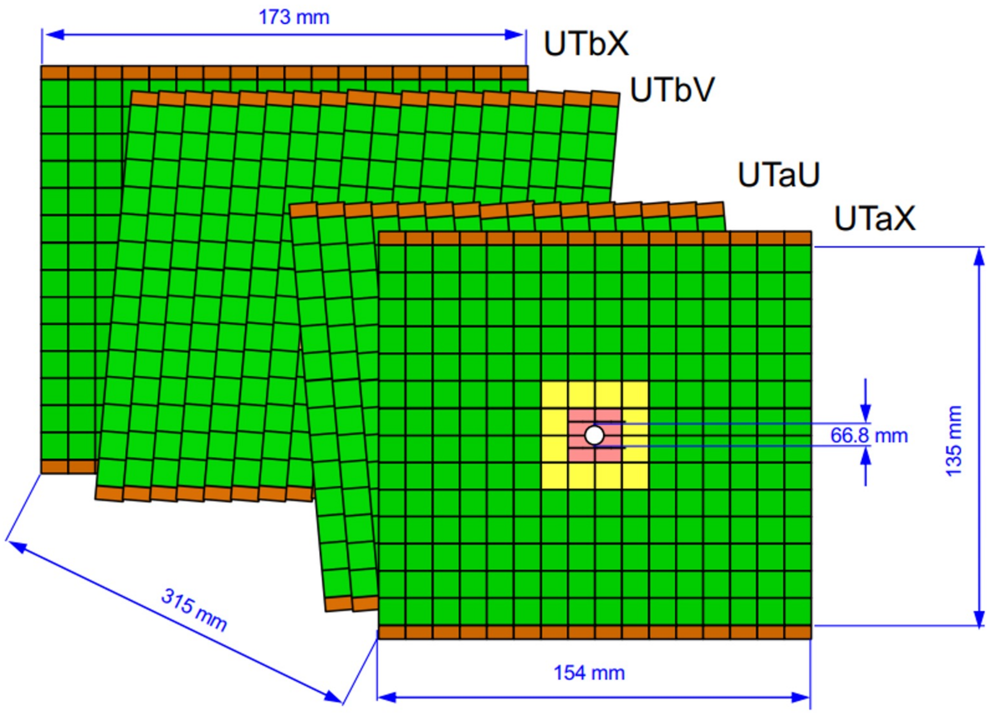
Tracking system

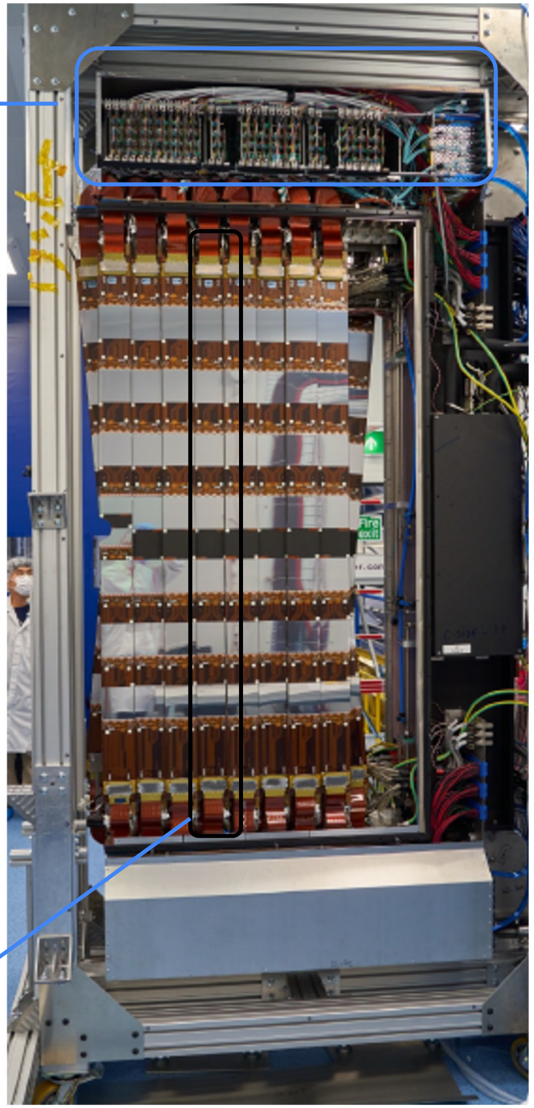
Particle identification system



Upstream Tracker (UT)

- **Silicon strip** detector
- **4 layers** with vertical and stereo (+/- 5 deg) orientation
- divided in **2 sides**: A-side and C-side
- organized in 68 **staves**

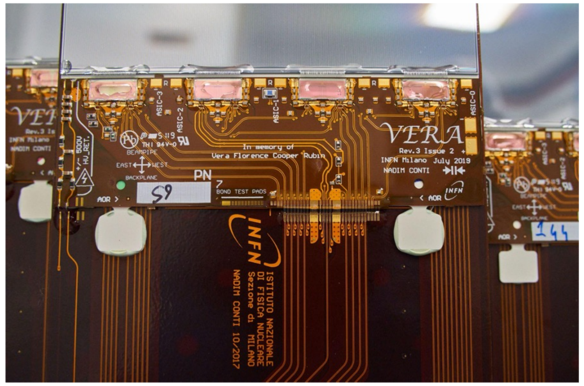


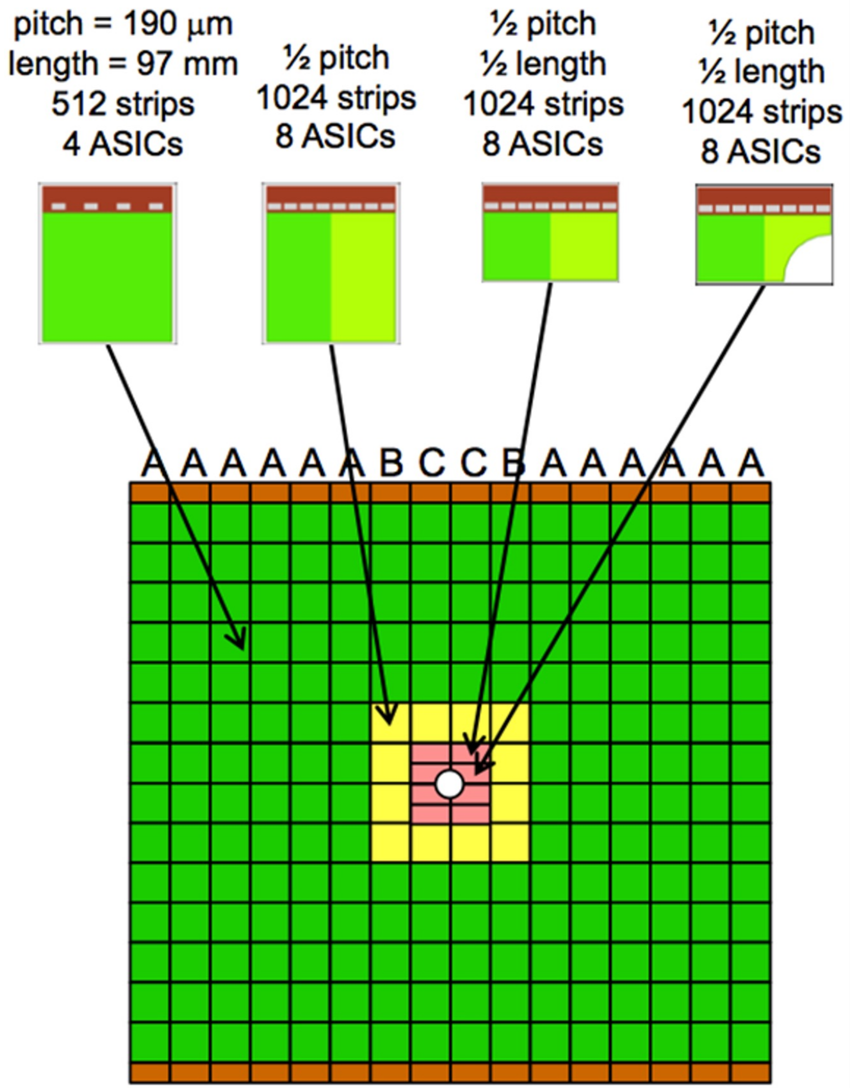


The LHCb Upgrade (arxiv.org)

Upstream Tracker (UT)

Modules





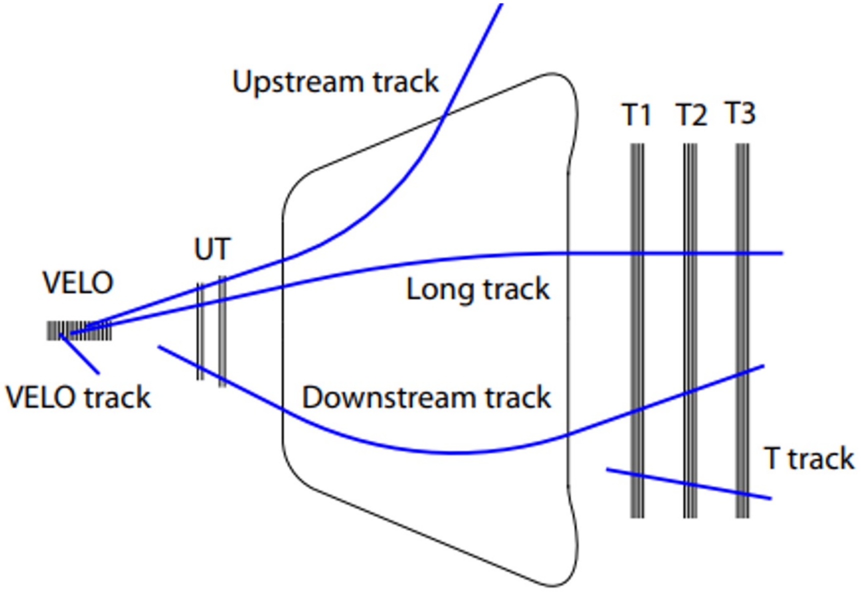
- **silicon** micro **strip** sensors (**A-Type**: p-in-n; **B-**, **C-**, **D-**type: n-in-p)
- Hybrids: VERA (4 ASICs), SUSI (8 ASICs)
- Front-end ASIC (**SALT**) glued and bonded to hybrid flex
- Ceramic stiffener (PBN): good thermal conductivity and electrical insulation

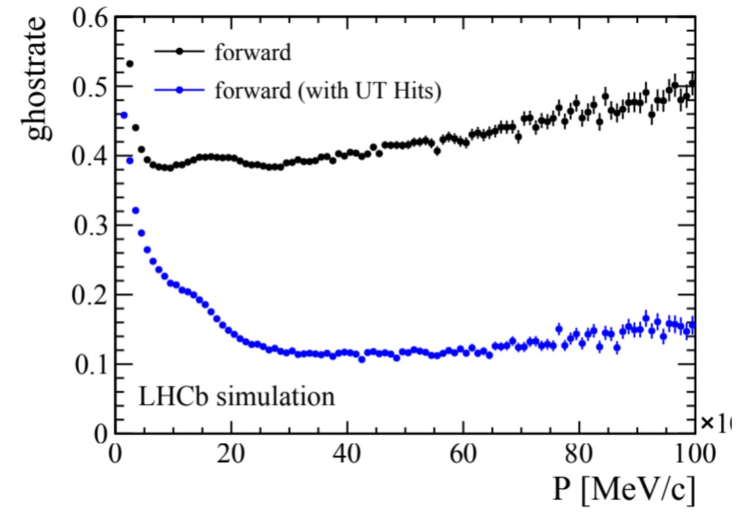
Importance of UT in LHCb

- **Ghost rate** reduction: factor 2 improvement, essential for the software trigger

- **Long lived particles reconstruction** decaying after the VELO (e.g. Λ, K^0_S)

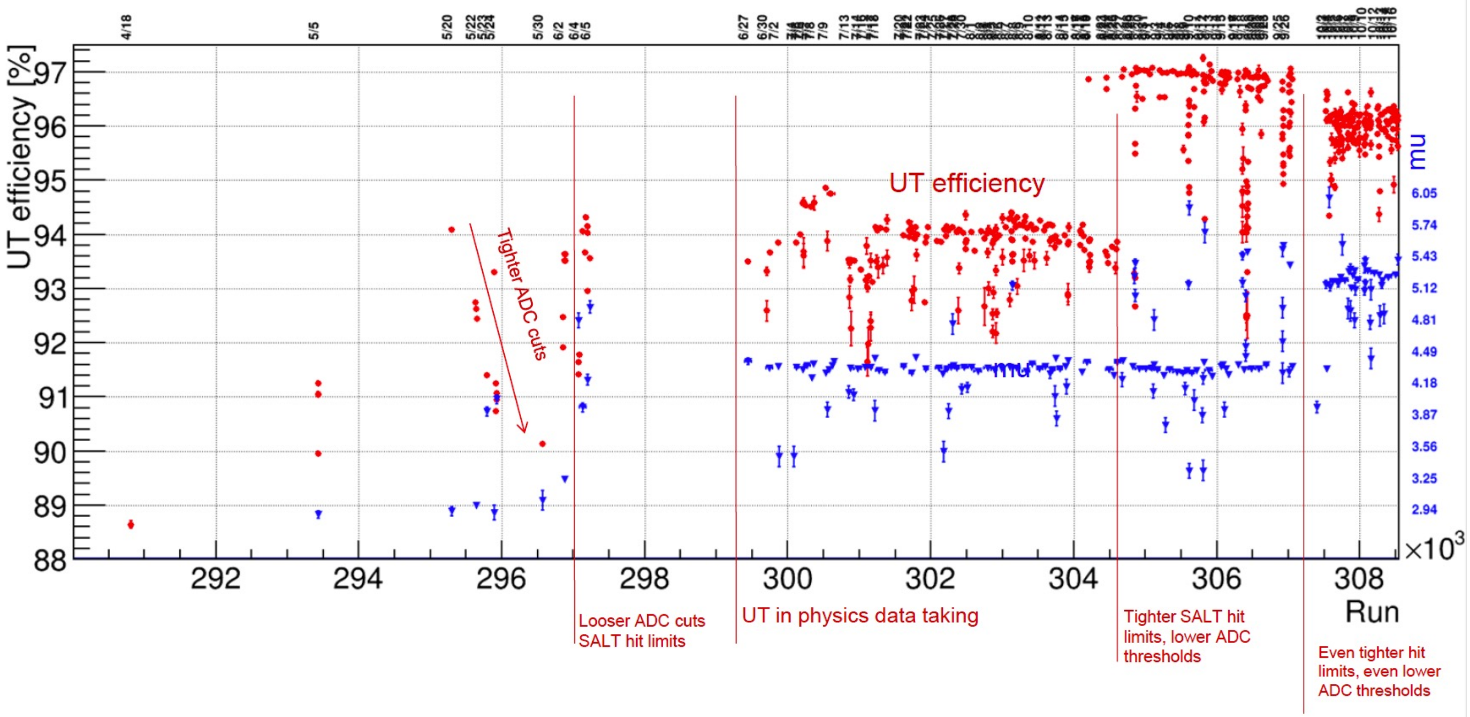
- Track reconstruction: UT fundamental to improve the **momentum resolution** of Long tracks

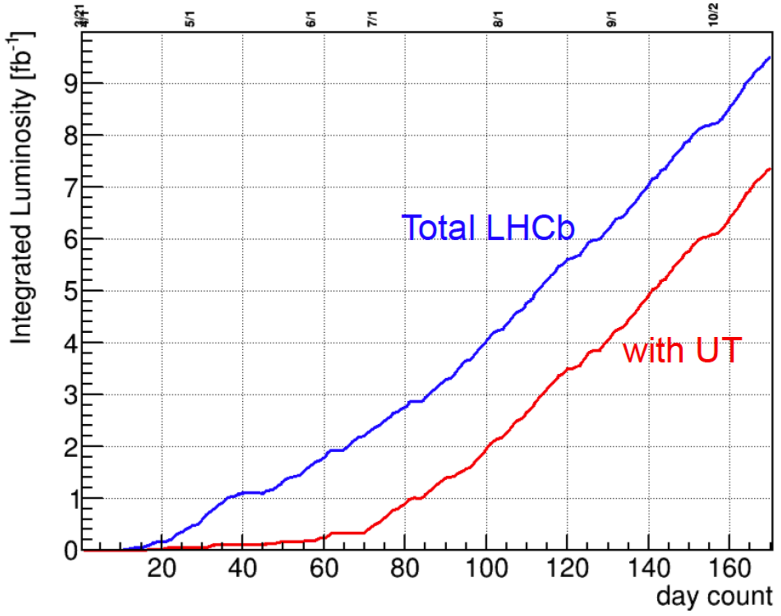




Run 3 timeline

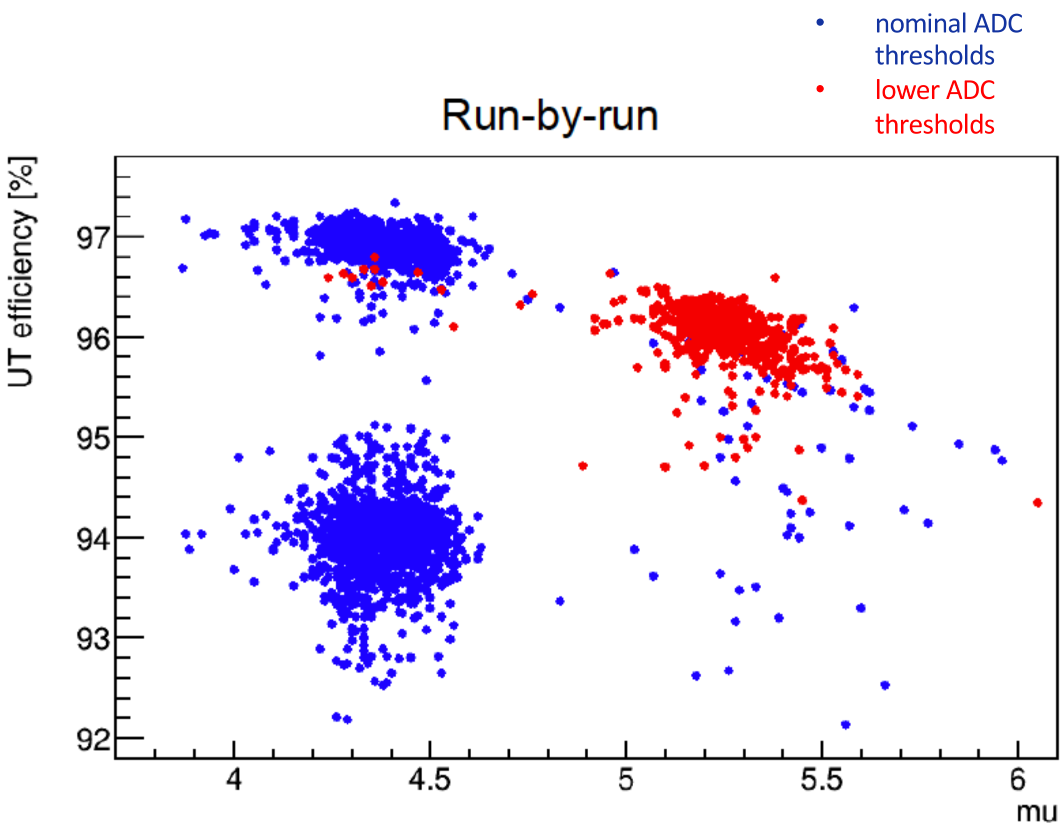
- November 2023: first data collected in the Global LHCb data taking during the Ions run (Pb-Pb collisions).
- Spring 2024: commissioning of the settings for the Global data taking.
- Summer 2024: the UT detector has been included in both HTL1 and HLT2.
- Now: reached stable and efficient data taking with both proton and ion collisions.





DAQ performance

- Stable data taking was achieved, including the highest collision rates (mu).
- Firmware adjustments and FE parameter tuning were necessary to achieve this result.
- Looser ADC thresholds increase the overall efficiency but are a challenge for the data acquisition at high luminosity.

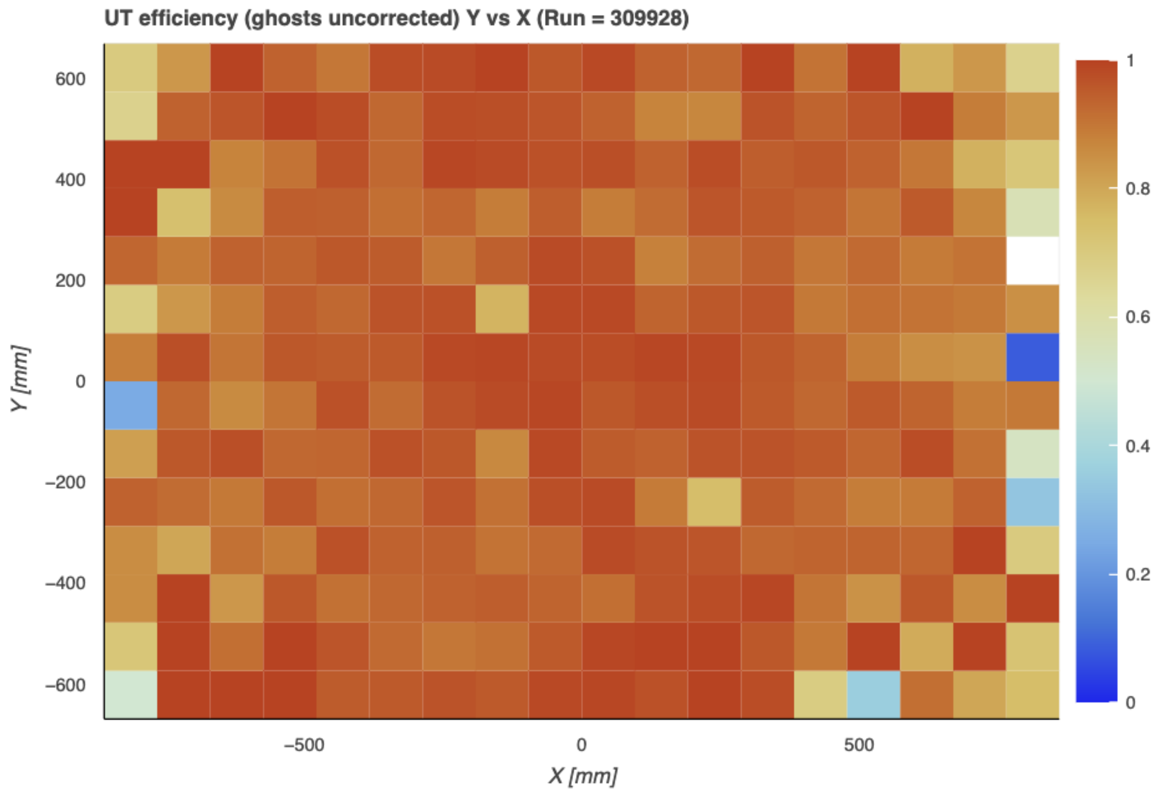


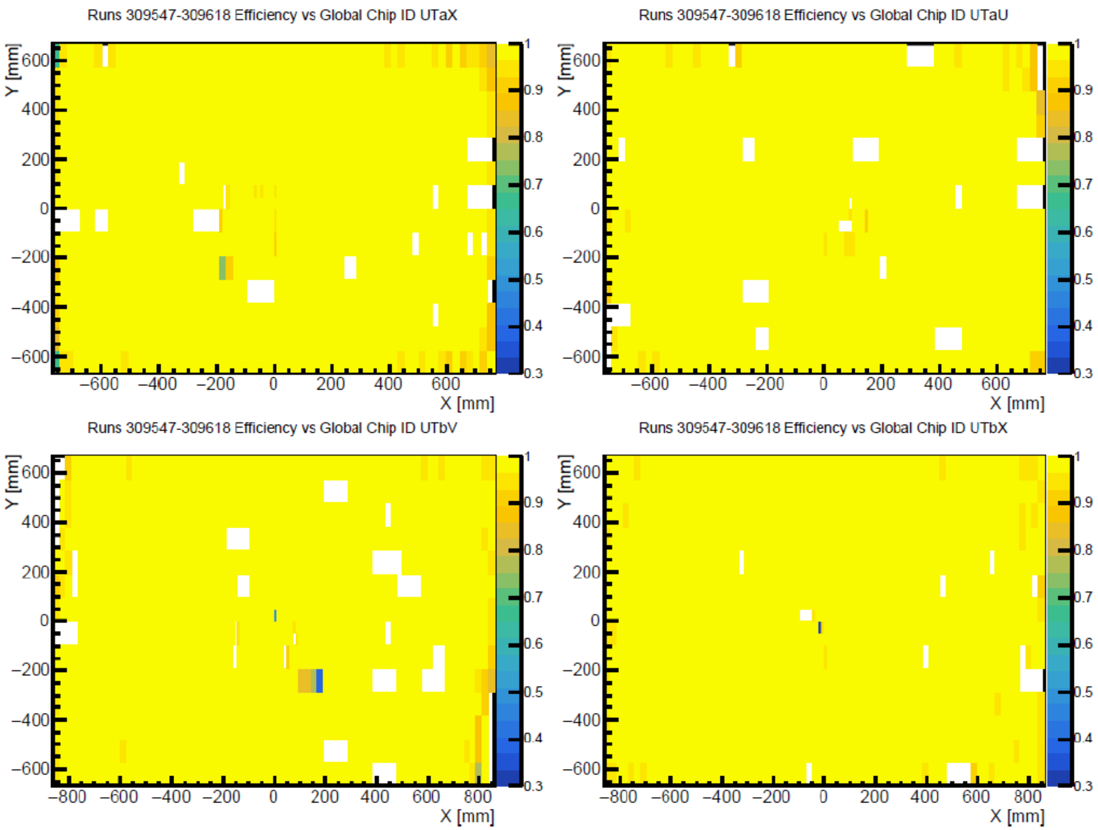
pp reference run

Very stable data taking and good efficiency during Run 3
pp reference run performed the last week of October 2024.

- Monitoring plots of DAQ efficiency vs Chip ID during the pp reference run at low energy and low luminosity.

- Overall Tracking efficiency



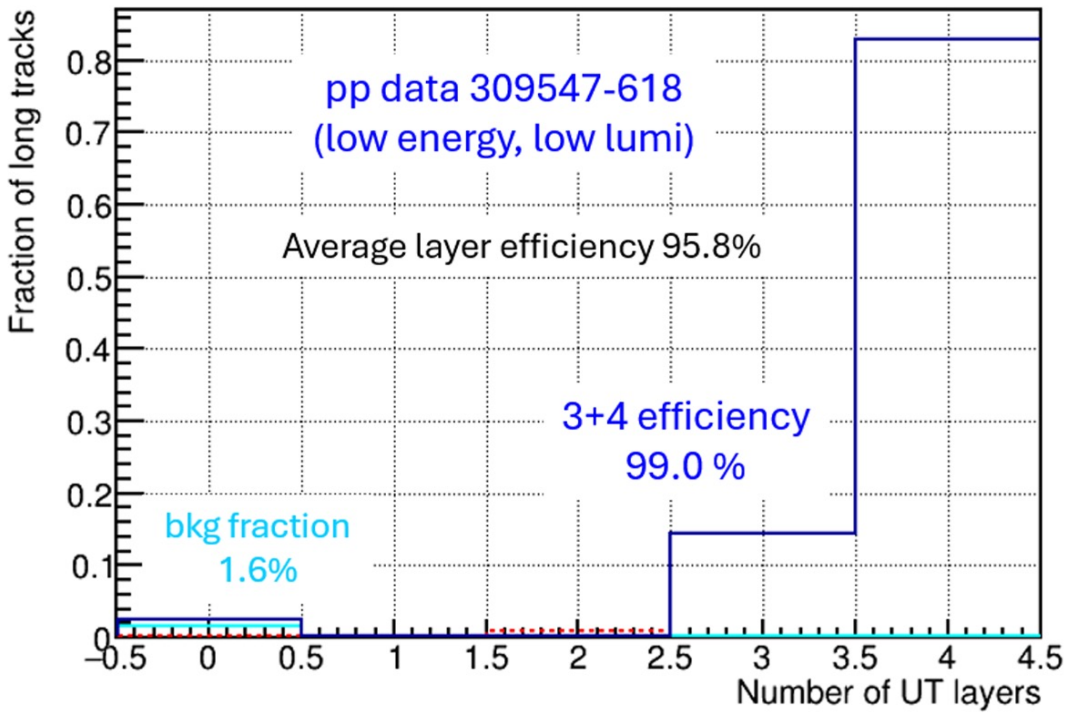


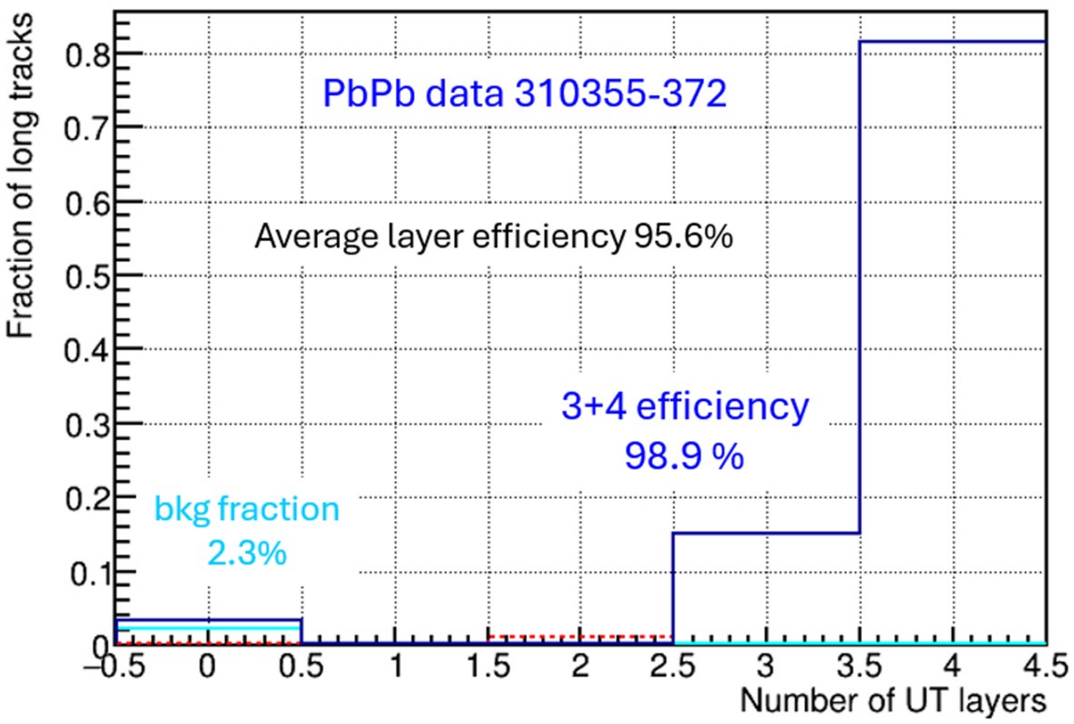
UT tracking efficiency

Heavy Ion run

- Extremely stable data taking
- Very low rate of DAQ errors

Number of UT layers matched to a long track and the relative tracking efficiency

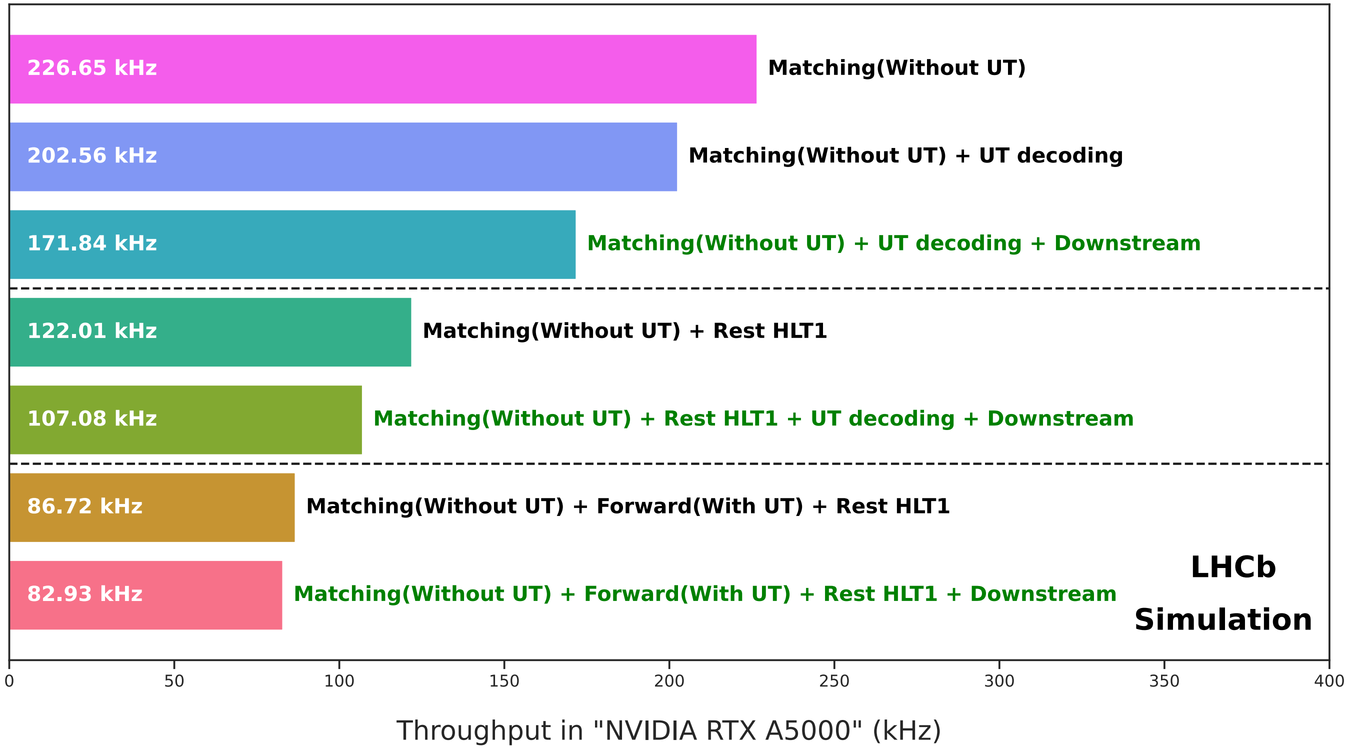


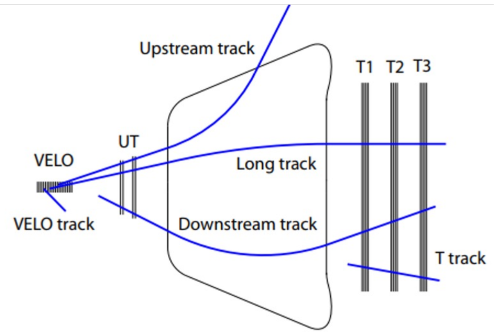


UT in HLT1 – Downstream tracks

- The new HLT1 downstream tracking is designed to reconstruct decays outside the VELO in HLT1 and has been running in Run 3 data-taking since October 2024.
- Downstream tracking will not be possible without UT in HLT1
- The algorithm reduces HLT1 throughput by approximately 9%, achieving 67.50 kHz per GPU, which meets the HLT1 requirement of over 60 kHz per GPU.

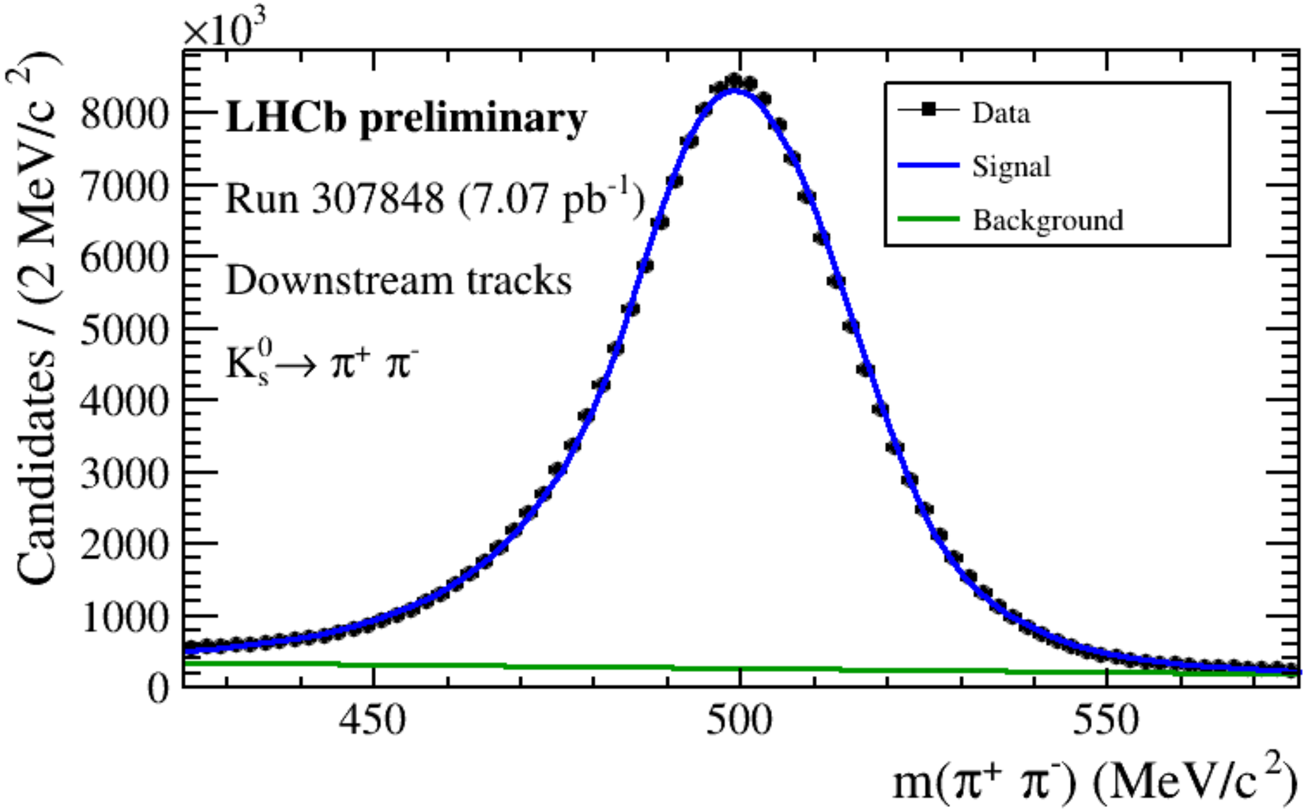
[LHCB-FIGURE-2023-028]





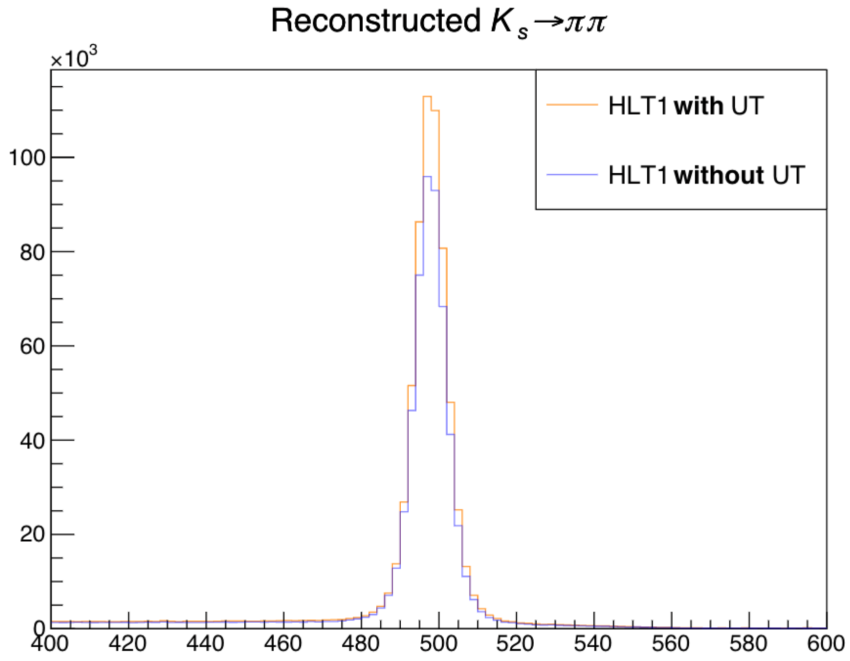
UT in HLT1 – Downstream tracks

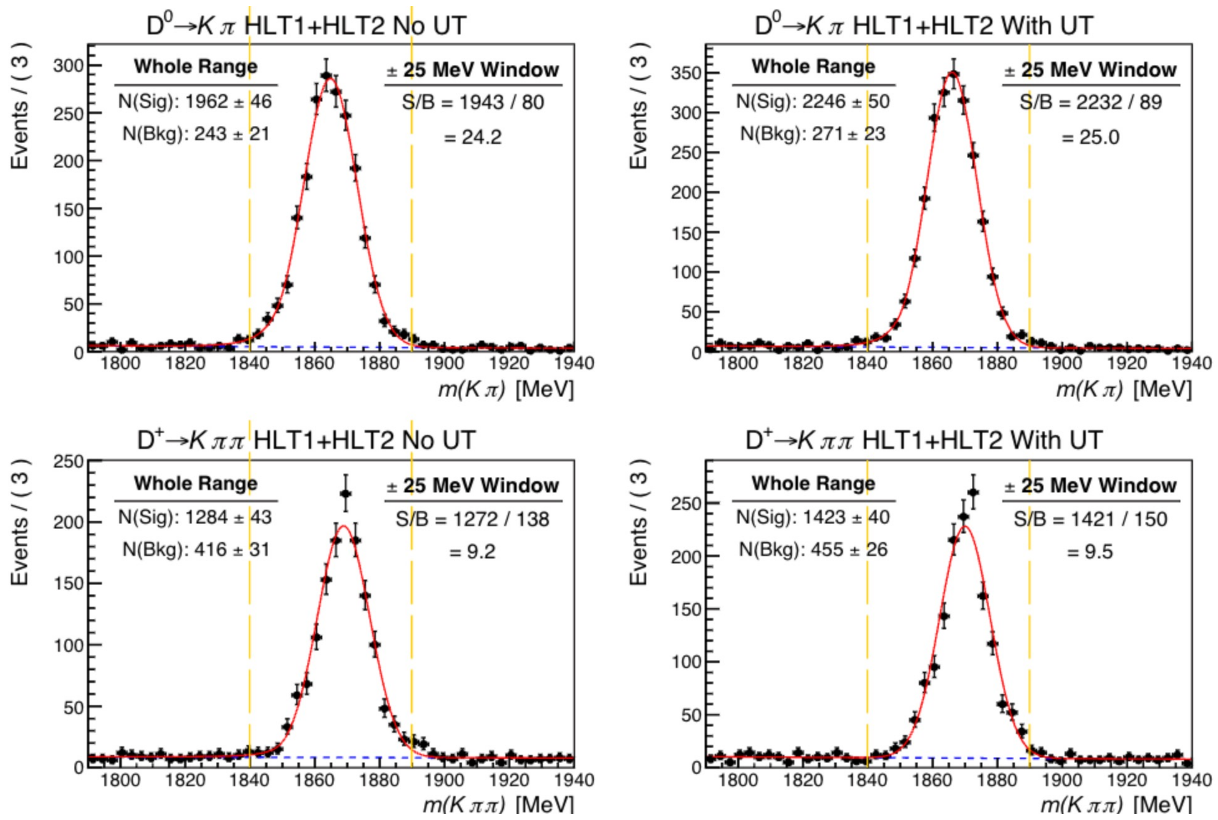
- Checking the mass distributions of the $\Lambda^0 \rightarrow p\pi^-$ and $K_S^0 \rightarrow \pi^+\pi^-$ decays can be used to benchmark the performance of Downstream tracking



Matching with UT in HLT1 + HLT2

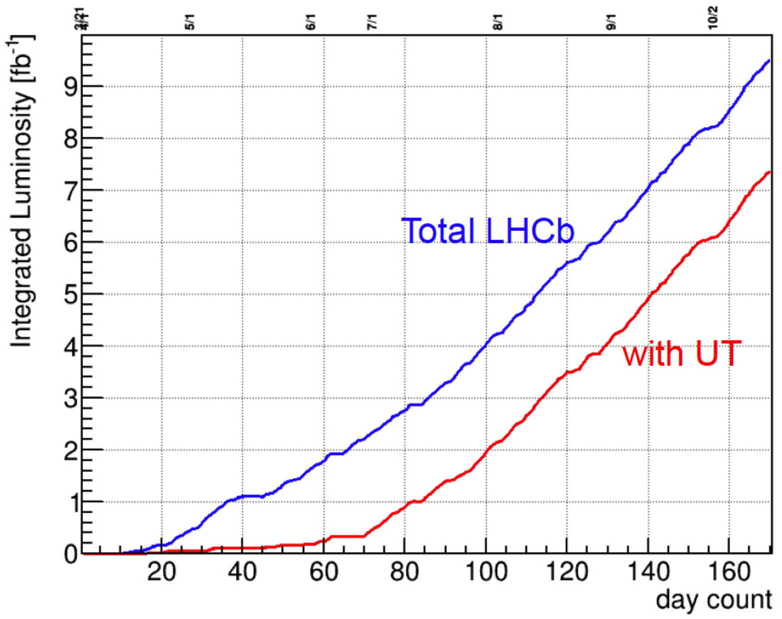
- The inclusion of UT in HLT1 and HLT2 has improved the physics performance of theLHCb experiment since it is important to improve the **momentum resolution** of Long tracks





Conclusions

- After commissioning in spring 2024, UT detector joined physics data taking in summer and improved LHCb physics performance.
- Efficiency of UT detector was improved during 2024 data taking. Suitable UT configuration was found for the design luminosity (mu=5.3)
- The best UT performance was achieved for heavy ion physics and in related low-energy pp reference run.
- The presence of UT in the software trigger has highly improved the physics performance of the LHCb experiment.



Thanks for the attention!

Backups

UT DAQ efficiency

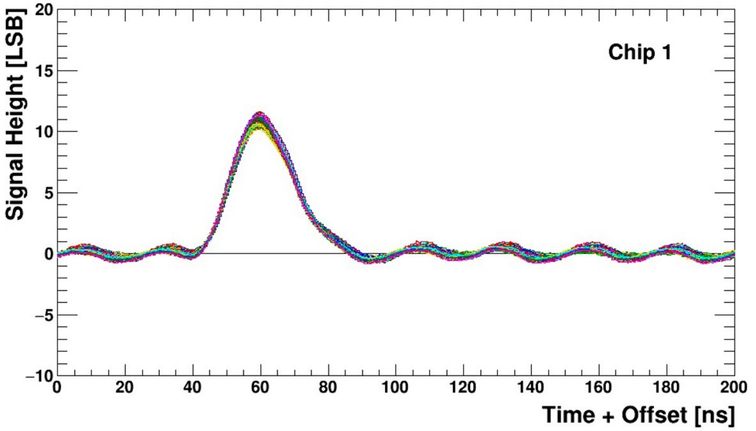
PP collisions

- Very stable data taking and good efficiency during Run 3 pp reference run performed the last week of October 2024.
- Data acquisition stable even with tighter ADC threshold

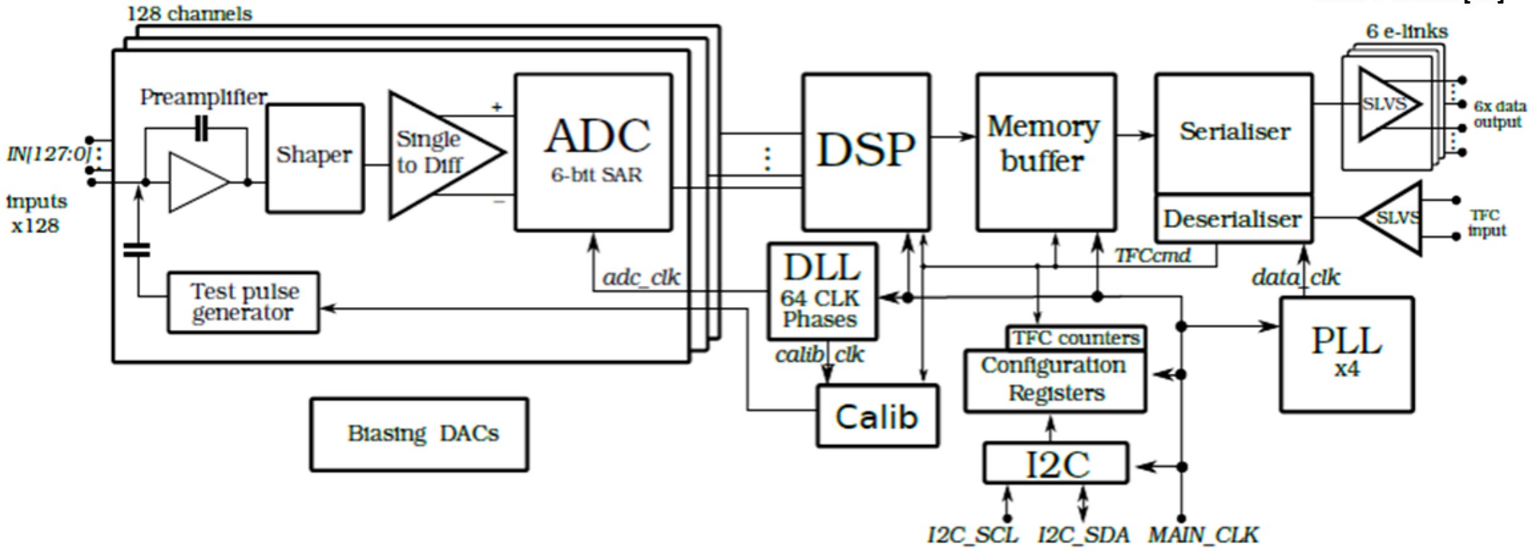
Heavy Ion run

- Extremely stable data taking
- Very low rate of DAQ errors

Backups



<u>**Silicon ASIC for LHCb Tracking (SALT):**</u>

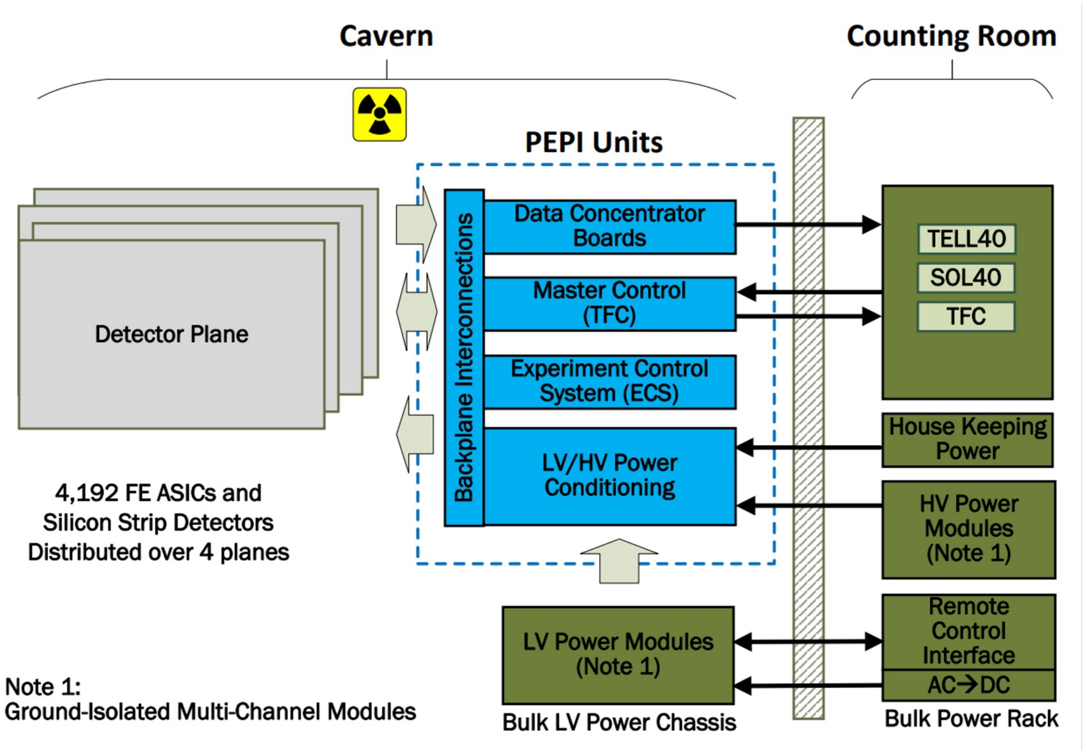


- **CMOS** 130 nm technology
- **128 channels** / ASIC
- **6 bit** ADC / channel
- Digital Signal Processing (DSP): pedestal and common mode noise subtraction, zero-suppression, data formatting, spillover correction
- peaking time~ 25 ns, S/N~ 20, input C=12 pF, power dissipation/channel < 6mW

Backups

Periphery electronics processing interface (PEPI) to read out and control the detector:

- 24 **backplanes**
- 24 pigtail power breakout boards (**P2B2**s)
- 248 data and control boards (**DCB**s)

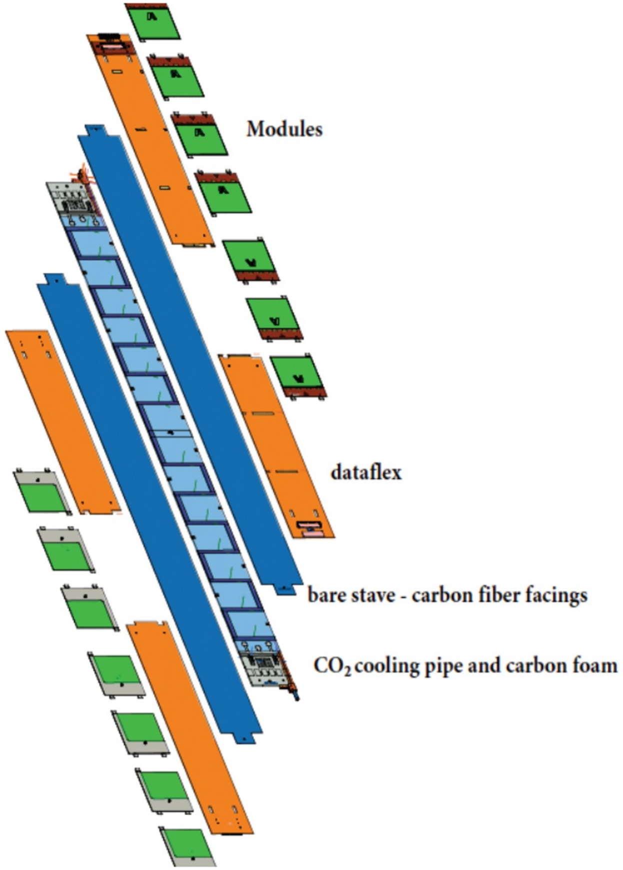


The **GBTx**, mounted on the DCBs, implements bidirectional **links** between the **detector** and the **counting room**

Backups

Stave:

- 99.5mm x 1640mm (width x length)
- **carbon fiber structure** with thermal and structural foam in between
- S-shaped titanium **cooling pipe**
- 4 Flex Cu- Kapton cables, power and data distribution
- Single stave can host 14 or 16 **modules**, on both sides



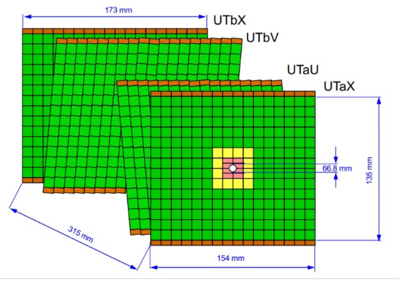
Backups

to make UT work..

DETECTOR SAFETY

DETECTOR MONITORING

UT



to take data..

FIRMWARE

ECS

Software

to take good quality data for physics..

Time alignment

Space alignment

Calibration

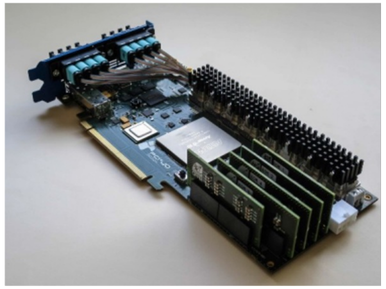
Data quality monitoring

Backups

- **Readout of the detector** possible with PCIe40 cards hosting

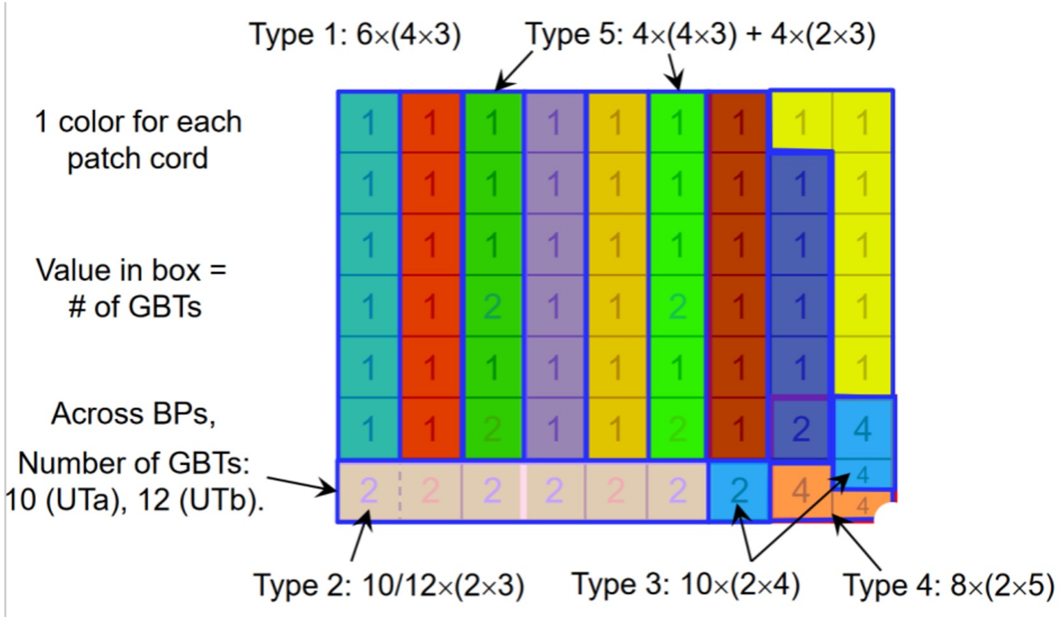
  Intel Arria 10 **FPGA**: transforms the data from ASIC to PCIe format

- **5 flavours**, design to cope with different occupancies and to minimize the cost



flavour= (#ASICs x #e-links)

GBT frame byte	13	12	11	10	9	8	7	6	5	4	3	2	1	0
4 x 3-eports			24-bit			24-bit			24-bit			24-bit		
2 x 3-eports			24-bit					24-bit						
2 x 4-eports			32-bit					32-bit						
2 x 5-eports			40-bit					40-bit						



Implemented to work in Non-zero-suppressed (NZS) and in Zero-suppressed (ZS) mode

Backups