# SciFi optimization during commissioning

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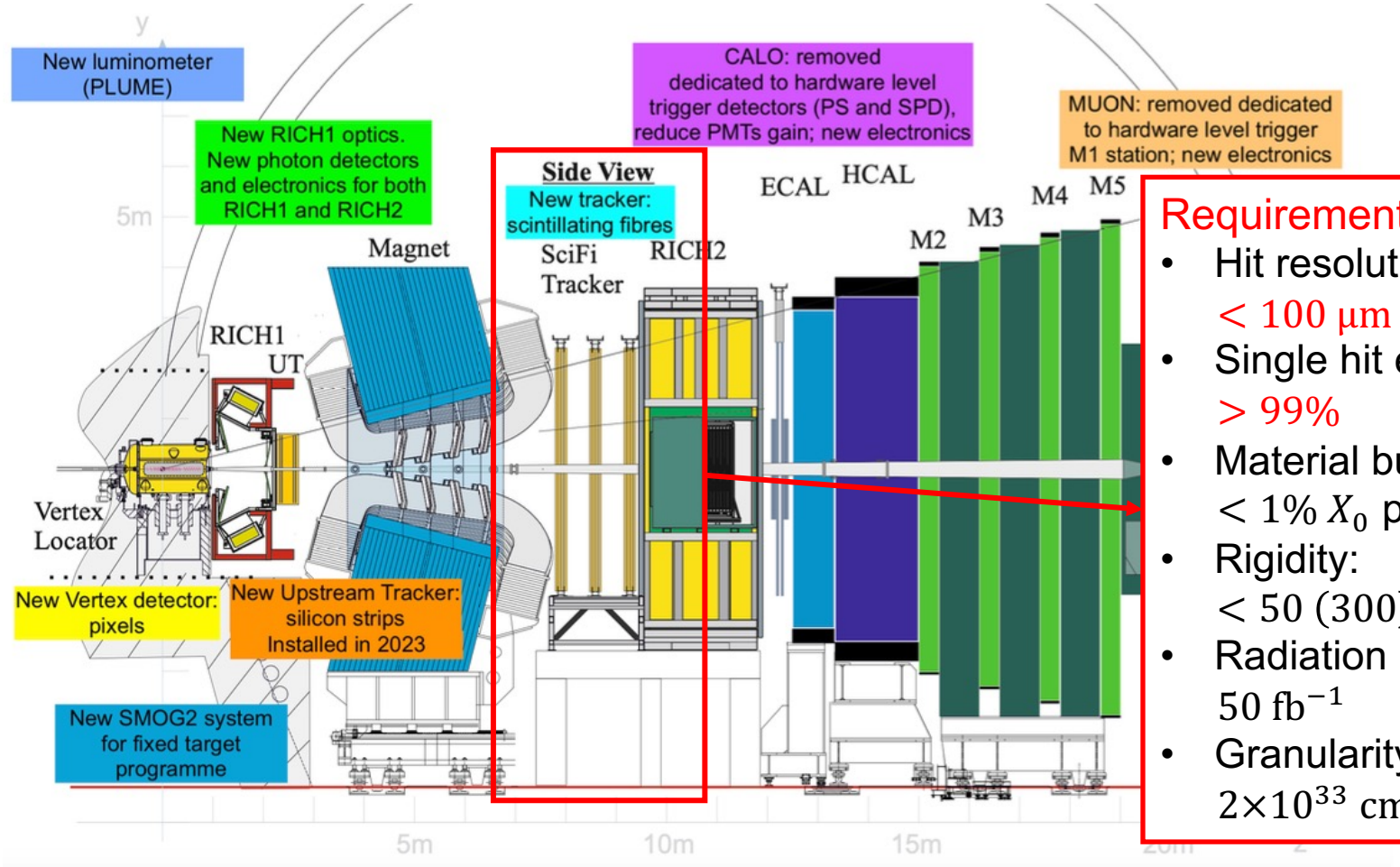
# The SciFi at the Upgraded LHCb

[arXiv:2035. 10515]



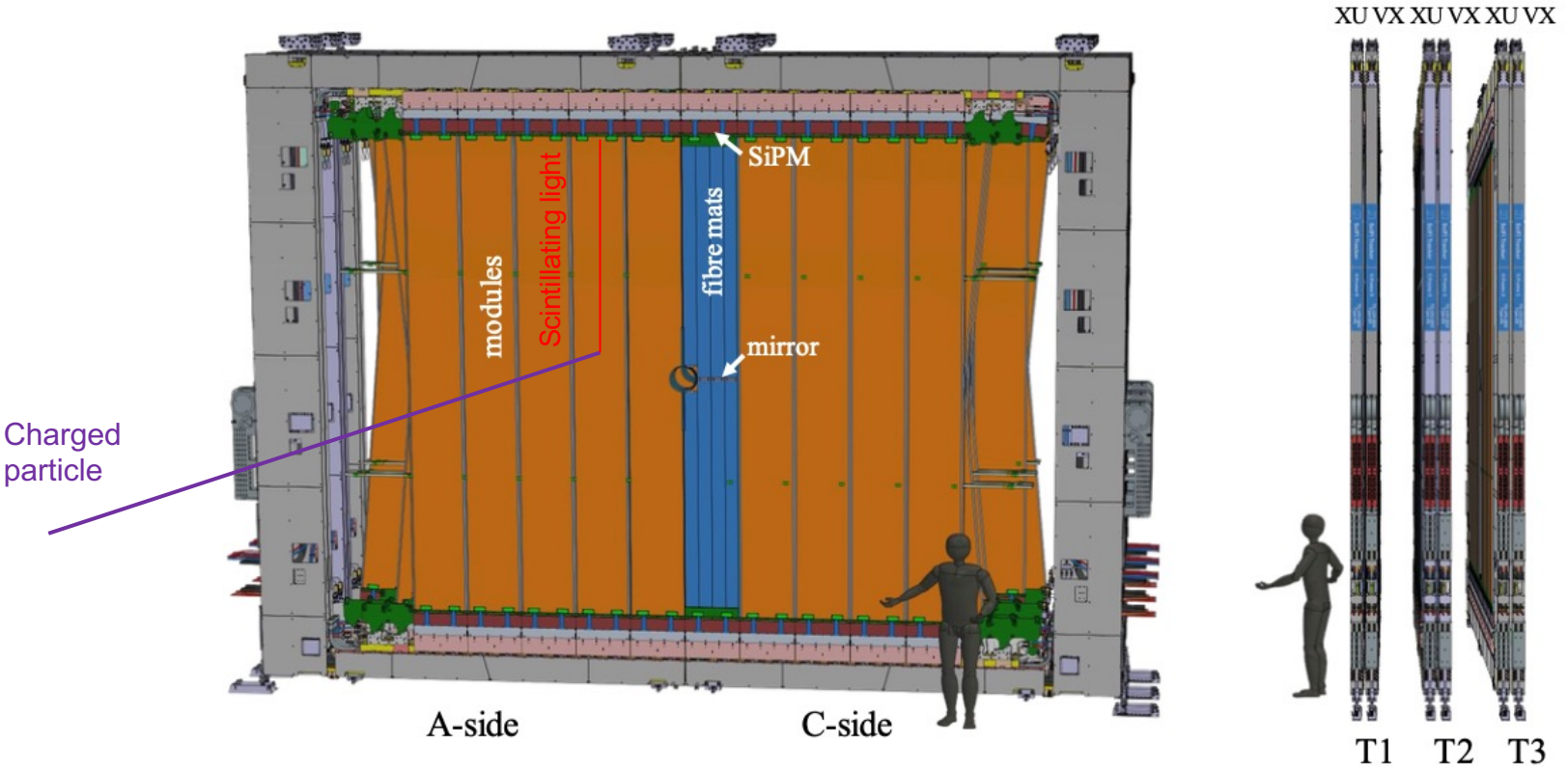

**Requirements:**

- Hit resolution: $< 100\ \mu m$
- Single hit efficiency: $> 99\%$
- Material budget: $< 1\%\ X_0$ per layer
- Rigidity: $< 50\ (300) \mu m$ in $x(z)$
- Radiation hardness: $50\ fb^{-1}$
- Granularity : $2{\times}10^{33}\ cm^{-2}\ s^{-1}$

➢ The scintillating fibres tracker (SciFi), the only downstream tracker of the dipole magnet :

- Hit resolution and efficiency optimized during beam commissioning

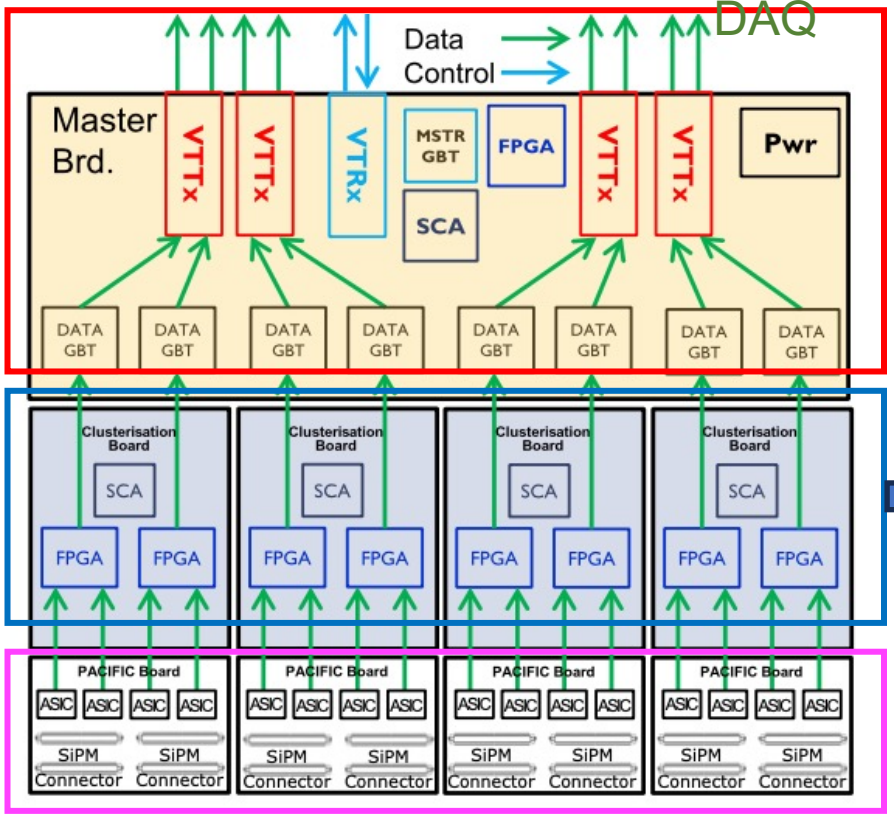
# SciFi layout and detector technology [arXiv:2035. 10515]

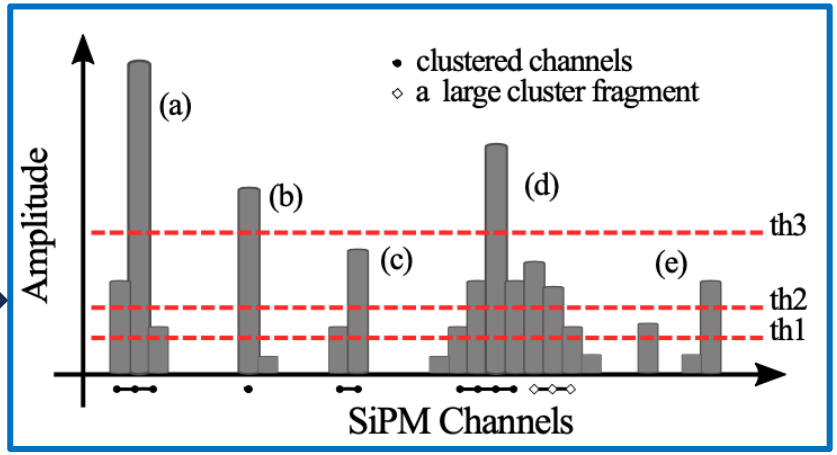



- Total 12 detection layers :
  - Per layer constructed by 10 (12) long modules
  - Per long module contains 8 mats
  - Mats produced by 250 μm diameter scintillating fibres
- Optical signal detected by silicon photomultipliers (SiPM)

# Frond-end electronics

[arXiv:2035. 10515]



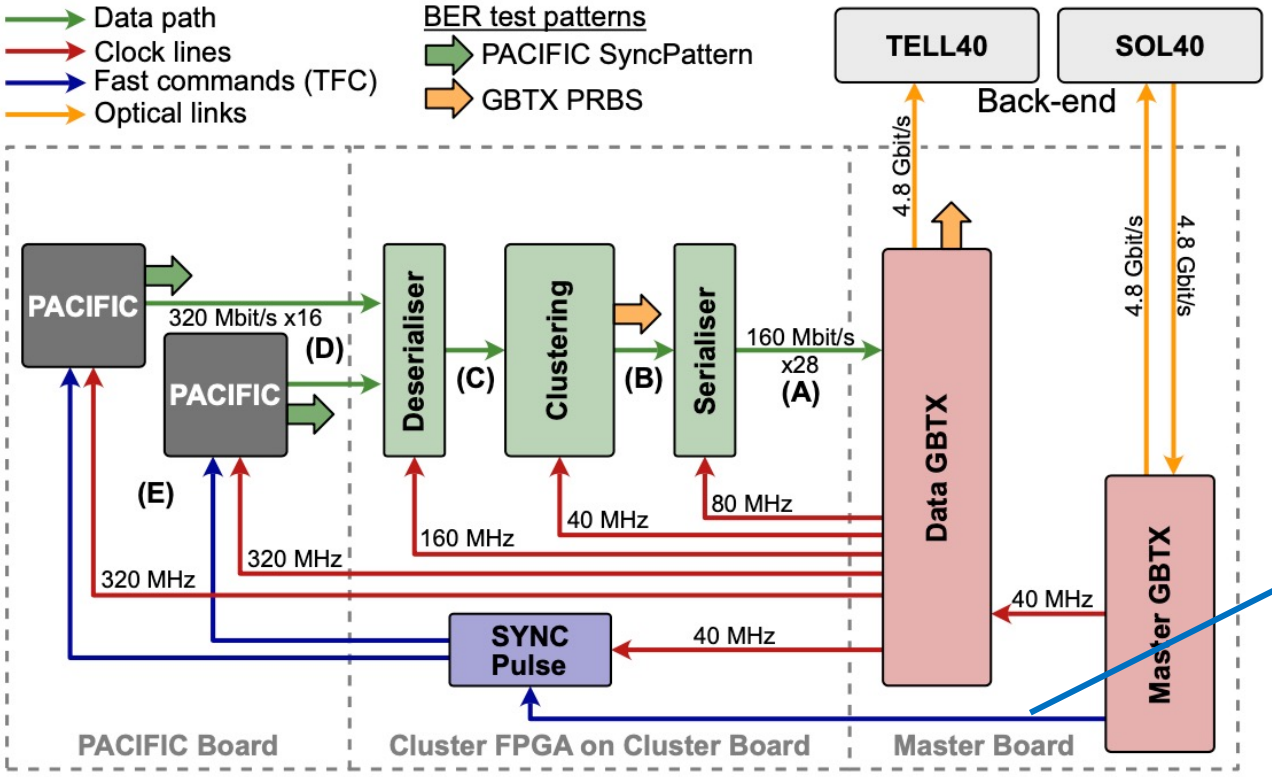




- The FEB contains 3 boards : PACIFIC, Clusterization, Master
  - SiPM pulses digitization in PACIFIC
  - Clusterization: zero-suppression and clustering signal
  - Master: 1) transfer data to DAQ; 2) distribution of control and time clock, monitoring, low voltage and SiPM bias

# Time alignment with beam

[arXiv:2035. 10515]

- FEB time phase needs to be optimized with respect to beam interactions
- The SciFi FEB data flow and clocking scheme (one HalfROB)




Coarse time alignment:

- Control time tuned by bunch interval (25 ns) to match the bunch crossing

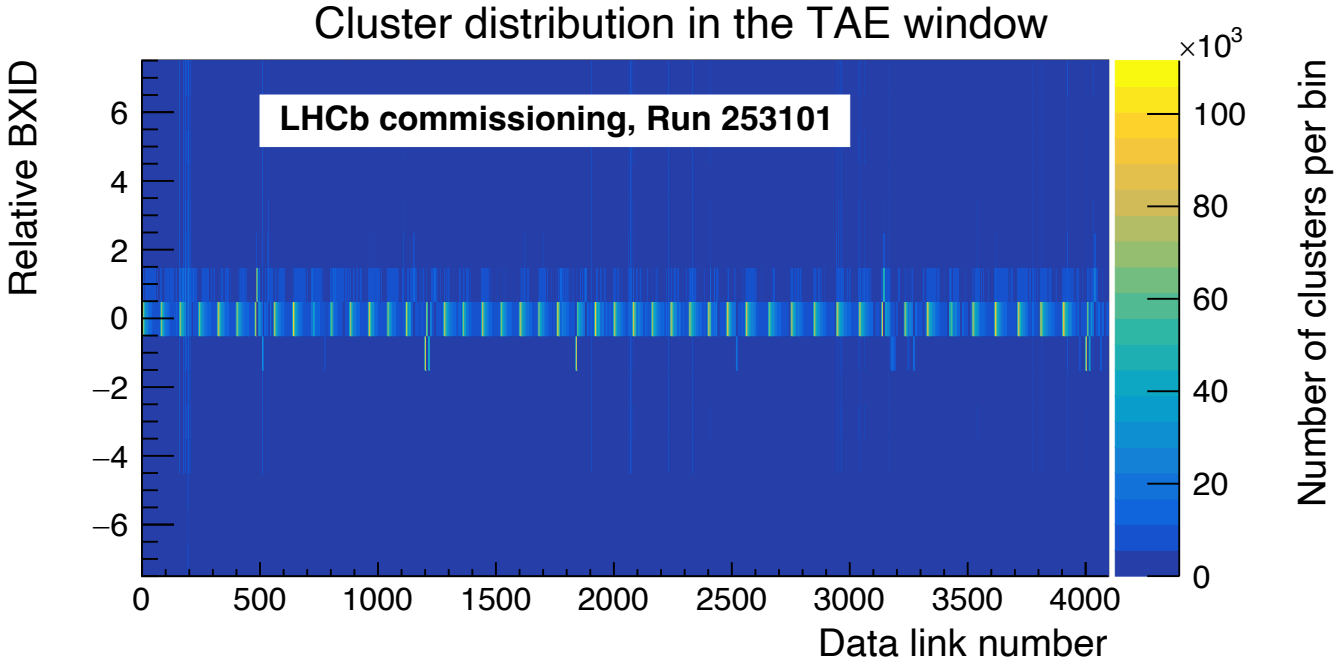
Fine time alignment:

- TFC command phase time: per ~0.78 ns
- Optimise signal integration time to maximise hit efficiency

- Both coarse time alignment and fine time alignment performed

# SciFi coarse time alignment

- Isolated bunch crossing used for time alignment
- Sequence of consecutive bunch cross sample (TAE sample)
- Main BXID per data link aligned in the same time window
  - Number of cluster per data link after coarse time alignment (below)

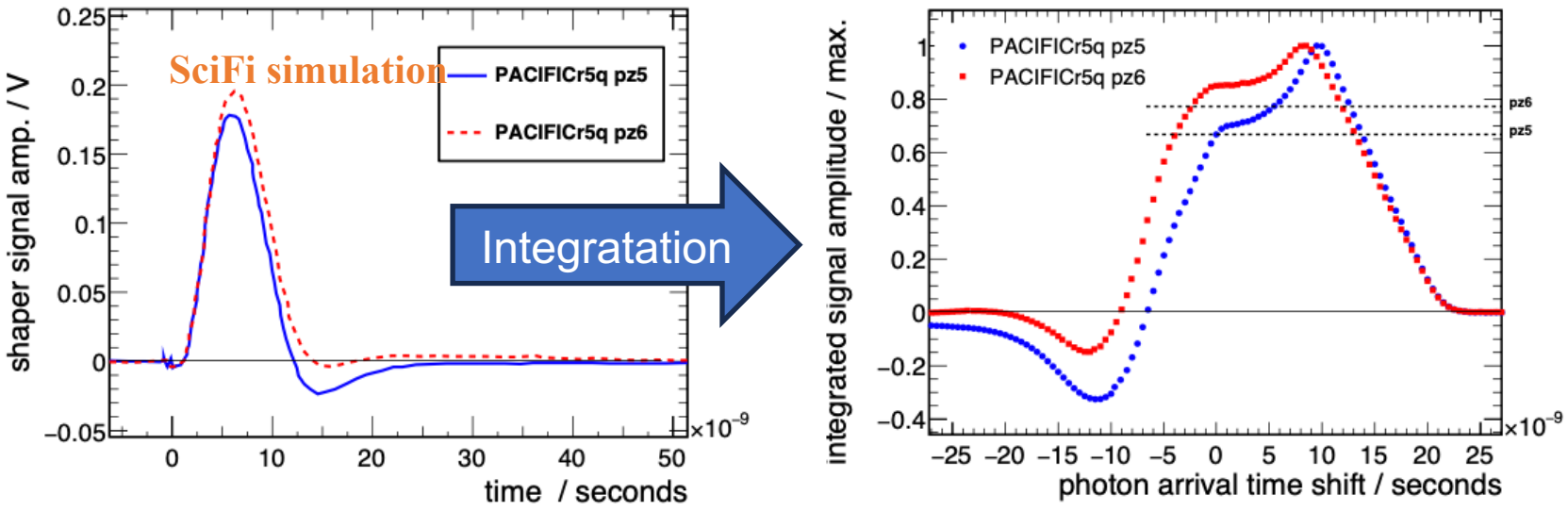



[LHCb-FIGURE-2022-017]

# Goal of fine time alignment

[arXiv:2035. 10515]

- PACFIC signal shape (left) and output of integration (right)



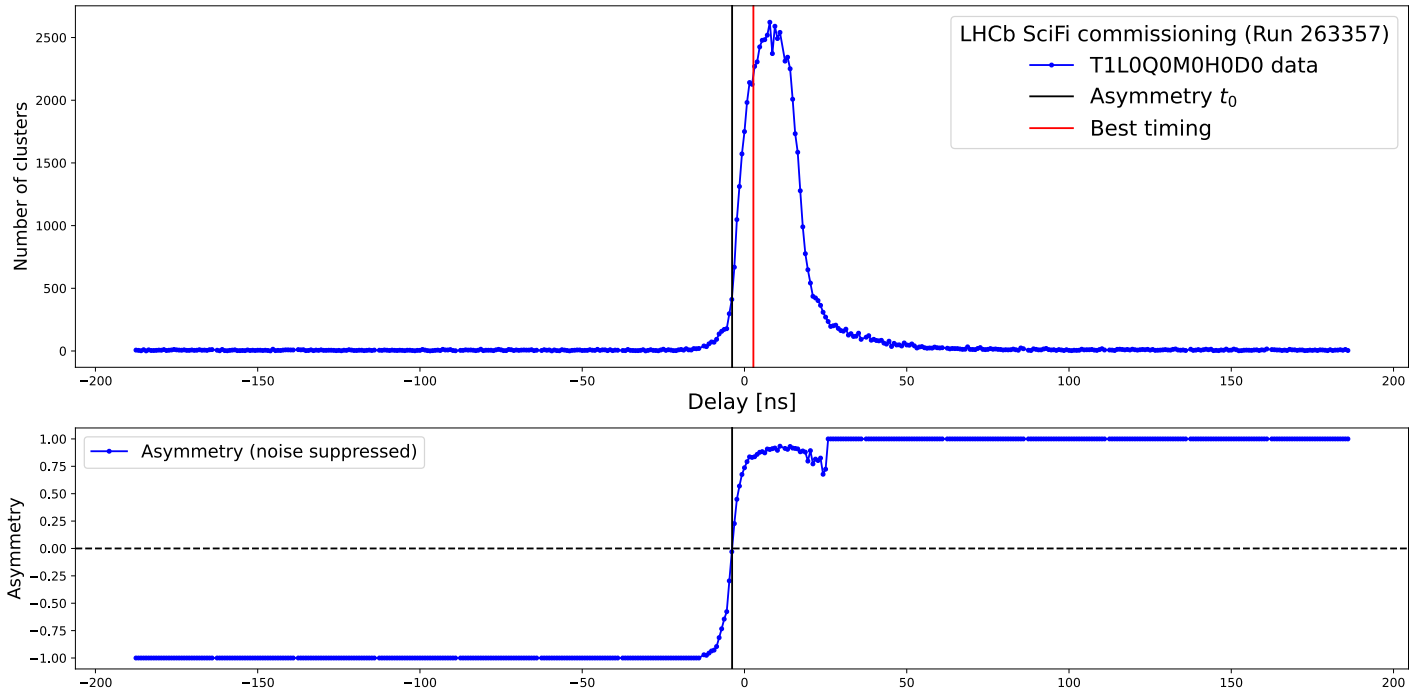

- Goal of fine time alignment:
  - Particles from $pp$ interaction with different flight time and optical signal transport time within the measurement region
  - To align photon arrival time for a largest/stable signal amplitude for physical signals

# Baseline time per datalink

[LHCb-FIGURE-2023-016]

New

- Beam scan data taken from LHC isolated bunch crossing:
  - TFC delayed time step-scan with $\sim 0.78$ ns step size
- Baseline time ($t_0$) defined from asymmetry:
  - $Asy = \frac{O(i+1) - O(i)}{O(i+1) + O(i)}$; $t_0$ is the time when $Asy = 0$
  - $i$ presents current time window; $O(i)$ is the cluster occupancy in $i$
  - The cluster occupancy and asymmetry over time (below)

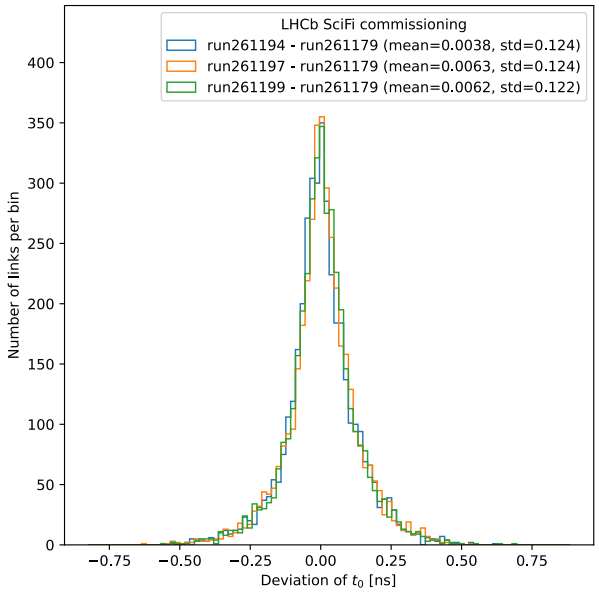


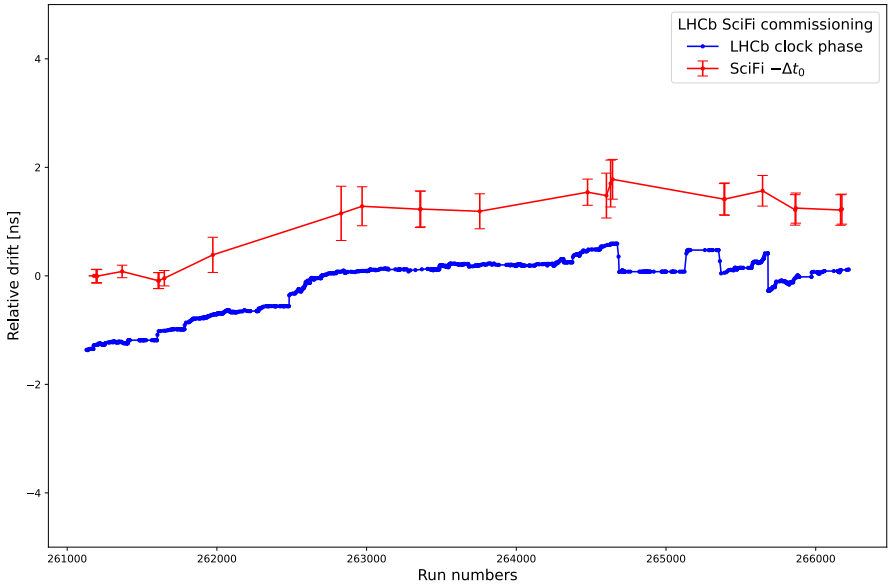
# $t_0$ stability

[LHCb-FIGURE-2023-016]

New

- Deviation of $t_0$ (from asymmetry) among 4 runs (*04-2023*) (left)
  - The spread shows the statistical effect
  - Small intrinsic time resolution

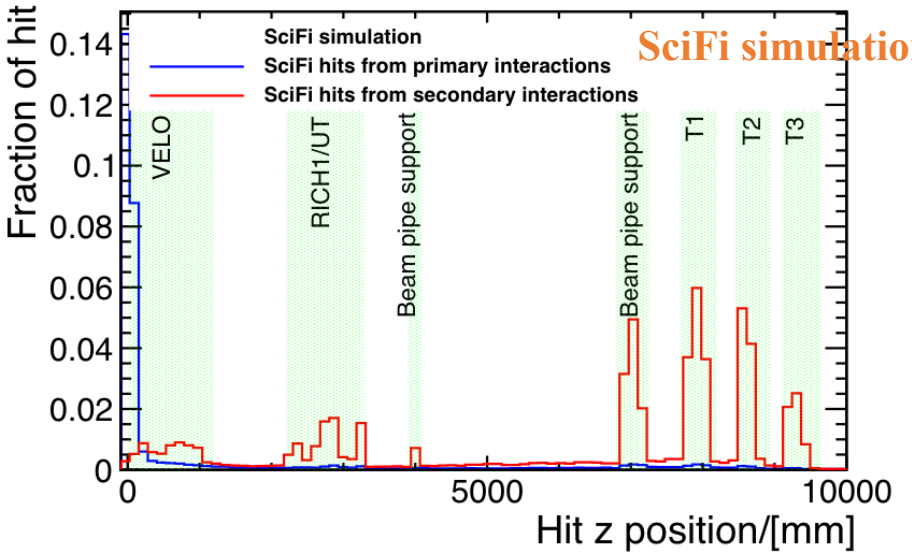


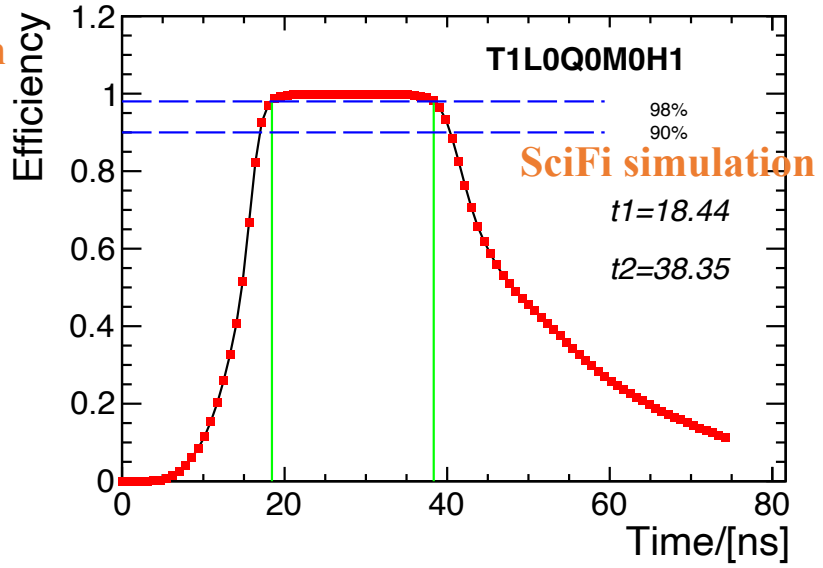




- $t_0$ variation trend over ~1 month (*04-2023 ~ 05-2023*) (right)
  - Variation of $t_0 < 2$ ns
  - SciFi FEB time follows LHCb clock phase
  - LHCb clock phase drift adjusted over time

# Time offset from simulation

- Source of hits in the SciFi (left)
  - $> 2/3$ of hits from secondary interaction (e.g. Velo, RICH1, UT…)
  - Cannot set FEB delay time at the maximum cluster occupancy time

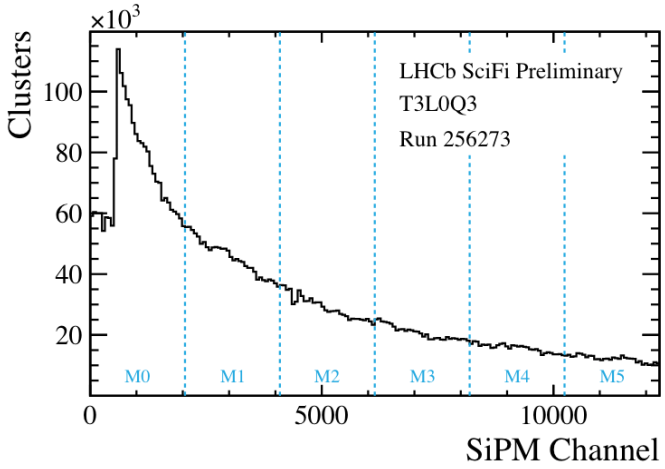



- Time offset ($t_{offset}$) obtained by optimizing the hit efficiency in long track reconstruction (from $pp$ collision):
  - The relation curve between the efficiency and delayed time (right)
  - $t_{offset}$: the middle of high efficiency plateau
  - Large plateau➔ stable hit efficiency

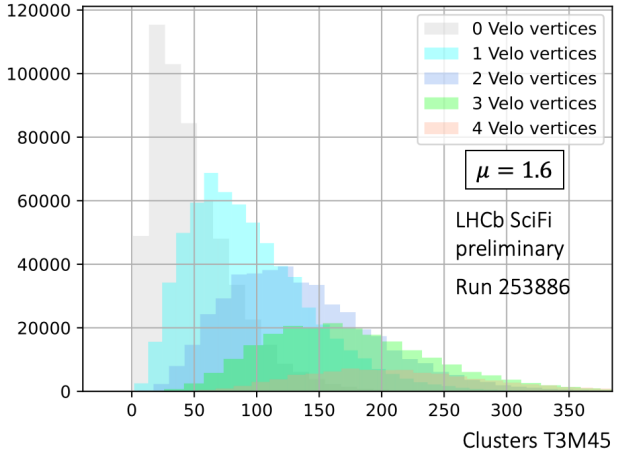
# Clusters distributions after time alignment

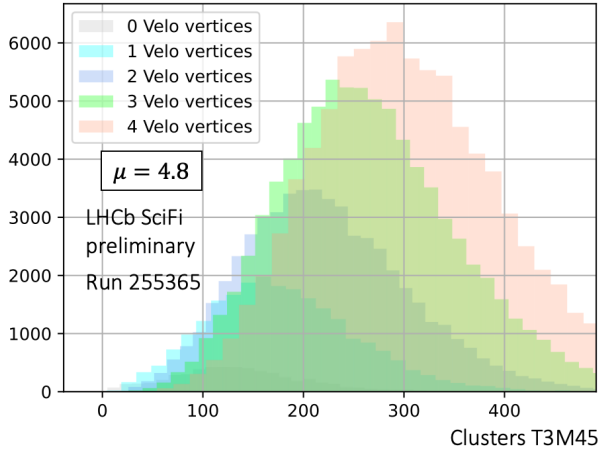
- Number of cluster as function of SiPM channel




[LHCb-FIGURE-2023-013]

- Cluster number in T3M45 with different pile-up

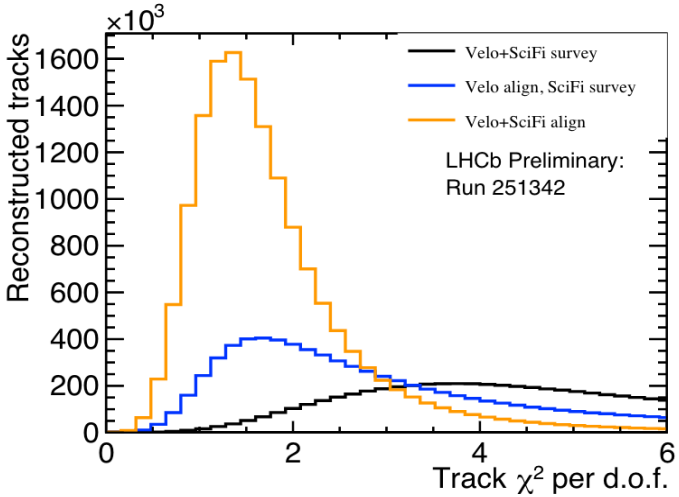


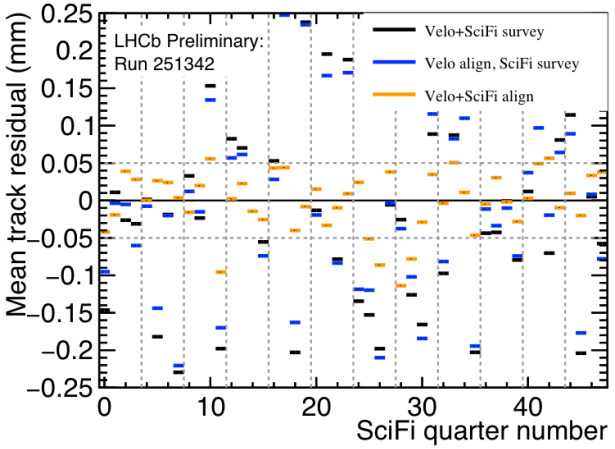




[LHCb-FIGURE-2023-012]

# The SciFi track-based alignment per module

- Alignment required for better track quality
- Long tracks provide more precision alignment for SciFi

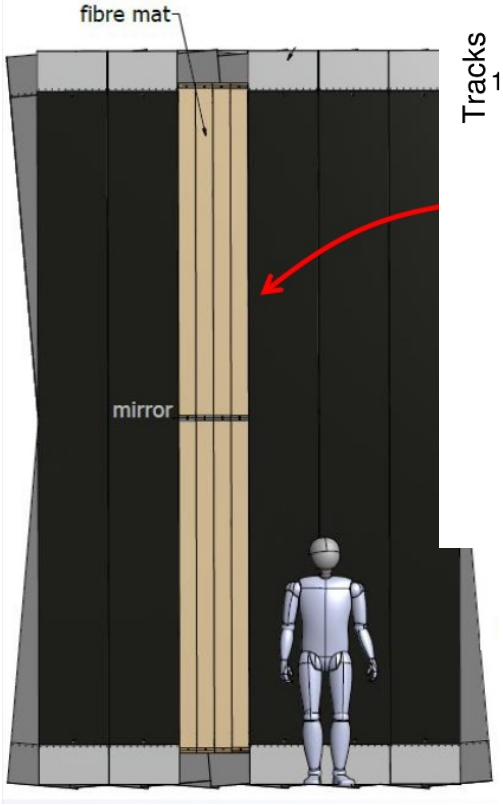



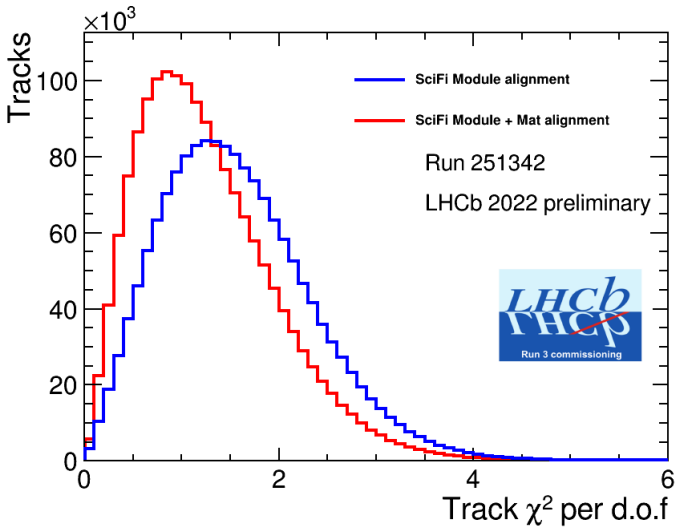

[LHCb-FIGURE-2022-018]

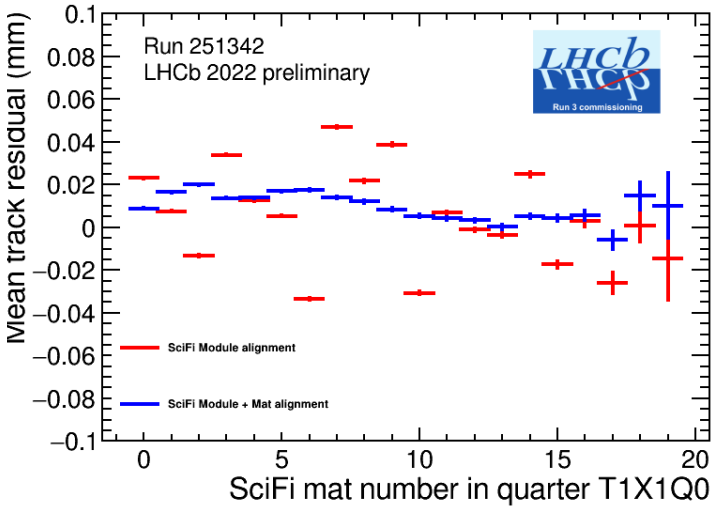
- Track quality improved after alignment per module
- Tracking efficiency improved as well

# The SciFi track-based alignment per mat

- Modules built from fibre mats
- Track-based alignment per mat further improve the position calibration




[LHCb-FIGURE-2023-018]

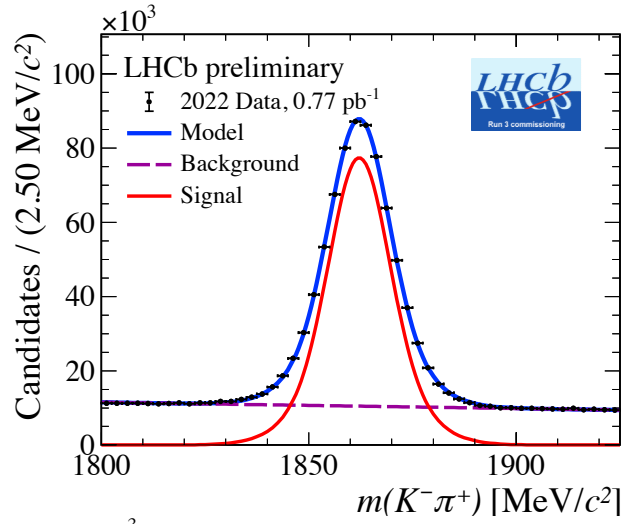
New

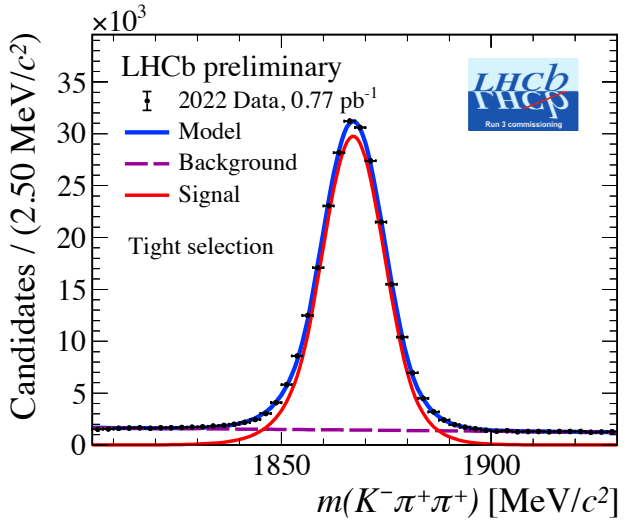
- Track quality and efficiency further improved
- Most of mean track residual per mat $< 0.02$ mm

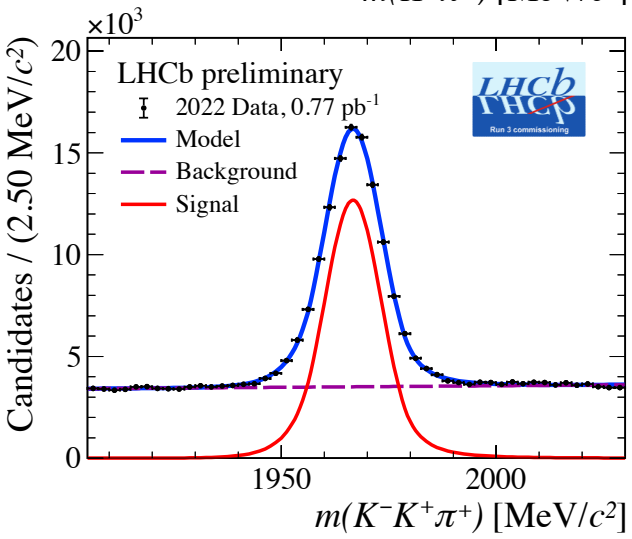
# Physics performance : charmed mesons

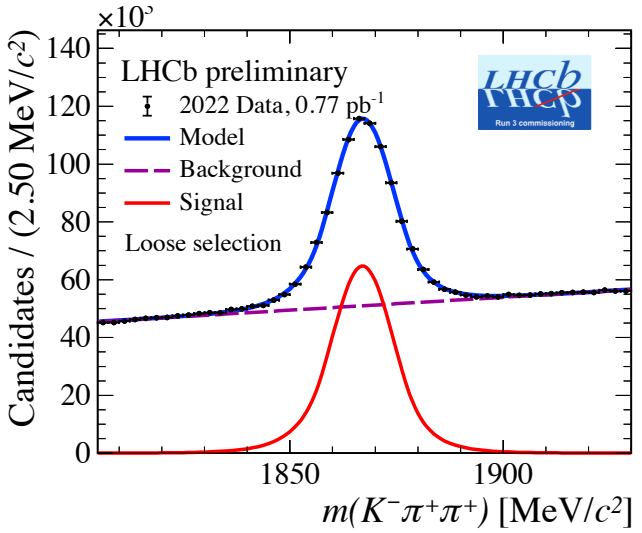
- SciFi as magnet downstream tracker:
  - Directly impact on signal mass resolutions

[LHCb-FIGURE-2023-011]



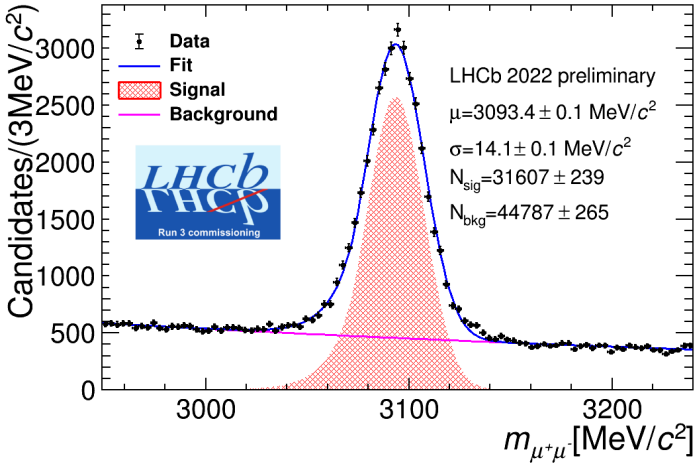



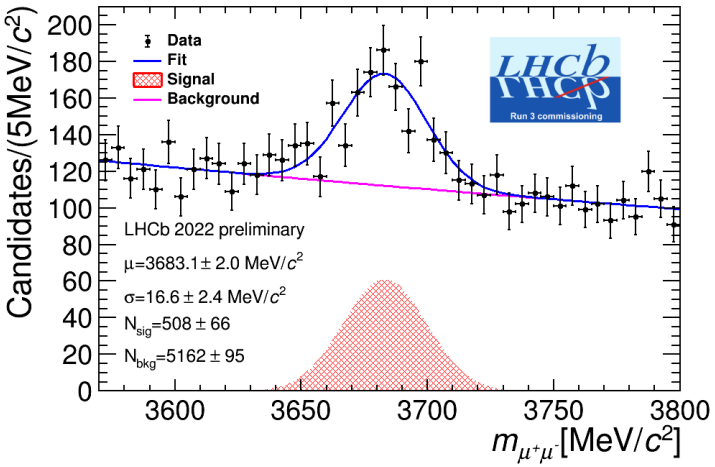



# Physics performance : di-muon

- From $pp$ collisons

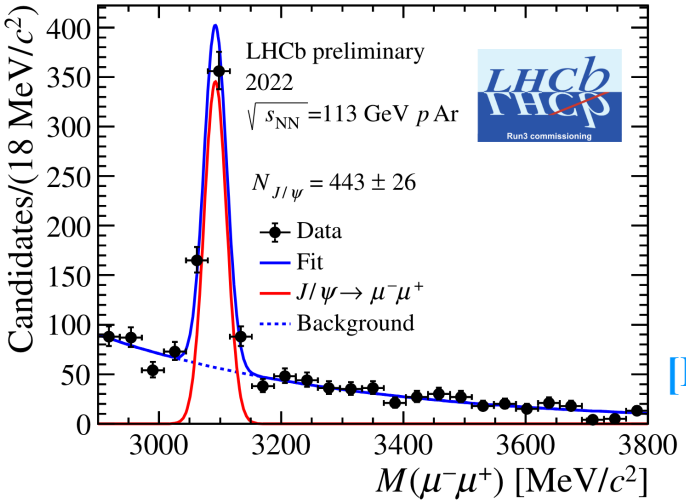



[LHCb-FIGURE-2023-015]




[LHCb-FIGURE-2023-014]

- From $p$Ar and $p$H collisons




[LHCb-FIGURE-2023-008]

# Summary and outlooks

**The SicFi has been under beam commissioning since April-2022:**

- Time alignment to optimize hit efficiency
- Track-based alignment to optimize track quality
- Physics signal mass resolution similar to MC expectations for Run3

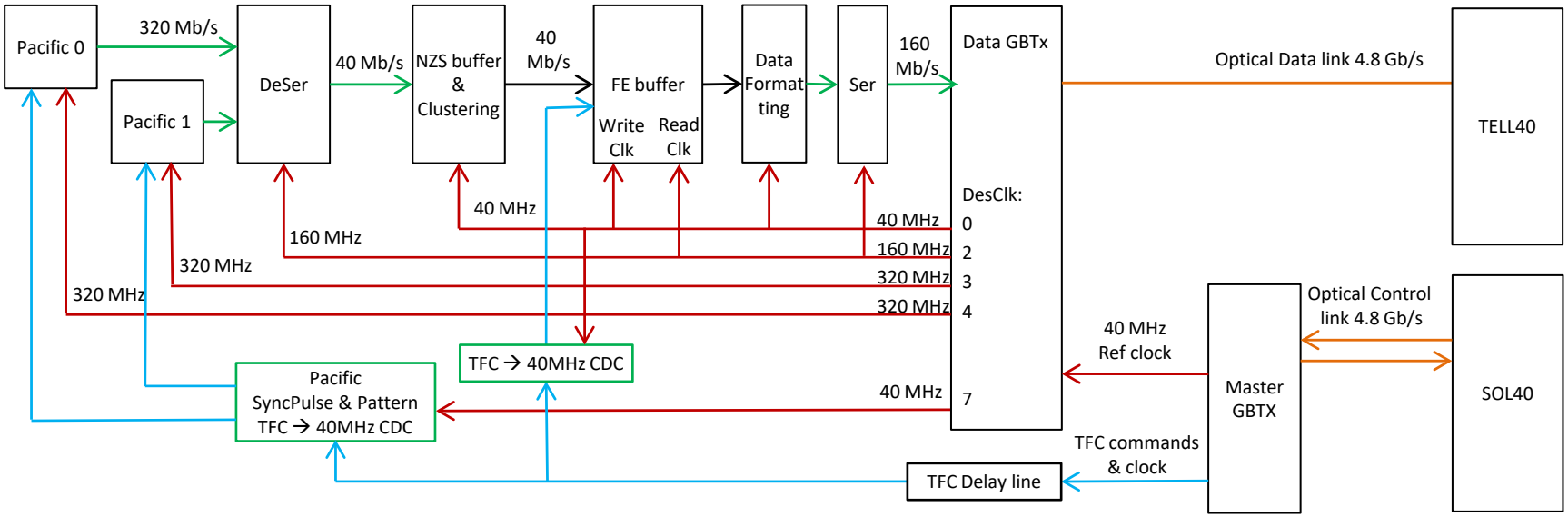
(FEB internal clock alignment, threshold calibration… not included)

**Outlooks:**

- Continue beam commissioning when LHC beam back this year
- Finer optimizations on time/thresholds/position alignment
- Look forward to SciFi performance results in next year
- Expect LHCb detectors running at Run 3 nominal instantaneous luminosity in 2024 and 2025

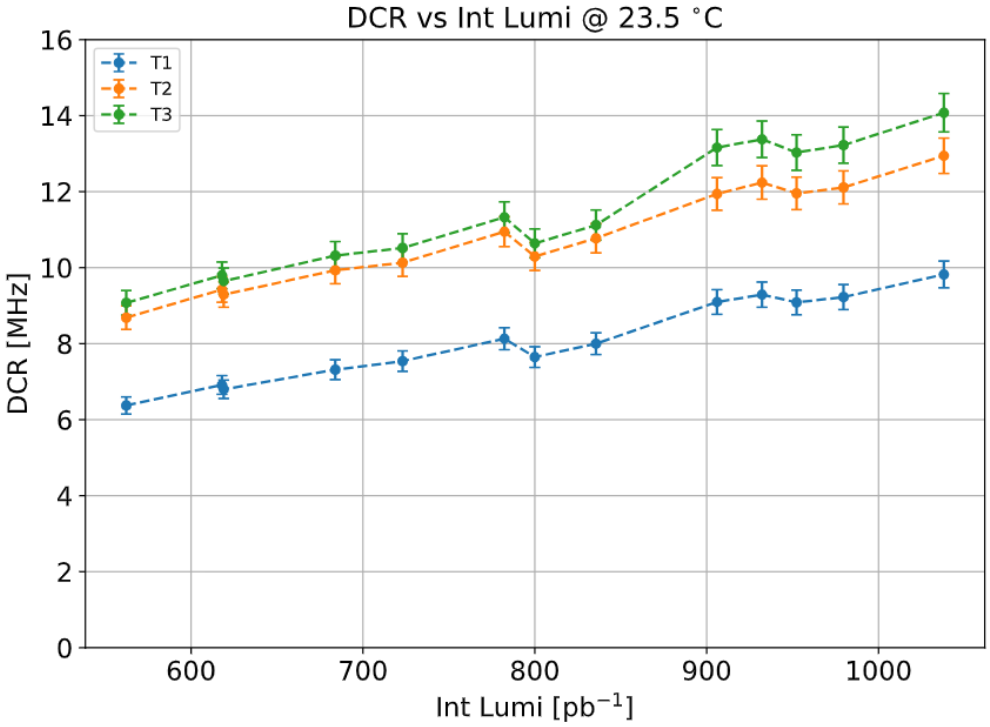
# Backup

# Frond-end electronics



# Dark count rate with absorbed dose

- Fibres coupled to SiPM operated at $-40\ ^{\circ}C$ during standard operations, reducing by a factor of 100 the dark counts rate: negligible contribution to track reconstruction since frontend thresholds set at $\geq 2.5$ photoelectrons equivalent
- Behavior of dark count rate as a function of the absorbed dose when operating at ambient temperature has also been studied during 2022




[LHCb-FIGURE-2023-004]