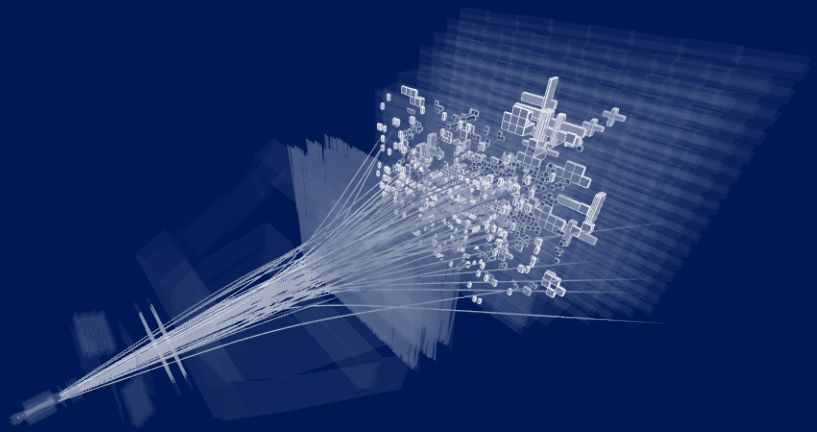
First performance of the real-time reconstruction at LHCb

Daniel Červenkov on behalf of the **LHCb** collaboration

July 9, 2022

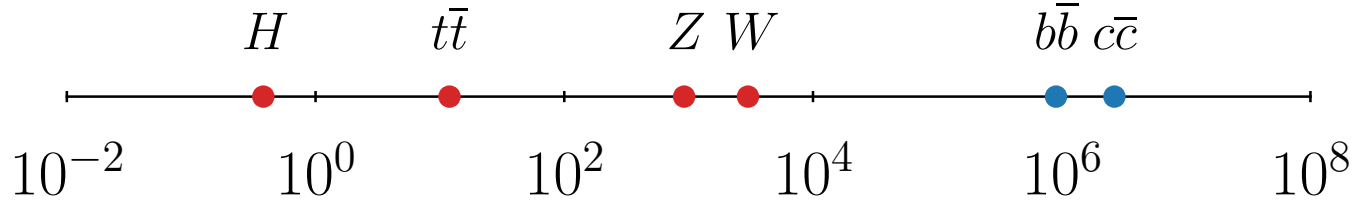
ICHEP 2022, Bologna, Italy



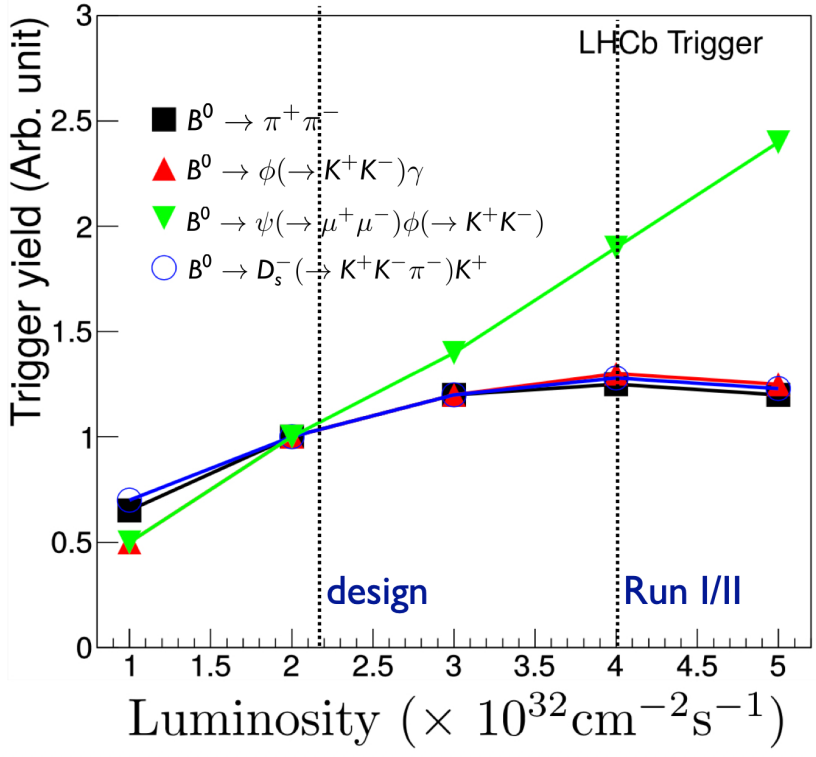
Signal Rates

J.Phys.: Conf. Ser. 878 012012

$\mathcal{L} = 2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (ATLAS/CMS) $\quad \sqrt{s} = 14$ TeV
$\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (LHCb)

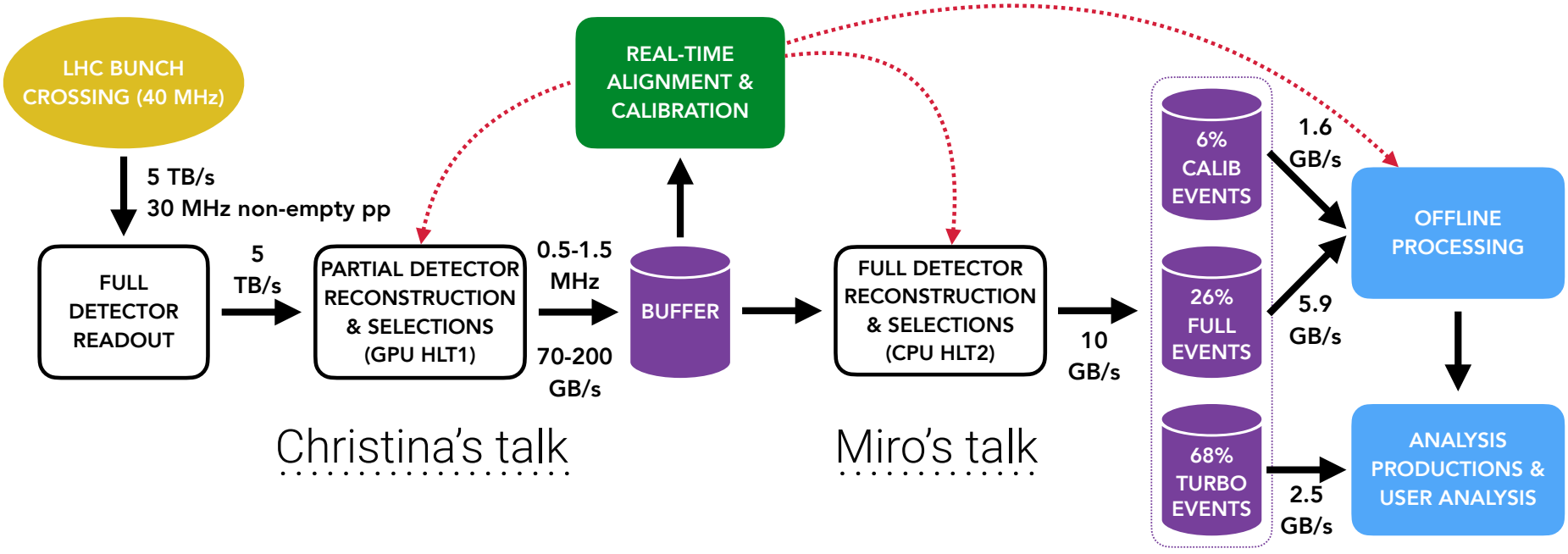


- $b\bar{b}, c\bar{c}$ look a lot like the underlying events from proton-proton collisions
- LHCb has to distinguish between signal and signal-like BG
- Can't effectively trigger on heavy flavor using hardware signatures
- Trigger for many hadronic channels saturated already at Run 1–2 luminosity



LHCb Data Flow

LHCB-FIGURE-2020-016



- Solution: Fully software trigger; online reconstruction at 40 MHz
- Offline-quality reconstruction in "real-time"
- Most events use selective persistence (Turbo)
- Allows to use more sophisticated selection; less BG to reduce bandwidth
- Increase of hadronic trigger efficiency by 2–4 wrt. Run 2

LHCb Data Flow

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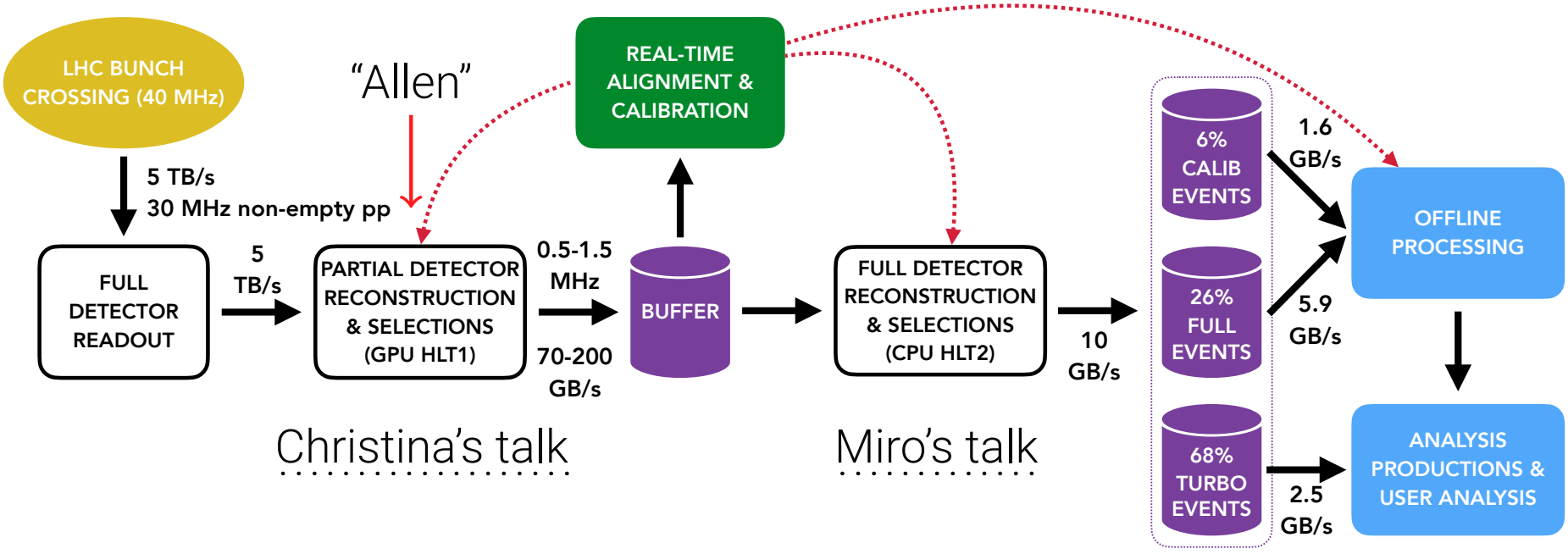

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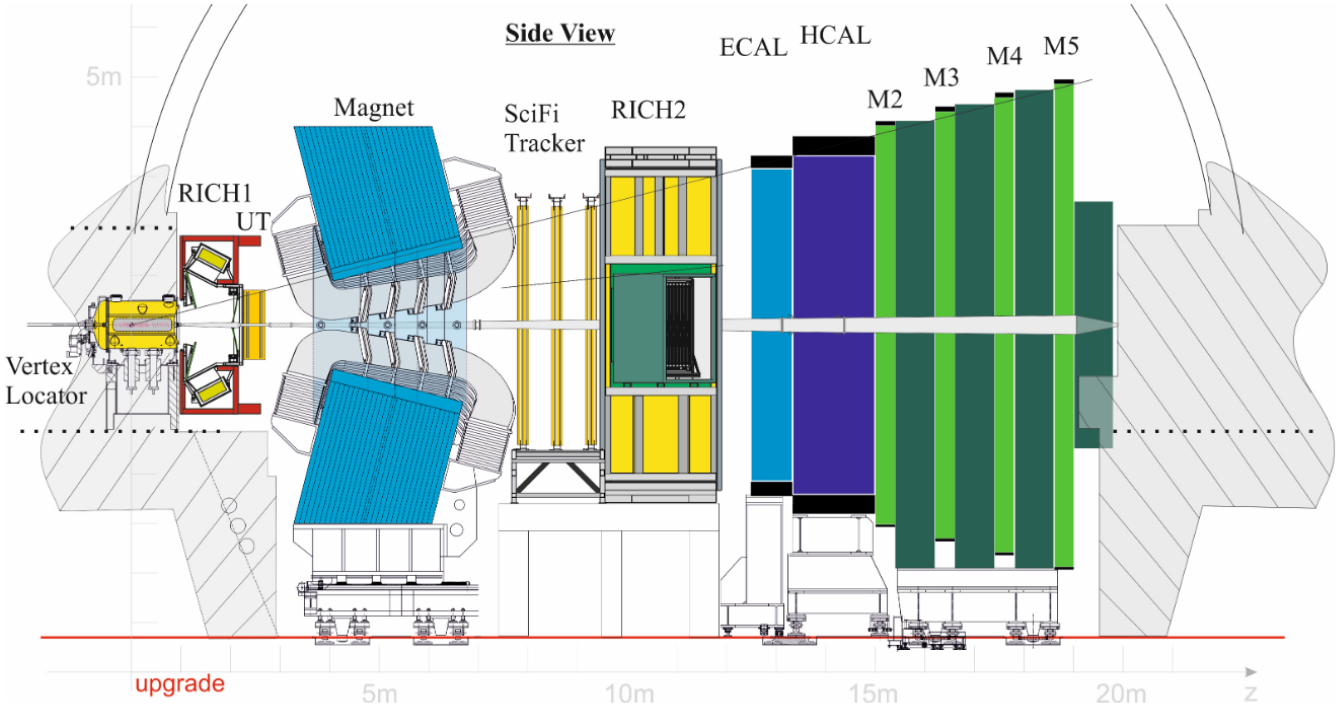
Hardware Upgrade

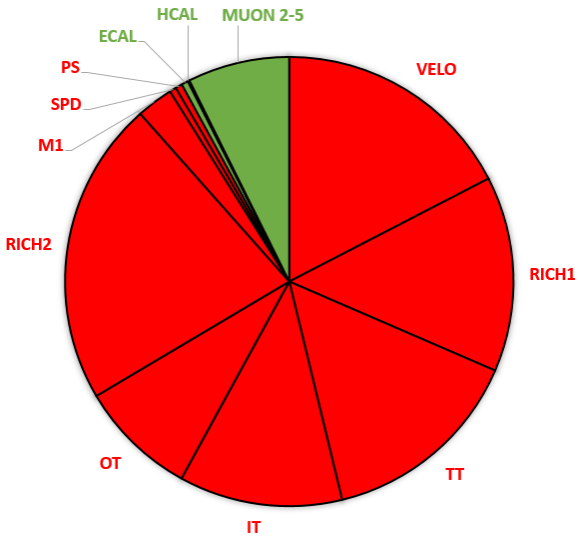


- Pixel vertex detector (55 × 55 µm pixels)
- Fine-granularity scintillating fibre (SciFi) and silicon-strip tracker (UT) (250 µm fibre diameter; 190/95 µm strip pitch)
- MaPMT-based high-resolution hadron particle identification (0.45–0.78 mrad Cherenkov angle resolution)

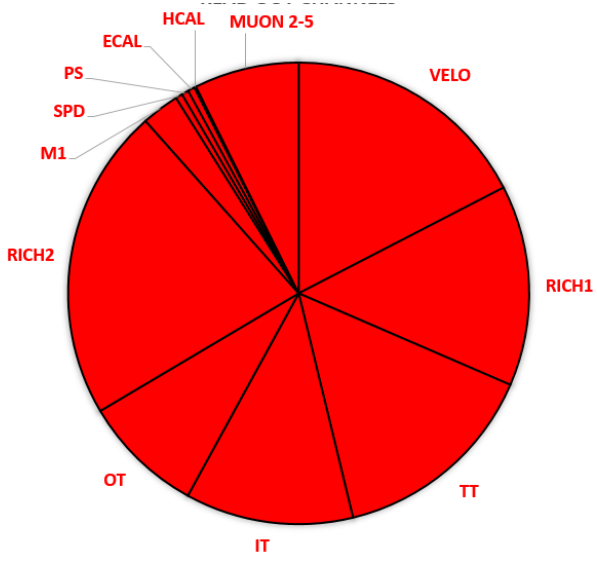
Upgrade Overview and Plans

CERN-LHCC-2012-007

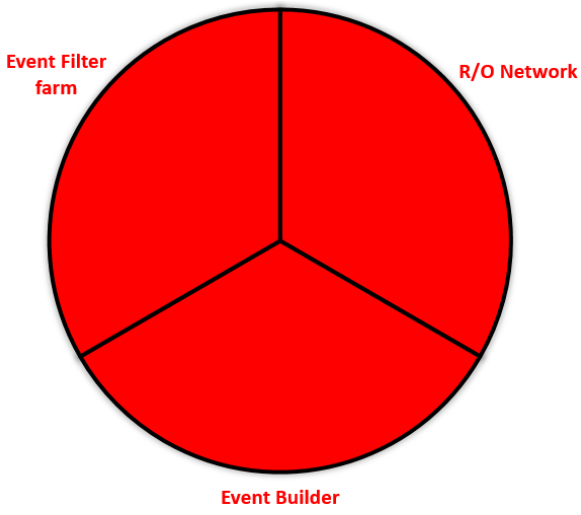
- Major upgrade of LHCb
- Upgraded, kept:



Channels

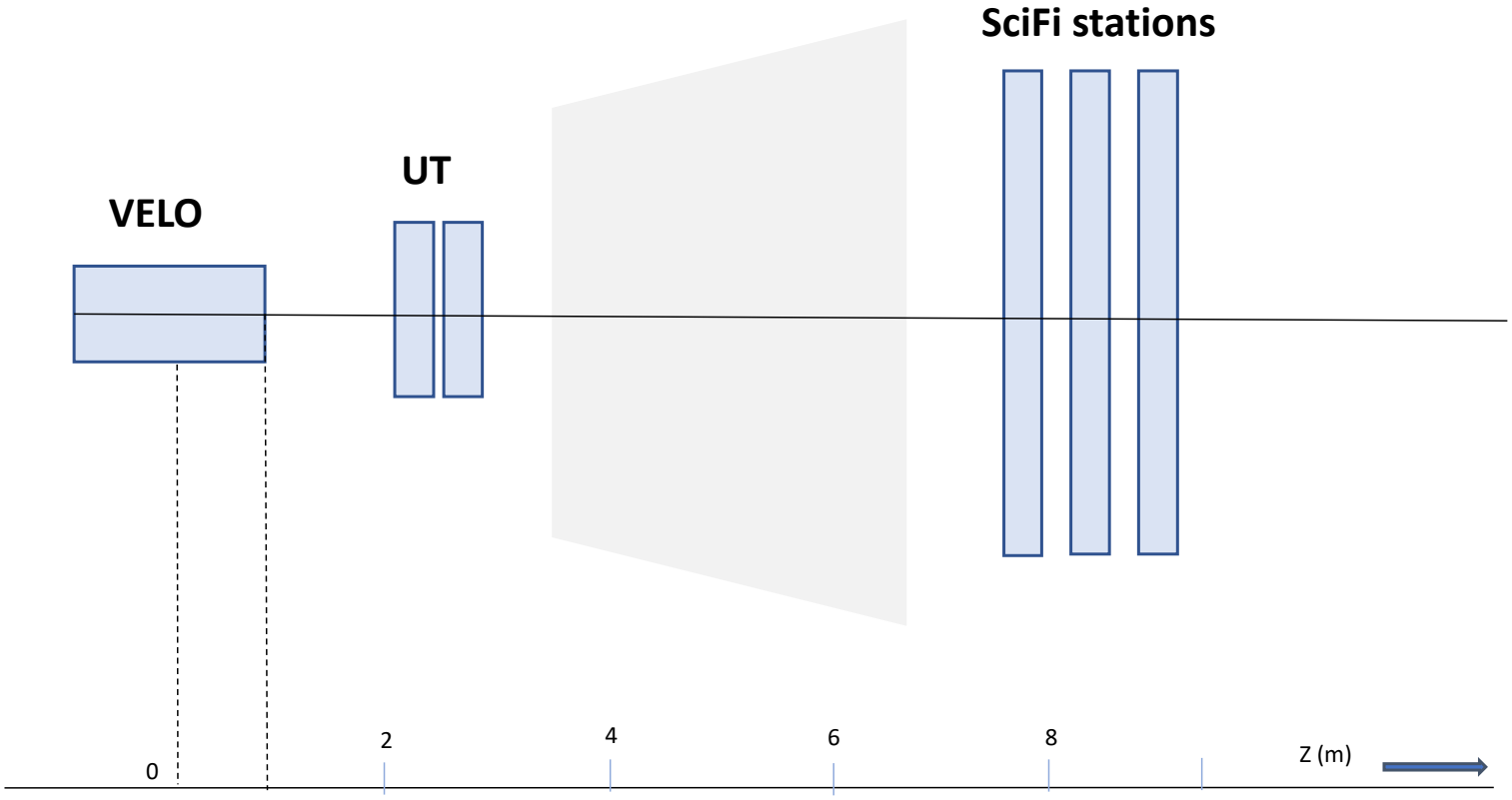


Electronics



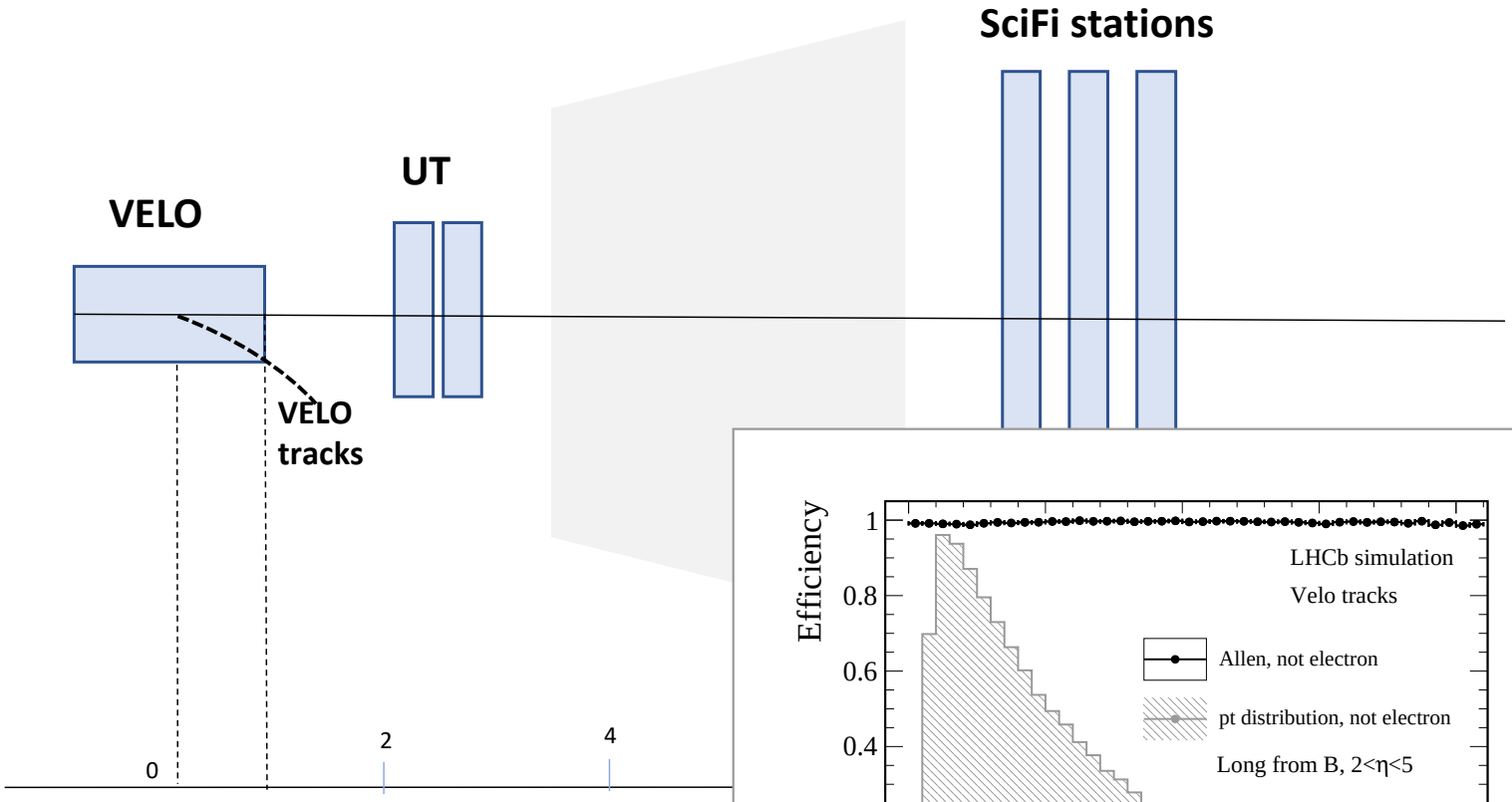
DAQ

- Run 2 collected 6 fb^{-1}
- Plan to record 15 fb^{-1} in Run 3; 50 fb^{-1} in Run 3+4
- Luminosity increased by a factor 5 to $2 \times 10^{33}\,\text{cm}^{-2}\,\text{s}^{-1}$
- Will have to deal with pile-up (increase from 1.1 to 5–6)


SciFi stations
UT
VELO
0
2
4
6
8
Z (m)

LHCb Real-time Tracking

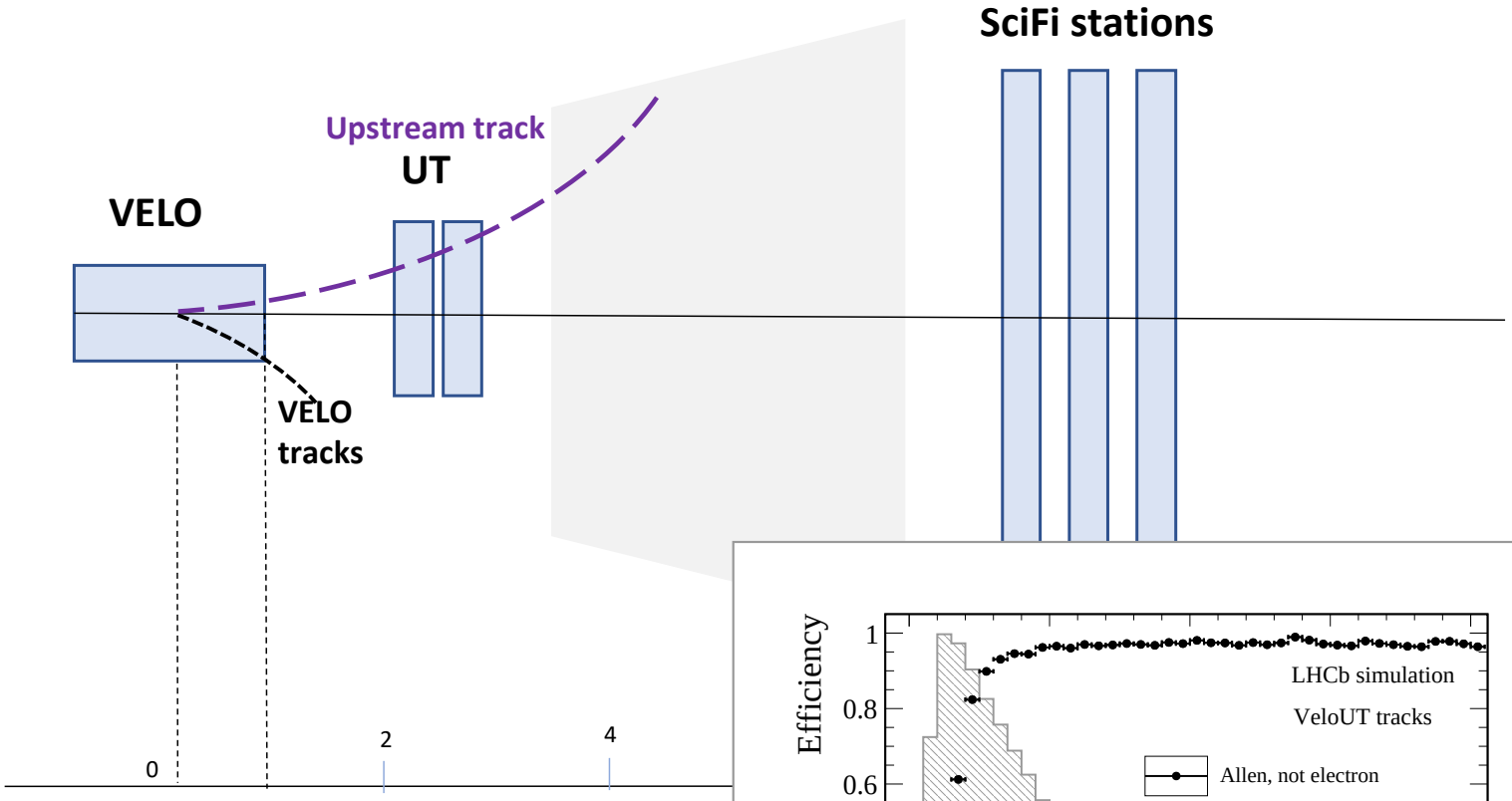
LHCB-FIGURE-2020-014

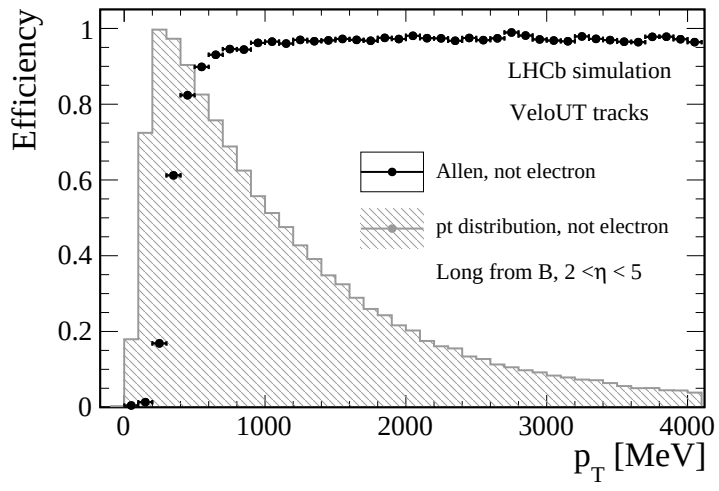


- VELO pattern recognition finds straight VELO tracks
- ∼ 99% efficiency

LHCb Real-time Tracking

LHCB-FIGURE-2020-014

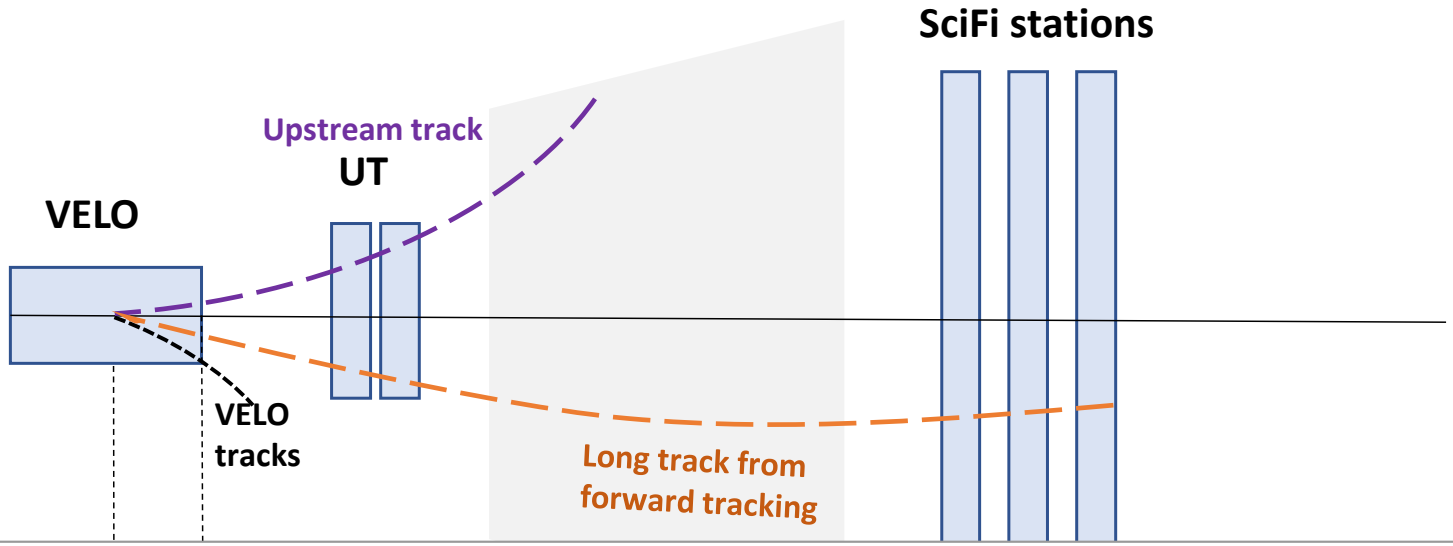


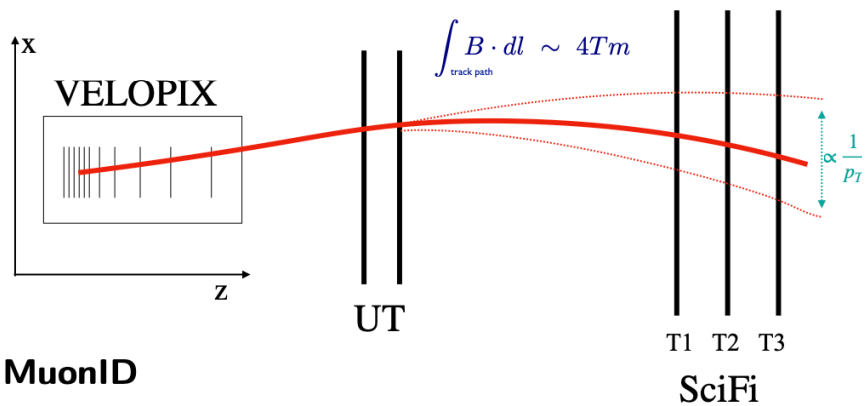


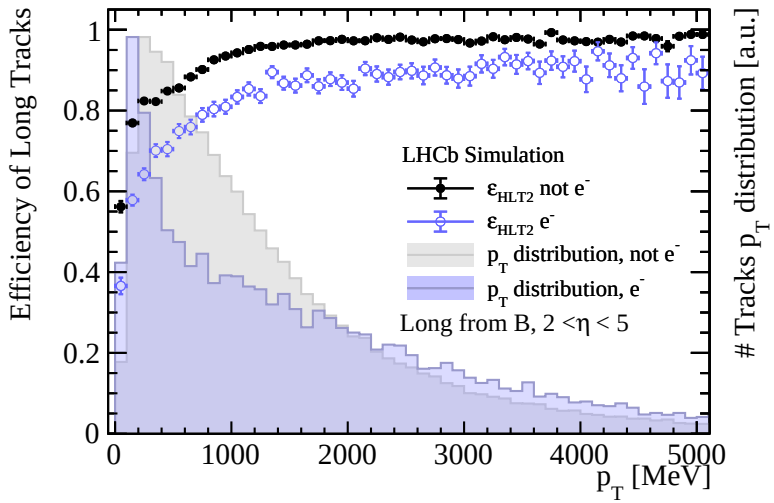
- HLT1 Upstream tracks

LHCb Real-time Tracking

LHCB-FIGURE-2022-005



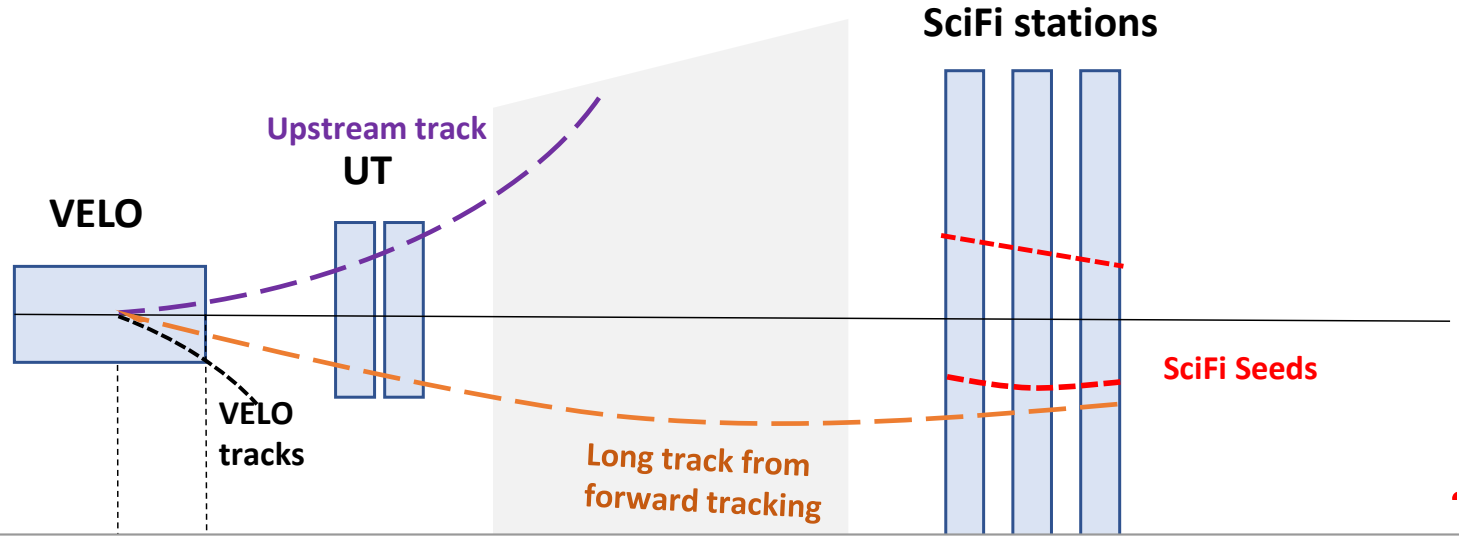


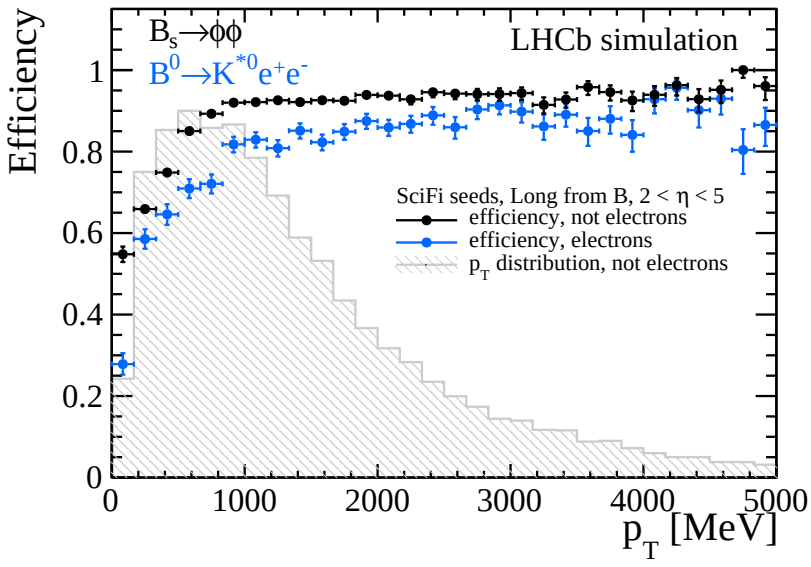


- HLT2 Forward tracking
- Utilize fringe field in the UT for momentum measurement

LHCb Real-time Tracking

LHCB-FIGURE-2022-010

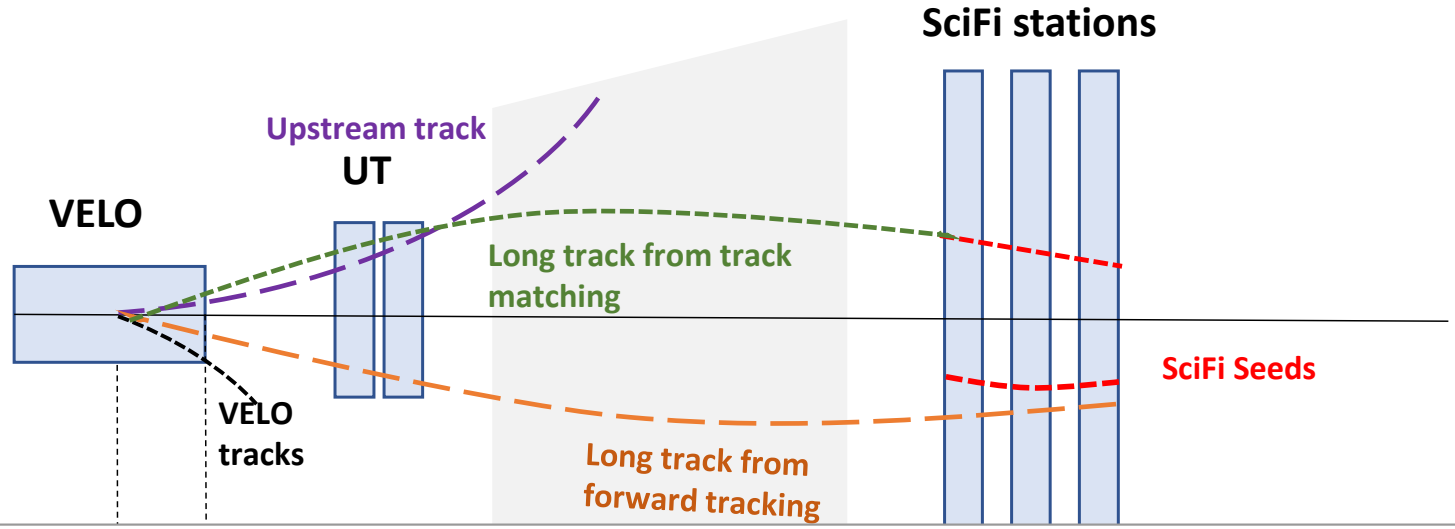


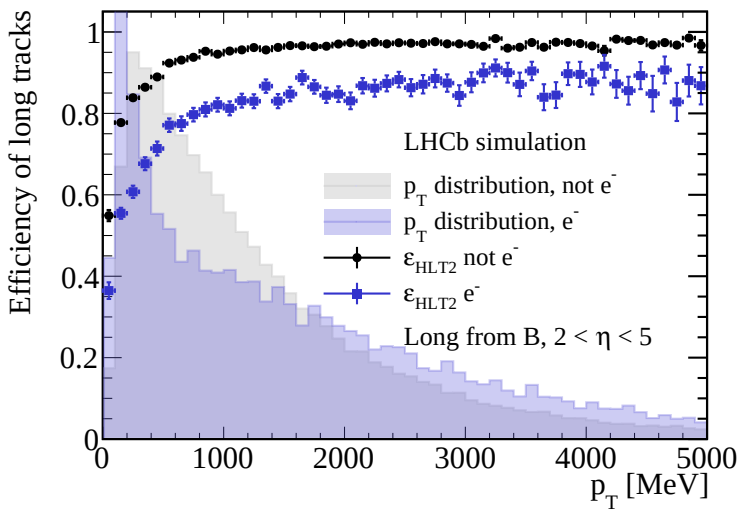


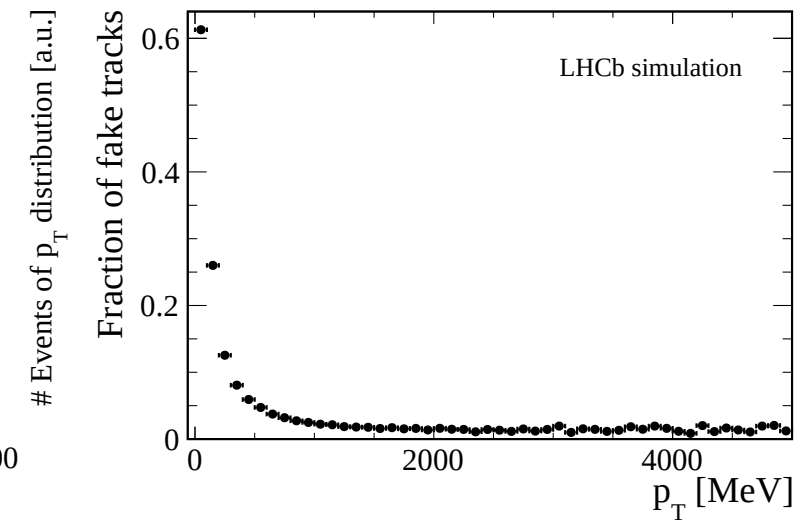
- SciFi Seeds from *B*-decays are found with 95% efficiency (for $p_T > 1$ GeV/c non-$e^{\pm}$ tracks) in HLT1

Combined LHCb Real-time Tracking

LHCB-FIGURE-2021-003

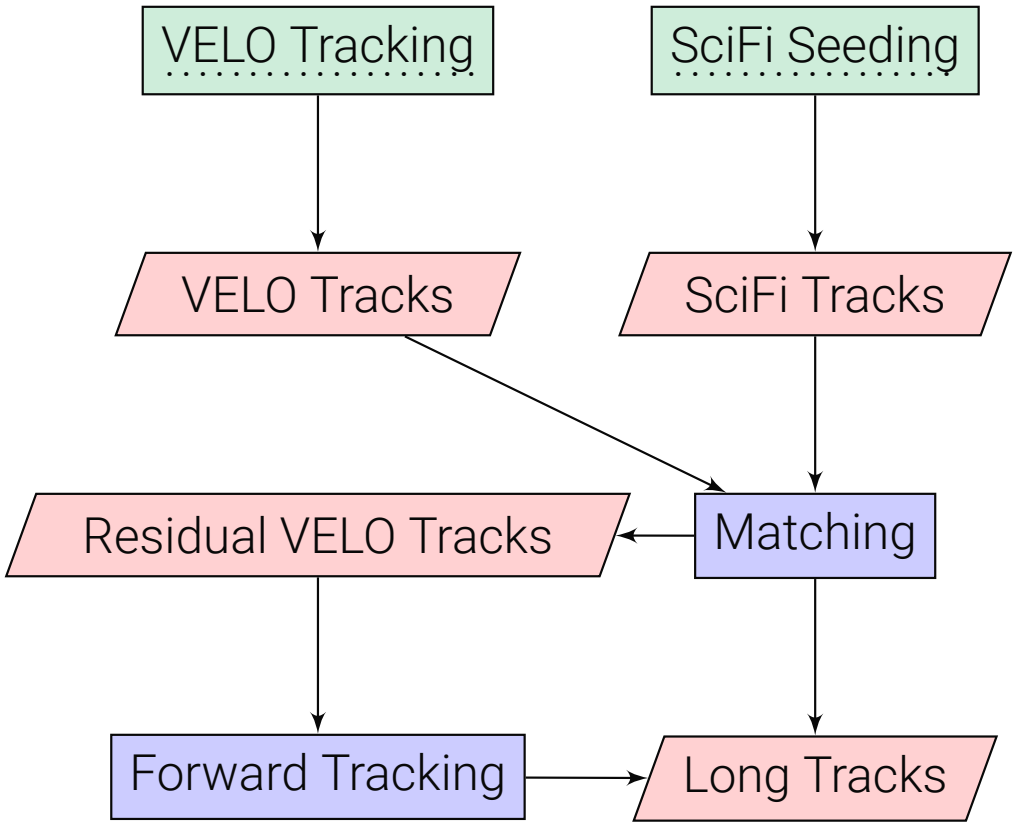






- Ghost (fake) track: less than 70% of hits from the same track

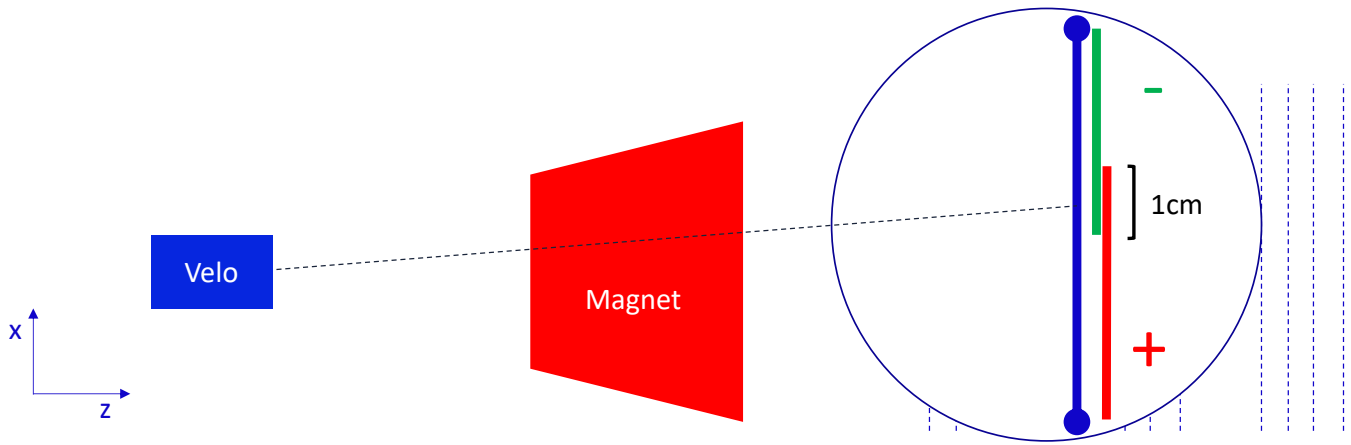
HLT2 Track Reconstruction Sequence



- Two algorithms to find Long tracks
  - Neural network matching VELO to SciFi tracks
  - Forward Tracking on *non-matched* VELO tracks
- Avoid redundancy

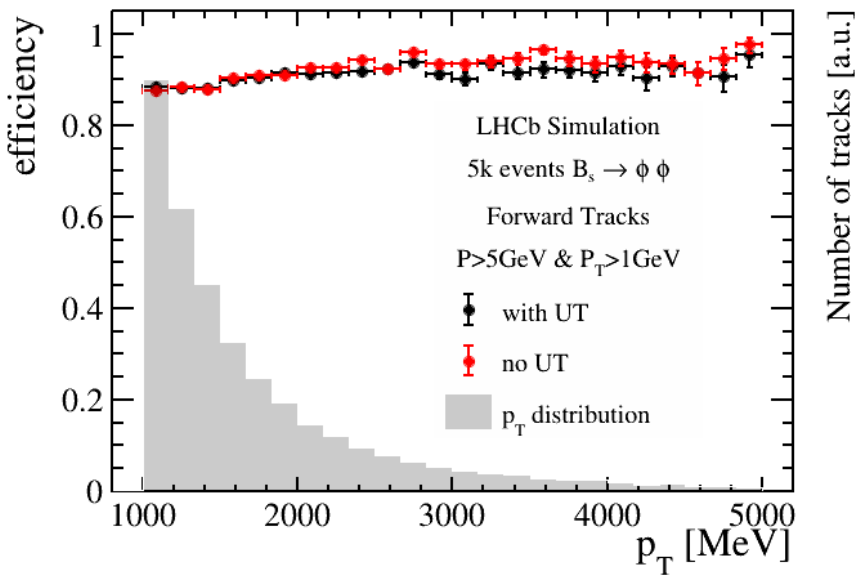
Tracking without UT

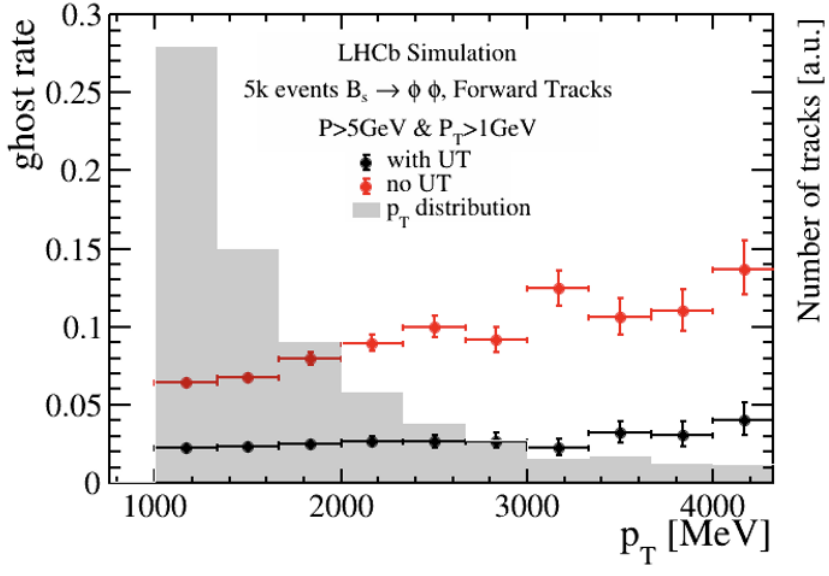
- UT won't be installed until the end of the year
- We need tracking algorithms that work without momentum & charge information
- Extrapolate VELO track as a straight line, make two windows — assuming positive/negative charge
- Assume $p > 5\,\text{GeV}, p_\text{T} > 1\,\text{GeV}$ (low-p tracks get bent out of the SciFi acceptance anyway)



Reconstruction Efficiency without UT

LHCB-FIGURE-2022-007

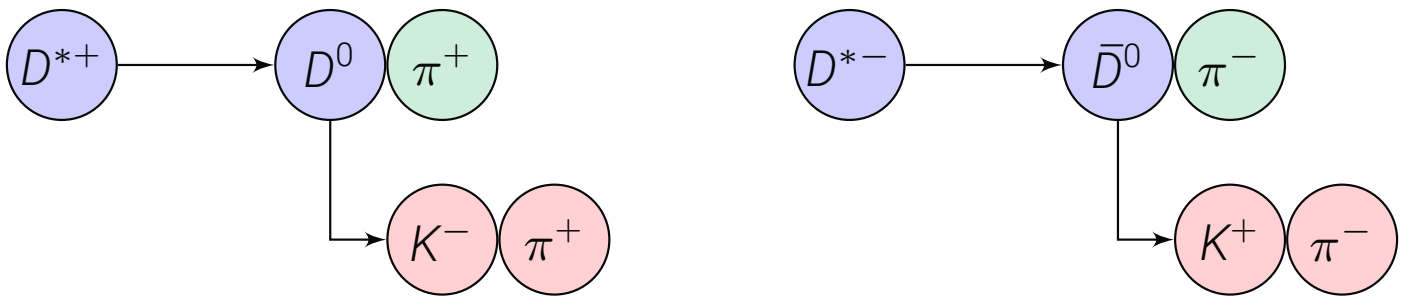




- HLT1 tracking tuned to keep the event throughput comparable to the baseline design
- Simulation shows the same efficiency for tracks from *B* decays is achieved, though with significant increase in ghost rate

PID Calibration

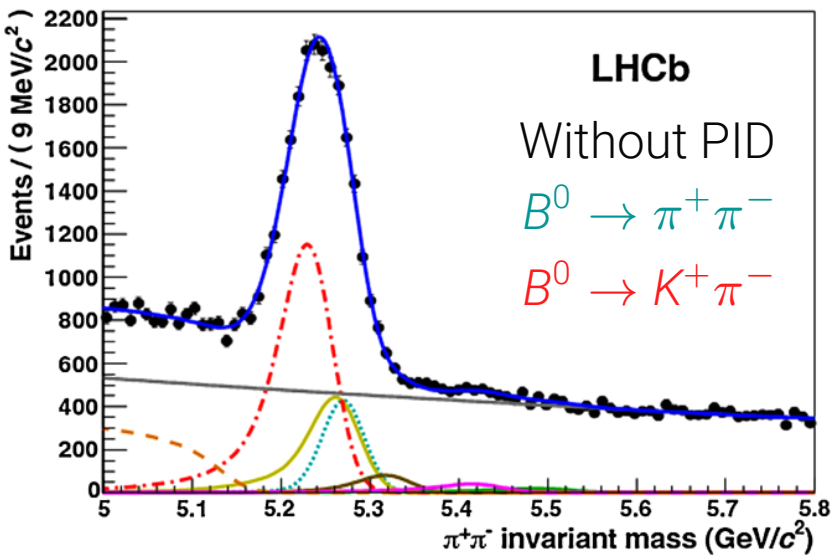
- PID combines information from RICH, calorimeters & muon system
- PID requirements used extensively in the trigger
- Simulation of PID difficult; data-driven techniques
- Self-tagging channels, e.g.:

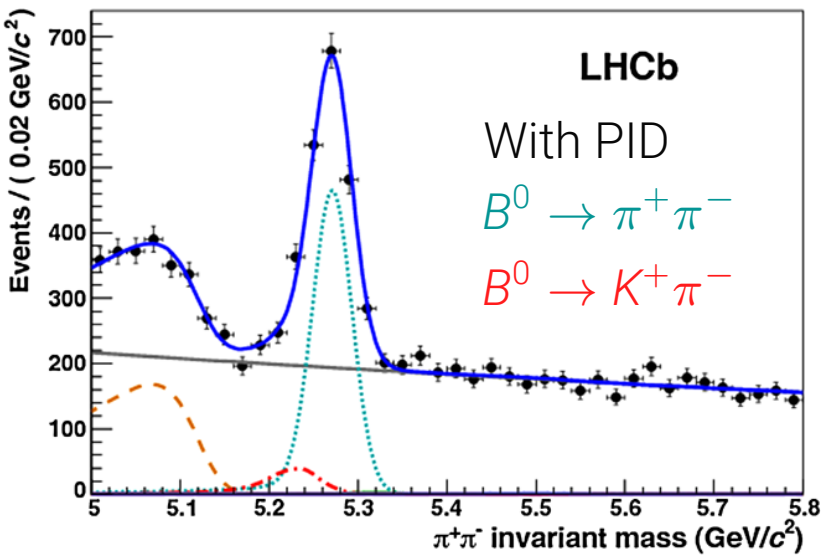


- Charge of the tagging pion used to determine particle type of the positive/negative track

PID Calibration Procedure

- Select events without PID (special trigger as most trigger lines use PID; proxy for the signal)
- Use sPlot technique to obtain 'pure' samples
- Apply chosen PID cuts (tuned for the particular analysis — leave cuts loose if you want more yield in a low BG study, or tighten cuts to kill a nasty BG)
- Bin calibration events in $p_{\mathrm{T}}, \eta, n_{\mathrm{tracks}}$ (PID response is non-uniform in these vars)
- Assign PID-cut efficiency to each track using a look-up in the calibration histogram (after cut/before cut)

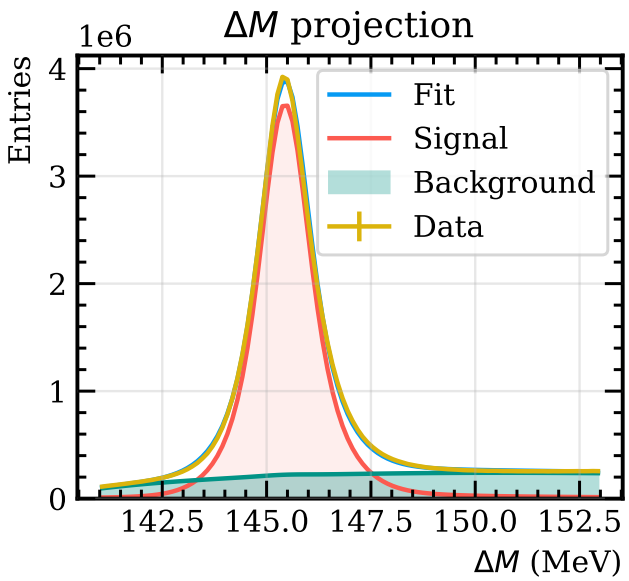


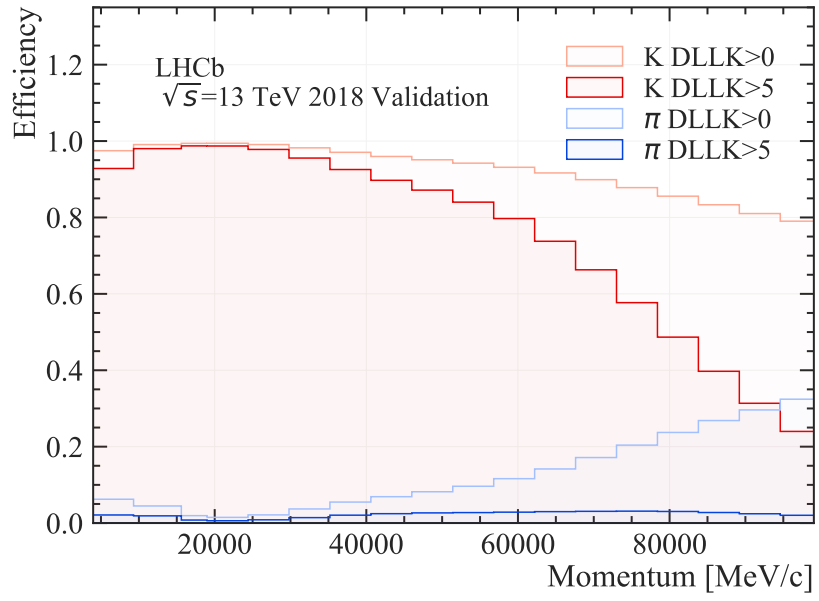


Eur. Phys. J. C 73, 2431 (2013)

New PID Calibration Approach

- Run2: global sPlot fit
- However, mass resolution depends on kinematics slightly
- Run3: new approach — conduct sPlot fits in kinematic bins to improve precision
- New Python-based fitting framework built on JAX
- Automatic pipeline that tuples the output of calibration HLT2 lines, runs the sPlot fits, saves the results
- New analyst tools that automatically process and assign PID efficiency to analyst samples using chosen cuts





LHCb Almost Ready

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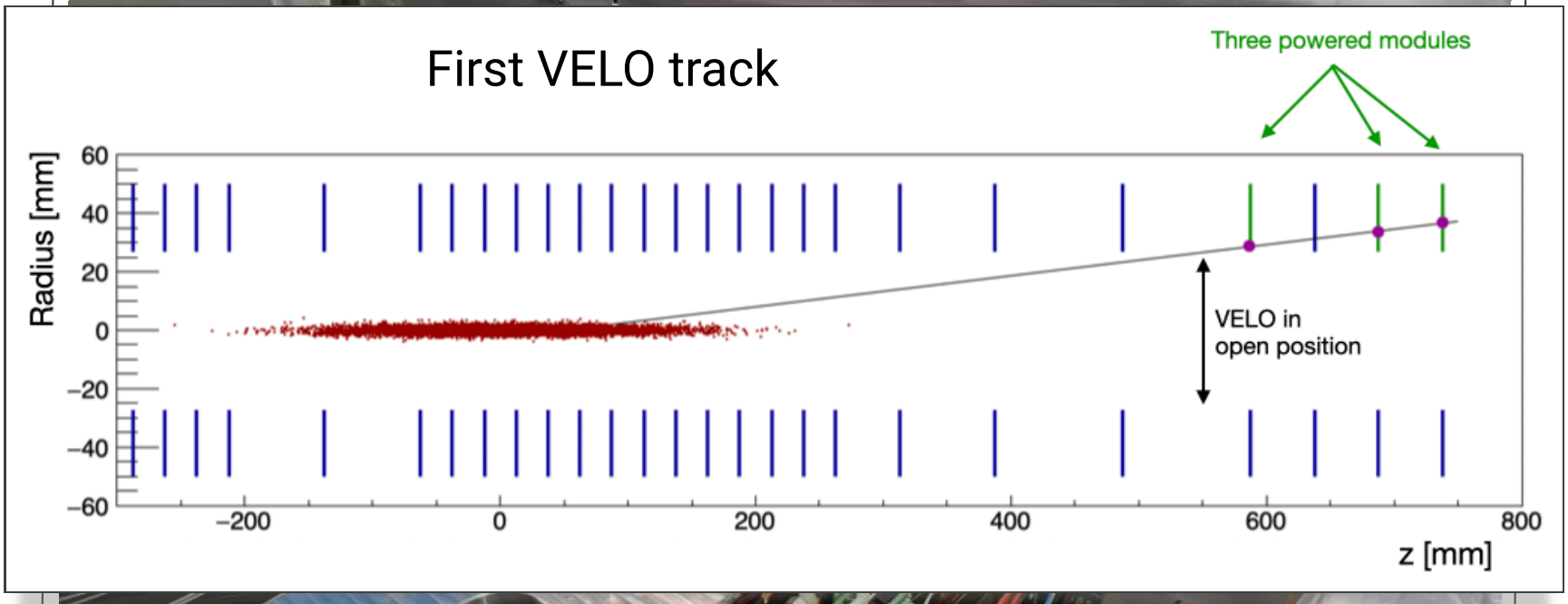

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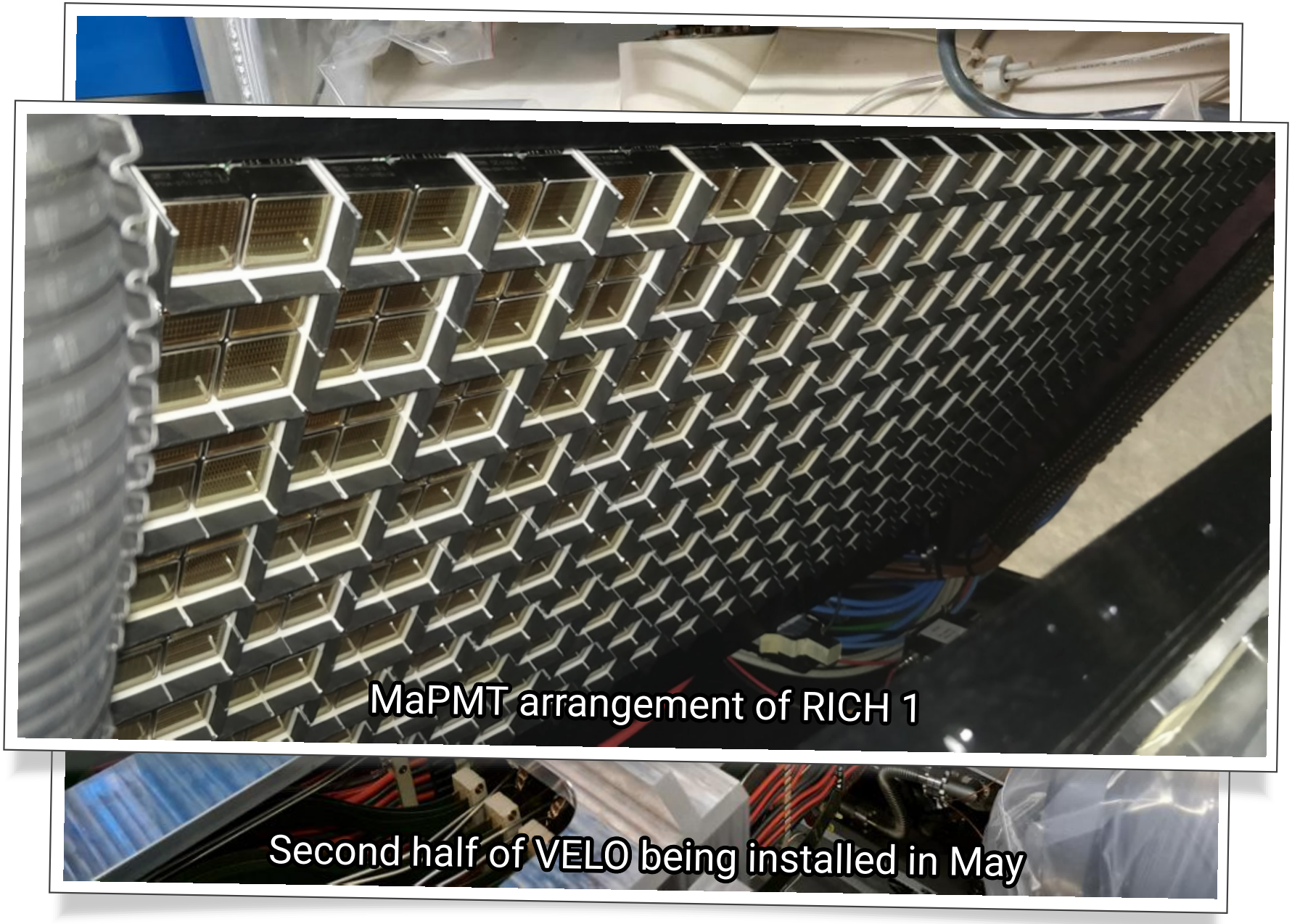
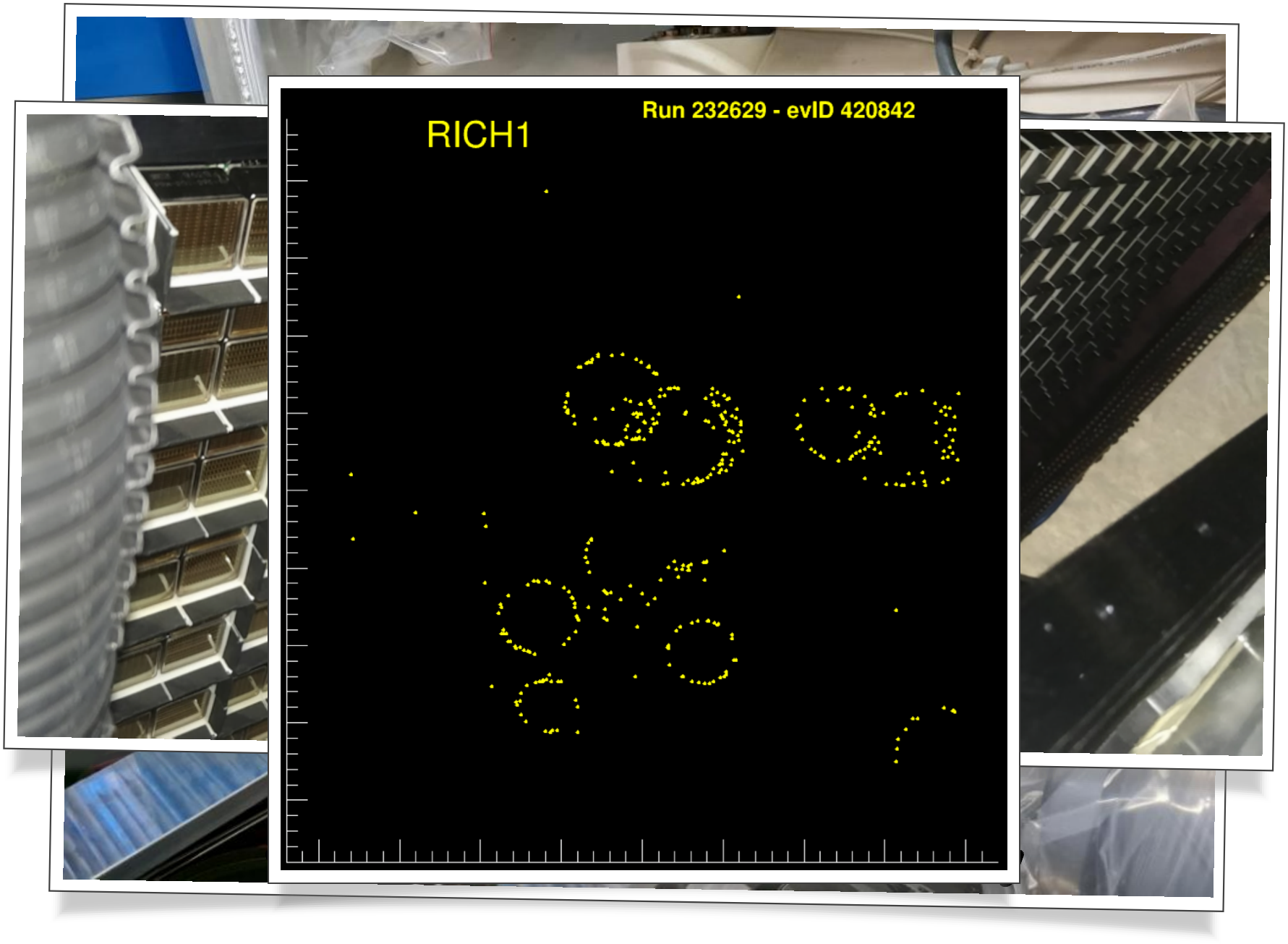


MaPMT arrangement of RICH 1

Second half of VELO being installed in May

LHCb Almost Ready



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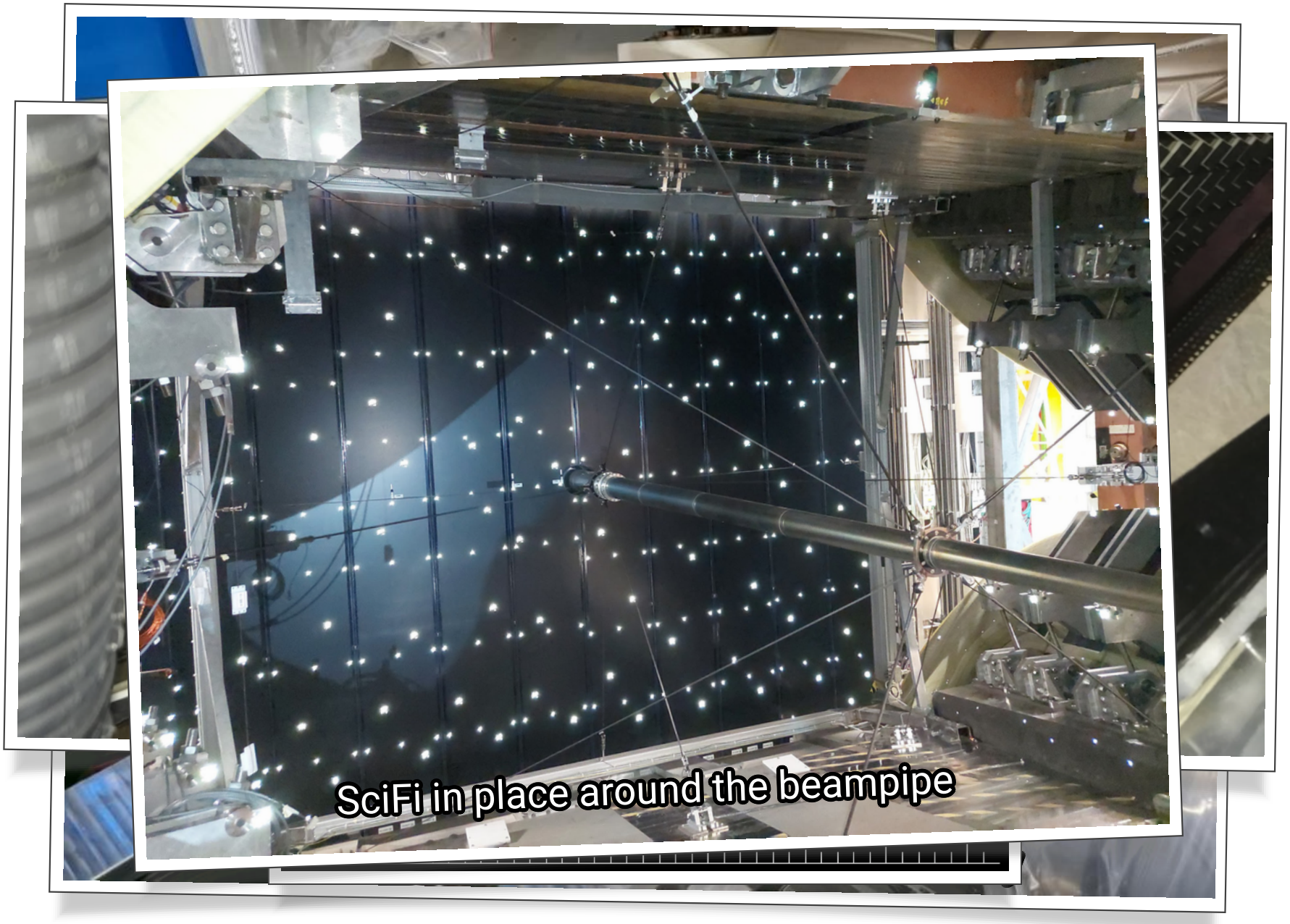

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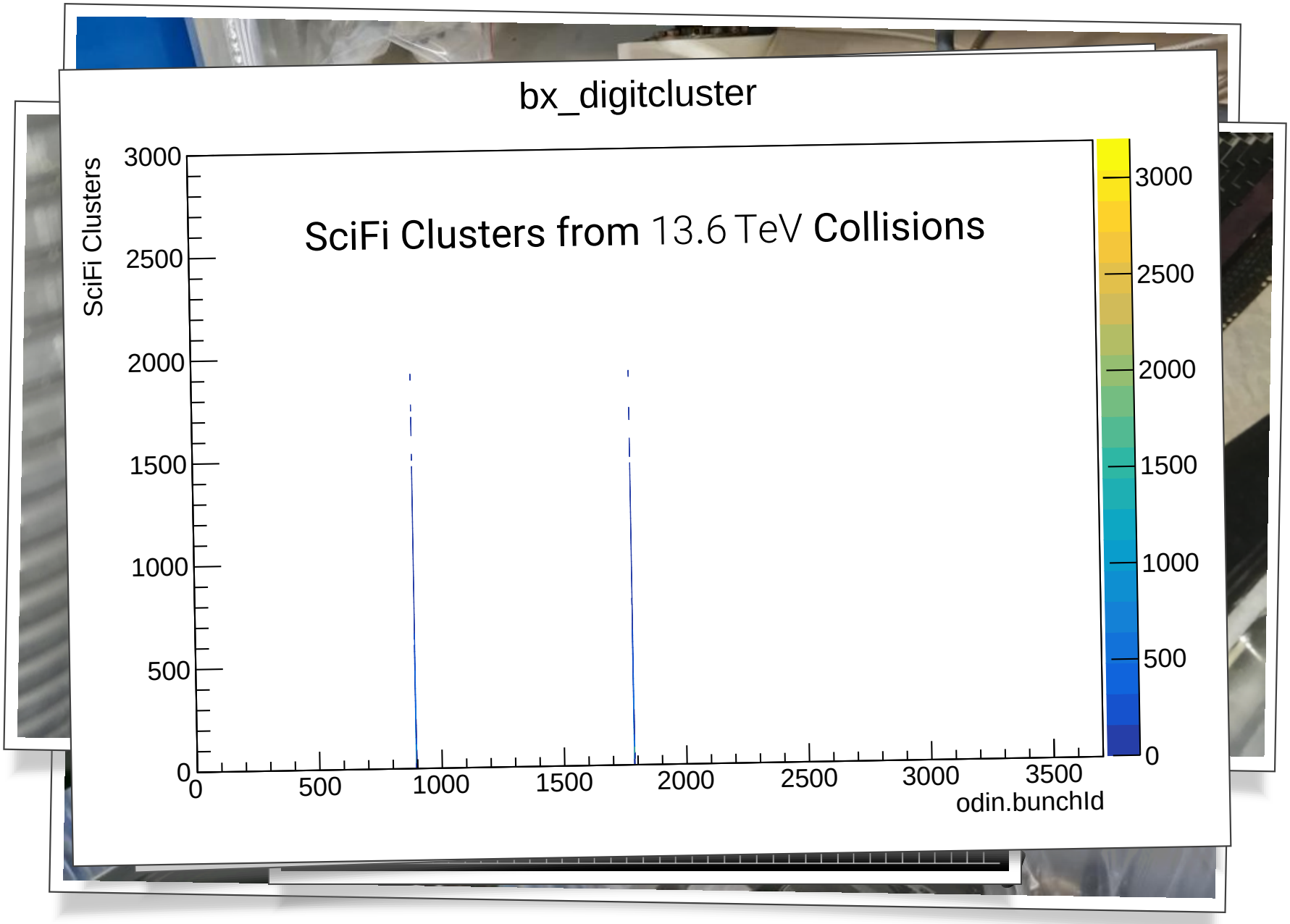

LHCb Almost Ready

Summary

- LHCb has undergone a major hardware upgrade
- A new fully software trigger has been implemented
- We expect excellent performance across the board, even with the five-fold increase in luminosity
- LHCb is almost ready to start collecting physics data with the brand new detector; stay tuned!

Thank you!