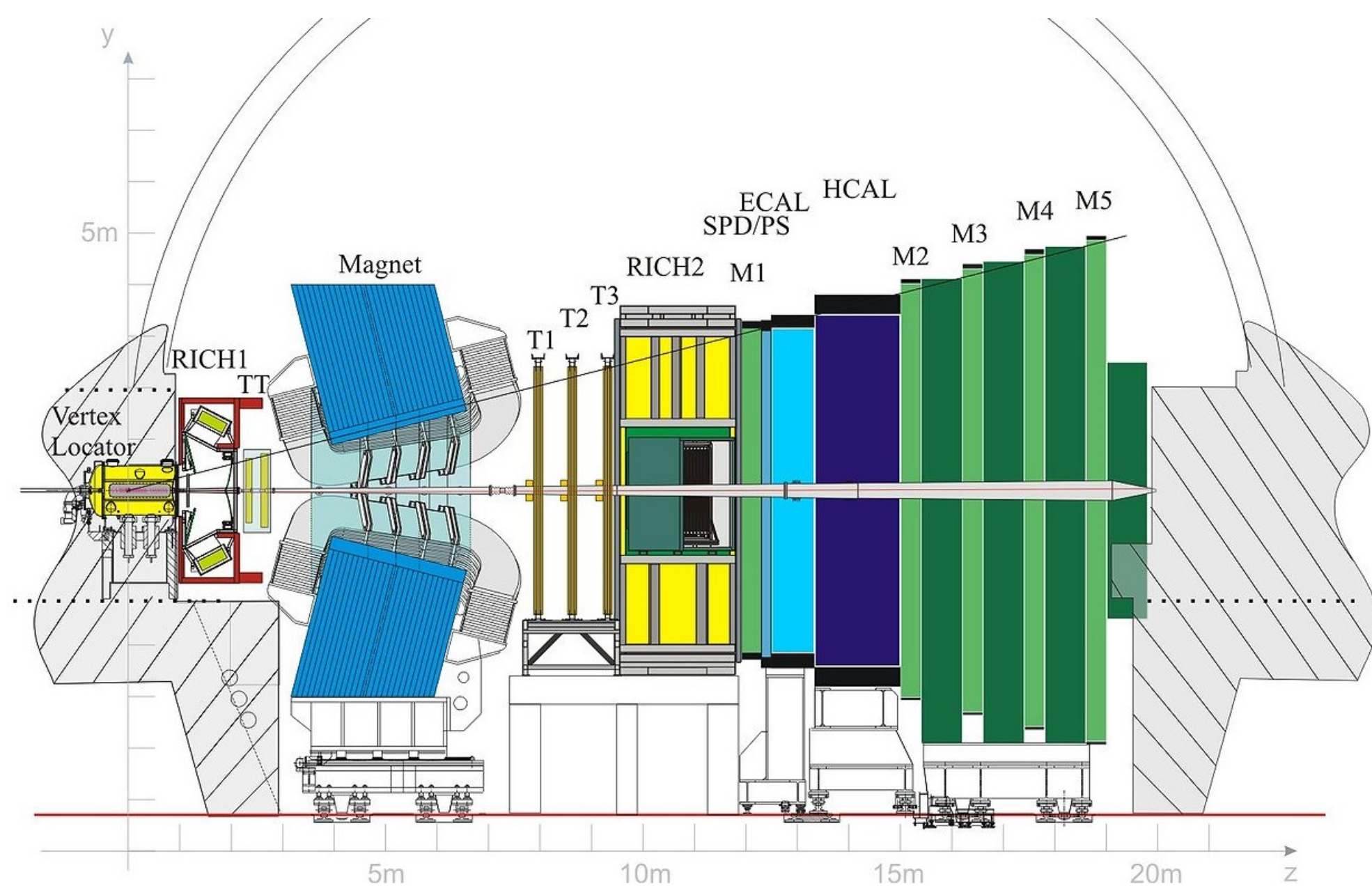


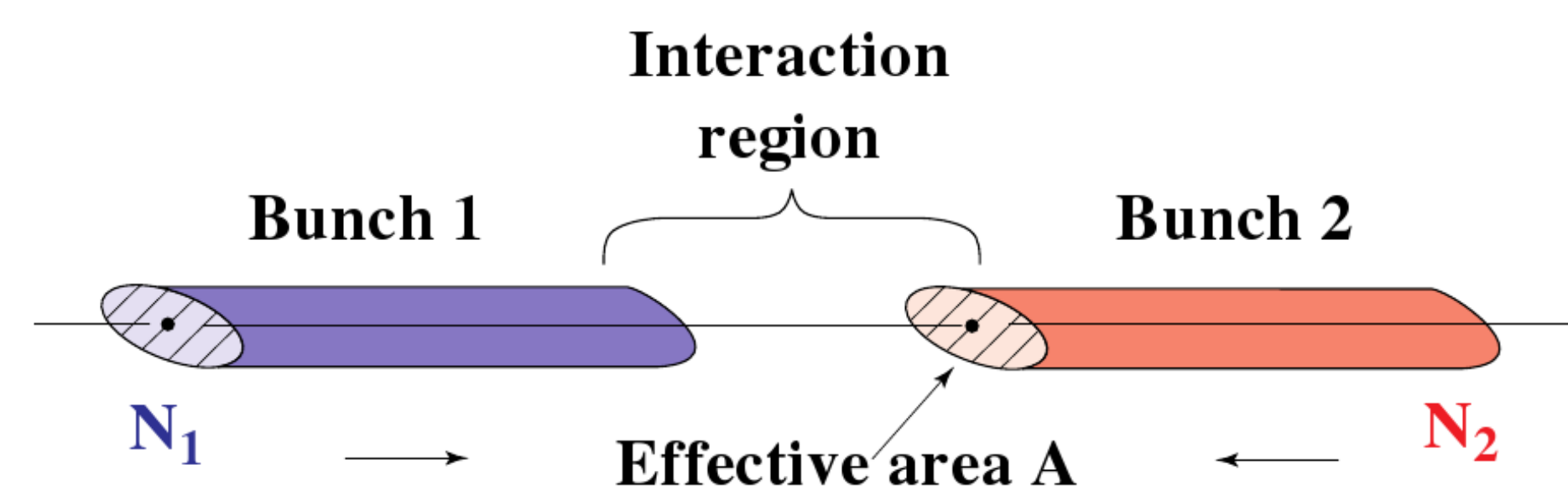
Introduction



- LHCb is a spectrometer designed to measure the decay properties of heavy hadrons [1]
- It has a forward-arm design to benefit from the predominantly forward production of $b\bar{b}$ and $c\bar{c}$ -pairs

Luminosity

- Luminosity is needed for any cross-section measurement $\sigma = \frac{N}{L}$, where N is the number of interactions
- Luminosity is found by counting the number of reference interactions, for accuracy this is done on a bunch by bunch basis
- The reference interaction cross-section σ_{ref} is found in a van der Meer scan



- The number of interactions per bunch crossing [2] is equal to the integral of the density functions of the two bunches $f_1(x, y)$ and $f_2(x, y)$, separated by distance x, y :

$$\frac{N}{N_1 N_2} = \sigma_{ref} \int \int f_1(x, y) f_2(x, y) dx dy \quad (1)$$

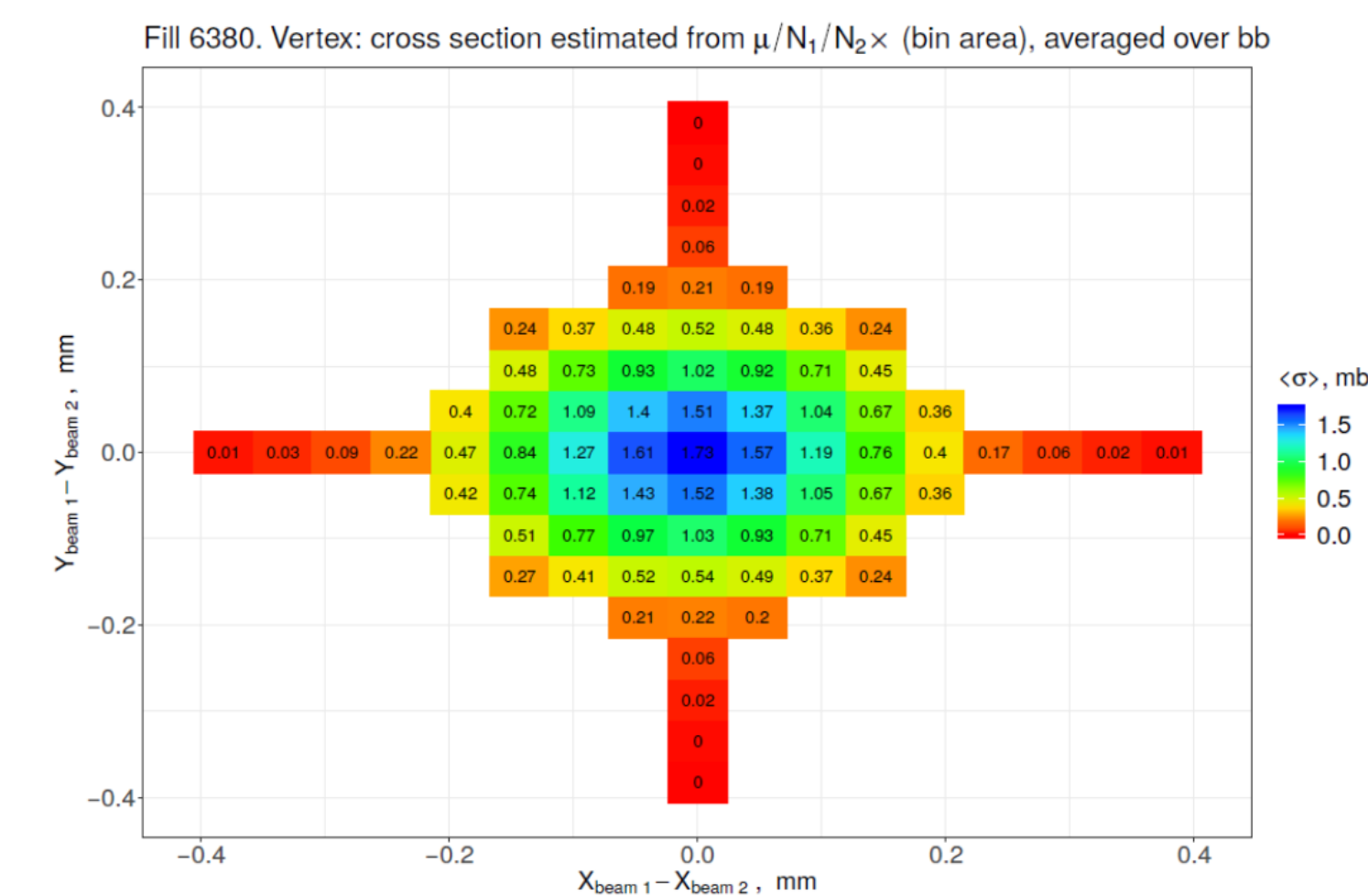
- From this σ_{ref} can be found by integrating over all x, y : a van der Meer (vdM) scan [3]

$$\sigma_{ref} = \frac{N}{N_1 N_2} \int \int dx dy \quad (2)$$

- LHCb makes use of luminosity levelling, in which the two colliding beams are deliberately offset and the gap gradually decreased as the bunch content is depleted, keeping the luminosity flat over time [4]

Novelties in van der Meer scans

- Previously these scans were performed by combining two one-dimensional scans assuming x, y factorization
- However, x, y non-factorization systematics are significant, and it is best measured with a close to full 2D scan, as first done by LHCb in 2017 [5]:



- Other significant systematics are the beam-beam electromagnetic repulsion and beam-orbit drift
- A dedicated B*B simulation for beam-beam effects was developed [2], leading to a 1% difference with previous methods, relevant to all LHC experiments
- As of Run-2, the DOROS Beam Position Monitors [6] are calibrated using the LHCb Beam-Gas Imaging system and allow for precise correction of the beam-orbit drift in vdM scans

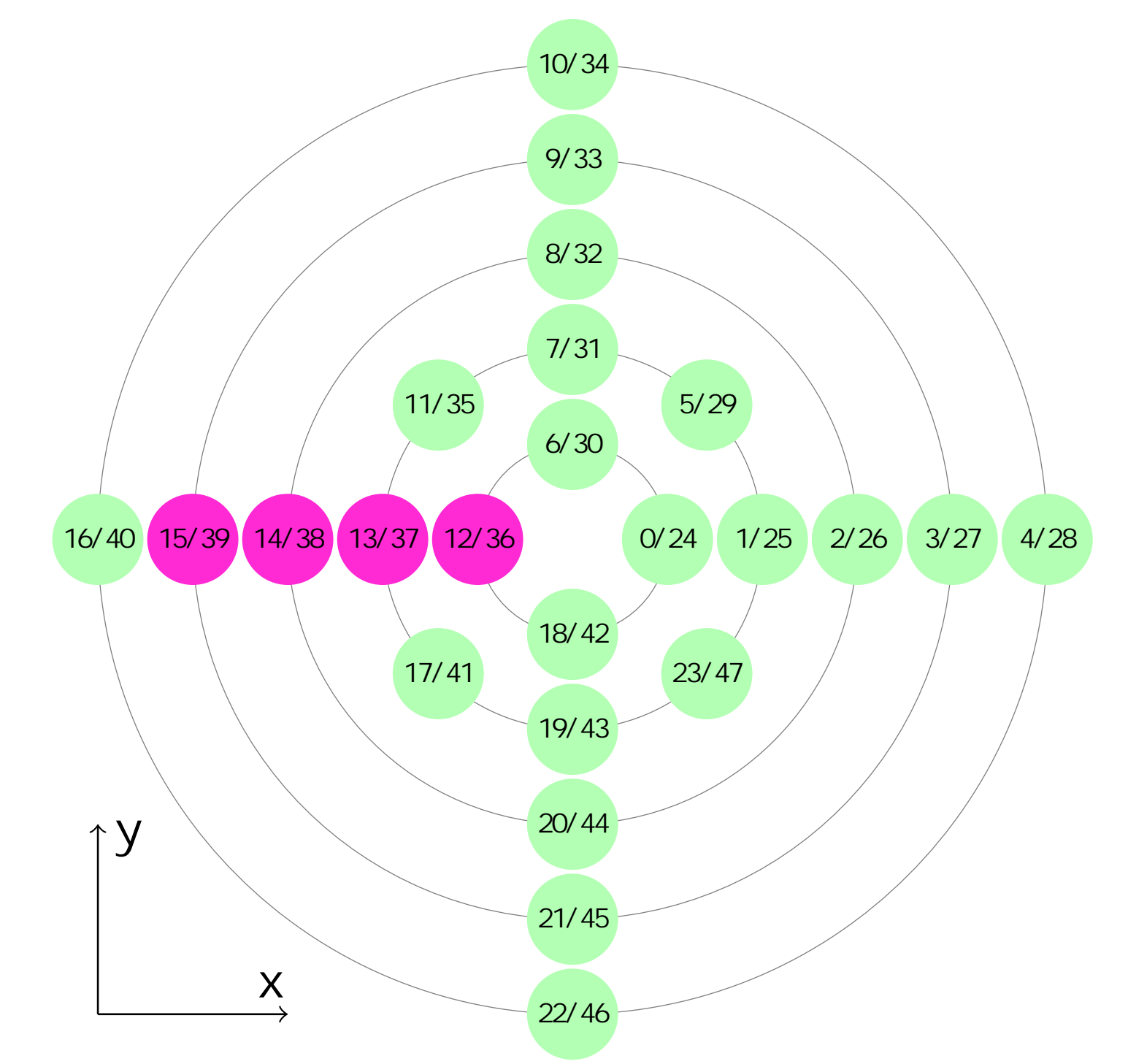
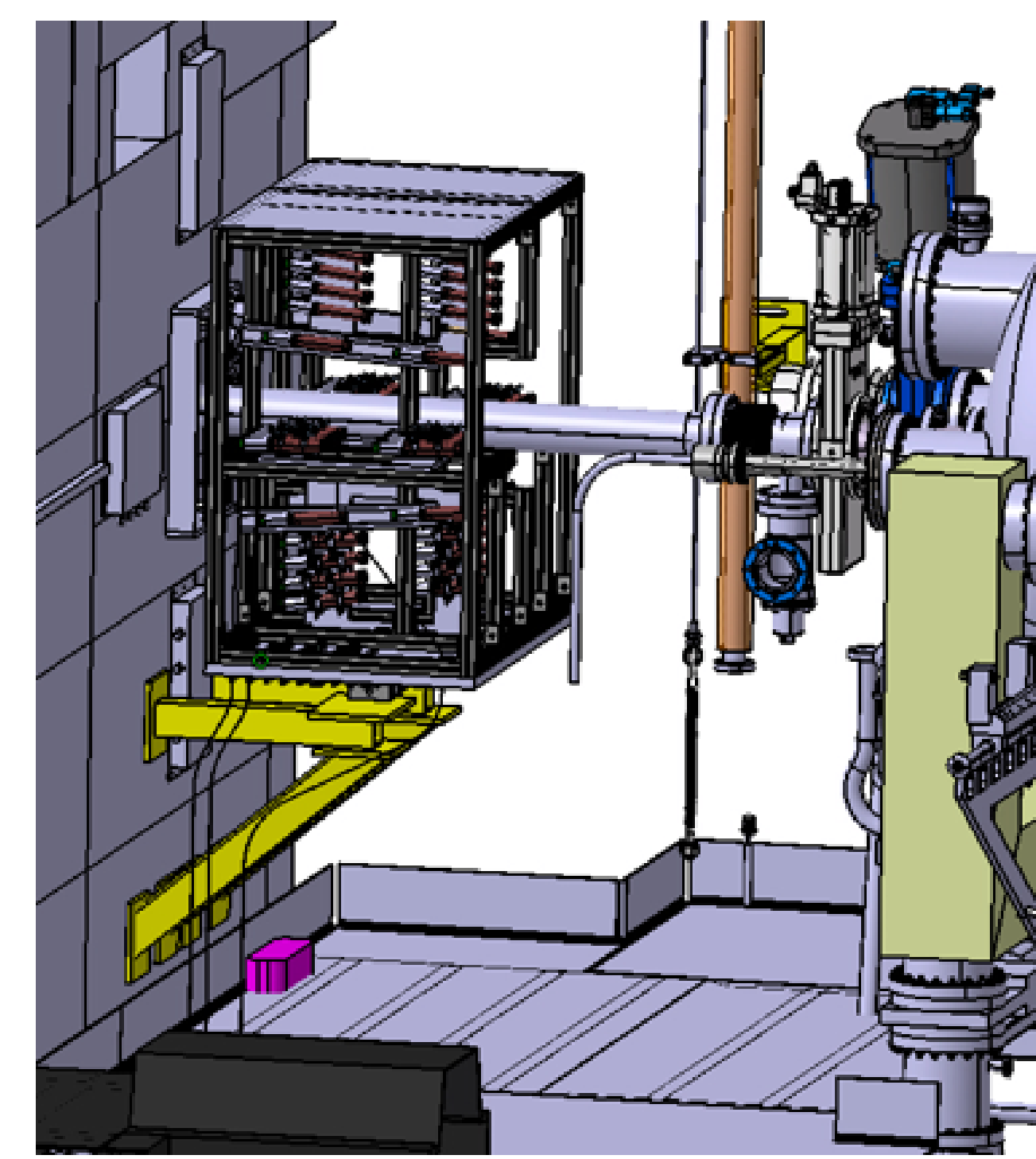
Luminosity at LHCb

- In Run 1, LHCb reached a relative precision of 1.16% on luminosity for pp interactions at $\sqrt{s} = 8$ TeV [7]
- For Run 1+2 online luminosity was mainly provided by the calorimeter, from observed transverse energy in the hardware trigger, which is no longer available in Run-3 due to upgrading to a software-only trigger
- Luminosity will go up a factor 5 from Run-3 onward
- PLUME will provide LHCb with dedicated online and offline bunch-by-bunch luminosity from Run 3 on [8]

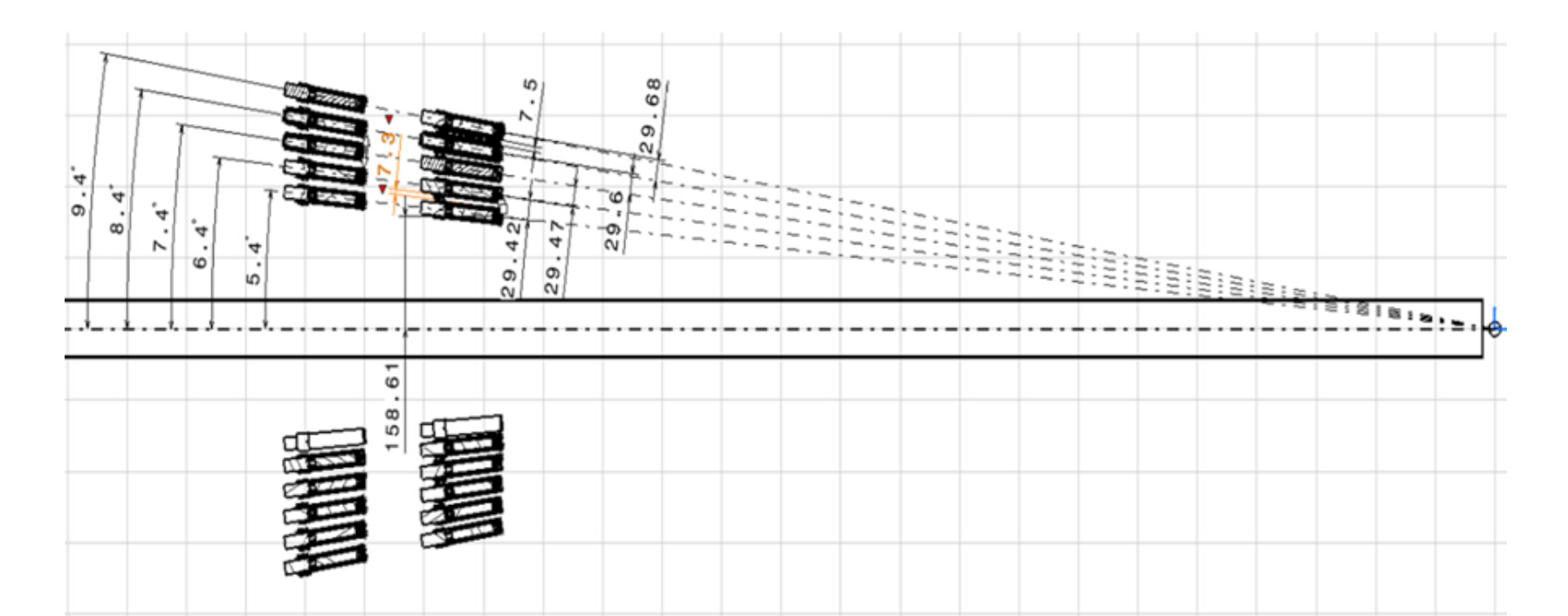
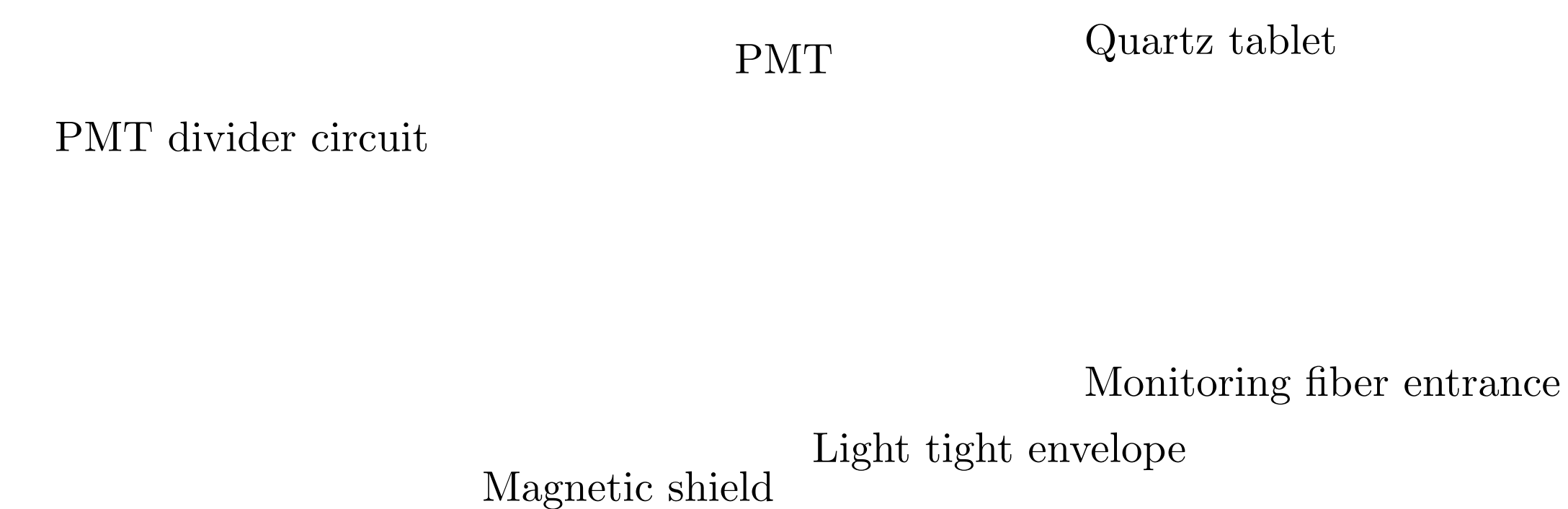
References

- [1] The LHCb Collaboration, *The LHCb Detector at the LHC*, JINST 3 (2008) S08005, <https://doi.org/10.1088/1748-0221/3/08/S08005>
- [2] V. Balagura, *Van der Meer scan luminosity measurement and beam-beam correction*, EPJ C 81 26 (2021), <https://doi.org/10.1140/epj/c/s10052-021-08837-y>
- [3] S. van der Meer, *Calibration of the effective beam height in the ISR*, ISR-PO/68-31 (1968), <https://cds.cern.ch/record/296752>
- [4] F. Follin et al., *Implementation and experience with luminosity levelling with offset beam*, CERN-2014-004.183 (2014), <https://cds.cern.ch/record/1955354/>
- [5] V. Balagura, *Non factorization at LHCb: Two-dimensional vdM scans*, LHC Lumi Days (2019), <https://indico.cern.ch/event/813285/>
- [6] M. Gasior et al., *First Operational Experience with the LHC Diode Orbit and Oscillation (DOROS) System*, IBIC16 (2016) MOPG07 <https://cds.cern.ch/record/2313935>
- [7] The LHCb collaboration, *Precision luminosity measurements at LHCb*, JINST 9 (2014) P12005, <https://cds.cern.ch/record/1951625>
- [8] The LHCb collaboration, *LHCb PLUME: Probe for LUMinosity MEasurement*, CERN-LHCC-2021-002, LHCb-TDR-022 (2021), <https://cds.cern.ch/record/2750034>
- [9] Y. Guz, *The LHCb Calorimeter System: Design, Performance and Upgrade*, LHCb-TALK-2017-032 (2017), <https://cds.cern.ch/record/2255089/>

The PLUME detector



- PLUME will share the region upstream of the VELO (top left figure) with two further detectors contributing to the luminosity, the BCM and RMS detectors, both of which are fixed to the downstream wall
- PLUME consists of two layers, with PMTs 0-23 forming the upstream layer (closest to the VELO) and PMTs 24-47 the downstream layer, arranged as a two-plane hodoscope pointing to the interaction point (see bottom right figure), to allow for rejection of secondaries generated downstream
- Phase-1 of PLUME (eight detector modules equipped with the monitoring system) were installed for the LHC test run in October (top right figure, shown in magenta) and the remainder will be installed for the start of Run-3



- Each PMT is equipped with a quartz radiator, and the signal is generated by Cherenkov light in the radiator and front window (left figure) encased in magnetic shielding
- The detector will be read out using LHCb ECAL electronics based on the ICECAL chip [9]
- PLUME will be laid out with a monitoring system allowing an LED pulse to be injected into each PMT, used to stabilize the gain as the PMT degrades
- Final calibration will use single tracks reconstructed in the VELO to check the light yield in the PMTs combined with the LED-based monitoring