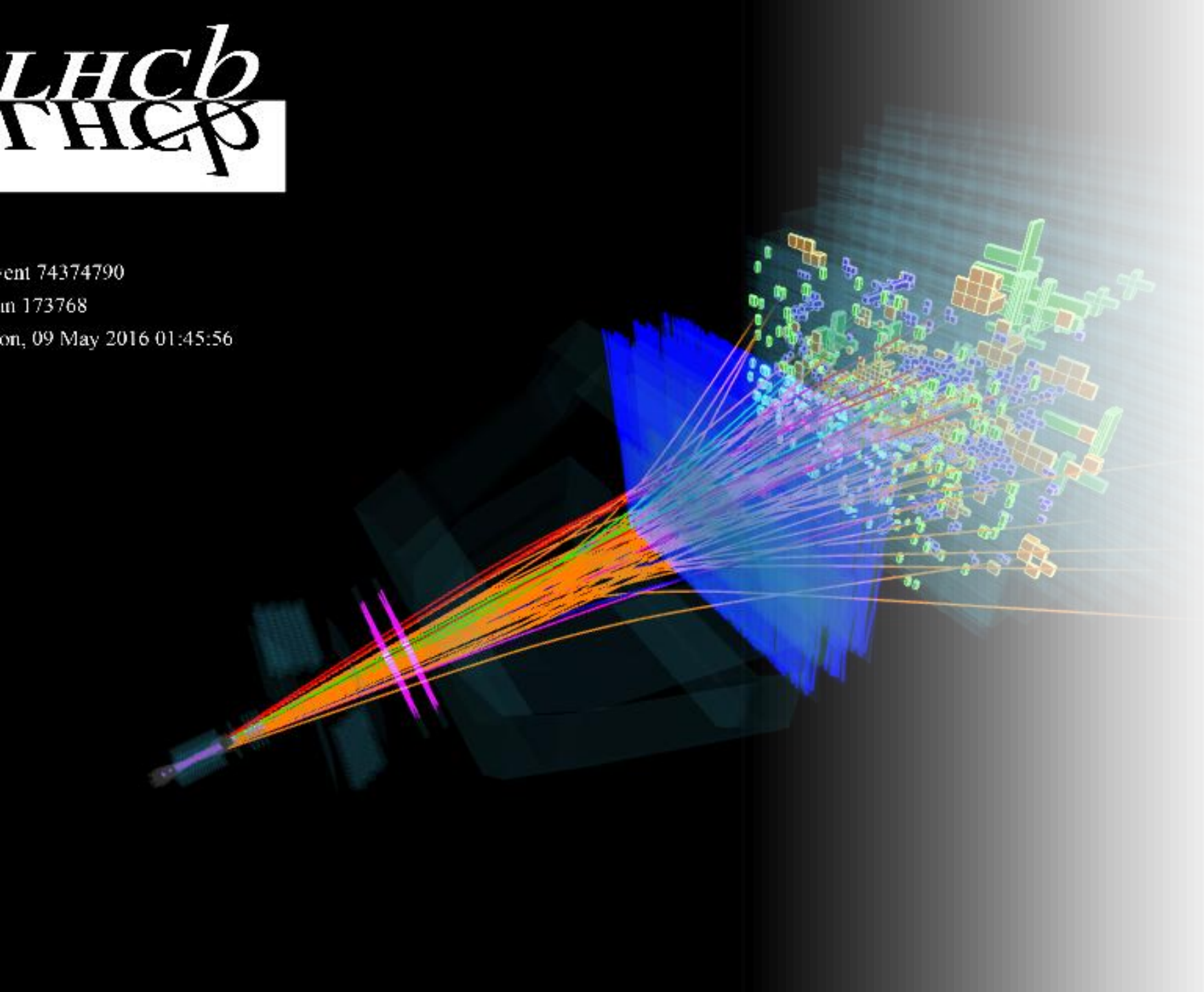
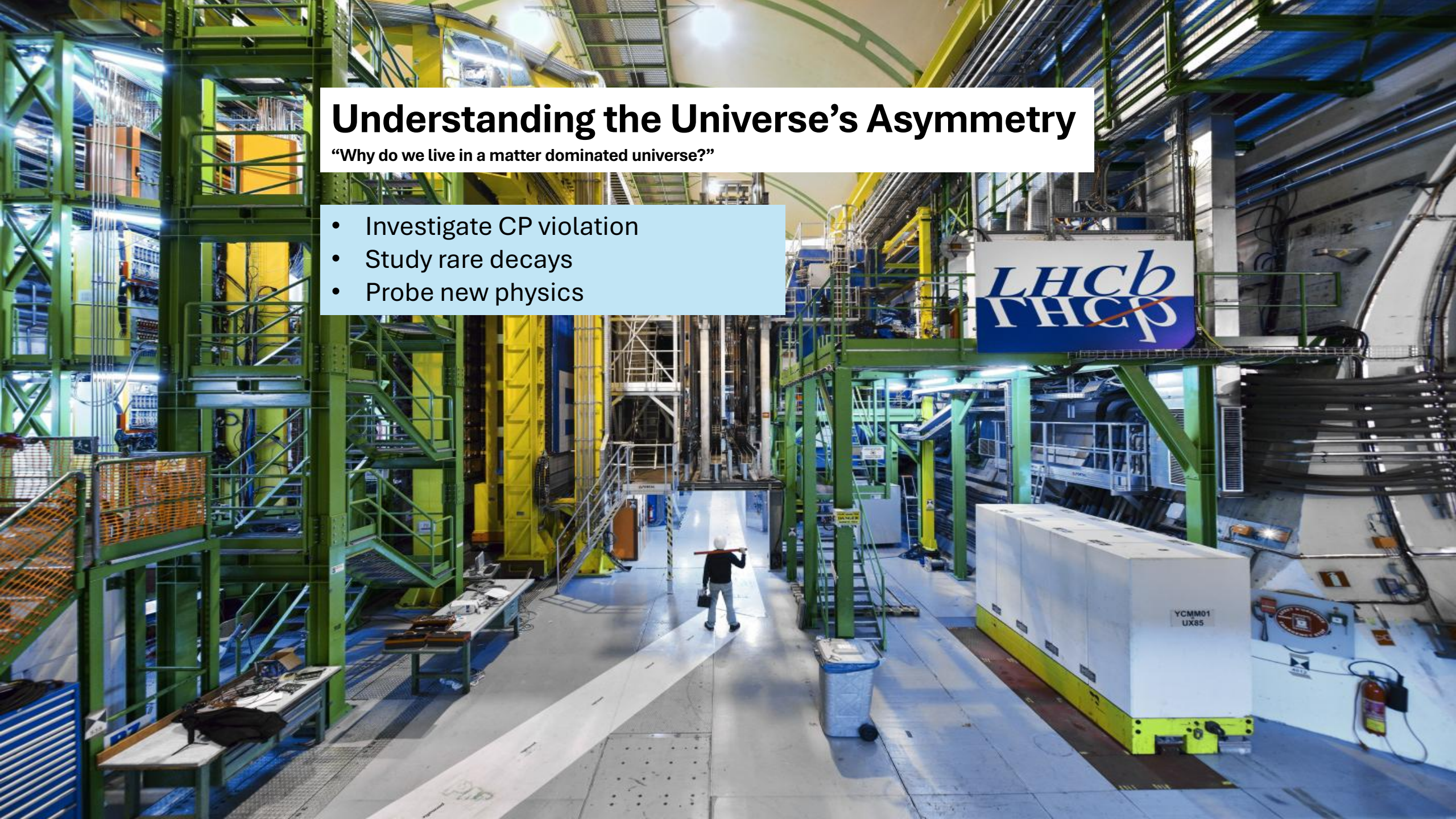


The LHCb VELO Detector

Introduction & Purpose of the LHCB
The VELO detector, introducing subcomponents: ASICs, Pixels
ASIC properties of the VELO detector
Calibration of pixels and ASIC
ASIC data collection architecture
Operational conditions of the VELO
References



Understanding the Universe's Asymmetry

"Why do we live in a matter dominated universe?"

- Investigate CP violation
- Study rare decays
- Probe new physics

Vertex LOcator

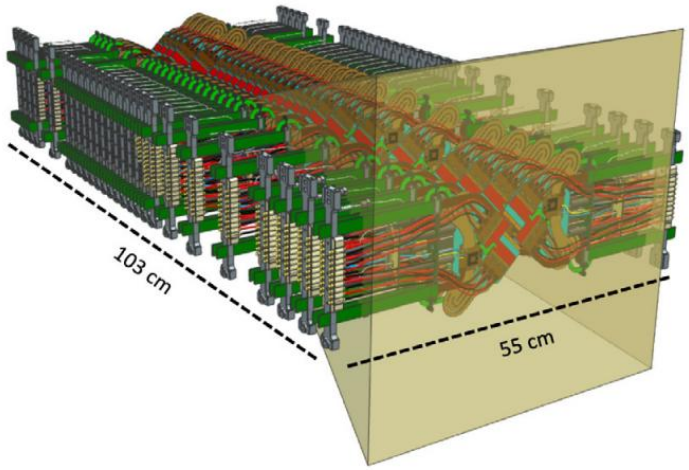
- The *primary vertex* is the point where protons collide (and where particles containing b quarks are created)

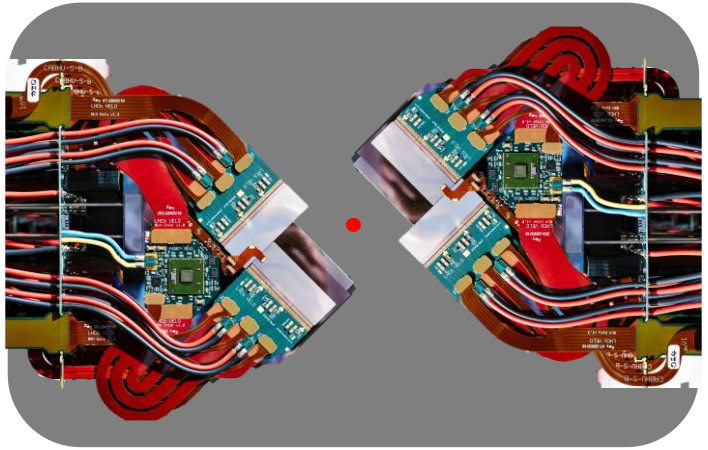
proton-proton interaction point

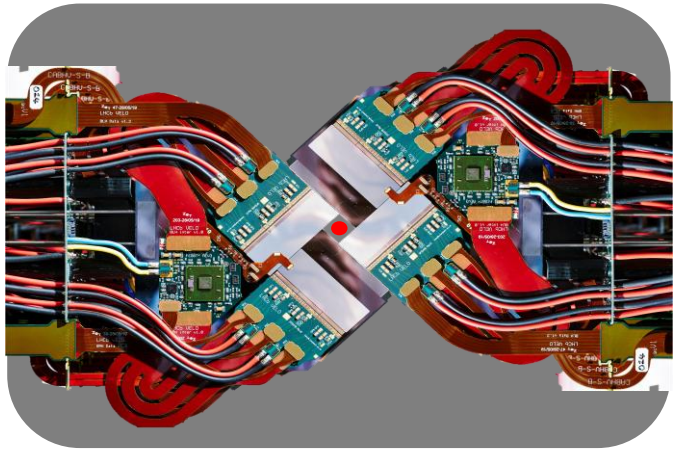
- The *secondary vertex* is the point where these particles decay, spraying out other particles which the LHCB detects

The VELO's purpose is to extremely accurately measure the position of these vertices to allow indirect measurements of B hadrons to within 10 microns

VELO Pixel Detector





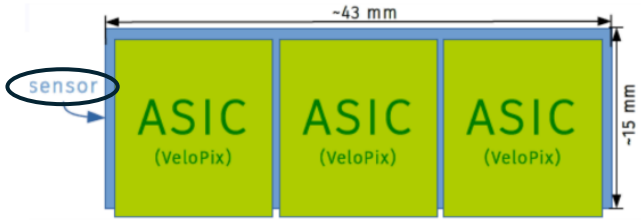


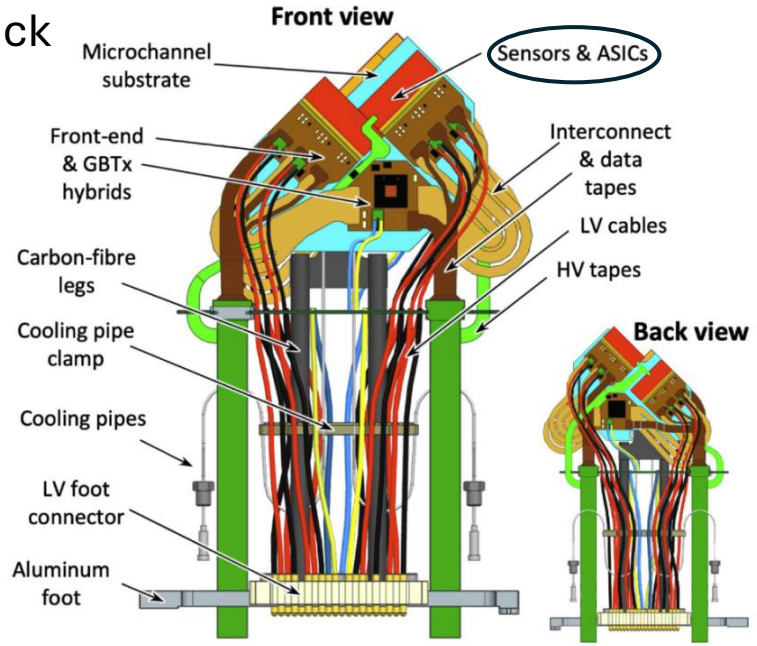
During injection the VELO is kept open to ~25 mm between the center dot, and the detector.

Once the beam is stable the VELO is slowly closed to be as close as possible to the beam, leaving a gap of ~5.1 mm between the center dot, and the detector.

Both with an accuracy of 10 µm

- 52 modules consisting of 200 µm thick n-on-p silicon detectors
- 1 module = 12 Velopix ASICS
- 1ASIC = 256x256 pixels
- 1 Pixel = 55 x 55 µm
- Total ~41 million pixels

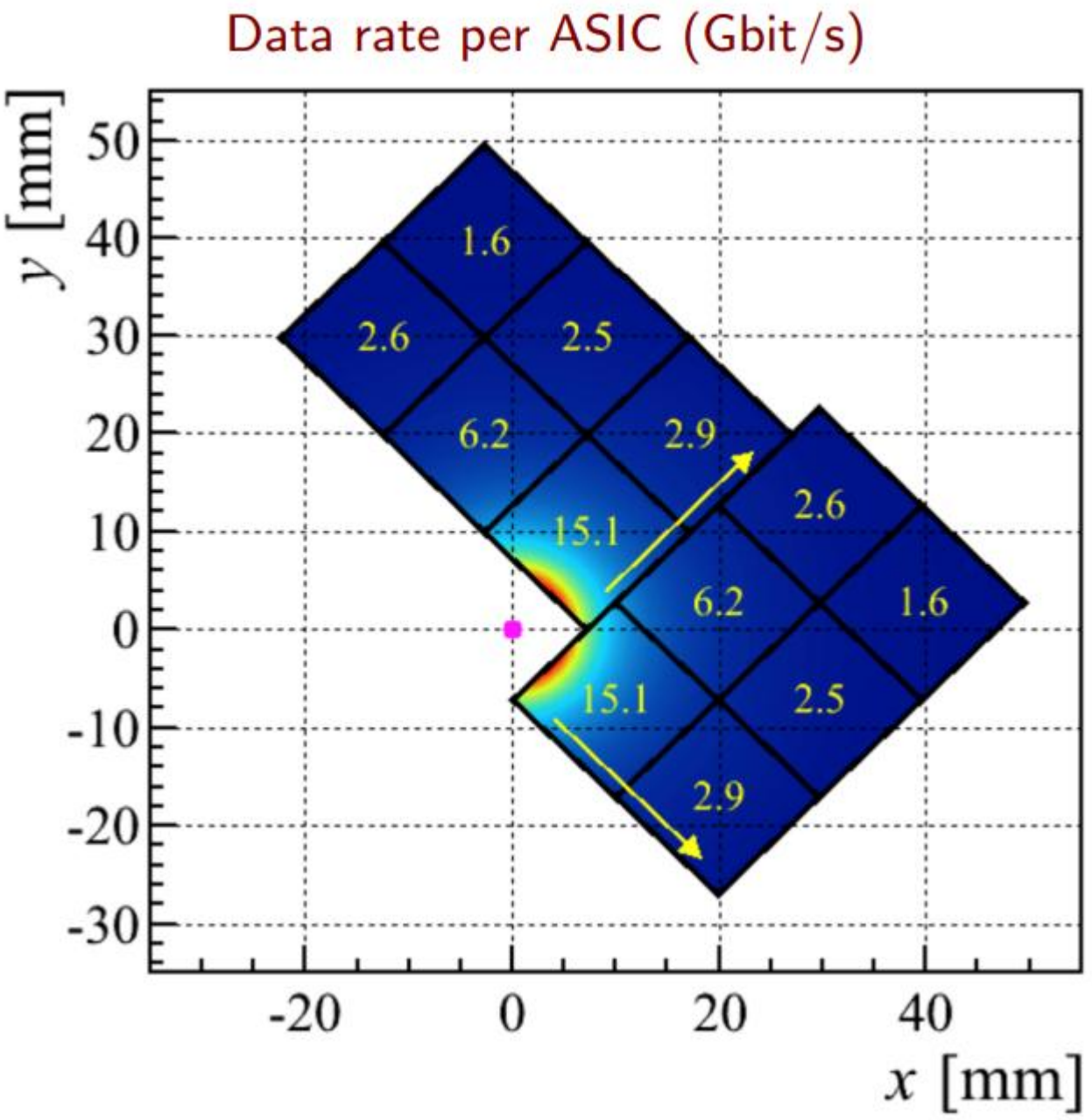




- Closest active element is 5.1 mm from interaction region
- Expected total ionizing dose 400Mrad
- Operate with leakage current of 7nA/pixel at end of life

- Average (Peak) rate of 600 (900) Mhits/s
- Hottest ASIC has rate of 15.1 Gbits/s
- Timing resolution: 25ns

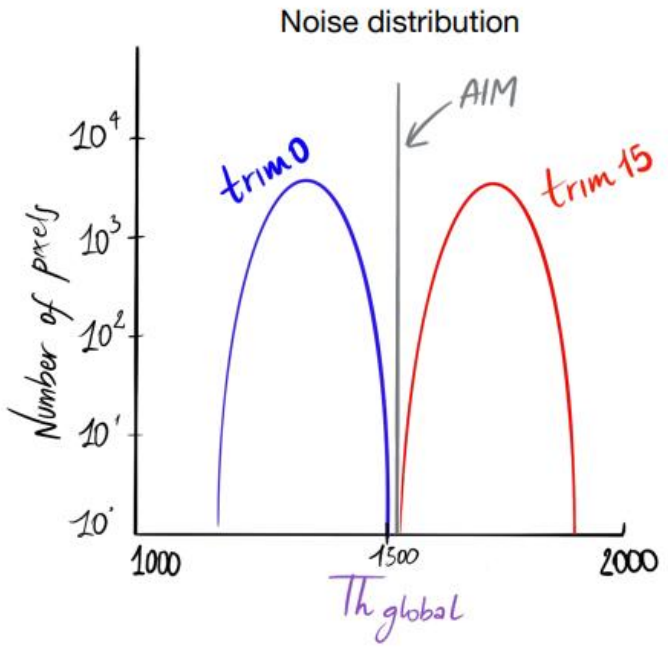
- Hit efficiency > 99%
- Qualified up to 1000 Volt bias current



2 important calibrations for proper measurement

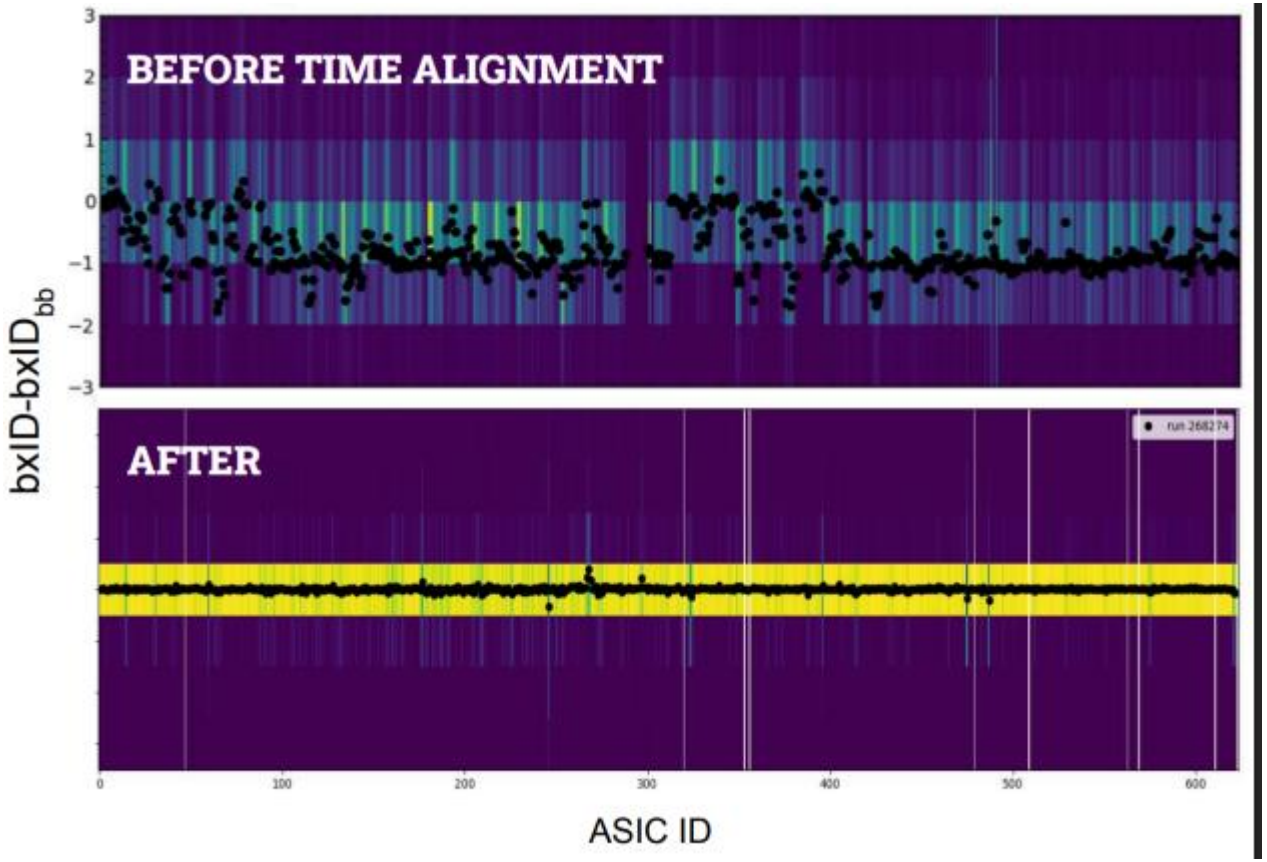
Equalization

$$Th_{local} = Th_{global} + trim$$



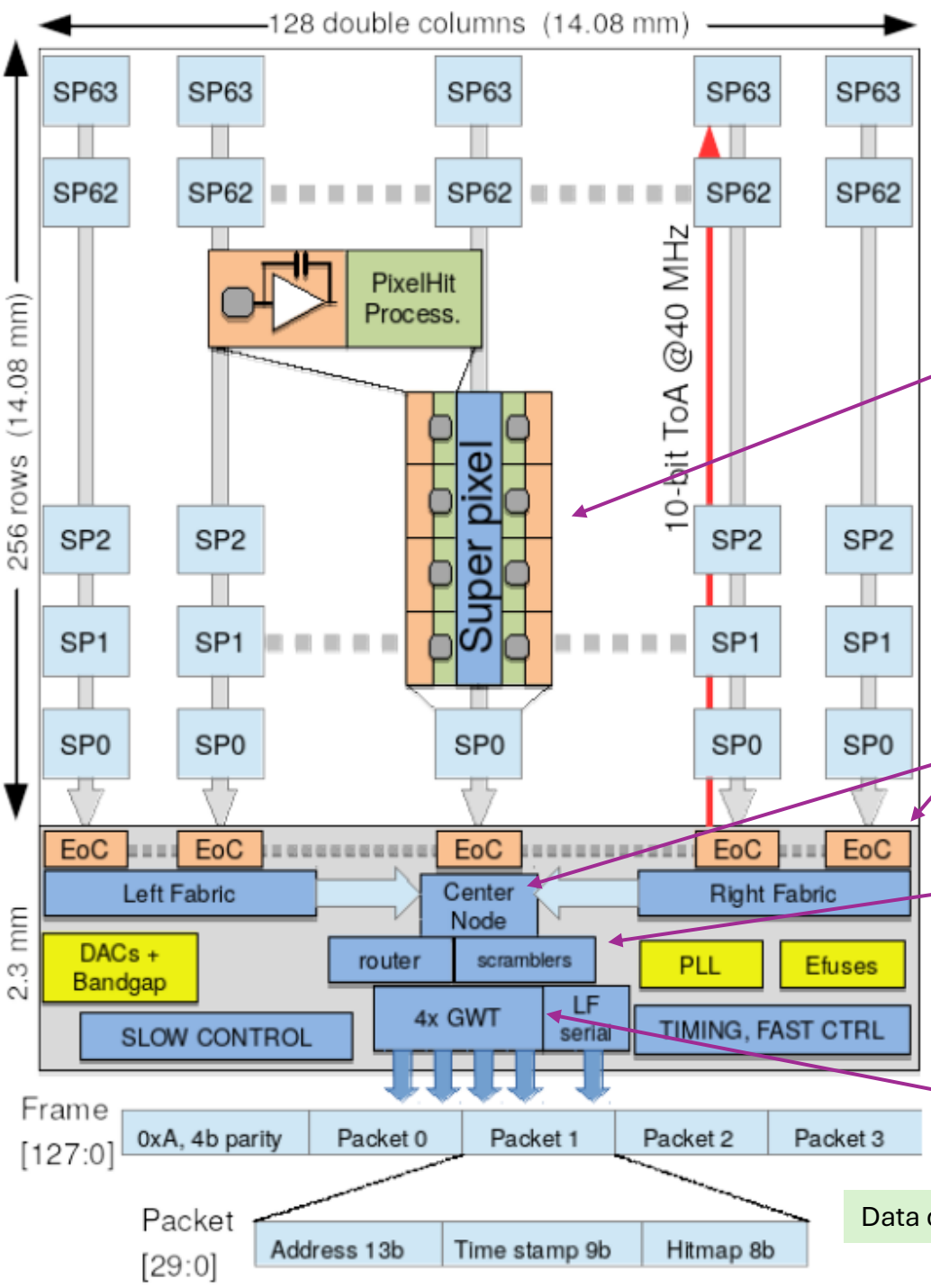
Calibrated each pixel to ensure consisten response to noise across the detector

Time alignment



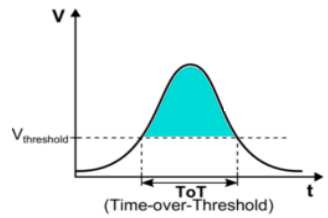
Due to different amplitudes hits have different ToT durations shifting the registration times of the hits. By synchronizing this with the LHC isolated bunch crossing ID (bxID), hits can be calibrated to the correct timing

Down the rabbit hole of VeloPix architecture



Data collection

- Velopix transmits binary data generated from ToT measurement in each pixel
- Combining information in “Super Pixels”, grouping 8 pixels in 2x4 grid sharing addres and time stamp info saving 30% data volume
- Data is vertically transmitted with clock rate of 160MHz until it reached End of Column block (Eoc)
- Data sent to Central node which assembles data in 128 bit frames and feed into the scrambler
- Scrambles uses Linear Feedback Shift Registers (LFSR) to avoid potential DC offsets, reducing electromagnetic interference and proper clock recovery
- Gigabit Wireline Transmitter (GWT) serializes the data feeding to ensure radiation hardening

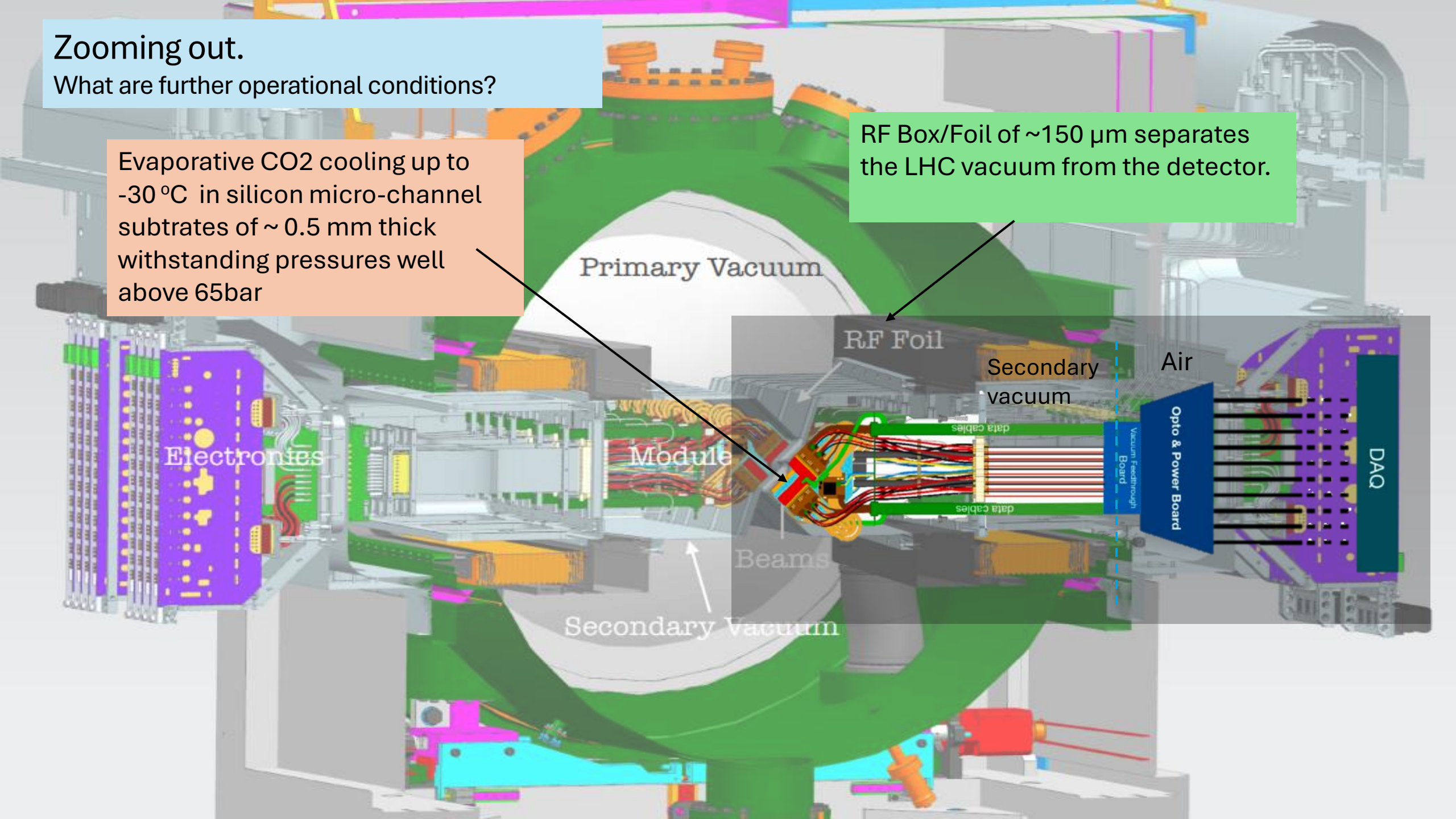


Zooming out.

What are further operational conditions?

Evaporative CO2 cooling up to -30 °C in silicon micro-channel subtrates of ~ 0.5 mm thick withstanding pressures well above 65bar

RF Box/Foil of ~150 µm separates the LHC vacuum from the detector.



References:

- https://indico.cern.ch/event/1291157/contributions/5876968/attachments/2899104/5083506/2024-07-18%20ICHEP.pdf
- https://cds.cern.ch/record/2802195
- https://cds.cern.ch/record/2655464/files/VeloPix_Pixel2018_KDeBruyn.pdf
- https://indico.cern.ch/event/1291157/contributions/5876968/attachments/2899104/5083506/2024-07-18%20ICHEP.pdf
- https://cds.cern.ch/record/2900026/files/Publication.pdf
- https://www.nikhef.nl/news/bloedstollend-lhcb-detector-sluit-zich-voor-het-eerst-behoedzaam-om-lhc-bundel/
- https://www.researchgate.net/publication/338926330_Phase_I_Upgrade_of_the_Readout_System_of_the_Vertex_Detector_at_the_Experiment
- https://ep-news.web.cern.ch/content/upgrading-vertex-detector-lhcb-experiment
- https://lhcb-outreach.web.cern.ch/detector/vertex-locator-velo/
- https://cds.cern.ch/record/2846414/files/LHCb-PROC-2023-001.pdf
- https://fse.studenttheses.ub.rug.nl/27620/1/bPHYS_2021_ClandfieldL.pdf
- https://indico.cern.ch/event/1233430/attachments/2591386/4471987/decapua_VeloUpgrade.pdf