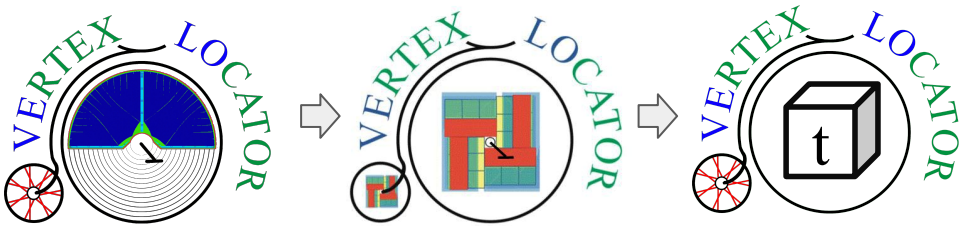
3D R&D for LHCb VELO

Kazu Akiba, Martin van Beuzekom, Victor Coco, Paula Collins, Adriano Lai, et al.



Requirements and Timeline

The LHCb Upgrade is planned for **Run 5**, installation in **LS4** (2032) → planned sensor Submission in **2028**.

The detector is planned (hoped) to have spatial resolution better than **10 μm** and timing better than **50 ps** per hit.

Radiation dose is estimated to be about **2.5E16 1MeV neq/cm2**.
Irradiation has a **nonuniform profile** approximately of 1/r2

Planarity of final assemblies needs to be within +/- 5 μm

Groups involved

Initiative from CERN, INFN/Cagliari and Nikhef. Open to more collaborators.

Dedicated workforce (>3 FTE) to contribute with simulations and characterisation.

Several industrial partners identified. Discussing further details with FBK and SINTEF.

Open to other partners. Full list of specifications available at:

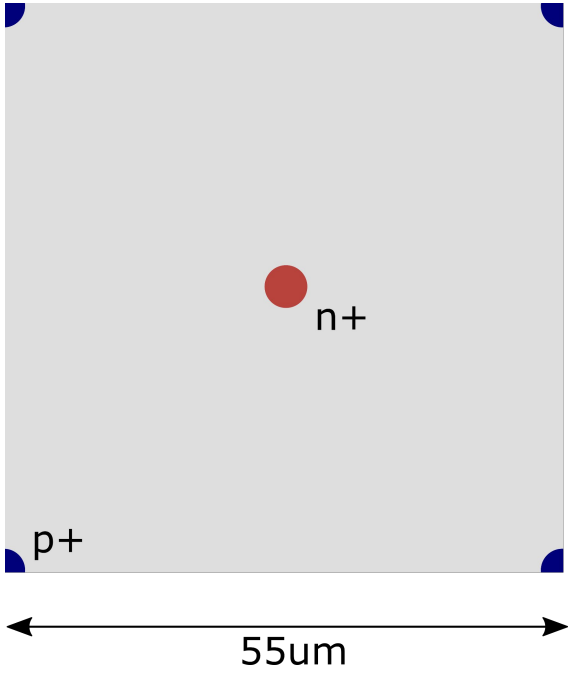
https://cernbox.cern.ch/s/yiXPHpK08aKSkQz

Pitch

Test ASIC is expected to be Timepix4 initially, followed by PicoPix (Jan/2026) -- Picopix aims for 50 ps overall with 40 ps TDC bin.

Picopix pitch will be defined soon and help decide the small 3D cell size. Expected to be between 45 and 50 μm.

IGNITE64 ASIC could also go as small as 45 μm.

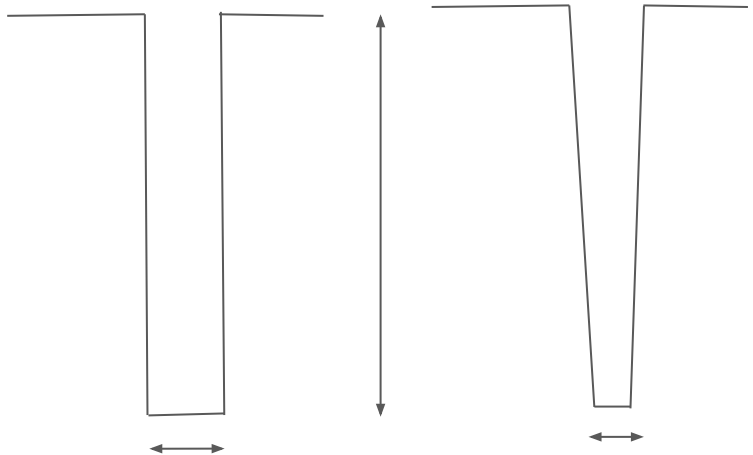


Aspect ratio and capacitance

In this proposed project we would like to emphasise the minimisation of column width → maximising aspect ratio.

Column tapering is a challenge for high voltage tolerance.

Controlling the capacitance is important for the amplification stage.



Different electrode configurations

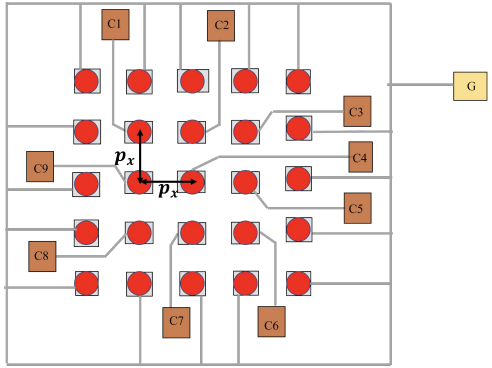
Test Structures:
"Single pixel" configuration cells

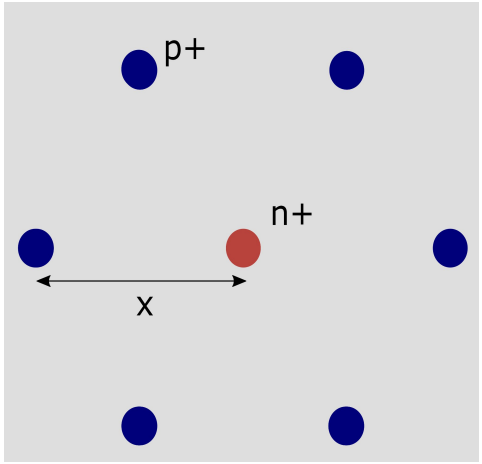
Multiple pixel configuration:

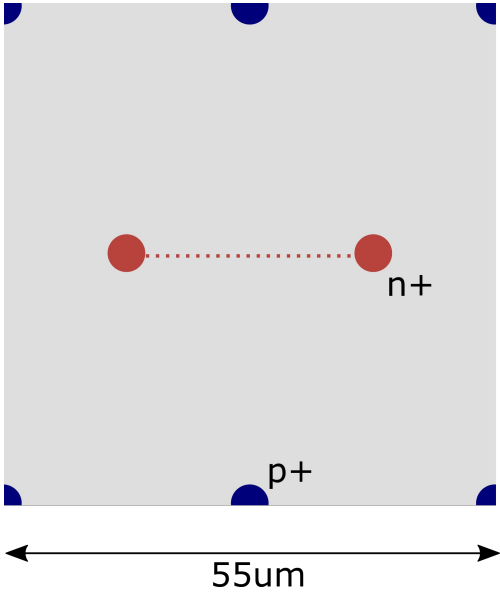
- 3x3, 4x4, 5x5 under consideration.
- to be connected to fast amplifier boards to allow measurements of charge sharing and interpixel efficiencies and time stamping capabilities
- And capacitance measurements

Small matrices:
- 64×64 pixels with the total matrix sizes bigger than 3x3 mm^2 to allow flip-chipping
- possibility to have several variants.

Large matrices:
- Timepix3 size: pitch 55×55 μm and 256×256 pixels





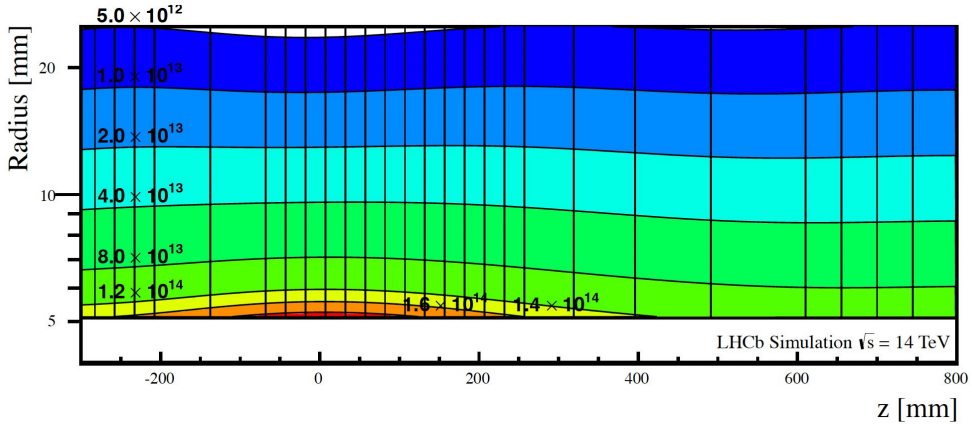


Irradiation + Characterisation campaign

Need to prove non-uniform radiation tolerance and Timing stability

→ Radiation profile can change by a factor 100 in 4 cm!

Characterization of timing and spatial resolutions to be performed before and after irradiation.

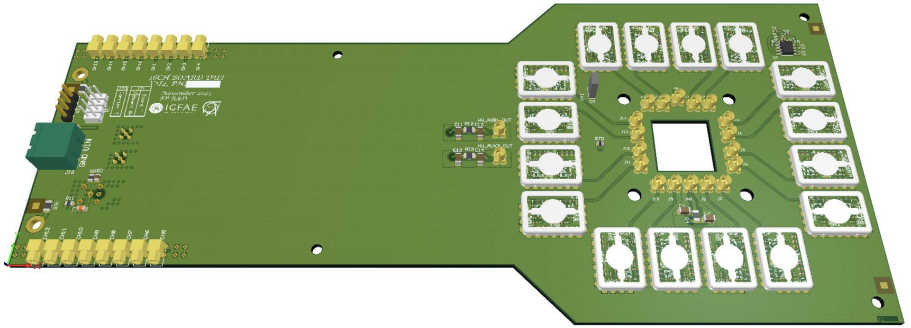


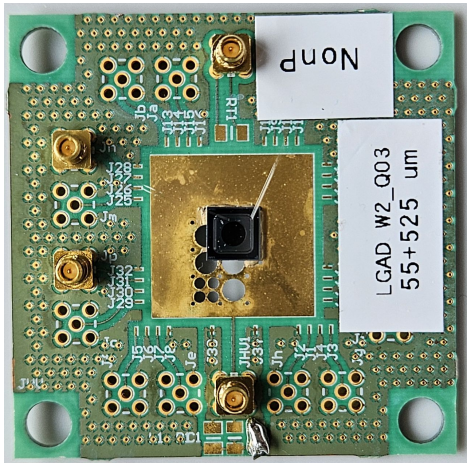
Tester board for test pixels.

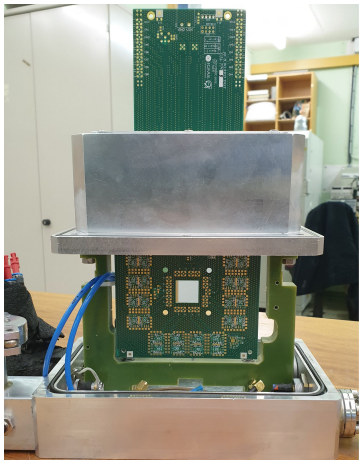
16 channel board based on two stage Transimpedance Amplifier (TIA)

Allows testing of test structures with any size of pixel cells

- Gain ~ 70
- PCB design with bandwidth > 6 GHz

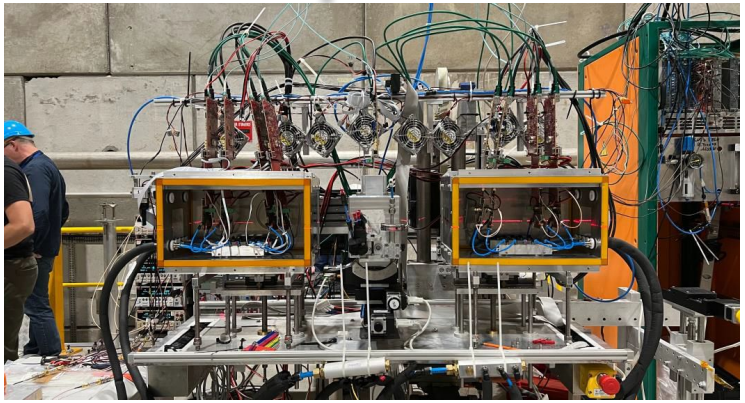




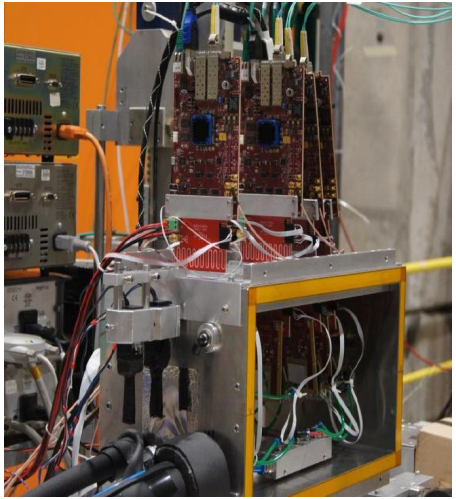


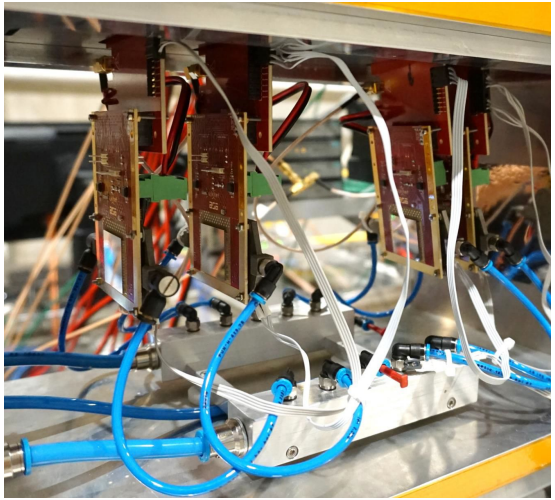
Characterisation at the Timepix4 Telescope

- The telescope aims to be a high rate (> 10 MHz) high resolution in space (~2 μm) and time (<20ps).

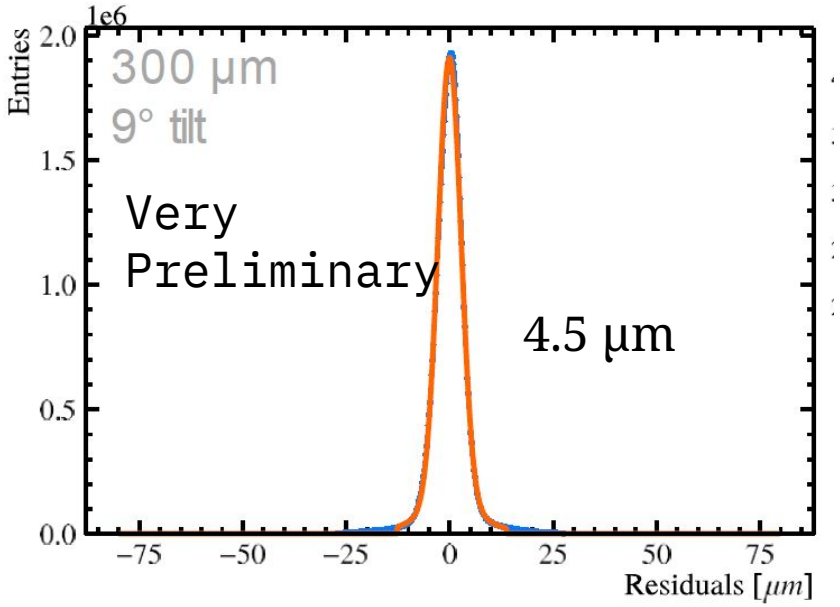


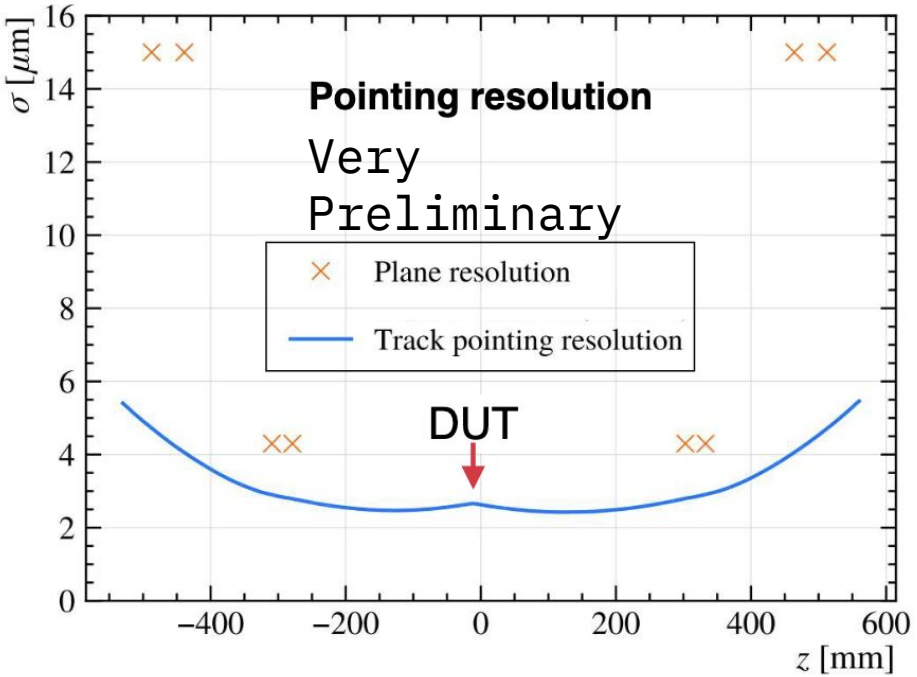
- Composed of spatial planes (300 μm thick) and timing planes(100 μm), plus Cherenkov-MCPs.



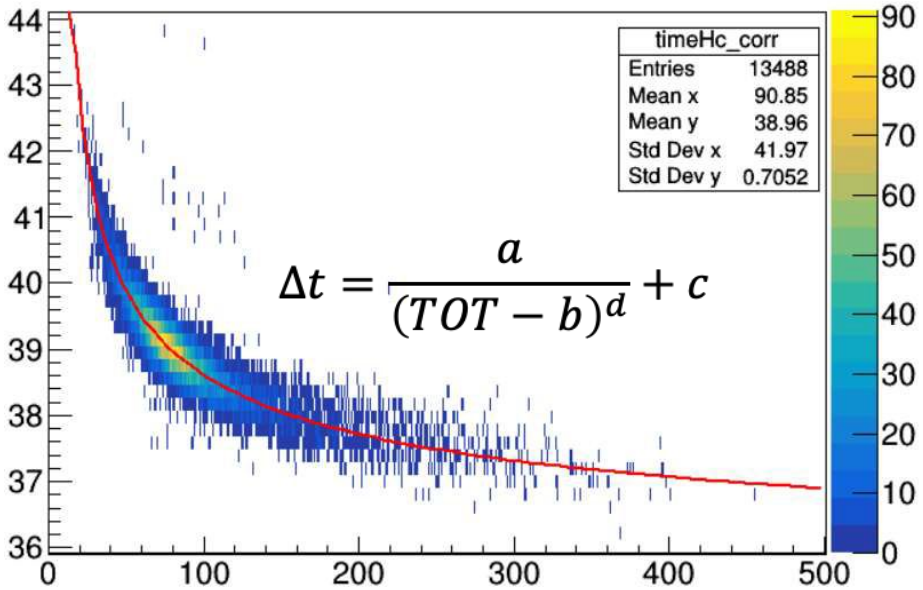


Spatial resolutions

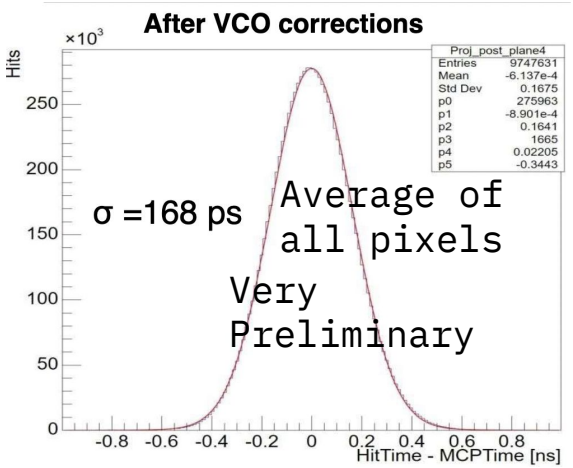


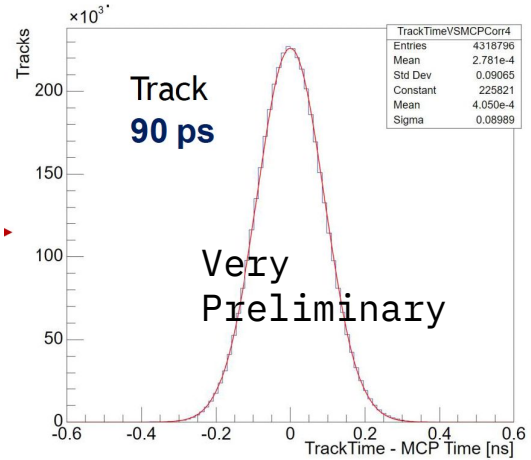


Timing - results of Timepix4+100μm planar



Timewalk curve – Small charge signals have worse resolution





Summary

Launching 3D R&D for pre-production, characterisation and irradiation.

Spatial resolution, Timing performance and efficiency as main simultaneous goals.

Radiation resistance is expected but nonuniform operation is a challenge

→ how does timing and efficiency compare at low and high irradiation doses in the same sensor?