Performance studies of the CE-65v2 MAPS prototype structure

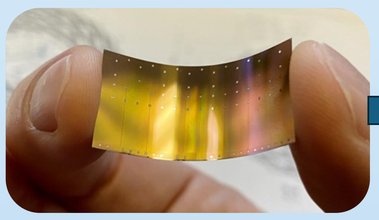
Alessandra Lorenzetti
University of Zürich
alessandra.lorenzetti@cern.ch

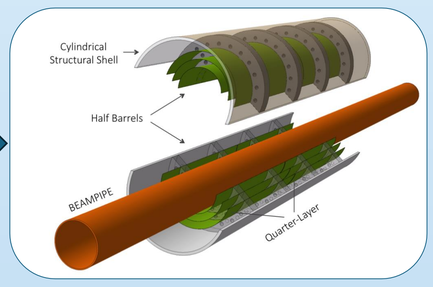
On behalf of the ALICE collaboration and the CE-65 team

Study of the global and in-pixel efficiency and resolution of different variants of the CE-65v2 MAPS

ALICE ITS3

- Upgrade of the Inner Tracking System, installation in 2027-30
- Three innermost layers of ITS2 will be replaced with wafer-scale, thin, bent sensors
- Ultra-light design to minimise multiple Coulomb scattering

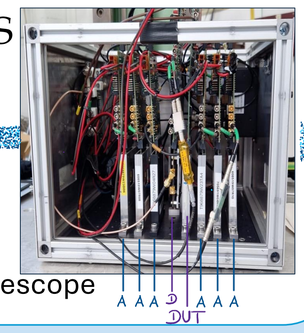


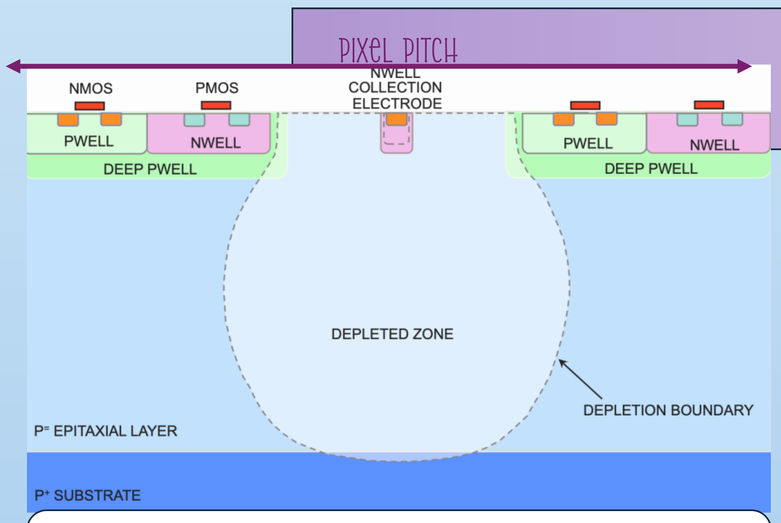


Requirements	ALICE ITS3	FCC-ee vertex
Sensor spatial resolution	5 µm	3 µm
Material budget per layer [X_0]	0.07%	< 0.3%
Radiation tolerance [1MeV n_{eq}/cm^2]	10^{13}	~ 10^{14} per year
First layer radius r_{min}	19 mm	13.7 mm
Power density	40 mW/cm^2	≲ 50mW/cm^2
Partial hit density	8.5 MHz/cm^2	~ 250 MHz/cm^2

Testbeam at CERN SPS

- Mixed hadron beam
- Telescope consists of:
  - 6 ALPIDE planes
  - DPTS as trigger
  - 2.2 µm resolution of telescope



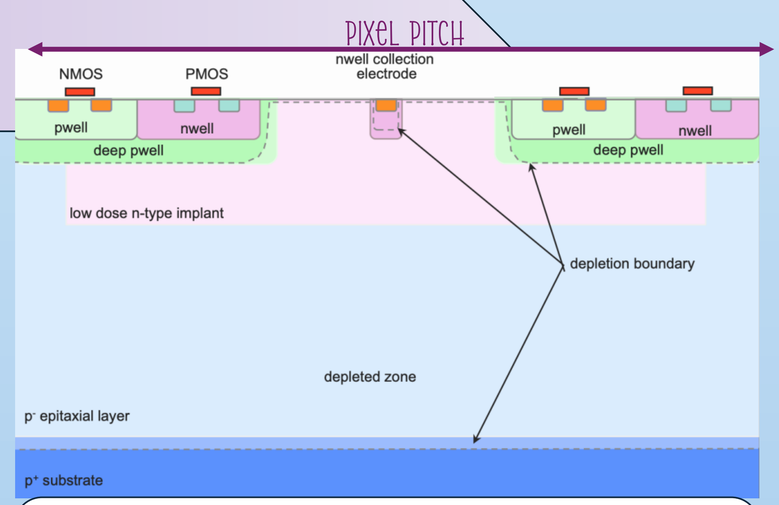


Undepleted regions at the pixel edges
→ Charge collection is *diffusion-dominated*

Faster charge collection, better efficiency

Standard process	Modified with gap process
• High charge sharing between neighb. Pixels	• Low charge sharing
• Slow charge collection	• Even at the edges fast charge collection
➢ subject to charge trapping, less radiation tolerant	➢ More radiation tolerant

More charge sharing, better resolution



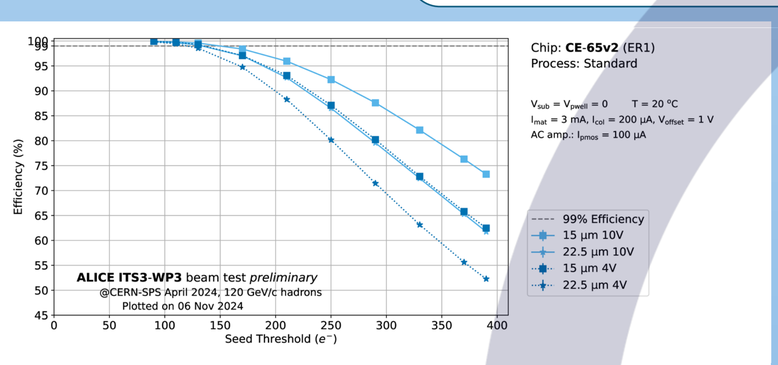
Electric field expands laterally due to gap in low dose n-type implant at pixel edges
→ Charge collection is *drift-dominated*

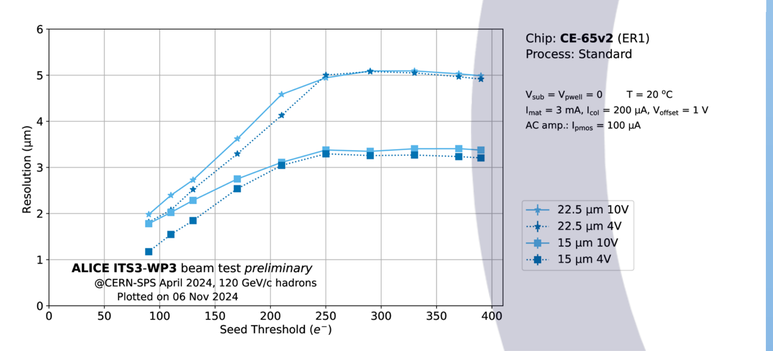
Test beam data analysis details

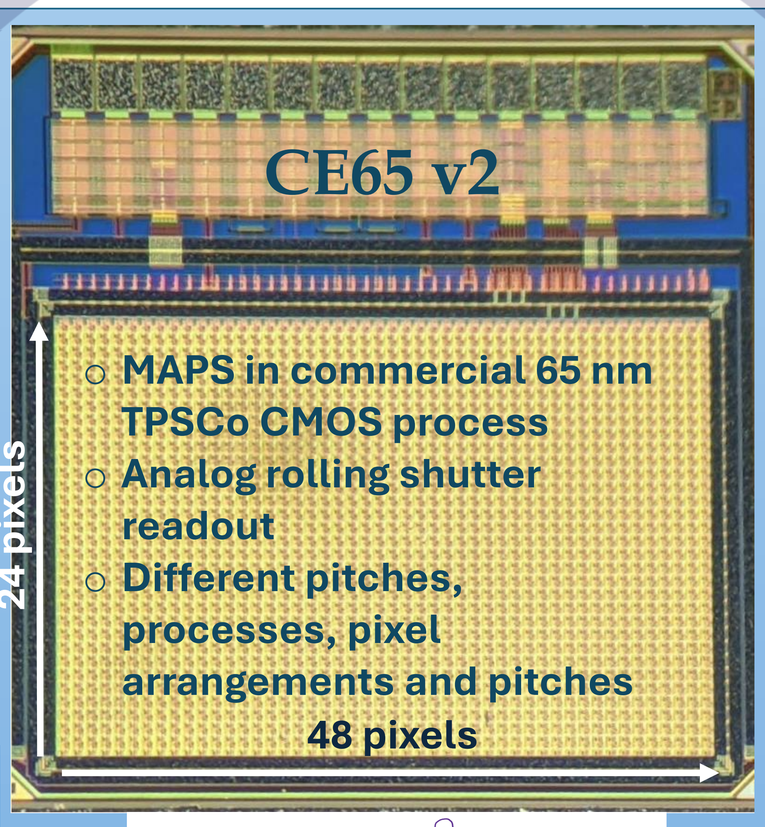
- Mask noisy pixels on reference and DUT
- Telescope pre-alignment and alignment → DUT pre-alignment and alignment → Analysis
- *Cluster* method with threshold$_{neibhbour}$ = threshold$_{seed}$
- First seed threshold at 3 x RMS noise
- Subtract telescope resolution in quadrature

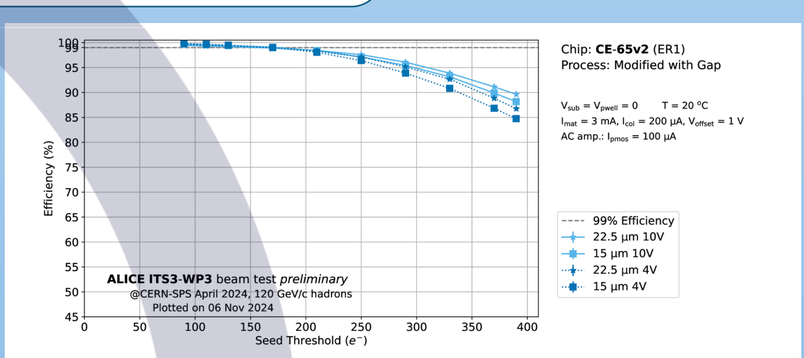
Standard process

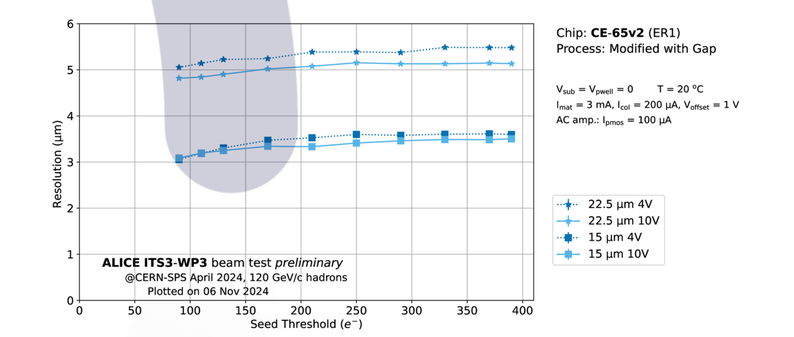
Modified with gap process





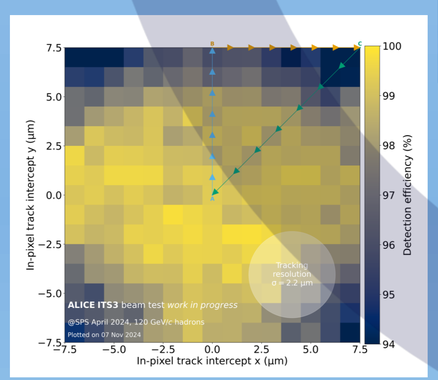


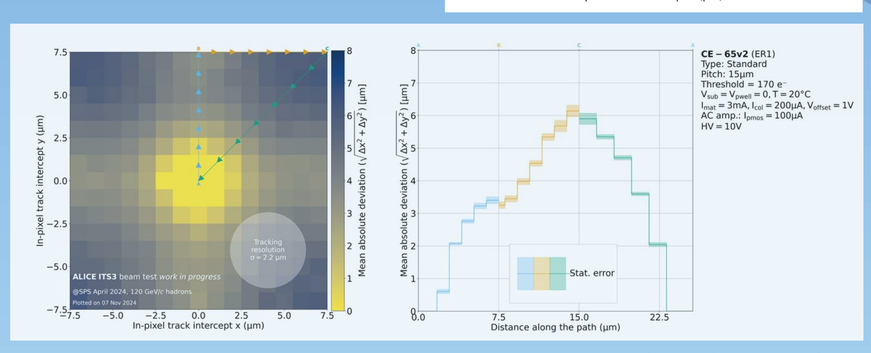


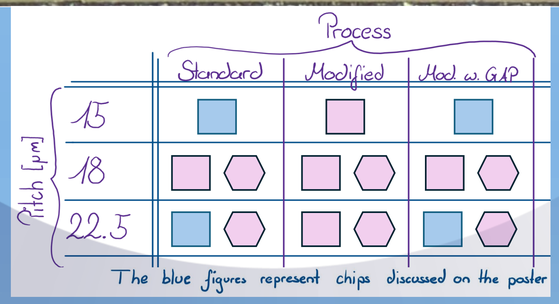


Standard

- Better efficiency for 10V than 4V
- < 2.5 µm and < 3.5 µm resolution for 15/22.5 µm pitch at efficiencies > 99%

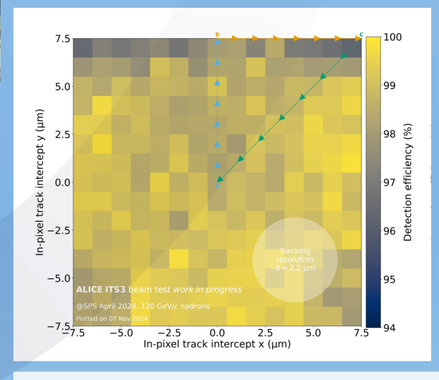


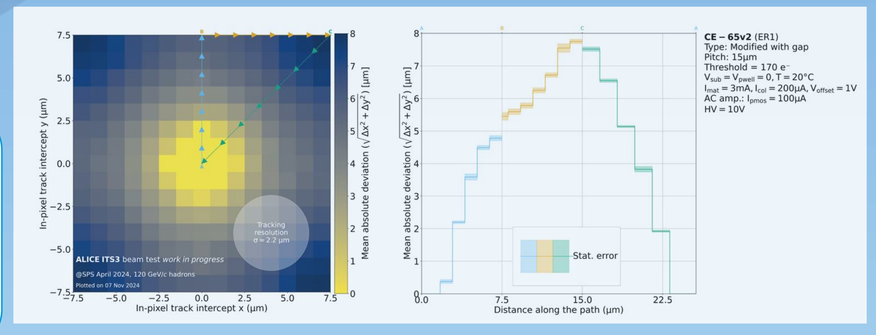




Modified with Gap

- Negligible impact of higher voltage
- < 3.5 µm and < 5.5 µm resolution for 15/22.5 µm pitch at efficiencies > 99%





In-pixel discussion

- Modified with gap process has higher efficiency at edges and corners, slightly worse in the centre
- Better resolution in standard process comes from edge and corner regions, thanks to charge sharing

Outlook and Conclusion

- Resolution < 3.5 µm resp. < 5.5 µm, efficiency greater than 99% at thresholds larger than 3 × RMS noise
  - Compatible with FCC-ee spatial resolution requirement. Further development needed to fulfil other requirements
- Detailed in-pixel studies possible thanks to large matrix size. Result confirming previous findings on process variations
- CE-65 v2 characterisation almost finished
  - ➢ Radiation tolerance of CE-65 under investigation (May 2024 test beam at DESY)
  - ➢ Request for SPS test beam in 2025 to test 18 µm pitch and modified process in detail

Bibliography

- The ALICE collaboration, Technical Design report for the ALICE Inner Tracking System 3 - ITS3 ; A bent wafer-scale monolithic pixel detector, (2024).
- Full report on the FCC Feasibility Study mid-term review. Scientific Policy Committee - Three-Hundred-and-Thirty-Sixth Meeting, (2023).
- S. Bugiel et al., Charge sensing properties of monolithic CMOS pixel sensors fabricated in a 65 nm technology, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **1040**, 167213 (2022).