Performance of the Analog Pixel Test Structure in 65 nm TPSCo CMOS imaging technology for the ALICE ITS3

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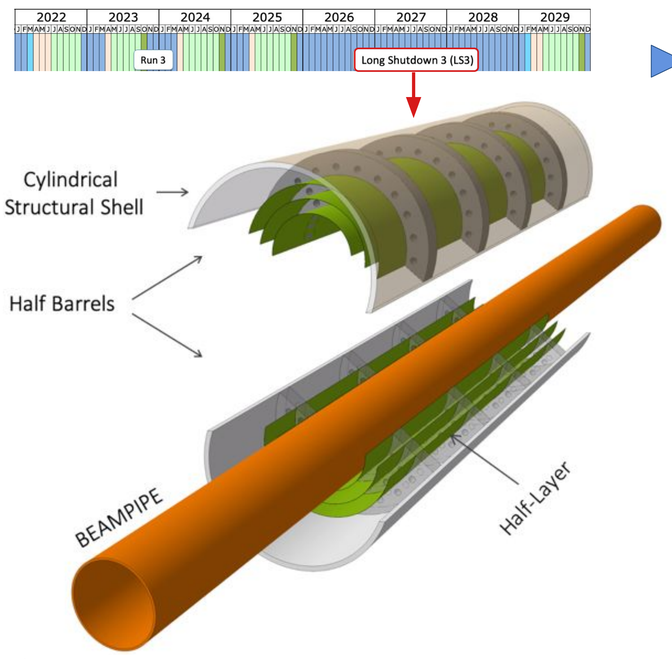
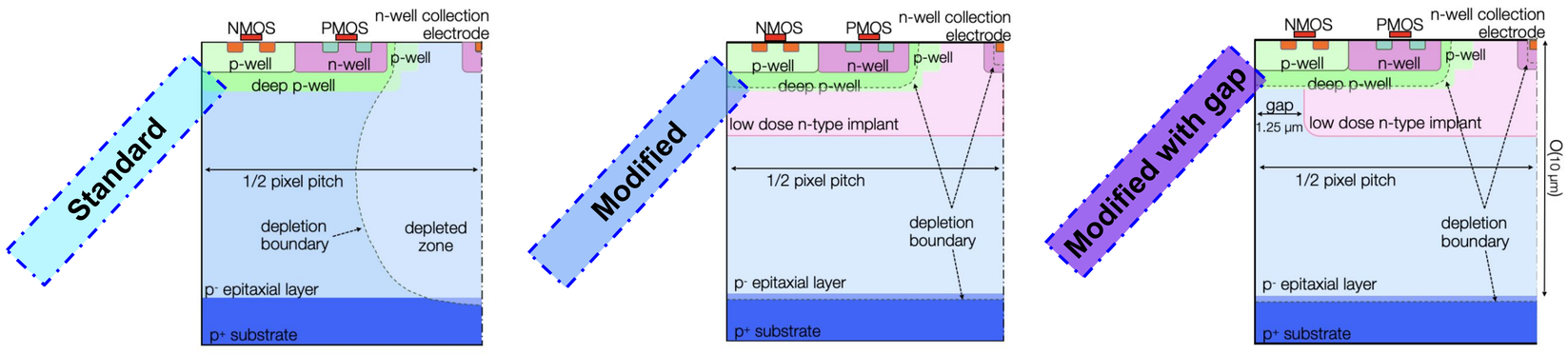
Technical Design Report of the ITS3 – A bent wafer-scale monolithic pixel detector, ALICE Collaboration, December 11, 2023, Journal of Physics G: Nuclear and Particle Physics

http://dx.doi.org/10.1088/1748-0221/14/05/C05013
https://doi.org/10.1016/j.nima.2017.07.046



ALICE ITS3 involved in the evaluation of the **TPSCo 65 nm technology** performance for particle detection: different process modifications with **small collection electrode**



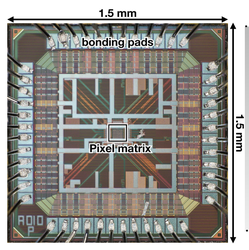
reduced charge sharing and faster charge collection

Multiple **L**ayer per **R**eticle "**MLR1**" submission: first sensor prototypes in TPSCo 65 nm process in collaboration with CERN EP R&D on monolithic sensors

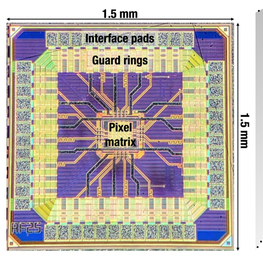
Two small-scale analogue pixel prototypes chip with different versions of the output buffer: a source-follower (**APTS-SF**) and an operational amplifier (**APTS-OA**)

addressed to measure the time resolution!

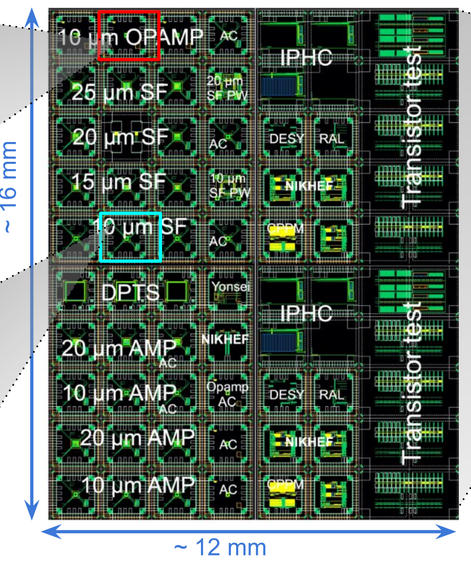
→ purpose: testing pixel cell
→ 6x6 pixels matrix
→ pitch: 10, 15, 20, 25 µm
→ direct analogue readout of central 4×4 submatrix
→ 3 process modifications

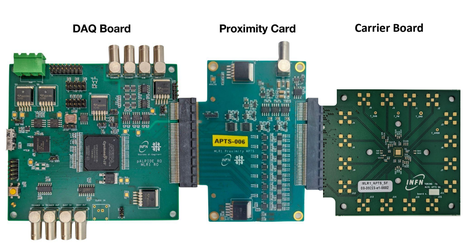


APTS-OA

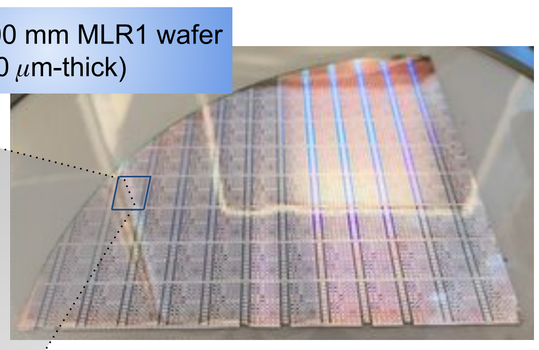


APTS-SF

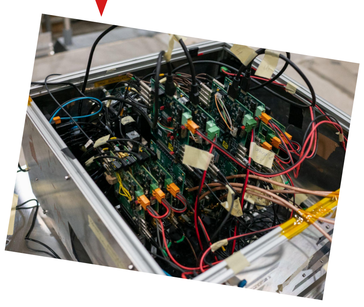




1/4 of a 300 mm MLR1 wafer (50 μm-thick)



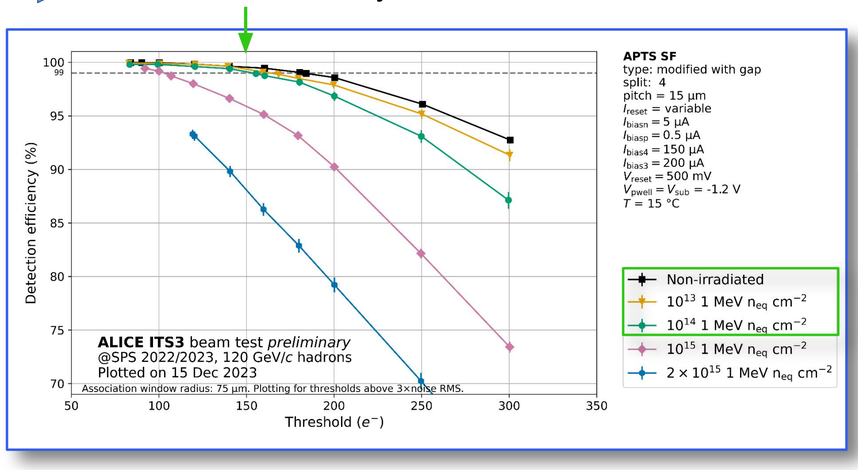
Characterization goals:
- detection efficiency
- radiation hardness
- spatial resolution



Several test beam campaigns from 2021
- use of charged particles (positive hadrons)
- reconstruction of particles tracks using the *Corryvreckan* framework: fit the cluster position on the reference planes
- tracks interpolated at the plane of the DUT
- association of tracks to cluster on the DUT plane

APTS-SF radiation hardness

Detection efficiency

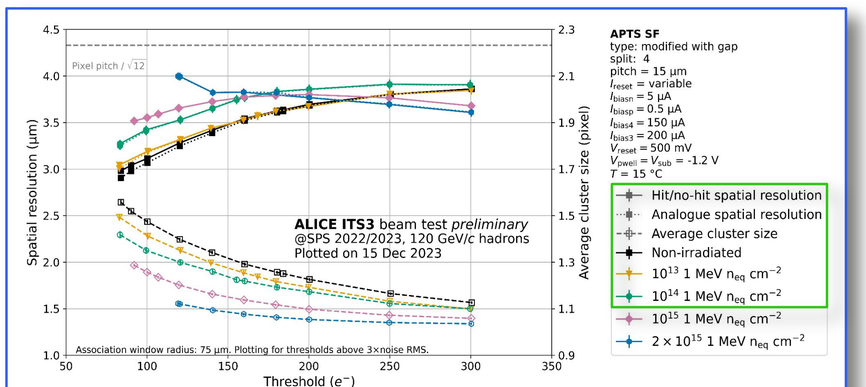


Detection efficiency >99% until 150 e^- threshold for NIEL irradiation level up to 10^{14} 1 MeV n_{eq} cm^{-2}

ALICE ITS3 requirement: **10^{13} 1 MeV n_{eq} cm^{-2}**

T = 15 °C

Spatial resolution

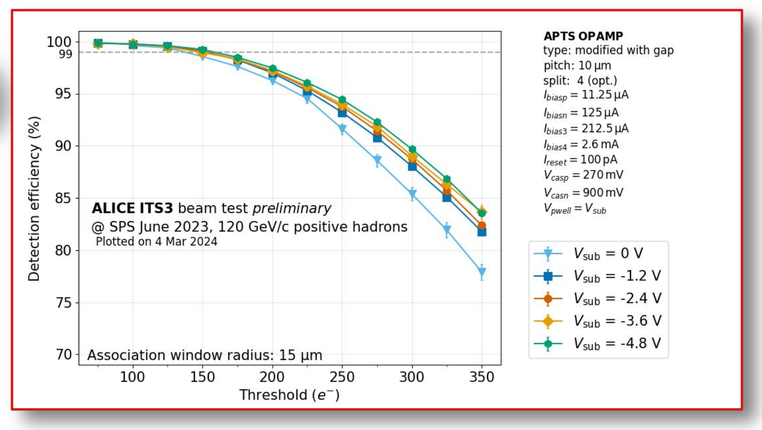


Average cluster size decrease with increasing NIEL dose:

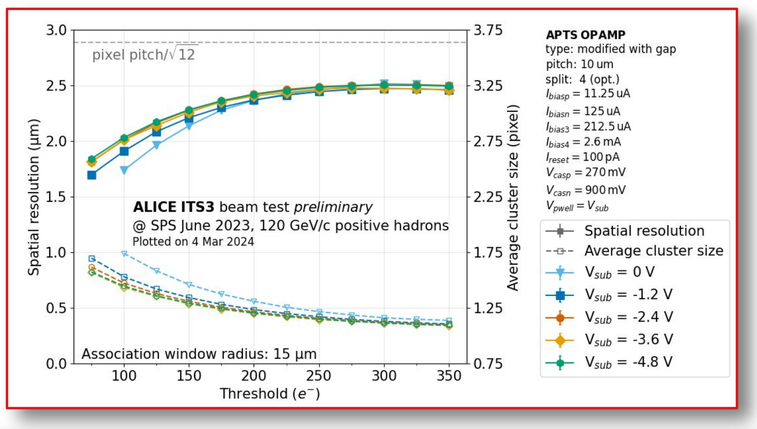
→ slight worsening in the spatial resolution for higher irradiation levels

G. A. Rinella, et al. "Characterisation of analogue monolithic active pixel sensor test structures implemented in a 65 nm cmos imaging process", 2024.

Detection efficiency and spatial resolution



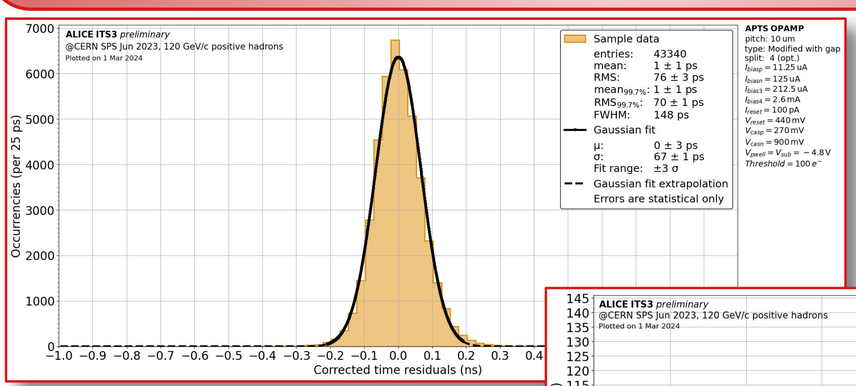
Detection efficiency > 99% up to a threshold of 150 e^- for all the V_{sub}



With increasing V_{sub}:
→ increase in the electric field
→ reduced charge sharing
→ average cluster size reduces

Spatial resolution ~ 2 μm at 100 e$^-$ threshold

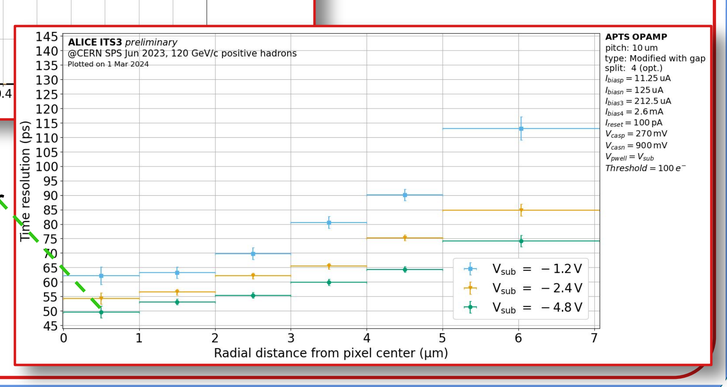
APTS-OA time resolution



Measured time resolution:
(63 ± 1) ps
@ Vsub = - 4.8 V

- Lowest time resolution: **(52 ± 4) ps** for tracks impinging in the pixel center

- Improvement in timing performance with increasing reverse bias



Conclusions

- **Above 99% detection efficiency** for a wide range of operating conditions
- **Radiation hardness** better than the requirement from ALICE ITS3 (10^{13} 1MeV n_{eq} cm^{-2})
- **Spatial resolution** better than the binary one can be achieved (~ 3 μm for 15 μm pitch not-irradiated, modified with gap APTS at a threshold of 100 e$^-$)
- **Time resolution of (63 ± 1) ps** measured for APTS-OA

The TPSCo 65 nm technology has been validated for particle detection and can be employed in several applications requiring precise timing measurements!