Characterization of analogue MAPS fabricated in 65 nm technology for the ALICE ITS3

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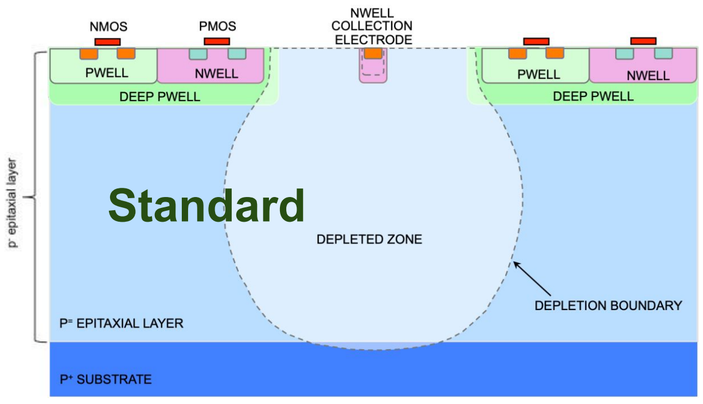
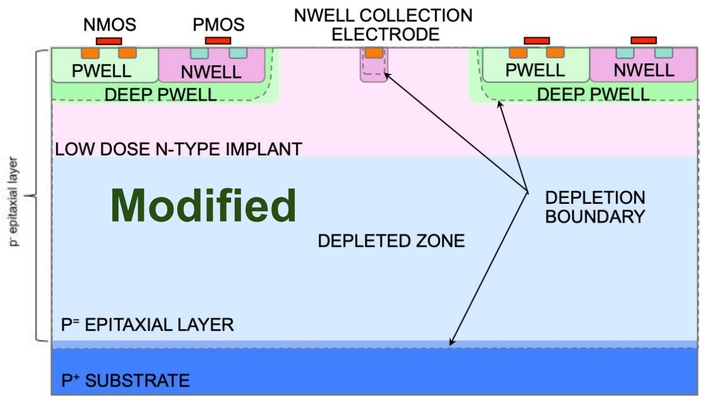
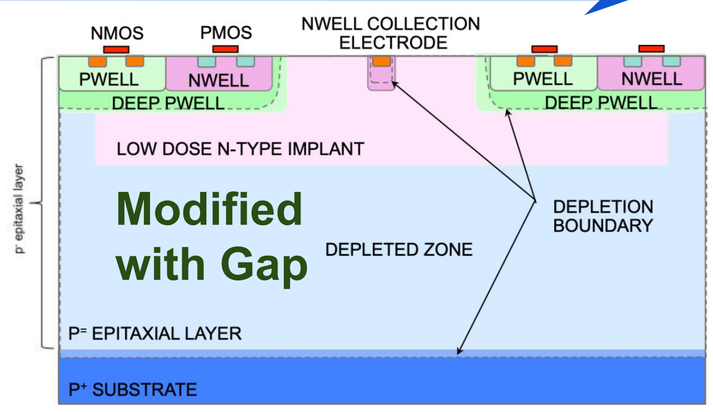
ALICE foresees the **ITS3 upgrade** using **65 nm** Monolithic Active Pixel Sensors with reduced material budget and improved pointing resolution

An additional **low dose n-type implant** is introduced for the full depletion of the sensor and improved radiation tolerance

faster charge collection

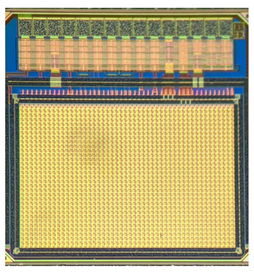






more charge sharing

Two Small-Scale Analogue Pixel Prototypes Chips

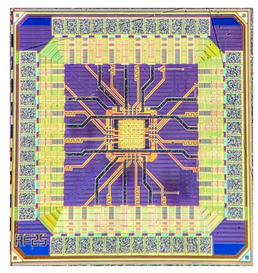


CE-65

Large matrix of **64x32** pixels
Rolling shutter readout
AC/DC-coupled preamp & **Source follower** configuration
Pitch sizes: 15, 25 µm

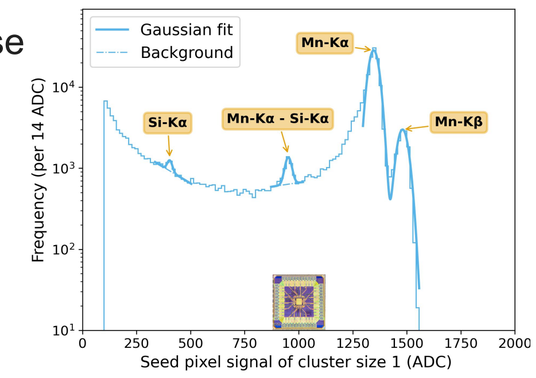
Small matrix of **6x6** pixels
Fast **direct** readout of inner **4x4** pixels
Source follower configuration
Pitch sizes: 10, 15, 20, 25 µm

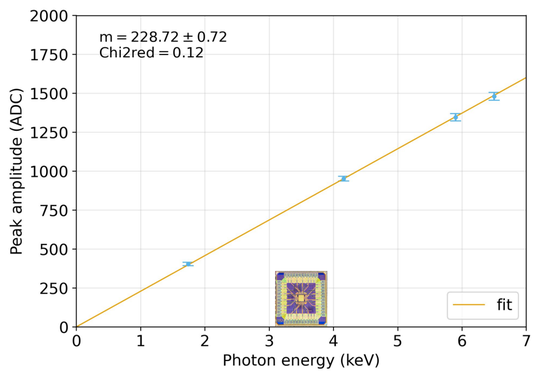
APTS



Energy Calibration and Linearity of Pixel Response

- Calibration of pixel response performed with **^{55}Fe radioactive source measurements**
- Only **central 4 pixels** considered to avoid edge effects

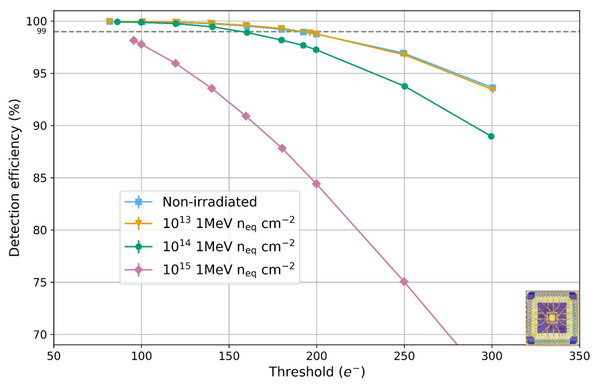




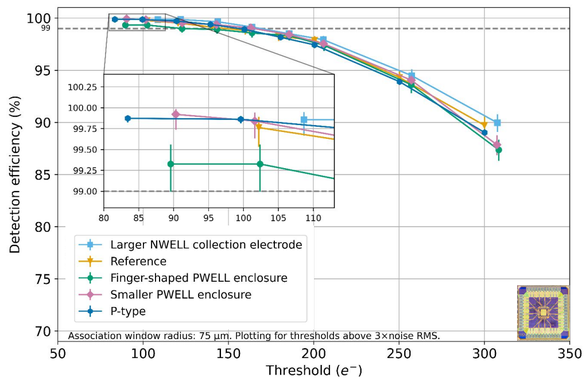
- **Mean** of the most prominent **Mn-K$_\alpha$ peak** used to convert **ADC units into e$^-$**
- Demonstrated the **linearity of energy calibration**

Radiation Tolerance

- Performant upto the irradiation level of **10^{14} NIEL**
- Minimal **bias voltage** application of **1.2 V**
- Modified with gap sensors with **15 µm** pitch size



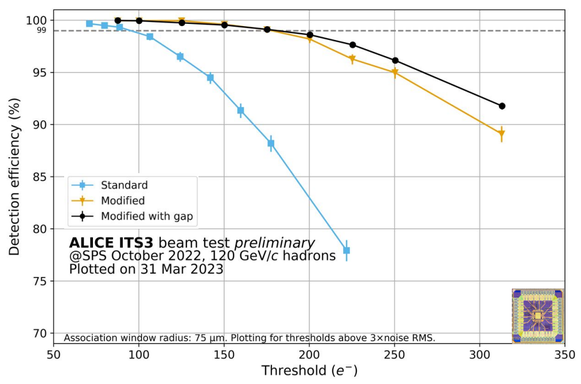
Pixel Geometry Variation



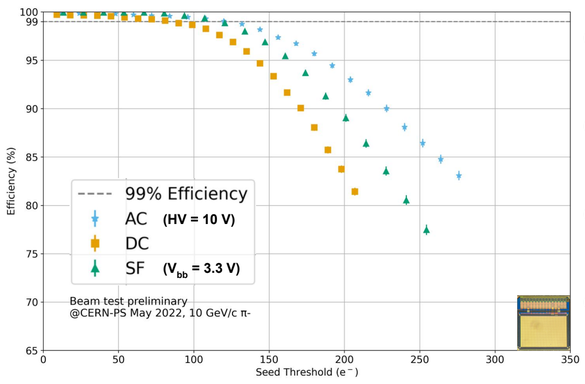
- All geometry variants achieve **over 99% efficiency**
- **Larger electrode** leads to **more noise** but better radiation tolerance
- Modified with gap sensors with **10 µm** pitch size

Process Modification

- Process **modification** drastically **increases the range of operation** over 99% efficiency
- **Charge sharing** causes efficiency to drop at higher threshold for the **standard** process



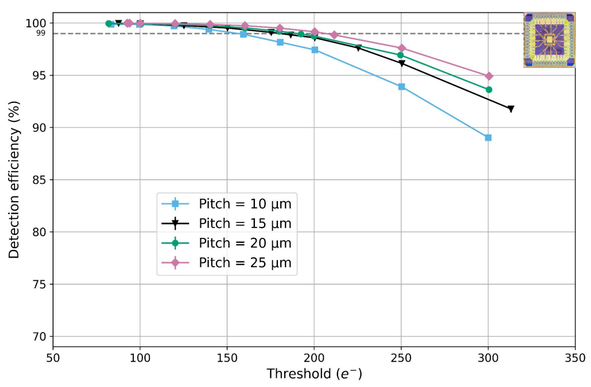
In-Pixel Readout Architecture

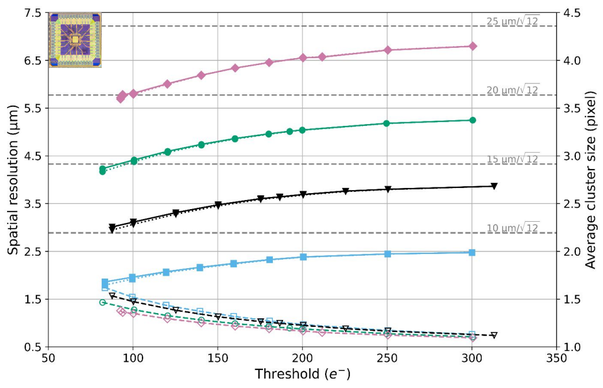


- **AC-coupled** high voltage provides **full depletion**
- **DC-coupled** variant only reaches **partial depletion**
- Depletion of the **SF** variant depends on **bias voltage**
- Standard process sensors with **15 µm** pitch size

Pitch Size and Spatial Resolution

- All pitches reach **over 99% efficiency**
- Bigger operational margin for larger pitches
- Non-irradiated modified with gap sensors at bias voltage of **1.2 V**





- Attained **resolution better than binary** resolution thanks to charge sharing
- Less than **3 µm** resolution **aligns with the FCC-ee requirements**

The performance satisfies ALICE ITS3 and ALICE 3 specifications

Outlook Effects of different matrix geometries on charge sharing in sensors with a large matrix are being studied

The 65 nm CMOS process has been validated and the analogue properties of the sensors have been characterised with small and large matrix prototypes with consistent results **Conclusion**

ALICE Collaboration, **Technical Design report for the ALICE Inner Tracking System 3 - ITS3 ; A bent wafer-scale monolithic pixel detector**, https://cds.cern.ch/record/2890181

Gianluca Aglieri Rinella et al., **Characterisation of analogue Monolithic Active Pixel Sensor test structures implemented in a 65 nm CMOS imaging process**, https://arxiv.org/abs/2403.08952

Talk by L. Aglietta
Poster by A. Villani