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Characterisation of irradiated Digital Pixel Test Structures produced in 65 nm TPSCo CMOS process

8. Annual Matter and Technologies Meeting
Detector Technologies and Systems session

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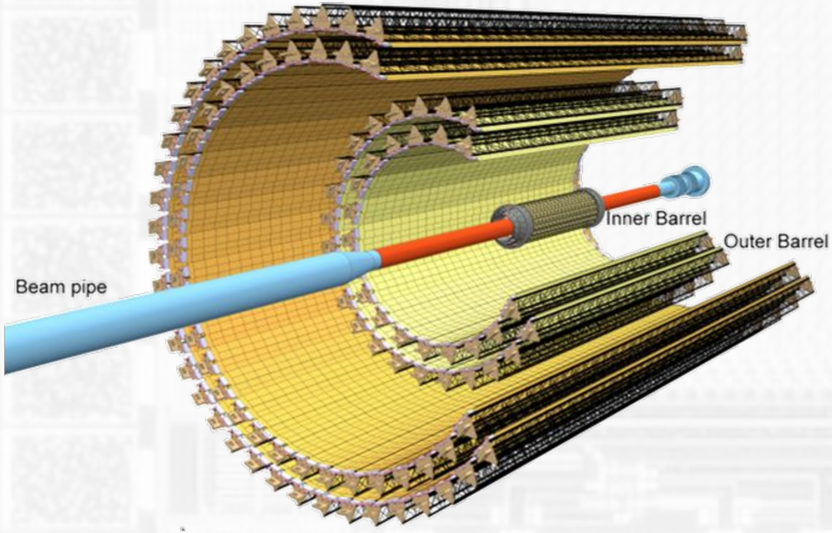
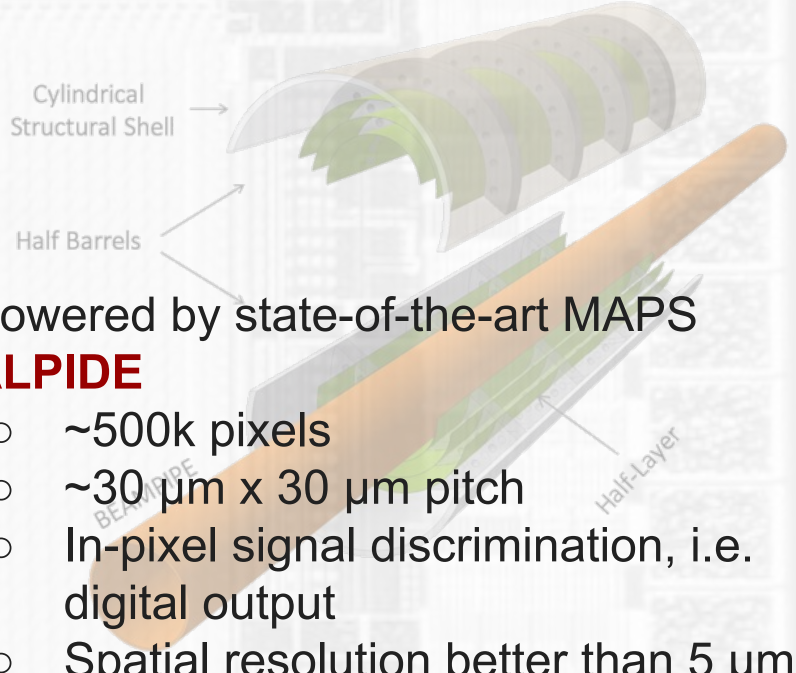
26 September 2022

From ALPIDE to a 65 nm CMOS MAPS prototype: ALICE inner tracker upgrades

- ITS2 installed for improved tracking resolution and rate capability in LHC run 3
- Especially true for low-momentum particles (new regions accessible)

Magnus Mager. CERN detector seminar. 24.09.2021





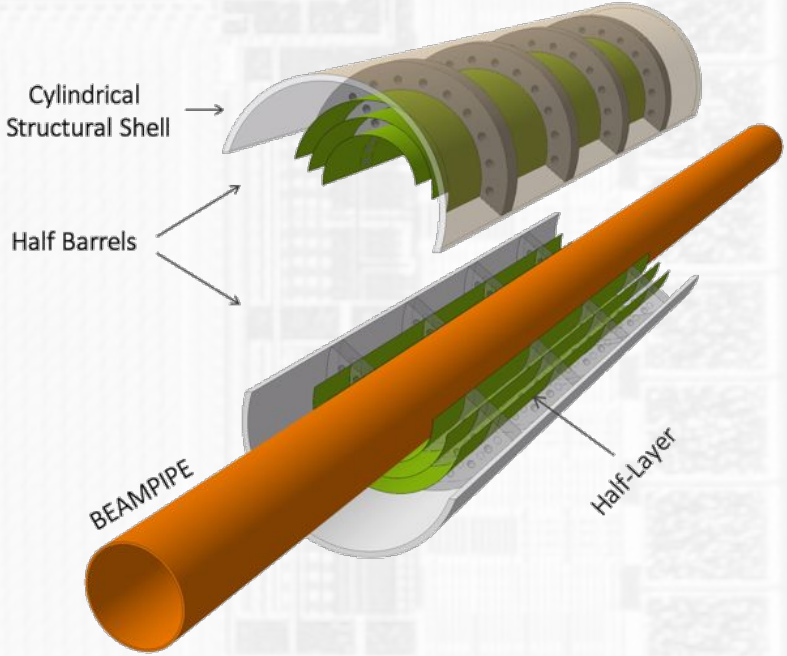
- Powered by state-of-the-art MAPS
- **ALPIDE**
  - ~500k pixels
  - ~30 μm x 30 μm pitch
  - In-pixel signal discrimination, i.e. digital output
  - Spatial resolution better than 5 μm
  - Optimised for low-power consumption
  - 50 μm thin chip

From ALPIDE to a 65 nm CMOS MAPS prototype: ALICE inner tracker upgrades

- Further improvement on material budget possible
- Move to truly-cylindrical, wafer-scale MAPS (ITS3)

ITS3

- Replace the innermost 3 tracking layers of ITS2
- Move closer to the beam pipe (18 mm, 24 mm, 30 mm)
- Sensors self-sustained by bending
- Thin sensors O(**30 µm**)
- Air cooling seems feasible

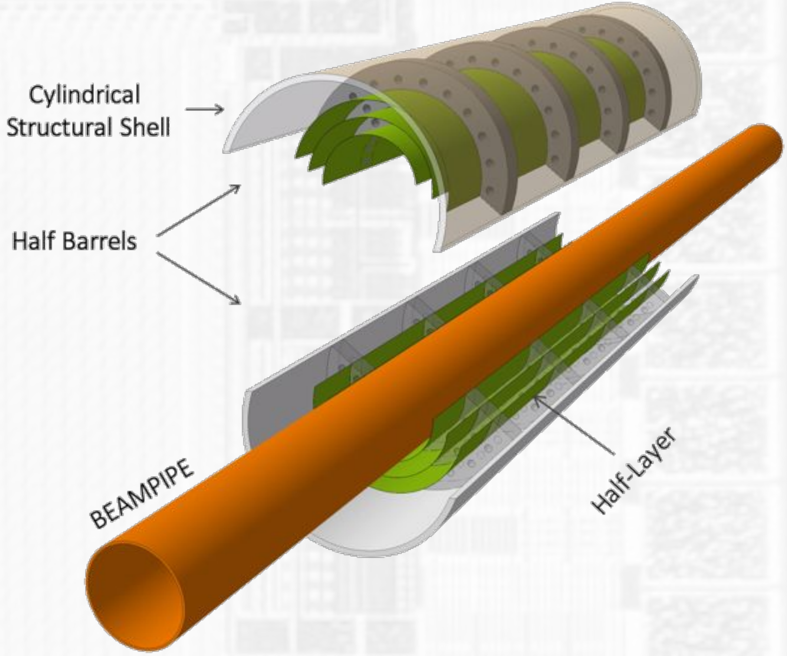


Luciano Musa et al. Letter of intent for an ALICE ITS upgrade in LS3. 2019

- New generation of tracking detectors
- R&D started on new sensors to face the challenges

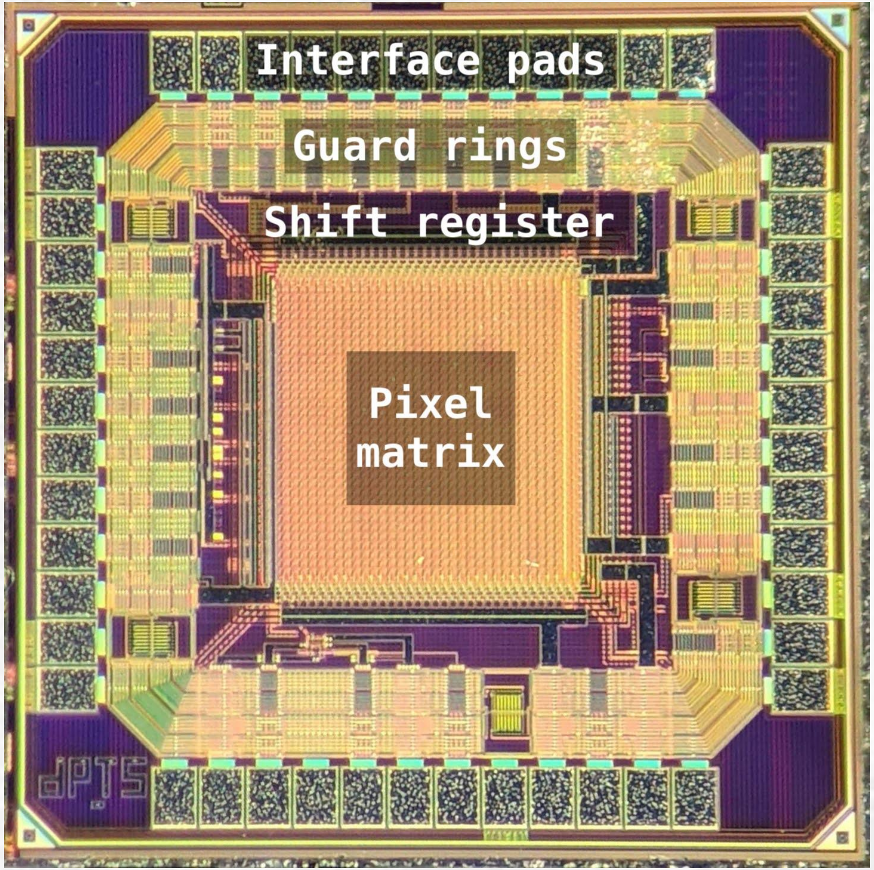
From ALPIDE to a 65 nm CMOS MAPS prototype: A new sensor for the ITS3

- 65 nm CMOS technology node is key
  - Larger available wafers (30 cm)
  - Stitching available for production of large area sensors
- Smaller feature size
  - O(200) transistors possible on pixel level
  - Various possibilities to implement in-pixel signal processing



- Small scale prototypes available since 2021
- Multi Layer Reticle1 (MLR1) submission

The MLR1 Digital Pixel Test Structure (DPTS)

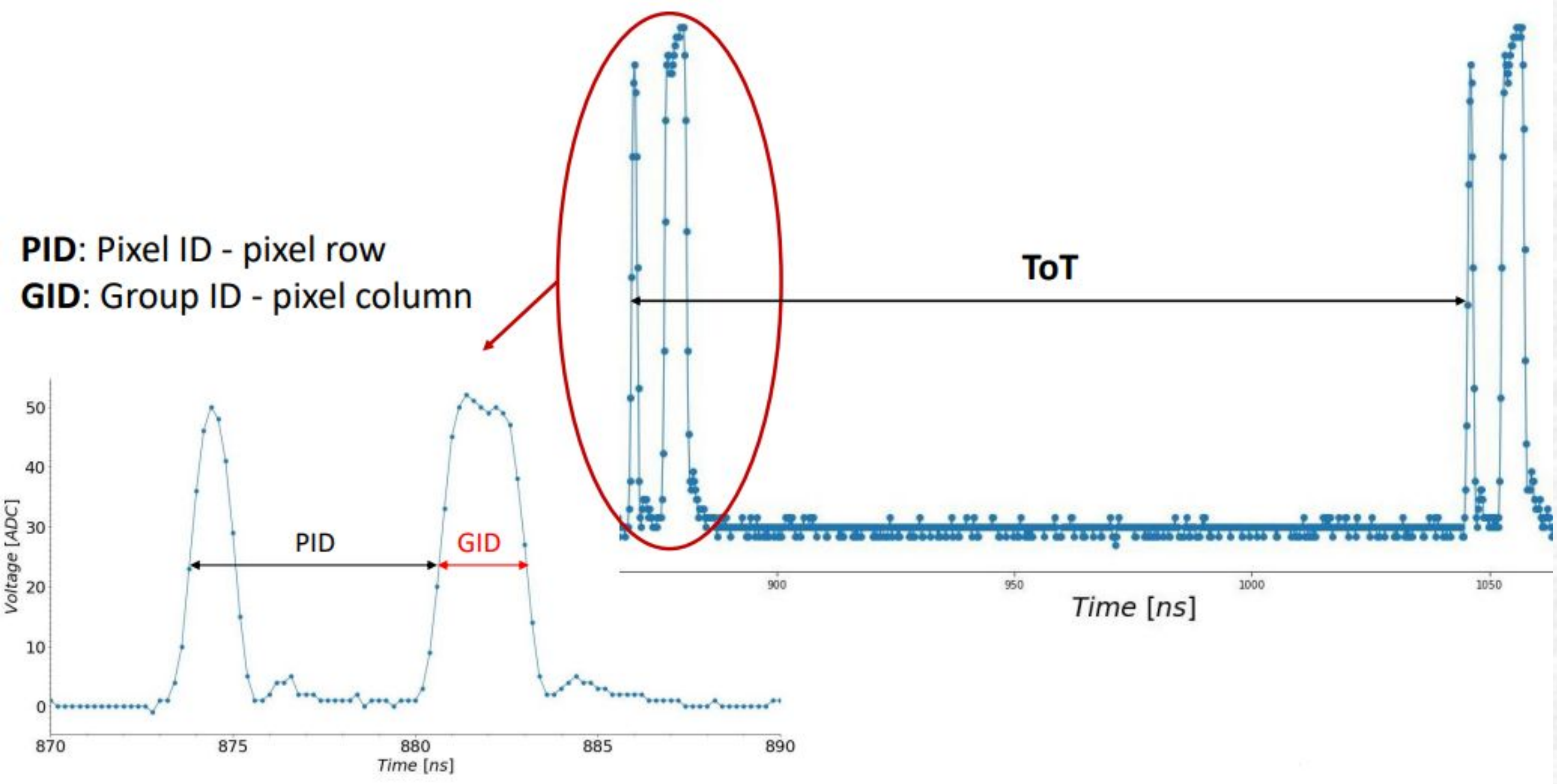


Magnus Mager. CERN detector seminar. 24.09.2021

- Most “aggressive” sensor in submission
- Full pixel matrix with in-pixel signal discrimination
  - Test front-end and digital building blocks
  - In-beam sensor performance characterisation
- 480 µm x 480 µm active area
- 32 x 32 pixel (15 µm x 15 µm)

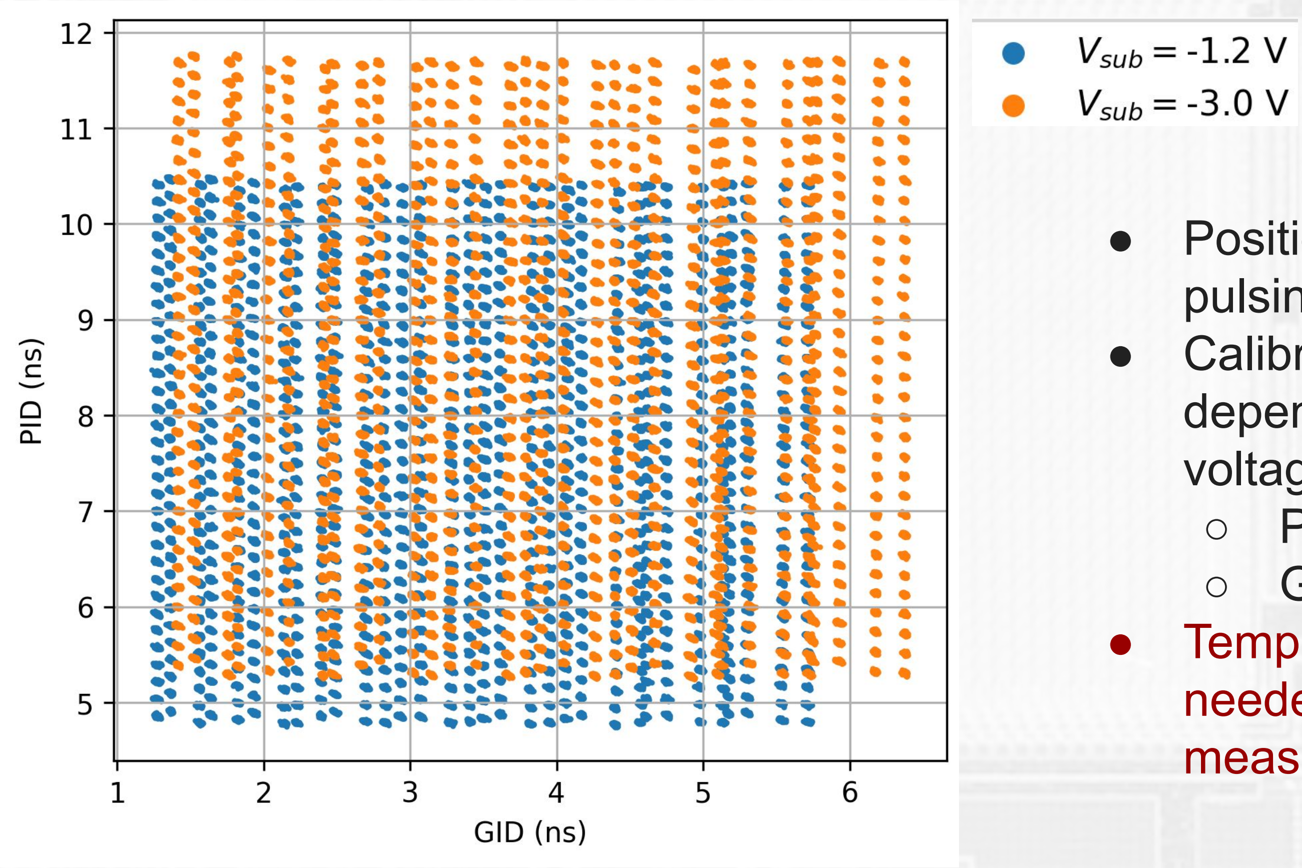
- Asynchronous digital readout (single output line)
- Time encoded position information
- Access to time over threshold

DPTS signals and position decoding



- Only first train used for position decoding in this work

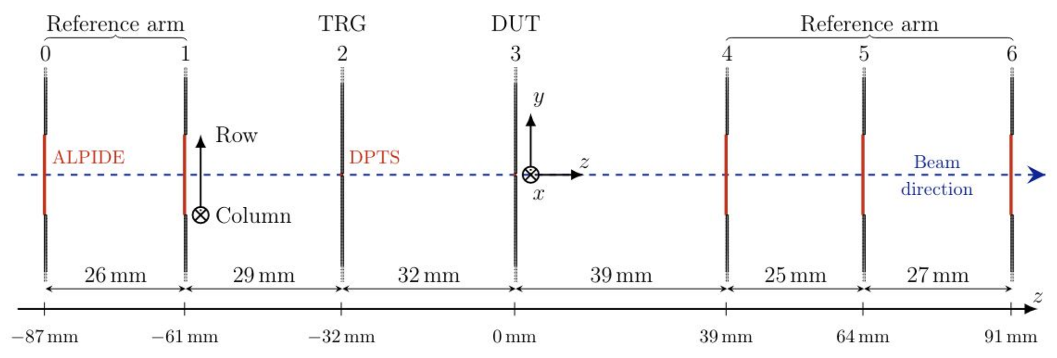
DPTS signals and position decoding



- Position calibration via pulsing
- Calibration map strongly depends on back-bias voltage and temperature
  - PID: ~0.05 ns / 5°C
  - GID: ~0.02 ns / 5°C
- Temperature control needed for reliable measurements

Testbeam campaign at CERN PS T10: 10 GeV/c positive hadrons

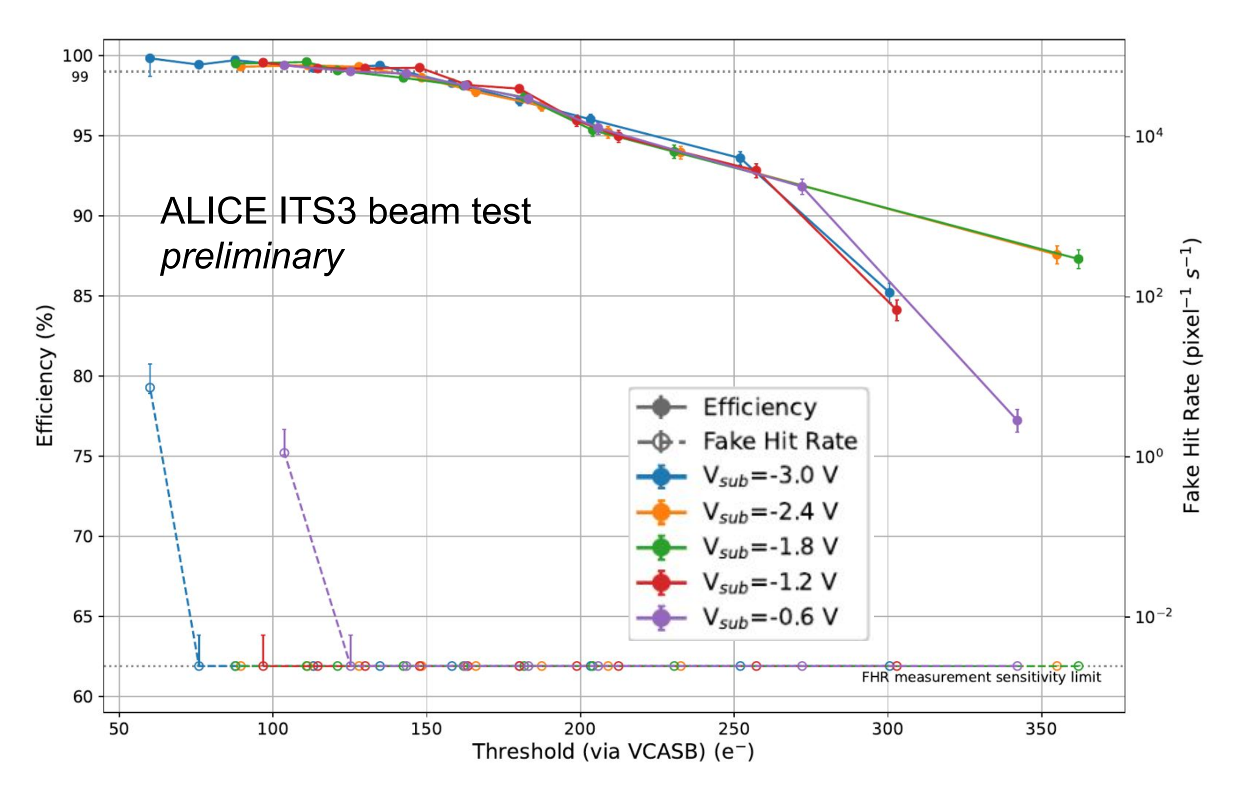
- ALPIDE as tracking planes
- 1 DPTS as trigger
- 1 DPTS as device under test (different irradiation levels)



- Temperature kept at 20°C with chiller
- In-situ fake hit rate, threshold scans
- In-situ position calibration
- DPTS waveforms read out with oscilloscope

- Data analysis with Corryvreckan
  - Alignment, Tracking

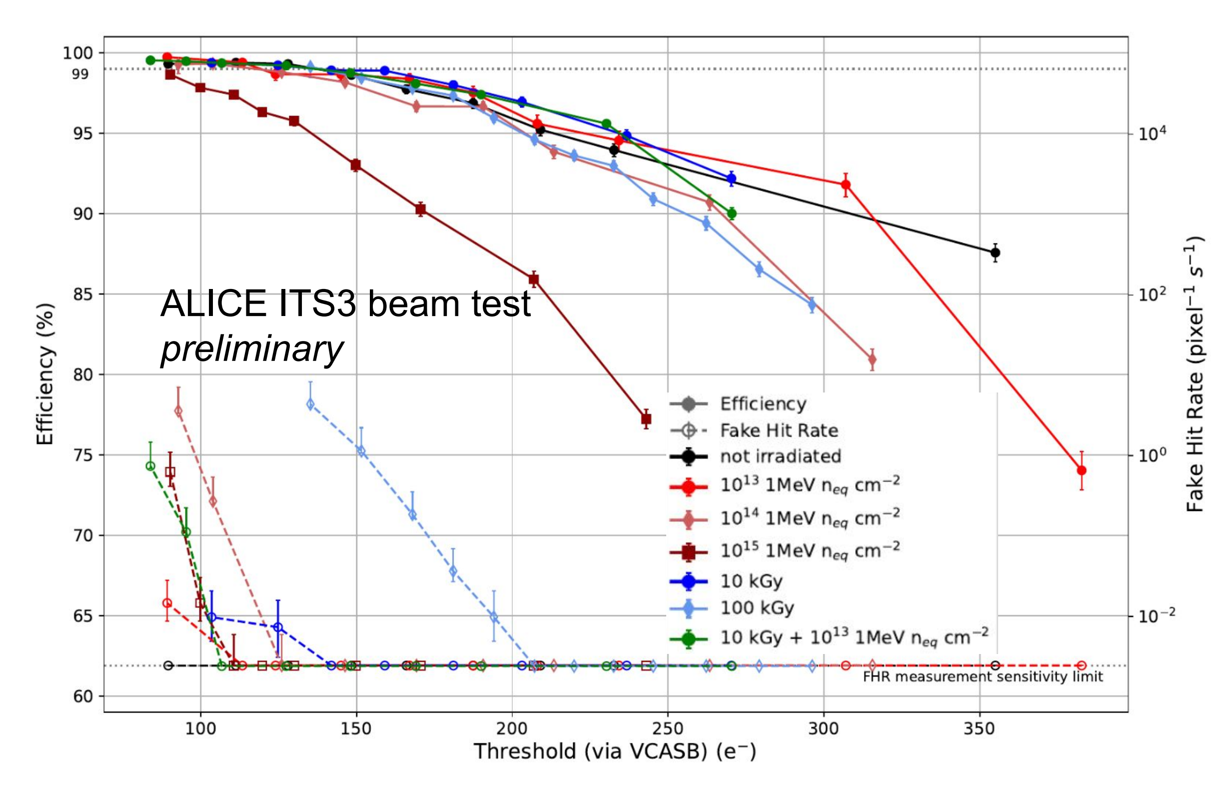
DPTS performance - Detection efficiency
Not irradiated



- Spatial window: 480 µm x 480 µm
- Time window: 1.5 µs
- Different back-bias

- Highly efficient for a large range of operating points
- Overall low noise level

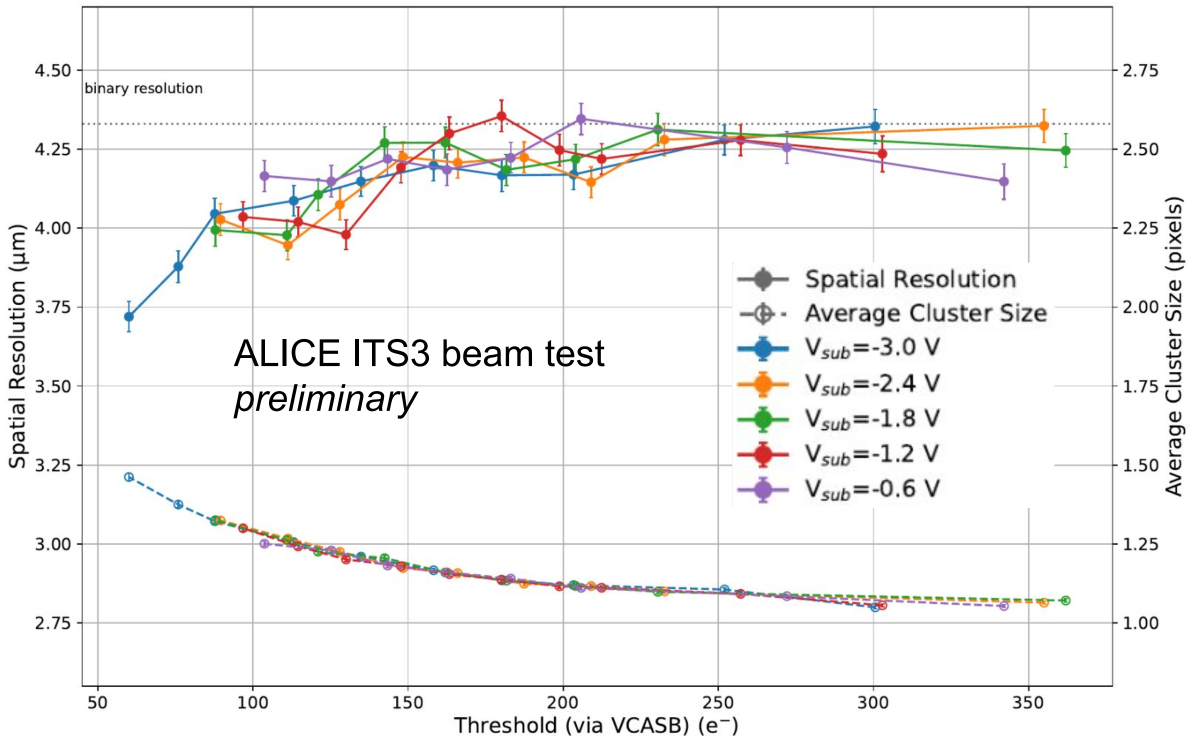
DPTS performance - Detection efficiency TID and/or NIEL irradiated



- Spatial window: 480 µm x 480 µm
- Time window: 1.5 µs
- -2.4 V back-bias

- Across different irradiation levels DPTS stays efficient
- Overall noise level is increased

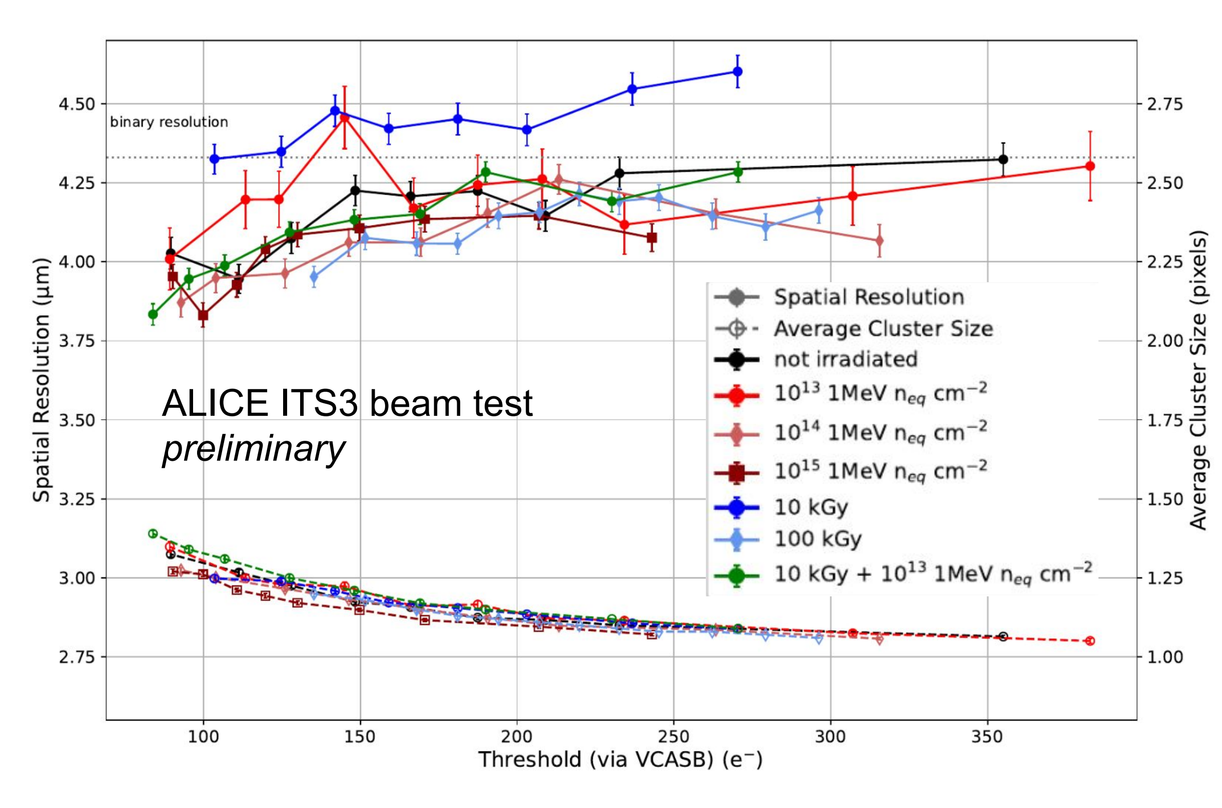
DPTS performance - Spatial resolution
Not irradiated



- Spatial window: 45 µm x 45 µm
- Time window: 1.5 µs
- Different back-bias

- Width of spatial residuals
- Telescope resolution subtracted
- Dominated by small pixel size

DPTS performance - Spatial resolution TID and/or NIEL irradiated



- Spatial window: 45 μm x 45 μm
- Time window: 1.5 μs
- -2.4 V back-bias

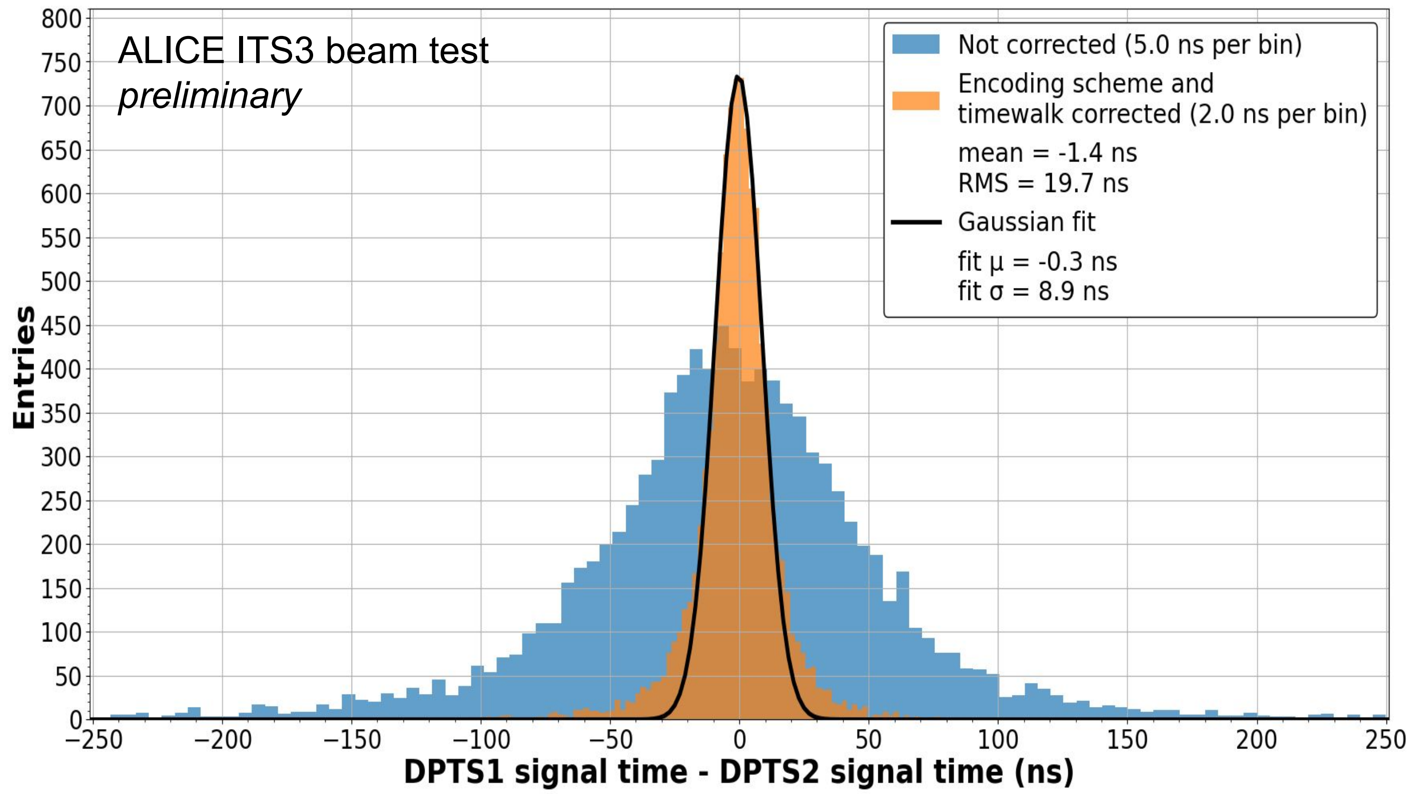
- Width of spatial residuals
- Telescope resolution subtracted
- No strong dependence of spatial resolution on irradiation level

Summary and Outlook

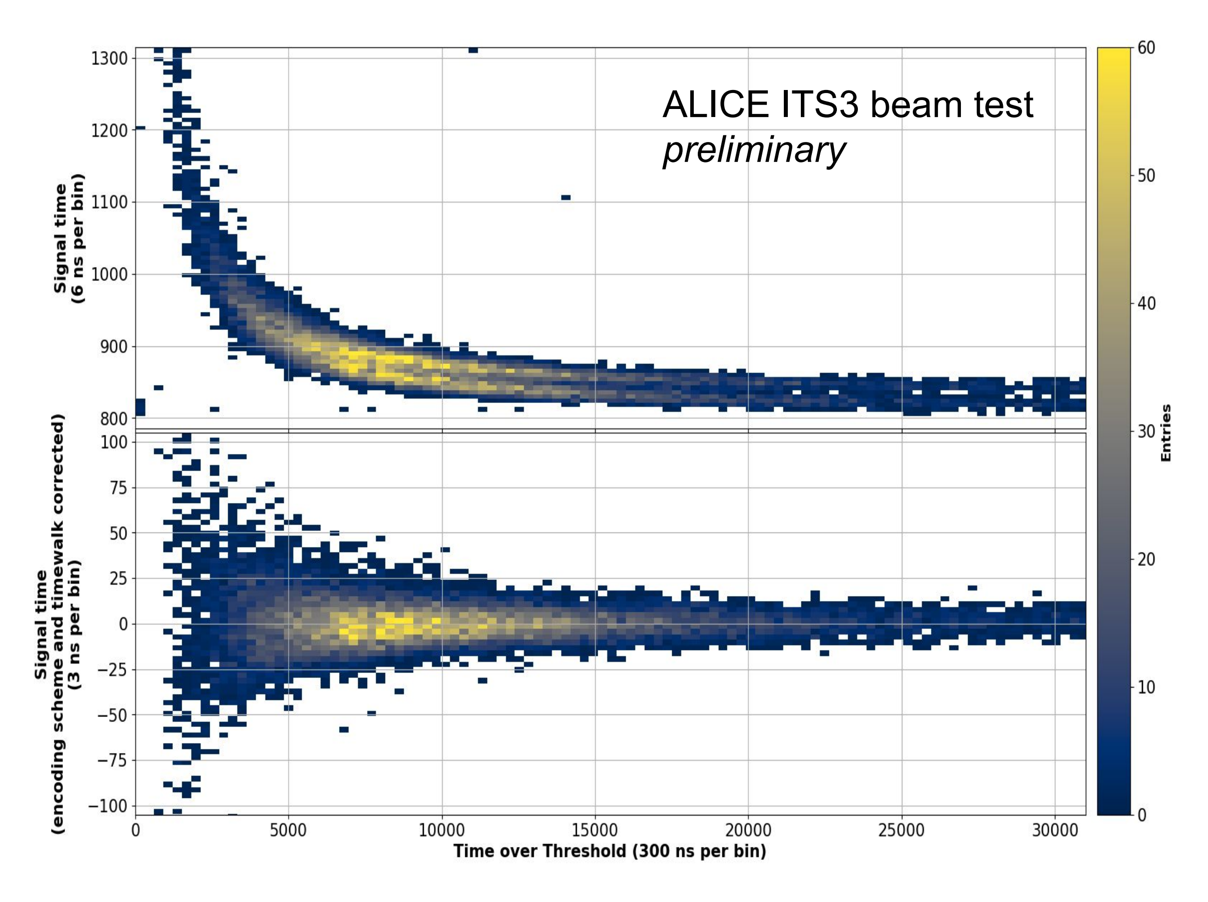
- First 65 nm CMOS technology MAPS available for testing
- DPTS sensor form MLR1 submission
  - 1024 pixels
  - In-pixel discrimination
- In-beam caracterisation at CERN PS
- Hit detection efficiency exceeds 99% for a large range of working points
  - Different back-bias values
- Efficiency maintained for several irradiation levels
- Spatial resolution limited by binary resolution
  - No strong dependence on irradiation level

- DPTS characterisation paper in pipeline
- Engineering run upcoming with stitched sensors

Backup - Timing resolution



Backup - Timing resolution



Backup - Energy resolution (irradiated sensor)