



SPONSORED BY THE  
Federal Ministry  
of Education  
and Research



UNIVERSITÄT  
HEIDELBERG  
ZUKUNFT  
SEIT 1386



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

**Pascal BECHT (Heidelberg University)  
for the ALICE collaboration**

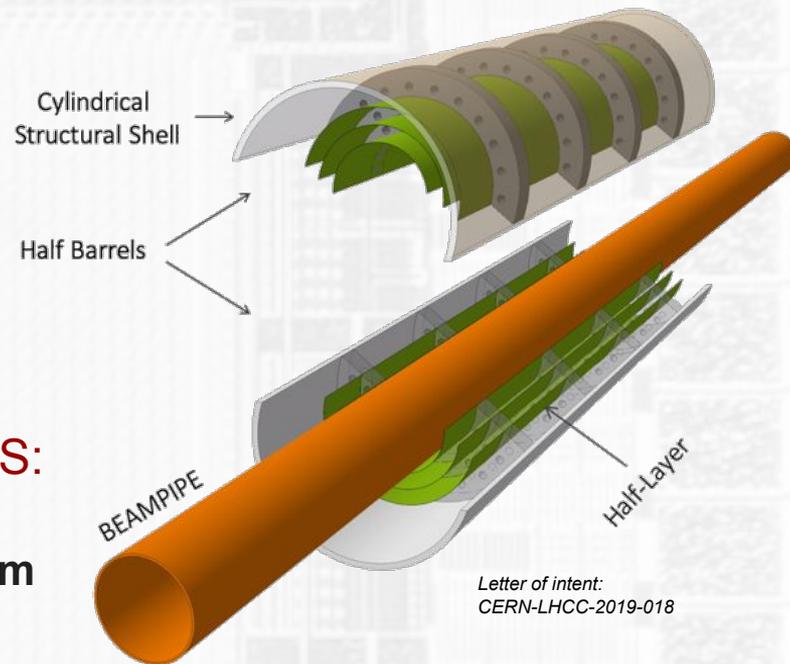
**VERTEX 2022**

**The 31st international workshop on vertex detectors  
24 -28 October**

**25 October 2022**

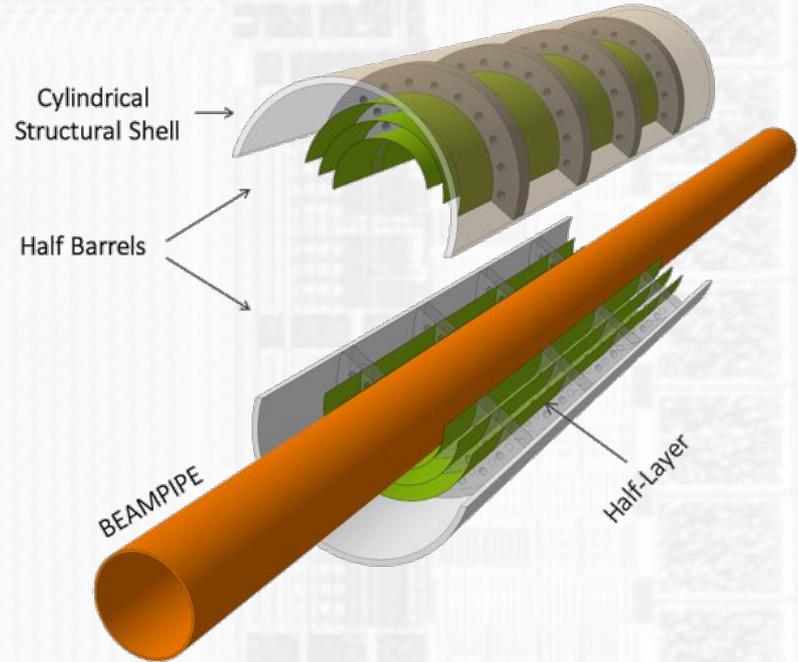
# From ALPIDE to a 65 nm CMOS MAPS prototype: ALICE inner tracker upgrades

- Further improvement on material budget possible (wrt. ITS2 with ALPIDE sensors)
  - **“Commissioning and performance of ITS2”** - I. Ravasenga
- **Move to truly-cylindrical, wafer-scale MAPS: ITS3**
- **“Upgrade of the ALICE Inner Tracking System for LHC Run 4 (ITS3)”** - F. Carnesecchi
- Sensors self-sustained by bending
- **“Beam test studies of bent MAPS for ALICE ITS3”** - L. Lautner
- Thin sensors  $O(30 \mu\text{m})$



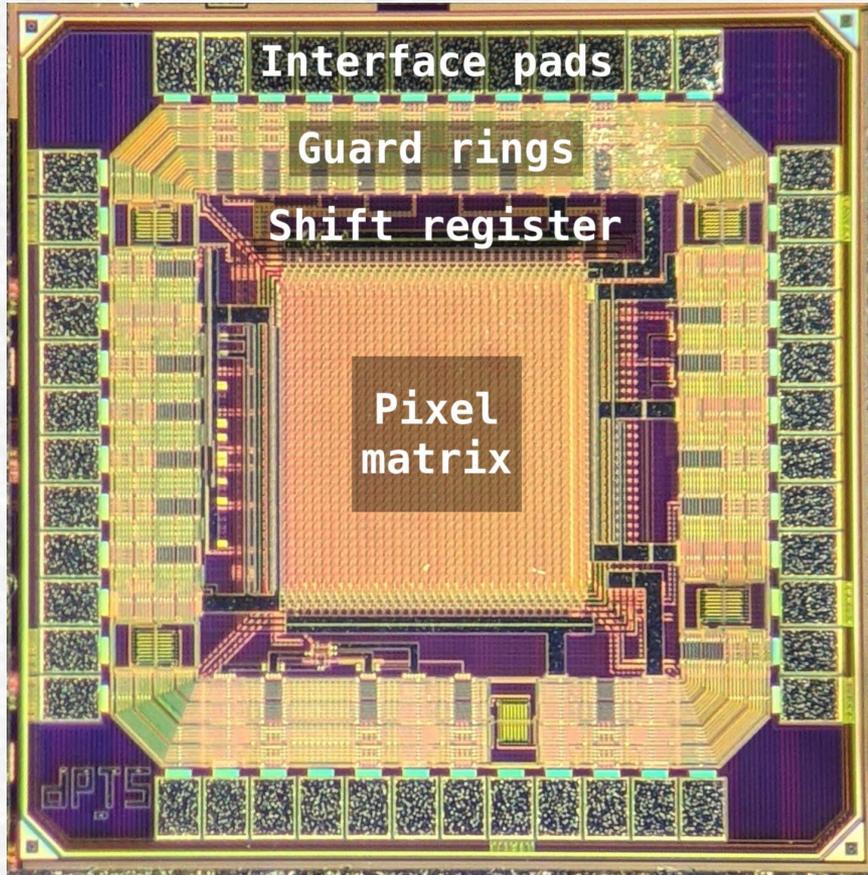
- New generation of tracking detectors
- R&D started on new sensors to face the challenges

# 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
  - Various possibilities to implement in-pixel signal processing
- Small scale prototypes are available since 2021
- Multi Layer Reticle 1 (MLR1) submission
  - Joint effort of CERN EP R&D and ALICE ITS3

# The MLR1 Digital Pixel Test Structure (DPTS)



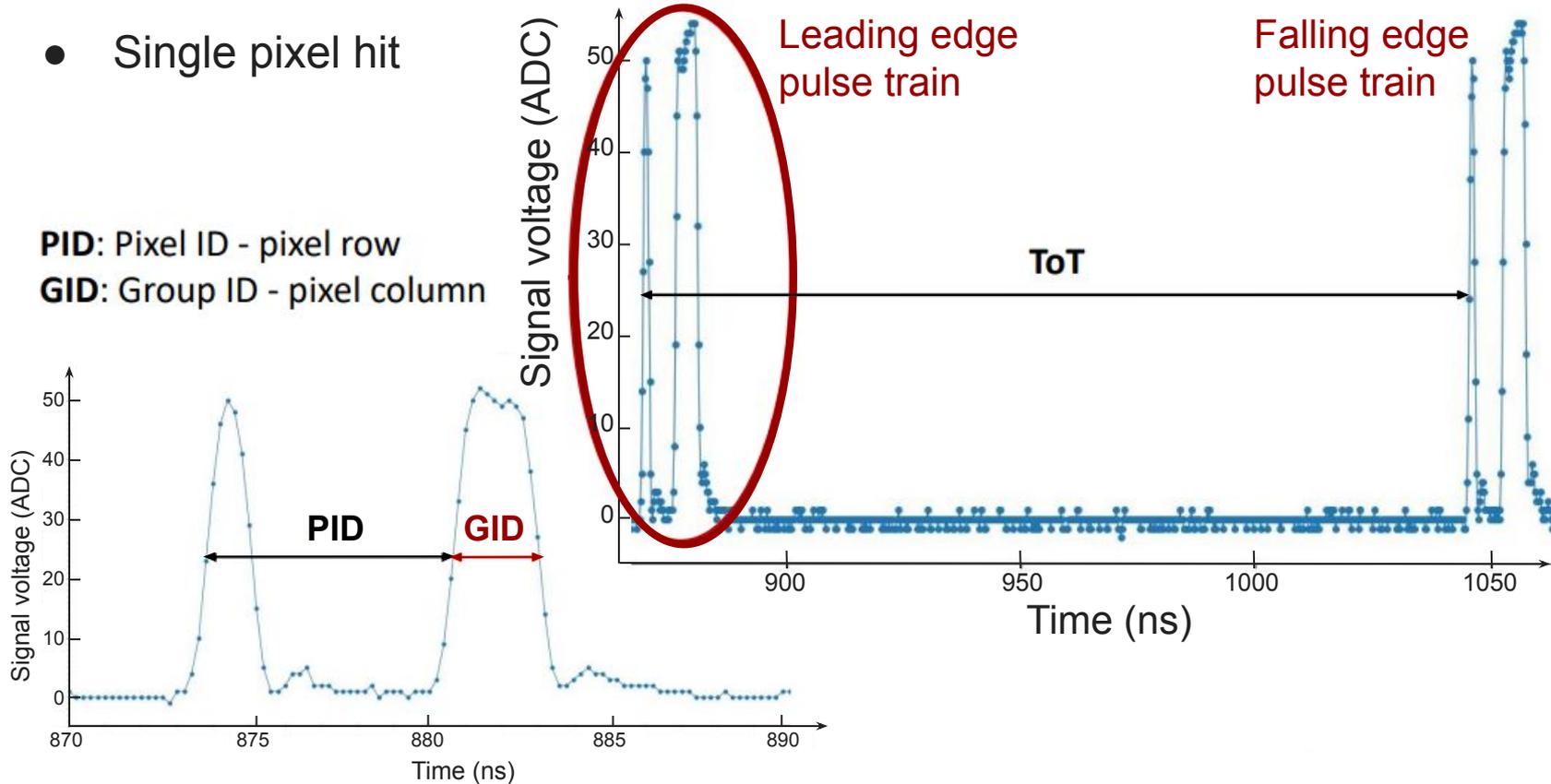
- Full pixel matrix with **in-pixel signal discrimination**
  - Test front-end and digital building blocks
  - In-beam sensor performance characterisation
- 480  $\mu\text{m}$  x 480  $\mu\text{m}$  active area
- **32 x 32 pixel (15  $\mu\text{m}$  x 15  $\mu\text{m}$ )**
- Asynchronous digital readout (single output line)
- **Time encoded position information**
- **Access to time over threshold**

# DPTS signals and position decoding

- Single pixel hit

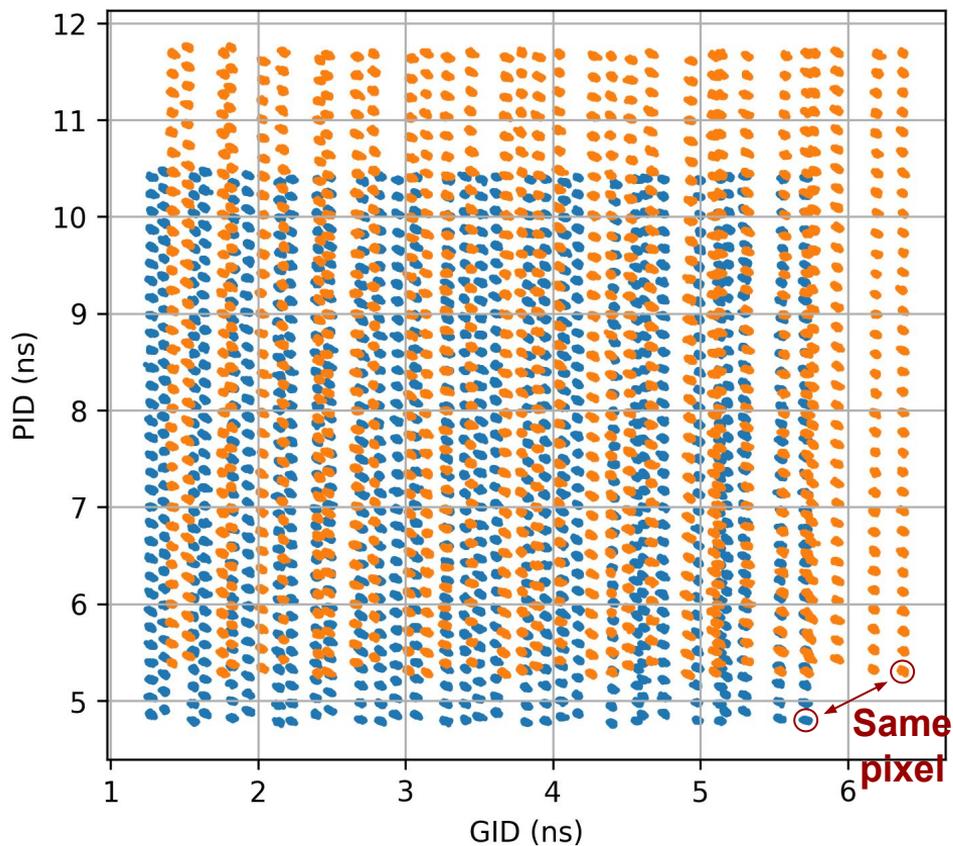
**PID:** Pixel ID - pixel row

**GID:** Group ID - pixel column



- Multiple pixel hits may cause signal collisions

# DPTS signals and position decoding

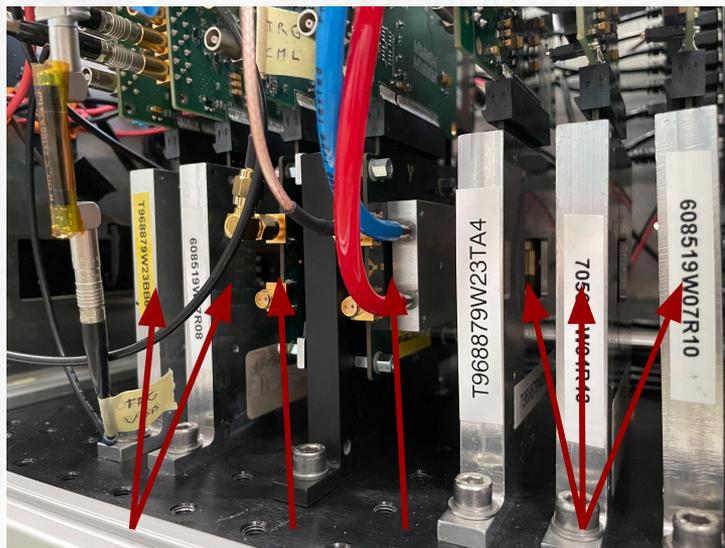


- $V_{sub} = -1.2$  V
- $V_{sub} = -3.0$  V

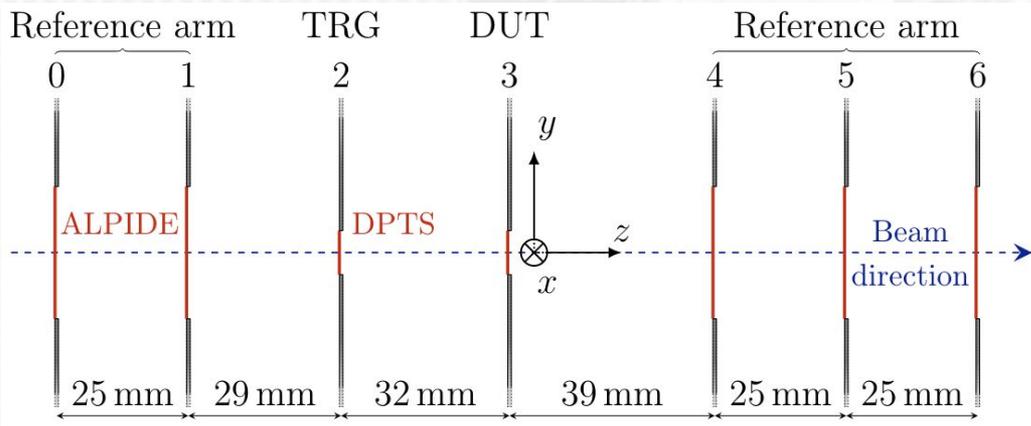
- Position decoding calibration via pulsing
  - One (GID,PID)-point per pixel
- Calibration map strongly depends on back-bias voltage and temperature
  - PID:  $\sim 0.04$  ns /  $5^{\circ}\text{C}$
  - GID:  $\sim 0.02$  ns /  $5^{\circ}\text{C}$
- Temperature control needed for reliable decoding

# Multiple testbeam campaigns

- DESY
- CERN SPS
- CERN PS
  - 10 GeV/c positive hadrons

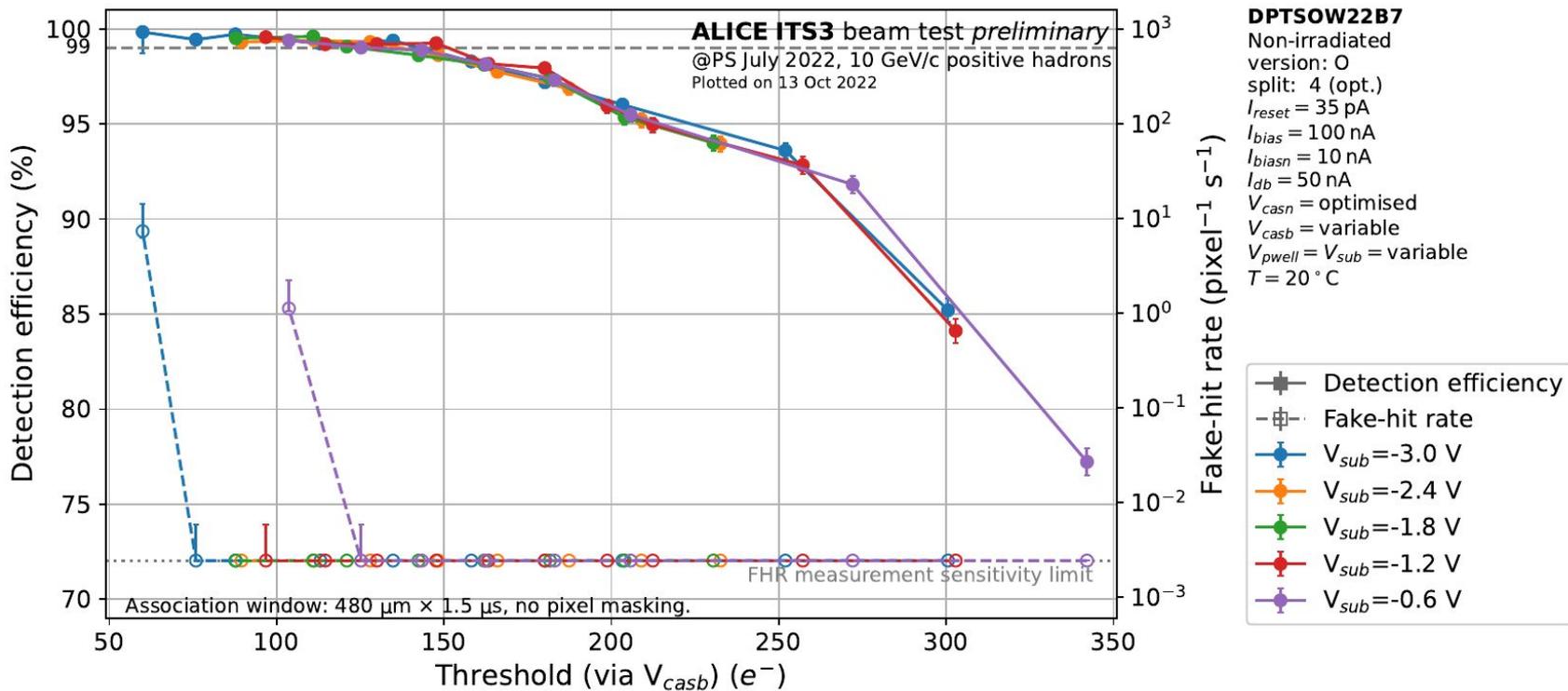


**ALPIDEs TRG DUT ALPIDEs**



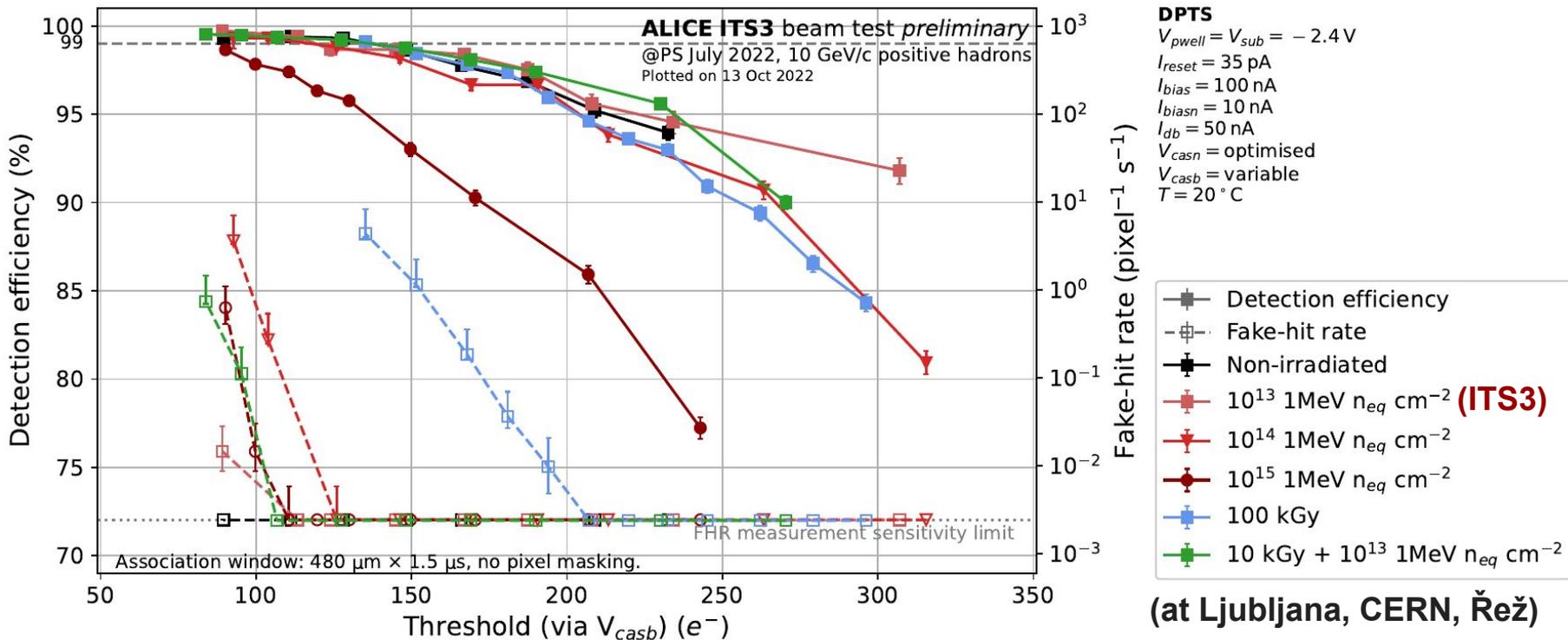
- Temperature kept at 20°C with chiller
- In-situ fake hit rate, threshold measurements
- In-situ position decoding calibration
- DPTS waveforms read out with oscilloscope
- Data analysis with Corryvreckan
  - Alignment, Tracking, DUT association
  - <https://gitlab.cern.ch/corryvreckan/corryvreckan>

# DPTS performance - Detection efficiency Non-irradiated



- Detection efficiency exceeds 99% for a wide range of working points
- Overall low noise level

# DPTS performance - Detection efficiency TID and/or NIEL irradiated

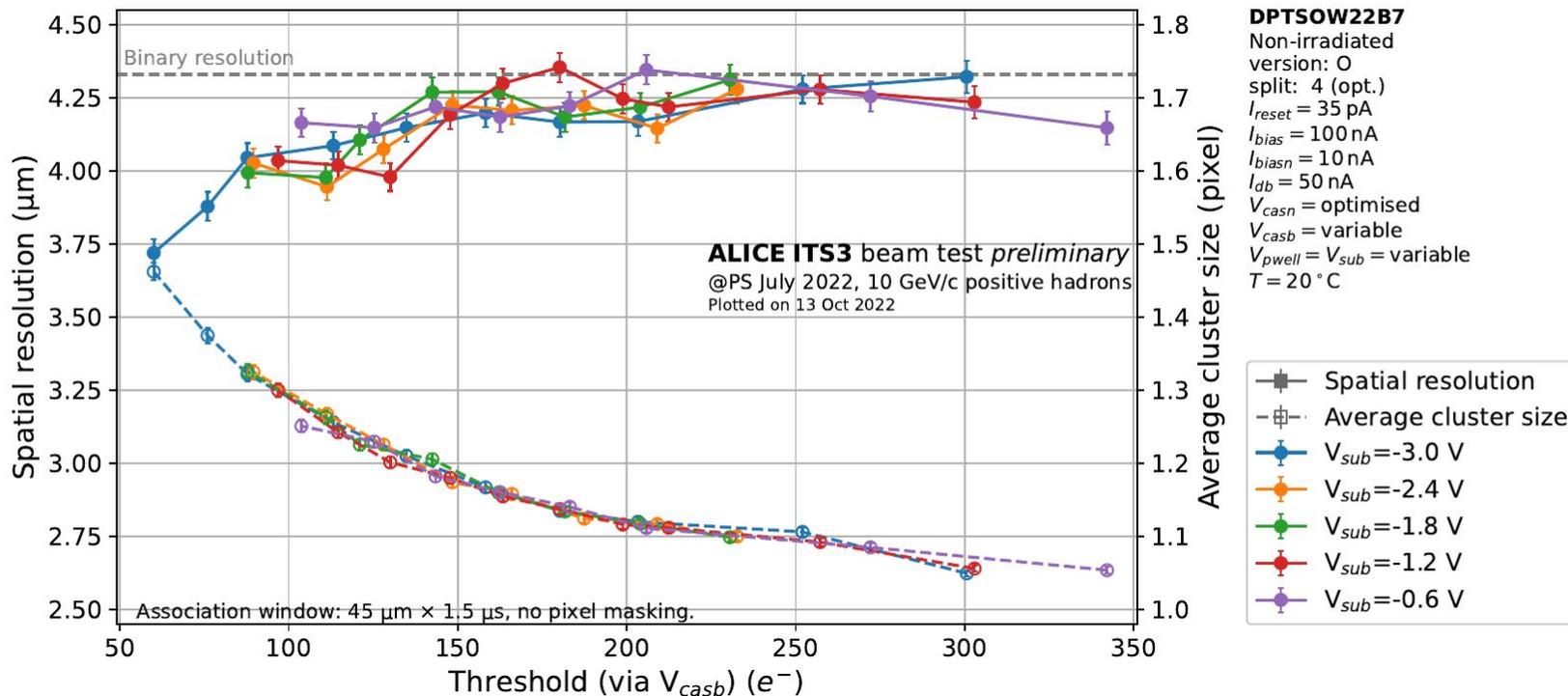


- Across different irradiation levels DPTS stays efficient

- Overall noise level is increased

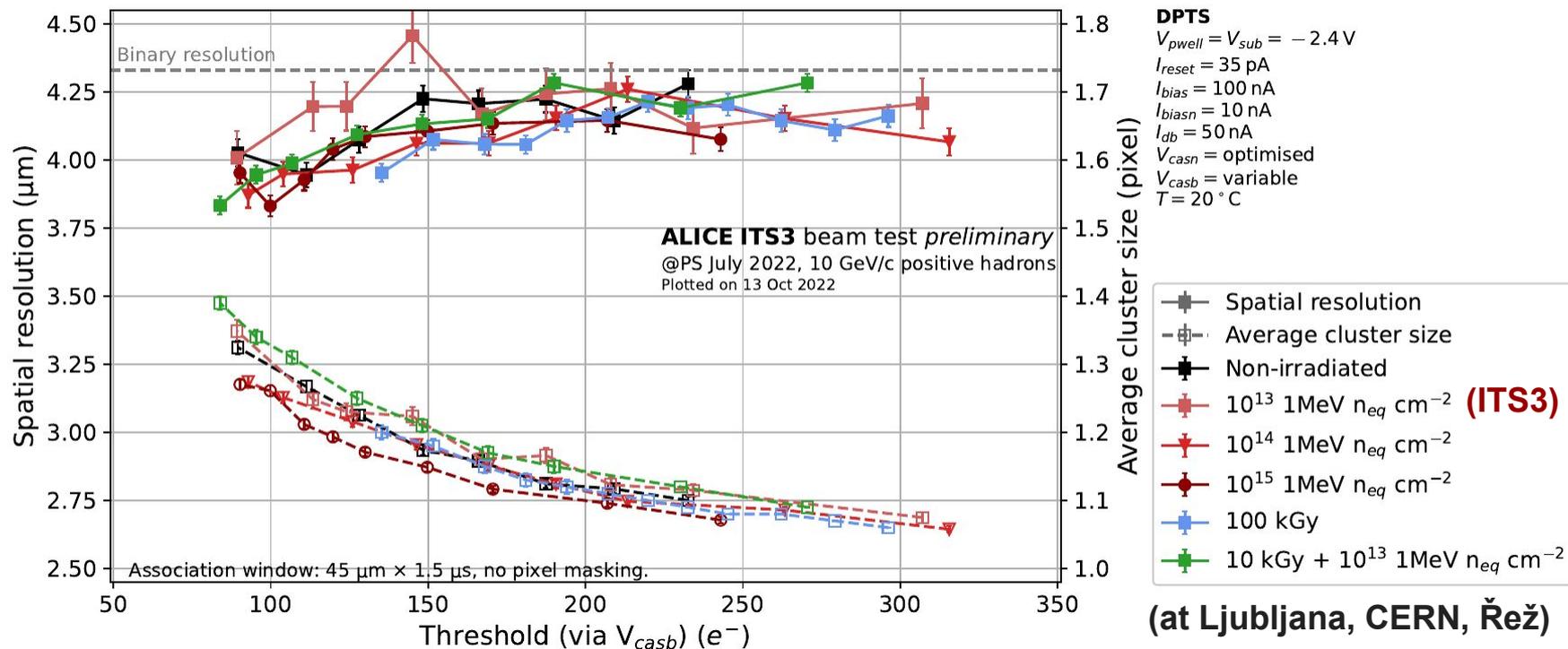
# DPTS performance - Spatial resolution

## Non-irradiated



- Dominated by small pixel size

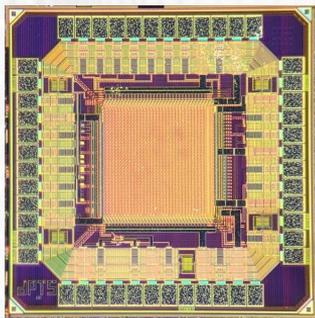
# DPTS performance - Spatial resolution TID and/or NIEL irradiated



- No strong dependence on irradiation level

# Summary and Outlook

- 65 nm CMOS technology qualified for the use in MAPS
- In-beam characterisation of DPTS



- Operational range for high irradiation levels
  - At room temperature!
  - Still reaches 99% detection efficiency
- Spatial resolution matches expectation

- DPTS characterisation paper in pipeline
- Additionally covers:
  - Full electrical characterisation
  - $^{55}\text{Fe}$  response
  - Timing resolution

Encouraging results  
from MLR1 submission

- Engineering run upcoming with stitched sensors