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Qualifying 65 nm CMOS monolithic active pixel sensors for cylindrical, lightweight vertex detectors

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EURIZON short presentations

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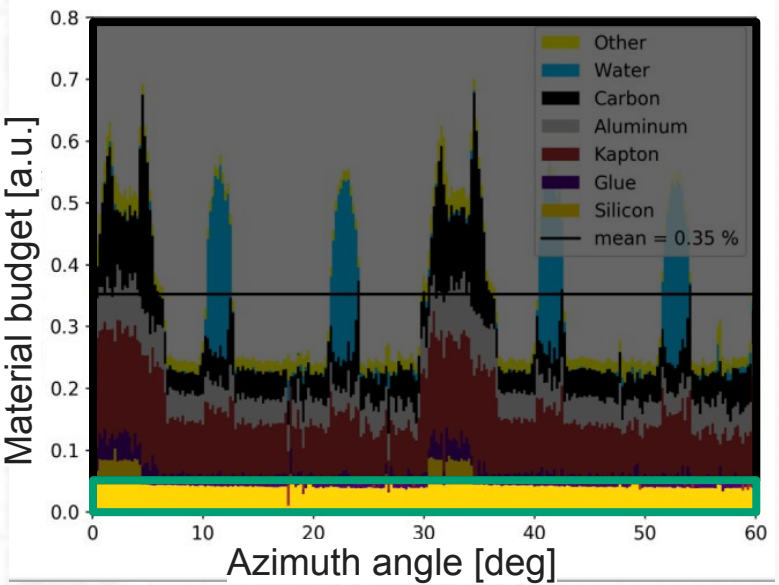
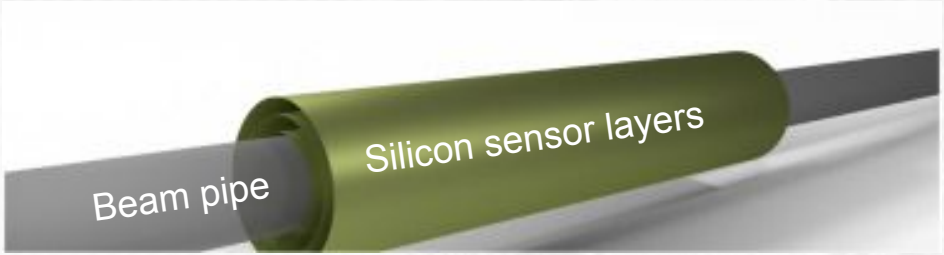
Feasibility of a lightweight vertex detector for the ALICE experiment





Motivation:

- Material distorts tracking performance
- **Only silicon** is the **sensitive** part
- Can we get rid of the rest?
  - **Self-supporting, air-cooled sensors**

Ingredients:

- Monolithic active pixel sensors (M. Deveaux - MAPS)
  - Integration on one wafer
  - Ultra thin sensors
- **Bent sensors**
  - Mechanical stability
- **Wafer-scale sensors**
  - No interconnections between small single sensors
- **65 nm CMOS technology**
  - Large wafers (30 cm)
  - “Intelligent”, small pixels

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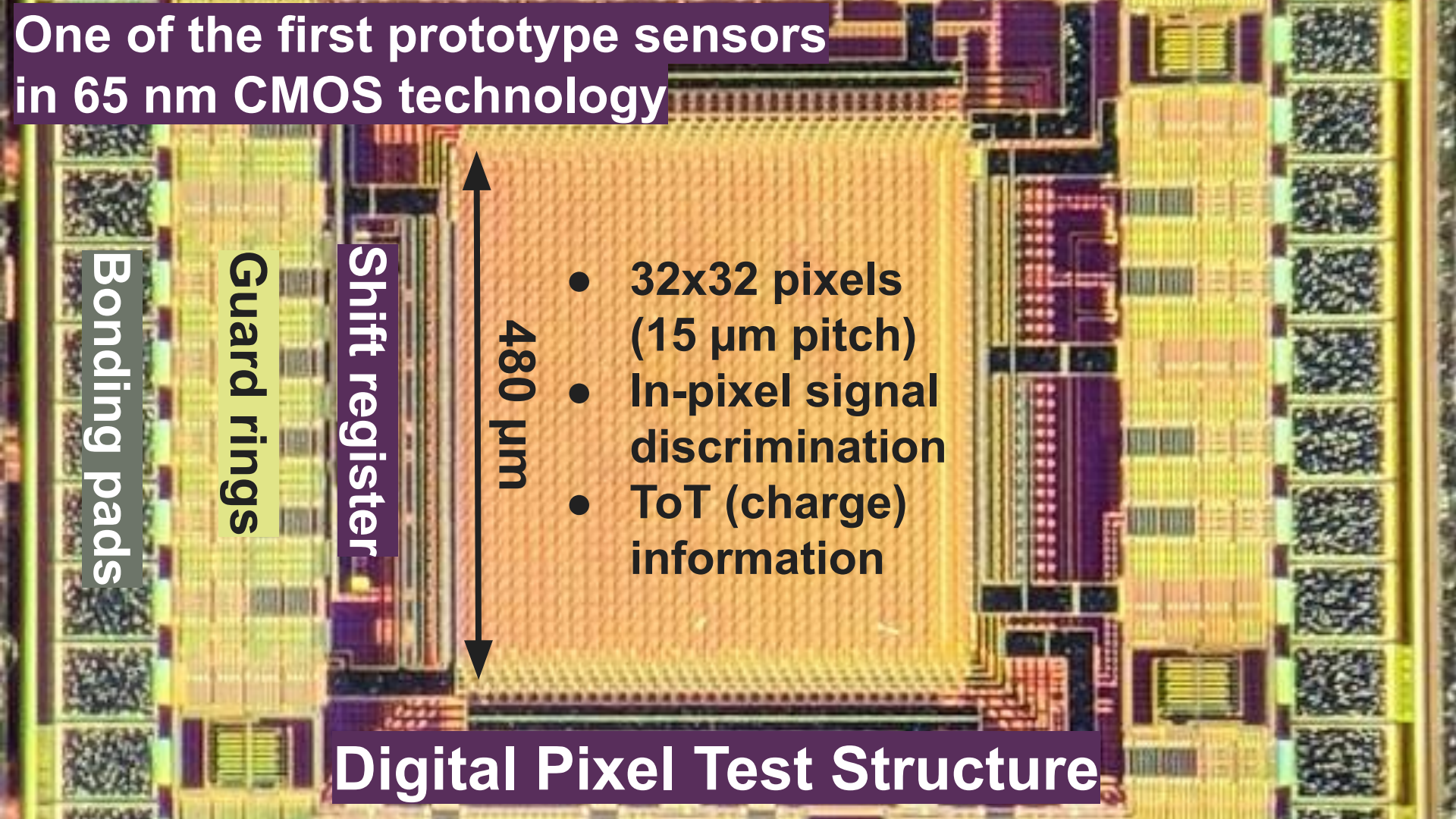
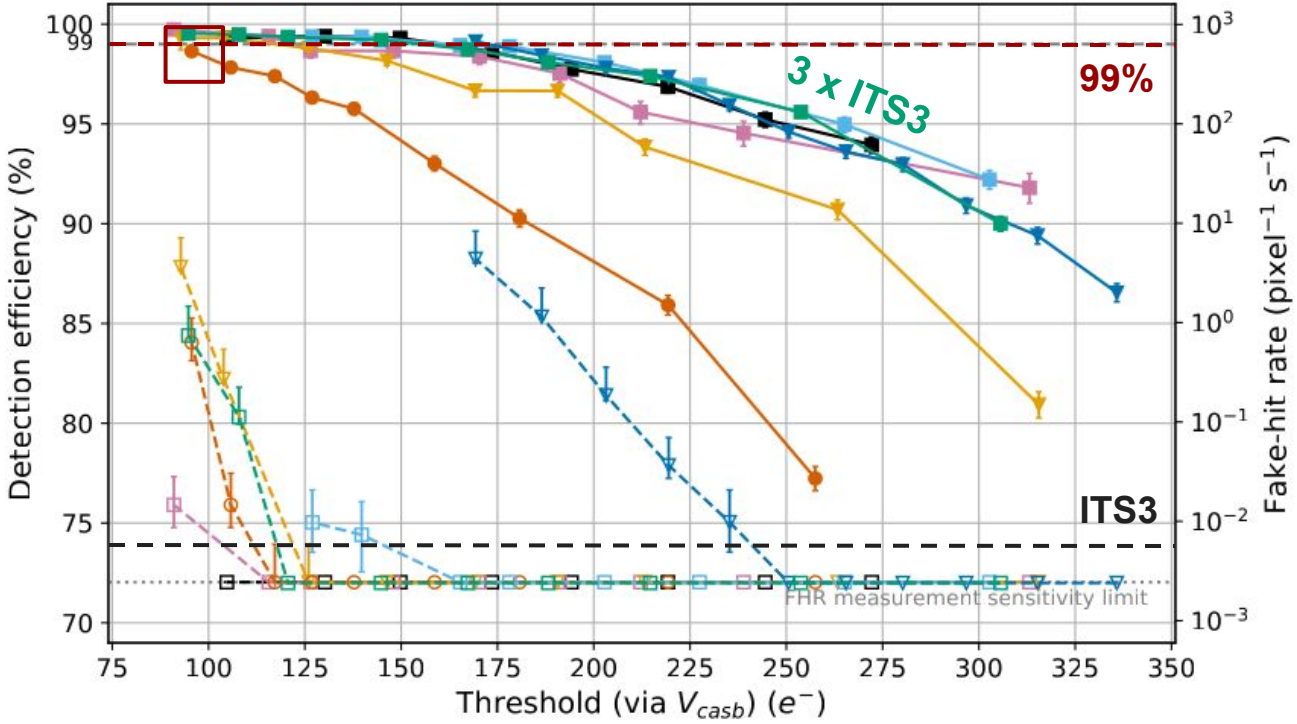

One of the first prototype sensors
in 65 nm CMOS technology
Bonding pads
Guard rings
Shift register
480 µm
• 32x32 pixels (15 µm pitch)
• In-pixel signal discrimination
• ToT (charge) information
Digital Pixel Test Structure

65 nm CMOS technology well suited for MAPS in the ITS3 and beyond



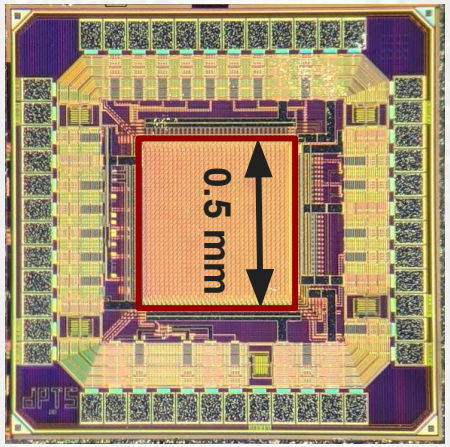
DPTS @ 20 °C (no cooling)

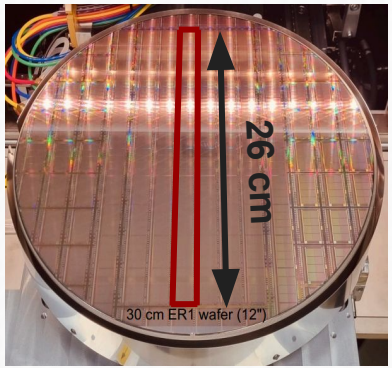
- Detection efficiency
- Fake-hit rate
- Non-irradiated
- 10^{13} 1MeV n_{eq} cm^{-2}
- 10^{14} 1MeV n_{eq} cm^{-2}
- 10^{15} 1MeV n_{eq} cm^{-2}
- 10 kGy
- 100 kGy
- 10 kGy + 10^{13} 1MeV n_{eq} cm^{-2}

Association window:
480 µm x 1.5 µs

- Performance exceeds ITS3 requirements
- 99% detection efficiency in reach for highest irradiation levels

On the way to a cylindrical wafer-scale chip produced in 65 nm CMOS technology





What we have:

- **65 nm CMOS technology** is suitable and sufficiently radiation hard
  - DPTS and other prototypes
- **Bending of MAPS** is feasible
- Stitching to achieve operable **wafer-scale sensors** is possible

How it should look like in ~2 years:

- **Full-scale vertex detector**
- To be inserted as the 3 innermost layers of the ALICE inner tracking system
- Until then:
  - Characterize
  - Develop
  - Understand

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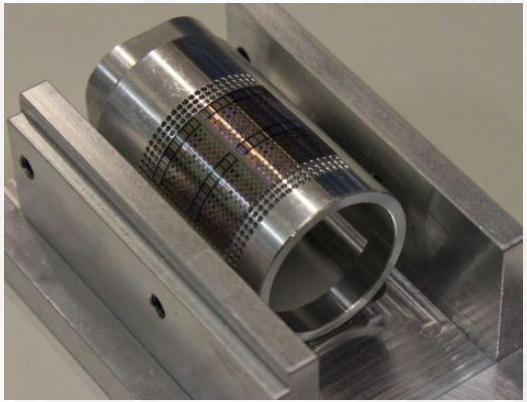
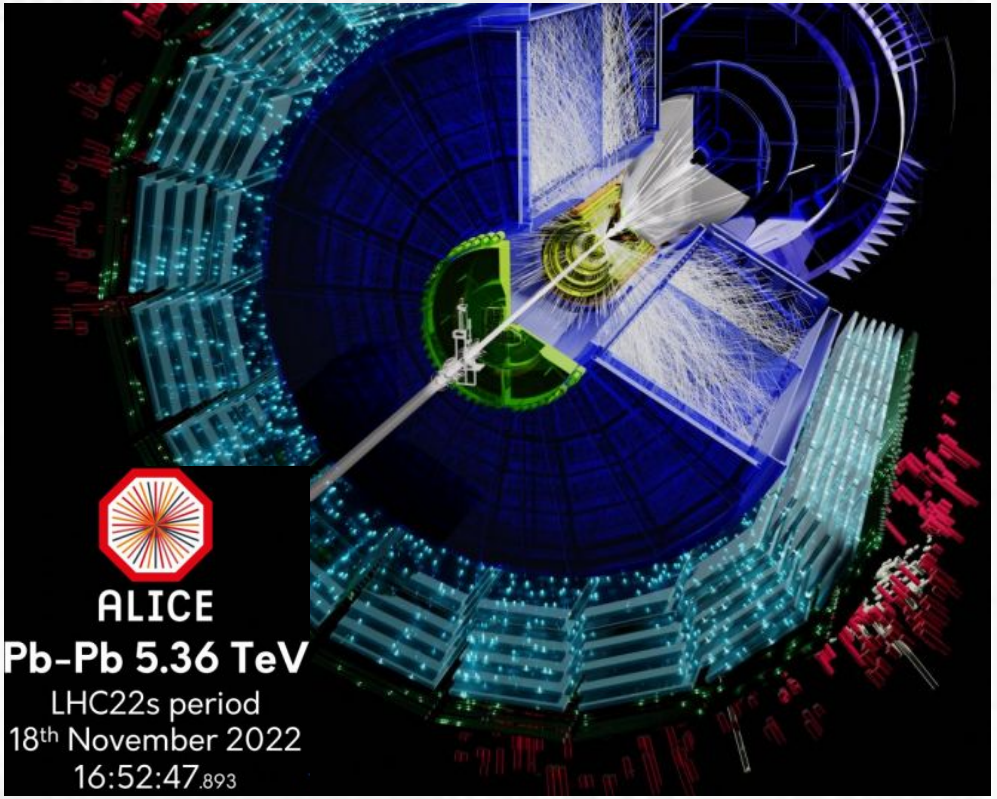
References and a quick getting started with the ITS3 project

- ITS3 overview paper
- ITS3 summary slides
- Mechanics and cooling
- DPTS performance paper

Stay tuned for more!



First bent 65 nm CMOS sensors



Event displays like this with the ITS3 included

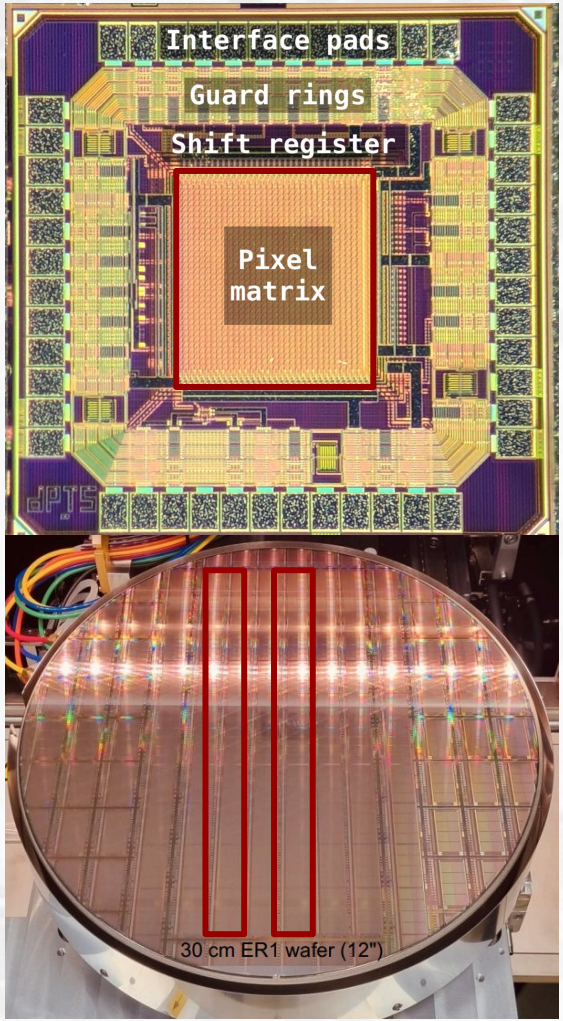
Auxiliary slides

The next ALICE inner tracker upgrade: sensors

- Improve tracking performance by reduction of material budget
  - E.g. pointing resolution by factor 2
  - Especially in low-momentum regime
- Truly cylindrical pixel detector wrapped around the beam pipe
  - Closer to interaction point
  - Less mechanical support
  - New beam pipe
- Cooled by airflow
- Waferscale sensors

ITS3 implies change to 65 nm CMOS technology node

- 30 cm diameter wafers, stitching possible
- Small pixel/feature size (occupancy)
- Two submissions so far (MLR1, ER1)



Digital Pixel Test Structure (DPTS)

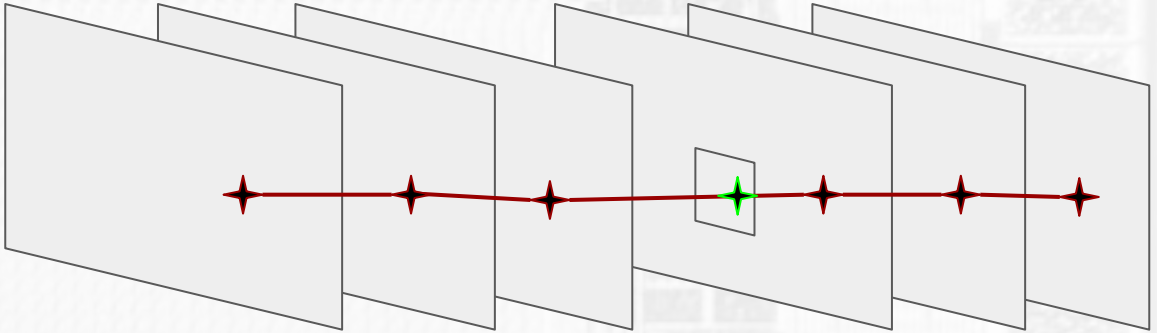
- 32x32 px
- 15 µm pitch
- 480 µm x 480 µm

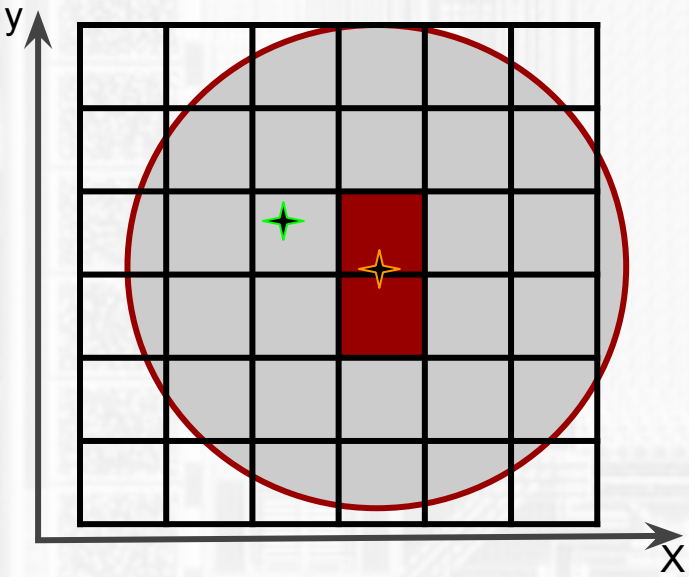
Monolithic Stitched Sensor (MOSS)

- 6.72 Mpx
- 18/22.5 µm pitch
- 1.4 cm x 25.9 cm

Testbeam data analysis

- Track fitting from reference planes
- GBL model used
- Multiple scattering taken into account
- Interpolation to DUT
- Associate measured DUT cluster





Efficiency calculation

- No spatial window
  - Undecodable events considered: “Signal clash”
  - Trigger mitigates false hit associations
- Time window: 1.5 µs

- Number-ratio of matched tracks and total reconstructed tracks

Testbeam data analysis

- Track fitting from reference planes
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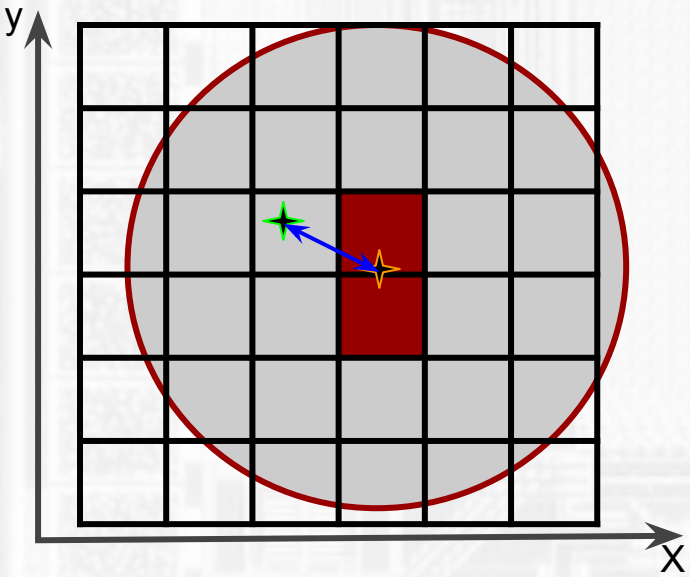
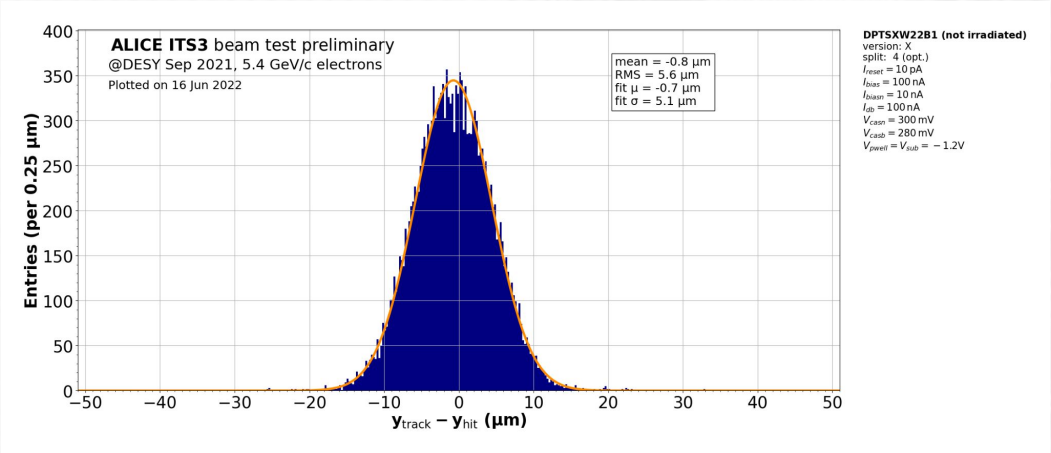


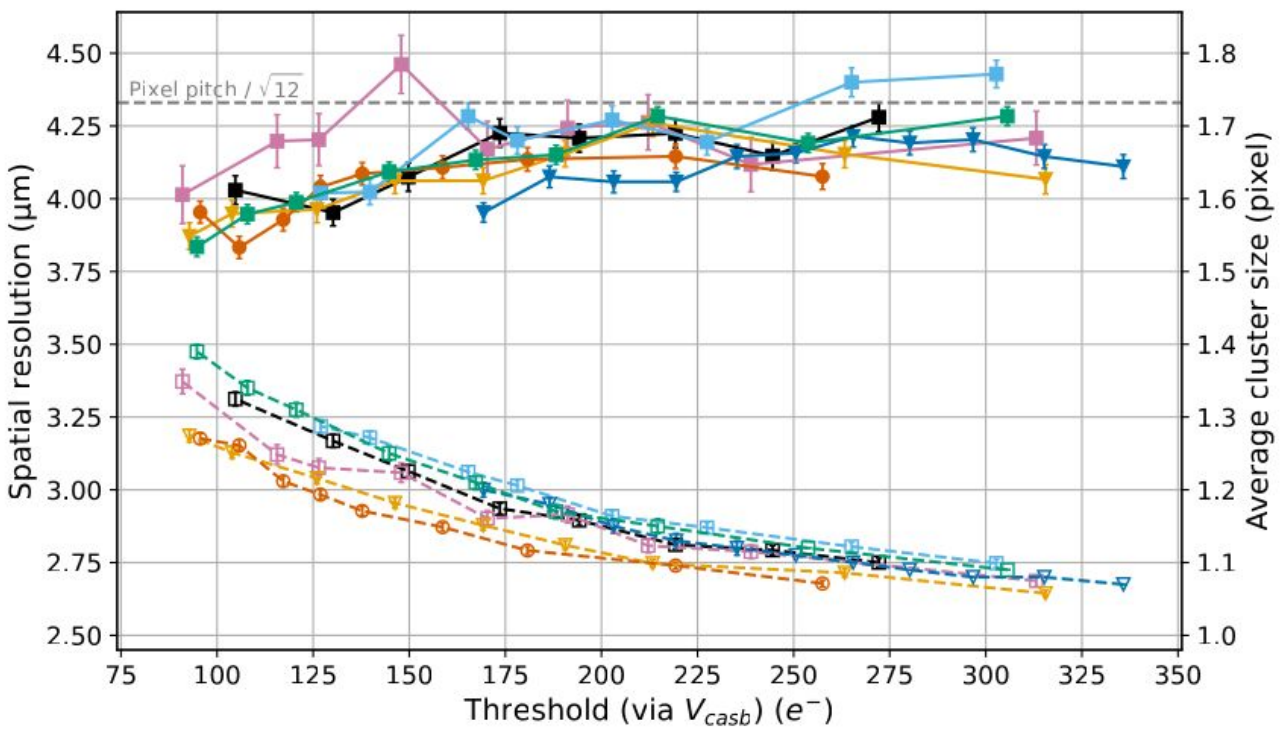
Position resolution calculation

- Spatial window: 45 µm (3 px)
- Time window: 1.5 µs



- Width of spatial residual distribution in x and y
  - Arithmetic mean
- Subtract telescope resolution from simulation: 2.43 µm

DPTS performance - Spatial resolution Irradiated sensors



DPTS @ 20 °C (no cooling)

- Spatial resolution
- Average cluster size
- Non-irradiated
- 10^{13} 1MeV n_{eq} cm^{-2}
- 10^{14} 1MeV n_{eq} cm^{-2}
- 10^{15} 1MeV n_{eq} cm^{-2}
- 10 kGy
- 100 kGy
- 10 kGy + 10^{13} 1MeV n_{eq} cm^{-2}

Association window:
45 µm x 1.5 µs

- No strong dependence on irradiation level
- Visible cluster size ordering according to NIEL dose

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