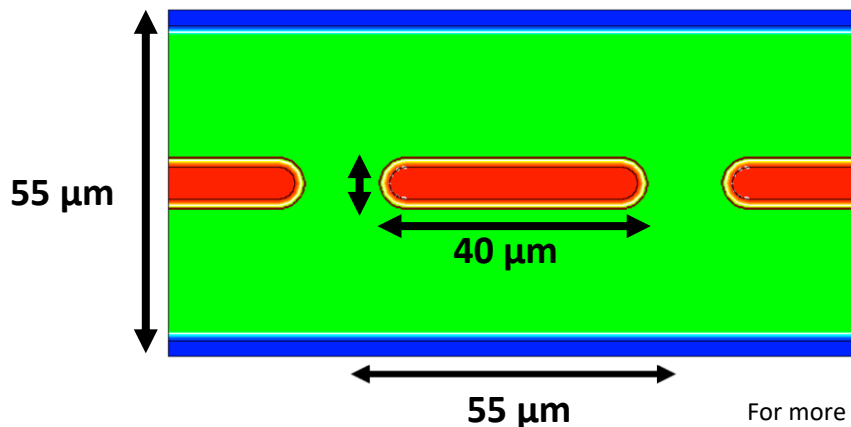# Time resolution of 3D silicon sensors with trench electrodes

Development, test and characterisation
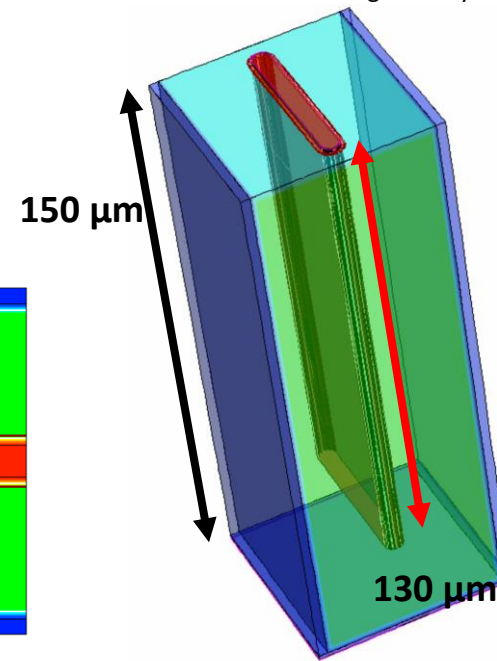
Angelo Loi
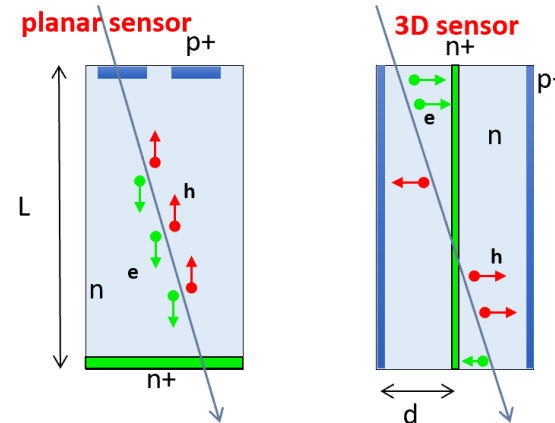
Technology and design

- **The approach within TimeSPOT was to use 3D silicon (and Diamond) sensors to achieve fast timing**
  - **Reducing inter-electrode distance**
    - **Reducing charge collection time**
      - **As well improving intrinsic time resolution**
    - **Increasing radiation hardness**

- **The final geometry selected for the fast timing 3D sensor is the "parallel-trench"**
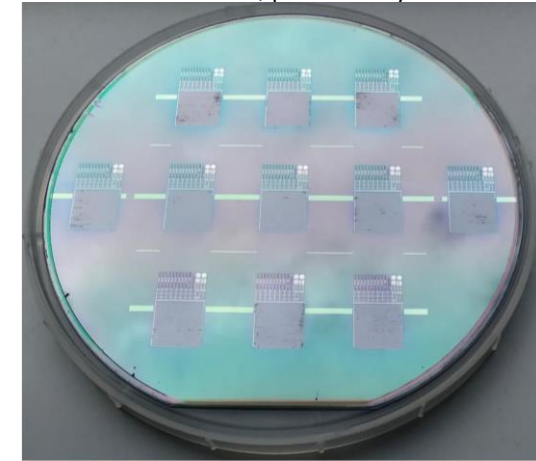 - **Already produced in two batches (2019 and 2021) by FBK**

planar sensor   3D sensor

First TimeSPOT batch, produced by FBK

TCAD model of the selected geometry

150 µm
130 µm

55 µm
40 µm
55 µm

Cut along a parallel trench device based strip sensor

For more A. Loi https://iris.unica.it/handle/11584/284136
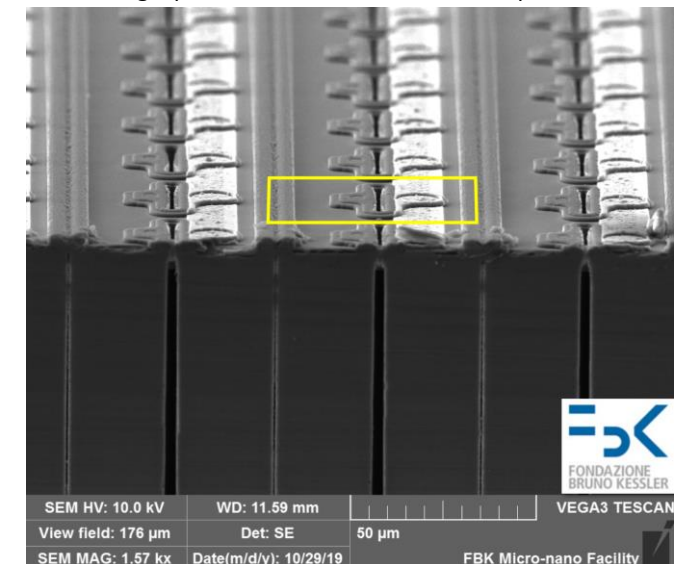
TimeSPOT TCT setup

Measurements

Test beam setup for intrinsic time resolution characterisation

- **Sensor has been characterised**
  - **Test beams (10/2019, 10/2021 and 5/2022) →**
    - **Intrinsic time resolution**
    - **Performance by tilting the device**
    - **Sensor Efficiency**
    - **Performance after radiation**
  - **← Own constructed TCT setup in Cagliari**
- **Customised fast readout has been developed in order to fully explore sensor performance ↓**
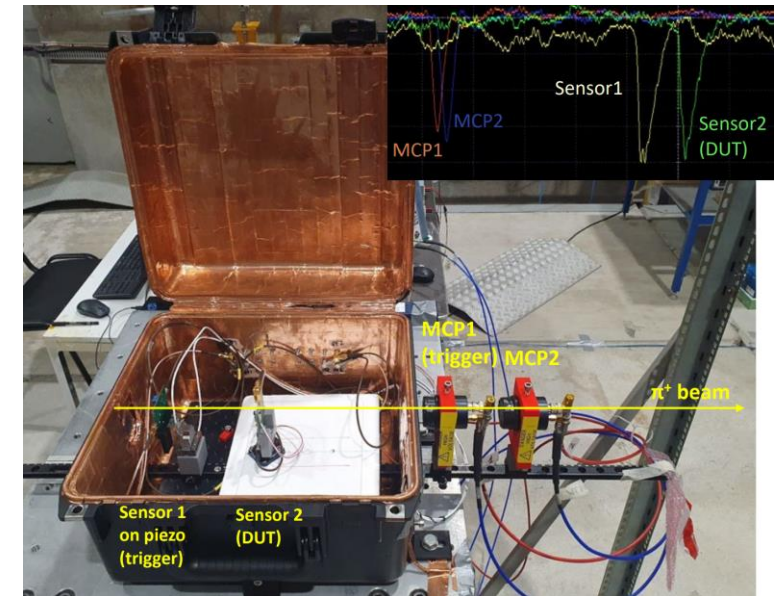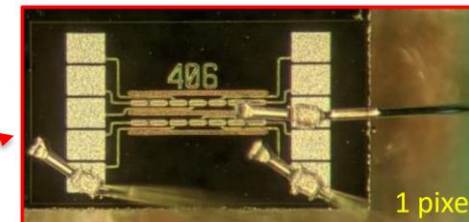
Dry ice enclosure for rad hard measurements
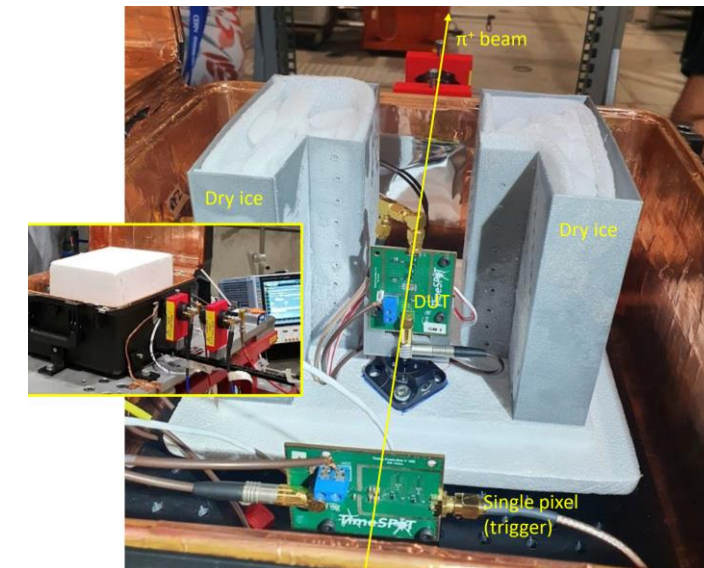
TimeSPOT fast-electronics

Single pixel test device

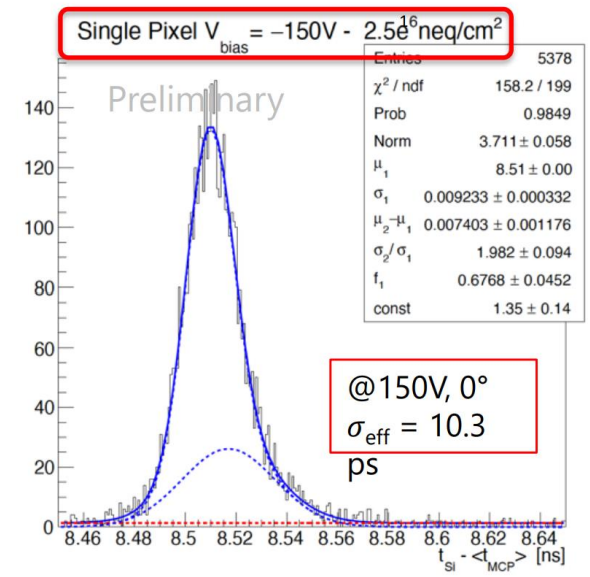For more G.M. Cossu https://arxiv.org/pdf/2209.11147.pdf

Results (1)

- **Intrinsic time Resolution before and after radiation damage above 10^{16} n_eq**

No rad damage

σ_{eff} = 11.5 ps @ 100V
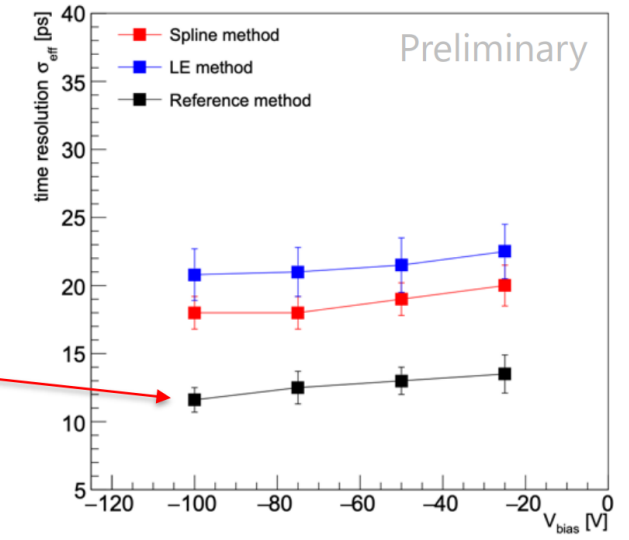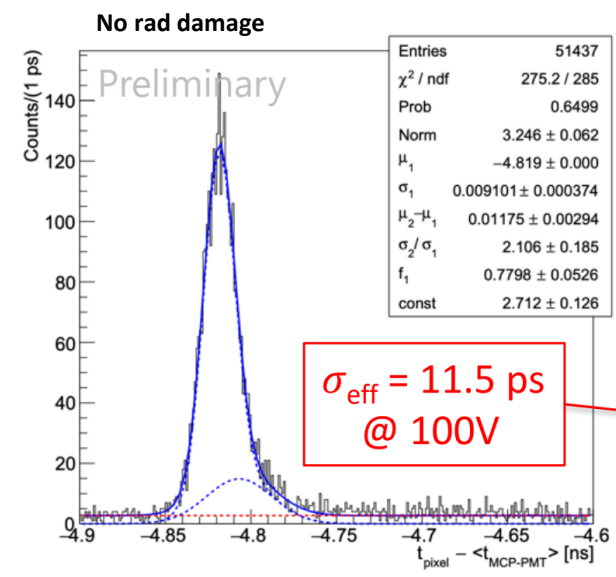
After rad damage ↓
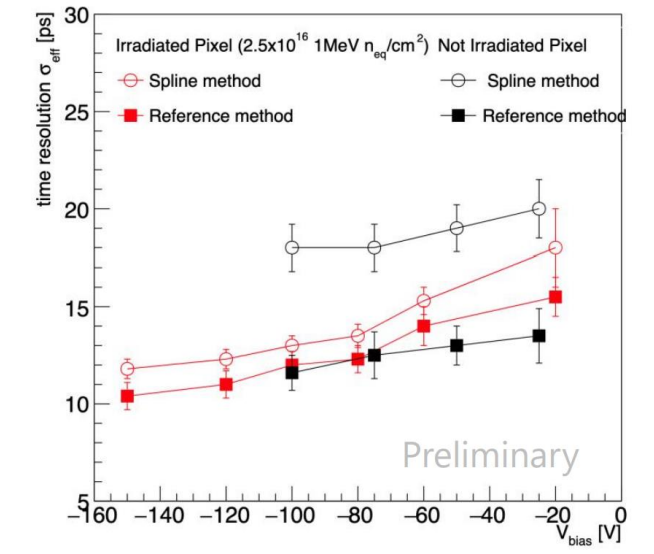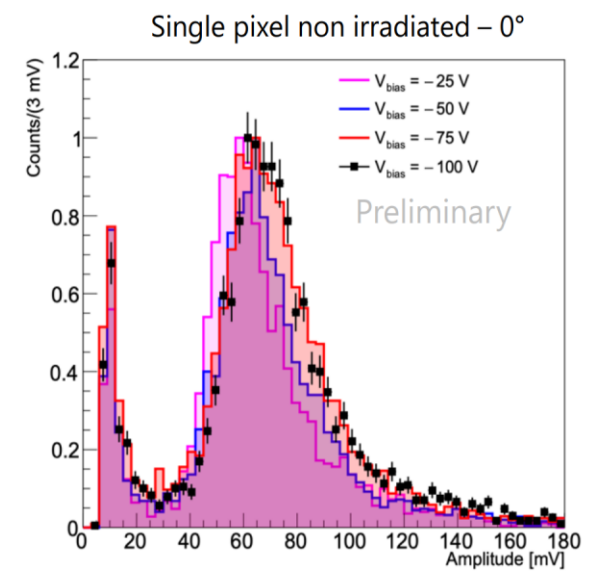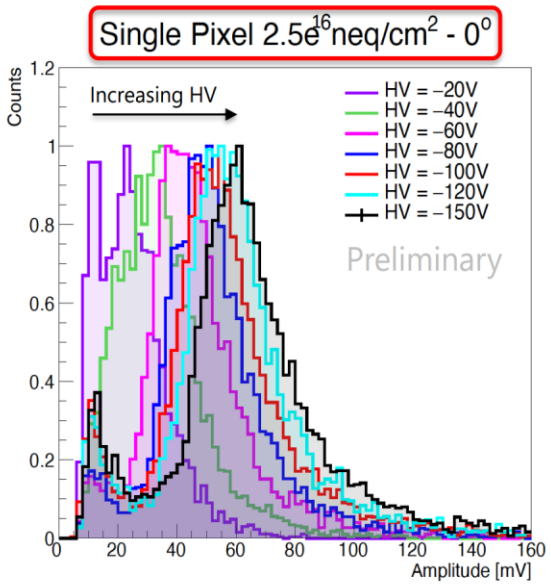
With a slightly larger bias voltage (w.r.t. non-irradiated pixel working point) the signal amplitude of irradiated sensors is recovered!
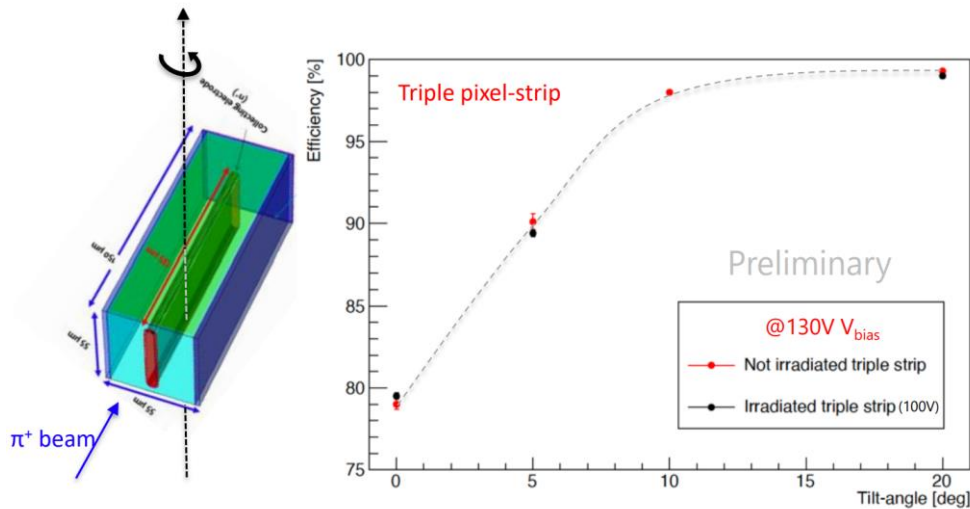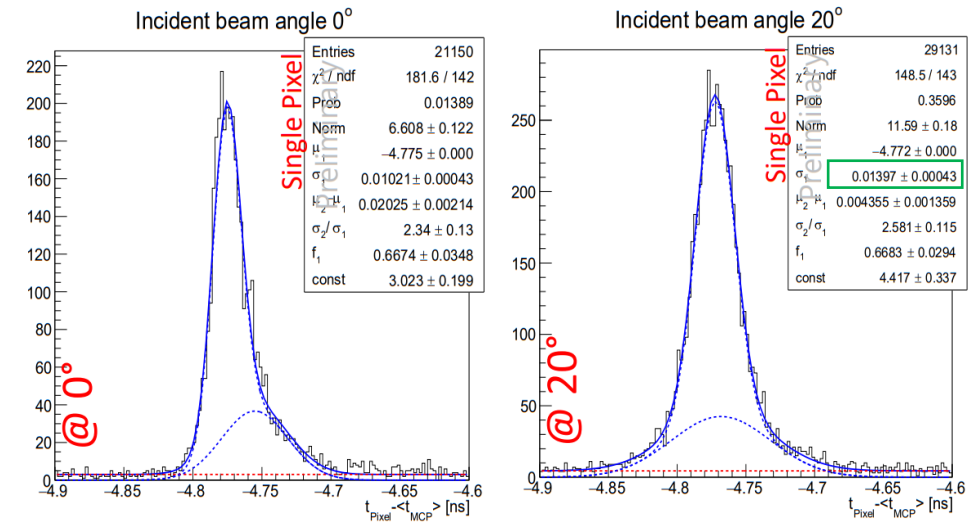
@150V, 0°
σ_{eff} = 10.3 ps

For more info: A. Lampis
https://indico.cern.ch/event/1120714/contributions/4867208/attachments/2472539/4242526/Andrea_Lampis_iworld2022.pdf
https://indico.cern.ch/event/1127562/contributions/4954529/attachments/2511647/4317271/TimeSPOT_TWEPP2022_Final.pdf

Results (2) and outlook

- **Sensor behaviour has been studied also by tilting it**
  - **ToA distribution at 20° becomes more gaussian**
  - **The inefficiency (at normal incidence) due to the dead-area of the trenches is fully recovered by tilting the sensors around the trench axis**
    - **It also works for irradiated sensors**

Incident beam angle 0°

Incident beam angle 20°

@ 0°

@ 20°

Triple pixel-strip

Preliminary

@130V V$_{bias}$

- Not irradiated triple strip
- Irradiated triple strip (100V)

π⁺ beam

- **Outlook:**
  - **32x32 pixel matrix has been bump-bonded on the TimeSPOT-1 ASIC and currently tested. Future 4D tracking detector and its components are under test and caracterisation (more about it on Lorenzo's slides)**