FONDAZIONE BRUNO KESSLER

FUTURE BUILT ON KNOWLEDGE

DRD3

Development of very small pitch, ultra rad-hard 3D sensors for tracking + timing applications @ FBK

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Background

DRD3

- FBK has been involved in the development of 3D sensors since 2004
- Long history of collaboration with INFN
- Key milestone was the production of half of the ATLAS IBL 3D pixels (double-sided technology)
- Since 2014, having passed to 6” diameter wafers, moved to single-sided technology, pioneering the use of Si-Si DWB substrates and stepper lithography for better alignment and detail definition
- Successfully developed small-pitch 3D pixels for HL-LHC upgrades of ATLAS and CMS, currently in production phase
- Also developed 3D pixels with trenched electrodes for optimal timing resolution

On-going productions for ATLAS and CMS

One very good wafer of 3D ATLAS 25x100

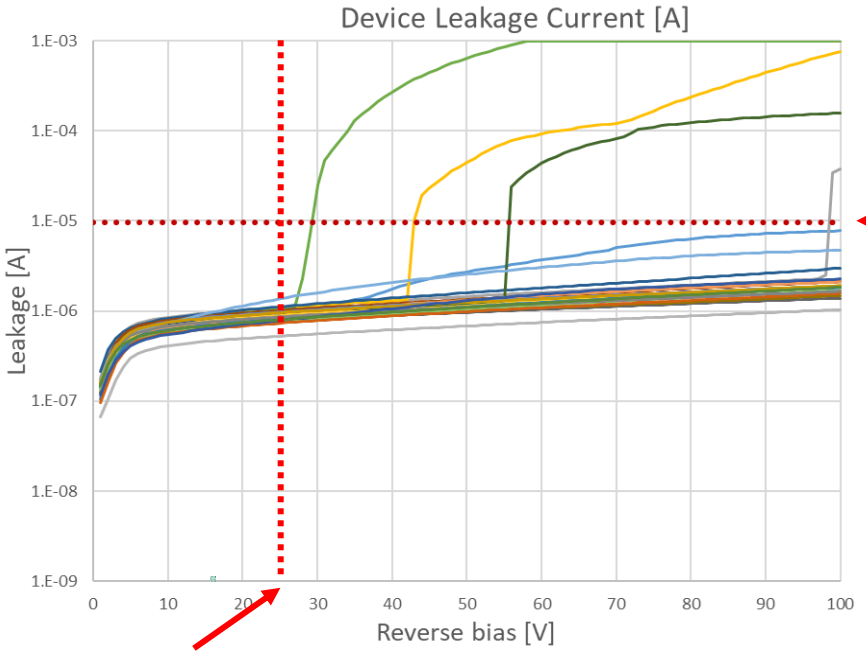
DRD3

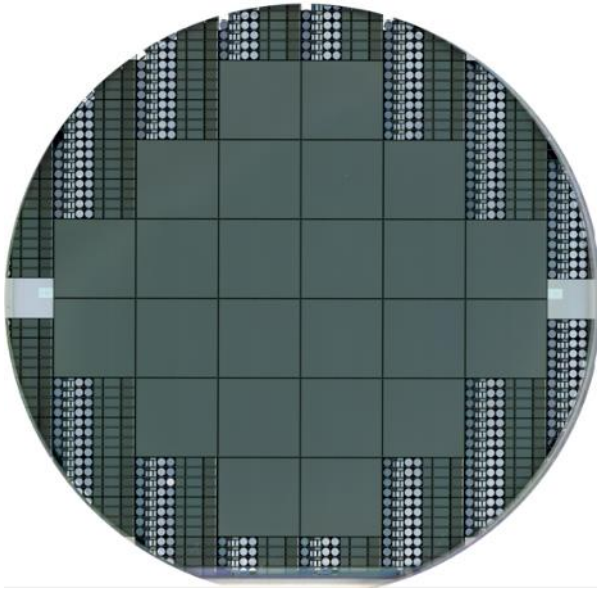
ATLAS Production

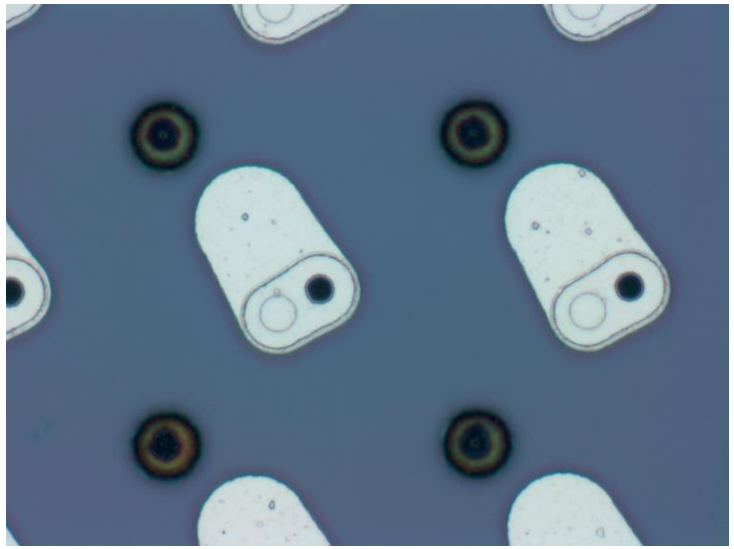
- 50x50: about 800 +350 sensors
- 25x100: about 500 sensors

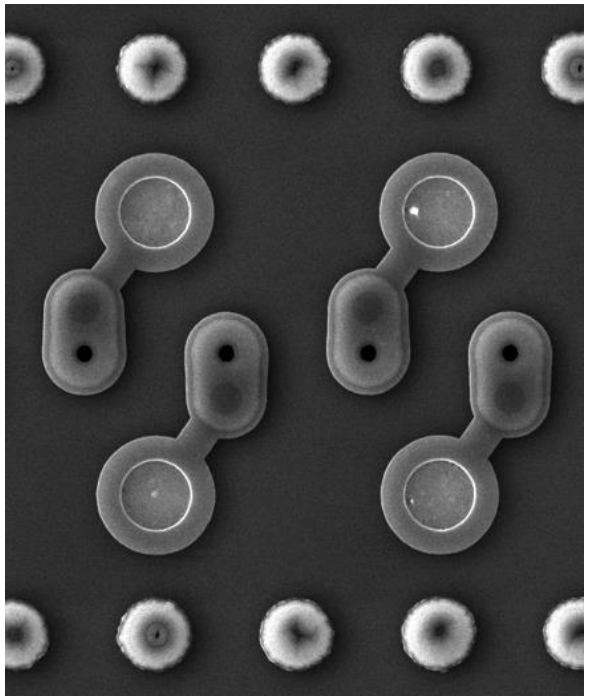
CMS Production 25x100

- 100 sensors pre-prod just completed
- Production: about 400 sensors









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3D-Trench pixels

DRD3

- Outstanding timing resolution demonstrated on single pixel

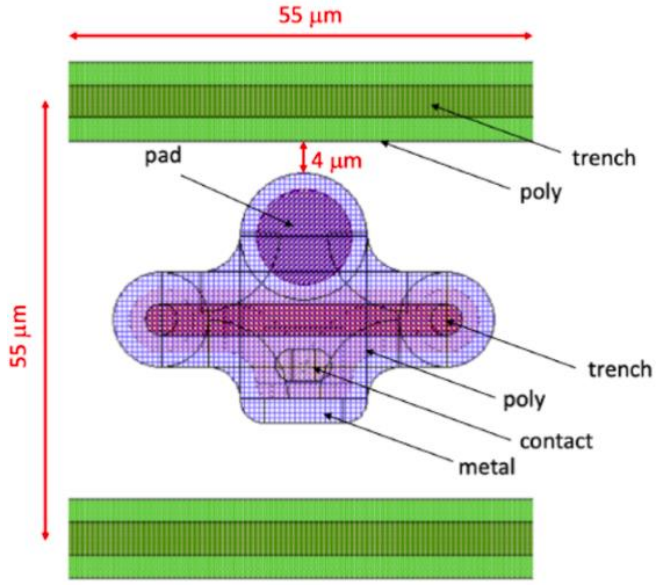
test structures with discrete electronics readout:

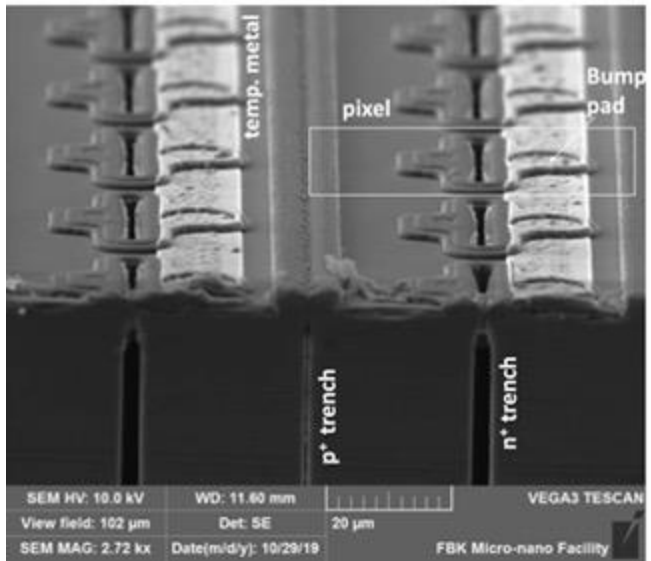
~ 10 ps both before irradiation (JINST 15 P09029 2020) and

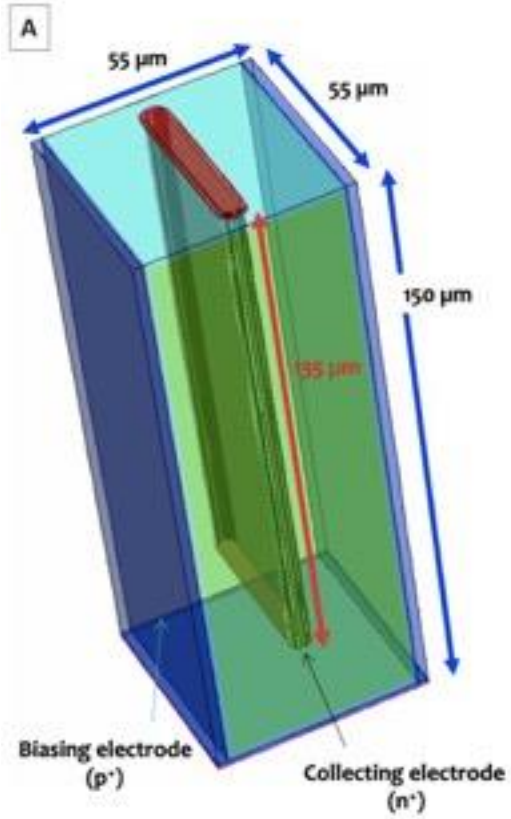
after irradiation up to 2.5x10^{16} n_{eq}/cm^2 (Front. Phys. 12:1393019 2024)

- Recent beam test on samples irradiated up to 1.0x10^{17} n_{eq}/cm^2,

analysis under way







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New batch AIDA Innova

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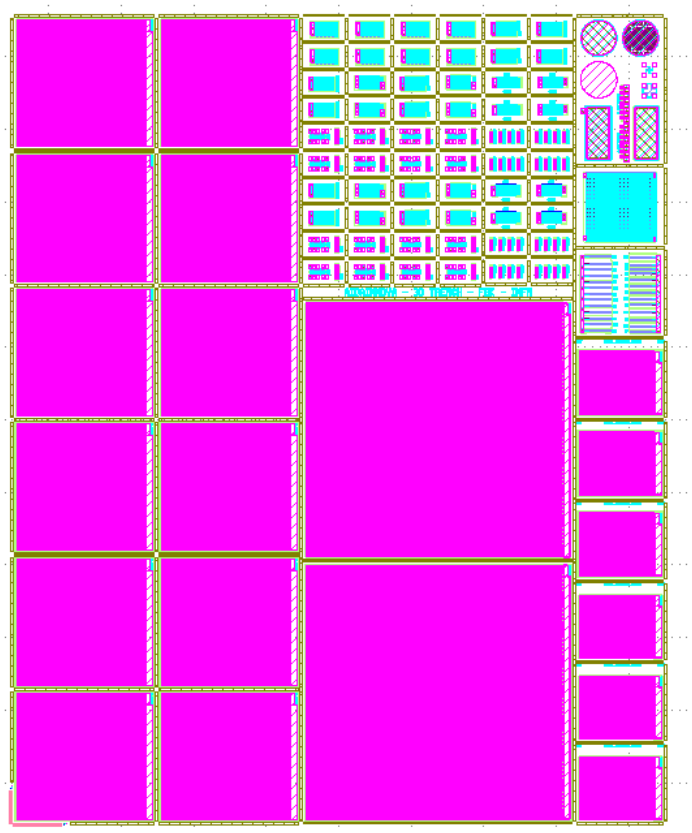
- Continuous ohmic trench (a - STD) vs dashed ohmic trench (b - DSH)



- **Pixel sensors (55 μm pitch)**
  - 32x32 pixels, multiplicity = 6 (3 std, 3 dashed)
  - 64x64 pixels, multiplicity = 12 (6 std, 6 dashed)
  - 128x128 pixels, multiplicity = 2 (1 std, 1 dashed)
- **Device test structures (55 μm pitch and 42 μm pitch, std and dashed)**
  - Groups of individual pixels
  - Strips
  - Diodes
- **Technological test structures**

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AIDA innova

Trenches Si-3D

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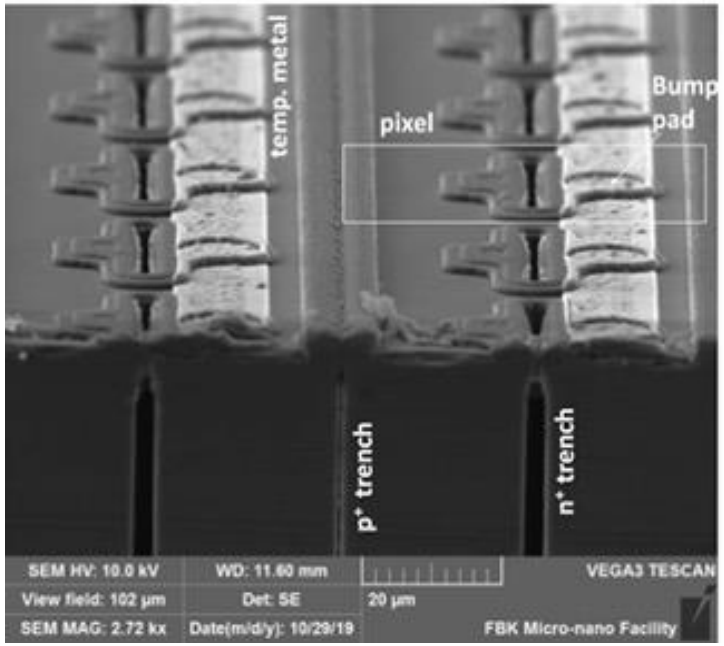
TIMESPOT

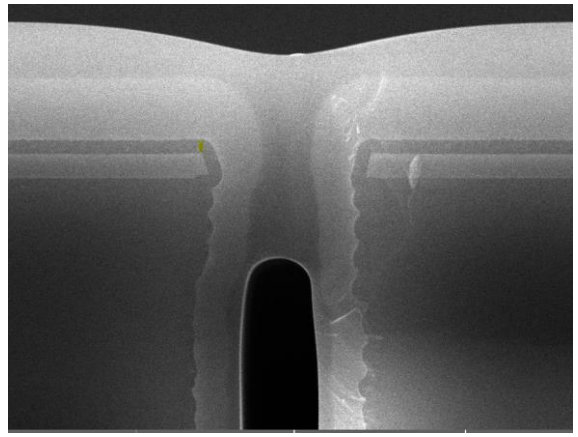


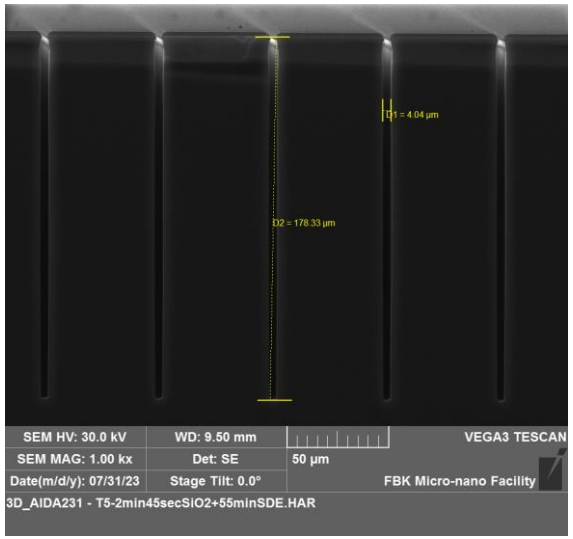
… to 3D AIDA

- ✓ DRIE on trenches process improvement: width & length of trenches optimization
- ✓ Optimization of Lithography processes (photoresist coating, exposition and developing)
- ✓ Adaptation of the design to the process (enlargement of the npoly area and removal of the contacts from the trench)
- ✓ Accurate Trenches drying before all depositions
- ✓ Study of Trenches filling
- ✓ Temporary metal removal improvement
- ✓ Renewal of Equipment (lithography, and Dielectrics Etching)
- ✓ Experience: recognition of defects, critical points and causes and study of ways to avoid or reduce them

- ✓ From 11 shot per wafers to full wafers (29 shot) low bow (about 16 micron)

Process completed last friday





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SENSORS AND DEVICES

From the DRD3 Research Proposal

DRD3

4.1 Spatial and temporal resolutions at extreme radiation levels

For this R&D, the new innermost layers of ATLAS/CMS and the LHCb velo pixel systems are used as stepping stones for the formidable developments needed for FCC-hh. Due to their short drift path and low depletion voltage, 3D sensors are strong candidates for these upgrades.

- **RG 2.1 Reduction of pixel cell size for 3D sensors.**
  - 2024-2025: 3D sensors test structures with pixel size smaller than the current $50 \times 50\ \mu m^2$ or $25 \times 100\ \mu m^2$
  - 2026-2028: Large size 3D sensors with reduced pixel size.
  - $\geq$ 2028: Expand the number of foundries capable of producing 3D sensors for HEP applications.
- **RG 2.2: 3D sensors with a temporal resolution better than 50 ps.**
  - 2024-2025: Production of a small matrix with pitch equal to or less than $55 \times 55\ \mu m^2$ to be connected with existing read-out ASICS
  - 2026-2028: Production of large-size sensors (using the selected geometry from the R&D runs) and interconnection with custom-made read-out ASIC

Workplan

DRD3

2024-2026

- Extensive characterization of AIDA Innova batch (well matches scope of RG 2.2)
- Includes both test structures and small-medium (up to 128x128) pixel arrays

New batch of small-pitch 3D column sensors, funded by INFN (well matches scope of RG 2.1 and RG 2.2), fabrication to start in 09/24

- Design optimized for timing, several layout options
- Cell size down to 45x45 μm^2 for pixels and below for test structures (also very small cell samples – 25x25 μm^2 , for charge multiplication studies)

2026-2028

- Implement the best layout solutions to large size arrays (funding not yet available)

Interested groups

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- FBK (Maurizio Boscardin) : device fabrication
- TIFPA – INFN (Gian-Franco Dalla Betta): design, simulation and characterization
- INFN Cagliari (Adriano Lai): simulation and characterization (+ readout design)
- INFN Firenze (Giacomo Sguazzoni): characterization
- INFN Genova (Claudia Gemme): characterization
- NIKHEF (Martin van Beuzekom): characterization
- Univ. New Mexico (Sally Seidel): characterization

Other groups welcome to join