WP proposal
Development of TI-LGAD technology towards 4D Tracking

DRD3

A. Macchiolo
University of Zurich

Participating institutes:

CERN
FBK (Trento, IT)
IJCLab (Orsay, FR)
IFIC (Santander, SP)
JSI (SI)
LPNHE (Paris, FR)
UHH (DE)
University of Zurich (CH)

The WP proposal is open for other interested institutes to join

TI-LGADs: status of the technology development

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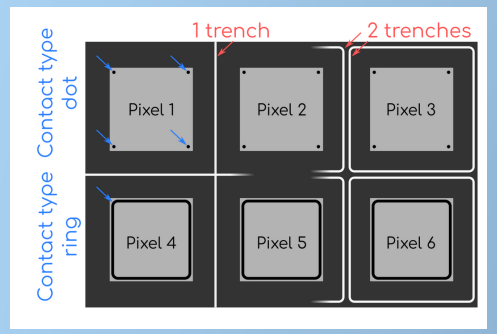
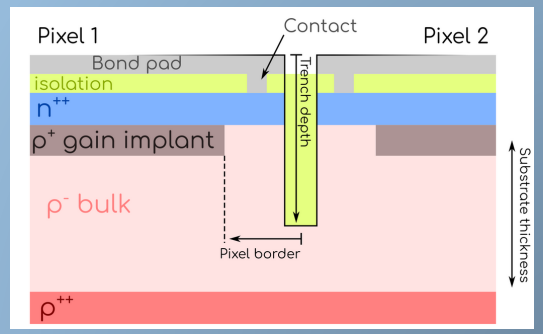
- TI-LGADs have been first proposed by FBK (Trento, IT) and after some prototyping runs further developed with two major productions

FBK RD50 Production

- Production completed in 2021
- Several trench designs:
  - Number of trenches (1,2)
  - Contact type (dot, ring)
  - Pixel border (V1<V2<V3<V4)
  - Trench depth (D1<D2<D3)

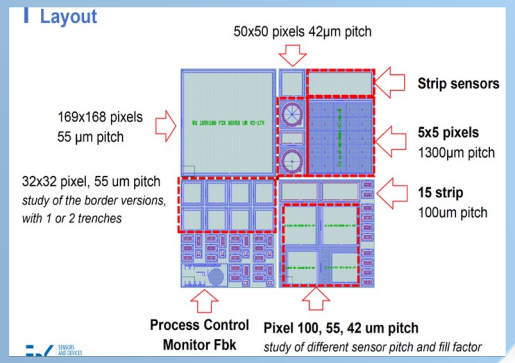




FBK AIDAInnova Production

- Production completed in 2023
- Still some process variations implemented
- Addition of carbon co-implantation
- Test structures and small pixel matrices for lab and beam tests and 1x1 cm^2 sensors for yield determination

Wafer	Thickness	Carbon	Trench depth	Trench process
1	45	Y	D2	P2
2	45	Y	D2	P2
3	45	Y	D1	P2
4	45	Y	D1	P1
5	45	Y	D2	P1
6	45		D2	P2
7	45		D2	P2
8	45		D1	P1
9	55	Y	D3	P2
10	55	Y	D2	P2
11	55	Y	D2	P2
12	55		D2	P2



TI-LGADs: Selected results

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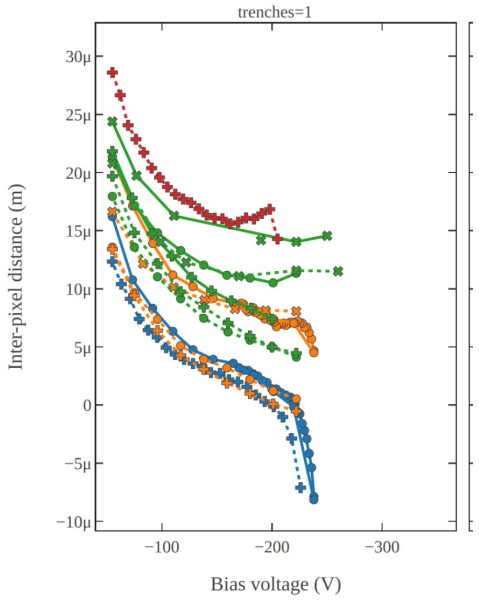
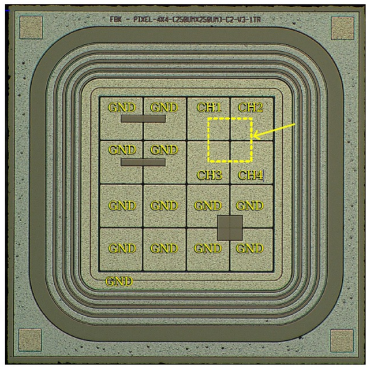
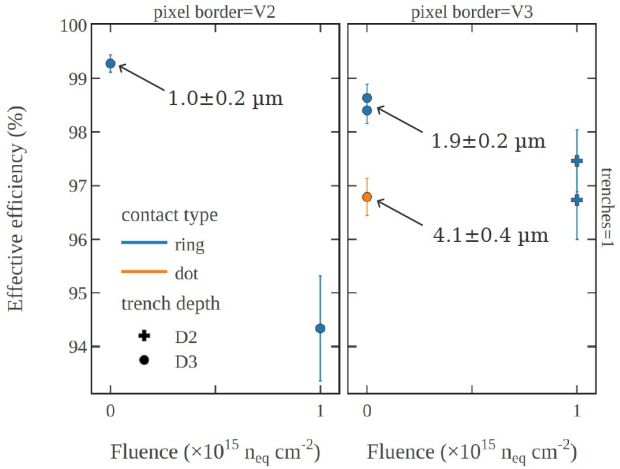


Small inter-pixel distance at moderate voltages determined with laser TCT

Confirmed with TB measurements up to a fluence of 1e15 n_{eq}

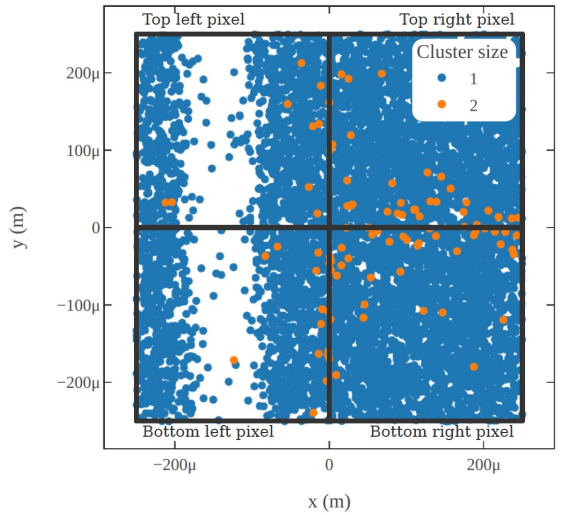


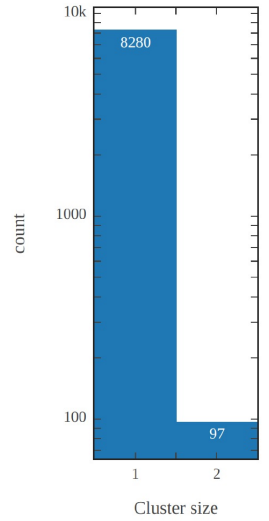


Only ~1 % of events share charge at perpendicular incidence, low value consistent with expectation, good isolation thanks to the trenches

Spatial resolution= digital resolution

Timing resolution similar to the standard LGADs for Phase-2 applications





Possible applications and R&D program

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- Possible application for the replacement of:
  - Inner rings of ATLAS HGTD
  - outer layers or disks in the CMS/ATLAS pixel systems in Phase-3
- The requested radiation tolerance can be in the range of 1-5x10^{15} n_{eq}/cm^2
- Use as timing reference in a telescope

Measurements still to be carried on the structures of the AIDAinnova production:

- Definition of the limit in fluence of the radiation hardness of the presently available structures co-implanted with Carbon
- Systematic study of the inter-pixel region (IPD) before and after irradiation as a function of the process parameters

Future productions and characterization, following the outline of DRD3 WG2 scientific proposal:

- Late 2025-2026: Production of small pixel matrices with pitches of 1.3 mm x 1.3 mm (HGTD) and pitches equal to or less than 55 x 55 μm^2 , compatible with the prototype ASICs being developed now in 28 nm CMOS for 4D Tracking.
  - Possible optimization of the Boron and Carbon doping profiles to improve radiation hardness
  - Characterization with laboratory and beam tests
    - Performance comparison with other LGAD technologies, especially with AC-LGADs, to identify solutions for different applications (for example different fluences, occupancy levels, etc) → driving the definition of requirements for future generation of timing ASICs for 4D Tracking
- 2027-2028: Productions of large pixel matrices (few cm^2) compatible with full scale ASICs that should become available in this period, to enable for example Phase-3 upgrades.

Resources needed for the project

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- The institutes participating to the proposal have all long experience in the development of silicon sensors for HEP
  - Wide range of instrumentation for the production and characterization of the devices already available:
    - FBK processing line
    - Probe-stations, TCT, TPA-TCT, beta source testing, x-ray, access to irradiation and test-beam facilities

- The project is expected to need resources for:
  - 2-4 production runs where the exact number and timeline depends primarily on the availability of new ASICs for 4D Tracking in the next 4 years
  - 7-8 FTE, including Ph.D. students, for the characterization of the devices over a time range of 4 years

Additional slides