Radiation Detectors Group

LGAD development at the IMB-CNM

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Centro Nacional de Microelectrónica IMB

CSIC Consejo Superior de Investigaciones Científicas

www.imb-cnm.csic.es

IMB-CNM in a Nutshell

Centro Nacional de Microelectrónica IMB

CSIC Consejo Superior de Investigaciones Científicas

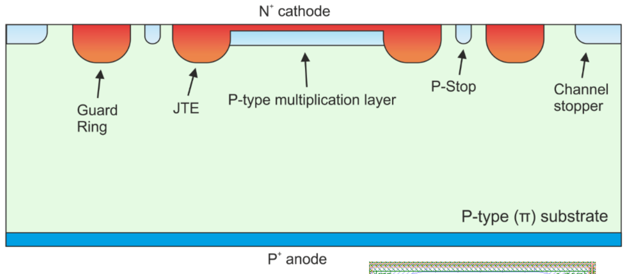
RDG Radiation Detectors Group

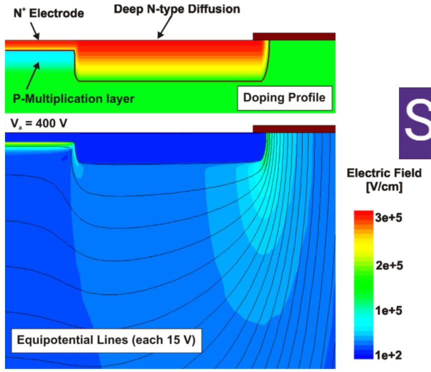
- We can contribute to all the sensor R&D steps

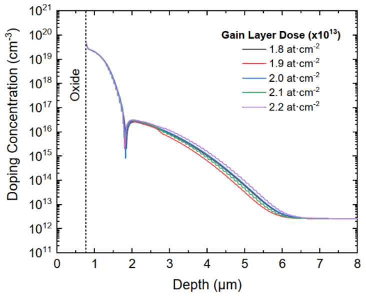
https://www.imb-cnm.csic.es/en
https://rdg.imb-cnm.csic.es/

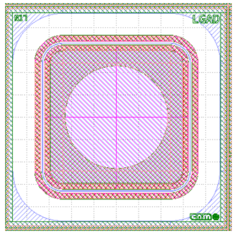
SYNOPSYS

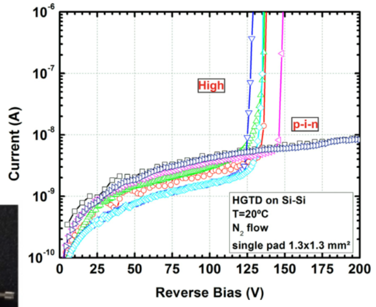
Synopsys TCAD

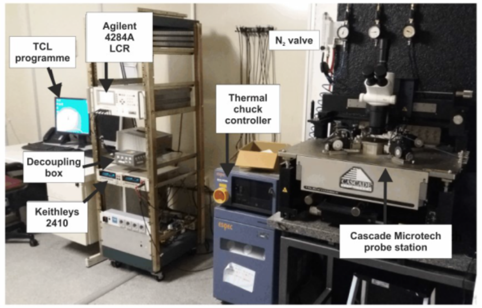


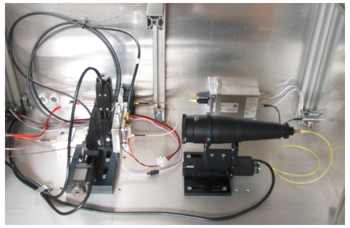


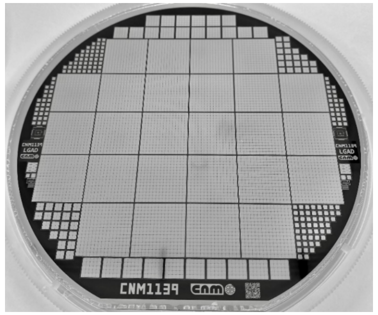


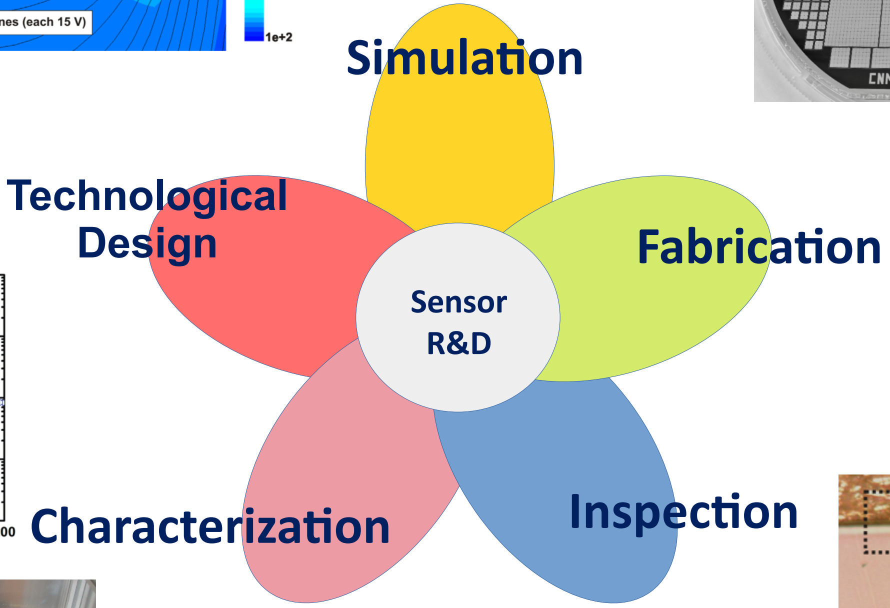


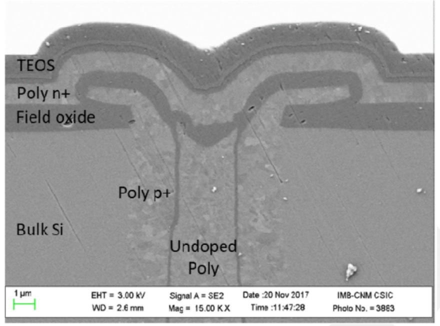


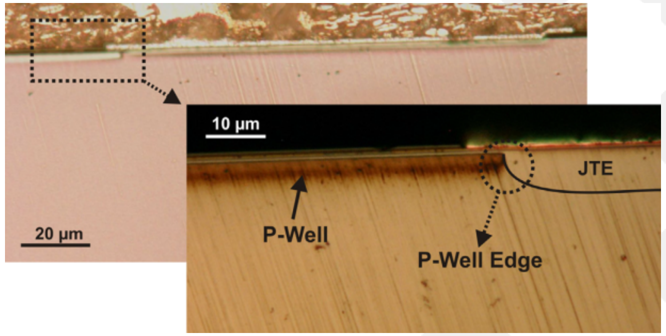










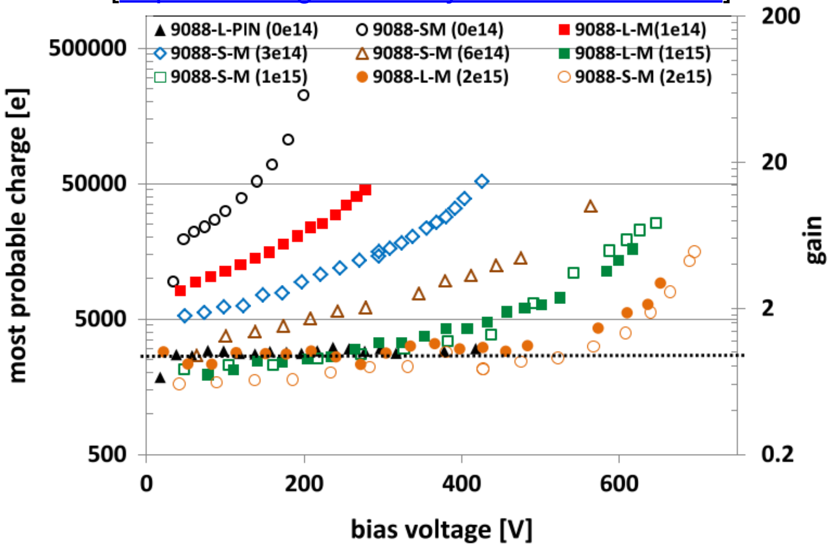


LGAD challenges

a) **Radiation Hardness:** Gain decreases with fluence

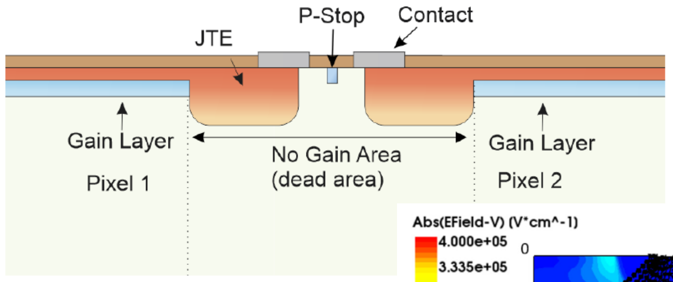
- Serious challenge for HL-LHC applications and beyond

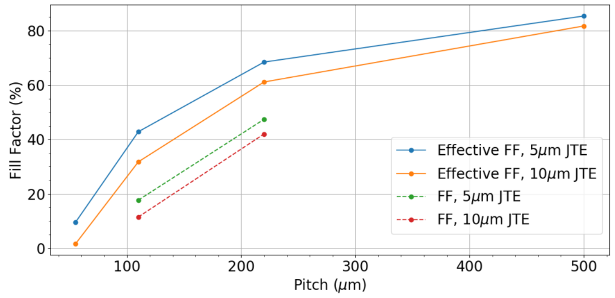
[https://doi.org/10.1016/j.nima.2018.02.018]



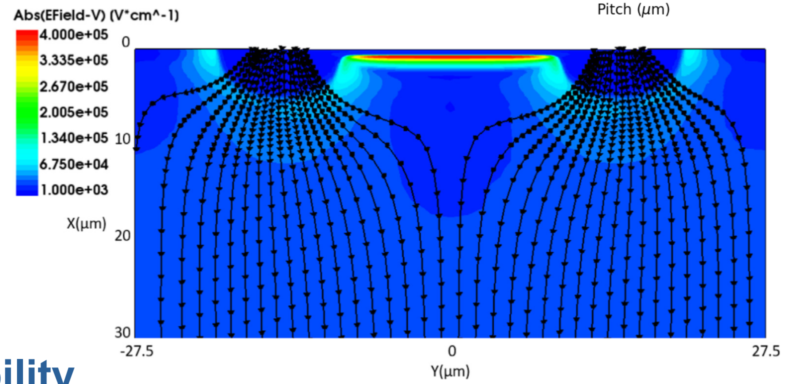
b) **Fill factor:** Termination (non-gain area) dominates for small pixels

- Need to account for drift to JTE
- Good timing reconstruction requires homogeneous weighting field





https://doi.org/10.1016/j.nima.2021.165746



c) Other certainly non-minor challenges: **Fabrication Yield** and **Device Reliability**

- Compromising many-pixel structures, large devices and even moderate productions

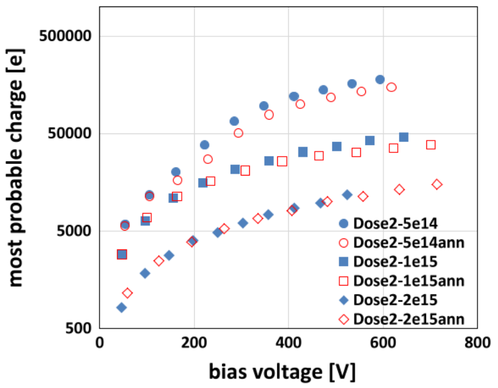
d) Classic design is not optimal for **low penetrating particles** (lower efficiency, lower gain)

- Many attractive applications in this category: low energy protons, soft X-rays, UV photons and beyond

What we have tried

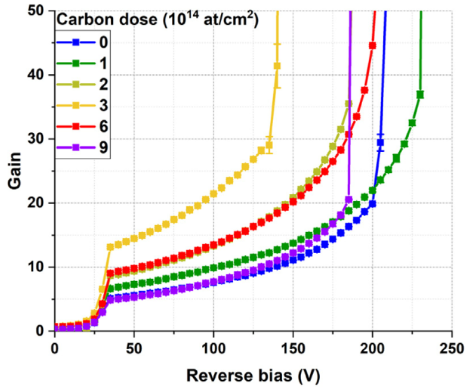
- Replace Boron with Gallium

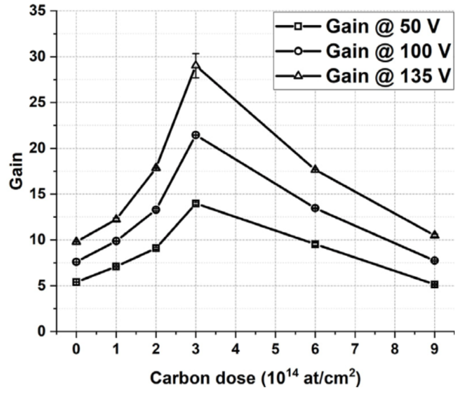
https://doi.org/10.1016/j.nima.2018.04.060



- Carbon enrichment

https://doi.org/10.1016/j.nima.2024.169424





Further steps:

- Partial activation of the gain implant (on going)

RD50 funding request
- Date: 15.11.2023 -

Title of project: **Partial Activation of Boron to enhance the radiation tolerance of the gain implant – PAB**

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- Links with other WG (or projects)

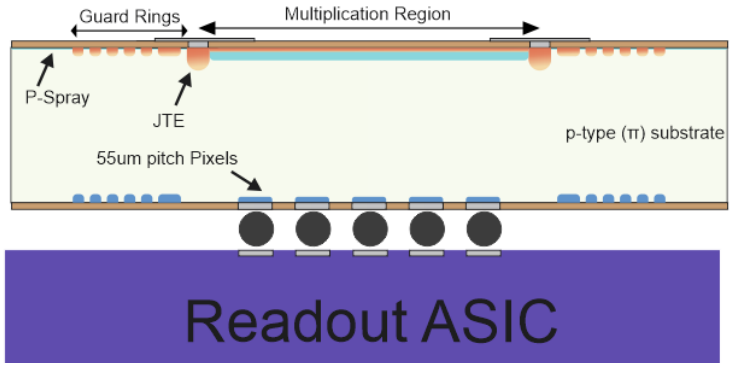
WG2
- 3D sensors for timing

WG3
- Radiation hardness techniques

WG6
- Other substrates (SiC, etc.)

Fill Factor Challenge

Inverse LGAD (iLGAD)

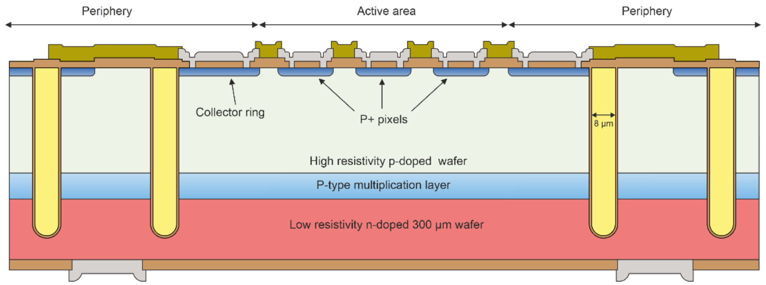


- Ohmic contact segmented
- Multiplication region extends over all the device

Cons
- Double side processing
- Backside sensitive to scratches
- Needs to be fully depleted

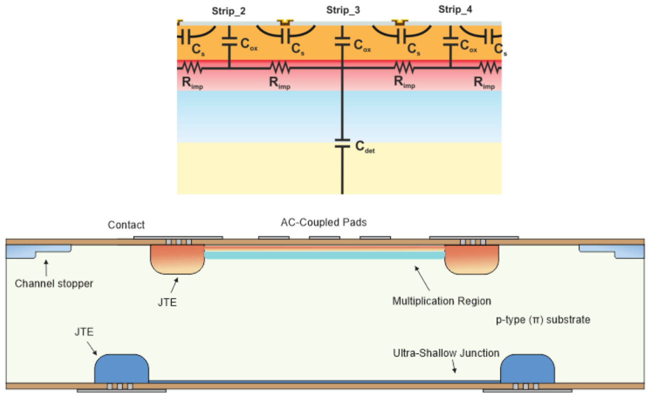
doi:10.1088/1748-0221/11/12/C12039
https://doi.org/10.1016/j.nima.2019.162545

Trench Isolated iLGAD



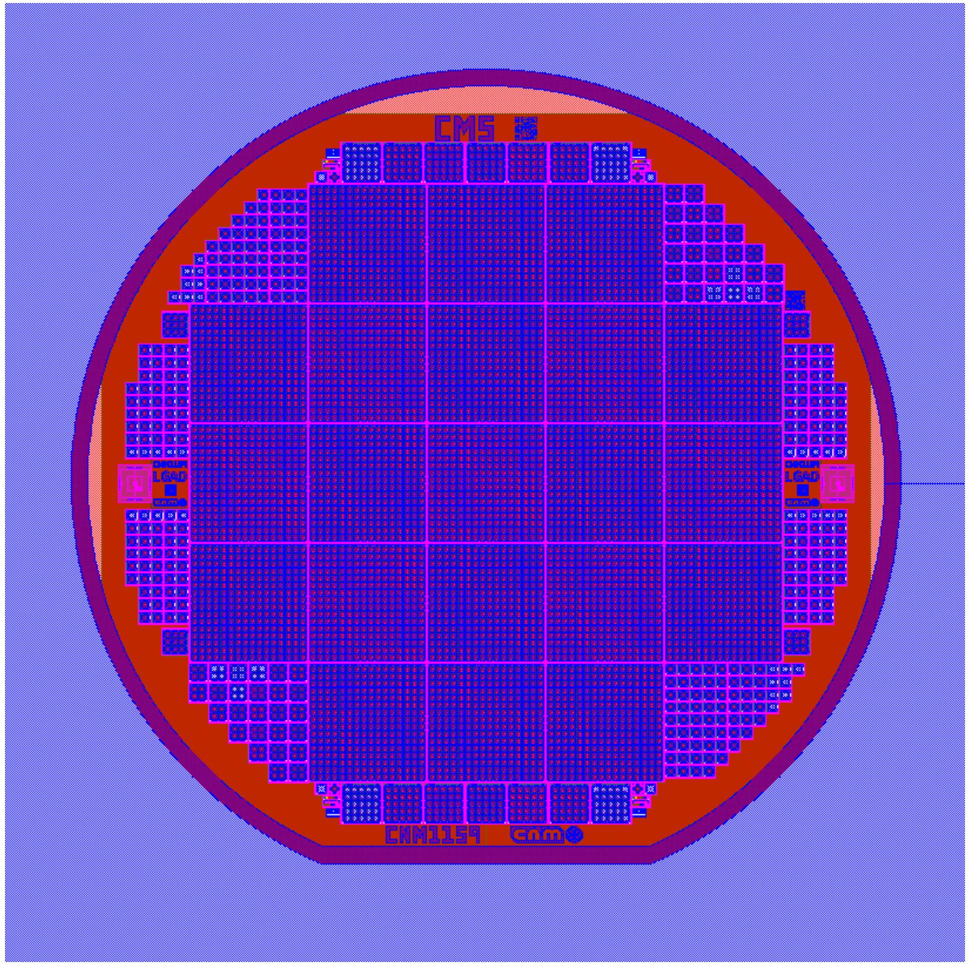
- Fully isolated multiplication region
- **Single-side** and **50% less** fabrication steps.
- **Higher voltages**
- **Slim-edge technology.**
- Optimization of the **multiplication layer is independent of charge collection and cross-talk at the electrodes.**

AC LGAD



- Pad segmentation replaced into **metal segmentation**
- The signal is AC-coupled into the metal pads by another continuous sheet of coupling oxide.

Yield + Reliability Challenge



Latest mask set with 16x16 pixel devices + single pad LGADs

- We have experienced fabrication issues with a clear impact on the yield of our technologies
  - In the latests runs, this might be partially attributable to the major upgrade of the CR equipments (but not only)
  - Many different technologies, broad variation of parameters → Not helping to standardize processes

↓

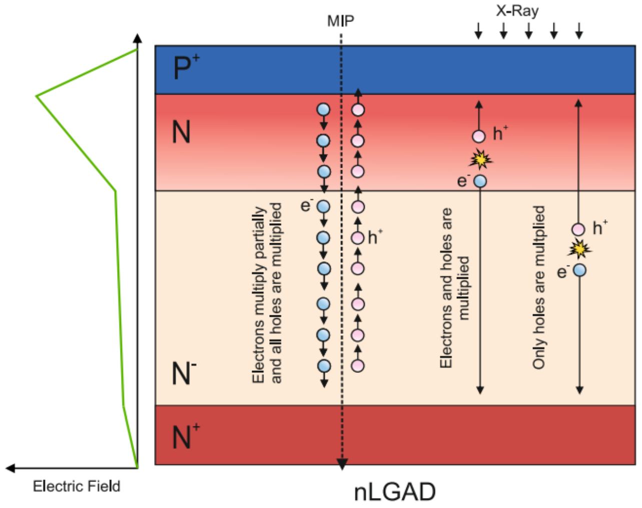
Dedicated runs to stabilize our technologies

- Looking for higher reliability (same performance and characteristics, among *and within* devices)
  - Increased number of inspection steps
  - Careful study of the metallization and passivation
  - Use of deep multiplication layer (on going)

Low penetrating particles

- Many applications beyond high-energy physis experiments…

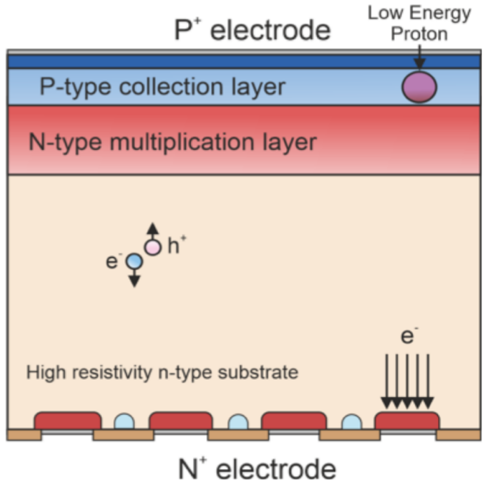
nLGAD



- Specifically designed to enhance low penetrating radiation detection (soft Xray, UV, etc.)
- Check previous talk [Fernandez DRD3]

J. Villegas - TREDI2024
https://doi.org/10.1016/j.nima.2023.168377

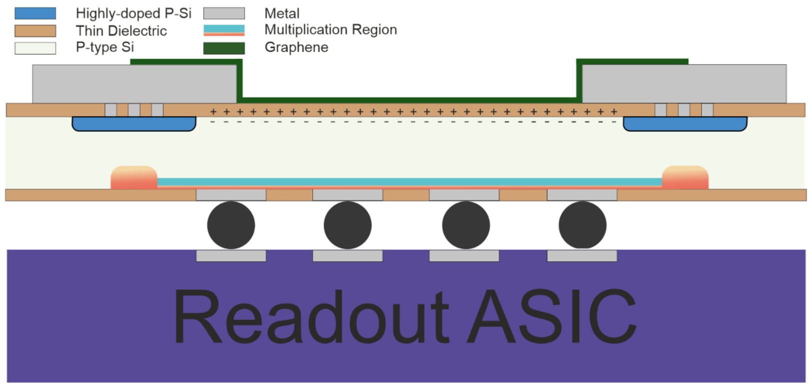
proton LGAD



- Version of nLGAD tailored for low energy proton detection
- Includes a collection layer with lower dose below the P+ electrode

10.1109/CDE52135.2021.9455752
https://doi.org/10.1016/j.nima.2022.167220
Patent: WO2022063852 A1

AC LGAD – Graphene on Silicon



- Absorption layer (the 35um Si) and bulk Si (the 300um Si)
- Graphene placed on top of thin dielectric (3nm) in electrical contact with metal

10.1109/NANO54668.2022.9928637

Takeout

We were there from the beginning…

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 765, 21 November 2014, Pages 12-16

Technology developments and first measurements of Low Gain Avalanche Detectors (LGAD) for high energy physics applications

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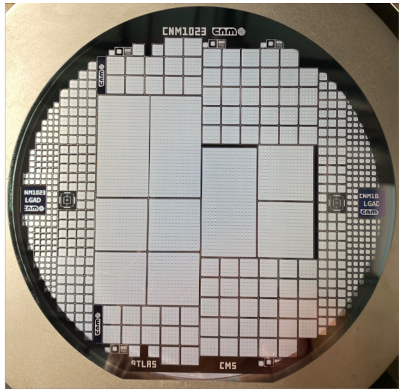
We took part in the advances…



RD50

We are eager to keep enjoying the fun…

DRD3

Foot Note: We need a logo…

Thanks for your attention

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This work has been funded by the Spanish Ministry of Science and Innovation (MICIU/AEI/10.13039/501100011033/) and by the European Union's ERDF program "A way of making Europe". Grant references: PID2020-113705RB-C32, PID2021-124660OB-C22 and PDC2021-121718-C32. Also, it was funded by the European Union's Horizon 2020 Research and Innovation funding program, under Grant Agreement No. 101004761 (AIDAInnova).

Thanks for your attention!

- Equipment:
  - Thermal processes, CVD and ALD
  - Ion Implantation
  - PVD and Metallisation (Sputtering and Evaporators)
  - Optical Lithography:
    - Proximity Aligners: single and double side
    - Steppers: g-line and i-line
    - Direct laser writing
  - Nano-lithography (e-beam, NIL, FIB and AFM)
  - Dry etching
  - Wet and dry micromachining
  - Wet etching and cleaning
  - On-line test
  - Conventional and advanced packaging
  - Electrical characterization