Last fabrication run of LGAD detectors at CNM-CSIC.

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Work supported by RD50 - Radiation hard semiconductor devices for very high luminosity colliders.

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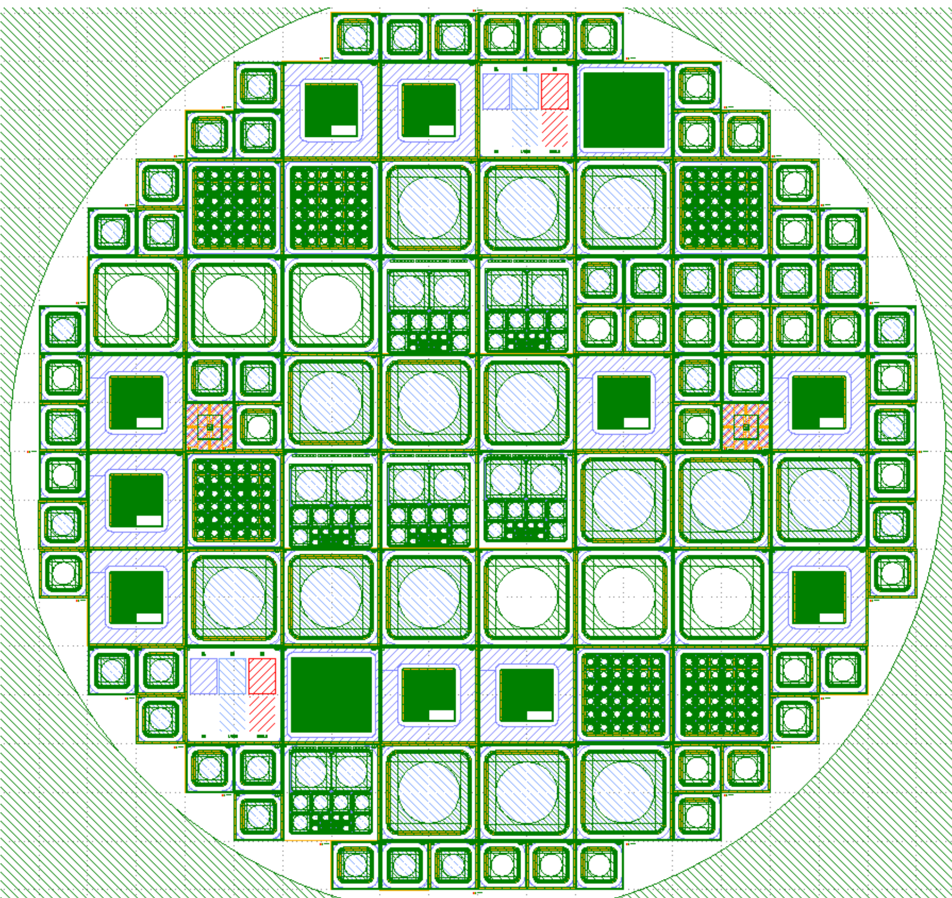
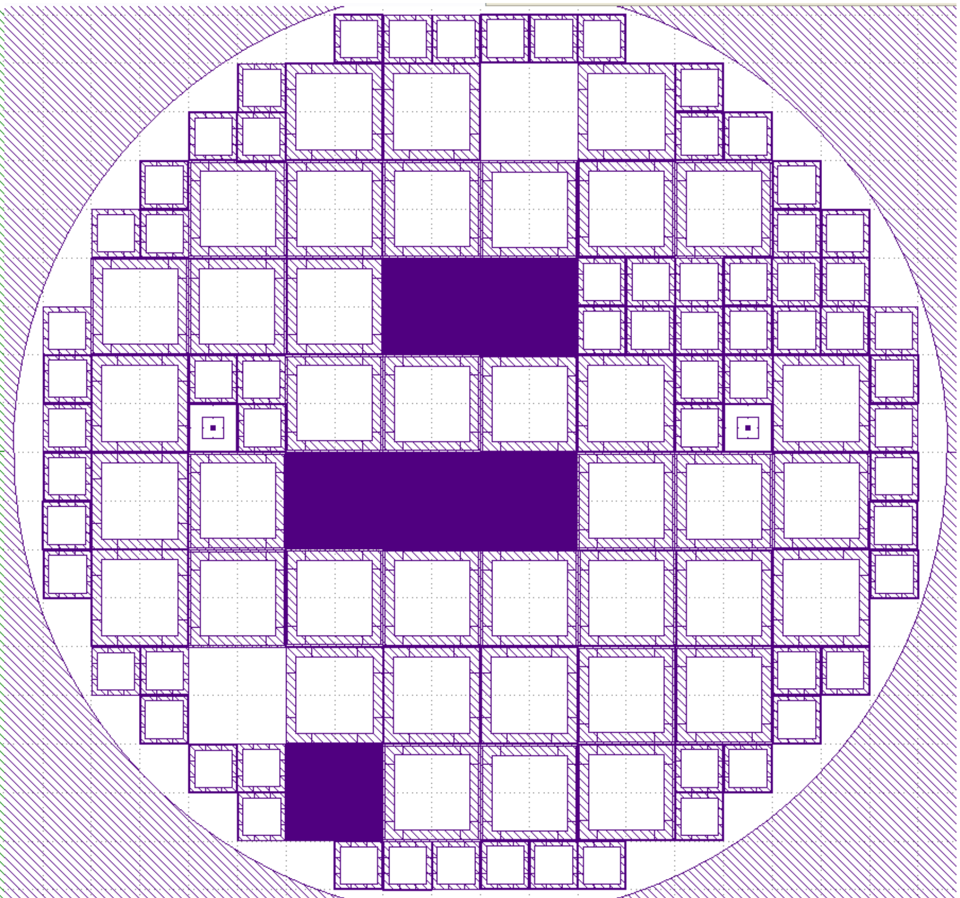
http://rd50.web.cern.ch/

New Fabrication Run

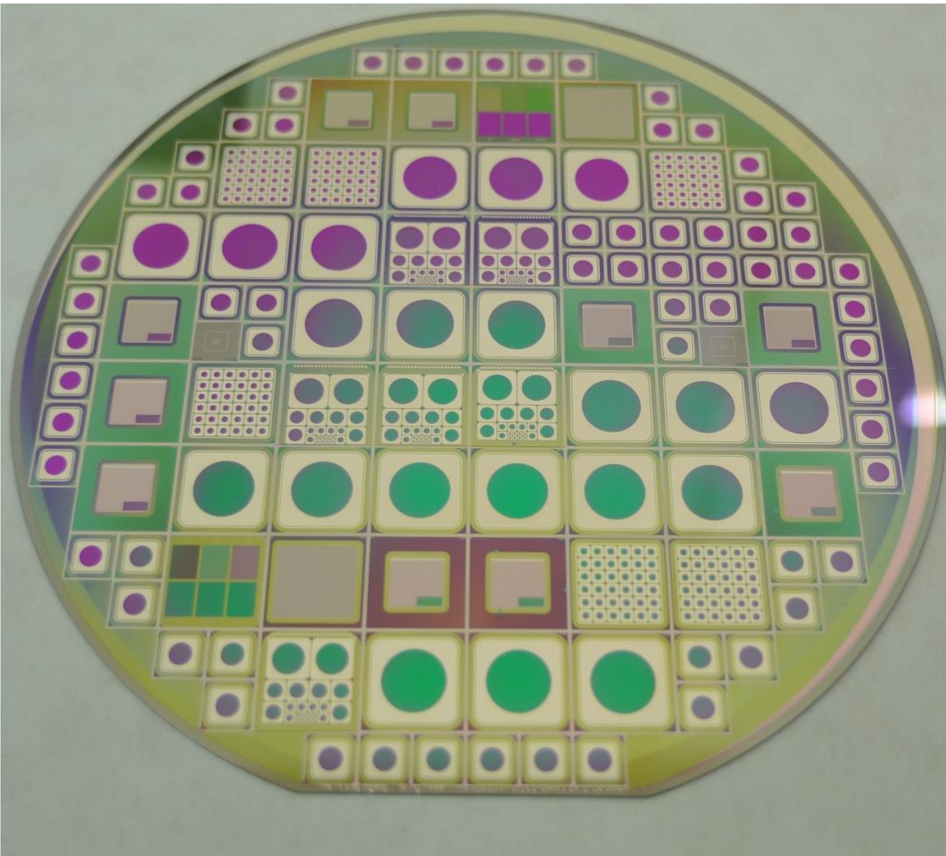


Top Distribution

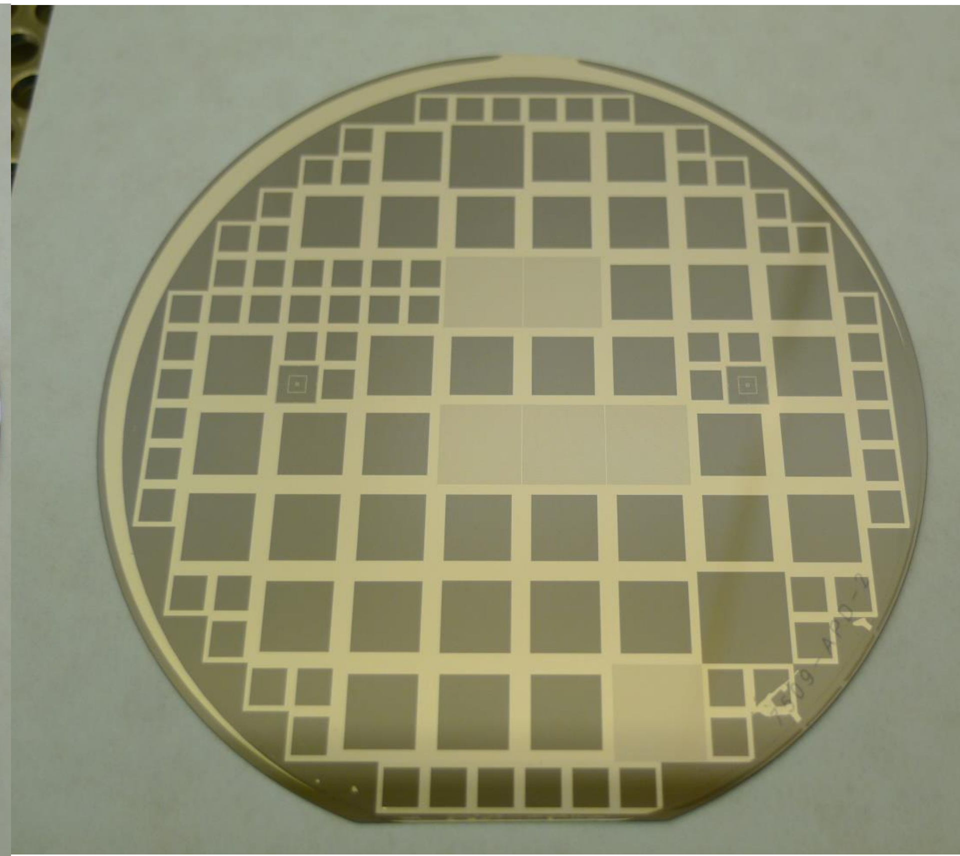


Back Metallization

New Fabrication Run



Top Distribution



Back Metallization

New Fabrication Run

- 9 LGAD Pad Detectors
  - ✓ 3 (8 x 8 mm multiplication area)
  - ✓ 6 (3 x 3 mm multiplication area)
- 9 PiN Detectors
  - ✓ 3 (8 x 8 mm active area)
  - ✓ 6 (3 x 3 mm active area)
- 4 LGAD pStrips Detectors
  - ✓ **32-160-50-06-24**
  - ✓ **32-160-62-06-12**
  - ✓ **64-80-10-06-24**
  - ✓ **64-80-22-06-12**
- 2 PiN pStrips Detectors
  - ✓ **32-160-50-06-24**
  - ✓ **64-80-10-06-24**
- 1 FEI4 compatible pStrip Detector

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- 1 Pixelated LGAD Detector (6 x 6 pixels)
- 1 Pixelated PiN Detector (6 x 6 pixels)

INFN Torino

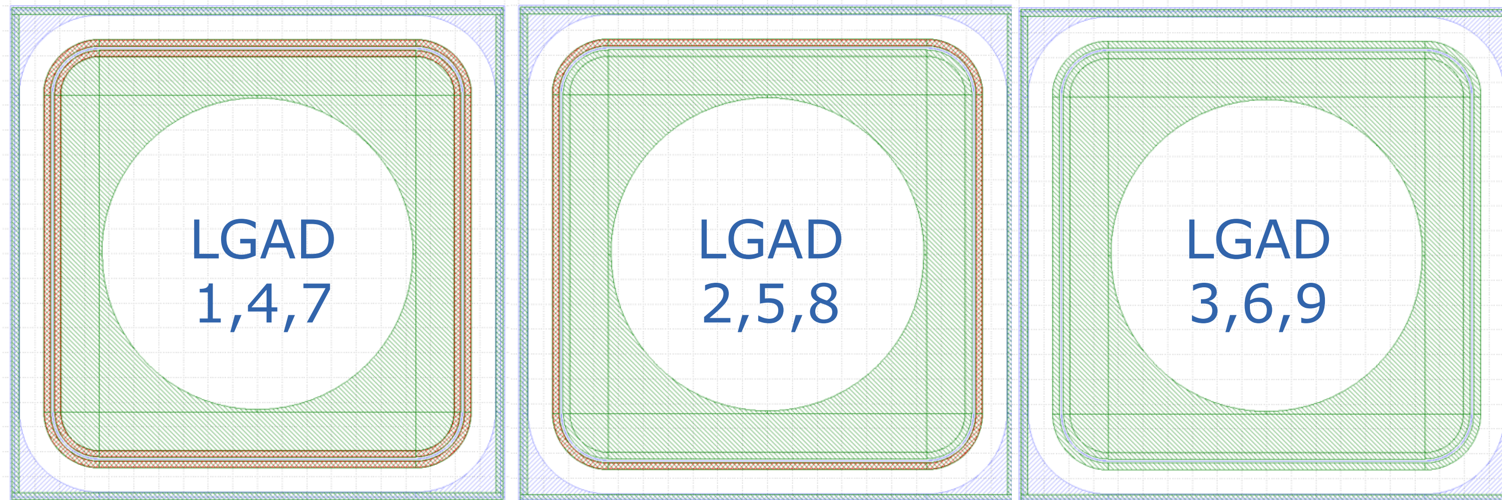
- 3 LGAD for Timing Applications
  - ✓ **200 um** to chip edge
  - ✓ **250 um** to chip edge
  - ✓ **800 um** to chip edge

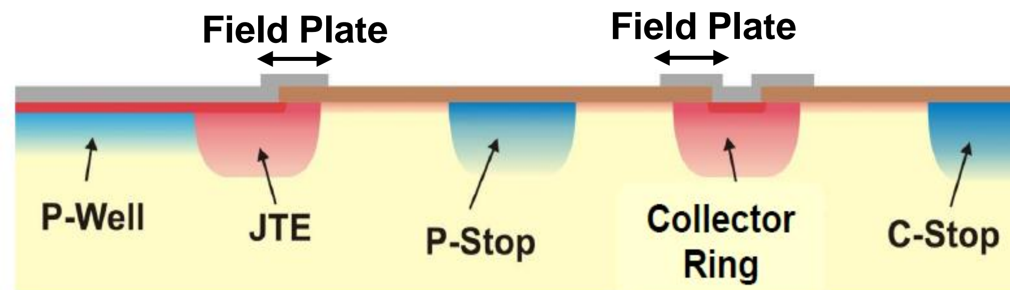
LAL Orsay

- 1 Specific Test Structure (SPR,SIMS,XPS)

- **113 Structures**
  - **47 (10 x 10 mm, total area)**
  - **66 (5 x 5 mm, total area)**

New Fabrication Run: LGAD & PiN *pad* Detectors





- LGAD & PiN Pad Detectors
  - ✓ Multiplication Area
    - **8 x 8** mm (Type 1, 2, 3)
    - **3 x 3** mm
  - Termination:
    - * P-Stop + N-Guard Ring (Type 3, 6, 9)
    - * P-Stop + N-Guard Ring with JTE (Type 2, 5, 8)
    - * JTE + P-Stop + N-Guard Ring with JTE (Type 1, 4, 7)
    - * Field Plate 10 µm, 0 µm (Type 7, 8, 9)

New Fabrication Run: LGAD & PiN *strip* Detectors

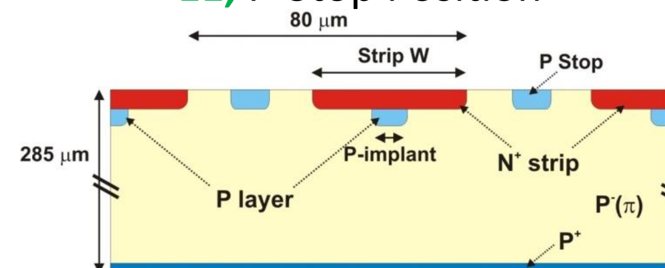
32.160.50.06.24

64.80.10.06.24

32.160.62.06.12

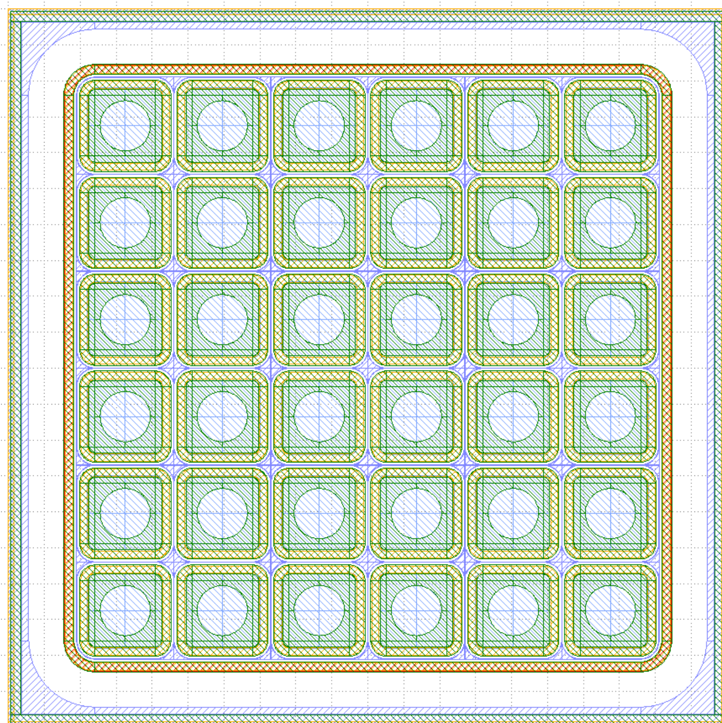
64.80.22.06.12

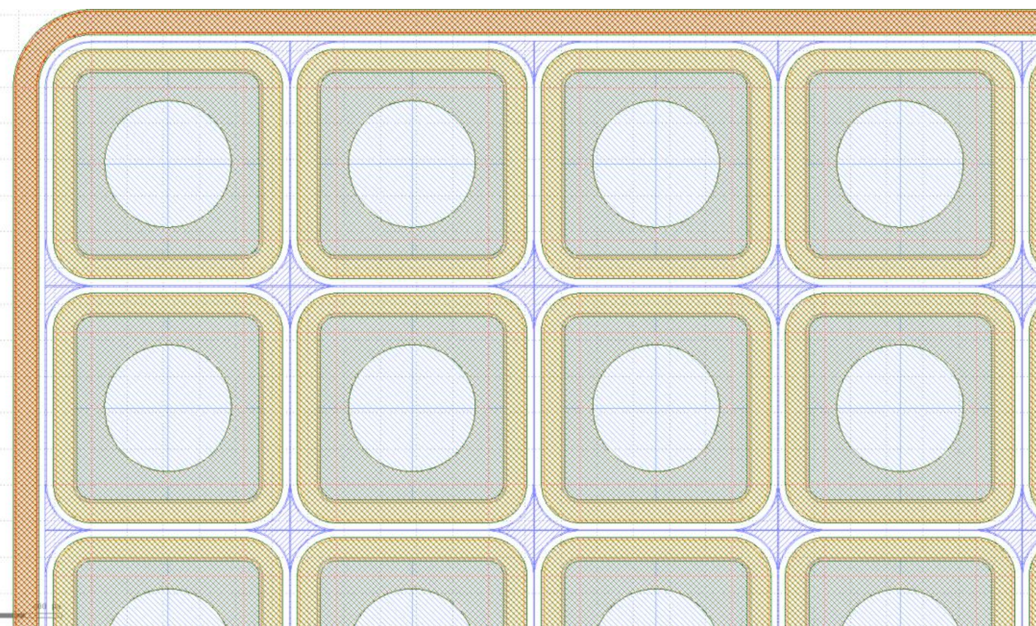
- 4 LGAD pStrips Detectors
  - ✓ 32-160-50-06-24
  - ✓ 32-160-62-06-12
  - ✓ 64-80-10-06-24
  - ✓ 64-80-22-06-12
- 2 PiN pStrips Detectors
  - ✓ 32-160-50-06-24
  - ✓ 64-80-10-06-24
- Key Legend
  - ✓ **AA-BB-CC-DD-EE**
  - ✓ **AA,** Number of channels
  - ✓ **BB,** Pitch
  - ✓ **CC,** Multiplication Width
  - ✓ **DD,** P-Stop Width
  - ✓ **EE,** P-Stop Position



LGAD and PiN Pixelated Detectors

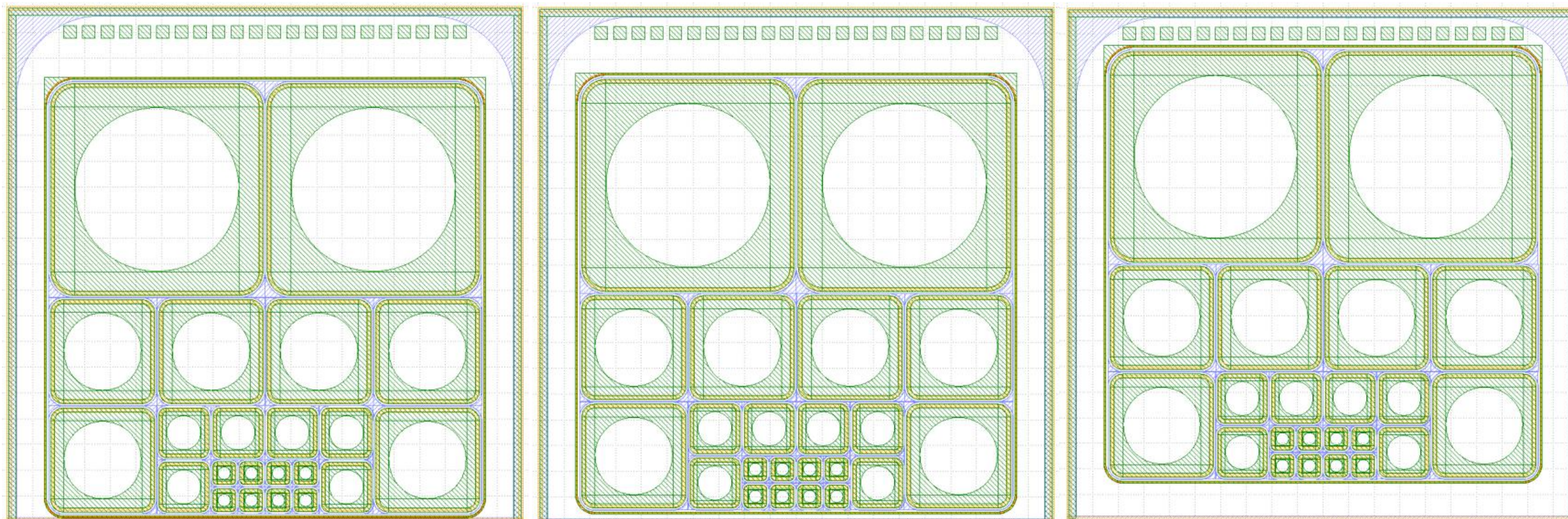
IJS Ljubljana





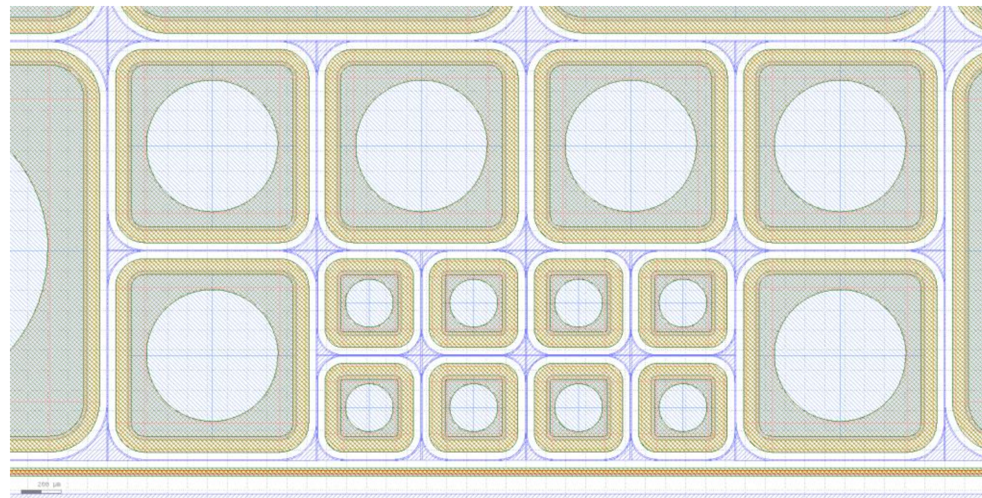
- 1 Pixelated LGAD Detector (6 x 6 pixels)
- 1 Pixelated PiN Detector (6 x 6 pixels)

LGAD for Timing Applications

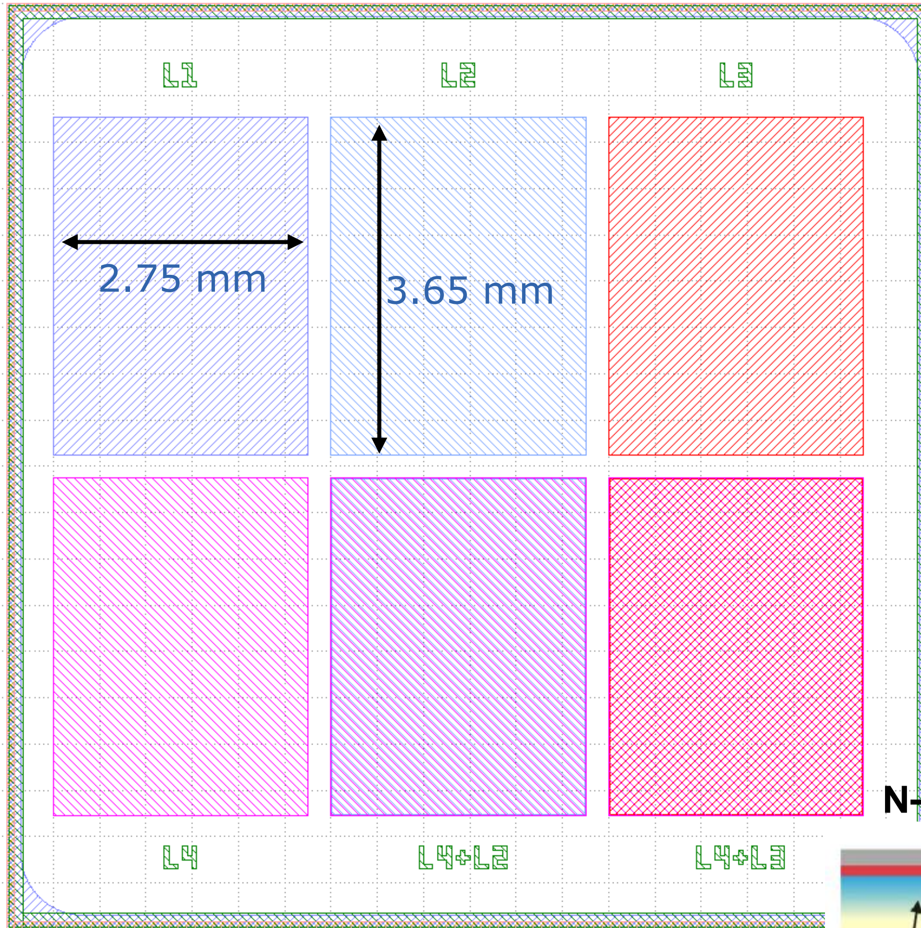


INFN Torino

- 3 LGAD for Timing Applications
  - ✓ **200 um** to chip edge
  - ✓ **250 um** to chip edge
  - ✓ **800 um** to chip edge

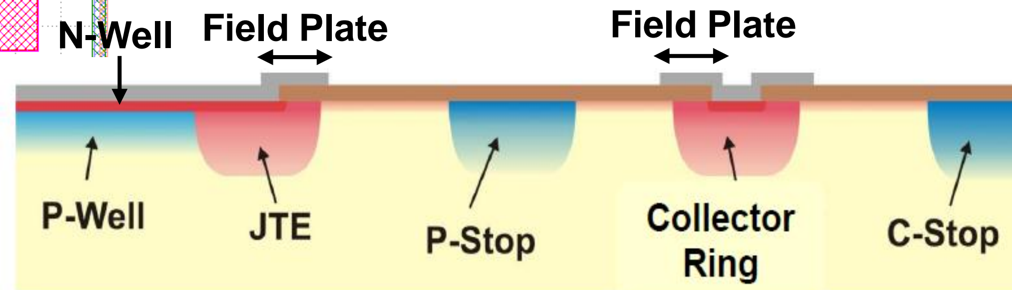


Specific Test Structure. SRP, SIMS, XPS

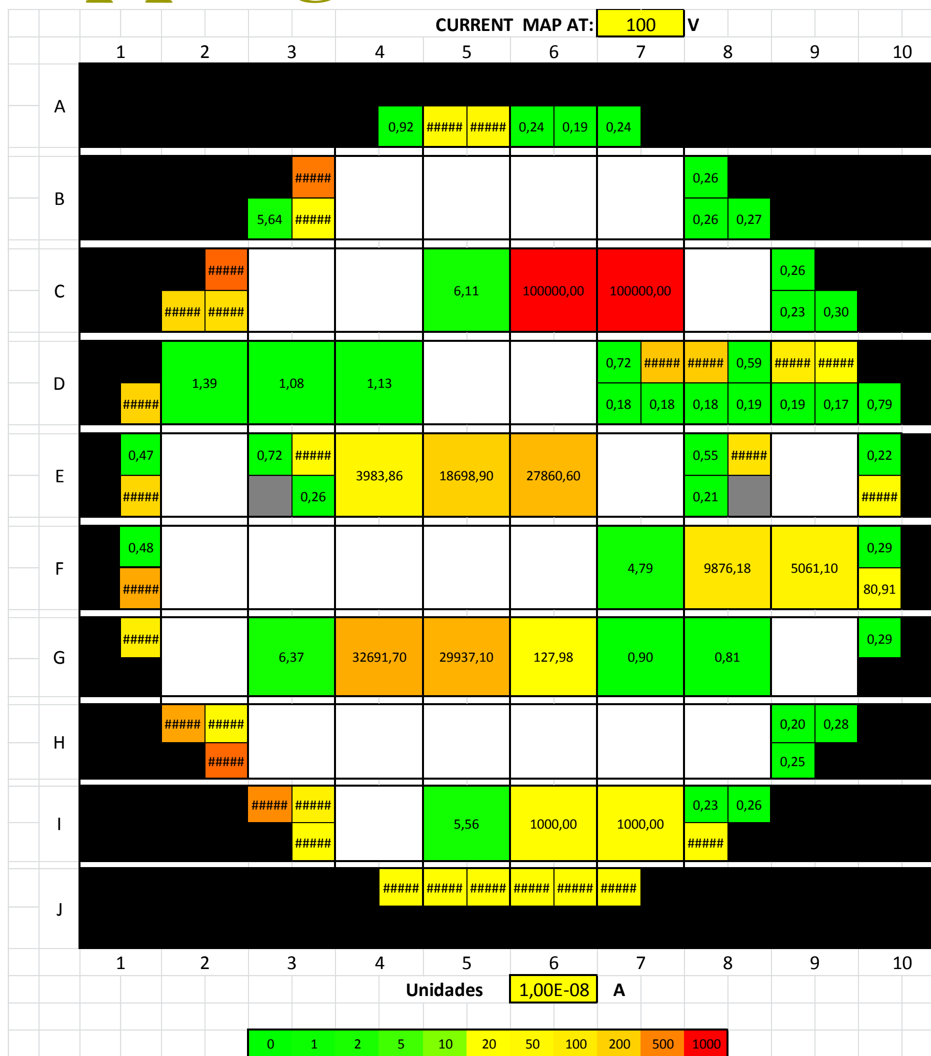


LAL Orsay

- L1 P-Stop, C-Stop Well
- L2 P-Well (P Multiplication)
- L3 JTE
- L4 N-Well
- L4 + L2 N-Well over P-Well
- L4 + L3 N-Well over JTE

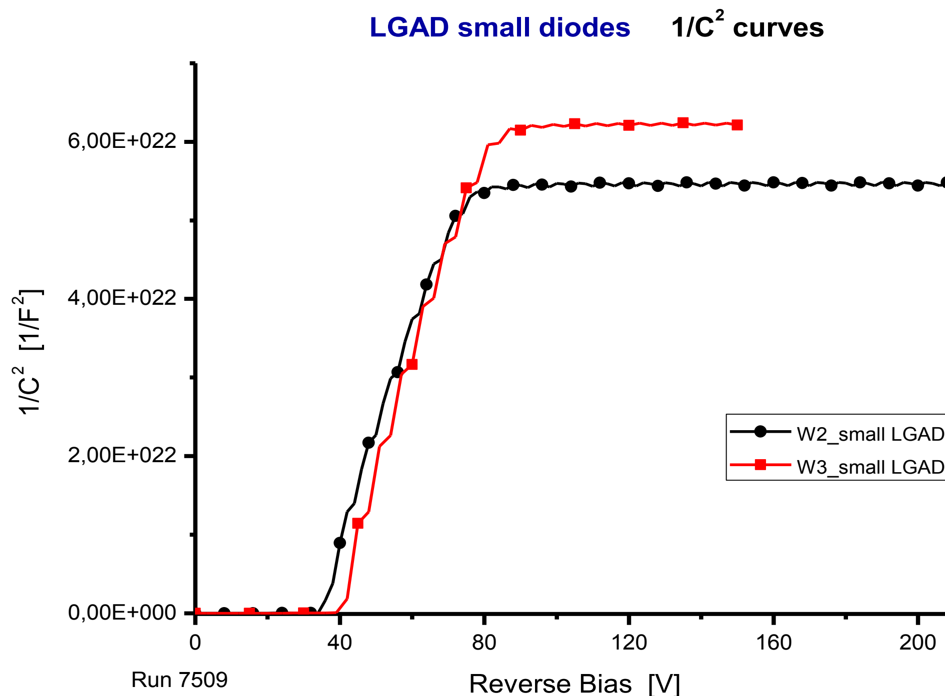


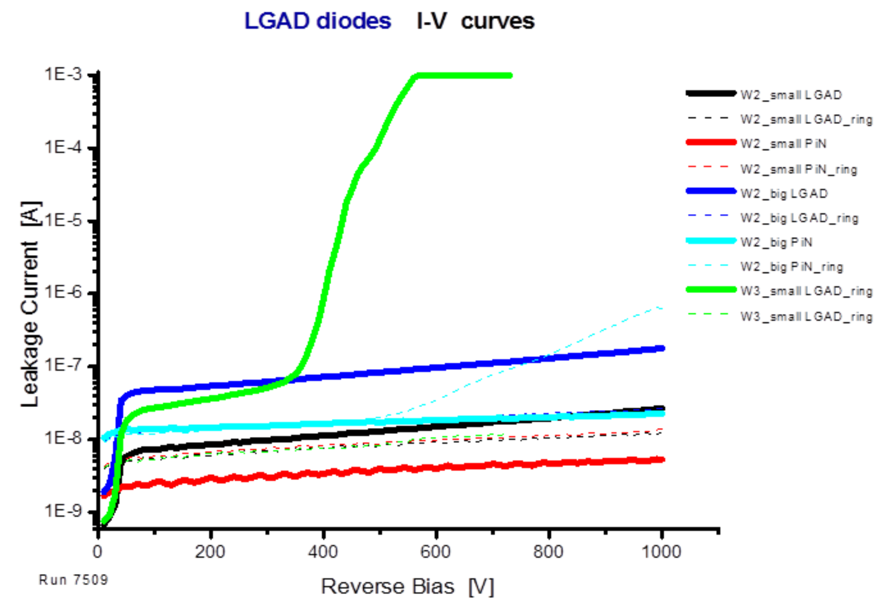
Wafer mapping



Wafer 2- low p-doping

Electrical characterization





- Good isolation, ring current small.
- Uniform IV curves within the wafer.

Alpha measurements

LGAD diodes GAIN

Alpha particles measurement

Top illumination

Gain [a.u.]

3,0
2,5
2,0
1,5
1,0
0,5

0 50 100 150 200 250 300 350 400 450 500

Reverse Bias [V]

Expected gain, 2-3.

Small LGAD
Big LGAD

Reference: PIN diode

Run7509

Wafer 2- low p-doping

Old run

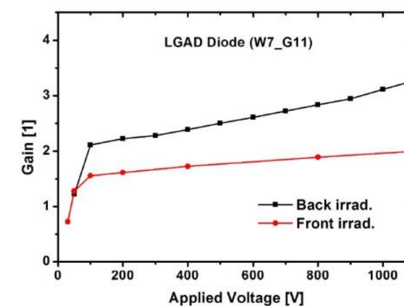


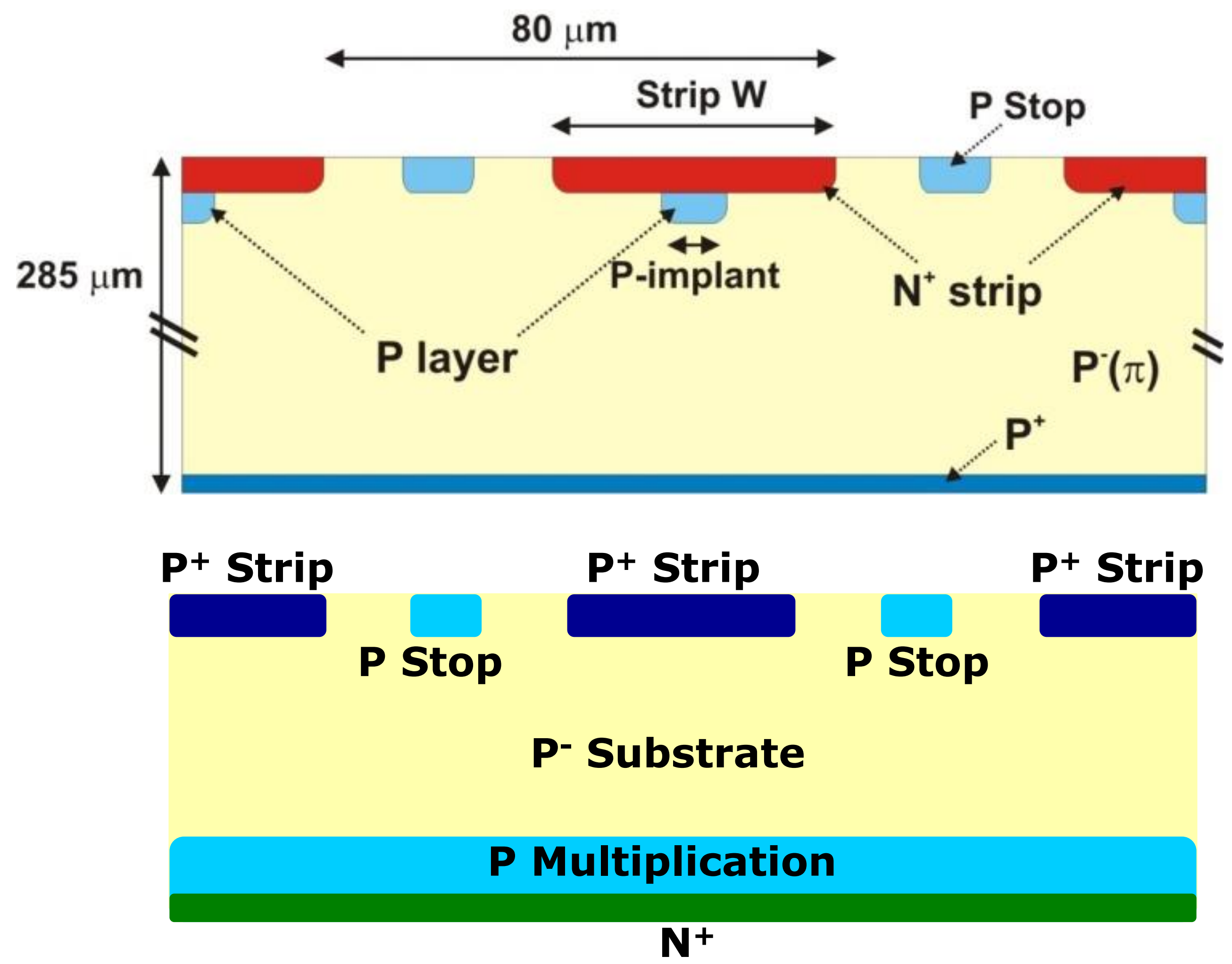
Figura 5.5: *Ganancia medida en el prototipo W7_G11 en función de la tensión inversa aplicada y la posición de la fuente: exposición por el frente (electrodo N^+) y por el dorso (electrodo P^+) del dispositivo.*

New Developments

- Avoid possible no-uniform charge collected in segmented detectors.
- Move segmentation to the ohmic contact.
- Useful for large area detectors but not radiation hard.

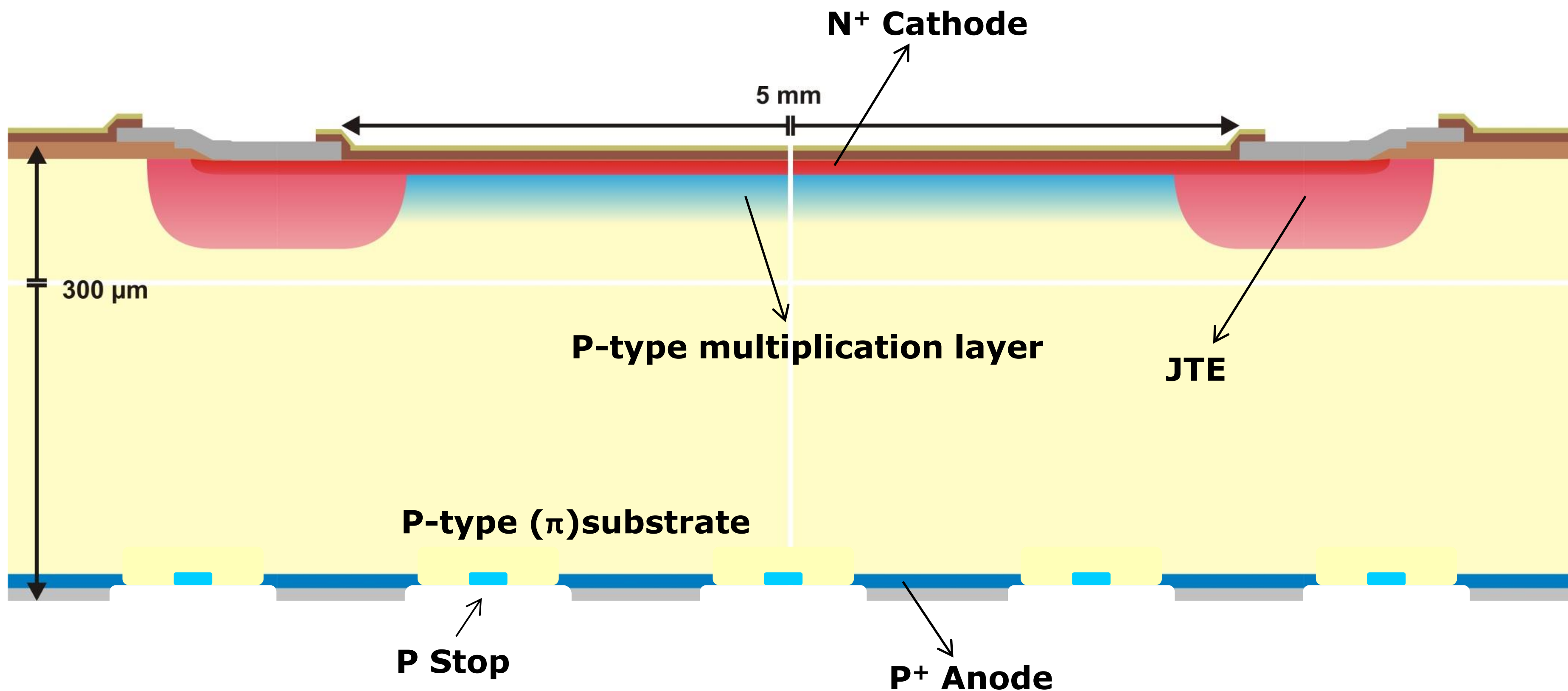
P on P MicroStrips with Low Gain

- N on P vs P on P LGAD microStrips Comparison



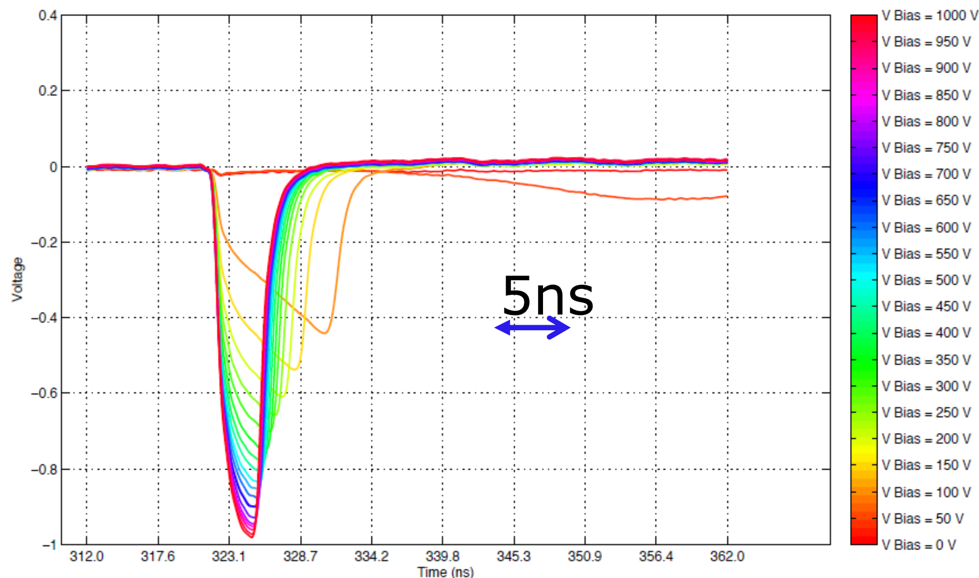
P on P MicroStrips with Low Gain

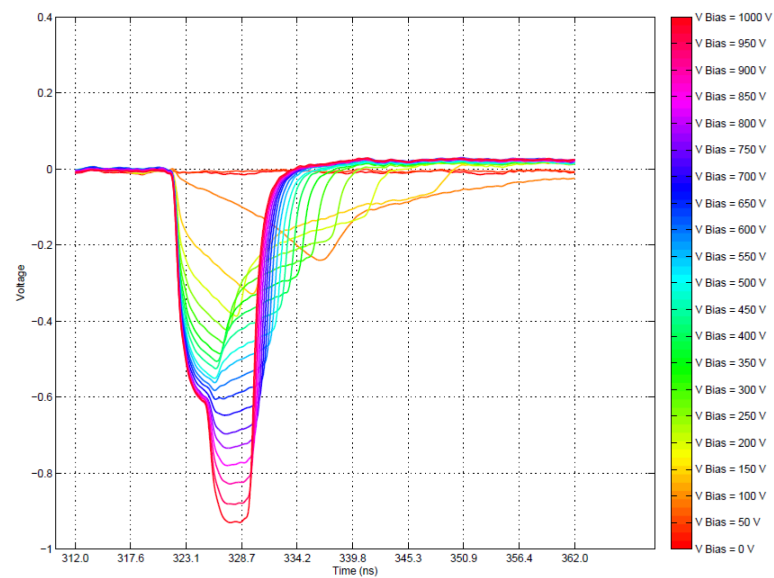
- **Pad Diodes LGAD** with P microStrips at Back Plane

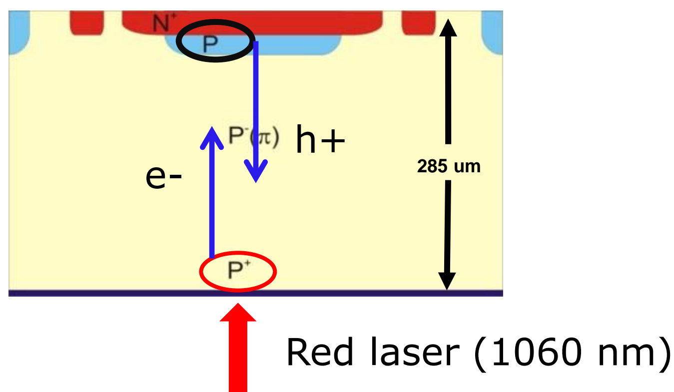


Pad Diodes with Low Gain

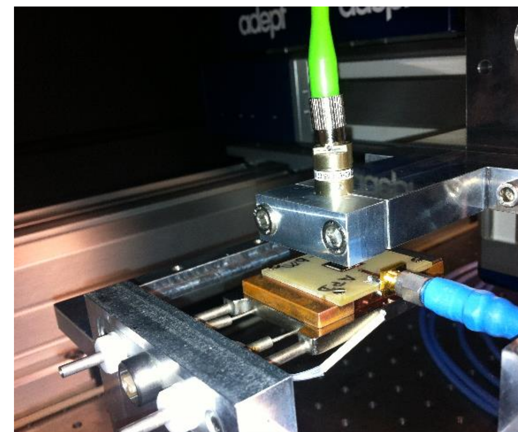
- **Red Laser TCT** Characterization. **Bottom** Injection





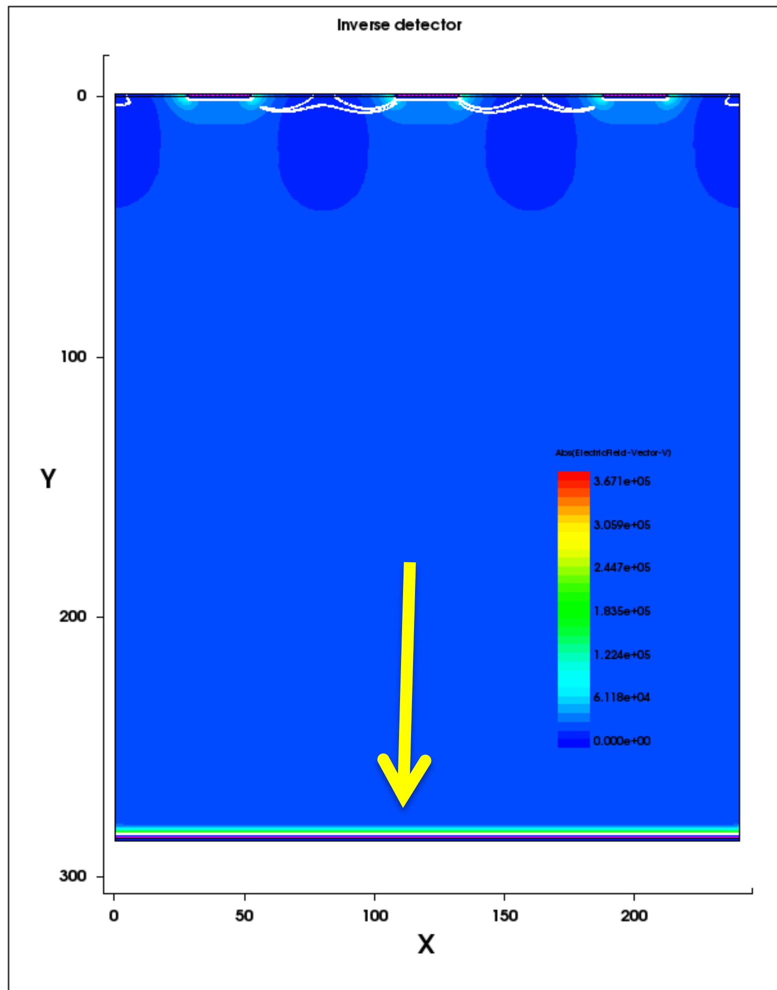


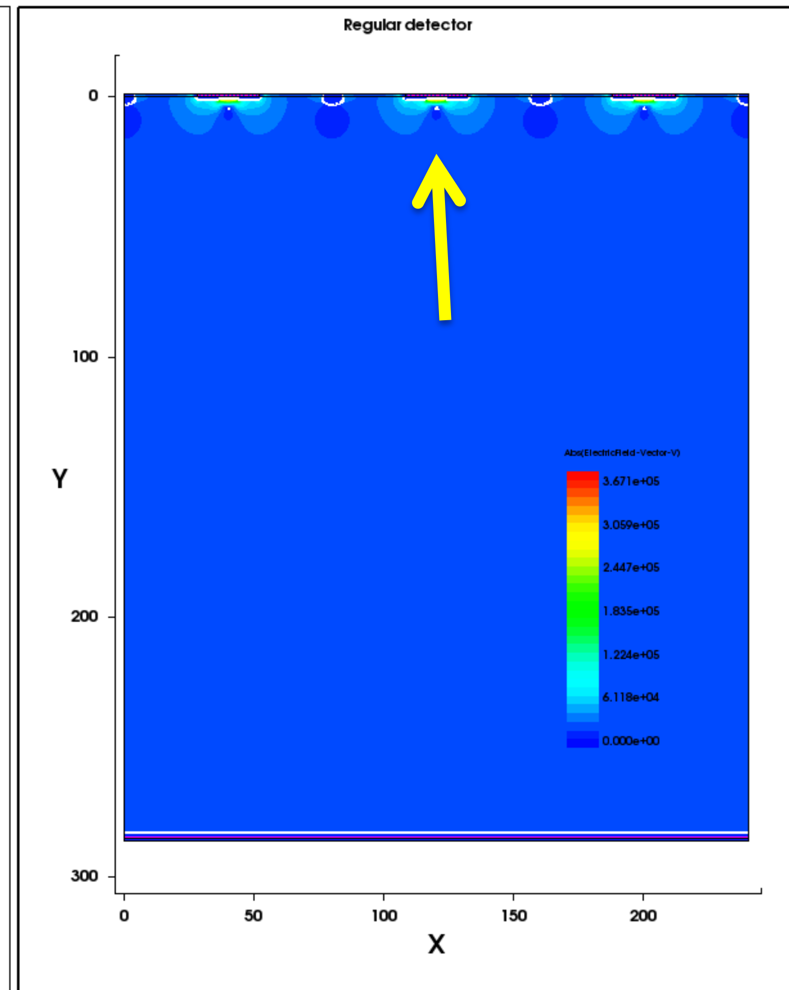
Red laser (1060 nm)



P on P MicroStrips with Low Gain

- **Three** microStrips Simulation. **Electric Field** 2D Distribution. **Maxim @ Junctions**

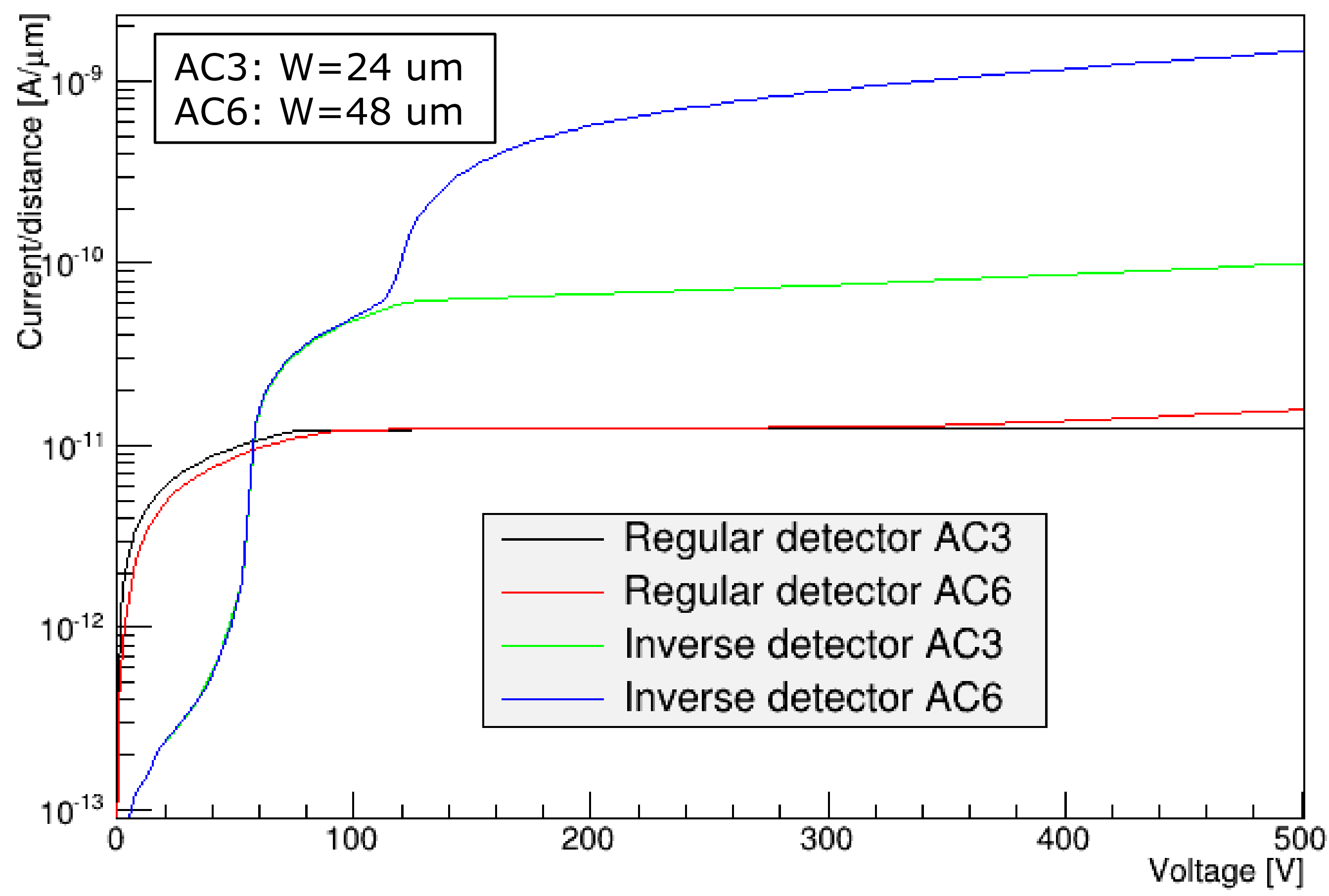




P on P MicroStrips with Low Gain

- **Three** microStrips Simulation. **I(V)**

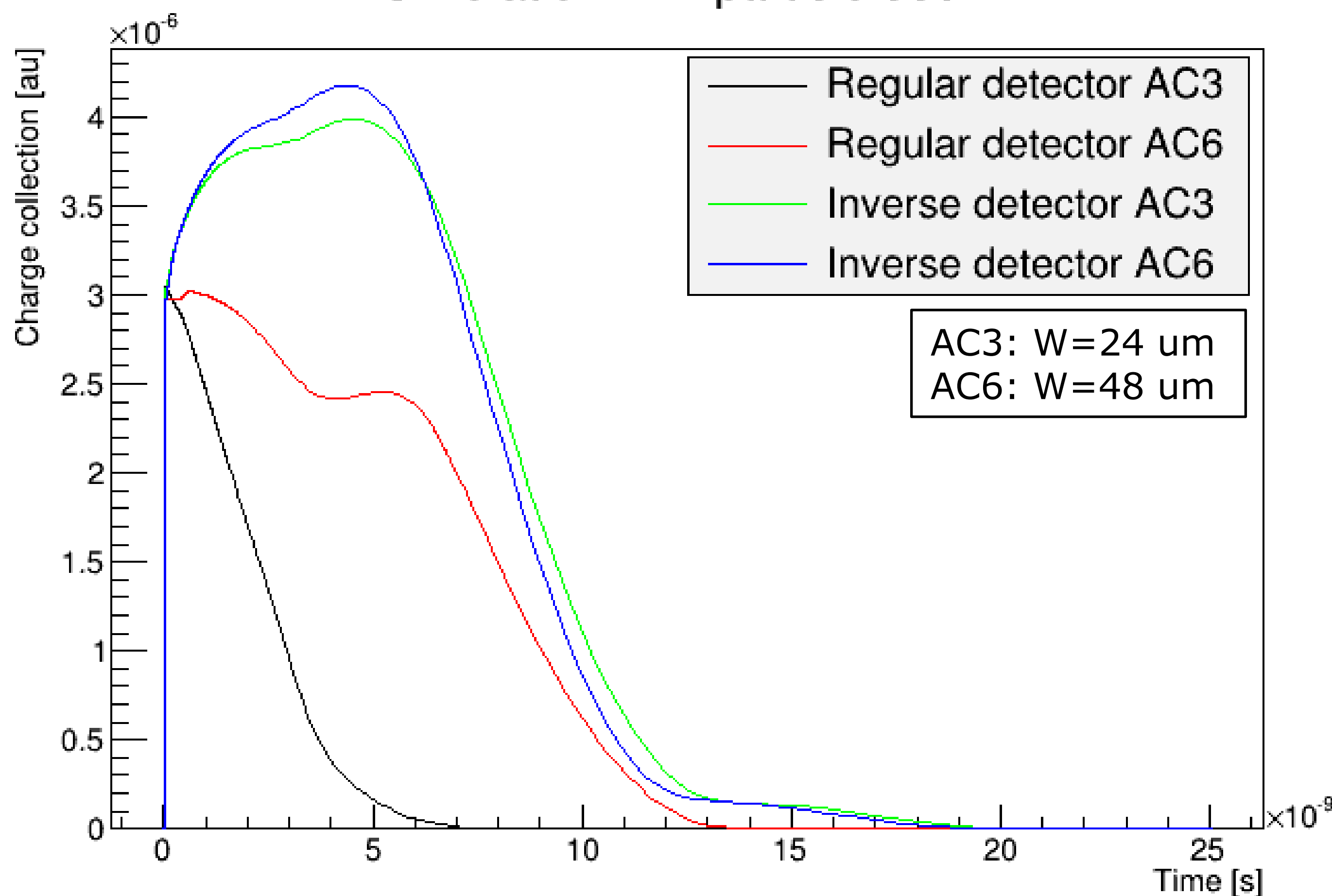
300um thick



P on P MicroStrips with Low Gain

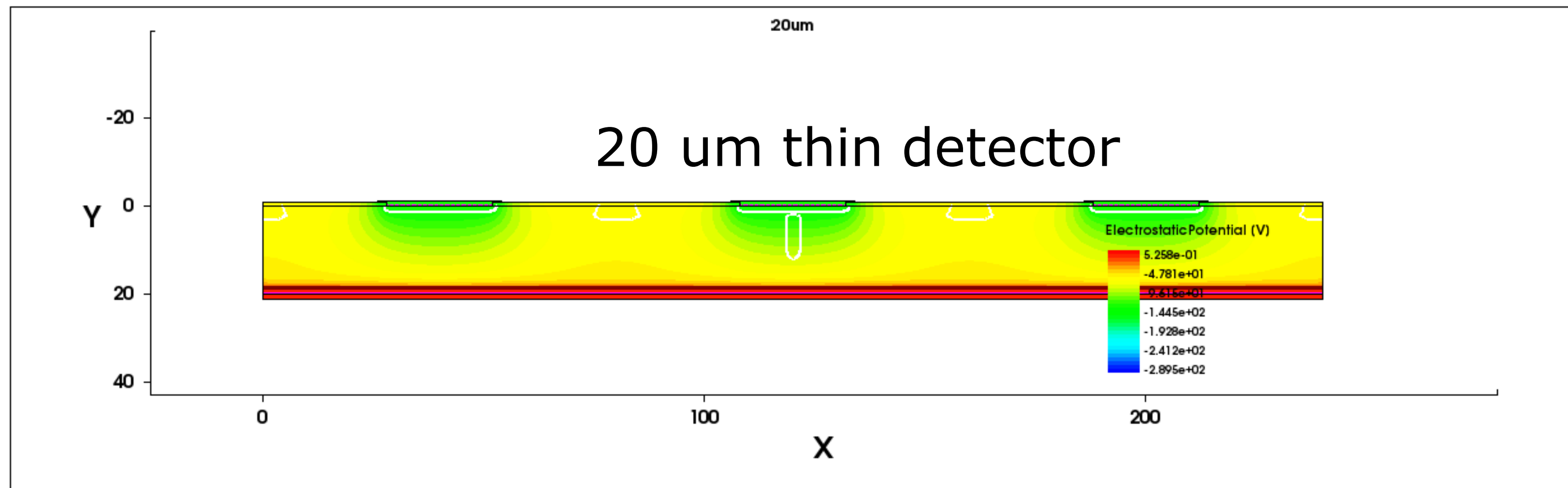
- **MIP** through the middle of the sensors (the central strip) **@ 500 V**

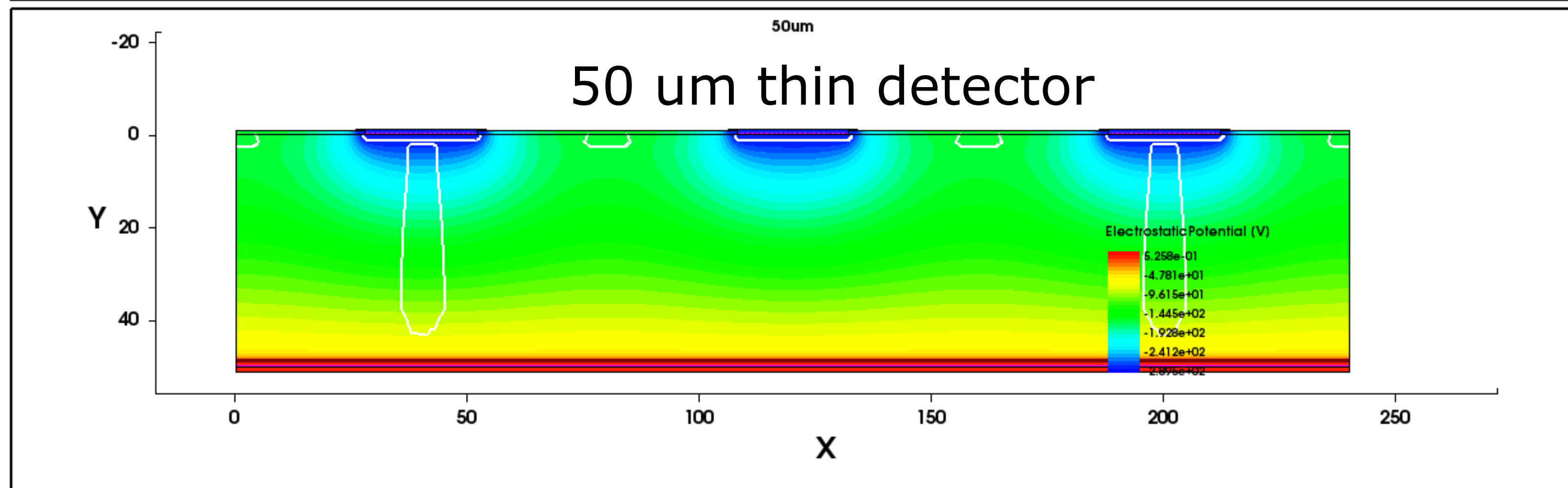
300um thick



P on P LGAD MicroStrips. Thin Detectors

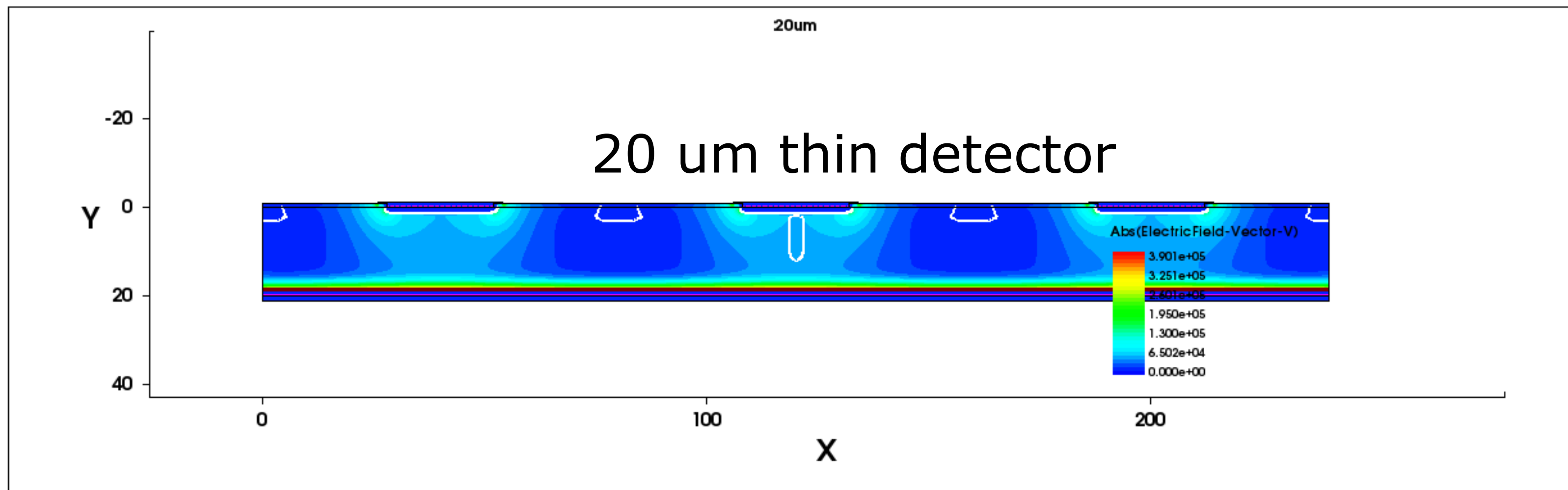
MicroStrips Simulation. **Electrostatic Potential** 2D Distribution **@ V_{BR}**

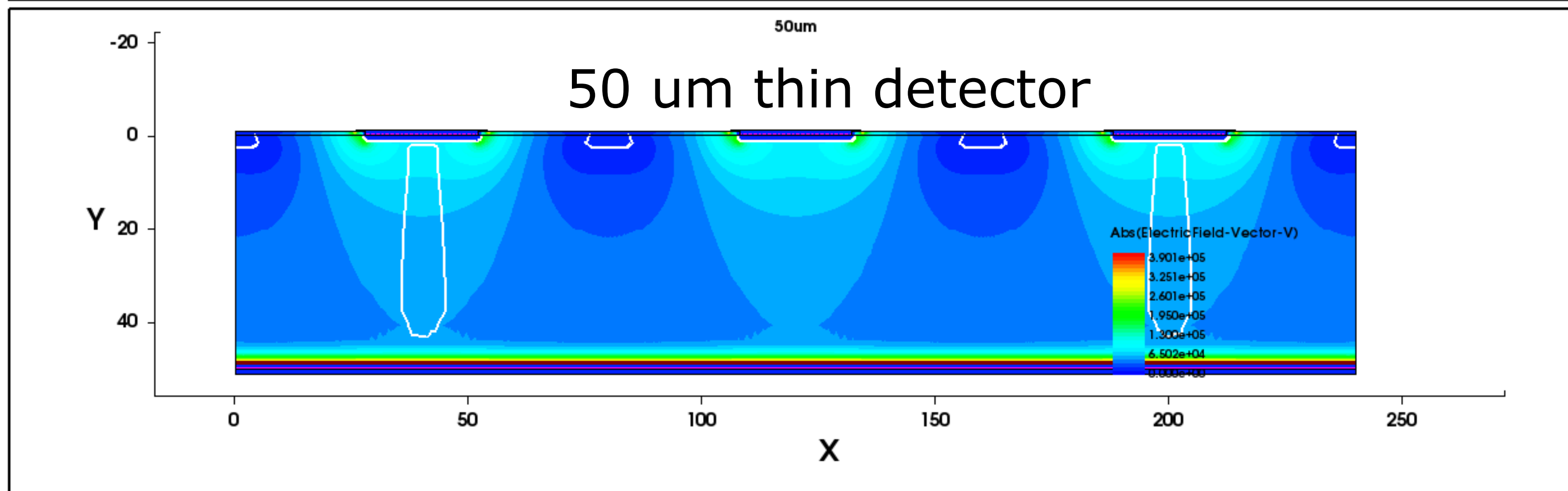




P on P LGAD MicroStrips. Thin Detectors

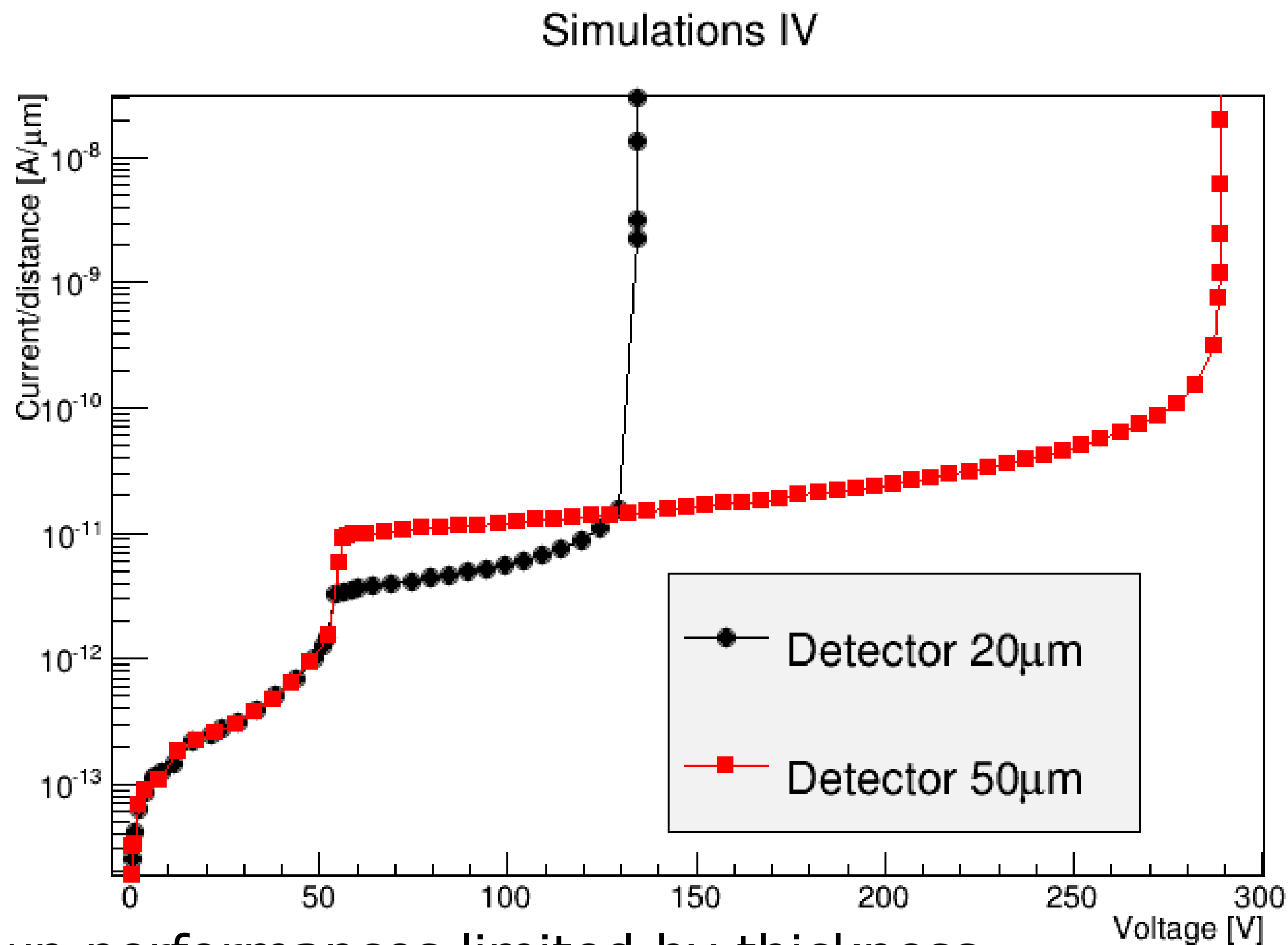
TicroStrips Simulation. **Electric Field** 2D Distribution **@ V_{BR}**





P on P LGAD MicroStrips. Thin Detectors

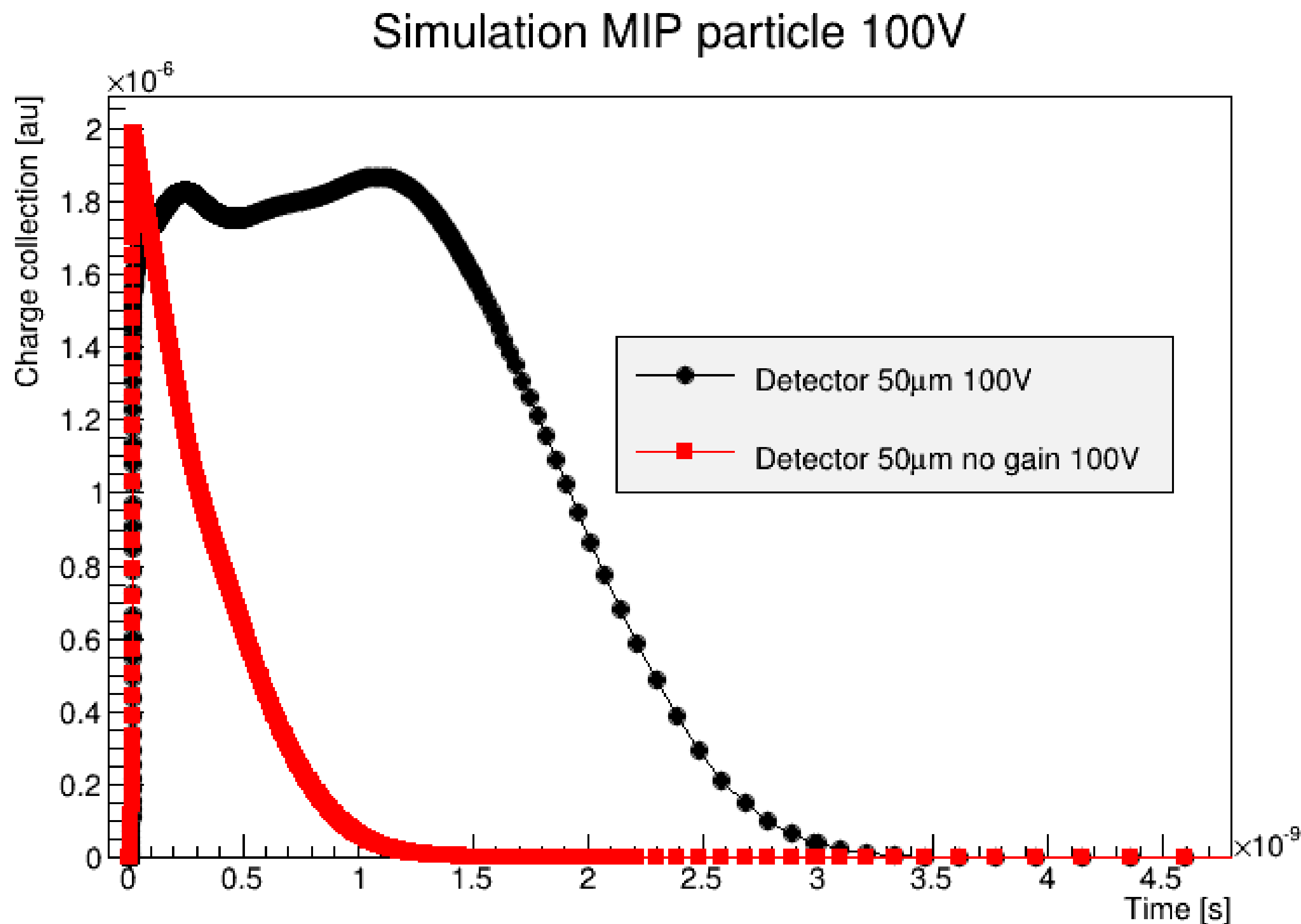
MicroStrips Simulation. **I(V)**



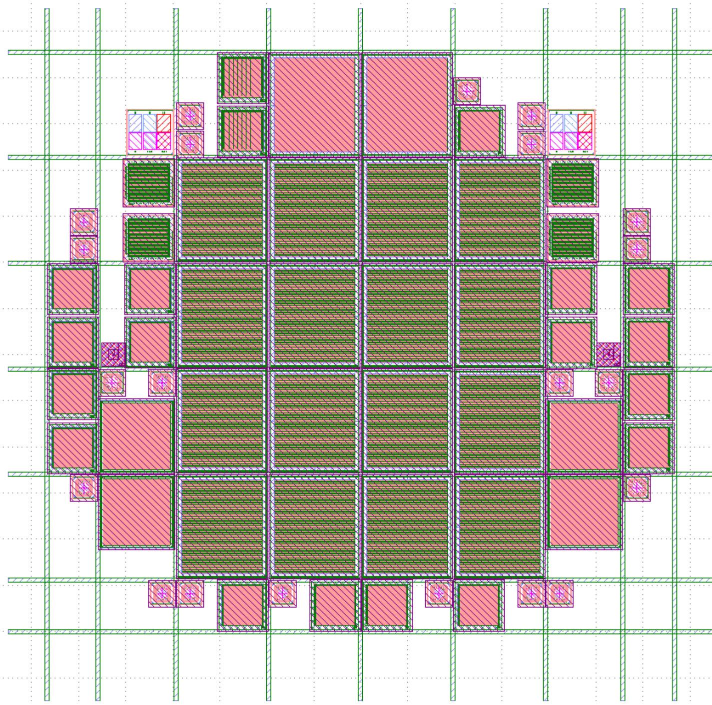
Breakdown performances limited by thickness

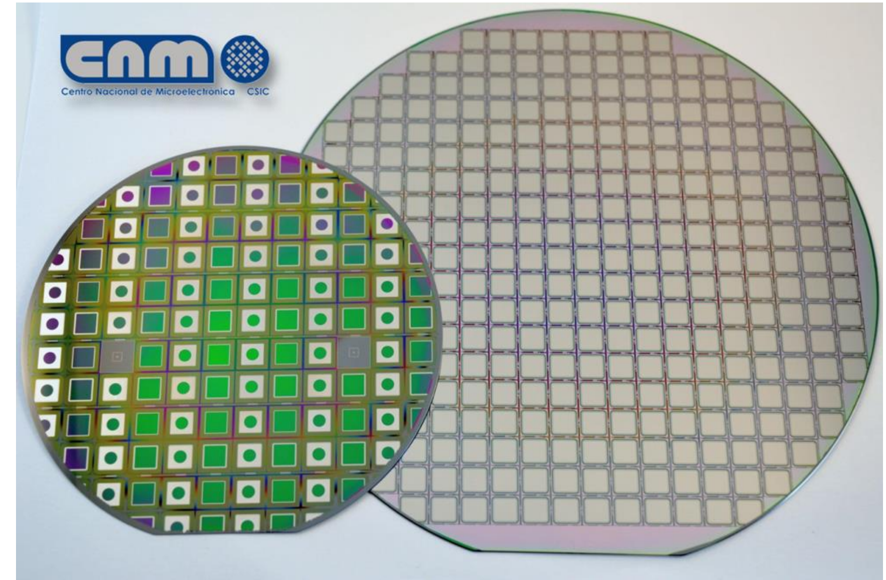
P on P LGAD MicroStrips. Thin Detectors

MIP through the middle of the sensors (the central strip) **@ 100 V**



Planar pixels in 6" wafers (and LGAD).





First pin diodes fabricated in 6" wafers.

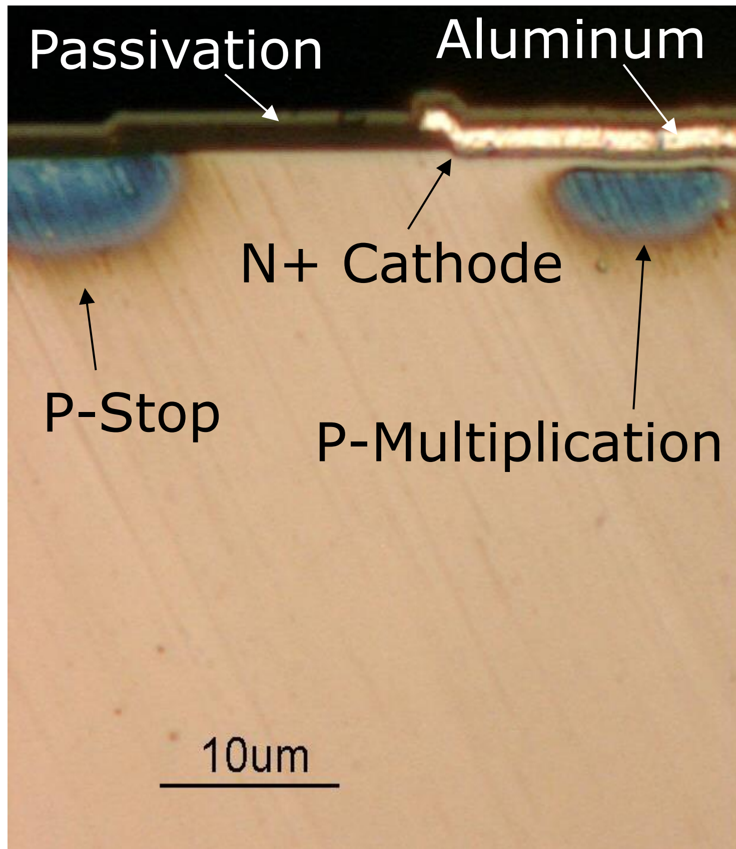
- 200um thick wafers (SOI).
- n-on-p technology.
- Atlas and CMS pixels included.
- Velopix (55x55um^2).
- Pin diodes.
- UBM will be done at CNM. Under test for 6".

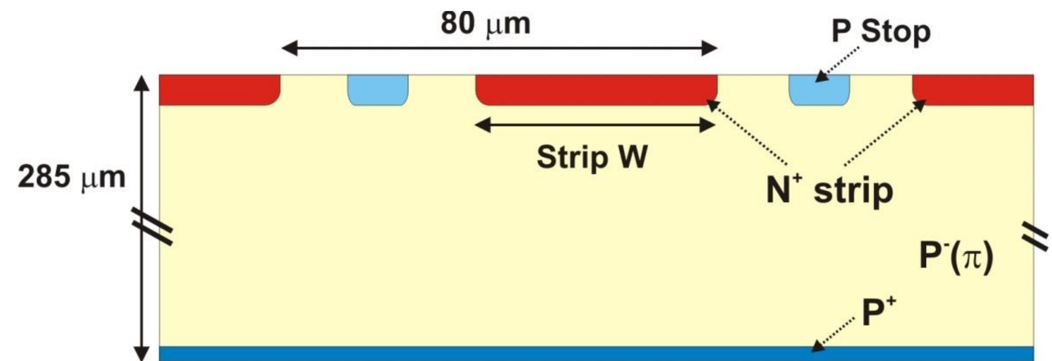
Conclusions

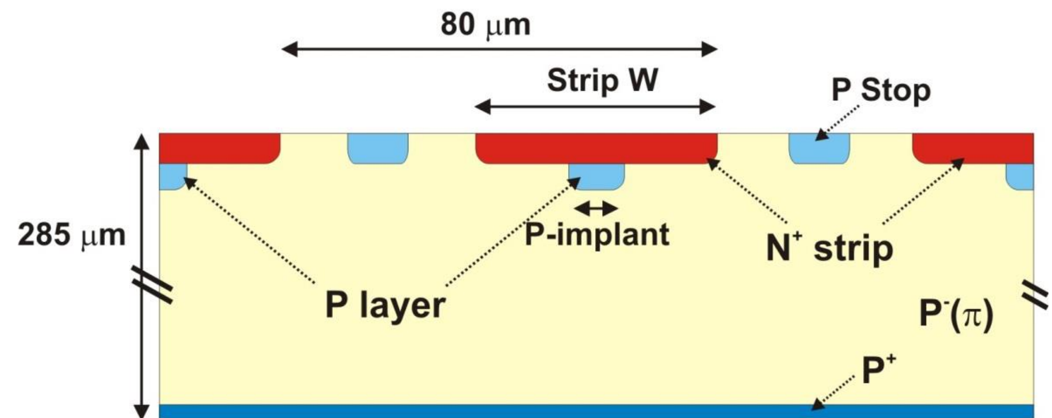
- Optimization of the LGAD peripheral region is crucial for the detector performance
  - Edge termination techniques confine the high electric field into the multiplication area and give voltage capability to the detector
  - Structures within the peripheral region avoid high leakage currents and degradation
- Deep N-diffusion termination technique has proved good performance
- Improved yield compared to previous fabrication.
- Good repeatability, stable technology.
- New production run at the IMB-CNM
  - LGAD with Gallium (p+ implant), run finished, measurements will start next week.
  - LGAD run in thin substrates, 200um thick, due in March.
  - LGAD 6” wafers run, Mask designed. Run will start in March.

PhysDetLc Project. P on P MicroStrips with Low Gain

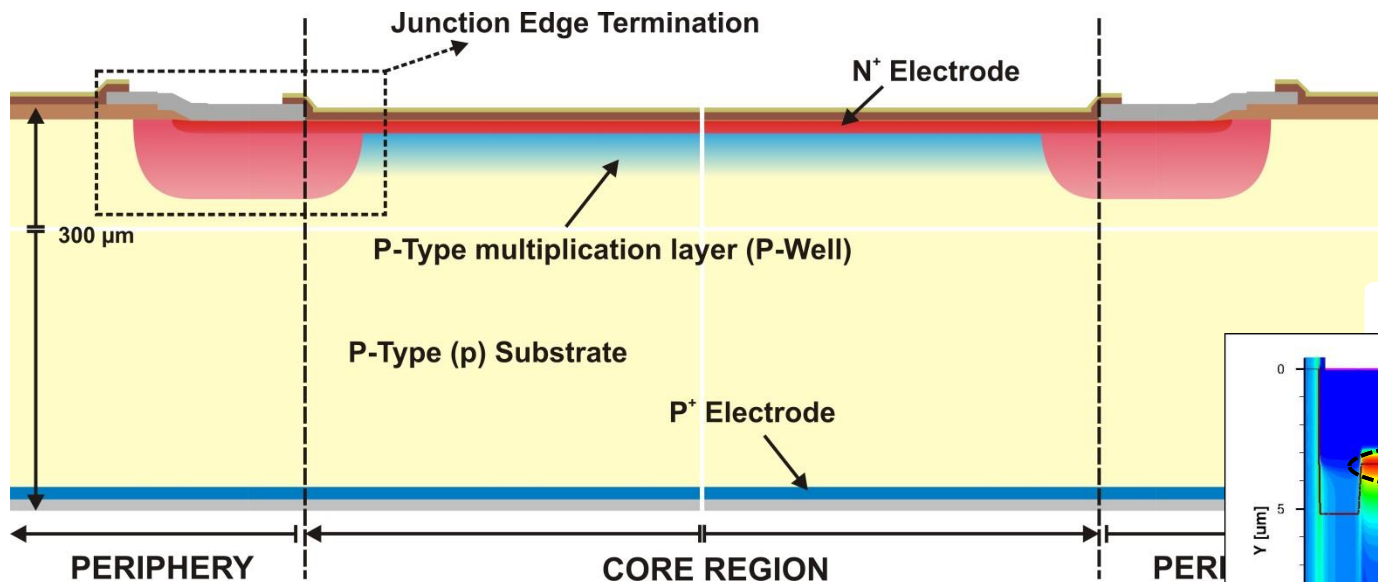
- N on P microStrips. PiN vs LGAD

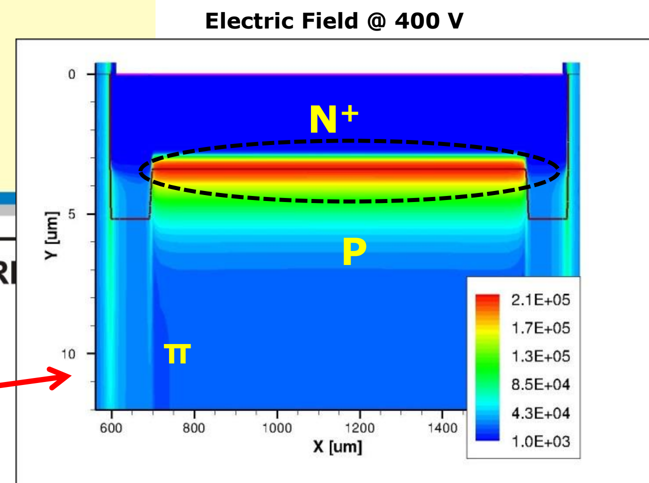






Critical aspects of the LGAD design





- **Core Region** → Uniform electric field, high enough to activate mechanism of impact ionization (multiplication)
- **Termination** → High electric field confined in the core region
- **Periphery** → (Dead region) Charges should not be collected. Reduction of the leakage currents

$$V_{BD}|_{\mathbf{Termination}} \gg V_{BD}|_{Central}$$

P on P LGAD MicroStrips. Thin Detectors

- **Three** microStrips Simulation. **Doping Concentration** 2D Distribution