Characterization of double-sided 3D sensors after proton and neutron irradiation

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9th "Trento" Workshop on Advanced Silicon Radiation Detectors (3D and P-type Technologies)

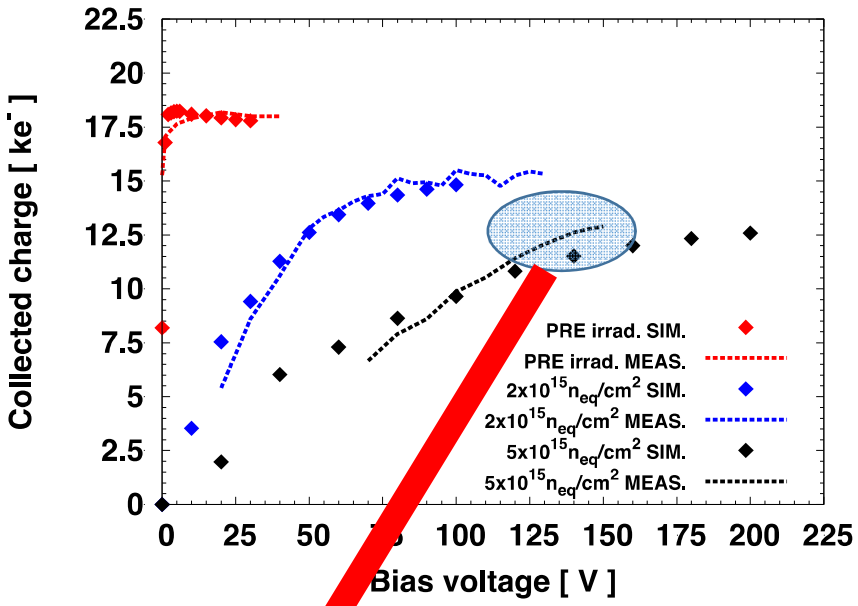
Outline

- Motivation
- 3D Detector with Modified technology at FBK
- Electrical characterization for different irradiations
- Functional tests:
  - Alpha particles
  - Laser beam
  - Beta particles
- Selected simulation results for irradiated sensor
- Conclusion

Motivation

Beta source charge collection tests with 3D sensors from FBK IBL wafers

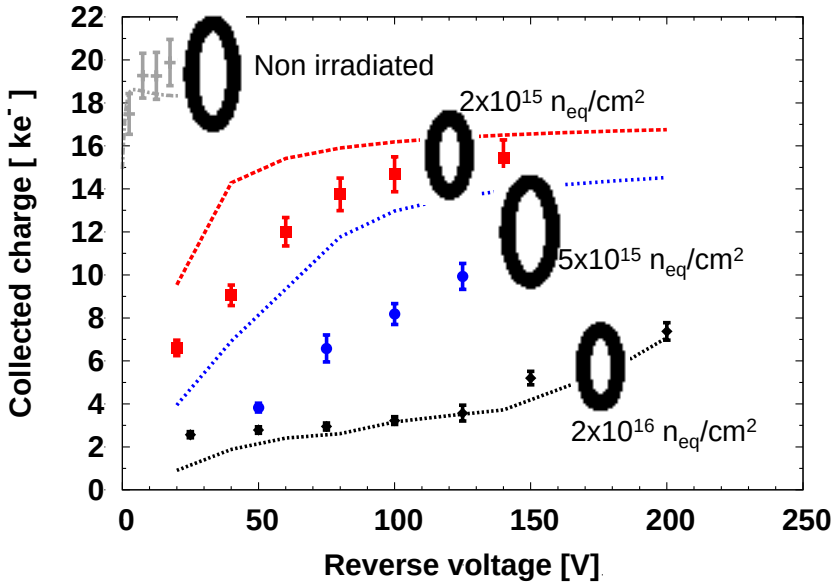
FE-I4 3D pixels



G.F. Dalla Betta et al,
Vertex 2012

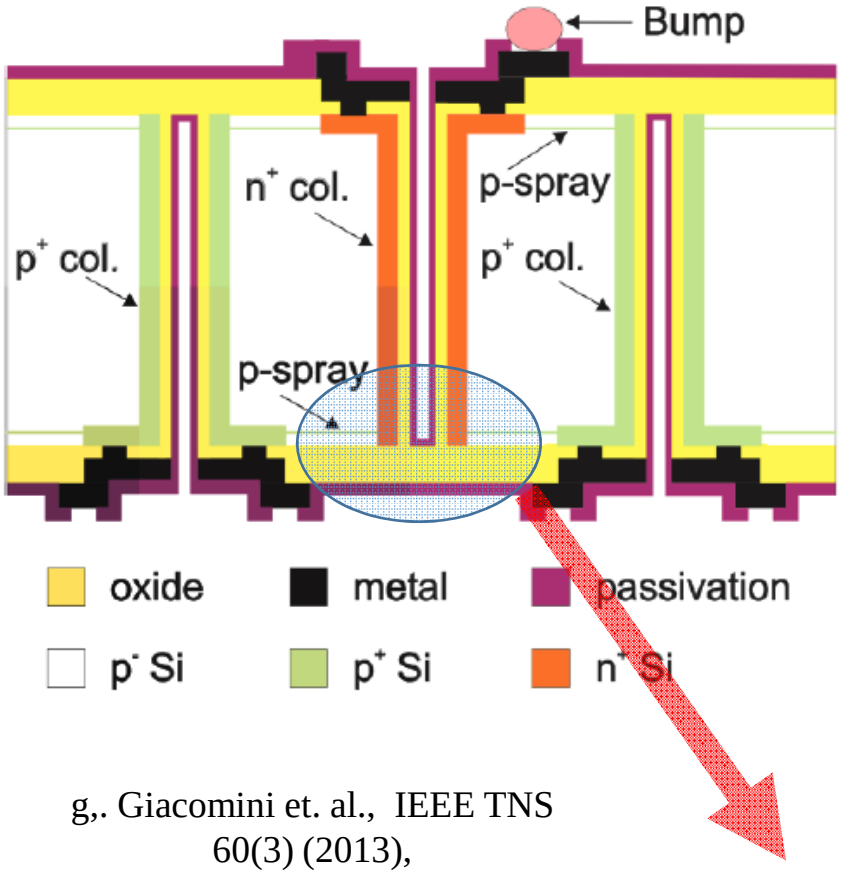
No charge saturation at large fluences before breakdown

3D strips



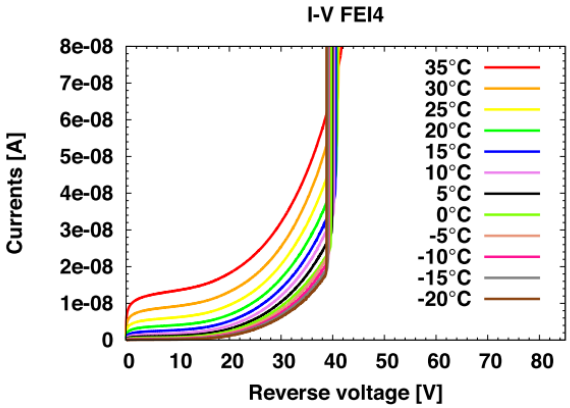
G.F. Dalla Betta et al,
HSTD9 2013

3D sensor technology at FBK

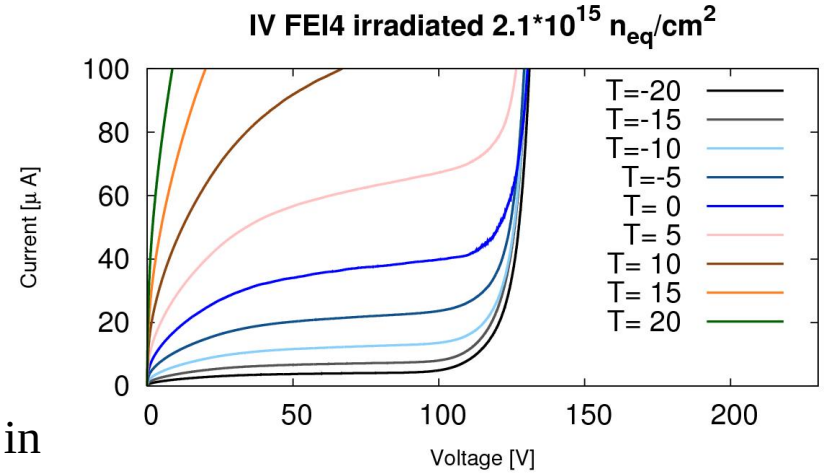


g,. Giacomini et. al., IEEE TNS 60(3) (2013),

The problem of the early breakdown was in this area

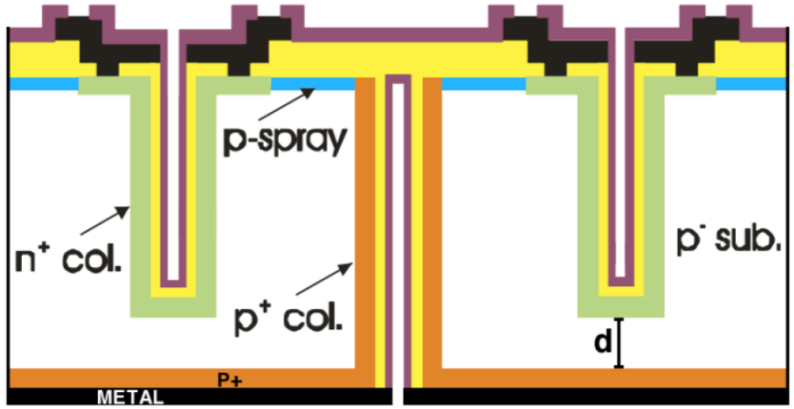


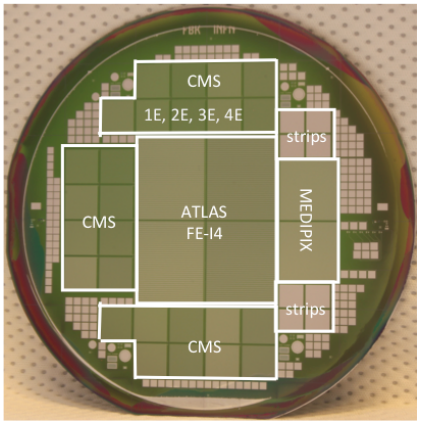
Povoli et al. 8th NIMA699, (2013), 22

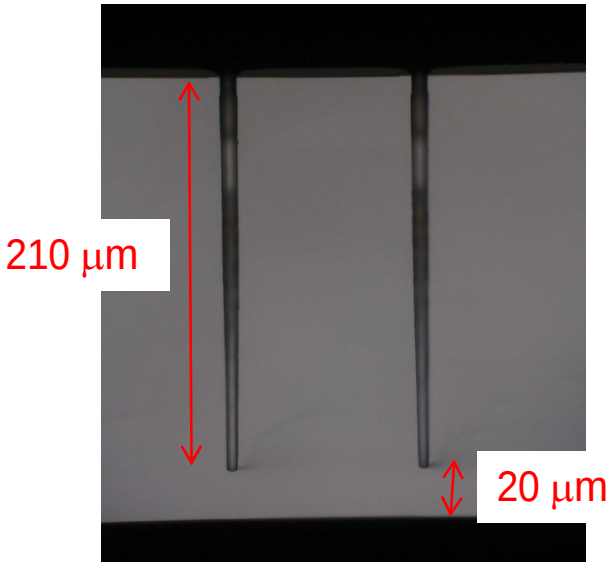


Mendicino et al. 8th "Trento" Workshop

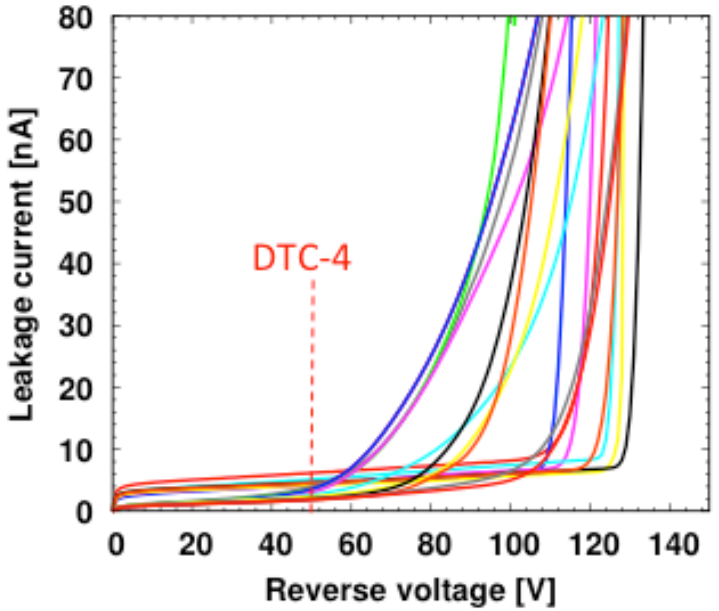
Modified 3D sensor technology at FBK







M. Povoli et al.,
IEEE NSS 2012



G.F. Dalla Betta et al.,
IEEE NSS 2013

Irradiation campaigns

✓ Proton irradiation:

➢ Los Alamos (LANSCE), USA: 800 MeV protons

- Thanks to Martin Hoeferkamp and Sally Seidel

➢ Karlsruhe (KIT), Germany: 25 MeV Protons

- Thanks to Alexander Dierlamm

✓ Neutron irradiation:

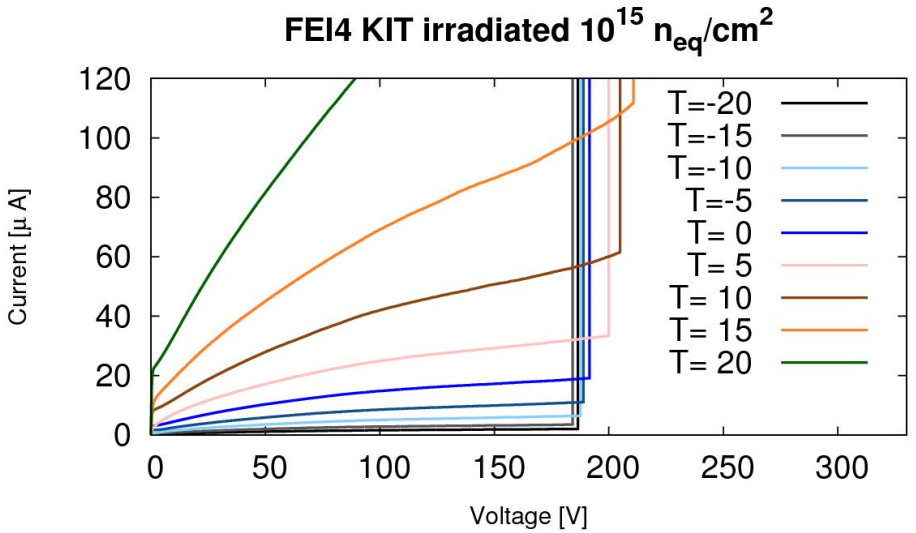
➢ TRIGA reactor at JSI Ljubljana, Slovenia

- Thanks to Vladimir Cindro

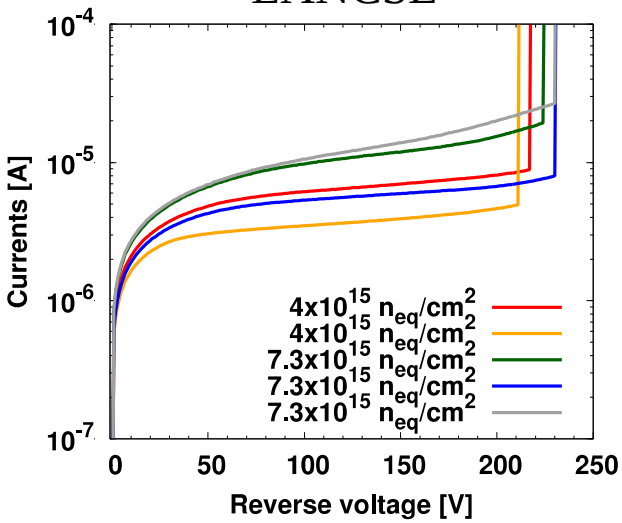
(*) Irradiation studies at the cyclotron in Karlsruhe (Germany) and at the TRIGA reactor in Ljubljana (Slovenia) have received funding from the European Commission under the FP7 Research Infrastructures project AIDA, grant agreement no. 262025.

Measurement on proton irradiated sensors (KIT and LANCSE)
IV curves

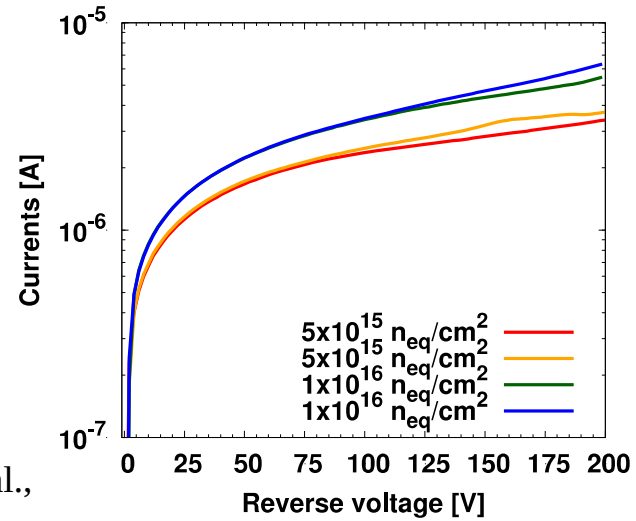
- ✓ Temperature variation between -20 ÷ +20 C inside climatic chamber
- ✓ Measured performed with HP 4145



LANCSE



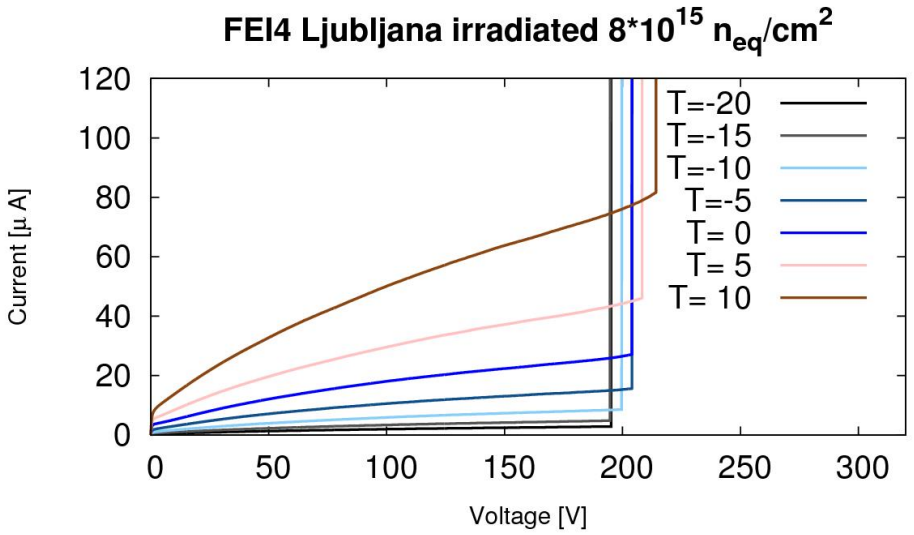
KIT



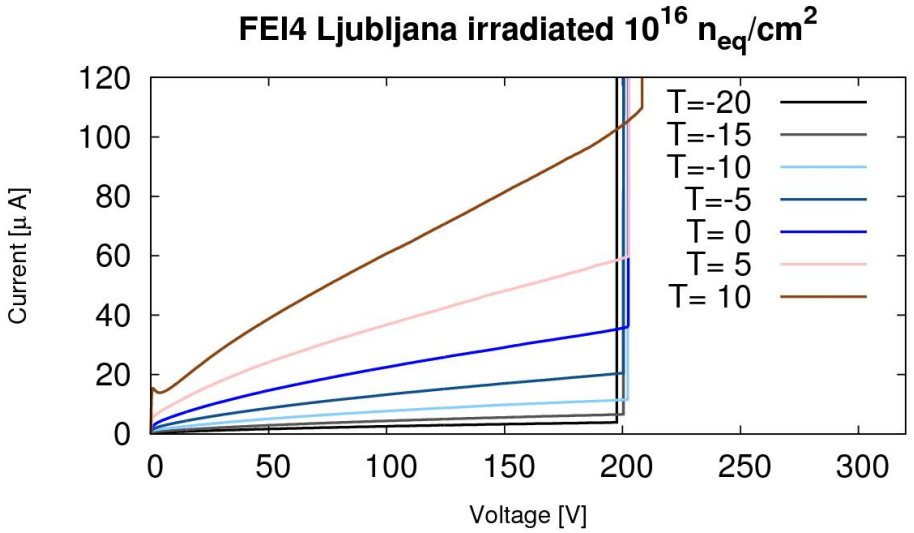
G.F. Dalla Betta et al., IEEE NSS 2013

Measurement on neutron irradiated sensor (JSI)
IV curves

- ✓ Temperature variation between -20 ÷ +10 inside climate chamber
- ✓ Measured performed with HP 4145



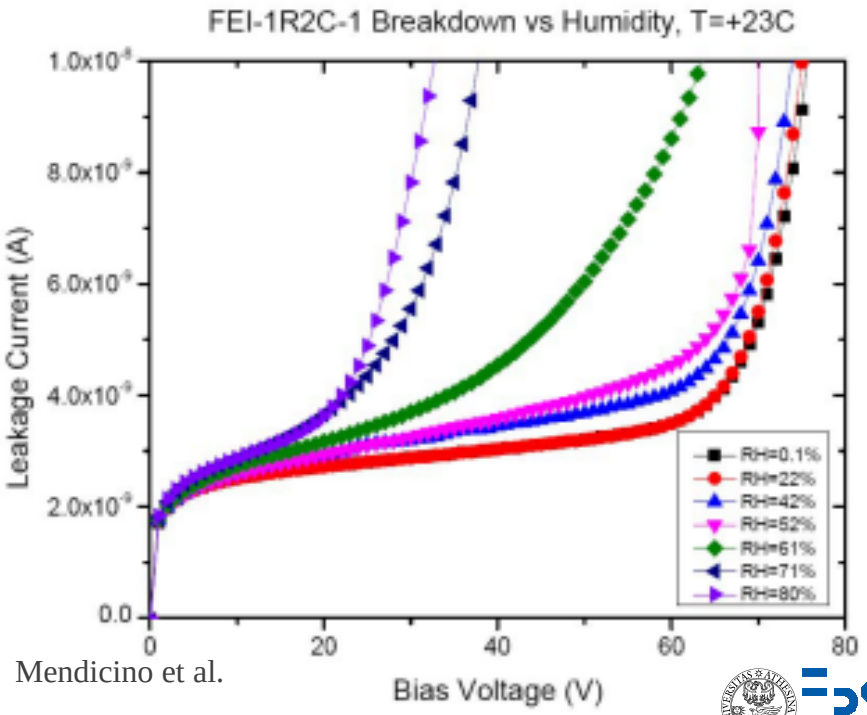
- ✓ Difficult to find the dependence between temperature and breakdown voltages
  - ➢ Breakdown dependence with humidity

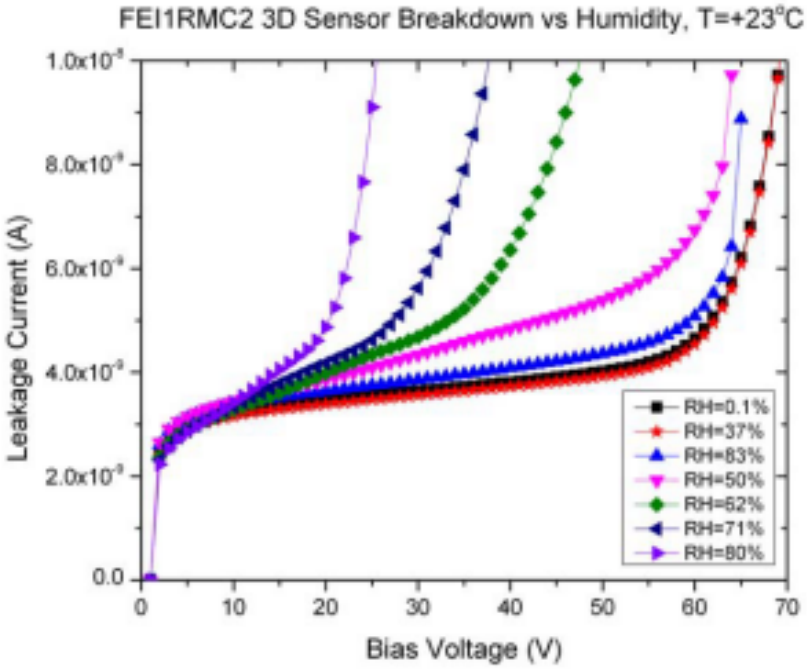


Humidity vs breakdown (measurements)

Thanks to Martin Hoeferkamp and Haley McDuff

- ✓ The leakage current increases and breakdown voltage decreases as the humidity increases





- ✓ TCAD simulations were performed to understand the phenomena

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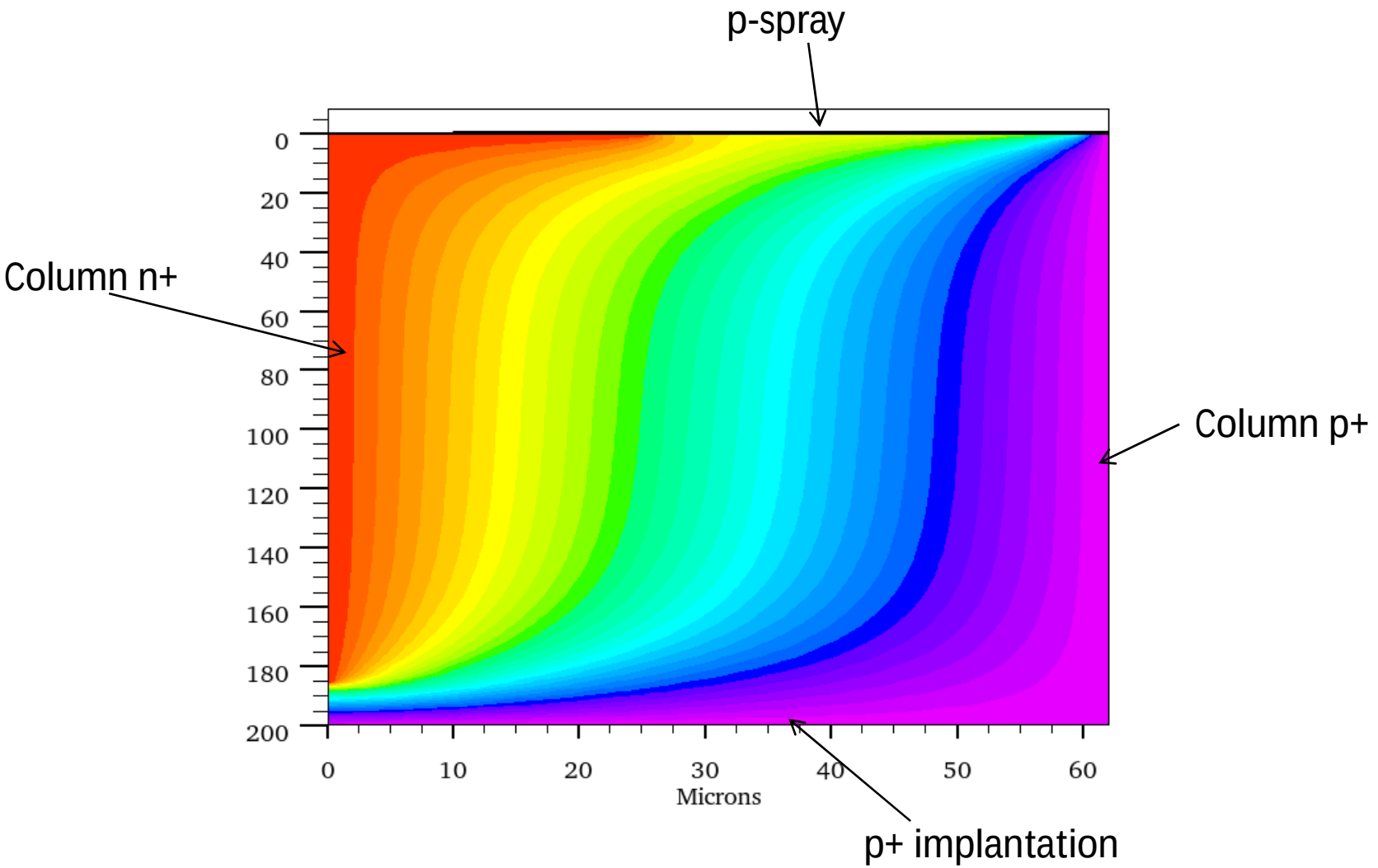
Humidity vs breakdown (1)

Thanks to Gabriele Giacomini



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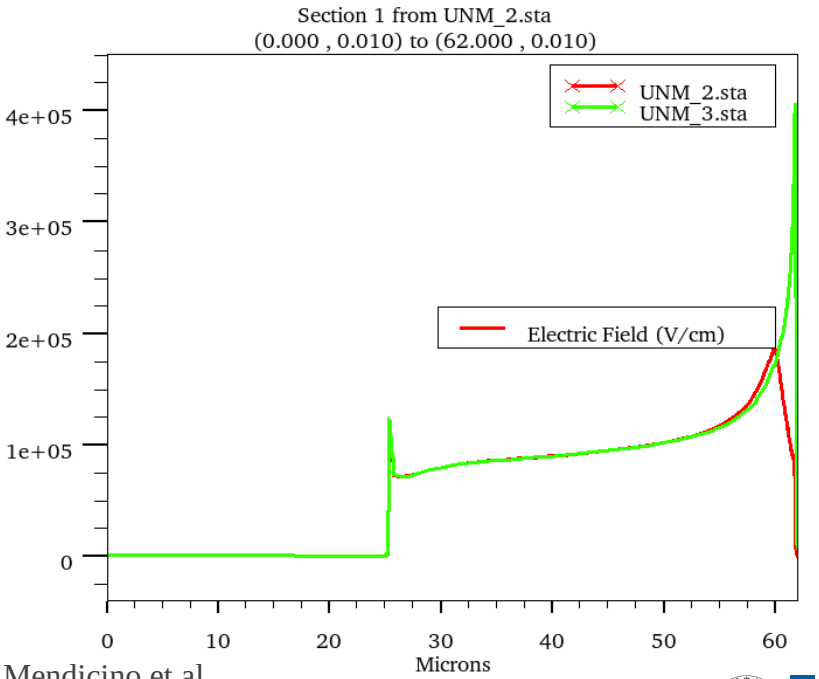
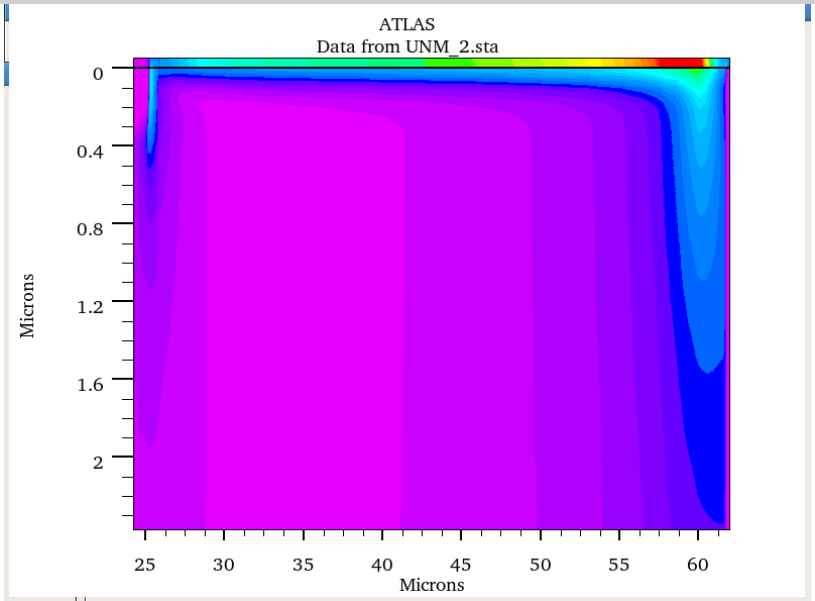
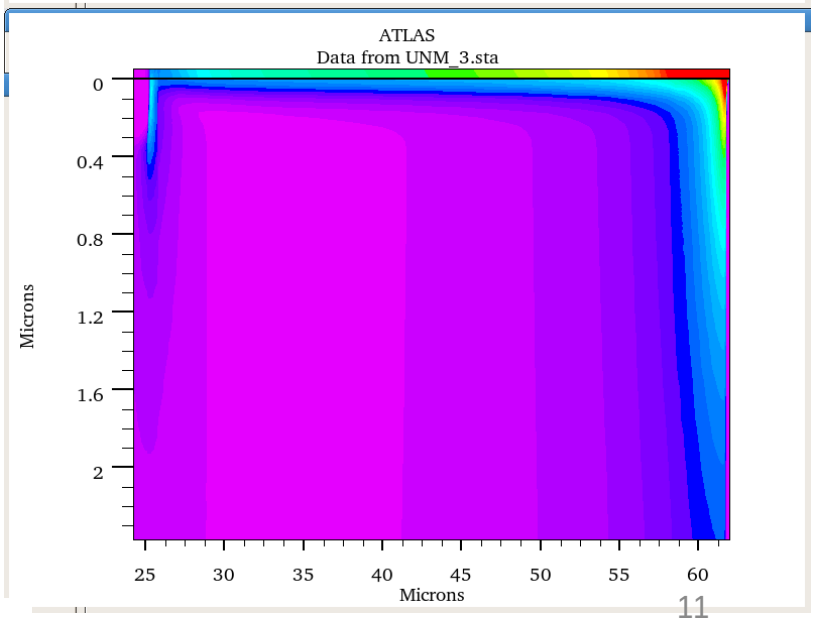
Humidity vs breakdown (2)

Thanks to Gabriele Giacomini

- ✓ Humidity is modeled as a equipotential gate:
- ✓ When it cover the column P+ the electrical field increase
- ✓ Electrical field color red = 3e5 V/cm violet=0 V/cm
- ✓ Cut section on 0.01 µm







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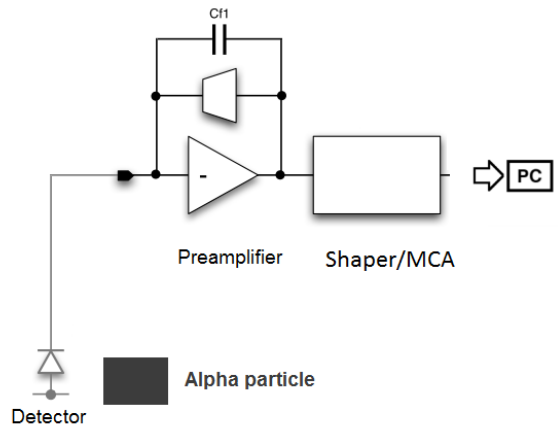
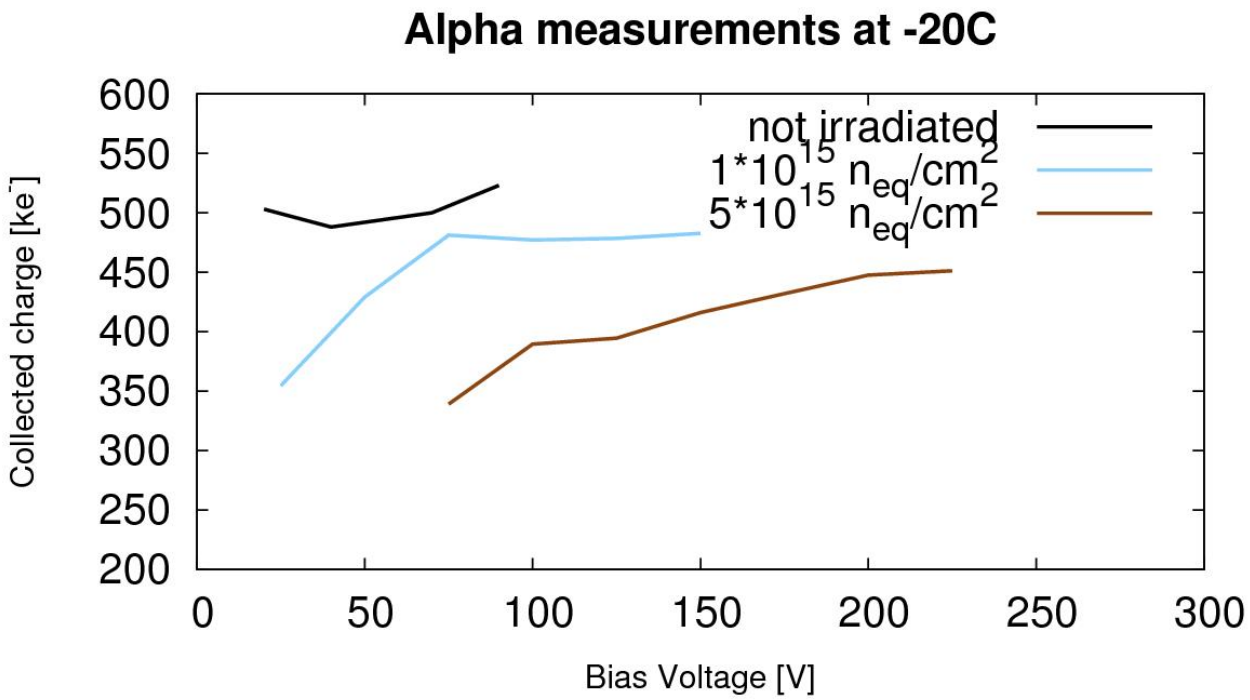
Alpha measurements
Irradiated and non irradiated samples

- ✓ Charge saturation for all the devices
- ✓ LANCSE irradiated device
- ✓ Irradiated sample at -20 C
- ✓ Shaping time: 500ns
- ✓ Measurements in air (1.5 cm of distance between





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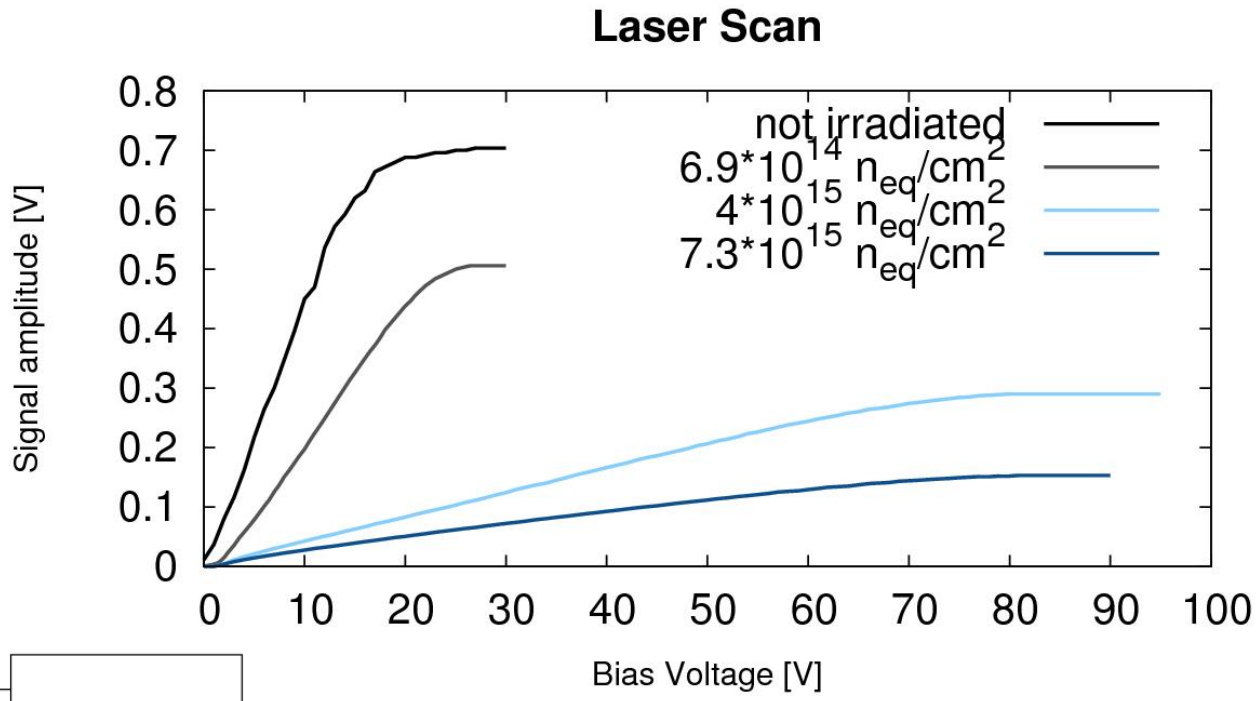
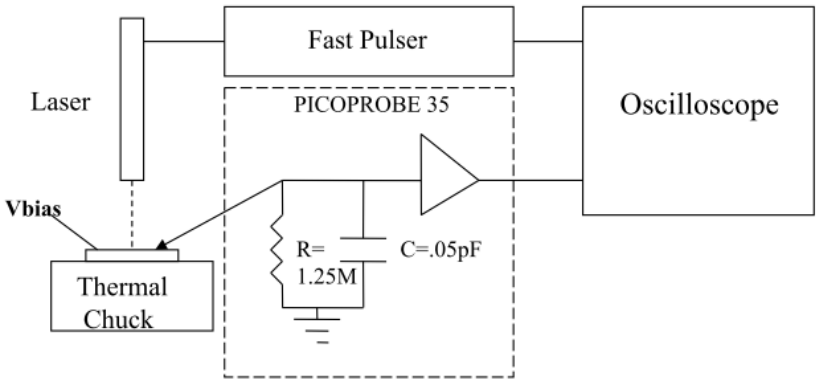
Laser measurements

thanks to Martin Hoeferkamp, Haley Mcduff and Sally Seidel

- ✓ Wavelength : 1064 nm
- ✓ Probes: Picoprobe 35 26 GHz, Cascade Microtech coaxial
- ✓ Oscilloscope: Tektronix TDS7254 2.5Ghz BW
- ✓ Thermal Chuck: Micromanipulator (-60C)





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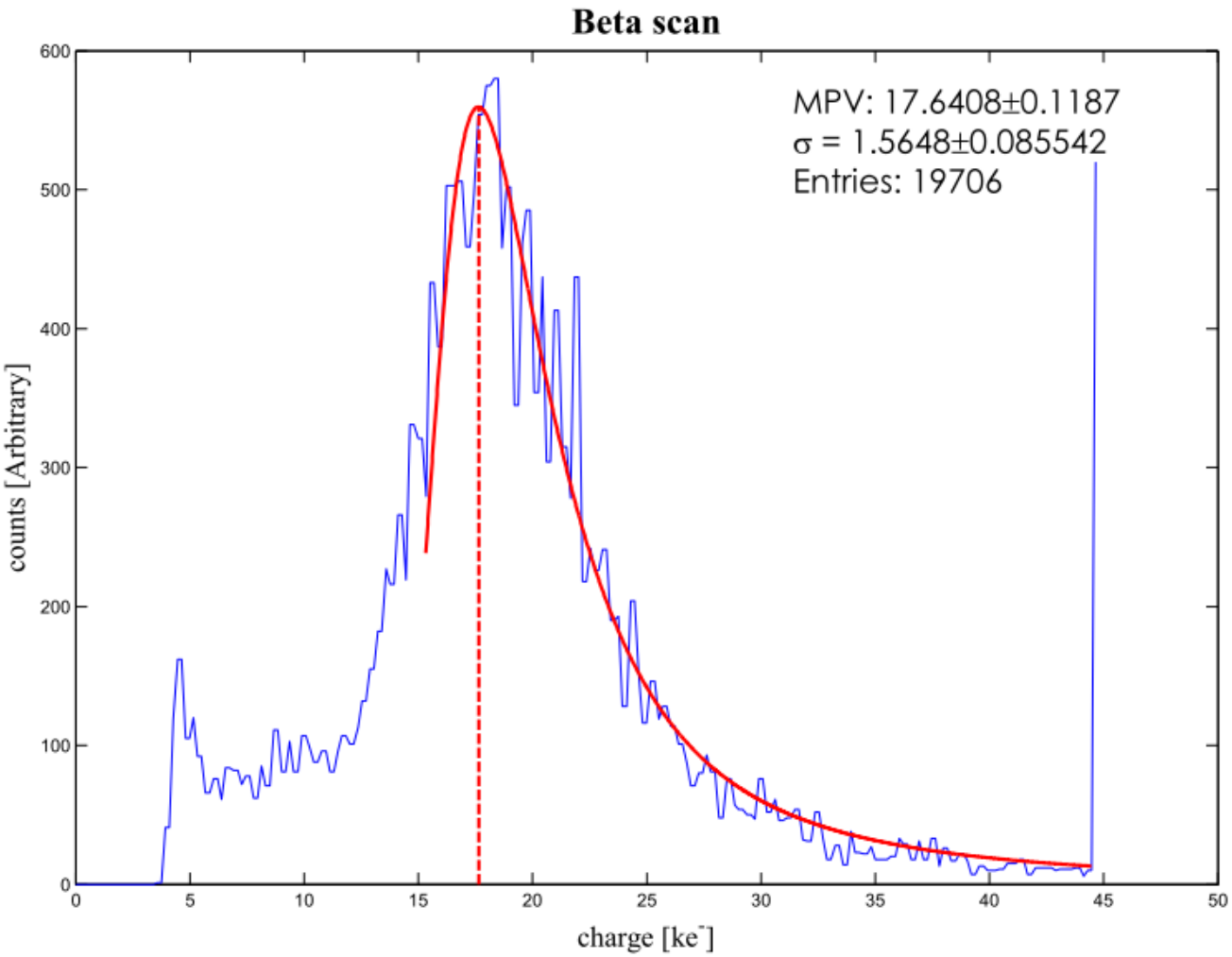
Beta scan
Non irradiated device

- ✓ Estimated noise: ENC~786 e- rms
- ✓ Reverse bias voltage: 25 Volt
- ✓ Shaping time: 1µs
- ✓ Plastic scintillator + PMT trigger



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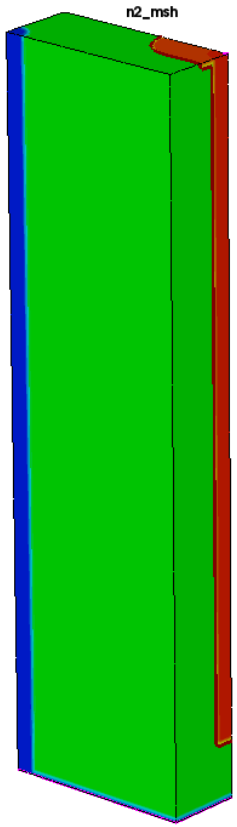
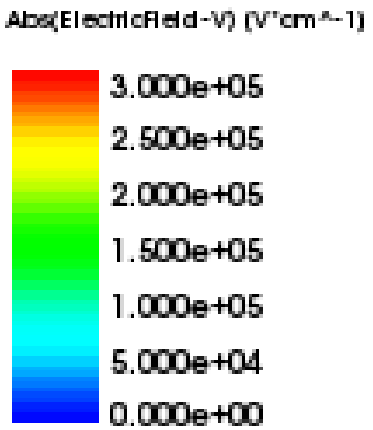
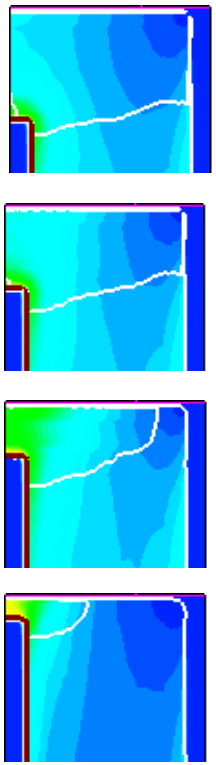
Simulation domain and electric field
IV and alpha



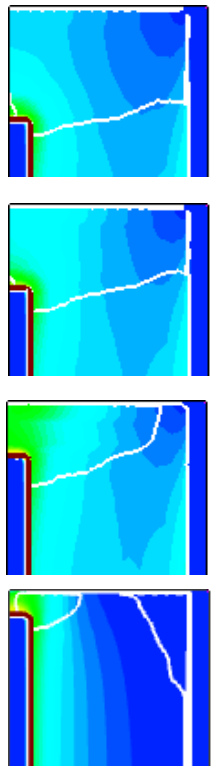
- ✓ No Oxide
- ✓ No surface effects
- ✓ 3 different fluences (1E15, 5E15 and 1E16 neq/cm^2)



Pplus

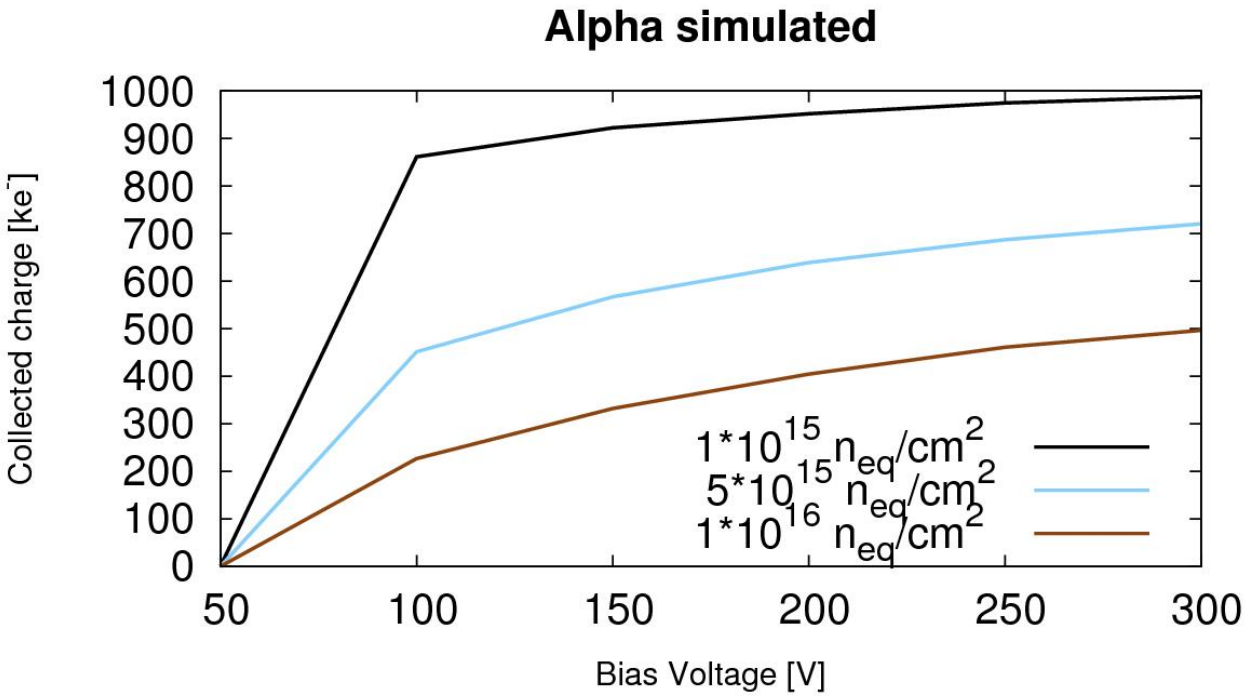


Pspray



Alpha simulations
Bias voltages vs collected charge

- ✓ Simulated alpha energy of 3.6 MeV → 1000 ke
- ✓ No avalanche effect
- ✓ No surface effects



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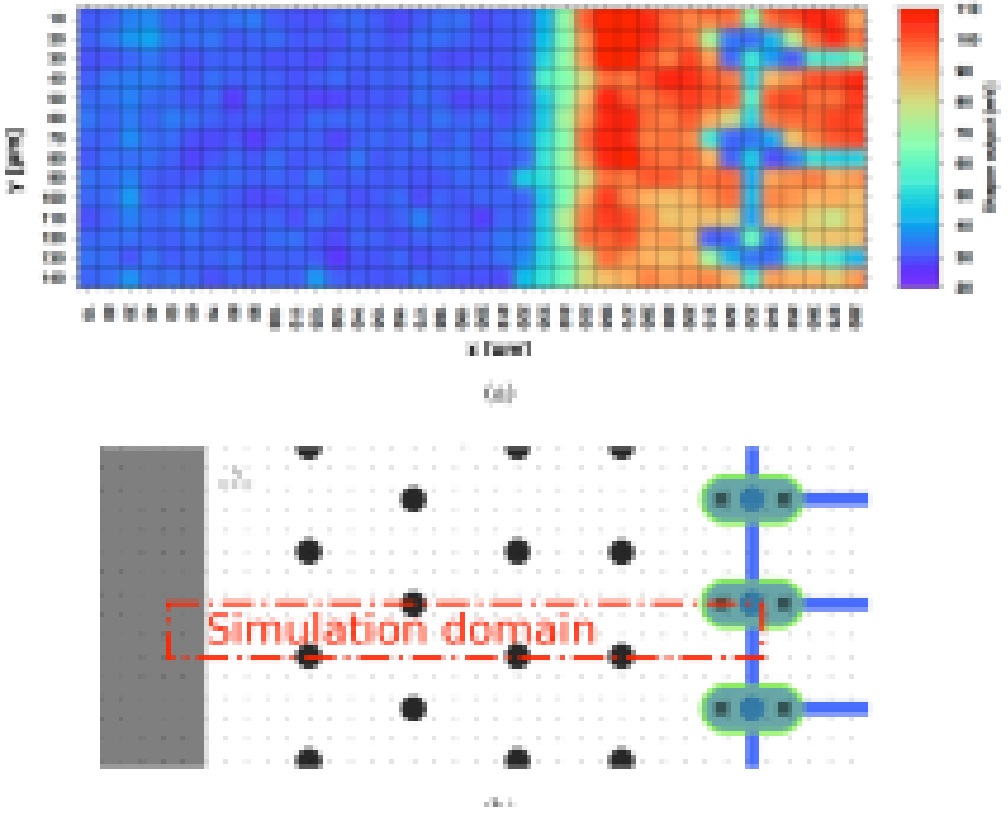
Conclusion

- The electrical behavior of irradiated 3D diodes fabricated at FBK with a modified technology has been studied
- Results confirmed a significant improvement in the breakdown voltage as compared to device from the IBL production
- A TCAD simulation study of irradiated devices has been started to better understand their electrical and functional properties
- Radioactive source (alpha and beta) tests and laser scan measurements are also under way to demonstrate that the increased breakdown voltage is beneficial for charge collection efficiency in irradiated devices.

Thank you for the attention!!

Active area in device edge



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Iworid 2012