TCAD Simulation of the HVCMOS sensor for the MIDAS personal active dosimeter

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MIDAS: Miniaturised Ionization Detector for Applications in Space

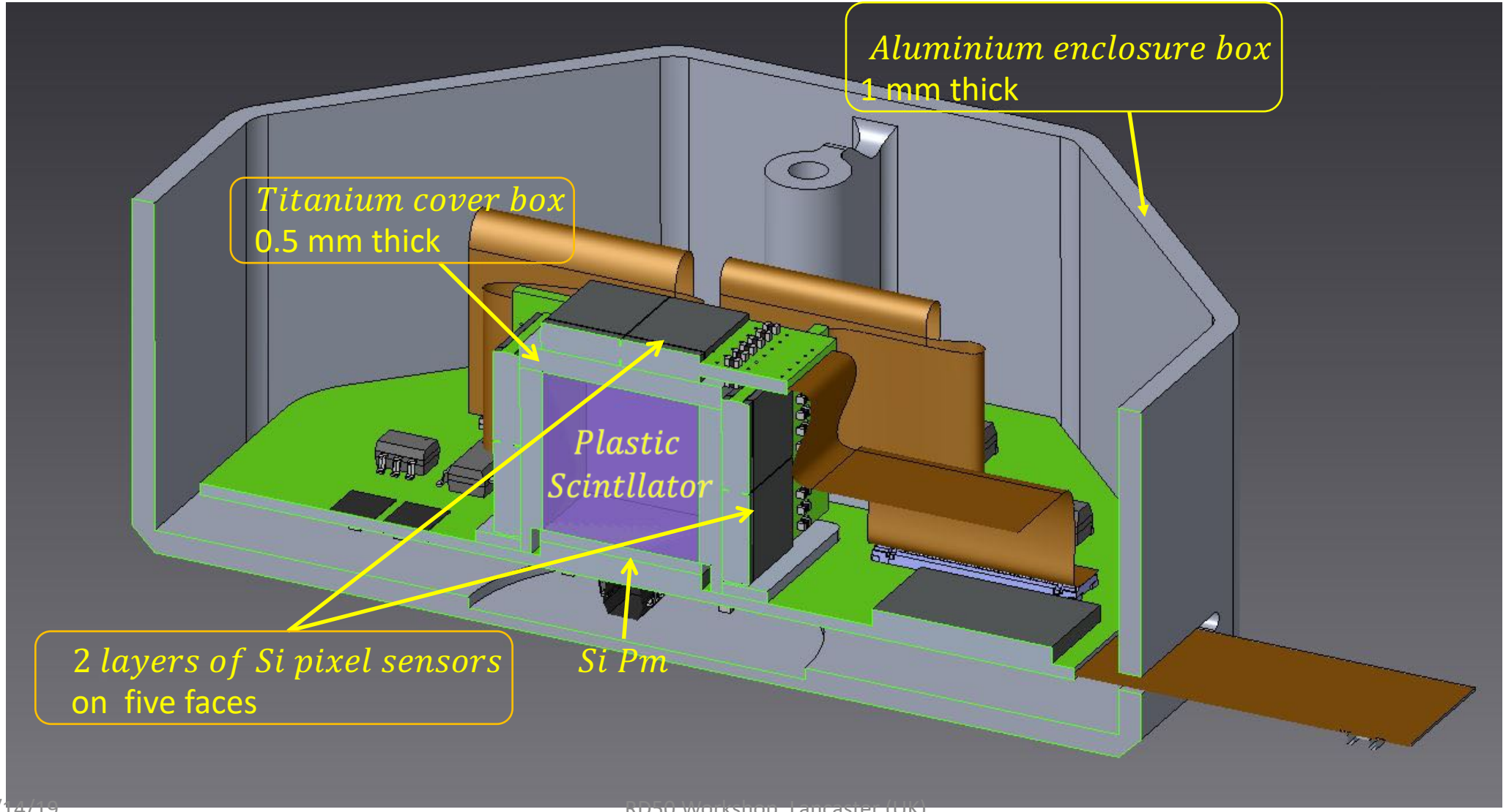
A project targeting the development of a miniaturized ASIC radiation detector

The project started in April 2017 under an ESA Contract

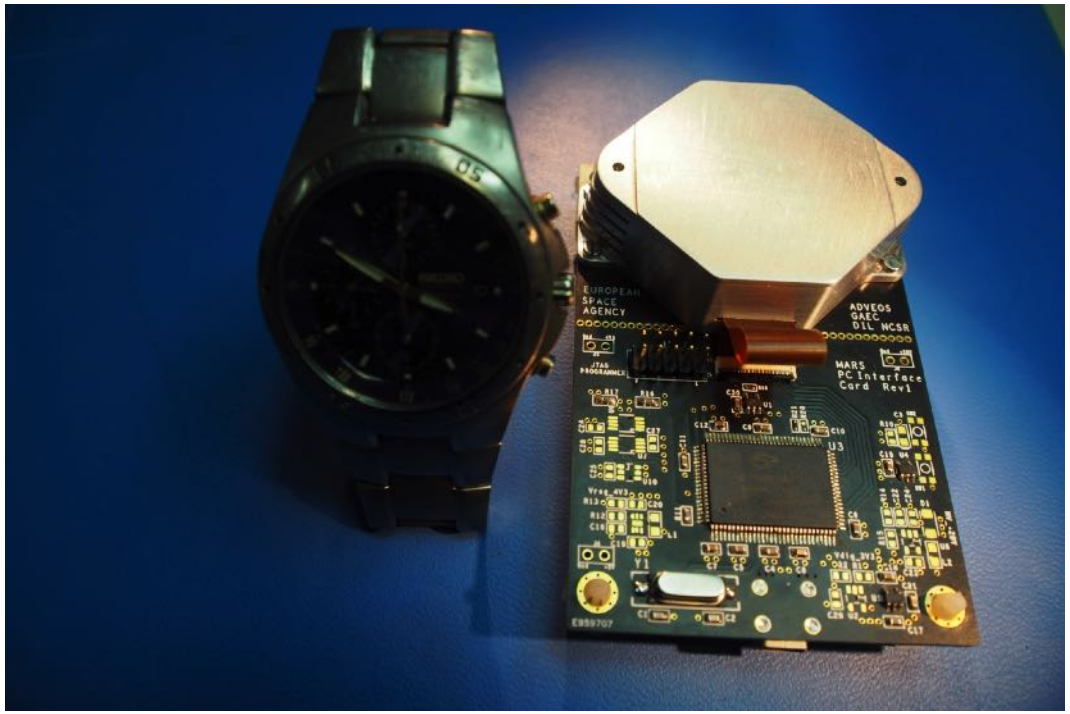
A consortium led by a Greek Company: ADVEOS Microelectronics Systems Company

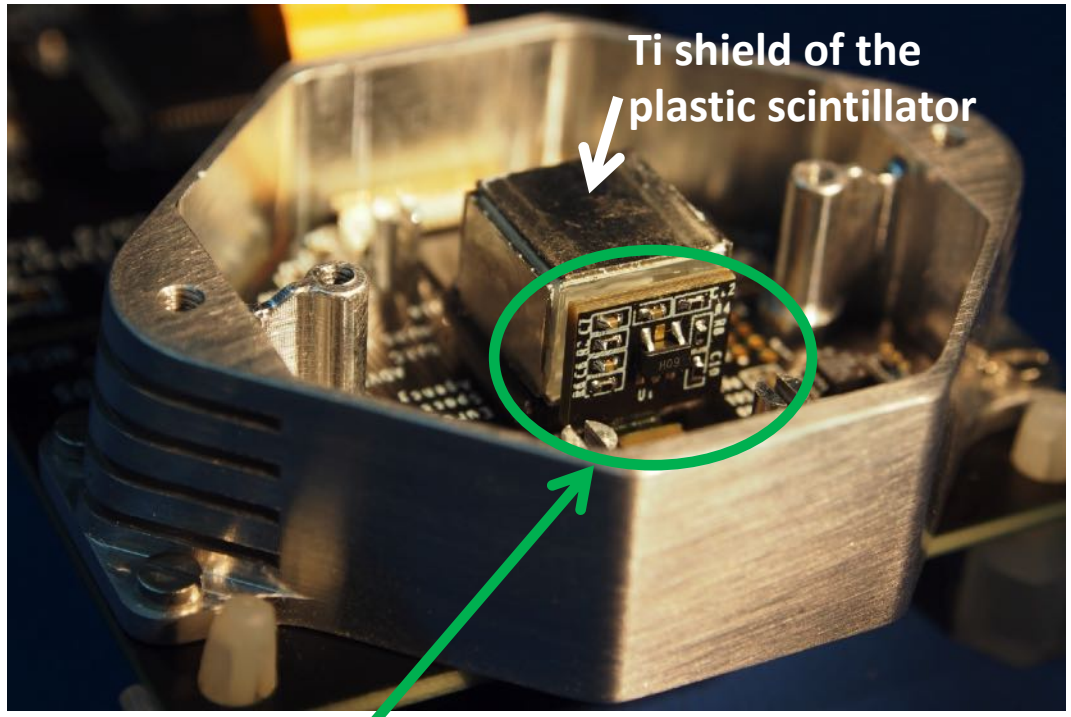
With participation of laboratories from:
Greek Atomic Energy Commission,
National Center of Scientific Research Demokritos
Physics Department of the University of Cyprus

Conceptual cut through



First Prototype

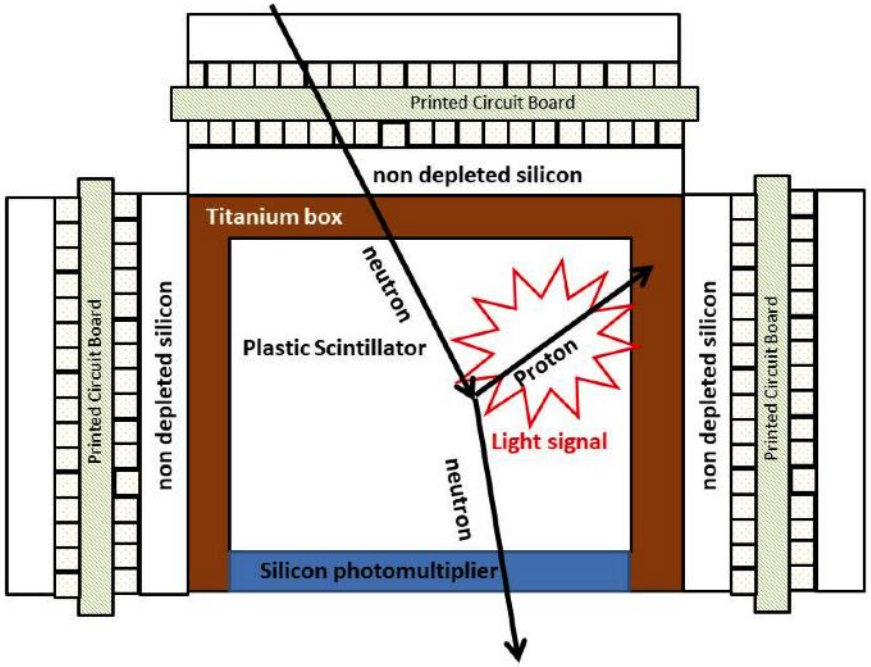




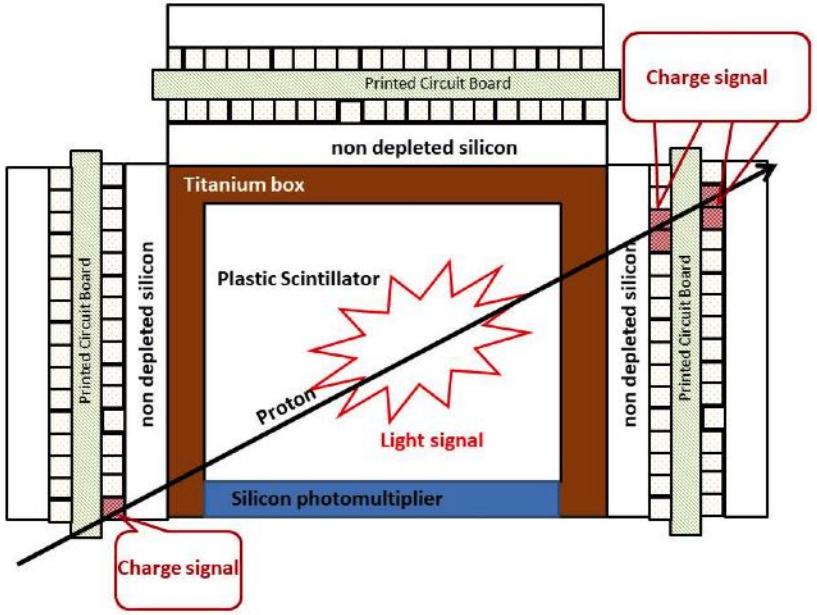
The silicon photomultiplier readout electronics

Principle of Operation

Neutron Detection



Charge Particle Detection



Efficient for neutron energies: 0.1 – 100 MeV

The LFoundry HVCMOS commercial process

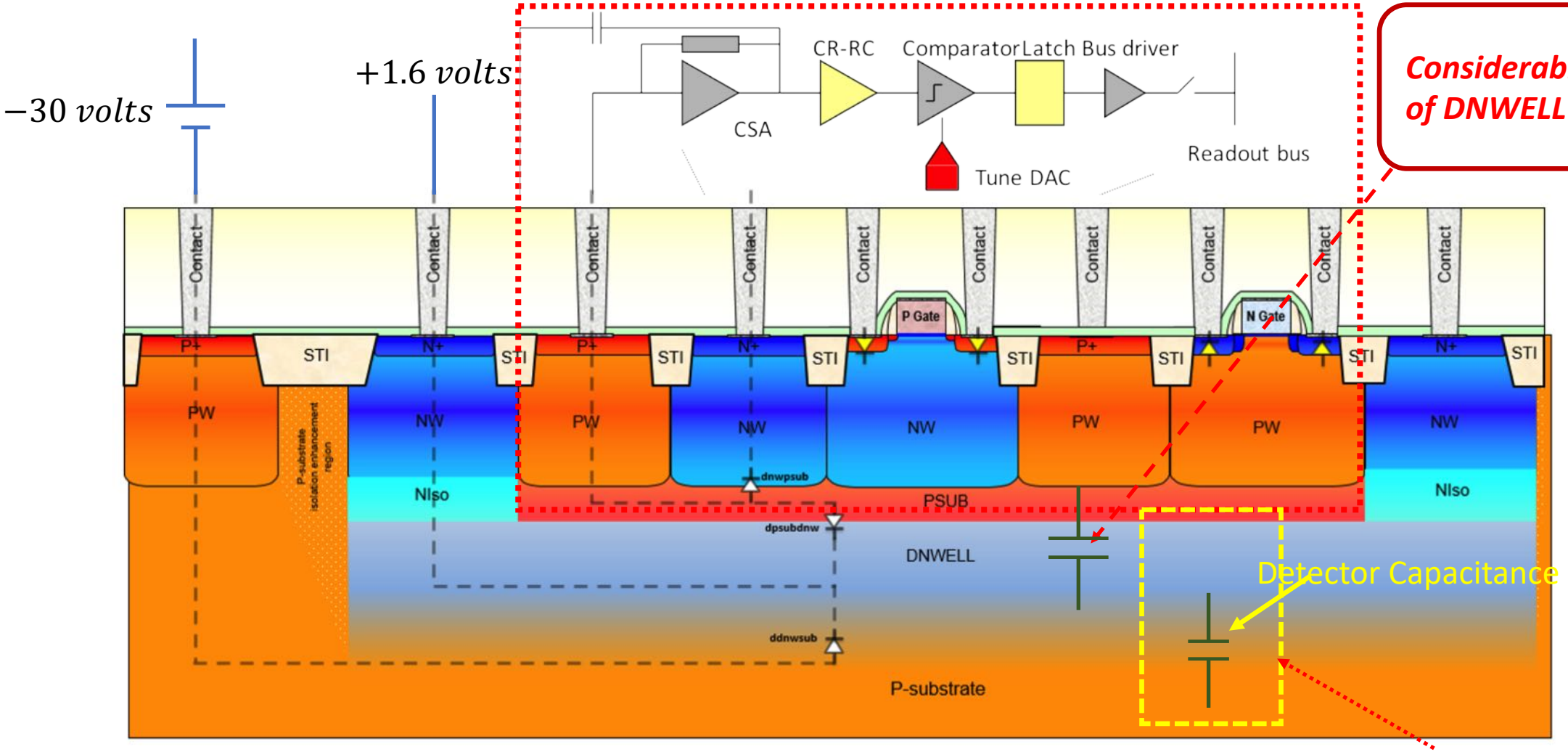
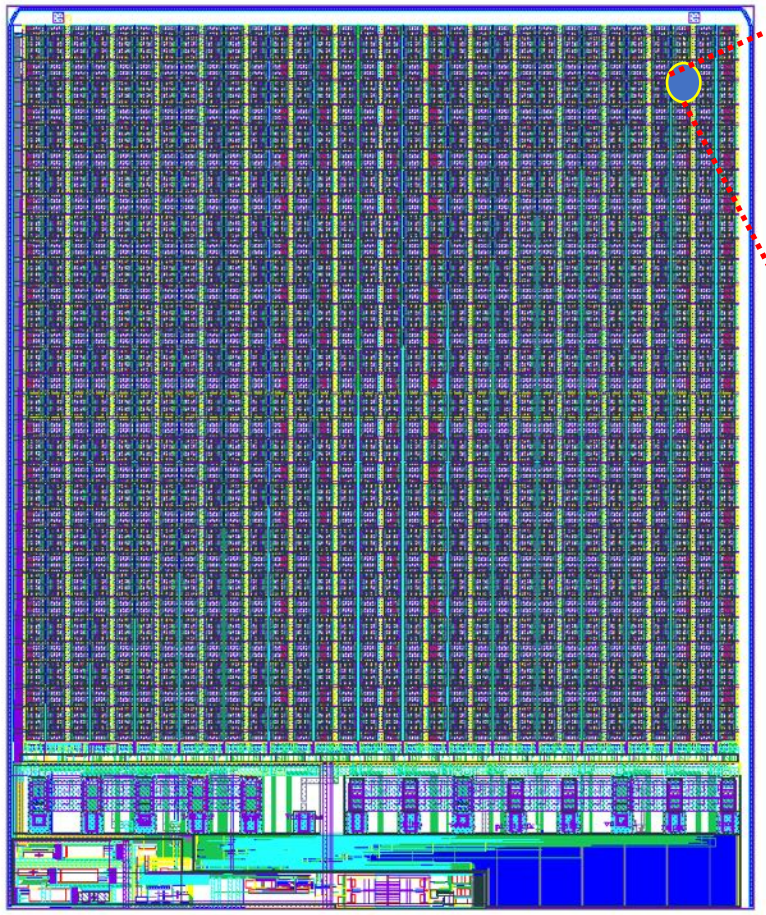
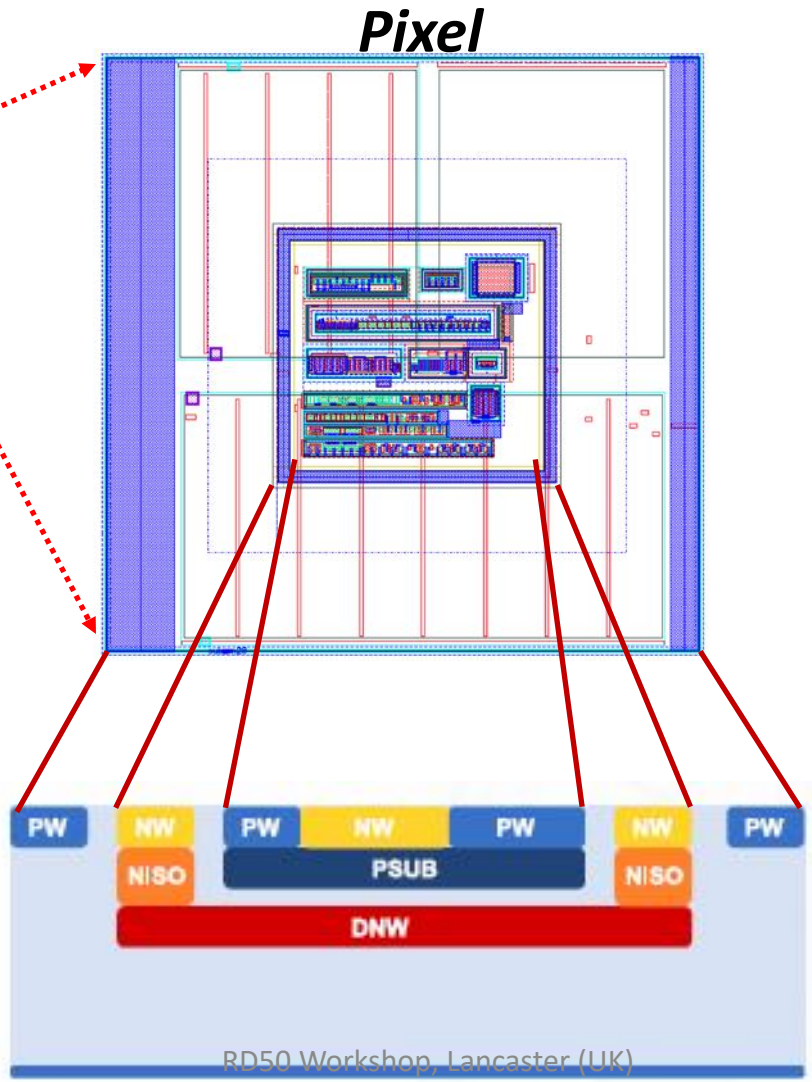


Figure 4.25.: DNWELL isolation scheme with indicated junction diodes

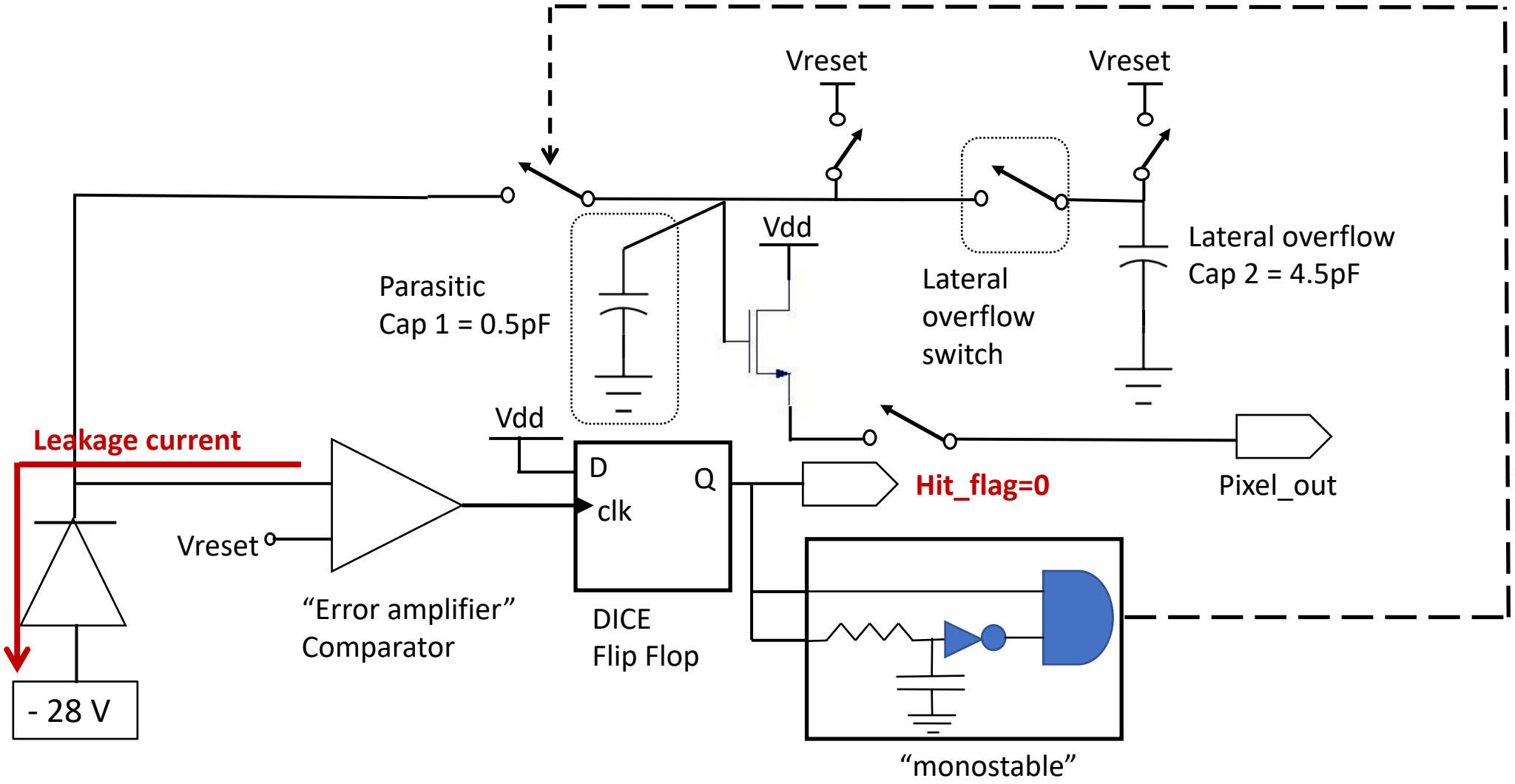
The MIDAS v1 monolithic chip



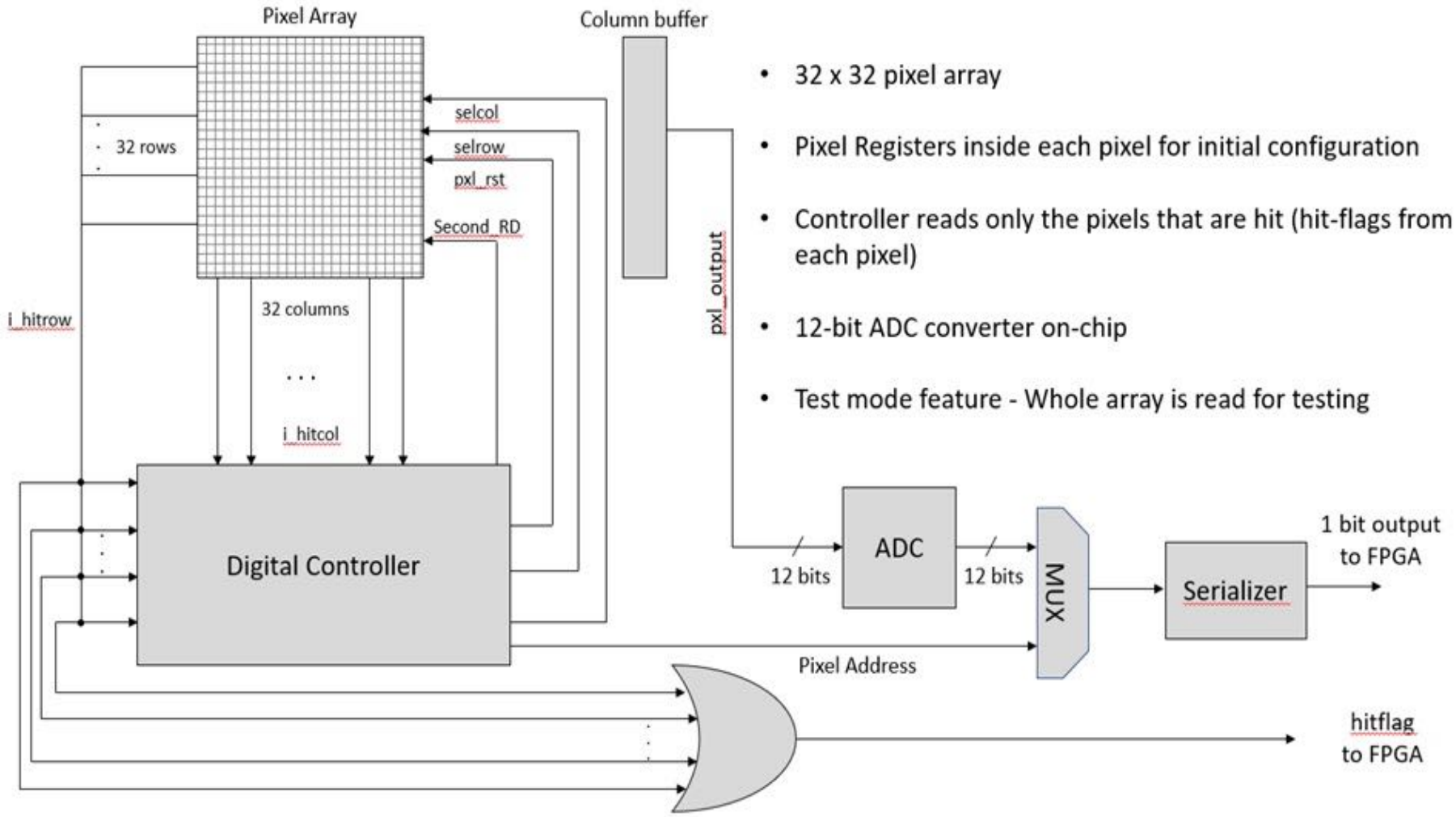


- ✓ 32 rows x 32 columns
- ✓ 105.5 um pixel pitch
- ✓ Charge signal dynamic range: Min:0.5f Cb, Max:6 pCb ***(80db)***
- ✓ Pixel consumtion < 10 mW/cm^2
- ✓ Embedded A/D converter (11 bits)
- ✓ Only hit pixels are readout
- ✓ 2-3 events/cm^2/sec for Galactic Cosmic Rays
- ✓ 10^3 events/cm^2/sec for Solar Event Particles
- ✓ Information output: Hit flag and from pixels hit: Serially, 10 bits address, 22 bits charge signal

On Pixel electronics

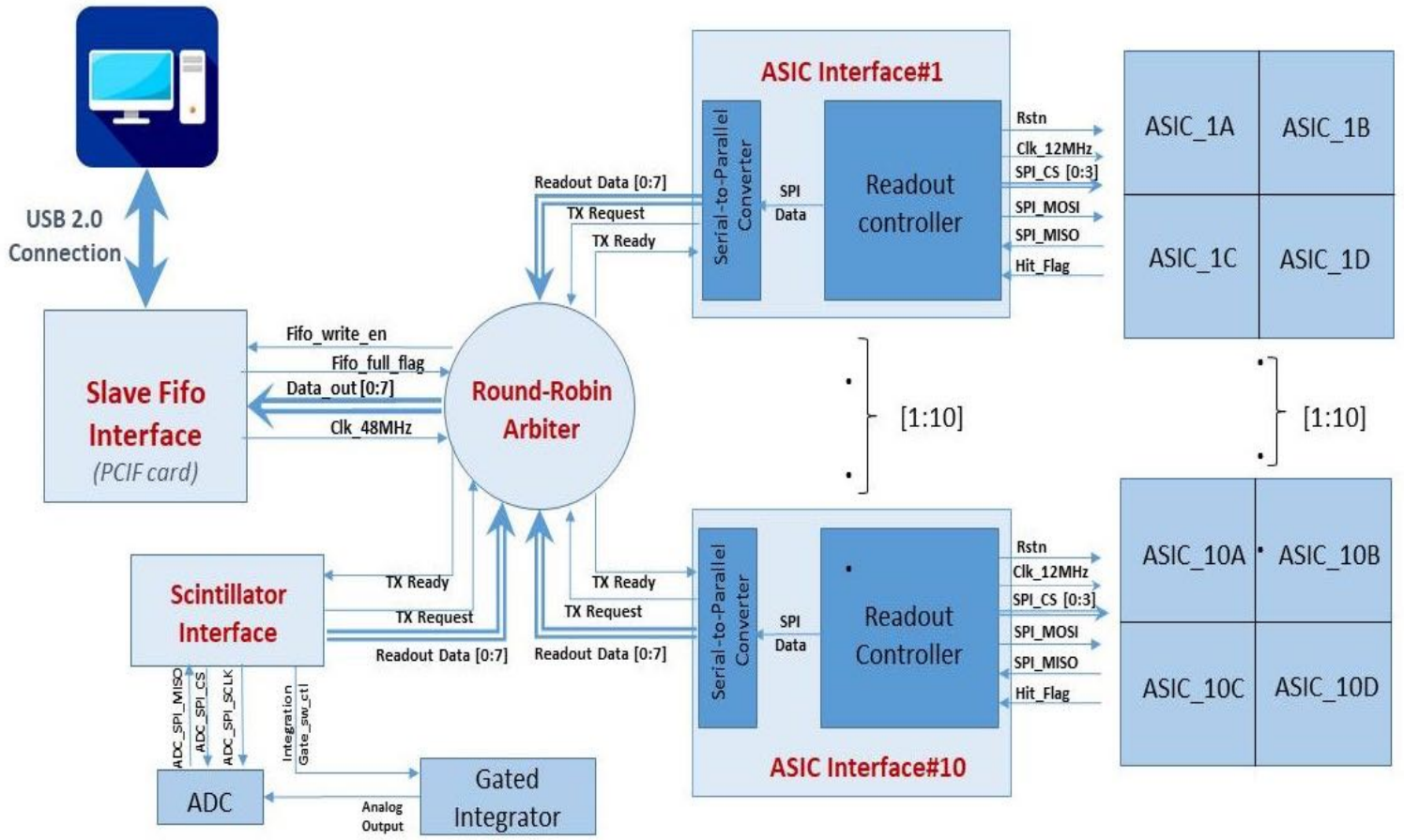


Block Diagram of the Chip



- 32 x 32 pixel array
- Pixel Registers inside each pixel for initial configuration
- Controller reads only the pixels that are hit (hit-flags from each pixel)
- 12-bit ADC converter on-chip
- Test mode feature - Whole array is read for testing

DAQ

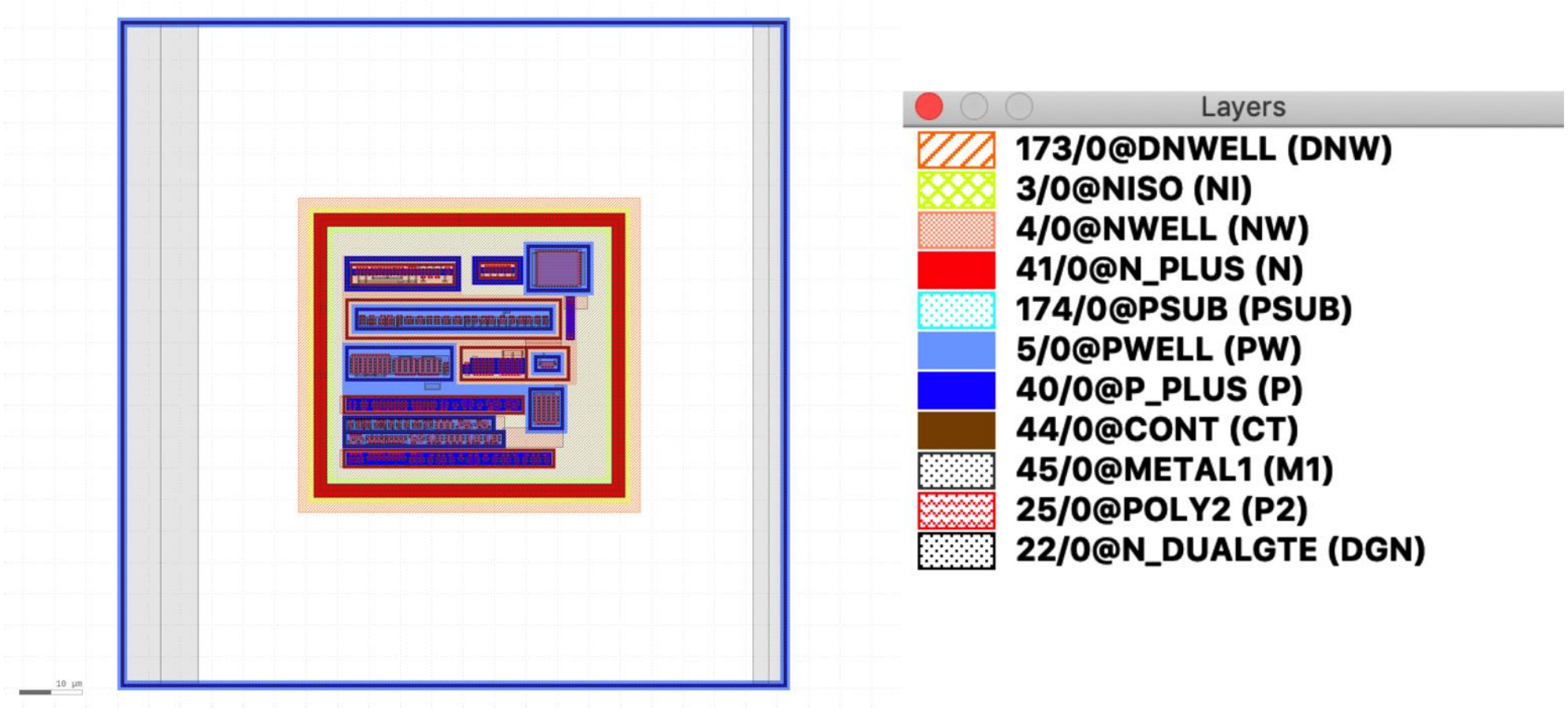


The DAQ card

Test Board

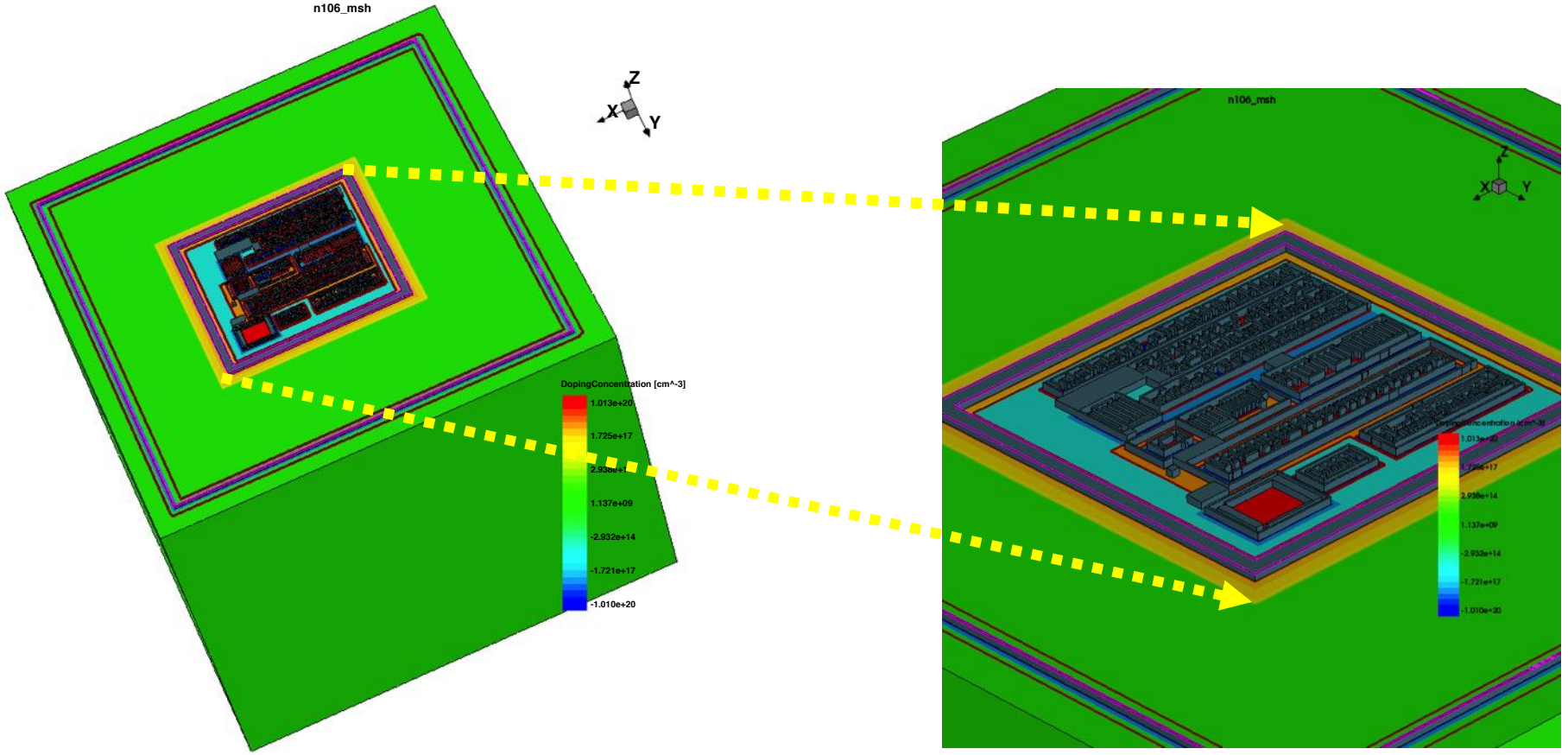
Simulation of the HVCMOS sensor

Import via IC_WorkBench the GDS files of the Lfoundry process to Sentaurus Structure Editor



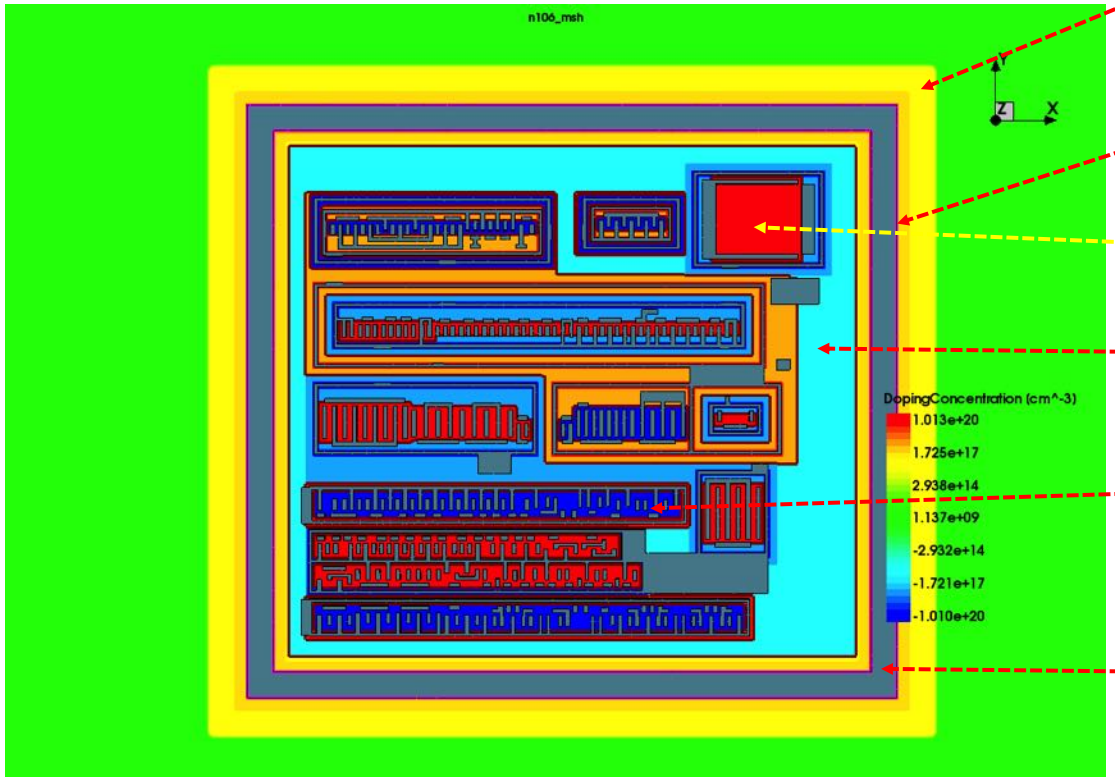
Simulation of the HVCMOS sensor

Implement the LFoundry process in Structure Editor and create the 3D HVCMOS pixel



Simulation of the HVCMOS sensor

Top view details of the pixel



Deep n well

niso

n +

psub

p+

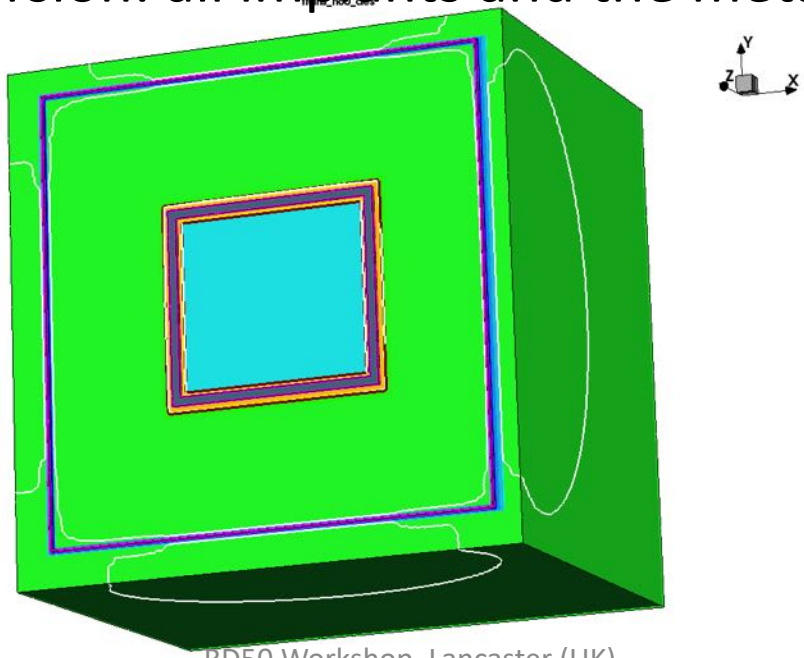
metal

Sparse information from Lfoundry on processing details …

Simulation of the HVCMOS sensor

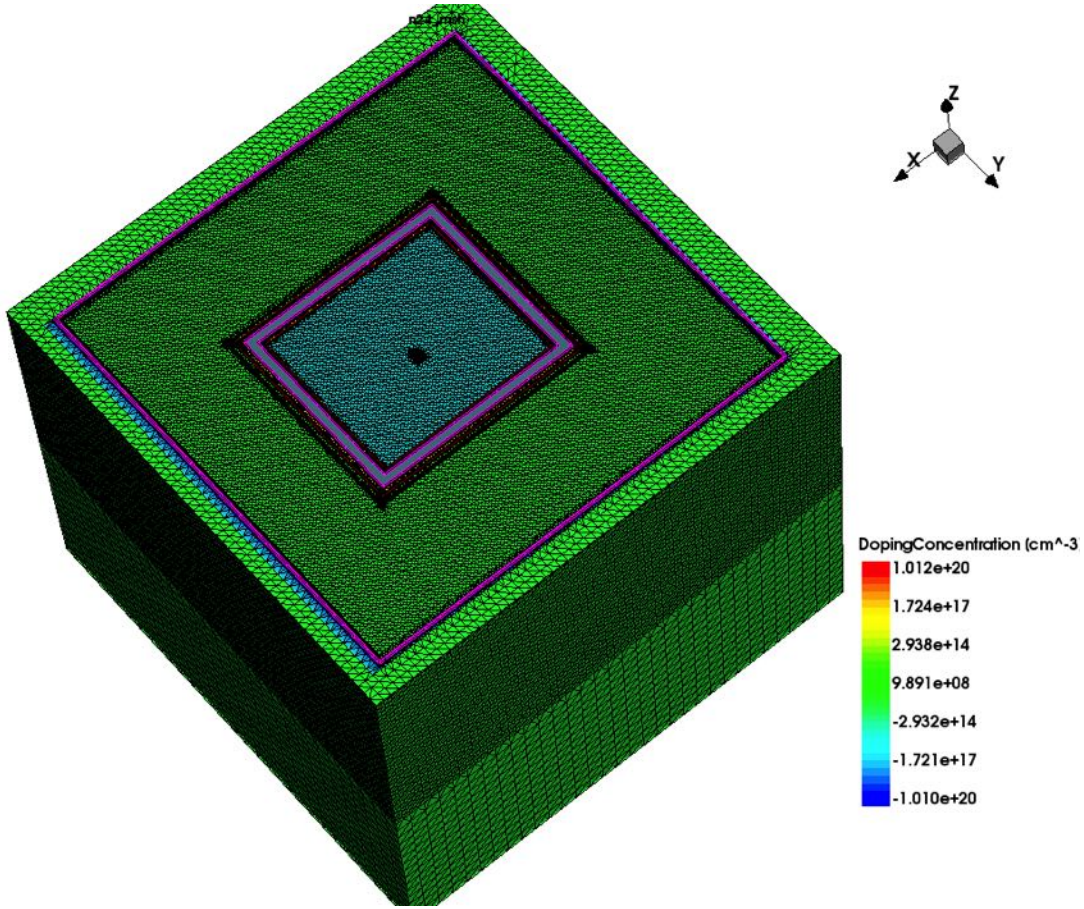
- A grid with 1 million elements requires ~2GB – 2.5GB
- Typical grid size for the adveos 3d full simulation can be over 20 million elements

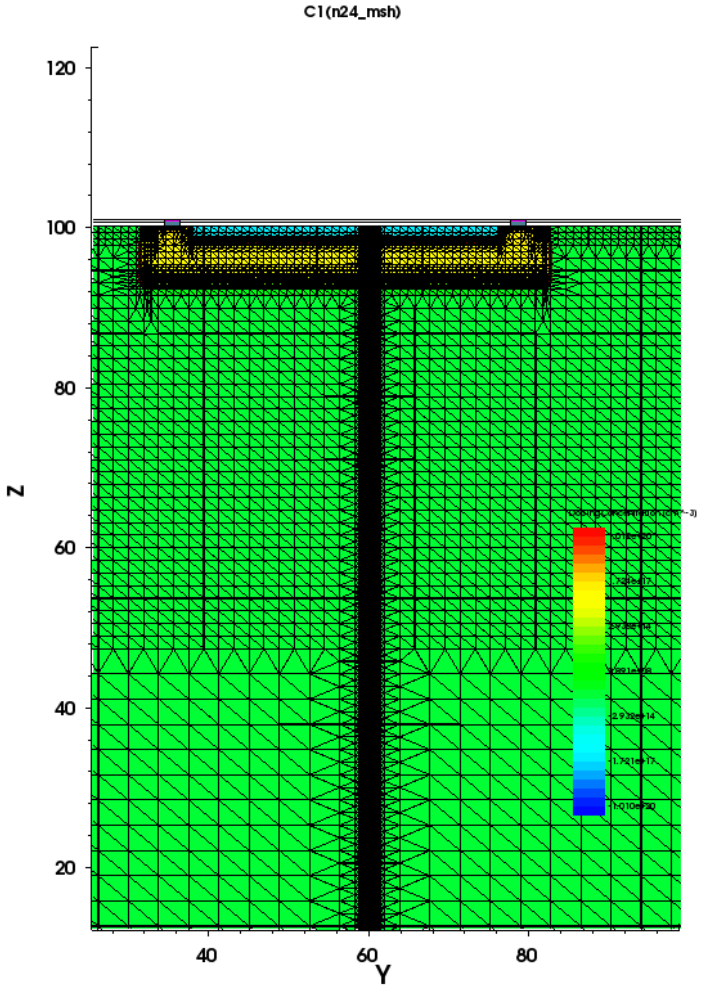
Start with a reduced version: all implants and the metal inside dnwell removed



Simulation of the HVCMOS sensor

Mesh and through going particle

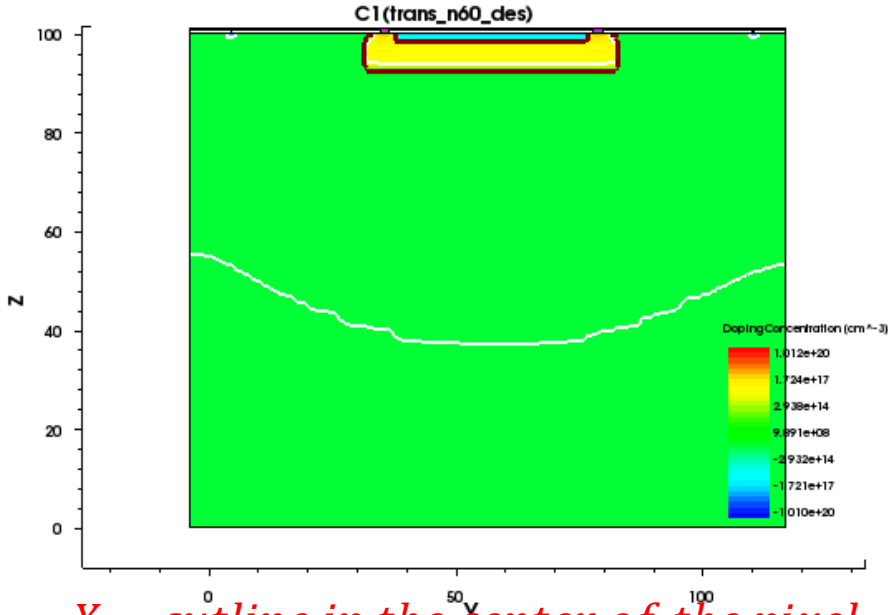




Simulation of the HVCMOS sensor

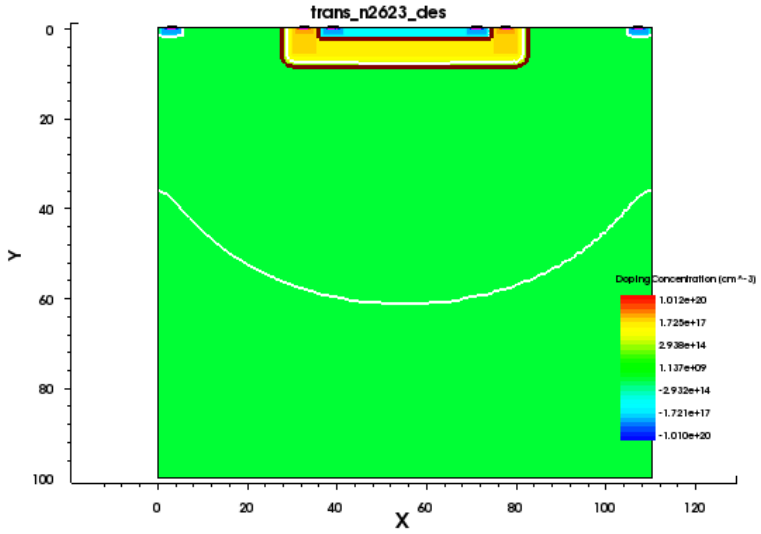
Comparison of Depletion Depths in 3D and 2D simulation

- **MIDAS device is a huge one to be simulated in detailed 3d mode, both in terms of our computer resources and time**
- **Use the 3d simulation to validate the 2d mode and proceed to detailed studies like charge sharing between pixels**



$X - cutline\ in\ the\ center\ of\ the\ pixel$

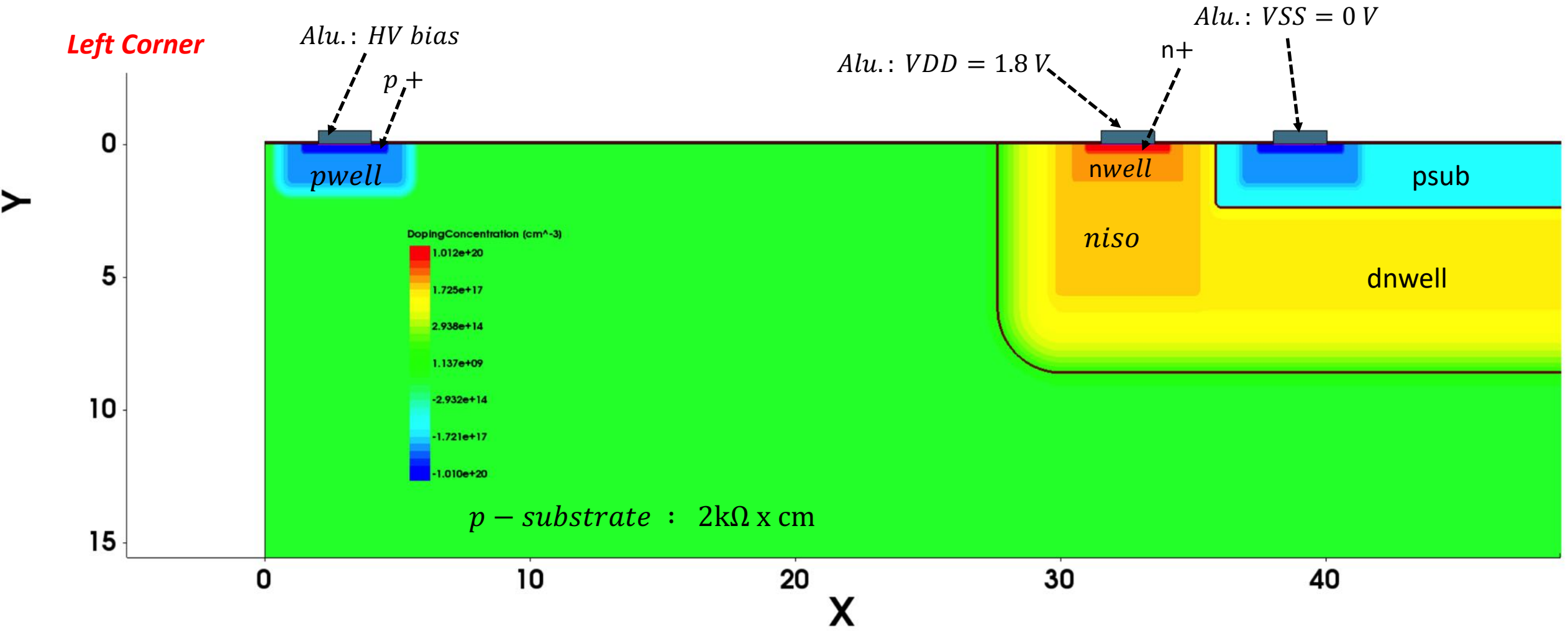
3d simulation – 30 volts



2d simulation – 30 volts

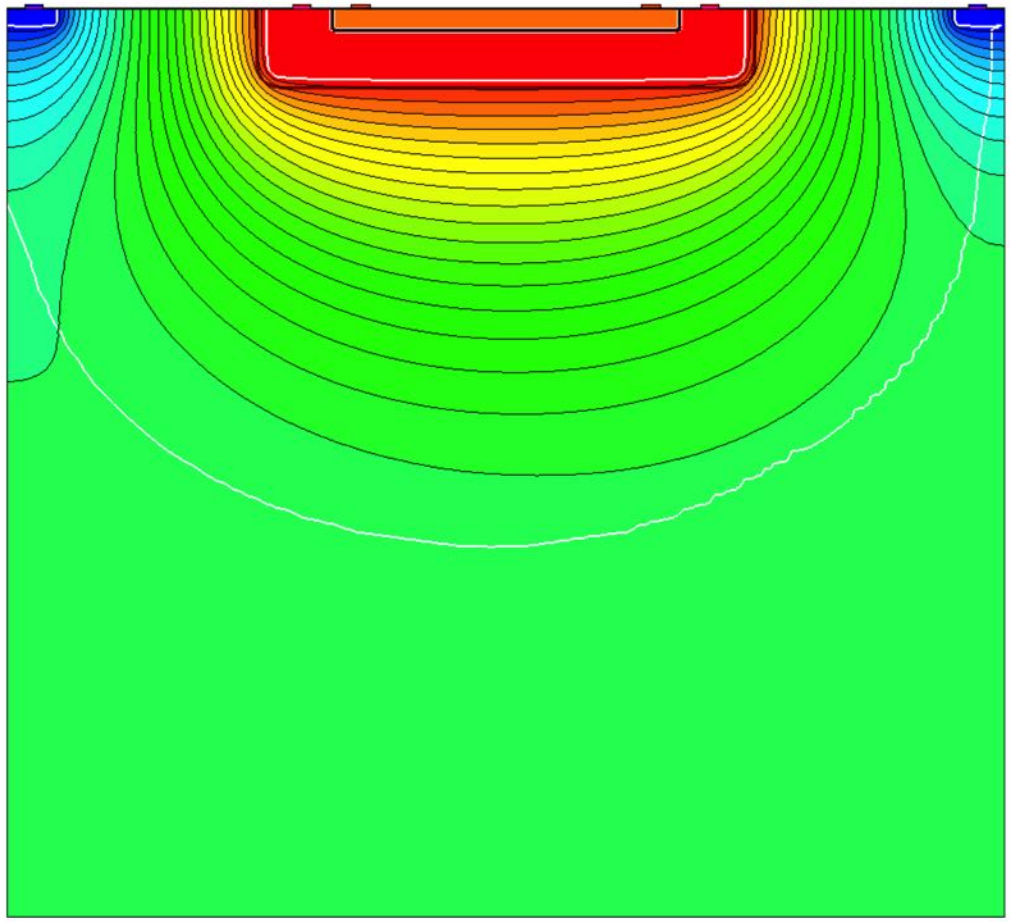
Simulation of the HVCMOS sensor

2D left corner of the pixel sensor

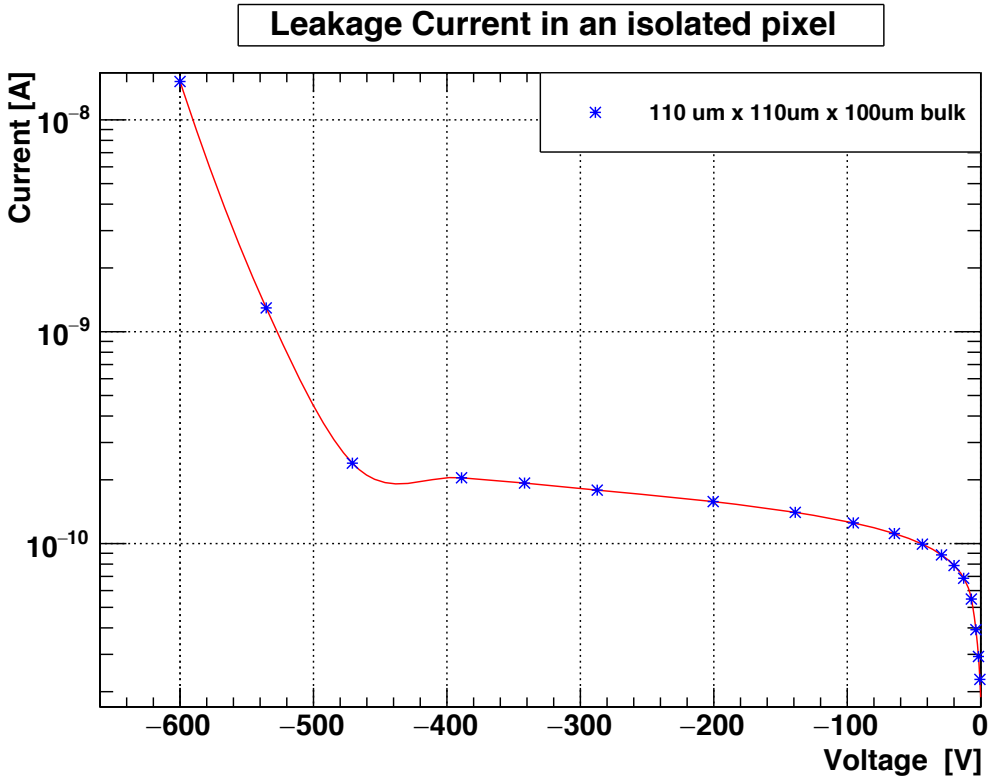


Simulation of the HVCMOS sensor

Leakage current in 2D

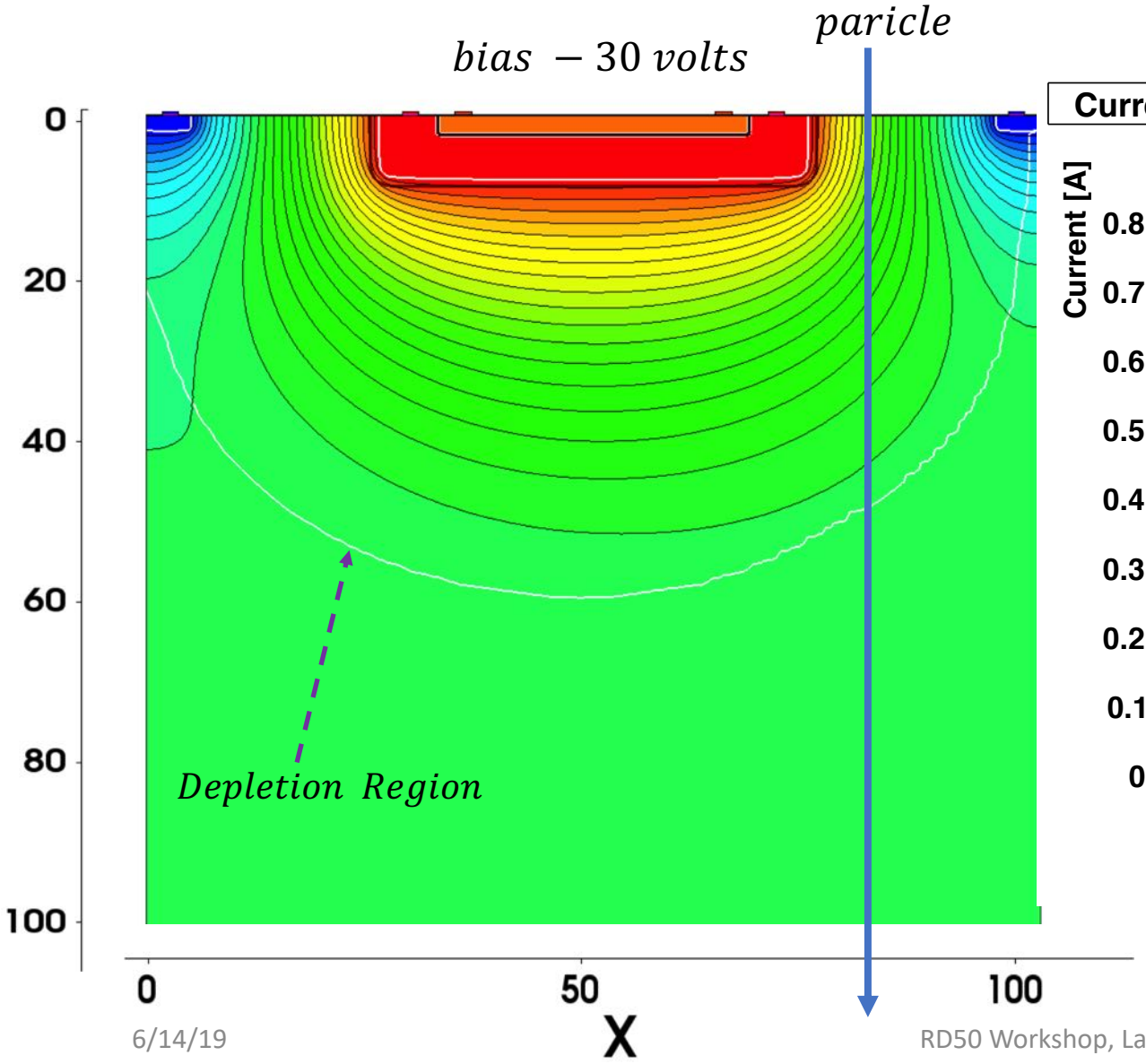


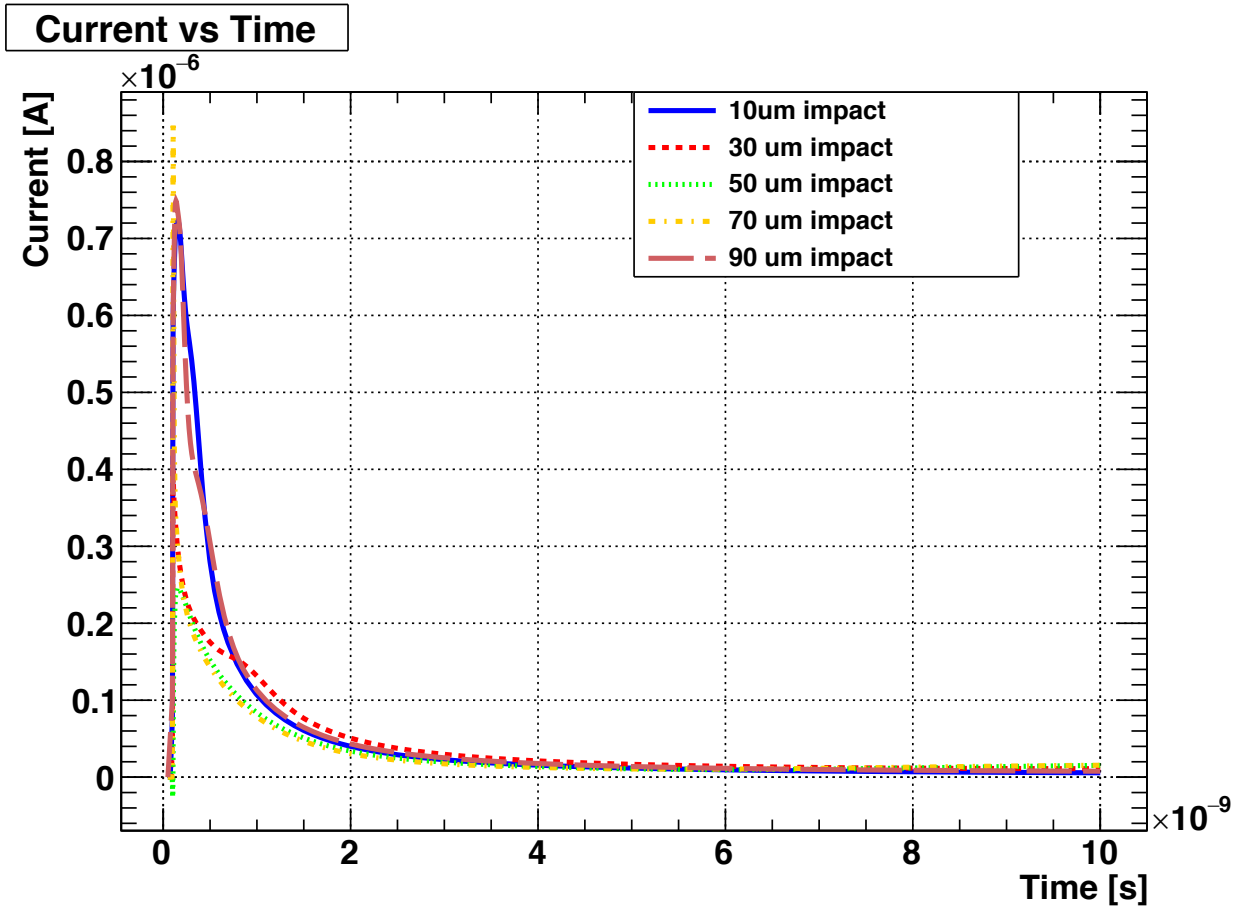
cm



Simulation of the HVCMOS sensor

2D: pixel response to mips

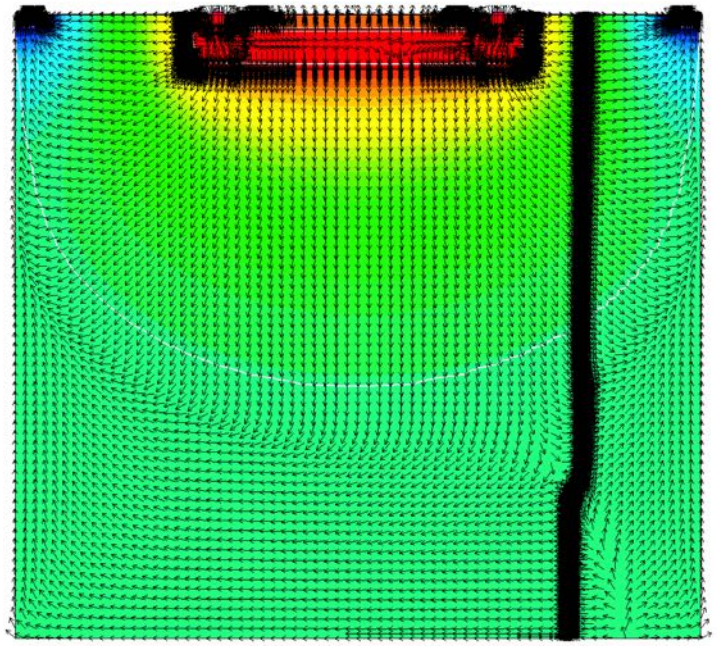




Simulation of the HVCMOS sensor

2D: Charge Collection

Nearly 100% charge collection in 50 ns

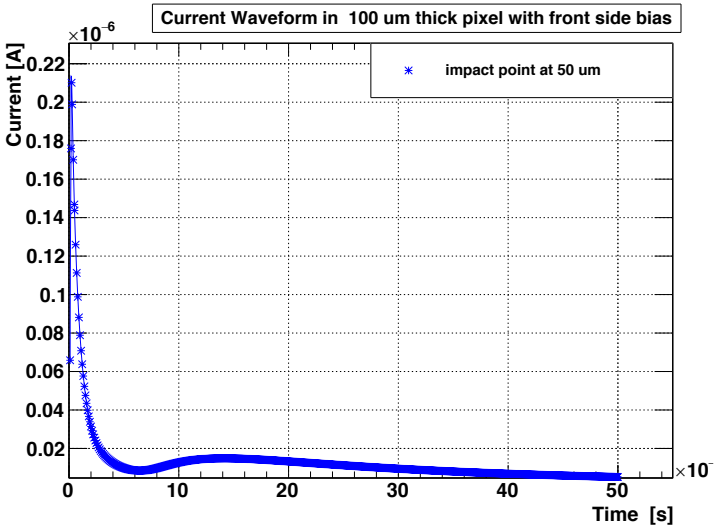


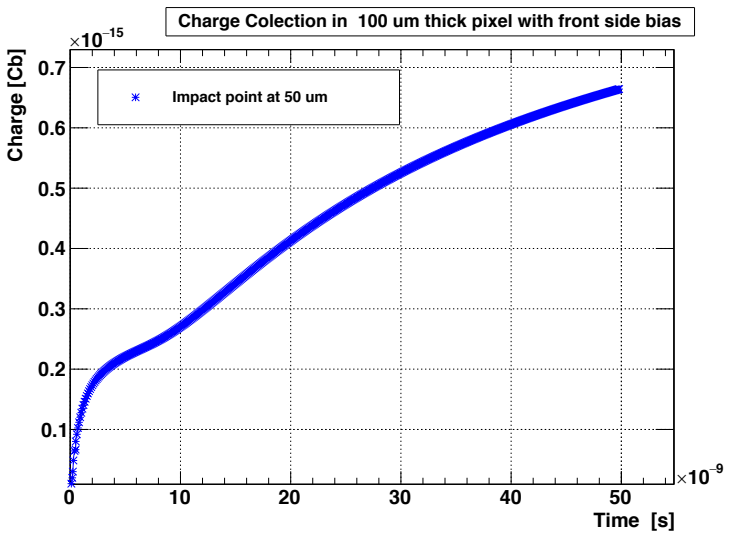
Charge collected in 50 ns :

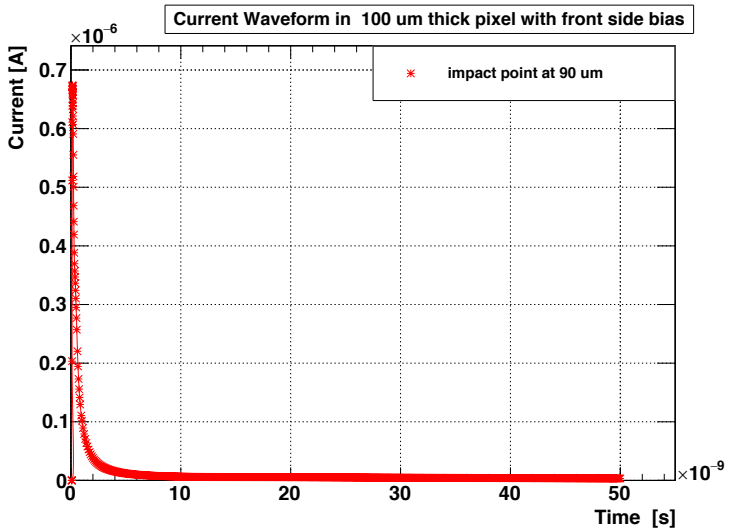
50 um impact: 6.6 x 10^{-16} Cb

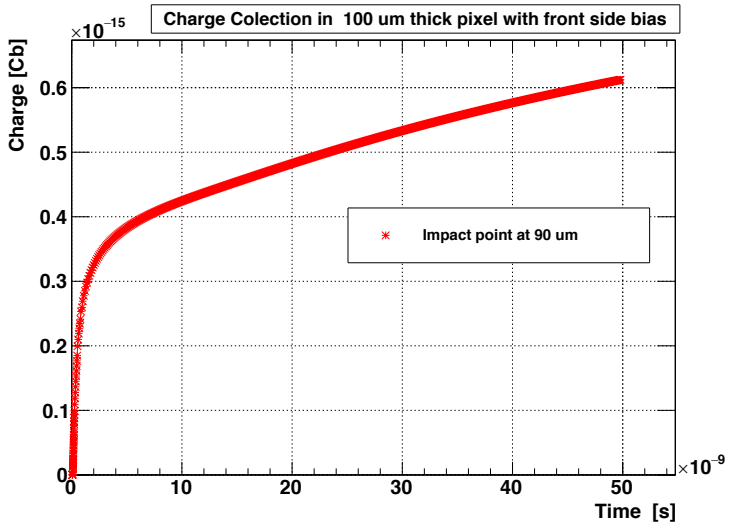
90 µm impact: 6.12 x 10^{-16} Cb

Estimated charge liberated by a mip in 50 µm of silicon is ~6.4 x 10^{-16} Cb



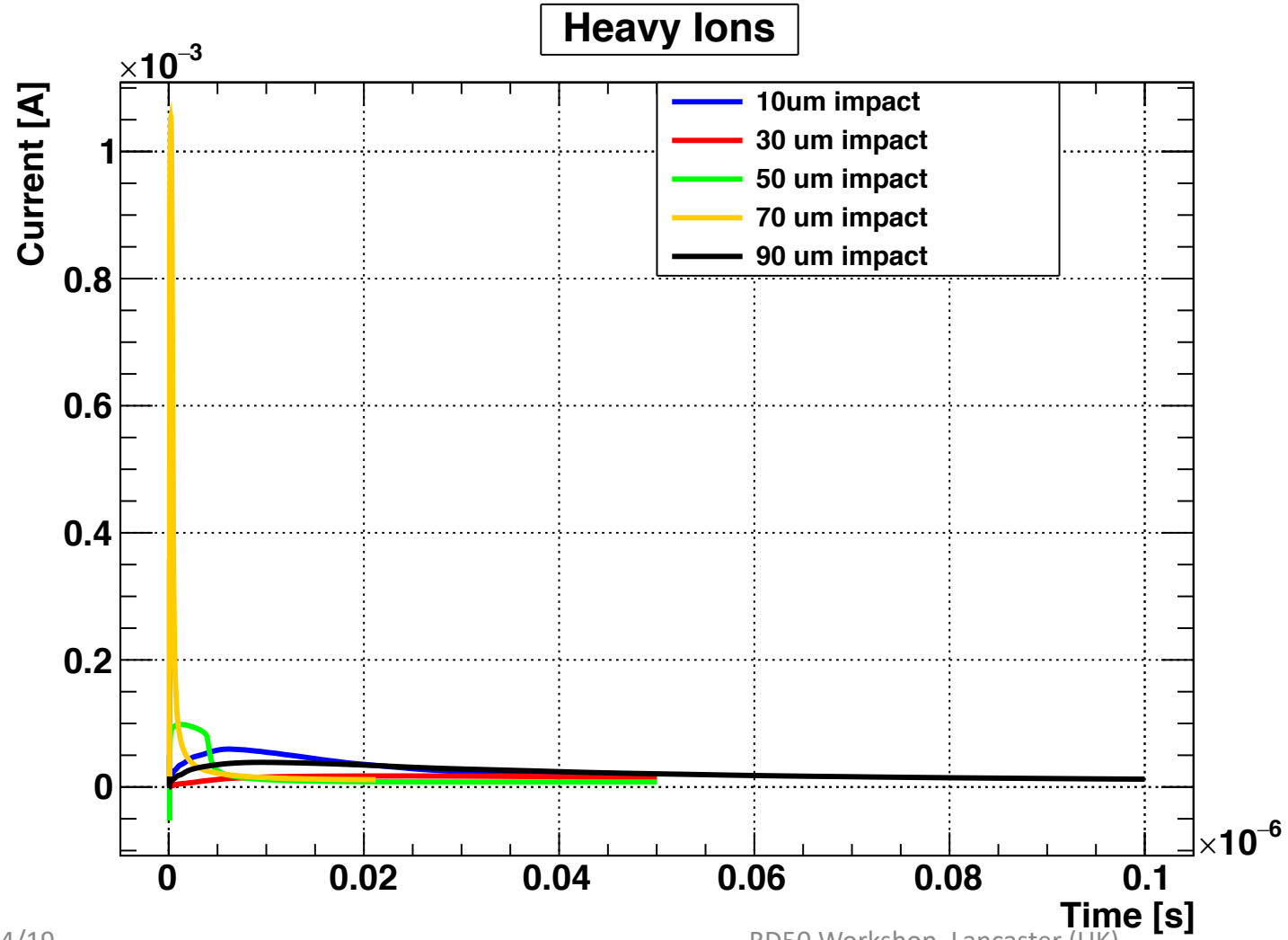






Simulation of the HVCMOS sensor

2D: Response to heavy ions

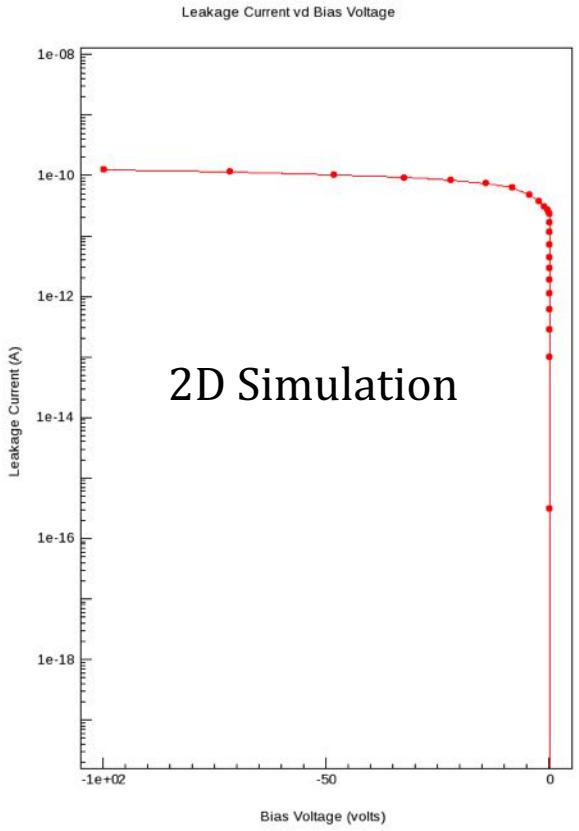


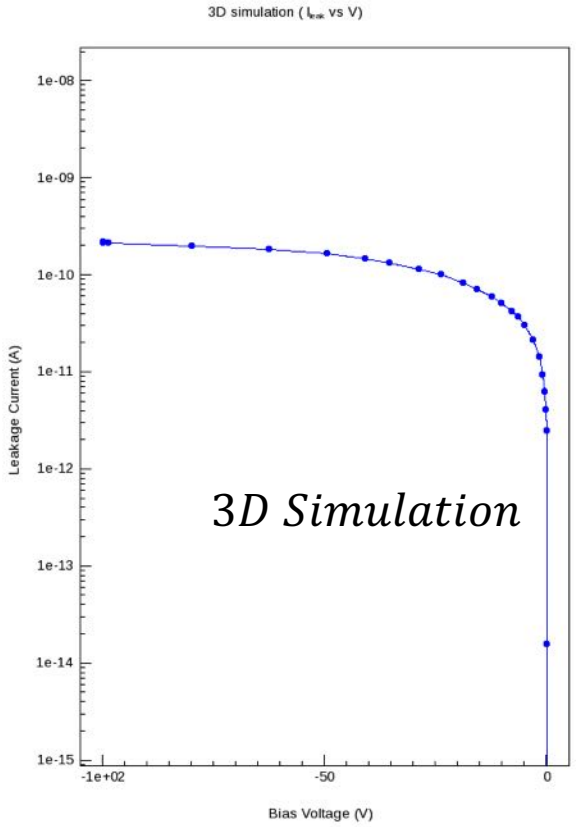
$mip\ LET: \sim 1.28 \times 10^{-5}\ pC/\mu m$

Heavy Ion $LET: \sim 0.1\ pC/\mu m$

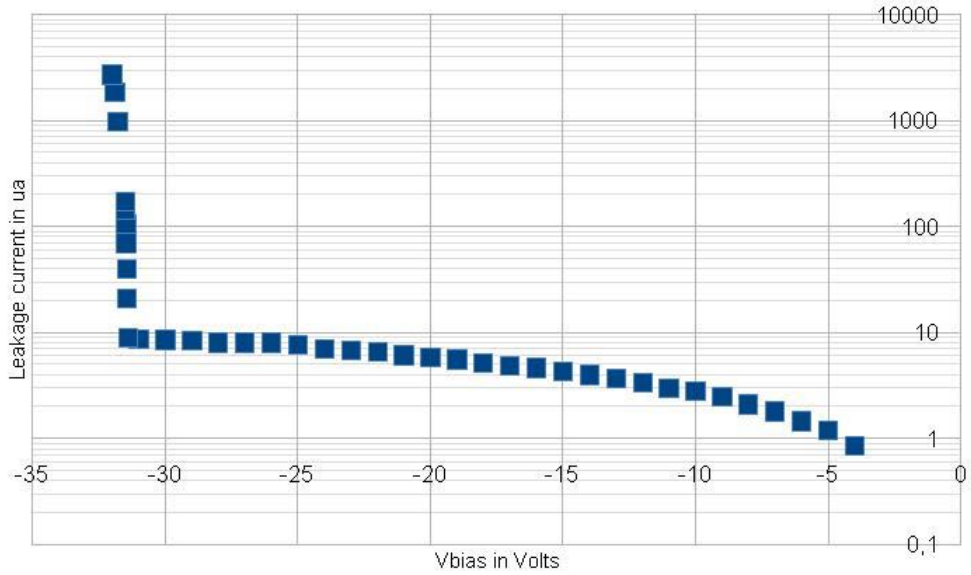
Simulation vs Reality !!!

Simulation





Reality

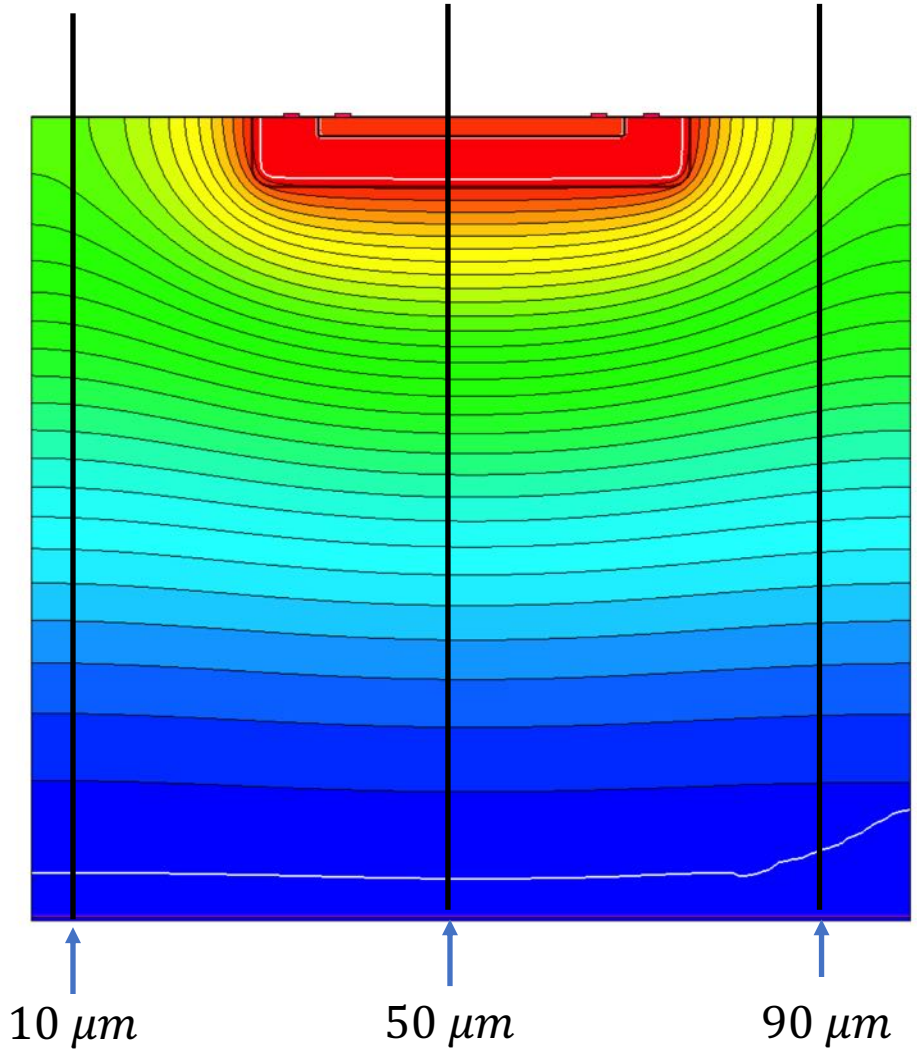


Early Breakdown at ~30 volts !

Conclusions

- **ESA MIDAS Project: 400 k€ budget**
- ***All the components for a first version of the MIDAS detector have been developed***
  (GEANT4@FLUKA simulation, TCAD simulation, VLSI prototype, neutron detector, DAQ system, mechanical enclosure)
- ***A new iteration scheduled, funding not secured…***
- ***Bottleneck of the first prototype: Early breakdown of the HVCMOS sensor***

Back Biased Pixel : Response to mips



A mip liberates ~1.28 x 10^{-15} Cb in 100 um silicon