Science & Technology Facilities Council

OVERMOS
CMOS HR detector for HEP applications

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on behalf of OVERMOS project collaboration

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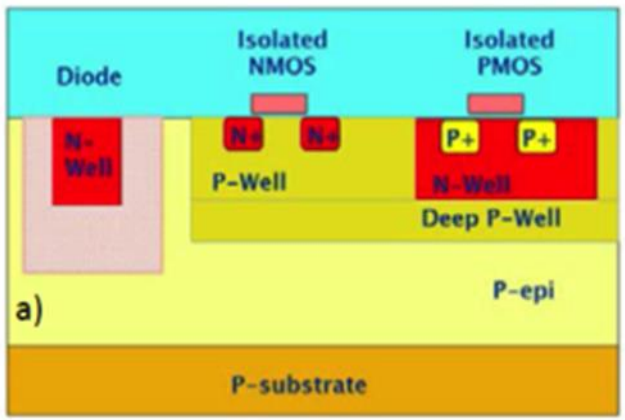
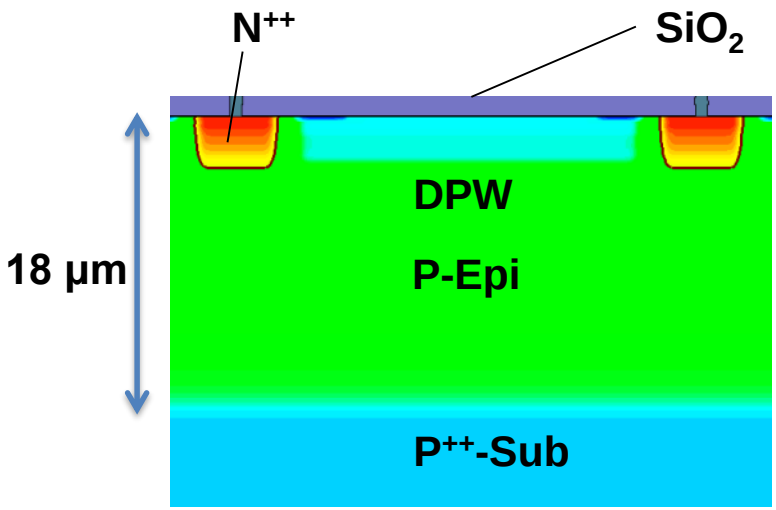
Overview

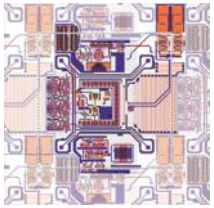
- OVERMOS1 description
- First test results of irradiated / non –irradiated OVERMOS1
- TCAD simulations
- Conclusions and next steps

OVERMOS description

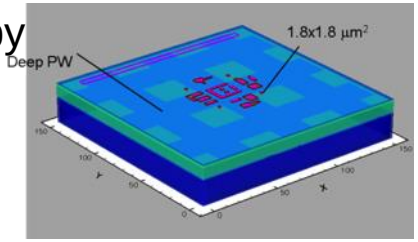




OVERMOS is a CMOS MAPS project demonstrator. Its main purpose is to investigate and understand radiation effects in HR CMOS structures, with a view to developing reliable TCAD models. It is fabricated using:



- TowerJazz 180 nm Hi-res 18 um thick epitaxial layer 1kOhm – cm
- CMOS DPW ~ originally proposed for DECAL of ILC to increase CCE by housing RO in PW -
- ‘Small’ n-collecting nodes
- Multi diode arrangements within pixel



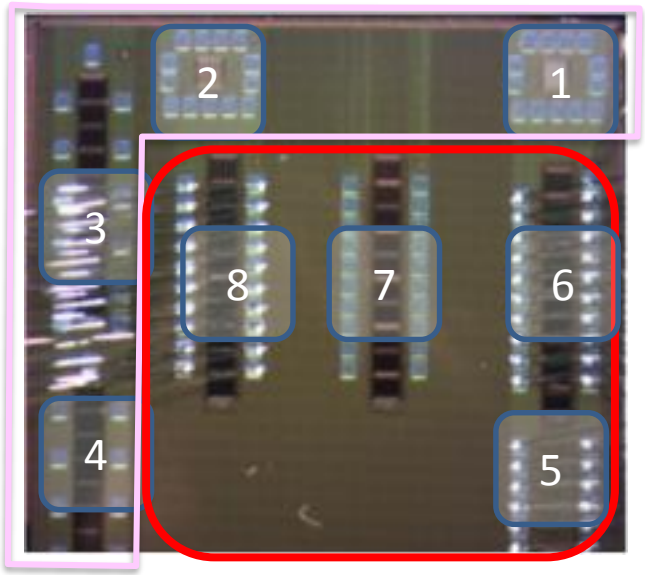
OVERMOS description

2: Basic Passive: 5x5 of 40 x 40 um

3: Basic Passive Large: 5x5 of 40 x 400 um merged

4: Basic Passive Large: 5x5 of 40 x 400 um

PASSIVE



1: Symmetric Passive: 5x5 of 40 x 40 um

8: Basic Active Large 5x5 of 40 x 400 um

7: Basic Active Large Merged 5x5 of 40 x 400 um

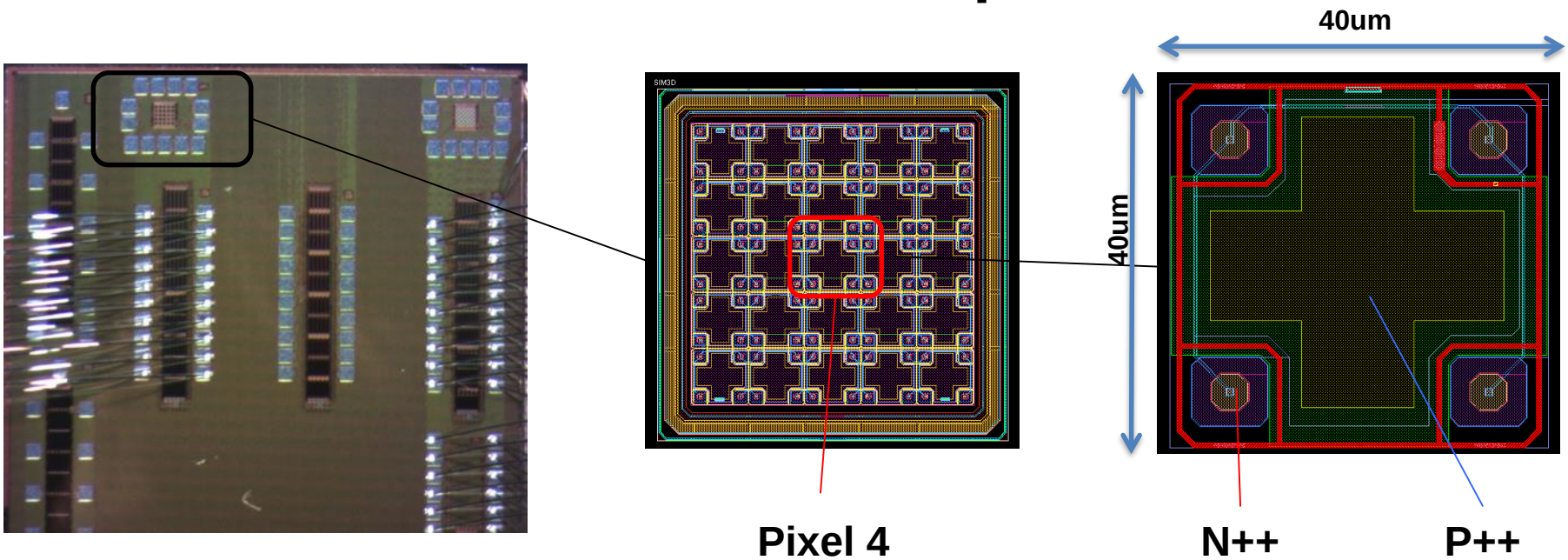
6: Basic Active AC Large 5x5 of 40 x 400 um independent diode biasing AC coupled

5: Basic Active: 5x5 of 40 x 40 um

ACTIVE

- The PASSIVE pixels feature different arrangements of the collecting 4 x 4 um2 nodes
- The ACTIVE pixels, i.e. with in-pixel electronics, allow analogue readout of the pixels

OVERMOS description



- All the pixels in the OVERMOS1 include a p++ region around each diode to reduce cross talk from neighbouring ones
- The OVERMOS1 ASIC ‘basic passive’ has been tested before and after n-irradiation for DC. Laser induced charge collection studies in progress

OVERMOS n-irradiation

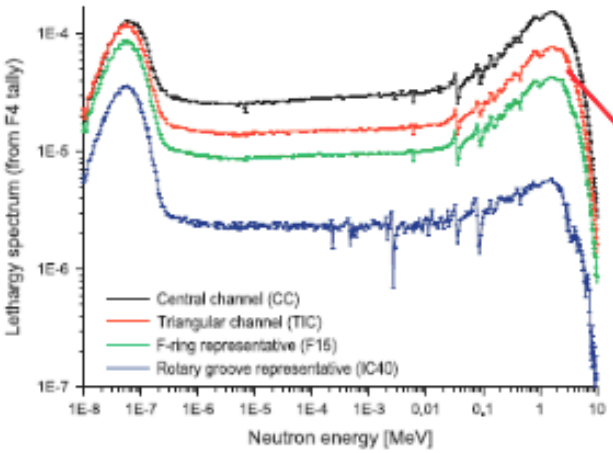


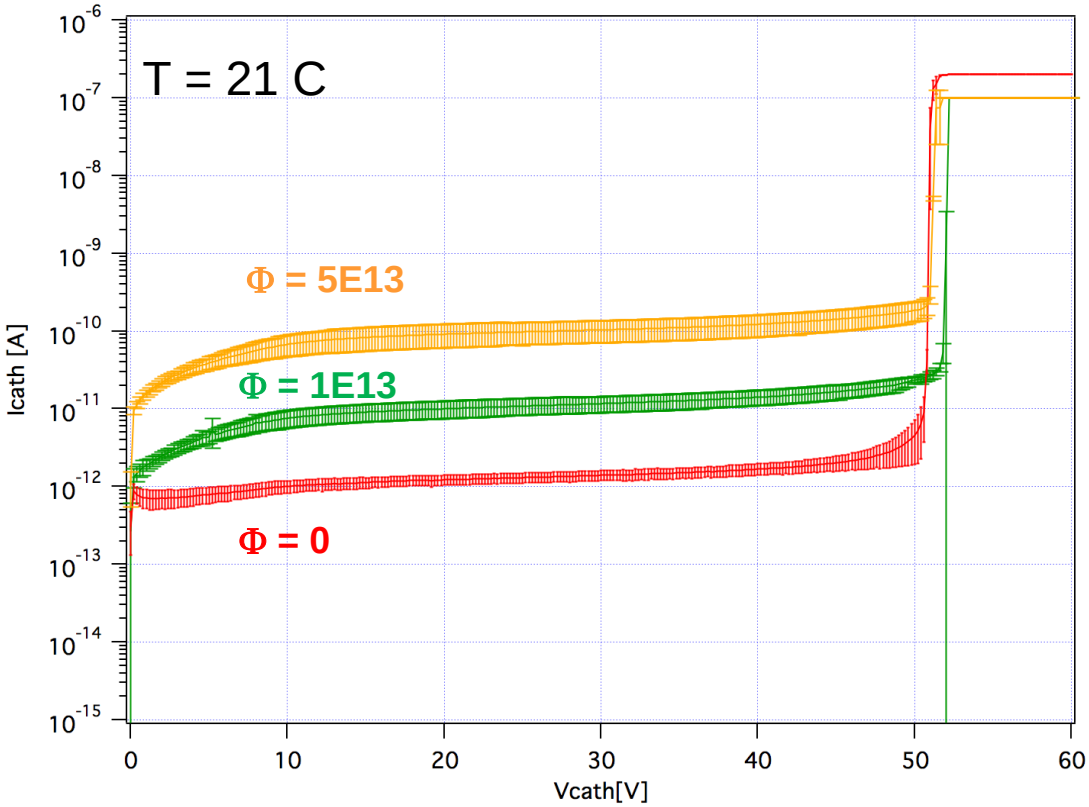
Fig. 4. Lethargy neutron spectrum in representative irradiation channels in core 189 of the TRIGA reactor. Normalization per source neutron.

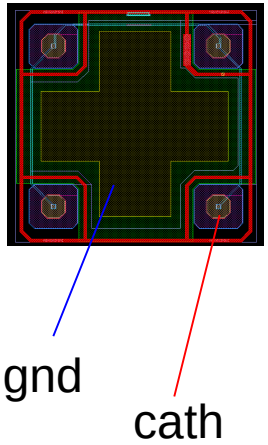
Fractions of thermal (<0.625 eV), epithermal (0.625 eV–0.1 MeV), and fast (> 0.1 MeV) neutron fluxes in TRIGA (core 189) irradiation channels.

Irradiation channel	**Thermal** (%)	**Epithermal** (%)	**Fast** (%)
CC	26.6	33.9	39.5
ThCol	79.0	14.4	6.6
RPP	57.2	23.9	18.9
RBP	83.3	12.2	4.5
TangCh	57.8	24.9	17.3
F15	42.6	28.5	28.8
F19	50.0	25.3	24.6
F22	47.8	26.2	26.0
F24	47.4	26.5	26.1
F26	48.4	25.9	25.7
IC40	60.4	25.1	14.5
TIC	37.9	29.4	32.7

- OVERMOS devices have been irradiated at Ljubljana in October 2017 to 1E13, 5E13,1E14 and 5E14 n fluence
- Estimated around 30% of fluence consisting of high energy neutrons (> 100keV)

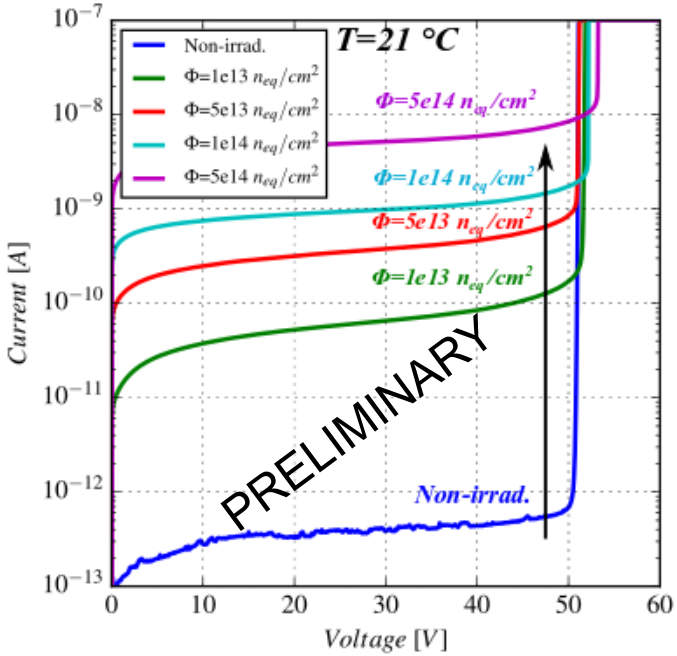
OVERMOS DC tests

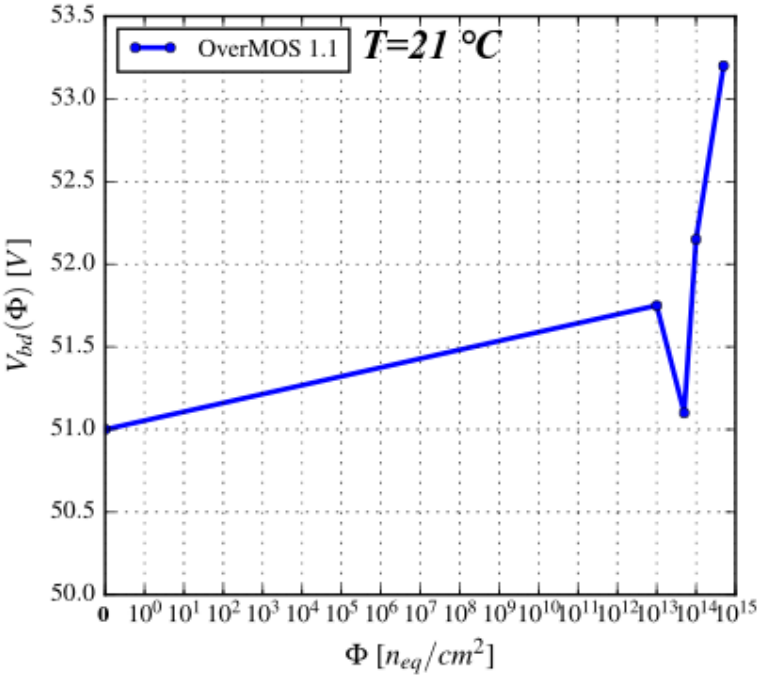




Changes in Ilk and BV characteristics vs. fluence
Average of 10 pixels + σ

OVERMOS DC tests

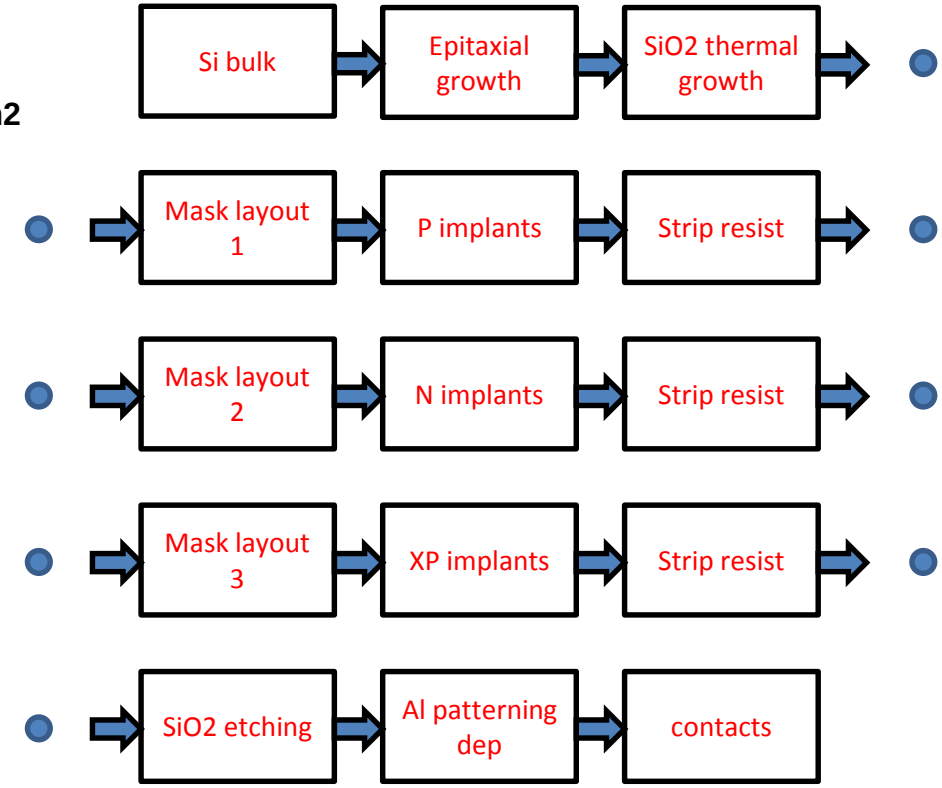




Changes in Ilk and BV characteristics vs. fluence

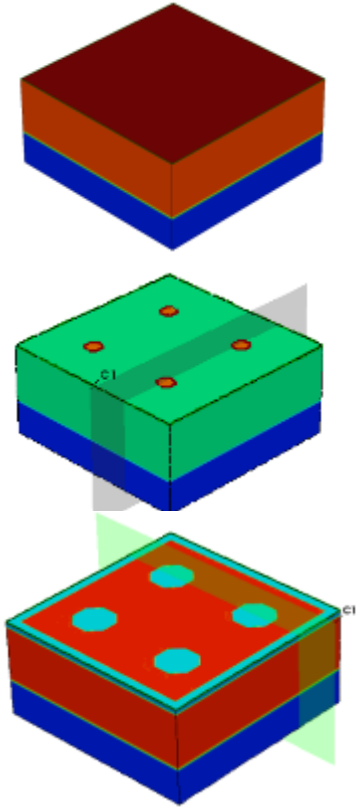
TCAD simulations

.gds layout of single passive pixel 40 x 40 um2

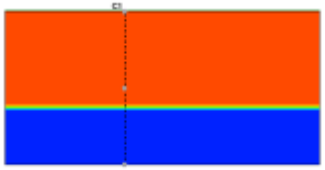


- 3D TCAD simulations are being performed to investigate accuracy of modelling capabilities
- Individual doping profiles for OVERMOS were obtained using **SPROCESS**, to simulate a (simplified) CMOS fabrication by TJ foundry

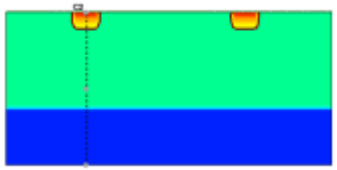
TCAD simulations



Epi-Bulk



NW



PW

Epitaxial growth

SiO2 thermal growth

Mask layout 2

N implants

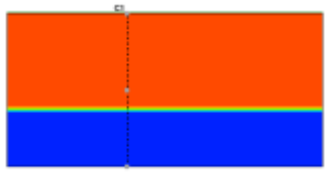
Mask layout 1

P implants

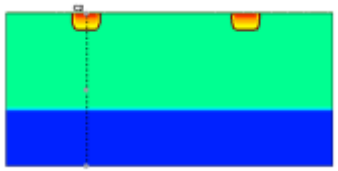
- Inclusion of surface charge effects at Si/SiO2 boundaries, B segregation in SiO2, crystal orientation (<100>) and interface stresses
- Final mesh 273868 points, 10 non-Delaunay elements around the SiO2/Si interface

TCAD simulations

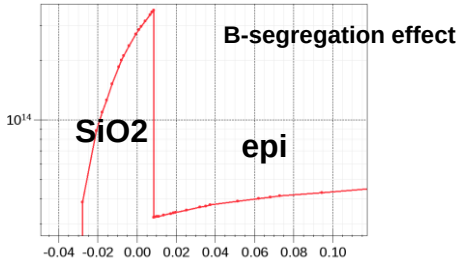
Epi-Bulk

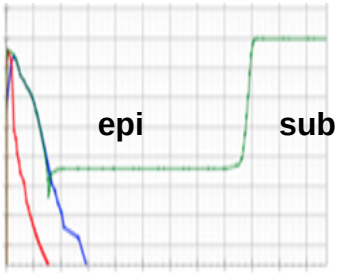


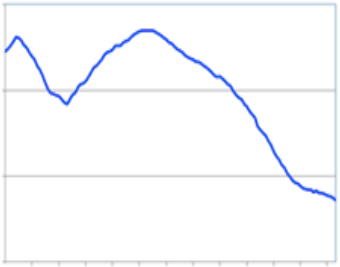
NW

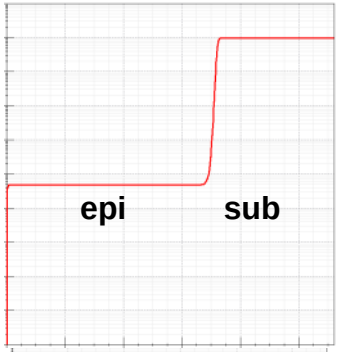


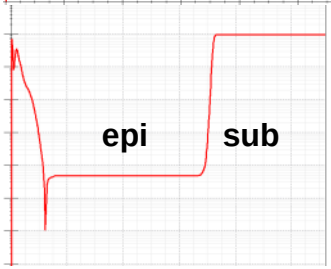
PW

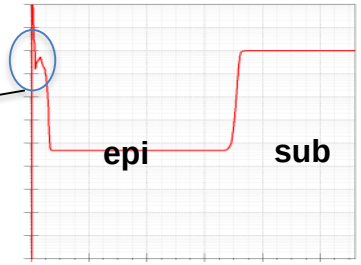










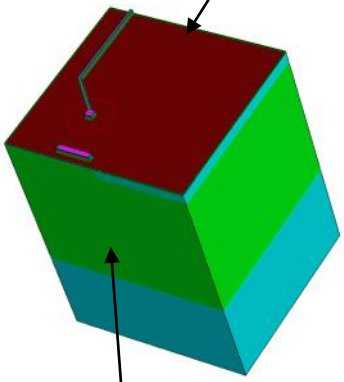


SIMS profiles

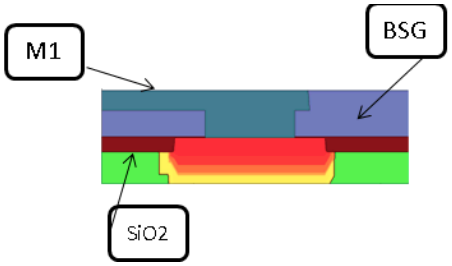
- Result is a 3D pixel mesh with realistic doping profiles

TCAD simulations

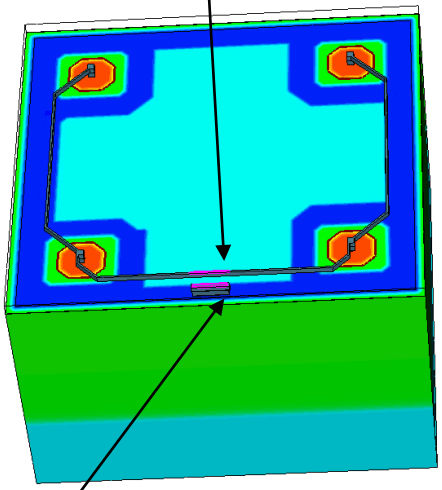
SiO2/Si trap density 1-2e11



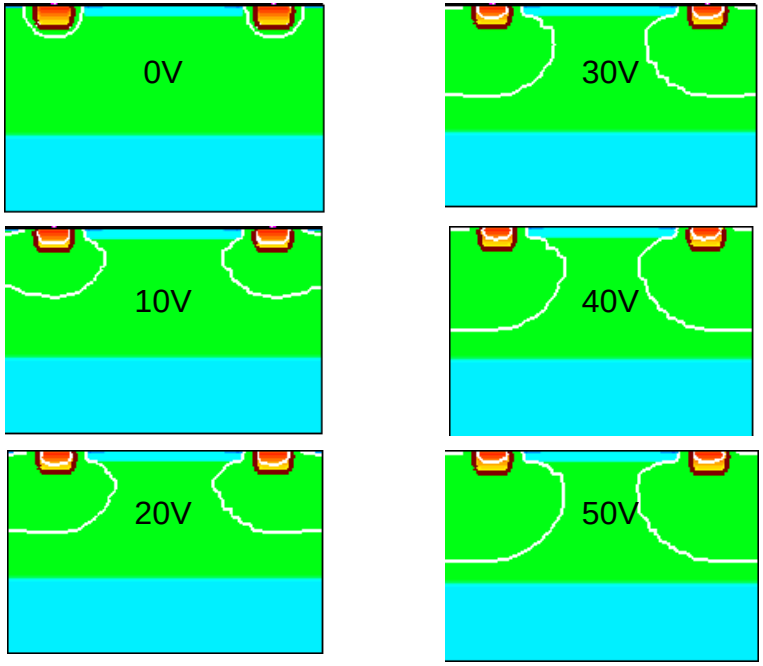
SRV=1e4



Vbias



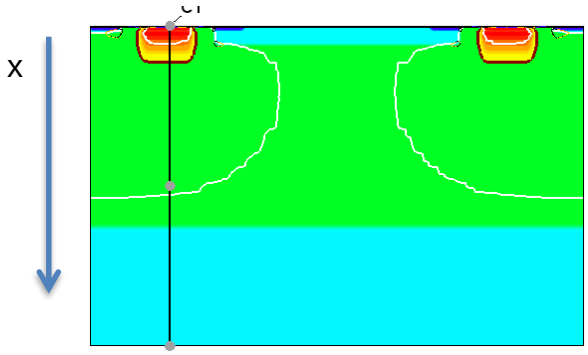
GND

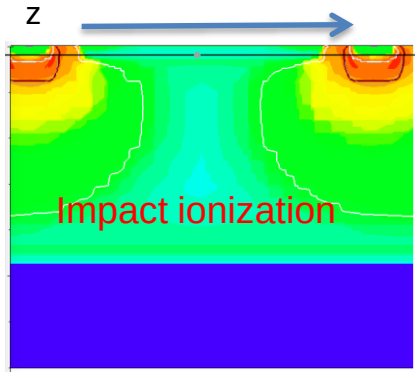


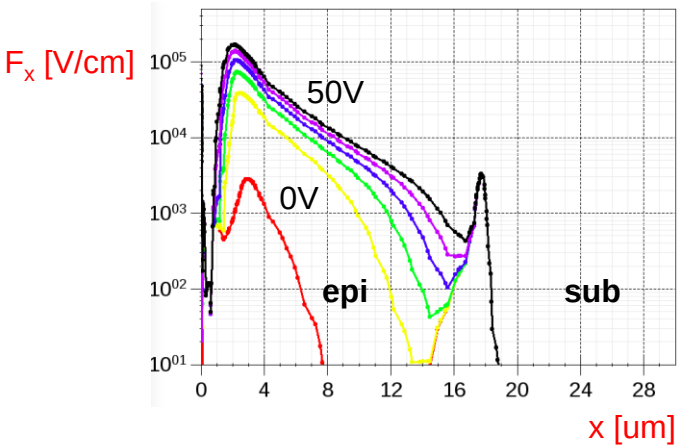
Depletion region vs. Vbias

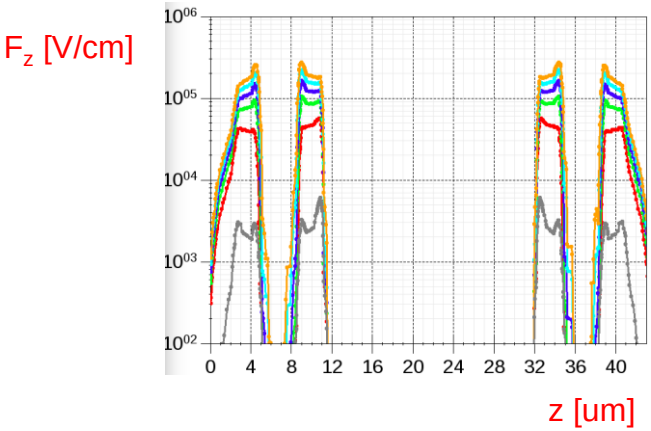
- TCAD DC results:
- Depletion region
- Internal electric field
- Impact ionization

TCAD simulations









- TCAD DC results:
- At around 50 V bias the strength of Fz is close to ‘typical’ F_{max}

TCAD & Test results
Leakage currents & BV

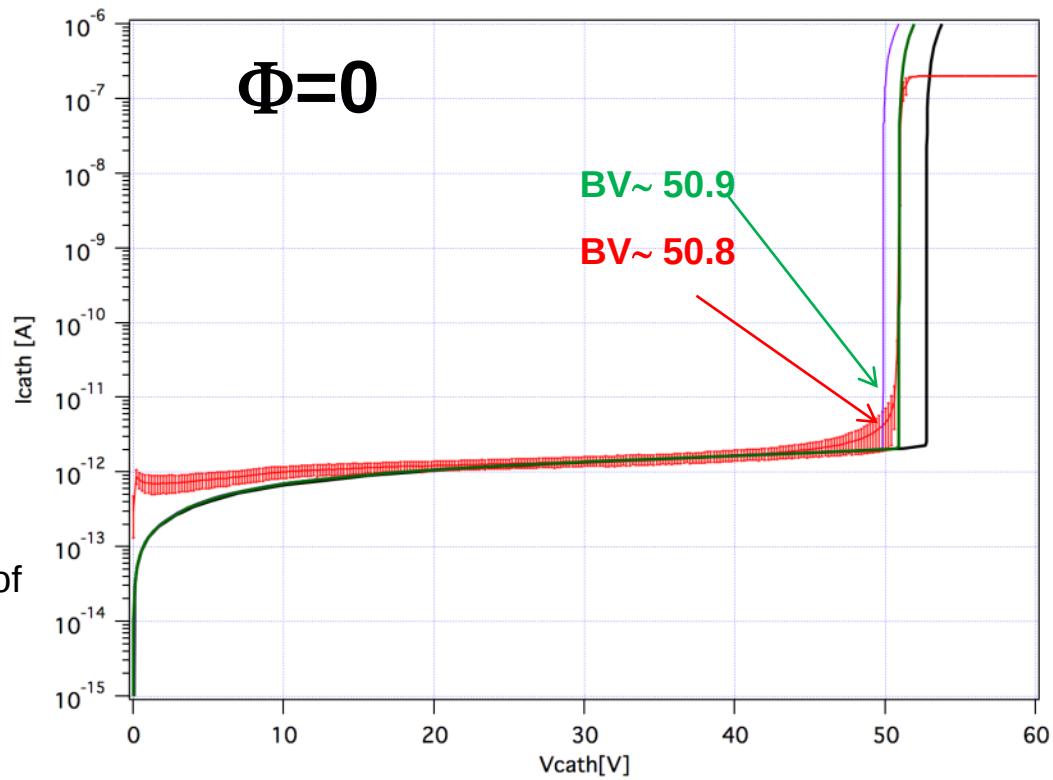
<I_{lk}> + σ 10 pixels
I_{lk} TCAD 0 OxQ
I_{lk} TCAD 1.7e11 OxQ
I_{lk} TCAD 2e11 OxQ

I_{lk} taken with CS4200, I_{compl} =1E-7
TCAD simulations with quench resistor 1E6

II model:UniBo + interpolation of avalanche driving forces

$$\alpha(F_{ava}, T) = \frac{F_{ava}}{a(T) + b(T)\exp\left[\frac{d(T)}{F_{ava} + c(T)}\right]}$$

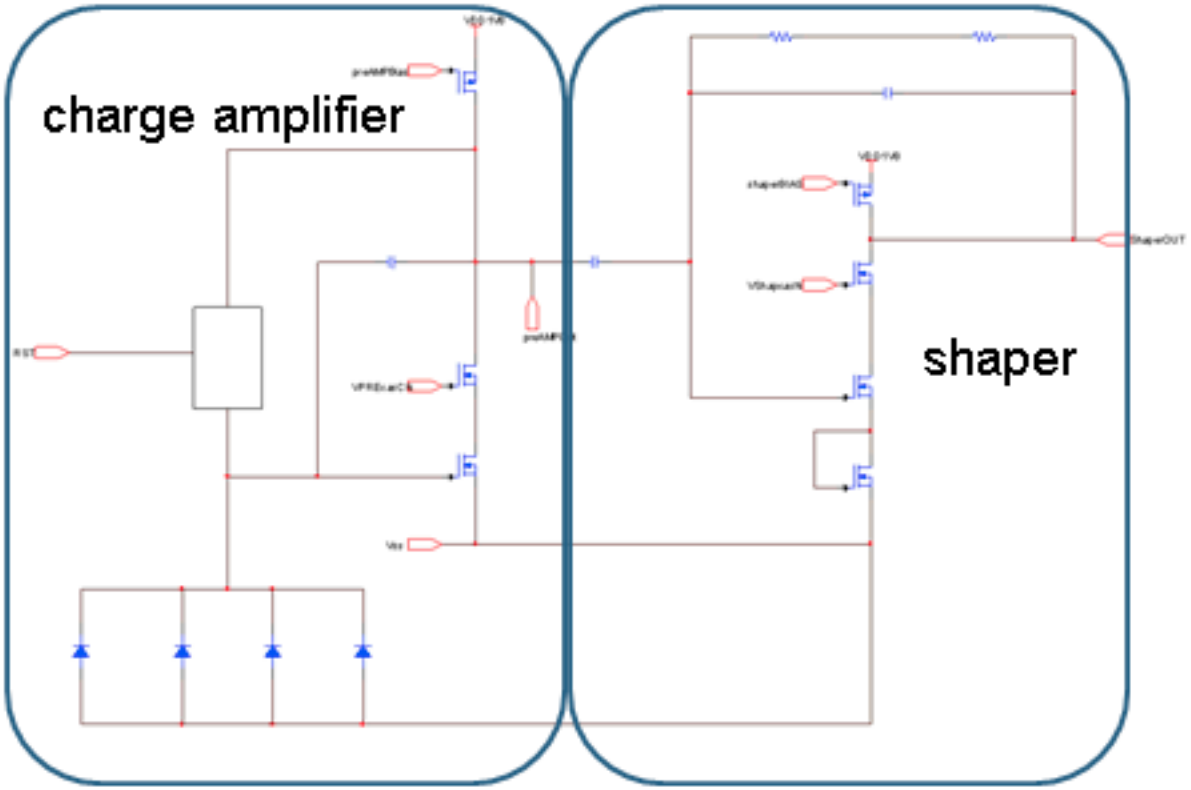
$$F_{ava,n} = \frac{n}{n+n_0}\left(\vec{F}\cdot\frac{\vec{J}_n}{J_n}\right) + \frac{n_0}{n+n_0}\left|\vec{F}\right|$$



Conclusions and next steps

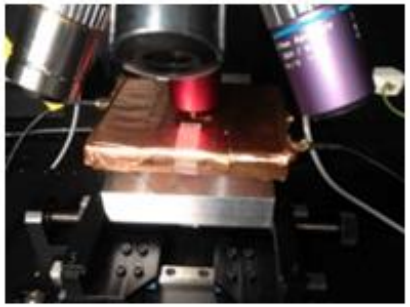
- OVERMOS device has been designed to investigate and understand radiation effects in HR CMOS structure
- A number of devices have been n-irradiated up to 5E14 fluence and are being characterised for DC and charge collection
- 3D TCAD simulations, relying on SPROCESS, to simulate CMOS process fabrication, have been implemented
- DC simulations up to BV match very well test results for non irradiated structures
- We are going to **investigate implementation of various radiation damage models in TCAD to verify their accuracy**
- From changes in I_{lk} and BV characteristics we are trying to **infer changes in N_{eff}, and compare them with those obtained by other means (i.e. TCT)**
- Charge collection test using IR laser to compare with TCAD simulations

Backup
OVERMOS Active Pixel



Backup
OVERMOS Laser Test

OVERMOS
In metal box
to reduce EMP noise



OVERMOS
Under Laser 100x optics