TIMESPOT

Daniele PASSERI
Università e INFN Perugia

Cagliari, 1 Dicembre 2017

TIMESPOT – INFN Perugia

√ INFN PG Activities/Involvements

- 3D Diamond and Silicon TCAD modeling.
- Radiation damage model development.
- DAQ development and test activity.

√ FTE / Funding request

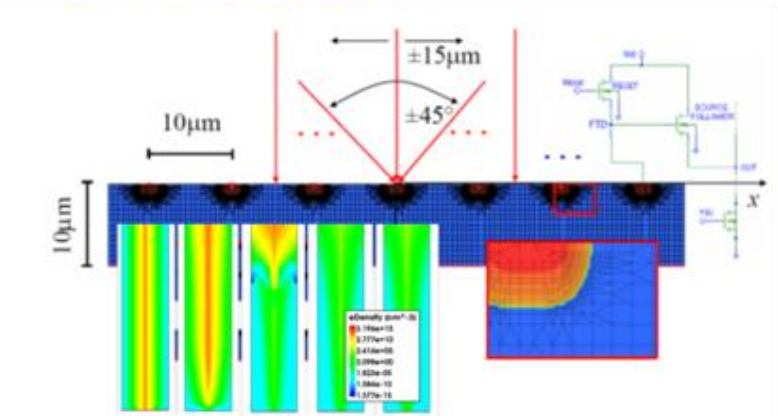
D. PASSERI	(PA)	0.5 (RL)
A. MOROZZI	(AR)	0.2
M. PICCINI	(Ric.)	0.2
L. SERVOLI	(I Ric.)	0.1
Total		1.0

F. MOSCATELLI (Ric.)
M. MENICHELLI (Ric.)

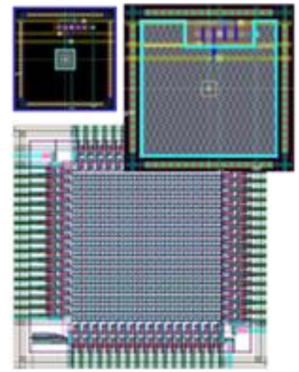
			2018	2019	2020	2021
	SEDE	WP				
Man Power (TCAD modeling /sensor design)	PG	1, 2		23	23	
Missioni per riunioni di collaborazione	PG		2	1	1	
Missioni per Conferenze	PG		2	2	2	2
Missioni per Test Beam	PG	6		2	2	2
TCAD Licence Maintenance	PG	1, 2		2	2	2
Materiale di consumo per contributo sviluppo del sistema di DAQ	PG	6	1	2	2	
TOTALE			5	32	32	6

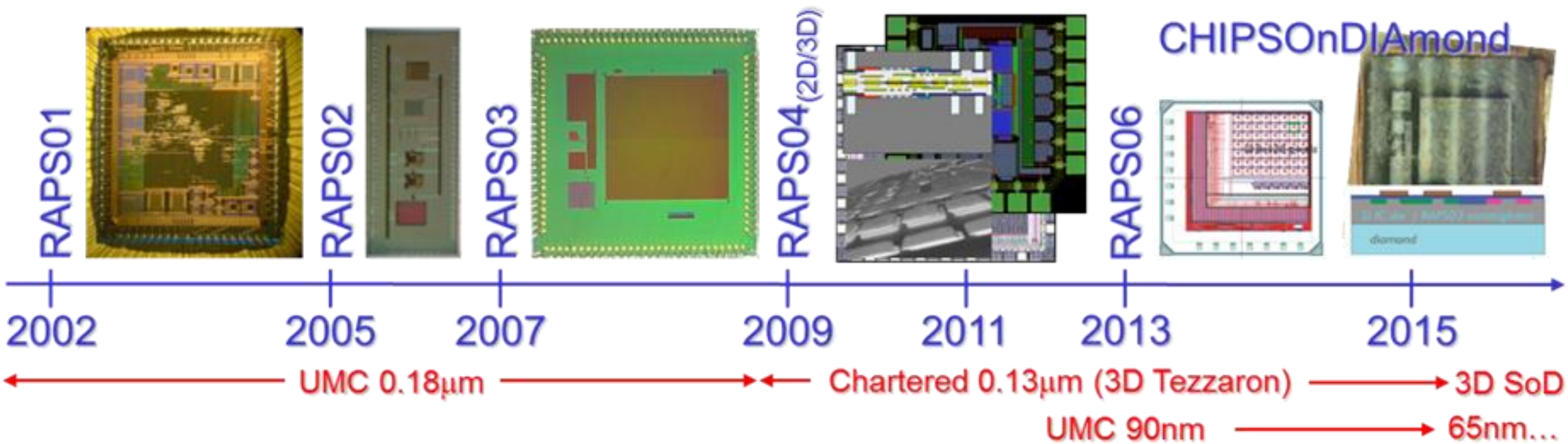
INFN Perugia Activities Timeline

Numerical Analysis and Physical Modeling of Solid-State Devices.



VLSI Design and Characterization of Integrated CMOS Active Pixel Sensors





INFN Perugia TIMESPOT related expertise

- √ Long term TCAD silicon particle detector simulation and radiation damage effects modeling (CMS, AIDA2020).
- √ DIAMOND TCAD modeling (RAPSODIA, 3DSOD, 3DOSE).
- √ Test and characterization of semiconductor / 3D diamond sensors and read-out systems for high rate/high performances detectors (NA62, 3DOSE).
- √ VLSI monolithic Active Pixel Sensor design & characterization (RAPS, SHARPS, VIPIX, SEED).
- √ …

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TCAD Radiation Damage Modeling

√ OLD Perugia Model – CMS Silicon Tracker design (since 1996)

1688 IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 48, NO. 5, OCTOBER 2001

Comprehensive Modeling of Bulk-Damage Effects in Silicon Radiation Detectors

Daniele Passeri, Paolo Ciampolini, Gian Mario Bilei, and Francesco Moscatelli

Abstract—In this paper, the issue of numerical modeling of radiation-damaged silicon devices is discussed, with reference to radiation detectors employed in high-energy physics experiments. Since the actual physical picture is far too complex to be accounted for at a first-principle (i.e., defect kinetics) level and not yet fully understood, a hierarchical approach has been followed looking for a suitable approximation of macroscopic changes of the electrical behavior of silicon device induced by radiation damage. In particular, a three deep-level trapping mechanism is accounted for by means of Shockley–Read–Hall theory, whereas shallow-level sensitivity on the radiation is considered by means of a donor-removal model.

Index Terms—Radiation damage, silicon detectors.

I. INTRODUCTION

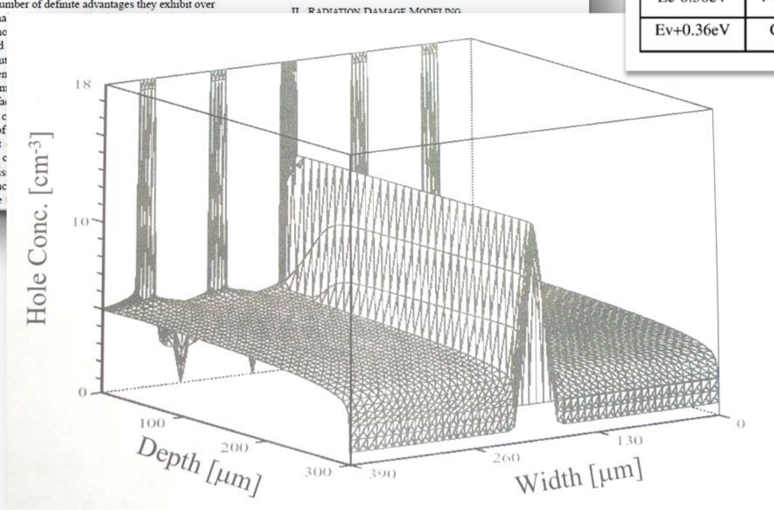
SOLID-STATE semiconductor particle detectors are being widely used in the context of high-energy physics experiments, due to a number of definite advantages they exhibit over more conventiona fabrication techno can be integrated fine spatial resolut noisy operating en depends on a num quest for a satisfa kept under strict c a full depletion of raises significant sumption and to c reliability is an is induced by the inc

Hence, despite

at a negligible fraction of the development time and expense required by experimental evaluation.

Such a capability gains further appeal when looking forward to experiments carried out at new hadron colliders, e.g., the CMS detector at LHC [6], where radiation fluences well in excess 10^{14} n/cm^2 are expected and devices are required to endure such a harsh environment for ten years. For this reason, the need emerges of equipping simulation tools with accurate, yet computationally manageable, models of the functional damage induced by the accumulated radiation. In this paper, we discuss such an issue, illustrating an enhanced radiation-damage model, which extends the two-deep-level modeling technique adopted in [7] by accounting for a third level within the gap and considering the shallow-level sensitivity on the radiation by means of a donor-removal model.

II. RADIATION DAMAGE MODELING

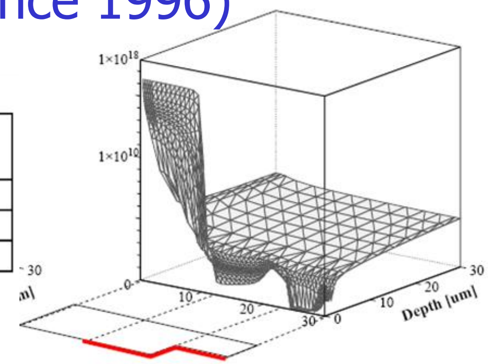


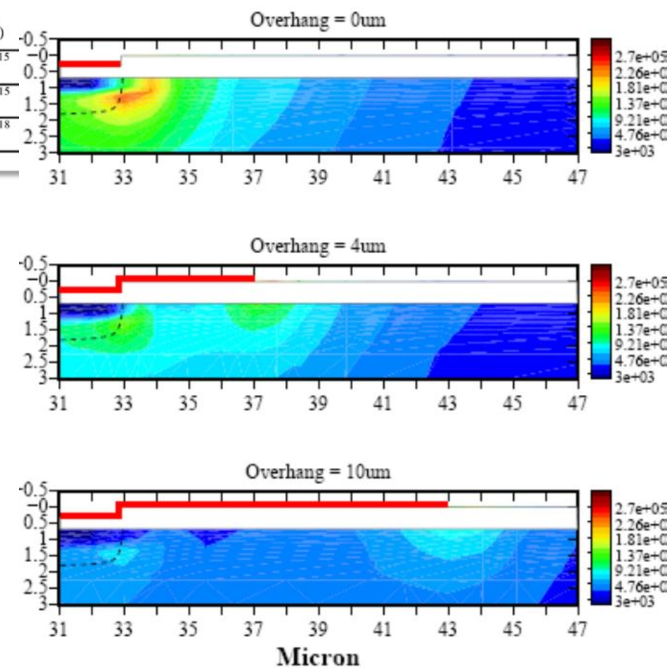
THE RADIATION DAMAGE MODEL FOR P-TYPE

Level	Ass.	$\sigma_{n,p}$ (cm^2) Exp.[2]	σ_n (cm^2)	σ_p (cm^2)	η (cm^{-1})
E_c-0.42eV	VV$^{(-/0)}$	$2\cdot10^{-15}$	2×10^{-15}	2×10^{-14}	1.613
E_c-0.46eV	VVV$^{(-/0)}$	$5\cdot10^{-15}$	5×10^{-15}	5×10^{-14}	0.9
Ev+0.36eV	CiOi	2.5×10^{-15}	2.5×10^{-14}	2.5×10^{-15}	0.9

TABLE II
THE THREE LEVELS RADIATION DAMAGE MODEL FOR N-TYPE

Level	Ass.	$\sigma_{n,p}$ (cm^2) Exp.[2,9]	σ_n (cm^2)
Ec-0.42eV	VV$^{(-/0)}$	2×10^{-15}	2×10^{-15}
Ec-0.50eV	VVO(?)	5×10^{-15}	5×10^{-15}
Ev+0.36eV	C_iO_i	2.5×10^{-15}	2×10^{-18}





TCAD Radiation Damage Modeling

√ NEW Perugia Model (2017)

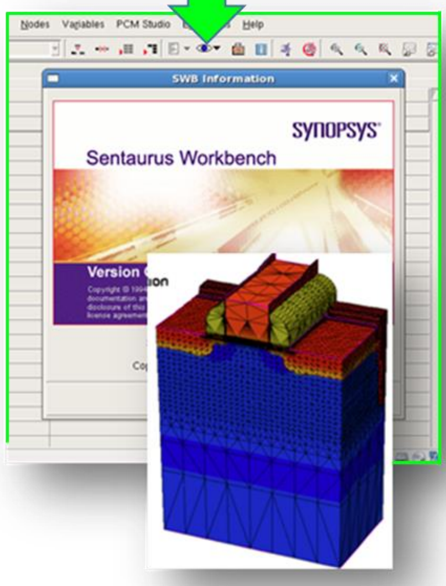
Bulk damage

Type	E (eV)	σ_e (cm^2)	σ_h (cm^2)	η (cm^{-1})
Acceptor	Ec-0.42	1.0×10^{-15}	1.0×10^{-14}	1.6
Acceptor	Ec-0.46	$0.1\times\sigma_h(\Phi)$	$\sigma_h(\Phi)$	0.9
Donor	Ev+0.36	3.2×10^{-13}	3.2×10^{-14}	0.9

Surface damage

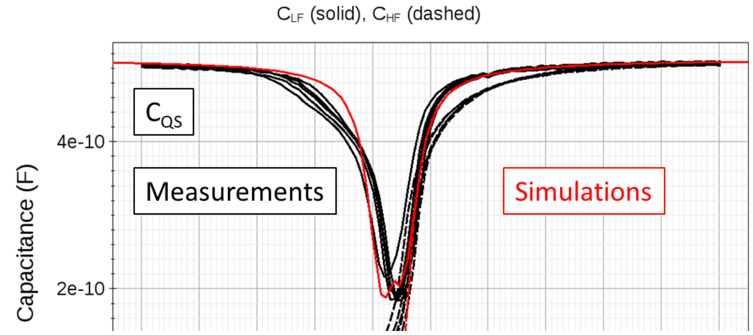
Type	Energy Band	Concentration (cm^{-2})	Oxide Charge density (cm^{-2})
Acceptor	$E_C-0.3 \pm 0.3$ eV	$D_{ITacc} = D_{IT}(\Phi)$	$N_{OX} = N_{OX}^{Pre\_Xray} + \Delta N_{OX}(\Phi)$
Donor	$E_V+0.45 \pm 0.15$ eV	$D_{ITdon} = D_{IT}(\Phi)$	

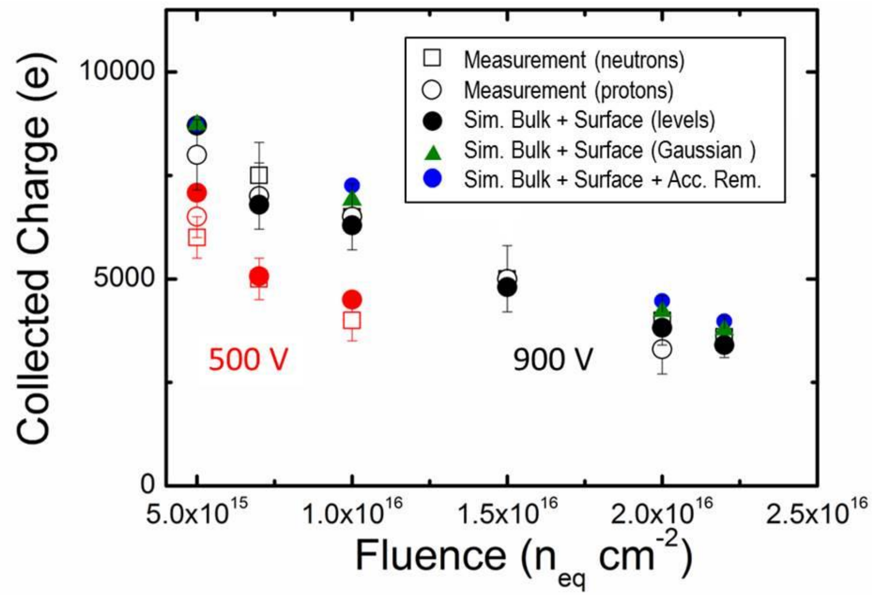
Radiation damage model



Model VALIDATION

Device OPTIMIZATION





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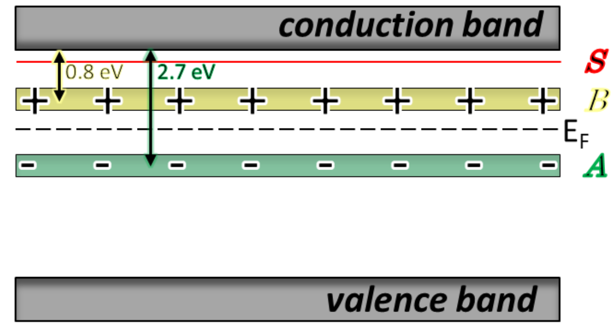
- √ …

TCAD Diamond Modeling

√ Innovative diamond modeling for DC, TV analyses within TCAD tools

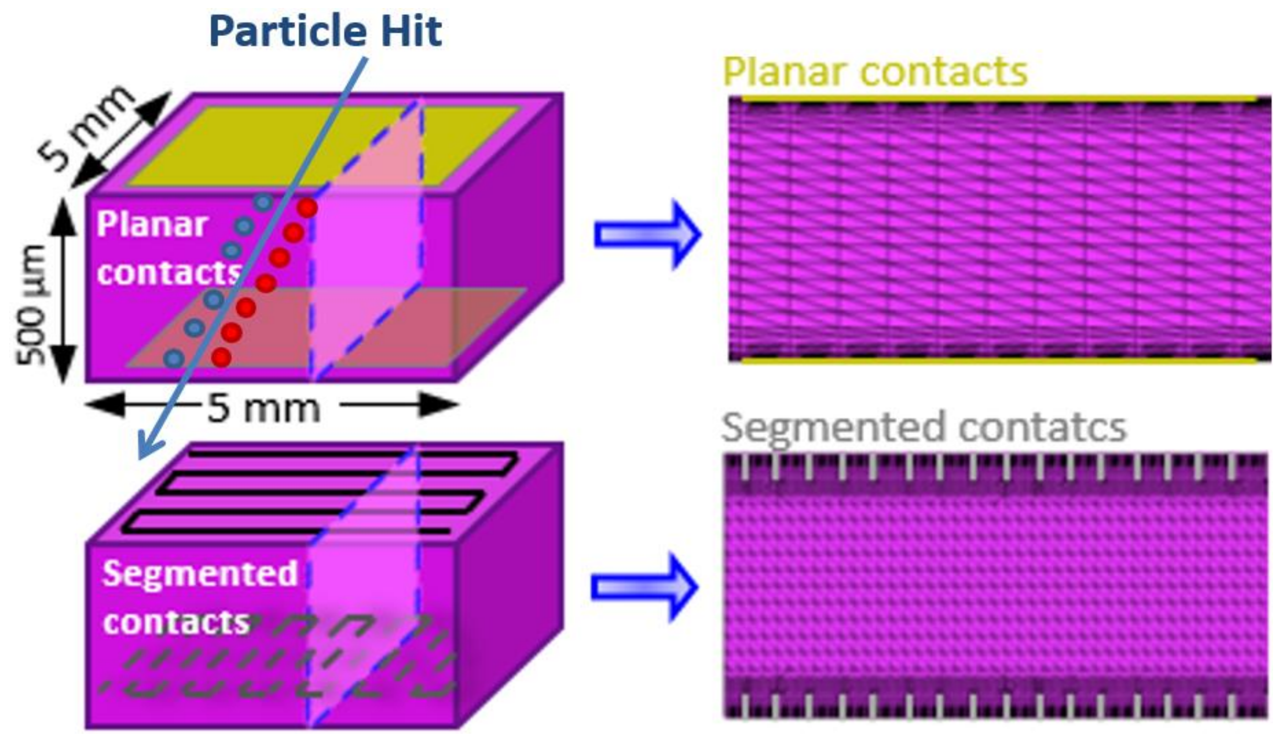


	Type	E (eV)	σ_e (cm^2)	σ_h (cm^2)	N_T (cm^{-3})
Level S	Donor	E_C - 0.05	$1\cdot10^{-13}$	$1\cdot10^{-18}$	$N_T/2$
Level B	Donor	E_C - 0.8	$1\cdot10^{-14}$	$1\cdot10^{-18}$	$N_T/2$
Level A	Acceptor	E_C - 2.7	$5\cdot10^{-16}$	$1\cdot10^{-13}$	N_T

2D Diamond simulated structures

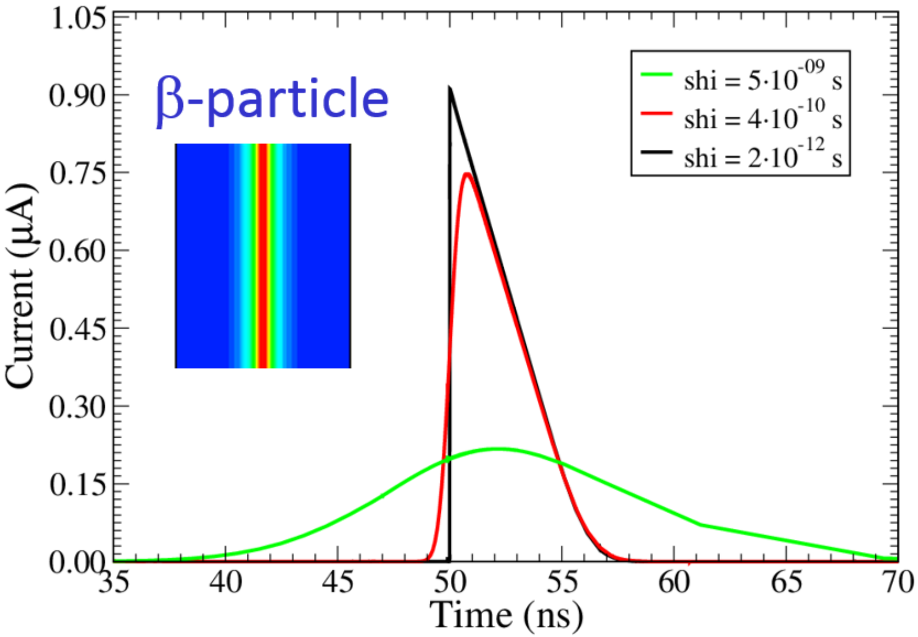
√ 3D layouts (5×5×0.5 mm^3) and simulated 2D cuts (5×0.5 mm^2) of the same device with planar or segmented contact strategy.

√ The effect of a single particle hit has been considered.

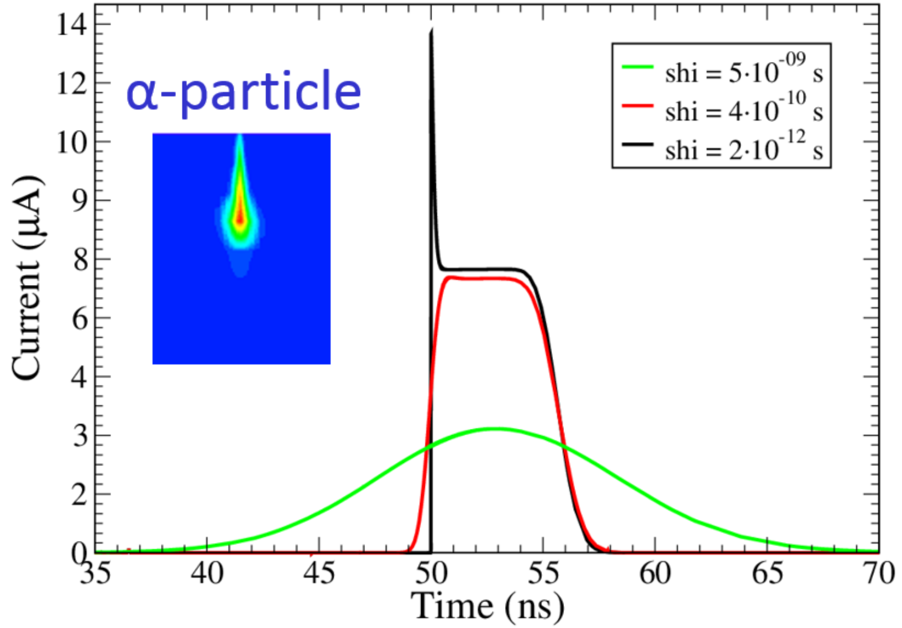


Timing issues in transient simulations

√ Proper time discretization of the stimulus with respect to the simulation time-step is critical for timing analysis.



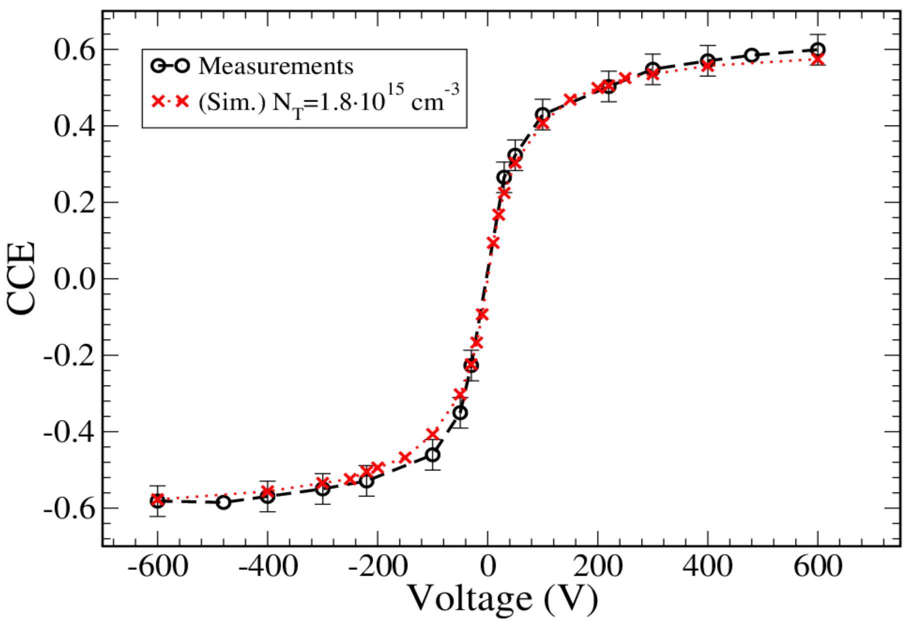
Transient analysis behavior as a response to β particles irradiation: different values of s_hi.



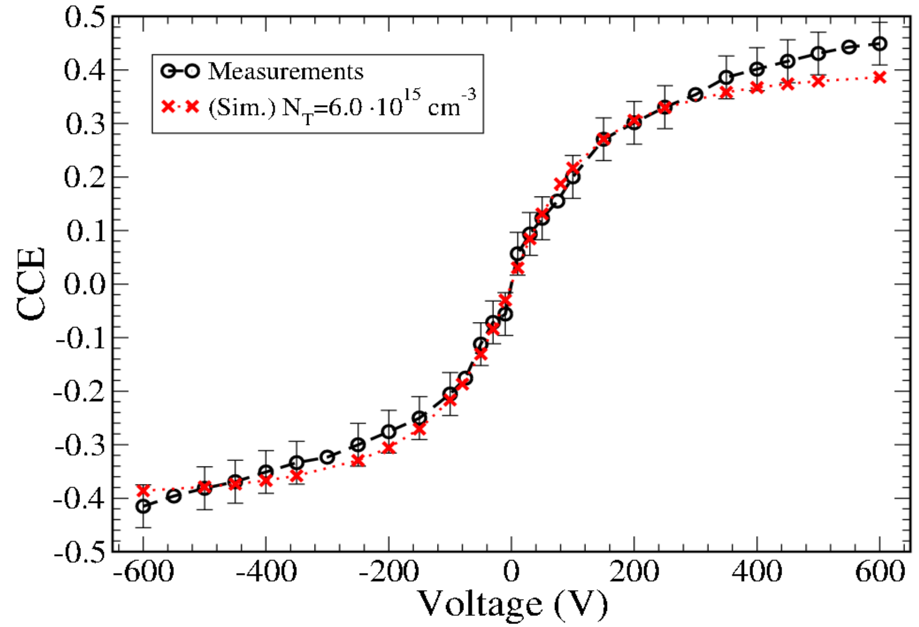
Transient analysis behavior as a response to α particles irradiation: different values of s_hi.

Validation/extension of the diamond model

√ Comparison between simulation results and measured data in terms of CCE as a function of the applied voltages.



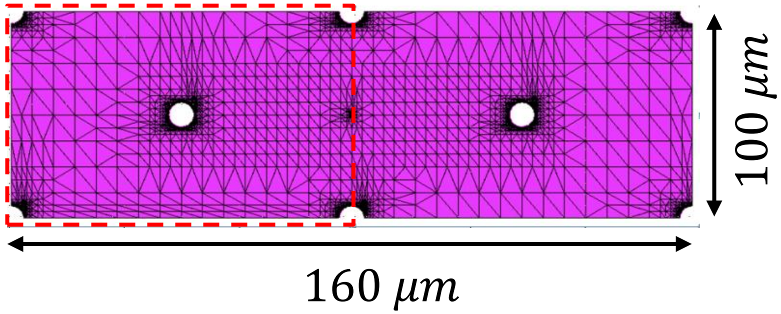
Sample from Element6
(5×5×0.5 mm^3), planar contacts (2D).

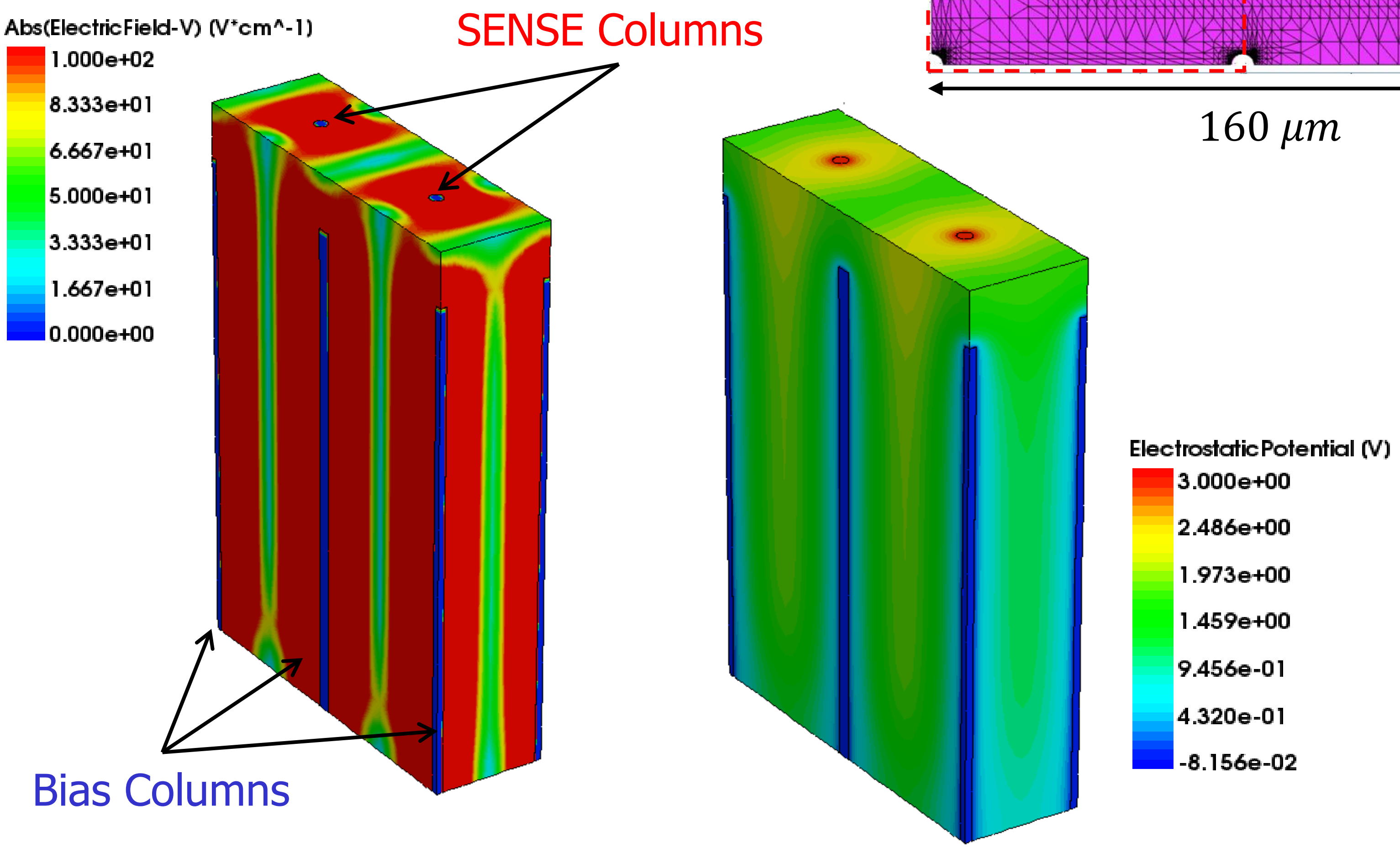


Sample of Diamond on Iridium
(5×5×0.5 mm^3), planar contacts (2D).

3D Diamond simulated structures

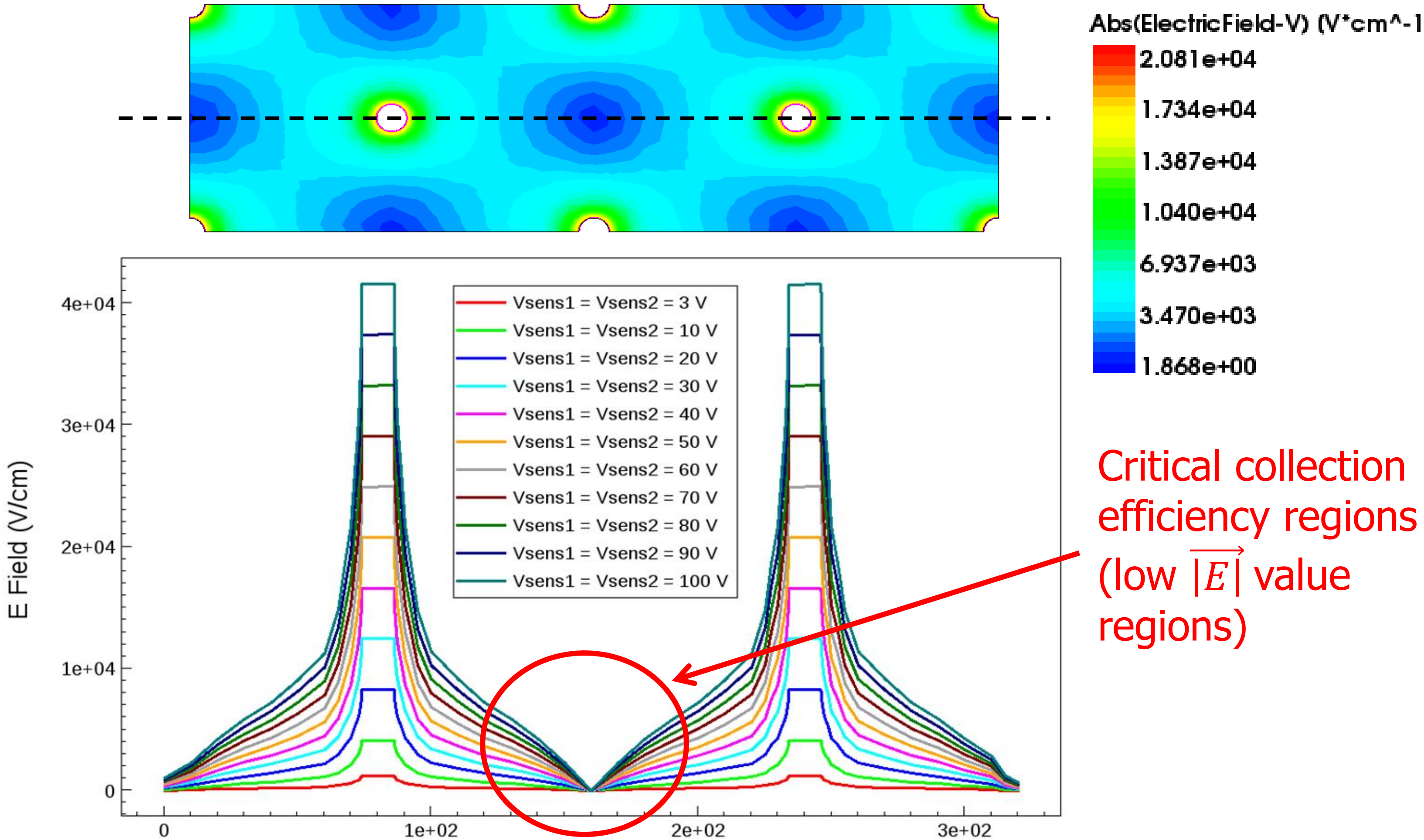
√ 3D layouts: two adjacent cells.





3D Diamond simulated structures

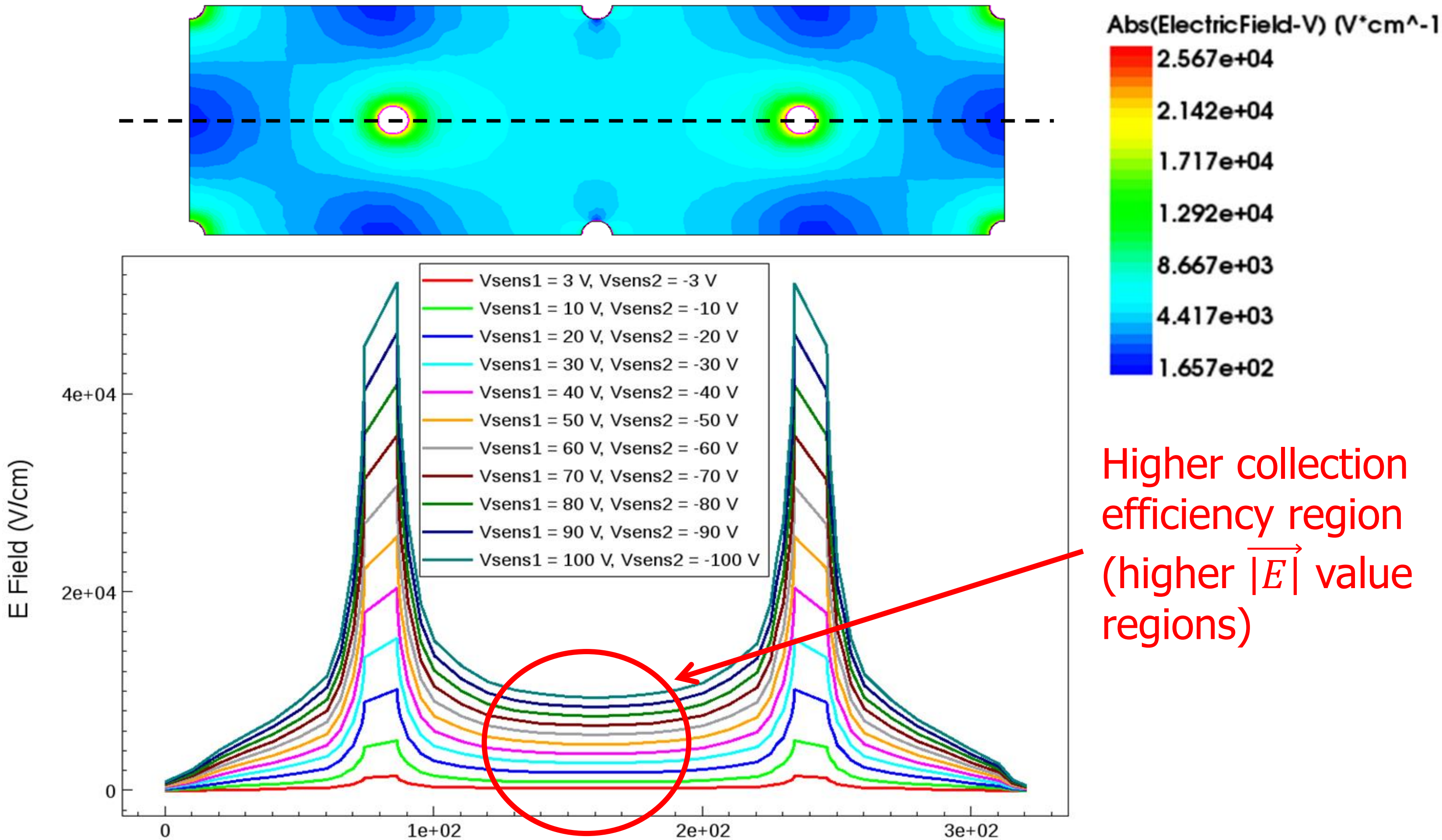
√ Effect of sense node biasing: same potential.



Critical collection efficiency regions (low $|\vec{E}|$ value regions)

3D Diamond simulated structures

√ Effect of sense node biasing: opposite polarity sense nodes.



Higher collection efficiency region (higher $|\vec{E}|$ value regions)