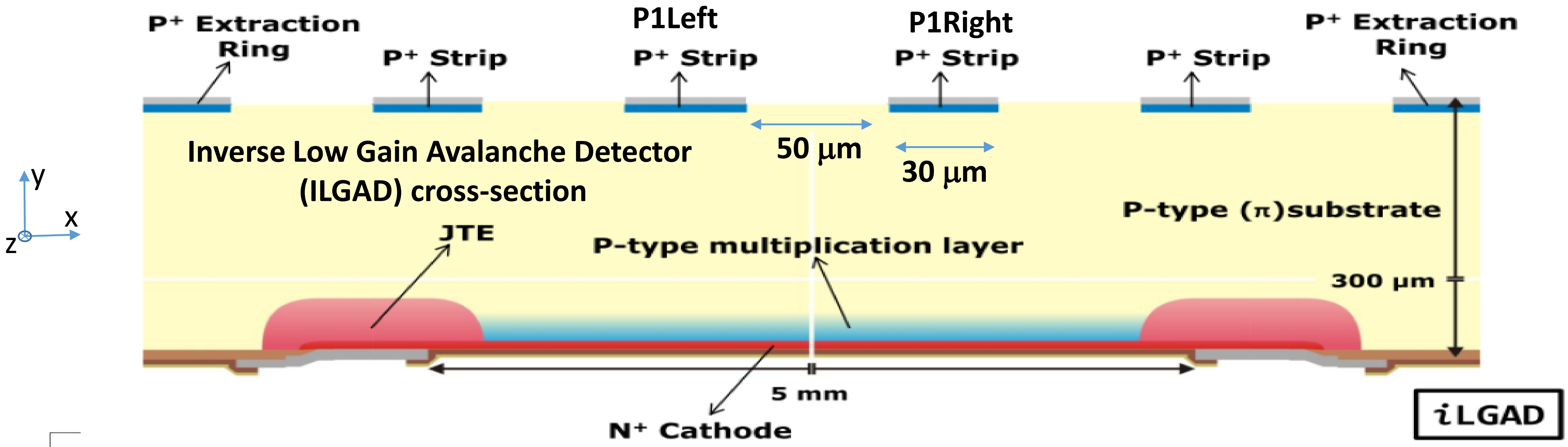
ILGAD TCAD Simulations: first approximations

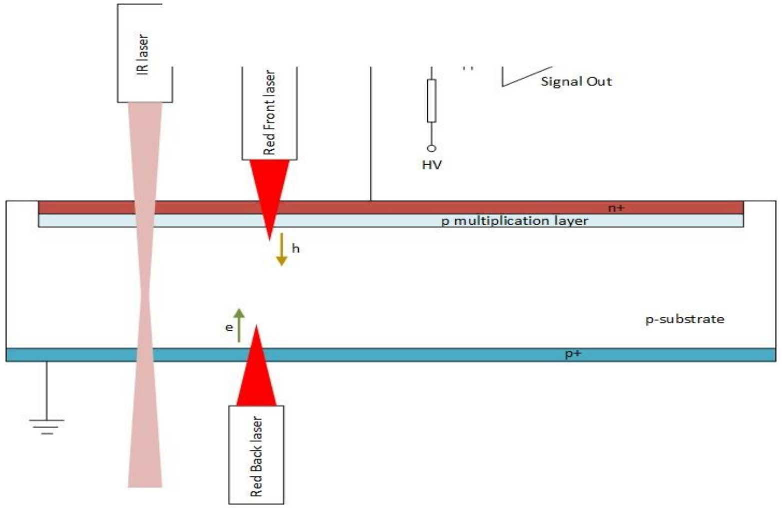
F.R. Palomo[1], S.Hidalgo[2], I.Vila[3]
fpalomo@us.es
[1]Dept. Ingeniería Electrónica, Escuela Superior de Ingenieros
Universidad de Sevilla, Spain
[2]CNM-IMB Barcelona, Spain
[3]IFCA Santander, Spain

Introduction

1. Development of several ILGAD models to test gain variation with bias and n+/pwell doping
2. Improvement in the ILGAD models compared with experimental data
3. Analisis of radiation effects in ILGAD
   1. 300um New Perugia Trap + Kramberger Acceptor removal models
   2. 50um New Perugia Trap + Kramberger Acceptor removal models

Sentaurus TCAD Simulation SetUp





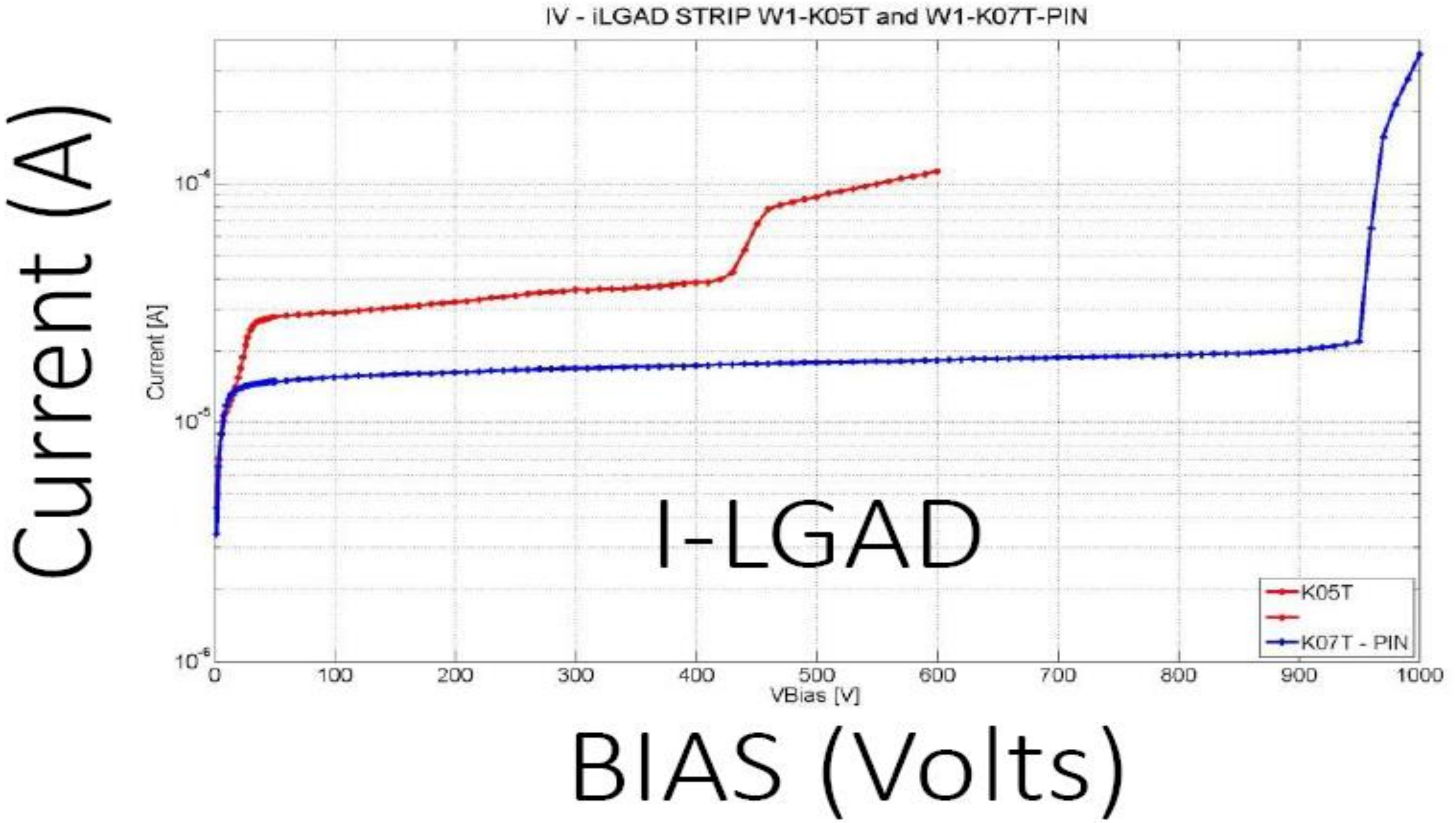
Simulation Setup:

- Red Pulsed Laser: 670 nm, 10 µm spot, 50W/cm^2, 200 ps,
- BackIllumination at P1 Right
- FrontIllumination aligned with P1 Right
- IR Pulsed Laser: 1064nm, 30W/cm^2,10 mm spot, 30W/cm^2, 200 ps at P1 Right
- 2D detector model: 1 µm in Z direction, 5 mm in X direction, 300/50 µm in Y direction)

Doping profiles under confidenciality rules

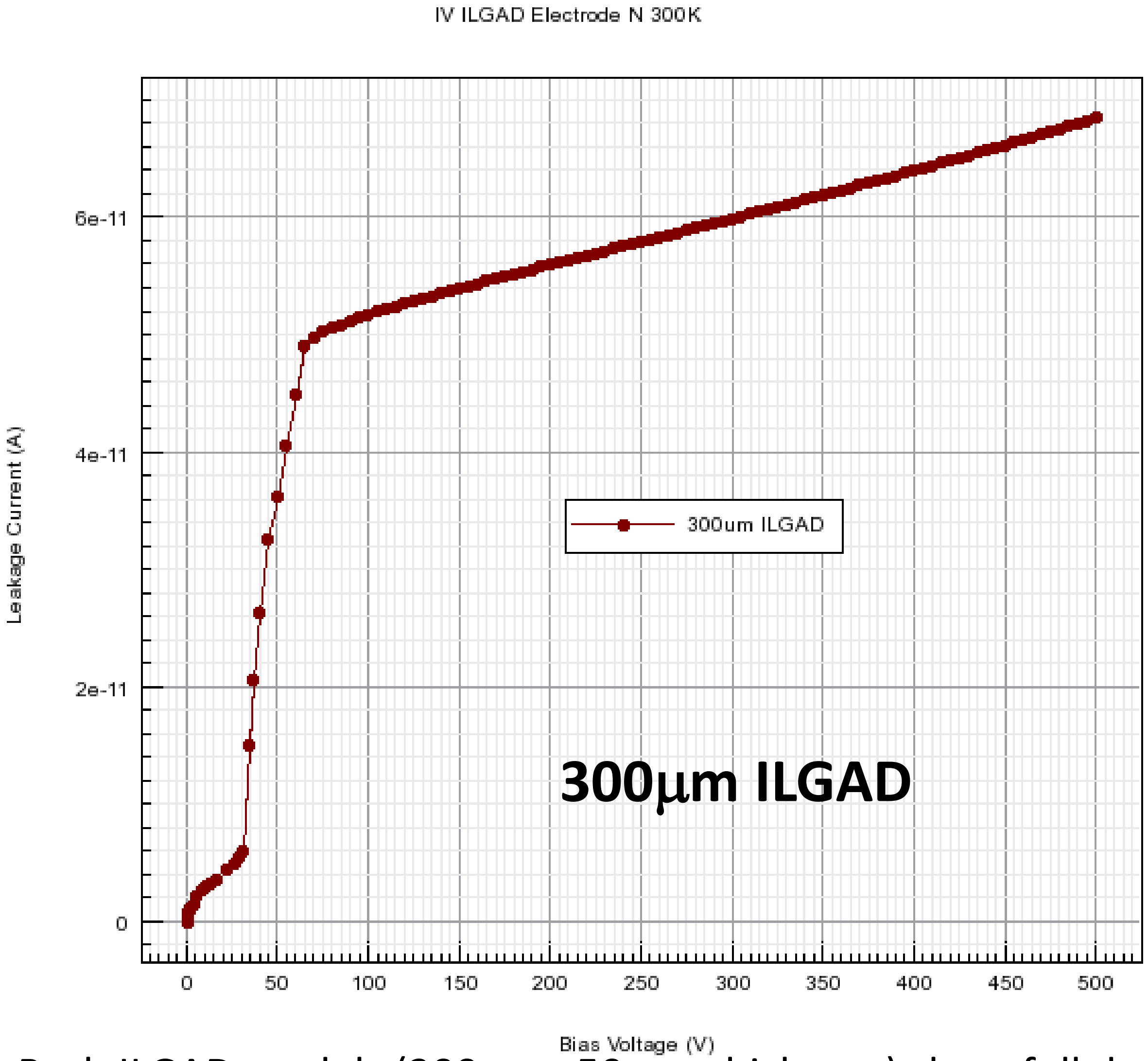
ILGAD IV Experimental

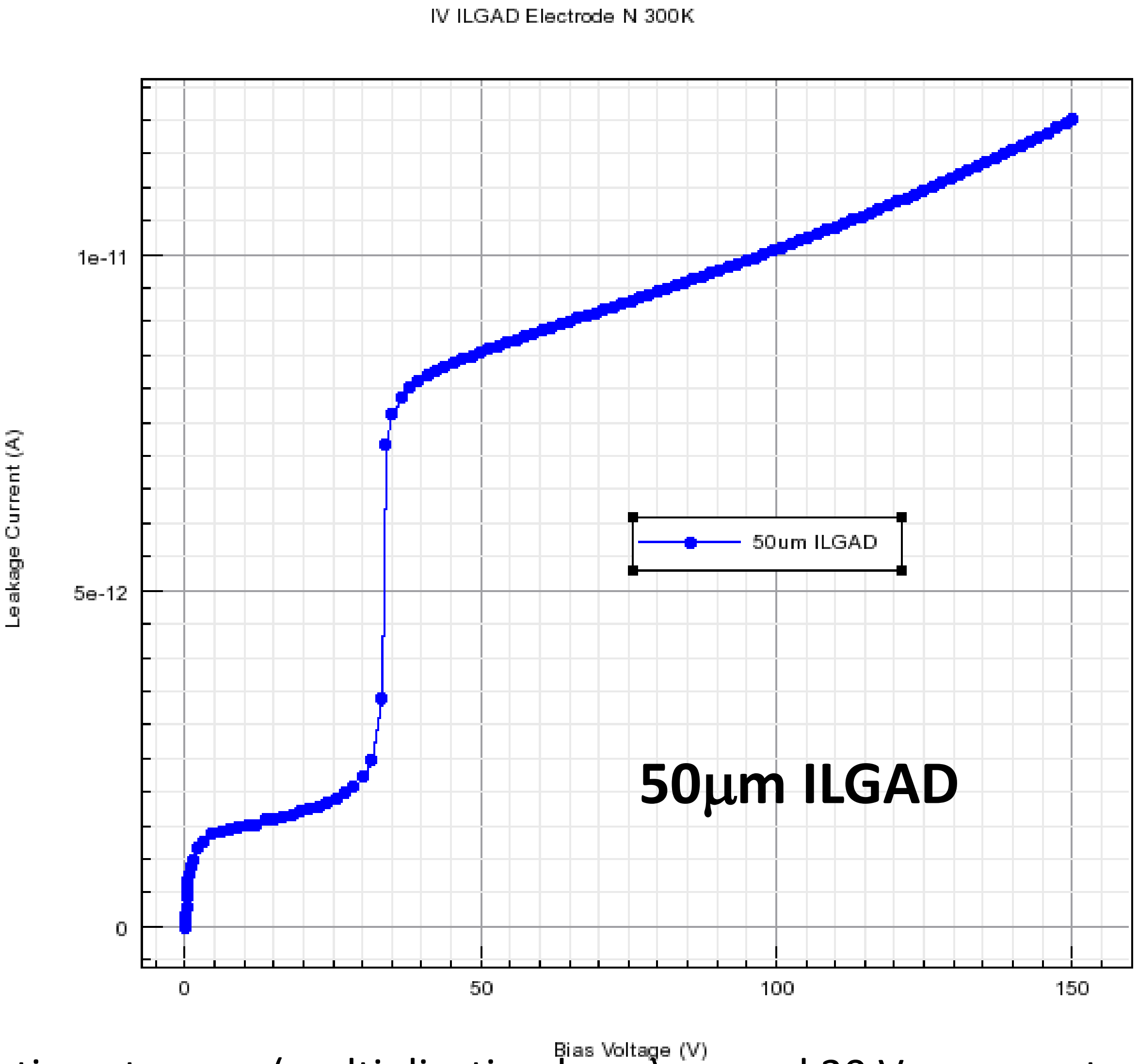
Experimentally we see a full depletion at the n++-p junction (multiplication layer) around 30V and a soft behaviour in the IV plot up to ~400 V



I.Vila, Update on the ILGAD characterization, RD50 Nov 22th 2016

ILGAD IV Simulation

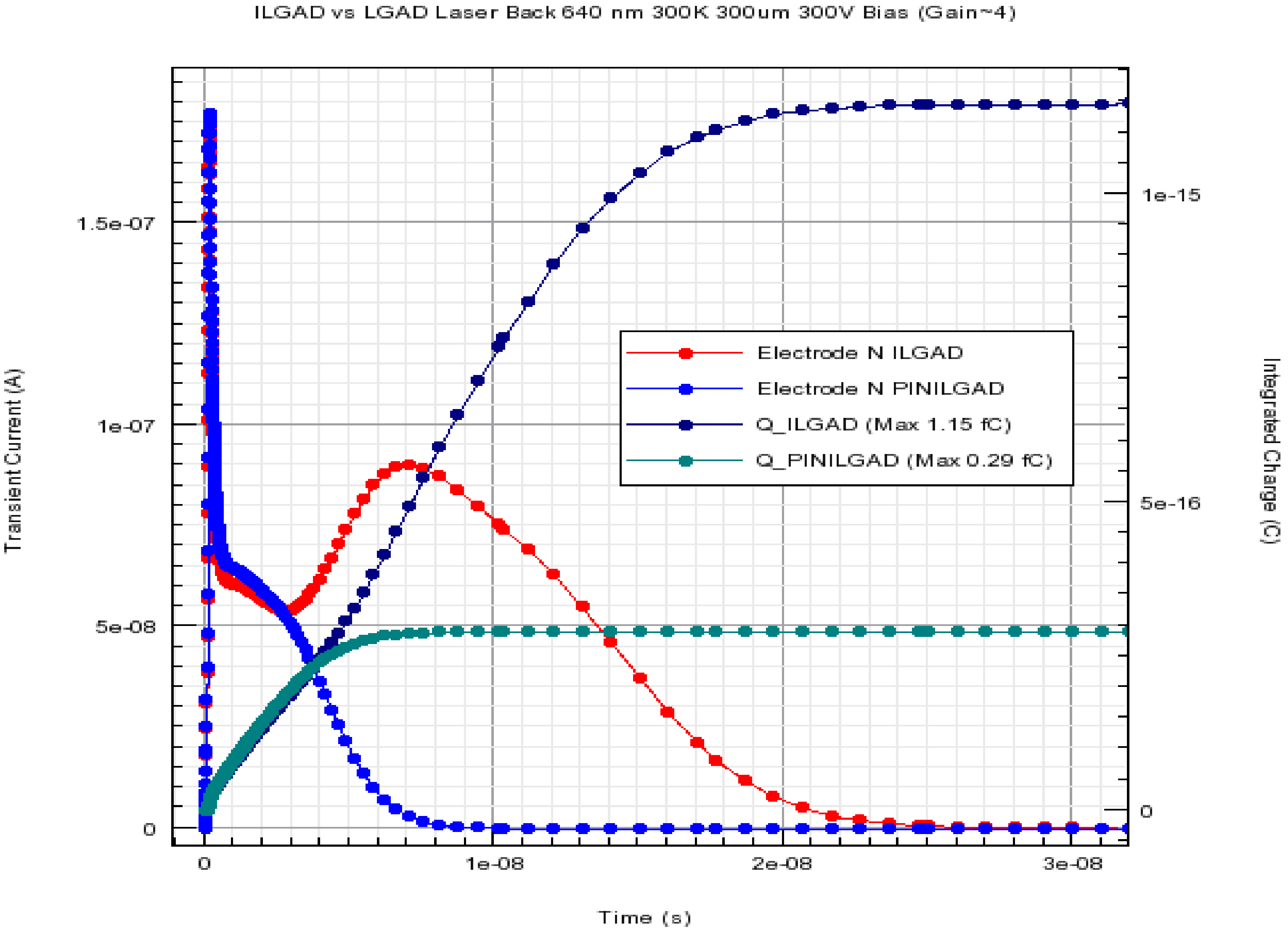




Both ILGAD models (300 µm, 50 µm thickness) show full depletion at n++-p (multiplication layer) around 30 V, as expected.
For the 300 mm we choose 150V, 300V, 450V as bias voltage, for the 50 mm we choose 50V, 100V, 150V as bias voltage

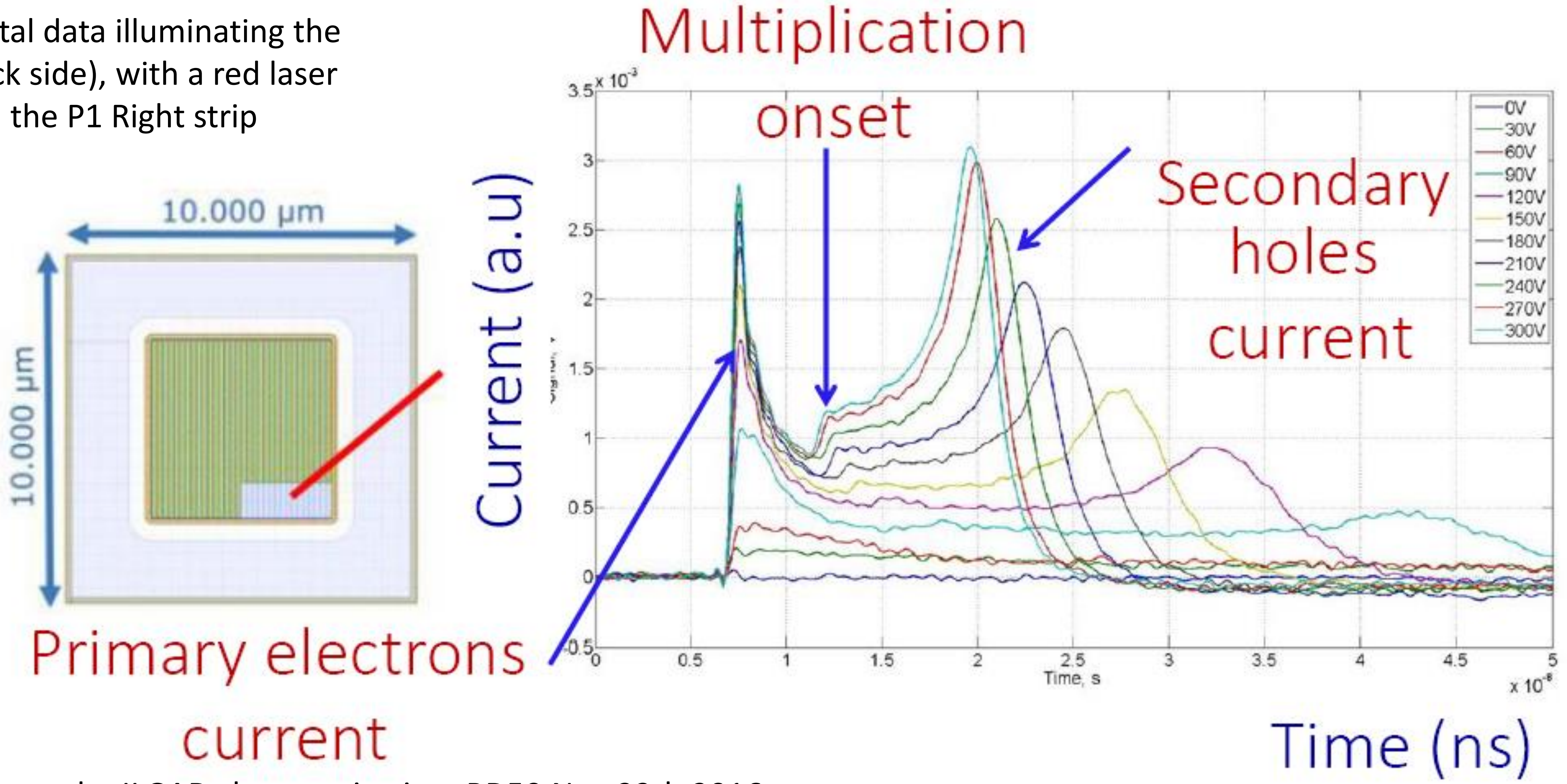
ILGAD 300 μm Red Laser Back Transient: Simulation shows gain (~4)

Laser 670nm (red), illuminating on P1 right strip (just in the middle), signal observed in the N electrode (cathode). Comparing ILGAD and its associated PIN (PINILGAD) the plot shows a gain factor around 4 (model verification).



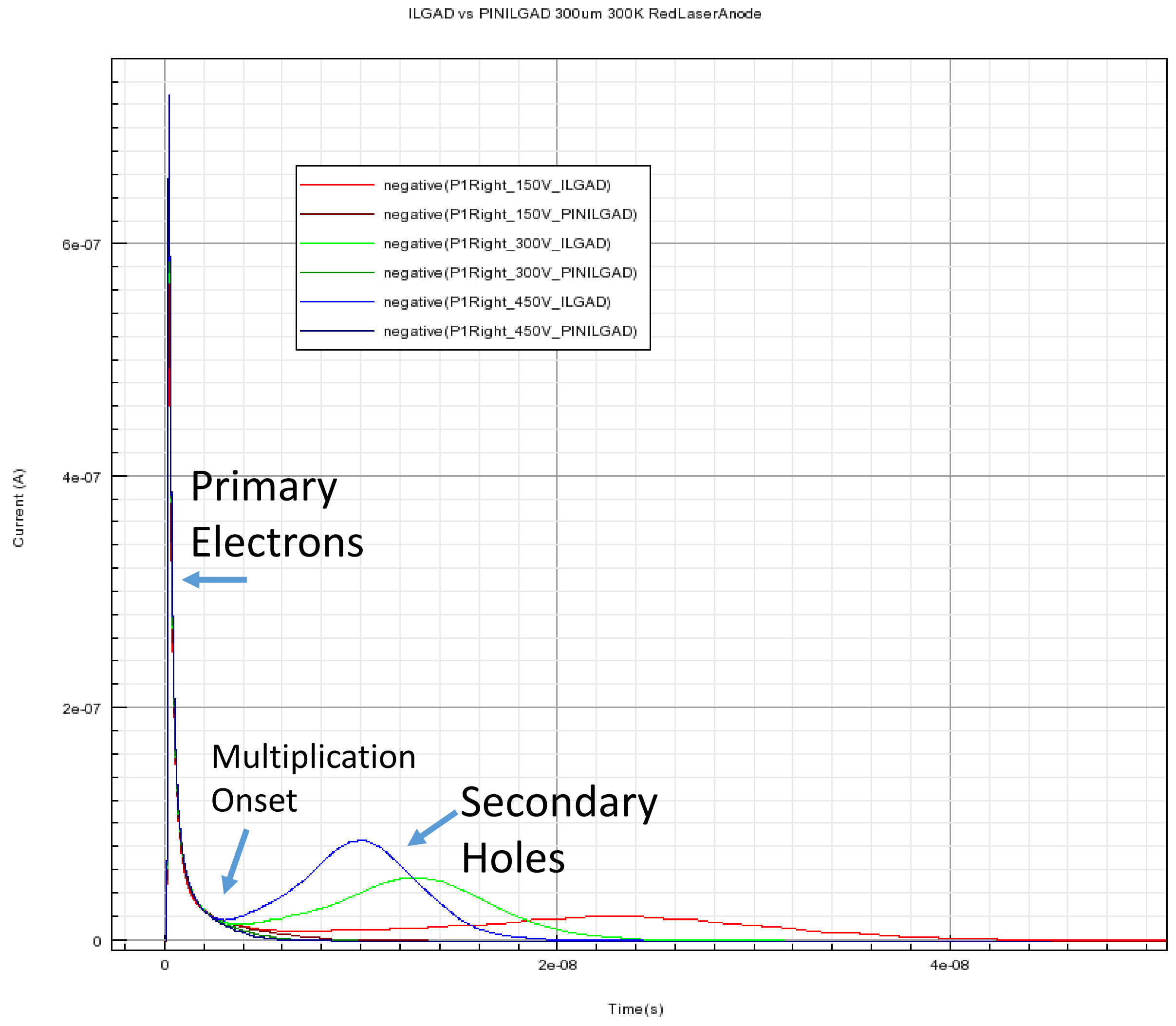
ILGAD Red Laser Back Transient Experimental 300K

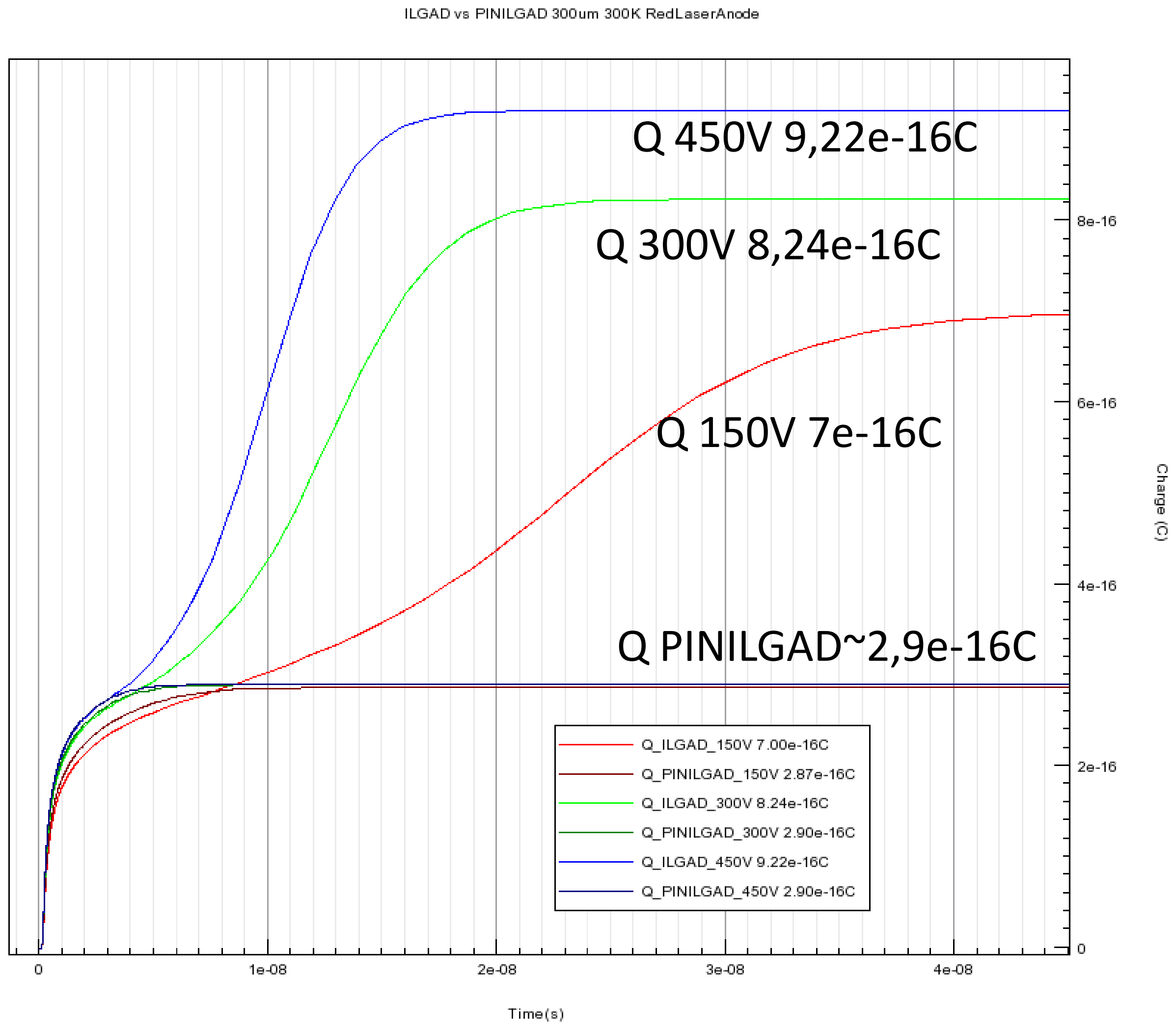
Experimental data illuminating the anode (back side), with a red laser (670nm) in the P1 Right strip



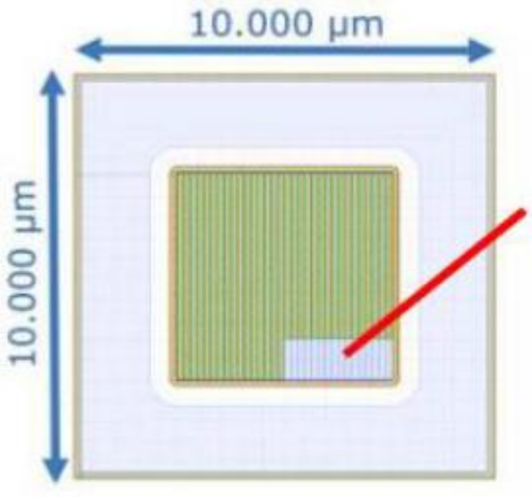
I.Vila, Update on the ILGAD characterization, RD50 Nov 22th 2016

ILGAD 300 um Red Laser (670nm) Back Transient P1Right

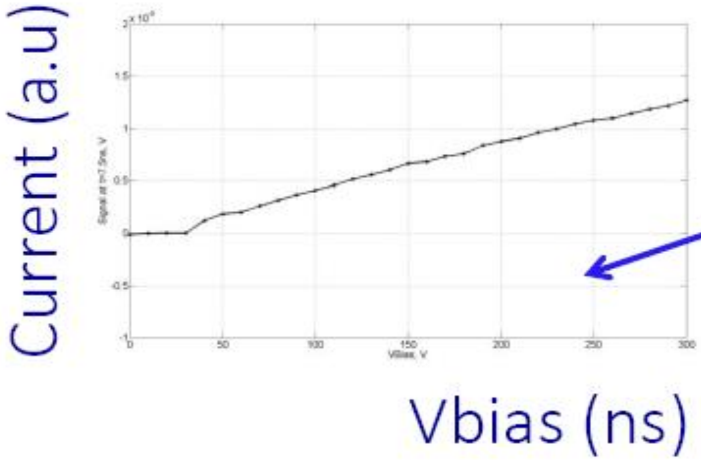


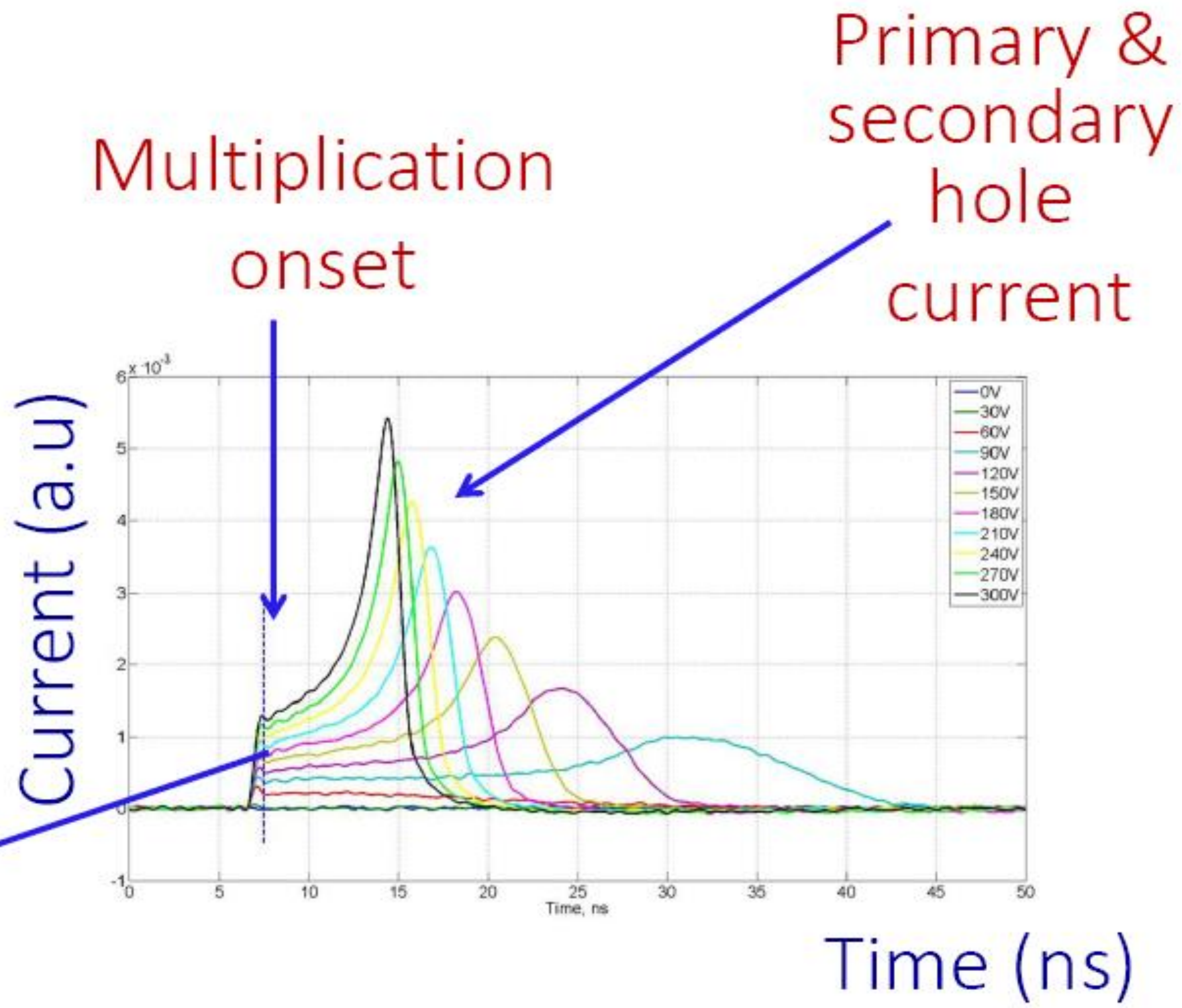


ILGAD Red Laser Front Transient Experimental 300K



Experimental data illuminating the cathode (front side), with a red laser (670nm) alligned with P1 Right strip

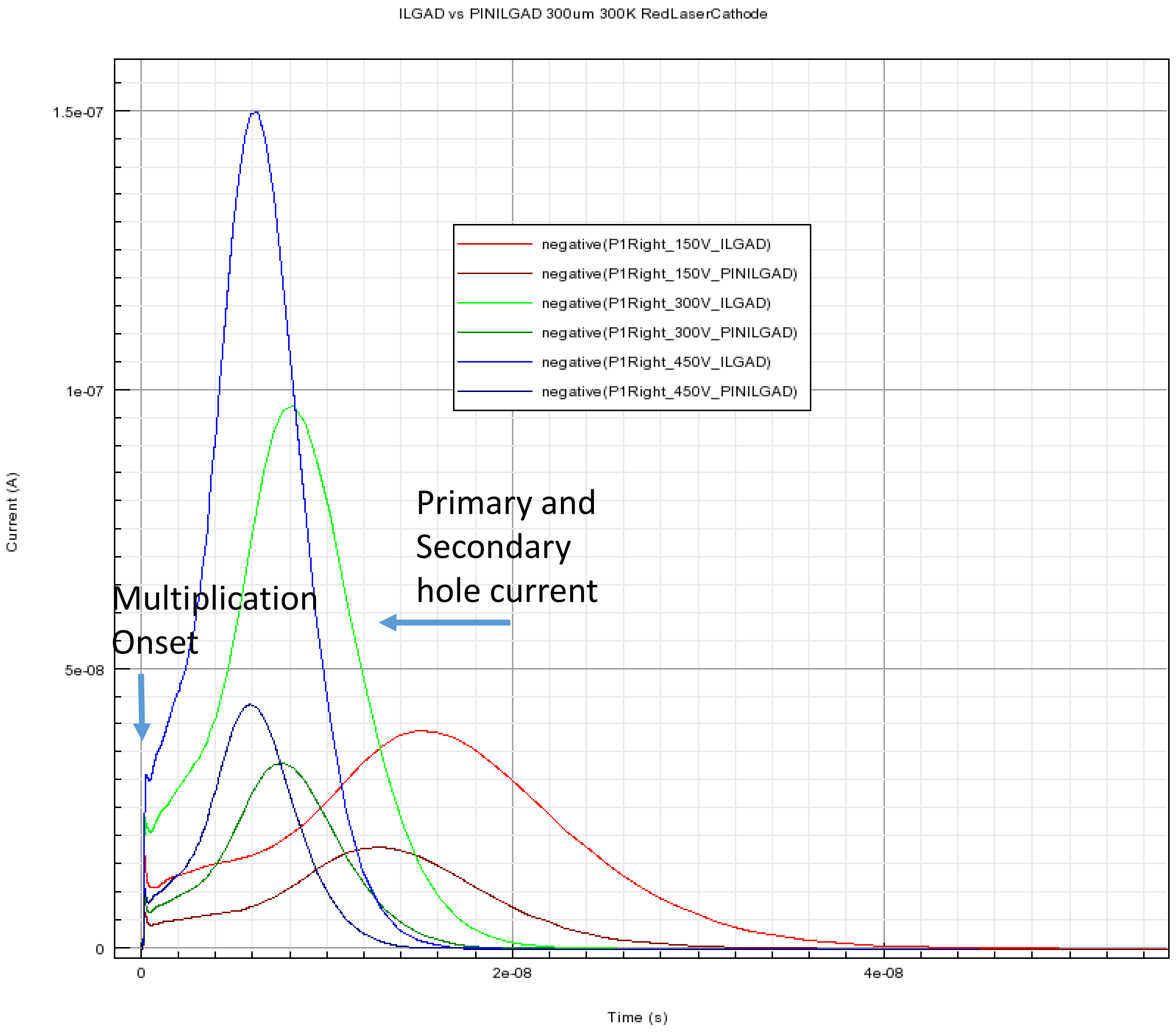


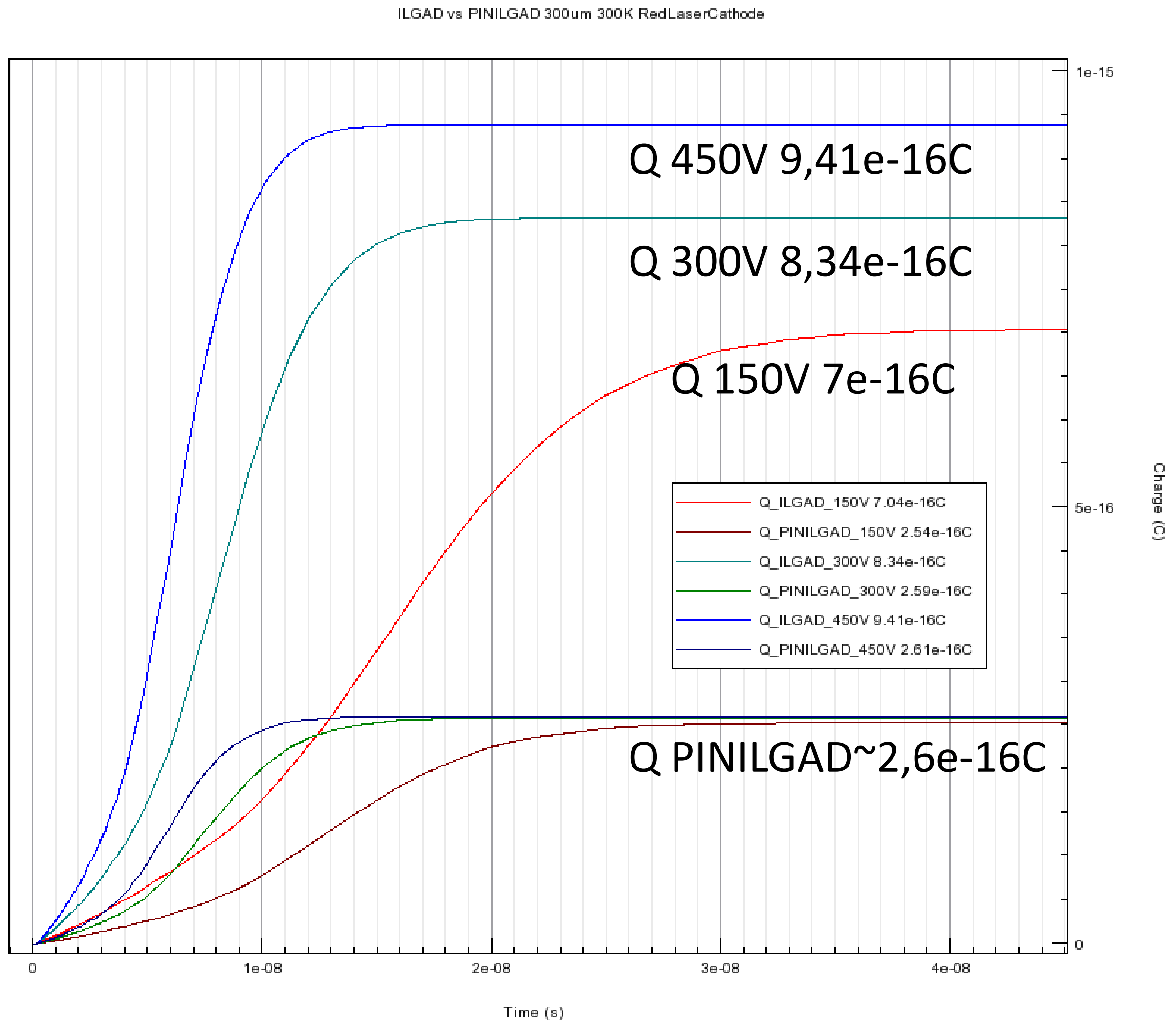


– Hole injection (BACK SIDE !)

I.Vila, Update on the ILGAD characterization, RD50 Nov 22th 2016

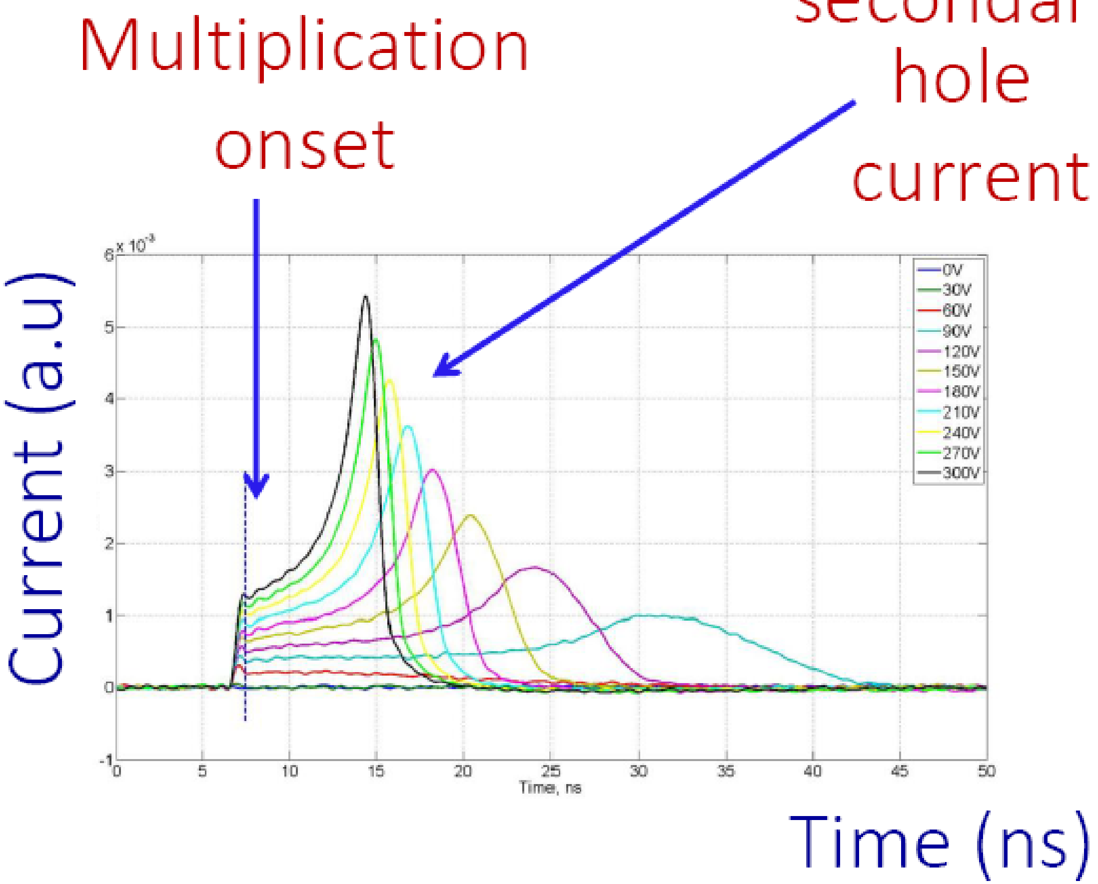
ILGAD 300μm Red Laser (670nm) Front

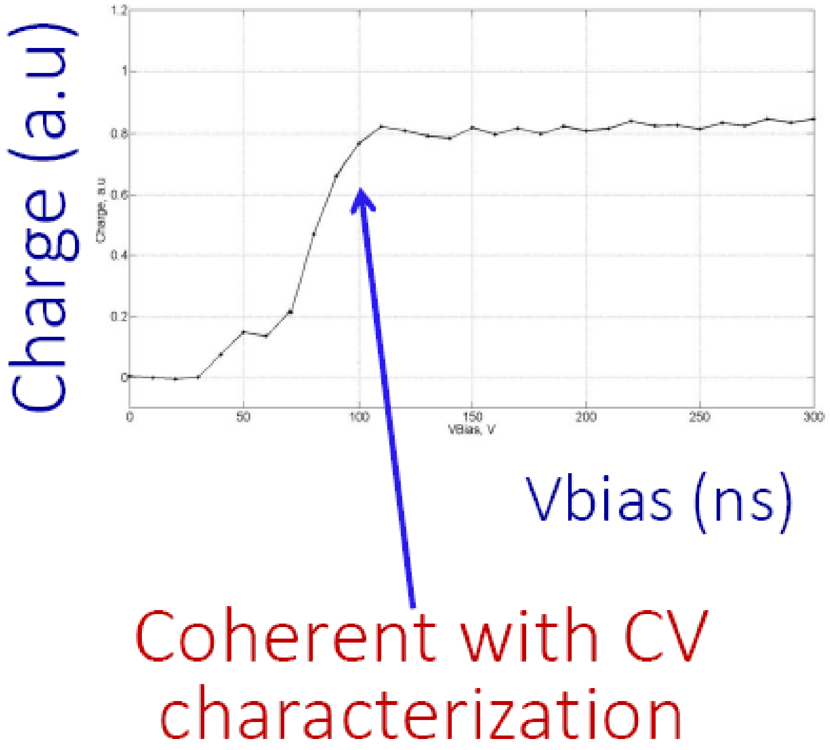




LGAD IR Laser Experimental Results

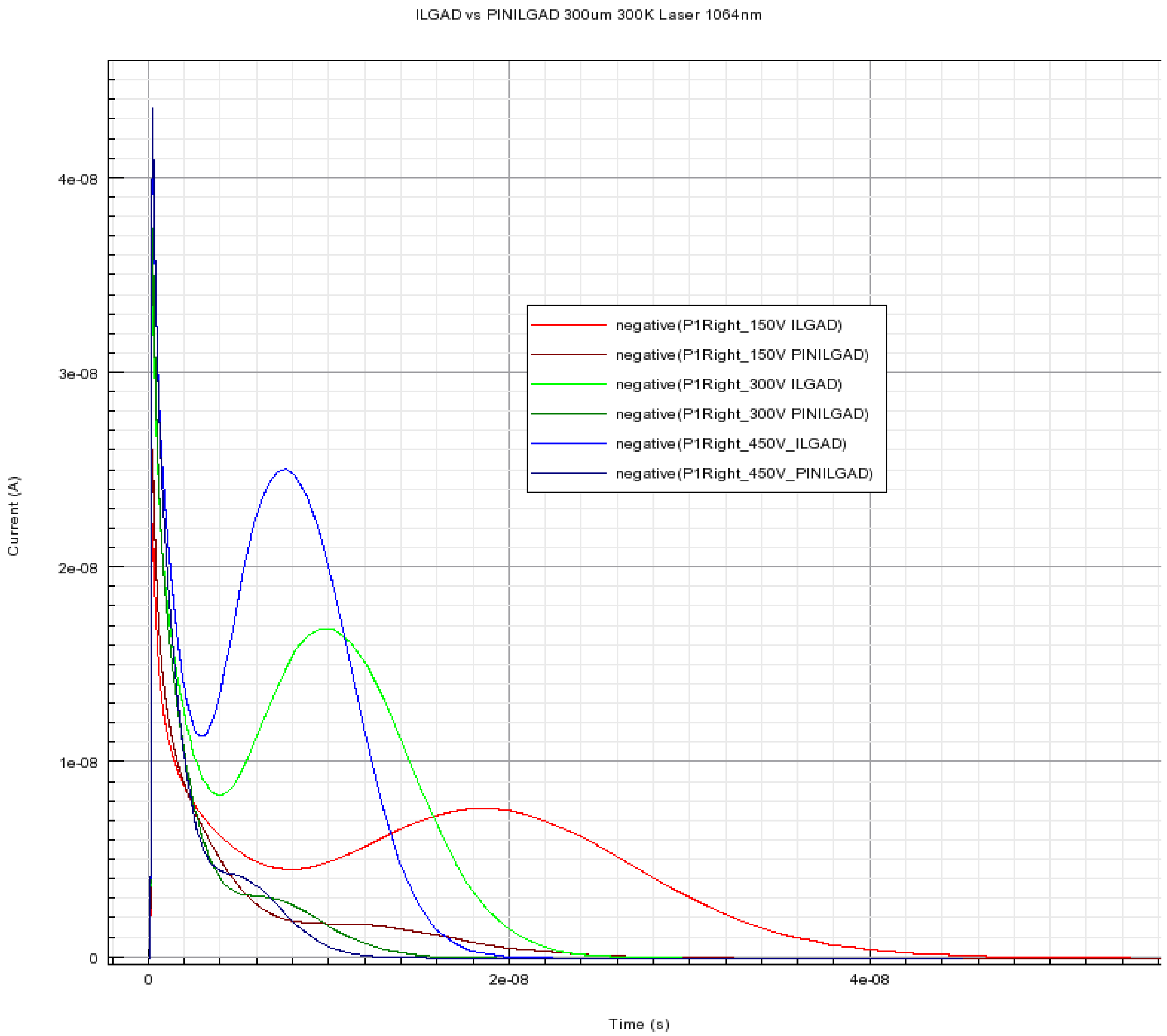
Experimental data TCT laser (IR, 1064nm) alligned with P1 Right strip

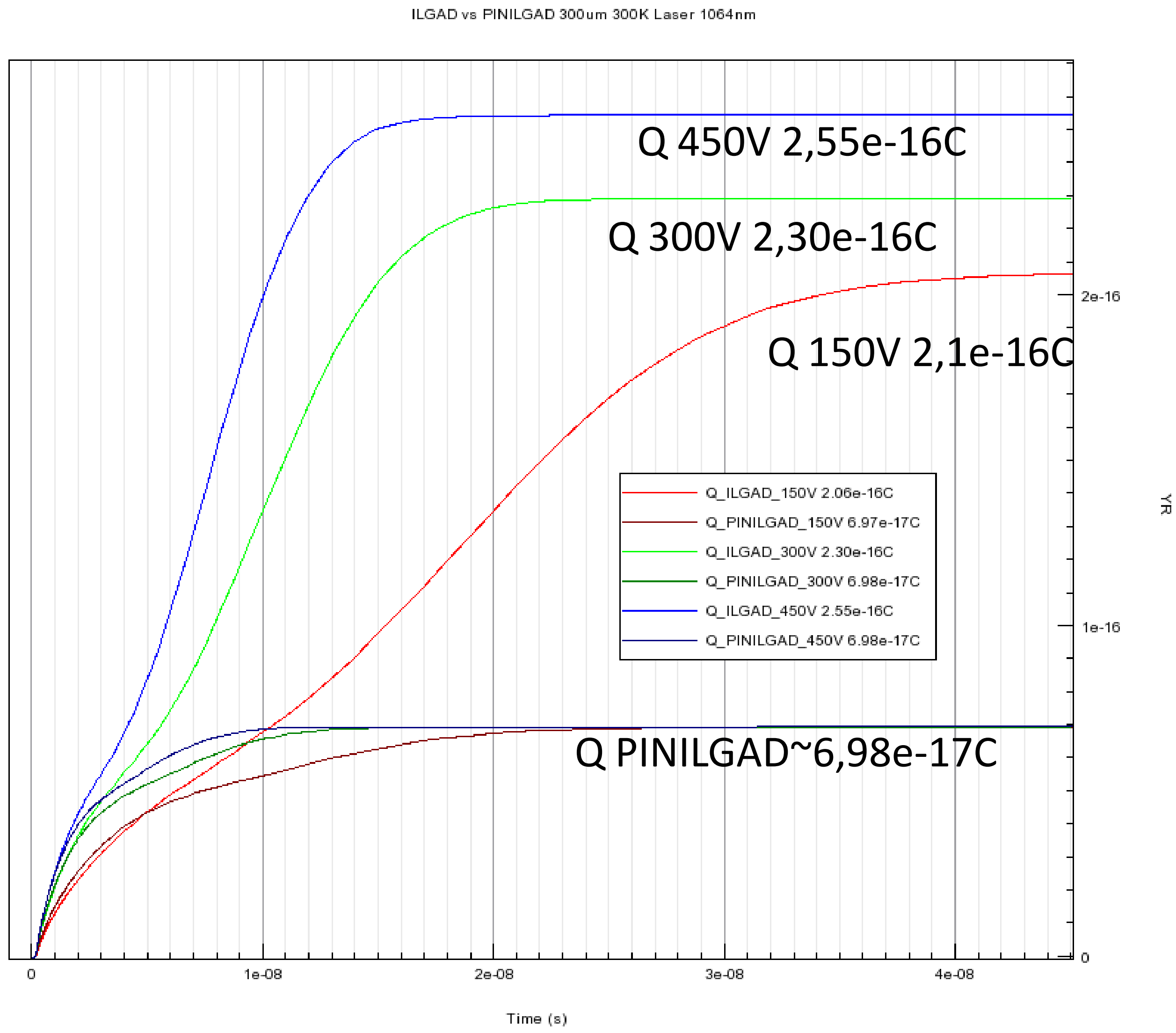




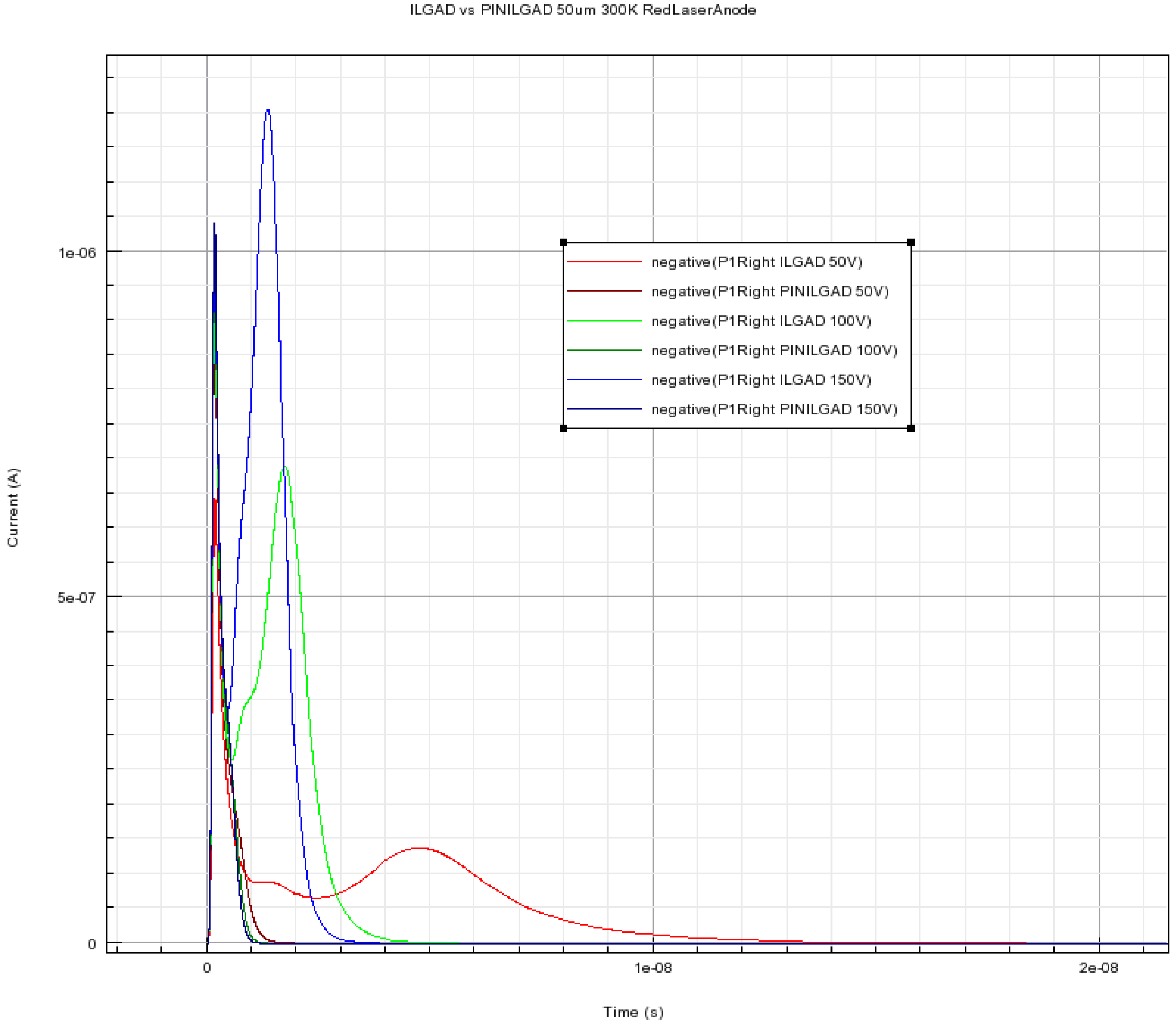
I.Vila, Update on the ILGAD characterization, RD50 Nov 22th 2016

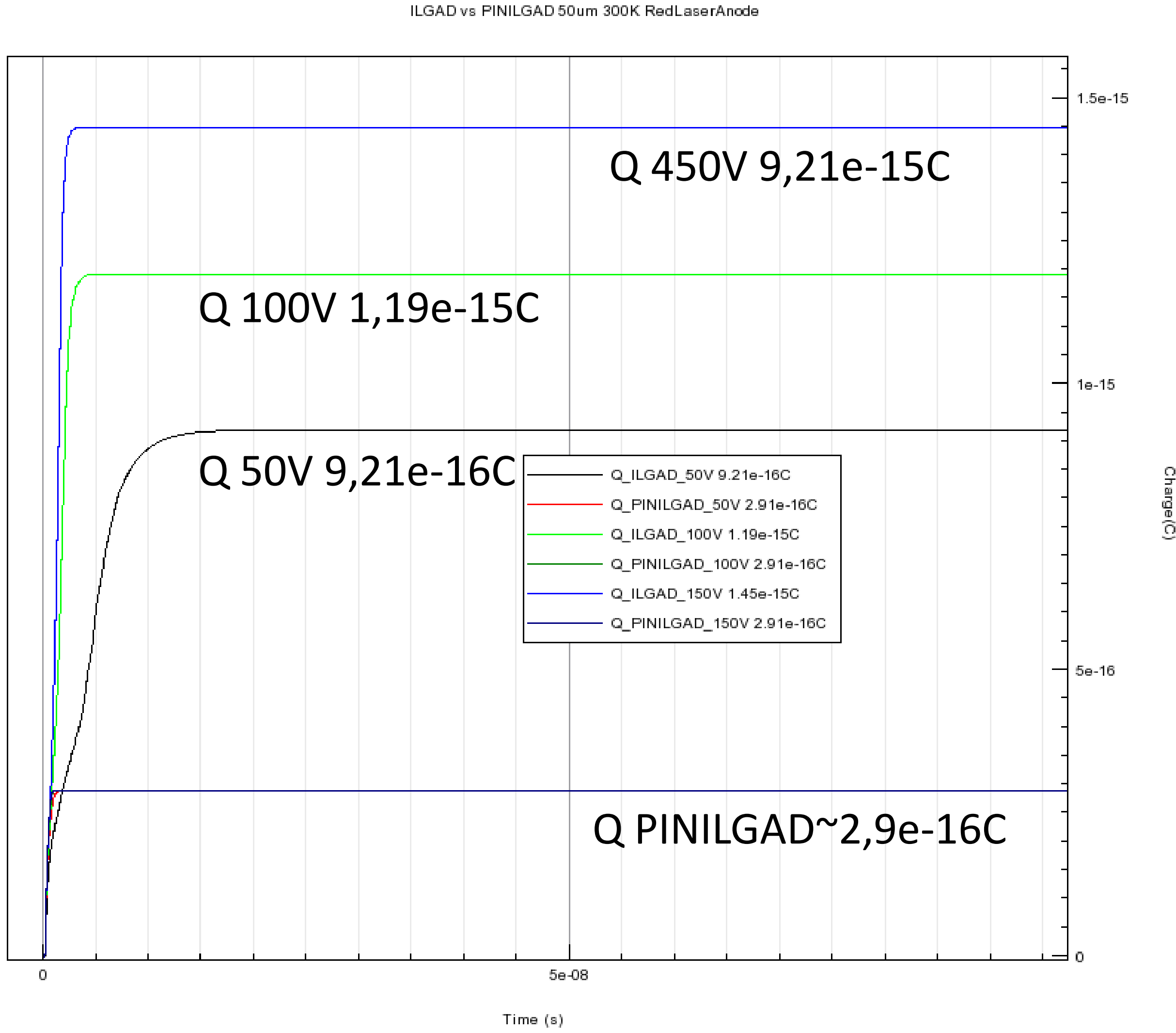
ILGAD 300um IR (1064nm) Laser



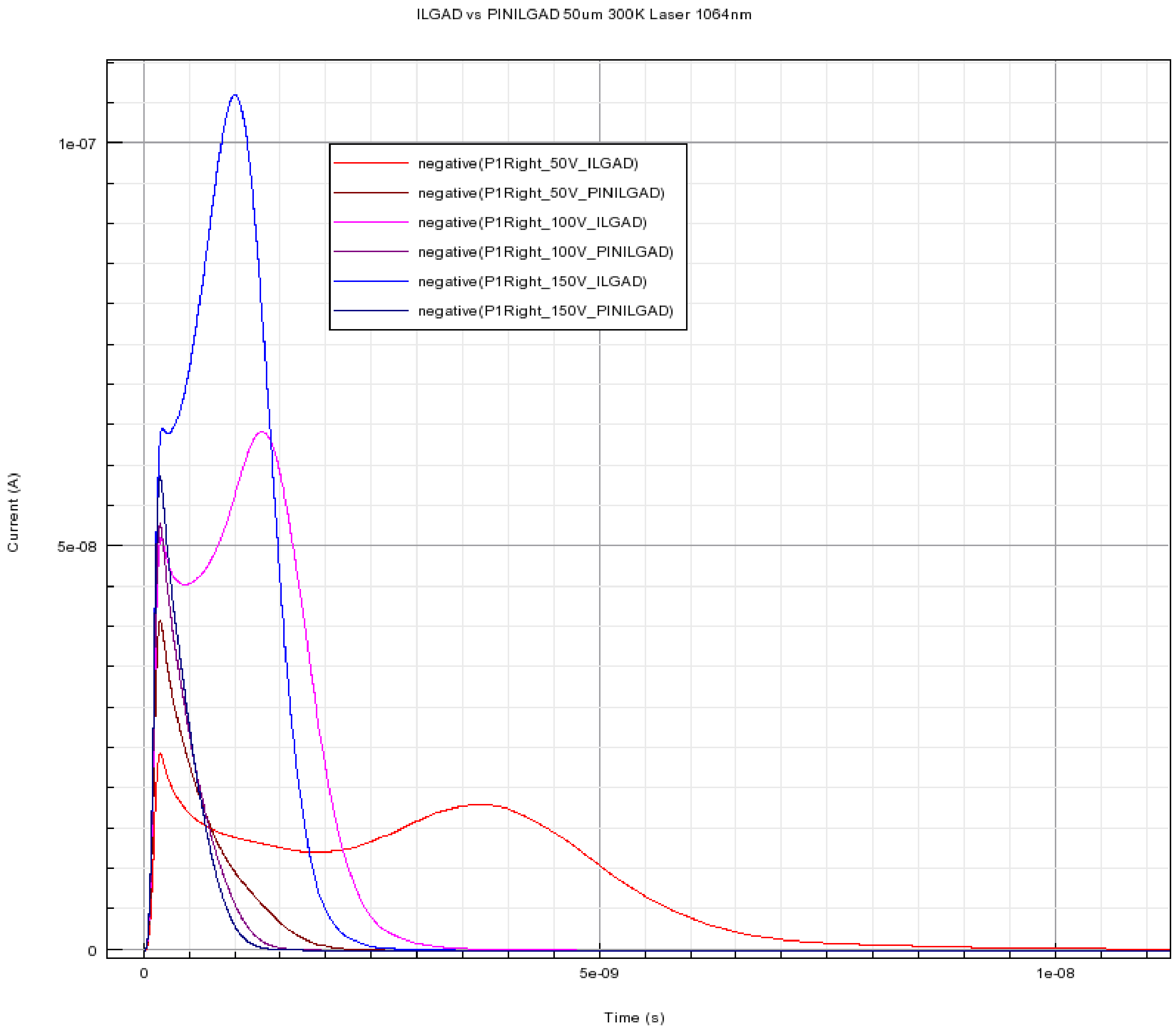


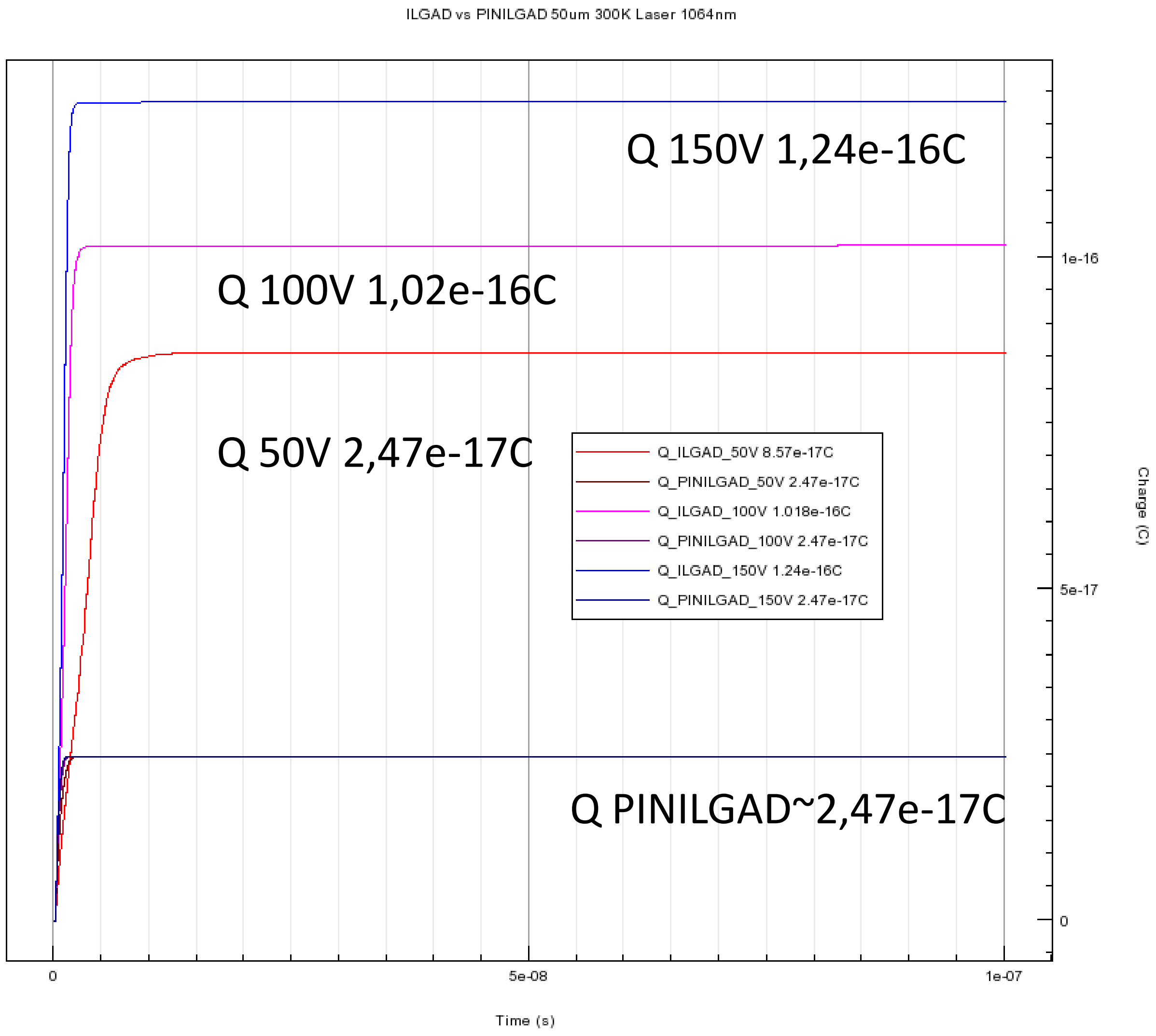
ILGAD 50 um Red Laser (670nm) Back Transient P1Right





ILGAD 50 um IR (1064nm) Laser Transient P1Right





Radiation Damage Models

One damage model, Traps+Acceptor Removal

1. New Perugia Model ϕ =1e15 up to 7,5e15 n_{eq}/cm^2
2. Acceptor Removal

$$N_A = N_A e^{-c\phi}$$

$c=10e^{-16}\ cm^{-2}$

Radiation effects in Low Gain Avalanche Detectors after hadron irradiations, G.Kramberger et al., JINST 2015 10 P07006

Parameters for fluences up to 7×10^{15} n/cm^2. New Perugia

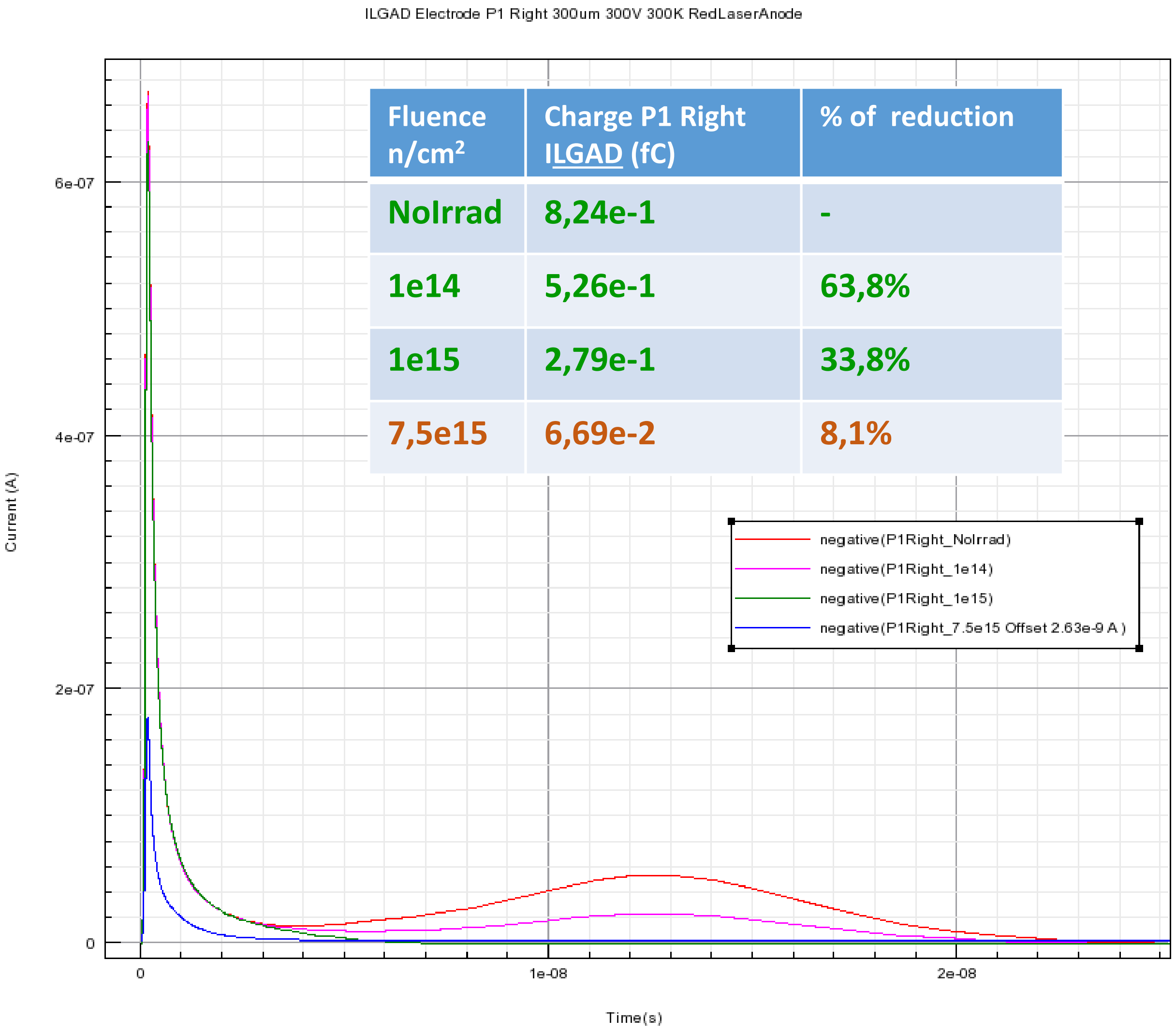
Defect	E (eV)	σ_e (cm^{-2})	σ_h (cm^{-2})	η
Acceptor	$E_c - 0.42$	1.00×10^{-15}	1.00×10^{-14}	1.6
Acceptor	$E_c - 0.46$	7.00×10^{-15}	7.00×10^{-14}	0.9
Donor	$E_v + 0.36$	3.23×10^{-13}	3.23×10^{-14}	0.9

Parameters for fluences within 7×10^{15} n/cm^2 and 2.2×10^{16} n/cm^2.

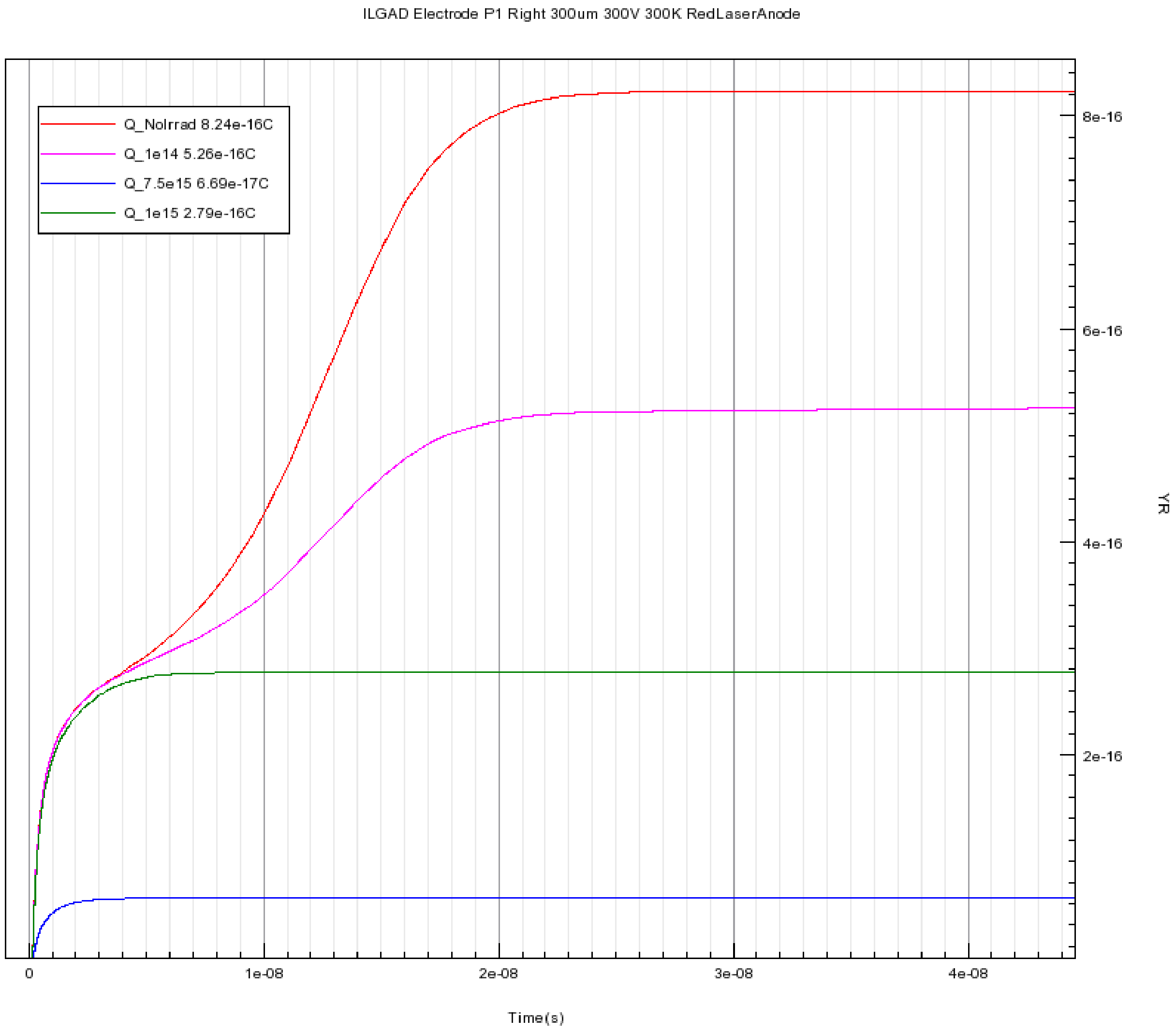
Defect	E (eV)	σ_e (cm^{-2})	σ_h (cm^{-2})	η
Acceptor	$E_c - 0.42$	1.00×10^{-15}	1.00×10^{-14}	1.6
Acceptor	$E_c - 0.46$	3.00×10^{-15}	3.00×10^{-14}	0.9
Donor	$E_v + 0.36$	3.23×10^{-13}	3.23×10^{-14}	0.9

Modeling of radiation damage effects in silicon detectors at high fluences HL-LHC with Sentaurus TCAD, D.Passeri et al, NIMA 824 (2016), 443-445

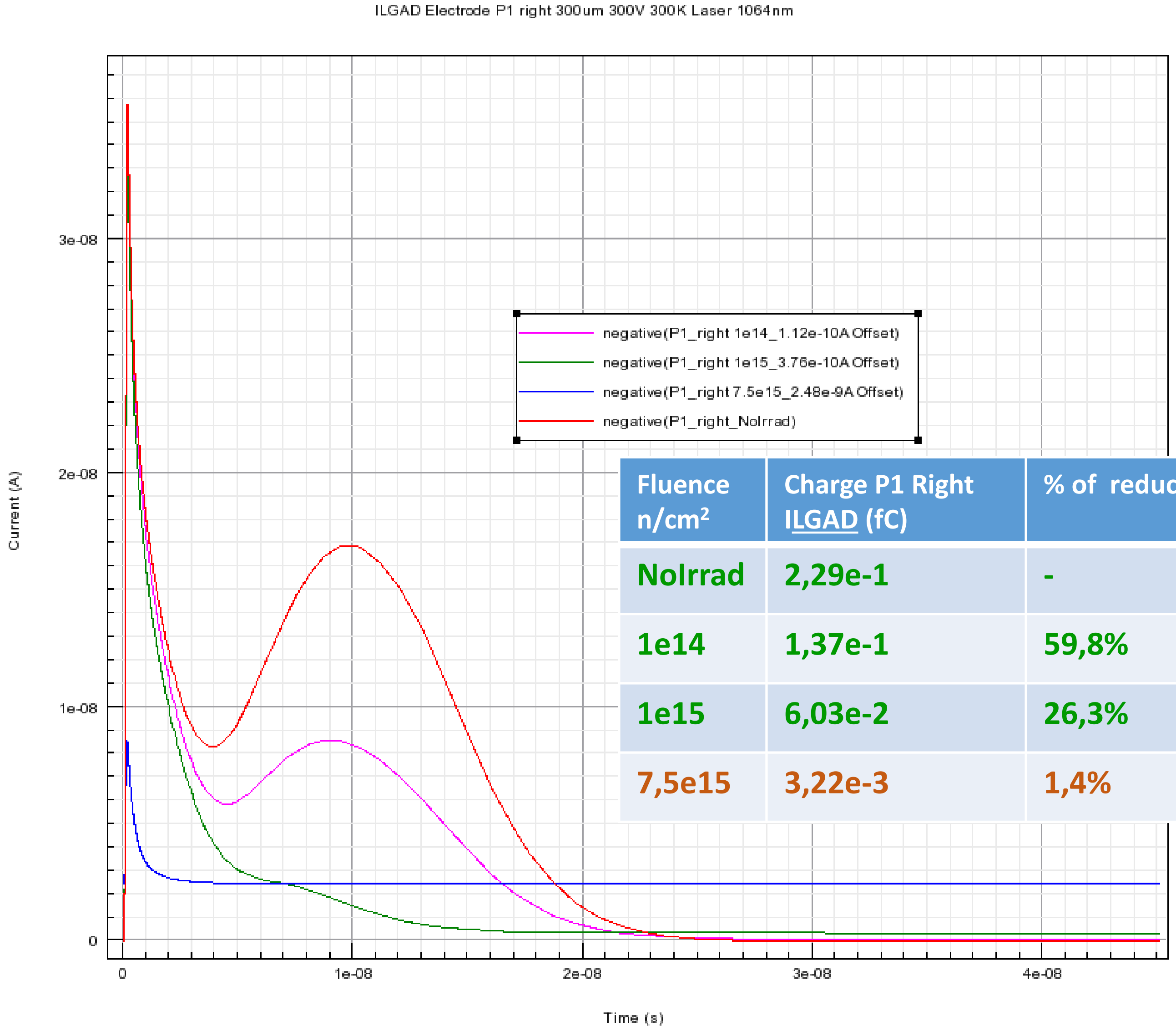
LGAD 300 um RedLaserBack 300K Irradiation P1 Right



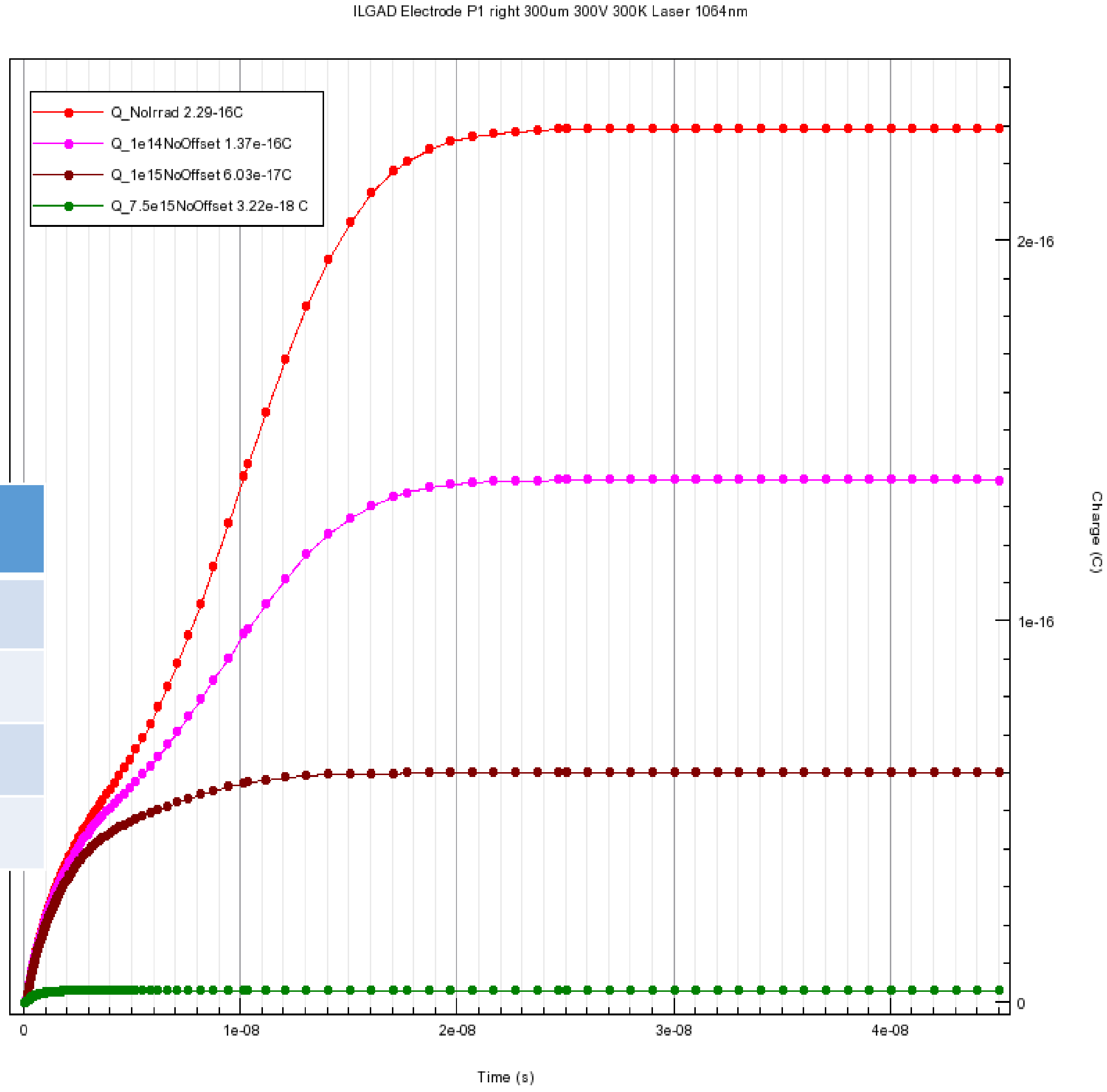
Fluence n/cm^2	Charge P1 Right ILGAD (fC)	% of reduction
NoIrrad	8,24e-1	-
1e14	5,26e-1	63,8%
1e15	2,79e-1	33,8%
7,5e15	6,69e-2	8,1%



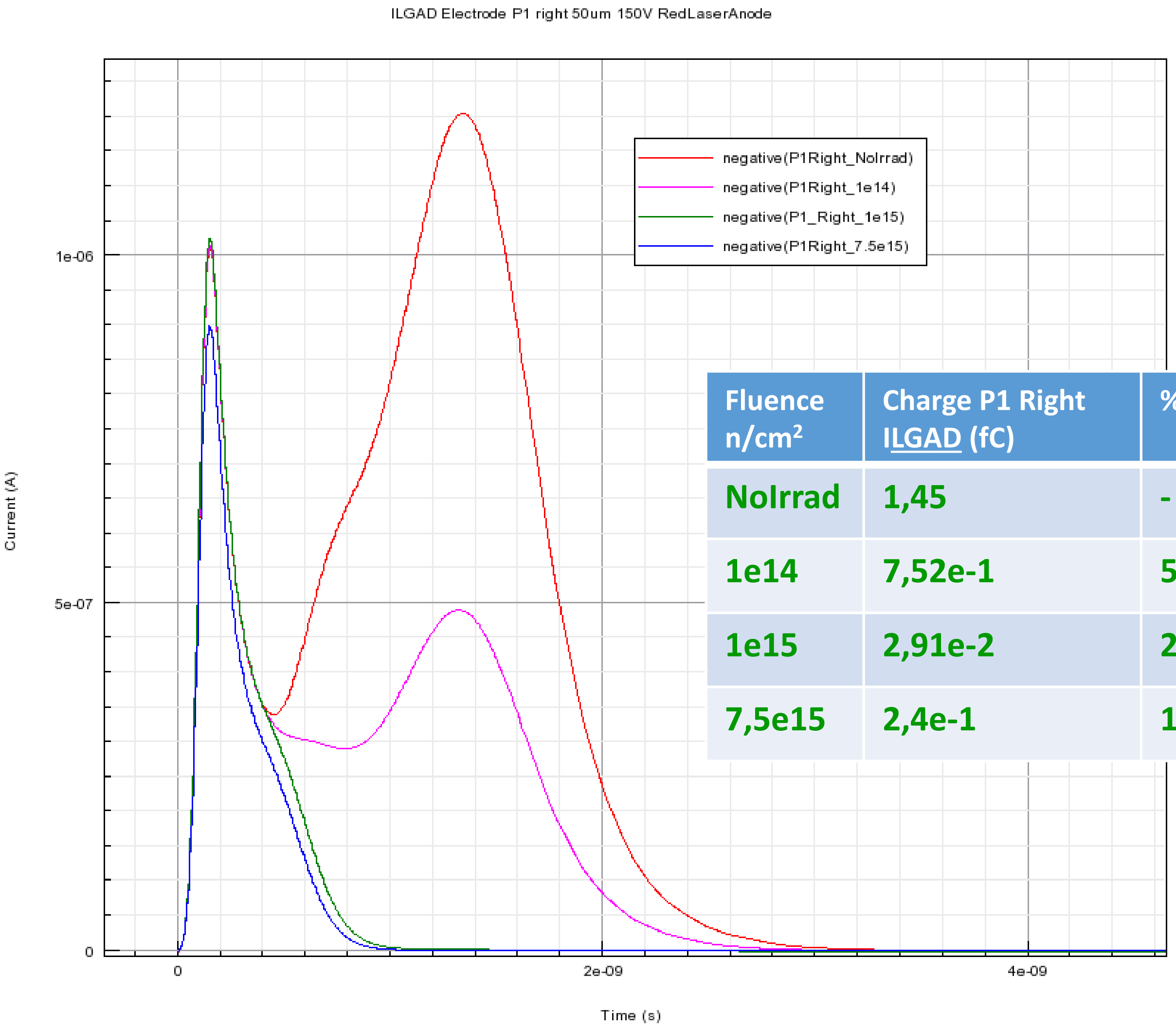
LGAD 300 um IR Laser 300K Irradiation P1 Right

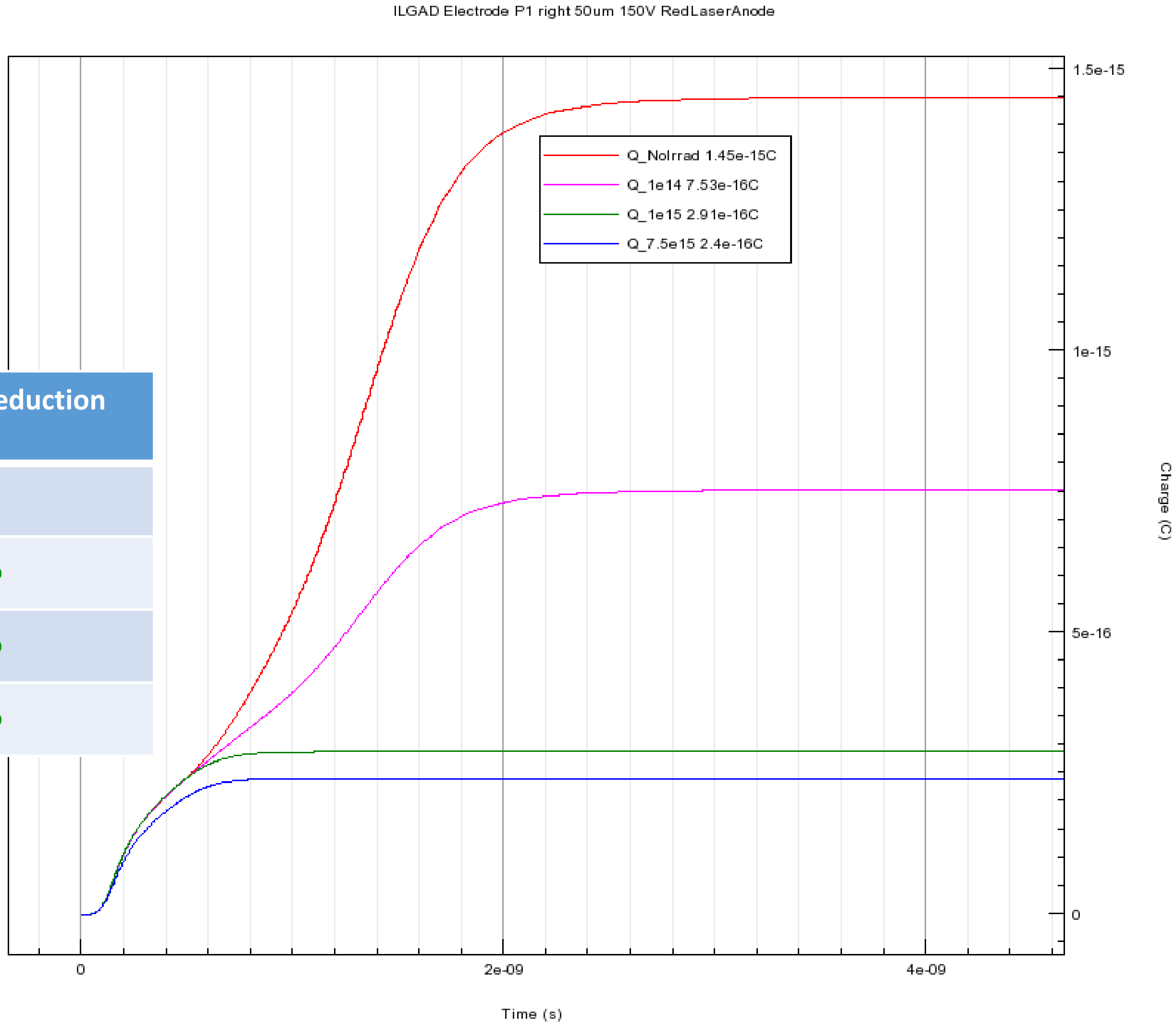


Fluence n/cm²	Charge P1 Right ILGAD (fC)	% of reduction
NoIrrad	2,29e-1	-
1e14	1,37e-1	59,8%
1e15	6,03e-2	26,3%
7,5e15	3,22e-3	1,4%



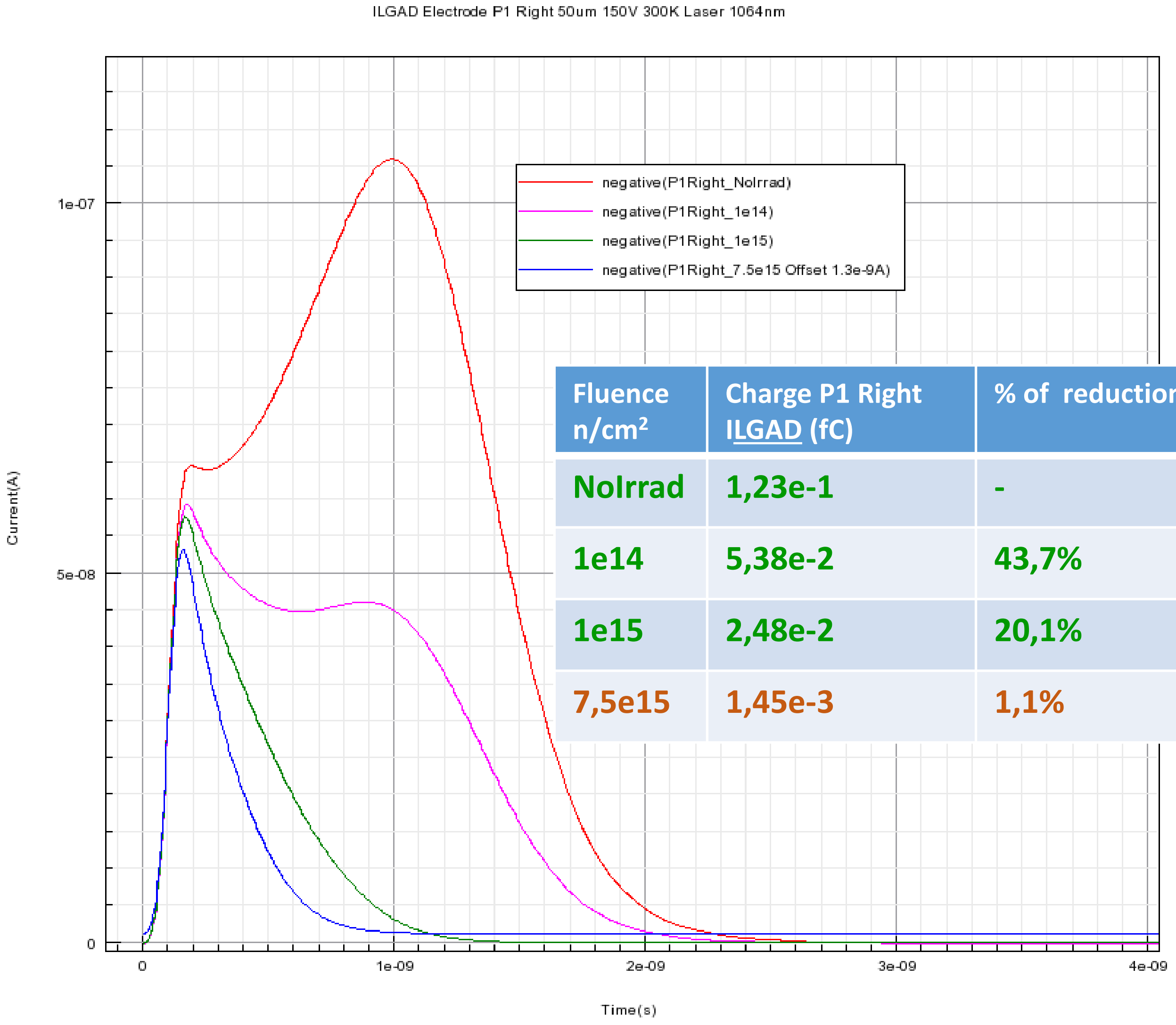
LGAD 50 um RedLaserBack 300K Irradiation P1 Right



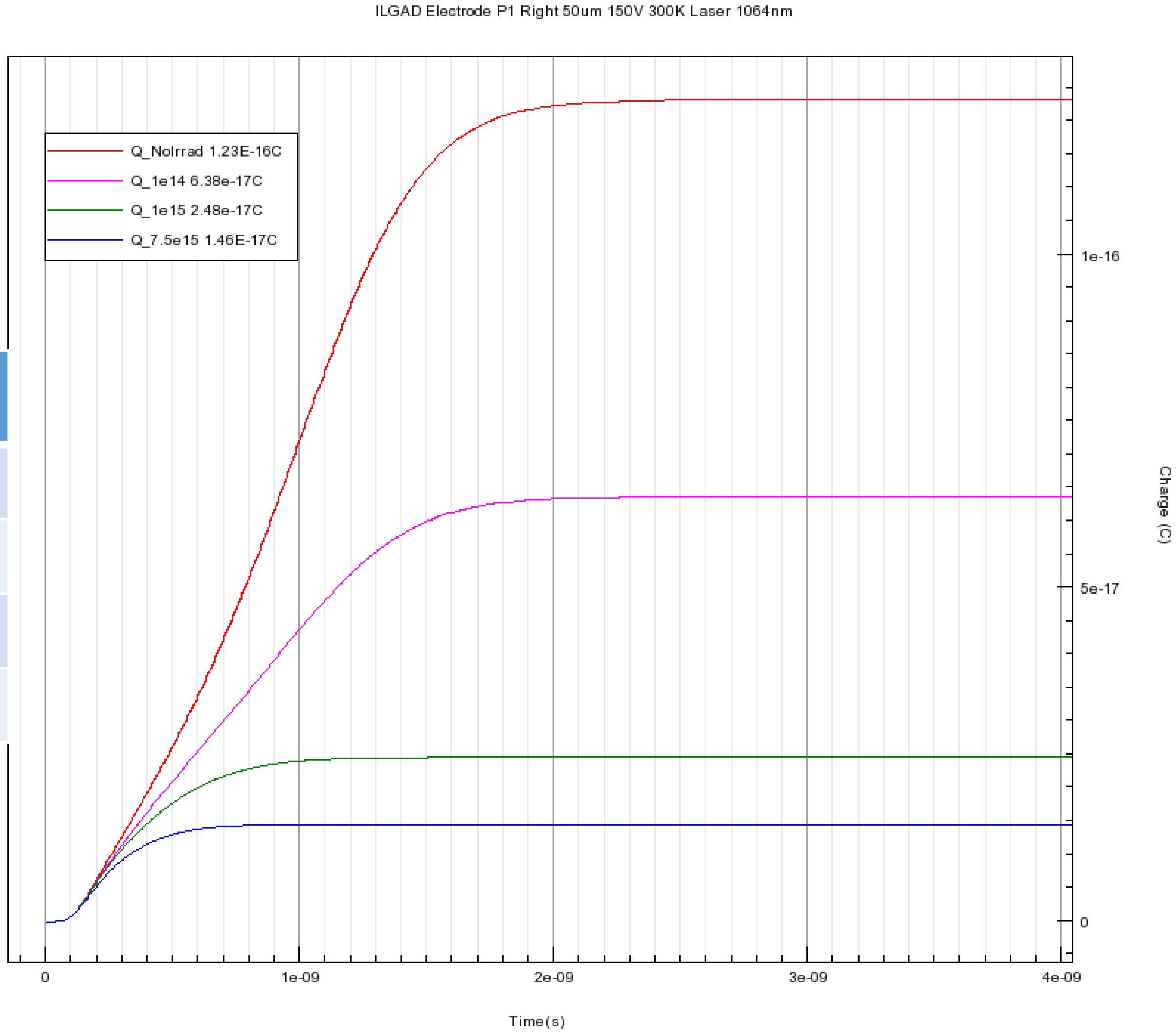


Fluence n/cm^2	Charge P1 Right ILGAD (fC)	% of reduction
NoIrrad	1,45	-
1e14	7,52e-1	51,8%
1e15	2,91e-2	20,1%
7,5e15	2,4e-1	16,5%

LGAD 50 um IR Laser 300K Irradiation P1 Right



Fluence n/cm²	Charge P1 Right ILGAD (fC)	% of reduction
NoIrrad	1,23e-1	-
1e14	5,38e-2	43,7%
1e15	2,48e-2	20,1%
7,5e15	1,45e-3	1,1%



Conclusions

- The ILGAD model shows reasonable agreement with experiments (experimental results available are for a similar model, no exactly the same).
- The timing behavior (rising edge) at the central right anode strip shows no dependence with radiation
- The gain and signal general behaviour under irradiation is similar to the LGAD as expected
- As expected, the 50 μm device shows better behaviour under radiation

Thanks for your attention

fpalomo@us.es