Radiation Damage in Weightfiled2

Three main effects of **radiation damage on silicon sensors** have been observed:

- Change of the effective doping concentration
- Increase of leakage current
- Decrease of charge collection efficiency

For what concerns **Weightfield2**, the main changes to be implemented are:

- A reduction in the current signal (due to carrier trapping)
- A no longer linear E field (due to non uniformity of Neff)

So far just **the first one has been addressed**.

For the second point, I'm investigating how to model the quadratic E field observed due to the double junction effects.

A Model for Carrier Trapping

The starting point is that the decrease in the current due to trapping is considered exponential [1],[2],[3]:

$$I(t) = I_0 \exp(-t/\tau_{EFF})$$

where τ_{EFF} is the effective trapping time, and it's considered inversely proportional the fluence φ:

$$1/\tau_{EFF} = \beta\varphi$$

where β is an experimentally determined parameter expressed in cm^2/ns, which is temperature dependant (T_0 = 263K):

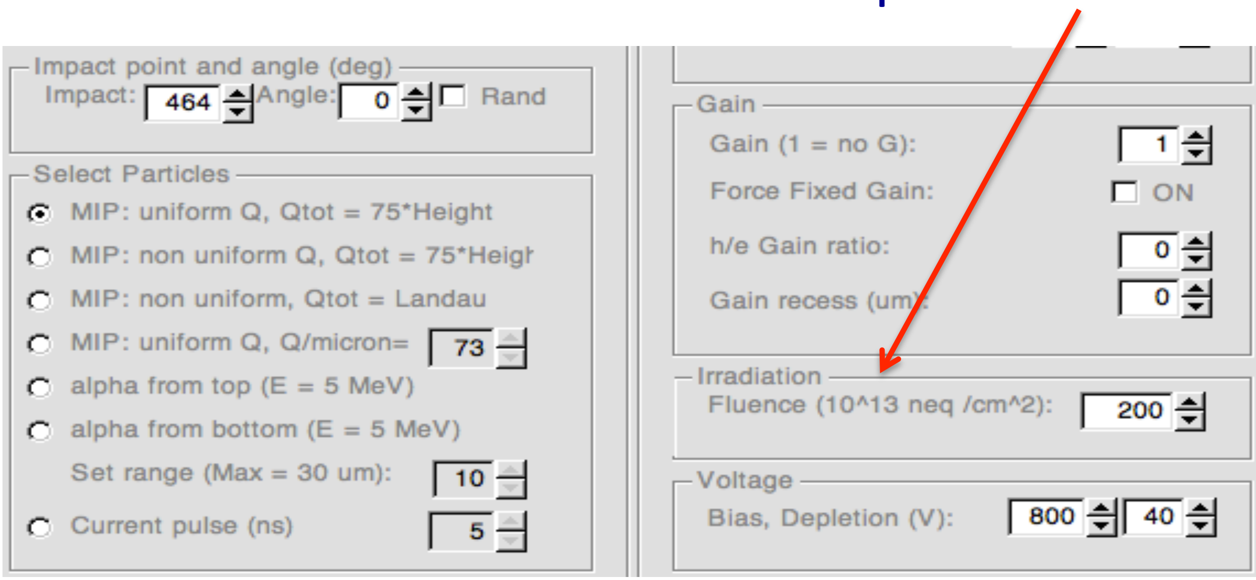
$$\beta(T) = \beta(T_0)*(T/T_0)^K$$

Thus a carrier gets trapped with probability per unit time:

$$P(trapping) = 1-\exp(-\beta\varphi)$$

Implementation in Weightfield2

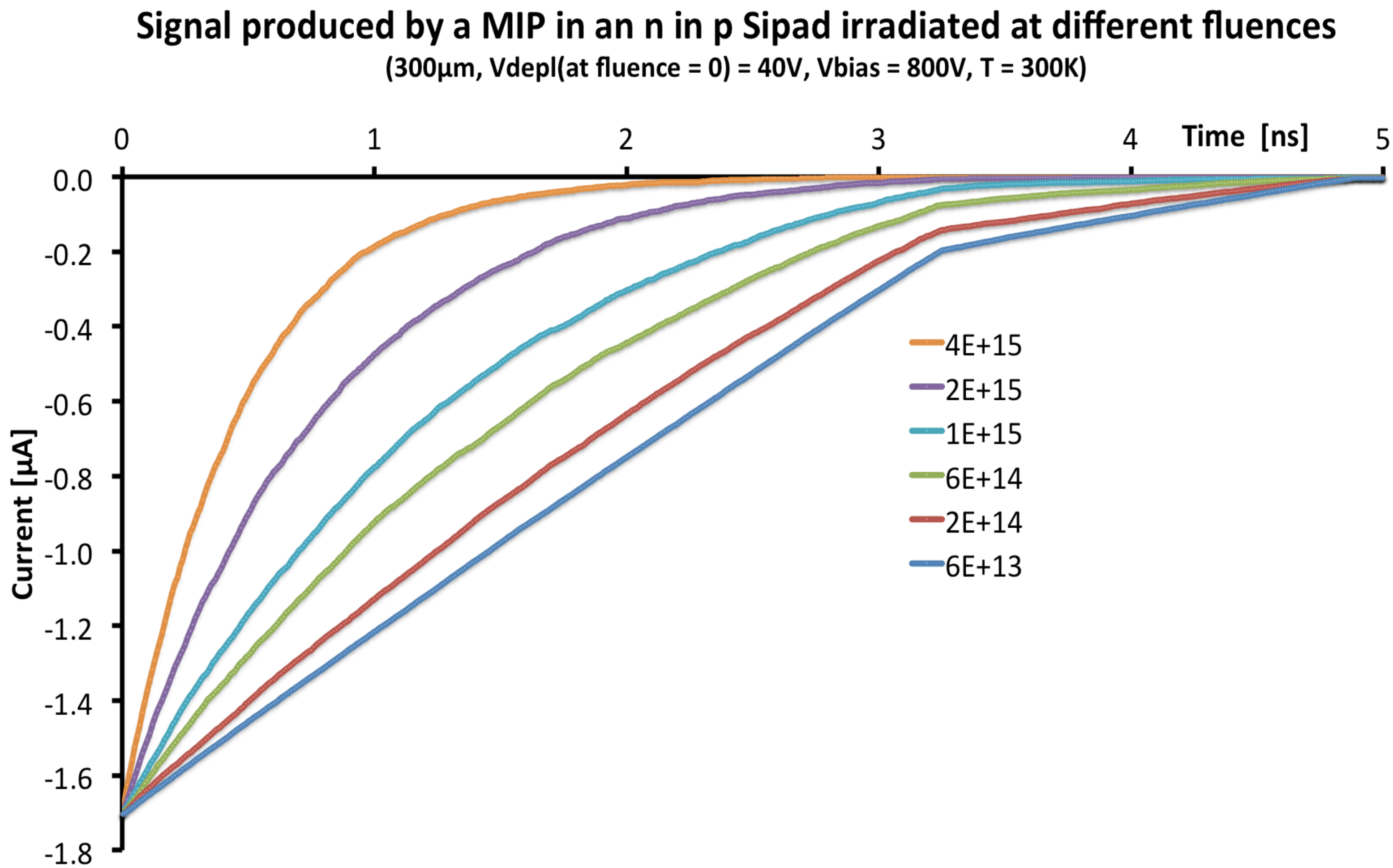
A window has been added to the GUI to input the fluence



At each time step, every carrier has a probability of being trapped that is calculated from the input fluence and values of β and κ taken from [1]:

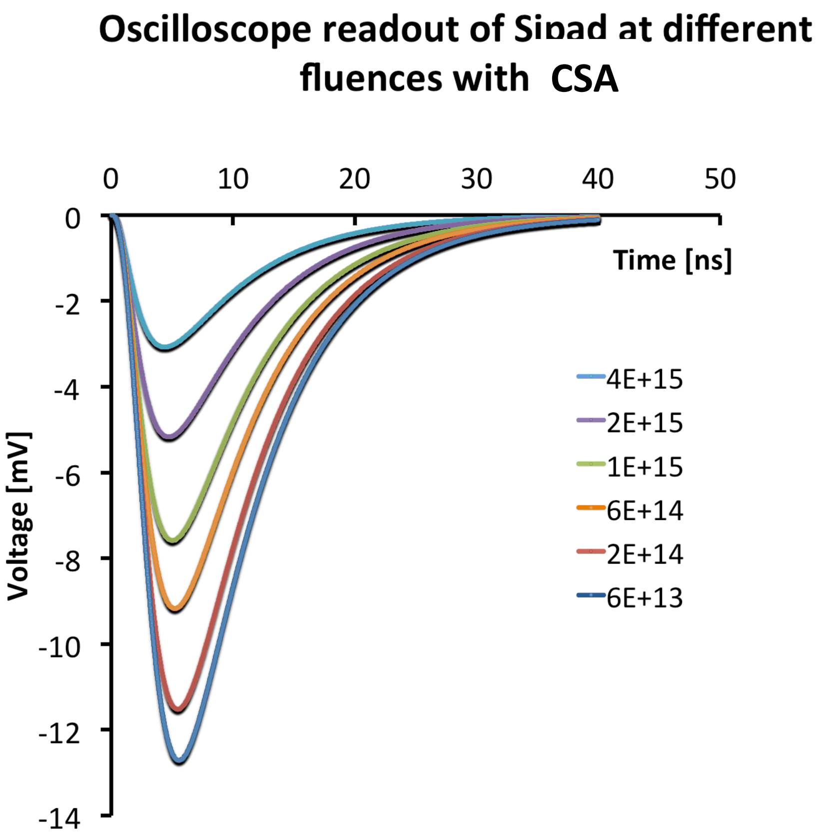
- β(electrons) = 4.1 ± 0.1 * 10^-16 cm^2/ns
- β(holes) = 6 ± 0.2 * 10^-16 cm^2/ns
- K(electrons) = -0.86 ± 0.06
- K(holes) = -1.52 ± 0.07

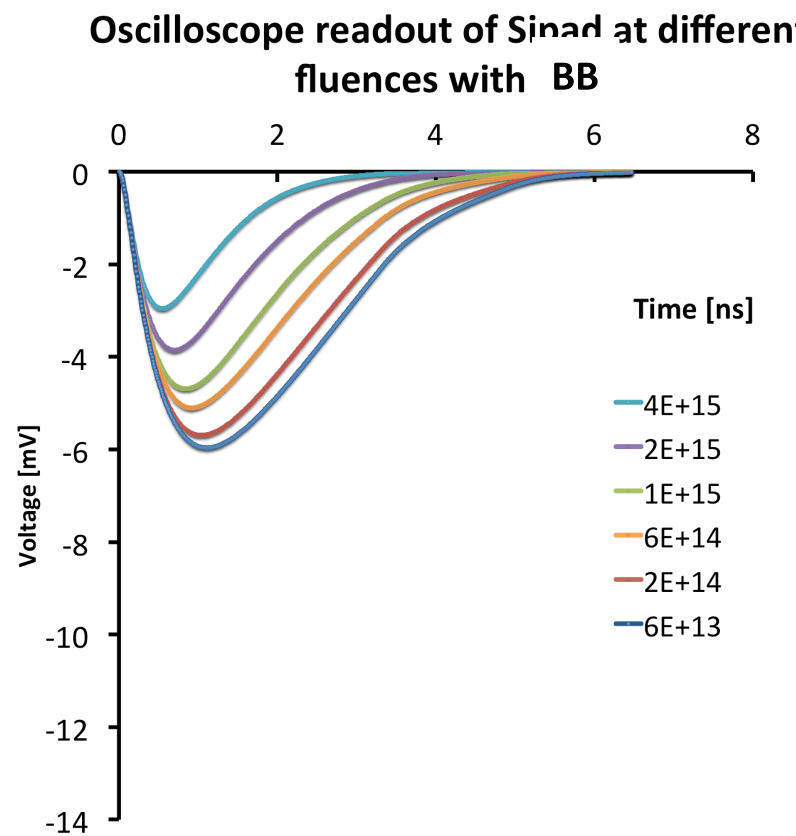
300 μm, No Gain:
Simulated Current for Different Fluences



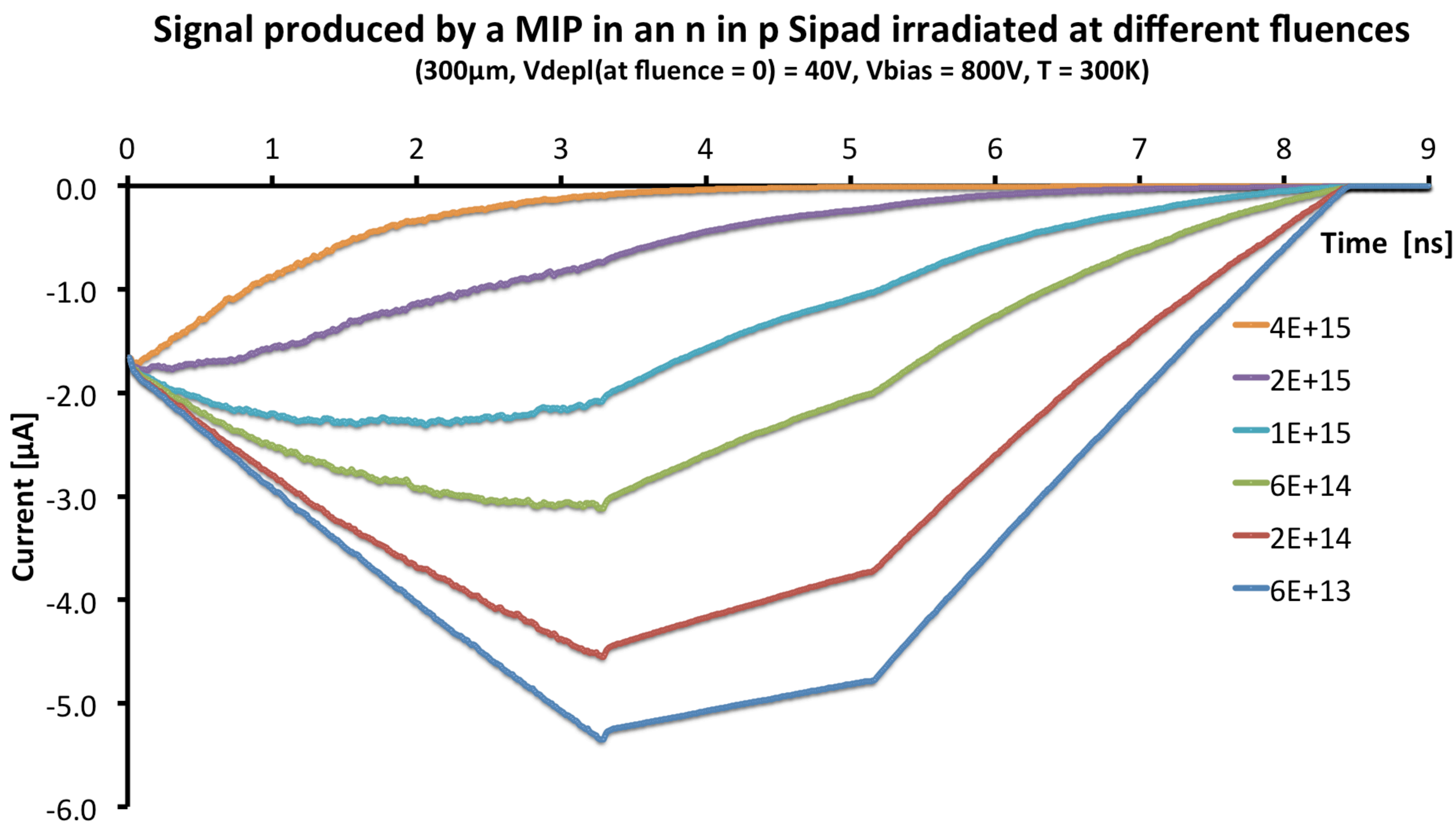
Bianca Baldassarri, CERN Summer Student 2015

<u>300µm, No Gain:</u>
<u>Simulated Signal Electronics for Different Fluences</u>





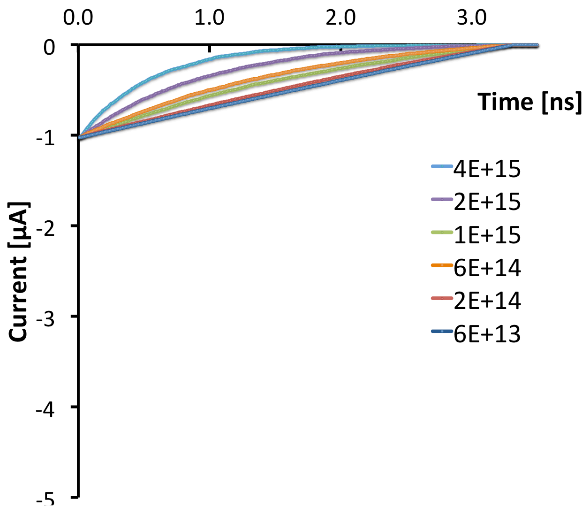
300µm, Gain = 10:
Simulated Current for Different Fluences



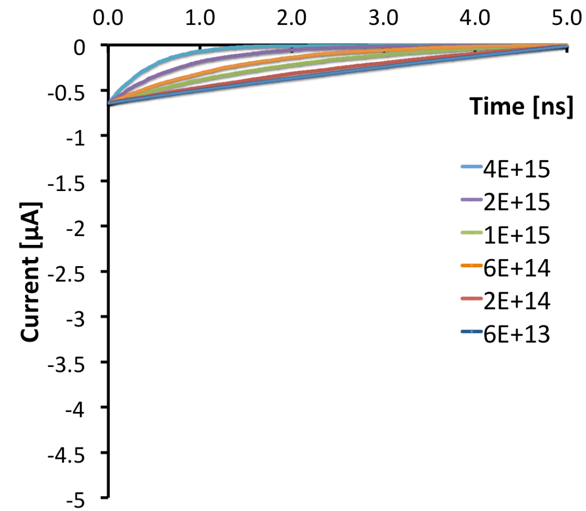
300μm, Gain = 10:

Signal Components

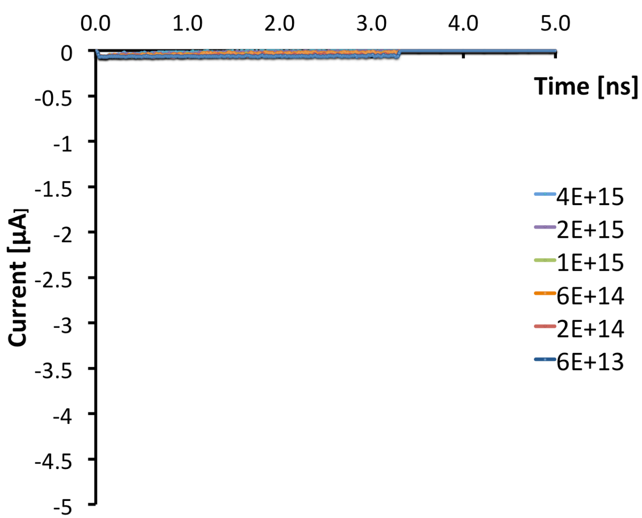
Electron current at different fluences



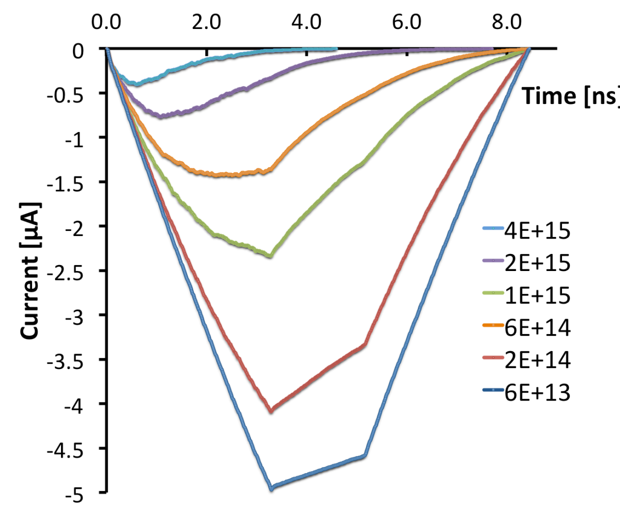
Hole current at different fluences



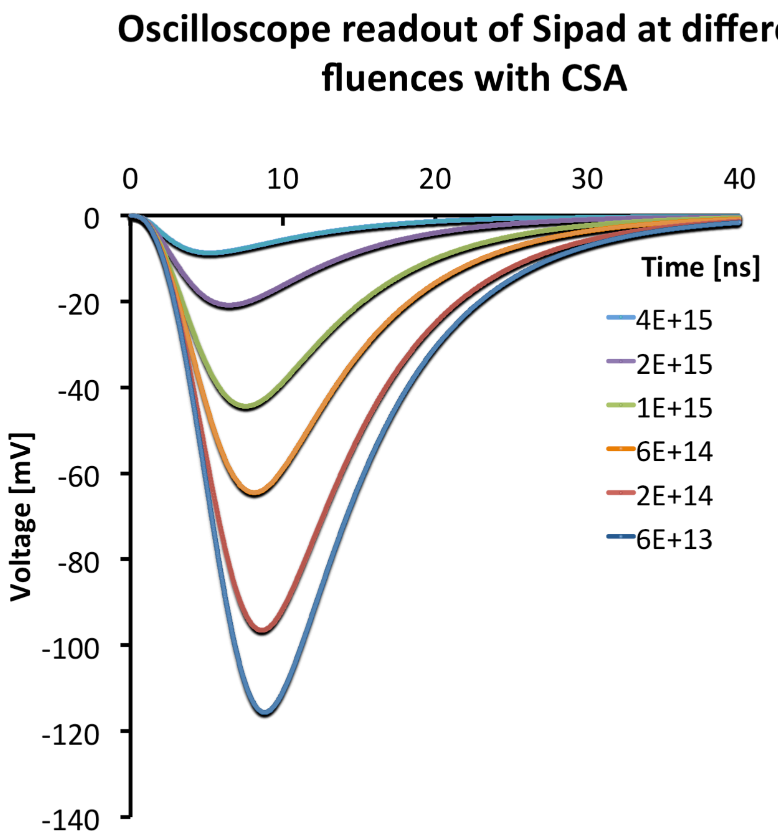
Gain e current at different fluences

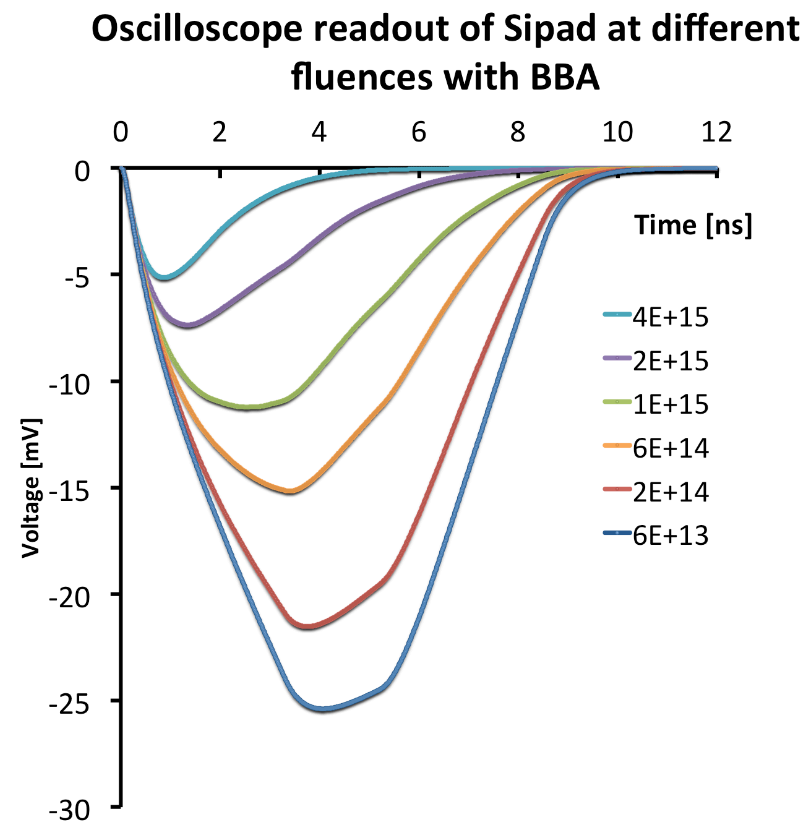


Gain hole current at different fluences

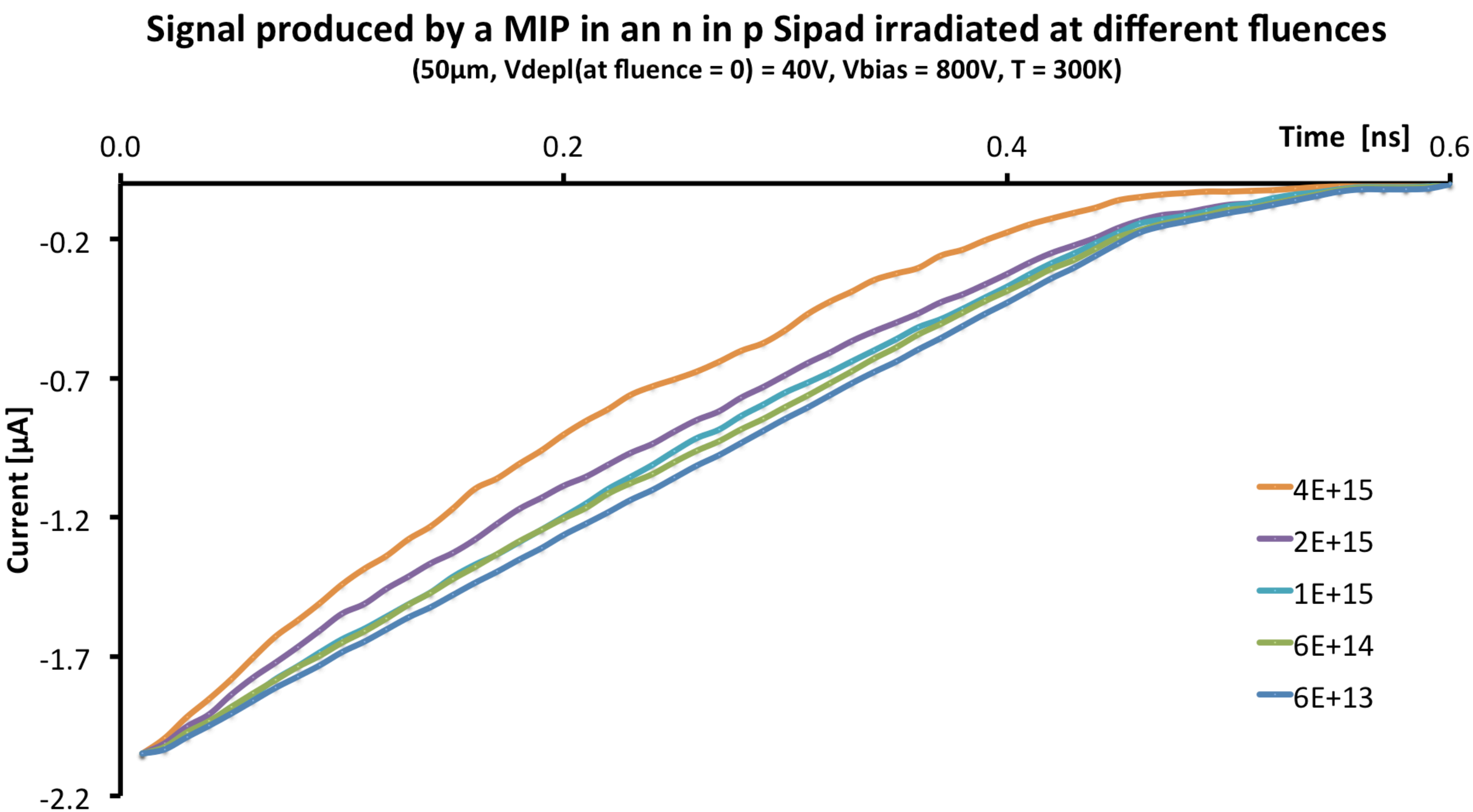


300µm, Gain = 10:
Simulated Signal Electronics for Different Fluences



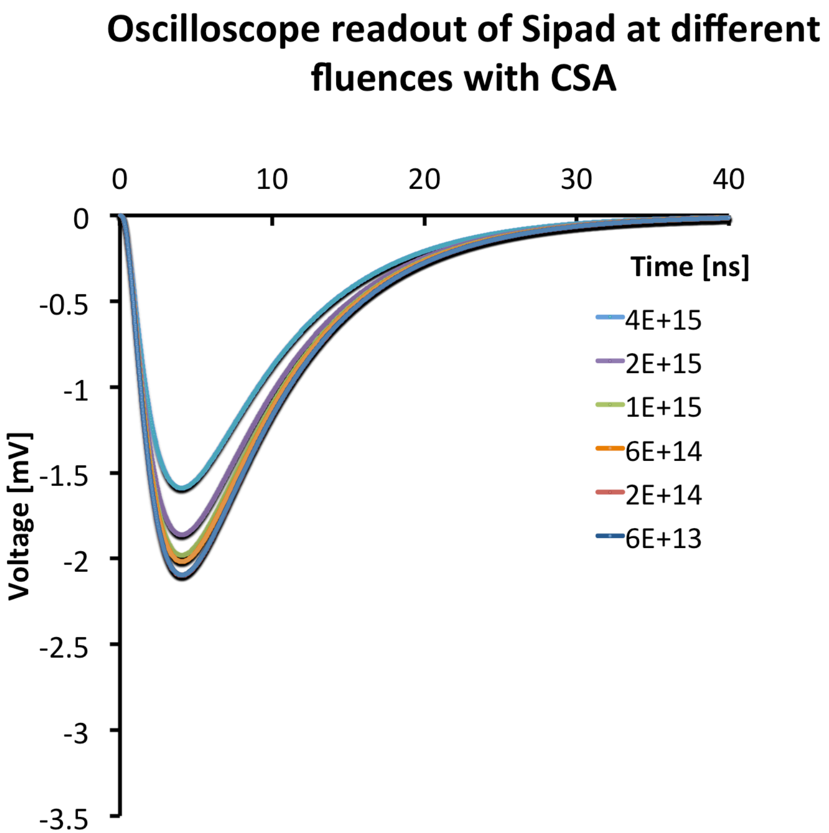


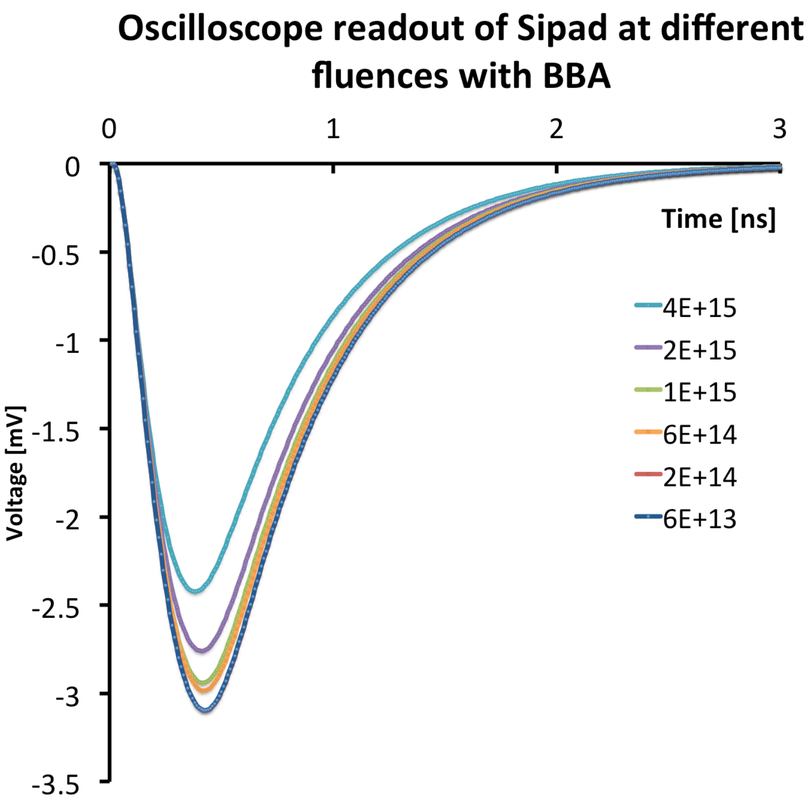
50 µm, No Gain:
Simulated Current for Different Fluences



50µm, No Gain

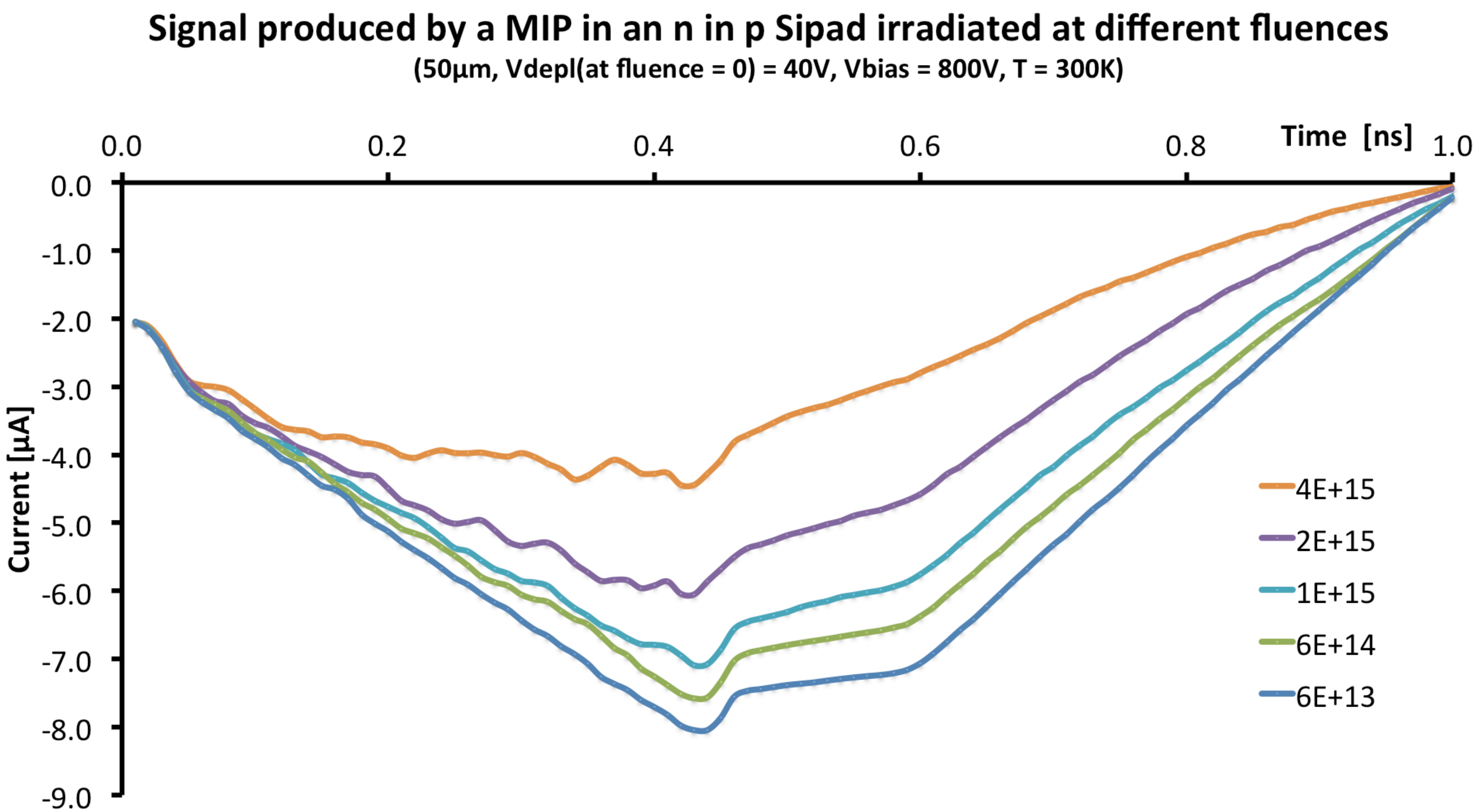
Simulated Signal Electronics for Different Fluences





50µm, Gain = 10:

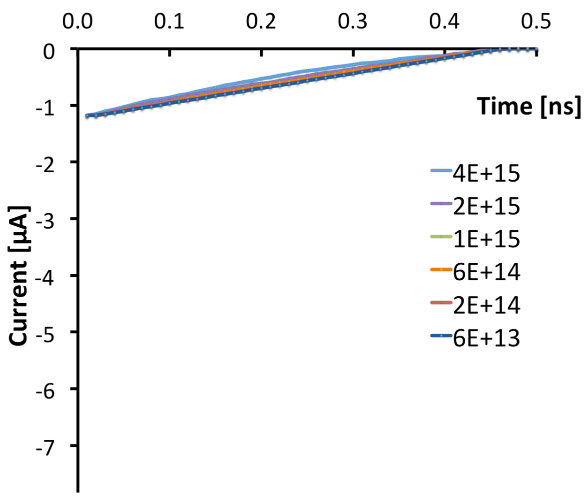
Simulated Current for Different Fluences



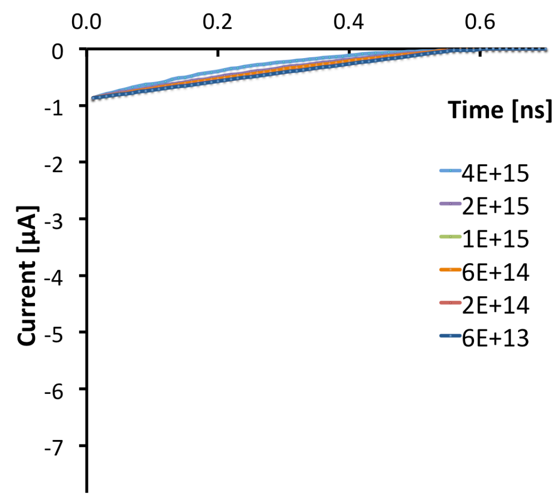
50µm, Gain = 10

Signal Components

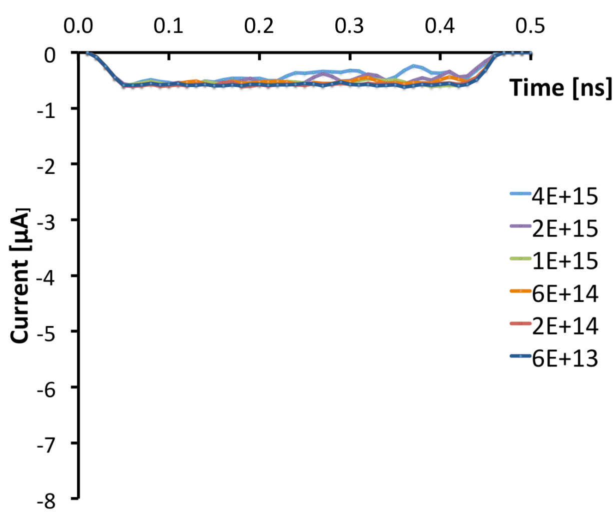
Electron current at different fluences



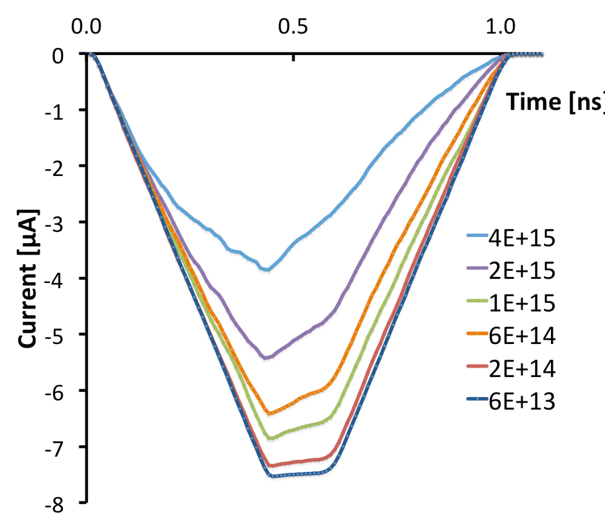
Hole current at different fluences



Gain e current at different fluences

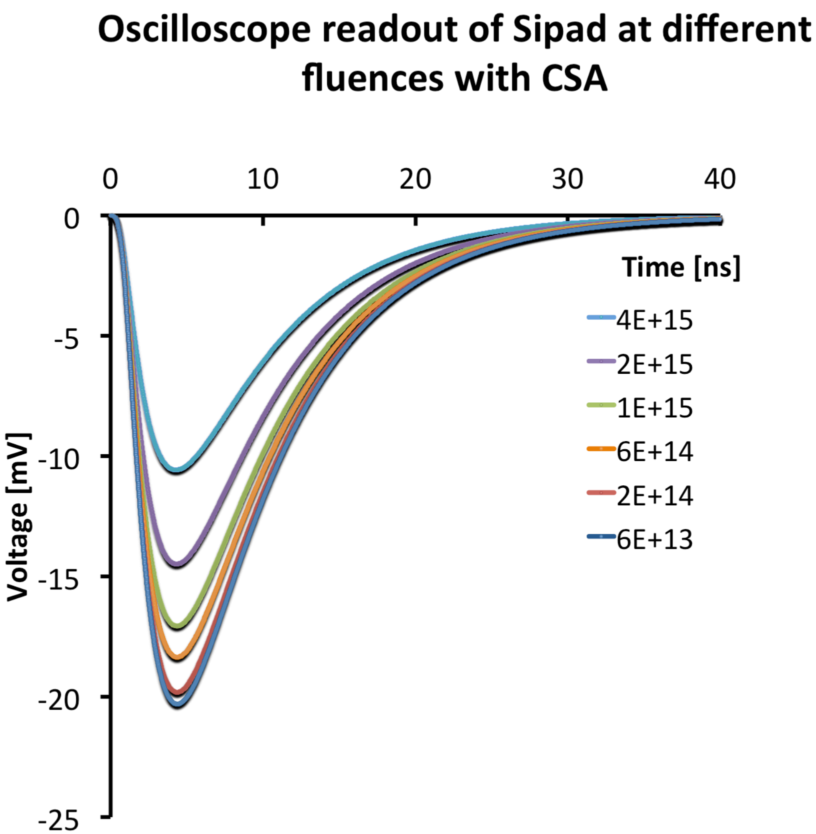


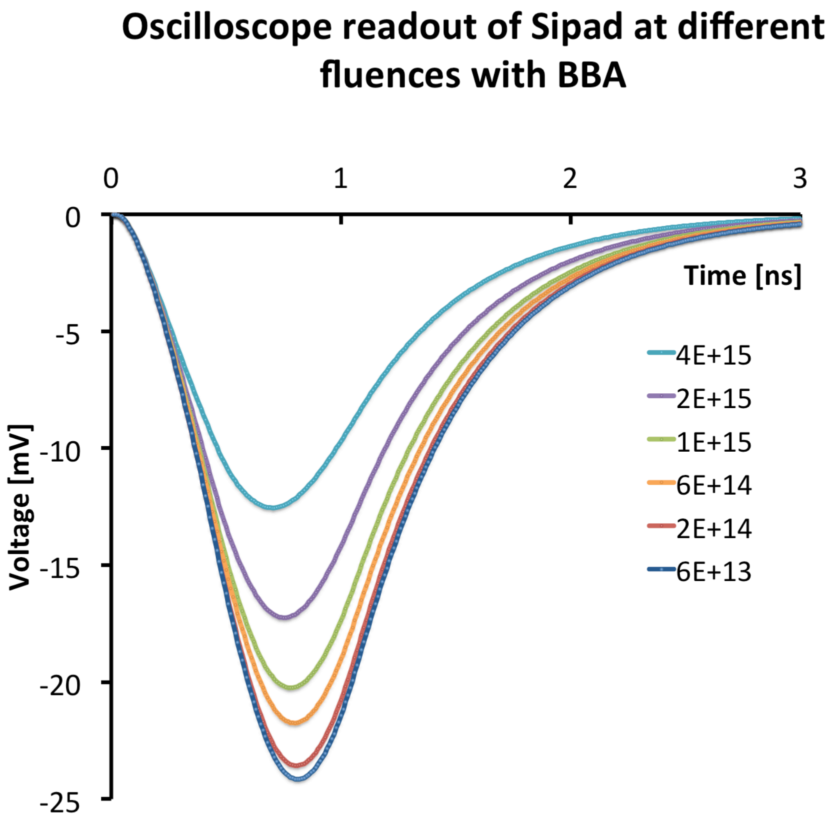
Gain hole current at different fluences



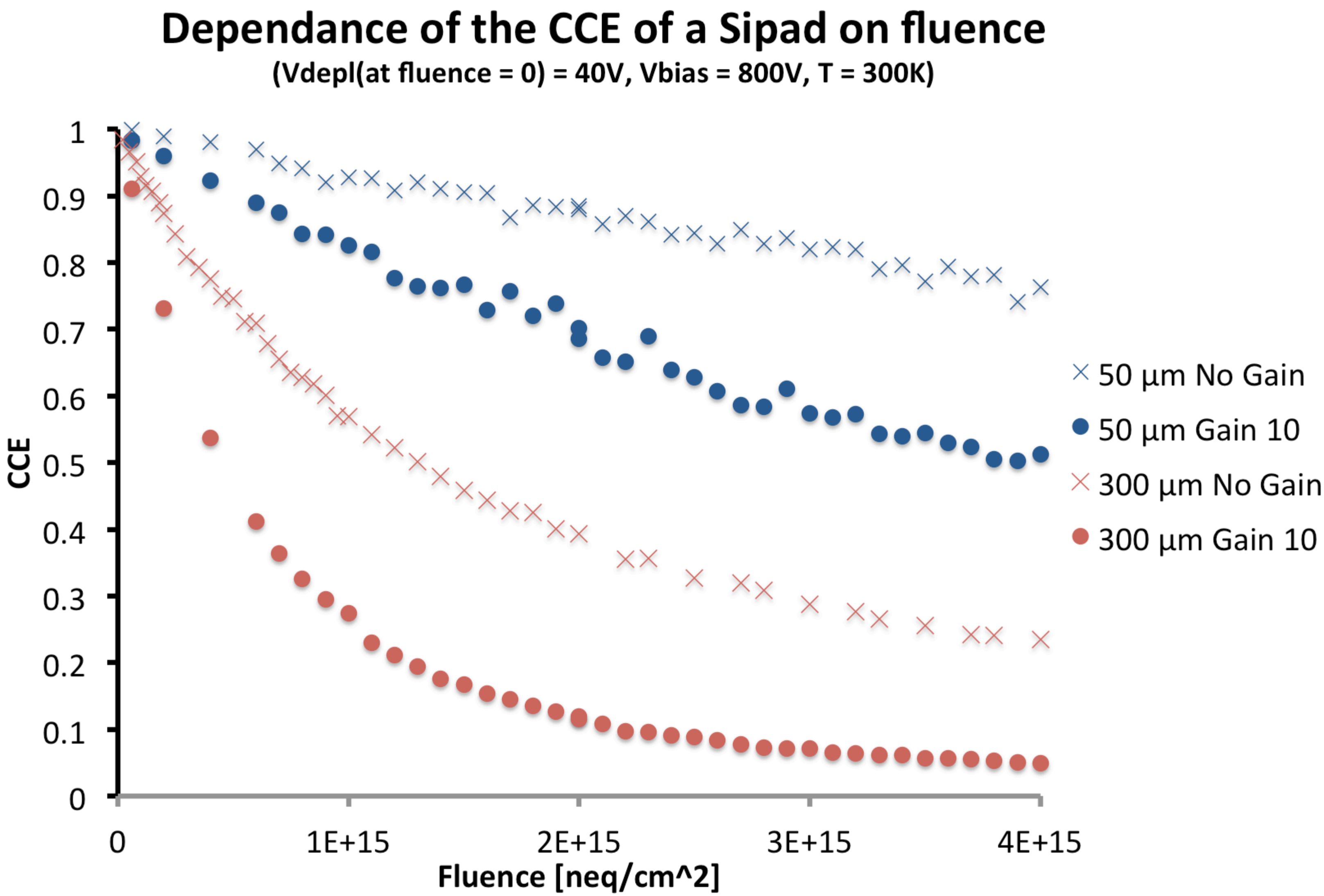
50μm, Gain = 10

Simulated Signal Electronics for Different Fluences





Simulated Charge Collection Efficiency as a function of Fluence



Warnings and Side Notes

1. **β is experimentally determined**

- Various researches show different results (sometimes in contrast with each other [2],[3],[4]). The data from [1] were chosen being the most complete amongst the sources examined.
- The value is always determined for a limited fluence range (extension to other fluences might well be incorrect)
- Simulations with other values of β from different articles have been conducted without seeing significant differences in the results

2. **Voltage dependant trapping**:

- The CCE has been observed to increase with Vbias (even well above Vdepl)
- Attempt to model a voltage dependant trapping time [5]:

  $\tau_{EFF} = \tau_0 + \tau_1(\text{Vbias-Vdepl})/100\text{V}$

  where τ_1 is again experimentally determined however the data is scarce
- The CCE correct dependence is most probably on E rather than on V

3. Differences in charged and neutral hadron irradiation :

- Charged hadrons produce only point defects while neutrons generate a large number of cluster defects
- The change in Neff is different, also with regards to type inversion [6], [7]
- Different values of β have also been observed, but again with no significant difference in the signal

4. Charge multiplication effects

- At high fluences and high voltages the charge multiplication has been observed to improve, and even push CCE greater than 1 [8]

5. Change in carrier mobility:

- A dependence of the carrier mobility on fluence has been observed [9], really limited data has been found on the topic
- The parameterization from [9] has been implemented in the model with modest changes in the output, and has thus been discarded also because it covered only the electron mobility and not the hole mobility

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⑤ J. Lange "Radiation Damage in Proton – Irradiated Epitaxial Silicon Detectors", Physikalische Diplomarbeit, Universität Hamburg (2008), 73-74

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⑧ G. Casse"Charge Multiplication In Highly Irradiated Planar Silicon Sensors", Procedings of Science (2010)

⑨ J.V.Vaitkus, A.Mekys, V.Rumbauskas, J.Storasta, "Analysis Of Electron Mobility Dependence On Electron And Neutron Irradiation In Silicon "