NOTES
on
Irradiated Detectors Simulation

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1a. There was a long discussion on the physics of current generation in the sensitive volume of irradiated detectors at the last RD50 workshop (2013 Nov. CERN). It was stimulated by the problem of temperature dependence of the bandgap in semiconductors.

Since the carrier generation rate is defined by the largest transition energy from the deep level to the conductance/valence band, the gap temperature dependence disappears from the mathematical equation.

The experimental data show the linear Arrhenius plots in a wide range of T, which allows unambiguous definition of the current activation energy.

1b. Then the generation current can be explained in terms of a single effective current generation level, or expressed as a combination of two (or more) deep levels, which occupancy by electrons and holes also affects the electric field distribution in the detector bulk. The details can be found in the recent paper [E. Verbitskaya, et al., NIM A 754 (2014) 63], which we propose to use as a common database for detector simulation.

Therefore it is suggested to accept the following conclusions:

♦ $E_g(T)$ will be used where it is directly related with the band-to-band process like the dependence of the intrinsic concentration on temperature.

♦ At the same time the temperature dependence will be disregarded for the definition of the activation energy of the midgap levels, which is defined from experimental data.

2. Comparison of parameterization of the current generation in proton and neutron irradiated detectors shows an insignificant difference.

This is a clear indication that the proposed current parameterization is valid for detectors after mixed irradiation. An additional argument to accept the proposed parameterization is that the current is a second-order factor which affects CCE via distortions of the electric field profile in the detector bulk.

Conclusion:

For simulation of any "mixed irradiated" detector the parameters specified in NIM A 754 (2014) 63 will be used for comparison of the results of simulations done in the frame of Simulation working group (SWG).

3. To calculate CCE, the dependence of the drift velocity on the electric field is essential. There are several parameterizations of the drift velocity. To start CCE calculation, we propose to use our parameterization of the drift velocity (see V. Eremin, et al., NIM A 535 (2004) 632):

$$v_n(E) = \frac{\mu_{no} E}{[1+(\mu_{no} E/v_{ns})^{1/b_n}]^{b_n}}$$

$$v_p(E) = \frac{\mu_{po} E}{[1+(\mu_{po} E/v_{ps})^{1/b_p}]^{b_p}}$$

Table 1
Transport parameters of free carriers used in Eq. (9) for drift velocity calculation

Parameter	Electrons	Holes
μ_o	$9.97 \times 10^7 T^{-2.13} \exp(1-T/3.09 \times 10^8)$	$8.54 \times 10^5 T^{-1.075} \exp(1-T/124)$
v_s	$1.59 \times 10^7 \exp(-1.38 \times 10^{-3} T)$	$1.44 \times 10^7 \exp(-2.29 \times 10^{-3} T)$
b	$-8.26 \times 10^{-8} T^3 + 6.817 \times 10^{-5} T^2 - 0.018467 T + 2.4292$	$2.49 \exp(-3.7 \times 10^{-3} T)$

In case you'll use different parameterization, please compare your *v(E)* with the data calculated using the equations shown above. I expect that these data will be a starting point.

4. After discussion at the previous meeting in Nov 2013 we got important contribution for the future development from Ljubljana group. Thanks Gregor for the weighting field parameterization in segmented detectors. This is essential for the signal simulation in position sensitive detectors, which we will start soon. The file prepared by Gregor is attached to this NOTES.

5. If your software allows calculating the current pulse response, please do this for comparison with the results of different groups.

6. I would like to remind you that we agreed to skip the following dependences in the simulations:

- mobility vs. doping and fluence,
- saturated drift velocity vs. doping and fluence,
- capture cross-section vs. electric field.

6. There are two related points mentioned in earlier discussions, which are still open:

♦ Whether the nonuniform profile of the midgap levels occupancy in the detector sensitive volume related with DP E(x) distribution influences on their current generation rate?

♦ Is there a current generated in a low-field region (in the active base between peaks in in DP E(x))?

7. To discuss in details presentations related to simulations we can conceder videoconference at the end of this month-beginning of July. Any ideas on the dates are welcome

Thank you for attention!

Weighting field parameterization in strips detectors

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The weighting potential is calculated for the strip detector segment of 9 strips as shown in the Fig. 1. The central strip (red) is assumed to be collecting strip with boundary condition of $U_w=1$ while all other strips and the back-plane are at $U_w=0$. Elsewhere at the detector borders the refractive boundary conditions were used. The weighting potential was calculated for several strip parameters (pitch, strip width) and thicknesses and 2D maps in the form of ROOT (http://root.cern.ch) histograms can be found in the file http://www-f9.ijs.si/~gregor/RD50/Ramo/RamoPotential.root. Using these histograms weighting field along any drift path in strip detector can be obtained. For the tracks through the strip(s) centre, which have due to symmetry reasons only the weighting field component in *y* direction, the weighting potential was extracted and can be parameterized as (no physics reasons for such parameterization though):

$$U_w(y) = \sum_{k=0}^{9} a_k \cdot y^k \qquad , \qquad E_w(y) = \sum_{k=1}^{9} k \cdot a_k \cdot y^{k-1}$$

where y is in [μm] and parameters a_k are obtained from the 9^{th} order polynomial fit to the calculated Weighting (also called Ramo) potential through the centre of the strips. An example of the determination can be seen in the Fig. 2 for tracks through the centre strip and two nearest neighbours. Note that the backplane is $y=0$ and strips are at y=thickness.

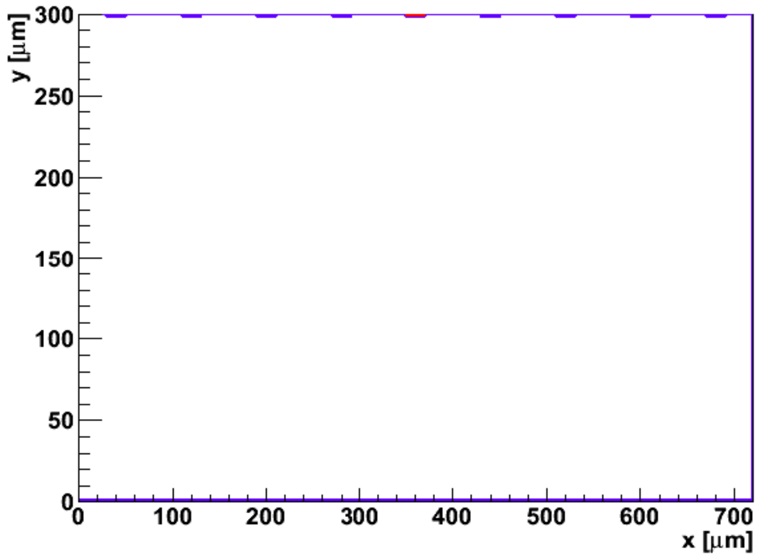

Figure 1: Example of simulated strip detector structure.

The parameters a_k are in the file http://www-f9.ijs.si/~gregor/RD50/Ramo/RamoParameters.dat . The file is composed of parameters for the each strip pitch, strip width and thickness as shown below. The first set of a_k are for centre strip and the next two for the two nearest neighbours.

Pitch=100.000000, Implant Width=40.000000, Thickness=300.000000

a0=1.161342e-03, a1=2.788111e-04, a2=4.164165e-05, a3=-1.405940e-06, a4=2.485248e-08, a5=-2.494755e-10, a6=1.481813e-12, a7=-5.136176e-15, a8=9.581388e-18, a9=-7.393198e-21,

a0=-8.316905e-04, a1=8.017866e-04, a2=-1.394304e-05, a3=4.775373e-07, a4=-8.423979e-09, a5=8.521306e-11, a6=-5.104946e-13, a7=1.787292e-15, a8=-3.374018e-18, a9=2.637804e-21,

a0=-2.378061e-04, a1=3.623112e-04, a2=-1.761211e-06, a3=5.674149e-08, a4=-1.016563e-09, a5=9.972925e-12, a6=-5.785218e-14, a7=1.942249e-16, a8=-3.484679e-19, a9=2.579311e-22,

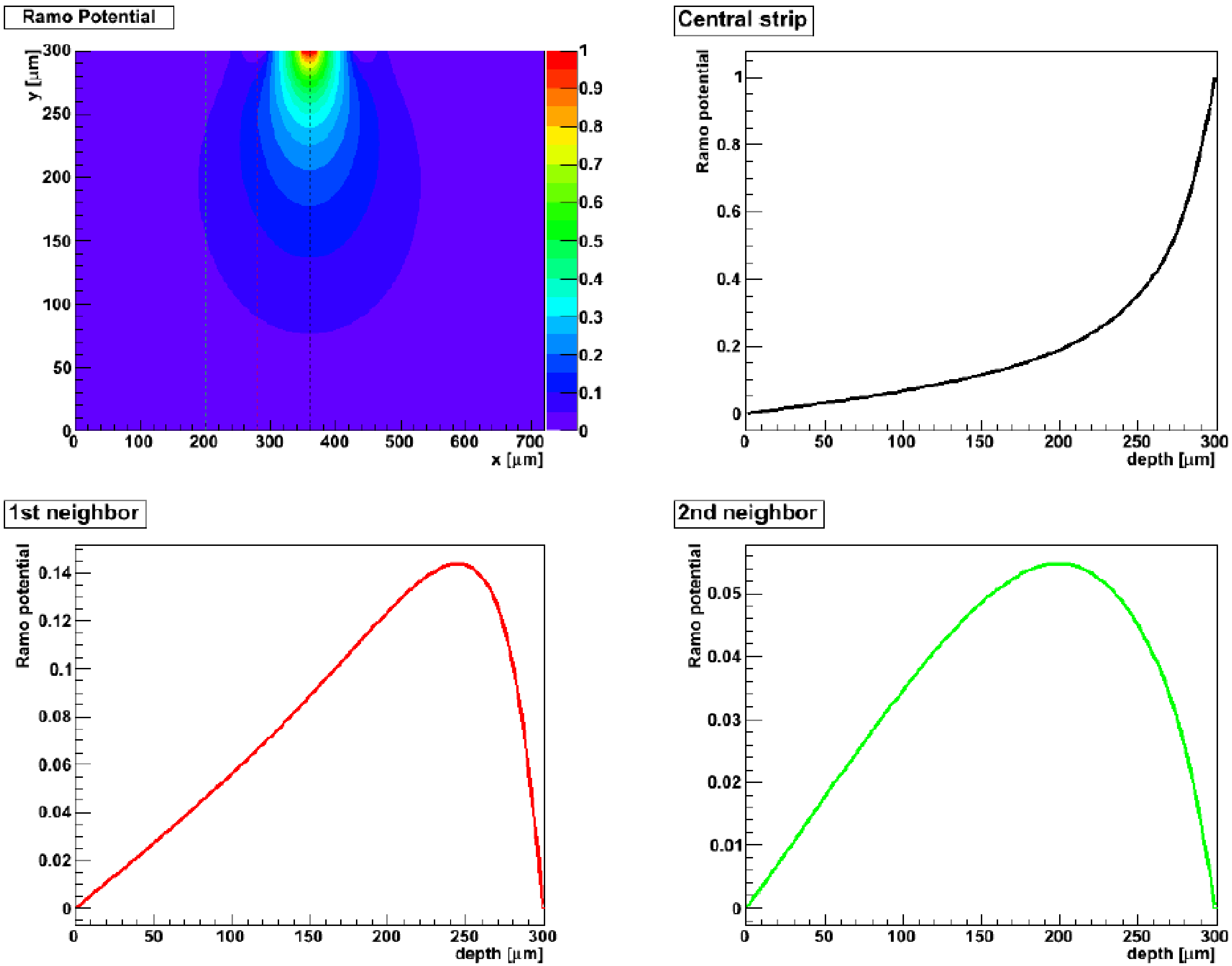

Figure 2: (top left) Example of calculated weighting potential for a strip detector shown in Fig. 1. (top rigth) Example of the weighting potential for the track through the center of the strip with the fit to the calculated values. (bottom) The same as “top rigth” plot, but for the two nearest neighbors. The tracks are denoted by the dashed lines in top left figure.

In case weighting potential for a special geometry in 2D (strip) and 3D (pixel, 3D detectors) etc. is required please contact: Gregor.Kramberger@ijs.si .