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Study of charge carrier transport properties and lifetimes in HR GaAs:Cr with Timepix3

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The response of a Timepix3 [1] (256 x 256 pixels, pixel pitch 55 μm) detector with a 500 μm thick HR GaAs:Cr [2] sensor was studied with proton beams at the Danish Centre for Particle Therapy in Aarhus, Denmark. The detector was irradiated at different angles with protons of 125, 171 and 219 MeV. The readout chip was configured to operate in electron or hole collection modes.

Measurements at grazing angles allow to see elongated tracks with well-defined impact and exit points, so that charge carrier production depths can be determined in each pixel. We extracted the charge collection efficiencies (Figure 1) and the charge carrier drift times (Figure 2) as a function of the distance to the pixel matrix plane.
It was found that measured proton tracks are shorter in hole collection than in the case of electron collection, which is explained by the shorter lifetime of holes. At the angle of 60 degrees with respect to the sensor normal, the average track length in hole collection is ˜600 μm, while it is 880 μm in electron collection mode.

To understand the experimental findings, models describing the properties of HR GaAs:Cr were implemented into the Allpix^2 simulation framework [3]. We added previously presented experimental results describing the dependence of the electron drift velocity on the electric field [4] and validated the response by comparing measurement and simulation or various X- and gamma-ray sources in the energy range from 5 –60 keV.

Results presented in Figure 1 and Figure 2 were reproduced in the simulation using the hole mobility μ_h = (300 ± 45) cm^2/V/s and the lifetime of holes as τ_h = (6 ± 2) ns. Further studies will include results seen for measurements at different proton energies and bias voltages.

[1] T. Poikela et al., 2014 JINST 9 C05013
[2] A.V. Tyazhev et al., 2003 NIM A 509 34.
[3] S. Spannagel et al., 2018 NIM A 901 164
[4] B. Bergmann et al., 2020 JINST 15 C03013

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