Estimation of the radiation damages of the Uppsala spectator detector

E. Białkowski[1], J. Majewski[2], P. Moskal[2], J. Uehlemann for the COSY–11 collaboration

The preparation of the Uppsala spectator detector [1] for use at the forthcoming COSY-11 experiments [2] was described in details in accompanying reports [3]. Here we present tests on the radiation damages due to the operation at the PROMISE/WASA facility, where the detector elements have been positioned at a distance of 11 cm from the interaction region of the circulating CELSIUS proton beam and the deuteron cluster target. At such circumstances an absorption of a high radiation dose which could cause significant structural defects in semiconductor material is expected. Therefore, it is important to identify its influence and accordingly perform a temperature annealing before the next application.

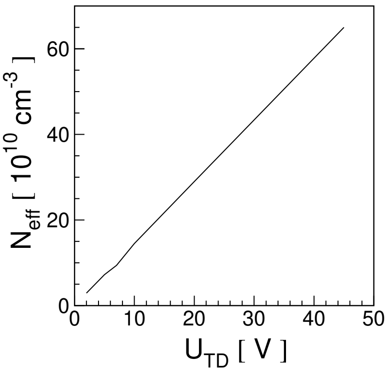

Fig. 1: Relation between total depletion bias voltage and the doping concentration for n-type silicon semiconductors [4].

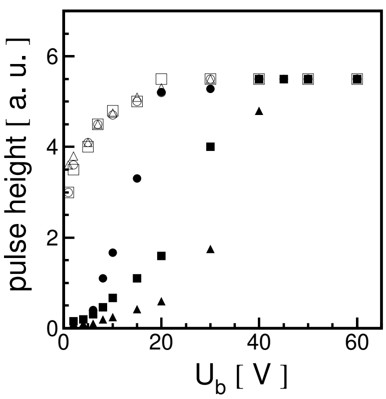

Fig. 2: Pulse height of the detector signals due to the illumination by monoenergetic alpha particles from the front (open symbols) and rear (full symbols) side, as a function of the applied bias voltage. As examples, result for three different detection pads is shown.

The appraisal of the irradiation can for example be performed by measuring the effective impurity concentration which diminishes with the growing number of defects in the active volume of the detector. One can uniquely relate the doping concentration to the thickness of the depleted region and the applied external bias voltage [4]. This dependence is shown in Figure 1 for the case of a 300 μm thick depletion for n-type material. Thus, knowing the detector thickness and the total depletion voltage one can estimate the effective impurity concentration in the detector. Since the total depletion voltage of the considered n-type 300 μm semiconductor silicon detectors, before usage in the Uppsala experiments, amounted to U_{TD} = 45 V, the impurity concentration was about 6.5 x 10^{11} cm^{-3}. For the estimation of the present value of the total depletion voltage we have irradiated the front and rear electrodes of the detector by short range monoenergetic 5.5 MeV ($\sim$ 25 μm in silicon) alpha particles emitted from a ^{241}Am isotope. Figure 2 shows that already at bias voltages U_b about 10 V a total depletion is achieved. Such a low total depletion voltage (U_{TD} = 10 V) indicates that the detectors were exposed to the radiation fluence which reduces the impurity concentration about a factor of ten. A similarly small value for U_{TD} was determined from the measured C-V characteristics. The irradiation was most probably caused by electrons since the last experiment with the detector was finished more than two years ago, and during that time the effect of self annealing at room temperature would be much stronger if the damages had been caused by protons or neutrons. Though at present, as shown in accompanying reports, the detectors still permit measurements with sufficient energy resolution, in order to ensure operability for next years a temperature enhanced annealing will be applied.

In order to optimize the bias voltage for the use in the COSY–11 experiments we checked also the changes of the signal width as a function of U_b. The ADC converters which will be used in the experiment [5] allow for the integration of signals up to 2 μs. Therefore, as can be deduced from Figure 3, bias voltages lower than 40 V should be avoided.

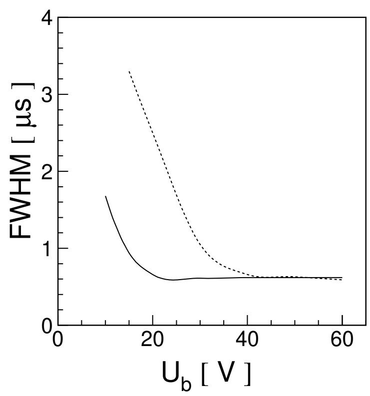

Fig. 3: Full signal width at half maximum as a function of an applied bias voltage. For pads of dimensions: 0.5 x 2.0 x 0.03 cm^3 (solid line) and 1.5 x 2.0 x 0.03 cm^3 (dashed line).

References:

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[2] P. Moskal, T. Johansson et al., COSY Proposal#100, April 2001, see also e-Print Archive: nucl-ex/0110001.
[3] J. Majewski et al., and R. Czyżykiewicz et al., contributions in this report.
[4] D. E. Groom et al., Eur. Phys. J. **C 15** (2000) 1.
[5] ADC 1885F, LeCroy Corporation, 700 Chestnut Ridge-Road, Chestnut Ridge, New York 10977, USA.

[1] Institute of Nuclear Physics, 31–342 Cracow, Poland
[2] Institute of Physics, Jagellonian University, 30–059 Cracow, Poland