Pulse shape discrimination between light charged particles using Si detectors

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At the S-DALINAC facility of TU darmstadt, we have used a new experimental method to determine the proton charge radius with elastic electron proton (ep) scattering at low momentum transfer, where instead of detecting the scattered electrons, the recoil protons are detected in a set of Si detectors [1, 2]. A halo-free, pulsed beam of 3 ns width and 50 ns repetition rate was used in order to distinguish the electron-induced background from the recoil protons, which is more critical at backward angles because of the low proton energies. At backward angles the protons are very well separated from the electrons, but at forward angles they are not. An alternative method could be to use pulse shape discrimination between protons and electrons at forward angles. Pulse shape discrimination (PSD) has been widely used in nuclear electronics for many years. It has application in particle identification in Si detectors. Recently, disrimination of intermediate mass fragments and of light charge particles has been demonstrated [3]. Discrimination between protons and alpha particles is also reported [4]. PSD is a very powerful tool for charge particle identification. For heavier particles, plasma erosion has a strong influence on the current shape also, what is not the case for light particles. For the light particles, pulse shape depends on finite drift time of charge carriers. Finite drift time of charge carriers is given by

$$v_e = \mu_e E, v_h = \mu_h E \tag{1}$$

where μ is the mobility of the charge carrier and E is the electric field. The mobility of the electrons is three times the mobility of the holes. In case of front side injection of light particles, the current pulse is dominated by electrons. As a result, the drift time is small and there is not much difference in the drift time for different light charged particle injection. However, in the rear side injection, the current pulse is dominated by holes and there is a significant difference in the drift time for different light charged particle injection.

A. Fazzi *et al.* [5], have shown that for a one MeV deposited energy, protons and electrons are very well separated using PSD method, if they are injected from the rear side of the Si detectors.

In this paper, we report the pulse shape discrimination (PSD) between electrons and alpha particles. For a good pulse shape discrimination using Si detectors, high homogeneity of the silicon material and fast low-noise front-end electronics are required. We have developed Si surface barrier detectors from homogeneously neutron-transmutation (nTD) doped silicon for PSD. nTD material was first used for PSD in [6]. Si detectors (thicknessses 800 μm) were irradiated from front and rear sides with alpha particles from an ^{241}Am source. The detectors were run at twice the bias required for full depletion. The range of $\sim$ 5 MeV alpha particles (25 μm) is negligible compared to the detector thickness. Therefore, current is dominated by electrons (in case of front side injection) or holes (in case of rear-side injection) moving towards opposite electrodes. Fig. 1 shows the energy versus time difference in case of front side as well as rear-side injection of alpha particles from an ^{241}Am source. Here, time difference is related

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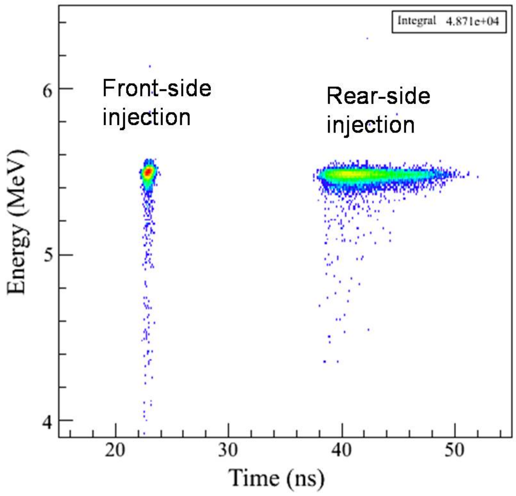

FIG. 1: Measured two-dimensional spectrum of energy versus time using ^{241}Am source

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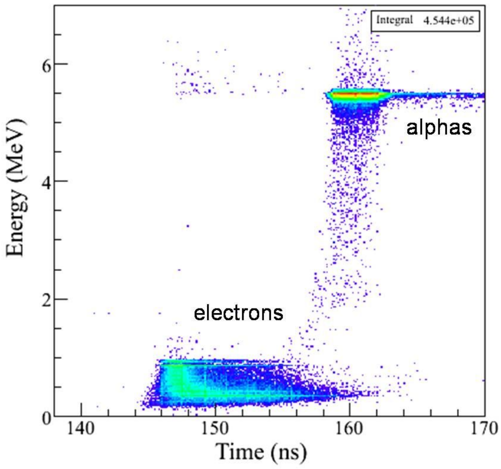

FIG. 2: Measured two dimensional spectra of energy versus time using ^{241}Am and ^{207}Bi source

to the drift time of the charge carriers. For pulse shape discrimination (PSD), light particles were injected from the rear side (reverse mount). Fast differentiated timing signal coming from the preamplifier is splitted into two parts. One part of the signal is amplified in one channel of a TFA and sent to a fast leading edge discriminator to generate the start signal for the TDC. The second part of the signal is fed to another TFA and the inverted, differentiated output is send to leading edge discriminator which provides the TDC stop. The electronic setup is similar to the scheme realized in Ref. [6, 7]. Our aim is to separate protons and electrons at low energies. As there is no source which could give protons, we have carried out a test experiment in our detector laboratory, where alpha particles from ^{241}Am source and electrons from the ^{207}Bi were injected from the rear side (reverse mount) in the Si detectors. Fig. 2 shows a measured two-dimensional spectrum of energy versus time using ^{241}Am and ^{207}Bi source. As can be seen from the figure, the alpha particles and electrons are very well separated. The time resolutions obtained was around 2.5 ns. In conclusion, we have demonstrated that low energy light ions like alpha particles from an ^{241}Am source and electrons from a ^{207}Bi source can be separated. This method will be employed to *ep* scattering experiment to identify protons and electrons at low energies.

Acknowledgments

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