Startrack: Nanodosimetric Measurements with 5.4 MeV Alpha Particles

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INTRODUCTION

In the recent past we have studied, experimentally and by Monte Carlo simulation, the probability of formation of ionization clusters by 5.4 MeV primary alpha particles in nanometric volumes of propane at 300 Pa (20 nm of diameter when scaled at density 1.0 g cm^{-3}). Satisfactory results of the comparison between measurements and calculation have already been published [1]. The overall experimental set up has later been mounted on the +50° beam line of the Tandem-Alpi LNL particle accelerator complex. Several changes have been necessary to adapt the set up to the new experimental environment. New 5.4 MeV alpha measurements were done to compare with reference data.

THE SINGLE ELECTRON DETECTOR

The Startrack track-nanodosimetric counter consists essentially of an electron collector defining the sensitive volume (***SV***) and a single electron counter (***SEC***) made of a long cylindrical drift column (in which the initial electrons diffuse) and an electron multiplier, a multi-step avalanche chamber [1]. Electrons generated within SV are transferred into the drift column and finally arrive at the MSAC at different times. In the MSAC each electron is counted one by one and the number of detected pulses is related to the number of ionization in a cluster. Not all the initial electrons are collected. The total detection efficiency ε can be considered as the product of three components: the efficiency ε_{sv} of the electron collector, the efficiency ε_{drift} of the drift column and the detection efficiency ε_{MSAC} for single electrons at the MSAC.

One of the main changes in the apparatus has been the construction of a new MSAC. The MSAC is made of 5 grids, the first of which is grounded and the last is set to 750-850 V. The voltage is equally divided between the 5 grids. All the electronic circuits have also been changed, in particular the distribution chain of all low and high voltages. Because of that, the detection efficiency of the detector could easily be changed from what it was.

MEASUREMENTS

First of all we have tested the working conditions of the new MSAC at different high voltages, in order to find the value which maximizes the detection efficiency ε_{MSAC}. Different measurements have been performed with HV varying from 740 V to 820 V. The efficiency ε_{MSAC} can be evaluated analyzing the pulse height spectrum of collected electrons. Each spectrum is fitted by a Polya distribution [2], then the best fit is extrapolated to zero. The efficiency is evaluated as the ratio of the detected signals (above noise threshold) to the integral of the polya fit from the maximum voltage down to zero. Experimental results are shown in figure 1 (750 V), figure 2 (780 V) and figure 3 (800 V).

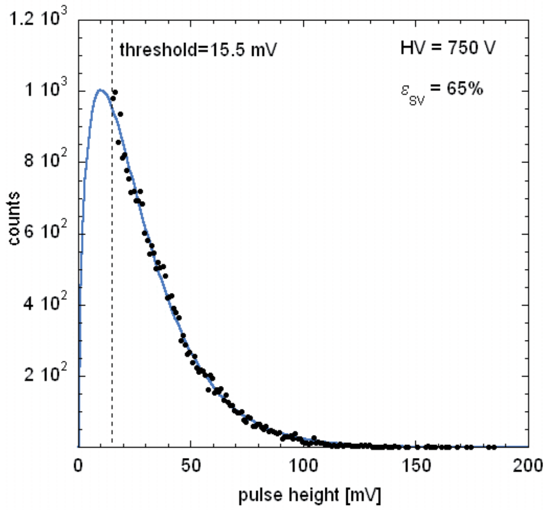

FIG. 1. *Pulse height spectrum at 750 V.*

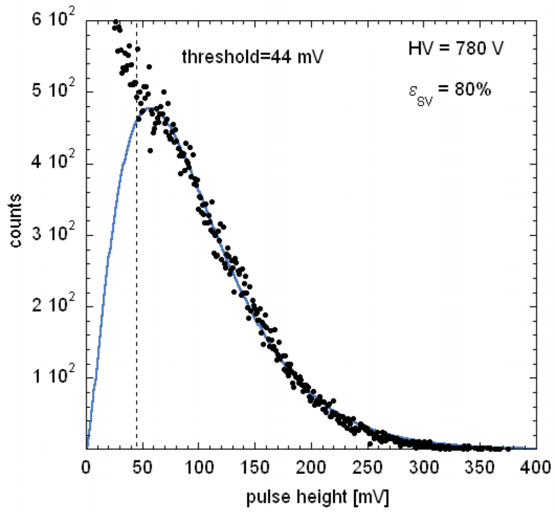

FIG. 2. *Pulse height spectrum at 780 V.*

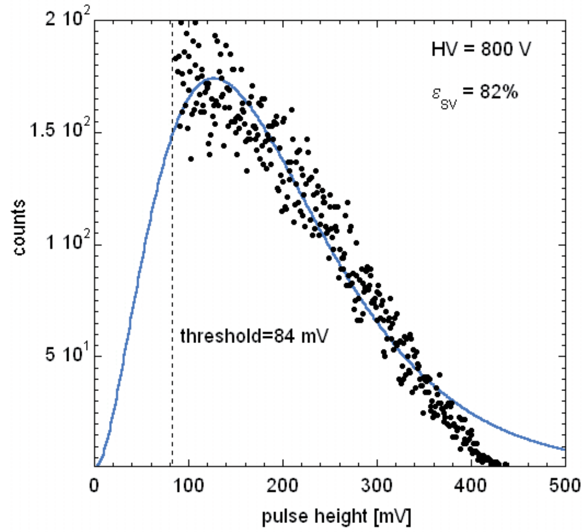

FIG. 3. *Pulse height spectrum at 800 V.*

Based on these results, we decided to work at 780 V. Then we spent a lot of effort to reduce the electronic noise coming from our electronic circuits and from surrounding environment. At the end we succeeded to raise the efficiency of the MSAC to the satisfactory level of 95%. In figure 4 the pulse height spectrum obtained in the new measurements is reported. The high voltage at the final stage of the MSAC was set at 780 V; the statistics of triggered events, at impact parameter d = 0 nm, was $2 \cdot 10^4$.

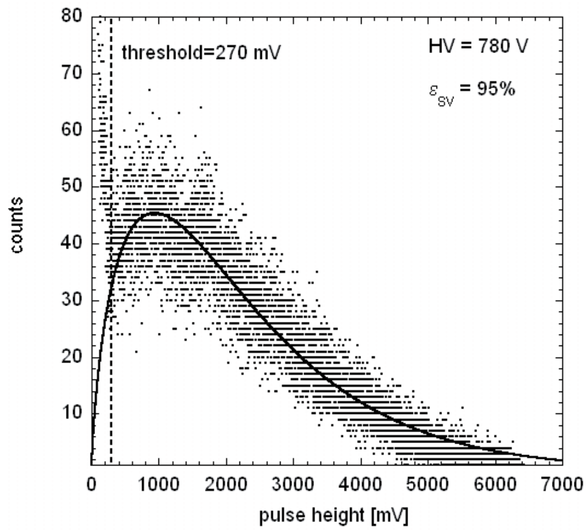

FIG. 4. *Pulse height spectrum at 780 V.*

In figure 5 we plot the measured cluster-size probability $P_\nu^{(on)}$, that is the probability of measuring a cluster of dimension ν, when the electric field in SV is attracting electrons inside the drift column.

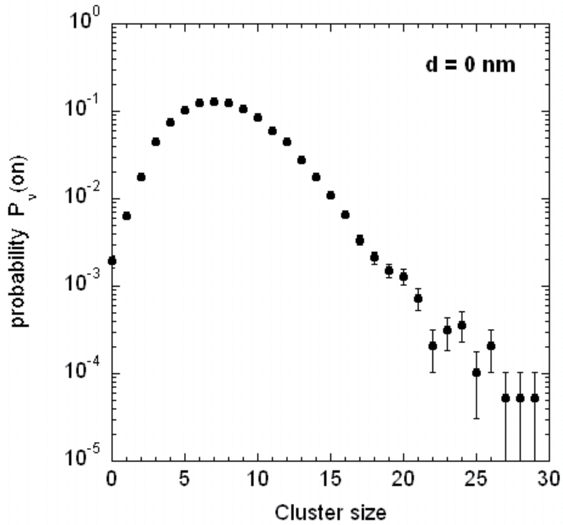

FIG. 5. *Cluster-size probability $P_\nu^{(on)}$ of 5.4 MeV alpha particles at impact parameter d= 0 nm*

In figure 6 we plot the mean electron cluster size M1 at different impact parameter d, and for comparison, the corresponding reference values [1]. Horizontal error bars have been added to take into account the uncertainty of 0.2 mm due to collimators of 0.8 mm.

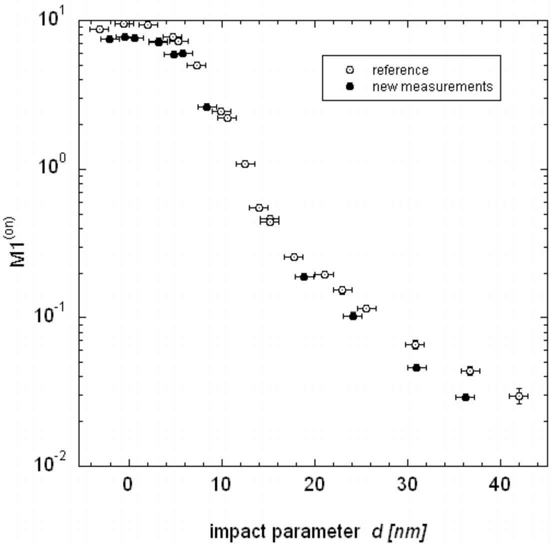

FIG. 6. *Mean electron cluster size at different impact parameter.*

According to figure 6, the current total efficiency ε is about 20% lower then in the past. The loss must be either in the drift column (was about 58%) or in the SV (was 20% on average). This is still under investigation.

[1] L. De Nardo et al., Rad. Prot. Dos., 122/1-4 (2006) 427.
[2] A. Ferretti et al., Nucl. Instr. and Meth., A599 (2009) 215.