Three-Dimensional Ionisation Distribution of 11.2 MeV/u Ar Ions in Triethylamine Gas

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Radiation action in matter and namely in living tissue depends on the microscopic details of the energy transfer in the nanometer range. Since it is not possible to measure with such a high resolution in condensed phase, various methods have been developed to substitute these measurements a) by measurements in low-pressure gases or b) by simulating the radiation transport through matter by Monte Carlo (MC) models and calculating the deposited energy or the number of ionisation events in the volumes of interest.

Most of the experimental approaches utilise tissue equivalent proportional counters, (TEPCs) whose geometrical size, scaled by the density ratio between tissue and gas simulates the size of the biological entity of interest. These methods are restricted to detector sizes which correspond to tissue volumes of a few 100 nm at best. On the other hand, the sizes of the radiation-sensitive cell structures range from several 100 nm (chromosome) down to 2 nm (distance of the DNA helices). An adequate instrument therefore should cover the full range of these sizes.

MC models, on the other hand, must simulate the whole complex process from particle degradation until the locii of all the energy transfers of all particles, produced along the particle trajectory. A prerequisite for such a Monte Carlo model is a comprehensive set of interaction cross sections, combined with a benchmarking of Monte Carlo results with appropriate experimental data.

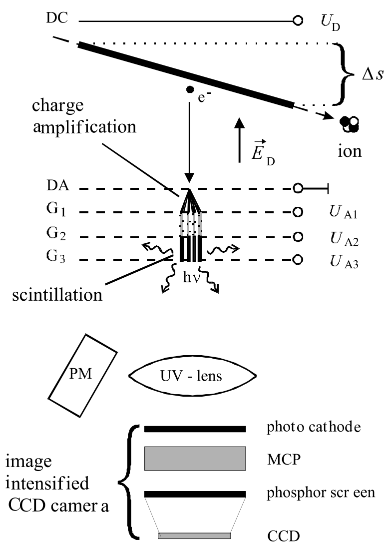

Fig. 1: Schematic view of OPAC

In recent years a gas-filled imaging system was developed at PTB which is able to measure the spatial pattern of energy deposition in a simulated cavity a few micrometer in diameter with a potential resolution of several 10 nm. With this instrument we obtain the full statistical correlation of ionisation events along the track of charged particles in the volume range from a few 10 nm to several micrometer. Furthermore, it is aimed as benchmark for testing results of MC calculations.

The experimental method is based on a time projection chamber with a parallel drift field, parallel-plate charge and proportional scintillation stages and optical readout (Optical Avalanche Chamber, OPAC). Fig 1 shows the experimental set-up. A description can be found in [1]. The chamber is operated with triethylamine (TEA) vapour at a pressure of typically 10 hPa. In the past this measurement system was successfully employed in low and medium energy light ion beams at the accelerator facilities at PTB and Frankfurt University [1-3]

Recently the chamber was applied in the 11.2 MeV/u Ar-beam at UNILAC / GSI. For this measurement the UNILAC beam had to be reduced in intensity down to a few particles per second, which was possible without problems. With this beam we were able to measure Ar tracks in a chamber pressures range from 2.5 hPa up to 80 hPa. Fig 2 shows a few samples of tracks. The energy loss of Ar-ions at that energy is about 10 to 100 times higher than that of the ions measured earlier. Therefore the chamber has to be operated at significant lower gain to prevent sparking. For this reason in these measurements efficient single electron detection could not be achieved.

In the further analysis it is planned to derive characteristic parameters from the measured tracks like average dE/dx or transversal ionisation distribution and compare these with corresponding theoretical results, e.g. with those obtained by the calculations of Krämer et al. [4]

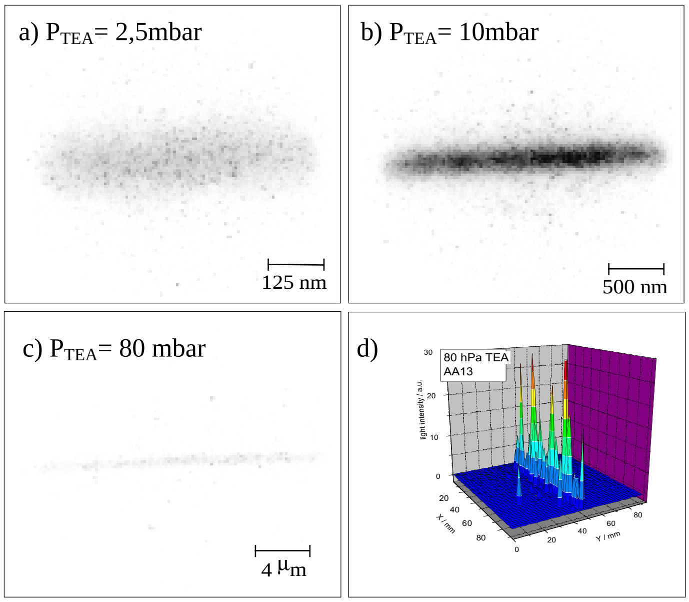

Fig.2: Images of 11.2 MeV /u Ar-tracks measured with OPAC at 3 different operating pressures. The particles crossed the chamber parallel to the CCD image plane in about 5 cm distance from the amplification region. The scale in figs. 2a–c is scaled to tissue density while the scale in d represents the distances in the gas filled chamber .

References:

[1] U. Titt et al, Nucl. Instrum. Meth. A416 (1998)85.
[2] U. Titt et al, Nuclear Physics B (Proc.Suppl.) 78 (1999) 444
[3] U. Titt, PhD-Thesis, University of Frankfurt, 1999
[4] M. Krämer, Nucl. Instrum. Meth. B105 (1995)14