TRAX simulation for the OPAC

M. Krämer[a], V. Dangendorf[b], and G. Laczko[b]
[a]GSI; [b]PTB Braunschweig

The main reason for the high effectiveness of ions compared to electrons and photons is the different microscopic pattern of energy deposition. An ion releases its energy to the penetrated matter through a cascade of low-energy δ-electrons. This leads to a very inhomogeneous energy distribution around an ion track. Although various measurements exist, e.g. radial dose distributions around ion paths in gas at low pressure, the detailed pattern at low distances still is worth further investigations.

A novel approach to this problem is the OPAC chamber [1]. It allows to create snapshots of ion tracks in a gas (Triethylamine, TEA) at low pressure. However, the information it provides is distorted by the ballistic motion of the δ-electrons, the presence of an eletric field and the diffusion of electrons in the gas. The question arises how far the performance of such a chamber could be simulated with a track structure code like TRAX [2, 3, 4]. Since the TRAX code works with single low-energy interactions rather than condensed random walk (like most other MC codes) it should be well suited to model the OPAC behaviour at a very basic level. Two problems arise immediately. The first one is the non-availability of basic interaction cross sections for TEA. This has been circumvented by using known cross sections for similar materials, in this report we chose nitrogen. Strictly speaking this is not correct, but sufficient at the present stage. Another problem is the inclusion of electromagnetic fields in the MC transport, a problem with no straightforward solution. It can approximately be solved by integrating the equations of motion along the short distance between two points of interactions. Special care has to be taken to account for boundary crossings and to ensure reasonable integration stepsizes.

Some sort of benchmark test for the combined action of electric field and inelastic interactions is the comparison with W-values measured in semi-infinite media as a function of field strength. Since the δ-electrons can take up or loose energy in the electric field the W-value (defined as the number of ionizations over the initial energy of the incoming particle) will change accordingly (Fig. 1).

Finally we apply the modified TRAX code to a "typical" OPAC scenario (Fig. 2, see also [1]). We calculated single ion tracks viewed from above in the direction of projection. As expected, the low-energy track exhibits a much higher density of inelastic interactions than the high-energy one. The distribution of events appears to be broadened due to the influence of the electric field.

However, such ab-initio calculations have a problem at the low-energy side (in the eV region and below) because here the interaction (excitation) cross sections are not known. Hence an artificial cutoff energy (in this case 1 eV) has to be applied in order to terminate electron histories.

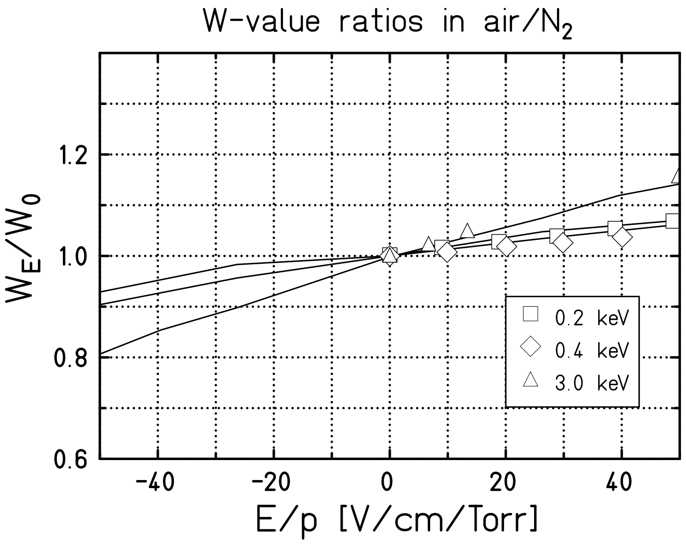

Figure 1: Electron W-values in an electric field (W_E) relative to those without field (W_0). Symbols: experiments (air) [5], lines: TRAX simulations (N_2)

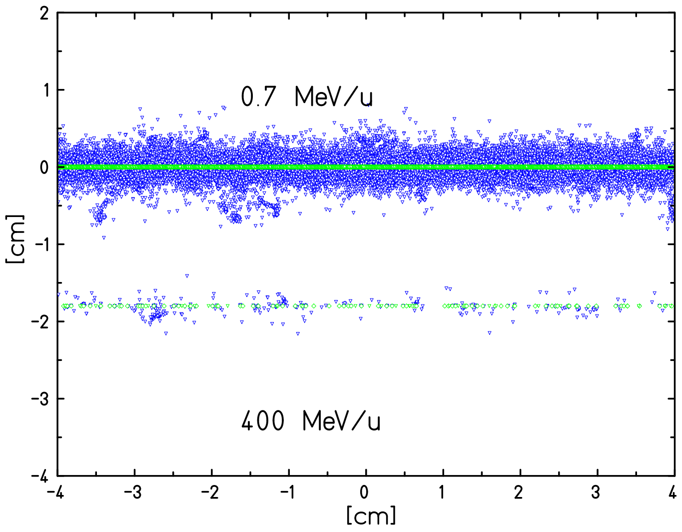

Figure 2: Simulated OPAC tracks of ^{12}C. Plotted are interaction points for ionization and excitations of both, the primary ions and their δ-electrons

References

[1] G. Laczko et al, this report
[2] M. Krämer, G. Kraft, Rad. Env. Bioph., 33 (1994) 91
[3] M. Krämer et al, GSI Scientific Report 2000
[4] http://www.gsi.de/ bio/DOCS/TRAX/DOCS/trax.html
[5] B. Grosswendt, E. Waibel, NIM, 155 (1978) 145-156