

Low Energy Electrons Emitted in Collisions of Heavy Ions with Solid State Targets

Natalia Lineva¹, C. Kozhuharov¹, S. Hagmann^{1,2}, M. Krämer¹, G. Kraft¹

¹GSI Darmstadt Germany; ²Universität Frankfurt am Main Germany

We have initiated a series of measurements of electrons emitted in collisions of heavy ions at UNILAC bombarding energies (up to $v/c \approx 0.16$) with solid-state targets utilizing an electrostatic toroidal spectrometer. An in-depth knowledge both of the emission processes as well as of the transport phenomena for low-energy electrons (below 1 keV) in liquids and solids is needed for the detailed understanding of the biological effects of heavy ions irradiation. The bulk of data used for the therapy planning and/or simulations is based on data from gaseous targets, scaled up to the density of liquids and solids. (For a recent comprehensive review of the tumor therapy with heavy ions at GSI confer [1].) We have combined the analysis of our heavy ion measurements with measurements of electrons emitted from solid state targets bombarded with 1 keV and 500 eV electrons as well as with the results of dedicated Monte Carlo simulations with the TRAX code [2] in order to develop methods to identify, study, and analyze the problems, which arise from the actual operating conditions that mask the complex and interdependent processes of electron emission and transport; conditions such as target properties and consistence, surfaces, etc. For instance, the typical diffusion pattern, exhibited by the angular distribution of electrons emitted when thin (evaporated) carbon foils (4.7 $\mu\text{g}/\text{cm}^2$ and 11 4.7 $\mu\text{g}/\text{cm}^2$) with 1 keV electrons revealed strong effects of target thickness fluctuations when we compared measurements with TRAX simulations. Based on such findings, we reassessed our data from collisions of protons, H³⁺, and carbon projectiles impinging on carbon foils. Within our experimental uncertainties, the spectra can be well described with the TRAX code.

[1] G. Kraft http://www.gsi.de/forschung/bio/tumorverein_eng190607_xs.pdf (2007)

[2] M. Krämer, *Nucl. Instr. and Meth.* **B105** (1995) 14.