Fragmentation of therapeutical carbon ions in bone-like materials

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Heavy-ion beams offer favourable conditions for the therapy of cancer diseases. The type of tumors treated with such method is still limited but increasing. An important step for widening and improving its application is to characterize the interaction of the primary ions with specific material, like bones, which are encountered by the primary radiation before reaching the tumor.

This work focuses on the characterization of nuclear interaction processes occurring when carbon ions in the therapeutical energy range transverse bone-like materials. In the measurements, 200 and 400 MeV/u ^{12}C beams interacted with compact bone targets (Gammex RMI 450) of different thickness (1, 3 and 5 cm). For each beam energy and target thickness, the yield and kinetic energy spectra of neutral and charged particles were acquired at 0, 2.5, 5, 10, 15, 20 and 30 degrees with respect to the primary beam direction.

The experiment

A scheme of the experimental setup is shown in Fig. 1. Two plastic scintillators of 2 and 9 mm thickness (START and VETO, respectively), and a 14 cm long barium fluoride scintillator (BaF_2) were used.

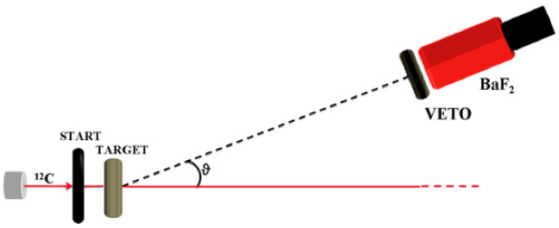

Figure 1: Scheme of the experimental setup.

The identification of the primary ions surviving the target as well as of the secondary particles produced by fragmentation of the former with the target nuclei was achieved with deposited energy (ΔE) and residual energy (E) measured with the VETO-BaF_2 telescope. Once a particle species is selected, the kinetic energy spectrum are obtained from the Time-Of-Flight (TOF) data measured between the START and BaF_2 detectors.

An example of a 2D plot of the ΔE and E signals collected with the telescope is shown in Fig 2.

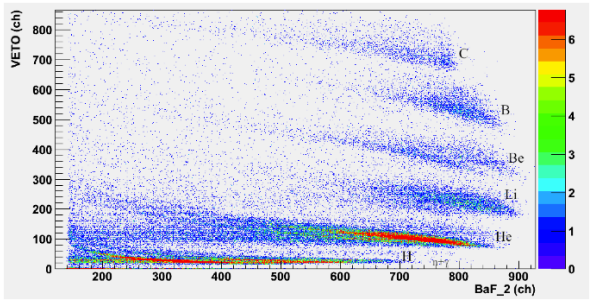

Figure 2: ΔE-E plot for a 200 MeV/u ^{12}C beam interacting with 3 cm compact bone at 5 deg with respect to the primary beam direction.

The trend of the particle yield as a function of the angle is shown in Fig 3.

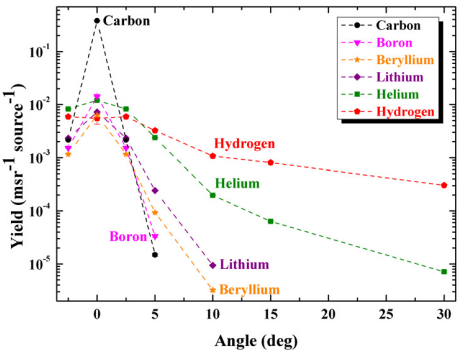

Figure 3: Angular distributions of particles measured at forward angles from -2.5° to 30° for a 400 MeV/u ^{12}C interacting with 5 cm compact bone target.

The angular distributions are all forward peaked. Primary ions and heavy fragments down to Li are detected in the range from 0 to 10 deg and cannot be found at larger angles. Neutrons, helium and hydrogen fragments present a different shape of the distribution, broader for the latter (hydrogen particles and neutrons) than for the former.