1 PROTON-INDUCED FRAGMENTATION OF CARBON AT ENERGIES BELOW 100 MeV

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Scientific Objectives

Radiation effects caused by single cosmic ray particles have been studied for many years in radiobiological experiments for different biological objects and biological end-points. Additionally, single event effects in microelectronic devices have gained large interest. There are two fundamental mechanisms by which a single particle can cause radiation effects. On the one hand, a cosmic ray ion with high linear energy transfer can deposit a high dose along its path. On the other hand, in a nuclear collision, a high dose can be deposited by short range particles emitted from the target nucleus. In low earth orbits a large contribution to target fragmentation events originates from trapped protons which are encountered in the South Atlantic Anomaly. These protons have energies up to a few hundred MeV.

We study the fragmentation of C, O and Si nuclei - the target nuclei of biological material and microelectronic devices - in nuclear collisions. Our aim is to measure production cross sections, energy spectra, emission directions and charge correlations of the emitted fragments. The present knowledge concerning these data is rather poor. M. Alurralde et al. [1] have calculated cross sections and average energies of fragments produced from Si using the cascade-evaporation model. D.M. Ngo et al. [2] have used the semiempirical cross section formula of Silberberg and Tsao [3] to calculate fragment yields and the statistical model of Goldhaber [4] to describe the reaction kinematics. Cross sections used in these models have uncertainties within a factor of two. Our data will help to test and improve existing models especially for energies below 300 MeV/nucleon. Charge correlations of fragments emitted in the same interaction are of particular importance, since high doses can be deposited if more than one heavy fragment with a short range is produced.

Experimental Method

The experiments are performed in inverse kinematics, using C, O and Si projectiles of the GSI SIS accelerator with energies of about 100 MeV/nucleon in combination with C and CH_2 targets. Thus the projectile fragments have energies which are sufficiently high to allow them to escape from the target. They move within a cone into forward direction. The incoming projectiles and outgoing fragments are measured using CR-39 plastic nuclear track detectors. These are mounted upstream and downstream the target. In our experiments we measure the charges and the emission angles of the fragments. Based on these data fragmentation cross sections and transverse momenta can be determined including all fragments with $Z \geq 2$. From the results for C and CH_2 targets the interaction characteristics for collisions with H target are derived. Results with high statistical significance can be achieved based on completely computerized track measurements of the etch cones in the detector foils [5].

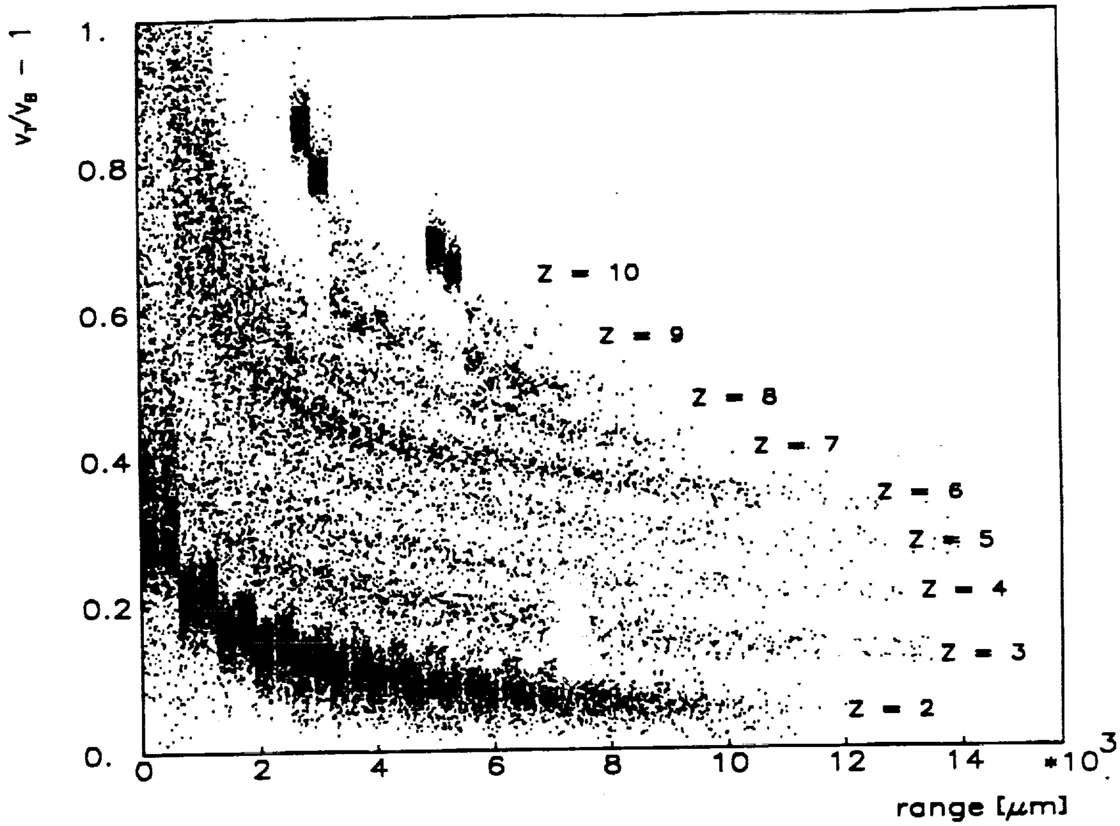

Figure 1: Track size as a function of residual range for Ne projectiles and projectile fragments produced in a CH_2 target. The track size is measured by the ratio of track etch rate v_T to bulk etch rate v_B.

Status of the Experiments:

Beam time for these experiments has been approved by the GSI Experiment- ausschuß. Exposures of our experimental setups will be performed in cave A of the SIS when the appropriate beams are scheduled. This will be frequently the case for C and O beams, since these ions are used in the GSI therapy project.

To develop the experimental technique we have started the investigations in 1993 with a prototype experiment exposed to 65 MeV/nucleon Ne ions. Fragments with charges between 2 and 9 and penetrating projectile nuclei with charge 10 have been measured behind the target. The trajectories of these particles have been reconstructed through the CR-39 stack. In figure 1 the measured track size for the individual etch cones is shown as a function of the residual range of the particles. These results show that charge resolution is excellent. The fragment production cross sections can be determined based on the fragment yields. Transverse momenta can be deduced from the angles of the fragments' trajectories in relation to the beam direction.

Recently (end of May 1994) a C beam of 80 MeV/nucleon was available. We have exposed 10 stacks with CH_2 target and 6 stacks with C target to the beam. The analysis of these stacks will provide cross sections and transverse momenta with reasonable statistical significance for the fragmentation of C nuclei hit by a 80 MeV proton.

References

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