Fragmentation of UH Nuclei*

C. J. Waddington[1], W. R. Binns[2], J. R. Cummings[3], T. L. Garrard[3], J. Klarmann[2] and B. S. Nilsen[1].

1.University of Minnesota, 2. Washington University, 3. Caltech.

Abstract

We have measured the total charge changing cross sections as a function of energy for projectile $_{36}$Kr nuclei in a wide range of targets ranging from polyethylene to lead. These cross sections are energy dependent and the dependence increases as the target mass increases.

Introduction

In order to better understand the propagation of UH cosmic ray nuclei, Z ≥ 30, in the interstellar medium we have continued our program of studying the fragmentation of heavy relativistic nuclei accelerated at the LBL Bevalac. In a new series of runs using a combination of ion chambers and Cherenkov counters, see OG 10.1.15, we have extended the range of target masses beyond that studied earlier[1,2] and have expanded the charge range of the projectiles to lighter nuclei. The overall coverage of charges of the projectiles and targets as a function of energy is shown in Fig.1.

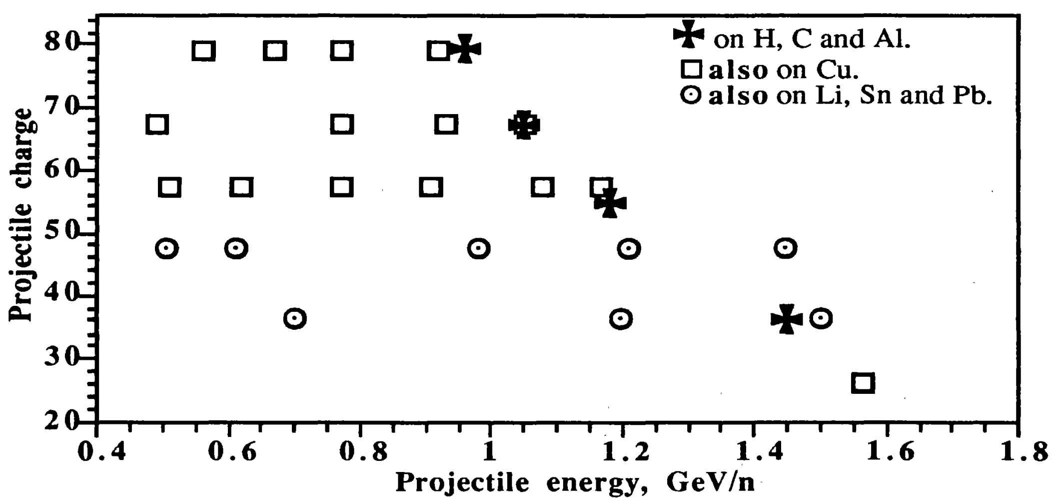

Fig. 1 Projectile charge as a function of energy for three different series of runs. Hydrogen cross sections were deduced from subtraction between C and CH_2 targets.

Results and discussion

From our preliminary analysis of the new data we can now report values for the total charge changing cross sections of krypton projectiles with energies between 500 and 1500 MeV/n interacting in targets of CH_2, C, Al, Cu, Sn and Pb. The charge resolution of the fragments produced in these interactions is excellent, see e.g.Fig. 2, and we will be able to report later on the partial cross sections for the production of these fragments in all these different targets. Here we confine our attention to the total charge changing cross sections and their dependence on energy and target mass.

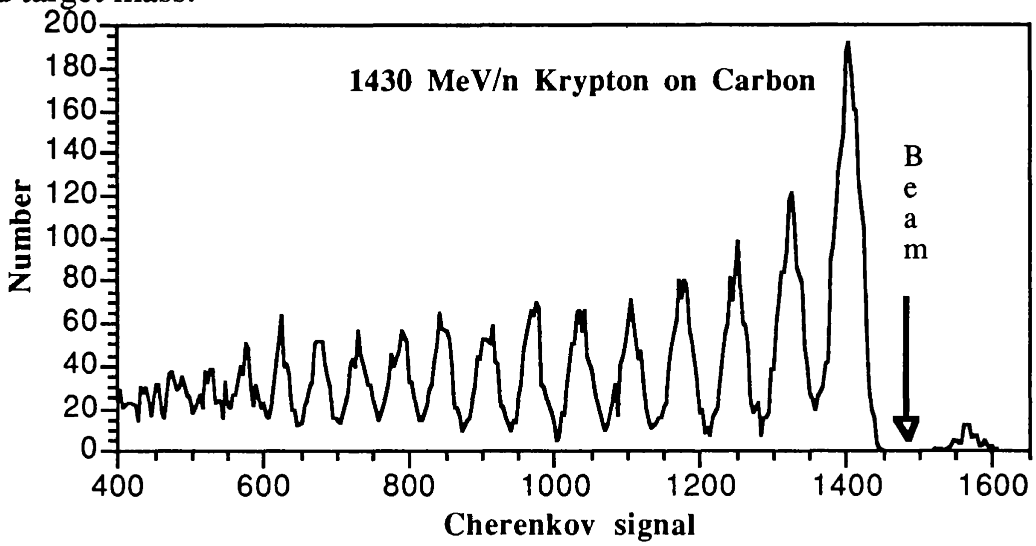

Fig. 2 A plot of the Cherenkov signal for fragments that have commensurate ion chamber signals. For high energy Kr on a carbon target. For clarity the beam peak has been suppressed.

In our previous study[2] with projectiles having multiple energies we were unable to determine these total cross sections due to the triggering requirements imposed during the data taking. As a result our estimates of these total cross sections have all been based on data taken earlier[1] at a single energy (the maximum Bevalac energy for the beam) and on a limited range of targets (H - Al).

These runs are shown in Fig. 1 by the symbol ✠. From these data we proposed a modified version of earlier[3] overlap models to calculate values for beams in this range of charges. This relation, Eq. 1, had the form:

$$\sigma_{total} = 10\pi(1.35)^2[A_{Targ}{}^{1/3} + A_{Proj}{}^{1/3} - p\,(A_{Targ} + A_{Proj})^q\,]^2 \quad \text{mb}$$

with p and q being determined to have values of 0.209 and 0.332 respectively. This expression differs from previous models in that the overlap term is dependent on both the projectile and target masses, but, like them, is energy independent. It may be compared with an expression proposed recently to fit data on lighter projectiles[4] of the form

$$\sigma_{total} = C\{A_{Targ}{}^{1/3} + A_{Proj}{}^{1/3} - [(t_o - t.A_{Targ}) - (b'A_{Targ}{}^{1/3}A_{Proj}{}^{1/3})]\}^2$$

which, however, blows up for large A_{Targ}, predicting a negative overlap. In view of the strong energy dependence of the partial cross sections found previously[2], and the energy dependence of the total cross sections observed for lighter projectiles[4], it is not surprizing to find from our new data that total cross sections for these heavy projectiles are also energy dependent. The measured cross sections as a function of energy are compared with those predicted from Eq. 1 in Fig. 3, which shows the cross sections for krypton of three different energies on six different targets. It can be seen that there is good agreement with the predictions for the lighter targets and the high energies, similar to those used to derive Eq. 1, but that the heavier targets and the lower energies have cross sections that are not well predicted by this equation. The deviations from the prediction values are shown in Fig. 4, which emphasizes how poorly the predictions are able to represent the very heavy targets, particularly at lower energies.

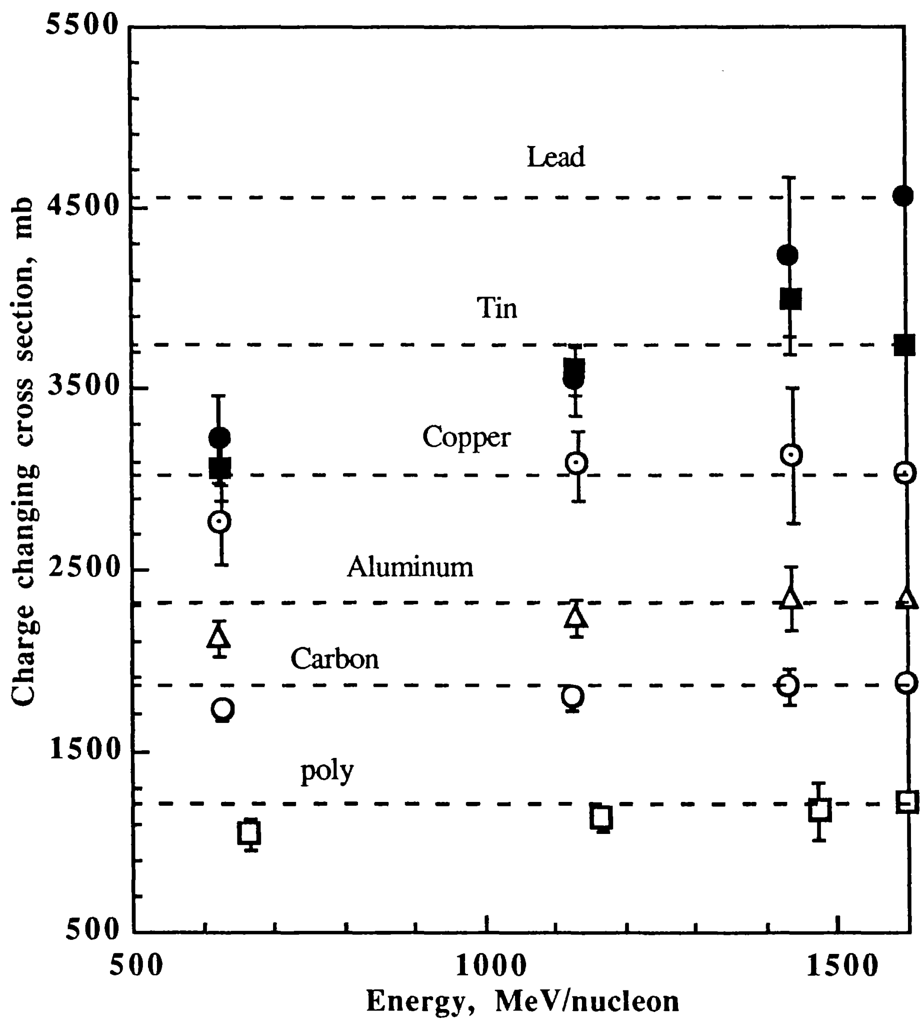

Fig. 3 Total cross sections as a function of energy. Predicted values from Eq. 1 are plotted at 1600 MeV/n

The measured cross sections are shown as a function of the atomic number of the targets in Fig.4, Also shown are logarithmic fits that have a fair degree of confidence. It appears that a relation of the form

$$\sigma_{total} = a.\exp\,[b(E)\,Z_{targ.}],$$

where $a(A_{targ},A_{proj})$ and $b(E)$ are functions, provides a good representation of the cross sections

When the data from the silver projectiles, where we have more energies and one more target, Li, have been similarly analyzed, we should be able to propose a modified version of Eq. 1 that will allow us to predict these cross sections as a function of energy and target mass. At present Eq. 1 must be used with caution and only in the parameter space where it is applicable.

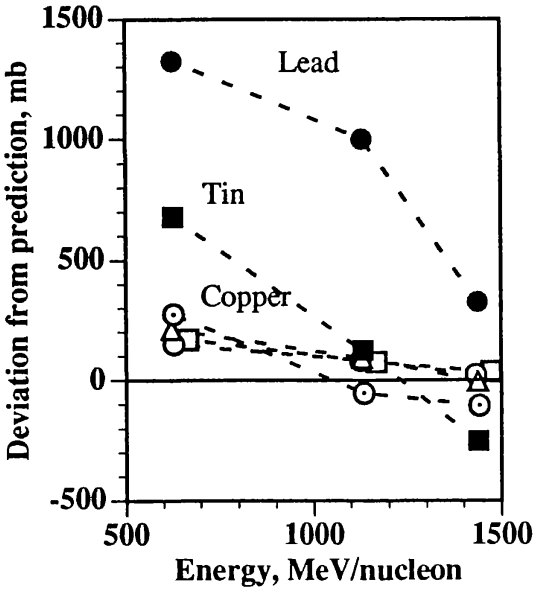

Fig. 4 Deviations of predicted cross section from measured value, in mb. Errors are suppressed for clarity.

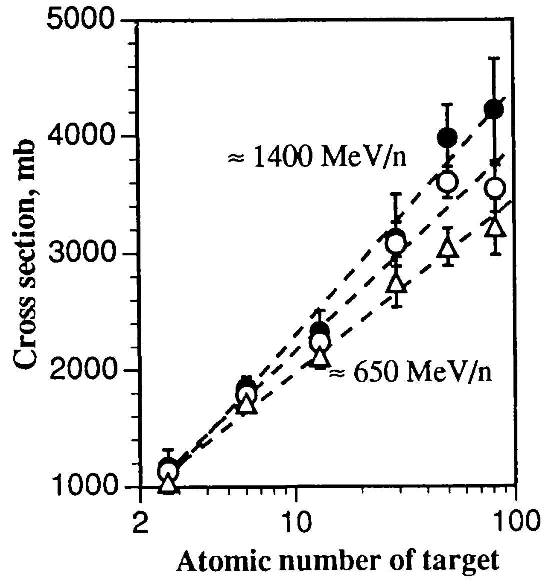

Fig. 5 Cross sections as a function of the atomic number of the target for the three energy groups

Conclusions

The total charge changing cross sections increase with increasing energy, and this effect become more significant for the heavier targets. Previous predictions are not adequate to represent these cross sections on the heaviest targets such as tin and lead.

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* Partially supported by NASA grants