FRAGMENTATION OF VERY HIGH ENERGY HEAVY IONS

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A stack of CR39 ($\text{C}_{12}\text{H}_{18}\text{O}_7$) nuclear track detectors with a Cu target was ex-
posed to a 158 A GeV lead ion beam at the CERN-SPS, in order to study the
fragmentation properties of lead nuclei. Measurements of the total, break-up and
pick-up charge-changing cross sections of ultrarelativistic Pb ions on Cu and CR39
targets are presented and discussed.

1 Introduction

We present experimental results on fragmentation charge-changing cross sec-
tions of 158 A GeV lead ions (charge $Z = 82e$) incident on Cu and CR39
targets. To detect and identify the relativistic ions, the nuclear track detector
CR39 was used. When an ion crosses a nuclear track detector foil, it produces
damages at the level of molecular bonds, forming the so called “latent track”.
During the chemical etching of the detector in a basic water solution, etch-pit
cones are formed on both sides of the foil. The base area and the height of
each cone are functions of the Restricted Energy Loss (REL) of the incident
ion and thus of its charge $Z$.\[1\]

2 Experimental procedure

A stack made of CR39 nuclear track detectors with a Cu target was exposed
in November 1996 at the CERN-SPS to a beam of 158 A GeV Pb ions. The
exposure was performed at normal incidence. The total number of lead ions
incident on the stack was about $7.8 \times 10^4$, distributed in 8 spots. The central
density in each spot was around 1500 ions/cm$^2$.

The stack had the following composition: 12 CR39 sheets $\sim 0.6$ mm thick,
a Cu target $\sim 10$ mm thick; 38 CR39 sheets $\sim 0.6$ mm thick. In the present
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P. Patrizii, V. Popa, I.E. Qureshi, M.A. Rana, M. Sajid, P. Serra, M.I. Shahzad, G. Sher
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analysis, the CR39 sheets immediately before and after the Cu target and the last sheet of the stack were used. After exposure, the sheets were etched for 72 h in a 4N KOH water solution at a temperature of 45 °C. Previous calibrations of the detectors have shown that for high Z nuclei, the height of the etched cone is more sensitive to Z than its base area or diameter.

In order to separate the lead ions from the nuclear fragments with charge $Z \geq 63e$, we performed manual measurements of about 6300 cone heights using an optical Zeiss microscope with a magnification of 40×. Fig. 1 shows the cone height distribution of Pb ions and heavy fragments measured on a single face of the CR39 sheet located after the Cu target. The charge resolution obtained is about 0.2e.

3 Total charge-changing cross sections

Using the survival fraction of lead ions for the Cu and CR39 targets, we measured the total charge-changing cross sections of lead ions using the formula:

$$\sigma_{tot} = \frac{A_T}{\rho_T t_T N_A} \ln \frac{N_{in}}{N_{out}}$$

(1)

where $N_{in}$ and $N_{out}$ are the numbers of lead ions before and after the target, respectively; $N_A$ is Avogadro’s number; $\rho_T$, $A_T$, $t_T$ are the density, the atomic
mass and the thickness of the target. The data are indicated by the black points in Fig. 2, the uncertainties are statistical only.

As shown in Fig. 2, the data are in agreement with previous data obtained by a similar experiment using the same beam and different targets with atomic masses ranging from 4.7 a.m.u. (CH$_2$) to 207 a.m.u. (Pb). The solid line in Fig. 2 is the fit of all the data to formula (2) of ref. [4] which yields $\chi^2/D.o.F. = 0.7$.

Results from other experiments using a 10 A GeV Au beam incident on various targets [5–7] are also shown.

4 Partial fragmentation charge-changing cross sections

The partial fragmentation charge-changing cross sections of Pb ions yielding fragments with charge $64e \leq Z < 82e$ were calculated for the Cu and CR39 targets using the formula:

$$\sigma_Z = \frac{A_T}{\rho_T t_T N_A} \frac{N_Z}{N_{82}}$$

where $Z = 64e \div 81e$, $N_Z$ is the number of fragment nuclei with charge $Z$ produced in the target, $N_{82}$ is the number of unfragmented beam nuclei and $\rho_T$, $A_T$, $t_T$, $N_A$ have the same meaning as in Eq. (1). In this procedure, the successive fragmentation processes are neglected. The results for the partial fragmentation cross sections of incident lead ions on Cu and CR39 targets are shown versus $\Delta Z$ in Fig. 3.
The square points in Fig. 3 refer to the charge pick-up cross sections, determined using Eq. 6 where $N_Z$ is the number of nuclei with $Z = 83e$ produced in the target.

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