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INVESTIGATION OF 158 A GeV Pb IONS FRAGMENTATION WITH NUCLEAR TRACK DETECTORS [1]

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Abstract. Five stacks of nuclear track detectors (mostly CR39 and LEXAN) were exposed to $^{207}Pb^{+82}$ ions of 158 A GeV at the CERN-SPS. The main purpose of the exposures was the calibration of the CR-39 nuclear track detector used in an experimental search for magnetic monopoles at the Gran Sasso Laboratory (the MACRO experiment). Different targets were used in order to study also the fragmentation properties of ultrarelativistic lead nuclei. The exposures were performed at normal incidence and at a density of about 400 ions/cm^2. The typical number of events in a stack is about 1.5×10^4.

1 Introduction

The study of the fragmentation properties of atomic nuclei of high energies is of relevance for both nuclear and cosmic ray physics.

In this paper we present a status report concerning the study of the fragmentation of 158 A GeV ^{207}Pb ions obtained using the CR-39 [2] ($C_{12}H_{18}O_7$) plastic nuclear track detector. The main purpose of the experiment was the calibration of the CR-39 [1] used in a large area experimental search for magnetic monopoles at the

[1] Presented by S. Manzoor and V. Popa at the Int. Symp. "Large Scale Collective Motions in Atomic Nuclei", Brolo (Messina), 15-17 October 1996.
[2] CR-39 is a Registered Trade Mark of PPG Industries Inc.

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Gran Sasso Laboratory (the MACRO experiment). The CR-39 was manufactured by the Intercast Europe Co. of Parma (Italy) [2].

The CR-39 track etch detector is characterized by a low detection threshold and a good charge resolution for a large range of relativistic ions and thus it is convenient for the investigation of high energy heavy ion fragmentation.

2 The Experimental Procedure

Five stacks of CR-39 nuclear track detector sheets were exposed to 158 A GeV Pb beam at the CERN-SPS in December 1994. Each stack was composed of two parts. The one designed for the study of the beam fragmentation in the target consisted of three CR-39 sheets 0.6 mm thick before the target and four 0.6 mm thick sheets after the target; additional foils of cellulose nitrate, Lexan and Makrofol detectors were placed also before and after the target, but were not used in this analysis. The second part of the stacks consisted of CR-39 detectors from different production batches and was used for calibration purposes [1].

Different targets were used: Cu, Pb, graphite, CR-39 and polyethylene, all 1 cm thick. The last three targets should allow the indirect determination of the Pb fragmentation cross sections in hydrogen and oxygen. In this paper we refer to the results obtained with the Pb target only. For the other targets the analyses are still in progress.

The exposures were carried out at normal incidence, to a beam intensity of $\sim$ 400 ions/cm^2; the typical number of incident ions in each stack was $\sim 2 \times 10^4$.

When an ion crosses the CR-39 nuclear track detector it produces damages at the level of molecular bonds, forming the so called latent track. During the chemical etching of the exposed detector, the etching velocity along the latent tracks, v_T, is larger than that in the bulk material, v_B, so that etching cones are formed on both sides of the sheets. The area of the base of the cone is a function of the Restricted Energy Loss (REL) of the incident ion and thus, for relativistic ions, of its electric charge.

The exposed CR-39 sheets were etched for 40 hours in 6N water

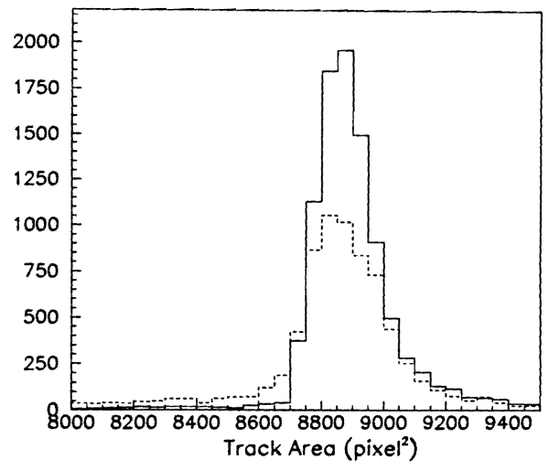

Figure 1: Area distribution of the tracks produced by Pb ions (plus heavy fragments) before (the solid histogram) and after (the dashed histogram) the lead target.

solutions of NaOH and KOH with 1:2 ratios by volume at a temperature of 60°C. The base cone areas were obtained from the etch-pit surface area measurements made with the Elbek image analyzer system [4].

The ion paths along the stack were reconstructed using a special tracking algorithm. In order to reduce the background due to polymerization defects or to the environmental α-radioactivity we considered only the tracks defined by at least two etch cones. In Fig. 1 we present the area distributions of the tracks measured before and after the lead target. One observes the peak due to Pb ions and some heavy fragments, plus a tail at lower area values.

The estimate of the overall efficiency is in progress.

3 Discussion and Conclusions

The charge resolution on the basis of diameter measurements in nuclear track detectors is worsening as the ion charge increases. Thus

some nuclear fragments close to lead are misinterpreted as being un-fragmented lead ions.

We computed the survival probability of the beam crossing the 1 cm thick Pb target. The first estimate of the probability based on the counting of the Pb tracks before and after the Pb target is 0.67 ± 0.02. For this estimate we considered as produced by lead ions the tracks with areas larger than a threshold value computed as the difference between the mean area of the Pb peak and twice its standard deviation. This result is in agreement (within the statistic and systematic uncertainties) with the result (0.61 ± 0.05) obtained by comparison of the Pb peak in two corresponding zones of the CR-39 sheets before and after the target using an optical microscope. Due to the above mentioned worsening of the charge resolution, the results overestimate the real survival probabilities.

We estimated the nuclear contribution to fragmentation by using the nuclear fragmentation cross sections given by the semi-empirical formula [5]:

$$\sigma_n = \pi \left[r_0 \left(A_p^{1/3} + A_t^{1/3} - b \right) \right]^2 , \qquad (1)$$

where A_p and A_t are the projectile and target atomic masses, $r_0 =$ 1.35 fm and $b = 0.83$. The survival probability obtained by simulating the analysed stack is about 0.78. This value is larger than the measured one. The difference indicates an electromagnetic contribution of at least 33% to the total fragmentation for the lead target. This is in agreement with different experimental results [6] indicating an increase of the electromagnetic fragmentation when heavy relatistic nuclei are involved.

A way to correct for the contamination of the data due to the presence of fragments with charge close to 82 is to perform cone length measurements [7] for tracks populating the "beam" peak. For this purpose, two CR-39 sheets from each stack (one before and the other after the target) were etched in 6N NaOH water solutions at 40°C for 180 hours. The measurement of the cone length distributions is presently in progress. We expect to find a larger number of heavy fragments in the "beam" peak after the targets than before, so that the corrected beam survival probabilities should be smaller than the preliminary results presented here.

In the next irradiation (scheduled for November 1996) we will

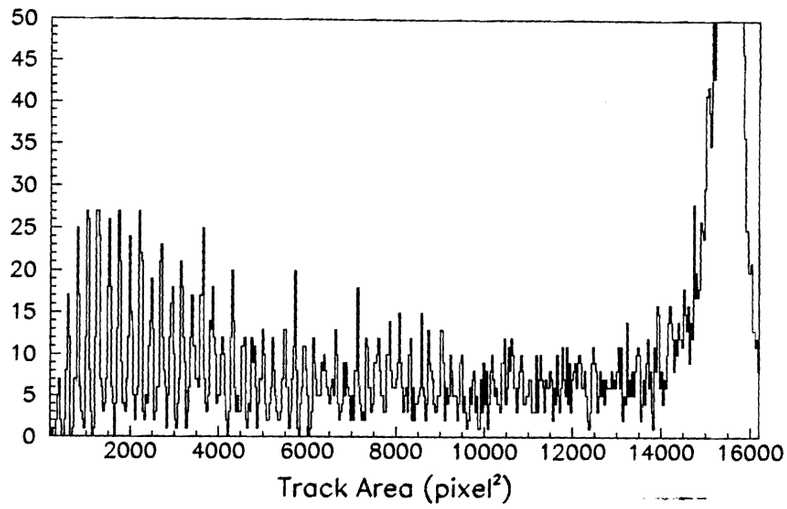

Figure 2: Area distribution of the tracks produced by lead ions and by their fragments after the copper target. Four etched cone diameters were used (see text).

use some stacks with a different geometry, to optimize the tracking. In order to achieve a better charge resolution different etching procedures are tested. In Fig. 2 is shown the preliminary distribution for tracks measured after the Cu target, using 4 cones for each track (the first peak is for $Z = 8$). The etching was performed in a 6N water NaOH solution at 40°C for 460 hours. The charge resolution obtained for light fragments ($Z \sim 9$) is about $0.15e$, where e is the unit electric charge, while in the Pb zone it is still larger than unity.

Acknowledgments

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