FIZIKA, 3 (1971) 135-140

Σ^- HYPERON CAPTURES ON THE LIGHT AND HEAVY EMULSION NUCLEI

M. JURIĆ and J. SIMONOVIĆ

Institute of Physics, Beograd

Received 13 January 1971

Abstract: In this work the nuclear captures of Σ^- hyperons have been studied by analogy with the analysis of K^- meson captures produced on the light and heavy emulsion nuclei. A stack of Ilford K-5 nuclear emulsions was exposed to a beam of slowed K^- mesons at the CERN proton-synchrotron. Of all the possible reactions that occurred in this detector, only the interactions of Σ^- hyperon and K^- meson with a bound proton from a complex nucleus of the emulsion were selected. The experimental measurements have shown, with restricted detection possibilities, that the Σ^- hyperon capture stars are produced with a frequency of (58.0 ± 2.6) % on heavy and with (42.0 ± 1.9) % on light nuclei.

1. Introduction

In this experiment the Σ hyperon captures at rest were investigated by verifying whether they were produced on the light or heavy emulsion nuclei. The Σ^- hyperon-one proton interactions were taken as the dominant channel for the nuclear capture of Σ^- hyperons:

$$\Sigma^- + p \to \lambda^{\circ} + n, \tag{1a}$$

$$\to \Sigma^{\circ} + n. \tag{1b}$$

The results obtained in such a way were compared to those obtained from the analogous K^- meson-one proton interactions, where two charged particles appear as the interaction products:

$$K^- + p \to \Sigma^{\pm} + \pi^{\mp}. \tag{2}$$

The criterion for discrimination between interactions (1) and (2) on the light and heavy nuclei was analogous to that used by Davis and collaborators[1]. They have studied the products of K^- meson captures at rest, separating the interactions with a proton from those with a neutron, and arrived at the conclusion that the rate of K^- meson captures on neutrons is considerably higher in heavy nuclei than in light ones. Considering K^- meson capture as a process occurring at the nuclear periphery, Burhop[2] has drawn from this work the conclusion that the outermost regions of heavy nuclei have a large neutron excess. However, our measurements have shown, using the same criteria, that Σ hyperon captures (on proton) occur more frequently on heavy than on light nuclei. We do not try to interprete the process itself, which, for heavy nuclei, is still not conclusively explained.

2. *Experimental method*

The stack of Ilford K-5 emulsions used in this work was exposed at the CERN proton-synchrotron to a beam of slowed K^- mesons of an incident momentum of 350 MeV/*c*.

For charged Σ^- hyperons, only interactions of the type (2) were taken into consideration. The selection of events was made in such a way as to record only two-prong K^- meson stars at rest, which contained each a light and a heavy track, with an eventual recoil track, a blob or an electron track.

The selection of these events was carried out by the area scanning method with a Zeiss microscope under a magnification of 20×15. Every black prong of the recorded two-prong stars was followed to the point of coming at rest, of decay or of interaction, or up to its end-point in the emulsion stack. By means of visual observation of the ends of the followed tracks all the Σ^- hyperon events were divided into a group of decays and a group of interactions. Furthermore, according to the way of formation of the star, the group of interactions was divided into two categories. The first category of interactions consists of the so-called Σ_σ stars, which are defined so that each of the capture stars contains at least one track longer than 200 μ, or two tracks longer than 5 μ[3]. The other category comprises Σ_ρ events which do not satisfy the former condition or do not include any visible track. Most Σ hyperon interactions belong to this kind of capture. Carrying out detailed analyses by the standard methods of identifying particles: the measurement of multiple scattering with a constant or a variable cell, the measurement of the track width or of mean gap and so on[4], we found 332 Σ_σ and 926 Σ_ρ events, or in total 1258. We note that the methods of measurement that we used were reliable to within an upper limit of error of 15%.

However, so far the total number of all the Σ hyperon interactions has been quantitatively inferred only by means of a definite correction factor

n ($n = \frac{\Sigma_\sigma + \Sigma_\rho}{\Sigma_\rho}$). The value of this factor is obtained from Σ hyperon interactions which are easily detected in K-H events. In our experiment, from 110 K-H stars n was determined to be $n = 3.3^{+0.4}_{-0.3}$. This value is in good agreement with those reported in similar works[5,6]. Applying the correction n to 332 recorded Σ_σ captures, we found that the total number of Σ^- hyperon interactions was 1094^{+133}_{-166}. We have thus confirmed that the number of expected events determined in such a way is in agreement, within the limits of error, with the number of all the Σ hyperon interactions detected, 1258. It

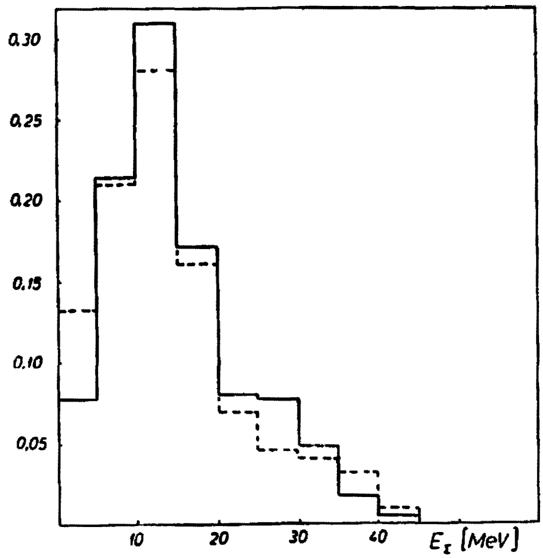

Fig. 1. Energy distributions of Σ^- hyperons: for Σ_ρ (solid line) and for Σ_σ stars (dotted line) normalised to the total number of events.

should be stressed that the present work is the first in which the total number of all the Σ hyperon captures is experimentally determined. Figure 1 presents energy distributions for Σ_σ (solid line) and Σ_ρ stars (dotted line) normalised to the total number of events. From the drawing it can be seen that there is no substantial difference between energy distributions for these two kinds of events, which shows that our way of selecting Σ_ρ »candidates« was correct.

3. *Discussion of results*

K^- meson capture and $\Sigma^\pm \pi^\mp$ pair production. Analyzing events of the type (2), we found 1205 events involving $\Sigma^\pm$ hyperons which decayed or interacted at rest. Identification of particles was carried out not only for Σ hyperons but also for the incident K^- mesons.

Every center of K meson star was studied in detail under a magnification of 15 · 100, taking into account whether the following »satellites« were present at the center:

a) recoil ($2\,\mu \leqslant R \leqslant 5\,\mu$),

b) blob ($R < 2\,\mu$) and

c) slow (Auger) electron with at least three grains in the track[7].

Table 1 presents the number of K meson captures on the light and heavy emulsion nuclei. This classification was carried out in such a way that condition a) corresponded to the capture on light nuclei, and b) and c) to that on heavy nuclei. The column for light nuclei also includes pure events, taking the criterion of some authors[7, 8, 1, 10]. From Table 1 it can be concluded that interactions of K^- mesons at rest with a proton, giving rise to a $\Sigma^{\pm}$ hyperon and a $\pi^{\mp}$ meson, occur more frequently on light than on heavy nuclei. This results is in agreement with the conclusion of Burhop[2], who assumes that the outermost regions of heavy nuclei have a proton defect.

Table 1

Capture on light nuclei		Capture on heavy nuclei	
Criterion	Number of events	Criterion	Number of events
recoil	620	blob	294
pure events	58	2 blobs, recoil	78
recoil, electron	29	electron	48
		blob, electron	78
In total	707		498
or (58.8 ± 1.9) %		or (41.2 ± 1.4) %	

Σ^- *hyperon capture on light and heavy nuclei.* One of the basic criteria for Σ hyperon capture on light nuclei is the condition that the capture star contain at least one track of length from 2 to $32\,\mu$[11]. Pure events also belong to this category. As in the case of K meson capture, the presence of a slow Auger electron or a blob is an indication for capture on a heavy nucleus.

Table 2, which also included Σ_σ and Σ_ρ captures, illustrates the rate of the former and latter events on light and heavy nuclei. 593 interactions of Σ hyperons, which were identified by standard methods of identifying particles, were taken for the analysis.

Table 2

Capture on light nuclei				Capture on heavy nuclei			
criterion	Σ_σ	Σ_ρ	in total	criterion	Σ_σ	Σ_ρ	in total
recoil	27	97	124	blob	36	91	127
recoil, electron	4	11	15	blob, electron	—	30	30
pure events	—	61	61	more blobs	7	4	11
1* $\leqslant R \leqslant 32\,\mu$	49	—	49	electron	38	138	176
In total	80	169	249		81	263	344
or (42.0 ± 1.9) %				or (58.0 ± 2.6) %			

Although Σ hyperons interact with only one charged nucleon (a proton), the results on all the interactions of Σ hyperons at rest with emulsion nuclei show that the rate of Σ hyperon captures is higher on heavy nuclei than on light ones. This is also the case with K^- meson interactions, but only if all the K meson interactions with one or more nucleons are considered as a whole.

Acknowledgement

We would like to thank professor Della Corte and Emulsion Group of the Institute of Physics at Florence for giving us a part of their stack and appreciate their cooperation during the course of study. We are grateful particulary to Mrs. D. Savić for her patient scanning and accurate measurements.

References

1) D. H. Davis, S. Lovell, M. Csejthey-Barth, J. Sacton, G. Schorochoff and O'Reilly, Nuclear Physics **B1** (1967) 434;
2) E. H. S. Burhop, Nuclear Physics **B1** (1967) 437;
3) European K^- Collaboration, Nuovo Cimento **14** (1959) 315;
4) M. Jurić, O. Adamović, D. Kačurkov, S. Popov, M. Raspopović and J. Simonović, Institute of Physics, Beograd, IF-78, (1967);
5) B. D. Jones, Nuovo Cimento **19** (1961) 400;
6) D. H. Davis and D. Skjeggestad, Enrico Fermi Inst. for Nuclear Studies, University of Chicago, 63—7, (1963);

* The lower limit of 1 μ is taken because it was found that more than 90% of the recoil tracks were longer than 1.5 μ.

7) M. Csejthey-Barth and J. Sacton, Bull. Univers. Libre de Bruxelles, 4 (1962);
8) G. T. Condo and R. D. Hill, Phys. Letters, 13 (1964) 271;
9) A. Ismail, Nuovo Cimento 33 (1964) 25;
10) S. Lovell and G. Schorochoff, Nuclear Physics B5 (1968) 381;
11) J. Sacton, M. J. Beniston, D. H. Davis, B. D. Jones, B. Sanjeevainah and J. Zakrzewski, Nuovo Cimento 23 (1962) 702.

ZAHVAT Σ^- HIPERONA NA LAKIM I TEŠKIM JEZGRAMA EMULZIJE

M. JURIĆ i I. SIMONOVIĆ

Institut za fiziku, Beograd

Sadržaj

Proučavani su nuklearni zahvati Σ hiperona na lakim i teškim jezgrama emulzije. Njihova klasifikacija je izvršena po analogiji sa zahvatima K^- mezona a na osnovi razlike u Coulomb-ovom potencijalu za laka i teška jezgra i emisije sporih, tzv. Auger-ovih elektrona.

Blok nuklearnih emulzija je bio ozračen snopom usporenih K^- mezona na proton-sinhrotronu u CERN-u. Od svih reakcija koje su se desile u ovom detektoru izdvajane su samo interakcije Σ hiperona i K^- mezona sa jednim vezanim protonom u kompleksnom jezgru emulzije. Pri tome su bile razmatrane samo interakcije K^- mezona čiji su produkti po dve naelektrisane čestice, dok su za interakcije Σ hiperona uzimani svi nastali produkti zahvata bez obzira na broj emitovanih čestica i njihovo naelektrisanje. Eksperimentalna merenja su pokazala da su zahvati Σ hiperona proizvedeni u $(58.0 \pm 2.6)\%$ na teškim i $(42.0 \pm 1.9)\%$ na lakim jezgrima.