Cross section for production of cumulative Λ^0 hyperons

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We measured the inclusive cross section for the production of cumulative Λ^0 hyperons from a mixture of C and Xe nuclei under the influence of 2.9-GeV/c π^- mesons. The spectra of the cumulative Λ^0 hyperons measured in the angle range $\theta_{lab} > 47°$ and the momentum range $p_{lab} > 150$ MeV/c are satisfactorily described by the function $f = Ed^3\sigma/d^3p = C\exp[-T/T_0]$. The slope parameter T_0 depends on the angle and ranges from 73 ± 10 MeV at $47° < \theta_{lab} < 50°$ to 36 ± 6 MeV at $120° < \theta_{lab} < 180°$. The parameter C ranges from 50 ± 13 to 8 ± 3 mb-c^3/GeV^2.

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Continuing the investigation of nuclear scaling (see, e.g.,[1]) which is typical of cumulative particle production (see, e.g.,[2]), i.e., particles produced on nuclei and having a momentum **p** in the region kinematically forbidden to production on a free nucleon at rest, we have obtained new data (for the preliminary results see[3]) on the cross section for the production of cumulative Λ^0 hyperons. Our interest in Λ^0 hyperons is motivated by the following: first, the well-known asymmetry in the $\Lambda^0 \to p\pi^-$ decay makes it possible to determine relatively simply the polarization of the Λ^0 hyperons and hence the dependence of the inclusive characteristics on a new variable—the particle-spin projection; second, the nonzero strangeness S of the Λ^0 hyperons differentiates them strongly from other particles, say, π, p, d, t so that a comparison of their inclusive characteristics permits an estimate of the degree of universality of the regularities observed in the production of cumulative particles. It is also important that the production of Λ^0 hyperons on protons has been quite well investigated.

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The data presented here are the results of a reduction of 200 000 photographs from the 120—Δ propane-xenon chamber of our Institute,[4] placed in a magnetic field of 18.6 kG. The chamber was exposed to a π^- meson beam with momentum 2.9 GeV/*c*. The Λ^0 hyperons with lab emission angle larger than 47° (under our conditions this was the limiting angle for production on a free nucleon at rest) were registered by the $\Lambda^0 \to p\pi^-$ decay, which produces a characteristic "fork" (V event) in the bubble chamber. These V events are produced as a result of the $K^0 \to \pi^+\pi^-$ decay. We registered and reduced altogether 1008 V events, of which 533 were identified as the $\Lambda^0 \to p\pi^-$ decay. The relative number of Λ^0 hyperons from the $\Sigma^0 \to \Lambda^0\gamma$ decay, estimated from the γ-quantum multiplicity emitted together with Λ^0 hyperons, does not exceed in any case 20%. The absolute normalization of the cross section was against the total inelastic cross section of the π^- mesons with the chamber material: we registered a total of $\sim$330 000 stars, 14% on P, 45% on C, and 41% on Xe (the cross sections $\sigma_{\rm P}^{in}, \sigma_{\rm C}^{in}$ and $\sigma_{\rm Xe}^{in}$ were taken from Refs. 5–7, respectively).

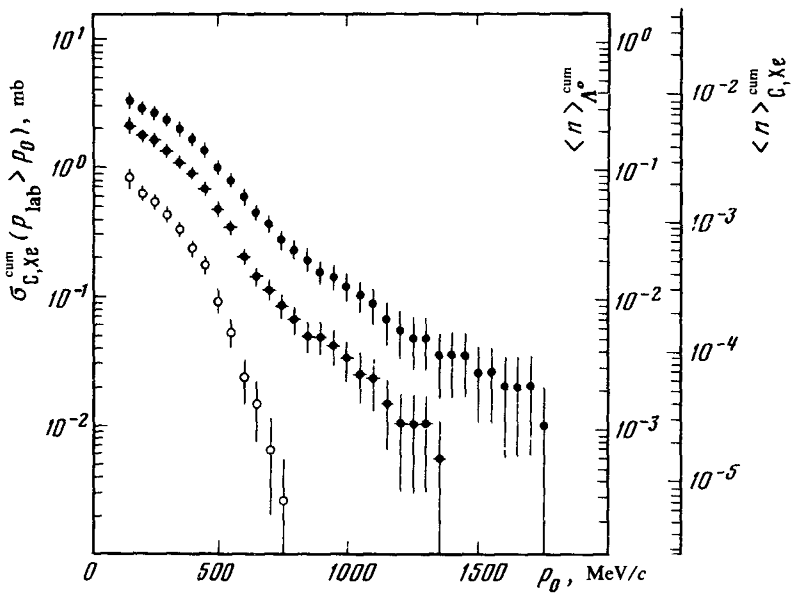

FIG. 1. Cross section for the production of cumulative Λ^0 hyperons with momentum larger than the given p_0 on the effective nucleus of the mixture: ✦–$\theta > 47°$, ●–$\theta > 60°$, ○–$\theta > 90°$.

Figure 1 shows the cross section $\sigma^{\rm cum}_{\rm C,Xe}$ for the production of cumulative Λ^0 hyperons with momentum larger than the given p_0 on the effective mixture nucleus. For the sake of clarity, two additional scales are shown on the right, one representing the average multiplicity of the cumulative Λ^0 hyperons $\langle n \rangle^{\rm cum}_{\rm C,Xe} = \sigma^{\rm cum}_{\rm C,Xe} / \sigma^{in}_{\rm C,Xe}$, where $\sigma^{in}_{\rm C,Xe}$ is the toal inelastic cross section of the π^- mesons on the effective mixture nucleus, $\sigma^{in}_{\rm C,Xe} = (\sigma^{in}_{\rm C} n_{\rm C} + \sigma^{in}_{\rm Xe} n_{\rm Xe})/(n_{\rm C} + n_{\rm Xe}) = 366 \pm 11$ mb (here $n_{\rm C}$ and $n_{\rm Xe}$ are the numbers of C and Xe nuclei per unit volume); the second shows the fraction of the cumulative Λ^0 hyperons $\langle n\rangle_{\Lambda^0}^{\rm cum}=\langle n\rangle_{\rm C,Xe}^{\rm cum}/\langle n\rangle_{\rm C,Xe}^{\Lambda^0}$, where $\langle n\rangle_{\rm C,Xe}^{\Lambda^0}$ is the average multiplicity of all the Λ^0 hyperons and is assumed here equal to 2.5×10^{-2} for $p>250$ MeV/c.[8]

The spectra of the cumulative Λ^0 hyperons are represented in Fig. 2 in the form of the invariant function $f=Ed^3\sigma/d^3p$ (E is the total Λ^0 energy) for different ranges of the emission angles. The angular distributions for different momentum ranges are shown in Fig. 3. It is seen that the function f depends strongly both on $T_{\rm kin}$ and on the angle.

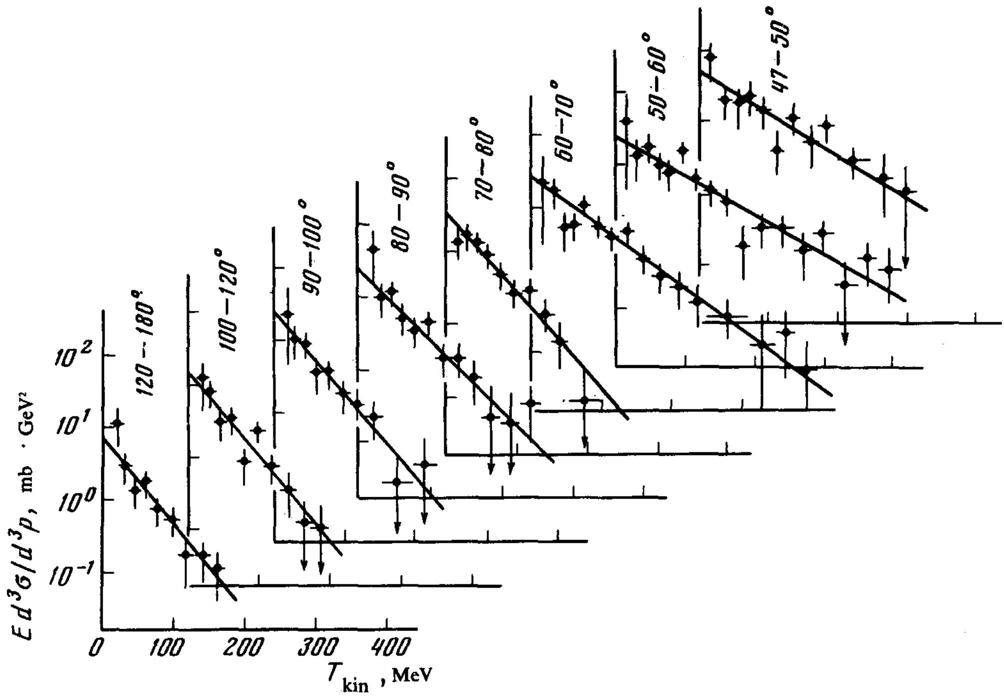

FIG. 2. The function $f=Ed^3\sigma/d^3p$ of cumulative Λ^0 hyperons vs $T_{\rm kin}$ for different emission-angle ranges. Solid lines— approximation in the form $f=C\exp[-T/T_0]$.

At large p, the dependence on the angle becomes stronger; the energy spectra become steeper with increasing angle. This behavior, as is well known,[9] is typical of cumulative protons. The solid lines in Fig. 2 are plots of the function

$$f = C\exp[-T/T_0] \quad (1)$$

with parameters C and T_0 that aproximate in best fashion the experimental points. The values of C, T_0, and χ^2 are listed in Table I as functions of the Λ^0-hyperon emission angle in the lab. The value of T_0 for large angles is close to T_0 for protons (see, e.g.,[9]) and is independent of angle within the limits of error. An abrupt increase of T_0 is observed near the kinematic boundary.

TABLE I.

Angle ranges, deg	C, mh $\cdot c^3/\mathrm{GeV}^2$	T_0, MeV	χ^2/deg. freedom
47 – 50	50 ± 13	73 ± 10	1.5
50 – 60	25 ± 5	78 ± 8	2.3
60 – 70	27 ± 5	62 ± 5	1.0
70 – 80	37 ± 8	38 ± 3	1.7
80 – 90	25 ± 7	44 ± 5	0.8
90 – 100	26 ± 9	38 ± 5	0.2
100 – 120	16 ± 5	37 ± 4	1.0
120 – 180	8 ± 3	36 ± 6	0.7

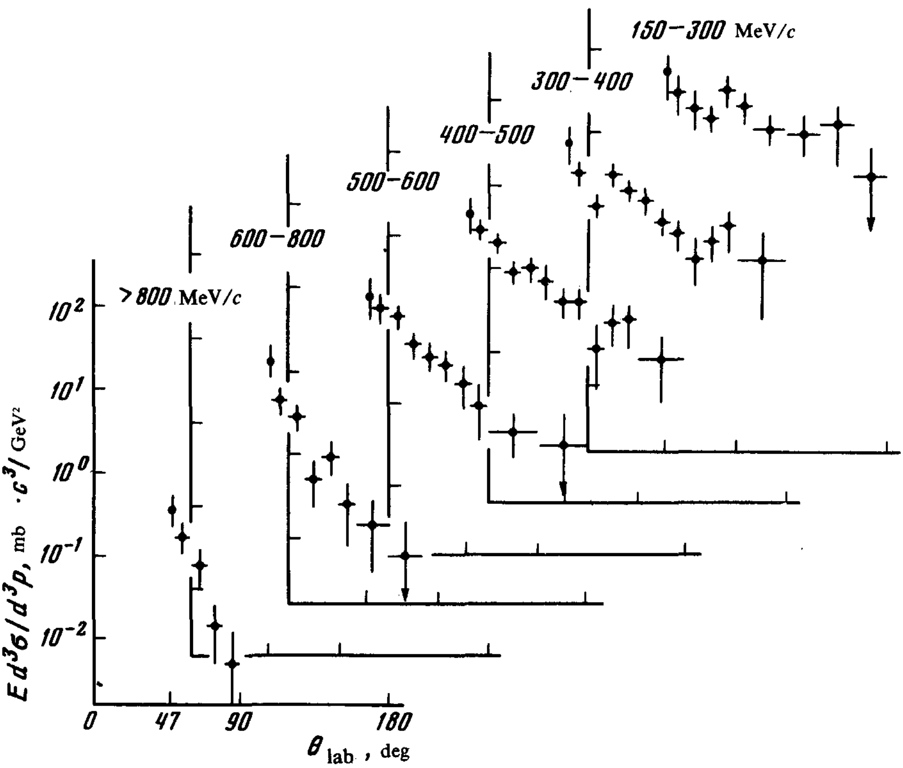

FIG. 3. The function $f = Ed^3\sigma/d^3p$ of cumulative Λ^0 hyperons vs the emission angle for various momentum ranges.

We have previously[10] found that the polarization of cumulative Λ^0 hyperons is independent of their momentum, within the limits of errors, i.e., the spectra of Λ^0 hyperons with spin directed parallel and antiparallel to the normal to the reaction plane are similar. Since the spectrum of the cumulative Λ^0 hyperons is satisfactorily described by the function (1), the energy spectra of the polarized particles are also described by an exponential dependence of the type (1) with a slope parameter T_0 that does not depend on the direction of the spin.

Since the cumulative Λ^0 hyperons are produced accompanied by protons, we can attempt to estimate the fraction of the Λ^0 hyperons produced on the nuclei C and Xe separately and determine the A-dependence of the yield $\sigma_A^{\rm cum}/\sigma_A^{in}$ of the cumulative Λ^0 hyperons. Assuming the accompanying protons to be independently emitted, we have approximated the distribution $\sigma_{\rm C,Xe}^{\rm cum}(n_p)/\sigma_{\rm C,Xe}^{\rm cum}$ in terms of the numbers of these protons in the regions $\theta_{\Lambda^0} > 47^\circ$ and $p_{\Lambda^0} > 150$ MeV/c by a sum of two Poisson distributions. Such an estimate allows us to conclude that the yield of the cumulative Λ^0 hyperons in the indicated kinematic region does not depend on A, in strong contrast to the yield of the cumulative protons.[11]

In conclusion, we wish to thank A.G. Meshkovskiĭ and the members of his laboratory for supplying the films from the propane-xenon chamber, and I.I. Vorob'ev and the late L.S. Novikov for great help with organizing and performing the work.

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