ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

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CROSS SECTIONS FOR STRANGE PARTICLE GENERATION

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Abstract

Multiple production of strange particles has been treated. The resonance interactions of strange particles are taken into account. The law of strangeness conservation is taken into consideration more exactly. It has been shown by an example of slow antinucleon annihilation and pion-nucleon collisions at 1.7 BeV that the theoretical cross sections for strange particle production may be brought into agreement with the experimental data.

1. Introduction

Strange particle production at high energies and in slow antinucleon annihilation has been considered in numerous papers (see /1/-/3/, where references are given). It has been shown that by choosing properly the spatial volumes in which strange particles are generated, it is possible to obtain the values of the total cross section for strange particle production σ_{st} close to experimental ones for (πN) - and (NN) - interactions. The introduction of different volumes is found to be a means for a phenomenological account of the differences in the magnitude of the interaction between particles of various kinds /1/-/4/. At the present time, however, there are experimental data which can hardly be accounted for by using such a rough model /5/-/9/. The most important result is that the experimental cross section for $\bar{K}$ - particle production exceeds the theoretical one approximately by an order. This can be illustrated by the annihilation of slow antinucleons where the cross section σ_{st} coincides with that for $\bar{K}$ - meson production

$$\sigma_{st}^{theor} / \sigma_{in} \simeq 0{,}3\ \%^{[3;4]} \quad ; \quad \sigma_{st}^{exper} / \sigma_{in} = (3 \div 5)\%^{[5]}$$

(σ_{in} is the total cross section for all inelastic processes).

2. Strangeness Conservation

From the mathematical point of view the difference between the theoretical and experimental cross sections σ_{st} is due to the fact that in the statistical weights the exponent of the parameter determining the ratio of the spatial volumes for K- and π- mesons, $\xi = V_K / V_\pi \ll 1$, turns out to be greater for the reactions involving K- mesons than for those involving hyperons.

From the physical point of view this is equivalent to the assumption that strange particles as well as π- mesons and nucleons may be generated one by one; the conservation of strangeness is required only when the statistical equilibrium is already established.

In order to bring the experimental and theoretical data into agreement we give up this assumption and will suppose that each time strange particles are produced by pairs. Each act of the strange particle pair generation is characterized by the "interaction constant" λ . The spatial factor in the expression for the statistical weight may be now put as

$$V=\frac{\lambda^{S/2}}{G}\left(\frac{K}{K+\ell}\right)V_K^{K-1}V_\pi^{\ell}+\frac{\lambda^{S/2}}{G}\left(\frac{\ell}{K+\ell}\right)V_K^{K}V_\pi^{\ell-1}=\lambda^{S/2}\xi^{K-1}\frac{K+\ell\xi}{G(K+\ell)}\,V_\pi^{K+\ell-1} \qquad (1)$$

where K is the number of K- and $\bar{K}$- mesons. S is the number of all generated strange particles; ($K+\ell$) is the total number of the generated particles; G is the factor which takes into account the identity of particles, V_π is the Fermi volume. (Just as in /1/, the law of centre-of-mass conservation is taken into account here).

3. Secondary Interactions

There are at present some experimental data which indecate the existence of an appreciable interaction between K- and π- mesons. The most important ones are the following:

1. An analysis of the correlations between K- and π-mesons produced in ($\pi^- p$) collisions at the energy E = 7 BeV enables us to draw a conclusion about the resonant interaction between K- and π- mesons with the "isobar" mass of $m_{K^*} \approx 0.82$ BeV /10/.

2. The asymmetry of the angular distributions of strange particles produced in the collisions of pions with nucleons (see e.g., /7/), may be understood if one takes into account the "peripheral collicions" of a primary π-meson with the K- meson cloud of a nucleon (cf. 5 in /11/). The consideration based on the theory of poles gives the estimate $\sigma_{K\pi} \sim \sigma_{\pi N}$ for the ($K\pi$) interattion cross section.

3. An optical analysis of elastic ($K^- p$) scattering indicates a considerable probability of ($K\pi$) interactions for a large collision parameter. For ($K\pi$) interaction cross section the estimate $\sigma_{K\pi} \sim \sigma_{\pi N}$ /12/ also follows from here.

It should be also emphasized that "$\mathcal{D}$ - like" of (πN) interactions which were observed at Dubna and other laboratories may be also interpreted as a result of K- and π- meson interaction.

The interaction of K- mesons with π-mesons must lead to an increase of the volume V_K. Since the experimental data available at present is still insufficient for an unambiguous choice of the two parameters λ and ξ , we shall suppose roughly, that $V_K = V_\pi$. Besides, the account of the resonance in ($K\pi$) interaction is equivalent to the introduction into the statistical theory a new particle - a "($K\pi$) -isobar" which then decays again into initial particles.

Apart from the resonance ($K\pi$) interaction and the resonance interaction of pions with nucleons, which is usually considered, one has to take into account the resonances occurring in the interactions of pions with pions and hyperons[1/]. In Table I are shown the parameters of the corresponding "isobars". It is worth while noting that in most cases the numerical data in Table I are tentative and the data for ($\Sigma\pi$) interaction are suggestive, such interaction has not yet been observed although is very likely from the theoretical point of view.

4. Production of Strange Particles in ($N\bar{N}$) and (πN) Collisions

Let us analyse now the numerical results to which the account of the above-mentioned considerations lead. As an example, we shall be concerned with the annihilation of slow antiprotons on protons and ($\pi^- p$) collisions at $E = 1.7$ BeV.

In Fig. 1 are given the values σ_{st}/σ_{in} calculated for different values of the parameter λ. The experimental data available so far are still insufficient for unambigous conclusions; the agreement with experimental value $\sigma_{st}^{exper}/\sigma_{in} \approx (3 \div 5)\%$ for both cases may be obtained in the interval of the values of $\lambda \simeq 0{,}1 \div 0{,}2$.

The annihilation of slow antinucleons is the most convenient form of an interaction for the investigation of multiple particle production. In this case only three kinds of particles are produced, and there are no peripheral interactions what simplifies considerably the analysis of experimental data. Additional information may be obtained from the measurements of the cross sections for different channels of K – meson generation. In particular, one event of ($K, \bar{K}$) pair production per approximately thousand annihilation events[13] is observed, i.e. $\sigma(p+\bar{p} \to K+\bar{K}) / \sigma_{st} \sim (2 \div 4)\%$,
if we take into account that $\sigma_{st}/\sigma_{in} = (3 \div 5)\%$.
The theoretical values of the cross sections for different channels of ($p\bar{p}$) annihilation is given in Table II (in %% with respect to σ_{st}). As is seen, the channel of ($K, \bar{K}$) pair production is noticeably suppressed when the resonance K – meson interaction is taken into account.

In Table III are presented the theoretical rations of the cross sections for $\bar{K}$ – meson production to those of Λ - and Σ – hyperon production. ($\sigma_{K\bar{K}} + \sigma_{K\Lambda} + \sigma_{K\Sigma} = \sigma_{st}$). The experimental value of these ratios at $E = 1.7$ BeV is unknown to us[2/]. However, in[7],[8] it has been shown that $\sigma_{K\bar{K}} / \sigma_{K\Lambda}$ is increasing rapidly with energy (from 0.5 at $E = 3$ BeV up to 1.5 at $E = 7$ BeV). It should be expected that at $E = 1.7$ BeV $\sigma_{K\bar{K}} / \sigma_{K\Lambda} < 0.5$.

Thus, a more exact account of the strangeness conservation law and secondary interactions of strange particles considerably improves the agreement of the theoretical and experimental cross sections for strange particle production. (See e.g., papers[1]-[4] in which the theoretical characteristics of the created nucleons and pions are compared with experiment).

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1/ The result to which the account of the resonance ($\pi\pi$) interaction leads are given in[2]-[4].

2/ The calculations for higher energies are being made.

Table I

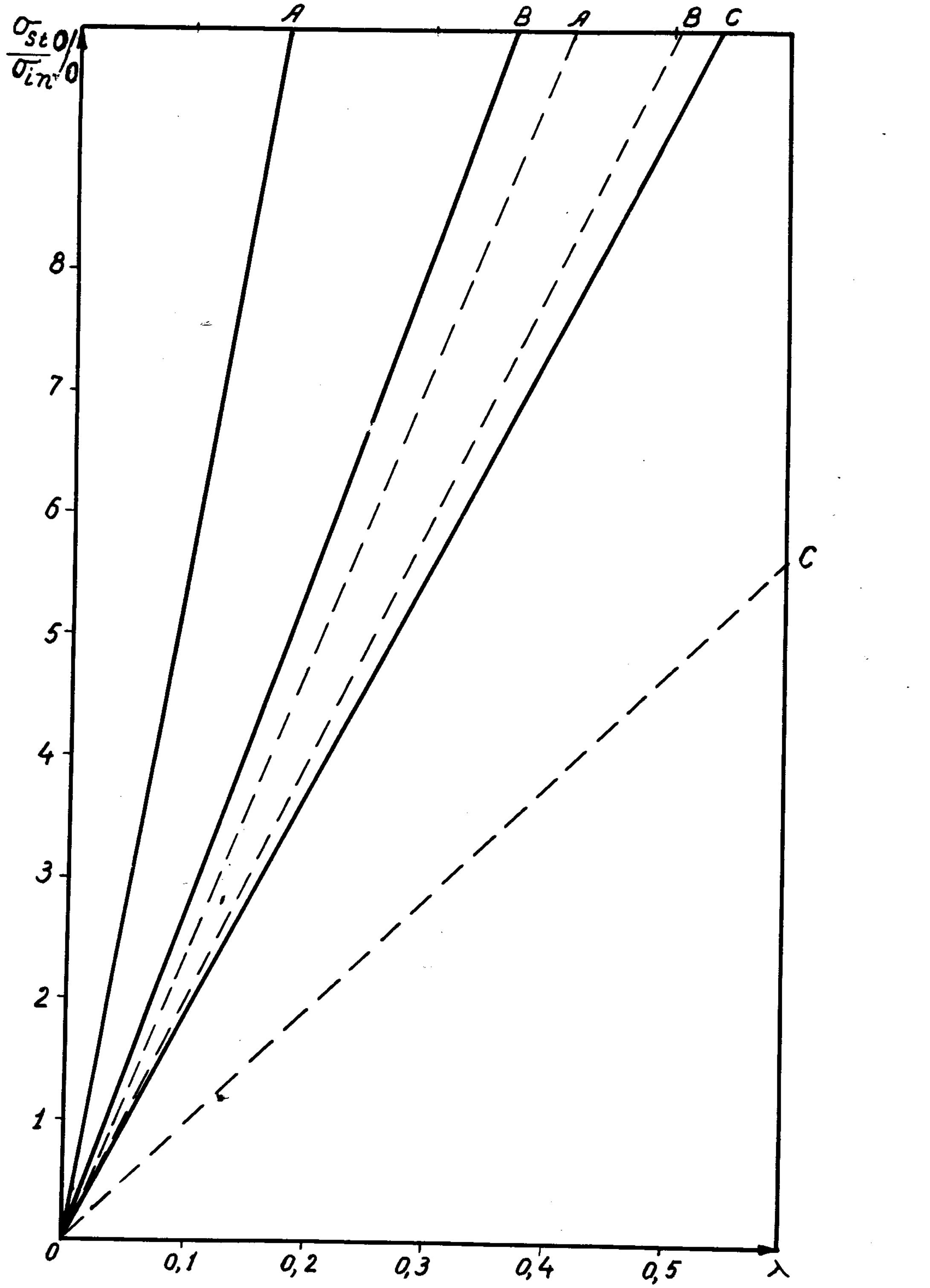
Interacting particles	Isobar mass (nucleon mass $M = 1$)	Isotopic spin	Spin
$\pi\pi$	0,6	1	1
$K\pi$ ($\bar{K}\pi$)	0,82 /10/	3/2	0 or 1
πN	1,32	3/2	3/2
$\pi\Lambda$	1,46 /13/	1	3/2
$\pi\Sigma$	1,54	1	3/2

Table II

Secondary interactions \ Reaction products	$K\bar{K}$	$K\bar{K}\pi$	$K\bar{K}2\pi$	$K\bar{K}3\pi$
all the interactions are taken into account;				
spin $S(K\pi)=0$	6	32	54	7
spin $S(K\pi)=1$	3	21	61	15
only ($\pi\pi$)	10	40	46	4

Table III

Secondary Interactions	all the interactions are taken into account		only
	$S(K\pi)=0$	$S(K\pi)=1$	$(N\pi)$ and $(\pi\pi)$
$\sigma_{K\bar{K}}/\sigma_{K\Lambda}$	0,174	0,15	0,28
$\sigma_{K\bar{K}}/\sigma_{K\Sigma}$	0,162	0,12	0,32



F i g. 1. Solid curves show the values of σ_{st}/σ_{in} for ($p+\bar{p}$); the dotted lines- the values of σ_{st}/σ_{in} for (π^-+p).
In calculating the curves **A** all the resonance interaction were taken into account; the spin of the ($K\pi$) - isobar $S(K\pi)=1$. The curves **B** show the same, but the spin $S(K\pi)=0$. In calculating the curves **C** the resonance interactions of strange particles were not taken into account (i.e., in the case of ($p+\bar{p}$) only the ($\pi\pi$) resonance considered, while in the case of (π^-p)–the (πN) and ($\pi\pi$) resonances).

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