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ON COHERENT INTERACTIONS BETWEEN HIGH ENERGY PARTICLES AND NUCLEI

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The problem of the so-called critical momentum of primary particles for which the nucleus involved in the reaction does not recoil is considered.

AT the present time, the solution of a number of important problems in the physics of hypernuclei (dependence of the binding energy B_Λ on the atomic weight A, the existence of excited states of hypernuclei, etc.) has been delayed owing to the lack of a reliable method of detecting and identifying hyperfragments with quite large values of A. The difficulties are aggravated by the fact that the production of hyperfragments is practically not subject to "planning" and in each specific instance we have to deal with a hyperfragment whose type is determined by various random circumstances.

It seems to us that the situation can be basically changed by a reasonable choice of the production conditions for hypernuclei. Let a K^- meson interact with any nucleon of a nucleus via the scheme

$$K^- + N \to \Lambda^0 + \pi. \qquad (1)$$

For K^- mesons at rest, the produced Λ^0 particles can have a rather large momentum $p \sim 250$ MeV/c, which leads, as a rule, to a partial breakup of the nucleus. We can readily see, however, that there exists some critical momentum of the K^- meson ($p_{cr} \sim 550$ MeV/c) at which the Λ^0 particle emitted backward in the c.m.s. is at rest in the laboratory system. In this case, the nucleus will not breakup and, as a result, a hyperfragment is produced. This hyperfragment will differ from the initial nucleus only by the substitution of a Λ^0 particle for one of the nucleons.

Hence we have to deal with the two-particle reaction

$$K^- + \text{nucleus} \to \text{hypernucleus}_\Lambda + \pi, \qquad (2)$$

which permits the determination of the quantity B_Λ (or the quantities B_Λ if the hypernucleus has excited states) by measurement of the pion momentum. The structure of the amplitude for the process $F(\mathbf{q})$ is determined by an expression of the type

$$F(\mathbf{q}) = f(\mathbf{q}) \int \Psi_f^* e^{i\mathbf{qr}/\hbar} \Psi_i \, d\tau, \qquad (3)$$

where $\mathbf{q}$ is the momentum transfer to the nucleus, $f(\mathbf{q})$ is the amplitude of (1), and the wave functions Ψ_i and Ψ_f describe the initial nucleus and the produced hyperfragment. The quantity $\exp(i\mathbf{qr}/\hbar)$ oscillates rapidly at large momentum transfers and is close to unity if $|\mathbf{q}|R < \hbar$ (R is the radius of the nucleus). Reaction (2) therefore proceeds with an appreciable cross section only if the pion is emitted approximately in the direction of the primary K^- meson ($\theta \lesssim 10°$) and if the kaon momentum differs little from the critical value [1)] ($|\Delta p| \lesssim 100$ MeV/c).

This can serve as a basis for various methods of investigating hypernuclei by means of both visual (emulsion, various types of track chambers) and electronic techniques. A detailed analysis of the possibilities discussed here is beyond the scope of the present note. We only indicate the favorable background conditions, since any departure from reaction (2), for example, the production of free Λ^0 particles, partial breakup of the nucleus, etc., leads to an appreciable decrease in the energy of the secondary pion.

Similar considerations also apply to other reactions, in particular, the so-called "peripheral" interactions, as a result of which the nucleus remains intact.[5-7] It should also be borne in mind that for some reactions the critical momentum is infinitely large. An example is the photoproduction of π^0 mesons:

$$\gamma + \text{nucleus} \to \pi^0 + \text{nucleus}. \qquad (4)$$

In these cases, the momentum transfer is always different from zero, but can be made as small as desired. In particular, if the π^0 meson in reaction (4) is emitted almost forward, we then obtain for the momentum of the nucleus

[1)]It goes without saying that under these conditions the production of hyperfragments will frequently be accompanied by the emission of one to two nucleons.

$$p_{\mathrm{nucl}} \approx \mu^2 c^2 / 2p_\gamma,$$

where μ is the π^0 mass and p_γ is the momentum of the primary γ ray. For sufficiently large p_γ, the value of p_{nucl} becomes very small. Under these conditions, the cross section for the reaction can increase as a result of the interference of processes involving different nucleons of the nucleus. A more detailed examination of the questions raised in this note will be given elsewhere.

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