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Antiproton Production

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(Received July 12, 1954)

RECENTLY a few Letters have appeared[1] which discuss the cross sections for antiproton production in nucleon-nucleon collisions, at energies which will soon be available at Berkeley. We should like to point out that there may be a more profitable way of producing antiprotons, by first producing a very energetic π meson which in turn produces an antiproton in colliding with a nucleon.

The reaction

$$p+N\rightarrow p+N+p+\bar{p}, \tag{1}$$

where N is a nucleon, has a threshold of $6Mc^2$ (5.6 Bev) for the incident proton. However, if we consider the two-step reaction,

$$\begin{aligned} p+N&\rightarrow N+N+\pi, \quad \text{(a)}\\ \pi+N&\rightarrow N+p+\bar{p}, \quad \text{(b)} \end{aligned} \tag{2}$$

the threshold for this double reaction, if we use the most energetic π produced in (a), is about 4.4 Mc^2 (4.1 Bev) for the incident proton in (a).

For the following reasons, then, we think that the reaction (2) may be more useful at Berkeley energies:

(i) If the N in (1) is a proton, the cross section is very small near threshold, since there are 3 final protons, one of which must be in at least a p-state.

(ii) For a given proton energy, say $\sim 7Mc^2$, reaction (2) will be a good deal above threshold, whereas (1) will not. Also in (b) of (2) there are only *three* final particles and thus the density-of-states factor will be considerably more favorable than for (1). The problem is then to produce the high-energy π mesons.

We can give a rough estimate for the cross sections for (1) and for (2b). We assume that we have protons of K.E.$\sim 7Mc^2$. Then we estimate the cross section for (1). The total energy in the c.m. system is about 4.24 Mc^2 and so the kinetic energy to be divided among the four final particles is 0.24 Mc^2. We estimate the matrix element crudely by conserving momentum at each vertex in Fig. 1 and putting in a factor $g/(2\omega)^{\frac{1}{2}}$ for each vertex, where g is the coupling constant and ω the meson energy. We can rearrange the vertices in 4! ways; we get $\frac{3}{2}g^4$ for

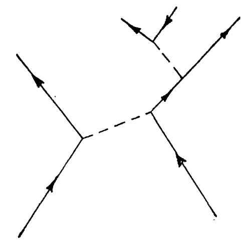

FIG. 1. Feynman diagram of reaction (1).

the matrix element. Combining this result with the density-of-final-states factor, we get

$$\sigma_{pN}\approx 0.54(g^2/4\pi)^4(T_1/M)^{7/2}\text{ mb},$$

where T_1 is the kinetic energy available in the c.m. system. In this example, $T_1\approx 0.24Mc^2$.

Now a proton of $7Mc^2$ could produce a meson of $6Mc^2$. The energy available in the c.m. system of (2b) is about $3.65Mc^2$ and thus the kinetic energy available is about $0.65Mc^2$. Using the same type of estimate for the matrix element as above, we get

$$\sigma_{\pi N}\approx 22(g^2/4\pi)^3(T_2/M)^2\text{ mb}.$$

This gives

$$\frac{\sigma_{\pi N}}{\sigma_{pN}}\approx\frac{2000}{g^2/4\pi},$$

which is at least 200 if $g^2/4\pi\approx 10$. ($g^2/4\pi$ is quite likely smaller than 10.) Thus it seems that if more than about 0.1 percent of the protons can produce high-energy mesons, reaction (2) would be better.

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Modified Nucleon Propagators*

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(Received July 26, 1954)

THE need for nonperturbation methods in meson theory has been increasingly felt in recent years. There are, however, several difficulties associated with them, one of which has been recently pointed out by Feldman.[1] He has found that a new (nonrenormalizable) type of divergence appears when one uses modified

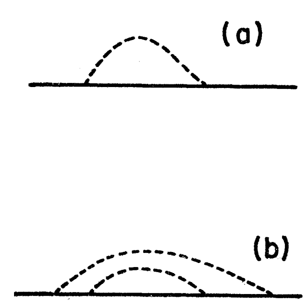

FIG. 1. Kernels for self-energy graphs.