POSSIBLE METHOD OF SEARCH FOR THE ρ^0 MESON

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IT has been shown by Wigner, Baz', and Okun'[1,2,3] that the cross section for a reaction proceeding through a given channel has singularities near the threshold for an inelastic process proceeding through a new channel. In this connection Baz', Okun', and Smorodinskiĭ suggested to us that a study of the energy dependence of the cross section for pion-nucleon scattering near the threshold for meson production $(\pi + N \rightarrow 2\pi + N)$ would be of interest for the purpose of obtaining information on the π-π interaction. We saw no singularities* in the total $\pi^- p$ cross section in experiments covering the energy range from 150 to 180 Mev; but became aware of the fact that a study of the energy dependence of the cross section for π-meson interaction with hydrogen, with high energy resolution, is of great interest not only near the meson production threshold but also at other energies where it may give information about the existence of the ρ^0 meson.

The aim of this note is to present the principle and outline the possibilities of a method† of search for ρ^0 mesons which in our opinion is more realistic than other methods proposed to date.[4]

We propose to look for a rather narrow singularity in the energy dependence of the $\pi^- p$ interaction cross section, because such a singularity would in principle testify to the existence of the ρ^0 meson. Indeed, it is to be expected that near the threshold for the reaction $\pi^- + p \rightarrow \rho^0 + n$ an anomaly should appear in the energy dependence of the reactions $\pi^- + p \rightarrow \pi^- + p$ and $\pi^- + p \rightarrow \pi^0 + n$. From the experimental point of view the first step should be a search for singularities in the energy dependence of the total $\pi^- p$-interaction cross section. Subsequent studies of angular distributions in the singularity region would be of great interest and could yield information on the relative parity of the ρ^0 and π mesons.

The width of the singularity depends on the interaction radius R and may be obtained from the condition $kR \ll 1$ where k is the wave vector of the produced ρ^0 meson[2] in the barycentric system. Assuming that $R \sim \hbar/m_\pi c$ then the maximum width of the singularity in the energy dependence of the $\pi^- p$-interaction cross section is $\Delta E \sim 40$ Mev for ρ^0 mesons with mass ~ 400 Mev/c^2. Here ΔE is the energy interval of the incident π mesons in the laboratory frame of reference outside of which the singularity disappears. The width of the singularity may be considerably less than ΔE which underscores the necessity for high energy resolution in the experiment.

It was assumed in the above that the lifetime of the ρ^0 meson is long compared to the nuclear time $\hbar/m_\pi c^2$, i.e., that the threshold for ρ^0 production is sharp. The relative amplitude of the singularity $\Delta\sigma/\sigma$ is of the order of magnitude of $\sigma(\pi^- p \rightarrow \rho^0 n)_{k=1/R}/\sigma_{\text{total}}(\pi^- p)$, and may therefore be as much as a few percent.

The method outlined above can be used to detect any neutral meson with sufficiently small natural width. We discuss here only ρ^0 mesons, assuming that they differ from π^0 mesons only in isotopic spin $(T = 0)$. In that case the ρ^0 meson cannot decay fast into either two π mesons (owing to parity conservation) or three π mesons (owing to conservation of the G quantum number[4,5]), but will decay through the channel $\rho^0 \rightarrow \gamma + \gamma$ or, if its mass is sufficiently large, $\rho^0 \rightarrow \pi + \pi + \gamma$. If the mass of the ρ^0 meson is substantially larger than 560 Mev/c^2 then a decay into four π mesons will proceed with a nuclear lifetime and our method would not be useful.‡

Independent of the nature of the ρ^0 meson one may ask whether the maximum observed in the energy dependence of the cross section of π-meson photoproduction on protons[6] and the peaks recently observed** in the energy dependence of the $\pi^- p$-interaction cross section at 700 and 1000 Mev are due to threshold effects. It seems to us that the answer to this question is negative: the widths of these peaks are apparently too great to be due to threshold effects. If one or both peaks are connected with the ρ^0 meson then it must be through a resonance interaction and the mass of the ρ^0 meson must be much less than 600 or 800 Mev/c^2.

Generally speaking the most outstanding difference between a resonance maximum and a threshold singularity (in the case when the latter is a peak and not a valley or step) is in their widths.

As regards the mass difference of the ρ^0 and π^0 mesons we observe that the experimental data accumulated in high energy physics indicates that interactions in different isotopic spin states have quite different intensities. It is just this circumstance that leads to the mutual transformations of different particles of an isotopic multiplet (the phenomenon of charge exchange scattering). In particular, as was pointed out to us by Ya. B. Zel'dovich, the very existence of antiproton exchange scattering ($\tilde{p} + p \rightarrow \tilde{n} + n$) implies a ρ^0-π^0 mass difference.

In a subsequent communication we shall describe the main features of an experimental setup which is being used in the search for ρ^0 mesons and report preliminary results of completed measurements.

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*It is easy to see that for a three-particle final state the threshold singularity practically disappears.[2]

†We have recently been informed that V. I. Gol'danskiĭ and Ya. I. Smorodinskiĭ proposed and analogous method.

‡Barrier effects, having to do with high orbital angular momentum, may appreciably slow down[4] the decay of the ρ^0 meson into four π mesons if its mass is only slightly larger than the sum of the four π-meson masses.

**Private communication from D. Frish to V. I. Gol'danskiĭ.

[1] E. P. Wigner, Phys. Rev. **73**, 1002 (1948).

[2] A. I. Baz', J. Exptl. Theoret. Phys. (U.S.S.R.) **33**, 923 (1957), Soviet Phys. JETP **6**, 709 (1958).

[3] A. I. Baz' and L. B. Okun', J. Exptl. Theoret. Phys. (U.S.S.R.) **35**, 757 (1958), Soviet Phys. JETP **8**, 526 (1959).

[4] Ya. B. Zel'dovich, J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 1644 (1958), Soviet Phys. JETP **7**, 1130 (1958).

[5] T. D. Lee and C. N. Yang, Nuovo cimento **3**, 749 (1956).

[6] R. R. Wilson et al., R. L. Walker et al., Proc. Annual Intern. Conf. High Energy Physics, Geneva, 1958, p. 87.

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SINGULARITIES OF THE S MATRIX AND THE ρ^0 MESON

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THE hypothesis that another neutral meson (ρ^0 meson) exists with zero spin and strangeness has been discussed in several papers. All the methods proposed for verifying this hypothesis were based on the observation of some reaction producing the ρ^0 meson or on the detection of its decay products.

We wish to point out here that still another method exists, based on an essentially different idea, which may turn out to be considerably more convenient for actual experiments. It has to do with the study of singularities in the energy dependence of a reaction near the threshold for the production of a new particle. This method was first studied in a general form by Wigner.[1] Later Baz'[2] indicated the interesting consequences resulting from an application of this method to nuclear reactions (see also the work by Breit and others,[3] which was published simultaneously).

The same idea was used in a study of photodisintegration near threshold for the γn reaction[4] and in a study of K-meson properties.[5] This same method was used[6] to detect the dineutron in a study of the energy dependence of elastic neutron scattering by nuclei near the threshold for the (n, 2n) reaction.

It is natural to apply the consideration of Baz' et al.[6] to a study of the analogous problem concerning the existence of the ρ^0 meson. Specifically let us consider elastic scattering on protons of π mesons with energy in excess of 270 Mev.* The scattering cross section for the process may exhibit two types of singularities.

a) Singularities connected with the "isobaric" state, e.g., $\pi^+ + p \rightarrow$ "isobar" ($T = 3/2$, $I = 3/2$). A pole in the S matrix in the complex energy plane corresponds to this type of singularity; and near this pole, for real values of the energy, the cross section curve has the well known resonance shape.

b) The threshold for the production of a new particle, e.g., $\pi^- + p \rightarrow \rho^0 + n$. A branch point on the real axis corresponds to the threshold of such a reaction.† At such a point the derivative (in our case, the first derivative) of the cross section is discontinuous. It is this type of singularity that we are interested in. Its existence leads to the appearance of breaks in the cross section curve in the form of a "step" or "valley" or "peak" type