# EXPERIMENTAL POSSIBILITY OF VERIFYING HYPOTHESES REGARDING THE NATURE OF RESONANCES

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It is pointed out that from the mass difference between the isotopic components of a resonance level it can be determined whether a given resonance is a bound state of a pair of particles or a resonance level of the Breit-Wigner type in a system of other particles.

A large number of narrow meson and baryon resonances have been recently observed in many experiments. It was found that the mass of many resonances is somewhat less than the sum of the masses of any two particles. Two alternate hypotheses can be advanced with regards to the nature of such a resonance Z, which breaks up into particles A and B, and which has a mass somewhat smaller than the sum of the masses of particles C and D, namely 1) Z is a bound state of the particles C and D, and the final width of the resonance is due to the transitions $C + D \rightarrow A + B$, which lead to the decay of the Z state; 2) Z is a resonant level (of the Breit-Wigner type) in the $A+B$ system.

The first hypothesis is more attractive, since it explains in a natural fashion the narrowness of the arising resonance. At low binding energy in the Z state the particles C and D are at large distances from each other and collisions between them are rare. Upon collision the particles $C+D$ go over into $A+B$ and the Z state decays. Inasmuch as collisions are rare, the width of the resonance should be small (proportional to $\sqrt{\epsilon}$, where $\epsilon = M_C + M_D - M_Z$).

The purpose of the present article is to call attention to the fact that an experimental check on the first of these hypothesis is feasible.

Let us consider a resonance Z with isotopic spin different from zero, and let us determine the mass differences between the different components of the isotopic multiplet. These mass differences comprise the mass differences $\Delta M_{C_j}$ and $\Delta M_{D_j}$ of the initial particles C and D, which form the resonant state, and electromagnetic corrections to the interaction between them. But at low binding energy the electromagnetic corrections to the interaction are also small[1)], of order $e^2\epsilon$ (if we disregard the little-likely case when the small binding energy is the result of cancellation of several terms in the interaction energy and there is no such cancellation in the electromagnetic corrections). Therefore, if the resonant Z is a bound state of the particles C and D with low binding energy ($e^2\epsilon \ll \Delta M_{C_j}, \Delta M_{D_j}$), then the mass difference $\Delta M_{Z_j}$ of the different isotopic resonance components should be equal to the mass difference of the initial particles constituting these components. In the case when Z is a resonant level of the Breit-Wigner type in the $A+B$ system, there should be generally speaking no such relationship between the mass differences of the isotopic components of the Z resonance, since these mass differences are determined essentially by the electromagnetic corrections to the interaction of the particles A and B.

Let us consider some specific examples.

1. $Y_1$ resonance [1]: isotopic spin 1, strangeness $s = -1$, mass 1385 MeV. According to the first hypothesis, the $Y_1$ resonance is a bound state of the nucleon and a K meson, with $Y_1^+$ the bound state of p and $\bar{K}^0$, $Y_1^-$ the bound state of n and $K^-$, and $Y_1^0$ the bound state of p and $K^-$ and n and $\bar{K}^0$ with equal weights. In accordance with the foregoing, the differences in the masses of $Y_1^+$, $Y_1^-$, and $Y_1^0$ should be

$$M_{Y_1^+} - M_{Y_1^-} = (M_p + M_{\bar{K}^0}) - (M_n + M_{K^-}) = 2.6 \text{ MeV},$$

[1)]The electromagnetic corrections to the interaction between particles C, D and A, B are also small, because of the small width of the resonance.

$$M_{Y_1^+} - M_{Y_1^0} = (M_p + M_{\bar{K}^0})$$
$$-\tfrac{1}{2}(M_p + M_{K^-} + M_n + M_{\bar{K}^0}) = 1.3 \text{ MeV}.$$

In the mass difference $M_{Y_1^+} - M_{Y_1^0}$ no account is taken of the Coulomb interaction of the proton with the $K^-$ meson, which should be of order 1 MeV. Taking this interaction into account we get $M_{Y_1^+} - M_{Y_1^0} = 1.8$ MeV.

2. $K\Lambda$ resonance[2,3]: isotopic spin $1/2$, mass 1650 MeV. This resonance can be regarded as a bound state of a $\Sigma$ hyperon and K meson, the component with isotopic spin projection $1/2$ being the bound state of $\Sigma^+K^0$ and $\Sigma^0K^+$ with relative weights $\left(C^{1/2,1/2}_{11;1/2,-1/2}\right)^2 = 2/3$ and $\left(C^{1/2,1/2}_{10;1/2,1/2}\right)^2 = 1/3$, while the component with isotopic spin projection $-1/2$ is the bound state of $\Sigma^-K^+$ and $\Sigma^0K^0$ with relative weights $\left(C^{1/2,-1/2}_{1-1;1/2,1/2}\right)^2 = 2/3$ and $\left(C^{1/2,-1/2}_{10;1/2,-1/2}\right)^2 = 1/3$. If the first hypothesis is true, we should have

$$M_{1/2} - M_{-1/2} = 2/3\,(M_{\Sigma^+} + M_{K^0}) + 1/3\,(M_{\Sigma^0} + M_{K^+})$$
$$- [2/3\,(M_{\Sigma^-} + M_{K^+}) + 1/3\,(M_{\Sigma^0} + M_{K^0})] = -3.1 \text{ MeV}.$$

Taking into account the Coulomb interaction between $\Sigma^-$ and $K^+$ we have $M_{1/2} - M_{-1/2} = -2.5$ MeV.

In both examples, the accuracy of the obtained mass differences is apparently of the order of 0.5–1 MeV.

We note that the application of similar arguments to the $\Sigma$ hyperon shows that the $\Sigma$ can apparently not be regarded as a bound state of $\Lambda$ and $\pi$. Although the binding energy of $\Sigma$ relative to $\Lambda$ and $\pi$ is not very small, 65 MeV, it is still difficult to expect to obtain the experimentally observed $M_{\Sigma^-} - M_{\Sigma^+} = 6.6 \pm 0.25$ MeV in place of the zero mass difference between $\Sigma^+$ and $\Sigma^-$, as called for by the hypothesis that $\Sigma$ is a bound state of $\Lambda + \pi$, or that the experiment will yield $M_{\Sigma^+} - M_{\Sigma^0} = -2.1 \pm 0.5$ MeV in place of the expected $M_{\Sigma^+} - M_{\Sigma^0} = 4.6$ MeV.

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