Comment on "Confirmation of the Sigma Meson"

In a recent Letter [1], Törnqvist and Roos reported on a re-analysis of $\pi\pi$ S-wave phase shifts using a coupled channel formalism in which the dynamics is totally determined by s-channel resonances. They found in their solution a broad $\frac{1}{\sqrt{2}}(u\overline{u} + d\overline{d})$-type scalar meson at 400 MeV which they associate with the long-controversial σ meson. They also drew from their analysis certain conclusions about the controversial $f_0(980)$ and $a_0(980)$ scalar states.

While we accept some of the elements of their analysis, we wish to point out why we have reached very different conclusions in our independent analyses [2,3] which included both the complete nonet of s-channel resonance poles *and* strong t-channel forces. In particular, we find the following: (1) Most of the broad rise of the S-wave $\pi\pi$ phase shifts is to be associated with t-channel attractive forces, not an intrinsic $q\overline{q}$ pole. (2) Our t-channel forces are also dominant in producing the attractive forces in the $K\overline{K}$ channels that create the $f_0(980)$ and $a_0(980)$.

We begin with a quick review of the essential elements of the three analyses [1–3] under discussion. The analysis of Törnqvist and Roos assumes that pseudoscalar-pseudoscalar (PP) scattering is controlled by its s-channel resonances, and focuses on the resonances' running mass functions $m^2(s) = m_0^2 + \Pi(s)$, with $\Pi(s)$ determined from a model for resonance $\rightarrow$ PP $\rightarrow$ resonance loop graphs. The distinctive feature of their approach is the use of very strong couplings to PP channels leading to sharp cusplike downward spikes in $\Pi(s)$ which allow the real part of $m^2(s)$ to intersect, or nearly intersect, s *twice*.

Our approaches [2,3], while distinct, have in common the very important role assigned to t-channel forces. Reference [2] grew out of a study of $qq\overline{q}\,\overline{q}$ systems which focused on the forces between two mesons arising from quark exchange. Reference [3] studied meson-meson interactions in an effective Lagrangian approach incorporating scalar, pseudoscalar, and vector mesons. In this latter approach it is mainly the vector mesons which produce very strong t-channel forces. Despite these differences, both Refs. [2] and [3] conclude that the $f_0(980)$ and $a_0(980)$ are $K\overline{K}$ states dominated by t-channel forces, and that the strong low energy $\pi\pi$ attraction is also dominantly due to t channel forces and not an intrinsic low mass $q\overline{q}$ σ meson. Note that all these approaches [1–3] are unitary scattering equations, so the different conclusions arising from [1] versus [2] and [3] are due to differences in the underlying dynamics.

The main purpose of this Comment is to suggest that the neglect of t-channel forces *of some kind* in Ref. [1] is untenable, and that this neglect therefore calls into question whether the interpretation of the data given in Ref. [1] is indeed an acceptable alternative to ours. The critical oversight of Ref. [1] is its neglect of the "exotic" $I = \frac{3}{2}$ and $I = 2$ PP scattering channels. In a pure s-channel-resonance-driven picture, the phase shifts in these channels would be zero. In Refs. [2] and [3] these channels are therefore used to set the scale of t-channel forces by using the data in these channels to fix the values of various crucial parameters. Indeed, one can view both Refs. [2] and [3] as having used the exotic channels to determine the t-channel forces, and then used various relations internal to the models [e.g., in Ref. [2] these are SU(6) spin-flavor Clebsch-Gordan coefficients, while in Ref. [3] they are SU(3) relations between coupling constants] to fix the t-channel forces in the $I = 0$, $\frac{1}{2}$, and 1 channels. For example, in Ref. [3], below 600 MeV t-channel ρ exchange dominates the $\pi\pi$ phase shifts; in the $I = 0$ $K\overline{K}$ channel the forces are even more attractive, because not only the ρ but also the ω and ϕ mesons add *coherently* to the attraction as demanded by SU(3). In Ref. [2] this attraction is somewhat weaker, but comparable. In both Refs. [2] and [3] the s-channel scalar resonances in the 1300 MeV region contribute further binding to the "$K\overline{K}$ molecules" but are not dominant.

In fact, Ref. [3] shows explicitly that t-channel forces lead to a broad "dynamical pole" that arises from the degrees of freedom already present in the meson-meson continuum, in contrast to an "intrinsic pole" that would arise from the insertion of a new $q\overline{q}$ degree of freedom into the dynamics [4].

We therefore suggest that the interpretation of the scalar resonances given in Ref. [1] be viewed with skepticism until their study is broadened to include in a systematic way the exotic $I = \frac{3}{2}$ and 2 channels. We are convinced that on doing so it will be discovered that the low energy attraction in $\pi\pi$ is dominated by t-channel forces and not by an intrinsic low mass σ meson. We also believe that it will emerge that the attractions in the $K\overline{K}$ channels leading to the $f_0(980)$ and $a_0(980)$, while not without important contributions from the s-channel resonances, are also dominated by ordinary t-channel "effective potentials."

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