Towards a model independent determination to the σ resonance

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The question of whether there exist the σ resonance in hadron physics is of great importance and has attracted interests among physicists for decades. There are increasing number of recent works claiming the existence of the σ resonance. However, owing to the strong interaction nature, it is very difficult to make any conclusion without heavily relying on assumptions and approximations which are often beyond control theoretically. For example, a careful analysis to the [1,1] and [1,2] Padé approximations [1] in $O(p^4)$ and $O(p^6)$ chiral perturbation theory reveals that in some cases the phase shifts are dominated by the contribution from spurious physical sheet resonances. Therefore it is necessary to study the problem from first principles and to reduce the model dependence as much as possible.

Our approach [2] sets up novel dispersion relations which reveal the exact relationship between the partial wave scattering phase shift and the pole contributions and cut contributions. It is found that the cut contribution to the $IJ = 00$ channel phase shift is negative and concave and therefore there must exist the σ resonance to explain the experimental data. In Ref. [3] we firstly generalize the single channel unitarity relation to the complex s plane which is equivalent to the generalized unitarity relation in quantum mechanics and apply it to study the property of the σ resonance. The 'high energy' contributions to the left cut integral are also briefly discussed in Ref. [3]. Our work can be further improved by using the Adler zero condition combining with analyticity in partial wave amplitudes, which is found to be very useful to give further constraints among parameters and to reduce the uncertainty of the background cut contributions to the phase shift [4]. The generalization to the couple channel case is also available which affords a unique tool in studying the analytic structure of the $\pi\pi$ scattering amplitudes around the $K\bar{K}$ threshold. [5] To conclude, a model independent determination to the σ resonance is within reach.

References

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