Three-body final state interactions in $D^+ \to K^- \pi^+ \pi^+$

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We stress the importance of three-body final state interactions in $D^+ \to K^- \pi^+ \pi^+$. The basic building block is the $K\pi$ amplitude with parameters determined by a fit to elastic LASS data. Based on a vector weak vertex, we can describe the $K\pi$ phase production experimental in the elastic region.

1 Introduction

Decays of D mesons became an important source of information about light scalars mesons, especially in the reactions $D^+ \to K^- \pi^+ \pi^+$and $D^+ \to \pi^+ \pi^+ \pi^-$. We calculate three-body effects in the decay $D^+ \to K^- \pi^+ \pi^+$and our main motivation is the discrepancy between the projection of $K^- \pi^+$ S-wave amplitudes from E791 [1] and FOCUS [2] experiments, and the scattering $K^- \pi^+$ S-wave from LASS [3]. To calculate the $D^+ \to K^- \pi^+ \pi^+$decay, we need to deal with two independent families of processes: the weak vertex, usually treated by quark factorization techniques in the literature [4], and the strong final state interactions (FSIs), which do take place after the weak decay. We concentrate on the three-body structure of FSIs and aim at identifying leading effects. Technical details of our calculation can be found in [5]. Among the simplifications made, we mention the absence in the $K\pi$ amplitude of both isospin 3/2 and P waves, as well as couplings to vector mesons and to inelastic channels.

The $K\pi$ amplitude is an essential ingredient in the three-body FSIs. We employ an elastic amplitude inspired on chiral perturbation theory, eqs.(1, 2), supplemented by unitarization. The tuning to elastic LASS data [3] defines the three free parameters in (1, 2). This amplitude contains two poles, associated with the κ and the $K_0^*(1430)$.

(1) $$\overline{T}_{1/2} = \frac{1}{F^2} \left[s + 3\,t/4 - (M_\pi^2 + M_K^2) \right] - \frac{\alpha(s)}{s - m_R^2} \,,$$

(2) $$\alpha = \frac{3}{2F^4} \left[c_d\, s - (c_d - c_m)\,(M_\pi^2 + M_K^2) \right]^2 .$$

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In our exploratory work, we assume three simple topologies for the weak amplitude, indicated schematically in fig. 1. The strengths of these vertices are respectively W_a, W_b and W_c, taken as constants, and their strong evolution is studied independently.

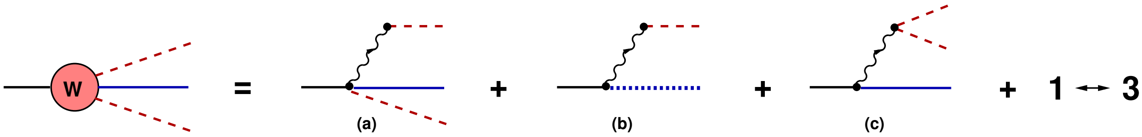

Figure 1: Topologies for the weak vertex: the dotted line is a scalar resonance and the wavy line is a W^+, which is contractile to a point in the calculation; in diagram c, one of the pions is neutral.

2 Three-body FSIs

Our treatment of FSIs departs from a Faddeev-like integral equation, represented in fig.2 top, which is subsequently expanded perturbatively, fig.2 bottom. Terms in the FSI series

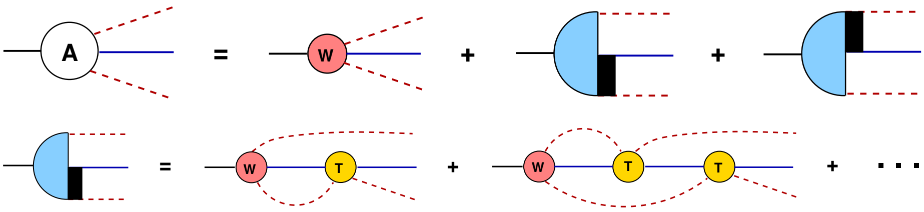

Figure 2: $D^+ \to K^- \pi^+ \pi^+$decay: (top) partonic amplitude (red) and hadronic multiple scattering in the ladder approximation; (bottom) rescattering series implementing three-body unitary.

contain a recursive component, the $K\pi$ two-body amplitude. Each weak topology in fig.1 is coupled to this series, giving rise to the amplitudes A_a (fig. 3), A_b (fig. 4) and A_c (fig. 5). Processes arising from the weak vertex (a) in fig.1 involves a tree term, whereas the three-body rescattering series starting from the weak vertex b has to be treated properly in order to avoid double counting. The bottom line in fig. 4 represents the construction of resonance width. In the case of process associated with the weak vertex c in fig.5, the series is simplified, since the π_0 produced directly from the W^+ decay is not present in the final state and the tree diagram does not play a role.

For simplicity, we show here contributions from FSI series up to a single rescattering. This is a good approximation, since higher order terms tend to decrease. In the case of A_a, the leading contributions are given in the first line in fig.3, which include both tree and one loop diagrams. In A_b, only the first diagram in the upper line of fig. 4 is kept and, in A_c, the leading term is just the one loop diagram in the middle of fig. 5. In graph 6,

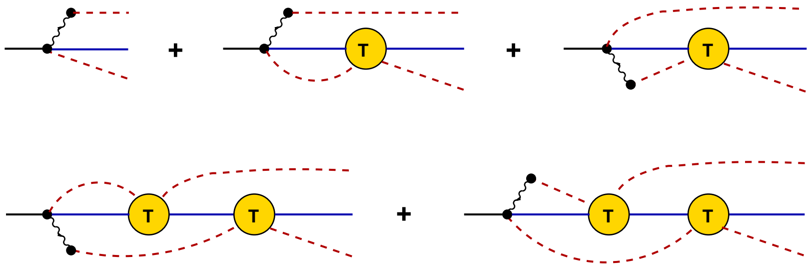

Figure 3: Diagrams involving the weak vertex W_a; the wavy line is a W^+, always plugged to a π^+; the π produced together with the $\overline{K}$ on the opposite side can be either positive or neutral.

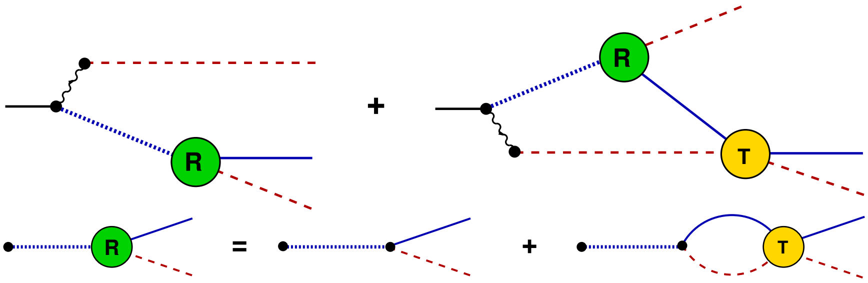

Figure 4: Diagrams involving the weak vertex W_b; the wavy line is a W^+, always plugged to a π^+ and the dotted line is a scalar resonance, which has a width given by the substructure R described at the bottom line.

we show these individual contributions for the phase, compared with the experimental scattering (LASS) [3] and production (FOCUS) [2] data. As we can see, while contributions from A_a and A_b fall exactly over the elastic $K\pi$ phase, the amplitude A_c coincides with FOCUS data [2] up to the region of the peak, when shifted by -163^0. The A_c topology is the only involving only a proper three-body interactions whereas A_a and A_b include tree contributions.

Thus, with a simple model of three-body final state interactions and a number of simplifying assumption we can reconcile experimental data between two-body interactions and weak decays, stressing the importance of proper three-body effects in the $D^+ \to K^- \pi^+ \pi^+$decay

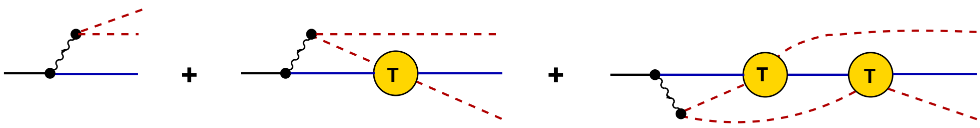

Figure 5: Diagrams involving W_c; one of the pions in the weak vertex is neutral.

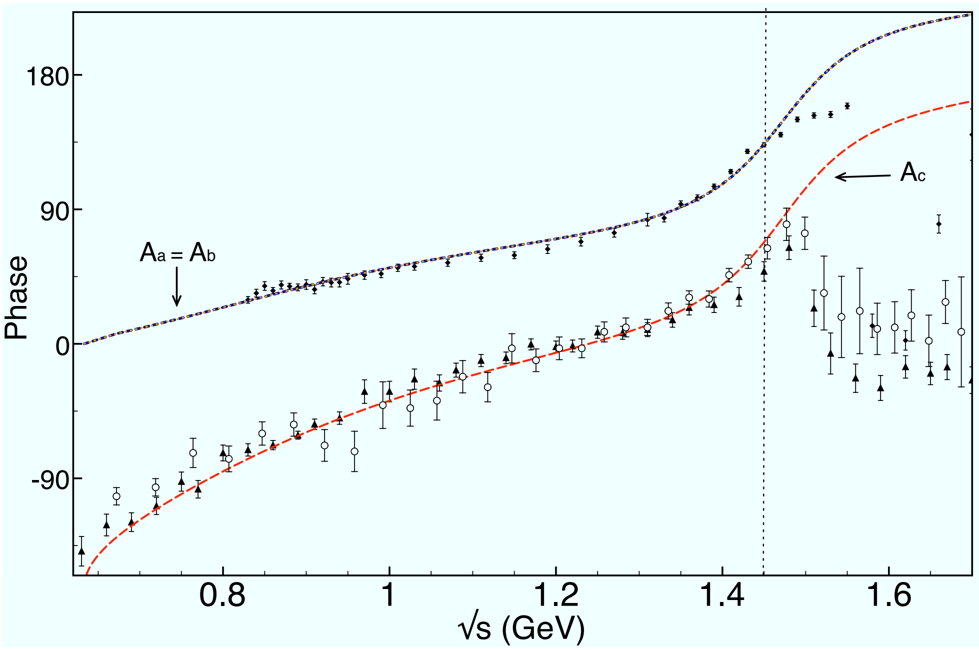

Figure 6: Leading contributions of the amplitudes A_a (blue doted), A_b (orange dashed) and A_c shifted by -163^0 (red long dashed), compared with FOCUS [2](triangle), E791 [1](circle), and elastic $K\pi$ results from LASS [3](diamond).

amplitude. More calculation details can be found in reference [5].

Acknowledgments

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