Universality of the multi-channel 4-body scattering system

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Abstract

We investigate the scattering system of 4 equal-mass quantum particles at energies where rearrangement channels are open. The interactions are renormalized to capture the essence of the pertinent nuclear 2-neutron, 2-proton system. A full treatment of the Coulomb interaction is included.

The quantity of most practical interest, namely the coupling between the deuteron-deuteron and the ^{3}H-proton/^{3}He-neutron channels, is subjected to a sensitivity analysis with respect to distorted, *i.e.* , screened Coulomb repulsion between the two protons.

a. Few is more The fundamental question of interest is on the behaviour of 4 identical spin-$^1/_2$ particles which can occupy 2 different isospin – to stress the significance to systems other than nuclei and mesons, we will use the more widely used notion of a flavour to discriminate internal states of a fermion – states. We limit the investigation to the experimental most relevant 2-fragment asymptotic configurations. These are defined by all partitions of the $N = 4$ particles into 2 clusters whose spectrum contains bound states.

Assuming zero-range, flavour[†] and spin-independent interactions

the scattering process is parametrized via a 3-channel S-matrix:

$$S_{ij} = \left\langle a\, L_a\, S_a \,\middle|\, \hat{S}^{J^\pi} \,\middle|\, b\, L_b\, S_b \right\rangle = \eta_{ij}\, e^{2i\delta} \quad , \tag{1}$$

and the almost decoupled d-d channel is encoded in $\eta_{dd} \approx 1$. Although, the Coulomb repulsion between protons provides a heuristic argument for this weak coupling, the comparison to the relatively strong coupling between the two 3-1 fragmentations seems to defy the argument as an equally strong force keeps the proton out of 3-helium.

b. Spin-wave-function overlap

	$\mid$ t-p$_1$ $\rangle$	$\mid$ t-p$_6$ $\rangle$	$\mid$ he-n$_1$ $\rangle$	$\mid$ he-n$_6$ $\rangle$	$\mid$ d-d $\rangle$	$\mid$ d$_q$ − d$_q$ $\rangle$	$\mid$ nn-pp $\rangle$
$\langle$ t-p$_1$ $\mid$	6						
$\langle$ t-p$_6$ $\mid$	−6	6					
$\langle$ he-n$_1$ $\mid$	−2	+2	0.66				
$\langle$ he-n$_6$ $\mid$	−6	+6	+2	6			
$\langle$ d-d $\mid$	+8.5	−8.5	−2.8	−8.5	12		
$\langle$ d$_q$ − d$_q$ $\mid$	−4.9	+4.9	+1.6	+4.9	−6.9	4	
$\langle$ nn-pp $\mid$	−4.9	+4.9	+1.6	+4.9	−6.9	+4	4

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†In nuclear physics the term isospin is more common to discriminate between internal states of a particle, *e.g.* , the neutron and proton, or the three charge states of a π meson.

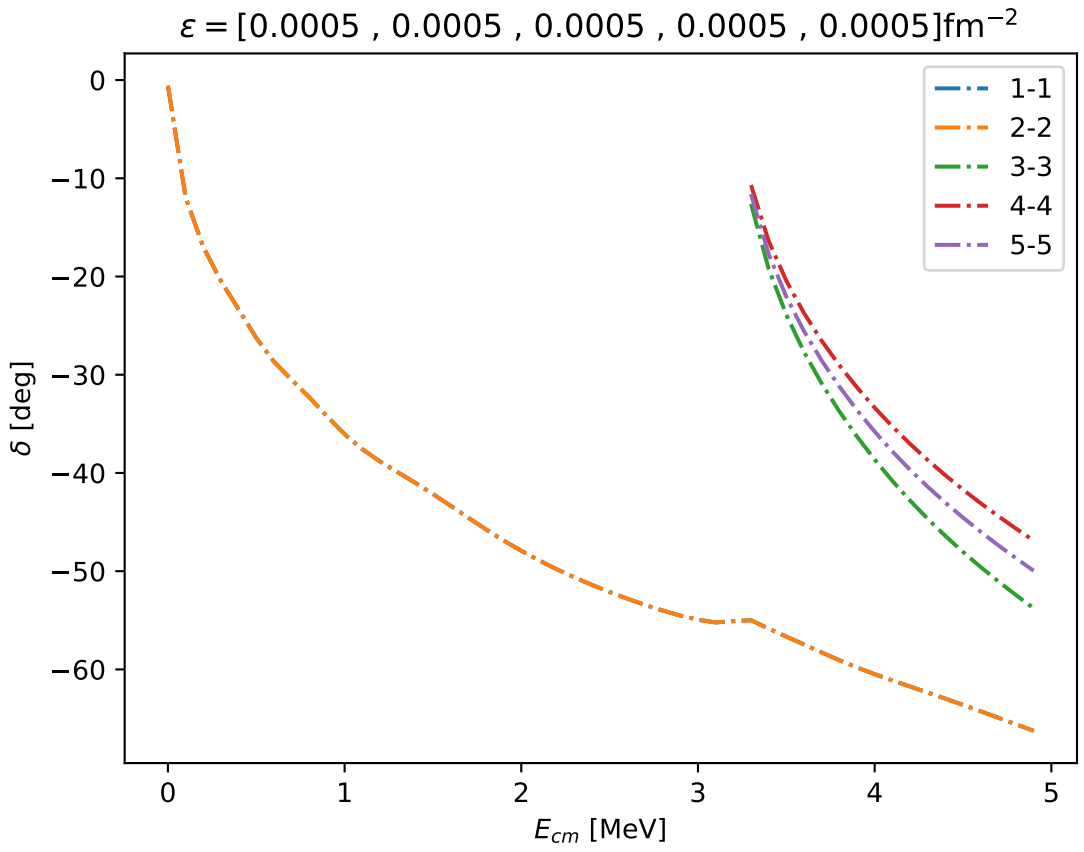

FIG. 1: Energy dependence of phase shifts which parameterize the coupled channel nnpp system in the $^1S_0$ α channel (1).