Pion Production Operators for $d + d \rightarrow^4 He\pi^0$

Charles J. Horowitz and Gerald A. Miller

1. One body term with recoil contribution of order m_π/M to make s-wave pions. See 2nd HW problem. Isospin violating coupling from $\pi - \eta$ mixing etc.

2. Weinberg term of 1st HW problem.

3. Isospin violating one-body coupling $(\tau \times \pi)_3$ and rescattering via W.T. term. This has the form of the Weinberg term of the 1st HW problem with a smaller coefficient. Both of these operators should include the nucleon recoil term in emitting the virtual pion.

4. Isospin violating one-body coupling (π_3) followed by π^0 rescattering via the λ_1 (isoscalar term of $\pi - N$ scattering) which is very small on-shell. This isoscalar operator has a larger matrix element than that of the 1st HW but the coefficient is much smaller.

5. Short range MEC from σ, ρ, or ω exchange with the isospin violating one-body operator of 1). By MEC we mean that part (Z graph) which is not contained in the ordinary NN potential.

6. Short range MEC from $\rho - \omega$ mixing coupled with an isospin conserving pion coupling.

7. MEC involving photon exchange. For large-angle, np scattering at 470 MeV, the simple photon exchange gives a CSB effect comparable to that of the ρ exchange (CSB from np mass difference in the vertex). The γ Z-graph contains parts of the same form as that of the σ MEC.

8. CSB in wave functions, either ^4He or in $d + d$ distortions. In particular, pre-scattering with an interaction of the form $\boldsymbol{\sigma}_1 \cdot \boldsymbol{\sigma}_2 \; \boldsymbol{\tau}_1 \cdot \boldsymbol{\tau}_2$ when acting before the Weinberg term changes the form to one which is maximally coherent. The zero of the 1st HW problem is removed. It is also true that the difference between the neutron and proton rms radii in ^4He is a very interesting number. There is no isospin violation in deuteron by parity conservation and the Pauli principle.

9. Operators involving the Δ. These are important for p -wave pion production because they can naturally produce the needed change in both spin and orbital angular momentum of two units each. Making a p-wave pion from the main components of the wave function requires a four-nucleon transition from $^5D_1$ to $^1S_0$. Recoil terms involving a Delta could contribute to s-wave pion production. These s and p wave terms get their CSB from pion-nucleon couplings with an isospin conserving Δ, or from Δ mass differences, or from CSB $\delta - N$ couplings.

10. CSB in the initial NN potentials occurring in the DD scattering wave functions could be followed by strong pion production.