SLAC-PUB-3147
June 1983
(N)

A MINIMAL UNITARY (Covariant) SCATTERING THEORY *

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In the minimal three particle equations developed by Lindesay[1] the two body input amplitude was an on shell relativistic generalization of the non-relativistic scattering model characterized by a single mass parameter μ which in the two body $(m+m)$ system looks like an s-channel bound state $(\mu < 2m)$ or virtual state $(\mu > 2m)$. Using this driving term in covariant Faddeev equations generates a rich covariant and unitary three particle dynamics. However, the simplest way of writing the relativistic generalization of the Faddeev equations can take the on shell Mandelstam parameter $s = 4(q^2 + m^2)$, in terms of which the two particle input is expressed, to negative values in the range of integration required by the dynamics. This problem was met in the original treatment by multiplying the two particle input amplitude by $\Theta(s)^1$. This paper provides what we hope to be a more direct way of meeting the problem.

Since we are not using a Hamiltonian interaction theory, the "off shell extension" required by the Faddeev integral equation dynamics is not initially defined. Guided by the successes of the earlier versions of the model, which stem from the fact that it goes to the physically desirable limits of non-relativistic scattering theory, we look for a fully off shell two body amplitude that preserves full off shell two particle unitarity. By requiring that there be no momentum structure at the vertices, which is what we mean by a "minimal" theory, we obtain the unique expression (where we have further restricted ourselves to single two particle "bound (or virtual)" states of mass μ_a in each input channel):

$$\tau_a(\vec{k}_{a+}, \vec{k}_{a-} | \vec{k}_{a+0}, \vec{k}_{a-0}; (Q_a^0, \vec{Q}_a)) =$$

$$1/\int d^3k'_{a+}(Q_a^0 - \epsilon_{\mu_a})[\epsilon'_{a+}\epsilon'_{a-}(\epsilon'_{a+} + \epsilon'_{a-} - Q_a^0)(\epsilon'_{a+} + \epsilon'_{a-} - \epsilon_{\mu_a})]^{-1}$$

* Work supported by the Department of Energy, contract DE-AC03-76SF00515.
Contributed to the 10th International Conference on Few Body Problems in Physics
Karlsruhe, Germany, August 21-27, 1983

where $\epsilon'_{a+} = (m^2_{a+} + |\vec{k}'_{a+}|^2)^{1/2}$, $\epsilon'_{a-} = (m^2_{a-} + |\vec{Q}_a - \vec{k}'_{a+}|^2)^{1/2}$, and $\epsilon_{\mu_a} = (\mu^2_a + |\vec{Q}_a|^2)^{1/2}$. In the once iterated Faddeev equations, the four-vector in the above expression is evaluated as $(Q^0_a, \vec{Q}_a) = (z - \epsilon_a, -\vec{k}_a)$, with $\epsilon_a = (m^2_a + |\vec{k}_a|^2)^{1/2}$.

This expression has all the correct two particle singularities. When used as the driving term in relativistic three particle Faddeev equations it leads to unique, unitary three particle amplitudes including three particle bound states, elastic and rearrangement scattering, and breakup. Extension of the equation to include spin has been carried through and will be presented elsewhere.

Since the model contains both *anelasticity* (i.e. two particle rearrangement collisions unitarily connected to elastic scattering) and *inelasticity* (i.e. breakup), the numerical investigation of the consequences of the model requires extensive investigation which is in progress. Satisfactory results will come, in all likelihood, only after both comparison to the version of the theory with a confined quantum[2] and after extension to four and higher particle sectors using relativistic Faddeev-Yakubovsky equations. Noyes and Lindesay have already shown using the original model that[3] this system provides a covariant unitary description of single quantum exchange and production. This was achieved by assuming that one of the three particles, called the "quantum", "binds" to each of the other two particles to form a system with the same mass and quantum numbers as that particle; the two particles cannot scatter directly. We have confidence that connection both to non-relativistic "potential" theory on the one hand and elementary particle theories on the other can eventually be made.

This work is obviously still in its infancy. However, we have found the rigorous results already achieved sufficiently exciting to hope that others will be encouraged to think along these lines.

This work was done in close collaboration with H.P. Noyes and G. Pastrana, without whose constant help we would not have been able to push it even this far.

[1] J.V. Lindesay, Ph.D. Thesis, Stanford, 1981; see SLAC Report No. 243.
[2] H.P. Noyes and G. Pastrana, contributed to Few Body X.
[3] H.P. Noyes and J.V. Lindesay, *Australian J. Phys.* (in press).