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Galilean Invariant Lee Model for All Spins and Parities*

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Abstract. Using the minimal $6S+1$ components required to describe a nonrelativistic particle of spin S within the framework of a first order formalism, the Galilean invariant Lee model as formulated by Levy-Leblond is generalized to the case in which all particles are allowed to have arbitrary spins and parities. It is found that when the product of the parities of the three fields is even the coupling term is unique and the physics essentially identical to the spin zero case. A more interesting situation occurs when one considers the odd parity case where the criterion that derivatives not be explicitly used in writing the interaction requires that the dependent components enter into the coupling term. In this case one finds that except for certain degenerate cases there exist three similar but distinct interactions. Upon selecting one of these couplings and eliminating the dependent components by means of the constraint equations one finds the existence of a P wave $VN\theta$ coupling as well as direct S wave interactions between pairs. The V particle propagator is derived and it is found that unlike the even parity case the wave function renormalization constant is divergent. The P wave phase shift is obtained and found to satisfy the exact effective range formula $q^3 \cot\delta = -1/a + \frac{1}{2} r_0 q^2$.

I. Introduction

One of the most difficult obstacles in recent years to further progress in quantum field theory has been the absence of a consistent set of rules for the quantization and renormalization of field theories describing particles with spin greater than unity. A conspicuous example of the type of difficulty encountered is contained in the demonstration by Johnson and Sudarshan [1] that the equal time anticommutators of a spin 3/2 field become indefinite in the presence of an external electromagnetic field. This inconsistency emerges as a consequence of the secondary constraints upon the fields, the existence of which is guaranteed for all half-integral spins greater than one-half. Although one suspects (with good reason) that these difficulties are a consequence of the rigid requirements of Lorentz invariance, a complete confirmation of this conjecture is dependent upon the presentation of a consistent theory of

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