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# MASSLESS PARTICLES WITH CONTINUOUS SPIN

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Among the unitary irreducible representations of the quantum mechanical Poincaré group discovered by Wigner[1] occurs a class of mass zero representations which have not hitherto been used for the description of elementary particles. They are usually referred to as continuous spin representations and are labelled by values of the Casimir invariants $P^2 = 0$, $W^\mu W_\mu = -\rho^2$ with $\rho > 0$. $W^\mu$ is the Pauli-Lubanski vector. A corresponding particle can exist in a denumerable set of helicity states $\lambda$, with $\lambda$ taking either all integer values $\lambda = 0$, $\pm 1, \pm 2, \ldots$ or all half-odd-integer values $\lambda = \pm\frac{1}{2}, \pm\frac{3}{2}, \ldots$ The state of a particle is completely determined by specifying momentum $\underset{\sim}{p}$ and helicity $\lambda$. By helicity we mean, of course, the eigenvalue of the helicity operator $\underset{\sim}{J} \cdot \underset{\sim}{p}/p^0$; it is not a Poincaré invariant here.

The present talk is a report on work[2] done in collaboration with Iverson on fields and interactions of such particles.

We start by constructing Lorentz covariant fields, describing one such particle, out of the creation and annihilation operators associated with the given Poincaré representation space. We use Gel'fand's theory[3] of SL(2, C) representations in terms of homogeneous functions of a complex 2-spinor variable $\zeta = (\zeta_1, \zeta_2) \neq (0,0)$ to write the fields as functions $\varphi(\zeta, x)$, with transformation law[4]

$$U[A]\,\varphi(\zeta, x)\,U[A]^{-1} = \varphi(\zeta A^{-1}, \Lambda(A)x) \qquad A \in SL(2,C) \quad .$$

$\Lambda$ is related to $A$ by the familiar 2-1 correspondence between SL(2C) and homogeneous Lorentz group. $x$ stands for the four space time variables.

These fields are then used as a convenient vehicle for constructing Lorentz invariant scattering amplitudes and vertex functions. <u>Our most interesting result is the following:</u>

One can find a (PCT-invariant) interaction involving "continuous spin" neutrinos $\nu_\mu$ and $\nu_e$, which approaches the conventional V-A theory of leptonic weak interactions as a limit when $\rho \to 0$.

In particular, to lowest order in $\rho$, neutrinos and antineutrinos will, for this particular interaction, be produced in $\mu$-decay only with helicities $-\frac{1}{2}$ and $+\frac{1}{2}$, respectively[5].

This result ought to provide sufficient incentive for further study, both theoretical and experimental, of the question whether or not the actually observed neutrinos should be assigned to a Poincaré representation of the continuous spin type, most likely with $\rho$ small but finite. In particular, it would be a strong indication in favour of such an assignment should future, more accurate measurements of the electron spectrum in $\mu$-decay near $E \approx E_{max}$ show inconsistency with the predictions of V-A theory for arbitrary $m_{\nu_\mu} \gtrsim 0$. Such would be the case if, for example, the differential decay rate were larger than the prediction of V-A theory for $m_{\nu_\mu} = 0$ and/or the spectrum exhibited oscillations. Here E is the electron energy in the rest frame of the muon, and we expect deviations from conventional V-A theory for

$$E_{max} - E \lesssim \frac{1}{2m_\mu} \rho^2 .$$

In contrast, the light quantum $\gamma$ is not a good candidate for a continuous spin particle for several reasons. Firstly, Weinberg's argument[6] demonstrating a close connection between gauge invariance and Lorentz invariance depends crucially on $W^\mu W_\mu = 0$. Gauge invariance implies conservation of electric charge, which is checked experimentally with extremely high accuracy. Further, if $\gamma$ belonged to a representation with $\rho$ small but finite, we should expect deviations from the Coulomb force law at large distances. This is unacceptable.

## REFERENCES


1) E. Wigner, Ann. Math. 40, 149 (1939).

2) G. J. Iverson and G. Mack, "Quantum fields and interactions of massless particles: the continuous spin case", CTS preprint CTS-T-Phys-69-2, Coral Gables, Fla., USA.

3) I. M. Gel'fand, M. I. Graev and N. Ya. Vilenkin, "Generalized Functions" Vol. 5 (Academic Press, New York 1966).

4) This is an example of a field over the homogeneous space of the Poincaré group discussed by Kihlberg (A. Kihlberg, talk presented at this conference).

5) There is, in principle, also the possibility that $\nu_\mu$ is a continuous spin particle but $\nu_e$ is not, or *vice versa*. This possibility we have not yet investigated.

6) S. Weinberg, Phys. Rev. 138, B988 (1965).