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Lagrangians for massive Dirac chiral superfields

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Abstract

A variant for the superspin one-half massive superparticle in $4D$, $\mathcal{N} = 1$, based on Dirac superfields, is offered. As opposed to the current known models that use spinor chiral superfields, the propagating fields of the supermultiplet are those of the lowest mass dimensions possible: scalar, Dirac and vector fields. Besides the supersymmetric chiral condition, the Dirac superfields are not further constrained, allowing a very straightforward implementation of the path-integral method. The corresponding superpropagators are presented. In addition, an interaction super Yukawa potential, formed by Dirac and scalar chiral superfields, is given in terms of their component fields. The model is first presented for the case of two superspin one-half superparticles related by the charged conjugation operator, but in order to treat the case of neutral superparticles, the Majorana condition on the Dirac superfields is also studied. We compare our proposal with the known models of spinor superfields for the one-half superparticle and show that it is equivalent to them.

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1. Introduction

More than forty years after its invention, supersymmetry still possesses some unexplored and/or not completely understood facets, providing a source of active research such as the study of massive supersymmetric theories. To gain further insight on the subject, we present a new framework for superspin one-half in $4D$, $\mathcal{N} = 1$ (see [1,2] for examples of well known free superspin one-half models). Over the last decade progress has been achieved in the formulation of free massive theories up to superspin three-halves [3–11]. Generalizations to the case of complex mass can be found in [12–15]. A common feature of these studies is the use of general off-shell superfields restricted only by their reality condition. Their convenience relies on the fact that taking appropriate products of superderivatives on these superfields, one can create constrained (by construction) spinor chiral superfields that have a smooth zero mass limit. An example of this situation is the relation between left and right strength superfields (Bianchi identities) in supersymmetric gauge theories.

We approach the study of massive one-half supermultiplets by working with spinor chiral superfields that are not further constrained. There are two models for these supermultiplets based on chiral spinor superfields [16,17]. A distinctive feature of our model is that auxiliary fermionic fields are essential for the off-shell closure of the superalgebra, and they play a key role in providing the mass terms of the propagating fermionic degrees of freedom, a situation that is not present in the current known models. The degrees of freedom of the component fields for the one-half superspin models in [16,17], represent a 8(fermionic) + 8(bosonic) realization of supersymmetry, the present work represents a new off-shell (16 + 16) irreducible realization of supersymmetry for the superspin one-half case.

Differences between models describing the same supermultiplet rely on the possible couplings of the corresponding interacting theory, and those couplings are in turn determined by the propagating fields that carry the particles of the supermultiplet. In [16], the spin-one particles propagate trough second-rank antisymmetric tensors. In addition, the spin-zero state in [17] is described by a 3-form field. As opposed to these models, where second-order derivatives and superderivatives are present in the free action, here we introduce only first order derivatives (in a similar fashion to Dirac theory in ordinary space), allowing us to represent the supermultiplet as a collection of fields with the lowest dimension possible: scalar, Dirac and vector fields.

The use of chiral superfields that are not further constrained makes very easy the implementation of the path-integral; the calculation of the superpropagator for the Dirac superfields is carried out on the same lines of the Wess–Zumino model, opening the possibility of further studies on the renormalization properties of interacting theories constructed with these superfields. We give the details of a super Yukawa model, the simplest possible interacting theory.

Recently, in the context of a superspace formulation of Weinberg's "noncanonical" methods [18], a set of super Feynman rules for arbitrary superspin massive theories has been presented in [19], together with the explicit form of the interaction picture superfields for arbitrary superspin. These superfields have the common feature of being exclusively constrained by the supersymmetric chiral condition, and therefore they bear a closer resemblance to the superfields of the Wess–Zumino model than those superfields constructed through superderivatives of general superfields. One of the main purposes of this paper is to construct an off-shell model by canonical and path-integral methods, beyond the superspin zero case, where the properties of [19] are met. We show that both the spinor superfields of Ref. [16] and the Dirac chiral superfields, in the interaction picture and the superpropagators of the models, coincide with those of [19], establishing a proof of consistency between both formalisms.