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Lagrangian formulation of massive fermionic higher spin fields on a constant electromagnetic background

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Abstract

We consider massive half-integer higher spin fields coupled to an external constant electromagnetic field in flat space of an arbitrary dimension and construct a gauge invariant Lagrangian in the linear approximation in the external field. A procedure for finding the gauge-invariant Lagrangians is based on the BRST construction where no off-shell constraints on the fields and on the gauge parameters are imposed from the very beginning. As an example of the general procedure, we derive a gauge invariant Lagrangian for a massive fermionic field with spin 3/2 which contains a set of auxiliary fields and gauge symmetries.

1. Introduction

Despite the recent progress in higher spin gauge theories (see e.g. [1–16] for review of various aspects of the subject) there are still a number of problems to address. Construction of the interacting Lagrangians of massive higher spin fields on various backgrounds and study of the properties of these systems is one of these problems. Apart from being interesting in its own right,

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it is also important from the string theory perspective [17]. As is well known, string theory contains an infinite tower of massive higher spin modes and therefore it is important to understand on which backgrounds these fields can propagate consistently.

Although many aspects of Lagrangian formulation of free fermionic higher spin fields have been studied well enough (see e.g. [18–20] and the references therein) the problem of interacting fermionic fields is much less understood than the problem of interacting bosonic fields (see also [16] for a recent review). In particular, that the cubic vertices which include fermionic higher spin fields have been constructed in the light cone framework in [21] and various problems of interaction with gravitational and electromagnetic fields have been addressed in [22–34].[1]

When considering interactions of massive fields with spin more than zero with a nontrivial background one faces several difficulties such as superluminal propagation and violation of the number of physical degrees of freedom. The requirement that no superluminal propagation takes place imposes in general certain conditions on the background fields [40,41] (see also [42] for a recent discussion). Similarly, when turning on nonzero background fields the invariance of the initial system under its gauge transformations can be partially or completely lost and this means in turn that nonphysical polarizations can appear in the spectrum. The requirement of preserving of physical degrees of freedom generically imposes some extra conditions on the background. The question is therefore to find if a background under consideration is physically acceptable i.e., if it satisfies the constraints imposed by the above mentioned conditions.

In this paper we consider a problem of interaction of massive totally symmetric fermionic higher spin fields with constant electromagnetic (EM) background in Minkowski space of an arbitrary dimension d. These higher spin fields are described by tensor–spinors with one spinorial index and an arbitrary number $n = s - 1/2$ of totally symmetric tensorial indices. Our main aim is to derive the gauge invariant Lagrangian using the method of BRST construction in the linear approximation in strength $F_{\mu\nu}$ of the external field. This method in fact yields a gauge invariant Lagrangian description for massive higher spin fields in extended Fock space and therefore the Lagrangian will contain, apart from the basic fields, some extra auxiliary fields such as Stückelberg fields. Some of these fields are eliminated with the help of gauge transformations, some of the others should be eliminated as a result of the equations of motion. Therefore, in order to have a consistent gauge invariant description for massive higher spin fields, one should have enough gauge freedom and have the "correct" equations of motion, which ensure the absence of ghosts.[2] Performing this analysis in a way similar to how it has been done in [43] one can show that the preservation of physical degrees of freedom indeed takes place for the Lagrangian under consideration, provided that the terms containing the strength of the external space are considered as a perturbation. Where the problem of superluminal propagation of higher spin fields is concerned we note that in the linear in $F_{\mu\nu}$ approximation this problem does not arise at all due to antisymmetry of $F_{\mu\nu}$ (see e.g. [40] for a spin 3/2 field).

The paper is organized as follows. Section 2 contains our main results. After a brief reminder of construction of Lagrangians for free massive fermionic higher spin fields we introduce interaction with background electromagnetic fields by modifying the operators which define the BRST charge. The requirement that the modified operators form a closed algebra determines free pa-

[1] Also one points out the papers [36,37] where non-Lagrangian equations of motion for higher spin fields in the external fields have been considered.

[2] One way to check this is to perform a complete gauge fixing in the equations of motion and obtain the equations in terms of basic fields. As a result one obtains equations defining the spectrum of the theory and check if it is ghost free or not.