SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15108
STSM title: Resurgent methods in the Worldline formalism
STSM start and end date: 07/02/2020 **to** 04/03/2020
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PURPOSE OF THE STSM:

The main objective of the STSM was to develop the so-called Worldline Formalism and combining it to methods from Resurgence in order to tackle non-perturbative problems in Quantum Field Theory (QFT). These problem are related to vacuum instability for QFTs in the presence of extended (classical) fields backgrounds. A known example of such instability is found when Quantum Electrodynamics is quantised on top of a constant homogeneous electric field. In this case, due to the presence of the background field, the vacuum is unstable and decays through production of electron-positron pairs (Schwinger effect). This decay is purely non-perturbative in the coupling constants of the theory, and is invisible to Feynman-diagram-based techniques. Non-perturbative treatment and generalisation of such a problem comprises of different backgrounds of (non-abelian) gauge or gravitational nature, relevant for a wide number of physical applications. As described in the Workplan Summary, this STSM was devoted in particular to non-abelian generalisations and the study of instanton and Sphaeleron background.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

We showed that in the case of Schwinger pair production, a direct computation of the first few effective action coefficients are sufficient for a numerical non-perturbative estimate of the electric field decay constant using Resurgence methods. This is in agreement with previous literature and work by Florio appeared in November 2019. The coefficients needed are relatively few, so that one can hope to apply the same methodology for instanton and Sphaeleron backgrounds.
In order to do so, we studied the problems related to the formulation of Worldline particle theories charged under non-abelian gauge fields. This is a recent topic developed by Corradini et al. in the last couple of years, and it became expecially suitable for computations upon the introduction of auxiliary fields implementing the path ordering along the Worldline.
We realised that, expecially in the case of instantons background, the computation of enough effective action coefficients might be a non-trivial task. We then decided to apply a different method initially proposed by Dunne and Schubert, the so-called “Worldline instanton” method.
In this approach, the instability of the background is related to the presence of particular closed orbits of virtual particles in the presence of the background. These are solutions of the classical equation of motion for the virtual particles.
As a starting point for this application we considered a non-abelian covariantly constat background, which is a direct generalisation of the constant electric/magnetic field of the Schwinger effect. This method has not been extended to such problems before, and the applications we are investigating represent a novelty in the subject.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

We proved that the Worldline Instanton methods proposed in the study of constant electric fields decay can be (not straightforwardly) extended to a non-abelian gauge group. The presence of these particular Worldline instantons orbits signals an instability of the background, and we found that these are present in the case of pure chromoelectric background configurations, but not for chromomagnetic ones. This is in agreement with previous literature, but in this context has a interesting geometric interpretation based on the presence of compact and non-compact directions in the complexified (non-abelian) Lie group manifold.
Moreover, we proved that the Wilson loop associated to the closed path corresponding to a Worldline instanton orbit equals exactly to the number of color of the gauge group. We suspect this to be due to a quantised non-abelian fields flux passing through the closed orbit.
Apart from the novel and intriguing geometrical interpretation, this method could present advantages when applied to even further generalisation. The reason being that it could be easier to prove the (non)-existence of a orbit solution for a classical problem than perform a full computation of field theory functional determinants.

FUTURE COLLABORATIONS (if applicable)

My stay in Durham has been extended with a short-term Postdoc position until June 2020. I plan to complete the work started during this STSM, which will lead to a publication in the near future. In the next months, we will further the relations between the presence of worldline instantons and the quantisation of their Wilson loops. A computation of the fluctuation determinant around such solutions is going to complete the computation of the background effective action and make this method competitive with more involved approaches employed in the past for this class of problems.