2020 HGF – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

Title of the project:

Scattering Amplitudes and Tropical Grassmannians

Helmholtz Centre, division/group:

DESY Hamburg, High-energy physics research (FH)

Project leader:

Georgios Papathanasiou

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Description of the project (max. 1 page)**:**

This project will focus on the central quantities encoding the information of how the elementary constituents of matter interact, known as scattering amplitudes. They describe the probability for a given event to happen in the quantum world, and while the well-established method of Feynman diagrams in principle allows us to compute them as a sequence of approximations with increasing accuracy, in practice complexity increases rapidly at each step, rendering the method unwieldy very quickly.

For these reasons, the main aim of the project will be to develop an alternative, more efficient approach for the calculation of scattering amplitudes. For a simpler cousin of the theory of the strong force we see in nature, known as super Yang-Mills theory, and when the number of elementary particles involved in the quantum event is low, great progress towards the development of such a method, known as the amplitude bootstrap, has been achieved. It crucially exploits the location and type of singularities of the scattering amplitude, which can be put in correspondence with the vertices of a geometric object known as a cluster polytope. This polytope, however, becomes infinite for eight or more particles, posing a great obstacle for the generalization of the amplitude bootstrap to higher multiplicity.

The fulfilment of the main aim of the project will therefore require curing the aforementioned infinity. Very recently it has been suggested that a particular coarse-graining of the cluster polytope, known as the tropical Grassmannian, or equivalently the Minkowski sum of a Newton polytope, may be the right cure. This leads to the two very concrete project objectives: First, to construct these finite polytopes corresponding to increasing particle number, which is a challenging task due to the very intricate structure of the boundaries of these geometric objects, vertices, edges, faces and so on. Then, to test whether they truly predict the expected singularities of scattering amplitudes, by comparing with certain limits where we can obtain these by other means. If successful, the final step of the project will be to explore whether similar constructions also hold for more realistic quantum theories.

Finally, the exact same geometric objects we will be considering, have also appeared in the context of generalizations of theories with spinless particles, that are believed to have string-theoretic origin due to their improved divergence structure. In this context, it is the volume of these objects, that yields the scattering amplitudes of the corresponding theories in the leading approximation. As a byproduct of our analysis, we will thus be able to explicitly compute the amplitudes in question, and deduce from them important properties of the theory, and its lagrangian description.

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

The project aims to establish a collaboration between DESY Hamburg and the Institute of Theoretical Physics, Chinese Academy of Sciences. In particular, both Professor Song He from the latter institute, and Dr.Georgios Papathanasiou from the former, are internationally leading experts on scattering amplitudes, and especially the geometric objects expected to encode their singularities, which will be the central focus of this project. It is thus very natural for the two researchers to join forces, and reinforce their collaboration with the support of a bright Chinese postdoctoral fellow. For this reason, Professor He has already been contacted, and has gladly agreed to be part of this collaboration. The experience of the involved researchers places them in a unique position to guide this ambitious project to fruition, which may change our understanding of quantum field theory, and bridge the gap between new mathematical structures and realistic applications.

Required qualification of the post-doc:

- PhD in Physics
- Experience with theoretical particle physics, and especially scattering amplitude computations
- Additional skills in computer algebra and symbolic manipulation software
- Language requirement English