Phenomenological implications from the dual interplay between gauge and gravity theories

Research Project / Research Group Description:
The main research tool in particle physics is the exploration of fundamental interactions at the high-energy frontier. The CERN's Large Hadron Collider (LHC) currently examines proton collisions at the highest possible energies, and the high-quality data from the LHC are providing a unique window of opportunity for the search of new physics. Particle physics is currently well described by the quantum field theory (QFT) called the Standard Model (SM). Still, there are fundamental questions about the underlying quantum structure of this theory that are unanswered. The SM does not account for the hierarchies of masses of particles, dark matter or dark energy. And most important, it cannot be valid until arbitrary high energies. Also, although gravity is omnipresent everywhere, the SM does not include gravitational interactions.

Although gauge and gravity theories have rather different physical behaviours, we know that they are intimately linked. Tree-level scattering amplitudes in quantum field gauge theories are known to satisfy colour-kinematics duality (CKD), i.e. they admit an expansion in terms of Feynman diagrams where the kinematic parts of the numerators satisfy the same anti-symmetry and Lie-Algebra identities as their corresponding colour factors. Once this duality is imposed, gravity scattering amplitudes can be obtained using two copies of gauge-theory diagram numerators. Gravity was also the main motivation for Feynman to develop the so-called Feynman's Tree Theorem.

The host group holds the chair of the COST Action PARTICLEFACE (http://particleface.eu), thus opening new possibilities for international collaborations that can be very beneficial for the scientific and professional development of the PhD candidate, and giving access to other experts in advanced phenomenology, experimental analysis, Monte Carlo event generators, mathematicians and leading software companies for scientific computing.

Job position description:
The host group has recently proposed a new perturbative method, known as four-dimensional unsubtraction (FDU), based on the loop-tree duality (LTD) also developed by the group and intimately related to the Feynman's Tree Theorem, which establishes a direct correspondence between quantum states that, although experimentally equivalent, are treated differently in quantum field theory.

The specific objective of the research consists of establishing CKD from FDU/LTD beyond the tree-level at higher loop orders and exploring the phenomenological implications at the LHC, obtaining theoretical predictions for the production at high-energies of the new states forecasted by CKD.

The direct product of two Yang-Mills theories with (D−2) states each (not counting colour), gives (D−2)^2 states corresponding to a theory with a graviton, an anti-symmetric tensor and a dilaton, therefore opening an interesting phenomenological scenario that can potentially be tested at the LHC. Scattering amplitudes with gravitons, anti-symmetric tensor matter and dilatons will be constructed to one and two loops and will be implemented in a Monte Carlo event generator for numerical evaluation, obtaining results that can be compared directly with the experimental data provided by the LHC.

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Research project/Research Group website
https://particleface.eu/