

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: LAPTh – Laboratoire d'Annecy de Physique Théorique
CNRS identification code: UMR 5108
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Internship location: LAPTh, 9 chemin de Bellevue, 74940 Annecy, France

Thesis possibility after internship: YES
Funding: YES

Solving the S-matrix with machine learning: how fast can quantum interactions grow?

Summary

What happens when particles interact at strong coupling? At weak coupling, quantum field theory gave us a beautiful map of consistent theories: the gauge theories of the Standard Model. At strong coupling the map is almost blank, even though it contains the strong force and string theory, our best-understood completion of gravity. Charting it is one of the central questions of 21st-century theoretical physics. The difficulty is unitarity: probability conservation is a fully nonlinear equation that ties all processes together. Our group has developed a new way to explore this territory, reviving the 1960s S-matrix bootstrap with machine-learning tools, and recently built, for the first time, four-dimensional amplitudes that conserve probability exactly in two-particle collisions while including the production of new particles.

This opens many avenues, and the internship focuses on a strikingly simple one: how fast can an interaction grow with energy? A universal limit, the Froissart bound, has been known since the 1960s, yet no one knows how real theories approach it. Protons look larger the harder they collide, a growth attributed to the mysterious Pomeron, and it is inside the Pomeron of early string models that the graviton was first discovered.

After learning the basics of the S-matrix approach, you can follow an analytic route, studying in simplified models how the nonlinear unitarity equation generates growth at high energy, or a numerical one, using our machine-learning solver to build full amplitudes and measure how fast they grow, or combine both. Guiding questions: is the Froissart bound approached? Do Regge behaviour and something like the Pomeron emerge? How do these amplitudes compare with string amplitudes? No prior experience with machine learning is needed. The internship naturally opens to a PhD extending the method to massless particles and gravity.

You will join a small, friendly team of postdocs and PhD students, with regular one-to-one supervision and weekly group meetings where questions of any level are welcome, and will have opportunities to visit CERN, one hour away, where part of this work is done in collaboration. LAPTh is located in Annecy, between the lake and the mountains, and student housing is usually available through the university.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: NO Soft Matter and Biological Physics: NO
Quantum Physics: NO Theoretical Physics: YES