Quantum field theory and the bootstrap

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Subjects:	theoretical physics, quantum physics
Personal website:	`https://www.cpht.polytechnique.fr/?q=en/node/546`
Collaboration website:	`http://www.bootstrapcollaboration.com`
Thesis possible:	yes, with funding available

Feynman diagrams provide a way to estimate quantum field theory observables to any desired order in perturbation theory. Non-perturbatively, however, the structure of quantum field theories is much less clear. The usual attempts to define quantum field theories (and their observables) in a rigorous and non-perturbative way proceed via the so-called Wightman axioms. With significant effort, one can show that these axiomatic systems actually imply concrete constraints on the physics, for example the Froissart-Martin bound on high-energy scattering. Any observed violation of such constraints would invalidate the very foundations of quantum field theory, so it is of interest to study them in detail.

Depending on your interests, there are several possible projects we can pursue.

In the first project you will investigate a completely new axiomatic approach. The idea is to set up the quantum field theory in a curved space, such that certain observables are known to obey simpler axioms and under good non-perturbative control. The aim of the project will be to investigate how the classic results (like the Froissart-Martin bound) can be obtained from these simpler axioms.

This would be a project about the foundations of quantum field theory that falls squarely in the “mathematical physics” category. The mathematics involved is that of complex and functional analysis.

A second direction would be more numerical. For example, we can then test to which extent experimental data on pion scattering would be consistent with the fundamental axioms of quantum field theory. Alternatively, we can investigate numerically whether the two axiomatic systems described above actually lead to the same bounds.

Numerical work will largely be performed on our Cholesky computer cluster, and to successfully complete this type of project will require some affinity with computer programming.

Finally, there is also the option to investigate a new numerical algorithm. This would be a project that almost falls in the applied mathematics or computer science category, more precisely in the domain of convex optimization.

There are many other directions to pursue, some of which can be found on the above website. If the general theme appeals to you then feel free to reach out to me by email so we can set up a meeting to discuss.