PhD thesis proposal

Genealogy of extreme particles in branching processes and links with particle physics observables

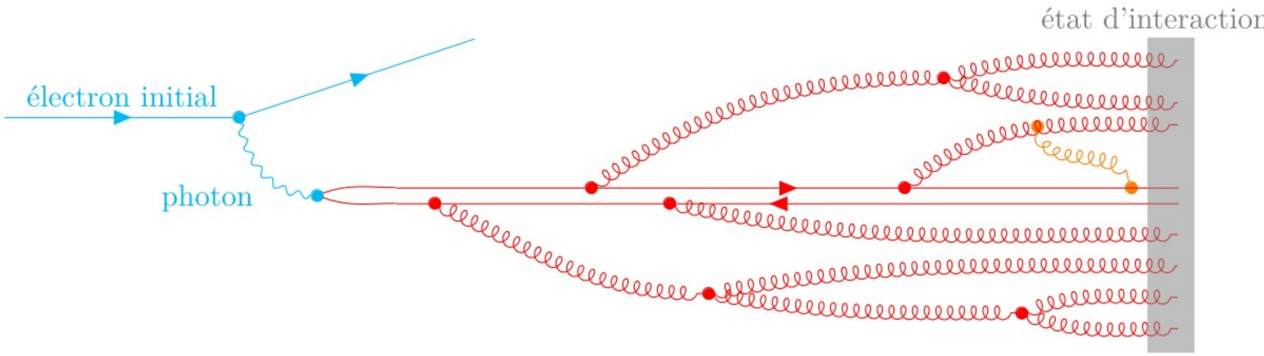

Illustration of the development of the hadronic interaction state of an initial electron. The tree colored red, made up of a quark-antiquark pair (arrowed solid lines) and a set of gluons ("springs"), represents the binary branching process that generates the interaction state with the target (not shown here). [At extreme energies and densities, recombination processes become probable (cf. the orange gluon)].

Branching Brownian motion (BBM) is a system of particles that move continuously and reproduce independently of each other. It is one of the simplest spatial branching processes. The BBM is a model currently much studied in mathematics, due to its links with the famous Fisher-Kolmogorov-Petrovsky-Piscounov (FKPP) reaction-diffusion equation (see e.g. [1,2,3]).

Branching processes in the BBM universality class are ubiquitous in the physical and natural sciences. They appear, for example, in spin glass physics, chemistry, evolutionary biology, etc. and, perhaps more surprisingly, also in particle physics. Indeed, the interacting state of quantum particles is generically a random set of elementary particles, which in a certain regime relevant to very high-energy colliders, appear generated by a branching process of the BBM universality class [4] (see the figure). The total cross sections can be mapped to the statistics of the extreme values of this process [4]. The genealogies of extreme particles [5], the detailed study of which is the subject of this project, correspond to final-state observables [6]. Their qualitative understanding will lead to predictions for electron-nucleus diffractive cross sections, which can be compared with measurements from the future electron-ion collider (EIC) planned in the USA.

The main goals of the proposed PhD thesis will be to describe the genealogical law and relationships of BBM extreme particles, and to establish quantitative correspondences with observables measured in electron-hadron collisions, such as the angular distribution of the diffracted mass in the final state. As the project progresses, we may extend the study to the case of branching-selection processes, which are also relevant in particle physics (see figure and [7,8]). The role of the PhD student will be both to participate in the elaboration of the mathematical proofs, and to develop a physical intuition that will help the formulation of conjectures about the properties of particles generated by a branching process.

The thesis, funded under a project of the CNRS Mission pour les initiatives transverses et interdisciplinaires, will last 3 years, ideally starting on October 1, 2024. The PhD student will be based at École polytechnique's Centre de physique théorique (CPHT), where they will be supervised by Stéphane Munier (CPHT mathematical physics group). Several long stays are planned at the Institut de Mathématiques de Toulouse (IMT), where they will be supervised by Bastien Mallein (project leader), Pascal Maillard and Michel Pain.

The candidates for this thesis have an excellent Master's degree level in theoretical physics or mathematics (specializing in probability). They must have a solid background in probability and/or advanced statistical mechanics, and an interest in quantum field theory and particle physics. Notions in these fields are a definite plus. They have a strong interest in rigorous mathematics and their application to particle physics.

To apply, **please upload the required documents on the CNRS application portal.** *Detailed instructions for completing your application can be found on the portal. (Before applying, please make sure you meet the prerequisites!).* **The final deadline is May 28, 2024.** *Feedback will be given by the end of May.*

References:

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