Title: **Branching processes and applications**

First Name: Stéphane | **Name**: Munier | **Laboratory**: CPHT

Email: stephane.munier@polytechnique.edu

Webpage: https://www.cpht.polytechnique.fr/?q=en/node/46

Research Area: Mathematical Physics (secondary: High Energy Physics)

Methods: Theory: analytical and numerical calculations

PhD track subject

Branching random walks (BRW) and the branching Brownian motion (BBM; see the figure) are stochastic processes that model phenomena appearing in a wide variety of contexts, from evolutionary biology to - quite unexpectedly - particle physics. In biology, when complemented by a selection mechanism, these processes can model the Darwinian evolution of populations. In particle physics, they happen to be tools for computing the quantum states of interacting hadrons, which determine various observables measured at colliders.

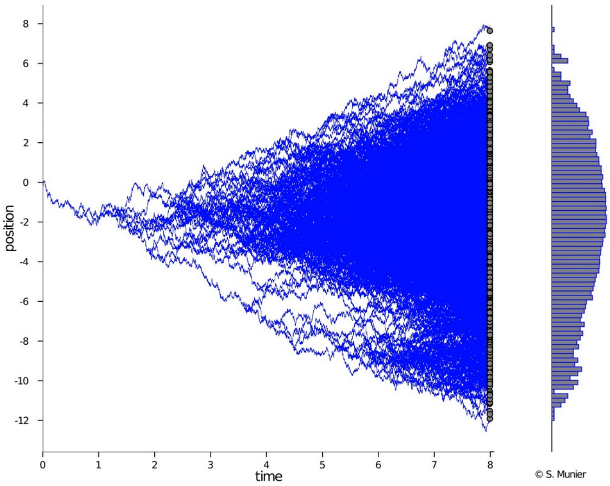

Figure 1: Left: one realization of a BBM. Particles diffuse on the line and branch to two particles at exponential times, independently of each other. Right: binned particle density at the final time in this particular realization (log scale).

Over the last years, we have contributed to the qualitative and quantitative understanding of observables and phenomena measured in particle collisions at very high energies, and more specifically in electron-hadron scattering. Such observables include the total cross section, but also the very surprising and counter-intuitive phenomenon of *hard diffraction*, in which the hadron emerges intact from its violent collision with the electron. Our results were obtained by a very original approach, consisting in exploiting the fact that the quantum states of hadrons can be thought of as being constructed in a branching process. Thus, we were able to formulate the calculation of the total electron-hadron cross section as a problem of statistics of extremes in a BRW, and hard diffraction as a problem of genealogy in the same process **[1]**. In parallel, we have arrived at general results on the BBM and BRW (see e.g. **[2]**), which have been taken up by mathematicians, thus allowing us to start a fruitful interdisciplinary dialogue. In our latest publication **[3]**, we have focused on the statistical properties of the particle density generated by the BBM at large times near its lead particle, which resonates with recent mathematical works.

The PhD track project will consist in trying to establish new mathematical properties of a class of branching processes that includes the BBM, starting from a physicist's intuition in the spirit of our previous works, and possibly using light numerical tools that we will develop (see **[4]** for an example of algorithms relevant to our investigations). This topic being resolutely interdisciplinary, among our goals will be - depending on the interest of the student - to reinforce the links with mathematical works, and/or to develop applications, in particular to high energy physics.

References

[1] Anh Dung Le, PhD thesis (2022) [arXiv:2203.00346]
[2] Brunet, Derrida, Mueller, Munier, Phys.Rev.E 73 (2006) [cond-mat/0512021]
[3] Le, Mueller, Munier, to be published [arXiv:2207.07672]
[4] Brunet, Le, Mueller, Munier, Europhys.Lett 131 (2020), [arXiv:2006.15132]