Improving the signal-to-noise ratio in quantum chromodynamics simulations

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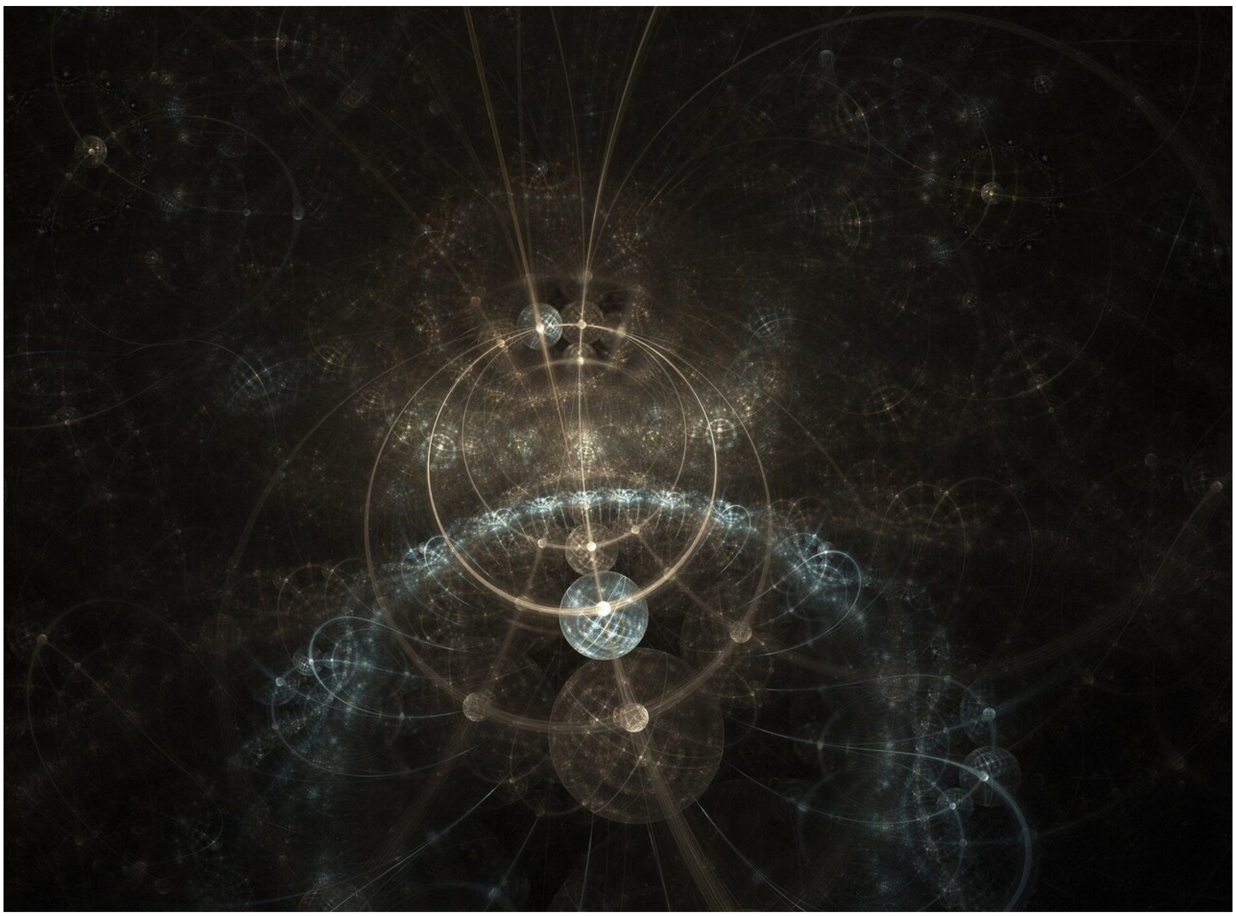

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Over the last few decades, the exponential increase in computer power and accompanying increase in the quality of algorithms has enabled theoretical and particle physicists to perform more complex and precise simulations of fundamental particles and their interactions. If you increase the number of lattice points in a simulation, it becomes harder to tell the difference between the observed result of the simulation and the surrounding noise. A new study by Marco Ce, a physicist based at the Helmholtz-Institut Mainz in Germany and recently published in *EPJ Plus*, describes a technique for simulating particle ensembles that are 'large' (at least by the standards of particle physics). This improves the signal-to-noise ratio and thus the precision of the simulation; crucially, it also can be used to model ensembles of baryons: a category of elementary particles that includes the protons and neutrons that make up atomic nuclei.

Ce's simulations employ a Monte Carlo algorithm: a generic computational method that relies on repeated random sampling to obtain numerical results. These algorithms have a wide variety of uses, and in mathematical physics they are particularly well suited to evaluating complicated integrals, and to modelling systems with many degrees of freedom.

More precisely, the type of Monte Carlo algorithm used here involves multi-level sampling. This means that the samples are taken with different levels of accuracy, which is less computationally expensive than methods in which the sampling accuracy is uniform. Multi-level Monte Carlo methods have previously been applied to ensembles of bosons (the class of particle that, self-evidently, includes the now famous Higgs particle), but not to the more complex fermions. This latter category includes electrons as well as baryons: all the main components of 'everyday' matter.

Ce concludes his study by noting that there are many other problems in particle physics where computation is affected by high signal-to-noise ratios, and which might benefit from this approach.

More information: Marco Cè, Locality and multi-level sampling with fermions, *The European Physical Journal Plus* (2019). DOI: 10.1140/epjp/i2019-12655-5

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