Abstract

Classical simulations became a part of a researchers toolkit during the second world war. During these times, Monte Carlo simulations were introduced to simulate nuclear detonation. After that, so many algorithms to simulate both classical and quantum systems were put forward. But soon, it became clear that a classical system like an ordinary computer is ill-equipped to simulate the complex quantum system. So, people began thinking about quantum simulations. In quantum simulations, we make one or more simple quantum systems to mimic the evolution of a complex system. It often involves some assumptions but does not suffer from an exponential explosion in the resources required as the classical systems do. Moreover, the quantum systems which we use to simulate the other should be designable and controllable. Thus, the main hurdle in quantum simulation is finding a mapping scheme that map one system on another. However, the usefulness of this approach is far-reaching. Nowadays, quantum simulations have found their way to Condensed matter physics, Cosmology, Nuclear Physics and quantum chemistry.

Now, we are interested in the quantum simulation of the neutrino oscillation problem. This problem has been thoroughly studied over the past half-century. It has given us many insights and is forcing us to look beyond the standard model. We limit our study of neutrino oscillation in the ultra-relativistic limit. We use the quantum algorithm or quantum circuit put forward by Arguelles and Jones in 2019 for simulating neutrino oscillation. We have studied the time evolution of the neutrino flavour state in both the two-flavour and three-flavour cases using the circuit. Further, using the same circuit, we studied the entanglement in neutrinos. Neutrinos are known to exhibit single-particle entanglement. As a consequence, flavour modes are entangled. The entanglement shown by neutrinos belongs to the class of dynamic entanglement. This means that entanglement between flavour modes changes with time. There are many kinds of measures of entanglement which quantify the entanglement in the system. For a system like a neutrino, which is in a pure state, the entanglement entropy has proven efficient in quantifying entanglement. Here we use linear entropy as a measure of entanglement. We used our circuit to predict the value of the linear entropy of the system. By studying how the linear entropy of the system changes with time, we were able to study the dynamics of the entanglement in the system.