International Conference on Quantum Energy 2025 hosted by Dipartimento di Fisica e Astronomia Galileo Galilei an event by ICQE

Contribution ID: **36** Type: **Poster presentation**

Nuclear deep strong coupling

The precise manipulation of electronic states is at the core of modern information technology and is now poised to also become an integral part of new energy technologies such as quantum batteries. Extending the quantum engineering principles deployed in these contexts to the domain of the nucleus follows naturally and is the focus of our work.

Some of the key principles in nuclear manipulation are similar to the electronic counterpart. Specifically, the gradual increase in "light-matter"coupling strengths has played an important role in the evolution of what is often called "Quantum 2.0". This is seen for instance in the use of Rydberg atoms [1], the exploitation of collective effects predicted by the Dicke model [2,3], and the engineering of artificial atoms [4] and optical lattices [5] to create large interaction strengths for single "atoms".

These developments have taken us from weak coupling [6] (e.g. small changes in decay rates) to strong coupling [1] (e.g. atoms and light behave as a single entity) through to ultra-strong coupling [3] (e.g. quantum vacuum emission) and finally to deep strong coupling [7] (e.g. where counterintuitively light and matter decouple). Deep strong coupling is reached when the coupling strength is greater than the energy of the light quanta. Systems with deep strong coupling have only in the last few years been experimentally realised [4,5].

Typical interactions with nuclei are weak due to the small nuclear size and it is perhaps not surprising that only recently accelerated nuclear decay via superradiance (anticipated in [8]) has been experimentally demonstrated [9]. However, we will show that some interactions with nuclei can be extremely far into the deep strong coupling regime with consequences that differ greatly from the electronic counterpart.

Specifically, in this presentation we will enumerate the type of interactions available for the manipulation of nucleons and contrast them with those typically considered for electrons. Particular attention will be given to the relativistic phonon-nuclear interaction [10] as both a mediator of nuclear excitation transfer and for energy exchange with nuclear states. We will also show how nuclear deep strong coupling fits into a larger theoretical framework [11] that can explain nuclear anomalies reported in hydrogen loaded metals and plays a central role in the emerging field of nucleonics.

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Theme

Theme 2. Quantum effects in energy processes and materials

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Track Classification: Theme 2. Quantum effects in energy processes and materials