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Frequency-based decay electron spectroscopy to measure neutrino mass and exotic interactions

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Precision measurements of $\beta-$decay spectra can provide exquisitely sensitive tests of various predictions and underlying symmetry assumptions of the Standard Model (SM) of Particle Physics. Hypothetical scalar- and tensor-type interactions can alter the shape of the $\beta-$decay spectrum across the full energy range, while the finite masses of neutrinos mostly alter its shape around the decay endpoint in a predictable but yet undetectable way.
Novel electron spectroscopy technologies are required to push the currently achievable sensitivity limits to new frontiers. One such technique, Cyclotron Radiation Emission Spectroscopy (CRES), determines the kinetic energy from the frequency of the feeble cyclotron radiation emitted by single decay electrons spiraling in a magnetic trap.

In a first step to design an experiment with a sensitivity of $40\,\mathrm{meV/c^2}$ to the neutrino mass scale, the Project 8 collaboration has recently measured the first frequency-based limit on the neutrino mass $\left(\leq\ 155\,\mathrm{eV/c^2}\right)$ based on CRES with molecular tritium.
In a small volume experiment the excellent energy resolution was demonstrated with conversion electrons from $^{83}\mathrm{Kr}$ and no background event beyond the tritium decay endpoint was observed. I will discuss this result and the identified R\&D plan including quantum sensor technology to investigate the path to sensitivity reaching down to the inverted mass ordering scheme of neutrino masses.

CRES has recently also been successfully demonstrated for MeV-electrons and -positrons within the He6-CRES collaboration using $^{6}\mathrm{He}$ and $^{19}\mathrm{Ne}$. This establishes CRES as a novel non-demolition frequency-based technology from the mildly to the highly relativistic energy range of electrons emitted in nuclear $\beta-$decays.

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