Machine Learning Meets Quantum Tech: Unravelling the Neutrino Mass Mystery

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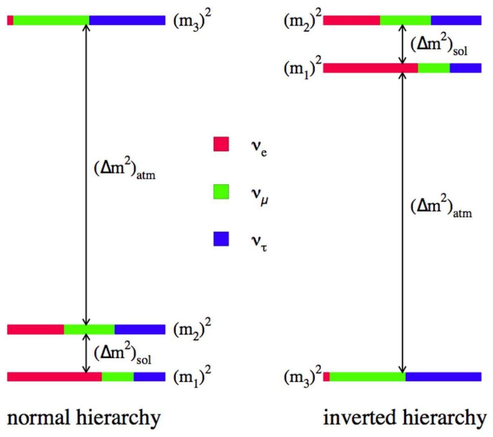
Quantum Technologies for the Neutrino Mass (QTNM)

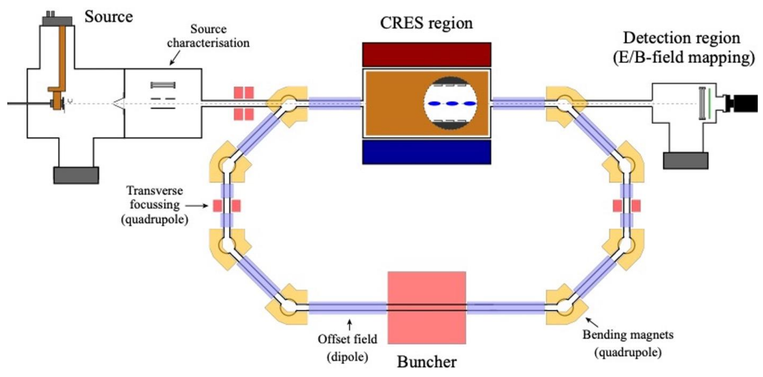
- The Quantum Technologies for Neutrino Physics (QTNM) project, funded by UK Research and Innovation, aims to measure the absolute neutrino mass.
- Quantum technologies are poised to transform the way particle physics experiments, like neutrino mass measurement, are conducted.
- Determining the absolute neutrino mass is **vital** for understanding the universe's origins and the composition of matter.
- Quantum technologies offer the potential for precise neutrino mass measurements, even at extremely low values like 10 meV, through the utilisation of CRES.



The Neutrino Mass Orderings

Cyclotron Radiation Emission Spectroscopy (CRES)

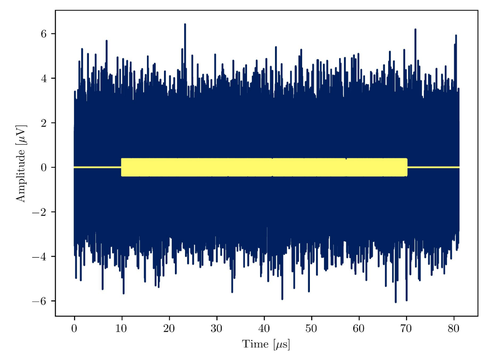
- Cyclotron Radiation Emission Spectroscopy (CRES) is a technique for measuring the energy of electrons emitted during beta decay.
- CRES allows for model-independent determination of neutrino mass by analysing electron spectra near the beta decay endpoint.
- Cyclotron Radiation Electron Spectroscopy Demonstrator Apparatus (CRESDA) addresses key challenges in CRES technology.
- CRESDA aims to produce and confine D/T atoms, map magnetic fields with precision, build a quantum-limited microwave detection system, and create a comprehensive analysis framework.



Schematic Design: The setup includes atomic sources, storage rings, magnet assembly, and an atom detection region.

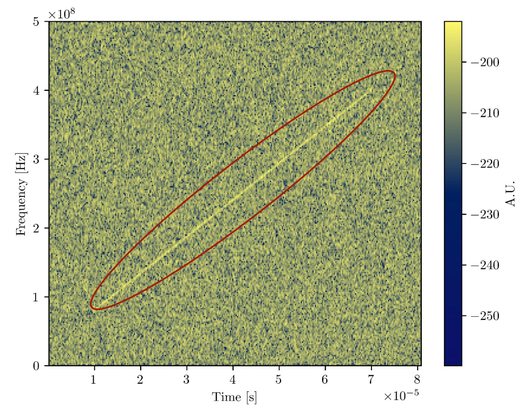
Edge Detection: ML Applications

- In this experiment electrons emitted from beta-decay lose energy via cyclotron radiation. This is detected and is the 'signal'.
- The hidden signal in the noisy voltage data is impossible to spot. It is completely shrouded in noise. Helpfully, it is shaded in yellow.



Noisy signal data shrouded by noise

- Plotting this as a spectrogram makes the hidden signal easier to spot. See inside the red oval.
- The end goal is to detect these tracks, extract and characterise their features to understand the electron trajectories that generated them.



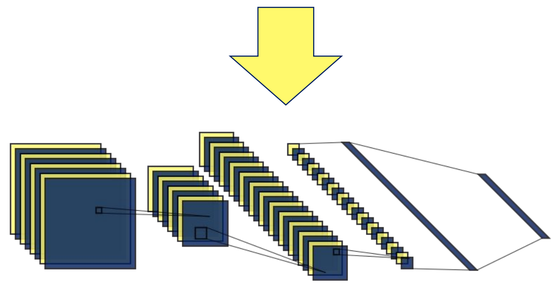
Represented by a spectrogram, the signal is there!

- The most important aspect of the tracks is the initial frequency value (see green arrow). This gives the electron energy via:

$$f_c = \frac{1}{2\pi}\frac{eB}{m_e + E_{kin}/c^2}$$

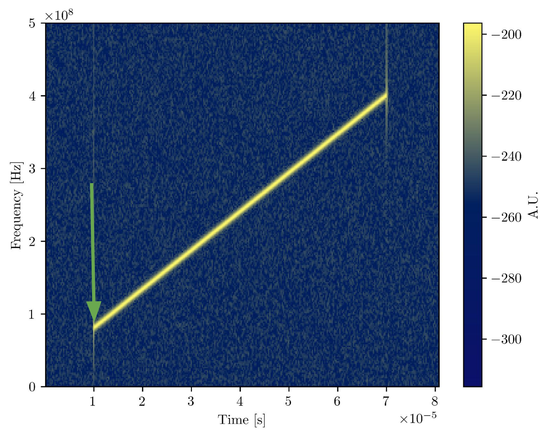
Frequency

Electron Kinetic Energy



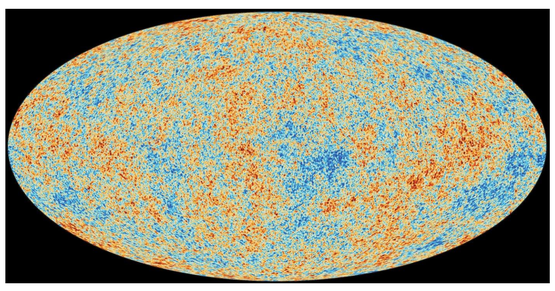
Apply some machine learning wizardry and voila!

- As the kinematics of tritium beta decay are well understood, it is possible to use this data to narrow in on the elusive neutrino mass!



What's the point?

Determining the absolute neutrino mass is crucial to understand the origin of matter and our universe's early evolution.



To find out more, scan the QR code below!