Resparking the Neutron Lifetime Debate with PENeLOPE

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Abstract

Over the past 30 years many experiments have been carried out to measure the neutron lifetime. With each successive experiment, the increase in the precision of the lifetime measurement brought about a significant discrepancy between beam and bottle measurement methods (See Fig. 2). The latest neutron lifetime measurement achieved a result of $877.75 \pm 0.28^{+0.22}_{-0.16} s$ [1], where PENeLOPE aims to achieve a precision of $\pm 0.1 s$.

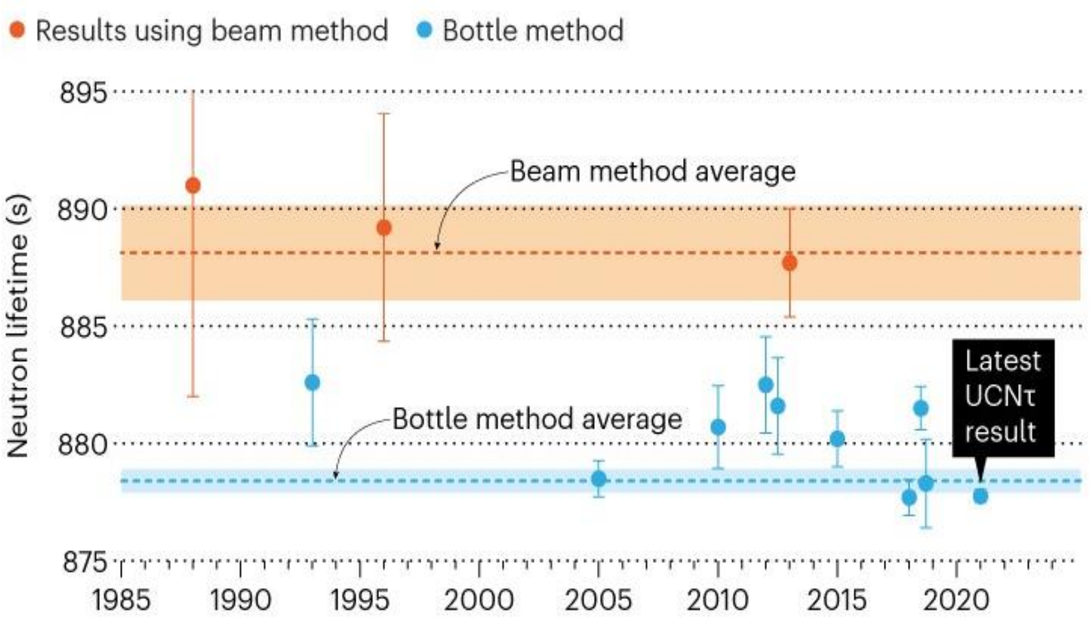

Fig. 2: Neutron Lifetime Measurements [2]

The Neutron Lifetime

CKM Unitarity Verification

- The Standard Model assumes that the CKM matrix is unitary
- The first element of the CKM matrix (V_{UD}) is inversely proportional to the neutron lifetime
- The neutron lifetime would help serve as a test for the Standard Model

The Early Universe

- Neutrons β-decay as: $n \rightarrow p + e^{-} + \overline{\nu_e}$, helping form the first elements
- The helium abundance is directly tied to the proton-to-neutron ratio
- We can use this to better understand the elemental makeup of the early universe

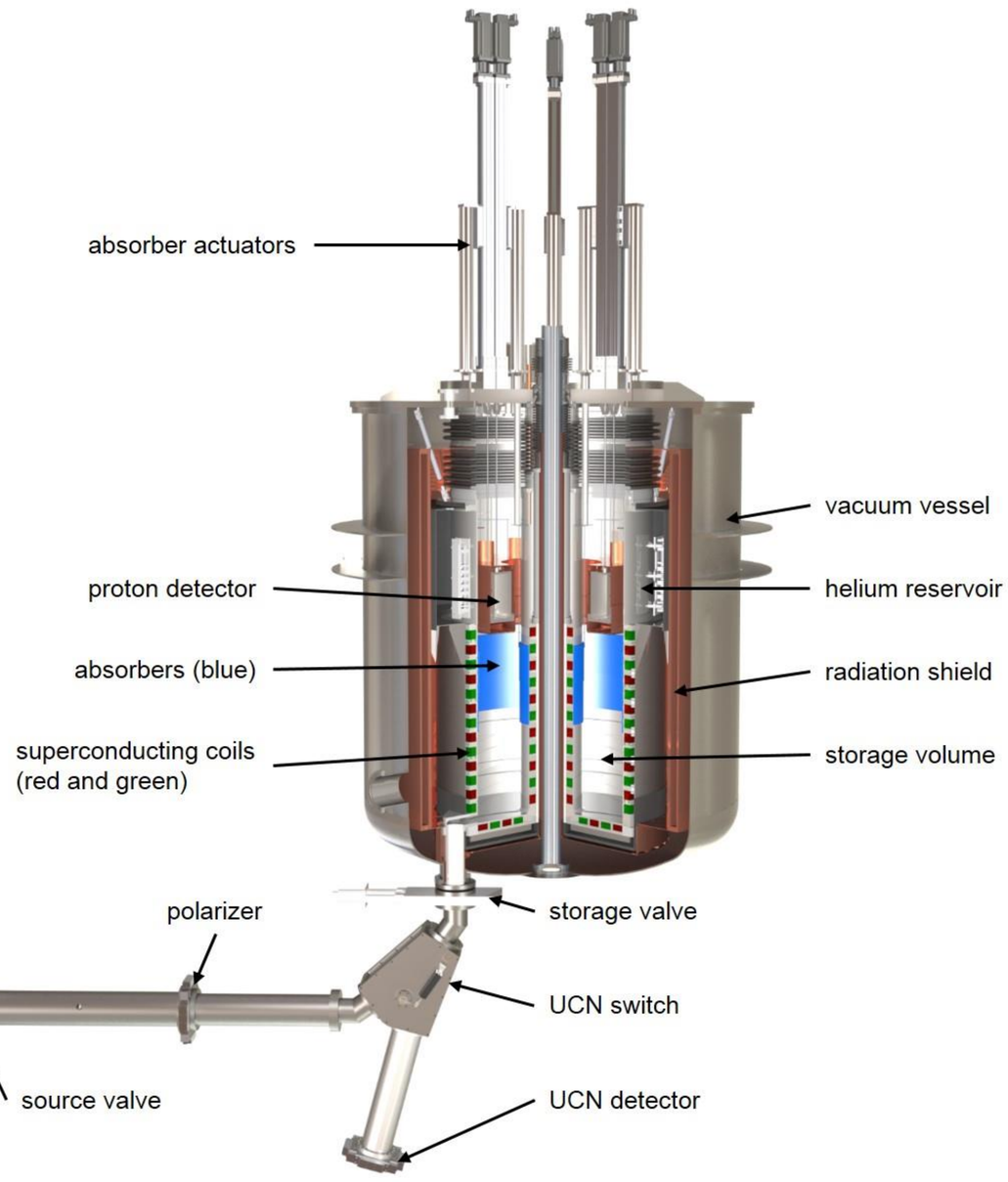

Fig. 1: A Labelled Render of PENeLOPE

Magneto-Gravitational Trap

- The Precision Experiment on Neutron Lifetime Operating with Proton Extraction (PENeLOPE) is a bottle-measurement experiment
- Ultra-cold neutrons are trapped using strong magnetic fields from superconducting coils
- The novel gravitational well is too steep for neutrons to fly out, allowing reliable proton detection
- Near lossless techniques gives confidence for high-precision measurements

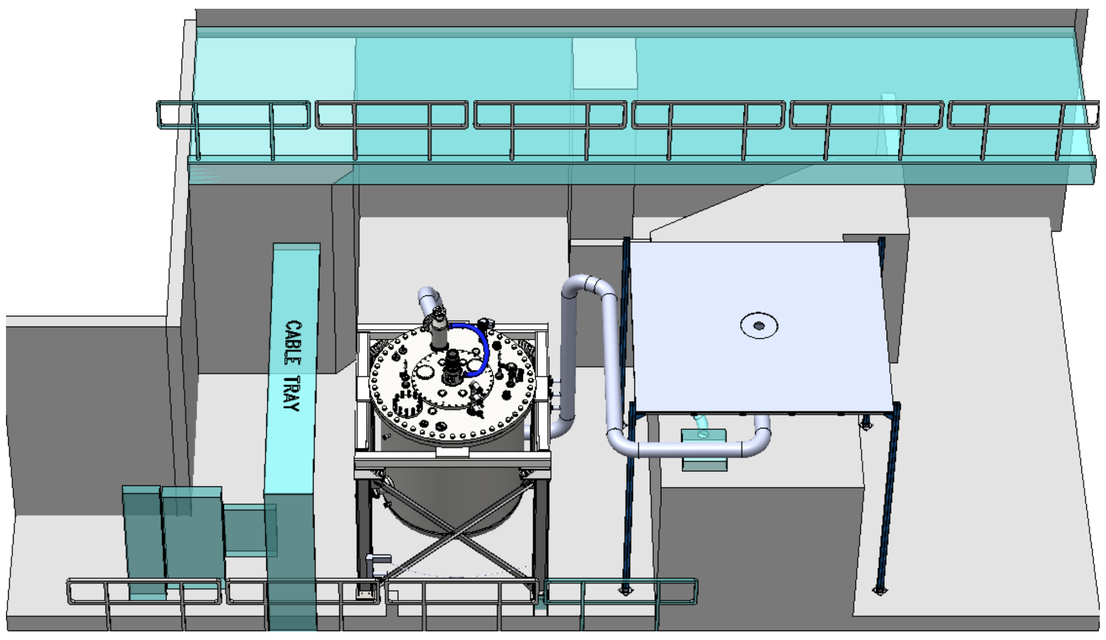

Fig. 3: Planned CAD Model of PENeLOPE at TRIUMF

PENeLOPE at TRIUMF

- PENeLOPE arrived at TRIUMF in late June for cooldown and magnet training
- A coil is cooled down and a current is passed through until the magnet quenches
  - A quench is when superconducting material loses its superconducting properties
- Coils can then be cooled down again, withstanding a larger current and generating a stronger field

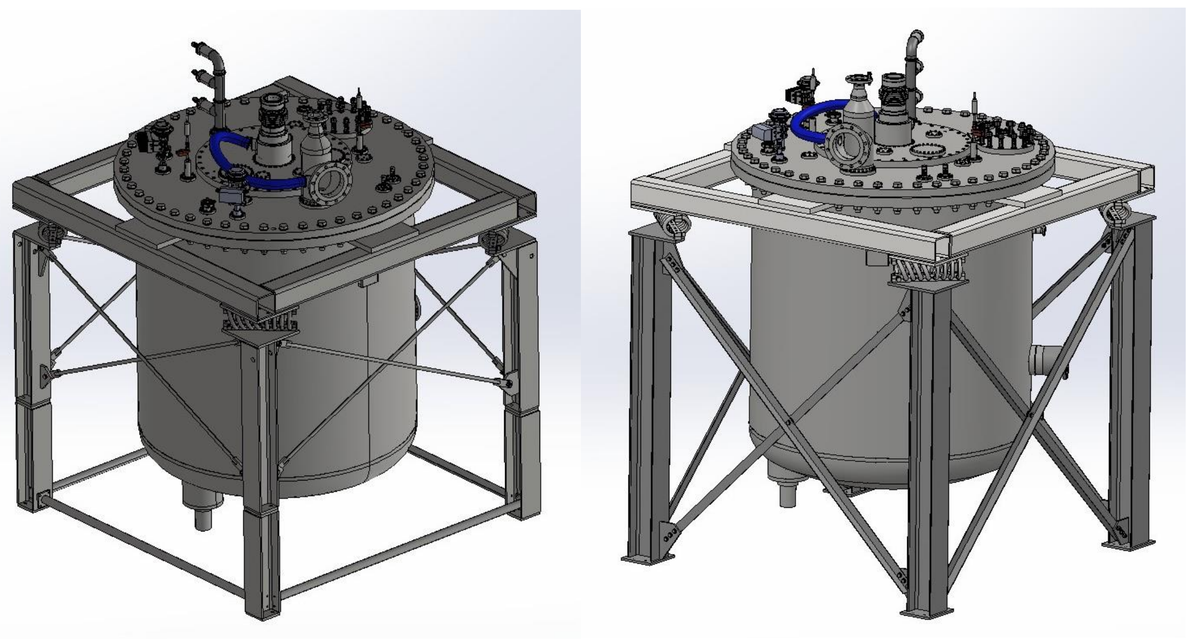

Fig. 4: Old (Left) vs. New (Right) Support Stand

Acknowledgements

[1] UCN_{τ} Collaboration collaboration, *Improved neutron lifetime measurement with* UCN_{τ}**,** *Phys. Rev. Lett.* ***127*** *(2021) 162501*
[2] D. Castelvecchi, *Physicists make the most precise measurement ever of neutrons lifetime, Nature* **598** (2021).

Discovery, accelerated