Measurements of the TUCAN vertical UCN Source Heat Load

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Sean Hansen-Romu
Supervisor: Dr. Blair Jamieson
TUCAN Collaboration

THE UNIVERSITY OF WINNIPEG

UNIVERSITY OF MANITOBA

TUCAN

The TUCAN collaboration, or

TRIUMF Ultra Cold Advanced Neutron source collaboration, is a Canadian-Japanese collaboration

Motivation

Hamiltonian $\hat{H}$ describes equations of motion of a neutron

$$\hat{H} = -d\vec{E} \cdot \vec{S} - \mu\vec{B} \cdot \vec{S}$$

$$= \hbar\omega \quad \leftarrow \text{Energy of the System}$$

$$\hbar\omega_{1\uparrow} = 2\,\mu B + 2dE$$

$$\hbar\omega_{1\downarrow} = 2\,\mu B - 2dE$$

Trying to measure this

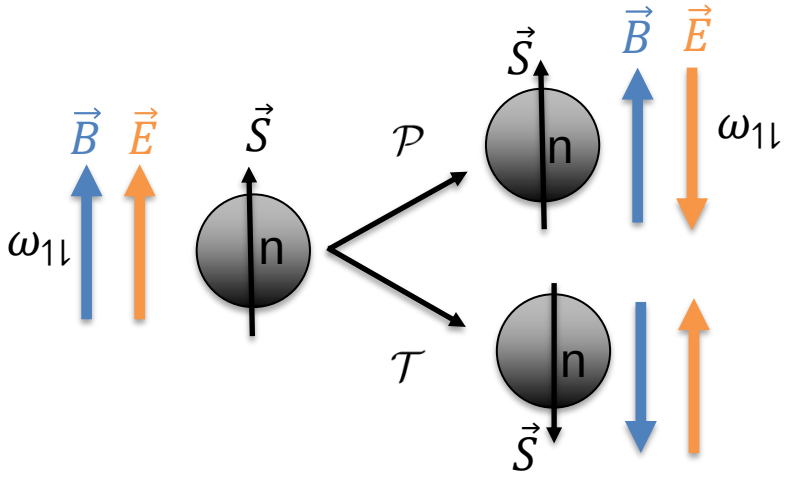
$$d = \frac{\hbar\Delta\omega}{4E}$$

$$\Delta\omega = \omega_{1\uparrow} - \omega_{1\downarrow}$$

Limits by Abel et al.(2020) is $|d_n| < 1.8 \times 10^{-26}$ e cm @ PSI, Switzerland

TUCAN's goal ultimate goal is $|d_n| < 10^{-27}$ e cm

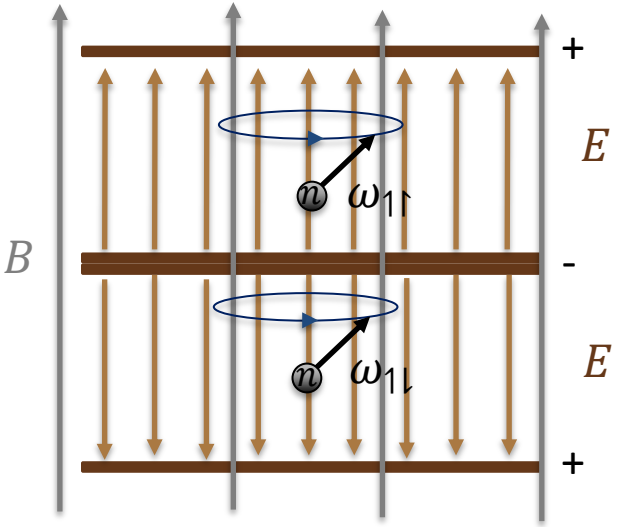
$$\hat{H} \neq \mathcal{P}(\hat{H}) = -\vec{d} \cdot (-\vec{E}) - \vec{\mu} \cdot \vec{B}$$



$$\hat{H} \neq \mathcal{T}(\hat{H}) = -(-\vec{d}) \cdot \vec{E} - (-\vec{\mu}) \cdot (-\vec{B})$$

EDM $\vec{d} = d\vec{S}$
Time Reversal – violating
Parity – violating
therefore violating combined CP

TUCAN nEMD Experiment



UCN Production

Low field NMR sequence

Detection of final polarization state

Statistical uncertainty

$$\sigma_d \cong \frac{\hbar}{2\alpha T E \sqrt{N}}$$

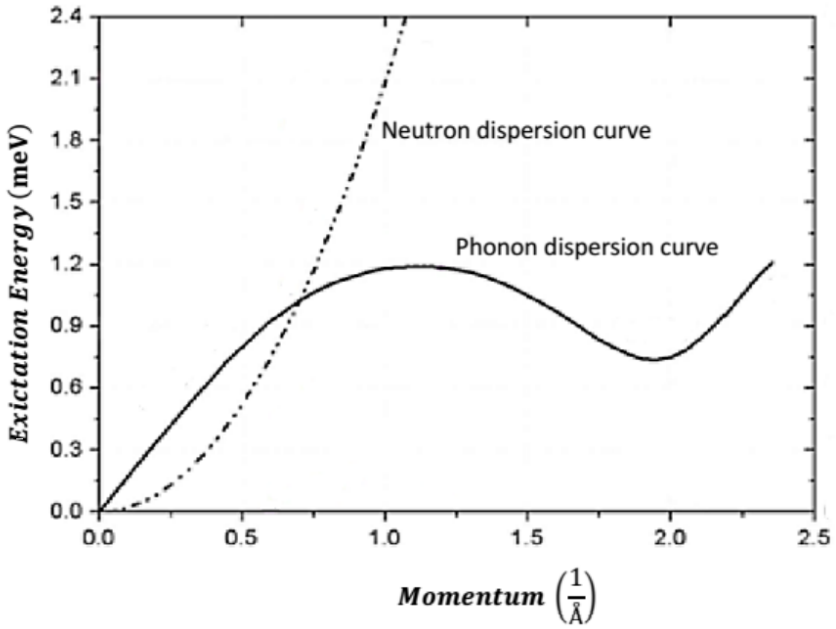
The neutron eclectic dipole moment (nEDM), is extracted from the difference in precision frequencies

Final spin state is the handle by which be measure the frequency of precession

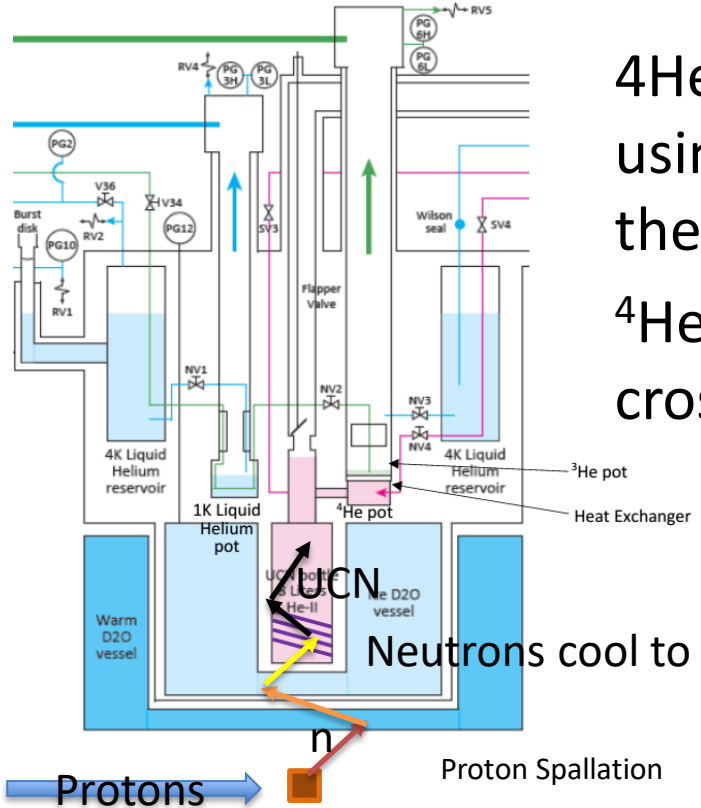
Neutron – Superfluid He-II Interaction

The neutrons can exchange energy and create phonon excitations in the superfluid helium

1 meV neutrons have large cross-section to loss energy to zero energy in superfluid helium



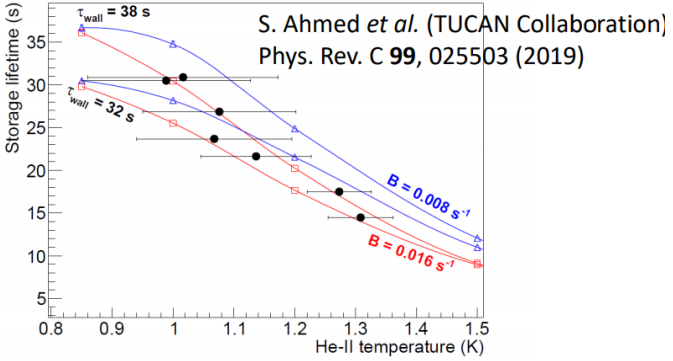
Ultracold Neutron Production



4He is cooled to He-II superfluid using a ^{3}He heat exchanger in thermal contact of a small channel

^{4}He is used since its low neutron cross-section

UCN Losses $\propto BT^7$



He-II Cryostat 1D Model

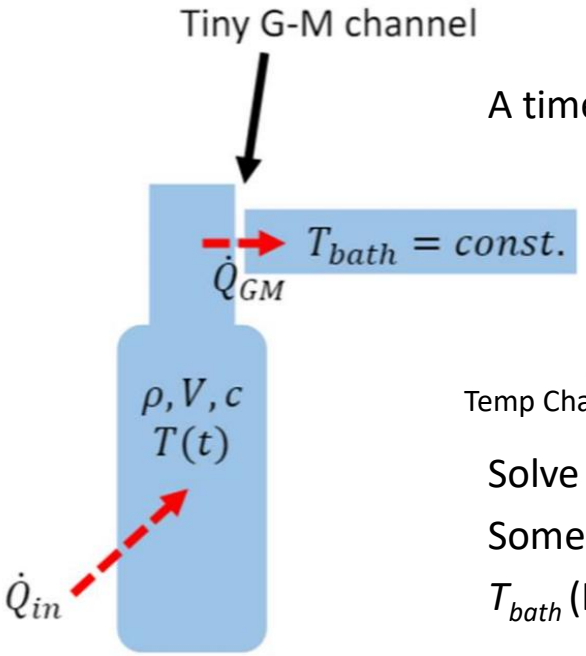
$$\frac{\partial T}{\partial t} = \frac{q_V}{\rho c} + \alpha \Delta T$$

Standard Heat equation

Temp Change

Heat input

How the material reacted to heat changes



A time dependent modified Gorter-Mellink equation

$$\frac{\partial T}{\partial t} = \frac{(\dot{Q}_{in}/V)}{\rho c} - \frac{1}{\rho V c}\left[\frac{A}{l}\int_{T_{bath}}^{T(t)} dT' f^{-1}(T', SVP)\right]^{1/3}$$

Temp Change

Heat input

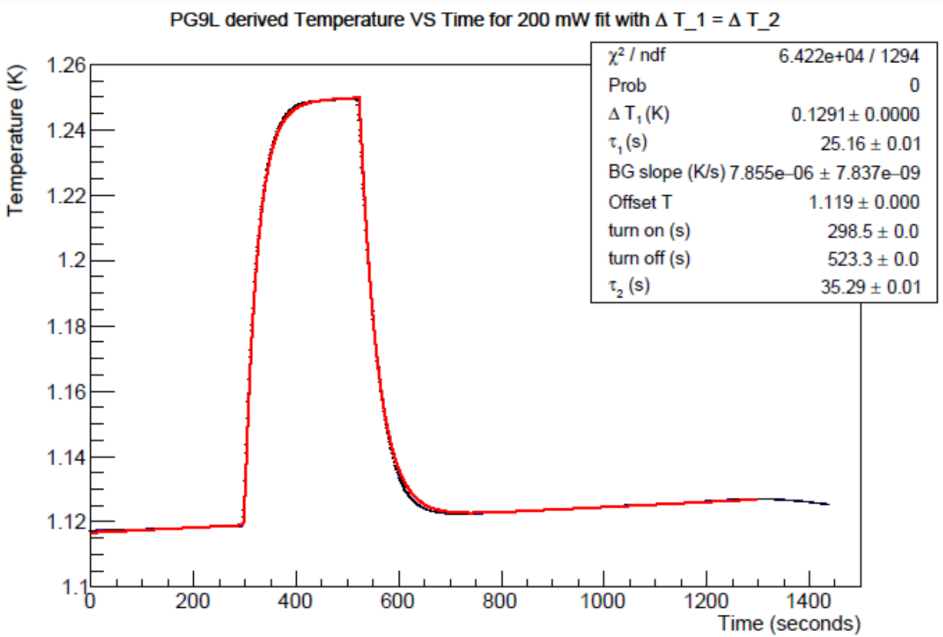
Model how helium reacted to heat changes

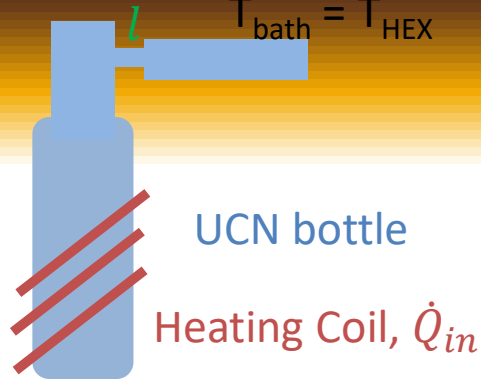
Solve for *T(t)*

Somewhat unknown *A* and *l* (area and length of channel),

T_{bath} (He-II temperature close to Heat exchanger), Background heat input

Heater Tests





The Theory parameters that minimizes the fit to the data

Q_{BG} fixed	channel lenth, l (m)	T_{hex} (K)
0.20 W	0.0066	0.92
0.15 W	0.0062	1.07
0.10 W	0.0056	1.11
0.05 W	0.0051	1.12

The model can explain the scale of heat flow restrictions, temperature rises, timescale, and background heat

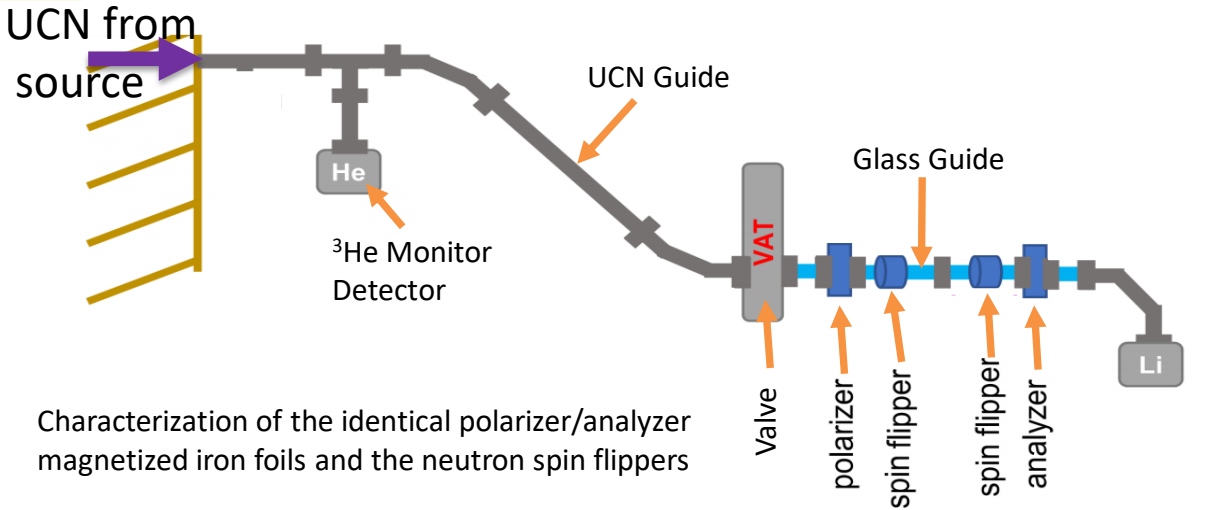
Conclusion

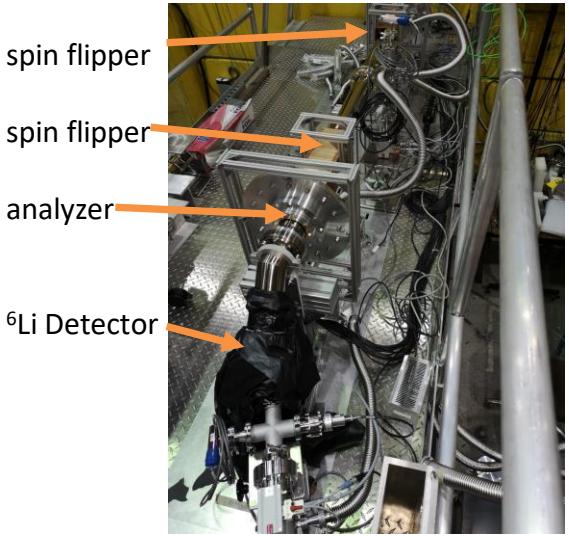
An improved final cryostat needs to handle larger heat loads

This calculation technique used to create the 1D model was benchmarked with the heat response data

This cryogenic model is being applied to the next generation cryostat design, show that cryogenically superior and able to handle higher heat response loads

Other Work





Characterization of the identical polarizer/analyzer magnetized iron foils and the neutron spin flippers

Four different power states of the spin flippers

Both on, Both off, 1st on with 2nd off, and 1st off with 2nd on

Uses the 4 sets we can extract the polarization power of the iron foil in the polarizer/analyzer, and the spin flipper efficiencies.

Polarizing foil $p_A = 60 \pm 2\ \%$
Spin flipper efficiency is $f_{1,2} = 97 \pm 3\ \%$

?

Question time

HEAT RESPONSE OF SUPERFLUID HELIUM UCN CRYOSTAT