Past UCN experiments

Material Bottles

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Systematic errors

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Report from Expert Panel (Prof. D. Dubbers, Prof. K. Kumar, Prof. J. Pendlebury)

Group A: Mechanism other than beta decay that can remove stored UCN from the trap

A1. Majorana spin flips

A2. Insufficient initial spectral cleaning to remove ‘marginally trapped’ UCN

A3. Gas scattering of the UCN due to H2 molecules

A4. UCN warming due to mechanical vibrations of the trap

A5. UCN warming due to noise in the B fields

A6. Uncontrolled variations in the initial UCN loading

A7. Incomplete emptying of the trap

A8. Leaks through any low magnitude holes in the B field

Group B: UCN detection problems

B1. Efficiency changes due to UCN warming in storage

B2. Inclusion of ‘marginally trapped’ UCN due to insufficient spectral cleaning

B3. General background counts

B4. UCN capture induced background near the detector

B5. Detector dead time losses

B6. Errors and uncertainties in the time of the detection

B7. When detecting decay products, build-up times and particle losses for the products.

Question: How well to measure each non-beta decay loss?

\[ F = \frac{1}{\tau_{\text{mea}}} = \frac{1}{\tau_{p}} + \frac{1}{\tau_{ab}} + \frac{1}{\tau_{up}} + \frac{1}{\tau_{sf}} + \frac{1}{\tau_{\text{heat}}} + \frac{1}{\tau_{\text{cb}}} + \ldots \]  

(1)

\[ \frac{dF}{d\tau_p} = \frac{df}{d\tau_{\text{mea}}} \times \tau_{\text{mea}}^{-2} - \frac{df}{d\tau_{\text{p}}} \times \tau_{\text{p}}^{-2} - \frac{df}{d\tau_{ab}} \times \tau_{ab}^{-2} - \ldots \]  

Each loss term needs an independent measurement (2)

If the trap storage time is long, so that the correction to the beta-decay lifetime is

\[ \tau_p = \tau_{\text{mea}} = \Delta \tau = 1 s \]  

From (1), \[ \tau_{\text{mea}} = \tau_{\text{p}} \times \tau_{\text{b}} \times \tau_{\text{up}} \times \tau_{\text{sf}} \times \tau_{\text{heat}} \times \tau_{\text{cb}} \times \ldots \]  

(3)

To reach \( \frac{d\tau_p}{\tau_p} = 0.01 \%, \) needs to measure \( \tau_{ab} \) at the 10% level of precision.

Phase space evolution

1) Trap techniques

1. Fill: populate the phase space with UCN.

- Is the filling uniform? How long does it take to establish static equilibrium?

2. Spectrum Cleaning: define the trappable volume in the phase-space, by loss boundaries.

- How long does it take to clean sufficiently?

3. Storage: Phase space evolution. Additional loss (when the trappable volume morphs to intersect with loss boundaries)

4. Detection: introduce a fast sink in the phase-space.

- In-situ detection: Temporal & Spatial uniformity of detection efficiency.

UCN detection (drain) outside the trap: detection efficiency changes?

2) Nonlinear kinematics: Chaos in the trap

UCN motion becomes chaotic when the height reaches R/2.

Three degrees of Freedom (in a symmetric trap)

- Increasing \( \phi \)

- Increasing stochasticity with \( \phi \)

Summary

- Although quasi-bound UCN can be cleaned from most traps, the evolution of the phase space motion and its effect on the experiment (fill, empty, detection, leakage) has not been even seriously considered in most previous experiments.

- Chaotic dynamics (work in progress)
  - Small perturbations of an integrable potential could have narrow stochastic regions near resonances. The evolution could have a long evolution time.
  - Large perturbations (with discontinuous derivatives) increase stochasticity.