Experimental report

09/09/2022

Proposal: **3-14-418**

Council: 4/2021

Title: UCN storage in small cells for the(EDM)^n project

Research area: Nuclear and Particle Physics

This proposal is a new proposal

Main proposer: **Skyler DEGENKOLB**

Experimental team: Skyler DEGENKOLB
Robert GEORGII
Stefan HUMMEL
Ralf ZIEGLER

Local contacts: Tobias JENKE
Stephanie ROCCIA

Samples:

Instrument	Requested days	Allocated days	From	To
PF2 EDM	16	16	23/09/2021	13/10/2021

Abstract:

Experiments based on storage of ultracold neutrons (UCN) are strongly limited by the absolute densities that existing sources can deliver to experiments. ¿Superthermal¿ sources based on 4He achieve in-situ densities exceeding 100 UCN/cc, with higher values expected from new instruments, but the densities in experiments remain practically limited to a few UCN/cc. Present-generation experiments face intrinsic limitations due to volume dilution and lossy transport. The (EDM)^n project seeks to prepare new technological solutions for next-generation experiments, where higher densities are needed to reach new levels of statistical precision. A multi-cell in-situ experiment is envisioned, based on small modular cells that serve simultaneously as UCN source and EDM spectrometer. Recent studies pioneered by the SuperSUN-PanEDM collaboration have identified materials with promising storage properties for small cryogenic cells. This proposal seeks to further explore the most promising cell configurations in terms of UCN storage, obtaining baseline results to inform the preparation of future experimental campaigns.

UCN storage in small cells for the EDM^n project

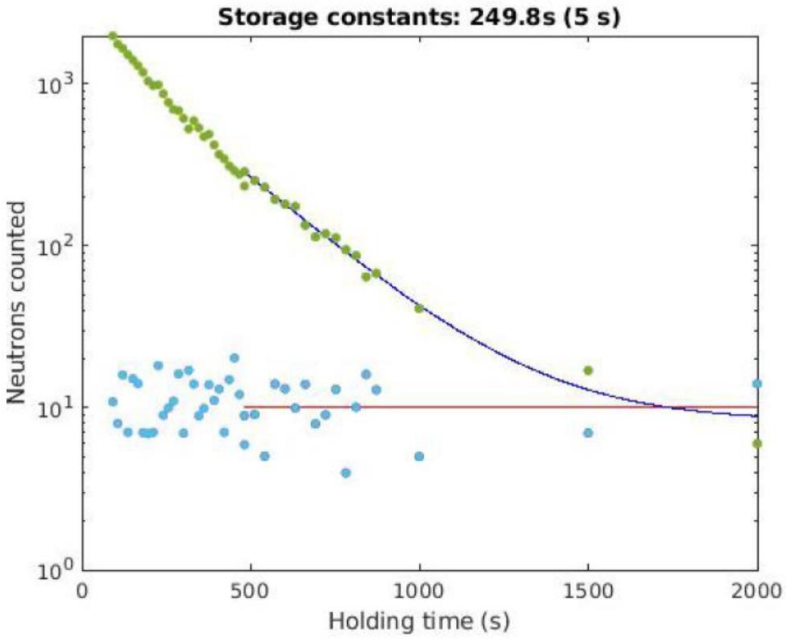
This experiment performed first tests of UCN storage in small quartz cells coated with the commercial fluoropolymer CYTOP. These tests were the first implementation of “A-” and “S-” type CYTOP polymers as wall coatings for UCN storage. Previous work [1] used the M-type polymer, in which the molecular chain includes a silane head group for direct coating of inorganic substrates. The A-type polymer includes only a -COOH head group, which is expected to exhibit reduced neutron absorption. The S-type polymer is fully perfluorinated, and would thus be expected to be the highest-performing for UCN storage.

Four cylindrical cell geometries were measured: two interior diameters (230mm/100mm) and two interior heights (100mm/50mm). The corresponding storage volumes were 0.39 l, 0.79 l, 2.1 l, and 4.2 l. The respective surface-area-to-volume ratios were 80 m^{-1}, 60 m^{-1}, 57 m^{-1}, and 37 m^{-1}. (The corresponding ratio for the storage volumes tested with M-type CYTOP at SUN-2 [1] was typically 48-54 m^{-1}.) A manuscript summarizing the results for publication is now in preparation; a representative storage curve from the largest cell is shown below. (This represents one of the longest storage time constants; see figure below.)

Several practical challenges and limitations were identified during beamtime, and subsequently addressed since then by later modifications of the experimental apparatus. These issues included:

- Short storage times when UCN are filled into the cells from above (due to gravity)
- Loss of UCN when filled into the cells from below (no adequate UCN switch was available)
- Transmission of supercritical UCN through quartz walls during the filling phase
- UCN leakage through the “disk”-type valve used to seal the cell (→ valve concept revision)
- Unreliable mounting of “disk”-type valves with CYTOP-coated o-rings (→ o-rings to be avoided)
- Valve motors running in open-loop (→ needs encoder and improved control loop)
- Free adjustability of cell height with respect to the feeding beam (filling from below)
- Breakage of a quartz plate, and of a glued seal on disk valves
- Usability of list-mode data

Further work in this direction will focus on comparisons, using the improved apparatus and cells, between PF2 and the ILL’s superthermal helium sources. It is hoped that a direct comparison (i.e., using exactly the same apparatus and cells) can help to resolve the apparent discrepancy in storage time constants for otherwise similar measurements. This discrepancy can be noted by comparing the “softest” component of the stored UCN spectrum from experiment 3-14-418 (see figure), to the “single-component” fits that were appropriate for UCN from SUN-2 [1]. (In fact this difference is more pronounced, for more-similar surface-area-to-volume ratios.)



Storage curve for the largest cell (4.2 liter storage volume and 15.5 dm^2 surface area), showing data (green points) and exponential fit line for only the longest holding times. The data are normalized according to the rate recorded in a monitor detector (blue points). While this fit line indicates a relatively longer time constant for storage of the softest UCN spectral components at long holding times, the value of approximately 250s is significantly shorter than that of 311 s observed for storage of UCN from a superthermal liquid-helium source [1]. Some of this difference may be attributed to gaps at the cell filling valves, and/or to differing UCN spectrum. Further studies are required to clarify the discrepancy.

[1] T. Neulinger *et al*., Ultracold neutron storage in a bottle coated with the fluoropolymer CYTOP. The European Physical Journal A volume 58, Article number: 141 (2022)