Experimental report

18/12/2020

Proposal: 3-14-404 **Council:** 4/2019

Title: PanEDM storage times and emptying efficiency

Research area: Physics

This proposal is a new proposal

Main proposer: Thomas NEULINGER

Experimental team: Thomas NEULINGER
Douglas howard BECK
Skyler DEGENKOLB
Magdalena PIELER
David WURM
Peter FIERLINGER
Hanno FILTER
Joachim MEICHELBOCK
Christopher KLAU
Andres MARTINEZ DE VELASCO
Stephanie ROCCIA

Local contacts: Tobias JENKE
Stephanie ROCCIA

Samples:

Instrument	Requested days	Allocated days	From	To
PF2 EDM	18	25	20/09/2019	09/10/2019
			09/01/2020	15/01/2020

Abstract:

The PanEDM experiment seeks to measure the neutron's permanent electric dipole moment (EDM) to an unprecedented sensitivity. The new SuperSUN source at the ILL will supply the PanEDM experiment with ultra-cold neutrons (UCNs). This proposal aims to perform a functional test of the PanEDM components for use with polarized UCNs at the PF2/EDM beamline. Such an experiment measures the neutron storage lifetime T_0, the UCN polarization lifetime T_1, emptying efficiency of the storage volume, and the polarization visibility α, factors which in part determine the ultimate statistical reach of PanEDM. In addition, it characterizes the intended coatings for storage cells, and tests the switches and valves constructed for filling and emptying polarized UCNs. These data are also of interest to SuperSUN, the HOPE neutron lifetime experiment, and any future experiments using UCNs from liquid-helium-based sources.

Experimental report for proposal 3-14-404

PanEDM storage times and emptying efficiency

T. Neulinger, D. H. Beck, S. Degenkolb, P. Fierlinger,
H. Filter, T.Jenke, J. Meichelbock, S. Roccia, S. Stuiber, D. Wurm, O. Zimmer

December 18, 2020

1 Summary and outlook

The experiment detailed in this report was carried out at the PF2/EDM beamline in two stages: the first from September 24th to October 15th, 2019, and the second from January 9th to January 15th, 2020. The goals of the experiment were to measure the unpolarized storage time constant (T_0), polarized storage time constant (T_1), emptying efficiency, and polarization visibility (α) in a mock-up of the storage and emptying components of the main PanEDM experiment. The storage volume consisted of a quartz ring coated in deuterated polyethylene (DPE), sandwiched between two aluminum plates coated with diamond-like carbon (DLC).

In the first stage of the beamtime, in addition to calibration measurements, a series of tests successfully verified the functionality of new polarizing foils and a new UCN switch. In addition to being necessary to subsequent steps of the experiment, these measurements provided validation of critical UCN components for the PanEDM collaboration. After these initial measurements, the storage volume was mounted. Unfortunately, a vacuum leak occurred via the failure of a bellows actuating the rotation of the storage cell emptying valve, and insufficient time remained to fix the problem and complete measurements. Through the generous efforts of the two PF2 instrument responsibles, the beamtime was extended and scheduled for early the next year. In the mean time, the faulty bellows was exchanged and the storage apparatus was thoroughly tested.

On January 9th, in the second stage of the experiment, an initial measurement of the storage time of the DPE-ring/DLC-electrode cell resulted in an unexpectedly-poor T_0, about $5.8 \pm 0.2\,\mathrm{s}$. After consulting with staff and collaborators, the storage system was purged with xenon gas in an attempt to clean the volume. This may have been responsible for an increase of about a second in the storage time, to $6.7 \pm 0.3\,\mathrm{s}$. An attempt was then made to improve the surface quality of the cell. The lengthy procedure of dismantling the storage system was initiated, and its inner surfaces were manually swabbed with wipes soaked in deuterated

xylenes. The system was then reassembled, but the storage time improved to only about 8.3 ± 0.2 s, still well below expectations. Another effort was made to isolate the source of the problem by replacing the DPE-coated ring with a bare quartz ring. This ring had previously been used for a test coating with polyethylene (PE), and an attempt was made to thoroughly remove any remaining PE before use. This involved scrubbing the quartz with sand paper soaked in toluene, and then baking it in an oven to outgas any remaining solvents. Again, the system was laboriously reassembled, but a non-zero storage time was not observable with the ring. In continuing efforts to exhaust all possibilities, a layer of Fomblin grease was applied to the quartz ring. This resulted in an improvement to the storage time, to about 16.5 ± 0.7 s. Similarly, the DLC-coated electrodes were later coated in Fomblin grease. This resulted in the maximum storage time of the experiment, about 20 ± 2 s. Finally, the Fomblin-coated ring was removed and the original DPE-coated quartz ring was inserted. This resulted in a storage time of about 13 ± 2 s.

By this time, the storage characteristics had not been improved to the point that the subsequently planned measurements were possible, and the beamtime had ended. It was hypothesized that the short storage times may have been due to surface contamination of one or both of the untested UCN coatings. However, it is also possible that the vacuum inside of the storage cell may have been insufficient to observe the expected longer storage times, something which would not have been directly observable. Although the experiment faced great difficulties, the UCN transmission measurements of the newly-designed polarizers and UCN switch are critical to the success of the PanEDM collaboration. Furthermore, the ongoing analysis of recent DPE storage measurements made during cycle 188 at the SUN2 UCN source at the ILL—and those planned with DLC for cycle 189—may offer additional insight into the source of potential issues during the early 2020 measurements.

2 Storage data

We provide storage data, specifically in the four configurations discussed above (in chronological order): DPE-ring/DLC-electrode (after cleaning with deuterated p-Xylene), Fomblin-ring/DLC-electrode, Fomblin-ring/Fomblin-electrode, and DPE-ring/Fomblin-electrode.

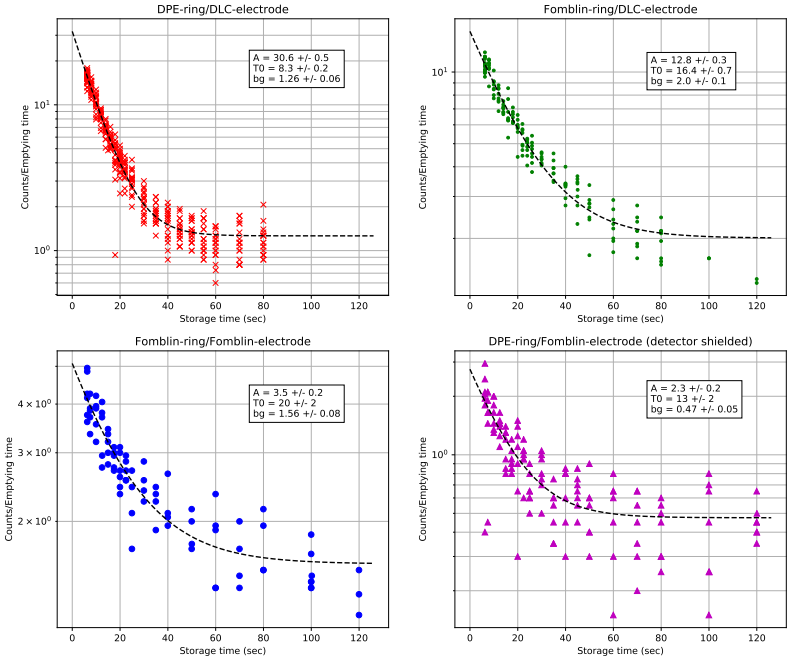

Figure 1: Storage data with fits. The vertical axis is counts recorded at the main detector during the emptying phase, divided by emptying times, and the horizontal axis is storage time in seconds.

All data and fits are show above in Figure 1. The fit is made with an exponential decay and constant background model: $y(t) = A\exp(-t/T_0) + bg$, with t the storage time, and $y(t)$ the number of counts recorded divided by the emptying time. The fit parameters are summarized below in Table 1.

Cell configuration	A	T_0(s)	bg	$A - bg$
DPE-ring/DLC-electrode	30.6 ± 0.5	8.3 ± 0.2	8.3 ± 0.2	22.3 ± 0.5
Fomblin-ring/DLC-electrode	12.8 ± 0.3	16.4 ± 0.7	2.0 ± 0.1	10.8 ± 0.3
Fomblin-ring/Fomblin-electrode	3.5 ± 0.2	20 ± 2	1.56 ± 0.08	2.0 ± 0.2
DPE-ring/Fomblin-electrode	2.3 ± 0.2	13 ± 2	0.47 ± 0.05	1.8 ± 0.2

Table 1: Fit parameters and error estimates.