Experimental report

07/09/2023

Proposal: 3-14-419 **Council:** 4/2021

Title: On the search of mirror neutron oscillations at low magnetic field with a beam experiment

Research area: Physics

This proposal is a continuation of 3-14-403

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Samples:

Instrument	Requested days	Allocated days	From	To
PF2 TES	2	2	08/06/2021	12/06/2021
PF2 EDM	12	12	27/05/2021	08/06/2021

Abstract:

This proposal is an extension of the project described in proposal No. 3-14-403. During the first campaign, neutron fluxes were measured as a function of the applied magnetic B-field. Oscillations towards the mirror world would be recognized by a sudden drop of the counting rate for a given magnetic field magnitude. The data analysis of the UCN counting rates, which were of the order of 3 x 10 5 counts/s, revealed non-counting-statistical fluctuations present in all scans whatever the applied B-field. We aim at characterizing the nature of these fluctuations since they reduce the sensitivity on the derived limit of the oscillation time tau_nn' by a factor between 2 and 3. Therefore, we plan to record the UCN flux under different configurations at the EDM beam port: as a function of the distance from the turbine exit, with two different counters, and without B-field.

Report: On the search of mirror neutron oscillations at low magnetic field with a beam experiment

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The first and second experimental campaigns on mirror neutron oscillations ($n - n'$) were dully completed (for a brief description of the experimental setup, see [1]). After a thorough analysis of the collected data, these experiments allowed reporting new limits on the parameter space $(\delta m/\mu_n, \tau_{nn'})$, where δm represents the neutron - mirror neutron mass splitting, μ_n the neutron magnetic moment and $\tau_{nn'}$ the characteristic time of oscillations.

Initially, the data revealed non-statistical fluctuations affecting the UCN counting rate. However, after comparing these fluctuations against the reactor power variations, it was found a non-negligible correlation at the scale of seconds. Such systematic effect was accounted for by scaling the UCN counting error bars by the factor

$$(s/\sigma_{\text{Pois}})_{R_{ABC}} = 2.23 \tag{1}$$

where s and σ_{Pois} are the standard deviation and Poissonian width of the distribution of normalized UCN fluxes R_{ABC}. Several other sources of systematics were studied. The dependence of the UCN detector efficiency to magnetic fields, the presence of background counts with non-constant rates and periodic fluctuations of the UCN counting, up to a few Hz, were all estimated smaller than the statistical fluctuations.

The search for a signal was carried out by comparing the normalized UCN flux at the different magnetic fields with the $n - n'$ model predictions. In this process, the dynamics of $n - n'$ oscillations was computed numerically via the Liouville-Neumann equation

$$\partial_t \hat{\rho} = -i[\hat{\mathcal{H}}_{nn'}, \hat{\rho}] = -i\hat{\mathcal{H}}_{nn'}\hat{\rho} + i\hat{\rho}\hat{\mathcal{H}}^{\dagger}_{nn'}, \tag{2}$$

where $\hat{\rho}$ is the 2×2 density matrix in the basis $(\psi_n, \psi_{n'})$ representing the quantum state composed of neutrons and mirror neutrons, and

$$\hat{\mathcal{H}}_{nn'} = \begin{pmatrix} \mu_n B & 1/\tau_{nn'} \\ 1/\tau_{nn'} & \delta m \end{pmatrix}. \tag{3}$$

Since no significant signal was found, the new limit on the $n - n'$ model parameters was set as [3]

$$\tau_{nn'} > 1\,\text{s for } |\delta m| \in [2 - 69] \times 10^{-12}\,\text{eV (95\% C.L.)}.$$

Using the same data set, the bound was also computed within the mirror magnetic field approach [2], which resulted

$$\tau_{nn'} > 1\,\text{s for } B' \in [50 - 1130]\,\mu\text{T (95\% C.L.)}.$$

References

[1] G. Ban, *et al.* (2022). Conf. proc.: Moriond 2022 - EW. 10.58027/9qzt-x624.

[2] Berezhiani, Z. (2009). The European Physical Journal C, 64(3).

[3] G. Ban, *et al.* (2023). To be published. arXiv:2303.10507.