Magnetic anomaly in UCN trapping: signal for neutron oscillations to parallel world?

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Present experiments do not exclude that the neutron transforms into some invisible degenerate twin, so called mirror neutron, with an appreciable probability. These transitions are actively studied by monitoring neutron losses in ultra-cold neutron traps, where they can be revealed by their magnetic field dependence. In this work we reanalyze the experimental data acquired by the group of A.P. Serebrov at Institute Laue-Langevin, and find a dependence at more than 5σ away from the null hypothesis. This anomaly can be interpreted as oscillation to mirror neutrons with a timescale of few seconds, in the presence of a mirror magnetic field $B' \sim 0.1 \text{G}$ at the Earth. If confirmed by future experiments, this will have a number of deepest consequences in particle physics and astrophysics.

There may exist a hidden parallel gauge sector that exactly copies the pattern of ordinary gauge sector. Then all particles: the electron $e$, proton $p$, neutron $n$ etc., should have invisible twins: $e'$, $p'$, $n'$, etc. which are sterile to our strong and electroweak interactions ($SU(3) \times SU(2) \times U(1)$) but have their own gauge interactions ($SU(3)' \times SU(2)' \times U(1)'$) with exactly the same couplings. A notorious example, coined as mirror world [1], was introduced long time ago against parity violation: for our particles being left-handed, parity can be interpreted as a discrete mirror symmetry which exchanges them with their twins which are assumed to be right-handed. Concerns about parity are irrelevant for our following discussions: they extend to a parallel sector (or sectors) of any chirality. Nevertheless, in the following we shall name the twin particles from the ‘primed’ parallel sector as mirror particles.

Mirror matter can be a viable candidate for dark matter [2]. The baryon asymmetries in both sectors can be generated by $B-L$ and $CP$ violating processes between ordinary and mirror particles [3]. This scenario can naturally explain the relation $\Omega_B/\Omega_B \simeq 5$ between the dark and visible matter fractions in the Universe [4]. The relevant interactions can be mediated by heavy messengers coupled to both sectors, as right handed neutrinos [3] or extra gauge bosons/gauginos [5]. In the context of extra dimensions, ordinary and mirror sectors can be modeled as two parallel three-dimensional branes and particle processes between them mediated by the bulk modes or “baby branes” can be envisaged [6].

On the other hand, these interactions can induce mixing phenomena between ordinary and mirror particles. In fact, any \textit{neutral} particle, elementary or composite, may oscillate into its mirror twin, as e.g. ordinary neutrinos $\nu_e, \nu_\mu, \nu_\tau$ into their mirror partners, sterile neutrinos $\nu'_e, \nu'_\mu, \nu'_\tau$ [7]. A kinetic mixing between photon and mirror photon [8] would induce the positronium – mirror positronium transition which is searched for experimentally [9]. Interestingly, this kinetic mixing may be responsible also for the dark matter signals observed by the DAMA, CoGeNT and CRESST experiments [10].

As it was shown in ref. [11], neither existing experimental limits nor cosmological and astrophysical bounds can exclude the possibility that the oscillation between the neutron $n$ and its mirror twin $n'$ is a rather fast process, hypothesis which can be tested in table-top laboratory experiments. The mass mixing, $\varepsilon(m' + \pi n)$, can emerge from $B$-violating six-fermion effective operators $(udd)(u'd'd')/M^2$ involving ordinary $(u,d)$ and mirror $(u', d')$ quarks, with $\varepsilon \sim \Lambda_{\text{QCD}}/M^2$ where $M$ is a cutoff scale of the respective new physics and $\Lambda_{\text{QCD}} \sim 250 \text{MeV}$ is the scale of strong interactions. Since the masses of $n$ and $n'$ are exactly equal, they have maximal mixing in vacuum and oscillate with timescale $\tau = \varepsilon^{-1} \sim (M/10 \text{TeV})^2 \text{s}$. (In this paper we use natural units, $\hbar = c = 1$.) It is striking that present probes do not exclude $n-n'$ oscillation faster than the neutron decay, $\tau < \tau_n \approx 880 \text{s}$. The reason is that for neutrons bounded in nuclei, a $n-n'$ transition is forbidden by energy conservation, while $\tau \sim 1 \text{s}$ is compatible with the bounds from primordial nucleosynthesis and neutron star stability. As for free neutrons, oscillation is affected by magnetic fields and coherent interactions with matter [11, 12].

In ref. [11] it was assumed that the mirror magnetic field vanishes at the Earth, in which case the $n-n'$ oscillation probability in vacuum after a time $t$ depends on the applied field $B$ as $P_{B}(t) = \sin^2(\omega t)/\omega^2$, where $\omega = \frac{1}{2} (m B) = (B/1 \text{mG}) \times 4.5 \times 10^5 \text{s}^{-1}$, with $B = |B|$ and $\mu = -6 \times 10^{-12} \text{eV}/G$ the neutron magnetic moment. Under this assumption the first limit was set on the $n-n'$ oscillation time, $\tau > 1 \text{s}$, using the beam monitoring data from the famous experiment [13], which provided the strongest limit $\tau_{n\bar{n}} > 0.9 \times 10^8 \text{s}$ on the neutron-antineutron oscillation [14].

In ultra-cold neutron (UCN) traps (see [15] for a recent review on cold and ultra-cold neutrons and their phenomenology) the $n-n'$ oscillation can be tested via anomalous magnetic field dependent losses of neutrons. With a neutron flight time between wall collisions of the order of $t \sim 0.1 \text{s}$, the experimental sensitivity can reach $\tau \sim 500 \text{s}$ [16]. Several dedicated experiments [17–21] were performed by comparing the UCN losses in large
reference magnetic field was evaluated approximately as small (b < 1 mG) magnetic fields. For small fields one has \( \omega t < 1 \) so that \( P_\text{B} = (t/\tau)^2 \), while for large fields one has \( \omega t \gg 1 \) and oscillations are suppressed, \( P_\text{B} < (1/\tau \omega)^2 \approx (t/\tau)^2 \). In this way, lower bounds on the oscillation time were obtained, which were adopted by the Particle Data Group \[22\]. The strongest bound, again under the no-mirror-field hypothesis, is \( \tau > 414 \text{ s at 90\% CL} \) \[18, 22\].

However, the above limits become invalid in the presence of a mirror matter or mirror field \[12\]. In particular, in the background of both ordinary \( B \) and mirror \( B' \) magnetic fields the \( n - n' \) oscillation is described by the Hamiltonian

\[
H_{nn'} = \left( \mu B \sigma - i \frac{\varepsilon}{m} B' \sigma \right),
\]

where \( \sigma = (\sigma_x, \sigma_y, \sigma_z) \) are the Pauli matrices. The probability of \( n - n' \) transition after flight time \( t \) was calculated in ref. \[12\]. It can be conveniently presented as

\[
P_B(t) = P_B(t) + D_B(t) \cos \beta,
\]

where \( \beta \) is the angle between the vectors \( B \) and \( B' \), and

\[
P_B(t) = \frac{\sin^2[(\omega - \omega')t]}{2\tau^2(\omega - \omega')^2} + \frac{\sin^2[(\omega + \omega')t]}{2\tau^2(\omega + \omega')^2},
\]

\[
D_B(t) = \frac{\sin^2[(\omega - \omega')t]}{2\tau^2(\omega - \omega')^2} - \frac{\sin^2[(\omega + \omega')t]}{2\tau^2(\omega + \omega')^2},
\]

with \( \omega = \frac{1}{2} |\mu B| \) and \( \omega' = \frac{1}{2} |\mu B'| \). By reversing the magnetic field direction the probability becomes \( P_{-B}(t) = P_B(t) - D_B(t) \cos \beta \). It is thus convenient to study the asymmetry \( P_B - P_{-B} = 2D_B \cos \beta \) in the neutron losses.

In this work we analyze in detail the data acquired in experiment \[21\] and find a dependence of the neutron losses on the magnetic field orientation, with more than 5\% deviation from the null hypothesis. This anomaly cannot be explained by standard physics, but can be interpreted in terms of \( n - n' \) oscillations in the background of a mirror magnetic field. Needless to say, the possible presence of the latter is striking in the light of mirror matter and strong implications for its presence of the latter is striking in the light of mirror matter or mirror magnetic field \[12\].

The neutron mean free-flight time between wall collisions and its variance were estimated via Monte Carlo simulation \[18, 21\]. For a storage time of 300 s one has \( \langle t \rangle = 0.094 \text{ s} \) and \( \langle t^2 \rangle - \langle t \rangle^2 = 0.0036 \text{ s}^2 \). For estimating the mean oscillation probability \( P_B = P_B + D_B \), the time dependent factors in \(3\) must be averaged and \( \frac{P_B}{\varepsilon} \) might be safely set to \( 1/\tau \) unless \( \omega \approx \omega' \).

Each measurement, taking about 10 min, consisted of three steps: filling of the trap during 130 s by unpolarized UCN through the basic neutron guide; closing of the entrance valve and storing of the UCN in the trap for 300 s; opening of the exit valves, counting the survived neutrons during 130 s by two independent detectors. The incident neutron flux during the filling was monitored by another detector located in the neutron guide.

The results of all measurements are reported in \[21\]. Here we concentrate on measurements in vertical magnetic fields directed up (+) and down (−), which were performed in three series. In the first series small \( (b < 1 \text{ mG}) \) and large \( (B \approx 0.2 \text{ G}) \) magnetic fields were used, repeating the sequences \( \{+b, +B, -b, -B, +B, +b\} \). Unfortunately, the neutron flux was strongly unstable, counts randomly fluctuated and soon the reactor was stopped for technical reasons. Due to this, only a small part of the data records, consisting of \( N=100 \) measurements for each of the \( \pm B \) and \( \pm b \) configurations, could be selected as acceptable for analysis.\(^2\) In a second series, only the large magnetic field \( B \approx 0.2 \text{ G} \) was employed, repeating 50 times the cycle \( \{B\} = \{-B, +B, +B, -B, +B, +B, -B, -B, -B, -B, +B, +b\} \), for a total of \( N=400 \) measurements in 72 hours of operation. The next 24 hours were devoted to the calibration tests in the UCN flow regime, totalling \( N=216 \) measurements (see later). The experiment was concluded by a third series of 16 cycles \( \{2B\} \) \( (N=128) \) under a magnetic field \( 2B \approx 0.4 \text{ G} \).

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\(^2\) Namely, three bands were selected in which the reactor power might be safely set to \( 1/\tau \) unless \( \omega \approx \omega' \).

\(^1\) The phenomenology of \( n - n' \) oscillations in case of many \((\sim 10^{26})\) parallel sectors was discussed in ref. \[23\].

\(^2\) Namely, three bands were selected in which the reactor power and the UCN flux were stable enough, with deviations no more than 10\% off the values of the normal functioning.
The raw data [21] can be tested for magnetic field dependence of UCN losses, as a probe for $n-n'$ oscillation. In fact, if between the wall collisions the neutron oscillates into a sterile state $n'$, then per each collision it can escape the trap with a mean probability $P_B$. The asymmetry in the magnetic field between the detector counts $N_B(t_* \propto \exp(-n_*P_B))$ and $N_{-B}(t_*) \propto \exp(-n_*P_{-B})$, directly traces the difference between the probabilities $P_B - P_{-B} = D_B$ [12]:

$$A_{B}^{\text{det}}(t_*) = \frac{N_{-B}(t_*) - N_B(t_*)}{N_{-B}(t_*) + N_B(t_*)} = n_* D_B \cos \beta,$$  \hspace{1cm} (4)

where we assume $n_* D_B \ll 1$. Clearly, the neutron loss factors related to regular reasons, which are magnetic field independent, cancel out from this ratio. These are the decay, the wall absorption or upscattering due to collisions with the residual gas, etc.\(^3\) On the other hand, since $P_B + P_{-B} = 2P_B$, the value

$$E_{B}^{\text{det}}(t_*) = \frac{N_B(t_*) + N_{-B}(t_*)}{N_B(t_*) + N_{-B}(t_*)} - 1 = n_*(P_B - P_{-B}),$$  \hspace{1cm} (5)

should not depend on the magnetic field orientation.

We compute then the values (4) and (5) by summing up the counts in two detectors, $N = N_1 + N_2$ (the individual counts $N_1$ and $N_2$ are used below for the stability check). For each detector we consider Poisson statistics, so that $\Delta N_{1,2} = \sqrt{N_{1,2}}$. In addition, we compute analogous asymmetries $A_{B}^{\text{mon}}$, $E_{B}^{\text{mon}}$ for the monitor counts $M_B$ and $M_{-B}$, and for the detector-to-monitor normalized ones $A_{B}^{\text{mon}}$, $E_{B}^{\text{mon}}$ using the ratios $(N/M)_{B}$ and $(N/M)_{-B}$.

The results are shown in Table I. We see that the value of $A_{B}^{\text{det}}$, based on 400 measurements in $\{B\}$ mode (see Fig. 1), has a 5.2σ deviation from zero.\(^4\)

\(^3\) As it was shown in ref. [24], the quantum mechanical corrections to $n-n'$ transition probability due to the finite size of the UCN traps are negligible.

\(^4\) In ref. [21] a somewhat different fitting procedure was adopted. The data were averaged between the $B$ and $2B$ magnetic fields and, as a result, a circa 3σ deviation was reported, which in our notation translates to $A_{B}^{\text{det}}(B, 2B) = (3.8 \pm 1.2) \times 10^{-4}$. However, because the probability of $n-n'$ oscillation (3) depends resonantly on the magnetic field, one should not average between different field values. After our communication, A.P. Serebrov and A.K. Fomin reanalyzed the experimental records and confirmed the 5.2σ anomaly in the $\{B\}$ mode data. We thank them for this cross check. For a joint proposal of new experimental series, to confirm definitely this anomaly or to exclude it, see [27].

Can this anomalous dependence on the magnetic field be induced by technical factors as e.g. fluctuation of the reactor power or unstable vacuum condition in the trap? Fig. 1 shows that the detector counts $N$ had up to 2% drift which is, however, well traced by the monitor counts $M$: the constant fit of ratios $N/M$ gives $\chi^2_{\text{dof}} = 1.55$. In addition, individual counts in two detectors are perfectly synchronous: $N_1/N_2$ is constant with $\chi^2_{\text{dof}} = 0.98$. In fact, the two detectors separately give $A_{B}^{\text{det}} = (8.40 \pm 1.92) \times 10^{-4}$ ($\chi^2_{\text{dof}} = 0.88$) and $A_{B}^{\text{mon}} = (5.62 \pm 1.86) \times 10^{-4}$ ($\chi^2_{\text{dof}} = 0.81$). It is important to note that since the measurements with switching field were taken at consecutive times, a drift in the reactor flux (or changing vacuum conditions or other factors that may affect the initial amount of neutrons in the trap) could contaminate the asymmetry itself. However, the cycles $\{B\}$ were configured to make the symmetry (4) insensitive to any slow drift. Clearly, a linear drift is cancelled in each of the measurement quartets ($-+$, $+-$, $-+$, $++$) and ($+-$, $-+$, $+-$, $-+$), while the quadratic component is cancelled between two consecutive quartets. In fact, we fit $A_{B}^{\text{det}}$ as the average of (4) in each complete $\{B\}$ cycle (8 measurements), and obtain an excellent $\chi^2_{\text{dof}} = 0.87$.

As a further check, the anomaly cannot be eliminated as well by normalizing to the monitor counts: we find a residual 4σ asymmetry also in $A_{B}^{\text{det}}$ (see Table I). This lower value is in agreement with the fact that this measure mildly underestimates the effect, at first by statistical reasons: accounting for the monitor fluctuations $\Delta M = \sqrt{M}$ one formally enlarges the errors; then, by dynamical reasons: during the 130 s of filling time nearly
half of the neutrons counted by the monitor are neutrons that reenter the neutron guide back from the trap, where they could oscillate into \( n' \) being exposed to the magnetic field. The UCN diffusion time in the trap when the entrance valve is open is estimated as \( t_{\text{diff}} \approx 60 \text{s} \). Hence, the monitor asymmetry \( A_{B; \text{mon}}^{\text{diff}} \) is expected to be one order of magnitude less than \( A_{B; \text{bet}}^{\text{bet}} \). In fact, analyzing the monitor data we get \( A_{B; \text{mon}}^{\text{mon}} = (0.96 \pm 0.72) \times 10^{-4} \left( \chi_{\text{ dof}}^{2} = 0.90 \right) \).

Finally, a series of calibration measurements were performed in order to check for possible systematic effects that could make the neutron counts sensitive to the magnetic field orientation, as for instance an influence of the alternating solenoid current on the counting electronics. Measurements were performed with high statistics in \( \{ B \} \) mode, with data taken in continuous flow regime, i.e. with entrance and exit valves of the trap open during 200 s of counting simultaneously with the two detectors and the monitor. With valves open, the effective diffusion time of the UCN in the trap is estimated via MC simulations as \( t_{\text{ UCN}}^{\text{ mon}} \approx 20 \text{s} \). Coherently, these counts show no systematic effects: we find \( A_{B; \text{mon}}^{\text{bet}} = (0.01 \pm 0.39) \times 10^{-4} \left( \chi_{\text{ dof}}^{2} = 1.23 \right) \) and \( A_{B; \text{mon}}^{\text{bet}} = (0.22 \pm 0.78) \times 10^{-4} \left( \chi_{\text{ dof}}^{2} = 1.16 \right) \). The counts of the two detectors were stable: the ratio \( N_{1}/N_{2} \) is fitted by a constant with \( \chi_{\text{ dof}}^{2} = 0.98 \).

**Interpretation of the results.** Let us now analyze the obtained results in the light of \( n-n' \) oscillations. Using (4) and (5), the values shown in Table I translate into

\[
\begin{align*}
\mathcal{D}_{B} \cos \beta &= (1.60 \pm 0.32) \times 10^{-7} \quad (6) \\
\mathcal{P}_{B} - \mathcal{P}_{b} &= -(1.03 \pm 1.11) \times 10^{-7} \quad (7) \\
\mathcal{D}_{2B} \cos \beta &= -(0.06 \pm 0.80) \times 10^{-7} \quad (8)
\end{align*}
\]

where we have conservatively taken \( A_{B; \text{bet}}^{\text{mon}} = (6.40 \pm 1.26) \times 10^{-4} \), by averaging the results of \( \{ B \} \) and \( \{ b,B \} \) cycles.

Eqs. (2) and (3) show that in the presence of strong enough mirror field, \( B' > 10 \text{ mG} \), the values of \( \mathcal{P}_{B} \) and \( \mathcal{D}_{B} \) have peculiar dependence on the experimental magnetic field, so the above results can be used to put constraints in the plane \( (B', \tau) \) or \( (B', \tau_{\beta}) = (\tau \cos \beta)^{-1/2} \).

Eq. (6), for a given \( B \), gives a correlation between \( B' \) and \( \tau_{\beta} \). We perform a 2-parameter fit in this plane, and find the preferred regions which are depicted as gray areas in Fig. 2. Since the homogeneity of the vertical field \( B \) was not precisely controlled in this experiment, and its effective value averaged over the trap could vary between \( B = 0.15 - 0.25 \text{ G} \), we consider that \( (B/0.2 \text{ G}) = 1 \pm 0.25 \) and marginalize over this range. The global fit also includes the constraint from (7), conservatively referring to the case \( \cos \beta = 1 \), as well the limits on \( \tau \) from experiments with horizontal magnetic field [18, 21] and the limit on the neutron losses in the Earth magnetic field [25]. These latter limits are also explicitly depicted, respectively as the yellow area peaked at 0.2 G and the blue area peaked at 0.5 G. The horizontal field measurements of ref. [21] (with \( B = 0.2 \text{ G} \)) imply \( \mathcal{P}_{B} - \mathcal{P}_{b} = -(3.60 \pm 1.95) \times 10^{-8} \). For \( B' > 1 \text{ G} \) this gives the lower limit \( \tau > 0.28 \text{s} \times (1 \text{ G}/B')^{2} \). The measurements of neutron losses in the Earth magnetic field \( (B \approx 0.5 \text{ G}) \) yield roughly \( P_{B} < 2 \times 10^{-6} \) [25]. For \( B' > 1 \text{ G} \) it gives the limit \( \tau > 0.1 \text{s} \times (1 \text{ G}/B') \).

As one can see from Fig. 2 the positive asymmetry (6) along with the constraint (7) and the limits from horizontal field measurements [18, 21], restrict the parameter space to three regions marked as (a), (b) and (c).

The \( \mathcal{D}_{B} \) and \( \Delta_{B} \) imply that the preferred region is (a), where the mirror magnetic field \( B' = 0.09 \) to 0.12 G at 90% CL, and the \( n-n' \) oscillation time is in the range 2 to 10 s. The region is considerably enlarged by the B magnetic field uncertainty which is marginalized in the fit. The best fit point, visible in the figure inset, is relative to \( B = 0.2 \text{ G} \) and corresponds to \( B' = 0.11 \text{ G}, \tau_{\beta} = 3 \text{s} \).

At 99% CL the region becomes larger and also region (b) beyond the 0.2 G resonance (of the horizontal-field measurements) becomes allowed. The region extends up to \( B' \approx 0.3 \text{ G} \), therefore we conclude that at 99% CL the mirror magnetic field is constrained in the range 0.08 G < \( B' < 0.3 \text{ G} \).

We note finally that at larger \( B' \) the horizontal-field measurements do not constrain the positive result of \( \mathcal{D}_{B} \) and a third region (c) is allowed, extending from \( B' = 1.5 \text{ G} \) to 15 G where the Earth-field constraint becomes dominant, with oscillation time in the range 0.15 s > \( \tau_{\beta} > 0.005 \text{s} \). This region has however higher minimum \( \chi^{2} \) and in addition it is disfavored by the constraint (8).

The positive result that emerged from the fit points to a nonzero mirror magnetic field at the Earth. Let us then comment whether this is plausible. If mirror particles represent dark matter, they must present in the Galaxy along with the normal matter. If by chance the solar system is traveling across a giant molecular cloud extended over several parsecs, there may exist a mirror field \( B' \), with \( B' \sim 10 \text{ to } 100 \text{ mG} \). Then, since the experimental field \( B \) rotates together with the Earth, the angle \( \beta \) between \( B \) and \( B' \) and thus \( P_{B} \) would show a periodic time dependence with period of sidereal day \( T = 23.94 \text{h} \).

On the other hand, if there exist strong enough interactions between ordinary and mirror particles, e.g. due photon–mirror photon kinetic mixing [8], then the Earth can capture a significant amount of mirror matter. The natural capture asymmetry due to the Earth rotation would also give rise to circular currents that could induce a mirror magnetic field up to several Gauss [12]. If the captured mirror matter forms a compact body rotating synchronously with the Earth, then \( \beta \) would not vary in time. However, if it forms an extended halo around the Earth with a differential rotation, the mirror field \( B' \) and hence \( P_{B} \) may have more complex time variations.

\footnote{According to ref. [26], the geophysical data on the Earth mass, moment of inertia, normal mode frequencies etc. allow the presence of mirror matter in the Earth with mass fraction up to \( 4 \times 10^{-3} \).}
Interestingly, the data of series \( \{B\} \) hint to a periodic time-dependence, consistent with sidereal day period (see Fig. 1). Fitting the up-down asymmetry as \( A_B^{det} = C + V \cos \left( \frac{2\pi}{T} (t - t_0) \right) \) (4 parameters) we obtain \( C = (7.09 \pm 1.26) \times 10^{-4}, V = (4.10 \pm 1.71) \times 10^{-4}, T = 24.0 \pm 1.8 \) h and \( t_0 = 8000.4 \pm 1.8 \) h, with \( \chi^2_{\text{ dof}} = 0.82 \). (Asymmetries in both detectors are consistent with such periodicity.) Clearly, since the constant fit already has a very good \( \chi^2 \), its further improvement with the periodic fit is not very significant, and testing the time dependence requires more statistics. To our regret, the data in \( \{b, B\} \) and \( \{2B\} \) were not broad and stable enough for a reliable time-dependent analysis.

**Summary.** The phenomenon of \( n-n' \) oscillation is particularly attractive, especially in the light of our findings, which clearly call for future experiments with higher precision. In particular, using the same 190 \( \ell \) UCN chamber with \( t_1 \simeq 0.1 \) s as in the experiments [18, 21] at the ILL PF2 EDM facility, these oscillations can be tested under properly controlled magnetic field profiles [27]. By tuning the magnetic field to the resonance value \( B = B' \) with a precision of 1 mG, the probability of \( n-n' \) transition can be increases up to \( P_{\text{res}}, D_{\text{res}} \simeq (t_1/\tau)^2 \), i.e. \( \sim 10^{-3} \) for \( \tau = 3 \) s. Then the neutron losses would be very sizable, \( A_B \sim 0.1 \), and also neutron regeneration \( n \rightarrow n' \rightarrow n \) and resonant corrections to the neutron spin-precession [12] could be optimally tested. If the DUSEL project [28] will be realized, the neutron flight time could be increased up to few seconds which would allow to test the \( n-n' \) oscillation in an exhaustive way.

Concluding, the experimental data [21] indicate that the neutron losses in the UCN trap in magnetic field \( B \simeq 0.2 \) G depend on the magnetic field direction, showing an anomaly about 5\( \sigma \) deviated from the null hypothesis, which can not be interpreted by standard physics. If this anomaly will be confirmed by future experiments, it can be explained by neutron oscillations into mirror neutrons, in the presence of a mirror magnetic field \( B' \sim 0.1 \) G. Such a discovery would shed light also on fundamental physical problems as the nature of dark matter, primordial baryogenesis, stability of neutron stars [11] and many other astrophysical issues as e.g. the origin of the pre-GZK cutoff in the cosmic spectrum [29]. In addition, the underlying physics at the scale \( M \sim 10 \) TeV could be testable at the LHC. The discovery of a parallel world via \( n-n' \) oscillation and of a mirror magnetic background at the Earth, striking in itself, would give crucial information on the accumulation the of dark matter in the solar system and in the Earth, due to its interaction with normal matter, with far reaching implications for physics of the sun and even for geophysics.

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