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Search for $n \rightarrow \bar{n}$ transitions in DUSEL

Scientific motivation:

Experimental observation of nucleon instability is one of the missing components required for the understanding of baryon asymmetry of the universe (BAU). “Traditional” proton decay with the modes and rates predicted by the original (B–L)-conserving SU(5) GUT and SUSY-GUT schemes was not observed by experiments. Furthermore, it was realized theoretically that (B–L)-conserving interactions at GUT scale couldn’t be an explanation of BAU. Alternatively, the processes violating (B–L) at the energy scale below GUT but above the scale of electro-weak non-perturbative *sphaleron* transitions should be responsible for the observed BAU. Such processes will be searched in the new generation of experiments at DUSEL. These processes include searches for (a) non-traditional (B–L) violating nucleon decay (for example, $n \rightarrow \nu\nu\bar{\nu}, p \rightarrow \nu\nu\bar{\nu}, nn \rightarrow \nu\bar{\nu}$) with Δ(B–L) = 2, (b) neutrinoless double-beta decays with ΔL = 2, and (c) most spectacularly process of neutron to anti-neutron transition with ΔB = 2. Neutron-antineutron transition will have magnificent and unambiguous signature and can be searched in experimentally controlled environment without background. With presently existing techniques the sensitivity of $n \rightarrow \bar{n}$ search can be increased by large factor > 1,000 as compared to the previous $n \rightarrow \bar{n}$ searches (with cold neutrons at ILL/Grenoble and with neutrons bound inside nuclei at Soudan-II). In the modern theoretical braneworld the global baryon and lepton charges might be not conserved as a result of quantum fluctuation of the brane worldvolume into higher-dimensional space. With low-energy gravity scale of ~ 100 TeV it can lead to the $n \rightarrow \bar{n}$ transitions, while the proton decay processes will be suppressed. Thus, the observation of $n \rightarrow \bar{n}$ can be the first experimental manifestation of existence of extra dimensions in nature.

Idea of possible experiment:

We anticipate a construction of a new $n \rightarrow \bar{n}$ search experiment at DUSEL facility. The proposed experiment should include a dedicated 3.4 MW neutron source of TRIGA type (to be purchased from General Atomic Company) with annular core and throughout vertical tube. To reach maximum sensitivity in $n \rightarrow \bar{n}$ search the bulk of produced neutrons should be cooled down to the lowest possible temperature (average velocities < 1,000 m/s) and maintained in-flight for a maximum time (~ 1s). Cold neutron source should be installed on the top of the vertical mineshaft of $\gtrsim$ 1 km in depth with diameter of few meters. A new scheme of experiment with enhanced sensitivity requires large elliptical reflector that intercepts neutrons in the large solid angle and direct them along ~ 1 km vacuum flight path to the detector. The *vertical* layout of the flight path will most efficiently mitigate the disturbing gravity effects (by factor of > 10 in sensitivity). Focusing neutron reflector will be installed inside the vertical vacuum chamber with vacuum better than 10^{-4} Pa. Earth magnetic field inside the vacuum chamber needs to be compensated by active and passive magnetic shields down to the level of few nT. Antineutrons transformed from neutrons during the flight through the vacuum chamber are to be detected by the antineutron annihilation detector located in the experimental hole at the bottom of the mineshaft. Inverse configuration with neutron source at the bottom of vertical mineshaft and detector on the top is also feasible and is the subject to engineering optimization. In the proposed experimental scheme the sensitivity of $n \rightarrow \bar{n}$ search can be factor of ~ 1,000 higher than in the previous experimental search at ILL/Grenoble source. With zero-background detector and with very distinctive signature of $\bar{n}$ annihilation, even one observed event would constitute a discovery. If no events will be observed after several years of measurements it will corresponds to a new limit on the stability of matter $\gtrsim 10^{35}$ years that cannot be obtained in the intranuclear search with large underground detectors. No other practical schemes for $n \rightarrow \bar{n}$ search exist with comparable sensitivity.