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Why does the Universe contain vast quantities of matter, but almost no antimatter?

In order to address this fundamental question, which has perplexed cosmologists for half a century, we need to look beyond our Standard Model (SM) of particle physics. Some of the most sensitive probes we have of such “new” physics arise from non-accelerator experiments. One such is the search for an electric dipole moment (EDM) of the neutron. EDMs violate both parity and time-reversal symmetries, and they therefore provide some of the tightest constraints upon models beyond the SM that attempt to reconcile the low level of CP violation observed in K and B systems with the large baryon asymmetry of the Universe. The current world limit of 2.9×10^{-26} e.cm, set in 2006 by the RAL-Sussex-ILL EDM collaboration, already requires considerable fine-tuning of MSSM parameters - the so-called "SUSY CP problem".

The measurement was carried out by using NMR to determine the Larmor precession frequency, in parallel and antiparallel magnetic and electric fields, of ultracold neutrons trapped in a storage cell - a sort of atomic clock, but using neutrons instead of atoms. A change in frequency with applied electric field is the signature of an EDM. The level of precision is astonishing: the system can detect an energy-level splitting of 10^{-21} eV, and yet it is sensitive to aspects of physics at energy scales well beyond that achievable at the LHC.

Amazing Facts about the Neutron EDM Experiment

- This experiment is said in the literature probably to have disproved more theories than any other experiment in the history of physics.
- The structural asymmetry we are sensitive to is so small that, if the neutron were expanded to the size of the Earth, the distortion would be less than a tenth of the thickness of a human hair.
- ... Or alternatively, if the structural asymmetry we're sensitive to were expanded to the size of, e.g., a football, then a football expanded by the same factor would be the size of the visible Universe.
- The neutron "clock" runs at 30 Hz, or 1800 rpm; about the same as a car engine. We can measure the frequency so precisely that we'd be sensitive to an extra one turn per year on top of it.
- We can sense energy changes of 10^{-21} eV, or 10^{-42} J; that's something like a million million million million million million million millionth of the amount of energy you need to boil water for a cup of tea.
- The developments in precision frequency measurements needed for the first nEDM experiment, back in 1950, led ultimately to atomic clocks; NMR and MRI; GPS...

nEDM experiment at Paul Scherrer Institute

An international collaboration consisting of about 50 physicists representing 14 institutions from Belgium, France, Germany, Poland, Switzerland, United Kingdom and USA continues quest for the neutron EDM at the Paul Scherrer Institute, Villigen, Switzerland. The ultimate goal is to improve the present accuracy by a factor of 50 and possibly detect a non-zero value signalling the existence of phenomena not described by the Standard Model.