

# Popular Science Summary

Rutger Nieuwenhuis

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Everything around us is made of matter, consisting of three fundamental building blocks: the positively charged proton, the negatively charged electron and the neutron without any charge. All types of matter have twins with opposite electric charge, called antimatter. The three fundamental building blocks of antimatter are the negatively charged antiproton, the positively charged positron and the neutral antineutron. When a matter and antimatter particle come together, they annihilate each other in a big burst of energy.

The current leading theory of particle physics, called the Standard Model, is nearly symmetric with respect to matter and antimatter. This means that every interaction allowed within the Standard Model creates nearly equal amounts of matter and antimatter. However, in everyday life we only encounter matter. After all, if there would be any antimatter around us, it would collide with the ordinary matter and annihilate into pure energy.

One of the current questions in physics is why there is so much matter, and so little antimatter in the universe. This observation has led physicists to speculate that there might be interactions beyond the Standard Model. These interactions would violate the matter-antimatter symmetry, allowing for a process that creates an excess of matter.

In this thesis, we consider such a process and analyze its consequences. Namely, we consider a model where the neutron decays to a new stable particle and an unstable particle, which can in turn decay to rays of energy. The new particle would not interact with particles in any other way, and hence it would create a different type of matter called dark matter.

This process would destroy a neutron, leading to matter disappearing instead of appearing. However, in the dense conditions of the early universe, the inverse of this process could occur frequently, leading to the creation of matter. In contrast, the process would be rare in the conditions of a laboratory. Many experiments have searched for such exotic neutron decays, putting very strict experimental limits on this model.

However, most of these experiments deal with *bound* neutrons, neutrons tied to other matter. If the difference between the mass of the neutron and the mass of the particles that it decays into is small, this decay cannot happen for bound neutrons. In contrast, the decay is possible for free neutrons.

The upcoming HIBEAM/NNBAR experiments at the European Spallation Source (ESS) analyze large amounts of free neutrons, and hence could observe this decay. In this thesis, we consider this case of a small mass difference and compute how rare the processes allowed by the model would be under this condition. Additionally, we run numerical simulations which allows us to see what it would be like to observe these interactions in experiments. We conclude that this model is a candidate for observation at HIBEAM/NNBAR and that the possibility of observing such exotic neutron decays should be further investigated.