PhD position in experimental nuclear physics

Is there a dark decay of neutrons in ^{6}He?

The neutron is one of the fundamental building blocks of matter. Along with the proton and electron, it makes up most of the visible Universe. Without it, complex atomic nuclei simply would not have formed. Although the neutron was discovered over eighty years ago and has been studied intensively thereafter, its precise lifetime remains one of the most remarkable open questions in fundamental physics. After decades of experimental struggle two different experimental methods appear to yield two lifetime values with the discrepancy between them on the level of about 4.0σ [1]. The first type of measurements, referred to as the bottle essentially counts the number of neutrons in the container as a function of time. In the second method, called the beam, one counts protons resulting from beta decay of known number of neutrons in the beam. On average, the latter method yields the longer neutron lifetime by about 1%.

Recently, two theoretical physicists put forward a thrilling hypothesis about the cause of the discrepancy [2]. They argued that neutrons might sometimes decay into dark matter - the invisible particles that seem to make up six-sevenths of the matter in the universe based on their gravitational influence. If neutrons sometimes transmogrify into dark matter particles instead of protons, then they would disappear from bottles at a faster rate than protons appear in beams, exactly as observed.

If such a neutron decay is possible, then it could occur also in nuclei with sufficiently low neutron binding energy, a quasifree neutron decay. In this PhD work, we would like to consider the case of ^{6}He which is one of the best candidates to observe such exotic decay [3]. The ^{6}He nucleus is compose of a core of ^{4}He surrounded by a halo of two neutrons with a low binding energy. If one of the neutrons of the halo decay in dark matter, the remaining ^{5}He is not bound and will decay instantaneously in one neutron and one ^{4}He. Therefore, the observation of a free neutron from ^{6}He decay would, although difficult to do, be a unique signature for the dark neutron decay. We propose to use the unique neutron detector TETRA and the high intensity and high purity of the GANIL/SPIRAL1 ^{6}He beams to observe this hypothesized decay channel for the first time or set an upper limit to branching ratio and thus help clarify the so-called “neutron lifetime anomaly”.

[1] W. Pattie Jr. et al, Science Science 11 May 2018 vol. 360 no. 6389 627-632
[2] B. Fornal and B. Grinstein, Phys. Rev. Lett. 120, 191801 (2018).
[3] M. Pfützner and K. Riisager, Phys. Rev. C 97, 042501(R) (2018).

Expected skills:
Good knowledge in nuclear physics, experimental profile and computing are desirable. Ability to work in team. Proficiency in English.

Contact: Hervé Savajols
GANIL, BP 55027, 14076 Caen France
Phone: +33 (0)2 31 45 46 99
mail: savajols@ganil.fr