Experimental studies of an exotic decay mode at the proton drip-line: the two-proton radioactivity

L. Audirac[1], N. Adimi[1], P. Ascher[1], B. Blank[1], C. Borcea[1], G. Canchel[1], C.E. Demonchy[1], F. de Oliveira Santos[2], C. Dossat[3], J. Giovinazzo[1], S. Grévy[2], L. Hay[1], J. Huikari[1], T. Kurtukian-Nieto[1], S. Leblanc[1], I.Matea[1], J.-L. Pedroza[1], L. Perrot[2], J. Pibernat[1], L. Serani[1], C. Stodel[2], J.-C. Thomas[2]

[1]CENBG, Chemin du Solarium, BP 120, F-33175 Gradignan Cedex, France

[2]GANIL, Bvd Henri Becquerel, BP 55027, F-14076 Caen Cedex 5, France

[3]DAPNIA, CEA Saclay, F-91191 Gif-sur-Yvette Cedex, France

Two-proton radioactivity for long-lived ground-state emitters was predicted by Goldanskii in 1960. This decay mode concerns proton-rich nuclei at the proton drip-line with even number Z, where only the emission of two protons is possible and emission of one proton is forbidden. Possible candidates are in the mass 50 region. This decay mode was first observed for ^{45}Fe in 2002, although no direct observation of the two protons was possible [1]. The heavy ions were implanted in a silicon detector. Therefore the total decay energy and the half-life could only be measured, since the two protons could not escape from the detector. A similar experiment for the study of the decay of ^{54}Zn was achieved in 2004 [2]. The 2-proton radioactivity of ^{54}Zn was clearly observed. In order to determine the mechanism of emission, it is necessary to observe directly the two protons emitted, especially to determine the energetic and angular correlations between the protons.

For this purpose, a new detector was developed at CENBG, consisting in a Time Projection Chamber (TPC). The active volume is made of P10 gas into which the heavy ions are implanted and the correlated decays are visualized. The detection setup consists in a two-dimensional matrix of two orthogonal sets of 768 strips, each one giving energy and time information with respect to the energy and the arrival time of the signal on the considered strip.

A first experiment was performed at the LISE3 separator of GANIL with the TPC in September 2006 for the study of ^{45}Fe. The total decay energy and the life-time were confirmed and the direct observation of the two protons emitted has been achieved for the first time [3]. Since the proton tracks could be reconstructed, the sharing of the decay energy and the relative angle between the two protons were especially determined. Moreover this experiment allowed to confirm the β-2p emission of ^{43}Cr and to compare the results obtained with ^{45}Fe.

A second experiment was performed at the LISE3 separator in July 2008. The direct visualization of 2-proton decay of ^{54}Zn was observed. In the same way, the sharing of the total decay energy and the relative angle between the protons could be studied.

[1] J. Giovinazzo *et al*., Phys. Rev. Lett. **89**, 102501 (2002)

[2] B. Blank *et al*., Phys. Rev. Lett. **94**, 232501 (2005)

[3] B. Blank *et al*., Nucl. Instr. and Meth. in Phys. Res. **A613**, 1 (2010)