

## Observation of Beta-delayed Three-proton Emission from $^{31}\text{Ar}$ with the Optical Time Projection Chamber at the FRS\*

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A characteristic feature of exotic nuclei at the proton drip-line is the large energy released in beta decay. As a consequence, highly excited, and unbound, states in the daughter nucleus can be populated in the decay. Thus, beta decay can be followed by emission of protons. Since the first observation of delayed proton emission almost 50 years ago, followed by the discovery of beta-delayed two-proton emission in 1983, such decays have provided a wealth of information on structure of neutron-deficient nuclei far from stability, allowing tests of nuclear models and yielding data needed for the understanding of the astrophysical  $rp$  process [1,2].

The first unambiguous observation of the beta-delayed three-proton emission ( $\beta 3p$ ) was succeeded only in 2007 when a new type of gaseous time projection chamber with optical readout (OTPC) was applied to study nuclei in vicinity of  $^{45}\text{Fe}$  [3,4]. This novel type of detector, developed at University of Warsaw (Poland), records tracks of particles emitted in the decay and can provide a direct and unambiguous evidence on the decay mode even if only one event is recorded. In the experiment carried out at NSCL/MSU laboratory (East Lansing, USA) the  $\beta 3p$  emission was identified in the beta decays of  $^{45}\text{Fe}$  and  $^{43}\text{Cr}$  [5,6].

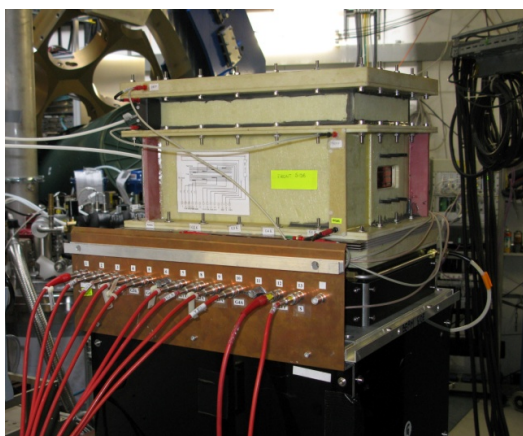


Figure 1. The Optical Time Projection Chamber mounted at the final focal plane of the FRS. Ions enter the active gas volume through a window seen on the right. The CCD camera is mounted inside the black support box below the chamber.

In August 2012 in an experiment at the GSI Fragment Separator (S388) the OTPC chamber was used to investigate the beta decay of  $^{31}\text{Ar}$ . A photo of the detector installed at the final (F4) FRS focus is shown in Figure 1.

The ions of  $^{31}\text{Ar}$  ( $T_{1/2}=15$  ms) were produced by the fragmentation of a  $^{36}\text{Ar}$  primary beam at 880 MeV/nucleon impinging on a  $8\text{ g/cm}^2$  beryllium target. During about five days of data taking, a few tens of thousands of  $^{31}\text{Ar}$  ions were implanted into the chamber and their decays with emission of protons were recorded. Among these decays a few events showing the simultaneous emission of three protons were clearly observed. An example event is shown in Figure 2. The probability of this decay branch and other spectroscopic features will follow from the analysis which is going on. The observation of the third case of this exotic decay branch – the emission of 3 protons following beta decay – was possible due to extreme sensitivity of the OTPC detector and the separation power of the FRS.

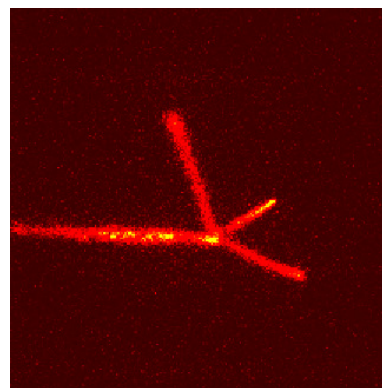


Figure 2. An example image, taken by the CCD camera, showing a  $\beta 3p$  decay event. An ion of  $^{31}\text{Ar}$  entered the chamber horizontally from left and stopped in the gas. Several milliseconds later three protons were emitted simultaneously from the same point where the ion was stopped.

### References

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