Fine Structure Studies in Proton Emission

In order to understand the evolution of single particle wave functions and deformations beyond the proton drip line, a program has been initiated to study fine structure decay in proton emission. Fine structure in the proton emission spectrum allows one not only to define low energy states in the daughter, but from a comparison of the proton energies and partial half-lives, enables determination of the composition of the single-particle proton states in the proton unbound state. In the case of an odd-Z, even-N decay to an even-even nucleus, the proton emission proceeds primarily to the 0^+ ground state with some fraction proceeding to the excited 2^+ state. The energy of this 2^+ state allows one to estimate the quadrupole deformation in the daughter. The situation with the decay of an odd-odd nucleus to an (even-Z, odd-N) isotope is quite a bit more complicated. The proton emitting state consists of coupled proton and neutron states, with the final state being a low-energy (not necessarily the ground state) neutron configuration in the daughter nucleus. The study of fine structure in the decay of these odd-odd nuclei can be used to identify and determine relative energies of these low-energy neutron levels in the (even Z, odd N) daughter nucleus. In order to understand the evolution of single particle wave functions and deformations beyond the proton drip line, a program has been initiated to study fine structure decay in proton emission.

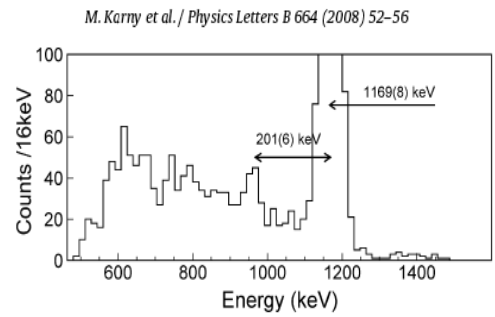
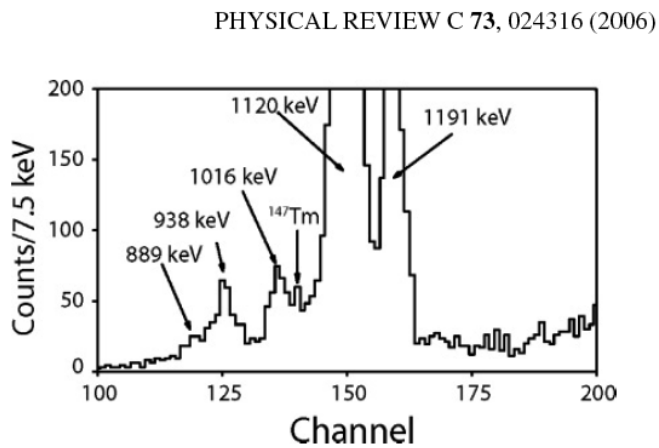


Fig. 1. The energies of decay signals within 1–16 ms after the implantation of ^{141}Ho ions. An energy difference of 201(6) keV was obtained for two observed proton peaks, the known transition at 1169(8) keV [13] and the peak at 0.97 MeV corresponding to a proton transition to the 202.1 keV 2^+ level in ^{140}Dy [16].

Some highlights of our recent studies in this area include the observation of fine structure proton emission from ^{141gs,m}Ho and ^{145}Tm to the first excited 2^+ state in ^{140}Dy and ^{144}Er respectively. These measurements have allowed us to interpret the wave functions of the proton emitting states (using coupled-channels formalism), and measure the deformation of the daughter nuclei. In addition, we have observed fine structure in the proton decay of ^{146}Tm resulting in the wavefunctions of three excited levels in the daughter ^{145}Er being characterized.



For proton and alpha emission of radioactive nuclei, the recoil mass separator (RMS) is the main research instrument. The RMS was built as a UNIRIB initiative and is the recoil mass spectrometer with the highest primary beam suppression worldwide. In addition, in particle decay experiments the digital electronics and detector technology developed with substantial contribution from the UNIRIB collaboration are crucial for the proper identification of the extremely rare decays studied.

"Shell Structure Beyond the Proton Drip Line Studied via Proton Emission from Deformed ^{141}Ho"
M. Karny, et al., Phys.Lett. B **664**, 52 (2008).

" Systematics of Isomeric Configurations in N-77 odd-Z isotones Near the Proton Drip Line
M. Tantawy, et al., Phys. Rev. C. **73**, 024316 (2006).

" Fine Structure in Proton Emission from ^{145}Tm discovered with the Novel technique of Digital Signal Processing"
M. Karny, et al., Phys. Rev. Lett. **90**, 012502 (2003).