Studies of nuclei in the region of ^{48}Ni using an optical time projection chamber

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Abstract

The dissertation presents results of decay spectroscopy of nuclei in the vicinity of the doubly magic ^{48}Ni, along with employed experimental techniques and detailed presentation of analysis algorithms developed specifically for this study.

The experiment providing data for the described studies was performed at the National Superconducting Cyclotron Laboratory at the Michigan State University using coupled K500-K1200 cyclotrons for acceleration of ^{58}Ni to the energy of 160 MeV per nucleon. A1900 separator was used to select ions of interest from reactions of the primary beam with a ^{nat}Ni target. Selected ions were implanted into the Optical Time Projection Chamber (OTPC), where their decays were recorded. Also recorded were ID data for each implanted event. The OTPC detector used in this study is a second version of this device and substantial part of the dissertation describes the detector itself and the experimental setup, in particular the controlling logic.

The OTPC detector was developed to record events of charged particles emission from exotic nuclei. It works in a manner similar to an ordinary time projection chamber, albeit with an additional step of converting the signal from electrical form to light. Each recorded event consists of an image describing projection on the XY plane and an accompanying trace from a photo multiplier providing information along the Z axis. When combined, the data from these sources allow for complete reconstruction of traces of charged particles stopped in the detector, providing their energy and direction. A procedure for precise reconstruction of events by comparing experimental results with a simulated detector response was developed for the analysis of experimental data. This procedure allowed reconstruction of traces of both protons emitted in the ^{48}Ni two-proton radioactivity, as well as β-delayed proton traces from ^{44}Cr and ^{46}Fe of energy up to $\sim$2 MeV.

This dissertation presents in detail the first four events of direct observation of the two proton radioactivity from ^{48}Ni. All these events are reconstructed in three dimensions, yielding energies and directions of individual protons. Also presented is the first observation of β-delayed two-proton emission from ^{46}Fe. Further analysis yields half-lives and branchings ratios for decays of ^{48}Ni, ^{46}Fe and ^{44}Cr. For ^{48}Ni and ^{46}Fe production cross-section is determined. Recorded proton spectra of low energy delayed protons from ^{46}Fe and ^{44}Cr are also presented.