Further studies of β-decay of proton-rich nucleus ^{23}Al

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In 2005, we had experiments to produce, separate and study the β-decay of ^{23}Al. In September 2005 we separated ^{23}Al and studied its β-decay using MARS and the fast tape transport system. The interest was spurned by a nuclear astrophysics problem: the need to unambiguously determine the spin and parity of ^{23}Al ground state, and remove an ambiguity of factors 30-50 in the ^{22}Mg(p,γ)^{23}Al cross section at astrophysically relevant energies. We successfully and easily determined the spin and parity $J^{\pi}=5/2^{+}$ from the beta-decay pattern. Parts of the results were already published [1]. It was for the first time that pure samples of ^{23}Al could be separated and their decay studied. In addition to the g.s. J^{π} determination, a number of other states in the daughter nucleus ^{23}Mg were populated and the absolute *logft* values for the transitions were determined. In particular we could identify the Isobaric Analog State (IAS) of ^{23}Al gs at E*=7803(2) keV through the measurement of its *logft*=3.31. Other states in ^{23}Mg above the proton threshold at Sp=7580 keV constitute resonances in the proton capture reaction ^{22}Na(p,γ)^{23}Mg and are crucially important for the depletion of ^{22}Na in ONe novae [2, 3]. We also determined the half-life of ^{23}Al with much better precision.

To further improve the data, two more experiments were planned and carried out in September and November 2006. The first one was meant to simply improve the statistics we had earlier (and we got about a factor of 2 higher statistics for gamma-ray energies above 4 MeV). We also re-measured the β-decay of ^{24}Al to improve the precision of our energy and efficiency calibration of the Ge detector at energies E_{γ}=3.5 to 8 MeV. In the second experiment we added a BGO Compton shield around our Ge detector to clean the gamma-ray spectrum at large energies (E_{γ}=6-8 MeV), in particular in the highly interesting region of the IAS.

In both experiments we used a 48 MeV/nucleon ^{24}Mg beam from the K500 cyclotron and the fusion-evaporation reaction ^{24}Mg(p, 2n)^{23}Al on a hydrogen gas cryogenic target cell cooled by LN_2. The ^{23}Al beam was obtained as described before [1, 4] and we could get the same parameters as in September 2005: about 4000 pps at the extraction slits in the MARS focal plane. Its β-decay was further studied using the fast tape transport system and the β-γ detectors. ^{23}Al was taken out in air through a 50 μm thick Kapton window, a stack of degraders and collected on the aluminized Mylar tape of the fast tape-transport system. Because the ranges of impurities in the beam are different from that of ^{23}Al, a virtually pure ^{23}Al sample was collected on the tape. In both measurements, we collected ^{23}Al on the tape for 1 second. Then we shifted the RF phase to stop the ^{24}Mg beam, moved the ^{23}Al sample in 177 ms with the tape transport system to the counting station which consists of a HPGe γ detector and a β detector. β and β-γ coincidence data were recorded for a predetermined counting period of 2 seconds. This cycle was precisely clock controlled and was repeated continuously. The sample was positioned between the HPGe γ-ray detector and a 1-mm-thick BC404 plastic scintillator used to detect β particles. This experimental setup is a typical one for measuring β-γ coincidences. In September 2006 the HPGe detector was closer than usual (d=4.9 cm) and in the November 2006 experiment the BGO shield was added around the Ge detector.

We measured γ-rays in the energy range E_γ=0-9 MeV. A spectacular cleaning of the background of gamma-ray spectrum at large energies was obtained with the BGO shield, as shown in Fig. 1. This spectrum and the better statistics data from the September run allowed us to identify weaker lines and improve the β-decay level scheme. We also separated pure samples of ^{24}Al, by tuning MARS for this product, and did a similar β-γ measurement. We use its known gamma-rays up to E_γ=7.8 MeV for energy and efficiency calibration in the range E_γ=4-9 MeV. The new data confirm the previous β & γ-branching ratios, strengthen and justify the previous level scheme.

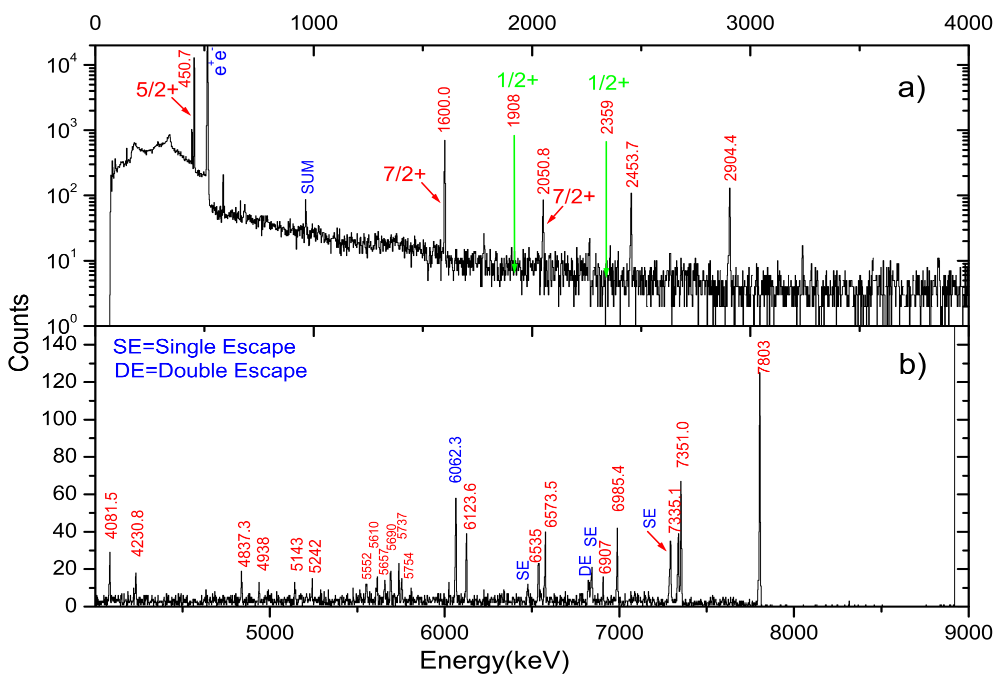

Figure 1. ^{23}Al β-γ coincidence spectrum taken with a BGO Compton shield around the HpGe detector.

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