Online spectroscopy of ^{114}Cd following (n_{th}, γ) reaction with an improved γ background in CIRUS reactor

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Introduction

The nucleus ^{114}Cd has been of several theoretical interests. With 66 neutrons, it rests exactly in the middle of N = 50 and N= 82 shell closure. Also, the fact that all the Cd isotopes are with two proton hole with respect to the Z = 50 shell closure, makes it interesting to carry out the investigation of its level structure. Not much information is known on ^{114}Cd which had mostly been studied with thermal neutron capture by ^{113}Cd [1,2], monoenergetic accelerated neutron bombardment on ^{114}Cd [3], and also with heavy-ion induced fission-fusion reaction [4].

Here we report the crucial improvements in the experimental set-up at CIRUS reactor facility to do prompt online γ-γ correlation spectroscopy at low background environment, and the preliminary results of a test experiment undertaken using that facility. The measurement was aimed at spectroscopic investigation of ^{114}Cd following thermal neutron capture of ^{113}Cd. The (n, γ) reaction is particularly suited for the study of ^{114}Cd since the very high capture cross section leads to a very good sensitivity so that weak γ branchings of higher-lying levels can be observed. These branchings can prove crucial in the correct theoretical interpretation of the nucleus.

Experimental details

The experiment was performed in CIRUS reactor facility. Thermal neutrons from the reactor were bombarded on a natural Cd sheet of thickness 5 mm. Natural Cd was used since the neutron capture by ^{113}Cd (σ = 20000 b, 12% isotopic abundance) predominates over capture by other Cd isotopes. The neutron-flux at the target position was of the order of 10^7 neutrons/cm^2/sec. Deexciting γ-rays from the fission fragments were collected by two clover detectors in coincidence mode, mounted in a vertical ring structure with $\varphi = 72^0$. A total of 3.4×10^5 γ-γ coincidence events were collected for further off-line analysis.

Fig. 1: Experimental set-up at CIRUS reactor facility to do prompt γ-γ spectroscopy

The initial set-up to do online spectroscopy which had combined beam-line radiation shielding for background neutron and γ-rays at the beam hole E-18 of CIRUS reactor along with Solid State Physics Division (SSPD) neutron radiography set-up [5]. The size of CIRUS beam hole E-18 was 100 mm in diameter. Along with that huge diameter of the beam hole, the rear shielding wall that was there for safety purpose were contributing a lot to the background γ-rays. To counter these hurdles while doing the experiment, the size of the hole was reduced to 25 mm by using 10 cm thick cylindrical borated rubber. In order to further reduce the background, a narrow slit (~1 cm of circular aperture) of Cd sheet was placed after the Bismuth plug arrangement inside the conical shaped Aluminum structure. This had reduced the gamma background to 5–7 mR in comparison to 20–30 mR (encountered with only Bismuth plug arrangement) at the detector position. Finally, the front wall was removed, and instead a beam catcher was placed in front [Fig.1]. All these initiatives resulted in a dramatic improvement of the background (1–2 mR) which allowed us to collect substantial amount of good data out of this reaction.

Analysis and Results

Symmetric as well as asymmetric γ-γ matrices were constructed from the acquired data set after performing the energy calibration followed by the software gain-matching over the entire range of the energy. The data sorting code was written in-house to construct asymmetric matrices (parallel/perpendicular scattered gamma vs. total gamma) to facilitate polarization measurement. The level scheme [Fig. 2], which agrees well with the previous work(s), was constructed from the symmetric γ-γ matrix. In the level scheme, we could see up to an excitation energy of ~9 MeV. The representative gated spectrum is shown in Fig. 3.

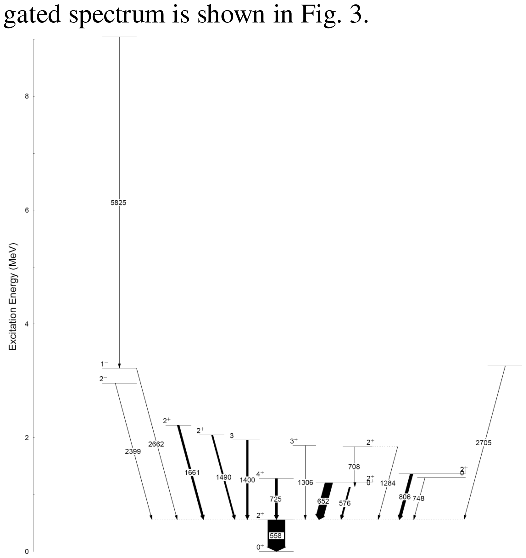

Fig 2: Partial level scheme of ^{114}Cd, as obtained in the present measurement.

The clover detectors used in the experiment act as Compton polarimeters. As both the detectors in our experimental set up were mounted in a 90^0 ring, it was very useful since polarization is maximum in that direction. Each crystal of a clover detector acts as a scatterer, and the two adjacent crystals act as the absorbers. The asymmetry between the perpendicular and parallel scattering with respect to the reaction plane distinguishes between electric and magnetic transitions.

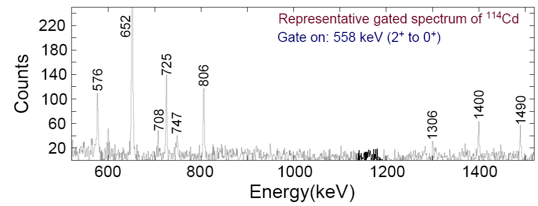

Fig 3: Representative gated spectrum of ^{114}Cd.

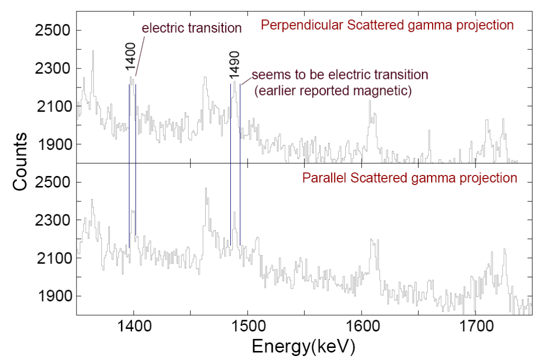

Fig 4: Projections of perpendicular and parallel scattered high energy γ-rays in ^{114}Cd.

Previously, 1400-keV ($3^- \rightarrow 2^+$) was reported as electric transition agrees with our experimental data [Fig. 4]. But, the transition 1490-keV ($2^+ \rightarrow 2^+$) which was reported as magnetic, seems to be electric, qualitatively, in the present data set [Fig. 4]. For more definitive answer, we certainly need more statistics. The analysis is in progress and will be presented.

References

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