On the experimental investigation of the angular distributions in the reaction $^{112}\mathrm{Cd}(p,\gamma)^{113}\mathrm{In}$

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NUSTRAP
Nuclear Structure, Reactions & Applications

Introduction & Motivation

Nuclear Astrophysics investigates the details of the mechanisms behind the generation of isotopes inside powerful stellar environments. Due to the vast network of nuclear reactions involved (e.g. p–process: ≈20'000 reactions) statistical models are often employed relying on experimental data, which are often scarce. In this work, the proton capture by ^{112}Cd is studied experimentally at energies of astrophysical interest. The experimental results are compared to theoretical calculations with TALYS v1.9 employing the Hauser–Feshbach model.

Experimental Technique

The reaction $^{112}Cd(p,\gamma)^{113}In$ was studied. The measurements were carried out at the 5.5 MV T11 Van de Graaff Tandem Accelerator of NCSR "Demokritos".

- 4 proton beam energies E_p=2.8, 3.0, 3.2, 3.4 MeV
- 4 HPGe detectors (100%)
- 8 different angles
- isotopically enriched ^{112}Cd target

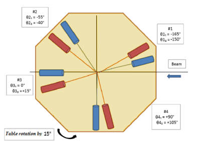

Figure 1: A scetch of the setup

Figure 2: The HPGe Detectors

Table 1: Main γ rays of ^{113}In feeding its ground state

E_{level} (keV)	E_γ (keV)	$t_{1/2}$	Multipolarity
391.70	391.70	99.48 min (IT)	M4
1024.28	1024.30	3.60 ps	E2
1131.48	1131.50	0.97 ps	E2
1191.12	1191.10		M1,E2
1509.01	1509.04	0.20 ps	

Angular Distributions

The γ–ray angular distributions of dexciting nuclei can be used to deduce the total reaction cross sections, see the analysis below.

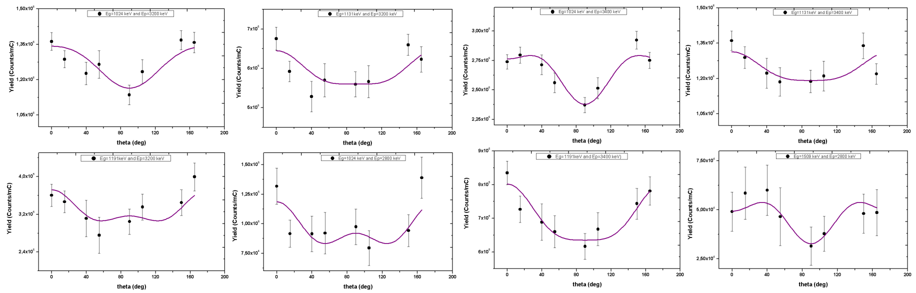

Figure 3: Experimentally deduced angular distributions for the γ–ray decays listed in Table 1. The isomeric decay (392 keV) is excluded.

Analysis

After measuring the number of counts N in a detector at an angle θ having absolute detection efficiency ε for γ–ray E^γ, the absolute yield for a particular beam energy E^p is:

$$Y(E_i^\gamma, E_j^p, \theta_k) = \frac{N(E_i^\gamma, E_j^p, \theta_k)\omega(E_j^p, \theta_k)}{\varepsilon_{abs}(E_i^p, \theta_k)Q(E_j^p)} \quad (1)$$

The angular distribution $W(\theta)$ can be extracted by fitting a function of the form:

$$W(\theta) = A_0\big(1 + a_2P_2(cos\theta) + a_4P_4(cos\theta)\big) \quad (2)$$

Cross Sections

The in–beam cross section, σ, for the $^{112}\mathrm{Cd}(p,\gamma)^{113}\mathrm{In}$ reaction is determined by the sum of all partial cross sections σ_i of transitions feeding the ground state of ^{113}In.

$$\sigma = \sum_{i=1}^{N}\sigma_i = \frac{A}{N_pN_A\xi}\sum_{i=1}^{N}(A_0)_i \quad (3)$$

A: target mass; N_p: number of projectile particles; N_A: Avogadro number; xi: target thickness

Results

Table 2: Total in–beam cross sections of $^{112}\mathrm{Cd}(p,\gamma)^{113}\mathrm{In}$

$E_{beam}(lab)$ (keV)	$\sigma_{in-beam}$ (μb)
2800	4.6 ± 0.4
3000	20.7 ± 2.4
3200	50.6 ± 1.6
3400	106.4 ± 2.2

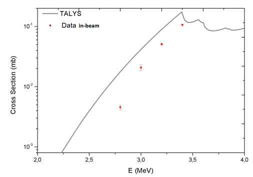

Figure 4: Experiment vs. TALYS [2]

Conclusion & Future Directions

The resulting in–beam cross sections were compared to Hauser–Feshbach calculations using the default settings of code TALYS v1.9. An overall good agreement was found in the trend despite some missing strength between the experimental and theoretical values. The angular distributions agree with what is expected for E2 multipolarities. Additional analysis is in progress to study the isomeric decay of ^{113}In with the activation method.

Acknowledgements

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References

[1] C. Kalfas. *SPECTRW-Spectra Analysis Program.*

[2] A. Koning, S. Hilaire and M. Duijvestijn. *TALYS: Nuclear Reaction Simulator.*