Measurement of ^{7}Li(n,γ) using AmBe neutron Time of Flight

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Introduction

^{7}Li(n,γ) is one the most prioritized reaction in the perspective of nuclear astrophysics as well as in the reactor physics, due to the situations of potential exposure of ^{7}Li to the strong neutron flux. ^{7}Li(n,γ) is considered as one of the destruction reaction of ^{7}Li and hence the Maxwellian averaged cross sections are demanded by the nuclear astrophysics. This reaction also emerges in the emergency shut down system Molten Salt Reactor life cycle, as a containment. Hence it is highly demanded to measure and evaluate the excitation function for ^{7}Li(n,γ) in the relevent energy ranges.

Because of the cross sections are in microbarns (μb) there it is challenging to produce the excitation function for ^{7}Li(n,γ) and hence there exist only two measurements in the energy range of 1 keV to 1 MeV by Imhof et al[1]. and Iszak et al[2]. Where the measurement by Iszak et al. couldn't measure the resonance contributions as the Columb dissociation method has utilized for the measurement. Imhof et al. measured the excitation function including the resonance contribution using quasi-monoenergetic neutrons. Due to the higher energy uncertainties, the resonances are showing higher width than the theoretical estimates.

Considering these, excitation function for ^{7}Li(n,γ) has been measured for the energy range of 1 keV to 1 MeV using time of flight tagged neutrons. The measured data has theoretically reproduced with Direct Capture Model with ENDF/B recommended resonance parameters. The details are in the following sections.

Materials and Methods

The ^{7}Li(n,γ)^{8}Li cross section measurement was performed with a TOF tagged neutrons. Neutrons from a 10Ci sealed AmBe source were utilized for the measurement. They are moderated by a 1cm thick paraffin wax to increase the population of neutrons in 1 keV to 1 MeV region. The neutrons were tagged by detecting 4.4 MeV γs with two 3-inch thick BaF_2 scintillator coupled to a fast PMT. The intrinsic efficiency of CZT detector, backed with CsI, has been generated with the standard ^{133}Ba, ^{137}Cs,^{60}Co and ^{22}Na sources. The geometry dependent efficiencies has been estimated from the Geant4 simulation of the detector and sample geometry, with accounting the attenuation corrections for the sample. The time to amplitude converter (TAC) has been calibrated using a standard time calibrator.

A time of flight path of 50 cm was selected with considering an optimization between energy resolution and number of events. 100g natural lithium sample, air-tightly packed in Al covering under argon environment has used as the target. The γ rays from Li on neutron capture were detected using Cadmium Zinc Telluride (CZT) detector, with lateral sides are covered with CsI-PIN scintillators. CsI readouts are add backed to CZT for increasing the photopeak efficiency.

The measurement performed as uninterested for 744 hrs(31 days). In order to estimate the background, a run without target was performed for a duration of 24 hours. The ToF-Eγ correlations gated with 4.4 MeV γ from the Am-Be source was generated. The γ bands corresponding to ^{8}Li excitation

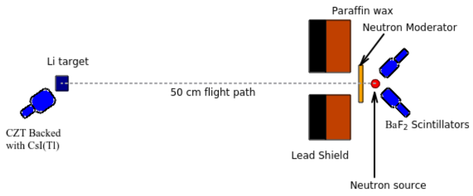

Figure 1: *Experimental Setup*

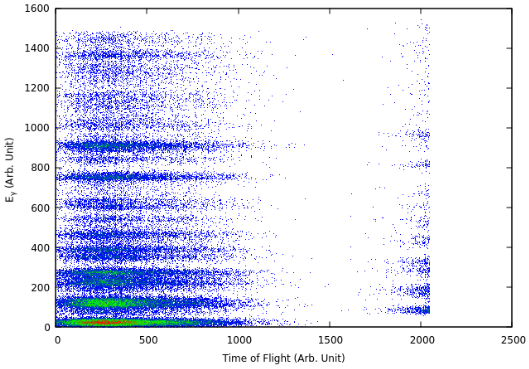

Figure 2: *ToF - E_γ correlation plot gated with 4.4 MeV γ events.*

levels were identified. These bands were banana gated and projected to the TOF axis. The counts in each bin have been converted to yields, by accounting the efficiencies corresponding to the γ energies and γ branching ratios. This is further normalized to the 4.4 MeV γ counts in the BeF$_2$ detector.

$^{10}B(n,\alpha)^7Li^*$ has been used as the normalization reaction. 25 grams of boron granules, sealed in the same geometry mentioned above was placed. The 477 keV γ band was projected to energy axis, and normalized by 4.4 MeV γ events as mentioned above. The ^{7}Li(n,γ) cross sections were estimated as,

$$\sigma_{^7\mathrm{Li}(n,\gamma)}(E) = \frac{Y_{^7\mathrm{Li}}(E)}{Y_{^{10}\mathrm{B}}(E)}\sigma_{^{10}\mathrm{B}(n,\alpha)}(E) \quad (1)$$

Where, $Y_{^7Li}(E)$ is the yield of neutron capture γ from ^{7}Li(n,γ) reaction per energy bin, normalized with 4.4 MeV γ from Am-Be source. Similarly $Y_{^{10}B}(E)$ is the yield for 477 keV γs from ^{10}B$(n,\alpha)^7$Li* per energy bin normalized to 4.4 MeV γs. $\sigma_{^{10}\mathrm{B}(n,\alpha)}(E)$ is the reaction cross-section for ^{10}B$(n,\alpha)^7$Li*. Cross sections were normalized to ENDF/B-VIII.0 evaluated nuclear data library.

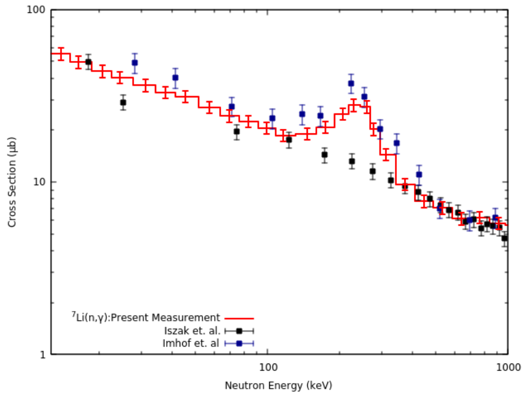

Figure 3: *Measured cross sections with the measurements by Imhof et al[1] and Iszak et al[2].*

Results and Discussion

The measured cross sections are illustrated in Fig. 2, as locally averaged histogram values. Present measurement is in good agreement with prior measurements. The present measurement provides clear identification of the non-resonant continuum for the range of 10 to 1000 keV. The contribution corresponding to 3^+ resonance state of ^{8}Li at 2.255 MeV excitation energy is also clearly identified. The continuum and resonant cross sections are in the range of microbarns(μb). Comparisons show all the data sets are in good agreement in the non-resonant region, even the measurement by Imhof et. al, is showing comparatively higher statistical uncertainty. Additionally, the measurement by Imhof et al. is showing a higher resonance width compared to the present study. The ex citation function measured by Iszak et. al is limited to the non-resonant component due to the limitation of the Columb dissociation technique employed.

Acknowledgments

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References

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