Monitor Controlled Single Projection Approach for Cross Section Unfolding

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Introduction

Due to the quasi-monoenergetic behavior of neutron sources, neutron induced reaction cross sections are usually measured as spectrum averaged in activation analysis methods. The established neutron sources having an energy spread higher than 2%, limits the cross section measurements in a finite energy bin. However such limitations can be overcome, up to some extant, using Fredholm integral based unfolding approach [1]. The unfolding problem inverts the projection, $Y_i = \int_{E_{min}}^{E_{max}} \sigma^i(E)\Phi(E)dE$, through iterative procedures to generate $\sigma^i(E)$, on the basis of neutron spectrum, $\Phi(E)$. Conventional unfolding approach employs multiple projections of cross section for generating inversion matrix, by tuning end point energy (E_{max}). This is not feasible in the neutron sources having fixed neutron spectrum like fission neutrons, sealed Am-Be neutrons etc. In such conditions, a single projection based unfolding approach has to be employed through inversion problem. However single projection based unfolding method is less popular due to the higher tendency to be biased in local minimas during iterative procedure[2].

The limitations of single projection based unfolding has been solved in the present approach, by introducing monitor cross section as an additional control parameter. The method has been verified with ^{115}In(n,n')^{115m}In cross section. Further the excitation functions for ^{47}Ti(n,p)^{47}Sc, ^{48}Ti(n,*)^{47}Sc are generated.

Materials and Methods

To include monitor cross section as a control parameter for the unfolding problem, the cross section term in the projection has been modified as the ratio of cross section for unknown to the monitor cross section, $\frac{\sigma_u^i(E)}{\sigma_m^i(E)}$. The projection also modified as $\frac{Y_u^i}{Y_m^i}$, as the ratio of the yields. The neutron spectrum has binned into n number of skewed Gaussians, $\phi^k(E)$, for converting single projection as a pseudo multi projection problem. The unknown cross section, $\sigma_u^i(E)$ has been calculated through iterative approach based on direct least square approach. The conventional χ^2 has modified accordingly as,

$$\chi^2 = \left[\sum_{k=1}^{n} \frac{\frac{\int \sigma_u^i(E)\phi^k(E)dE}{\int \phi^k(E)dE}}{\frac{\int \sigma_m^i(E)\phi^k(E)dE}{\int \phi^k(E)dE}} - \frac{Y_u^i}{Y_m^i} \right]^2 \quad (1)$$

The present method has been verified using ^{115}In(n,n')^{115m}In reaction. 183 mg of ^{nat}In, along with a packing of 17 mg Al foil, was irradiated with fast neutrons from D-T neutron generator facility at Purnima Laboratory, BARC, with an incident neutron energy of 150 keV. The neutron spectrum has been simulated using Geant4 simulation toolkit with incorporating ENDF/B-VIII.0 recommended cross section, and verified with previously reported data[3].

The residual activity of ^{115m}In and ^{24}Na has been measured using HPGe detector, at radiotherapeutical division, BARC and fur-

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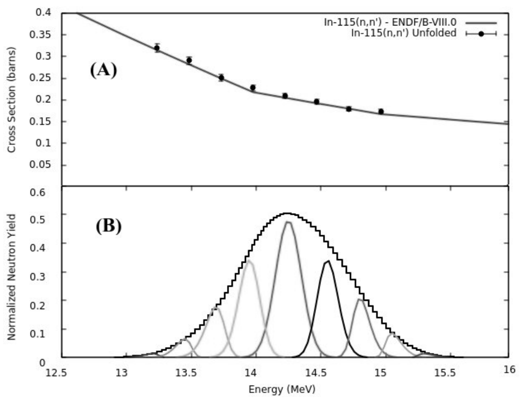

FIG. 1: **(A):** Unfolded cross section for ^{115}In(n,n')^{115m}In and ENDF/B-VIII.0 Recommended data. **(B):**Rebinned neutron spectrum for pseudo multiple projection

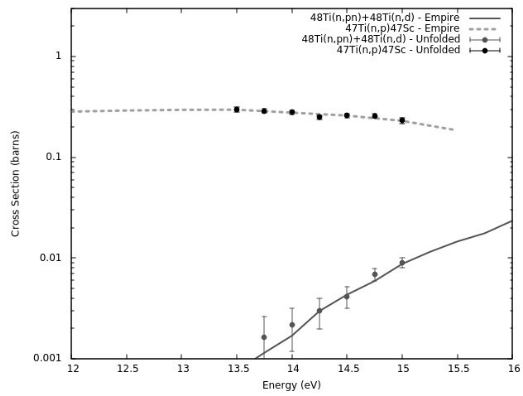

FIG. 2: The unfolded cross section for ^{47}Ti(n,p)^{47}Sc and ^{48}Ti(n,*)^{47}Sc channels

ther residual yield of the isotopes are calculated. The cross sections for ^{115}In(n,n')^{115m}In in the spectral coverage of 12 to 15 MeV was unfolded with choosing ^{24}Al(n,α)^{24}Na as a monitor. The monitor data was retrieved from ENDF/B-VIII.0 evaluation. he Likelihood function and its covariance matrix are calculated using Empire 3.2.3 via total Monte-Carlo through all level density models. The unfolded data has been compared using benchmarked cross section. Similarly a 83mg of ^{nat}Ti enclosed in 20mg Al foil also irradiated in the same condition and the residual yield has been calculated. Channels ^{47}Ti(n,p)^{47}Sc and ^{48}Ti(n,*)^{47}Sc are contributing to the yield of ^{47}Sc. Hence the Likelihood function, covariance matrix are modified accordingly and the χ^2 is expressed as the sum of individual channel yields projected to the experimental yield. The projected yield unfolded with respect to the monitor and compared with the theoretical results.

Results and Discussion

The feasibility analysis of single projection based excitation function unfolding controlled by monitor, using ^{115}In(n,n')^{115m}In reaction shows the unfolded excitation function is in a good agreement with ENDF/B-VIII.0 benchmarked data. The uncertainties, of residual yield, monitor cross sections and Likelihood estimates, propagated through the covariance matrices are significantly reasonable to the unfolded data points. Similarly the unfolded excitation function for ^{47}Ti(n,p)^{47}Sc, ^{48}Ti(n,*)^{47}Sc are also very well matches with theoretical as well as the previously reported experimental data, measured using enriched samples.

This method opens a better control for the unfolding problems, which implies more confidence for using unfolding methods. However, in the both cases presented above, excitation functions are differentiable at all the region of interest. Generally they are not alike always. Hence the method has to be evaluated seriously for sharply varying region of excitation function, such as (n,γ) at low energies, for generalising the technique

Acknowledgements

This work is a part of DAE-BRNS supported research project, Sanction Order :36(6)/14/30/2017-BRNS/36204

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