

Examination of Weisskopf-Ewing approximation for the determination of (n,α) reaction cross-sections



By – Jyoti Pandey
Research Associate
Inter-University Accelerator Centre
(IUAC)
New Delhi
India

Contents

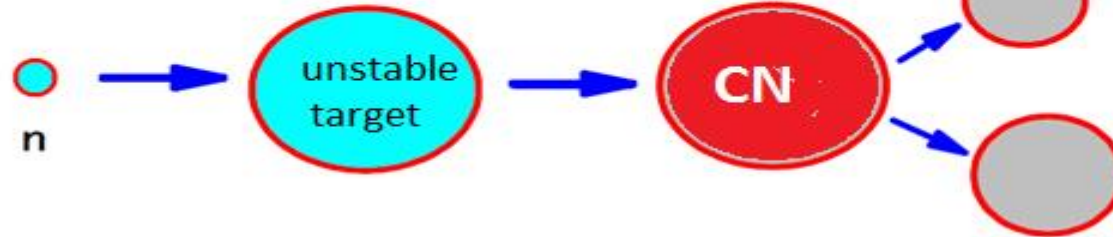
- ❖ Introduction & motivation
- ❖ Surrogate method
- ❖ Examination of Weisskopf-Ewing approximation for the determination of (n,α) reaction cross-sections
- ❖ Results and Discussions
- ❖ Summary & Conclusions

Introduction & motivation

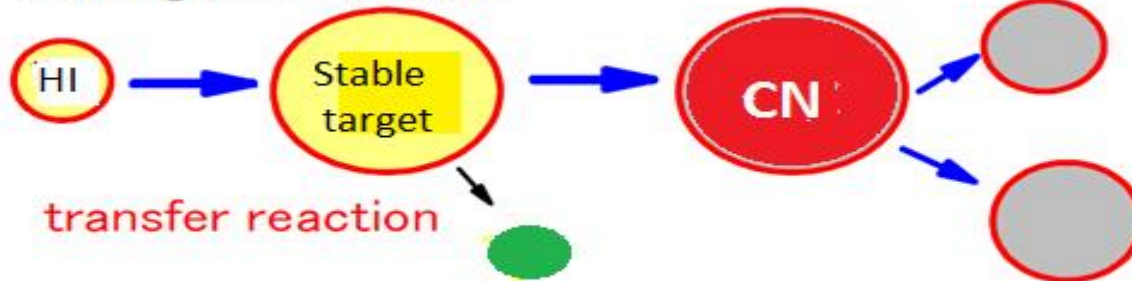
- ❖ High-quality **nuclear data** is one of the fundamental pre-requisites for an upcoming fusion reactor, in order to model the reactor design and functioning.
- ❖ The cross-sections of the **neutron-induced reaction** of various **stable and unstable nuclides** are not measured and studied till now. So, there is a large gap in the nuclear data library.
- ❖ The surrogate method has been used for cross-section measurement. The surrogate method assumes that the reaction takes place through the compound nucleus mechanism only, but at high energies, pre-equilibrium and direct reaction channels also occur.
- ❖ The present study explores the surrogate reaction method by determining the validity of Weisskopf-Ewing approximation for (n,α) reaction on $n+^{54}\text{Fe}, ^{56}\text{Fe}$ reaction.
- ❖ The cross-sections. for (n,α) reaction of radionuclide's are important for estimating **helium production** in the structural material of the upcoming fusion reactors.
- ❖ In order to use surrogate reaction technique for such cross section determination, underlying approximations need to be examined.

Surrogate technique

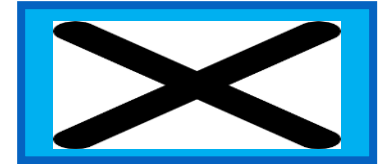
Desired reaction



Surrogate reaction



Experiment
difficult



Experiment
possible



The surrogate method is an indirect method to measure reaction cross-section.

Central assumption: Both reactions form the same compound nucleus

Examination of Weisskopf-Ewing approximation for (n, α) reaction

- ❖ A surrogate experiment is mostly concerned with experimentally determining the specific **decay probability** of the desired compound nucleus formed in a surrogate reaction.
- ❖ The alpha decay probabilities as measured in the surrogate experiment can be simulated as

$$P_{\delta\chi}(E_{ex}) = \sum_{J\pi} F_{\delta}^{CN}(E_{ex}, J, \pi) G_{\chi}^{CN}(E_{ex}, J, \pi)$$

where $F_{\delta}^{CN}(E_{ex}, J, \pi)$ is the probability of the formation of the compound nucleus, excitation energy E_{ex} in a specific spin-parity state (J, π) and $G_{\chi}^{CN}(E_{ex}, J, \pi)$ is the alpha branching ratio of the compound nucleus in that state.

- ❖ Assuming that W.E. is valid then the desired cross-section for a reaction with entrance channel α and exit channel χ can be calculated as –

$$\sigma_{\alpha\chi}(E_{ex}) = \sigma_{\alpha}^{CN}(E_{ex}) P_{\delta\chi}^{CN}(E_{ex})$$

❖ To check the validity of the Weisskopf-Ewing approximation, we have calculated the α decay probabilities that are **highly dependent on the spin of the compound nucleus**, as shown in Fig.1.

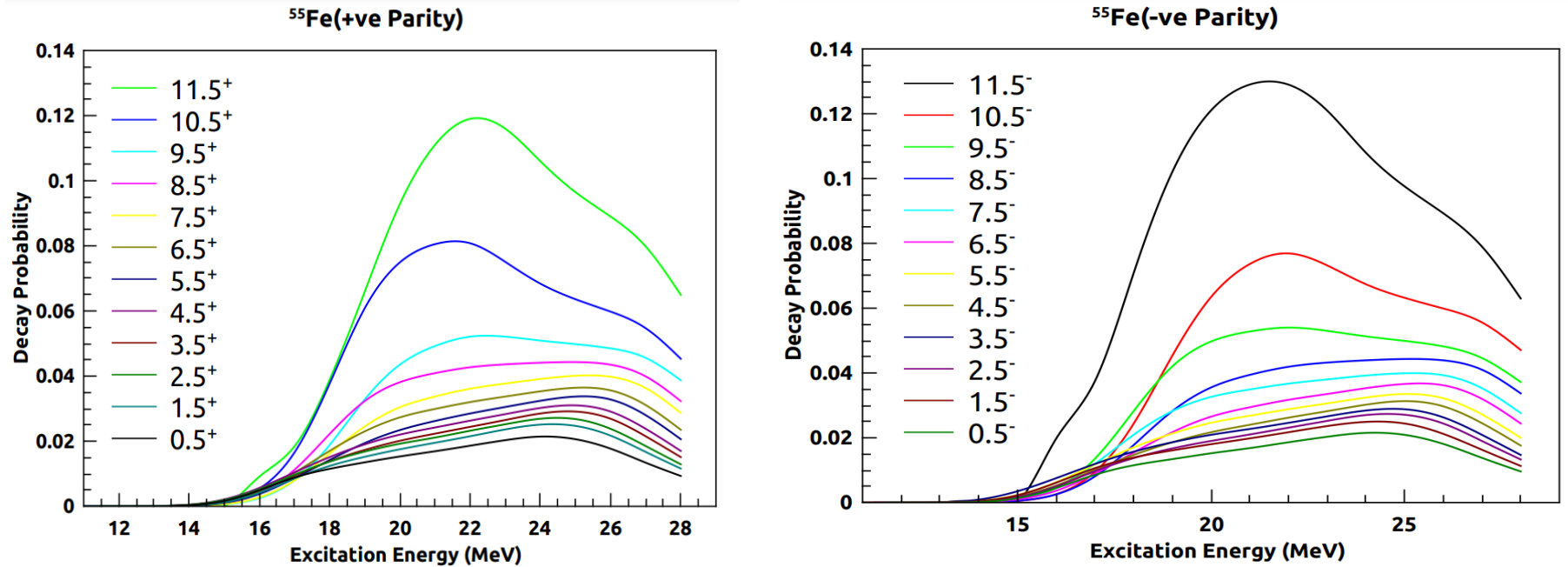


Fig. 1: Spin dependent alpha decay probabilities as a function of compound nucleus excitation energy/corresponding equivalent neutron energies for ^{55}Fe compound nuclei for +ve and -ve parity states.

- ❖ The surrogate results corresponding to each schematic distribution a,b,c,d,e (as shown in Fig. 2) have been calculated individually and we have studied the effect of the difference in the spin-parity distribution of the compound nucleus.
- ❖ The trends of the results **is similar to the trend of the results for neutron energies below 14 MeV** but for the neutron energies greater than 14 MeV the trend of the simulated results is different from the desired cross-sections, as shown in Fig.3. This is because the surrogate method doesn't consider the pre-equilibrium emission.

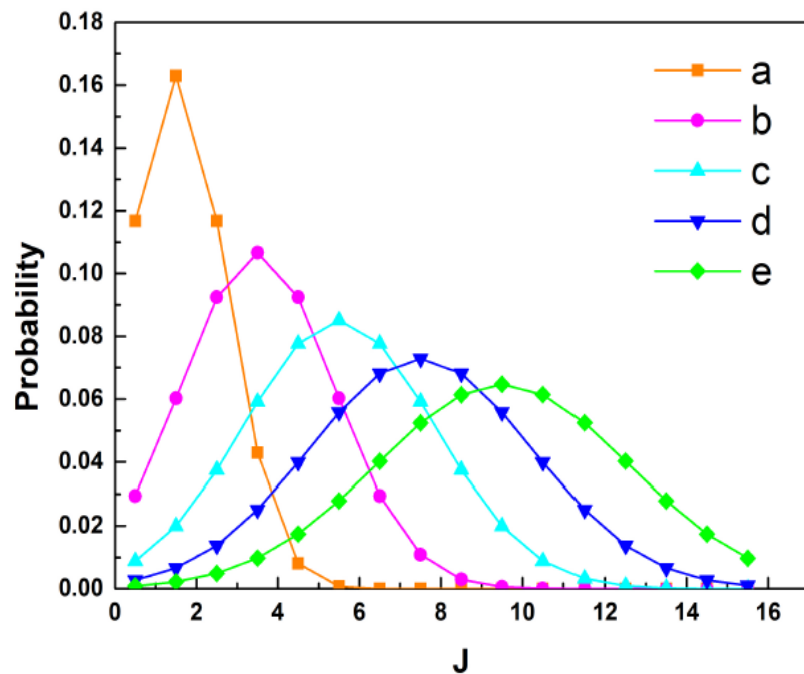


Fig. 2: Energy-independent schematic spin distributions used in the present work.

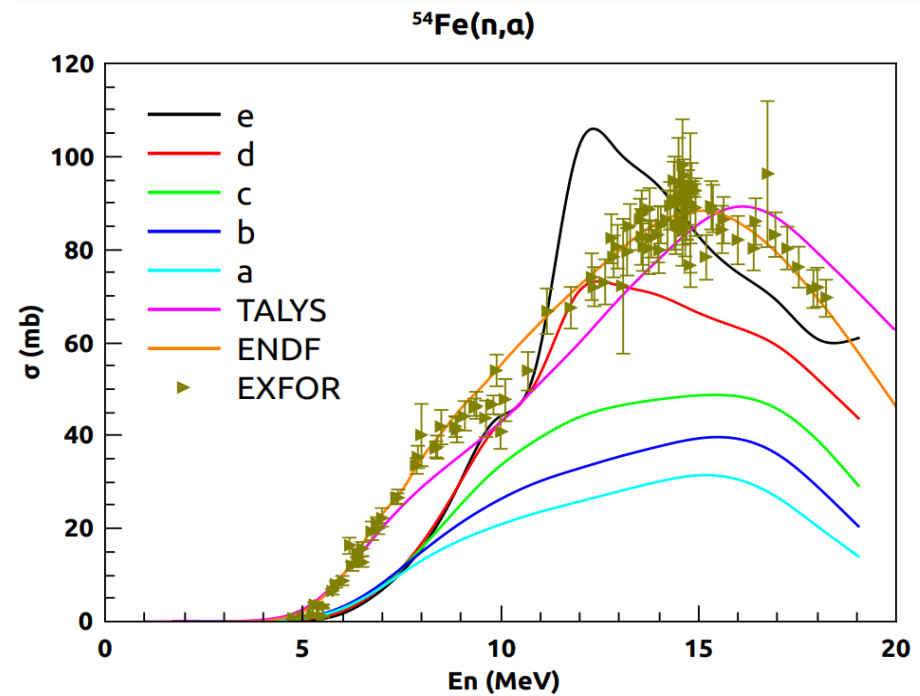


Fig. 3: $^{54}\text{Fe}(n, \alpha)$ cross sections corresponding to different schematic distributions derived by assuming the validity of Weisskopf-Ewing approximation.

- ❖ We have explored the validity of Weisskopf-Ewing approximation for (n,α) reaction by taking $n+^{56}\text{Fe}$ reaction as a test case.

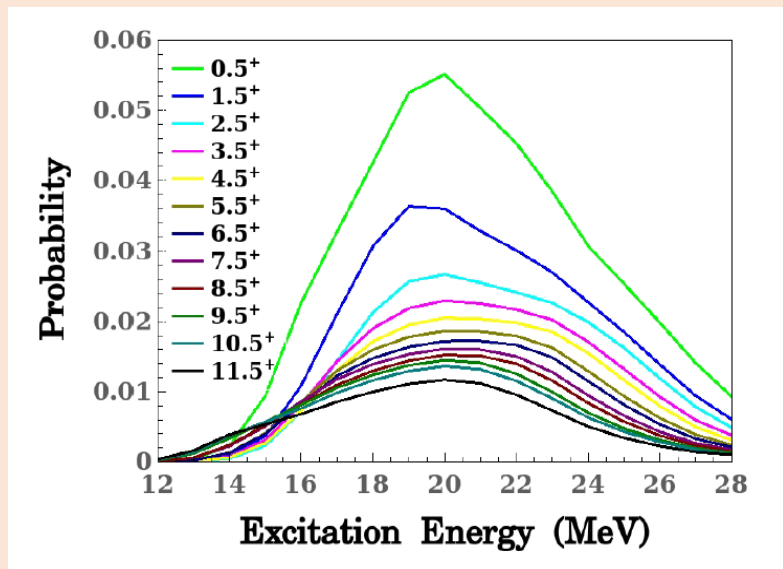


FIG. 1: Spin-dependent alpha decay probabilities of ^{57}Fe compound nuclei as a function of compound nucleus excitation energy for positive parity states.

Conclusion

- ❖ It is concluded that the **absolute** surrogate reaction method relying solely on the Weisskopf-Ewing approximation is not sufficient for determining the (n,α) cross sections and further development of the surrogate technique is required.
- ❖ Further we will check whether surrogate ratio method can produce reliable estimates to these cross sections.
- ❖ It will be interesting to check whether **SRM can reduce the effect of spin-dependence of the α decay probabilities.**

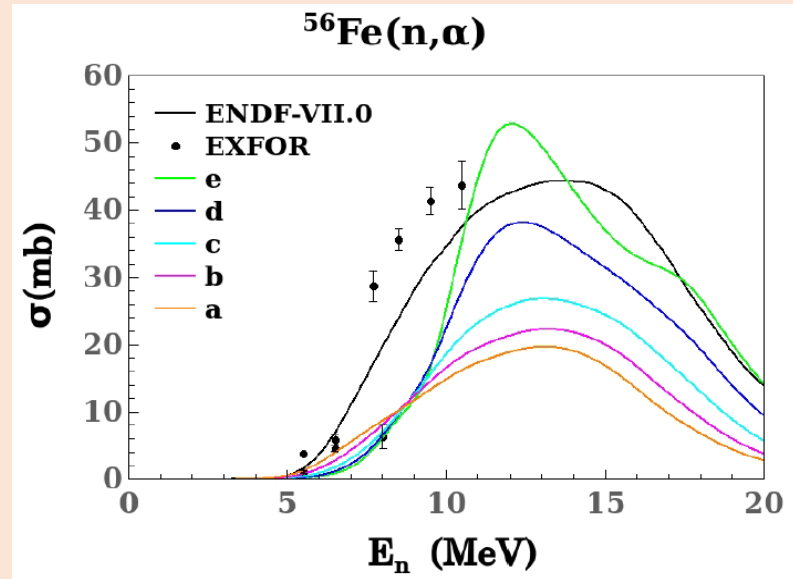


FIG. 2: $^{56}\text{Fe}(n,\alpha)$ cross sections corresponding to different schematic distributions derived by assuming the validity of the Weisskopf-Ewing approximation.

Summary & Conclusions

- ❑ From the present study, we come to the conclusion that neutron-induced reactions are the backbone for the development and designing of the upcoming nuclear fusion reactors.
- ❑ It is concluded that the **absolute** surrogate reaction method relying solely on the Weisskopf-Ewing approximation is not sufficient for determining the (n,α) cross sections and further development of the surrogate technique is required.
- ❑ Further we will check whether surrogate ratio method can produce reliable estimates to these cross sections.
- ❑ It will be interesting to check whether **SRM can reduce the effect of spin-dependence of the α decay probabilities.**
- ❑ Here we have checked the W-E approximation for the neutron-induced (n, α) reactions.
- ❑ Further we will check whether the surrogate ratio method can produce reliable estimates for these cross-sections.

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Thank you