



New (and old) methods to measure direct neutron capture cross sections for astrophysics

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Location: Lise Meitner Lecture Hall
9. Boltzmannngasse 5

Neutron capture reactions play a crucial role for the understanding of the synthesis of elements heavier than iron in stars and stellar explosions via the slow (s), intermediate (i), and rapid (r) neutron capture processes. In all three processes, the fine balance between neutron capture and beta-decay rates under the given astrophysical conditions defines how long a nucleus can accumulate material before decaying into the next isotopic chain.

Almost all of the neutron capture cross section on stable as well as 16 longer-lived nuclei ($t(1/2) \gg 1$ y) have been measured in the past 50 years [1]. With this data, theoretical reaction models were benchmarked and improved, allowing to reproduce known neutron capture cross sections within a factor of 2 with the statistical Hauser-Feshbach model. However, once one moves away from stability to the unknown territory, these predictions start deviating strongly. To overcome these limitations, neutron capture cross sections for shorter-lived nuclei have to be directly measured and used to improve theoretical predictions.

Since the production of "physical" samples large enough for direct neutron activations becomes impossible for these short half-lives, measurements in "inverse kinematics" at radioactive beam facilities have been developed in the past decades. With a storage ring coupled to an innovative "confined free neutron target", for the first time the direct measurement of neutron capture cross sections of short-lived radionuclides could become possible. I will summarize a path forward for the construction of such a pioneering "direct neutron capture facility" at the existing CRYRING facility of GSI Darmstadt [2].

A dedicated future storage ring could be built in the next decade and allow the community to measure neutron capture cross sections of short-lived nuclei down to seconds. In the meantime, neutron activations with following AMS measurements of the reaction product can continue to fill some gaps. This method was developed more than 20 years ago and has allowed to contribute to >10 neutron capture cross section measurements at stellar energies. With recent and future developments at VERA, this list can be extended.

I will give a summary of the past activation + AMS measurements, potential future AMS measurements, as well as a prospective for a "neutron capture storage ring".

[1] I. Dillmann, O. Kester, et al., Eur. Phys. J. A59 (2023) 105

[2] A. Tarifeno-Saldivia, C. Domingo Pardo, I. Dillmann, and Y.A. Litvinov, subm. to Phys. Rev. Acc. and Beams (2025); <https://arxiv.org/abs/2508.15465>.

**As part of the presentation, there will be a teaching demonstration on the topic
"The classical and the quantum harmonic oscillator".**