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Editorial: Cross section data of interest for nuclear astrophysics: experimental and theoretical status, and perspectives

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Editorial on the Research Topic
Cross section data of interest for nuclear astrophysics: experimental and theoretical status, and perspectives

Taking advantage of various nuclear facilities and improved techniques, the cross-sections can now be experimentally determined, both by indirect and direct methods, at much lower energies and with much higher precision compared to the past. In particular, underground laboratories and advanced facilities with high-power lasers and high-density γ-ray beams are expected to provide opportunities for experimental studies of nuclear physics. Meanwhile, significant efforts have been put towards better predictions of cross-sections that cannot be experimentally determined. The phenomenological models have been used to evaluate the cross-sections at the lower energies in which the experiment cannot be conducted. Furthermore, microscopic theory has been developed to predict the reaction features, which especially applies to reactions involving unstable and exotic nuclei.

This Research Topic collects papers from a community of authors with extensive experience in nuclear reaction measurement or well-established expertise in nuclear reaction theory and model calculation. The contributors describe their research, by reporting not only the new experimental setup (Ananna et al.) and measured results (Zhang et al.) but also the theoretical calculations (Avrigeanu and Dubovichenko), regarding the determination of the cross-sections for astrophysical reactions. Additionally, the authors review recent progress in nuclear astrophysical data (Smith) and planned measurements (Söderström et al.), pointing out some future challenges in the study of nuclear reactions of astrophysical interest.

Studies of elements synthesis involved in early Universe formation and star evolution need advanced knowledge in nuclear science. However, the nuclear results obtained from laboratory measurements and theoretical calculations should be prepared before used for nuclear astrophysics studies, involving the compilation of nuclear reaction datasets, construction of nuclear libraries, and development of necessary codes for processing the nuclear data. In the contribution by (Smith), it is pointed out that there are still some challenges in these activities, so that it is significant to plan the future work in the field of nuclear data for astrophysical application. In this contribution, the available data resources and the needs of specific nuclear data are also discussed, and valuable initiatives are also suggested to improve the research of nuclear astrophysics data.

To determine the cross sections of nuclear astrophysical reactions, direct measurement at the low energies of astrophysical interest is the most straightforward way. The Laboratory for Underground Nuclear Astrophysics (LUNA) collaboration is dedicated to this field for the last 35 years, and many significant results have been achieved in the underground experiments with low background conditions at the Laboratori Nazionali del Gran Sasso. In the contribution of (Ananna et al.), a key aspect to successfully perform the reaction measurement, namely, the production and characterization of a variety of solid targets, is reviewed, including the description for the production techniques of solid targets and the common methods adopted for target degradation monitoring. Recent results used such developed targets, as well as some future measurement plans are presented. Meanwhile, measurement utilizing advanced facilities with high-power lasers is expected to provide new results and insights to nuclear astrophysics. In this Research Topic (Zhang et al.), reports the new experiment of the isomeric yield ratio for ^{165}Ho(γ,n)^{164m,g}Ho using the laser-accelerated electron beams. With the off-line analysis of the measured γ-ray spectra, the production yields are extracted and the resulting isomeric yield ratio is obtained. Such result is crucial to verify the traditional measurement, and provides a new method to experimentally study the nuclear properties related to nuclear astrophysics.

On the other hand, theoretical study is important to explain the measurement results. In the low energy range, the potential model is widely used to compute the cross sections for the nuclear reactions of which the direct reaction mechanism is dominant, especially involving the light nuclei. In this Research Topic (Dubovichenko et al.), presents the cross section calculations for ^{8}Li (n,γ)^{9}Li using a modified potential cluster model. The deduced astrophysical reaction rates are then compared with those obtained from other theoretical models, and the discrepancy found in the comparison indicates that further experimental efforts are required. For the heavy nuclei (Avrigeanu and Avrigeanu), performs the analysis of the latest high–precision cross sections of (α,γ) and (α,n) reactions on ^{144}Sm within the statistical model. Different behaviour of the cross sections of (α,γ) and (α,n) is found, which indicates that more studies are needed for the α-particle potential below the Coulomb barrier.

Besides the existing experimental and theoretical research, new photo-nuclear measurements using the high-intensity, narrow bandwidth γ-ray beam at variable energy at the ELI-NP facility in Romania are proposed (Söderström et al.). In particular, photodisintegrations involved in astrophysical p-process can be studied with the developed high-efficiency neutron detector systems, ELIGANT-TN and the ELI-NP γ-ray beams.

In conclusion, this Research Topic summarizes the current status of experimental and theoretical studies on reaction cross-sections at low energies of interest for nuclear astrophysics, providing insights into future directions for this research field. Furthermore, the Research Topic provides valuable guidance for young scientists who intend to enter the discipline.

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YX: Conceptualization, Writing–original draft, Writing–review and editing. DL: Conceptualization, Writing–review and editing. DP: Conceptualization, Writing–review and editing.

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Conflict of interest

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