ENSA Position Paper 2025

Executive Summary

The European Neutron Scattering Association (ENSA)[1] recognizes that European neutron science is an ecosystem comprising both national and international neutron sources as well as scientists at Universities, institutes and industry. Neutron science delivers impact to society in expanding the frontiers of knowledge across diverse fields, from materials science to biology and beyond. The scientific community is responsible for shaping our future and a coordinated effort is required to advance the field of neutron science.

- European neutron science enjoys a world leading position but is experiencing an alarming decline in terms of the numbers of annually accessible experiments and experienced scientists, thereby limiting opportunities to train the next generation of scientists, and as a result Europe is in serious danger of compromising its scientific excellence.
- The neutron community clearly expresses a need for a reliable, sustainable and sufficient provision of neutrons via a network of several types of neutron sources with different characteristics located across Europe.
- Neutron users drive the development of the neutron ecosystem through engagement in inter-disciplinary and inter-facility cooperation by carrying out educational activities and raising awareness of neutron science among the entire scientific community, general public and governing bodies.
- While technical developments allow more advanced and complex experiments, a significant change in the user profile is taking place, with an increasing number of less experienced users, and as a result there are higher expectations in terms of experimental and analytical support.

Based on these observations, ENSA:

- is highly concerned by the significant reduction in the capacity of neutron facilities across Europe resulting from the recent closures of several national sources;
- recognizes that, in part, the recent shortfall in neutron provision can be mitigated by the continued and reliable operation of remaining national sources and the Institut Laue Langevin (ILL[2]) together with the successful start of operations of the European Spallation Source (ESS[3]);
- supports any activity that increases the capability of European neutron facilities, but not at the expense of their capacity in terms of the number of available beam days to the user community;
- encourages ESS, being the next generation flagship of European neutron science, to start user operation as soon as possible, opening new scientific frontiers;
- encourages efforts to maintain and upgrade national facilities to ensure their long-term operation and scientific excellence, requiring adapted models of national and international collaboration;
- applauds initiatives in organizing a European Laboratory for Neutron Science, as suggested by League of European Neutron Sources (LENS[4]), to cooperate on technological projects, and to coordinate efforts between the neutron facilities;
- welcomes activities aiming at fostering the training and development of human resources, particularly early career researchers, in the field of neutron instrumentation and technique development;
- recommends the conception of a European roadmap for a coordinated implementation of High-Current Accelerator-driven Neutron Sources (Hi)CANS[5], which currently presents a promising new technology for increasing long-term neutron provision.

In summary, ENSA proposes to engage all national and European stakeholders, in a joint effort with LENS, to reinforce the collaboration within the European neutron landscape considering its current status, needs, strategic opportunities and funding mechanisms.

[1] European Neutron Scattering Association (ENSA)
[2] Institut Laue Langevin (ILL)
[3] European Spallation Source (ESS)
[4] League of Advanced European Neutron Sources (LENS)
[5] High Current Accelerator-based Neutron Sources (HiCANS)

Introduction

Neutron scattering has made invaluable contributions to scientific advancement over the last six decades, of undeniable fundamental, applied, societal and economic impact. European neutron science has a world leading position with more than half of the world's regular users, distributed over a wide range of disciplines[6]. The European Neutron Scattering Association (ENSA) is the independent representative of the European neutron user community. It consists of one delegate per member country who represents the respective national neutron user community. Collecting the overall user interests with respect to different national conditions and demands, ENSA is the voice of the user community when dealing with the research infrastructures and political decision makers. ENSA works collaboratively to support the national user communities from the European point of view and with a collective benefit in mind. The missions of ENSA are to Engage, Unite, Represent, Organize, Promote and Enhance the neutron user community in all its activities (Figure 1).

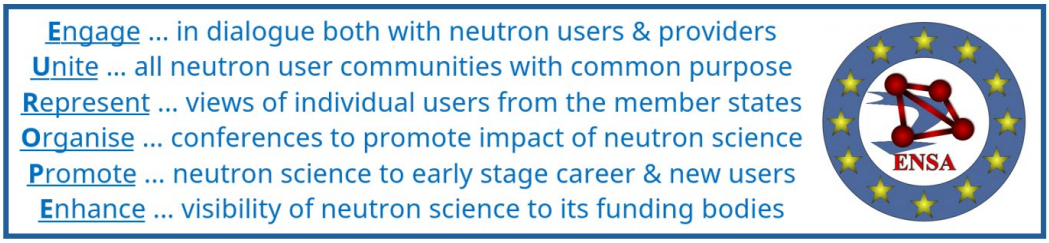


Figure 1. ENSA and its 'EUROPE' missions.

As part of its role, ENSA provides here its strategic position on the status and future of European neutron science in response to the changes in the scientific, infrastructural, technological and political conditions in Europe. This position paper focuses on the perspective of the European neutron users, which is driven by the need to continue, develop and perform high impact science. The paper further intends to be a starting point for a discussion of a joint strategy for the future of European neutron science with all interested partners.

Neutron Science

Experiments exploiting neutrons as a probe are indispensable to solve numerous questions raised by both academic and industrial research (for specific examples see the 2022 LENS position paper[7] or the ENSA Brochure[8]). Neutron science stands at the birth of scientific questions, and together with complementary methods advances the understanding of scientific, fundamental and applied problems that previously could not have been explored.

Its usage has shifted during the last decades from a partially independent analysis to often being a part of extended studies involving a range of other experimental techniques or methods. This approach not only enables enhancement of the understanding and modeling of the underlying mechanisms of observed phenomena, but also significantly extends the number of complementary methods and participating scientists [9]. Therefore, neutron science is increasingly integrated into a network of state-of-the-art experimental and computational methods, which has drastically changed the scientific environment of users compared with the situation 20 years ago. More scientists are participating in neutron studies just occasionally and therefore have less experience and expertise in the technique. This evolution leads to increased expectations with regards to the level of support required by experts to plan and execute experiments as well as the subsequent data analysis.

There are two crucial points that render neutron science distinct from scientific research that can be conducted in local laboratories in Universities or industry. Firstly, neutron experiments currently need to be

[6] ESFRI Landscape Analysis (May 2024)
[7] Neutron Science in Europe LENS June 2022
[8] Neutrons for Science and Technology. ENSA Brochure 2020
[9] ENSA publication: Rendering the European Neutron Research Landscape, Scientific Reports 15, 5722, **2025**

performed at dedicated research facilities, similar in nature and complexity to research in large-scale facilities for particle physics and astronomy. Secondly, neutron science serves a huge number of disciplines with different communities, sizes and interests (*e.g.* from physics to cultural heritage), similar to but distinct from science at synchrotron and X-ray free electron laser facilities.

To enable successful research programs across this wide range of scientific disciplines does not only depend on the essential provision and development of dedicated neutron facilities, but also on co-located round-the-clock support infrastructures, which have seen increasing complexity and scale over the last decades. These include but are not limited to:

- instrument support by local scientific and technical experts;
- peripheral laboratories for sample preparation and handling (e.g. deuteration and biology labs);
- effective and novel sample environments;
- complementary techniques to provide in-situ data during experiments;
- user friendly data reduction tools;
- effective data analysis software and platforms for in-situ / on-the-fly analysis;
- intuitive, sustainable and FAIR[10] data management.

All these components are driven forward by the feedback and constructive exchange of ideas between users and facilities. Attempts to coordinate efforts between the facilities are appreciated by the users. Shared sample environments and joint software development projects are highly beneficial for the user community.

Capability vs. Capacity of Neutron Facilities

To provide excellent science, and to develop the leading position of European neutron science, European neutron facilities must continuously and simultaneously provide the user community with both the highest **capability** and **capacity**. With capability, we refer to the most state-of-the-art neutron facilities that are characterized by the brightest, most intense neutron sources. In contrast, capacity is defined as the number of available instrument beam days over a given period available to the neutron user community at a range of sources with different beam characteristics.

High **capability** enables investigation of increasingly smaller samples, high resolution scattering/imaging experiments, experiments under extreme conditions (high pressures or magnetic fields). High **capacity** allows experiments (most often in soft matter, biology, catalysis or thin film growth) which are governed by longer timescales of intrinsic system processes such as cell growth, molecular interactions where samples need to reach equilibrium, or slow kinetic or dynamic processes in response to a system perturbation. High capacity makes is possible also to carry out high-risk experiments requiring more than one attempt, address scientific questions requiring access to several instruments, develop novel neutron instrumentation, long experiments where complex sample environment is installed and optimized and, last but not least, run training programs for future users. Loss of capacity leads inevitably to oversubscribed instruments, thus prohibitively long waiting times (order of years) and ultimately the shrinking of the user community.

A common misconception is that improved capability automatically solves the capacity issue because brighter neutron sources may be exploited to perform experiments faster, and therefore the same number of instruments can serve more users. This is far from correct, as has been shown by a recent analysis of user behaviour at the Swiss Spallation Source, SINQ[11]. In short, improved instruments are used to tackle new scientific challenges and not to simply repeat the same type of experiments faster. This is a very positive result and is precisely what is desirable for advancing science, technology and society.

ENSA therefore highlights that to maintain a healthy neutron science landscape, improvements in neutron capability have to achieved while neutron capacity is at least to be kept constant or even better improved. ENSA supports any activity or strategy that achieves balancing neutron capacity and capability, with a minimal goal allowing to sustain the size of the European neutron user community.

[10] FAIR principles

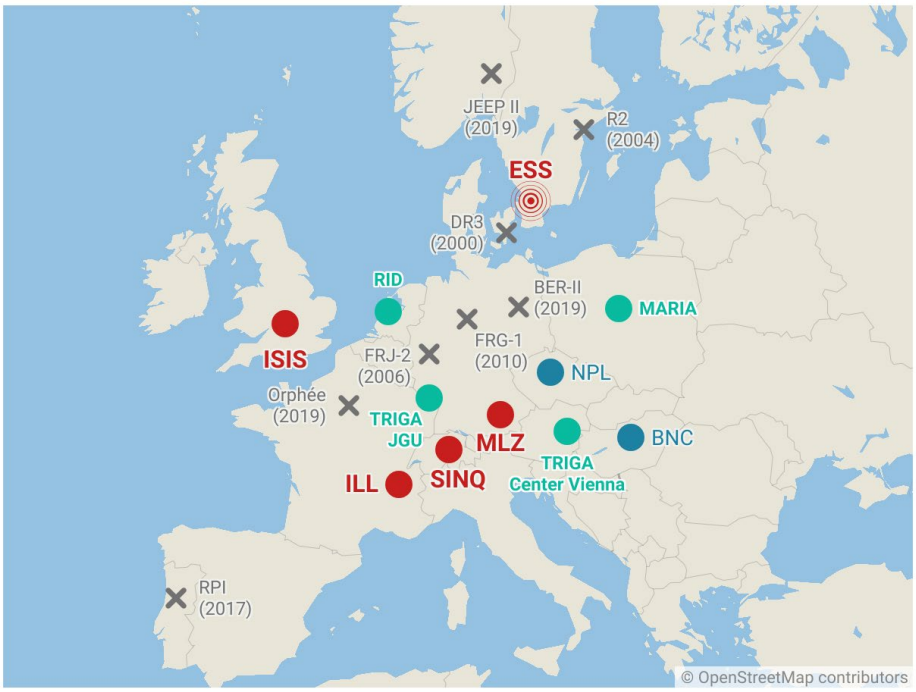
[11] Neutron Science Community Roadmap 2024. Update of Swiss Community Needs for Research Infrastructures 2029-2032, Swiss Academies Reports 19 (13), **2024**

Network of Sources within the Neutron Ecosystem and its Sustainability

The neutron ecosystem is not only a network of neutron sources, but it also includes the scientists at Universities, institutes and industry as well as at the national and international neutron sources, driving the scientific request and thus the instrumental development.

The network of European sources – well described in the 2022 LENS position paper[7] – contains several facilities of different characteristics, sizes and funding models. The access schemes are not identical but adhere to the same principles of awards based on an independent peer review of proposals. Technically, there are continuous and pulsed sources, affecting the experimental techniques, which are funded nationally or jointly at the European level. The international spirit of neutron science is obvious: a) several national sources provide free of charge beamtime to scientists affiliated to other countries; b) the operation of ILL[2] and the construction of ESS[3] (Lund, Sweden) are funded via international partnerships; c) the European neutron user community is involved in the design, construction, commissioning and upgrade of instruments at existing facilities, as well as at ESS. In the following, it is highlighted how national sources are needed to complement the science conducted at the international sources.

The European community contains extremely rich expertise in neutron science, relying on three pillars: 1) the current hub at ILL; 2) the growing competence center at ESS; and 3) national neutron sources of different sizes, scientific focus and competences. This third pillar is essential for maintaining the equilibrium of the ecosystem and contributing to experience, education, competence and scientific diversity. While both large and small national facilities contribute to scientific excellence on a global scale, with overall up to hundreds of peer review papers published annually, the smaller national facilities serve also as an essential accessible gateway for new users to integrate into the neutron community, and they are very well suited for running experiments that do not require the highest neutron flux. At the same time, the operation of all of the facilities in the ecosystem is extremely important in compensating for periods of upgrades and maintenance (either of facilities or instruments) in others. The dramatic change of this pillar due to the closure of eight national sources in just over the last two decades, however, results in a serious danger of losing the competence necessary within each national community and beyond[7,12]. Recently, the neutron



Created with Datawrapper

Figure 2. Neutron Facilities in Europe. Based on Neutron Science in Europe. LENS June 2022

[12] ESFRI Landscape Analysis (May 2024)

user community has clearly expressed a need for a reliable and sustainable network of several types of neutron sources[13], in response to the evolving neutron ecosystem.

On the global scale, European neutron science has set the pace for the global development of the field for several decades and currently enjoys a world leading position, sharing its expertise and benefiting from exchanges with the rest of the community. This world-leading position of Europe has always rested upon the availability of the necessary tools. Due to recent closures of so many national neutron sources (Figure 2), Europe is experiencing an alarming decline in terms of annually-accessible neutron access and experienced scientists – thereby limiting opportunities to train the next generation of scientists. Thus, Europe is in a serious danger of losing the competence necessary for continuing its scientific excellence.

In Europe, the development of high-current accelerator-driven neutron sources (Hi-CANS), which are scalable in size and cost, is being driven forward to improve this situation. In the future, these sources could become an important additional pillar of the neutron source network. In recent years, there have been very promising developments in this area that have demonstrated technical feasibility[14,15]. Concerted action within Europe to realize operation of the Hi-CANS technology, *e.g.* by developing a European strategy for the type, timing and size of sources to be built, could be greatly beneficial for the neutron user community in the decades to come. This aim could be realized if the Hi-CANS community involves the present neutron user community to find the most efficient way for Hi-CANS to contribute to European neutron research as a whole going forward.

In order to continue delivering scientific discoveries and breakthroughs in the future, and in line with several recent statements of the national neutron user communities[16,17,18,19], ENSA supports the three pillars of the neutron ecosystem discussed above – ILL, ESS and national sources – to continue to deliver neutrons within their essential infrastructure for many years to come (Figure 3).

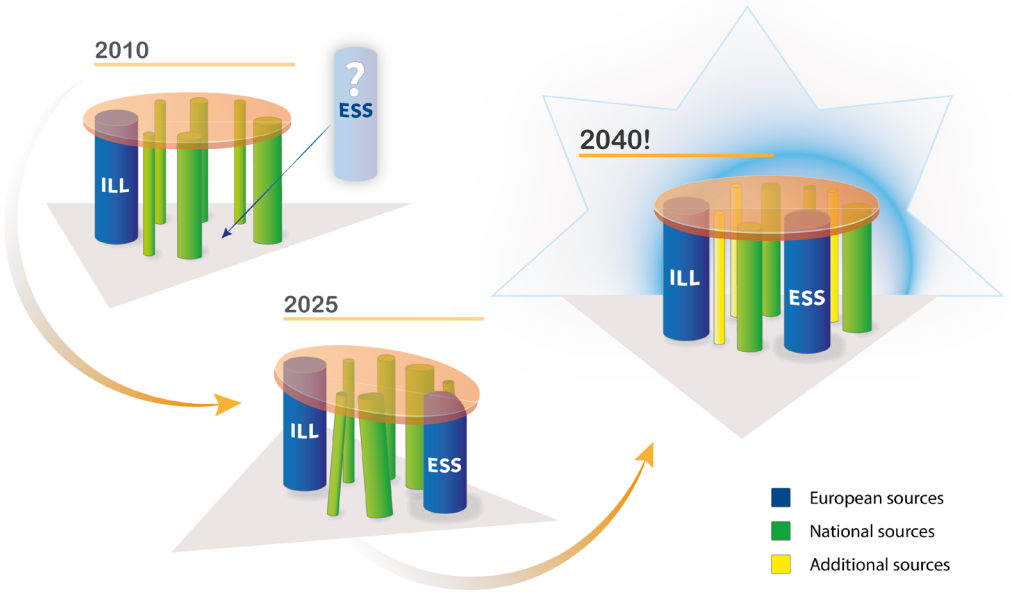


Figure 3. Towards a reliable, sustainable and sufficient provision of neutrons in Europe, relying on several types of neutron sources ("pillars"). Copyright by Iris Köhler, FZ Jülich

13 Bringing Together a Neutron Ecosystem for Sustainable Science with ESS (BrightnESS2 report, June 2022)
14 ICONE, a new French neutron scattering source (2024)
15 Julich High Brilliance Neutron Source (BHS)
16 French Resources for neutron scattering: request for a national strategy (October 2023)
17 Swiss Neutron Science Roadmap (2024)
18 UK Neutron Scattering Group Statement (September 2023)
19 Status and Future of Neutron Scattering 2023-2045 (Germany)

The cooperation between European neutron facilities has increased significantly in the last decade or two, *e.g.* through coordination of predictable shutdowns and joining forces in a more efficient way to address technical and technological issues. This approach brings huge advantages to the user community through increasing efficiency and creating synergies. Therefore, ENSA supports the initiative of organizing a European Laboratory for Neutron Science, as suggested by LENS[7], and the idea of cooperating on technological projects such as the development and production of detectors and choppers. Respecting the complexity of national and international funding principles, it would be beneficial also to coordinate upgrade programs (especially at ISIS[20], SINQ[21] and MLZ[22], with some of these already ongoing) in order to achieve a minimum overall downtime of similar types of instruments. Examples follow: the development of adapted concepts for national sources could be joined in by ENSA, collaborating research group (CRG)[23] instruments at national sources could be developed through further collaboration with Universities, institutes and industry, international contributions to upgrades/extensions of existing national sources could be supported financially, *e.g.* ISIS-2 and SINQ^{++}, shared user operation models could be implemented etc., and all in close exchange with the participating national communities. In summary, it is clear that the community would only benefit from increased cooperation between the facilities.

Despite all the recent efforts made in terms of higher efficiency of the use of neutron beamtime, as well as the development of more or new instruments or building new future sources, neutron beamtime will remain extremely precious. The appreciation of its value by scientists who are not currently involved in neutron science is one of the key responsibilities of the user community. National communities and ENSA need to expand their initiatives that support and train scientists in proposal writing, as well as in understanding the costs, efforts and impact of neutron results in relation to complementary information.

A crucial aspect of the neutron user community is the training of a new generation of scientists, including early career scientists and graduate students. Training, hands-on experience, participation in neutron experiments and data analysis are indispensable and must be safeguarded despite the overall reduction in experimental time and the increased demand for neutron experiments today. The pre-requisite for the most efficient exploitation of neutrons is the presence of competent and experienced scientists.

Joint efforts of the neutron user community and the neutron facilities are needed to sustain and develop competences in the field of neutron science through:

- PhD programs with Universities[24];
- attractive early career opportunities in academia and at national research institutes;
- exciting scientific projects given by tenure-track positions also providing further PhD positions[25] etc.;
- virtual experiments for training students, advanced simulations for preparing neutron experiments and artificial intelligence or robotic tools for efficient beamtime use to complement the suite of current improvements;
- partnership with industry.

ENSA supports the neutron user community to influence the national communities on all levels to strengthen neutron-related science as a domain. Conferences, prizes and network activities of ENSA are only part of this effort and must be supported in each country nationally.

Access Principles and Transnational Access

Today, access to neutron beamtime is provided by individual neutron facilities based on the quality of scientific proposals they receive, with the national affiliation of the principal investigator or of all proposers considered in varying ways. The current system is well-functioning for experienced users. However, a

20 ISIS Neutron and Muon Source (UK)
21 Swiss Spallation Neutron Source (SINQ, Switzerland)
22 Heinz Meier-Leibnitz Zentrum (MLZ, Germany)
23 Cooperating Research Groups (CRG)
24 GNeUS, ILL PhD Programme, Tasso-Springer Fellowships, Rudolf-Mößbauer Tenure
25 SwedNESS Graduate School, Nordic Neutron scattering program

flexible pan-European single-portal access point for instruments at multiple facilities, providing guidance with respect to the most appropriate instrument to use, would greatly enhance the efficiency of beamtime allocation for new users in particular. Enhanced communication and collaboration within the sub-communities who determine the allocation of beamtime – driven by the instrument scientists and experienced users – would help to ensure that the best science is performed on the best-suited instrument, at whatever European facility that may be. The improved provision of information about the different strengths, limitations and properties of instruments and their available sample environments in a coordinated and objective way would be greatly beneficial. All instruments and facilities would benefit from such an initiative through higher scientific productivity, which may encourage open minds for further developing the access models later. ENSA supports any such process in the direction of any single-point, multi-facility access system.

As a user association initiative, the Neutron and Photon Elevating Worldwide Science (NEPHEWS)[26] joint project of photon, neutron and free-electron laser sciences started in 2024 to broaden the national user basis of large-scale research facilities. The scheme provides training opportunities for less experienced neutron user communities, combined with transnational access funding – and thereby also supports the development and organization of national communities.

The Role of the European Neutron Scattering Association

The neutron user community is accustomed to its multi-faceted role within neutron science and will naturally and unquestionably continue to play its part. Some traditional aspects of this role (encouraging, teaching, connecting etc.) are evolving due to the expanding capacities of technical opportunities (*e.g.* on-line teaching, virtual experiments, continuous exchange and short-term activities).

ENSA, as the independent representative of the European neutron user community, realizes and respects the presence of very different situations in its member states, which create distinct economical, scientific and cultural environments for neutron scientists. These differences naturally influence the size, scientific directions and specific aims or interests of the national communities, which should flourish individually within the European neutron science community.

While considering special national interests, the agreement on a successful neutron ecosystem going forward will not only foster greater collaboration between the national communities, but it will also deliver significant economic benefits. Furthermore, such an approach will maximize the impact of financial resources. ENSA supports this approach and provides a connection to the facilities via LENS / ELENA[27] for:

- a structured European approach for Horizon Europe proposals;
- cooperative timeline for Hi-CANS as a promising option for future sources;
- European process for developing and updating a strategic roadmap for the neutron ecosystem;
- in the longer term, a coordinated collaborative platform, ideally leading up to a shared decision body, between the European neutron user communities and neutron facilities on one side and the national and European-level funding agencies on the other, the concerned partners of which ENSA invites to devise a possible structure along these lines.

Neutron scattering continues to be essential to European science. The longevity of ILL for the next decade and beyond is materially essential to the efforts mentioned above, ESS is the keystone to our future success as a community, and national sources with diverse characteristics are vital to complete a healthy neutron ecosystem for the 21st century, together with a flourishing community of competent and experienced users. ENSA is committed to being centrally involved in support of this vision.

[26] NEutrons and PHotons Elevating Worldwide Science
[27] European Low Energy accelerator-based Neutron facilities Association