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1. General context

High-quality nuclear data are essential for ensuring the safety and optimal operation of existing nuclear reactors, managing nuclear waste, designing news systems, and for many non-energy nuclear applications. Europe has a rather large Nuclear Data community, which has benefited from several EURATOM projects since FP6, among which EUROTRANS/NUDATRA, ANDES, EUFRAT, ERINDA, CHANDA, and now SANDA and ARIEL. These projects have contributed to bringing together the various European groups working in the field within research organizations and universities. They generally cover all the aspects of the production of ND: detector developments, target production, differential and integral measurements, data analysis, evaluation, nuclear theory, and simulation codes, which is mandatory to produce high-quality ND for energy and non-energy applications. Today, the community is well organized and has strong links with the International Agencies (IAEA, NEA/OECD, JEFF), following their indication on priority for topics and isotopes. It has major assets, combining expertise in all these areas, a number of research infrastructures enabling cutting-edge experiments, and great capacity for training young researchers. However, this situation is rather precarious as it depends on the funding of successive projects financed by EURATOM, with the risk of gaps between projects and a lack of medium and long-term visibility. Although the amount of funding provided by these projects may seem small compared to the total amount invested by the Member States, taking into account the man-power and the infrastructures, it is nonetheless crucial for maintaining the community at the forefront of the domain. First, because this funding allows the emergence of innovative techniques and experiments, fosters the collaboration between complementary groups, and provides support to teams, in particular from small laboratories and universities, in accessing relevant research infrastructures. Secondly, because it has a leveraging effect with regard to funding agencies for laboratories, thanks to the visibility acquired through these projects and to raising awareness of the importance of nuclear data.

The goal of Task 2.6 was therefore to try to find ways and, as far as possible, a framework that would ensure the continuity and the sustainability of the major efforts made over all the years in the field of nuclear data and guarantee that Europe remains a key player. This is all the more important as we have entered a period of renaissance for nuclear energy, which for instance is expected to at least double in capacity by 2050 in the Net Zero Emissions scenario of IEA. This implies the extension of the lifetime of existing reactors, the building of new ones and the developments of new reactor concepts such as SMRs, which could be used also for non-electrical applications. In all cases, more precise or new nuclear data are required. This means that efforts in this area must not only be sustained, but amplified if Europe is to retain its sovereignty over nuclear energy.

2. Investigating the possible EURATOM frameworks

At the beginning of SANDA, it was envisaged to propose a co-funded European Partnership, such as for instance PIANOFORTE for radiation protection research, which would have been established between the Member States partners of SANDA, possibly extended to others, and the European Commission. To establish this Partnership in the FP10 EURATOM Work Program, it would have been necessary to prepare it within a CSA of the next WP 2023-2025.

Because of the COVID pandemic it was not possible to organize a workshop to approach the representatives of EU Members States to evaluate the support to a ND joint initiative. However, informal discussions were held with representatives of several SANDA partner Member States and with the EURATOM Programme Committee. It was concluded that the Nuclear Data community was not large enough for such a framework and ideas to extend the Partnership to neighboring communities, for instance basic data for nuclear materials, have not been successful, mainly because a Co-funded European partnership for research in nuclear materials was foreseen. Therefore, the community, through its MS representatives, has

mobilized to convince the EURATOM Programme Committee to recommend a call in the 2023-2025 WP, to which the ND community could respond, ensuring, at least in the short-term, the sustainability of the efforts made in the domain, and in particular of the JEFF project.

This mobilization proved fruitful, as a call, HORIZON-EURATOM-2023-NRT-01-06, Improved nuclear data for the safety of energy and non-energy applications of ionising radiation, was included in the WP 2023-2025. The SANDA community has then prepared and submitted the APRENDE (Addressing PRiorities of Evaluated Nuclear Data in Europe) project in response to this call in November 2023. APRENDE gathers 36 institutions from EU plus 5 from UK and Switzerland. Its goal is to improve nuclear data for modelling and simulation tools used by European stakeholders in the application areas identified as a priority by stakeholders of nuclear data and by national, European, and international projects. APRENDE has been selected for funding by EURATOM.

3. The Consultants' meeting at IAEA

The production of high-quality ND requires the collaboration of experts from both fundamental research and applied sciences. In particular, the involvement of nuclear physicists, both experimentalists and theoreticians, is crucial for the detailed understanding of nuclear reaction mechanisms and nuclear structure, and the development of theoretical models used in the evaluation process. This is why it is important that NuPECC, the Nuclear Physics European Collaboration Committee, which provides advice and makes strategic recommendations to European funding agencies and decision-making bodies, is aware of the importance of the subject and of the difficulties in the domain, and supports it.

On the occasion of the preparation of the new Long Range Plan 2024 for Nuclear Physics, NuPECC has engaged with the Nuclear Data Section of IAEA to promote a concerted and comprehensive approach in support of nuclear data activities in Europe that would be sustainable and, at the same time, allow to maintain the locally produced nuclear data expertise and skills.

A Consultants' Meeting on Comprehensive European plan to acquire and curate nuclear data was held on 25-27 April 2023 in Vienna with invited participants representing the nuclear physics research and nuclear data community from EU countries. The goal was to discuss the needs for a Comprehensive European Plan to acquire and curate nuclear data. The participants were: M. Lewitowicz (France), NuPECC Chair; E. Widmann (Austria), NuPECC Deputy Chair; E. Körner (Germany), NuPECC Secretary; A. Böltzig (Germany) for ChETEC-INFRA; S. Leray (FRANCE) for CEA; R. Garbil (EU) for EURATOM, and IAEA staff S. Charisopoulos and D. Ridikas (Physics section), A. Koning and P. Dimitriou (Nuclear Data section). The agenda of the meeting is shown below. It includes one remote presentation from US by K. Jankowski, coordinator of the US Nuclear Data Program and the presentation of the slides from E. Gonzalez about SANDA.

Tuesday, 25 April

09:00 - 09:10	**Opening of the meeting**, A. Koning / NDS Section Head
	Welcome and Introduction, P. Dimitriou / Scientific Secretary
	Election of Chair and Rapporteur(s), Adoption of Agenda
09:10 - 11:10	**Presentations I (45'+15')**
	- Curated nuclear data at the Nuclear Data Section (P. Dimitriou) - Nuclear Data in the NuPECC Long Range Plan 2024 for European Nuclear Physics (M. Lewitowicz)
11:10 – 11:30	*Coffee break*
11:30 – 12:30	**Presentations I (45'+15')**
	- Nuclear Data at CEA (S. Leray)
12:30 – 14:00	*Lunch break*
14:00 – 16:00	**Presentations II (45'+15')**
	- Nuclear Data Activities in EURATOM (R. Garbil) - US Nuclear Data Program (K. Jankowski, guest speaker)
16:00	*Coffee break*
16:30 – 17:30	**Presentations II cont' (45'+15')**
16:30	- Nuclear Data and Nuclear Astrophysics - ChETEC-INFRA (A. Boeltzig)

Wednesday, 26 April

09:00 – 11:00	**Roundtable discussion**
	- SANDA project – slides by Enrique Gonzales (in absentia)
11:00 – 11:30	*Coffee break*
11:30 – 13:00	**Roundtable discussion cont'**
13:00 - 14:00	*Lunch break*
14:00 – 18:00	**Seibersdorf Lab Tour**
19:00 – 21:00	***Dinner at a Restaurant***

Thursday, 27 April

09:00 – 12:50	**Roundtable discussion cont' - Drafting of recommendations**
12:50 – 13:00	**Closing of the meeting**

This meeting was an opportunity to discuss the current European situation and in particular compare it with the one in US. One important point is the fact that the need for data goes far beyond the field of nuclear fission energy and also concerns fusion, with the interest on new compact fusion devices, medicine (radiotherapy and particle therapy), space exploration and fundamental physics, as for instance astrophysics. The presentation on the US Nuclear Data Program (USNDP) by K. Jankowski from DOE was particularly instructive, as it showed that US has a coordinated program, led by DOE but gathering all the federal funding agencies that need ND (for instance NASA for space applications, NFS for basic science, NIH for medicine, etc…) and universities. This program allows to define priorities, fund targeted experimental and theoretical developments and support data compilation, evaluation, dissemination, and

archiving in databases. Actually, in April 2022, Office of Science/NP and the National Science Foundation (NSF) put forth a charge to the Nuclear Science Advisory Committee to look specifically at nuclear data with the goals listed below:

1) Assess USNDP Status, which would include the following actions:
    a. Assess and document recent achievements in nuclear data and their impact.
    b. Survey current and future federal and non-federal needs for reliable, accurate, secure, accessible nuclear data.
    c. Assess the role, competitiveness, and importance of the USNDP in an international context.
2) Based on the USNDP Status Report above, provide recommendations for maintaining effective stewardship of nuclear data, which includes the following actions:
    a. Identify challenges for nuclear data stewardship in the future, including identifying and prioritizing the most compelling opportunities to enhance and advance NP stewardship of nuclear data and the impact if those opportunities can be realized.
    b. Describe possible ways the Nuclear Data (ND) community can work to train and retain a diverse, equitable, and inclusive workforce capable of sustaining the U.S. ND enterprise.
    c. Identify access needs for facilities and instrumentation, crosscutting opportunities with other federal programs, and potentially mutually beneficial interactions with other domestic and international stakeholders.

A concern shared by most participants was the lack of qualified evaluators, in particular for nuclear structure data. This is largely due to the fact this work needs people with a wide range of skills, enabling them to estimate the quality of experimental data and associated uncertainties, develop phenomenological or theoretical models, and deal with databases, but is not recognized for its true value. Academic institutions are often reluctant to support work that is considered as not innovative enough and does not lead to many high-rank publications as it is generally a painstaking and long-term work. In the new APRENDE project, efforts have been made to support more evaluation activities.

The recommendations issued at the end of the meeting are given below (from [1]):
The European nuclear physics community should:

- *establish priorities for nuclear data measurements and evaluations for applications that will be addressed by a comprehensive European nuclear data program - the priorities should be based on existing priority lists maintained by the different stakeholders.*
- *recognise the importance of curated nuclear data also for fields beyond nuclear physics and its applications, e.g., research in astrophysics and particle physics, and strive to maintain the related databases based on FAIR (findable, accessible, interoperable, reusable) principles.*
- *strive to establish a sustainable source of funding of measurements and data evaluation, including well-defined career paths in nuclear data that will involve national funding agencies and the European Commission (EC) (EURATOM and all other relevant EU work programs).*
- *maintain access to key experimental infrastructures that enable specific measurement methodologies including target preparation and supply to produce nuclear data relevant for applications.*
- *Reinforce cooperation with international organizations (IAEA, NEA), which should provide support in the form of coordination, training,*

And a list of actions was proposed:

- *Organize meetings at international and European level to bring together stakeholders including national funding agencies, EC (incl. EURATOM) representatives, nuclear technology industrial partners, representatives of the nuclear physics research community (NuPECC), the nuclear physics research infrastructures (EURO-LABS and ChETEC-INFRA), and the nuclear data community (JRC, EURATOM-funded project coordinators) as well as international organizations (IAEA, NEA).*
- *Consider organizing a side event at the IAEA General Conference 2023 to highlight the importance of nuclear data programs for basic sciences, nuclear energy development and other applications worldwide.*
- *Reach out to JRC to explore opportunities to establish a sustainable nuclear structure and decay data evaluation effort in addition to the existing nuclear reaction data evaluation effort.*
- *Reach out to national funding agencies and EU large-scale facilities to investigate ways of strongly enhancing the support of curation of nuclear data in addition to the production of nuclear data.*
- *Ensure adequate funding is allocated to nuclear structure and decay data evaluation in the next proposal submitted to the open call HORIZON-EURATOM-2023-NRT-01-06: Improved nuclear data for the safety of energy and non-energy applications of ionizing radiation.*
- *Organize workshops, summer schools, and webinars to raise awareness of the importance of nuclear data and to enhance capacity building in nuclear data evaluation methods, validation, and dissemination.*

4. The side event at the IAEA General Conference

The second action on the previous list has been completed and a side event on nuclear data has been organized during the 67th IAEA General Conference 2023. The description and agenda are given below.

Providing the best nuclear data for tomorrow's nuclear solutions: challenges and opportunities

Side Event at the 67th IAEA General Conference 2023
Tuesday 26 September 2023 | 14:00 to 15:30 | Room M7

Description

Advances in nuclear technologies for energy, waste, medicine, environment, earth and space exploration, security, safeguards, and cultural heritage rely on quality-assured nuclear data characterizing nuclear reactions and decay radiation. Progress depends strongly on the latest scientific insights promptly incorporated into the databases. The competencies, research infrastructures, and best practices required for data development transcend the resources of a single application, calling for a coordinated and concerted effort at the national and international levels. A panel of experts presents challenges and opportunities in transforming the best scientific knowledge to quality-assured nuclear data, ready for use in developing new nuclear solutions.

Background

The progress of nuclear technologies is contingent upon modelling and operations, and relies heavily on code, data, and expertise. Accurate quantification of nuclear reaction and radioactive decay data is crucial for establishing fundamental parameters with a high level of confidence. Although nuclear technology organizations possess knowledgeable professionals to handle nuclear data, there are obstacles associated with its development, primarily stemming from constrained budgets and divergent priorities.
To overcome this obstacle and guarantee the accessibility of high-fidelity nuclear data for future challenges, it is vital to have united funding and collaborative endeavours spanning various applications and transcending national programs. The establishment of a framework that bolsters competencies, infrastructures, and enhancements in nuclear data is indispensable.

Agenda

Moderated by Ulla ENGELMANN (European Commission, Joint Research Centre, Director)

- **Innovation, research and development for tomorrow's nuclear solutions** (20')
  - Yolanda BENITO (CIEMAT, Director General)
  - Héloïse GOUTTE (CEA, Scientific Director for Energy)
  - Michael FLEMING (OECD-NEA, on behalf of the DG)
- **Opportunities, challenges and ways forward for nuclear data** (50')
  - **Introducing nuclear reaction and decay data**, Arjan KONING (IAEA)
  - **A European perspective**, Arjan PLOMPEN (JRC)
  - **A United States perspective**, Keith JANKOWSKI (US DOE)
  - **A Japanese perspective**, Tokio FUKAHORI (JAEA)
  - **A Chinese perspective**, Nengchuan SHU (CIAE)
- **Round table on resources, competences, research infrastructures, new technology, organisation, and cooperation** (15')
- **Closing (5')**

After a keynote address by Ulla Engelmann, Director of Nuclear Safety and Security at the Joint Research Center (JRC), Yolanda Benito, Director General of CIEMAT, Héloïse Goutte, Scientific Director of Energies at CEA-DES and Melissa Denecke, Director of the IAEA Division of Physical and Chemical Sciences, presented the opportunities and challenges in the field of nuclear data.

Experts from DOE, JRC, JAEA and CIAE (China's Institute of Atomic Energy), then presented the state of the art and perspectives in the field from American, European, Japanese and Chinese perspectives. The event concluded with the need to highlight the importance of nuclear data in many fields, and to raise awareness among stakeholders of the difficulty of maintaining an efficient, high-quality data production chain, which, as stressed by A. Plompen (JRC), requires resources in the form of skilled staff and research infrastructure for delivering

- Precise and comprehensive measurements
- Evaluated nuclear data libraries
- Established processing routes
- Quality assurance through benchmarking and validation
- Feedback-loops with users

One of the bottlenecks being the lack of evaluators and infrastructures for validation.
The need to strengthen international coordination and exchanges in this field was also emphasized.

After the meeting, the organizers and participants of the side event (E. Gonzalez (CIEMAT), S. Leray (CEA), A. Koning, P. Dimitriou (IAEA/NDS), Tokio Fukahori (JAEA), N. Shu, K. Jankowski (DOE), M. Lewitowicz, S. Koerner, E. Widmann (NuPECC), M. Fleming (OECD/NEA)) held a meeting at IAEA/NDS to discuss a possible follow-up. Some actions to better explain the value of Nuclear Data were proposed, as the preparation of a brochure with examples from different domains. As regards the European ND community, it again appeared that a European program similar to the one existing in the US, with strong international links, would contribute to keep Europe at the forefront of the domain.

5. NuPECC Long Range Plan 2024

NuPECC is presently completing its new Long Range Plan for the future of European nuclear physics, which should be published end of 2024. The Working Group on Applications and Societal Benefit, to which several members of SANDA have participated, [2], has emphasized the needs for higher accuracy Nuclear Data in several domains and indicated priorities. The importance of mastering the complete Nuclear Data Cycle has been stressed, together with the maintenance of competencies in the nuclear data sector and the necessary support to relevant research infrastructures and target laboratories. Strong recommendations on Nuclear Data are expected in the Executive Summary that will be discussed and finalized during the Town Meeting in Bucharest on April 2024.

6. Conclusions

The goal of this Task was to explore possible frameworks for the coordination of the European Nuclear Data community that would ensure the continuity and the sustainability of the major efforts made over all the years in the field of nuclear data and guarantee that Europe remains a key player in a context of renewal of nuclear energy and development of non-energy applications. In the short term, the APRENDE project will partially play this role. On the longer term, it does not seem that a solution can be found within the EURATOM framework program alone. A good example for Europe to follow would be that of the US Nuclear Data Program, which gathers all the national funding agencies that need Nuclear Data.

Therefore, it is proposed to create a European Nuclear Data Program that would:

- Bring together ND providers, database managers and stakeholders from all the domains needing ND to discuss current needs
- Ensure the coordination of the work done by the ND community in Europe, identifying challenges and opportunities, and guarantying that ND end up in nuclear databases

- Support key infrastructures for the production of ND
- Ensure that a sufficient workforce is available, in particular for evaluation
- Invest in education and training to bring new people into the nuclear data community
- Ensure the liaison with international partners and agencies (NEA, IAEA)

This program could be co-funded by the Member States and EC through either a special program or contributions from Work Programs concerned, EURATOM Fission and Fusion, Space, Health, Security, etc… This program could be hosted by the JRC.

7. References

[1] "Summary Report of the IAEA Consultants' Meeting IAEA Headquarters, Vienna, Austria 25 – 27 April 2023," 2023. [Online].

[2] NuPECC, "LRP 2024 - TWG7," 2024. [Online]. Available: https://indico.ph.tum.de/event/7629/contributions/8946/attachments/6015/8084/7F_NUPECC%20LRP%202024%20-%20TWG7%20-%20with_figures.pdf.