

The PIANOFORTE partnership: Elevating European research for enhanced radiation protection

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Abstract. The PIANOFORTE partnership (2022–2029) aims to enhance radiation protection for the public, patients, workers, and the environment across various exposure scenarios. This European initiative addresses key barriers in health and environmental risk research related to ionising radiation and promotes findings that support effective radiation protection policies. By building a comprehensive pan-European scientific and technological foundation, PIANOFORTE ensures that the radiation protection system remains fit-for-purpose, delivers science-based policy recommendations and improved practices across sectors using nuclear technology and ionising radiation, including both energy-related and non-energy applications. In the medical field, PIANOFORTE works to reduce uncertainties in health risk estimates and support innovations in cancer diagnosis and therapies. Other key priorities include developing reliable methods for evaluating radiation protection related to new technologies and managing radiation emergencies, improving strategies for both immediate response and long-term recovery. The Partnership’s multi-stage prioritisation mechanism of research needs ensures that developed efforts reflect the perspectives of a broad range of stakeholders, including researchers, policy makers, regulators, implementers and practitioners. This inclusiveness aligns research priorities with pressing societal challenges, such as climate change impacts and nuclear technology safety. PIANOFORTE’s open call process funds research projects that align with its strategic goals, expanding its network from 58 to 108 partners after inclusion of new partners of granted projects during the two first open calls. Additional calls will continue to foster collaboration and increase research capacity across Europe. By adopting FAIR (Findable, Accessible, Interoperable, and Reusable) data management practices and embracing open science, PIANOFORTE supports the broader radiation protection community in sharing infrastructure and research outcomes. Educational initiatives are central to PIANOFORTE’s mission, as it builds Europe’s expertise in radiation protection through training programmes for current and next generation scientists. Structured dialogue with stakeholders strengthens the Partnership’s impact, bridging research and policy and helping to create a well-informed, resilient society capable of making sound, risk-aware decisions about nuclear and radiation-related issues.

1 Introduction: PIANOFORTE’s European roots and overall ambition

The PIANOFORTE partnership (2022–2029) is committed to improving radiation protection for the public, patients, workers, and the environment across all expo-

sure scenarios. Its overarching goal is to address barriers and challenges in human and environmental health risk research associated with ionising radiation, while effectively promoting successful strategies to inform radiation protection policies. As a European initiative, PIANOFORTE seeks to strengthen radiation protection research and innovation, aiming to support both EU and national authorities. Its mission is to advance knowledge, methodologies, technologies, and skills and expertise

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in radiation protection to address current knowledge gaps, societal concerns, and emerging issues or threats. PIANOFORTE consolidates diverse fit-for-purpose expertise (knowledge and know-how) in areas where nuclear science and technologies are crucial (e.g., medical applications, nuclear and non-nuclear industries, environmental issues stemming from mining or nuclear disasters).

Building on over a decade of EU-supported efforts in radiation protection research, PIANOFORTE coordinates efforts across medical, industrial, and environmental radiation exposure and related risk management from prevention to mitigation, including emergency preparedness, response and recovery. The partnership benefits from the advancements achieved by six major European radiation protection research platforms operating under the MEENAS consortium [1] (MELODI, EURADOS, EURAMED, NERIS, ALLIANCE, SHARE), established in 2020, as well as various past EU-funded projects.

PIANOFORTE aims to align with national radiation protection programmes to share research resources and infrastructures, avoid unnecessary redundancy in research themes, and eventually facilitate harmonised policies and practices across Europe. Its ambitions include advancing scientific understanding of ionising radiation exposure, effects and risks, developing databases, models, and tools for effective risk assessment and management, and enhancing societal resilience. A key focus is to contribute to the EU's "Beating Cancer Plan", optimising the benefit:risk ratio for radiation uses in cancer diagnosis and treatment with personalised and safe approaches across Europe [2]. Additionally, PIANOFORTE is distinguished from other EC-funded initiatives related to radiation protection research by its highly multidisciplinary and cross-sectoral approach, bridging research, policy and practice. The partnership also actively promotes inclusive stakeholder engagement to maximise the impact of its research and innovation activities, ensuring that scientific advancements translate effectively into policy and practice.

A central cross-cutting feature of PIANOFORTE is its strong emphasis on stakeholder engagement strategies that foster inclusiveness and continuous dialogue on health and well-being, as well as environmental concerns. These engagements span multiple levels - local, national, European and international - and bring together a wide range of stakeholders, including the research and education community, nuclear and non-nuclear industries, policy makers, regulators, risk assessors, practitioners, professional radiation protection associations, civil society groups, NGOs, citizen-led thematic groups, etc. Eventually, by generating the most up-to-date evidence-based expertise and advice to protect the public, workers, patients, and the environment from deleterious effects of ionising radiation, the partnership supports international recommendations currently under review by the ICRP [3], but also the European Basic Safety Standards [4].

In parallel, PIANOFORTE promotes training for new experts, fostering a strong radiation protection workforce. Through this comprehensive, EU-wide partnership, PIANOFORTE aims to translate scientific innovation into

impactful, standardised, and effective radiation protection measures that elevate public health and quality of life and citizen's health across Member States.

This present publication describes the organisation of PIANOFORTE, with emphasis on its governance and tools. It illustrates some of the past achievements and explains how open calls and selected research projects enhance radiation protection for all stakeholders. The final section outlines the foresight strategy, notably in preparation for the 10th EU Framework Programme for Research and Innovation (2028–2034) (FP10).

2 PIANOFORTE's objectives, governance and tools

2.1 Overall structure and governance

PIANOFORTE, currently with 108 partners from 26 countries is structured as in Figure 1, and contributes to the EU policy by addressing three global challenges through one overarching goal and six specific objectives (Fig. 2). To fulfill these ambitious aims, the partnership is built on three foundational pillars: coordination, integration, and dialogue among stakeholders.

PIANOFORTE is pivotal in advancing radiation protection research governance and outcomes. It focuses on fostering a collaborative and multidisciplinary approach, employing a multi-stage mechanism for prioritising research topics. This process involves stakeholders representing European research platforms, Member States, and independent Stakeholder and Advisory Board (SAB) composed of experts from international organisations and associations. By incorporating diverse perspectives, this governance model seeks to enhance coherence in radiation protection research across Europe, encouraging collaboration between research institutions and universities while ensuring effective sharing of resources and knowledge. Additionally, PIANOFORTE integrates scientific, technological, and societal considerations, ensuring that research outcomes contribute to both European and global radiation protection efforts.

2.2 Tools to facilitate coordination, integration and dialogue

PIANOFORTE governance is impact-driven, with the aim of conducting research that addresses current and future challenges in radiation protection, ultimately improving radiation protection of humans and the environment. 73% of its EC budget of 30 M€ is allocated to research activities (including prioritisation of topics, call evaluation and research projects), with the remainder supporting access to national infrastructures (3%), stakeholders' involvement (8%), education and training (6%), and dissemination of results (3%) (Fig. 1). In this sense, PIANOFORTE operates thanks to the following strategic tools:

- (1) *PIANOFORTE's open call process for the funding of targeted research projects.* The PIANOFORTE open

call process funds research projects beyond the original consortium, allowing external research teams to contribute. These calls are designed to support small, specialised research teams. Projects are selected based on scientific excellence and relevance to priority areas identified through PIANOFORTE's periodic evaluations. Successful applicants join the consortium, contributing to a broader research network focused on addressing pressing issues in radiation protection. Evidence from the first two open calls demonstrates the effectiveness of this approach. Since its inception, the research community involved in PIANOFORTE has expanded from 58 partners to 83 after the first call and to 108 after the second. This expansion not only broadens expertise but also underscores the need for structured coordination mechanisms to ensure integration across diverse research efforts.

- (2) *PIANOFORTE's investments in education and training.* This ensures that students, early-career researchers and professionals acquire essential knowledge alongside the latest research insights. By promoting skill-building across radiation protection sectors, PIANOFORTE is nurturing a pipeline of future experts who will continue to strengthen the field. These efforts include structured training programmes, workshops, and collaborative exchanges to strengthen Europe's research capacity. Dedicated calls are organised each year to support the development of early-career researchers and professionals, and also co-fund doctoral and post-doctoral fellowships (to date ca. 30 young researchers have been granted).
- (3) *PIANOFORTE's support to strengthen Europe's research infrastructure, both in terms of sustainability and accessibility.* By improving the resilience of research facilities and widening access to data repositories, PIANOFORTE helps to ensure that Member States have equal opportunities to access to high-quality research resources, thereby strengthening innovation capacity across the continent.
- (4) *To amplify the impact of its findings, PIANOFORTE prioritises outreach and dissemination* using open science practices, social media, and targeted engagement strategies to communicate with policy makers, educators, and the general public. These efforts make radiation research accessible and relevant to society, ultimately fostering an informed, supportive public stance on radiation protection.

Beyond publications in peer-reviewed journals and scientific presentations at key events like e.g., the European Radiation Protection Week, PIANOFORTE organises other events, including info days for EU researchers and national-level information sessions across Europe, fosters stakeholder engagement through regular online topical meetings and collaborations with radiation protection-related organisations (e.g., UNSCEAR, ICRP, HERCA, ESA). High-level outreach extends to European Commission officials, elected commissioners, national representatives at the parliament, as well as Euratom expert groups (e.g., Scientific and Technical Committee). One example of high-level outreach is the PIANOFORTE's white paper

which raises awareness and increases visibility of radiation protection across diverse applications, addressing the consequences of potential lack of research fundings in Europe [5].

A core pillar of PIANOFORTE governance is structured dialogue among key stakeholders from academia, industry, government, and regulatory bodies [6]. This ongoing dialogue aligns PIANOFORTE's research with policy and regulatory needs, enabling the production of recommendations that support tangible improvements in radiation protection policy and practices.

Regarding areas of interest, PIANOFORTE's openness and transparency also drive its mission in the medical sector, where it is committed to improving the safety of ionising radiation use, particularly for cancer diagnosis and treatment. PIANOFORTE's open-call process allows the partnership to address emerging priorities such as the use of artificial intelligence, radiation protection challenges related to new nuclear technologies, and radiological or nuclear emergency management, including long-term recovery strategies. Overall, PIANOFORTE emphasises a collaborative approach to drive impactful, high-quality research and foster wide-reaching advancements in radiation protection practices across Europe.

Recognising the need for collaborative efforts across European programmes, PIANOFORTE aligns with the Euratom programme and some clusters defined in Horizon Europe (e.g., the Health cluster to further research on cancer and degenerative diseases linked to low-dose radiation exposure). With a foundation rooted in the CONCERT Joint Roadmap [7], PIANOFORTE is well-positioned to tackle multifaceted human and environmental health risks through ongoing support and strategic funding. This comprehensive governance model enables PIANOFORTE to drive impactful scientific and technological innovations across Europe, contributing significantly to a safe and well-informed society.

3 Overview of open calls and ongoing research and innovation projects

Since its launch in June 2022, PIANOFORTE has organised annual open calls for research each of them addressing priority topics (Tab. 1). The periodic prioritisation process to rank research topics to be tackled by the open calls involves a series of surveys to gather the views of European research platforms, Member States, and an independent Stakeholder Advisory Board. This process is consistently applied whenever PIANOFORTE issues an open call for research. Each call results in the selection of a limited number of co-funded projects. The review of proposals is managed by a dedicated work package, utilising external reviewers who assess submissions blindly, applying a multi-criteria scoring system that emphasises excellence and impact creation. The multi-criteria scoring system ensures a fair and rigorous evaluation of proposals. Each proposal is independently reviewed by at least three external international experts, who assign scores from 1 to 5 based on three predefined criteria, namely, excellence, impact, and implementation quality and efficiency. The

Table 1. Overview of PIANOFORTE research topics that were selected as priorities for each of the three open calls (2023, 2024 and ongoing 2025) [4]

Open Call (with some statistics)	Topics
First Open Call implemented in 2023 <i>22 proposals, 9 selected for funding</i>	<ol style="list-style-type: none"> 1: Developing a knowledge base for a better understanding of disease pathogenesis of ionising radiation-induced cancer to improve risk assessment. 2: Individualised diagnostic as well as therapeutic procedures with regard to optimisation of the benefit/risk ratio. 3: Development of risk assessment and risk management approaches and technological capabilities to cope with scenarios arising from threats due to war or armed conflicts situations or natural disasters taking into consideration social, ethical and legal issues.
Second Open Call implemented in 2024 <i>21 proposals, 8 selected for funding</i>	<ol style="list-style-type: none"> 1: Developing a knowledge base for a better understanding of disease pathogenesis of ionising radiation-induced cancer to improve risk assessment. 2: Ensure readiness and scientific knowledge to support Environmental Impact Assessment and Emergency Preparedness and Response for novel nuclear technologies 3: Development of techniques and methods to go beyond effective dose in case of internal exposures following a nuclear or radiological emergency 4: Implementation of new and optimised radiation therapy approaches for better targeting to protect healthy tissues better against detrimental effects of ionising radiation.
Third Open Call under implementation in 2025	<ol style="list-style-type: none"> 1: Investigating the effects of temporal and spatial variations in dose delivery on the risk of health effects. 2: Developing an integrated approach for risk assessment and evaluation from environmental exposure to ionising radiation. 3: Use of Artificial Intelligence and Big Data techniques to improve emergency response – covering radiological impact assessments, decision support, data collection response and recovery strategies and public engagement, communication and education.

maximum possible score is 15, with an overall funding threshold set at 10 and a minimum of 3 points required per criterion. Final scores are determined by averaging the three experts' evaluations. During the two open calls issued in 2024 and 2025, this selection process maintained a competitive ratio of funded projects to total submissions of ca. 40% for a total of 22 and 21 eligible proposals respectively. The process has been proven to allow for flexibility, with adjustments approved by the Executive Board and subsequently the General Assembly to ensure the overall research agenda remains relevant and responsive to emerging topics. Table 2 lists the 17 ongoing projects awarded during call 1 and call 2 [8].

Identification of research priorities is driven by emerging issues reflecting societal needs, such as the consequences of climate change and war, as well as the benefits of using nuclear technology in both energy and non-energy sectors. This aims to create a risk-informed society with improved public awareness and engagement on nuclear and technological issues, ultimately boosting societal resilience and aligning perceptions with actual risks. While high priority remains on medical applica-

tions –given that medical exposures are the largest artificial source of radiation for the European population and the fight against cancer is a key focus of the European Commission– other priorities are emerging in response to global societal changes. These include: (1) further understanding and reducing uncertainties in health risk estimates for low-dose exposure to consolidate regulations and improve practices, and (2) enhancing a science-based European methodology for radiation emergency management and long-term recovery.

After two open calls (2023 and 2024), PIANOFORTE has demonstrated its commitment to co-funding research in various areas. In the medical field, PIANOFORTE is committed to reducing uncertainties in health risk estimates and contributing to the safe use of ionising radiation, especially in cancer diagnosis and treatment, focusing on optimising radiotherapy efficiency and protecting healthy tissues from harmful effects. The partnership also contributes to the SAMIRA plan [9] through various projects related to new nuclear medicine applications. Radiation protection challenges related to innovative technologies, such as Small Modular Reactors constituted one of the priority topics of the open call in 2024. Additionally, PIANOFORTE addresses radiation

Table 2. Overview of PIANOFORTE ongoing research projects [4]

Topics of PIANOFORTE Open Call	Selected Projects
Topic 1 (2023, 2024): Developing a knowledge base for a better understanding of disease pathogenesis of ionising radiation-induced cancer to improve risk assessment.	From the 2023 open call • DISCOVER – <i>Dissecting radiation effects into the Cerebellum microEnvironment driving tumour promotion</i> (from call 2023) From the 2024 open call • CORNET – <i>Deciphering the role of microenvironment after low-dose exposure for colon carcinogenesis and radiation risk</i> • MIRAMARE – <i>Mechanisms of the inverted relationship between menarche age and radiation-induced breast and endometrial cancer</i> • UBT-Rad – <i>Unraveling brain tumor formation after low dose irradiation exposure</i>
Topic 2 (2023): Individualised diagnostic as well as therapeutic procedures with regard to optimisation of the benefit/risk ratio.	• IMAGEOMIGS – <i>Optimizing Benefit/Risk Ratio in Breast Cancer Diagnosis and Radiotherapy: Identifying Molecular, Cellular and Imaging Signatures of Breast Cancer Heterogeneity to Improve Personalised Therapeutic Strategies for Synergistic Treatment Combinations</i> • IMPRINT – <i>Integrated molecular imaging for personalized biomarker-based breast cancer characterization and treatment</i> • LUTADOSE – <i>Personalized dosimetry to improve the clinical outcome of prostate cancer patients treated with ¹⁷⁷Lu/225Ac-PSMA targeted therapies</i> • SONORA – <i>Towards safe, optimized and personalized radiology and radiotherapy procedures for pregnant patients</i> • VERIFIED – <i>In vivo patient-specific real-time dosimetry for adaptive radiotherapy</i>
Topic 3 (2023): Development of risk assessment and risk management approaches and technological capabilities to cope with scenarios arising from threats due to war or armed conflicts situations or natural disasters taking into consideration social, ethical and legal issues.	• CITISTRA – <i>Citizen measurements as complementary radiation monitoring strategy in threats due to armed conflict or natural disasters</i> • PREDICT – <i>Improvements in atmospheric dispersion modelling and protective action strategies in case of nuclear detonations</i> • RRADEW – <i>Resilience to Radiological Events in Wartime</i>
Topic 2 (2024): Ensure readiness and scientific knowledge to support Environmental Impact Assessment and Emergency Preparedness and Response for novel nuclear technologies	• CATAPULT – <i>Comprehensive Assessment and Preparedness for Emerging Nuclear Technologies</i> • GIROSCOPE – <i>Guidance for Innovative Reactor Off-Site Consequences, Planned and Emergency</i>
Topic 4 (2024): Implementation of new and optimised radiation therapy approaches for better targeting to protect healthy tissues better against detrimental effects of ionising radiation	• DOSELIA – <i>Computing whole-body radiation dose distributions and subsequent cancer risks from modern radiotherapy techniques in paediatric patients</i> • EMPATHY – <i>Evaluation and optimization of proton arc therapy</i> • KAYAC+ – <i>Knowledge on outcome of adolescent and young adults with cancer</i>

protection challenges related to armed conflict through projects like PREDICT, CITISTRA and RRADEW (Tab. 2). The partnership is also keen on exploring the use of artificial intelligence in various radiation protection fields, notably to improve emergency response and recovery to nuclear or radiological incidents, which will be highlighted in the third open call planned for 2025 (Tab. 1).

PIANOFORTE continuously assesses the impact created for the continuum research-to-application, tackling the research needs expressed by all communities, not solely researchers, but also policy makers, regulators, implementers, and practitioners. The PIANOFORTE's vision is to establish a pan-European scientific and technological basis for a robust system of radiation protection and more consolidated science-based policy recommendations to decision makers in all the different sectors of energy and non-energy application of ionising radiation. A key focus will be ensuring that research outputs (e.g., publications, datasets, trained staff) translate into meaningful outcomes (e.g., recommendations, improvements of practices, support to regulation) for various target groups (e.g., government authorities, radiation protection experts, civil society organisations representing groups or communities of common interest, NGOs, academia).

4 Strategic foresight: a vision beyond PIANOFORTE

The PIANOFORTE partnership envisions a robust, pan-European scientific foundation for radiation protection, aiming to produce policy-relevant research that strengthens safety measures across both energy and non-energy sectors involving ionising radiation. A core objective is to translate research outputs into actionable outcomes, with a focus on data management aligned with FAIR principles

[10], open science, and impactful communication. This approach aims to enhance policy frameworks and amplify real-world applications of scientific findings.

Building on the groundwork of the CONCERT Joint Project (which concluded in 2020) [7], PIANOFORTE provides structured pathways for timely, socially relevant radiation protection research. PIANOFORTE has identified several potential improvements to governance:

- **Facilitate mechanisms to systematically consider the long-term perspectives of a broad range of stakeholders in a sustainable way, including researchers, policy makers, regulators, implementers, and practitioners.** PIANOFORTE aims for enhancement and sustainability of stakeholder networking and dialogue, leveraging the trust built within this network to promote cross-sectoral collaboration and interactions.
- **Recognise and implement through open call process, the need to co-fund various dynamic types of research accordingly to the topics/areas.** This includes long-term research to unravel mechanisms of radiation-induced biological effects in human and non-human species or new medical applications ensuring e.g., a more efficient fight against cancer as well as short-term projects to increase Technology Readiness Levels towards practice, or to preliminary address/delineate complex emerging topics.
- **Support for disruptive/novel research.** This means ensuring financial backing as long as significant breakthroughs are on the horizon.
- **Facilitate accessibility to third parties through simplification of the legal and financial process.** This is especially important to allow researchers from universities to contribute to radiation protection research, including university hospitals to be involved to ensure practical and clinical use of radiation protection research.

- **Forster the shift from multidisciplinary approaches** (defined as parallel efforts with limited interactions within disciplines) **to inter- and trans-disciplinary ones** (defined as coordinated activities across disciplines -Inter- and involvement beyond -Trans-), with more interactions across disciplines and extended engagement with external stakeholders (e.g., researchers/scientists, local/regional population communities, policy makers, regulators, industry). Enhancing the capacity to address research and innovation to advance global challenges should be achieved by making concrete bridges (mechanism with dedicated financial envelope) with European clusters and other partnerships where radiation protection is relevant (e.g., health, inclusive society, civil security for society, space, climate-energy, environment) in the Research and Innovation programme.
- **Accelerate the path to leadership of the next radiation protection professional generation** through comprehensive education and training.
- **Enhance access to research infrastructures**—including biobanks, data repositories, and regional harmonisation through intercomparison and intercalibrations— while ensuring their suitability and visibility, and collaborating with sectors like the nuclear industry (e.g., via the Sustainable Nuclear Energy Technology Platform – SNETP).
- **Express and underline policy/political interest from the Member States for specific topics through clear guidance on how to implement open calls in a simpler and more balanced approach for reflecting stakeholders’ views.** One option is to significantly increase the open funding available from the radiation protection partnership to allow for larger and/or longer-term projects while retaining the flexibility to focus on specific research topics of policy/political interest, such as supporting fundamental research to unravel biological mechanisms of radiation-induced effects on living organisms, or aligning more closely with high-tech space research or artificial intelligence communities.

Looking ahead, PIANOFORTE envisions a more inclusive and mature partnership consortium that directly addresses global challenges such as climate change, geopolitical shifts, and emerging threats. The goal is to contribute to a “fit-for-purpose” European research agenda that remains at the forefront of innovation and societal relevance, particularly in the context of emerging threats. This is essential as radiation protection research will play a significant role in supporting ICRP efforts to update recommendations and solidify scientific consensus around the Euratom Basic Safety Standards [4].

5 Conclusion

Given the rapid advancements in nuclear science and technology, combined with the flowering of AI-driven methods and tools enabling e.g., big data mathematical

processes, alongside with advances in cellular technologies (e.g., ‘omics’), the development of radiation protection has become more than ever a critical and urgent societal issue. Radiation protection plays a vital role for European citizens across many essential functions of society, including health, energy, security, and innovation. The next 10–15 years are vital for generating new policy insights, shaping strategic frameworks, so that any potential regulatory update can be analysed in terms of benefits/disbenefits to address challenges posed by both technological advancements and complex/global situations. By integrating new scientific insights and enhancing training activities, the European Commission can ensure that the directive should align with the latest evidence, thereby optimising radiation protection for all exposure scenarios (meaning better protection proportionate to all risks). This proactive approach will help mitigate risks more effectively and promote the health and safety of workers, patients, the public and the environment.

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Conflicts of interest

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This article has no associated data generated and/or analysed.

Author contribution statement

Jacqueline Garnier-Laplace and Jean-Christophe Gariel from the PIANOFORTE coordination team led the proposal and authored the initial draft of the manuscript. The co-authors, all members of the PIANOFORTE executive board and work package leaders, provided valuable feedback and insights, which enriched the submitted article.

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