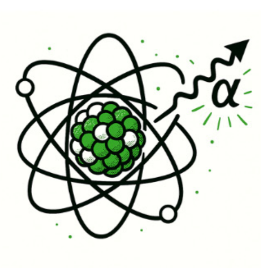
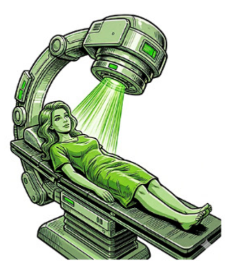
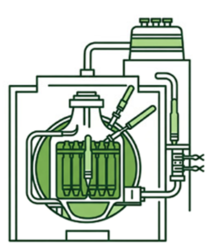
SOCIAL RELEVANCE OF ICRR-2027 TOPIS

SCIENCE

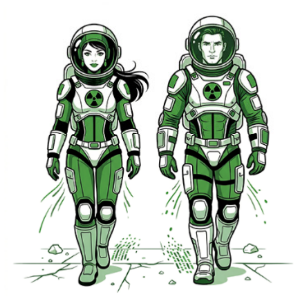


MEDICINE





TECHNOLOGY



SAFETY

International Congress on Radiation Research – ICRR-2027

SOCIALLY SIGNIFICANT TOPICS AND BENEFITS OF ICRR-2027 FROM A GLOBAL AND CZECH PERSPECTIVE

This brochure provides an overview of ICRR-2027 topics that are highly pertinent to society and the development of the Czech Republic, considering current advancements and challenges from a global perspective.

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Prof. Andrey V. Solov'yov, Ph.D.

Assoc. Prof. Ivan Štekl, Ph.D.

CONTENT

I. TOPICS OVERVIEW

BASIC RADIATION RESEARCH — FOUNDATIONS FOR FUTURE PROGRESS

1. **Radiation Physics, Chemistry & Biology — The Scientific Bedrock for Radiation Technologies**

   Fundamental research that enables medical, industrial, environmental, and security applications of radiation. Without this foundation, none of the advances below are possible.

2. **Artificial Intelligence (AI), Supercomputing & Multiscale Modeling — A Game Changer for Radiation Research, Medicine, Technology, and National Security**

   Artificial intelligence and high-performance computing are revolutionizing how we predict radiation effects, design therapies, protect populations, and accelerate innovation across all fields of human activity.

MEDICINE & WELLBEING — PROTECTING LIVES AND IMPROVING HEALTH

3. **Next-Generation Radiotherapy — New Hope Against the Rising Tide of Cancer and Better Palliative Care**

   Novel, personalized, more precise, more effective, and less toxic combined (radiation) treatments for a disease whose incidence and mortality are dramatically increasing, especially among younger populations. The Masaryk Memorial Cancer Institute in Brno and the Proton Center Czech in Prague represent world-recognized and directly benefitting players in the field

4. **Radon & Smoking — A Synergistic, Widespread Threat to Public Health and the Economy**

   The Czech Republic exhibits some of the highest radon levels in Europe. When combined with smoking, this substantially amplifies the risk, elevates the likelihood of lung cancer, and increases healthcare expenditures, rendering this a major preventable cause of lung cancer.

5. **Jáchymov and Radiation Balneotherapy — A Unique Czech Tradition with Medical, Tourism, and Regional Asset**

   The world's first radioactive spa, with a century-long tradition. A scientifically grounded therapy with strong potential for regional development, medical tourism, and wellbeing.

6. **Ultraviolet (UV) radiation — The Primary Catalyst for Melanoma, One of the Most Rapidly Progressing and Frequently Lethal Forms of Cancer**

   Understanding and preventing UV damage is essential for effective prevention, early detection, and development of public health strategies.

SAFETY — NATIONAL RESILIENCE IN A VOLATILE WORLD

7. **Radiation and CBRN Safety & Czech National Resilience — A Cornerstone of National Security and Public Protection in an Era of Nuclear Tension and New Energy Projects, National and Cross-Border Emergency Preparedness**

   From the expansion of nuclear energy to threats of dirty bombs and nuclear weapon detonations, radiation protection science is an essential component of national security, emergency preparedness, and public confidence. The Czech and international expertise in radiation monitoring, modeling, and crisis communication serves to enhance both national and regional security.

8. **Space Radiation & Human Spaceflight — Advancing Space Radiobiology Studies for the Inevitable Human Space Age-II**

   In the era of the Artemis Project and planned long-term extra-orbital spaceflights to the Moon and Mars, radiation is one of the main limits for astronauts' safety and mission success. Research in this area enhances Czech participation in the world's most prestigious space programs.

9. **Radiation Accidents and Disasters – Learning from the Past to Protect the Future**

   The most comprehensive data source on low-dose radiation effects, offered by nuclear accidents, is essential for understanding long-term health and environmental risks, not only to improve emergency response but also, for example, to reduce risks from expanding medical diagnostics.

TECHNOLOGY & ECOLOGY — INNOVATION FOR A SUSTAINABLE FUTURE

10. **Nuclear Energy and Emerging Reactor Technologies — The Only Powerful, Stable, Low-Carbon Pillar of Europe's Future Energy Mix for the (Near) Future**

    Modern (modular) reactors currently represent the sole source offering stable, safe, and low-carbon electricity production simultaneously, which is directly relevant for the Czech Republic's energy security and independence. Scientific research on radiation underpins the development of reactor types, operational management, waste disposal, and long-term sustainability.

11. Brno: A Global Microscopy Hub — Seeing the Invisible in Space and Time

The visualization of radiation-induced processes like DNA damage and repair provides a new perspective—studying these phenomena in space and time, at the level of individual molecules. Meanwhile, Brno is a leading center for enterprises in electron and super-resolution optical microscopy, driving advances in materials science, biology, medicine, nanotechnology, and innovation in the Czech Republic.

12. Lasers & Non-Ionizing Radiation — ELI Beamlines as a World-Class Czech Research Flagship

Extremely powerful lasers, as produced, e.g., by the world's most powerful laser facility, ELI Beamlines situated near Prague, inaugurate new opportunities for radiation research, medical applications, and high-technology innovation, including a partial substitution for large particle accelerators, which are essential for radiation research but provide only very limited beam times.

13. New Radioprotective Materials

A new generation of shielding textiles and foils is currently under development. These advanced materials offer transformative and wide-ranging advantages: significantly lighter and more comfortable protective garments; breathable and transparent shielding solutions applicable across various fields of human activities.

14. PFAS & Microplastics — Application of Ionizing Radiation for Environmental Remediation and Water Treatment

Novel radiation-based techniques present promising solutions for the degradation of persistent chemicals, such as polyfluoroalkyl substances (PFAS) and microplastics, thereby confronting some of the most pressing environmental challenges in protecting water, food, and ecosystems.

EDUCATION —

— BUILDING THE NEXT GENERATION OF EXPERTS AND INFORMED SOCIETY

15. Education & Public Engagement in Radiation Science — Investing in the Next Generation of Experts and Decision-Makers, and Fostering an Informed, Resilient Society.

Public lectures and debates, engaging with leading global experts, hands-on courses for students supported by Czech and international companies, mediation of radiation-related topics in Czech media, and cooperation among major scientific, medical, technological, and governmental institutions, will serve to inspire students, facilitate the training of specialists, and inform the public about realistic radiation effects, applications, and protection. This comprehensive approach ensures a resilient, innovative society equipped to meet future challenges.

II. A BRIEF INDIVIDUAL TOPICS INTRODUCTION

BASIC RADIATION RESEARCH
— FOUNDATIONS FOR FUTURE PROGRESS

1. Radiation Physics, Chemistry & Biology — The Scientific Bedrock for Radiation Technologies

Every technology and activity involving radiation — from medical diagnostics and cancer therapy to industrial processing, nuclear energy, radiation protection, and environmental and security monitoring — rests on a single foundation: a deep understanding of how radiation interacts with matter and with living systems. **Radiation physics, chemistry, and biology form the essential scientific triad that makes all modern radiation technologies possible. Without this fundamental research, none of the advances showcased at ICRR-2027 could exist**.

Radiation physics reveals how particles and photons deposit energy, how materials respond at the atomic and molecular levels, and how radiation fields can be measured, controlled, and optimized. Radiation chemistry uncovers the ultrafast processes that unfold within femtoseconds after energy deposition — the formation of radicals, molecular fragmentation, and the cascade of chemical reactions that ultimately shape biological outcomes. Radiation biology connects these physical and chemical events to cellular responses, DNA damage and repair, tissue effects, and long-term health consequences.

A central mission of modern radiobiology is to understand why different cell types — including various cancers — respond differently to irradiation. These insights are essential for the development of **personalized radiotherapy**, where treatment is tailored to the biological characteristics of each tumor and each patient. By identifying tumors that are intrinsically radioresistant or radiosensitive, radiobiology enables more effective dose planning, combination therapies, and individualized treatment strategies.

Radiobiology also plays a critical role in **human spaceflight**, where exposure to cosmic radiation is a major health challenge. **Understanding inter-individual differences in radiosensitivity** helps identify astronauts who are naturally more radioresistant, improving mission safety.

Conversely, recognizing radiation-hypersensitive individuals is vital in medicine: some patients carry genetic or molecular traits that make them unusually vulnerable to radiation. For these individuals, standard radiotherapy could cause severe or even life-threatening toxicity — and radiobiological screening can guide safer, alternative treatment choices.

Another enduring "evergreen" question of radiobiology concerns **the biological effects of very low or near-zero radiation doses**. Despite decades of research, the dose–response relationship at low doses remains one of the most challenging and consequential issues in radiation science, with major implications for radiation protection, medical imaging, environmental regulation, and public perception.

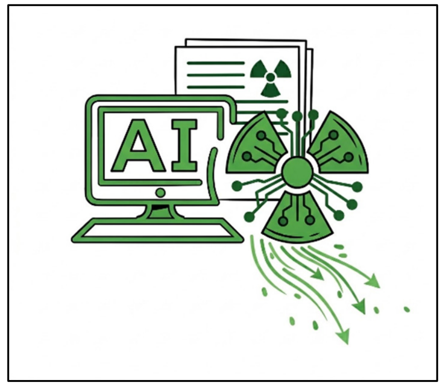
Equally fundamental is a question rooted in radiation chemistry: **What role did radiation play in the origin of life?** Ionizing radiation and ultraviolet light from the early Earth's environment may have driven key prebiotic chemical reactions — forming simple organic molecules, enabling radical-mediated synthesis, and shaping the chemical pathways that ultimately led to the first self-replicating systems. These processes are not limited to early Earth. Cosmic radiation continuously drives chemical evolution throughout the universe — in interstellar clouds, on icy moons, in cometary nuclei, and in planetary atmospheres. Radiation-induced chemistry can create complex organic molecules, modify ices, and generate reactive intermediates that may serve as precursors to life. Understanding these mechanisms provides insight not only into life's beginnings on Earth, but also into the potential for life elsewhere in the cosmos.

These are only a few examples where radiation physics, chemistry, and biology collectively offer mechanistic insights into fundamental inquiries and the essential questions **needed to design safer radiotherapy treatments, develop advanced detectors and dosimeters, engineer radiation-resistant materials, enhance nuclear-energy systems, and assess environmental and health risks. They also form the foundation of emerging disciplines such as space radiation protection, radiopharmaceutical development, nanodosimetry, and precision radiobiology**.

At ICRR-2027, the world's leading experts will present breakthroughs across this entire spectrum — from fundamental particle interactions to multiscale biological responses. These insights drive innovation across all radiation-related technologies and ensure that future applications are effective, safe, and scientifically grounded.

By strengthening the foundations of radiation physics, chemistry, and biology, we enable every discovery that follows. **This is the scientific bedrock upon which the future of radiation research — and many of humanity's deepest scientific questions — are built**.

2. Artificial Intelligence (AI), Supercomputing & Multiscale Modeling — A Game Changer for Radiation Research, Medicine, Technology, and National Security



Artificial intelligence, high-performance computing, and multiscale modeling are not merely new tools — they represent a total revolution with an extent and impact never before seen in radiation science. These technologies are reshaping how we understand radiation interactions, predict biological outcomes, design therapies, engineer materials, protect populations, and ensure global security. Their influence reaches into every single domain of radiation physics, chemistry, biology, medicine, space research, industry, and policy.

In radiation physics and chemistry, supercomputing and AI allow us to simulate particle tracks, energy deposition, and ultrafast chemical reactions across femtosecond to macroscopic timescales. Machine-learning-enhanced quantum chemistry reveals radical formation, diffusion, and reaction pathways — essential for understanding radiation damage, radiolysis, and even the radiation-driven chemistry that shapes prebiotic evolution on Earth and throughout the cosmos.

In radiation biology, AI connects molecular events to cellular, tissue, and organism-level responses. Deep-learning models analyze DNA damage patterns, chromatin architecture, repair kinetics, and cell-type-specific radiosensitivity. These insights are revolutionizing personalized radiotherapy, enabling treatment plans tailored to the biological characteristics of each tumor and each patient. AI also supports the identification of radiation-hypersensitive individuals, preventing severe toxicity, and helps select radioresistant astronauts for long-duration space missions.

In medicine, AI transforms imaging, diagnostics, and therapy. It enhances CT, MRI, PET, and radiotherapy dose calculations; segments tumors automatically; predicts treatment response; and enables adaptive radiotherapy guided by real-time analysis. AI-driven clinical decision support is rapidly becoming indispensable.

In industry and technology, AI accelerates the development of radiation-resistant materials, detectors, and electronics. Supercomputing enables virtual prototyping of nuclear-energy systems, radiation shielding, and space-mission architectures, dramatically reducing cost and development time.

In national and global security, AI enhances radiation detection, nuclear-forensics analysis, anomaly recognition, and emergency preparedness. Multiscale models support environmental dispersion forecasting and resilience planning.

Yet this revolution comes with unpredictable benefits and risks. AI promises breakthroughs of extraordinary magnitude — but also raises concerns about transparency, bias, misuse, over-reliance, and the potential for unintended consequences in medicine, security, and policy.

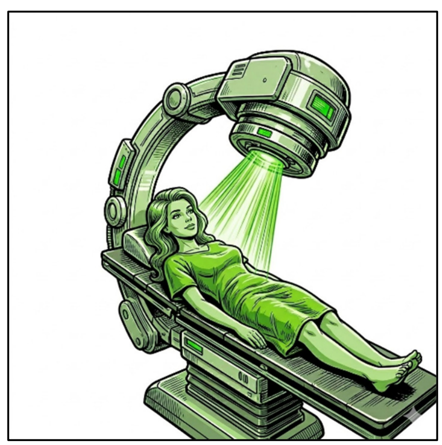
To address these issues openly and responsibly, **ICRR-2027 will host a dedicated scientific debate featuring teams of experts presenting the pros and cons of AI in radiation research and applications**. This structured dialogue will explore the transformative potential of AI, the ethical and societal implications, and the safeguards needed to ensure that this powerful technology serves humanity safely and effectively.

Together, AI, supercomputing, and multiscale modeling form a new scientific paradigm — one that unites radiation physics, chemistry, and biology into a coherent predictive framework. This convergence is reshaping the future of radiation science, enabling discoveries that will define the next generation of medicine, technology, space exploration, and global security.

At ICRR-2027, the world's leading experts will showcase breakthroughs across this entire spectrum — from quantum-level simulations to patient-specific treatment models and planetary-scale risk assessment. AI is not just accelerating progress; it is fundamentally redefining what is possible.

MEDICINE & WELLBEING — PROTECTING LIVES AND IMPROVING HEALTH

3. Next-Generation Radiotherapy and Nuclear Medicine — New Hope Against the Rising Tide of Cancer and Better Palliative Care



Cancer incidence and mortality are rising dramatically worldwide — and increasingly, this burden affects younger populations. In this landscape, next-generation radiotherapy stands as one of the most powerful and rapidly advancing tools in modern medicine. Today's radiation treatments are becoming increasingly precise, personalized, biologically informed, and technologically sophisticated, resulting in significantly reduced side effects. Consequently, they promise renewed hope for a cure and an improved quality of life.

Breakthroughs in radiation physics, chemistry, and biology, combined with the transformative impact of AI, supercomputing, and multiscale modeling, are reshaping how we understand and treat cancer. Radiobiology now reveals why different tumors — and different patients — respond differently to irradiation. These insights enable personalized radiotherapy, where dose, fractionation, and treatment combinations are tailored to the biological characteristics of each tumor and the individual radiosensitivity of each patient. This is especially crucial for younger patients, who confront decades of life following treatment. Moreover, this is also crucial for expanding the field of **radiotherapy for benign diseases**.

A major frontier is **high-LET heavy-ion therapy**. While carbon ions are already used clinically, research is expanding to other ions such as oxygen, helium, and even more exotic species. These particles offer unique physical and biological advantages: sharper dose distributions, higher relative biological effectiveness, and the ability to overcome radioresistance. Heavy-ion therapy also overlaps with space-radiation research, as both fields investigate the biological effects of high-LET cosmic particles — creating a powerful synergy between oncology and space science.

Next-generation radiotherapy and nuclear medicine also include radiopharmaceuticals, which deliver **targeted radiation directly to cancer cells through molecular recognition**. These agents — including alpha- and beta-emitting radionuclides — enable systemic treatment of metastatic disease with remarkable precision. **Boron neutron capture therapy (BNCT)** represents another innovative approach, using boron-containing compounds that selectively accumulate in tumors and produce high-LET particles upon neutron capture, destroying cancer cells from within.

The field is further transformed by **tumor-specific radiosensitizers**, such as metal nanoparticles, targeted small molecules, and **immunomodulatory agents**. These compounds enhance the effect of radiation selectively in tumors, allowing dose reduction, improved tumor control, and reduced toxicity to healthy tissues. These foundations represent a basement for **radiotheranostics (RLT – radioligand therapy)**, which is expected to redefine cancer treatment possibilities.

New modalities such as **FLASH** radiotherapy, **ultra-precise image-guided radiotherapy**, **theranostics** (simultaneous tumor imaging and irradiation), **adaptive radiotherapy**, and **combined modality treatments** (radiation with **immunotherapy**, targeted agents, or radiosensitizers) are revolutionizing clinical possibilities. These technologies allow clinicians to escalate dose to tumors while sparing healthy tissues, treat previously inoperable cancers, and reduce long-term side effects. (Radio)theranostics

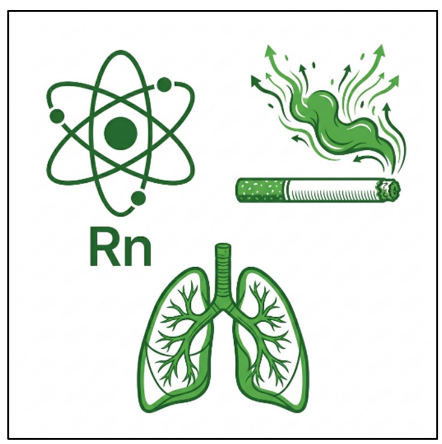
The Czech Republic plays a prominent role in this global transformation. **The Masaryk Memorial Cancer Institute in Brno**, a leading European comprehensive cancer center, and **the Proton Center Czech in Prague**, recognized internationally for its clinical excellence, are at the forefront of implementing and advancing next-generation radiotherapy. Their expertise directly benefits patients and contributes to international research, clinical trials, and technological innovation.

Next-generation radiotherapy also brings **major advances in palliative care**, offering more effective symptom relief, better pain control, and improved quality of life for patients with advanced disease. Modern techniques allow rapid, targeted treatment with minimal side effects — a crucial benefit for patients who cannot tolerate aggressive therapies.

At ICRR-2027, world experts will present breakthroughs across the entire spectrum of modern radiotherapy: from molecular and cellular mechanisms to clinical implementation, from AI-driven treatment planning to heavy-ion and proton therapy, from radiopharmaceuticals and BNCT to nanoparticle-enhanced treatments, from radiobiological personalization to global strategies for addressing the rising cancer burden. The congress will highlight how cutting-edge science, advanced technology, and clinical innovation converge to create a new era of cancer treatment.

Next-generation radiotherapy is not just an incremental improvement — it is a profound shift in how we understand, target, and treat cancer. It offers new hope for patients, new tools for clinicians, and new strategies for societies facing the escalating challenge of cancer in the 21st century.

4. Radon & Smoking — A Synergistic, Widespread Threat to Public Health and the Economy



Radon (^{222}Rn) is the leading source of natural radiation exposure for the general population and a well-established human lung carcinogen. The Czech Republic belongs to the European countries with the highest indoor radon concentrations, largely due to its geological composition and building characteristics. National surveys consistently show that a significant proportion of Czech households exceed the reference level recommended by international radiation-protection bodies.

Radon (^{222}Rn) is a naturally occurring radioactive noble gas produced from the decay of uranium present in soils, rocks, and groundwater. **Due to its colorless, odorless, and chemically**

inert properties, radon can accumulate indoors without detection, especially in buildings with inadequate ventilation. Prolonged exposure to high radon levels significantly elevates health risks, primarily through the inhalation of radon progeny that emits alpha particles capable of damaging lung tissue.

Epidemiological studies — including large pooled European, North American, and Chinese residential radon analyses — demonstrate a clear dose–response relationship between long-term radon exposure and lung-cancer risk, identifying **radon as the second leading cause of lung cancer following cigarette smoking**. **The risk increases approximately 10–16 % per 100 Bq/m^3** of long-term indoor radon concentration, with no evidence of a safe threshold. **In the Czech Republic, radon is estimated to contribute to thousands of lung-cancer cases annually**, making it one of the most significant environmental carcinogens in the country.

The public-health impact is dramatically amplified by **tobacco smoking**, which remains the dominant cause of lung cancer. **The interaction between radon and smoking is multiplicative, not additive**: smokers exposed to radon have a several-fold higher lung-cancer risk compared to non-smokers at the same radon level. This synergy is one of the clearest examples of combined environmental and behavioral carcinogenesis. As a result, radon-attributable lung-cancer incidence is disproportionately concentrated among smokers, although non-smokers are also affected.

From a biological perspective, when radon undergoes decay, it generates short-lived radioactive progeny such as polonium-218 and polonium-214, which adhere to airborne particles and deposit within the respiratory tract, thereby delivering localized radiation doses. Radon progeny emits alpha particles that deposit high-LET energy in bronchial epithelial cells, **inducing complex DNA damage, chromosomal aberrations, and genomic instability**. Smoking introduces additional carcinogens, promotes chronic inflammation, impairs DNA repair, and alters epithelial cell turnover — together creating a microenvironment highly susceptible to malignant transformation.

The economic consequences are substantial. Lung cancer remains one of the costliest malignancies to treat, with high mortality rates and significant indirect costs attributed to lost productivity. Given that radon exposure and smoking are both preventable risk factors, the synergistic effect between radon and smoking constitutes a major opportunity for cost-effective public health interventions. Strategies such as radon mitigation in residential settings, the enhancement of building codes, systematic radon mapping, and smoking cessation initiatives are among the most effective measures to reduce the burden of lung cancer.

Effective mitigation strategies focus on reducing indoor radon levels by implementing enhanced ventilation, sub-slab depressurization systems, radon-resistant construction practices, and sealing foundation cracks that allow soil gas infiltration. In water supplies containing dissolved radon, aeration and granular activated carbon filtration are efficacious methods for substantially decreasing concentrations prior to distribution. Consistent monitoring through devices such as scintillation cells, solid-state nuclear track detectors, or continuous radon monitors is essential for detecting environments at elevated risk and ensuring that radon levels do not surpass the thresholds recommended by public health authorities.

At ICRR-2027, experts in radiation protection, epidemiology, public health, and policy will examine the radon–smoking interaction through multiple lenses and policy frameworks for reducing exposure and improving health outcomes.

The Czech Republic has long been a leader in radon research, mapping, and regulation, and continues to serve as a model for evidence-based radon-risk management. **Addressing radon and smoking together is one of the most effective strategies for reducing preventable lung cancer** — a scientifically well-understood, technically feasible, and socially urgent public-health priority.

5. Jáchymov and Radiation Balneotherapy — A Unique Czech Contribution to Global Medical Heritage with Medical, Tourism, and Regional Asset

Radiotherapy in balneology, known as *radiobalneotherapy*, represents a distinctive integration of spa medicine with the therapeutic use of natural ionizing radiation. Its development is closely linked to the discovery of radioactivity at the end of the 19th century and to **the long tradition of European spa culture.**

Czech medicine has been historically intertwined with spa treatment, which enjoys a high and internationally recognized standard. **The Czech Republic has achieved numerous milestones in balneology. Teplice—coincidentally the birthplace of the ICRR-2027 Congress Chair, Martin Falk—is considered the oldest spa town in Central Europe**, with the first written references dating back to the 8th century. Among the world's most renowned spa destinations is Karlovy Vary, founded in 1358 by the Holy Roman Emperor Charles IV of the Luxembourg dynasty.

The world's first radon spa was established in 1906 in Jáchymov, located 20 km north of Karlovy Vary in the Ore Mountains. However, the therapeutic use of radon in this region had been documented already in the late 19th century.

A key impulse for the development of radiobalneotherapy came from the groundbreaking research of Marie and Pierre Curie, who isolated radium and polonium in 1898—remarkably, using ore tailings from the Jáchymov mines. Around this time, it became clear that certain spa springs contained radon (^{222}Rn), a radioactive gas formed by the decay of uranium. This discovery prompted physicians and physicists to intensify research into its biological effects and, subsequently, its therapeutic potential.

The success of Jáchymov physicians, who used radon-rich mine water for therapeutic baths, led to the expansion of radon-based treatments in other European spa centers in the early 20th century, including Teplice, Bad Gastein, Bad Kreuznach, Bad Brambach, and Bad Oberschlema. During this period, the healing properties of radon were often overestimated—sometimes commercially. Products such as radon butter, radon bread, and radon beer appeared on the market, and patients were advised to drink radon-rich water six to eight times daily, even after returning home from their spa stay.

Radiobalneotherapy experienced its greatest development between 1918 and 1938, when it became an established component of spa medicine. Systematic research into the effects of low-dose radiation on the human body was conducted, treatment protocols were standardized, and dosing and indications became more strictly regulated.

The importance of this therapeutic approach did not diminish after 1945 and continues to this day. **Radiobalneotherapy is practiced in several spa centers, particularly in Central Europe (notably in the Czech Republic, Austria, Germany, Poland, and Hungary)**. Radon therapy is administered through water baths or inhalation in underground galleries. **Based on extensive experience and intensive radiobiological research, treatment strategies are continuously refined to minimize potential adverse effects of ionizing radiation**. Indications and contraindications are clearly defined. The most suitable indications include chronic musculoskeletal disorders such as osteoarthritis, rheumatoid arthritis, ankylosing spondylitis, and certain chronic pain syndromes.

Jáchymov is also home to another globally unique therapeutic method: non-oncological brachyradiotherapy using radium-226, practiced since 1911. This treatment, historically known as the "Jáchymov boxes" (or "radium boxes"), involves applying small containers with radium directly to the patient's skin at the affected site. It is a one-time procedure lasting several hours, depending on the required radiation dose. It is indicated primarily for severe chronic arthritic pain, advanced ankylosing spondylitis, and intractable neuralgias and neuritis—especially in elderly patients for whom surgical treatment is contraindicated.

Radiotherapy in balneology thus represents a unique fusion of natural healing resources, modern physics, and radiobiology. From the early enthusiasm following the discovery of radioactivity, it has evolved into a regulated and scientifically monitored therapeutic discipline. Despite occasional controversies, it continues to hold an important place in spa medicine, particularly in Central Europe, where it has deep historical roots. Prominent and respected centers include Jáchymov in the Czech Republic, St. Blasien-, Menzenschwand, and Bad Brambach in Germany, and Bad Gastein in Austria.

At ICRR-2027, these unique Czech therapeutic modalities will be presented alongside current radiobiological research. Discussions will focus on how scientific advances can further enhance the safety and effectiveness of radiobalneotherapy. Given the limited availability of this treatment in other countries, the continued development of radiation balneotherapy in the Czech Republic offers a rare combination of preserving tradition, improving care for both Czech and international patients, strengthening medical tourism, and revitalizing regions that were once flourishing spa centers but later affected by uranium mining and decades of neglect.

6. Ultraviolet (UV) radiation — The Primary Catalyst for Melanoma, One of the Most Rapidly Progressing and Frequently Lethal Forms of Cancer

Ultraviolet (UV) radiation is the most widespread form of non-ionizing radiation that humans encounter in everyday life. Although UV photons do not carry enough energy to ionize atoms in biological tissues, they are biologically highly damaging. UV radiation is the leading environmental cause of melanoma, one of the fastest-growing and deadliest cancers worldwide. Its impact is profound because UV exposure induces characteristic DNA lesions — especially cyclobutane pyrimidine dimers and 6-4 photoproducts — which can trigger mutations that drive malignant transformation.

Melanoma incidence continues to rise sharply across Europe and globally, with particularly alarming trends among younger adults. **This makes UV radiation not only a scientific concern but a major public-health priority**. Understanding how UV light damages DNA, overwhelms cellular repair mechanisms, and suppresses local immune responses is essential for designing effective prevention strategies, improving early detection, and reducing mortality.

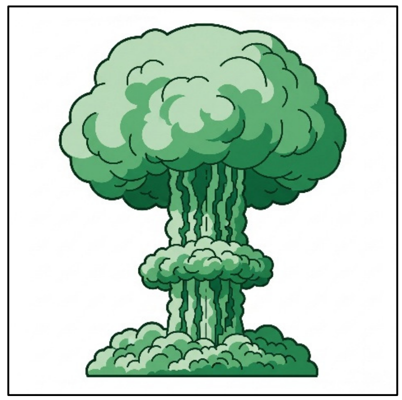
Modern radiobiology has shown that even low-level, repeated UV exposure accumulates into significant genetic damage. These mutational signatures are now well-established hallmarks of melanoma and are transforming approaches to dermatology, oncology, and public-health policy. Advances in molecular diagnostics, dermatoscopy, and AI-assisted imaging are improving early detection, while new photoprotective materials and sunscreen technologies offer better prevention.

At ICRR-2027, leading experts will present the latest breakthroughs in UV-induced carcinogenesis, molecular biomarkers for early melanoma detection, and innovative approaches to prevention. Discussions will also address how climate change, ozone variability, and lifestyle shifts are altering global UV exposure patterns — creating new challenges for public health and requiring updated strategies for risk communication and protection.

By deepening our understanding of UV radiation and its biological effects, we gain powerful tools to protect future generations. The science is unequivocal: melanoma is one of the most preventable cancers, and the knowledge shared at ICRR-2027 will help translate scientific knowledge into effective public-health action.

SAFETY — NATIONAL RESILIENCE IN A VOLATILE WORLD

7. Radiation and CBRN Safety & Czech National Resilience — A Cornerstone of National Security and Public Protection in an Era of Nuclear Tension and New Energy Projects, National and Cross-Border Emergency Preparedness



Radiation safety stands as one of the essential pillars of modern civilization. It protects human health, safeguards the environment, and ensures that the many benefits of ionizing radiation — in medicine, industry, research, and energy — can be used safely and responsibly. **Today, this field is more important than ever**. Our understanding of radiation effects continues to evolve, enabling experts to design protective measures and clear procedures for radiation workers, emergency responders, and the public.

Yet the world around us is changing rapidly. **Global security instability has brought new and complex risks**: armed conflicts near nuclear facilities, the need to protect nuclear infrastructure from both physical and cyberattacks, and the growing threat of radiological materials being misused for malicious purposes. The International Atomic Energy Agency (IAEA) repeatedly warns that strengthening the protection of radioactive materials and critical infrastructure is now a global priority.

A particularly serious concern is the potential misuse of high-activity radioactive sources — commonly used in healthcare — to construct radiological dispersal devices, often referred to as “dirty bombs.” Such scenarios, once considered unlikely, must now be taken seriously.

Radiation emergencies — whether caused by accidents, technological failures, or deliberate attacks — can have profound and long-lasting consequences. These include acute radiation injuries, increased cancer risks, psychological and social disruption, environmental contamination, and significant economic losses. Entire regions may require evacuation or long-term restrictions, and critical infrastructure can be severely affected.

This is why the work of scientists and specialists in radiation safety is indispensable. Their research helps us understand risks, prevent incidents, and minimize consequences when emergencies occur. **Today’s innovations include advanced decontamination technologies, nanomaterials capable of capturing and immobilizing radionuclides, and new generations of protective equipment. Equally important is the development of improved physical and biological methods for assessing radiation exposure. Research on biomarkers, for example, is opening the door to rapid triage of victims directly at the scene of an incident and later in hospital care**.

These advances significantly strengthen our ability to respond to radiation risks and maintain a high level of safety in a world facing rapidly evolving security challenges.

The organizer of the International Congress on Radiation Research (ICRR-2027) is the Czech Society for Radiobiology and Crisis Planning — a partnership that reflects a deep and natural connection. It highlights the urgent need to ensure that the Czech healthcare system and the Integrated Rescue System (IZS) are prepared for the consequences of serious emergencies involving dangerous radiation exposure.

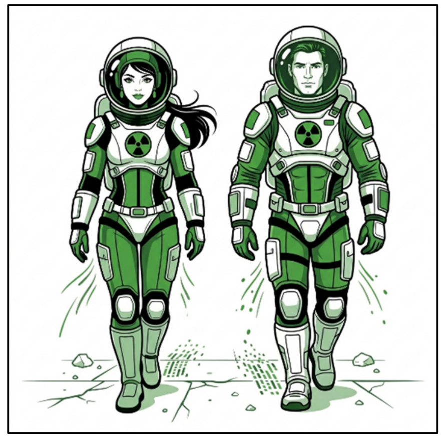
Preparedness for such events cannot be separated from crisis readiness in general. Healthcare crisis preparedness — including medical crisis planning — is not a luxury. It is a near-existential requirement for protecting the population and ensuring the security of the state.

For many years, the importance of healthcare preparedness was underestimated. Numerous conferences and expert meetings, including sessions held in the Chamber of Deputies of the Parliament of the Czech Republic, have repeatedly warned about the unsatisfactory state of readiness — so far without meaningful improvement. Experts have summarized the issue succinctly: without a prepared healthcare system, there can be no real security, nor even effective protection of the population.

ICRR-2027 will therefore include a dedicated symposium on healthcare crisis preparedness, led primarily by Czech experts but open to leading specialists from abroad. The goal is not to expose shortcomings, but to use the presence of world-class experts to enrich the discussion, share solutions, and highlight the potential for improvement. The Czech Republic is not alone in facing these challenges — but it has the opportunity to lead by example.

In the context of today's dramatic international security situation, this topic deserves the highest attention. Support and patronage from the country's top constitutional officials would send a clear message: building national security is not only about armaments — it is about preparedness in every dimension, including healthcare.

8. Space Radiation & Human Spaceflight — Advancing Space Radiobiology Studies for the Inevitable Human Space Age-II



As we prepared this brochure, the Artemis II mission is approaching the most distant point from Earth that any human has ever reached. For the first time in fifty-six years, humanity is returning to the Moon — and the crew of Artemis II will become the first people in history to witness parts of the Moon's far side with their own eyes. At a moment when our own planet is facing profound and often tragic challenges, Artemis II stands as a powerful reminder of what humanity can accomplish when knowledge, courage, and international cooperation prevail. It is a symbol of our highest aspirations — and a call to protect the world we have while reaching for the worlds beyond. It must be emphasized that **ionizing radiation remains one of the greatest challenges in the renewed human quest to reach the Moon and, ultimately, Mars**. For the Artemis II crew, mastering the ability to protect themselves from an unexpected solar flare is not just a technical requirement — it is a mission-critical skill. Their training reflects the reality that radiation **is the single most formidable natural hazard awaiting humanity beyond Earth's protective magnetic shield**.

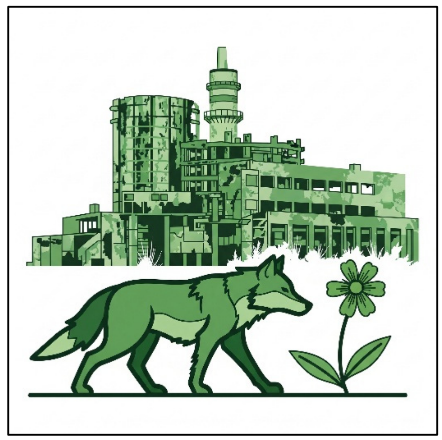
The Artemis-II Mission for the Moon marks a clear resurgence in human interest for exploring interplanetary terrestrial environments, discovering valuable universal resources, and even building human bases for transitory habitation. **As more countries as well as private companies stepping into the race to build space stations and the frequency of human space missions increases, astronaut exposure to Galactic Cosmic Radiation and Solar Flares will surely become more frequent and extensive in the near future**. The subsequent health risks to astronauts are thus inevitable.

Radiobiological effects of Heavy Ions in the space environment, especially due to the compounding effects of microgravity, isolation, and altered circadian rhythm or psychological stress during long-term missions, need greater understanding. Studies on the biological effects of space radiation and long-term disease susceptibility are therefore urgent. An additional noteworthy aspect of human exposure arises from the fact that astronauts are subjected to **mixed and complex radiation fields**. The effects of such exposures are only partially understood; however, they unquestionably cannot be regarded merely as a cumulative sum of the effects of individual radiation components.

From the scientific point of view, it is critical to unravel molecular pathogenesis and long-term susceptibility factors following prolonged exposures to GCR during human space missions.

The ICRR-2027 Congress expects leading research contributions in the following Space Radiobiology topics: Acute or delayed health effects of prolonged exposures; Carcinogenesis risks; Neurocognitive effects; Microgravity effects; Confounding effects of circadian disturbances and other factors; Molecular pathogenesis studies in animal models; Simulation of intracellular, extracellular or systemic pathways; Transgenic models for long-term susceptibility factors; Epigenetics of prolonged exposures; Exploring the effects of allelic polymorphisms; Transgenerational studies; Molecular cytogenetics; Modelling studies; besides other relevant topics in this area.

9. Radiation Accidents and Disasters — Learning from the Past to Protect the Future



Our understanding of ionizing radiation — its risks, its long-term effects, and its impact on both human health and the environment — has been shaped by some of the most tragic events in modern history. **These disasters, though devastating, have provided the world with irreplaceable scientific knowledge that now forms the backbone of global radiation protection**.

The atomic bombings of Hiroshima and Nagasaki created the most comprehensive long-term dataset on the effects of acute, high-dose radiation exposure. Over decades, these data have revealed essential insights into cancer risks, genetic and trans-generational effects, and the remarkable resilience and vulnerability of human biology. They remain the cornerstone of modern radiation safety standards. **Chernobyl — whose 41st anniversary will be marked in 2027** — offered the world the most extensive evidence on the consequences of large-scale environmental contamination and chronic low-dose exposure. It also provided unprecedented insight into how radiation affects ecosystems, wildlife, and entire landscapes. The Chernobyl Exclusion Zone has become a living laboratory, showing both the fragility and the surprising adaptability of nature under long-term radiation stress. **The Fukushima Daiichi accident of 2011** became a defining moment in global nuclear safety, not because it revealed unknown risks, but because it demonstrated how extreme, compound external events can simultaneously disable multiple protective layers. Triggered by a massive earthquake and an unprecedented tsunami, the accident was ultimately driven by a prolonged loss of electrical power and cooling

— a station blackout that confirmed a reality long understood by safety and security professionals: nuclear safety must be built on the principle of expecting the unexpected, including scenarios far beyond conventional design assumptions.

This insight has acquired even greater relevance in today's security environment. Russian military actions affecting nuclear facilities in Ukraine — at both the Chernobyl site and the Zaporizhzhia Nuclear Power Plant — have shown that loss of off-site power, isolation of facilities, and prolonged disruption of safety systems are no longer hypothetical scenarios. At the same time, modern nuclear safety must now explicitly address emerging threats such as cyberattacks on control systems, disinformation campaigns, and the potential misuse of unmanned aerial systems, including drones. These risks, whether military, terrorist, or hybrid in nature, reinforce the need for resilience against prolonged blackouts, external interference, and cascading failures — preparedness for which has become unprecedentedly critical.

The Czech Republic's nuclear safety framework is already firmly grounded in these principles. Its regulatory system, operational culture, physical protection standards, and cybersecurity requirements rank among the most stringent internationally. This reflects a long-standing commitment to conservative design, multiple layers of defense, and continuous verification — not only against historically known hazards, but also against evolving technological and security threats. This approach, strengthened through post-Fukushima stress tests, international peer review, and close cooperation with allied institutions, forms a cornerstone of national security, energy stability, and public confidence.

Fukushima also left another, more ambiguous legacy. In parts of Europe — most notably in Germany — **the accident accelerated a political retreat from nuclear energy and led to the closure of highly modern and safe nuclear power plants. With today's experience, it is increasingly evident that this path has weakened energy security**, increased dependence on fossil fuels, and complicated climate commitments. **The emerging consensus is clear: nuclear energy is an indispensable component of a secure, low-carbon energy mix. Rather than withdrawal, the true lesson of Fukushima is the need to invest even more decisively in advanced nuclear technologies, scientific excellence, highly trained operators, and robust safety and security research** — ensuring that nuclear energy continues to support energy sovereignty, technological progress, and long-term resilience.

The extensive datasets obtained from the nuclear disasters are not static historical records. They are continuously re-evaluated, re-interpreted, and refined as new scientific methods emerge. Advances in genomics, dosimetry, epidemiology, and environmental science allow researchers to revisit decades-old data with fresh eyes — revealing new patterns, correcting earlier assumptions, and improving our understanding of radiation risks. This ongoing scientific process is one of the central themes of ICRR-2027, where experts from around the world will present the latest reinterpretations of these foundational datasets. Among them will be specialists from Ukraine and Japan who directly participated in the Chernobyl and Fukushima emergency response efforts, bringing invaluable first-hand experience to the congress discussions.

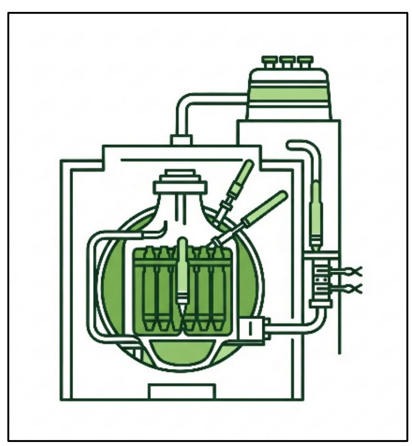
Together, the lessons from Hiroshima, Nagasaki, Chernobyl, Fukushima, and other radiological events form the most complete body of knowledge humanity possesses on radiation effects. **They guide emergency response strategies, medical triage protocols, environmental monitoring systems, and international safety standards**. **They also help us reduce risks from the rapidly expanding use of medical imaging** — now the largest source of man-made radiation exposure to the global population.

As we look toward 2027, the message is clear: the past must inform the future. Modern research builds on these hard-won **insights to develop better predictive models, more effective decontamination technologies, and more accurate methods for assessing exposure in both humans and non-human organisms. New biomarkers promise faster triage in emergencies. Advanced materials and nanotechnologies offer improved ways to capture and immobilize radionuclides**. **Ecological studies reveal how radiation reshapes entire ecosystems over generations**. By learning from the past, we honor the victims of these tragedies. By applying these lessons, we ensure that their suffering leads to safer technologies, better protection, and a more resilient future for all.

The International Congress on Radiation Research (ICRR-2027) will bring these themes to the forefront. It will highlight how the continuous re-evaluation of historical data — combined with cutting-edge radiobiology — strengthens global preparedness in an era of expanding nuclear energy, increasing medical radiation use, and rising geopolitical instability.

TECHNOLOGY & ECOLOGY — INNOVATION FOR A SUSTAINABLE FUTURE

10. Nuclear Energy and Emerging Reactor Technologies — The Only Powerful, Stable, Low-Carbon Pillar of Europe's Future Energy Mix for the (Near) Future



The energy sector covers many areas of R&D&I. It has a crucial impact on society, industrial production, buildings, mobilities and the environment. A secure and cost-effective energy supply is a major factor for

economic development and safety. Worldwide electricity consumption is constantly increasing, regardless of progress in efficiency of transmission or reduction of energy needs in industry.

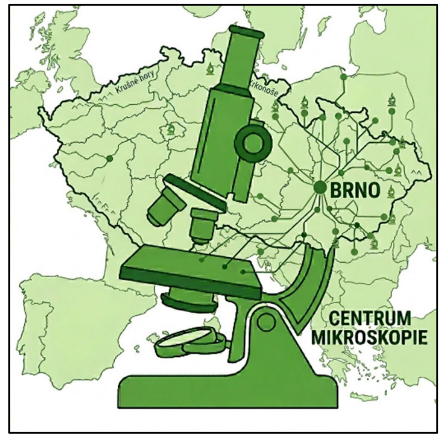
Even though the global role of nuclear energy has been decreasing in the electricity mix, it continues to have an important share. Innovation is the key to an expanding role for nuclear energy. The strategic objectives in nuclear energy are safety aspects, nuclear science (e.g., advanced nuclear technologies for fission and fusion, and accident-tolerant fuels), radioactive waste management, radiological protection, and nuclear education. **A new generation of advanced nuclear technologies is being actively developed (e.g., fast neutron reactors, including sodium- and lead-cooled systems; Molten salt reactors; Thorium-based systems and accelerator-driven subcritical reactors)**.

Small modular reactors (SMRs) have emerged as one of the most promising near-term innovations. Their modular design allows for factory fabrication, standardized components, and incremental deployment, reducing construction risks and enabling faster project timelines. In addition to electricity generation, SMRs can provide high-temperature heat for industrial processes, district heating, and hydrogen production. Emerging engineering concepts can be also mentioned, i) **deep-borehole reactors placed at depths of over one kilometer, using the surrounding geology as a natural barrier and pressure vessel**; ii) **microreactor technologies–ranging from transportable container-sized units to long-life "nuclear batteries"**–are being developed to supply reliable **energy to remote regions, critical infrastructure, military bases, and for deep space planetary missions**.

These developments are particularly relevant for countries like the Czech Republic, with its long-standing expertise in nuclear engineering. The Czech Republic is thus well-positioned to contribute to international collaborations and to benefit from emerging global markets in SMR and advanced reactor technologies. Participation in the development and deployment of advanced nuclear technologies can strengthen domestic supply chains, stimulate high-value engineering and manufacturing sectors, support scientific research and innovation, and education.

In the coming decades, modular and advanced nuclear systems are not expected to replace all existing energy sources. However**, they can play a crucial role as a stable backbone of a diversified, low-carbon energy mix, supporting the integration of renewable energy and ensuring long-term energy security**.

11. Brno: A Global Microscopy Hub — Seeing the Invisible in Space and Time



Understanding radiation-induced processes requires the ability to observe life at its most fundamental scales — to watch DNA break and repair, to follow proteins as they assemble and respond to stress, and to visualize molecular events unfolding in real time. Modern microscopy has transformed this challenge, allowing scientists to study radiation effects in space and time, down to the level of individual molecules.

Brno stands at the forefront of this revolution. **The city is home to one of the world's most concentrated clusters of companies and research institutions specializing in electron microscopy and advanced imaging technologies**. With a tradition spanning more than 70 years, Brno has become a global powerhouse whose electron microscopes are used in laboratories, hospitals, and high-tech industries across the world. These instruments enable researchers to visualize structures at the nanometer scale — from DNA repair complexes to radiation-damaged materials.

While Brno is not a manufacturer of complete super-resolution optical confocal microscope systems, **its research institutions are major users and developers of cutting-edge optical microscopy methods, integrating them into biological, medical, and materials-science research**. Through cooperation with Heidelberg University, ICRR-2027 participants will also gain access to single-molecule localization microscopy (SMLM) — a unique super-resolution technology that breaks the diffraction limit and allows radiation-induced processes to be studied across multiple spatial scales, from whole cells down to individual molecular events.

To support the next generation of radiation researchers, ICRR-2027 will feature an associated theoretical and hands-on course on microscopy and spectroscopy in radiation research. Participants will learn how to apply advanced imaging techniques — from electron microscopy to super-resolution optical methods — to visualize DNA damage, repair dynamics, chromatin remodeling, and radiation-induced cellular responses.

The congress will also include an excursion to Brno's leading microscopy companies, offering delegates a rare opportunity to see where world-class electron microscopes are designed and built, and to meet the engineers and scientists driving innovation in imaging technology.

Brno's microscopy ecosystem fuels advances far beyond radiation biology. Its instruments and expertise are central to breakthroughs in materials science, semiconductor engineering, nanotechnology, medicine, and environmental research. The city's unique combination of academic excellence, industrial strength, and technological innovation has made it a global destination for imaging specialists and a key contributor to the Czech Republic's scientific and economic growth.

By enabling us to visualize the invisible, Brno's microscopy community is helping to unlock the deepest mysteries of radiation biology and paving the way for breakthroughs in science, medicine, and technology.

12. Lasers & Laser-Driven Radiation — ELI Beamlines as a World-Class Czech Research Flagship

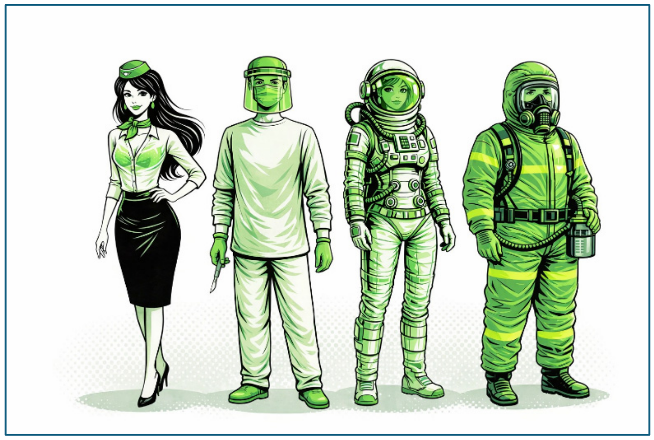
The ELI Beamlines facility in Dolní Břežany is a unique laser research infrastructure providing some of the world's most powerful lasers to the international scientific community. In addition to fundamental research in laser, plasma, and astrophysics, one of the strongly supported and rapidly developing fields at ELI is radiobiology, with clear potential for future clinical translation.

Over 50 % of cancer patients worldwide are in need of radiation therapy in the course of their treatment. However, access to modern treatment centers is limited, and further technological innovation in accelerator development is essential. Researchers face the same limitations in accessing beamtime at large particle accelerators — facilities that are indispensable for their experiments. This is especially true for studies of high-LET space radiation and for the development of new, safer, and more effective cancer therapies based on beams of accelerated heavy ions. **ELI Beamlines explores laser-driven accelerators as novel sources of ionizing radiation for medical applications, offering a complementary approach to conventional machines. Their spatially compact, potentially more economical, architecture and their distinctive beam characteristics, such as ultra-short pulses and extremely high instantaneous dose rates, could be beneficial for both technological innovation and radiobiological research**. These properties may not only improve the accessibility of advanced radiotherapy but could also lead to enhanced biological effectiveness under specific conditions.

Currently at ELI Beamlines, radiobiological experiments with laser-driven protons, electrons, and X-rays are already being conducted and **are accessible to international users through biannual calls for proposals. The number of available radiation types is continuously expanding, and beam parameters are steadily improving. In the near future, the infrastructure is expected to include heavier ions such as carbon, nitrogen, or neon, further strengthening not only the scientific excellence of the facility but also the long-term potential for societal benefit**.

This shows the flexibility provided by laser-driven accelerators and explains the significant interest from the scientific community, ICRR-2027 participants included. **I had the honor to briefly meet you during your visit to our facility in 2024, and as you noted, we have this unique technology in our "backyard" and should use it to its full potential and share it with the world – the congress represents an ideal opportunity to do so. The Czech Republic can showcase its advanced radiation research, strengthen international collaborations, and reinforce its role as a hub for innovation with global relevance.**

13. New Radioprotective Materials



Current radiation-shielding materials remain fundamentally inadequate: they rely on heavy lead plates or dense composites such as Demron that are bulky, non-breathable, and opaque. Their weight and handling requirements severely limit practical use—mobility is restricted, external cooling is often needed, and prolonged wear is impractical—so in many critical activities these protections cannot be used effectively.

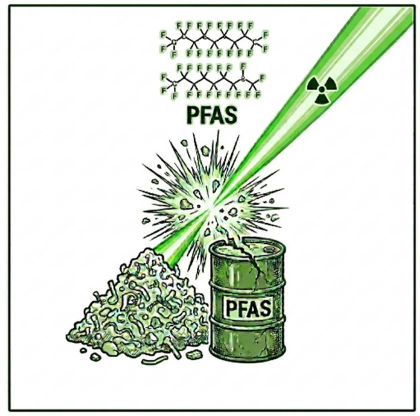
A new generation of shielding textiles/foils is now under development based on micro- and nano-fibers doped with low-toxicity shielding components. These advanced materials promise transformative, wide-ranging benefits: dramatically lighter and more comfortable protective garments; breathable and even transparent shielding enabling protective goggles and face shields previously impossible; and reduced health risks compared with heavy lead-based solutions. Immediate, high-impact applications include

- **radiation-protective undergarments for aircrew (protecting breast tissue vulnerable to cancer),**
- **lightweight protective apparel and eye/face protection for interventional surgeons working under X-ray,**
- **tailored suits for astronauts and first responders,**
- **and modular multilayer solutions for CBRN incident response.**

The societal importance is urgent: improving occupational and public protection against ionizing radiation will save lives, reduce long-term healthcare costs, strengthen emergency preparedness, and position our research and industry at the forefront of a strategically vital field. The International Conference on Radiation Research (ICRR-2027) will gather the leading scientific teams and industrial partners advancing these technologies and translating them into practical solutions.

Of course, lasers have much wider applications, from direct usage in medicine to industry and, e.g., the military.

14. PFAS & Microplastics — Application of Ionizing Radiation for Environmental Remediation and Water Treatment



The escalating contamination of water resources by persistent and emerging pollutants represents a major challenge for environmental protection, public health, and sustainable infrastructure. Among the most problematic contaminants are per- and polyfluoroalkyl substances (PFAS), a large class of synthetic chemicals, including **Teflon**, used in industrial processes, firefighting foams, textiles, and consumer products. Their extreme chemical stability — driven by the strength of carbon–fluorine bonds — makes them resistant to conventional treatment methods, and PFAS are now detected in drinking-water sources worldwide and contribute to the extreme environmental risks.

At the same time, **microplastics, radon contamination,** and **complex mixtures of industrial pollutants are accumulating in aquatic environments**, highlighting the limitations of traditional water-treatment technologies based on chemical oxidation, filtration, or biological degradation. These systems often fail to break down highly persistent molecules or require large quantities of chemicals, generating secondary waste streams.

Ionizing radiation technologies, particularly electron-beam (e-beam) irradiation, offer an innovative, scalable, and chemically clean strategy for environmental remediation. When high-energy radiation interacts with water, it induces water radiolysis, generating highly reactive oxidative and reductive species — hydroxyl radicals (•OH), hydrated electrons (e^-_{aq}), and hydrogen atoms (•H). These intermediates can degrade persistent organic pollutants, modify polymer structures, and inactivate pathogens **without the need for added chemicals**.

- **PFAS:** Experimental studies have demonstrated that electron-beam irradiation can effectively degrade PFAS such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), producing shorter intermediates and releasing fluoride ions during defluorination. **Radiation-based advanced oxidation and reduction processes (AORPs) are particularly attractive, as they operate without the need for supplementary chemical**

reagents and can be seamlessly integrated with biological or catalytic treatment modalities to enhance removal efficiency. Operational studies indicate that the radiation component of e-beam treatment costs <0.4 USD per m^3, with total treatment costs (including biological post-treatment) around 1.1–1.2 USD per m^3, making this approach competitive with advanced oxidation technologies such as ozonation or Fenton chemistry.

- **Mitigation of microplastics contamination:** Ionizing radiation has been extensively studied for the remediation of microplastics in aquatic environments. Gamma and electron-beam irradiation induce polymer chain scission and oxidative degradation in plastics such as polyethylene and polypropylene, thereby reducing molecular weight and introducing oxygen-containing functional groups that enhance hydrophilicity and susceptibility to biodegradation or filtration. Additionally, radiation treatment can alter the surface charges of microplastics, thereby improving sedimentation and removal efficiency during wastewater treatment processes.
- **Water Purification and Environmental Remediation:** Ionizing radiation is progressively utilized in water purification and environmental remediation, where it can facilitate the degradation of organic pollutants and serve as a disinfectant for microorganisms concurrently. Electron-beam irradiation has been effectively implemented in large-scale industrial facilities for the treatment of dyeing wastewater and other refractory effluents. In full-scale treatment plants processing tens of thousands of cubic meters of wastewater daily, operational costs for electron-beam treatment are estimated to range from approximately 0.28 to 0.35 USD per cubic meter, demonstrating that radiation-based treatment can be economically competitive with chemical advanced oxidation processes such as Fenton oxidation. Although the capital investment for electron-beam accelerators may range from several hundred thousand to several million USD per m^3, depending on capacity, the technology offers advantages including high throughput, minimal chemical consumption, and continuous automated operation, which can contribute to lowering the overall cost per unit of treated water. Therefore, electron-beam irradiation is increasingly regarded as a cost-effective advanced treatment option for emerging contaminants such as PFAS, pharmaceuticals, dyes, and microplastics, particularly when integrated with conventional biological or physicochemical treatment methods.

Developing and deploying radiation-based technologies aligns national and international priorities for:

- **resilient water infrastructure**,
- **mitigation of emerging contaminants**,
- **sustainable environmental management**,
- and **circular economy strategies**.

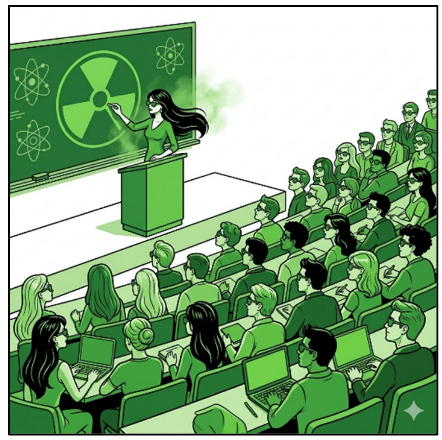
Ionizing radiation offers a chemically clean, highly effective, and scalable approach to addressing some of the most persistent pollutants of the 21st century. As accelerator technologies continue to advance, radiation-based remediation is poised to become a key component of next-generation water treatment systems. Recent advances in accelerator design, energy efficiency, and modular deployment have made radiation-based treatment increasingly practical for large-scale water purification.

Treatment Technology	Typical Cost Range (USD m^{-3})	Key Cost Drivers	Advantages	Limitations
Electron Beam Irradiation	0.25 – 1.20	Electricity consumption, accelerator maintenance	Chemical-free process; effective for PFAS and refractory contaminants; rapid treatment	High capital investment
Fenton / Advanced Oxidation	0.50 – 1.50	Chemical reagents, sludge disposal	Strong oxidation capability for organic pollutants	Chemical consumption and sludge generation
UV / UV-H_2O_2 Treatment	0.20 – 0.80	Electricity, lamp replacement	Effective for disinfection and some micropollutants	Limited effectiveness for highly persistent contaminants
Chlorination	0.02 – 0.10	Chemical dosing and monitoring	Very low cost; widely used for disinfection	Formation of disinfection by-products; ineffective for PFAS
Membrane Filtration (RO/NF)	0.50 – 2.00	Energy for pressure, membrane replacement, fouling control	High removal efficiency for dissolved contaminants	High energy demand and concentrate disposal

Table: Operational Cost Comparison of Water Treatment Technologies: To evaluate operational feasibility, approximate treatment costs per cubic meter (USD m^{-3}) for several common water treatment technologies are summarized below. Actual costs vary depending on plant capacity, contamination concentrations, energy costs, and system design. These comparisons indicate that radiation (e.g., electron-beam) treatment can be economically competitive with other advanced treatment methods, particularly when targeting contaminants that are resistant to conventional chemical or biological processes. While EB systems require higher initial capital investment, their low chemical requirements and ability to treat large wastewater volumes make them attractive for industrial effluents and emerging contaminant removal. Hybrid systems combining (electron-beam) irradiation with biological treatment or membrane filtration may further reduce overall treatment costs while improving removal efficiency for complex pollutant mixtures.

EDUCATION — BUILDING THE NEXT GENERATION OF EXPERTS AND INFORMED SOCIETY

15. Education & Public Engagement in Radiation Science — Investing in the Next Generation of Experts and Decision-Makers, and Fostering an Informed, Resilient Society.



Building a safe, innovative, and resilient future requires more than scientific excellence — it requires a society that understands radiation, its real risks, its benefits, and its transformative potential. **Education and public engagement are therefore central pillars of ICRR-2027, designed to inspire young people, strengthen professional training, and foster informed public dialogue**.

Public lectures, **open debates**, and **outreach events** will bring leading global experts into direct contact with students, teachers, journalists, and the general public. In cooperation with the Brno Observatory and Planetarium and other partner institutions, **radiation research and its applications will be actively communicated to the wider population through popular-science lectures accompanied by moderated discussions**. **These activities will help demystify radiation, counter misinformation, and present a balanced, evidence-based view of radiation effects, applications, and protection**. Through collaboration with major Czech and international scientific, medical, technological, and governmental institutions, radiation-related topics will be **widely mediated in Czech media, ensuring that accurate and accessible information reaches broad audiences**.

To support the next generation of specialists, **ICRR-2027 will feature eye-opening educational lectures for students, a special symposium for students and early-career scientists, and a rich program of hands-on courses supported by Czech and international companies**. Outstanding contributions will be recognized through **poster awards**, **Young Investigator Awards from the European Radiation Research Society (ERRS)** and **the European**

Space Agency (ESA), and other incentives designed to motivate and empower emerging talent.

ICRR-2027 will also host an associated symposium of the MSCA RADAM project, dedicated to cultivating a new generation of excellent PhD students within a vibrant international community of world-leading experts. To maximize the congress's attractiveness and impact for students and early-career researchers, a dedicated Committee for Students and Early Career Scientists has been established to shape the program, coordinate opportunities, and ensure meaningful engagement.

This comprehensive approach — combining public outreach, structured training, international collaboration, and recognition of excellence — strengthens the pipeline of future experts and decision-makers. It also builds a society that is informed, resilient, and capable of navigating the complex challenges and opportunities that radiation science brings.

By investing in education and public engagement today, ICRR-2027 helps secure a safer, more innovative tomorrow.

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