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REVIEW



## Education and training to support radiation protection research in Europe: the DoReMi experience

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### ABSTRACT

A review is presented to the program of education and training setup within the DoReMi Network of Excellence. DoReMi was funded by Euratom under the EU 7th Framework Programme to coordinate the EU research into risks from low-dose ionizing radiation. It was seen to be necessary to form a network of expert institutions in order to tackle the scientific questions with the resources available. From the start, importance was given to the need to stimulate and support education and training to build up the capability of the research community. DoReMi dedicated a workpackage to education and training that put in place a number of activities that have been successful in attracting new students into the area and introducing research scientists to new topic areas and technologies. The program of education and training in DoReMi provided a significant contribution to the low-dose radiation research community and has been further developed and extended in the following Euratom-funded project OPERRA and the European Joint Programme CONCERT.

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### Introduction and background

At the low level of radiation exposure generally of concern for radiation protection, the incidence of radiation-induced harmful effects can be obscured by the noise in natural occurrence rates. To obtain reliable radiation risk estimates requires studies over many years, even decades, employing a wide range of scientific disciplines. This long-term broad-scope process requires management to ensure continuity and cross-fertilization of all the necessary disciplines. It is precisely this stewardship of the necessary resources of knowledge, skills, and expertise that calls for a strategic program of education and training specifically designed to ensure a continuing influx of new top-level students into the needed scientific areas.

It was recognized by the High Level Expert Group (HLEG, <http://www.hleg.de/>) in their report of 2009 that education and training were a key component in the development and maintenance of expertise in the area of research into the risks from exposure to low-level ionizing radiation. The main concern of HLEG was that many EU member states have lost key competences and are no longer capable of independently retaining their current research activities in radiation sciences, with implications for effectively fulfilling operational and policy needs and obligations. The conclusion of the report was that for Europe to progress effectively in answering the questions critical to radiation protection, an integrated coordinated approach is necessary to get maximum advantage from the centers of excellence that remain. The group recommended the formation of a network or platform of institutions with expertise or an interest in radiation

research to be set up to facilitate the practical aspects of coordination.

In 2010, the Network of Excellence (NoE) DoReMi (<http://www.doremi-noe.net/>) was funded for six years by Euratom under the EU 7th Framework Programme to promote the sustainable integration of low-dose risk research in Europe and to provide the initial structure for the platform, MELODI (Multidisciplinary European Low Dose Initiative, <http://www.melodi-online.eu/>). Consistent with the HLEG importance given to education and training (E&T), DoReMi included a dedicated workpackage for E&T. The aim of the E&T workpackage, as formulated at the time of the proposal, was to develop a sustainable integrated network for E&T that would provide and coordinate high-level training for research scientists and a career structure to attract and retain top-level graduates within the research discipline. The objectives of the workpackage were as follows:

- Review the education streams through which students entered the radiation research field;
- Investigate the areas where support for E&T was needed;
- Make an inventory of current courses and educational/research institutes as candidate members of a new integrated network;
- Set up an integrated network with a structure and function that optimally answers the E&T needs with available resources;
- Provide funding support for new courses at the MSc and PhD levels.
- Explore possible sustainable funding to continue E&T support into the future.

## The teaching of radiobiology in Europe before DoReMi

The discipline central to radiation risk research is radiobiology. In 1992, the European Commission (EC) called for a course to be set up to provide a new group of experts in radiobiology to supplement the European capability in radiation protection research. The call was worded as follows:

The aims are to maintain and increase the competence in all fields of radiation protection research by training a small but highly selected group of postgraduate students from all European countries. Teaching is based on a multinational and multidisciplinary network of universities specialised in different areas of radiobiology research.

The course that was supported was the European Master of Science in Radiation Biology. It ran from 1992 to 2012. The degree of MSc was awarded by member Colleges of London University (St Bartholomew's Medical College, London Medical College, University College London), but teaching was spread over five universities in five European countries (the United Kingdom, Belgium, the Netherlands, Germany, and Austria). Teaching covered all aspects of radiobiological research. The various partners taught different aspects: Leiden University taught Molecular Radiation Biology and Cytogenetics; Ludwig-Maximilians University Munich taught Radioecology, Nuclear Energy Production Cycle, and Radiation Protection; Université Catholique de Louvain focused on Medical Radiology; Salzburg University taught metrology and health effects of radon. Formal teaching lasted eight months and was followed by a four months research project which the students could choose from a list of projects offered by radiobiological institutions from all European countries. The funding from the European Commission continued for more than 10 years and amounted to more than €500,000 in total. Altogether more than 140 students were awarded the degree. The course was also supported with studentships from the Swedish Radiation Protection Institute, the Government of Bavaria, and in particular the Fridericus Foundation.

Participants in the course came from a wide area. A quarter was from the former Soviet Bloc, and a fifth from outside Europe. Since more than half of the candidates came with a first degree in biology (the rest mainly from medicine and physics), a major emphasis was on teaching all aspects of physics, dosimetry, medical physics, environmental radioactivity metrology, evaluation of dose distribution over time and anatomy. Most of the students continued with a PhD in radiation sciences or continued working in related research fields. Over the 20 years the graduates have made a considerable contribution to radiation research.

In spite of support for the course from HLEG, it was discontinued in 2012 because the new user-pays fees structure in the United Kingdom meant that it was no longer financially viable. Finding a replacement course or an equivalent means of attracting new students into the field became a major task of DoReMi.

## Education and training in DoReMi, 2010–2015

### Scope of E&T supported by DoReMi and areas of interest

The DoReMi Network of Excellence was created to investigate the low-dose radiation risks that form the basis of the principles of radiation protection. The research topics are: basic mechanisms, health risk evaluation, and impact of radiation exposure characteristics. Therefore, the research is aimed at the understanding and quantification of the risks of the range of manifestations of harm, in the various exposure situations. Importantly, it does not include radiation risk prevention or remediation, so it is not 'radiation protection' in the usual sense. Rather, this research area provides the risk estimates derived from biological and epidemiological data from which radiation protection policy and practice are derived. The E&T support in DoReMi was focused specifically on developing expertise and capability in this area. The range of topics and disciplines was largely defined by the interests and specialization of the institutions that were participating in DoReMi. The topics included:

- Radiation biology
- Molecular and cellular radiation biology
- Cytogenetics
- Molecular radiation epidemiology
- Main principles of radiation genetics and embryology
- Radiosensitivity and possibility for its modification
- Non-targeted radiation effects and epigenetics, their role in low-dose radiation risk
- Immunology
- Physics
  - Initial interactions of radiation with biological systems
  - Track structure modeling
  - Radiation metrology and dosimetry of ionizing radiation
- Mathematics and statistics
  - Radiation epidemiology
  - Systems radiation biology
  - Bioinformatics

### The E&T workpackage in DoReMi

At the time of drafting the DoReMi proposal in 2009, the E&T Workpackage took account of the suggestions contained in the HLEG Report:

International networking of education and training programmes is beneficial. It does not only ease the burden of researchers engaged in education and training but would also broaden the scientific background of the training programmes and contribute to increasing the mobility of the trainees. Graduate school(s) of radiation sciences would to some degree alleviate the lack of sufficient geographically situated experts. One option would be a virtual European school, with an exchange of students between host institutes; the alternative would be a centralized European Graduate School with input from seconded experts.

The EC concept of a Network of Excellence was that a network of collaborating institutions should be developed during a period of EC funding of integration and joint research, leading to a sustainable structure that could continue after the end of the funding period. Accordingly, the

overall aim of WP3 was to set up an organization that could be developed within the structure and funding support of DoReMi, but at the end of the six years could continue as an autonomous body sustained by secure funding. This body was termed an 'Integrated Training and Education Network' (ITEN). It could potentially run courses (as a 'virtual European School' following the HLEG suggestion) or rather have a role promoting or coordinating courses or course elements offered by European education and research institutions. As a corporate structure, it could take whatever form was feasible within the constraints of DoReMi, and whatever was most cost-effective. Initially, the activities of the ITEN would be funded within the rules of DoReMi and FP7. It was intended that the networking would not be restricted to the closed DoReMi consortium, but rather, in the spirit of a Network of Excellence, it would be inclusive rather than exclusive.

A Training and Education Committee (TEC) was formed from representatives of DoReMi partners with an interest in E&T. This formed the consultative group for development of policy and priorities. The first year of E&T activities was taken up with a period of consultation and discussion to develop the structure of the ITEN. The result was as follows:

- The membership of the ITEN consisted of the subset of the DoReMi membership with an involvement in E&T. The FP7 rules restricted financial support to DoReMi members, but by the end of the project this included 15 universities as well as many research institutes active in E&T, so the network represented a substantial body of expertise in the research area. This was a compromise on the initial plan for inclusiveness, but the constraints had to be accepted.
- The management structure of the ITEN was chosen to be simple yet effective. There was no enthusiasm on the part of any party (DoReMi, or the EC) for a separate corporate entity. Instead, a structure that reflected the size of the network and how it could be most effectively run was chosen. In effect, the University of Pavia (UniPv), as work-package leader acted as the ITEN Executive, the TEC as the board of management, and the DoReMi Coordinator as the administration.

A program of actions was formulated, in line with the description of work in the DoReMi contract. This is described in the next sections.

#### *E&T activities sponsored by DoReMi*

DoReMi initiated several E&T activities that continued through the six years' duration of the NoE. One of the most successful of these was the sponsorship by DoReMi of an annual series of short 1–3-week courses hosted by DoReMi members, each featuring the particular expertise of their institution. The courses were funded through annual calls for proposals from DoReMi partners. Proposals were assessed and approved by the TEC and the funding administered by

the Coordinator. There were five calls between 2011 and 2015. The topics covered were as follows:

- Human radiation genetics
- Molecular radiation carcinogenesis
- Cellular effects of low doses and low-dose rates with focus on DNA damage and stress response
- Inter-individual responses to low-dose ionizing radiation: from damage formation to biomarkers
- Non-cancer effects of low-dose radiation
- Radiation epidemiology and radioecology
- Environmental Radiobiology
- Modeling radiation effects from initial physical events
- Data interpretation and uncertainty analysis
- Interdisciplinary radiation research focusing on radiation protection

A total of 38 courses were held. Details of each course are given in the Appendix. Approximately 500 students attended overall. Preference was given to participants from EU countries, but participants from non-EU countries were also accepted if spaces were available. The sponsorship allowed the courses to be offered free of charge with accommodation generally provided for students. This meant that they were widely available, and presented a valuable 'free taster' to give students an introduction to new areas in low-dose research and to get hands-on experience, through the practical sessions, of working in the topic area. Feedback from participants indicated that they also benefited from the opportunities for networking among other students and personnel at the host institutions. There were a number of instances of students subsequently taking up courses of study with course hosts.

DoReMi support was also provided for ad hoc E&T activities. Proposals were submitted to the TEC for approval. A particularly successful event was the one-day course on Systems Radiation Biology, held in Oxford, United Kingdom, in September 2012. It attracted 15 students, many of whom are now respected researchers in the area. This course was one of the first initiatives to introduce the methods of systems biology to modeling the effects of ionizing radiation on biological systems.

Throughout the term of DoReMi, student travel grants were offered to enable students to attend conferences or other institutions in order to further their studies in an area not available at their home institution. And in order to further enhance the training activities, a new funding instrument 'Student project' combining PhD training with research work was established in autumn 2014, resulting in four projects:

- Institut Curie, Paris: Assessing whether carrying a heterozygous mutation in the ATM gene influences telomere length and whether telomere length is influenced by past-radiation exposure
- L'Institut de Radioprotection et de Sûreté Nucléaire (IRSN): Epidemiology of cardiovascular diseases in cohorts of French and Canadian uranium processing workers

- Dublin Institute of Technology Ireland and University of Pavia, Italy: Characterization of low-dose radiosensitivity in Shwachman-Diamond syndrome patients using Raman spectroscopy
- Sofia University 'St. Kliment Ohridski', Bulgaria (SUN): Implementation of the CD/DVD method in the laboratory course on Dosimetry of MSc/PhD students

### *Support for development of a European MSc course in radiation biology*

It was acknowledged both by the authors of the HLEG Report, and by the ITEN, that the key to building up the research capability in low-dose radiation research is to attract new students at the MSc level. This is the level at which the student is deciding on specialization and possible career options. Experience had shown that many of the personnel currently in the field had graduated from the discontinued European Master of Science in Radiobiology described above.

From the original HLEG-driven formulation of the WP3 plan of work it was always intended to investigate possible ways of rebuilding the European Masters course. A review of courses available at the start of DoReMi showed that undergraduate university teaching was largely restricted to training in the principles, rules and regulation of radiation protection to medical students as part of radiology modules. However, these training units contained very little teaching of radiobiology. Most education and training in radiation biology at the postgraduate level was part of Master Courses in Medical Physics. In some universities this extended to complete teaching modules, e.g. in University of Stockholm, in others it was just a small series of lectures closely based on the foundations of radiation protection rules as defined by the International Commission on Radiological Protection (ICRP). Another important mechanism of spreading the current concepts and results of radiobiological research are postgraduate teaching courses which radiation oncologists are expected to attend to qualify for professional accreditation. They are usually concentrated into one week with up to 6–8 lectures per day, most of which are addressing aspects of the radiobiology of early and late normal tissue damage.

There was a clear need to set up a new Masters course, incorporating European expertise as widely as possible, and with the help of DoReMi if possible. A proposal for the cooperative development of a European Masters course supported by the Erasmus Mundus program ([http://eacea.europa.eu/erasmus\\_mundus/index\\_en.php](http://eacea.europa.eu/erasmus_mundus/index_en.php)) was considered. A consortium would be formed from three to five universities possibly within the DoReMi consortium. As per the Erasmus Guidelines, the course would be of two years' extent, Bologna-compliant (the Bologna Process is an agreement between European countries to ensure comparability in the standards and quality of higher-education qualifications), and have a commitment to offer five consecutive editions. The initial planning and coordination of the group of institutions to develop a proposal development could be supported by DoReMi funding, and would have input from the TEC. However, after long consideration, this option was not taken up. Two of the factors were the high level of competition to

get Erasmus funding, and the limited period of continuation. But the main problem was that there was a timetabling incompatibility between universities that offered full-time topic modules in single-term blocks (Scandinavian) and universities that distributed modules over longer times within an integrated course (most other EU). So it was not possible for the interested universities in DoReMi to construct a workable program. At the time of writing, the Erasmus Mundus program has been superseded by Erasmus+ (<https://eacea.europa.eu/erasmus-plus/>).

In the end a single-university MSc was developed at Technische Universität München by DoReMi partners Helmholtz Zentrum München and UniPv: <https://www.tum.de/en/studies/degree-programs/detail/radiation-biology-master-of-science-msc/>

The course is fully Bologna-compliant, two years' full-time, and covers all areas of radiation biology research. Because the course is held in Bavaria, Germany, there are no tuition fees. The first edition started in September 2015. It is organized jointly by the Medical Faculty of the Technical University and the Helmholtz Centre Munich in cooperation with two other local academic institutions: Bundesamt für Strahlenschutz BfS, Munich and Medical Academy of the German Armed Forces, Munich.

### *An annual networking forum*

It was important throughout the six-year period that DoReMi was in touch with the needs of the research community and aware of what was going on in European E&T in the low-dose research and related areas. To this end, the concept of a regular forum was developed to enable the members of the network of DoReMi institutions engaged in E&T to get together for discussions. The purpose of the forum was as follows:

- Networking function; to get the key individuals from the key institutions together
- Define and clarify the E&T needs of the low-dose research community
- Discuss and resolve practical problems of access and mutual recognition
- Compare priorities and initiatives with other radiation protection platforms

The first such forum was a half-day Workshop that was held in conjunction with the Third MELODI Workshop in Rome, on 2 November 2011. The meeting reviewed some of the existing European courses relevant to research into low-dose radiation risks, and held an open discussion about options for the development of an E&T network. Subsequently, fora were held at each of the annual MELODI workshops: Helsinki 2012, Brussels 2013, Barcelona 2014, and Munich 2015. Speakers were invited from other groups involved in radiation protection, including ALLIANCE (European Radioecology Alliance), NERIS (Preparedness for Nuclear and Radiological Emergency Response and Recovery), EURADOS (European Radiation Dosimetry Group), EUTERP (European Training and Education in Radiation

Protection), and ENEN (European Nuclear Education Network). The discussions with the first four of these were very useful in the preparation of the Euratom-funded actions that followed on from DoReMi, in which MELODI worked in collaboration with these other radiation protection platforms. The interaction with ENEN led to the successful collaboration between MELODI and ENEN in the Euratom-funded project ANNETTE (Advanced Networking for Nuclear Education, Training and Transfer of Expertise).

### **Beyond DoReMi**

#### **MELODI education and training working group**

As mentioned previously, an important stage in the development of a Network of Excellence is to find a way to sustain the network after the initial funded joint programming is finished. In the case of E&T it was seen that the key was to ensure there existed a continuing body that would drive the support of E&T. During the second E&T forum in Brussels, 2013, the proposal was discussed of creating a Working Group (WG) under the rules of MELODI that could set priorities and make recommendations for E&T actions. This was endorsed by the forum, and the WG was inaugurated in April of 2014. The WG has a membership of 10 people appointed by the MELODI Board of Directors, and its role is to set priorities for E&T support for low-dose risk research and propose actions to be taken. In September 2016 a first draft of a Strategic Agenda for Education and Training in support of the Multidisciplinary European Low Dose Initiative (MELODI) was completed and placed on the MELODI website with an invitation for comments (<http://www.melodi-online.eu/sra.html>). One of the recommendations of the Strategic Agenda was to stress strongly the role of E&T as an integral part of on-going research, and inclusion of an element of E&T for support and dissemination in future EC-funded research programs.

#### **OPERRA**

Following the success of DoReMi in the organization and administration of calls for new network members through joint research projects, Euratom launched a call for a combined Collaborative Project and Coordination and Support Action (CP-CSA) to develop an umbrella coordination structure to manage future calls for research in radiation protection. The funded project was OPERRA ('Open Project for the European Radiation Research Area', [www.melodi-online.eu/operra.html](http://www.melodi-online.eu/operra.html)). It was based on the MELODI-DoReMi network, but broadened the scope to include the other radiation protection platforms (ALLIANCE, NERIS, and EURADOS). During the course of OPERRA, the structure was also setup for a platform to cover the medical use of radiation (EURAMED). This has the participation of each of the medical radiation societies and has developed an initial research program in the same way as the other platforms. OPERRA started in June 2013, running for four years. There was no dedicated workpackage providing E&T support to the research program. However, there were subtasks for development of a strategic plan to extend the DoReMi E&T support to incorporate the

wider interests and priorities of the other platforms, and to explore ways in which targeted E&T could help stimulate the wider use of major EU research infrastructures. The MELODI E&T Strategic Agenda formed a valuable basis for this work.

#### **CONCERT**

The experience of OPERRA showed that the radiation protection community could manage the organization and funding of the research program. The next step was to set up a European Joint Programme for the Integration of Radiation Protection Research under the rules of Horizon 2020, to continue and extend the functions and capabilities developed in OPERRA. The resulting Action was CONCERT ([www.concert-h2020.eu](http://www.concert-h2020.eu)), which started in June 2015 and will run for five years. Unlike OPERRA, which was largely based on MELODI, CONCERT has equal participation of all the radiation protection platforms, and has provision for the contribution to research priorities from the Social Sciences and Humanities. In line with the recommendations from the MELODI E&T WG and OPERRA, a dedicated workpackage was included to coordinate and manage support for E&T. The workpackage has the following tasks:

1. Attracting and retaining students and junior scientists into the Radiation Protection research fields: A program of travel grants will run for the duration of the EJP in order to provide greater opportunities for students to gain experience and networking through attending conferences, courses, and visiting other institutions.
2. Education and training as an essential part of dissemination and knowledge management within CONCERT: E&T is taken to be an intrinsic part of all research programs so that students can gain in-depth experience of the topic. The CONCERT open research calls require applicants to provide a plan as to how they will involve universities, and provide thesis and project opportunities for students.
3. Targeted E&T initiatives: There is an annual call for institutions to host short (1–3 weeks) courses in topics of their expertise. Sponsorship from CONCERT allows the courses to be offered at no cost and, in some cases, with accommodation provided. This is a continuation of the calls initiated in DoReMi. The topics specified in the calls are extended to align with the E&T priorities of all of the partner research platforms.
4. Coordination and collaboration on E&T policy and strategy: An annual forum is held to discuss the E&T priorities of the platforms and other interested parties to provide guidance for the overall program.
5. European integration of junior scientist career development: A European network of students and professors is being set up as a way of information sharing and career development.

#### **Beyond**

In spite of the original aim for DoReMi to work toward self-sustainability, radiation protection has a large component of

public health protection, and as such there is likely to be always a need for some form of public support, of both the research program and the intrinsic E&T. CONCERT will end in 2020, and it is not certain what will replace it. The Horizon 2020 rules for an EJP have not been ideal for CONCERT. They make it very difficult for institutions that are not members of the consortium to participate. The current climate is one of lobbying and negotiation of a possible new instrument to take radiation protection research on into the future. It seems reasonably certain that E&T is now accepted as an essential element of the research effort, but just exactly how remains to be seen.

### Conclusion and final comments

- The importance of E&T is now widely recognized in order to develop and maintain the expertise and knowledge to carry out the long-term research needed to provide the essential radiation risk information on which to base the principles and practice of radiation protection.
- All continuing research into radiation protection should include an integral component of E&T in order to provide continuing opportunities for new scientists and students to enter the field, and to ensure new research is fed directly back into educating the next generation of scientists.
- Greater (strategic) targeting of topics/disciplines and participants is needed in order to steer the development of the research community and to motivate the incorporation of new disciplines, technologies, and infrastructures.
- Continuing networking and communication within the RP E&T community (universities, RP platforms, research institutes) and stake-holders is needed in order to share resources and intelligence.
- There is reasonable reassurance that in the immediate future, public funding will continue to be available to sponsor and support E&T for RP research through the Euratom Horizon 2020 program, although the long-term picture is less clear.

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## Appendix: courses sponsored by DoReMi

### 2011

- *14–25 February*: Radiation-induced effects with particular emphasis on genetics, in utero development and space-related health issues. SCK-CEN, Mol, Belgium.
- *28 February to 11 March*: Molecular radiation carcinogenesis. HMGU, Neuherberg, Germany.
- *14 March to 25 March*: Radiation epidemiology and radioecology, HMGU, Neuherberg, Germany.
- *28 March to 8 April*: Cellular effects of low doses and low-dose rates with focus on DNA damage and stress response. SU, Stockholm, Sweden.
- *2 May to 13 May*: Interdisciplinary radiation research focusing on radiation protection. BFS, Neuherberg, Germany.
- *30 May to 10 June*: Modeling radiation effects from initial physical events. UNIPV, Pavia, Italy.

### 2012

- *13 February to 2 March*: Radiation epidemiology and radioecology. HMGU, Neuherberg, Germany.
- *5 March to 16 March*: Radiation-induced effects with particular emphasis on genetics, development, teratology, cognition as well as space-related health issues. SCK-CEN, Mol, Belgium.
- *16 April to 27 April*: Cellular effects of low doses and low-dose rates with focus on DNA damage and stress response. SU, Stockholm, Sweden.
- *16–27 April 2012*: Interdisciplinary Radiation Research Focusing on Low Doses. BFS, Neuherberg, Germany.
- *30 April to 13 May*: Training course in molecular mechanism of radiation carcinogenesis. HMGU, Neuherberg, Germany.
- *28 May to 8 June*: Modeling radiation effects from initial physical events. UNIPV, Pavia, Italy.

### 2012–2013

- *10–21 December*: Molecular consequences of low dose and low-dose rate exposures: impact of individual susceptibility on outcome and biomarker development. IC/CEA, Paris, France.
- *28 January to 15 February*: Training course in Radiation Epidemiology and Radioecology. HMGU, Neuherberg, Germany.
- *18 February to 1 March*: Radiation-induced effects with particular emphasis on genetics, development, teratology, cognition as well as space-related health issues. SCK-CEN, Mol, Belgium.
- *18–29 March*: Molecular mechanism of radiation carcinogenesis. HMGU, Neuherberg, Germany.
- *22 April to 3 May*: Cellular effects of low doses and low-dose rates with focus on DNA damage and stress response. SU, Stockholm, Sweden.
- *6–17 May*: TIETO non-cancer effects of low-dose radiation. HMGU, Neuherberg, Germany.
- *27 May to 7 June*: Modeling radiation effects from initial physical events. UniPv, Pavia, Italy.
- *10–21 June*: Interdisciplinary radiation research. BFS, Neuherberg, Germany.
- *24–28 June*: Environmental Radiobiology (5 ECTS accredited course). UMB, Oslo, Norway.

**2013–2014**

- *4–22 November*: Training course in Radiation Epidemiology and Dosimetry. HMGU, Neuherberg, Germany.
- *8–20 December*: Inter-individual responses to low-dose ionizing radiation: from damage formation to biomarkers. IC/CEA, Paris, France.
- *3–14 February*: InterRad: Interdisciplinary radiation research. BFS, Neuherberg, Germany.
- *17–28 March*: Radiation-induced effects with particular emphasis on genetics, development, teratology, cognition as well as space-related health issues. SCK-CEN, Mol, Belgium.
- *31 March to 11 April*: Cellular effects of low doses and low-dose rates with focus on DNA damage and stress response. SU, Stockholm, Sweden.
- *5–16 May*: Training course in molecular mechanism of radiation carcinogenesis. HMGU, Neuherberg, Germany.
- *26 May to 6 June*: Modeling radiation effects from initial physical events. UniPv, Pavia, Italy.
- *9–20 June*: Assessing Risk to Man and Environment: MSc Accredited Course. UMB, SU, Oslo, Norway.

**2014–2015**

- *1–5 September*: Data interpretation and uncertainty analysis for the combined low-dose radiation research disciplines. PHE, Oxford, UK.
- *3–21 November*: Training course in Radiation Epidemiology and Dosimetry. HMGU, Neuherberg, Germany.
- *8–19 December*: Inter-individual responses to low-dose ionizing radiation: from damage formation to biomarkers. IC/CEA, Paris, France.
- *9–20 March*: Radiation-induced effects with particular emphasis on genetics, development, teratology, cognition as well as space-related health issues. SCK-CEN, Mol, Belgium.
- *13–24 April*: Training course in molecular mechanism of radiation carcinogenesis. HMGU, Neuherberg, Germany.
- *13–24 April*: Cellular effects of low doses and low-dose rates with focus on DNA damage and stress response. SU, Stockholm, Sweden.
- *25 May to 5 June*: Modeling radiation effects from initial physical events. UniPv, Pavia, Italy.
- *8–15 June*: Assessing Risk to Man and Environment: MSc Accredited Course. UMB, SU, Oslo, Norway.
- *6–15 June*: InterRad: Interdisciplinary radiation research. BFS, Neuherberg, Germany.