# Report on the EUROMET Ionising Radiation Technical Committee activities 2005-2007

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## 1. Projects

From the 59 projects of the IR TC 12 have been running and 7 belong to dosimetry subfield. Some details are in the table below.

| Project No. | type | subfield | No. of. part. | Pilot lab. | Status | Term |
|---|---|---|---|---|---|---|
| **909** | **traceability** | **activity** | **2** | **PTB** | **Measurements in progress** | **2006-2007** |
| **907** | **R(II)-S5.Sb-124 comparison** | **activity** | **9** | **LNE** | **Measurements in progress** | **2006-2007** |
| **822** | R(III) S2 comparison | neutron | 3 | PTB | Draft A report in progress | 2004-2007 |
| **814** | R(I) S6 comparison | dosimetry | 2 | LNE | Draft A report in progress | 2004-2007 |
| **813** | R(I)-K1&K2 | dosimetry | 26 | MKEH | Interim Draft A in progress | 2005-2008 |
| **749** | Co-operation | activity | 5 | IRMM | Final report in progress | 2004-2007 |
| **739** | R(I) S2 comparison | dosimetry | 8 | PTB | Measurements in progress | 2004-2007 |
| **738** | R(I) S5 comparison | dosimetry | 17 | PTB | Measurements in progress | 2005-2008 |
| **628** | comparison | dosimetry | 4 | NPL | Measurements in progress | 2005-2008 |
| 608 | comparison | neutron | 3 | IPSN | Measurements in progress | 2002-2008 |
| **605** | Co-operation | dosimetry | 6 | METAS | Final report in progress | 2004-2007 |
| **545** | comparison | dosimetry | 9 | PTB | Draft B report in progress | 2001-2007 |

### Ongoing Dosimetry Projects:

### Co-operations in research:

**Project 749: Alpha –particle emission probabilities and energies in the decay of $^{240}$Pu**

The challenge is that the small alpha peaks are hidden in the tailing of the larger peaks in the spectrum. The IRMM has sent their vacuum evaporated $^{240}$Pu sources to CIEMAT,NPL, and PTB. The bolometer measuring technique of CEA/LNHB laboratory was unsuitable and the alpha counter of NPL had technical problem unfortunately. The measured 7 alpha spectra are sent to participants for analysis. From the measured gamma spectra at the IRMM additional information on the alpha particle emission can be derived. The data analysis is scheduled by the end of this year.

**Project 605: Beam Quality Specification of High- Energy Photon beams**

An unique and easily measurable beam quality specification of high-energy (4 MeV-21 MeV) photon beams used at hospitals and standard laboratories is essential to decrease the uncertainty of delivered dose to the patients. The calibration of four ionisation chambers in different beams has already completed. One ionisation chamber had to replace during the program. Monte Carlo simulation of METAS' beams have also been performed. Some additional correction factors of the chambers required for final analysis have been supplied by the NMi. Draft report is under preparation. The expected completion of the project is June 2007.

## Comparisons

**Project 907: EUROMET.RI(II)-S5.Sb-124 Measurement of Sb-124 activity and determination of photon emission probabilities.**

SB-124 having high energy gamma rays. could be excellent for energy calibration of gamma spectrometers. Decay scheme is not well known. Only three laboratories have contributed to the Sb-124 standartisation up to now in the frame of SIR. (BIPM key comparisons of radionuclides). The different techniques delivered not coherent results so the participants requested to use all techniques as they could. The ampoules of Sb-124 samples have been prepared and are sending to the participants. The expected completion of the project is June 2007.

**Project 814: EUROMET RI(I)-S6 Bilateral comp. of air kerma standards of BNM-LNHB and NPL for $^{192}$Ir HDR brachytherapy sources**

Brachytherapy sources' dose distribution determination is recent challenge of dosimetry laboratories. Air kerma rate determination in vacuum at a reference distance is usually a first step in this procedure. The calibration coefficient of BNM-LNHB ionisation chamber type NE 2571 used for air kerma measurements is based on the extrapolation technique of 250 kV X-ray, $^{137}$Cs and $^{60}$Co calibrations. The NPL absolute chamber sensitivity is calculated on the basis of its volume, the uncertainty budget is under review. The final report of the comparison is scheduled for April 2007

**Project 813: EUROMET RI(I)-K1&K2 Comparison of air kerma and absorbed dose to water measurements of $^{60}$Co radiation in radiotherapy**

This star-shaped double key comparison with 26 participants started on January 2005 involving four transfer chambers and two complete current measurement systems. The itinerary is pretty tight and organised in three subgroups. The first group including the 13 SSDLs have been completed by August 2006. An interim Draft A has been drawn up using relative data only to support the relevant CMCs of these laboratories as soon as possible. The stability of transfer instruments is excellent. Expected completion of the project is June 2008.

**Project 739: EUROMET RI(I)-S2 Intercomparison of extrapolation chamber measurements of the absorbed dose rate in tissue for beta radiation.**

The involved radionuclides were $^{147}$Pm; $^{204}$Tl; $^{85}$Kr; ($^{90}$Sr/$^{90}$Y) with radiation angle of 0º, 45º and or 60º. All the seven participants having primary standard completed their measurements by November 2005 even if that some delay occurred. The measuring protocol had to be revised by the new coordinator in 2006. Draft A report is under preparation at PTB. The NMIJ (Japan) participation as a late joiner was accepted in January 2007 by all the participants. Draft A report including the degrees of equivalence is expected by the end of 2007.

**Project 738: EUROMET RI(I)-S5 Intercomparison of the personal dose equivalent ($H_p$10) for photon radiation**

Hp(10) as operational quantity for individual monitoring to access the effective dose in radiation protection was adopted by 96/29 EURATOM directive. All the laboratories which have CMC lines for personal dose equivalent quantity for X-ray beam qualities have joined to this project. Unfortunately the ENEA participation is problematic. Eleven participants have already completed the measurements from the 18 participants. The special transfer chamber dedicated to measure the $H_p$(10) and the complete current measuring system have good stability during the comparison. Preliminary evaluation of the results shows a good agreement within the stated uncertainties. The expected lasting of the comparison measurements is February 2008.

**Project 628: Direct comparison of primary standards of air kerma for medium energy (300 kV) X-rays**

A free air chamber primary standard has recently constructed at NPL that can be transported and reassembled, is a first for direct comparison of primary standards of participant laboratories in the 40 kV-300 kV X-ray energy region. From the 6 laboratories having primary standard, the PTB and NMi have already completed the comparisons involving the BIPM reference beam qualities, the ISO 4037 narrow beam qualities and IEC 61267 RQR, RQA beam qualities. The preliminary results are in good agreement with the stated uncertainties of the standards. The re-evaluation of the uncertainties of NPL chamber is delaying the publication of the results.

**Project 608: EUROMET RI(III)-S1 Test program of instrument calibrations for neutron dosimetry**

The calibration capabilities surveying of neutron laboratories having radionuclide neutron beams by two rem-meters ( Harwell Monitor N91 and a Studwick 2202D) has suffered several technical and administrative difficulties. The instability of the Studwick monitor was not acceptable. New comparison programme was proposed in 2005 and launched in December 2005 using only the Harwell monitor for testing the procedures are being used for calibration area survey instruments with standard neutron sources available in EUROMET laboratories. The calibration has already been performed by IRSN, SCK, KRISS, CMI, IEA, SMU. The rest of the participants (NPL,PTB, VNIIM, CIAE) will have completed the measurements by the end of this year.

**Project 545: EUROMET RI(I)-S3 Intercomparison of NMI's air kerma standards for ISO 4037 narrow spectrum series X-ray radiation**

An indirect comparison of the national primary standards was performed by a small (4 cm) diameter transfer chamber for these important beam qualities used in radiation protection. The influence of the different field sizes, uniformities and dose rates to the calibrations claimed in the CMC database was investigated by two other large diameter (14 cm, 27.5 cm) transfer chambers. The ten participants have completed their measurements within two years using star-shape arrangement. Draft A report including degrees of equivalence was circulated and Draft B is under preparation at PTB.

### Traceability:

**Project 909: Calibration of an ionisation chamber for activity measurements**

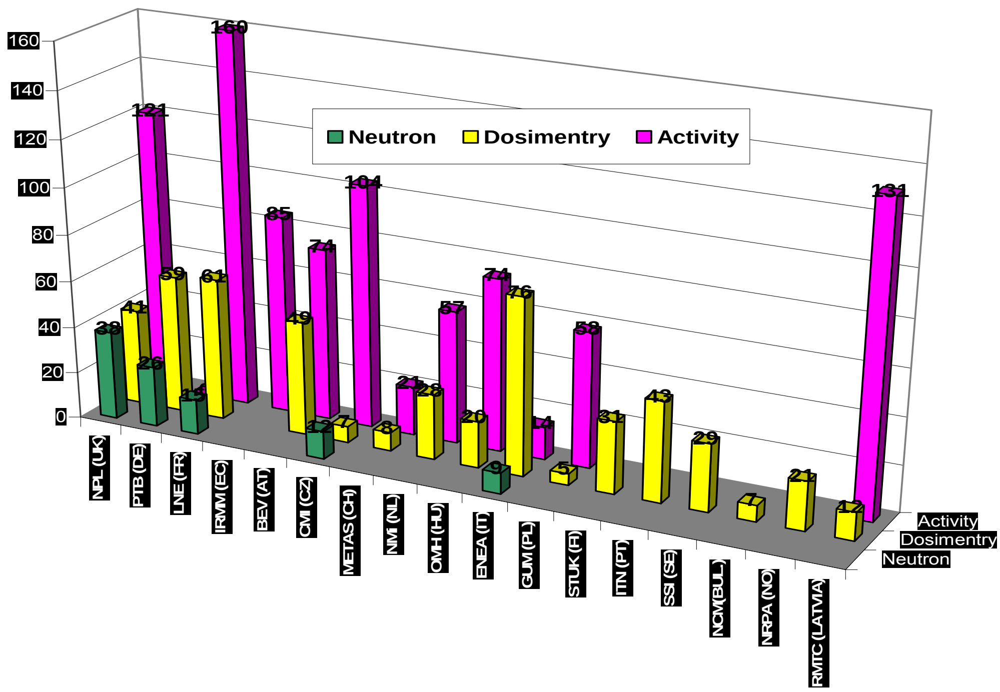
The calibration of a widely used radionuclide calibrator type PTW Curiementor 3 belong to the NCM (Bulgaria) started in 2006 at PTB. In addition to ensure the traceability, establishing efficiency curve to use it for almost any photon-emitting nuclide is also task of the project. Some beta emitting nuclide and geometry correction have been investigated. A new data acquisition program for the curiementor was developed at the PTB. The involved radionuclides for the calibration are: *Na-22; P-32; Cr-51; Mn-54; Co-57; Co-58; Co-60; Zn-65; Sr-85; Y-88; Sr-89; Sr-90; Y-90; Mo-99; Ru-106; Cd-109; Sn-113; I-125; I-131; Ba-133; Cs-134; Cs-137; Ce-139; Pm-147; Eu-152; Tl-201; Tl-204; Pb-210; Am-241*. The data analysis and publication of results scheduled by the end of 2007

## 2. MRA CMC

From the 34 laboratories 11 have no any published CMC. Additional six laboratories intend to publish service lines. All the active laboratories have already presented their QMS to the EUROMET TC Quality. The QMS of LNE-LNHB; NPL; NMi; METAS; and SSI (Sweden) were re-evaluated at the last TC Q meeting in January 2007.
Some statistics from the published 1500 CMC claims can be seen in the table and figure bellow.

**Published CMCs**

| Subfield | JCRB file name | Date of publication | NMIs | Claims |
|---|---|---|---|---|
| Radioactivity | RI.1.2001 | 15/09/2003 | 10 | 768 |
| | RI.6.2006 | 18/01/2007 | 1 | 131 |
| Dosimetry | RI.3.2001 | 11/03/2005 | 13 | 460 |
| | RI.7.2001 | 06/10/2006 | 1 | 1 |
| | RI.6.2006 | 18/01/2007 | 1 | 12 |
| | RI.5.2006 | 14/02/2007 | 2 | 28 |
| Neutron meas. | RI.4.2001 | 19/05/2005 | 5 | 99 |




Pending EUROMET IR CMC claims are in different phases:

| | | |
|---|---|---|
| **Inter RMO review**: | ---- | |
| **Internal review**: | Dosimetry: | Slovakia Spain, Greece |
| | Activity : | Slovakia |
| | Neutron: | Slovakia |
| **Under prep.**: | Dosimetry: | Croatia, Lithuania, Romania |
| | Activity : | Germany, Romania |

IR TC review of other RMO's new CMCs in 2006-2007

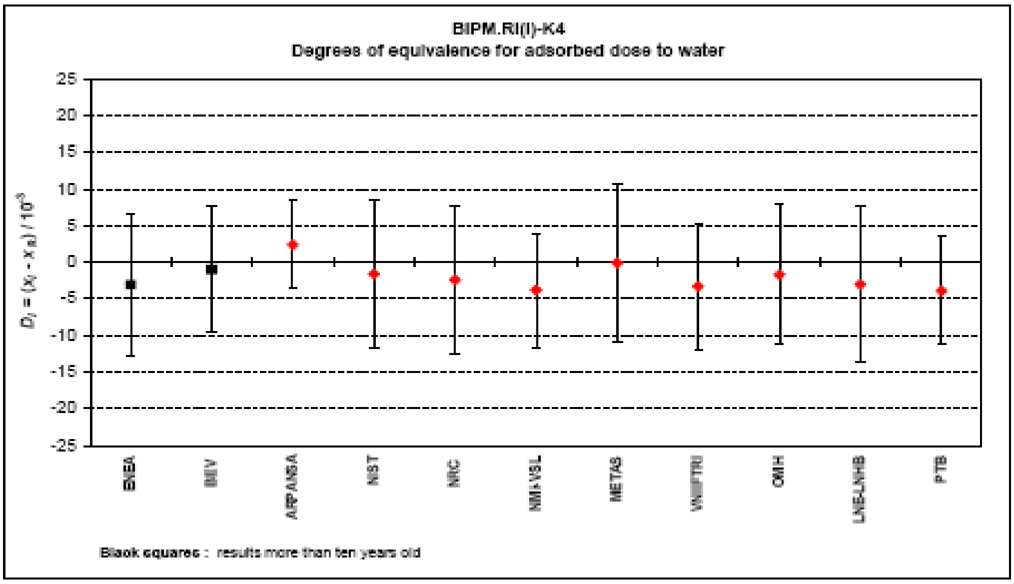
| Subfield | RMO | Num. NMIs | Num. claims |
|---|---|---|---|
| Dosimetry | APMP | 5 | 64 |
| Dosimetry | IAEA | 1 | 13 |
| Neutron measurements | APMP | 5 | 23 |
| total | | 6 | 100 |

According to the three subfields within the IR TC, three CMC working groups have been working led by the three convenors listed below:

**Dosimetry:** **T. Aalbers** *(NL)*, H.- M. Kramer *(De* ,H. Bjerke *(No)*, C. Hourdakis *(Gr),)*, J.-M Bordy *(Fr)*
**Radioactivity:** **N. Coursol** *(Fr)*, L. Johansson (UK), F.-J. Maringer *(AT)*, J. M[a] Los Arcos *(ES),*
**Neutron:** **M. Kralik** *(Cz)*, A. Zimbal *(De),* L. van Ryckeghem *(Fr)*

## 3. MRA Key comparisons

The nine primary dosimetry laboratories are taking part in the ongoing BIPM.RI(I) K1-K5 comparisons for air kerma of $^{60}$Co,$^{137}$Cs, low and medium energy X-rays, as well as absorbed dose to water of $^{60}$Co radiations. The degrees of equivalence for air kerma of $^{60}$Co gamma radiation have not been published yet because the SI reference value is under re-evaluation. The recently published degrees of equivalence of primary standard calorimeters being standard of absorbed dose to water can be seen in the figure below.




Seven of the ongoing supplementary comparisons are also organised and coordinated by the EUROMET IR TC.

## 4. Meetings and Workshops

- The regular CCRI RMOs Working Group meeting on Ionizing Radiation CMCs was held at BIPM in September 2005. The 'Fast track' procedure in case of country by country submission of CMC was strongly recommended. There was an agreement on submission of CMC files of the three subfields to the JCRB separately.
- IR CP Meeting at Greek Atomic Energy Committee, in Athens, in December. 2005 Introduction of **five new laboratories from Belgium, Romania, Ireland, Denmark was welcomed.**
- There were two brainstorm meetings to elaborate the IR roadmaps in November 2005 at PTB and in January 2006 at NPL. Some contact persons on voluntary basis and experienced scientists from NPL and PTB were invited.
- There was an extra Contact Persons Meeting to finalise and agree on the three roadmaps at NPL on 6 March. **Details are in Annex 1**.
- IR CP Meeting was held 26-27 October 2006 at NMi- Van Swindenlaboratorium, Delft The Netherland. All the presentation of the 28 participant NMIs and the minutes of meeting are available on the restricted area of MKEH website. In addition to the routine discussion of IR projects and CMC business the three IR roadmaps and the EMRP were the main issues. István Csete was nominated to act further two year as TC Chair and an EMRP Taskgroup was elected on voluntary basis. The next IR TC CP meeting will be held at PTB, Braunschweig, 25-26 October 2007.
- The regular CIPM CCRI RMOs Working Group meeting on Ionizing Radiation CMCs was held at BIPM in November 2006. CIPM MRA workshops will be held in the close future. The IR CMC Service Categories and filling rules were revised. There was recommended that the inter RMO CMC review process may proceed prior to the approval of an NMI's

QMS, provided the known date by which it will be implemented. The NMIs got accesses to download their CMC excel files from the restricted part of JCRB website... After completing of a key comparison, the participants have to update their uncertainty of relevant CMC lines

- The first IR EMRP Taskgroup meeting was held at LNE, Paris, on 15 January 2007. Participants were: Jean Mark Bordy, Nelcy Coursol and Bruno Chauvenet (LNE- LNHB), Tony Aalbers, end Eduard van Dijk, (NMi), Michael Kramer (PTB), Alan Du Sautoy (NPL)., Nick Reynaert, from Belgium and István Csete. Luc Erard as the new chair of EMRP Committee informed us about the EC decision on supporting the EMRP in the frame of the **ERANET+ program as part of the EU 7th Frame Program. Five activities will be founded (including ionisation radiation metrology within the "Health challenge") from the potential 21M € EC founding plus 42 M€ national contributions.** The projects should be last up to 3 years. After having looked through the IR roadmaps concerning their relation to Health, taking into account the enable national research resources of potential participants and the three years term to complete it as well, the Taskgroup has identified two research areas, "**D Accurate 3D dosimetry of Co-60 and High energy X-rays"** and "**HDR and LDR brachytherapy dosimetry based on absorbed dose to water"** to focus on. An action plan was accepted to formulate EoIs within IR TC, draw up project proposals to be potential part of targeted programme "Health".

## 5. Project proposals for „Health challenges" targeted program within the ERANET+ program

The two IR proposals prepared by the EMRP task group have been circulating among the laboratories being EMRP member to comment and survey manpower offered in term of €. The deadline to elaborate the final program proposals is September 2007

### 1. Accurate 3D dosimetry of Co-60 and High energy X-rays.

| Work package | Delivery |
|---|---|
| 1.Homogeneous system | Dw ≤ 1% in voxel size 2 $mm^3$ for IMRT |
| 2.Inhomogeneous system | Phantom of increasing complexity, Dw ≤ 1% for $1cm^2$ beam including off axis area |
| 3.Traceability | Extend scope of primary standards to small fields |
| 4.Benchmarking* | Monte Carlo calculations for Workpackages 1,2,3 |
| 5.Validation* | Real phantom with target volume, dose distr. measurement, comp. with treatment plan |

*need hospital medical physicist collaboration

### 2. HDR and LDR brachytherapy dosimetry based on absorbed dose to water

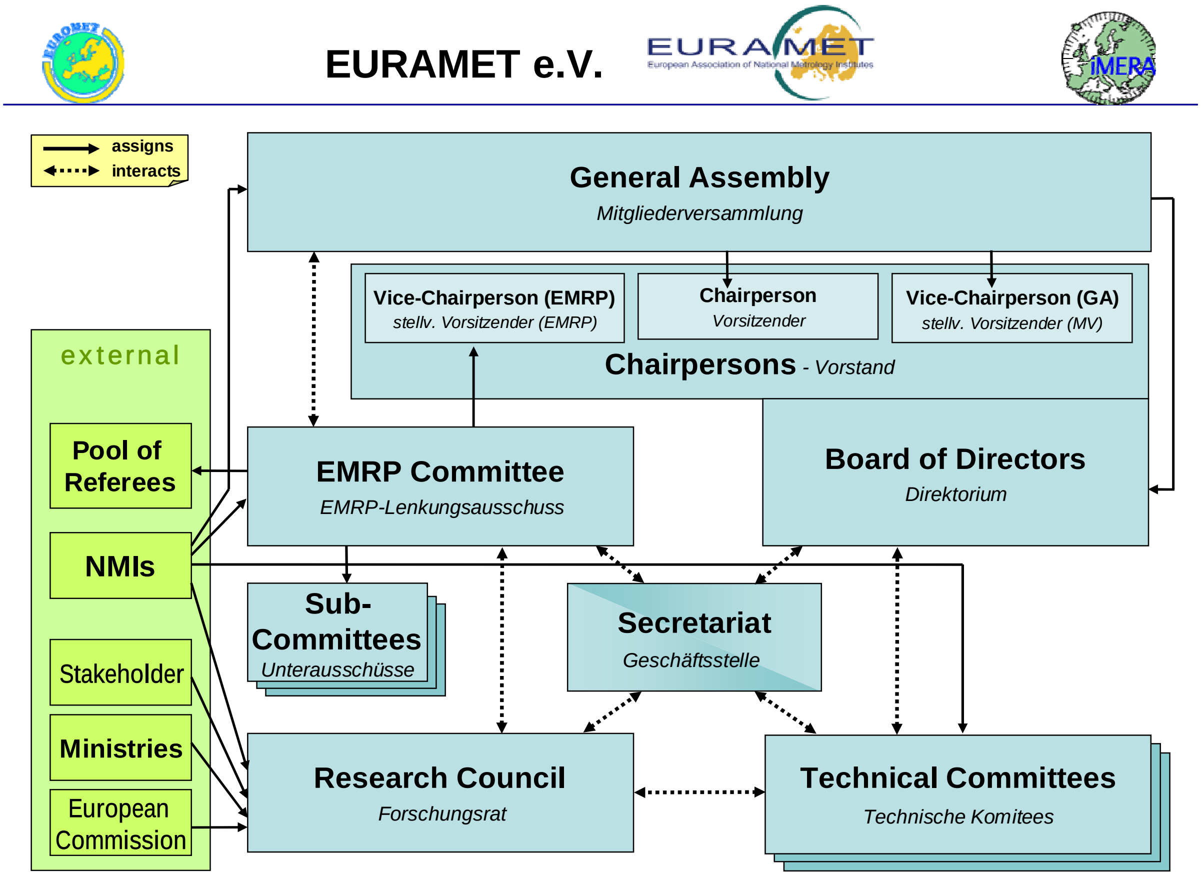
Actual dosimetry protocol is based on the air kerma rate or „apparent" activity of encapsulated sources (Ir-192, Co-60, Cs-137 for HDR and I-125, Pd-103, Yb-169 for LDR ) using generic conversion factors to get absorbed dose. The adequate quantity must be the Dw at 1cm reference distance accompained by 3D dose distribution.

**Workpackages:**

1. Establish the Dw in a large water phantom in which the source is in its centre by new water or graphite calorimeter, extrapolation or other suitable chambers. u(Dw)≤2% (k=1)
2. Calibration of well type chambers in term of Dw linkage to the old calibration values and determination of its spread for a given source type.
3. Experimental and MC determination of 3D distribution of Dw and comparison with those obtained by existing protocol.

## 6. Transition of EUROMET to EURAMET

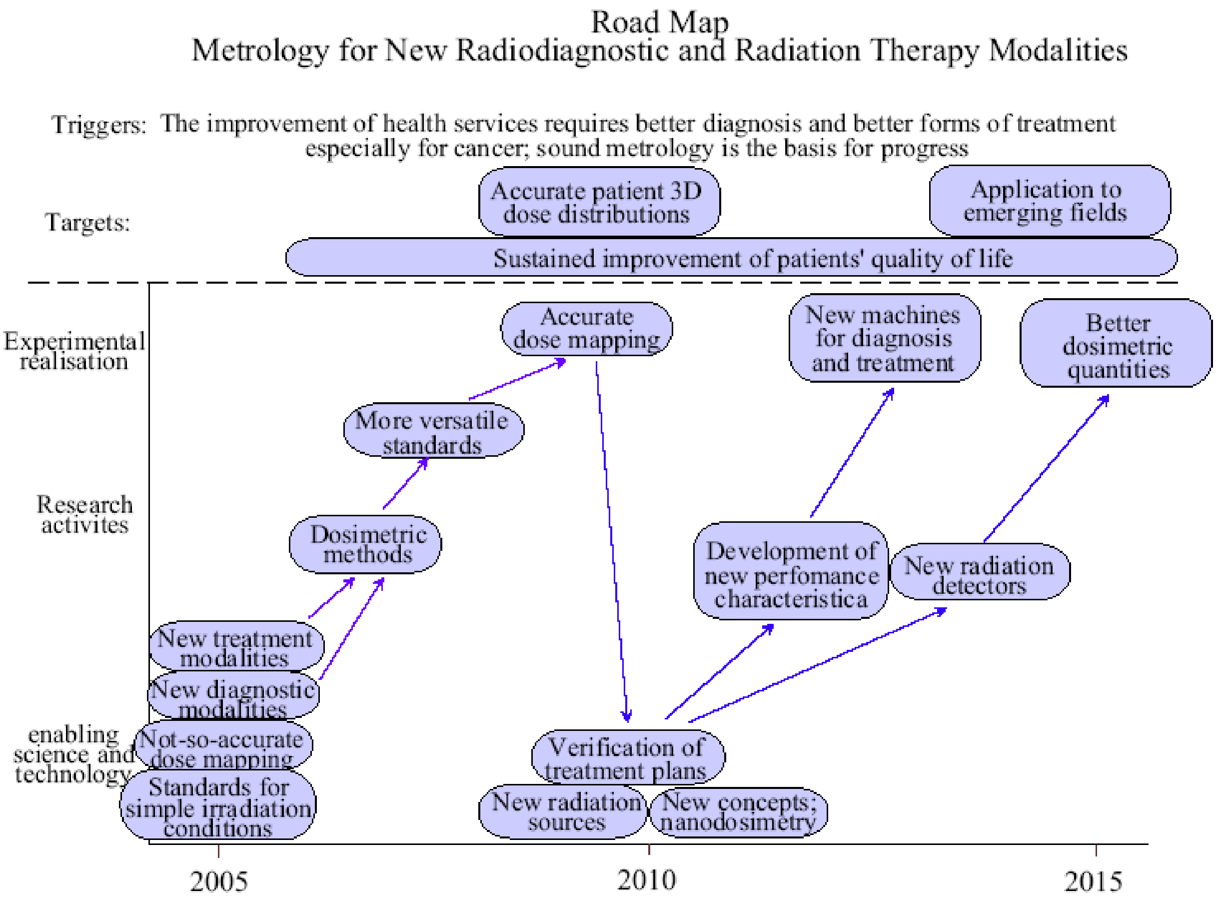
The EUROMETwas established in 1988 and was not a legal entity. In January 2007 the EURAMET e.V. (see the organigramm) acting as a non-profit asssociation according to the German Law has been established and will take over all activities of EUROMET on the next General Assebly on 31 May 2007. The EURAMET being legal entity could be founded by external sources i.e. EC.to implement its EMRP as the main additional new task of EURAMET. Further details Byelaw, RoPs EMRP Committee, etc. are or will be available soon on the EUROMET website. [www.euromet.org](http://www.euromet.org)



## Annex 1

The IR TC has compiled three roadmaps in the frame of the iMERA Project reflecting to the challenges in medical applications, radiation interaction with matter and metrology of new radiation sources. These roadmaps include wide variety of new dosimetry, radioactivity and neutron measurement techniques, novel measuring probes and standards, and nano scale approach of new dosimetry quantities as well. The IR TC believes that the elaboration of these roadmaps could contribute to the successful compilation of the EMRP. However we are required to involve the ascending laboratories as much as possible in the new projects derived from the EMRP. The three roadmaps and their short descriptions see below:

## Roadmap 1




### Description of Road Map 1

# Metrology for New Radiodiagnostic and Radiation Therapy Modalities

The quality of health services is of prime social importance. It has an immediate impact on the quality of life. Of particular importance is the diagnosis and treatment of cancer. In the European Union there are about 1.2 Mio new cancer incidents every year. In the number of death causes per year cancer ranges second in the European mortality statistic. With increasing age of the population these figures are likely to rise.

Over recent years and decades, the medical profession has launched many new and improved diagnostic and therapeutic methods. Among these there are techniques without sound metrological background. This has a long tradition: first medical use of X-rays followed immediately their discovery, at a time when nobody had the faintest idea of how the 'quantity' of x-rays could be measured. Another example is the use of electron accelerators for radiation therapy in the early forties despite the absence of suitable dosimetric standards. Medical doctors have paid dearly for their boldness by insufficient success of treatments or avoidable radiation damage to the patient or to the medical doctor himself.

The tendency to employ new diagnostic and therapeutic modalities regardless of a lacking metrology has persisted right up to the present time. Modern examples are forms of the Intensity Modulated Radiation Therapy (IMRT), in particular tomotherapy, certain forms of brachytherapy and the use of protons, heavy ions and neutrons for therapeutic purposes. Similarly, diagnostic procedures like CT, NMR, PET are frequently used at face value, without having given evidence that they are capable of presenting the location of organs free from artefacts down to a millimetre scale or even below, as it is now frequently requested.

This Road Map describes approaches how metrology is capable of improving the success rate of diagnostic and therapeutic measures using ionizing radiation.

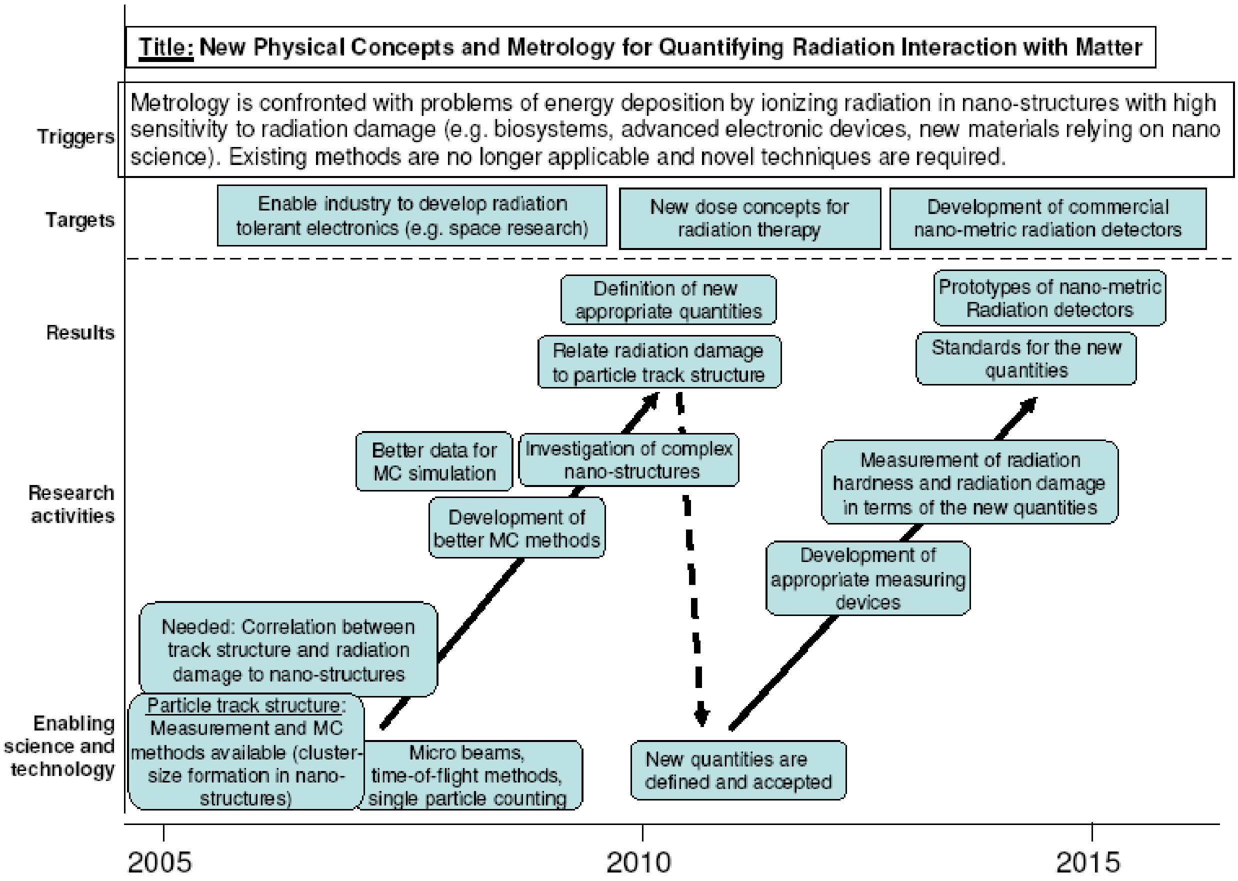
On the diagnostic side, methods are required which permit reliable diagnoses avoiding any unnecessary patient exposure. To this end relevant components of diagnostic equipment need to be characterised in their dose sparing functionality. Examples are artefact-free geometrical localisations of organs, particularly in the context of image guided techniques, image receptor sensitivity, modulation transfer functions, detective quantum efficiency and the capability of measuring correct electron densities, to name some important features. In functional imaging, the measurement of quantities like blood velocities, nerve currents etc. need to be traceable to the SI-system.

Recent rapid advances of three dimensional Conformal Radiation Therapy and IMRT have created an urgent need for the introduction of high resolution three-dimensional methods of dosimetry. By escalating the dose to the lesion, while minimizing the dose to the surrounding healthy tissue all modern treatment techniques make deliberate use of steep dose gradients, regardless whether external therapy or brachy therapy is employed. Problems associated with these techniques are the absence of proven methods for specifying the radiation quality, the energy and angular dependence of the detectors' responses, unwanted, detector-specific properties like fading of the radiation induced (latent) signal. Additionally, organs or tissues moving during the radiotherapeutic procedures require new treatment methods. In such modalities, often referred to as 4D, the beam is gated, e.g. by the breathing of the patient. Existing protocols on clinical dosimetry for radiation therapy are only designed for simple standard situations and unsuited for IMRT conditions, let alone 4D applications. The dosimetry based on portal imaging and with advanced detectors like radiochromic films, polymerizing gels, alanine, scintillators and liquid ionisation chambers has to be improved in order to achieve accurate dose mapping. With the support of Monte Carlo radiation transport simulations secondary standards suitable for a reliable dose mapping under routine clinical conditions need to be established, which also allow the verification of treatment plans.

Having achieved this goal will open the window for the development of new radiopharmaceuticals, sources and external beams which in turn are better suited for an optimized delivery of any desired dose profile. The achievements of metrology will enable European manufacturers of medical devices to improve their products systematically. Apart from the undisputed improvement of the quality of life associated with an increasingly successful fight against cancer there will also be an important economic offspring of these activities from which the European economy will draw its advantage.

In a long term perspective the activities in the frame of Roadmaps 'New Physical Concepts and Metrology for Quantifying Radiation Interaction with Matter' and 'Metrology for Novel Radiation Sources' will begin to pay off also in the context of this Roadmap. The investigation of interaction processes of ionizing radiation on the scale of a DNA-molecule will provide the key for a better understanding of the effects which are today referred to by the term of biological effectiveness. In the future, the optimisation of a radiotherapeutic measure will include the deliberate choice of the best suited kind of radiation (photons, electrons, protons, heavy ions) as well. The understanding of these effects will allow for a direct comparison between exposures to different kinds of radiation without the need to refer to empirical equivalence values as used today in the administration of doses from different types of radiation. Novel types of radiation sources will be the basis for further optimizing treatment methods provided they are backed by the necessary metrology.

## Roadmap 2




## Description of Road Map 2

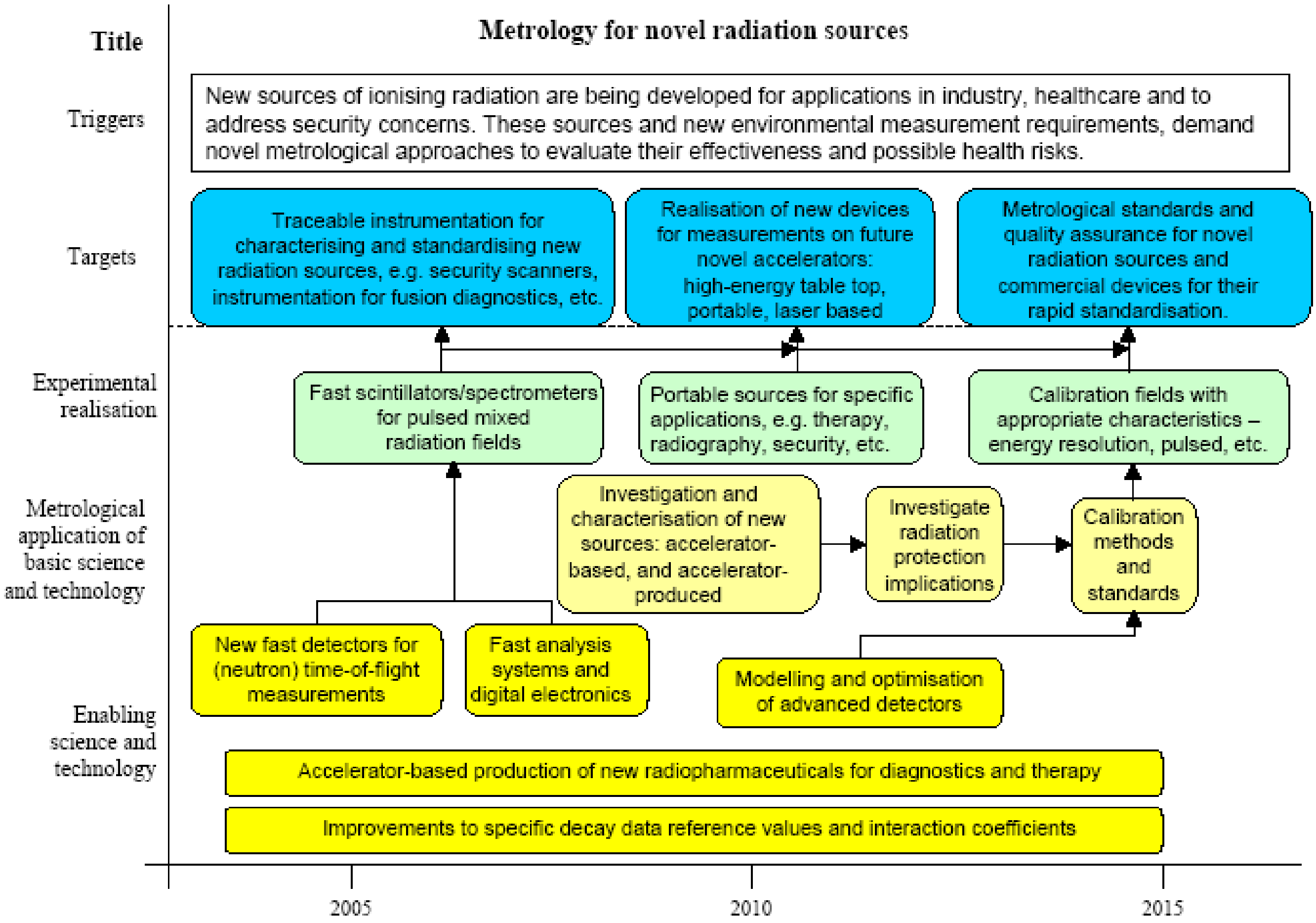
New physical concepts and metrology for quantifying radiation interaction with matter

It is generally accepted, today, that the damage to new materials in nano-technology, to advanced electronic devices of the future (memories, processors, …), and to nano-metric biosystems like the DNA due to ionizing radiation is, to the greater part, determined by the passage of single ionizing particles, a process which cannot be described satisfactorily by traditional quantities like absorbed dose. In consequence, a new understanding of physical principles involved and the development of a new metrology are needed. This opens the way for the development of radiation-tolerant electronics, the improvement of dose concepts in radiation therapy, particularly in hadron therapy, and the development of commercial nano-metric radiation detectors.

It is, therefore, a new challenge of radiation metrology to define physical quantities which are, first, easily measurable and are, second, based on the track structure of single ionizing particles as well as on the properties of radiosensitive nano-metric structures in nano-technology, nano-electronics, and bioscience including radiation therapy and radiation protection. To tackle this challenge, systematic studies are necessary aiming at determining more accurate interaction data of ionizing particles with matter, the detailed investigation of radiation damage to nano-metric structures like nano-tubes or new materials based on silicon, and the development of specific Monte Carlo methods. They will allow to simulate both the track structure of ionizing particles and the damage to complex nano-metric structures. Based on such investigations, the correlation of track structure with radiation damage and the definition of new appropriate measurable quantities characterizing this connection will be possible. This enables the development of new dose concepts and appropriate radiation detectors. They need to be closely related to particle track structure and radiation damage and should be well suited for characterizing the quality of ionizing radiation in medical applications, in nano-metric biosystems, and in nano-technology.

A good starting point to this metrology of the future is the break through of experimental nano-dosimetry a few years ago. It was proved, firstly, that the formation of ionization cluster size in nano-metric volumes due to single particles can be derived from highly sophisticated measurements based on single-particle counting and, secondly, that the frequency of ionization cluster size is strongly correlated with radiation damage to nanometric structures like the DNA.

**Roadmap 3**




**Description of Road Map 3**

# Metrology for Novel Radiation Sources

Metrologists working in the ionising radiation area are increasingly being asked to provide standards for novel types of radiation sources and to advise and help with the development of instrumentation to measure the radiation fields produced by these sources. The two requests are intimately linked since appropriate instrumentation will be needed to characterise any new standard fields. These novel sources are either accelerator-based, i.e. the radiation is produced using beams of particles from new accelerators developed using innovative technology; or accelerator-produced, e.g. new radionuclide sources for medical applications. In the former the accelerator is the source, in the latter the accelerator is used to produce the sources. Without the necessary metrological capabilities the full potential of these new sources cannot be realised and the opportunity to capitalise on exciting new technology areas may be missed for Europe. Amongst the application areas, which can already be envisaged are:

a) medicine, e.g. potential new accelerators for proton therapy and new isotopes for nuclear medicine.

b) industry, e.g. sources for on-site neutron radiography.

c) energy production, e.g. fusion or transmutation of radioactive waste.

d) environmental studies, new instrumentation for environmental studies of radioisotopes in the environment.

e) security issues, devices for scanning individuals or vehicles for illicit materials.

Some of these new source types already exist, or soon will, while others are still in a very early state of development. A specific example of a new type of radiation source is the Petawatt (PW)-laser which can produce several types of radiation fields; electron, gamma, proton, and neutron beams. Hence, possible applications are of a wide range. Furthermore, devices for scanning individuals or vehicles, new on-site radiography sources, and applications for fusion facilities etc. are already in use and new applications are emerging rapidly. Amongst the characteristics of the accelerator-based radiation fields that will need to be measured are: the time structure for pulsed sources, the energy distribution, and the particle composition.

The first target, “Traceable instrumentation for characterising new sources”, is concerned with accelerator-based sources which already exist at some stage in the development process, and the metrological needs can be defined reasonably clearly. For example, faster types of pulse-mode detectors, probably scintillator detectors, are required to cope with the pulse characteristics of the source. In fusion diagnostics, the application requires better energy resolution.

The second target, “Realisation of new devices for measurements on future novel accelerator sources” is concerned with new radiation sources whose characteristics are more difficult to predict. The metrological requirements are not fully understood and it is not yet completely clear what types of instrumentation or standard fields will be required.

The third target: “Metrological standards and quality assurance” represents the completion of both the metrological work and novel source development work.

One of the items under “experimental realisation” is concerned with the development of portable devices producing ionising radiation, which will be performed by teams outside the metrology sphere. This explains why this is a stand-alone item in the road map, having no inputs, but feeding into two of the targets. Some requirements for the experimental realisation of the targets can already be conjectured. They include: fast detectors (probably scintillators) for neutron time of flight measurements, fast analysis systems for a range of instruments – probably based on digital electronics, large area high-energy neutron imaging systems for fast neutron radiography, and optimised liquid scintillator systems or cryogenic detectors for characterising new radio-pharmaceuticals.