Director's Report on the Activity and Management of the International Bureau of Weights and Measures

Supplement: Ionizing Radiation Department

(1 January 2012 – 31 December 2012)

March 2013

Bureau International des Poids et Mesures

BIPM Ionizing Radiation Department

Director: J.M. Los Arcos (from 1 July 2012)

(1 January 2012 to 31 December 2012)

1. Staff Changes

P.J. Allisy-Roberts, former Director of the Ionizing Radiation Department retired on 31 May 2012; D.T. Burns acted as *ad interim* Director until J.M. Los Arcos took over on 1 July 2012.

2. X- and γ-rays (D.T. Burns, C. Kessler, S. Picard, P. Roger)

2.1 Dosimetry standards and equipment

Work on the development of cavity ionization chambers continues. Chambers were constructed for the new Theratron ^{60}Co beam, including the development of a more robust waterproof sleeve arrangement, and for the transportable calorimeter system. Each of these chambers is mechanically measured using the 3D coordinate-measuring machine and characterized in the reference ^{60}Co beam, thus building up confidence in the determination of air volumes. A thin-walled chamber with a waterproof exterior was developed for the medium-energy absorbed-dose project and remains to be tested. The supply of a primary standard to the ININ was completed in 2012 with measurements in the BIPM reference beam. A secondee from the ININ was trained at the BIPM in the use of the Monte Carlo code PENELOPE to evaluate correction factors for this standard.

During 2012, the BIPM carried out two calorimeter comparisons in accelerator beams. The fourth comparison in the series BIPM.RI(I)-K6 was carried out at the LNE-LNHB (France) from 5 to 23 March 2012 in the 6 MV, 12 MV and 20 MV beams of their Saturne 43 accelerator. Preliminary results have been evaluated and a Draft A report prepared. The fifth K6 comparison was carried out at the ARPANSA (Australia) from 20 September to 9 October 2012 in the 6 MV, 10 MV and 18 MV beams of their Elekta Synergy accelerator. The BIPM equipment was shipped in advance, with the exception of the calorimeter core and ionization chambers which were hand carried. Preliminary results have been evaluated and a Draft A report is in progress. These comparisons serve to validate the NMI dose reference used in the calibration and audit services offered to hospitals in each country. The Draft B report for the comparison previously carried out at the NIST (USA) is close to publication.

The calorimeter is used at regular intervals in the BIPM reference ^{60}Co beam; the statistical standard uncertainty in the determination of the reference absorbed-dose rate from these accumulated measurements is around 4 parts in 10^4. The calorimetric absorbed-dose determination is around 1 part in 10^3 higher than the reference ionometric determination, which is well within the combined standard uncertainty.

As well as the additional transfer chambers noted above, a second calorimeter core and jacket were fabricated, to serve both as independent verifications and as replacements in the event of failure. The second core was tested in a 12 MV accelerator beam and was shown to agree with the first core at the level of the statistical standard uncertainty of the measurements of 1.7 parts in 10^3. However, a mechanical failure was identified on the second core and jacket ensemble on return from the comparison at the ARPANSA. The unusual calorimeter response noted in the BIPM ^{60}Co beam towards the end of 2011 was revealed to be a one-off event; the origin of this behaviour could not be established.

Monte Carlo calculations for the absorbed-dose conversion from graphite to water have continued, with calculations being made for the comparison with the LNE-LNHB (France) using photon spectra supplied by the LNE-LNHB. The results using these spectra show a curious behaviour that is thought to originate from the use of variance reduction at the LNE-LNHB. However, the final results are consistent with those of the other NMI participants, which demonstrates the robustness of the BIPM dose-conversion procedure. Measurements and calculations were made of the depth-dose distribution in water (in the BIPM ^{60}Co reference beam) for a fixed detector distance. These complement corresponding work carried out in graphite in 2011. The level of agreement between the measurements and calculations was used to derive a standard uncertainty for the ratio of photon attenuation coefficients in graphite and water of less than 1 part in 10^3. This completes the evaluation of the dose-conversion uncertainties, which will now be published.

Following the installation of the new Theratron irradiator in November 2011, the ^{60}Co source was finally installed in October 2012. The delay resulted from problems related to authorizations. Characterization of the new reference beam continues.

The project to develop an absorbed-dose standard for medium-energy x-rays has progressed and will continue into the Programme of Work 2013 to 2015. By simulating the x-ray tube and filter arrangement, phase-space spectra were generated for the four radiation qualities; the energy spectra observed were found to be in close agreement with those obtained using the Spekcalc software. The BIPM method for measuring the mean air-attenuation coefficient, μ_a, for each quality, using an evacuated tube, was simulated, allowing the photon interaction cross-section data for air used by PENELOPE to be tested. Using a 3 mm slab of graphite, and simulating this arrangement, a similar test was made of the cross-section data for graphite (measurements were also made using a water 'slab' for use later). Interestingly, while the calculated μ-values for air and graphite are each lower than the corresponding measured values by around 3 parts in 10^2, the calculated and measured ratios $\mu_{a,c}$ agree within the statistical standard uncertainty of 1 part in 10^2, except at 100 kV where a difference of 4 parts in 10^2 is observed. While this is a positive result, there is at present no explanation for differences exceeding 5 parts in 10^2 between the preliminary air-kerma rates determined using a thin-walled graphite cavity chamber and the reference values determined using the free-air chamber. Similar differences are observed using a chamber with air-equivalent walls.

The work on evaluating best estimates for the W_a-value for air and the I_c-value for graphite was completed and published in *Metrologia*. The conclusion is to change the recommended value for I_c from 78 eV to 81 eV (with standard uncertainty 2 eV) with no evidence for a need to change the present recommendation for W_a of 33.97 eV. However, the uncertainty of W_a should be increased from 1.5 parts in 10^3 to 3.2 parts in 10^3, which will result in a significant increase in the air-kerma determination using free-air chambers. The recommended value for the product $W_a\, s_{c,a}$ entering in the air-kerma determination for ^{60}Co using graphite-walled cavity standards is 33.72 eV with a standard uncertainty of 8 parts in 10^4. This work will be incorporated into the International Commission on Radiation Units and Measurements (ICRU) Report on Key Data.

The ICRU Report Committee on Key Data must also make a recommendation on the *I*-value for water. This is a complex data set including measurements made over the past 40 years and values derived from theory, with uncertainty estimates which are sometimes unreliable or non-existent. An analysis was made and presented to the Report Committee, the recommendation being the value I_w = 78 eV with standard uncertainty 2 eV. The aim is to finalize the draft report during 2013.

Primary measurements and reference chamber calibrations have continued in all of the reference x- and γ-ray beams. Comparisons and calibrations are underpinned by a significant effort in equipment calibration and maintenance, as required by the BIPM Quality Management System, and which were

successfully audited in April 2012. Procedures, technical instructions, forms and laboratory records were subsequently modified in response to the audit (and to the change in Director of Department).

2.2 Dosimetry comparisons

Two comparisons in air kerma in gamma radiation were carried out, one in the ^{60}Co beam and the other in the ^{137}Cs beam, both with the NMIJ (Japan). Four air-kerma comparisons were carried out in x-ray beams, with the VSL (Netherlands) at low energies and with the VSL, the IAEA and the VNIIM (Russia) in the mammography beams. Two high-energy absorbed-dose comparisons were carried out in the accelerator beams of the LNE-LNHB (France) and the ARPANSA (Australia), as described earlier.

Seven comparison reports were published in the *Metrologia Technical Supplement*, two reports for the ARPANSA (Australia) and one each for the GUM (Poland), the MKEH (Hungary), the NIST (USA), the NPL (UK) and the VNIIM (Russia).

The report "*A blind test of the alanine dosimetry secondary standard of the PTB conducted by the BIPM*" of the irradiations made in the BIPM reference ^{60}Co beam at the end of 2011 has been submitted to *Metrologia*. This comparison was made at the request of the PTB to validate changes made to its alanine system.

2.3 Characterizations of national standards for dosimetry

Twenty-four characterizations of national standards were carried out; four in low-energy x-rays for the NIS (Egypt), ININ (Mexico) and the CMI (Czech Rep), three in mammography x-rays for the ININ and the CMI, three in medium-energy x-rays for the NIS, the ININ and the CMI, eleven in ^{60}Co for the NIS, the METAS (Switzerland), the CMI, the BIM (Bulgaria) and the KRISS (Republic of Korea) and three in ^{137}Cs for the NIS, the CMI and the BIM.

The IAEA/WHO dosimetry assurance programme continues to be supported by biannual reference irradiations, which in 2012 involved one series of irradiations for the radiotherapy level in the ^{60}Co beam and one for the radiation-protection level in the ^{137}Cs beam.

3. **Radionuclides** (J.M. Los Arcos, S. Courte, C. Michotte, M. Nonis and G. Ratel)

3.1 International Reference System (SIR) for γ-ray emitting radionuclides

3.1.1 SIR submissions in 2012

During 2012, the BIPM received nine ampoules filled with six different radionuclides from six laboratories (i.e. one ampoule each containing ^{59}Fe (PTB), ^{60}Co (BARC and NRC), ^{109}Cd (LNE-LNHB), ^{131}I (LNE-LNHB and NIST), ^{133}Ba (BEV and LNE-LNHB) and ^{222}Rn (LNE-LNHB). All the submissions had been made to generate equivalence values in the associated ongoing BIPM key comparisons BIPM.RI(II)-K1.

Two radionuclides with short half lives, a gas, ^{222}Rn ($T_{1/2}$ = 3.8235 d, u = 0.0003 d) to supersede a previous entry which was questionable, and ^{131}I ($T_{1/2}$ = 8.021 d, u = 0.001 d) were measured in 2012.

Reporting forms for four previous submissions which were pending were received in 2012; in consequence the corresponding SIR results have been evaluated; this concerns ^{60}Co, ^{152}Eu and ^{241}Am from the CNEA (Argentina) and ^{64}Cu from the ENEA (Italy).

3.1.2 SIR Reports and quality assurance

Updated reports of three comparisons were published in the *Metrologia Technical Supplements* covering ^{57}Co and ^{222}Rn. Each result prior to 2008 has now been published in the *Metrologia Technical Supplements* except for two which are now in preparation. There are three outstanding results from 2008 pending publication, one of which is actually in circulation. To date, all the Draft A reports have been submitted except for 3 results that are still to be received from the NMIs concerned.

There are 47 results awaiting publication in the KCDB and every effort will be made to ensure that reports are published as quickly as possible, particularly when NMIs make submissions that are to replace out-dated results already removed from the KCDB.

All the SIR measurements are covered by the BIPM Quality Management System and a successful external audit, including for the first time the extension to short-lived radionuclides, was carried out on 21 September 2012 by Prof Dr F.O. Bochud from the IRA-METAS (Switzerland).

3.2 Gamma spectrometry

Routine measurements of potential impurities in SIR ampoules are made using the Ge(Li) and HPGe spectrometers. No impurity was detected in the ^{131}I and ^{109}Cd solutions submitted to the SIR by the LNE-LNHB and the NIST. Measurements of several swabs for BIPM sealed source leakage tests were carried out and a certificate issued.

No time was available to analyze the calibration measurements of the high-purity germanium spectrometer (HPGe).

3.3 Extension of the SIR to short-lived radionuclides

The BIPM.RI(II)-K4.Tc-99m key comparison using the SIR Transfer Instrument (SIRTI) is now running at a rate of two comparisons per year: the NIM (China) and the CNEA (Argentina) participated in 2012 and the publication of the results is in preparation. Although the measurements suffered some technical problems at the NMIJ in 2011, the result of this third ^{99m}Tc comparison, show agreement with the KCRV within one standard uncertainty and has been published. The LNMRI (Brazil), the IFIN-HH (Romania), the VNIIM (Russian Federation) and the NMISA (South Africa) are the next planned participants. A copy of the SIRTI electronics was updated for running in connection with a new laptop with Windows 7. A backup copy of the SIRTI detector has been purchased and is being characterized before calibration against the SIR.

The extension of the SIRTI for measuring ^{18}F is in development. Test measurements are in progress before calibration against the SIR. The NIST already volunteered to participate together with the ENEA which will participate immediately in the ^{99m}Tc and ^{18}F comparisons.

3.4 Extension of the SIR to pure beta emitters

Within the framework of the comparison initiated by the Working Group for the extension of the SIR to the measurement of pure beta emitters, seven laboratories (ENEA (Italy), IRMM (EU), LNE-LNHB (France), NIST (USA), NMISA (South Africa), PTB (Germany) and POLATOM RC (Poland)) have sent an ampoule filled with a solution of ^{63}Ni previously standardized with their own appropriate methods as already reported in the BIPM Director's Report 2011. The radionuclide ^{63}Ni decays with a 100 % probability by an allowed transition of energy 65.87 keV, u = 0.20 keV, to the ground state of ^{63}Cu.

The BIPM received a further ampoule of this radionuclide prepared by the NPL (United Kingdom) during 2012. Three sets of five samples were prepared from the ^{63}Ni solution with the three commercial scintillators, Ultima Gold, Hionic Fluor and Bio Fluor + already used in the first part of this exercise. In parallel three sets of ten quenched standards were prepared by addition of increasing number of drops of nitromethane from the same solution of ^{3}H provided by the LNE-LNHB and used in 2011.

All these samples were measured with the BIPM Beckman LS spectrometer, for which the method based on the use of universal efficiency curves (UEC) were used, and the BIPM TDCR spectrometer.

The analyses of the parallel TDCR measurements are ongoing.

3.5 CCRI activity comparison of ^{99}Tc

The CCRI(II)-K2.Tc-99 activity comparison was organized and piloted by the NPL in 2012. The deadline for the results obtained by the laboratories was the end of July 2012; this date was set after a first postponement of the original deadline. A further extension to the end of February 2013 has been accepted by the participants. The BIPM participated in the activity comparison of this long-lived ($T_{1/2}$ = 211.5 ×10^3 a, u = 1.1 × 10^3 a) almost pure beta emitter. Only the second order transition to the ground state with an end-point energy of 293.6 keV, u = 1.8 keV was considered in this study, since the emission probability of the other existing (second forbidden) beta transition is 1000 times smaller. Further, the gamma emission with an emission probability amounting to 1.6 × 10^{-3} was also neglected. At the same time three sets of quenched standards of ^{3}H from a solution of tritiated water provided by the LNE-LNHB have been prepared, using nitromethane as a quenching agent, to enable the use of the CIEMAT/NIST method. The measurements were carried out with the commercial liquid-scintillation Beckman spectrometer and the BIPM developed TDCR instrument. Three commercial scintillators were used to prepare the samples (Ultima Gold, Hionic Fluor and Bio-Fluor+) by the pycnometer technique. The deposited masses of radioactive solution in the form of 0.1 M ammonium hydroxide ranged from 60 mg to 84 mg. Results obtained for the three scintillators were in good agreement but only the value obtained at reference date with Ultima Gold A = 56.09 kBq/g, u = 0.20 was kept as the BIPM result. The BIPM will take advantage of the postponement of the deadline to evaluate the data obtained with the TDCR spectrometer.

3.6 Other CCRI activity comparisons with BIPM involvement

The final report of the CCRI(II)-K2.Pu-241 comparison piloted by the NPL at the end of 2009 has been published. The comparison results were communicated by the participants using the Excel-based reporting forms produced by the BIPM and the corresponding BIPM software, KCsoft, helped to speed up the publication process.

4. **Thermometry** (S. Picard, M. Nonis)

The Ionizing Radiation Department provides internal calibration services for thermometry at the BIPM, under the BIPM Quality Management System. An external audit was carried out in May 2012 and the recommendation was made that the BIPM should participate in key comparisons of fixed points or standard platinum resistance thermometers (SPRTs). In June 2012, the BIPM was invited by the Consultative Committee for Thermometry (CCT) to take part in the CCT-K9 comparison which was already under way and piloted by the NIST (USA). For this purpose, comparison measurements were carried out at the BIPM during September 2012 and two BIPM SPRTs were hand-carried to the NIST at the end of September for subsequent measurement.

In 2012, 18 SPRTs and nine commercial laboratory thermometers belonging to the Chemistry, Electricity, Mass, Time and Ionizing Radiation Departments were calibrated.

5. Publications

External publications

1. Burns D.T., An analysis of existing data for W_{air}, I_c and the product W_{air} $s_{c,air}$, *Metrologia*, 2012, **49**, 507-512.
2. Andreo P., Burns D.T., Salvat F., On the uncertainties of photon mass energy-absorption coefficients and their ratios for radiation dosimetry, *Physics in Medicine and Biology*, 2012, **57**, 2117–2136.
3. Burns D.T., Kessler C., Roger P., Csete I., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the MKEH, Hungary and the BIPM in low-energy x-rays, *Metrologia*, 2012, **49** *Tech. Suppl.*, 06010.
4. Burns D.T., Lye J.E., Roger P., Butler D.J., Key comparison BIPM.RI(I)-K3 of the air-kerma standards of the ARPANSA, Australia and the BIPM in medium-energy x-rays, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06007.
5. Burns D.T., Kessler C., O'Brien M., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the NIST, USA and the BIPM in low-energy x-rays, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06006.
6. Burns D.T., Roger P., Villevalde A.Y., Oborin A.V., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the VNIIM, Russian Federation and the BIPM in low-energy x-rays, *Metrologia*, 2012, **49,** *Tech. Suppl.*, 06003.
7. Burns D.T., Roger P., Knyziak A.B., Key comparison BIPM.RI(I)-K2 of the air-kerma standards of the GUM, Poland and the BIPM in low-energy x-rays, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06002.
8. Kessler C., Burns D.T., Allisy P.J., Butler D., Lye J., Webb D., Comparison of the standards for absorbed dose to water of the ARPANSA and the BIPM for ^{60}Co gamma-radiation, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06009.
9. Kessler C., Allisy P.J., Burns D.T., Duane S., Manning J., Comparison of the standards for absorbed dose to water of the NPL, United Kingdom and the BIPM for ^{60}Co gamma-rays, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06008.
10. Bé M.-M., Cassette P., Lépy M.C., Amiot M.-M, Kossert K., Nähle O.J., Ott O., Wanke C., Dryák P., Ratel G., Sahagia M., Luca A., Antohe A., Johannsson L., Keightley J., Pearce A., Standardization, decay data measurements and evaluation of ^{64}Cu, *Appl. Radiat. Isot.*, 2012, **70**(9), 1894-1899.
11. Michotte C., Ratel G., Cassette P., Update of the BIPM.RI(II)-K1.Rn-222 comparison of activity measurements for the radionuclide ^{222}Rn to include the LNE-LNHB, France, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06001.
12. Michotte C., Ratel G., Courte S., Fitzgerald R., Sahagia M., Activity measurements of the radionuclide ^{57}Co for the NIST, USA and the IFIN-HH, Romania in the ongoing comparison BIPM.RI(II)-K1.Co-57, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06005.

13. Michotte C., Johansson L., CCRI(II) activity comparison of ^{241}Pu: CCRI(II)-K2.Pu-241, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06012.

14. Michotte C., Sato Y., Unno Y., Yunoki A., Activity measurements of the radionuclide ^{99m}Tc for the NMIJ, Japan, in the ongoing comparison BIPM.RI(II)-K4.Tc-99m, *Metrologia*, 2012, **49**, *Tech. Suppl.*, 06013.

BIPM publications

15. Michotte C., 2012, Verification of the linearity of the new SIR using sources of ^{64}Cu and ^{99m}Tc *Rapport BIPM*-2012/02, 12 pp.

16. Roger P., 2012, High-voltage measurement for the BIPM x-ray generators *Rapport BIPM*-2012/04, 8 pp.

6. Activities related to the work of Consultative Committees

P.J. Allisy-Roberts was Executive Secretary of the CCRI until she retired on 31 May 2012. D.T. Burns acted as *ad interim* Executive Secretary until J.M. Los Arcos took over as the new Executive Secretary on 1 July 2012. There was one CCRI meeting in May and six Working Group meetings during 2012.

J.M. Los Arcos is the coordinator of the CCRI(II) Working Group on the Extension of the SIR to beta-emitters using liquid scintillation (ESWG(II)), which met in May 2012.

C. Michotte is the coordinator of the CCRI(II) Transfer Instrument Working Group (TIWG(II)), which met in May 2012, and a member of the Key Comparisons Working Group (KCWG(II)) which met in May and December 2012.

G. Ratel is a member of the CCRI(II) Working Group on the Extension of the SIR to beta-emitters using liquid scintillation (ESWG(II)), which met on 9 May 2012 and of which he was the *rapporteur*, the KCWG(II) which met on 10 May and 3-4 December 2012, the Transfer Instrument Working Group (TIWG(II)) which met on 10 May 2012 and the Working Group on Realization of the becquerel (BqWG(II)) which met on 9 May 2012.

D.T. Burns is a member of the CCRI(I) Key Comparisons Working Group (KCWG(I)), Accelerator Dosimetry Working Group (ADWG(I)) and Brachytherapy Standards Working Group (BSWG(I)) and the *ad hoc* group evaluating the effect of excess charge on the value for W_{air}. Since 2009 he has been *rapporteur* at annual meetings of the CCRI.

S. Picard is Executive Secretary of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), which held its 8th meeting on 13 to 14 June 2012. She is a member of the CCAUV Working Group for RMO Coordination (CCAUV-RMOWG), the CCAUV Working Group on Strategic Planning (CCAUV-SPWG) and the newly constituted CCAUV Working Group for Key Comparisons (CCAUV-KCWG) which met on 11 to 12 June 2012. She was appointed Interim Acting Executive Secretary of the Consultative Committee for Thermometry (CCT) in August 2012.

7. Activities related to external organizations

D.T. Burns is a Fellow of the Institute of Physics (FInstP) in the UK and in 2012 was elected as a Commissioner of the ICRU. He is a member of the ICRU Committee on Fundamental Quantities and Units and of two ICRU Report Committees (on Key Data for Dosimetry and on Operational Quantities for Radiation Protection). He is also Commission Sponsor for two reports (Key Data for Dosimetry and

Small and Non-Standard Fields) and is the BIPM contact person for the EURAMET-TC for ionizing radiation (replaced for the 2012 meeting by S. Picard).

C. Michotte is the contact person at the BIPM and *rapporteur* for the JCGM/WG1 meetings in June and November 2012.

G. Ratel is the BIPM representative on the International Committee for Radionuclide Metrology (ICRM), is President of the ICRM Nominating Committee, and a member of the Scientific Committee for the 19th International Conference on Radionuclide Metrology and its Applications (ICRM 2013) which will be held in Antwerp (Belgium) on 17 to 21 June 2013.

P.J. Allisy-Roberts has been the BIPM representative on the IAEA SSDL Scientific Committee which she currently chairs. She is a member of the Working Group for the UK NMS programme for ionizing radiation and acoustics and of the *Comité scientifique rayonnements ionisants* (LNE, France). She is a member of the editorial board of the Journal of Radiological Protection and of the *Revue Française de Métrologie*. She was elected to the Board of the European Federation of Medical Physicists where she currently serves as the European Matters Committee Chairman.

8. Travel (conferences, lectures and presentations, visits)

D.T. Burns to:

- Saclay (France), 5 to 9 March 2012, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the LNE-LNHB;
- Saclay (France), 10 September 2012, to participate in the jury for the defence of the thesis by N. Perichon (LNE-LNHB) entitled "*Etablissement des références nationales en termes de dose absorbée, par calorimétrie dans l'eau, pour les faisceaux de rayons X de moyenne énergie, applicables en radiothérapie*";
- Yallambie (Australia), 20 to 28 September 2012, to participate in the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the ARPANSA and to give a joint talk with S. Picard entitled "The BIPM Graphite Calorimeter Standard for Absorbed Dose to Water".

S. Picard to:

- Saclay (France), 17 February 2012, to prepare the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the LNE-LNHB;
- Saclay (France), 5 to 23 March 2012, to carry out the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the LNE-LNHB;
- Beijing (China), 25 to 26 May 2012, to visit the dosimetry department of the NIM and to give a talk entitled "The BIPM Graphite Calorimeter Standard for Absorbed Dose to Water";
- Beijing (China), 26 to 31 May 2012, to participate in the 2012 World Congress on Medical Physics and Biomedical Engineering and to chair a session and give an oral presentation entitled "The BIPM Calorimetric Standard for Accelerator Dosimetry";
- Yallambie (Australia), 20 September to 9 October 2012, to carry out the BIPM.RI(I)-K6 comparison of absorbed dose to water in accelerator beams with the ARPANSA; she also gave a joint talk with D.T. Burns entitled "The BIPM Graphite Calorimeter Standard for Absorbed Dose to Water";
- Melbourne (Australia), 8 October 2012, to attend a seminar given by T. Knöös at the Peter MacCallum Cancer Centre entitled "Flattening Filter Free Linacs";

- Bucharest (Romania) 25 to 26 October 2012 to attend the EURAMET TC-IR meeting and to give a talk entitled "The BIPM Graphite Calorimeter Standard for Absorbed Dose to Water";
- Sèvres (BIPM) 15 to 16 November 2012 to attend the BIPM Workshop on Challenges in Metrology for Dynamic Measurements.

G. Ratel to:

- LNE-LNHB, Saclay (France) 11 September 2012, to attend the defence of the thesis of Florestan Ogheard for which he was the rapporteur;
- Roissy (France), 17 to 20 September 2012, to attend an APAVE course to obtain the aptitude certificate for the transport of dangerous goods;
- LNE, Paris (France) 8 and 9 October a.m. 2012, to attend the DDEP Workshop and to give a talk entitled "The BIPM and the International Reference System (SIR)";
- PTB, Braunschweig (Germany), 26 to 28 November 2012, to attend the ICRM LSCWG and to give a talk entitled "^{63}Ni pilot comparison";
- Issy-les-Moulineaux (France), 29 to 30 November 2012, to attend the "*les 8èmes rencontres des personnes compétentes en radioprotection*";
- IRMM, Geel, 11 to 13 December 2012, ICRM 2013 Scientific Committee;
- IRMM, Geel, 14 December 2012, ICRM 2013 Executive Board.

C. Michotte to:

- Saclay (France), 15 March 2012, to give a seminar on the SIRTI and the ^{99m}Tc comparison;
- Saclay (France), 7 September 2012, as member of jury for a PhD thesis at the LNE-LNHB.

C. Michotte and M. Nonis to:

- Beijing (China), 22 to 29 March 2012, to carry out an activity comparison of ^{99m}Tc (BIPM.RI(II)-K4.Tc-99m) at the NIM using the SIR Transfer Instrument;
- Buenos Aires (Argentina), 8 to 16 November 2012, to carry out an activity comparison of ^{99m}Tc (BIPM.RI(II)-K4.Tc-99m) at the CNEA using the SIR Transfer Instrument.

Internal seminars

- The SIR transfer instrument, a tool for international comparisons of ^{99m}Tc activity measurements, C. Michotte, October 2012.

9. Visitors

- F.L. Prez and L. Joulaeizadeh (VSL), 23 January to 3 February 2012
- L. Joulaeizadeh (VSL), 8 February 2012
- G. Hassan (NIS), 7 to 18 May 2012
- N. Saito and T. Kurosawa (NMIJ/AIST), 6 June 2012
- L. Czap (IAEA), 18 to 22 June 2012
- M. Marobela (BOBS), 26 July 2012

- Delegation from the NMI of Colombia, 24 August 2012
- Delegation from the NIM (China), 16 to 17 October 2012
- D. Mohamad (Deputy Director General IAEA) and A. Fajgelj (IAEA) 12 November 2012
- Steering committee of the BIPM Workshop on Dynamic Measurements, 14 November 2012
- A. Villevalde (VNIIM), 23 to 30 November 2012
- J. Ullrich, (President of the PTB) 4 December 2012.

10. Secondees and guest workers

- C. Carmeli (University of Birmingham), 18 June to 18 July 2012
- J. Alvarez (ININ), 20 March to 26 June 2012.