LNE-LNHB Highlights 2011-2012

1. Dosimetric references for "Papillon 50" (contact radiotherapy)

. The purpose of this study was to determine the *modus operandi* to calibrate ionization chambers used in "Papillon 50", a new device of Ariane Medical System for contact radiotherapy.

The first step consisted in measurements of the energetic spectra of "Papillon 50" with a Cd-Te spectrometer corrected by Monte Carlo calculations. CCRI 50(b) appears to be close to the beam of "Papillon 50".

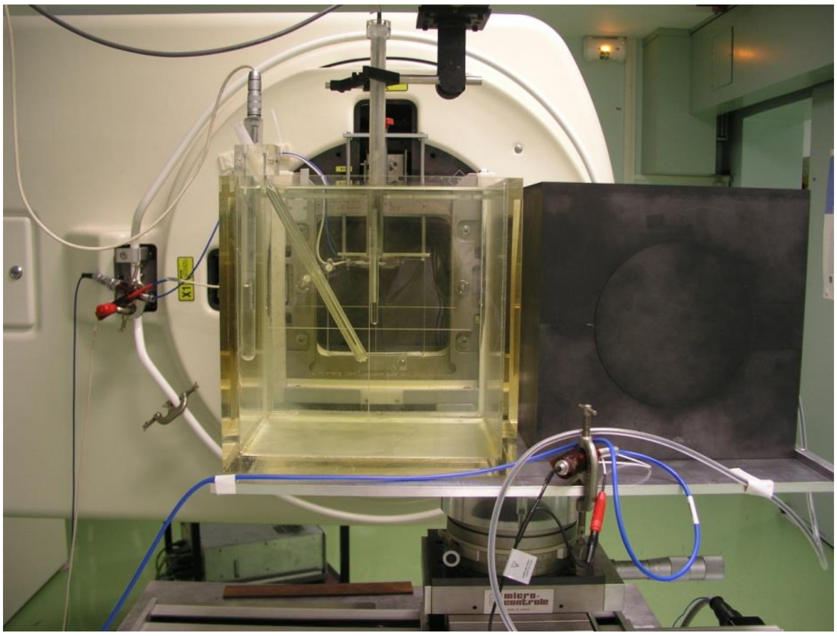
The second step consisted in checking the effect of some parameters on the calibration coefficient: variation of +2.5 % in function of the beam diameter (8 to 2 cm), variation of -0.6 % in function of the distance (30 to 50 cm). The air kerma calibration coefficient uncertainty should be around 0.35% (k=1).

2. Absorbed dose to water references for high-energy X-ray beams in $2x2\ cm^2$ fields (JRP7)

This study was part of the European metrology project JRP7 “External Beam Cancer Therapy”. The purpose of the experiments done in 2011 was to determine the absorbed dose to water in $2x2\ cm^2$ fields for the 6 and 12 MV beams as well as the 6 MV beam without flattening filters.

The method is based on graphite calorimetry measurements in a graphite phantom. First the absorbed dose in the calorimeter core is determined. Second, the ratio between the absorbed dose to water in the reference conditions to the absorbed dose in the calorimeter core is calculated with EGSnrc. And finally, a reference ionization chamber set up at the reference point in the water phantom is calibrated in absorbed dose to water.

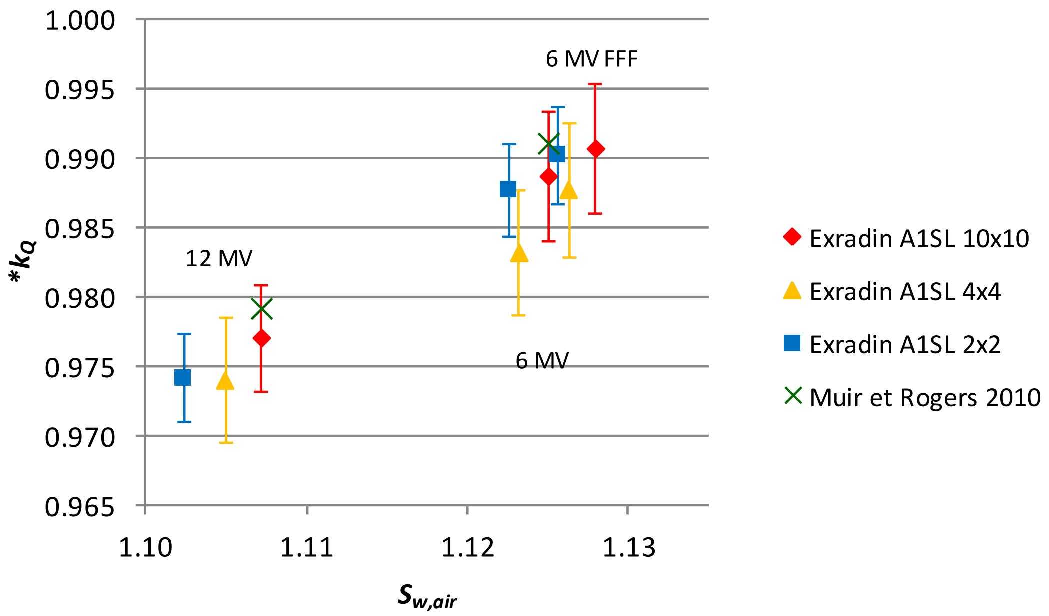
The absorbed dose to water is based solely on measurements in graphite. Only the final calibration of the reference ionization chamber is done in water. This method is valid if the beams characteristics between the water and graphite phantom irradiations are stable enough. To insure the beam stability, the graphite calorimeter and the water phantom are positioned on a perpendicularly-to-the-beam mobile plate in order to automatically and quickly alternate both phantoms in the beam (see photo). This method implies that the beam monitor measurements relationship, when the graphite phantom and the water phantom are irradiated, can be determined precisely (influence of the backscattering difference). For the influence of the backscattering difference on the monitor, the ratios of different monitors responses positioned at different distances of the phantoms were compared in function of the irradiated phantom. Measurements were not able to show a difference for our usual monitoring system when the water or the graphite phantoms were irradiated.



Graphite and water phantom alternating plate in front of LNE-LNHB linac

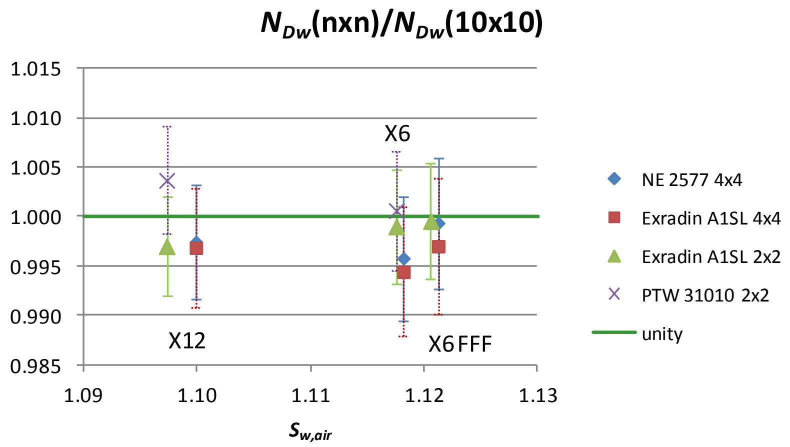
An Exradin A1SL is used as reference ionization chamber for the 2 cm x 2 cm fields. The Exradin A1SL has also been calibrated in the 4 cm x 4 cm and 10 cm x 10 cm fields. Monte-Carlo was used to calculate water-to-air stopping power ratios $S_{w,air}$ for the three field sizes. The following table and figure show experimental $^*k_Q$ values for the Exradin A1SL. The star means that the definition of k_Q factors has been extended to field sizes different from the reference conditions (10 cm x10 cm).

Exradin A1SL $^*k_Q$					
X6 FFF	*u* (%)	X6	*u* (%)	X12	*u* (%)
10 cm x10 cm					
0.9908	0.56	0.9888	0.55	0.9771	0.49
4 cm x4 cm					
0.9878	0.57	0.9833	0.55	0.9740	0.54
2 cm x2 cm					
0.9903	0.46	0.9878	0.44	0.9742	0.44



$*k_Q$ as function of $S_{w,air}$ for one Exradin A1SL ionization chamber

The graph below presents the ratio of the ionization chamber calibration coefficients for a given field size divided by the calibration coefficient for the 10 cm x 10 cm field size as function of the water-to-air stopping–power ratio. At one standard uncertainty, there is no significant difference on the calibration coefficient between 10 cm x 10 cm and 2 cm x 2 cm field sizes. However the ratio should be lower than unity for field sizes smaller than 10 cm x 10 cm.

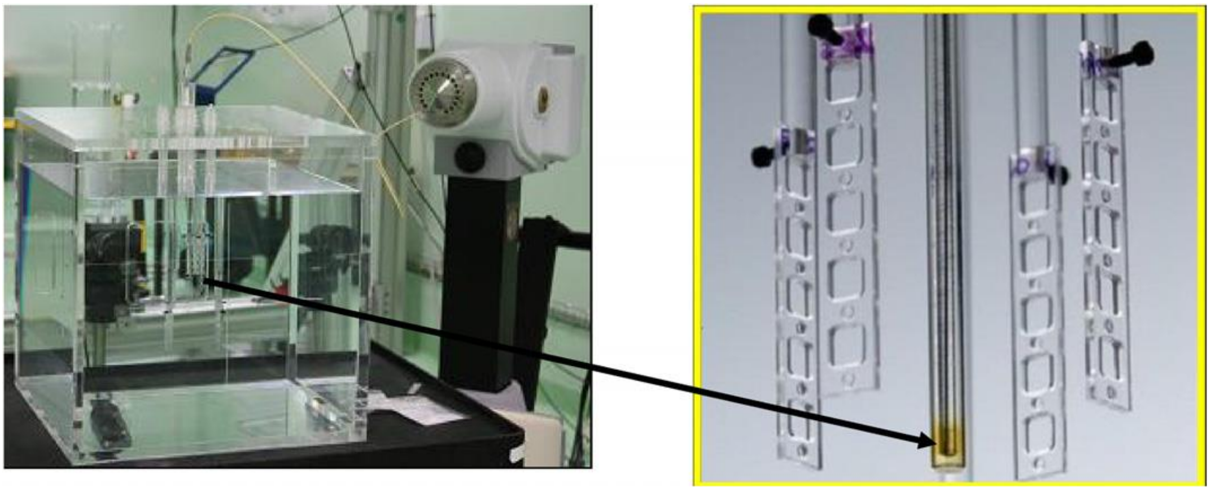


ratio of the ionization chamber calibration coefficients for a given field size divided by the calibration coefficient for the 10 cm x 10 cm field size

3. Brachytherapy (JRP6)

- Absorbed dose to water distribution measured around an HDR ^{192}Ir brachytherapy source by thermoluminescent dosimeters

The purpose of this work was to develop a procedure to directly estimate the spatial distribution of the absorbed dose rate to water, D_w, around an HDR ^{192}Ir brachytherapy source. The methodology developed was based on Monte Carlo calculations and measurements in air and in water with thermoluminescent detectors.

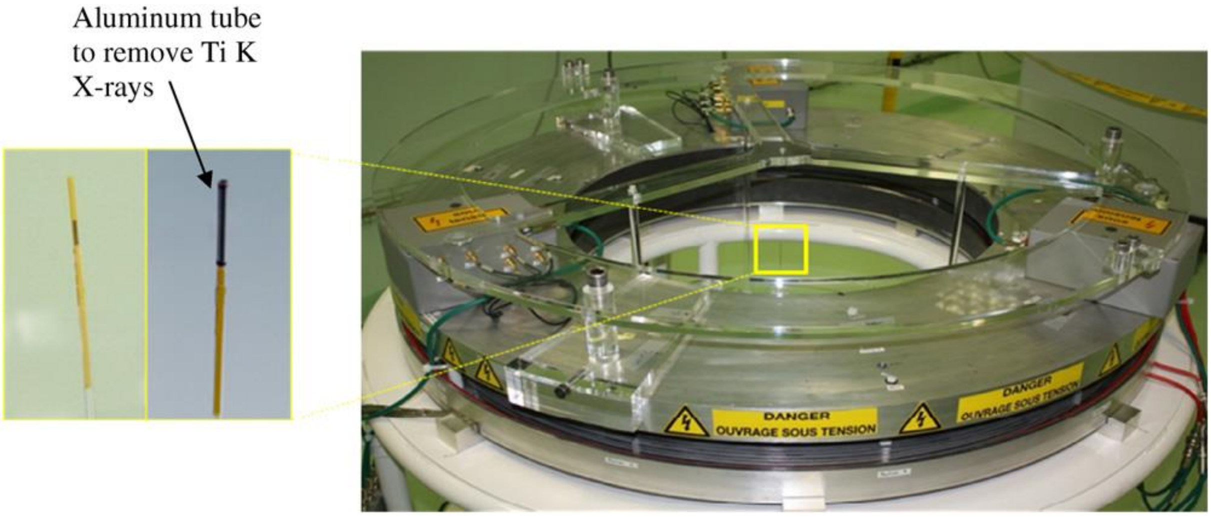


Experimental setup of TLDs in water during irradiations with an HDR ^{192}Ir source (left). The arrow points to the source location. Dimensions of the source and TLD holders were enlarged in the right image for clarity purposes

Variations in detector positioning had a significant influence near the brachytherapy source (20 % at 1 cm). The method leads to a mean difference of about 7 % with the CLRP TG-43 Parameter Database when the absorbed dose to water is characterized along the transverse plane to the source (from 1 cm to about 11 cm). This mean difference, however, is within an uncertainty of 7.7 % over all distances. This method therefore can be used to provide direct estimates of the absorbed dose rate to water for HDR brachytherapy source irradiations which are more realistic than those which use other phantom materials. In addition, measurements are indicative of the source geometry and material composition.

- LNE–LNHB air-kerma and absorbed dose to water primary standards for low dose-rate ^{125}I brachytherapy sources

The devices and methods applied for the LNE–LNHB primary standards in terms of reference air-kerma in an elementary volume of air surrounded by vacuum and absorbed dose to water —at a reference depth of 1 cm in water in the source transverse plane— for low dose-rate brachytherapy sources are based on ionometric measurements, using a circular-shaped free-in-air ionization chamber, and Monte Carlo calculated conversion factors.

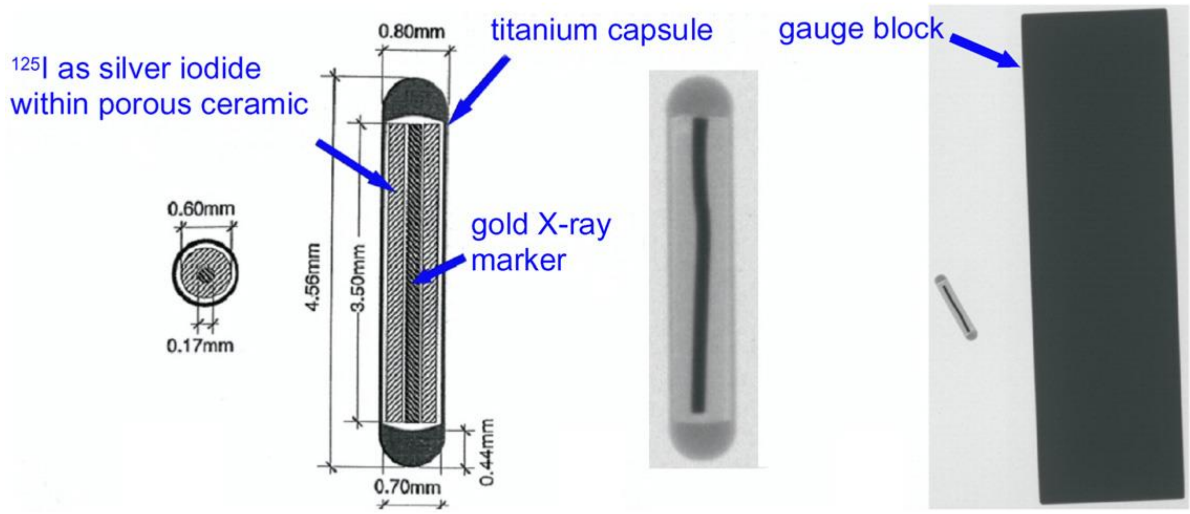


Photograph of the circular-shaped free-air ionization chamber

Results for an IBt Bebig ^{125}I source are used to assess the dose-rate constant. Uncertainties of 1.5 % and 1.6 % (with k = 1) were found for the air-kerma rate and the absorbed dose to water rate estimated with the new primary standards. Good agreement was found between our values and the AAPM published dose-rate constants. The new devices will be fully commissioned as primary standards after further investigations concerning the sensitive volume and the conversion factor assessments.

- Full characterization of the ^{125}I IBt Bebig I25.S16 brachytherapy source and sensitivity study of the absorbed dose to water due to the seed dimensional variations (collaboration with ITN)

^{125}I brachytherapy sources have a complex geometry with very small dimensions. Those specificities induce problems of reproducibility in the manufacturing process.



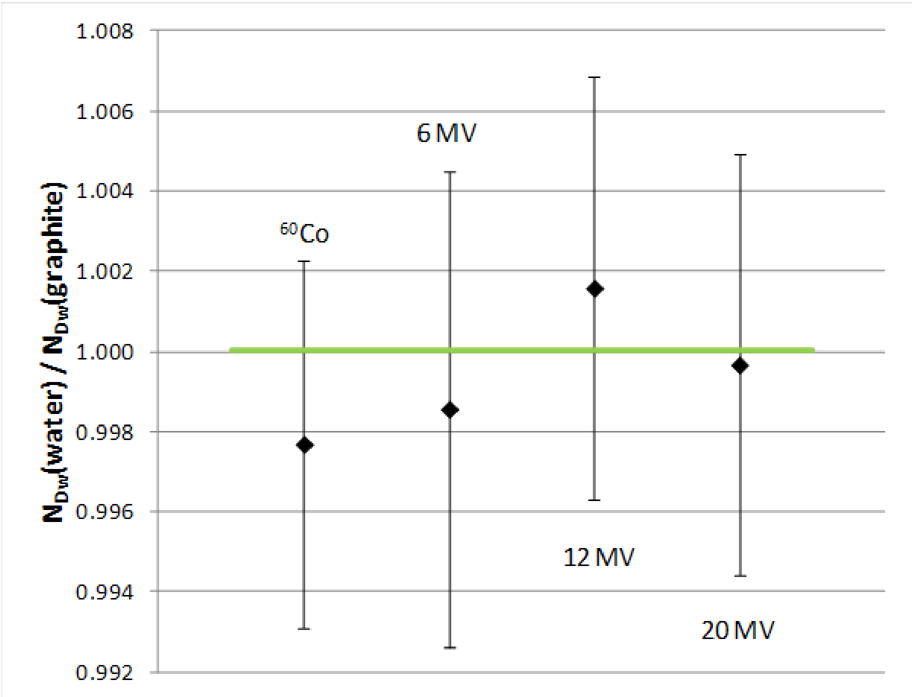
Internal and external structures of an IBt Bebig I25.S16 seed

The consequence of this lack of reproducibility is a variation of the flux of the photonic emission from one seed to another. Consequently, it was observed that the spatial distribution of the absorbed dose to water is very dependent on the seed characteristics (geometry and components of the internal and wrapping materials).

The purpose of this study was to quantify the sensitivity of the distribution of the absorbed dose to water due to the multi-element constitution and dimensional variations of the seeds. The sensitivity of the absorbed dose to water distribution due to the seed dimensional variations was quantified by MC simulations based on experimental geometrical characterization using a batch of 15 seeds. After correction of the photon absorption due to the 40 cm air layer between the source and the Si-PIN detector, experimental results of the anisotropy measurements are in good agreement with the simulation results. Nevertheless, the uncertainties associated with the simulated radial dose function may be underestimated due to the fact that the methodology used does not take into account possible heterogeneities in the transverse plane. It appears that the tolerances of the seed dimensions should be smaller.

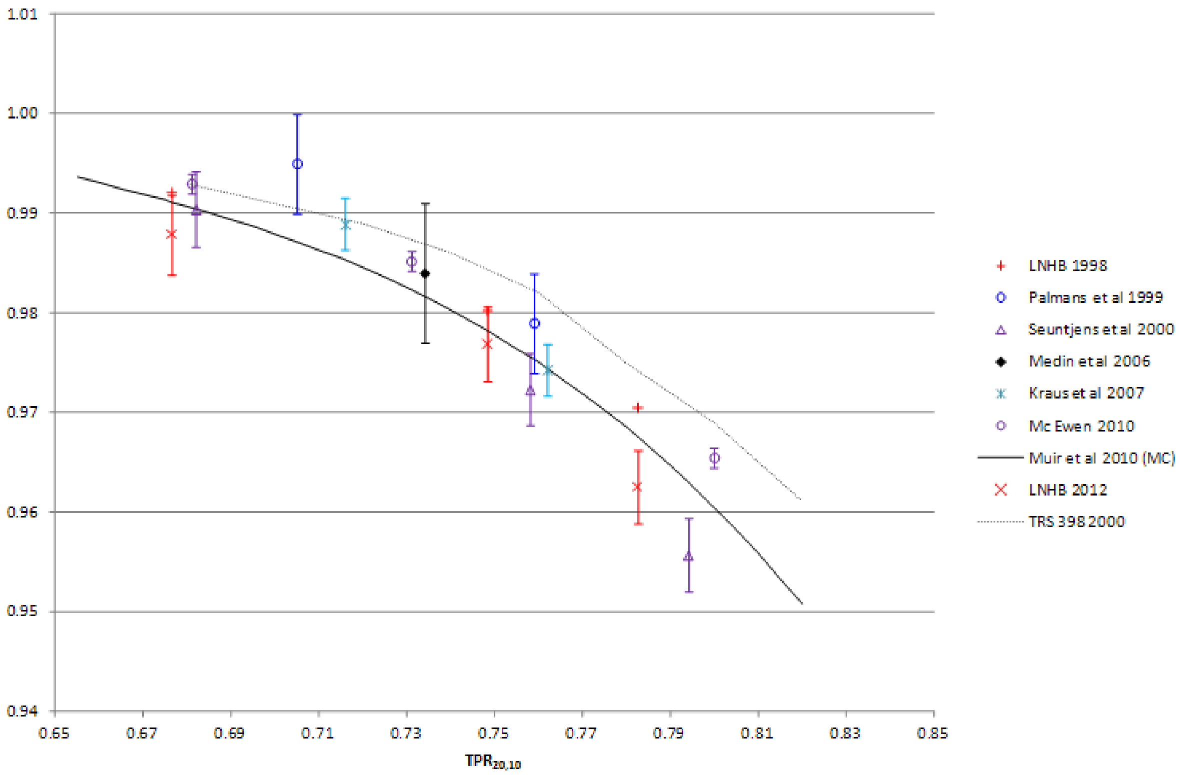
4. New absorbed dose to water references for XHE (6 MV, 12 MV and 20 MV) in 10 cm x10 cm fields by water and graphite calorimetry

The LNE-LNHB has developed two primary standards to determine the absorbed-dose to water under reference conditions (10 cm x 10 cm fields) in cobalt-60, 6 MV, 12 MV and 20 MV photon beams: a graphite calorimeter and a water calorimeter. The methodology to calculate the absorbed-dose to water with the graphite calorimeter is refined and based on the absorbed-dose in the core and Monte Carlo calculations. The two calorimetry methods give results in good agreement with differences lying between 0.04 % (20 MV) and 0.23 % (^{60}Co).



Ratio with its standard deviation of the absorbed-dose to water calibration coefficients of the linac reference ionization chamber (NE 2571 # 2791) obtained with the water calorimeter and with the graphite calorimeter

The arithmetic mean value of both calorimeter results is chosen to determine the absorbed-dose to water in the cobalt-60 beam and the calibration coefficients of the reference ionization chamber for the high-energy x-ray beams. The new relative standard uncertainties (k = 1) of absorbed-dose to water are between 0.25 % (cobalt-60) and 0.32 % (6 MV).

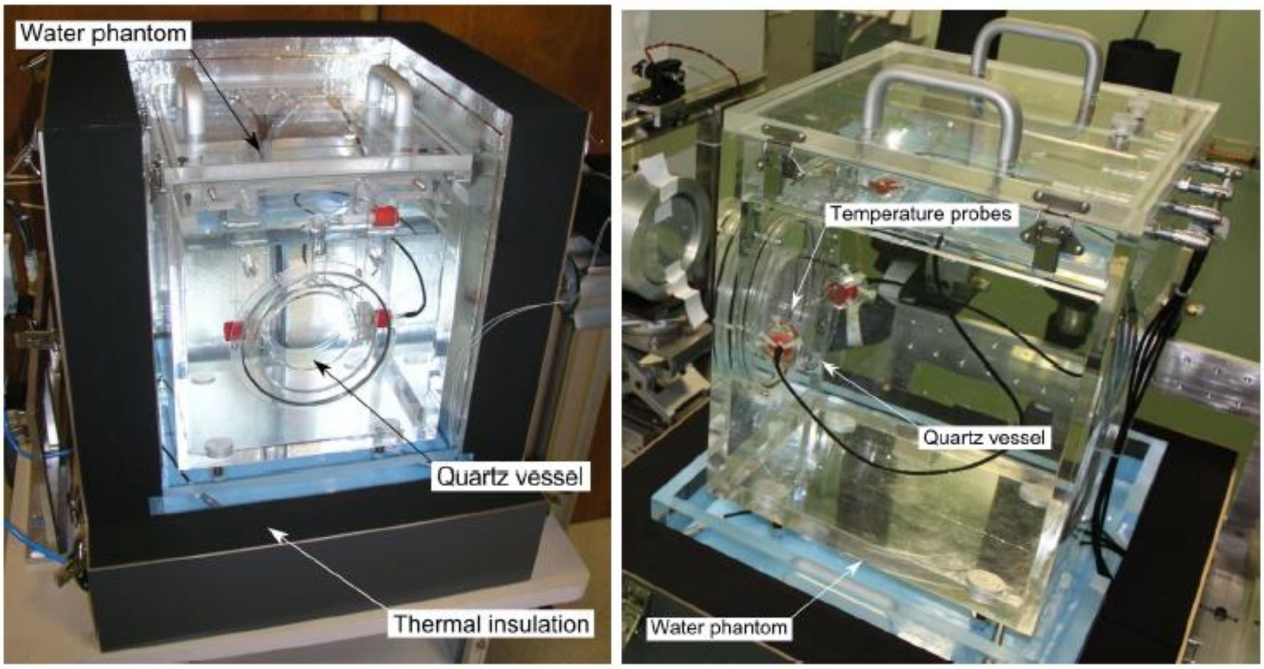


Experimental and calculated k_Q values for a NE 2571 ionization chamber according to different sources (uncertainties on LNHB 1998 values around 1%)

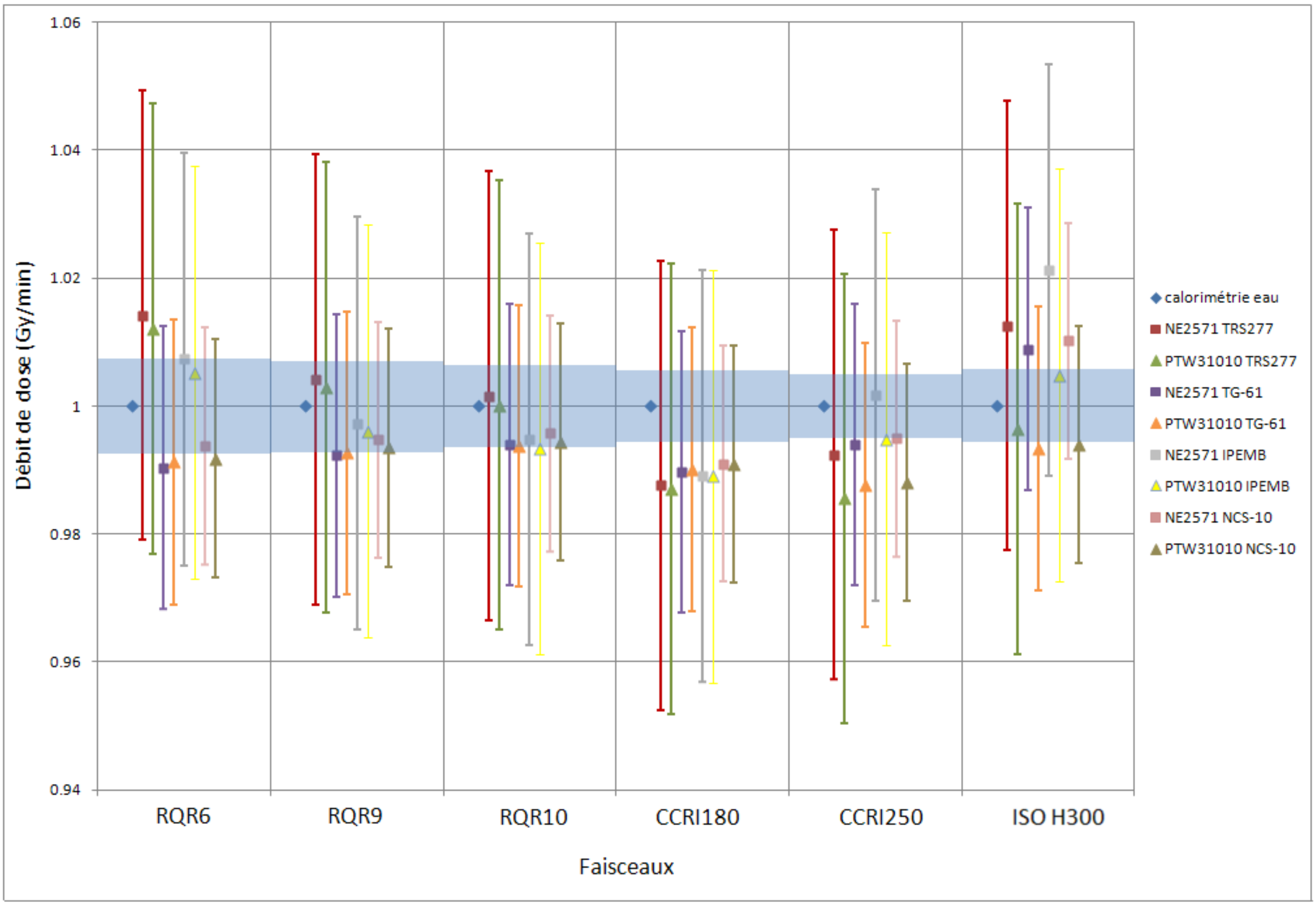
The new reference for ^{60}Co is now used for customer calibrations. For the high-energy photon beams, as there are larger differences between the new and the previous references (0.8 % at 20 MV), the LNE-LNHB will implement them in the French metrological system only after the analysis and publication of the results of the comparison with the BIPM.

5. References in absorbed dose to water for medium energy x-rays by water calorimetry

A water calorimeter has been built for measurements at 2 cm depth. The water phantom has been holed on the front to accommodate the quartz vessel with the thermistors. Cold air is blown on the quartz vessel front window and the underside of the water phantom with Ranque-Hilsch vortex tubes. The uncertainties on the absorbed dose to water lie between 0.49 % to 0.72 % (k = 1) according to the different beams.



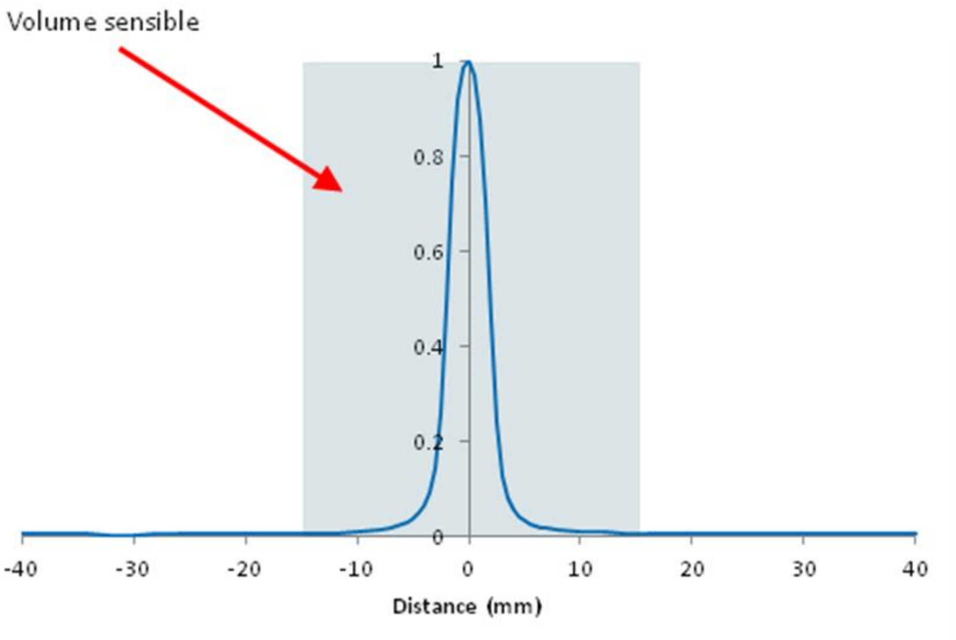
The comparison results between the water calorimeter and different air kerma protocols (IAEA TRS-277, AAPM TG-61, IPEMB, NCS-10) are shown on the next figure for a NE2571 and a PTW 31010 ionization chambers. The maximum difference is of 2.1 % well inside the uncertainty values.


1.06
1.04
1.02
1
0.98
0.96
0.94
Débit de dose (Gy/min)
RQR6
RQR9
RQR10
CCRI180
CCRI250
ISO H300
Faisceaux
calorimétrie eau
NE2571 TRS277
PTW31010 TRS277
NE2571 TG-61
PTW31010 TG-61
NE2571 IPEMB
PTW31010 IPEMB
NE2571 NCS-10
PTW31010 NCS-10

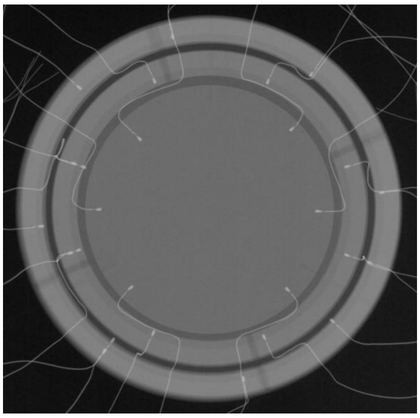
6. References in absorbed dose to water for high energy x-rays in small fields (diameter < 2 cm) by graphite calorimetry (HLT09)

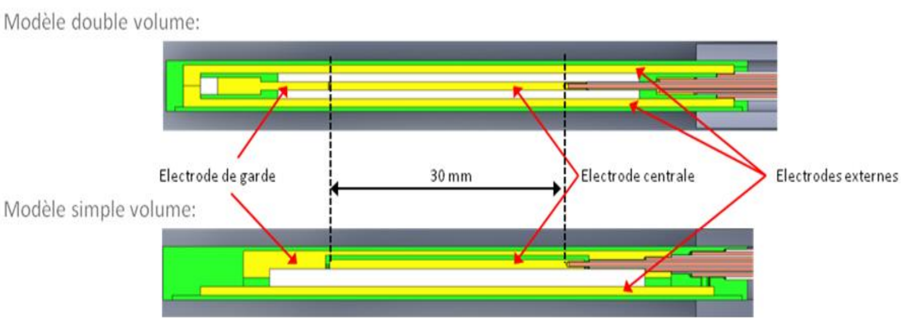
Work in Progress

As graphite and water calorimeters become impractical in small beams, a new quantity (dose area product), measured over a large surface, will be checked instead of the usual absorbed dose at a reference point.



A graphite calorimeter with a diameter of 3 cm has been built as well as two parallel plate ionization chambers with collecting electrodes of the same diameter.

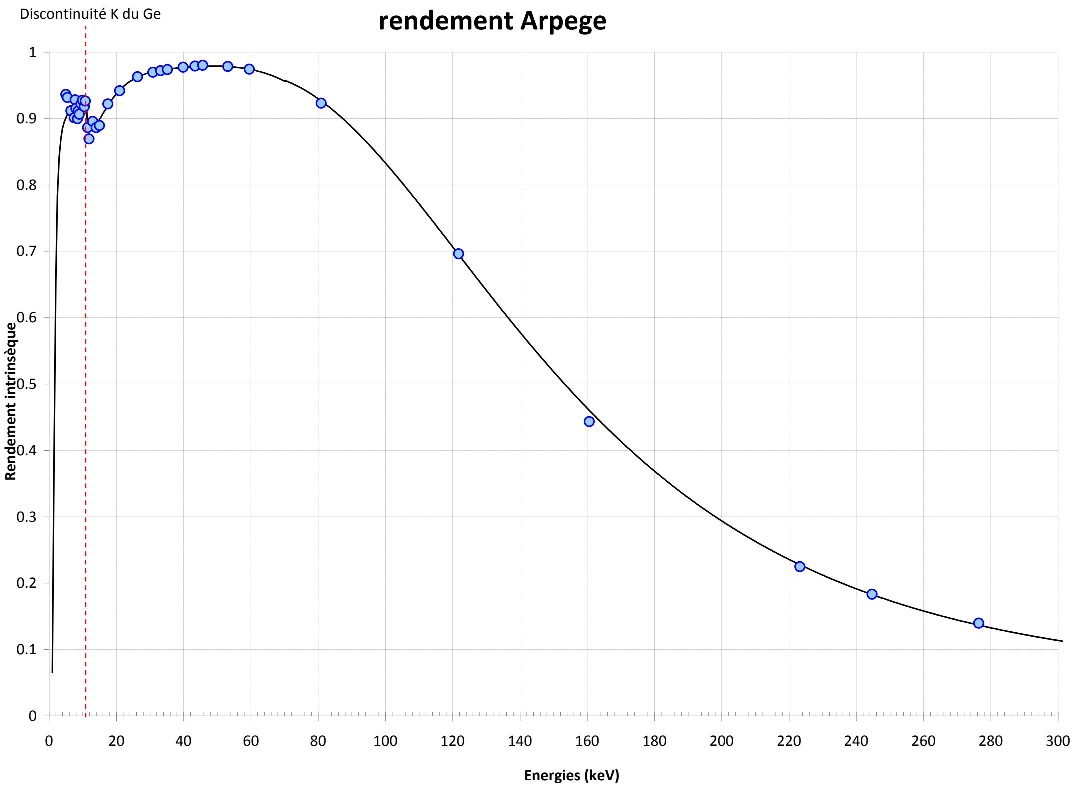




7. Quality indices and purity study of x-ray beams of energy smaller than 300 keV

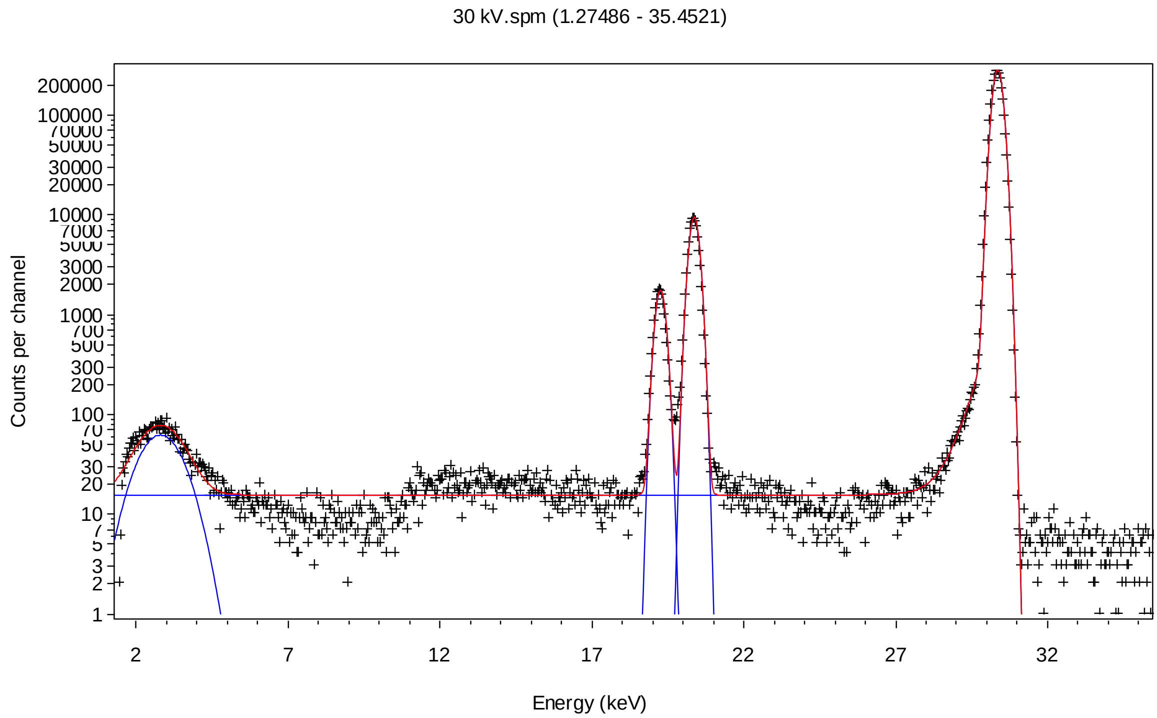
Work in Progress

The study purpose is to significantly improve x-ray energetic spectra knowledge (x-ray tubes, ^{125}I) using semiconductor detectors. First, two different detectors (Si-PN and GeHP) were calibrated in term of form and yield factors with sealed sources and the LNE-LNHB SOLEX facility (monoenergetic Source of Low Energy X-rays).



GeHP yields

Once calibrated, the intrinsic behavior of the detectors and their associated electronic can be corrected to determine the emission spectrum.



Spectral measurements of ESRF 30 keV monoenergetic beam

As x-ray tubes have a too high beam-rate for the detectors, the detection solid angle has been reduced with collimators of very small aperture (Ø 500 or 150 µm). In this case, the alignment between the detector, the collimators and the source becomes very difficult to achieve. Two alignment benches have been developed: one for sealed sources and one for x-ray generators. The last one has 6 motorized movement axis operated with a program developed on Labview. This allows the exploration of the irradiation field in 2D (20 cm x 20 cm), to measure its homogeneity and its energetic spectra in every point. Both detectors were used on this bench under irradiation with a mammographic x-ray beam of 25 kV and their results compared thus validating the low energy corrections.

In the next step, the scattering from outside sources (bench, collimators…) will be identified and quantified with Monte Carlo calculations (PENELOPE) in order to remove them from the measured energetic spectra. A program to help applying the corrections will be written. It will then be used on the LNE-LNHB x-ray beams of less than 300 keV to determine the energetic spectra and to help in researching a new quality index for small and medium energy x-rays.

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