



list

Primary reference in terms of air kerma for ionizing radiation fields produced by a electrostatic accelerator

LABORATOIRE NATIONAL HENRI BECQUEREL
CEA-LNE-LNHB

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* ATRON METROLOGY

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French regulation:

Mandatory renewing of radiative source every 10 years
Extension of use for 5 years after integrity check

Additional operating costs for French calibration laboratories**Take advantage of this difficulty****Previously:**

Reference high energy radiation fields for radiation protection (Medical LINAC Saturne 43)

- Electrons energy 18 MeV
- target + filter -> Bremssthalung X-rays $\bar{E} \sim 7$ MeV

❑ Needs expressed by a private company « ATRON METROLOGY » to establish a new calibration / verification service for dosimeters based on a LINAC beam for a lower energy domain namely close to ^{137}Cs (0.662 MeV)

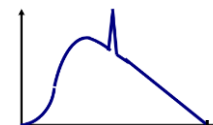
**Establish the metrological traceability
of the ATRON METROLOGY radiation fields to the SI**

- 1) ATRON METROLOGY facility
- 2) Determination of the fluence distribution
- 3) Calculation of the conversion coefficient from air kerma toward ambient dose equivalent (quantity used for area dosimetry)
- 4) Traceability to the CEA-LNE-LNHB national references
- 5) Design of a primary vented cavity chamber
- 6) Results of primary measurement on site of the air kerma normalized to the monitors

Electrostatic accelerator - Singletron HVVEE (High Voltage Engineering Europa B.V.)

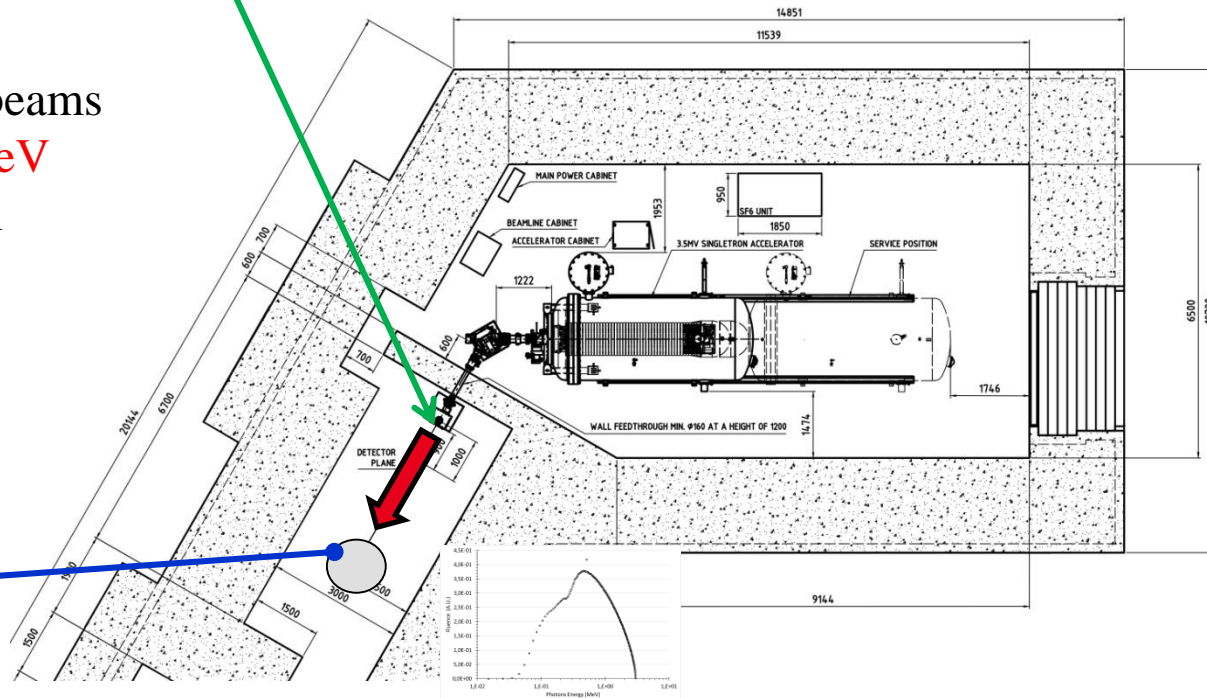
- HV maximum **3,5 MV**
- Scanned target ^{73}Ta (1,5 mm) 22 x 4 cm²
- Current range **0,1 pA à 1 mA**

Bremsstrahlung



Presetting: continuous electrons beams
1,25 MeV - 2 MeV & **3 MeV**
Two distances: **1** & **3 m**

Automatic sample conveyor

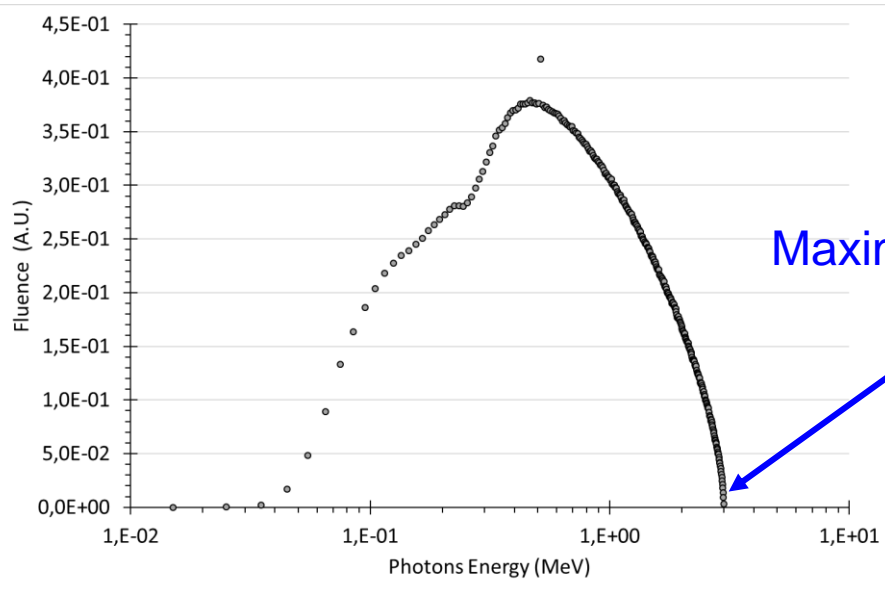


Monitors: 2 cavity chambers PTW TM32002 (1 L), associated with PTW UNIDOS Weblin T10021 electrometers

We need to know the fluence distribution without the spectrometer perturbation to:

- ❑ Calculate the correction factors to be applied to the primary measurement of air kerma with an ionization chamber
- ❑ Calculate the conversion coefficient from air kerma into ambient dose equivalent (Sv / Gy)

First of all : Calculate the “spectra” at the measurement point in air (MCNP)

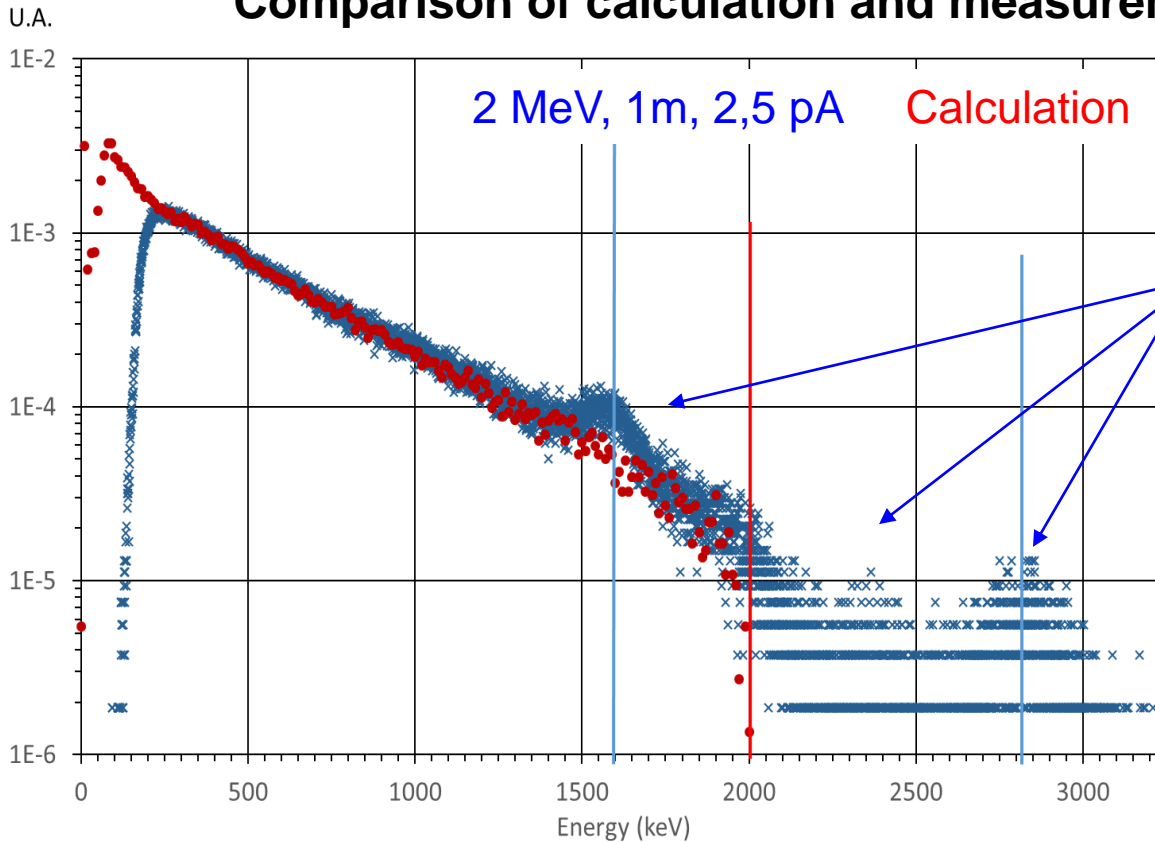


Calculated spectrum Distance 1 m

Maximum electron energy
3 MeV

Average X-rays energy ~ **0,64 MeV**

Comparison of calculation and measurement of the raw spectra



Three peaks around 1600, 2350 & 2800 keV can be seen on the measured spectra:

Environment ^{40}K and ...

WWW.nucleide.org/Laraweb

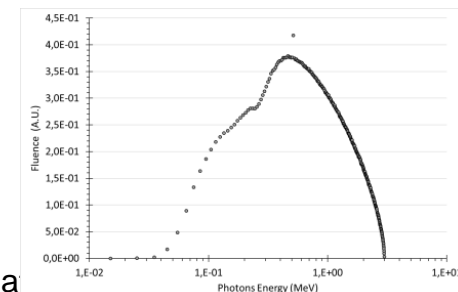
Fondamental data

CEA/LNE/LNHB website

Computation with MCNP
« tally F8 » (deposited energy in the scintillator volume)

Above the threshold, **very good agreement between the calculated and measured spectra**

The comparison of the pulse distributions validates the use of the code therefore the calculation of the spectra



«AM»: ATRON METROLOGY radiation field ; «LNHB»: CEA-LNE-LNHB Co/Cs beams

Calibration Coef . : $N_{\text{quantity, detector, field}}$
 K_a Monit AM or LNHB

Config.1 m 3MeV
 Close to
 ^{137}Cs (ISO 4037)
 1,21 Sv/Gy

$$\overline{h_{k,AM}^*} = \frac{H^*(10)}{K_a} = \frac{\int h_k^*(E) E \Phi_{AM}(E) dE}{\int E \Phi_{AM}(E) dE} = 1,20 \text{ Sv/Gy}$$

$$H^*(10)_{AM} = K_{a,AM} \cdot \overline{h_{k,AM}^*}$$

K_a Primary measure on site

$$H^*(10)_{AM} = I_{\text{Monit}} \cdot N_{K_a, \text{Monit}, AM} \cdot \overline{h_{k,AM}^*}$$

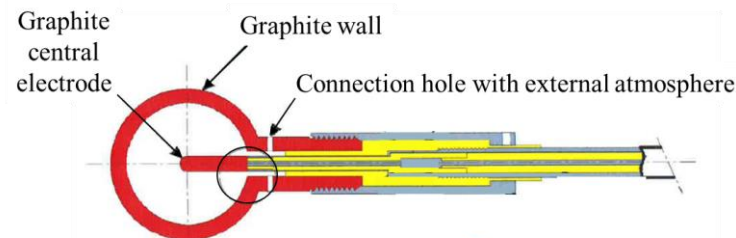
$$H^*(10)_{AM} = I_{\text{Monit}} \cdot N_{K_a, \text{Monit}, \text{LNHB}} \cdot k_{AM, \text{LNHB}} \cdot \overline{h_{k,AM}^*}$$

$$k_{AM, \text{LNHB}} = \frac{N_{ka, \text{Monit}, AM}}{N_{ka, \text{Monit}, \text{LNHB}}}$$

**Traceability to the SI through
 the CEA/LNE/LNHB
 national references in terms of air kerma**

$$\dot{K}_a = \frac{I_{cor/monit}}{V \rho_{air}} (W/e)_{air} \prod_i k_i$$

Primary vented cavity ionization chamber CEA-LNE-LNHB Design



\dot{K}_a : Air kerma rate normalized to monitor Gy / M.U.

$I_{cor/Monit}$: Corrected current (ambient condition, BG, ...) normalized to monitor

$(W/e)_{air}$: average energy to produce an ion-electron pair divided by the electron charge

ρ_{air} : Dry air density at 293,15 K and 1013,25 hPa

V : Effective collection volume Measured at the French primary lab. LNE

$$\left. \begin{array}{l} \text{J / M.U.} \\ \text{kg} \end{array} \right\} \frac{\quad}{\quad} = \text{Gy / M.U.}$$

$\prod_i k_i$: Correction factors for the perturbation due to the IC itself (electron and photon fluence, attenuation diffusion in the IC wall, radiative air kerma)

$$I_{cor/monit} = \frac{(I_{raw,CI} - I_{BG,CI}) \prod_j k_j}{(I_{raw,monitor} - I_{BG,monitor})} \quad \text{A / M.U.}$$

$I_{raw,XX}$: Average value of the current at the measurement point under irradiation. (A $\xrightarrow{\quad}$ C)

$I_{BG,XX}$: Average value of the current at the measurement point with the beam off. (M.U.)

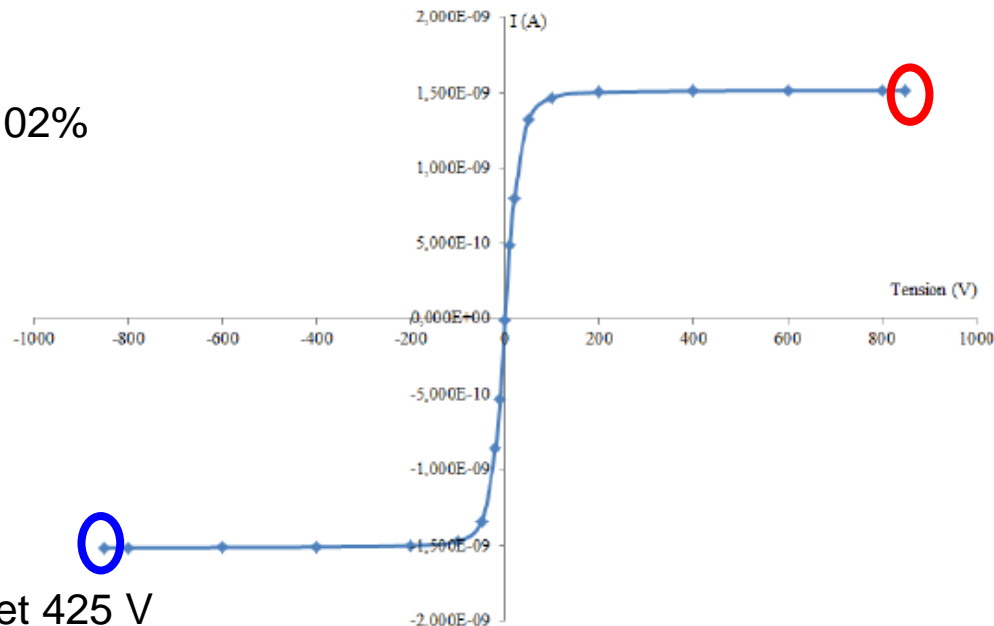
$\prod_j k_j$: Correction factors (humidity, diffusion of the RX on the IC stick, influence of the temperature on the capacitor value).

Electrical test:

Current Stability (7 hours): Max deviation 0,02%

Leakage current: 10^{-16} to 10^{-14} A

$$k_{pol} = \frac{(abs(I_{cor,+850V}) + abs(I_{cor,-850V})) / 2}{abs(I_{cor,+850V})}$$



Polarisation correction: stable between 850 et 425 V

-> working condition +850 V
(best collection without multiplication)

| $k_{pol} +850 V$ | $k_{pol} +425 V$ |
|------------------|------------------|
| 1,000235 (12) | 0,999955 (13) |

Saturation correction:

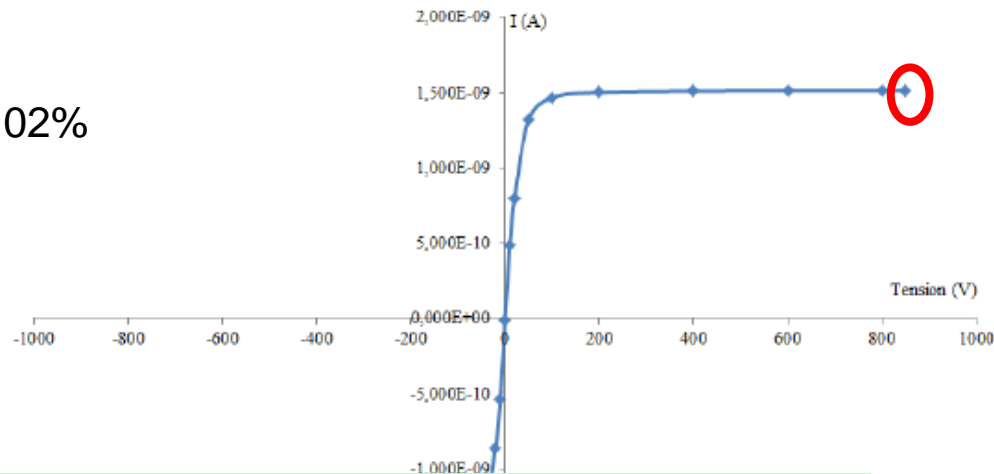
$$k_s = \frac{I_\infty}{I_0} = 1 + \frac{\frac{I_0 - I_1}{V_0} - \frac{I_0}{V_1}}{\frac{I_1}{V_1} - \frac{I_0}{V_0}}$$

Very close to unity so very good collection efficiency

Electrical test:

Current Stability (7 hours): Max deviation 0,02%

Leakage current: 10^{-16} to 10^{-14} A



$$k_{pol} = \frac{(abs(I_{cor,+850V}) + abs(I_{cor,-850V}))}{2}$$

Saturation and polarisation corrections very close to unity,
low leakage, good current stability

Very good ionization chamber

Polarisation

-> working

(best collection without multiplication)

| $k_{pol} +850 V$ | $k_{pol} +425 V$ |
|------------------|------------------|
| 1,000235 (12) | 0,999955 (13) |

Saturation correction:

$$k_s = \frac{I_\infty}{I_0} = 1 + \frac{\frac{I_0 - I_1}{V_0} - 1}{\frac{I_0 - I_1}{V_1} - 1}$$

Very close to unity so very good collection efficiency

Results, 3 MV at 1 m

| Parameter | Value | Standard uncertainty |
|-------------------------------------------------------------|-------------|----------------------|
| $(I_{\text{cor}} - \text{BF}) / (\text{Monit} - \text{BF})$ | -1,0475E-04 | 0,405% |
| Volume | 7,1735 | 0,004% |
| Air density (g/cm ³) | 1,2047E-03 | 0,001% |
| k_{pol} | 1,0017 | 0,286% |
| k_{s} | 0,9994 | 0,573% |
| k_{stick} | 0,9983 | 0,257% |
| A_{wall} | 0,9798 | 0,200% |
| $(\mu_{\text{en}} / \rho)_{\text{air,graph}}$ | 0,9975 | 1,000% |
| $(S/\rho)_{\text{graph,air}}$ | 0,9979 | 1,000% |
| W_{air}/e (J/C) | 33,97 | 0,350% |
| 1-gair | 0,9968 | 1,400% |
| | | |
| $K_{\text{a}} / \text{monit}$ (Gy/M.U.) | 2,52E+04 | 2,183% |
| | | |
| $h^*(10)$ | 1,20 | 0,200% |
| | | |
| $H^*(10) / \text{monit}$ (Sv/M.U.) | 3,02E+04 | 2,2% |

Confirmation that k_{pol} k_{s}
are very close to unity

Uncertainty mainly
due to μ , S and g

Uncertainty is better than
it would have been using
a transfer device

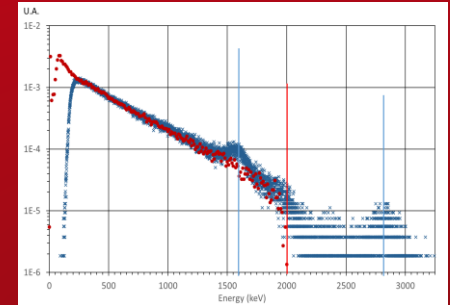
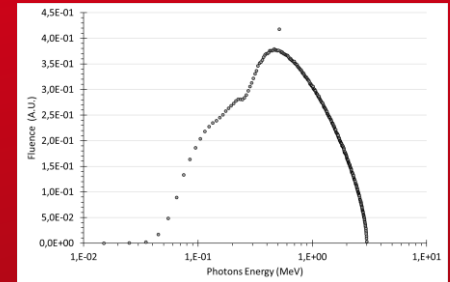
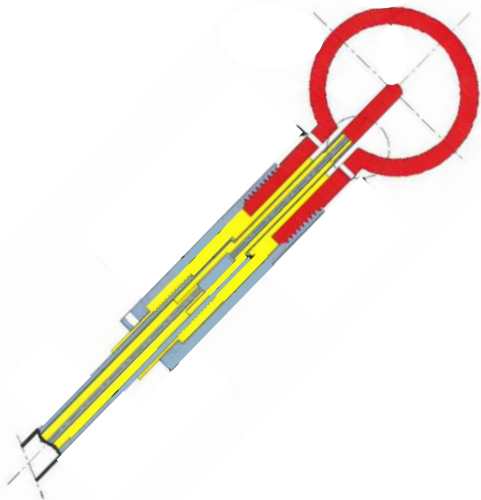
An innovative way to meet the needs of nuclear industry in terms of dosimeter verification and calibration services has been developed through an efficient collaboration between the French national metrology lab (CEA-LNE-LNHB) and industry

CEA- LNE-LNHB maintains and develops its irradiation and calibration capabilities thanks to the French legislation

*“The best things
one can do
are the things
we do together”*

**Thank you for
your attention**

$$\dot{K}_a = \frac{I_{cor/monit}}{V \rho_{air}} (W/e)_{air} \prod_i k_i$$



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