X-rays @ LNF
25-10-2023

X-ray facility in the 40-110 kV range for medical physics and dosimetry

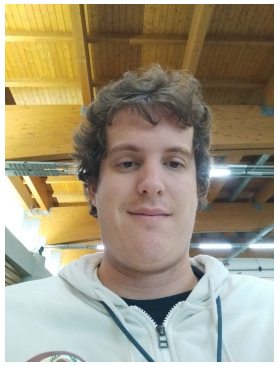
R. Bedogni, A. Calamida, L. Russo, A.I. Castro-Campoy, M.A. Caballero-Pacheco, D. Dashdondog, C. Cantone

LEMRAP
Laboratory for Environmental and Medical RAdiation Physics

X-rays @ LNF
25-10-2023

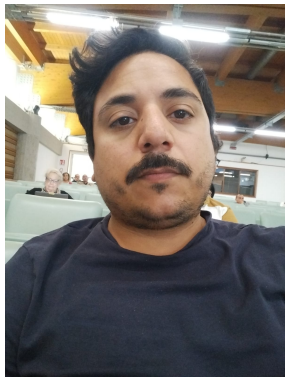
INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

LEMRAP
Laboratory for Environmental and Medical RAdiation Physics



Alessandro Calamida

Luigi Russo



Ivan Castro

Miguel Angel Caballero

Dolzodmaa Dashdondog

Summary

- The international normative
- The facility
- The monitoring equipment
- The measurement capabilities

The international normative

TC 85 Nuclear Energy
SC2 Radiological Protection
WG2 Reference radiation fields

ISO 4037

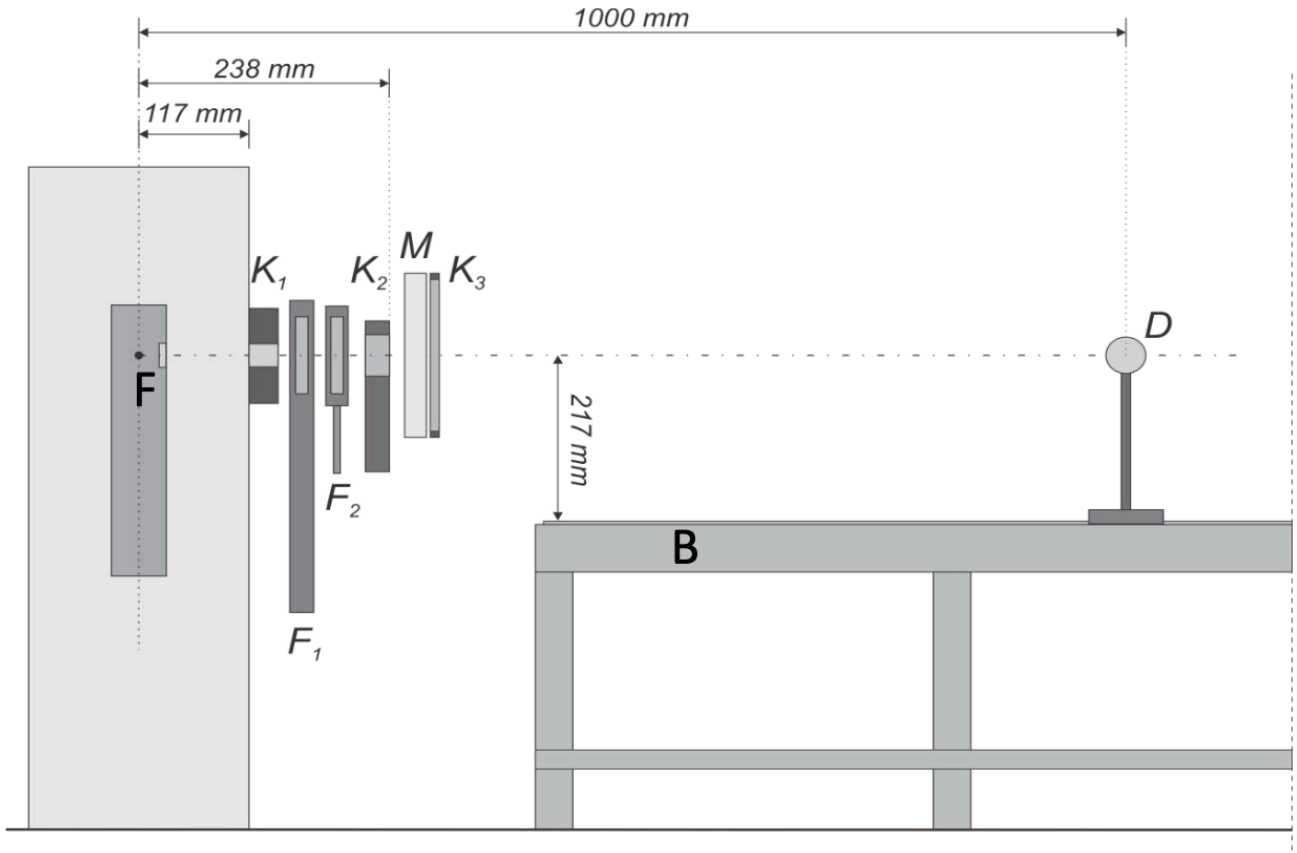
X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy

- ISO 4037-1:2019 Radiation characteristics and production methods
- ISO 4037-2:2019 Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV;
- ISO 4037-3:2019 Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence;
- ISO 4037-4:2019 Calibration of area and personal dosemeters in low energy X reference radiation fields.

The facility

Conceptual scheme of a reference X-ray facility

- F – focus
- K_1, K_2, K_3 – collimators
- F_1 – additional filtration
- F_2 – filter wheel
- M – Monitor chamber
- D – detector
- B – calibration bench

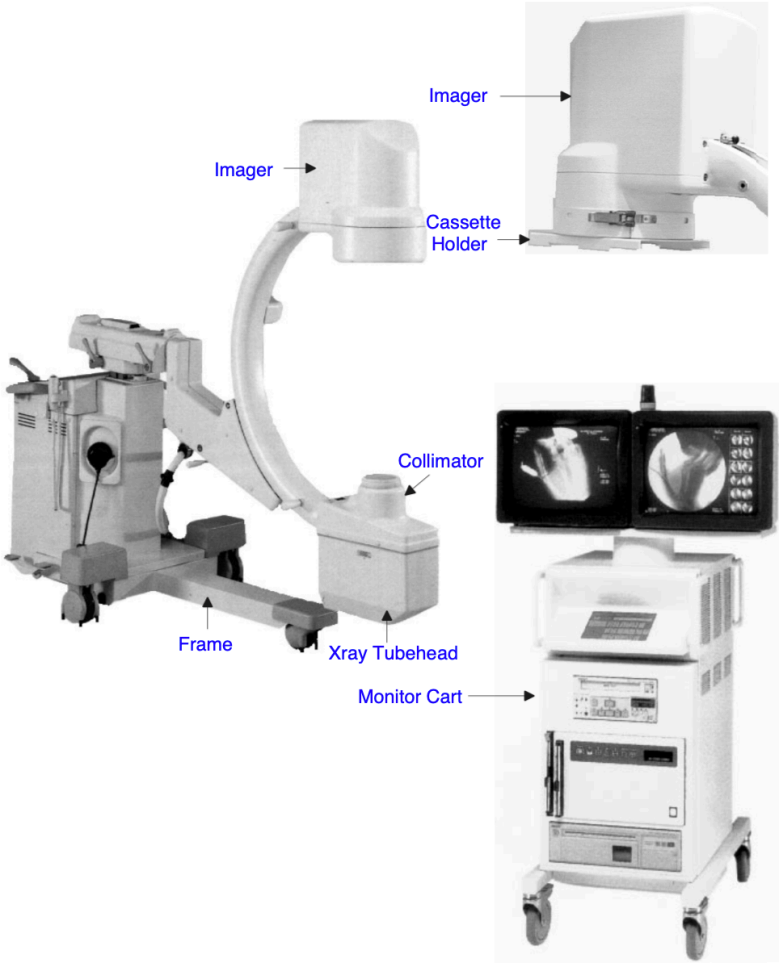


The facility

GENERAL ELECTRIC STENOSCOP 9000

Caratteristiche

- W anode
- Constant potential
- Filtration 1,5 mm Al + added
- Anode 1,8x1,8 / 0,5x0,5 mm^2
- 40 to 110 kV
- 0.1 to 3 mA

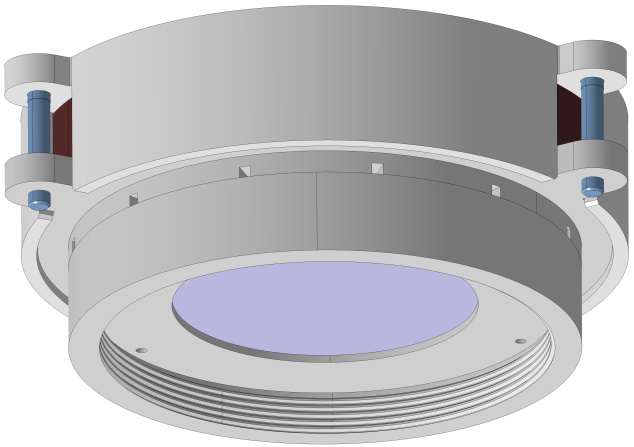


The facility (Ed. 17 retro)

- Bunker 2 mm Pb 2 x 2 x 2 m^3
- Sliding door
- Interlocked (RP approved)
- Cables in/out

The facility (Ed. 17 retro)

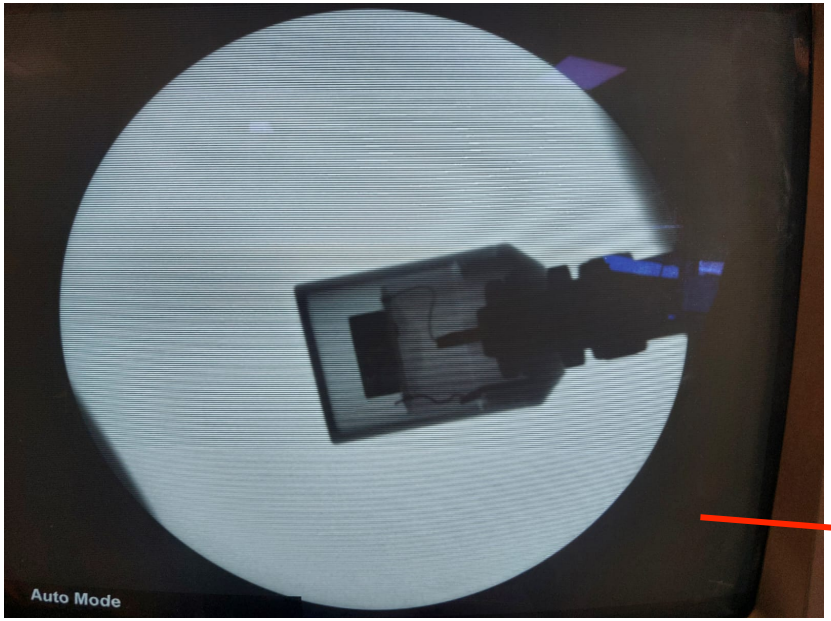
Filter system



From T Napolitano

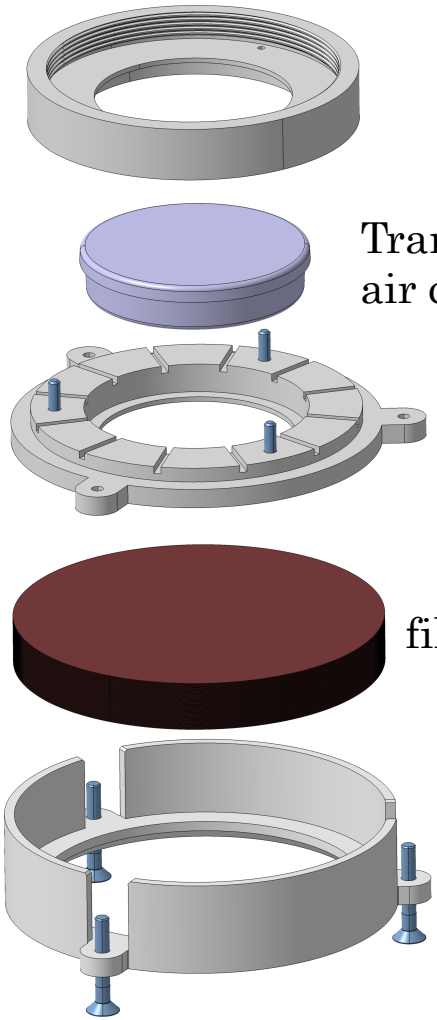
The facility

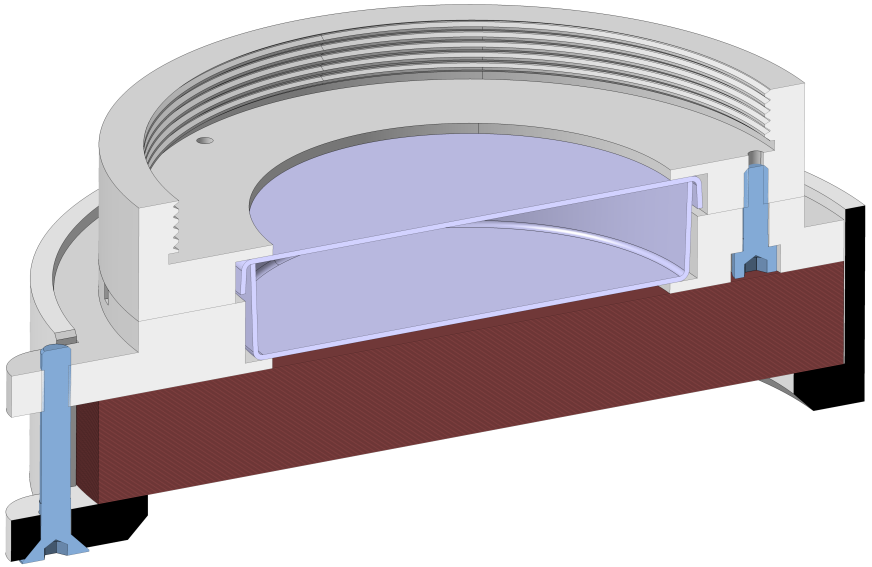
Imaging capability



The facility

Filter system

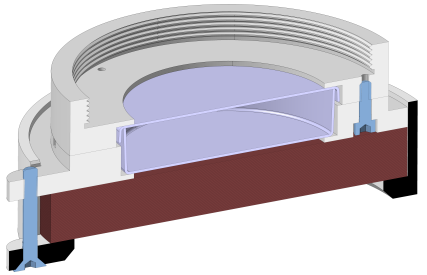




From T Napolitano

The measurement capabilities

Achieving "reference" photon fields



If

- ✓ kV well-known and constant
- ✓ Application of standard filters (ISO 4037)
- ✓ Tube output:
  - Continuously monitored with a transmission free-air ionisation chamber
  - Measured at reference distance with a calibrated ionisation chamber

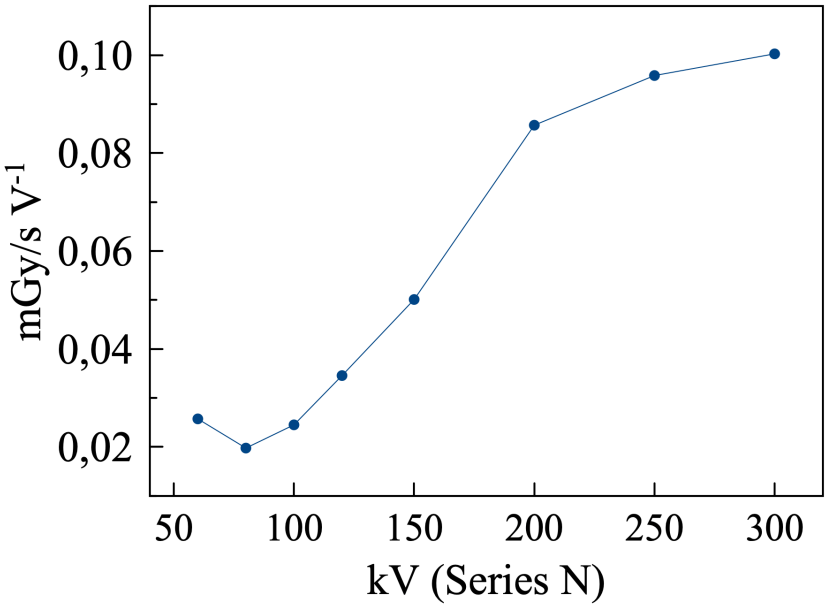
Then

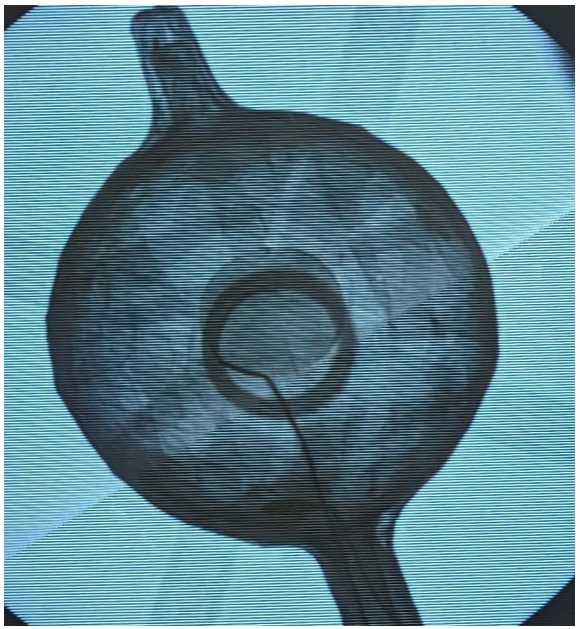
The energy distribution of the photon field is known

The field intensity is known

The measurement capabilities

Reference ionisation chamber





Concentrical spherical electrodes

R_{int}= 1 cm

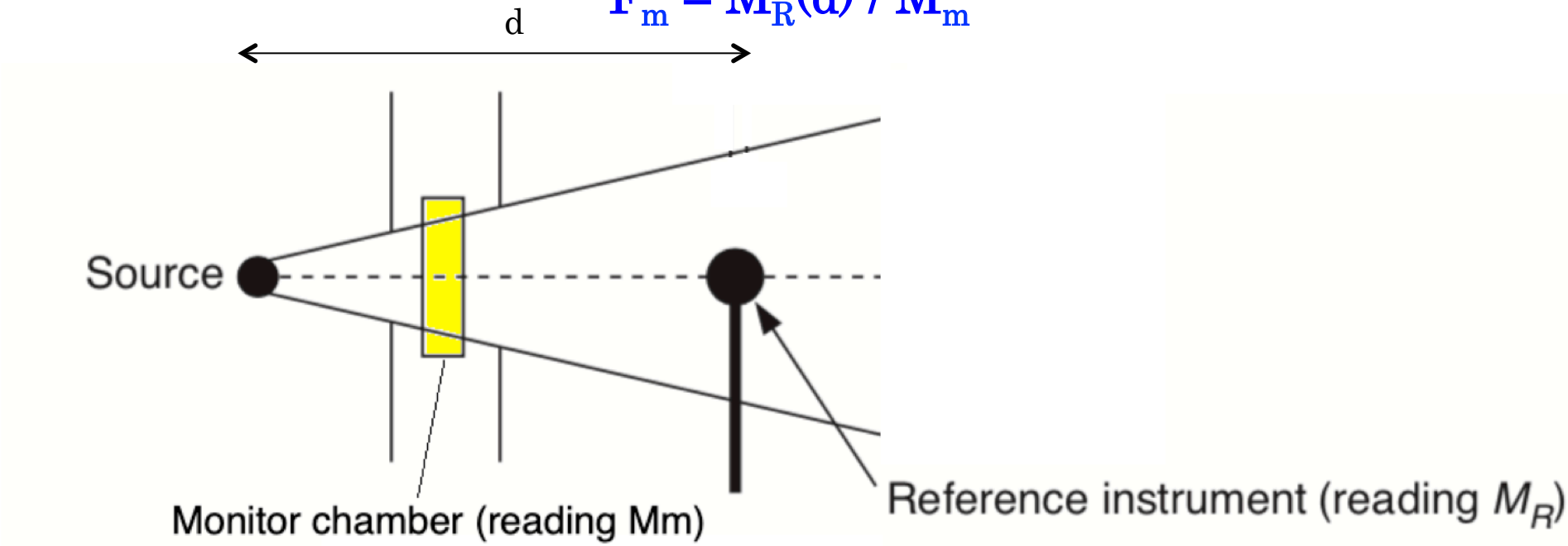
R_{ext} = 3 cm

The measurement capabilities

Measurement method

Step 1
Calibrating the Monitor chamber

$$F_m = M_R(d) / M_m$$

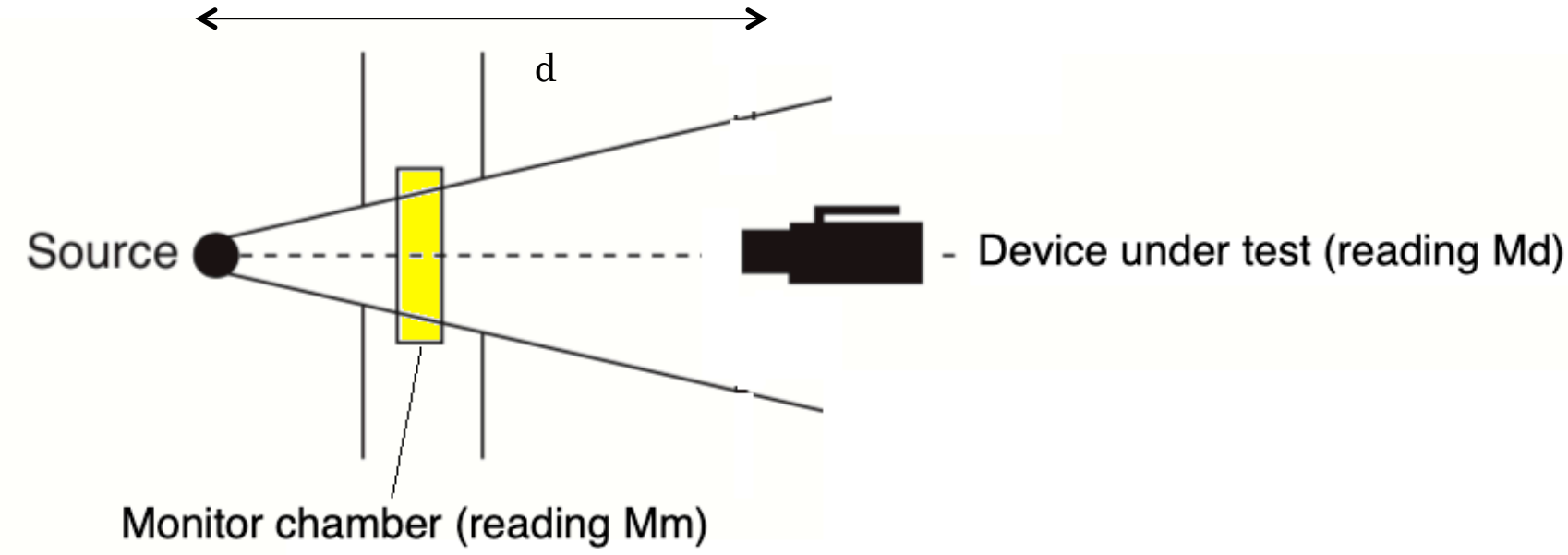


The measurement capabilities

Measurement method

Step 2
Determining the amount of fluence / dose delivered to the Device under test:

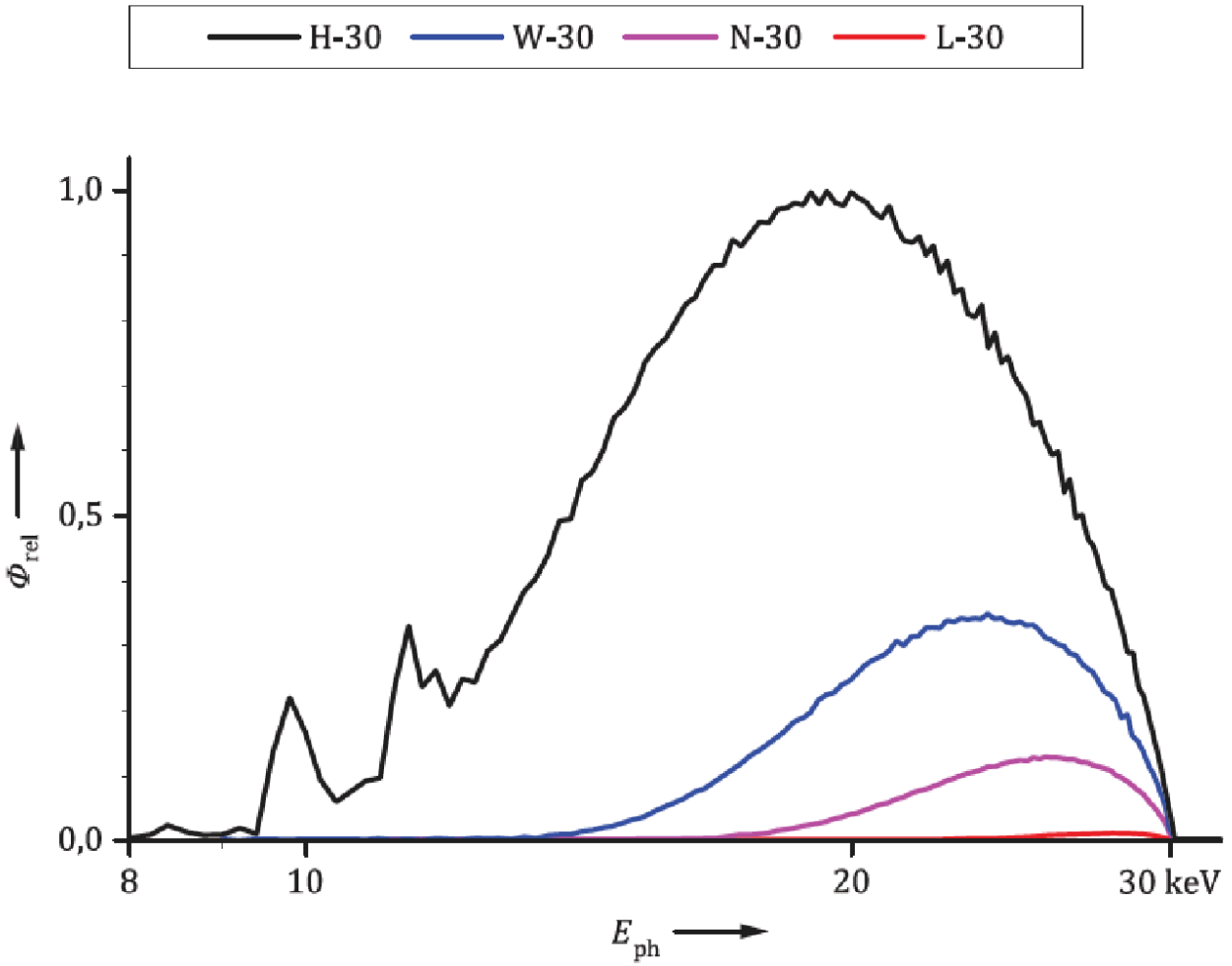
$$D = F_m \times M_m$$



The measurement capabilities

ISO 4037 Series

N - Narrow spectrum
W - Wide spectrum
H - High-kerma

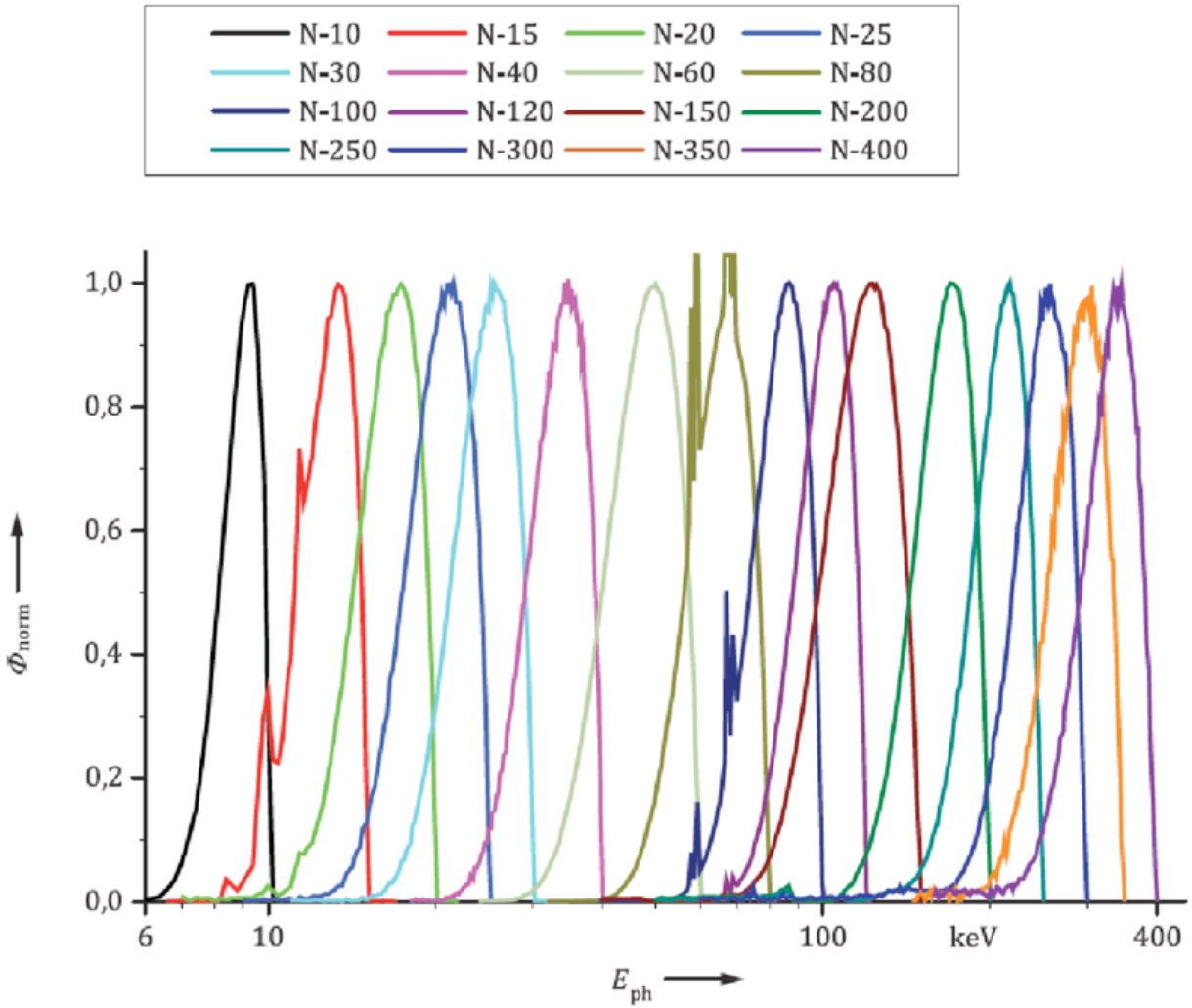


The measurement capabilities

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

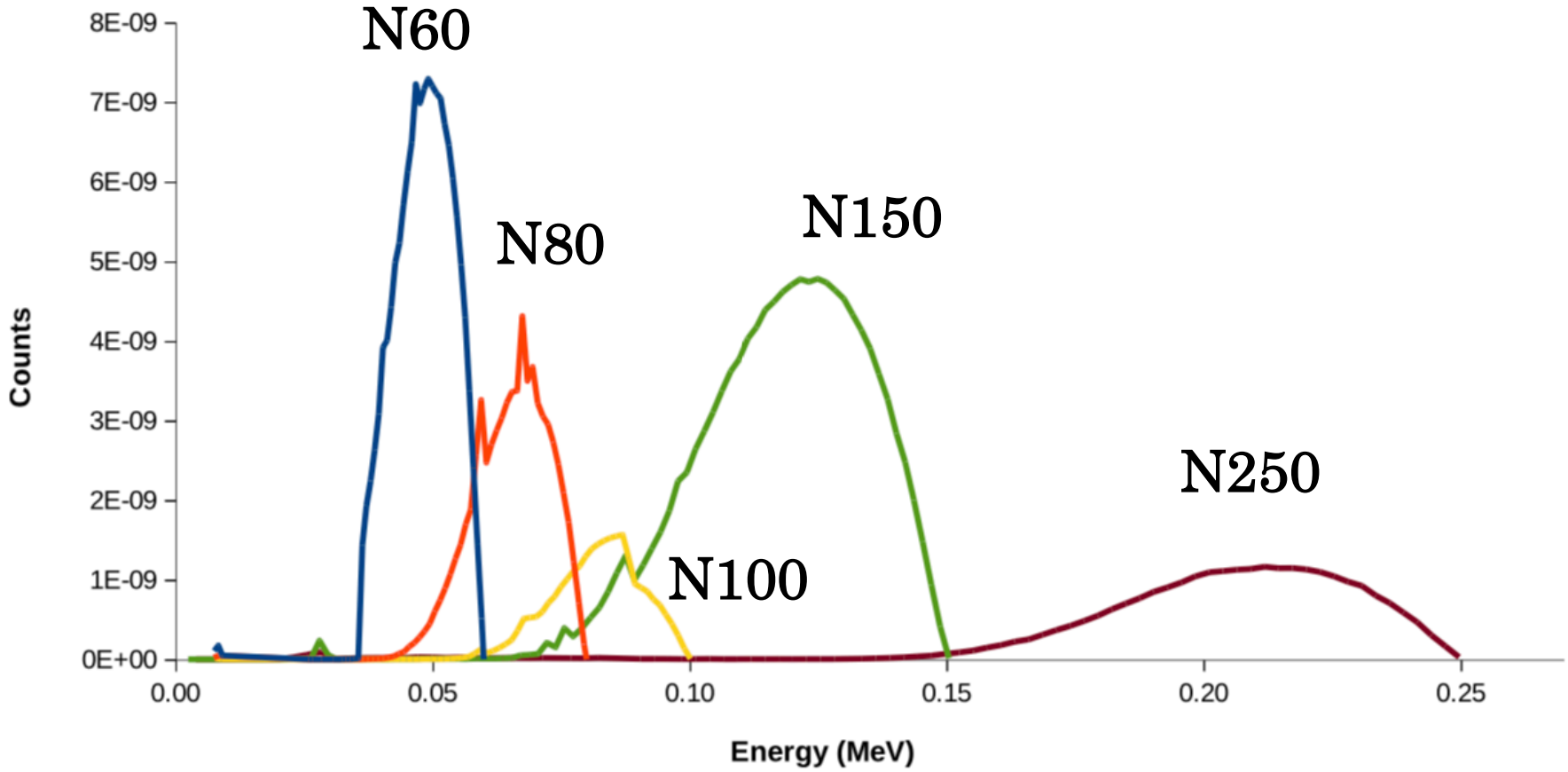
ISO 4037 Series

N - Narrow spectrum



The measurement capabilities

Series “Narrow spectrum” (N)



The measurement capabilities

Series "Narrow spectrum" (N)

Beam code	kV	filtration	<E> (keV)	dK/dt (mGy/h) 1 mA, 40 cm	dΦ/dt cm^{-2} s^{-1} 1 mA, 40 cm
N40	40	4 Al + 0.21 Cu	33,3	18	7×10^{6}
N60	60	4 Al + 0.6 Cu	47,9	33	3×10^{7}
N80	80	4 Al + 2 Cu	65,0	18	2×10^{7}
N100	100	4 Al + 5 Cu	83,1	9	8×10^{6}

By operating on distance (20 cm to 60 cm) and current (0.1 to 3 mA) the field intensity can be varied

from ÷20 to ×200

The measurement capabilities

Series "Wide spectrum" (W)

Beam code	kV	filtration	<E> (keV)	dK/dt (mGy/h) 1 mA, 40 cm	dΦ/dt cm^{-2} s^{-1} 1 mA, 40 cm
W40	40	4 Al	29.8	160	6×10^{7}
W60	60	4 Al + 0.3 Cu	44.9	94	9×10^{7}
W80	80	4 Al + 0.5 Cu	56.6	175	2×10^{8}
W110	110	4 Al + 2 Cu	78.8	131	1×10^{8}

By operating on distance (20 cm to 60 cm) and current (0.1 to 3 mA) the field intensity can be varied

from ÷20 to ×200

The measurement capabilities

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Series "High-kerma rate" (H)

Beam code	kV	filtration	<E>	dK/dt (mGy/h) 1 mA, 40 cm	dΦ/dt cm^{-2} s^{-1} 1 mA, 40 cm
H40	40	1 Al	25.7	960	4×10^{8}
H60	60	3.9 Al	37.4	460	4×10^{8}
H80	80	7.2 Al	49	560	5×10^{8}
H100	100	3.9 Al + 0.15 Cu	57.5	900	8×10^{8}

By operating on distance (20 cm to 60 cm) and current (0.1 to 3 mA) the field intensity can be varied

from ÷20 to ×200

Testing potentialities

- New X-ray detectors
  - ✓ Response in dose in air
  - ✓ Reponse in Photon Fluence

- Measurement complex for radiodiagnostics
  pulse duration, dose in air, kV, SEV

Testing potentialities

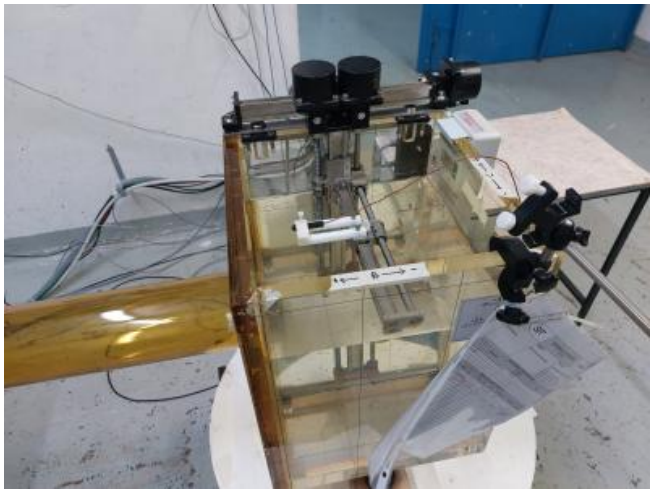
- Dose-meters for radiation protection

Testing potentialities

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

UCD (innovative dosimeter for FLASH Radiotherapy)

INFN patent



Conclusions

- Collaboration in progress with PEROV (M. Testa)
- Testing TL chips for private company
- Determining X-ray parasitic sensitivity of neutron sensors
  - CSN 1 \ CMS \ BRIL