DE LA RECHERCHE À L'INDUSTRIE

X-Ray Measurements for LB650 Cryomodules (DRAFT)

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Main objectives

- **To perform radiation rate measurements during the LB650 cryomodule test in accordance with the Acceptance Criteria requirements**

- **To be able to compare the results of radiation dose rate measurements to be performed at CEA and Fermilab:**

  - CEA/ESS and FERMILAB radiation equipment comparison: performances and calibration

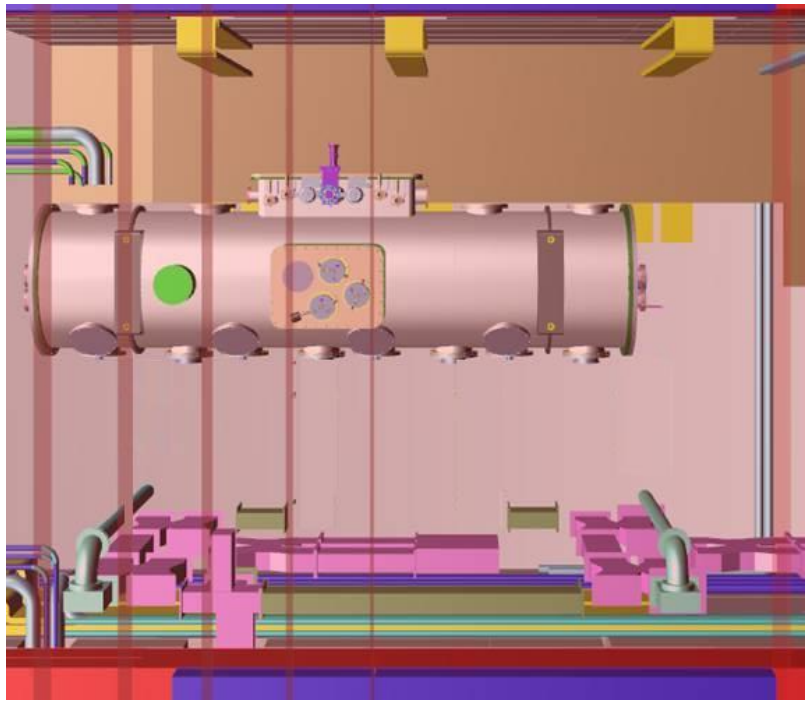
  - Use the same layout of the detectors around the cryomodule in both facilities (Supratech and PIP2IT)

Key information and values (current inputs)

- All the radiation rates giving below are defined as measured by radiation detectors situated 2m from cavity centerline
- Maximum X-Ray dose rate during the test of an individual cavity is 200 mRd/h (2 mSv/h) ➔ condition for detection range
- Maximum X-Ray dose rate for a single cavity at its maximal operating gradient after processing : 50 mRd/h (0.5 mSv/h)
- Field Onset for a single cavity: measurable radiation above background
- Individual LB650 cavities reach maximum test gradient (Administrative Limit) : 19.5 MV/m
- 6 measurement detectors will be used for the cryomodule test: 4 positioned each at 2 m from the respective cavity centerline, 2 others will be placed each face to a respective cryomodule endcap.

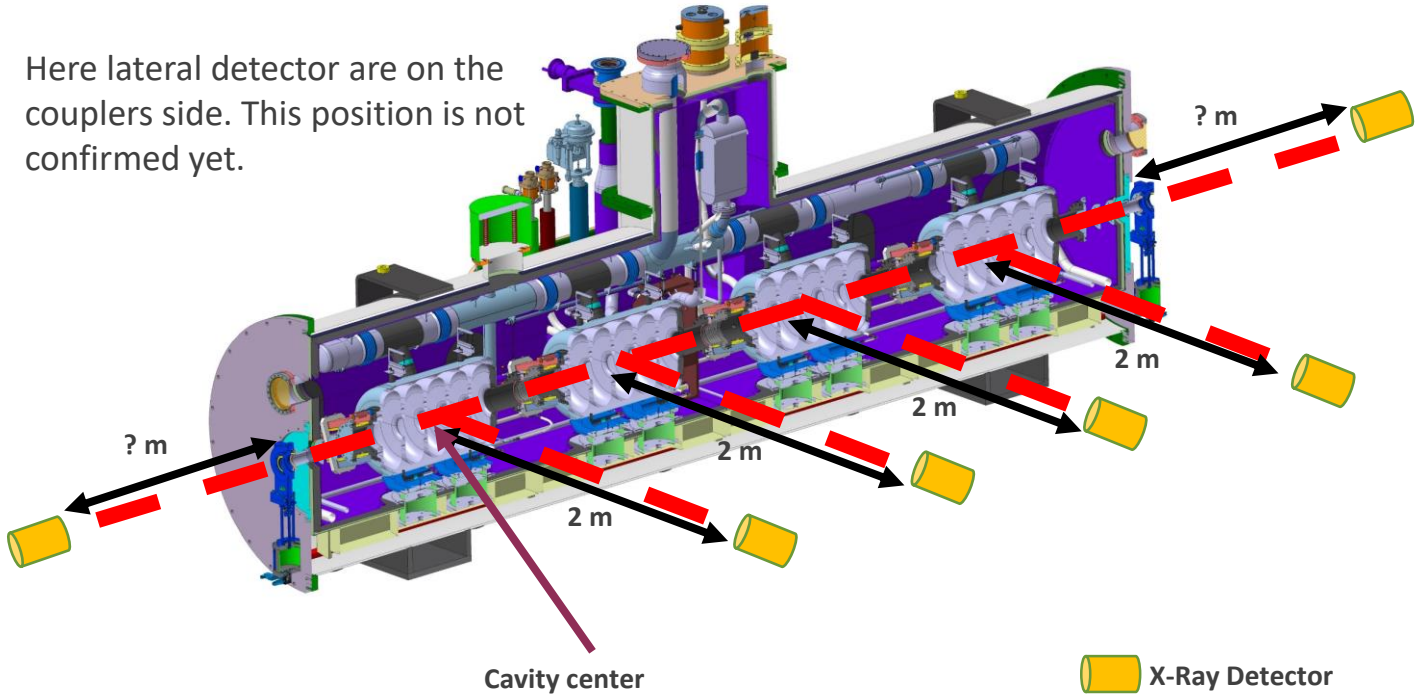
X-Ray detectors layout

- X-Ray measurement detectors option LB 6500-4-H10, if FOX detectors are not available
- 6 measurement detectors are needed and will be placed following the layout presented in the figure below (layout to be equivalent to what is expected in PIP2IT)
- This layout is to be considered for the choice of the CM module in the bunker



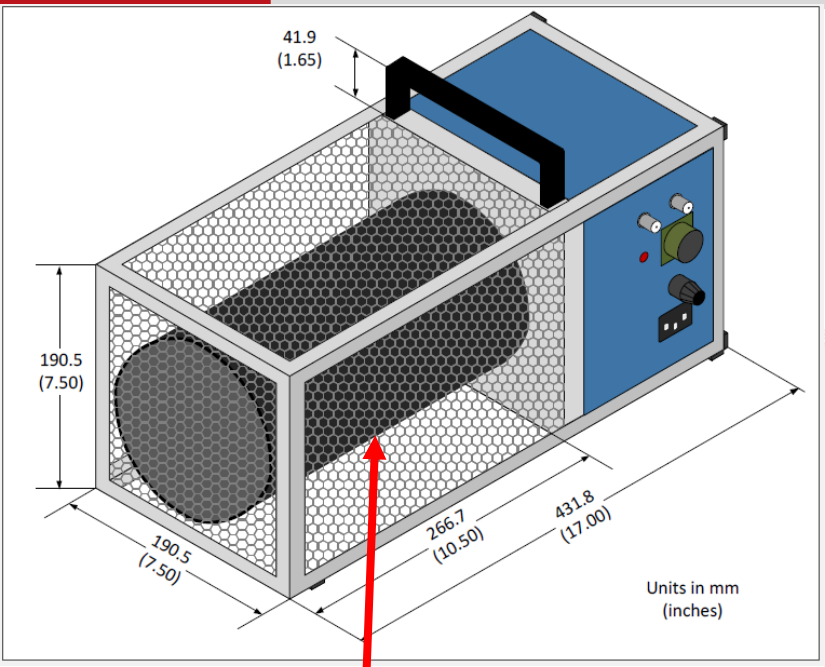
Cryomodule position in the test bunker

Here lateral detector are on the couplers side. This position is not confirmed yet.



X-Ray detectors layout

FOX detector presentation



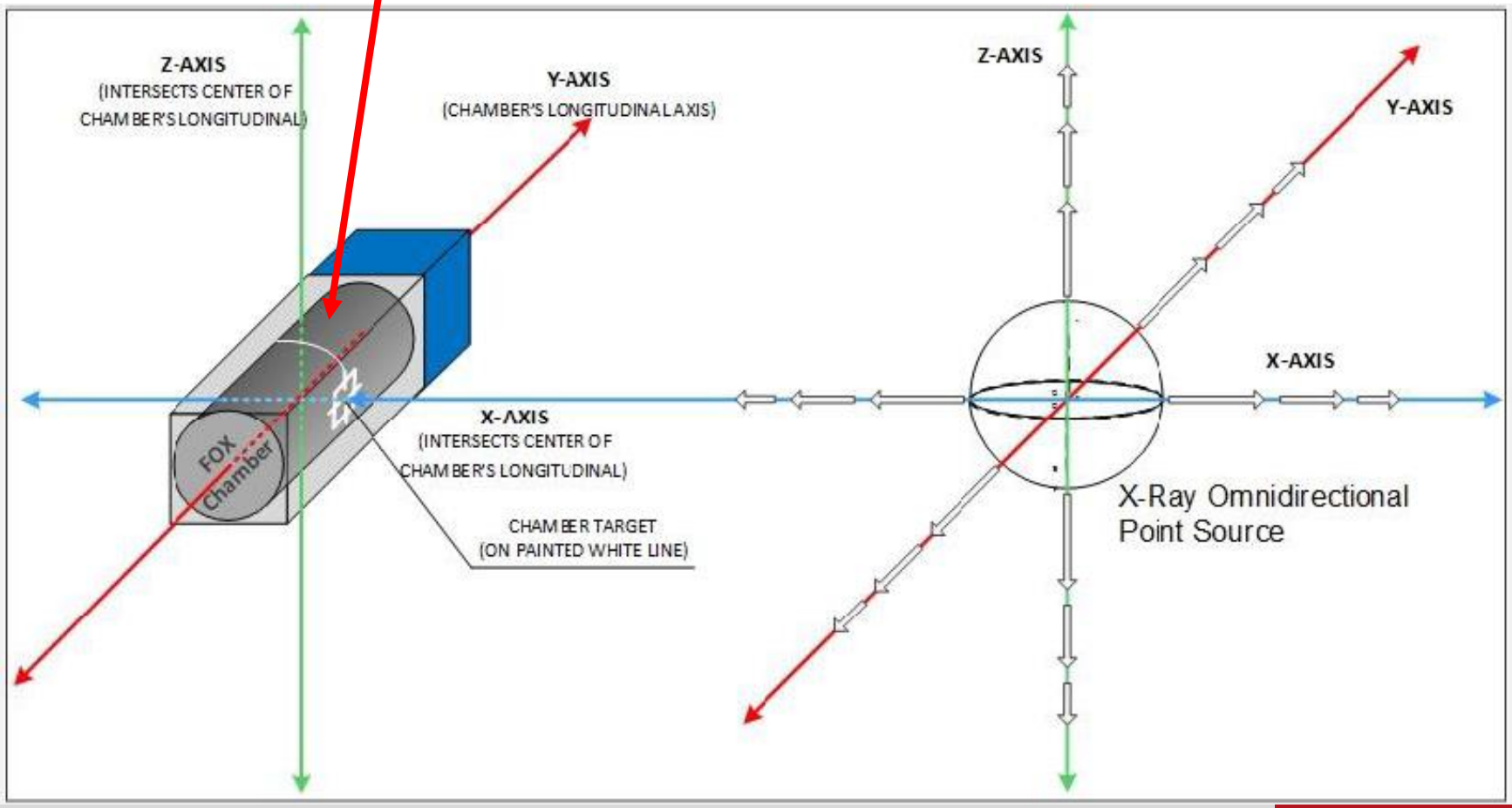
Relatively large ionization chamber.

Ionization chamber with polycarbonate material (coted with conductive material)

➔ Less dense than the metal of a typical chamber used for photons of higher energies

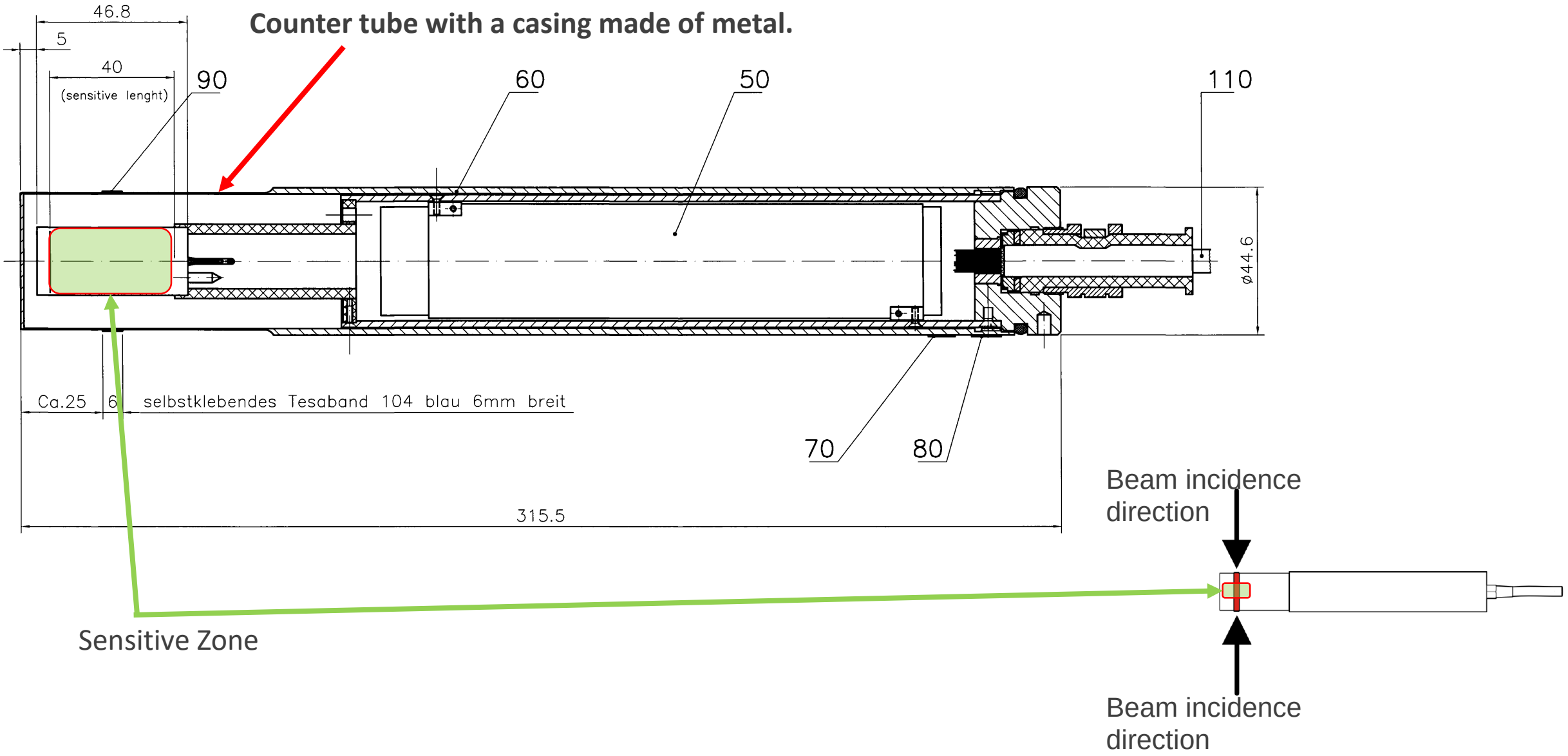
➔ X-ray photons of relatively low energies are able to penetrate the chamber's active area

➔ increase the instrument's response at these low energies.



LB6500-4-H10 detector presentation

Counter tube with a casing made of metal.



Comparing detectors

	Fox (Fermilab)	LB 6500-4-H10 (ESS)	Needs
Dose rate range	270* µR/h– 18 R/h (2.7 µSv/h– 0.18 Sv/h)	100 nSv/h – 10 mSv/h (Type approved: 500 nSv/h – 3 mSv/h)	? From background to maximum allowable
Energy Range	19.8 keV – 1.33 MeV	65 keV – 1.3 MeV ± 40% with regard to Cs-137 and 0° Angular response +/- 45°	?

*Lower limit due to the internal ^{137}Cs check source

- **The LB6500-4-H10 detector uses the ZP1202 Geiger Müller tube. Characteristics are in the table below**

Difference between tube documentation and detector documentation?

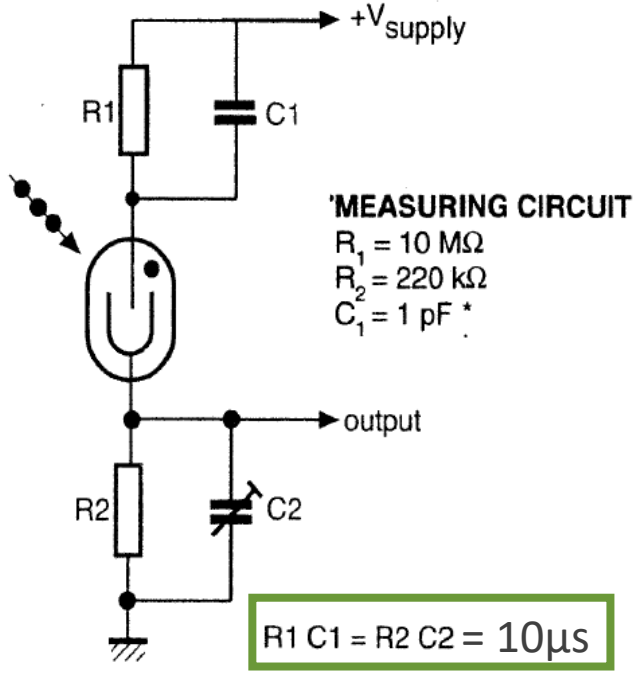
Type	Sensitivity				Plateau			Counting Rate At	Dead Time	Back-Ground Shielded	Dose Rate Range
	Band			Length	Threshold	Length	Slope	10^{-2}Gy/h (count/s)▲			
	α	β	γ	(mm)	(V)	(V)	(% / V)		(µS)	(count/min.)	(mGy/h)
ZP1202 **			•	40	400	200	0.04	20	110	10	10^{-3} – 40

** Ambient dose compensated

▲ = ^{137}Cs

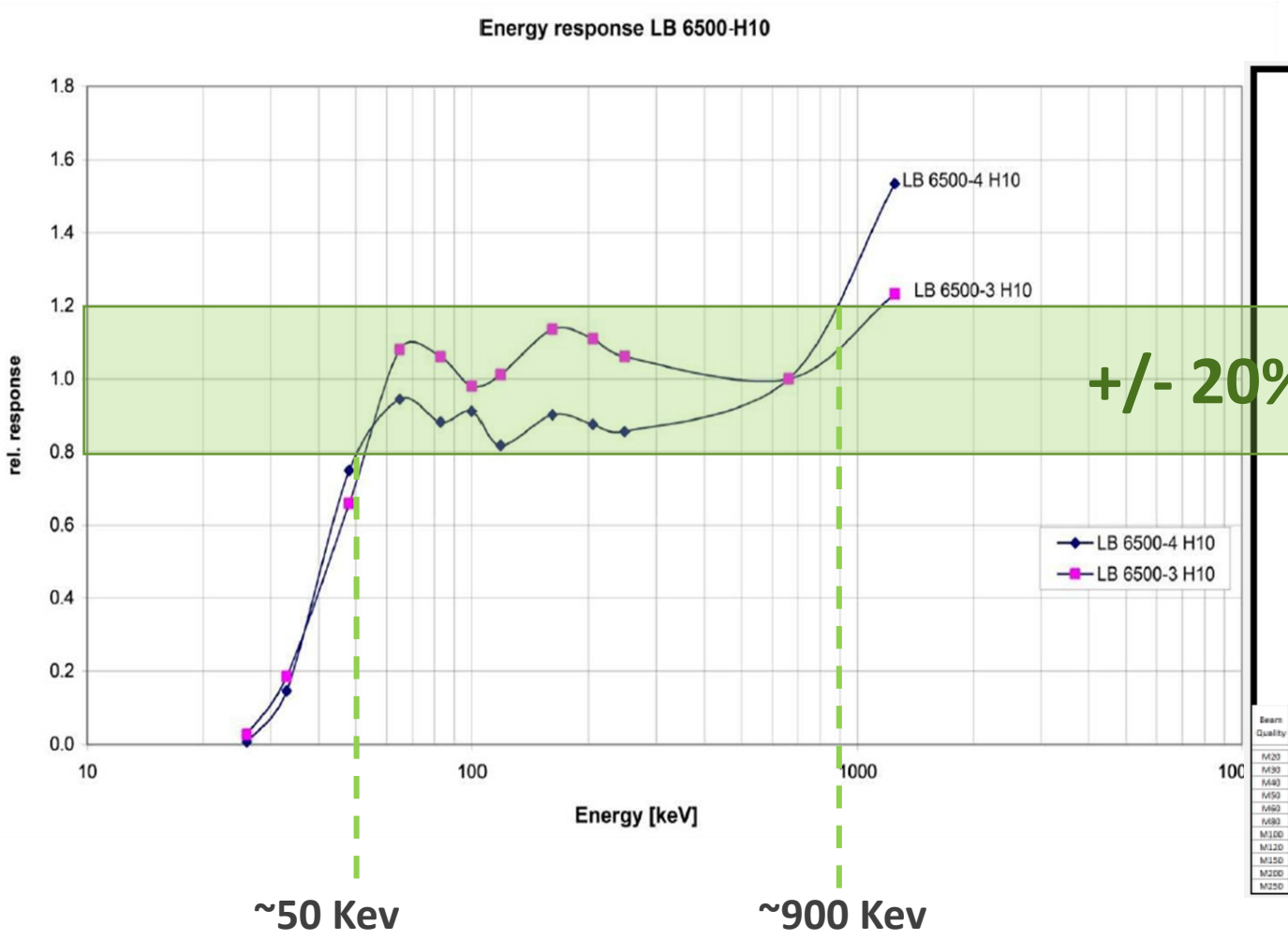
1 Gy =1 Sv= 100 R

FOX detector has no dead time.
Impact on the measurements?

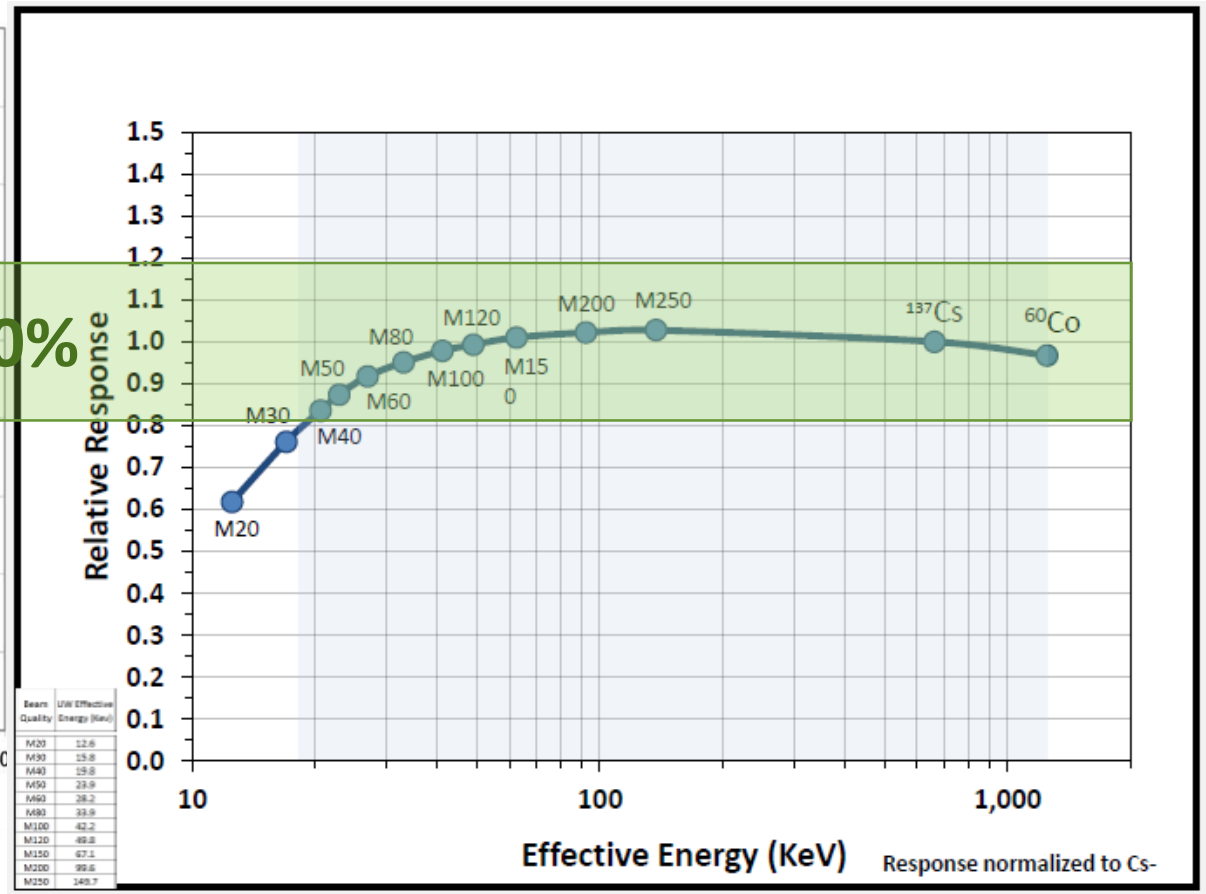


We expect to meet Berthold representative to have more explanation

Energy response comparison (1)

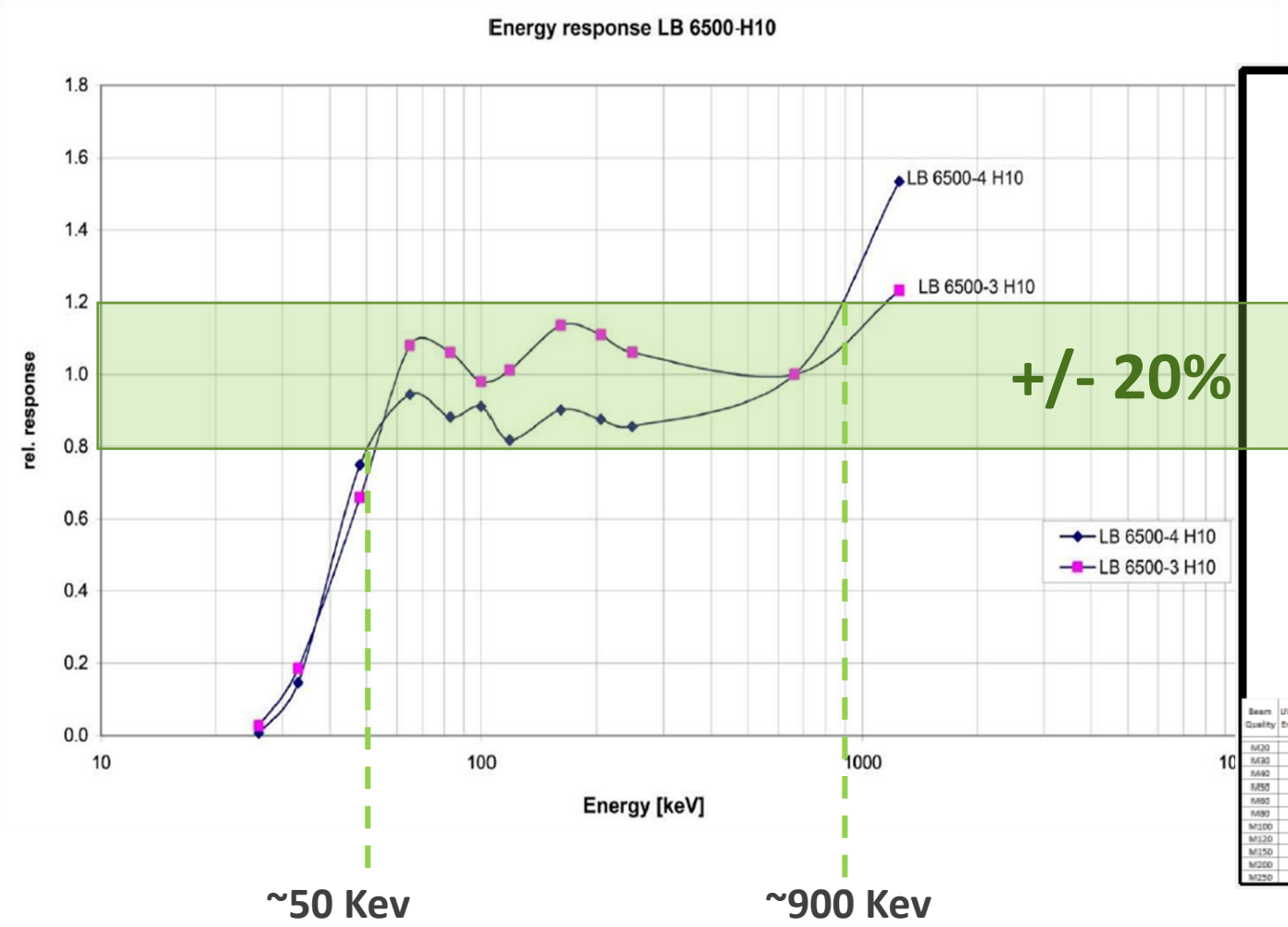


FOX

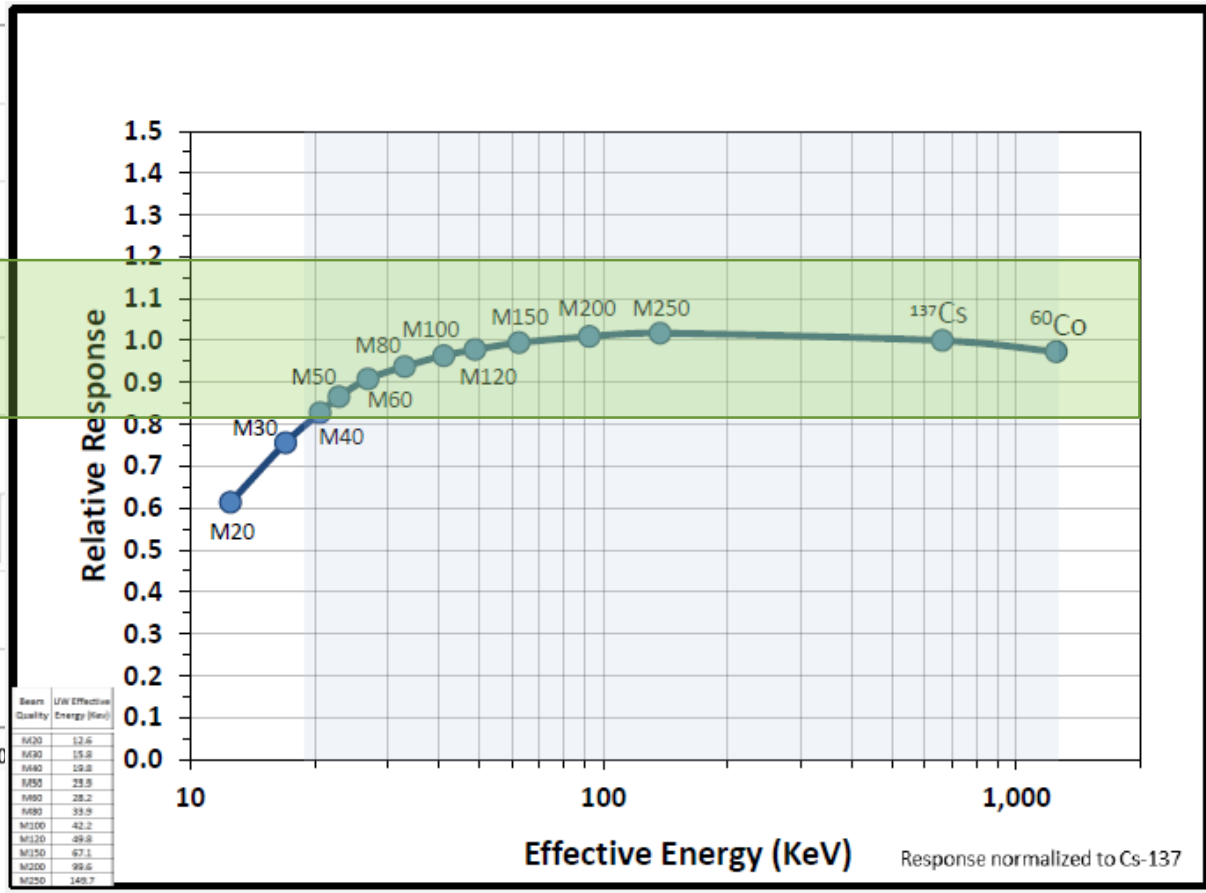


Photon energy responses **from the horizontal orientation**, incident radiation at 0˚, from 12 different energies. Shaded region represents the useful energy range: ±20% of normal response.

Energy response comparison (2)

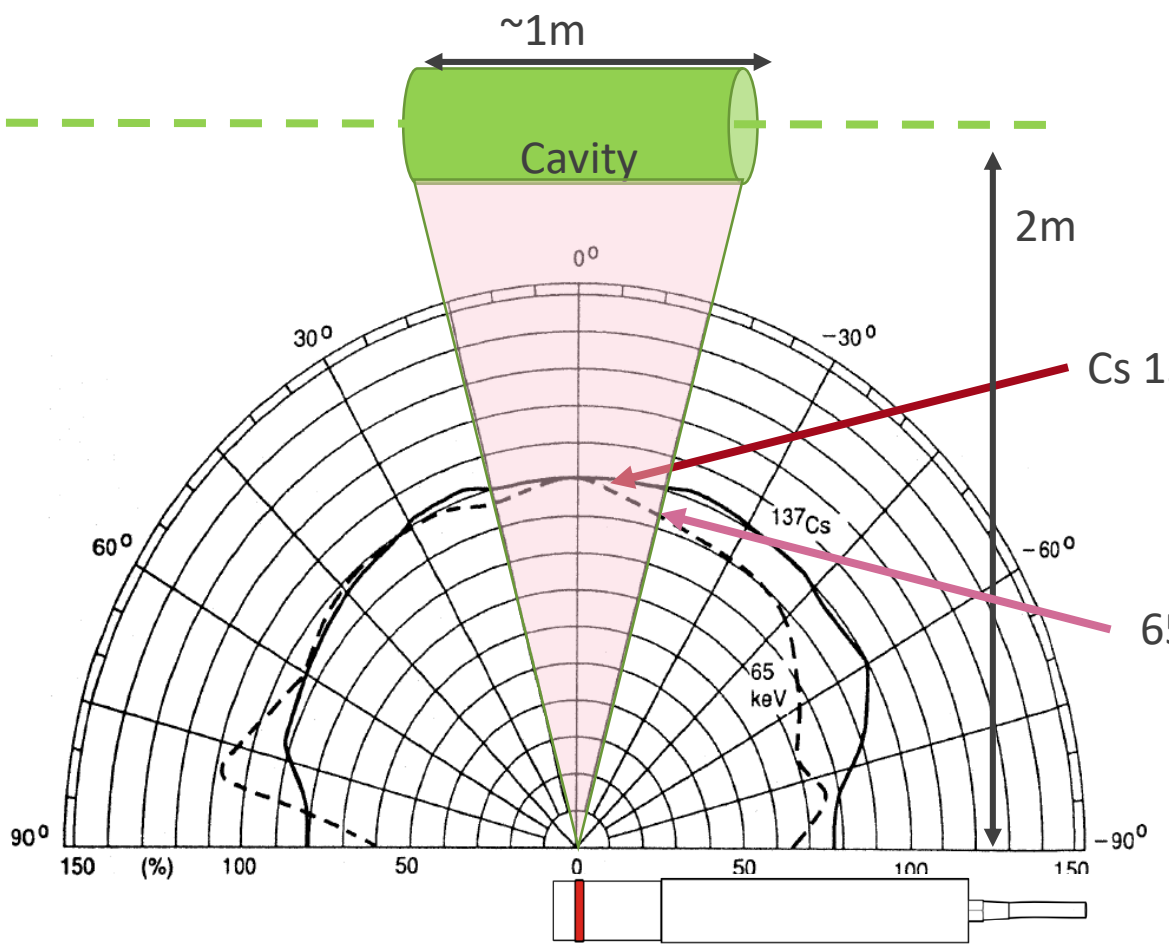


FOX



Photon energy responses **from the vertical orientation**, incident radiation at 0˚, from 12 different energies. Shaded region represents the useful energy range: ±20% of normal response.

Typical polar response normalized

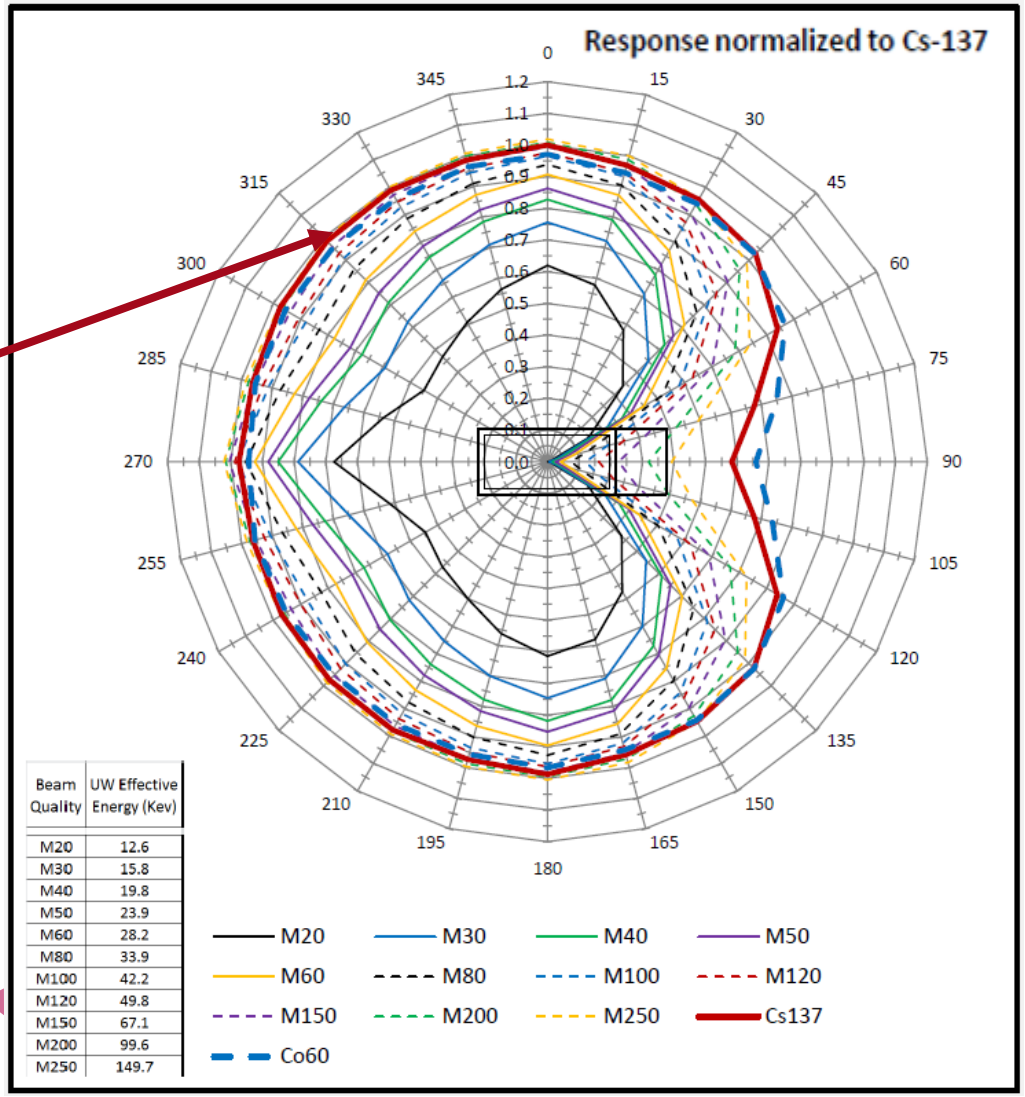


ZP1202 Geiger Müller tube used for the LB6500-4-H10

Typical polar response normalized to 100% at 0°

Cs 137

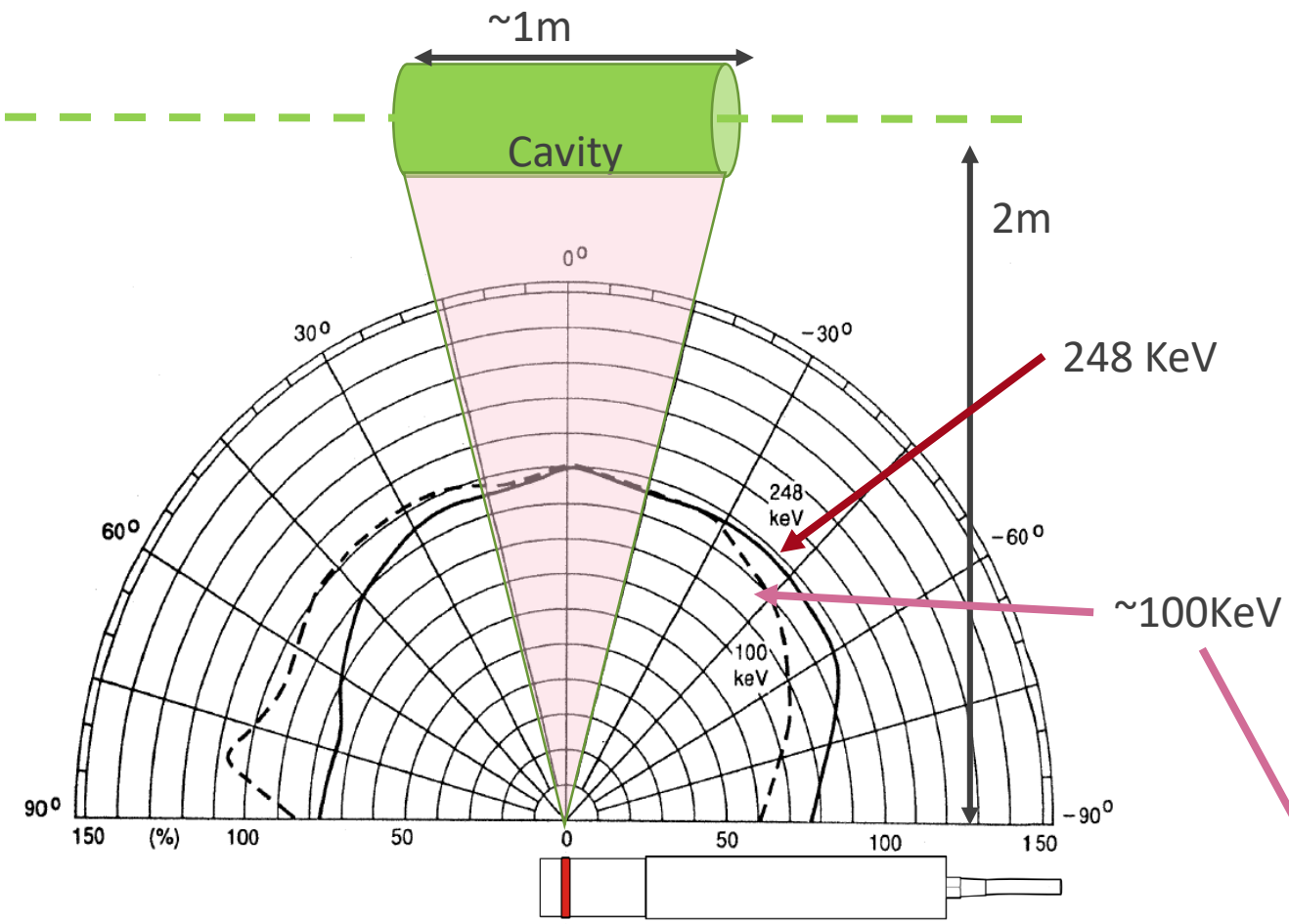
65 / 67KeV



Beam Quality	UW Effective Energy (Kev)
M20	12.6
M30	15.8
M40	19.8
M50	23.9
M60	28.2
M80	33.9
M100	42.2
M120	49.8
M150	67.1
M200	99.6
M250	149.7

Angular response of the **FOX in the horizontal orientation** at various energies relative to Cs-137. The inner most response curve is at 12.6 KeV and response generally increases up to 1.25 MeV photons at the outer curve.

Typical polar response normalized



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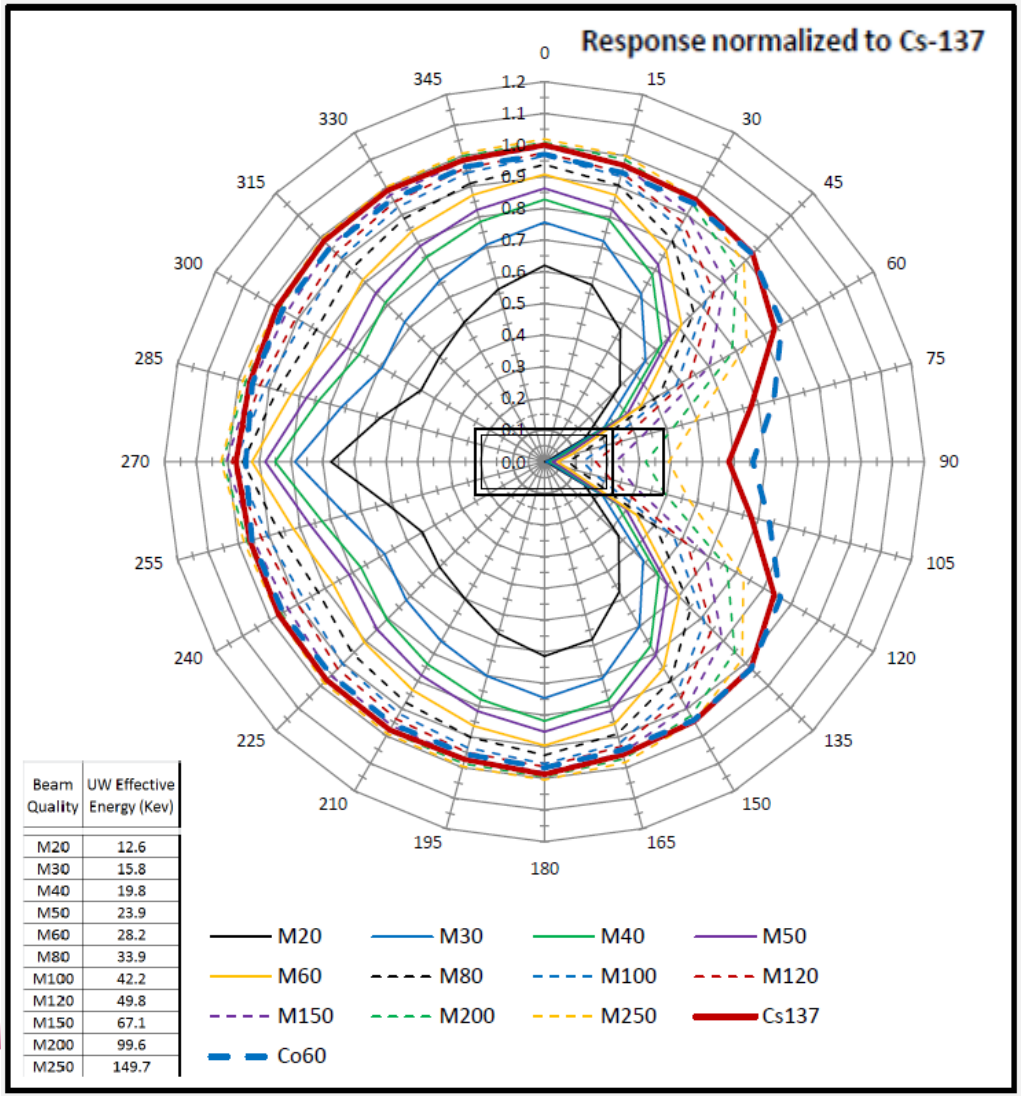

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What is H10

Definition of the Ambient Dose Equivalent H*(d)

For the purposes of routine radiation protection, it is desirable to characterize the potential irradiation of individuals in terms of a single dose equivalent quantity that would exist in a phantom approximating the human body. The phantom selected is the so-called ICRU sphere for made of 30-cm-diameter tissue-equivalent plastics with a density of 1 g/cm^3 and a mass composition of 76.2 % oxygen, 11.1 % carbon, 10.1 % hydrogen and 2.6 % nitrogen. The "ambient dose equivalent", $H^*(d)$, at a point in a radiation field is the dose equivalent that would be produced by the corresponding expanded and aligned field at a depth d in the ICRU sphere, on the radius opposing the direction of the aligned field. In an expanded field the fluence and its directional and energy distribution have the same values throughout the volume of interest as in the actual field at the point of reference. An expanded and aligned radiation field requires additionally that the fluence is unidirectional. For strongly penetrating radiations a reference depth, d, of 10 mm was recommended.

Source :
https://inis.iaea.org/collection/NCLCollectionStore/_Public/36/097/36097704.pdf?r=1&r=1