

Secondary standards, the link between primary lab and end user

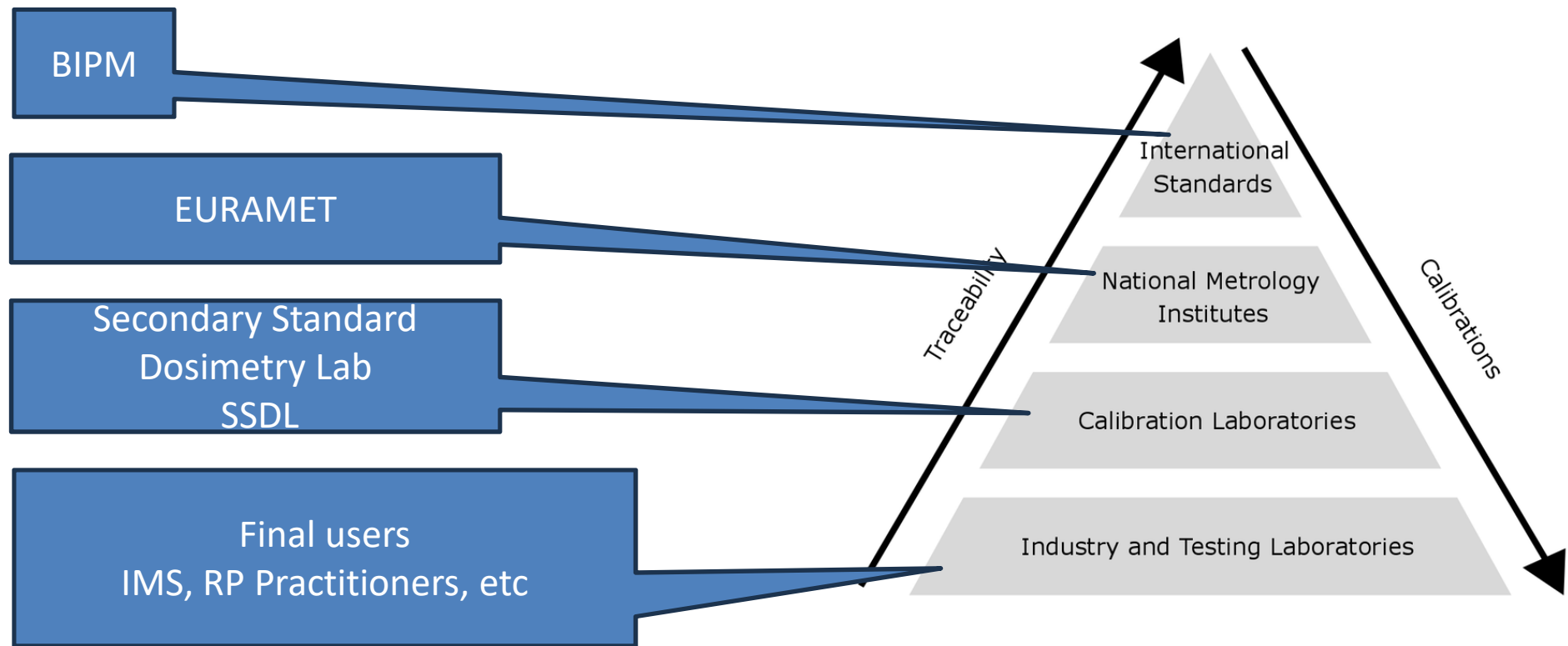
February 27th, 2025 EURADOS Annual Meeting Bucharest

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Politecnico di Milano

Presentation outlook

- Traceability to primary standards
- Uncertainty evaluation
- Uncertainty of dose conversion coefficient
- Usability of the calibration certificate from the user point of view

Traceability to primary standards



Traceability to primary standards – Radiation qualities

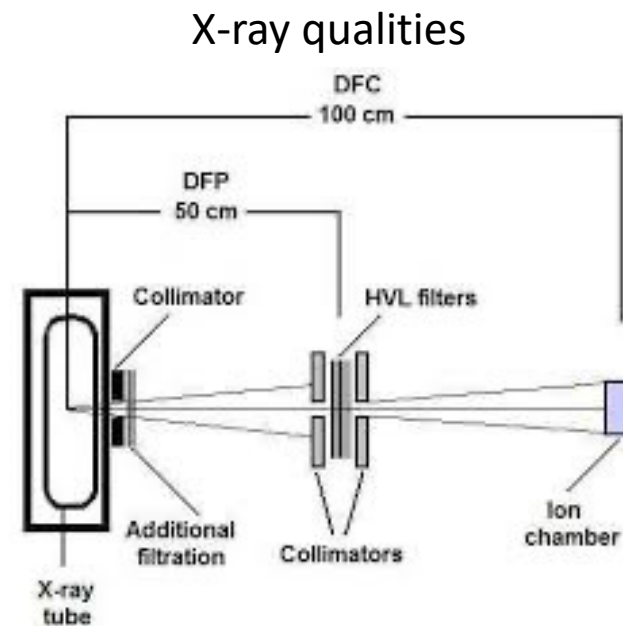
ISO-4037 qualities:

Gamma qualities

- Am-241 $E = 60 \text{ keV}$
- Cs-137 $E = 662 \text{ keV}$
- Co-60 $E_{\text{average}} = 1250 \text{ keV}$

X-Ray qualities

- L series Low air kerma rate
- N series Narrow spectrum
- W series Wide spectrum
- H series High air kerma rate



Traceability to primary standards – Radiation qualities

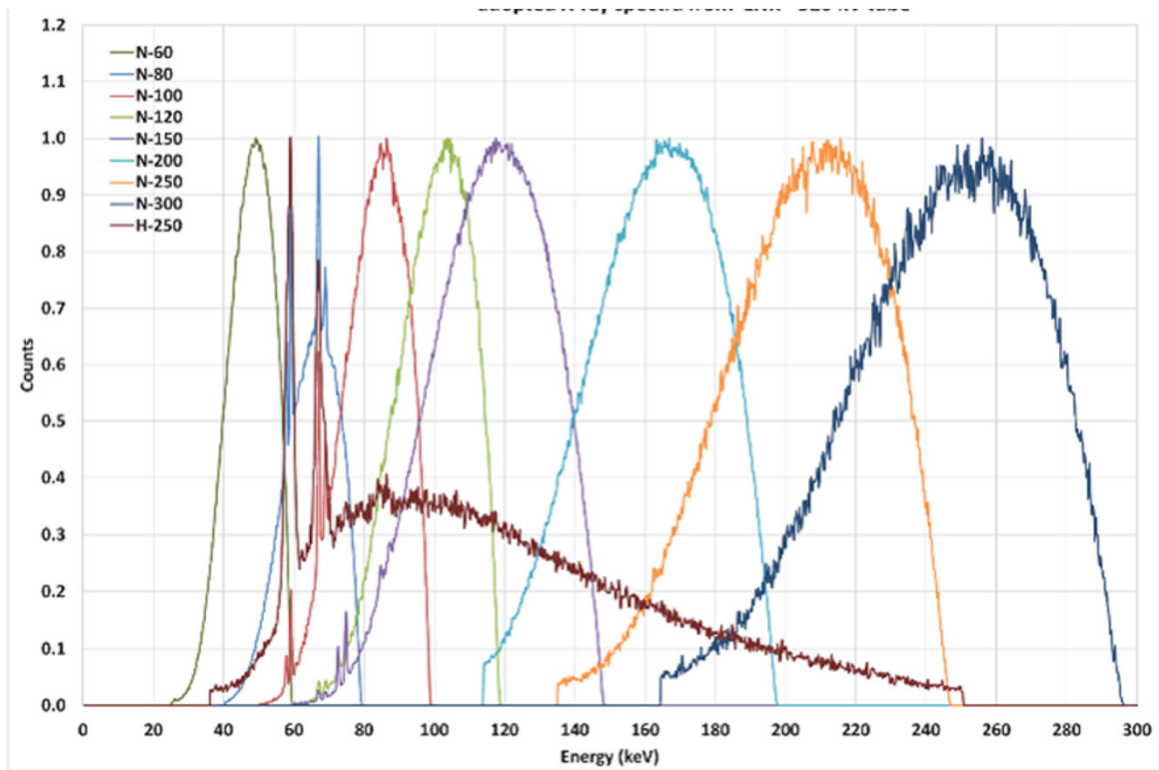
Short name	Mean energy, $\bar{E}(\Phi)$	Resolu- tion, R_E	Tube poten- tial ^a	Recom- mended inherent filtration ^b	Additional filtration ^b , thickness, D , in				1 st HVL at a dis- tance from the focal spot of ^c		2 nd HVL at a distance from the focal spot of ^c	
	keV	%	kV		mm Pb	mm Sn	mm Cu	mm Al	1,0 m	2,5 m	1,0 m	2,5 m
N-30	24,6	32	30	1 mm Be				4,0	1,16 Al	1,17 Al	1,28 Al	1,29 Al
N-40	33,3	30	40	4 mm Al			0,21		2,63 Al	2,65 Al	2,83 Al	2,84 Al
N-60	47,9	36	60	4 mm Al			0,6		0,234 Cu	0,235 Cu	0,263 Cu	0,264 Cu
N-80	65,2	32	80	4 mm Al			2,0		0,578 Cu	0,580 Cu	0,622 Cu	0,623 Cu
N-100	83,3	28	100	4 mm Al			5,0		1,09 Cu	1,09 Cu	1,15 Cu	1,15 Cu
N-120	100	27	120	4 mm Al		1,0	5,0		1,67 Cu	1,67 Cu	1,73 Cu	1,74 Cu
N-150	118	37	150	4 mm Al		2,5			2,30 Cu	2,30 Cu	2,41 Cu	2,41 Cu
N-200	165	30	200	4 mm Al	1,0	3,0	2,0		3,92 Cu	3,91 Cu	3,99 Cu	3,99 Cu
N-250	207	28	250	4 mm Al	3,0	2,0			5,10 Cu	5,08 Cu	5,14 Cu	5,14 Cu
N-300	248	27	300	4 mm Al	5,0	3,0			5,96 Cu	5,94 Cu	6,00 Cu	5,99 Cu
N-350	288	29	350	4 mm Al	7,0	4,5			—	6,69 Cu	—	6,74 Cu
N-400	328	27	400	4 mm Al	10,0	6,0			—	7,31 Cu	—	7,34 Cu

Reference standard
ISO 4037:2019

The SSDL must get
HVL values as in the
standard, within a
defined tolerance

**Matched
reference fields**

Traceability to primary standards – Radiation qualities



Energy distribution of N and H qualities.

Traceability to primary standards – Dosimetric quantities



Reference instruments are graphite ion chambers
Calibrated by an NMI

Reference quantity: air kerma (Rate)

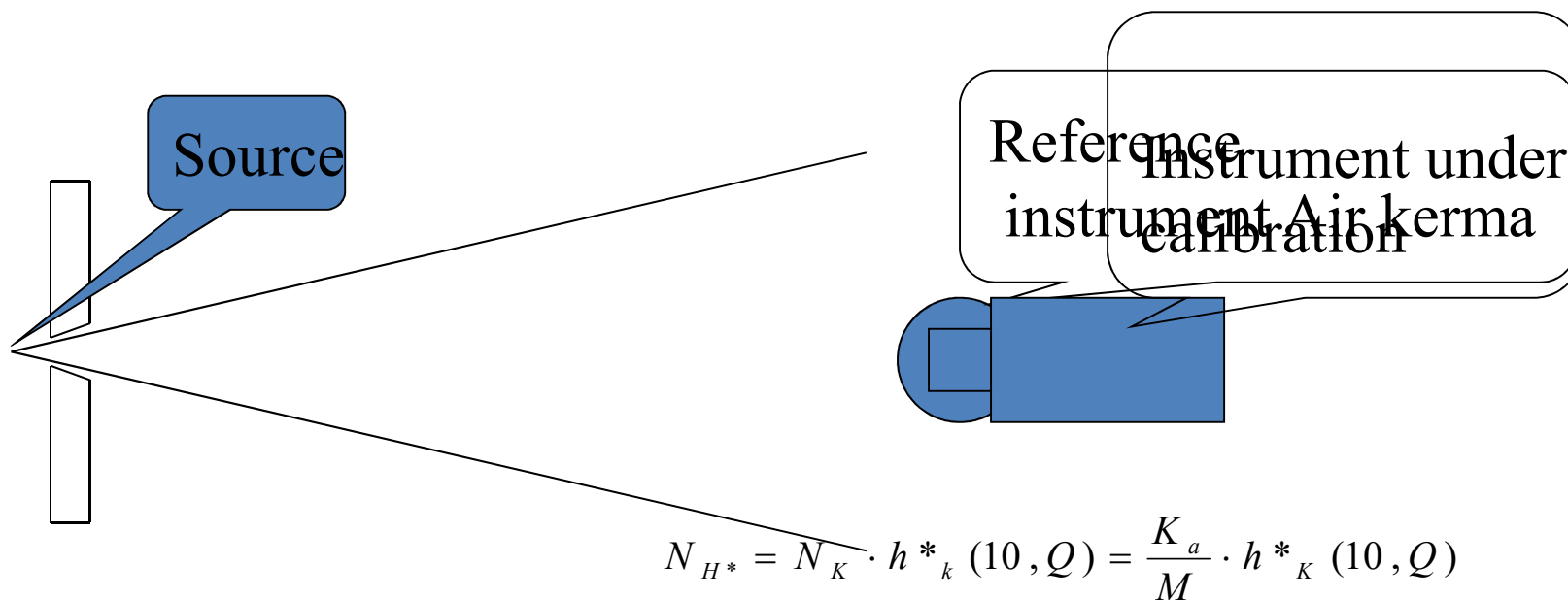
Typical uncertainty (95% C.I.) are 2% - 3%

Uncertainty contributions:

- Calibration uncertainty (around 1.4%)
- Positioning
- Beam non-homogeneity
- Ion recombination
- P and T correction
- Air attenuation
- Repetition uncertainty
- Dimension of the ion chamber

**The uncertainty in energy distribution has
no impact on the air kerma uncertainty**

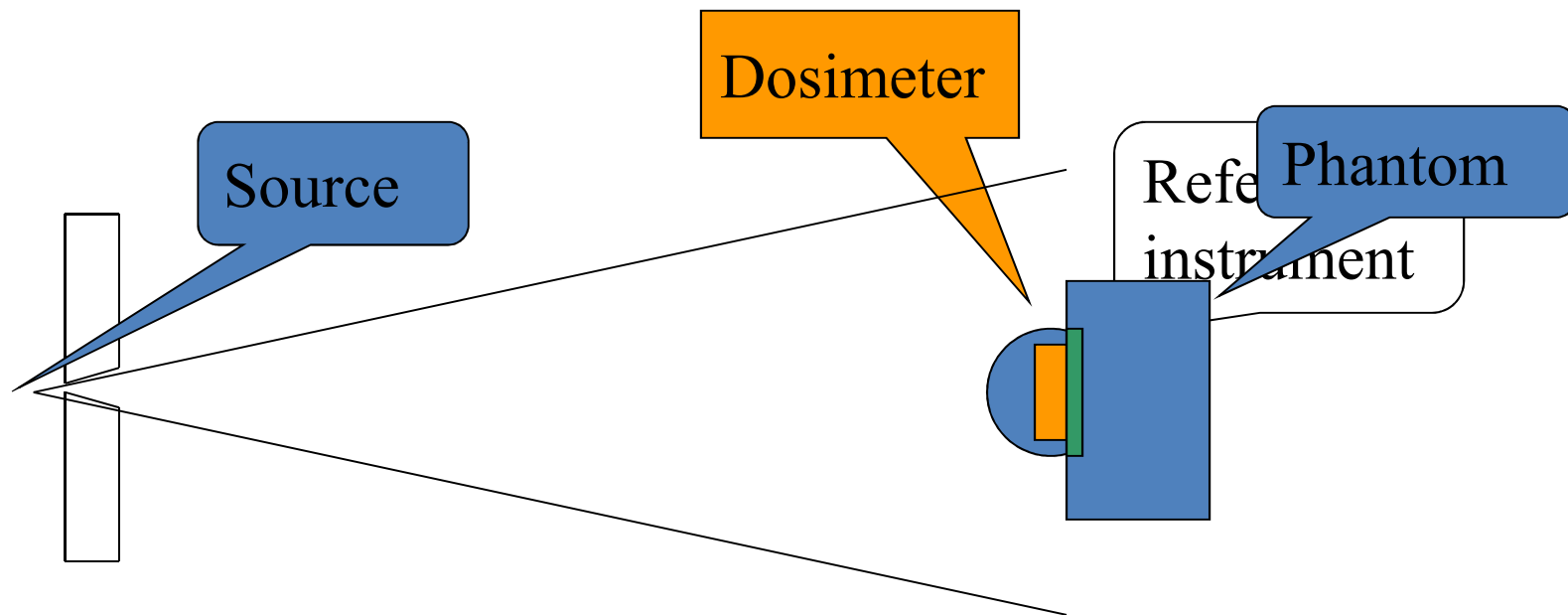
Calibration of final user's instruments



$$N_K(E) = \frac{K}{M}$$

$$N_{H'} = N_K \cdot h'_k(0.07, Q, \alpha) = \frac{K_a}{M} \cdot h'_K(0.07, Q, \alpha)$$

Irradiation of personal dosimeters



$$H = K_a \cdot h_{pK}(d, E, \alpha)$$

Uncertainty of conversion coefficients

Matched reference fields

$$H = K_a \cdot h_{pK}(d, E, \alpha)$$

Operational
Quantity

U= 4.5% – 7%

Air Kerma

U=2% - 4%

Conversion coefficient

U=4% (Minimum)

Coming from the small
differences in energy
distribution of the radiation
qualities

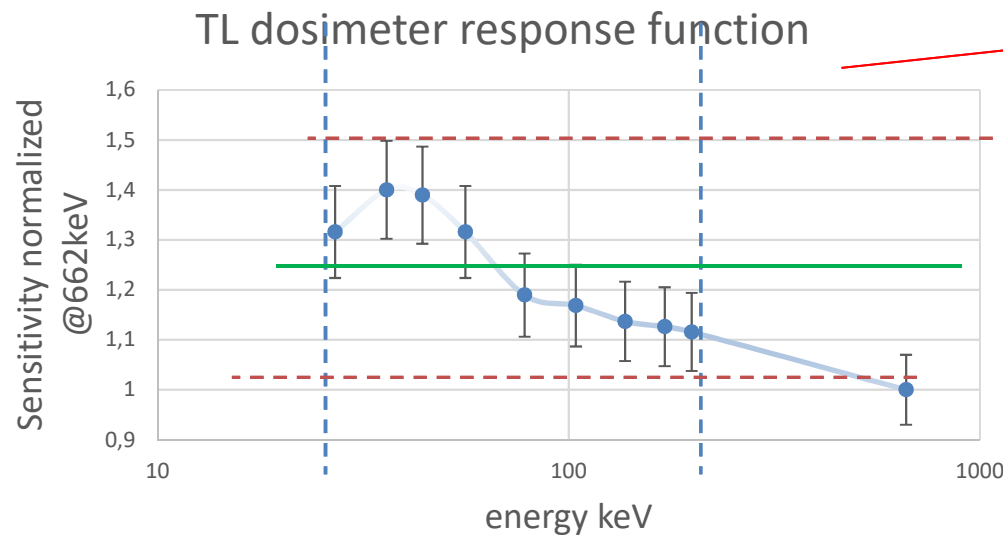
Uncertainty from user POV

Example of a calibration certificate (in Italian for obvious reason)

Risultati degli irraggiamenti in Equivalente di dose Personale $H_p(10)$ Fantoccio: Solid Slab Phantom			
1	2	3	4
Codice della Qualità di radiazione U_{ref}	Codice dosimetro	Equivalente di dose Personale $H_p(10)$ / mSv	Incertezza estesa relativa U associata all' equivalente di dose Personale $H_p(10)$
Cs-137	5081-4479-4997-4487 BASE 201 – <u>Portadosimetro</u> BLU	0,502	7,0%
Cs-137	4685-5056-4941-5068 BASE 201 – <u>Portadosimetro</u> BLU	0,503	7,0%
Cs-137	5064-5063-4801-4681 BASE 201 – <u>Portadosimetro</u> VERDE	5,002	6,1%
Risultati degli irraggiamenti in Equivalente di Dose Personale $H_p(3)$ Fantoccio: Cylinder Phantom			
1	2	3	4
Codice della Qualità di radiazione U_{ref}	Codice dosimetro	Equivalente di Dose Personale $H_p(3)$ / mSv	Incertezza estesa relativa U associata all' equivalente di Dose Personale $H_p(3)$
W-80 (L2)	A01367-A02793-A02301 - A02106- A01470-A02857 EXTRAD Pacchetto A	0,498	7,0%
W-80 (L2)	A05656-A02710-A02471 - A02982-A00425 EXTRAD Pacchetto D	3,113	6,0%

The final user will never measure in reference beam qualities

Uncertainty from user POV



Lab conditions

In Field

We do not know the energy distribution, but we can speculate it is in the range 40 keV - 200 keV

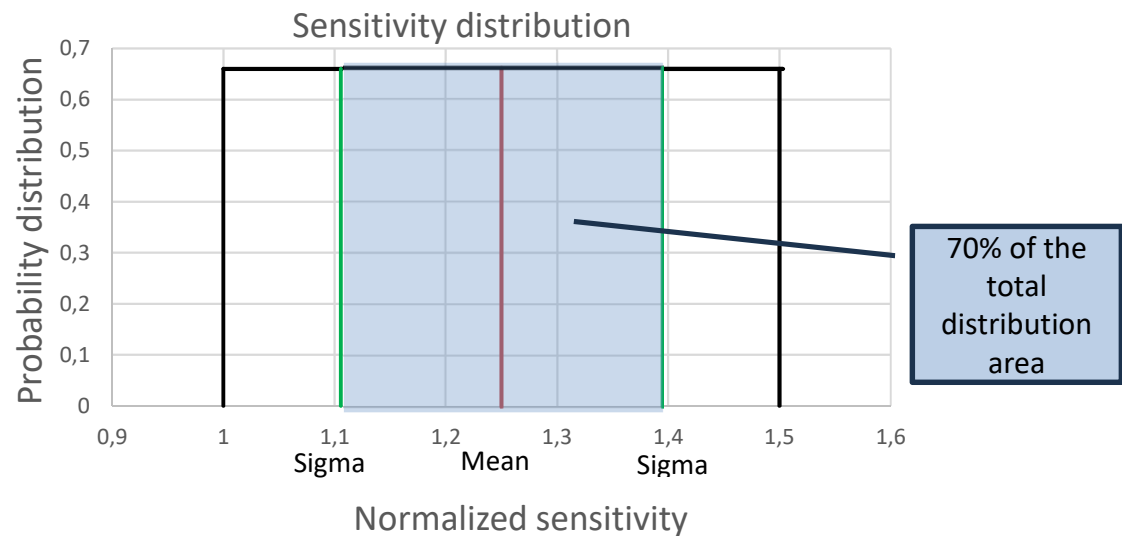
each point has a standard uncertainty (67% confidence) around $u=3,5\%$

Mean sensitivity=1,25

Max sensitivity=1,5

Min sensitivity=1,02 $\approx$ 1

Uncertainty from user POV



$$u = \frac{\max - \min}{2\sqrt{3}}$$

$$u\% = 12\%$$

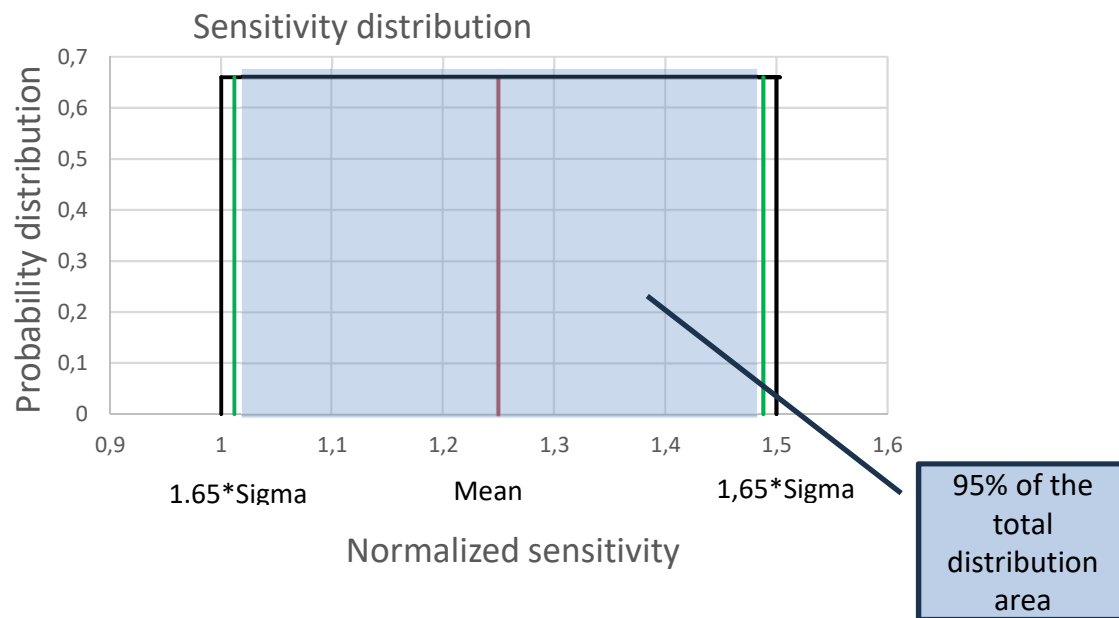
To be compared with

u each point around 3,5%

The uncertainty from the uniform distribution is dominating and so is the distribution itself

Uncertainty from user POV

How to get the expanded uncertainty?



$k = 1.65$ (Coverage factor)

$$U\% = 1.65 \cdot u\% = 20\%$$

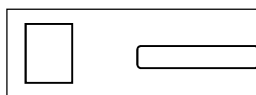
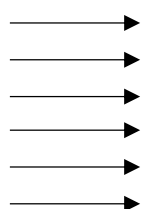
Uncertainty from user POV

For the practical on-filed measurements, the main uncertainty contribution is coming from the ignorance about the energy distribution of the radiation filed

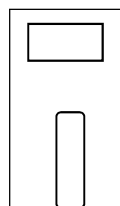
Of course, there can be other uncertainty contribution, for instance the direction of the radiation beam. Actually, personal dosimeter calibration is performed at different angles as well.

Uncertainty from user POV

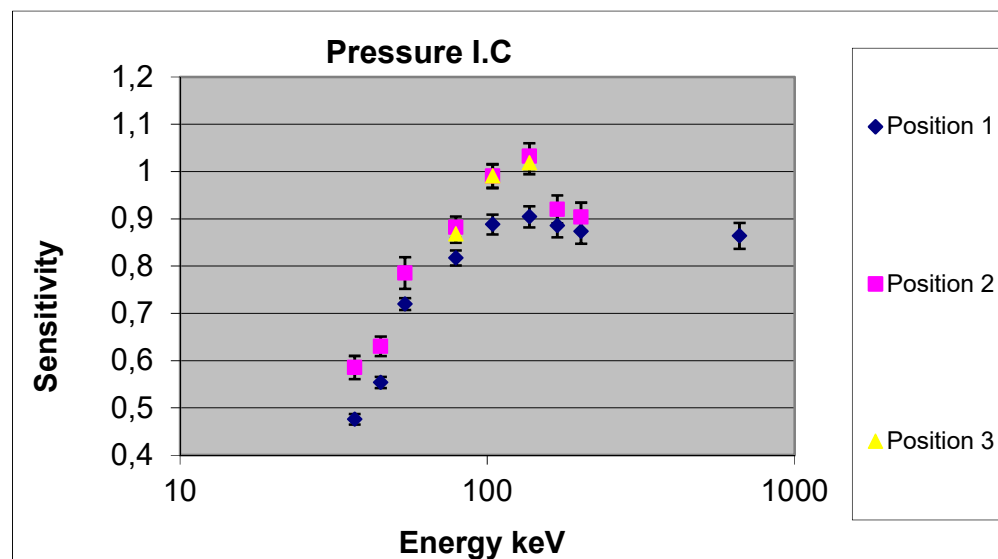
Beam direction



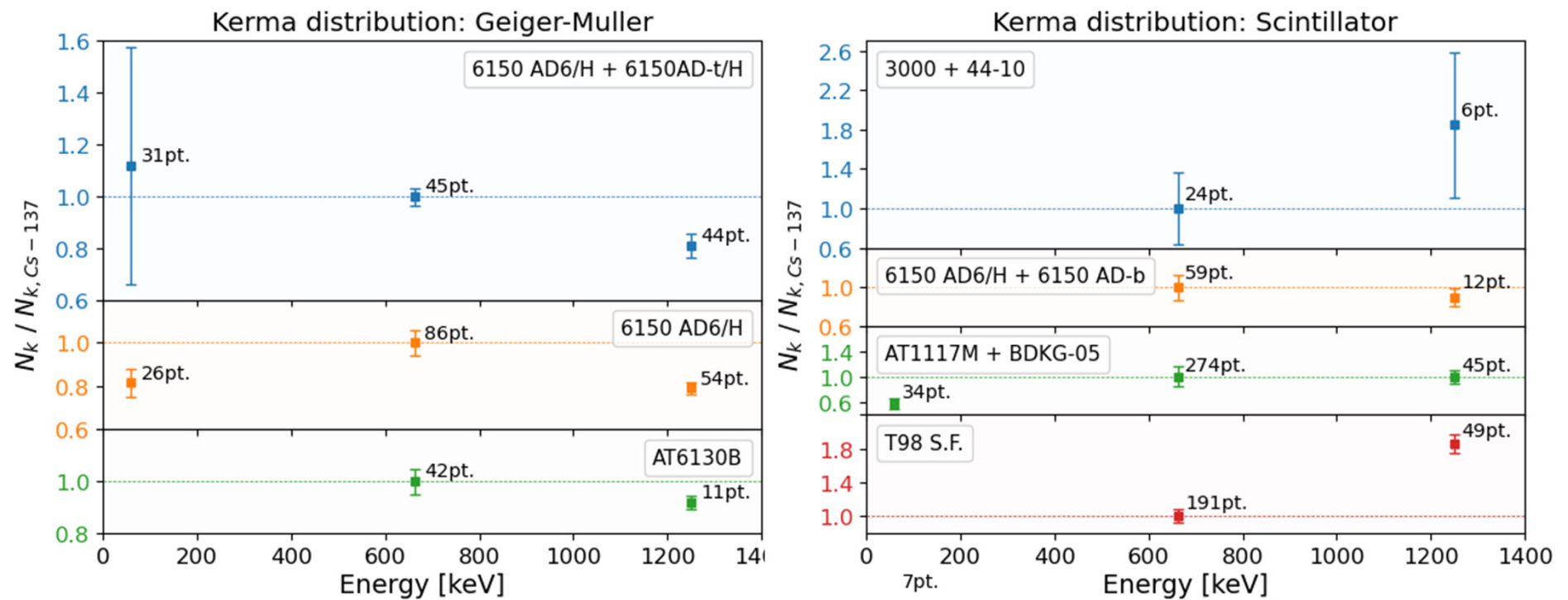
Position 1



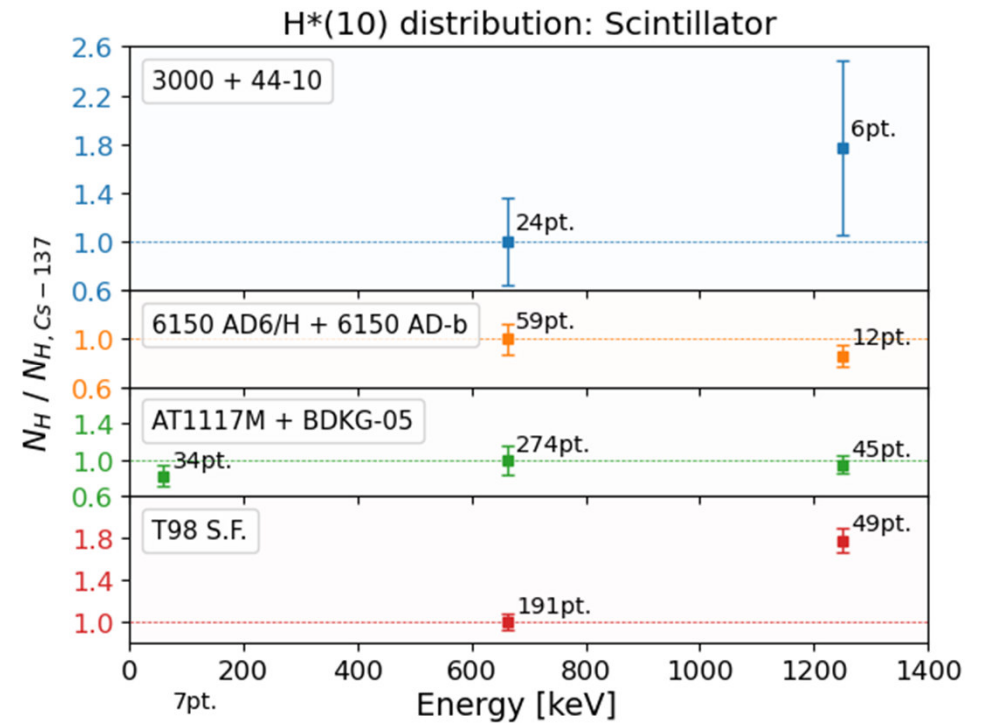
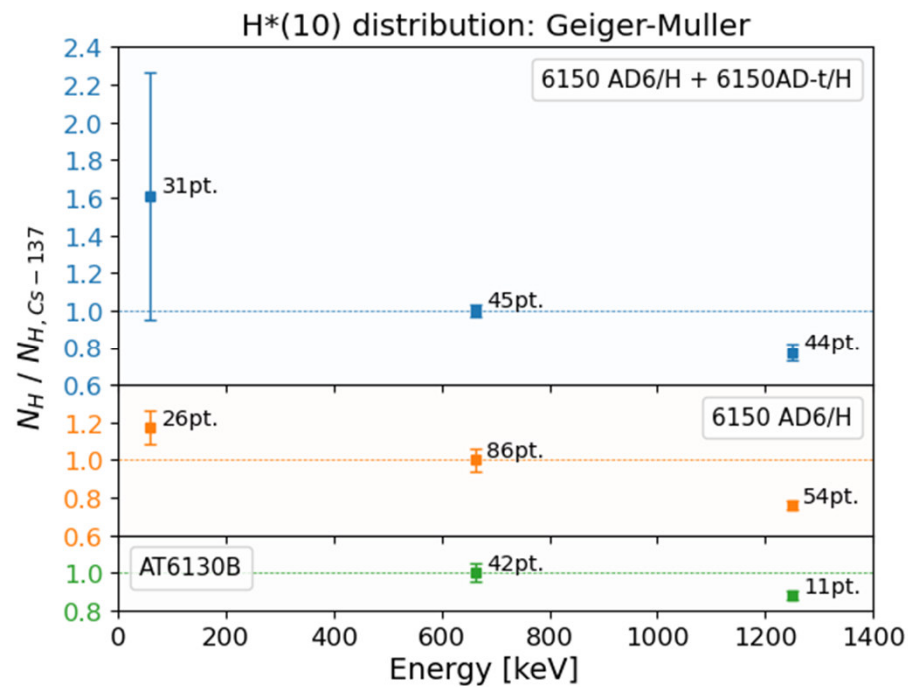
Position 2 / 3



Comparison of GM and scintillators



Uncertainty from user POV

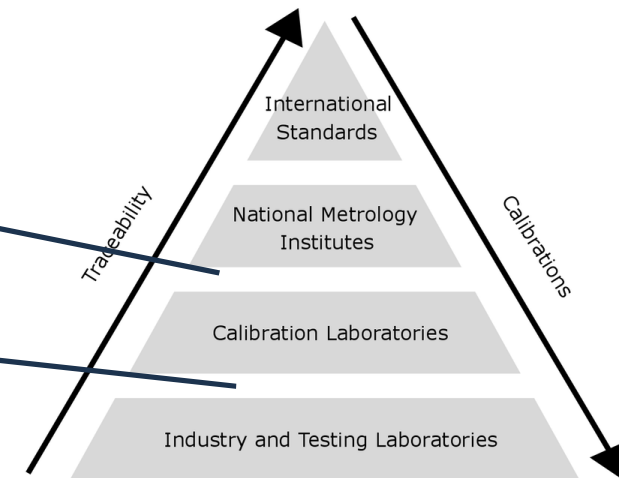


Issues for maintaining the accreditation

- The ISO 17025 requires that accredited labs participate to intercomparisons
- The Intercomparison should address both the CMC and the routine procedures for routine calibration of customers' instruments
- At present there are no intercomparison exercises on a harmonized basis
- EURADOS is a good candidate to fill this harmonization gap

CMC
I.C.

Routine
I.C.



Conclusions

- SSDL should be better called SSCL
- SSDLs are the link between NMI and final users, They are fundamental for disseminating the reference quantities and to guarantee metrological traceability (thousands of calibration certificates per year)
- The harmonization of calibration procedures is missing
- The final user cannot use the calibration factor and the uncertainty “as they are”, but must consider the specific on-filed environment
- SSDLs are important for an education action to the final user

Thanks for your attention

