Performance of a new NIRP TL-dosemeter -Uncertainty and detection limit estimation

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TL-dosemeter & TL-reader

NIRP TL-dosemeter

Harshaw 4-element TL-card

Position 1, Neutron Sensitive
Element: TLD-600H, ^{6}LiF: Mg,Cu,P
3.6 mm x 0,015"
Foil: PET 12µm / MET PET 12µm / PE 50µm

Position 2, $H_p(10)$
Element: TLD-700H, ^{7}LiF: Mg,Cu,P
3.6 mm x 0,015"
Badge: PP / PTFE - 1000 mgcm^{-2}

Position 3, $H_p(3)$
Element: TLD-700H, ^{7}LiF: Mg,Cu,P
3.6 mm x 0,015"
Badge: PP - 300 mgcm^{-2}

Position 4, $H_p(0,07)$
Element: TLD-700H, ^{7}LiF: Mg,Cu,P
3.6 mm x 0,010"
Foil: PET 12µm / MET PET 12µm / PE 50µm

Thermo Fisher Scientific,

Harshaw 8800Plus TL-reader

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Overview

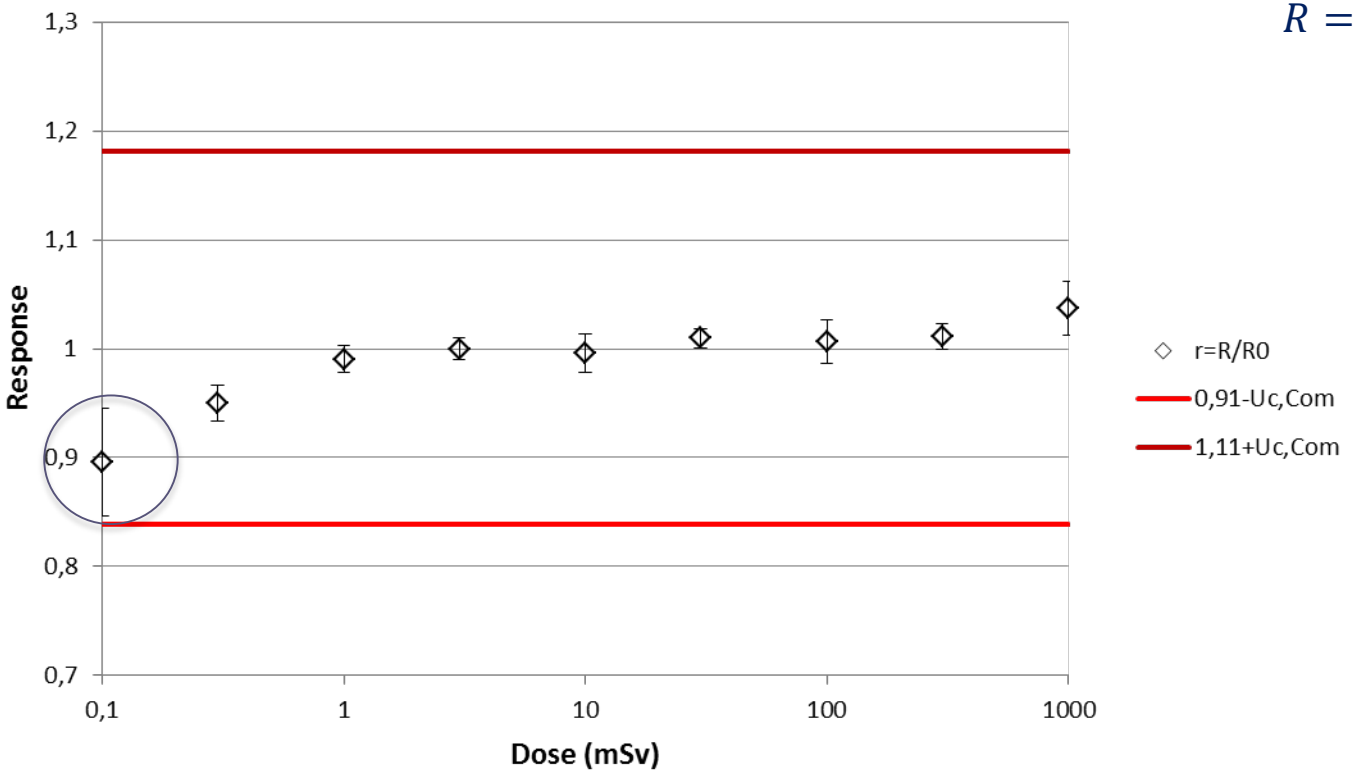
- Evaluation of the performance (uncertainty and detection limit) by application of the Standards:

  - ISO 62387-1 ”Passive integrating dosimetry systems for environmental and personal monitoring”
  - JCGM 100:2008 ”Evaluation of measurement data—Guide to the expression of uncertainty in measurement” (GUM)
  - ISO 11929 ”Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation”

Exposures performed by HPE (HPA/NRPB) – ISO 4037 (γ)

Linearity (ISO 62387-1)

Type Test Results, Hp(10), Cs-137



$$R = \frac{D_M}{D_T}$$

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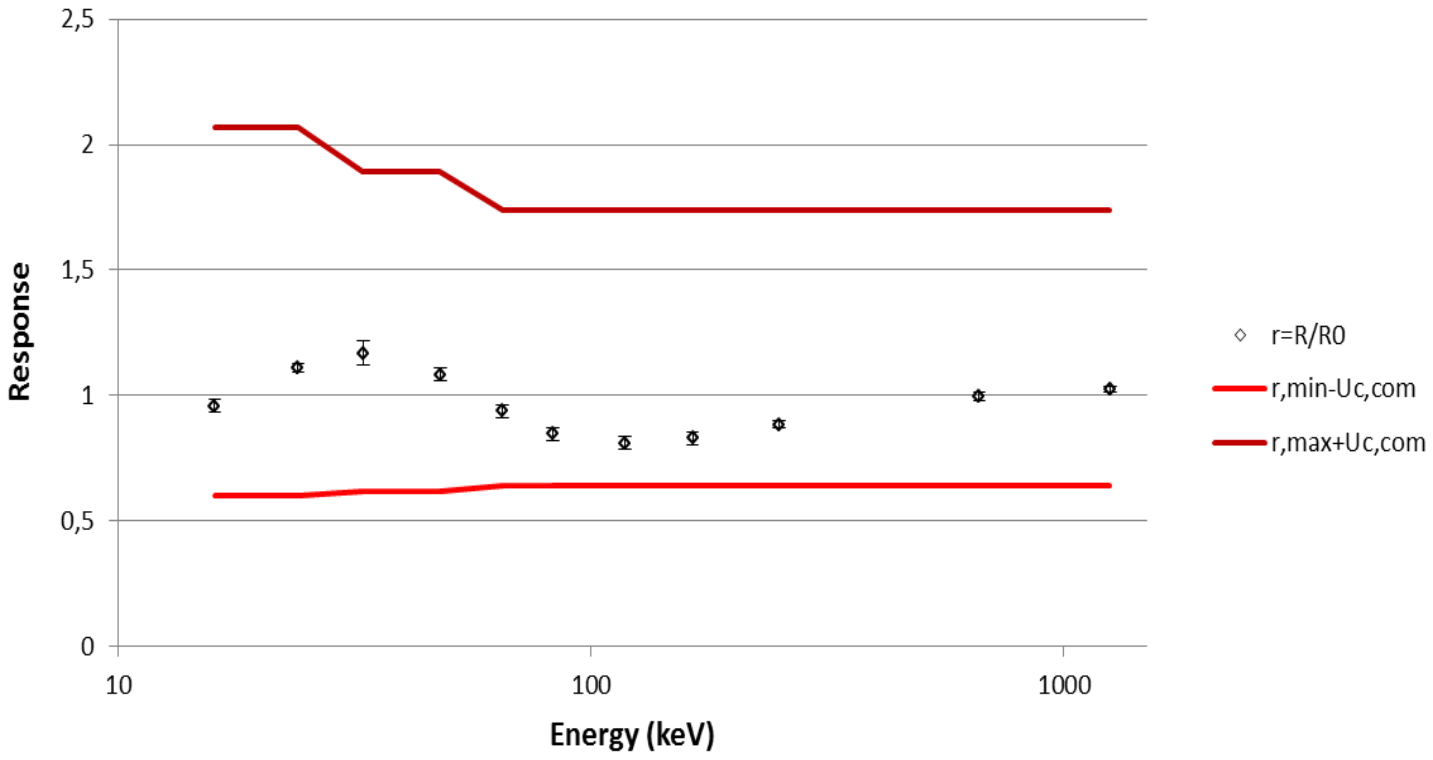
Energy Response (ISO 62387-1)

Type Test Results, Hp(10), N-20 <-> Co-60



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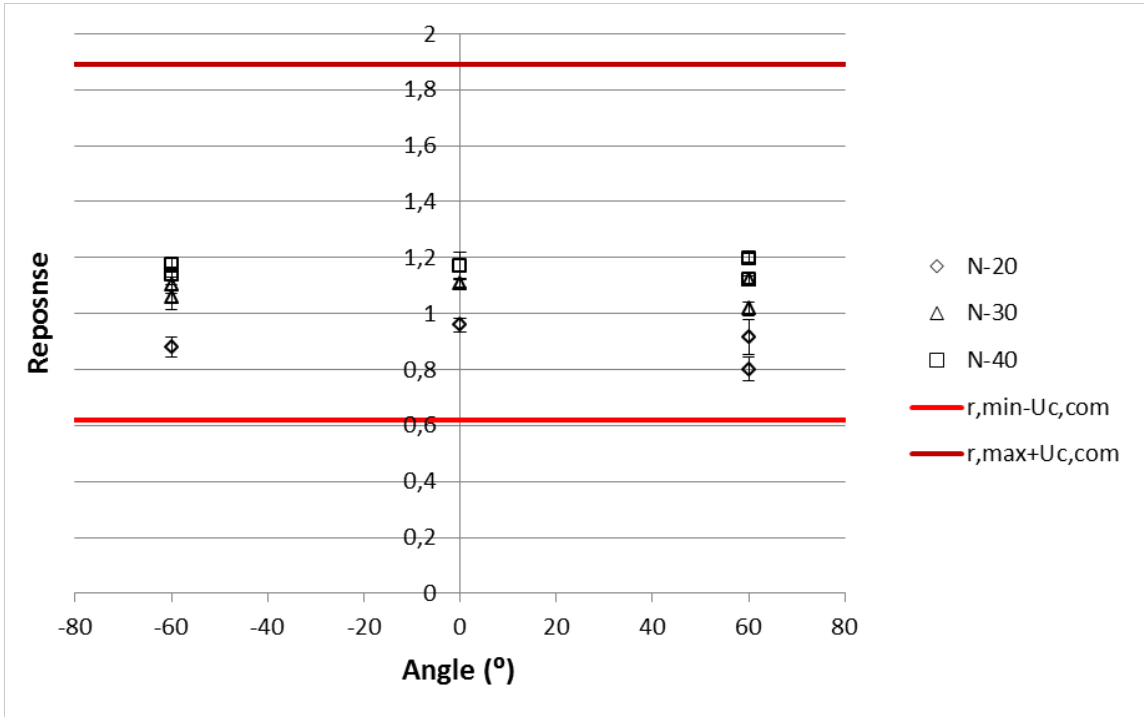
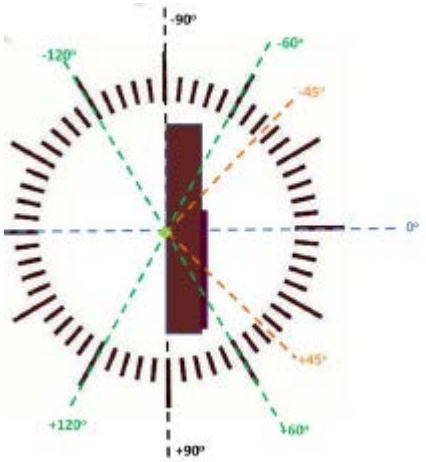
Directional Response (ISO 62387-1)

Type Test Results, Hp(10), Vertical & Horizontal plane





Conclusion: Response within limits!

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Dose uncertainty (GUM)

Model function:

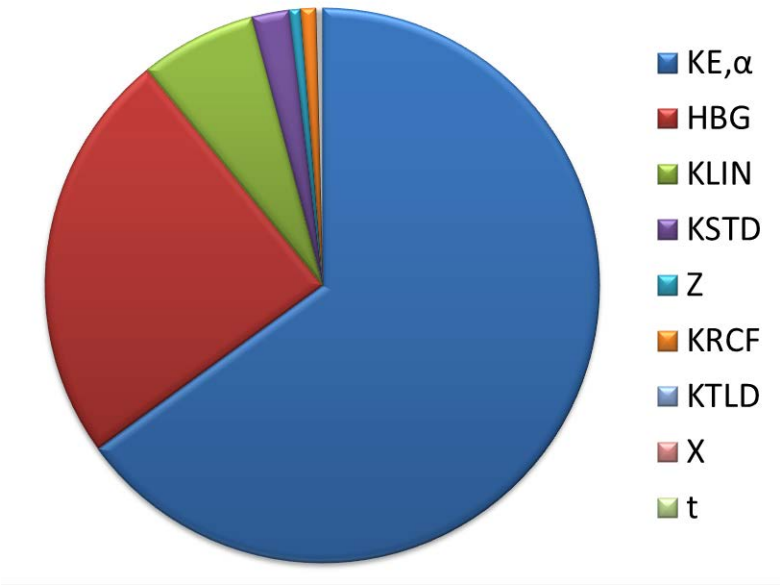
$$D_{gross} = K_{E,\alpha} \cdot K_{LIN} \cdot K_{TLD} \cdot K_{RCF} \cdot K_{STD}(X - Z)$$

$$D = D_{gross} - t \cdot \dot{H}_{BG}$$

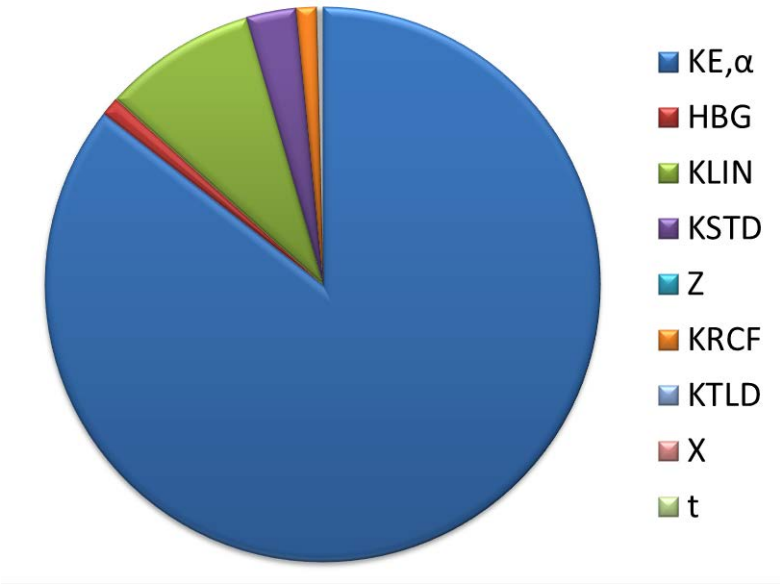
Uncertainty budget

Quantity	Unit	Exp. value	|ci|	u(Xi)	Distribution	|ci|u(Xi)		|ci|u(Xi)	(|ci|u(Xi))^2
X	gU	8,31	Yg/(X-Z)	0,006*X	Normal	**0,006**	YgX/(X-Z)	0,000661148	4,37117E-07
Z	gU	0,50	Yg/(X-Z)	0,4*Z	Triangular	**0,4**	YgZ/(X-Z)	0,002651893	7,03254E-06
H_{BG}	mSv/d	0,00173	t	0,00027	Normal	**0,00027**	t	0,016128	0,000260112
t	d	60	H_{BG}	0,58	Uniform	**0,58**	H_{BG}	0,000996522	9,93057E-07
K_{LIN}	1	1,04	Yg/K_{LIN}	0,042*K_{LIN}	Uniform	**0,042**	Yg	0,004349589	1,89189E-05
$K_{E,\alpha}$	1	1,05	Yg/$K_{E,\alpha}$	0,13*$K_{E,\alpha}$	Uniform	**0,13**	Yg	0,013463014	0,000181253
K_{TLD}	1	1	Yg/K_{TLD}	0,006*K_{TLD}	Normal	**0,006**	Yg	0,00062137	3,86101E-07
K_{RCF}	1	1	Yg/K_{RCF}	0,015*K_{RCF}	Uniform	**0,015**	Yg	0,001553425	2,41313E-06
K_{STD}	mSv/gU	0,0121	Yg/K_{STD}	0,024K_{STD}	Normal	**0,024**	Yg	0,002470331	6,10253E-06
								u	0,021855171
								u,rel	**22%**

Sensitivity coefficients



Hp(10) = 0,1 mSv



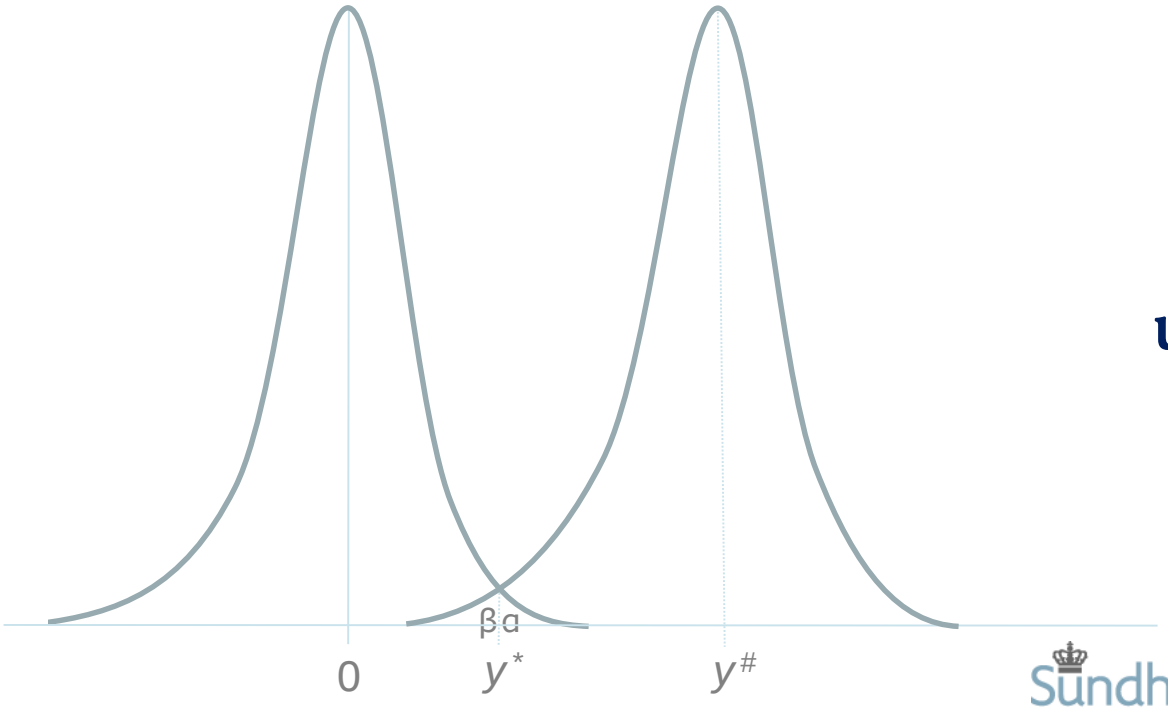
Hp(10) = 1 mSv

Minimum Detectable Dose, MDD

ISO 11929

Decision threshold: $P(X > y^* \mid X = 0) = \alpha \quad , y^* = k_{1-\alpha}u(0)$

Detection limit: $P(X < y^* \mid X = y^\#) = \beta \, , \quad \mathbf{y^\# = k_{1-\alpha}u(0) + k_{1-\beta}u(y^\#)}$



$\mathbf{u(0) \neq u(y^\#)}$

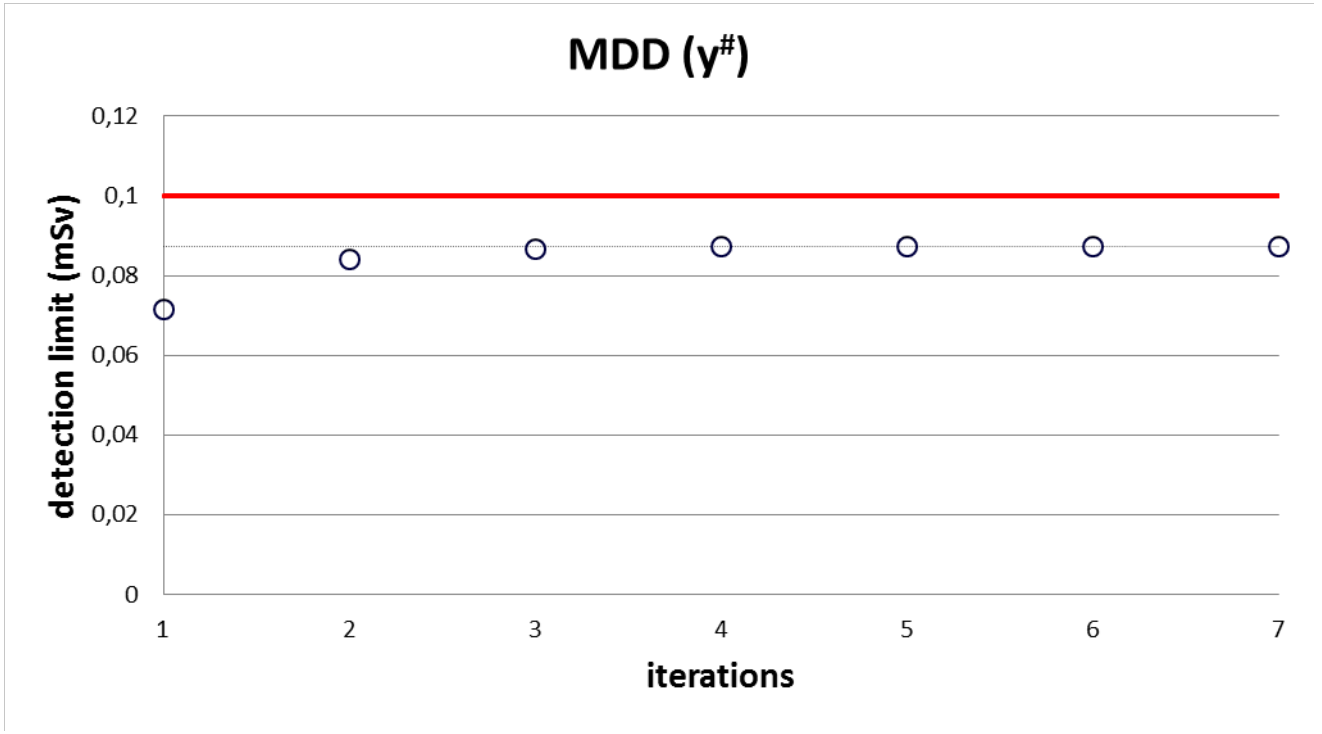
MDD iterative determination, Hp(10)

ISO 11929

$$\tilde{y}_{i+1} = y^* + k_{1-\beta} u(\tilde{y}_i)$$

$$y^{\#} = \tilde{y}_{\infty}$$

$\alpha = \beta = 0{,}05$



For a 1 monthly issued dosemeter MDD should be less than 0,1 mSv

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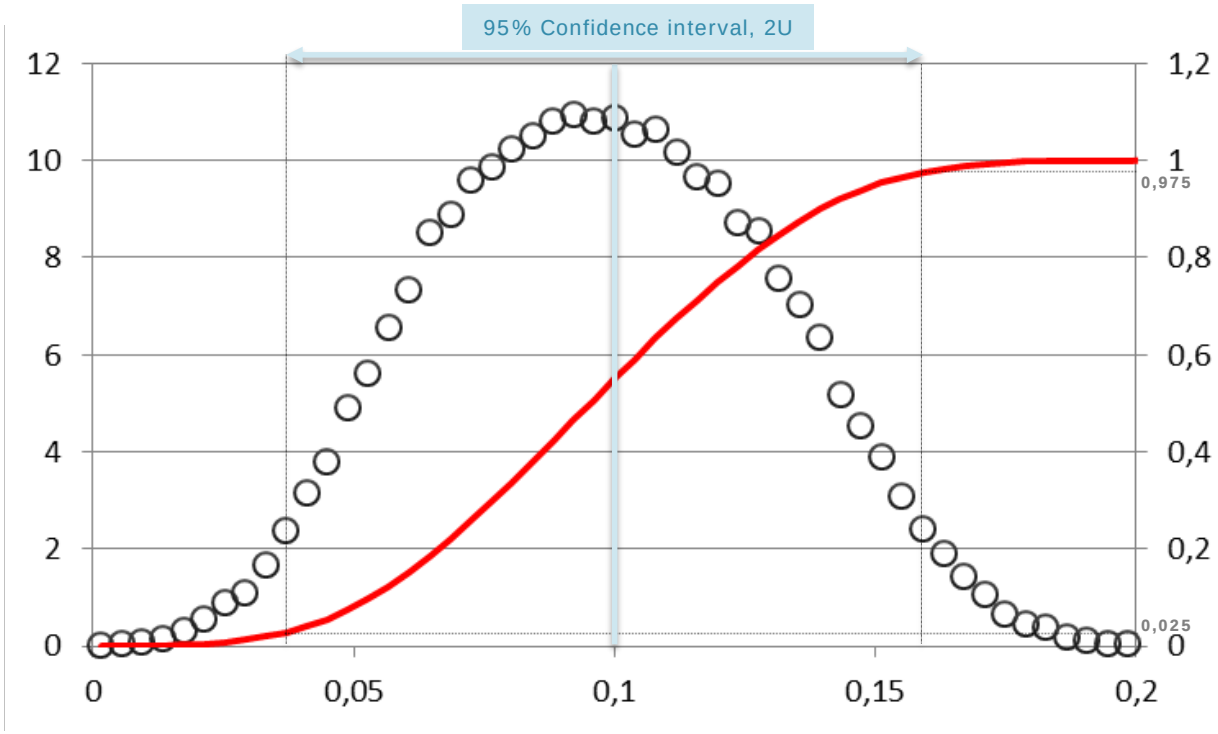
Monte Carlo simulation, Confidence interval (coverage factor)



Hp(10) = 0,1 mSv

N= 100.000

$U = k_{0,95}(d)u(d)$

$k_{0,95}(0,1\text{mSv}) = 1,88$

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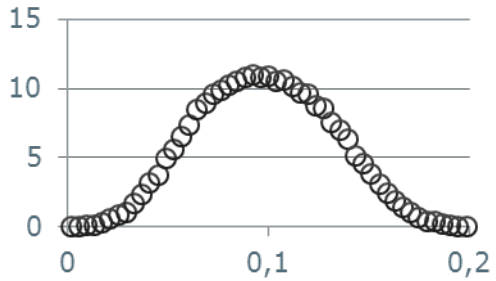
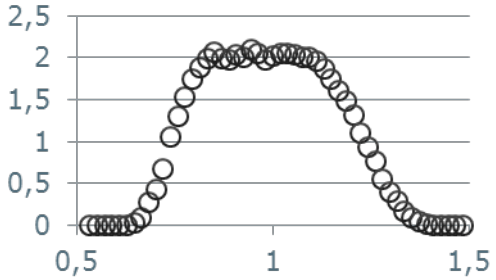
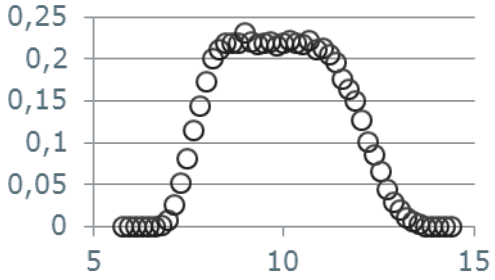
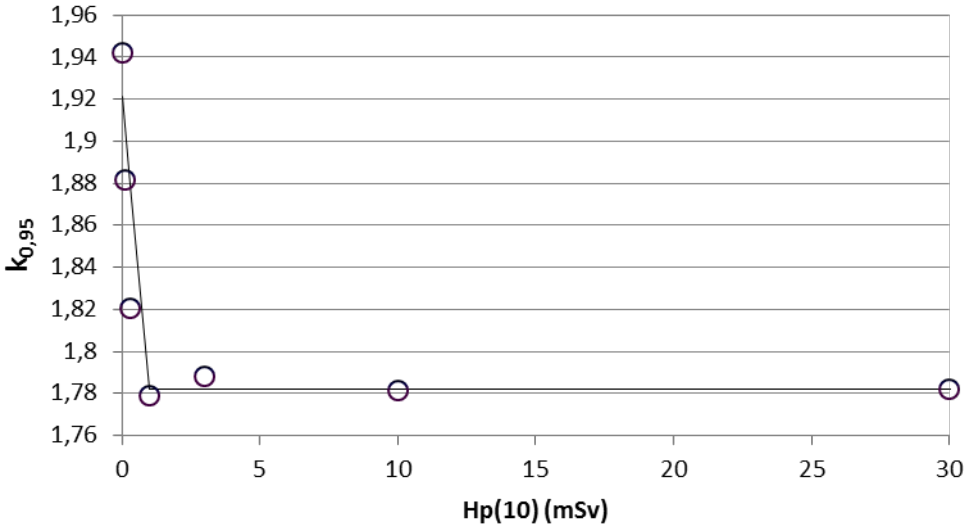
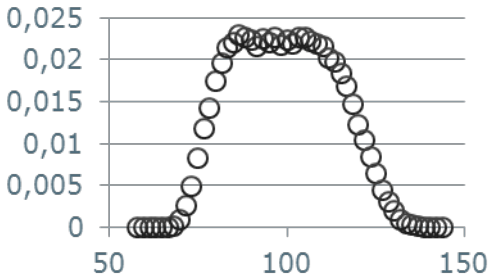
Coverage factor (MC)











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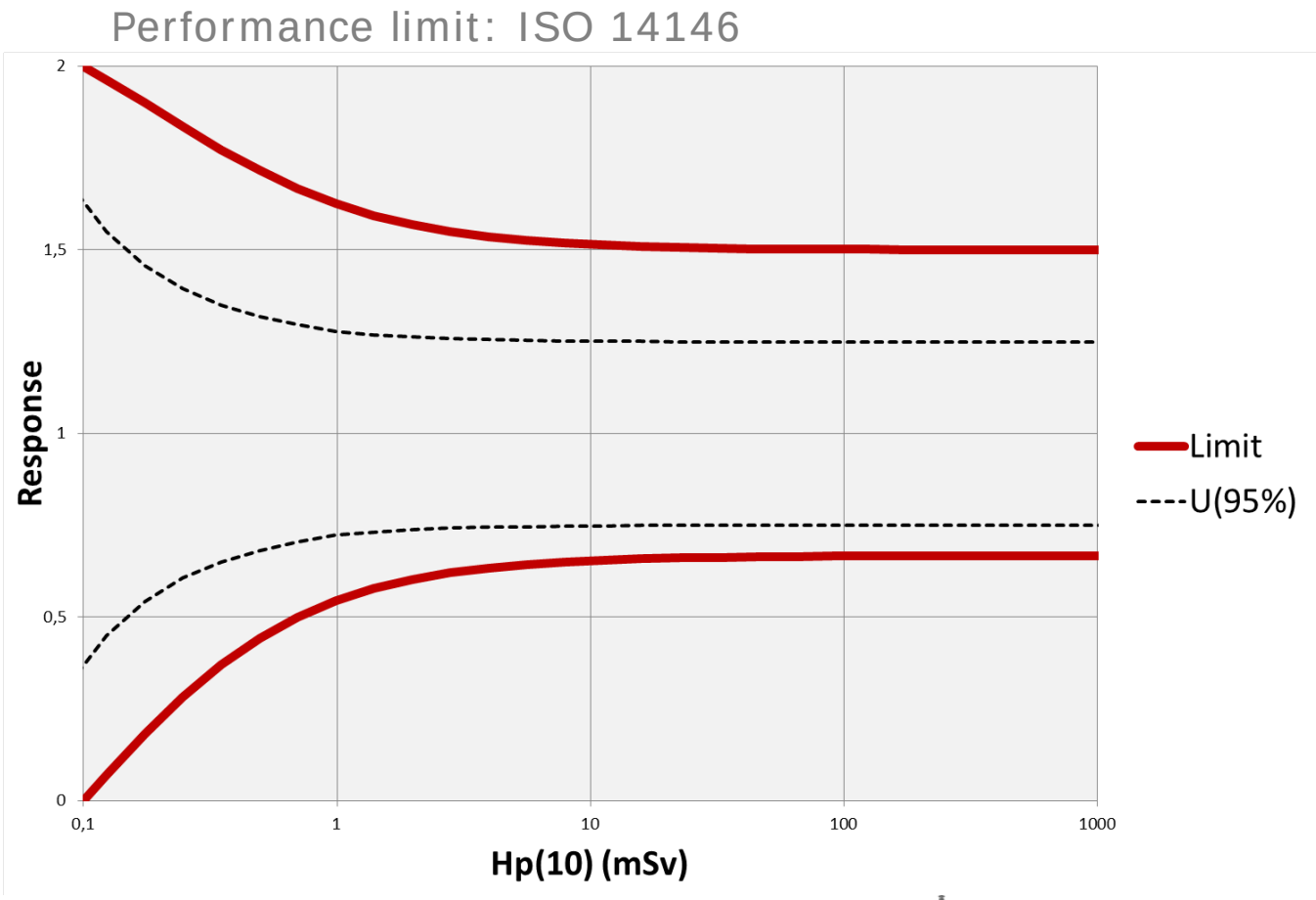
Performance limit vs. Confidence int.



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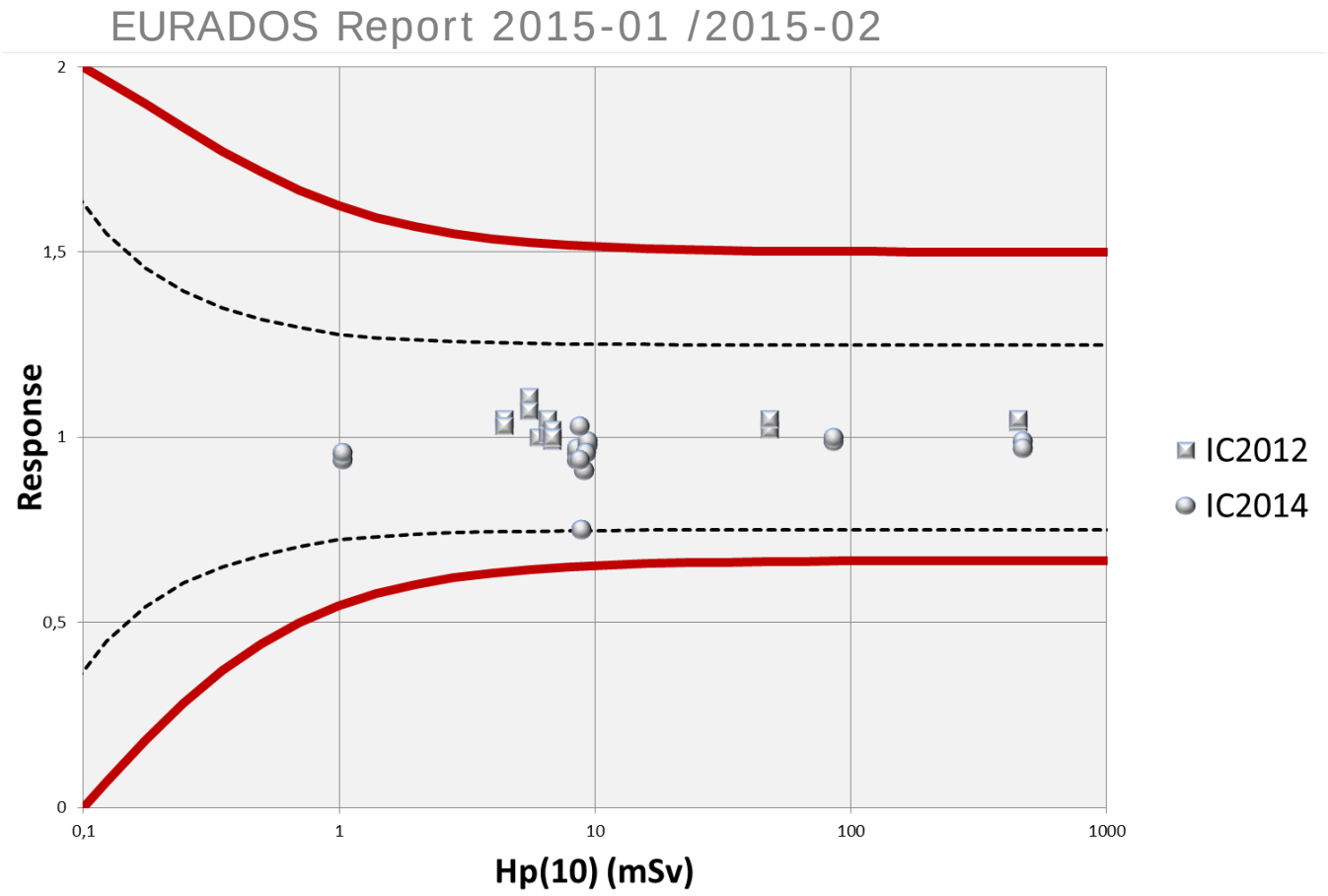
Results from intercomparison



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Conclusion

- Minimum Detectable Dose, Hp(10) < 0,1 mSv
  - Main Influence parameters:
    - Background radiation variation
    - Dosemeter dependence on energy & angle of radiation
- Dosemeter capable of measuring Hp(10):
  - Energy [16 keV ⇔ 1,3 MeV] (γ)
  - Dose: [0,1 mSv ⇔ 1 Sv]
  - Angle: [-60° ⇔ +60°]

Thank you, ?

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