

22NRM01 TraMeXI

Traceability in Medical X-ray Imaging Dosimetry

Performance of X-ray multimeters

Workshop on X-ray Imaging Dosimetry

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Data on XMM performance

- ▶ Manufacturer specifications
 - ▶ Measurement ranges for different quantities and parameters
 - ▶ Stated measurement uncertainties
 - ▶ Analysis based on the multimeters available on the market
- ▶ Research results
 - ▶ General radiography
 - ▶ Interventional procedures
 - ▶ Performance in standard and non-standard radiation fields.

Manufacturer specifications

- ▶ Data on approximately 50 SSDs was collected
- ▶ Both current and previous dosimeter models were considered
- ▶ Single-element and multi-element detectors
- ▶ Realized either as stand-alone devices or connected to EMMs
- ▶ Devices from 5 different manufacturers
 - ▶ RTI Electronics, Raysafe, Radcal, IBA and PTW

Stated ranges and uncertainties (Kair, kV)

Dosimeter	Modality	Kair	U(Kair)	kV	U(kV)
MPD	R/F/D	40 nGy/s - 350 mGy/s	5 %	R/F: 35 - 155 kV	1.5 %
R100B	R/F/M	40 nGy/s - 160 mGy/s	5 %	N/A	N/A
Cobia Flex R/F	R/F	2.5 µGy/s - 175 mGy/s	5 %	38 - 155 kV	2 %
Piranha Multi	R/F	15 nGy/s - 320 mGy/s	5 %	35 - 160 kV	1.5 %
	M	25 nGy/s - 530 mGy/s		18 - 49 kV (A/F)	1.5 % (A/F)
	D	15 nGy/s - 320 mGy/s		35 - 125 kV	1.5 %
Xi R/F Low	R/F/D	10 nGy/s - 1 mGy/s	5 %	35 - 160 kVp	2 % / 3 %
Xi R/F High	R/F/D	20 µGy/s - 1 Gy/s	5 %	35 - 160 kVp	(<0.5 / <1.0 mm Cu)
X2 R/F	R/F/D	1 nGy/s - 500 mGy/s	5 %	40 - 150 kVp	2 %
MagicMax XR	R/F/D	100 nGy/s - 160 mGy/s	5 %	40 - 150 kV	2 %
AGMS-D+	R/F/D	40 nGy/s - 200 mGy/s	5 %	40 - 160 kV	2 %
DDX6-WL	R/F	500 pGy/s - 5.7 mGy/s	5 %	N/A	N/A
NOMEX Multimeter	R/F/D	5 µGy/s - 500 mGy/s	3.5 %	50 - 150 kV	1.5 %

Stated ranges and uncertainties (HVL, TF)

Dosimeter	Modality	HVL	U(HVL)	TF	U(TF)
MPD	R/F/D	1.2 – 14.0 mm Al	10 %	1.5 – 38.0 mm Al	10 %
Cobia Flex R/F	R/F	1.2 – 14 mm Al	10 %	1.0 – 90.0 mm Al	10 %
Piranha Multi	R/F M	0.72 – 13.0 mm Al 0.19 – 4.3 mm Al	10 %	1.0 – 90.0 mm Al N/A	10 %
Xi R/F Low Xi R/F High	R/F/D	1.0 – 14.0 mm Al	10 %	1.5 – 35.0 mm Al	10 %
X2 R/F	R/F/D	1.0 – 14.0 mm Al	10 %	1.5 – 35.0 mm Al	10 %
X2 MAM	M	0.2 – 3.6 mm Al	5% (> 25 kV) 10% (< 25 kV)	N/A	N/A
MagicMax XR	R/F/D	1.3 – 10 mm Al	10 %	2 – 22 mm Al	N/A
AGMS-D+	R/F/D	1.3 – 13.5 mm Al	5 %	2.0 – 24.0 mm Al 25.0 – 40.0 mm Al	N/A
NOMEX Multimeter	R/F/D	0.95 – 13.5 mm Al	10 %	1.5 – 40.0 mm Al	10 %

Manufacturer specifications - Summary

- ▶ Often not clearly indicated if the stated value pertains to MU, or response deviation, accuracy/innaccuracy...
- ▶ Air kerma, commonly stated limit of 5 %, some models 3.5 % or 2.5 %
- ▶ In case of mammography often higher value of 6.5 % stated
- ▶ XMMs provide X-ray tube voltage indication in terms of kilovoltage-peak, practical peak voltage, etc...)
- ▶ Stated uncertainty 2 % for most devices, in mammography 1.5 % - 2 % based on A/F setup
- ▶ HVL and TF usually stated 10 %, in mammography TF not measured (due to various A/F)

XMM performance

- ▶ XMM response to different influence quantities.
 - ▶ Photon energy, angle of incidence, dose rate – most important radiation based influence quantities
 - ▶ Absolute response ($R = X_M / X_{REF}$) / Relative response ($r_{i,j,k} = R_{i,j,k} / R_0$)
- ▶ Evaluation of XMM response against IEC stated limits of variation.
- ▶ Development of new radiation qualities not covered in existing IEC standard.
- ▶ Performance testing in standard and non-standard radiation qualities.

Interventional procedures – Results from VERIDIC project

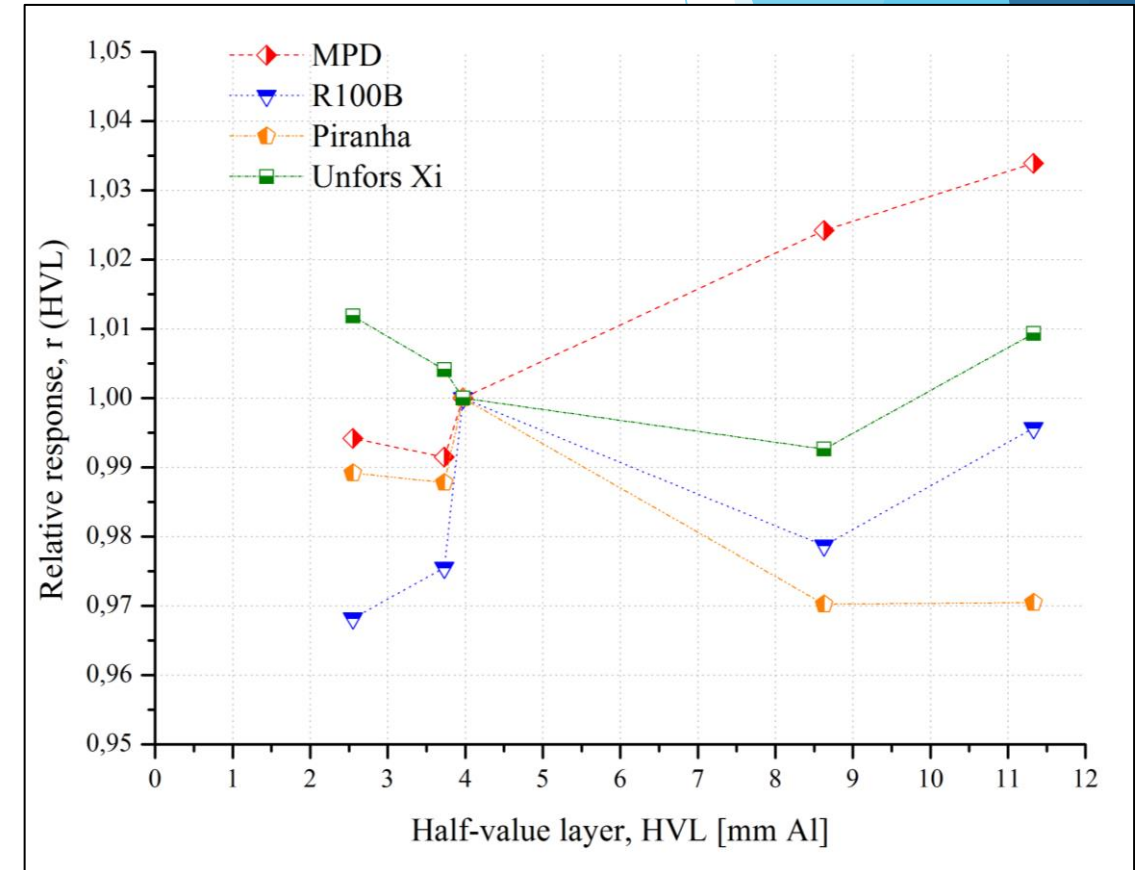
- ▶ Radiation qualities which correspond to IC/IR procedures.
- ▶ Comparison of dosimeter performance in standard RQR8 radiation quality and 4 non-standard radiation fields.
- ▶ Non-standard fields derived from examination of IC/IR procedures on several interventional X-ray units, a total of 180 RDSRs.
- ▶ A range of X-ray tube voltage 57 – 125 kV and added filtration 0 – 1.0 mm Cu was observed.

RQ	U [kV]	HVL [mm Al]	f add [mm Cu]	Nk [mGy nC ⁻¹]
RQR8	100	3.97	/	17.82
Veridic1 80Al	80	2.55	0	17.90
Veridic3 80AlCu	80	8.63	0.9	17.66
Veridic2 120Al	120	3.73	0	17.76
Veridic4 120AlCu	120	11.33	0.9	17.39

<https://doi.org/10.1016/j.radmeas.2021.106515>

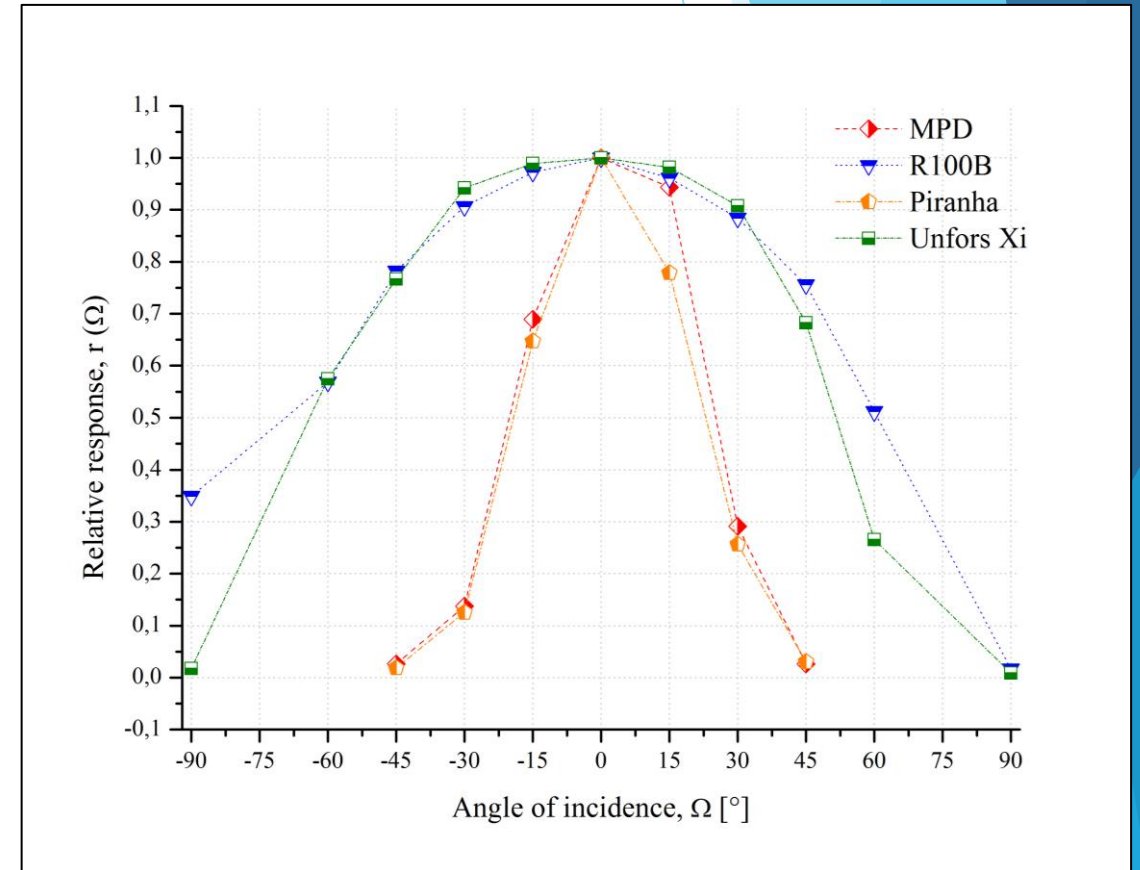
Interventional procedures – Results from VERIDIC project

- ▶ Energy dependence was evaluated in terms of relative response.
- ▶ Normalization to the standard RQR8 radiation quality of similar kV.
- ▶ Observed deviations less than $\pm 5\%$!



Interventional procedures – Results from VERIDIC project

- ▶ Angular dependence was evaluated in terms of relative response.
- ▶ Normalization to the 0° for each radiation quality separately. Examination done for RQR8 and one of the non-standard beams 80AlCu.
- ▶ Angular dependence significantly more pronounced in the case of multi-element detectors MPD and Piranha.



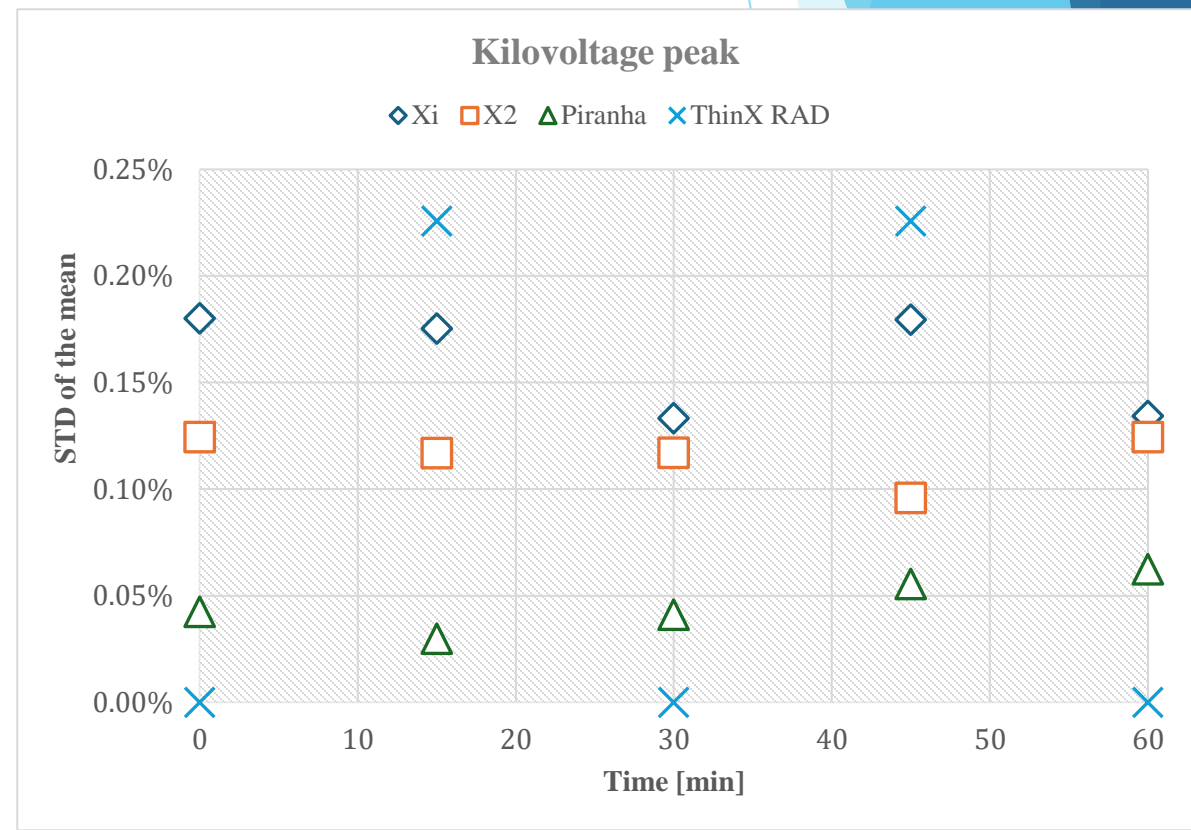
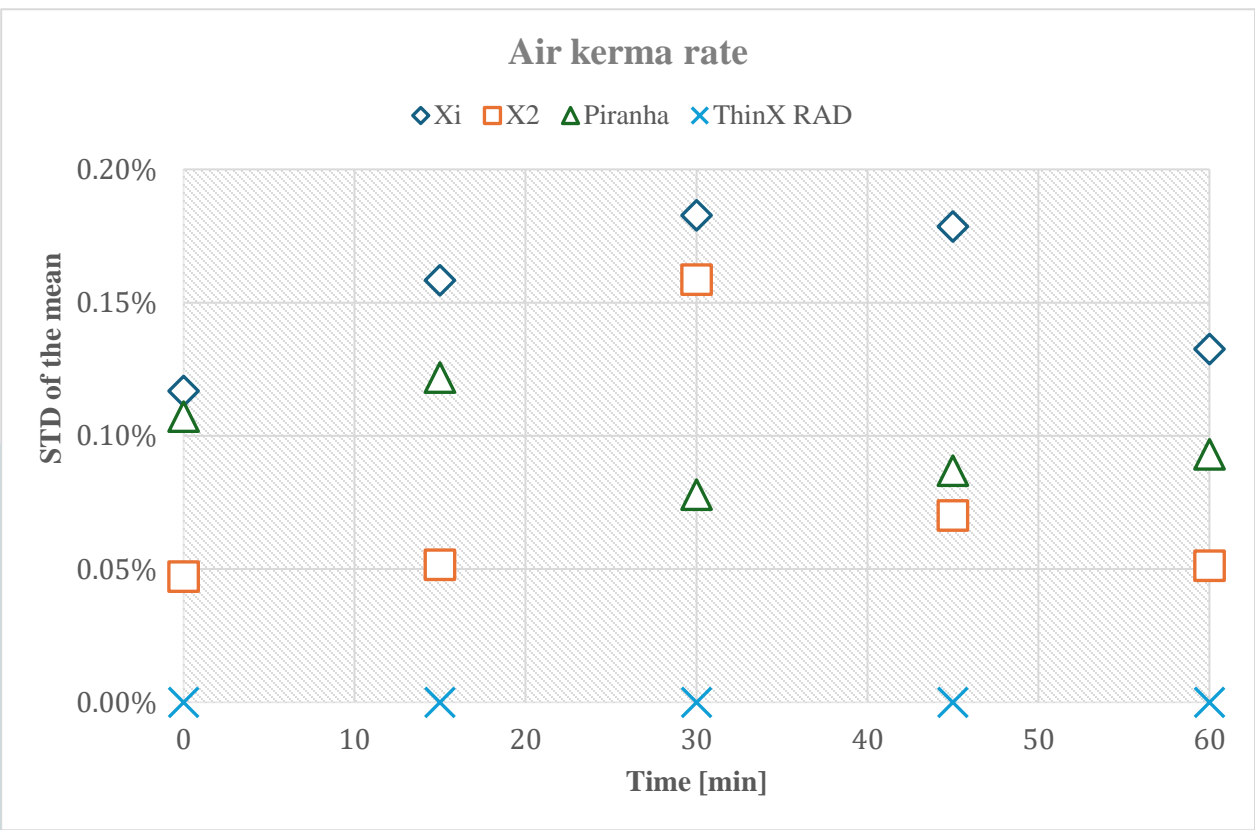
Development of CCPRQs – Results from TraMeXi project

- ▶ Development of new radiation qualities to update IEC 61267:2005.
 - ▶ New Clinically Relevant Copper-filtered beams (CCPRQs)
- ▶ CCPRQs to extend the range of well defined RQR and RQT radiation qualities, to properly cover clinical use of added Cu filtration (0.1 – 0.9 mm Cu).
- ▶ Performance testing of XMMs in standard and non-standard radiation fields as an input for the update of IEC 61674:2012.
- ▶ e.g., Comparison of HVL values with SpekCalc.

RQ	U [kV]	HVL [mm Al]	f add [mm Cu]
RQR5	70	2.57	/
RQR8	100	4.02	/
RQT8	100	7.00	0.2
CCPRQ5	70	7.65	0.9
CCPRQ8	100	10.1	0.9
CCPRQ9	120	11.2	0.9

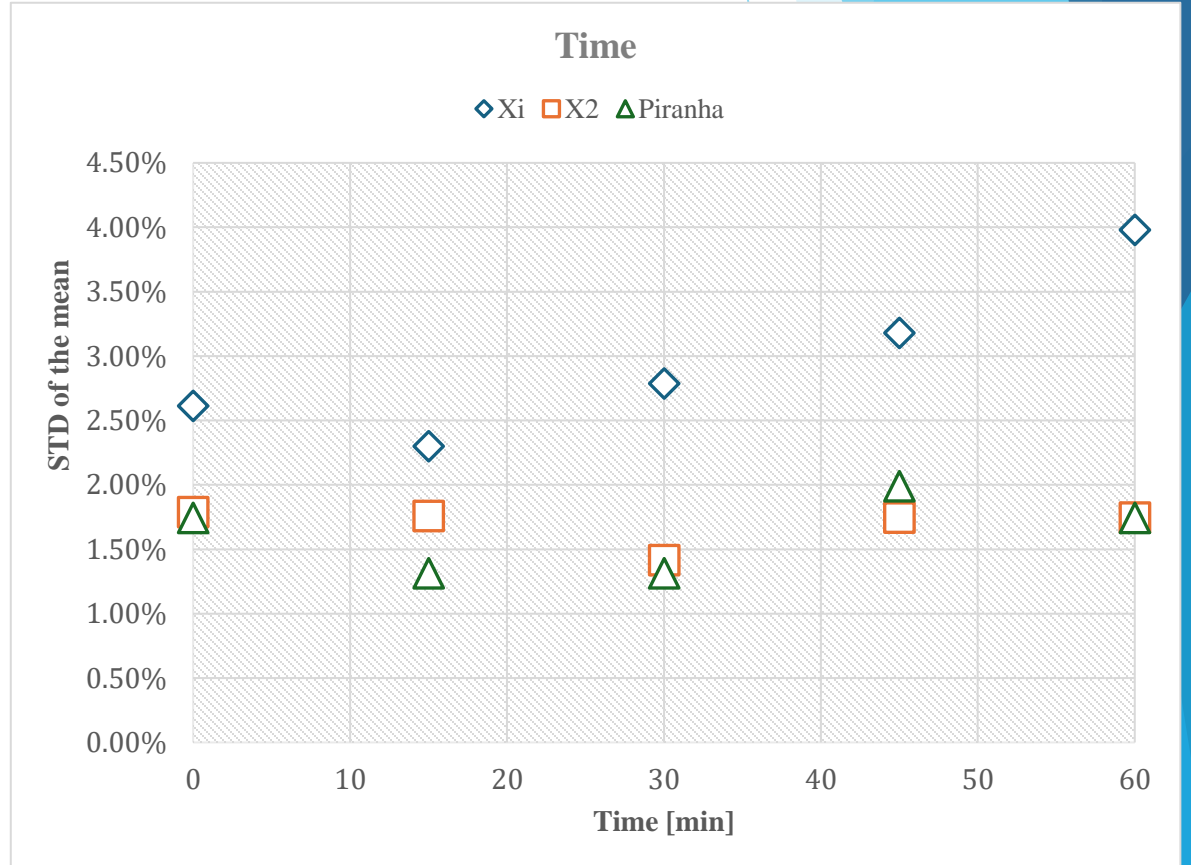
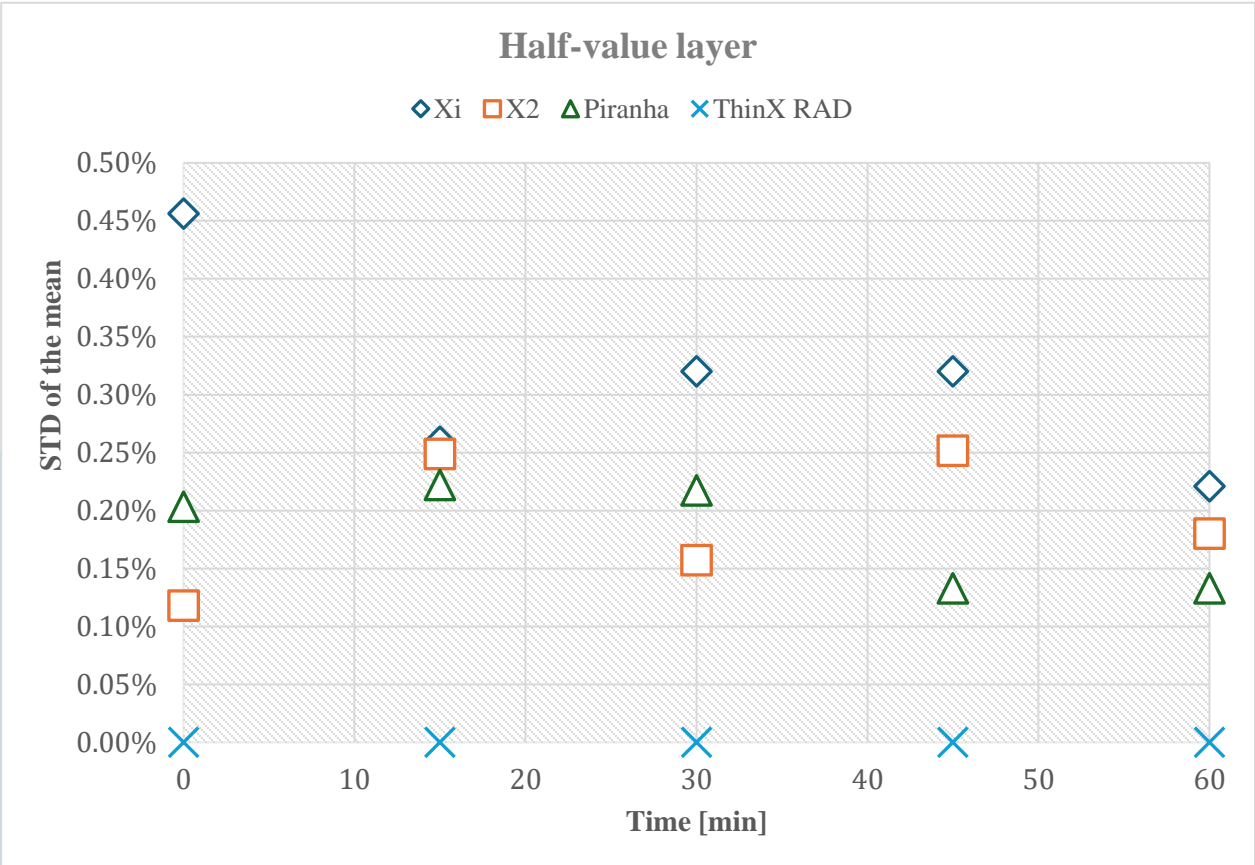
XMM performance – Stabilization – Results from TraMeXI Project

▶ RQR5; XMM indication acquired in 15 min intervals; Evaluation of standard deviation of the mean.



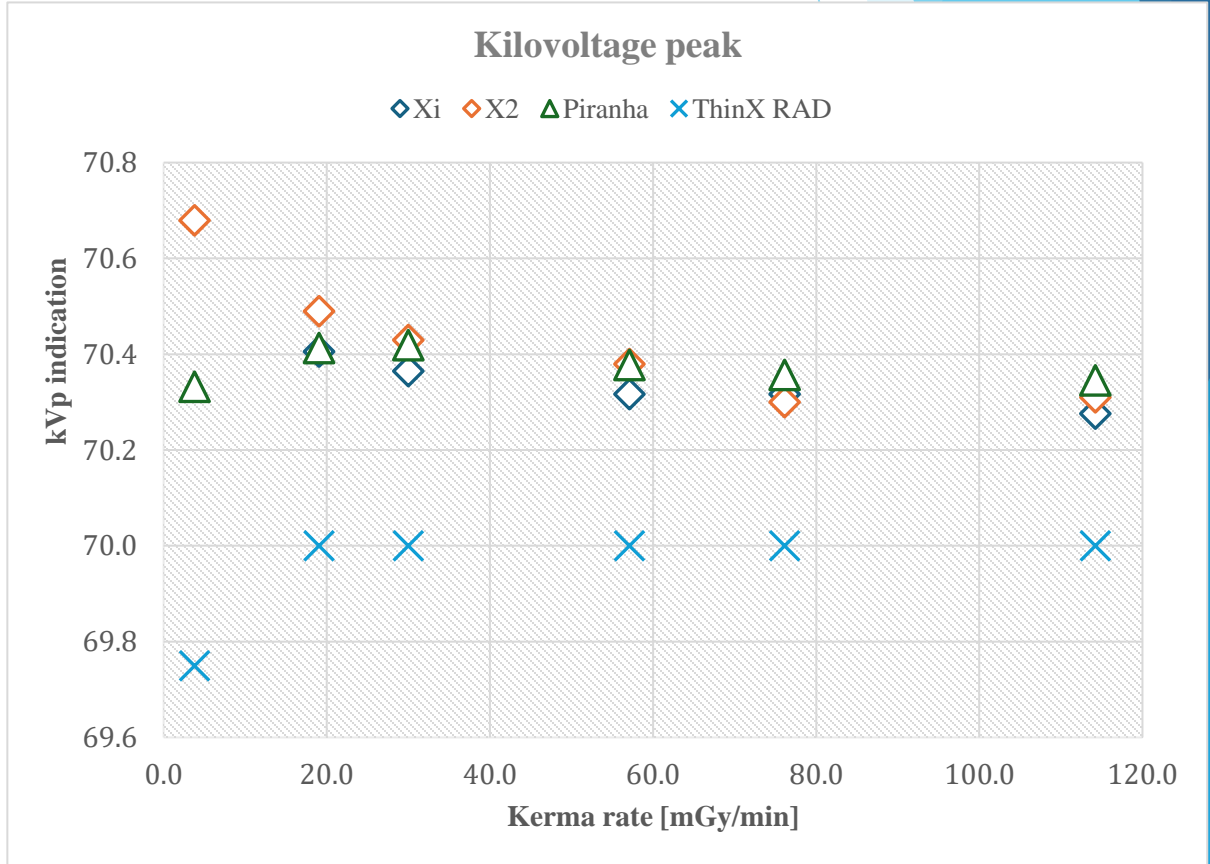
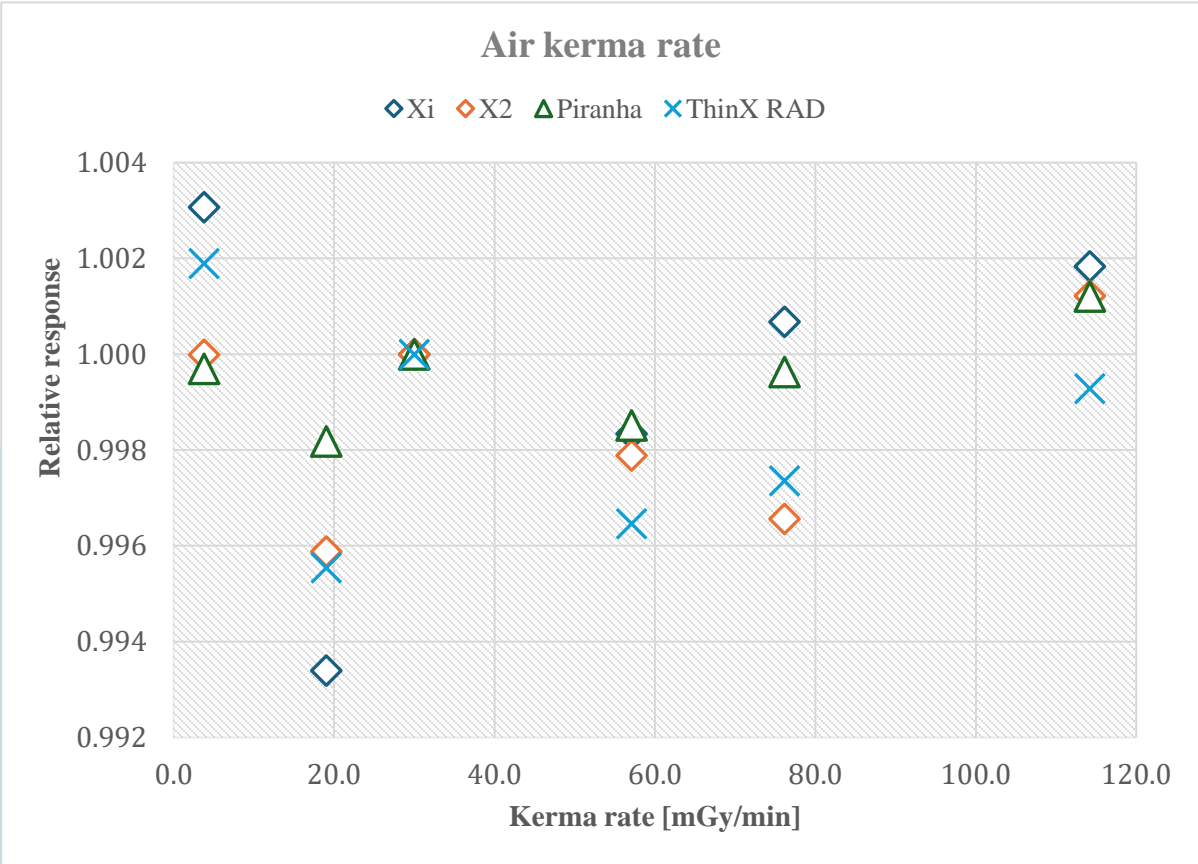
XMM performance – Stabilization – Results from TraMeXI Project

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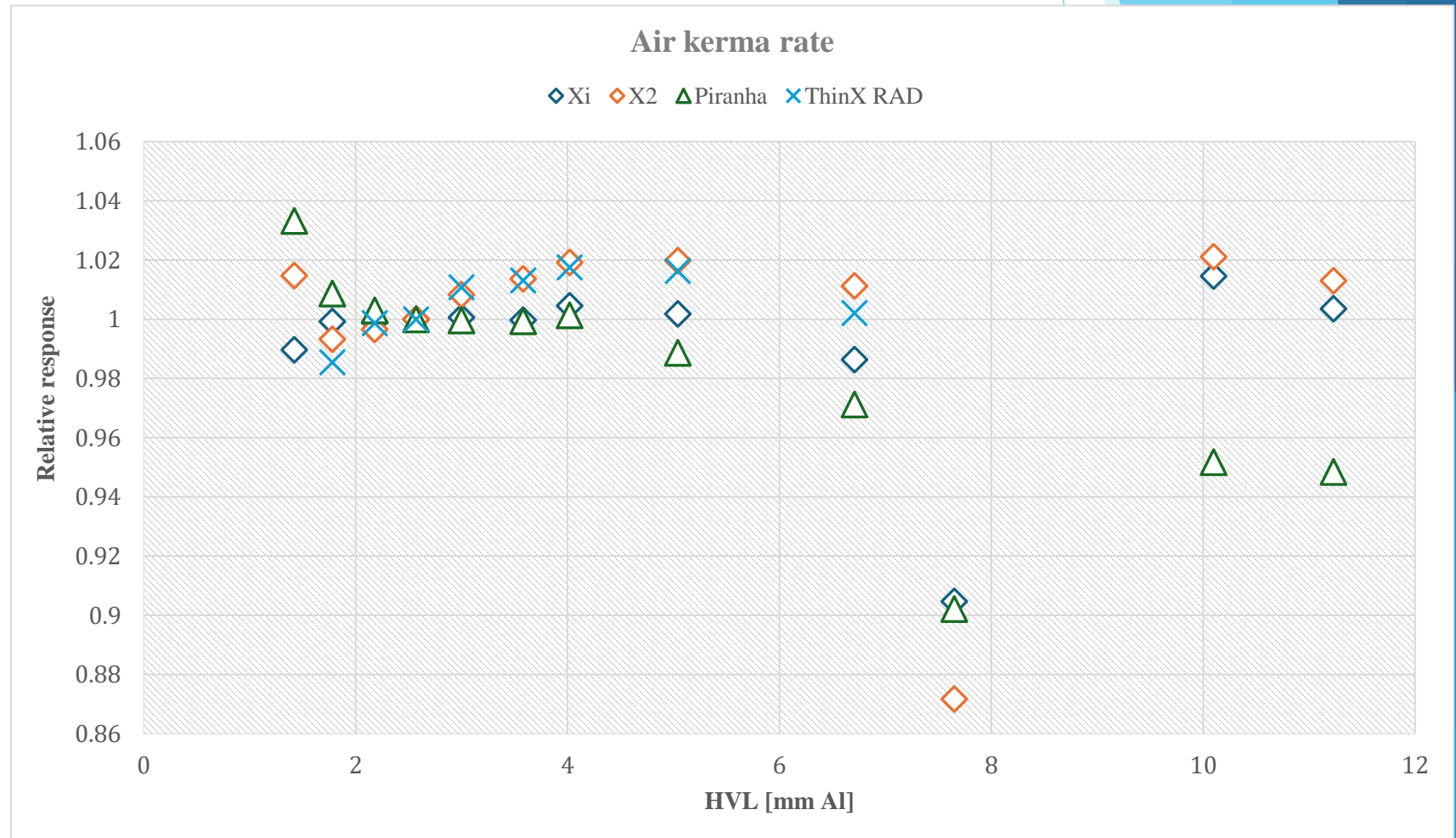
XMM performance – Linearity – Results from TraMeXI Project

► RQR5; Analysis of relative response normalized to 30 mGy/min (7.88 mA) in terms of air kerma; variation in indication of other parameters observed.



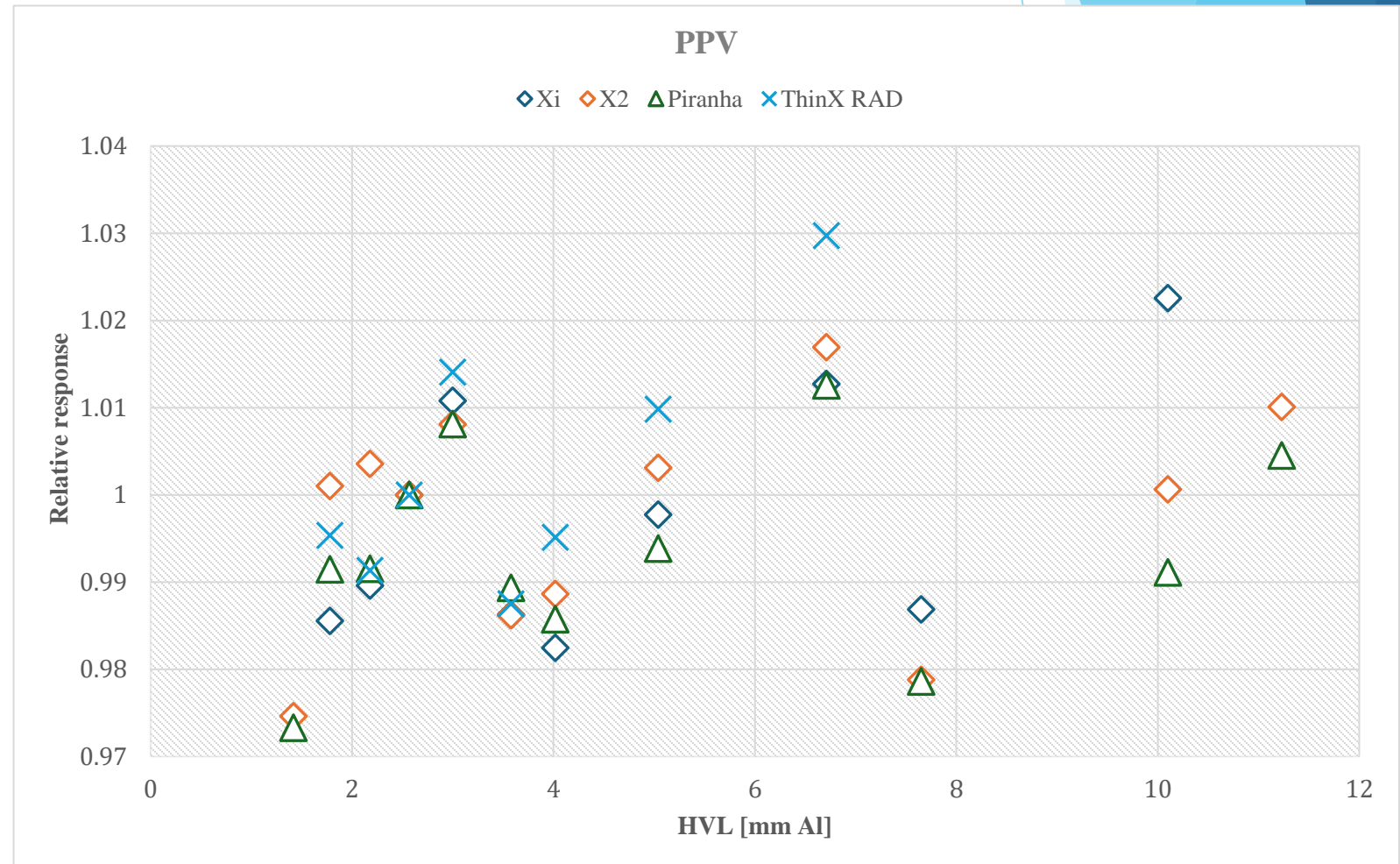
XMM performance – Energy response – Results from TraMeXI Project

- ▶ Normalization to RQR5
- ▶ N_k for K_{air} obtained with interpolation in the HVL dependence of the reference IC.
- ▶ Deviations larger than 5 % observed for CCPRQ5



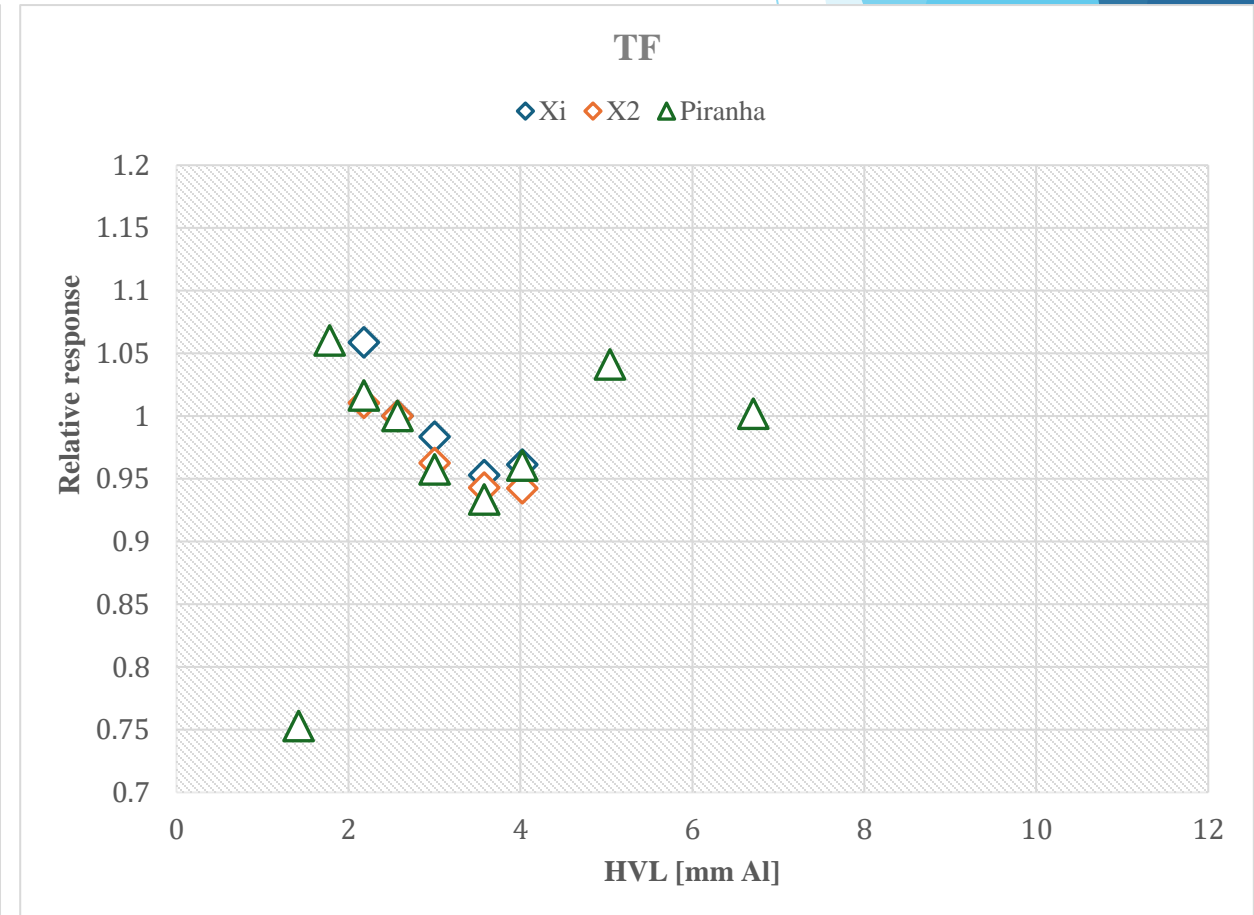
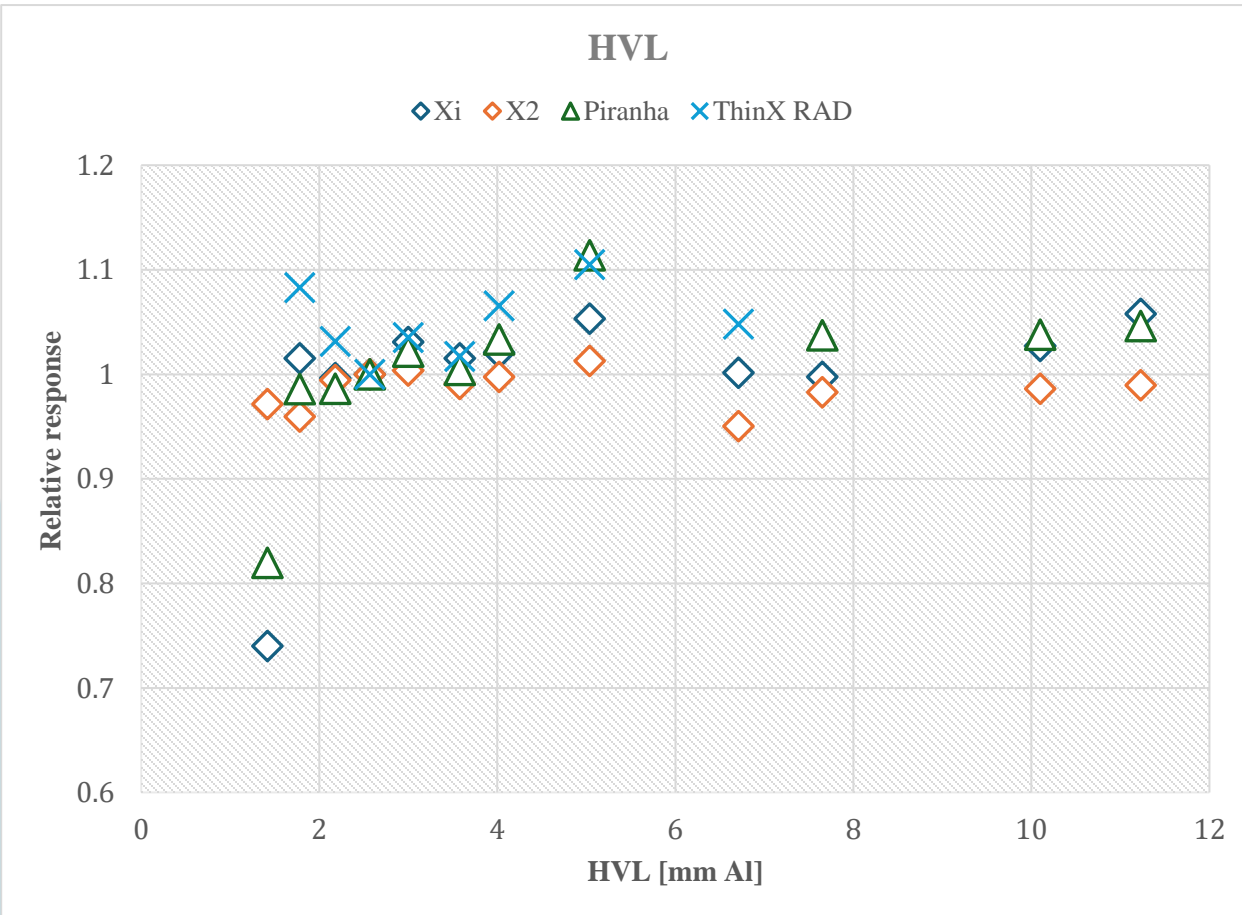
XMM performance – Energy response – Results from TraMeXI Project

- ▶ Normalization to RQR5
- ▶ Nu not determined for CCPRQs
- ▶ Reference device indications used for Uref



XMM performance – Energy response – Results from TraMeXI Project

► Normalization to RQR5; HVL response within 10% for CCPRQs; XMMs unable to determine TF for CCPRQs



Thank you for your attention!



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