TraMeXI

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Traceability in Medical X-ray Imaging Dosimetry

Workshop on X-ray imaging dosimetry
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stuk RADIATION AND NUCLEAR SAFETY AUTHORITY
CZECH METROLOGY INSTITUTE
INMRI ISTITUTO NAZIONALE DI METROLOGIA DELLE RADIAZIONI IONIZZANTI ENEA
TÉCNICO LISBOA
IMBIH STÄDTISCHES KLINIKUM BRAUNSCHWEIG
PTB Physikalisch-Technische Bundesanstalt National Metrology Institute
HUS Helsinki University Hospital
TENMAK NÜKEN
Bambino Gesù OSPEDALE PEDIATRICO
VSL National Metrology Institute
EEAE ΕΛΛΗΝΙΚΗ ΕΠΙΤΡΟΠΗ ΑΤΟΜΙΚΗΣ ΕΝΕΡΓΕΙΑΣ GREEK ATOMIC ENERGY COMMISSION
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skbs

Quality control in mammography

Measurement of several output parameters (K_a ,*U*, *It*, *t*, *HVL*…)

x-ray generator oriented tests:

- Accuracy and repeatability of x-ray tube voltage - ***U***
- Repeatability of exposure time - ***t***
- Radiation output = Entrance dose – Accuracy , Repeatability and Linearity (dependence of It [mAs]), air kerma (rate) - K_a
- First half-value layer of the primary beam - ***HVL***

Image Quality oriented tests:

- Automatic Exposure Control (***AEC***) test – determination of output parameters by using PMMA-based phantom
- Mean glandular dose (***MGD***) – for the AEC output parameters for 45 mm PMMA

Quality control dosimeters

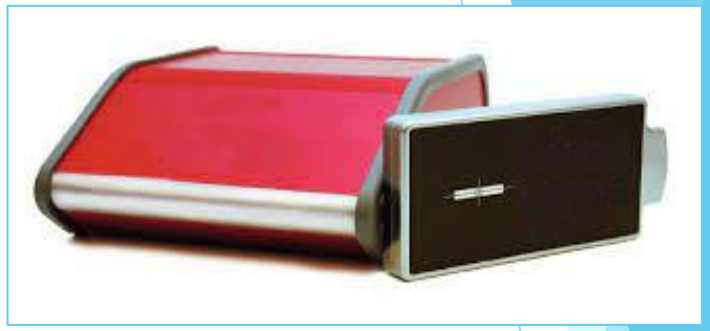
- Ionization chambers - ICs
- Spherical or plane-parallel geometry with entrance window
- Used with associated electrometer
- Requires correction for air density
- Relatively constant energy response

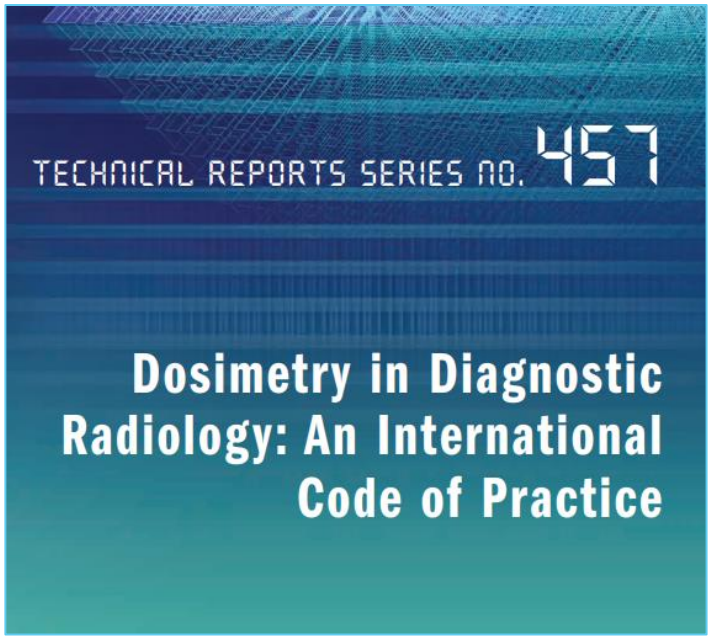
Quality control dosimeters

- Solid-state detectors (SSDs) –

Si-based semiconductor detectors

- Based on single-element or multi-element detectors
- Incorporated inherent detector filtration for energy compensation and/or with software corrections
- Able to measure multiple quantities and pseudoquantities
- X-ray multimeters (XMMs)





Calibration & traceability

- IEC 61267 defines radiation qualities – reference fields of known spectra covering different DR modalities
- Standardized RQ series used for calibration of dosimeters and establishing traceability chain in DR
- RQR (40 – 150 kV), RQT (100 – 150 kV), RQC…
- RQR-M (25 – 35 kV)
- Dosimeter calibrations performed in reference fields – IAEA guidelines (TRS 457)

$$N_K = \frac{K_{\mathrm{a,ref}}}{M} = \frac{Q N_{\mathrm{K,ref}} k_i}{M}$$

XMM performance

- Air kerma measurements with XMMs can differ due to changes in A/F setup in the same HV range
- Requirements defined in IEC 61674
- Absolute response and relative response

$$R(U, HVL) = \frac{M}{K_a}$$

$$r(U, HVL)_{A/F} = \frac{R(U, HVL)}{R_0\ (28, HVL_{28})}$$

- Criterion: ±5 % deviation for the radiation quality series – from the reference HV of 28 kV

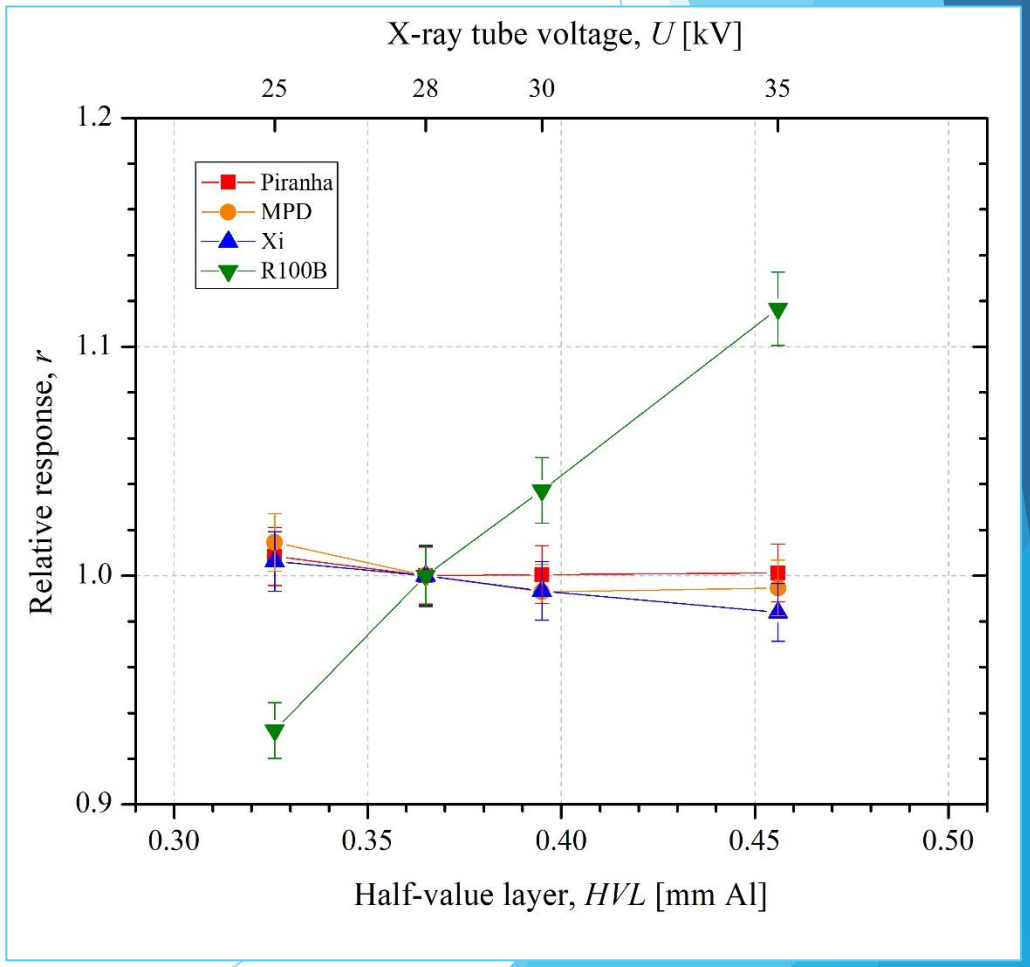
SSDL measurements

W/Al response

- Reference SDD = 100 cm: minimization of scattered radiation with sufficient signal level
- W/Al non-standard radiation qualities for the 25, 28, 30 & 35 kV HV values
- MPD, Piranha, Xi: -1.6% - +1.5%
- R100B: -6.8% - +11.7%
- R @ 28 kV – R100B ≫ Xi > (MPD,Piranha)

Radiation quality	1st HVL
W/Al 25	0.326
W/Al 28	0.365
W/Al 30	0.395
W/Al 35	0.456

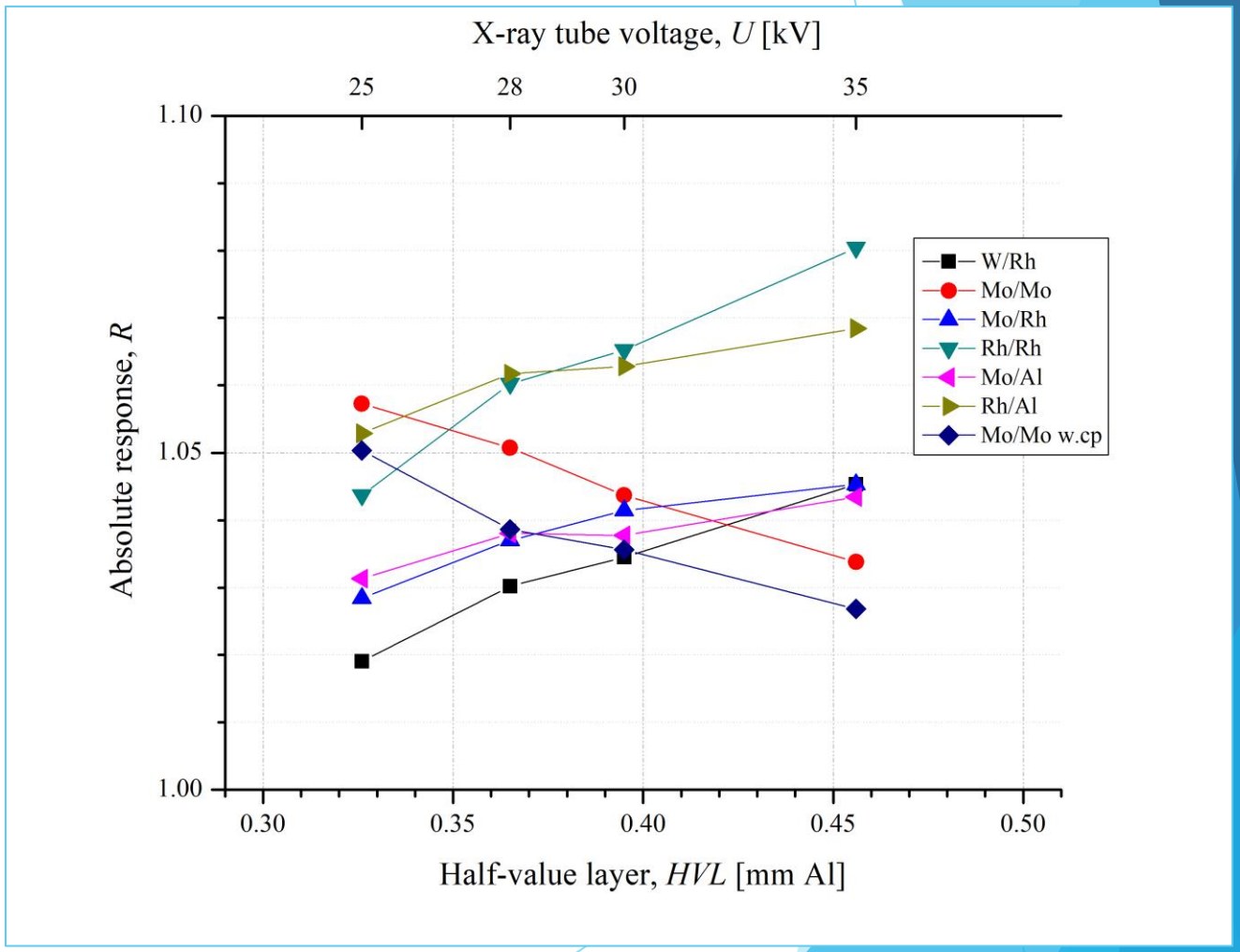
XMM	A/F (s)
MPD	W/Al
Piranha	W/Al
Xi	Mo/Mo
R100B	Mo/Mo



SSDL measurements

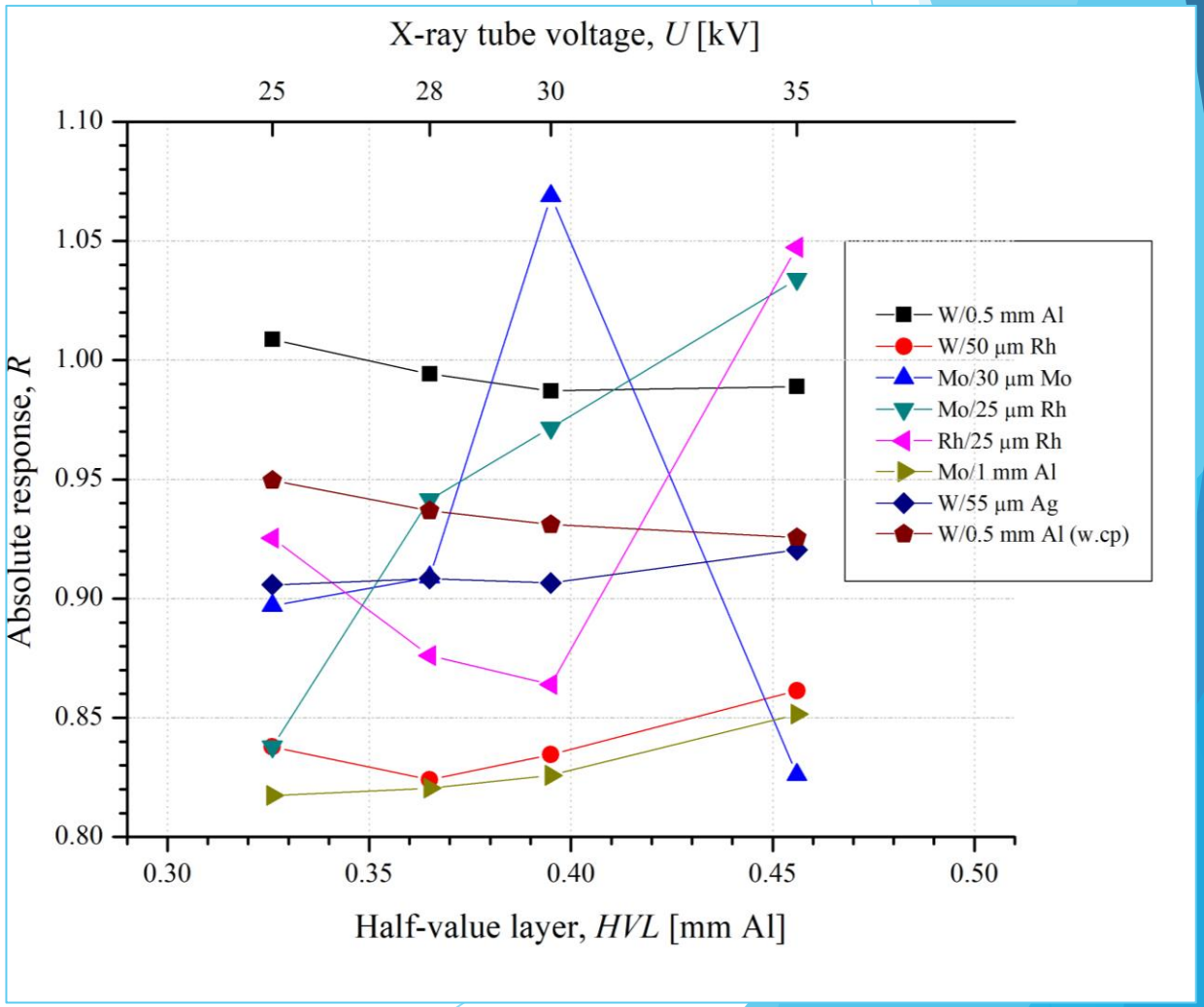
XMM A/F setting effect

- Response of XMMs with variation of A/F setting in W/Al laboratory radiation field was checked
- Deviations up to 15 - 20 % for all XMMs
- Variation in energy compensation of multi-element detectors



SSDL measurements

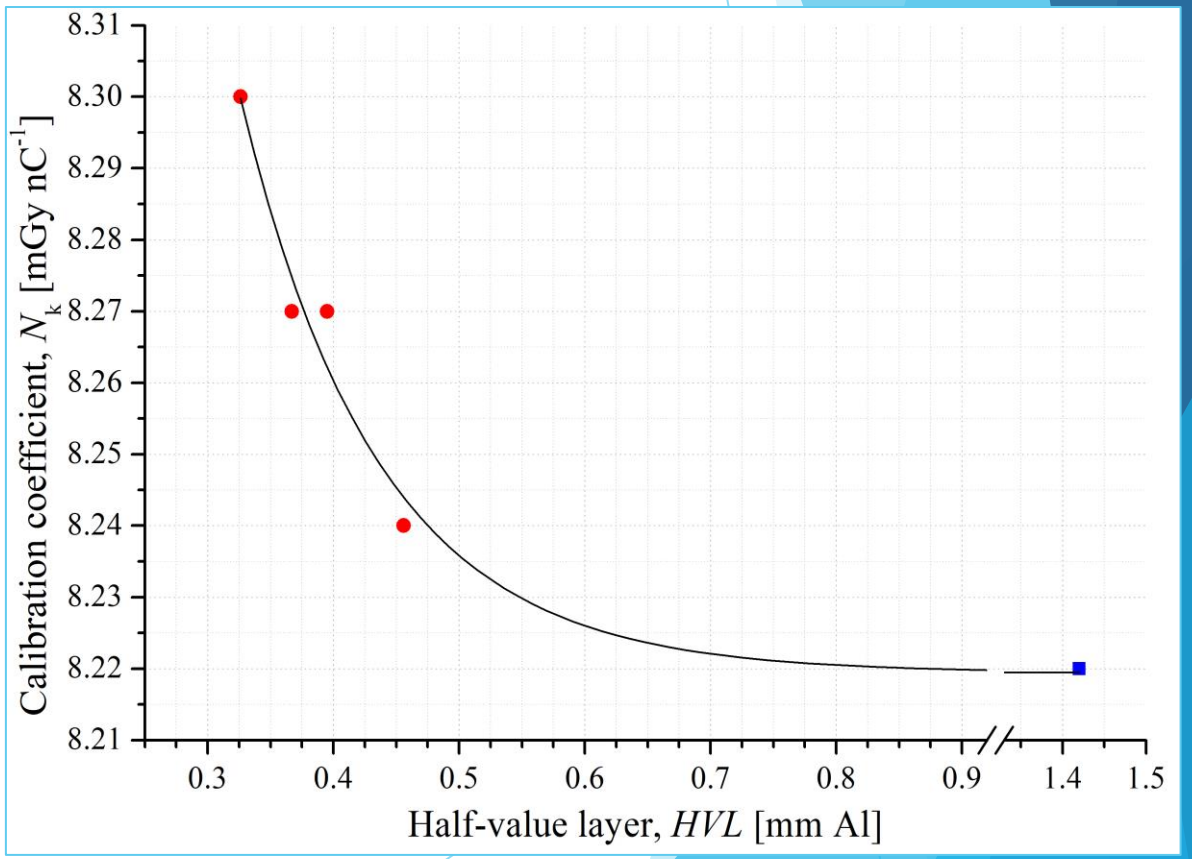
XMM A/F setting effect



Clinical measurements - HVL

- Prior activity – HVL in clinical conditions – influence of c.p.

Mammography unit	Unit type	A/F	c.pFD [cm]	U [kV]	HVL [mm Al]	Nk [mGy/nC]
Fujifilm Amulet Innovality	Digital	W/ 50 µm Rh	13.9	25	0.527	8.232
				28	0.553	8.230
				30	0.564	8.229
				35	0.589	8.227
Hologic Selenia Dimensions	Digital	W/ 55 µm Ag	20.0	25	0.526	8.232
				28	0.560	8.229
				30	0.573	8.228
				35	0.596	8.226
Hologic Lorad M-IV	CR	Mo/ 30 µm Mo	25.7	25	0.332	8.295
				28	0.367	8.275
				30	0.385	8.266
				35	0.415	8.255
		Mo/ 25 µm Rh	25.7	28	0.470	8.241
				30	0.481	8.239
				35	0.500	8.236

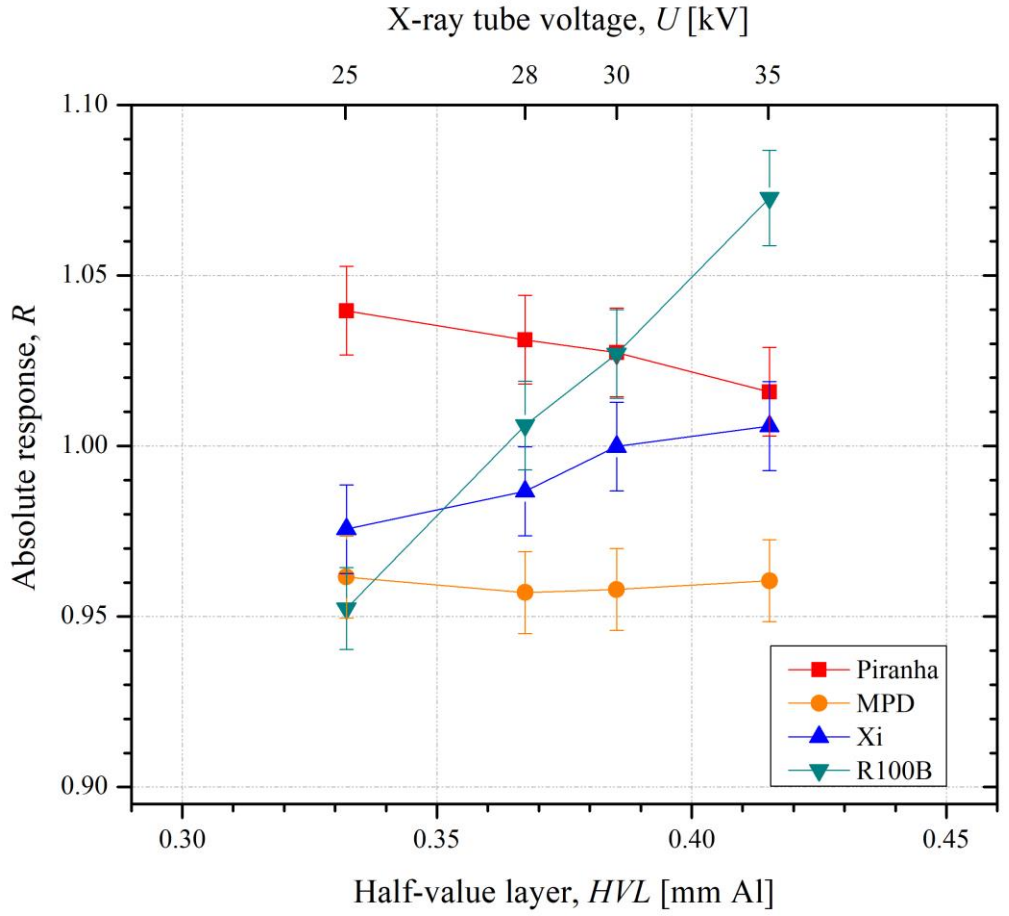


- Estimation of reference K_a
- Interpolation of N_K as a $f(HVL)$
- W/Al series and RQR2 points

Clinical measurements

Mo/Mo response

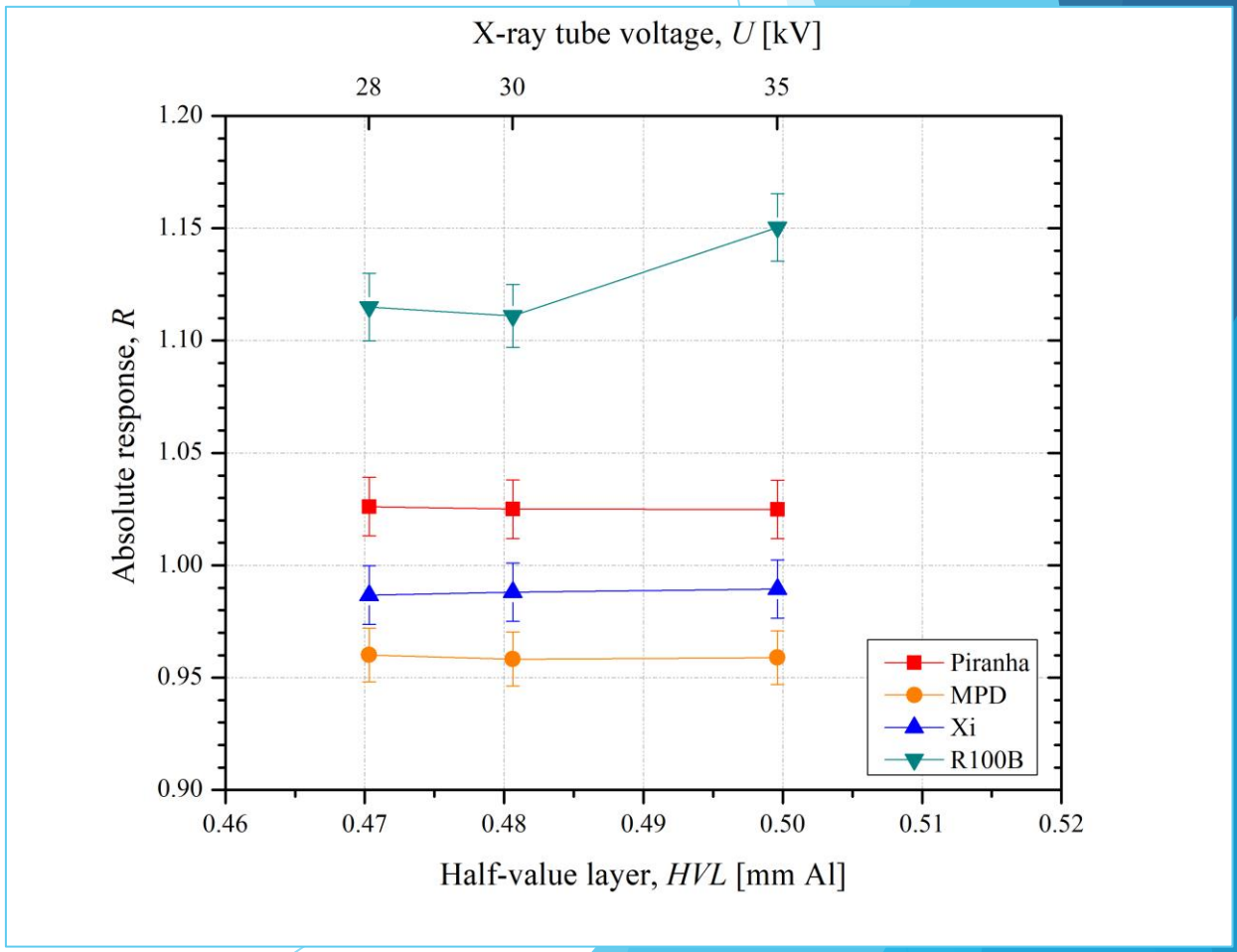
- All XMMs had matching software setting (Mo/Mo) selected
- MPD: stable constant underesponse
- Piranha: decreasing overresponse
- Xi: increasing response – lowest deviation from unity
- R100B: pronounced energy dependence
- c.p. in the field; non-ideal laboratory test conditions



Clinical measurements

Mo/Rh response

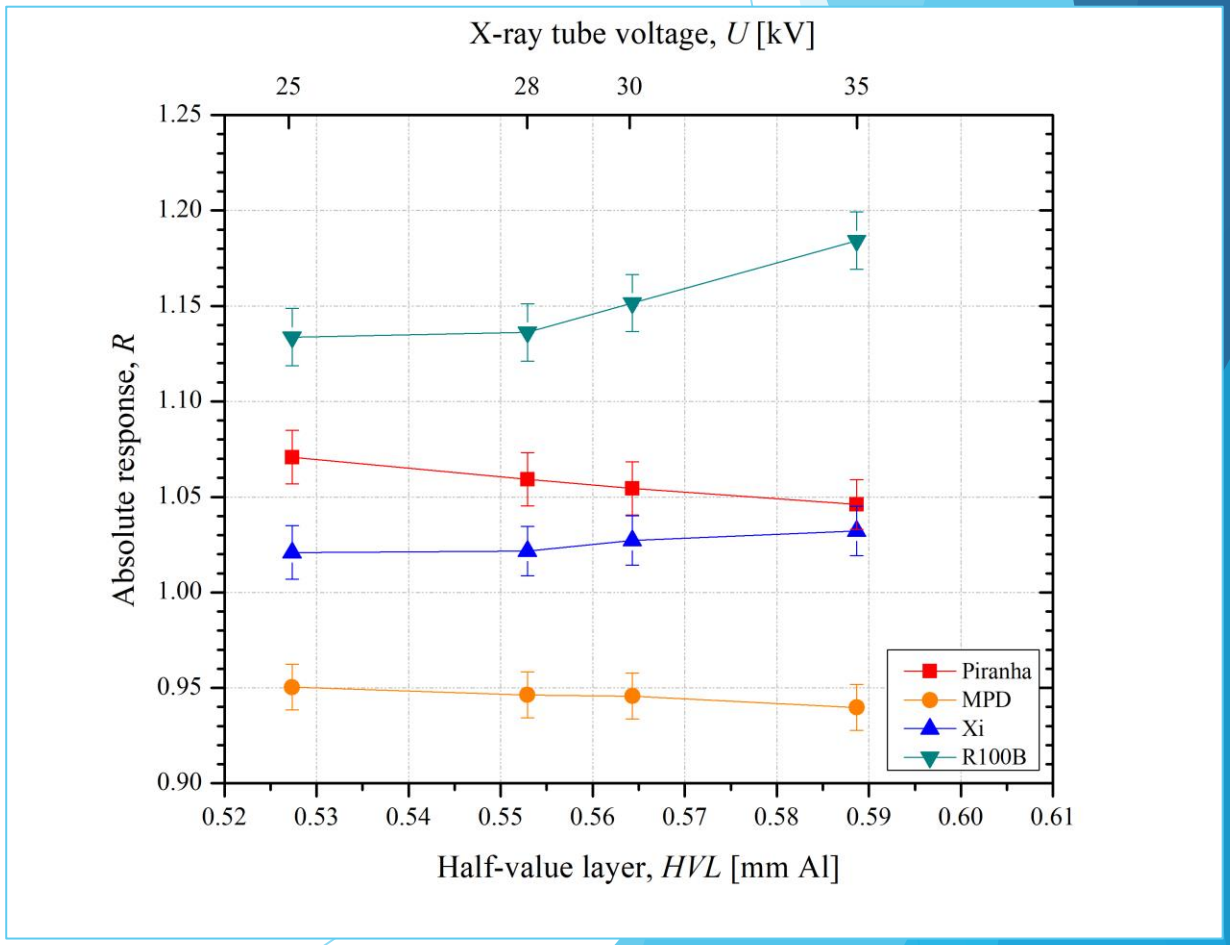
- Voltages below 27 kV for this mammography unit unavailable
- 3 XMMs had appropriate setting chosen
- MPD, Piranha, Xi: flat energy response
- R100B: dependence on HVL due to single software option



Clinical measurements

W/Rh response

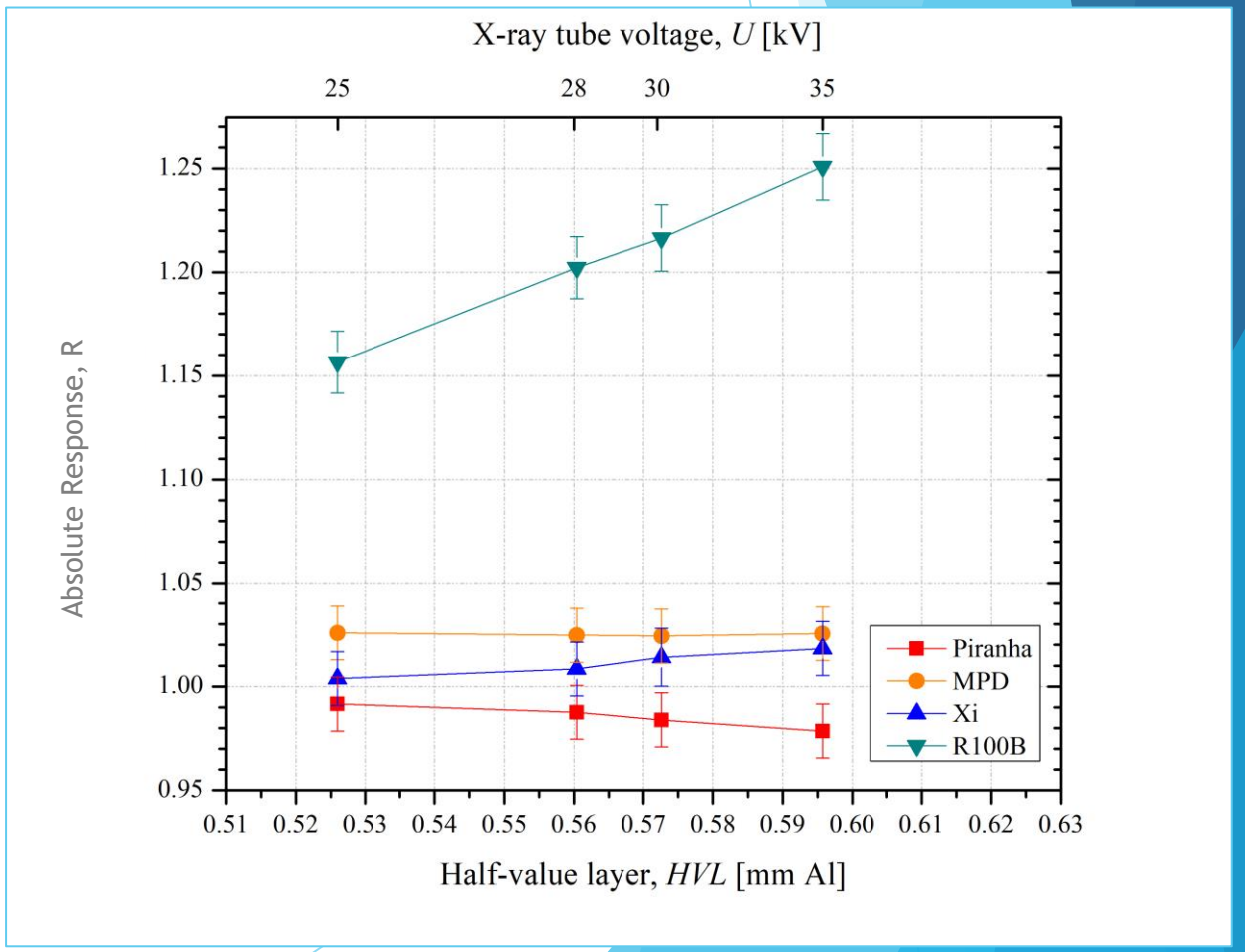
- 3 XMMs had appropriate setting chosen
- More pronounced changes in trend compared to Mo/Rh



Clinical measurements

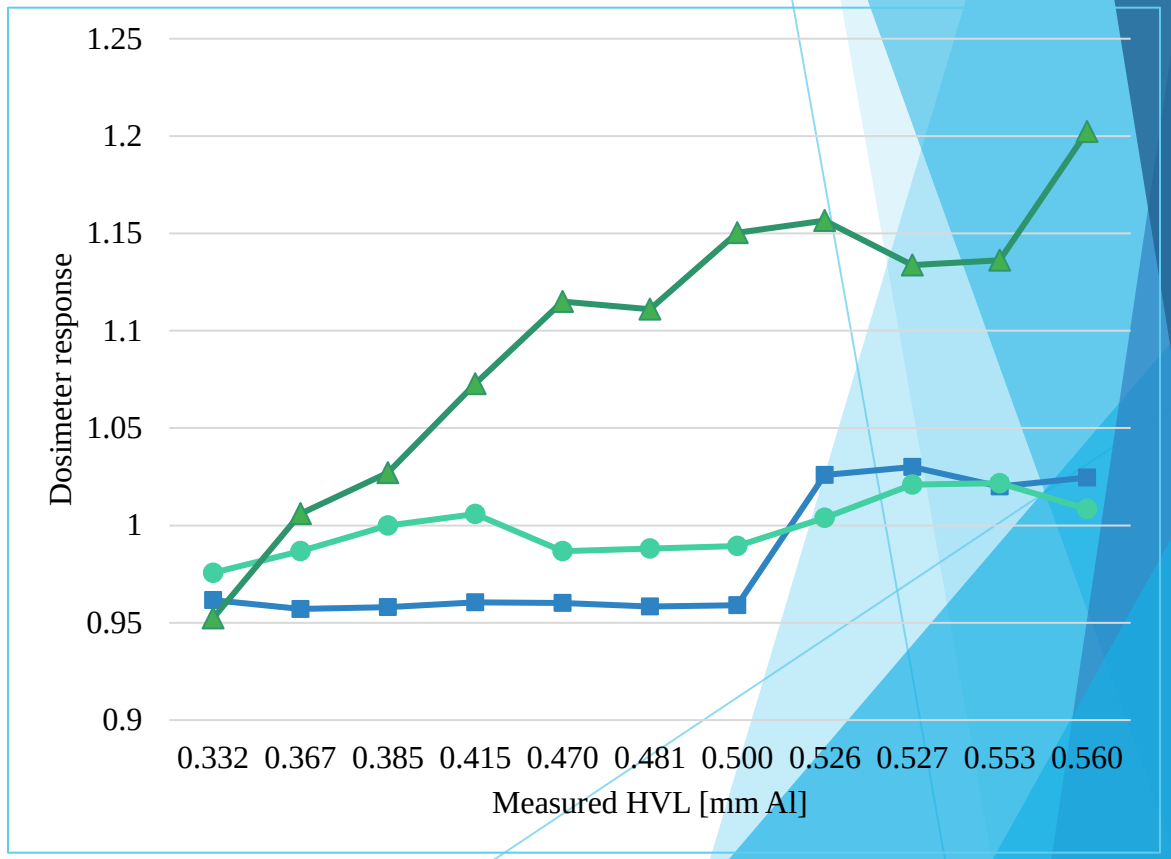
W/Ag response

- 2 XMMs had W/Ag option available
- Xi: W/Rh was selected with respect to the same anode material
- Xi response values similar to XMMs with appropriate A/F setup



Response function

- Response function for three detectors
- Single-element detector has only one software setting
- Correction factor curve for the detector response function based on HVL



Influence of anode/filtration setup on X-ray multimeter energy response in mammography applications

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Conclusions

- Mo/Mo A/F setup often not available in SSDLs – inability to establish reference RQR-M series
- Development of traceability for available W/Al setup (calibrations in e.g., RP and DR)
- Discrepancy in SSDL conditions and A/F setups in clinical mammography units
- Variation in XMM response up to +20 % due to software induced changes
- Derivation of response curves for HVL dependence of response
- Future revision of relevant standard documents
- IEC 61267, IEC 61764, IAEA TRS 457

Thank you for your attention!

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