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X-ray Spectra and Beam Qualities

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And its Clinical Implementation
11 - 15 May 2009; Miramare, Trieste, Italy

X ray spectra and beam qualities

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Establishing radiation qualities

- General importance of X ray spectra in diagnostic radiology
- Standard radiation qualities RQR
- Standard radiation qualities RQA and RQT
- Standard mammography radiation qualities RQR-M, RQA-M and others

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General beam qualities

- The X ray beam quality or spectral composition has effects on
  - Patient entrance dosimetry
  - Image contrast
  - Dosimetry instrumentation response
  - Calculation of dosimetric parameters

- The X ray beam quality or spectral can be determined by
  - Computer simulation
  - Spectral measurement
  - Beam quality measurement with the 1st & 2nd HVL

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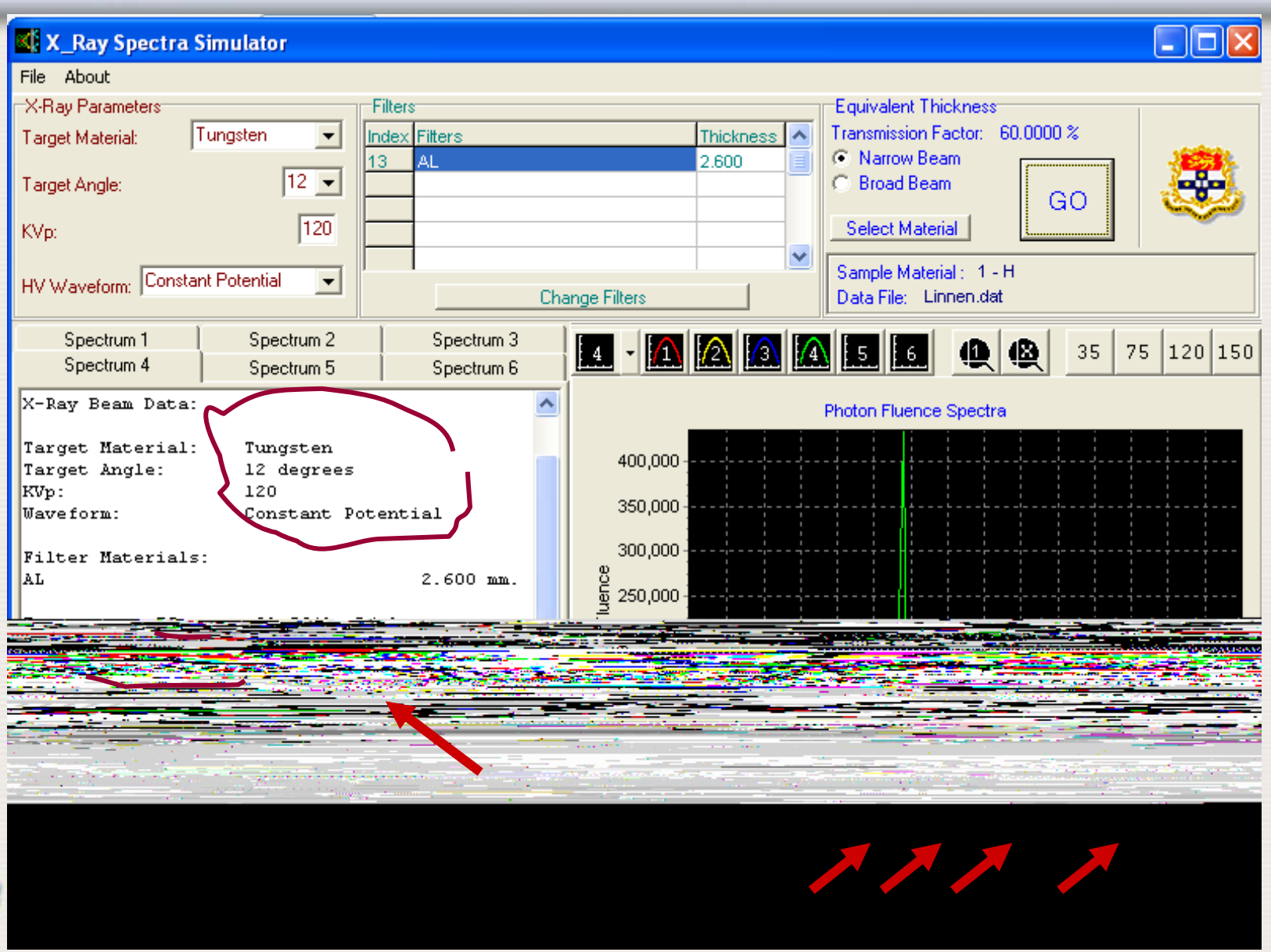
Factors that effect spectral shape: Tube voltage



How many photons are used in radiation medical?

Nuclear medicine photons

- A lung scan used 240 MBq of 99mTc: That is 240,000,000 photons released per second in all directions!
- However at 75 cm the number of this reduces to 34 photons per second per mm^2.

X-ray photons

- A chest X-ray procedure of 110 kVp, 3 mAs produces 15,770,000 photons at 75 cm per mm^2.

How many photons do you produce per day?

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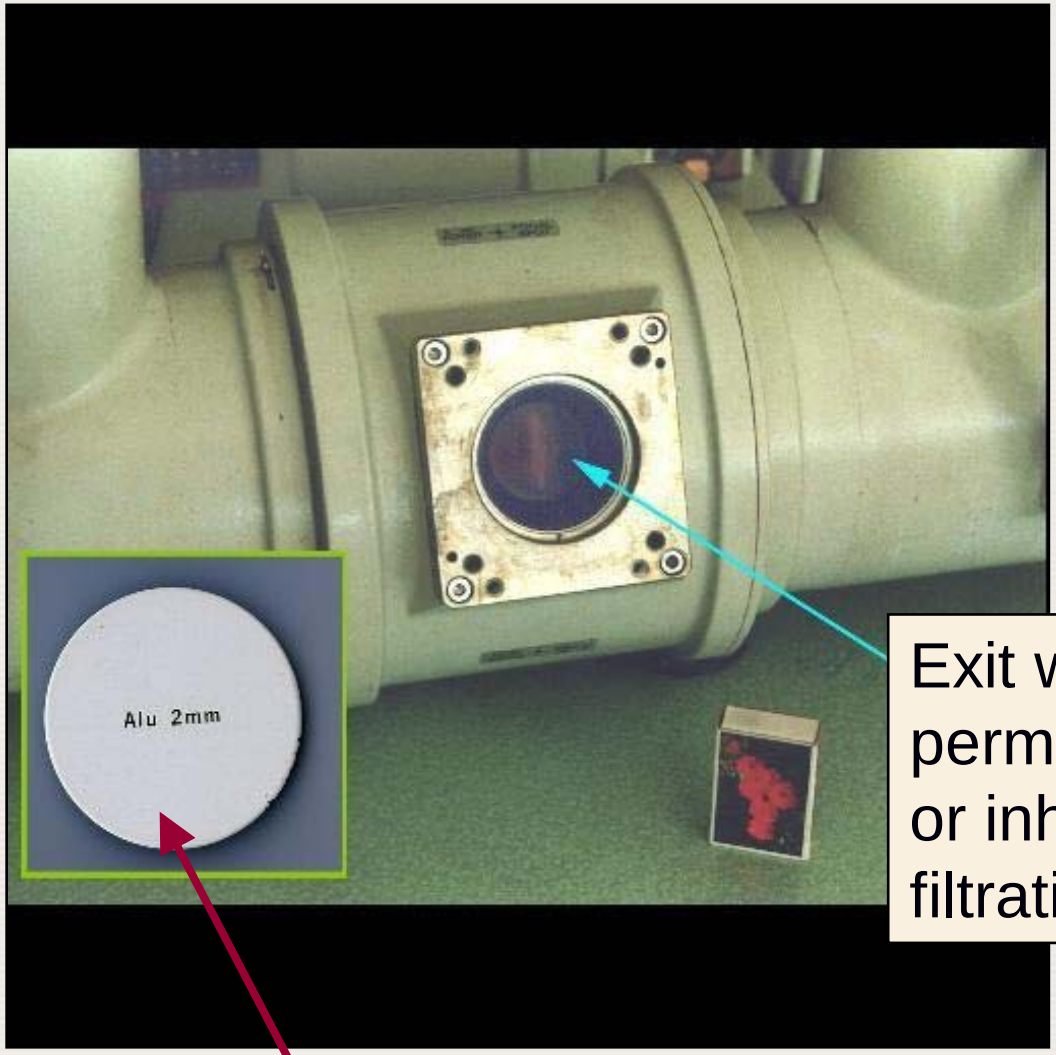
Tube filtration

Total filtration equals the inherent filtration plus the added filtration



Factors that effect spectral shape: Total filtration

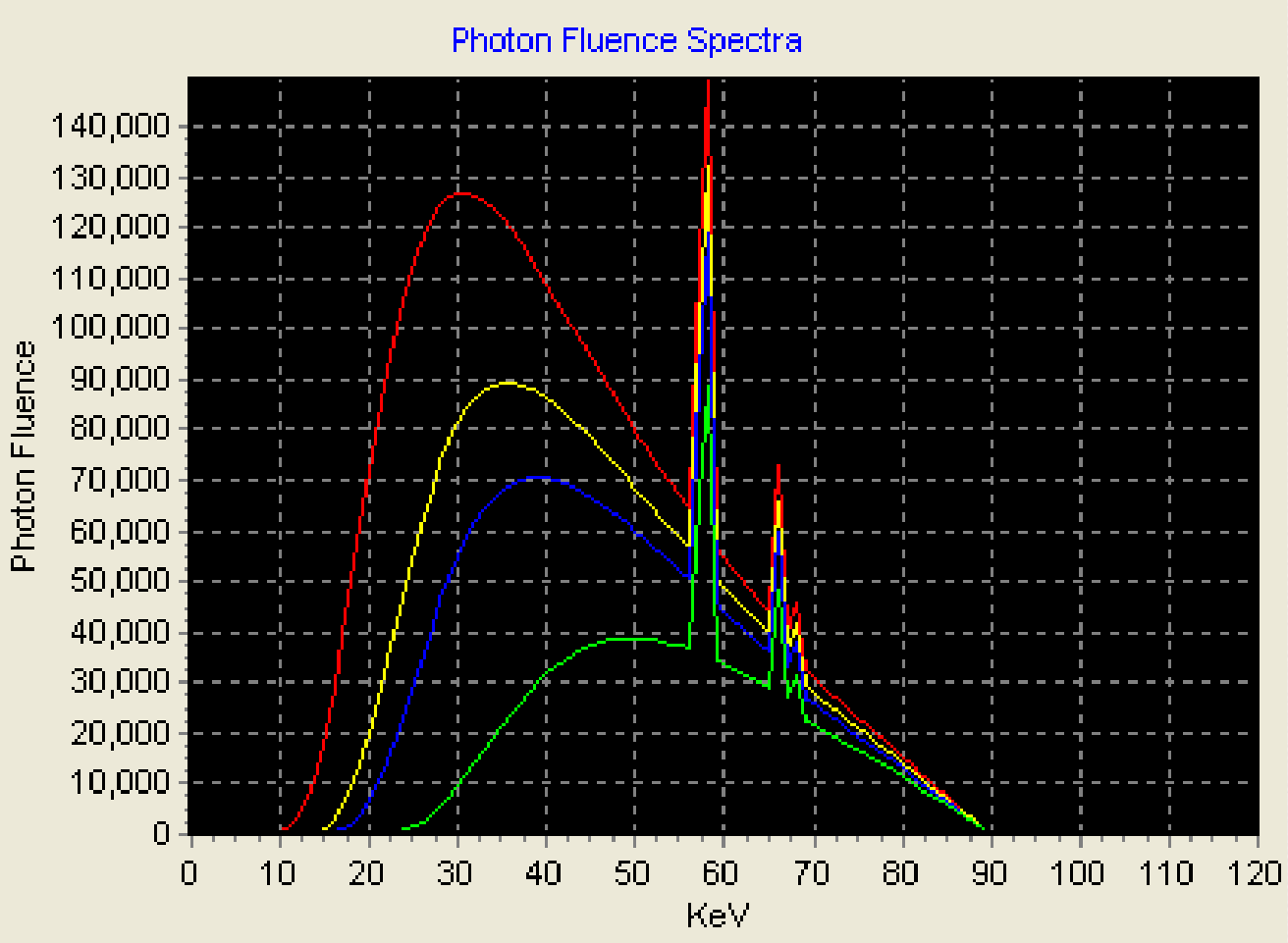
Total filtrations:

1 mm Al

2.6 mm Al

4 mm Al

4 mm Al + 0.2 mm Cu



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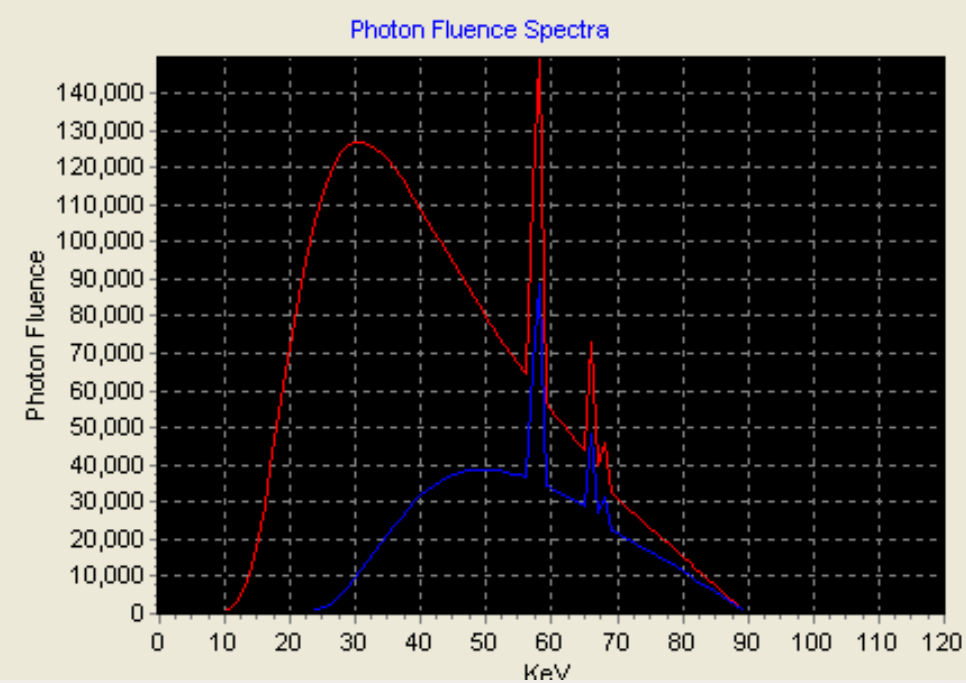
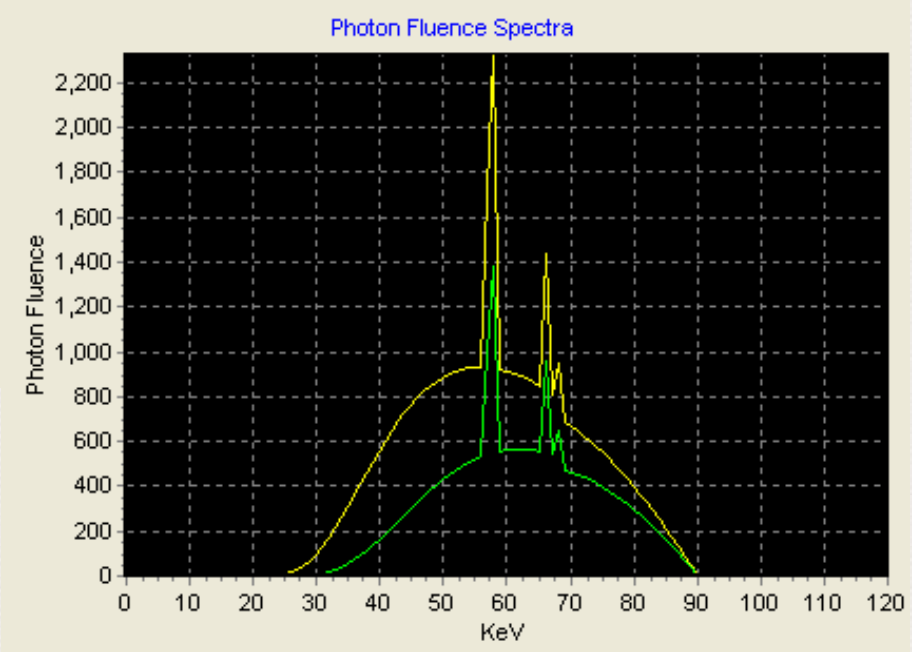
Effect of filtration on patient dose

Entrance Spectrum



Exit Spectrum



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Factors that effect spectral shape: Target angle

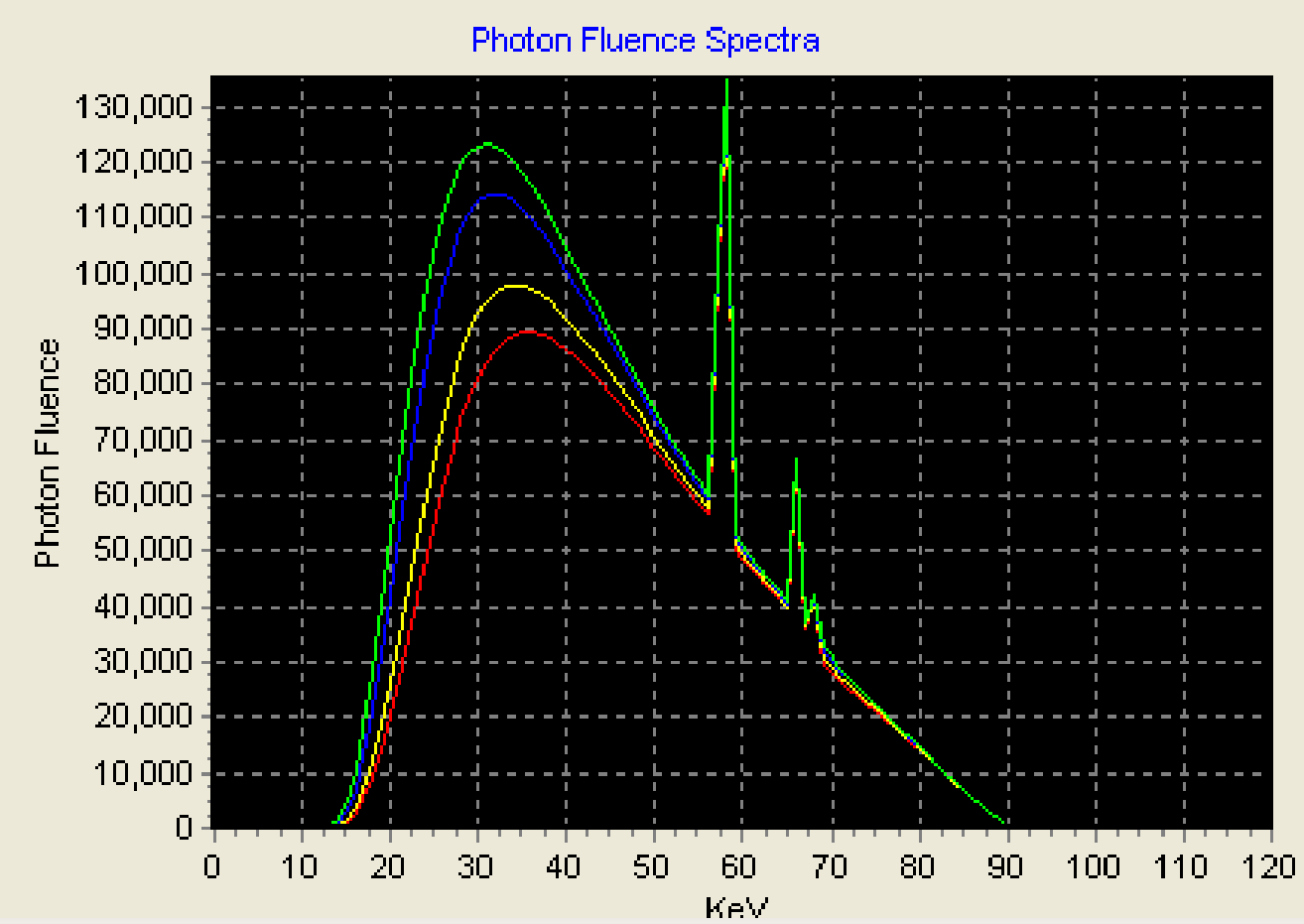
Target angles:

12 degrees

16 degrees

30 degrees

45 degrees



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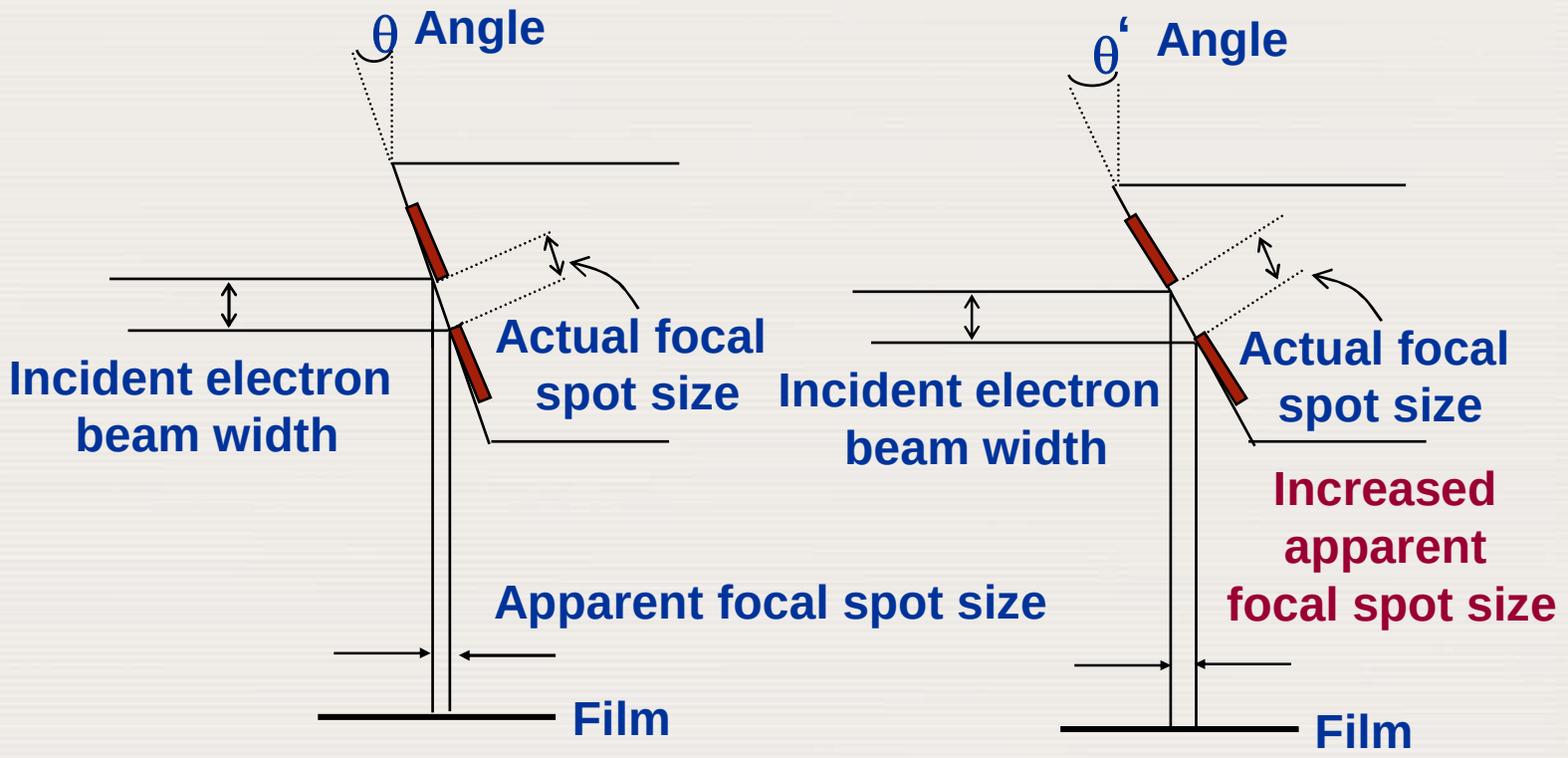
Anode or target angle



Smaller angles give
- Harder beams
- Better resolution or
- Better heat dissipation

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Radiation qualities for calibrations of diagnostic dosimeters

Radiation quality	Radiation origin	Material of an additional filter	Application
RQR	Radiation beam emerging from X ray assembly	no phantom	General radiography, fluoroscopy and dental applications (measurements free in air)
RQA	Radiation beam with an added filter	Aluminium	Measurements behind the patient (on the image intensifier)
RQT	Radiation beam with an added filter	Copper	CT applications (measurements free in air)
RQR-M	Radiation beam emerging from X ray assembly	no phantom	Mammography applications (measurements free in air)
RQA-M	Radiation beam with an added filter	Aluminium	Mammography studies

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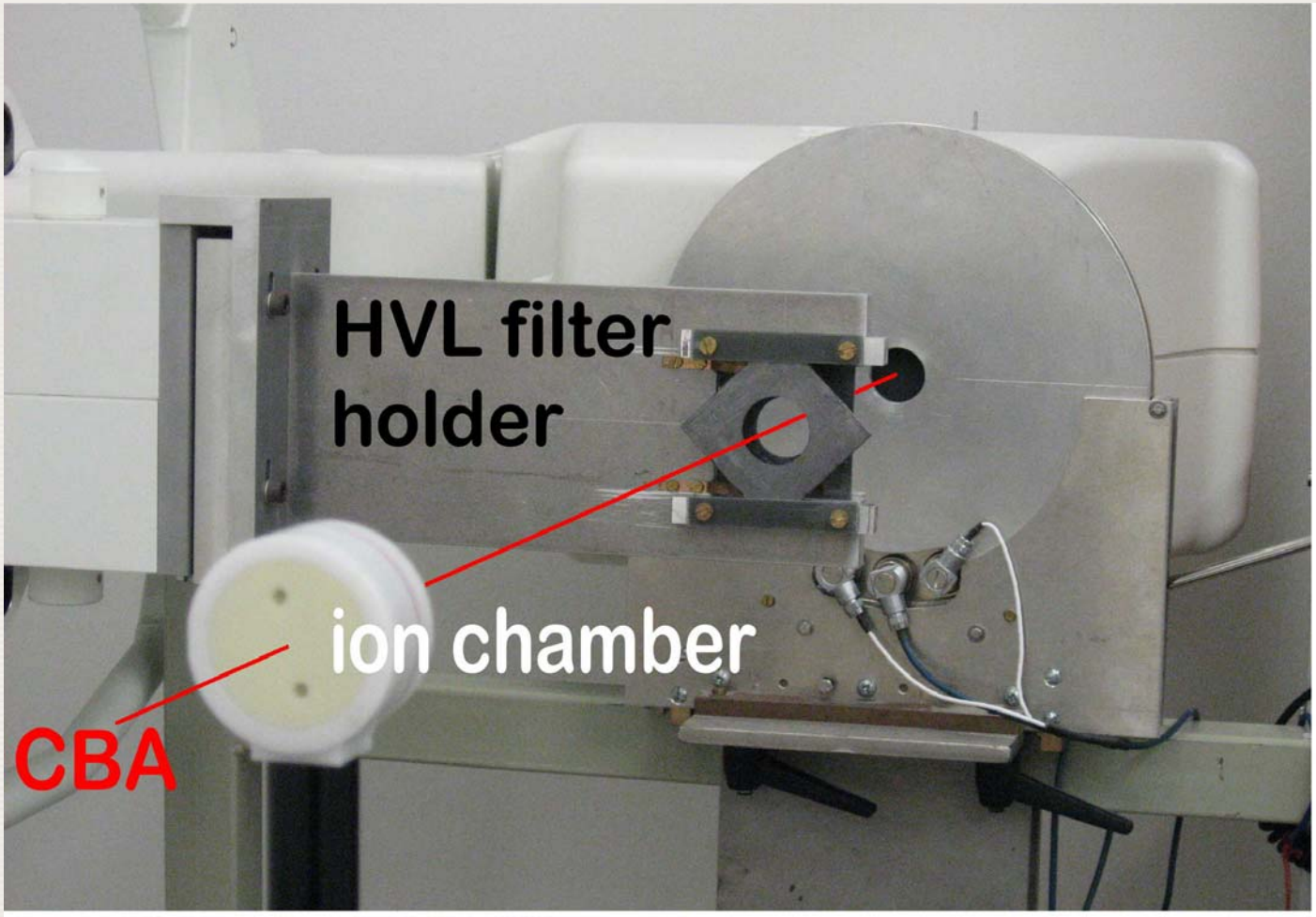
established according to IEC 61267

HVL measurment



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Characterization of radiation quality series RQR

Radiation quality	X ray tube voltage kV	First half-value layer mm Al	Homogeneity coefficient h
RQR 2	40	1.42	0.81
RQR 3	50	1.78	0.76
RQR 4	60	2.19	0.74
RQR 5*	**70**	**2.58**	**0.71**
RQR 6	80	3.01	0.69
RQR 7	90	3.48	0.68
RQR 8	100	3.97	0.68
RQR 9	120	5.00	0.68
RQR 10	150	6.57	0.72

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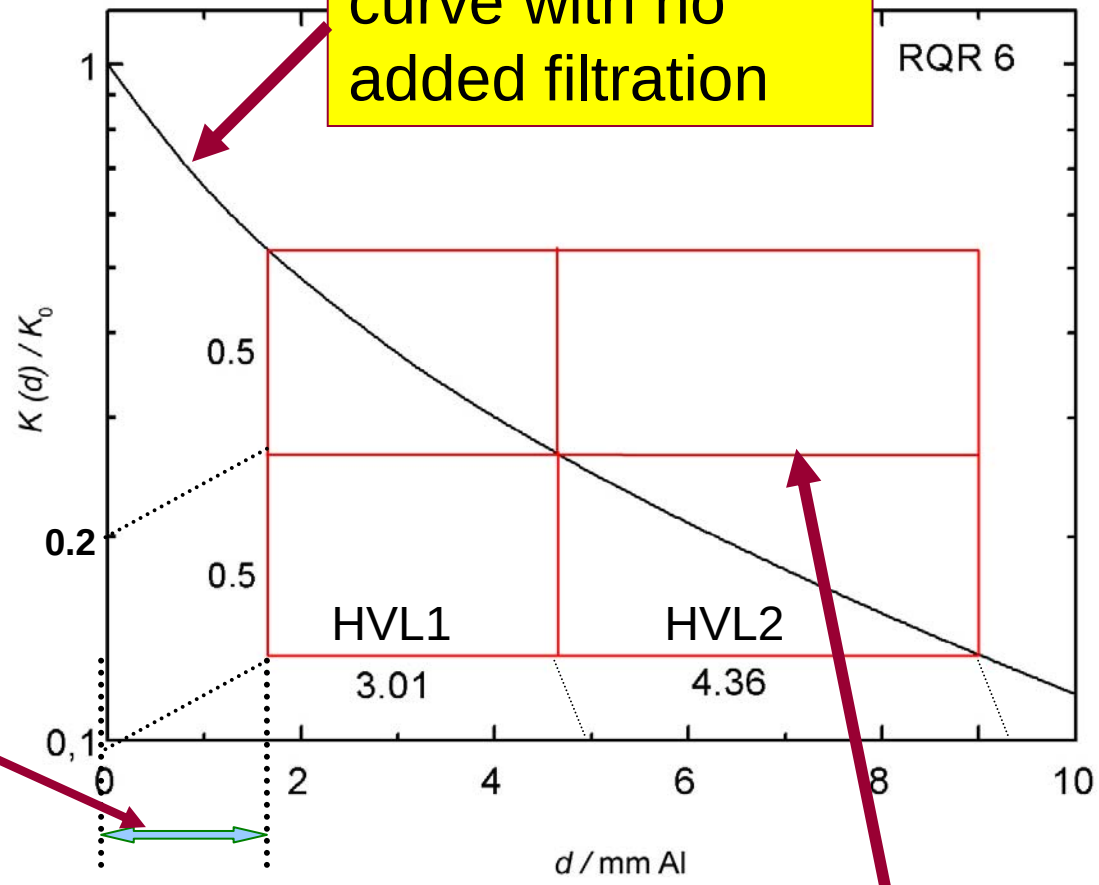
h = HVL1/HVL2: (4.36 = 2nd HVL)

Determining the added filtration needed to establish a beam quality

- Position overlay so that edges are parallel with the curve axis
- Position overlay so that corners and centre are on the attenuation curve.



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Standard radiation qualities RQA and RQT

- RQA series represent simulations of the radiation field behind a patient
- RQT series simulate the unattenuated beam used in CT

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RQT series

Radiation quality	X ray tube voltage kV	Added filtration mm Cu	Nominal first half-value layer mm Al
RQT 8	100	0.2	6.9
RQT 9*	**120**	**0.25**	**8.4**
RQT 10	150	0.3	10.1

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RQA beam

Radiation quality	X ray tube voltage	Added filtration	Nominal first half-value layer
	kV	mm Al	mm Al
RQA 2	40	4	2.2
RQA 3	50	10	3.8
RQA 4	60	16	5.4
RQA 5*	**70**	**21**	**6.8**
RQA 6	80	26	8.2
RQA 7	90	30	9.2
RQA 8	100	34	10.1
RQA 9	120	40	11.6
RQA 10	150	45	13.3

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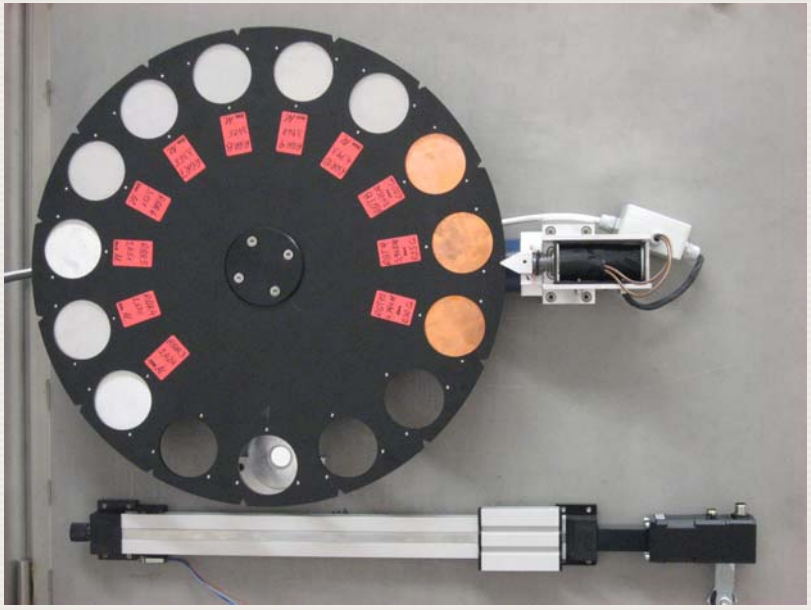
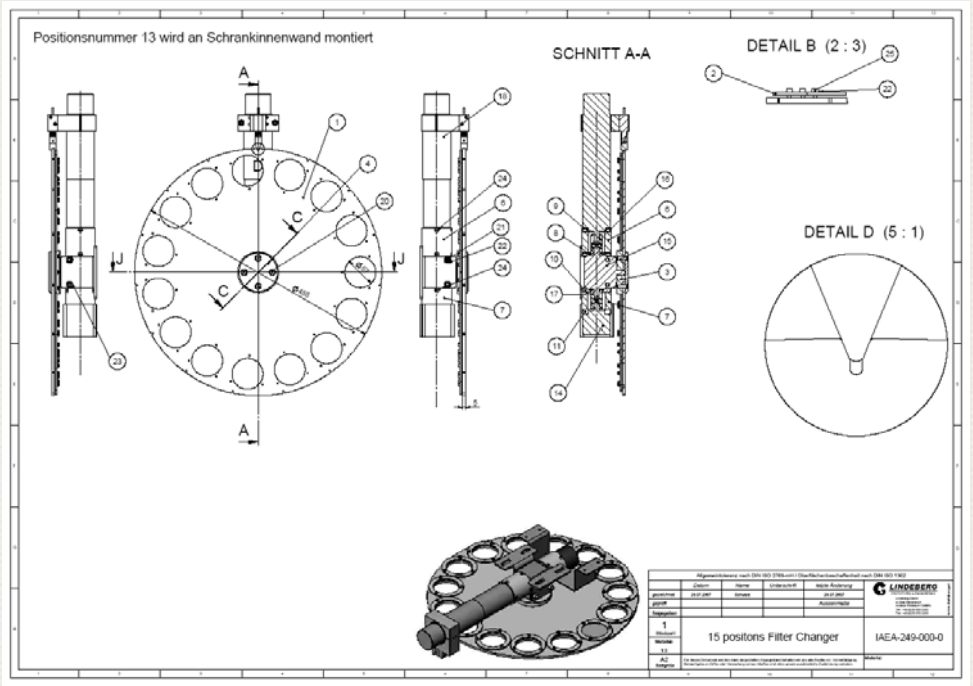
Remote controlled Filter Wheel

Filter wheel with 15 positions, loaded with auxiliary filters for RQR- (identical to RQA-) and RQT-beam qualities





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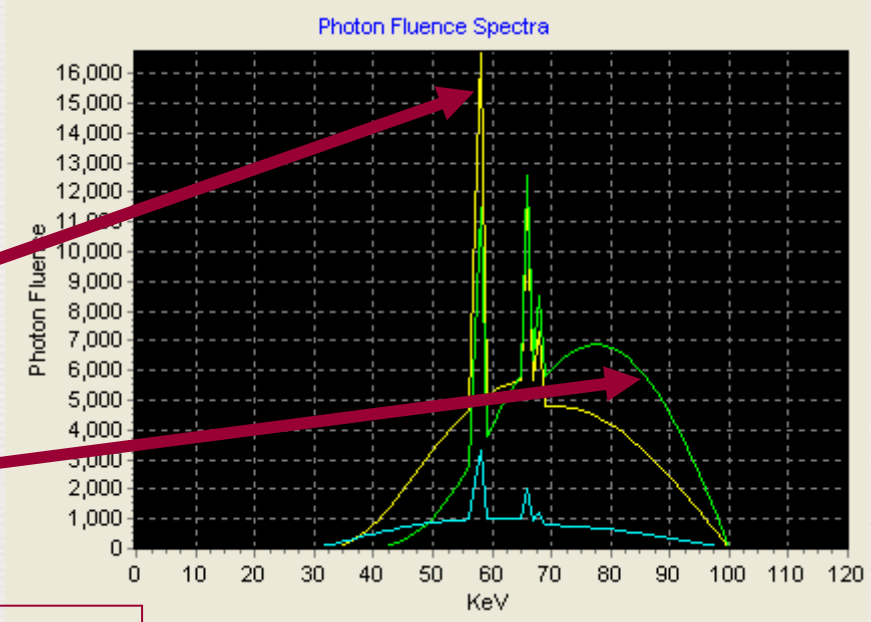
RQC – ‘engineer’ spectra*

Beam quality	HVL mm Al	Relative intensity
RQA3	3.76	53.7
exit with 20 cm water	4.18	1.0
RQC3	4.44	24.4

Beam quality	HVL mm Al	Relative intensity
RQA5	6.74	10.7
exit with 20 cm water	6.17	1.0
RQC5	8.44	3.5

Beam quality	HVL mm Al	Relative intensity
RQA8	10.07	4.8
exit with 20 cm water	8.66	1.0
RQC8	11.54	5.1



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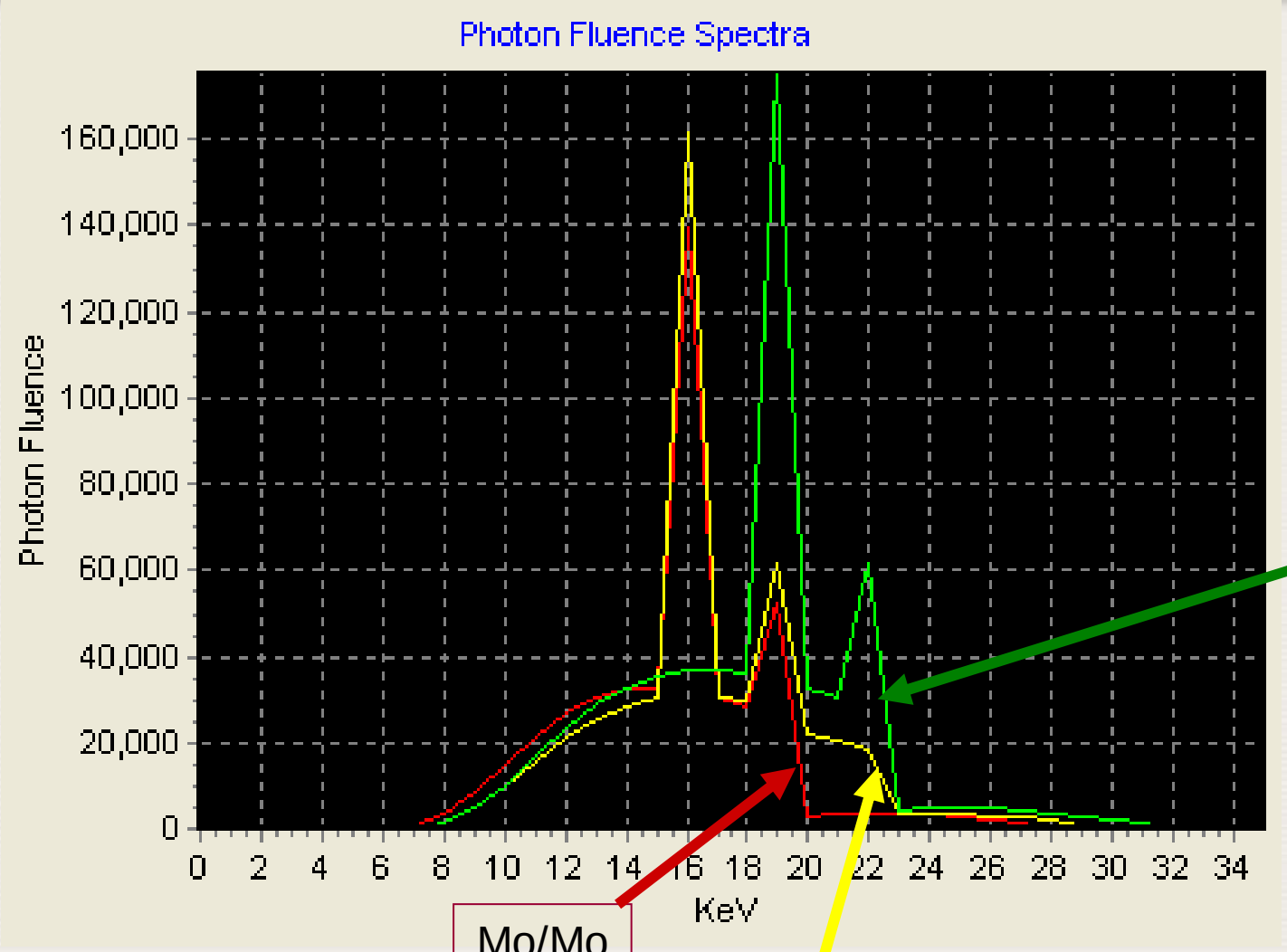
*** Not used in TRS 457**

Standard radiation qualities RQR-M and RQA-M

- The most commonly mammography was achieved using Mo targets and Mo filters
- However significant numbers of units use Rh targets and filters
- More recently with the advent of digital mammography the tube voltage used has increased and new target and filter materials are now used

Mammography spectra



Radiation qualities for calibrations of diagnostic dosimeters

Radiation quality	Radiation origin	Additional filter	Application
RQR-M Mo target	**Radiation beam emerging from x-ray assembly**	**no phantom**	**Mammography applications (measurements free in air)**
RQA-M Mo target	**Radiation beam with an added filter**	**Aluminium**	**Mammography studies**

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RQR-M and RQA-M series

Radiation quality	X ray tube voltage	Nominal 1st HVL
Mo target		
	kV	mm Al
RQR-M 1	25	0.28
RQR-M 2*	**28**	**0.31**
RQR-M 3	30	0.33
RQR-M 4	35	0.36

Radiation quality	X ray tube voltage	Added filtration	Nominal 1st HVL
Mo target	kV	mm Al	mm Al
RQA-M 1	25	2	0.56
RQA-M 2	28	2	0.60
RQA-M 3	30	2	0.62
RQA-M 4	35	2	0.68

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Standard radiation qualities RQR-M and RQA-M

- The most commonly mammography used Mo targets and Mo filters (Mo/Mo)
- However significant numbers of units use Mo/Rh & Rh/Rh
- More recently with the advent of digital mammography the tube voltage has increased and new target and filter materials are used e.g. W/Ag & W/Al
- PTB now provides a full range calibrations up to 50 kV

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Thank you for your attention

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Standard radiation qualities RQR

- IEC standards have been established to standardise the calibration of diagnostic detectors.
- Establishing the exact beam conditions is important for dosimetry laboratories involved in calibration
- RQR qualities simulate most entrance beams used in diagnostic radiology

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