Calibration of kerma-area product meters with a patient dose calibrator

IDOS

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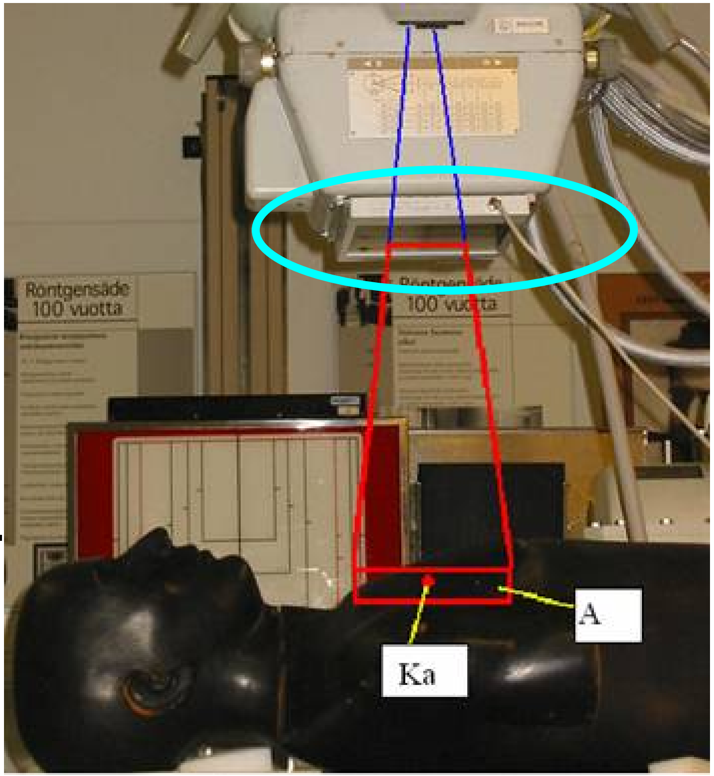
Patient exposure in x-ray imaging:
How big uncertainty you would tolerate?

- 100%
- 50%
- 25%
- 15%
- 10%
- 7%
- 5%

(95%, k=2)

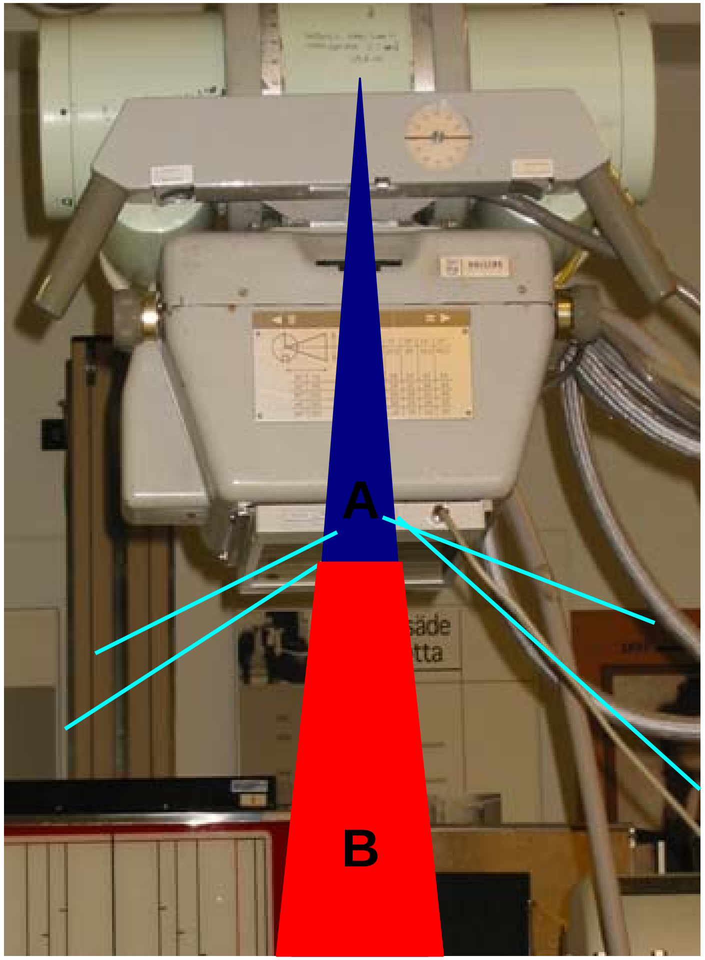
Kerma-area product, *KAP*, P_{KA}

- *KAP* quantity is used in x-ray imaging to **monitor patient exposure**.
- *KAP* is generally measured with a transparent ionization chamber.
- KAP meters measure the surface integral of air kerma limited by the area of the ionization chamber (Gy·m²).
- *KAP* is almost independent of measuring distance.
- *KAP* ≈ $K_a * A$ is an approximation.



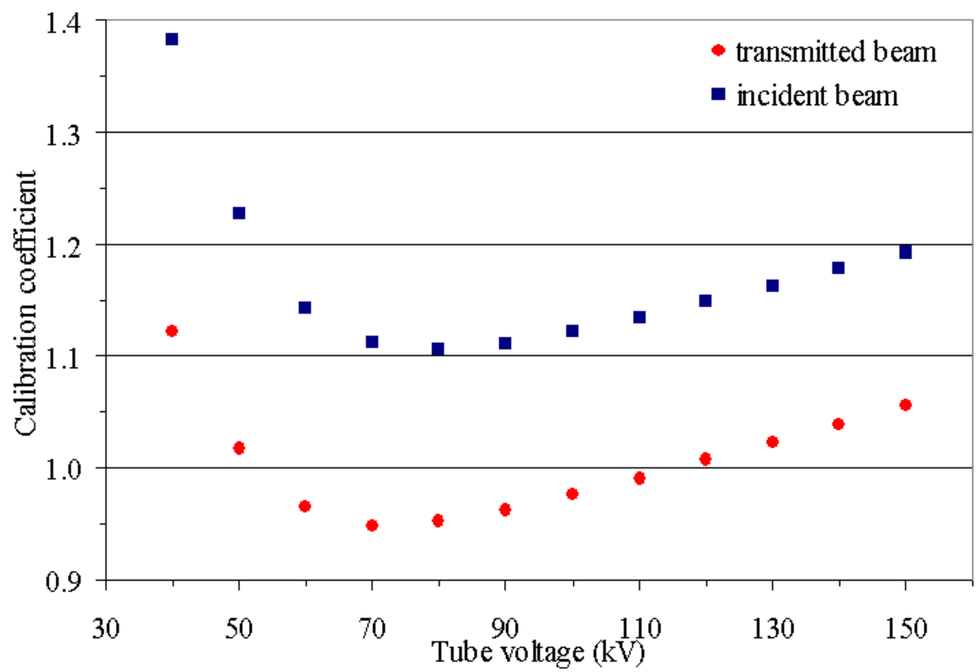
$$KAP = \iint_{\infty} K_{air} \cdot dx \cdot dy$$

Calibration of a KAP meter



Malusek et al. Phys. Med. Biol. 2007.

- Field KAP meter should measure the radiation incident to patient.
- KAP meter should be calibrated using the same X-ray equipment and beam geometry as in actual measurements.

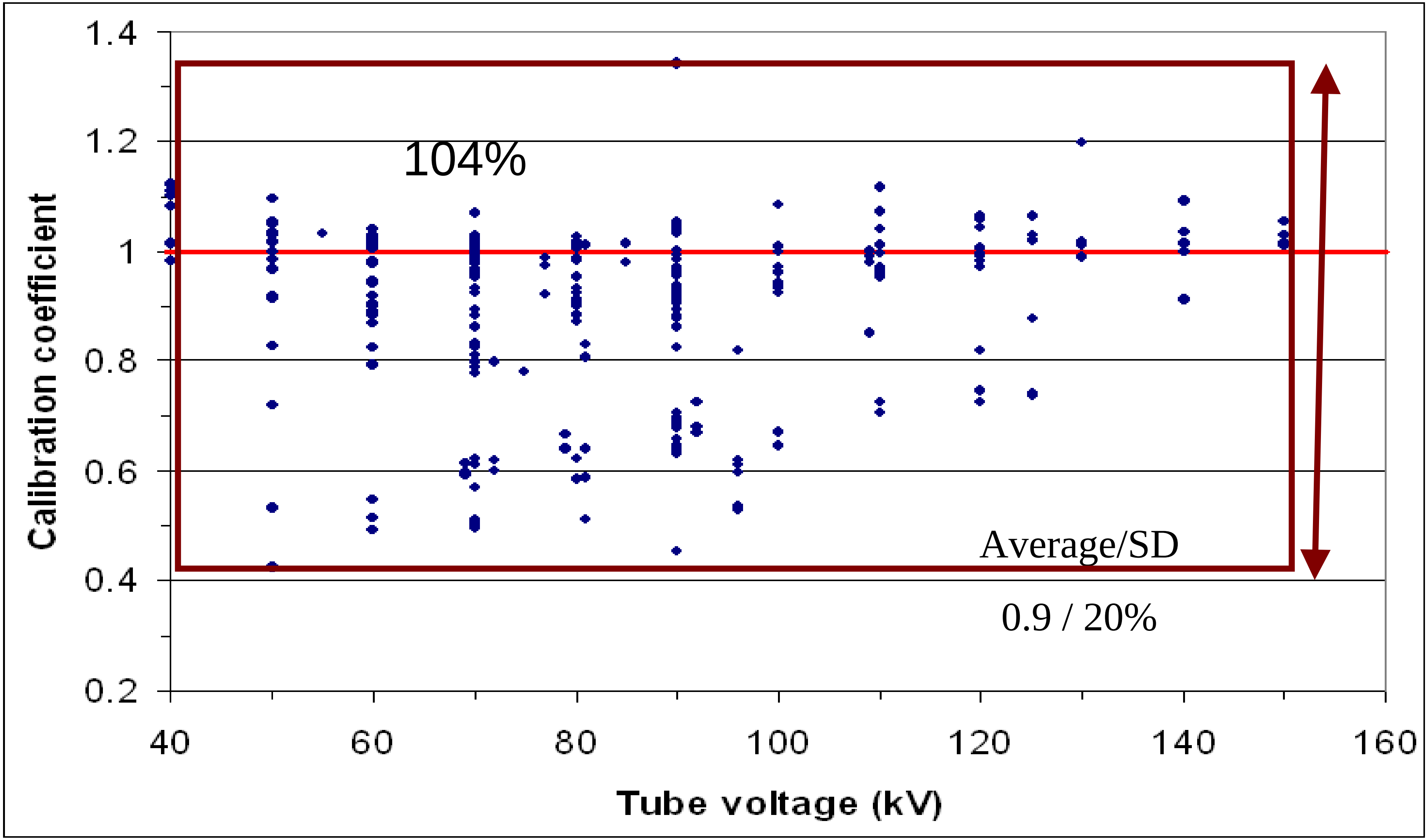


Motivation for the calibration

- To get **comparable** and **reliable** results, the calibration should be **traceable** to international measuring system.
- Typically meters are **adjusted** by using **one radiation quality** (spectra) and **geometry**.
- Internationally an uncertainty of **< 7 %** is pursued in exposure measurements[*,1,2]
- The aim of this study was to investigate whether **better accuracy** can be achieved by **improving the calibration procedures** for KAP meters.

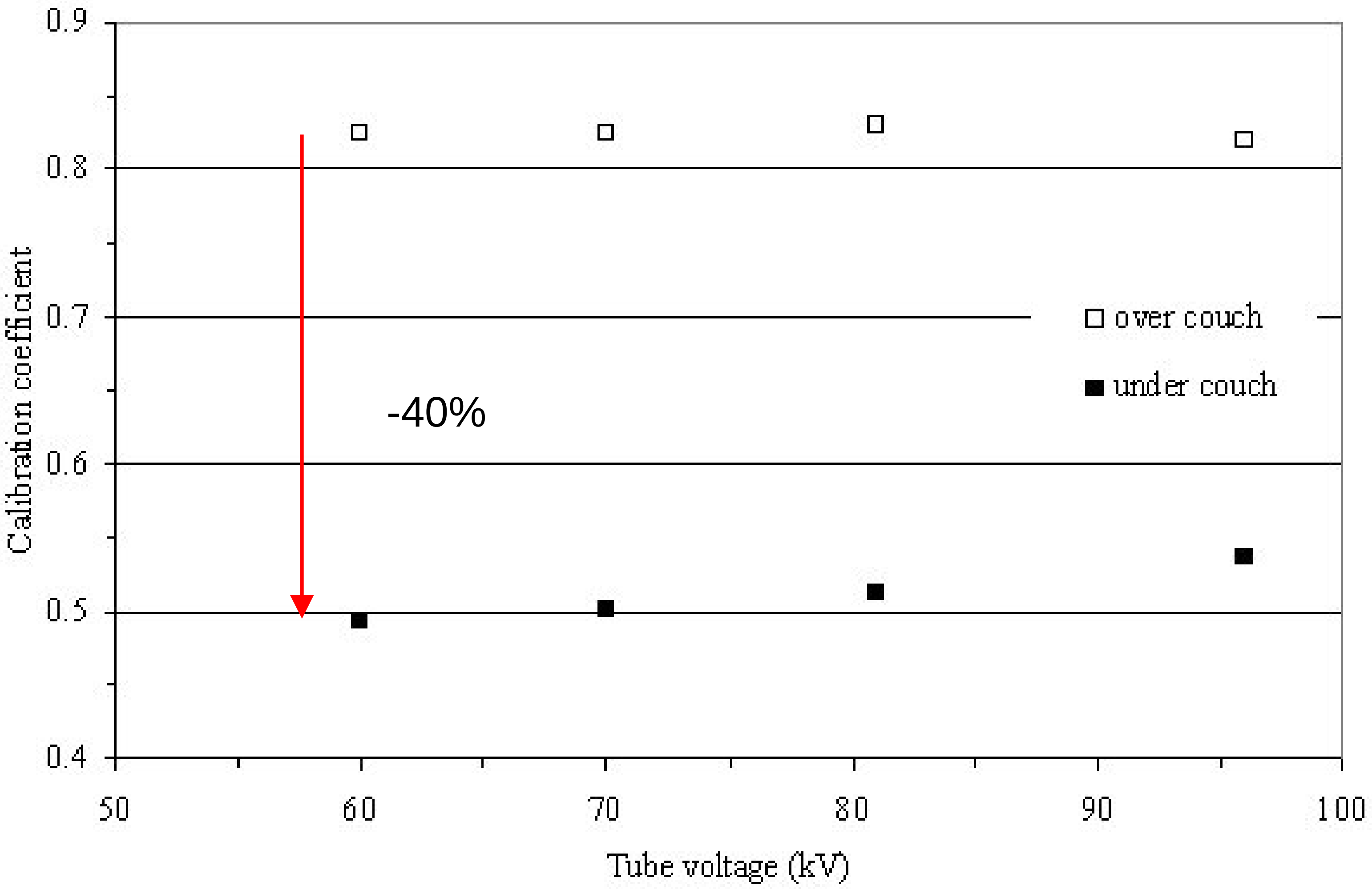
[*] (95%, k=2)1,2
[1] ICRU Report 74, (2005).
[2] IAEA TRS 457 (2007)

Comparable results?



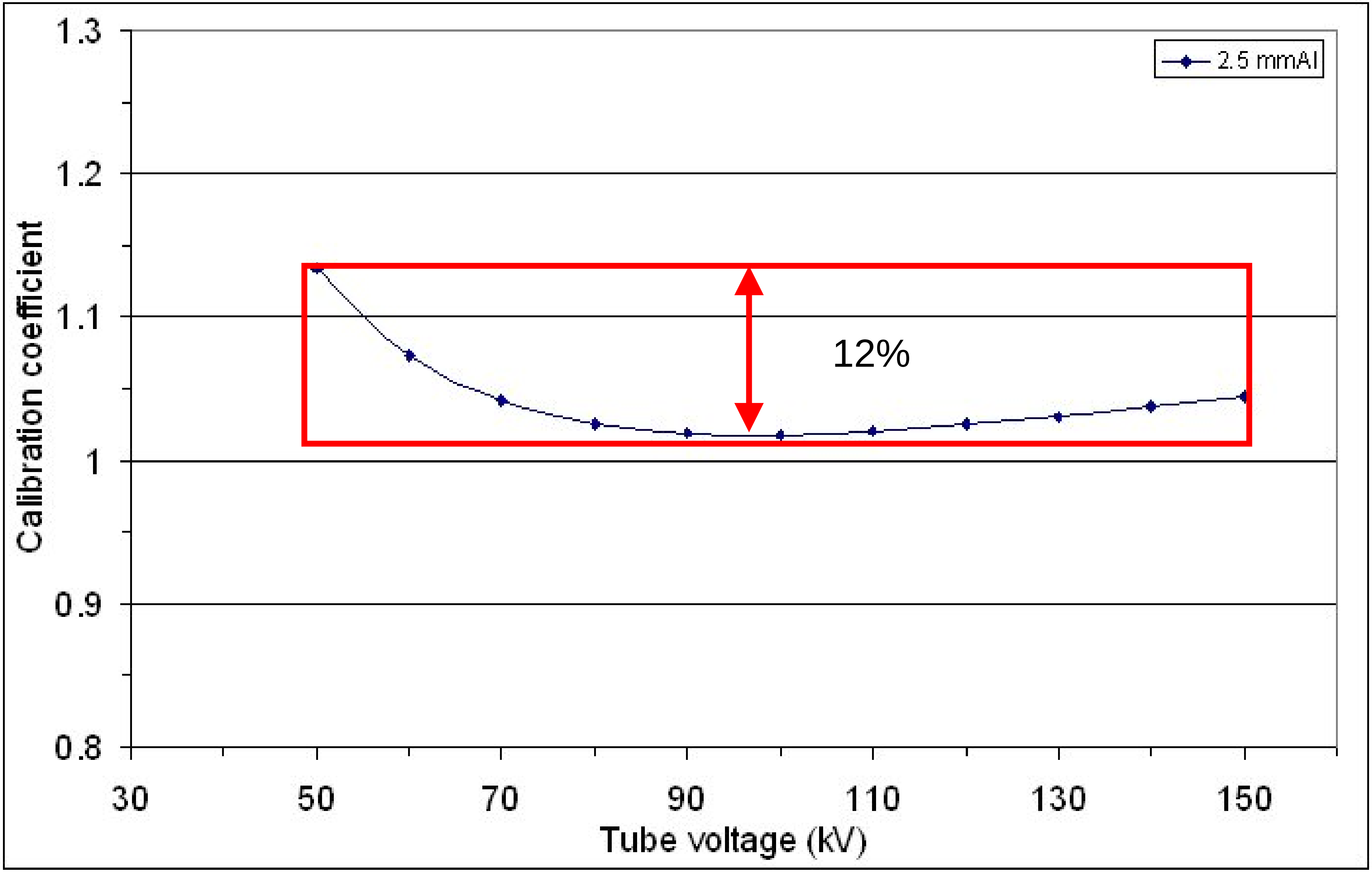
See also: Larsson et al. 1996, 1998, 2006, Jankowski 2008, Hetland 2009.

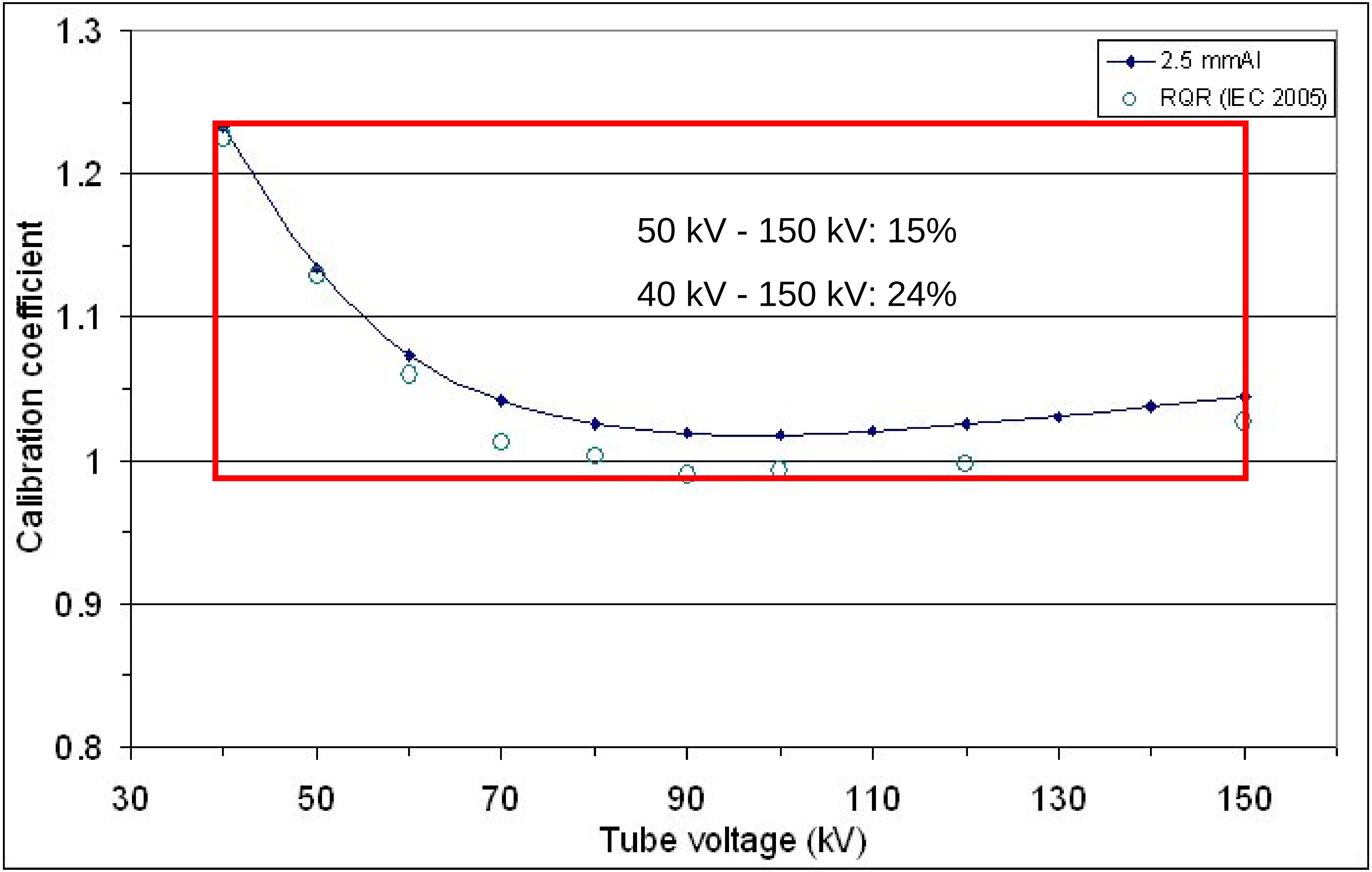
Effect of patient couch => in situ calibration?



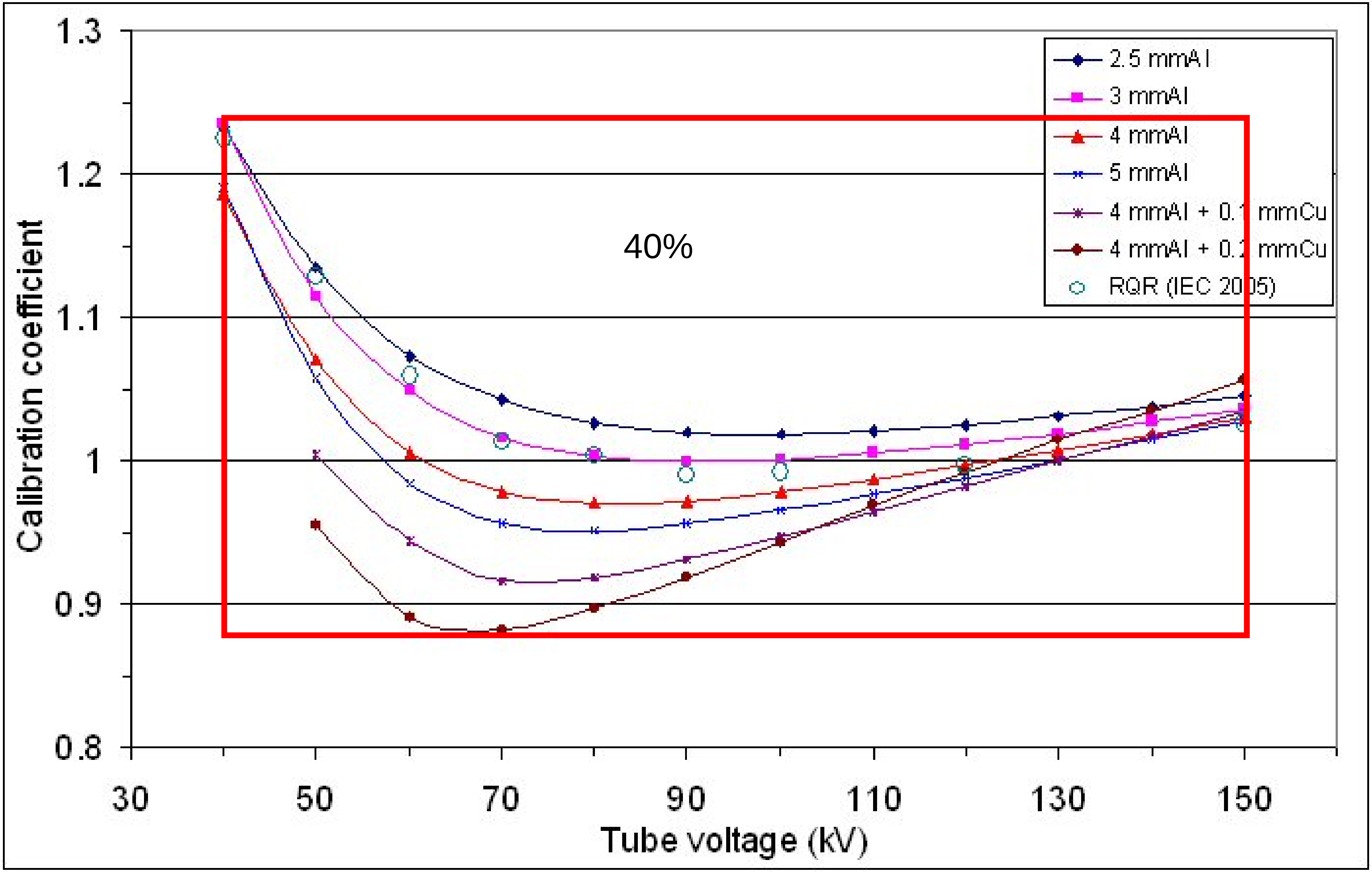
Energy dependence

- The energy dependence should be studied in calibrations by using different radiation qualities.
- The standard (IEC 60580, 2000) for KAP meters defines **±8%** limit of deviation when the total filtration is **2.5 mm Al** and the tube voltage is between **50 kV and 150 kV**.
- For other filtrations, no requirements are stated.

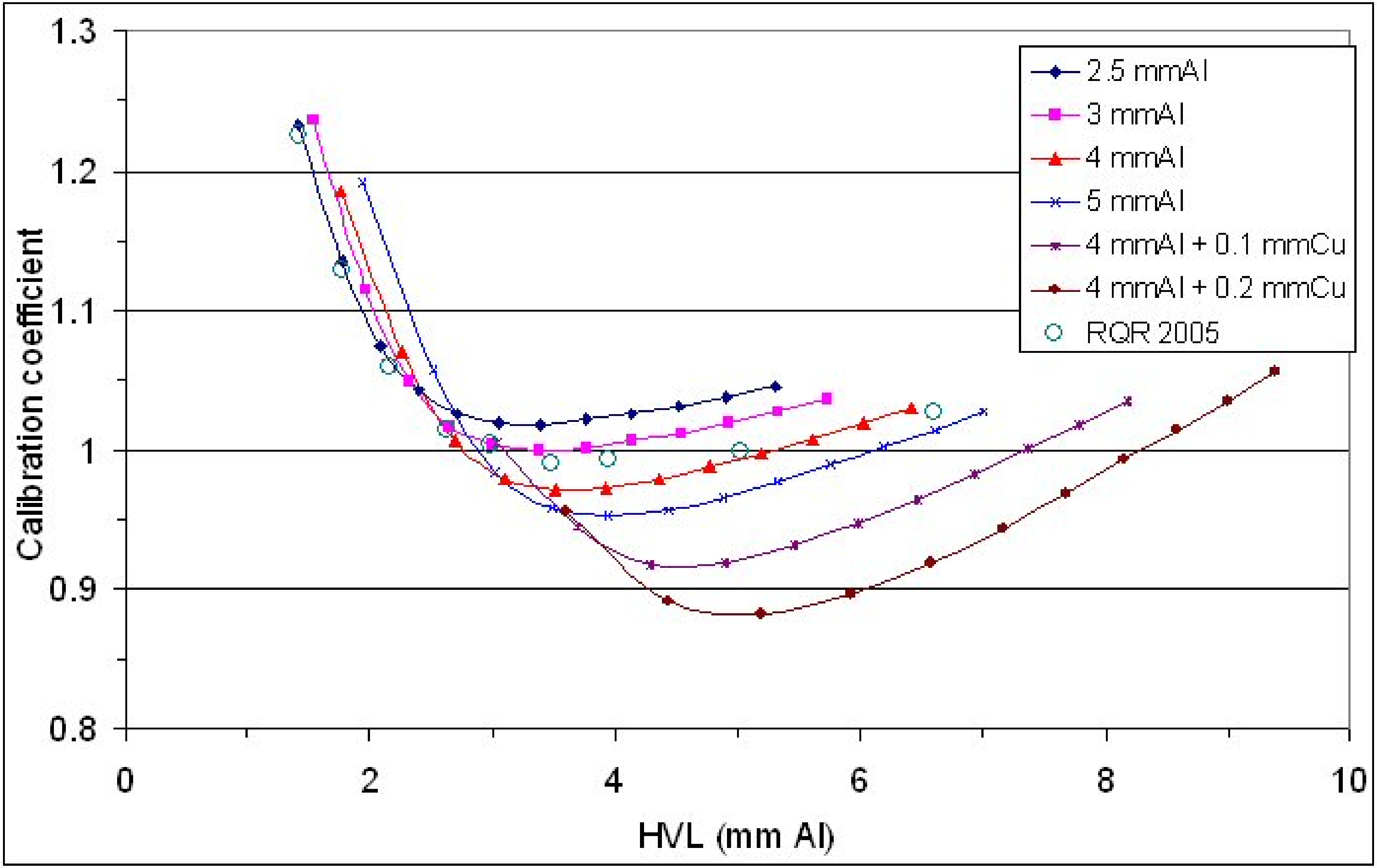

1.3
1.2
1.1
1
0.9
0.8
Calibration coefficient
2.5 mmAl
12%
30
50
70
90
110
130
150
Tube voltage (kV)



1.3
1.2
1.1
1
0.9
0.8
Calibration coefficient
30
50
70
90
110
130
150
Tube voltage (kV)
2.5 mmAl
RQR (IEC 2005)
50 kV - 150 kV: 15%
40 kV - 150 kV: 24%



Toroi et al. Phys. Med. Biol. 2008



Toroi et al. 2008

Half-value layer (HVL) alone is not the answer

How we do it?

Calibration methods

Calibration methods

Laboratory method:

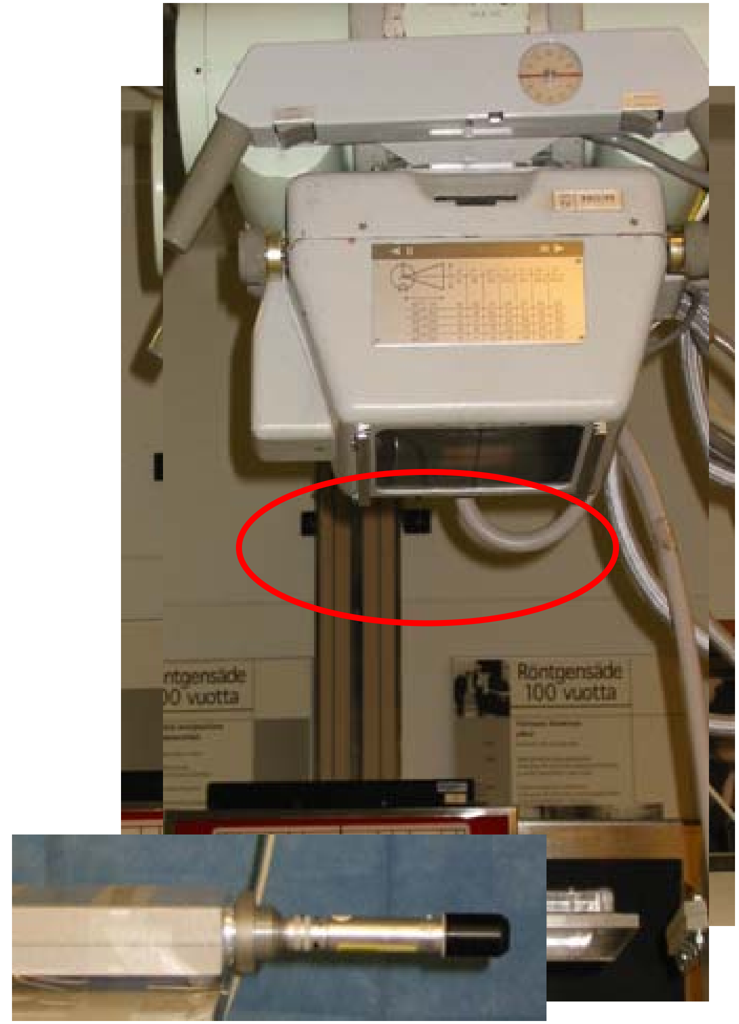
- Field KAP meter is sent to a laboratory for calibration
- Corrective measurements are made in situ.

Beam area method:

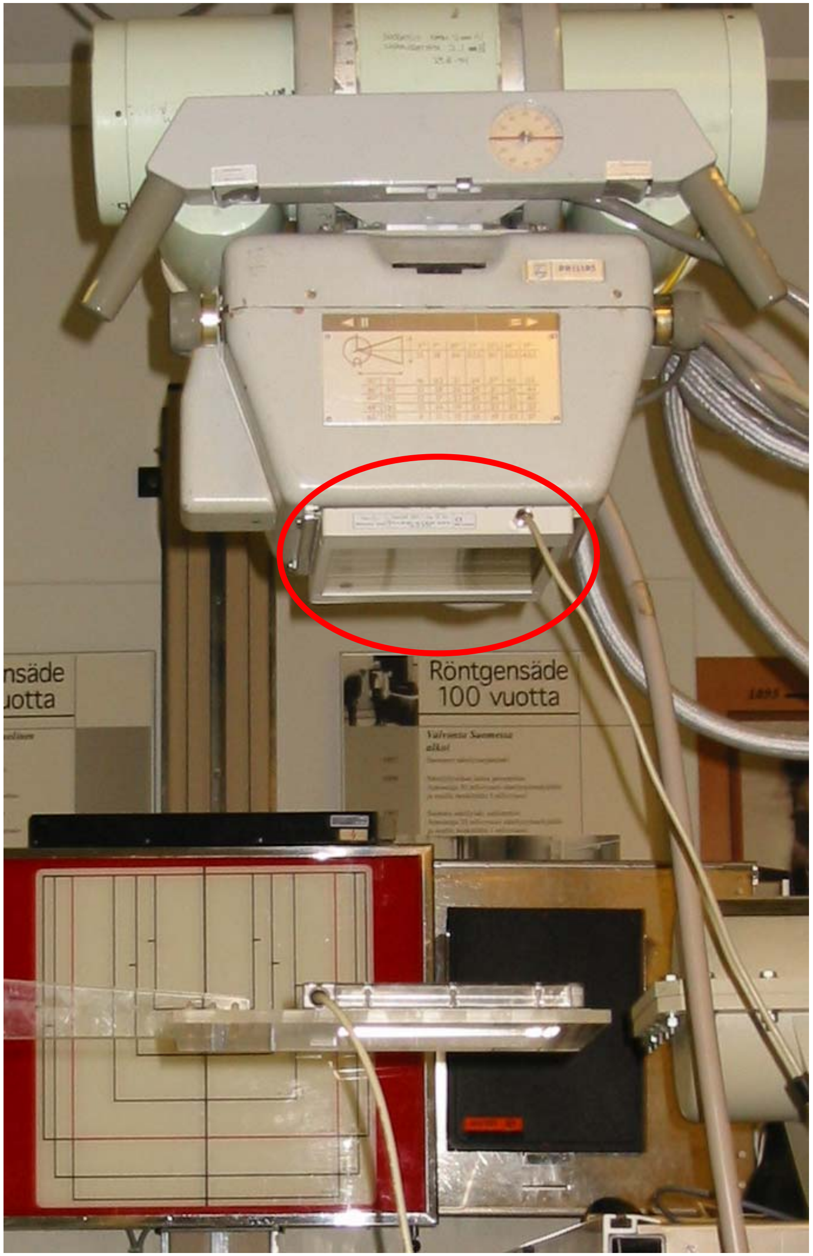
- Reference value is measured with an air kerma meter and multiplied with the beam area.

Tandem method:

- Reference value is measured with the reference KAP meter

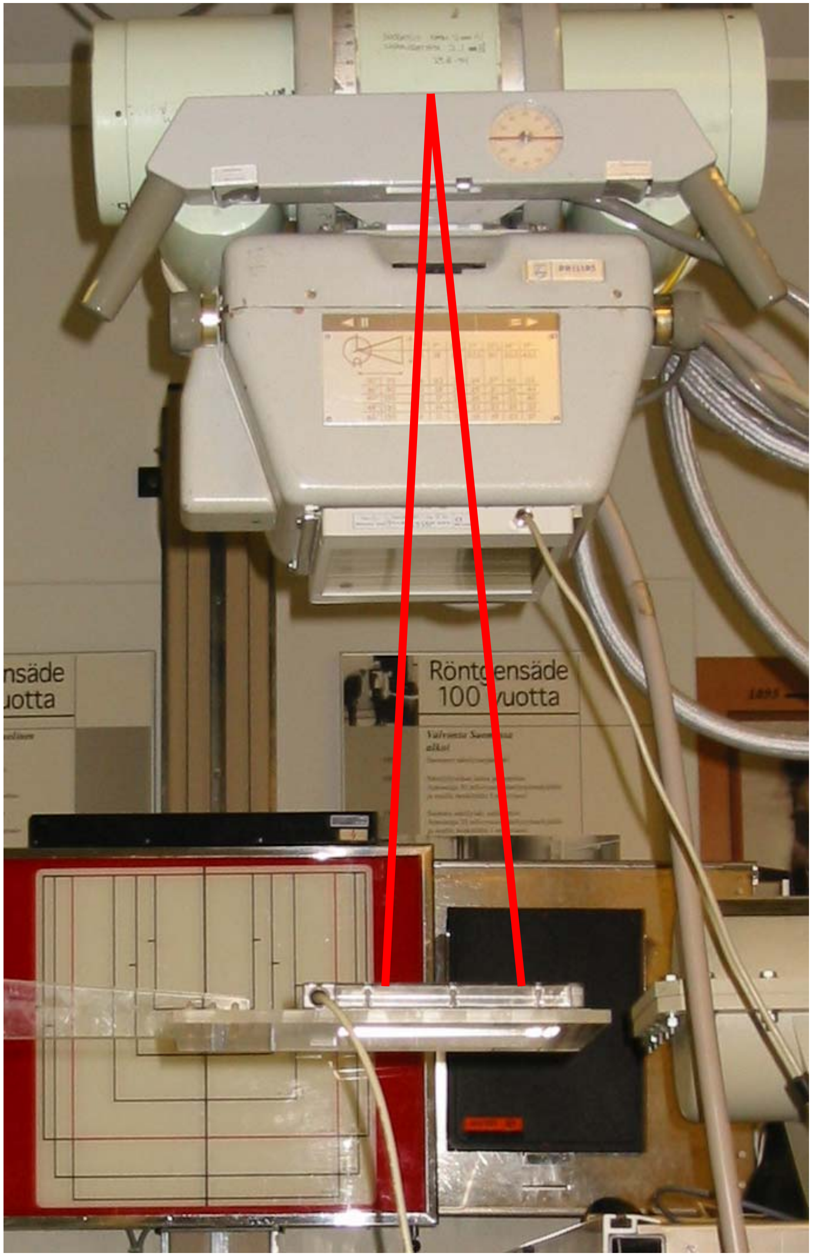


Uncertainties in beam area method:
Larsson et al. 1998



Tandem method

- **Reference KAP meter** is calibrated in laboratory for the incident beam.
- **Field KAP meter** is kept in the place where it is in patient measurements.
- Reference KAP meter is placed in the x-ray beam **simultaneously** with the field KAP chamber.
- The reference meter is mounted to the **distance** where entrance surface of patient usually is (> 30 cm).



Tandem method

Pros:

- Both meters measures the same quantity.
- Accurate measurements of the irradiation geometry are not required.

Cons:

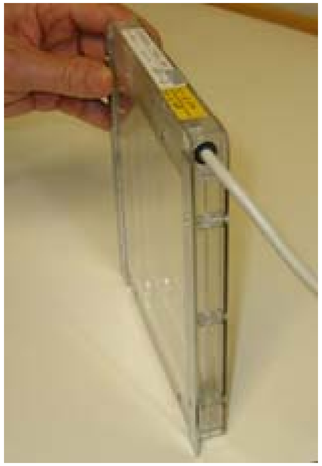
- A comprehensive calibration for the reference KAP meter is needed.
- Useful beam sizes are limited by the size of the reference meter.

Patient dose calibrator, PDC

- •In this study the PDC meter (Radcal) was used as a reference meter.
- •The response of this meter have lower energy dependence.
- •Large size of the meter made it possible to use larger field sizes.

Patient dose calibrator (PDC):

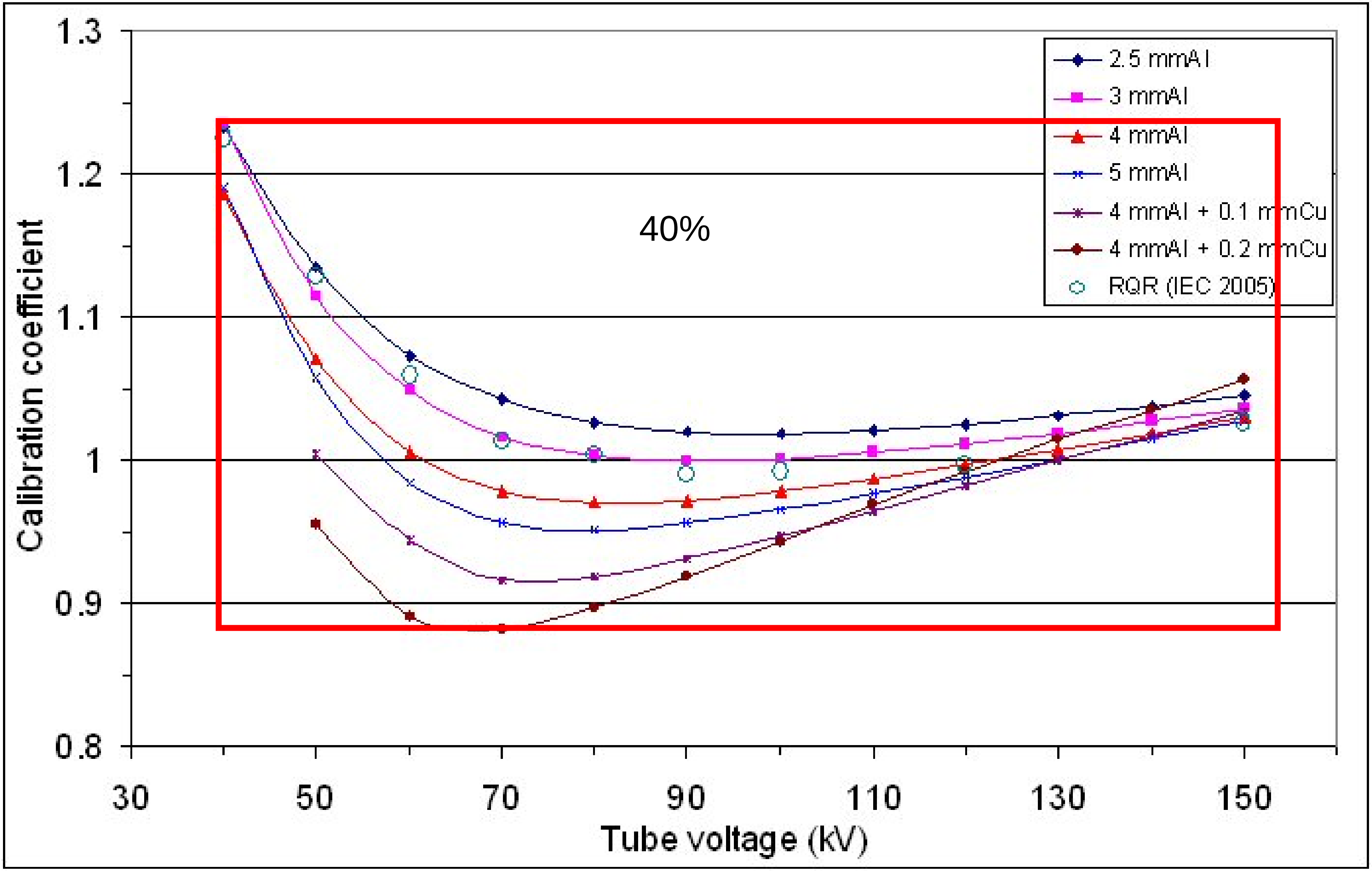
- 30cm*30cm
- non light transparent



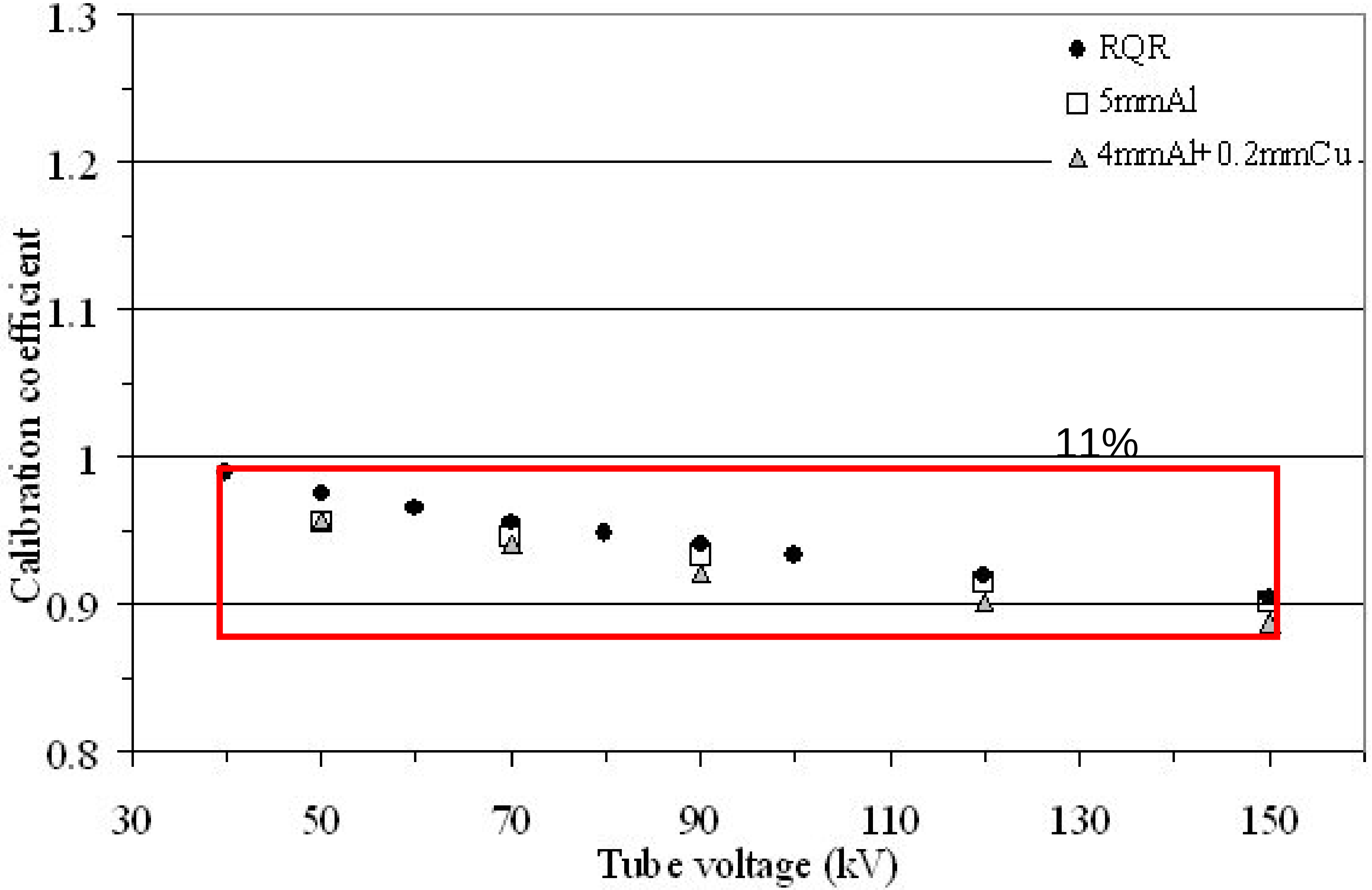
Conventional KAP meter:

- 14 cm*14 cm
- light transparent
- strong energy dependence

Conventional KAP meter

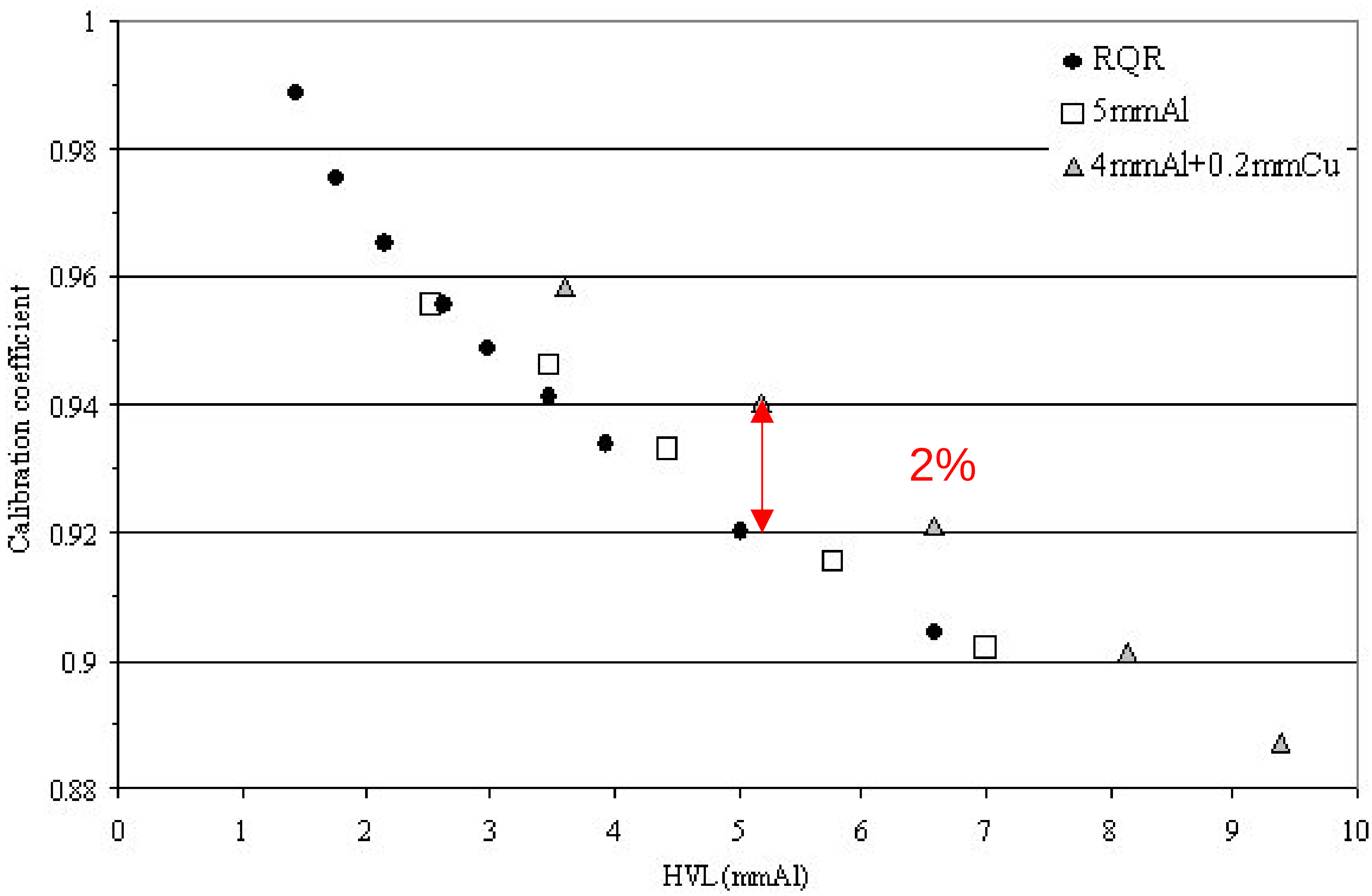


PDC meter

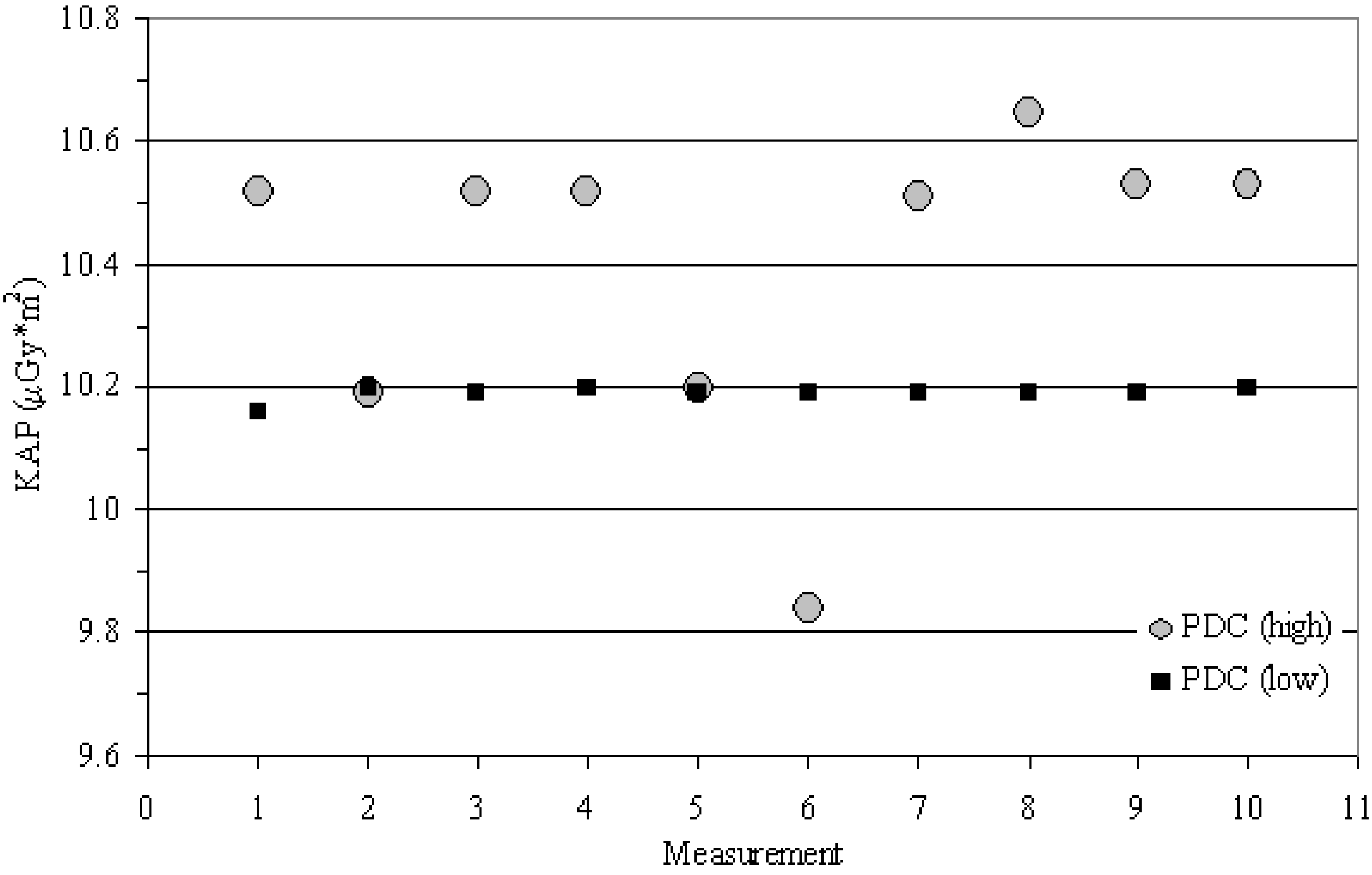


1.3
1.2
1.1
1
0.9
0.8
Calibration coefficient
RQR
5mmAl
4mmAl+0.2mmCu
11%
30
50
70
90
110
130
150
Tube voltage (kV)

Interpolations



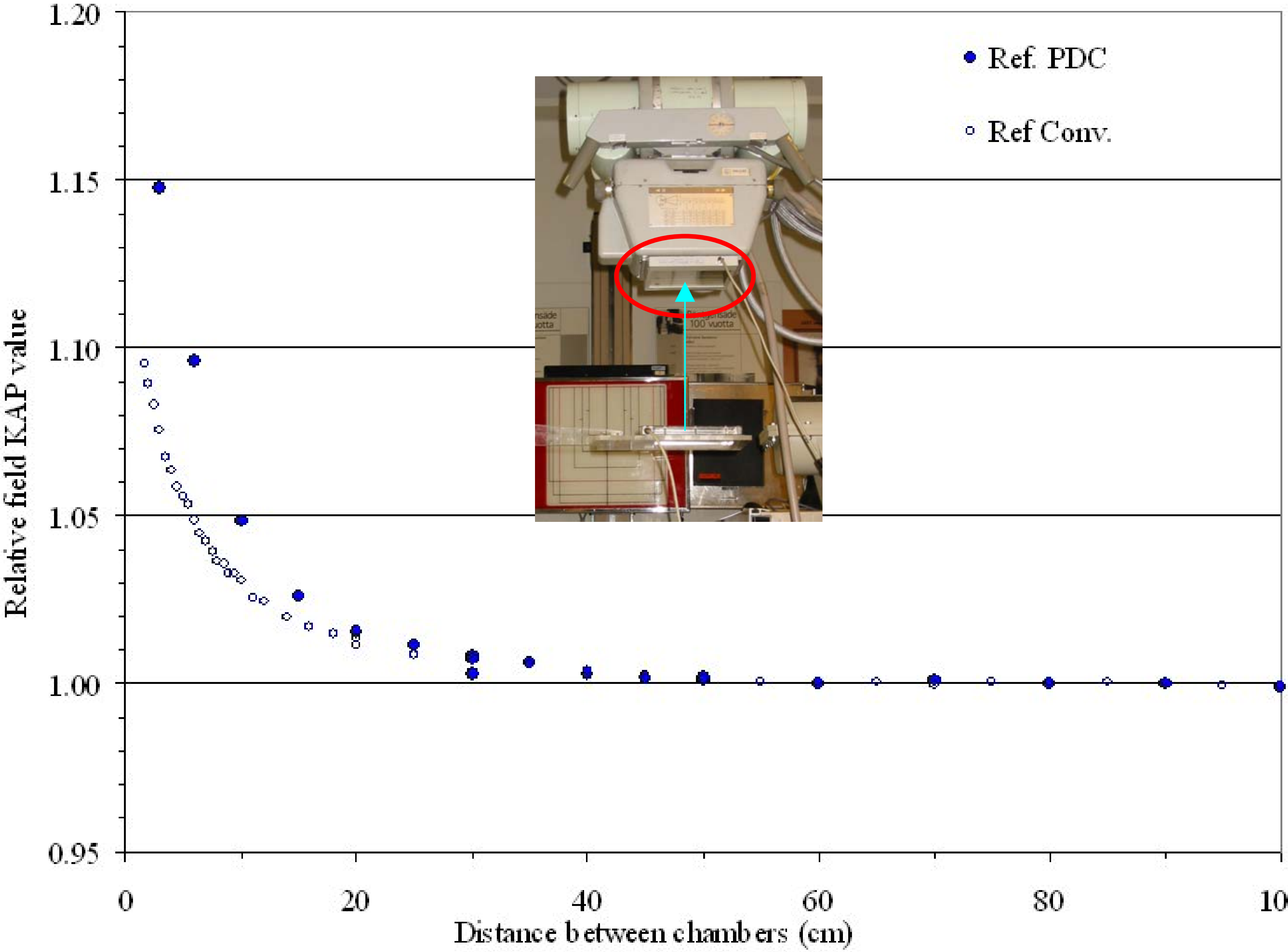
Repeatability



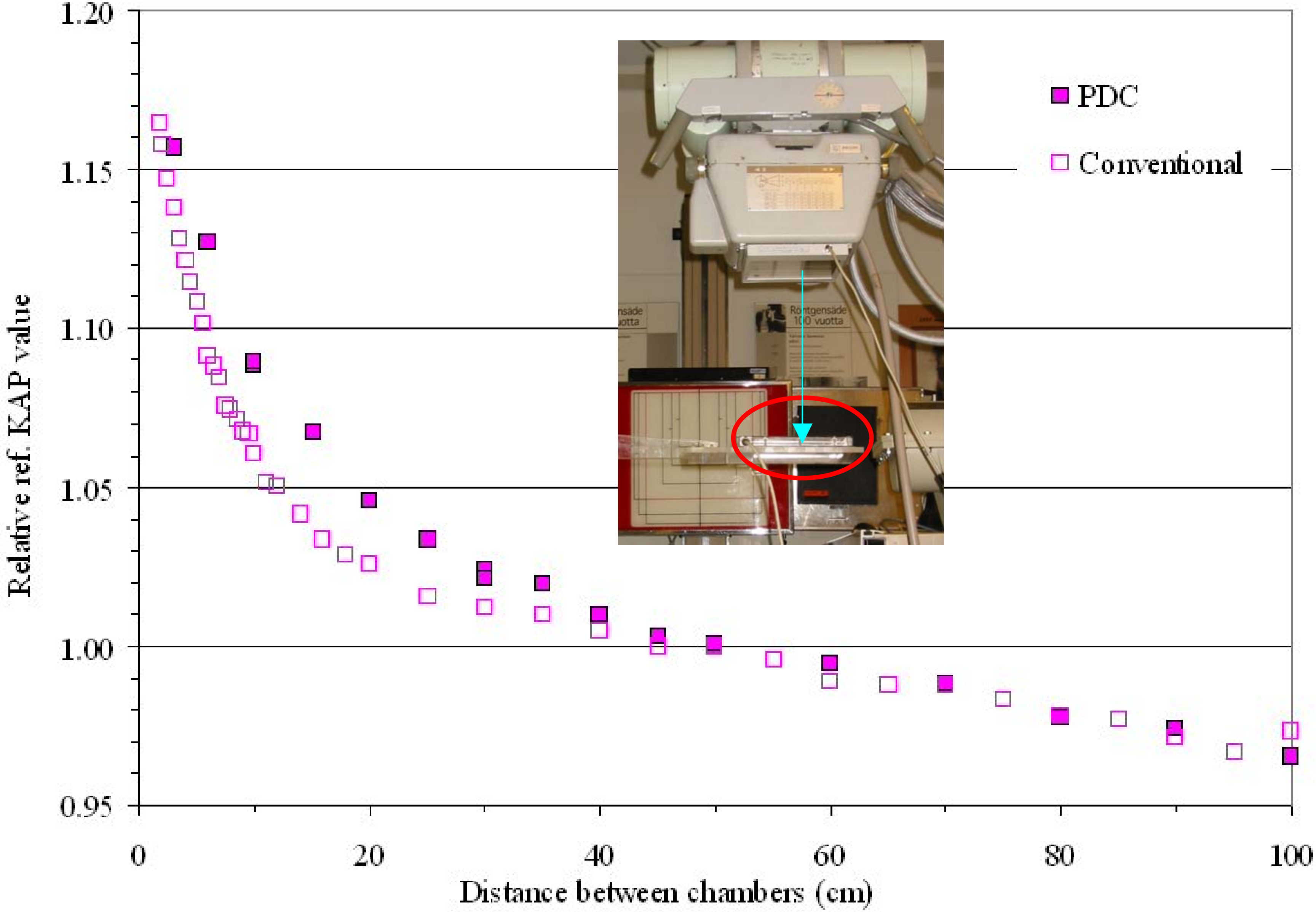
Beam area dependence

- **In laboratory** for small range of beam sizes (Ø 42 - 96 mm) the deviation of calibration coefficient was ~1%.
- In **clinical measurements** the deviations were larger.
- Is it a problem in high rate mode or some other effect?
- In the range Ø 30 - 200 mm ≈5%
- Ø <30mm or >200 mm should not be used.

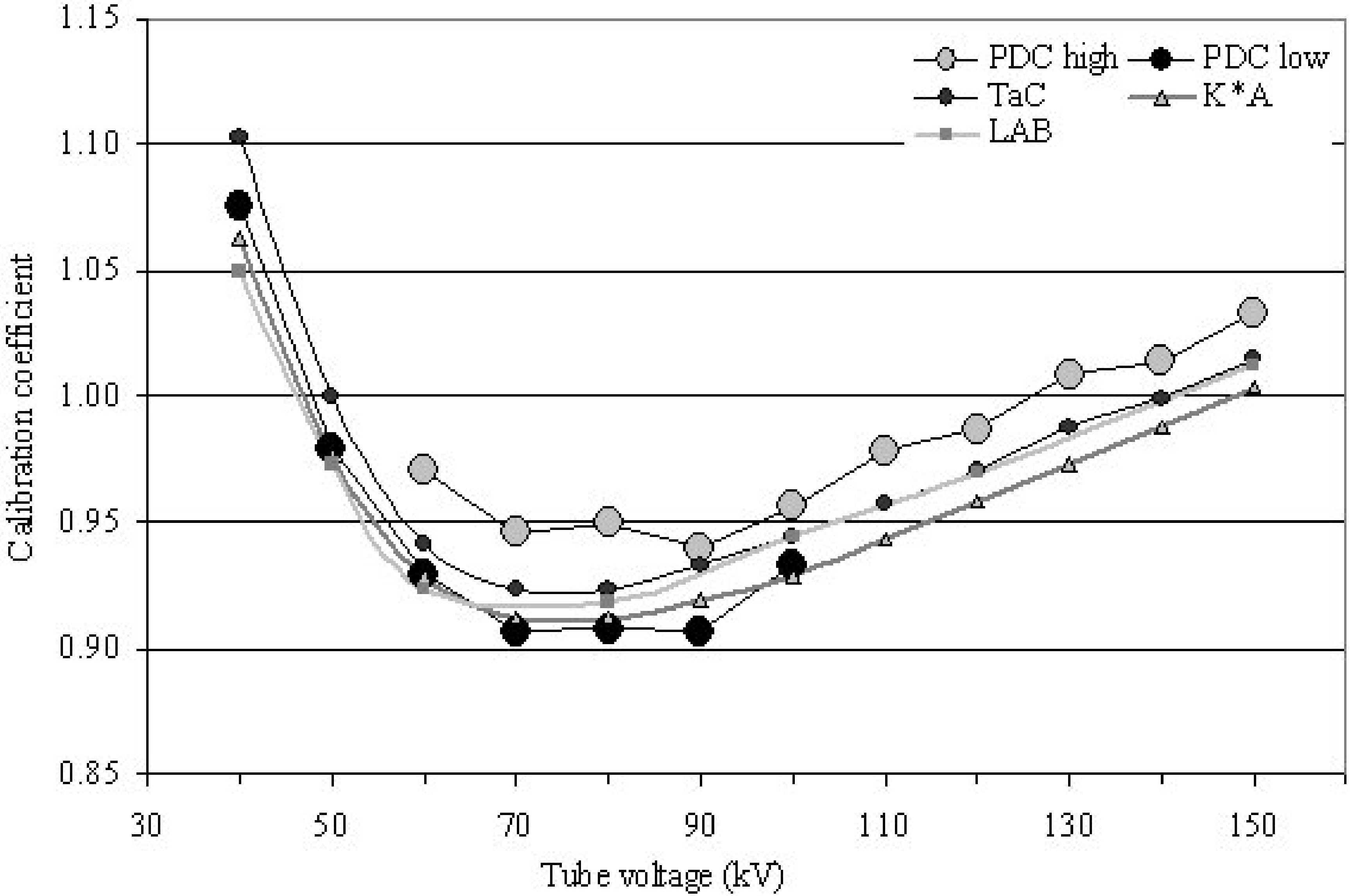
Distance between meters: field meter



Distance between meters: reference meter



Method comparison



Final conclusions

1. KAP meters should be calibrated:
   - **traceable** to international standards
   - **in situ** for **transmitted beam**
   - cover **clinically used radiation qualities**.
2. The method is not so important.

Patient exposure in x-ray imaging:
How big uncertainty you would tolerate?

- 100% No traceable calibration or
- 50% no in-situ adjustment.
- 25% One point calibration.
- 15% Limited range of RQ.
- 10% Calibration covering clinical RQs
- 7% Good calibration and use
- 5% Very difficult task

See also Paper 266
Hetland, Norway

(95%, k=2), RQ= radiation quality

Some references:

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THANK YOU!