TraMeXI Workshop

PRACTICAL EXAMPLE FOR CLINICAL MEASUREMENTS

21st Nov 2024, Niko Kiiskinen (Specializing Medical Physicist / Researcher)

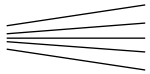
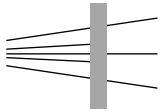
Contents

What can affect radiation measurements?

Laboratory conditions vs. clinical reality

Uncertainties of clinical measurements

EFFECTS ON RADIATION MEASUREMENTS

- Environment (temperature, air pressure, humidity, EM interference) 
- Calibration 
- Long-time stability of the dosimeter 
- Resolution of the meter (e.g. 50.3 = 50.25 … 50.34) 
- Warm-up time (both) 
- Measurement setup 
- Radiation quality (→ interpolation of calibration coefficients?) 
- Beam intensity 
- Field size 
- Other attenuating material 

EFFECTS OF MEASUREMENT ENVIRONMENT

Laboratory

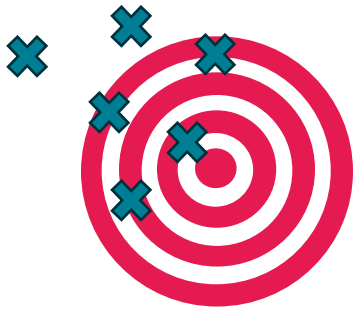
- Controlled temperature, air pressure and humidity
- Fixed setup
- Lots of time
- Enough data points
- Uncertainties known and controlled well
- Calibration according to standardized radiation qualities

Hospital

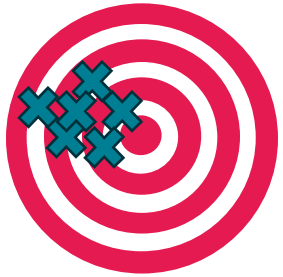
- More prone to temperature, air pressure and humidity alterations
- Setup may vary
- Tighter time slots (patient flow)
- Enough data points?
- Uncertainties typically bigger and not known so well
- Clinical radiation qualities → how to estimate calibration coefficients?

UNCERTAINTIES

ERROR



↓ Accuracy
↓ Precision



↓ Accuracy
↑ Precision

↑ Accuracy
↓ Precision

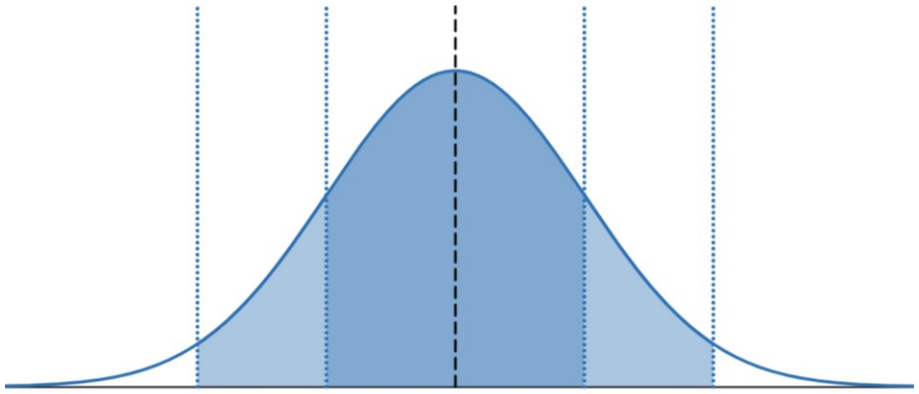
↑ Accuracy
↑ Precision

→ Random error and systematic error

SOURCES OF ERROR

Random (Type A)

- Readout fluctuation due to functional variations of…
  - Dosimeter
  - X-ray device

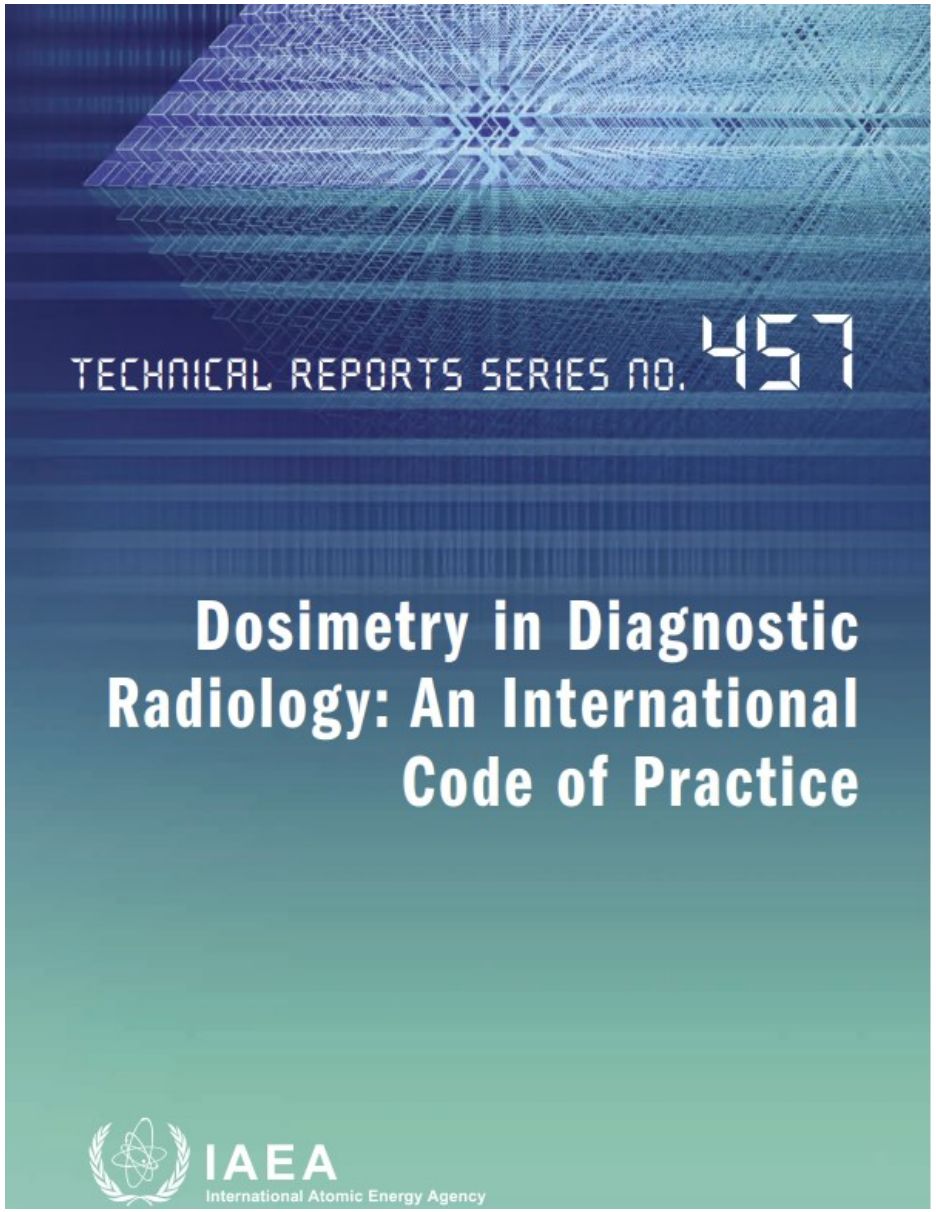


Systematic (Type B)

- Environment
- Calibration
- Long-time stability of the dosimeter
- Resolution of the meter
- Warm-up time (both)
- Measurement setup
- Radiation quality
- Beam intensity
- Field size
- Other attenuating material

WHERE TO START?

- IAEA TRS-457 Dosimetry in Diagnostic Radiology: An International Code of Practice
  - Chapter 8: CoP for Clinical Measurements



WHERE TO START?

- IEC 61674:2024 Medical electrical equipment – Dosimeters with ionization chambers and/or semiconductor detectors as used in X-ray diagnostic imaging

Requirements for diagnostic dosimeters
(20–150 kV)


IEC 61674

Edition 3.0 2024-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Medical electrical equipment – Dosimeters with ionization chambers and/or semiconductor detectors as used in X-ray diagnostic imaging

IEC 61674

If no prior data available…

±6.6 %!
(*k* = 1)

Table A.1 – Estimation of COMBINED STANDARD UNCERTAINTY for dosimeter performance

PERFORMANCE CHARACTERISTIC	Subclause	Relative STANDARD UNCERTAINTY[a] %
Calibration factor[b]		±2,89
Linearity	5.1	±1,15
Repeatability	5.2	±0,58
RESOLUTION of reading	5.3	±0,58
STABILIZATION TIME	5.4	±1,15
Long term stability	5.6.1	±1,15
Accumulated dose stability	5.6.2	±0,58
RADIATION QUALITY	6.2	±2,89
AIR KERMA RATE	6.3	±1,15
Incidence of radiation	6.4	±1,73
Operating voltage	6.5	±1,15
Air pressure	6.6	±1,15
Temperature and humidity	6.8	±1,73
Electromagnetic compatibility	6.9	±2,89
Field size	6.10	±1,73
COMBINED STANDARD UNCERTAINTY		±6,6

[a] Relative STANDARD UNCERTAINTY assuming that there is no additional information about the PROBABILITY DISTRIBUTION of the PERFORMANCE CHARACTERISTIC within the allowed interval other than it has an uniform distribution, i.e. 0,577 *L* for symmetric limits.

[b] Although no requirement on the accuracy of the calibration factor is laid down in this document, a maximum error of the calibration factor is included here and assumed to be ±5 %. A uniform distribution is also assumed.

PRACTICAL EXAMPLE

EXAMPLE OF ESTIMATING UNCERTAINTY

Projection radiography: **air kerma with XMM**

- Parameters: 70 kV, no add. filtration (2.5 mm Al inherent)
- Calibr. factor: uncertainty u_B 1.3 % (k = 2) → 0.65 % (k = 1)
- Linearity: let's assume similar air kerma rate → u_B ~0 %

AIR KERMA

Set voltage	Anode target	Nominal tube filtration	Added filtration	Air kerma rate µGy/s	Instrument setting	Standard	Measured	Deviation from standard	Expanded uncertainty	Result
70 kV	W	2.5 mm Al	0 mm Al	5018	–	1607 µGy	1596 µGy	-0.7 %	1.3 %	P

IEC 61674 "sticky note"

PERFORMANCE CHARACTERISTIC
Calibration factor[b]
Linearity
Repeatability
RESOLUTION of reading
STABILIZATION TIME
Long term stability
Accumulated dose stability
RADIATION QUALITY
AIR KERMA RATE
Incidence of radiation
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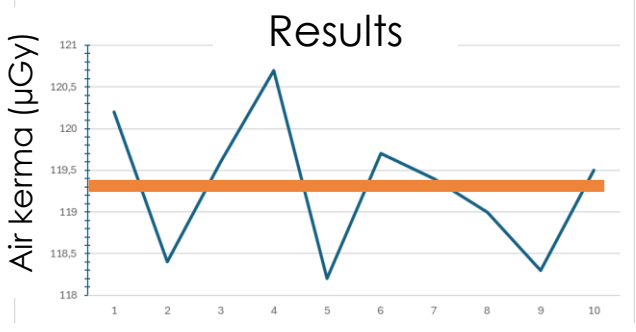
Air pressure
Temperature and humidity
Electromagnetic compatibility
Field size

EXAMPLE OF ESTIMATING UNCERTAINTY

Projection radiography: **air kerma with XMM** (quite new)

- Repeatability: standard error of the mean u_A 0.22 %
- Resolution: u_B 0.042 %
- Stabilization time: u_B 0.20 % (result variation 15…60 min)
- Long term stability: cannot estimate → u_B 1.15 %
- Accumulated dose stability: u_B ~0 % (new, just calibrated)
- Radiation quality: same quality → u_B 0 %
- K_a dependence on K_a rate: not measured → u_B 1.15 %

$$\sigma_{\langle x \rangle} = \sigma / \sqrt{N}$$



Mean: 119.3 µGy

IEC 61674 "sticky note"

PERFORMANCE CHARACTERISTIC
Calibration factor[b]
Linearity
Repeatability
RESOLUTION of reading
STABILIZATION TIME
Long term stability
Accumulated dose stability
RADIATION QUALITY
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Incidence of radiation
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Electromagnetic compatibility
Field size

EXAMPLE OF ESTIMATING UNCERTAINTY

Projection radiography: **air kerma with XMM** (quite new)

- Incidence/dosimeter angle: u_B ~0 %
- Operating voltage: full battery → u_B ~0 %
- Air pressure, temperature, humidity: based on clinical measurements u_B 0.50 %
- EM compatibility: u_B ~0 % *
- Field size: 10 x 10 cm^2, little effect → u_B ~0 %

IEC 61674 "sticky note"

PERFORMANCE CHARACTERISTIC
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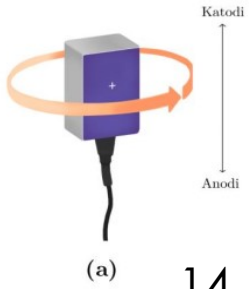
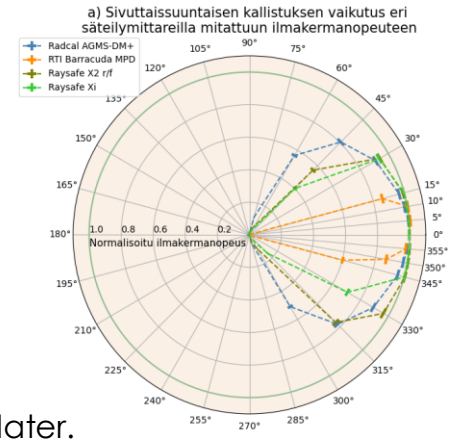
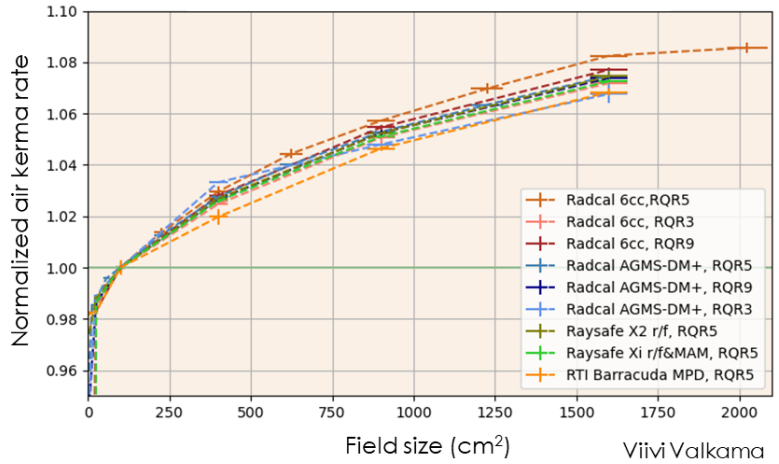
Viivi Valkama





Air kerma rate dependence on field size



Viivi Valkama

Mean: 119.3 µGy

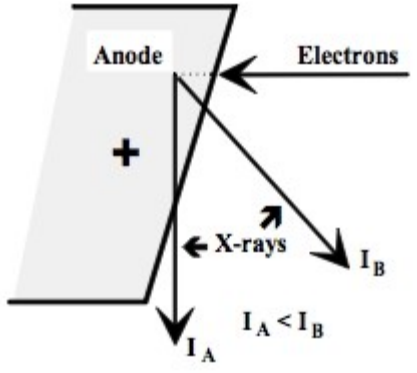
*) 0 % for now. More later.

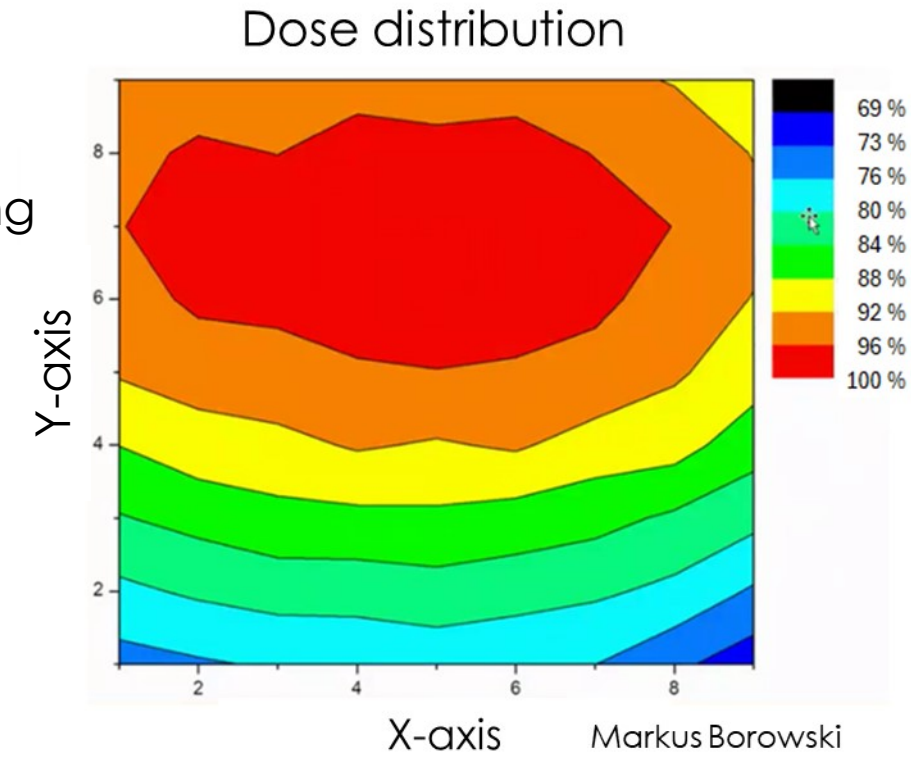
EXAMPLE OF ESTIMATING UNCERTAINTY

Projection radiography: **air kerma with XMM** (quite new)

- Measurement setup
  - Vertical: ±2 mm → u_B 0.40 %
  - Horizontal plane:
    - Centering the reference point of the dosimeter along the optical lines: ±2 mm
  - Effect on air kerma? (Heel effect)

    ± 2 % → u_B 0.58 %





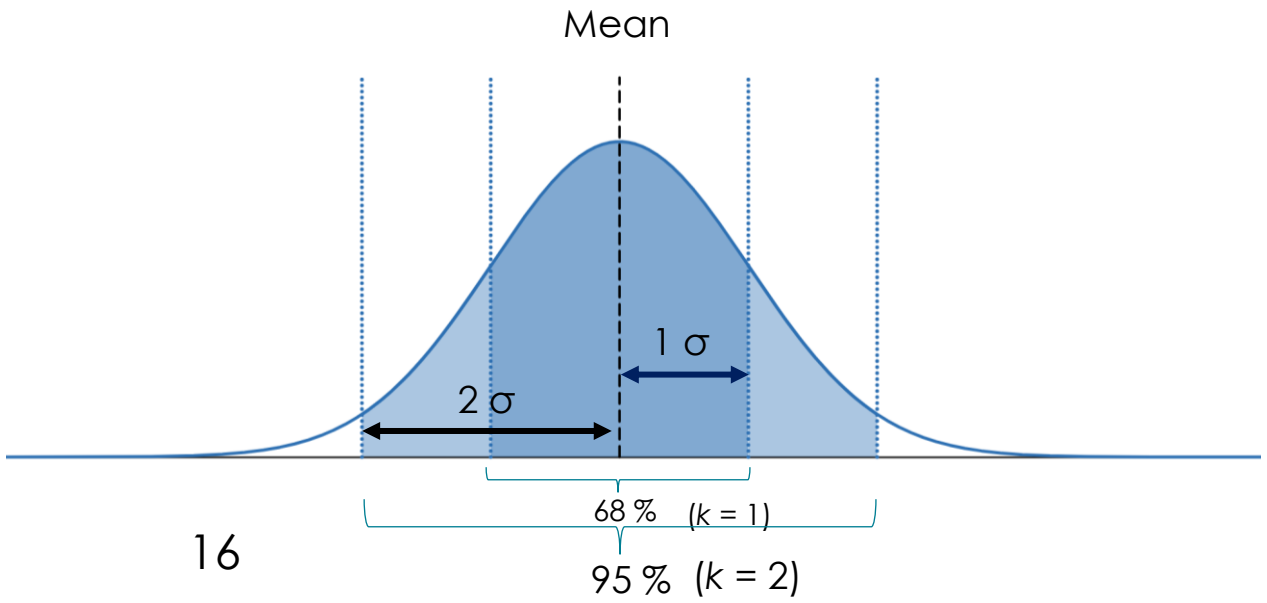
Mean: 119.3 µGy

COMBINED STANDARD UNCERTAINTY

- u_C = ±2.0 % (k = 1, ~68 %)

→ u_C = ±4.0 % (k = 2, ~95 %)

→ **Result: (119.3 ± 4.7) µGy**



Component	Relative standard uncertainty (± %)	
	IEC 61674	Our estimate
Calibration factor	2.89	0.65
Linearity	1.15	0
Repeatability	0.58	0.22
Resolution of reading	1.15	0.042
Stabilization time	1.15	0.20
Long term stability	1.15	1.15
Accumulated dose stability	1.15	0
Radiation quality	2.89	0
Air kerma rate	1.15	1.15
Incidence of radiation	1.73	0
Operating voltage	1.15	0
Air pressure	1.15	0.50
Temperature and humidity	1.73	
Electromagnetic compatibility	2.89	0
Field size	1.73	0
Measurement setup: vertical	-	0.40
Measurement setup: horizontal	-	0.58
Combined standard uncertainty	**6.6**	**2.0**

$$u = \sqrt{\sum_{i=1}^{n} u_i^2}$$

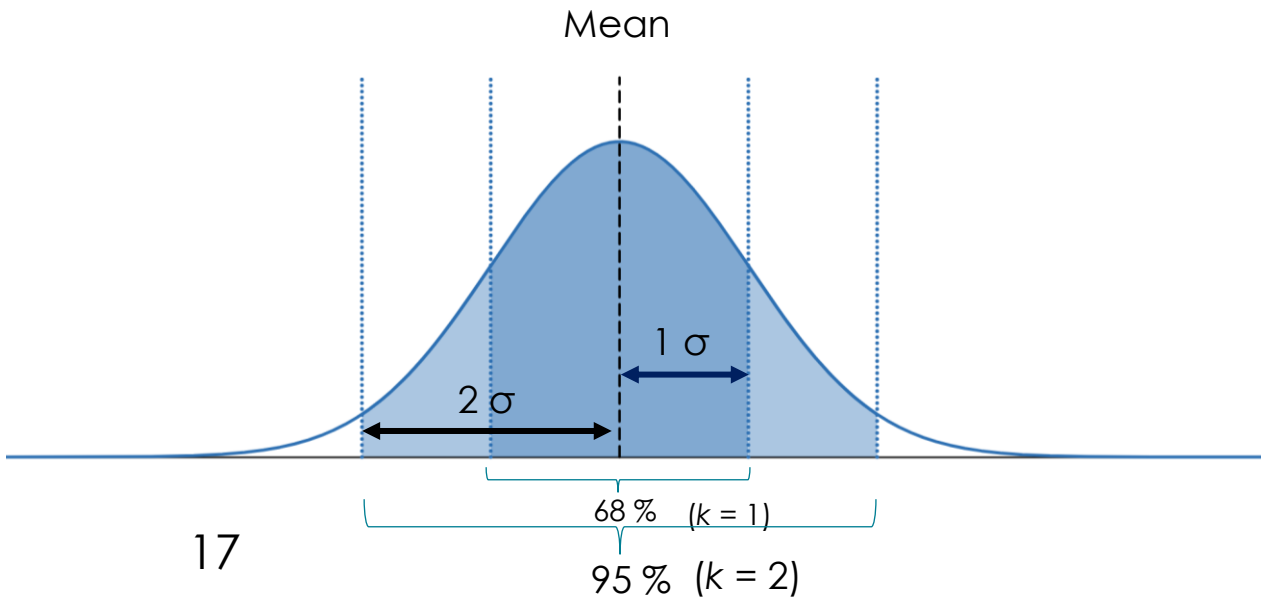
Mean: 119.3 µGy

WHAT IF EM COMPATABILITY ≠ 0?

- u_C = ±3.5 % (k = 1, ~68 %)

→ u_C = ±7.0 % (k = 2, ~95 %)

→ **Result: (119.3 ± 8.4) µGy**



Component	Relative standard uncertainty (± %)	
	IEC 61674	Our estimate
Calibration factor	2.89	0.65
Linearity	1.15	0
Repeatability	0.58	0.22
Resolution of reading	1.15	0.042
Stabilization time	1.15	0.20
Long term stability	1.15	1.15
Accumulated dose stability	1.15	0
Radiation quality	2.89	0
Air kerma rate	1.15	1.15
Incidence of radiation	1.73	0
Operating voltage	1.15	0
Air pressure	1.15	0.50
Temperature and humidity	1.73	
Electromagnetic compatibility	2.89	**2.89**
Field size	1.73	0
Measurement setup: vertical	-	0.40
Measurement setup: horizontal	-	0.58
Combined standard uncertainty	**6.6**	**3.5**

$$u = \sqrt{\sum_{i=1}^{n} u_i^2}$$

Mean: 119.3 µGy

CONCLUSION

- **Measurements** are important!
- **Uncertainty estimation** is vital for reliability
- Learn how to read and interpret **calibration certificates** (Paula's presentation)

THANK YOU!