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New Danish research laboratory for medical dosimetry

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Duration: 20 min

Outline

Laboratory for Fundamental Medical Dosimetry

1. Radiation sources and research objectives.

2. Specific details (mainly related to calibration system).

3. Radiation protection measurement in pulsed beams.

Donation (21. juni 2012) from:

The John and Birthe Meyer Foundation

Accelerator, cobalt irradiation facility and advanced instrumentation.

The overall objective for the laboratory:

To support development and introduction of new forms of radiotherapy on Danish hospitals and to contribute to the maintenance of high standards for patient safety during modern radiotherapy.

Varian Truebeam linear accelerator system

Full imaging (kV, MV, gating)
Eclipse TPS
Developer mode

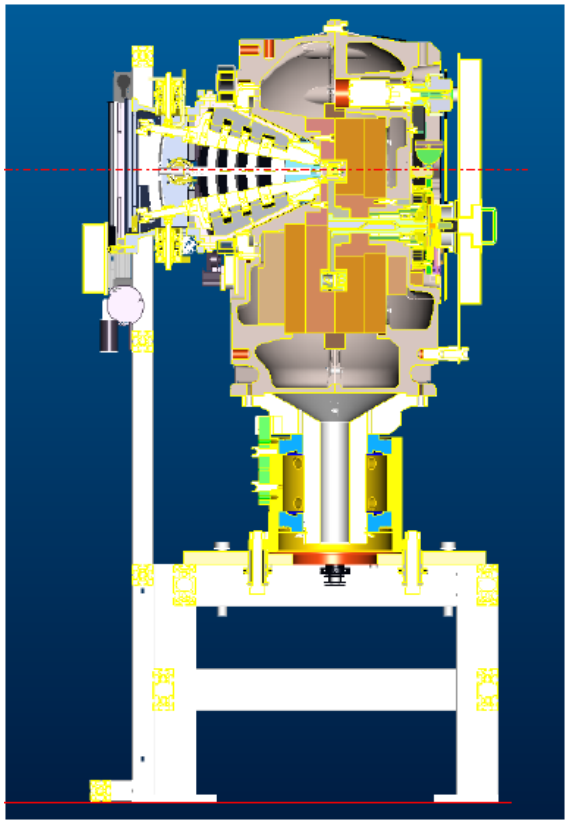
Photon beams: 4, 6, 10, 15 and 18 MV
FFF photon beams: 6 and 10 MV
Electron beams: 6, 9, 12, 15, 16, 18, and 20 MeV

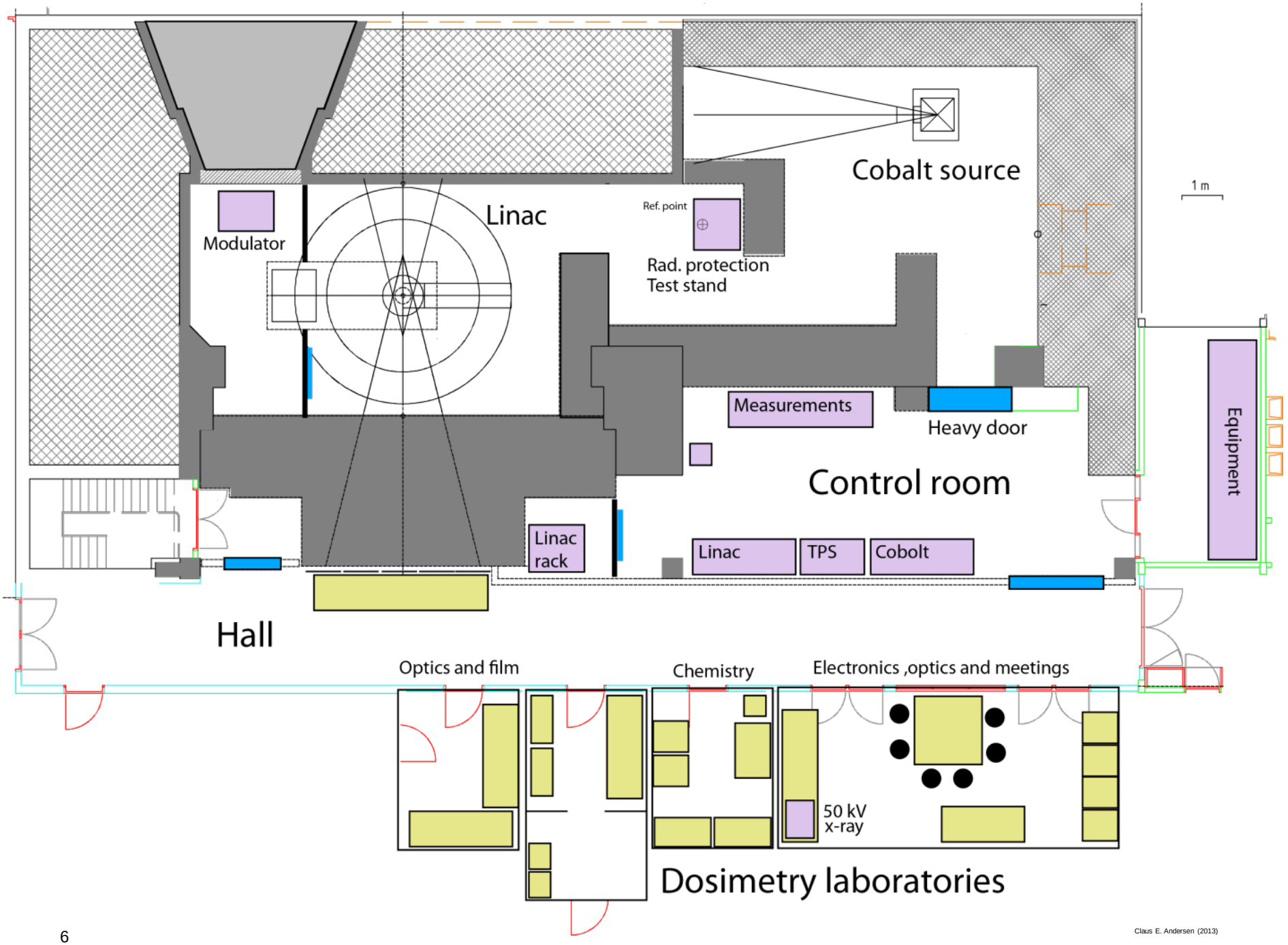
Terabalt (UJP Praha, Czech Republic)
Cobalt-60 source

455 TBq activity

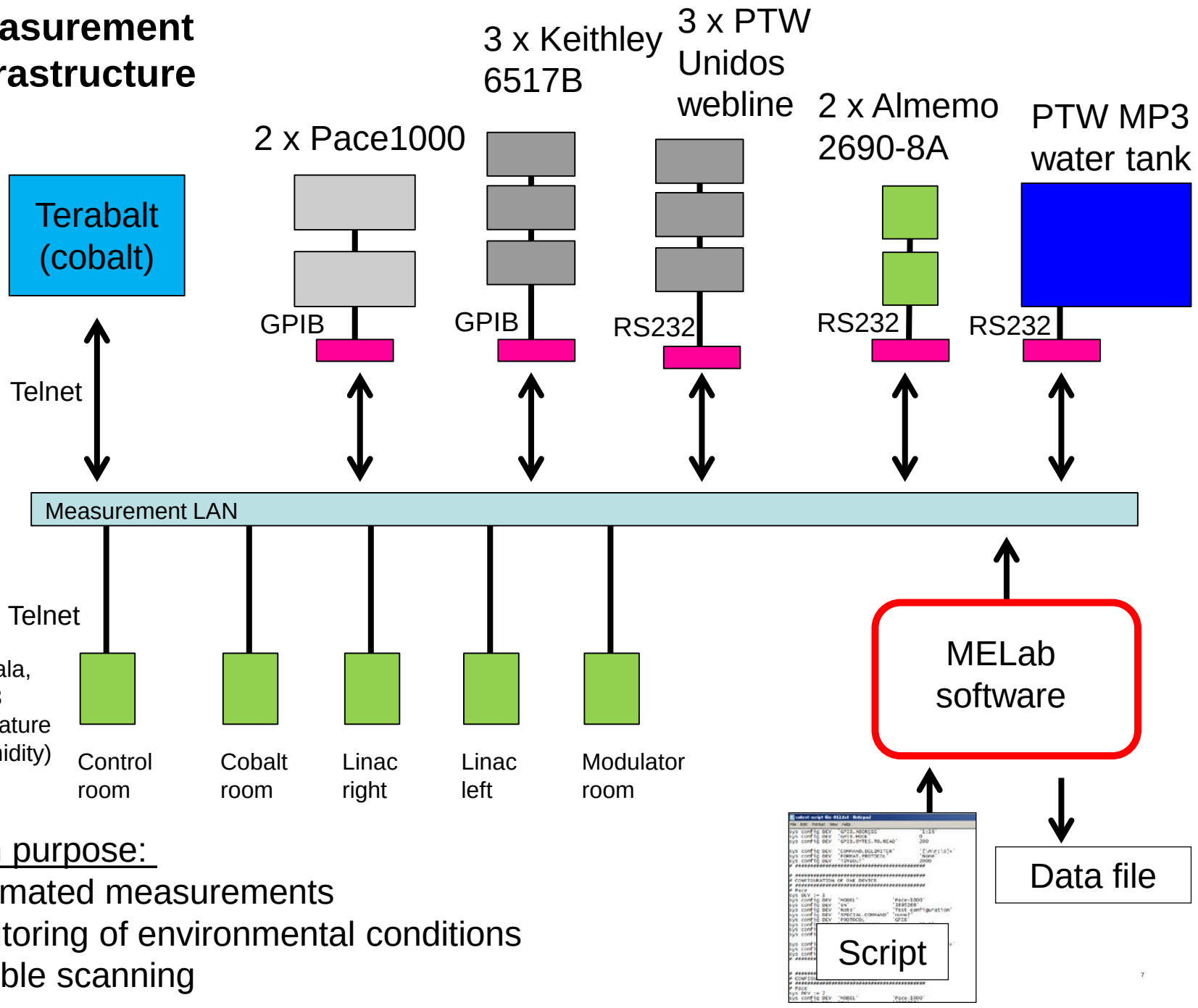
Fixed horizontal beam

Full computer control





Measurement infrastructure



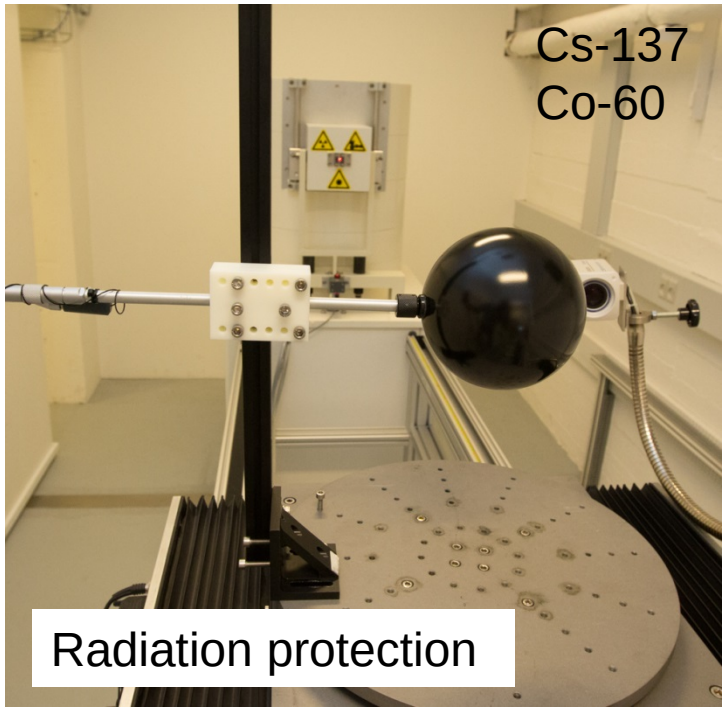
Main purpose:

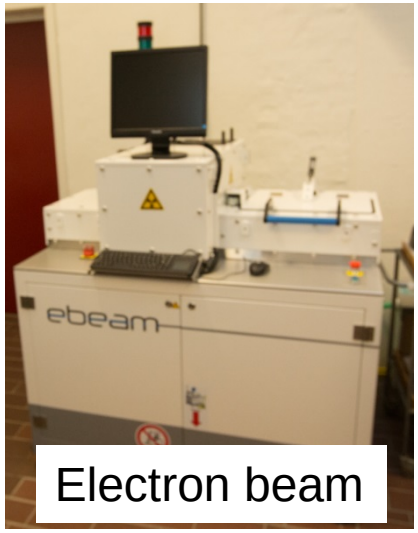
Automated measurements

Monitoring of environmental conditions

Flexible scanning

Other irradiation facilities at DTU Nutech





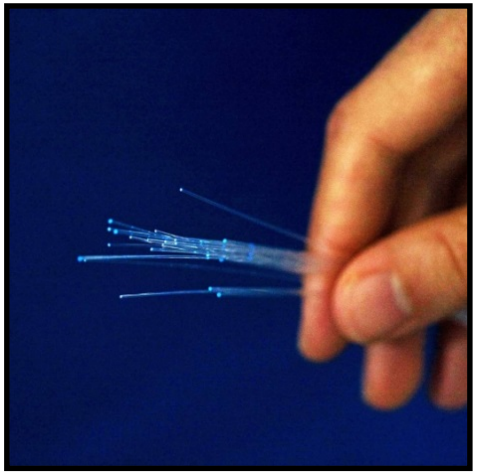
Types of research at the new laboratory:

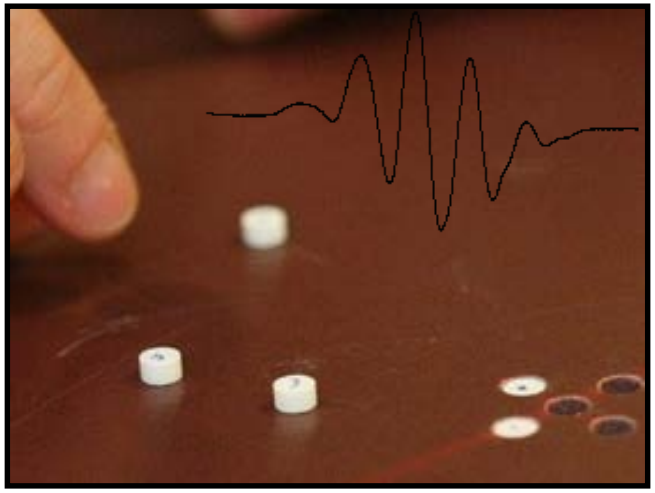
1. Detector oriented research

Organic scintillator dosimetry

Alanine dosimetry

3D optical dosimetry





2. Clinically oriented projects

Lung tumor dosimetry

3. Calibrations and standards

Accredited calibrations and measurements

Standards for accelerator dosimetry

Audit methods

Project examples:

- **Research projects within EURAMET**
- **Small-field dosimetry (Danish Research Council)**

Radiobiology

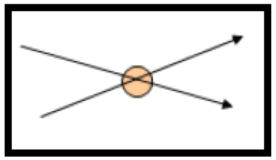
Mikael Jensen
Torsten Groesser
Pil Fredericia
(Hevesy Laboratory)

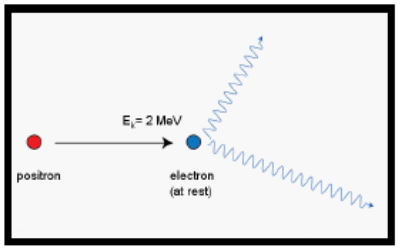
Mainly a theoretical course

Next time: June 2016

Medical Radiation Dosimetry Course

www.mrdc.dtu.dk

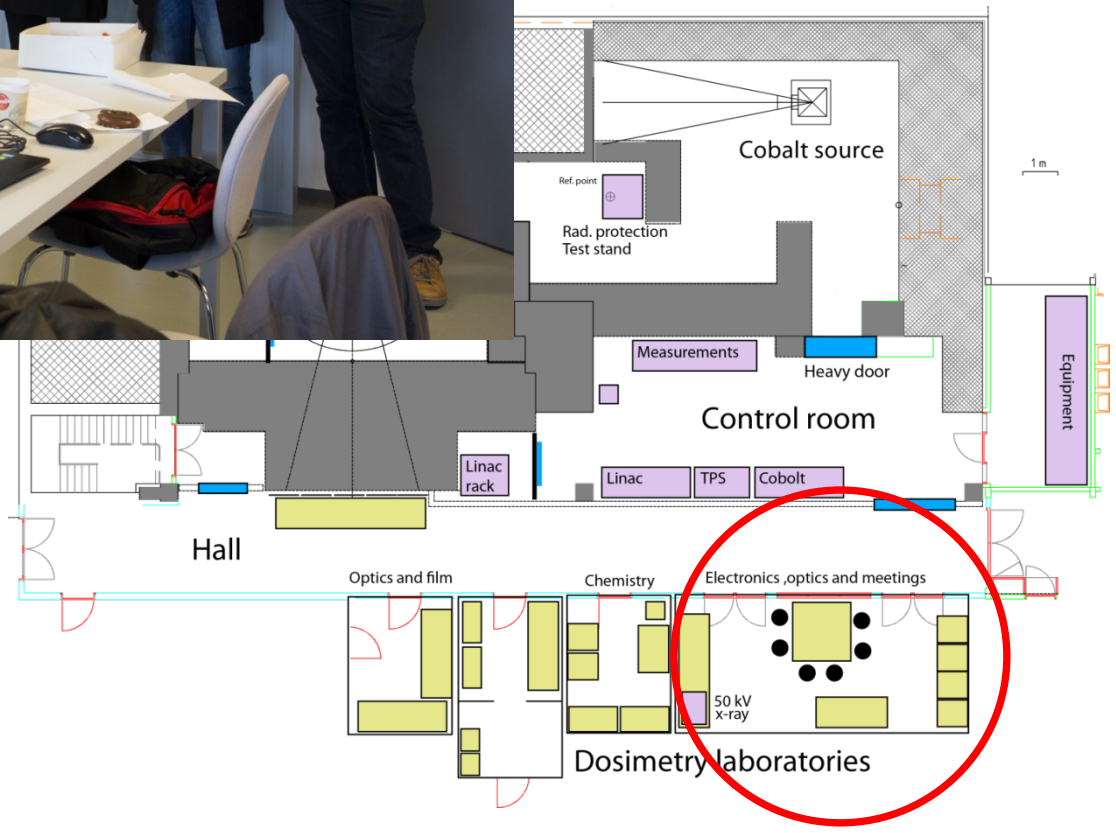




$$D = \int_{T_{\mathrm{cut}}}^{\infty} \Phi_T \frac{S_{\mathrm{col}}(T)}{\rho} k_{\mathrm{col}}(T)\, dT$$

The DTU Nutech course "Medical Radiation Dosimetry" provides the theoretical and metrological background for measurement of radiation doses in radiotherapy, diagnostic radiology, and nuclear medicine. The five-day intensive course is based on the classic textbook by F.H. Attix and supplementary material.

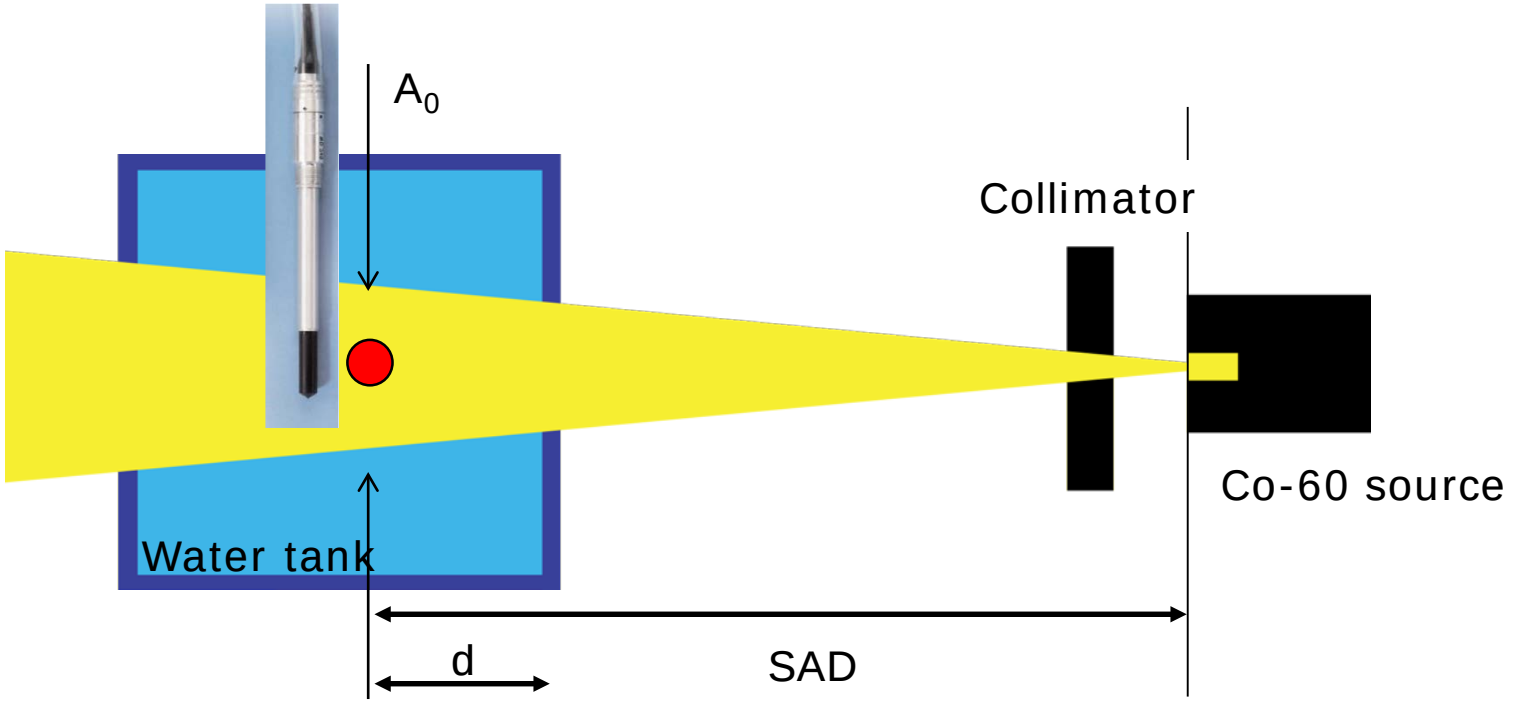
Platoon 6 (June 15-19, 2015)



Details about

the cobalt source calibration system

Absorbed dose to water calibration procedure



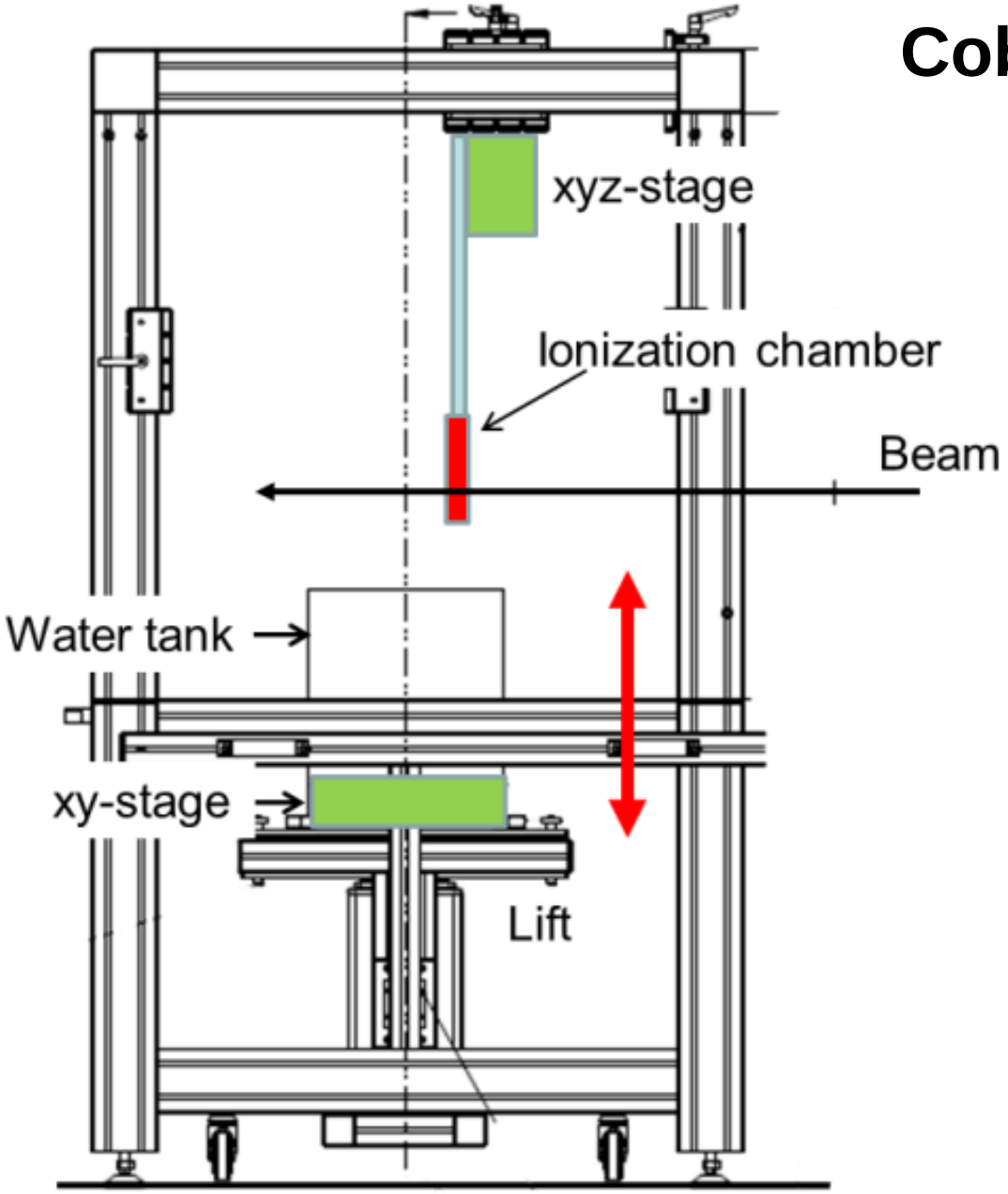
$d = 5\ g/cm^2$

$SAD = 100\ cm$

$A_0 = 10 \times 10\ cm^2$

Need cobalt to:
- calibrate one chamber against another (substitution method)
- calibrate chamber against standard

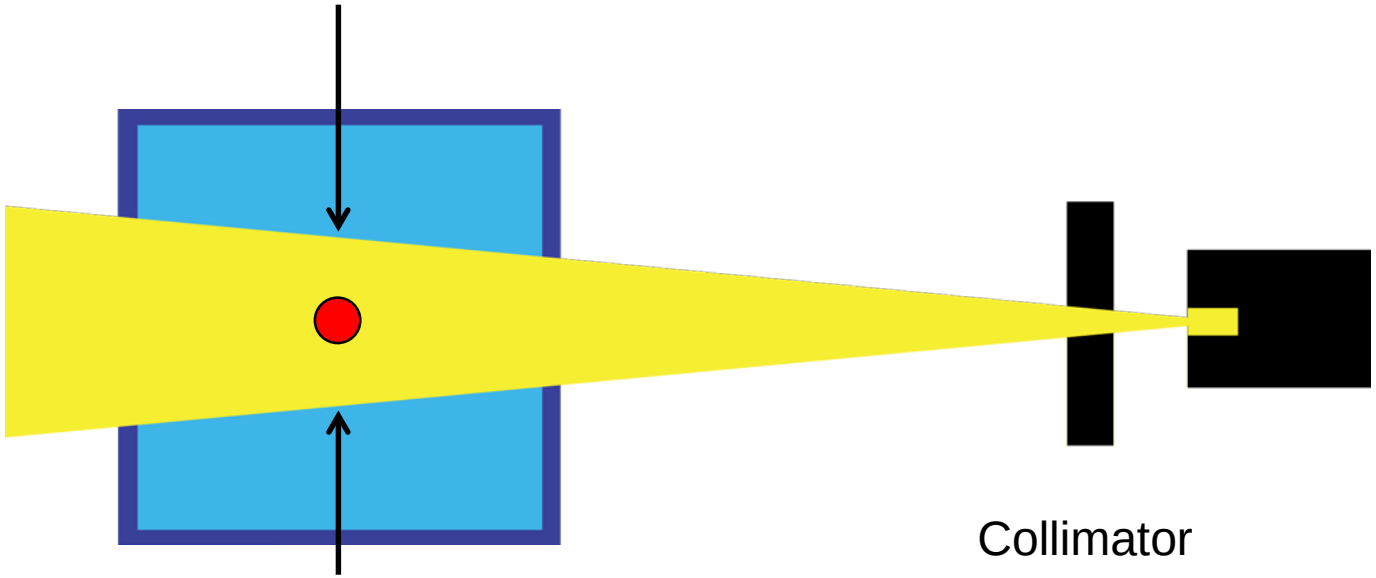
Cobalt calibration rig

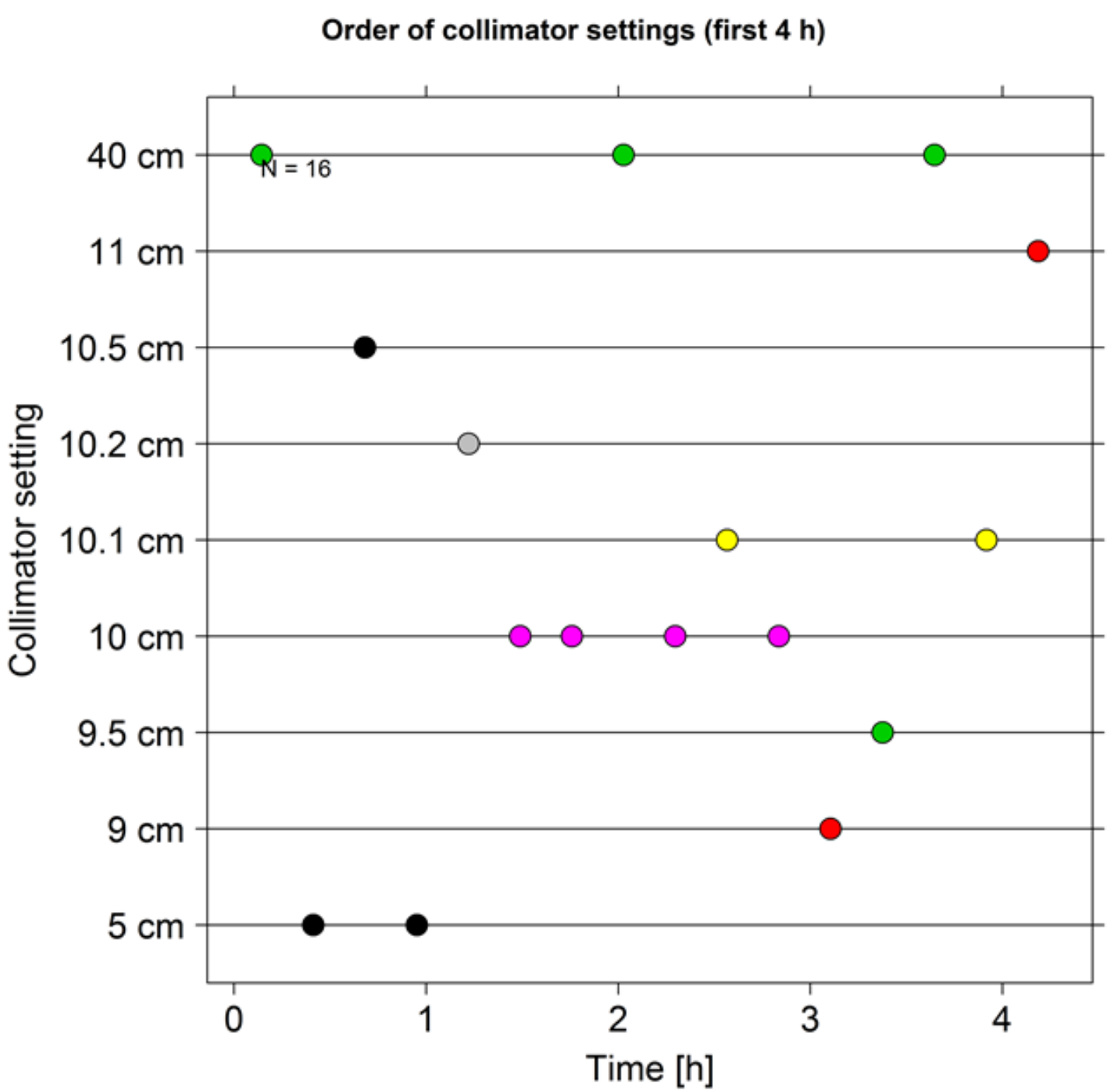


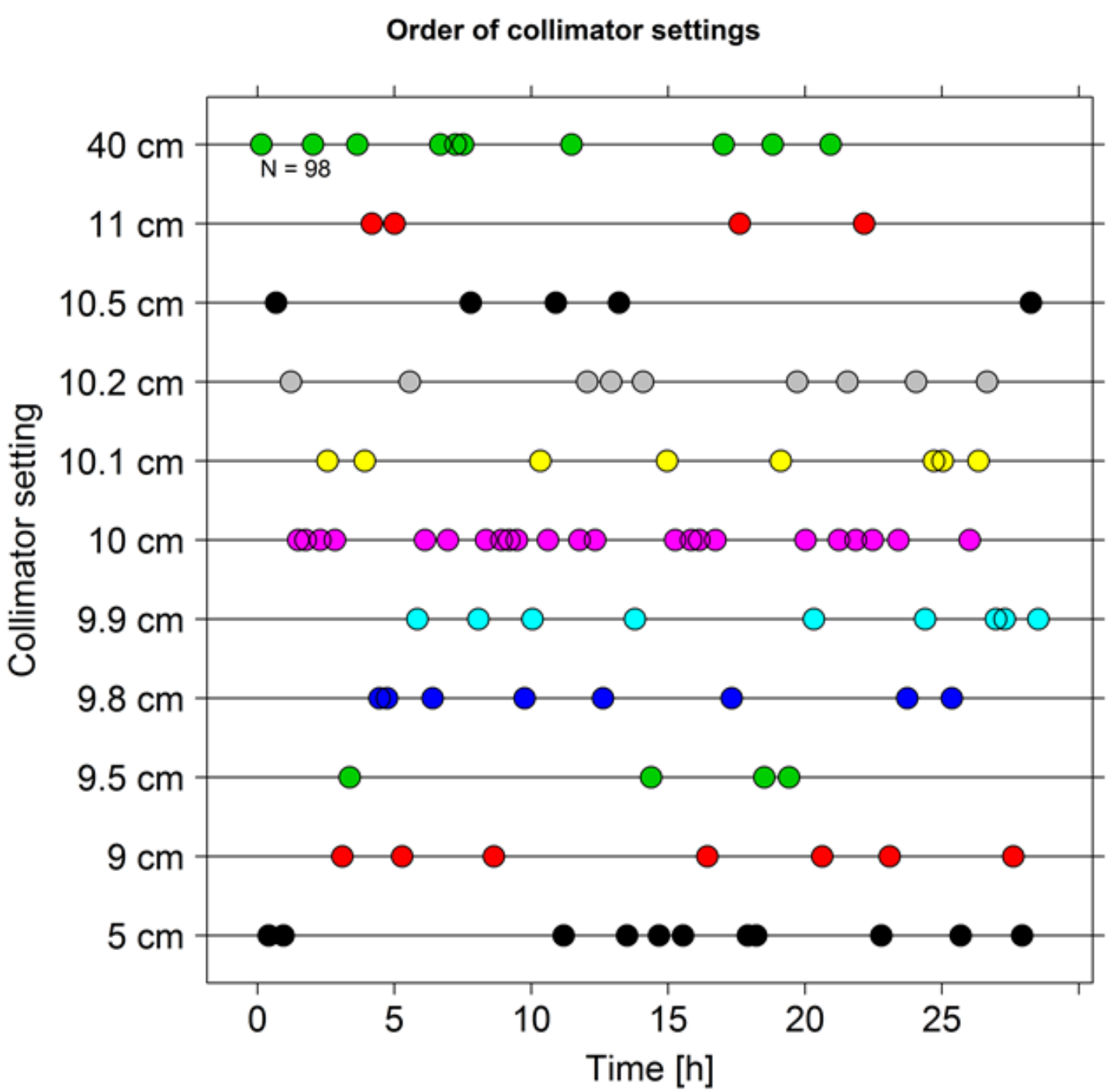

Alignment telescope

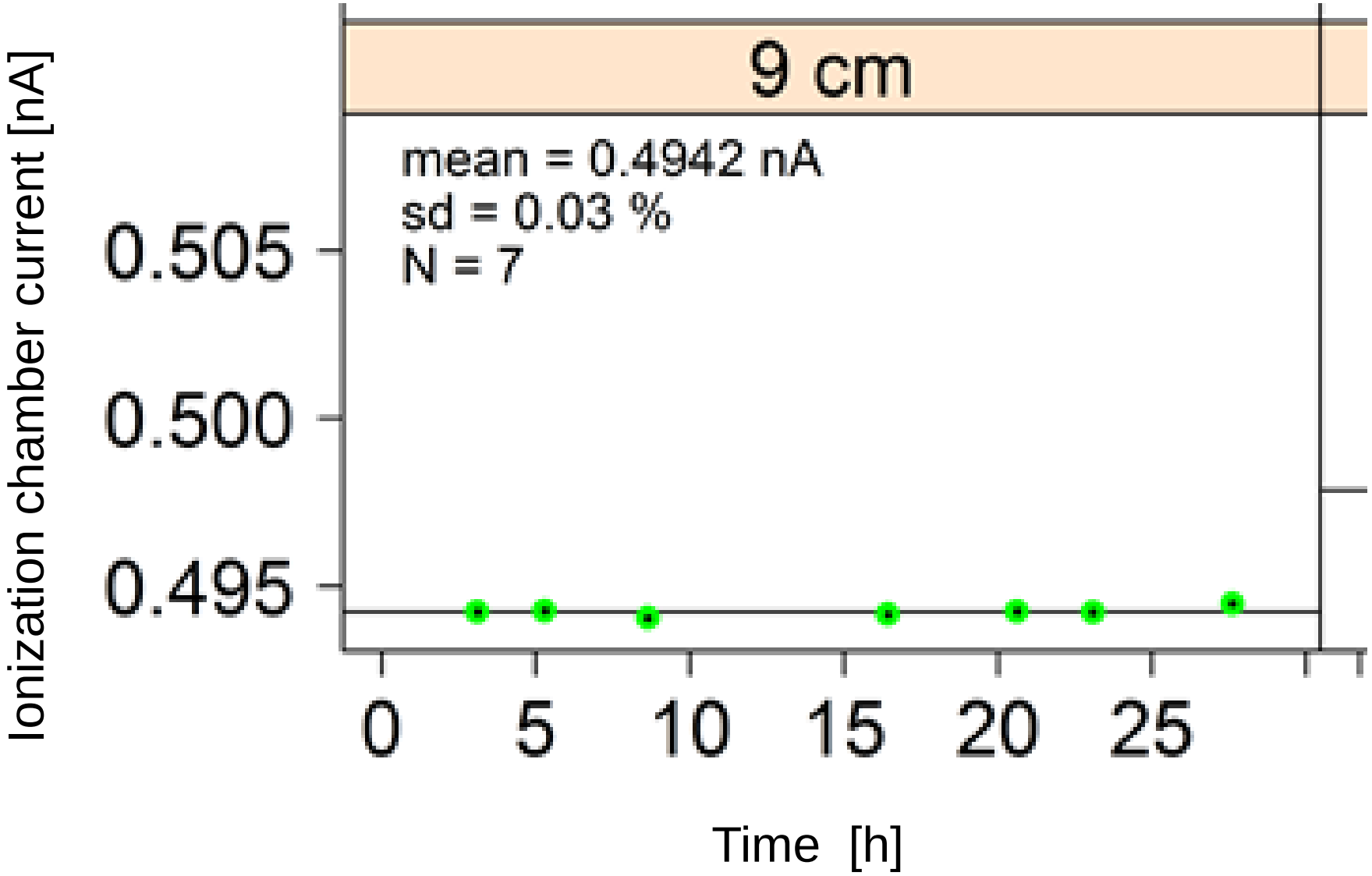
Characterizing the cobalt source (one example)

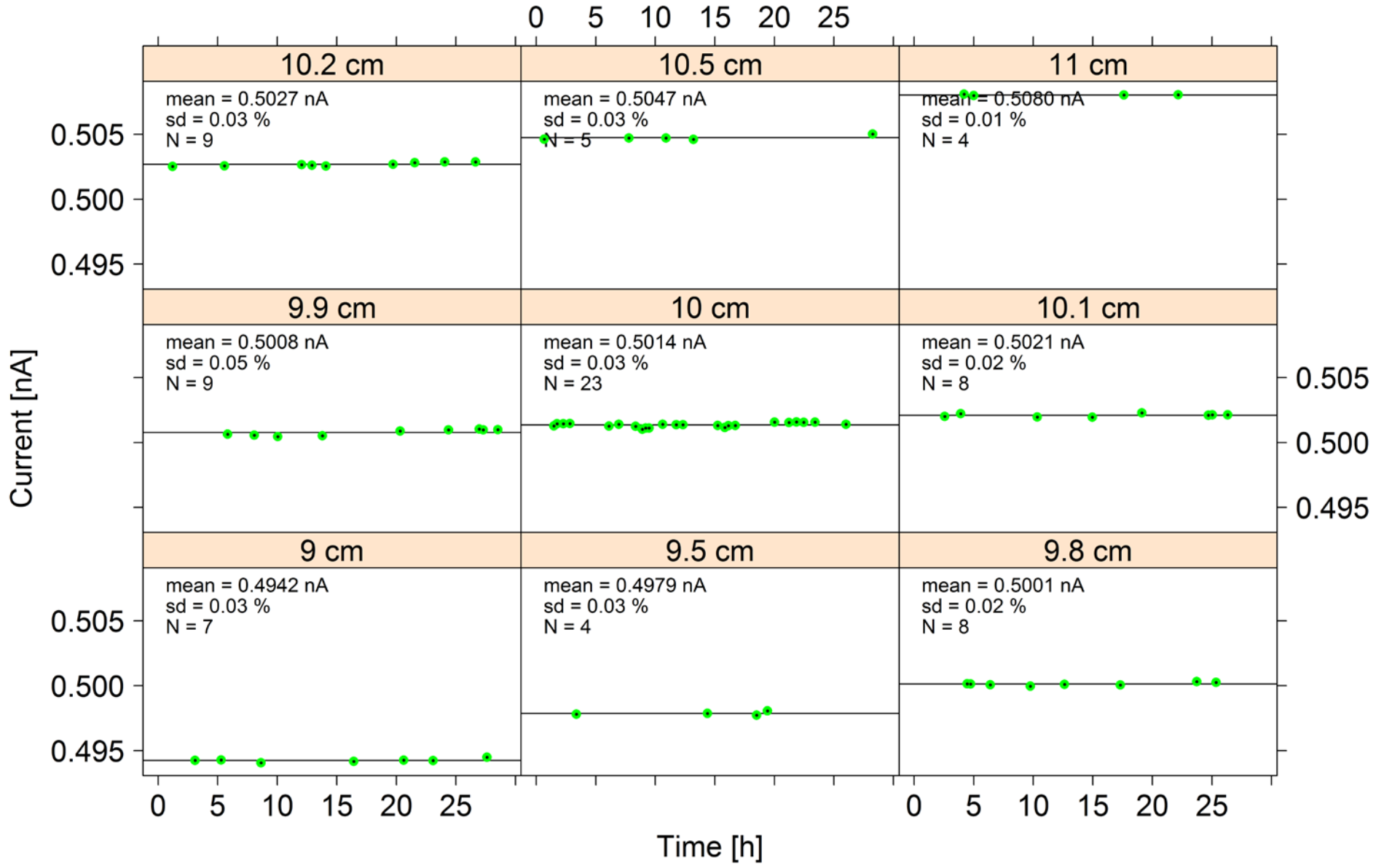
Collimator reproducibility



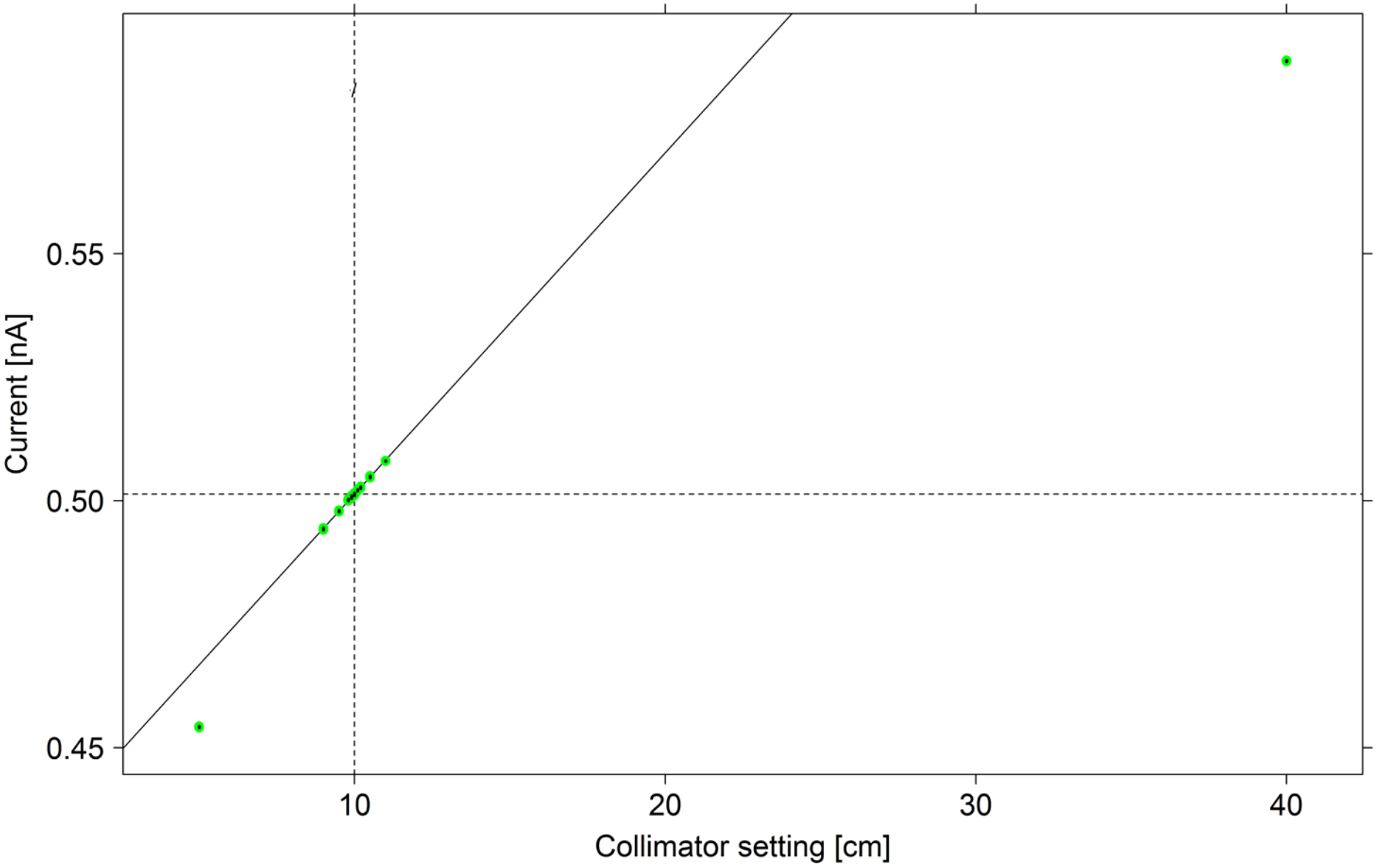

Order of collimator settings (first 4 h)
N = 16
40 cm
11 cm
10.5 cm
10.2 cm
10.1 cm
10 cm
9.5 cm
9 cm
5 cm
Collimator setting
0
1
2
3
4
Time [h]


Order of collimator settings
N = 98
40 cm
11 cm
10.5 cm
10.2 cm
10.1 cm
10 cm
9.9 cm
9.8 cm
9.5 cm
9 cm
5 cm
Collimator setting
0
5
10
15
20
25
Time [h]


9 cm
mean = 0.4942 nA
sd = 0.03 %
N = 7
0.505
0.500
0.495
0
5
10
15
20
25
Ionization chamber current [nA]
Time [h]


10.2 cm
mean = 0.5027 nA
sd = 0.03 %
N = 9
10.5 cm
mean = 0.5047 nA
sd = 0.03 %
N = 5
11 cm
mean = 0.5080 nA
sd = 0.01 %
N = 4
9.9 cm
mean = 0.5008 nA
sd = 0.05 %
N = 9
10 cm
mean = 0.5014 nA
sd = 0.03 %
N = 23
10.1 cm
mean = 0.5021 nA
sd = 0.02 %
N = 8
9 cm
mean = 0.4942 nA
sd = 0.03 %
N = 7
9.5 cm
mean = 0.4979 nA
sd = 0.03 %
N = 4
9.8 cm
mean = 0.5001 nA
sd = 0.02 %
N = 8
0 5 10 15 20 25
0.505
0.500
0.495
Current [nA]
Time [h]

Sensitivity coefficient: (0.14 +/- 0.01) % pr. mm



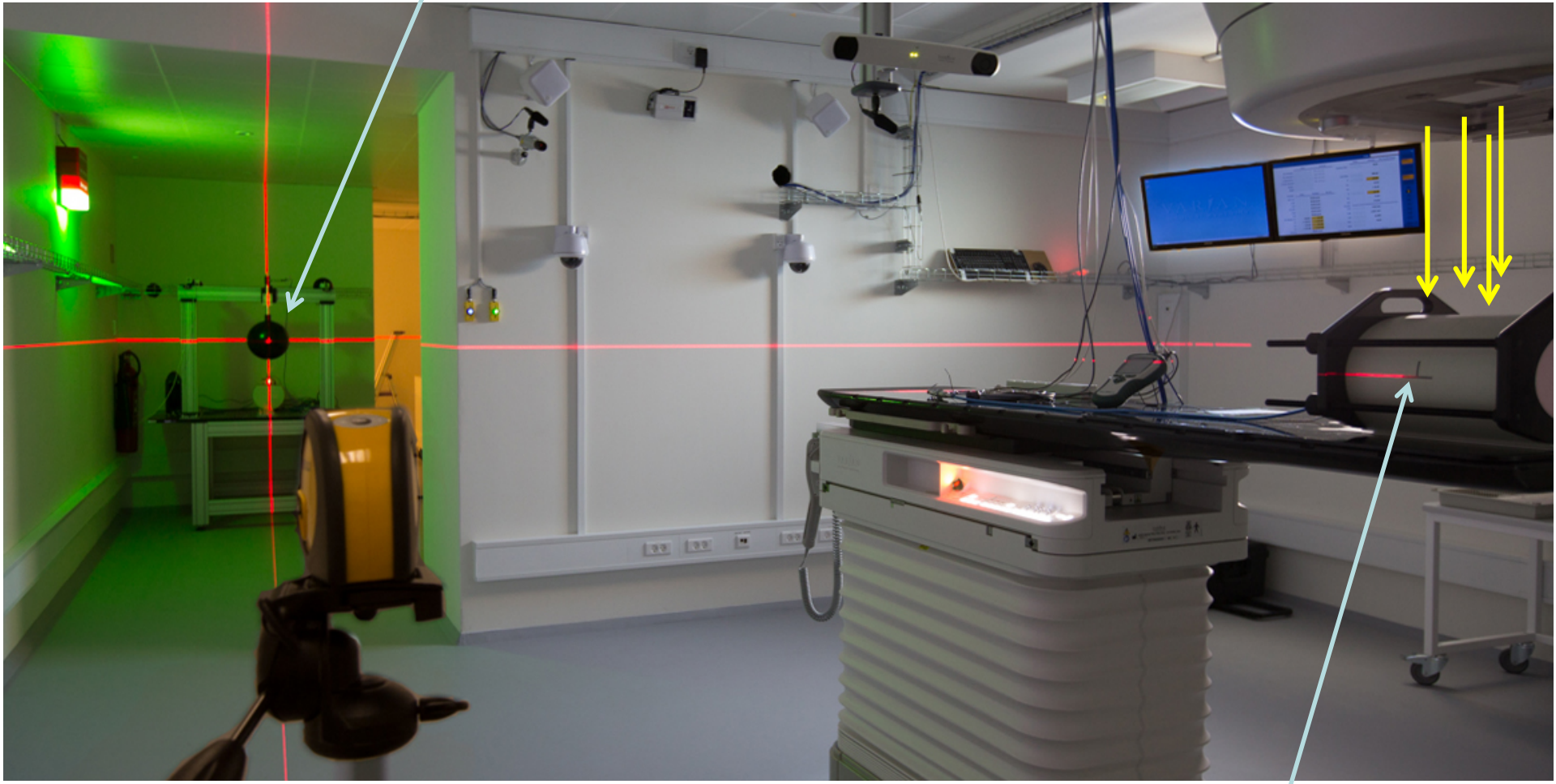
Radiation protection

in pulsed beams

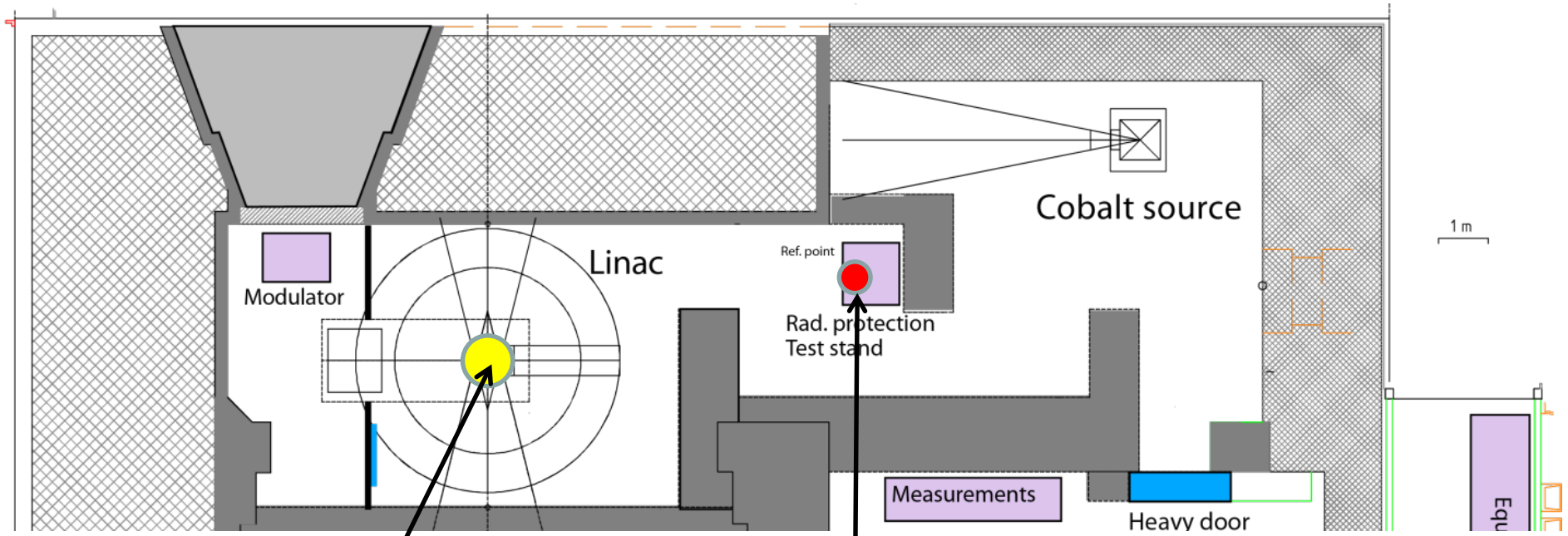
Motivations:
(1) NSFS
(2) previous experience
(3) no specification from manufacturer

Spherical ionization chamber

Accelerator



Phantom
(patient scatter)


Cobalt source
1 m
Linac
Ref. point
Modulator
Rad. protection
Test stand
Measurements
Heavy door
Linac iso-center
Reference point

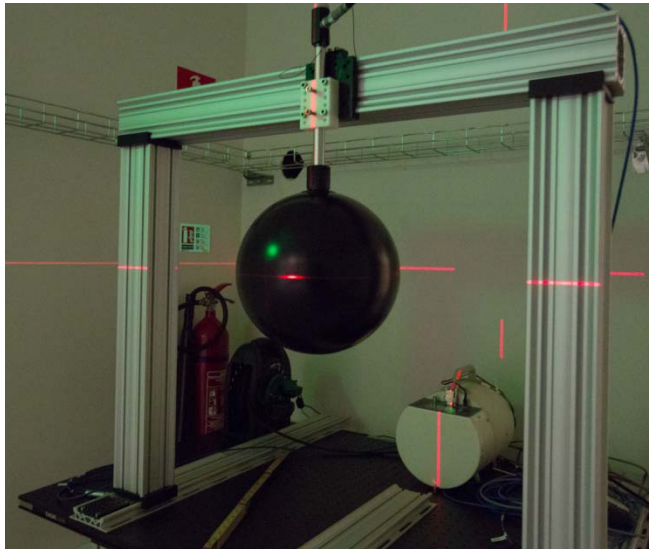


Table 1 Measurement results and standard uncertainties for the two spherical ionization chambers (1 L and 10 L) and the Ludlum 9DP* survey meter in scattered beams from the medical accelerator and the cobalt source at the reference position shown in Fig. 1 and 4. The phantom dose was measured with a thimble chamber.

Beam	Phantom dose Gy
4 MV	4.0
6 MV	8.5
10 MV	9.4
15 MV	9.8
18 MV	10.2
6 MV, FFF	8.0
10 MV, FFF	9.0
Cobalt-60	-

FFF = Flattening Filter Free

Table 1 Measurement results and standard uncertainties for the two spherical ionization chambers (1 L and 10 L) and the Ludlum 9DP* survey meter in scattered beams from the medical accelerator and the cobalt source at the reference position shown in Fig. 1 and 4. The phantom dose was measured with a thimble chamber.

Beam	Phantom dose Gy	Irradiation time s	Pulse width µs	Pulse-to-pulse ms	No. of pulses
4 MV	4.0	120	3.7	2.5	48.1×10^3
6 MV	8.5	120	3.7	3.3	36.0×10^3
10 MV	9.4	120	3.5	3.3	36.0×10^3
15 MV	9.8	120	3.2	6.7	18.0×10^3
18 MV	10.2	120	2.9	6.7	18.0×10^3
6 MV, FFF	8.0	150	4.4	4.9	30.9×10^3
10 MV, FFF	9.0	150	4.1	8.3	18.0×10^3
Cobalt-60	-	-	-	-	-

FFF = Flattening Filter Free

Time structure measured with ME40 + oscilloscope

Table 1 Measurement results and standard uncertainties for the two spherical ionization chambers (1 L and 10 L) and the Ludlum 9DP* survey meter in scattered beams from the medical accelerator and the cobalt source at the reference position shown in Fig. 1 and 4. The phantom dose was measured with a thimble chamber.

Beam	Phantom dose Gy	Irradiation time s	Pulse width µs	Pulse-to-pulse ms	No. of pulses	H*(10) 1 L µSv/h
4 MV	4.0	120	3.7	2.5	48.1×10^3	260 ± 30
6 MV	8.5	120	3.7	3.3	36.0×10^3	480 ± 50
10 MV	9.4	120	3.5	3.3	36.0×10^3	380 ± 40
15 MV	9.8	120	3.2	6.7	18.0×10^3	910± 100
18 MV	10.2	120	2.9	6.7	18.0×10^3	1600 ± 180
6 MV, FFF	8.0	150	4.4	4.9	30.9×10^3	240 ± 30
10 MV, FFF	9.0	150	4.1	8.3	18.0×10^3	180 ± 20
Cobalt-60	-	-	-	-	-	67 ± 7

FFF = Flattening Filter Free

Spherical chamber calibrated in Co-60 beam for air kerma, free in air converted to ambient dose equivalent H*(10) using a conversion coefficient of 1.2 Sv/Gy (reservation: energy spectrum and angular dependency).

Table 1 Measurement results and standard uncertainties for the two spherical ionization chambers (1 L and 10 L) and the Ludlum 9DP* survey meter in scattered beams from the medical accelerator and the cobalt source at the reference position shown in Fig. 1 and 4. The phantom dose was measured with a thimble chamber.

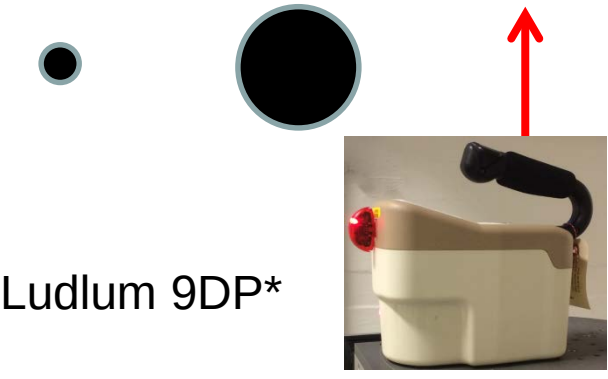
Beam	Phantom dose Gy	Irradiation time s	Pulse width µs	Pulse-to-pulse ms	No. of pulses	H*(10) 1 L µSv/h	H*(10) 10 L µSv/h
4 MV	4.0	120	3.7	2.5	48.1×10^3	260 ± 30	260 ± 30
6 MV	8.5	120	3.7	3.3	36.0×10^3	480 ± 50	500 ± 60
10 MV	9.4	120	3.5	3.3	36.0×10^3	380 ± 40	400 ± 40
15 MV	9.8	120	3.2	6.7	18.0×10^3	910± 100	930 ± 100
18 MV	10.2	120	2.9	6.7	18.0×10^3	1600 ± 180	1700 ± 180
6 MV, FFF	8.0	150	4.4	4.9	30.9×10^3	240 ± 30	250 ± 30
10 MV, FFF	9.0	150	4.1	8.3	18.0×10^3	180 ± 20	190 ± 20
Cobalt-60	-	-	-	-	-	67 ± 7	67 ± 7

FFF = Flattening Filter Free

Table 1 Measurement results and standard uncertainties for the two spherical ionization chambers (1 L and 10 L) and the Ludlum 9DP* survey meter in scattered beams from the medical accelerator and the cobalt source at the reference position shown in Fig. 1 and 4. The phantom dose was measured with a thimble chamber.

Beam	Phantom dose Gy	Irradiation time s	Pulse width µs	Pulse-to-pulse ms	No. of pulses	H*(10) 1 L µSv/h	H*(10) 10 L µSv/h	H*(10) 9DP* µSv/h
4 MV	4.0	120	3.7	2.5	48.1×10^3	260 ± 30	260 ± 30	240 ± 30
6 MV	8.5	120	3.7	3.3	36.0×10^3	480 ± 50	500 ± 60	440 ± 40
10 MV	9.4	120	3.5	3.3	36.0×10^3	380 ± 40	400 ± 40	330 ± 30
15 MV	9.8	120	3.2	6.7	18.0×10^3	910± 100	930 ± 100	770 ± 80
18 MV	10.2	120	2.9	6.7	18.0×10^3	1600 ± 180	1700 ± 180	1500 ± 150
6 MV, FFF	8.0	150	4.4	4.9	30.9×10^3	240 ± 30	250 ± 30	220 ± 20
10 MV, FFF	9.0	150	4.1	8.3	18.0×10^3	180 ± 20	190 ± 20	170 ± 20
Cobalt-60	-	-	-	-	-	67 ± 7	67 ± 7	62 ± 6

FFF = Flattening Filter Free

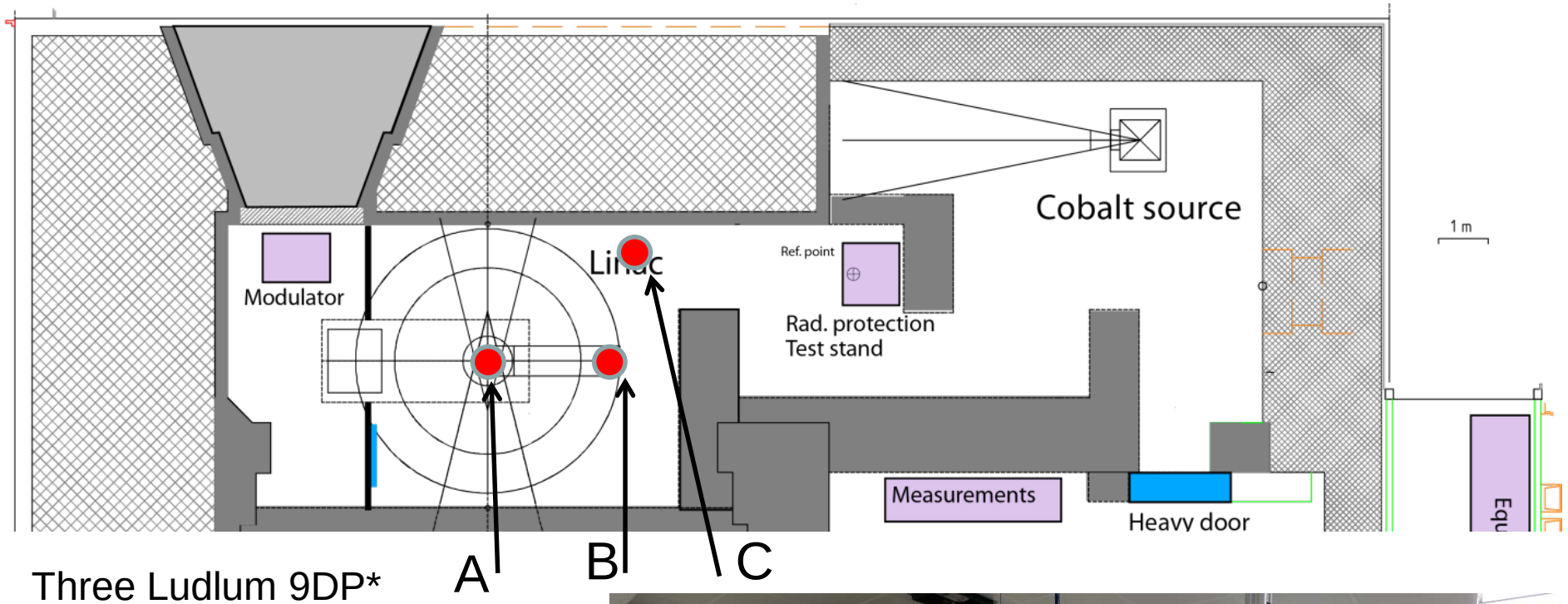


Ludlum 9DP*

Radiation protection

Dose rate around the accelerator after 4000 MU of 18 MV (40 Gy)

A somewhat unexpected result

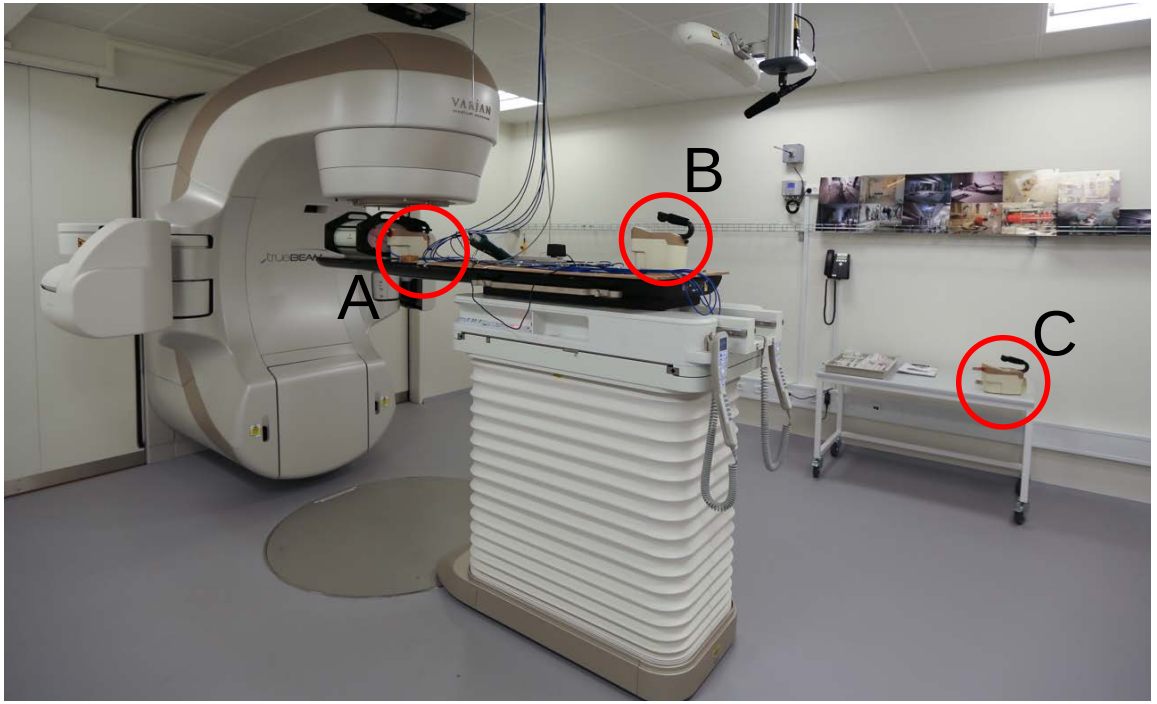


Three Ludlum 9DP*

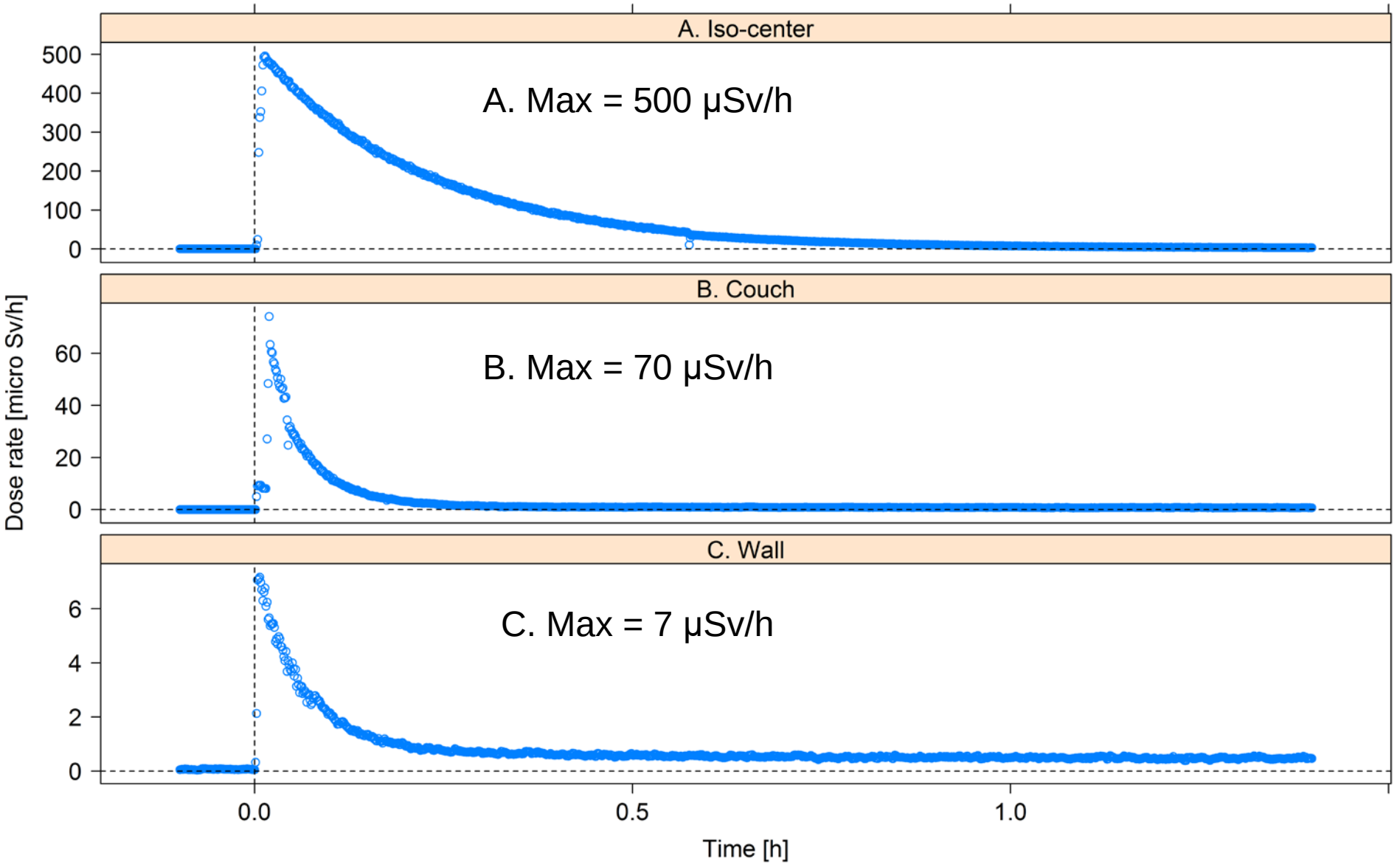
Datalogging
1 record pr. 5 s

Positioned after
beam stop

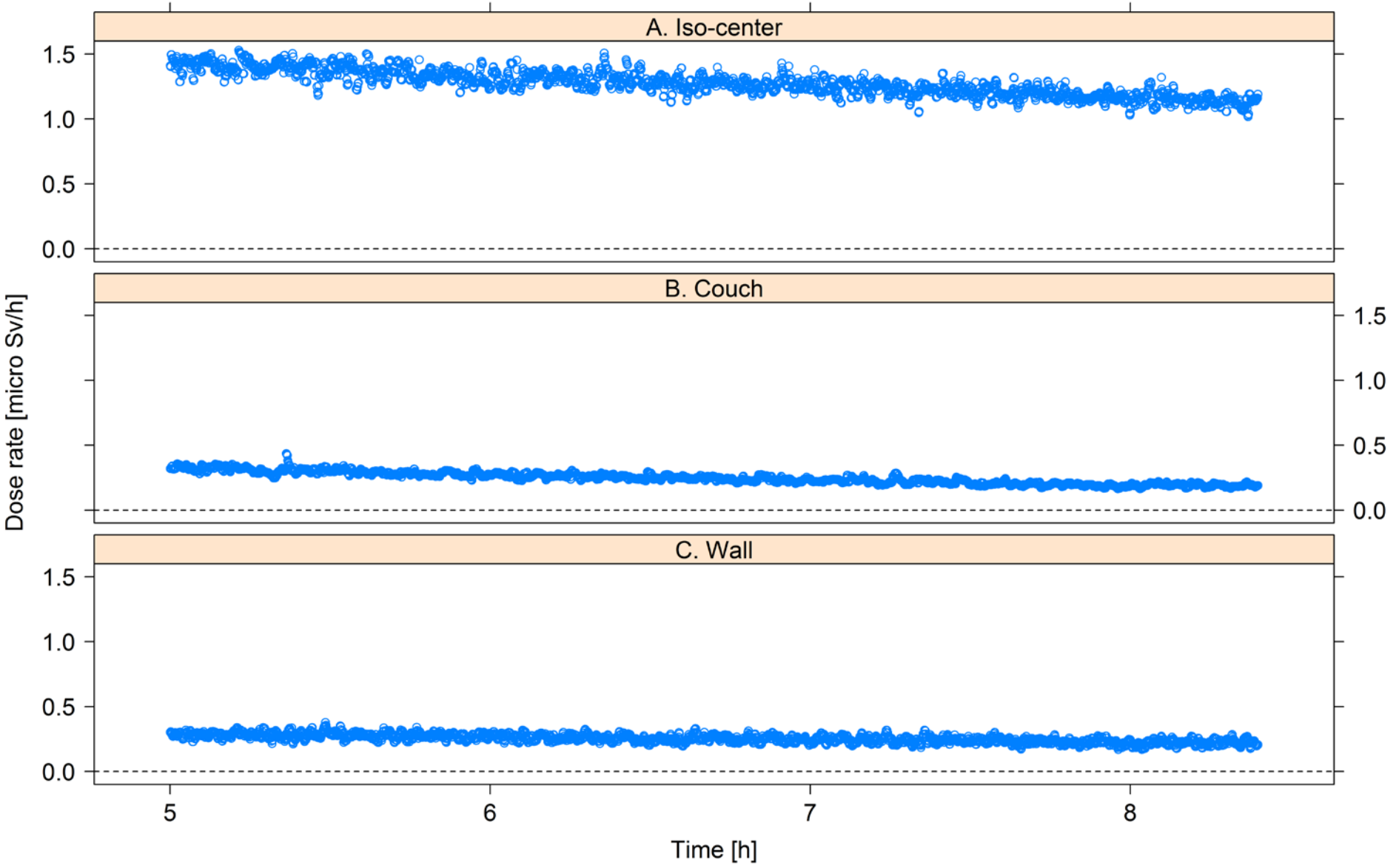
(i.e. instruments were not activated).



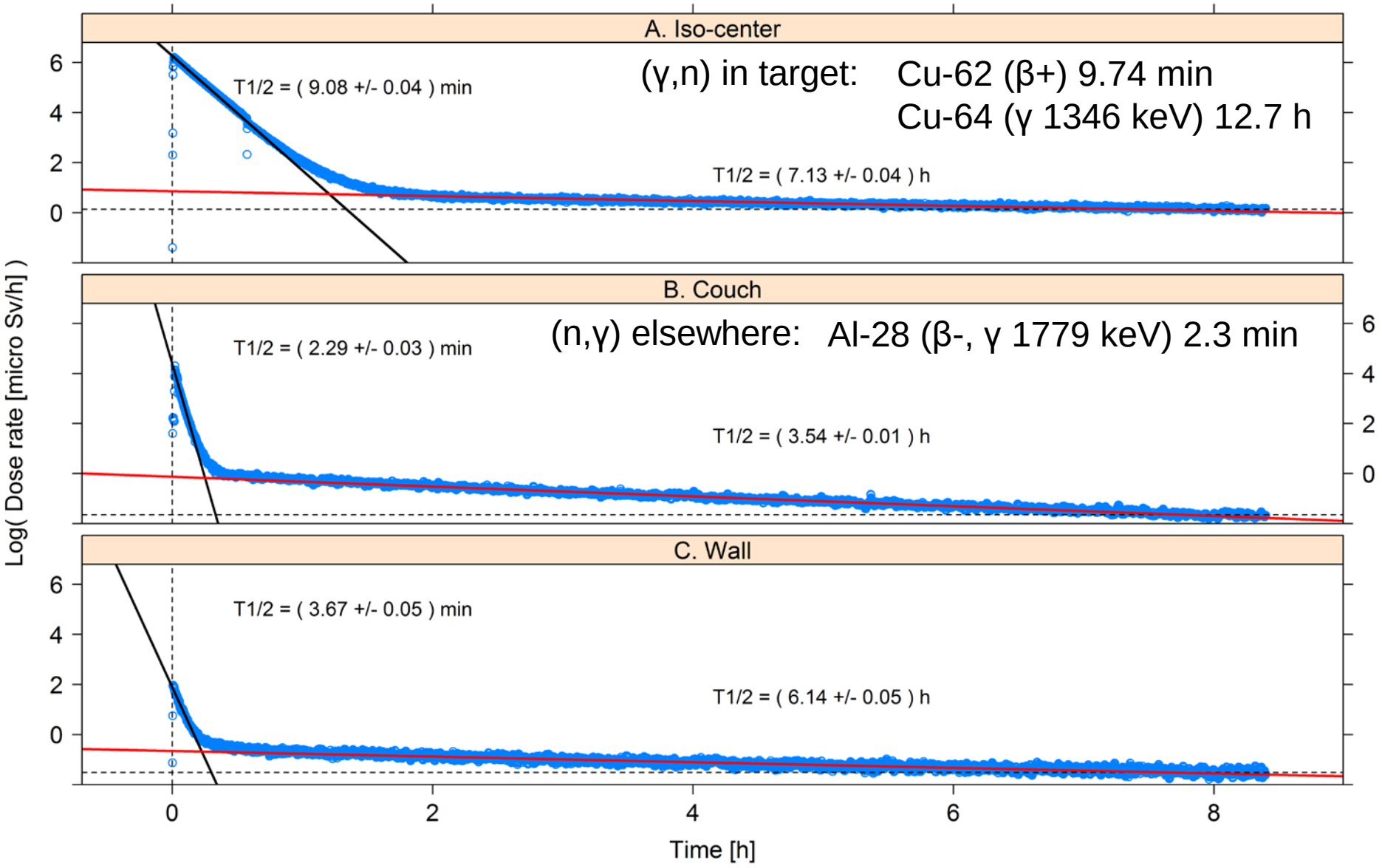
Dose rate around the accelerator after 4000 MU of 18 MV (initial 1.5 h)



Dose rate around the accelerator after 4000 MU of 18 MV (after 5 h)



Dose rate around the accelerator after 4000 MU of 18 MV (log scale)



Conclusions

- A laboratory for medical dosimetry has been established. Only few countries have similar facilities.
- Three types of research:
  (1) Detector projects, (2) Clinical projects, and
  (3) Calibration and standards (+ radiobiology).
- Showed: Automated cobalt calibration details
- Designed simple test stand for radiation prot. measurements in pulsed beams.
- Found relatively high dose rates due to induced activity after long 18 MV irradiations.