

CCRI(III)-S1:

Supplementary Comparison for the Calibration of Ambient Dose Equivalent (Rate) Meters in ISO Neutron Reference Fields

Technical Protocol

updated: October 2020 (time schedule and packing list)

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1. Introduction

The monitoring of neutron ambient dose equivalent (rate) is an important task in practical radiation protection, e.g., at nuclear power plants and in the nuclear industry. In practice, difficulties occur, e.g., unknown energy distributions of the neutron fields, demanding a careful interpretation of the instrument reading. A traceable calibration of the instruments used for this purpose at reference or standard test conditions is the basis for this task. Various national metrology institutes offer the calibration of neutron ambient dose equivalent (rate) dosimeters and are listed in the CMC table of the BIPM.

The quantity neutron ambient dose equivalent rate for radionuclide sources is calculated from the neutron source strength (neutron emission rate) of the sources. For the most common sources, ^{252}Cf and $^{241}\text{Am-Be}$, key comparisons for the source strength were successfully completed (CCRI(III)-K9.AmBe, CCRI(III)-K9.AmBe.1, CCRI(III)-K9.Cf-252), but up to now, no CCRI comparison for the quantity neutron ambient dose equivalent was conducted. Two local attempts were made, a Euromet comparison (EUROMET.RI(III)-S1) which was finished in 2007 without completing the original schedule and an APMP comparison (APMP.RI(III)-S1), finished successfully in 2012.

The response or calibration factor of a device is a unique property of the type of device, and may depend on the dose-equivalent rate, the neutron source spectrum or the angle of incidence of the neutrons, but should not be a function of the characteristics of the calibration facility or experimental techniques employed.

ISO 8529, parts 1 to 3, [1-3] recommends several radionuclide sources for the calibration of neutron ambient dose equivalent (rate) meters and describes procedures to correct for the influence of scattered neutrons.

The free-field fluence response, R_ϕ , of an instrument measuring a rate is given by

$$R_\phi = M_c / \phi , \quad (1.1)$$

with the measured reading corrected for all extraneous effects M_c and the fluence rate ϕ of the direct neutrons from the source to the point of test, calculated by $\phi = B_\Omega / l^2$ using the neutron angular source strength B_Ω (l being the distance from the source axis of symmetry to the point of test, see ISO 8529-2 [2]).

The proposed measurand is the calibration factor, N , obtained by (for an instrument measuring rate)

$$N = h_\phi \phi / M_c , \quad (1.2)$$

with the calibration factor N of the instrument at calibration conditions and the fluence-to-dose-equivalent conversion coefficient h_ϕ pertaining to the energy and angle distribution of the neutron fluence at the point of test.

The calibration procedure should follow the recommendations of ISO 8529, 1-3 [1-3], using those neutron reference fields of radionuclide sources available at the participating laboratory. The sources have to be characterized in terms of neutron

emission rate and anisotropy. The participants should follow the same procedure for correcting the influence of scattered neutrons (shadow object / distance variation) as they use for the calibration of devices of external customers.

2. Participants

The following laboratories agreed to participate:

Particip. No.	Institute	Country	Contact person	Contact person (e-mail)
1	PTB	Germany	Désirée Radeck	desiree.radeck@ptb.de
2	NPL	UK	Graeme Taylor	graeme.taylor@npl.co.uk
3	CMI	Czech Republic	Zdenek Vykydal	zvykydal@cmi.cz
4	CIEMAT	Spain	Roberto Méndez	roberto.mendez@ciemat.es
5	SMU	Slovak Republic	Pavol Blahušiak	blahusiak@smu.gov.sk
6	NMIJ	Japan	Akihiko Masuda	aki-masuda@aist.go.jp
7	KRISS	Korea	Jungho Kim	jungho@kriss.re.kr
8	NIM	China	Zhang Hui	zhanghui@nim.ac.cn
9	NIST	USA	Alan K. Thompson	akt@nist.gov
10	IRSN	France	Bruno Asselineau	bruno.asselineau@irsn.fr
11	VNIIM	Russia	Nikolay Moiseev	n.n.moiseev@vniim.ru
12	NRC	Canada	John Paul Archambault	johnpaularchambault@nrc-cnrc.gc.ca
13	NMISA	South Africa	Refuoe Peppenene	rpeppenene@nmisa.org
14	SCK/CEN	Belgium	Liviu-Cristian Mihailescu	lmihaile@sckcen.be
15	LNMRI/IRD	Brazil	Walsan Wagner Pereira	walsan@ird.gov.br

Full contact information is given in Appendix A. PTB will act as pilot laboratory and evaluate the results.

3. Schedule

Two transfer instruments will be circulated. In between the measurements at the participating laboratories, the stability of the transfer instruments will be checked at the pilot laboratory (PTB).

It is proposed to send the instruments first to the European participants. One month is scheduled for the calibration measurement. The following month is planned for

transport back to PTB, check of stability, and transport to the next participant. For the non-European participants, an additional month is added due to customs formalities but the stability tests at PTB are suspended during measurement periods at participants of one continent.

Start of the comparison **2017-11**

No.	Participant	Measurement at the participant	Transfer to next participant or to PTB	Report of the results to pilot
1	PTB, DE	2017-11		
	PTB*	2017-11	2017-11	
2	NPL, UK	2017-12	2018-01	2018-03
	PTB*	2018-02	2018-02	
3	CMI, CZ	2018-03	2018-03	2018-06
	PTB*	2018-04	2018-04	
4	CIEMAT, ES	2018-09	2018-09	2018-12
	PTB*	2018-10	2018-10	
5	SMU, SK	2018-11	2018-11	2019-02
	PTB*	2018-12	2019-02	
6	NMIJ, JP	2019-03	2019-04	2019-06
7	KRISS, KR	2019-05	2019-06	2019-08
8	NIM, CN	2019-07	2019-08	2019-10
	PTB*	2019-10	2019-09	
9	NIST, USA	2019-11	2020-01	2020-03
	PTB*	2020-07	2020-08	
10	IRSN, F	2020-09	2020-09	2020-12
	PTB*	2020-10	2020-10	
11	VNIIM, RU	2020-11	2020-12	2021-02
	PTB*	2021-01	2021-01	
12	NRC, CA	2021-02	2021-03	2021-05
	PTB*	2021-04	2021-05	
13	NMISA, ZA	2021-06	2021-07	2021-09
	PTB*	2021-08	2021-08	
14	SCK/CEN, BE	2021-09	2021-09	2021-12
	PTB*	2021-10	2021-10	
15	LNMRI/IRD, BR	2021-11	2021-12	2022-02
	PTB*	2022-01		
End of the comparison		2022-01		
Draft of Report		2022-07		
Comments of partners		2022-11		

* stability test

Any participant should inform the pilot laboratory as soon as possible if the scheduled procedure has to be changed. In case of delays of more than one month, the whole schedule might be changed in accordance with the availability of the calibration facilities of the participants. The pilot laboratory will cover the expenses for shipping

the equipment to the participants while the participants have to cover the costs of the return shipment or shipment to the next participant, respectively (for participant no. 7, 8, and 10). After arrival of the transfer instruments the participant should inform the pilot about the reception. Before dispatching the package for delivery to the pilot or next participating laboratory, the participant should inform the contact person of the pilot laboratory or contact person of the next participant giving transportation details. Information on dimensions, content, and weight of the transport containers are given in Appendix B.

4. Measurements

4.1. Quantity to be measured by the participants

The participants should determine the fluence response and calibration factor in terms of ambient dose equivalent for the two transfer instruments for the radionuclide neutron sources recommended by ISO 8529, part 1-3 [1-3] that are available at their laboratory. The operation of the instruments is briefly described in Appendix C. The fluence responses (eq. 1.1) and calibration factors (eq. 1.2) should be determined for one direction of incidence as defined in Appendix C.

4.2. Neutron reference fields

ISO 8529 recommends the following neutron reference fields for the calibration of neutron area dosimeters:

- ^{252}Cf
- $^{241}\text{Am-Be}$
- $^{252}\text{Cf}(\text{D}_2\text{O moderated})$
- $^{241}\text{Am-B}$

Each laboratory should determine the fluence response and calibration factor for the ISO recommended sources they have available, at least for those for which CMC entries exist. For rarer sources like $^{241}\text{Am-B}$, $^{241}\text{Am-F}$, $^{241}\text{Am-Li}$, and $^{238}\text{Pu-Be}$, values for the fluence response and calibration factor should be provided as well and the results will be included if at least two participants will do so.

4.3. Transfer instruments

The comparison will be performed with two identical transfer instruments, two SmartREMs, manufactured by FST (Freiberger Sensortechnik).

- 1) SmartREM: REM 004 15
SmartDisplay: SMD 009 15
SMC2100: MCA 010 15

- 2) SmartREM: REM 005 12
SmartDisplay: SMD 011 12
SMC2100: MCA 012 12

Handling and usage advice is given in Appendix C.

The pilot laboratory (PTB) will determine the fluence response and calibration factor for both devices at the beginning of the comparison. Before and after the calibration measurements of the participants, the stability of the reading of the devices will be checked with a small $^{241}\text{Am-Be}$ source which can be positioned in a geometrically reproducible position next to the transfer instruments.

4.4. Reports from the participants

The participants should prepare a detailed report about the calibration procedure and the results. The report should contain at least:

- Date and place of calibration.
- Description of the calibration room (size, position of the source in the room, reference point, ...).
- Description of the neutron sources used:
 - ^{252}Cf source, $^{241}\text{Am-Be}$, $^{241}\text{Am-B}$, $^{241}\text{Am-F}$, $^{241}\text{Am-Li}$, $^{238}\text{Pu-Be}$:
Source strength and anisotropy factor with uncertainty, source of traceability, size and geometry of the neutron source.
 - $^{252}\text{Cf}(\text{D}_2\text{O})$ moderated source:
Source strength of the ^{252}Cf source, diameter of the moderator, thickness of housing, drawing of the moderator (if available), information about H/D ratio in heavy water, thickness of Cd shell.
- Details of the reference conditions, calibration conditions, and/or standard test conditions.
- Description of the calibration procedure and geometry.
- Method used for the correction for scattered neutrons.
- Description of shadow objects (size, shape) if used and fitting procedures applied.
- Fluence responses R_ϕ (eq. 1.1) determined for the two transfer instruments in the neutron fields available. (Please note that the reading M_c is given in $\mu\text{Sv/h}$ (not in s^{-1}) so that the unit of the fluence response R_ϕ will not be cm^2 but an artificial “ $\mu\text{Sv cm}^2$ ”.)
- Fluence-to-dose-equivalent conversion factors h_ϕ used with their uncertainties.
- Calibration factors N (eq. 1.2) in terms of $H^*(10)$ determined for the two transfer instruments and the neutron fields available.
- List of uncertainties considered.

Uncertainties should be calculated in accordance with the “Guide to Uncertainty in Measurement” (GUM) [4] for a coverage factor of $k = 1$.

The report is to be sent to the pilot laboratory at the latest three months after finishing the measurements.

5. Evaluation and Publication of the Results

The participants are asked to determine the fluence response R_ϕ and calibration factor N in terms of ambient dose equivalent for the two transfer instruments for the reference neutron fields available and used in routine service at their laboratory.

For the comparison, the calibration factors reported by the participants will be evaluated by the pilot laboratory. Since the evaluation of uncertainties is not uniform and differs for the participants and to avoid bias due to small uncertainties, the arithmetic mean will be used for the determination of the reference values [5].

As there are two transfer instruments, the single value for each participant and the supplementary comparison reference value (SCRV) have to be derived by combining the results obtained for the two instruments in every specific neutron field. This procedure was already used in a similar way in CCRI(III)-K1 [6] and CCRI(III)-K8 [7]. Should one instrument fail during the stability test or not be operational anymore only one value will be evaluated and the procedure described below will be simplified.

In a first step the reference value \bar{N}_j for the calibration factor of each transfer instrument j ($j=1,2$) is calculated by $\bar{N}_j = \frac{1}{n} \sum_{i=1}^n N_{i,j}$. For each participant i the deviation for each transfer instrument is calculated by $\bar{x}_{i,j} = \frac{N_{i,j}}{\bar{N}_j}$. A single value \bar{x}_i for each participant i is derived by averaging the two results $\bar{x}_i = \frac{1}{2} \sum_{j=1}^2 \bar{x}_{i,j}$. The supplementary comparison reference value \bar{x} for the specific neutron field is then $\bar{x} = 1$.

From the SCR and the specified uncertainties, the degree of equivalence (DoE) will be calculated.

Since the pilot laboratory will also participate in the comparison, the report of the pilot will be sent to the BIPM before the participants send their report to the pilot laboratory. The pilot laboratory will inform the participants about the date when it has sent its report to the BIPM.

The Draft A report on the comparison will be sent by the pilot laboratory to the participants for correction of any typographical or transcription errors (at this stage the report is confidential to participants). Once the final version of the Draft A report has been agreed by the participants, it will be renamed the Draft B report and will be circulated to the CCRI for approval. Once approved, the Draft B report will become the Final Report which will be entered into the Key Comparison Data Base (KCDB) and published in Metrologia (short summary and results).

6. References

- [1] International Standard ISO 8529-1 *Reference neutron radiations: Characteristics and methods of production* (2001).
- [2] International Standard ISO 8529-2 *Reference neutron radiations: Calibration fundamentals of radiation protection devices related to the basic quantities characterizing the radiation field* (2000).
- [3] International Standard ISO 8529-3 *Reference neutron radiations: Calibration of area and personal dosimeters and determination of their response as a function of neutron energy and angle of incidence* (1998).
- [4] JCGM 100:2008 *Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement*, www.bipm.org.
- [5] G. Ratel, *Evaluation of the uncertainty of the degree of equivalence*, Metrologia 42 140-144 (2005).
- [6] D.J. Thomas, V.E. Lewis, H. Klein, P.J. Allisy-Roberts, *International Key Comparison of 24 keV Neutron Fluence Measurements (1993-2009) – CCRI(III)-K1*, Metrologia 47 Tech. Suppl. 06014 (2010).
- [7] R. Nolte, R. Böttger, J. Chen, H. Harano, D.J. Thomas, *International Key Comparison of Thermal Neutron Fluence Measurements - CCRI(III)-K8*, Metrologia 52 Tech. Suppl. 06011 (2015).

7. Appendix

A) Full contact information of the participants

Participant	Institute	Address	Contact person
1	PTB	Physikalisch-Technische Bundesanstalt (PTB) Department 6.4 Neutron Radiation Bundesallee 100 38116 Braunschweig Germany Phone: +49 531 592 6401	Désirée Radeck desiree.radeck@ptb.de +49 531 592 6427 Sven Koch sven.koch@ptb.de +49 531 592 6541
2	NPL	National Physical Laboratory Hampton Road, Teddington, Middlesex, TW11 0LW United Kingdom Phone: +44 20 8943 7087	Graeme Taylor graeme.taylor@npl.co.uk
3	CMI	Czech Metrology Institute Okružní 31, 638 00 Brno Czech Republic Phone: +420 266 020 299 Fax: +420 266 020 466 Shipping address: Czech Metrology Institute Radiová 1a, 102 00 Praha 10 Czech Republic	Zdenek Vykydal zvykydal@cmi.cz
4	CIEMAT	CIEMAT Laboratorio de Patronos Neutrónicos (E31.P1.11) Av. Complutense 40 28040 Madrid Spain Phone: +34 91 346 0811	Roberto Méndez roberto.mendez@ciemat.es
5	SMU	Slovenský Metrologický Ústav (SMÚ) Karloveská 63 842 55 Bratislava Slovak Republic Phone: +421260294282 Fax: +421265429592	Pavol Blahušiak blahusiak@smu.gov.sk
6	NMIJ	National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology (NMIJ-AIST) Address: 1-1-1 Umezono, Tsukuba, Ibaraki Country: Japan Phone: +81-29-861-5565 Fax: +81-29-861-5673	Akihiko Masuda aki-masuda@aist.go.jp

Participant	Institute	Address	Contact person
7	KRISS	Korea Research Institute of Standards and Science 267 Gajeong-ro, Yuseong-gu, Daejeon 34113 Country: Rep. of Korea Phone: +82-42-868-5788 Fax: +82-42-868-5671	Jungho Kim jungho@kriss.re.kr
8	NIM	National Institute of Metrology P. R. China No.18, Bei San Huan Dong Lu, Chaoyang Dist, Beijing, P.R.China Country: China Phone:+86-10-64525006 Fax:+86-10-64214927	Zhang Hui zhanghui@nim.ac.cn
9	NIST	National Institute of Standards and Technology 100 Bureau Dr., Stop 8461 Gaithersburg, MD 20899 USA Phone: 1-301-975-4666 Fax: 1-301-926-1604	Alan K. Thompson akt@nist.gov
10	IRSN	IRSN/PSE-SANTE/SDOS/LMDN Cadarache, Bat 159 BP3 F-13115 Saint Paul Lez Durance France Phone:+33(0)442199700	Bruno Asselineau Bruno.asselineau@irsn.fr
11	VNIIM	D.I.Mendelejev Institute for Metrology 19, Moskovsky Pr. St. Petersbyrg 190005 Russian Federation +7 812 323 96 14 +7 812 713 01 14	Nikolay Moiseev n.n.moiseev@vniim.ru
12	NRC	National Research Council Canada 1200 Montreal Road, Building M35 Ottawa, Ontario, K1A 0R6 Canada Phone: 613-993-2715 x252 Fax: 613-952-9865	John Paul Archambault JohnPaul.Archambault@nrc- cnrc.gc.ca
13	NMISA	National Metrology Institute of South Africa CSIR Campus Meiring Naude Road Brummeria South Africa Phone: +27 12 841 2190 Fax: +27 12 841 4458	Refuoe Pepenene rpepenene@nmisa.org

Participant	Institute	Address	Contact person
14	SCK/CEN	SCK-CEN / Laboratory for Nuclear Calibrations (LNK) Boeretang 200, B-2400 Mol Belgium Phone: +32 14 33 23 89 or +32 14 33 2005	Liviu-Cristian Mihailescu lmihaille@sckcen.be
15	LNMRI/IRD	IRD - Instituto de Radioproteção e Dosimetria LN - Laboratório de Metrologia de Nêutrons Av. Salvador Allende, s/n - Barra da Tijuca 22783-127 - Rio de Janeiro – RJ Brazil Phone:+55 21 2173-2870 Fax: +55 21 2173-2709	Walsan Wagner Pereira walsan@ird.gov.br

B) Details on transport containers

Two packages will be sent with the following dimensions and weights:

a) Large aluminium box

- dimensions: 80 cm x 60 cm x 40 cm
- weight: 41 kg
- main content: SmartREMs

b) Small box

- dimensions: 40 cm x 40 cm x 40 cm
- weight: 7.5 kg
- main content: stand

c) Detailed packing list

Item No.	Description
1	SmartREM SN 005 12 with MCA SMC 2100 SN MCA 012 12
2	SmartDisplay SN C4 SMD4 011 12
3	Connecting cable from Display to MCA
4	Connecting cable for battery supply
5	Connecting cable for data transmission
6	Power supply
7	Power cable
8	Source holder
9	Stand
10	SmartREM SN 004 15 with MCA SMC 2100 SN MCA 010 15
11	SmartDisplay SN C4 SMD4 009 15
12	Connecting cable from Display to MCA
13	Connecting cable for battery supply
14	Connecting cable for data transmission
15	Power supply
16	Power cable
17	All-aluminium-Box (78 x 58 x 41) cm
18	Aluminium-pressboard-box
19	Aluminium-pressboard-box
20	Aluminium-film-coated-plywood-box
21	Manual



Item 1, 2, 3, 4, 5, 6, 7, 19



Item 10, 11, 12, 13, 14, 15, 16, 18



Item 8, 9



Item 17, 20, 21

C) Instructions for the use of the equipment provided by the pilot laboratory

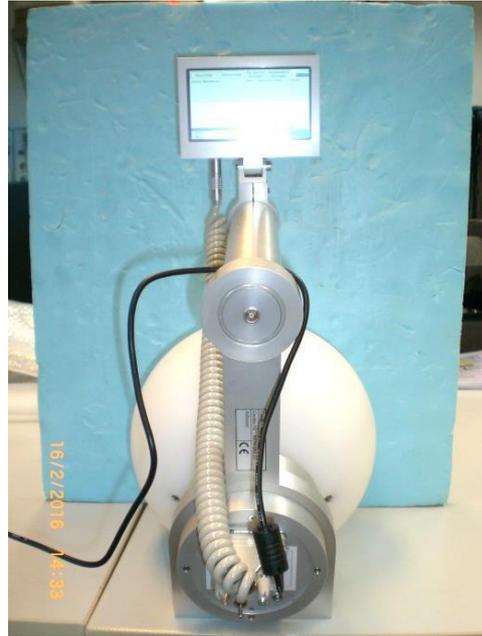
a) Equipment provided by the pilot laboratory

- 1 SmartREM with Display
- 2 Connecting cable from Display to MCA
- 3 Connecting cable for battery supply
- 4 Power supply
- 5 Cable for data transmission



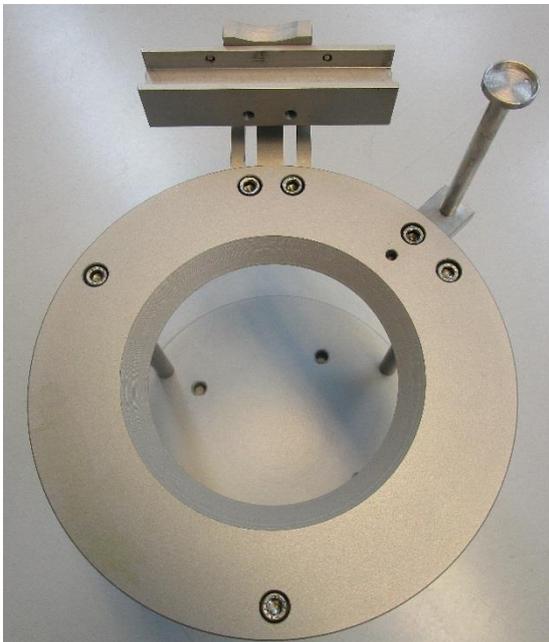
Powered by batteries

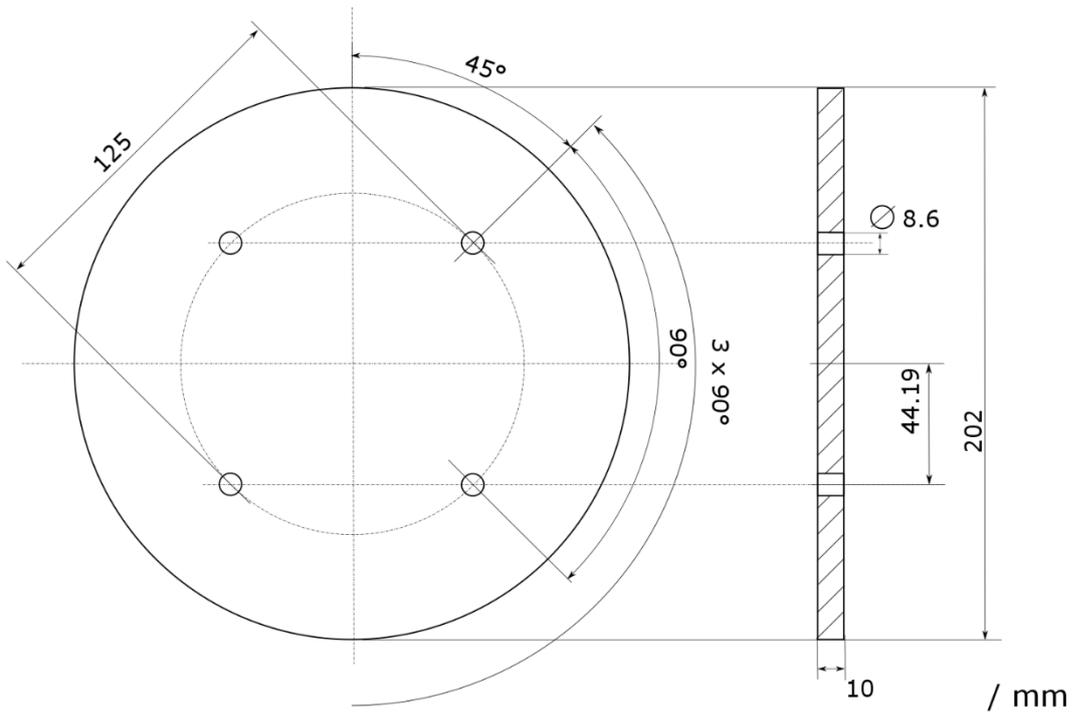
Powered by power supply



A stand is provided as well:

Radius:	101 mm
Height:	170 mm
Height of SmartREM reference point above stand bottom:	252.5 mm





b) Description of reference conditions for the calibration

Reference point:

The centre of the moderator sphere (diameter 208 mm) is defined as the reference point of the instrument.

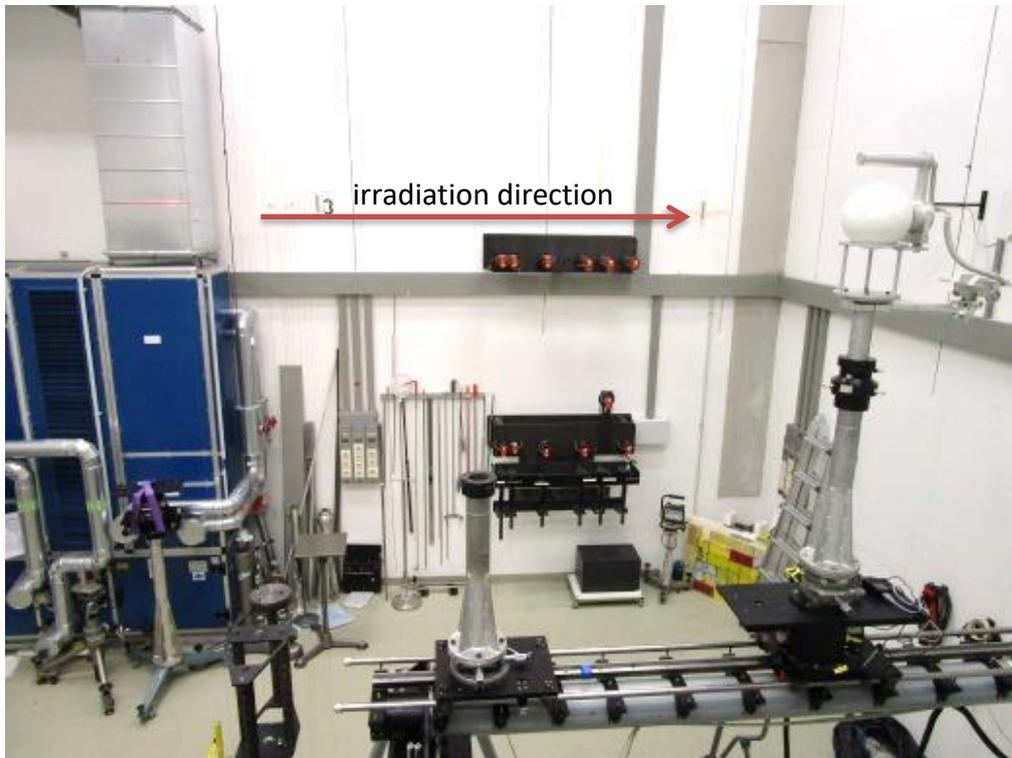


Relative to the irradiation direction (direction of incidence, from source to instrument) the electronics should be placed behind the moderator sphere.



Bare source:

Picture for illustrating the neutron irradiation geometry of the SmartREM with the bare $^{241}\text{Am-Be}(\alpha,n)$ source or ^{252}Cf source (viewed from an angle of 90° relative to the direction of incidence).



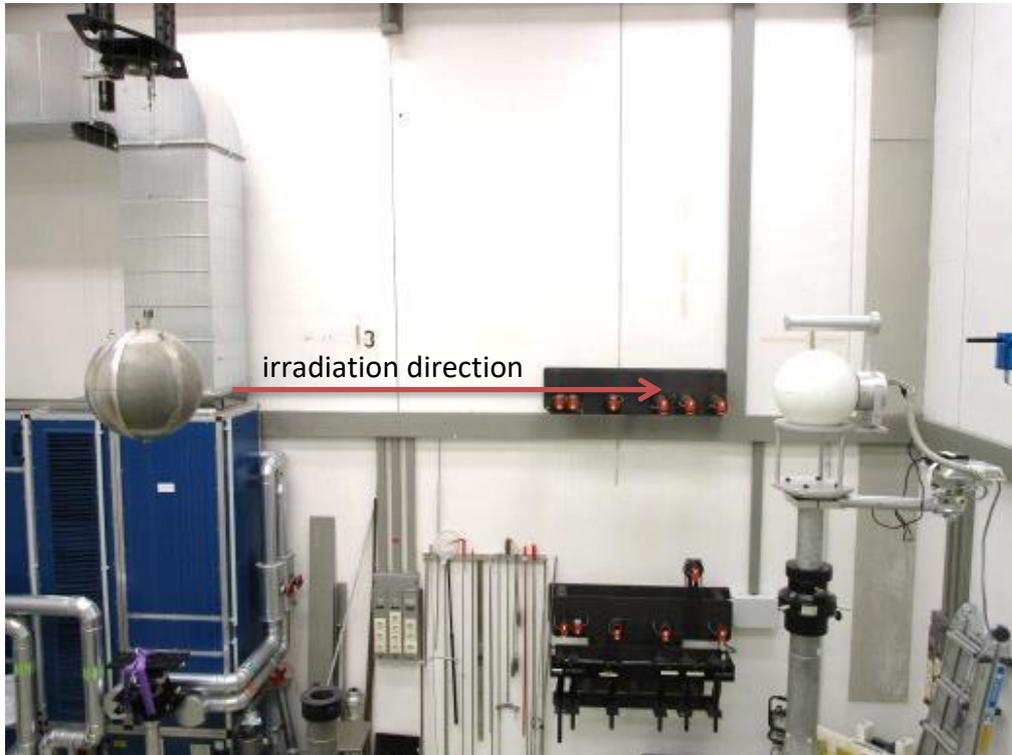
Shadow cone with bare source:

Picture for illustrating the neutron irradiation geometry of the SmartREM with the bare $^{241}\text{Am-Be}(\alpha,n)$ source or ^{252}Cf source behind shadow cone.



Moderated source:

Picture for illustrating the neutron irradiation geometry of the SmartREM with the $^{252}\text{Cf}(\text{D}_2\text{O mod, 1 mm Cd})$ source (viewed from an angle of 90° relative to the direction of incidence).



Shadow object with moderated source:

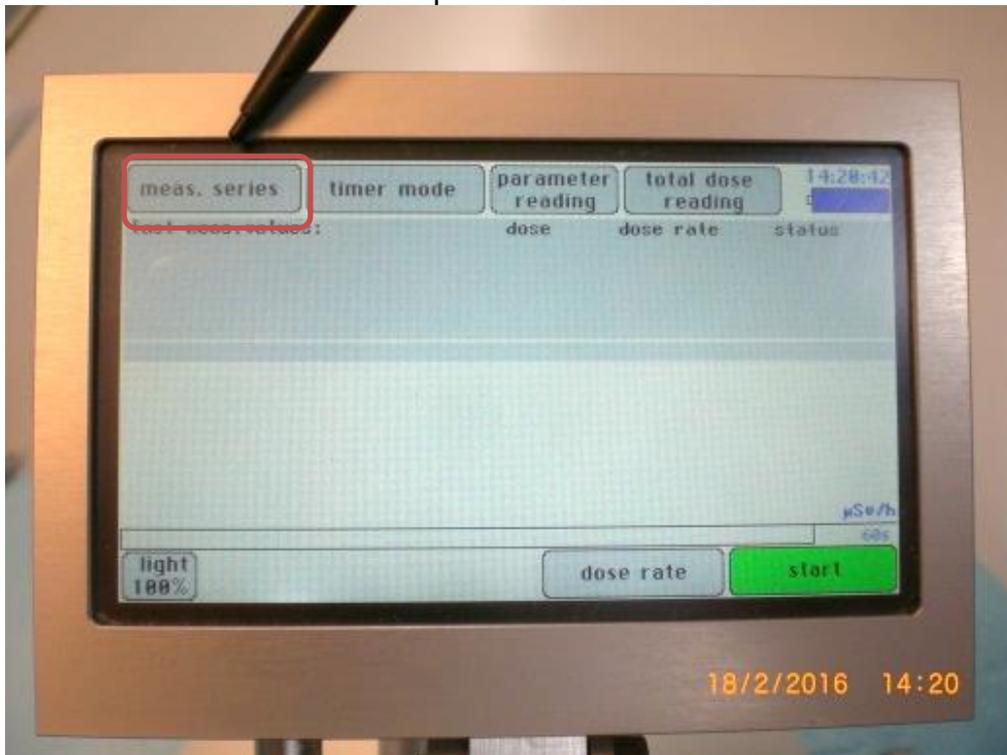
Picture for illustrating the neutron irradiation geometry of the SmartREM with the $^{252}\text{Cf}(\text{D}_2\text{O mod, 1 mm Cd})$ source behind shadow block.



c) Setup of the instrument

Measurement type “*meas. series*”:

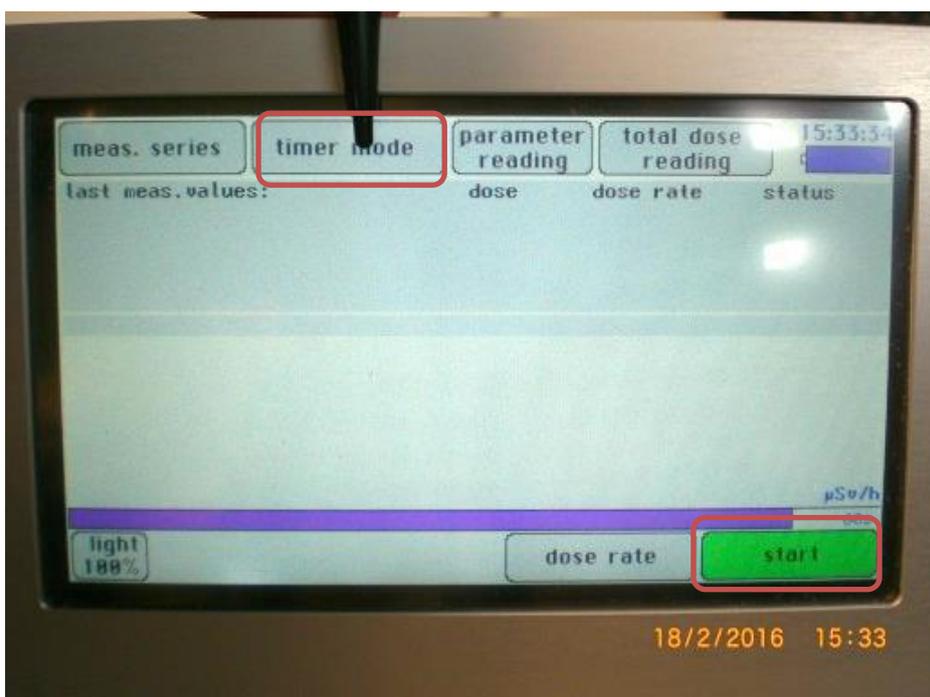
Touch the left button on the top line to select *meas. series*.



Measurement mode “*timer mode*”:

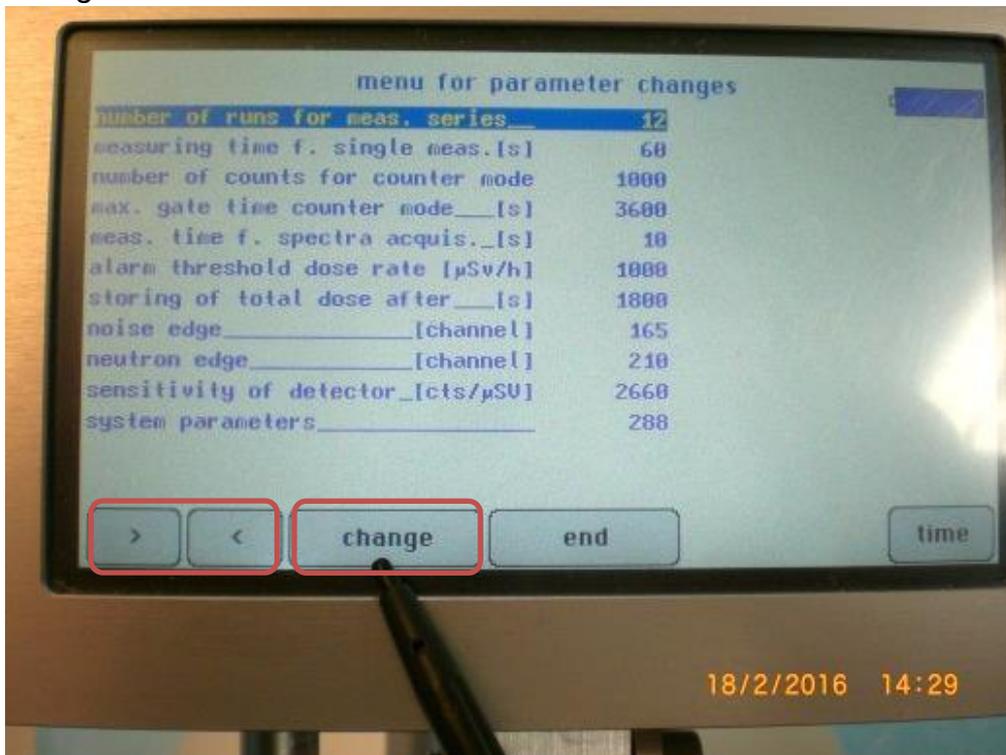
Touch the second button from the left on the top line to select *timer mode*.

In this mode the parameter *measuring time f. single meas.[s]* can be adjusted.



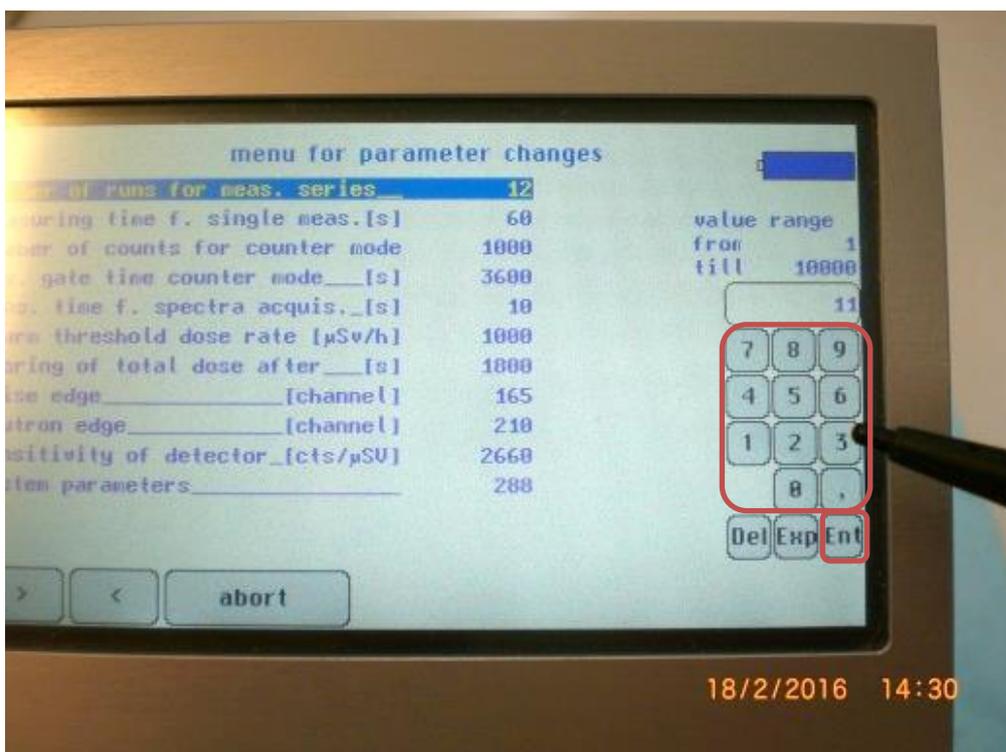
Menu for parameter changes:

The menu for parameter changes appears by choosing *parameter reading*. Select the parameter from the list and adjust it by touching the ">" or "<" sign and finish by touching *change*.



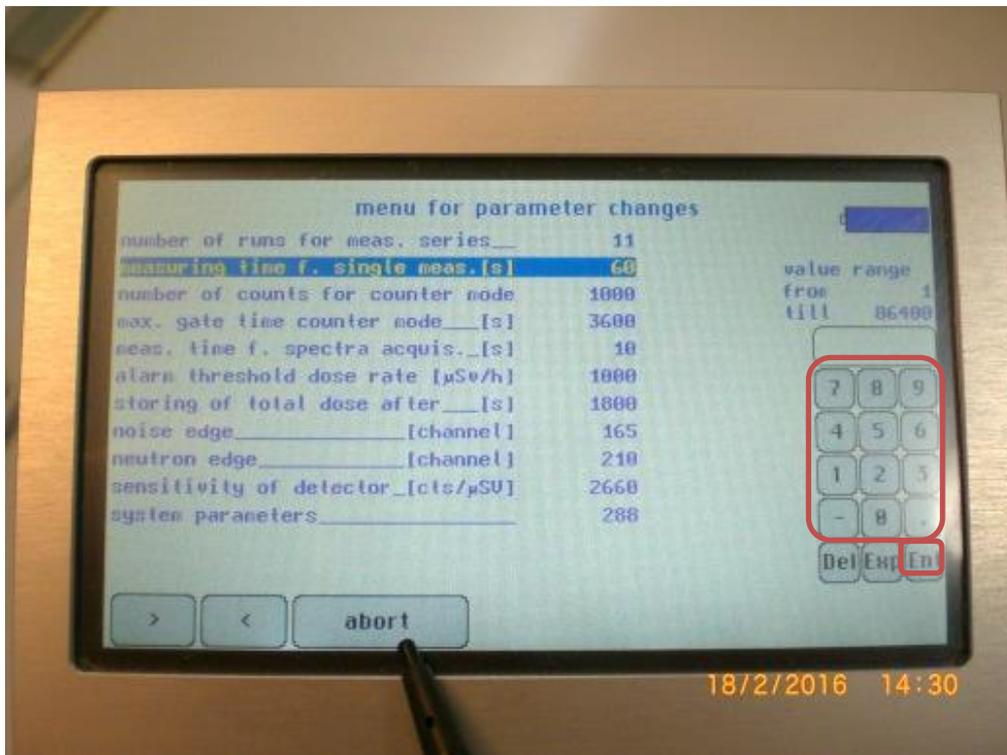
Adjustment of *number of runs for meas. series*:

Enter how often the measurement with the *measuring time f. single meas.[s]* is to be repeated. Submit with enter (*Ent*).



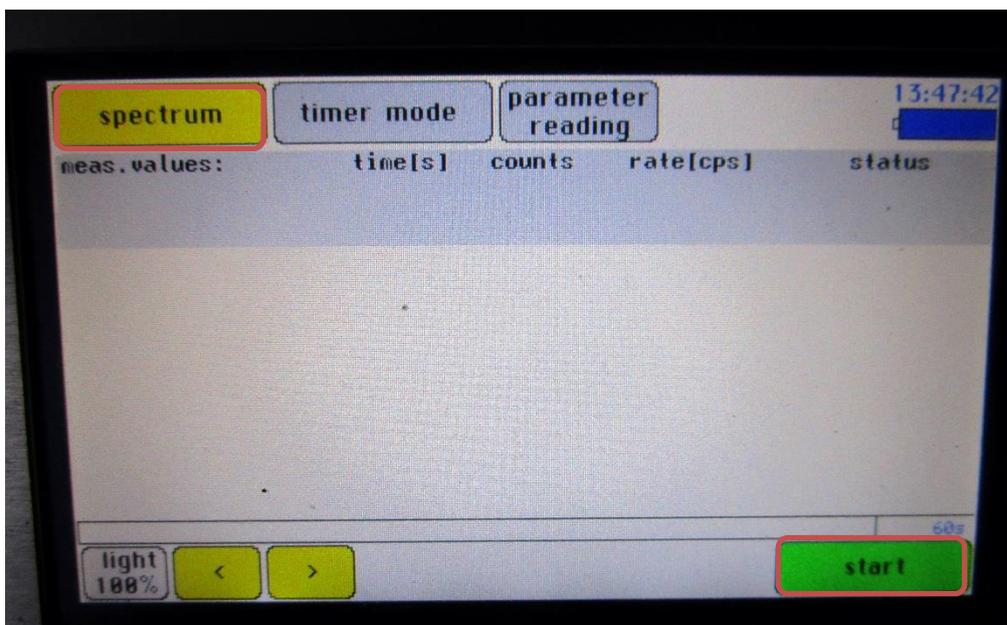
Adjustment of *measuring time f. single meas.[s]*:

Enter the length of the measurement as the *measuring time f. single meas.[s]*. Submit with enter (*Ent*).



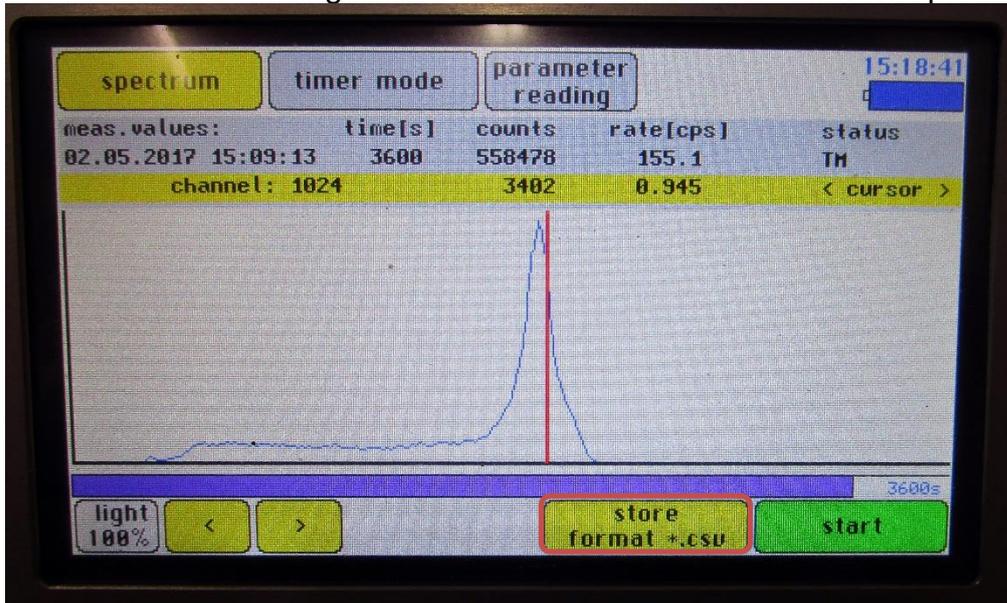
Measurement type *spectra acquis.*:

Touch the left button on the top line to select the type of measurement. Touch the right button on the bottom line to confirm the chosen mode.



Storage of the spectrum:

Touch the second to right button on the bottom line to store the spectrum.



The SmartDisplay can be connected with a free USB port of a PC/Notebook.



You can find the stored files on the SmartREM at the path removable disc (E:)

\SMARTREMMR130227.CSV

SmartREM with SMC-MCA	SMC_MCA
Version 1.70 of 03.04.2012	012_12
	V2.10 15.03.2012

no.	date	meas. value	unit	meas. value	unit	meas. time [s]	status
134	27.02.2013 00:18	0.005	uS	0.005	v	3600	TM-
135	27.02.2013 01:18	0.002	uS	0.002	v	3600	TM-
136	27.02.2013 02:18	0.003	uS	0.003	v	3600	TM-
137	27.02.2013 03:18	0.005	uS	0.005	v	3600	TM-
138	27.02.2013 04:18	0.003	uS	0.003	v	3600	TM-
139	27.02.2013 05:18	0.005	uS	0.005	v	3600	TM-
140	27.02.2013 06:18	0.004	uS	0.004	v	3600	TM-
141	27.02.2013 07:18	0.003	uS	0.003	v	3600	TM-
142	27.02.2013 08:18	0.002	uS	0.002	v	3600	TM-
143	27.02.2013 09:18	0.008	uS	0.008	v	3600	TM-
144	27.02.2013 10:18	0.001	uS	0.001	v	3600	TM-

SMARTREM\SE000038.CSV

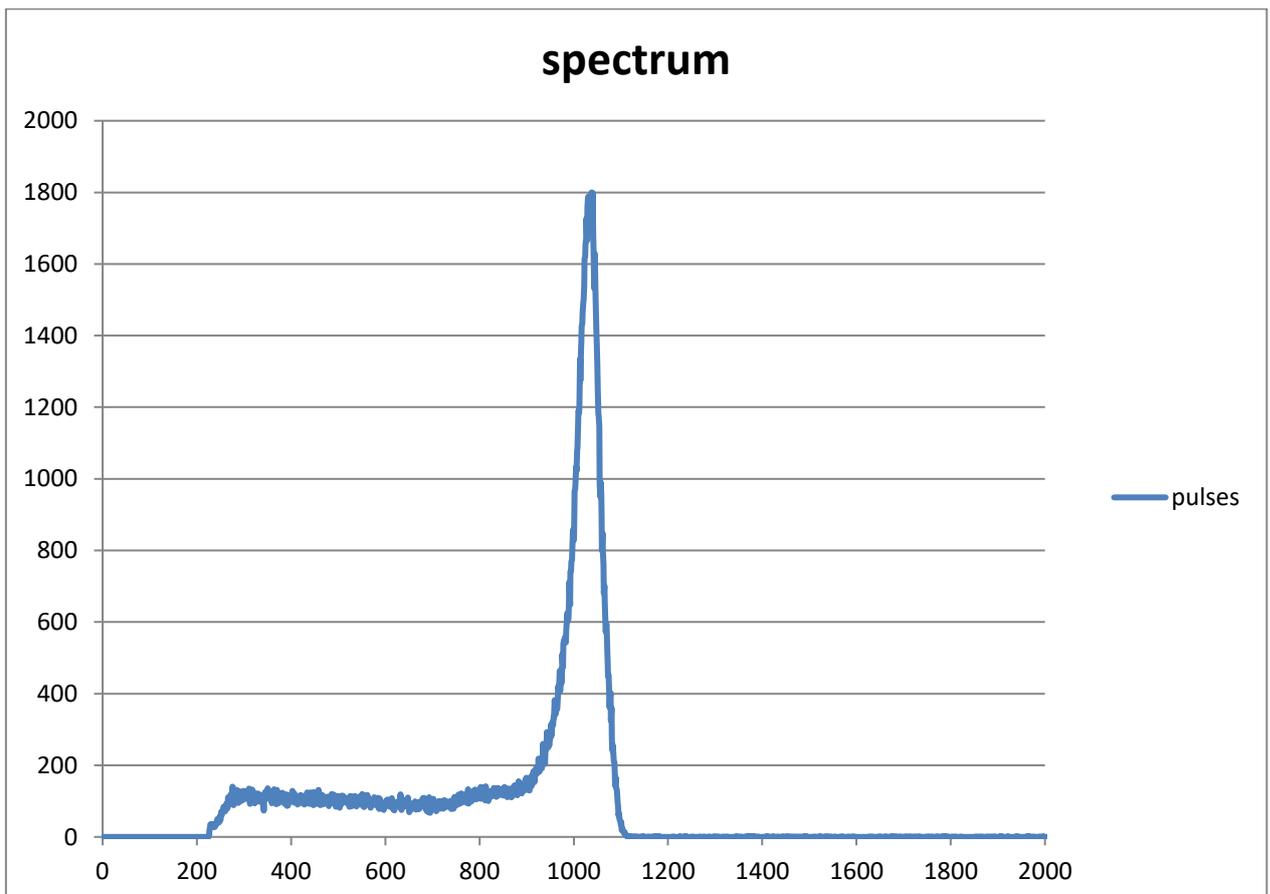
SmartREM mit SMC-MCA
Version 1.70 vom
03.04.2012

SMC_MCA 012_12
V2.10 15.03.2012

Hochspannung [V]: +810
Verstärkung: +50,00
Fenster [kan]: 225 - Dis.

Datum	Zeit[s]	Impulse	Rate[ips]
06.01.2010 05:32	1800	202337	112.4

A	pulses
0	0
1	0
2	0
3	0
4	0
5	0



D) Information by FST



SmartREM Neutron Monitor with MCA

Detector

- new spherical **Leake** Neutron REM Counter with boron loaded polyethylene moderator
- construction with clearly increased neutron sensitivity
- proportional detector SP9 with Helium-3 gas filling
- energy response according to ICRP 74, corresponds to ambient dose equivalent
- REM response from thermal till fast neutrons, from 0.025eV up to 14MeV
- measurement of neutron ambient dose rate equivalent $H^*(10)$

Electronics

- multi-channel analyser SMC 2100 / MCA with 2048 channels, direct on the handle of the sphere
- MCA with serial interfaces RS232 & RS485 for PC connection and link-up
- 4.3" colour display with touch functions, resolution 480x272 pixels
- storage of measuring values on MicroSD card
- readout of measuring values and spectra via USB connection
- battery and mains operation



Firmware and Software

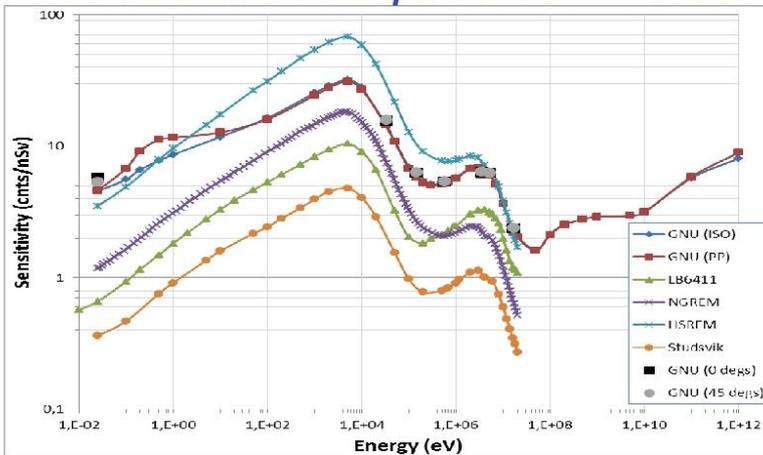
- Firmware for *SmartDisplay*
 - measurement of neutron dose and dose rate $H^*(10)$ and of total dose
 - acquisition of neutron reaction spectrum [^3He (n,p) T]
 - single measurement, series of measurements or continuous runs
 - time or pulse pre-selection
- Software AM-SMCA01 for Windows operating systems



Technical Data

- multi-channel analyser
 - shaping time 3µs and 9µs peak times
 - channel number 2048 channels
 - pulse rate up to 100'000cps
 - pulse content up to 2²⁴ pulses / channel
- detector measurand H*(10)
 - neutron neutrons from 0.025eV (thermal) till 14MeV
 - sensitivity 2.66 pulses / nSv resp. 0.74cps per µSv/h (1MeV)
 - gamma suppression ratio better than 3000:1
 - sensitivity in the range from 3MeV till 7MeV
- connections MCA with RS232 & RS485, SmartDisplay with USB
 - interfaces
 - power supply 3x R20 batteries or 5Vdc (2.5V till 5V)
- construction sphere with 208mm diameter
 - total mass 6.5kg

Neutron-Monitors in comparison with the SmartREM Series



Source:
Nuclear Instruments
& Methods in Physics
Research

SmartREM Series	Sensitivity counts/nSv	Energy Range	Sphere Diameter mm	Total Mass kg
SmartREM	2.66	10 MeV	208	6.5
SmartHSREM	7.85	10 MeV	214	6.6
SmartLINUSREM	1.27	10 GeV	240	10.0
SmartGNUREM	5.76	10 GeV	240	10.1

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