Lessons learnt from neutron inter-comparisons

EURADOS 8th webinar - 28th October 2021
Inter-comparisons of personal dosimeters: Lessons learnt

Elena Fantuzzi – ENEA Radiation Protection Institute

on behalf of ***Organization Group members*** for EURADOS IC2012n and IC2017n: *Marie-Anne Chevallier (IRSN, F), Rodolfo Cruz-Suarez (IAEA, UN-Vienna), Elena Fantuzzi (ENEA, I), Michael Hajek (IAEA, UN-Vienna), Marlies Luszik-Bhadra (PTB, D), Sabine Mayer (PSI, CH), David J. Thomas (NPL, UK), Rick Tanner (PHE, UK), Filip Vanhavere (SCK-CEN, B)*

IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Public Health England

NPL National Physical Laboratory

PAUL SCHERRER INSTITUT PSI

IAEA International Atomic Energy Agency

SCK•CEN STUDIECENTRUM VOOR KERNENERGIE CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

PTB

EURADOS Neutron Inter-comparisons

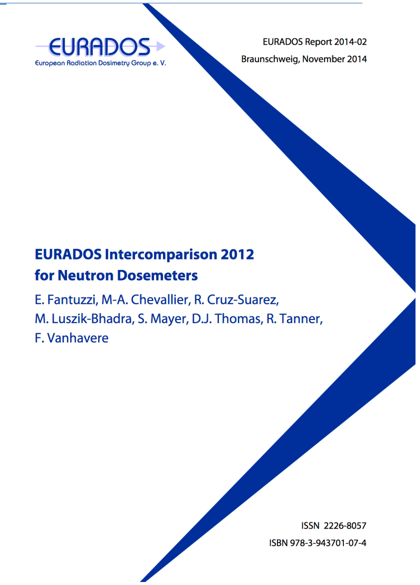
IC2012n

Organization Group: *Marie-Anne Chevallier (IRSN, F),* ***Elena Fantuzzi (ENEA, I - Coordinator)****, Rodolfo Cruz-Suarez (IAEA, UN-Vienna), Marlies Luszik-Bhadra (PTB, D), Sabine Mayer (PSI, CH), David J. Thomas (NPL, UK), Rick Tanner (PHE, UK), Filip Vanhavere (SCK-CEN, B)*

Participant's meeting *@ NEUDOS12 - 12th Neutron and Ion Dosimetry Symposium (June 2013)*

EURADOS Report: 2014-2 E. Fantuzzi et al. "Eurados Intercomparison 2012 for Neutron Dosemeters"

https://eurados.sckcen.be/sites/eurados/files/uploads/Publications/19_IC2012n_report_2014-02%20online-version.pdf



IC2017n

Organization Group: *Marie-Anne Chevallier (IRSN, F), Elena Fantuzzi (ENEA, I), Michael Hajek (IAEA, UN-Vienna), Marlies Luszik-Bhadra (PTB, D),* ***Sabine Mayer (PSI, CH – Coordinator),*** *David J. Thomas (NPL, UK), Rick Tanner (PHE, UK), Filip Vanhavere (SCK-CEN, B)*

Participant's meeting *@ EURADOS AM2019 (February 2019)*

EURADOS Report: 2021-X S. Mayer et al. "Eurados Intercomparison 2017 for Neutron Dosemeters" – in press – expected within 2021

IC2022n – Call for participants in 2022

Organization Group: ***Marie-Anne Chevallier (IRSN, F - Coordinator)****,*

Elena Fantuzzi (ENEA, I), Michael Hajek (IAEA, UN-Vienna), Sabine Mayer (PSI, CH)

Désirée Radeck (PTB, D)

Organization of EURADOS ICn

AIM: performance of neutron dosemeters intended to measure neutron personal dose equivalent $H_p(10)$ provided by individual monitoring services.

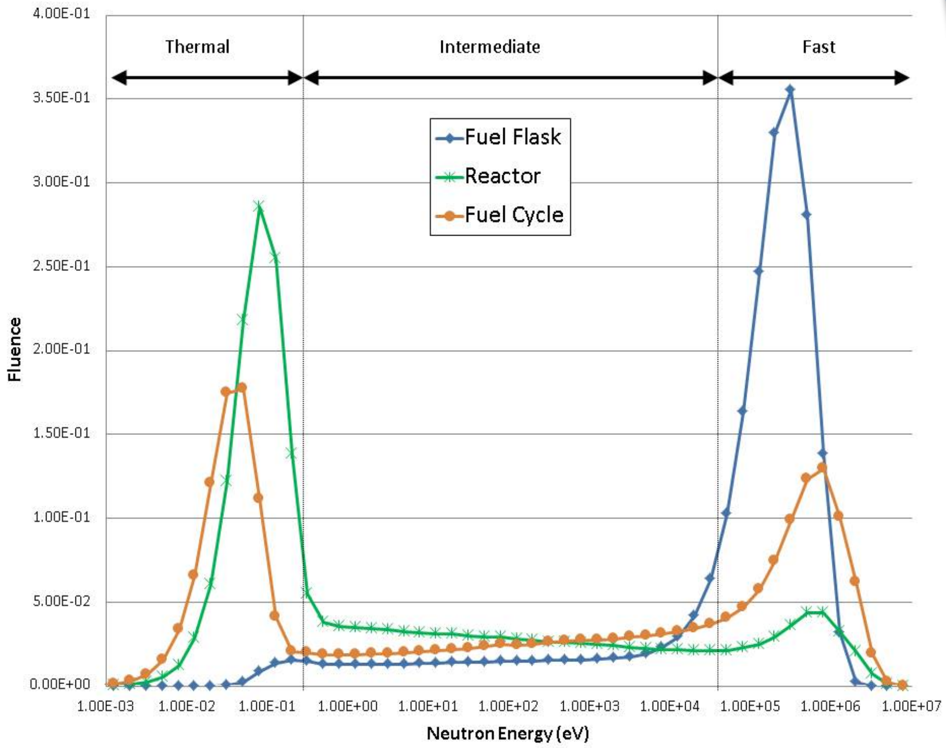
The neutron dosemeters may have been passive or active, but must be used routinely in individual monitoring of exposed workers.
No systems under development were allowed in the intercomparison.

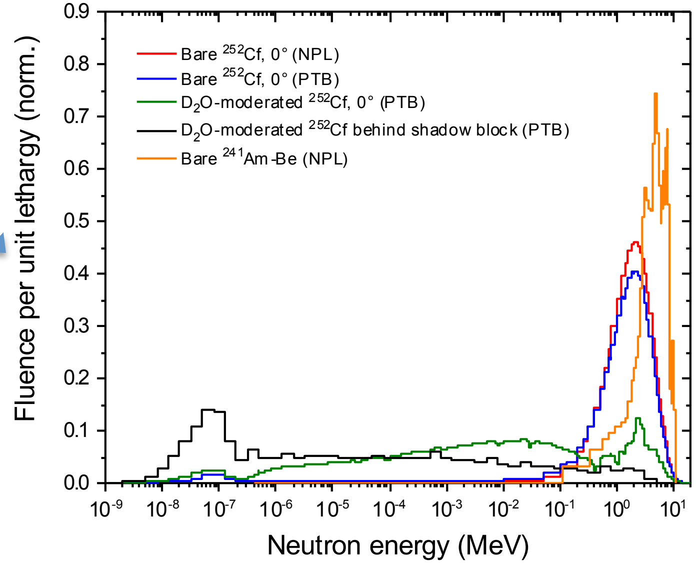
Main differencences from EURADOS ICph

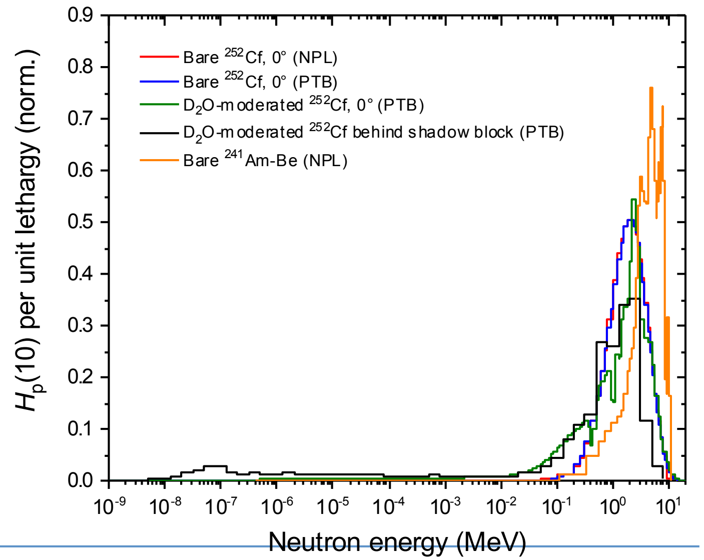
- Frequency: every 5 years
- Number of participants: about 30 (instead of about 100)
- Availability of reference radiation fields and of Accredited Irradiation Labs
- Range of incident neutron energy (from thermal to 10s MeV) vs individual monitoring
- Still gaps in neutron dosimetry for individual monitoring (see challenge 5.3 in EURADOS SRA – Eurados report 2020-04 available on EURADOS website)
- 1 or 2 step procedure => need of *a priori* information.
- Evaluation criteria

Neutron fields: workplace fields *vs* reference and simulated workplaces fields

e.g. IC2017 neutron fields







Workplace fields from measurements @EVIDOS Project

Features of EURADOS IC2012n and IC2017n

	$IC2012_n$	**$IC2017_n$**
Participants / Countries	34 from 31 IMS / 18	32 from 33 IMS / 18
Dosemeters required	36 (24 for irradiation)	40 (28 for irradiation)
Quantity compared	$H_p(10)$	$H_p(10)$
Radiation categories	250 keV, ^{252}Cf(0°, 45°), ^{252}Cf(D_2O), ^{252}Cf + shadow cone	^{252}Cf(0°, 45°), ^{252}Cf(0°)+^{137}Cs(0°), ^{241}Am-Be (α,n)(0°), ^{252}Cf(D_2O), ^{252}Cf(D_2O) behind shadow block
Irradiation Lab	**NPL** and **PTB**	**NPL** and **PTB**
Irradiation / IC duration	2 / 14 months	4 / 23 months
Procedure	2 step procedure	1 step procedure
Criteria for analysis	0,5 < R < 2	ISO14146 - 2018

IC2017n: 1 step procedure with simplified *a priori* information

Participants were requested to

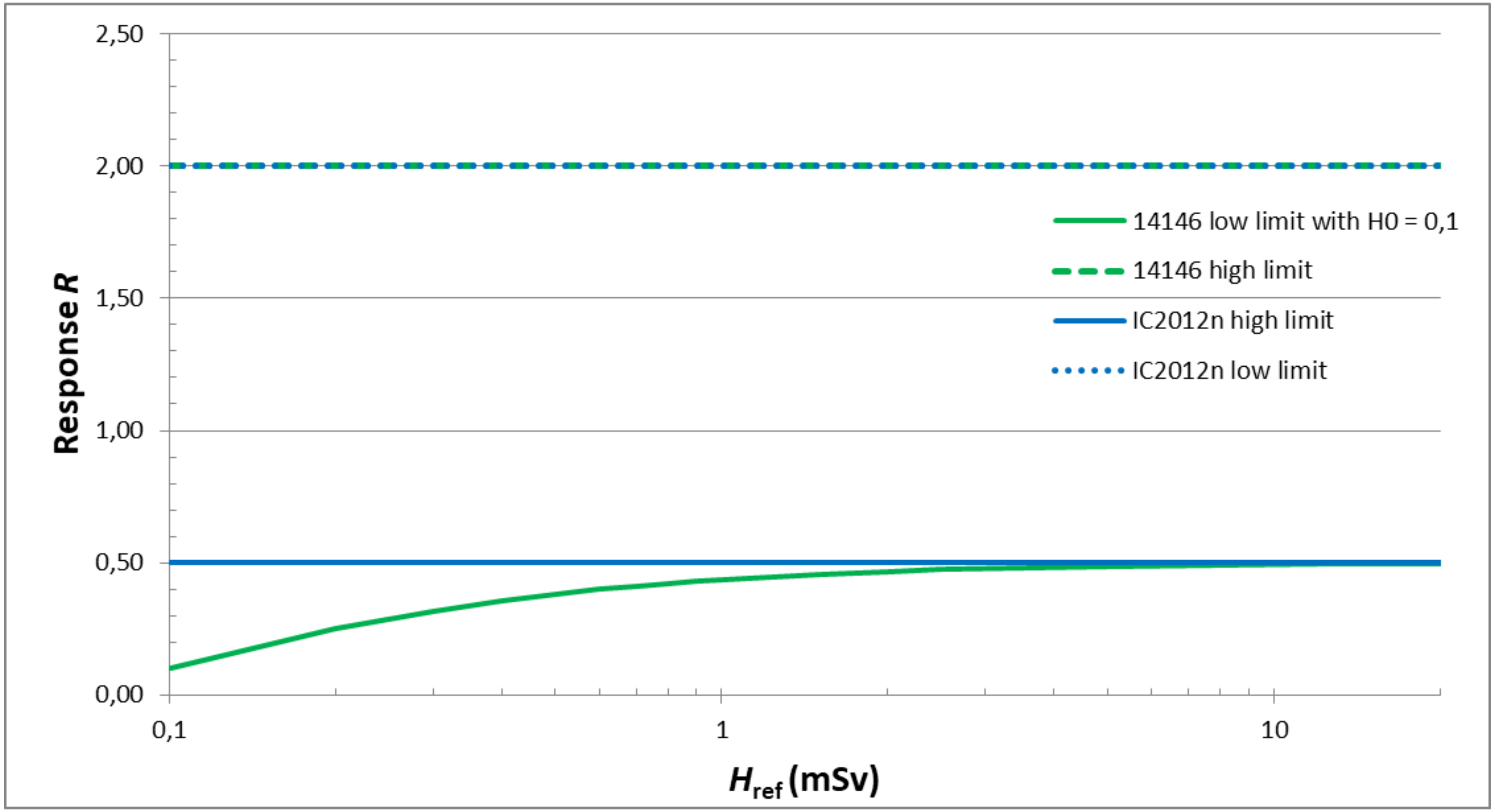
→ **only apply routine procedures as declared in the application form**

→ **declare whether they needed additional simplified *a priori* information on the energy distribution of the radiation fields to allow correction of the bare results of neutron personal dosemeters.**

→ **Additional field information was requested by 22 out of the 33 participants; all but 1 of the 15 albedo services and 8 of the 18 track services**

Irradiation conditions	Information provided to participants	
	NO a priori information requested	with a priori information requested
^{252}Cf at 0°, 45° and ^{241}Am-Be(α,n)	irradiated	bare radionuclide source
^{252}Cf at 0° and additional photons	irradiated	bare radionuclide source
^{252}Cf (D_2O moderated) at 0° and ^{252}Cf (D_2O moderated) behind a shadow block	irradiated	radionuclide source, significantly moderated

Evaluation criteria: IC2012n *vs* IC2017n



Dosemeters @ IC2012n intercomparison

Dosemeters @ IC2017n intercomparison

Types of neutron dosemeters

Dosemeters have been classified into 3 main groups:

- **Albedo dosemeters**
- **Track dosemeters,**
- **Other (e.g. electronic dosemeters)**

BUT within each of the first 2 groups dosemeters are differently assembled:

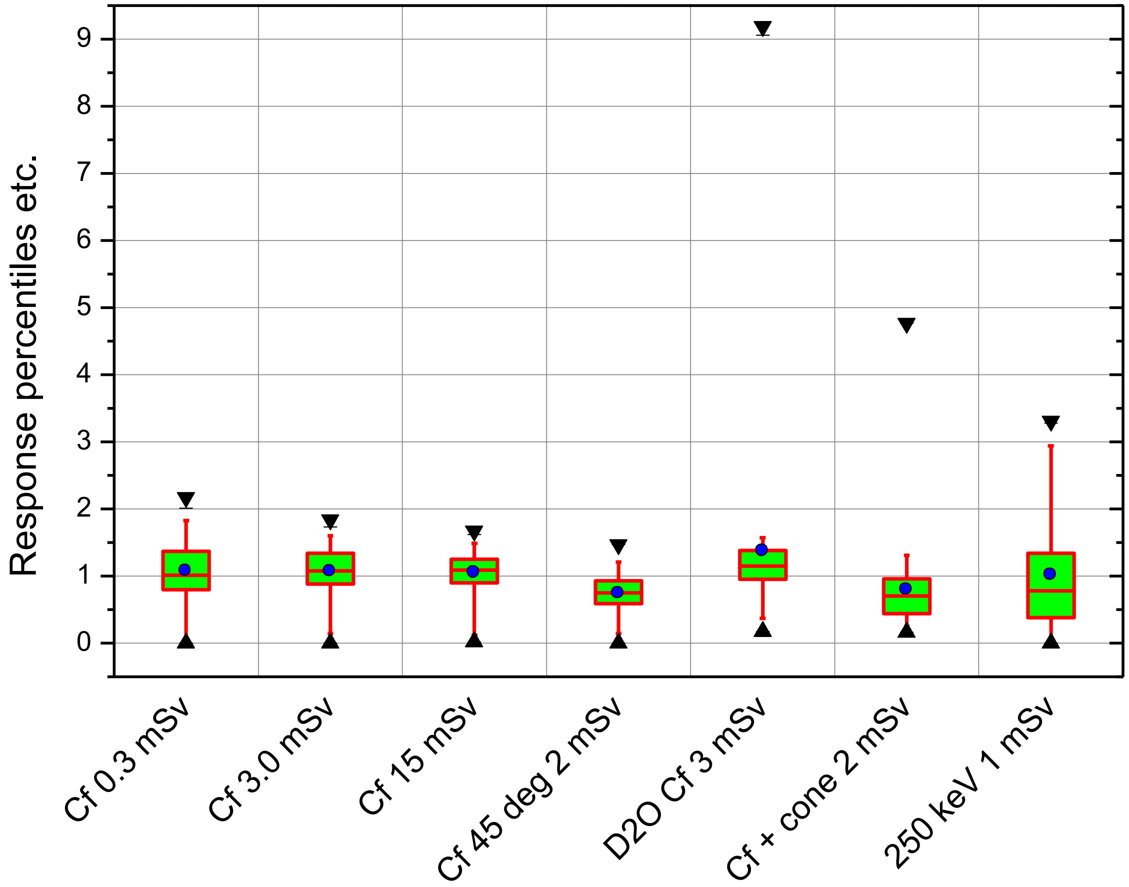
TRACK DOSEMETERS

- Track for fast neutrons
- Track + TLD for thermal neutron,
- Track + thermal neutron converters,
- Track without evidence of thermal sensor,
- Fission track detectors

ALBEDO DOSEMETERS

- TLD with boron-loaded shield,
- TLD + with cadmium shield,
- TLD with no information shielding against direct thermal neutrons
- OSLD

Results of IC2012n



Distribution of response values *R* for irradiations with different radiation qualities.
Circle = mean value, **box** = 50% range, **vertical red line** = 90% range, **horizontal red line inside the box** = median,
up and down triangles = minimum and maximum values

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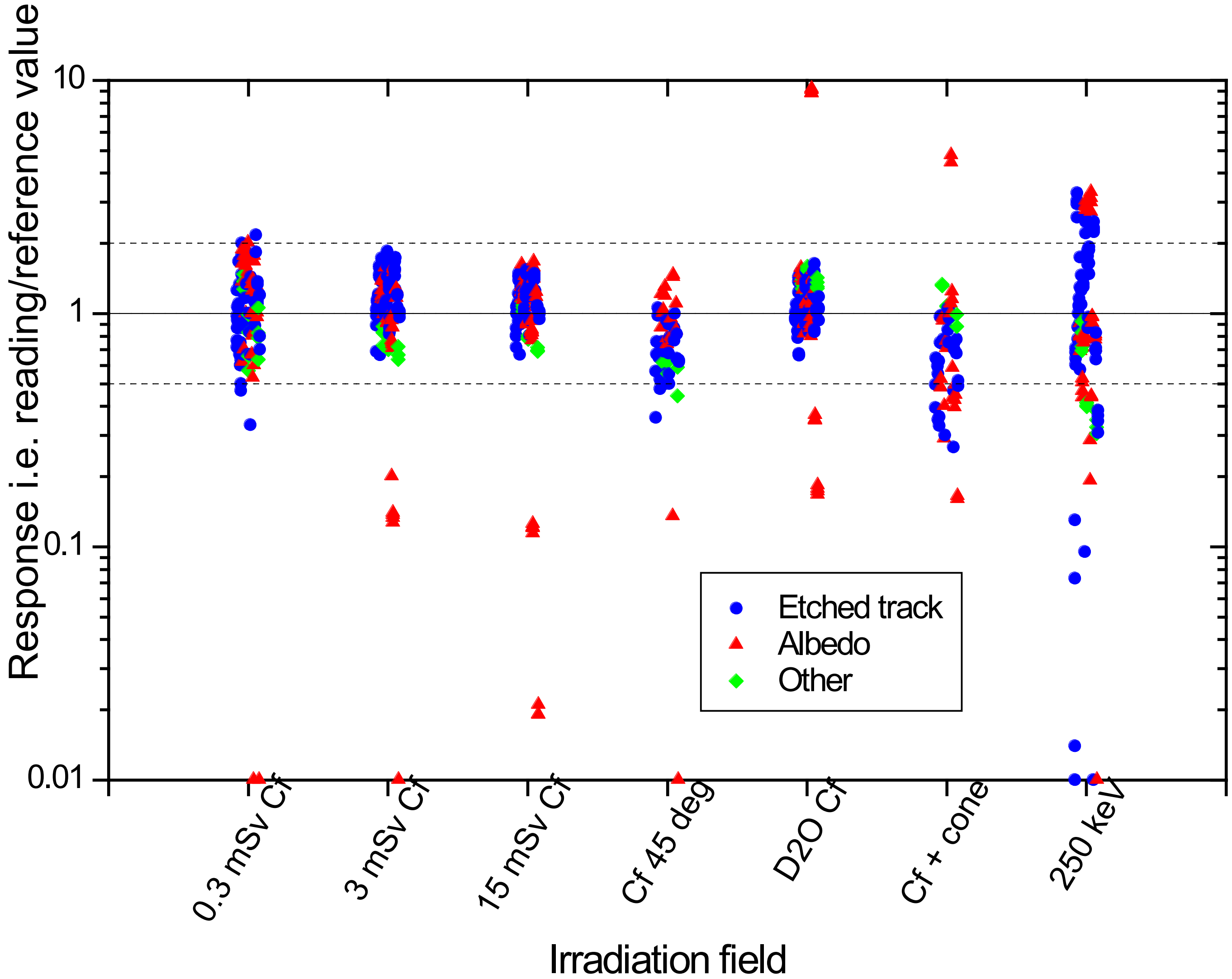
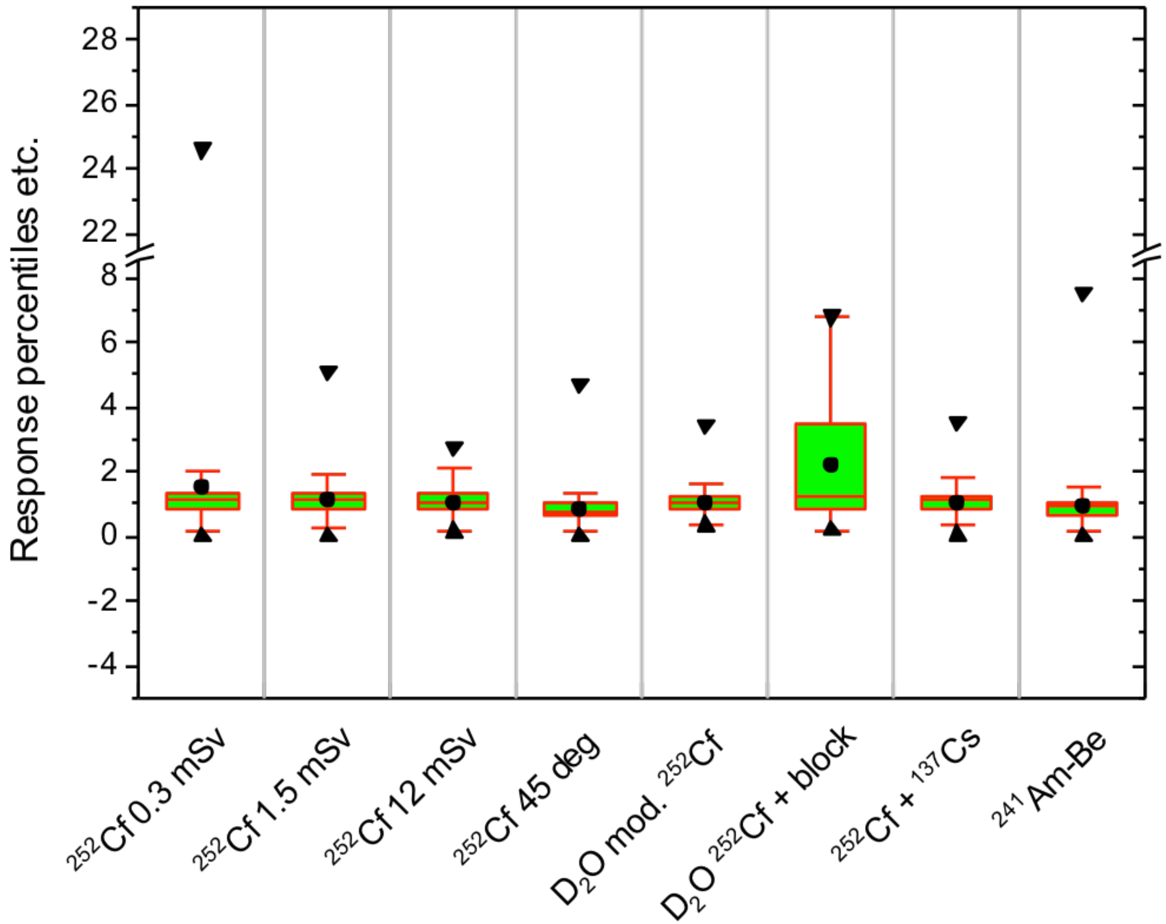


Results of IC2017n



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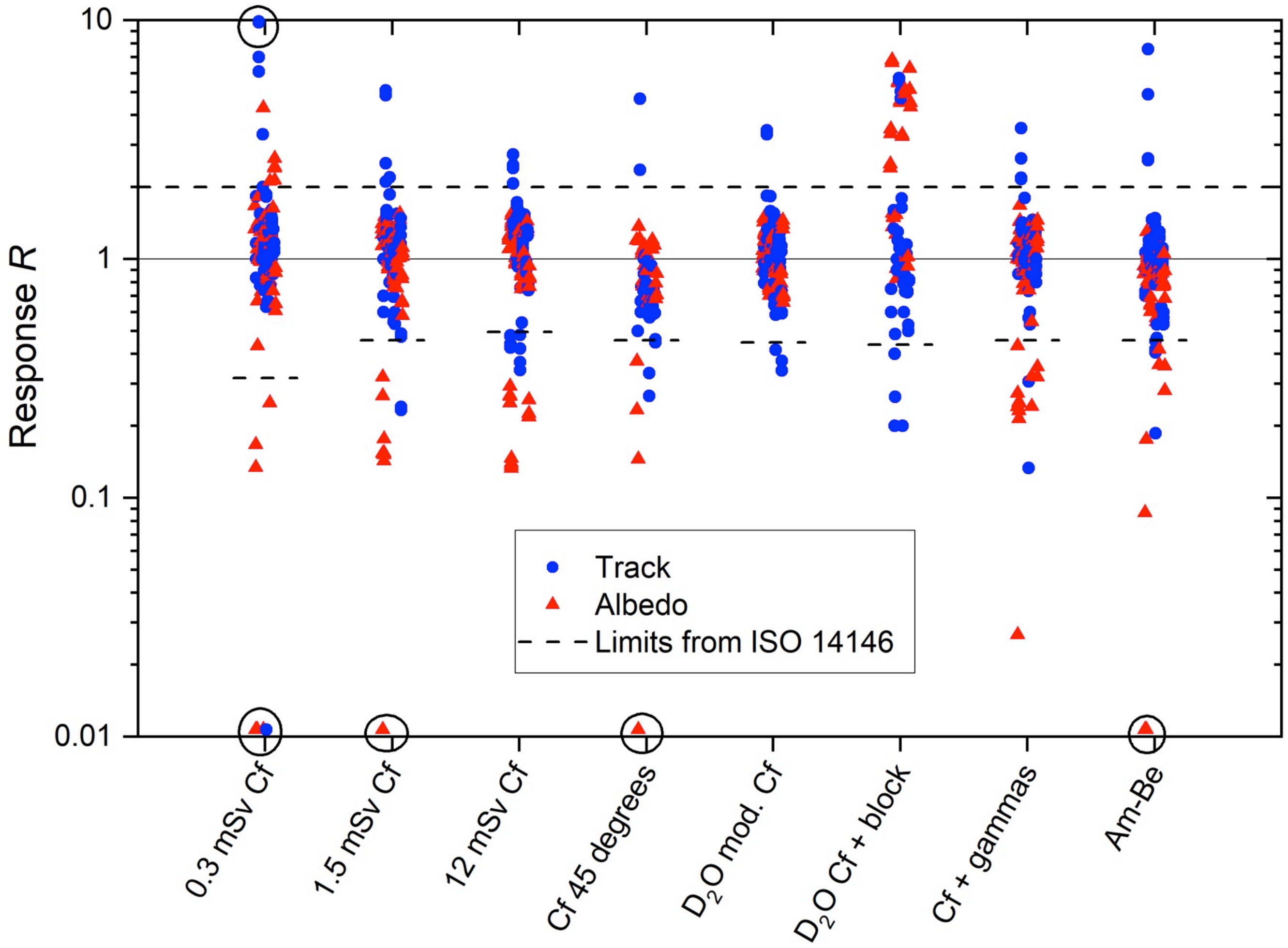
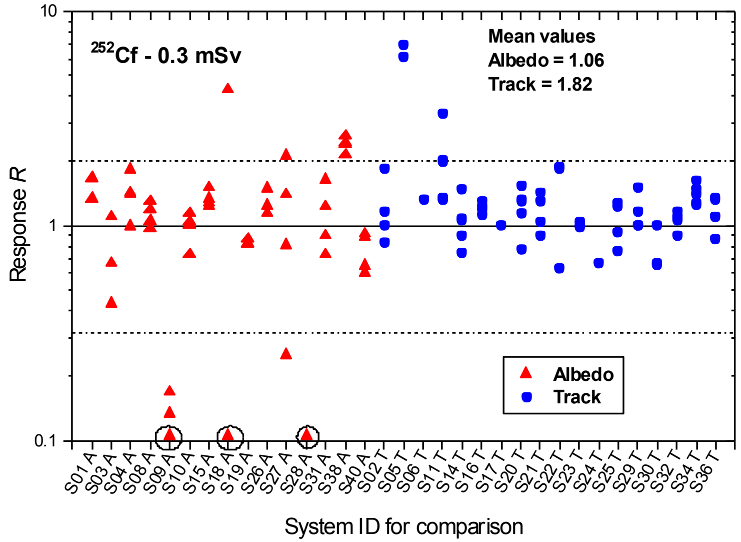
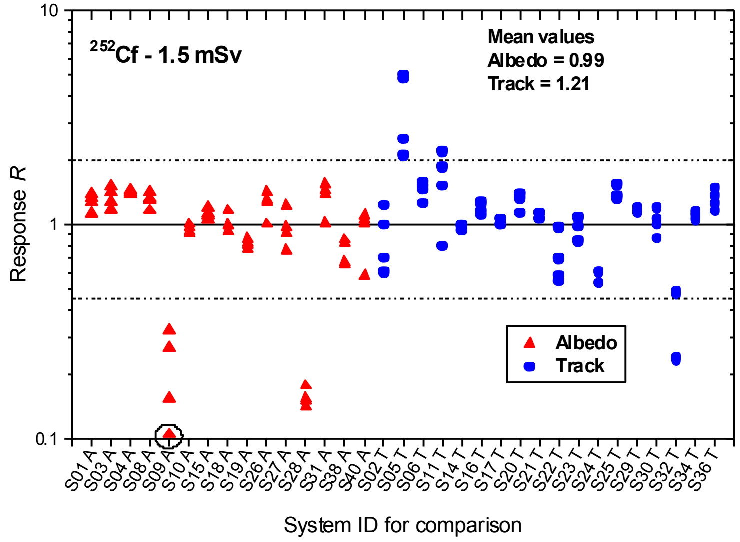
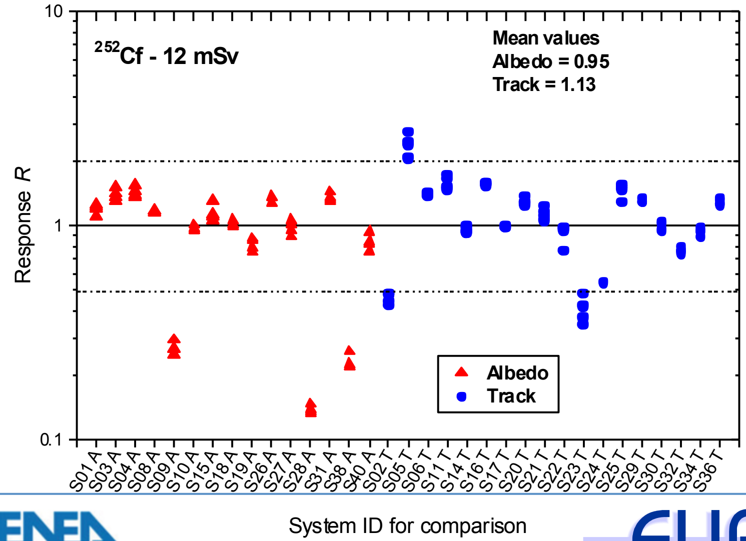
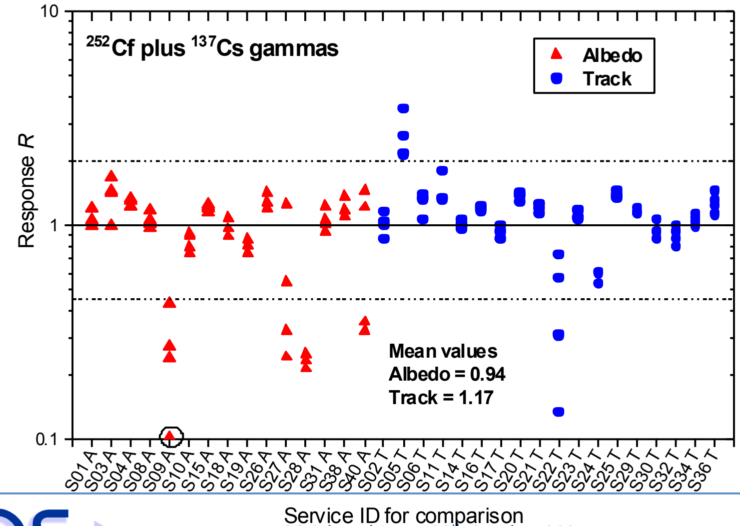


IC2017n - Dosemeter bare ^{252}Cf, 0° at different doses









Comments on overall results of previous IC

Most, but not all, participants performed acceptably well

- ***in IC2012n less than half within the factor 2 with less than 2 outliers (with no trend for the dosemeter types);***
- ***in IC2017n 21 out of 33 less than 2 outliers within ISO14146:2018 criterion (with no trend for the dosemeter types); whilst 14 showed all results within the ISO14146:2018 limits.***

COMMENTS RELATED TO RADIATION FIELDS

- **bare ^{252}Cf source at 0° (reference condition): still not all results within the limits;**
- **bare ^{252}Cf source at 45°: several underestimations**
- **250 keV monoenergetic neutrons: various results not only reflecting the detection principle**
- **$^{252}Cf(D_2O)$: results more spread than for the bare source but still within a factor of 2 for most participants**
- **^{252}Cf bare source + shadow cone: mainly underestimation**
- **$^{252}Cf(D_2O)$ bare source + shadow block: general overestimation and spread results for albedo, varied for track. Wide spread of all results.**
- **Am-Be bare source at 0°: most results within limits (for albedo R lower than for ^{252}Cf)**

Main lesson learnt in ICn (1/2)

As organizer:

- albedo dosemeters need mostly *a-priori* information on the field characteristics differently from most track and other dosemeters => an intercomparison for any type of dosemeter must be planned accordingly
- no international standards available for criteria and performance limits for neutron dosemeters. IC2012n showed "factor 2 achievable" => Recommendation=> ISO filled the gap with ISO14146: 2018
- 30 IMS acceptable number of participants (how many more IMSs provide personal dosemeters in EU and worldwide?)
- although one can understand the reason why services requested *a-priori* additional information, even though not strictly needed by their systems, further attempts might be made to have results from the services as they perform routinely, which is most often without any *a priori* field information.

Main lesson learnt in ICn (2/2)

As IMS/dosimetry community:

- doses as low as 0.3 mSv are still challenging for some participants (both albedo and track)
- energy equal/lower than 250 keV are challenging for many Track system currently in use
- neutron and gamma discrimination performance needs further investigations as one would expect differences for track and albedo based devices, which was not the case
- generally better results in radionuclide source fields; worst results in simulated workplace fields

  => is due to the fact that they are seldom used for calibration?, is it for little availability of such irradiation facilities?

Conclusions

1. The exercises has emphasised the need for development work on neutron personal dosemeters
2. Results are generally good though for some participants results are poor
3. Great value of EURADOS ICn either for IMS but also for Authorities, Accreditation Bodies
   - are important for informing the radiation protection community about the present state of the art in neutron dosimetry
   - unearth potential difficulties
   - provide the dosimetry services with opportunities to demonstrate the capabilities of their dosemeters and any recent improvements they have made

   especially for neutron dosimetry which faces gaps and challenges in individual monitoring => see Challenge 5.3 EURADOS SRA
4. No possible conclusion on the "best type of dosemeter" (albedo Vs track => both advantages and disadvantages; e.g. Results for the field with additional gammas surprisingly did not show a clear difference between the performance of the 2 types of dosemeters)
5. The management of the IMS and the dosimetric system can influence the results (quite different results for similar dosemeters/systems)

Publications on EURADOS IC intercomparisons

1. Fantuzzi, E., Chevallier, M.-A., Cruz-Suarez, R., Luszik-Bhadra, M., Mayer, S., Thomas, D. J., Tanner, R., & Vanhavere, F. (2014). *EURADOS intercomparison 2012 for neutron dosemeters* (EURADOS Report No. 2014-02). European Radiation Dosimetry.

2. Fantuzzi, E., Chevallier, M.-A., Cruz-Suarez, R., Luszik-Bhadra, M., Mayer, S., Thomas, D. J., Tanner, R., Vanhavere, F. 2014. EURADOS IC2012n: EURADOS 2012 intercomparison for whole-body neutron dosimetry. Radiat. Prot. Dosim.161, 73-77. doi: 10.1093/rpd/nct295 (WG2)

3. Chevallier, M.-A., Fantuzzi, E., Cruz-Suarez, R., Luszik-Bhadra, M., Mayer, S., Thomas, D. J., Tanner, R., Vanhavere, F., (2016). EURADOS IC2012n: Further Information Derived from a EURADOS International Comparison of Neutron Personal Dosemeters. Radiat. Prot. Dosim. 170, 78-81. doi: 10.1093/rpd/ncv518 (WG2)

4. Mayer, S., Chevallier, M. A., Fantuzzi, E., Hajek, M., Luszik-Bhadra, M., Tanner, R., Vanhavere, F. (2020). *Results of the EURADOS 2017 intercomparison for whole body neutron dosemeters (IC2017n)*. Radiation Measurements, 135, 106364 (4 pp.). https://doi.org/10.1016/j.radmeas.2020.106364.

5. Mayer, S., Chevallier, M.-A., Fantuzzi, E., Hajek, M., Luszik-Bhadra, M., Thomas, D. J., Tanner, R., & Vanhavere, F. (2021 – in press). *EURADOS intercomparison 2017 for neutron dosemeters* (EURADOS Report No. 2021-XX). European Radiation Dosimetry.

thank you!

IC2012n: 2 step procedure

As some (few) IMSs using albedo dosemeters needed information on the radiation field prior to the evaluation procedure;

as we need to keep the procedure fair to every IMS participating though allow of course all IMS to provide results according to their routine procedure,

the participants were asked to provide the results in 2 steps - Participants were allowed to change their results between the first and the second step only according to their routine procedure which has to be described and justified

1st step: with no information on the radiation fields (es. only *radionuclide source, mono-energetic fields or workplace fields.Some of the fields contained significant contributions from slow and intermediate energy neutrons)*

2nd step: with information on the radiation fields though it was up to the IMS to choose the proper calibration factor to be applied.

Irradiation conditions	Information provided to participants
Bare Cf-252 source at 0° , 45°	Bare radionuclide source
250 keV mono-energetic neutrons at 0°	250 keV mono-energetic neutrons at 0°
Cf-252 (D2O moderated) at 0°	Radionuclide source with significant moderated neutron fluence component
Bare Cf-252 shielded with shadow cone	Radionuclide source with significant moderated neutron fluence component