# EURADOS INTERCOMPARISON ON WHOLE BODY DOSEMETERS (2016) –

## IC2016 - participants meeting

European Radiation Dosimetry Group

EURADOS

# Organisation Group / Coordinators

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# EURADOS IC2016 Participants Meeting

## AM2017, Karlsruhe
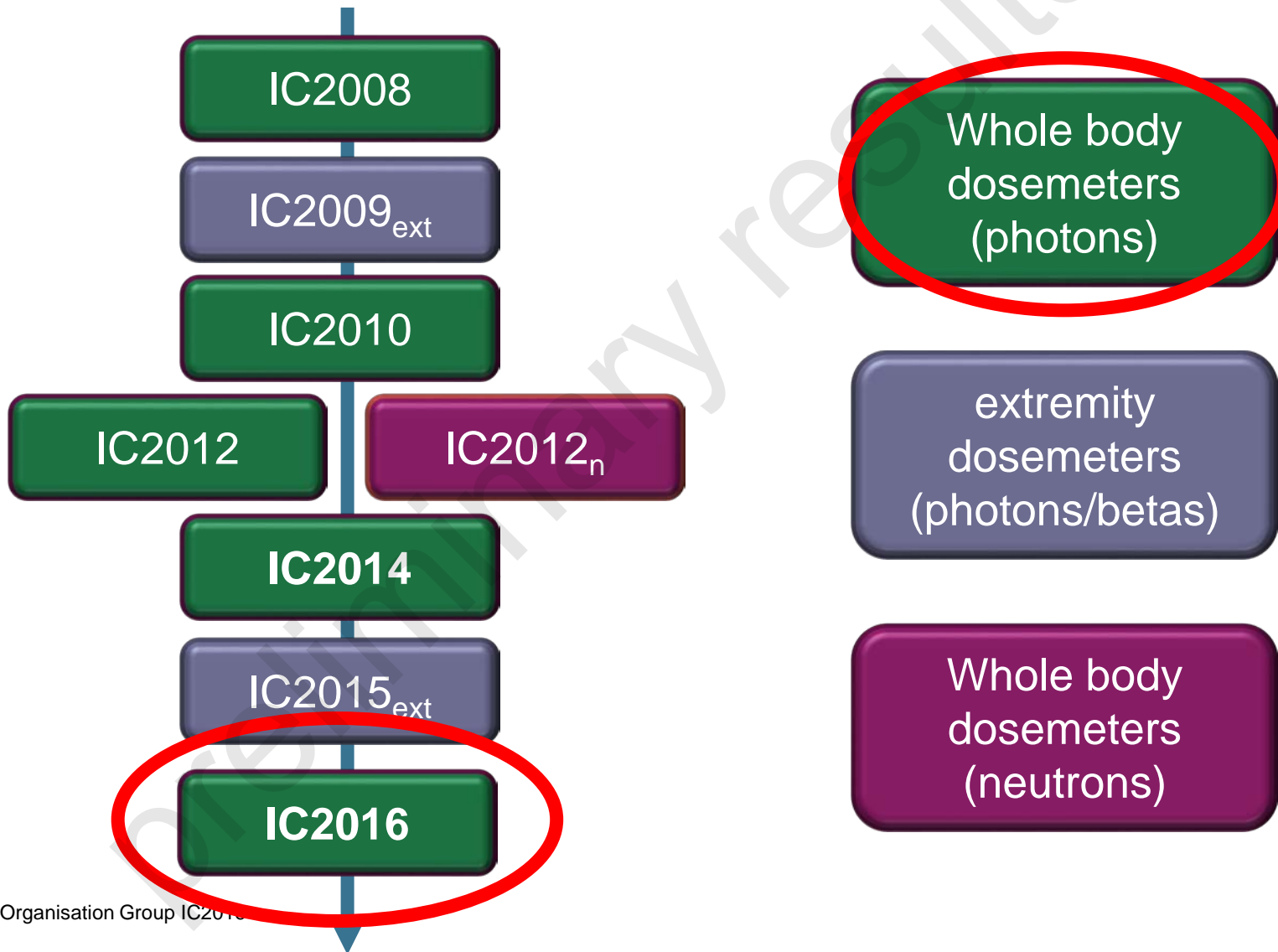### Tuesday 28th of February 2017

## Agenda

| Time | | Speaker | Topic |
|---|---|---|---|
| 09:00 – 10:30 | 5 min | Phil Gilvin, PHE, ADS | Welcome to the 1st Learning Network |
| | 5 min | Andrew McWhan, Berkley ADS | Introduction to the intercomparison programme |
| | 10 min | Hannes Stadtmann & Christian Gärtner, Seibersdorf Lab | Coordination of IC2016 |
| | 30 min | Bartel Jansen, VSL Cristian Hranitzky, SL | Irradiations at VSL/SL Lab |
| | 10 min | Hannes Stadtmann, Seibersdorf Lab | Results of IC2016 |
| | 10 min | Ana Mª Romero, CIEMAT | IC2016: Special Cases |
| | 10 min | OG | Participants' questions or suggestions |
| | 05 min | Hannes Stadtmann, Seibersdorf Lab | Conclusions and future plans |

EURADOS Organisation Group IC2016

# Historical context

- Krakow Feb. 2005

- First discussions establishing a new Programme

- 8 Intercomparisons are now completed

- Intercomparisons are  a Team effort with all members supporting the coordinator

- It appears that these Intercomparisons are becoming more and more important
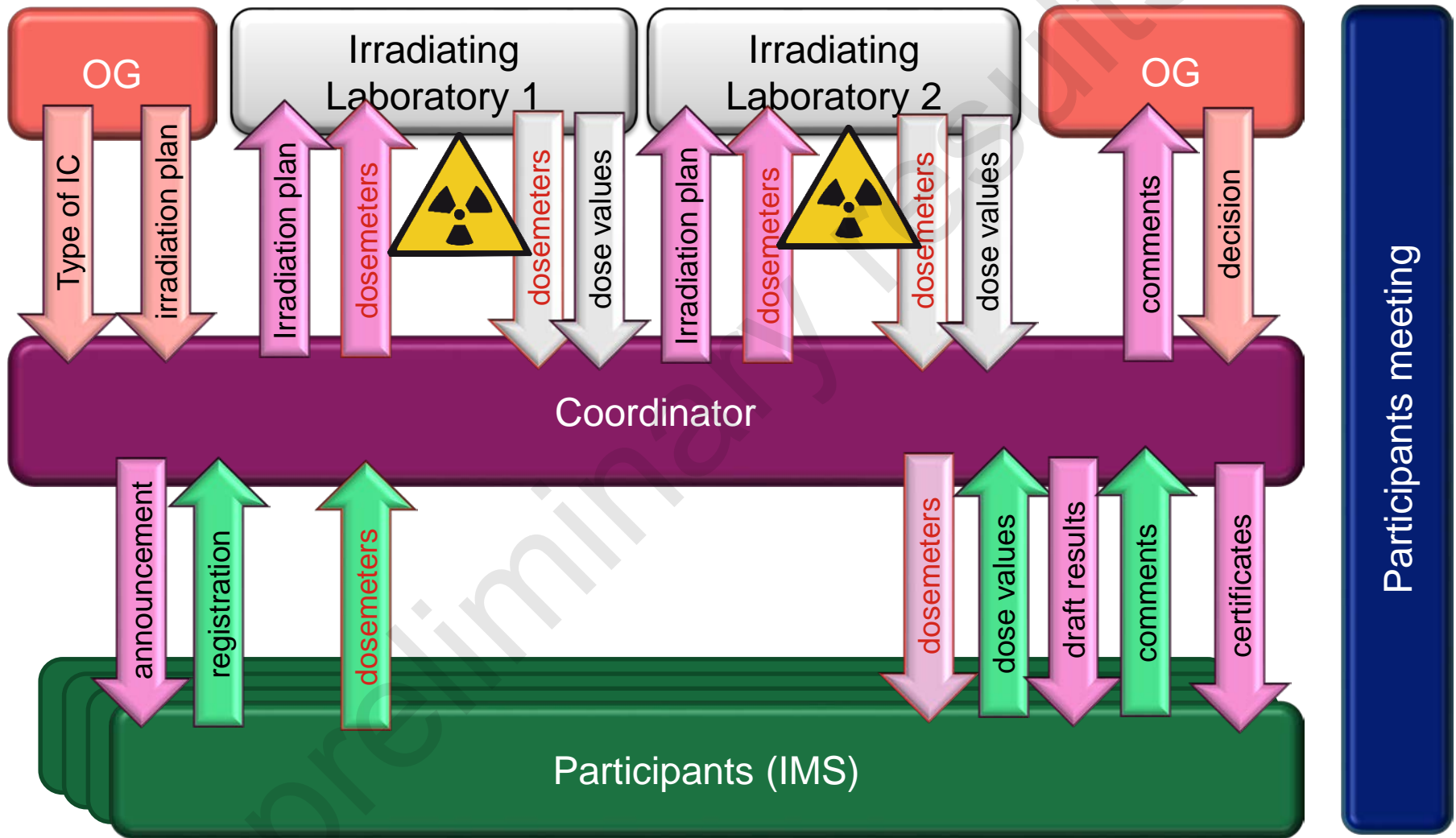
# Intercomparisons WG2

IC2008

IC2009$_{ext}$

IC2010

IC2012     IC2012$_n$

**IC2014**

IC2015$_{ext}$

**IC2016**

Whole body dosemeters (photons)

extremity dosemeters (photons/betas)

Whole body dosemeters (neutrons)

# Participants meeting IC2015 in Milano last year

# Transfer and communication

# Timetable

**EURADOS** European Radiation Dosimetry Group

*Whole body dosemeter intercomparison IC2016ph*

**Timetable**

Announcement – Call for Participants.........................................15 April 2016

Registration process for IMS.......................................................May 2016

Deadline for IMS sending signed Application Form(s).................31 May 2016

Deadline for IMS sending dosemeters to Coordinator.................30 June 2016

Irradiations ................................................................................July / August 2016

Coordinator sending dosemeters back for readout......................30 September 2016

Deadline for IMS sending results to Coordinator.........................11 November 2016

Draft results available................................................................04 December 2016

Final results available.................................................................16 January 2017

IMS receiving Certificates of Participation...................................February 2017

# Announcement

## Scope

The 2016ph intercomparison is for whole body dosemeters used for the assessment of $H_p(10)$ and/or $H_p(0.07)$. Irradiations for photons, will be carried out in an accredited or primary standard European irradiation facility in terms of $H_p(10)$ and $H_p(0.07)$ in the following ranges:

> Energy: 30 keV to 1.3 MeV
> Dose equivalent: 0.2 mSv to 1 Sv
> Angle of incidence: ± 60°

In addition few dosemeters will be irradiated in the field of a $^{90}$Sr beta source ($E_{max}$ = 2.3 MeV) in terms of $H_p(0,07)$.

> 20 dosemeters for irradiation
> 10 transit / spare dosemeters

# Online Plattform

EURADOS — European Radiation Dosimetry Group

## Whole body dosemeter intercomparison IC2016ph

Start page ◆ Documents ◆ Login ◆ Registration

◆ **Welcome!** ◆

Welcome to the EURADOS Whole body dosemeter intercomparison IC2016ph!

On this homepage, participants of the **Whole body dosemeter intercomparison IC2016ph** can log in and check the current status of the intercomparison, receive information about the irridiation process, enter their dose values and much more.

For the documentation please have a look at the file 'IC2016ph Online Platform Documentation.pdf' which is available via the 'Documents' link!

As the deadline for registration is over (Friday, 2016-06-10, 23:59 (CEST)), registration is no longer possible.

By the way: you can change the language of this homepage in the bottom left corner.

# IC2016ph Online Platform Security Measures

# Online Platform Key Features

- <u>easy to use</u>
- <u>platform independent:</u> useable regardless of the participant's browser (only standard html, no java-script, …)
- <u>secure:</u> https, database on a different server, login data is one-way-encrypted, extensive logging, detecting of brute-force-attacks, …
- <u>real-time:</u> participants can monitor the status of the intercomparison and their Dosimetry System in real-time
- <u>one-stop-shop:</u> all relevant information regarding the IC2014 is available (including documents, copies of the mails sent, …)
- <u>multilingual:</u> available in different languages (at the moment in English and German, more languages can be added easily)
- <u>reusable:</u> all intercomparison-specific data is stored in a configuration file and so the online platform can be easily used for the next intercomparison

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# HTTPS Connection

- HTTP (Hypertext Transfer Protocol) is a protocol for distributed hypermedia information systems. It is the foundation of data communication for the World Wide Web.

- HTTPS (also called HTTP over TLS, HTTP over SSL, and HTTP Secure) is a protocol for secure communication over a computer network. It consists of communication over HTTP within an encrypted connection.

- The main motivation for HTTPS is authentication of the visited website and protection of the privacy and integrity of the exchanged data.

- The IC2016ph Online Platform uses HTTPS only.

- If the IC2016ph Online Platform is accessed via HTTP, the user is automatically redirected to a secure HTTPS connection.

Internet
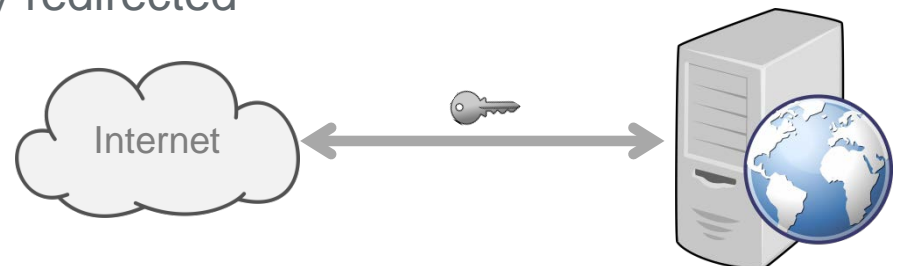
# Distributed Data

- The IC2016ph Online platform runs on three different servers:
  - server 1 hosts the website
  - server 2 hosts the database (only accessible via server 1)
  - server 3 is the email server



Internet

- Certain information is distributed by email only (e.g. the passwords for the encrypted Final Reports) and is not stored in the database or on the webserver.

- One always needs access to at least two sources of data:
  - example: Final Report
  - 1. access to the webserver to download the Final Report
  - 2. access to the email in order to obtain the password

4
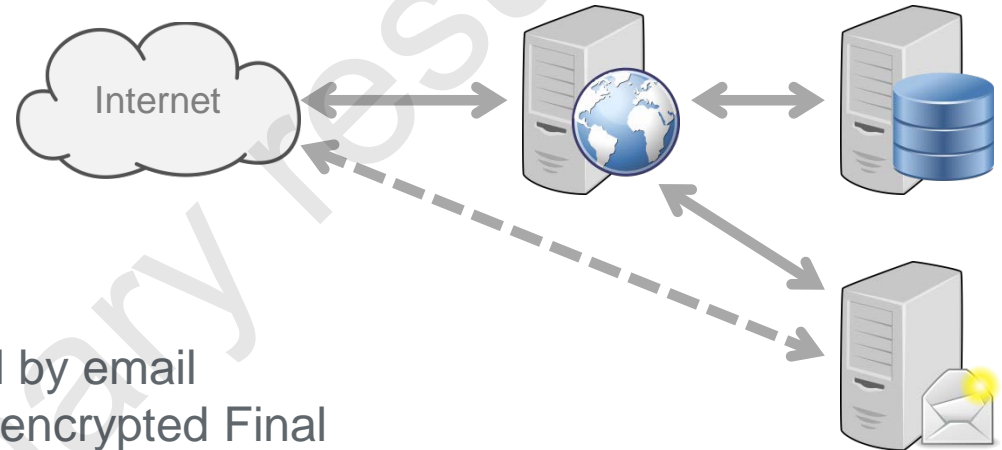
# Encrypted Login Data

- The login passwords are stored using a cryptographic hash function.
- A cryptographic hash function allows one to easily verify that some input data maps to a given hash value, but if the input data is unknown, it is deliberately difficult to reconstruct it by knowing the stored hash value.
- It is very easy to calculate the hash value of some data, but it is extremely difficult or even impossible to reconstruct the data if only the hash value is known.

- Example: SHA-1 (outdated)
  - data: "my secret password"
  - hash value: "ca90213b8b911f48a180abf8002934658bf63828"
  - data: "my secret passwor<u>t</u>"
  - hash value: "9f41d7c1b79b13942b80bd67ea74dc74f4421f13"

# Encrypted Login Data

- The participant chooses a password during the registration process.
- The Online Platform calculates the hash value.
- The hash value is stored in the database.
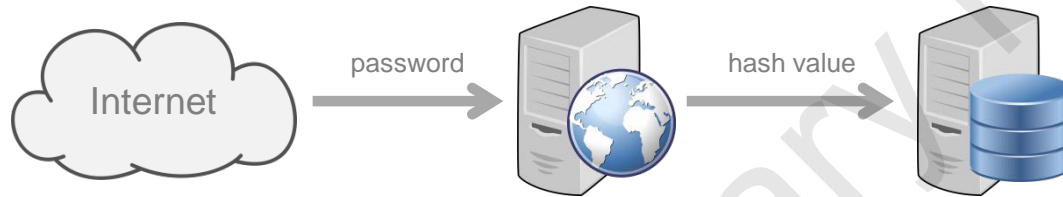


- If the participant wants to log in, he provides the password.
- The Online Platform calculates the hash value.
- The Online Platform retrieves the stored hash value from the database.
- If the calculated hash value is equal to the stored hash value, the participant has entered the correct password and access is granted.



6

# Detecting Brute Force Attacks

- The term "Brute Force Attack" is known as a technique to simply try all possible candidates for a given problem.

- Related to a website protected with a login, this means trying all possible combinations for a simple password starting with "aaaa" to "zzzz" for a password of four characters (456,976 possible passwords).

- A more secure password contains lower case and upper case characters, which increases the number of possible passwords to 7,311,616.

- An ideal password also contains numbers and special characters like "_.*-+:#!?%{}|@[];="&$\,()". This increases the number of possible passwords to 59,969,536.

- If you double the password length, there are 3,596,345,248,055,296 possible passwords.

- If someone managed to try 1,000 passwords per second, it would take 114,000 years to crack the password!

# Detecting Brute Force Attacks

- After five unsuccessful login attempts to the Online Platform with a wrong password, the login for this participant is locked for one hour.
- This makes it impossible to try a reasonable number of passwords within a given period of time.
- Additionally, the IP address of the alleged hacker is logged.

# Participants / Systems

| | | | | |
|---|---|---|---|---|
| Argentina | 1 | Italy [EU] | 12 | |
| Austria [EU] | 3 | Japan | 2 | |
| Bosnia and Herzegovina | 1 | Lebanon | 1 | |
| Belgium [EU] | 9 | Lithuania [EU] | 1 | |
| Bulgaria [EU] | 1 | Luxembourg [EU] | 1 | |
| Switzerland | 3 | Netherlands [EU] | 2 | |
| Czech Republic [EU] | 3 | Norway | 1 | |
| Germany [EU] | 4 | Poland [EU] | 1 | |
| Denmark [EU] | 1 | Portugal [EU] | 3 | |
| Estonia [EU] | 2 | Romania [EU] | 1 | |
| Spain [EU] | 4 | Serbia | 3 | |
| Finland [EU] | 2 | Sweden [EU] | 1 | |
| France [EU] | 3 | Slovenia [EU] | 1 | |
| United Kingdom [EU] | 5 | Slovakia [EU] | 1 | |
| Greece [EU] | 1 | Turkey | 4 | |
| Croatia [EU] | 1 | Ukraine | 1 | |
| Israel | 2 | United States | 2 | |
| Iraq | 1 | Kosovo | 1 | |

- <u>86 Participants</u> (*Pnnn*)
- (24 sponsoring Institutions)
- <u>103 Systems</u> (*Snnn*)
- <u>36 Countries</u>
- (one Participant withdraw)

# Almost ready for delivering to VSL

# Ready!

# Transport dose



background / transport dose
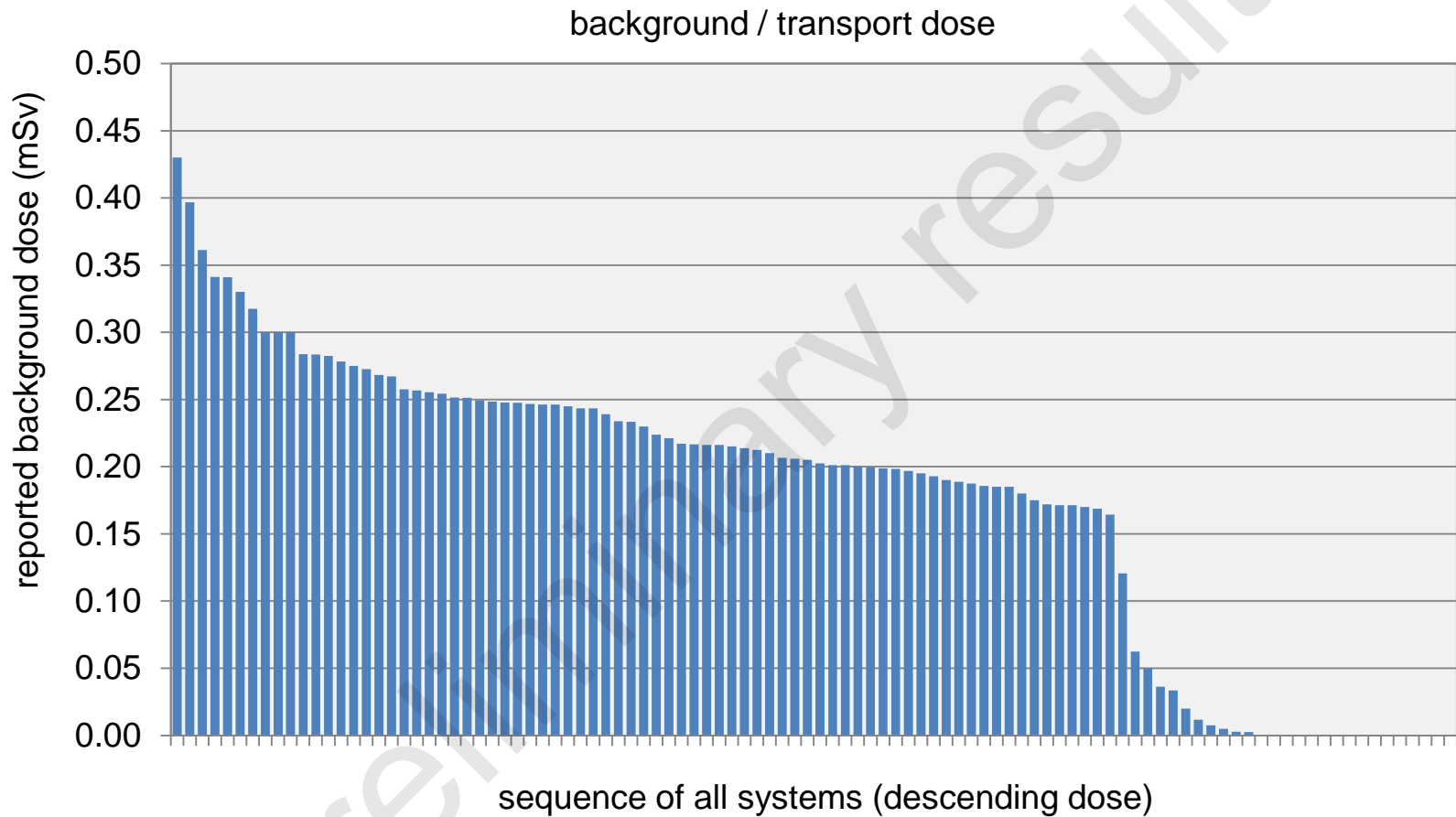
Max: 3.3 mSv (RID 33)

# 103 different dosemeters!

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# Dosemeter types and detectors

| | systems | % of all | % of type |
|---|---|---|---|
| **TL** | **68** | **66%** | |
| LiF:Mg,Ti | 39 | 38% | 57% |
| LiF:Mg,Cu,P | 14 | 14% | 21% |
| Li2B4O7/CaSO4 | 12 | 12% | 18% |
| Other | 3 | 3% | 4% |
| **Film** | **8** | **8%** | |
| Agfa | 6 | 6% | 75% |
| FOMA | 2 | 2% | 25% |
| **OSL** | **17** | **17%** | |
| Al2O3:C | 12 | 12% | 71% |
| BeO | 5 | 5% | 29% |
| **other** | **10** | **10%** | |
| DIS | 6 | 6% | 60% |
| RPL | 3 | 3% | 30% |
| APD | 1 | 1% | 10% |
| **All** | **103** | **100%** | |

| | Hp(10) | Hp(10) and Hp(0.07) | All |
|---|---|---|---|
| **TL** | 11 | 57 | 68 |
| **Film** | 4 | 4 | 8 |
| **OSL** | 2 | 15 | 17 |
| **other** | 1 | 9 | 10 |
| **All** | **18** | **85** | **103** |
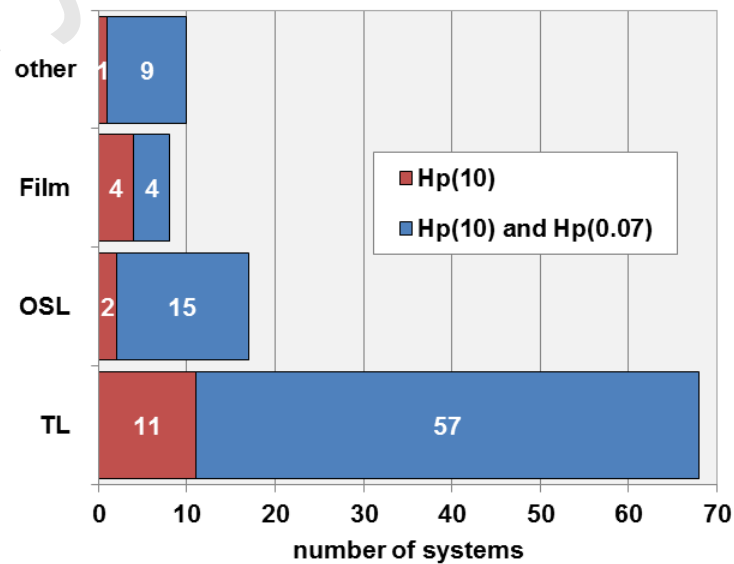
# Radiation Qualities

Radiation Qualities and average photon energies or maximum beta energies:

- Beta Radiation:
  - Sr-90:          2.3 MeV   (Emax)          (ISO 6980)

- Gamma Radiation:
  - S-Co:          1250 keV          (ISO 4037)
  - S-Cs:          662 keV          (ISO 4037)

- X-Rays:
  - N-40:          33 keV          (ISO 4037)
  - N-150:          118 keV          (ISO 4037)

# Irradiation doses

| Hp(10) | | Dose (mSv) | | | dose-meter |
|--------|--------|------|-----|-----|------------|
| **Radiation** | **Quality** | **Mean** | **Min** | **Max** | |
| **X-Ray** | **N-40** | 1.0 | 0.9 | 1.2 | 206 |
| | **N-40/60°** | 0.9 | 0.8 | 1.1 | 206 |
| | **N-150** | 2.1 | 1.8 | 2.5 | 206 |
| | **N-150/45°** | 2.0 | 1.7 | 2.3 | 206 |
| **Gamma** | **S-Cs-S** | 0.5 | 0.4 | 0.6 | 206 |
| | **S-Cs-L** | 5.0 | 4.5 | 5.6 | 412 |
| | **S-Co-S** | 0.5 | 0.4 | 0.5 | 206 |
| | **S-Co-M** | 108 | 99 | 118 | 206 |
| | **S-Co-H** | 491 | 473 | 510 | 202 |
| **mixed** | **S-Cs/Sr-90** | 2.2 | 1.9 | 2.6 | 206 |
| **All** | | 55.4 | 0.4 | 510.4 | 2262 |

# Irradiations at VSL and SL

# Trumpet curve for $H_p(10)$

# All response values



Hp(10) - All (2256 values)

| Hp(10) - All (2256 values) | |
|---|---|
| number | 2256 |
| σ+ | 2.15 |
| mean | 1.11 |
| σ− | 0.06 |
| min | 0.05 |
| 5.0% | 0.70 |
| 25.0% | 0.89 |
| median | 0.98 |
| 75.0% | 1.10 |
| 95.0% | 1.55 |
| max | 21.55 |
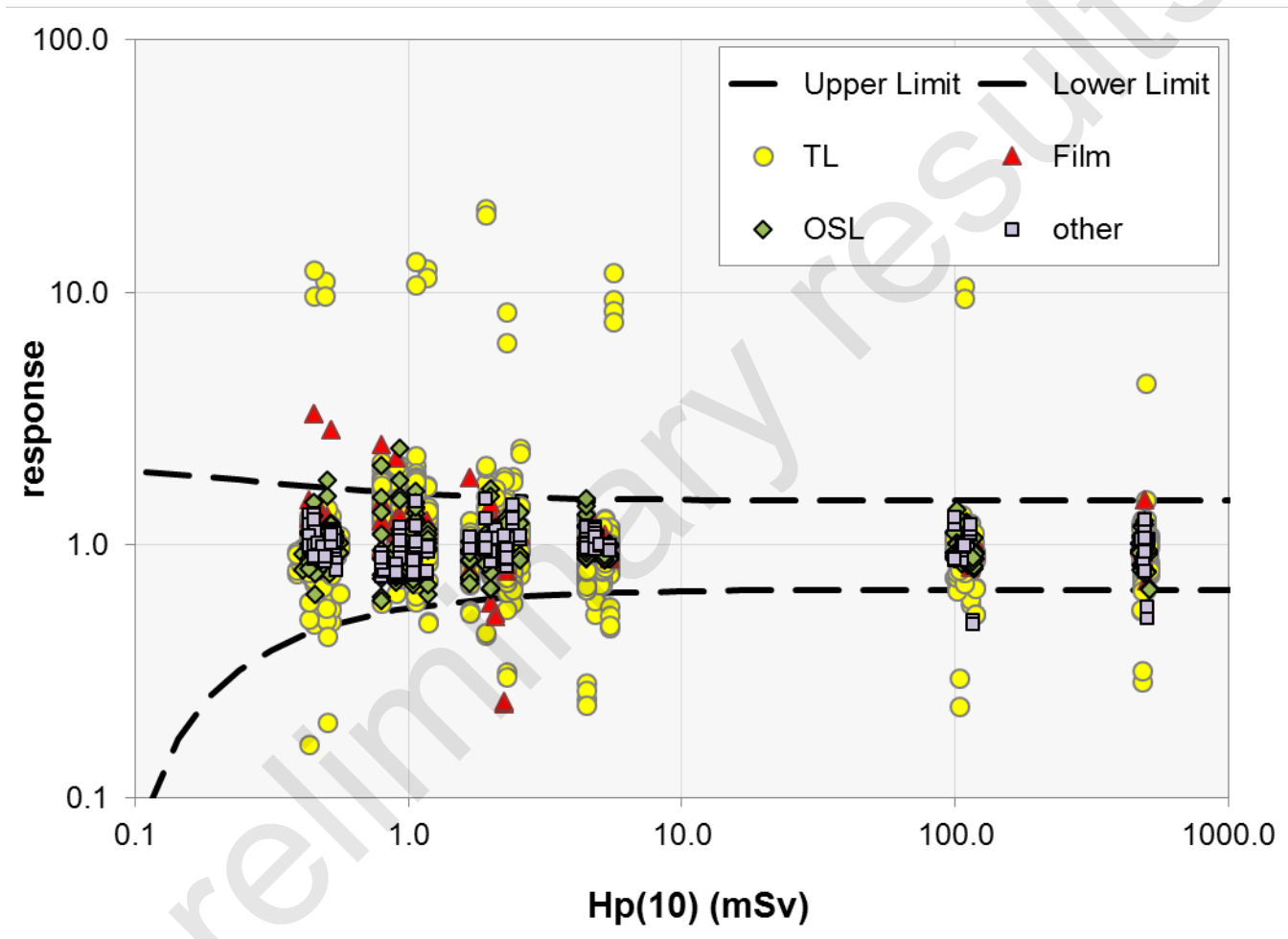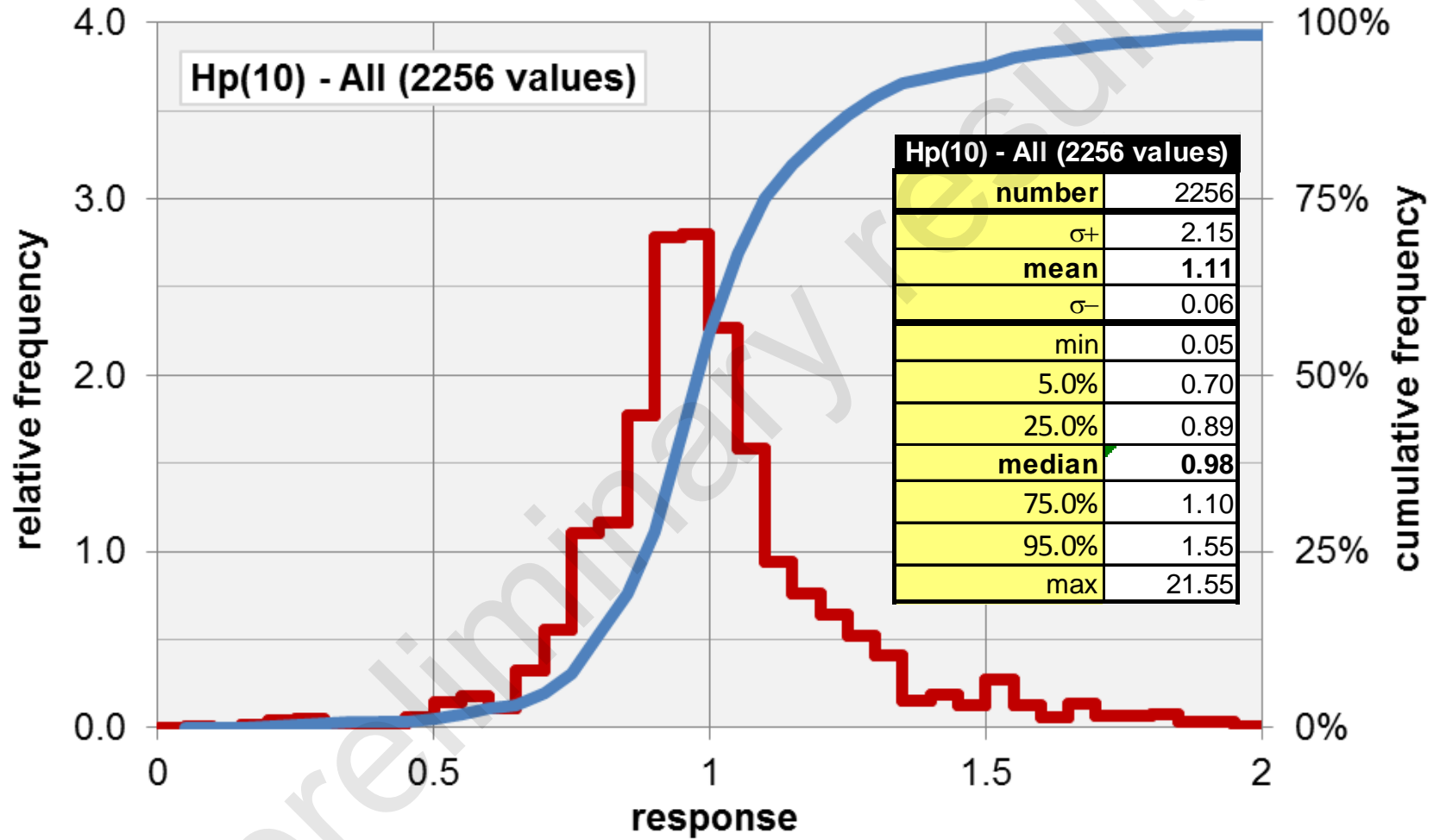
# All response values Hp(0.07)
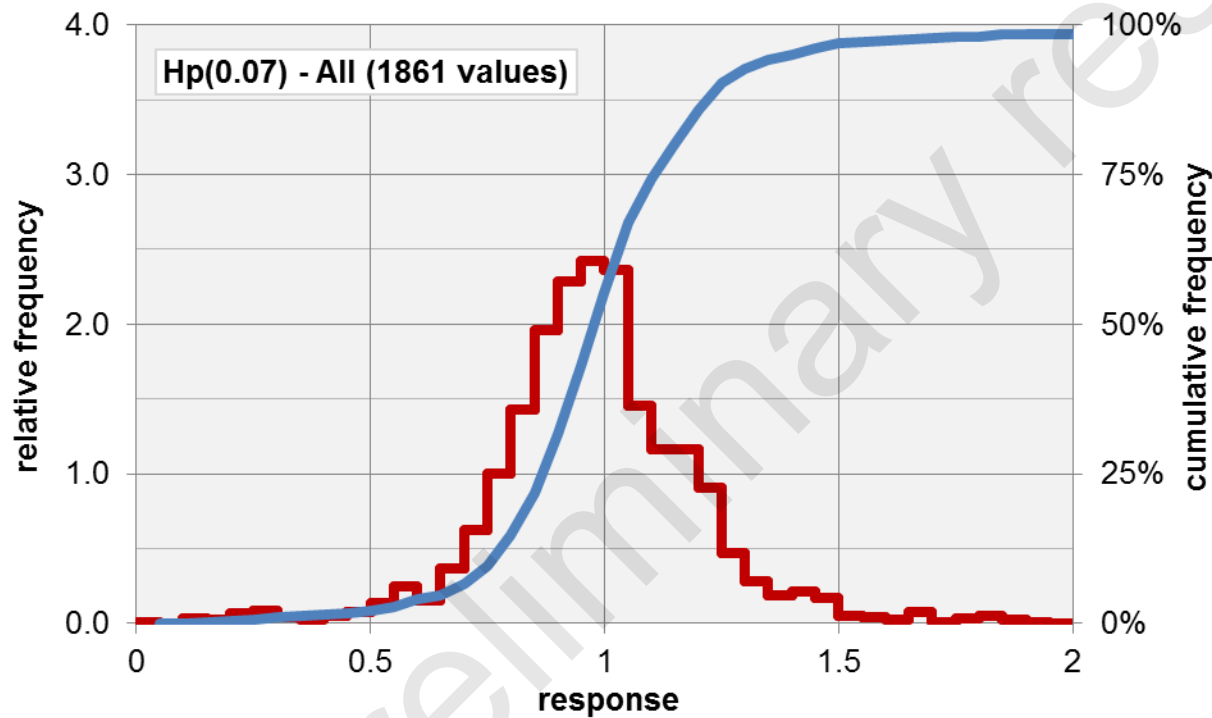


| Hp(0.07) - All (1861 values) | |
|---|---|
| number | 1861 |
| σ+ | 1.96 |
| mean | 1.08 |
| σ− | 0.19 |
| min | 0.00 |
| 5.0% | 0.66 |
| 25.0% | 0.87 |
| median | 0.98 |
| 75.0% | 1.11 |
| 95.0% | 1.39 |
| max | 12.96 |

# Coefficient of variation (CV)
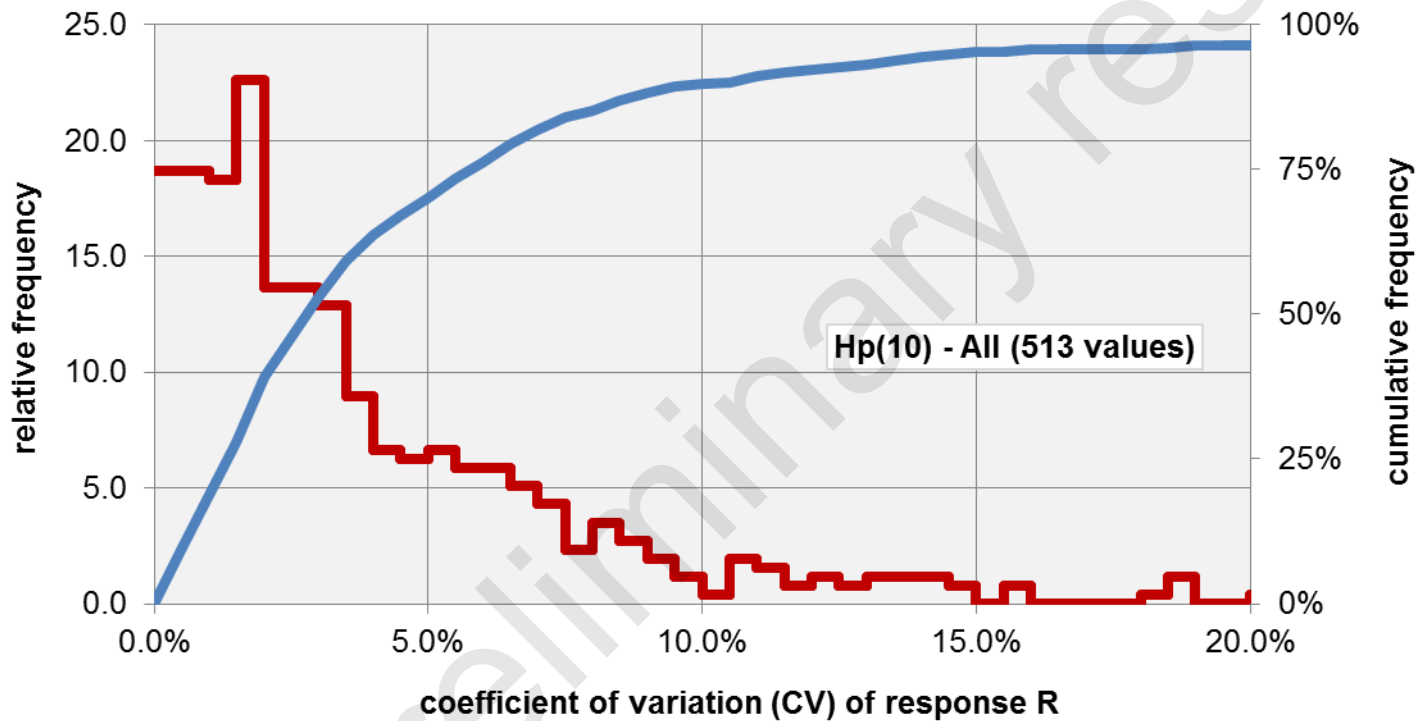


| Hp(10) | |
|---|---|
| **number** | 513 |
| σ− | *12.6%* |
| **mean** | ***4.9%*** |
| σ+ | *-2.8%* |
| min | 0.0% |
| 5.0% | 0.3% |
| 25.0% | 1.3% |
| **median** | **2.8%** |
| 75.0% | 5.7% |
| 95.0% | 14.4% |
| max | 73.9% |

Hp(10) - All (513 values)

coefficient of variation (CV) of response R

relative frequency

cumulative frequency

All: - Hp(10) (102 systems)

excl. RID: 33

40

All:  - Hp(0.07) (84 systems)

excl. RID: 33

TL : - Hp(10) (67 systems)

OSL : - Hp(10) (17 systems)

Film : - Hp(10) (8 systems)

other: - Hp(10) (10 systems)

excl. RID: 33
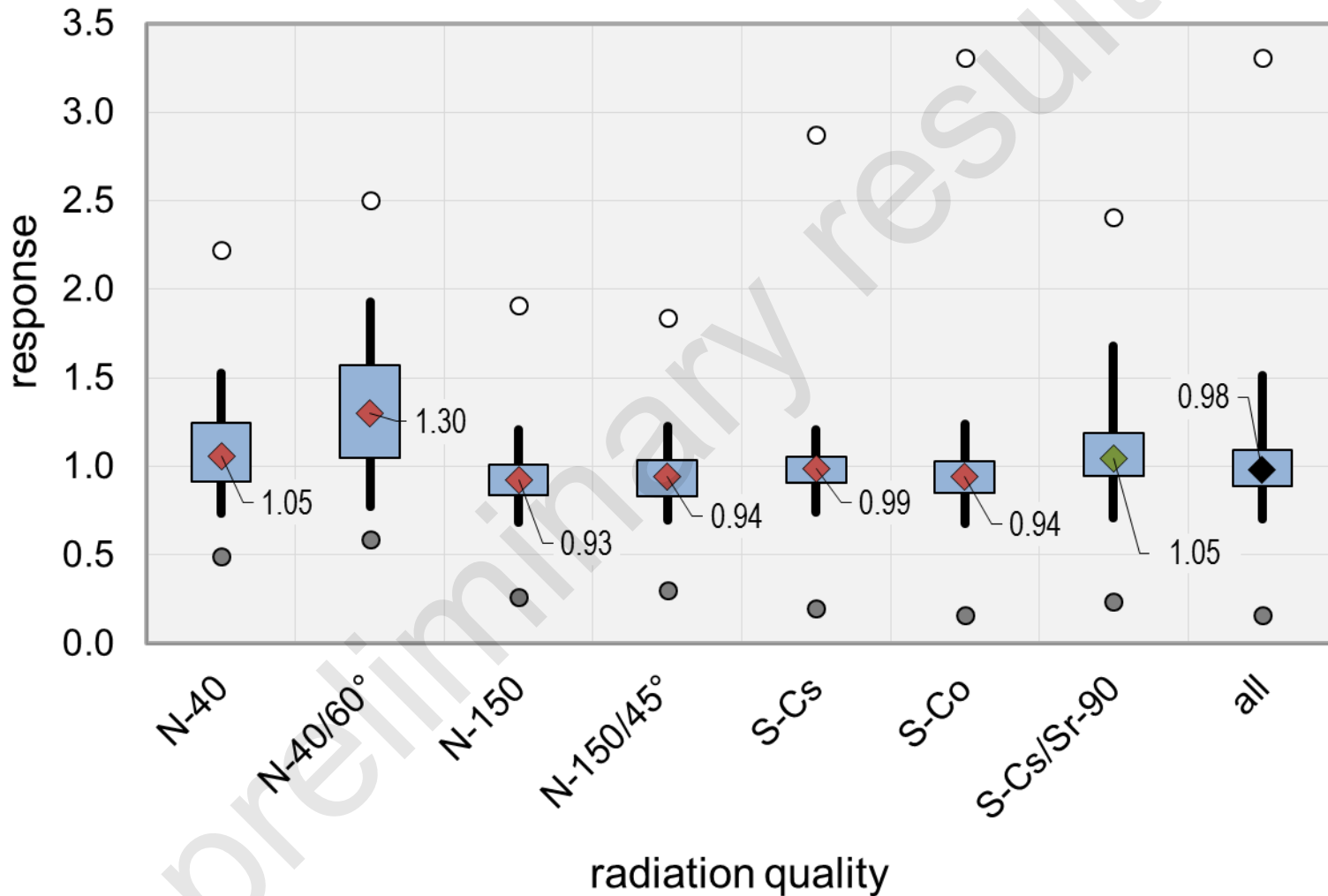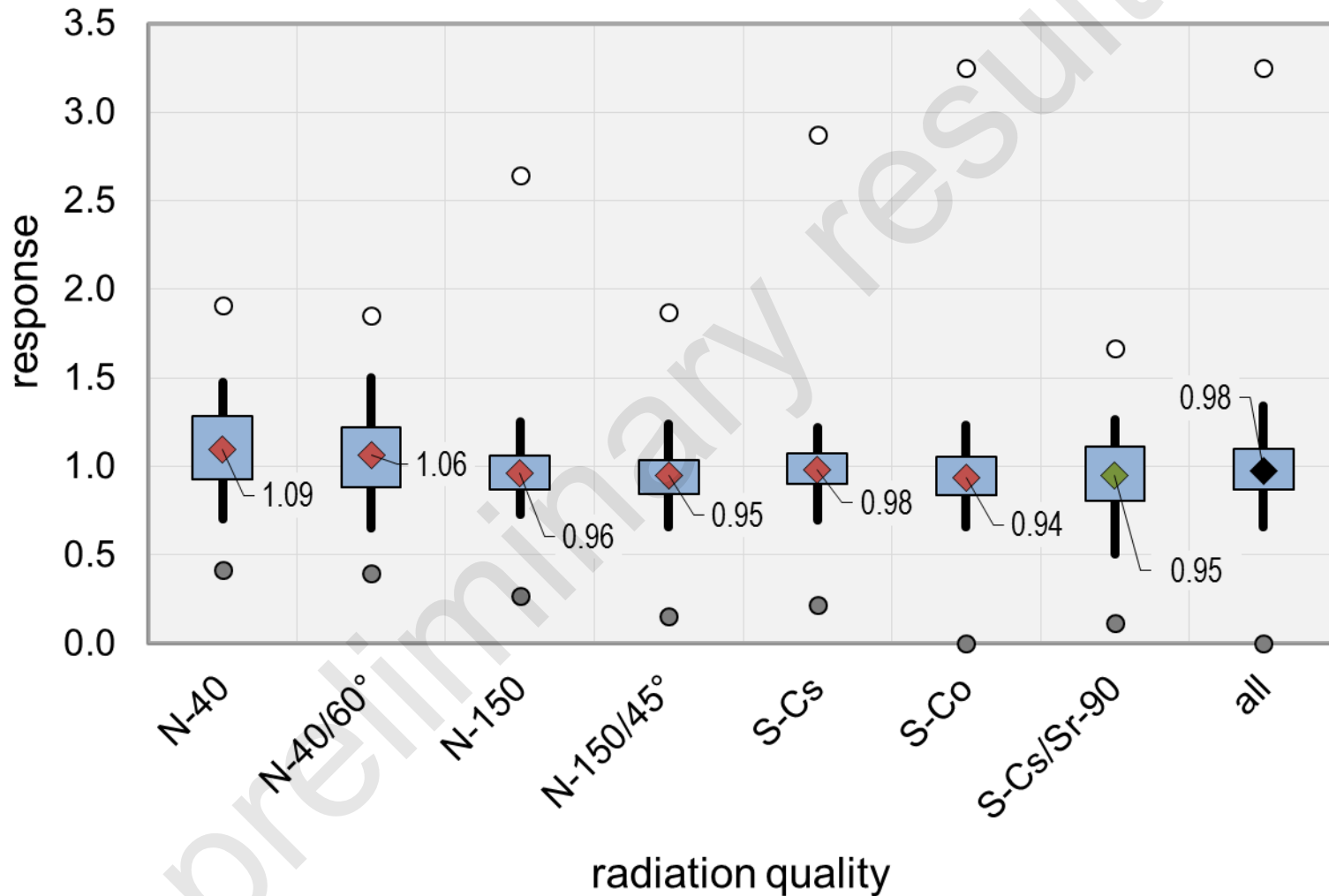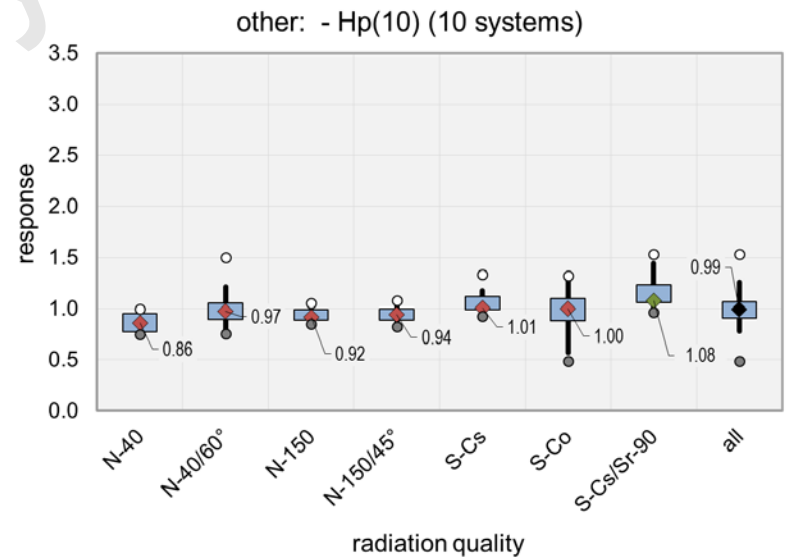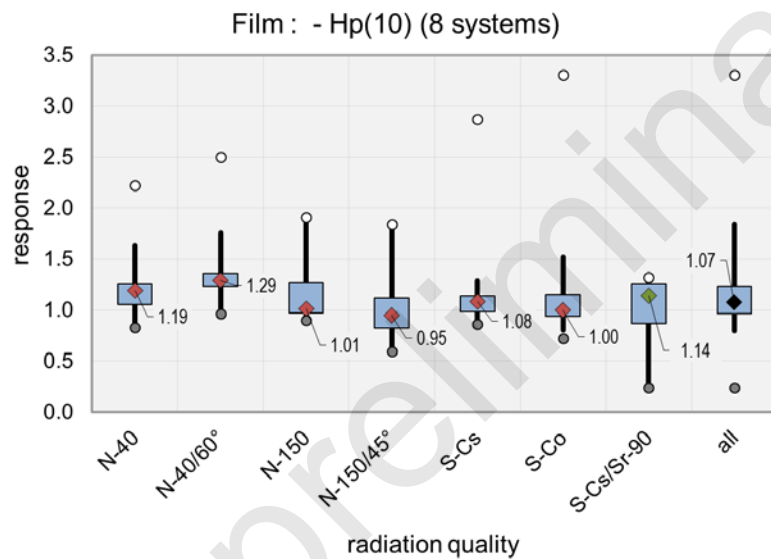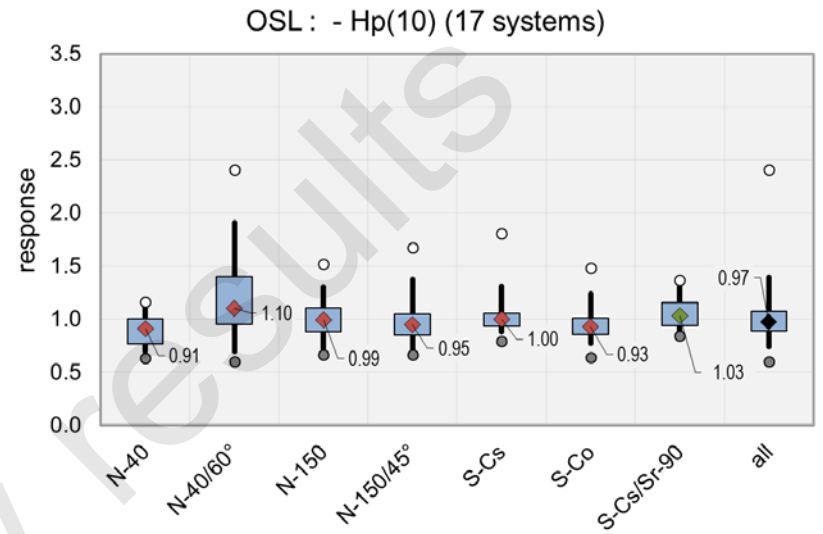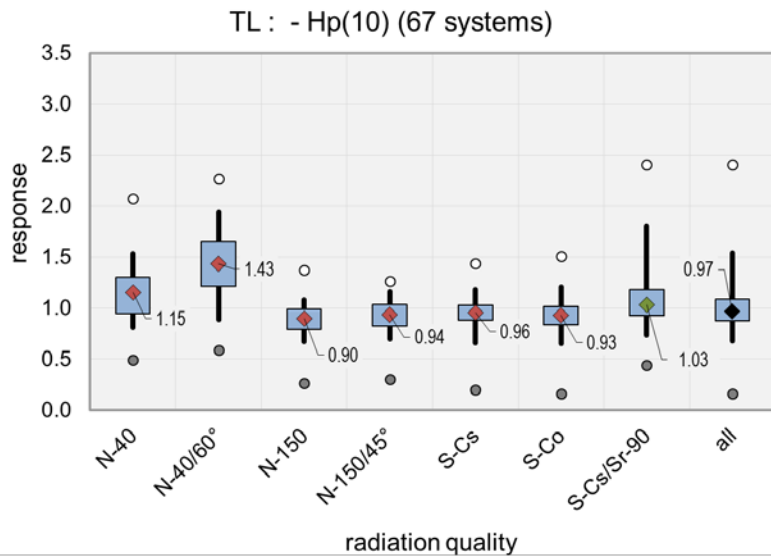
# Outliers (trumpet curve)

| Outliers / Trumpet | | | | | | |
|---|---|---|---|---|---|---|
| Quantity | Quality | TL | Film | OSL | other | All |
| Hp(10) | N-40 | 7% | 6% | 0% | 0% | 5% |
| | N-40/60° | 32% | 6% | 12% | 0% | 24% |
| | N-150 | 6% | 13% | 0% | 0% | 5% |
| | N-150/45° | 5% | 25% | 3% | 0% | 6% |
| | S-Cs | 5% | 4% | 2% | 0% | 4% |
| | S-Co | 5% | 8% | 0% | 7% | 5% |
| | S-Cs/Sr-90 | 17% | 25% | 6% | 0% | 14% |
| | All | 9% | 10% | 2% | 2% | 7% |

| Outliers / Trumpet | | | | | | |
|---|---|---|---|---|---|---|
| Quantity | Quality | TL | Film | OSL | other | All |
| Hp(0.07) | N-40 | 9% | 13% | 0% | 0% | 6% |
| | N-40/60° | 9% | 13% | 3% | 28% | 10% |
| | N-150 | 6% | 25% | 3% | 0% | 6% |
| | N-150/45° | 7% | 50% | 7% | 0% | 8% |
| | S-Cs | 6% | 8% | 1% | 0% | 5% |
| | S-Co | 8% | 8% | 0% | 9% | 7% |
| | S-Cs/Sr-90 | 11% | 75% | 10% | 0% | 13% |
| | All | 8% | 20% | 2% | 5% | 7% |

# Previous intercomparisons

| | Outliers / Trumpet | | | | | |
|---|---|---|---|---|---|---|
| Quantity | Quality | TLD | Film | OSL | Other | All |
| Hp(10) | RQR7 | 5% | 8% | 0% | 10% | 5% |
| | W-80 | 6% | 8% | 0% | 0% | 5% |
| | W-80/60° | 8% | 25% | 0% | 5% | 9% |
| | W-150 | 5% | 17% | 0% | 0% | 5% |
| | S-Cs | 1% | 14% | 0% | 2% | 3% |
| | S-Co | 5% | 24% | 0% | 0% | 6% |
| | All | 4% | 17% | 0% | 2% | 5% |

IC2014

| | Outliers / Trumpet | | | | | |
|---|---|---|---|---|---|---|
| Quantity | Quality | TLD | Film | OSL | other | All |
| Hp(10) | S-Cs | 4% | 0% | 0% | 0% | 3% |
| | S-Co | 8% | 0% | 2% | 5% | 6% |
| | N60 | 8% | 4% | 5% | 0% | 6% |
| | N60/60° | 14% | 25% | 0% | 0% | 13% |
| | All | 8% | 4% | 2% | 3% | 6% |

IC2012

# Number of outliers (approx. 1 out of 10)

| Hp(10) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # outliers (sys) | 0 | 1 | 2 | 3 | 4 | 6 | 11 | 14 | 15 | 16 | 22 | 0-2 | > 2 |
| TL | 44% | 13% | 29% | 3% | 3% | 1% | 1% | - | 1% | 1% | 1% | 87% | 13% |
| Film | 63% | - | 25% | - | - | - | - | 13% | - | - | - | 88% | 13% |
| OSL | 76% | 12% | - | 6% | 6% | - | - | - | - | - | - | 88% | 12% |
| other | 90% | - | - | - | 10% | - | - | - | - | - | - | 90% | 10% |
| All | 55% | 11% | 21% | 3% | 4% | 1% | 1% | 1% | 1% | 1% | 1% | 87% | 13% |
| | 87% | | | 13% | | | | | | | | | |

| Hp(0.07) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # outliers (sys) | 0 | 1 | 2 | 4 | 5 | 6 | 9 | 12 | 18 | 22 | 0-2 | > 2 |
| TL | 74% | 5% | 5% | 7% | 2% | - | 2% | - | 4% | 2% | 84% | 16% |
| Film | - | - | 75% | - | - | - | - | 25% | - | - | 75% | 25% |
| OSL | 87% | - | 7% | - | - | 7% | - | - | - | - | 93% | 7% |
| other | 44% | 22% | 22% | 11% | - | - | - | - | - | - | 89% | 11% |
| All | 69% | 6% | 11% | 6% | 1% | 1% | 1% | 1% | 2% | 1% | 86% | 14% |
| | 86% | | | 14% | | | | | | | | |

$$\frac{1}{F}\left(1-\frac{2H_0}{H_0+H_c}\right) \le R \le F\left(1+\frac{H_0}{2H_0+H_c}\right)$$

$F = 1.5 \qquad H_0 = 0.085\,mSv$

10% of outliers are accepted

# All individual results for Hp(10)

# Certificates

# All mean response (R) results

## TL

| Quality / RID | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N-40 | 1.10 | 1.39 | 0.91 | 1.39 | 1.29 | 1.36 | 1.34 | 1.21 | 1.13 | 1.10 | 1.15 | 0.79 | 1.18 | 0.91 | 0.79 | 0.90 | 0.94 | 1.37 | 1.22 | 0.50 | 0.97 | 0.94 | 1.72 | 1.32 | 11.89 | 0.89 | 1.26 | 1.26 | 0.92 | 0.96 | 0.83 | 0.99 | 0.99 | 1.04 | 0.84 | 1.62 | 1.21 | 1.20 | 1.04 | 2.07 | 1.04 | 1.08 | 1.52 | 0.94 | 1.23 | 0.94 | 1.53 | 1.18 | 1.35 | 0.72 | 0.96 | 0.91 |
| N-40/60° | 1.13 | 1.81 | 1.03 | 1.80 | 1.66 | 1.63 | 1.82 | 1.53 | 1.46 | 1.49 | 1.07 | 0.79 | 1.54 | 0.91 | 0.80 | 0.95 | 1.79 | 1.34 | 1.50 | 0.61 | 0.93 | 1.70 | 2.17 | 1.71 | 11.96 | 1.39 | 1.76 | 1.78 | 1.41 | 0.97 | 1.31 | 1.32 | 1.51 | 1.48 | 1.34 | 1.76 | 1.52 | 1.36 | 1.69 | ### | 1.30 | 1.39 | 1.63 | 1.28 | 1.56 | 1.32 | 2.05 | 1.55 | 1.66 | 1.13 | 1.16 | 1.18 |
| N-150 | 0.75 | 0.90 | 0.68 | 0.98 | 0.96 | 0.89 | 1.00 | 0.91 | 0.73 | 0.78 | 0.75 | 0.53 | 0.77 | 0.87 | 0.89 | 0.72 | 0.83 | 0.94 | 1.04 | 0.28 | 0.88 | 0.87 | 1.12 | 0.94 | 8.26 | 0.97 | 0.94 | 0.91 | 0.81 | 0.79 | 0.85 | 0.91 | 1.06 | 1.04 | 0.91 | 1.33 | 0.95 | 0.81 | 0.77 | 0.95 | 1.00 | 0.83 | 1.01 | 0.87 | 1.05 | 0.69 | 1.09 | 0.84 | 1.06 | 0.57 | 0.95 | 0.94 |
| N-150/45° | 0.76 | 1.04 | 0.72 | 1.04 | 1.00 | 0.92 | 1.06 | 0.93 | 0.81 | 0.80 | 0.76 | 0.60 | 0.88 | 0.95 | 0.92 | 0.71 | 0.79 | 1.00 | 1.07 | 0.31 | 0.99 | 0.94 | 1.16 | 0.99 | 7.38 | 0.92 | 0.98 | 0.96 | 0.85 | 0.81 | 0.90 | 0.97 | 1.11 | 1.05 | 0.93 | 1.16 | 1.06 | 0.93 | 0.86 | 1.00 | 1.10 | 0.76 | 1.06 | 0.88 | 1.09 | 0.75 | 1.14 | 0.89 | 1.24 | 0.55 | 0.93 | 0.82 |
| S-Cs-S | 1.03 | 1.39 | 0.94 | 1.01 | 0.97 | 1.33 | 0.98 | 0.94 | 1.00 | 0.74 | 1.04 | 0.32 | 1.12 | 0.93 | 0.92 | 0.64 | 1.01 | 0.96 | 1.03 | 0.96 | 0.94 | 0.86 | 1.09 | 0.97 | 11.04 | 0.93 | 0.97 | 0.96 | 0.62 | 1.32 | 0.77 | 1.00 | 1.06 | 1.06 | 0.96 | 0.99 | 1.22 | 1.24 | 0.84 | 0.95 | 1.08 | 0.98 | 0.98 | 1.06 | 1.28 | 0.96 | 1.10 | 0.87 | 1.06 | 0.58 | 0.99 | 1.05 |
| S-Cs-L | 1.00 | 0.86 | 0.96 | 0.96 | 0.94 | 0.82 | 0.98 | 0.91 | 0.97 | 0.81 | 0.97 | 0.51 | 0.98 | 0.91 | 0.89 | 0.68 | 0.91 | 0.95 | 1.07 | 0.26 | 0.91 | 0.89 | 1.06 | 0.92 | 9.39 | 0.88 | 0.91 | 0.91 | 0.82 | 1.03 | 0.76 | 1.01 | 1.02 | 1.03 | 1.15 | 1.18 | 0.74 | 0.95 | 1.04 | 0.95 | 1.00 | 1.00 | 1.25 | 0.92 | 1.06 | 0.81 | 1.03 | 1.03 | 0.91 | 1.11 | 0.84 |
| S-Co-S | 1.03 | 0.98 | 0.90 | 0.94 | 0.93 | 1.28 | 0.89 | 0.94 | 1.00 | 0.60 | 1.01 | 0.34 | 0.92 | 0.87 | 0.81 | 0.53 | 0.93 | 0.89 | 1.01 | 0.26 | 0.92 | 0.96 | 1.06 | 0.91 | 10.42 | 0.82 | 0.87 | 0.87 | 0.53 | 1.04 | 0.72 | 0.98 | 0.96 | 1.01 | 0.93 | 0.85 | 1.23 | 1.25 | 0.79 | 0.95 | 0.99 | 0.96 | 0.94 | 1.05 | 1.24 | 0.92 | 1.03 | 0.76 | 1.03 | 0.51 | 0.90 | 0.97 |
| S-Co-M | 1.07 | 0.81 | 0.98 | 0.93 | 0.91 | 0.75 | 0.96 | 0.92 | 1.07 | 0.76 | 1.05 | 0.53 | 1.03 | 0.87 | 0.84 | 0.68 | 0.87 | 0.93 | 1.09 | 0.26 | 0.92 | 0.96 | 1.06 | 0.91 | 10.09 | 0.87 | 0.91 | 0.89 | 0.71 | 1.02 | 0.80 | 1.00 | 1.01 | 1.01 | 0.94 | 0.94 | 1.21 | 0.94 | 0.78 | 0.92 | 0.99 | 0.92 | 0.93 | 1.01 | 1.26 | 1.00 | 1.06 | 0.80 | 0.91 | 0.60 | 1.09 | 0.89 |
| S-Co-H | 1.04 | 0.84 | 0.97 | 0.95 | 0.93 | 0.79 | 0.98 | 0.95 | 1.26 | | 1.03 | 0.55 | 0.96 | 0.89 | 0.86 | 0.67 | 0.91 | 0.95 | 1.04 | 0.30 | 0.92 | 0.93 | 1.06 | 0.92 | 2.21 | 0.95 | 0.91 | 0.88 | 0.95 | 1.06 | 0.81 | 1.00 | 1.03 | 1.03 | 0.96 | 0.92 | 1.20 | 0.94 | 0.72 | 0.93 | 0.96 | 0.87 | 0.79 | 1.06 | 1.21 | 1.18 | 1.07 | 0.81 | 0.93 | 0.70 | 0.81 | 0.83 |
| S-Cs/Sr-90 | 1.04 | 0.94 | 1.09 | 0.99 | 0.96 | 1.60 | 0.97 | 1.07 | 1.02 | 0.81 | 1.03 | 0.63 | 1.83 | 1.25 | 1.22 | 0.69 | 0.96 | 1.43 | 0.97 | 0.45 | 1.00 | 0.86 | 1.17 | 0.94 | 20.97 | 1.04 | 0.93 | 0.91 | 1.01 | 2.05 | 0.79 | 0.87 | 0.93 | 1.07 | 1.00 | 1.07 | 1.58 | 1.40 | 0.74 | 2.36 | 0.99 | 1.31 | 1.14 | 1.07 | 1.67 | 0.94 | 1.08 | 0.85 | 1.48 | 0.80 | 0.76 | 1.83 |
| All | 1.00 | 1.07 | 0.92 | 1.08 | 1.05 | 1.11 | 1.09 | 1.02 | 1.04 | 0.87 | 0.98 | 0.56 | 1.11 | 0.93 | 0.89 | 0.71 | 0.98 | 1.06 | 1.10 | 0.47 | 0.94 | 0.97 | 1.24 | 1.04 | 10.27 | 0.96 | 1.03 | 1.02 | 0.86 | 1.10 | 0.84 | 1.00 | 1.06 | 1.08 | 0.97 | 1.15 | 1.23 | 1.13 | 0.88 | 1.20 | 1.05 | 1.00 | 1.09 | 1.02 | 1.28 | 0.96 | 1.21 | 0.92 | 1.16 | 0.67 | 0.98 | 1.01 |
| Outliers | | 2 | | 2 | 2 | 2 | | | | | | 15 | 2 | | | 1 | 2 | | 1 | 16 | | 2 | 4 | 2 | 22 | | 2 | 2 | 1 | 2 | | | | 3 | 2 | 1 | 1 | 6 | | | 1 | | 3 | | 2 | | 2 | 11 | | 2 | | |

## Second part

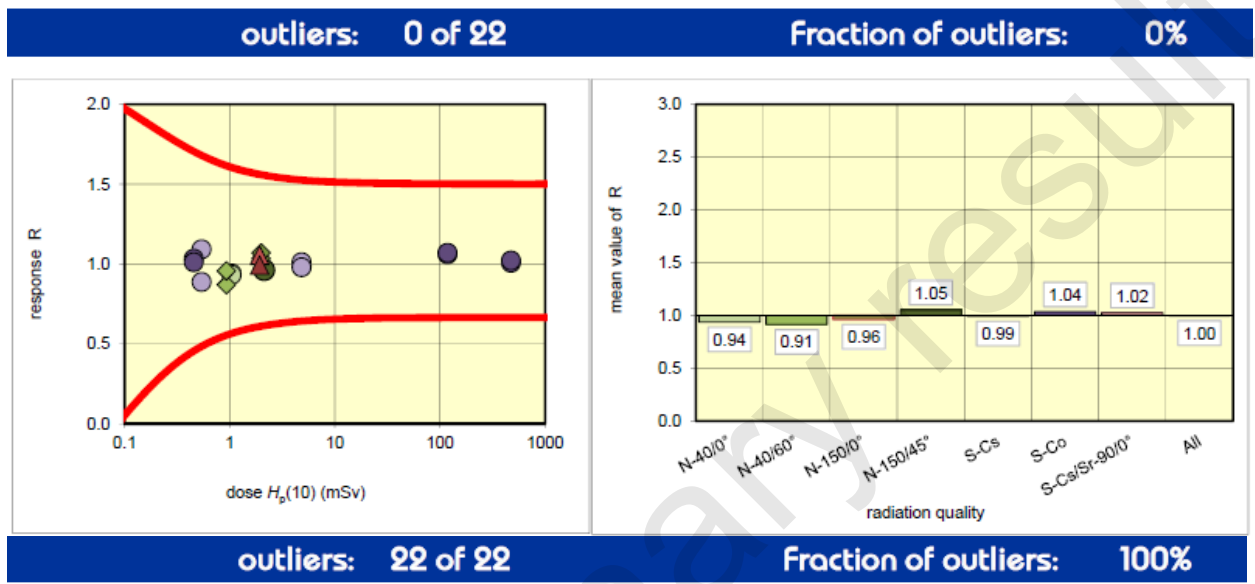| Quality / RID | TL 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | Film 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | OSL 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | other 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N-40 | 1.20 | 1.38 | 1.23 | 1.32 | 1.03 | 1.11 | 1.11 | 1.23 | 1.24 | 1.30 | 1.21 | 1.42 | 1.05 | 1.53 | 1.11 | 1.26 | 1.25 | 0.84 | 1.44 | 1.02 | 1.25 | 1.05 | 1.19 | 1.67 | 0.97 | 1.04 | 0.95 | 0.67 | 0.73 | 1.14 | 0.88 | 0.77 | 0.94 | 0.78 | 0.81 | 1.12 | 0.71 | 1.09 | 0.88 | 0.96 | 0.95 | 0.99 | 0.97 | 0.96 | 0.92 | 0.81 | 0.77 | 0.76 | 0.95 | 0.76 | 0.78 | 1.19 |
| N-40/60° | 1.60 | 1.67 | 1.59 | 1.34 | 1.28 | 1.30 | 1.15 | 1.37 | 1.21 | 1.60 | 1.44 | 1.11 | 1.44 | 2.01 | 1.14 | 1.42 | 1.50 | 0.98 | 1.24 | 1.19 | 1.37 | 1.30 | 1.31 | 1.88 | 1.33 | 1.01 | 1.23 | 1.56 | 0.92 | 1.30 | 0.75 | 0.61 | 0.91 | 1.81 | 1.66 | 1.00 | 0.77 | 1.99 | 1.01 | 1.13 | 1.11 | 1.35 | 1.02 | 1.02 | 1.06 | 0.88 | 0.92 | 0.79 | 1.15 | 0.85 | 0.92 | 1.44 |
| N-150 | 0.92 | 1.02 | 0.87 | 0.99 | 0.93 | 0.77 | 0.79 | 0.80 | 1.02 | 0.91 | 0.86 | 0.85 | 0.78 | 1.07 | 0.76 | 0.99 | 0.90 | 1.03 | 1.55 | 1.00 | 0.99 | 1.16 | 0.95 | 1.91 | 1.15 | 1.22 | 1.03 | 0.97 | 0.68 | 1.03 | 1.04 | 0.83 | 0.96 | 0.94 | 1.20 | 0.89 | 0.75 | 1.48 | 0.83 | 0.92 | 1.11 | 0.92 | 0.85 | 1.04 | 0.93 | 1.00 | 0.90 | 1.00 | 0.87 | 0.98 | 0.89 | 1.00 |
| N-150/45° | 0.89 | 0.96 | 0.88 | 1.03 | 0.93 | 0.81 | 0.82 | 0.93 | 1.19 | 0.96 | 1.06 | 0.93 | 0.86 | 1.13 | 0.77 | 1.05 | 0.81 | 1.00 | 1.33 | 0.99 | 0.86 | 0.59 | 0.87 | 1.84 | 1.13 | 1.23 | 0.98 | 0.98 | 0.72 | 1.05 | 0.91 | 0.74 | 1.05 | 0.91 | 0.91 | 0.80 | 0.67 | 1.62 | 0.85 | 0.92 | 1.05 | 0.88 | 0.83 | 0.96 | 0.95 | 1.03 | 0.94 | 1.05 | 0.86 | 1.07 | 0.93 | 1.01 |
| S-Cs-S | 0.86 | 1.02 | 0.83 | 0.94 | 0.96 | 0.78 | 0.81 | 0.99 | 0.78 | 0.95 | 0.91 | 1.16 | 0.70 | 1.08 | 1.05 | 1.10 | 1.07 | 1.08 | 1.29 | 1.10 | 1.05 | 0.86 | 1.24 | 2.87 | 1.03 | 1.00 | 0.96 | 0.90 | 0.91 | 0.99 | 1.00 | 0.89 | 0.99 | 0.94 | 0.96 | 1.04 | 0.91 | 1.44 | 1.12 | 1.19 | 1.05 | 1.06 | 0.99 | 1.02 | 1.17 | 1.03 | 1.14 | 1.03 | 0.99 | 1.02 | 1.14 | 1.12 |
| S-Cs-L | 0.82 | 0.99 | 0.83 | 0.94 | 0.98 | 0.77 | 0.79 | 1.11 | 1.00 | 0.90 | 0.94 | 1.29 | 0.77 | 1.08 | 1.00 | 1.10 | 0.99 | 0.96 | 1.14 | 1.01 | 1.08 | 0.89 | 1.06 | 1.19 | 1.03 | 1.00 | 0.96 | 0.90 | 0.91 | 0.99 | 1.00 | 0.89 | 0.99 | 0.94 | 0.96 | 1.04 | 0.91 | 1.44 | 1.12 | 1.19 | 1.00 | 0.99 | 0.98 | 1.01 | 1.08 | 0.99 | 1.15 | 0.99 | 0.97 | 1.02 | 1.16 | 1.05 |
| S-Co-S | 0.77 | 0.94 | 0.80 | 0.90 | 0.91 | 0.71 | 0.78 | 1.11 | 0.76 | 0.85 | 0.85 | 1.14 | 0.72 | 1.01 | 1.01 | 0.95 | 1.13 | 1.01 | 1.39 | 1.11 | 1.02 | 0.81 | 1.34 | 3.31 | 0.83 | 0.92 | 0.70 | 0.84 | 0.89 | 0.93 | 0.93 | 0.83 | 1.02 | 0.89 | 0.90 | 1.01 | 0.99 | 1.39 | 1.12 | 1.22 | 0.86 | 0.89 | 0.89 | 0.90 | 1.29 | 1.05 | 1.13 | 0.99 | 0.82 | 0.99 | 1.26 | 1.06 |
| S-Co-M | 0.84 | 0.94 | 0.86 | 0.94 | 1.03 | 0.75 | 0.75 | 1.30 | 0.98 | 0.84 | 0.94 | 1.18 | 0.72 | 1.04 | 1.08 | 1.10 | 0.93 | 0.95 | 0.94 | 1.10 | 0.84 | 0.90 | 1.06 | 1.24 | 0.88 | 0.97 | 0.82 | 0.84 | 0.93 | 0.92 | 1.02 | 0.94 | 1.07 | 0.87 | 0.92 | 0.95 | 0.93 | 1.34 | 1.12 | 1.23 | 0.89 | 0.88 | 0.89 | 0.50 | 1.18 | 0.99 | 1.11 | 0.97 | 0.87 | 1.05 | 1.25 | 1.03 |
| S-Co-H | 0.82 | 0.88 | 0.87 | | 1.00 | 0.76 | 0.78 | 1.11 | 1.01 | 0.74 | 0.95 | 1.50 | 0.71 | 1.05 | 1.19 | 1.23 | 0.98 | 0.98 | 0.87 | 1.16 | 0.72 | 0.94 | 1.00 | 1.52 | 0.95 | 0.85 | 0.67 | 0.78 | 0.94 | 0.94 | 0.94 | 0.78 | 0.82 | 0.94 | 0.93 | 1.23 | 1.08 | 1.19 | 0.82 | | | 0.87 | 0.88 | 0.54 | 1.17 | 1.02 | 1.04 | 0.99 | 0.85 | 1.05 | 1.17 | 0.96 |
| S-Cs/Sr-90 | 0.89 | 1.08 | 0.84 | 0.99 | ### | 1.26 | 0.83 | 1.67 | 0.96 | 1.05 | 1.08 | 1.59 | 0.96 | 1.10 | 1.03 | 1.17 | 1.18 | 0.53 | 1.22 | 1.32 | 1.10 | 0.99 | 1.28 | 0.24 | 0.97 | 1.03 | 1.01 | ### | 1.05 | 1.29 | 1.06 | 0.88 | 1.02 | 0.85 | 0.89 | 1.03 | 0.90 | 1.32 | 1.14 | 1.24 | 1.17 | 1.07 | 0.97 | 1.07 | 1.41 | 1.09 | 1.36 | 1.08 | 0.98 | 1.11 | 1.25 | 1.29 |
| All | 0.95 | 1.08 | 0.95 | 1.03 | 1.00 | 0.89 | 0.85 | 1.16 | 1.01 | 1.00 | 1.02 | 1.22 | 0.86 | 1.20 | 1.01 | 1.14 | 1.07 | 0.94 | 1.23 | 1.11 | 1.03 | 0.94 | 1.12 | 1.71 | 1.03 | 1.03 | 0.93 | 0.94 | 0.88 | 1.05 | 0.96 | 0.82 | 1.00 | 0.98 | 0.99 | 0.99 | 0.85 | 1.46 | 1.14 | 1.12 | 1.00 | 0.99 | 0.93 | 0.91 | 1.11 | 0.99 | 1.06 | 0.97 | 0.94 | 0.99 | 1.08 | 1.11 |
| Outliers | 1 | 2 | 1 | | 2 | | | 2 | | 1 | | 4 | | 2 | | | 2 | | | | 2 | | | 14 | | | | 3 | | | | | 1 | 1 | | | 4 | | | | | | | 4 | | | | | | | | | 164 |

# Special cases

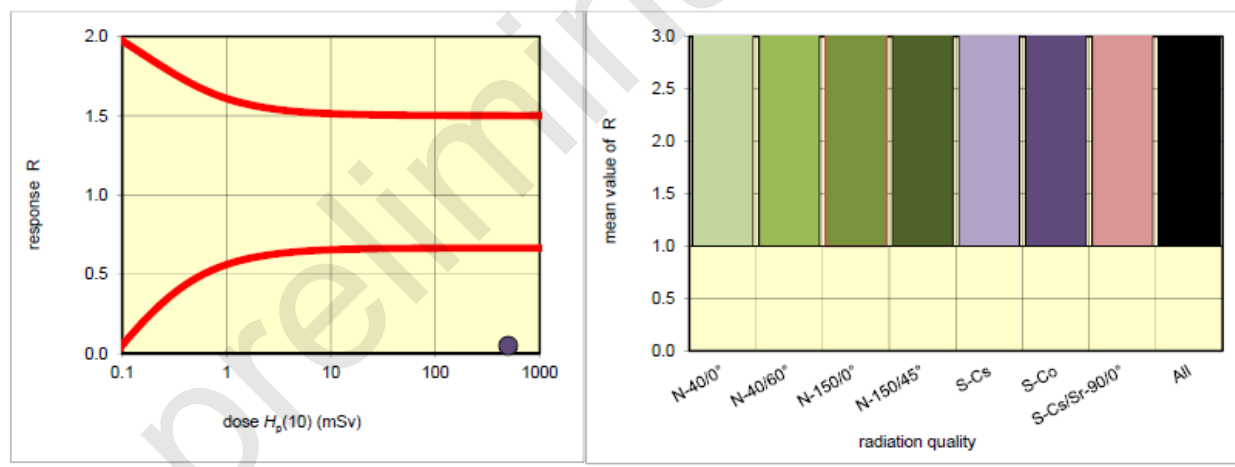# Irradiation plan was designed to check:
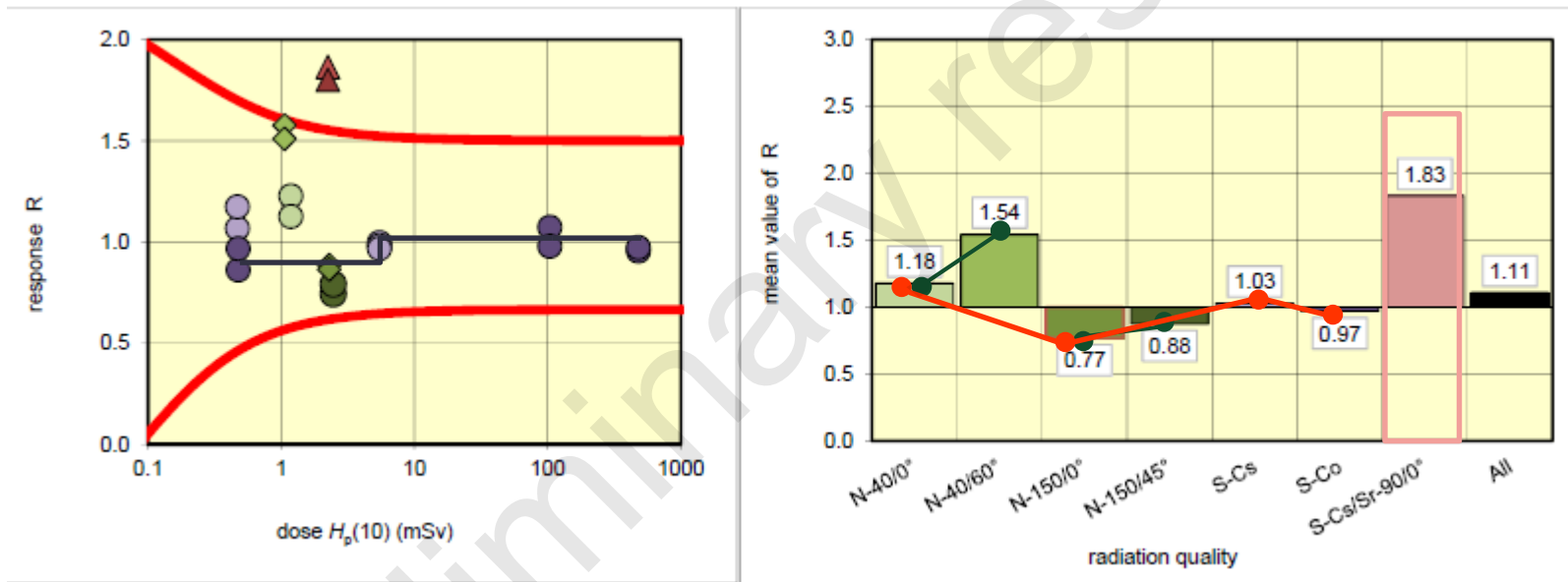


**ENERGY RESPONSE**     **ANGULAR RESPONSE**     **LINEARITY**     **MIXED BETA+GAMMA**

Compliance with ISO-14146: "trumpet curves"
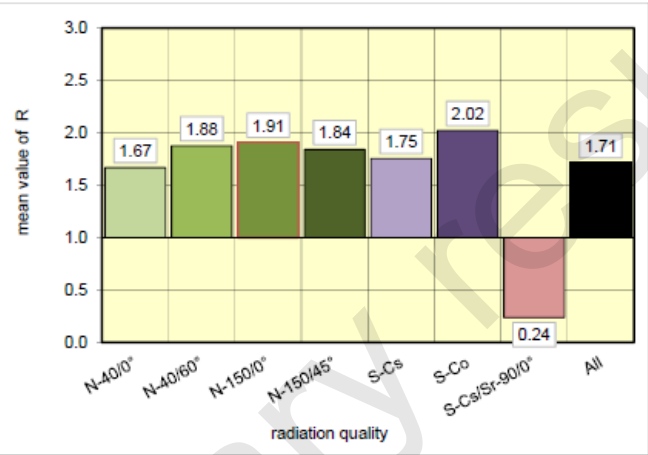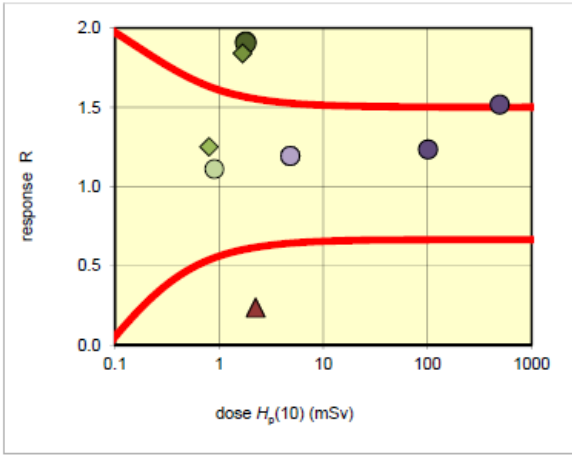
# Very GOOD / POOR performance:



$H_p(10)$

Reporting IDs: 85 (OSL), 33 (TL)

# Calibration problems:



Over response

$H_p(10)$

Under response

Reporting IDs: 8 (FILM), 28 (TL)

# Angular response:
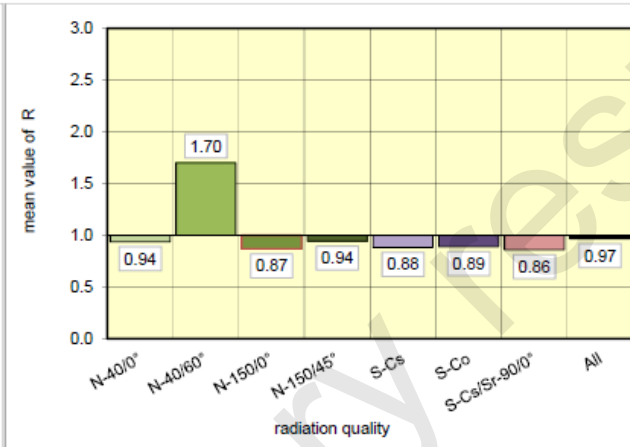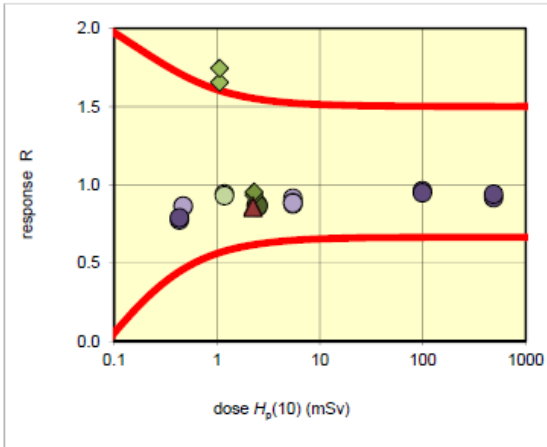


Significant angular dependence for N-40:60° that is not shown for N-150:45° - very common behaviour in IC2016 -
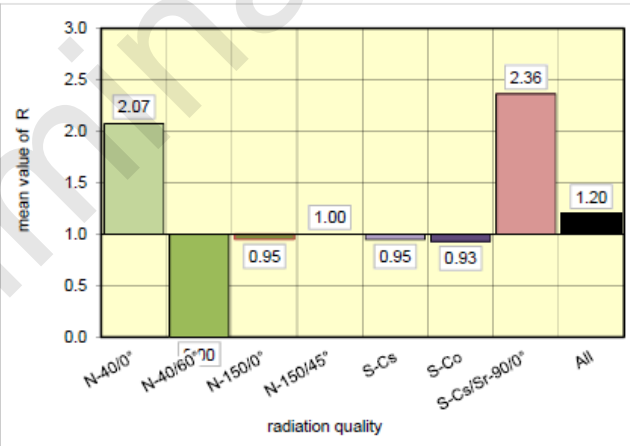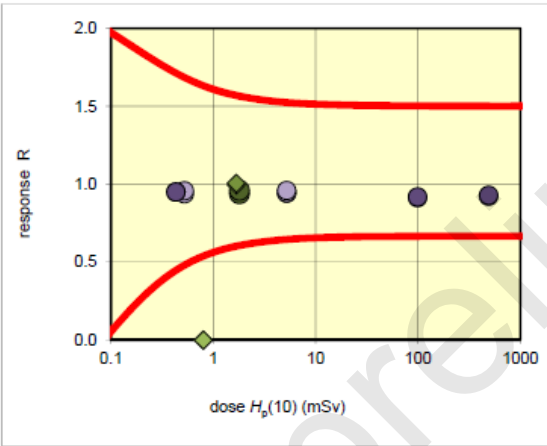
$H_p(10)$

Anomalous response for N-40 angular response – range of application? -

Results: IC2016    4 points outside diagramme (> 2)

trumpet curve parameter: 1.5 / 0.085 mSv

EURADOS Organisation Group IC2016

Reporting IDs: 30 (TL), 48 (TL)

# Mixed beta+gamma field response:
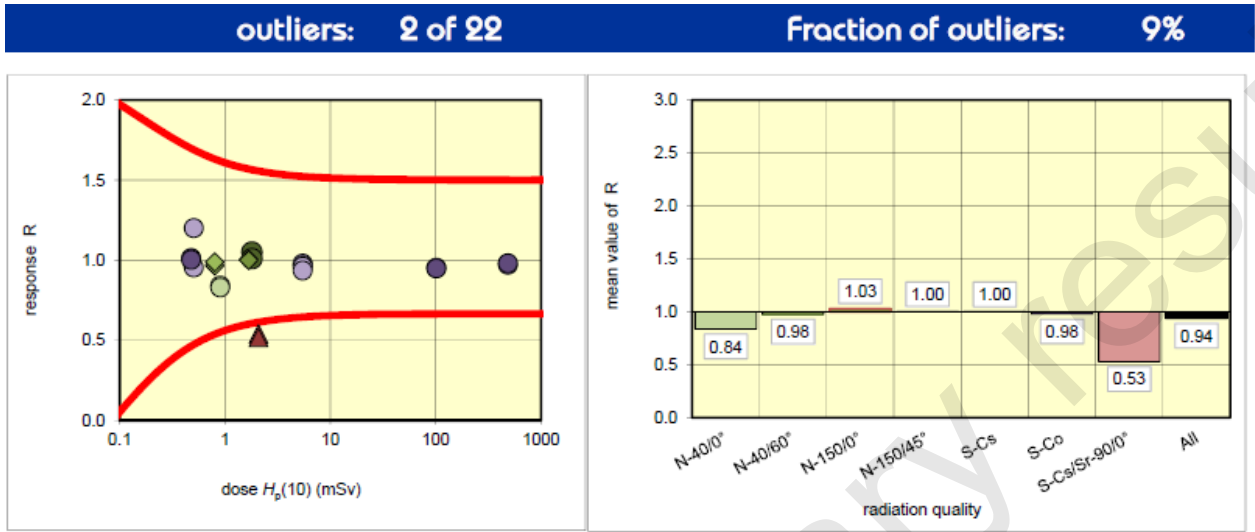


$H_p(10)$

Significant under response for mixed beta+gamma field
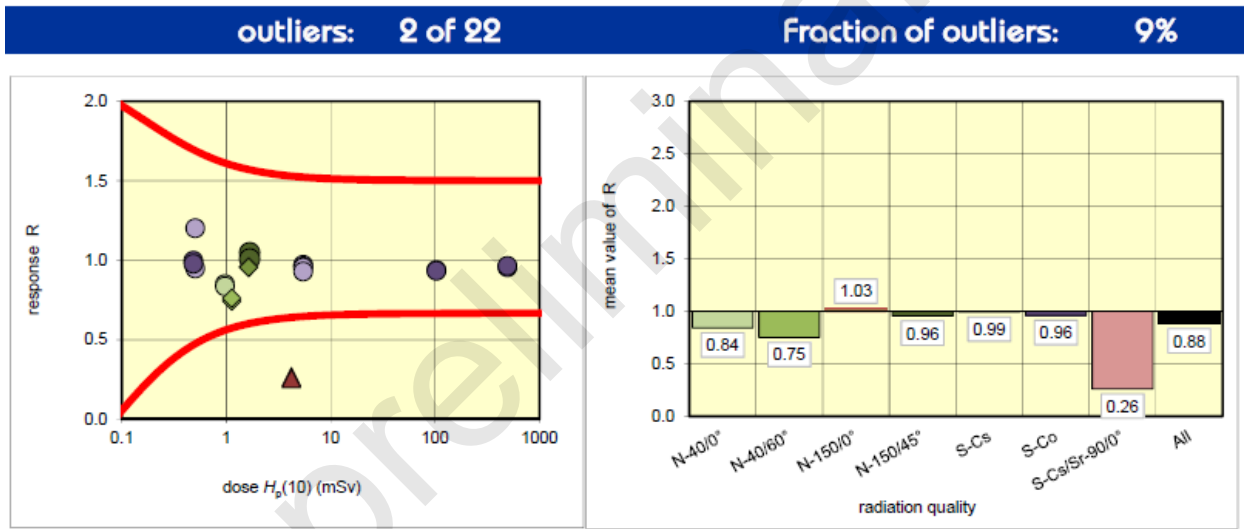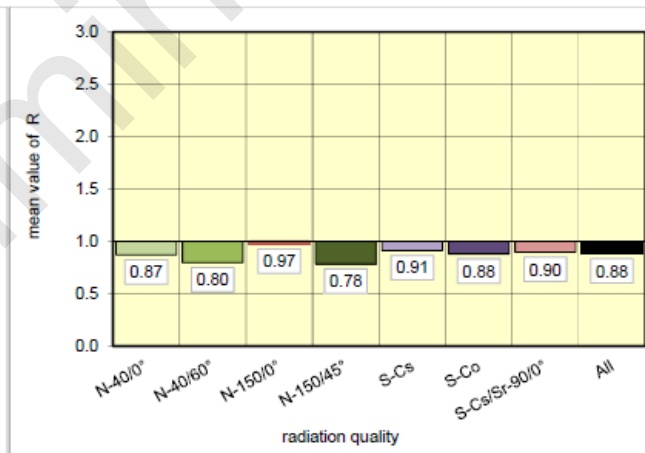
$H_p(0,07)$

Same behaviour

Reporting IDs: 2 (FILM)

# Mixed beta+gamma field response:
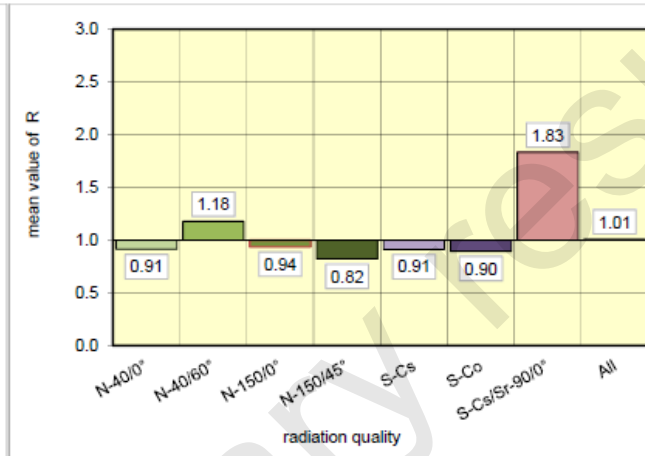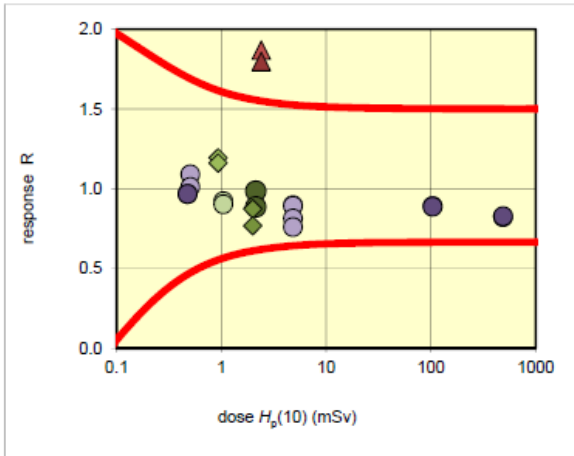


$H_p(10)$

Significant over response for mixed beta+gamma field
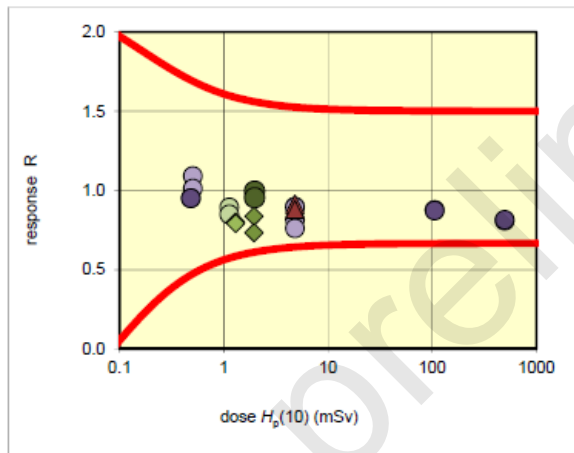
$H_p(0,07)$

Not reproducible behaviour

EURADOS Organisation Group IC2016

Reporting IDs: 60 (TL)

# Problems with high doses:
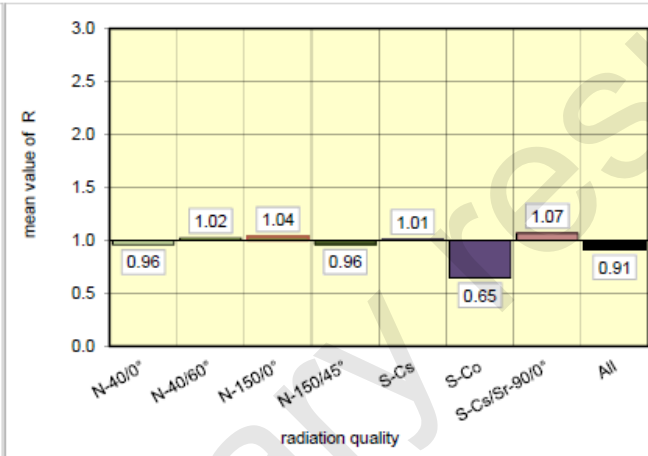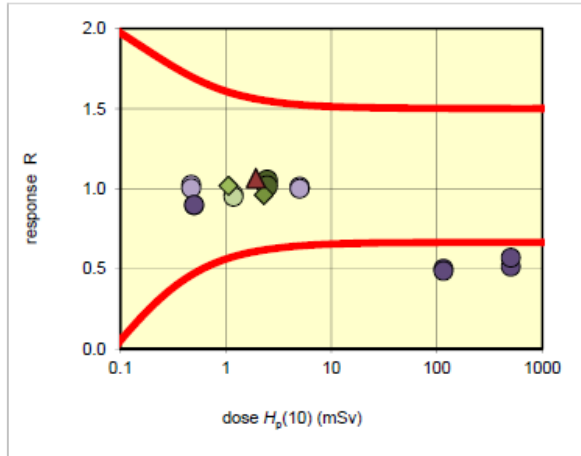


$H_p(10)$

Outliers only for high doses
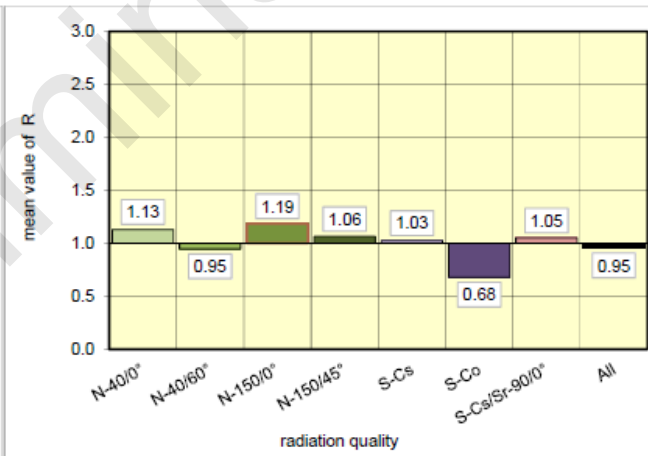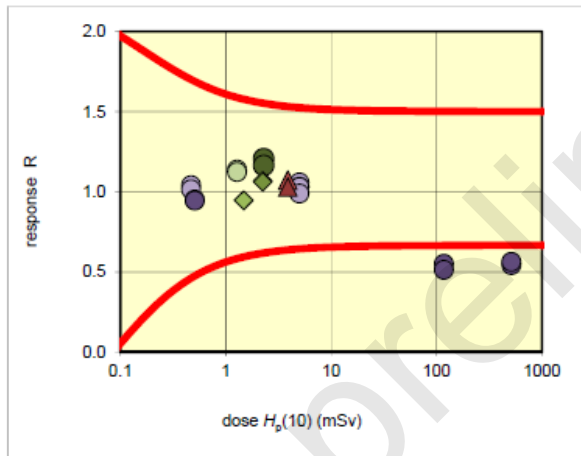
$H_p(0,07)$

Reproducible behaviour

Reporting IDs: 96 (Other)

# Conclusion

Results show a wide variety of behaviour for all kind of systems:

- It´s not only the physical characteristics of the detectors and the dosimetry systems but, what is more important, the working procedures of each IMS

- Some systems could avoid outliers by improving calibration procedures

# Summary 1

**Number of participating systems was a little decreasing (from 112 to 103)**

**Radiation qualities:**
- Photon and Betas were used (Betas only for a mixed radiation field)

**Fraction of outliers :**
- 55% systems show no outliers of the trumpet curve criteria.
- **87% systems fulfil the ISO 141406 performance criteria** (max. 2 outliers are allowed)
- **Overall performance individual results** remains stable (from 5% to 7%)
- FILM performance increased (from 17% to 10%)
- TLD performance decreased (from 4% to 9%)
- OSL performance decreased (0% to 2%)

# Summary 2

**Responses:**

- Overall <u>mean</u> response **1.11 (1.08)**
- Overall <u>median</u> response **0.98 (0.98)**

**Calibration:**

- Better results could be achieved by <u>improved calibration procedure</u> by some services

**Radiation qualities/Problems:**

- The <u>radiation Quality</u> N-40/60° show <u>significant over response</u> by a number of systems (24% outliers)

**Coefficient of variation:**

- Typical <u>CV for identical irradiation</u> condition are 2 - 5% (similar in previous intercomparisons)

# Next intercomparisons WG2

Whole body dosemeters (photons)

extremity dosemeters (photons/betas)

Whole body dosemeters (neutrons)

IC2008

IC2009$_{ext}$

IC2010

IC2012

IC2012$_n$

**IC2014**

IC2015$_{ext}$

**IC2016**

IC2017$_n$

IC2018

IC2019$_{ext}$