ORAMED's MEASUREMENT AND SIMULATION CAMPAIGN FOR EXREMITY AND EYE LENS DOSES OF MEDICAL STAFF INVOLVED IN INTERVENTIONAL RADIOLOGY AND CARDIOLOGY

Carinou E., Brodecki M.,Domienik J., Donadille L., Ferrari P., Jankowski J., Koukorava C., Krim S., Nikodemova D., Ruiz-Lopez N., Sans Merce M., Struelens L.,Vanhavere F. and Zaknoune R.

ORAMED why?

IR and IC procedures require the operator and assisting personnel to remain close to the patient, and close to the primary radiation beam.
Despite the fact that the body area can be individually shielded by protective lead aprons, the hands, legs and the eye lenses often remain practically unshielded.

•Previous experience – extremity doses can exceed the operational limits
• Absence of systematic study on extremity and eye lens doses

What's new?

ORAMED WP1: Extremity and eye lens doses in IC and IR

• To perform a systematic study of **measurements** and **simulations** of extremity and eye lens doses of medical staff in selected IR and IC procedures
• To study the parameters that influence the **extremity** and **eye lens** doses for the medical staff in IR and IC
• To propose a methodology for reducing the doses of medical staff (guidelines/recommendations)

Measurement campaign:
- 6 different countries,
- 3 hospitals per country
- 8 types of procedure
- 10 measurements/type of procedure/hospital

3 Cardiology
5 Radiology
>1300 measurements

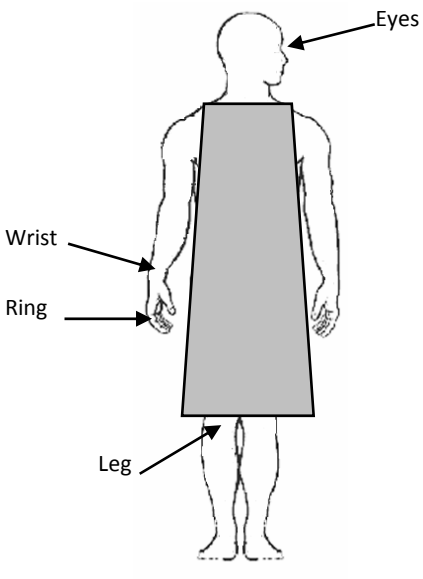
Interventional Cardiology:
- CA and PTCA
- RF Ablations (RFA)
- Pacemakers and Cardiac Defibrillator Implantations (PM/ICD)

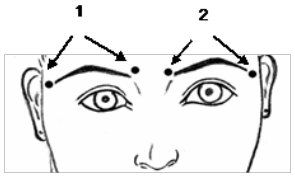
Interventional Radiology:
- Angiography (DSA)/Angioplasty (PTA)
  - o Lower limbs (LL)
  - o Carotids and Brain (C/B)
  - o Renal arteries
- Embolisations
- Endoscopic retrograde cholangiopancreatography procedures (ERCP)

Measurement campaign

TL dosemeters were used for the measurements in eight measurements points

Hp(0.07) the quantity used for all the points





List of the hospitals per country and the type and number of procedures monitored

	Interventional Cardiology			Interventional radiology				
Country	CA+PTCA	RF	PM/ ICD	DSA PTA LL	DSA PTA C	DSA PTA R	Embolization	ERCP
Belgium	104	69	62	38	11	16	54	93
Greece	34	20	30	43	33	12	32	28
France	20	24	24	30	1	26	25	26
Switzerland	38	32	26	19	0	2	23	25
Poland	40	20	43	22	25	3	28	0
Slovakia	30	18	18	18	9	6	12	17
TOTAL	266	183	203	170	79	65	174	189

Total number of procedures	**1329**

An intercomparison was performed in order to establish a common basis for the measurement campaign in the IR and IC fields, among the WP1 partners.

6 TLDs per participant were sent to CEA-LNHB
(4 for irradiation + 2 for background).

The irradiations were performed at X -rays and Cs-137 beams.

$H_p(0.07)$ (mSv)					
	Cs-137				
	1	2	average	CV%	dev % from reference
Participant					
SMU	8.60	8.70	8.65	0.8	8.2
SCK	7.40	8.70	8.05	11.4	0.7
GAEC	7.24	7.80	7.52	5.3	-6.0
IRSN	8.00		8.00		0.0
CHUV	8.63	8.60	8.62	0.25	7.7
NIOM	7.80	7.68	7.74	1.1	-3.2
Reference dose			**8.00**		
	70kV				
	1	2	average	CV%	dev % from reference
Participant					
SMU	7.40	7.80	7.60	3.7	14.9
SCK	6.00	6.00	6.00	0.0	-9.3
GAEC	5.87	5.67	5.77	2.5	-12.8
CHUV	6.85	6.68	6.77	1.78	2.2
NIOM	7.00	6.99	7.00	0.1	5.8
Reference dose			**6.62**		

A 15% deviation from the conventional true dose is considered acceptable

A measurement protocol was established according to which the same **parameters** should be recorded for every procedure.

Using the same protocol, the measurements are **homogenized** and all data can be compared and evaluated.

No.....

MEASUREMENT PROTOCOL

Date .....

Hospital : _____

System / Detector : _____ Tube Above/Below: _____

Procedure : _____

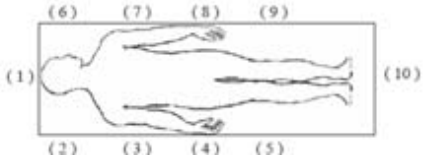
Physician (initials) : _____

1. PROTECTIVE EQUIPMENT

		mm Pb
Lead Apron		
Thyroid Collar		
Eyewear		
Lead Gloves		
Table Curtain		
Patient Shield		
Ceiling		
Floor		

2. STAFF POSITION

Number of persons in the room / position[1]	
MDs :	A
	B
	C
Techn.:	A
	B
	C
Nurses:	A
	B
	C
Others:	A
	B
Access [2] (R / F / P / IJV)	



3. GENERAL PARAMETERS

FSD[3] _____

FDD[3] _____

FOV _____

ZOOM _____

Biplane (Y/N) _____ (Tube 1 / Tube 2)

DAP present (Y/N)? _____

4A. FLUOROSCOPY

Projection[4]					
kV					
mA					
Pulses/s					
Pulse duration ms					
Filtration mm Cu					
Mode					

B. CINE

Projection [4]					
kV					
mA					
Frames/s					
No of Frames					
Pulse duration ms					
Filtration mmCu					
Mode					

No.....

5 *KAP VALUES* (units: .....)

FLUORO : _____ Fluoroscopy Time (.....) : _____

CINE : _____ Total Frames Acquired : _____

TOTAL : _____

6. ***OTHER REMARKS***

Body part irradiated : _____ **Physician's Height** : _____

Patient size (child / S / M / L) : _____ **Complexity of procedure (Low / Medium / High)** : _____

Physician's experience (Low / Medium / High) : _____ **Physician's Dominant Hand (R / L/ Both)** : _____

COMMENTS: _____

_____

_____

_____

_____

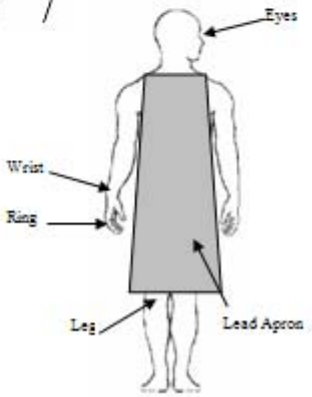
_____

7. ***TLDs – MEASURING POINTS - RESULTS***

TLD type : _____

Number of TLDs : _____

TLD positions	Pellet No R	Pellet No L	Measured Dose (mSv) R	Measured Dose (mSv) L
1. Ring finger [5]	☐	☐		
2. Wrist [6]	☐	☐		
3. Leg [7]	☐	☐		
	Middle	R/L side	Middle	R/L side
4. Eyes [1]	☐	☐		



Analysis

•Analysis of the measurements:

- The way that the parameters affect the doses
- A multi variant analysis to examine if the parameters interact with each other

IC results: Brodecki M. et al.

IR results: Nikodemova D. et al.

Eye lens doses: Vanhavere F. et al.

- Correlation of the various doses with the KAP values and extrapolation to annual doses

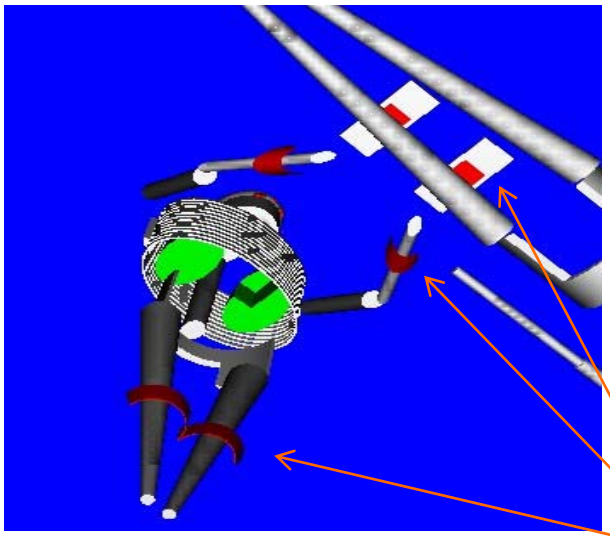
Krim S. et al.

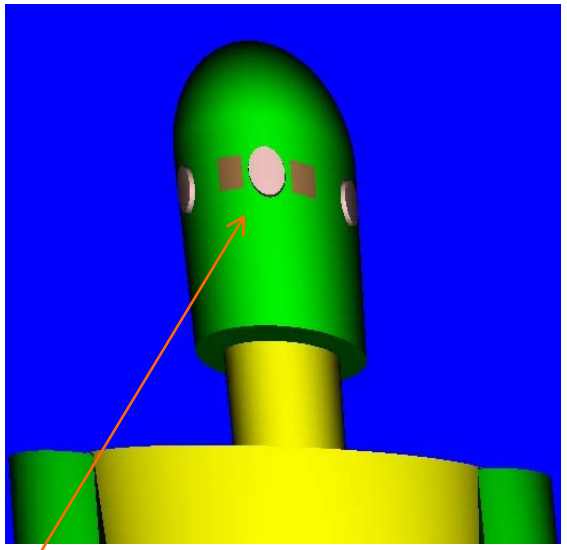
MCNP X was used for the simulation campaign

- The MIRD anthropomorphic phantom was used for the simulation of the patient and the operator.
  - The “patient” phantom is at supine position, and
  - The “operator” phantom is standing close to the patient, representing the geometry of a typical examination
- The original MIRD phantom was modified : eyes and hands have been added to the "operator" phantom and the forearms are bent in a more realistic position.
  - A lead apron of 0.5 mm Pb in front of the operator’s body and a thyroid collar of 0.5 mm Pb have also been added.
  - A cell filled with air representing the KAP chamber and an image intensifier have been added to the input file.

MCNP X was used for the simulation campaign

- Tallies were added for the eye lenses, hands, wrists and legs
- DXT spheres were used around the eyes and hands region to improve the statistics





tallies

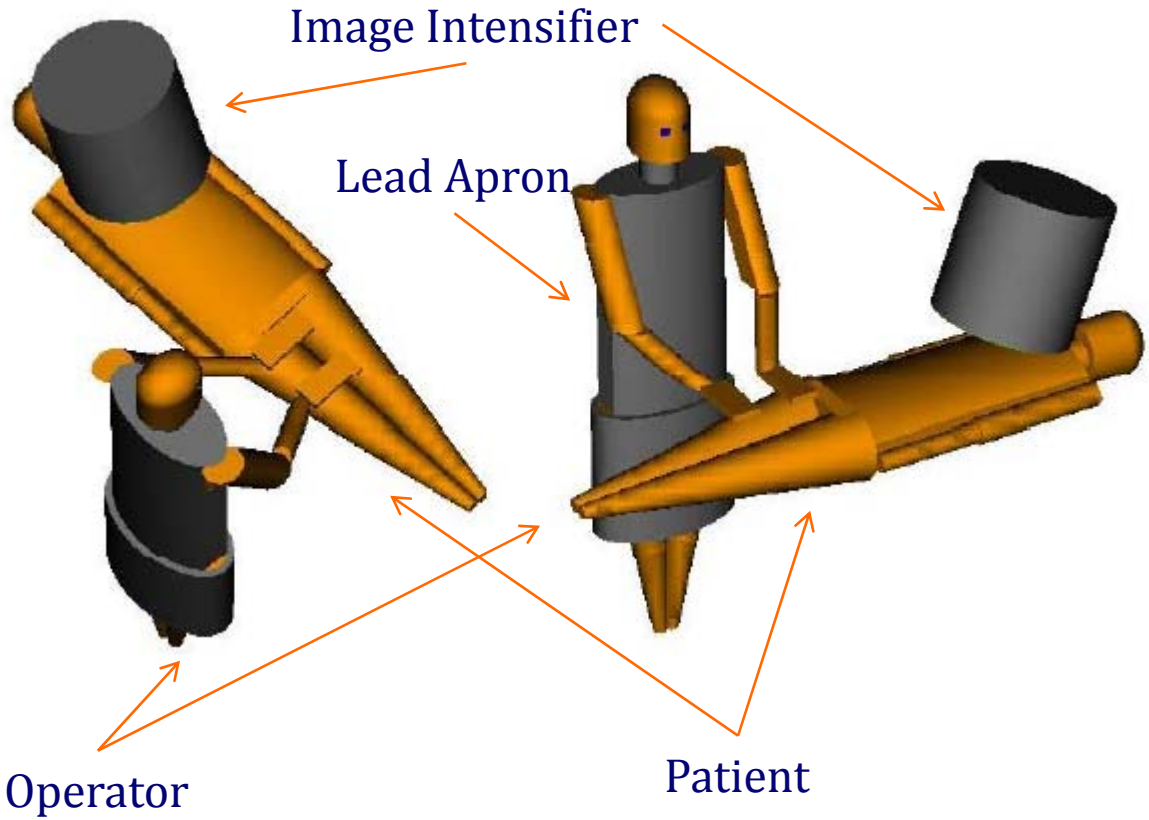
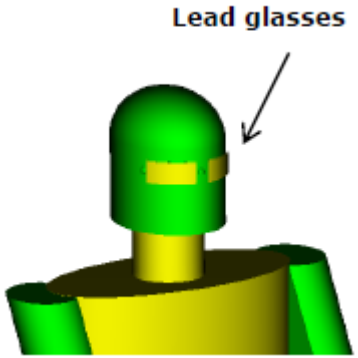
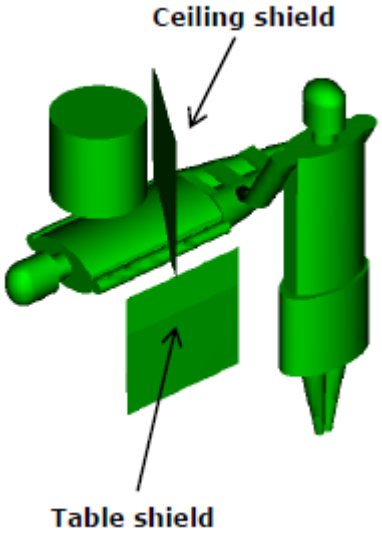


Image Intensifier
Lead Apron
Operator
Patient

The parameters that were examined are:

- Beam quality (filters: 3 to 6 mm Al and 0 to 0.9 mm Cu and kVp values: 60 to 110 kVp)
- Beam projections (PA, LAO, RAO at angles of 30°, 60° and 90°, CAU and cranial CRA projections at 20° and 40° and several realistic combinations of these projections)
- Field size (diameter of 14 to 40 cm)
- Use of eye lead glasses (no glasses, lead glasses equivalent to 0.5, 1 mm Pb)
- Use of shields (table curtain, and ceiling shield)
- Position of the operator (femoral or radial access)





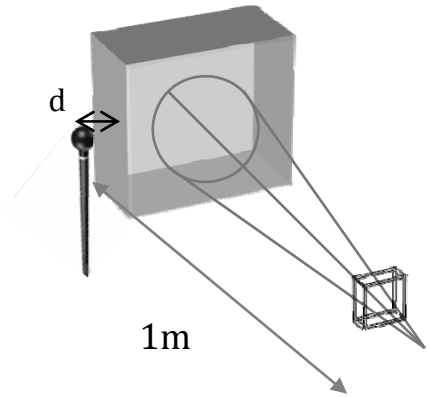
Validation methodology:

In order to validate the numerical methodology a series of measurements in the primary and scattered beam were performed and compared with the results of similar simulations.

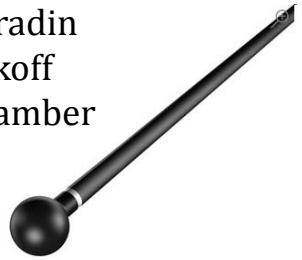
The measurements were performed by two partners, GAEC and SCK.

SSDL/MCNP (GAEC)

ISO phantom
30x30x15 cm^3



Model A3 Exradin
Shonka-Wyckoff
Spherical Chamber



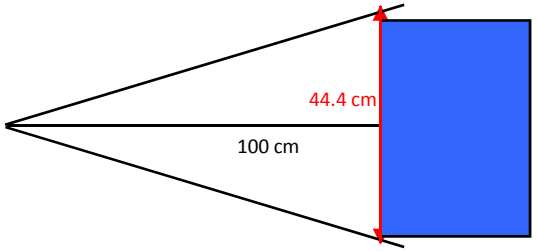
Source: RQR5 (70kV)
Field size: 13.4cm diameter @ 1m

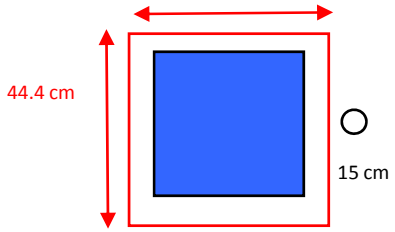
KAP and Chamber corrected for K_{PT}, N_Q

	LAB	MCNP	dif
Kair / KAP (µGy/µGy·m²) (primary @ 1m)	72.51	68.97	5%
Kair / KAP (µGy/µGy·m²) (scattered on the side) d=10cm	0.189	0.199 3%	5%

SSDL/MCNP (SCK • CEN)

• A source beam spectrum of 60 kVp ; 4 mm Al and 0.6 mm Cu (ISO N-60) was used.
• A PMMA slab phantom to represent the patient was positioned at 1 m from the focal spot.

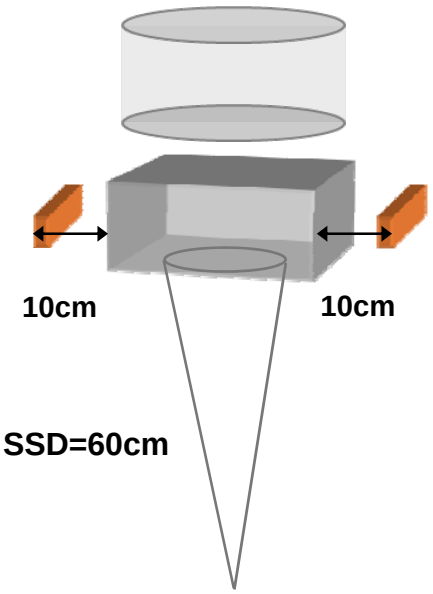




• Measurements were performed with an ionization chamber (Farmer, 600 cc) and with TLDs.

measurements		**difference**
Scattered dose/K_{air} @ 1m [µGy/µGym^2]	0.057	
Simulation with F6 tally		
Scattered dose/K_{air} @ 1m [µGy/µGym^2]	0.059	**-4%**

HOSPITAL/MCNP (GAEC)

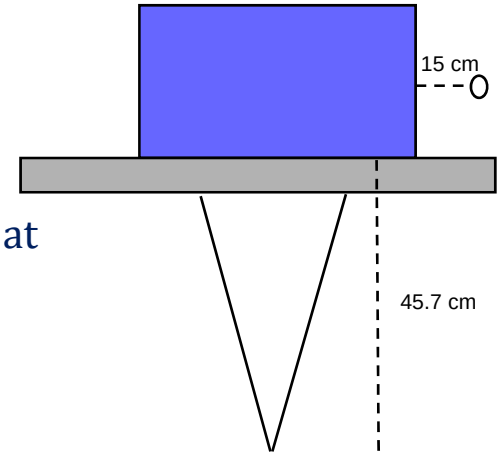


- C-arm angiographic system
- 72 kVp, HVL=5.2 mm Al
- 3 TLDs taped on Styrofoam were positioned at a distance of 10 cm from a 30x30x20 cm^3 PMMA phantom

	Angiograph	MCNP	dif
K_{air} / KAP (μGy/μGy·m^2) (I.I. not present at simulation)	$7.17 \cdot 10^{-5}$	$6.73 \cdot 10^{-5}$	**6%**

HOSPITAL/MCNP (SCK • CEN)

- X ray tube at a hospital
- 70 kVp, 4.5 mm Al and 0.1 mm Cu
- The measurements in the scattered field were performed at 15 cm from a 30x30x20 cm^3 slab phantom.



measurements		difference
Scattered dose/KAP [µGy/µGy.m^2]	0.281	
Simulation with F6 tally		
Scattered dose/KAP [µGy/µGy.m^2]	0.306	**-9%**
Simulation with *F8 tally		
Scattered dose/KAP [µGy/µGy.m^2]	0.301	**-7%**

Sensitivity study

The number of the simulations and the respective computing time increased to an unrealistic level when trying to include all parameters one by one ...

BEAM QUALITY

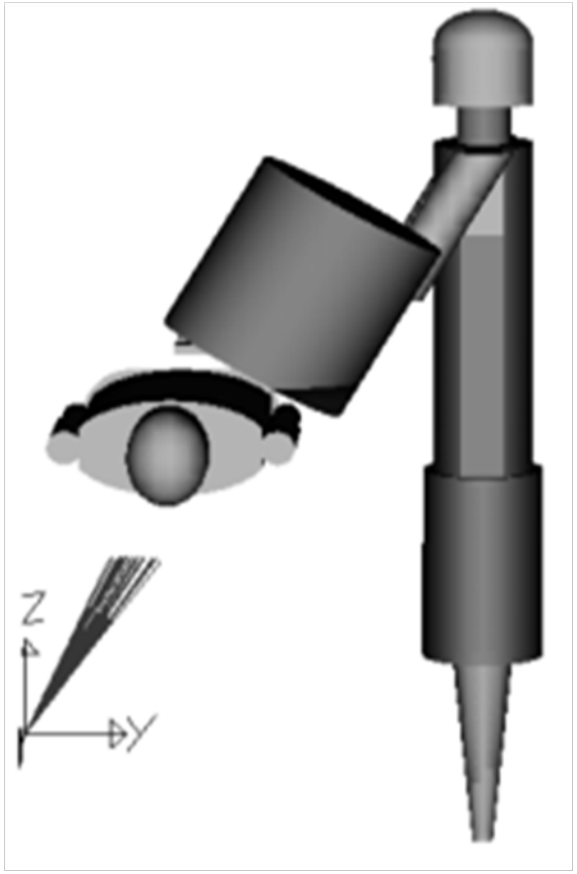
the patient ➡ a simplified phantom
no phantom for the doctor is included.

For the different parts of the body that is irradiated different phantoms are used:

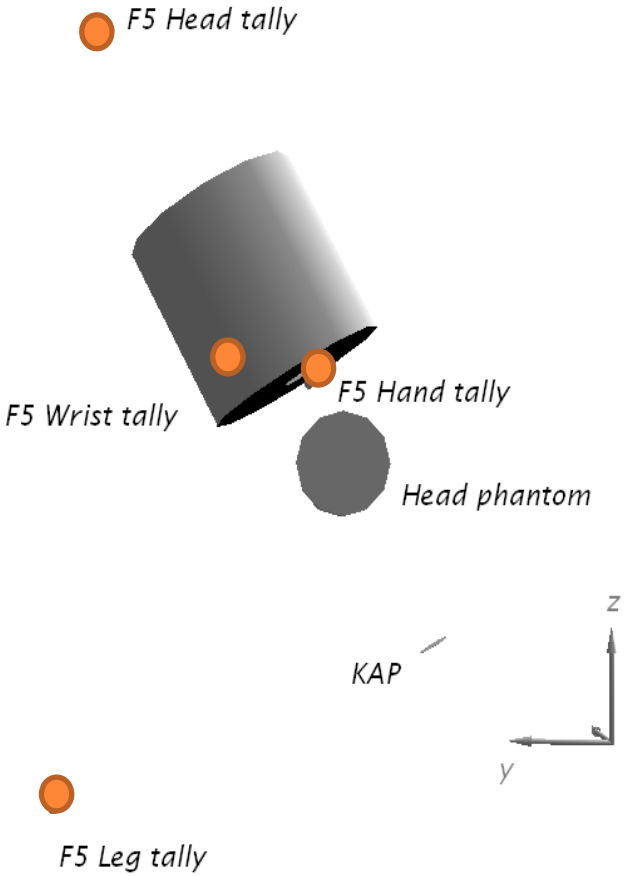
•For head and neck irradiations, a head phantom is used (a cylinder with 20 cm diameter and 20 cm height, walls of PMMA with water inside

•For lower limbs and abdomen irradiations the ISO 4037 phantom is used

Sensitivity study *BEAM QUALITY*



Detailed geometry



Simplified geometry

Sensitivity study and detailed calculations:

• the influence of the beam quality on extremity and eye lens doses was determined from the sensitivity study

• the results of the sensitivity study were used to determine 'correction factors'
in order to interpolate results from the detailed simulations for one beam quality to different beam qualities

Sensitivity study and detailed calculations:

ref pos - 40 cm - no shielding

kV	mm Al	mm Cu	eye/ex dose	hand/ex dose	wrist/ex dose	leg/ex dose
70	3	0	2,87E-02	3,05E-01	1,75E-01	2,19E-01
		0,2	2,77E-02	2,84E-01	1,65E-01	1,67E-01
		0,4	2,80E-02	2,82E-01	1,65E-01	1,53E-01
		0,6	2,77E-02	2,75E-01	1,62E-01	1,43E-01
		0,9	2,80E-02	2,77E-01	1,64E-01	1,38E-01
	4	0	2,82E-02	2,97E-01	1,71E-01	1,84E-01
		0,2	2,79E-02	2,85E-01	1,66E-01	1,65E-01
		0,4	2,78E-02	2,80E-01	1,64E-01	1,51E-01
		0,6	2,77E-02	2,76E-01	1,62E-01	1,43E-01
		0,9	2,81E-02	2,78E-01	1,64E-01	1,38E-01
	5	0	2,83E-02	2,96E-01	1,70E-01	1,95E-01
		0,2	2,78E-02	2,84E-01	1,65E-01	1,63E-01
		0,4	2,78E-02	2,80E-01	1,64E-01	1,49E-01
		0,6	2,81E-02	2,80E-01	1,64E-01	1,44E-01
	6	0	2,79E-02	2,91E-01	1,68E-01	1,87E-01
		0,2	2,75E-02	2,79E-01	1,63E-01	1,58E-01
		0,4	2,79E-02	2,80E-01	1,64E-01	1,49E-01

CF eye

CF hand

CF wrist

CF leg

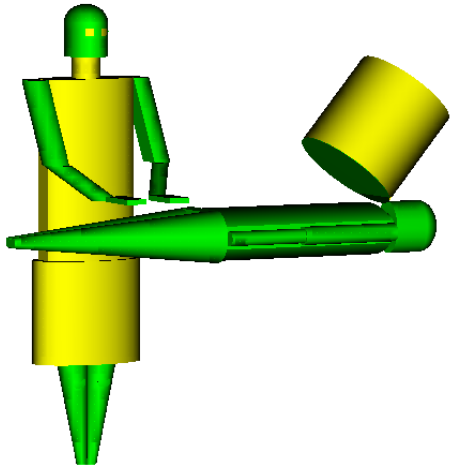
Uncertainty evaluation of the sensitivity study

An uncertainty evaluation was needed since the results for the beam quality were based on the interpolated values.

$$\text{deviation\%} = [(\text{interpolated} - \text{detailed})/\text{detailed}]$$

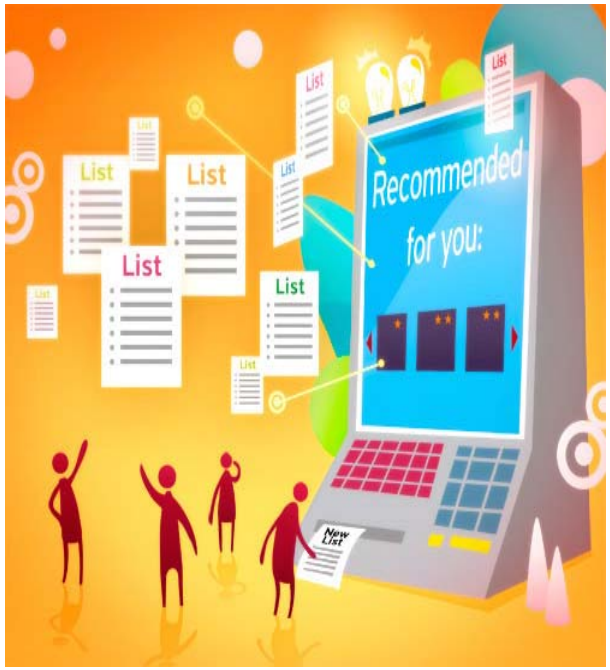
The interpolated values are calculated for a beam quality X, starting from the detailed calculations for a beam quality Y, using the correction factors Y/X from the sensitivity study.

The maximum deviation was found 38% for the RAO30 and LAO90 projection



Monte Carlo simulation results:

Koukorava et al.



Recommendations:

Domienik et al.

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

CHUV Institut de radiophysique

Thank you for your attention!

NOFER INSTITUTE OF OCCUPATIONAL MEDICINE

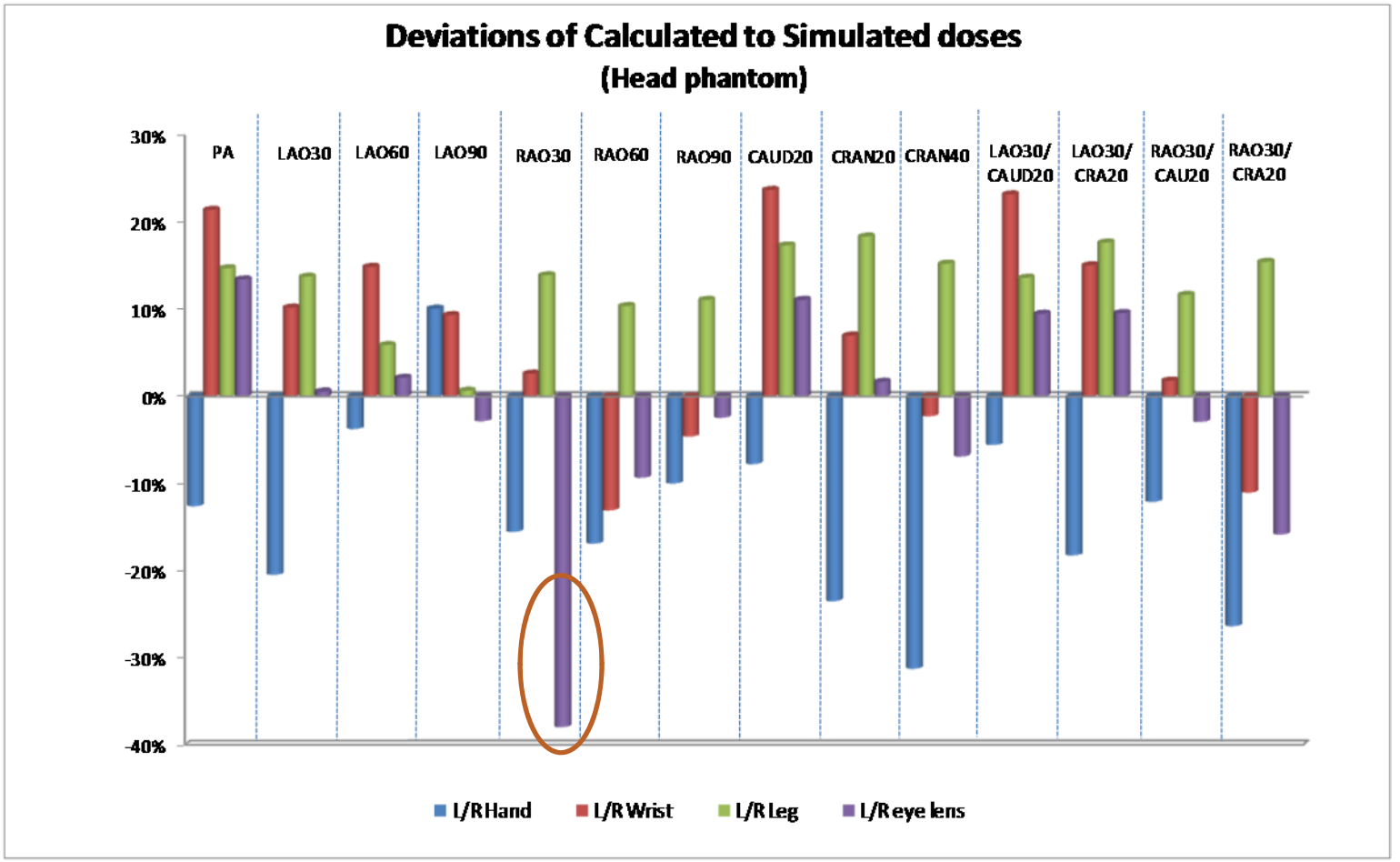
GAEC

ENEA

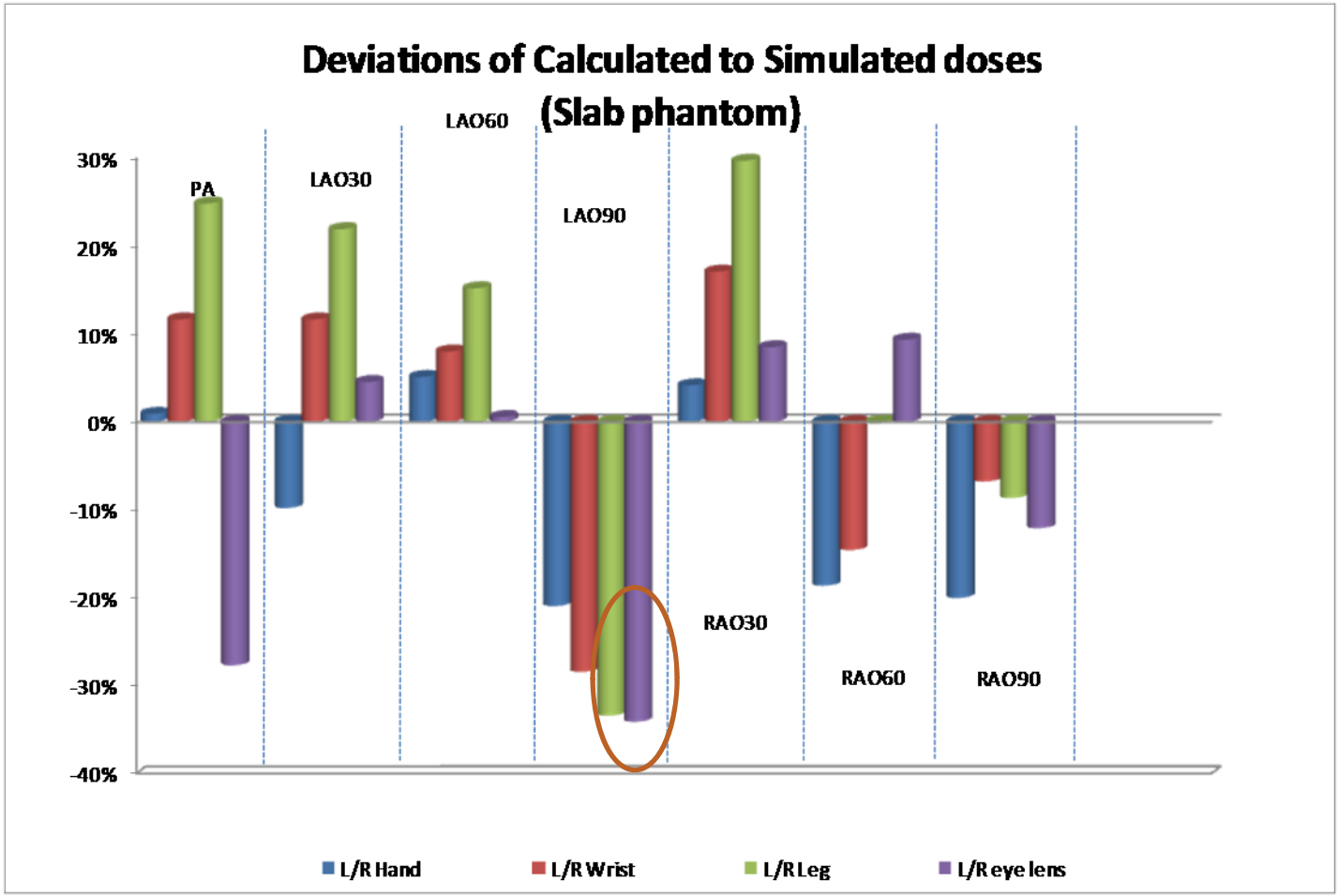
IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

SLOVAK MEDICAL UNIVERSITY

ORAMED



The maximum deviation for the head phantom is *38%* for the *RAO30* projection while all the rest are below 26% with an average deviation of 12% (in absolute values). In general, the deviations are considered acceptable from the radiation protection point of view.



For the slab phantom the maximum deviation is 37% for *LAO90* projection while the rest are well below 30%. In general, the deviations considered acceptable from the radiation protection point of view.