



MAIN RESULTS OF THE MONTE CARLO STUDY CARRIED OUT FOR NUCLEAR MEDICINE PRACTICES

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Why simulations in WP4 are needed?

WP4 -> measurements using TLDs

The data are affected by an inter-variability (i.e. for two different operators) and by an intra-variability (i.e. for the same operator)

THEN?

Monte Carlo simulations employing MCNPX and PENELOPE codes simulations were used with hand models



injection

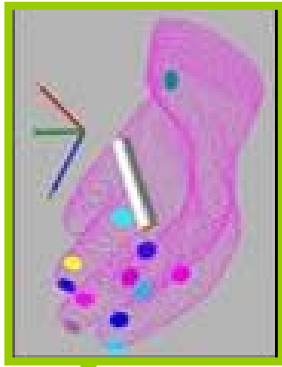


preparation

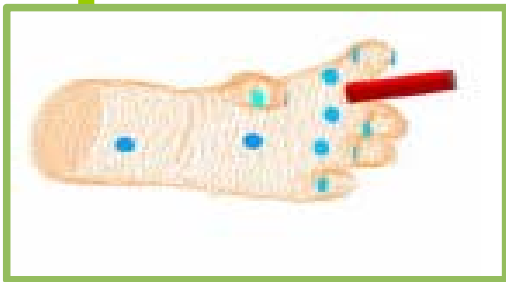


The employed *voxel* models

I2



I1

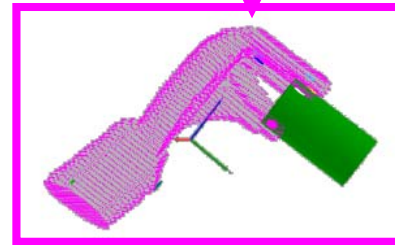


injection

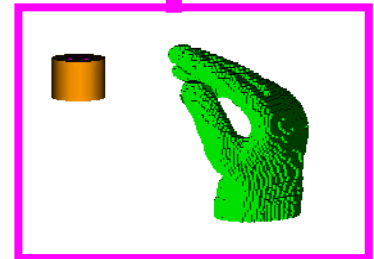
preparation



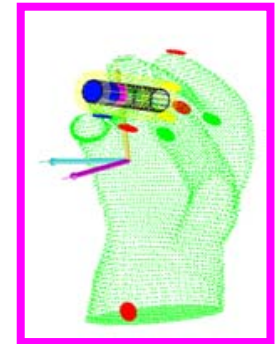
PVM



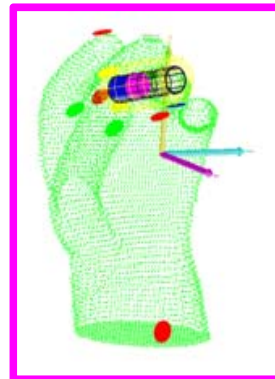
PTR



PSM1



PSM2



General scheme of the simulations

Parameters considered in the MC studies:

- 1- the source : Tc-99m, F-18, Y-90
- 2- the shielding : type and thickness
- 3- the position of the source along its axis
- 4- the orientation in space of the source axis
- 5- the position of the source inside the palm of the hand
- 6- source / syringe volume

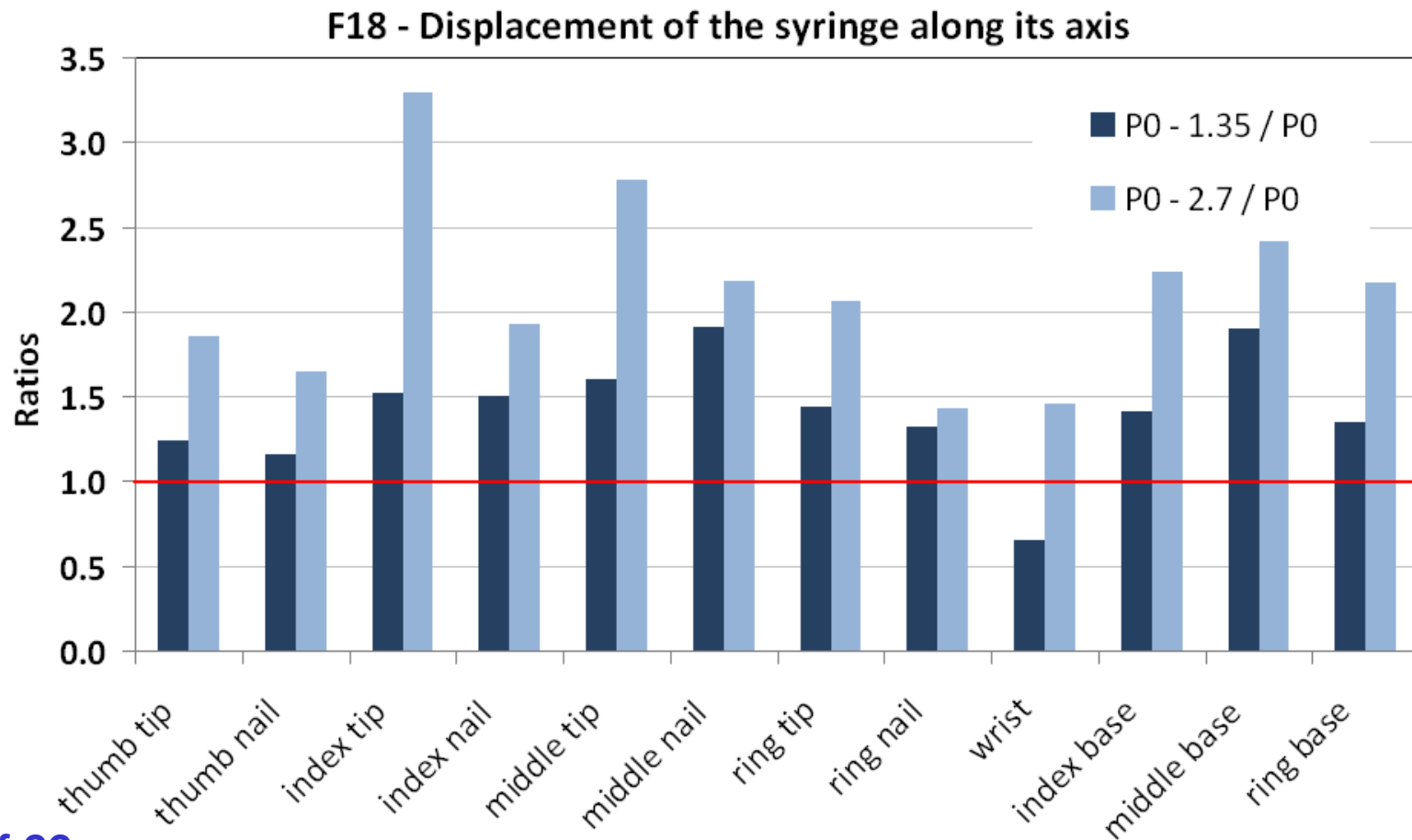
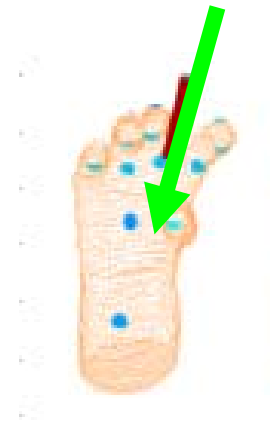
The doses were evaluated at the 11 points on the voxel hand model corresponding to the TLDs positions.

Analysis of the simulations' results

PART 1: the sensitivity analysis

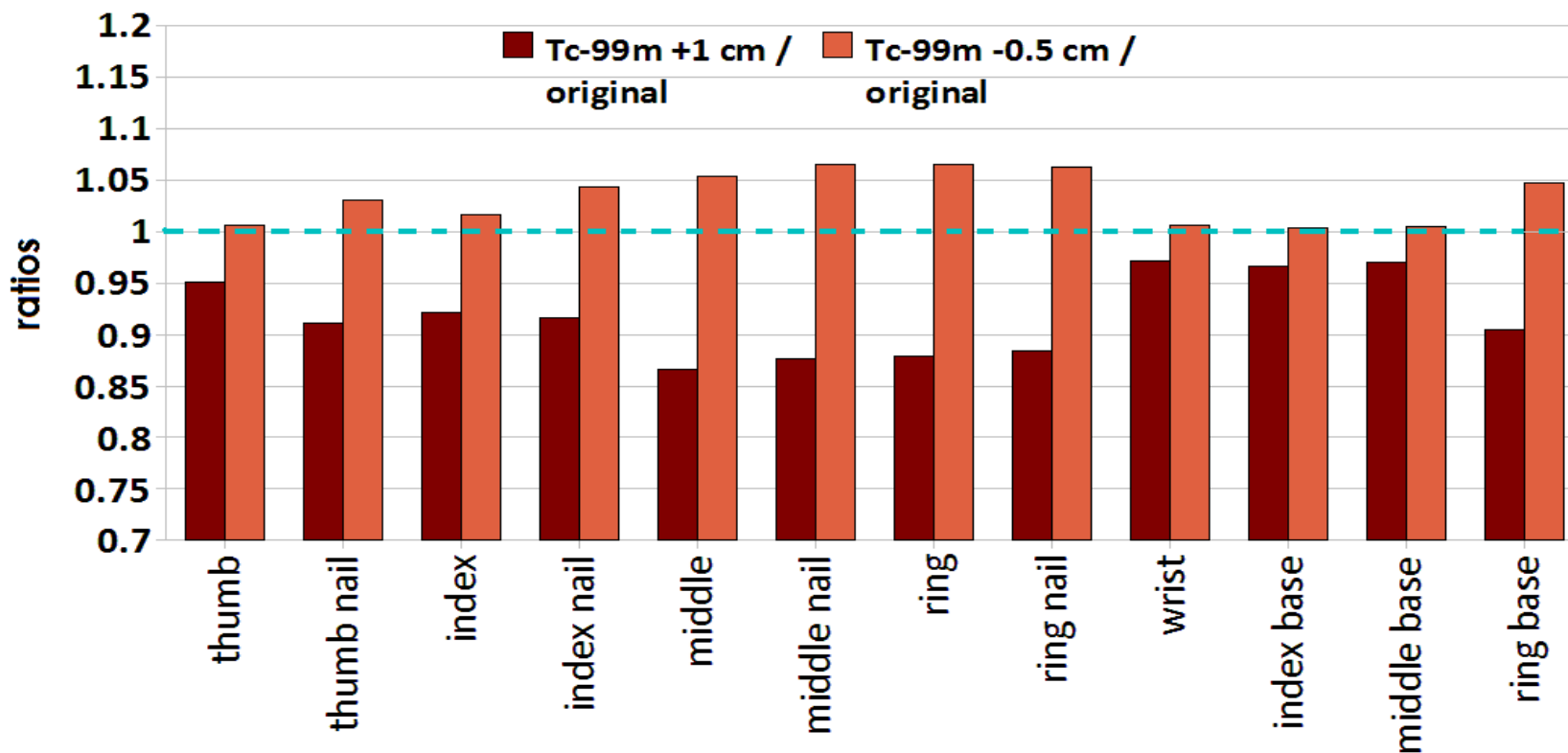
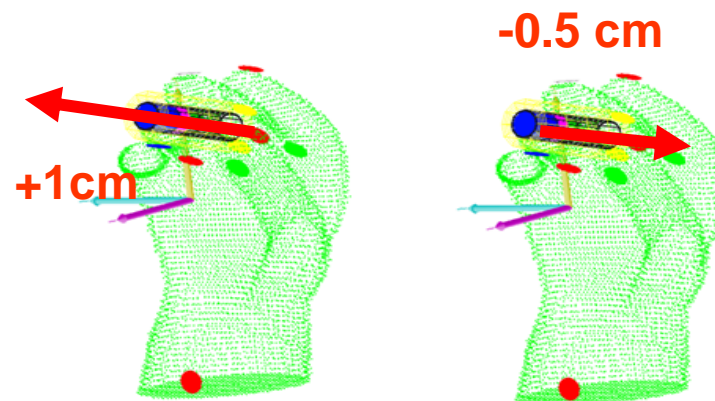
Example of shifting 1

Syringe shifted along its axis of 1.4 and 2.7 cm towards the thumb: increase the doses.



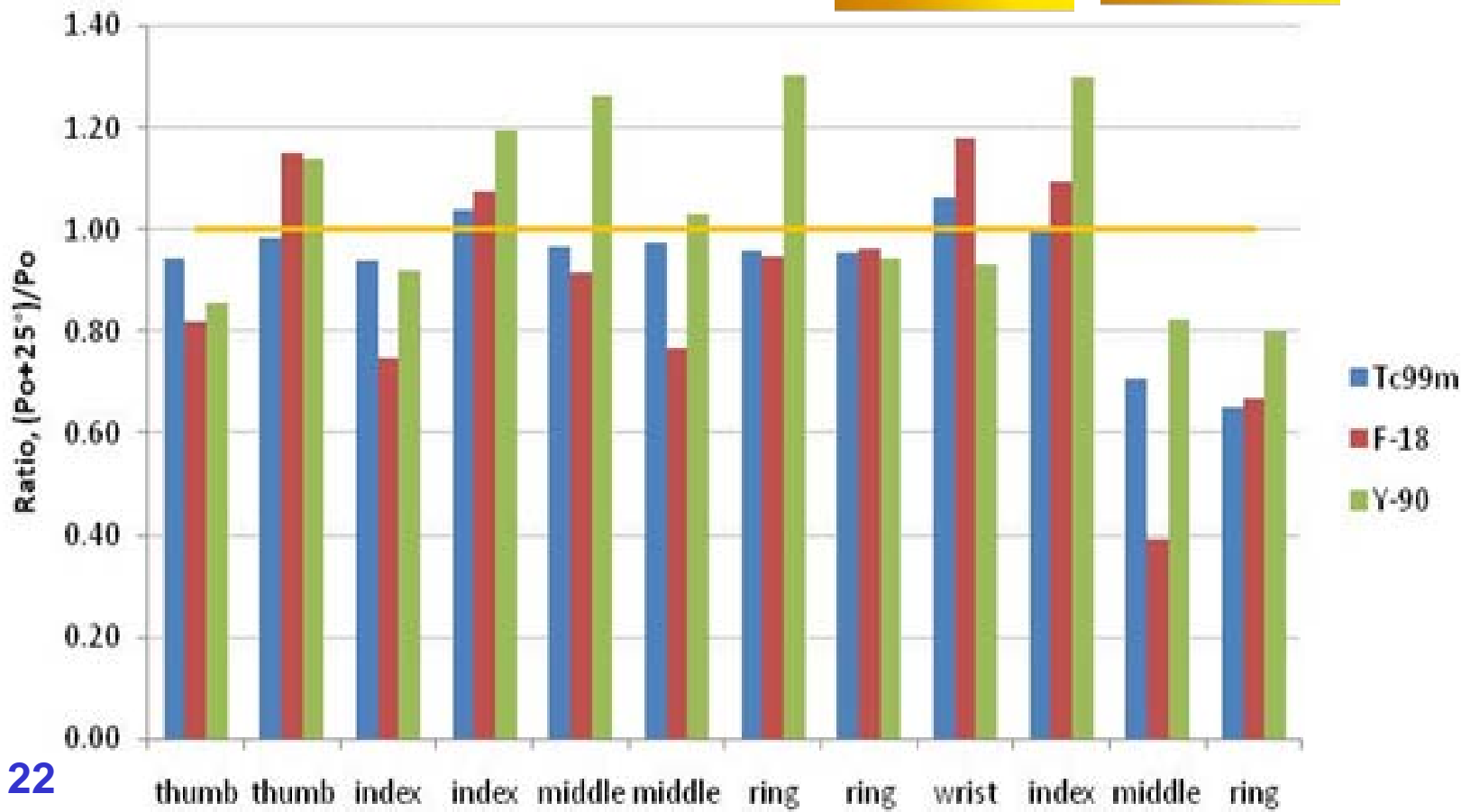
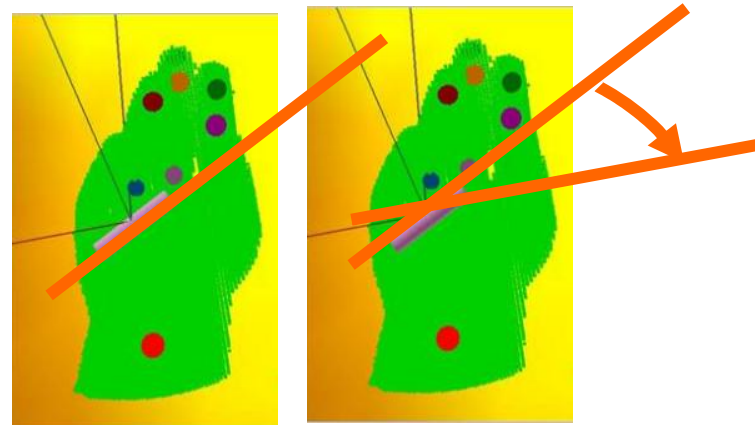
Example of shifting 2

The syringe was moved along its axis of -0.5 cm toward the hand and $+1$ cm out of hand.



Example of moving the syringe in the hand

Rotation of 25° was applied to the syringe: variation of doses



Summarising PART 1 results

The examples taken from I1 and PSM1 cases, on syringe shifting along its axis, show a variability in doses ranging from **0.5** to **3**.

That can be related to **INTER-OPERATOR variability** derived from different operators' hand dimensions, strength and ability.

The example taken from I2 case on syringe orientation in the hand shows factors ranging from **0.4** to **1.2**.

These small changes in “every day” operation are among the causes of the **INTRA-OPERATOR variability**

Measurements + simulations



Non dominant hand

Measurements without shield (2nd & 3rd Q)

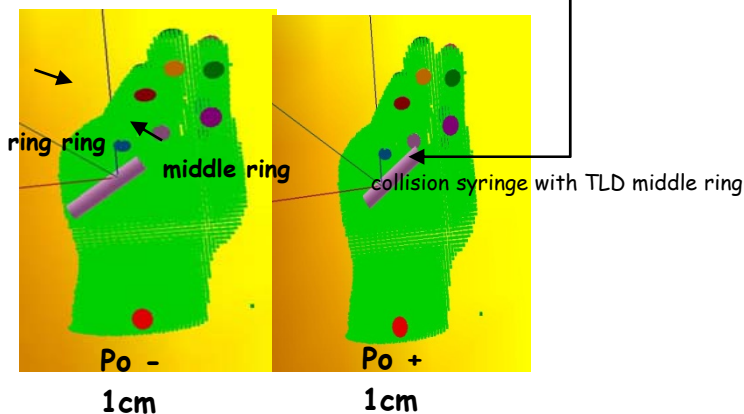
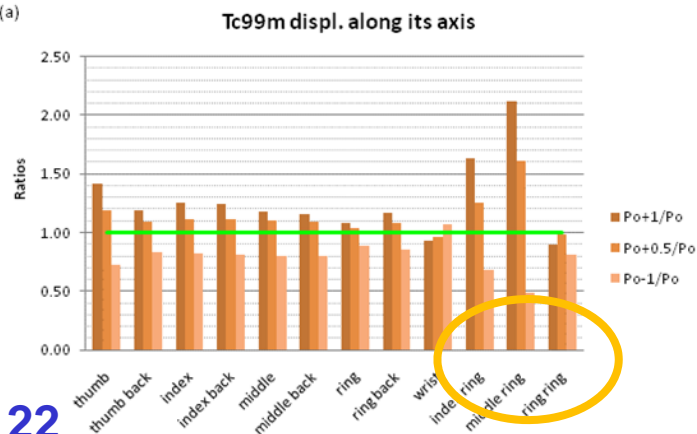
Scenario I2N

MC simulations 0.5 to 2.1

Measurements 11-77

			Non Dominant hand											
			thumb	thumb back	index tip	index back	middle tip	middle back	ring tip	ring back	wrist	index ring	middle ring	ring ring
measurements	MEAN doses ($\mu\text{Sv}/\text{GBq}$)		262	--	76	185	175	55	32	33	63	56	40	25
	range (min-max)		73-543	--	50-100	44-547	26-553	16-93	18-40	13-55	7-210	25-92	11-77	12-36
Simulations P'/Pinitial	Displ along its axis	Po+1/Po	1.4	1.2	1.3	1.2	1.2	1.2	1.1	1.2	0.9	1.6	2.1	0.9
		Po+0.5/Po	1.2	1.1	1.1	1.1	1.1	1.1	1.0	1.1	1.0	1.3	1.6	1.0
		Po-1/Po	0.7	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.1	0.7	0.5	0.8
	Orientation of the syringe	Po+25°/Po	0.9	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.1	1.0	0.7	0.7

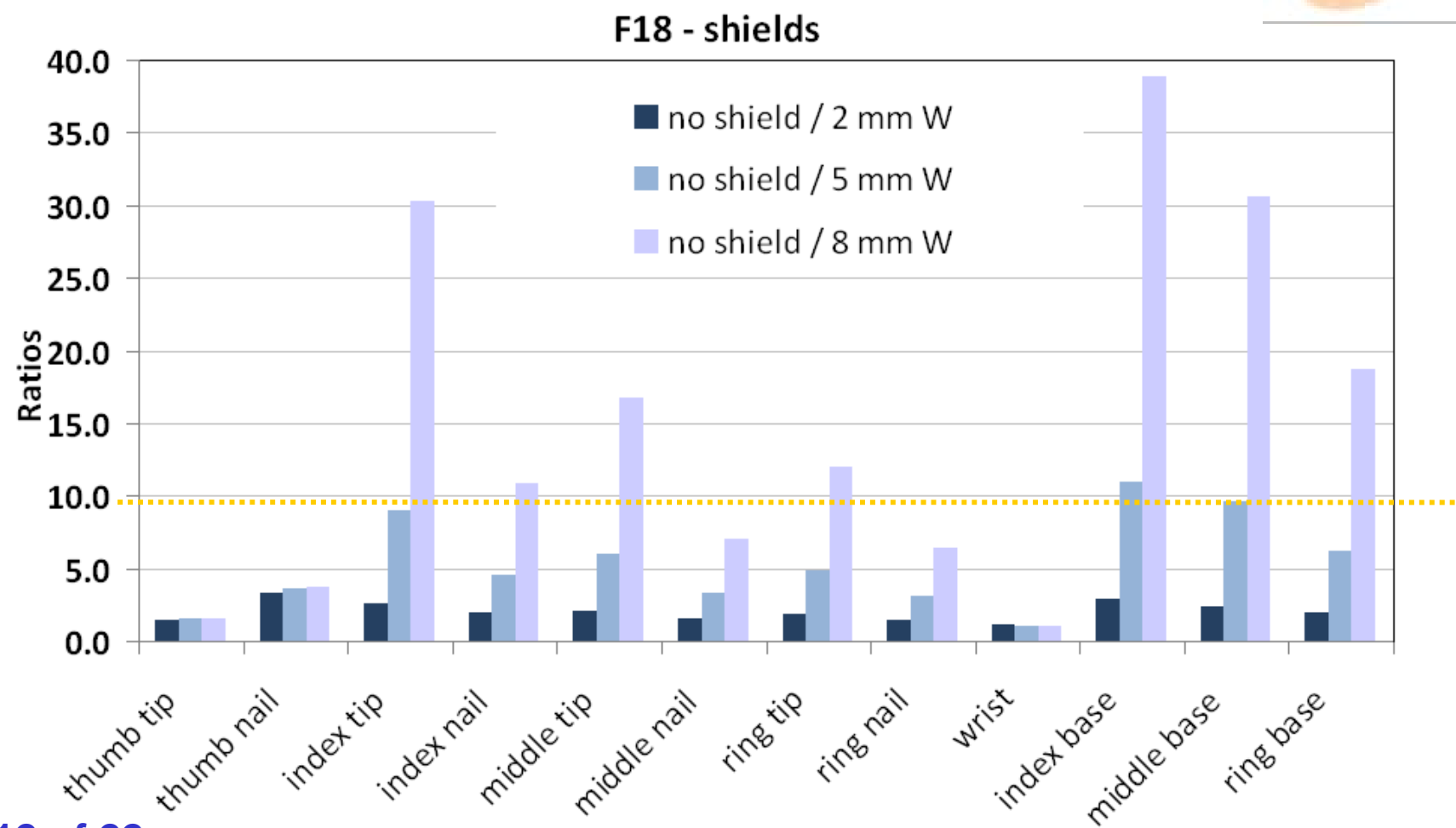
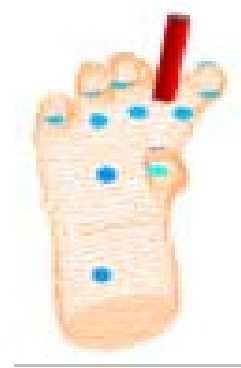
(a)



PART 2: what we learned and some possible suggestions for better practicing

F-18 shielding in administration

F-18: (the best is 8 mm W) 5 mm W provide a factor from 5 to 10

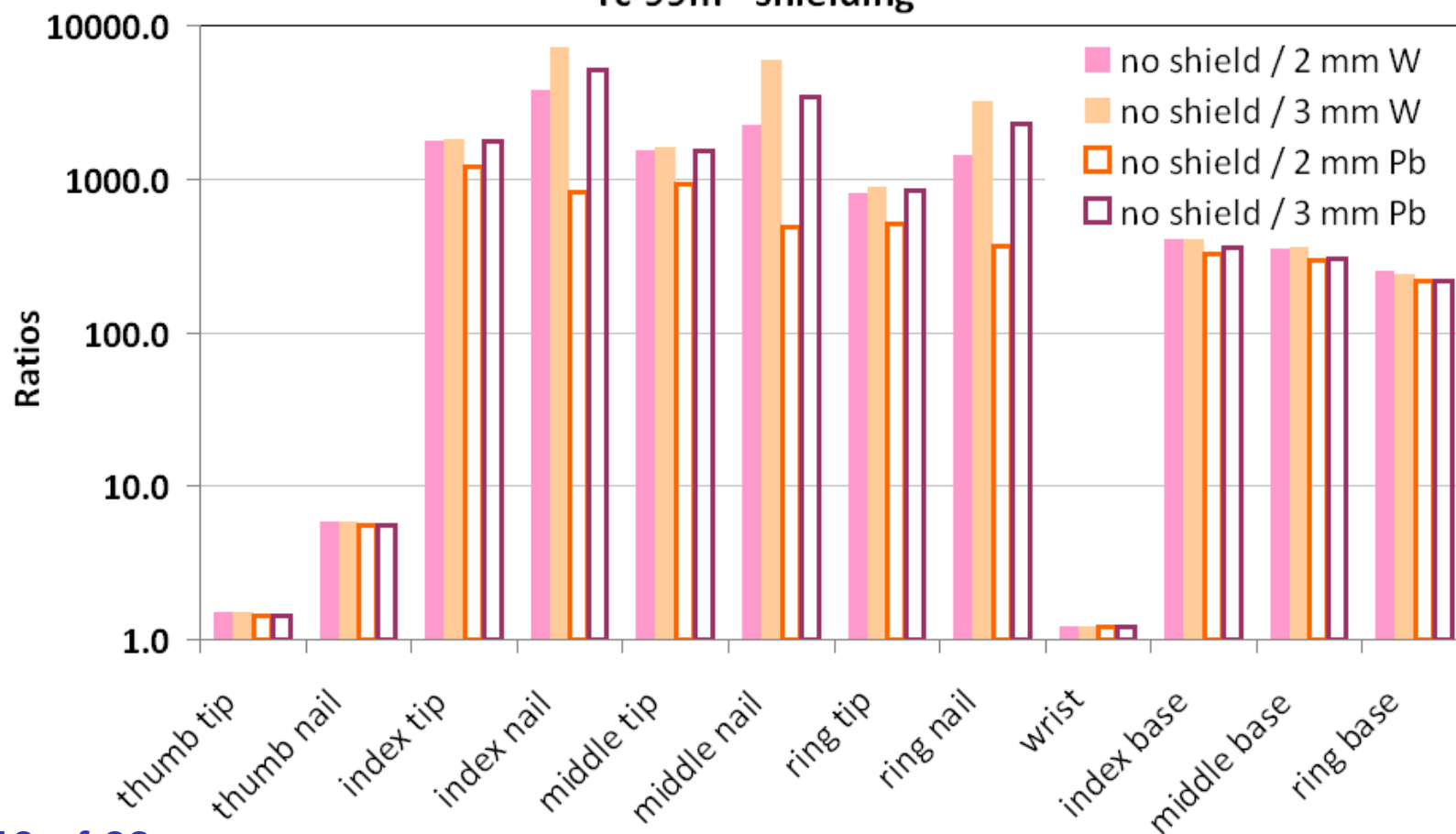


Tc-99m shielding in administration

Tc-99m: 2 mm W provide more than 2 orders of magnitude of attenuation.

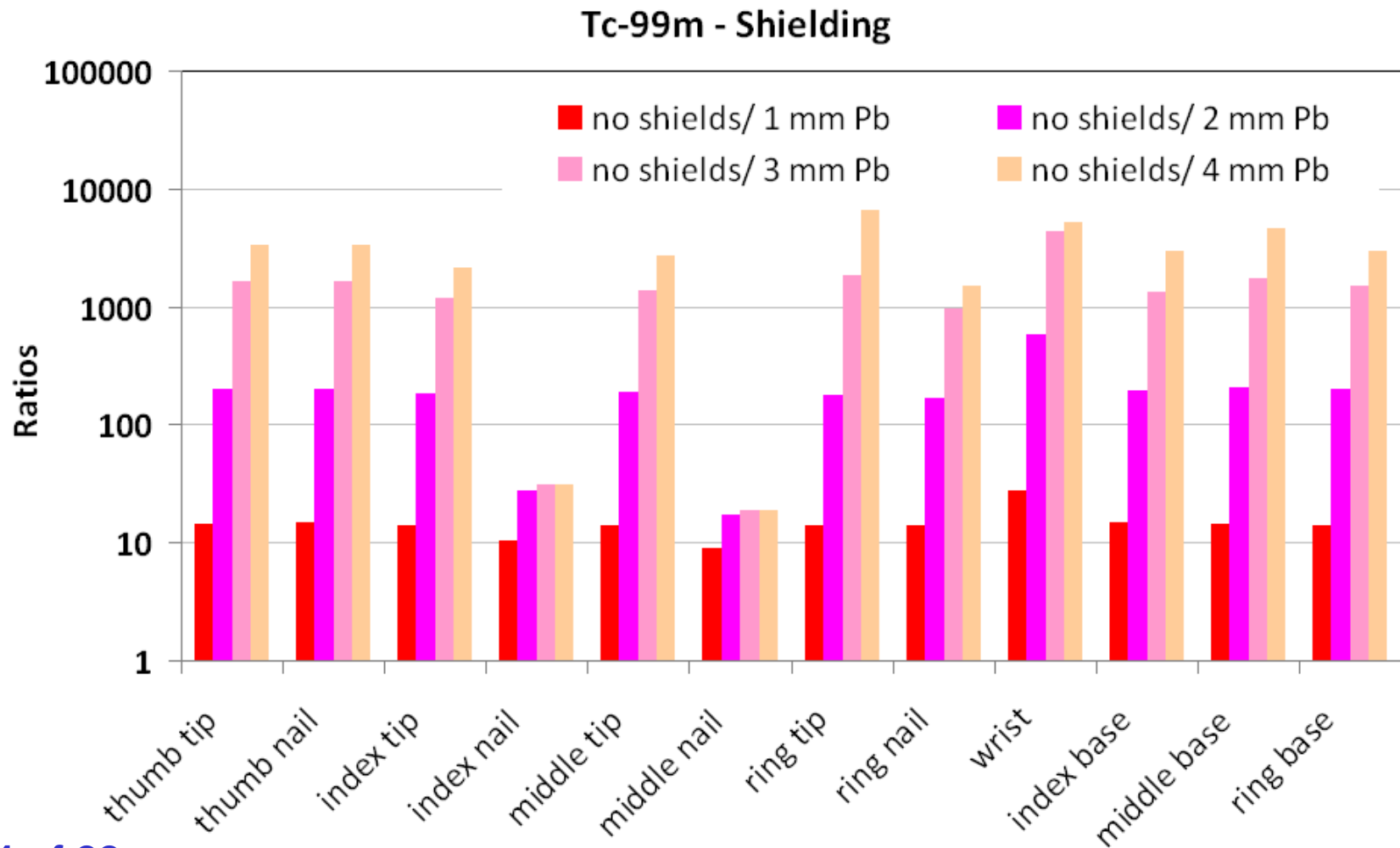
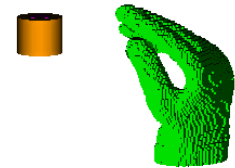


Tc-99m - shielding



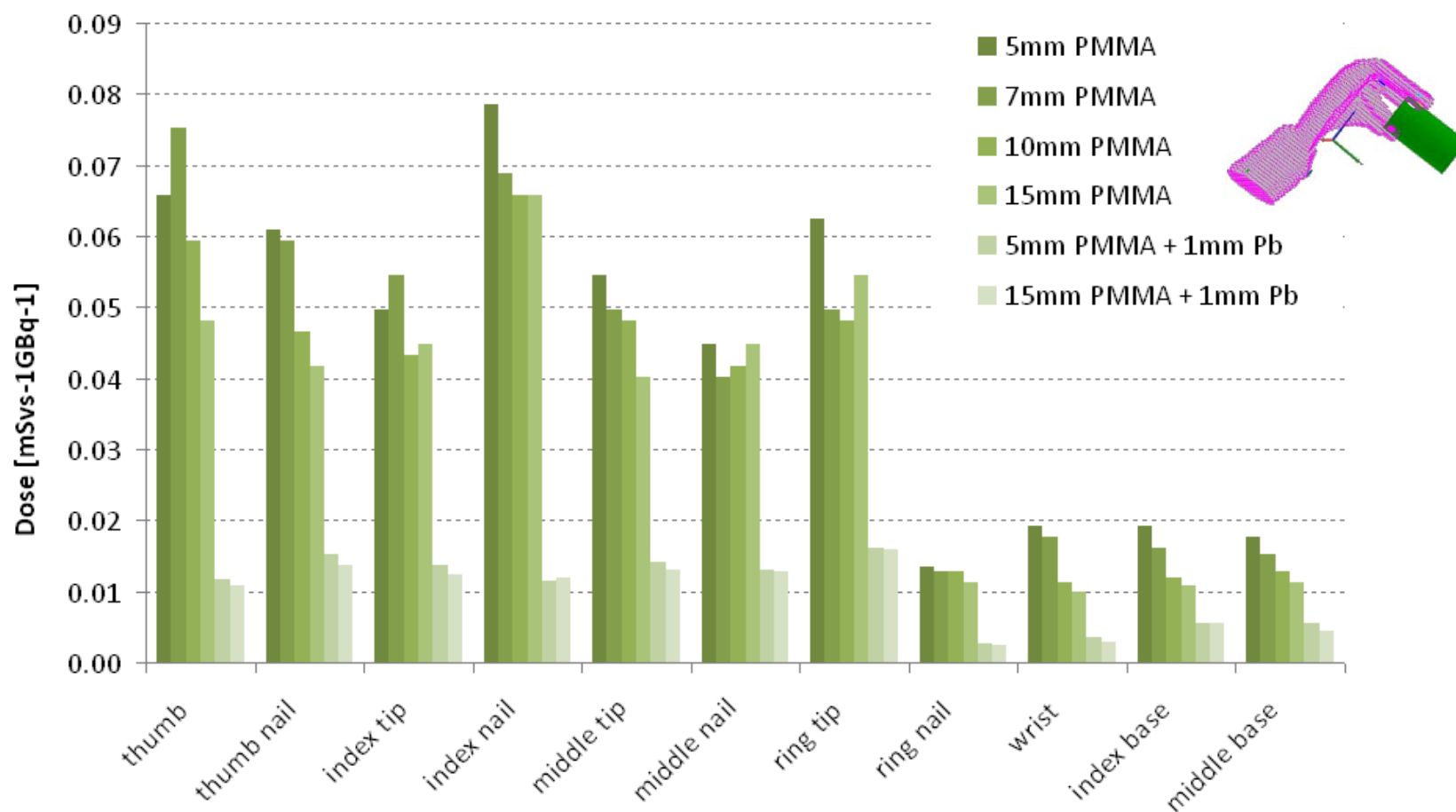
Tc-99m shielding in preparation

Tc-99m: 2 mm Pb provide more than 2 orders of magnitude of attenuation.



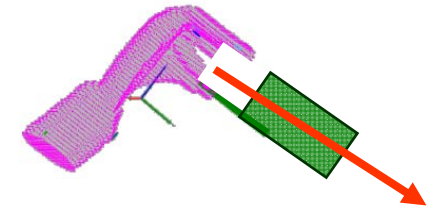
Y-90 shielding in preparation

Y-90: composite shielding is OK – 10 mm PMMA (to stop beta emission) + Pb to reduce Bremsstrahlung. In this case at least 1 mm Pb is needed.

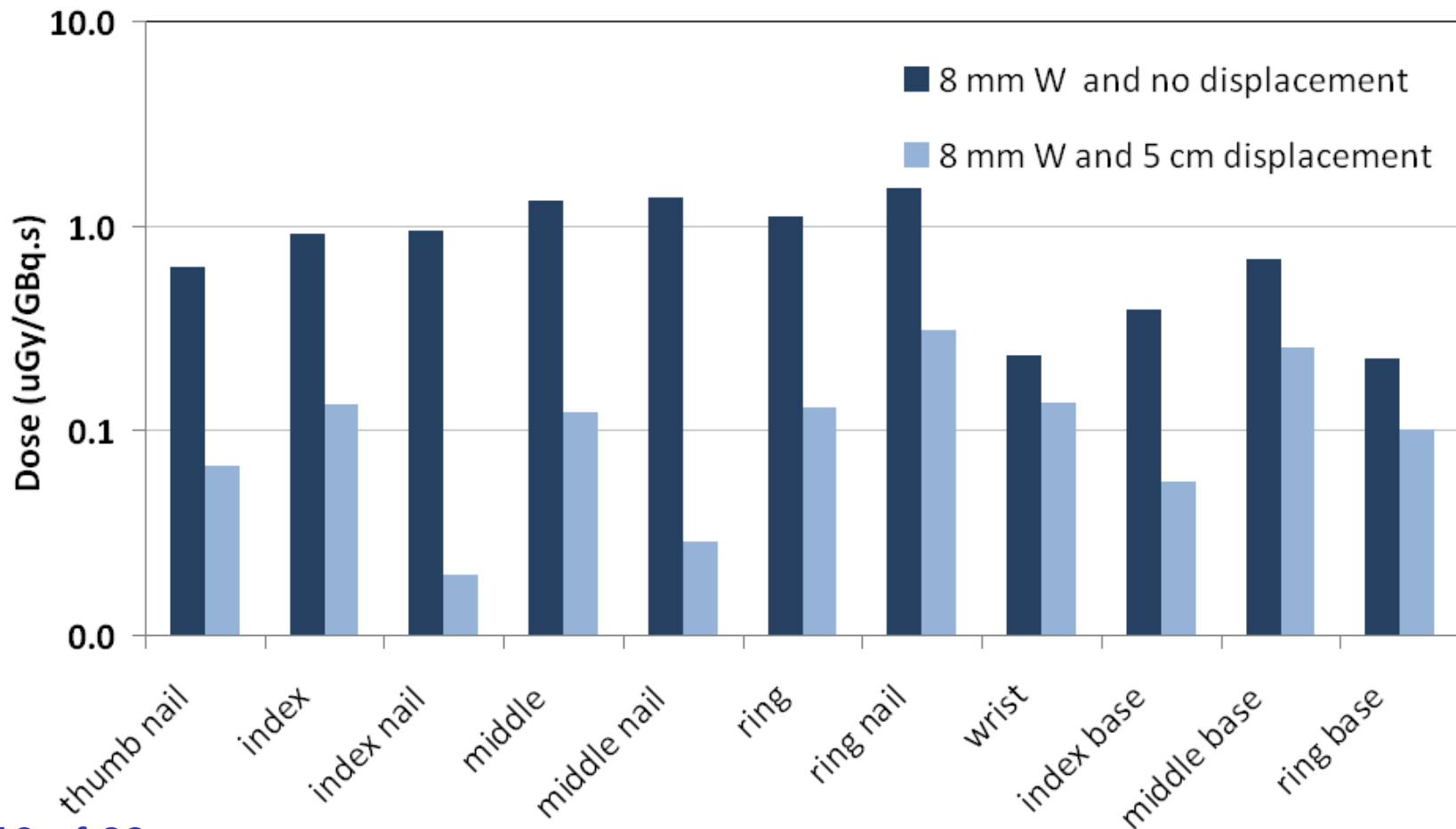


Distance from the source

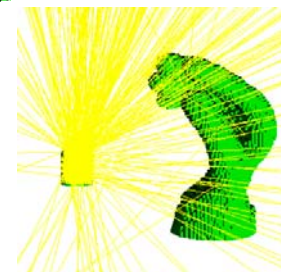
Use forceps when possible, also with shielded sources.



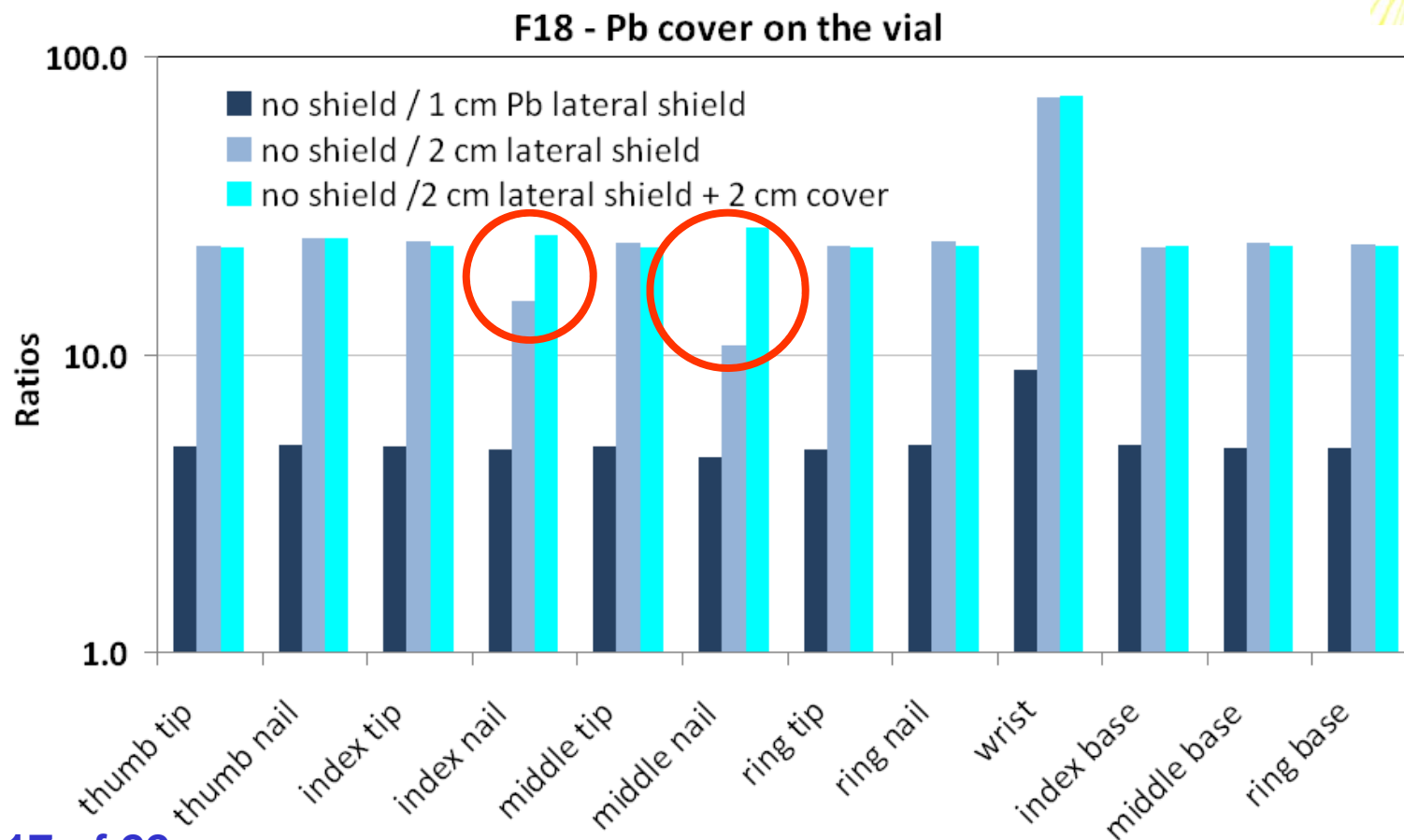
F18 - Displacement of the vial



Use the correct shielding



The extremities of the fingers can be reached by the radiation of the non-shielded part of the vial.



Summarising PART 2 results

Shielding for the injection :

2 mm W (or Pb) for Tc-99m reduce doses of 2 orders of magnitude;

5 mm W provide a factor from 5 to 10 in reduction of doses for F-18

5 mm W provide 3 orders of magnitude for Y-90

Shielding for the preparation :

2 mm Pb for Tc-99m reduce doses of 2 orders of magnitude;

3 cm of Pb provide 2 orders of magnitude for F-18.

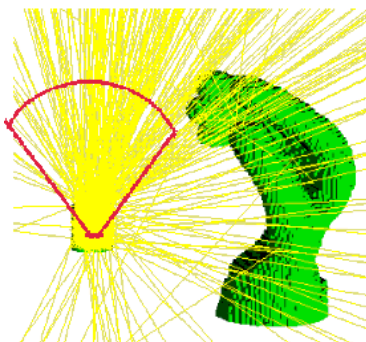
5 mm Pb (added to 5 mm PMMA) can be suggested for Y-90.

CAVEAT: Because of the “steady” conditions of the simulations, the calculated shielding “theoretical” factors should be considered among the other elements as availability, weights, visibility etc...

Summarising PART 2 results

Keep the distances: forceps, when possible, are suggested also in presence of shielded vial (it's a linear source at first approximation).

Use the protecting cover: use a complete vial shield (lateral + cover) when possible during dose preparation.

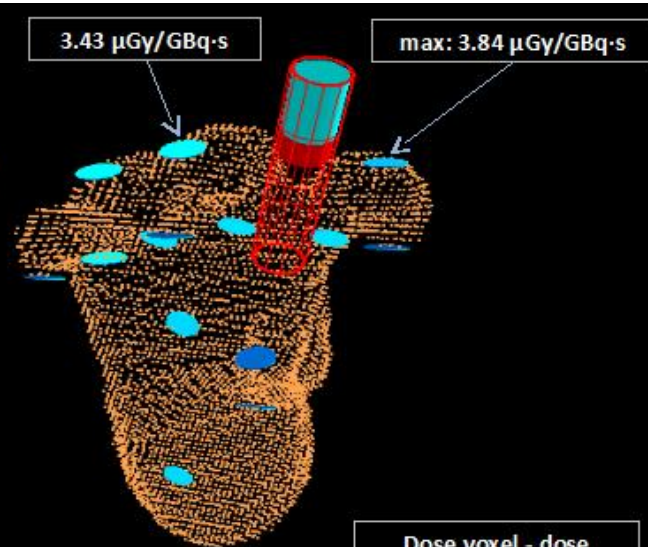


The dose mapping 1/2

To check the consistency between the position of the maximum in the hand and the position of the collected data maximum in case of I1 injection.



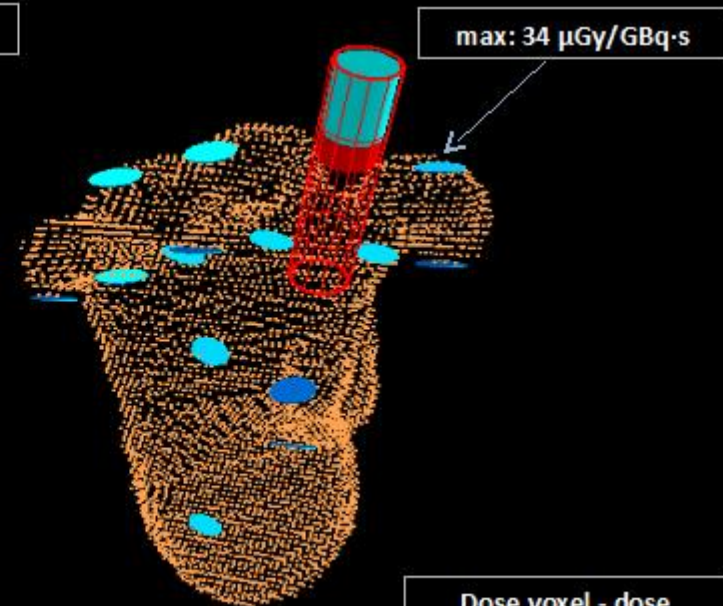
Tc-99m without shield



Dose voxel - dose
dosemeter = 20 %



F-18 without shield



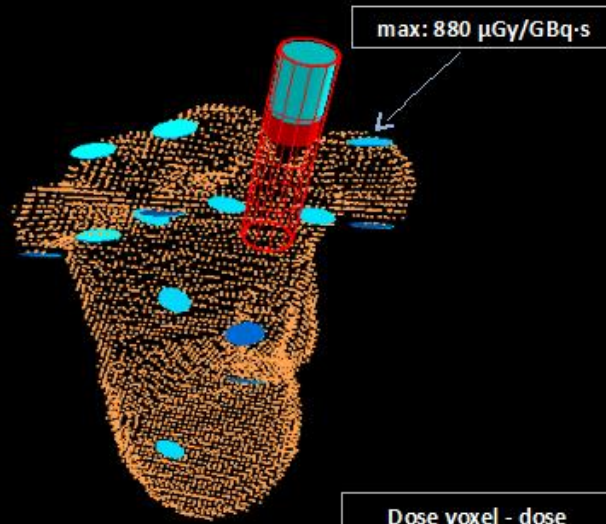
Dose voxel - dose
dosemeter = 17 %

The dose mapping 2/2

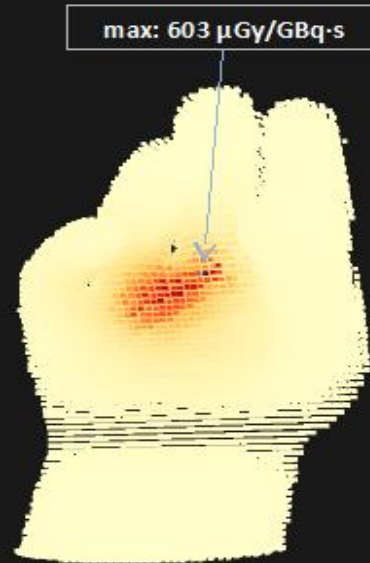
With Y-90 (beta radiation) the position of the maximum is more difficult to be determined



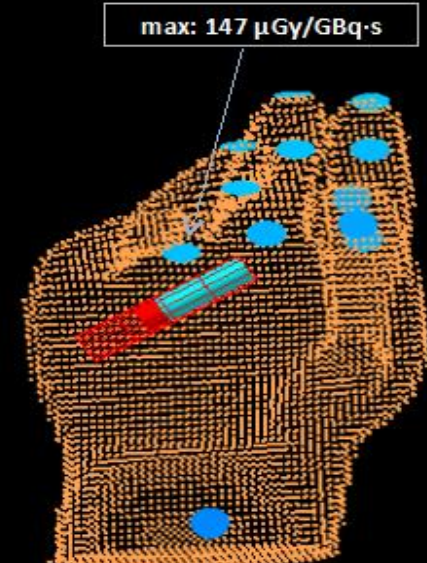
Y-90 without shield



Remember however we are looking to a “steady” situation (the position of the maximum can change during the procedure)



F-18 without shield



General conclusions

The Monte Carlo calculations were employed to determine the effect of some selected parameter changes in the evaluated doses.

Notwithstanding they represent “steady” scenarios the sensitivity analysis performed can be considered valuable to understand at what extent the variability encountered in the collected data are intrinsically related to the studied conditions.

The simulations were proficiently used to determine the effectiveness of the employed shields and of the “operator habits and attitudes” during such practices.

***Thank you for you
attention!***