

- P4 -

PHOTON IRRADIATION FACILITY : UNCERTAINTY BUDGET ON AIR KERMA

Loïc de CARLAN & Jean-Marc BORDY
CEA-LIST/LNHB-France

Introduction

Q0

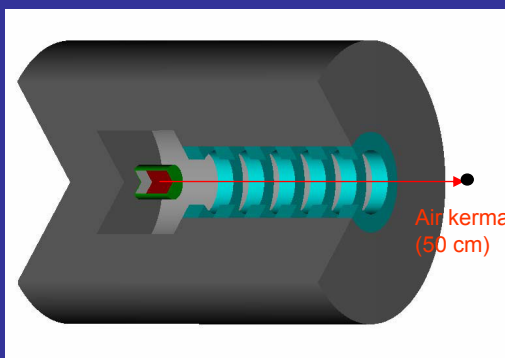
Q1

Q2

Q3

Q4

Conclusion

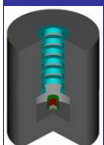


Goal of the exercise

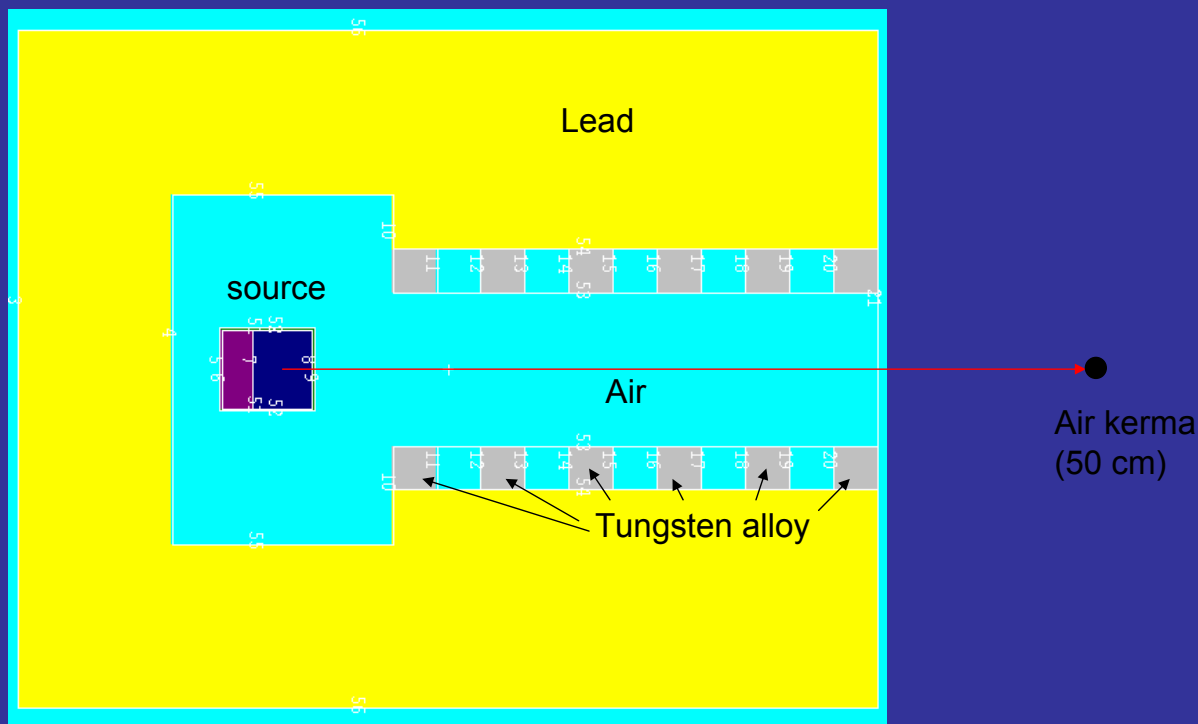
Study of the uncertainty budget of a ^{137}Cs irradiator

Quantities of interest :

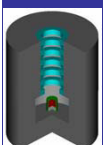
- Air Kerma
- Kerma profile
- Spectral fluence distribution



Geometry of the problem



Air kerma
(50 cm)



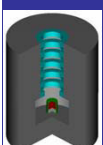
Loïc de CARLAN, Jean-Marc BORDY : uncertainty budget on air kerma



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Questions to the participants

- ✓ Q1 : the only mandatory question : uncertainty analysis of the kerma value when varying separately many parameters in the geometry : position of the source, density of the materials, diameter of the collimator ...
- ✓ Q2 : Influence of the source encapsulation on air Kerma, fluence & profile
- ✓ Q3 : influence of the collimator on air Kerma, fluence & profile
- ✓ Q4 : influence of the source chamber dimensions on air kerma & spectral fluence
- ✓+ Q0 : reference kerma value @50 cm (not requested but very useful)



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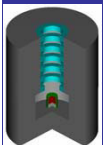
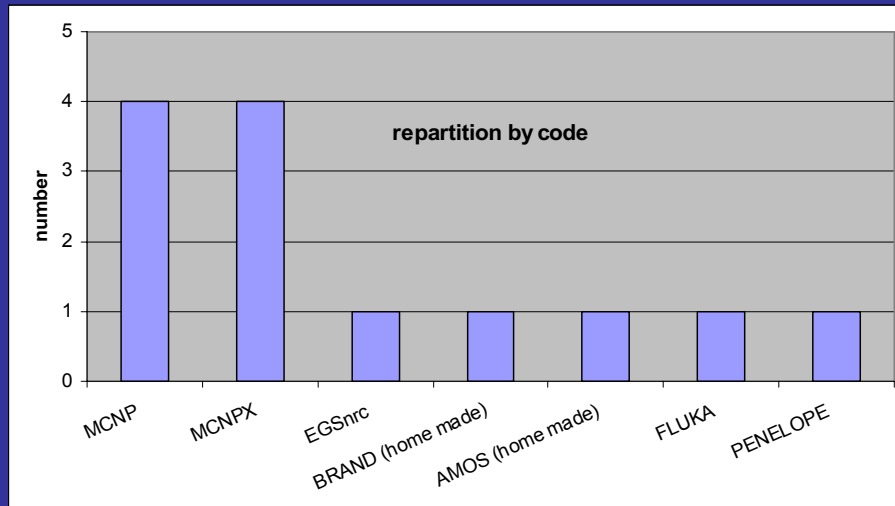


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Participants and codes

12 institutes / 10 countries

UK (1), CZECH REPUBLIC (1), USA (2), RUSSIA (1),
GERMANY (1), POLAND (1), SPAIN (1),
SWITZERLAND (2), PORTUGAL (1), FRANCE (2)

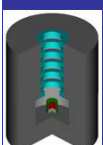
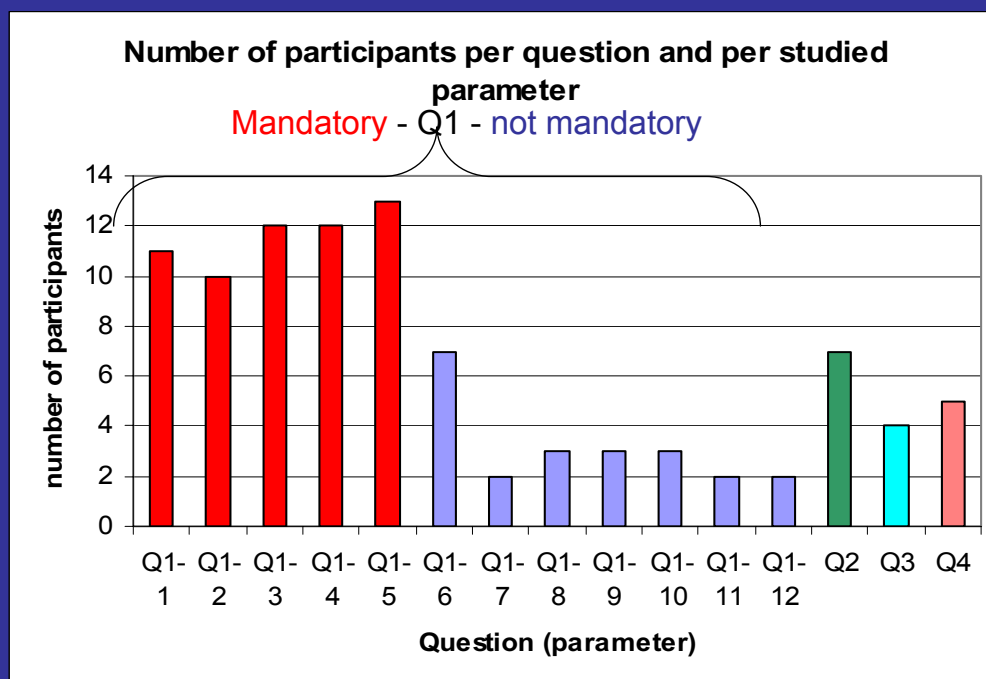


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Distribution of the answers

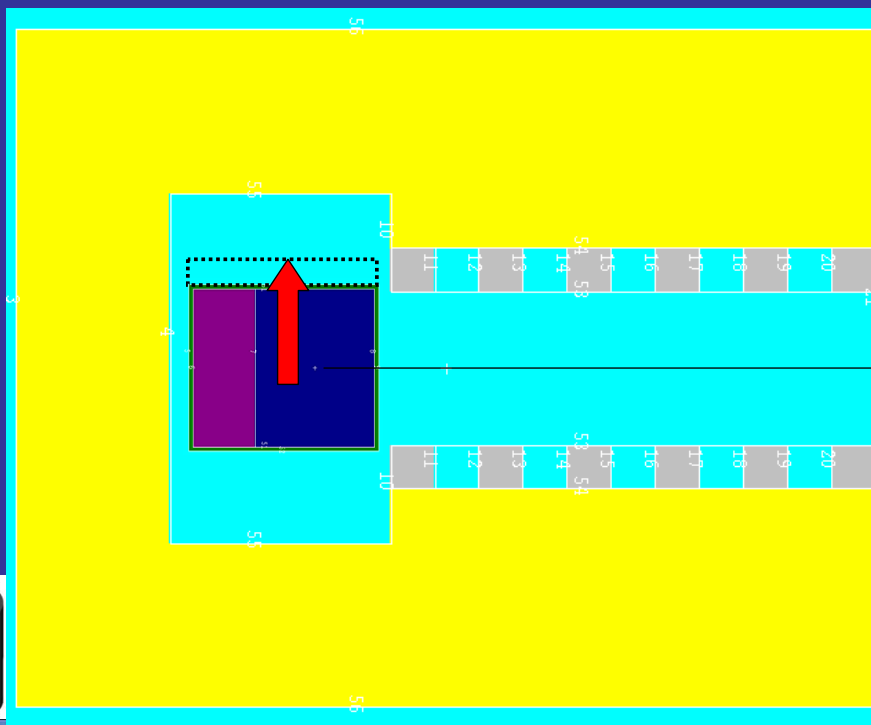


Loïc de CARLAN, Jean-Marc BORDY : uncertainty budget on air kerma

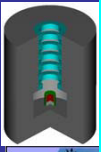


6

1) Position of the source



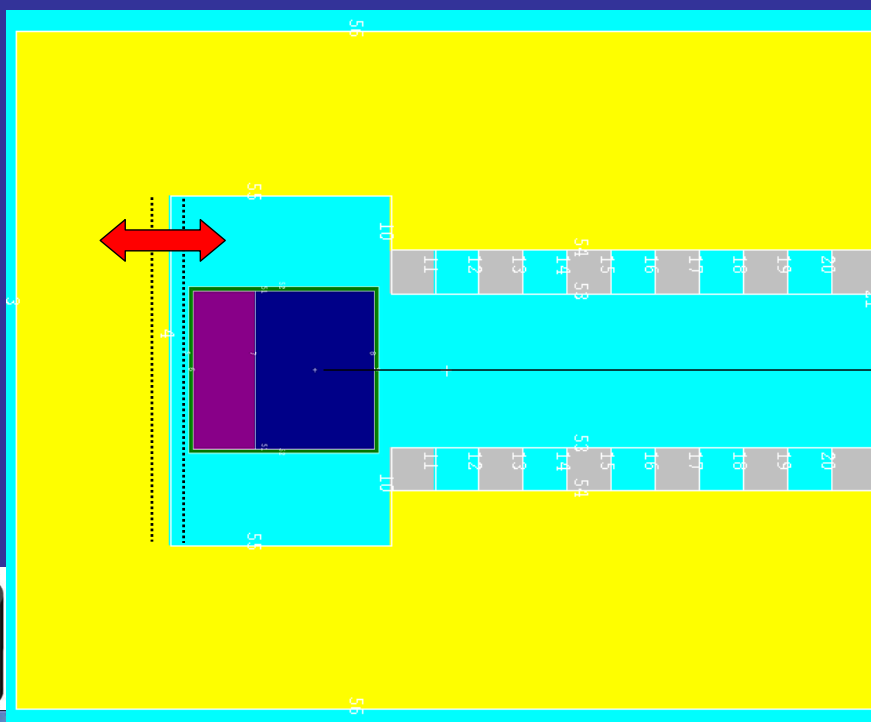
Air kerma
(50 cm)



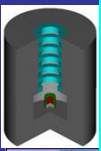
Loïc de CARLAN, Jean-Marc BORDY : uncertainty budget on air kerma



2) Depth of the source chamber



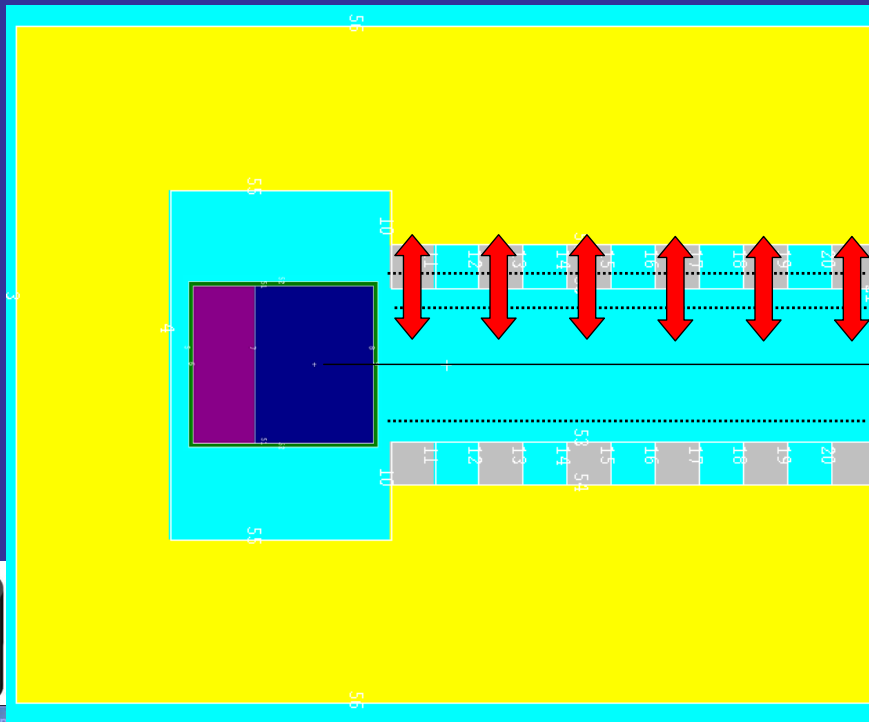
Air kerma
(50 cm)



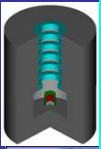
Loïc de CARLAN, Jean-Marc BORDY : uncertainty budget on air kerma



3) Diameter of the rings



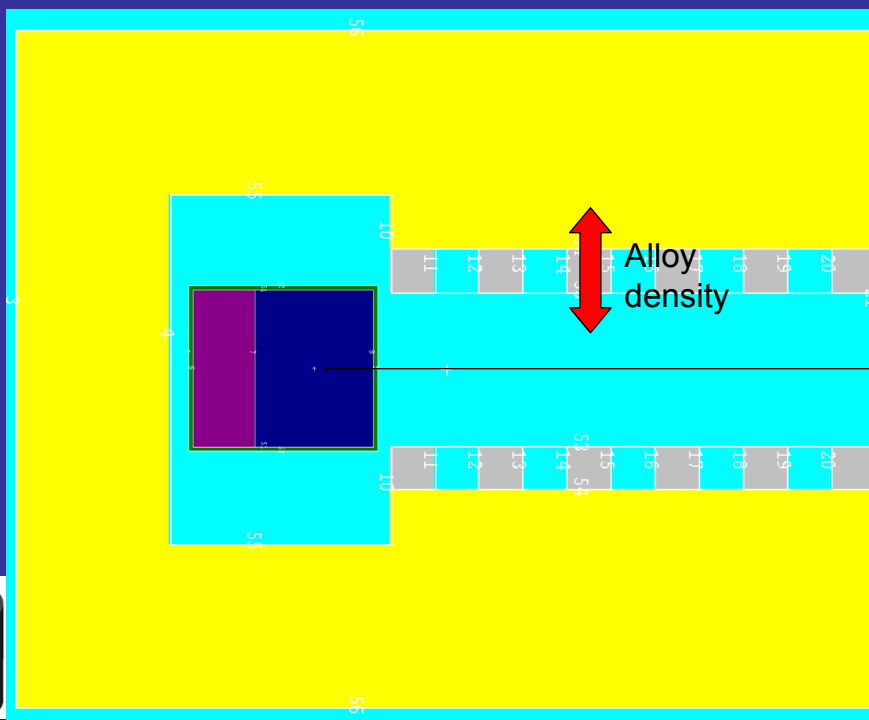
Air kerma
(50 cm)



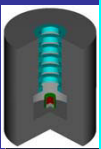
Loïc de CARLAN, Jean-Marc BORDY : uncertainty budget on air kerma



4) Density of the tungsten alloy



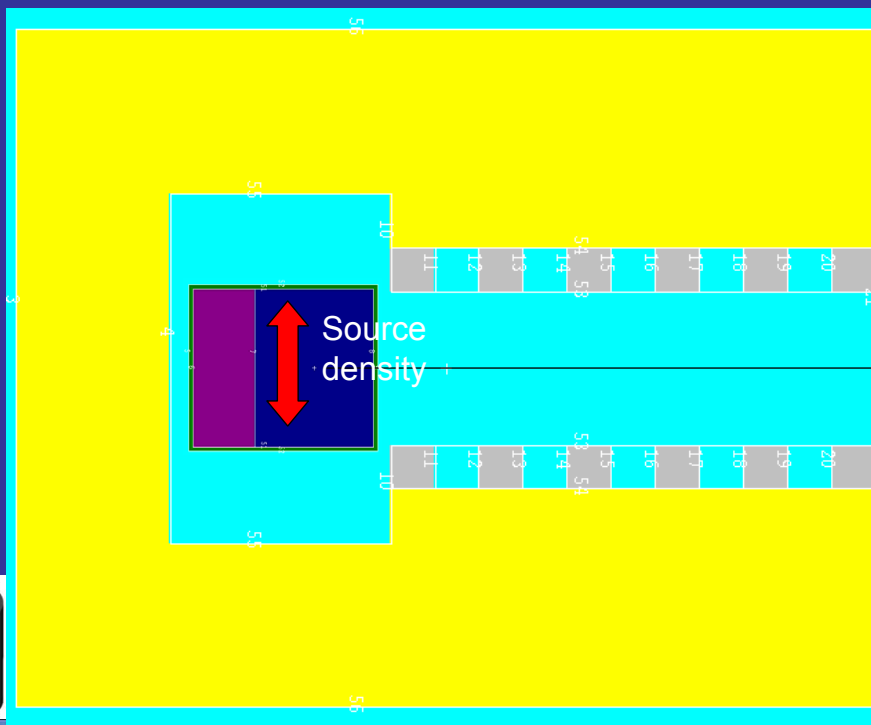
Air kerma
(50 cm)



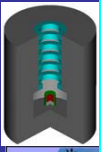
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5) Density of CsCl



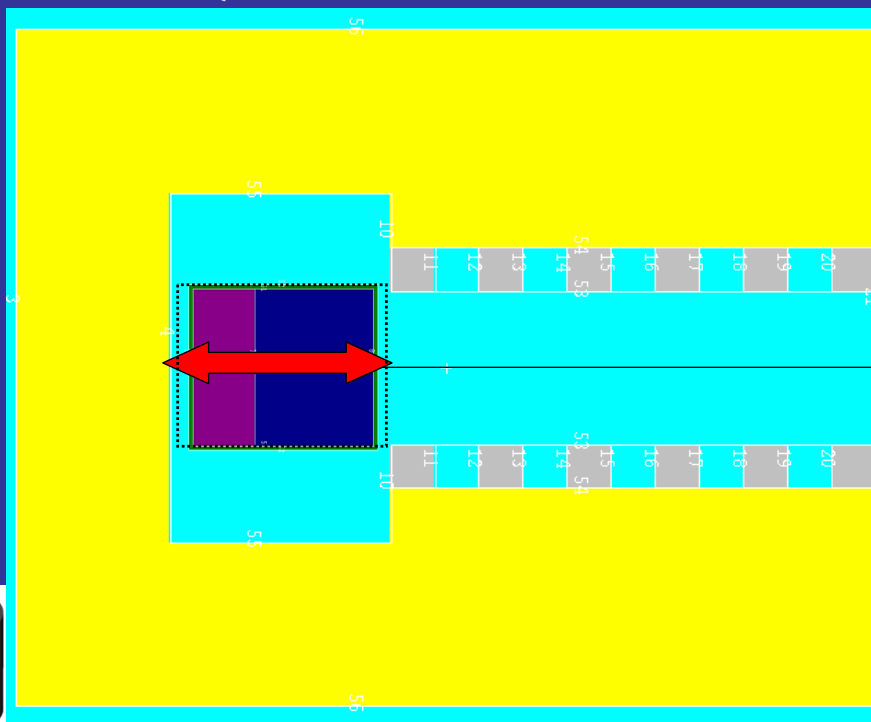
Air kerma
(50 cm)



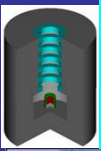
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6) Position of the source (not mandatory)



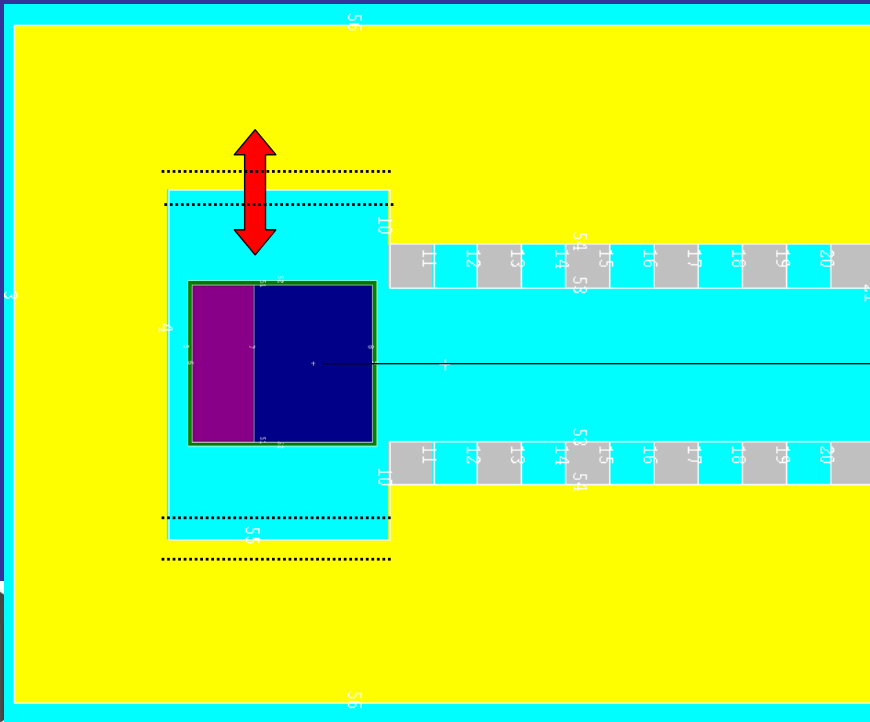
Air kerma
(50 cm)



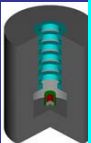
Loïc de CARLAN, Jean-Marc BORDY : uncertainty budget on air kerma



7) Source chamber diameter (not mandatory)



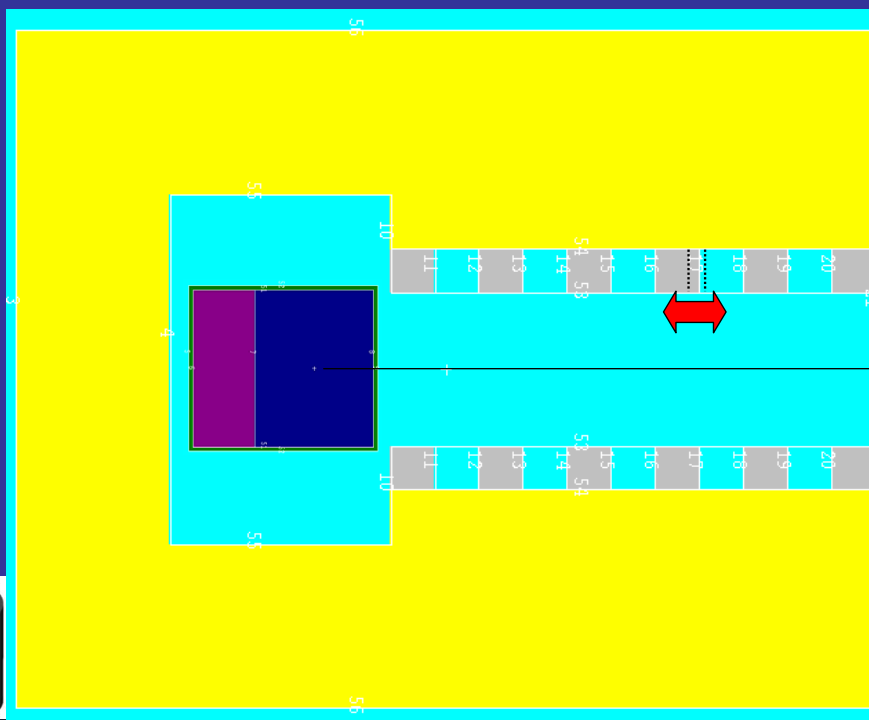
Air kerma
(50 cm)



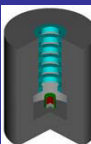
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8) Length of the rings of the collimator (not mandatory)



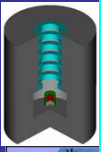
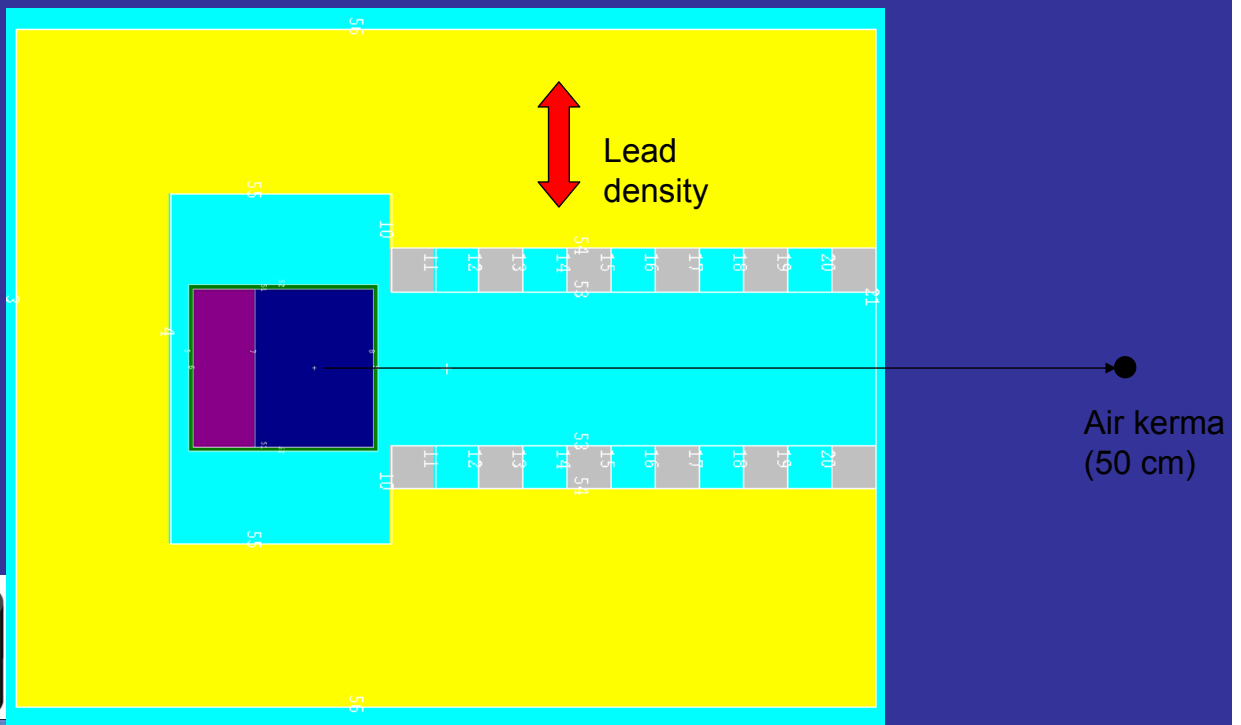
Air kerma
(50 cm)



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11) Density of Lead (not mandatory)

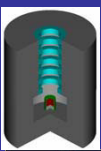


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12) Energy Cut off (not mandatory)

+ ... other parameters
decided by the user



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Method proposed for solving Q1

Variation on the air Kerma very low due to the small variation of the parameters (eg 1 mm on the distance source-Kerma) :

how to see the influence of each parameters without spending too much calculation time ?

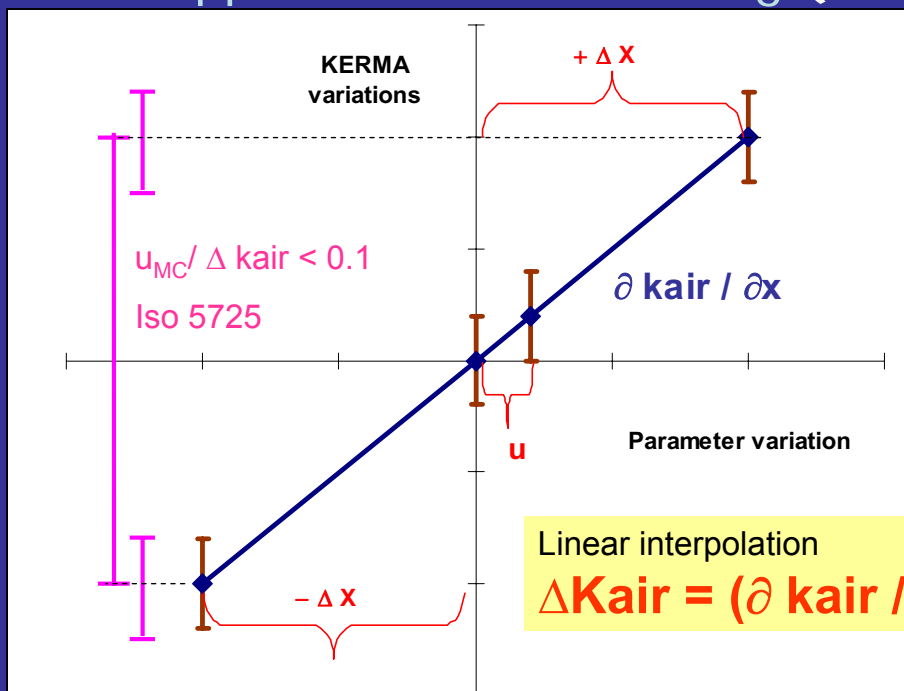
- 1) Increase the variation of the parameters (ΔX instead of dx)
- 2) Calculate the slope of the kerma variation ($\partial \text{kair} / \partial x$) provided that $u_{MC} / \Delta \text{kair} < 0.1$ (influence of the uncertainty on kerma variation is low)
- 3) Calculate the estimated St uncert. u (gaussian distrib, triangular or rectangular) variation of the parameter dx (eg 1mm) $u = 2 \cdot dx / (2\sqrt{3})$ (rect. Distribution)
- 4) Calculate $\Delta \text{kair} = (\partial \text{kair} / \partial x) \cdot u$ provided that $u_{MC} / \Delta \text{kair} < 0.1$ (influence of the uncertainty on kerma variation is low)

CON

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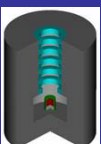
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Different approaches for calculating $(\partial \text{kair} / \partial x)$



Linear interpolation

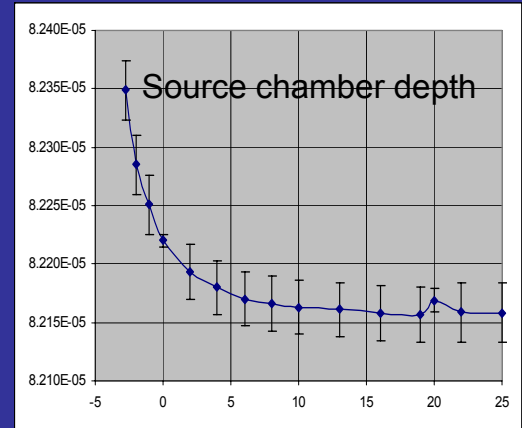
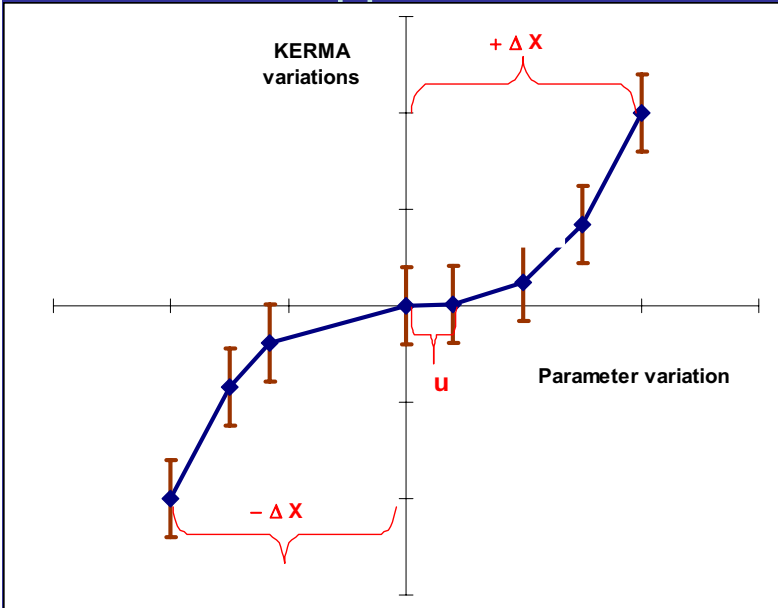
$$\Delta \text{Kair} = (\partial \text{kair} / \partial x) \cdot u$$



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Different approaches for calculating $(\partial k_{air} / \partial x)$



Curve fitting

$$\Delta K_{air} = F_{(k_{air})}(u) - F_{(k_{air})}(0)$$



Table to be filled by the participants

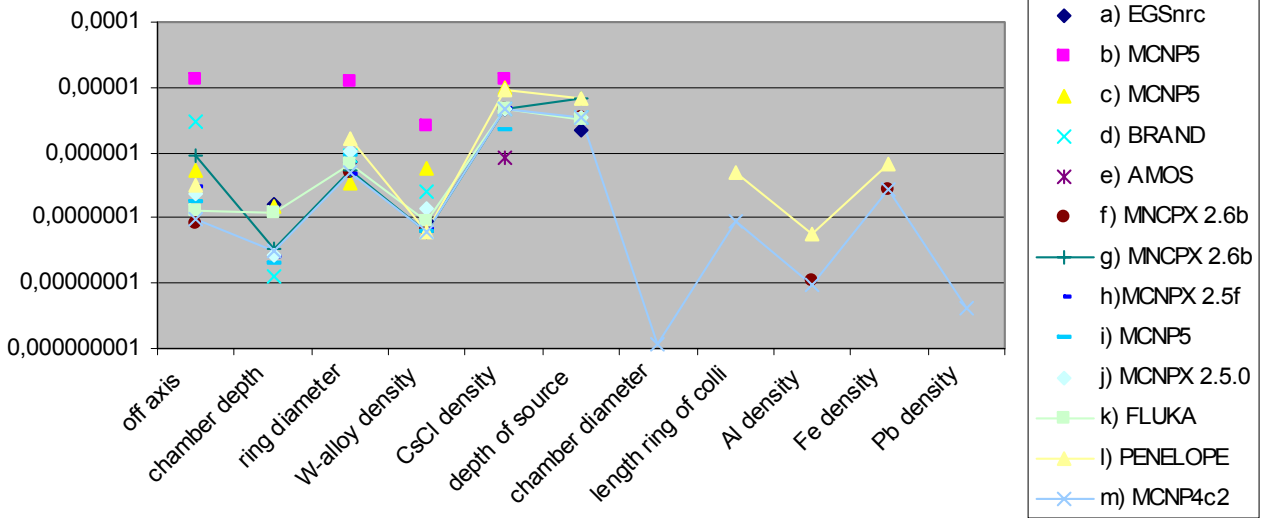
Parameter identification X	Parameter variation in the calculation			Reported uncertainty in parameters (4)	Standard uncertainty of experimental parameter	
	ΔX (1)	$(\partial k_{air} / \partial x)$ (2)	$(\partial k_{air} / \partial x) \Delta X$ CC mGy (3)		u (5)	Δk_{air} (6)
Position of the source (throw off centre)	+/- $(\Delta X/2)$ (1)	(2)	CC mGy (3)	+/-0.05 cm	$0.1 / 2\sqrt{3}$	$\frac{CC}{\Delta Y} u$ (6)
Source chamber (depth)				+/-0.2 cm	$0.4 / 2\sqrt{3}$	
Rings collimator (diameter)	1	S	S. ΔX	+/-0.05 cm	$0.1 / 2\sqrt{3}$	S. u
tungsten alloy density				+/-0.2 g/cc	$0.4 / 2\sqrt{3}$	
Density of CsCL				+/-0.2 g/cc	$0.4 / 2\sqrt{3}$	

Many misunderstandings



Parameter identification X	Parameter variation in the calculation			Reported uncertainty in parameters (4)	Standard uncertainty of experimental parameter	
	ΔX	$(\partial k_{air} / \partial x)$	$(\partial k_{air} / \partial x) \Delta X$		u (5)	Δk_{air}
Rings collimator (diameter)		X		+/-0.05 cm	$0.1 / 2\sqrt{3}$	

$$S = (\partial k_{air} / \partial x)$$



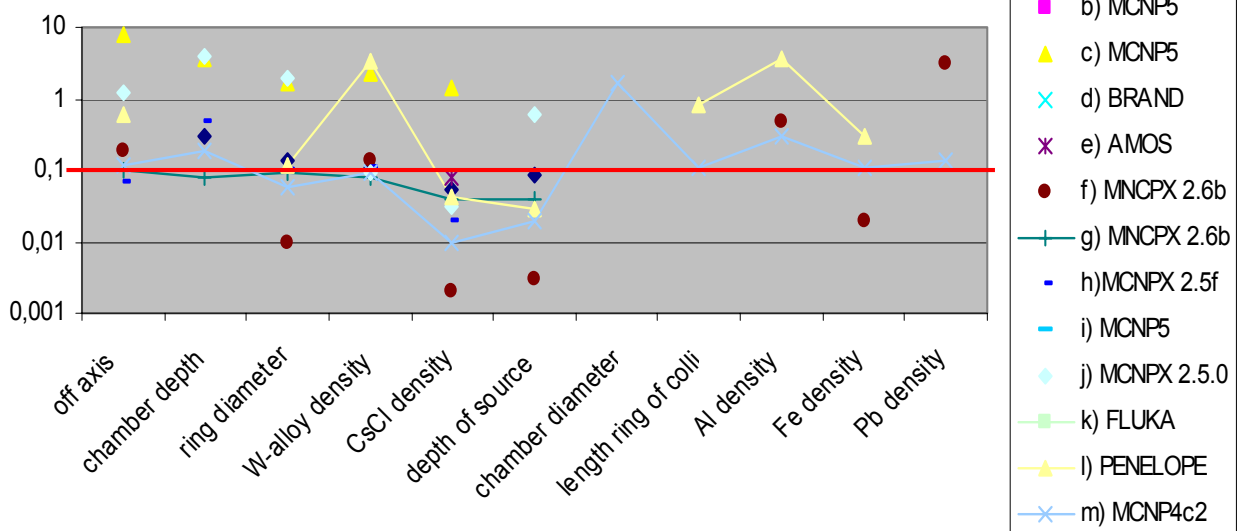
Variation of one decade ...

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Parameter identification X	Parameter variation in the calculation			Reported uncertainty in parameters (4)	Standard uncertainty of experimental parameter	
	ΔX	$(\partial k_{air} / \partial x)$	$(\partial k_{air} / \partial x) \Delta X$		u (5)	Δk_{air}
Rings collimator (diameter)		X		+/-0.05 cm	$0.1 / 2\sqrt{3}$	

$$u_{MC} / \Delta k_{air} (< 0.1)$$

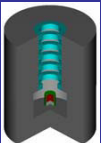
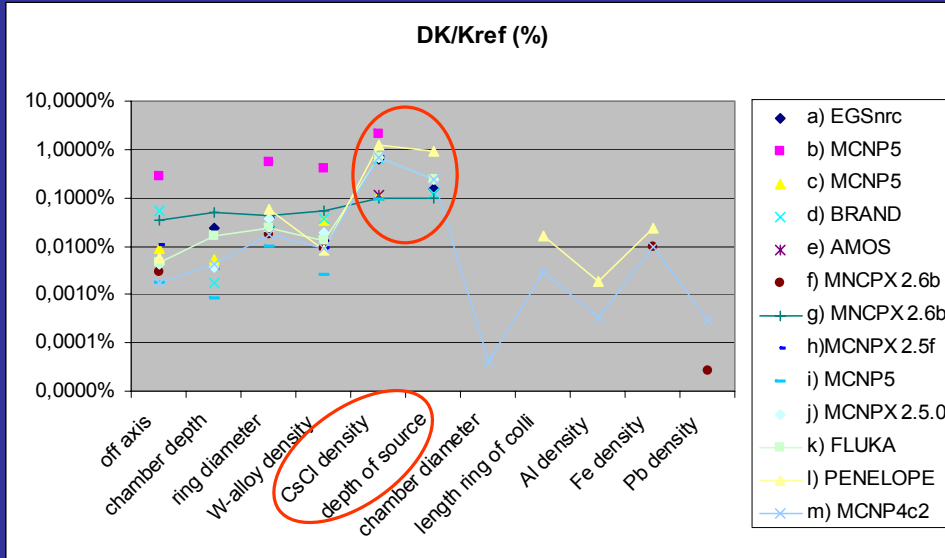


~ half of the values are higher than 0.1

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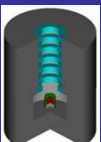
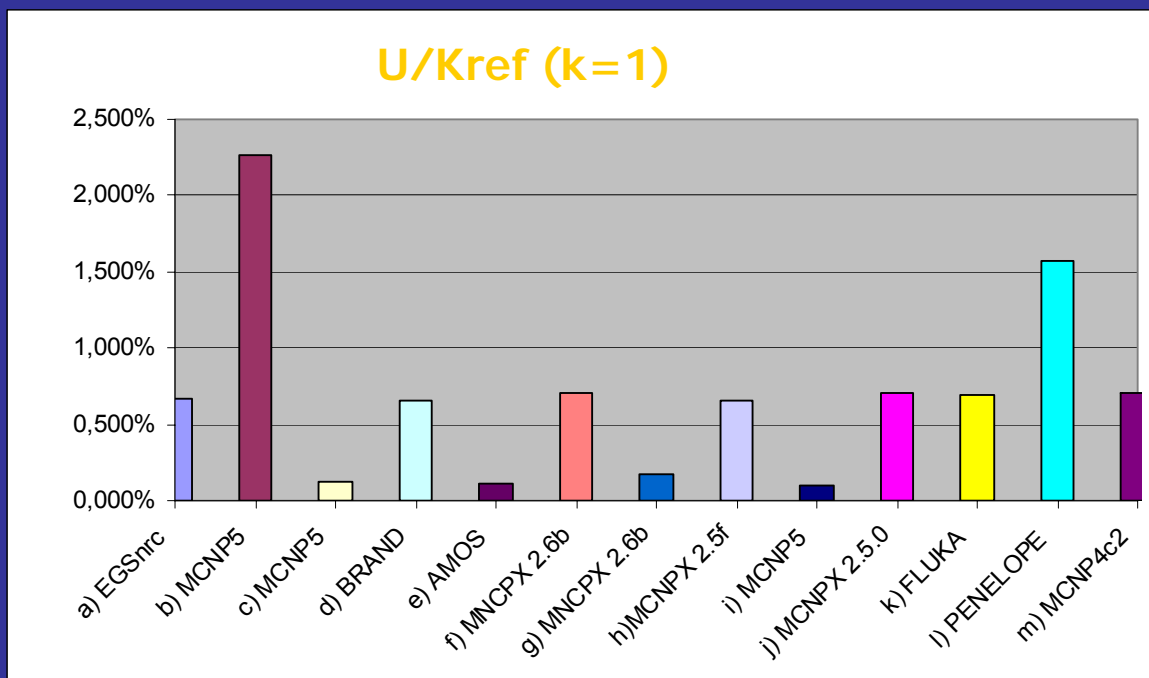


Parameter identification X	Parameter variation in the calculation			Reported uncertainty in parameters (4)	Standard uncertainty of experimental parameter	
	ΔX	$(\partial k_{air} / \partial X)$	$(\partial k_{air} / \partial X) \Delta X$		u (5)	Δk_{air}
Rings collimator (diameter)				+/-0.05 cm	$0.1 / 2\sqrt{3}$	X



Important variations

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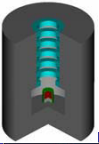
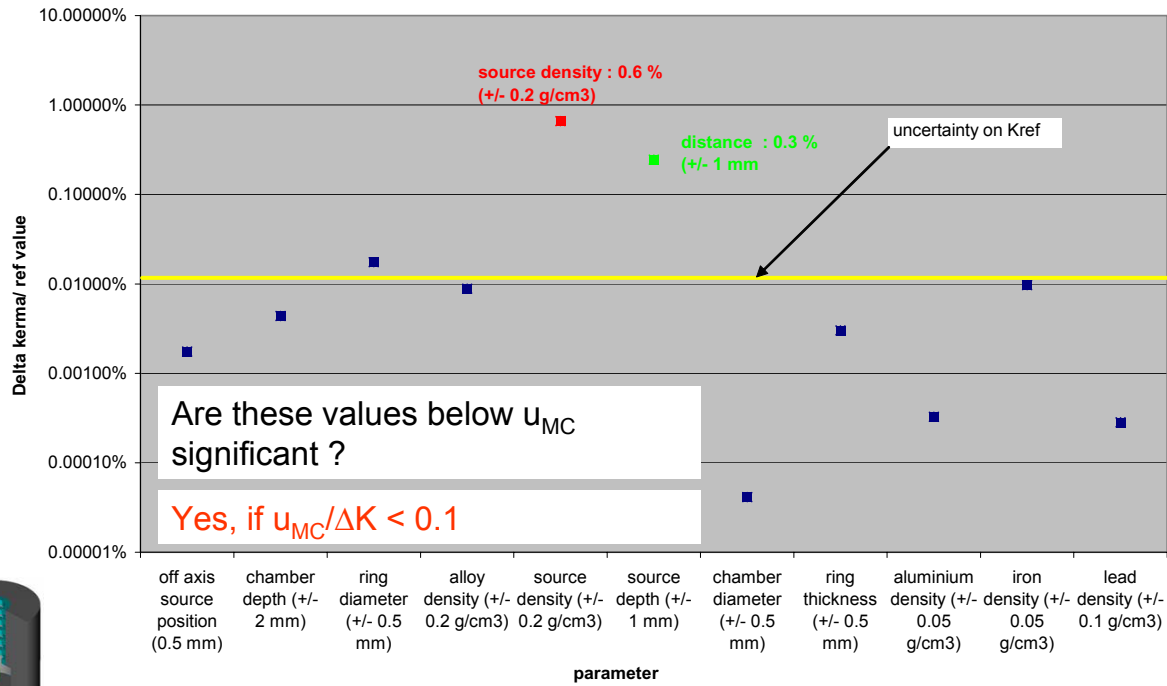
Important variations

Depends of the number of studied parameters

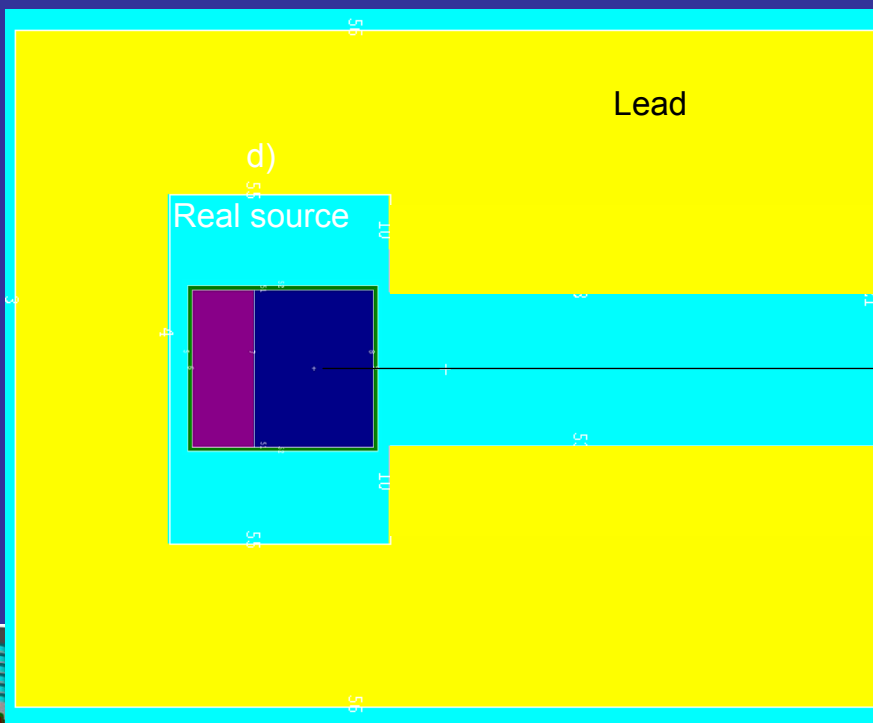
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REMARK

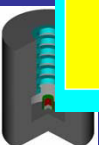


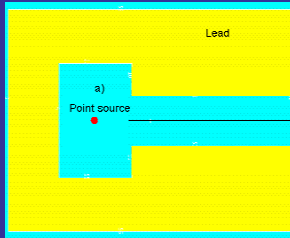
Question 2 : Influence of the source encapsulation (not mandatory)



Simple collimator \neq Q1

- Air kerma (50 cm)
- + kerma profile
- + fluence



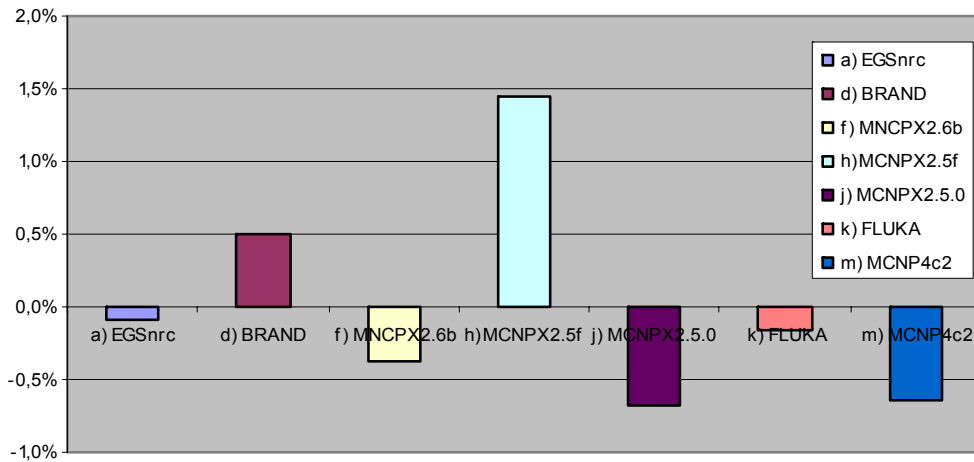


Air kerma
(50 cm)
+ kerma
profile

Question 2a : Air Kerma value

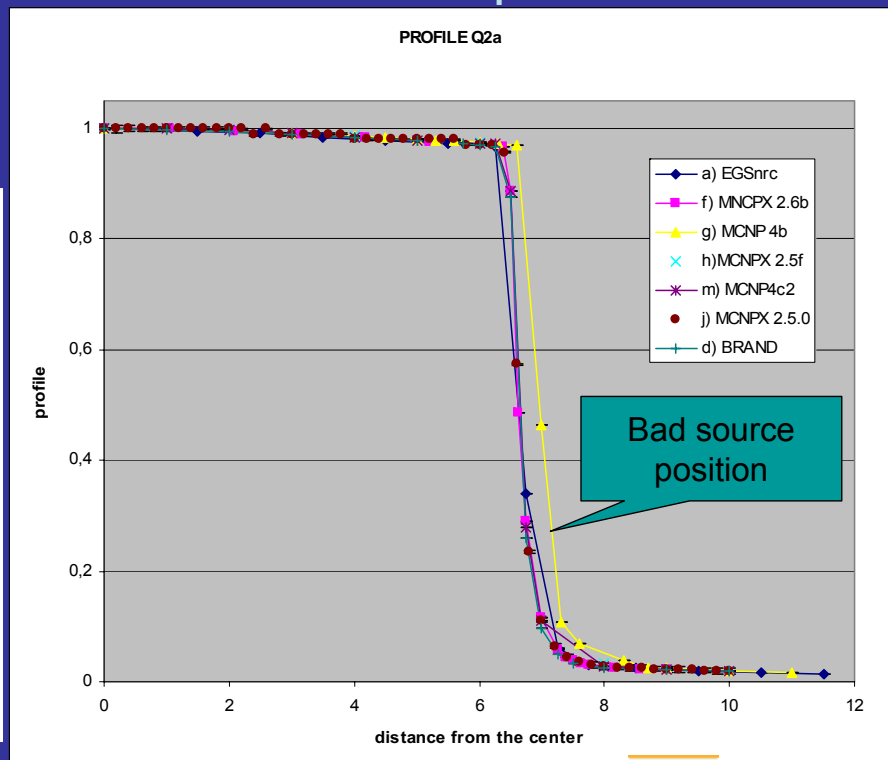
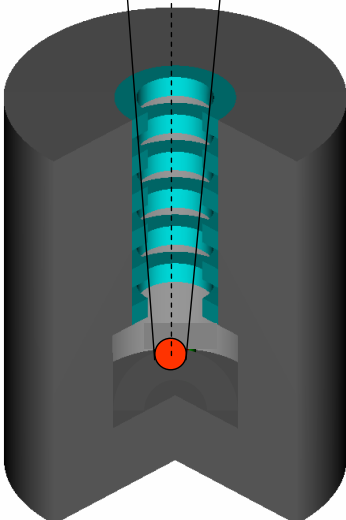
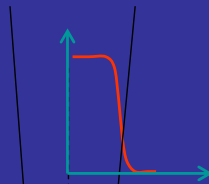
shift to the mean

$$\sigma / \langle \rangle = 0.7 \%$$



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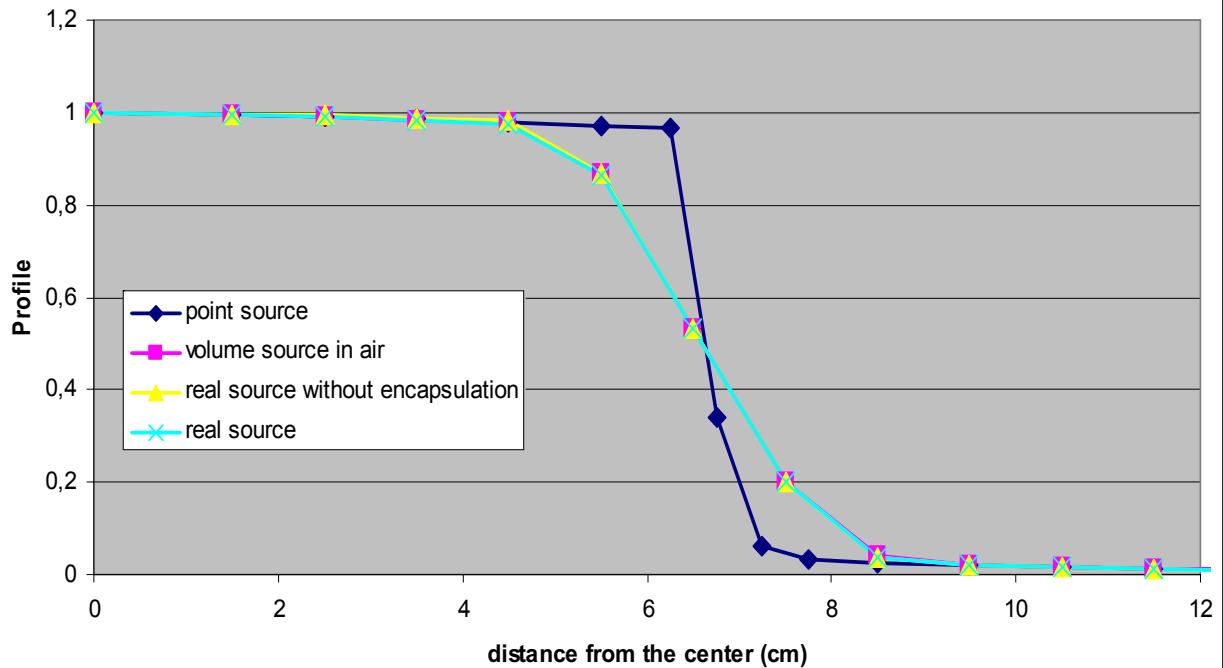
Question 2a : Air Kerma profile



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Question 2 : Air Kerma profile

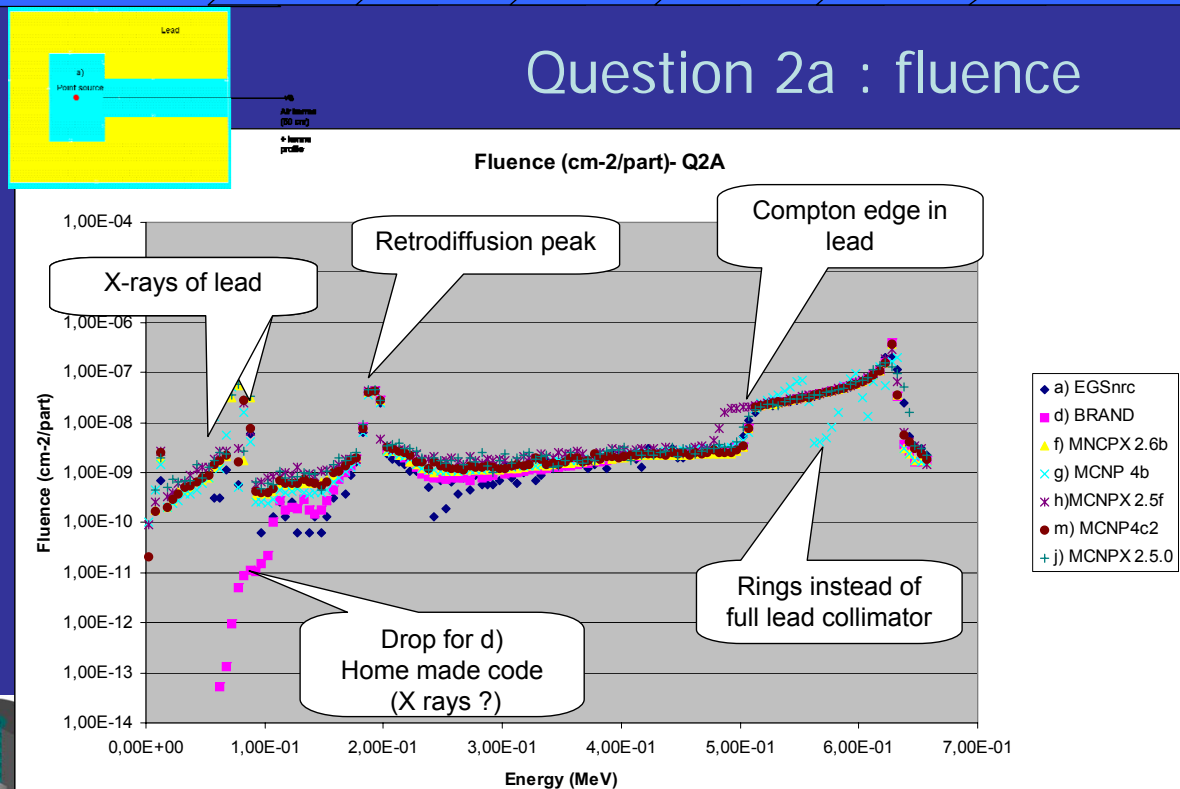
exemple of a representative PROFILE Q2 (participant a)



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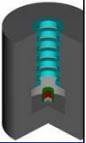
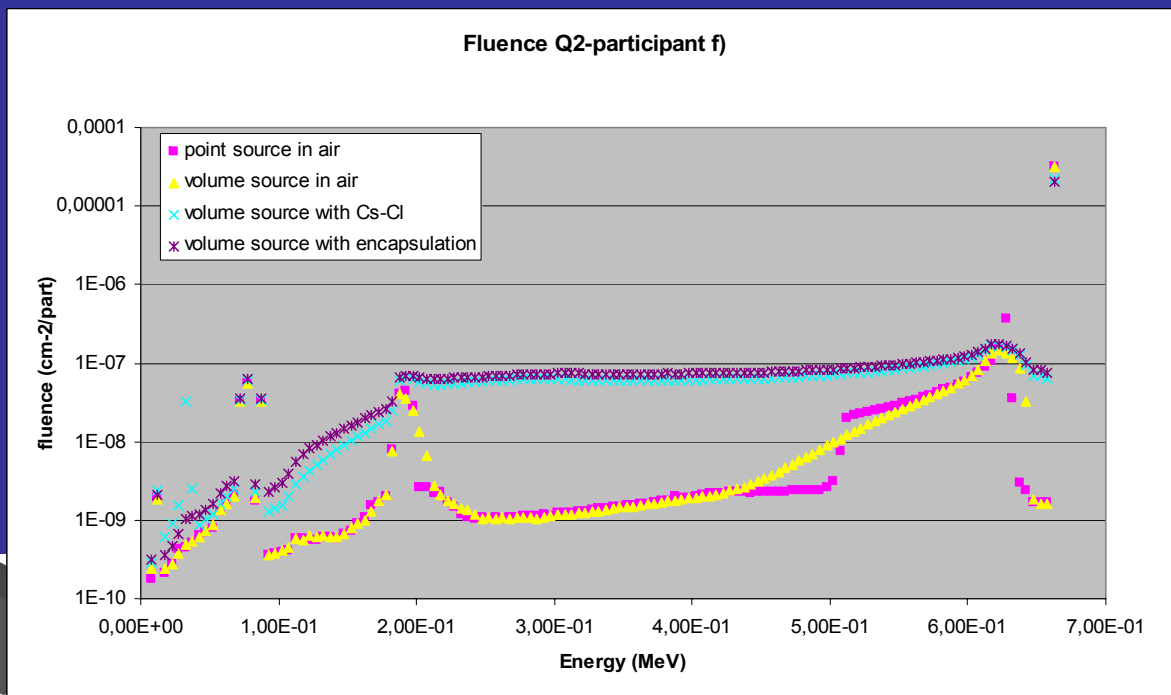
33

Question 2a : fluence



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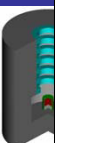
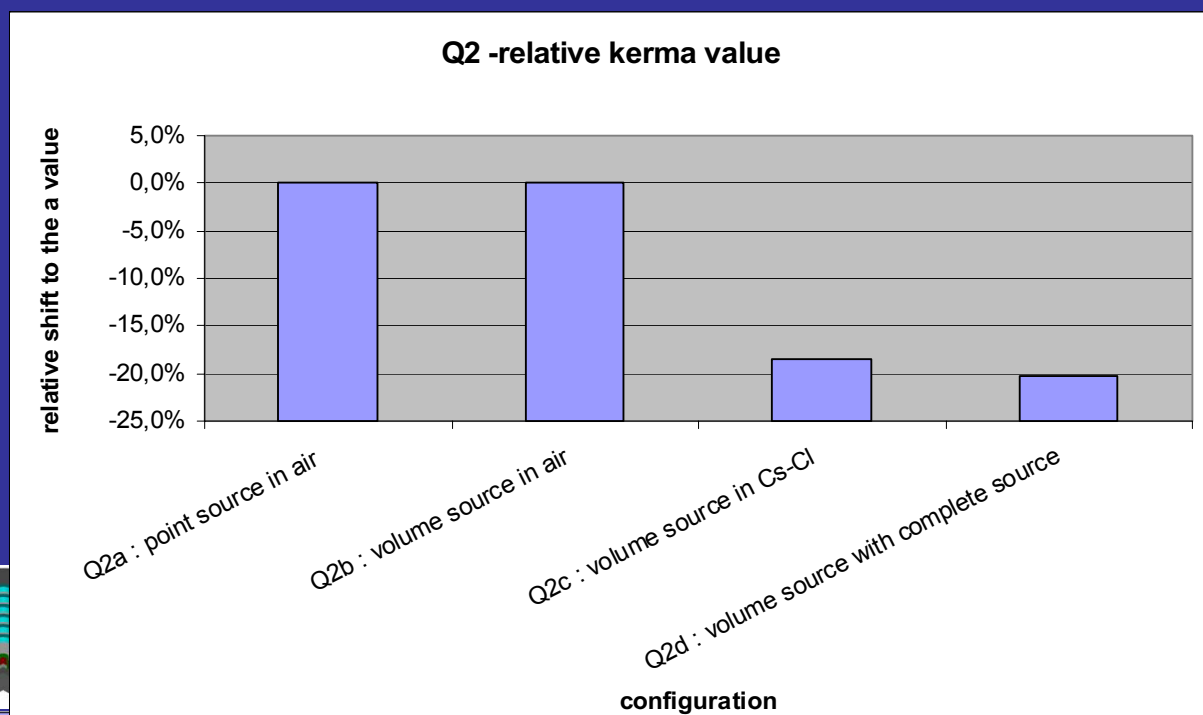
Question 2 a-b-c-d : fluence



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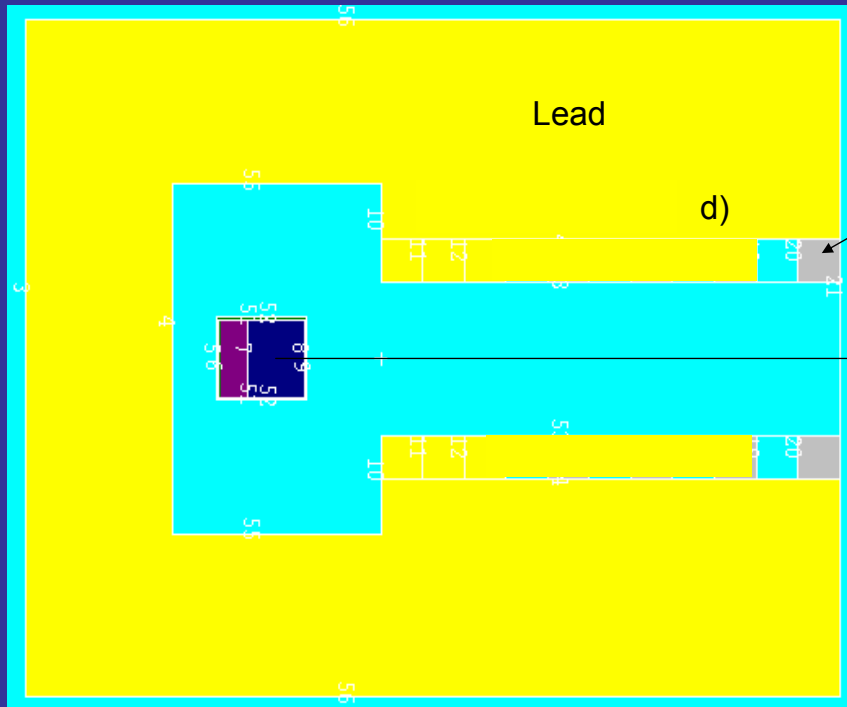
Kerma value



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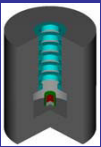
Question 3 : influence of the collimator



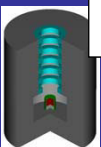
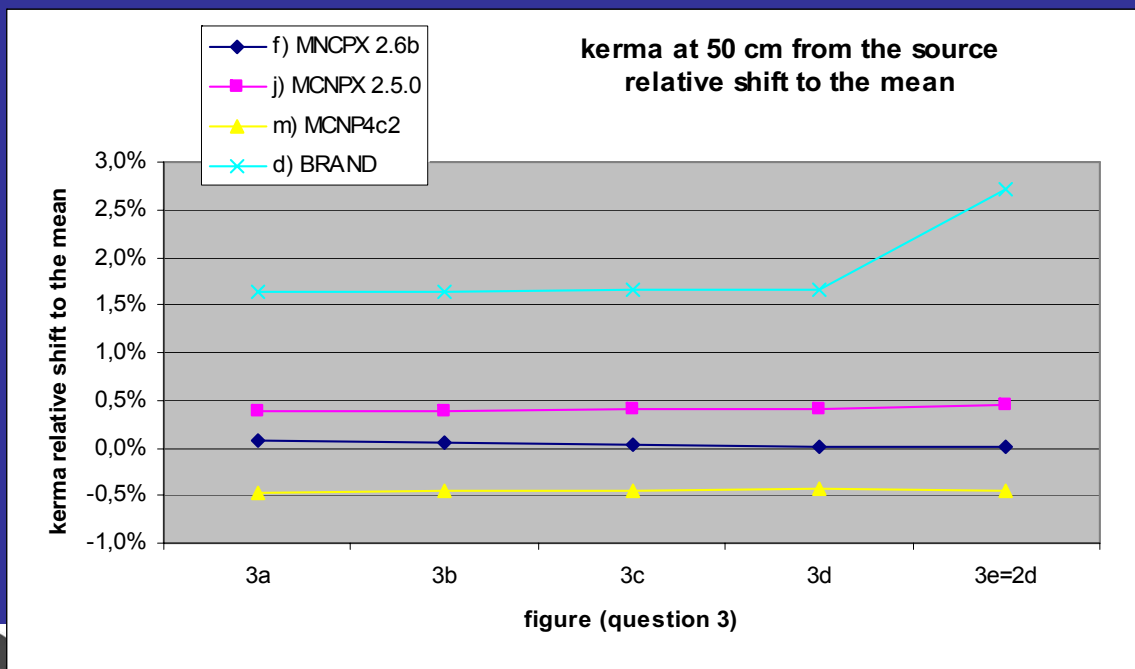
Tungsten alloy

Air kerma (50; 100 cm)

+ kerma profile

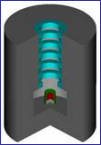
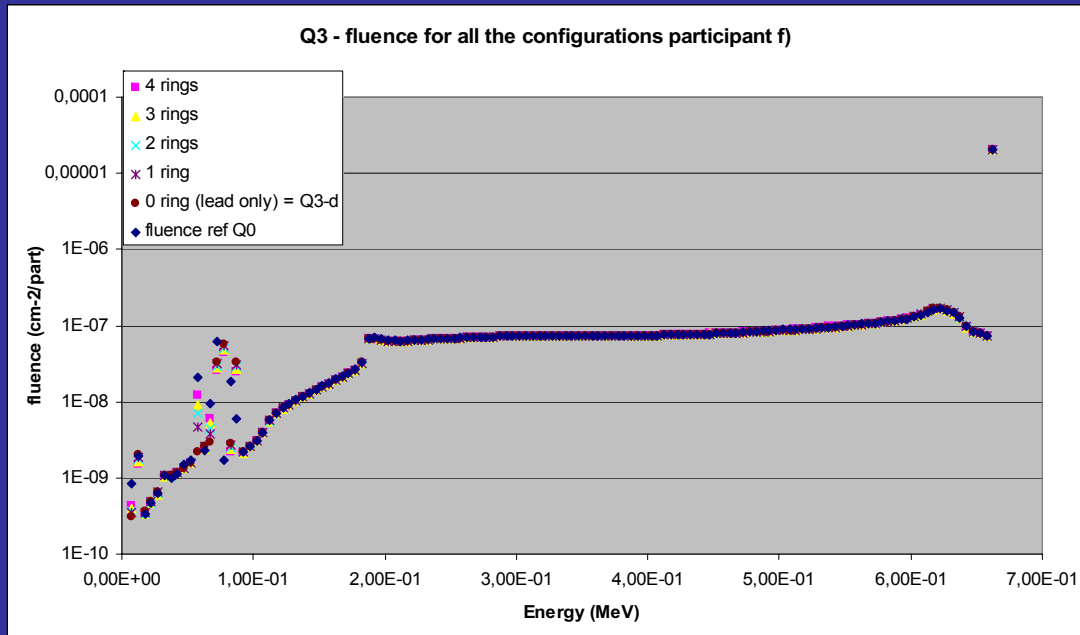


Q3 : Air Kerma



Negligible variations
of kerma vs number of the rings

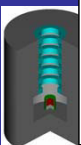
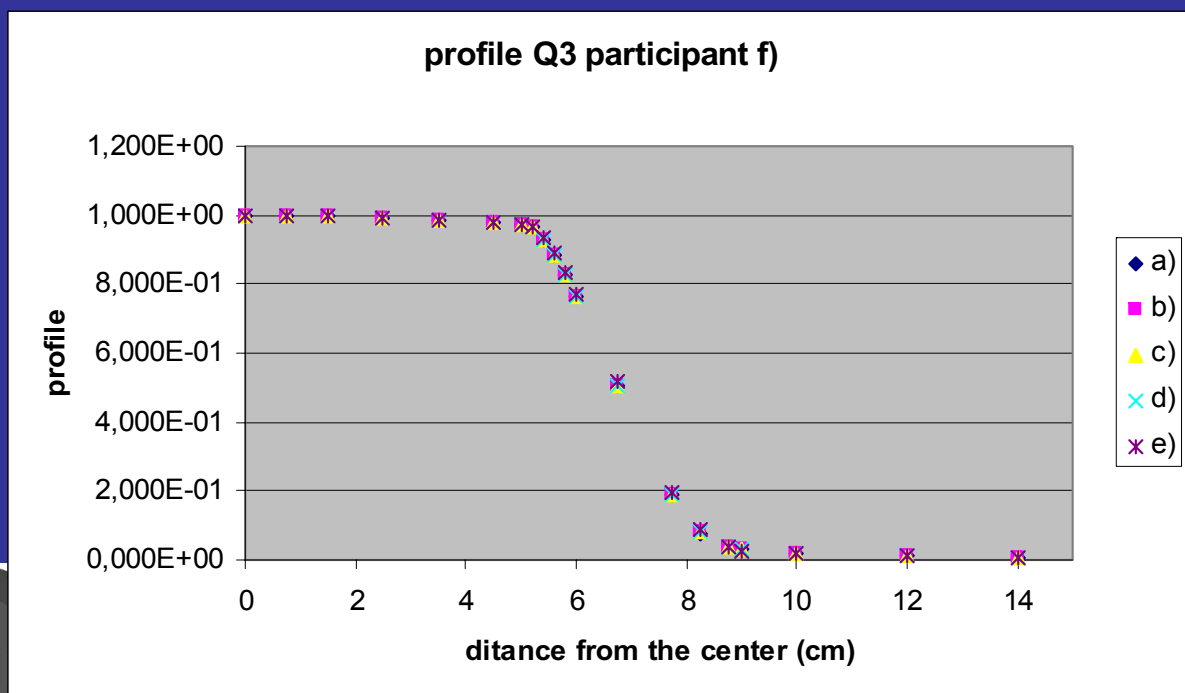
Q3 : fluence



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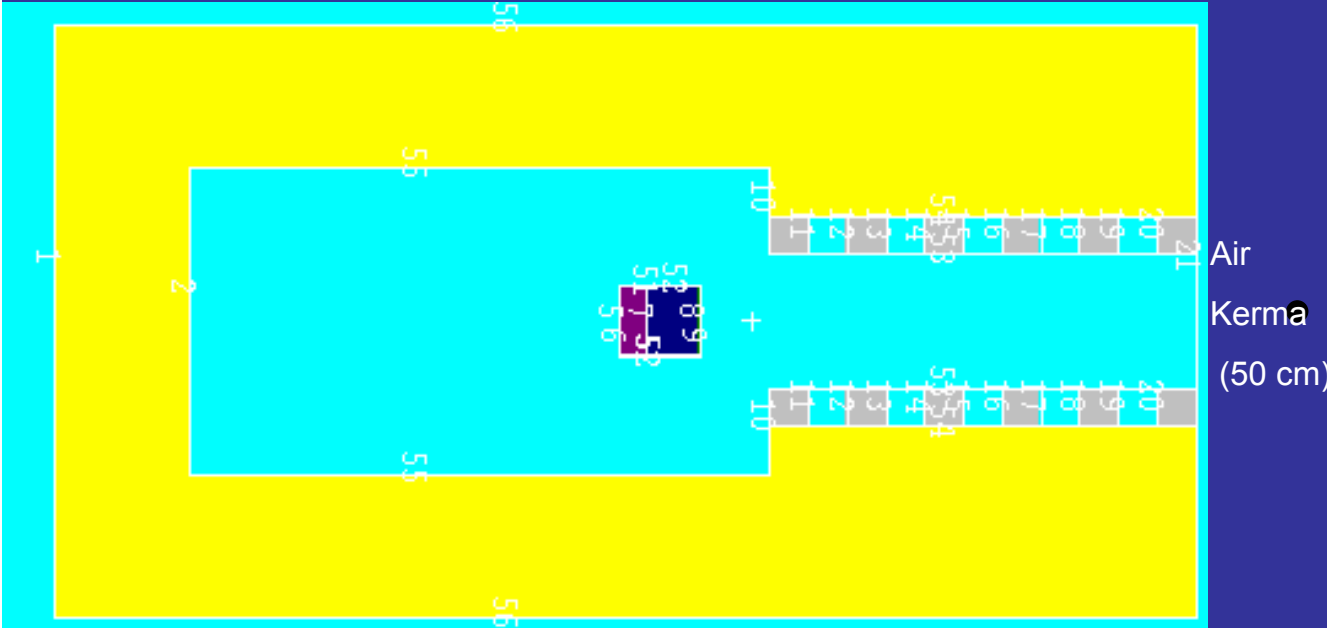
Q3 : Air Kerma profile



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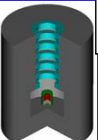
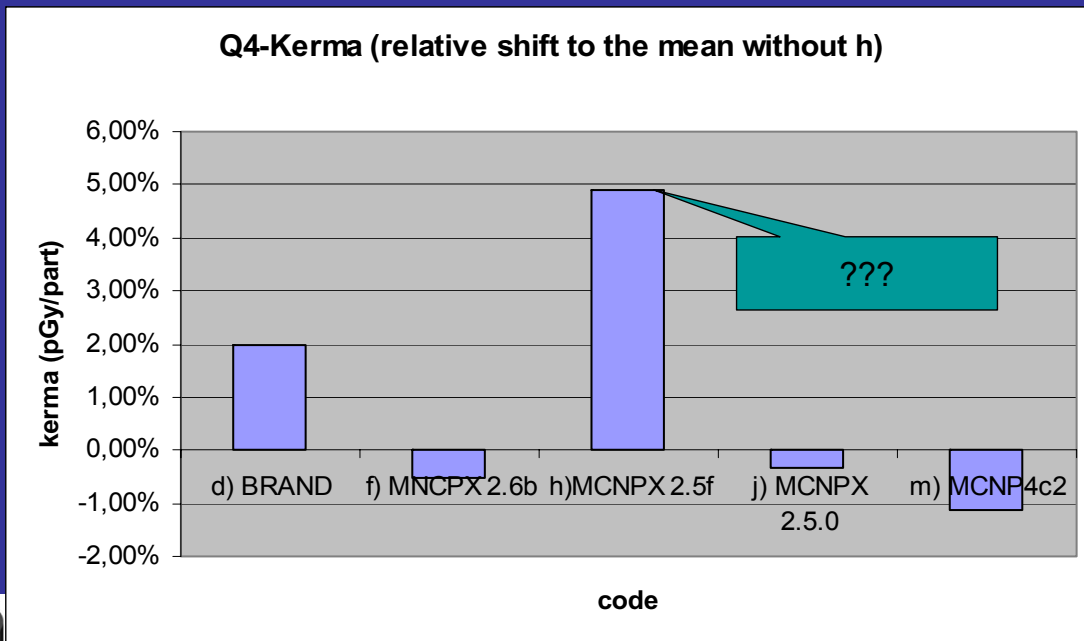
Question 4 : influence of the chamber depth



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Question 4 : Air kerma

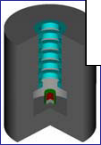
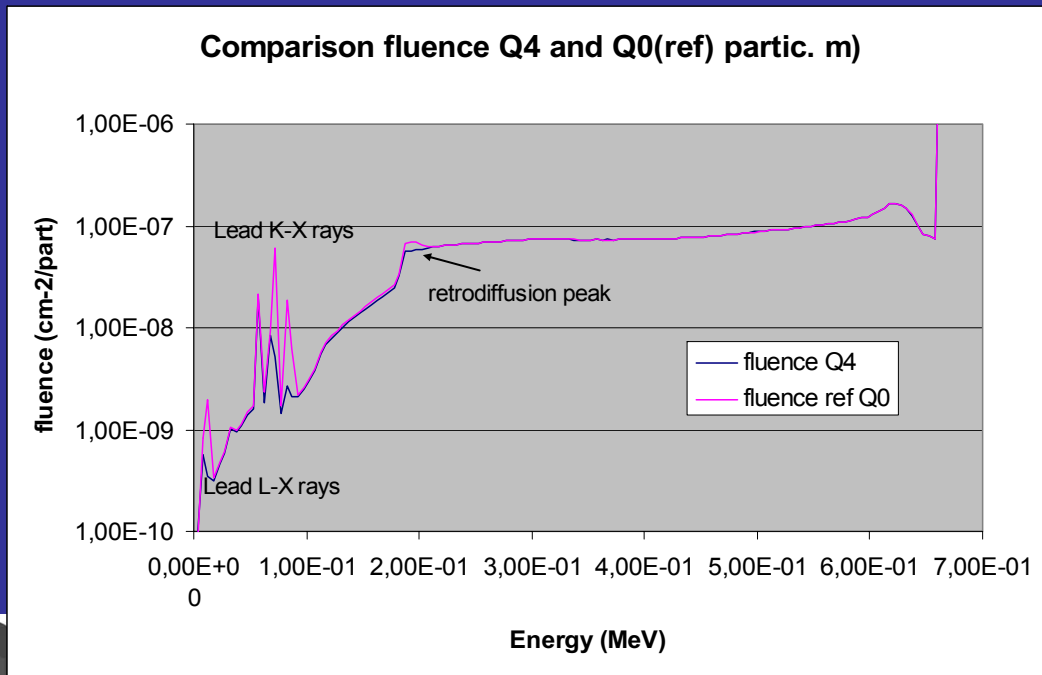


No variation of the kerma with the chamber depth (see Q1)

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Question 4 : fluence



Reduction of the X rays intensity & reduction of the retrodiffusion peak



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Conclusions

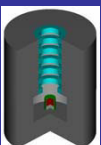
- ✓ successful work : 13 participants from 10 countries
- ✓ Large amount of data : many parameters with many configurations
- ✓ Specific approach in the determination of the uncertainty budget:

$u \sim 0.7 \% (k=1) :$

- ❖ source density : 0.6 % (+/- 0.2 g/cc)
- ❖ distance : 0.3 % (+/- 1 mm)
- ❖ other parameters

- ✓ rather large discrepancies in the uncertainty budget (Q1) due to:

- ❖ (i) low sensitivity of kerma with parameter variation: $U_{MC}/\Delta K$ is usually too high : calculation time can be prohibitive
- ❖ (ii) human factor in the parameterization of the calculation: geometry, physics in the code.



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Conclusions

✓: Q2 : penumbra - point source : ~ 4 mm ; volume source 2 cm
decrease of kerma value due to self absorption 20 %

✓Q3: no influence of the shape of the collimator on kerma value and
fluence : ring versus full collimator

✓Q4 : no influence of source chamber depth (Q1) on kerma value.
Small effect on X rays intensities

**MANY THANKS TO THE PARTICIPANTS
FOR THEIR CONTRIBUTIONS**

&

THANK YOU FOR YOUR ATTENTION

