

## Analysis of computational problems expressing the overall uncertainties: photons, neutrons and electrons

Loïc de Carlan, CEA-LIST/LNHB-France  
and Robert Price, City University, London UK

presentation on behalf of all the exercise authors

Stochastic  
uncertainty

- P1: Recoil proton telescope
- P2 : Bonner spheres
- P3 : sigma facility

G. Gualdrini and  
R. Tanner

- P4 :  $^{137}\text{Cs}$  facility
- P5 : Manganese Bath

} 1<sup>st</sup> presentation  
L. de Carlan

overall  
uncertainty

- P6 : Iron sphere
- P7 : RADFET: Radiation detector
- P8 : proton telescope :  
uncertainty analysis

} 2<sup>nd</sup>  
presentation  
R. Price

- P4 -

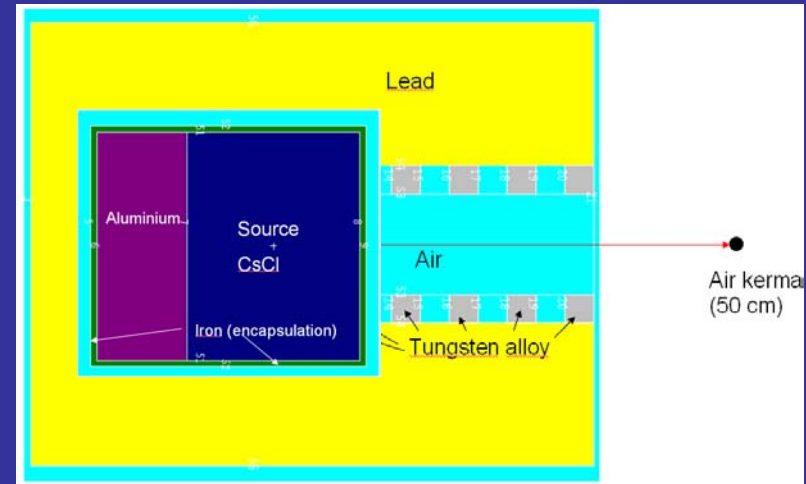
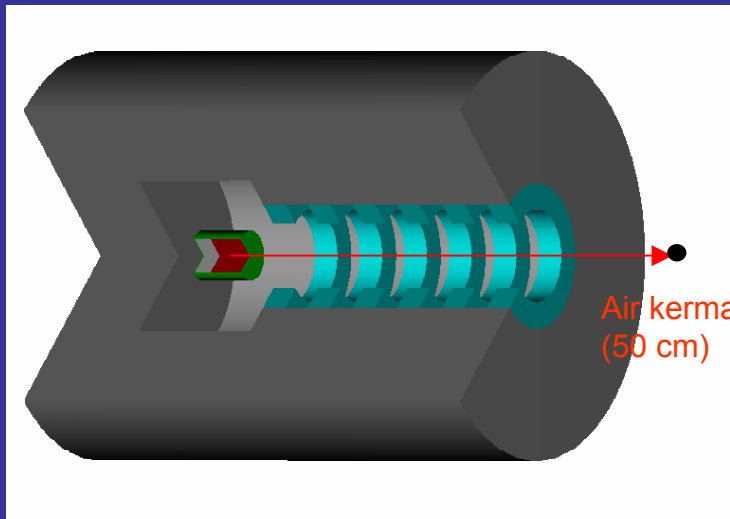
## PHOTON IRRADIATION FACILITY : UNCERTAINTY BUDGET ON AIR KERMA

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2 : CERN-Switzerland

3 : ARCS-Austria



## Study of the uncertainty budget of a $^{137}\text{Cs}$ irradiator

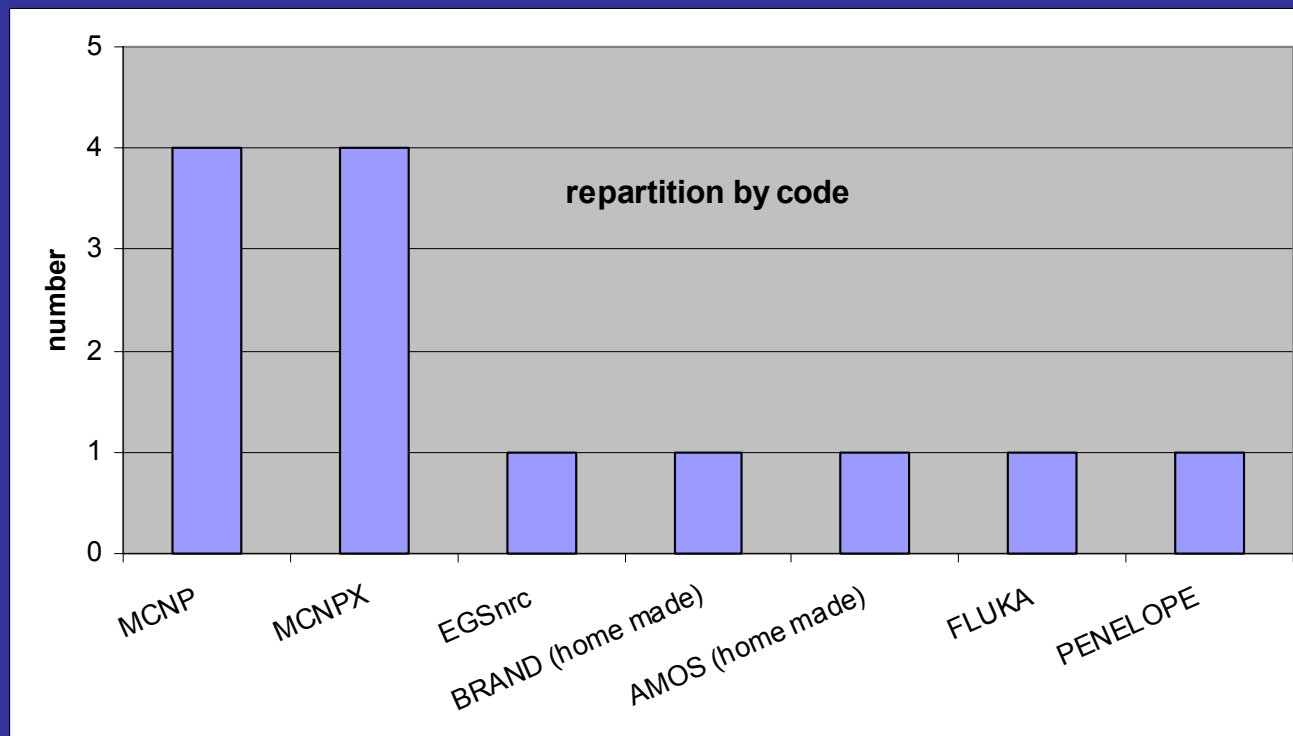
✓Q1 : the only mandatory question : uncertainty analysis of the kerma value when varying separately many parameters in the geometry : position of the source, density of the materials, diameter of the collimator ...

✓Q2 ....

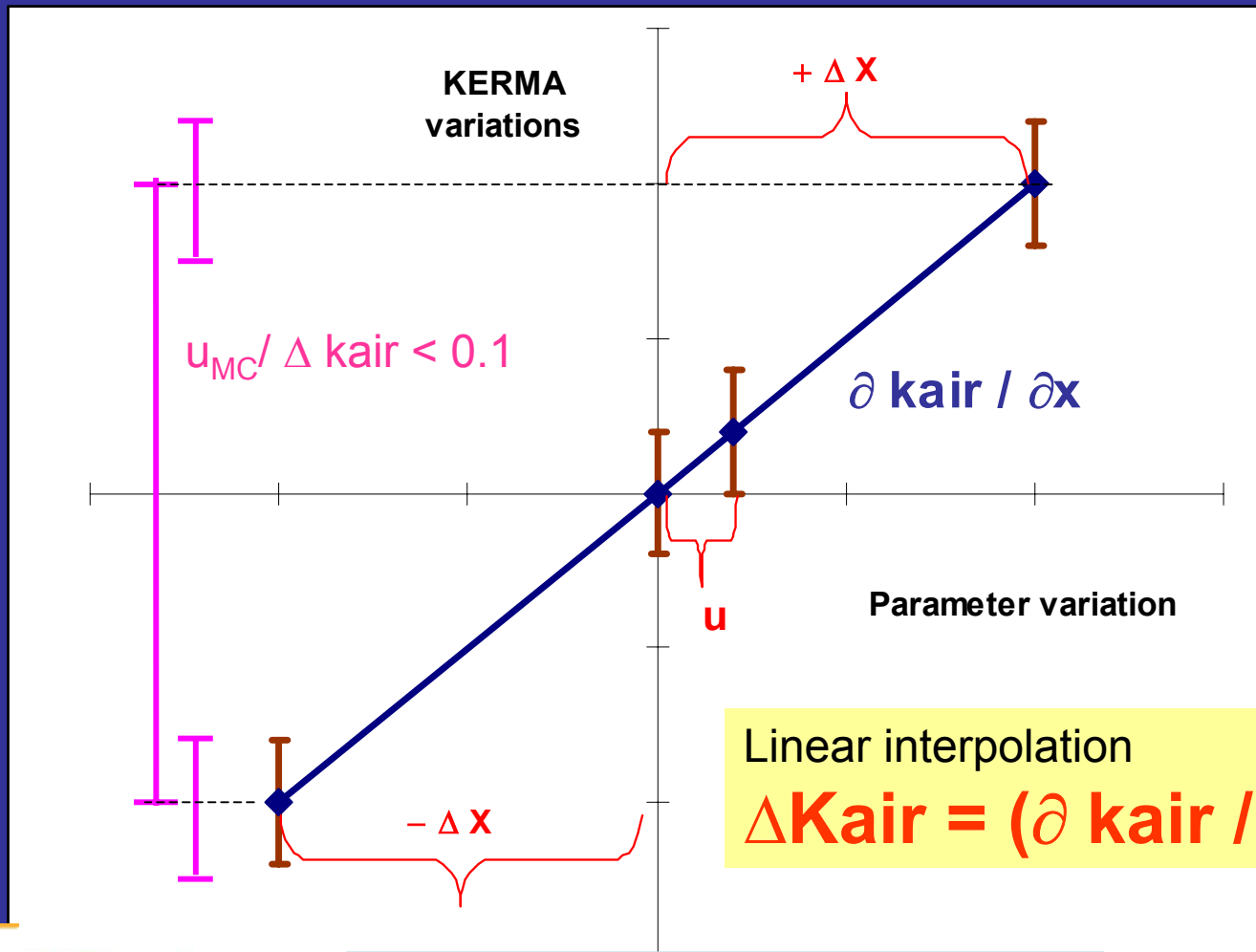
# Participants and codes

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)



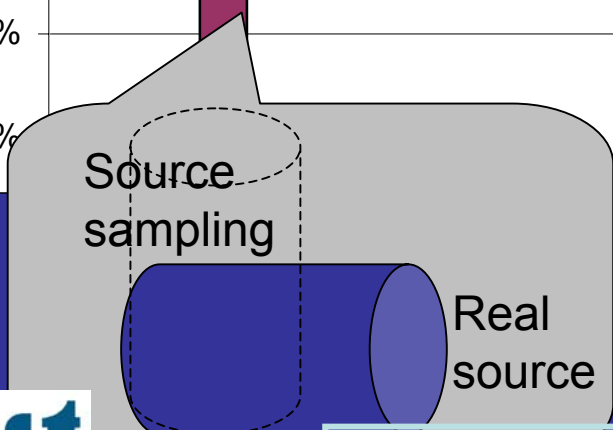
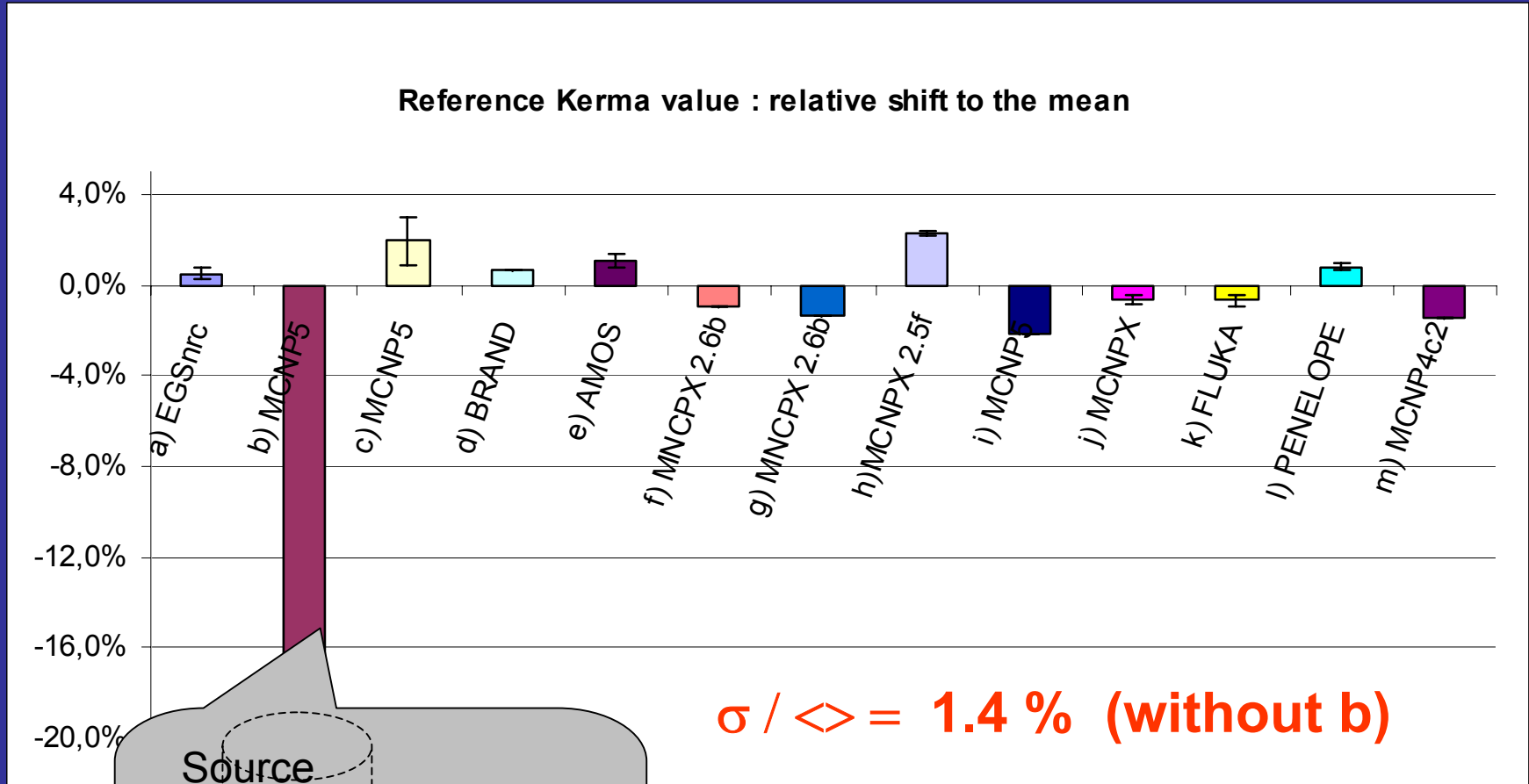
Variation on the air Kerma very low (eg 1 mm on the distance)  
 how to see the influence of each parameters without  
 spending too much calculation time ?



Linear interpolation

$$\Delta K_{air} = (\partial k_{air} / \partial x) * u$$

# Reference Kerma value

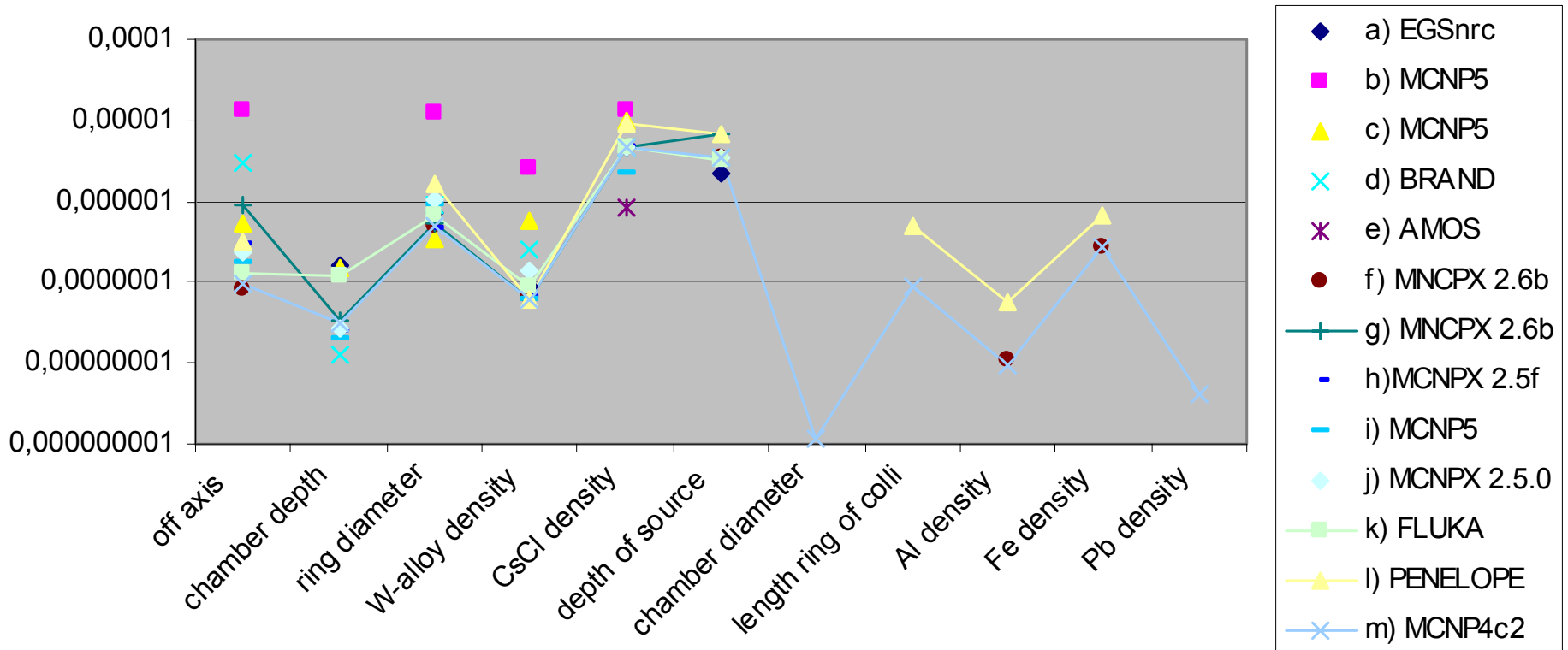


Rather good agreement

# P4 : Cs facility

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

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

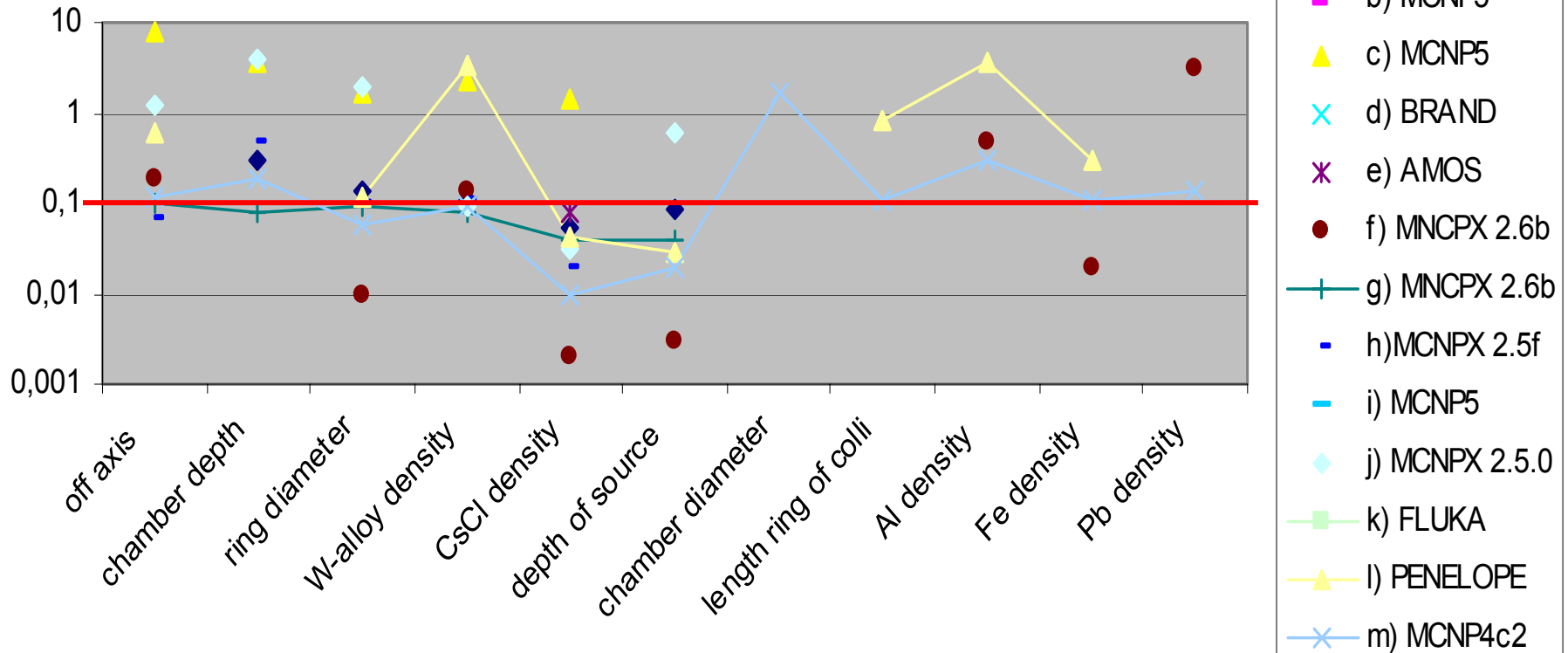


Variation of one decade ...



Eurados annual meeting, 23 January 2008

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



~ half of the values are higher than 0.1

# 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 ~ 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: calculation time is not enough can be prohibitive
  - ❖ (ii) human factor in the parameterization of the calculation: geometry, physics in the code.

- P5 -

## MANGANESE BATH

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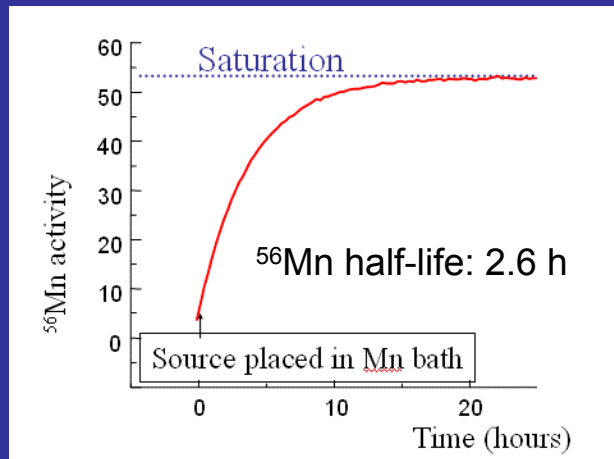
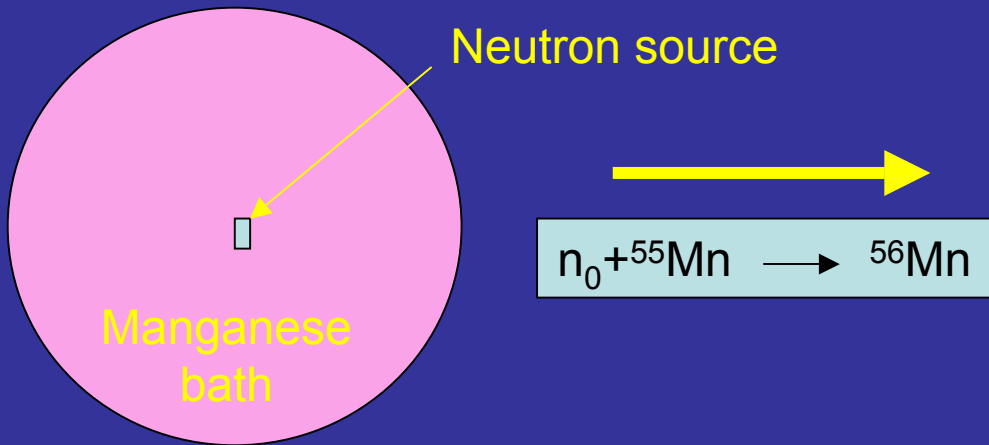
# Manganese bath technique

- Calibration of neutron sources in terms of emission rate in  $4\pi$  sr used in National Metrology Labs
- Activation of Mn in a  $MnSO_4$  solution  $\rightarrow$   $^{56}Mn$
- Neutron emission rate proportional to the  $^{56}Mn$  activity:

$$B = A / f(1-\delta)$$

Neutron emission rate over  $4\pi$  ←  $B$   
 $^{56}Mn$  activity : Cerenkov gamma coincidence counting ←  $A$

$f(1-\delta)$  → correction factor (Oxygen, recapture, Leakage)  
 Fraction of n captured by Mn / total n reactions  
 To be calculated + uncertainty



# P5 problem participation

- 7 participants:
  - Brazil : 1
  - USA : 2
  - Spain : 1
  - France : 2
  - U.K. : 1
- Codes: MCNP4-c2, MCNP5, MCNPX 2.5.0 and beta 2.6, Tripoli 4
- 2 models of the Mn bath facility:
  - ‘Simplified model’ solved by all participants (point srce)
  - ‘Realistic model’ solved by 4 participants, partial results by others
  - Options: air and concrete environment model

# Uncertainties evaluation

Based on the investigation of the Influence of :

- Addition of air and concrete floor and walls
- Density of the solution :  $\pm 0.5 \%$
- Density of the radioactive material:  $\pm 20 \%$
- Source positioning :  $\pm 10 \text{ mm}$
- Spherical tank radius :  $\pm 5 \text{ mm}$
- Neutron cross-sections (Mn, H ,  $\text{O}$ , S, ....)

Overall relative standard uncertainties assigned to  $f(1 - \delta)$ :  
from 0.4 % to 1.3 %

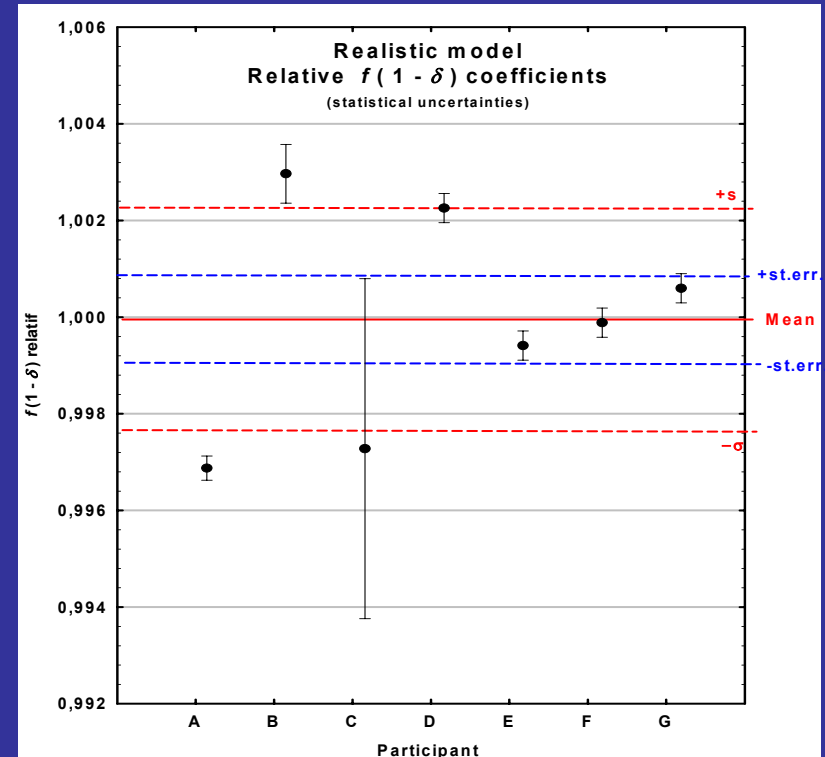
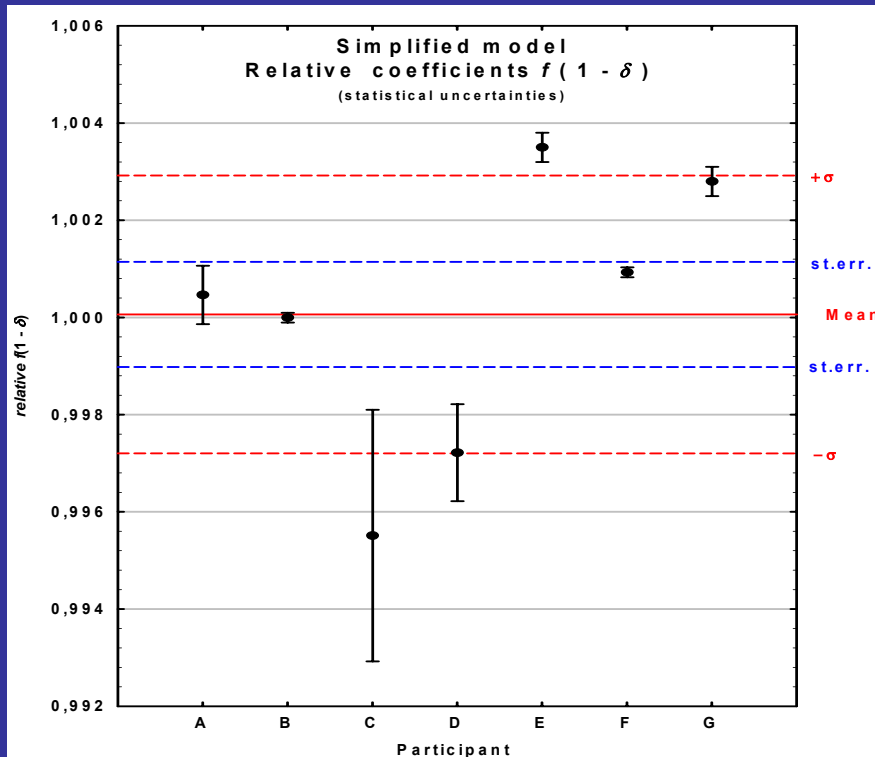
Mean value of  $f(1 - \delta) = 0.425$

$\sigma_{f(1 - \delta)} = 0.6\%$

# Relative $f(1 - \delta)$

Simplified model only stoch. uncert.

Realistic model model only stoch. uncert.



Deviations of results is about 0.4%... But declared uncertainties are much lower than observed dispersion of the results

# Experimental validation

Difficulties to find a standard source of known flux  
(the reference measurement method is the manganese bath !)

- relative measurement of neutron leakage
- calculation of  $f(1-\delta)$  from the measured activity using a reference neutron source (from an international comparison)

*Reasonable agreement between calculated and experimental results but large experimental uncertainties*

*These experimental results are OK to confirm the order of magnitude of calculated results... but cannot be used as reference solution for P5*

# Some conclusions of P5

- For both models, capture fractions and  $f(1 - \delta)$  results are quite consistent
- Several participants have dealt with the evaluation of the uncertainty assigned to the final result, but some uncertainty budgets need to be clarified,
- No precise experimental evaluation available
- Simple exercise to distinguish between neutron current and fluence!
- Brings a better knowledge of the Mn bath facility (modelling of the source) and uncertainty assessment
- The investigation of the influence of cross-sections should be extended to recent libraries (ENDFB-VII) (oxygen)