Medical Staff Dosimetry

Restricted Problem – CONRAD WP4 & WP7

Jean-Marc Bordy -	Design of a Realistic Calibration Field for Diagnostic Radiology
Frank Schultz -	Simulation of an Interventional Cardiac Catheterization Procedure
Lara Struelens -	Summary of the Submitted Problem Solutions

Uncertainty Assessment in Computational Dosimetry:
A comparison of Approaches
Euratom VI Framework Programme

Design of a realistic calibration field for diagnostic radiology (medical staff dosimetry)

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In collaboration with WP 7 of CONRAD
(WG 9 - Medical staff Radiation Protection Dosimetry)
EURADOS

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Where are the most important doses for medical staff ?

Diagnostic ? External Radiotherapy ? Surgery ? Brachytherapy ? Nuclear Medicine ?

Diagnostic + Surgery

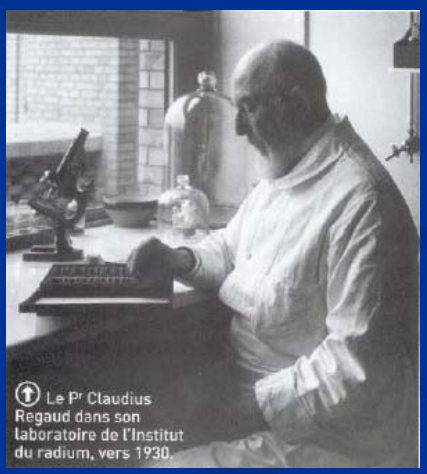
surgery + brachytherapy

Medical staff must stay around the patient during exposure, and In the scattered radiations

History : 1916

Marie and Irene Curie

Claudius Regaud



Le Pr Claudius Regaud dans son laboratoire de l'Institut du radium, vers 1930.

Photos journal de l'institut curie

Design of a realistic calibration field for diagnostic radiology (medical staff dosimetry)

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History : 1916

Marie and Irene Curie

20 « petite curie »

For surgery as close as Possible of the battle field

Claudius Regaud

In Bouleuse (Marne) close to Reims

Groupement de services chirurgicaux et scientifiques

Photos journal de l'institut curie

Salle d'opération du centre de Bouleuse dans la Marne. Guidé par le radiologiste équipé d'une « bonnette » de radioscopie frontale, le chirurgien effectue un repérage du corps étranger à extraire. On distingue la source de rayons X, placée sous la table d'opération.

Examples of radiological surgery

Heart surgery

The surgeon at the level of the hip of the patient

70 kV, 640 mA, 100 ms, 4.5 mm Al + 0.2 mm Cu

Side view

Surgeon

Patient

17x17 cm²

32.5 cm

15 cm

47.5 cm

X rays generator

Lead shield

Square collimator

Top view

Surgeon

45 cm

32.5 cm

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A real geometry is usualy not necessary,

Elements could be withdrawn

- **Table is considered as being transparent to X rays**
- **Image intensifier does not scatter significantly X Rays**

This leads to a simplified geometry for calibration purposes

BUT this geometry must be validated (experiments and computations)

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Principle of the simplified geometry for calibration

Side view

Surgeon phantom
ISO Slab phantom
30 x 30 X 15 cm³

Top view

Patient phantom
Water or TE lung or …

Dosemeter

17x17 cm²

15 cm

47.5 cm

45 cm

X rays generator

Lead shield

Square collimator

32.5 cm

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Principle of the simplified geometry for computing a reference value in terms of $H_p(10)$

Side view

Top view

10 mm depth

Surgeon phantom
ICRU 4 elements slab

F6, (*F8) tallies

X rays generator

Lead shield

Square collimator

32.5 cm

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Principle of the simplified geometry for computing a reference value in terms of $H_p(10)$ through Fluence and K_a

Side view

Top view

Calibration point (free in air)

Patient phantom Water or TE lung or …

47.5 cm

45 cm

32.5 cm

X rays generator

Lead shield

32.5 cm

Square collimator

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Principle of the simplified geometry for computing a reference value in terms of $H_p(10)$ through Fluence and K_a

Side view

Top view

Calibration point (free in air)

Patient phantom

F2, F4, F5 or F6 tallies

X rays generator

Lead shield

32.5 cm

Square collimator

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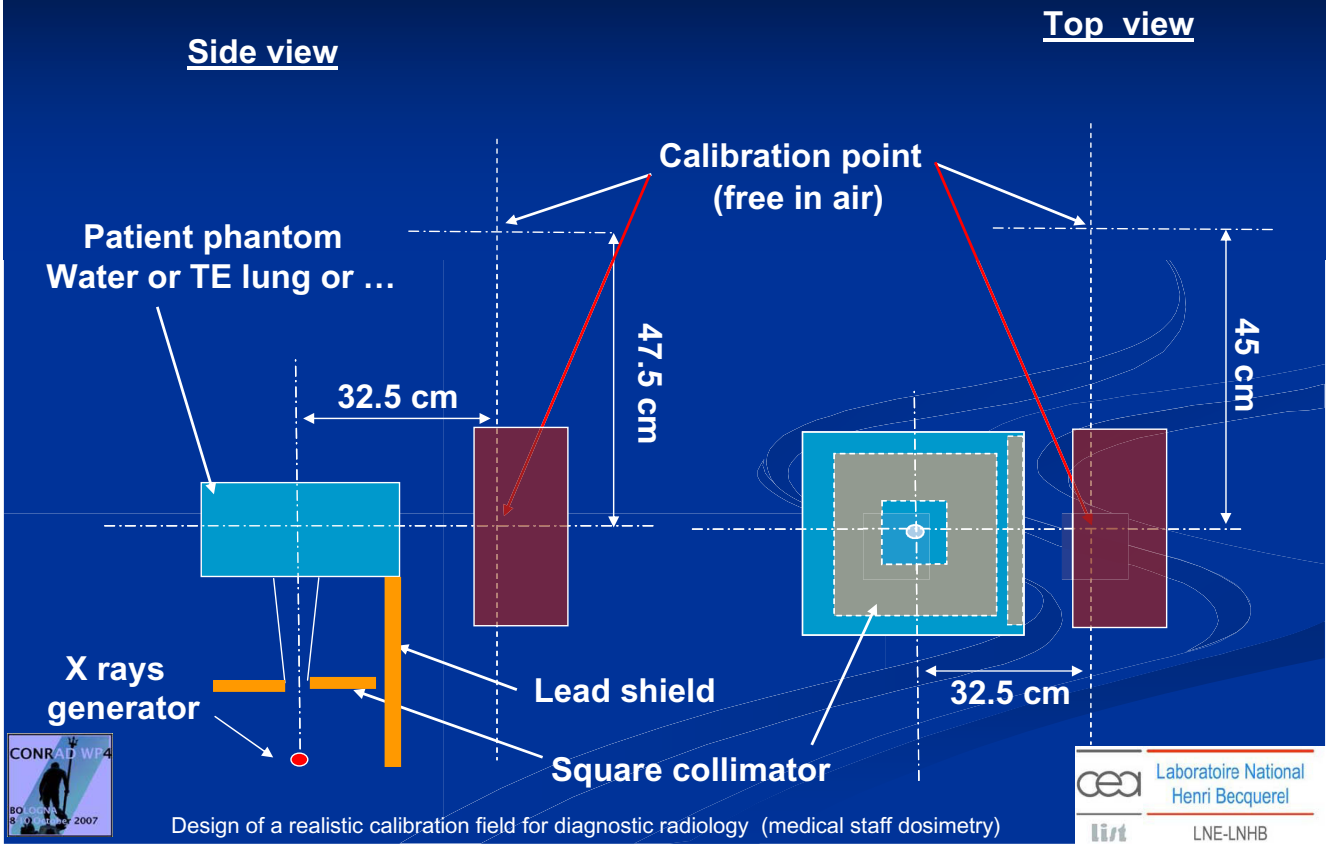
Differences a **REAL** and a **REALISTIC** configurations

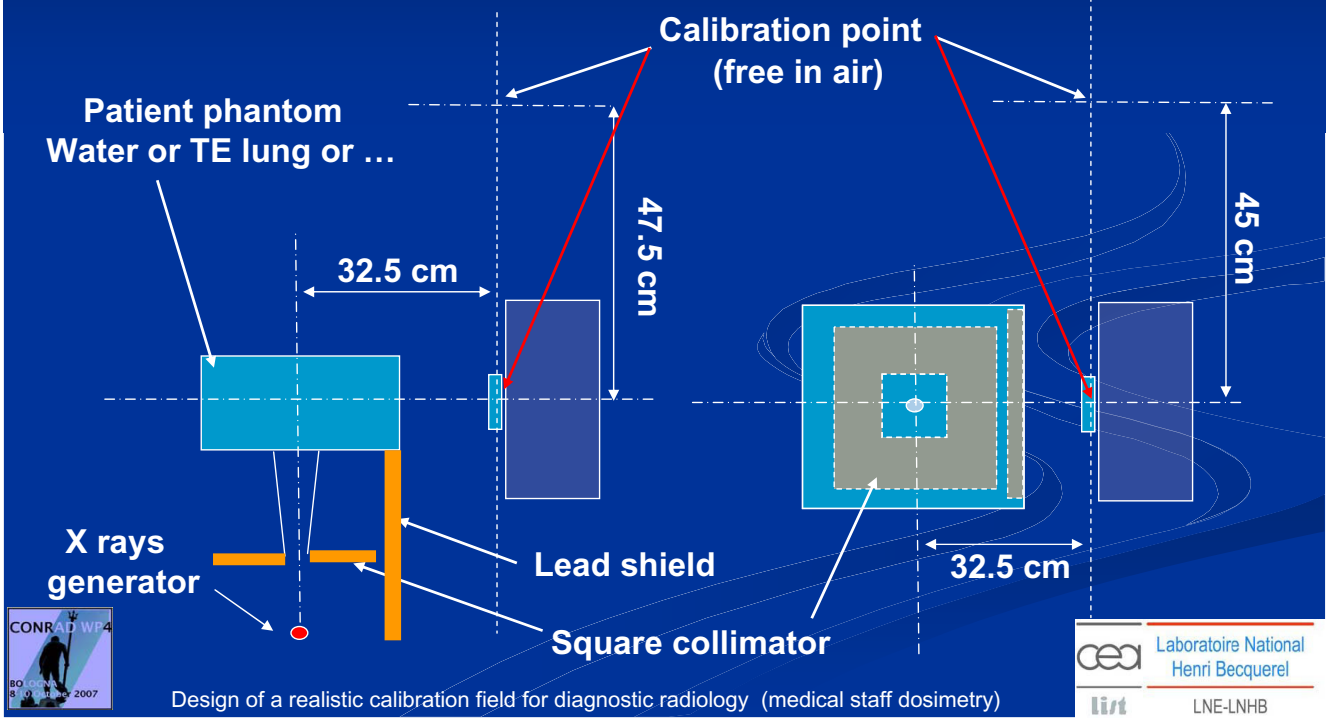
Goals for a realistic configuration :

- To increase the dose equivalent rate at the calibration point
- To use a beam as parallel as possible (to comply $H_p(10,\alpha)$)

Principle of the MORE simplified geometry



Principle of the MORE simplified geometry



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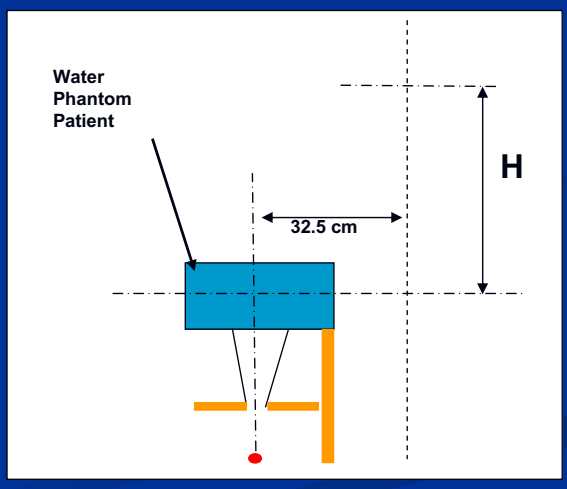
Water phantom for the patient

ISO slab 30 x 30 x 15 cm^3



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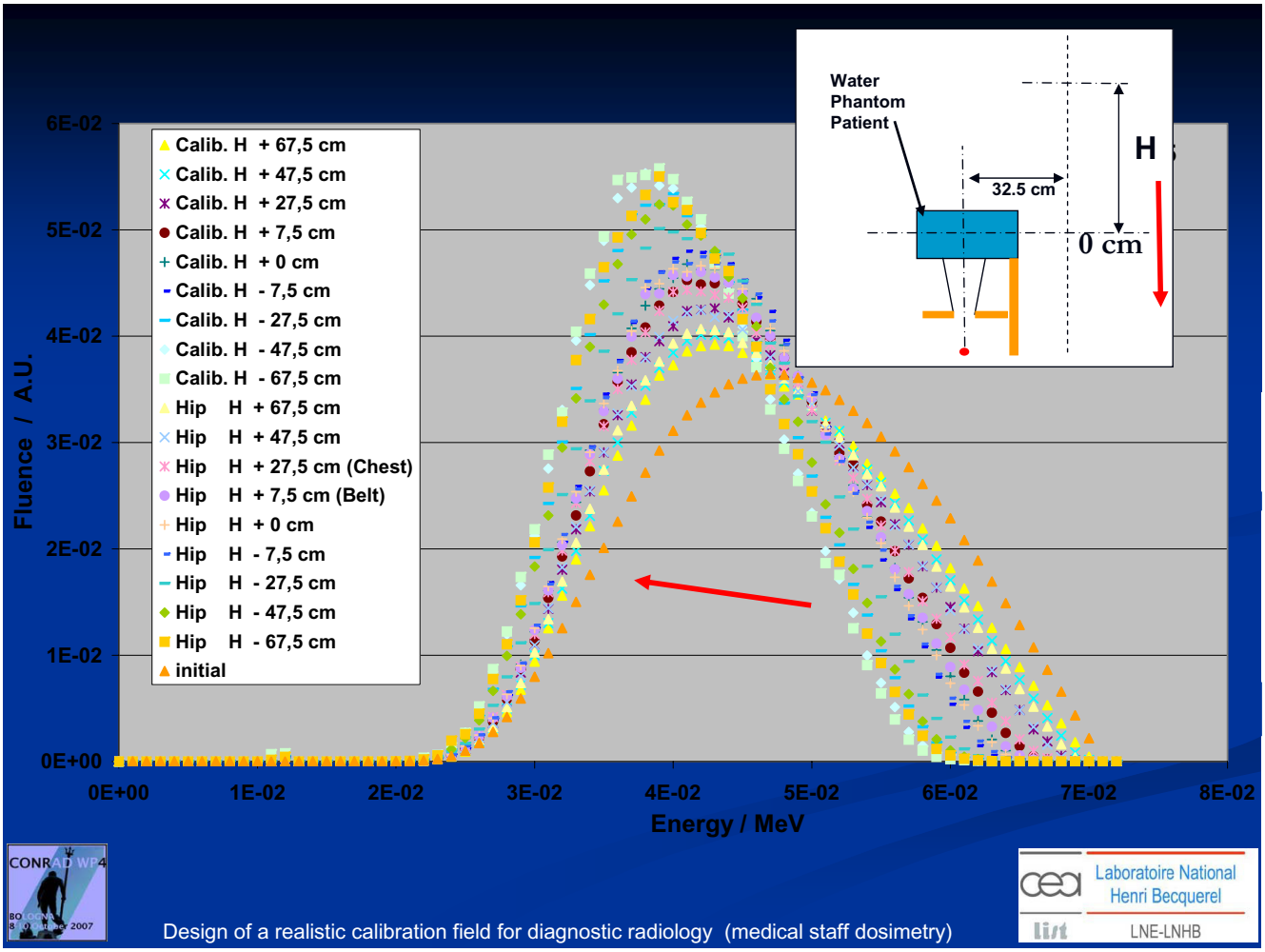

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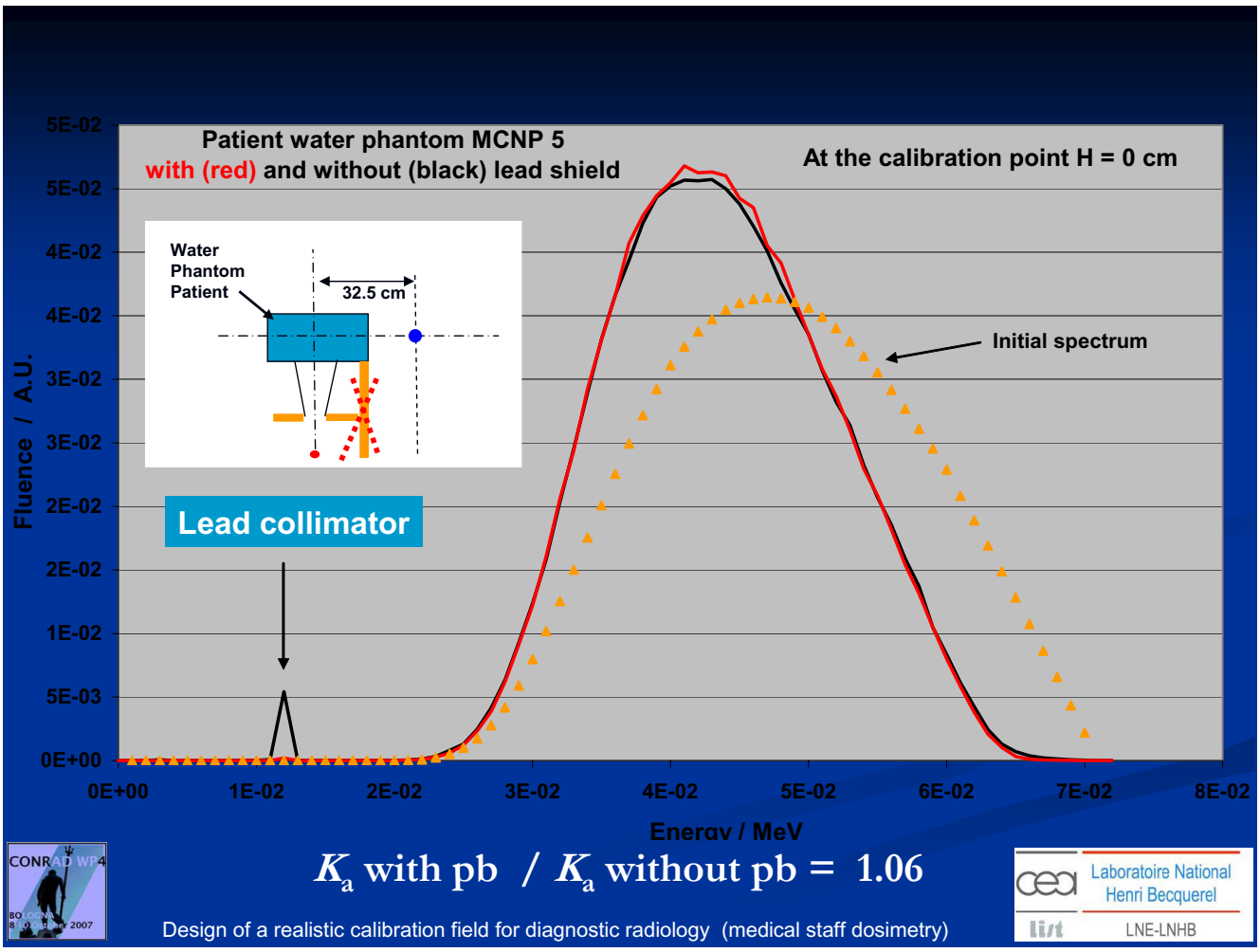

K_a with pb / K_a without pb = 1.06

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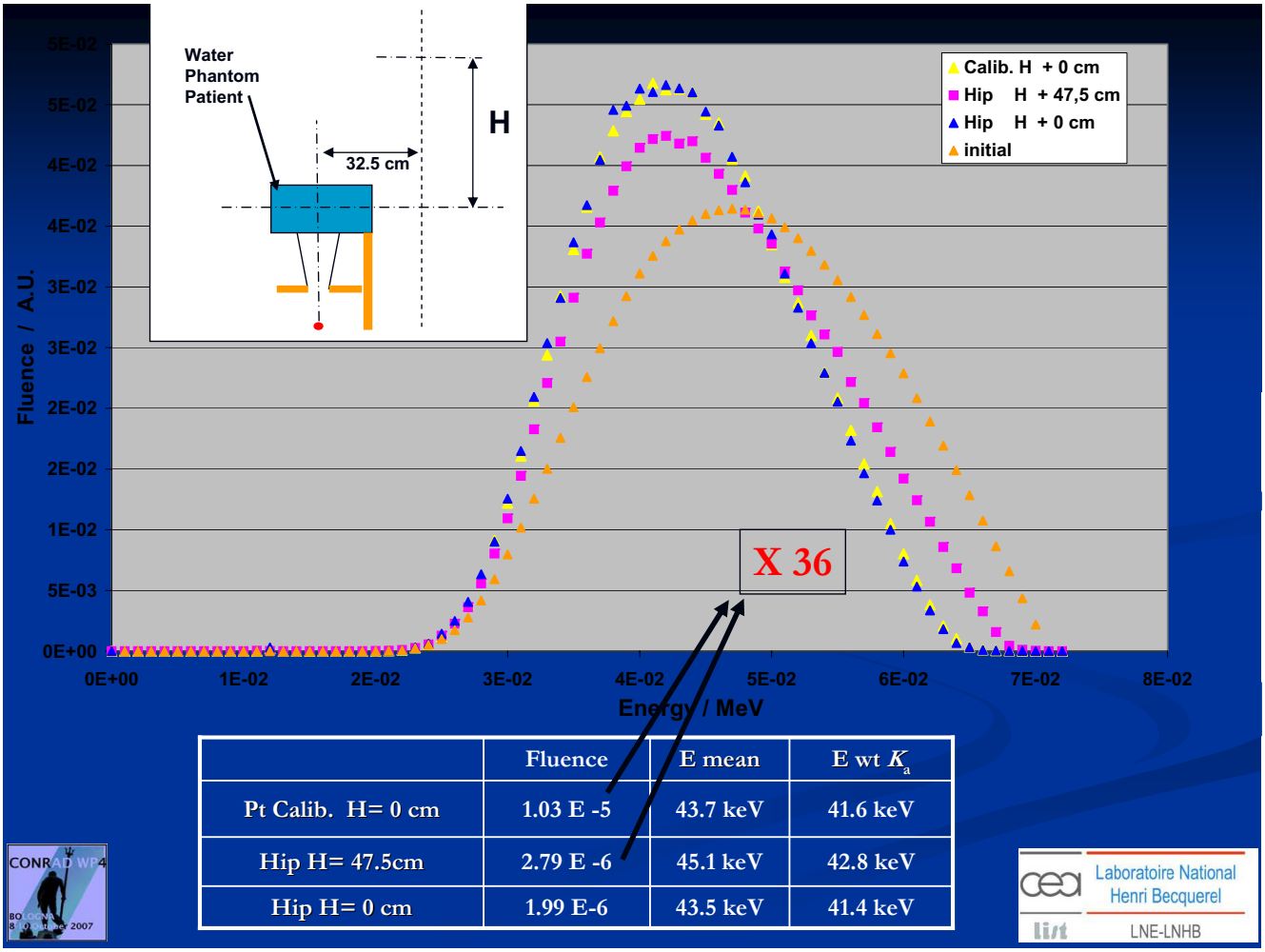

	Fluence	E mean	E wt K_a
Pt Calib. H= 0 cm	1.03 E -5	43.7 keV	41.6 keV
Hip H= 47.5cm	2.79 E -6	45.1 keV	42.8 keV
Hip H= 0 cm	1.99 E-6	43.5 keV	41.4 keV

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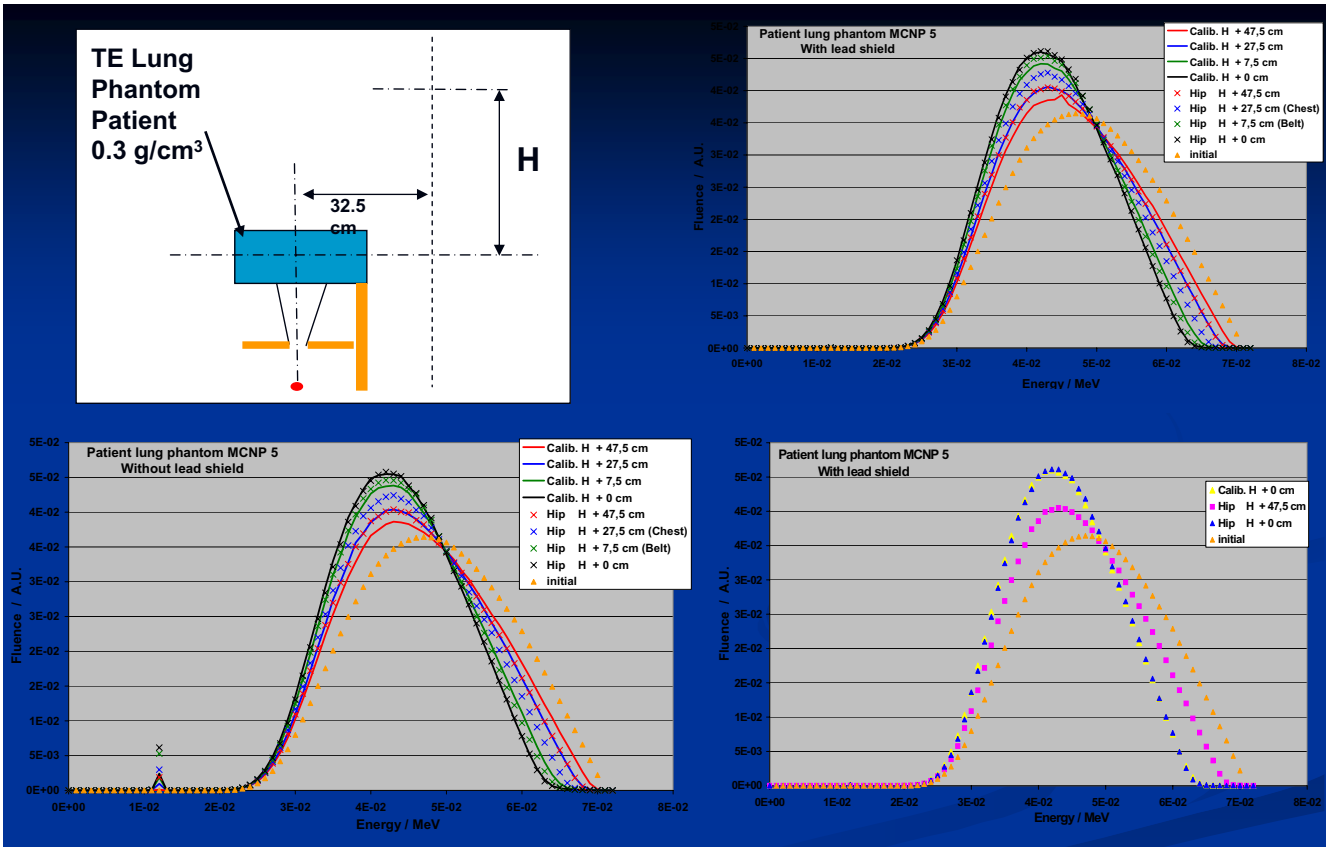

From hip to calib. Point X 33

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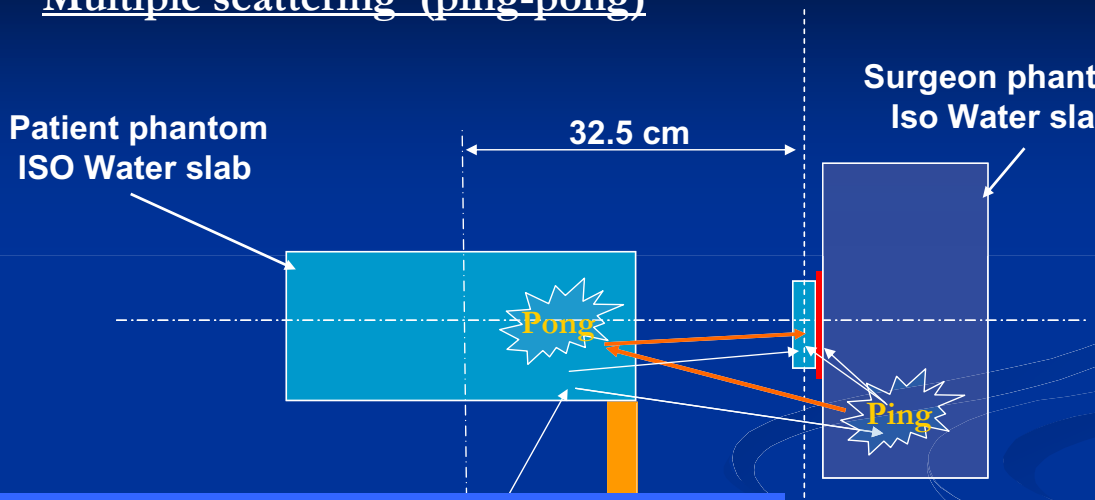
Multiple scattering (ping-pong)



Without « surgeon » : 11.12 E-6 photons /history

With « surgeon » : 15.55 E-6 photons / history

With « surgeon » and IMP 0 : 11.13 E-6 photons /history

Albedo + ping-pong = 1.40

Ping-pong = 1.0003

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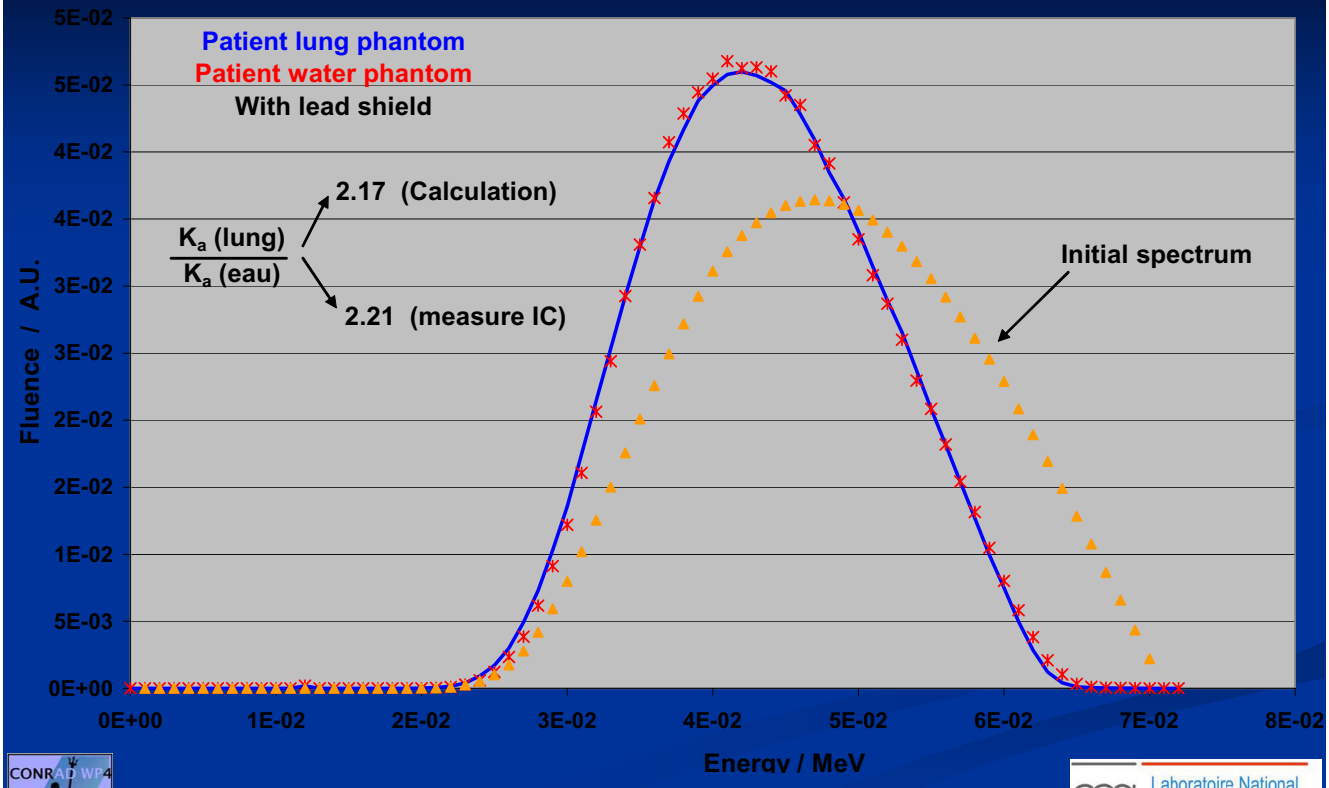
Comparison water and TE lung patient phantom at the point of calibration



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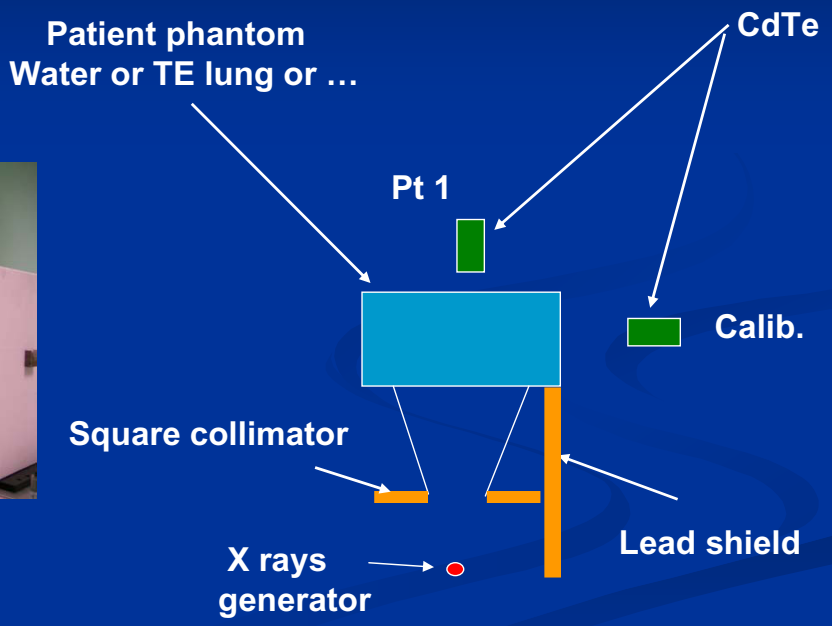
Experimental validation of the calculation results. Measurement of the fluence distribution.

(Detection efficiency of CdTe in the range between 10 to 60 keV is 100%)



Side view

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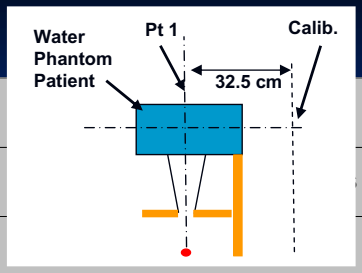

Water patient phantom, CdTe measurements

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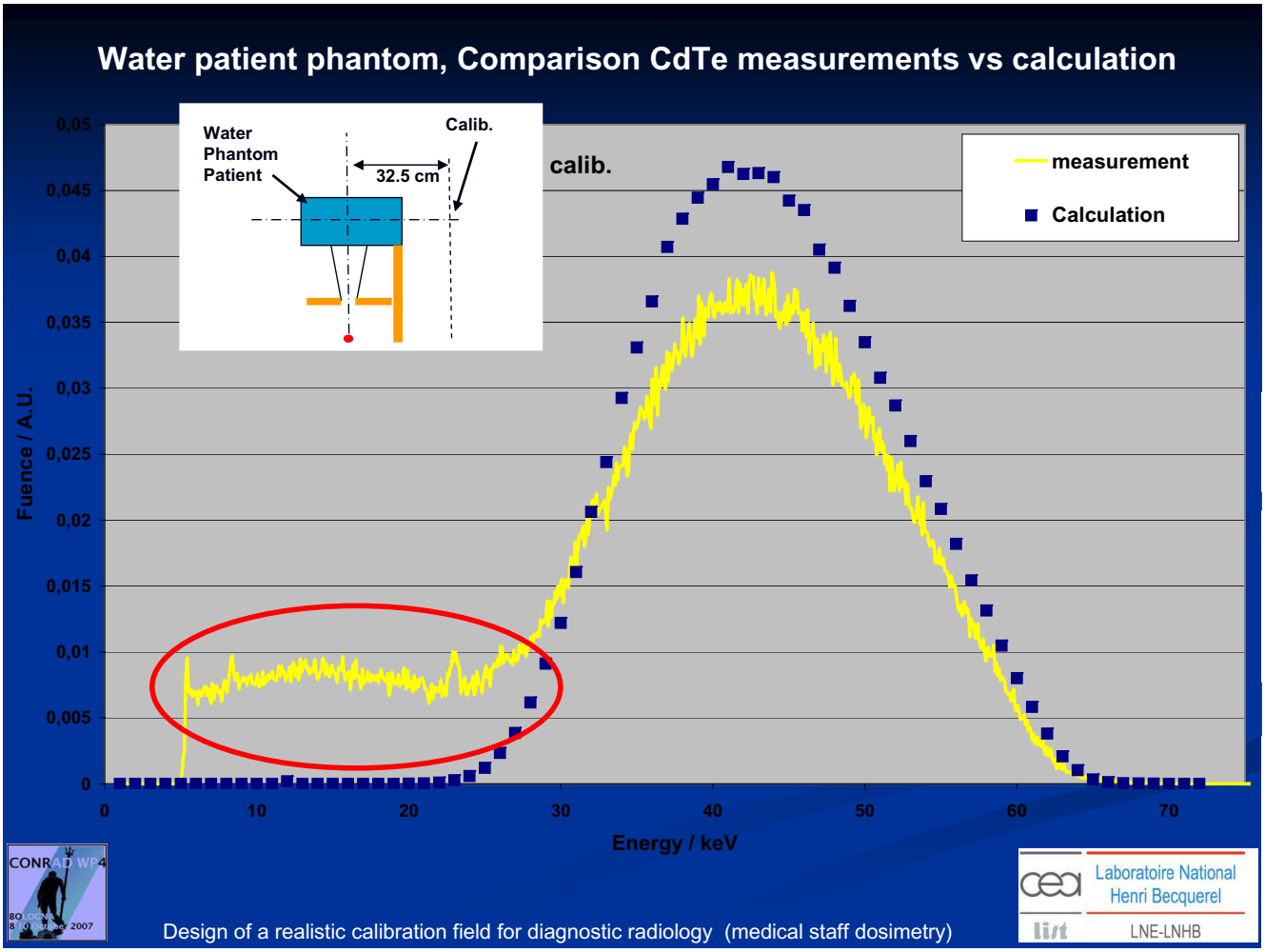
Water patient phantom, Comparison CdTe measurements vs calculation



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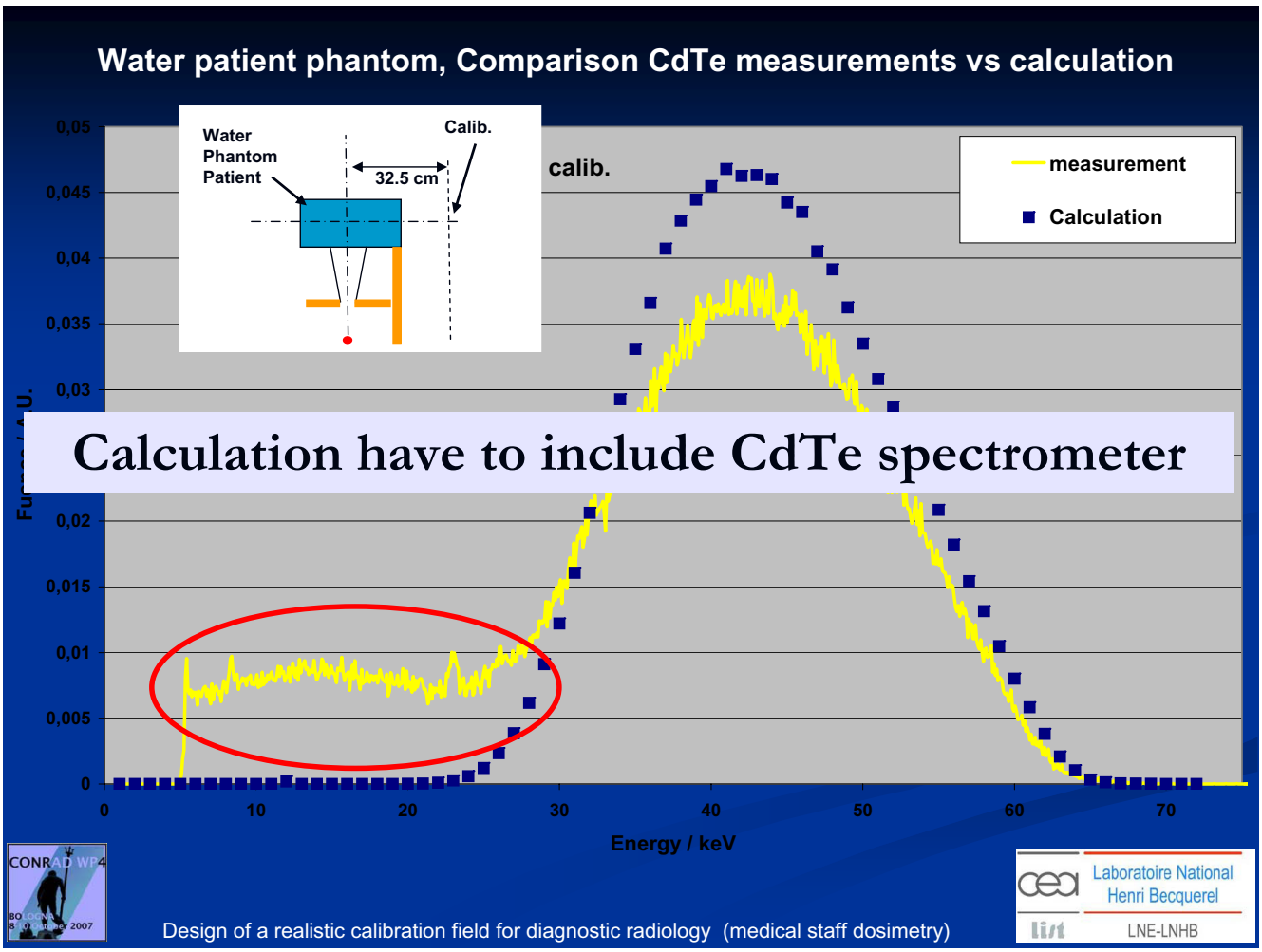
Water patient phantom, Comparison CdTe measurements vs calculation



Calculation have to include CdTe spectrometer

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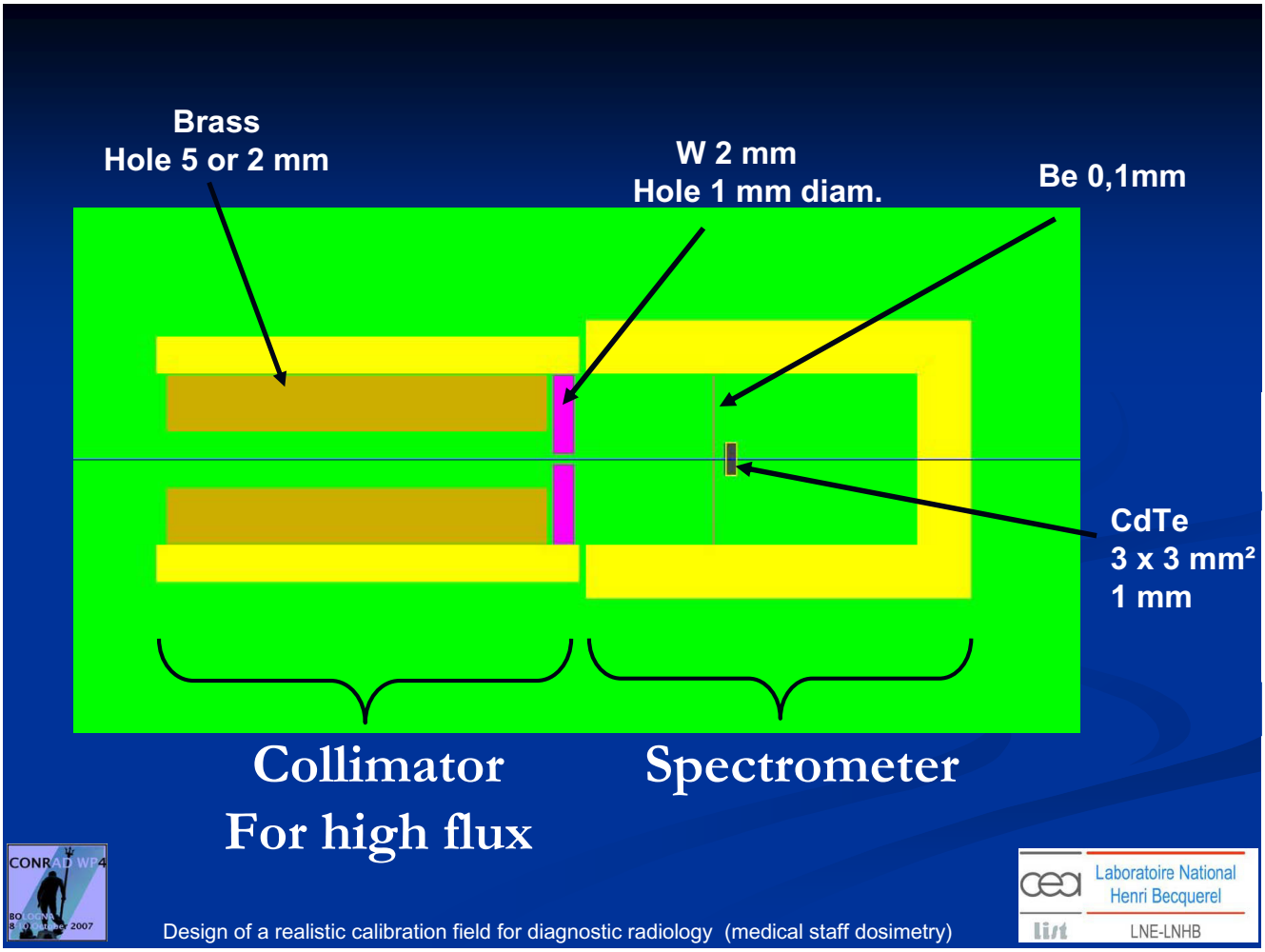
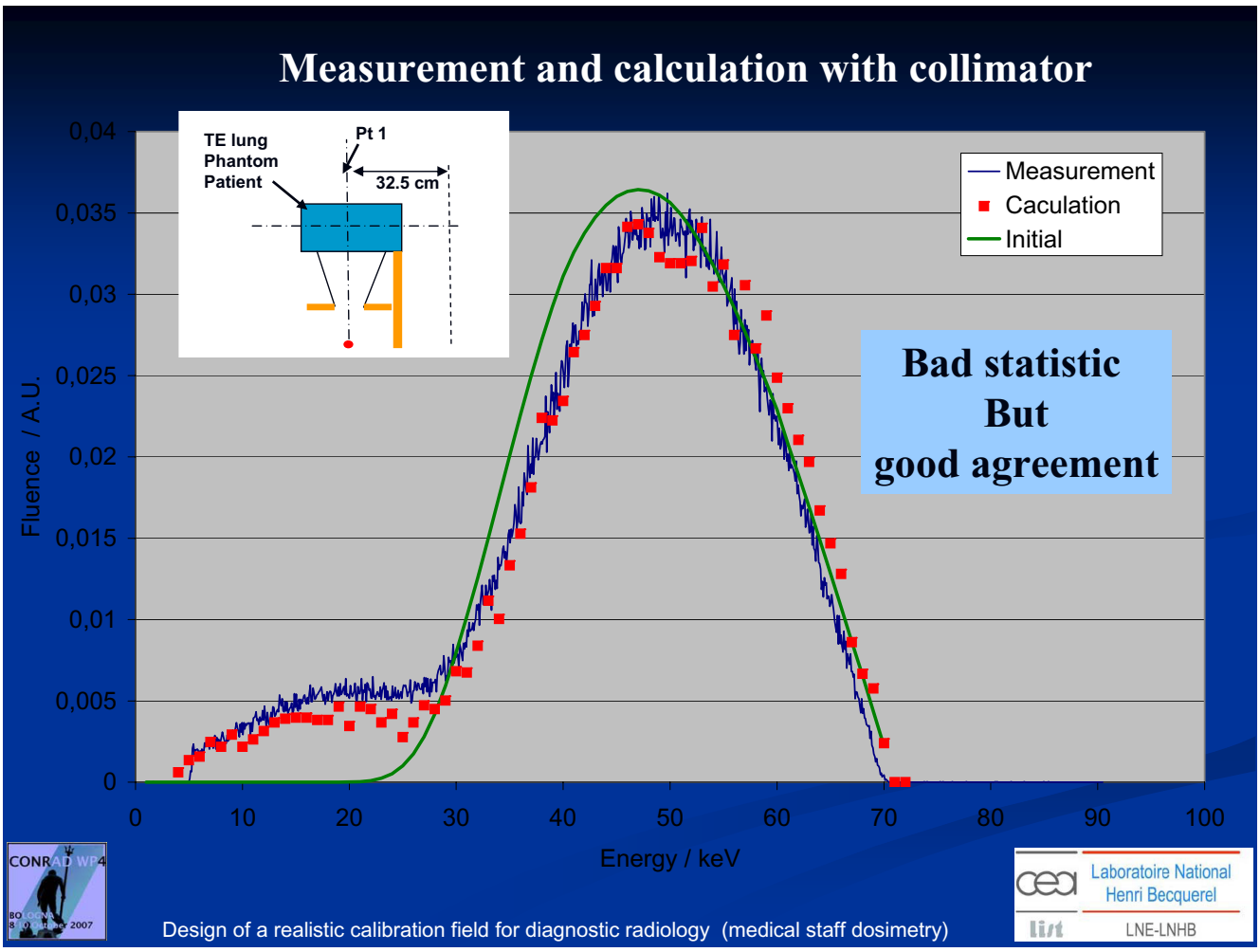
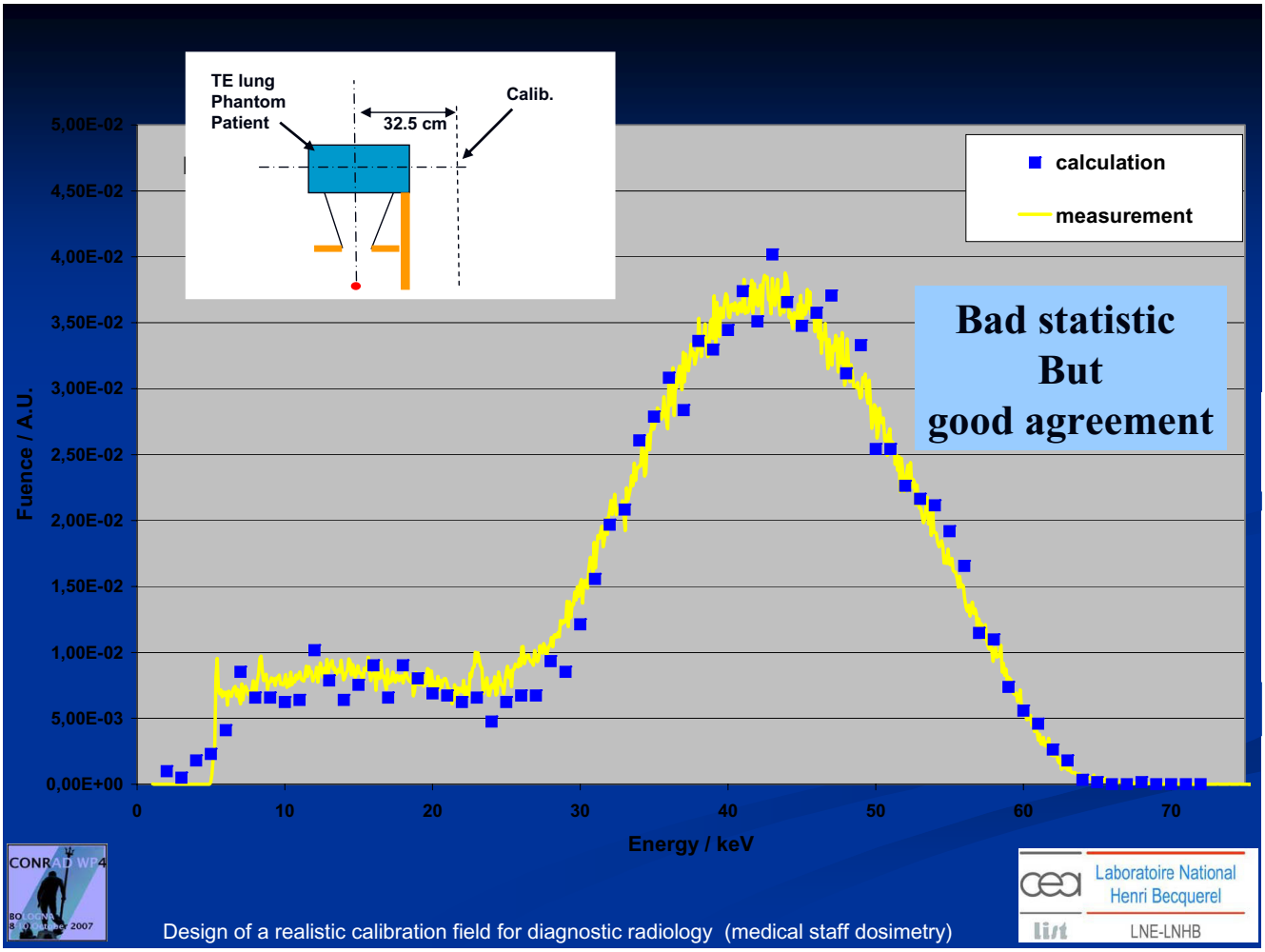


Measurement and calculation with collimator





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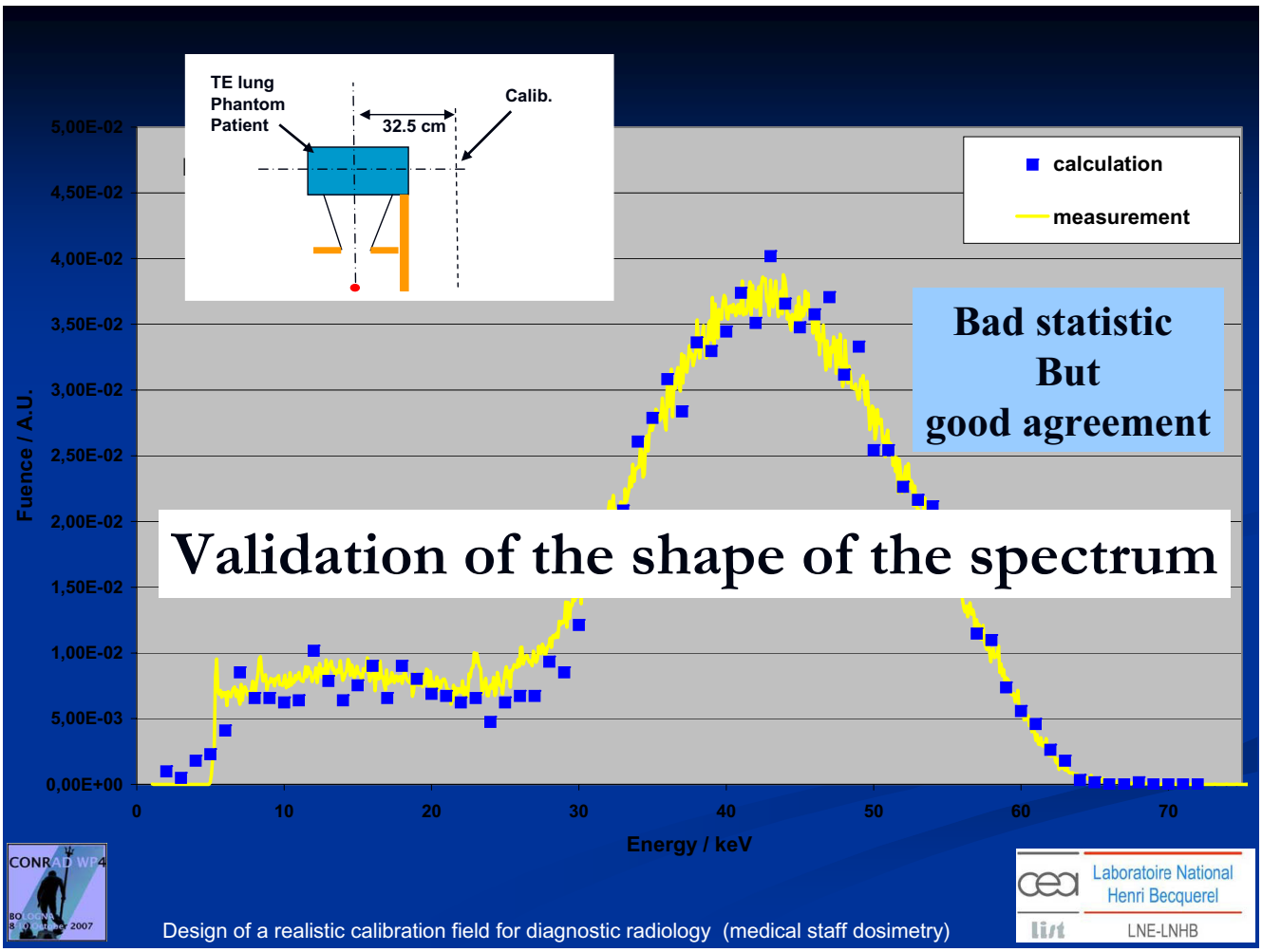

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Measurements of K_a ; Ion chamber (30 cc cyl. PTW TM 23361)

1st step
Calibration against primary standard

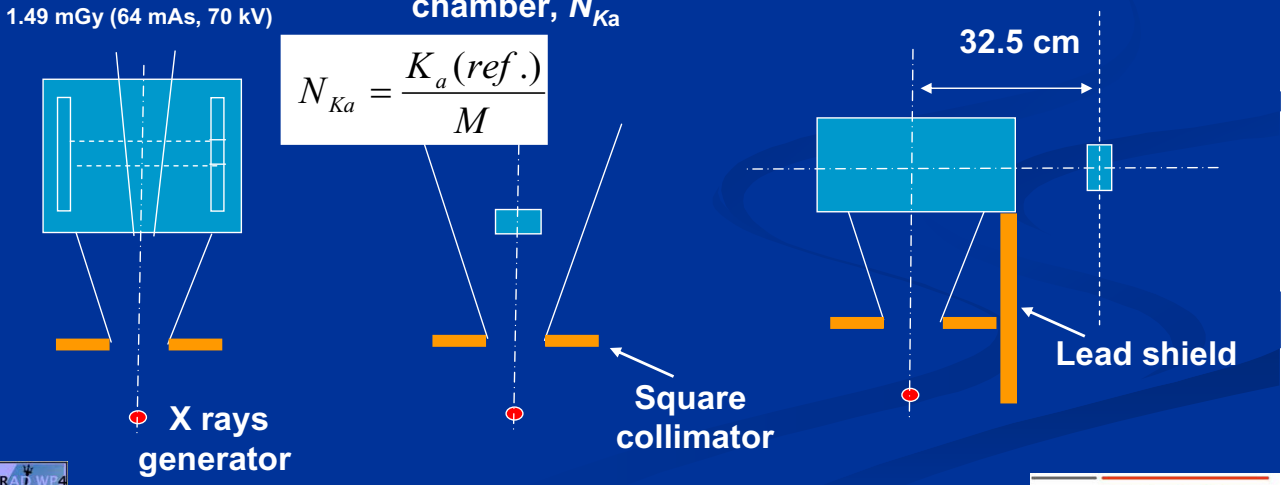
Free air ion chamber Measure of K_a
1.49 mGy (64 mAs, 70 kV)

Calibration of the cavity ion chamber, N_{Ka}

$$N_{Ka} = \frac{K_a(ref.)}{M}$$

2sd step
Measurement at the calibration Pt

$$K_a(scat.) = M\, N_{Ka}$$



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Results at the calibration point with the water patient phantom and the lead shield

X 10-6 (pGy /history or pSy /history) Standard deviation (k=1)		F5	F6	*F8
K_a	MCNP4C – lib 02	4.64 (0.2%)	4.40 (0.3%)	4.42 (1.2%)
	MCNP5 – lib 04	4.29 (0.2%)	4.38 (0.2%)	4.35 (0.7%)
$H_p(10)$	MCNP4C – lib 02	6.97 (0.2%)	6.31 (0.6%)	6.33 (3.0%)
	MCNP5 – lib 04	6.44 (0.2%)	6.23 (0.4%)	6.16 (1.9%)
$H_p(10)/K_a$		1.50	1.44	1.43

Penelope 2006 (~F6)	IC
4.87 (2.6%)	3.21 µGy (64 mAs, 100ms, 70 kV) 1.5 %
6.77 (0.54%)	
1.39	

ISO 4037 (0°) : N60 (1.65) ; L70 (1.87)

$$H_{p,slab}(10,0) = \int_E \phi(E)\left[\frac{H_{p,slab}(10)}{\phi}\right](E)\,dE \qquad K_a = \int_E \phi(E)\left[\frac{K_a}{\phi}\right](E)\,dE$$

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Results at the calibration point
with the TE lung patient phantom and the lead shield

X 10-6 (pGy /history or pSy /history) Standard deviation (k=1)		F5	F6	*F8
K_a	MCNP5 – lib 04	9.31 (0.1%)	9.51 (0.1%)	9.55 (0.5%)
$H_p(10)$	MCNP5 – lib 04	13.9 (0.1%)	13.7 (0.3%)	13.5 (1.3%)
$H_p(10)/K_a$		1.49	1.44	1.41

IC
7.08 µGy (64 mAs, 100ms, 70 kV) 1.5 %

ISO 4037 (0°) : N60 (1.65) ; L70 (1.87)

$$H_{p,slab}(10,0) = \int_E \phi(E)\left[\frac{H_{p,slab}(10)}{\phi}\right](E)\,dE \qquad K_a = \int_E \phi(E)\left[\frac{K_a}{\phi}\right](E)\,dE$$

Conclusions

- A realistic calibration facility for scattered radiation in medical surgery has been defined
- The scattering material can be any TE material
- The modeling studies allow to compute the conversion coef from K_a to $H_p(10)$ (≠ ISO 4037)
- The reference values of K_a are measured
- This facility was used for a comparison of APD

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