Using RayXpert© Monte Carlo code to optimize radiological protections in a nuclear medicine service

B. Simony, C. Dossat, A. Ghilardi (TRAD)
J. F. Rauch, L. Whitfield (Hôpital Albi)

PLAN

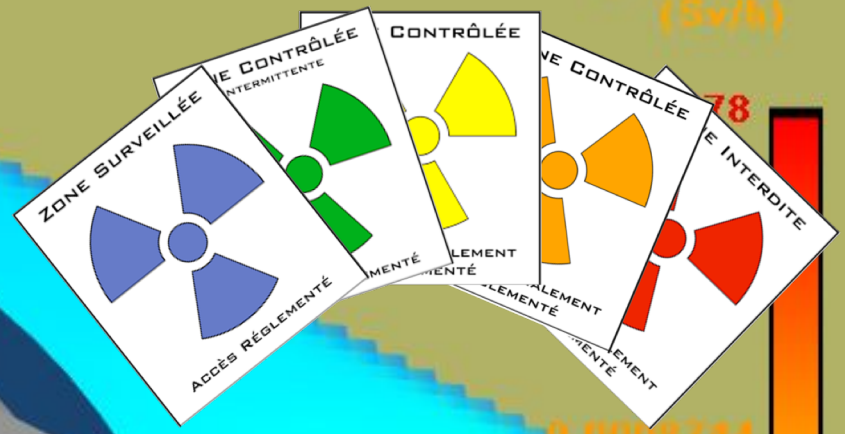
1 Problematics : Albi Hospital

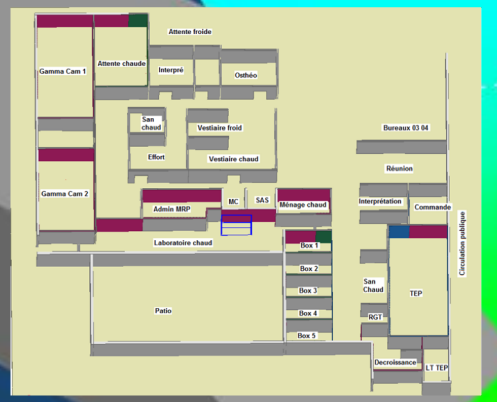
2 Modelling of the hospital with RayXpert© code

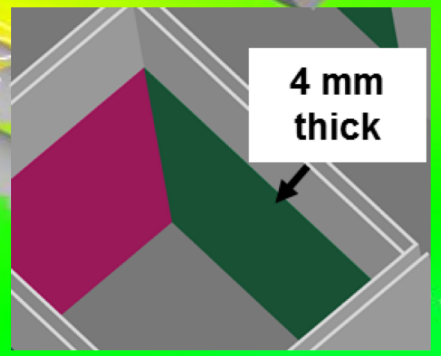
3 Optimizing radiological protections

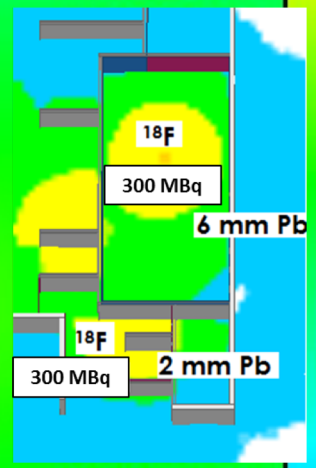
4 Conclusion of the study

5 About TRAD Tests & radiations





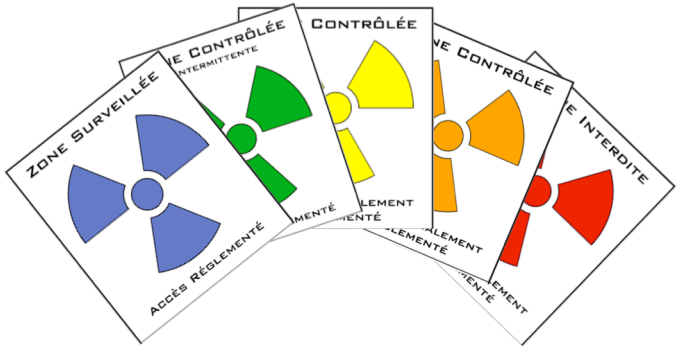




Problematics

Context

- Rebuilt of Albi Hospital nuclear medicine service
- New X-rays-emitting equipements (γ-camera, PET)
- Presence of radio-isotopes (^{99}Tc-M, ^{18}F, ^{111}In…)

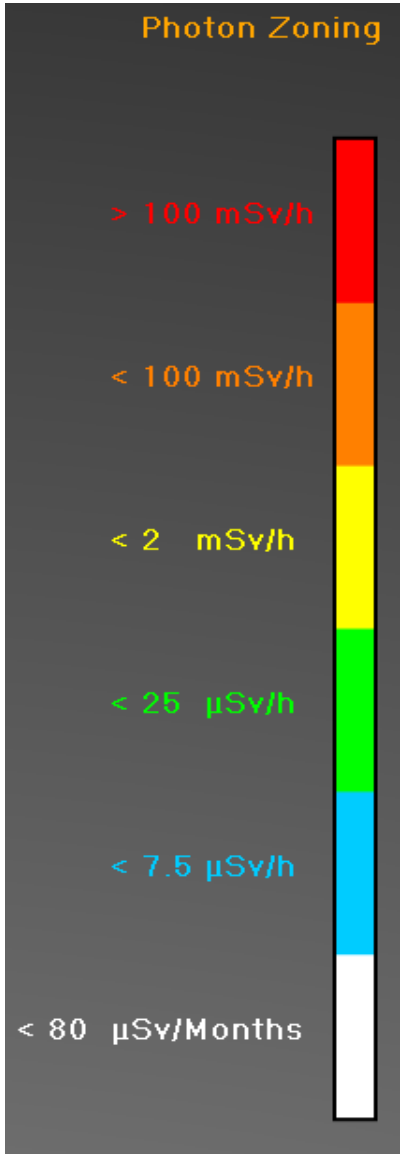


Goals

- Optimize radiological protections
- Respect of the fixed dosimetric goals → french zoning decree

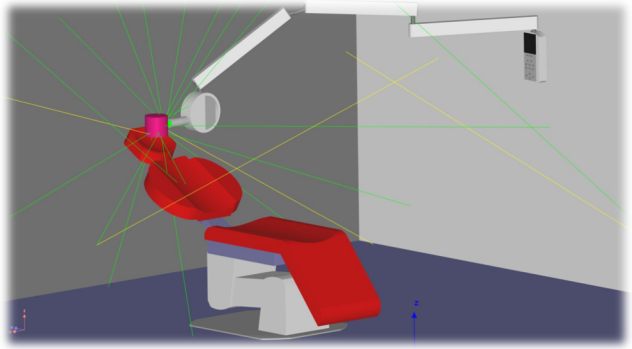
Resources

- Close collaboration with the radiophysics and radioprotection of the hospital and the project architect
- Decisive point : get full informations (type and number of sources)
- Use of the RayXpert radioprotection software developed by TRAD



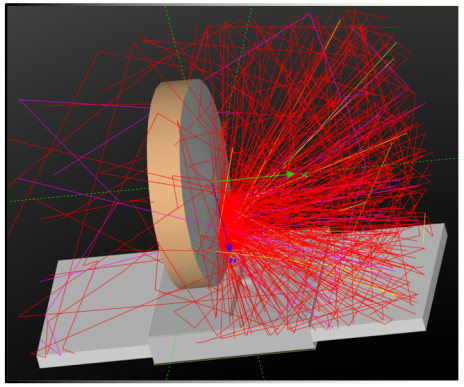
TRAD Tests & radiations

Our tool
RayXpert© software



Complex 3D modelling

- STEP files importation
- Numerous options of modelisation

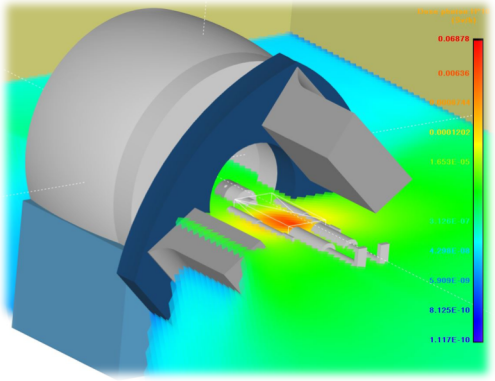


Monte Carlo transportation of particles

- Tracking of particles (electrons, photons, neutrons, …)
- Radionuclides decays or user-defined sources (beam, surface, volume, etc.)

3D Dose mapping

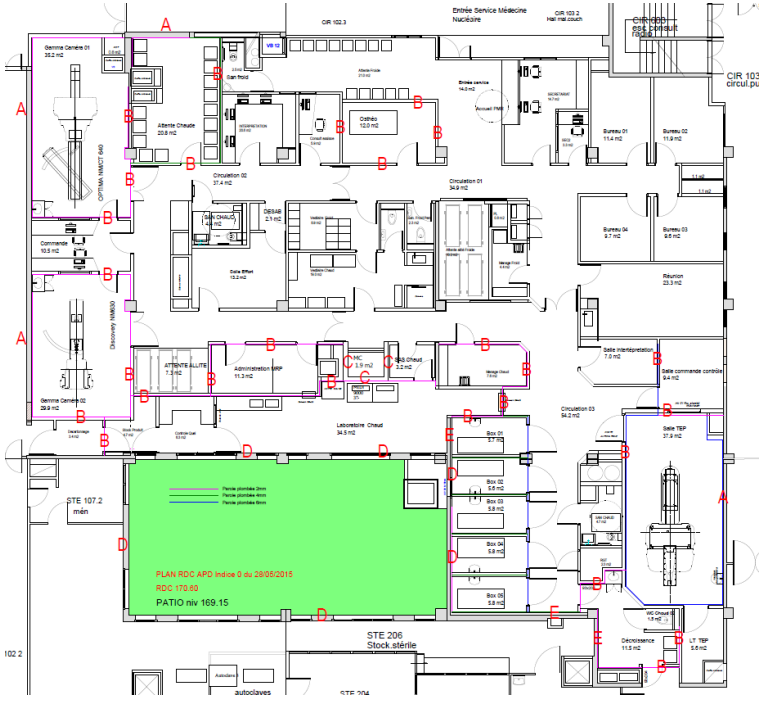
- Mapping definition (dimension and resolution)
- Regulatory zoning



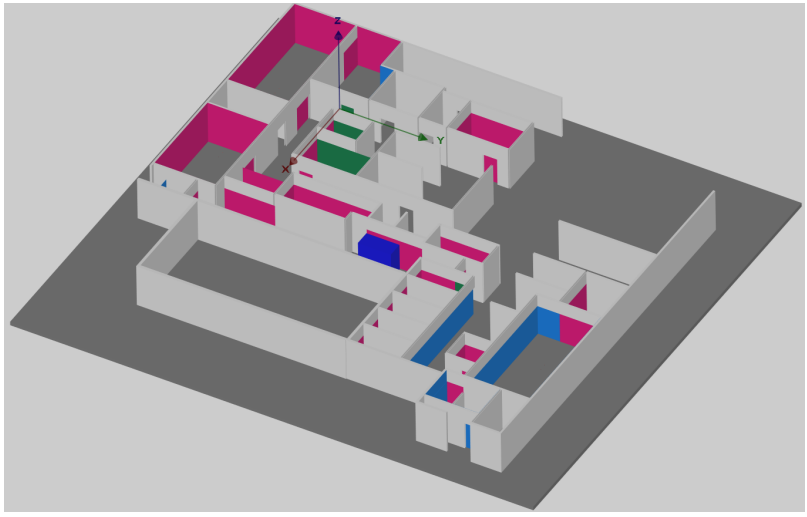
TRAD
Tests & radiations

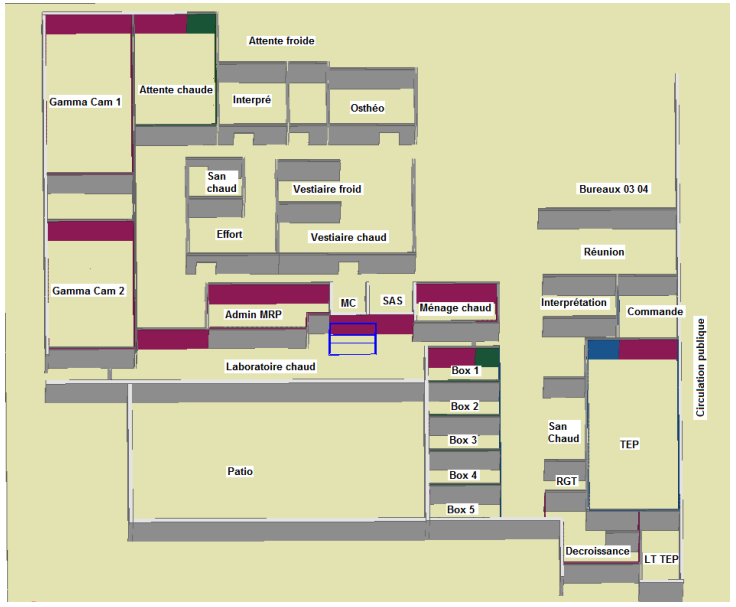
3D model

From a 2D-plan …



… to a 3D model with RayXpert©





… and materials …

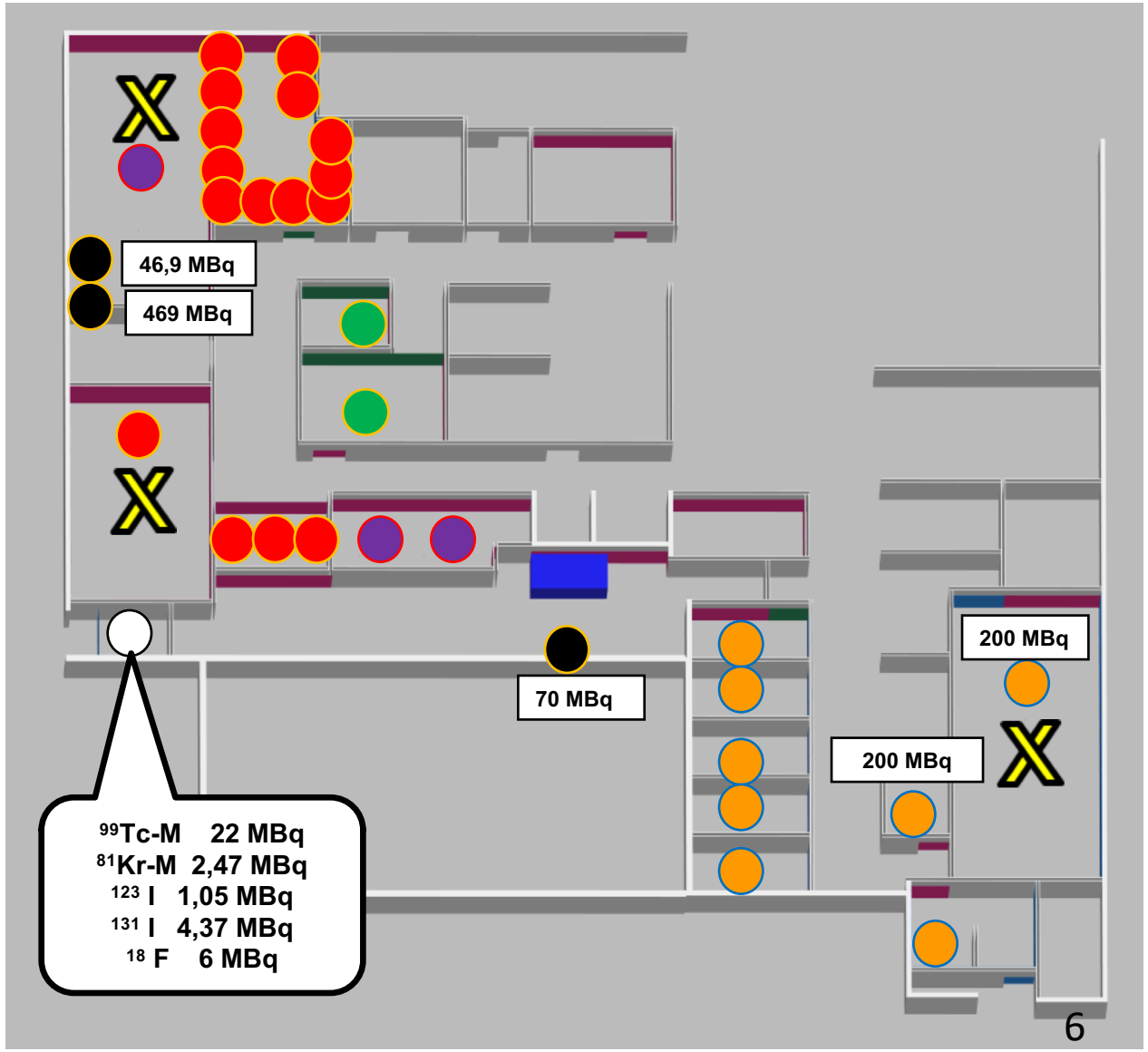
E-TYPE Density 0.9 g/cm^3	15 cm Existing hollow building block 10 mm Cement coating on 2 faces One 13 mm plasterboard on inside face
Flooring to underground	25 cm solid concrete
Ceiling tile to 1st floor	25 cm solid concrete, 311 cm height under flooring Horizontal 15 mm false ceiling with glass wool

TRAD Tests & radiations

Source term (1/4)

40 localizations

- ^{99}Tc-M, 925 MBq
- ^{131}I, 740 MBq
- ^{57}Co
- ^{18}F, 300 MBq
- ^{111}In 148 MBq
- Other sources
- X Ionizing-particle-emitting machines

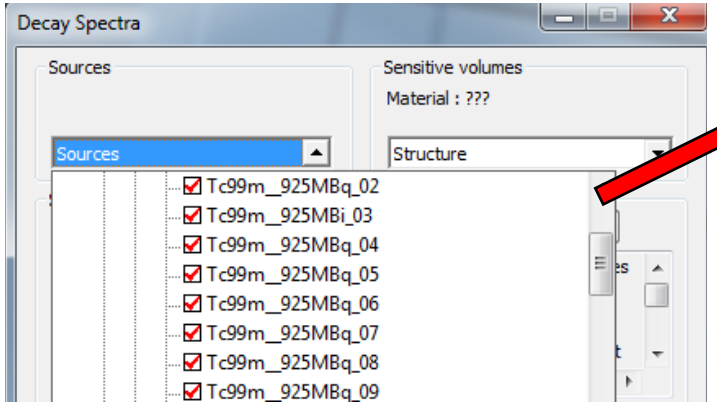


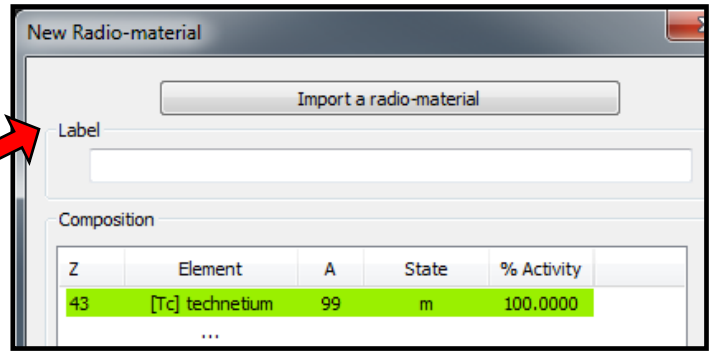
TRAD Tests & radiations

Source term (2/4)

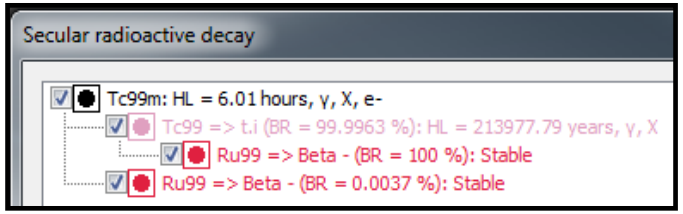
Decay spectrum

- Is already integrated in RayXpert©
- EAF 2010 and JEFF 3.1.1 databases





➡ **Secular equilibrium**



➡ **Gamma rays**

Ray description and corresponding emission rate for Tc99m (1/1)

Energy (MeV)	Emission rate (%)
0.322400	9.694e-05 (Gamma)
0.232800	8.510e-06 (Gamma)
0.142630	1.870e-02 (Gamma)
0.140511	8.906e+01 (Gamma)
0.089600	1.036e-03 (Gamma)
0.002173	6.201e-09 (Gamma)

➡ **X rays**

Ray description and corresponding emission rate for Tc99m (1/1)

Energy (MeV)	Emission rate (%)
0.021700	1.621e-04 (X)
0.020600	1.204e+00 (X)
0.019279	5.288e-04 (X)
0.019150	2.776e-04 (X)
0.018367	4.015e+00 (X)
0.018251	2.100e+00 (X)
0.002560	7.481e-05 (X)
0.002420	4.828e-01 (X)

➡ **Electrons**

Ray description and corresponding emission rate for Tc99m (2/2)

Energy (MeV)	Emission rate (%)
0.089532	8.883e-06 (Electron)
0.089056	5.141e-05 (Electron)
0.086557	2.745e-04 (Electron)
0.068556	1.220e-03 (Electron)
0.016200	2.528e-04 (Electron)
0.015500	2.076e+00 (Electron)
0.002530	1.421e-03 (Electron)
0.002170	1.025e+01 (Electron)
0.001629	9.921e+01 (Electron)

➡ **β-**

Ray description and corresponding emission rate for Tc99m (1/1)

End-Point (MeV)	Emission rate (%)
0.436182	1.000e-03 (Beta moins)
0.346582	2.600e-03 (Beta moins)
0.113783	1.080e-04 (Beta moins)

TRAD Tests & radiations

Source term (3/4)

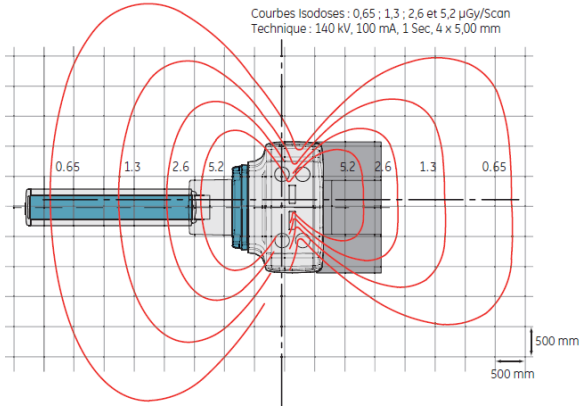
3 distinct machines are emitting X-rays :

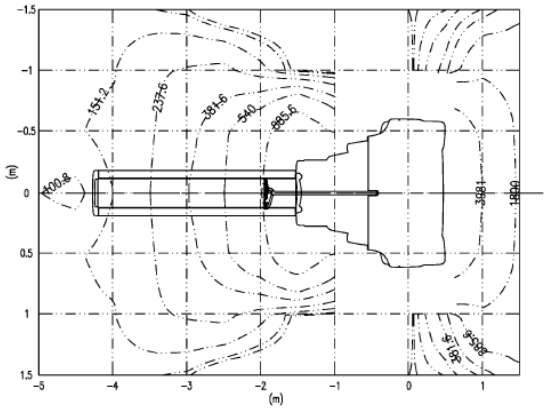
DISCOVERY NM/CT 670

OPTIMA NM/CT 640

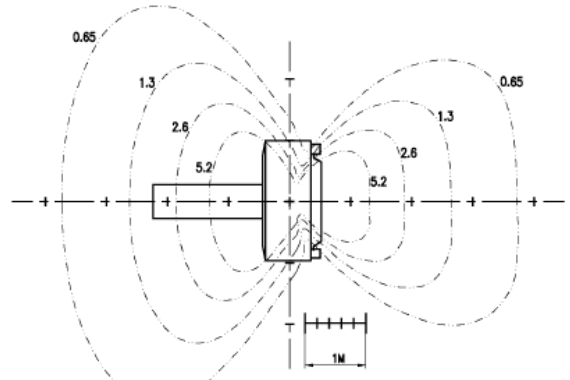
DISCOVERY IQ PET/CT

Isodose curves are indicated :





COURBES ISODOSES A L'ISOCENTRE EN MICROGRAY PAR HEURE
TECHNIQUE : 120KV, 20MA



NIVEAU DE COURBES ISODOSE VUE DE DESSUS : 0.65, 1.3, 2.6, ET 5.2 microGray/ACQUISITION
TECHNIQUE D'ACQUISITION : 140KV, 100mA, 1 sec, 4 X 5,00mm

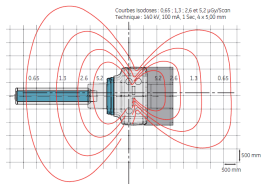
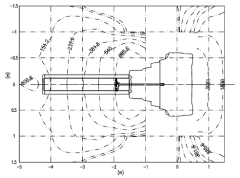
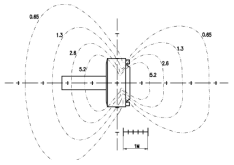
TRAD Tests & radiations

Source term (4/4)

Integration in RayXpert :

- Isotropic point sources
- Particules : photons
- Energy = W_{max}

- Emission rate ($\gamma.s^{-1}$) based on:
  - ➢ # of scans / day
  - ➢ Acquisition time / scan
  - ➢ Dose rate at 1 m

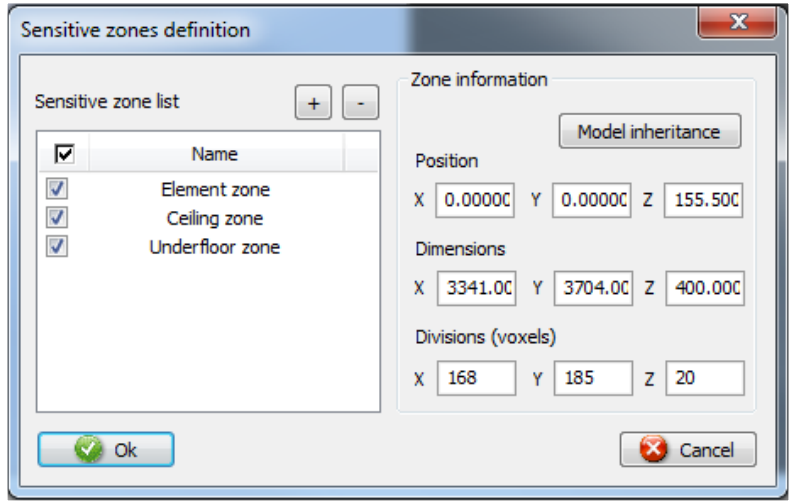
	Room	Machine Type	Max # of scans / h	Mean acquisition time / scan	W_{max} (kV)	Emission rate ($\gamma.s^{-1}$)
	**Gamma Camera 1**	**OPTIMA NM/CT 640**	**2**	**30 s**	**140**	**$6.84^{E}8$**
	**Gamma Camera 2**	**DISCOVERY NM/CT 670**	**2**	**20.5 s**	**120**	**$4.63^{E}9$**
	**PET**	**Discovery IQ PET-CT**	**2**	**20.5 s**	**140**	**$6.84^{E}8$**

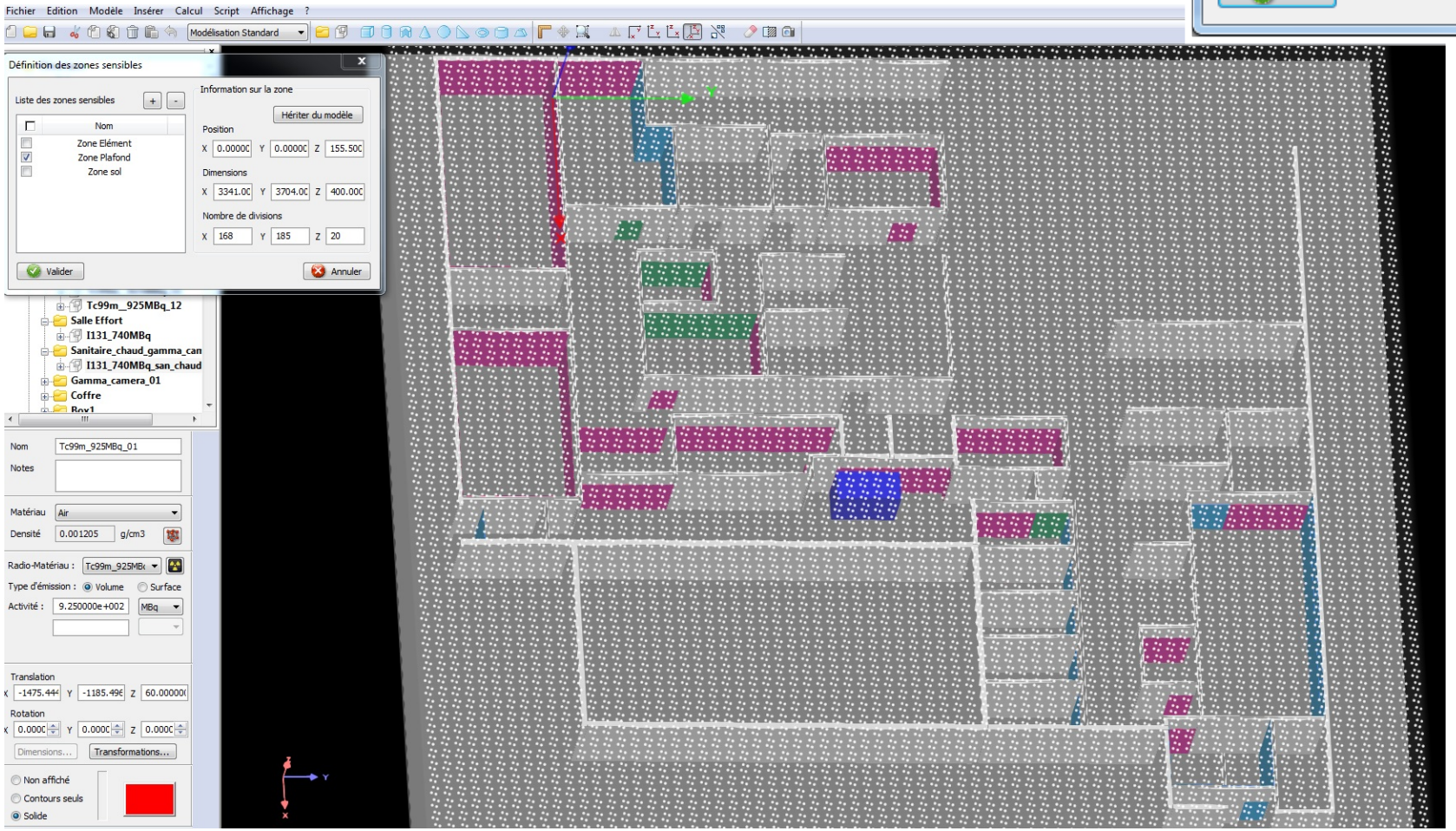
TRAD Tests & radiations

3D mapping

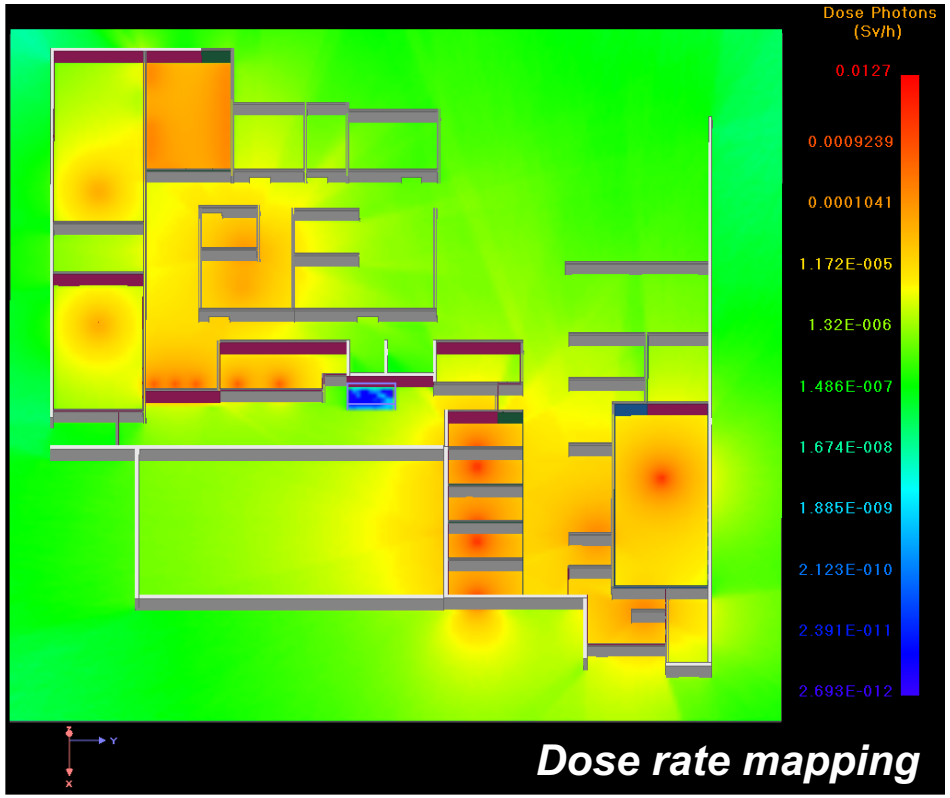
Sensitive zones definition for H*(10) dose rate computation :

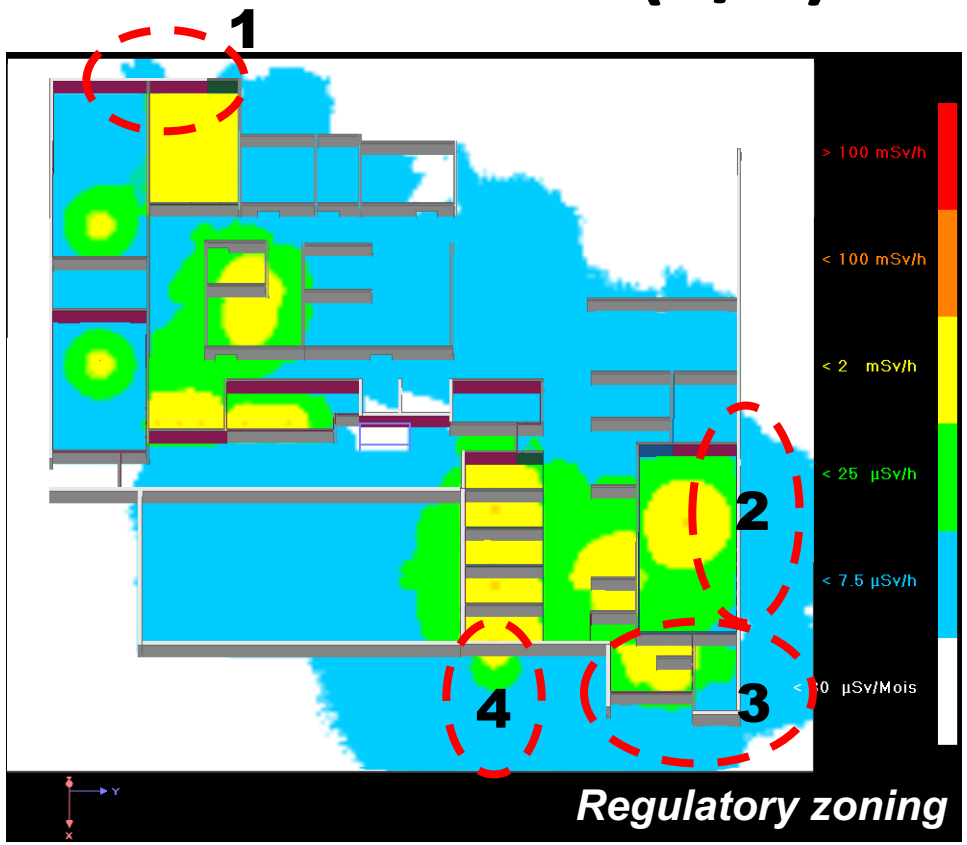
- Generating a 3D mesh with RayXpert© = virtual detectors
- About 650 000 dose rate detectors / resolution 20 x 20 x 20 cm^3





Results with initial model (1/2)





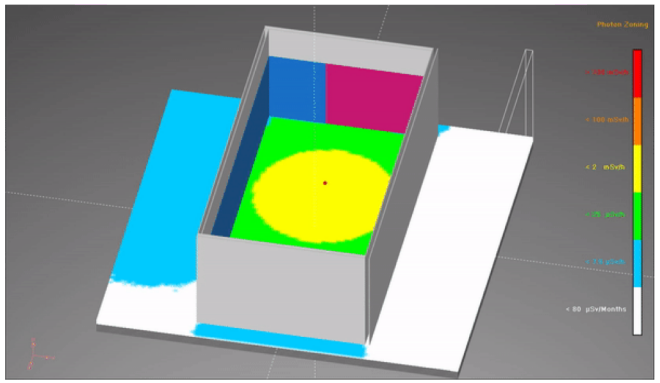
Dosimetric goals are not reached for 4 distinct zones

- Rest room close to gamma-camera room (1)
- Corridor close to the PET zone (2)
- Decay zone after the PET room (3)
- Storage room close to decay box (4)

TRAD Tests & radiations

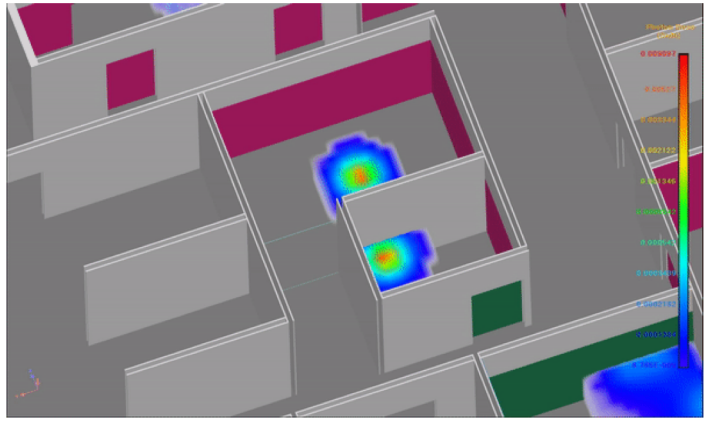
Results with initial model (2/2)

Main issues affecting dosimetric goals :



1- Skyshine effect

2- Effects of concurrent activities



… and an undersize of initial biological protections.

TRAD Tests & radiations

Skyshine effect

Rest room close to gamma-camera room (1)

12 × 925 MBq of ^{99}Tc-M

2 mm lead; height 220 cm

Ceiling height : 311 cm

DED ~ a few µSV/h due to skyshine

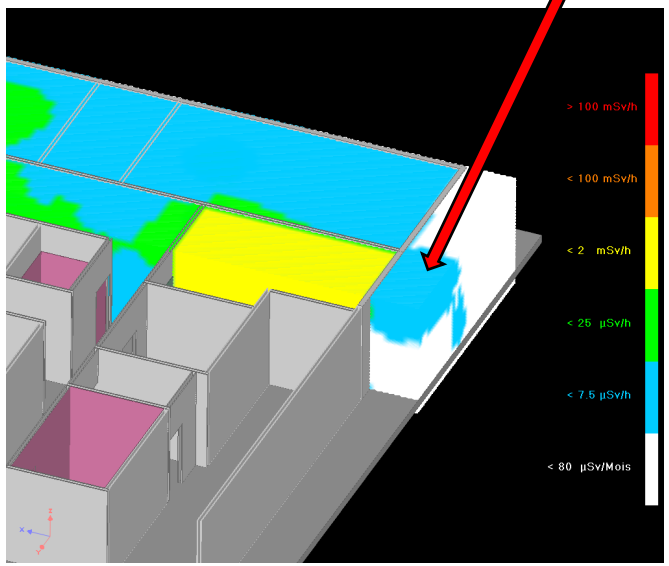
Corridor close to the PET zone (2)

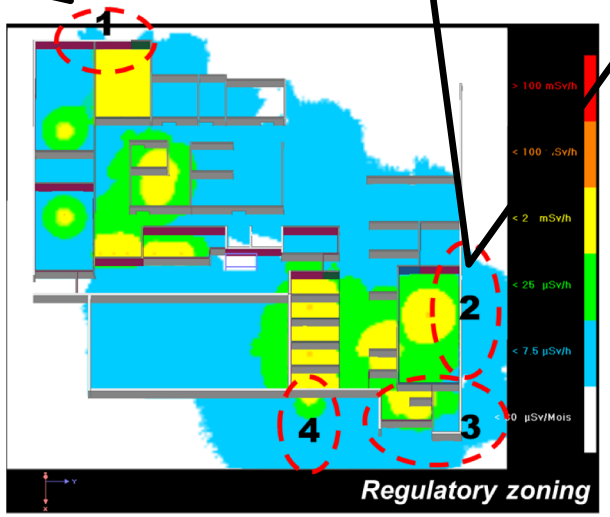
300 MBq of ^{18}F

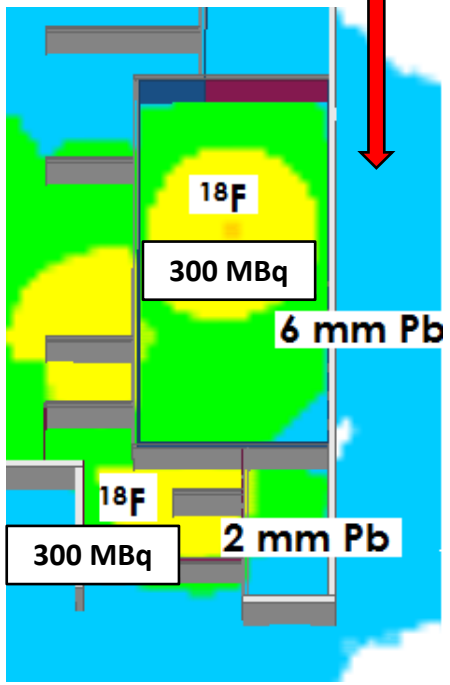
6 mm lead

Distance source - corridor ~ 2.5 m

DED ~ a few µSV/h due to lack of attenuation







Currently : **blue** controlled zone (< 7.5 µSv/h)

Goal : **white** public zones (< 0.5 µSv/h)

TRAD Tests & radiations

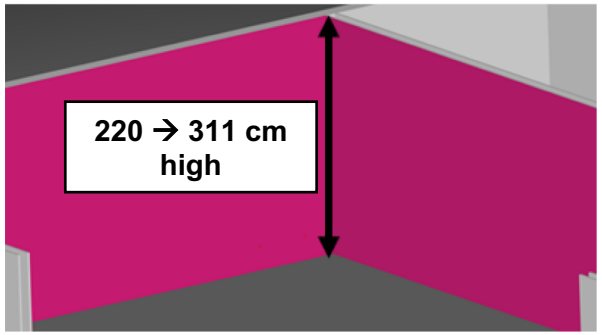
Shielding optimization # 1

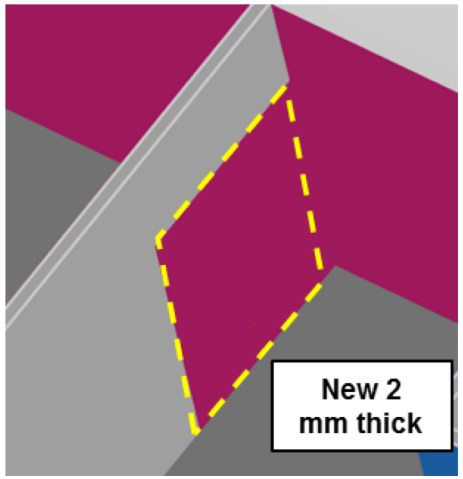
Rest room close to gamma-camera room (1)

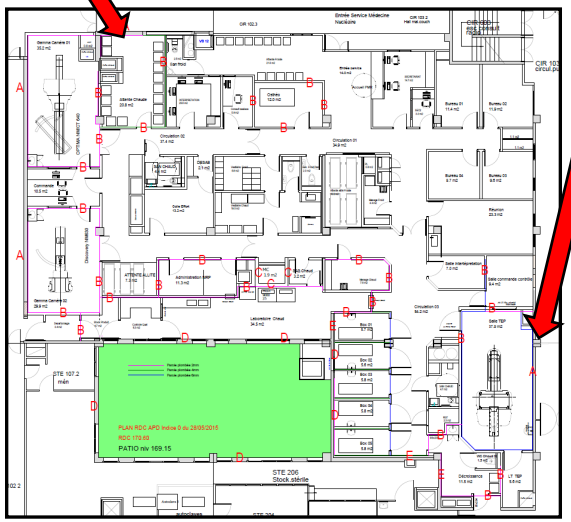
Lead height 220 cm → 311 cm + new 2-mm-thick protection

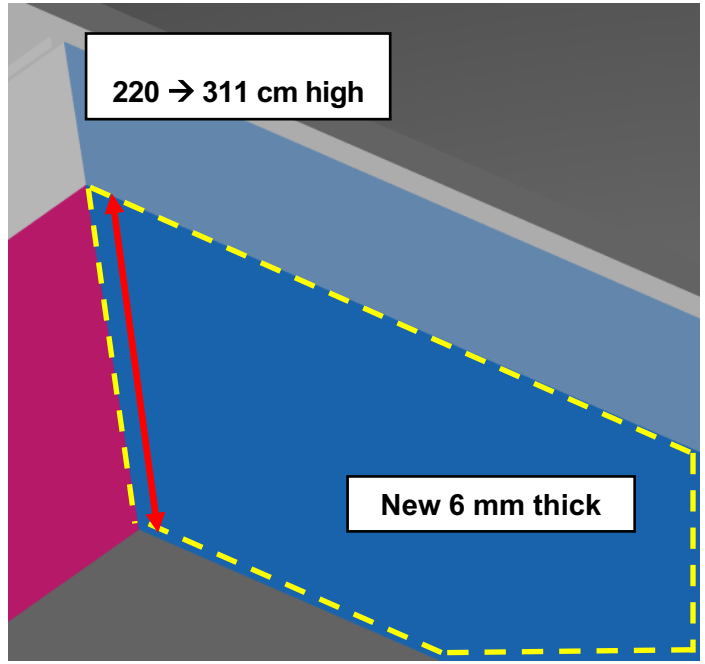
Corridor close to the PET zone (2)

Lead height 220 cm → 311 cm + new 6-mm-thick protection





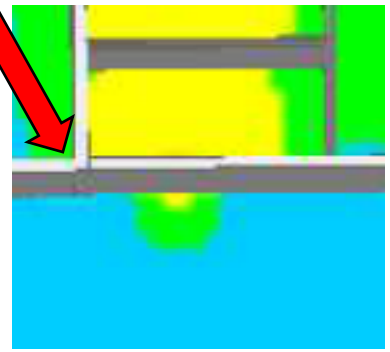


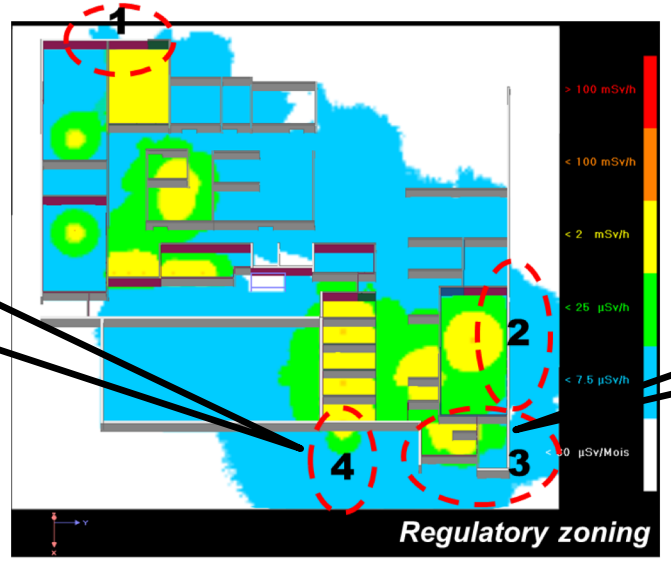


Concurrent activities effects

Storage room close to decay box (4)

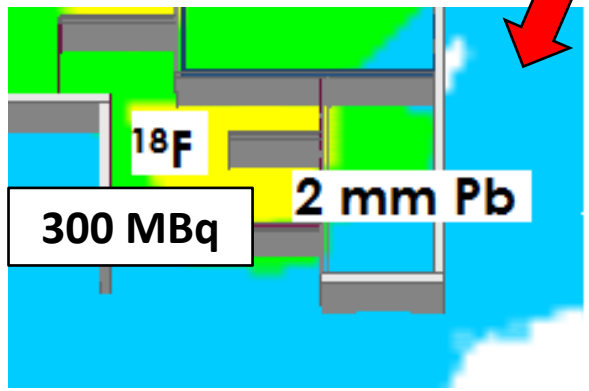
300 MBq of ^{18}F
6 mm lead
Distance source - wall ~ 50 cm
DED ~ 30 µSV/h due to lack of attenuation





Decay zone after the PET room (3)

300 MBq of ^{18}F
2 mm lead
Distance source - corridor ~ 2.5 m
DED ~ a few µSV/h due to lack of attenuation



Currently :
green controlled zone (< 25 µSv/h)
Goal :
blue controlled zone (< 7.5 µSv/h)

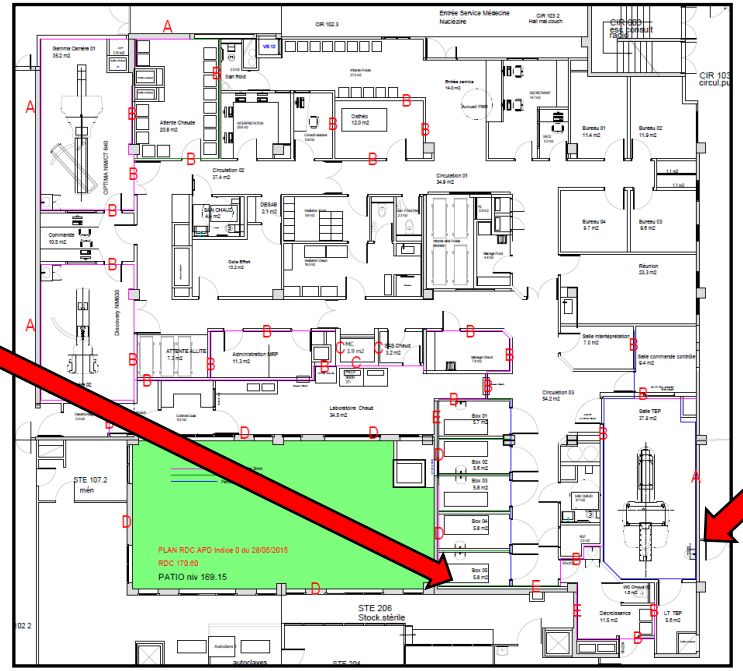
Currently :
blue controlled zone (< 7.5 µSv/h)
Goal :
white public zones (< 0.5 µSv/h)

TRAD Tests & radiations

Shielding optimization # 2

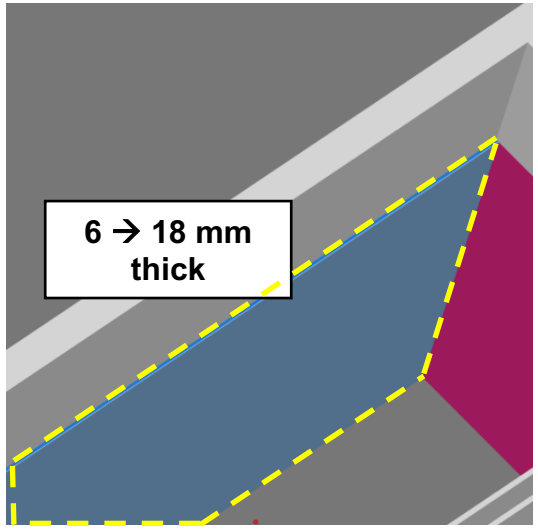
Storage room close to decay box (4)

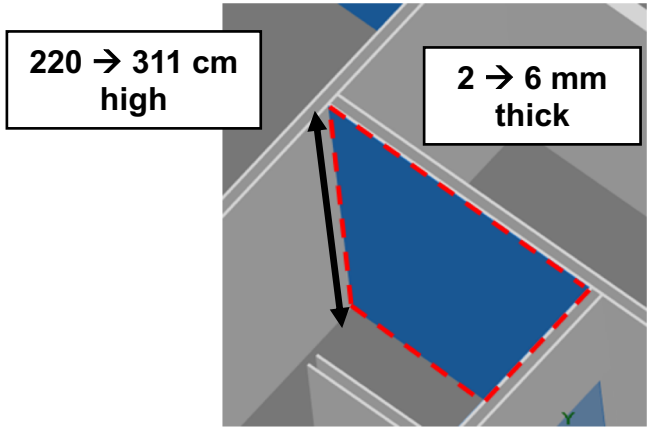
Lead thickness :
6 mm → 18 mm

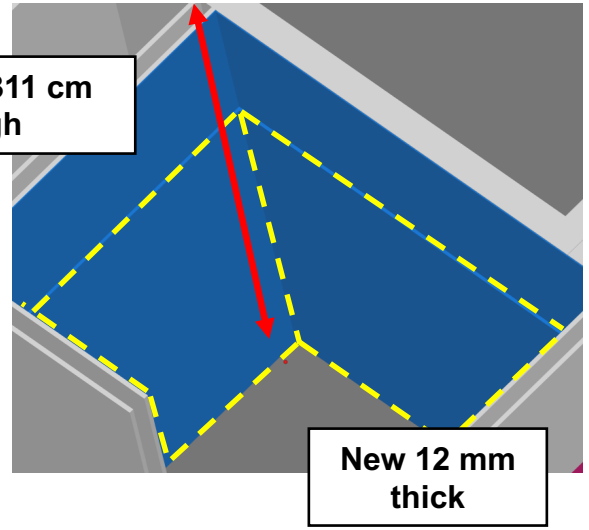


Decay zone after the PET room (3)

Lead height : 220 cm → 311 cm
Lead thickness : 2 mm → 6 mm
+ 2 new protections (6 mm and 12 mm)







Results after optimization

Dosimetric goals are reached :

Dose rate in public zones are now < 80 µSv/month

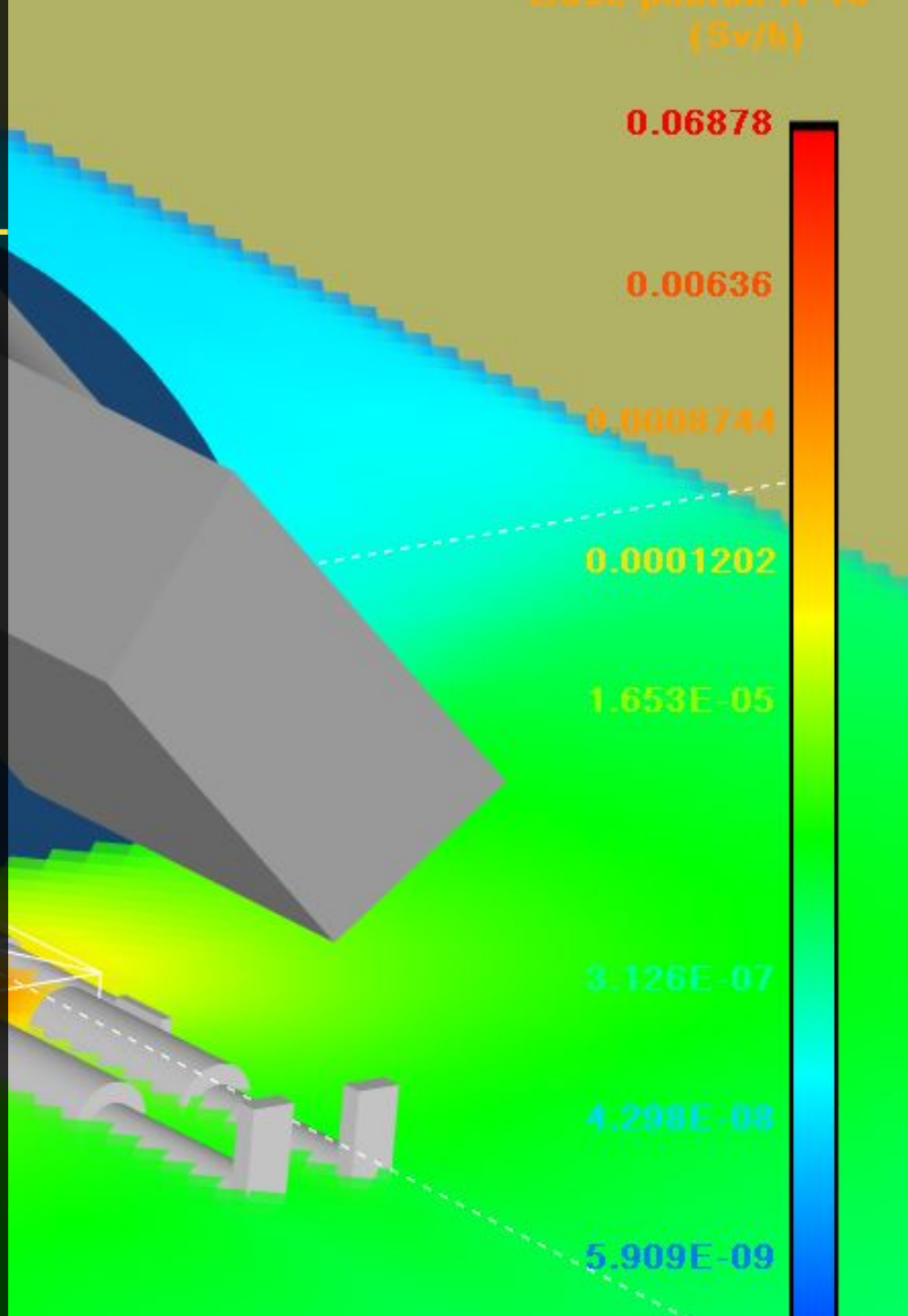
All these results are integrated in the file for French Agency for Nuclear Safety (ASN)

TRAD Tests & radiations

CONCLUSION

Thanks to this study with RayXpert©:

- ASN has validated the request of exploitation
- Albi hospital is now exploited with the optimized configuration
- Importance of the communication to get full and safe information (number of sources, patients, shielding sizes, …)



TRAD Tests & Radiations

For nearly 25 years, TRAD, Tests & Radiations, is recognized as a leading and innovative company providing radiation protection studies and equipment characterization in severe environments: space, defense, nuclear and medical.

1994
Creation

Labège (31)
Montpellier (34)

+50
Employees

6 M€ turn over

OUR ACTIVITIES

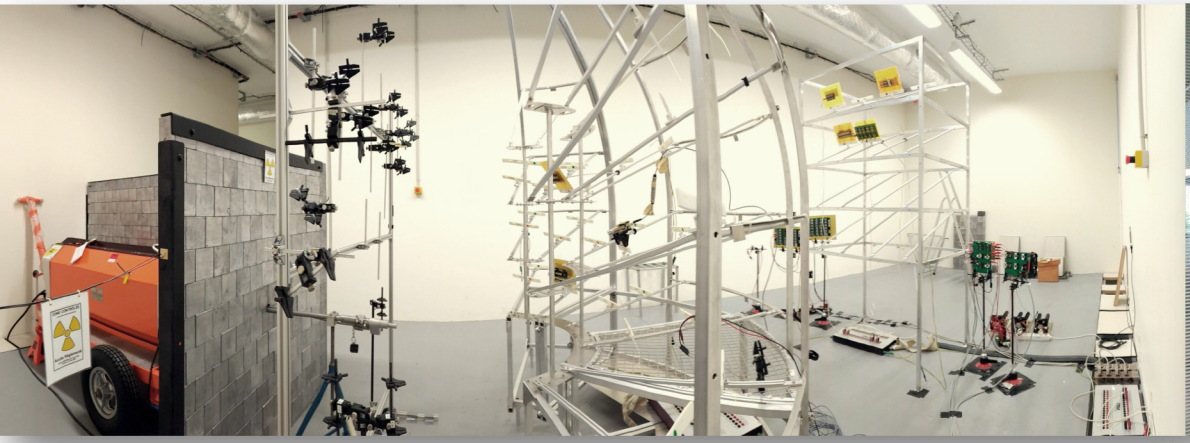
SPACE | NUCLEAR | MEDICAL | AERO-SPACE

- Radiation engineering
- Material qualification & characterization
- Radiation software publishing

- Electronic components testing
- Components reliability testing
- Qualified components sourcing

- Research and development
- Training center

An Approved Training Organization
N° 73 31 04810 31



Thank you for your attention

Any question ?

Contacts

benoit.simony@trad.fr

antoine.ghilardi@trad.fr