Study of the ^{133}Xe exposure

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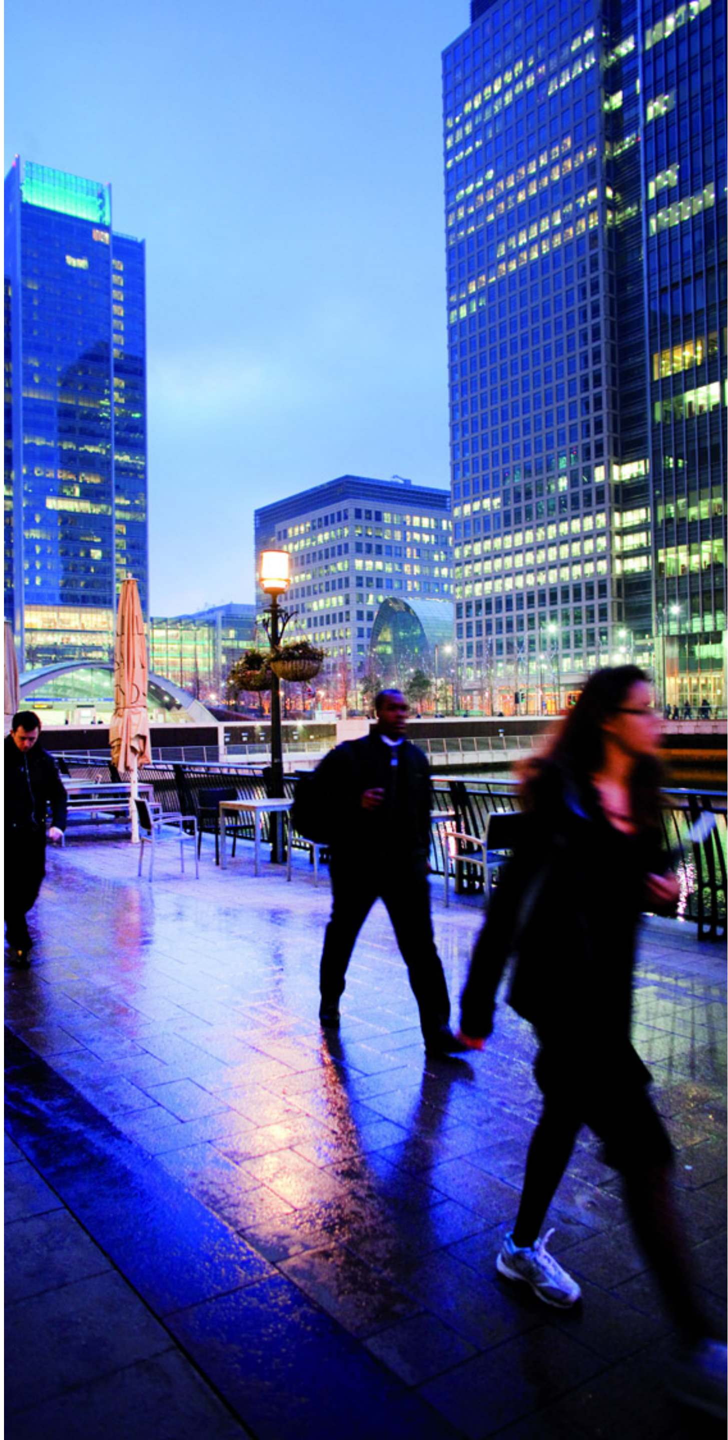
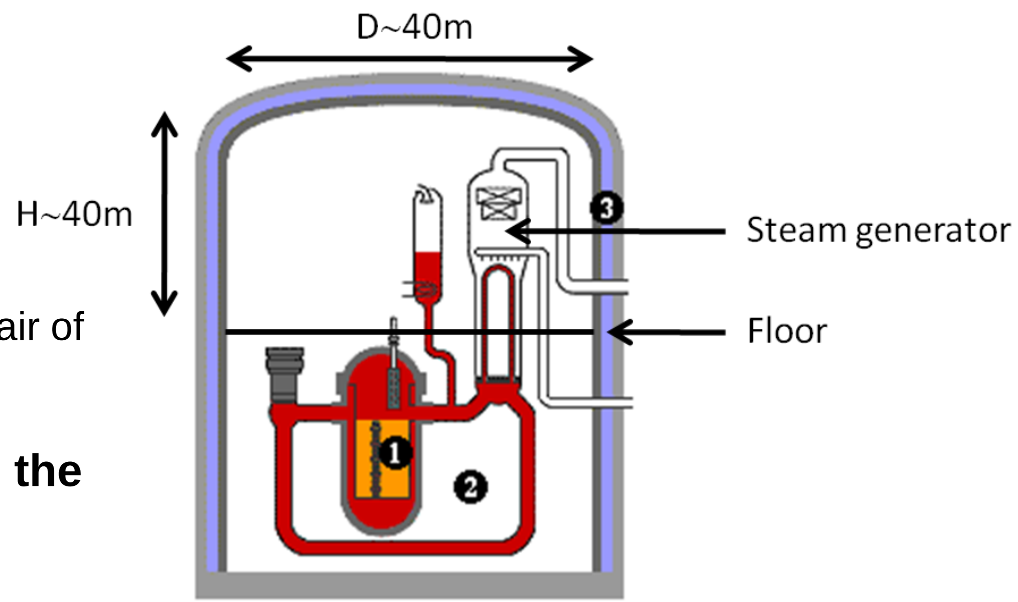


CONTEXT

- **Fission products**
  - In the fuel claddings
  - In the primary circuit in case of clad defect
- **Unit outage**
  - Opening of the primary circuit if the radiochemical criteria are reached
  - Potential dilution of fission products in the air of the reactor building in case of clad defect
- **Measurement of air contamination in the reactor building**
  - Plant Radiation Monitoring System
- **^{133}Xe**
  - Half-life of 5.2 days
  - Photons: 31.6 keV (46.9 %) , 81.0 keV (37.3 %)
  - β-: 100 keV (mean), 346 keV (max)
- **Exposure scenario**
  - Workers on the pool floor



- **3 confinement barriers**
  - Fuel cladding (1)
  - Primary circuit (2)
  - Reactor building wall (3)

XENON-133 EXPOSURE

- **State of the art**
  - Radioactive inert gas: external exposure (ICRP 30)
  - Semi-infinite cloud of ^{133}Xe: $\dot{E} = 5.0\ \mu Sv.h^{-1}.MBq^{-1}.m^{3}$ (ICRP 68)
  - Data available for an exposure in a semi-infinite cloud of ^{133}Xe

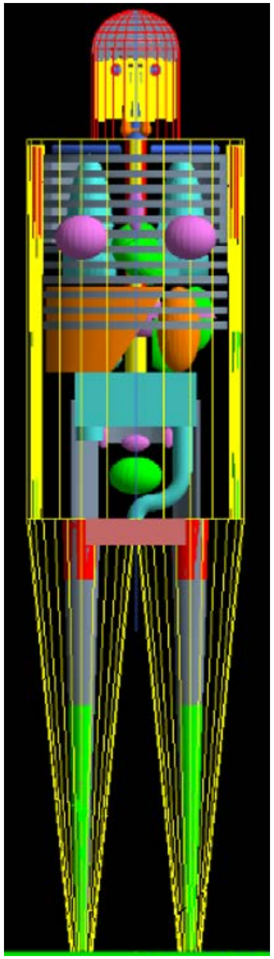
- **Objectives**
  - To study the external exposure to ^{133}Xe in a reactor building (realistic scenario)
  - To study the impact of the change in ICRP 103 for the limit equivalent dose to the eye lens

- **Method**
  - To model the external exposure to ^{133}Xe in a semi-infinite cloud to compare with the data available
  - To model the external exposure to ^{133}Xe in a reactor building (realistic scenario)
  - To determine the scenario of maximum exposure to ^{133}Xe
  - To obtain the dose rates (eye lens, whole body)

MODELING OF HUMAN BODY

- **GEANT4**
  Monte-Carlo code to simulate the interaction of ionizing radiation with the matter

- **MIRD phantom**
  - MIRD phantom is made up of 70 volumes
  - Addition of the eyes, the eye lenses and their radiosensitive part

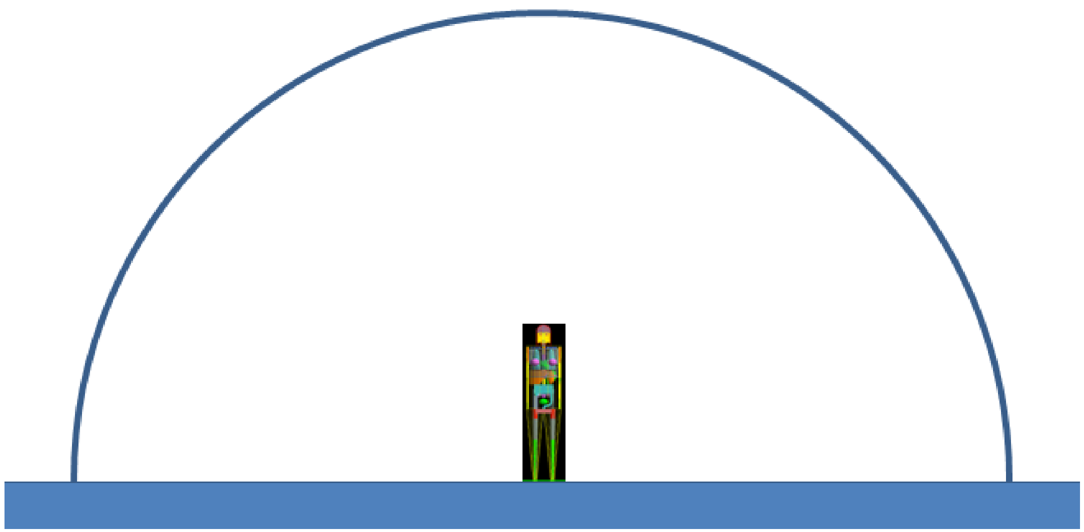


MIRD phantom

EXPOSURE IN A SEMI-INFINITE CLOUD

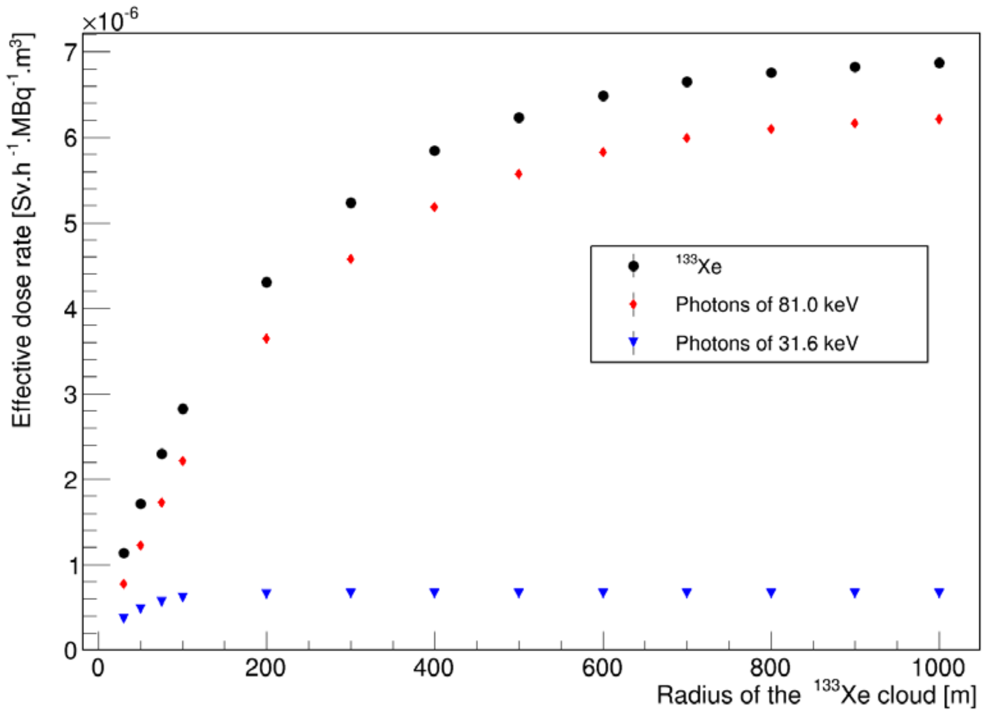
- **Validation by a comparison with the data available in a semi-infinite cloud of ^{133}Xe**

- **Simulations**
  - Phantom on the floor, in a cloud containing air
  - In a hemispherical cloud, a source of monoenergetic photons is generated: 31.6 keV (46.9%), 81.0 keV (37.3%)
  - Fitting of effective dose rates $\dot{E}_{31.6\ keV}$ and $\dot{E}_{81.0\ keV}$ versus the radius of the cloud
  - Extrapolation of effective dose rate: $\dot{E}_{31.6\ keV}$ and $\dot{E}_{81.0\ keV}$



EXPOSURE IN A SEMI-INFINITE CLOUD

EFFECTIVE DOSE RATE



In a cloud of xenon-133 with a 1000 m radius and with a concentration of 1 $MBq.m^{-3}$

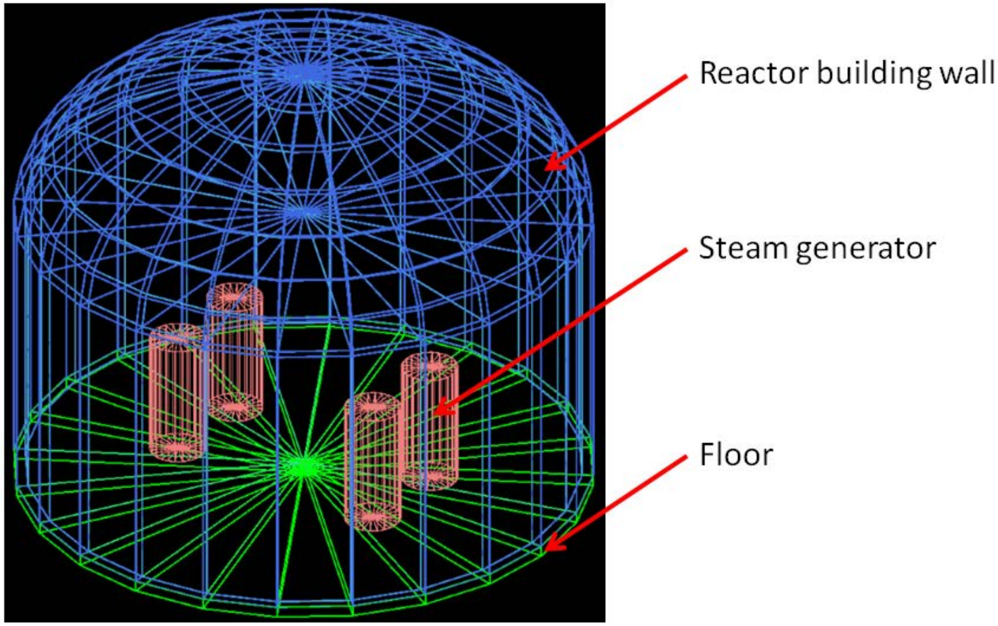
Source	$\dot{E}$ ($\mu Sv.h^{-1}.MBq^{-1}.m^3$)
^{133}Xe	**6.87 ± 0.03**
31.6 keV photons	0.66 ± 0.01
81.0 keV photons	6.21 ± 0.03

Statistical uncertainty in the results

Studies	R_{cloud} (m)	Methods	Dose rate ($\mu Sv.h^{-1}.MBq^{-1}.m^3$)
Poston & Snyder (1974)	infinite	Monte-Carlo	$\dot{E}$=6.01
Piltingsrud & Gels (1985)	1000	Calculation	$\dot{H}p(10)$=7.24
Eckerman & Ryman (1993)	infinite	Monte-Carlo	$\dot{E}$=5.62
Perier (2013)	**1000**	**Monte-Carlo**	**$\dot{E}$=6.87 ± 0.03**

- **Result consistent ⇒Method validated**

MODELING OF A REACTOR BUILDING



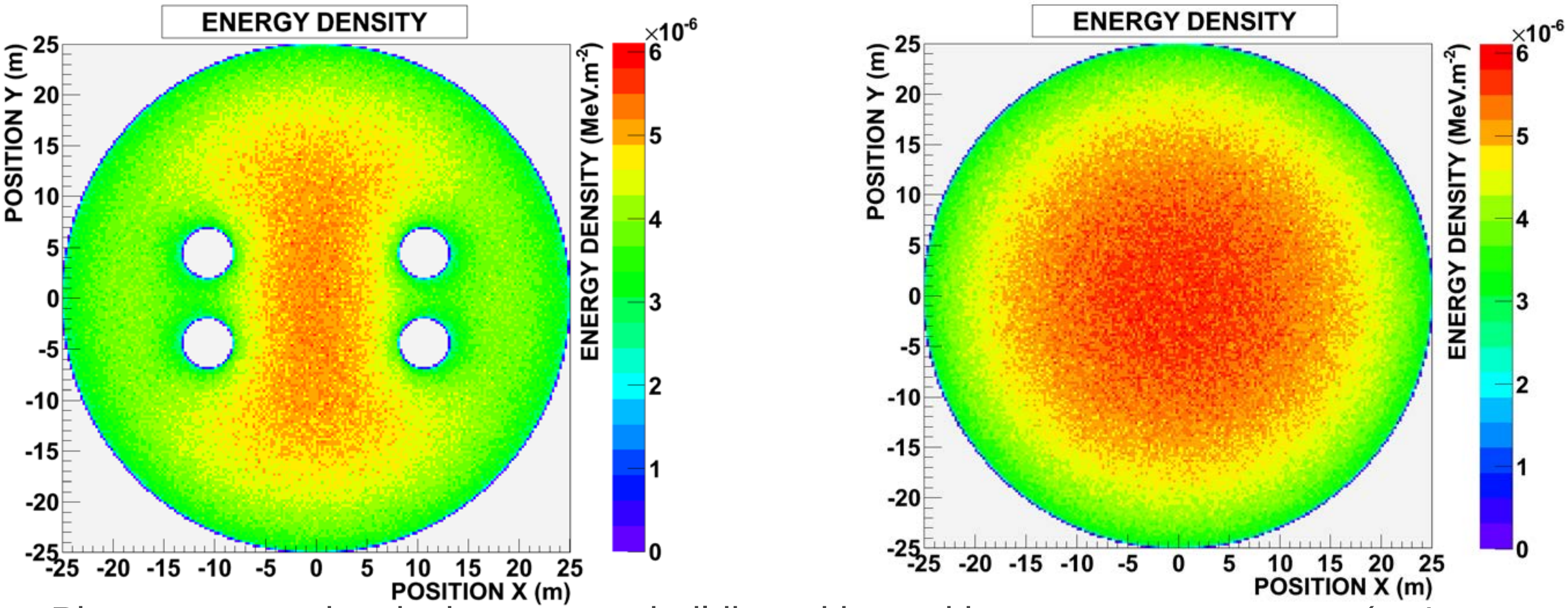
Modeling of the reactor building above the pool floor

- **Reactor building above the floor**
  - Modeling with GEANT4
  - PWR - 1300 MW
  - Diameter = 50 m
  - Height = 40 m
  - Largest elements: 4 steam generators

- **Find the scenario of maximum exposure to ^{133}Xe**
  - Modeling of the reactor building
  - Position of the phantom

EXPOSURE SCENARIO IN THE REACTOR BUILDING

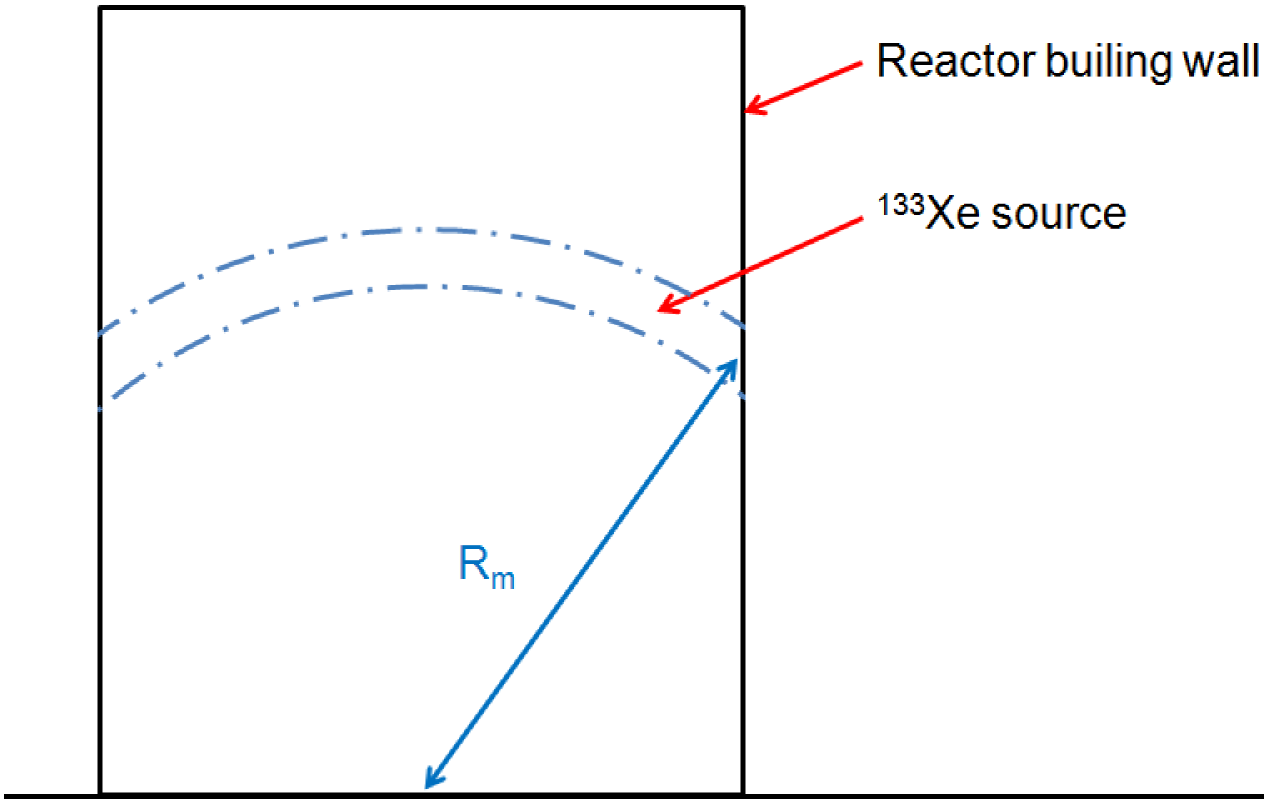
- **Effect of steam generators on the exposure at the floor level**
  - Energy density: maximum in the center of the reactor building
  - Energy density: lower in the reactor building containing the steam generators



Photon energy density in a reactor building with or without steam generators (at 1 m above the floor) - 5 x 10^8 disintégrations de ^{133}Xe in the air of the reactor building

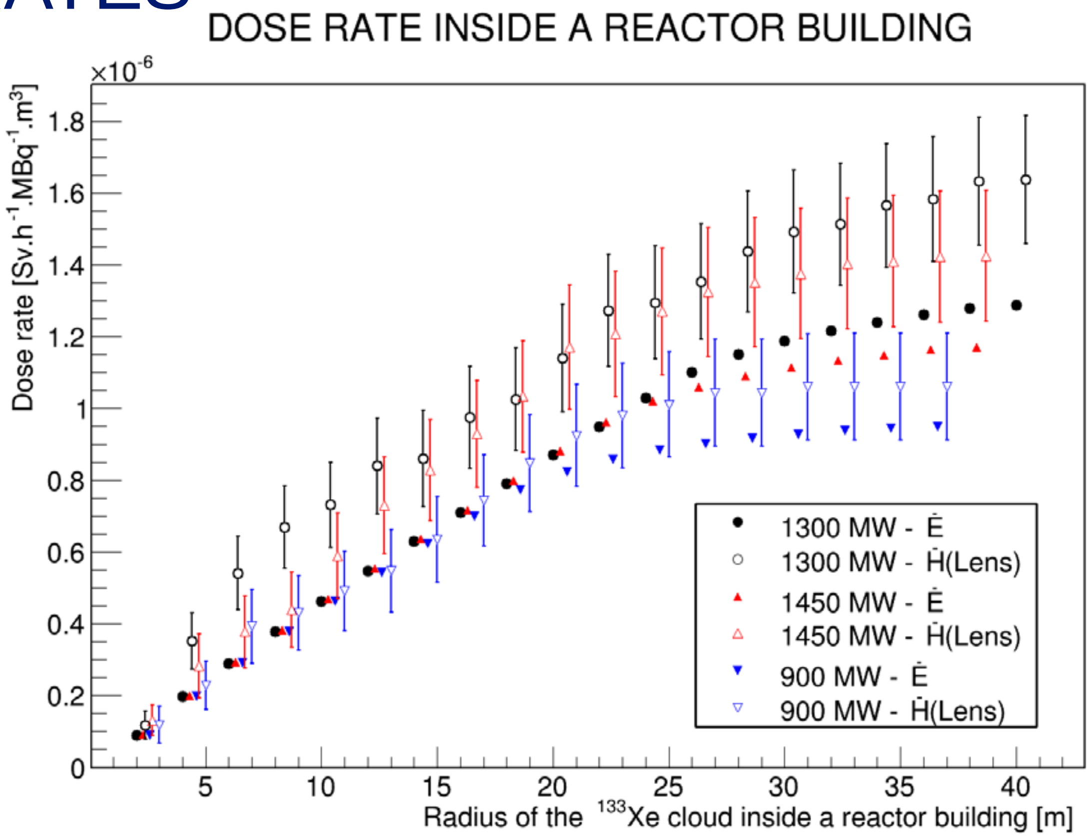
- **Scenario of maximum exposure**
  - Reactor building without steam generators
  - In the center of the reactor building

MODELING OF THE XENON-133 CLOUD



- **Monte-Carlo simulation technics**
  - ^{133}Xe cloud is included in the reactor building
    - ⇒ To use several hemispherical shells of ^{133}Xe truncated by the reactor building wall
    - ⇒ To sum each contribution to obtain the dose rates in the reactor building
- **Advantage**
  - Evolution of dose rates versus the radius of the cloud

DOSE RATES



Series	Vol (m^3)	$\dot{E}$ ($\mu Sv.h^{-1}$)	$\dot{H}_{lens}$ ($\mu Sv.h^{-1}$)	$\dot{H}_{lens.rad.sens}$ ($\mu Sv.h^{-1}$)
900 MW	34.3×10^3	0.95 ± 0.01	1.06 ± 0.15	1.09 ± 0.27
1450 MW	49.6×10^3	1.17 ± 0.01	1.42 ± 0.19	1.72 ± 0.35
1300 MW	68.5×10^3	1.29 ± 0.01	1.64 ± 0.19	1.60 ± 0.32

Dose rates with a ^{133}Xe concentration equal to 1 $MBq.m^{-3}$
(Statistical uncertainty in the results)

CONCLUSION

- **Exposure to ^{133}Xe**
  - In a ^{133}Xe cloud (A_{xe-133} = 1MBq.m^{-3}): $\dot{E}$ = 5 µSv.h^{-1} (ICRP 68)
  - Validation of the modeling by a comparison with the data available
  - Modeling of the exposure in a reactor building

- **Objectives**
  - To evaluate the exposure in a reactor building for a ^{133}Xe concentration equal to 1 MBq.m^{-3} (by using a conservative scenario)
    - $\dot{E}$ < 5 µSv.h^{-1}
    - $\dot{H}_{Lens}$ < 5 µSv.h^{-1}
  - To evaluate the impact of the new equivalent dose to the eye lens
    - E = 20 mSv/year
    - H_{Lens} = 150 mSv/year, new limit : H_{Lens} = 20 mSv/year

$\Rightarrow$**Positive impact**

- **Perspectives**
  - Feasibility study for a validation in a reactor building
  - Partial validation with dosimeters and an X-ray generator

THANK YOU