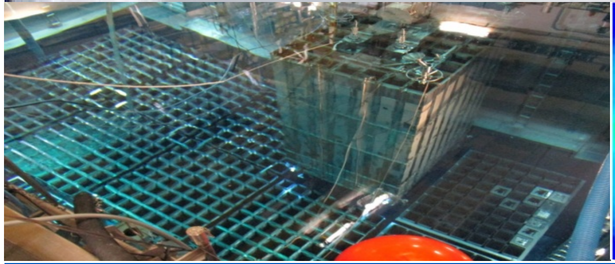
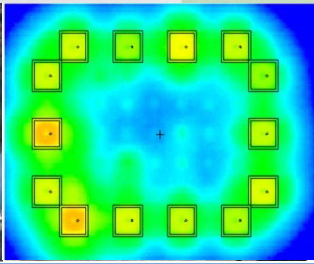
SPENT FUEL STORAGE RACK REPLACEMENT

ISOE Uppsala 2018





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CONTEXT

- **Scope:**
  - Spent Fuel Storage Rack in Fuel Building pool at plant series P'4
  - 10 racks per unit, 63 disposal cells per rack (9x7)
  - Racks manufactured by Sulzer in neutron-absorbing material => **Boral** (Change from plant series P4 to increase storage capacity)

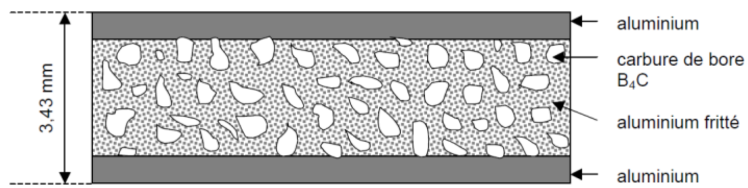
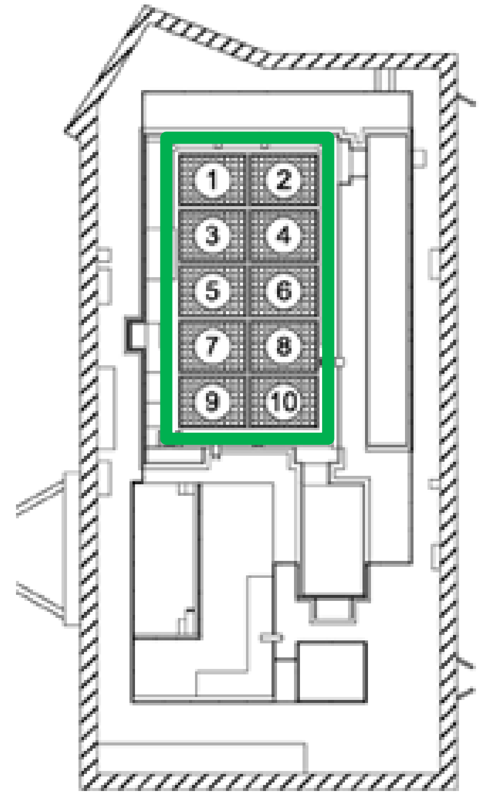
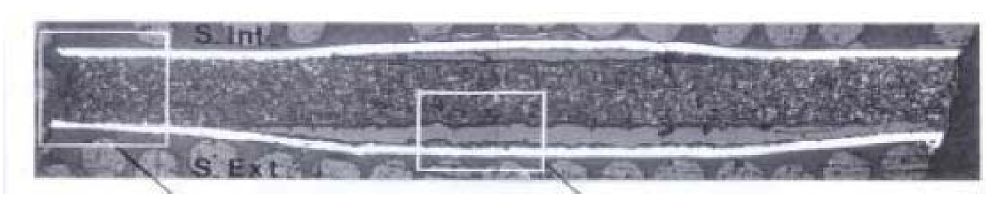


Figure 3 : Coupe schématisée à travers une plaque de boral



- **Issue with Boral:**
  - Swelling of Boral sheets due to corrosion of the aluminum in the presence of water (gas released)
  - Local deformation of the cell internal wall (blistering)
  - Possible jamming of a Fuel Assembly in a cell

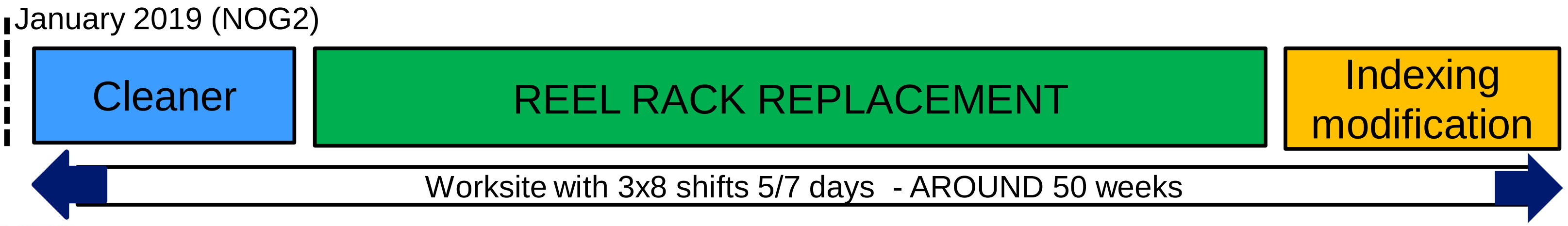


CONTEXT

- **Decision to replace a rack at CATTENOM 3, NOGENT 2 and PENLY 2 :**
  - RSCU renovation by replacement of the 10 racks,
  - New stainless steel racks associated with neutron-absorbing in borated stainless steel BSS: very good international OPEX with respect to the BSS,
  - New RSCU with the same dimensions, identical capacity (630 cells), with iso-requirement (criticality, cooling capacity and earthquake resistance) and iso-functionality.
  - CAT3 renovated in 2016 by CEGELEC (PENLY1 renovated in 2001)

- **Replacement of Nogent 2 and Penly 2 racks by REEL:**
  - Design of the new racks by REEL,
  - Design and qualification of tools for the removal of Boral racks and the installation of BSS racks by REEL,
  - Licensing Dossier by REEL (with support of Millennium for criticality analysis)
  - Decontamination under water (hydro-laser), radiological characterization and removal of old racks,
  - Installation of the new racks by REEL with support of ORYS,
  - **Significant optimizations to reduce the work time and replace the racks**
  - Modification of Bridge Crane indexing
  - Cleaning of pool bottom (improve reliability of radiological measurements under water)

- **Duration of site work**



RADIATION PROTECTION OBJECTIVES

- **The storage rack condition requires replacement. As these racks are contaminated, it is necessary to clean them and characterize them radiologically before carrying out any operations.**

- **Three requirements govern the operations in this project: Transport risk analysis, the internal rules of the contractor responsible for reprocessing and the ALARA dose reduction objectives. In order to comply with these regulations it MUST be possible to:**
  - Transport the rack in a type A container (DER < 2 mSv/h on contact and < 100 µSv/h at 200 cm),
  - Reprocess the rack (total activity < 43 GBq including all the uncertainties and radionuclides).

- **Two questions must then be asked:**
  - What are the DER limits in water allowing compliance with the transport risk analysis once the rack is removed and inserted into the container?
  - How can the maximum permitted activity per rack be calculated?

- **This type of study requires the contribution of three radiation propagation phenomena:**
  - straight radiation in the direction of the detector,
  - radiation diffused by the structures,
  - radiation leakage via singularities.

- **In order to take into account of these phenomena and the contribution of the radiation, the calculation tool selected for the study is MCNP code version 6**

Hypotheses of the MCNP model - Sources

- **The contamination of the racks is modelled in a fine layer on the vertical and horizontal walls listed below:**
  - At the bottom of the cell,
  - At the bottom between the cells,
  - At the bottom of the foot box,
  - On the upper surface of the anti-introduction frame,
  - On the vertical walls.

- **The calibration of the sources is automated according to the following principle: under water, 1 DER measured = 1 activity in the MCNP model, the sources are therefore calibrated so that the following formula is complied with.**

$$A_{tot} = \sum_{i}^{i_{max}} DER_{T,i} \times coef_T$$

A_{tot}: Total activity,

$DER_{T,i}$: i[th] DER for a type T source (cell's base plate, anti-introduction frame, foot box, cells walls),

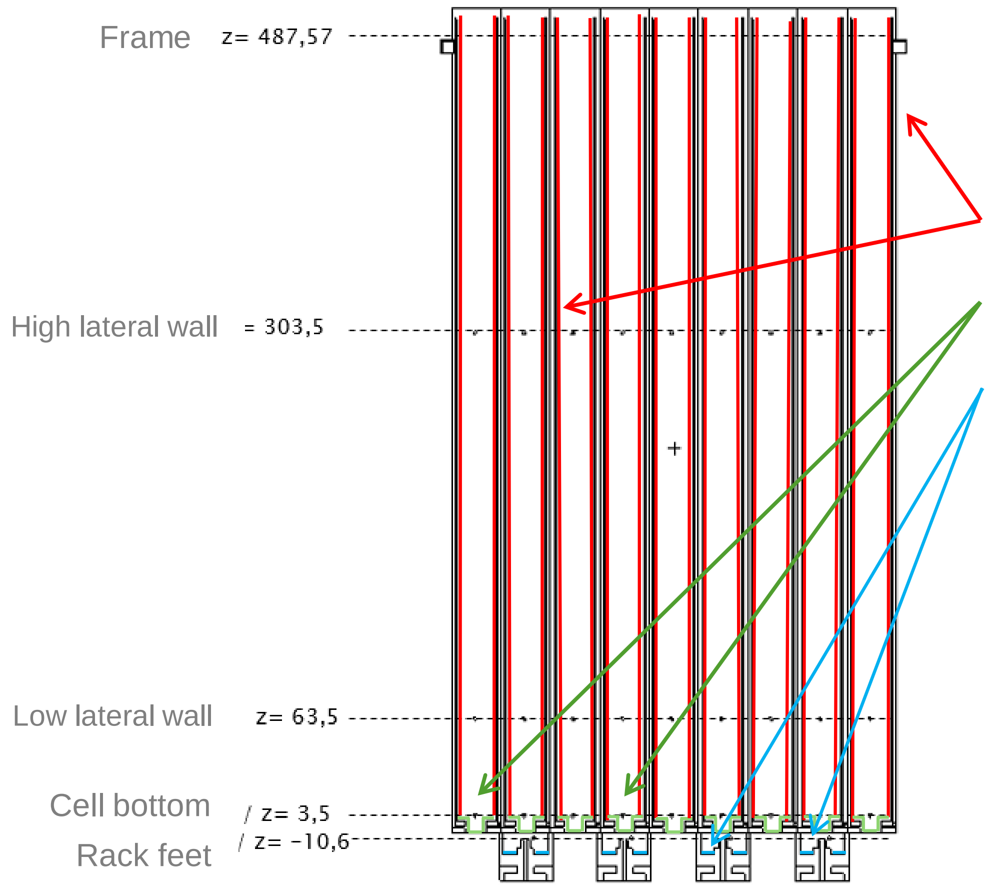
$Coef_T$: Coefficient (activity/DER) for a type T source.

- To determine the activity of a rack, a set of DER measurements under water is carried out. Because the measurements are carried out under water, the different DERs measured are mainly affected by the measured source, which enables the source terms to be calibrated effectively.

- Coefficients allowing a DER/activity change per type of source have thus been determined by MCNP calculations based on CAT3 previous measurements.

MCNP MODELLING – RACK CHARACTERIZATION

OPEX of the distribution of sources (activities) in the rack to define the measurement points



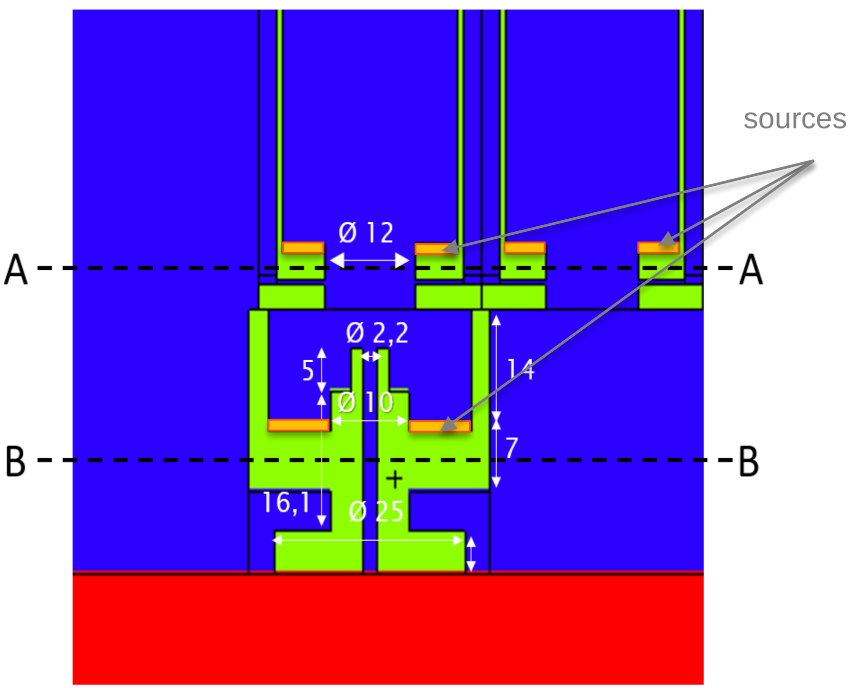
OPEX of the distribution of activities by source

Rack activities	Contribution (%)
Inside vertical walls	≈ 63 %
Cell bottom	≈ 30 %
Rack feet	≈ 6 %

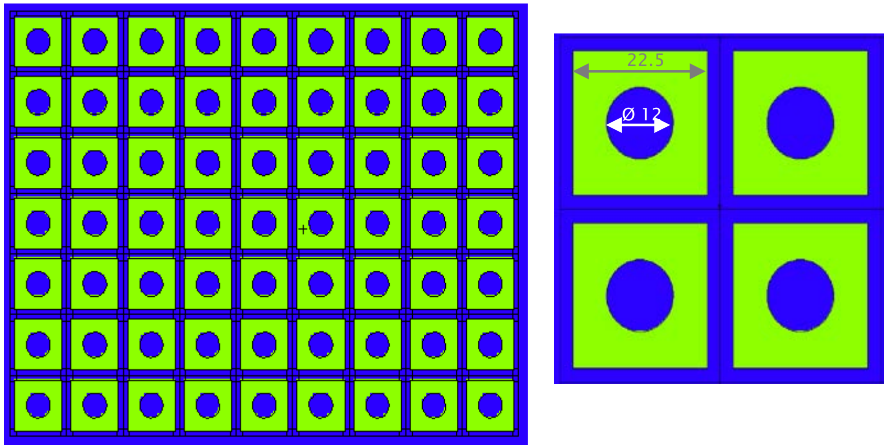
Brand sensors are used to measure the DER, under water, upstream of the cleaning phases (first module only), and downstream of these same phases to monitor changes in the DER and ensure the efficiency of the under water cleaning phases of the racks.

MCNP MODELLING – RACK CHARACTERIZATION

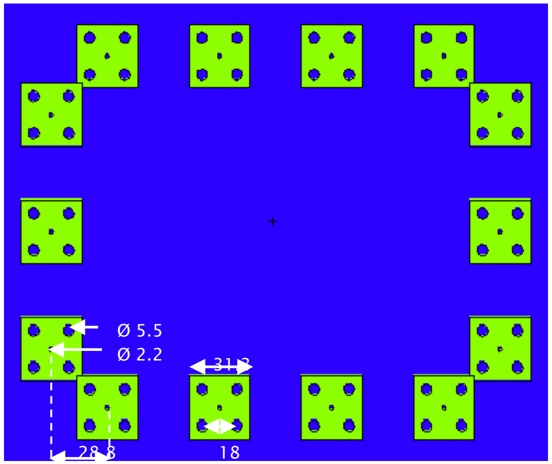
Creation of a model with the MNCP code



MCNP model VIEW AA



MCNP model VIEW BB



VALIDATION OF MCNP MODEL

The method is validated in three steps :

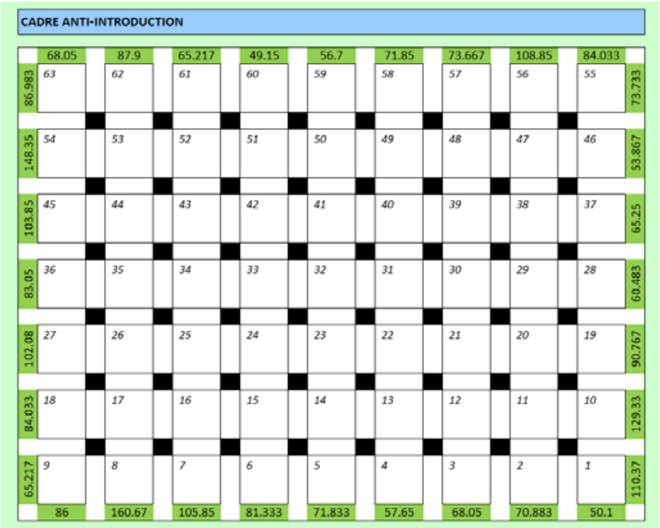
- **Validation by comparison of the DERs** calculated and measured with the help of the CAT 3 OPEX: A MCNP model representing rack 3 of CAT 3 is developed. The rack activity is calculated mathematically by the method explained previously. The DERs are used directly by the MCNP code corresponding to the different sources in order to regulate the probability of emission (setting of the model). The MCNP model then has a consistent set of sources respecting the distribution of the activity by type of source for rack 3 of CAT 3. The under water DERs obtained by this model are then compared to the DERs measured under water on the site for rack 3 of CAT 3.

- **Validation by comparison of activity:** The activities of the first 8 racks of CAT 3 are calculated and compared with the OPEX of the activities calculated on CAT3 and the OPEX of the activities calculated by gamma spectrometry by the entity responsible for rack reprocessing.

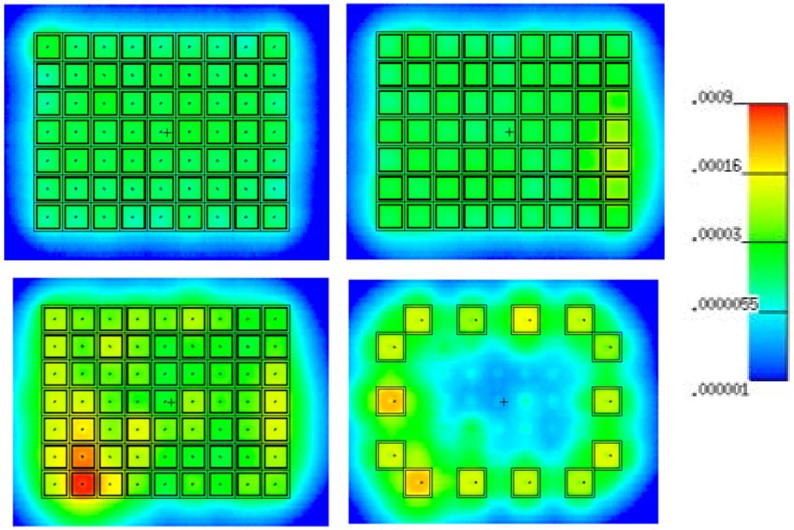
- An **additional validation by comparison to a simplified model** (PANTHERE calculation code) to :
  - Ensure that the 2 models lead to the same decision as regards the removal of a rack or not.
  - Cover questions of responsibility

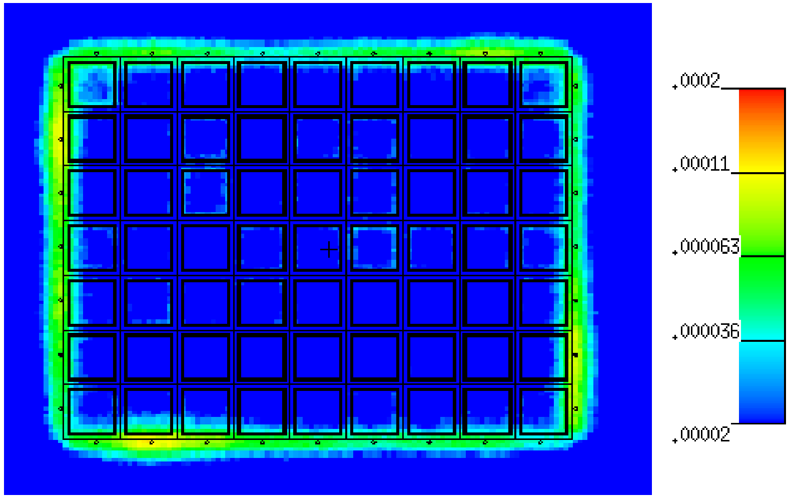
VALIDATION OF MCNP MODEL

MEASUREMENT of DER Rack 3 CAT3 (µSv/h)



CALCULATION of DER Rack 3 CAT3 (Sv/h)





VALIDATION OF MCNP MODEL

VALIDATION BY COMPARISON OF THE DER

- The results of the mappings of DERs clearly show the consistency between the results of the calculations and the measurements.
- The average calculation/measurement deviation is lower than 17%. The standard deviation calculated in the measurements and the calculations by type of source is similar.

VALIDATION BY COMPARISON OF THE ACTIVITIES

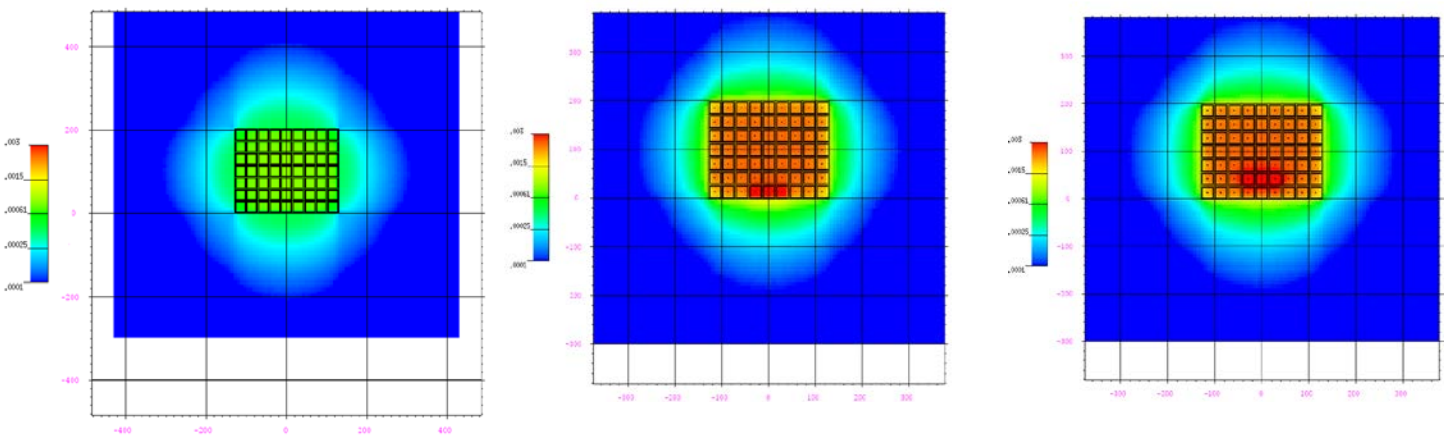
- The average calculation deviation between CAT3 OPEX and MCNP model is around 6%.
- The activity calculated and introduced into the MCNP model allows us to find the DERs measured on the site. The activity calculation methodology allows efficient calibration of the sources.
- The order of magnitude of rack activity is complied with.

DETERMINING EMERGENCE SIGNAL CRITERIA

- **Several calculation configurations with and without hot spots were carried out in order to establish the criteria for DER under water allowing compliance with the legal DER limits in the air.**

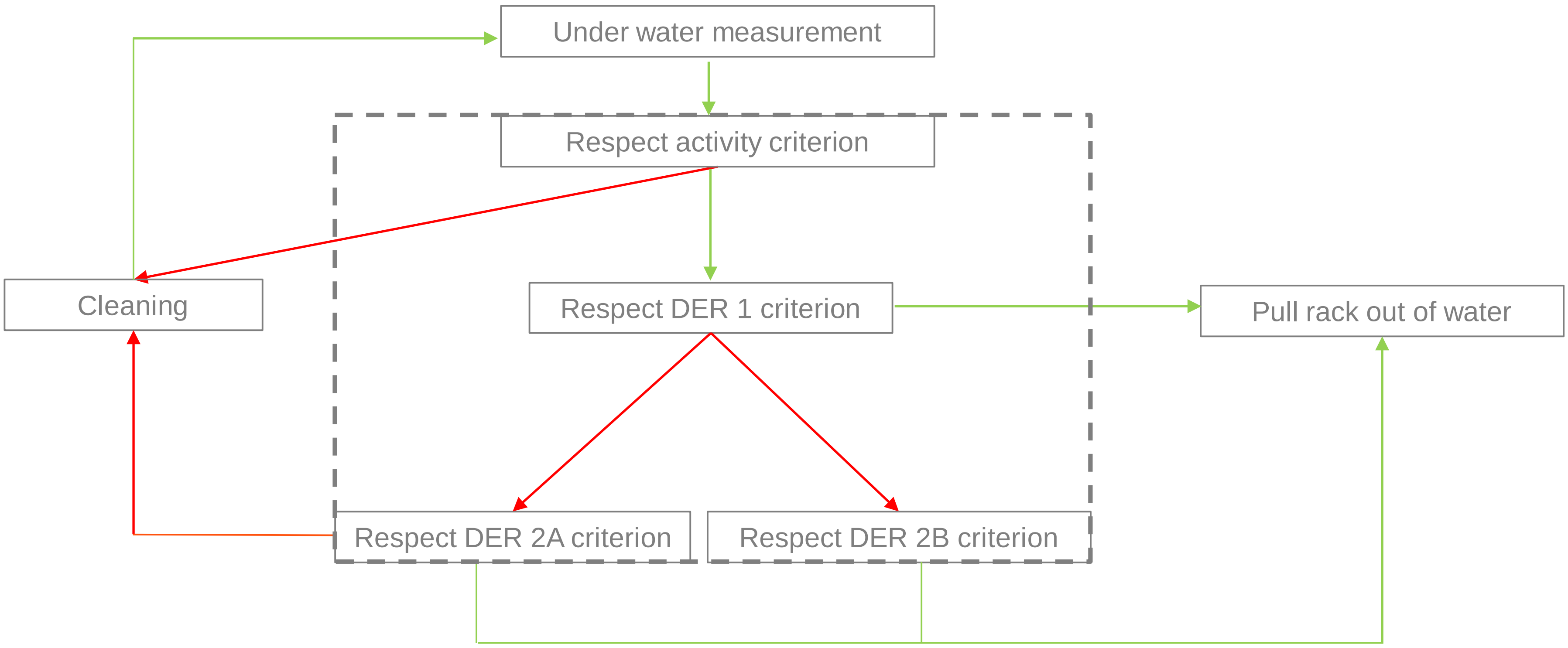
- **According to an analysis of the CAT 3 OPEX, the hot spots are located at the bottom, the maximum DER criteria must be in place at the bottom of the cell and at the bottom of the foot box.**
  - Criterion 1 represents a rack without hot spots.
  - Criterion 2A represents a rack with 3 hot spots in the first ring of cells.
  - Criterion 2B represents a rack with 3 hot spots in the second ring of cells.

- **These criteria are established on the basis of DER measurements of the anti-introduction frame, the walls, the bottom of the cell and the feet boxes. They make it possible to guarantee compliance with the transport Risk Analysis i.e.: 2 mSv/h on contact with the container and 100 µSv/h at 200 cm.**



DETERMINING EMERGENCE SIGNAL CRITERIA

- **In order to ensure that all criteria are met before emerging the rack , a site decision tool will be created following this flowchart :**



Authorization to remove the rack for the entity responsible for reprocessing the racks

- **Characterization by measurements of DER in air during drying phase: each rack is measured individually before being placed into the container.**
  - measurements at 50 cm from the side surfaces, perpendicular to the cells
  - measurements carried out according to 4 height levels (60 cm, 200 cm, 325 cm, 450 cm)

- **32 measurements for each rack.**

- **Simplified modelling of the main elements making up the rack. The contamination of the racks is modelled by surface sources in internal and external deposits for each cell.**

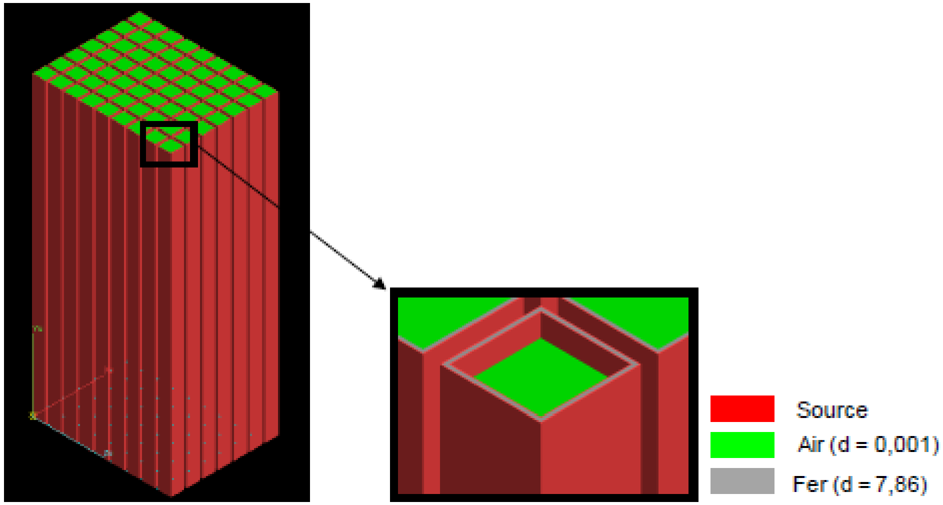
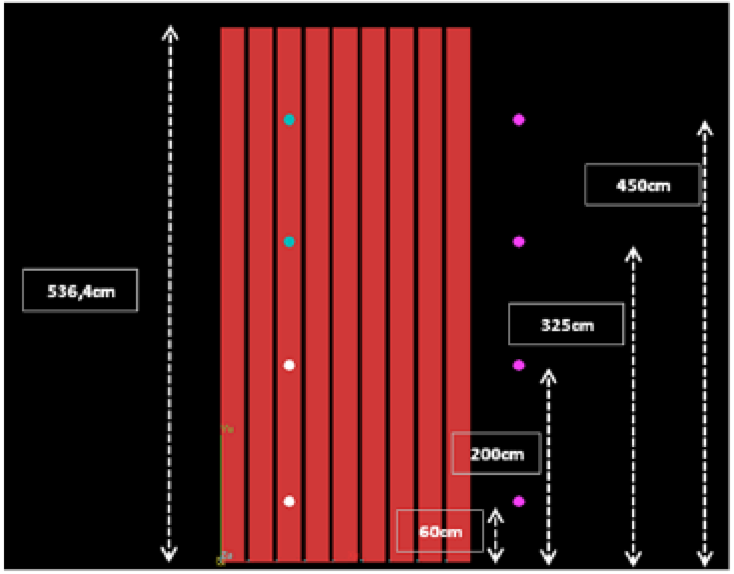


Figure 5 : Rack - Extraction PANTHERE



ALARA ANALYSIS OF WORKSTATIONS

- **Workforce and provisional duration:**
  - 10 months with 3x8 shifts – 5/7 days
  - Approximately 6 persons per station + site staff, which is an overall workforce of 20 to 25 persons

- **DER Optimisations:**
  - Decontamination of racks under water (hydro-laser)
  - Installation of heavy cover plates and biological protections on the hot spots
  - Use of telescopic rods and extensions : DER measurements
  - Decontamination of the rack feet in the air: systematic jet cleaning and possible disassembly, according to DER measurements on removal from the pool
  - Fuel pool cleaning and water in the transfer compartment

Dose	(Man.mSv)
PDA i	≈ 225
PDA o	≈ 50

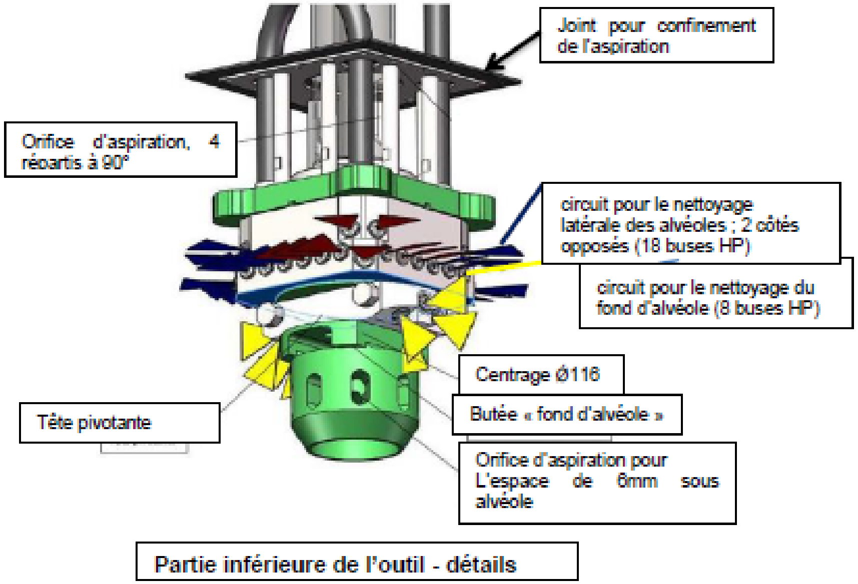
- **Measurement of the efficiency of the hydro-laser**
  - DER measurements carried out on the first rack before hydro-laser lancing
  - DER measurements carried out on all the racks after hydro-laser lancing to validate removal

- **The analysis of the DER measurements carried out under water allows to:**
  - Anticipate the DERs in the air
  - Estimate module activity
  - Decide whether to remove the rack or to carry on with hydro-laser lancing (PC processing and/or additional hydro-laser (final cleaning operation))

MAIN OPTIMISATION: HYDRO-LASER CLEANING

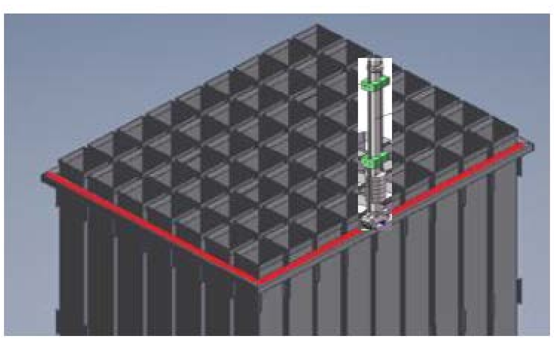
Tool for cleaning the inside of the cells

- **This tool is designed to:**
  - Vacuum in the contamination deposits in the rack cells.
  - Hydro-laser the rack cells and suck in the suspended particles during cleaning.
  - The lower part of the hydro-laser head swivels so as to reach all the areas at the bottom of the cell.
  - Hydro-laser area (in red)

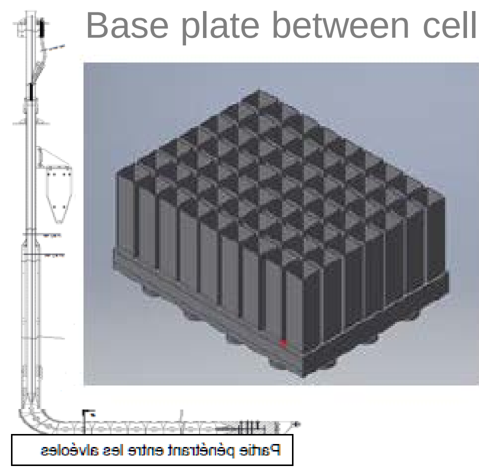


Other Tools for cleaning other parts

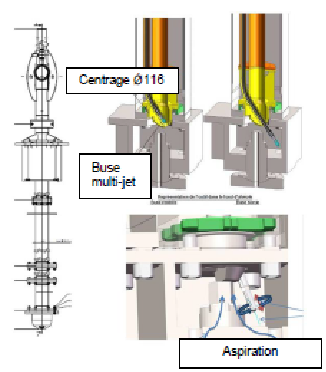
Anti introduction frame



Base plate between cells



Rack feet



CONCLUSION: RACK REMOVAL PROCEDURE

- **Rack removal procedure**
  - Cleaning by hydro-laser
  - Mapping of DER under water (for validation),
  - Lifting the rack out of the water,
  - SED rinsing of the 4 sides + above the feet,
  - DER measurement 0.5m from the lower surface (in the air),
  - Rack transfer above the drip collector,
  - Rack drying,
  - DER measurement 0.5m from the vertical wall,
  - Opening of the opening and rack moved inside
  - DER measurement 0.5m above and below the rack,
  - Insertion of the rack into a type A container,
  - Absence of water checking
  - Removal from the site

THANKS FOR YOUR ATTENTION

DIPDE

ENGINEERING SUPPORT, DISMANTLING AND ENVIRONMENTAL SERVICES DIVISION