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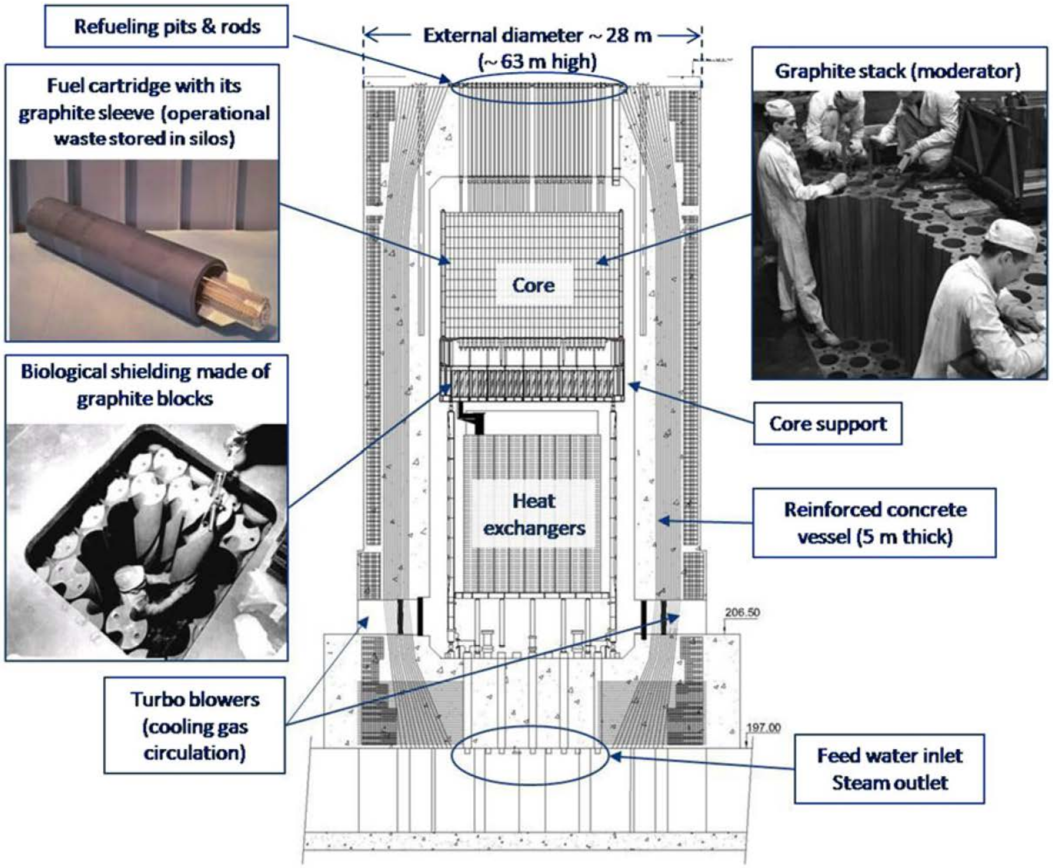
A reverse method for the determination of the radiological inventory of irradiated graphite at reactor scale

- **UNGG reactors and activated graphite waste**
- **A specific physical problem of radiological inventory determination**
- **The proposed reverse method**
- **Output results and physical analysis**
- **Further work**

EDF - UNGG reactors and activated graphite

- **U**ranium **N**atural **G**raphite **G**as (Graphite-moderated, gas-cooled (CO_2)



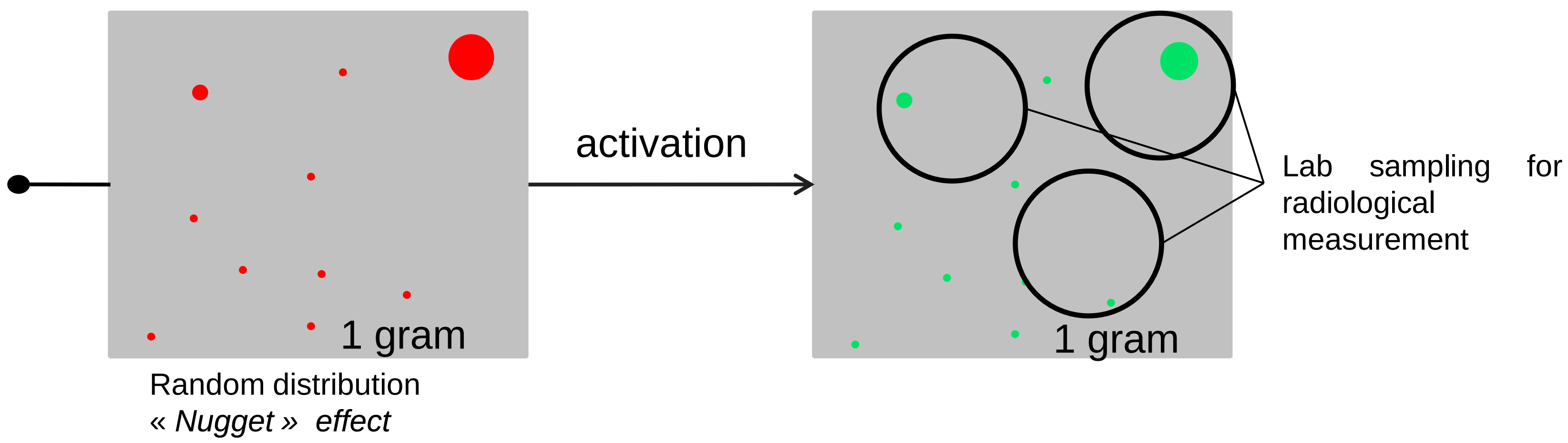
~17000 tons of activated graphite in 6 UNGG reactors of EDF

Graphite actived waste are Low-Level Long-Lived waste

($<10^6$Bq/g, >100y)

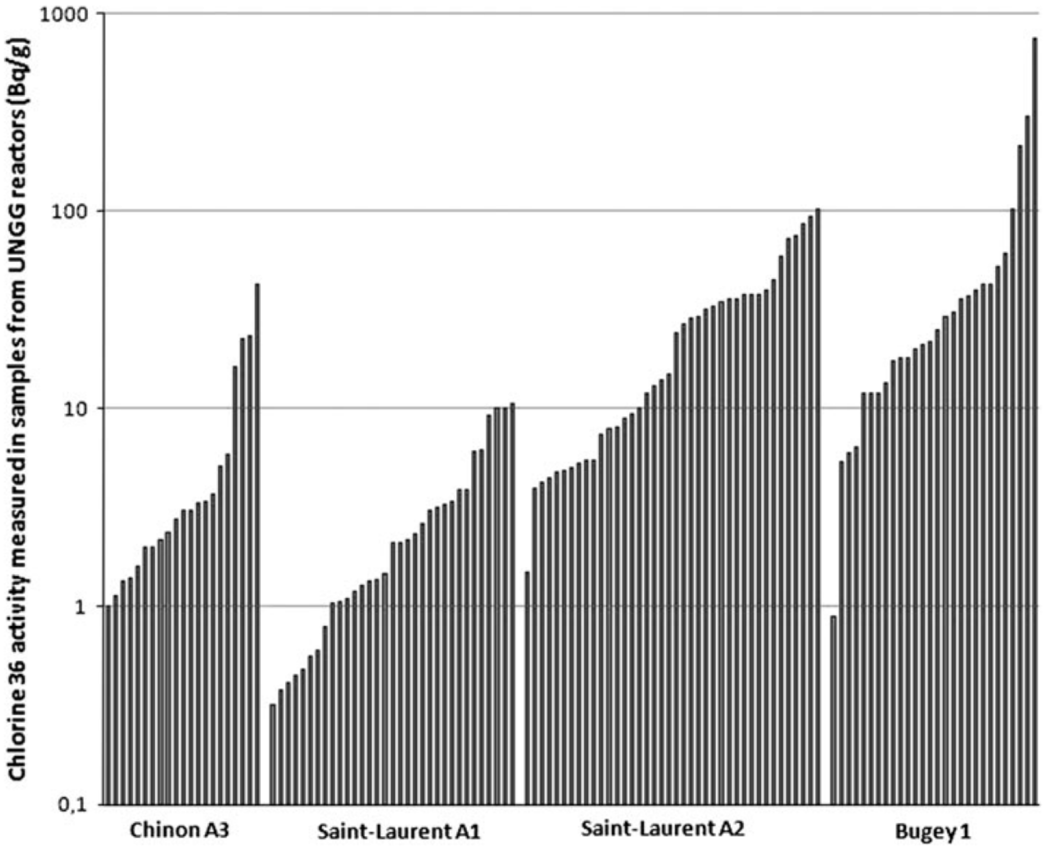
A specific physical problem of radiological inventory determination

- Radioactivity comes from activation of ^{13}C isotopic content in graphite (1%) + impurities at trace levels, **far below ppm**



For many radionuclides, radiological measurements exhibit high discrepancies (2-3 orders of magnitude) that do not correlate with the neutron flux variation (1 order of magnitude), or the temperature variation (280-530°C)

Example of ^{36}Cl activity measurements



Considering only the highest values is not reasonable for disposal designing

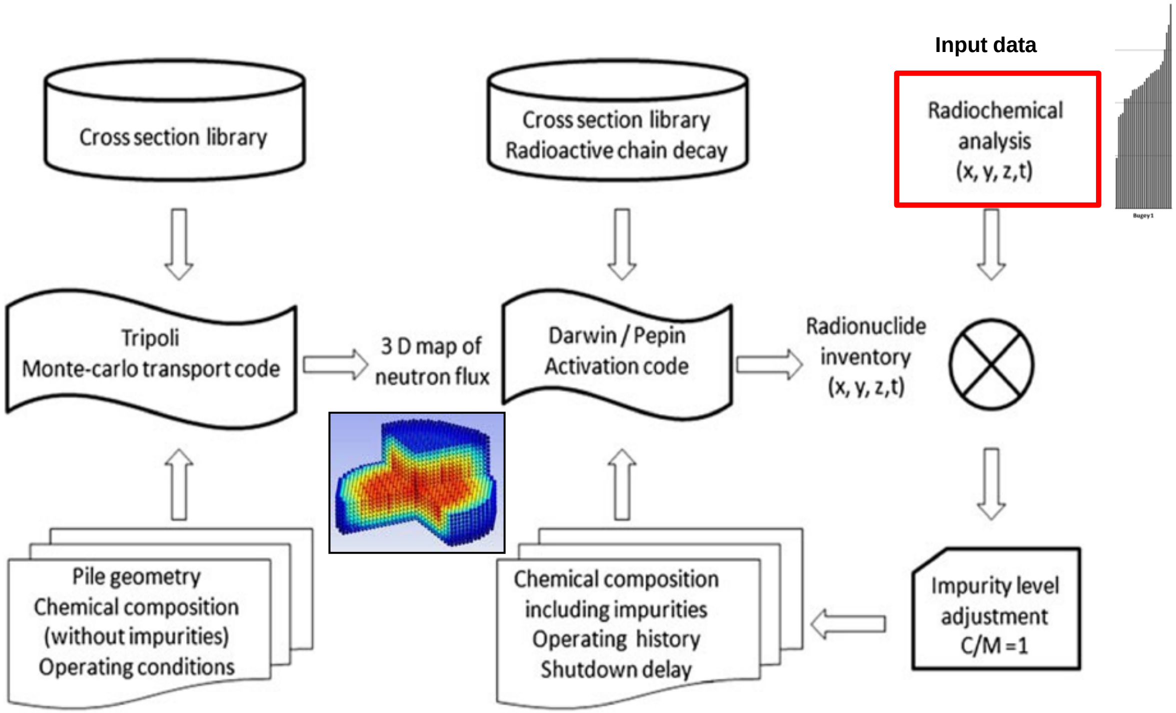
A geometric or arithmetic average should not be representative of the physical process of the activation of impurities

Activation calculation is needed but impurities content is not known

A reverse method to find the best set of impurities content is needed, using <u>all</u> the available radiological measurement

The reverse method in details

52 impurities (k) are considered to find 144 radionuclides (i) which are measured (j) ~30 times



For each of the j local measures $M_{ij}(x_j, y_j, z_j, t_j)$ of a radionuclide i, a local activation matrix A_j is analytically built using the calculated local neutron flux.

It links the local content of an impurity X_{kj} to the local activity concentration after activation of a radionuclide C_{ij}

$X_{kj} \cdot (a_{ki})_j = C_{ij}$

Then the quantity X_{kj} is adjusted by iterations to minimize the cost function:

$$\sum_i \mu_i^2 = \sum_i \left(\frac{1}{N_i} \sum_{j=1}^{j=N_i} ln \frac{C_{ij}}{M_{ij}} \right)^2$$

A vector of ajusted impurity content is therefore obtained for each of the j prelevement.

An average is performed on all these vectors to get the average impurity content of all the pile **$<X_k>$** .

A final activation is performed using this vector as input data to get the radiological inventory of all the pile.

Output results to analyse

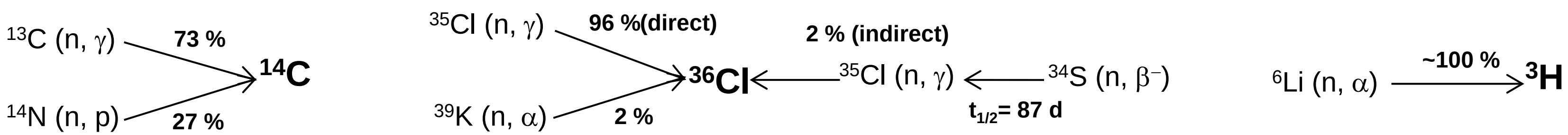
1- IMPURITIES CONTENT

^{35}Cl (precursor of ^{36}Cl) is evaluated to **81 mg/t on Bugey 1 reactor**

^{35}Cl (precursor of ^{36}Cl) is evaluated to **83 mg/t on Saint Laurent A2 reactor**

This similarity is promising.

2- ACTIVATION SCHEMES AT THE REACTOR SCALE



These schemes are obtained at reactor scale at the end of ajustement process. They need to be compared from a reactor to another (further work) to assess that the method is not reactor-dependant.

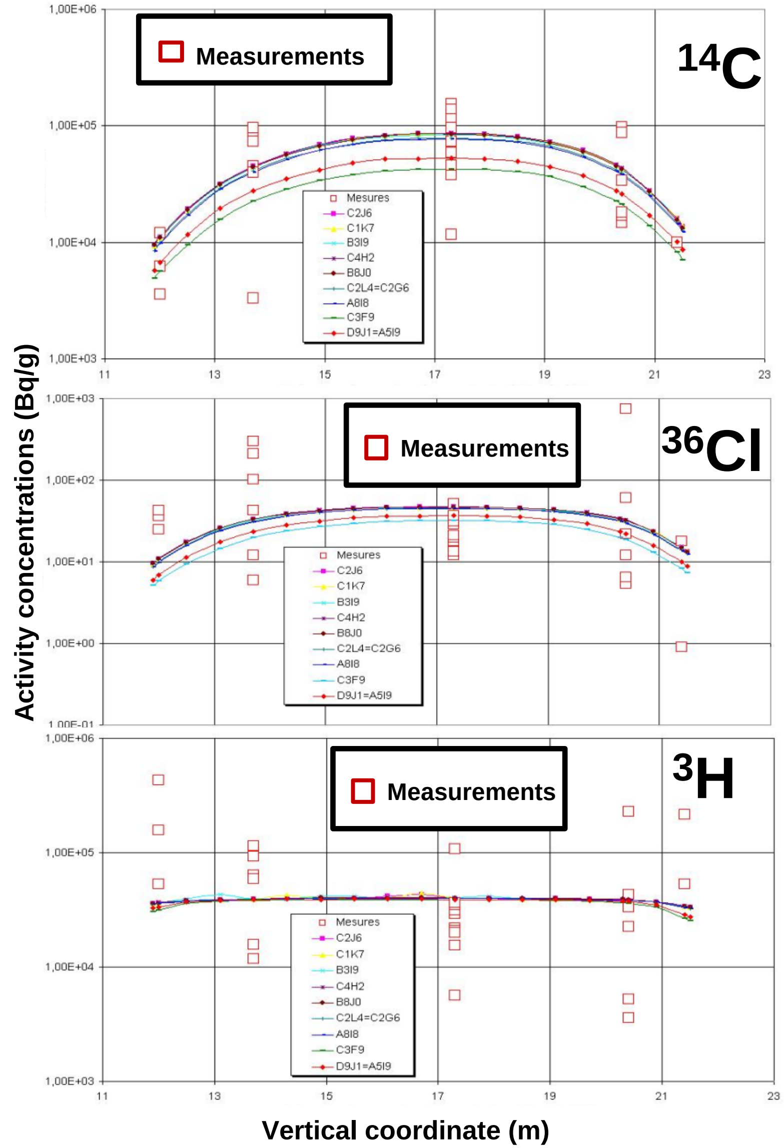
Output results to analyse

3- CALCULATED ACTIVITY CONCENTRATION PROFILE

There is a strong correlation between the shape of neutron flux and the profile of calculated activity concentration taken into account the neutron capture cross section of the precursors:

- **σ_{capt} of the ^{13}C (n,γ) ^{14}C reaction is 10^{-3} barn**
- **σ_{capt} of the ^{35}Cl (n,γ) ^{36}Cl reaction is 43 barns**
- **σ_{capt} of the ^{6}Li (n, α) ^{3}H reaction is 940 barns**

A very dependant to the neutron flux profile of ^{14}C activity concentration distribution, and a flat profile of ^{3}H (saturation) are very physical results regarding to σ_{capt}



Conclusion and further work

The reverse method gives some physical and coherent results on Bugey 1 reactor.

The declination of this method on the 6 EDF UNGG reactors is ongoing (EDF).

Intercomparison and interpretation of impurity contents, activation schemes, activity concentration profiles will be used for the physical validation of this mathematical method (IRSN).

In case of satisfying level of validation, radiological inventories will be calculated with a narrow uncertainty range, compared to measurements variability.