CHOOZ-A
STEAM
GENERATORS
CHARACTERIZATION

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CONTEXT

- FRENCH NUCLEAR WASTE MANAGEMENT
- CHOOZ A DECOMMISSIONING

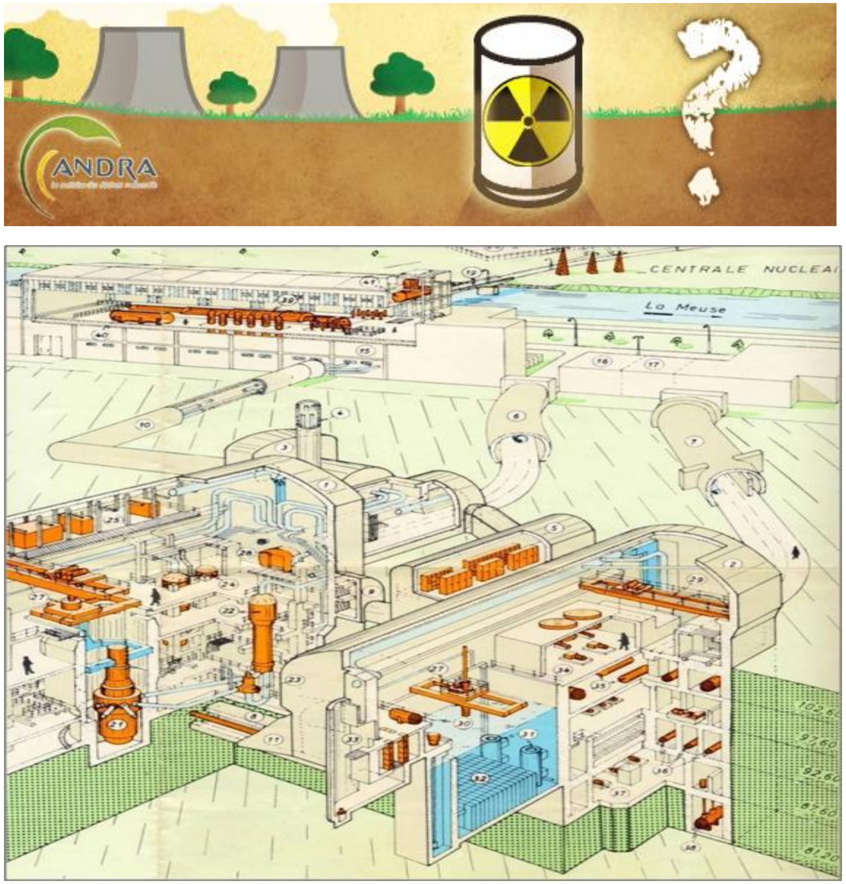
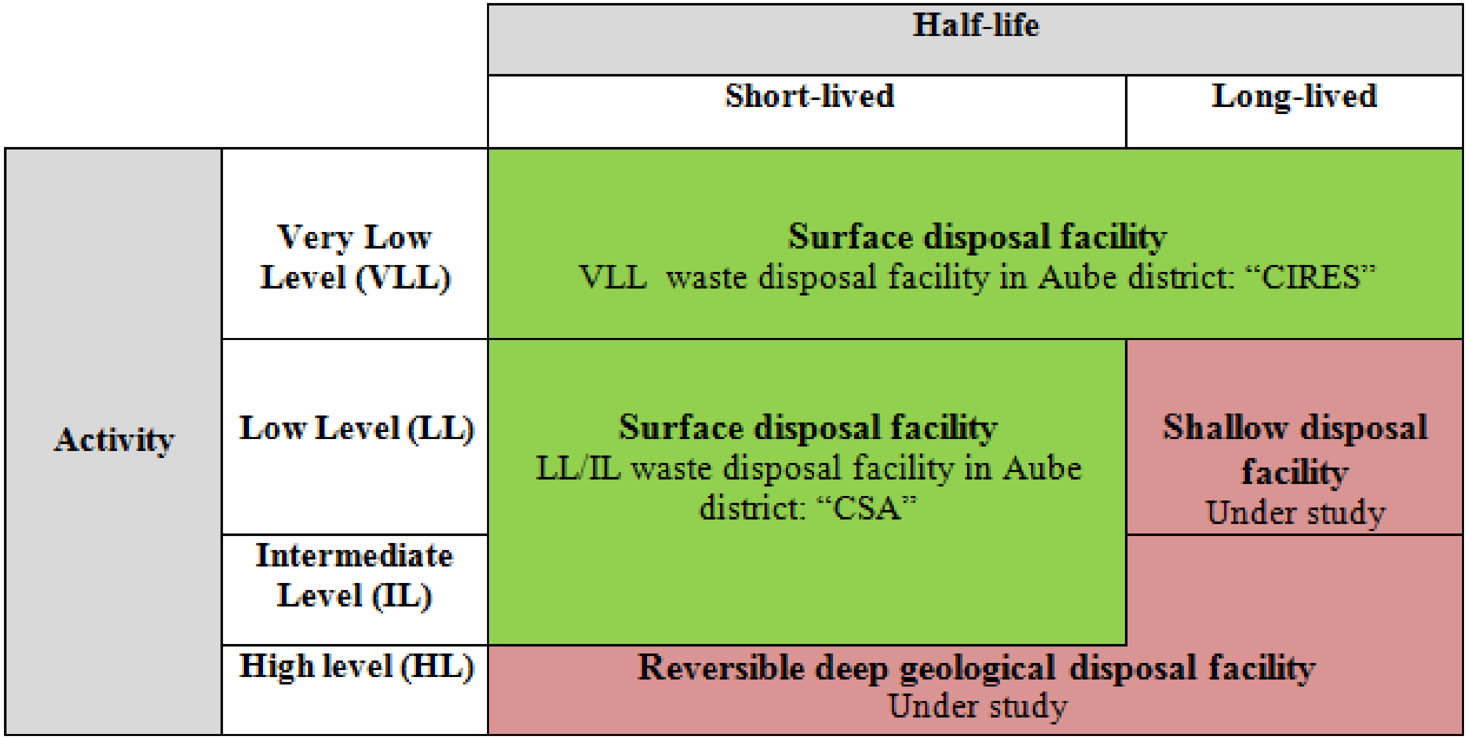


Fig.1. French nuclear waste management and Chooz-A underground reactor and fuel buildings

FRENCH NUCLEAR WASTE MANAGEMENT

- A single public body in charge : ANDRA



		Half-life	
		Short-lived	**Long-lived**
Activity	**Very Low Level (VLL)**	**Surface disposal facility** VLL waste disposal facility in Aube district: “CIRES”	
	Low Level (LL)	**Surface disposal facility** LL/IL waste disposal facility in Aube district: “CSA”	**Shallow disposal facility** Under study
	Intermediate Level (IL)		
	High level (HL)	**Reversible deep geological disposal facility** Under study	

TABLE I. French nuclear waste classification

CHOOZ A DISMANTLING

- 1st French PWR dismantling
  - Net power: 305MW
  - Commercial operation :1967-1991
  - Complete Decommissioning licence :2007
  - Primary loops+ 4SGs + pressurizer decontamination and evacuation:2011-2013
  - Reactor vessel decommissioning :2016

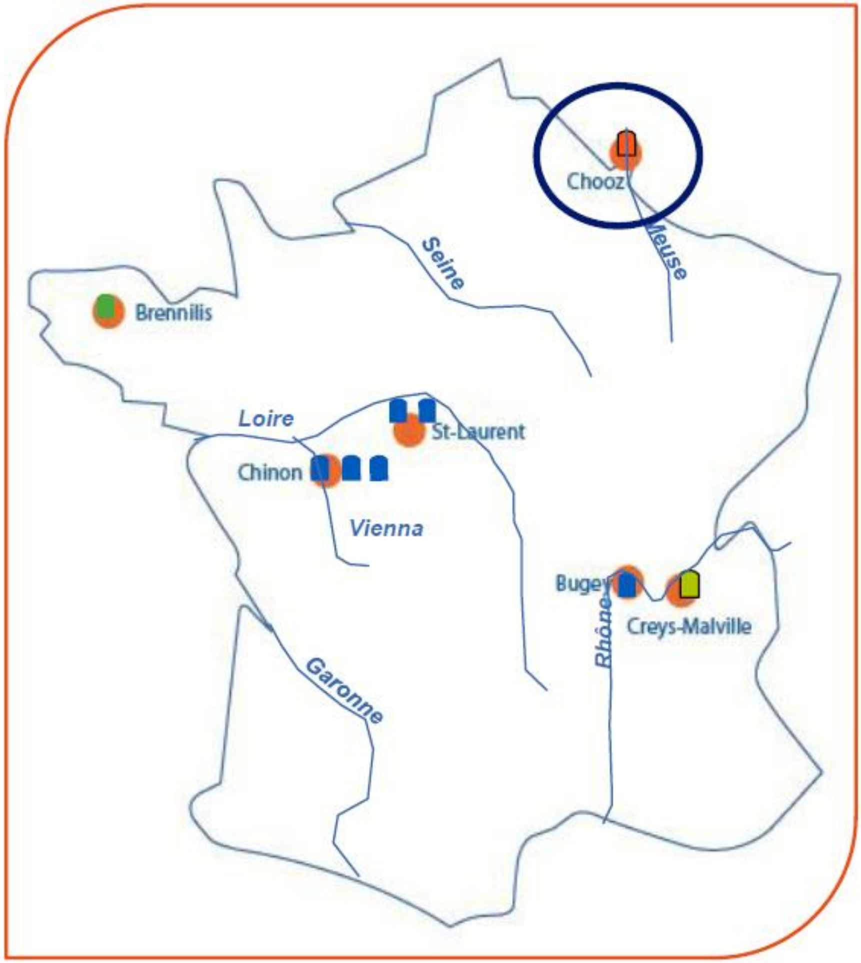


Fig.2. French 1st nuclear decomissioning program

CHOOZ-A STEAM GENERATORS CHARACTERISATION

1. CHOOZ-A SG CHARACTERISTICS
2. MEASUREMENT DEVICES
3. SIMULATIONS FOR MEASUREMENTS DATA EXPLOITATION : HYPOTHESES AND ACTIVITY CALCULATION
4. DISCUSSION : UNCERTAINTIES AND CHALLENGES OF THE METHOD

1. CHOOZ-A SG CHARACTERISTICS 2/2

- 20 years after shutdown
- Main radionuclides :
  - ☐ γ emitter → ^{60}Co : key nuclide
  - ☐ β emitter → ^{63}Ni
  - ☐ α emitter → ^{241}Am
- Activity level :
  - ☐ After decontamination : ~2 GBq (FD>100)
- Different levels of activity in the tube bundle

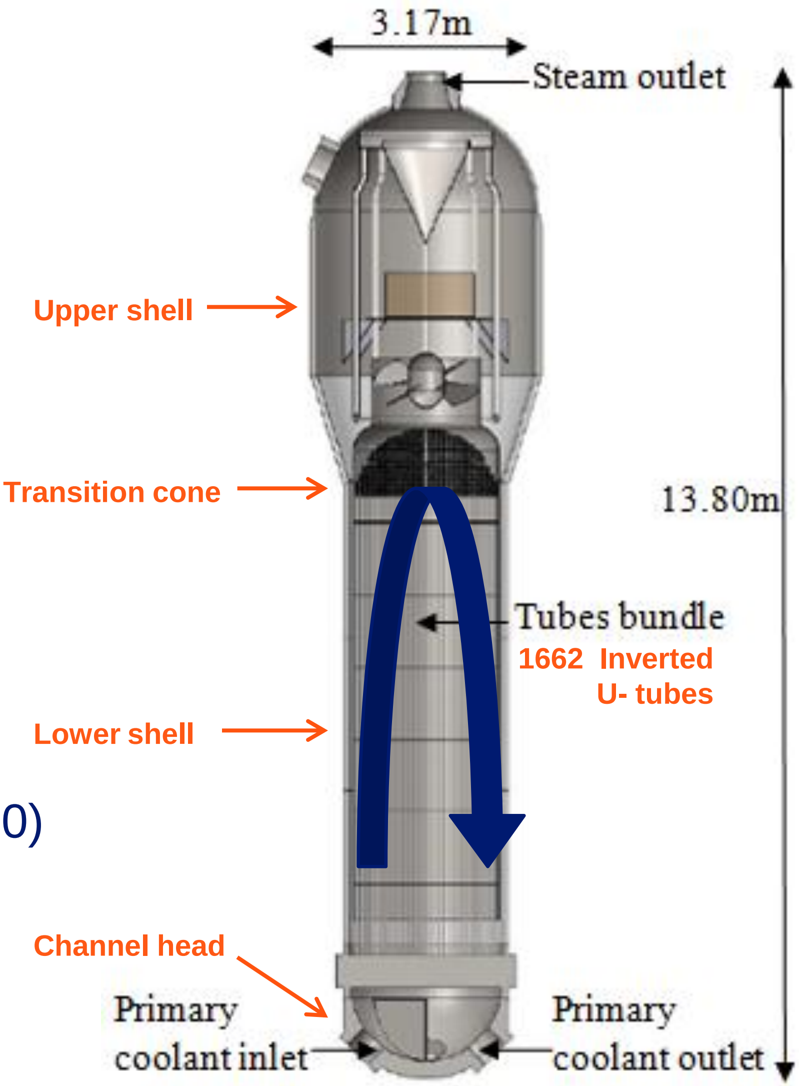


Fig.3. CHOOZ-A SG dimensions

2. MEASUREMENTS DEVICES 1/3

- External gamma spectrometry measurement: NaI Scintillation counter

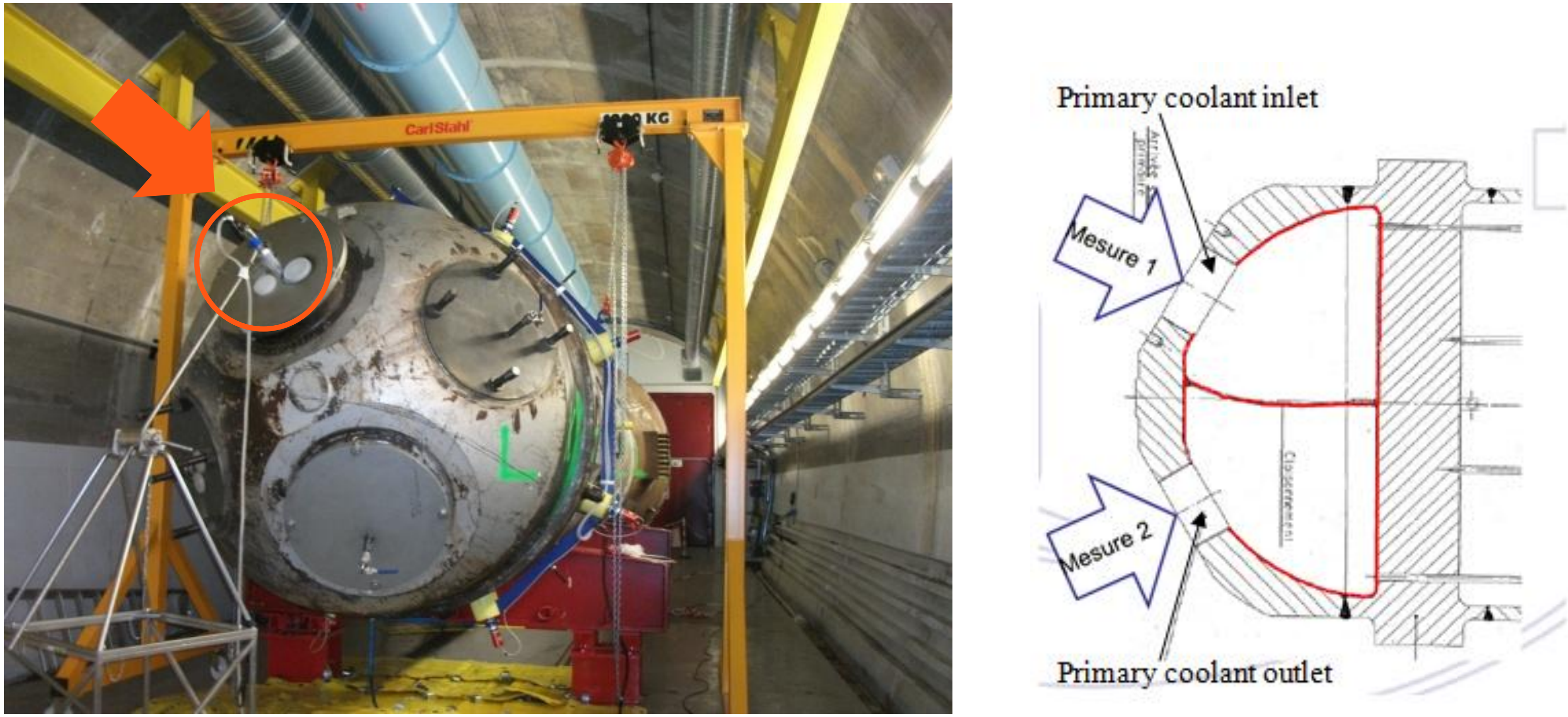


Fig.4. Measurements device for the channel head

2. MEASUREMENTS DEVICES 2/3

- External gamma spectrometry measurement: NaI Scintillation counter

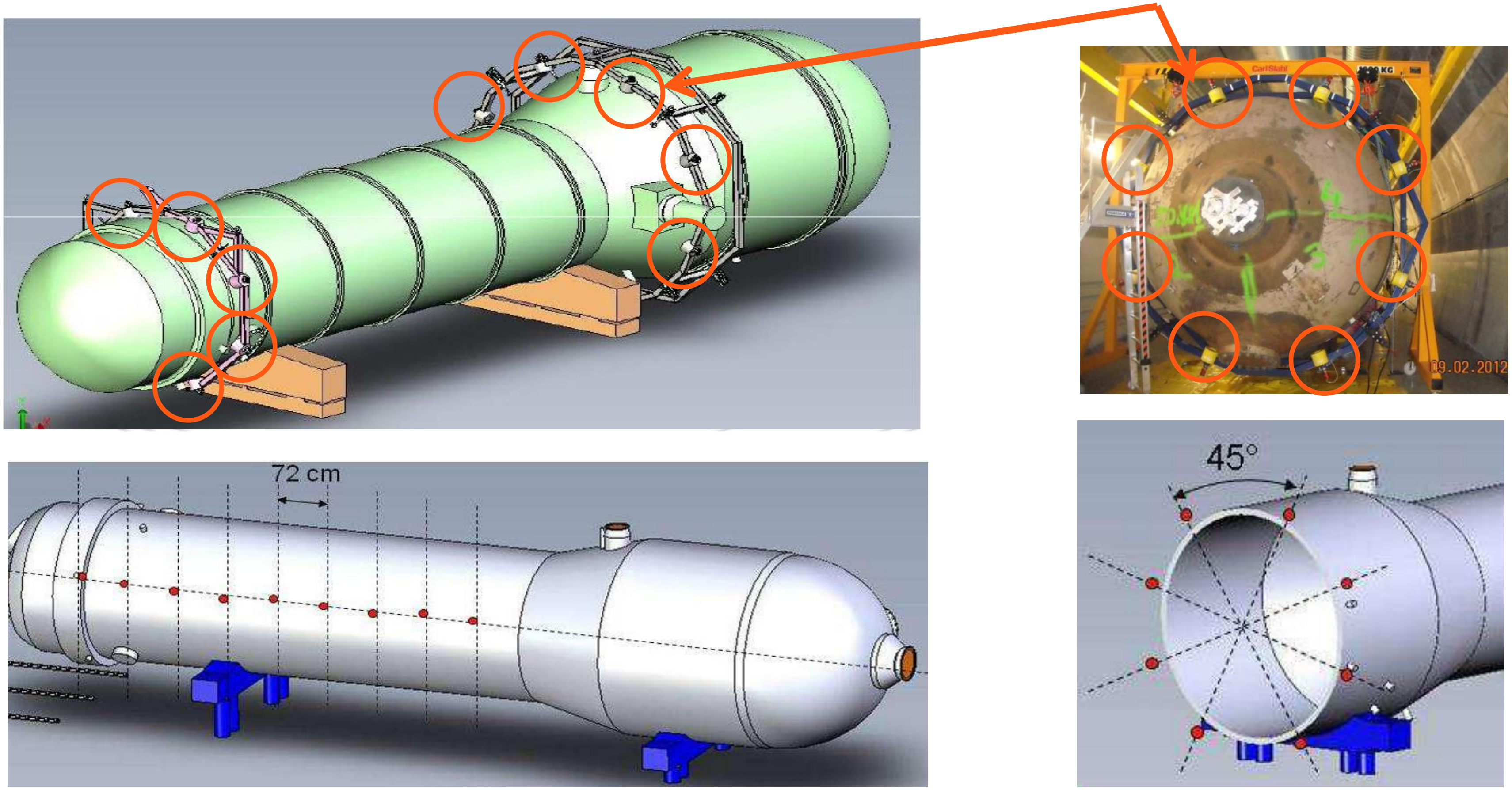


Fig.5. Measurements on the tube bundle

2. MEASUREMENTS DEVICES 3/3

- Inner tubes measurements: CZT semiconductor probe

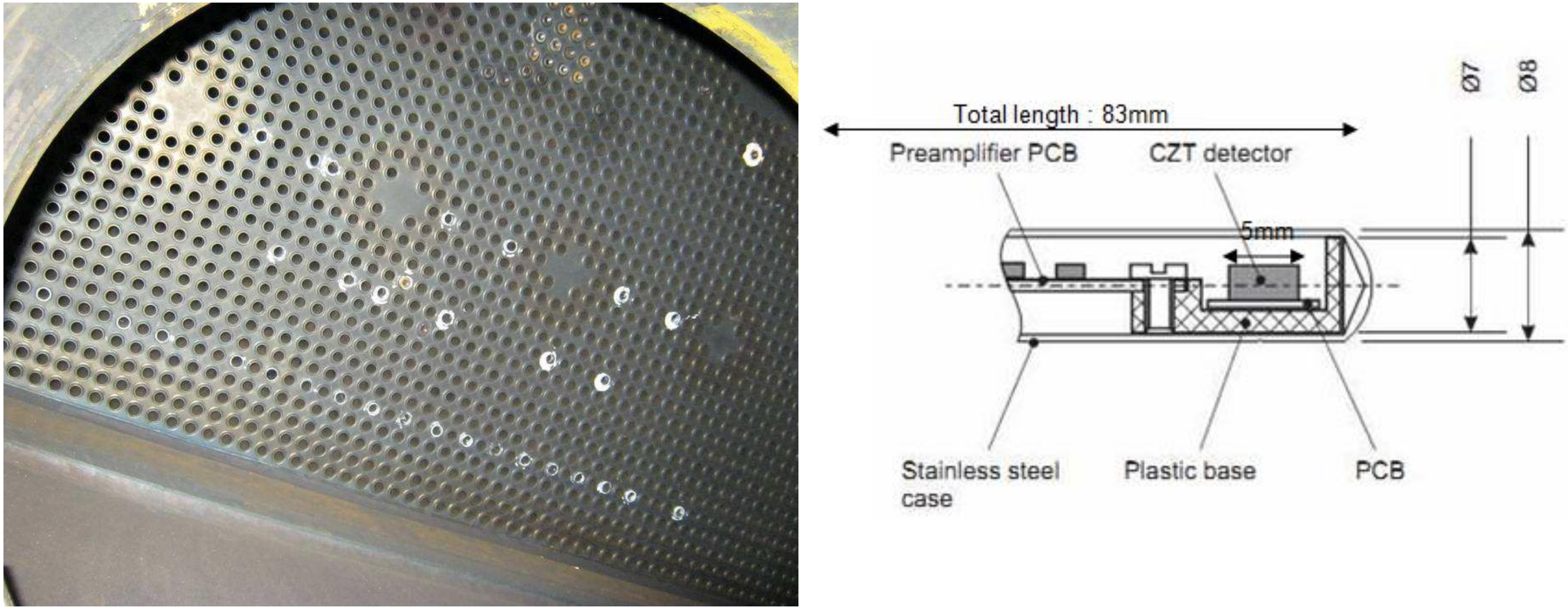


Fig.6. Inner tube measurements

3. SIMULATIONS FOR MEASUREMENTS DATA EXPLOITATION : HYPOTHESES 1/2

- Calculation of the transfer functions :

  MERCURAD simulation

- Principal hypotheses :
  - □ Channel head, transition cone, upper shell : very simple model, contamination uniformly spread
  - □ Tube bundle : specific model with different activity level weighted thanks to inner measurements

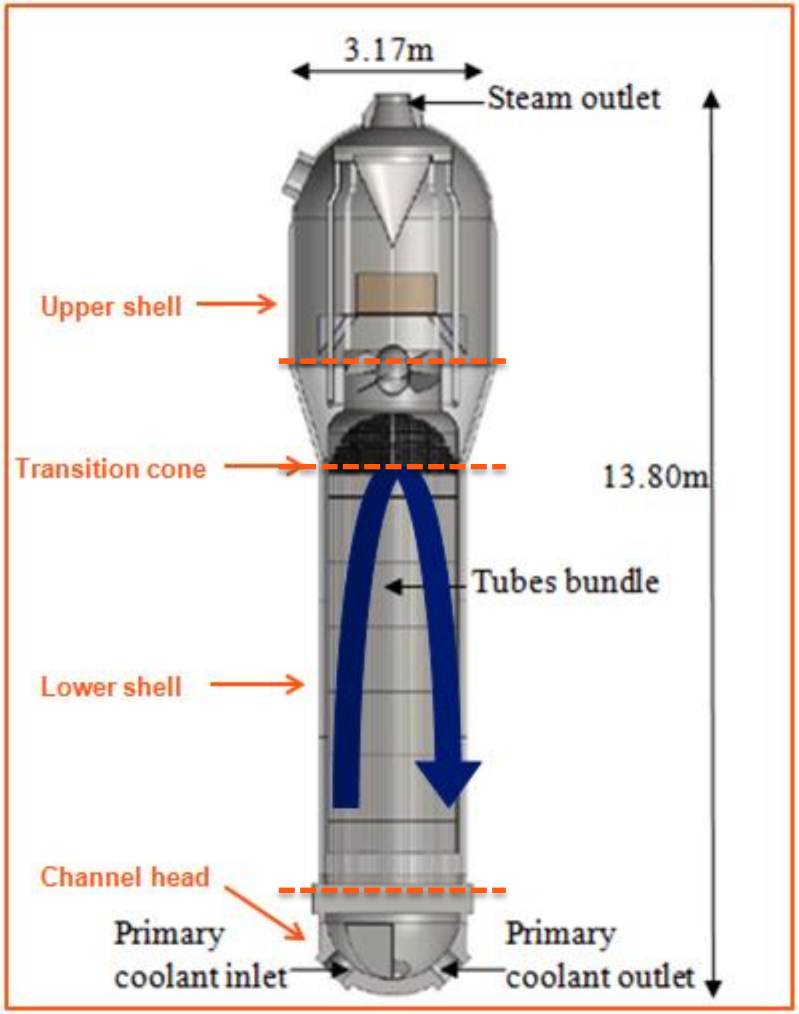


Fig.7. Subsections for MERCURAD model

3. SIMULATIONS FOR MEASUREMENTS DATA EXPLOITATION : HYPOTHESES 2/2

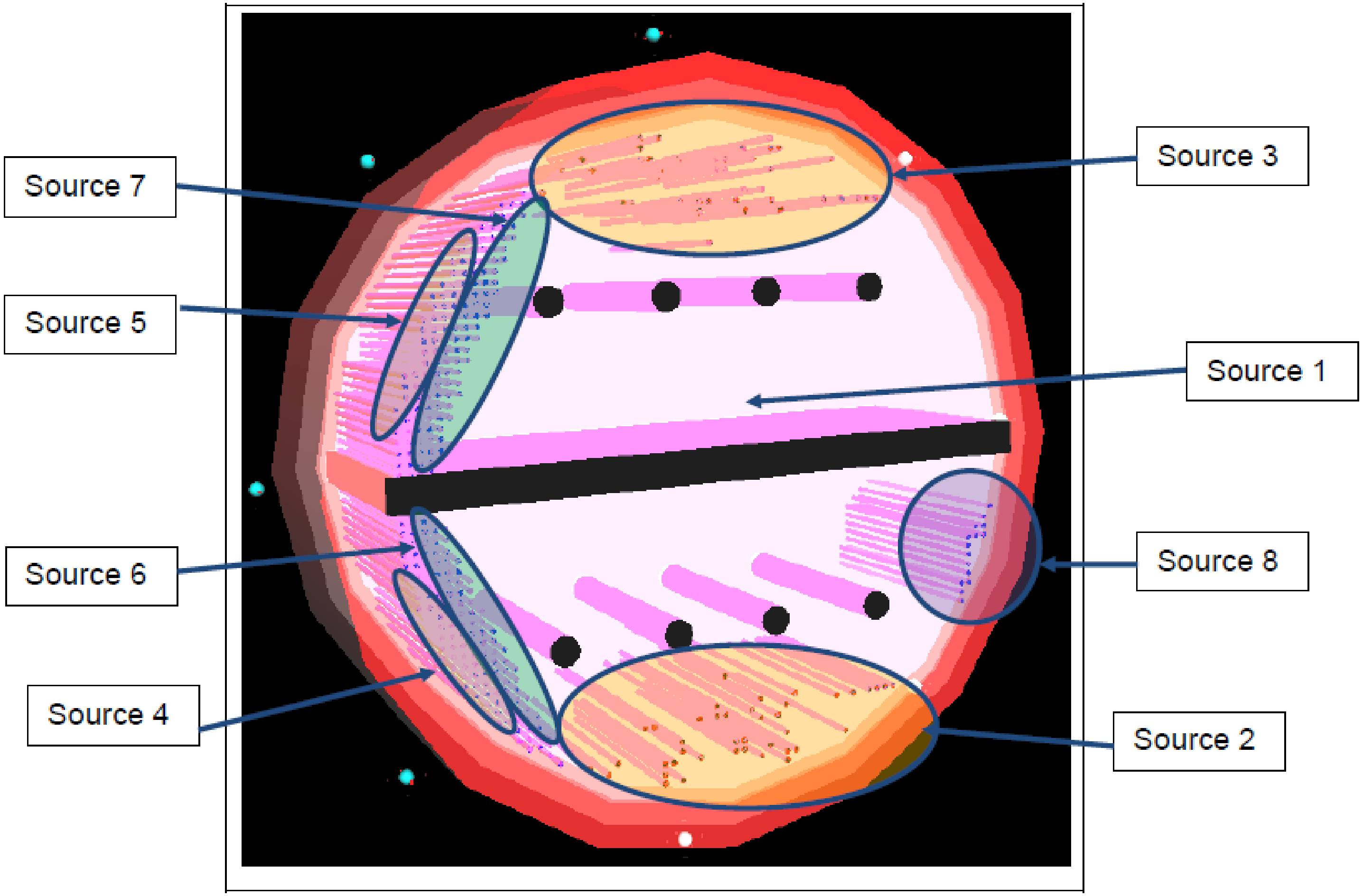


Fig.8. Chooz-A SG4 tube bundle MERCURAD model

3. SIMULATIONS FOR MEASUREMENTS DATA EXPLOITATION : ACTIVITY CALCULATION

- Key nuclide ^{60}Co :
  - Transfer function calculated for each activity source/detector/position
  - Channel head ^{60}Co activity : $\overline{X}$(2 detectors' measurements)
  - Tube bundle ^{60}Co activity : $\sum\overline{X}$(8 detectors'measurements)$_i$

    i=1 to 10 = positions lenghtwise along the SG
  - Upper shell activity : activity surface measurements (swipe measurements)
- Difficult to mesure nuclides: calculation with Chooz-A scaling factors

4. DISCUSSION : UNCERTAINTIES

- Measurements uncertainties
- Detector calibration uncertainties
- Simulation uncertainties (hypotheses of the 3D model, of activity distribution)

⚠ Tube bundle

4. DISCUSSION : CHALLENGES OF THE METHOD 1/2

Understanding of the tube bundle activity distribution:

- Tubes’ operating and treatment history →definition and localisation of the tubes for inner measurements

Feedback

- External detection of particular activity area → local specific study (additional measures)

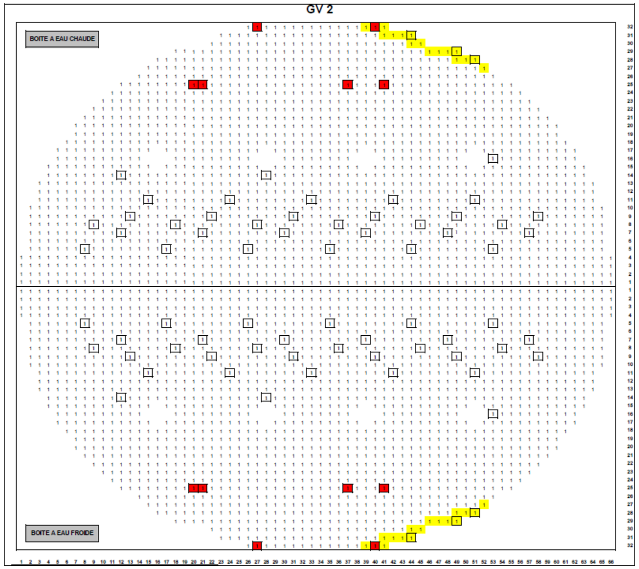


Fig.9. SG2 inside tube measurements

4. DISCUSSION : CHALLENGES OF THE METHOD 2/2

VLLW criterion = specific activity level + nuclides radiotoxicity

Weighted specific activity IRAS(4 SGs) < 1

Average specific activity (Chooz-A SG) < 30 Bq/g

	Number of singular tubes	Number of measured tubes	IRAS
SG1	23	55	0.6
SG2	9	41	0.6
SG3	41	73	1.2
SG4	109	141	1.1
4 SGs			0.79

TABLE II. Number of measured tubes and VLLW radiological storage acceptance index

CONCLUSION

Decontamination

+

specific characterization

4 SGs stored as

VLL single pieces

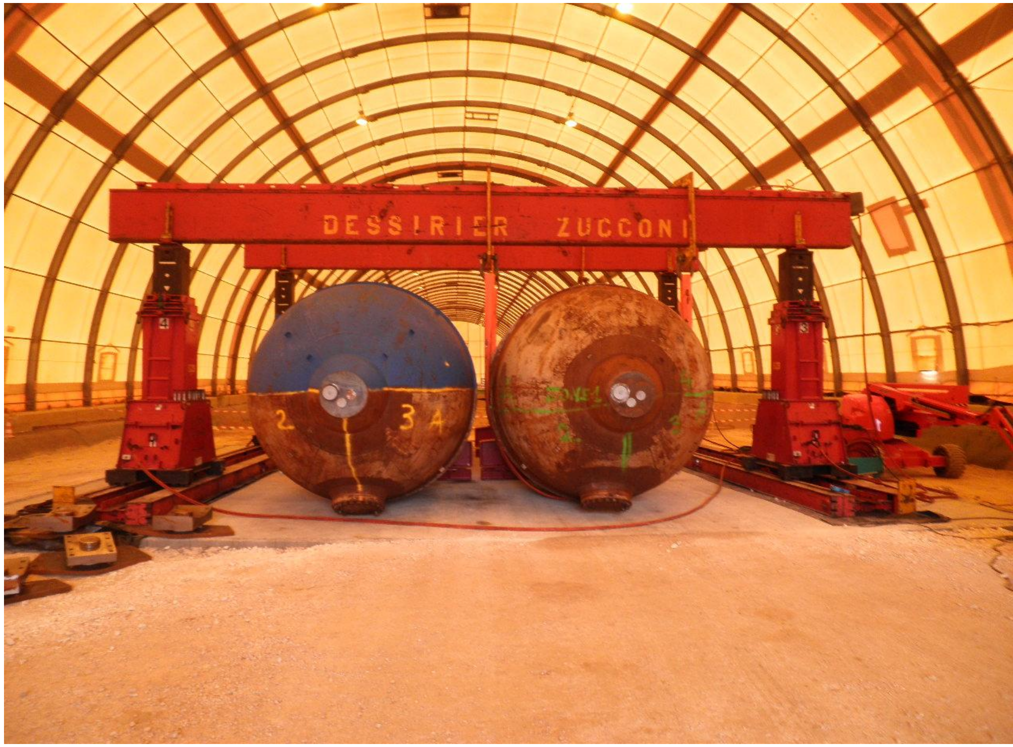


Fig.10. Chooz-A SGs at ANDRA VLL waste repository

THANK YOU FOR YOUR ATTENTION
QUESTIONS OR COMMENTS?

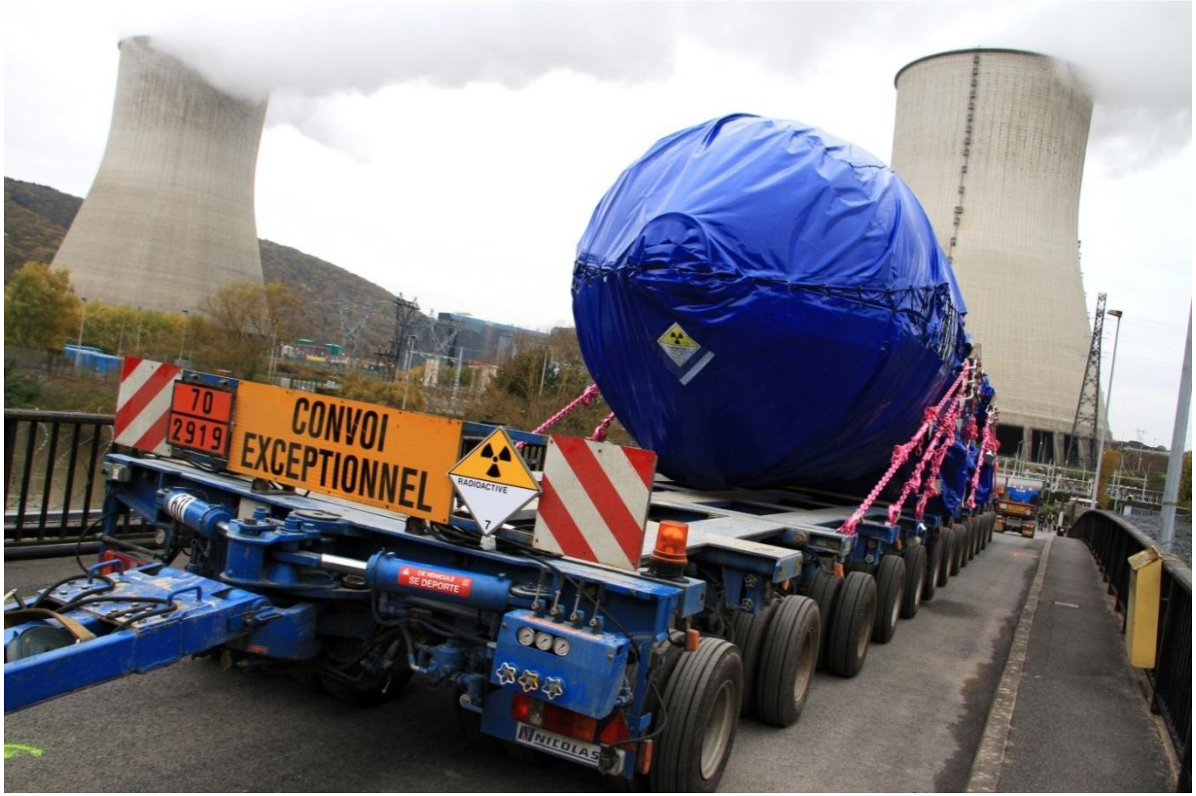


Fig.11. Chooz-A SGs transport to ANDRA VLL waste repository

ANNEXES

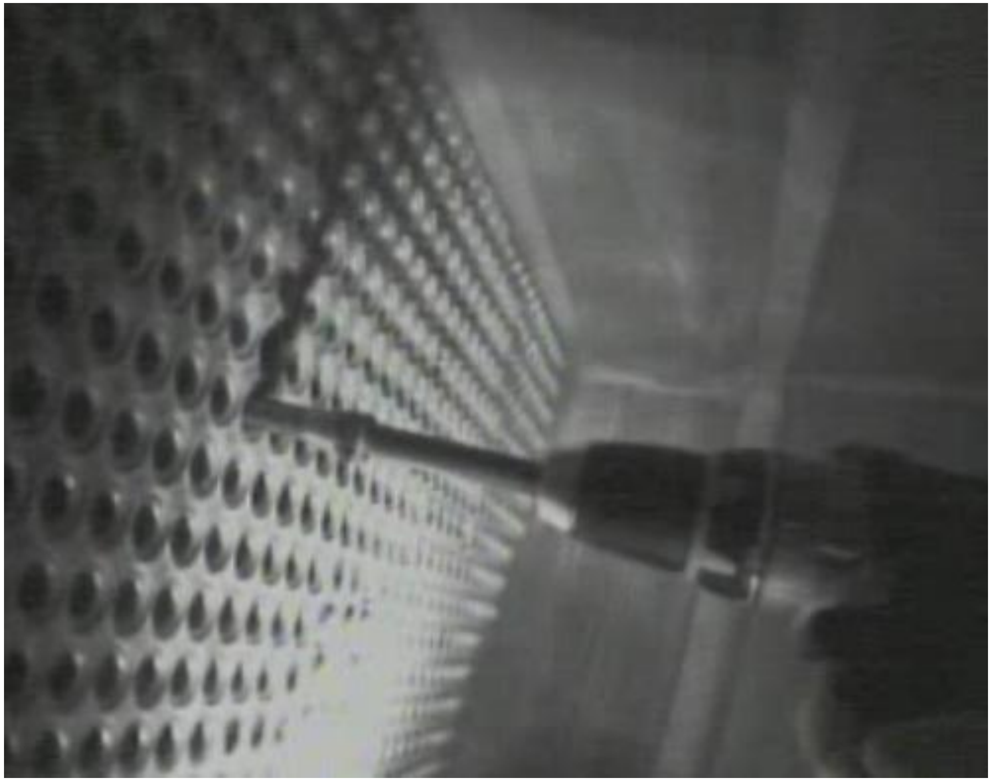


Fig.12. Tubes sampling for radiochemical analyses after decontamination

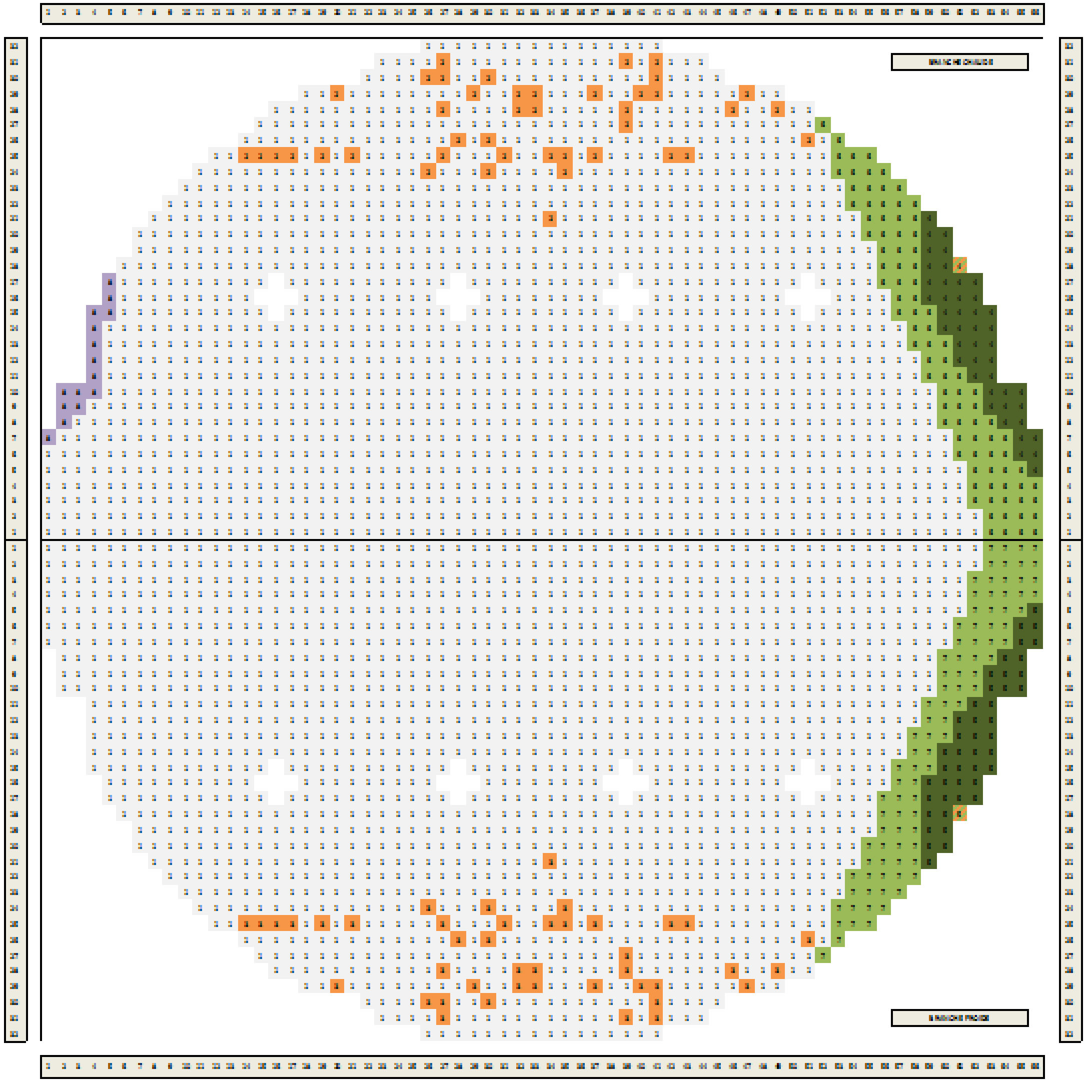


Fig.13. Activity distribution in SG4 tube bundle

$$\overrightarrow{N} = [E].\overrightarrow{A}$$

$$\underbrace{\begin{bmatrix} N_1 \\ \vdots \\ N_i \\ \vdots \\ N_n \end{bmatrix}}_{\overrightarrow{N}} = \underbrace{\begin{bmatrix} e_{0,0} & \cdots & e_{1,j} & \cdots & e_{1,n} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ e_{j,1} & \cdots & e_{0,0} & \cdots & e_{j,n} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ e_{n,1} & \cdots & e_{n,j} & \cdots & e_{0,0} \end{bmatrix}}_{[E]} \underbrace{\begin{bmatrix} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{bmatrix}}_{\overrightarrow{A}}$$

Fig.14. Tube bundle influence matrix resolution

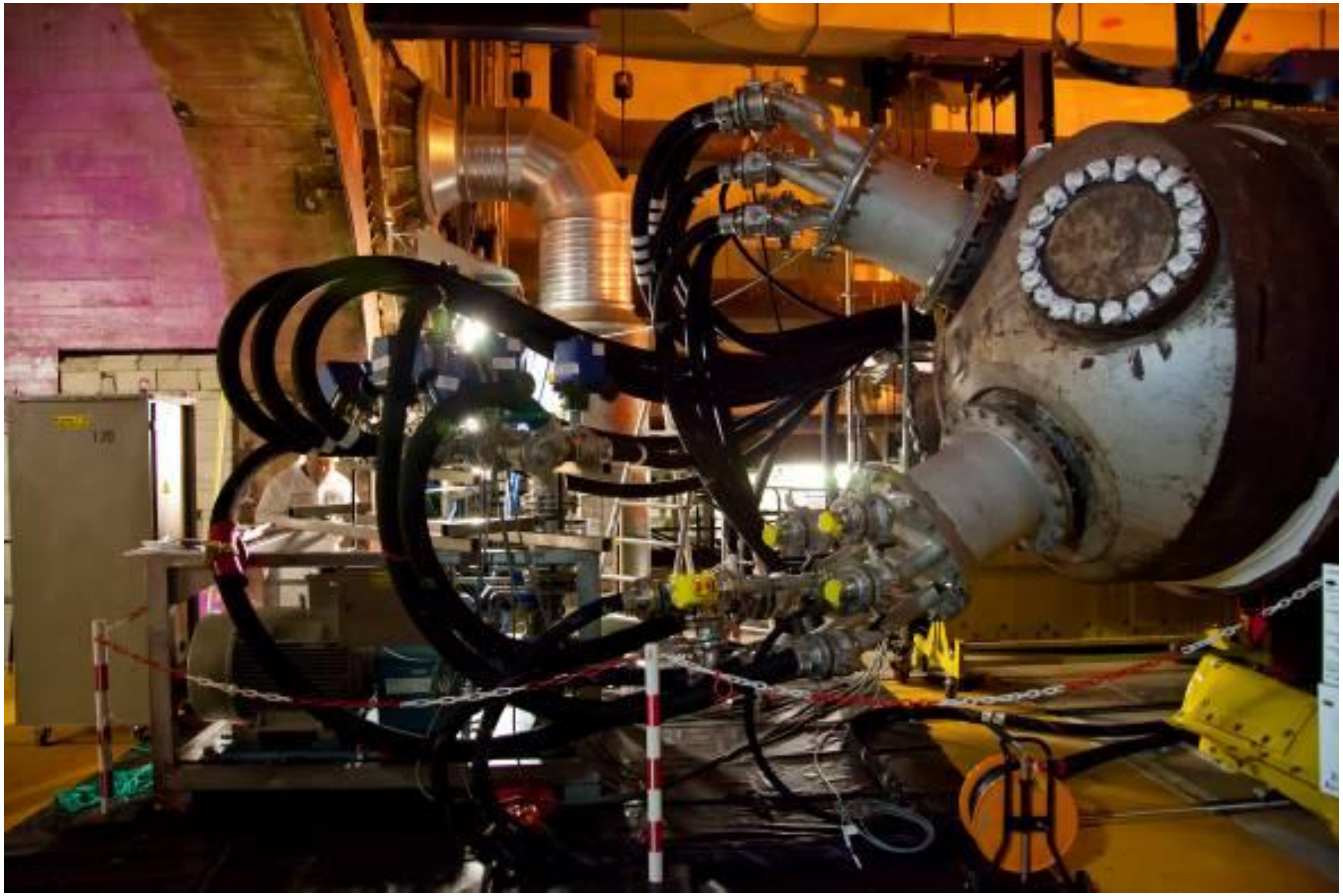


Fig.15. Connexion of a SG to the AMDA© (Automated Mobile Decontamination Appliance) deployed by AREVA NP to apply the CORD© process.

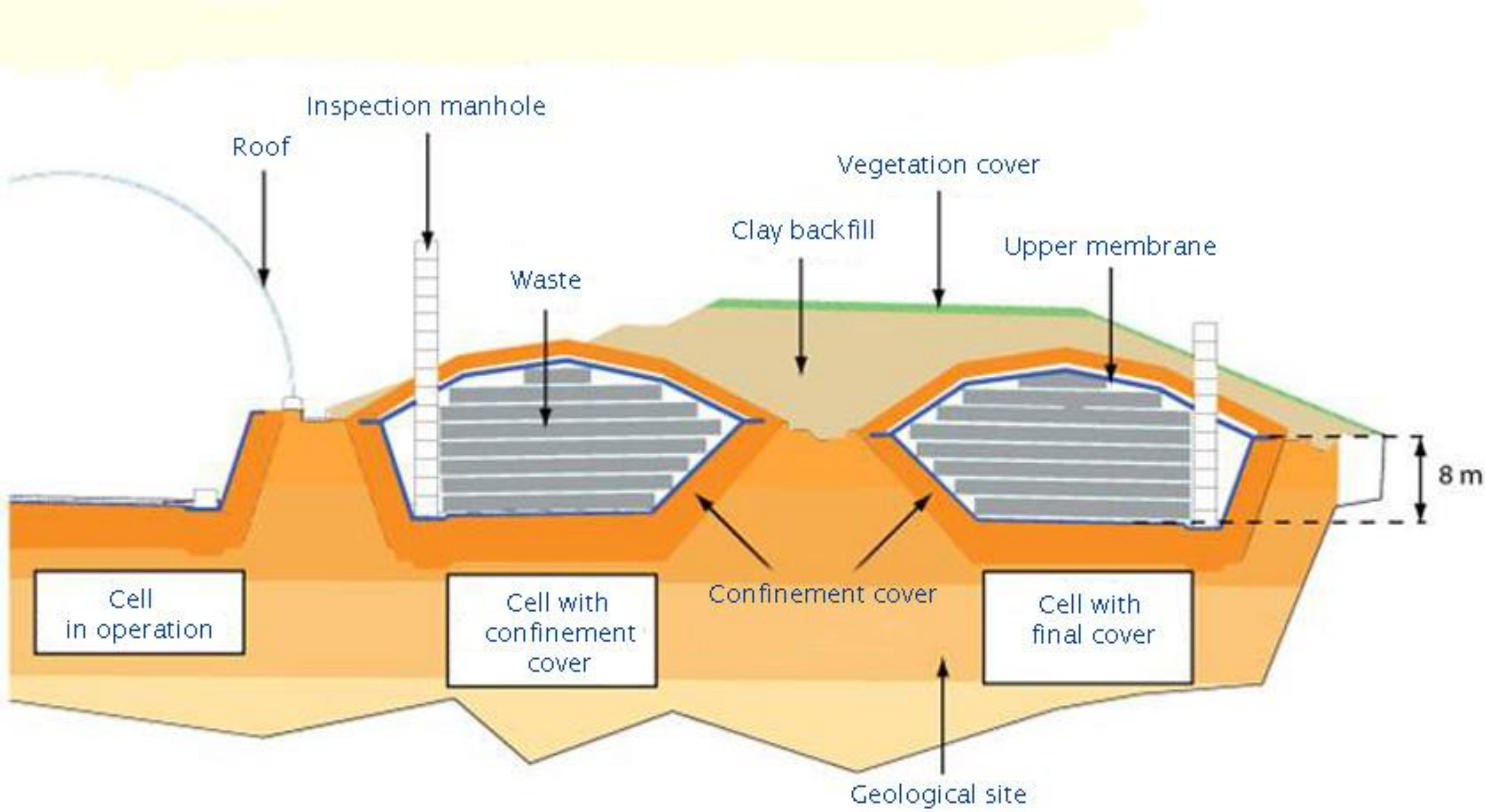


Fig.16. Schematic diagram of a disposal cell at ANDRA VLL waste repository