Spent fuel containers:

too well shielded !

The European Commission's science and knowledge service

Joint Research Centre

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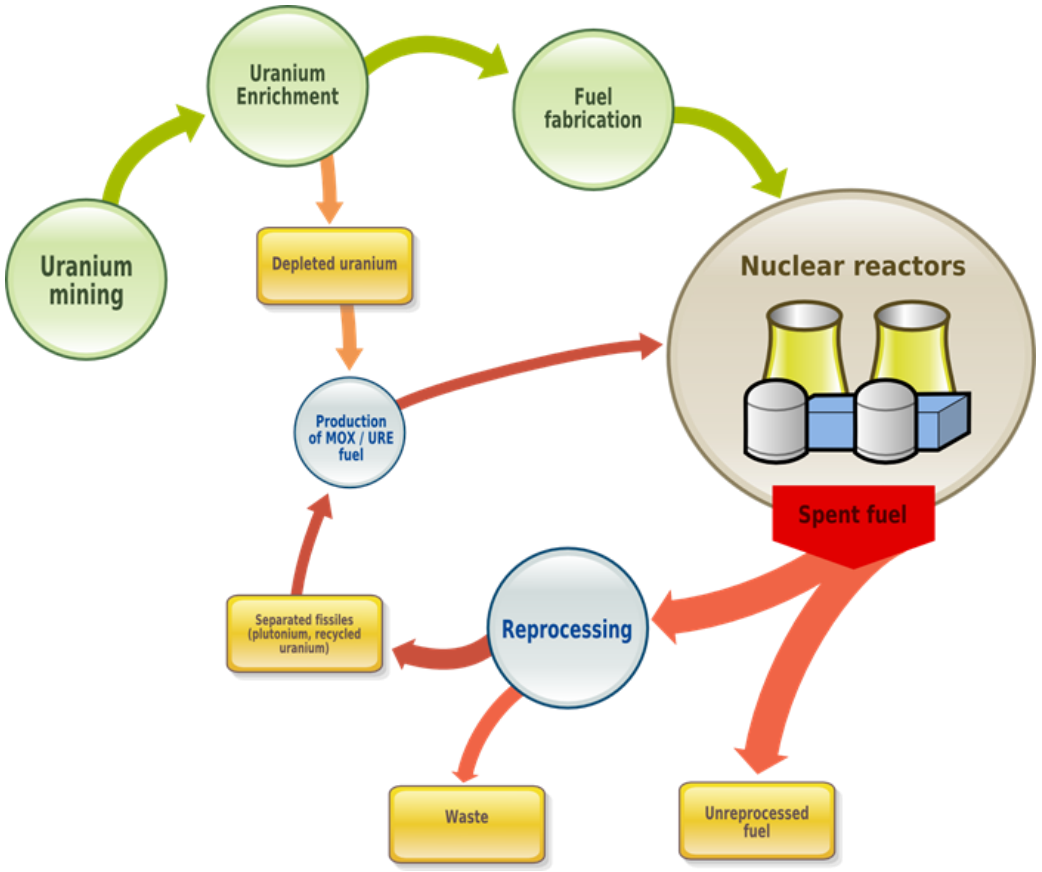
Spent nuclear fuel



World		EU
70	States with nuclear programmes	14 (21)
370 000	t HM spent fuel	162 300
120 000	t HM spent fuel in reprocessing	104 000
250 000	t HM spent fuel in storage	58 000

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Safety requirement for spent fuel containers

- **Criticality control**: prevent criticality → moderator exclusion, n absorbing materials, n flux traps
- **Radiological safety**: prevent release of radioactive material, direct radiation from surface, surface contamination → shielding
- Structural and thermal design: to maintain criticality and radiological safety also under structural and thermal (internal and external) stresses

Canister + overpack

Cask

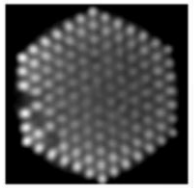
Safeguards approach for spent fuel management facilities

*It can be cost effective to perform any desired **measurements** on an item before placing it into **difficult to access storage***

*Once an item has been measured by the operator and verified by the IAEA, more rigorous **surveillance, containment and monitoring** measures can be applied to reduce the need for re-measurement*

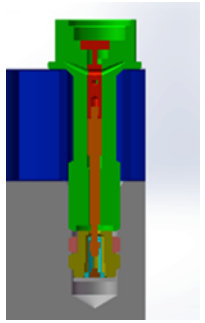
IAEA, International Safeguards in the Design of Facilities for Long Term Spent Fuel Management, NF-T-3.1, 2018

Safeguards measures for spent fuel management facilities



Verification of Nuclear Material

- Identification and localisation of fuel elements: no missing, no dummies = partial defect verification
- Characterisation of the fuel:
  - ➢Burn up
  - ➢Initial enrichment
  - ➢Cooling time

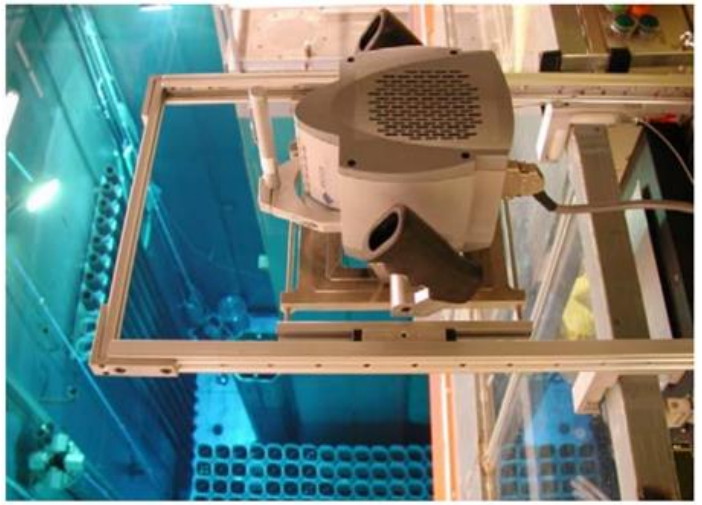


Continuity of Knowledge

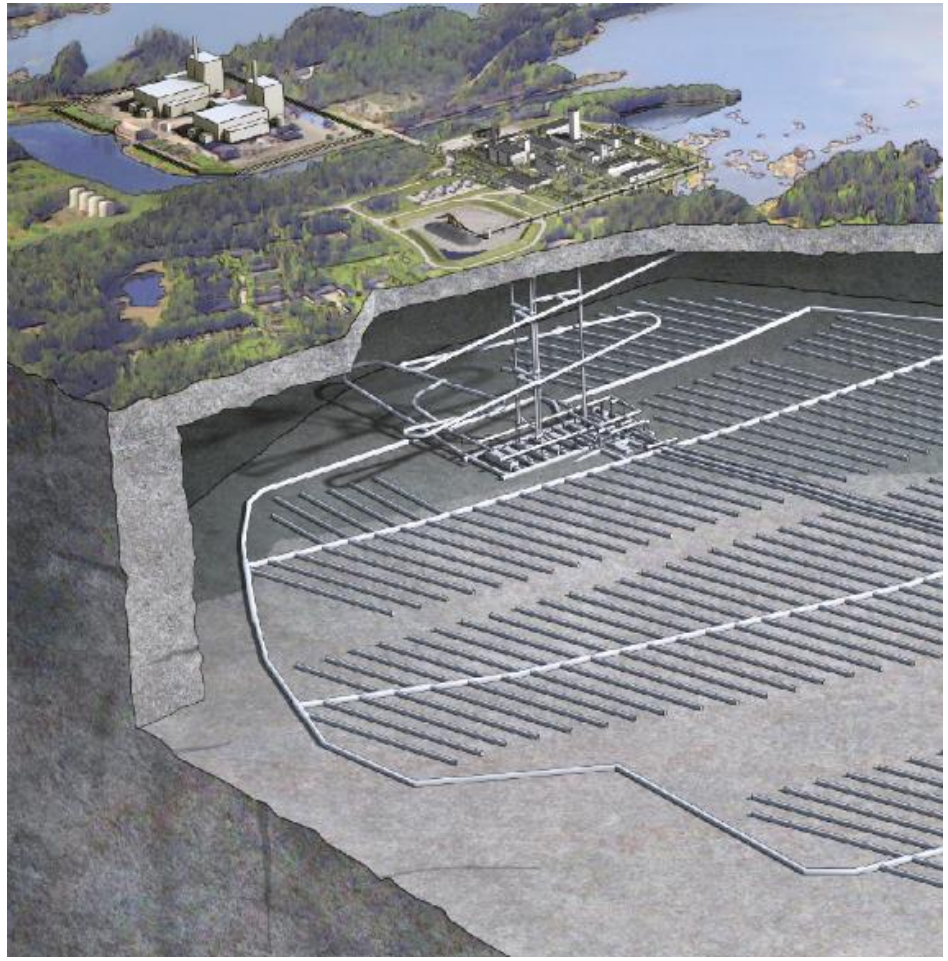
- Containment: seals
- Surveillance: surveillance camera, laser based systems
- Monitoring: radiation monitoring

Instruments approved by IAEA for verification

- **attended verification**: Cerenkov Viewing Device
  - partial defect verification
  - verifies that fuel has been irradiated, can distinguish non fuel
  - only in wet storage
  - needs access from above for each assembly

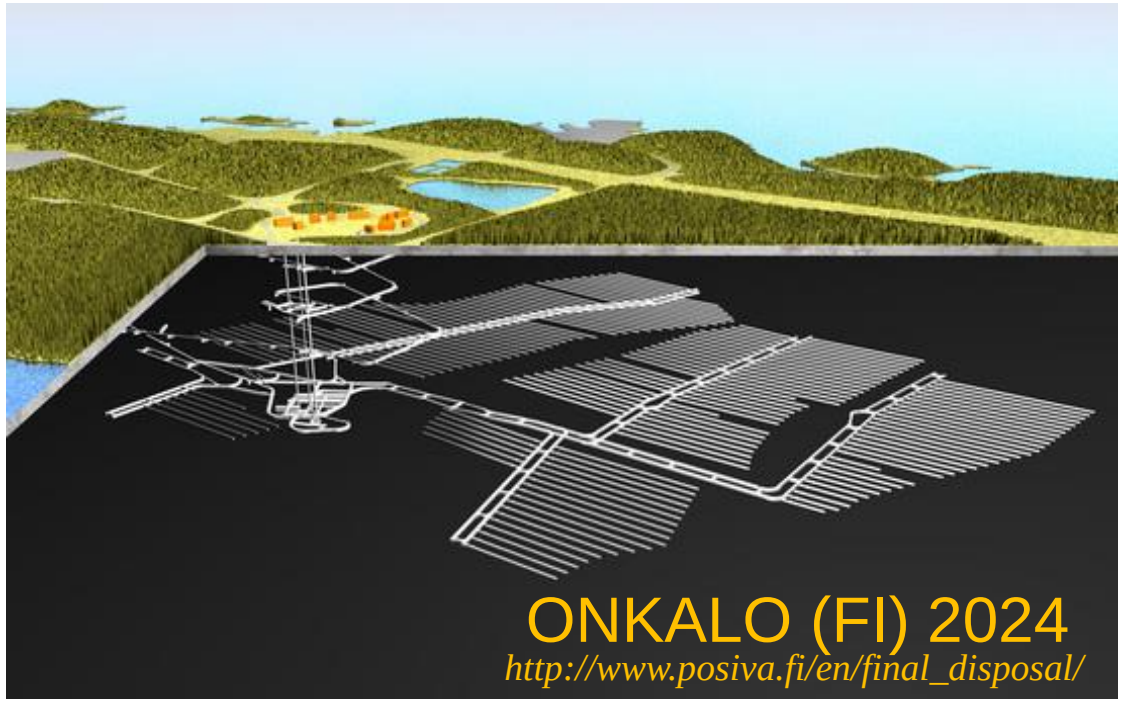


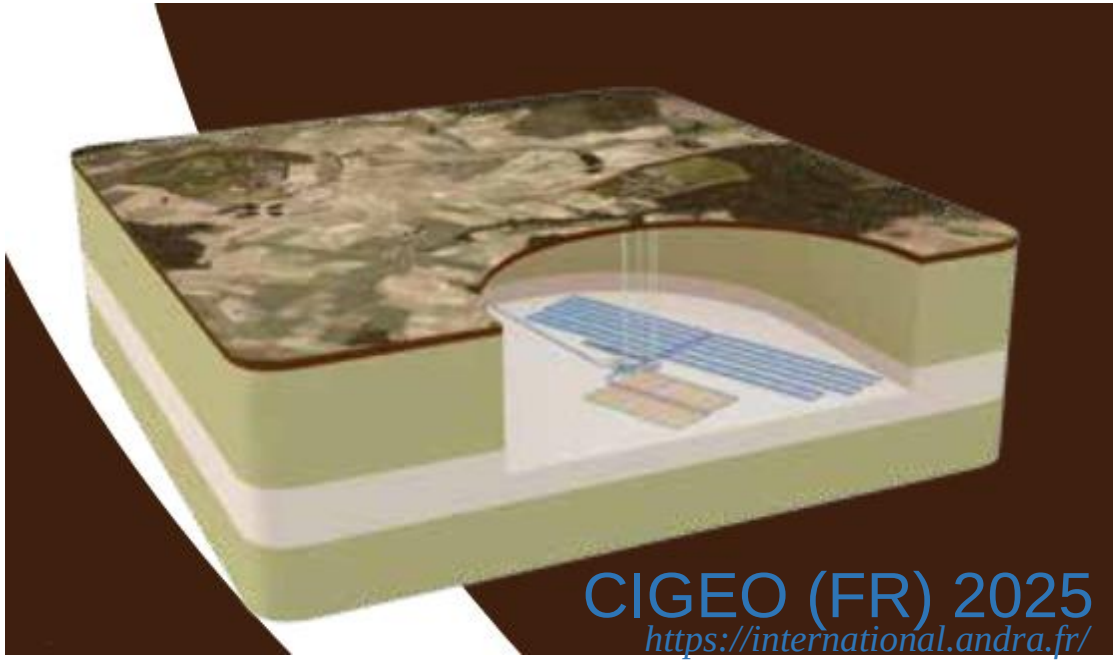
- **unattended method**: Fork DETector (FDET) gamma and neutron measurement
  - total n count and gross gamma intensity
  - assess burnup (more quantitative verification of U and Pu content)
  - but assemblies must be moved to the detector
  - unattended: can provide near real time measurement



Forsmark (SW) 2030

https://www.skb.com/



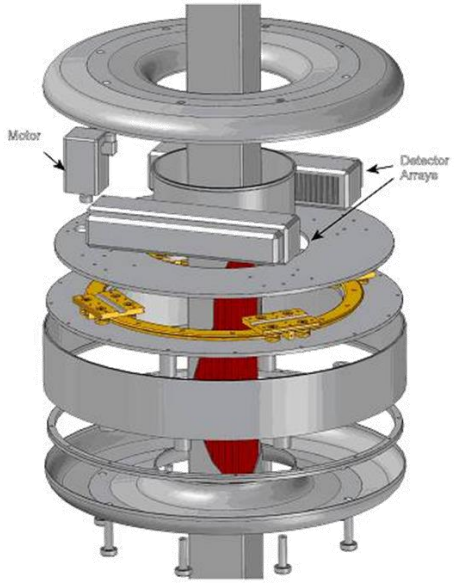


Proposed solution for the verification of spent fuel at the ONKALO encapsulation plant

Integrated NDA system based on 2 complementary techniques:

PGET – Passive Gamma Emission Tomography – can perform pin level detection but cannot measure neutron multiplication in assembly

PNAR – Passive Neutron Albedo Reactivity instrument that complements PGET: can measure neutron multiplication in assembly but cannot perform pin level detection



V. Litichevskyi et al, Helsinki Institute of Physics, *Spent Fuel Assembly Characterisation by a Passive Neutron Albedo Reactivity Instrument as a part of Integrated NDA System for Encapsulation Safeguards,* at ESARDA Annual Meeting (Luxembourg, 2018)

- Loss of Continuity of Knowledge (e.g. broken seal)
- Loss of integrity of the container (leakage)
- Failure of surveillance system

➢ **re-verification**

of a sealed container with heavy shielding, bulk material

- Needs highly penetrating probes
- Requires low absorption of probe and emitted signal

➢Possible techniques: **muon** or **antineutrino**

Future R&D for spent fuel verification and re-verification

- **Hybrid integrated systems** based on complementary NDA techniques for the verification of spent fuel
- **Exotic techniques** for the re-verification of spent fuel
- **Imaging techniques** (e.g. tomography): best use of information for partial defect localisation
- **Modelling and simulation**: increase reliability of nuclear material characterisation for confrontation with measured results
- Strengthening **containment**, **surveillance** and monitoring
- Better use of **data** from operator's process monitoring and control, data analytics, secure data management

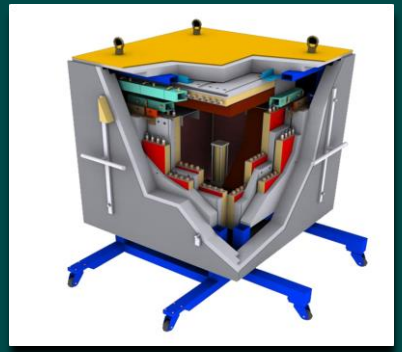
Ongoing research at JRC

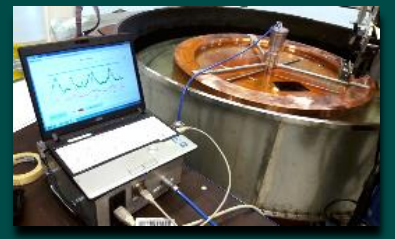
Nuclear material **verification, NDA**

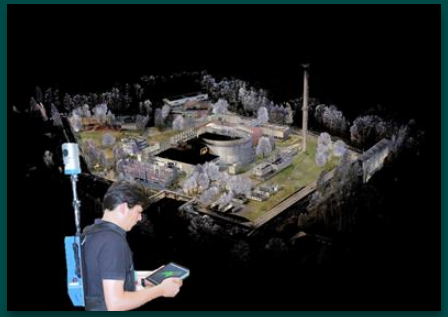
- Pulsed n interrogation facility
- Gamma Spectroscopy and Delayed Gamma Spectroscopy
- Muon tomography (exploratory research)

Containment, surveillance and monitoring

- Ultrasonic seal, ultrasound identification and authentication of welding in copper canisters
- Laser based systems for Containment and Surveillance
- Integrated nuclear process monitoring







Acknowledgments

Stefan Nonneman, Kamel Abbas, Francesco Raiola – Nuclear Security unit

References

- *IAEA, Status and trends in spent fuel and radioactive waste management*, 2018
- *IAEA, International safeguards in the design of facilities for long term spent fuel management*, 2018
- *International Conference on the Management of Spent Fuel from Nuclear Power Reactors: Learning from the Past, Enabling the Future*, 24-28 June 2019, IAEA – Vienna (Austria)
- ESARDA Symposium, May 2019, Stresa (Italy)
- ESARDA Bulletin n. 56, June 2018

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