# Non-Destructive Assay of Spent Nuclear Fuel Prior to Geological Disposal in Finland

Measurement methods for nuclear safeguards

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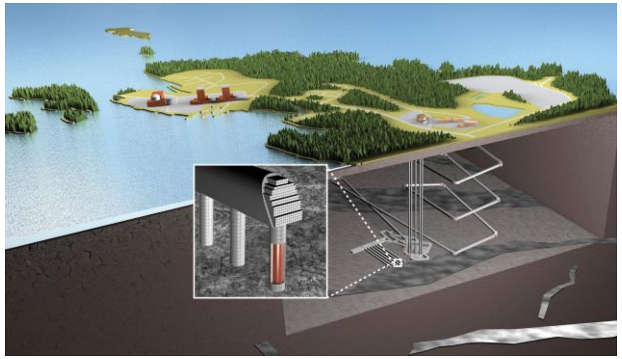
# Background

# Finnish nuclear energy landscape

TVO: Olkiluoto
(OL1, OL2, OL3)



Posiva (owned by TVO & Fortum): encapsulation plant and geological repository for spent nuclear fuel

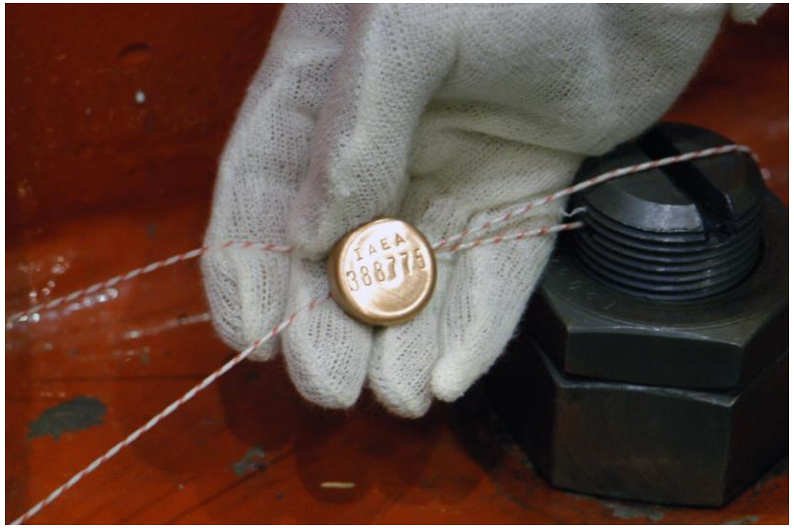
Fortum: Loviisa
(LO1, LO2)

# Nuclear fuel

*Areva*

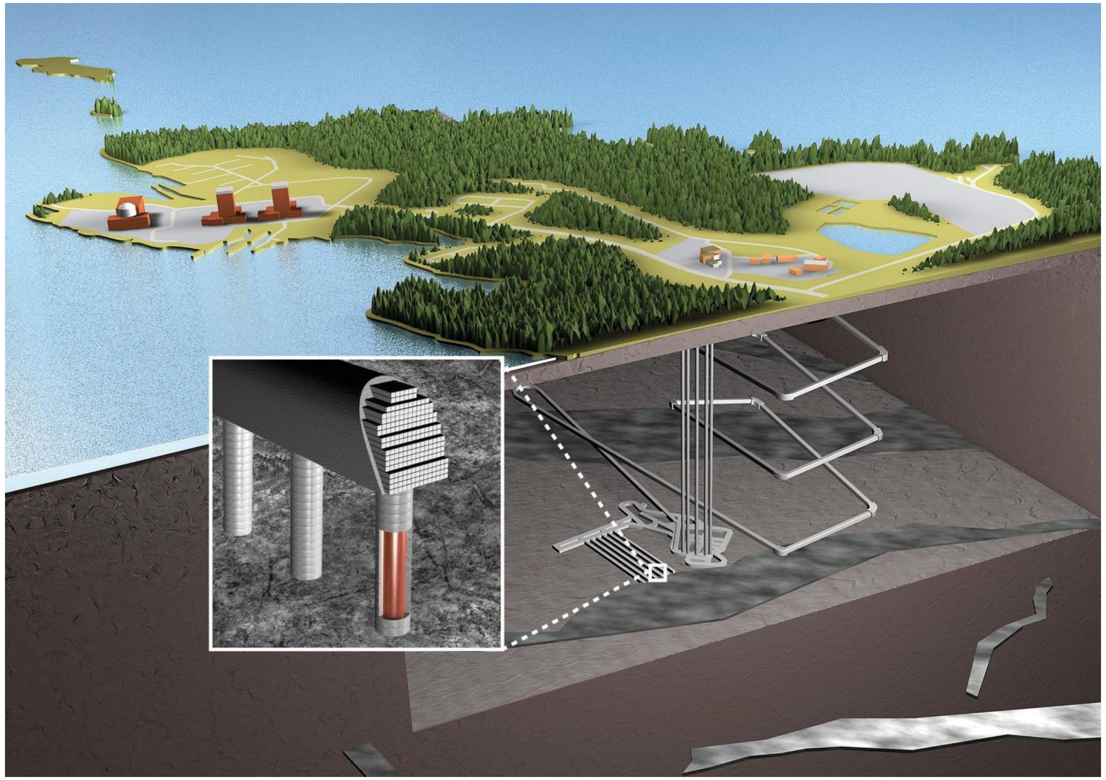
*Ruslan Krivobok/RIA Novosti*

# Nuclear safeguards




*Dean Calma/IAEA*

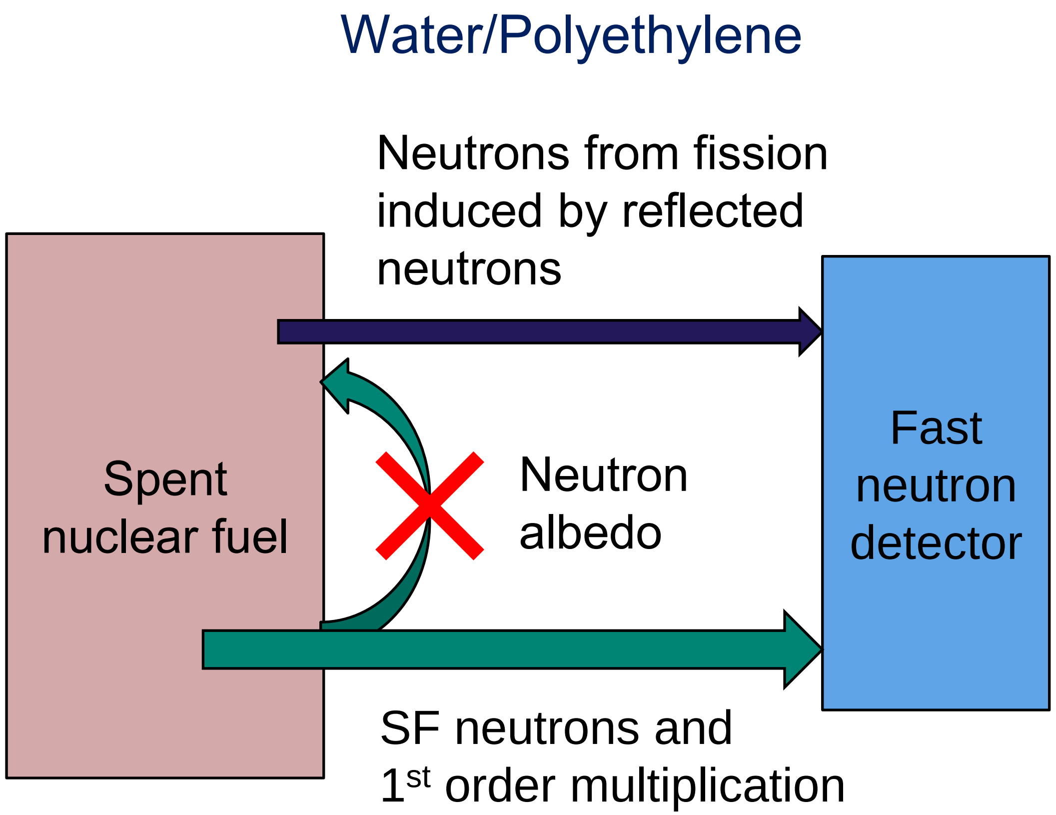
# Geological disposal

*Posiva*

# Non-destructive assay methods

# Passive Neutron Albedo Reactivity (PNAR)



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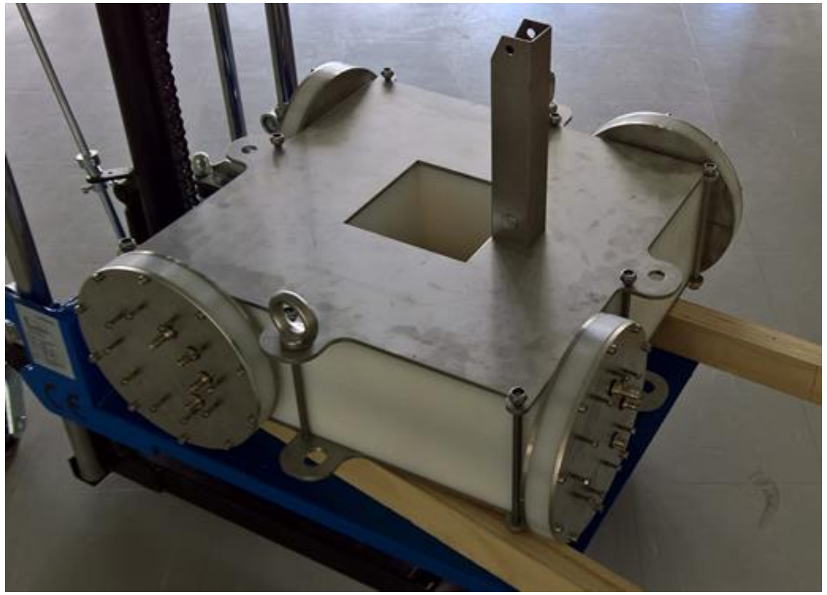
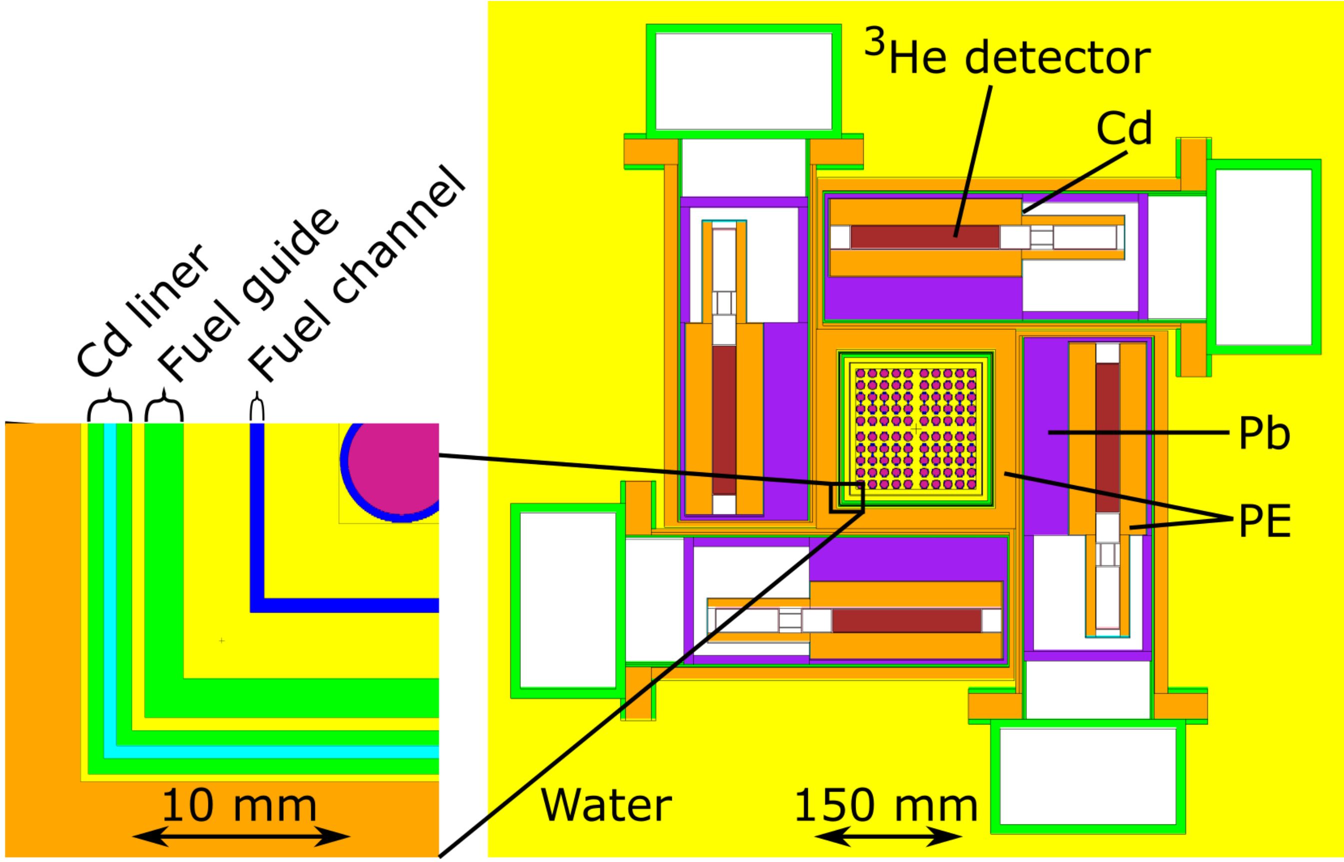
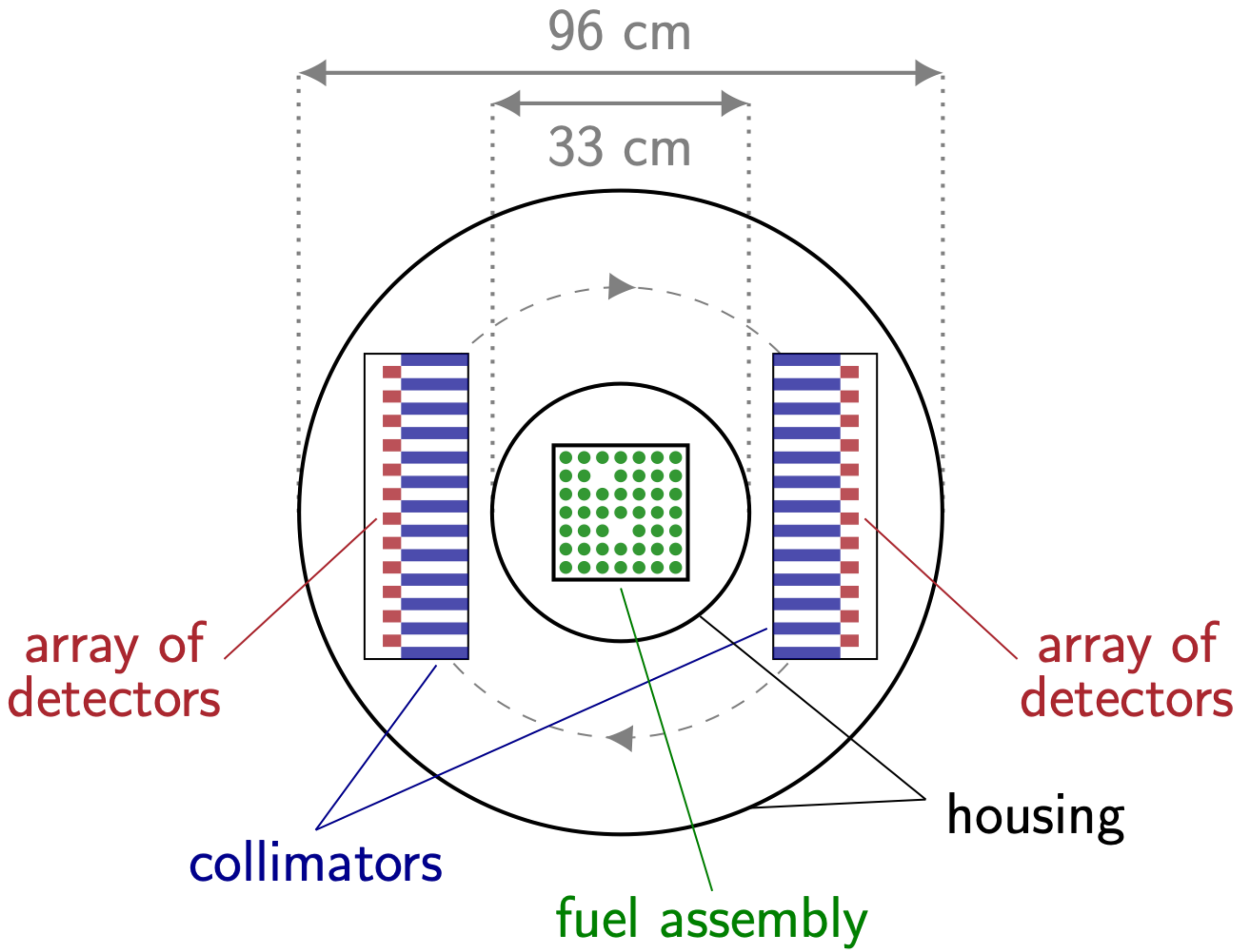
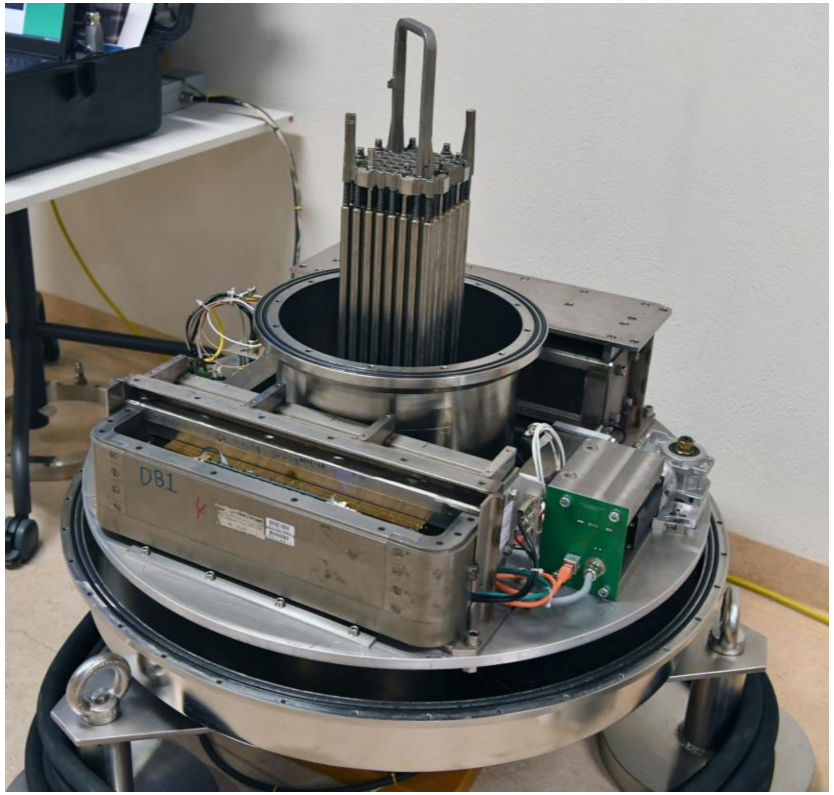




# Passive Gamma Emission Tomography (PGET)

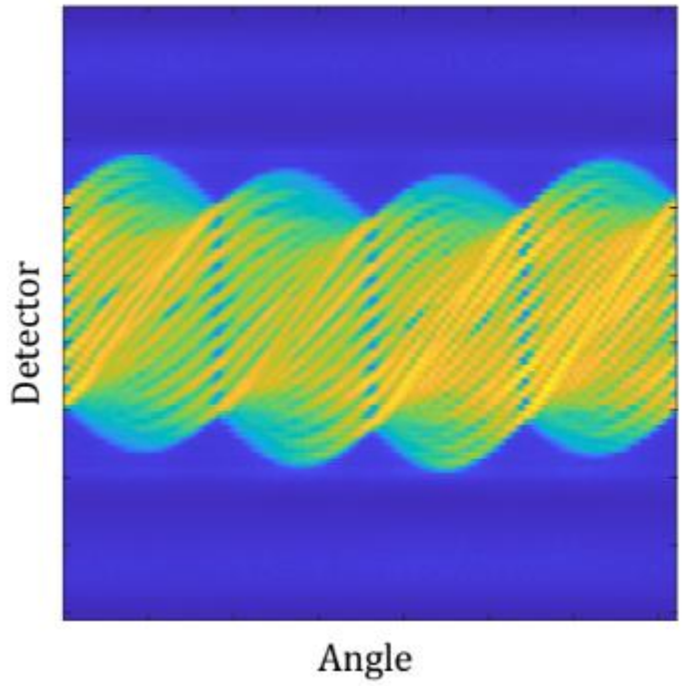


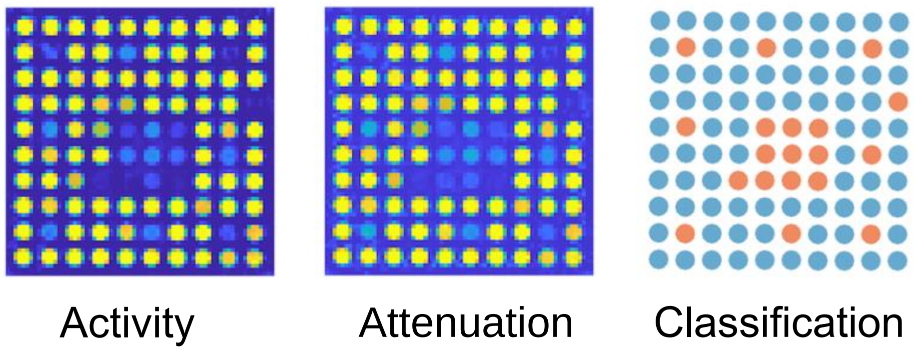
*Dean Calma/IAEA*

# Passive Gamma Emission Tomography (PGET)

**Sinogram**




**Reconstruction**

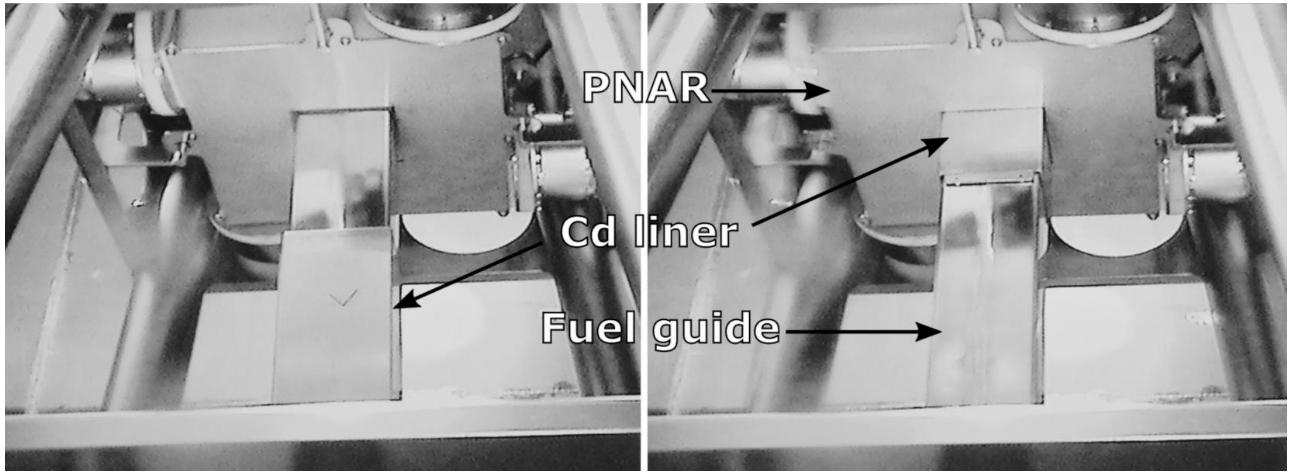


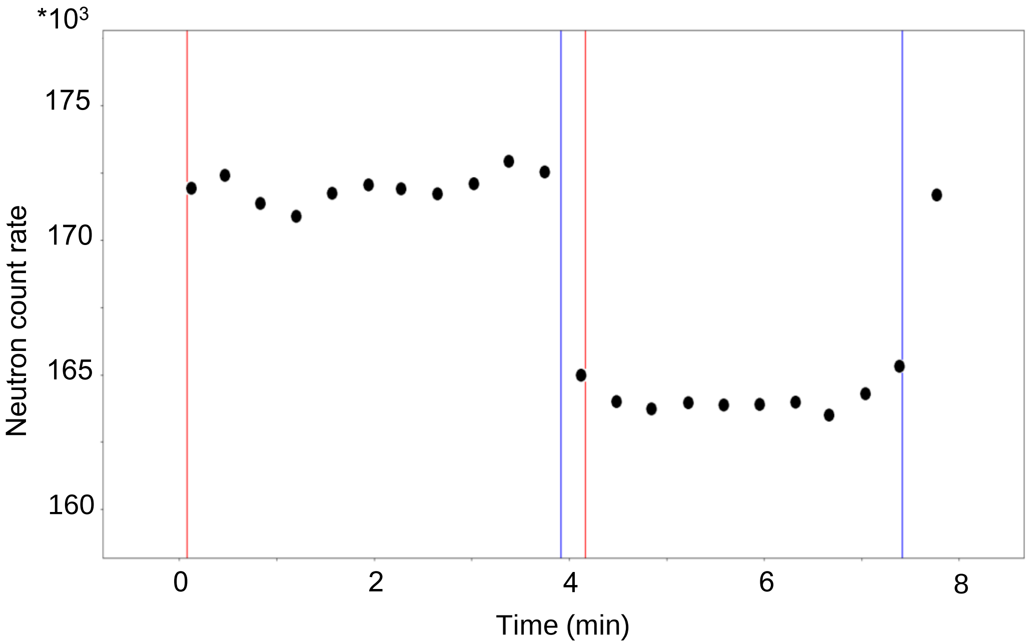
# Analysis and results

# PNAR – Passive neutron albedo reactivity

# PNAR response

- Neutron albedo is suppressed with a Cd liner
- This causes fast neutron detection rate to drop
  – But only if measuring fissile material!
- PNAR Ratio = the ratio of the count rates

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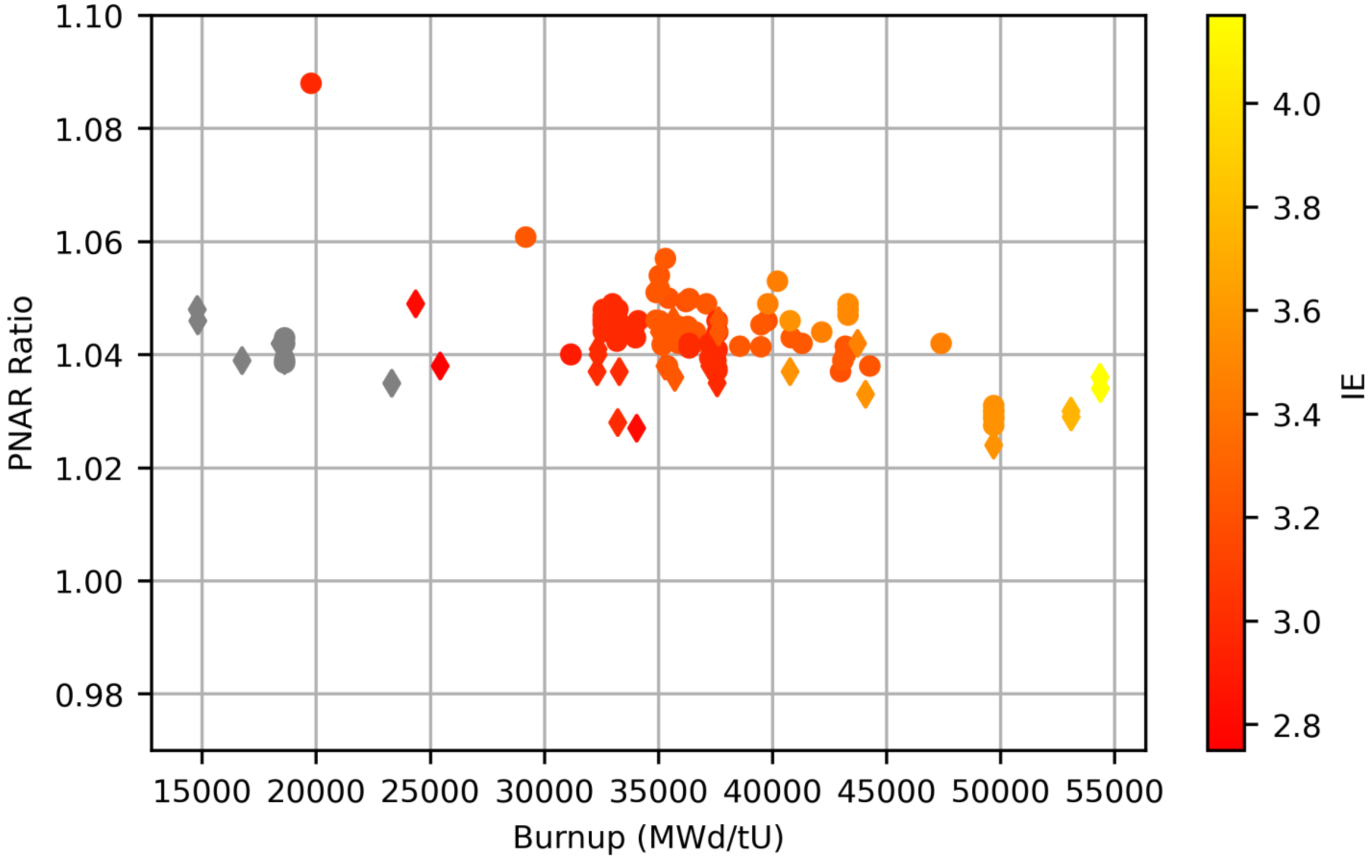
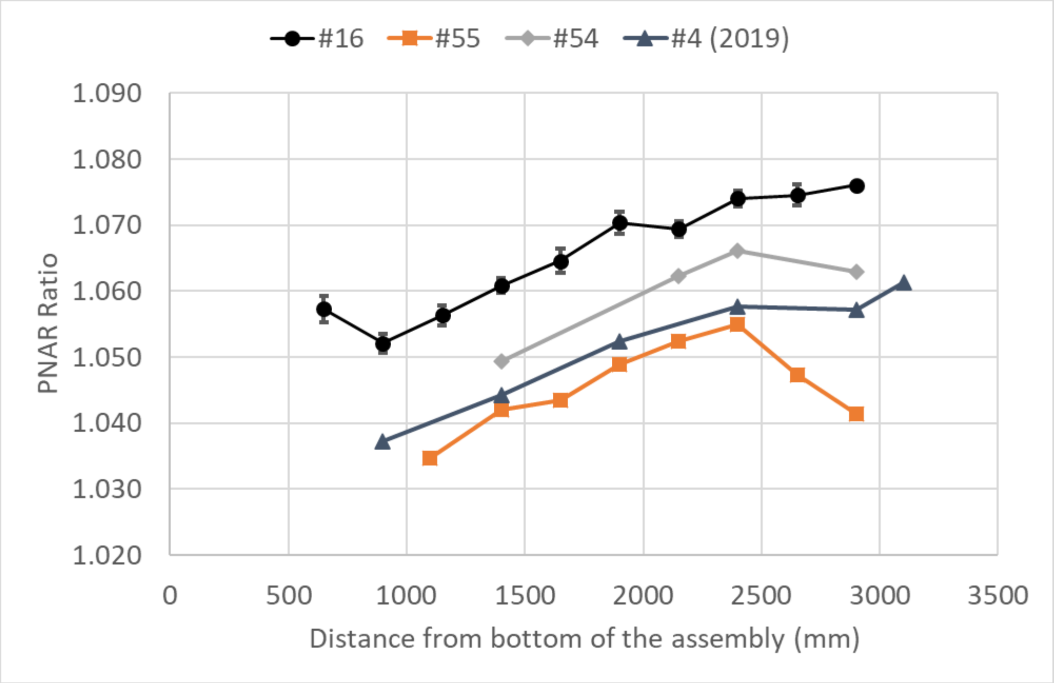
# PNAR results




- Gray < 2.0 % IE
- Diamonds = 2024-2025 measurements (slightly different measurement height)
- PNAR Ratio = 0.97 is the theoretical PNAR Ratio of non-multiplying nuclear fuel

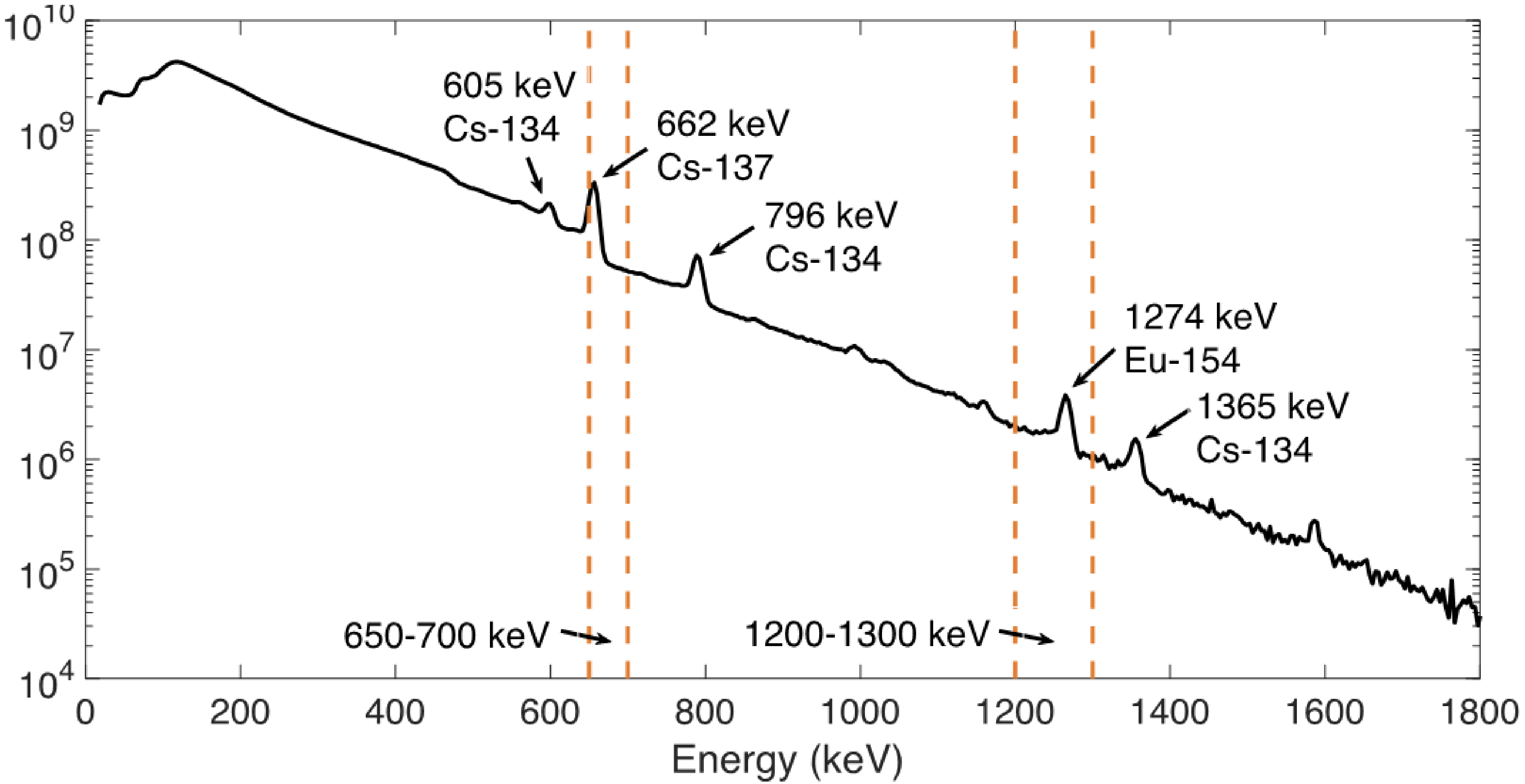
# PNAR results

- Easy to qualitatively assess whether fissile material is present
- Quantitative analysis harder
  - Many unknowns and small amount of experimental data to assess which ones are important
  - Parameters affecting PNAR Ratio include
    - Burnup, enrichment, cooling time
    - Different fuel types and enrichment profiling
    - Anisotropic axial burnup history
    - Operational history effects, e.g. position in core, off-cycles



# PGET – Passive gamma emission tomography

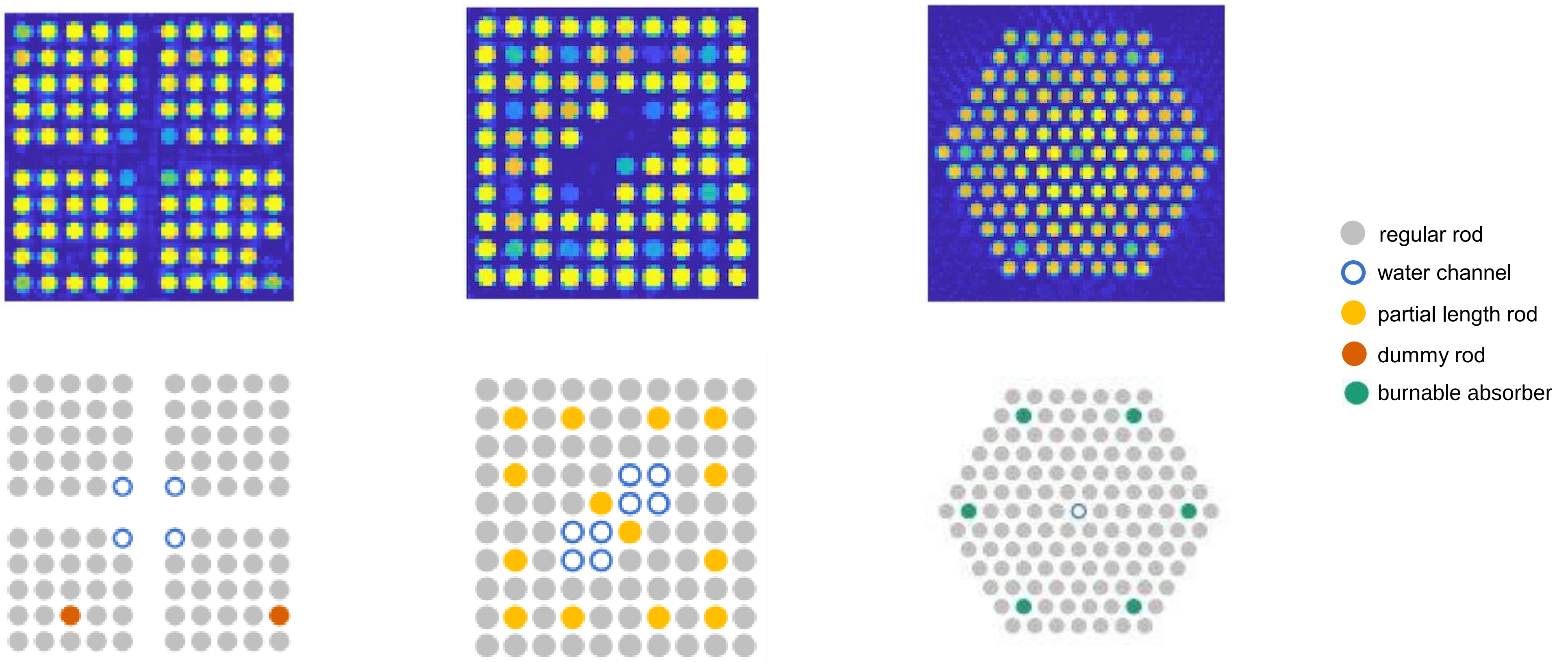
# Gamma energy windows



# Example results

activity

placement of rods




Main gamma energy window: 650-700 keV
photopeak of Cs-137 at 662 keV

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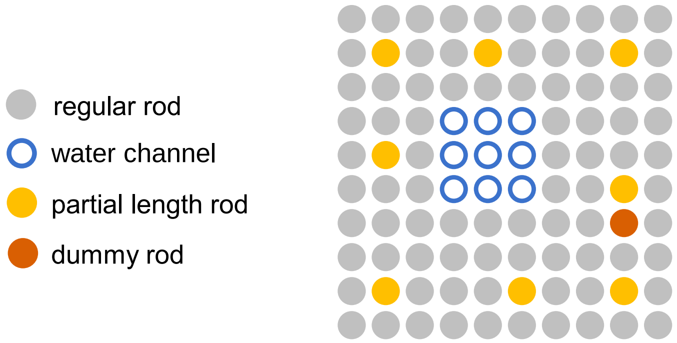
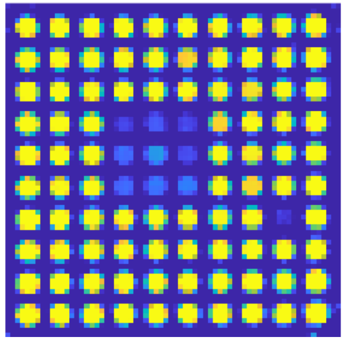
# Analysis competence



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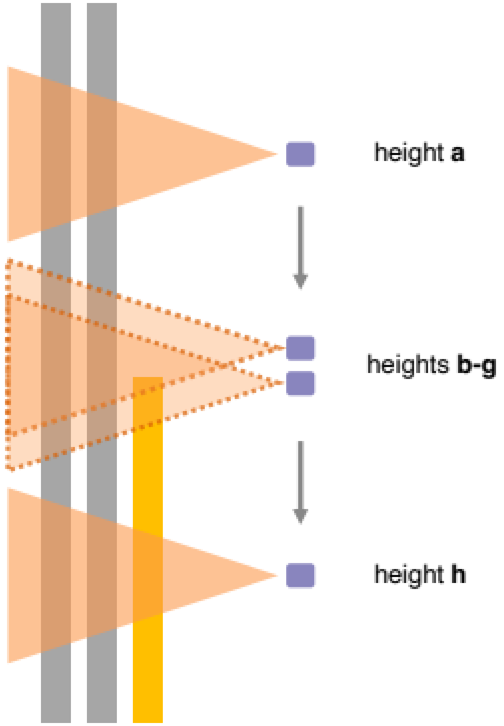


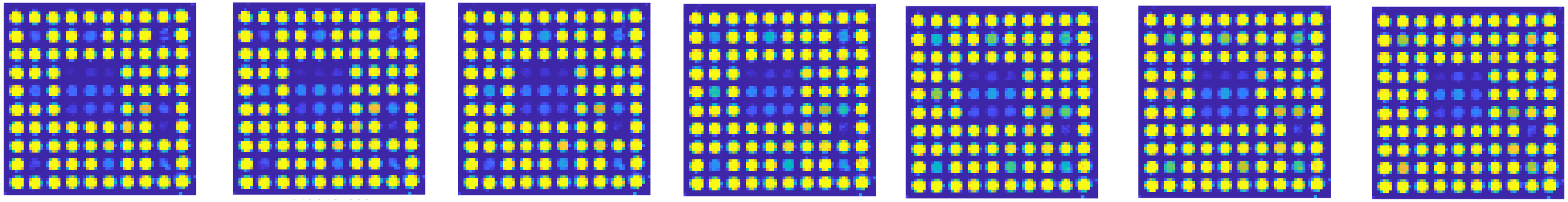

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# Where do we stand now?

# Ready for disposal

- Safeguards concept ready
- Most of the safeguards equipment installations done
- Measurement methods ready
- Trial run of encapsulation plant done

- Upcoming:
  - Trial run of geological repository
  - Operating license approval
  - Start of operations (currently scheduled for 2026)

*Posiva*

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# Thank you!

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# Questions, discussion?