Investigating the gamma and neutron radiation around quivers for safeguards verification purposes

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Content

- Nuclear Safeguards
- Quivers
- Computational methodology
- Flux around quivers

Nuclear Safeguards

Why

- Nuclear material should be used only for peaceful purposes
- Accountancy of nuclear materials

What

- With respect to verification of spent nuclear fuel, an inspector verifies operators' declarations
- Burnup, Cooling time, Initial enrichment, Fissile-content, Integrity

How

- Isotopic composition of fuel depends on reactor operation and fuel history
- Non-destructive (gamma, neutron radiation)

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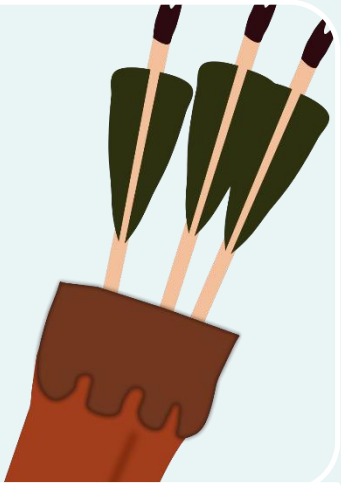
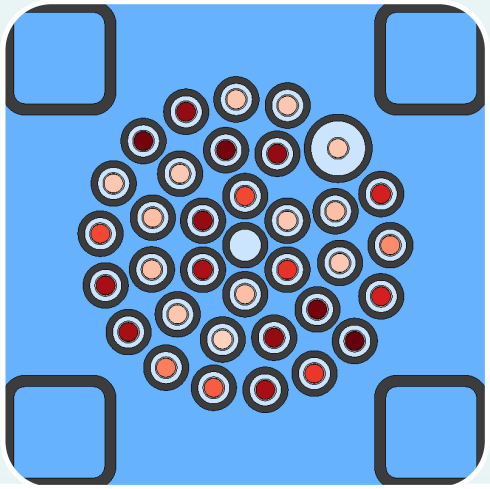
QUIVERS

Quivers



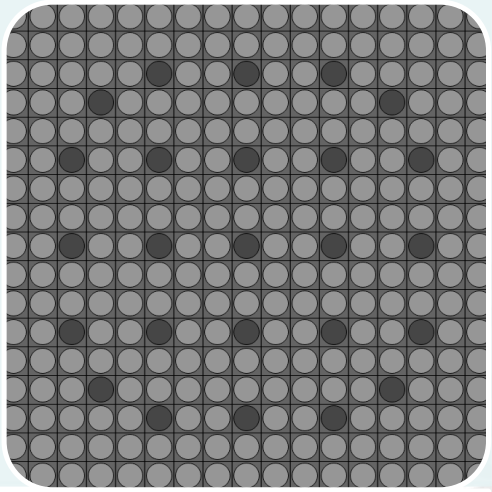
An archer's case for holding arrows



Cluster of stainless steel tubes to house damaged fuel

(cladding rupture)

Designed by Westinghouse



Identical dimensions as regular fuel.

No special handling required.

Quiver specifications

- For PWR and BWR fuel
- 14-28 BWR rods or 30-60 PWR rods
- Actual design may depend on request
- But in Sweden there is one BWR and one PWR type
- Temporary lid and long-term storage lid
- After closure: water evacuated, filled with helium
- New product (cca 20 in Sweden)

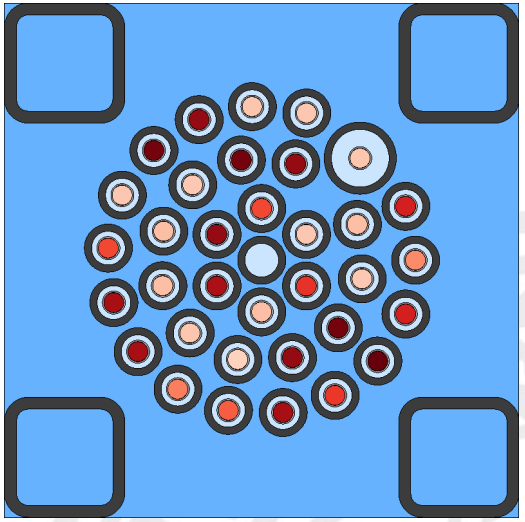
See leaflet for images

Safeguards verification of quivers

- Gross defect: is there nuclear material inside?
- Non-destructive assay
- Measurements from top do not require fuel movement
- Cherenkov viewing device did not see anything in Forsmark NPP
- Focus on SFAT now (and possibly the FORK later)

Studied quiver

- From Ringhals PWR
- 34 rods from 20 assemblies
- Thicker tube holds rod as well
- 5-36 MWd/kgU (low burnup)
- 30-42 years old (high cooling time)
- 2.5-3.5 w% initial enrichment



Darker red implies higher burnup

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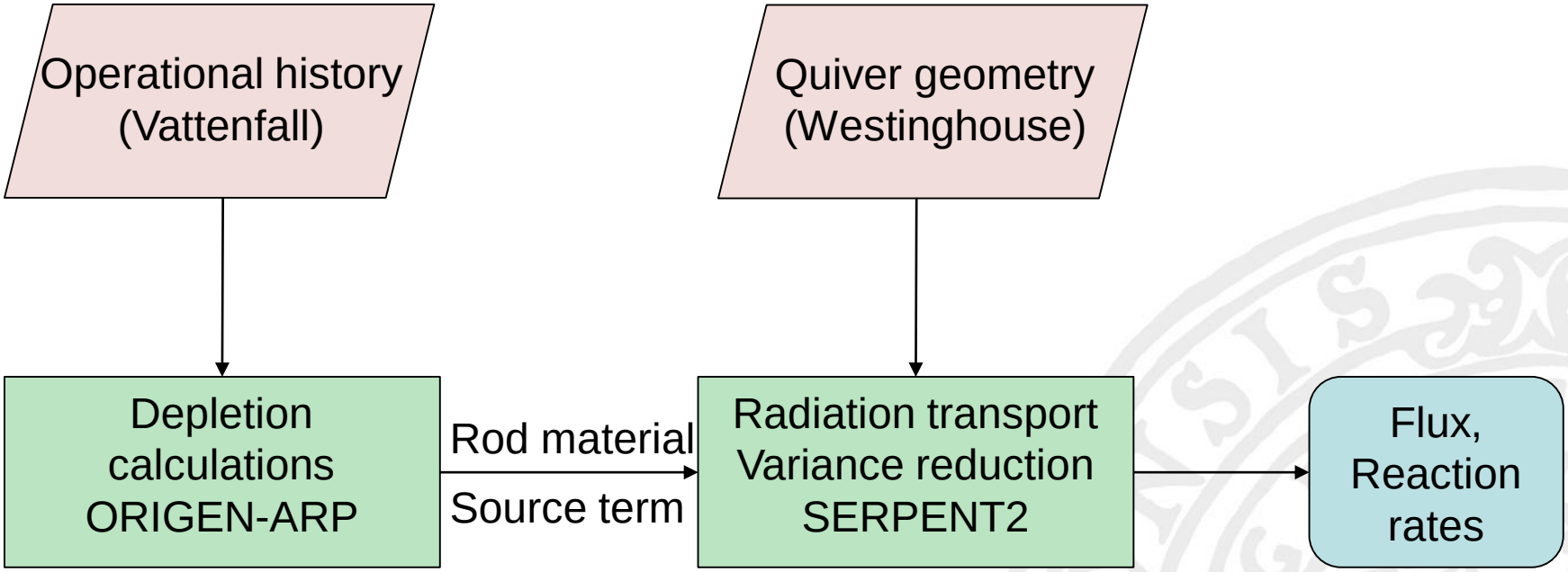
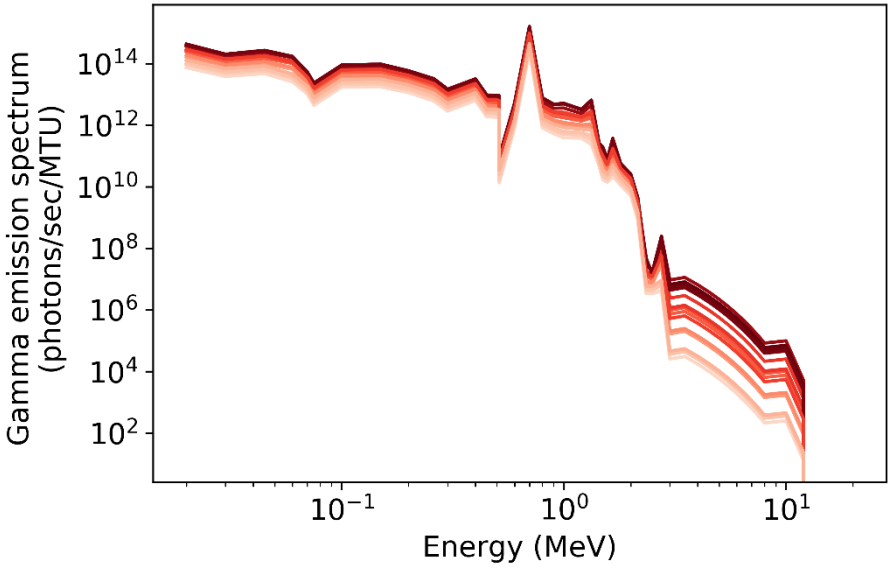
COMPUTATIONAL METHODOLOGY

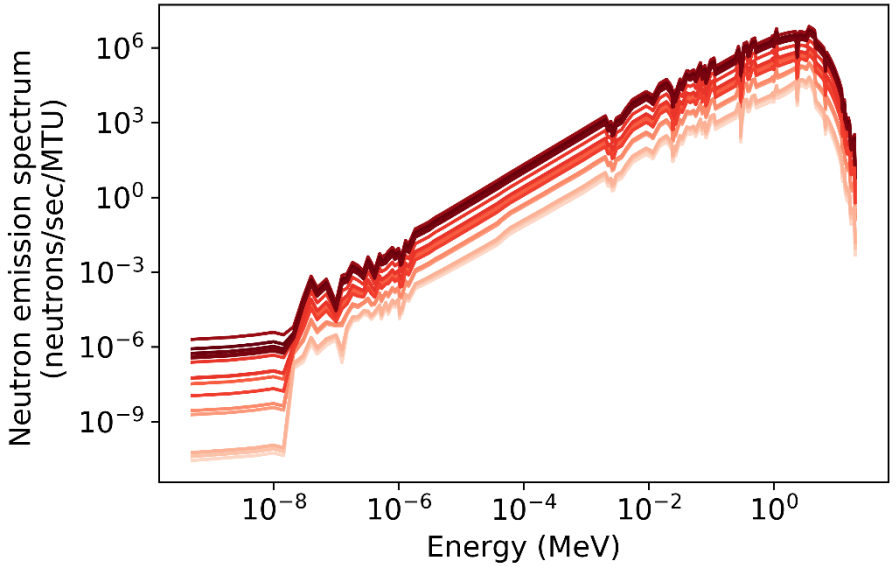
Methodology



Depletion calculations

- Operating history of fuel rods from Vattenfall
- ORIGEN-ARP depletion calculations
- Nuclide inventory
- Gamma and neutron emission intensity

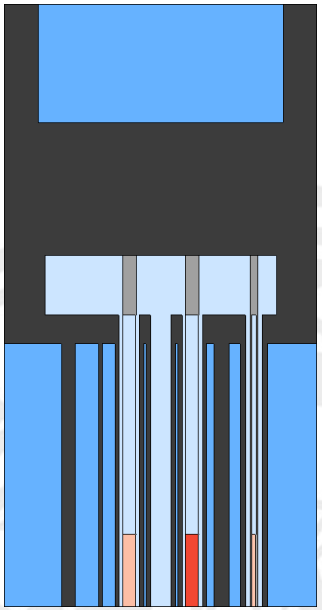




ORIGEN-ARP simulations run by E. Branger

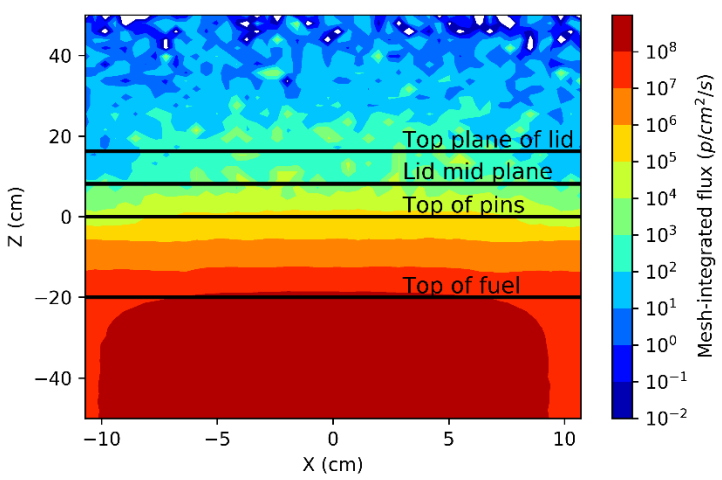
Particle transport

- Quiver geometry details from Westinghouse
- SFAT from available geometry details
- Serpent2 gamma and neutron transport
  - ORIGEN-ARP results as input
  - material and source term
- Neutron and gamma flux estimated around the quiver
- Gamma flux from Cs-137 estimated in the SFAT

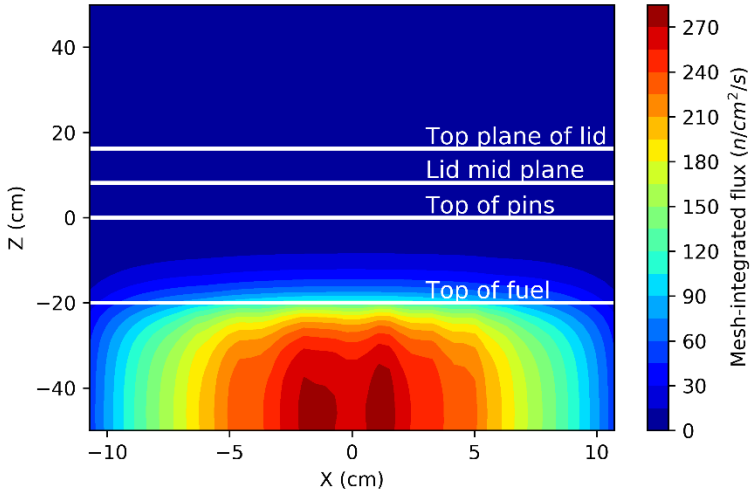


Results: flux around and above

Gamma
(600-800 keV)

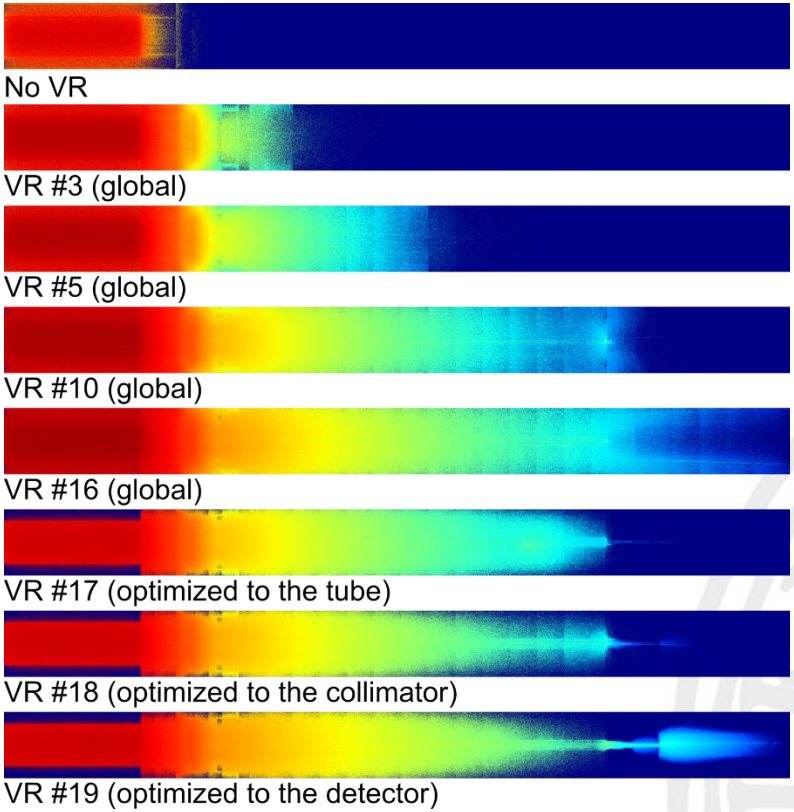


Neutron
(0-14 MeV)



Indicates that measurements should focus on the side.

Results: SFAT (variance reduction)

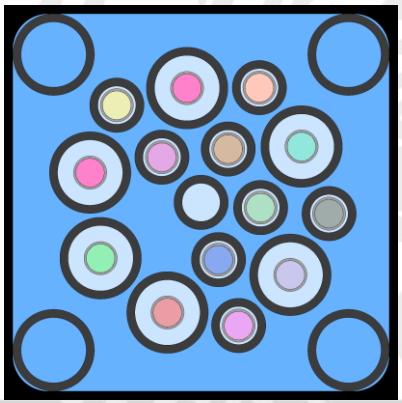


Less than 3 counts in 5 minutes is estimated with the modeled SFAT.
Work in progress, VR scheme needs to be double checked.

Conclusions and outlook

- Measurements from the top are probably not possible
- Measurements from the side may be possible
  - FORK detector (neutron and gamma detector)

- Experimental data from one IAEA SFAT measurement campaign exists
- Possibility to perform additional measurements on quivers at Clab
- Investigating BWR quivers
  - Less fuel, greater challenge



Thank you for the attention!

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