Transport Criticality Assessment Methodologies for the RWMD SF Disposal Canister Transport Container

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Introduction

- Over the years, UK has operated many reactor systems inc. Magnox, AGR, PWR, MTR, Research reactors and breeders.

- The UK's Nuclear Decommissioning Authority is considering various options to deal with the spent fuel (SF).

- One option for some SF is direct disposal into a generic disposal facility using a transport package to carry a copper canister based on the Swedish KBS-3 design by SKB.

Introduction cont'd

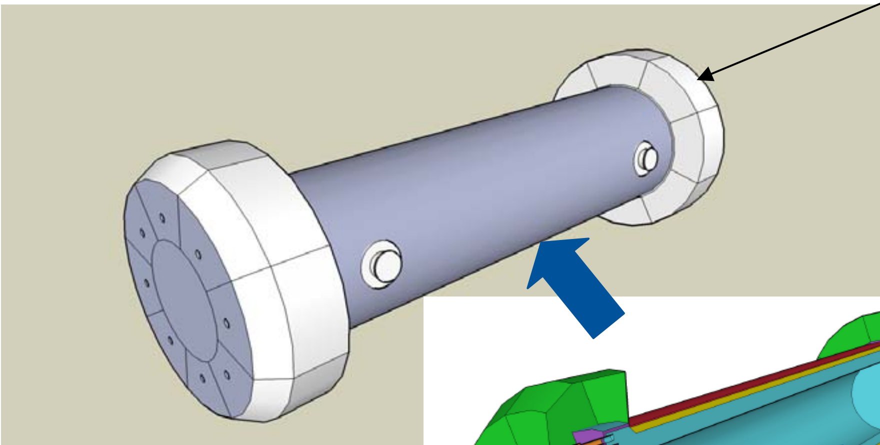
- In this option, the outer container is referred to as the Design Concept Transport Container (DCTC).

- This paper describes the preliminary results of investigations into how the criticality justification should be made.

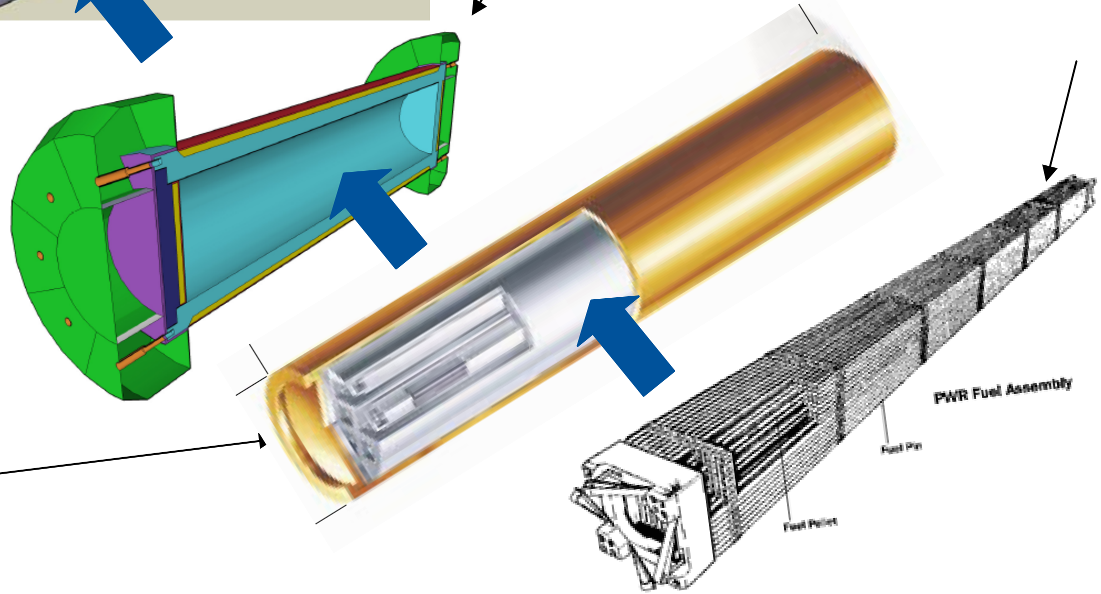
- Also illustrates the benefits of using automated criticality calculations to perform large-scale surveys.

The Package

- Outer shell (with Shock Absorbers)

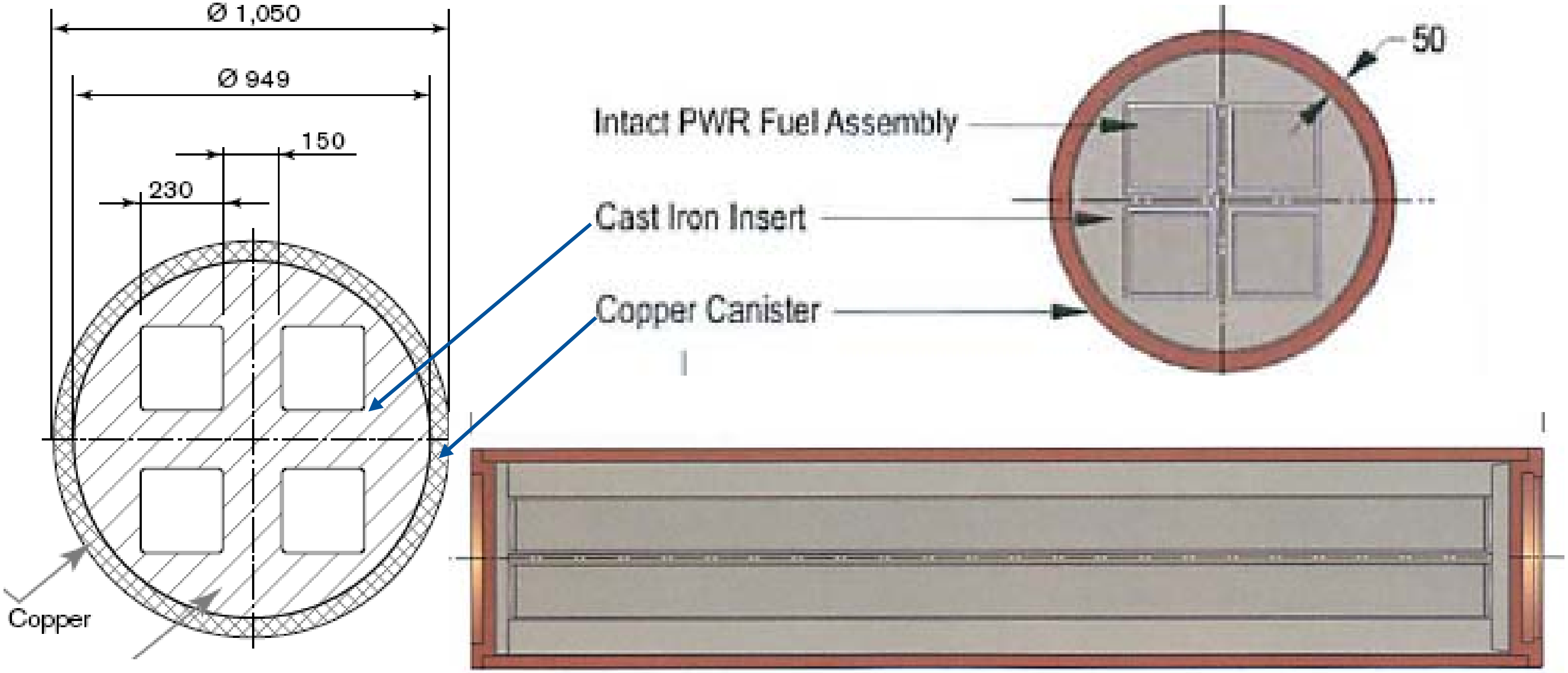


- Fissile contents (4 Fuel Assemblies)



- Inner CU canister

PWR spent fuel canister – reference design



Possible SF Payloads

- Up to 4 x Sizewell, AP 1000, or EPR Fuel Assemblies – UO_2 up to 5w/o U235 in U, up 65 GWd/tU
- Up to 20 AGR fuel bundles – UO_2, up to about 3.8 w/o U235, up to 18 GWd/tU
- HLW (not considered here)
- Mainly for current and future fuels – not for “historic” fuels (eg breeder, MTR outside scope)

Initial considerations - requirements for packages containing fissile material (para 671-681)

Requirement	Remarks
Individual package in isolation • Normal conditions • Accident conditions	Unless multiple water barriers are present **MUST** consider flooding. This means that fuel accident states are important to criticality safety.
Arrays of packages. • Normal conditions • Accident conditions	No need to consider flooding if package survives ACT.
For massive transport flasks, calculations can usually concentrate on a single damaged package.	

Basic criticality results

- FWR single or infinite array of packages
- Sizewell 17x17 PWR fuel 4.2% U235 in U.
- 4 x fuel assembly in DCTC

Model	K+3σ	Remarks
Internally dry	< 0.5	Typical neutron multiplication factor for package with multiple water barriers
Internally flooded	1.05 -1.09	Exact value depends on assumptions. No fuel damage modelled.

Design variants for further analysis

- Results show that the simple conceptual design unlikely to work for all UK fuels - Need to alter design concept. But how?

- Various ideas are being investigated:
  - Reducing payload
  - Using different materials (than iron) for the insert – eg boronated iron.
  - Adding flux traps (water + slabs of boron, boronated stainless steels) to the DCTC.
  - Using burn-up credit for the criticality assessment
  - Adding sand (diluent) to the void space (to reduce the density of the water in the model)
  - Adding a multiple water barrier to the package.

Parameter variations

- Some of the parameter variations that were investigated:
  - Enrichments = 3.0, 3.5, 4.0, 4.5, 5 and 6% U235 in U (as UO2 pellets).
  - Various insert materials besides cast iron, including: copper, void, water and boronated stainless steel and at various densities.
  - A range of separations between fuel assemblies (1, 5, 10, 15 & 20cm).
  - Flooding of the void space by a range of water densities (0 to 1 gcm^{-3}) to represent void, water mists and full flooding.
  - Differential flooding
  - Lodgement walls (the structures containing the fuel assemblies) were generally modelled as boronated stainless steel at various thicknesses and with various levels of Boron - other materials were also considered.
- **Just these alone give 4000 combinations**

Criticality calculations

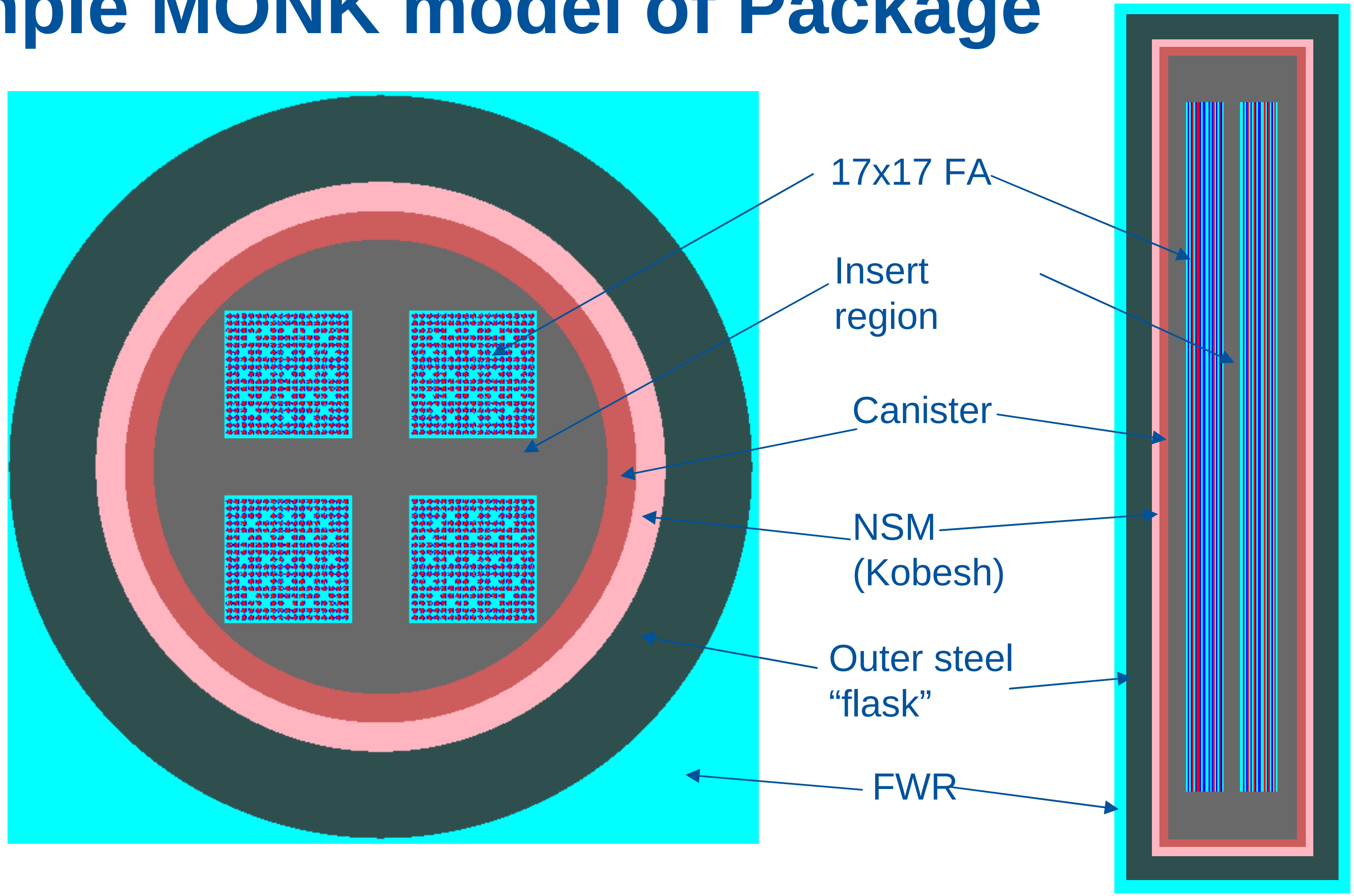
- Monte Carlo simulation using MONK with JEF 2.2 data.

- Automated procedures for surveying parameter variations

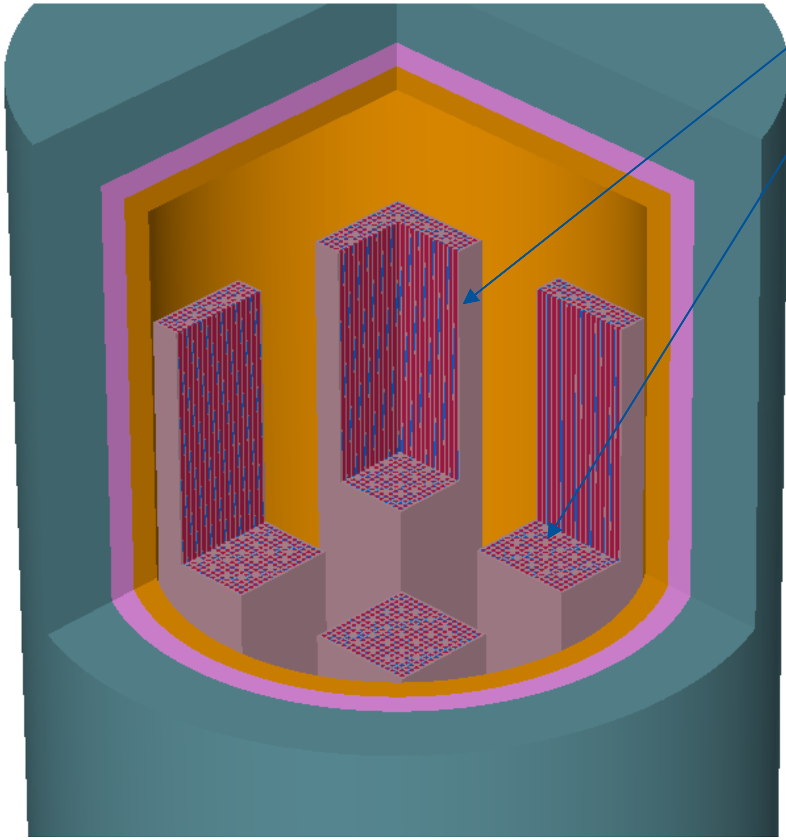
- Criticality calculations carried out using Beowulf cluster of ~ 100 CPU cores.

- Allows many design variants to be thoroughly investigated in reasonable time.

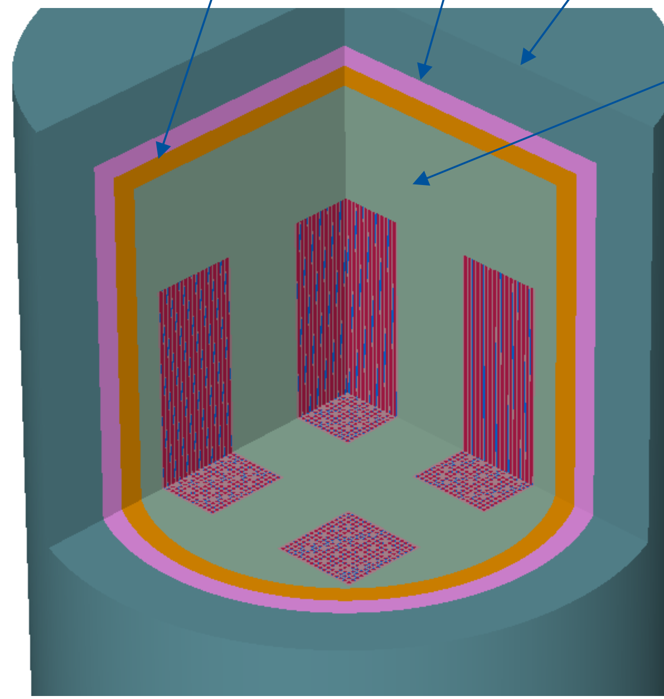
Example MONK model of Package



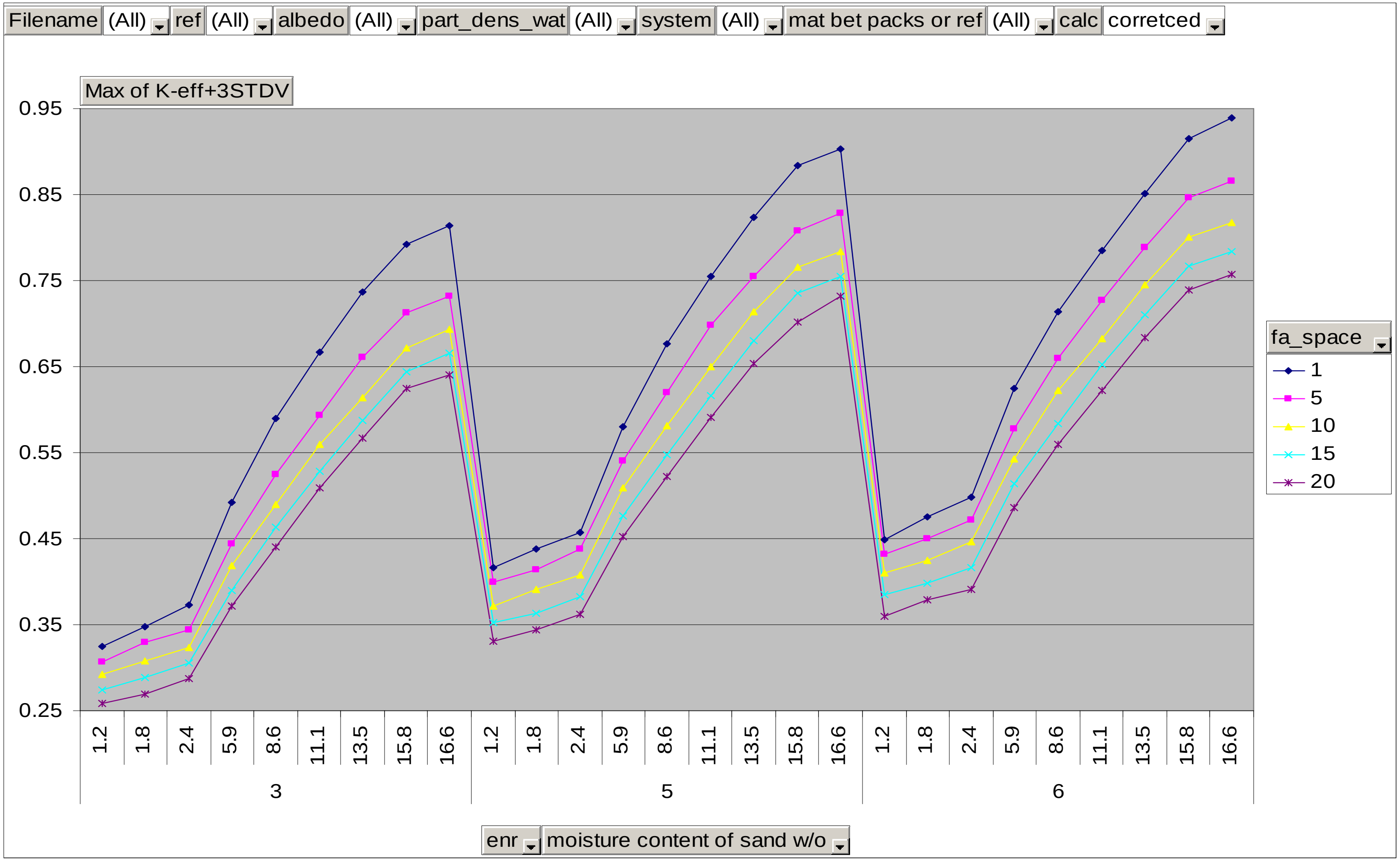
Example model - Material (sand) in the Void Space



(Insert region modelled but excluded from view)



Example results - Material (sand) in the Void Space



Conclusions

- Results show that none of the options are completely free from one sort of difficulty or other.
- Only some of the options appear to be capable of accommodating all of the fuels of current interest:
  - Multiple water barriers:
  - Adding conventional flux traps
  - Additional materials with fuel assemblies (eg sand)
- However, any of these would require major changes to copper canister and/or DCTC concept.

Conclusions cont'd

- Results show that there are a number of hybrid approaches – that is two options simultaneously – with the potential to allow the transport of the full range of fuels of current interest, eg:
  - sand + boron in the insert

- Further studies needed to identify a preferred design and optimise it.

Conclusions cont'd

- Clustered PCs and automated criticality codes can provide a valuable aid for assisting in the design of transport packages – ideas can be tested thoroughly and quickly.

- This study involved many thousand of separate Monte Carlo calculations.

- Enables many design variants to be investigated in a reasonable time.