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EMBER

Enhanced multi-physics calculation capabilities for fuel
behaviour and reactor analyses

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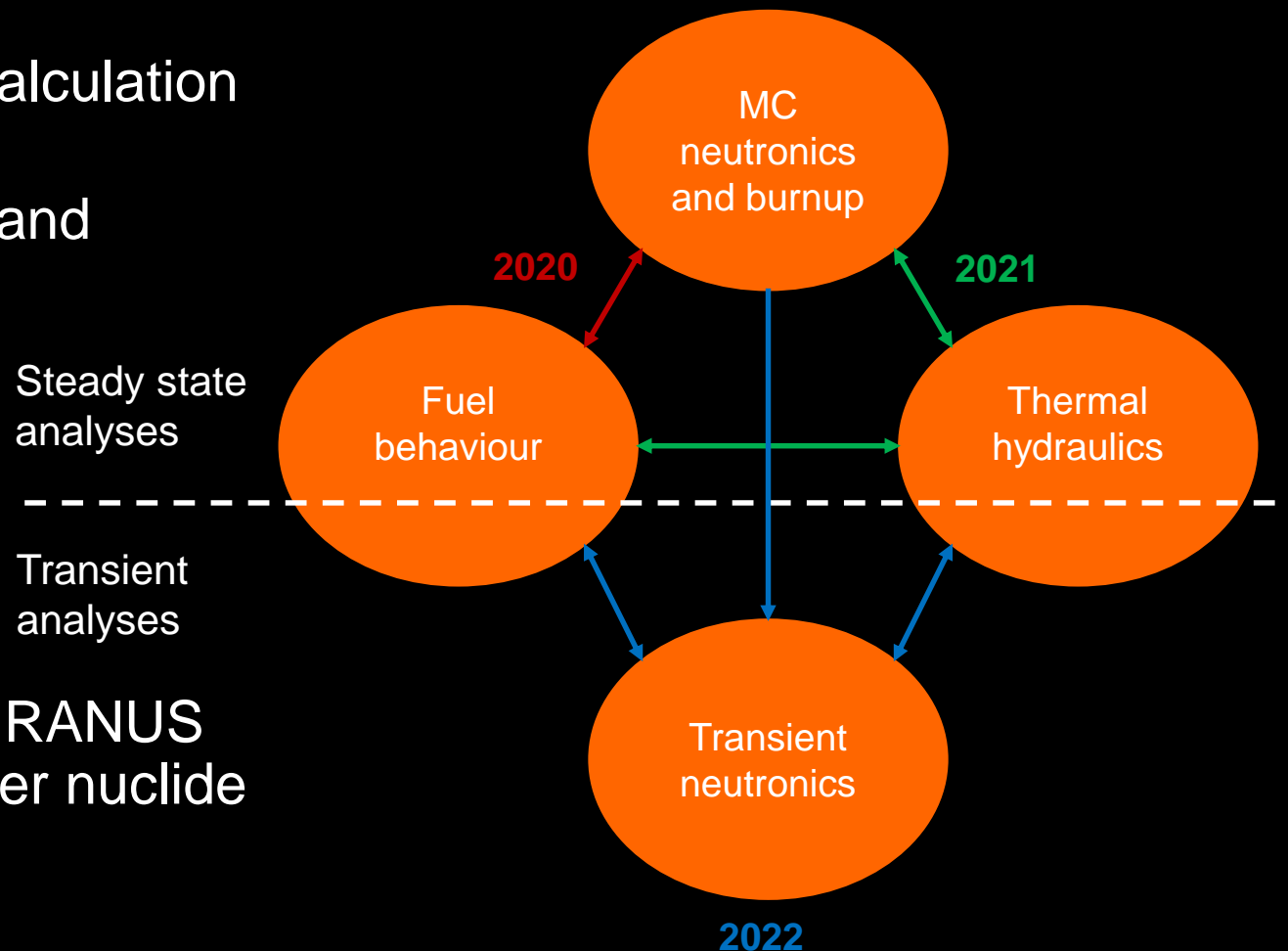
GENERAL OVERVIEW OF EMBER

» Developing coupled multi-physics calculation capabilities at LUT

- Neutronics, thermal hydraulics and fuel behaviour
- Couple existing solvers

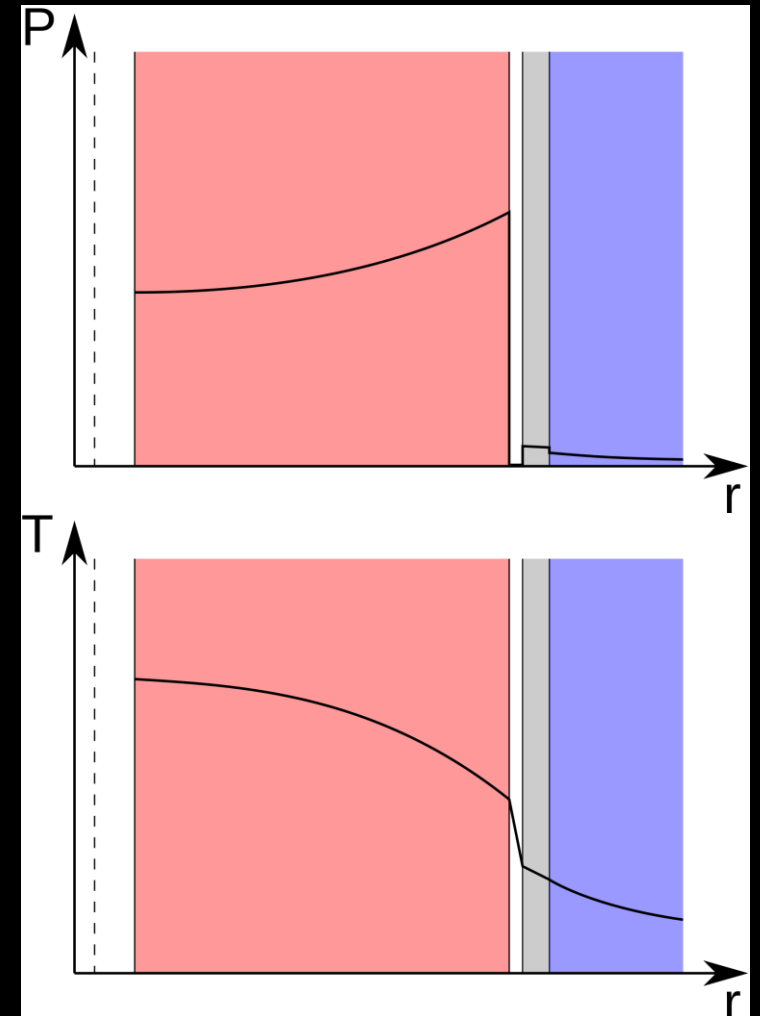
» EMBER started in 2020:

- Extending coupling developed between Serpent and TRANSURANUS by including possibility to transfer nuclide information



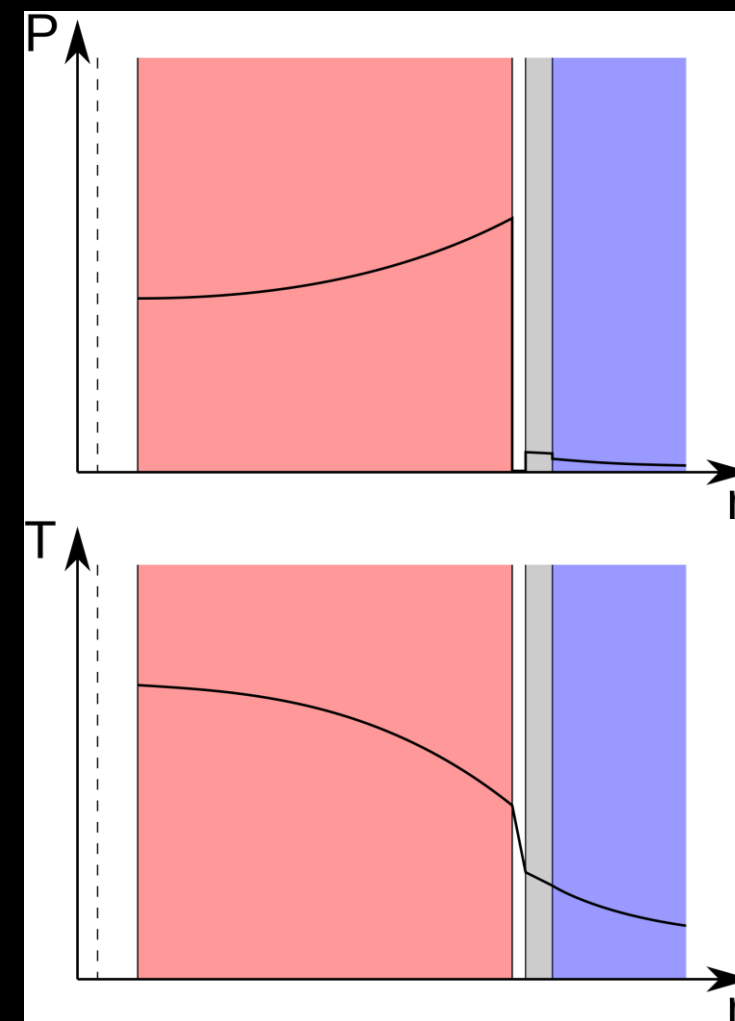
MONTE CARLO REACTOR PHYSICS AND 1.5D FUEL BEHAVIOUR CODE COUPLING

- Fuel behaviour codes
 - Calculates fuel rod behaviour in operation conditions
 - Prevention of fuel failures
 - Traditional 1.5D fuel behaviour code calculates single pin at a time
 - Power profile calculated with diffusion solver
 - Single pin model not taking neighbouring pins into account
- MC reactor physics provides accurate results
 - Computationally costly



OVERVIEW OF SERPENT-TU COUPLING

- External coupling via Kytkin; a Perl program written to handle data transfer and the coupled calculation solution process.
 - Makes use of Serpent multi-physics interface and existing data input and output features in TRANSURANUS.
 - Serpent provides TRANSURANUS pin internal power distributions and fast neutron flux in the pin cladding.
 - TRANSURANUS provides Serpent pin internal temperature distribution and changes in pin radii.



ADDING NUCLIDE TRANSFER TO COUPLING

- Serpent calculates nuclide compositions during burnup calculation
 - No reason to use TRANSURANUS nuclide compositions
- Data interface was implemented to TRANSURANUS to allow reading nuclide data
 - Data provided via files (nuclides.ifc)
 - Current use for bringing in nuclide data, could easily be modified to import any node-wise data
- Kytkin was modified to read Serpent nuclide outputs and write TRANSURANUS nuclide data interface files

EXERPT OF AN INTERFACE FILE

Time interval the data is valid

Part defining TU nodalization and the number of nuclides in each axial section

Data part. First line gives the axial slice, atomic number and mass number. Second line has data values in each radial node. These line pairs repeat until data for whole rod is given.

```

1 4.288790000000D+02 5.968790000000D+02
2 10
3 5 5 5 5 5 5 5 5 5
4 5 5 5 10 15
5 5 5 5 10 15
6 5 5 5 10 15
7 5 5 5 10 15
8 5 5 5 10 15
9 5 5 5 10 15
10 5 5 5 10 15
11 5 5 5 10 15
12 5 5 5 10 15
13 5 5 5 10 15
14 4 4 4 4 4 4 4 4 4
15 1 54 134
16 1.608625000000D-03 1.609320000000D-03 1.611243000000D-03 1.614243000000D-03
  * 1.618230000000D-03 1.618230000000D-03 1.623152000000D-03 1.628974000000D-03
  * 1.635672000000D-03 1.643234000000D-03 1.643234000000D-03 1.651650000000D-03
  * 1.660917000000D-03 1.671037000000D-03 1.682013000000D-03 1.682013000000D-03
  * 1.687169000000D-03 1.692500000000D-03 1.698006000000D-03 1.703691000000D-03
  * 1.709557000000D-03 1.715611000000D-03 1.721859000000D-03 1.728313000000D-03
  * 1.734983000000D-03 1.734983000000D-03 1.739395000000D-03 1.743914000000D-03
  * 1.748549000000D-03 1.753312000000D-03 1.758222000000D-03 1.763303000000D-03
  * 1.768591000000D-03 1.774143000000D-03 1.780037000000D-03 1.786418000000D-03
  * 1.793532000000D-03 1.801895000000D-03 1.812884000000D-03 1.838650000000D-03
17 1 36 85
18 2.234490000000D-04 2.235453000000D-04 2.238116000000D-04 2.242270000000D-04
  * 2.247790000000D-04 2.247790000000D-04 2.254606000000D-04 2.262665000000D-04
  * 2.271940000000D-04 2.282409000000D-04 2.282409000000D-04 2.294059000000D-04
  * 2.306884000000D-04 2.320883000000D-04 2.336063000000D-04 2.336063000000D-04
  * 2.343193000000D-04 2.350559000000D-04 2.358164000000D-04 2.366012000000D-04
  * 2.374105000000D-04 2.382452000000D-04 2.391055000000D-04 2.399927000000D-04
  * 2.409081000000D-04 2.409081000000D-04 2.415123000000D-04 2.421297000000D-04
  * 2.427614000000D-04 2.434084000000D-04 2.440725000000D-04 2.447561000000D-04
  * 2.454629000000D-04 2.461983000000D-04 2.469697000000D-04 2.477912000000D-04
  * 2.486868000000D-04 2.497061000000D-04 2.509823000000D-04 2.536847000000D-04

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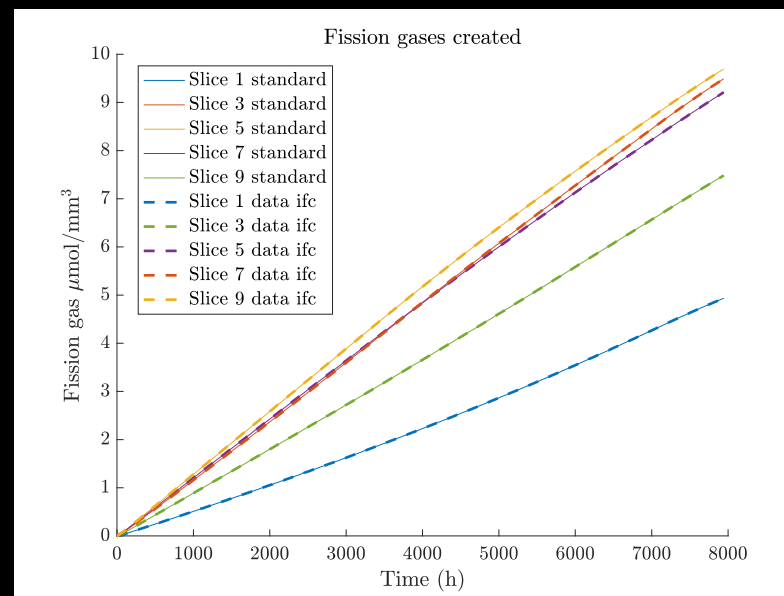
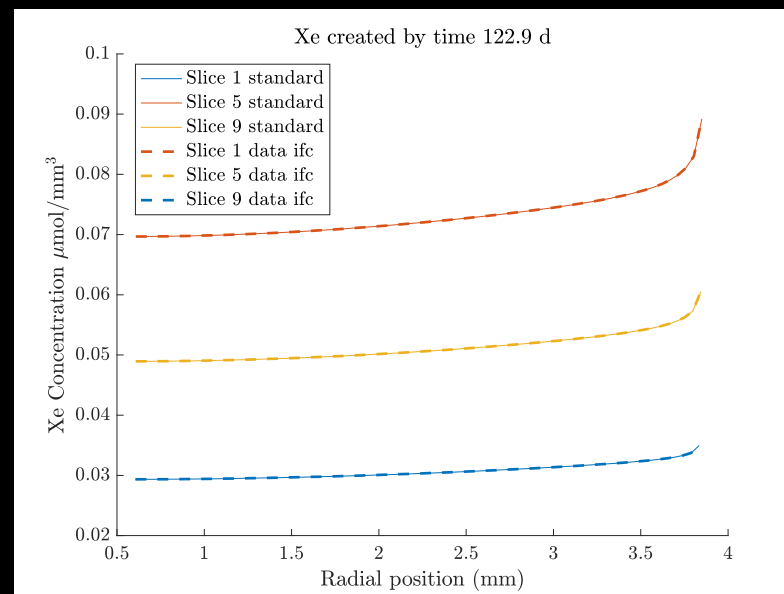
UTILIZING THE INTERFACE-PROVIDED DATA

- Currently used for bringing in fission product data
- Standard TU considers Xe, Kr, Cs and Nd. Their creation is solved by Fpcrea subroutine
- Fpcrea was modified, bypassing the internal solving of the creation of these fission products and reading the data from the data structure of the data interface.

VERIFICATION

1. Perform regular fuel rod simulation in TU (simulated one cycle of a Loviisa rod)
2. Extract concentrations of fission products in calculation nodes at each macro step
3. Process the data into the format that the data interface can read
4. Repeat the calculation but now providing the concentrations via the interface instead of solving them.
5. Compare the results, which should be identical if everything works correctly

Results of the verification calculation show that data is imported correctly through the interface.



CONCLUSIONS AND FUTURE WORK

- Nuclide transfer from Serpent to TRANSURANUS was implemented to coupling
- Actual demonstration calculation results with Loviisa related data given by Fortum will be reported in journal article
- EMBER 2021
 - Coolant temperature have been assumed to be known in calculations
 - During 2021 subchannel code is included in coupling and coolant temperatures are going to be solved in coupling
 - Boundary conditions are thermal power and core inlet temperature after this modification



THANK YOU

»» Questions?

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