RBWR-Th Approach to Equilibrium

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Overview of today's presentation

- **General RBWR-Th description**
- **Coupled depletion challenges**
- **In-house solution (MocDown)**
- **Future planned developments**
- **What I'd like from Serpent**

The RBWR-Th is an advanced BWR core design which is …

- **… under-moderated**
  - **P ÷ D = 1.13**
  - **αout ≈ 80%**
- **… fuel self-sustaining at equilibrium**
- **… derived from the Hitachi RBWR-AC**
  - **U/Pu → Th/U**
  - **Internal blanket eliminated**

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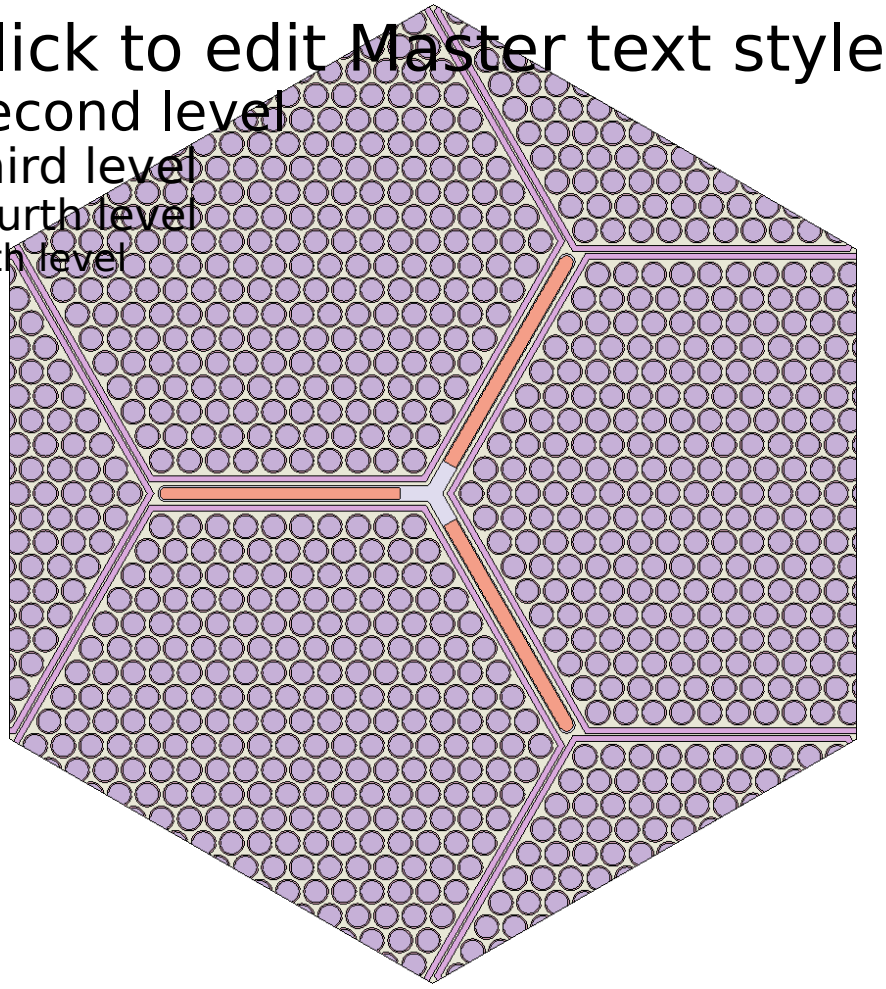
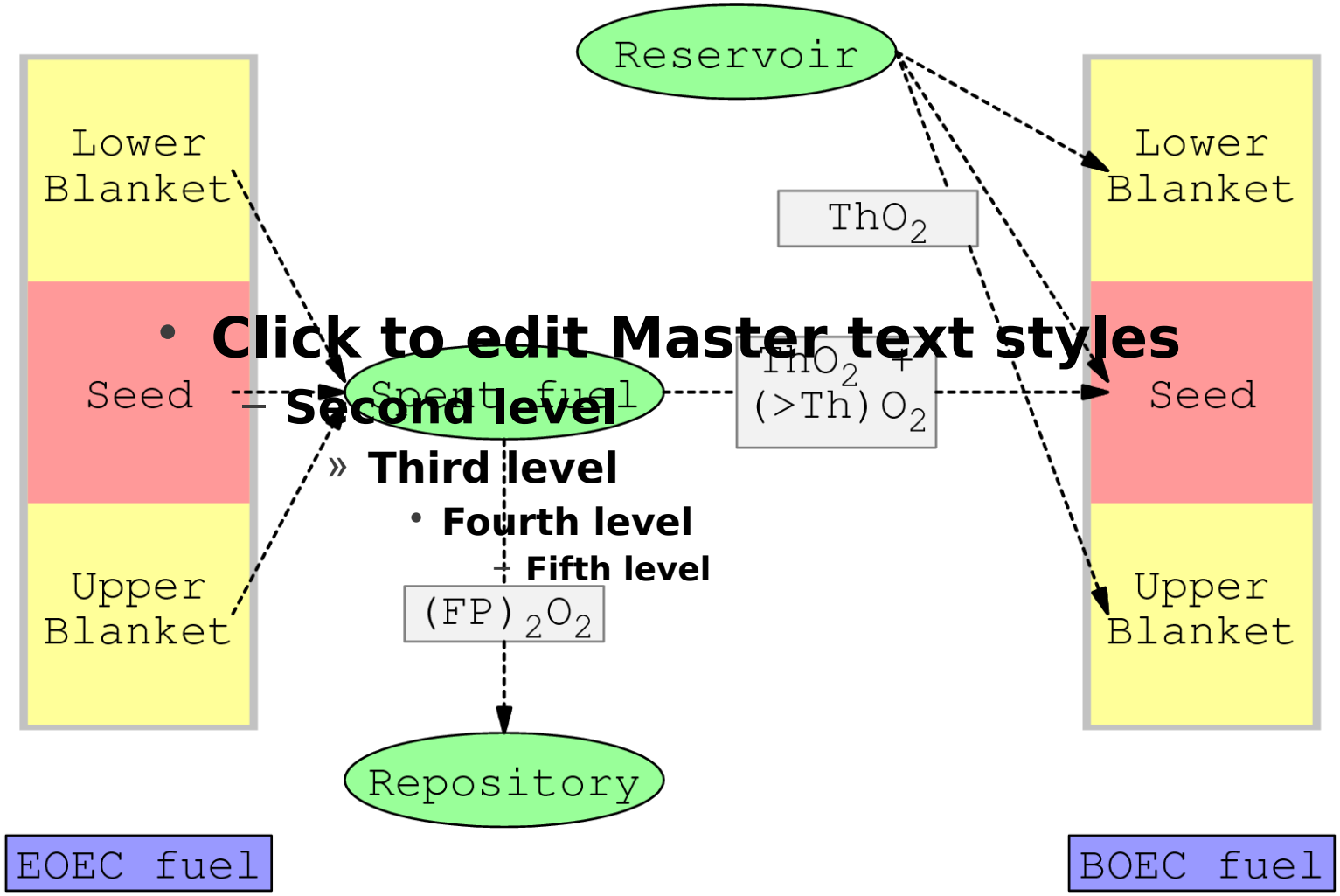


RBWR-Th assembly unit cell

The RBWR-Th recycles all transthoria and uses unenriched thoria as makeup



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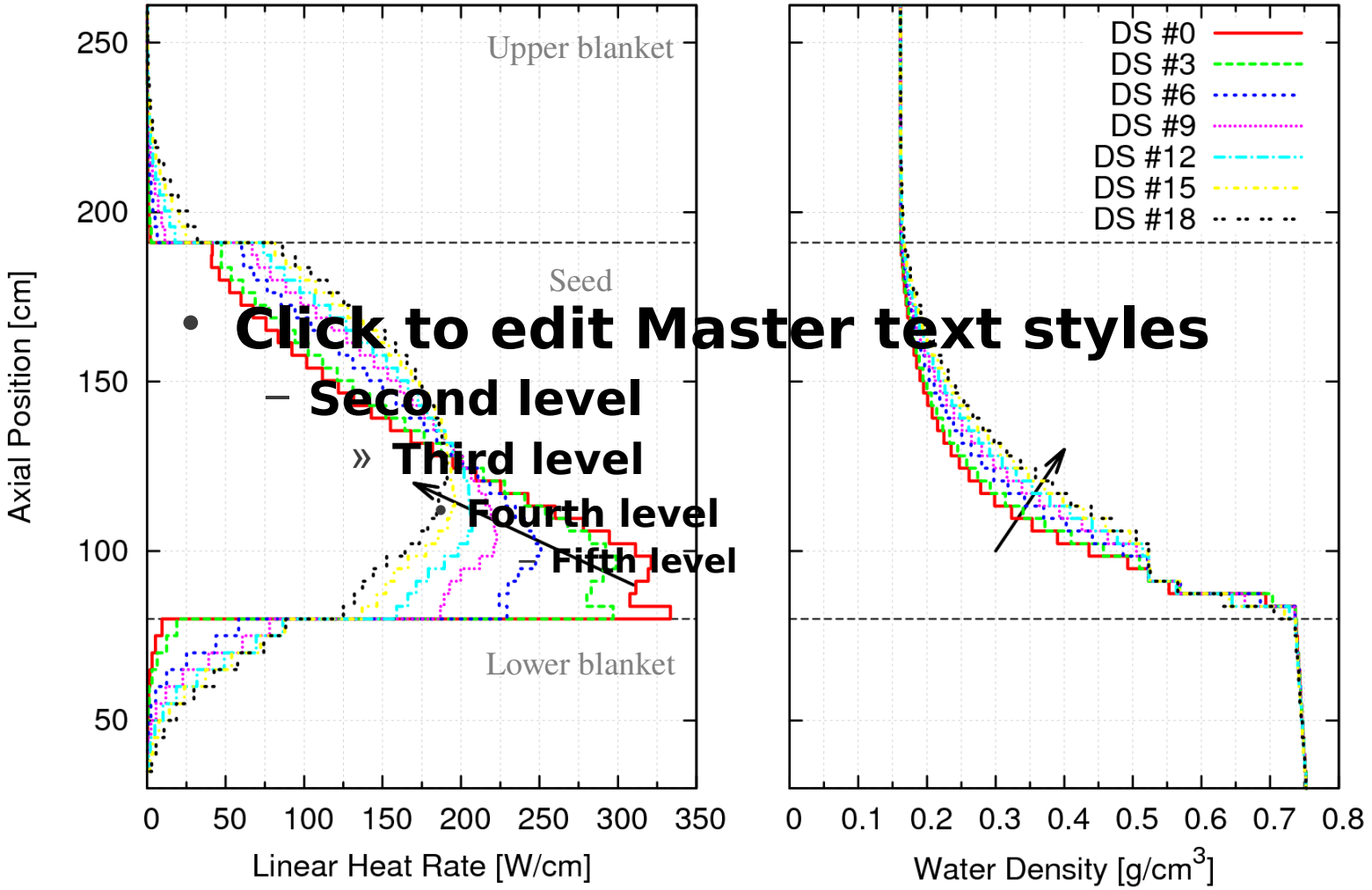
The RBWR-Th has strong physical coupling between neutron transport and thermo-fluids



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DS ≡ depletion step

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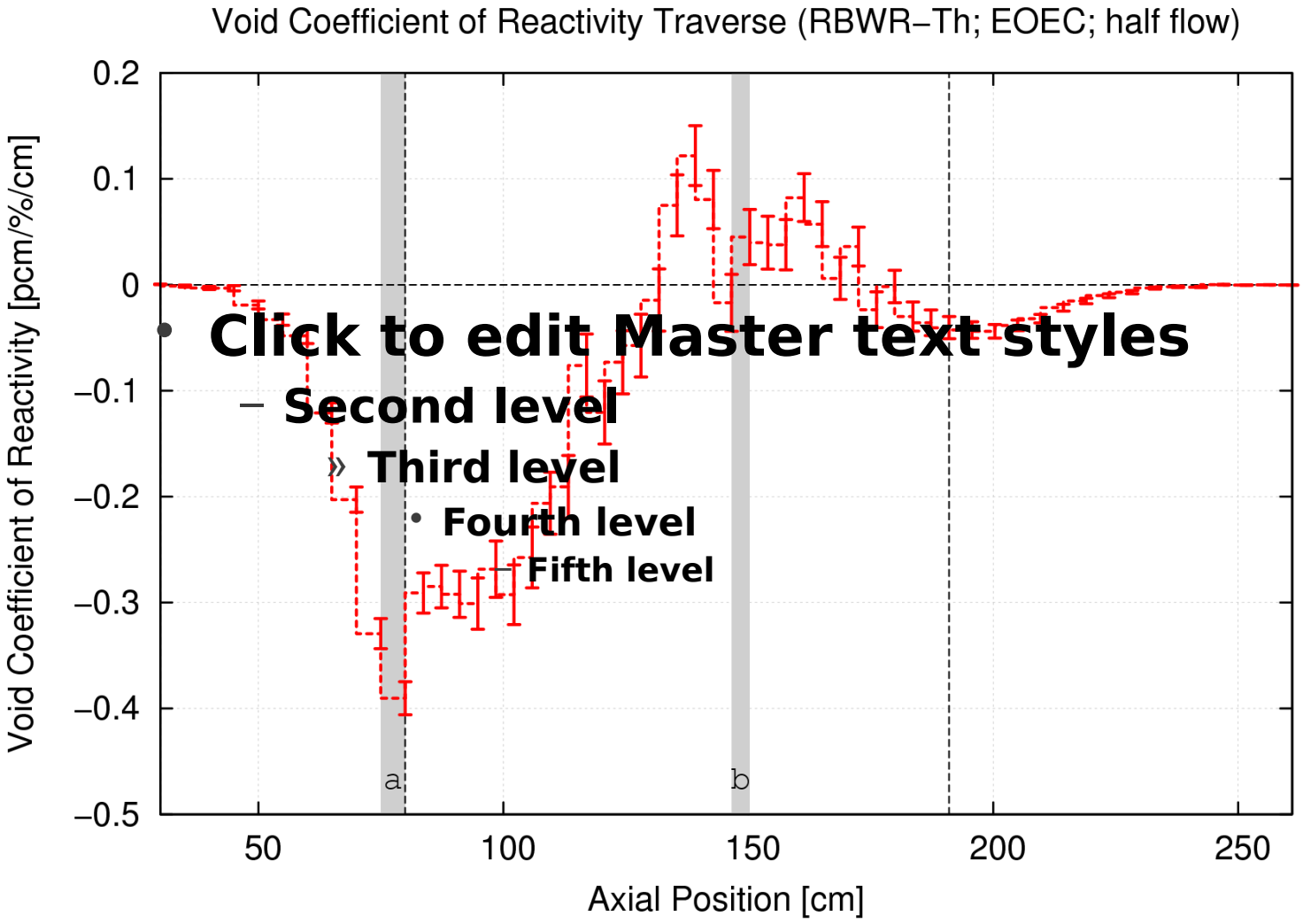


The RBWR-Th has stringent simulation requirements because …

- **… it has strong axial variation in flux spectrum and magnitude**

→ Continuous-energy three-dimensional Monte Carlo neutron transport

- **… it has tight and variable physical coupling between neutron transport and thermo-fluids**

→ Tight numerical thermo-fluids coupling

- **… it operates in fuel self-sustaining equilibrium**

→ Equilibrium core composition search

- **… it is undergoing parametric design studies**

→We'd like computationally inexpensive simulation

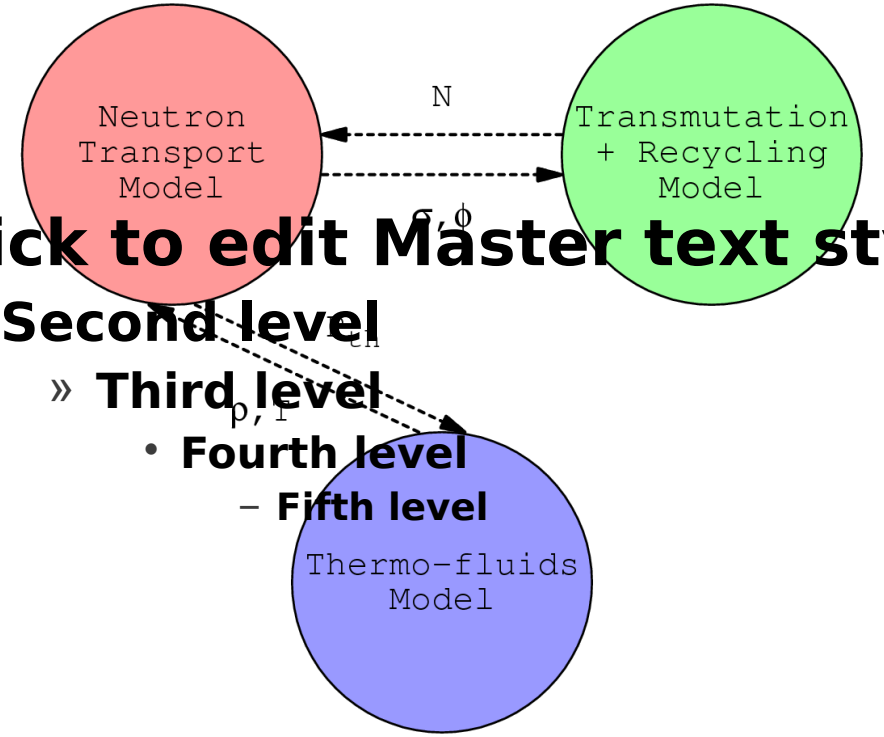
MocDown was written to fulfill these simulation needs

MocDown is …

- **… a Monte Carlo depletion simulator …**
  - **MCNP6.1 for neutron transport**
  - **ORIGEN2.2 for transmutation**
  - **Monteburns, MOCUP, VESTA, …**

… with an accelerated equilibrium search capability
and online thermo-fluids coupling

Full-fidelity thermo-fluids coupled depletion and multi-recycling to equilibrium is expensive



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A typical case requires …

40 fuel recycles

each with 20 time-steps

each with 2 thermo-fluids iterations

… for a total of >1000 neutron transport, thermo-fluids, and transmutation calculations!

Neutron transport/thermo-fluids calculations expense is >20× that of transmutation

They must be eliminated!

MocDown accelerates the equilibrium search by simulating a larger number of less-coupled cycles

- **Outer iterations continue until multiplication factors converge**
  - **Fully-coupled physics**
  - **~4.5 h each**
- **Inner iterations continue until isotopic abundances converge**
  - **Neutron transport and thermo-fluids are not updated**
  - **~0.2 h each**
- **Instead of (40 × 4.5 h) 7.5 d, equilibrium is found after only (4 × 4.5 h + 85 × 0.2 h) 1.5 d!**

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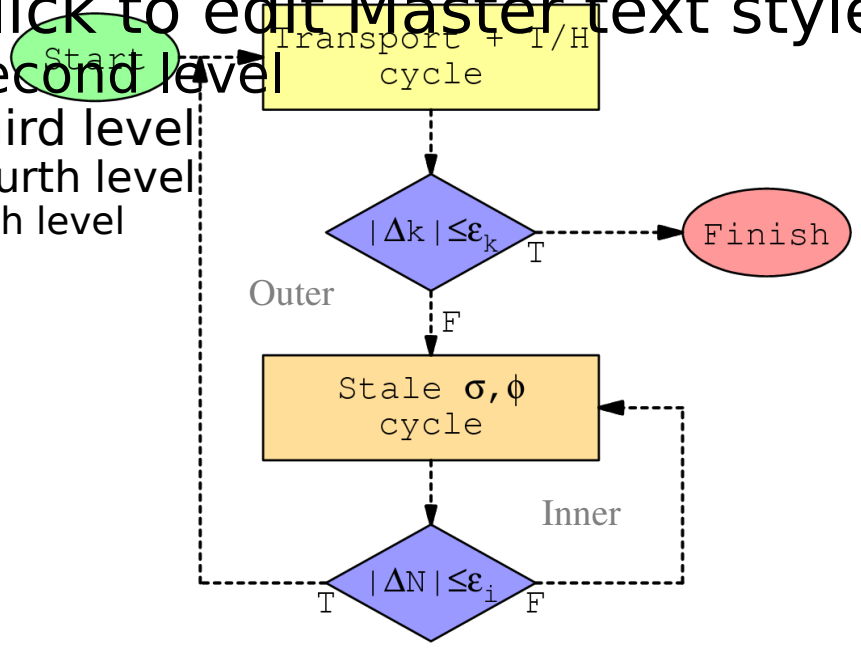
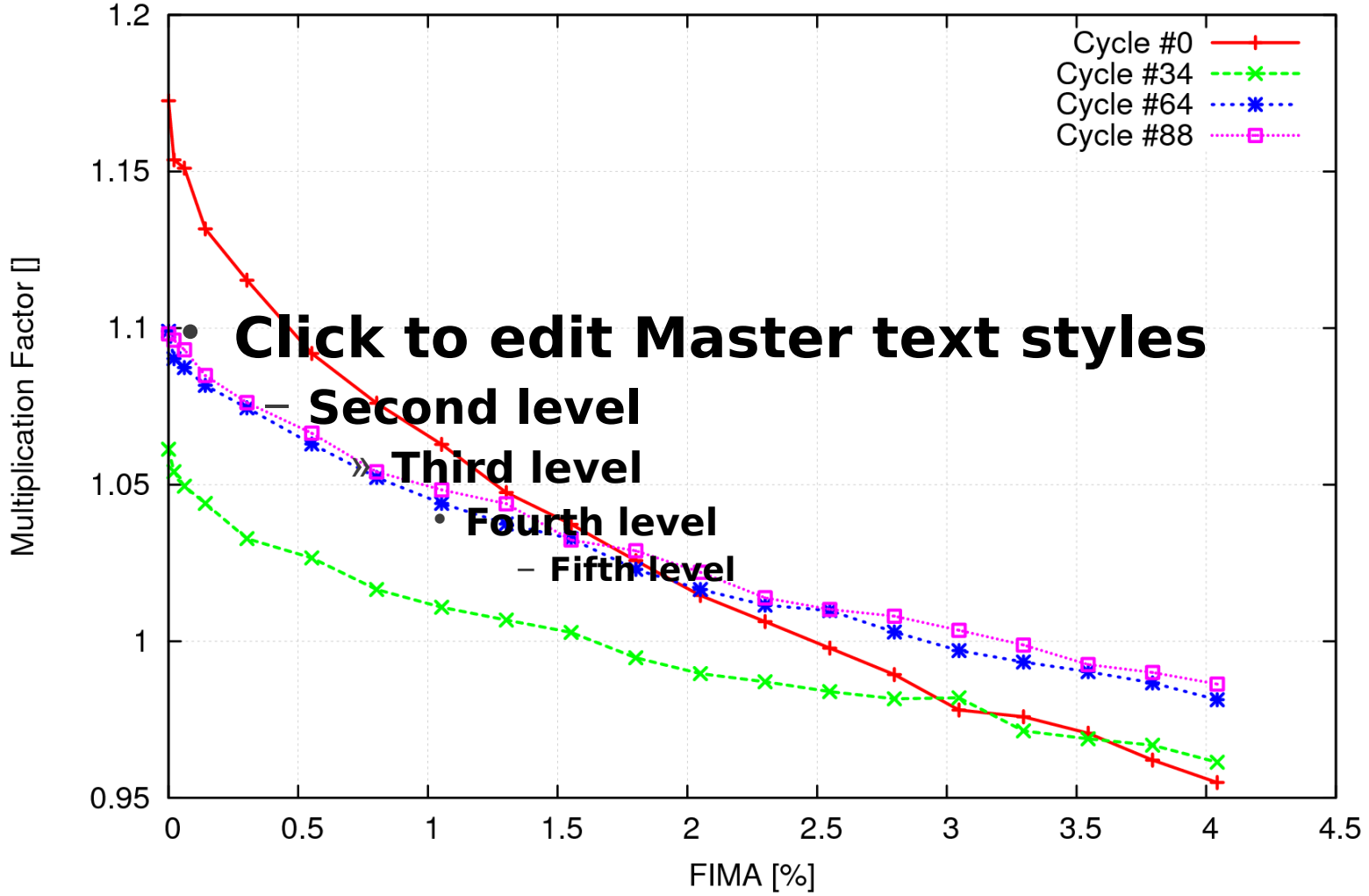
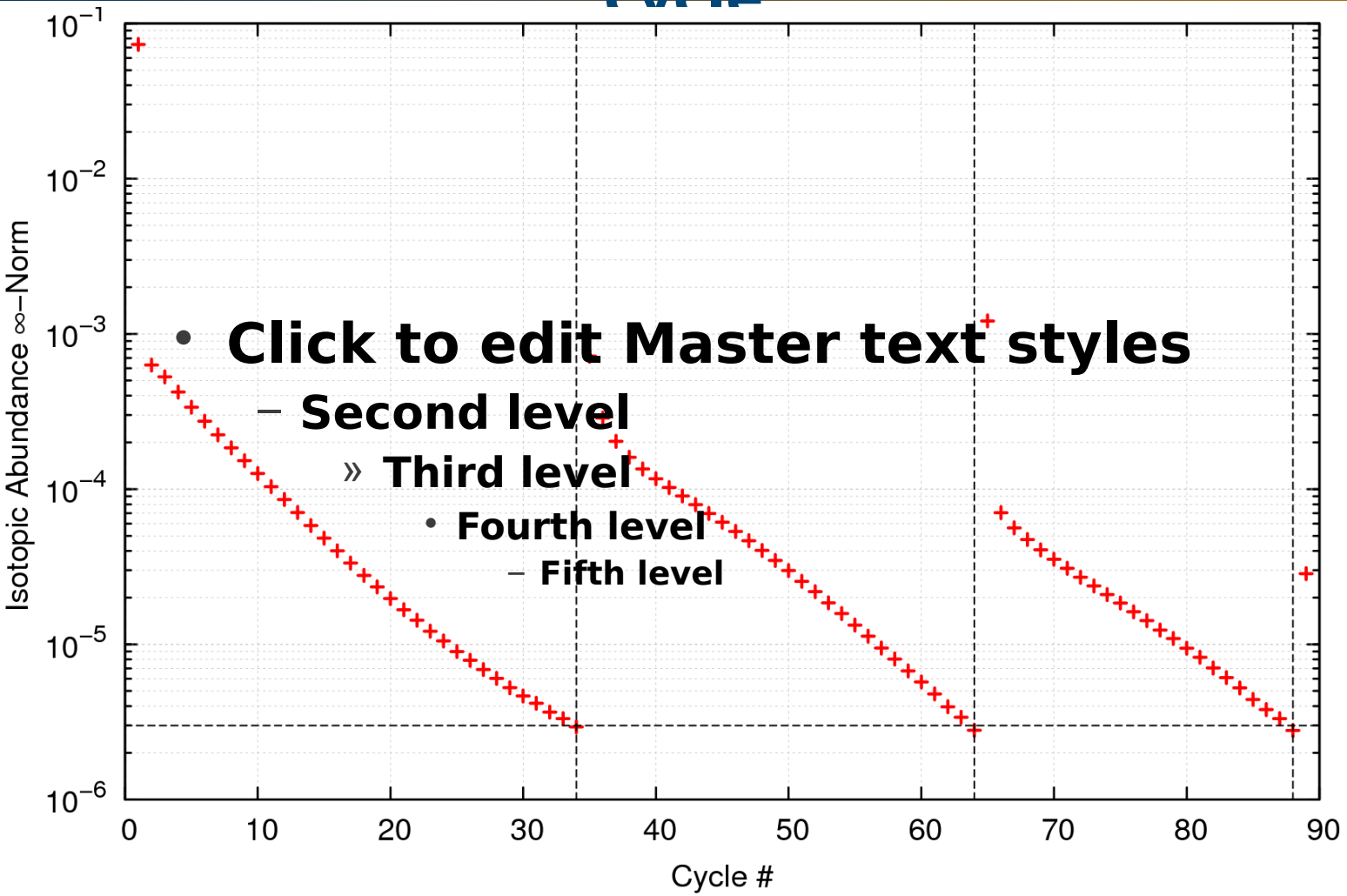


MocDown efficiently finds the equilibrium cycle, so that multiplication factors remain unchanged with cycle



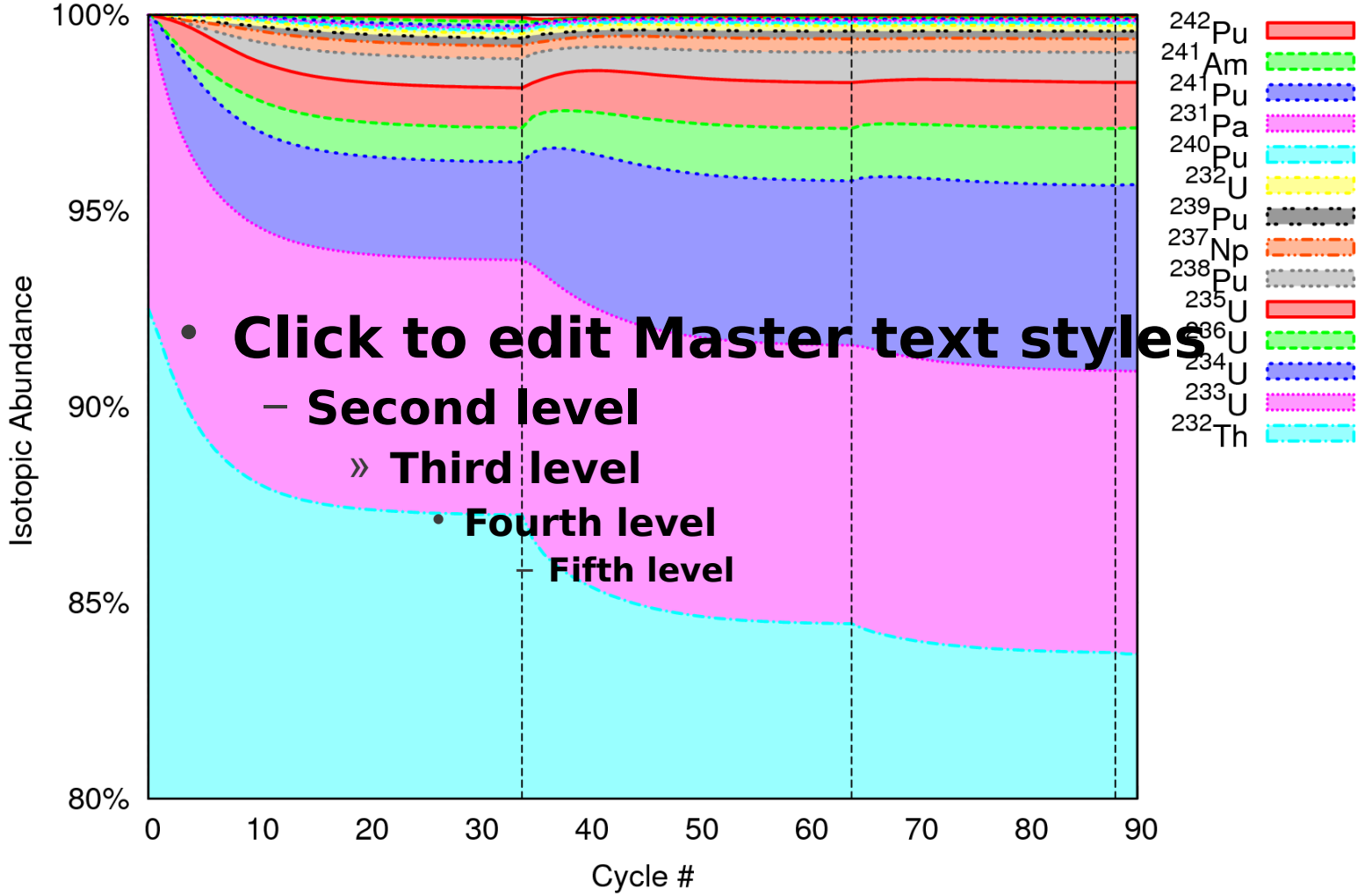
Only four cycles are simulated with fully-coupled physics

MocDown efficiently finds the equilibrium cycle, so that isotopic abundances remain unchanged with cycle



Dashed lines denote these four cycles

MocDown efficiently finds the equilibrium cycle, so that isotopic abundances remain unchanged with cycle

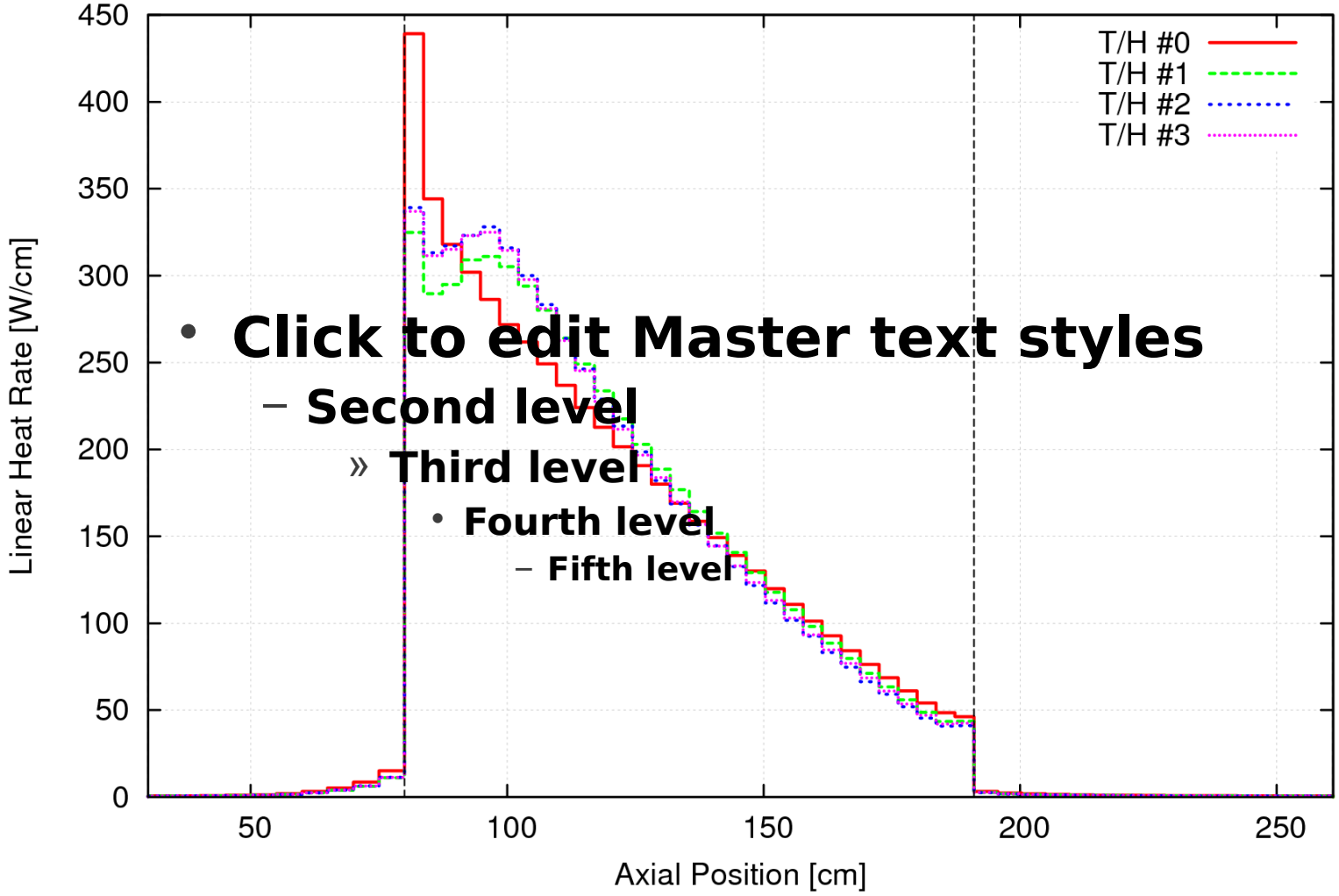


Dashed lines denote these four cycles

MocDown allows for user-defined thermo-fluids models

- **They are written in external modules**
  - **System-specific models are isolated from general depletion models**
  - **Code verification is simplified**
  - **Modules can contain the entire model, or serve as the interface between MocDown and another program**
- **MocDown handles the rest**
  - **System temperatures and densities are updated automatically**
  - **Results are carried along fuel recycles**
  - **Users can provide auxiliary controls like convergence tolerances and damping coefficients**

MocDown continues online neutronics/thermo-fluids coupling until the solutions converge



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Future Planned Developments for MocDown

- **Expanding existing thermo-fluids models**
  - **Currently, no variation of saturation parameters with local pressure**
- **Even faster equilibrium search based off of steady-state approximations for Bateman equations**
- **Possible integration into PyNE?**

What I'd like to see in Serpent

- **Accelerated equilibrium search**
  - **Currently, we have accelerated equilibrium search and concurrent transmutation reduces runtime by a factor of 10 over previous tools**
  - **By keeping cross sections in memory with no I/O, can make it faster**
- **Online thermo-fluid coupling brings better accuracy than previous tools available to us**
  - **Glad to see it's in progress for Serpent 2!**

Questions?

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