Adaptive Design and Criticality Analysis of the DARWIN Reactor Core Concept

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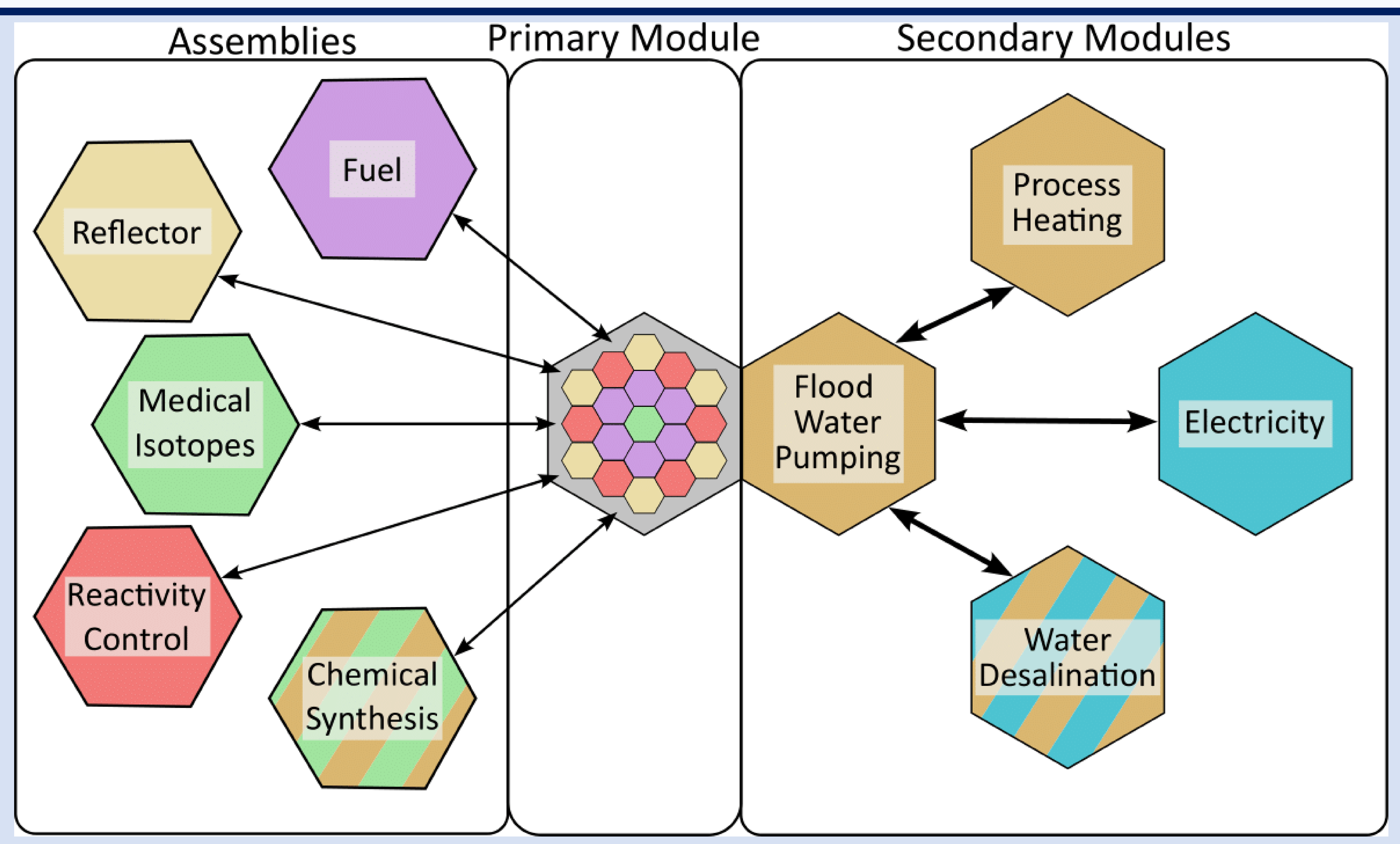
PROBLEM

- Flexible needs:
  - Load-following mode of operation
  - Medical isotopes production
  - Heat
  - Etc.
- Dispatchable Adaptive Reactor With Interchangeable compoNents
- Modular design
- Conditions for specific applications
- Finding limits of phase space

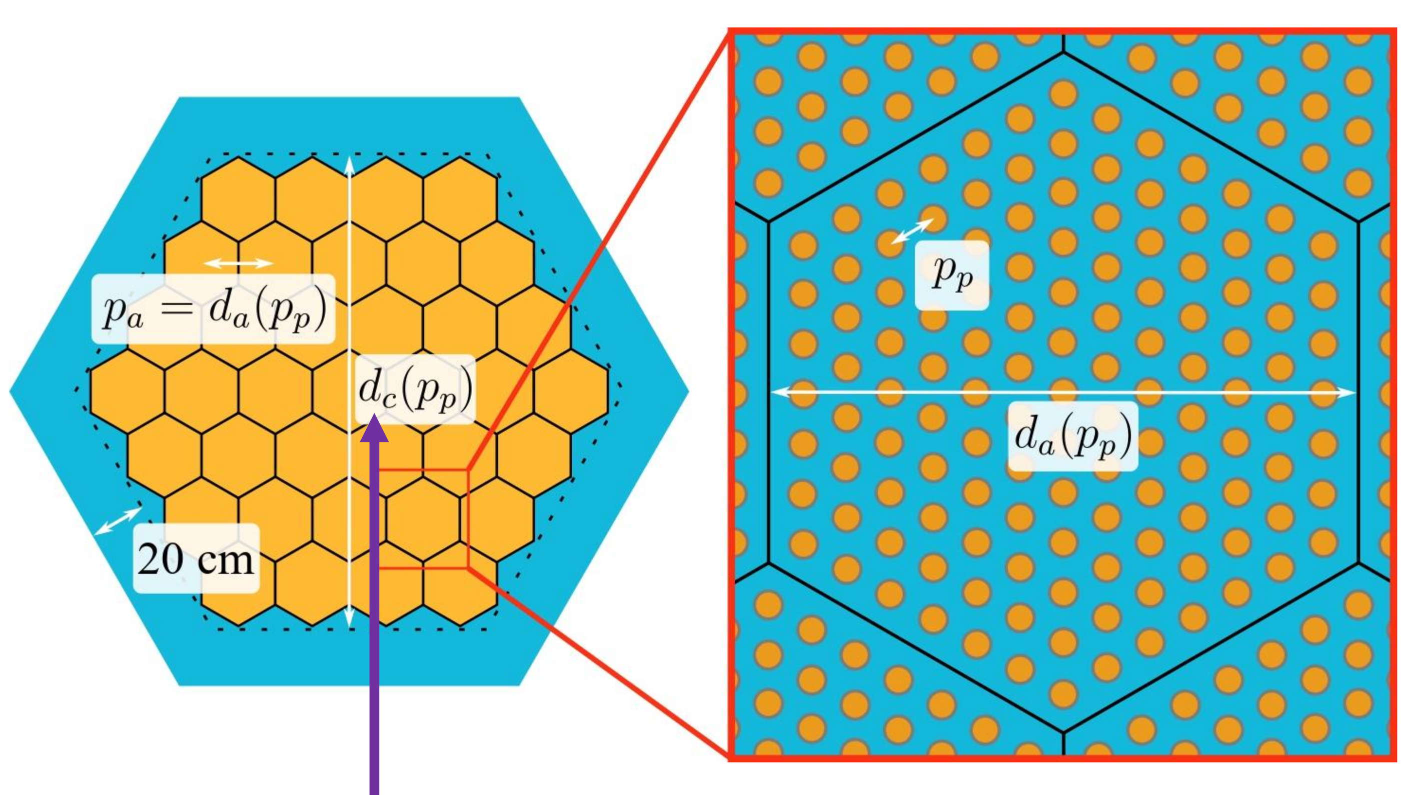


CONCLUSION

- $k_{eff} \geq 1$ for $p_p \geq 1.1$ cm
- Under-moderated region $p_p \leq 1.6$ cm
- $\alpha_{moderator} < 0$ for $p_p \leq 1.8$ cm
- $\alpha_{fuel} < 0$ for all p_p
- For tight packed assemblies the hottest fuel rod is on core periphery
- For 1.1 cm $\leq p_p < 3.0$ cm the hottest fuel rod on the periphery of central assembly
- Water gap between fuel assemblies has significant impact on power distribution

COMPUTATIONAL MODEL

- 2D hexagonal geometry
- Serpent 2.2.0 with ENDF/B-VII.0 nuclear data
- 3 % enriched UO_2 fuel
- 37 fuel assemblies, 127 fuel rods per assembly

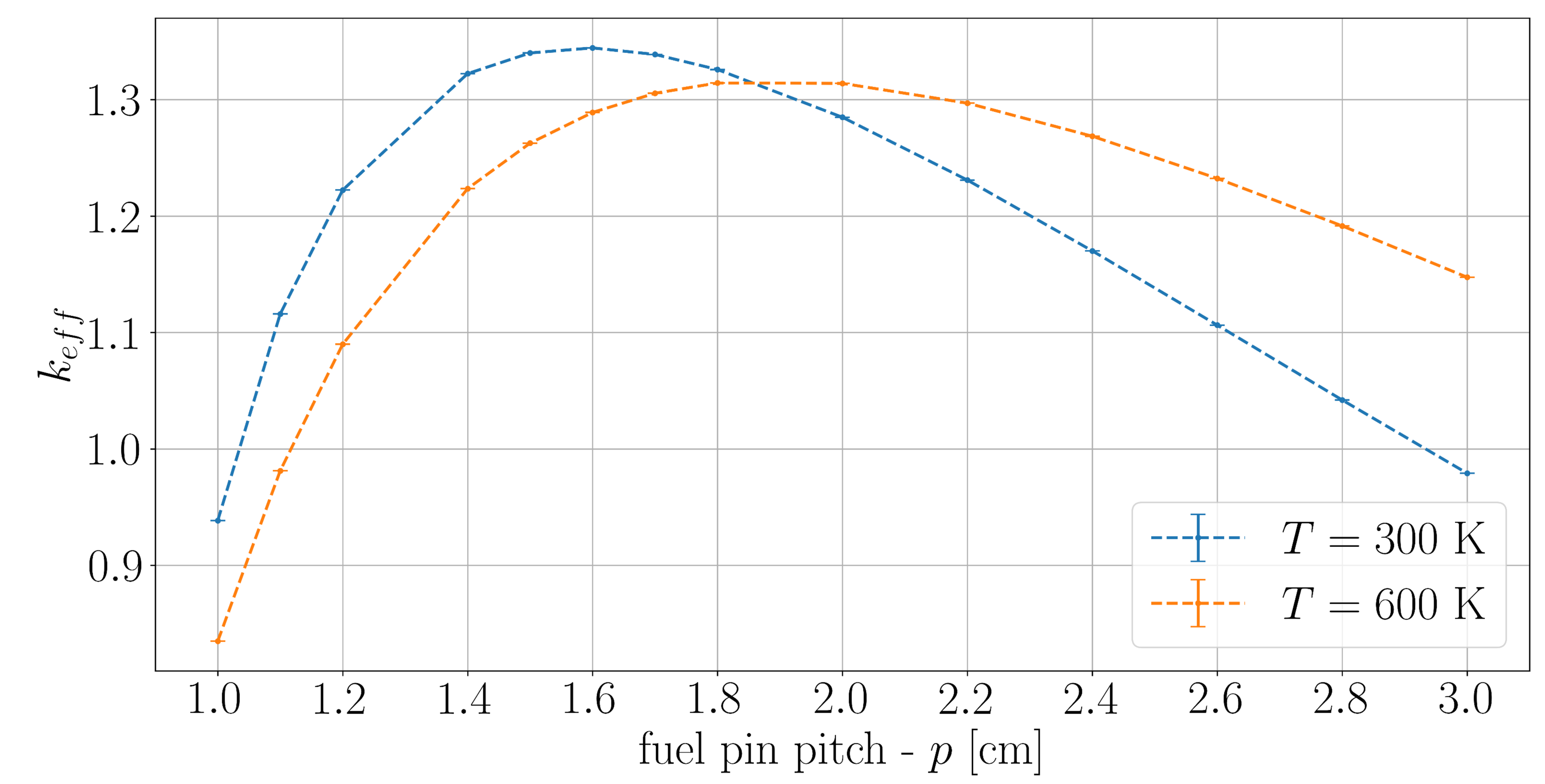


- p_p - fuel pin pitch
- d_a - assembly size
- p_a - fuel assembly pitch
- d_c - core size

$d_c = 113$ cm for $p_p = 1.0$ cm → $d_c = 260$ cm for $p_p = 3.0$ cm

CRITICALITY ANALYSIS

- All materials at the same temperature: $T \in \{300\text{ K}, 600\text{ K}\}$
- Under-moderated region for $p_p \leq 1.6$ cm
- Negative temperature feedback for $p_p \leq 1.85$ cm

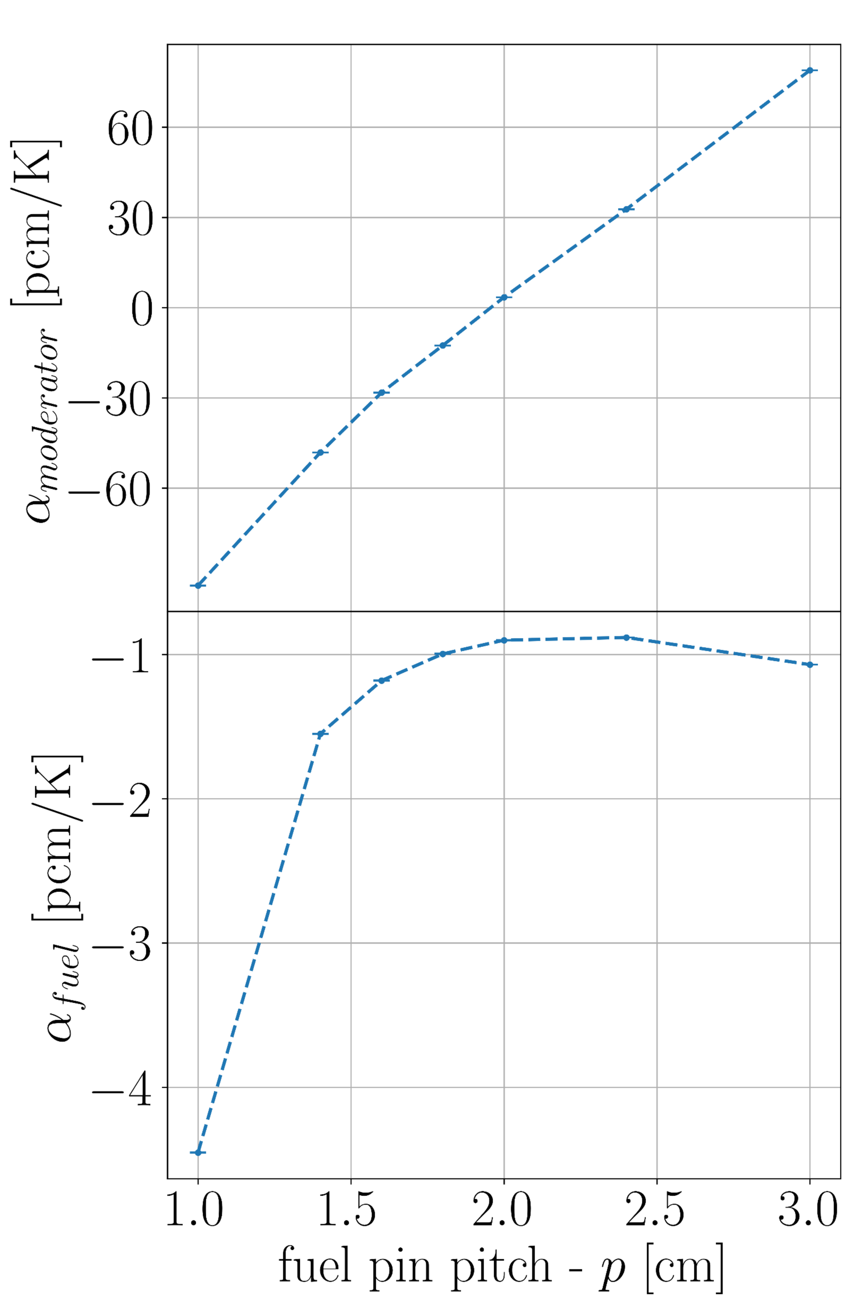


TEMPERATURE FEEDBACK EFFECTS

- Temperature coefficient of reactivity for a material j:

$$\alpha_j = \frac{\partial \rho}{\partial T_j}$$

- Requirement: $\alpha_j < 0$
- $T_{moderator} \in [560\text{ K}, 600\text{ K}]$ including density
- $T_{fuel} \in [560\text{ K}, 1080\text{ K}]$
- Fitting a straight line for values at individual p_p
- Without boron which should have a significant effect on moderator temperature feedback



HOT ROD POWER PEAKING FACTOR

- Searching for the hottest fuel rod on the whole core vs. in only central assembly:
  - For $p_p < 1.1$ cm the hottest rod is on the core periphery
  - For 1.1 cm $< p_p < 3$ cm on the periphery of central assembly (effect of water gap between assemblies)
- Hot rod power peaking factor definition:

$$f_{hr} = \frac{(P_{rod})_{max}}{(P_{rod})_{av}}$$

- $(P_{rod})_{max}$ is max. power released by a single rod and $(P_{rod})_{av}$ is average power released by a single rod