IAEA
International Atomic Energy Agency

Joint ICTP-IAEA Workshop on Reactor Physics, Thermal Hydraulics and Plant Design Engineering of Small Modular Reactors
13th April 2026 – 17th April 2026

Multiphysics for MSRs
Why and when we need it

15th April 2026

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Multiphysics for MSRs

We will have a look on:

- What is Multiphysics?
- Why do we need multiphysics in nuclear engineering?
- When (if) is multiphysics necessary for MSRs simulation?
- How can we model a multiphysics problem?

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What is multiphysics?

"Multiphysics is a **computational discipline** which treats simulations that involve multiple physical models or multiple simultaneous physical phenomena" (Wikipedia et al., 2017)

"Multiphysics refers to the field of study in **science and engineering** where **physical phenomena** from multiple branches of physics are **coupled** or integrated to analyze and solve complex problems. It involves the simultaneous consideration of multiple physical processes that interact with each other in a system or a phenomenon." (ChatGPT, 2026)

What is multiphysics?

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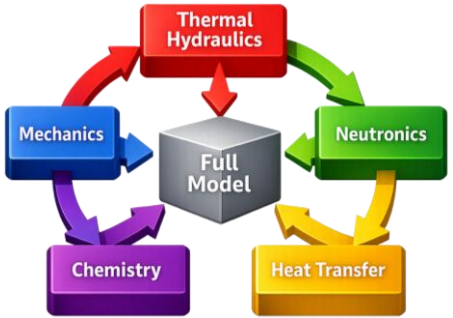
Physics → **Simulation**

- Fluid dynamics
- Heat transfer
- Neutronics
- Chemistry
- Mechanics
- BoP



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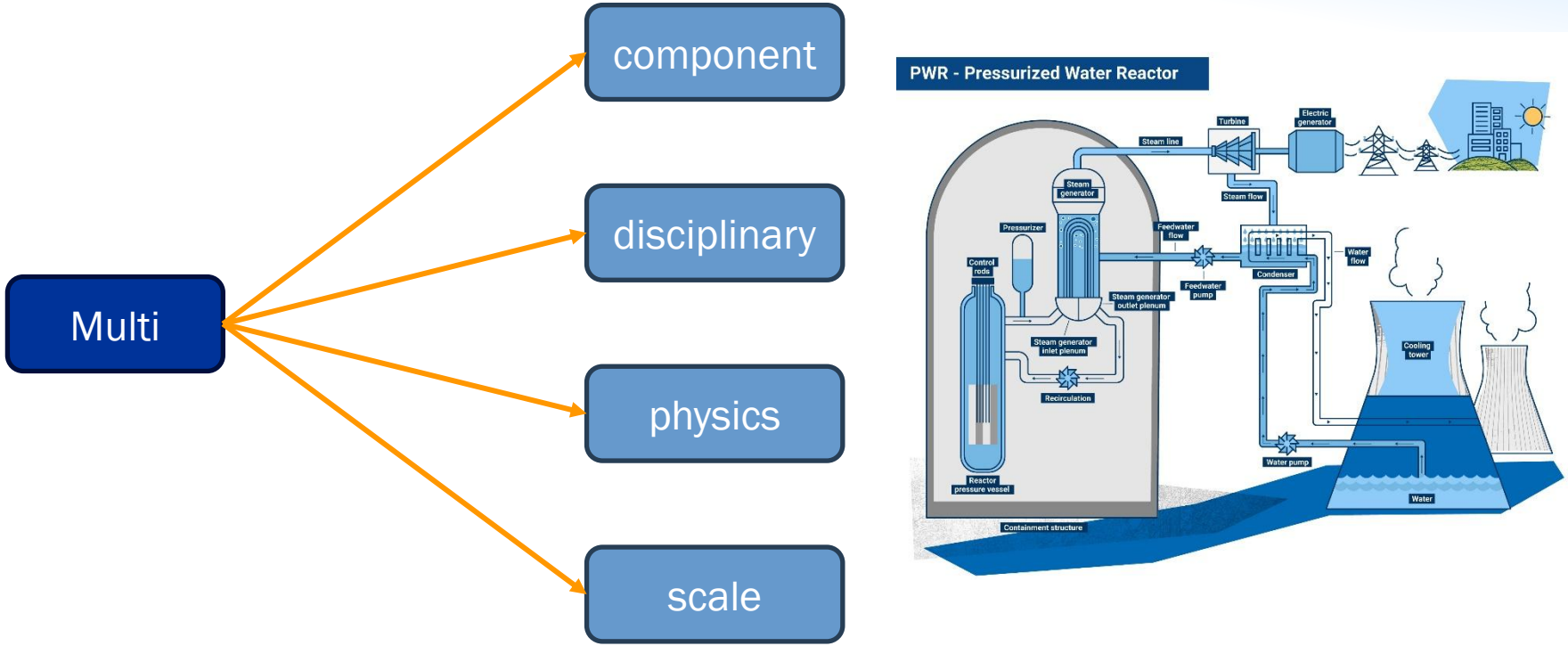
Why do we need MP in nuclear engineering?

Nuclear systems are complex systems



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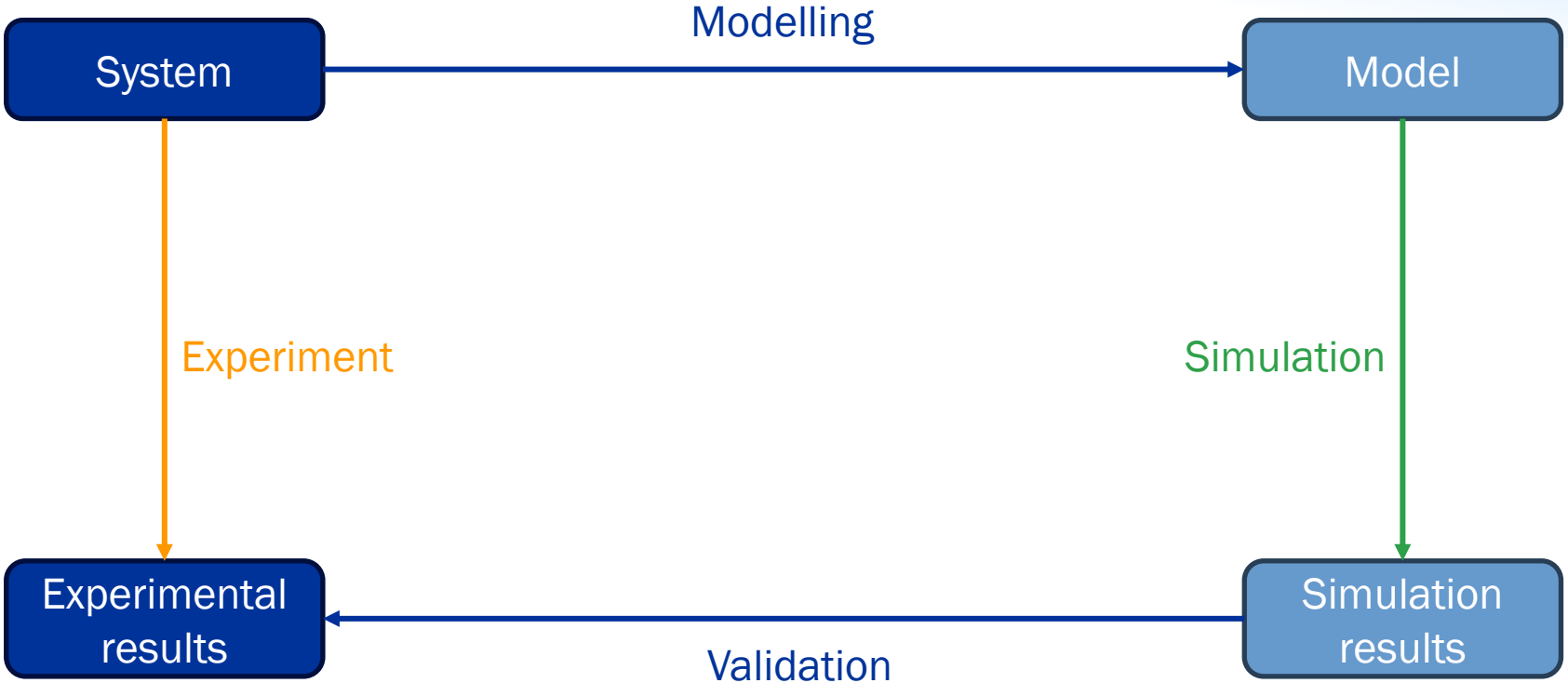

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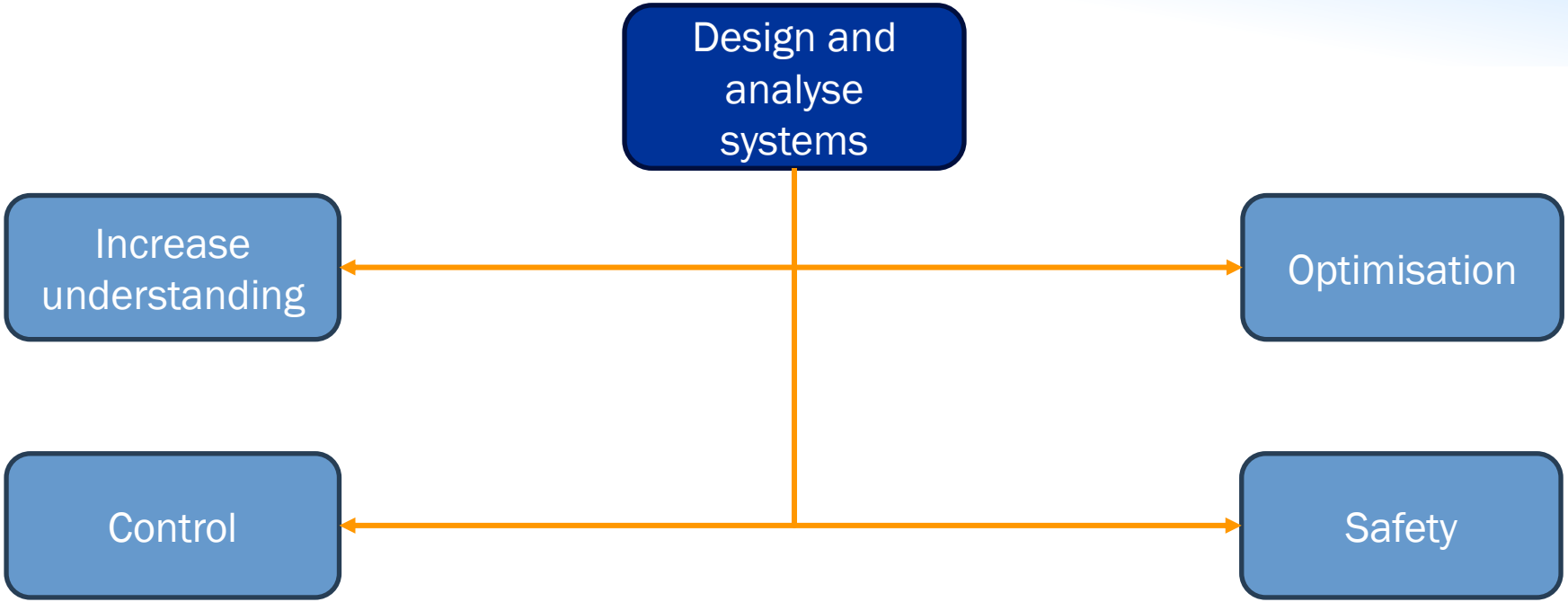

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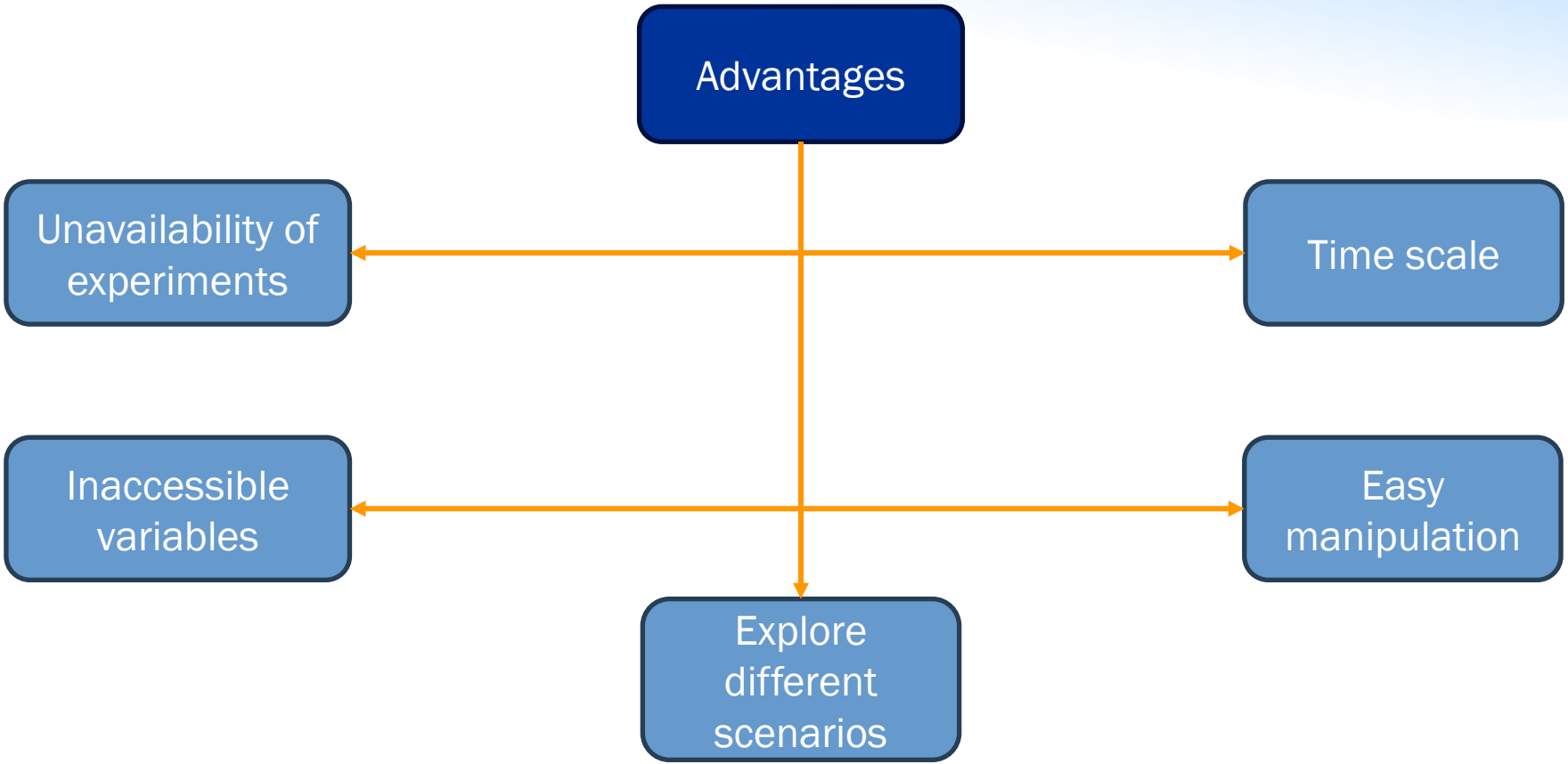

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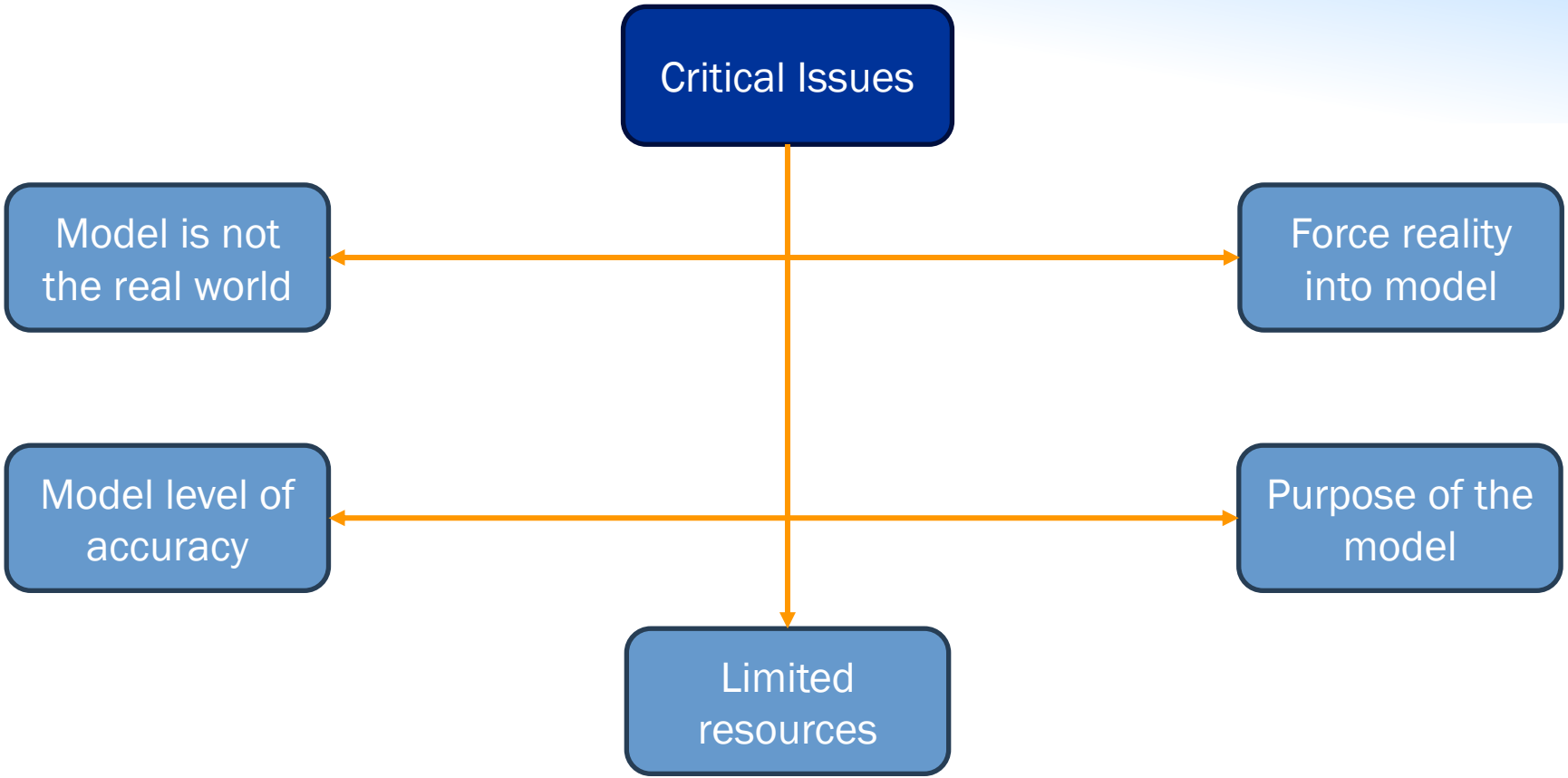

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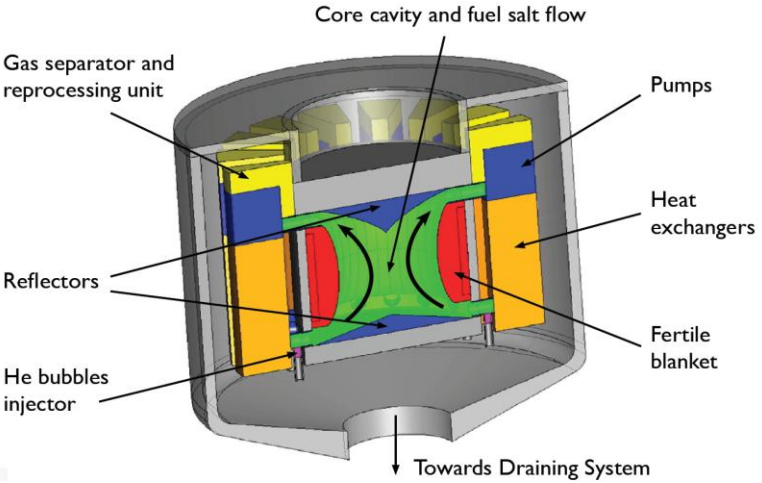
When (if) is MP necessary for MSRs simulation?

MP in MSRs

- Design features?
- Phenomena by design
- Modelling implications



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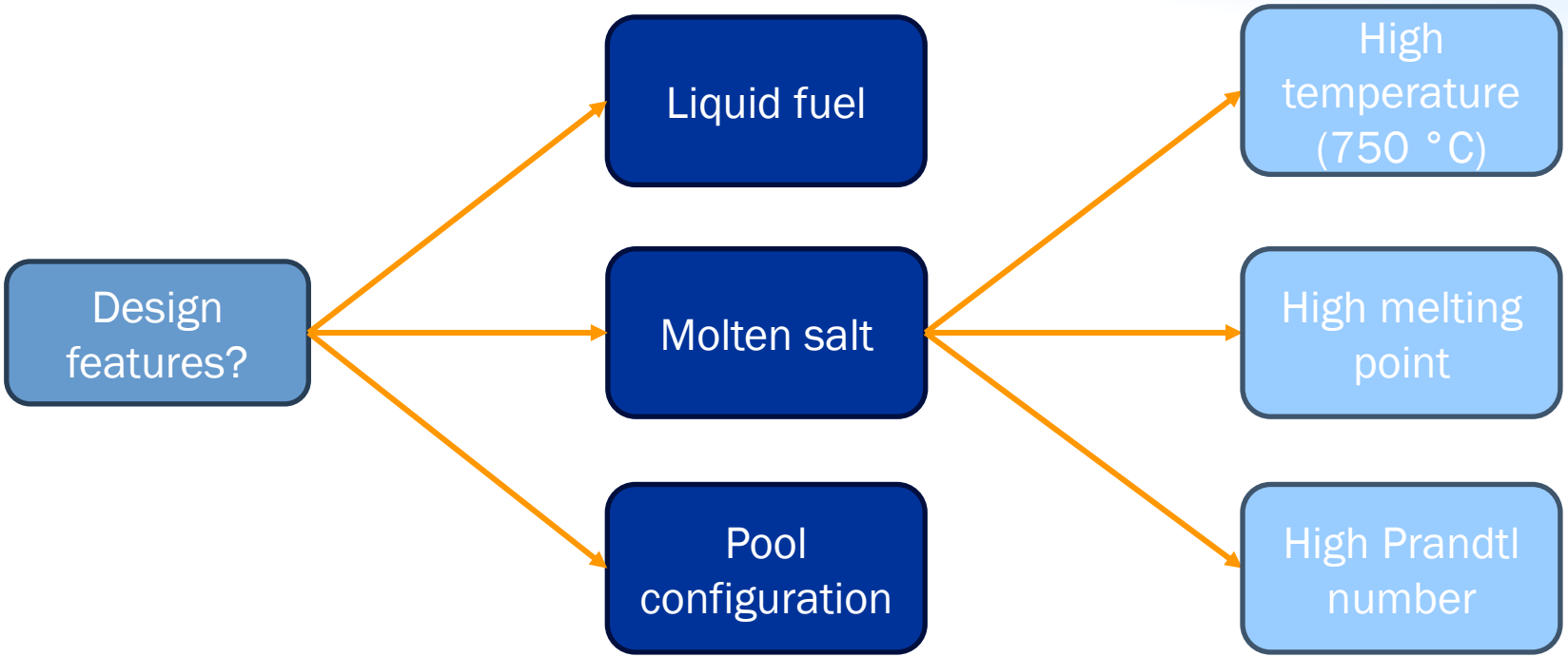

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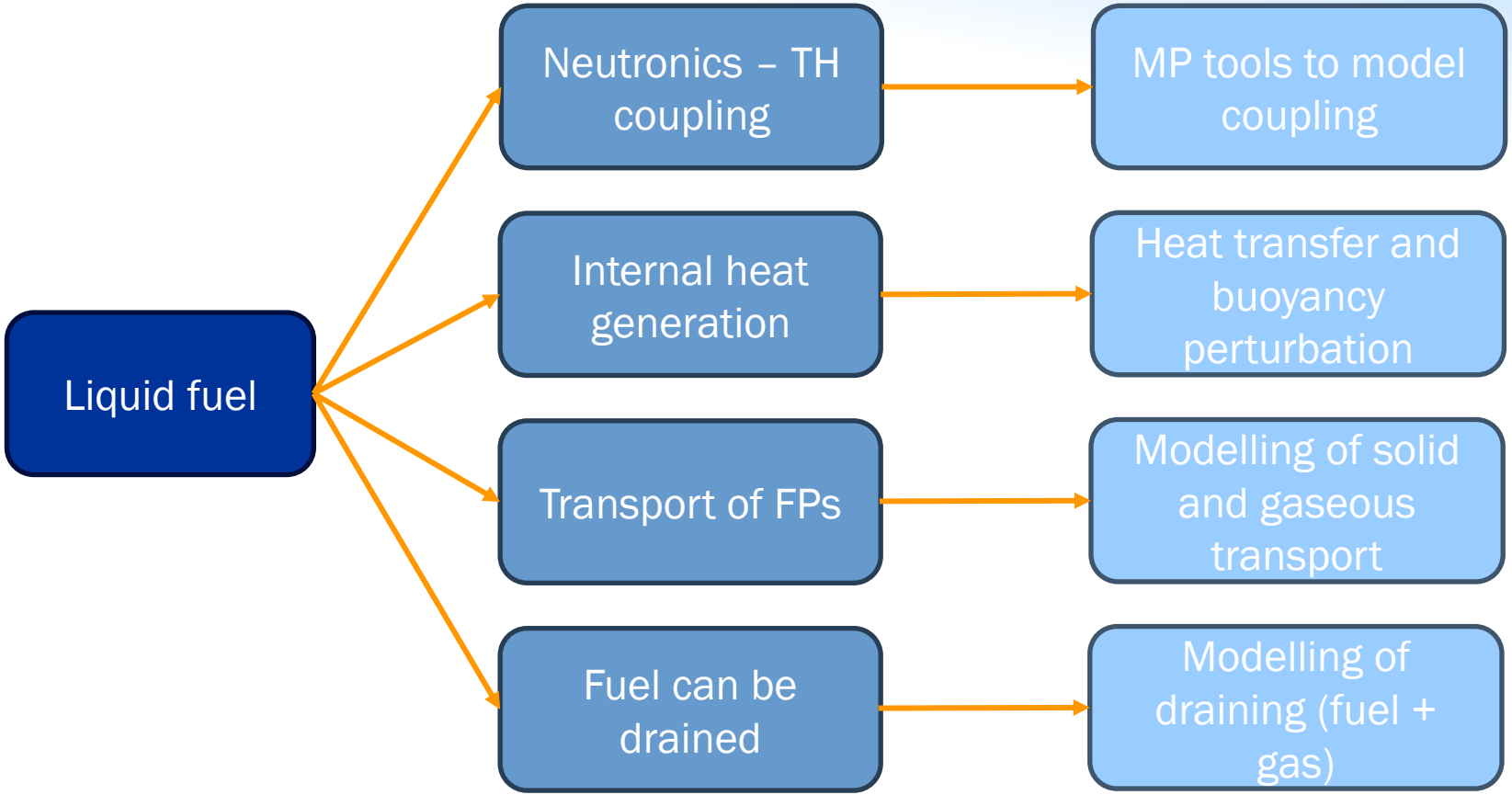

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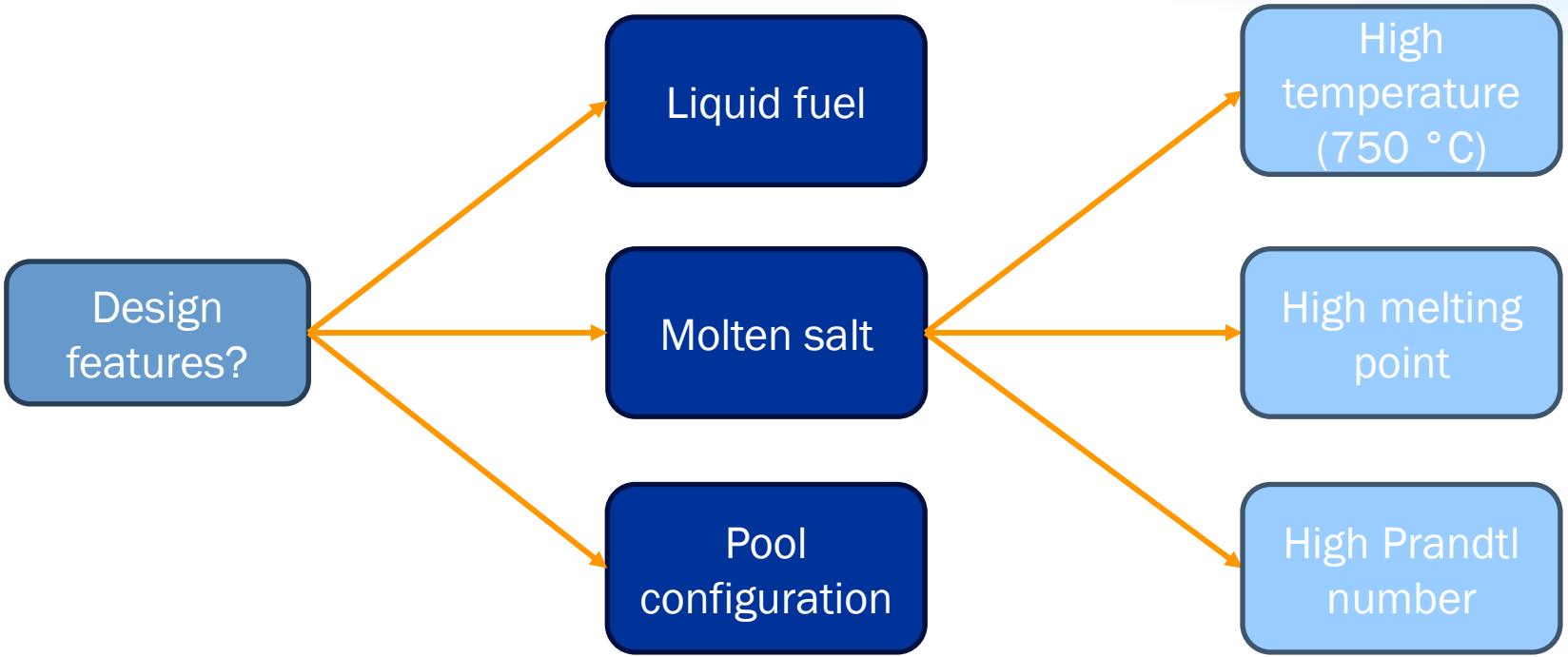

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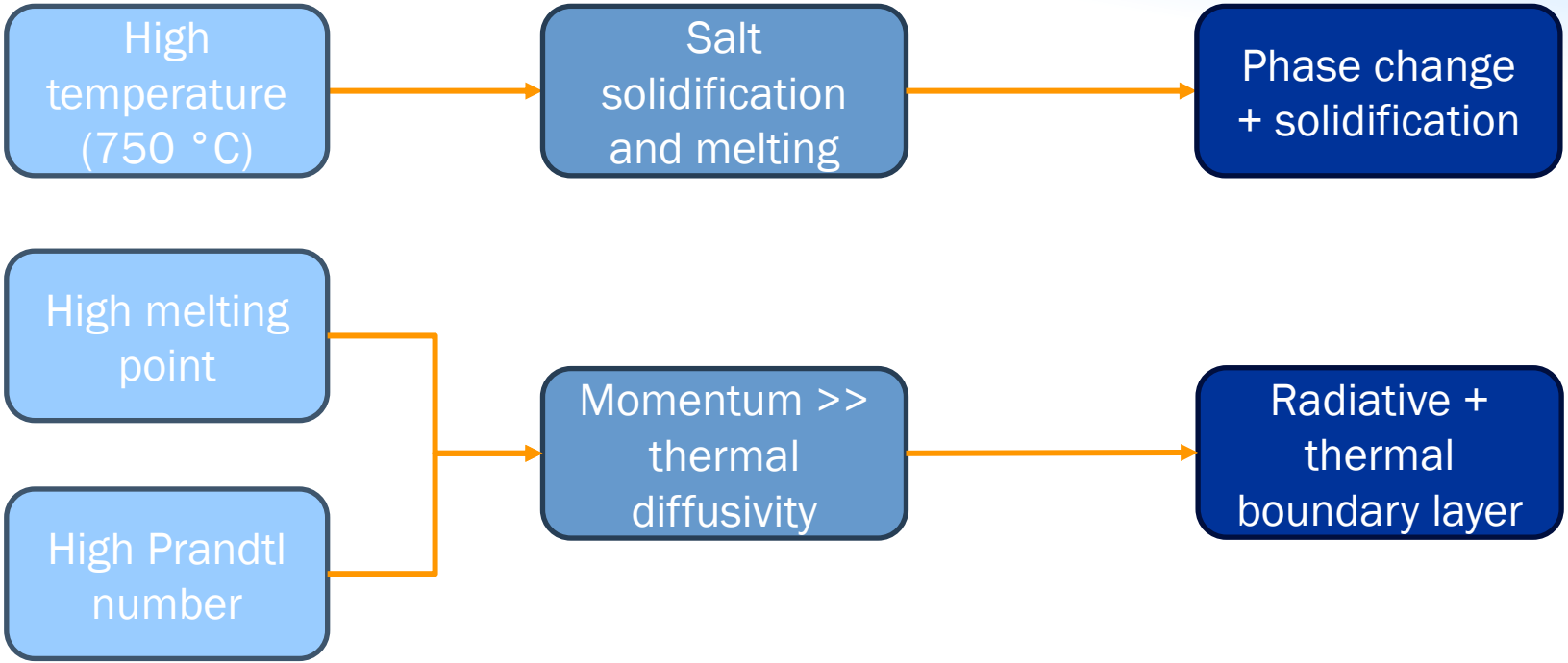

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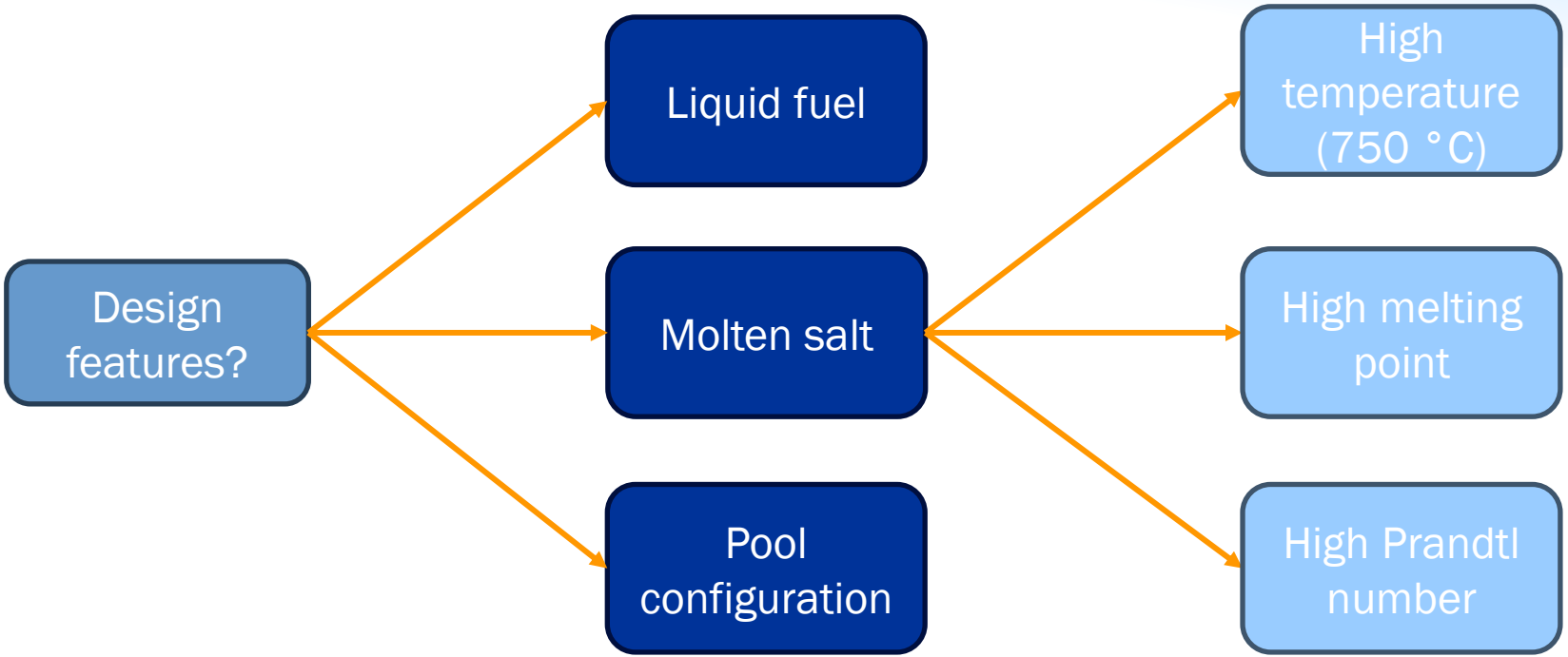

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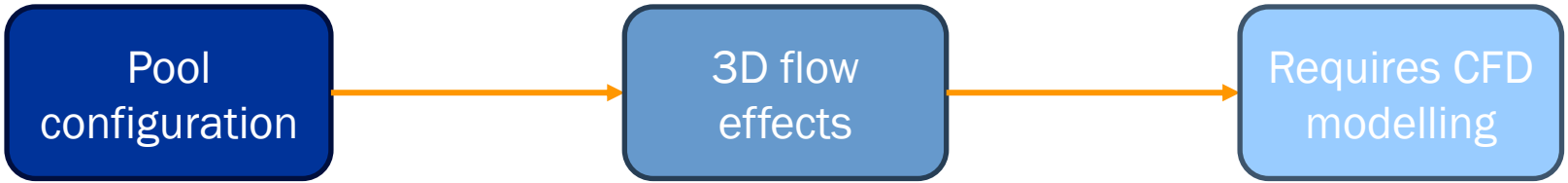

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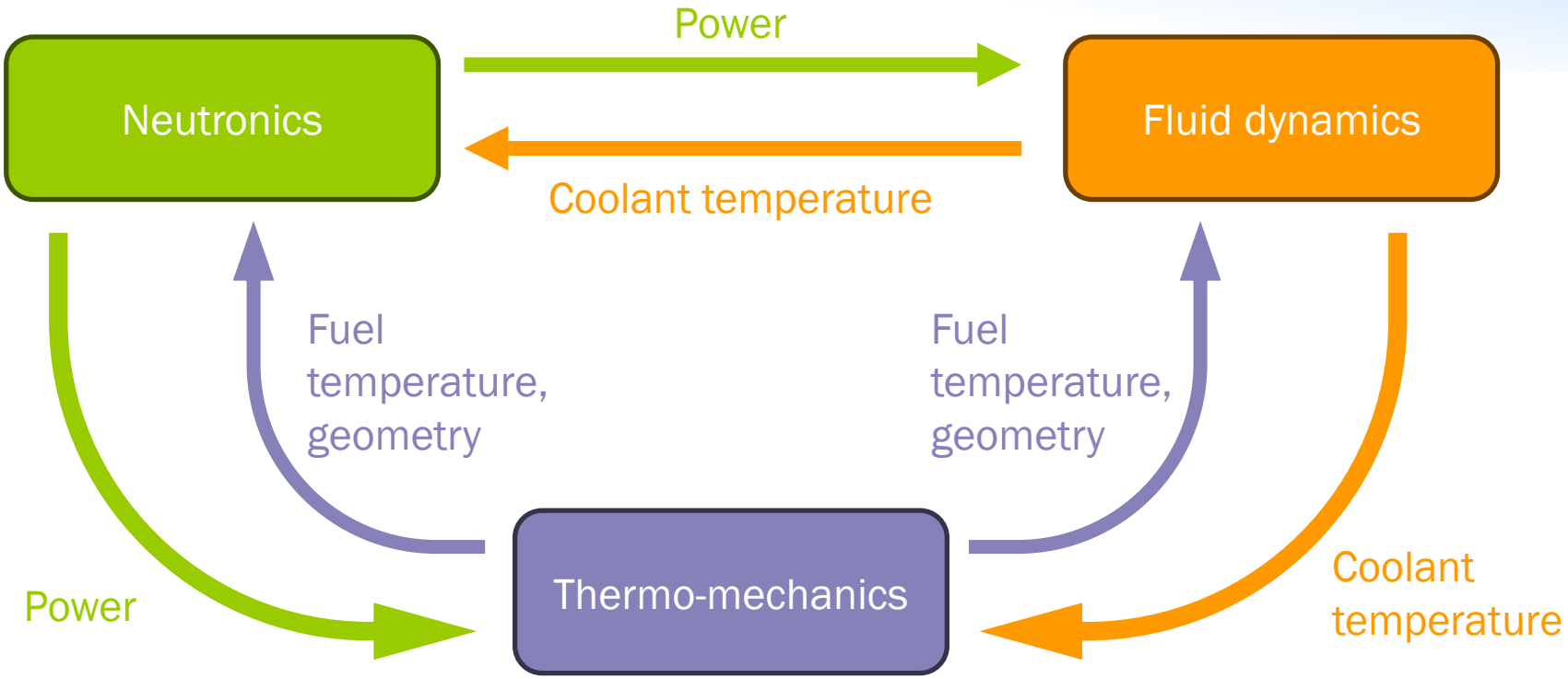
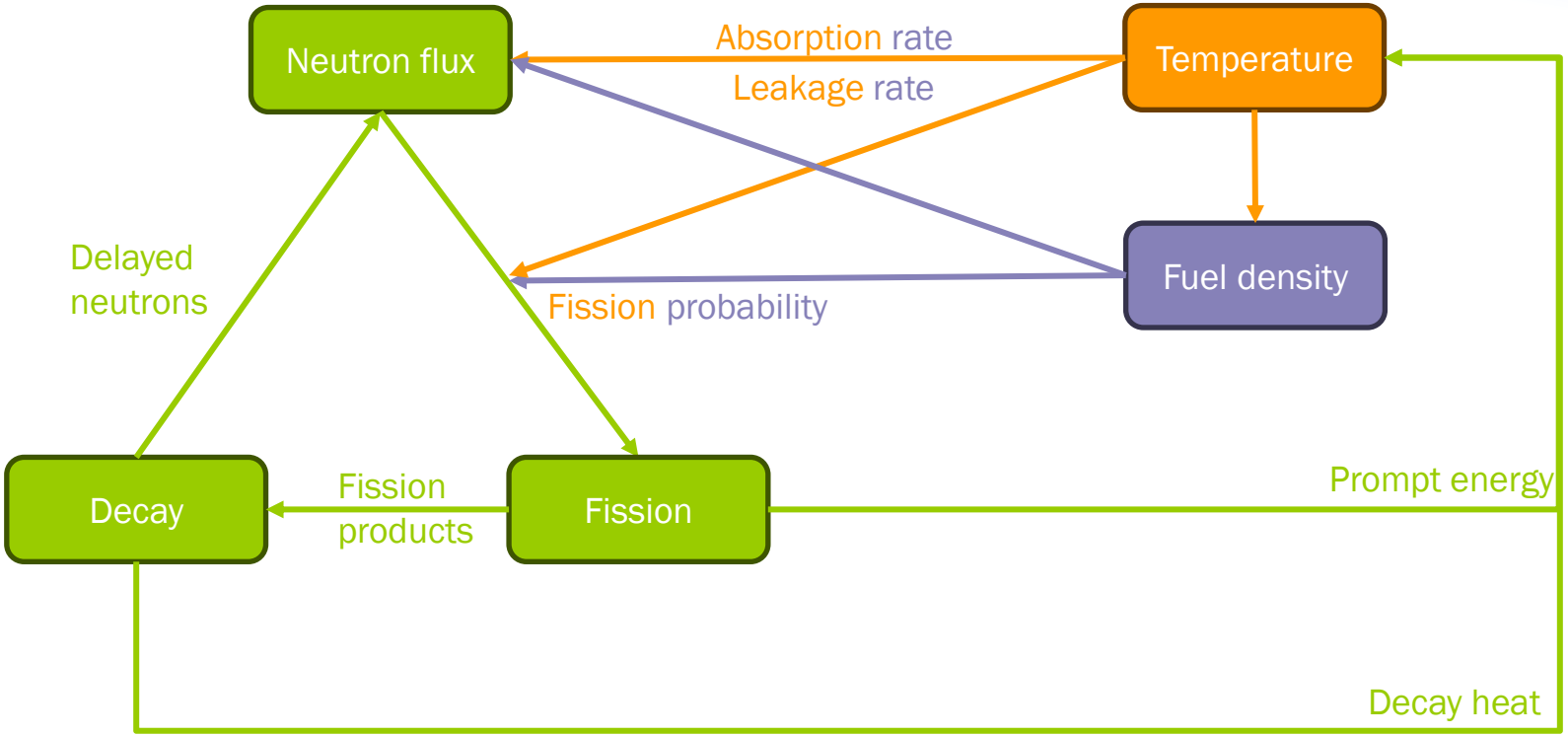
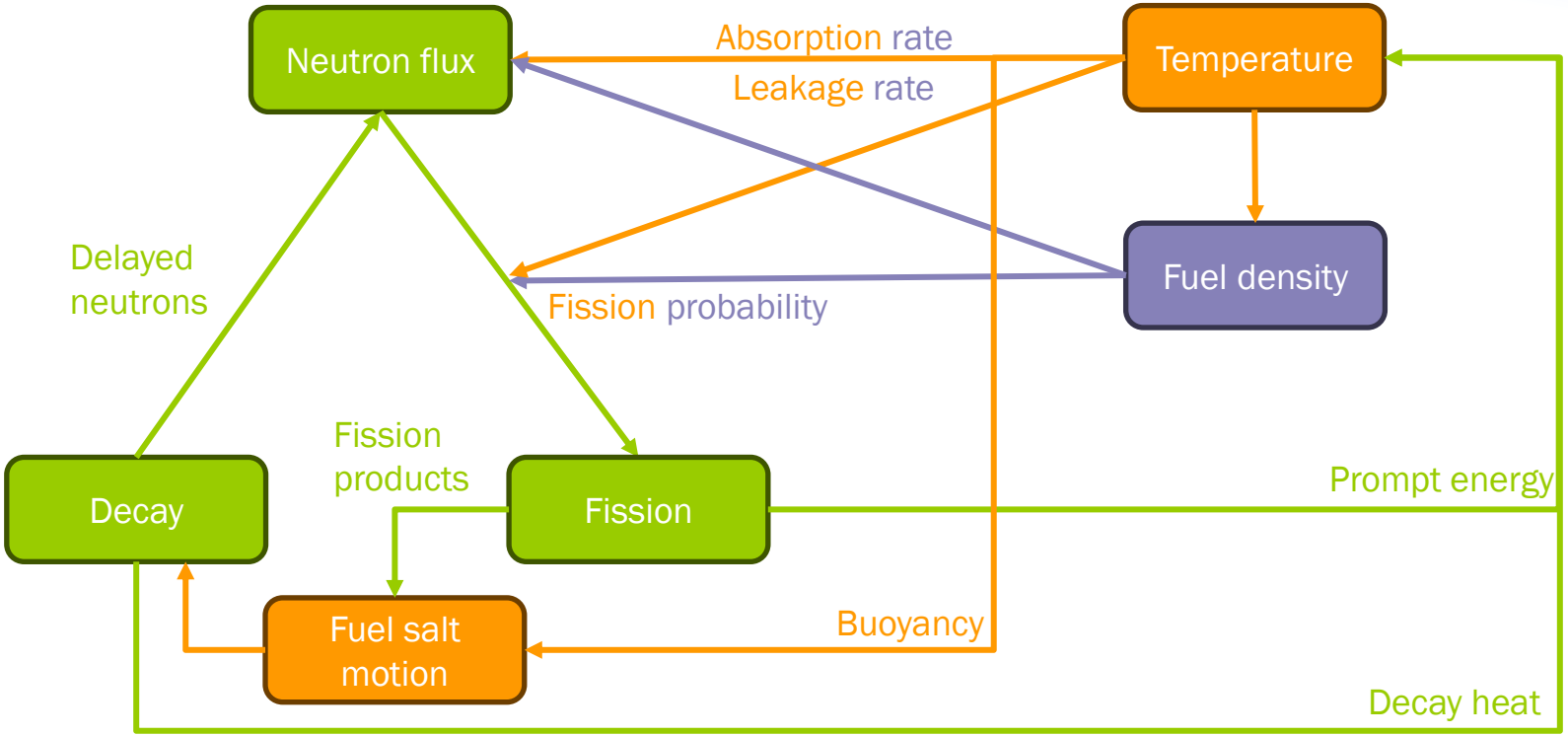


When (if) is MP necessary for simulations?



When (if) is MP necessary for MSRs simulations?



Multiphysics: focus on neutronics

$$\begin{cases} \dfrac{d\psi(t)}{dt} = \dfrac{(\rho-\beta)}{\Lambda}\psi(t) + \sum_{i=1}^{6}\dfrac{\beta_i}{\Lambda}\eta_i(t) \\ \dfrac{d\eta_i(t)}{dt} = \lambda_i\psi(t) - \lambda_i\eta_i(t) - \dfrac{1}{\tau_c}\eta_i(t) + \dfrac{1}{\tau_c}\eta_i(t-\tau_{ec})e^{-\lambda_i\tau_{ec}} \end{cases}$$

τ_c = time inside the core

τ_{ec} = time outside the core

precursors flowing out

precursors returning into the core without decaying

Multiphysics: focus on neutronics

D_{eff} = effective diffusion coeff. of precursors in the salt

$$\frac{\partial C}{\partial t} - \beta \nu \Sigma_f \phi + \lambda_p C + \nabla \cdot (\boldsymbol{u} C) - \nabla \cdot (D_{eff} \nabla C)$$

precursors advection

precursors diffusion

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Modelling of an engineering problem

"Which are the step required to model a nuclear engineering problem?"

1. **Physical modelling**: choose the proper modelling approach (PDEs)

2. **Domain modelling**: establish the boundary of the system and create the geometry (with possible assumptions)

3. **Domain + equation discretization**: selection of a discretization method (FV, FE, DG,...) + mesh creation + equation discretization (including selection of boundary and initial conditions)

4. **Solution of (discretized) equations**: selection of the method to solve the system of linear algebraic equations

5. **Post-processing**: visualization of the results

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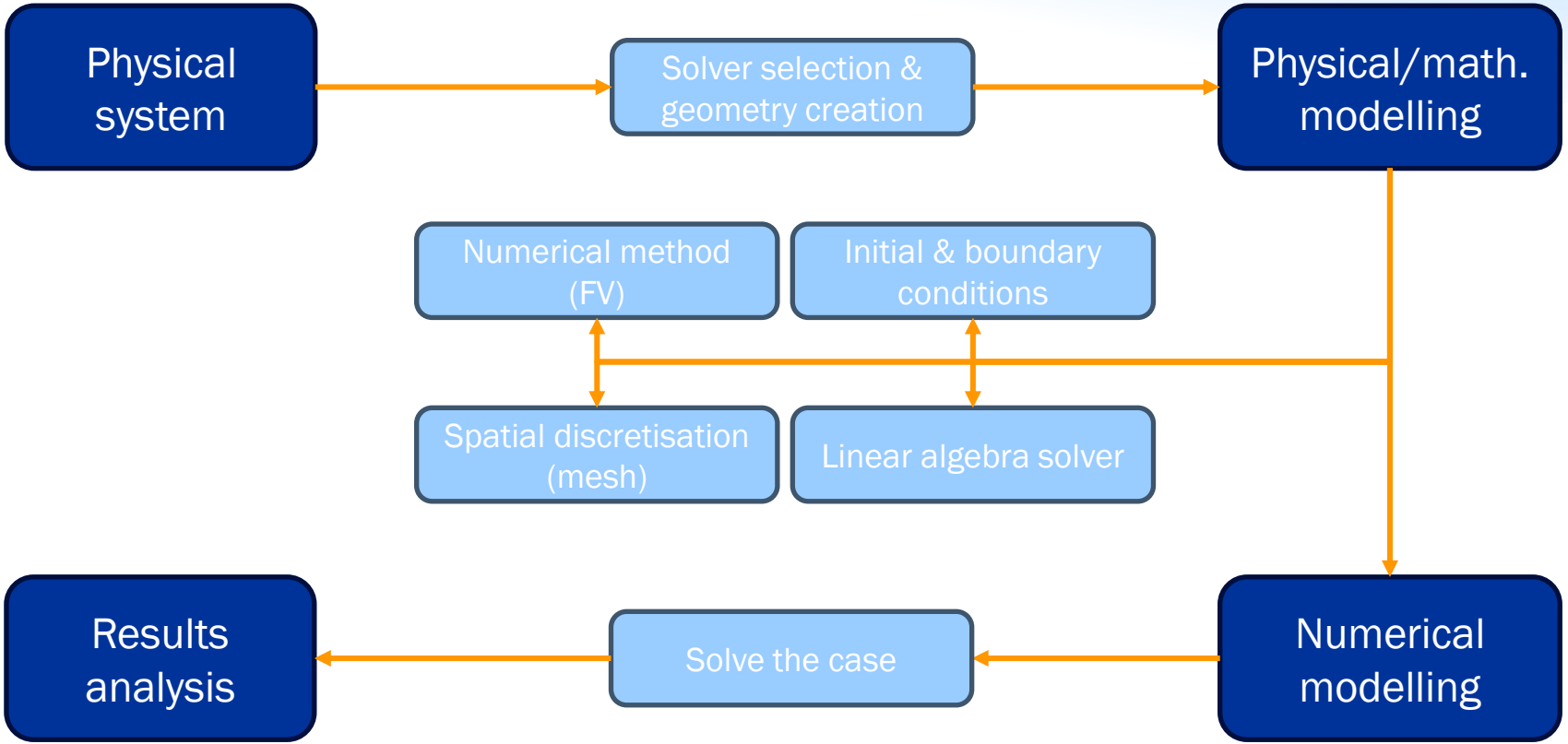
Solver vs Simulation case

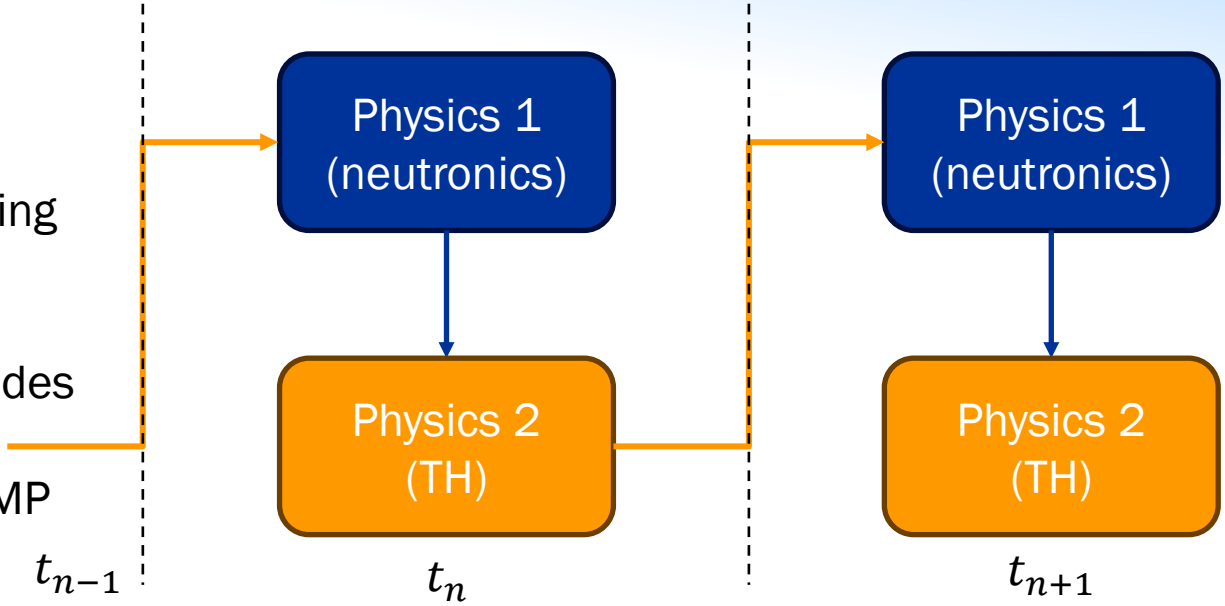
How can we model a multiphysics problem?



How can we model a multiphysics problem?

Operator-split coupling

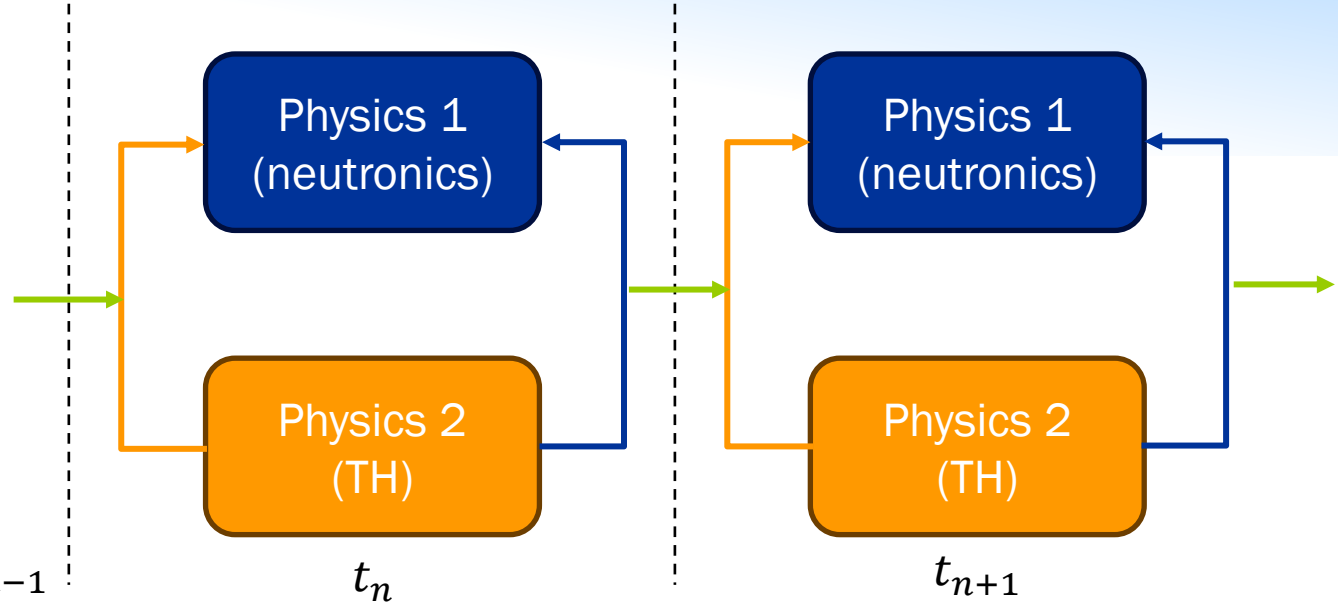
1. Explicit (weak) coupling
2. Existing specialised mono-disciplinary codes
3. Often non-iterative, MP non-linearities not resolved in time
4. Reduced accuracy



How can we model a multiphysics problem?

Iterative (Picard iteration)

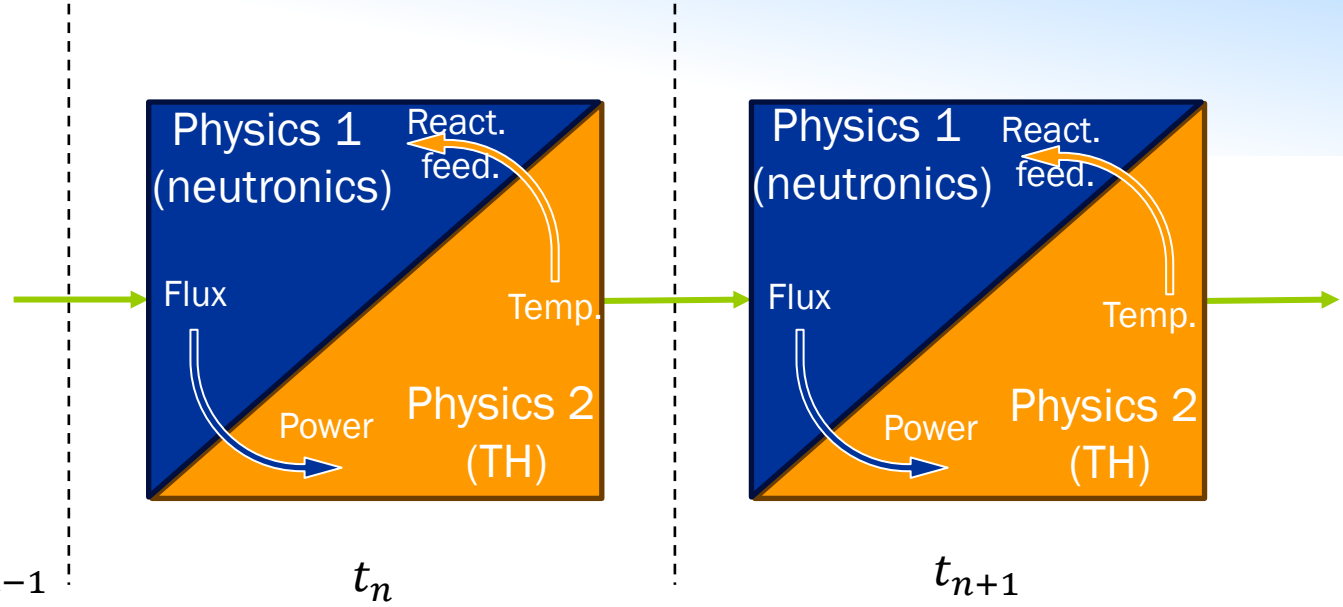
1. Implicit coupling
2. Reuse of existing specialised mono-disciplinary codes
3. Avoid solving large monolithic system
4. Convergence of iteration can take time



How can we model a multiphysics problem?

Monolithic approach

1. Implicit coupling
2. Need of creating codes from scratch
3. Numerical issue due to high non-linearity
4. Highest level of accuracy



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Questions?