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MIRA: a high fidelity system/design code for advanced fusion reactor system analysis

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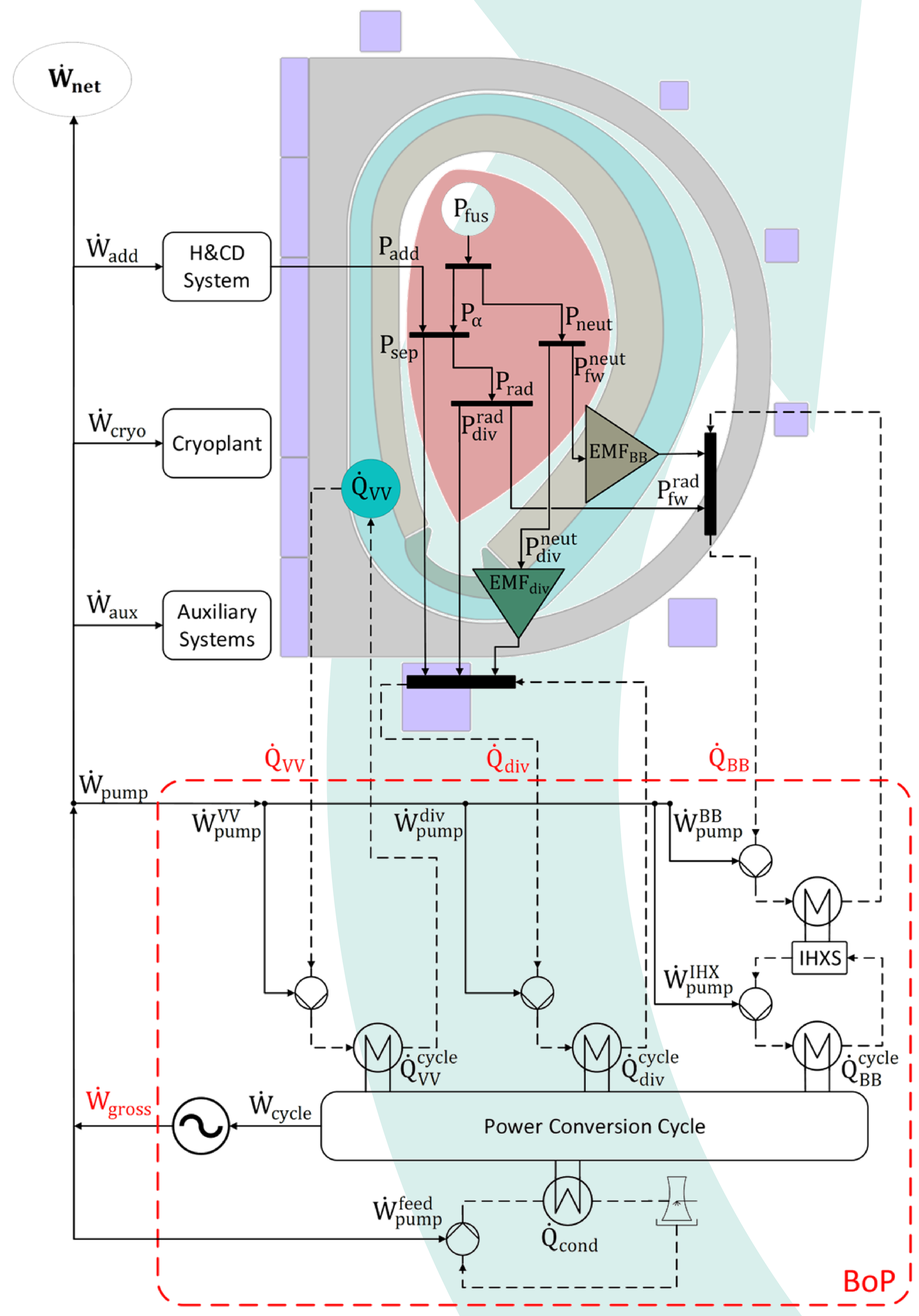
Motivation

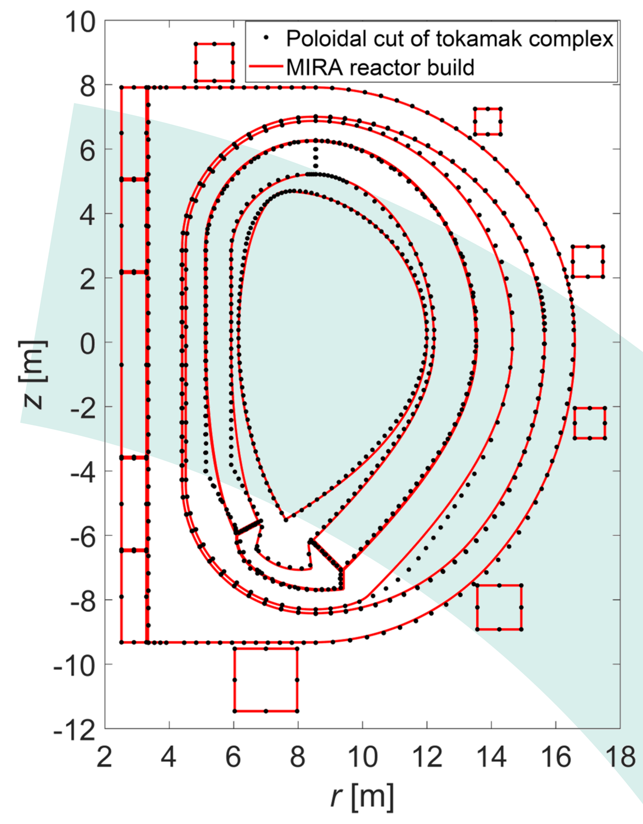
- Systems codes (SC): vital tools for the simulation and design of FPPs
- Existing SCs rely on rather basic physics and engineering models (0D/1D)
- Main goal: refine SC modelling (up to 3D) and allow for exploring multiple engineering solutions → speed-up design process
- MIRA → multiphysics approach for an integrated FPP design

Plant power balance



- 0D plant power balance

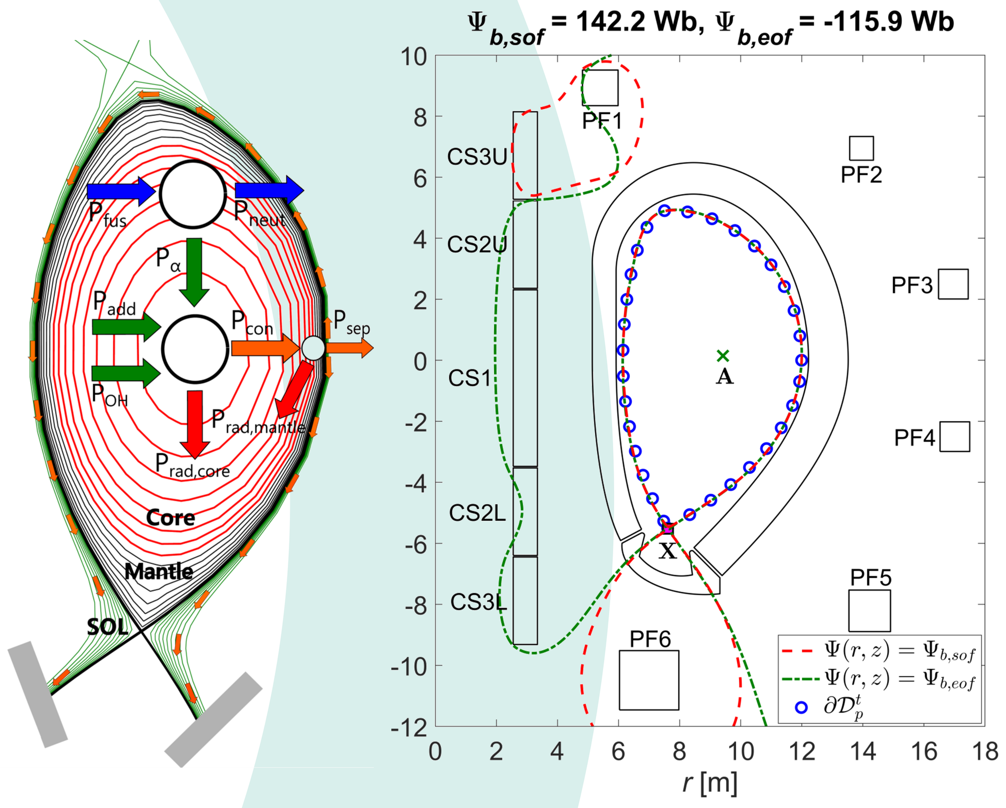
Core reactor architecture & plant engineering layout



- Reactor geometric construction
- Flexible definition of blanket technologies (HCPB/WCLL)
- Flexible defintion of SC cable technologies (LTS/HTS)
- Definition of plant power balance properties ($\eta_{\mathrm{gross}}, \eta_{\mathrm{add}}, f_{\mathrm{pump}}$)

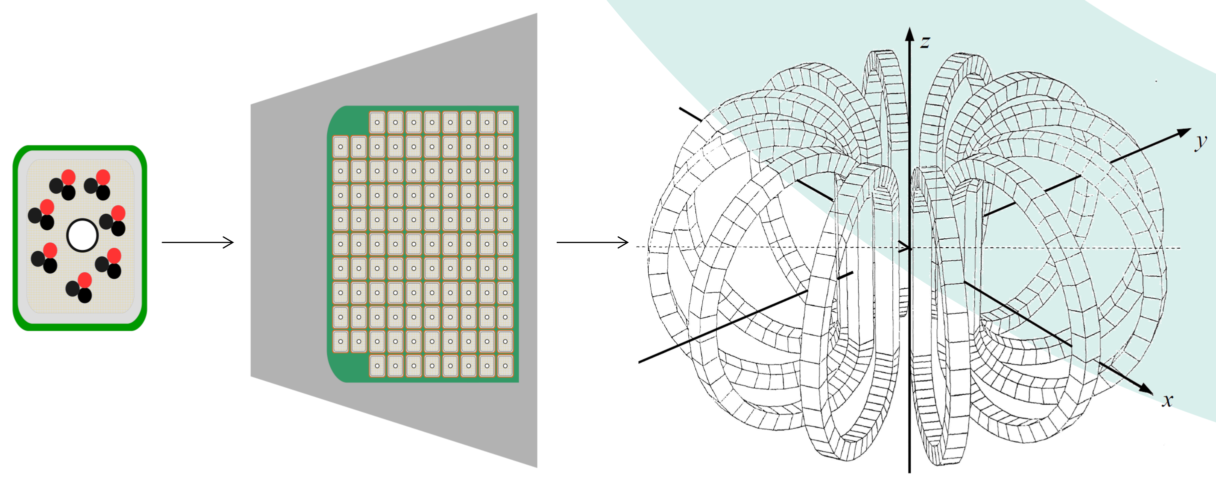
Modular Integrated Reactor Analysis

Core physics & plasma scenario



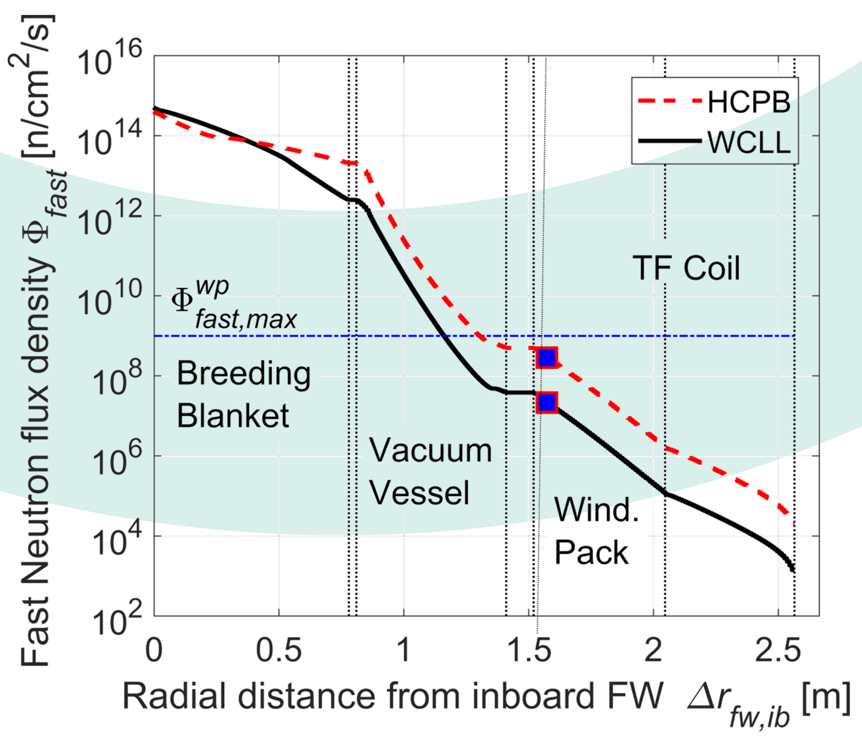
- Power/particle/current 0D SS balances
- 2D free boundary equilibrium solver
- Breakdown and flat-top simulations

Electromagnetics & conductor technology



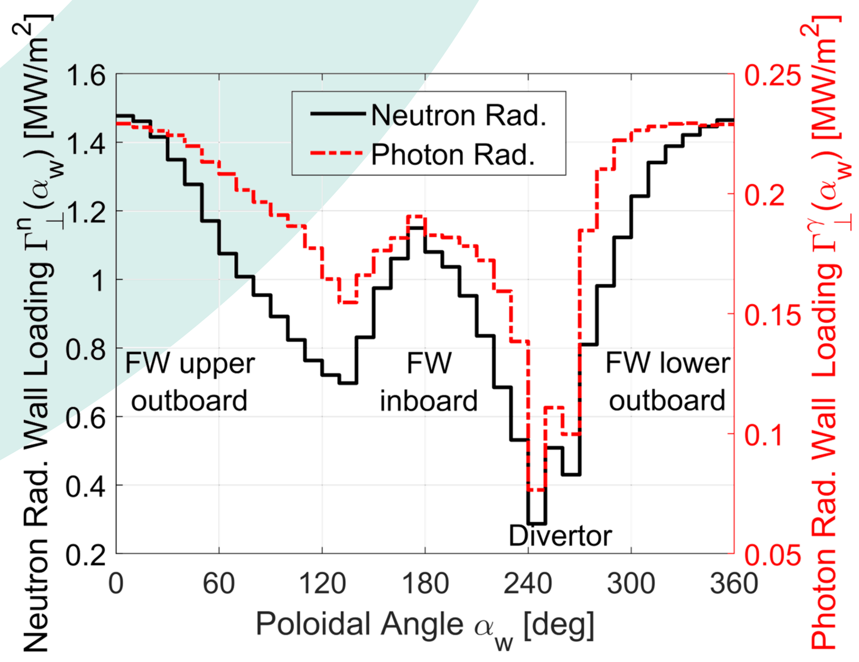
- 3D magnetostatics (Biot-Savart)
  - Magnetic field, energy, inductances, Lorentz forces
  - Toroidal field ripple
- Conductor verification (Temp. margin and stability)

Reactor Neutronics



- 1D n-γ radiation transport (reactor)
  - TBR, nuclear heating (NH)
  - n-γ radiation shielding, dpa

FW & Divertor Heat Loads



- 2D n-γ radiation transport (plasma)
  - FW/divertor n-γ wall loading
- Heat fluxes on divertor targets

Verification study of the DEMO 2015 baseline

- Implications on the major reactor parameters derived from modelling approximations of SCs
- Violation of operational limits and design targets
  - Safety factor q_0: high l_i → spatial effects of magnetic flux surfaces not considered
  - TF ripple δ_{tf}: oversimplified modelling of ripple
  - Burn time τ_{burn}: overstimation of coils capabilities

*Fixed target

	P_{fus} [MW]	B_t [T]	l_i [-]	q_0 [-]	**TBR [-]**	NH_{BB} [MW]	$B_{\mathrm{peak}}^{\mathrm{TFC}}$ [T]	δ_{tf} [%]	**τ_{burn} [h]**	$\dot{W}_{\mathrm{pump}}$ [MW]	η_{gross} [%]	**$\dot{W}_{\mathrm{net}}$ [MW]**
MIRA (HCPB)	2037.1	5.49	1.15	0.55	1.20	2026	12.36	0.68	1.32	165	33.2	448.8
MIRA (WCLL)					1.14	1814				22	30	445.2
Baseline	2037	5.67	1.15	1	n.a.	1826	12.32	0.6	2	155	37.4	500
Limit/ target	≈ 2037*	n.a.	≈ 1.15*	≥ 1	≥ 1.10	n.a.	≤ 12.44	≤ 0.6	≥ 2	n.a.	n.a.	300-500