MIRA: a Multiphysics Approach to Designing a Fusion Power Plant

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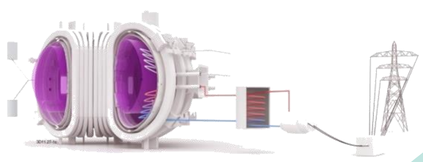
Motivation

- ❑ Systems codes (SC) are vital tools for the design of fusion power plants (FPP)
- ❑ Existing SCs in the EU-DEMO conceptual design (PROCESS, and SYCOMORE) rely on rather basic physics and engineering models (0D/1D)
- ❑ Main goal: refine SC modelling (up to 3D) to improve interfaces between SCs and detailed design codes
- ❑ MIRA → a multi-fidelity reactor design code for a multiphysics approach towards an integrated FPP design

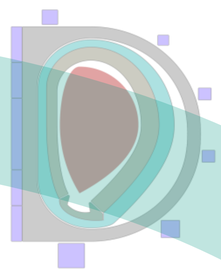
MIRA Physics and Engineering Modelling

Reactor Integration into Plant System



- ❑ Integral plant power balance
- ❑ Reactor pulse characterization

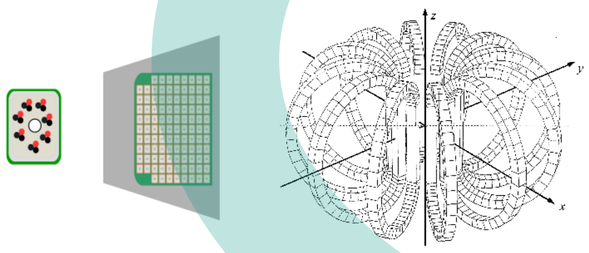
Reactor Architecture



- ❑ 2D geometric construction
- ❑ Blanket material composition
- ❑ Coil cable technology

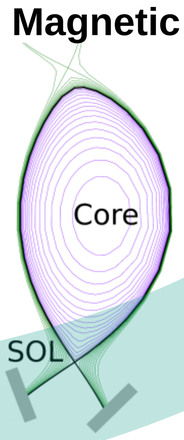
MIRA Multiphysics Approach

Coils Engineering



- ❑ 3D magnetostatics
  - ❑ Magnetic field, force, energy
  - ❑ Toroidal field ripple
- ❑ Conductor design

Magnetic Equilbrium & Plasma Physics



- ❑ 2D free-boundary equilibrium
- ❑ 0D plasma power, particle, current integral balances
- ❑ SOL plasma power balance
- ❑ Divertor peak heat flux

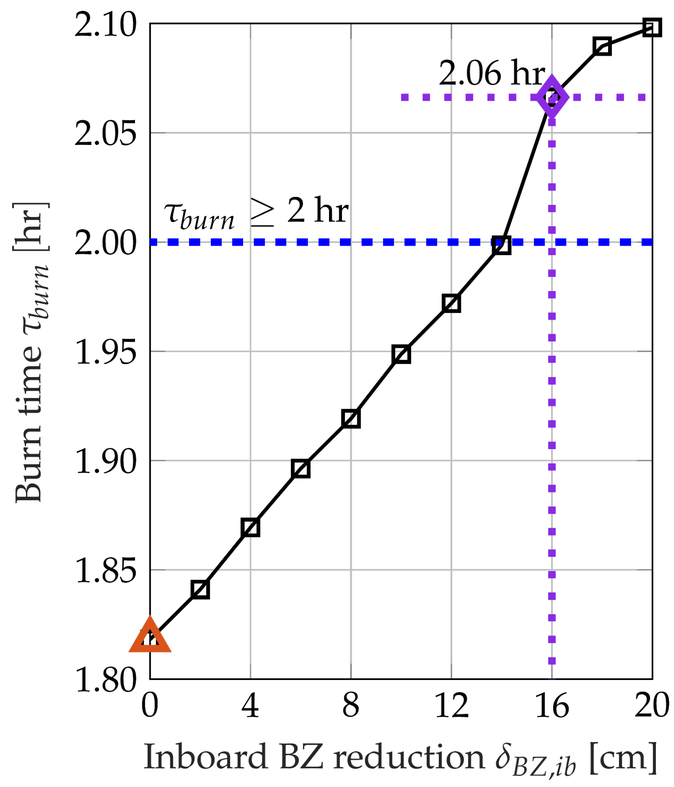
Reactor neutronics

- ❑ 2D n-γ plasma chamber
- ❑ 1D n-γ reactor
- ❑ TBR, nuclear heating
- ❑ Neutron shielding, dpa

MIRA Analysis of the EU-DEMO 2015 baseline from PROCESS

Parameter [unit]	MIRA	PROCESS	Type
Plasma major radius [m]	9.07	9.07	I
Plasma aspect ratio [-]	3.1	3.1	I
Toroidal field at plasma center [T]	5.49	5.67	O
Plasma current [MA]	19.26	19.60	O
Fusion power [MW]	2037	2037	DT ≈ 2000
Radiation power [MW]	304.2	305.5	O
Additional heating power [MW]	50	50	DT ≈ 50
Transport loss across the separatrix [MW]	154.1	154.2	O
TBR (HCPB/WCLL) [-]	**1.20/1.14**	**n.a.**	**DT ≥ 1.05**
Total thermal power (HCPB/WCLL) [MW]	2624/2371	2436	O
Net electric power (HCPB/WCLL) [MW]	**365/350**	**500**	**DT ~ 300-500**
Plasma Burn time [hr]	**1.81**	**2.00**	**DT ≥ 2 hr**

Design Improvement



Conclusion

- ❑ Advanced reactor systems analyses highlight non-trivial interdependencies between different reactor systems.
- ❑ Refined 2D/3D reactor design codes like MIRA are beneficial to the conceptual design of DEMO and of FPPs.