Karlsruhe Institute of Technology

Max-Planck-Institut für Plasmaphysik

Systems Codes Rapporteur Part II

MIRA: a Multiphysics Approach to Designing a Fusion Power Plant

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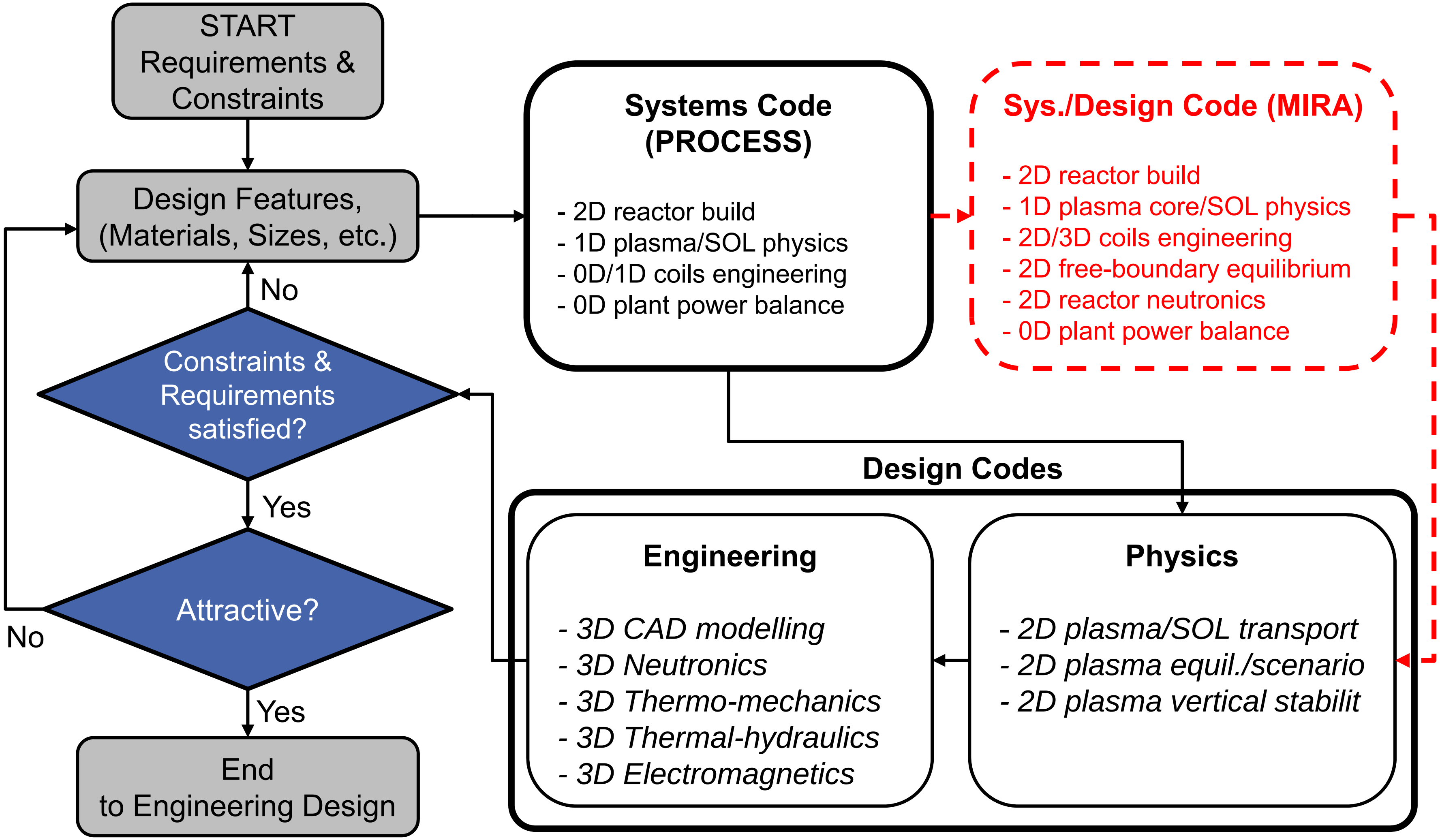
Conceptual Design of the EU-DEMO Reactor



Modular Integrated Reactor Analysis (MIRA)

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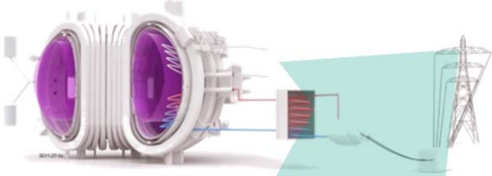
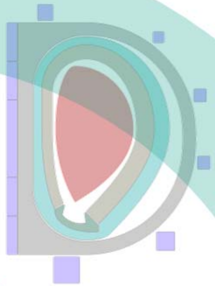
MIRA Multiphysics Approach

Reactor Integration into Plant System



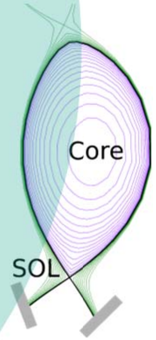
- ❑ Integral plant power balance
- ❑ Reactor pulse characterization

Reactor Architecture



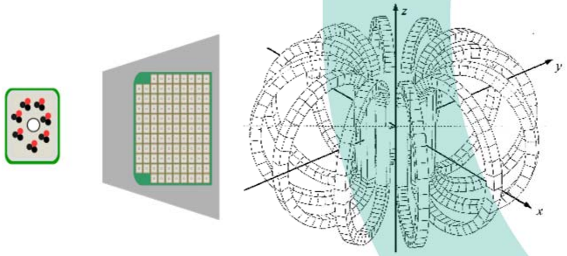
- ❑ 2D geometric construction
- ❑ Blanket material composition
- ❑ Coil cable technology

Magnetic Equilbrium & Core/SOL Physics



- ❑ 2D free-boundary equilibrium
- ❑ Plasma power, particle, current integral balance

Reactor Magnetics



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

Reactor neutronics

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

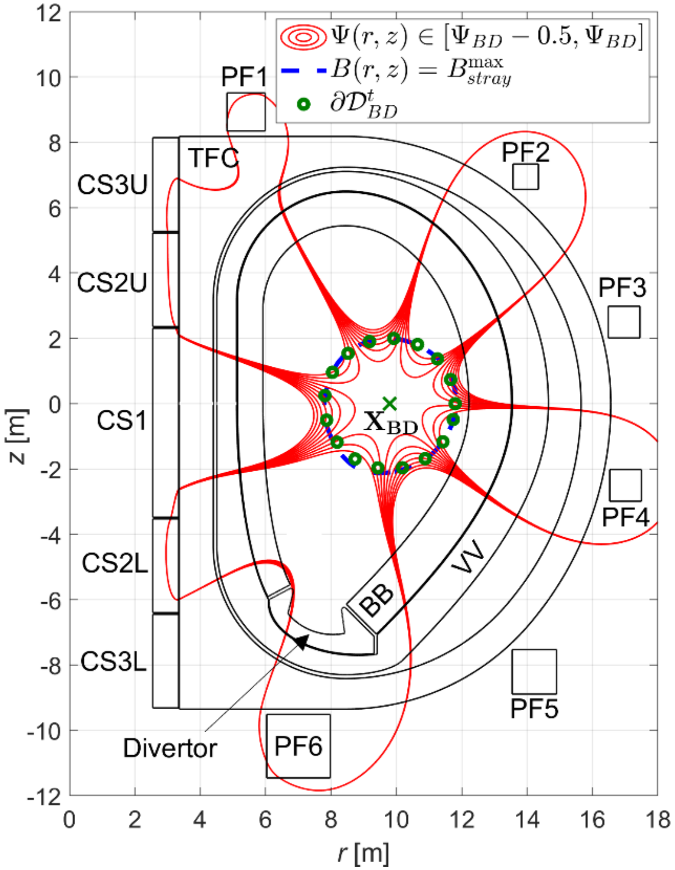
MIRA analysis of the EU-DEMO 2015 Baseline

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
Tritium Breeding Ratio (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**

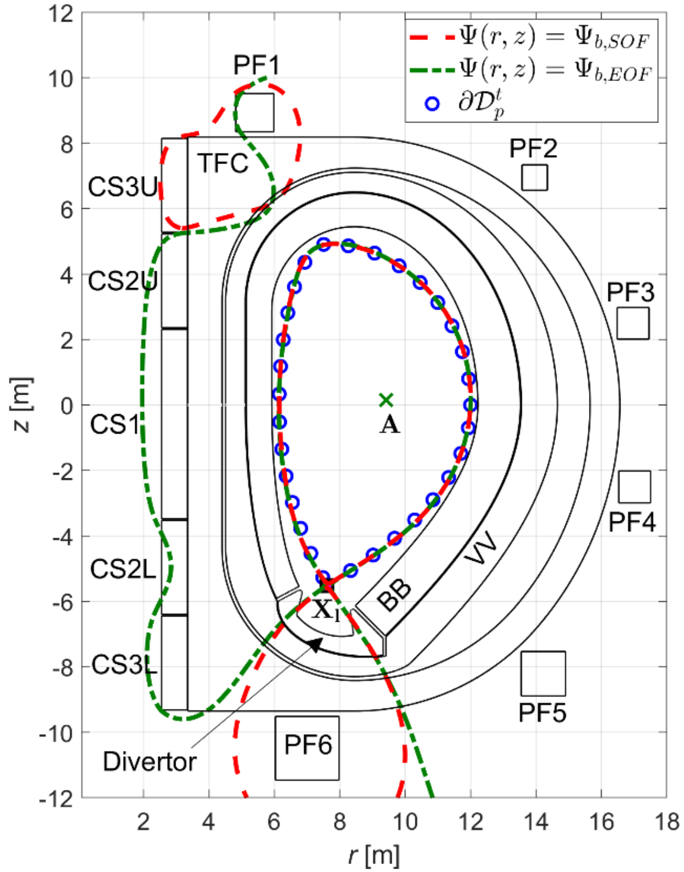
I = Input, O = Output, OL = Operational Limit, DT = Design Target

MIRA scenario analysis of the EU-DEMO 2015

Plasma breakdown



Plasma flat-top

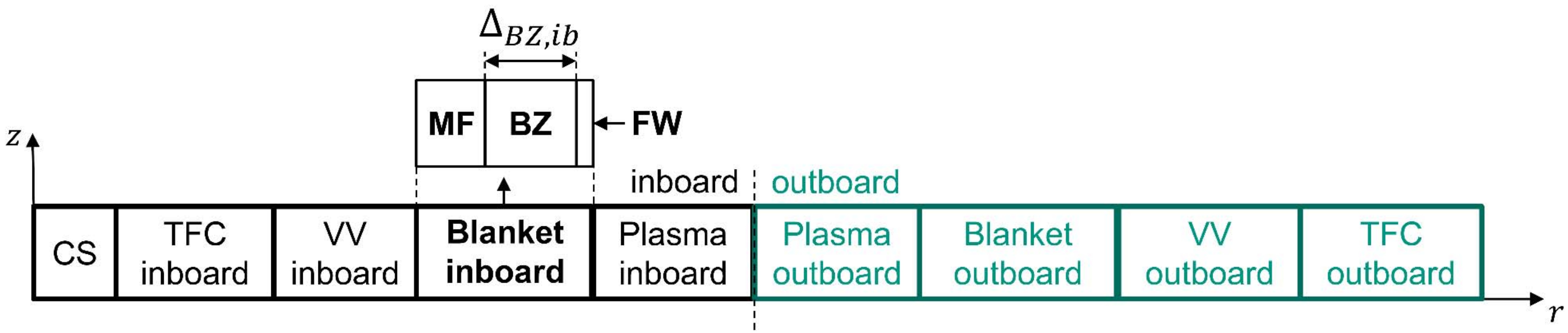


$\tau_{burn}(\text{PROCESS}) \sim r_{CS}^2 B_{max,CS}$

$\tau_{burn}(\text{MIRA}) \sim \Psi_{b,SOF} - \Psi_{b,EOF}$

Improvements of EU-DEMO 2015 Baseline

- MIRA analysis of DEMO 2015 baseline issued by PROCESS
  - $\tau_{burn} = $ **1.81 hr** → violation of long pulse requirement ($\tau_{burn} \geq 2$ hr)
  - $\mathrm{TBR} = 1.20$ (HCPB), 1.14 (WCLL) → exploitable margin ($\mathrm{TBR} \geq 1.05$)
- Strategy: reduction of **inboard breeding zone thickness**
  - CS closer to plasma → increase of τ_{burn}
  - Reduction of material inventories → cost benefits
  - Parameter scan of $\Delta_{BZ,ib}$ → $\delta_{BZ,IB} = \Delta_{BZ,ib}(\mathrm{DEMO\ 2015}) - \Delta_{BZ,ib}$



Parametric Scan of Inboard BZ Thickness

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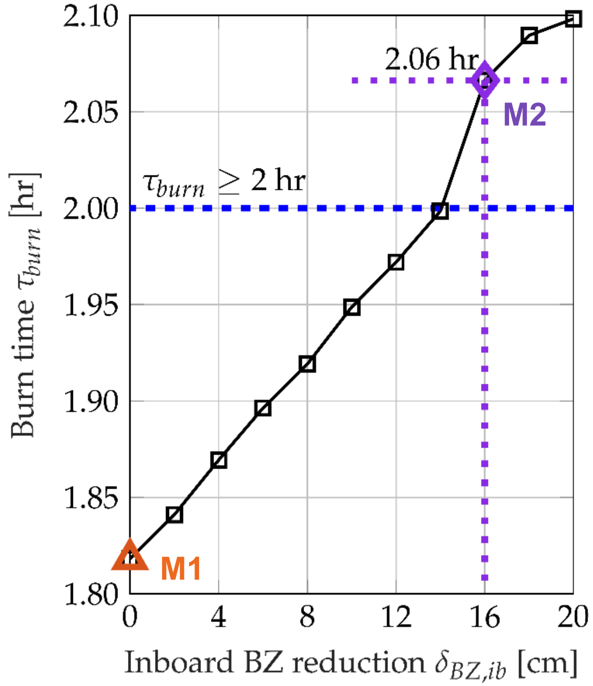
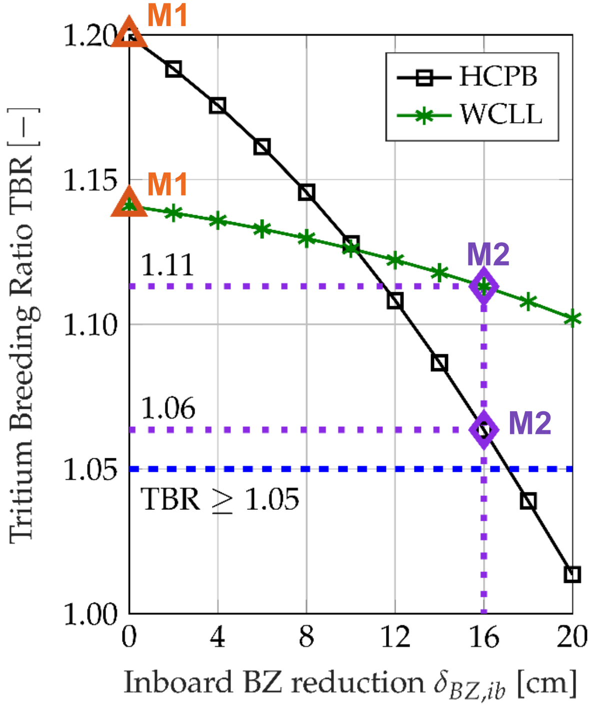
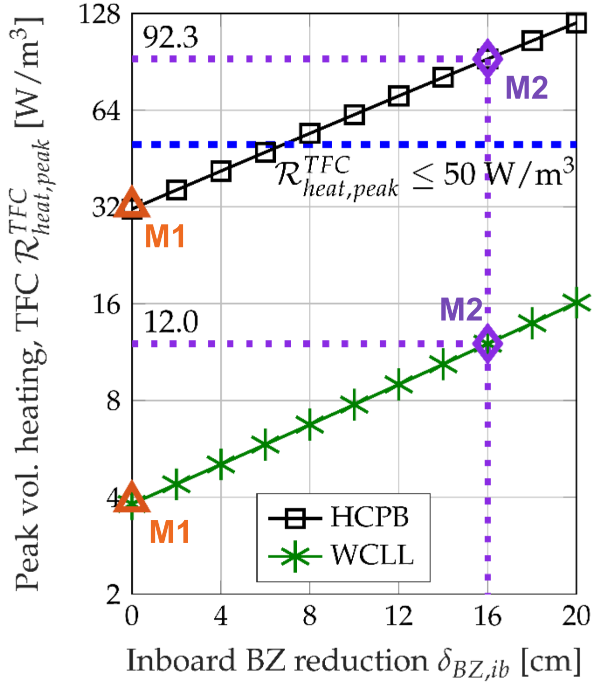
Plasma burn time



Tritium Breeding Ratio



Peak nuclear heating at inboard TFC



△ EU-DEMO 2015 baseline (M1) ($\delta_{BZ,ib} = 0$ cm) → ◇ MIRA DEMO Design Point (M2) ($\delta_{BZ,ib} = 16$ cm)

Conclusion & Outlook

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Achievements

- High-fidelity fusion system/design code MIRA
- Enhanced physics & engineering modelling → from 0D/1D to 2D/3D
- Refined mathematical representation of key reactor parameters
- Improved EU-DEMO 2015 reactor design

	Req./ Const.	DEMO 2015 PROCESS	DEMO 2015 MIRA	Improved DEMO 2015 MIRA
Plasma burn time [hr]	≥ 2	**2.00**	**1.81**	**2.04**
Tritium Breeding Ratio [-]	≥ 1.05	**None**	**1.16**	**1.11**

Outlook

- EUROfusion, TSVV Task 14: *Multi-Fidelity Systems Code for DEMO*
  Development of BLUEMIRA → BLUEPRINT (CCFE) + MIRA (KIT)