Uncertainty Quantification in Fusion Power Plant Design

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Introduction

In the **EUROfusion roadmap** [1] there are **three goals addressed** to achieve magnetic confinement fusion as a large scale sustainable low-carbon electricity generator:

1) Demonstrate the **technical feasibility** of large scale fusion power with **ITER**;
2) Demonstrate **electrical power production** with **DEMO**;
3) Develop science, technology and industry to facilitate the **transition** from DEMO to a **commercial fusion** power plant (FPP).

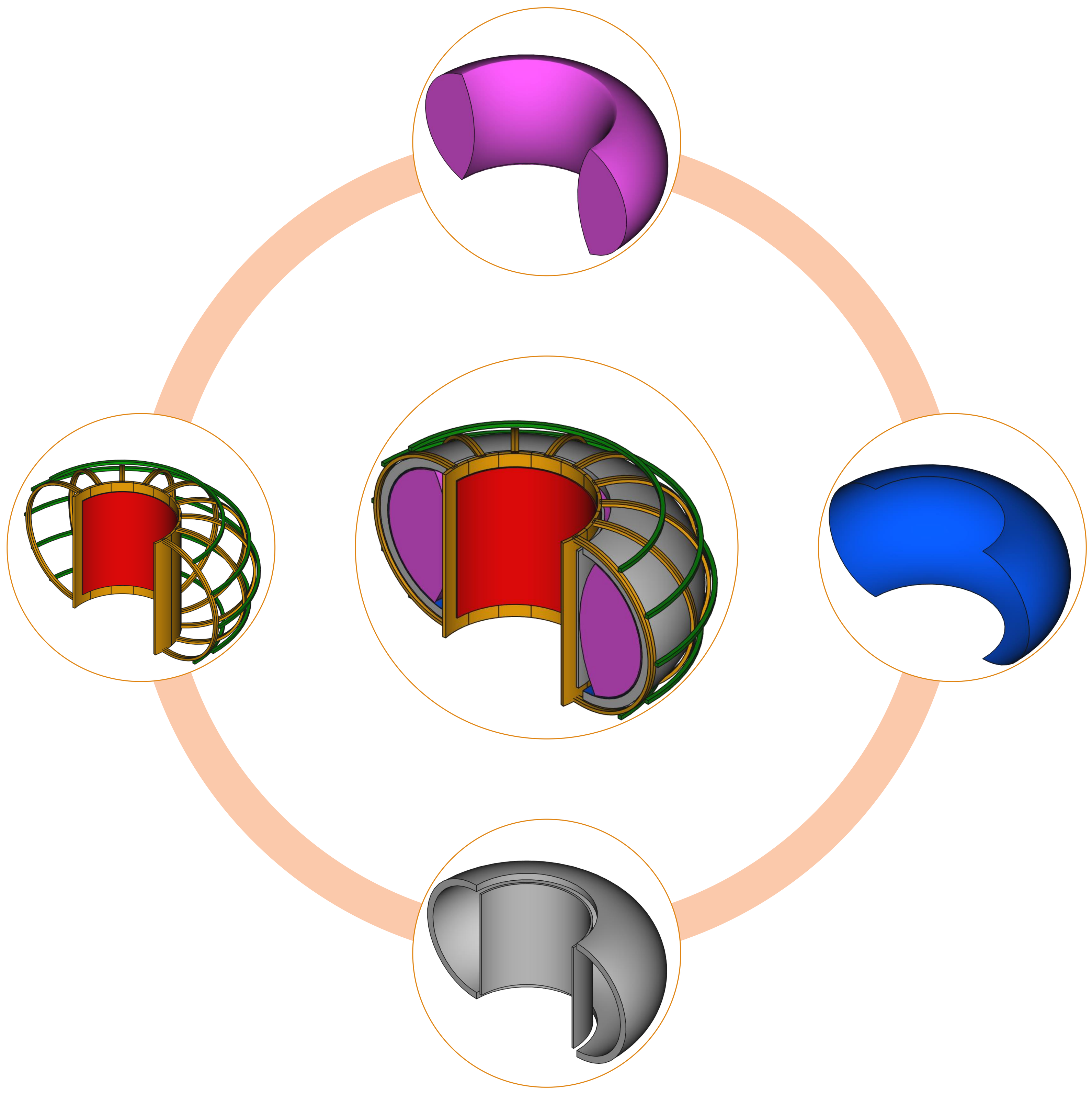
DEMO is currently in the pre-conceptual design phase and **different concepts** are being investigated. Evaluating the risks and uncertainties of these concepts can be useful to **identify design and integration issues**, helping to highlight areas that need to be investigated in more depth to **avoid delays** in the development of fusion technology.

ITER
- Experimental device
- Q ≥ 10
- Burning plasma

DEMO
- Produce net electricity
- Fuel self-sufficient
- Scalable performance

FPP
- Commercial Fusion Power Plant

PARAMETER	ITER	DEMO	Flexi-DEMO
Major radius (m)	6.2	9	[8.5, 9.5]
Pulse length (h)	0.11	2	[1.47, s.s.]
Blanket	TBM	HCPB/WCLL	HCPB/WCLL
N of TF coils	18	16	16
PF material	Be	W	W
Elongation	1.85	1.78	1.85
Fusion gain	10	~40	[10, +40]



PROCESS

PROCESS [2] is a **systems code** that **simulates** all parts of a future **fusion power plant** by **integrating** physical and engineering **models**.
Systems codes can be used to **optimise** power plant **designs**, **evaluate** the **effects** of design **uncertainties** or run **sensitivity analyses** to rank the **impact** of each **system** to the fusion **power plant performance**.

Physics + **Engineering** = **PROCESS**

DEMO Technical Challenges

Tritium breeding blanket
- TBR>1 near current eng. limit
- Performance uncertainties

Power exhaust
- Heat fluxes near tech limits
- Challenging integration

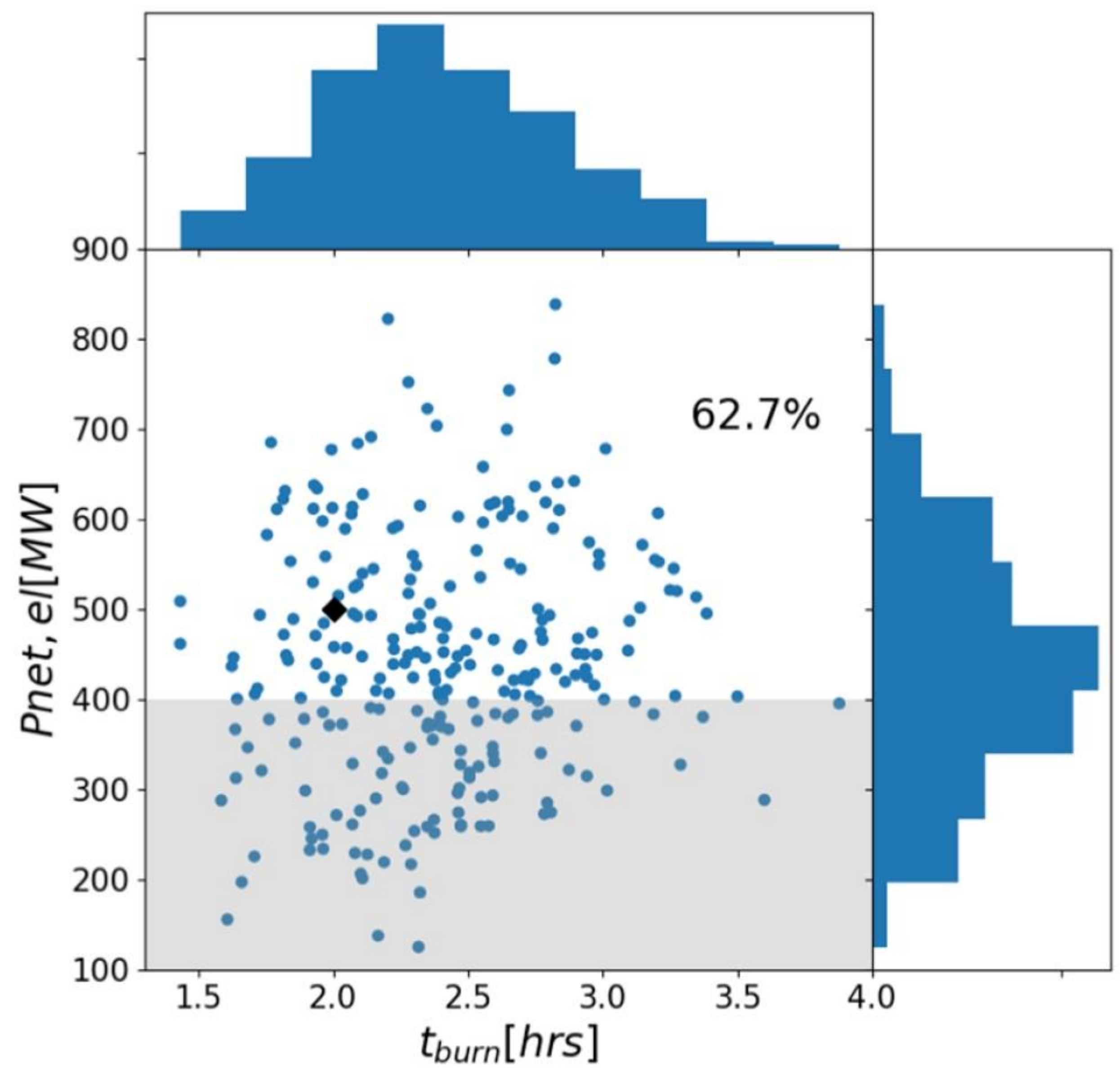
Remote maintenance
- Strong impact on design
- Large activated materials

Previous Work

Lux *et al.* carried out an **uncertainty quantification analysis** of the **2017 European DEMO1** [3], exploring the **implications** that current known **uncertainties** have on the expected **performance** paramenters. **Some** of these were:

- **L-H threshold limit**
- **Tungsten number density fraction**
- **Elongation**
- **ECRH efficiency**
- **Maximum power flow to divertor**

These **design parameters** were implemented with **probabilistic distributions** that would **capture** both model **limitations** and **uncertainties**. The analysis was performed using **Monte-Carlo sampling**.



Predicted machine performance for the 2017 DEMO baseline design assuming a range of uncertainties in design parameters. The black diamond indicates the nominal baseline performance [3].

References

[1] Donné, A. J. H. "The European roadmap towards fusion electricity." *Philosophical Transactions of the Royal Society A* 377.2141 (2019): 20170432.
[2] Kovari, M., et al. "“PROCESS”: A systems code for fusion power plants—Part 1: Physics." *Fusion Engineering and Design* 89.12 (2014): 3054-3069.
[3] Lux, H., et al. "Implications of uncertainties on European DEMO design." *Nuclear Fusion* 59.6 (2019): 066012.
[TBR figure] Shimwell, Jonathan, et al. "Multiphysics analysis with CAD-based parametric breeding blanket creation for rapid design iteration." *Nuclear Fusion* 59.4 (2019): 046019.
[Divertor figure] http://fusionwiki.ciemat.es/wiki/Divertor
[Remote maintenance figure] RACE 2018 AMF Concept Review

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EUROfusion

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