

PREPARING SYSTEMS CODES FOR POWER PLANT CONCEPTUAL DESIGN

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PROCESS and BLUEPRINT used in EU-DEMO and STEP pre-conceptual design phases

- Additional UKAEA focus on building up spherical tokamak model detail in codes.

Systems codes at UKAEA are being retooled for later stages of conceptual design.

Aim is to move systems codes to cover the middle of the design cycle.

- BLUEPRINT already covers a number of these areas

Evolve PROCESS to be modern python package library for 0-D, 1-D modelling.

EUROfusion TSVV-14 project – Multi-fidelity systems code for EU-DEMO

- Kicked off April 2021
- Target is open-source reactor design tool

Within PROCESS there are a number of spherical tokamak specific options that have been added

- ST centrepost (including resistive)
- ST plasma shaping
- ST plasma current scalings
- ST TF magnets

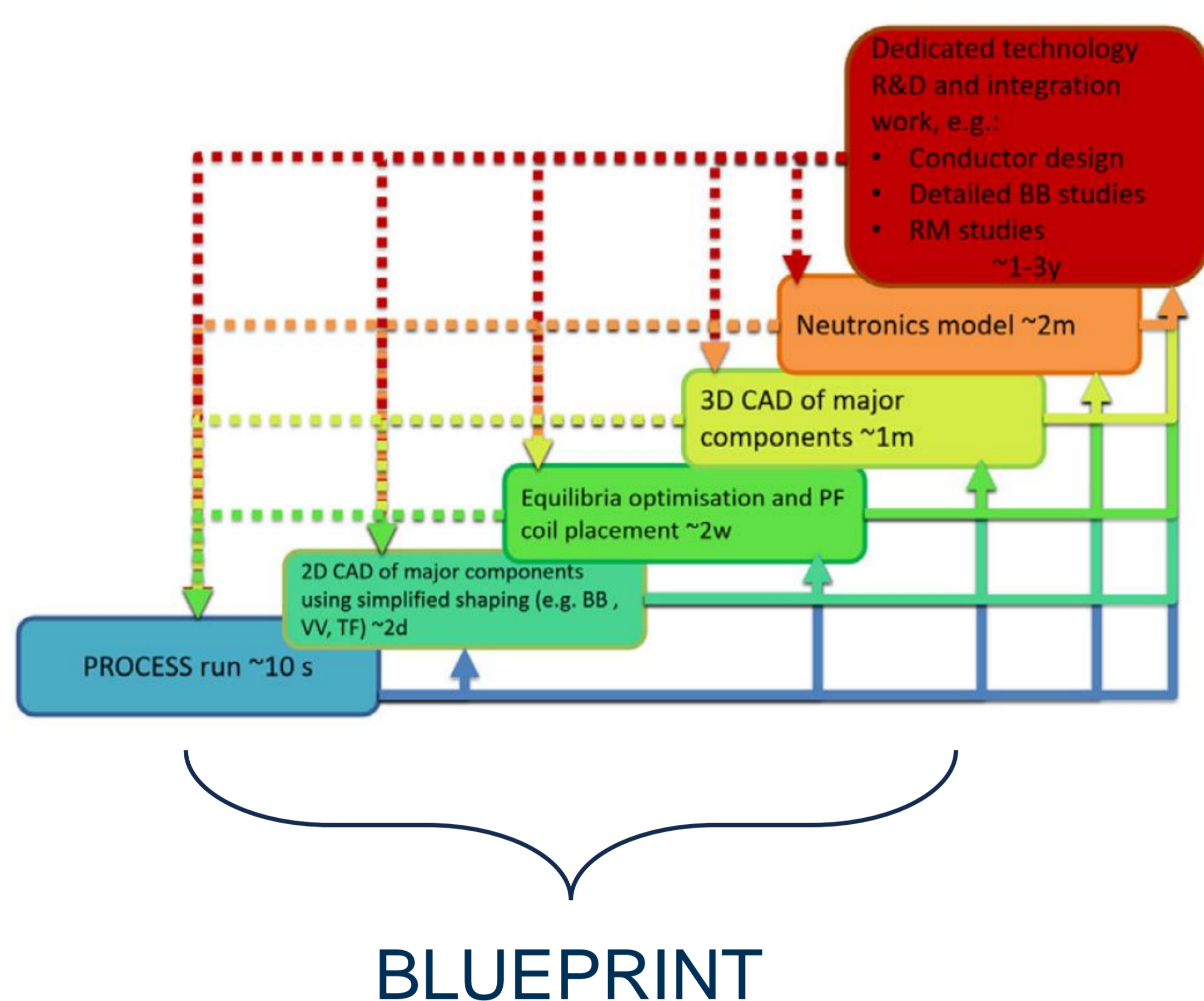
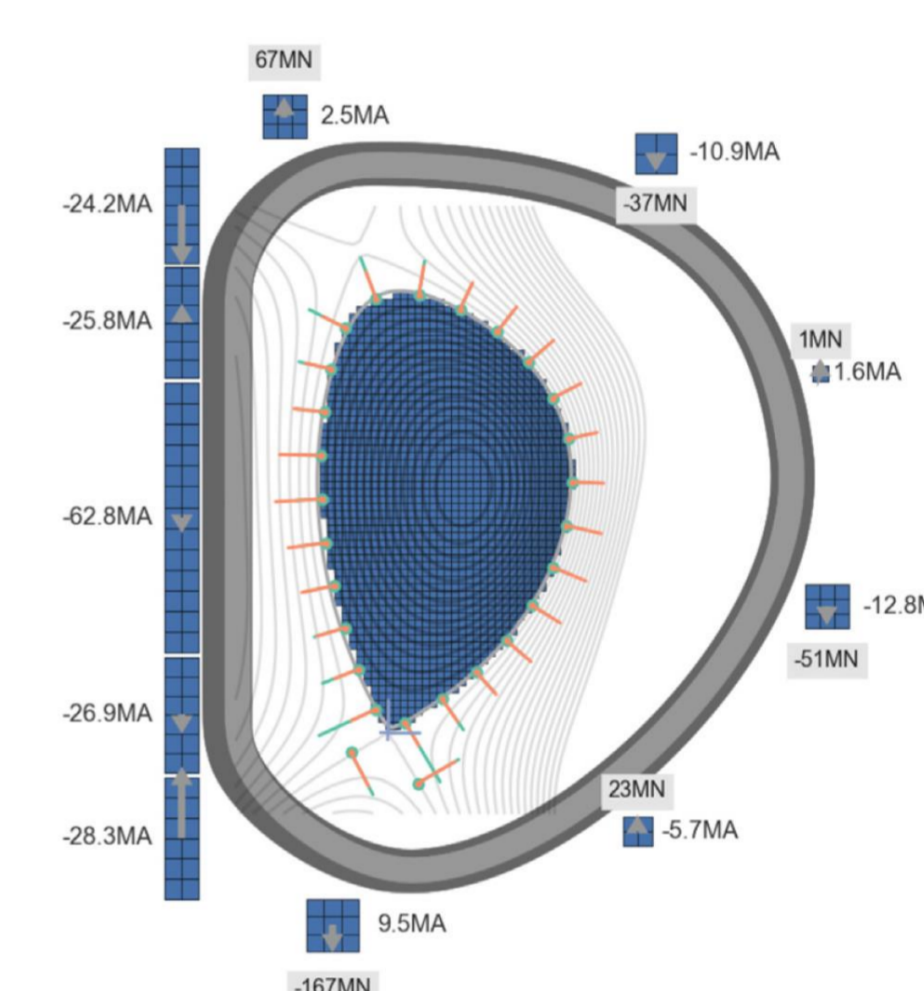
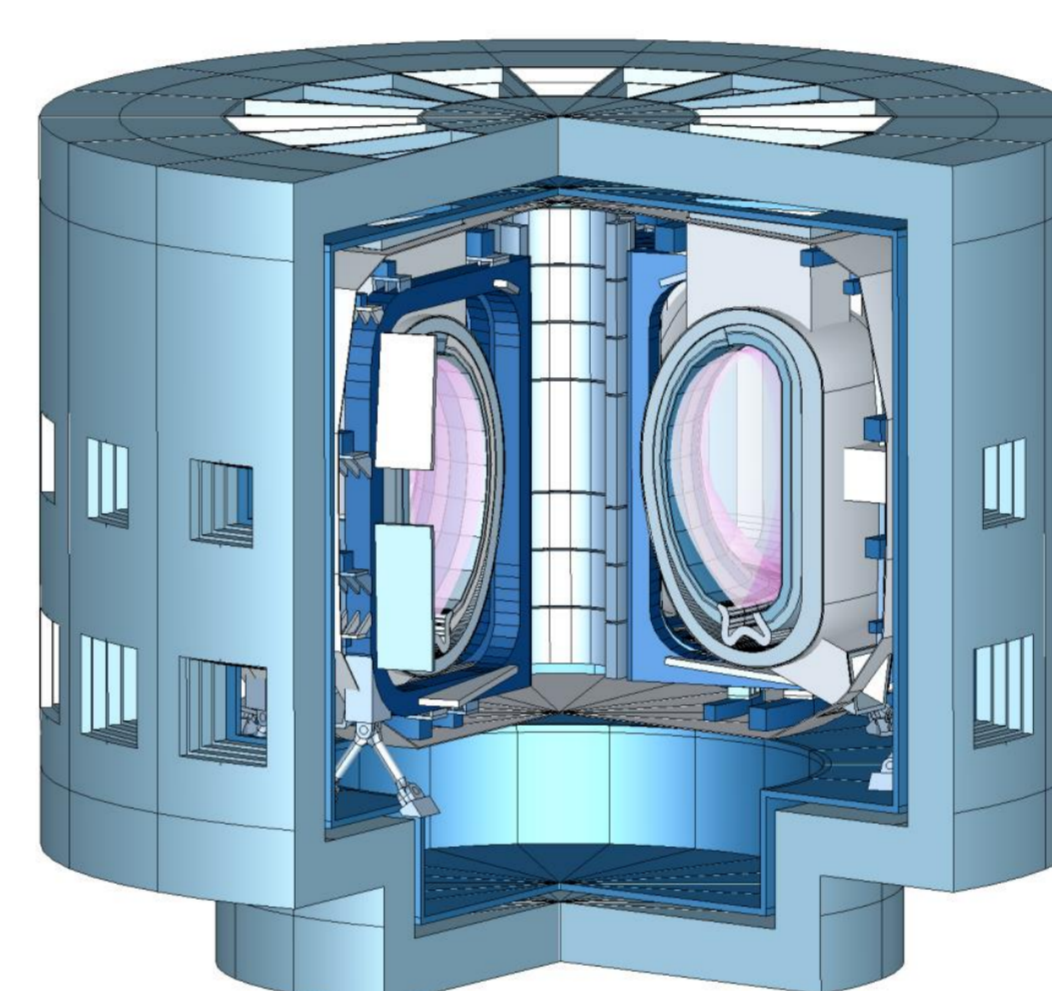
New option for resistive monolithic centre-column

- with either picture frame or D-shaped return limbs.

To minimise resistive losses, the centre-column is tapered, being thinnest at the midplane where space is tightest and widening at the top.

Some key BLUEPRINT capabilities

- Toroidal field (TF) coil design
- Equilibria and poloidal field (PF) system design
- Remote handling engineering considerations
- 2-D geometry and 3-D CAD generation
 - with the goal of performing Monte Carlo neutronics simulations
- Fuel cycle modelling



Inboard mid-plane stress model

Stress model revised using generalized plane strain assumption

- Valid for inboard TF geometry
- Provides vertical stress distribution
- Stress, strain and displacement radial distribution as output

Formulation for any number of major layers of different geometry

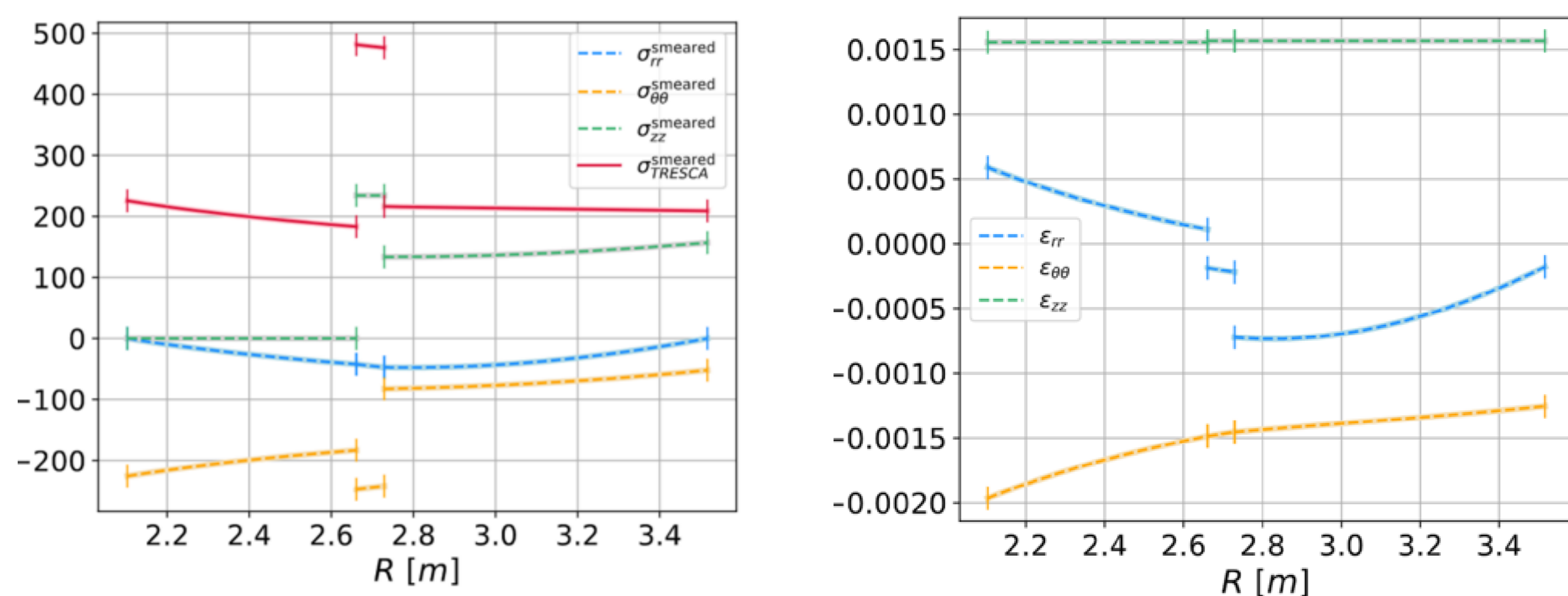
- Advanced structural designs
 - Wedged TF bucked on CS
 - Graded Winding pack (under development)

Vertical tension improvement (analytical)

- Including conductor thickness effect
- Calculated in/out tension split for sliding joints

CS-TF bucked design for DEMO-like machine

- TF structure reduction ~20 cm
- Not enough size reduction to justify design complexity at first inspection – investigations away from DEMO-like machines needed.



PROCESS stress/strain distribution for CS-TF bucked design

TSVV-14

UKAEA will be leading the EUROfusion TSVV-14 task working together with KIT

Create an open-source fusion power plant design framework and toolset

The task will be built on the groundwork of merging UKAEA code BLUEPRINT and KIT code MIRA.

Key Outcome

Aim is to create a well supported and widely used open-source reactor design tool. It will be a useful tool for reactor design projects (e.g. STEP and EU-DEMO).

BLUEPRINT

Added

- Heat flux calculation from charged particles
- Spherical tokamak geometry
- PF coil optimisation in defined regions
- Enhanced interfaces to other codes – JETTO & PROCESS
- Computational speed improvements

Planned

- Merge BLUEPRINT with MIRA
- Open sourcing and build dev community
- Strong integrations with FEA libraries
- 2-D/3-D radiation models
- 2-D TF magnet winding pack analysis
- Plasma vertical stability model
- Coupling of 1.5-D transport solver PLASMOC and free-boundary EQ-solver

PROCESS

Added

- New sensitivity analysis tools
- Advanced divertor geometries
- 1-D SOL model
- HTS – REBCO
- TF magnet layered stress modelling
- Spherical tokamak models

Planned

- Refactor – python package + API
- Further spherical tokamak models
- Updated costing models with available contract data
- Continued UQ tool development
- Modelling of EU-DEMO performance robustness
- Integration with BLUEPRINT-MIRA