Quantifying uncertainty in the mechanical performance of fusion materials

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Our vision is to design and assess the structural components critical for fusion plant using probabilistic analysis. To this end, the uncertainty in the predicted mechanical behaviour of components must be quantified so it can be used as an input parameter. Traditionally, uncertainty quantification is carried out experimentally, testing a large number of specimens to capture the statistical distribution of the parameters driving component performance. This is a costly and, in some cases (e.g., irradiated materials), impossible task.

Our proposed solution is to use physics-based simulations, calibrated via a limited number of targeted experiments, to accelerate and arguably improve uncertainty quantification for the performance of fusion materials. Our focus will be on the mechanical behaviour of high-purity copper as a function of its microstructural features. We will use crystal plasticity finite element modelling to simulate the microstructure (e.g. grain size, shape, morphology) and will leverage machine learning algorithms (e.g., Gaussian Regression) to significantly reduce the computational overhead that comes with multiple simulations probing the microstructural probability space.

Finally, we will perform model validation through a series of high-fidelity tests, employing advanced high-resolution digital image correlation capabilities at the Henry Royce Institute to track material deformation at the microstructural level.