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Uncertainty and multiphysics for predictive breeder blanket modelling

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Predicting tritium generation, retention, and release in a breeder blanket is essential for the design of fusion experiments, reactor prototypes, and ultimately commercial systems. Sensible and reliable design choices requires close alignment between simulations and experiments overseeing a variety of processes and physical scales. Assessing the predictive accuracy of tritium transport simulations therefore demands close attention to several factors: the completeness of the participant physical phenomena; the reliability of material property values used as simulation parameters; and the translation of coupled phenomena across physical scales.

Because any simulation is necessarily imperfect in each of these aspects, understanding how uncertainties combine to affect the model's final predictive capability is a challenging but extremely important question. The Tritium Reaction Integrated Multiphysics Analysis eXperiment (TRIMAX) project is addressing this through the development of a materials-level multiphysics tritium transport model equipped with an Uncertainty Quantification (UQ) wrapper. In addition to predicting key performance metrics, this approach explicitly captures uncertainty within input parameters and propagates it through the model to produce self-consistent distributions of outputs. This enables identification of the most influential material parameters, highlighting where new measurements or modelling efforts will yield the greatest improvements in yield or reduction in uncertainty, and where current tolerances may be relaxed without compromising safety or performance.

By revealing the drivers of predictive confidence, TRIMAX supports efficient research prioritisation to provide a robust foundation for breeder blanket design considerations in forthcoming fusion systems.

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