Fusion Twin Platform: An Innovative Tool for Fusion Research and Education

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The Fusion Twin Platform (FTP), recently launched at https://fusiontwin.io/, is a free web-based tool designed to democratize access to advanced tokamak simulations, enable collaborative research in fusion science, and enhance plasma physics and fusion engineering education. FTP allows researchers, educators, and students to use pre-built digital replicas of tokamaks, enabling precise simulations, exploration of machine learning models, visualization of plasma dynamics, and flexible data management. By leveraging NSFsim [1], a free boundary equilibrium and transport solver, FTP supports fast customizable simulations and discharge scenario development.

FTP is a cornerstone of Next Step Fusion's mission to remove barriers to entry in fusion research, education, and collaboration. The platform supports diverse tokamak configurations, providing access to essential datasets and machine geometry while ensuring user privacy and proprietary data security. Transformative for both research and education, FTP provides tokamak simulations by offering a suite of powerful tools, including machine learning model integration, advanced visualization capabilities, and collaborative functionalities. Fully web-based, FTP requires no additional software or hardware to run, making it accessible to users worldwide. Researchers and educators can leverage these resources to conduct fusion experiments, optimize control strategies, and engage students with hands-on, interactive learning experiences, all within a secure and accessible digital environment.

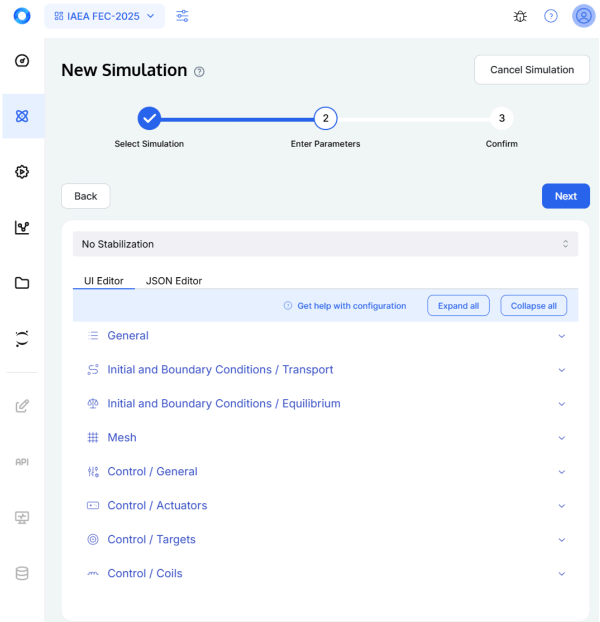

Fig. 1. Flexible configuration of new tokamak simulation using the FTP

Key Features of FTP:

- **Fast and Precise Simulations:** FTP offers tools for customizing magnetic equilibrium simulations, developing and optimizing new discharge scenarios, and evaluating plasma stability across various operational regimes with exceptional accuracy for tokamaks such as DIII-D, ISTTOK, SMART, NSF NTT, and others. These capabilities drive rapid advancements in tokamak design and operations. An example of an interface for starting a simulation is shown in Figure 1.
- **Customizable Visualization and Analysis:** FTP provides a fully integrated environment where users can plot, visualize, and analyze data, whether uploaded or generated on the platform. Advanced AI-based tools facilitate intuitive, human-like interactions for data interpretation and decision-making, streamlining research workflows. Examples of plots are given in Figure 2.
- **Comprehensive Data Management:** FTP enables seamless access to fusion datasets, allowing users to upload their data for analysis or download platform-generated outputs. This flexibility ensures efficient data management and smooth integration into broader research workflows.

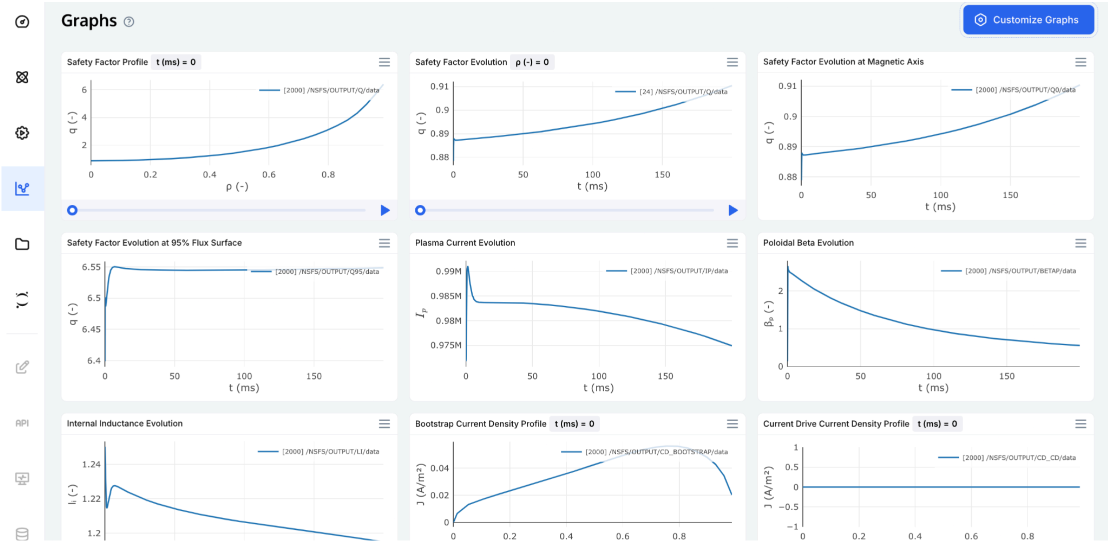

Fig. 2. Visualization of a DIII-D discharge simulation performed using NSFsim, displayed on the FTP Graph tool

- **Collaborative Workspace Tools:** FTP includes robust collaborative features, enabling users to share workspace data with team members, create public links for wide sharing or publication, and maintain a shared context among collaborators. These tools enhance teamwork and support open science initiatives.
- **Integrated JupyterHub Environment:** FTP offers a built-in JupyterHub environment with Python notebooks and advanced extensions, such as an HDF5 viewer. This integration empowers users to perform detailed data analysis, automate workflows, and interactively explore simulation results in a familiar coding environment.
- **ML Demonstration and Integration:** FTP serves as a showcase and integration point for machine learning tools developed by Next Step Fusion, such as a plasma boundary reconstruction ML model trained on the DIII-D experimental dataset. It also provides access to training reinforcement learning (RL) agents for plasma shape and position control, enabling users to explore cutting-edge AI-driven solutions for tokamak operations.

Besides being a powerful tool for fusion research, the Fusion Twin Platform (FTP) also has the potential to become an exceptional educational tool. It provides educators, students, and professionals transitioning from other fields to fusion with access to realistic tokamak simulations and interactive tools that bring fusion concepts to life. FTP enables hands-on learning experiences by allowing users to explore plasma dynamics, test machine learning models, and simulate real-world discharge scenarios within a secure, user-friendly environment. Furthermore, its collaborative features, such as shared workspaces and public link generation, foster teamwork among students and professionals while encouraging interaction between institutions. By integrating cutting-edge technology with practical educational applications, FTP bridges the gap between theoretical knowledge and practical understanding, inspiring both the next generation of fusion scientists and engineers and those seeking to expand their expertise into this exciting field.

References

[1]. R. Clark et al. Fusion Engineering and Design 211 (2025) 114765