**On Data-driven Approaches in Predicting Turbulence Characteristics of Tokamak Plasmas**

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**Abstract**

Confinement mode transitions, particularly between L-mode, H-mode, and I-mode, are among the most critical phenomena in tokamak plasmas. These transitions are intrinsically linked to the formation and evolution of transport barriers, including internal transport barriers (ITBs), edge transport barriers (ETBs), and double transport barriers (DTBs). The formation of these barriers is governed by the interplay of turbulence, shear flows, and equilibrium profiles. Accurate prediction of instability characteristics during such transitions is therefore essential for optimizing the plasma performance.

In this work, we propose a data-driven framework to analyze and predict turbulence type associated with the L-H transitions in tokamak experiments. We are trying to use diagnostic data from magnetic probes, ECE, reflectometry, and FIDA, and extract key turbulence features such as frequency evolution, spectral broadening, and mode amplitude across different confinement modes. Given the limited availability and complexity of experimental data, we complement these analyses with reduced transport modes, i. e. , the Dynamical Critical Gradient (DCG) model. By systematically scanning the heating power, density, and pressure gradient thresholds, our method can reproduce the turbulence behaviors and transport barrier formation, creating a database that links experimental signatures. Leveraging this database, we are trying to construct transformer-based models capable of efficiently recognizing and predicting the turbulence transport, as well as identifying barrier-related thresholds, directly related with experimental observations.

Looking forward, we aim to extend this data-driven approach to HL-3 and EAST experiments, with particular emphasis on predicting power threshold of L-H transitions. This methodology has the potential to guide real-time confinement optimization and contribute to the development of advanced control strategies for next-generation fusion devices.

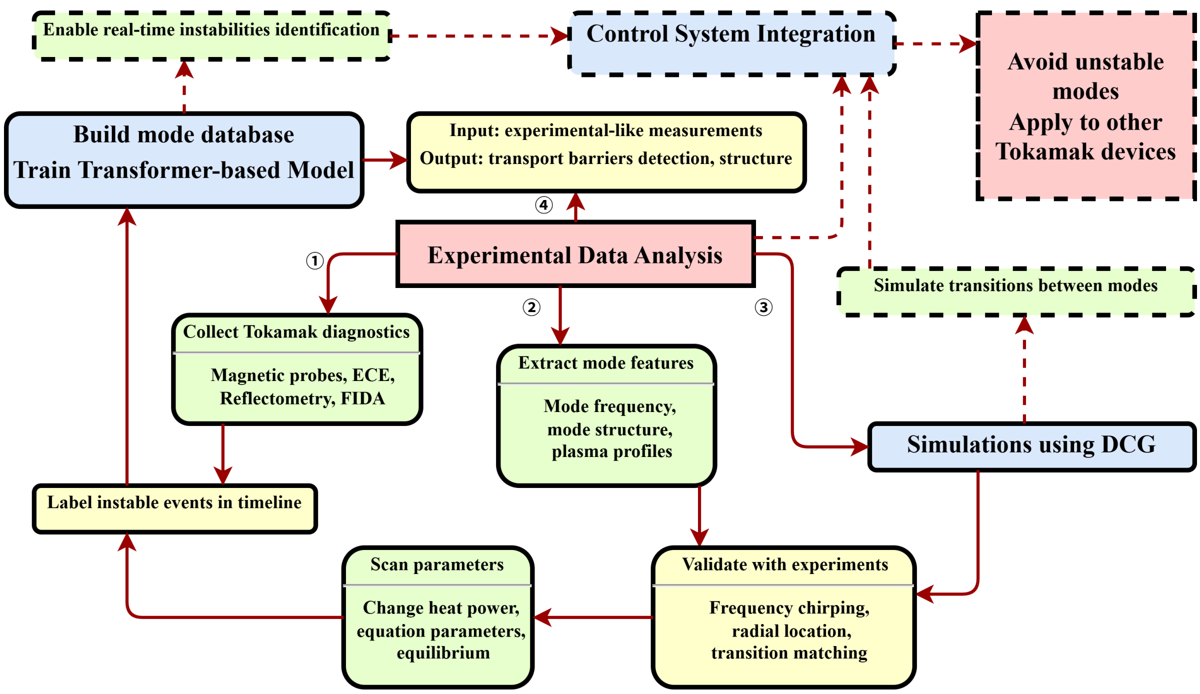

Fig 1: Workflow: From Simulation to Transformer-based Model to Control System.