FSD: Science meeting on EUROFUSION ML & AI projects

AI-assisted Plasma State Monitoring for Control and Disruption-free Operations in Tokamaks

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Swiss Plasma Center

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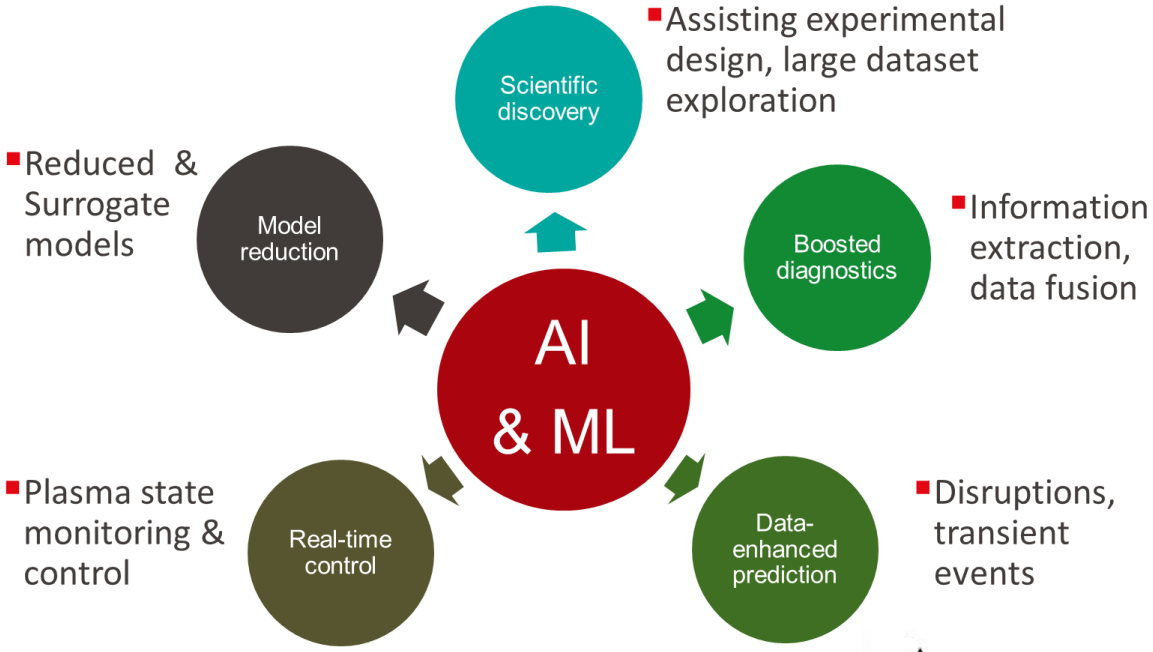
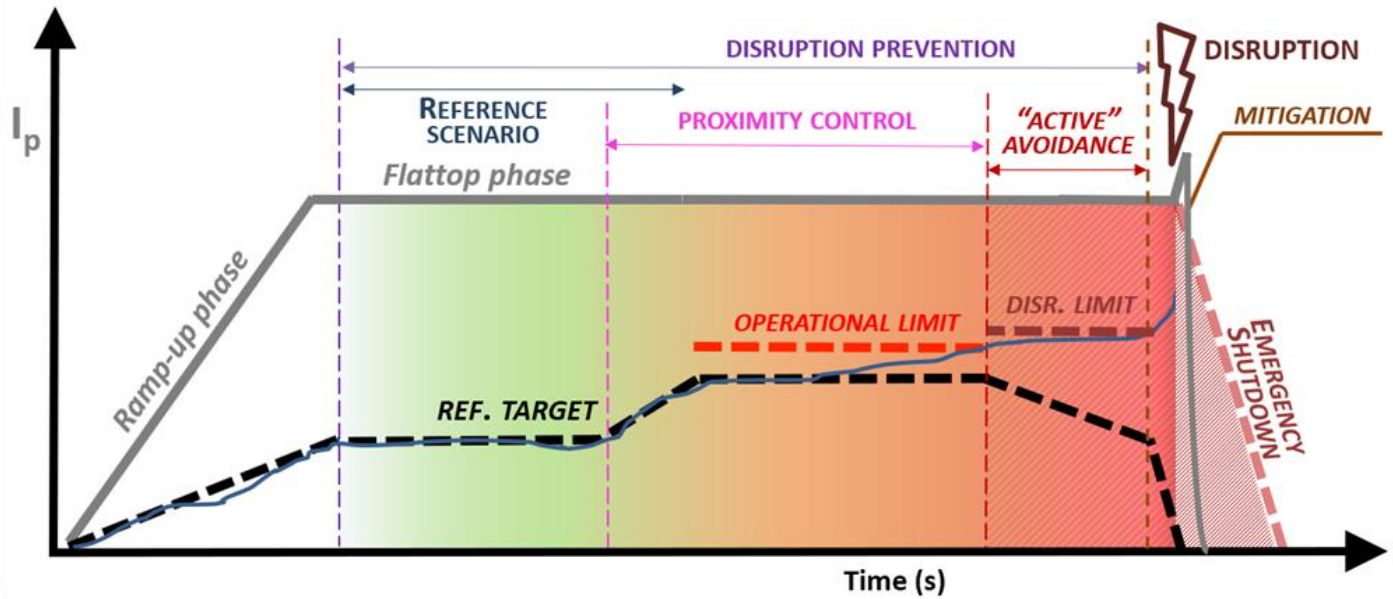
EUROfusion

AI-assisted Plasma State Monitoring for Disruption-free Operations



- Advancing **fusion** with AI and ML technologies
- **Disruption prevention** embraces many areas (**plasma state monitoring**, transient events, information extraction and large-scale analysis)

- Design of **robust reference scenarios**
- Control of the **proximity** to stability, controllability and disruption boundaries
- Continuous **control** and **exception handling**, monitoring plasma and actuators states.



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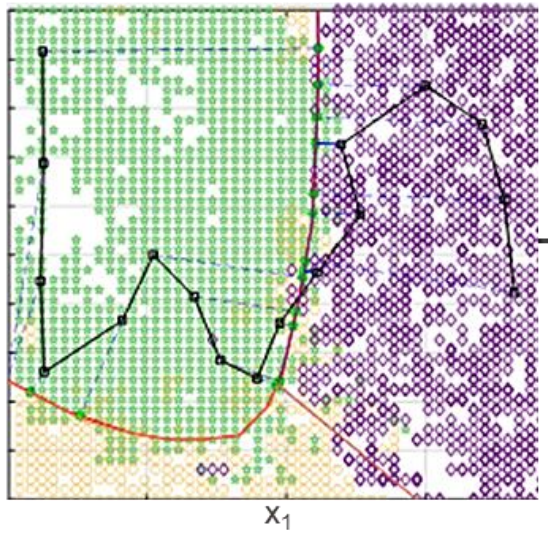
Deep generative modeling for plasma state dynamics estimation

Generative Topographic Mapping (JET)

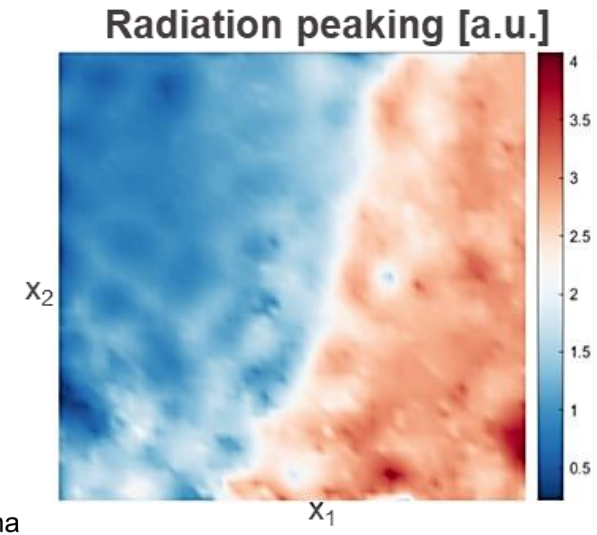


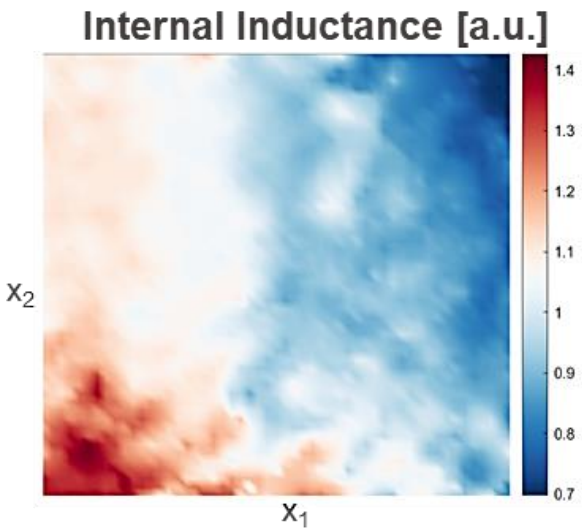
*REF: [Bishop et al **IEEE** 1998]*

*REF: [Pau et al **NF** 2019]*

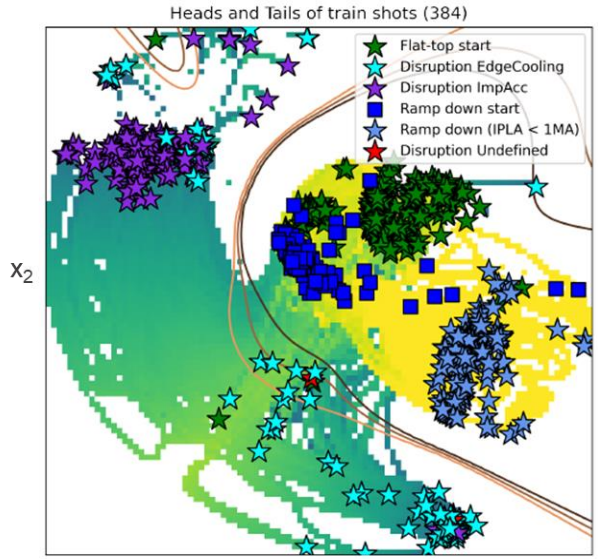
Posterior probability over 2D latent space

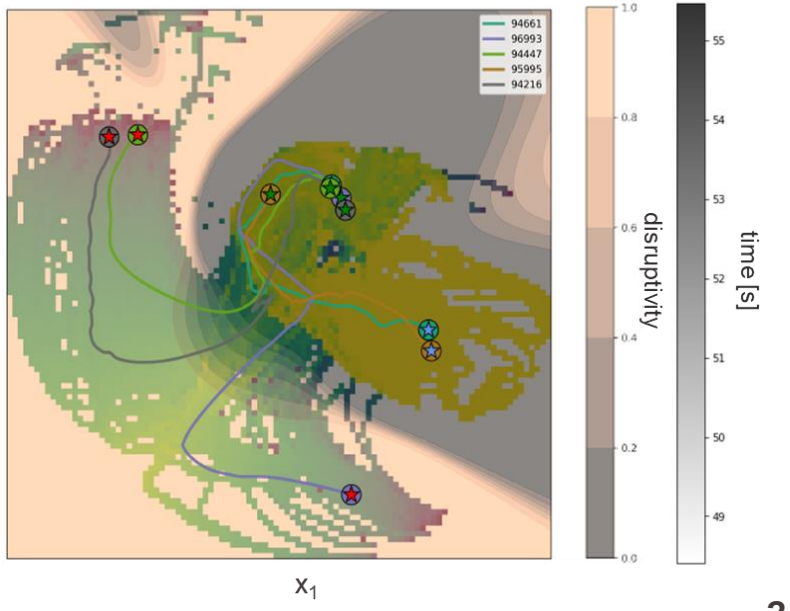
Off-normal plasma regimes





Generative DL with sequence-based models





***REF:** Bürli, Pau et al. to be submitted (EUROfusion Pinboard)*

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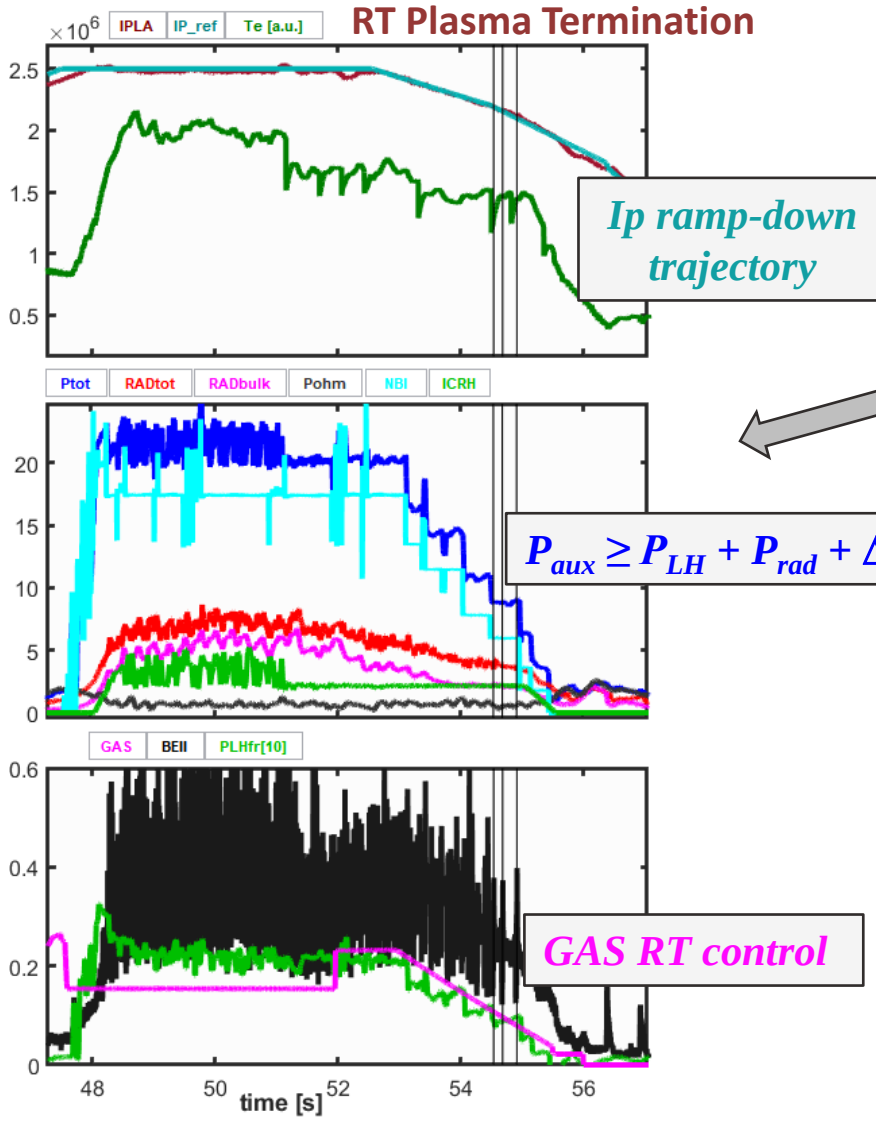
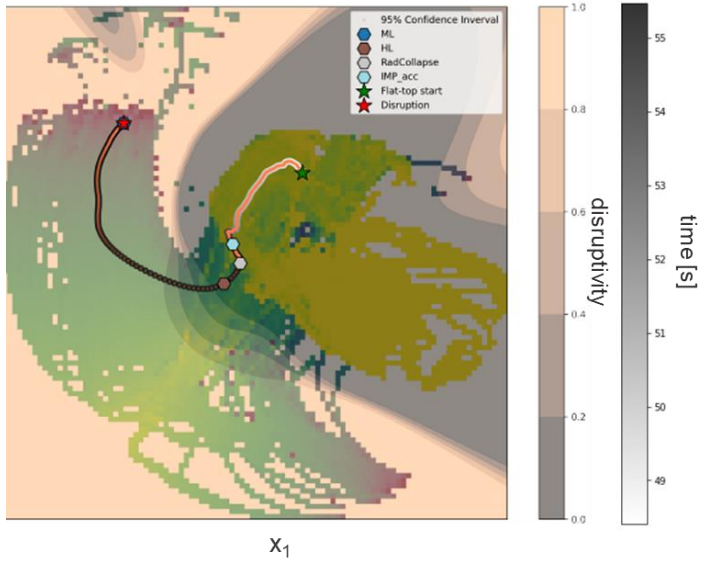
A control room tool based on AI-assisted Plasma State Monitoring



REF: [A. Pau et al IAEA 2023]

DEFUSE

Plasma Trajectory Optimization + Disruption Prevention



- **Large scale analysis** and efficient **parallel processing** of large amounts of data (time-series modeling with long-range dependencies, etc.)
- **Iterative optimization of plasma trajectories** for different plasma scenarios, exploiting rich **metadata** description (**EUROfusion DDB**)

Outlook

- **Main deliverables**
  - High-capacity **Deep Generative Model** for **Plasma State Monitoring**
  - Formulation & integration of a **Physics-Informed Latent Representation**, including **disruption boundaries** and **off-normal events**
  - Extension of modeling framework (**multi-task learning**) to include (1) dynamics and (2) **prior knowledge** based on **events**, **plasma state** and **actuator states, domain invariance**.

- **Expected outcomes**
  - achieve first demonstration of a **generative model** aligned with **physics-based** evaluation (off-normal events sequence, plasma state and proximity to disruptions).
  - **Plasma State Estimation** workflow for integrated into a **web-based application** (control room tool with interactive interface available to operators and scientist).

- **Relevance**
  - Practical tool for routine use during **control room operation**, e.g. for **pre-shot planning**, **inter-** and **post-shot analysis**, and demonstration of large-scale data analyses pipeline.