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Estimation of Plasma Parameters Based on Discharge Settings On West

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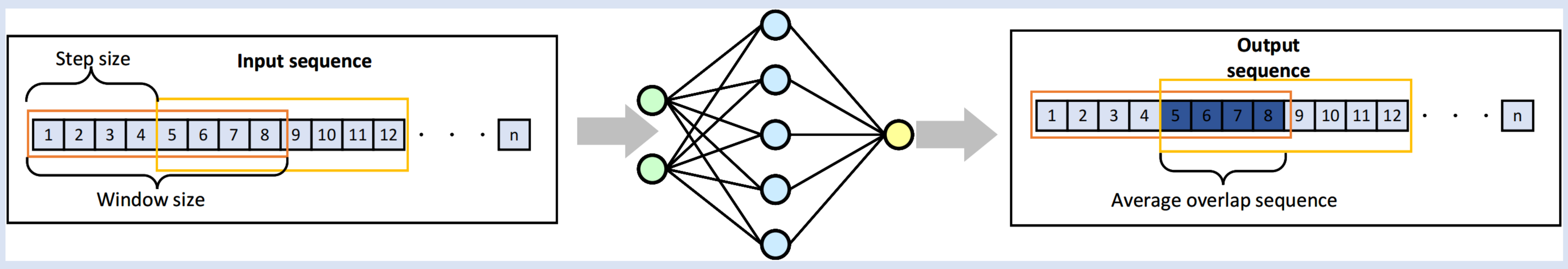
Abstract

- Physics-based integrated modeling codes such as ETS, PTRANSP, and JINTRAC offer high-fidelity predictions but demand heavy computation, making them unsuitable for rapid scenario design or real-time control
- Enable fast, accurate forecasting of key plasma parameters to support discharge planning and real-time control in tokamaks.
- Transformer-based machine learning model using only controllable pre-discharge signals (19 input channels), outputs: $\beta_n, \beta_t, \beta_p, W_{mhd}, q_0, q_{95}$
- 550 well-controlled WEST discharges, uniformly resampled and processed for model training and testing.
- Achieved mean squared error of 0.026 and R² of 0.94, with inference times of about 0.1 s, outperforming other tested architectures.
- Fast discharge planning and scenario evaluation, large-scale parameters sweeps and optimization supporting

Main workflow

- Transformer-based model developed with sliding window data processing.
- Step size < window size enables numerical stability and data augmentation.

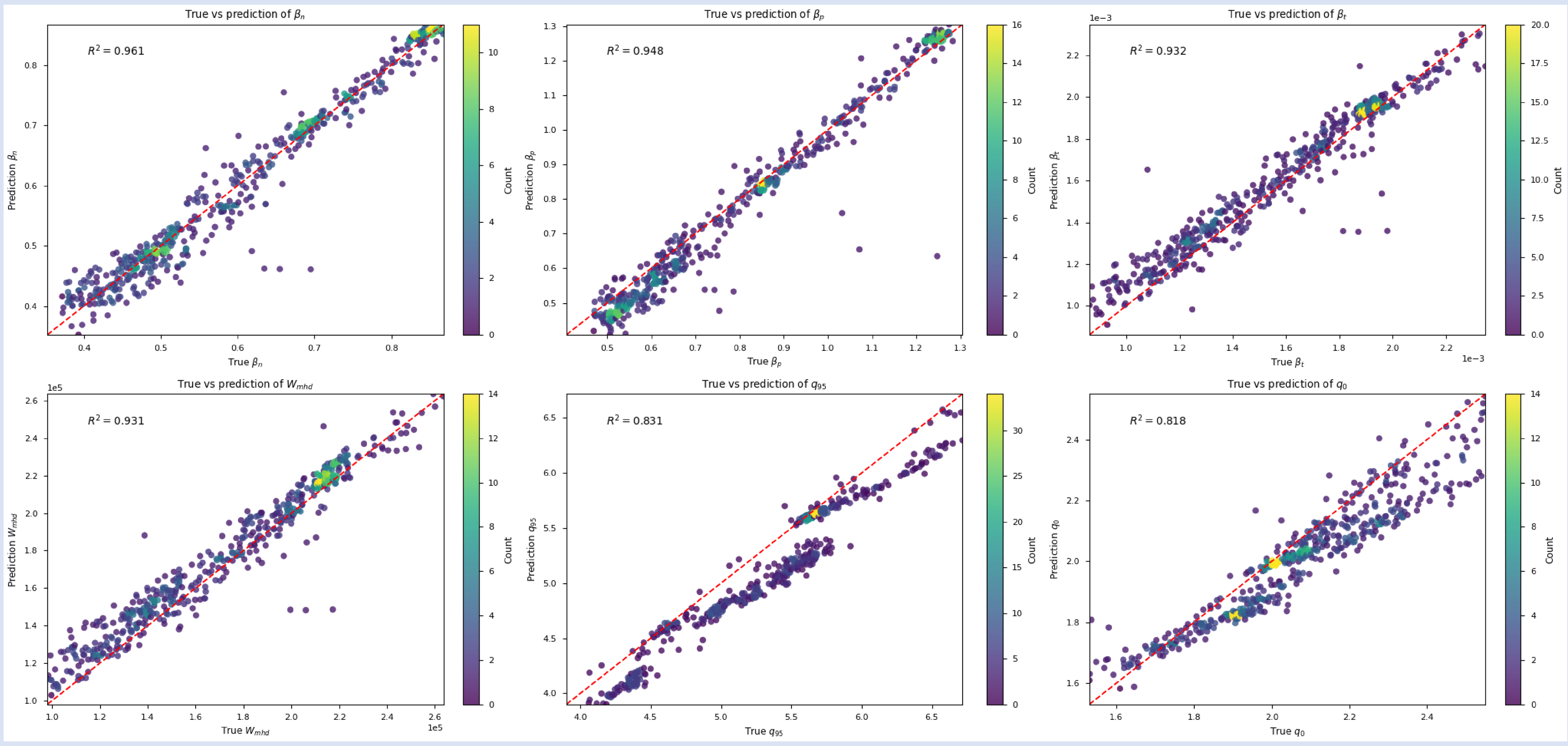


Workflow of machine learning model

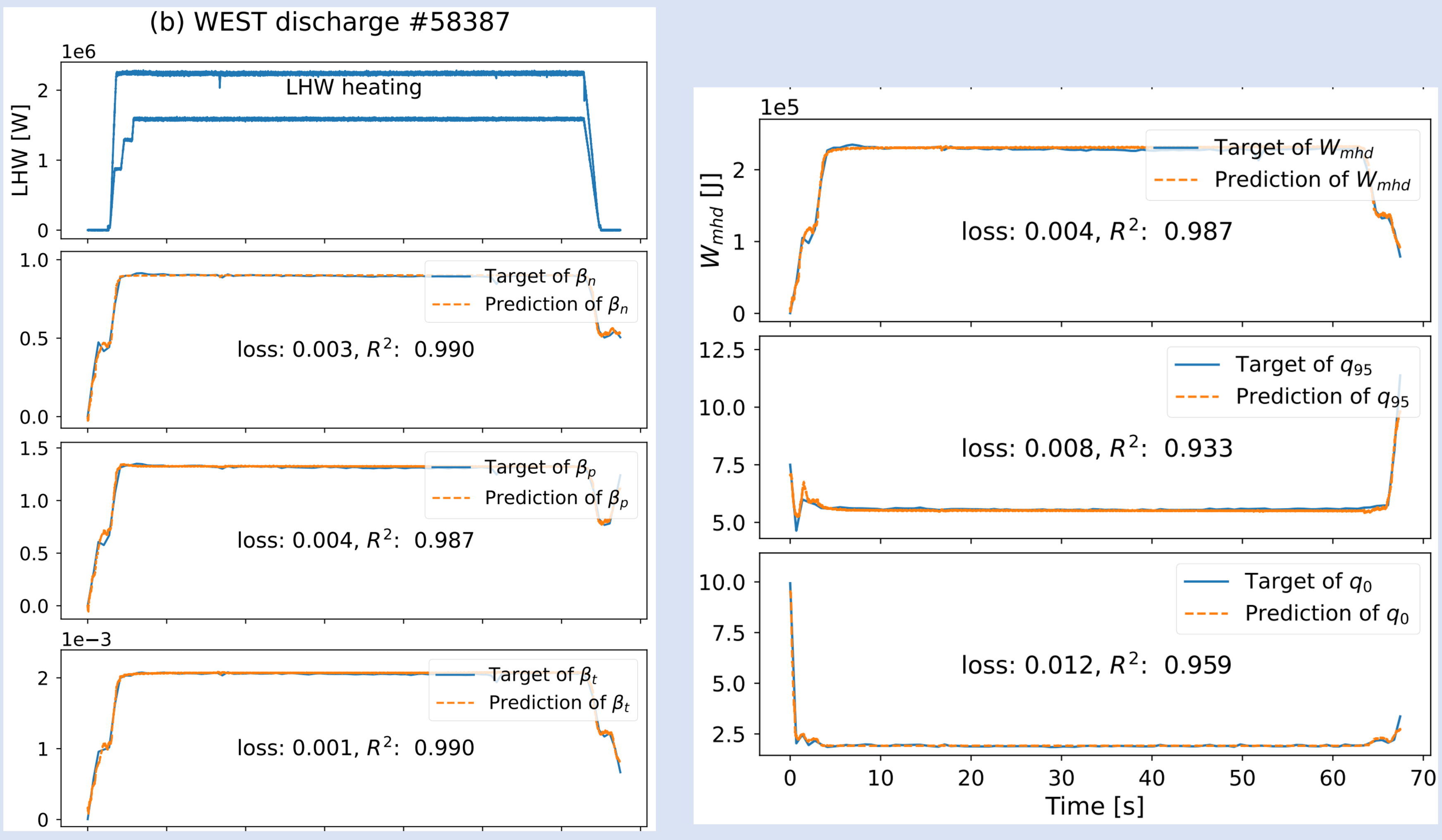
Results

- Successfully reproduced the entire discharge evolution for most WEST shots, including ramp-up, flat-top, and ramp-down phases.
- Performed well across 110 discharges, with minor accuracy reduction only for q0 and q95 due to limited pressure profile information.
- Prediction accuracy decreased for rare discharges with unusual magnetic fluctuations or dual auxiliary heating, highlighting the need for broader training data.

Results



Regression plots of output signals.



The outputs predicted by our model in WEST # 58387

Conclusions

- A transformer model have been trained to predict **six global parameters** from WEST database: normalized beta (β_n), toroidal beta (β_t), poloidal beta (β_p), plasma stored energy (W_{mhd}), safety factor at the magnetic axis (q_0), and safety factor at the 95% flux surface (q_{95})
- Good prediction with an average MSE loss of 0.026 and an average R^2 of 0.94, an inference time of **~ 0.1 s** (single A100, it really depends).
- **102 out of 110 discharges** had a R^2 greater than 0.95
- Incorporate physical knowledge to improve generalization to rare scenarios
- Extend predictions to more parameters: loop voltage V_{loop}, and internel inductance l_i as well as 1D profile like density temperature profile.

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