

Data-driven models for Alfvén eigenmode classification based on ECE diagnostics at DIII-D

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Collaboration: DIII-D Team

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Alfvén eigenmode instabilities in DIII-D

○ Project:

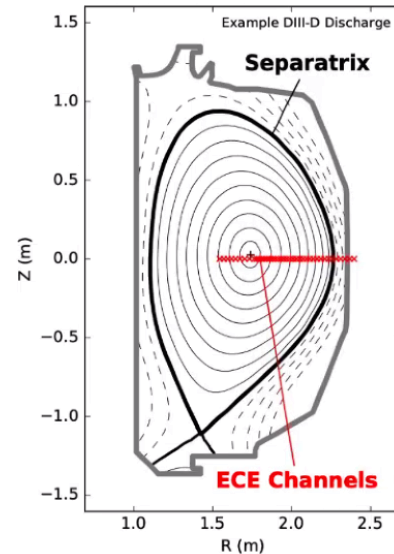
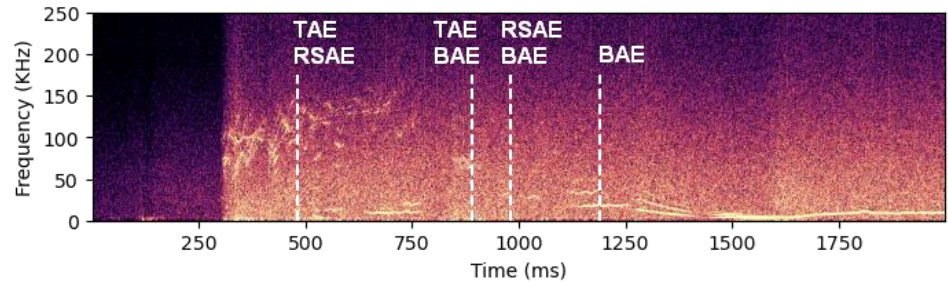
- Machine Learning for Real-time Fusion Plasma Behavior Prediction and Manipulation (DE-SC0021275)

○ Data

- 40 ECE diagnostics as inputs (ECEs provide spatial information)

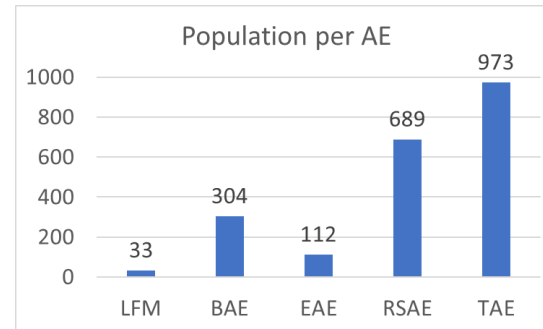
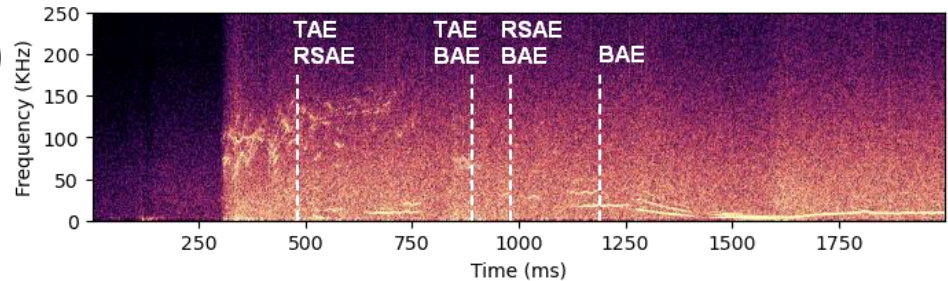
○ Tasks

- Detect/classify Alfvén eigenmode (AE)
- Detect the location and shape of AE in plasma
- Predict and control AE



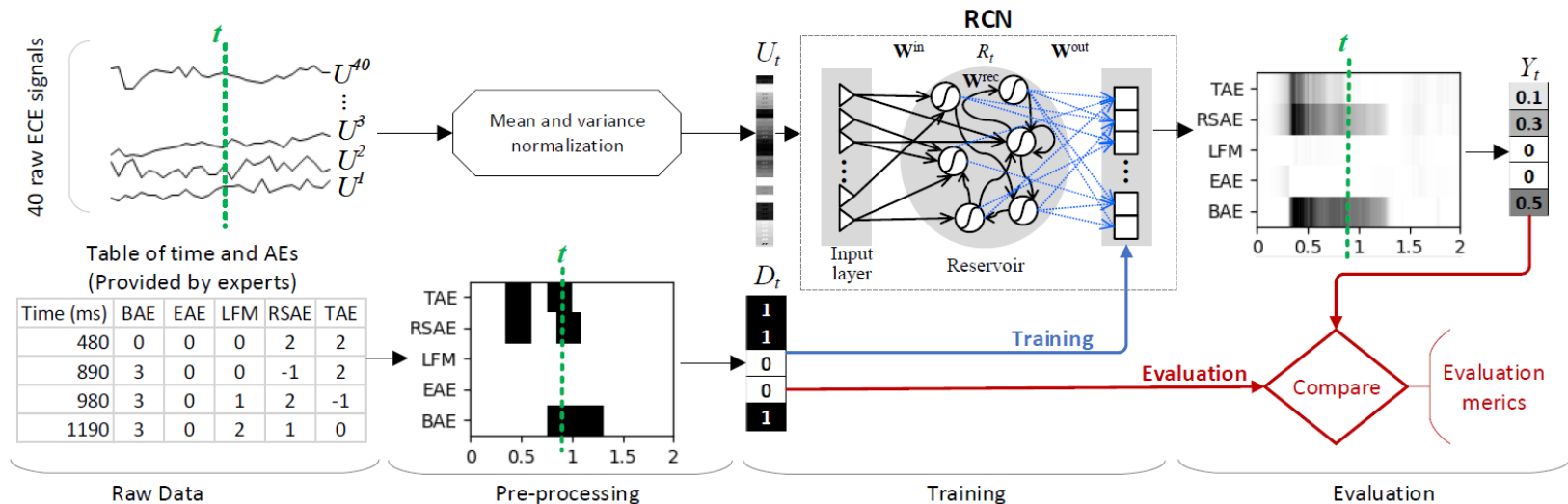
Alfvén eigenmode dataset

- 919 shots of 2 seconds
- 5 AE modes (BAAE/LFM, BAE, EAE, RSAE, TAE)
- Challenges
 - Labels are not perfect
 - Duration of events is not available
 - Subject to the experts' opinion (w.w. Heidbrink et al 2021 Nucl. Fusion 61 016029)
 - Imbalanced data
 - ECE is Noisy (Low SNR)
- **We did not do any preprocessing rather than mean-variance normalization on ECE signals**

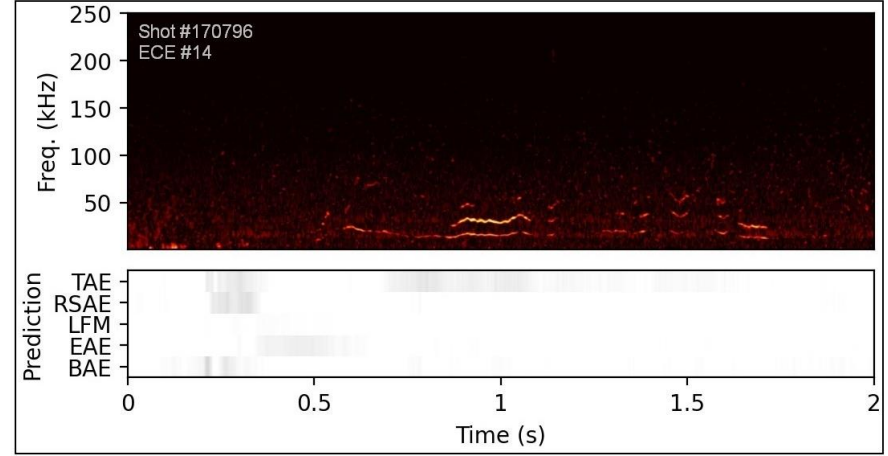
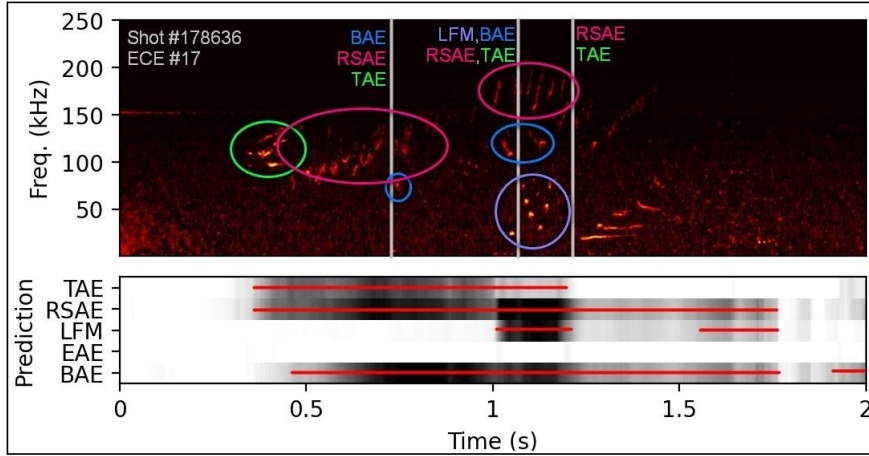


Alfvén eigenmode classification using ECE

- Reservoir computing network (RCN)
 - **Recurrent** neural network with **Random** connections
 - Suitable for **time-series** data analysis
 - Only Last layer is trained using **linear regression**.
- Input to RCN: **40 ECE signals**
- Output: Probability of AE modes at each time step



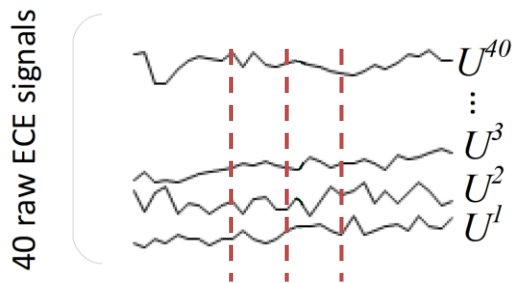
Alfvén eigenmode classification using ECE



True Positive Rate: **%91**

False Positive Rate: **%7**

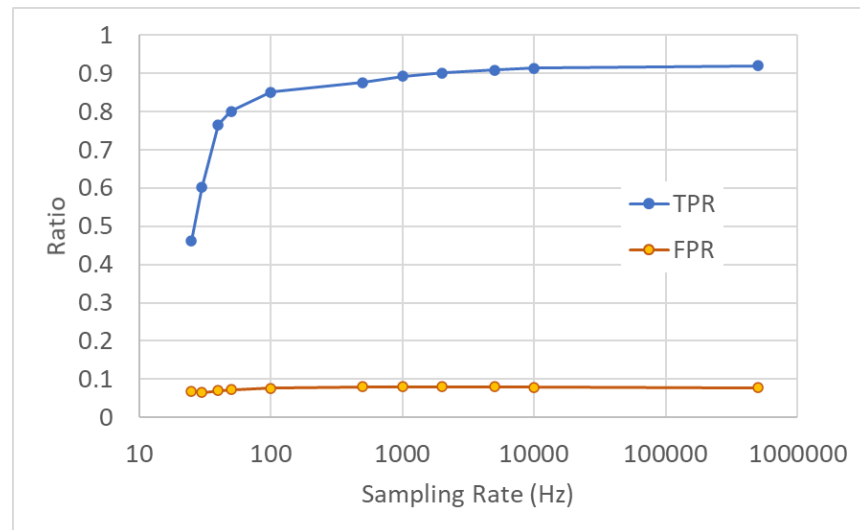
Subsampling the ECE signals



Subsampling the ECE signals has minor impact on the AE classification performance

Hypotheses:

- Lower frequencies still contain enough information.
- The model's memory covers missing data
- Other ideas?



Conclusion

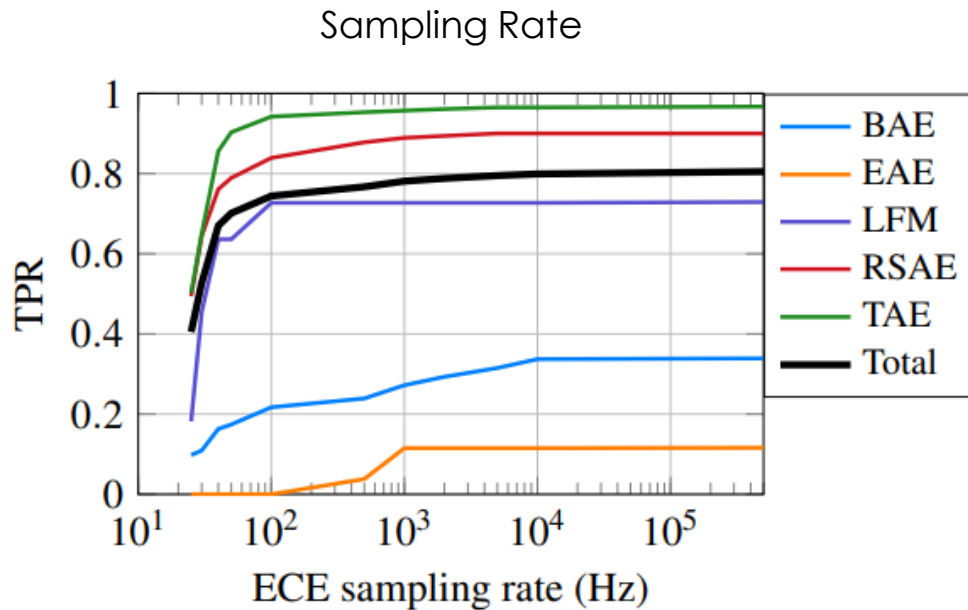
- Promising performance in detecting AE modes With minimum feature engineering on ECE data
- Possible future work
 - Re-labeling the data using the current model's output?
 - Enriching the input features by including more diagnostics
 - More advanced ML techniques
 - Locating AE modes using ML and image processing techniques

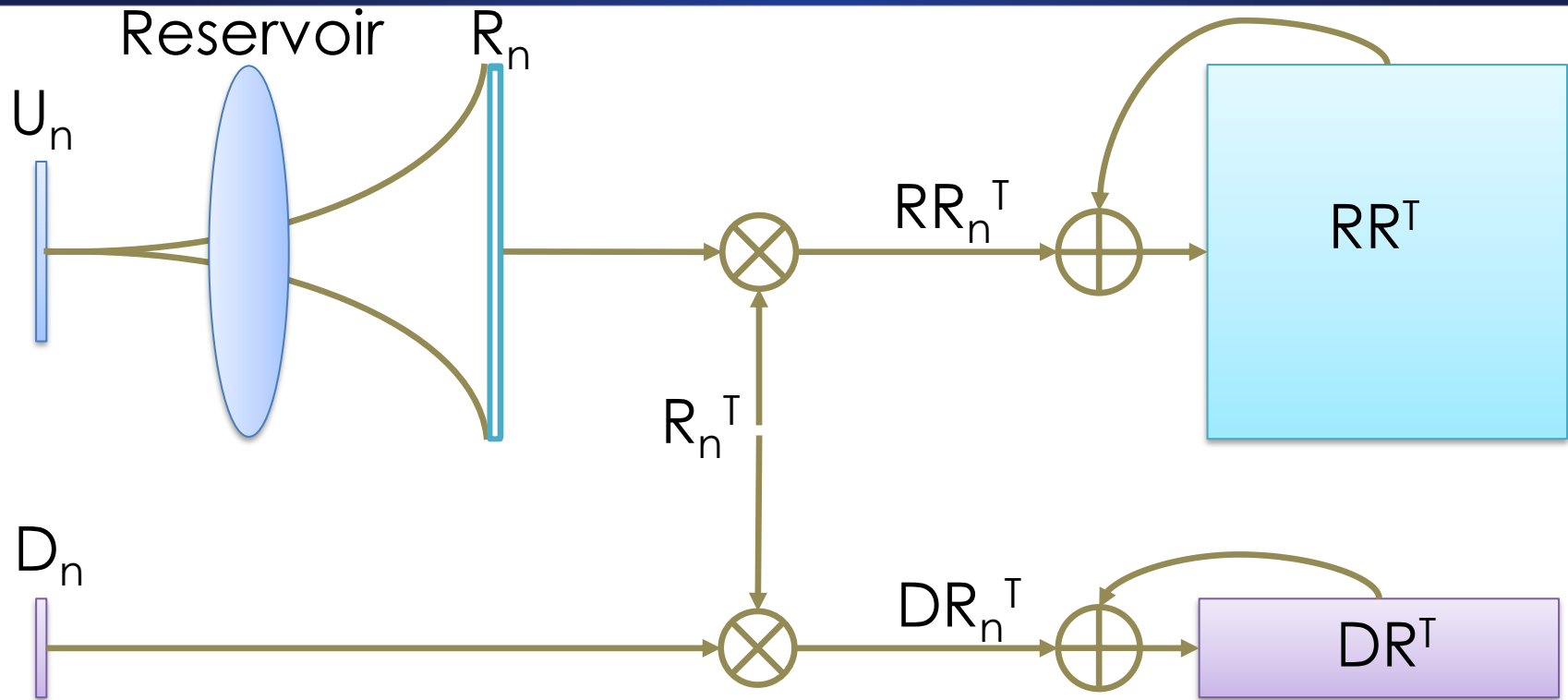
Related presentations at APS-DPP21

- ML for monitoring plasma (overview of the DOE project): **UM10.00003**
- ELM detection using BES diagnostics: **CP11.00067, PP11.00160**
- Locating AE using ECE diagnostics: **CP11.00101, PP11.00154**
- AE spectrogram enhancement using image processing: **JP11.00102**
- Autoencoders for BES data compression: **JP11.00107**
- AE classification using interferometry data: **PP11.00133**
- ELM detection using BES diagnostics: **PP11.00138**

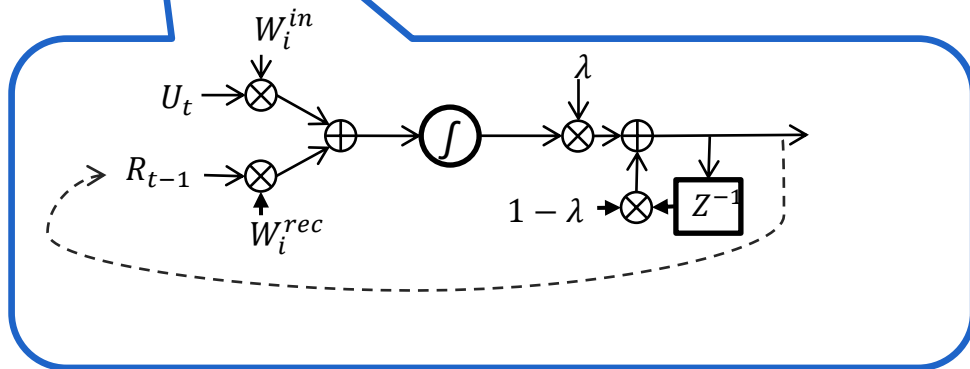
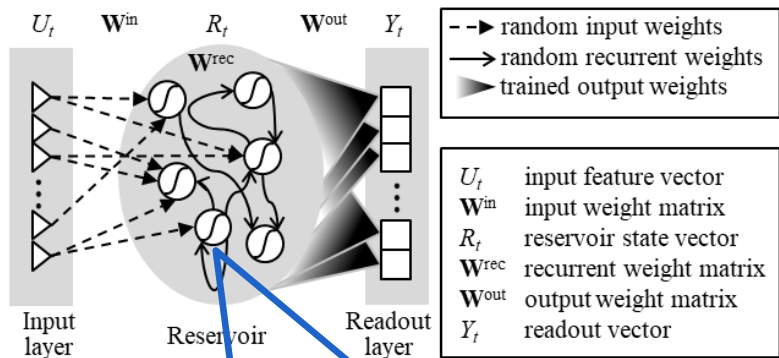
THANK YOU!

AE mode classification based on ECE data





Reservoir computing networks



Hyper-parameters

- W^{in} and W^{rec}
 - Density of the matrix
 - Scale of the weights
- Leakage
- Reservoir size