TSVV-H: Pedestal MHD surrogate model update

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June 2026

The surrogate model is supposed to give a fast approximation of the MHD stability of a given equilibrium

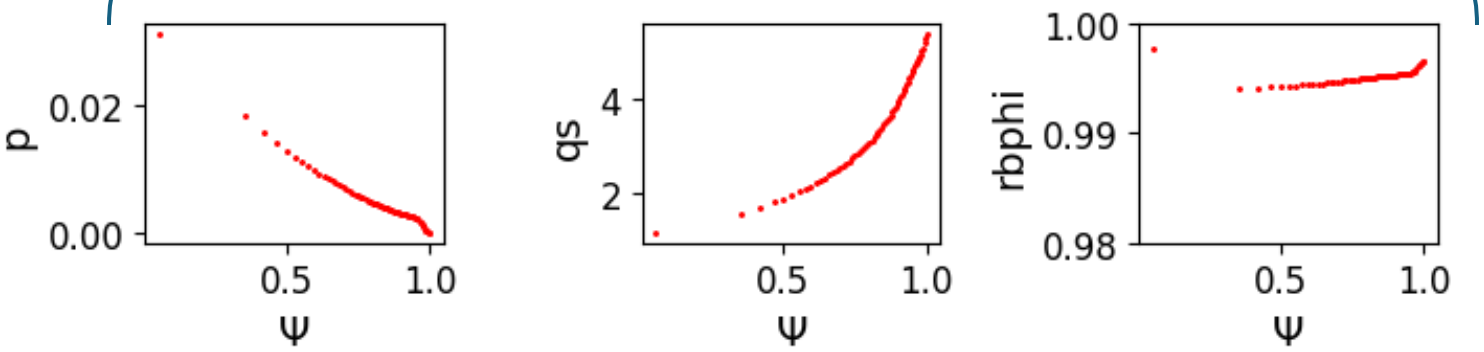
- What the surrogate looks like now
- What we are working on
- What does the integrated workflow need?

The current model takes the MISHKA equilibrium mapping as input

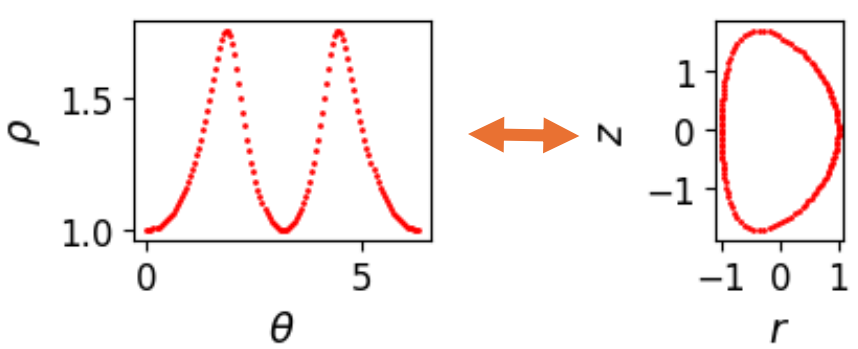
- Pressure profile
- Safety factor profile
- RB_phi profile
- Plasma boundary shape in polar coordinates
- R_mag, B_mag

Different input setups for different applications, for example:
- Te, Ti, ne profiles
- Scalar values for BT, Ip, and more
- Parametrized boundary

Interpolated to fixed psi grid

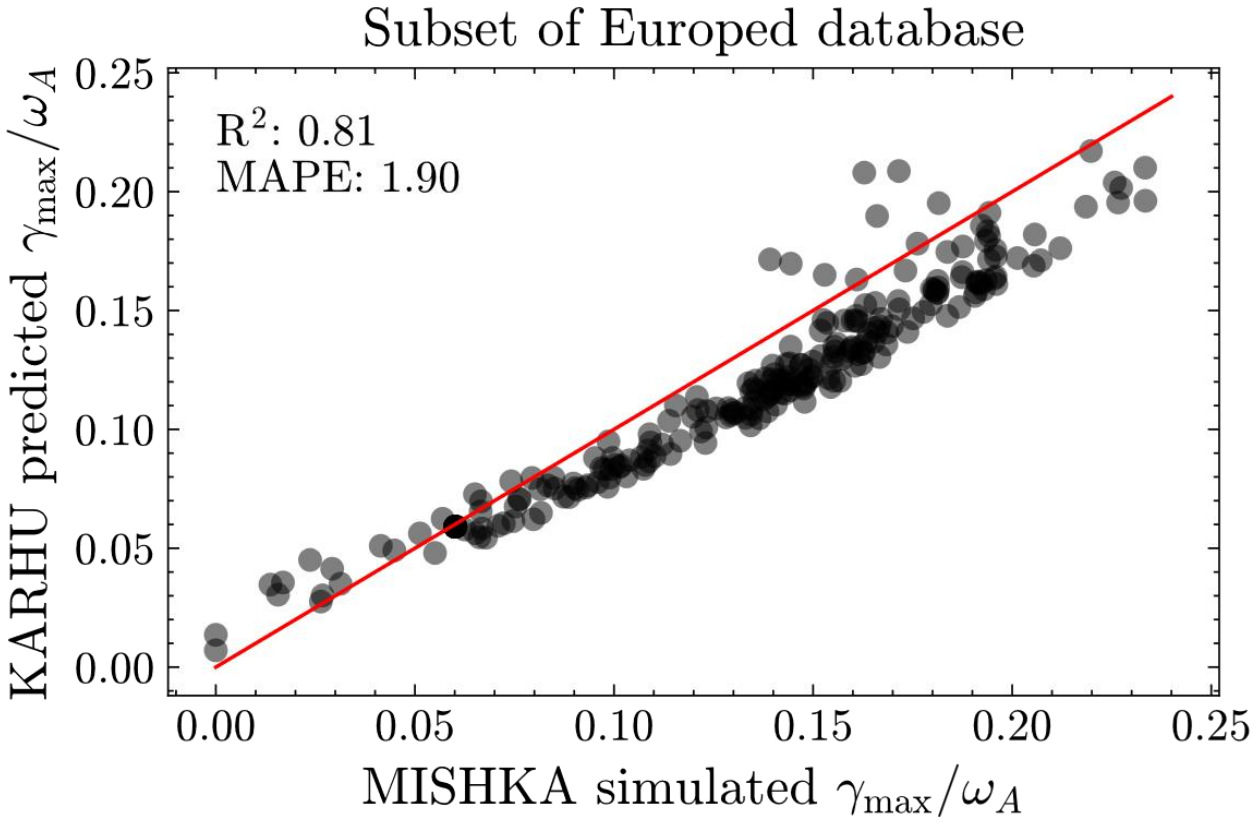


Interpolated to fixed theta grid



The previous regression model only outputs the ideal MHD growth rate of the most unstable mode

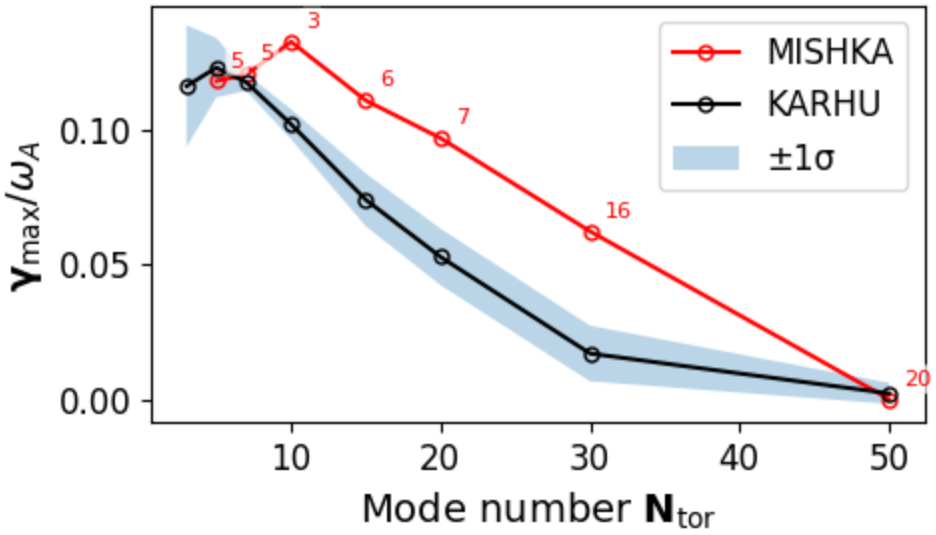
- Only Alfvén criteria possible for evaluating MHD stability



Next model will predict the growth rates for a spectrum of toroidal mode numbers Ntor

- Ongoing efforts to output growth rate spectrum over Ntor with probabilistic model --> diamagnetic criteria possible
- Model architectures being tested
- Ntor spectrum is being extended from [3, 5, 7, 10, 15, 20, 30, 50] to [1-10,15, 20, 30, 50]

Preliminary result/example using CVAE

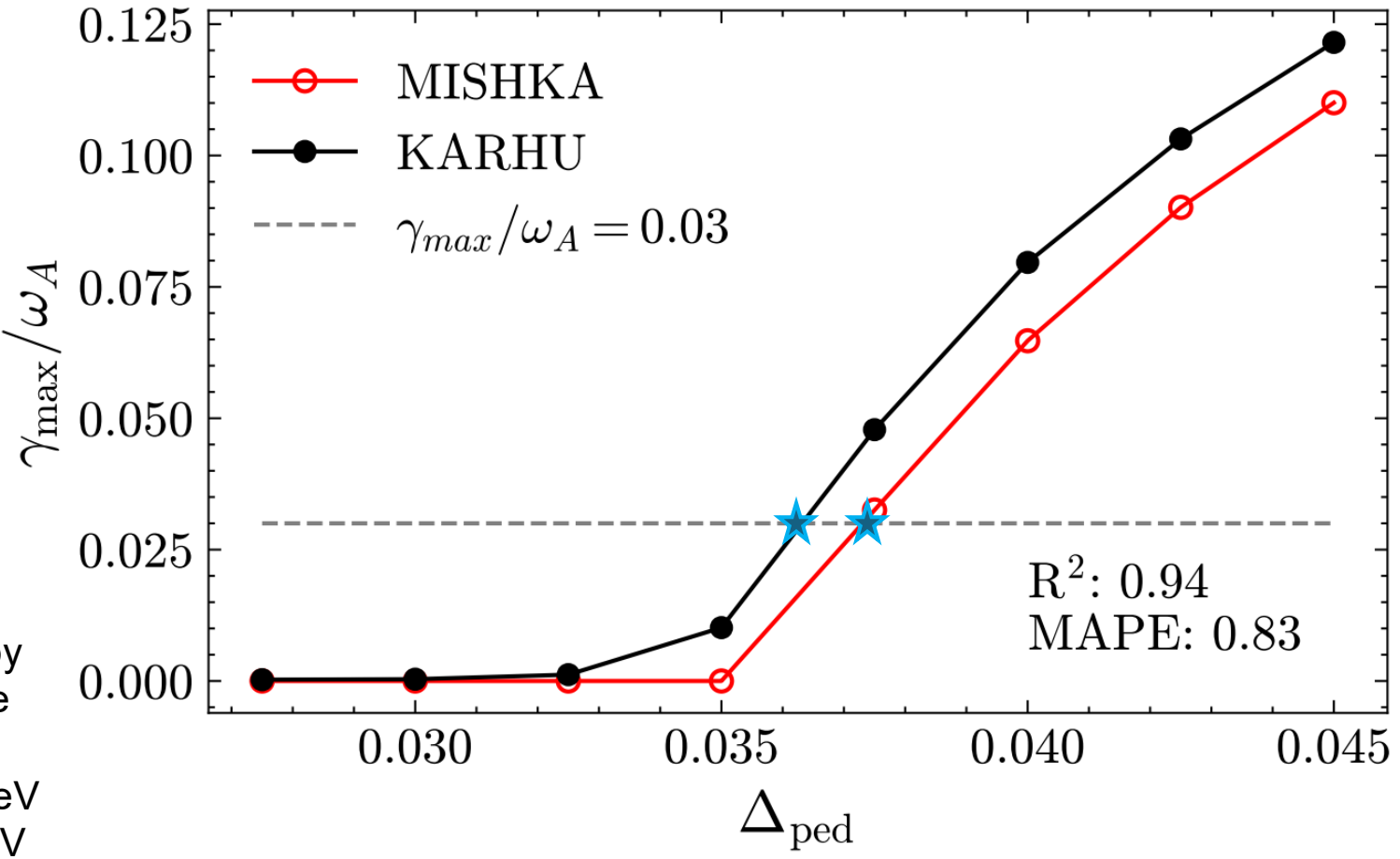


The training data is covering multiple devices

- JET (1H, 2H, 3H), DIII-D, JT-60SA, TCV, AUG, MAST-U. (Some only partial coverage, issues with high triangularity.)
- "Brute force" random sampling with pedestal with scan for different device-specific input spaces
- The training data still contains some assumptions that need relaxing:
  - n_esep = n_eped*0.25 <--Sampling the multiplier
  - T_eped following KBM constraint <-- either sampling the constant or directly sampling T_eped
  - no density offset <-- range?
  - mtanh profiles <-- ESSIVE-like sampling by perturbing dT and J?

How much of the normalized space are we actually covering? Are we oversampling (-->overtraining) on some part of the space?

KARHU is integrated into Europed resulting in a 72% speedup of the workflow



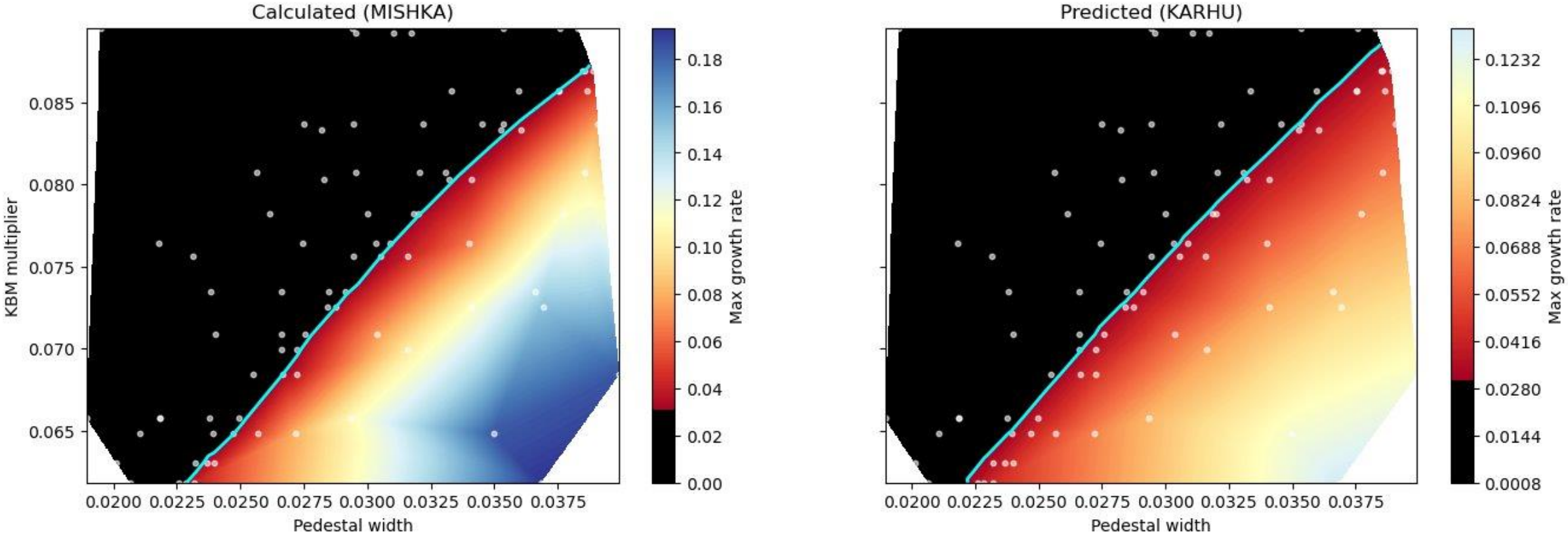
(KARHU v1)

The critical profiles lie on the intercept with the dashed line

Critical height prediction by Europed for example case JPN 84541:

- With MISHKA: 0.40 keV
- With KARHU: 0.38 keV
- 5% difference in prediction

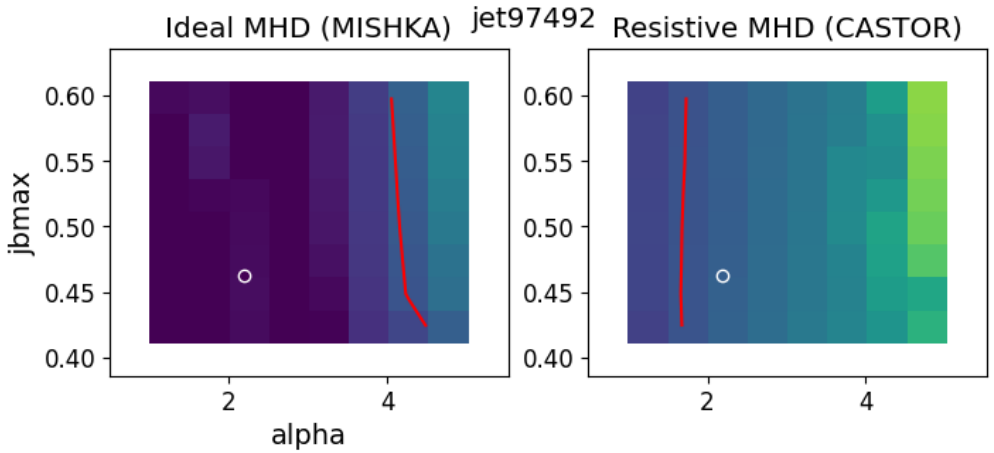
The ES+KARHU workflow can also be used to find critical profiles in a Europed-like way – but over many parameters



The critical profiles lie on the blue line.

Resistive MHD is being added to the model

- Dataset takes much longer to generate, smarter sampling?
- Added model input: the resistivity profile?
- Resistivity in destabilizing
  - if resistive MHD stable →ideal MHD is stable
  - if ideal MHD unstable → resistive MHD stable



- Can resistive and ideal MHD estimates be combined in one surrogate model? Or is it preferable to have two different ones? We have a lot of ideal MHD data in comparison to resistive MHD data..

Technical details and integrations

- Python >= 3.9
- Pytorch
- Github repository
- Data stored as hdf5 files, Zenodo
- Europed+KARHU integration works BUT struggled to find fitting modules on Heimdall, had to make a miniconda environment (not very user-friendly)
- JETTO integration by Adam, but KARHU predictions not good