ICF Design Analysis Using Machine Learning

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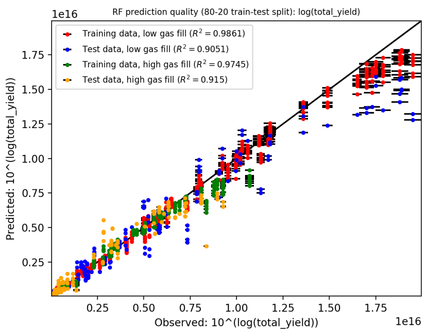
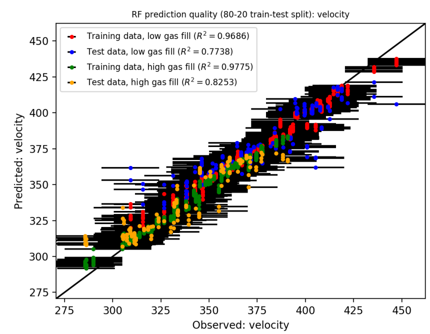
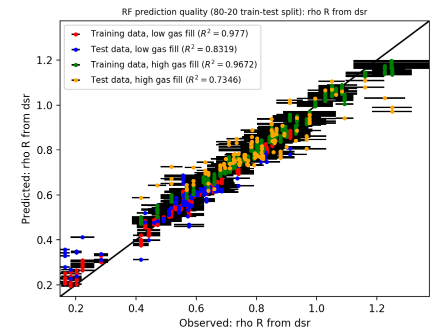
Overview: ML and ICF

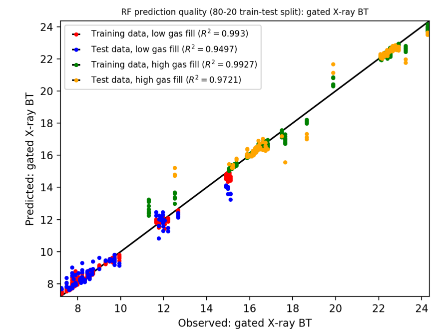
- Inertial confinement fusion (ICF) generates nuclear fusion reactions by heating and compressing a fuel capsule
  - Plasma ignition would yield many times the input energy
- We train a random forest (RF) regressor on data from ICF experiments
  - We use Accumulated Local Effects (ALE) to extract feature importance results from RF model
- Goal: analyze sensitivity of experimental outputs to controllable design inputs

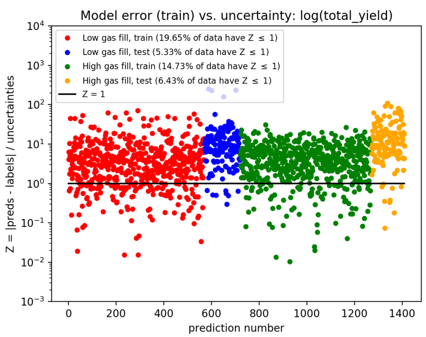
The random forest is a highly accurate predictor across groups and outputs

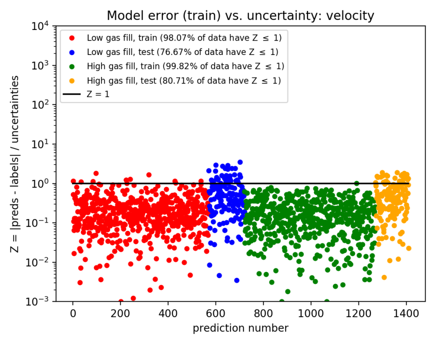


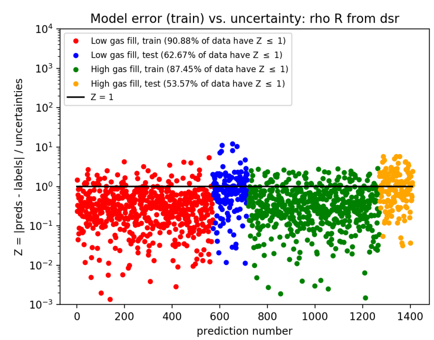


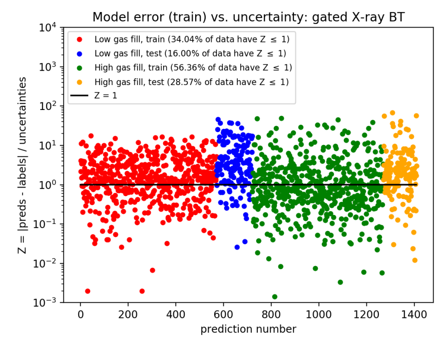






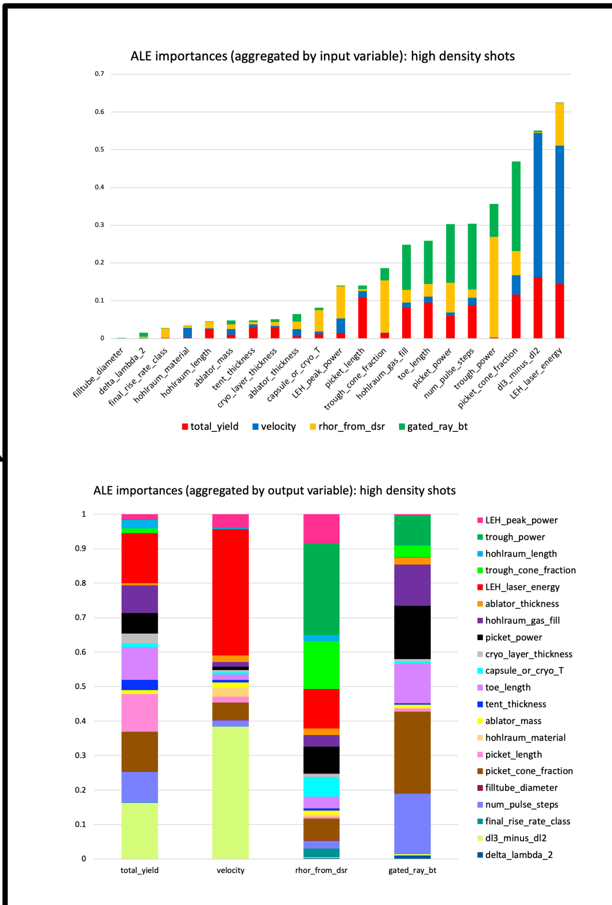




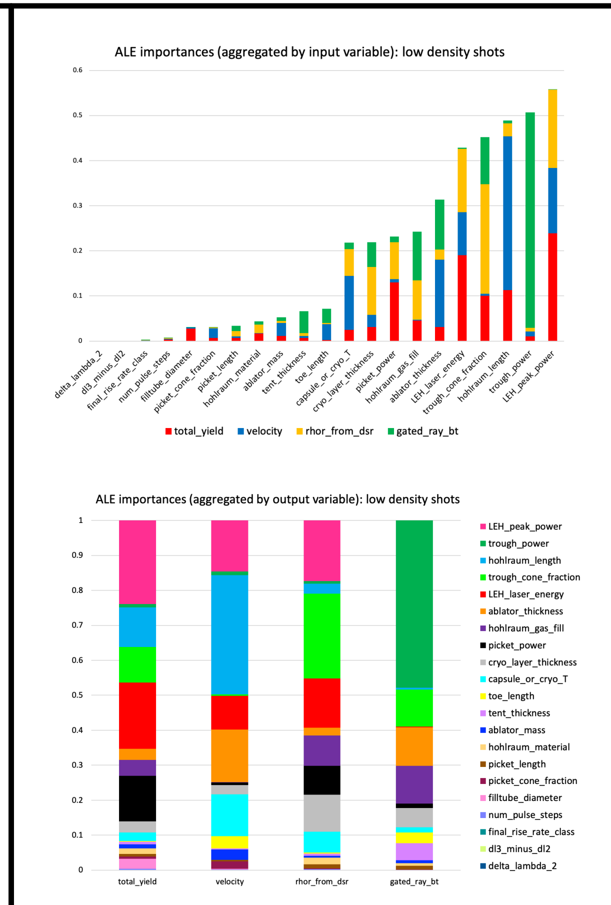


Importance rankings differ significantly between high and low density shots, consistent with experimental design changes

High Gas Fill (Group I)



Low Gas Fill (Group II)



Summary

- Random forests are able to learn and predict on ICF experimental data with high accuracy
- The RF model is able to detect key experimental design changes, and ALE importance results are consistent with the effects of such design changes
- Feature importance results provide insight into relationships between design inputs and measurable outputs
  - These relationships can inform future ICF design

References

Apley, D. W., & Zhu, J. (2019). Visualizing the Effects of Predictor Variables in Black Box Supervised Learning Models. *ArXiv:1612.08468 [Stat]*. http://arxiv.org/abs/1612.08468

Nakhleh, J., Fernández-Godino, M., Grosskopf, M., Wilson, B., Kline, J. and Srinivasan, G. (2020). Exploring Sensitivity of ICF Outputs to Design Parameters in Experiments using Machine Learning. Paper submitted to *IEEE Transactions on Plasma Science.* Available at *ArXiv:2010.04254 [Physics].* http://arxiv.org/abs/2010.04254