Detecting JET Outliers in the Tokamak Database

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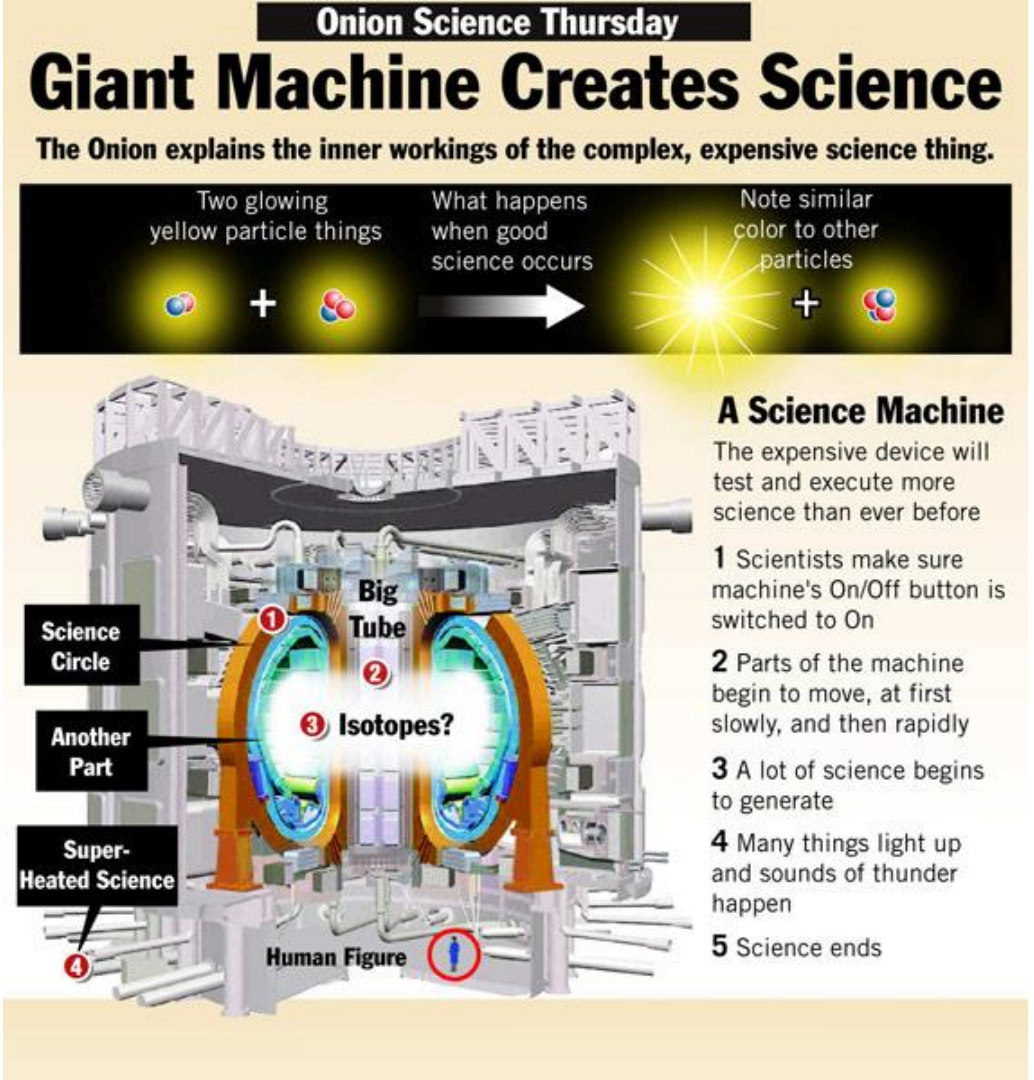
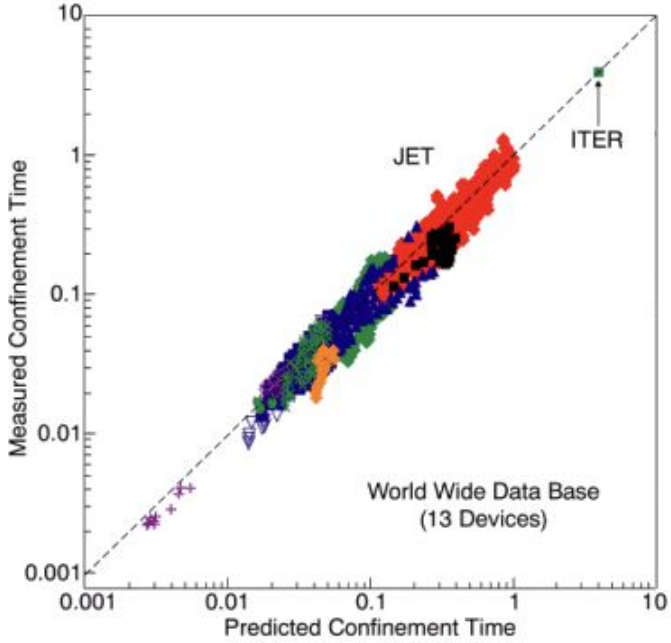
Tokamaks will be fusion reactors that compete with baseload power sources – like coal

ITER, at $20B, is the second most costly experiment in the world



ITER was built using a linear regression on confinement:

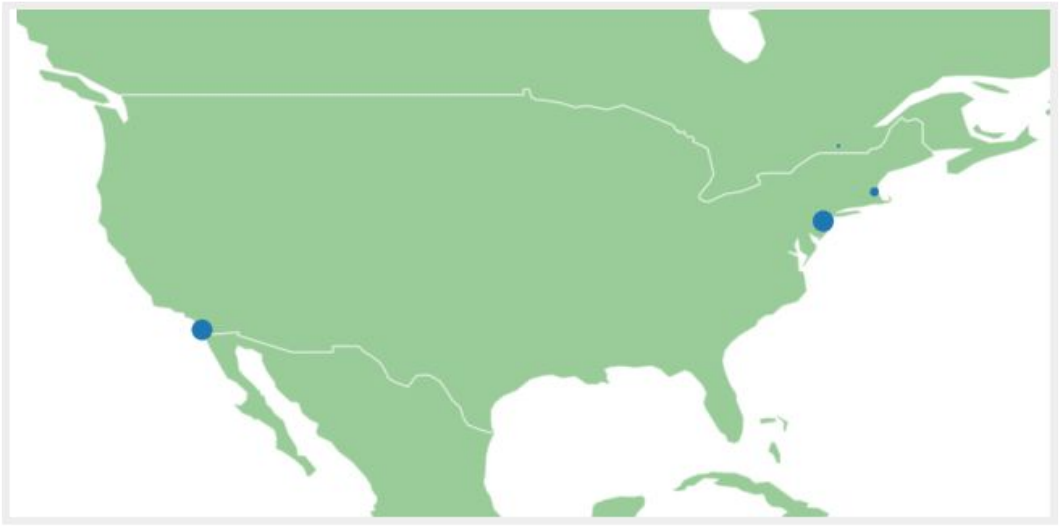
$$\tau_E^H = 0.145\, H\, \frac{I_P^{0.93}\, R_0^{1.39}\, a^{0.58}\, \kappa^{0.78}\, \overline{n}^{0.41}\, B_0^{0.15}\, A^{0.19}}{P_{src}^{0.69}}$$



Our goal is to detect JET outliers

	Good	Bad
JET	**1434**	1710
Else	2097	913

The first step is balancing shots from all the tokamaks



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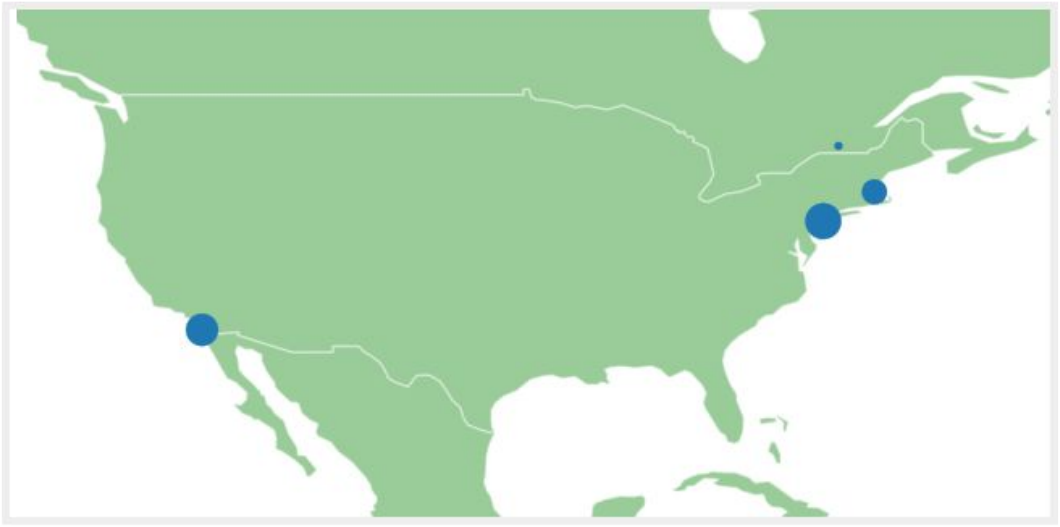

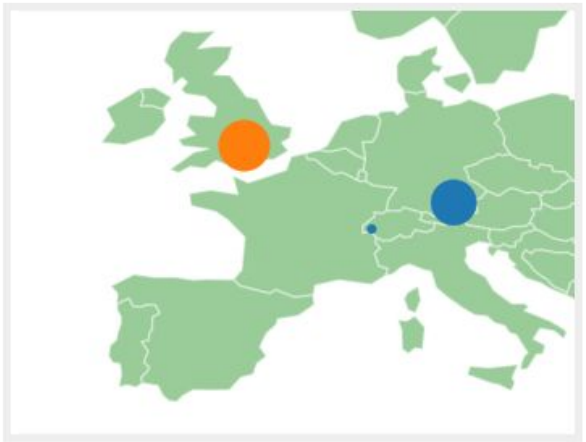

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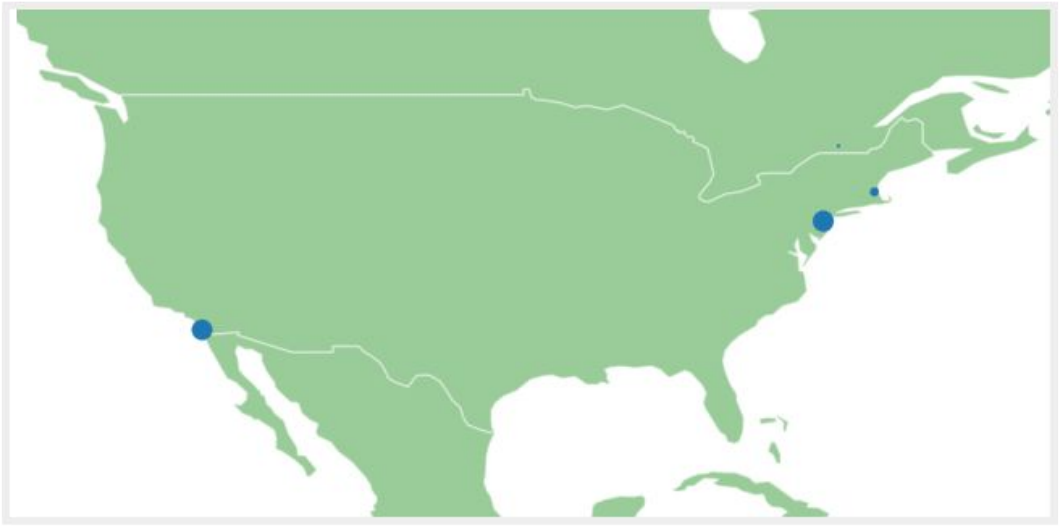
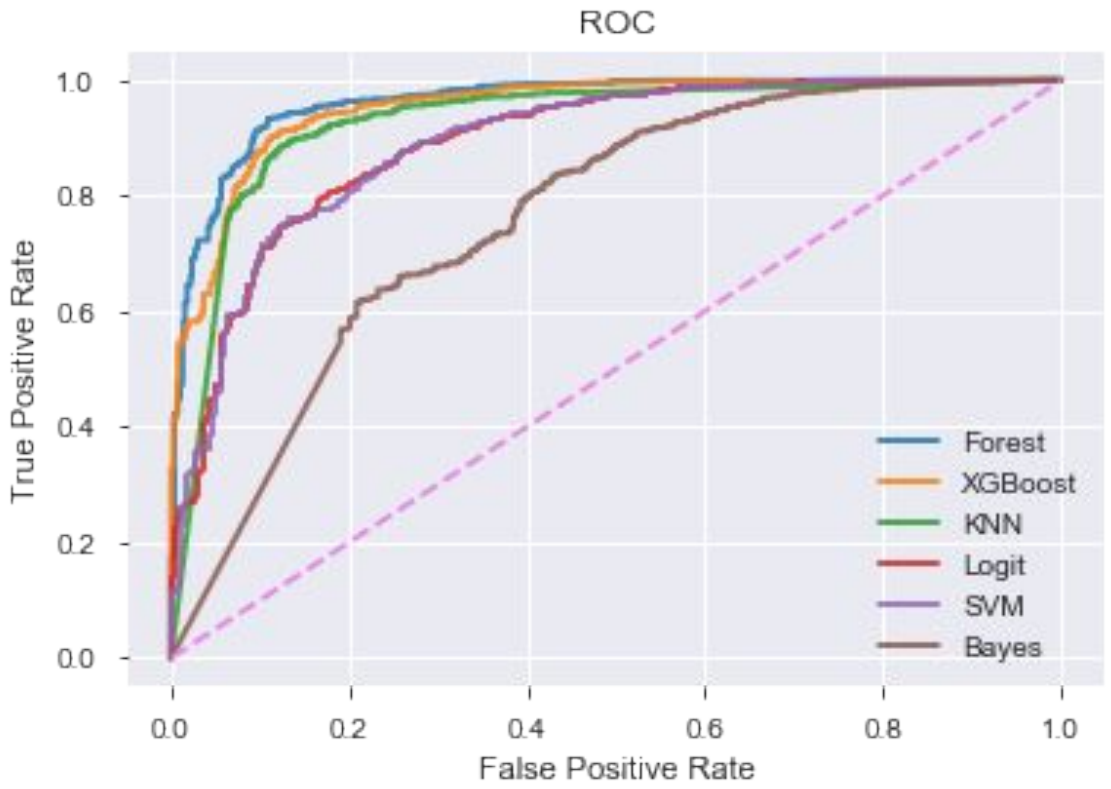
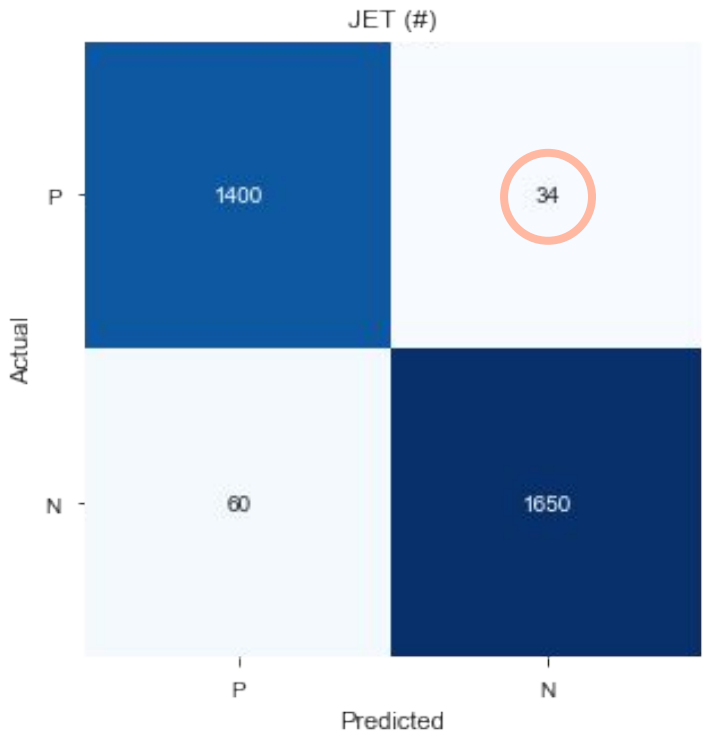
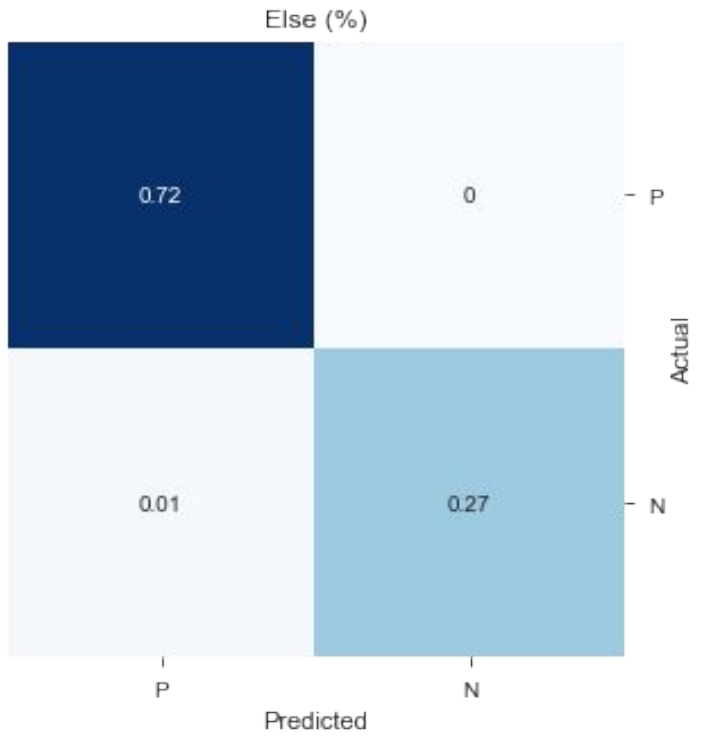


Next we will plug 10k rows into 6 classifiers using the 50 strongest features

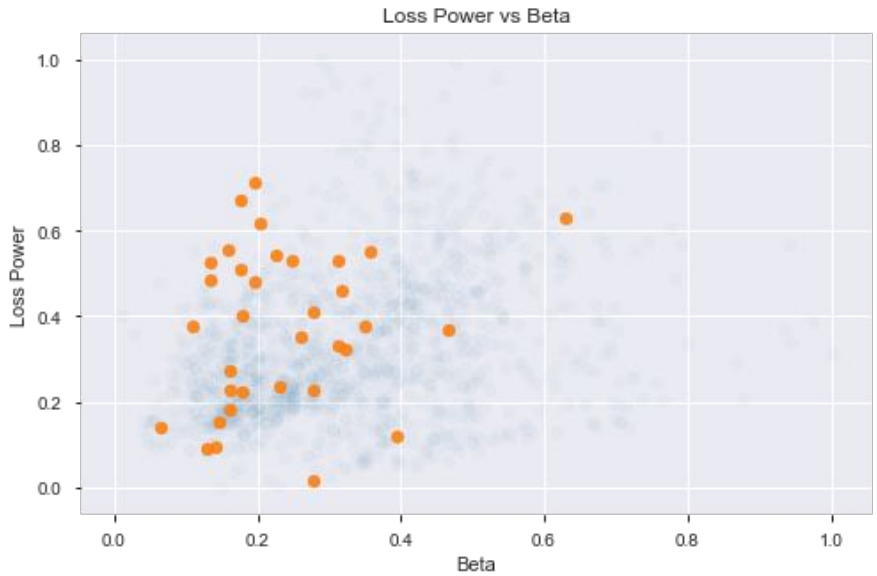
Model	AUC (%)
Forest	96
XGBoost	95
KNN	93
Logit	89
SVM	89
Bayes	*77*




JET (#)
P
N
1400
34
60
1650
Actual
P
N
Predicted

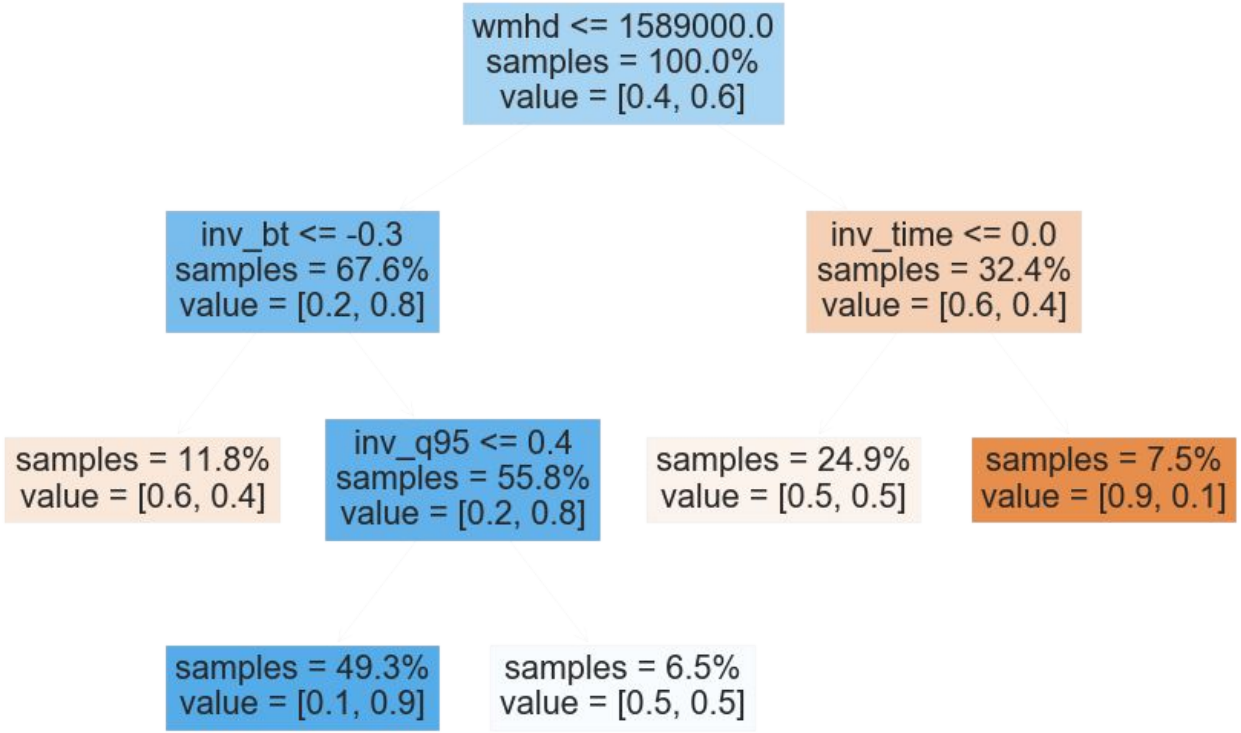

Else (%)
0.72
0
0.01
0.27
P
N
Actual
P
N
Predicted

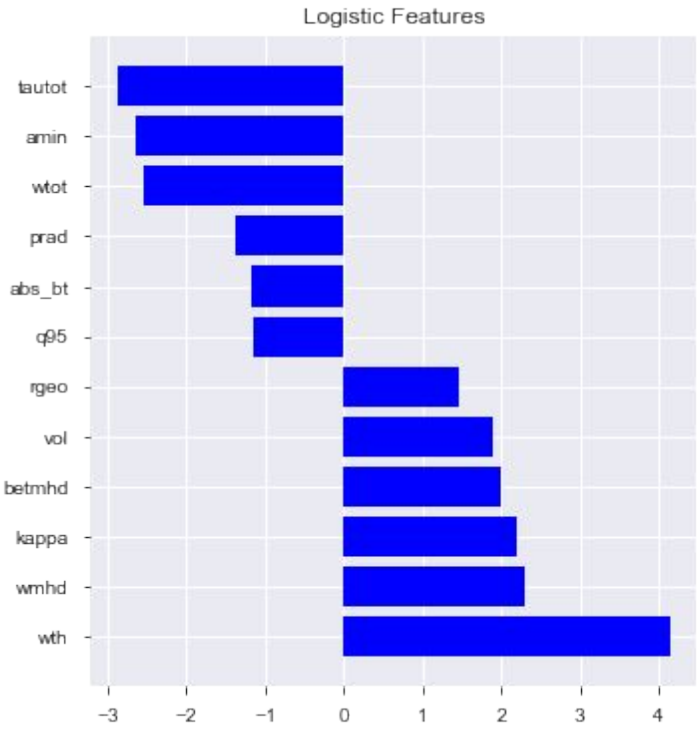
The 34 outliers tend to have low betas and high loss powers

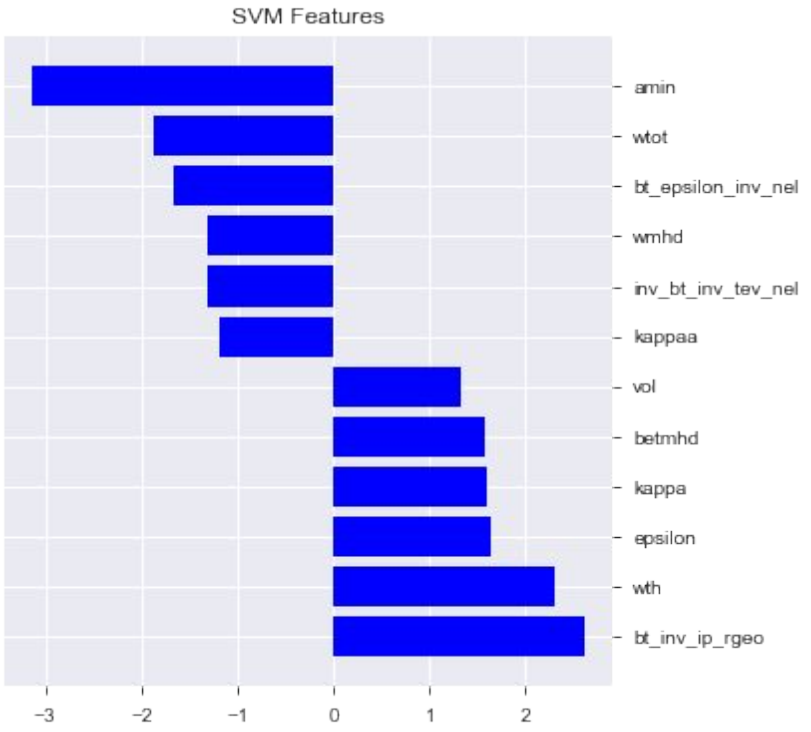


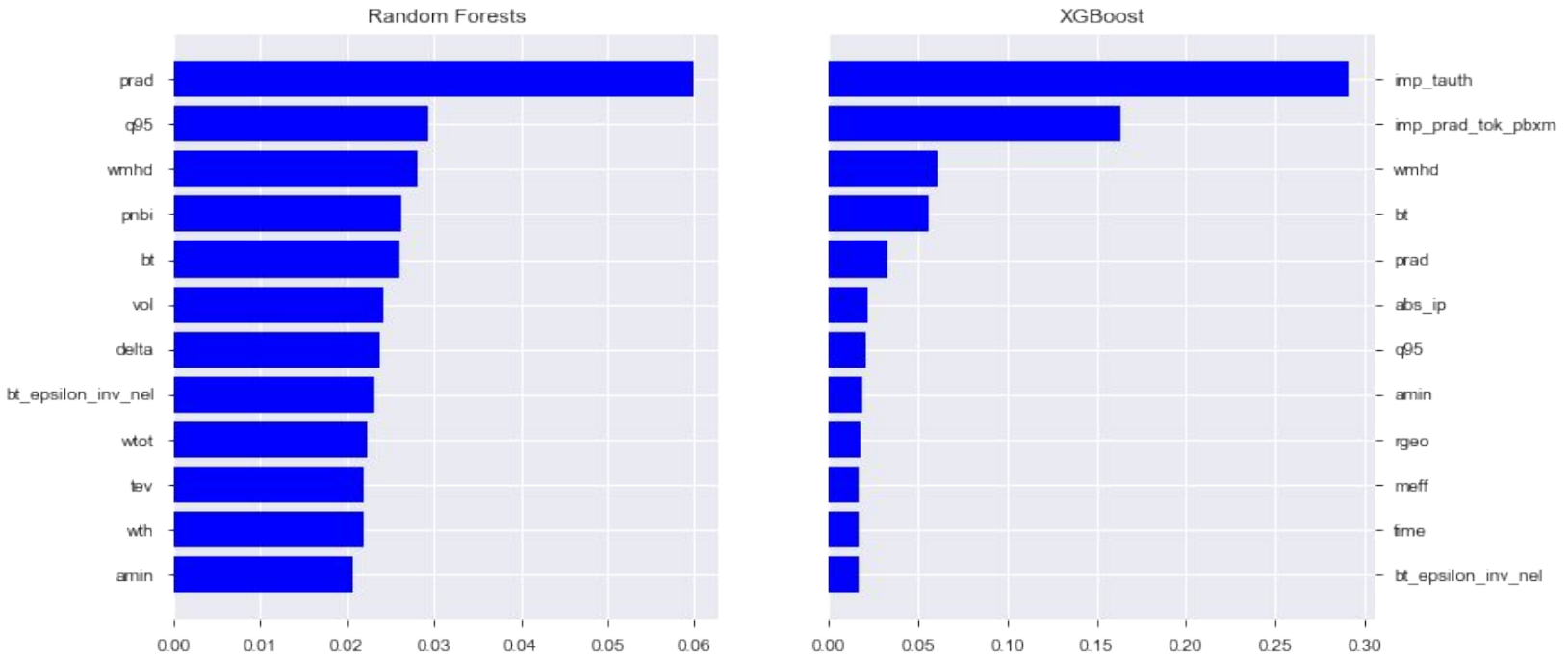
Features

- Started with ~100 numeric parameters
- Imputed NaNs with median or predicted
- Expanded to ~1000 parameters w/ polynomials
- Removed ~500 highly correlated variables
- Eliminated ~200 variables with random forests
- Dwindled to ~50 variables with L1 classifiers


wmhd <= 1589000.0
samples = 100.0%
value = [0.4, 0.6]
inv_bt <= -0.3
samples = 67.6%
value = [0.2, 0.8]
inv_time <= 0.0
samples = 32.4%
value = [0.6, 0.4]
samples = 11.8%
value = [0.6, 0.4]
inv_q95 <= 0.4
samples = 55.8%
value = [0.2, 0.8]
samples = 24.9%
value = [0.5, 0.5]
samples = 7.5%
value = [0.9, 0.1]
samples = 49.3%
value = [0.1, 0.9]
samples = 6.5%
value = [0.5, 0.5]


Logistic Features
tautot
amin
wtot
prad
abs_bt
q95
rgeo
vol
betmhd
kappa
wmhd
wth
−3
−2
−1
0
1
2
3
4


SVM Features
amin
wtot
bt_epsilon_inv_nel
wmhd
inv_bt_inv_tev_nel
kappaa
vol
betmhd
kappa
epsilon
wth
bt_inv_ip_rgeo
−3
−2
−1
0
1
2


Random Forests
prad
q95
wmhd
pnbi
bt
vol
delta
bt_epsilon_inv_nel
wtot
tev
wth
amin
0.00
0.01
0.02
0.03
0.04
0.05
0.06
XGBoost
imp_tauth
imp_prad_tok_pbxm
wmhd
bt
prad
abs_ip
q95
amin
rgeo
meff
time
bt_epsilon_inv_nel
0.00
0.05
0.10
0.15
0.20
0.25
0.30