Introducing machine learning for high-performance scenario access and accurate EC control

A. Rothstein[1], C.S.Byun[1], S. K. Kim[2], M.S. Kim[1], M.H. Woo[3], M.S. Cha[4], Y.H. Lee [3], S.M.Yang[2], G.W.Shin[3], H.H. Lee[3], Y.H. Lee[3], H.S.Kim[3], Q.Hu[2], M.W.Kim[3], J.Chung[3], G.Y.Park[3], J.W. Kim[3], W.H. Ko[3], J.Lee[3], and E.Kolemen[1,2]

[1] PU, [2] PPPL, [3] KFE, [4] SNU

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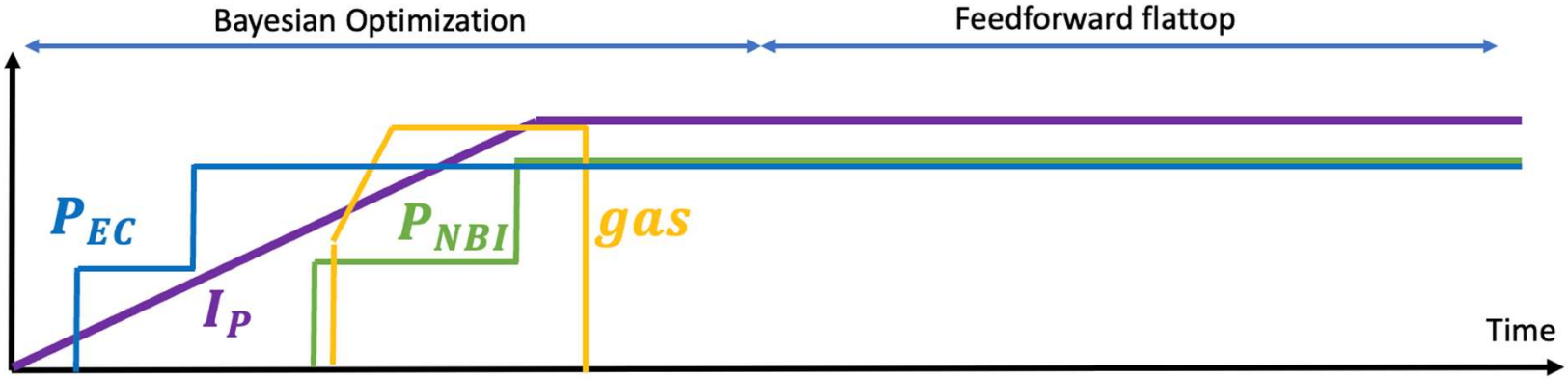
Plasma Control

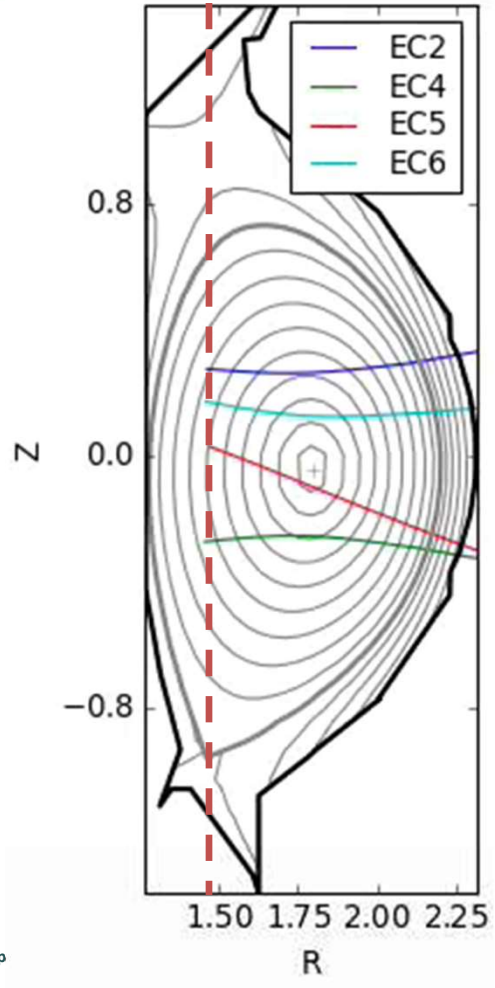
Intershot Bayesian Optimization for developing high-performance KSTAR scenario

- Goal of maximize performance (β_N) in the flattop of the shot
- Use historical KSTAR data to pretrain models, then update model based on results during experiment
- Adjust I_P, P_{NBI}, P_{EC} , gas feedforward waveforms between shots according to ML optimization
  - Do more exploration in early shots and focus in on high performance in later shots



ML TORBEAM surrogate for feedback EC steering

- Accurate EC steering and control is desirable for variety of tasks:
  - NTM island suppression
  - ST control
  - Improved ELM suppression with edge ECCD
  - Impurity shielding effects
- Real-time TORBEAM code computationally expensive to run and can be inaccurate due to instability in rtEFITs
  - ML surrogate faster to run and more robust to numerical noise in real-time equilibria



KSTAR Exp

Torbeam-nn Inputs
rtEFIT scalars
Real-time n_e profile - NERECON

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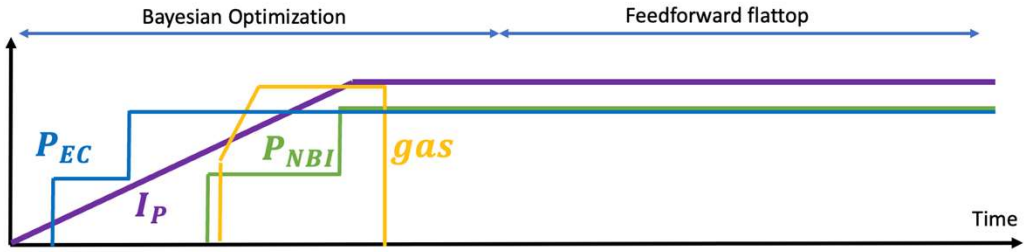
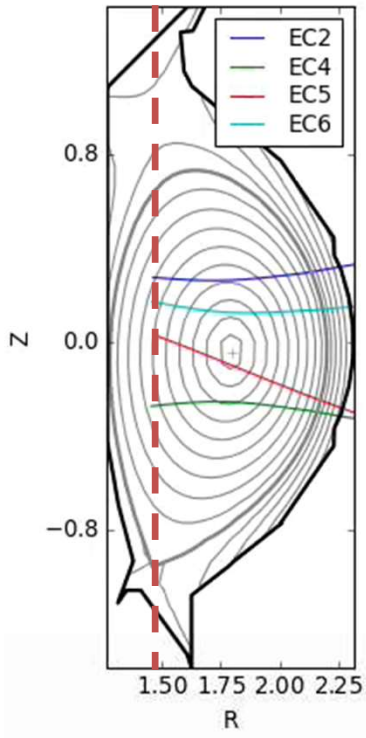
Shot Plan (13-20 shots)

1. Stage 1: Restore H-mode reference (36497) (1-2 shots)
2. Stage 2: Bayesian optimization exploration (10-14 shots)
   I. Start Start with larger exploration BO settings for BO of feedforward waveforms.
   II. Commission feedback EC steering in flat-top.
      I. Scan ECH Z positions to tune PID gains and assess accuracy of Torbeam-nn
3. Stage 3: Bayesian optimization high performance (2-4 shots)
   I. Reduce exploration settings for BO to achieve high performance ramp-up scenario
   II. If Torbeam-nn steering successful, add in scans over toroidal angles to validate tracking





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Hardware requirements and team

- B_T: -1.9T
- I_P: 0.5MA
- 5 NBI (all except NB2B)
- EC4 and EC5
  - Feedback mirror steering required
- Standard feedforward gas

- SL: Andy Rothstein
- CPO: Sanghee Lee
- ECH aimer: Minho Woo
- BO task coordinator: Minseok Kim
- PID tuning coordinator: Cheolsik Byun