NSTX-U

NSTX-U is sponsored by the
U.S. Department of Energy Office of Science
Fusion Energy Sciences

# Review of NSTX-U research milestones R18-6 and R19-4

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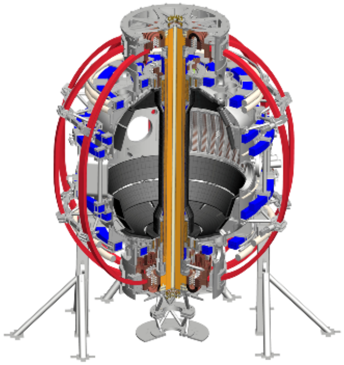
FY2018-19 Research Milestone Review
May 25, 2017

PPPL



# Proposed changes to milestones

- R18-6 Simulation framework development for NSTX-U high-performance scenarios
  - Divide original milestone over FY18 and FY19
  - Provide greater detail on tasks in each fiscal year
  - Increased emphasis on connection to MAST-U collaboration
    - Add startup modeling (planned for FY17 summer)

- R19-4 Commission physics and operational tools for obtaining high-performance discharges in NSTX-U
  - Defer to FY20

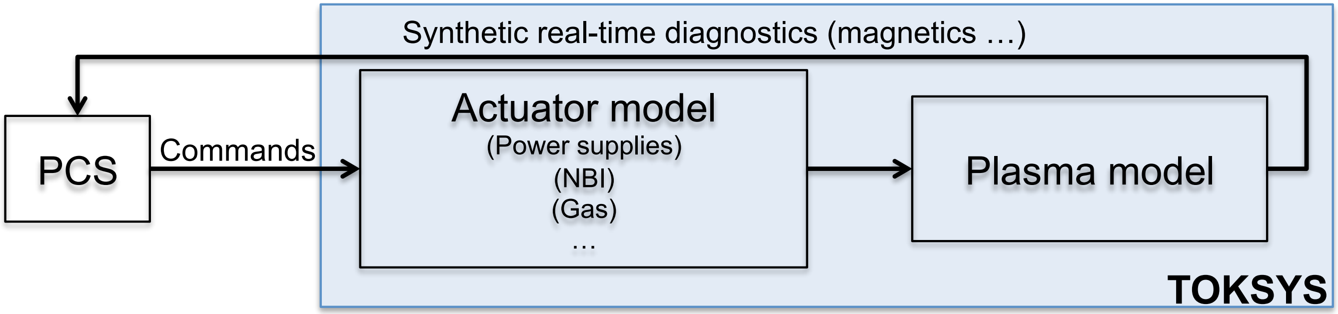
# Review of R(17-5): Analysis & modeling of current ramp-up dynamics

- Evaluate elongation limits during ramp-up phase using data and calculations
  - What factors limit the elongation before, during and after diverting?
  - Identify growth rate of vertical instability to predict controllability of high-κ shapes in ramp up
- Establish the dependence of the L-H transition on density, plasma shape, etc. to inform modeling of threshold criteria and scenario targets
- Perform stability analysis of experimental and modeled discharges to identify MHD limits during ramp-up
- Prepare for R18-6: work through technical issues for TOKSYS framework with GA
- Prepare for R18-6: begin TRANSP analysis of ramp-up phase

# R(18-6): Develop simulation framework to optimize *breakdown and* ramp-up *in STs*

- Develop TOKSYS framework with free-boundary equilibrium solver in plasma model
  - Reproduce ramp-up cases from NSTX-U with fixed profile evolutions, plasma inductance, resistance, etc.
    - Evaluate if observed shape evolutions are reproduced using PCS algorithms
  - Requires wall, power supply, magnetic diagnostic models (FY17)
    - Implement the same for MAST-U (FY18)

- Apply model to gain insight into shape limits and control
  - Evaluate vertical stability limits during ramp-up in simulation
    - Consider MAST-U and NSTX-U with both pre- and post-recovery designs
  - Use simulation tool to optimize shape control during ramp up
    - Most interested in control around time of diverting (avoid “the bobble”)
    - Evaluate trade-off between rtEFIT resolution / constraints and computational time



# R(18-6): Develop simulation framework to optimize *breakdown and* ramp-up *in STs*

- Investigate NSTX-U ramp-up dynamics using TRANSP
  - Identify range of NSTX / NSTX-U cases to characterize
    - Use equilibrium and TRANSP results to evaluate MHD and fast ion stability
  - Investigate impact of changes in NBI heating mix on stability with fixed equilibrium and T, n, $Z_{eff}$ profiles
    - Which beams and shapes are best for startup?
- Develop and evaluate start-up calculations for NSTX-U and MAST-U

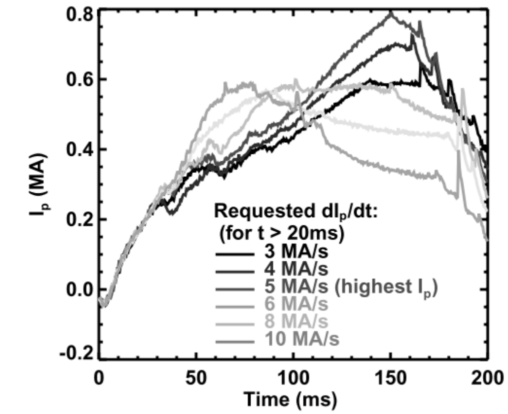
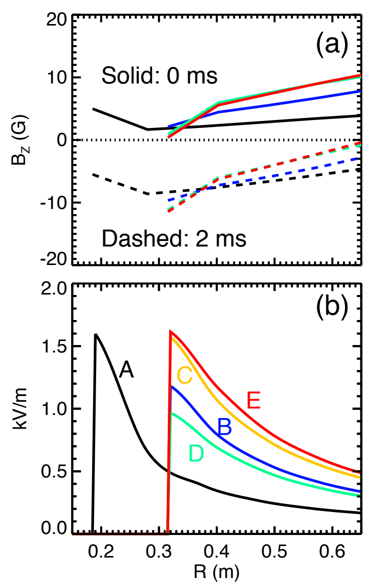



**Figure 2.** Plasma current traces obtained during a systematic scan of the plasma current ramp rate.

NSTX-U breakdown calculations



# R19-?: Optimize ramp-up scenarios and control for spherical tokamaks

- Extend TOKSYS to use reduced models for current and pressure profiles and in L- and H-mode
  - Investigate scenario and control optimization for ramp-up with early heating and examine resiliency to timing of L-H transition
- Extend TRANSP simulation to employ more physics-based models
  - Evolve $T_e$ and $T_i$ based on transport model or neural-net model found to best reproduce experimental data
  - Use neutral fueling feedback in TRANSP to match density request, if available
  - Use free-boundary solver to optimize shape evolution

# R19-?: Optimize ramp-up scenarios and control for spherical tokamaks

- Apply available tools to investigate impact of heating mix and timing
  - Experiments will ask for beams at different voltage combinations
- Investigate influence of early density on the ramp-up
- Evaluate the trade-offs in $I_p$ ramp-rate
  - What are the stability limits?
  - What is the impact on shape and stability due to wall currents?
  - Apply MHD and fast-ion stability calculations to characterize stability boundaries in a range of cases
- Perform targeted experiments on MAST-U and NSTX-U

# Original FY19 milestone should be deferred to FY20

- Evaluate wall-conditioning boron vs lithium in NSTX-U
  - Evaluate ELM-pacing for impurity control in ELM-free regimes
- Demonstrate optimize ramp-up scenarios for achieving high-elongation and large $I_p$
  - Assess vertical stability at low-li, identify limiting mechanisms
- Re-optimize EFC and implement in control algorithm
  - Also, start active RWM feedback
- Evaluate stability limits and non-inductive fraction

# Backup

# FY18/19 Milestone modifications

- Google doc:
  - https://docs.google.com/a/pppl.gov/document/d/1sY-dJ4M2e2xNhQ-B7AMjGFuwSOUqN9mBHn4r7cw8qQA/edit?usp=sharing

# H-mode flattop performance depends on the $I_p$ ramp-up

- **NSTX fiducial** had L-H transition before 150ms
  - $l_i$ ~ 0.5, κ ~ 2.4 with $P_{NBI}$ = 5.8 MW

- NSTX-U: progress in obtaining early L-H transition, higher $I_p$ and κ
  - **202946 → 203679 → 204112**
  - Enabled by increase in $P_{NBI}$, improvements in shape control, EFC

- Access to higher $I_p$ (> 1.6 MA) and κ (> 2.4) requires further ramp-up development during next run