NSTX-U

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# EP-TSG
# Research Milestones for FY18-19

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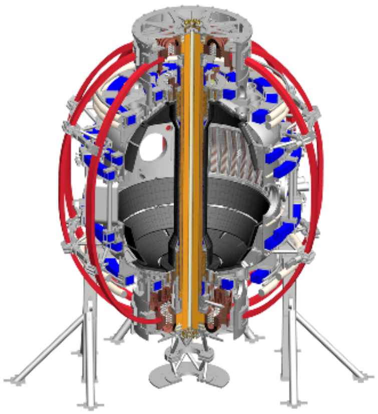

# R(18-4): Optimization of the energetic particle distribution function for improved plasma performance

- Goal: optimize NBI parameters for reproducible, reliable discharges
  - Focus on start-up, early flat-top (but include sawteeth)
  - Leverage on ASC-TSG work on start-up scenarios
- Aim at discharges with mitigated/suppressed EP-driven instabilities: maximize NB-CD, predictability
- Main tool is TRANSP
  - Aided by NOVA, ORBIT, RBQ, kick model, GTS, M3D* and others for AE transport analysis
    - Developing representation of NUBEAM fast ion distribution function in constants of motion as input for stability codes
- Expect collaborations with DIII-D and MAST-U
  - DIII-D: validate models, complement ST scenarios with conventional a/R data
  - MAST-U: assist in re-start of operations, modeling (e.g. extend ‘kick model’ to fishbones, improve sawtooth model in TRANSP)

# R(19-2): Assess the effects of NBI parameters on the fast ion distribution function and NB-driven current profile

- Goal: characterized NB-CD performance and NB-driven current profiles vs NBI parameters
  - Include effects of NB ions from different sources on EP-driven instabilities
- NSTX-U data from FY19 welcome… if no ops, more emphasis on collaborations
- Modeling work has heavy “validation” component
  - E.g. TRANSP + kick model/RBQ results vs fast ion diagnostics
  - Extend previous studies to “phase-space resolved” measurements
- Expect collaborations with DIII-D and MAST-U
  - DIII-D: validate models, complement off-axis NB-CD data with previous results from conventional a/R device
  - MAST-U: assist with OA-NBCD studies (modeling)
  - All three devices have similar diagnostics – helps to develop common “analysis/validation” procedures

# R(18-4): Optimization of the energetic particle distribution function for improved plasma performance

The improved neutral beam injection (NBI) capabilities that are available on NSTX-U enable a flexible tailoring of the fast ion distribution function resulting from NBI. In collaboration with DIII-D and MAST-U, this milestone will explore the use of different NBI sources and timing of NB injection to improve plasma performance and reproducibility by affecting fast ion-driven instabilities, e.g. through their mitigation or suppression. A main focus of this study are the current ramp-up and early flat-top phases, during which strong fast ion-driven activity can be destabilized (cf. NSTX-U shots from the FY-16 experimental campaign). Instabilities include toroidal and reversed-shear Alfvénic modes (TAE/RSAE) as well as energetic particle modes and fishbones. Sawteeth during the stationary phase of L-mode NSTX-U discharges will also be included. All these instabilities have the potential to cause substantial fast ion redistribution, thus affecting the overall efficiency of NB heating and current drive. Thus, if not properly accounted for in simulation codes, the effects of fast ion driven instabilities make the discharge evolution difficult to predict. Work within the Energetic Particle TSG will leverage and contribute to scenario development activities by the Advanced Scenarios and Control TSG, including the planned collaboration with MAST-U in FY17-18. Once a suitable ramp-up scenario is identified, AE and fishbone stability will be assessed. The analysis will include exploration of different NBI combinations (e.g. on- vs. off-axis) and timing in time-dependent simulations to identify the optimum NB mix and resulting safety factor and current profiles that lead to reduced mode activity. Scenario development will rely on the TRANSP code. TRANSP analysis will be assisted by results from the NOVA/NOVA-K and ORBIT codes and from reduced models such as the ‘kick’ and Resonance-broadening Quasi-linear (RBQ) models to infer the mode stability. Validation of the ‘kick model’ for scenarios with unstable fishbones will be conducted in collaboration with MAST-U. In collaboration with DIII-D, a recently developed criterion to predict the nonlinear behavior of Alfvénic instabilities (e.g. quasi-stationary vs. bursting/chirping) will be validated to gain further confidence in predictions of the fast ion transport instabilities can cause. Test particle simulations of fast ion scattering by plasma turbulence will be performed using the GTS code to assist the validation of the theoretical criterion for instability chirping.

# R(19-2): Assess the effects of NBI parameters on the fast ion distribution function and NB-driven current profile

Accurate knowledge of neutral beam (NB) ion properties is of paramount importance for many areas of tokamak physics. NB ions modify the power balance, provide torque to drive plasma rotation and affect the behavior of MHD instabilities. Moreover, they determine the non-inductive NB driven current, which is crucial for future devices such as ITER, FNSF and STs with small or no central solenoid. With the additional more tangentially-aimed NB sources, NSTX-U is uniquely equipped to characterize a broad parameter space of fast ion distribution (Fnb) and NB-driven current properties, with significant overlap with other STs such as MAST-U and conventional aspect ratio tokamaks such as DIII-D. The two main goals of this milestone are (i) to characterize the NB ion behavior and compare it with classical predictions, and (ii) to document the operating space of NB-driven current profile. If NSTX-U operations resume in FY19, Fnb will be characterized through the upgraded set of NSTX-U fast ion diagnostics (e.g. fast-ion D-alpha: FIDA, solid-state neutral particle analyzer: ssNPA, scintillator-based fast-lost-ion probe: sFLIP, neutron counters, and possibly a fusion products diagnostic) as a function of NB injection parameters (tangency radius, beam voltage) and magnetic field. Building on the initial results obtained in the NSTX-U FY-2016 run campaign, well controlled, single-source scenarios at low NB power will be used to compare fast ion behavior with classical models (e.g. the NUBEAM module of TRANSP) in the absence of fast ion driven instabilities. Collaboration with MAST-U and DIII-D is foreseen for joint studies on NB-CD and validation of the modeling tools. Diagnostics data will be interpreted through the “beam blip” analysis technique and other dedicated codes such as FIDASIM. Then, the NB-driven current profile will be documented for the NB parameter space attainable on the three devices, e.g. by comparing NUBEAM/TRANSP predictions to measurements from Motional Stark Effect (if available), complemented by vertical/tangential FIDA systems, ssNPA and neutron/fusion product diagnostics to assess modifications of the classically expected Fnb. Particular emphasis will be placed on documenting driven current profile variations as a function of injecting beam tangency radius. If NSTX-U cannot support plasma operations during FY2019, additional emphasis will be placed on collaboration on MAST-U and DIII-D to support the experimental research goals of this milestone on characterization of the fast ion distribution from NBI and of the NB-driven current profile.