JRT-2018: Conduct research to test predictive models of fast ion transport by multiple Alfvén eigenmodes. (Led by NSTX-U)

Fusion alphas and injection of energetic neutral particle beams provide an important source of heating and current drive in advanced tokamak operating scenarios and burning plasma regimes. Alfven eigenmode (AE) instabilities can cause the redistribution or loss of fast ions and driven currents, as well as potentially decreasing fusion performance and leading to localized losses. Measured fast ion fluxes in DIII-D and NSTX-U plasmas with different levels of AE activity will be used to determine the threshold for significant fast ion transport, assess mechanisms and models for such transport, and quantify the impact on beam power deposition and current drive. Measurements will be compared with theoretical predictions, including quantitative fluctuation data and fast ion density, in order to validate models and improve understanding of underlying mechanisms. Model predictions will guide the development of attractive operating regimes.

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

Description: The improved neutral beam injection (NBI) capabilities that are available on NSTX-U enable a more flexible tailoring of the fast ion distribution function resulting from NBI. This milestone will explore the use of different NBI sources and timing of NB injection schemes 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 is the early phase of the discharge (current ramp-up and early flat-top), during which strong fast ion-driven activity is destabilized as observed in most 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. The effect of sawteeth on the fast ion distribution function and NB current drive during the stationary phase of L-mode NSTX-U discharges will also be examined. 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. Once a suitable ramp-up scenario is identified, AE stability will be assessed for typical NSTX-U ramp-up scenarios. The analysis will include exploration of different NBI combinations 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.

R(19-2): Assess the effects of neutral beam injection parameters on the fast ion distribution function and neutral beam driven current profile

Description: 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 conventional aspect ratio tokamaks. 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. 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. 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 attainable NB parameter space by comparing NUBEAM/TRANSP predictions to measurements from Motional Stark Effect, complemented by the vertical/tangential FIDA systems and ssNPA 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. During FY2019, significant effort will be put toward fast-ion diagnostic re-commissioning and MSE commissioning for these experiments on NSTX-U. If NSTX-U cannot support plasma operations during FY2019, additional emphasis will be placed on collaboration on MAST-U and possibly DIII-D to support the beam characterization and driven current profile research goals of this milestone.