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The NSTX-U Research Program

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NSTX-U research will be critical for informing the design of a compact and potentially lower cost Fusion Pilot Plant (FPP) by exploring ST physics at reduced collisionality and high-beta to extend the understanding of enhanced confinement and stability properties found on NSTX, developing a unique, high-beta and high-shaping route to non-inductive operation for high-average power densities, and, in the longer-term, exploring liquid lithium PFCs for heat flux mitigation. In particular, NSTX-U will provide critical data at low aspect ratio ($A = 1.7$), strong boundary shaping ($\kappa > 2.5$, $\delta > 0.7$), low collisionality ($\nu_e^* < 0.01$), high bootstrap current fraction ($f_{BS} > 0.7$) and high normalized beta ($\beta_N > 5$) needed to quantify the optimum aspect ratio when designing next-step steady-state high-P_{fus} facilities. Furthermore, NSTX-U will operate in a parameter space that overlaps with that expected in ITER and other burning plasma experiments both at low and higher aspect ratio, enabling it to explore the non-linear, fast-ion (or α-) driven instabilities and their on-linear characteristics that are expected in such regimes, as well as enabling the development of techniques to mitigate deleterious effects.

NSTX-U [1] (Figure 1) consists of three new major components: (1) a new center-stack capable of doubling the toroidal field, tripling the solenoid flux, and increasing the flat-top duration up to a factor of 5, (2) a second more tangentially injected neutral beam to double the plasma heating and external current drive while also increasing the current drive efficiency and controllability, and (3) structural enhancements to withstand up to a factor of 4 increase in electromagnetic loads enabling a doubling of the plasma current.

The doubling of the toroidal field, plasma current, and NBI heating will allow NSTX-U to access 3-5 times lower collisionality ν^* at similar β and shaping (κ, δ) as NSTX.

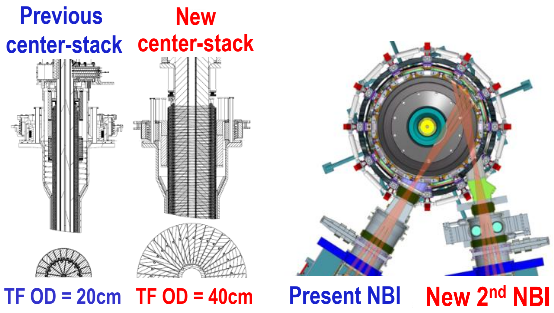

Fig. 1 (left) Comparison of preview vs new center stack of NST-U, (right) comparson of present and new 2nd NBI.

Dimensionless energy confinement times ($\Omega_{ci}\tau_E \sim B\tau_E$) in NSTX scaled almost inversely with electron collisionality (ν_e^*) and exhibited minimal degradation with β, in contrast to conventional-A devices [2]. This scaling projects NSTX-U will access collisionalities 3 - 6 times lower than achieved on NSTX, to where the energy confinement time is several times larger than what would be achieved with the ITER-basis scaling. Anomalous transport in the core of conventional-A devices is typically governed by electrostatic drive waves, but many features of low-A and high-β stabilize the electrostatic modes, leaving ion transport governed by neoclassical transport and electron transport due to electromagnetic microtearing modes and in some cases kinetic ballooning and electron temperature gradient modes [3].

Low-A configurations simultaneously access large f_{BS} ($\sim \varepsilon^{-1/2} (\beta_N/l_i)\, aB_0/I_p$) and large β ($= \beta_N(I_p/aB_0)$) by operating at low average q ($\sim aB_0/I_p$) and large β_N/l_i, i.e., broad pressure and current profiles. These characteristics, coupled with the potential for higher confinement and stability at lower collisionality in NSTX-U, will allow for characterizing the trade-off between B_T and β_T in the optimization of the aspect ratio for achieving a fully non-inductive, low disruptivity, and high f_{BS} regimes.

NSTX-U will address fast ion confinement in regimes that overlap those expected for fusion devices in terms of high fast ion β vs thermal β. The typical super-Alfvénic NB ions in NSTX-U result in a large, potentially non-linear, drive for instabilities, whose effects in terms of fast ion redistribution and loss must be understood to develop reliable and quantitative predictive capabilities for future burning plasma devices.

NSTX-U will operate with high heat loads, up to 8 MW/m^2 for up to 5 sec, thus making it ideal to study the mitigation of these heat loads on conventional plasma facing components and to develop plans for installing liquid lithium divertor components in a future upgrade of the device. NSTX-U will also be critical in validating XGC1 predictions of expanded midplane heat flux widths due to the destabilization of Trapped Electron Modes, similar to what is predicted for ITER.

References

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