NSTX-U Weekly Report (May 13, 2016)

FY 2016 NSTX plasma operations
Operation Targets: Total – 18 run weeks
Completed: 8.88 run weeks and 934 plasma shots

The paper "Quasi-linear gyrokinetic predictions of the Coriolis momentum pinch in National Spherical Torus Experiment" by W. Guttenfelder (PPPL) et al. was published in Physics of Plasmas, http://scitation.aip.org/content/aip/journal/pop/23/5/10.1063/1.4948791. Previous perturbative measurements in NSTX H-modes indicated the existence of an inward momentum pinch that was similar to analytic theory predictions based on conventional tokamaks. This paper shows that linear gyrokinetic simulations run for the NSTX discharges in fact predict a momentum pinch that is small or even outward, in contradiction to the experimental results and simpler analytic theory. The small predicted pinch is a consequence of both electromagnetic effects at relatively large beta and low aspect ratio minimizing the allowed symmetry-breaking of the instabilities necessary for a pinch. A stronger inward pinch is predicted either at increasing aspect ratio or in the electrostatic (low beta) limit, the latter of which motivates new NSTX-U experiments. (W. Guttenfelder)

The paper "Role of density gradient driven trapped electron mode turbulence in the H-mode inner core with electron heating," by D. Ernst (MIT), K.H. Burrell (General Atomics), W. Guttenfelder (PPPL), T. Rhodes (UCLA) et al. was published in Physics of Plasmas, http://scitation.aip.org/content/aip/journal/pop/23/5/10.1063/1.4948723. The paper is a culmination of a substantial multi-institutional collaboration following the DIII-D National Fusion Science Campaign experiments in 2013, and shows observations of reduced core density peaking and increased core turbulence measured by Doppler Backscattering (DBS) reflectometry with the application of ECH in DIII-D QH modes. The observations were used to validate transport and turbulence predictions from nonlinear gyrokinetic simulations, including a synthetic DBS diagnostic calculation, performed by NSTX-U collaborators. The predicted changes show quantitative agreement with the measurements and indicate the presence of density gradient driven trapped electron modes. The developed synthetic DBS diagnostic routine is planned to be used for future NSTX-U validation efforts. (W. Guttenfelder)

R. Lunsford (PPPL)presented the outreach talk "Skipping Rocks off the Sun : Taming fusion plasma eruptions through controlled microgranule injection" at the inaugural Princeton Research Day on May 5th. The talk was a portion of the "Designing the Future" session and introduced fusion research, challenges in the plasma material interface, and the utilization of granule injection to attempt to mitigate ELM peak heat fluxes through ELM pacing in current and future fusion devices. (R. Lunsford)

Luis F. Delgado-Aparicio (PPPL) visited the plasma laboratory at General Fusion (GF) in Vancouver, Canada. Luis met with the company officials and their scientists and engineers to discuss the GF's physics-approach to fusion as well as the design and construction of optical and soft x-ray (SXR) diagnostics. The implementation of optical filter scopes (e.g. using Li, C, O lines) will facilitate the characterization of gettering techniques as well as the time evolution of low-Z impurities during the plasma formation and compression phase; the latter lasts only tens of microseconds. The motivation for developing also a multi-energy SXR capability is based on the need for measuring electron temperature during the compression phase where the density is expected to increase by factors of 10^2-10^3. Two methods have been identified; the first, using pulse-height analysis (PHA) of data obtained from a silicon PIN diode or drift detector coupled to a charge sensitive pre-amplifier, and a second technique using a multi-energy SXR diagnostic with a at least two metallic filters, a fast and efficient scintillator and red-enhanced photomultiplier tubes with a dynamic gain settings. The plasma temperature diagnostics will be tested first in their plasma laboratory in Vancouver and compared with data from a convectional Thomson Scattering, to be implemented later in the "field" where the compression experiments will take place. (L.F. Delgado-Aparicio)

Run Coordination (J. Menard, S. Gerhardt)

Operations on Monday 5/9/2016 started with XMP-141 (Loop Voltage Proportional Error Field Correction), with the goal of seeing whether MHD activity in the current ramp could be reduced with additional pre-programmed error field correction. Approximately eight discharges were taken to develop a suitable 900 kA ohmic target, and then two loop-voltage-proportional compass scans at different amplitudes were conducted. The applied fields did have an impact on the plasma, and a slight asymmetry in the ramp-up performance was observed. Analysis is ongoing to determine whether these results should be incorporated into the standard NSTX-U feed-forward error field correction recipe.

When these scans were complete, a few shots were taken from XMP-142 (Reduced MHD H-mode Development). These shots had difficulty achieving reliably H-mode timing during the current ramp, and improving the reliability of H-mode access will be a feature of future development.

At the end of the day on 5/9/2016, the MSE-LIF TIV was opened to the vessel, and the gas+RF used for making a beam was fired during a clock cycle. In this first test, the NSTX-U vessel pressure rise was found to be minimal. Also, the LLNLEUV spectrometers at Bay E all collected initial data. Two of the instruments were found to need improved alignment.

The first shots of 5/10/2016 were dedicated to XMP-149 (MSE Diagnostic Neutral Beam Checkout). These showed that the DNB gas load on the torus did not impact the NSTX-U breakdown, and that the DNB did not have a significant impact on the plasma. It also confirmed that operation of the DNB plasma source was unaffected by the NSTX-U fields, and demonstrated injection of the DNB into the torus.

There was then a multiple hour break to troubleshoot some issues with the gas delivery system. This was followed by further shots towards XMP-142, where a pause in the plasma current ramp rate was found to be highly beneficial in achieving reliable H-mode timing.

The morning of 5/11/2016 was dedicated to XMP-142 (Reduced MHD H-mode Development). It was observed that a brief pause in the plasma current ramp that reduced the loop voltage below 1V was effective in improving the access to H-mode early in the current ramp. It was also important to divert before or during the pause, however shot-to-shot variations in the neutral beam heating evolution made the transition to a diverting timing difficult to control, especially when near double null. In response to this observation, a discharge under isoflux dnull control with Xpoint R and Z control starting at 135 ms (the time the xpoints enter the vessel) and diverting at about 240 ms was developed and worked well. It is hoped that this technique will be more resilient to minor changes in wall conditioning and NB timing than was the case when controlling the divertor coils in current feedback mode.

During the afternoon of Wednesday 5/11/2016, a second error field correction compass scan was conducted at higher density under XP-1506 (C. Myers, Low-beta error field correction). Several discharges were taken to stabilize the density at ~3e13 cm^{-3} in a 650 kA, 1 MW L-mode scenario. This density is ~2.5 times the original low density compass scan, which was conducted at ~1.2e13 cm^{-3}. Once the density stabilized, a new four shot compass scan was performed. First, this new compass scan confirmed the optimum feed-forward error field correction of 0.088 A/A PF5 and 15 degrees that was obtained from the original low density compass scan. Secondly, it showed a 10% higher absolute locking threshold than that of the low density compass scan. While it is expected that the locking threshold would go up with increasing density, the modest observed increase in the locking threshold indicates that rotation and other variables are contributing to the locking behavior. Finally, a few attempts were made to vary the density and raise the plasma current. These shots were subject to an n=2 rotating mode that impacted the plasma rotation and the locking behavior.

Shots on 5/12/2016 were dedicated to XMP-153 (H-mode access and control development in boronized wall conditions). One goal of this XMP is to develop a control strategy that achieves a consistent diverting and L-H transition timing over a range of neutral beam heating evolutions. Most of the development used 600 kA H-mode discharges that achieve poloidal beta above 1.5. The early X-point control strategy demonstrated improved resilience to shot-to-shot variations in NBI heating. However, the results also indicated that this effort would benefit from a new control scheme for the plasma shape when it is limited on the inner wall. In this scheme, the reference flux for the shape control points on the outer boundary of the plasma within the ISOFLUX double null algorithm is the minimum of the flux at each X-point and the inner wall. The afternoon transitioned to XMP-151 (L-mode development), where a higher density, 800 kA L-mode target was established on the first attempt. However, the discharge ended slightly early due to a locked mode, likely as a consequence of having no current in RWM coil 4. Investigating the problem with SPA #2, sun-unit #1 took the remainder of the day, and the problem was ultimately traced to a loose wire on a relay.

On 5/13/2016 the morning was dedicated to H-Mode development. The use of the algorithm in the PCS that allows the minimum of flux at the 2 Xpoints and the inner wall tangency to be used as the reference flux solved the issue of poor control in the double null algorithm when the plasma is in contact with the inner wall. That provided more reproducible plasma when in contact with the inner wall. The difficulty of making a clean transition from inner wall limited to double null with a significant inner gap remained. By the end of the scheduled period incremental progress led to plasmas with an inner gap for about 70 ms. This was achieved by a series of small changes to the requested plasma shape; this process will be continued on Monday. The afternoon again transitioned to XMP-151 (L-mode development) using the 800 kA L-mode target. Using source 1B for consistent shot startup, a transition to each of the six beam sources was successfully tested on a shot-by-shot basis, with excellent beam reliability at ~1 MW. Changes in rotation and MHD behavior were seen after the source transitions at 500 ms. However, the shots transitioned into H-mode for brief periods due to slightly lower densities caused by inaccurate HFS gas fuelling pressure readings. It has also been noted that all

L-mode fiducials run after the last maintenance period have one or more brief L-H transitions which were not evident in the fiducials run prior to the maintenance period.

Experimental Research Operations (S. Gerhardt, R. Kaita)

The reinstallation of the 16-channel UCLA reflectometer system at Bay-J has been completed. Final tasks were BNC data and power cable terminations and debugging of a digitizer connection. First plasma data was obtained and all 16 quadrature channels worked properly. Clear evidence of high frequency coherent mode activity (~1.8 MHz) was observed during neutral beam heating consistent with GAE activity. Some minor noise issues are currently being addressed as well as proper setting of gains. Neal Crocker (UCLA) visited NSTX-U this week working on this system as well as collaborating on data analysis and upcoming experiments. (T. Rhodes, UCLA)

The vacuum conditioning of high harmonic fast wave (HHFW) antennas is progressing with voltages reaching ~ 20 kV using rf sources 1 - 4. If these voltages hold during a plasma discharge we should be able to apply ~ 2 - 3 MW of the HHFW heating and current drive power to the plasma. We are stopping vacuum conditioning now to allow the new relays to be installed for sources 5 and 6 so that these sources can be conditioned as well in the near future. (J. Hosea, PPPL)

Ahmed Diallo (PPPL) visited Physical Science Laboratory in Madison (05/02 through 05/06) to continue tests for the integration of the custom power supplies to the laser head for the pulse burst laser system. During this week, the beam laser beam was injected into the amplifier where pulse energy in the range of 1.7 J was successfully measured. In addition, measurements of the beam characteristics in the far field were performed using Phantom camera on loan from NSTX-U. Initial tests at 30 Hz, 1kHz, and 10kHz were successful. The status of the pulse burst system and analysis of the beam characteristics will be presented at the High temperature plasma diagnostics in June 2016. We are now mapping out the operating parameters to finalize the characterization of the laser. Work is in progress to finalize the control software to be delivered to NSTX-U. (A. Diallo)

Engineering Operations (A. von Halle, P. Titus)

NSTX-U plasma operations continued this past week with experiments on H-mode access and control development utilizing ~ 6MW of NB injection, and L-mode discharges utilizing error field correction proportional to loop voltage and at higher plasma densities. We performed an initial MSE-LIF diagnostic experiment with Diagnostic Neutral Beam injection into an NSTX-U discharge. The new LLNL EUV spectrometers (XEUS, LOWEUS, Mona LISA) have now all taken data. A Pre-Job brief for the installation of the new IR Bolometer at Bay J has been held, and that installation is planned for the weekend. Conditioning of the neutral beam ion sources continues with all six sources operational at a total power level of over 9MW.

The NSTX-U Test cell will be in restricted access this coming week during plasma operations. Limited access is expected to be available for approved work on second shift.

Fatigue testing of the NSTX-U lead extensions was completed over the weekend. The most highly loaded lead extension was tested at the 1.0 Tesla load level and survived 400,000 cycles. Cyclic testing will be augmented with a Charpy impact test of the CuCrZr base material and e-beam welded joint material. The successful testing of the lead extension supports near term 0.8 T operation and supports the design, analysis and quality assurance programs for the upgraded lead extensions planned for installation in the Fall. Installation of fiberoptic strain gauges on the toroidal field coil outer legs is progressing and will provide measurements of the structural integrity of the new and original outer legs also to support 0.8 Tesla operation. (P. Titus)