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| **Princeton Plasma Physics Laboratory****NSTX-U Experimental Proposal** |
| Title:Validation of gyrokinetic codes in NSTX-U NBI-heated L-mode plasmas |
| **OP-XP-1521** | Revision: **0** | Effective Date:*(Approval date unless otherwise stipulated)*Expiration Date:*(2 yrs. unless otherwise stipulated)* |
| **PROPOSAL APPROVALS** |
| **Responsible Author:** Y. Ren, W. Guttenfelder, S.M. Kaye, S. Gerhardt, A. Diallo, S. Kubota, J. Lang, B.P. LeBlanc, R.E. Bell,V. Soukhanovskii, D.R. Smith, W. Wang, H. Yuh | Date |
| **SG, TSG or TF Leader (assigned by RC):** | Date |
| **Run Coordinator (RC):**  | Date |
| **Responsible Division: Experimental Research Operations** |
| **RESTRICTIONS or MINOR MODIFICATIONS** (Approved by Experimental Research Operations) |
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NSTX-U EXPERIMENTAL PROPOSAL

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| TITLE:Validation of gyrokinetic codes in NSTX-U NBI-heated L-mode plasmas | No. **OP-XP-1521** |
| AUTHORS:Y. Ren, W. Guttenfelder, S.M. Kaye, S. Gerhardt, A. Diallo, S. Kubota, J. Lang, B.P. LeBlanc, R.E. Bell,V. Soukhanovskii, D.R. Smith, W. Wang, H. Yuh | DATE: **06/08/2015** |

# 1. Overview of planned experiment

The planned experiment is to conduct a comprehensive validation study of gyrokinetic codes in NSTX-U NBI-heated L-mode plasmas. The plan is to exploit MHD-quiescent quasi-stationary NBI-heated L-mode plasmas. Toroidal field and plasma current scan will be carried out to change neoclassical/turbulent transport. In particular, if long-pulse MHD-quiescent quasi-stationary NBI-heated L-mode plasmas are achieved earlier in the run, this experiment could share shots with the perturbative particle transport experiment because of similar BT and Ip scans. The experimental measurements will be compared with GYRO, GTS and XGC-1 nonlinear simulations through TRANSP analysis and synthetic diagnostics. Cross-code comparison will also be carried out.

# 2. Theoretical/ empirical justification

Validation of first-principle gyrokinetic codes is important for our ultimate goal of achieving predictive capabilities for future devices. The validation should not only compare transport level between experiments and nonlinear gyrokinetic simulations, but also compare fluctuations through synthetic diagnostics. L-mode plasmas offer some favorable properties to facilitate this study: easier to obtain stationary profiles; easier to maintain MHD quiescence; no complications from edge transport barrier. The experiment will also allow us to assess L-mode transport shortfall seen in DIII-D L-mode plasmas (not yet seen in a set of NSTX L-mode plasmas) under different conditions, e.g. different q profile. Furthermore, this experiment will also provide a database for developing reduced transport models, e.g. TGLF, for NSTX-U parameter regimes.

# 3. Experimental run plan

This XP will follow Deyong Liu’s XP “FIDA and SSNPA checkout”, in which MHD quiescent NBI-heated L-mode scenario will be developed or a dedicated XMP for developing MHD quiescent NBI-heated L-mode scenario. Reference shot number is to be determined. If we could achieve long quasi-steady-state MHD quiescent L-mode (may need the dedicated XMP to develop it), perturbative particle transport experiment could be combined with this XP due to similar BT and Ip scan is planned (will discuss further later).

Stefan Gerhardt has explored possible equilibria for L-mode in NSTX-U for different BT and Ip combinations. The conclusion is that for BT of 0.65 T, the highest possible current is 0.7 MA to avoid disruption and the Ip/BT should not exceed 1.077 MA/T. Taking into account of this constraint, we consider two plans for planning BT and Ip scan. Plan A is to use the following BT and Ip combinations: (0.65 T, 0.7 MA), (0.65 T, 0.55 MA), (0.5 T, 0.55 MA) if the corresponding L-mode is successfully developed. If developing good L-mode for BT=0.5 T is unsuccessful, we will resort to plan B which includes higher BT scenarios: (0.75 T, 0.7 MA), (0.75, 0.55 MA), (0.65 T, 0.7 MA), (0.65 T, 0.55 MA). Note that BT of 0.75 T is likely to happen in later in the run campaign. If we ought to use plan B, then one part of this XP can be run early in the run campaign and the other with BT=0.75 T case will be run when the higher BT capability becomes available.

Ideally NBI source 1A at 90 kV will be used throughout the whole discharge for CHERS and MSE measurement. Other NBI source combinations will be used if mandated by the results from L-mode scenario development (from a possible dedicated XMP).

1. The first scan is the BT and IP scan
2. Plan A

[Bt (T), Ip (MA)]

(0.5, 0.55) **2 shots+1 contingency**

(0.65, 0.55) **2 shots+1 contingency**

 (0.65, 0.70) **2 shots+1 contingency**

The BT and Ip scan is summarized in the following table (arrow denotes the sequence):

|  |  |  |
| --- | --- | --- |
|  Bt (T) Ip (MA)  | 0.5 | 0.65 |
| 0.55 | **2+1** | **2+1** |
| 0.7 | Not accessible | **2+1** |

For plan A, the possible total number of shots for this scan will be 6 **shots + 3 contingency**.

(b) Plan B

[Bt (T), Ip (MA)]

(0.65, 0.55) **2 shots+1 contingency**

(0.65, 0.70) **2 shots+1 contingency**

 (0.75, 0.70) **2 shots+1 contingency**

 (0.75, 0.55) **2 shots+1 contingency**

The BT and Ip scan is summarized in the following table (arrow denotes the sequence):

|  |  |  |
| --- | --- | --- |
|  Bt (T) Ip (MA)  | 0.65 | 0.75 |
| 0.55 | **2+1** | 2+1 |
| 0.7 | **2+1** | **2+1** |

The possible total number of shots for this scan will be 8 **shots + 4 contingency**.

1. If long quasi-steady-state MHD quiescent L-mode is achieved (current flattop >2.5 s), then we can incorporate SGI density perturbation in shots in the BT and IP scan, i.e. first second of current flattop for the validation study and the SGI density perturbation induced for the rest 1.5 second. The 1.5 second duration is should allow us to have about 8 cycles in density perturbation, good enough for a decent Fourier analysis. SGI configuration is from an XMP optimizing SGI parameters.
2. Walter Guttenfelder’s perturbative momentum transport XP can also be run on the same day as this XP, if long quasi-steady-state MHD quiescent L-mode is achieved (current flattop ~2 s). The plan is to apply 2-3 short RMP pulses (~10-50 ms duration, every ~200 ms) that could be used for the perturbative momentum transport XP.

# 4. Required machine, NBI, RF, CHI and diagnostic capabilities

NBI 1A (90 kV) and NBI 1B (65 kV)

Profile diagnostics required for TRANSP analysis

All turbulence diagnostics

# 5. Planned analysis

LRDFIT, TRANSP, GTS, GYRO, GS2, XGC-1, TGLF

# 6. Planned publication of results

Physics of Plasmas, Nuclear Fusion etc.

# 7. Estimated Neutron Production

Based on the number of shots, plasma current levels, and expected durations, estimate the maximum neutron production of this experiment. See calculator in Appendix #2 for this calculation.

# of Shots used in Estimate:\_\_\_\_\_\_\_\_ Estimated Total Neutron Production:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

PHYSICS OPERATIONS REQUEST

|  |  |
| --- | --- |
| TITLE: | No. **OP-XP-** |
| AUTHORS: | DATE: |

 *(use additional sheets and attach waveform diagrams if necessary)*

|  |
| --- |
| **Brief description of the most important operational plasma conditions required and any special hardware requirement:** |
| **Previous shot(s) which can be repeated:** **Previous shot(s) which can be modified: 141716** |
| **Machine conditions** *(specify* ***ranges*** *as appropriate, strike out inapplicable cases)*BT Range (T):0.5-0.65/0.75 T Flattop Duration (s): IP Range (MA): **0.5-0.7 MA** Flattop Duration (s): **~ 1 s**Configuration: **center stack limited**Equilibrium Control: **Isoflux** (rtEFIT)Outer gap (m): **0.06** Inner gap (m): **0** Z position (m):  **0**Elongation:Triangularity (U/L):OSP radius (m):Gas Species: **D** Injector(s):**NBI** Species: **D** Heating Duration (s): **See XP plan for details** Voltage (kV) 50 cm (1C): 60 cm (1B):65 kV 70 cm (1A): 90 kV Voltage (kV) 110 cm (2C): 120 cm (2B): 130 cm (2A): **ICRF** Power (MW): Phase between straps (°): Duration (s):**CHI**: **Off / On** Bank capacitance (mF):**LITERs: Off / On** Total deposition rate (mg/min) or dose per discharge (mg):**EFC coils: Off/On**  |

DIAGNOSTIC CHECKLIST [1]

|  |  |
| --- | --- |
| TITLE: | No. **OP-XP-** |
| AUTHORS: | DATE: |

 *Note special diagnostic requirements in Sec. 4*

| **Diagnostic** | **Need** | **Want** |
| --- | --- | --- |
| Beam Emission Spectroscopy | **x** |  |
| Bolometer – midplane array | **x** |  |
| CHERS – poloidal |  | **x** |
| CHERS – toroidal | **x** |  |
| Divertor Bolometer (LADA) |  |  |
| Divertor visible cameras |  |  |
| Dust detector |  |  |
| Edge deposition monitors [2] |  |  |
| Edge neutral density diag. |  |  |
| Edge MIGs [2] |  |  |
| Penning Gauges [2] |  |  |
| Edge rotation diagnostic |  |  |
| Fast cameras – divertor [2] |  |  |
| Fast ion D\_alpha - poloidal |  |  |
| Fast ion D\_alpha - toroidal |  |  |
| Fast lost ion probes - IFLIP |  |  |
| Fast lost ion probes - SFLIP |  |  |
| Filterscopes [2] |  |  |
| FIReTIP | **x** |  |
| Gas puff imaging – divertor |  |  |
| Gas puff imaging – midplane |  | **x** |
| H cameras - 1D [2] | **x** |  |
| Infrared cameras [2] |  |  |
| Langmuir probes – divertor |  |  |
| Langmuir probes – RF |  |  |
| Langmuir probes – RF ant. |  |  |
| Magnetics – Diamagnetism |  |  |
| Magnetics – Halo currents |  |  |
| Magnetics – RWM sensors |  |  |

*Note special diagnostic requirements in Sec. 4*

|  |  |  |
| --- | --- | --- |
| **Diagnostic** | **Need** | **Want** |
| MAPP |  |  |
| Mirnov coils – high f. | **x** |  |
| Mirnov coils – toroidal array | **x** |  |
| MSE-CIF | **x** |  |
| MSE-LIF |  | **x** |
| Neutron detectors [2] | **x** |  |
| Plasma TV |  |  |
| Reflectometer – 65GHz |  |  |
| Reflectometer – correlation | **x** |  |
| Reflectometer – FM/CW |  |  |
| Reflectometer – fixed f |  | **x** |
| Reflectometer – SOL |  |  |
| SSNPA [2] |  |  |
| RF edge probes |  |  |
| Spectrometer – divertor |  |  |
| Spectrometer – MonaLisa |  |  |
| Spectrometer – VIPS |  |  |
| Spectrometer – LOWEUS |  |  |
| Spectrometer – XEUS |  |  |
| TAE Antenna |  |  |
| Thomson scattering | **x** |  |
| USXR – pol. Arrays |  |  |
| USXR – multi-energy |  |  |
| USXR – TG spectr. |  |  |
| Visible Brems. det. [2] | **x** |  |

Notes:

[1] Check marks in this table do not guarantee diagnostic availability. Check with diagnostic physicists or research operations management to ensure diagnostic coverage.

[2] In some cases, a given line represents multiple diagnostics. For instance, there are multiple SSNPAs, multiple IR cameras, multiple neutron detectors, and multiple Langmuir probe arrays.

**Appendix #1: Allowed Neutral Beam Power vs. Pulse Duration**

Heating of the primary energy ion dump limits the beam duration to that given in the following table[[1]](#footnote-1):



Table A1: Beam power and pulse length as a function of acceleration voltage

**Appendix #2: Table for neutron rate estimations:**



Table A2: Neutron Emission Rate Calculator. Double click to open in excel for automatic calculation. Change only the blue cells.

1. J.E. Menard, et al., Nuclear Fusion **52**, 2012 (83015) [↑](#footnote-ref-1)