Princeton Plasma Physics Laboratory

NSTX Machine Proposal

Title: **FIDA/ssNPA/sFLIP checkout**		
OP-XMP-	Revision**: 0**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

Proposal Approvals

Responsible author: **D. Liu et al.** Digitally signed by Deyong Liu DN: cn=Deyong Liu, o=UC Irvine, ou, email=deyongl@uci.edu, c=US Date: 2015.07.12 13:10:54 -04'00'	Date
ATI (NSTX Physics Ops): Dennis Mueller Digitally signed by Dennis Mueller Date: 2015.07.15 14:40:32 -04'00'	Date
RLM (NSTX Expt. Research Ops): Stefan Gerhardt Digitally signed by Stefan Gerhardt DN: cn=Stefan Gerhardt, o=Physics, ou=PPPL, email=sgerhard@pppl.gov, c=US Date: 2015.07.15 15:45:57 -04'00'	Date

Responsible Division: **Experimental Research Operations**

Procedure Requirements

designated by RLM

	NSTX Work Permit		T-MOD (OP-AD-03)
	Independent Review		ES&H Review

RESTRICTIONS AND MINOR MODIFICATIONS

Approved by RLM

REVIEWERS (designated by RLM)		
Organization/Position	Name	Signature
ATI	D. Mueller	Dennis Mueller Digitally signed by Dennis Mueller Date: 2015.07.15 14:41:45 -04'00'
Test Director		
Independent Reviewer		
NB system		
RF systems		
FCPC systems		
Diagnostics		

TRAINING (designated by RLM)

Training required: No ■ Yes ☐ Instructor ______________________

Personnel (group, job title or individual name)	Read Only	Instruction	Hands-On

RLM ________________________________

NSTX MACHINE PROPOSAL

TITLE: **FIDA/ssNPA/sFLIP checkout**	No. **OP-XMP-**
AUTHORS: **D. Liu, W. W. Heidbrink, D. S. Darrow et al.**	DATE:

1. Overview:

The FIDA and ssNPA systems, which include tangential-FIDA, vertical-FIDA, radial-ssNPA and tangential-ssNPA, are critical diagnostics to characterize the confinement of beam ions from the 2nd NBI line on NSTX-U. The main purpose of this XMP is to check and optimize the performance of these fast ion diagnostics, and assure they are ready to support the XP 1522 "Beam ion confinement of 2nd NBI line" experiment and whole group's research. To be more specific, the XMP has four major goals:

(i) Check the accuracy of two background subtraction approaches (beam modulation vs. passive views) for the FIDA systems

(ii) Compare the phase space response of vertical-FIDA and tangential-FIDA, radial-ssNPA and tangential-ssNPA. In principle, tangential-FIDA and tangential-ssNPA are more sensitive to passing particles, while vertical-FIDA and radial-ssNPA are more sensitive to trapped particles.

(iii) Optimize the angle of the filter of f-FIDA systems

(iv) Test s-FLIP diagnostic

and two secondary goals:

(i) Assess the FIDA spectral and intensity response for different neutral beam sources.

(ii) Obtain a few quiescent discharges (where fast ions are expected to behave classically and fast ion distriubton is well modelled) for TRANSP/ FIDAsim simulations.

The main approach is to inject neutral beams with many different modulation patterns and source mix in quiescent L mode plasmas, and check the FIDA/ssNPA background/passive signals and diagnostic response in phase space. The background signal check can be performed with neutral beam modulations. To verify the diagnostic response in phase space, it will require varying the fast-ion distribution, which in experiment can be achieved by injecting different neutral beam sources.

2. Justification:

Both FIDA and ssNPA diagnostics rely on the charge-exchange reactions between beam ions and neutrals from NBI. They are indirect measurements of fast ion distribution in a small portion of velocity space. Tests of these systems in a controlled scenario are required to gain confidence in the data interpretation, primarily for three reasons. First, tangential-FIDA and ssNPA systems are new/upgraded diagnostics. Also, experimentally the capability of inferring the background signal from the passive view/beam modulation is critical for the FIDA measurements. More importantly, the relation between the fast ion distribution function and the raw data is complicated; hence the diagnostic response in phase space must be assessed directly.

3. Plan:

Many different and unusual neutral beam modulation patterns will be used in this XMP. The run plan is divided into two parts based on the neutral beam energy. Part A requires NB source 1A (R_{tan}=70cm) operated at ~90kV and all the other sources at ~65kV. Part B needs NB source 1A (R_{tan}=70cm), 1C (R_{tan}=50cm), and 2A (R_{tan}=130cm) with E_{inj}~90kV and all the other sources at ~65kV. It is envisioned that this XMP will be ran in two half-days, the first half day focusing on Part A and the other half day for Part B. All the discharges for Part A and Part B will be similar to the "template" discharge as shown in Figure 1. The plasma conditions and neutral beam timing are given below.

Baseline conditions: NSTX-like plasma, B_t~0.65T, I_p~0.7MA, density 3-4x10^{13} cm^{-3}, deuterium gas, quiescent L mode, and reference discharge NSTX 128742 (exact conditions are not crucial). Based on Stefan Gerhardt's exploration of possible L-mode equilibria on NSTX-U, the highest possible current in L mode with B_t=0.65T is ~0.7MA to avoid disruption. If a higher plasma current quiescent L-mode scenario could be developed in the dedicated L-mode development XMP, we would run this XMP at the higher plasma current. In addition to the dedicated L-mode development XMP. Neutral beam source 1A at ~90kV will be used to pre-heat the plasma and slow down the evolution of the q profile. The plasma and neutral beams settings in the ramp-up will be optimized to avoid early low-frequency MHD. The target q_{min} is 2-2.5 around 0.2s. The current flat-top is expected to at least 0.5s, and it is assumed the flat-top starts at 0.2s and ends at 0.7s in this XMP.

Neutral beam timing: employ source 1A at 90kV during current ramp-up (60-200ms) and near the end (650-700ms) of flat-top to get good MSE and CHERS data, see Figure 1. The second pulse of 1A can be moved earlier if the current flat-top is not long enough.

There are various beam modulation patterns during the current flat-top, which is named as "NB modulation phase" in Figure 1. A detailed description of neutral beam source mix and modulation patterns during the "NB modulation phase" is given in Tables 1 and 2.

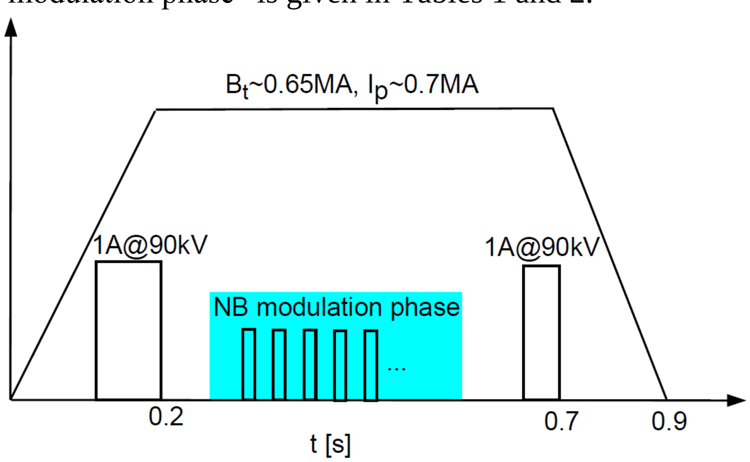


Figure 1: Template discharge. NB source 1A at 90kV is injected in the ramp-up phase and the end of flat-top to get good MSE and CHERS data. The second pulse of 1A can be moved earlier if necessary. During the "NB modulation phase" (blue shaded region), there are various neutral beam mix and modulation patterns.

Part A: NB source 1A at ~90kV, all the others at ~65kV [7+5 optional+3 development shots]

(1) Target plasma development. [1+3 development shots]

- Start with beam modulation pattern I in Table 1. It is critical to make the plasma go into a quiescent L mode scenario in this XMP. Two techniques can be used: (a) adjust inner gap to achieve a center stack limited configuration, (b) lower beam energy. Should the plasma go into H mode, consider the following options: (a) bias the plasma upward, (b) change elongation, (c) delay NB injection or change NB period, (d) use high-field side fueling, and/or (e) adjust plasma density. The target density is n_e~3-4x10^{13} cm^{-3} at t=0.2s. It is desirable to keep the density relatively low and get reproducible discharges.
- Optimize the settings in the ramp-up to avoid/minimize early low frequenc MHDs, e.g. modifying the current/q-profile evolution by adjusting NB timing, plasma current, and/or plasma density
- When the target quiescent L mode plasma is achieved, try one shot with beam modulation pattern II in Table 1. Check whether the added source 1C induce any low frequency MHDs.

(2) Characterization of FIDA/ssNPA background/passive signals with beam modulation [1 shot]

- Use the best shot in step I to check FIDA, r-SSNPA passive signals
- 1 shot with beam modulation pattern III in Table 1 to check t-ssNPA background signals

(3) Comparison of t-FIDA and v-FIDA response in phase space [2+2 optional shots]

- 1 shot +1 optional shot with beam modulation pattern IV in Table 1
- 1 shot +1 optional shot with beam modulation pattern V in Table 1

(4) Isolated beam blips for TRANSP/FIDAsim verification [1 +1 optional shot]

- 1 shot with beam modulation pattern VI
- 1 optional shot with beam modulation pattern VII, which also provides CHERS data.

(5) [optional] FIDA response for different neutral beam sources [2 optional shots]

- 1 optional shot with beam modulation pattern VIII in Table 1
- 1 optional shot with beam modulation pattern IX in Table 1

(6) sFLIP checkout [2 shots]

- 1 shot with beam modulation pattern X in Table 1 and plasma current to 0.7MA
- 1 shot with beam modulation pattern X in Table 1 and plasma current to 0.55MA

Part B: NB source 1A, 1C and 2A at ~90kV; all the others at ~65kV [11 shots w/ filter angle scan or 10 shots w/o filter angle scan]

One of the main tasks of this XMP is to optimize the filter angle of f-FIDA systems since the filter angle determines which portion of fast-ion spectrum will be collected by PMT. This task may be completed in piggyback if there are many (>7) repeat shots (or with >200ms repeat phase) with NBI in other XMPs, for example, in "Initial H-mode access on NSTX-U" XMP. Just in case the filter angle scan is not completed before this XMP, start with Step 1. Otherwise, start with start with Step 2 and all optional shots in Table 2 will be changed priority 1.

(1) Scan of the filter angle (0, 2, 4, 6, -2, -4, -6 degrees) of two f-FIDA systems [7 repeat shots?]

- Use the beam modulation pattern I in Table 2.

(2) Characterization of FIDA/ssNPA diagnostic response in phase space [2+4 optional shots]

- 1 shot +1 optional shot with beam modulation pattern II in Table 2
- 1 shot +1 optional shot with beam modulation pattern III in Table 2
- 1 optional shot with modulation pattern IV
- 1 optional shot with modulation pattern V

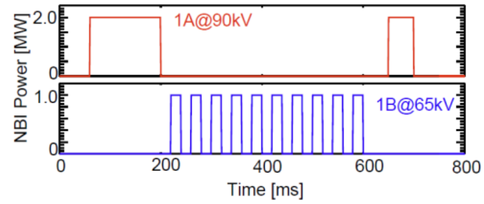
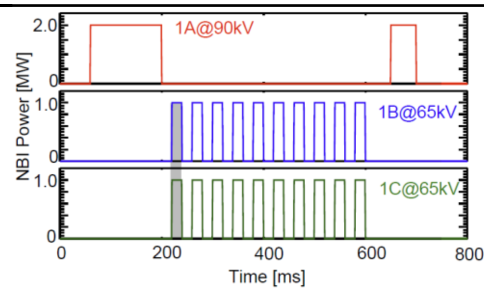
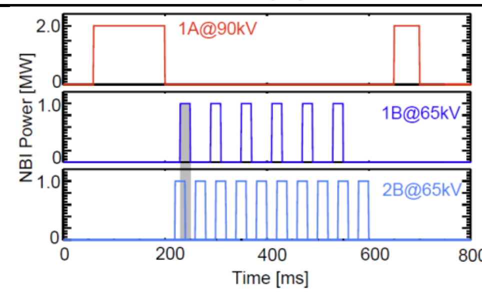
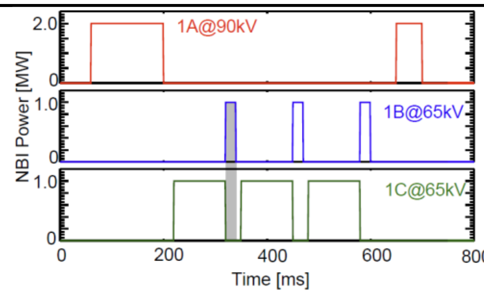
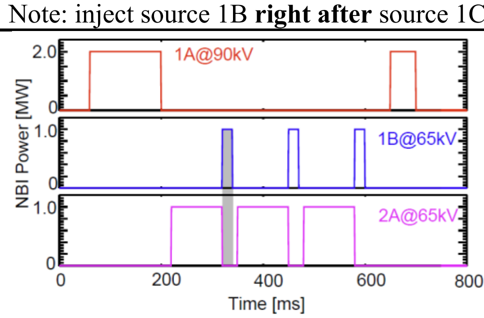
(3) Beam blips for FIDA/ssNPA background subtraction and TRANSP simulations [2 optional shots]

- 1 optional shot with modulation pattern VI
- 1 optional shot with modulation pattern VII

(4) sFLIP checkout [2 shots]

- one shot with beam modulation pattern VIII in Table 2 and plasma current to 0.7MA
- one shot with beam modulation pattern VIII in Table 2 and plasma current to 0.55MA

Table 1: neutral beam modulation patterns and source mix for Part A (7 good+5 optional shots+3 development shots)

Pattern #	Priority	NB Source	E_{inj} [keV]	Pulse Start Time [ms]	Duration [ms]	NBI modulation pattern and notes
I [~3 shots]	1	1B	65	220,260,300,340,380, 420,460,500,540,580	20	
II [1 shot]	1	1B	65	220,260,300,340,380, 420,460,500,540,580	20	
		1C	65	220,260,300,340,380, 420,460,500,540,580	20	
III [1 shot]	1	*1B (?)*	*65 (?)*	*230,290,350,410,470 (?)*	*20 (?)*	
		2B	65	220,260,300,340,380, 420,460,500,540,580	20	Notes: (1)If there are strong MHD in #II, then source 1B is not used (2)If source 1B is used, inject source 1B **10ms later** than source 2B
IV [1 shot +1 optional]	1	1B	65	320,450,580	20	
		1C	65	220,350,480	100	Note: inject source 1B **right after** source 1C
V [1 shot +1 optional]	1	1B	65	320,450,580	20	
		2A	65	220,350,480	100	Note: inject source 1B **right after** source 2A

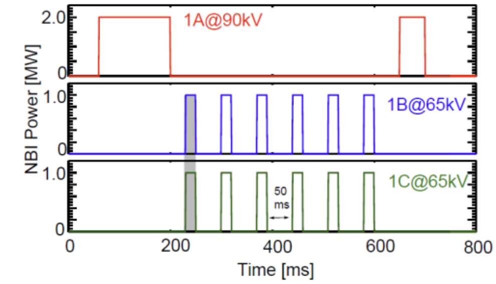
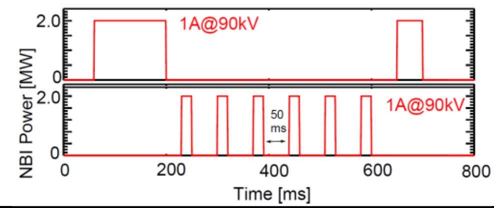
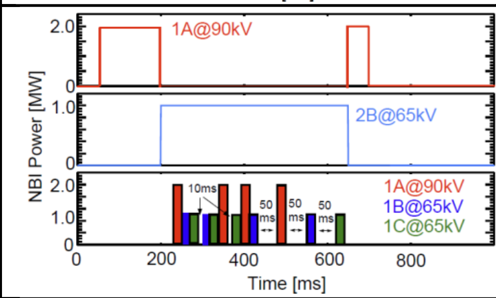
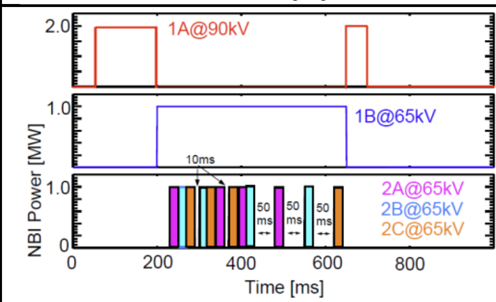
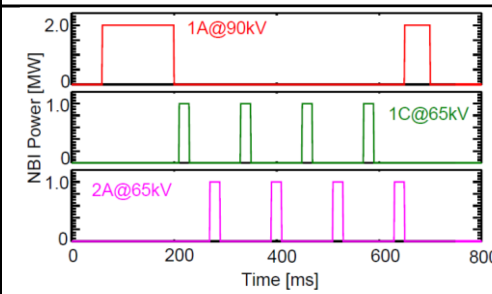
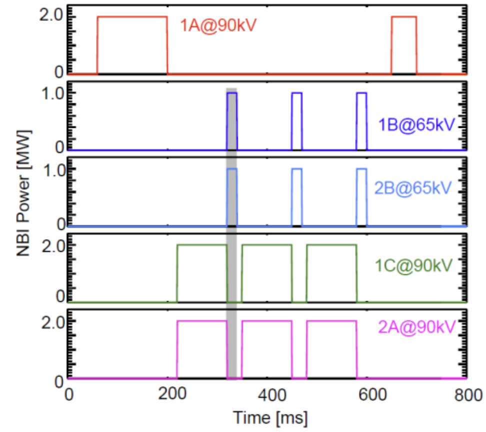
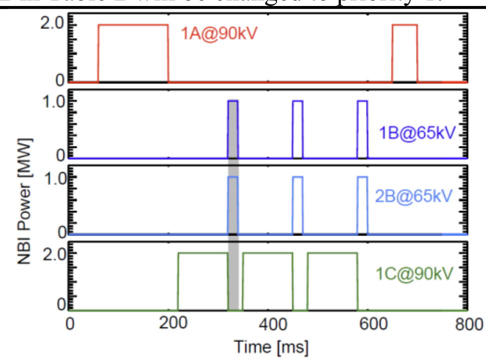
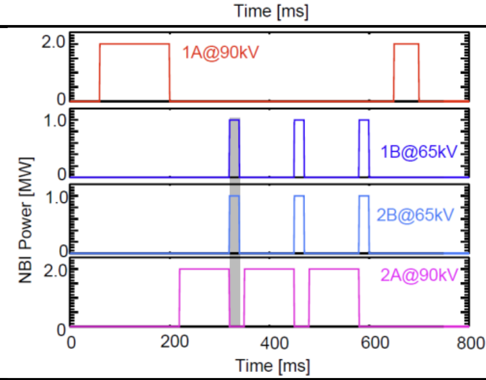
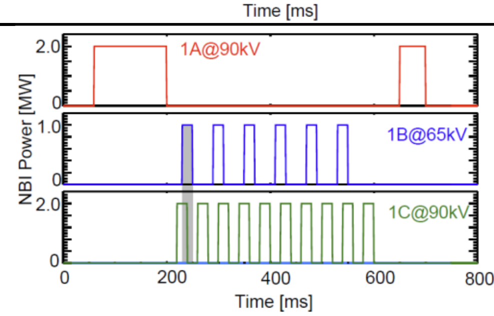
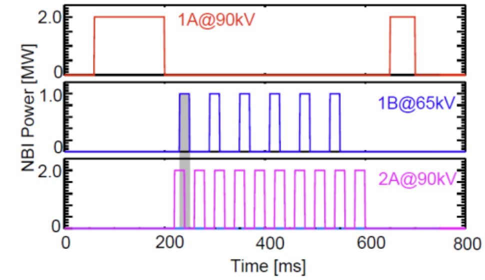
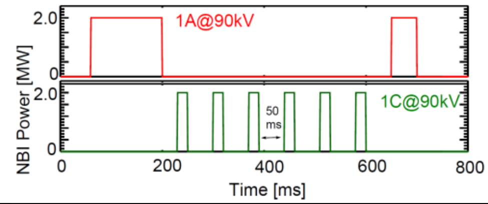
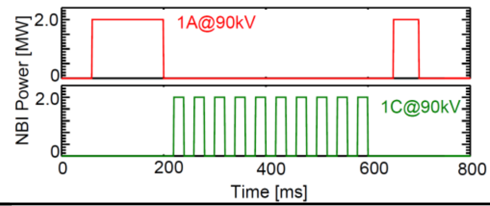
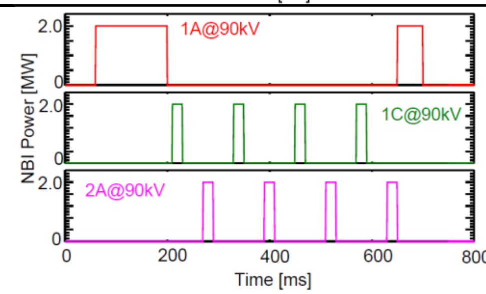
VI [1 shot]	1	1B	65	230,300,370,440,510	20	 Notes: (1)If there are strong MHD in pattern #II, then source 1C is not used
		1C (?)	*65 (?)*	*230,300,370,440,510*	*20*	
VII [1 optional]	2	1A	**90**	230,300,370,440,510	20	
VIII [1 optional]	3	2B	2B	200	450	
		1A	**90**	220,340,400,470	20	
		1B	65	240,300,420,540	20	
		1C	65	260,320,380,610	20	
IX [1 optional]	3	1B/ 1A	65	200	450	
		2A	65	220,340,400,490	20	
		2B	65	240,300,420,560	20	
		2C	65	260,320,380,630	20	
X [2 shots]	1	1C	65	210,330,450,570	20	 Note: 1 shot at I_p=0.7MA 1 shot at I_p=0.55MA
		2A	65	270,390,510,630	20	

Table 2: neutral beam modulation patterns and source mix for Part B

(11 shots w/ filter angle scan or 10 shots w/o filter angle scan)

Note: if the step 1 is skipped, then all shots in priority 2 will be changed to priority 1.

Pattern #	Priority	NB Source	E_{inj} [keV]	Pulse Start Time [ms]	Duration [ms]	NBI modulation pattern and notes
I [7 repeat shots]	1	1B	65	320,450,580	20	 Note: If the scan of f-FIDA filter is completed before this XMP, then the 7 shots in step I will be skipped and all the shots with priority 2 in Table 2 will be changed to priority 1.
		2B	65	320,450,580	20	
		1C	90	220,350,480	100	
		2A	90	220,350,480	100	
II [1 shot +1 optional]	1 (2 for optional shot)	1B	65	320,450,580	20	
		2B	65	320,450,580	20	
		1C	90	220,350,480	100	
III [1 shot +1 optional]	1 (2 for optional shot)	1B	65	320,450,580	20	
		2B	65	320,450,580	20	
		2A	90	220,350,480	100	
IV [1 optional]	2	1B	65	230,290,350,410,470	20	 Note: inject source 1B **10ms later** than source 1C
		1C	90	220,260,300,340,380,420,460,500,540,580	20	

<table>
<tr><td rowspan="2">V
[1
optional]</td><td rowspan="2">2</td><td>1B</td><td>65</td><td>230,290,350,410,470</td><td>40</td><td rowspan="2">
Note: inject source 1B **10ms later** than source 1C</td></tr>
<tr><td>2A</td><td>90</td><td>220,260,300,340,380,
420,460,500,540,580</td><td>20</td></tr>
<tr><td>VI
[1
optional]</td><td>2</td><td>1C
or
2A</td><td>90</td><td>230,300,370,440,510</td><td>20</td><td></td></tr>
<tr><td>VII
[1
optional]</td><td>3</td><td>1C
or
2A</td><td>90</td><td>220,260,300,340,380,
420,460,500,540,580</td><td>20</td><td></td></tr>
<tr><td rowspan="2">VIII
[2 shots]</td><td rowspan="2">1</td><td>1C</td><td>90</td><td>210,330,450,570</td><td>20</td><td rowspan="2">
Note: 1 shot at I_p=0.7MA
1 shot at I_p=0.55MA</td></tr>
<tr><td>2A</td><td>90</td><td>270,390,510,630</td><td>20</td></tr>
</table>

4. Required machine, beam, ICRF and diagnostic capabilities:

The XMP requires reproducible L mode plasmas with flat-top >0.5s at B_t=0.65T, I_p=0.7MA. Need 1A/1C/2A operational at ~90kV (or highest available/reliable), 1B/1C/2A/2B/2C operational at ~65kV. Five or four (four is the minimum requirement) neutral beam sources are OK, but source 1A must be included. Require Mirnov coils, plasma profile diagnostics (MPTS, CHERS, MSE) and fast ion diagnostics (FIDA, ssNPA, sFLIP, neutron). The machine needs to be relatively clean to avoid impurity contamination on FIDA spectra.

The optimal timing for running this XMP is at least a week later than the CHERS checkout XMP, at least two weeks earlier than the XP1522 “Beam ion confinement from 2^{nd} NBI line” so that initial analysis can be done to help optimize the FIDA and ssNPA diagnostics. Neither RF nor CHI is needed.

5. Sign off at run time:

5.1 Permission to Proceed: ______________________________

Physics Operations Head

5.2 Documentation of results:

Documentation of the results completed, attached to proposal and sent to Ops. Center with copies to Cognizant Physicist and Head of Physics Operations.

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Cognizant Physicist/Test Director