Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Controlling density rise through helium conditioning

OP-XP-	**Revision:**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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ATI – ET Group Leader:	Date
RLM - Run Coordinator: S. M. Kaye	Date

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

Controlling density rise through helium conditioning **No.: _____**

1. Overview of planned experiment

Describe the scientific goals of the experiment.

One run day:

Goal 1: Assess role of divertor temperature in density rise by scanning strike point

Goal 2: Reduce density rise by depleting D in divertor with He conditioning with NBI.

Goal 3: (time permitting) Compare conditioned LSN to unconditioned USN discharges.

2. Theoretical/ empirical justification Brief justification of activity including supporting calculations as appropriate

Wall conditioning is key to high performance. In NSTX the density typically continues to rise throughout the discharge. Extending the duration of high β, high τ_E discharges will require density control to avoid beta limits. The IPPA 5 year goal (for end FY 2005) includes "Determine the ability for managing intense energy and particle fluxes in the edge geometry and for increasing pulse durations…"

On TFTR, helium ohmic discharges were used to deplete the walls of deuterium and were key to achieving 'supershots'. These discharges appeared to be more effective than He GDC on TFTR but there was no systematic comparison. On DIII-D, Rensink modelled the density rise in H-mode discharges and found that the observed density rise during the quiescent period following the L-H transition was due both to the longer particle confinement time and a increased fueling rate due to the increased transparency of a thinner SOL. [Phys Fluids B5 (1993) 2165].

On NSTX CY2000 IWL He discharges improved wall conditions (Efthimion OP-XP-13, Maingi APS 2000 poster). After boronization, ohmic helium plasmas showed less CIII emission than deuterium plasmas and reached 1.2 n_{eGW} [Kaye, Phys Plasmas 8 (2001) 1980.] At present 7-10 minutes of He GDC is performed between shots to deplete the walls of deuterium and aid density control. We note that D ions impact the divertor target plate at higher energies during an attached plasma discharge than during GDC and access regions untouched by the GDC.

The divertor target plate temperature increases to 300 C in 0.2 s with 2 MW NBI (Maingi) and this temperature rise will increase with pulse length and NB power. At higher temperatures, the decrease in the saturated atomic ratio of H/C will cause hydrogenic release and influx to the plasma. The temperature rise also increases the chemical sputtering yield, generating CH_4 and other hydrocarbons. CH_4 generation can be detected spectroscopically with a VIPS2 fiber aimed at the divertor. [Pospieszczyk JNM 241-243 (1997) 834 cites CD band @ 430.7 nm (±0.75nm), C_2 @ 515.75nm (±0.75), CI @ 247.8nm, CII @ 514.5 nm, CIII @ 464.7 nm]. Chemical sputtering is expected to be important in (future) detached plasmas. On the other hand, a boron layer will reduce chemical sputtering above 600 K [Vietkze & Haasz]. A recent study (Soukhanovskii, PSI-15) showed a divertor ion flux more than an order of magnitude higher than that at the midplane. However Rensink modeling of DIII-D showed only 3-11% of divertor neutrals fueled the core plasma. Soukhanovskii [PSI-15]

estimates 1.3 torr-l/s fueling per MW of NBI; LFS gas injection up to 170 torr-l/s; HFS gas injection up to 50 torr-l/s and dNi/dt of up to 30 torr-l/s

This XP aims to identify the influence of divertor tile temperature and D content on the density rise, and attempts to reducing the density rise by strike point jogs and conditioning divertor with helium discharges. It includes long pulse fiducial discharges and USN, LSN comparisons so the effects are clearly apparent. One difference to TFTR is the onset of locked modes at low densities. Menard [IAEA 2002] finds a lower density limit of 1.8e19 m^{-3} at t=290 ms in deuterium discharges.

3. Experimental run plan

Describe experiment in detail, including decision points and processes

PART I Identify effect of temp rise through strike point jogs/sweeping in deuterium.

1. Fiducial: High performance long pulse shot e.g. 108741 LSN, H-mode in D @ 5 kG, similar to 109063 record 0.8 MA, 1 s, 0.7 s flattop 4.8 MW NBI H-mode in D, but with lower voltage beams and longer flattop. Run with all beams @ 80 kV to improve reliability. 1-2 shots. Diagnostics to include VIPS2 looking for CD molecular bands at 431 nm, IR divertor camera viewing divertor, realtime EFIT….
2. Repeat with strike point jog (change triangularity). 2-3 shots. Look for reduced density rise, decrease in CD emission, lower divertor temperature…. Typical 'natural' sweep rate is 12 cm in 300 ms, - quite slow. Look for CD4 band with VIPS2.

Dicussion points:

- *Rajesh suggests changing X point height and private flux region screening.*
- *80kV beams will likely reduce bootstrap current shortening pulse length ?*
- *Use HFS D puff to establish H-mode.*
- *Should we just jog strike point or sweep it ? Dennis suggests jogs easier than sweeps.*
- *Size of high heat flux footprint 5 – 10 cm - IR response time 20 ms e-folding, 33 ms framing rate. Difficult to see rapid changes*

3. Repeat fiducial to ensure there were no secular changes. 1-2 shots

PART II He conditioning: Deplete D trapped in lower divertor tiles. Compare USN performance to LSN. No active strike point sweeping.

4. 2 hours of long pulse fiducial (like 108741) but in He, e.g. LSN 800 kA. 5 kG, monitor Ha, CII, find lower limit of He plenum pressure without locked modes. 4-6 shots to setup. Monitor ratio of Da to CII and He 4686Å emission. [NBI fuels D @ 1.3 torr-l/s/MW cf 170 torr-l/s x 5-20% from gas feed, but will increase energy and flux on divertor plate.]

- *He H-modes would be advantageous as duration longer, but need controlled access to switch HFS gas feed + development time*

5. Repeat D fiducial to see any effect on density rise.

- *How to set D gas feed parameters ?*

6. If Ha/CII still going down, continue as time permits.
7. If time allows, perform similar USN discharge and compare unconditioned divertor to He conditioned one. to see if density rise is less on D depleted upper divertor.

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

Describe any prerequisite conditions, development, XPs or XMPs needed.
Attach completed Physics Operations Request and Diagnostic Checklist

- Prerequisites:
  Recent boronization,
  NBI available,
  IRTV available.
  VIPS2 set to look for CD4 band emission on lower divertor.
  Filterscopes set to monitor Da/CII and Da / HeII 4686.

5. Planned analysis

What analysis of the data will be required: EFIT, TRANSP, etc.

- Model discharges with UEDGE to challenge / benchmark model.
- Assess contribution of CH_4 to density rise.

6. Planned publication of results.

What will be the final disposition of the results; where will results be published and when?

- Follow up using He conditioning to routinely improve performance.
  With more data possible journal article in Physics of Plasmas.

PHYSICS OPERATIONS REQUEST

Controlling density rise through helium conditioning **No.: _____**

Machine conditions (specify ranges as appropriate) **D Fiducial**

I_{TF} (kA): **-58** Flattop start/stop (s): **0 / 0.9**

I_P (MA): **800** Flattop start/stop (s): **0.2 / 0.8**

Configuration: **LSN**

Outer gap (m): **0.11**, Inner gap (m): **0.1**

Elongation κ: **2**, Triangularity δ: **0.5**

Z position (m): **0**

Gas Species: **D**, Injector: **Midplane / Inner wall / Lower Dome**

NBI - Species: **D**, Sources: **A, B**, Voltage (kV): **80**, Duration (s): **0.6**

ICRF – Power (MW): **0**, Phasing: **na**, Duration (s): **0**

CHI: **Off**

Either: List previous shot numbers for setup: **108741**
Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values

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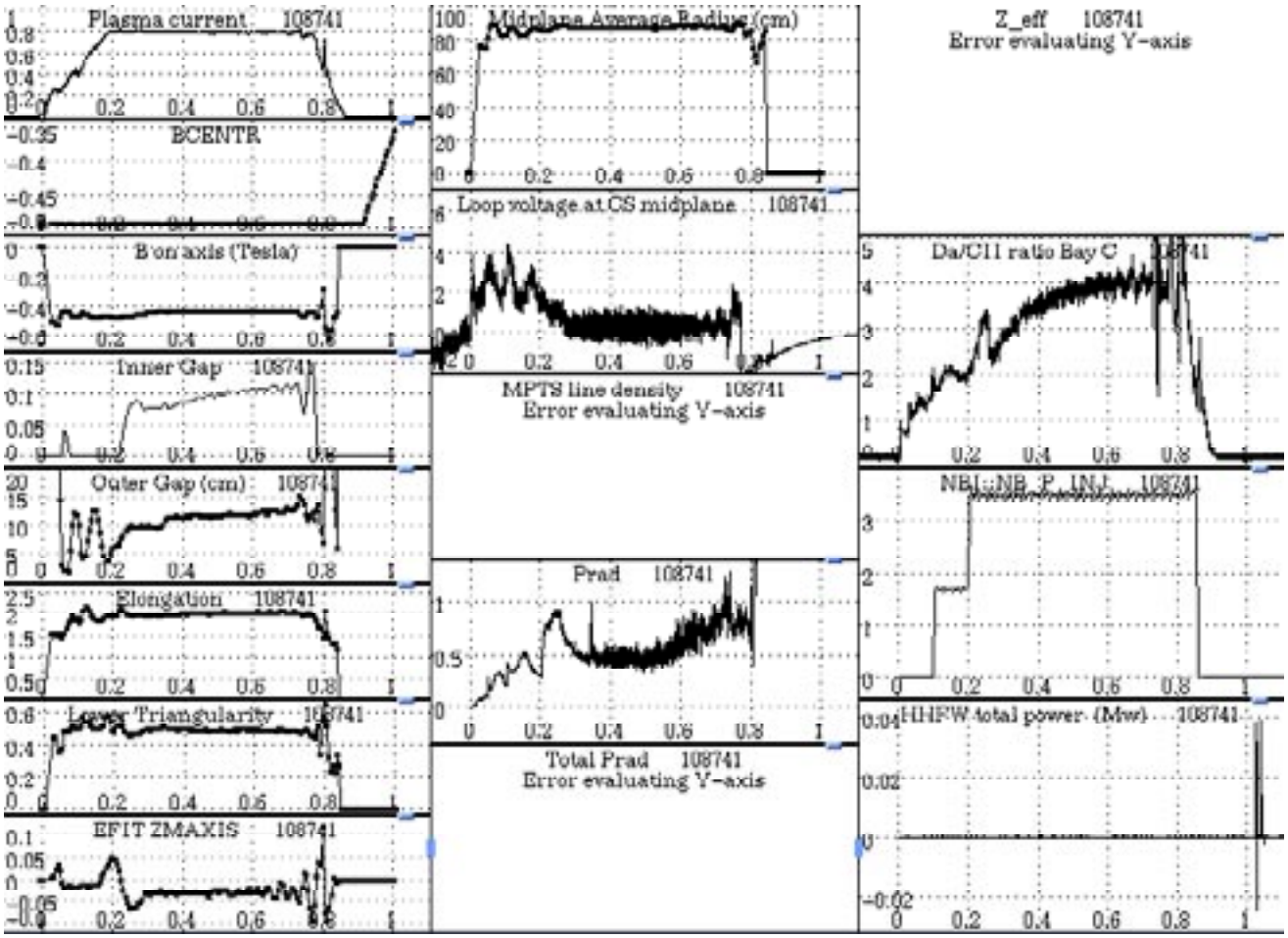

Plasma current 108741
BCENTR
B on axis (Tesla)
Inner Gap 108741
Outer Gap (cm) 108741
Elongation 108741
Lower Triangularity 108741
EFIT ZMAXIS 108741
Midplane Average Radius (cm)
Loop voltage at CS midplane 108741
MPTS line density 108741
Error evaluating Y-axis
Prad 108741
Total Prad 108741
Error evaluating Y-axis
Z_eff 108741
Error evaluating Y-axis
Da/C11 ratio Bay C
NBI::NB_P_INJ 108741
HHFW total power (Mw) 108741

Machine conditions (specify ranges as appropriate) **D Strike point sweep.**

I_{TF} (kA): **-58** Flattop start/stop (s): **0 / 0.9**

I_P (MA): **800** Flattop start/stop (s): **0.2 / 0.8**

Configuration: **LSN**

Outer gap (m): **0.11**, Inner gap (m): **0.1**

Elongation κ: **2**, Triangularity δ: **0.5** ***SWEEP TBD***

Z position (m): **0**

Gas Species: **D**, Injector: **Midplane / Inner wall / Lower Dome**

NBI - Species: **D**, Sources: **A, B**, Voltage (kV): **80**, Duration (s): **0.6**

ICRF – Power (MW): **0**, Phasing: **na**, Duration (s): **0**

CHI: **Off**

Either: List previous shot numbers for setup: **108741**
Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values

Machine conditions (specify ranges as appropriate) **He Conditioning**

I_{TF} (kA): **-58** Flattop start/stop (s): **0 / 0.9**

I_P (MA): **800** Flattop start/stop (s): **0.2 / 0.8**

Configuration: **LSN**

Outer gap (m): **0.11**, Inner gap (m): **0.1**

Elongation κ: **2**, Triangularity δ: **0.5**

Z position (m): **0**

Gas Species: **He,** 20% more than D, Injector: **Midplane / Inner wall / Lower Dome**

NBI - Species: **D**, Sources: **A, B**, **C** Voltage (kV): **80**, Duration (s): **0.6**

ICRF – Power (MW): **0**, Phasing: **na**, Duration (s): **0**

CHI: **Off**

Either: List previous shot numbers for setup: **108741**
Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values

Machine conditions (specify ranges as appropriate) **USN comparison**

I_{TF} (kA): **-58** Flattop start/stop (s): **0 / 0.9**

I_P (MA): **800** Flattop start/stop (s): **0.2 / 0.8**

Configuration: **USN**

Outer gap (m): **0.11**, Inner gap (m): **0.1**

Elongation κ: **2**, Triangularity δ: **0.5**

Z position (m): **0**

Gas Species: **D**, Injector: **Midplane / Inner wall / Lower Dome**

NBI - Species: **D**, Sources: **A, B**, Voltage (kV): **80**, Duration (s): **0.6**

ICRF – Power (MW): **0**, Phasing: **na**, Duration (s): **0**

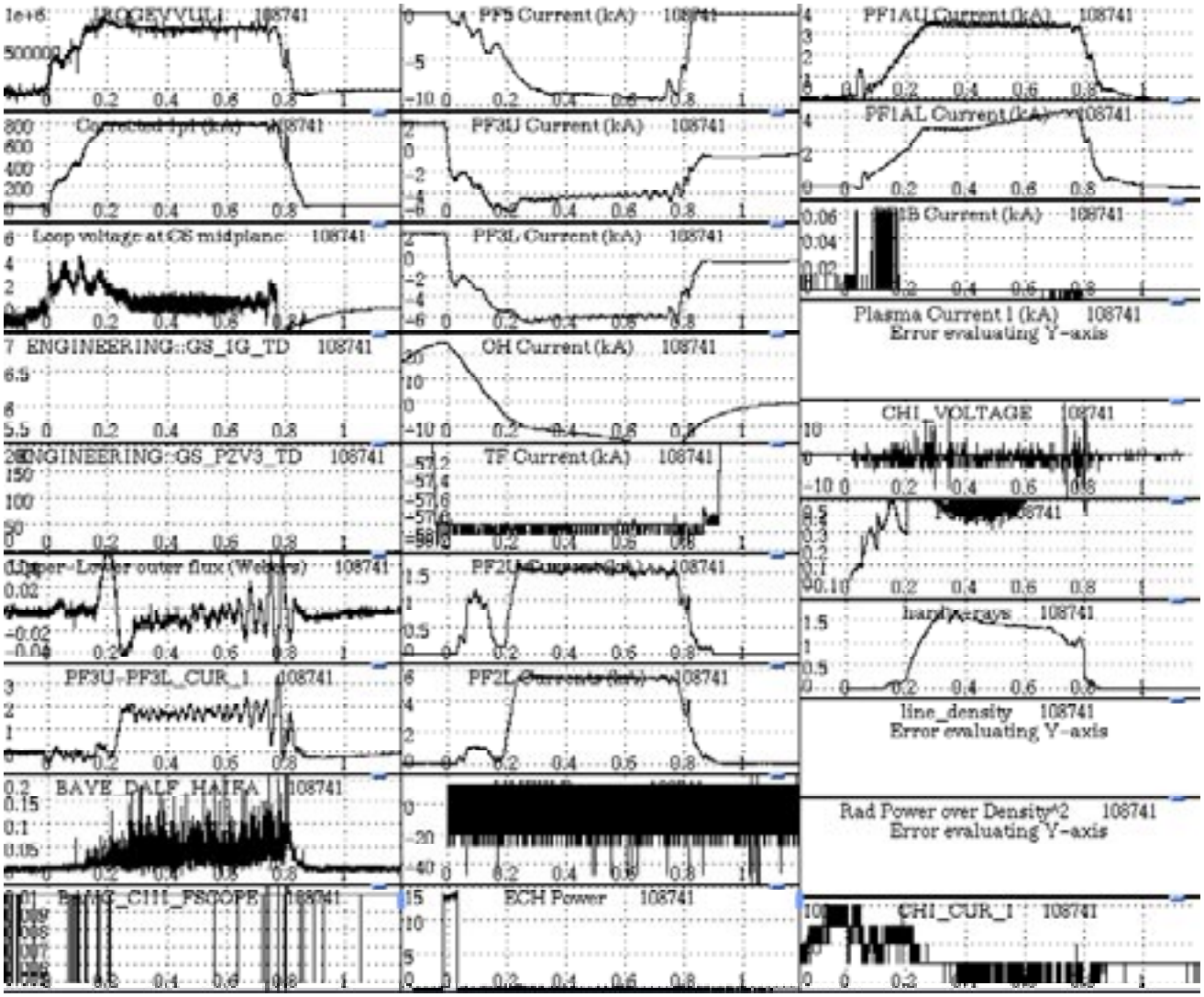
CHI: **Off**

Either: List previous shot numbers for setup: **108741**
Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values

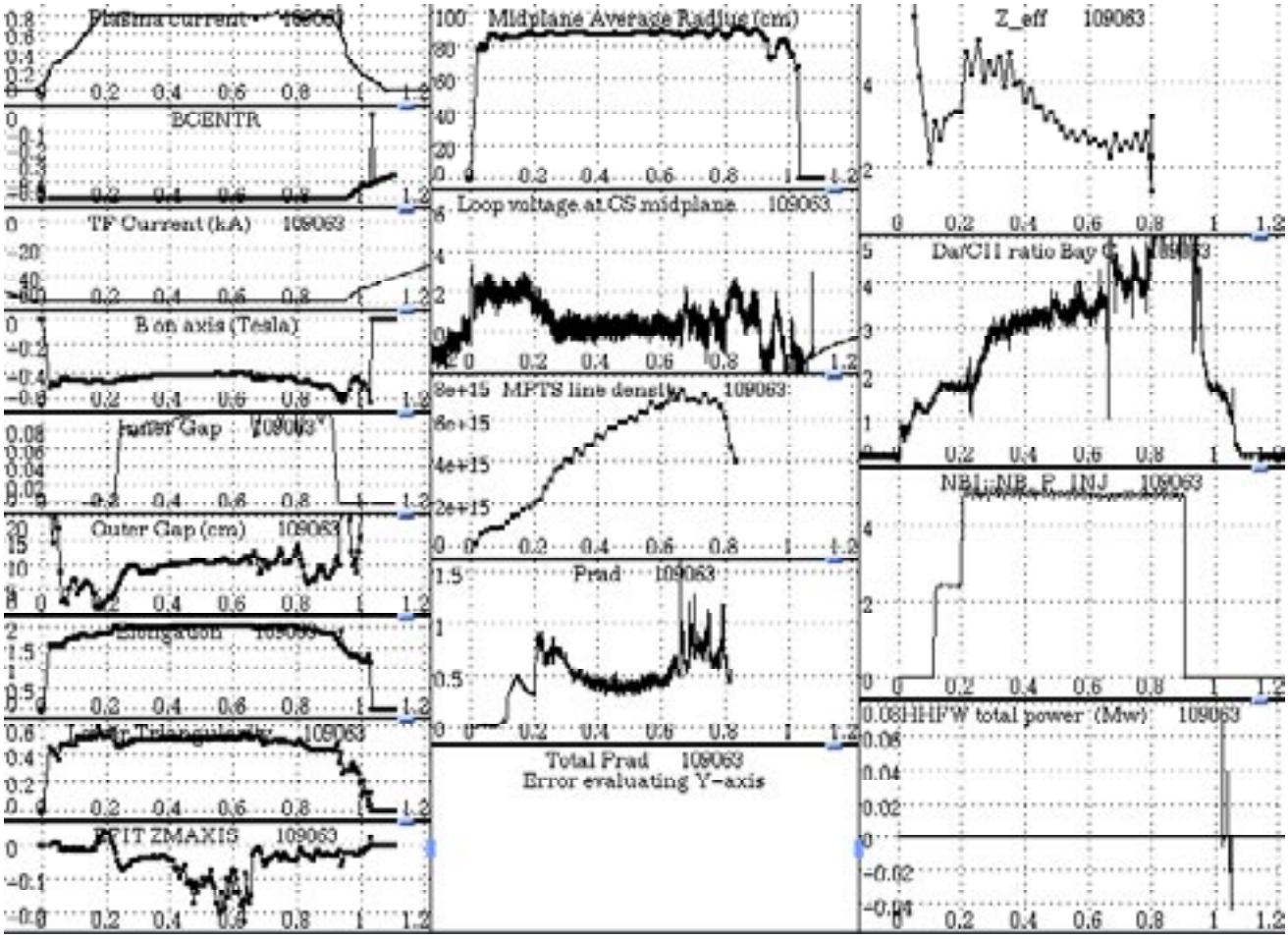
DIAGNOSTIC CHECKLIST

Title: _____ **No.** _____

Diagnostic system	**Need**	**Desire**	**Requirements** (timing, view, etc.)
Magnetics	✓		
Fast visible camera			
VIPS-1			
VIPS-2	√		
SPRED		√	
GRITS			
Visible filterscopes		√	
VB detector		√	
Midplane bolometer			
Diamagnetic flux			
Density interferometer (1mm)		√	
FIReTIP interf'r/polarimeter		√	
Thomson scattering		√	
CHERS			
NPA			
X-ray crystal spectrometer			
X-ray PHA			
EBW radiometer			
Mirnov arrays			
Locked-mode detectors	√		
USXR arrays			
2-D x-ray detector (GEM)			
X-ray tangential camera			
Reflectometer (4 ch.)			
Neutron detectors			
Neutron fluctuations			
Fast ion loss probe			
Reciprocating edge probe		√	
Tile Langmuir probes		√	
Edge fluctuation imaging			
H-alpha cameras (1-D)		√	
Divertor camera (2-D)		√	
Divertor bolometer (4 ch.)		√	
IR cameras (2)	√		View lower divertor
Tile thermocouples	√		
SOL reflectometer			



PF5 Current (kA) 108741
PF1AU Current (kA) 108741
Corrected 1pl (kA) 108741
PF3U Current (kA) 108741
PF1AL Current (kA) 108741
Loop voltage at CS midplane 108741
PF3L Current (kA) 108741
Plasma Current I (kA) 108741
Error evaluating Y-axis
ENGINEERING::GS_1G_TD 108741
OH Current (kA) 108741
CHI_VOLTAGE 108741
ENGINEERING::GS_PZV3_TD 108741
TF Current (kA) 108741
Upper-Lower outer flux (Webers) 108741
PF2U Currents (kA) 108741
hardx-rays 108741
PF3U-PF3L_CUR_1 108741
PF2L Currents (kA) 108741
line_density 108741
Error evaluating Y-axis
BAYE_DALF_HAIFA 108741
Rad Power over Density^2 108741
Error evaluating Y-axis
ECH Power 108741
CHI_CUR_1 108741


Plasma current 109063
BCENTR
TF Current (kA) 109063
B on axis (Tesla)
Inner Gap 109063
Outer Gap (cm) 109063
Elongation 109063
Lower Triangularity 109063
PFIT ZMAXIS 109063
Midplane Average Radius (cm)
Loop voltage at CS midplane 109063
MPTS line density 109063
Prad 109063
Total Prad 109063
Error evaluating Y-axis
Z_eff 109063
Da/CII ratio Bay G
NBI: NB_P_INJ 109063
HHFW total power (Mw) 109063