NSTX Experimental Research Operations

NSTX Research Forum

January 31 - February 2, 2000

Presented by Joel Hosea

NSTX Experimental Start-up Operations Achieved Excellent Results

- Plasma development and control used successfully to establish good operations in center stack limited, single null diverted and double null diverted regimes
- Conditioning - especially GDC and bakeout - resulted in considerable reduction of recycling and improvement of density control
- CHI was used to produce a start-up plasma with a current of 130 kA
- HHFW was used successfully to deliver 2 MW of RF power to the NSTX plasma
- Many diagnostics were commissioned to permit detailed physics studies to begin

Operations Groups Have Worked Very Well Together to Implement Operations for Ohmic, CHI and HHFW Plasmas

- Physics and CHI Operations - D. Mueller
  - Plasma Development and Control

Plasma operations:	Machine operations:
D. Mueller	C. Neumeyer
R.Bell	R.Hatcher
D. Gates	W. Blanchard
J. Menard	G. Pearson

  - EFIT/Magnetics/Control

S. Sabbagh Columbia U.	F. Paoletti Columbia U.
J. Menard	R. Kaita
D. Gates	R. Marsala
M. Schaffer	S. Kaye
H. Kugel	

- Preionization

Filaments:	ECPI:
H. Kugel	T. Bigelow ORNL
	J. R. Wilson
	E. Fredd

- CHI

R. Raman	U. of Washington	D. Mueller
Brian Nelson	U. of Washington	R. Ramakrishnan
T. Jarboe	U. of Washington	

- Boundary Physics Operations - H. Kugel
  - Wall Conditioning and Edge Physics

H. Kugel	R. Mangi ORNL
R. Marqueda LANL	Bakeout Engineer
C. Skinner	S. Zweben
J. Wilgen	

- RF Physics Operations - J. R. Wilson
  - HHFW

J. R. Wilson	D. Swain ORNL
P. Ryan ORNL	R. Pinsker GA
S. Bernabei	R. Ellis
E. Fredd	C. Brunkhorst
N. Greenough	

  - ECPI (noted under preionization above)

  - EBW Development

P. Efthimion	G. Taylor
T. Bigelow ORNL	

- Diagnostic Development and Operations - D. Johnson and R. Kaita
  - Diagnostic Physicists

M. Bitter	P. Efthimion	E. Fredrickson
K. Hill	M. Iovea JHU	S. Kubota UCLA
H. Kugel	R. Maingi ORNL	R. Maqueda LANL
E. Mazzucato	J. Menard	S. Paul
A. Ramsey	C. Skinner	B. Stratton
D. Stutman JHU	G. Taylor	J. Wilgen ORNL
S. Zweben		

  - Diagnostic Engineers

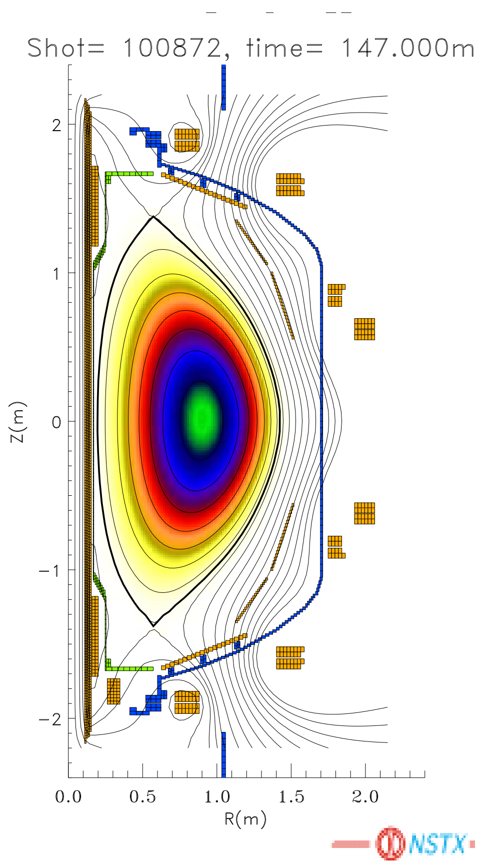
R. Ellis	R. Hatcher	D. Loesser
D. Long	B. McCormack	R. Parsells
L. Roquemore	X. Nguyen UCLA	

PRESENT PLASMA CONTROL

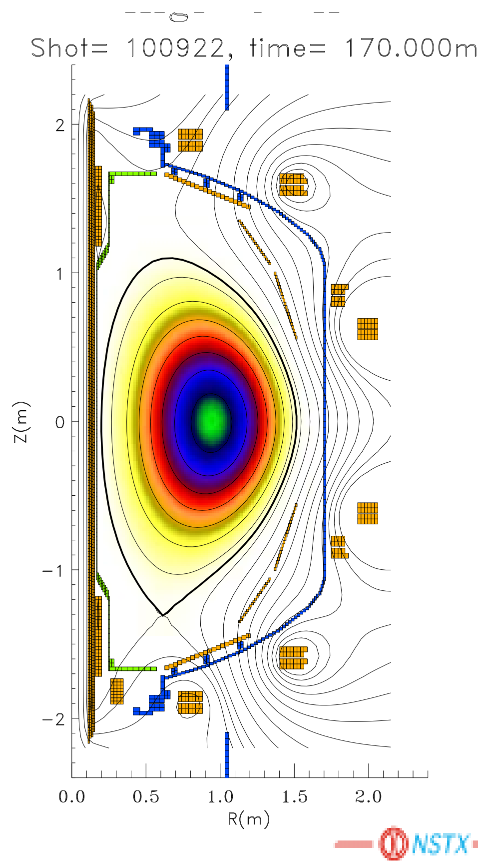
- Present control system, Ip, coil currents, 5 flux loops, 3 B-Field measurements
- Ip closed loop control
- Outer gap feedback control
- Vertical position feedback control
- Shape control is open loop (coil currents)
- CHI open loop control
- Gas injection open loop control
- Plasma control system software from GA

MANY DIFFERENT PLASMA CONFIGURATIONS PRODUCED

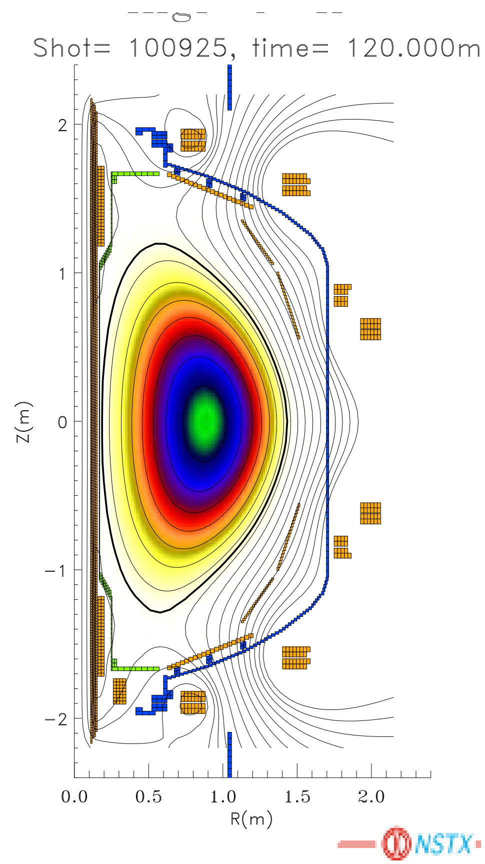
Double Null



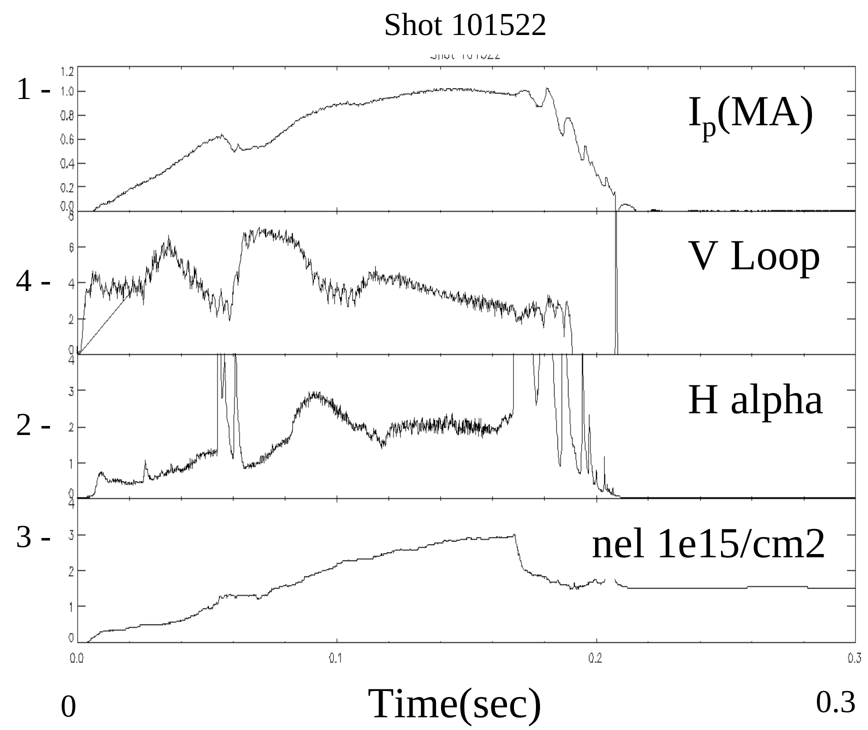
Single Null



Inboard Limited



ACHIEVED 1 MA MILESTONE



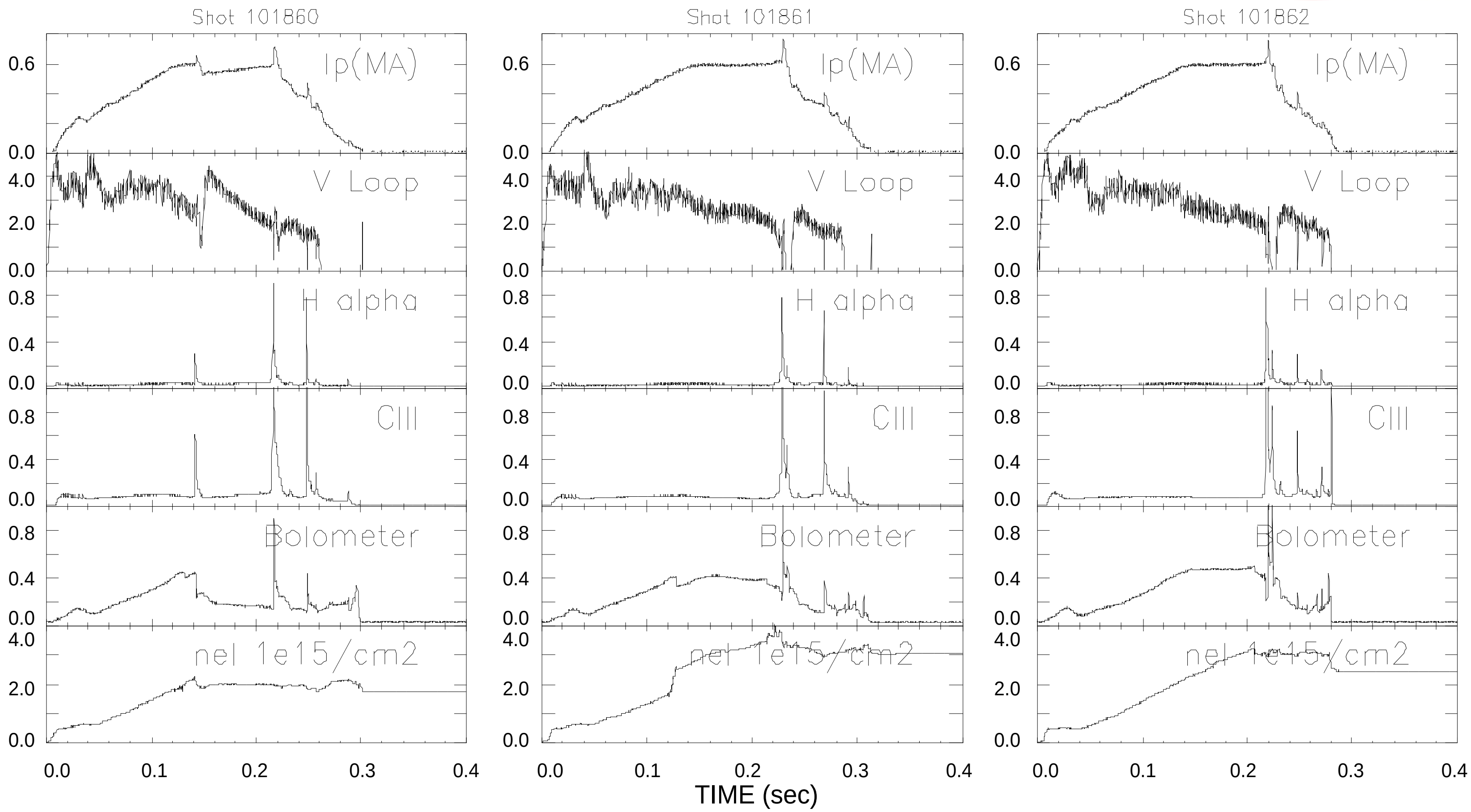
- 1 MA Ohmic Plasma Current in December
- Position controlled in feedback mode
- As expected only short flattop

Control Plans and Issues

- Move to rtEFIT for real-time reconstruction.
- Bring gas injection into real-time control system
- Use new high power low cost processors (G4)
- Preserve investment in software
- Problems:
  - Mirnov Magnetic Sensors: magnetic wire, toroidal asymmetry (between passive plates)
  - Irreproducible Conditions
- Eventual goal - real time pressure and current profile control

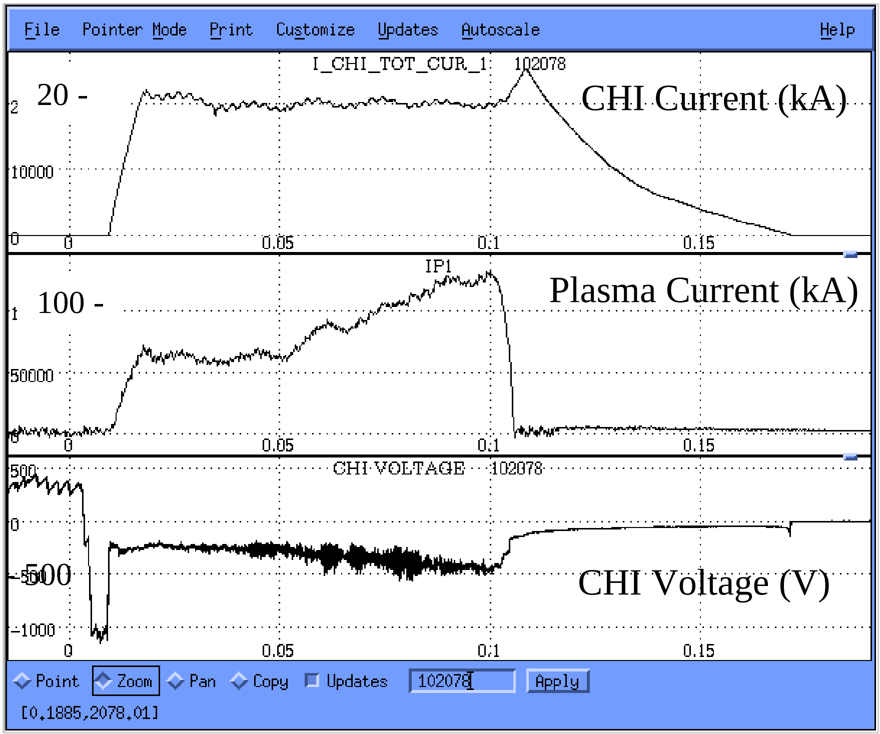
SHOT-TO-SHOT VARIABILITY

NSTX



- 600 kA discharges with only modest changes in the control parameters. Comparison with other shots suggests that it is shot-to-shot variability that is responsible for the differences, not control parameters.
- Discharges like 101860 with multiple events are normal good shots, shots like 101862 were rare.
- Essentially all discharges terminated with an event like at ~0.22 s in the above shots. (Requested end of Ip flattop was 0.24 s.)

Summary of CHI Discharge



- Maintained stable current for up to 130ms with pre-programmed coil currents and injector voltage.
- MFIT simulations of these plasmas shows evidence for some flux closure
- Used high injector flux to produce a discharge that did not rapidly expand into the absorber, resulting in lower current multiplication (60kA Ip for 20kA I-CHI).
- Reduced the injector flux in time to achieve higher multiplication.
- The injector voltage was preprogrammed to maintain a constant injector current .

CHI Operational Requirements for the Next Campaign

- Need to reduce the ripple in PF3U, 2U, 1AU
  – To obtain better control over field null generation in the absorber
- Need fast pressure sensors in the upper and lower divertors
  – For optimizing CHI pressure control
- Copper in the absorber/initiation regions needs to be shielded from arcs
  – To prevent copper from entering the discharge and depositing on the graphite tiles

Boundary Physics Operations Activities and Status

Vertical Slide

NSTX

- **Filament Preionization**
  - Developed, installed, operated
  - Used routinely for preionization of GDC and OH

- **GDC System**
  - Developed, installed, operated
    - Fixed, dual anode system
  - HeGDC breakdown at the actual operating pressure and voltage
  - Fully remote controlled manually
    - He GDC performed manually between shots

- **Sample Coupons and Tiles Installed**
  - Toroidal Midplane Array: 4 , 304-SS, and 2 Si
  - Poloidal Array: 12 in Passive Plate Gap
  - Center Stack Tiles: 2 Midplane tiles w/ Si markers

- **ORNL Filterscope System installed**
  - Used to measure D, B, C, and O edge luminosities

- **Solid Target Boronization Probe Installed**
  - Used to initiate edge contact experiments

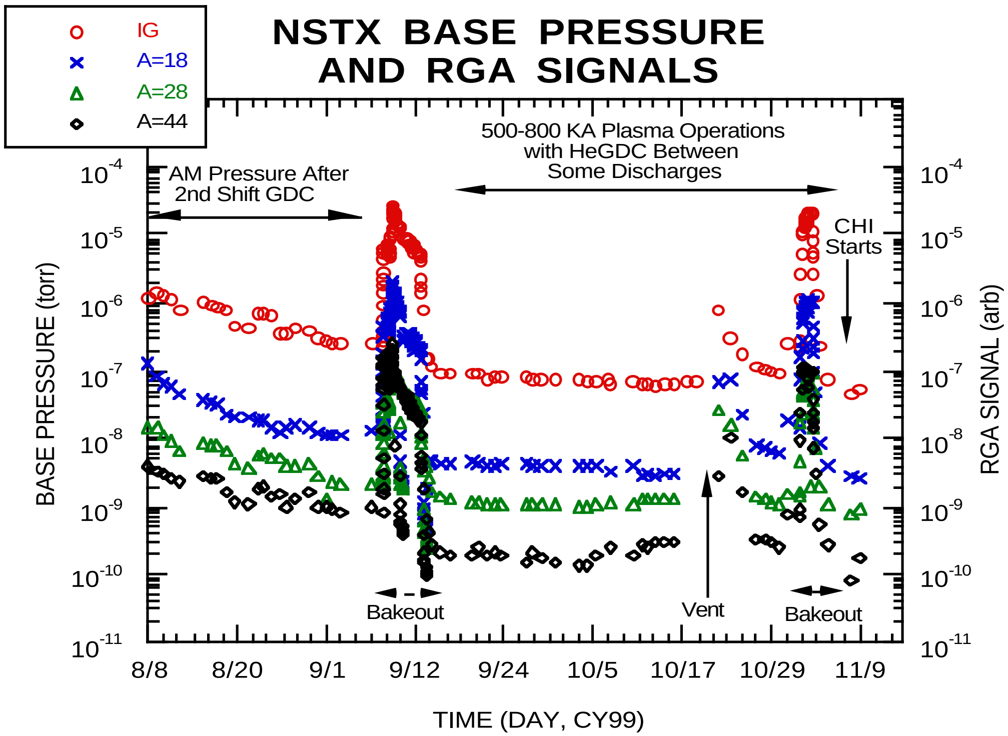
- **IR Camera**
  - Used to measure Passive Plate temperatures

GDC System Operated Routinely Via Manual Remote Control

Vertical Slide

Filament Preionization Used to Facilitate Breakdown At The Actual Operating Pressure And Voltage

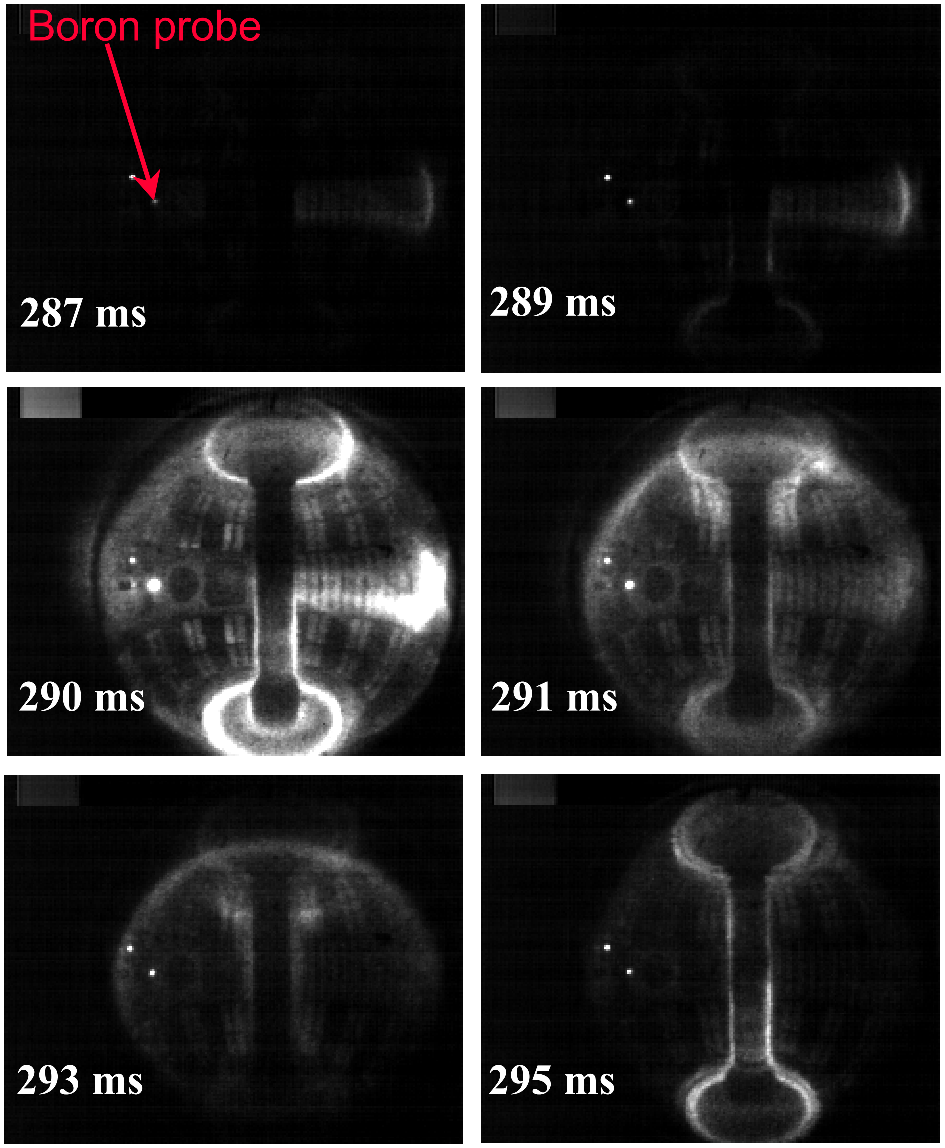
NSTX



- 9/99 Bakeout: Center Stack resistively heated to 209 °C
- 11/99 Bakeout: Center Stack resistively heated to 280 °C
- HeGDC applied between selected discharges

- NSTX Walls Conditioned for 1 MA Discharges Using HeGDC, and Mild Bakeouts

Solid Target Boronization Probe Used to Initiate Edge Contact Experiments



- Initial incandescence of probe tip was observed with LANL Fast Plasma TV camera which lasted until after the discharge.
- Probe floating potential decreased to - 25 V, indicating a plasma edge contact lasting ~ 20 msec.
- No boron was observed spectroscopically for this short plasma contact.
- Probe was inserted manually; remote control in progress.

Conditioning Plans and Issues

- Conditioning of vessel/internals will be pursued vigorously to improve discharge density control and possibly stability control
  - Between shot GDC, bakeout to 350 deg C, boronization
- Metal impurities must be minimized to give optimum plasma performance
  - Coatings on windows contain C, SS and Cu from GDC
  - Copper is observed in ohmic and CHI plasmas
  - Copper surfaces need to be covered during this opening
- Metal deposition on tiles needs to be removed during the opening
- Boronization implementation is needed to improve edge plasma conditions and overall discharge performance

HHFW System

This Run

- 8 Antenna Straps
- 2 Transmitters
- Two fixed phases
  - 0–π–π–0 0–π–π–0
  - 0–π–0–π 0–π–0–π

- 2 MW power for 0.1 s
- ~12 kV during plasma
  >25 kV vacuum (for 0.3 s)

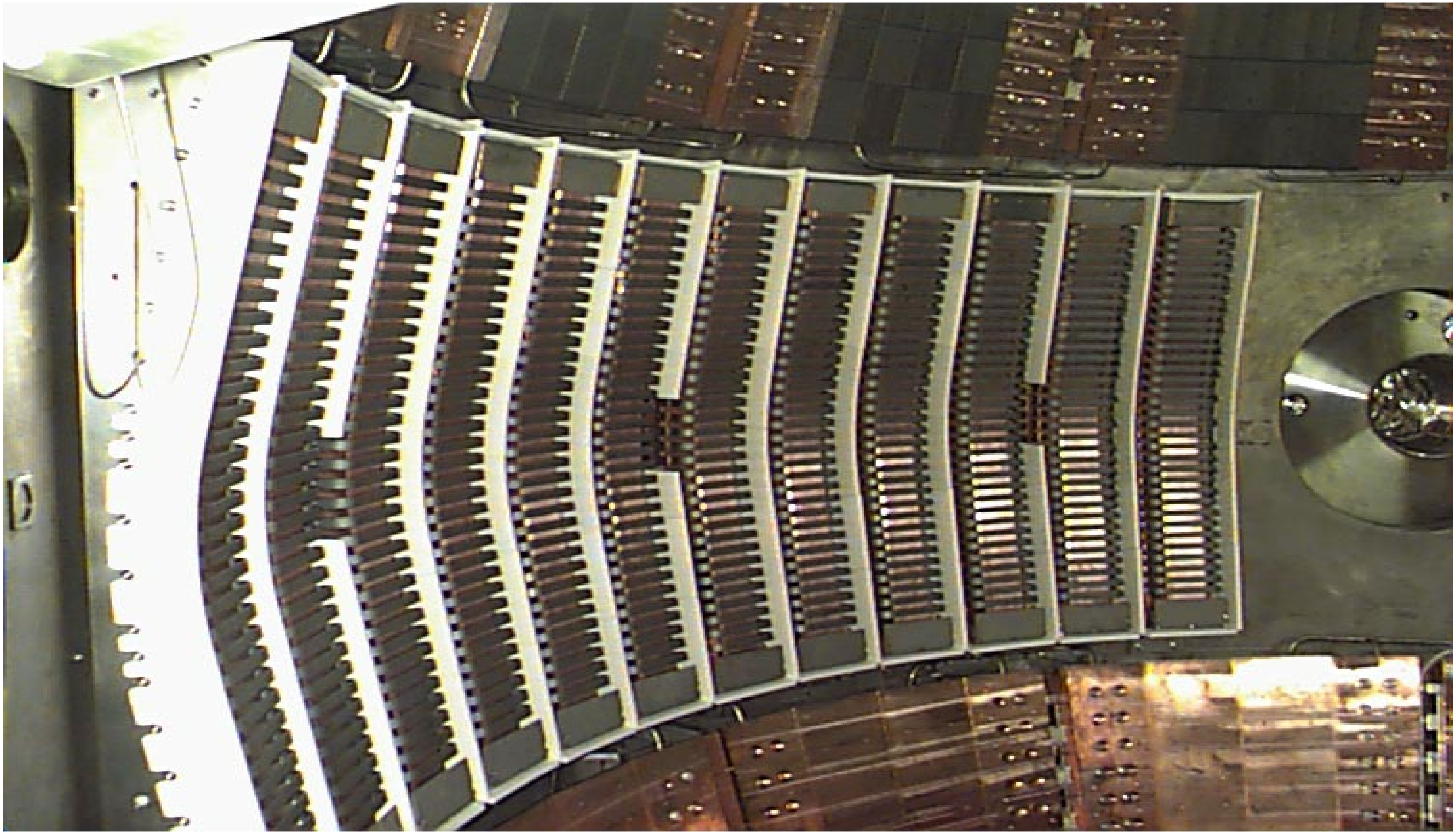
Next Campaign (2000)

- 12 antenna straps
- 6 Transmitters
- Variable phase

Ultimate Operation

- 6 MW for 5 s
- ~25 kV plasma
  30 kV vacuum

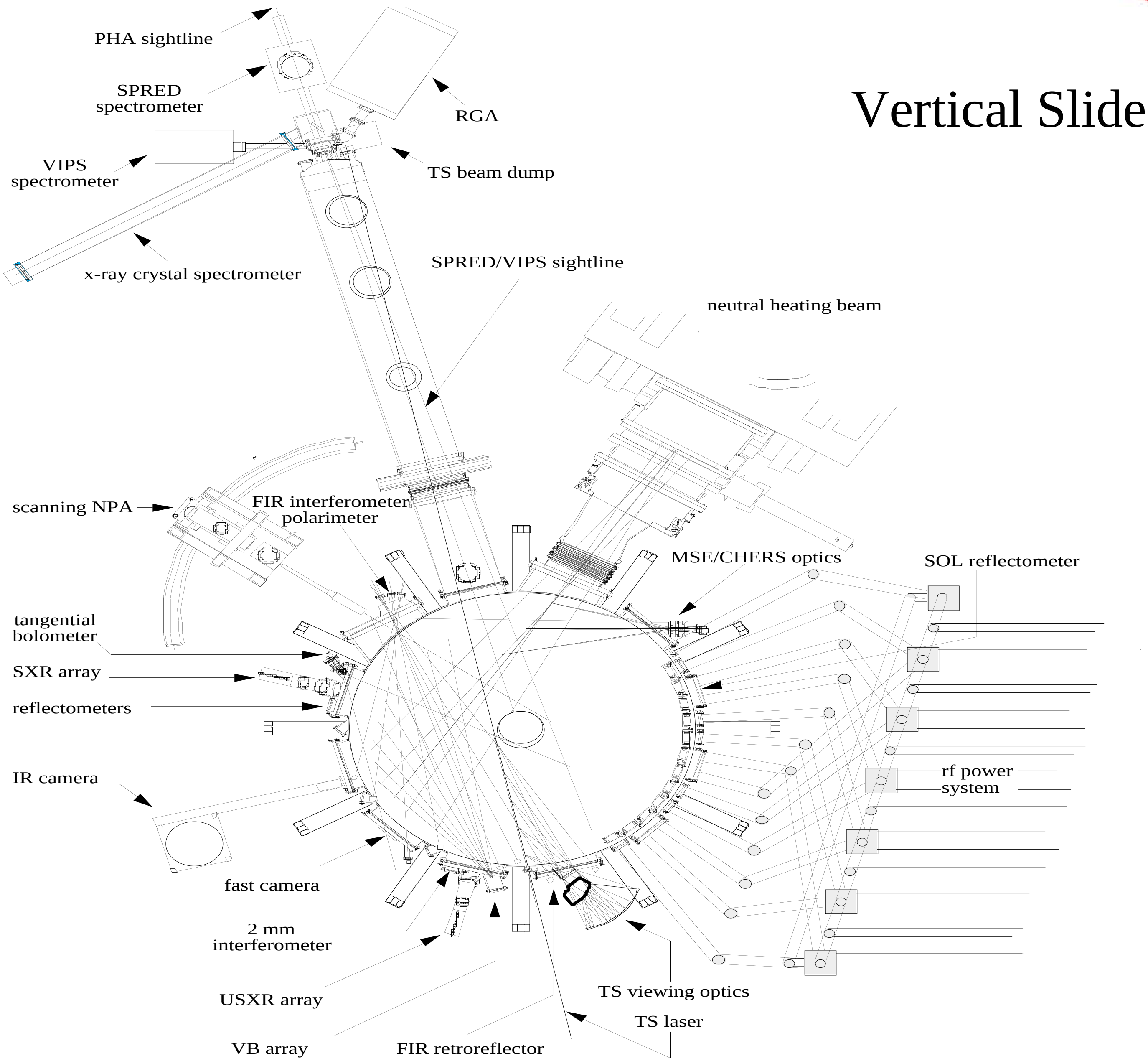
HHFW Antenna Installed



Next steps in HHFW ops

- Complete HHFW System to support completion of Phase I goals (initial heating) and begin Phase II research (high power heating and current drive)
  - Complete resurrection of transmitters
  - Complete antenna tuning and matching system including decoupler loops
  - Complete controls for phase feedback, loading feedback
- Issues:
  - Understanding high antenna loading
    - Are quarter wave transformers/decouplers desirable?
  - Sustaining beam losses on antenna protection
    - Thicker tiles to be installed on one side of array

NSTX Diagnostic, HHFW and NBI Layout



Research Operations Summary

- Excellent progress has been made toward establishing state-of-the-art ST plasmas in NSTX
  - 1 MA ohmic discharge produced
  - 130 kA CHI start-up current achieved
  - 2 MW RF power delivered
  - Significant diagnosis of plasma begun
- Many opportunities have been identified for improving the plasma performance for the upcoming campaign
  - Introduction of real time plasma control with the new control system
    - Better reproducibility and improved stability
  - Enhanced conditioning
    - GDC, bakeout, boronization and removal of metal impurities
  - Current startup with CHI leading into an optimized ohmic plasma regime
  - HHFW heating and current drive at higher electron temperatures with higher power
  - Considerably greater ability to diagnose the plasma response for optimizing operating regimes
- The introduction of NB injection will open the way to high beta operation