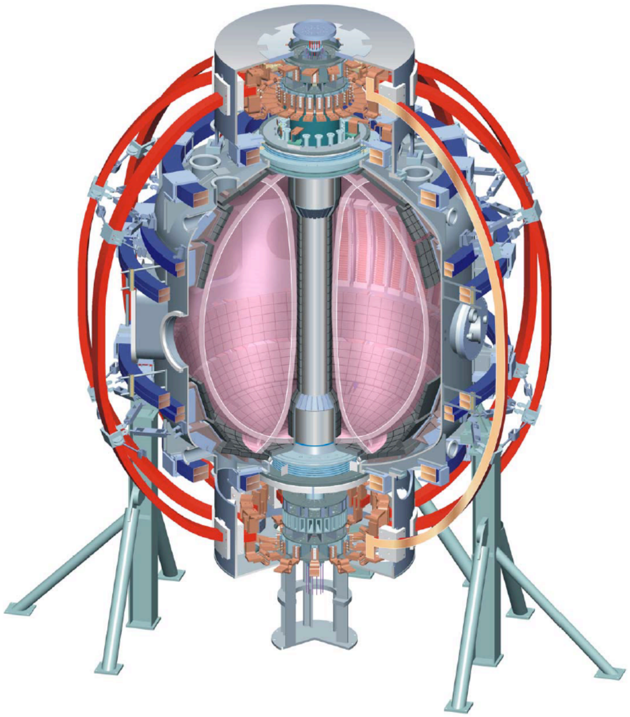
Supported by

NSTX Facility/Diagnostic Status



Masayuki Ono

NSTX PAC Meeting

Sept. 9 -10, 2004

Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
NYU
ORNL
PPPL
PSI
SNL
UC Davis
UC Irvine
UCLA
UCSD
U Maryland
U New Mexico
U Rochester
U Washington
U Wisconsin
Culham Sci Ctr
Hiroshima U
HIST
Kyushu Tokai U
Niigata U
Tsukuba U
U Tokyo
JAERI
Ioffe Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
U Quebec

NSTX Facility/Diagnostic Status Outline

- Facility and Diagnostic Status
  - TF Joint Support Structure Issues and Resolution
- Draft FY05-07 Facility and Diagnostic Upgrade Plan
- Summary

NSTX successfully completed the run on Aug. 5

Completed 21.1weeks*

With 2460 plasmas

Supported 43 XPs & 9 XMPs

Exciting FY 04 Research Activities

* Run details are available on the NSTX Web.

Met FY 04 Joule (SC7-6a) milestone: 18 weeks:

Programmatic goal: 20 weeks

New Facility/Diagnostic Capabilities in FY04

Facility Improvements:

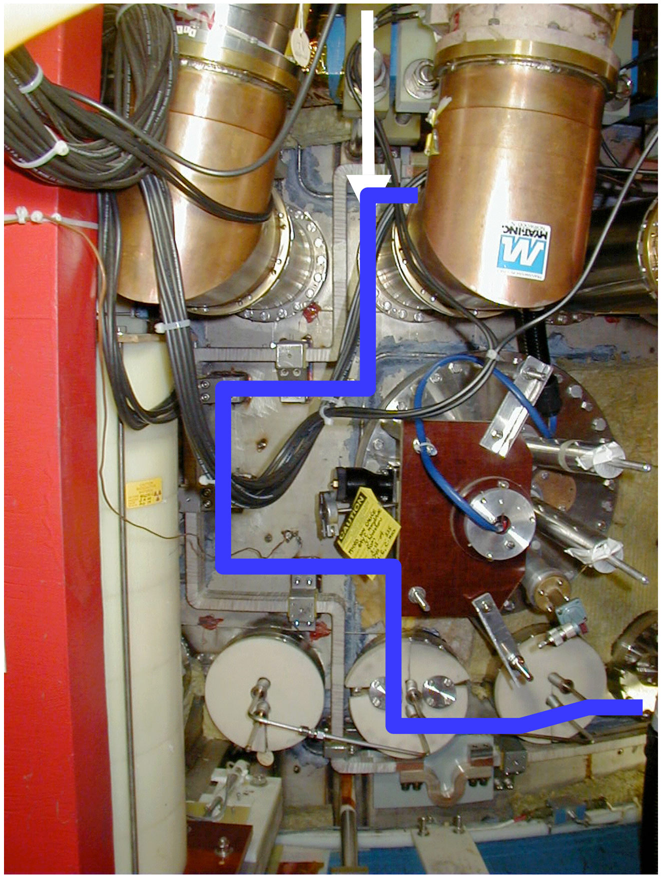
- Two (out of six) RWM Coils
- Control system upgrade for higher elongation (All areas)
  - Reduced latency (<1 msec)
  - rtEFIT2 external EF/RWM control coils (Macro)
- CHI capacitor bank – (Macro)
- Li pellet injector (Interface)
- Supersonic gas injector – (Interface)
- PF4 commissioning – (Macro)
- Improved boronization schemes (Interface)

Diagnostic Improvements:

- MSE – up to 8 channels (All areas)
- Fast tangential x-ray camera
- Divertor Mirnov arrays, internal RWM sensors (Macro)
- 51 channel CHERS (Transport, Macro)
- Scanning NPA (Transport, Macro, Wave/Part)
- USXR, FIRETIP upgrades (Macro, Transport)
- Edge rotation diagnostic to measure edge T_i, $v_{\phi,\theta}$, E_r (Transport, Wave/Part)
- Upgraded correlation reflectometry – long λ turbulence (Transport)
- Fast cameras (Transport, Interface)
- RF Probe (Wave/Part)

Two RWM coils successfully installed during the run and energized using a rectifier power supply.

NSTX



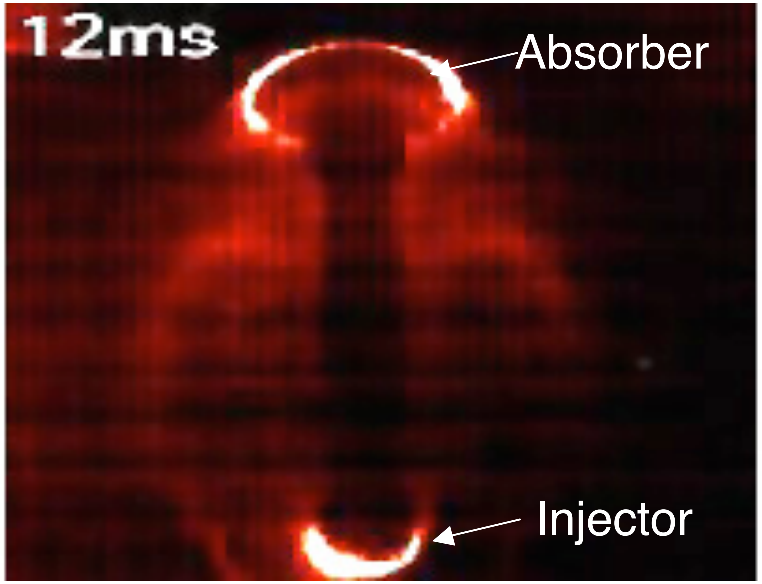
Yielded some exciting results:

- Locked-modes were shown to be stabilized in a factor of 2 lower density regime.
- Enabled start of exciting RWM investigation (Talk by S. Sabbagh)
- Used to control the plasma rotation velocity

The full Six-element RWM coil system powered with the SPA (Switching Power Amplifier) supply is scheduled to be available for the FY 05 run.

Capacitor Bank for Transient-CHI Start-Up Commissioned

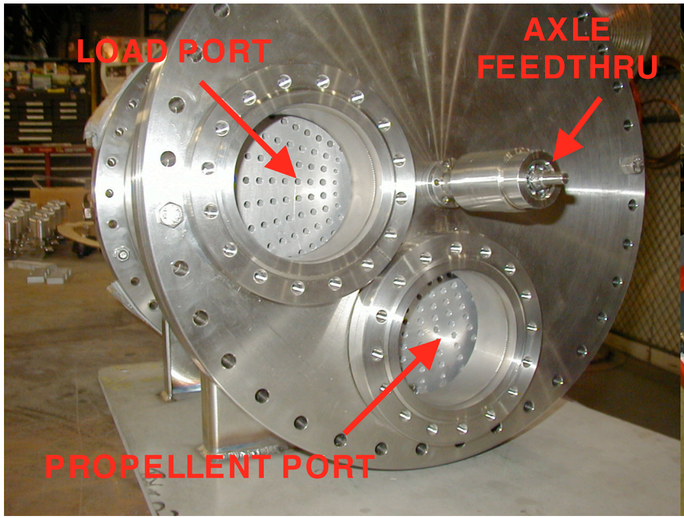
- Operated reliably up to 1 kV
- Produced reliable breakdown with lower gas pressure
- Generated I_p ~ 140 kA with I_{inj} ~ 4 kA in a few milliseconds
- Measured peaked profiles T_{e0} ~ 16 eV



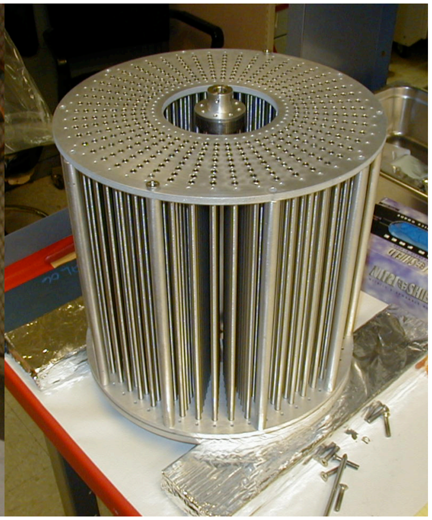
Future improvement possibilities:

- T_e increased with reduced pressure - can we reduce it further by:
  - Gas + ECH injection into injector?
  - Higher voltage > 1 kV?
- Plasma stability/controllability
  - Energize absorber coils
  - Need to develop control algorithms

Injected Lithium Pellets into NSTX Discharges



OUTBOARD VIEW



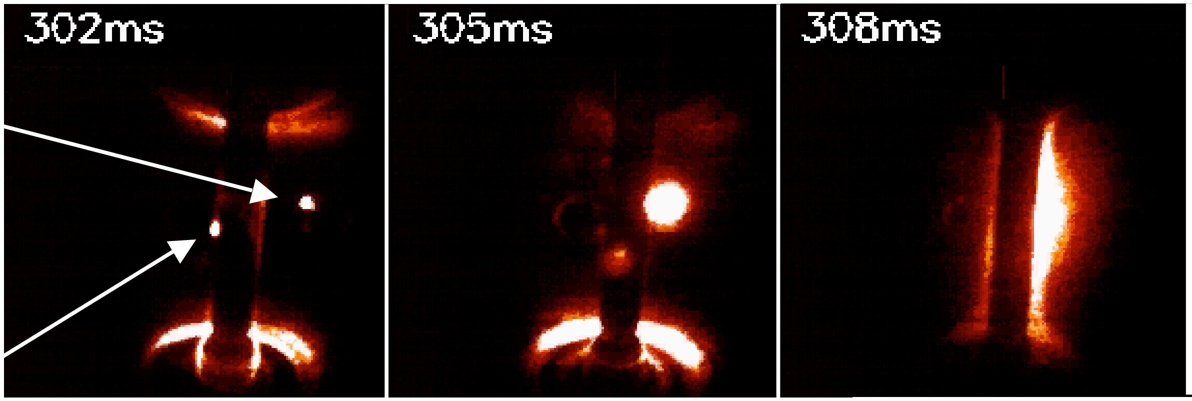
400 BARREL TURRET

- Capability for injecting solid pellets (<1 – 5 mg) & powder (micro-pellets)
- 10 – 200 m/s radial injection
- 1 – 8 pellets per discharge
- 400 pellet capacity
- Need to optimize performance

Lithium vapor spreading along the center-stack

Lithium Pellet moving through plasma after entering at 296ms

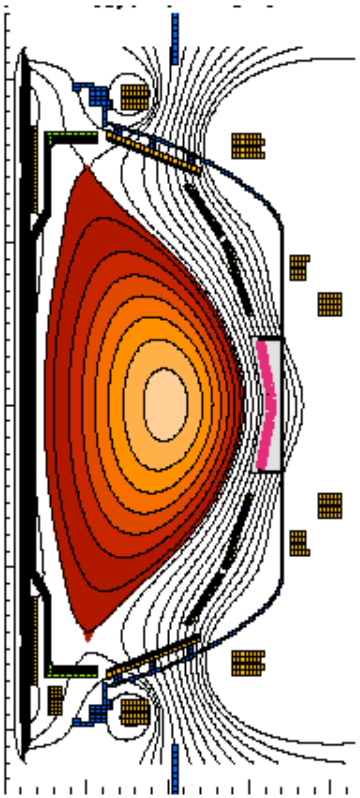
In-board gas injector



Lithium “vapor ball” surrounding pellet as it approaches the center-stack

Facility Upgrade Highlights Continue

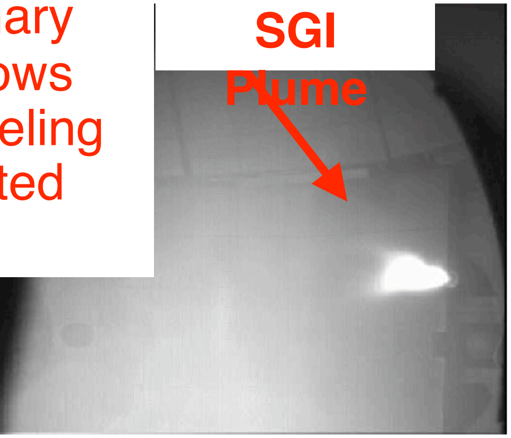
Plasma Control System

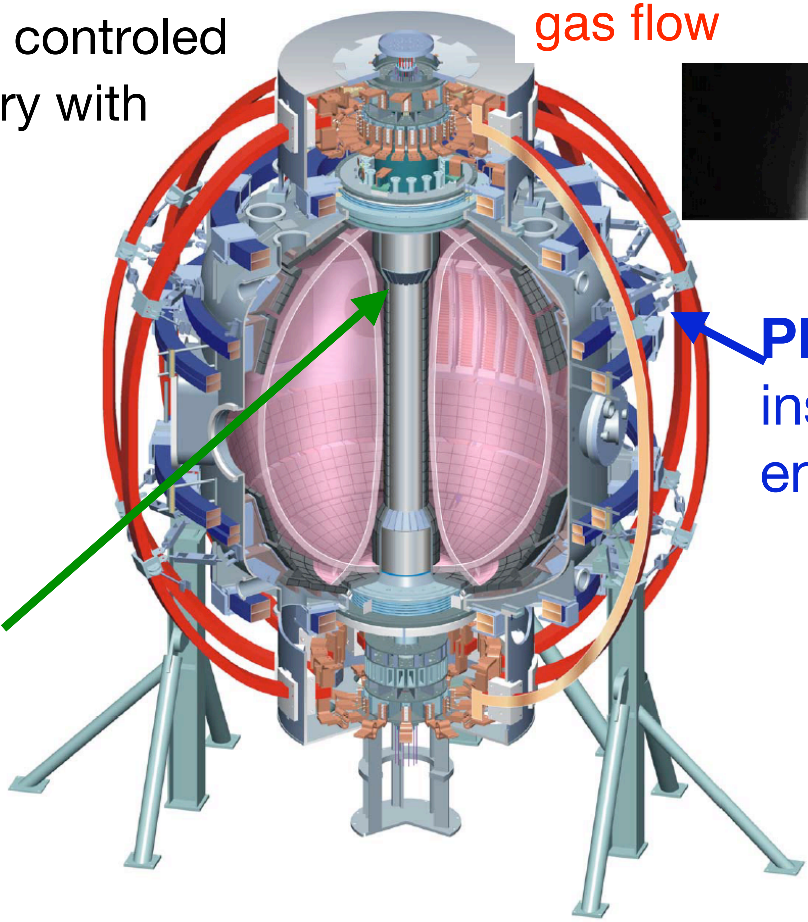


- Achieved κ ~ 2.6 by latency reduction
- rtEFIT controled boundary with κ ~ 2.3

Supersonic Gas Injector

- Preliminary analysis shows improved fueling with collimated gas flow





Shoulder Gas Injector

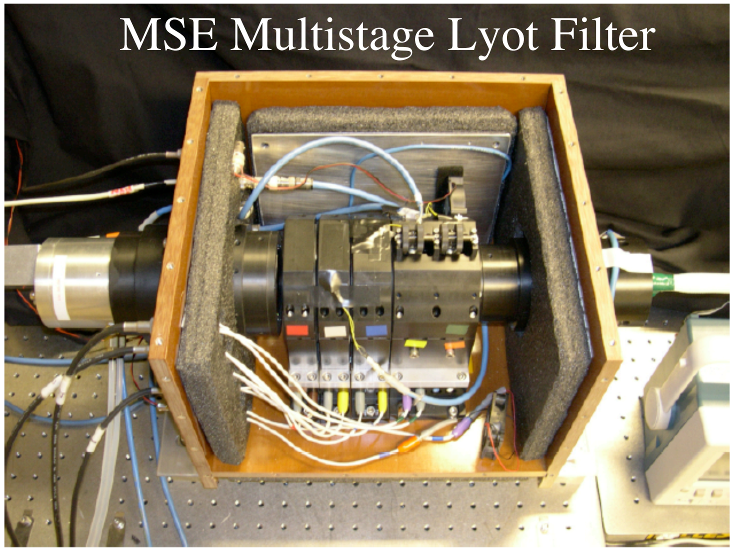
- Successfully utilized for H-mode studies

PF-4 (previously installed but not energized)

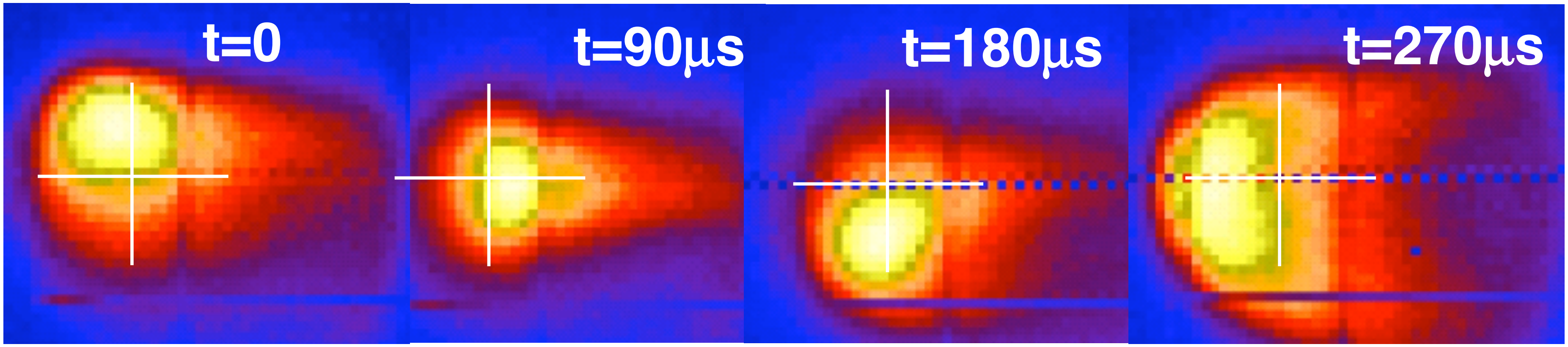
- Energized using RWM power supply for poloidal field coil start-up experiment

MSE and Fast X-ray Camera Commissioned

- Motional Stark Effect (MSE) diagnostic based on the collisionally induced fluorescence (CIF) from heating neutral beams took profile data with 8 channels during experiments *(Nova - Fred Levinton's talk)*

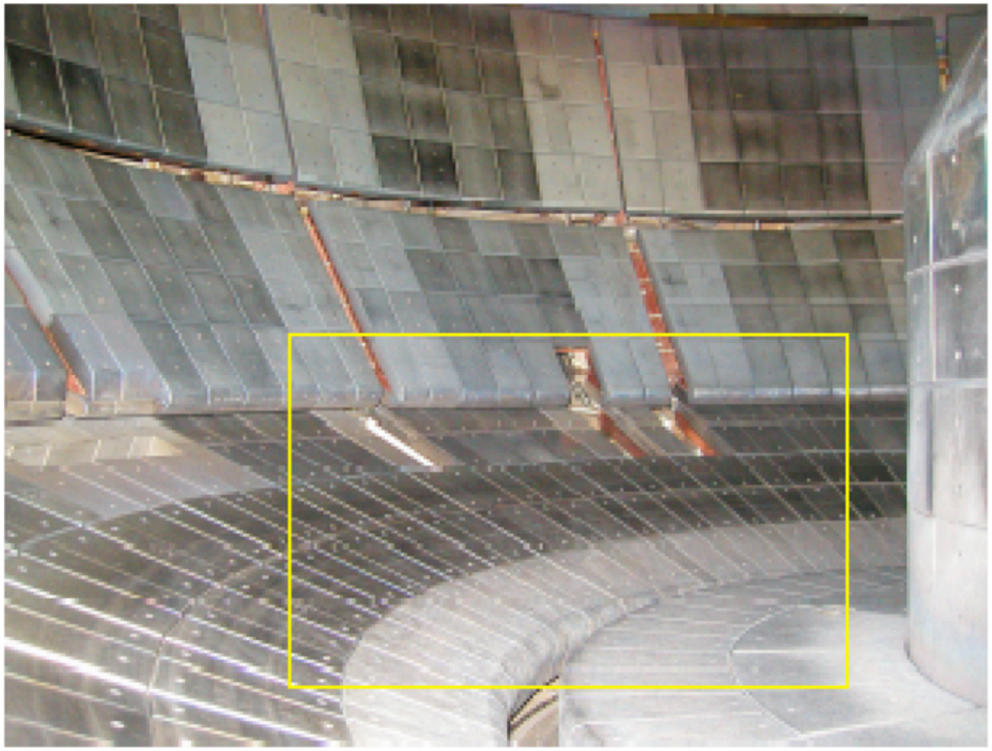

MSE Multistage Lyot Filter

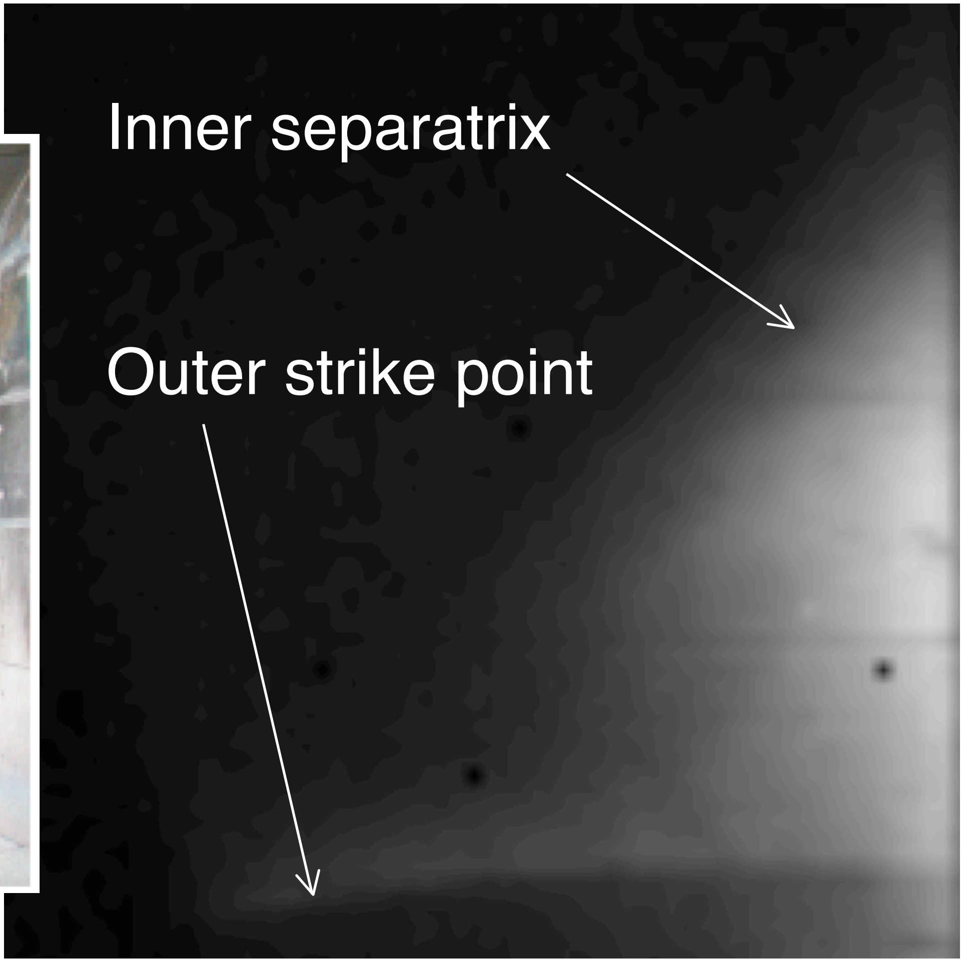
- Images of the soft x-ray emission along tangential sightlines recorded by an ultra-fast camera with time resolution down to ~ 2 μs



Hiroshima Divertor visible camera shows clear differences between Type I (large) and Type V (small) ELMs

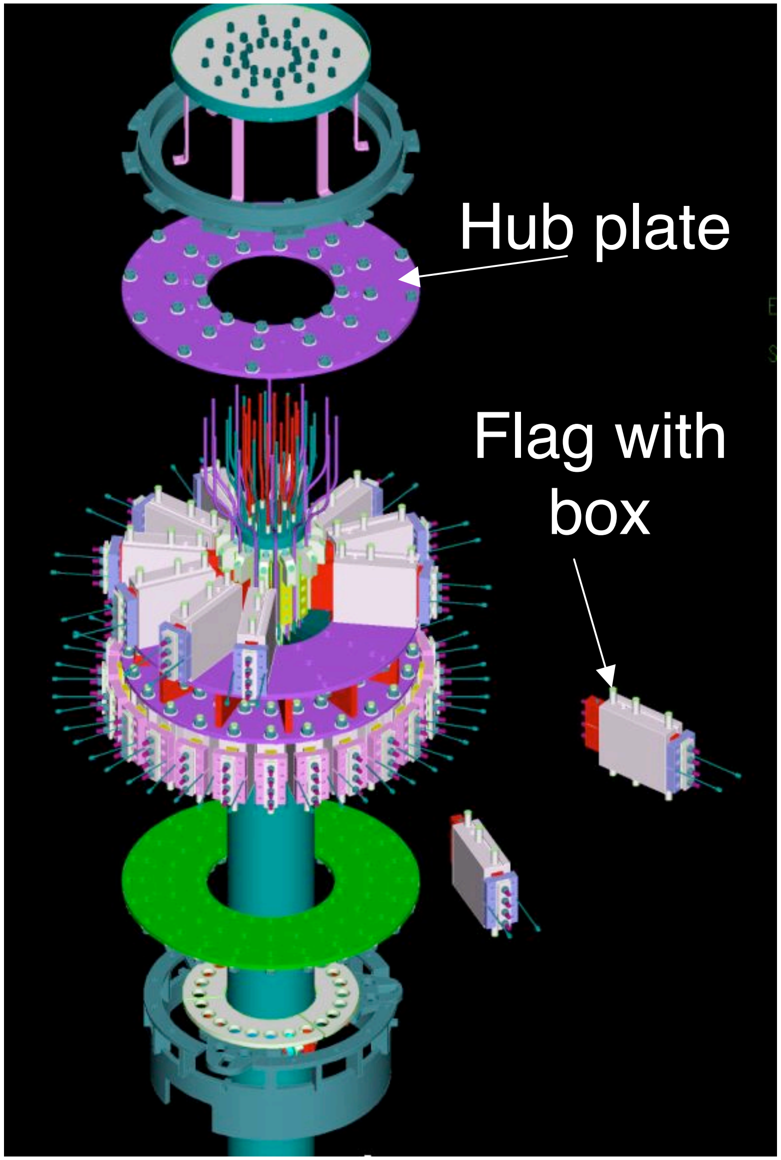
- Periodic Type V ELMs interrupted by a Type I ELM (approximate camera field of view in LHS yellow box)





Nishino (U. Hiroshima), Roquemore, Maingi (ORNL)

TF Joint Behavior Has Been Monitored and Studied Throughout the Run



- In January, an integrated system test was conducted to qualify the machine.
- The measured resistance of each joint was well below the <700nΩ design goal at 4.5kG and the temperature rise was in accord with expectations.
- However, a closer examination of the data and trends over time raised some concerns.

New Data and Analysis Has Identified Some Concerns About the TF Joints

NSTX

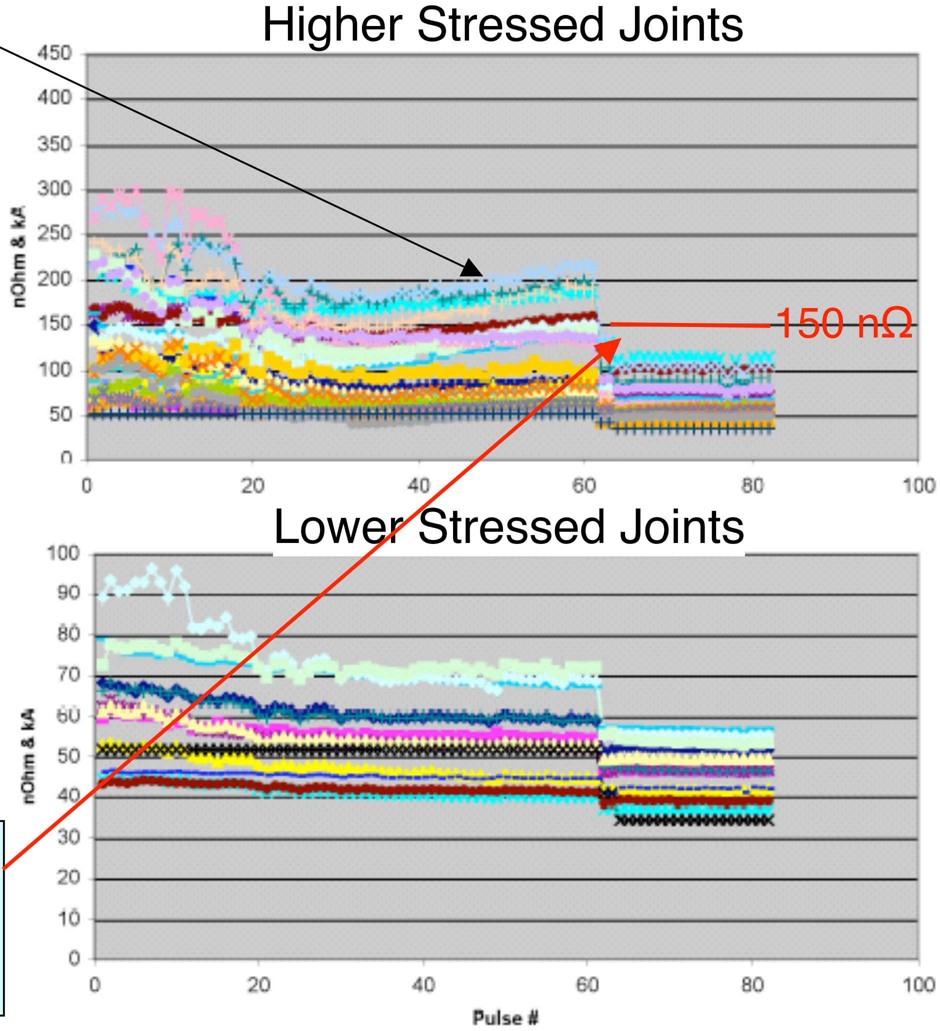
- Small upward drift in the joint resistances observed over ~4 months of operation.

  - All remained well below 700nΩ.
- Temperature and strain gauge measurement also revealed changes over time.
- Subsequent measurements showed larger than expected TF-flag displacements.
- New simulations and bench tests indicate the measurements are consistent with larger than expected joint “lift-off”.

To assure safe device operation, we instituted TF operational limit of 3kG with R_{max}<150 nΩ in July.

TF Joint Resistance in nΩ

[Start-of-Flat-Top. Test Shots]



Working to Resolve These Concerns

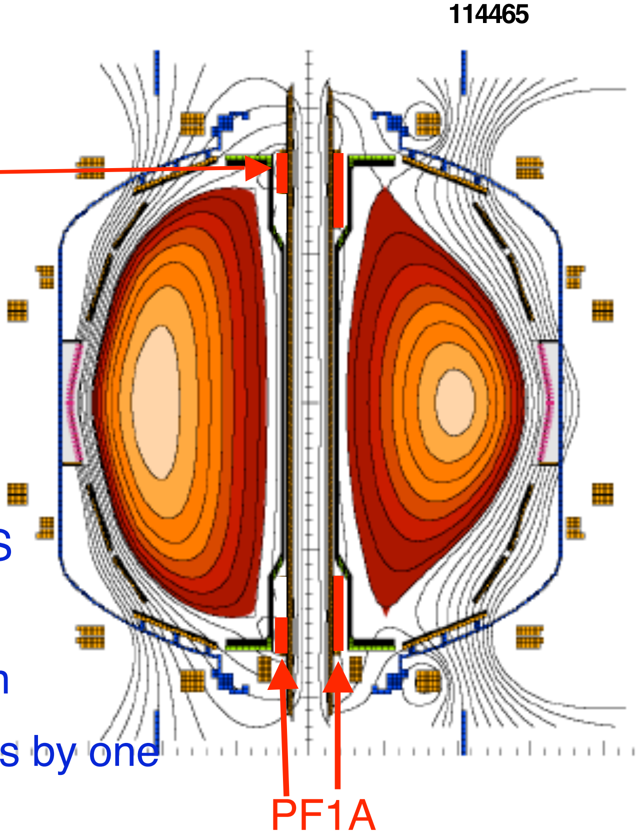
- Progress in understanding the TF joint behavior:
  - Movement of flag joints confirmed and quantified through a number of measurements
  - Modeling suggests that the cause of the flag movements is softer than expected epoxy fill in the flag box
  - Bench tests of the removed flags did confirm this shortcoming
  - Alternate fill material being tested to give adequate strength for the next run

Project decision: Replace epoxy in all the flag joints

- Outage schedule developed:
  - Complete the in-vessel work and pump down in mid-Nov. 04
  - Complete the magnet assembly in Dec. 04
  - ISTP of magnets in Jan. 05 and plasma operation in Feb. 05 (similar to this year)
- Present Status: Outage activities progressing on schedule
  - Central TF-OH bundle is moving to the work stand
  - Lower flag box disassembly completed

Adjustments of Facility/Diagnostic Plan

- Taking advantage of the center-stack removal:
  - Implement PF 1A coil upgrade one year ahead of schedule for better shaping capability — simultaneous high κ and δ — for advanced ST operations
  - Repair/improve plasma current Rogowski coils



- Remaining facility/diagnostic upgrade plan:
  - Complete full RWM coil with SPA power supply
  - Install high-k scattering system and 10 additional MPTS channels
  - Install HHFW antenna BN side limiter for NBI protection
  - Delay purchase of CHERS spectrometers and detectors by one year
  - Delay the lithium evaporator by one year but continue R&D

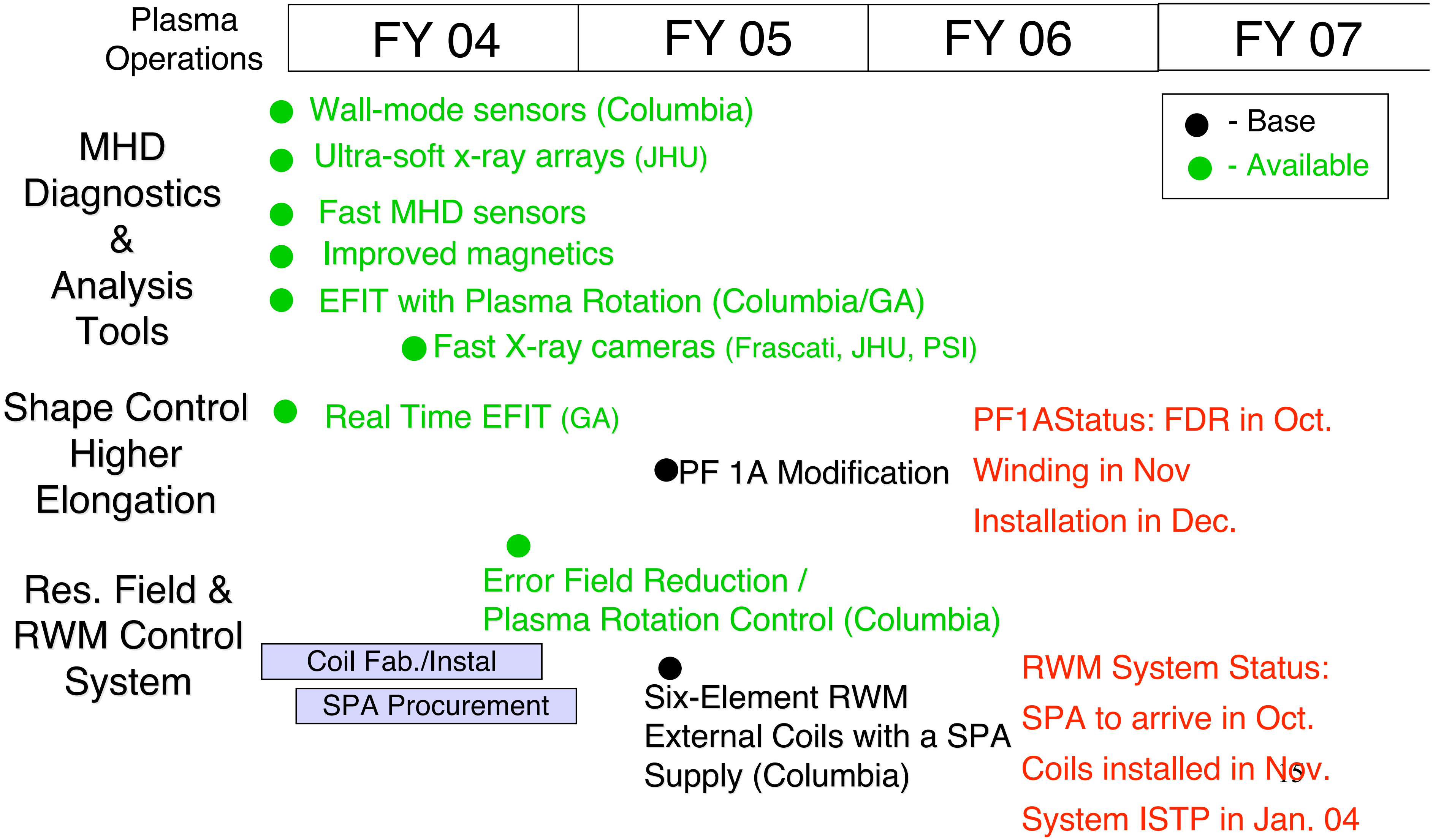
    Emphasize experiments with lithium pellet injector in FY 05

    Higher priority on moveable between-shots GDC probe than neutron collimator

MHD Mode Stabilization **DRAFT**

Opportunity Areas are Shaping and RWM Controls.

NSTX



Plasma Operations	FY 04	FY 05	FY 06	FY 07

● - Base

🟢 - Available

MHD Diagnostics & Analysis Tools

- 🟢 Wall-mode sensors (Columbia)
- 🟢 Ultra-soft x-ray arrays (JHU)
- 🟢 Fast MHD sensors
- 🟢 Improved magnetics
- 🟢 EFIT with Plasma Rotation (Columbia/GA)
- 🟢 Fast X-ray cameras (Frascati, JHU, PSI)

Shape Control Higher Elongation

- 🟢 Real Time EFIT (GA)
- ● PF 1A Modification

PF1AStatus: FDR in Oct.
Winding in Nov
Installation in Dec.

Res. Field & RWM Control System

Coil Fab./Instal

SPA Procurement

- 🟢 Error Field Reduction / Plasma Rotation Control (Columbia)
- ● Six-Element RWM External Coils with a SPA Supply (Columbia)

RWM System Status:
SPA to arrive in Oct.
Coils installed in Nov.
System ISTP in Jan. 04

Confinement and Transport **DRAFT**

Exciting Opportunities For Advanced Fluctuation Diagnostics

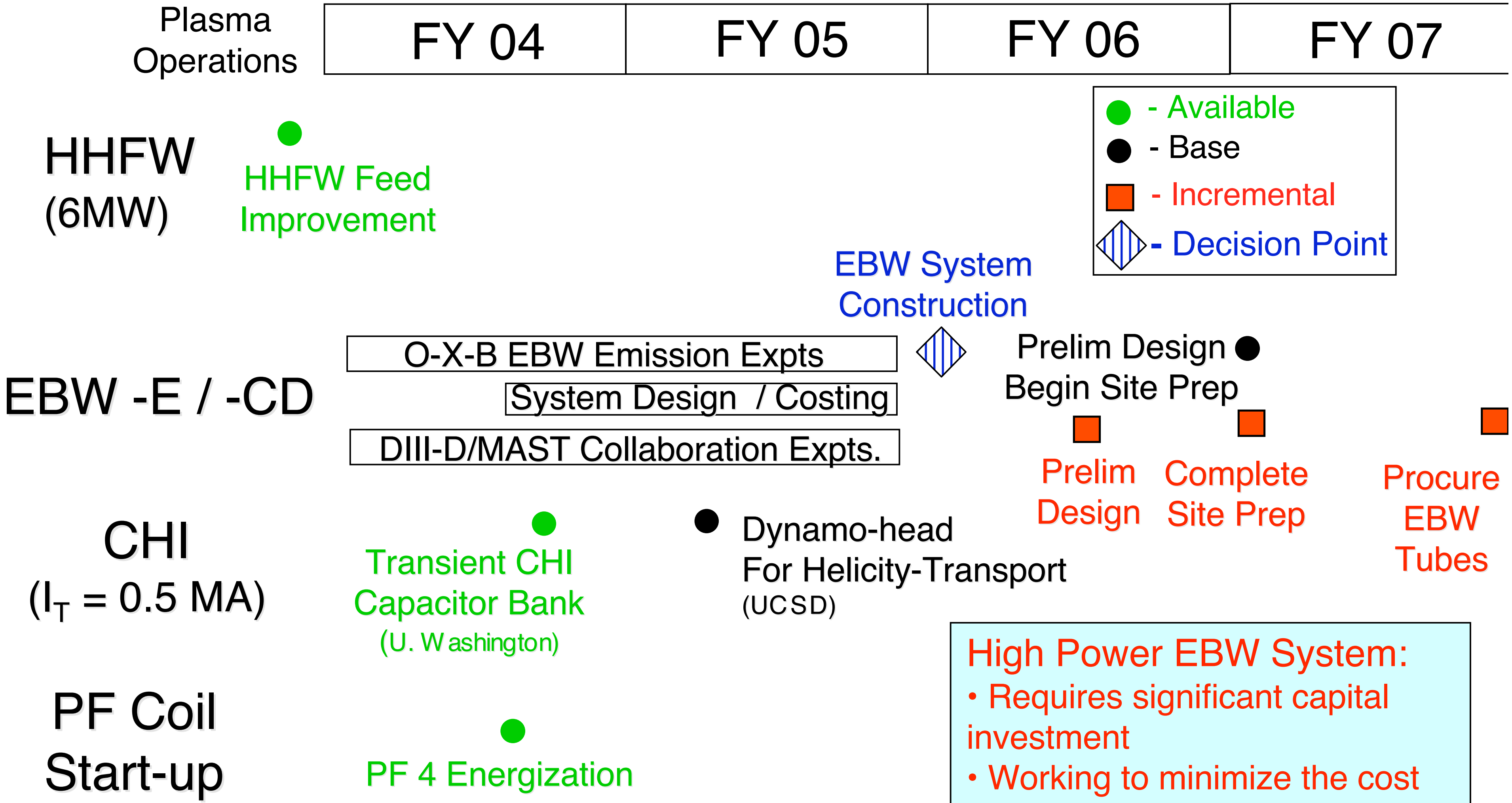
Plasma Operations	FY 04	FY 05	FY 06	FY 07
(F	🟢 Tor. CHERS (51 ch)		Edge Pol CHERS ●	
Profile Diagnostics	🟢 Edge Rotation Spect.	● ERS Upgrade		
	🟢 MPTS 20 ch, two laser	● MPTS 30 ch	● MPTS Third laser	
	🟢 FIReTIP 4 ch (UCD)	●FIReTIP 6 ch (UCD)		
	🟢 MSE/CIF 4- 8 ch (Nova) →	● MSE / CIF 12-14 ch (Nova)		● MSE / LIF (Nova)
Energetic Particles	🟢 Fast Loss Ion Probe		●Neutron Collimator	
Fluctuation Diagnostics	🟢 Low k Reflectometer (UCLA)	● Prototype High k Microwave Scattering(UCD)		Low k Imaging Reflectometer ●
	🟢 Gas-puff Imaging(LANL, PSI)			
	🟢 Reciprocating probe (UCSD)			

● - Base

🟢 - Available

Non-Inductive CD Systems **DRAFT**

Enhancement Opportunity areas are EBW and Solenoid-free Start-up



Plasma Operations

FY 04	FY 05	FY 06	FY 07

- ● - Available
- ● - Base
- 🟥 - Incremental
- ◇ - Decision Point

HHFW (6MW)
- ● HHFW Feed Improvement

EBW -E / -CD
- O-X-B EBW Emission Expts
- System Design / Costing
- DIII-D/MAST Collaboration Expts.
- ◇ EBW System Construction
- Prelim Design ●
- Begin Site Prep
- 🟥 Prelim Design
- 🟥 Complete Site Prep
- 🟥 Procure EBW Tubes

CHI (I_T = 0.5 MA)
- ● Transient CHI Capacitor Bank (U. Washington)
- ● Dynamo-head For Helicity-Transport (UCSD)

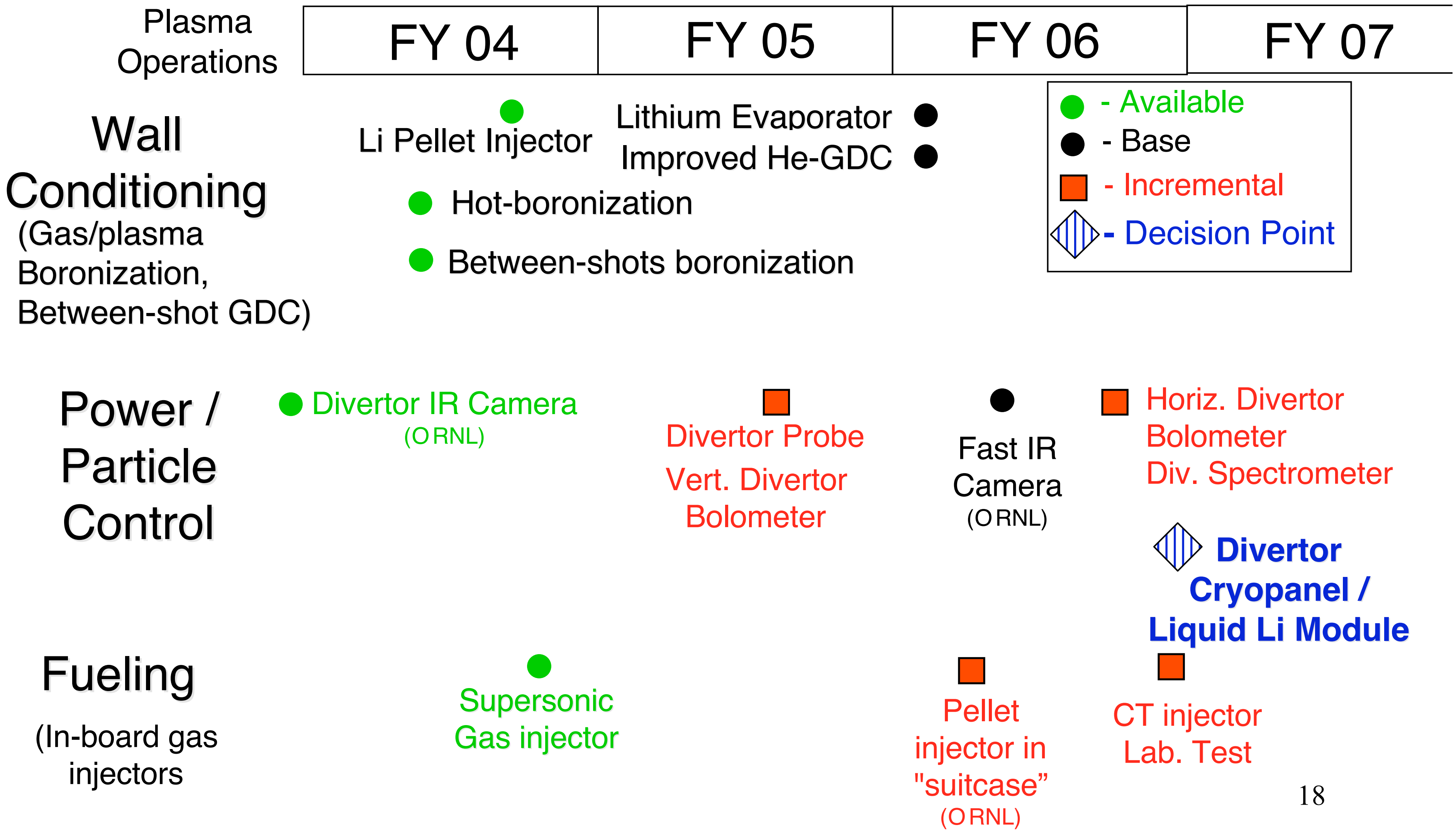
PF Coil Start-up
- ● PF 4 Energization

High Power EBW System:
- Requires significant capital investment
- Working to minimize the cost
- To explore collaboration opportunities

DRAFT

Boundary Physics

Exciting Enhancement Opportunity in Core Fueling and Boundary Physics



Plasma Operations

FY 04 | FY 05 | FY 06 | FY 07

🟢 - Available
⚫ - Base
🟧 - Incremental
◈ - Decision Point

Wall Conditioning
(Gas/plasma Boronization, Between-shot GDC)

🟢 Li Pellet Injector
Lithium Evaporator ⚫
Improved He-GDC ⚫
🟢 Hot-boronization
🟢 Between-shots boronization

Power / Particle Control

🟢 Divertor IR Camera (ORNL)
🟧 Divertor Probe
Vert. Divertor Bolometer
⚫ Fast IR Camera (ORNL)
🟧 Horiz. Divertor Bolometer
Div. Spectrometer
◈ **Divertor Cryopanel / Liquid Li Module**

Fueling
(In-board gas injectors

🟢 Supersonic Gas injector
🟧 Pellet injector in "suitcase" (ORNL)
🟧 CT injector Lab. Test

NSTX Facility/Diagnostic Status Summary

- Productive FY 04 run completed on Aug. 5, 2004
  - Successfully operated for 21.1 weeks with 2460 plasmas
  - Met the Joule milestone of 18 weeks and programmatic goal of 20 weeks.
- Many exciting new capabilities were implemented
  - RWM coil energization, CHI capacitor bank, rapid boronization, PF4…
  - MSE, Fast tangential X-ray cameras, Divertor cameras, Improved GPI…
- TF joint monitoring showed larger than expected movement
  - TF limit of 3 kG was imposed during the last month of operation
  - The cause of movement traced to softer than expected epoxy fill
  - TF bundle has been removed and improved epoxy fill will be implemented
- Some upgrade adjustments made for the outage
  - Accelerate PF 1A upgrade
  - Complete RWM coils with SPA, high-k scattering, 10 extra MPTS channels
  - Delay lithium evaporator and poloidal CHERS detector by one year

Restart in Feb. 2005 with significantly improved facility and diagnostic capabilities for up to 21 run weeks