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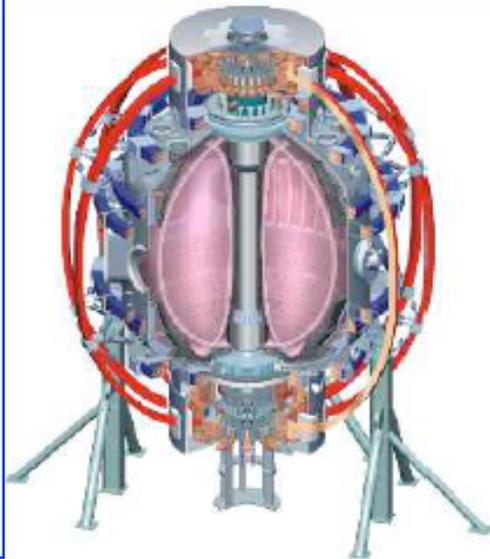
NSTX Project

Facility Operations, Upgrades and Budget Plans

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U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

Masayuki Ono
for the NSTX Team

FY 2010 Budget Planning Meeting
March 11-12, 2008



Culham Sci Ctr
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NSTX FY 08 Run Started

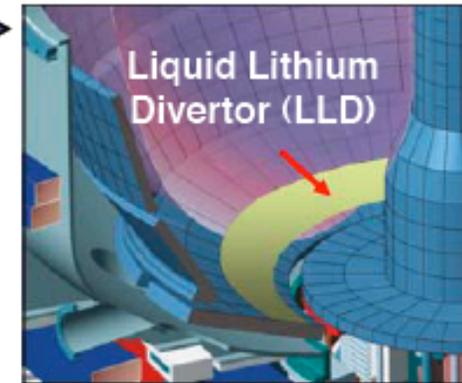


- **NSTX FY 07 Outage completed on schedule.**
- **New facility capabilities for the FY 08 run:**
 - **Two lithium evaporators to complete coverage of lower divertor**
 - Shutters will stop deposition during HeGDC and plasma shots
 - **New control computer with reduced latency and more channels**
 - **Flexible EF/RWM/RMP configuration with n=1,2,&3 capability**
 - **Moly / BN protection plates on select areas**
- **New diagnostic capability to be available in FY 08 run:**
 - **Poloidal-CHERS 70 channel system**
 - **Fast-Ion Deuterium-alpha (FIDA) utilizing PCHERS views (UCI)**
 - **Divertor bolometer: two views - 12 channels**
 - **Remote control of spatial scanning for high-k scattering (UCD)**
 - **Polarizer to reduce MPTS stray light and internal calibration probe**
 - **Sensors for “halo current” in lower divertor**
- **Research run started in February with 15 run week goal:**
 - **Vertical stability control and RMP-ELM physics to contribute to resolving ITER design issues**
 - **Momentum transport (FY 08 Joule Milestone) experiments**

FY 08-10 Facility and Diagnostic Plan to Support Three Highest Research Priorities for Future STs

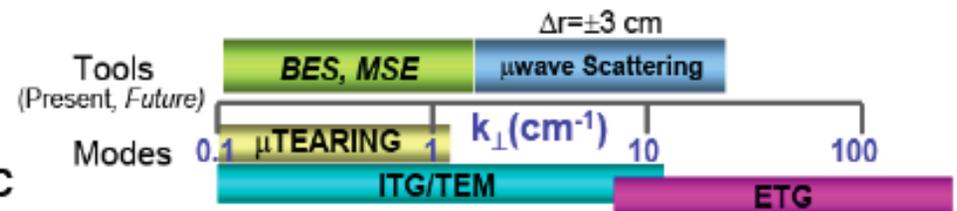


1. Implement liquid lithium divertor for pumping, and investigate other potential benefits:
 - Improved confinement
 - Reduction/elimination of ELMs
 - Compatibility of LLD with high flux expansion
 - Longer-term: steady-state high-heat-flux handling



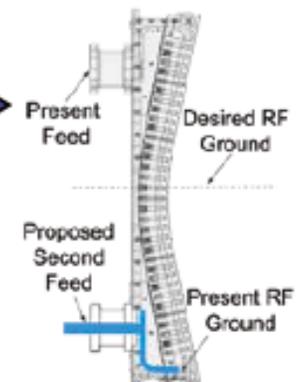
2. Implement BES to complement existing high-k scattering diagnostic

- Measure full wavenumber spectrum of turbulence
- Determine modes responsible for anomalous transport



3. Upgrade HHFW system for higher P_{RF} + ELM resilience

- Determine if HHFW can ramp-up I_p in H-mode (BS+RF overdrive)
- Determine if HHFW can heat high- β_N advanced H-mode scenarios
- HHFW/ICRF also important for NHTX/CTF/ITER



Transport and Turbulence

Measure full k-spectrum of turbulence to better understand ion and electron energy transport

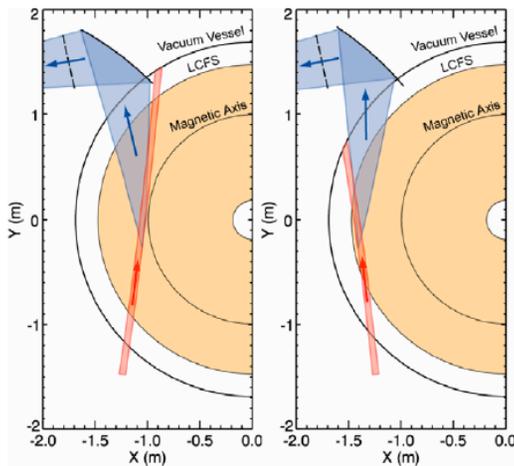
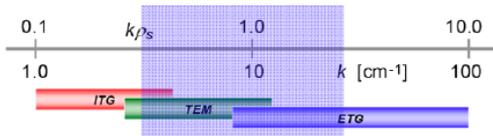


FY 08	FY 09	FY 10
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Run Weeks
Base / Increment

○ Increment
◆ Full Utilz

Tangential High-k Scattering (3 MHz)



UC Davis
(Ph.D. thesis)

Profile Diagnostics

- P-CHERS(70 ch)
- MSE/CIF (16 ch)
- Multi-Color-T_e(r) JHU
- MSE/LIF (4 ch)
- MSE/LIF (12 ch) Nova Photonics
- ◆ MPTS High Spatial Resolution

Turbulence Diagnostics

- Corr. Reflect (low-k) UCLA
- Improved High-k Scattering
- BES U. Wisconsin
- High-k Scattering k-θ

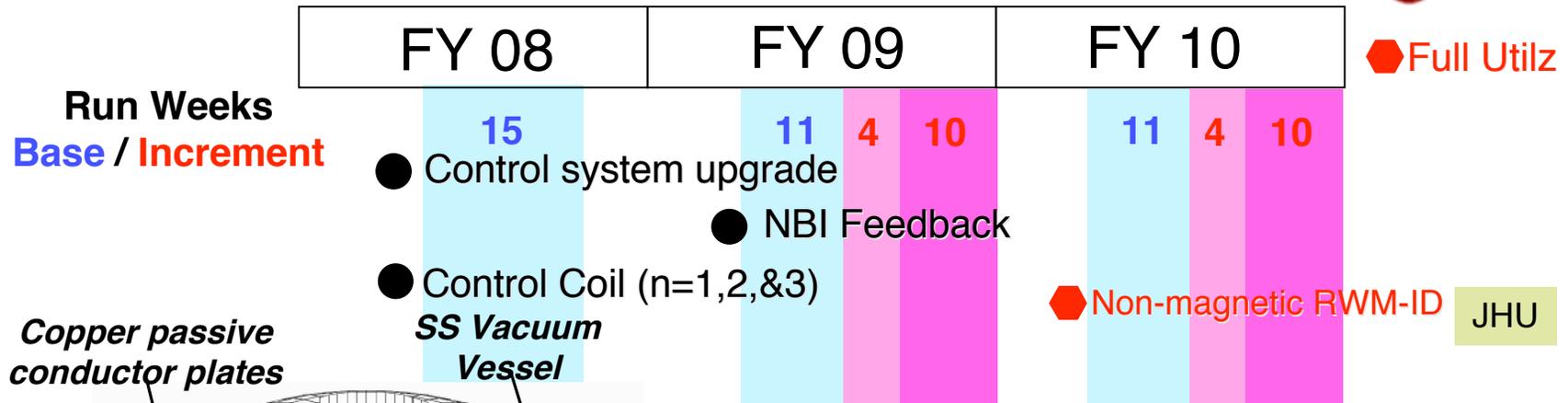
MSE-LIF w/o heating beam
 • Direct reconstruction of total plasma pressure
 • Radial electric field profiles

BES - Localized low-k turbulence structures to complement high-k
 → full turbulence k-spectrum

To enable extrapolation to next-step STs

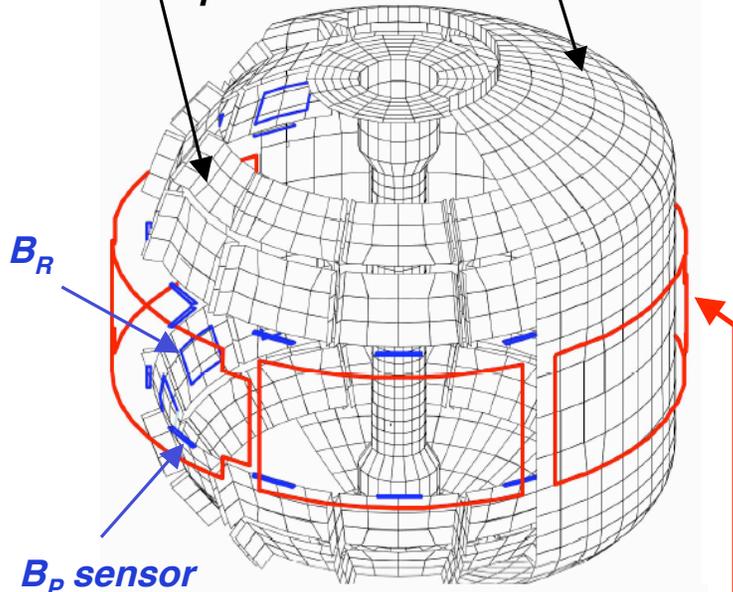
Macrostability

Advanced Tools Enabling Cutting-Edge EF/RWM/RMP Research



Copper passive conductor plates

SS Vacuum Vessel



B_p sensor

Columbia U

VALEN Model of NSTX (Columbia Univ.)

6 ex-vessel midplane control coils

ITER design issue related activities:

- Vertical control
 - PF configuration similar to ITER
- ELM suppression
 - Attractive single row of coils test for improved RMP understanding (n=1,2,&3)
- RWM control – impact of missing control coils on feedback performance

GA

To provide basis to extrapolate high-beta operation to next-step STs

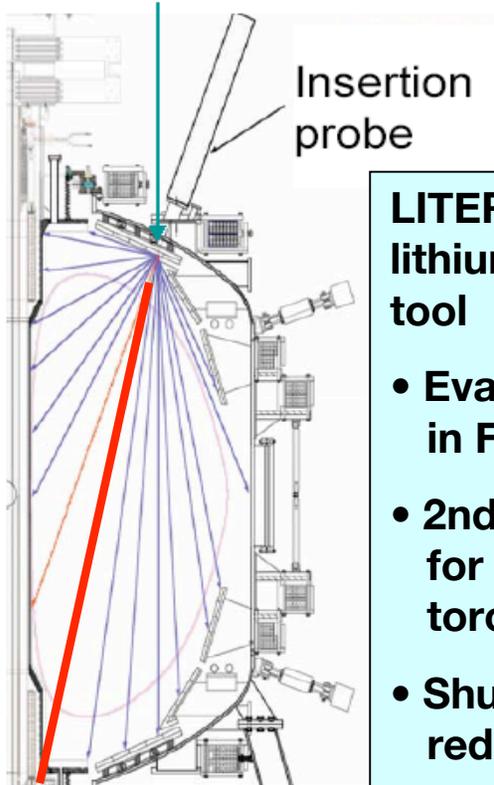
(Ph.D. thesis)

Liquid Lithium Divertor for Particle Control

Unique Capability for Diverted H-mode



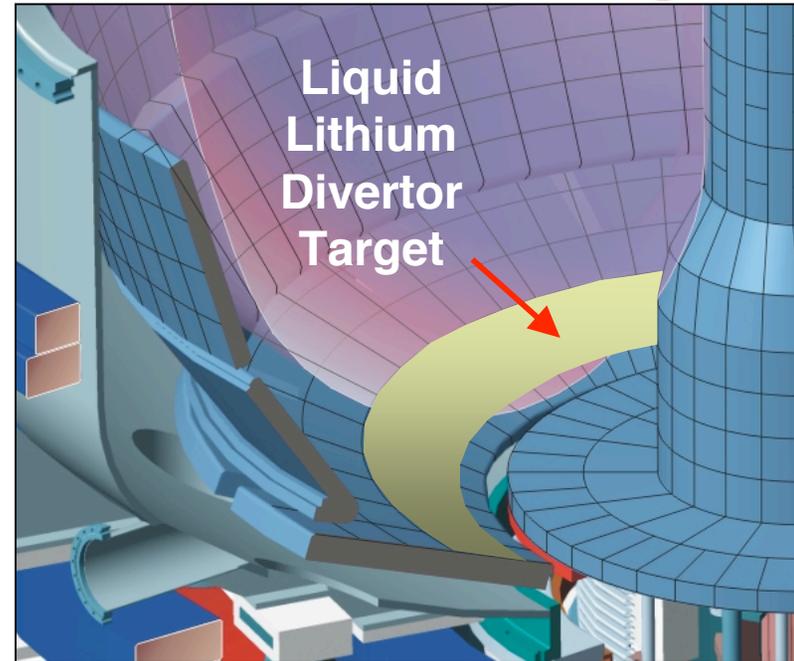
LITER



LITER - a reliable lithium evaporation tool

- Evaporated ~ 100 g in FY07
- 2nd LITER in FY 08 for complete toroidal coverage
- Shutters installed to reduce window coating

The LITER evaporators will be used to provide fresh thin liquid lithium surfaces on the LLD module



Demonstrate particle control in long pulse advanced discharges

FY 09: Install LLD-I - Plates (thin active film to demonstrate pumping)

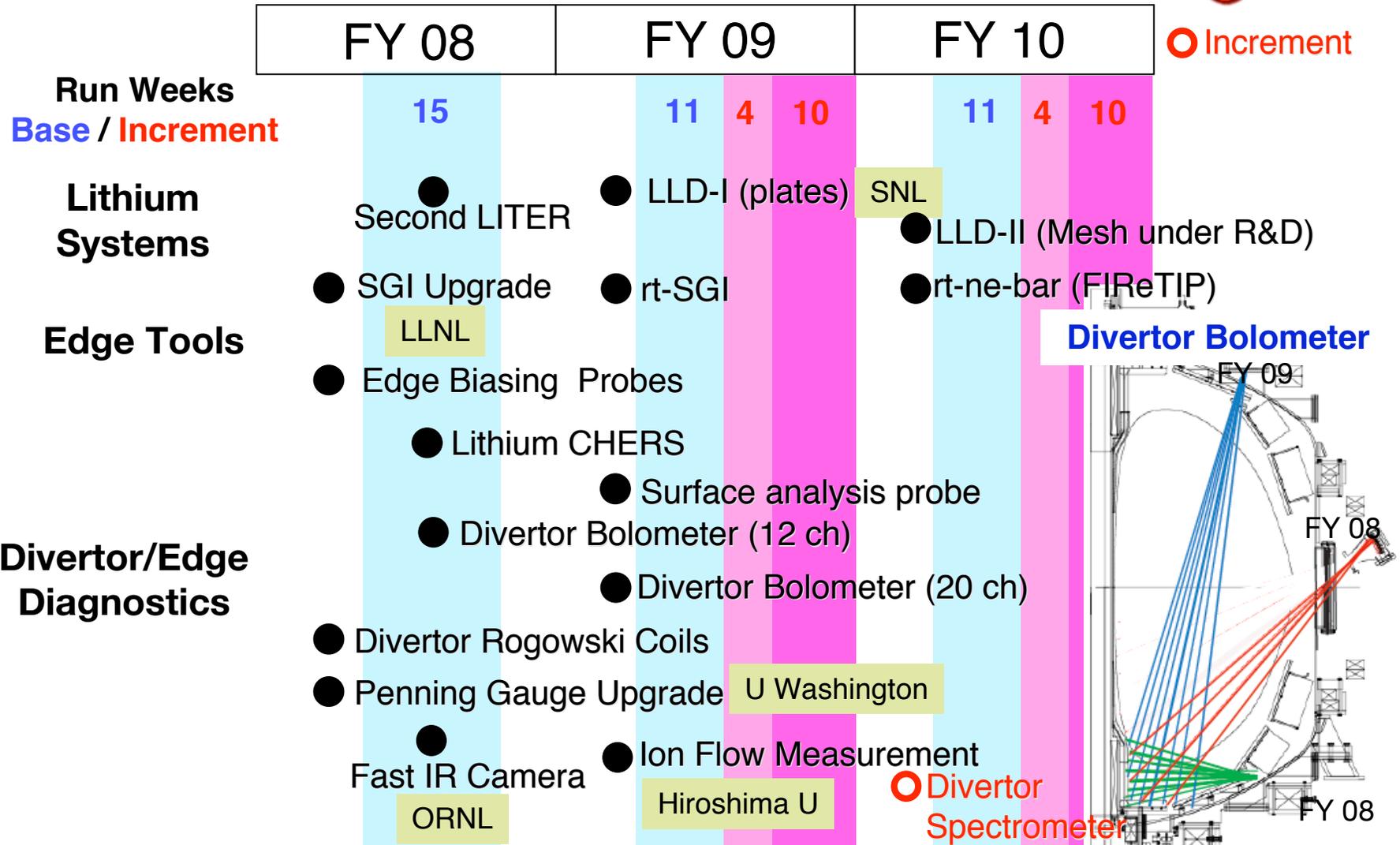
- Operate LLD-I with LITERS in FY09

FY 10: Install LLD-II - TBD - mesh under R&D (thicker film for long pulse)

SNL

Boundary Physics

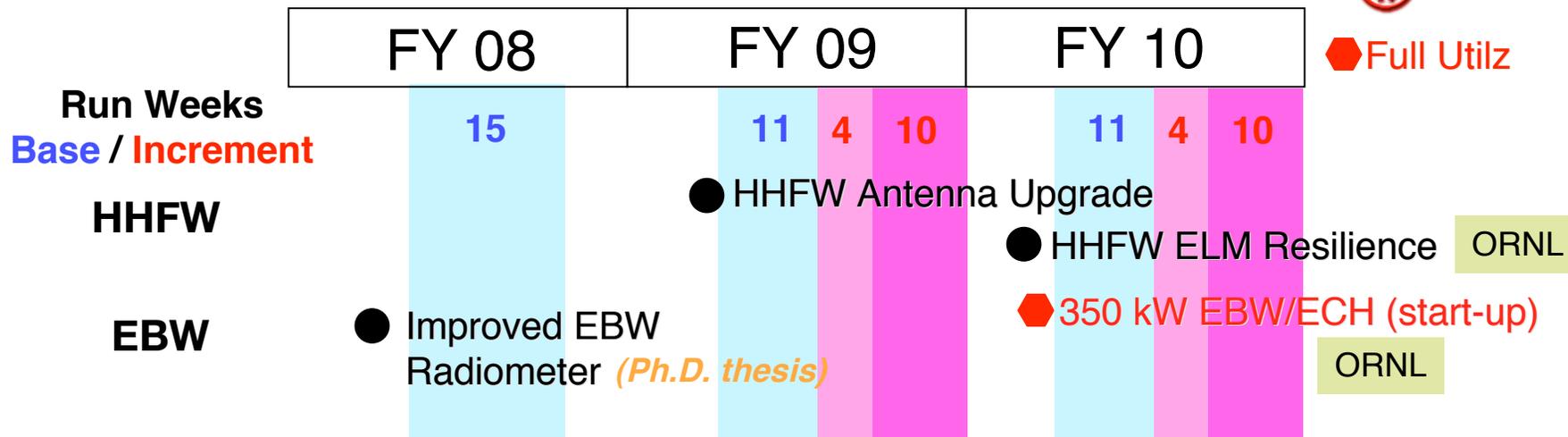
Unique Facility Capability for Divertor Particle Control Using Lithium



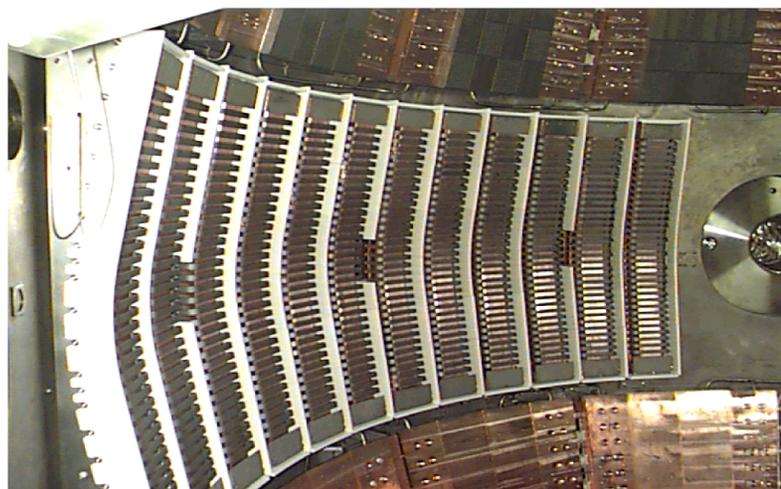
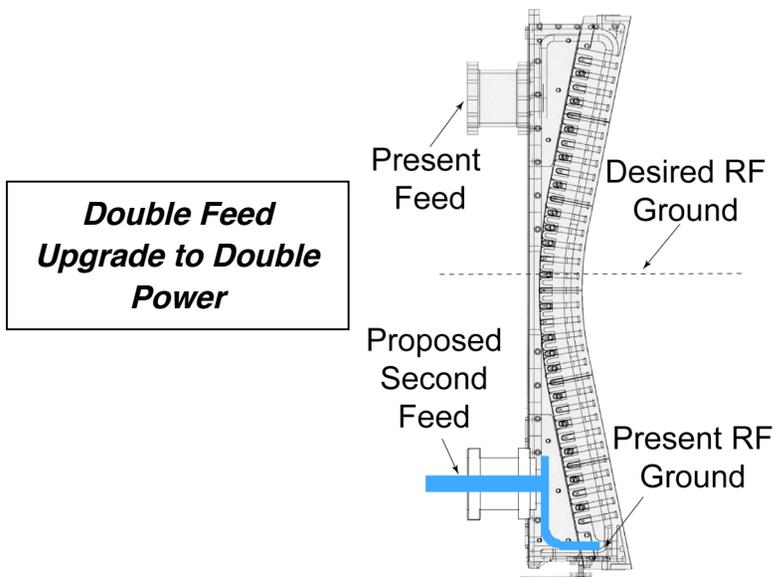
To provide basis for extrapolation of edge heat flux in next-step STs

HHFW and EBW

Improving HHFW Coupling for Advanced Scenarios,
Deepening EBW H-mode Coupling Understanding



HHFW Antenna Upgrade - FY 09



HHFW/ICRF and EBW can provide heating and CD for next-step STs

Energetic Particles

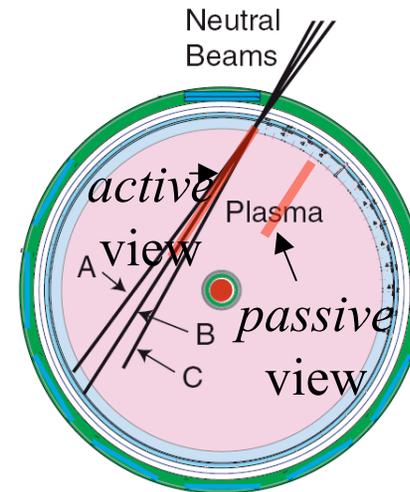
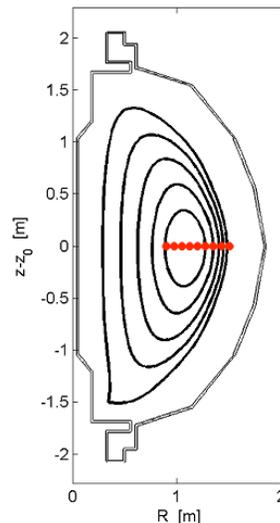
Deepening Fast-Ion Physics Understanding



	FY 08	FY 09	FY 10
Run Weeks			
Base / Increment	15	11 4 10	11 4 10
Energetic Particles	<ul style="list-style-type: none"> ● Fast Ion Dα Camera ● Fast SFLIP ● Fast IR Camera 	UCI	<div style="border: 1px solid black; padding: 5px;"> Other EP Diagnostics: <ul style="list-style-type: none"> ● Scanning NPA, SS-NPA ● MSE-LIF, Neutron detector </div>
Energetic Particle Mode	<ul style="list-style-type: none"> ● FIReTIP (3 MHz) 	UCD	<div style="border: 1px solid black; padding: 5px;"> Other EP Mode Diagnostics: <ul style="list-style-type: none"> ● High-k scattering, μ- Reflectometer ● BES, Magnetic Sensors </div>

FY 08 FIDA
2x16 channels

- Resolution:
- 10keV, 5cm, >5ms

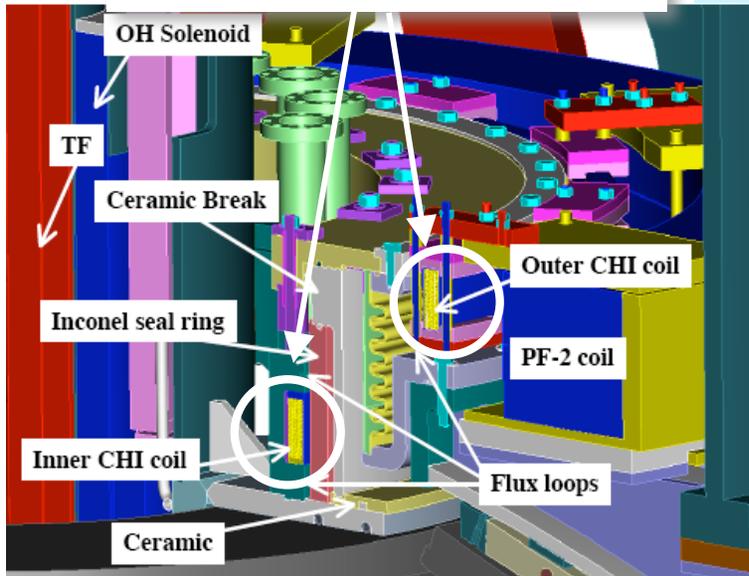
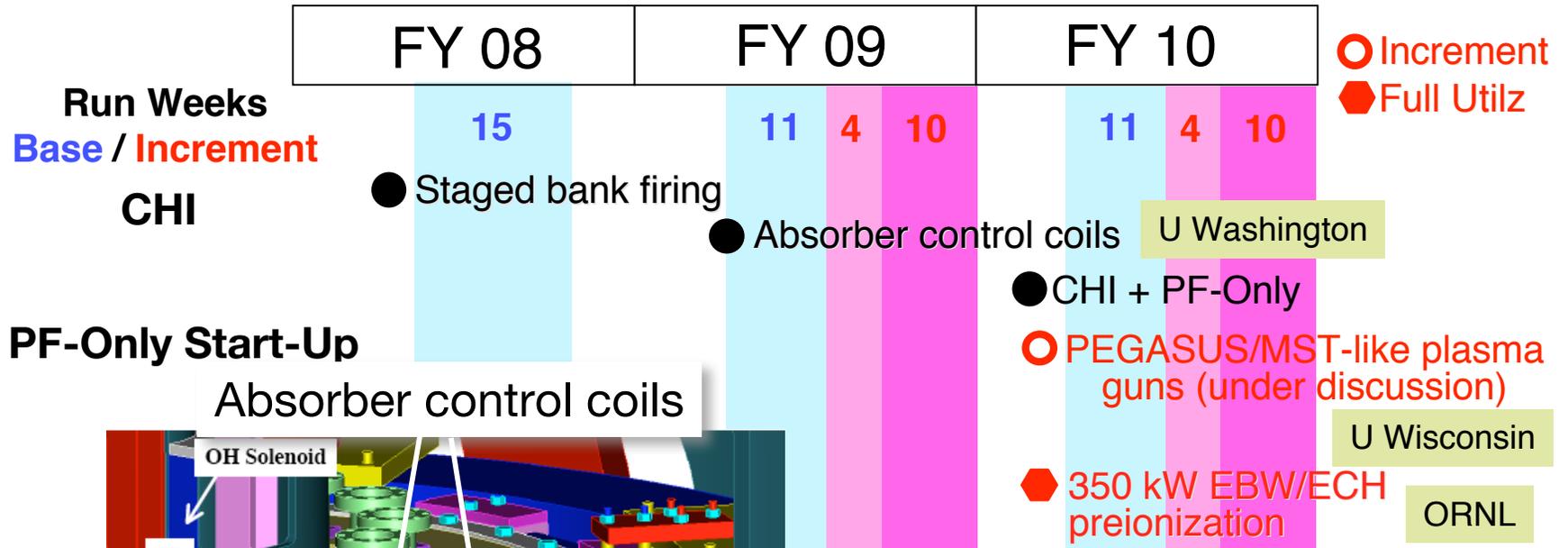


(Ph.D. thesis)

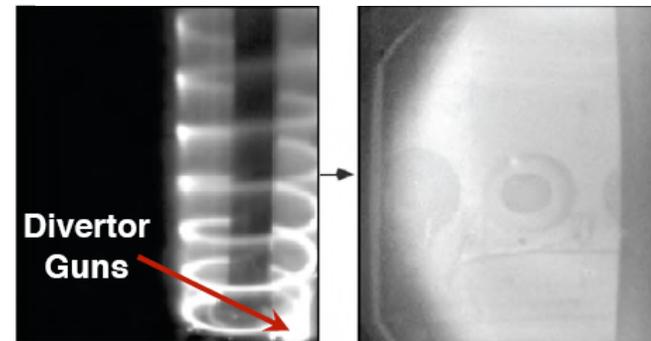
To provide basis for modeling energetic particles in next-step STs

Solenoid-free Start-up

NSTX Well Positioned for Cutting-Edge EF/RWM Research



PEGASUS Gun Start-up



$I_p \sim 30$ kA achieved with one gun

NHTX can test start up techniques so ST-CTF can have slender iron core

Productive Collaborative Research Team



FY 07 was a productive year for NSTX:

- Facility operated reliably with 1,879 good plasma shots (up 15% from FY 06)
- Recent upgrades contributing strongly to scientific productivity
 - High-k scattering for ETG/electron transport physics in B_T scaling, HHFW heated, reversed shear, and ELM-pulse experiments
 - Lithium evaporator for improved electron energy confinement and improve EBW coupling in H-mode
- Presented eight 2007 APS-DPP invited talks and contributed a strong set of IAEA synopses on key research topics
- Educational: 43 post-docs and students

NSTX Research Team

	PPPL	Non-PPPL
Researchers	57	145
Post Doc.	1	10
Grad. Students*	9	12
Undergrad.	1	10

*Twelve Ph.D. Thesis students

NSTX Budget Summary (\$M)



	FY 2008	FY 2009			FY 2010		
Budget cases	Base	Base	Increm	Full Util	Base	Increm	Full Util
Run Weeks	15	11	15	25	11	15	25
Facility Operations	19.7	19.1	20.0	21.8	19.4	20.3	22.2
Facility Upgrades	0.9	0.2	0.7	1.9	0.2	0.5	0.9
Diag. Upgrades	1.5	0.1	0.4	0.8	0.1	0.3	0.7
Facility Total	22.1	19.4	21.1	24.5	19.7	21.1	23.8
PPPL Research	10.3	10.0	10.2	10.4	10.4	10.5	10.7
Collab Diag Interf.	0.5	0.3	0.5	0.5	0.2	0.5	0.7
Collaborations	5.9	5.6	5.8	6.1	5.7	6.1	6.3
Science Total	16.7	15.9	16.5	17.0	16.3	17.1	17.7
NSTX Total	38.8	35.3	37.6	41.5	36.0	38.2	41.5

- 11 run week base cases in FY 09 and 10 assumes very minimal upgrades.
- Requested ~ 17% budget increase to allow full facility utilization (25 run weeks) and acceleration of high priority facility and diagnostic upgrades.

Modest Budget Enhancement Significantly Increases Science Output



Incremental: + ~ 7%

- Increase Operations from 11 to 15 run weeks toward
- Accelerate Key Facility/Diagnostic Upgrades:
 - Plasma gun in FY 10
 - Divertor Spectrometer in FY 09-10
 - High k - θ scattering

Full Utilization : + ~ 17%

- Increase Operations from 11 to 25 run weeks toward
- Accelerate Additional Key Facility/Diagnostic Upgrades:
 - Non-Magnetic RWM-ID
 - MPTS higher spatial resolution in FY 10
 - Install ECH/EBW System 350 kW for pre-ionization and EBW study in FY10
- Improves Facility Reliability and Availability
 - Better Preventive Maintenance and
 - Critical spare parts

10% Budget Cut Case (FY10)



The 10% budget cut case is particularly difficult for NSTX since the base budget is already reduced to provide very little upgrades:

- **50% reduction in runtime (from 11 to 6 weeks)**
- **NSTX staff reduction of ~ 14.5 FTE relative to the base case**
- **Further reduce facility and diagnostic upgrades procurement ~50%**
 - **Delay HHFW ELM resilience**
 - **Defer preventive maintenance**
- **Research progress slowed by ~ 50%**
 - **Focused on transport studies with BES and exploiting liquid lithium divertor.**
 - **Eliminate studies of non-inductive startup and high power RF.**

Exciting Opportunities and Challenges

Optimized Plans Developed for FY 2008 - 2010



- **Very productive FY2007 run with all milestones completed.**
- **FY 2008 run started with timely new capabilities in January**
 - Two LITERS, RMP for $n=1,2,&3$, SGI, new real-time control,
 - Two view divertor bolometer, FIDA, 70 ch p-CHERS, div. halo current
 - Improved high-k, FReTIP, MPTS, USXR, Reflectometer
- **Facility upgrades to support exciting FY 2009-2010 research plan to address next step ST device design issues**
 - Liquid lithium divertor target (Boundary) in FY 09-10
 - HHFW antenna upgrades for H-mode (Waves) in FY 09
 - BES to complement high-k (T&T, EP) FY 09-10
 - MSE-LIF to complement MSE-CIF (MHD, T&T, EP) FY 09-10
 - Three view Divertor Bolometer (Boundary) FY 09
- **Incremental budget greatly enhances science output**
 - Increase the run weeks from 11 to 15 and 25 (full utilization)
 - Plasma Gun and EBW/ECH (Solenoid-free Start-up) FY 10
 - Accelerate High- $k\theta$, MPTS upgrades, Divertor Spectrometer

Backup

Not Running FY 10 Devastating for FY 08 - 10 Plan



FY 10 Run likely to be the most scientifically productive due to implementation and maturing of key advanced diagnostics critically needed to enable extrapolation to Next Step STs:

- **Not able to utilize BES and High- k_{θ} to measure full k-spectrum of turbulence for electron / ion transport studies.**
- **Not able to utilize MSE-LIF for E_r and total pressure profile measurements for complete plasma profiles and to support energetic particle studies.**
- **Not able to test LLD-II and density feedback for long-pulse particle pumping for advanced operations.**
- **Not able to implement HHFW ELM Resilience upgrade needed for robust heating and CD in H-mode.**
- **Not able to test CHI + PF-Only start-up.**
- **Not able to implement Plasma Gun for start-up study**