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NSTX

NSTX Project

Facility Operations, Upgrades and Budget Plans

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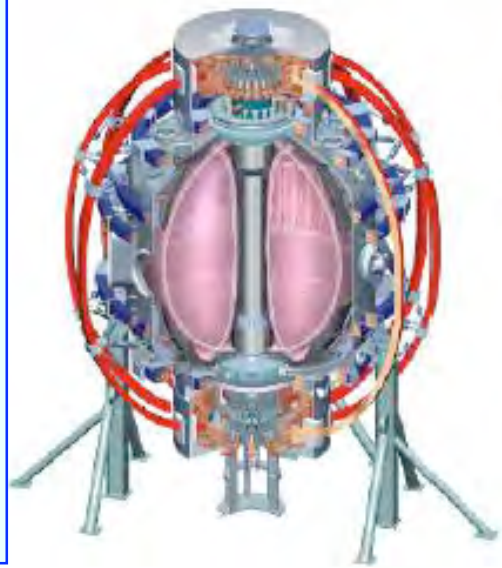
Masayuki Ono
for the NSTX Team

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 for FY 08 Joule milestone
  - 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 - experiments thus far conducted:
  - Vertical stability control, RMP-ELM, NTV, NTM physics to contribute to resolving ITER design issues
  - Momentum transport (FY 08 Joule Milestone) experiments

Transport and Turbulence

Increase and Understand H-mode Confinement at Lower n_e, ν^*

NSTX

	FY 08	FY 09		FY 10		
Run Weeks Base / Increment	15	11	4 10	11	4	10

○ Increment
⬣ Full Utilz

Profile Diagnostics

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

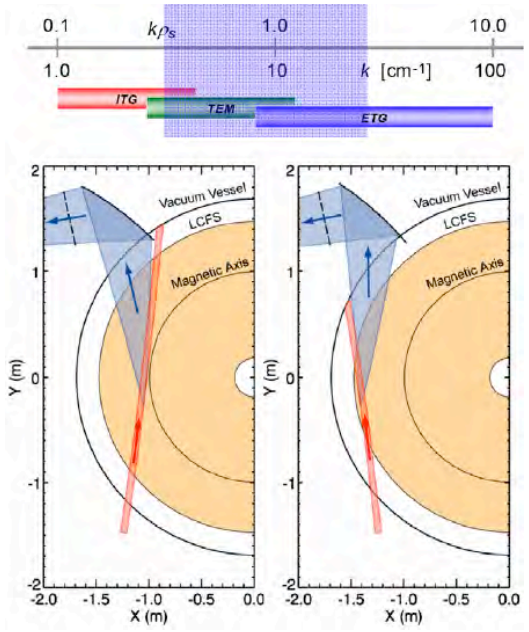
MSE-LIF w/o heating beam
- **Direct reconstruction of total plasma pressure**
- **Radial electric field profiles**

Turbulence Diagnostics

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

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

Tangential High-k Scattering (3 MHz)



UC Davis
(Ph.D. thesis)

To enable extrapolation to next-step STs

Macrostability

Sustain β_N and Understand MHD Near and Above No-Wall Limit

NSTX

FY 08	FY 09	FY 10

Full Utilz

Run Weeks
Base / Increment

15

- Control system upgrade
- Control Coil (n=1,2,&3)

11 4 10

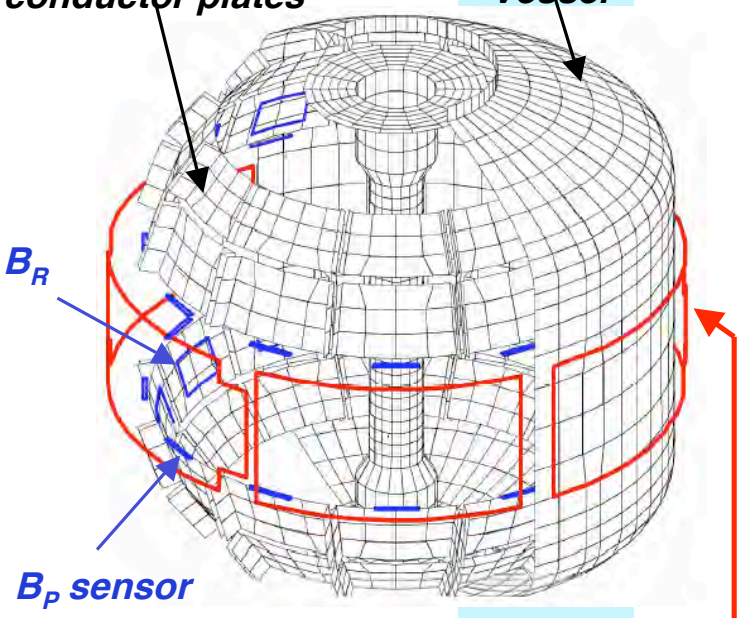
- NBI Feedback

11 4 10

- Non-magnetic RWM-ID — JHU

Copper passive conductor plates

SS Vacuum Vessel



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** — GA
  - **Attractive single row of coils test for improved RMP understanding (n=1,2,&3)**
- **RWM control – impact of missing control coils on feedback performance**

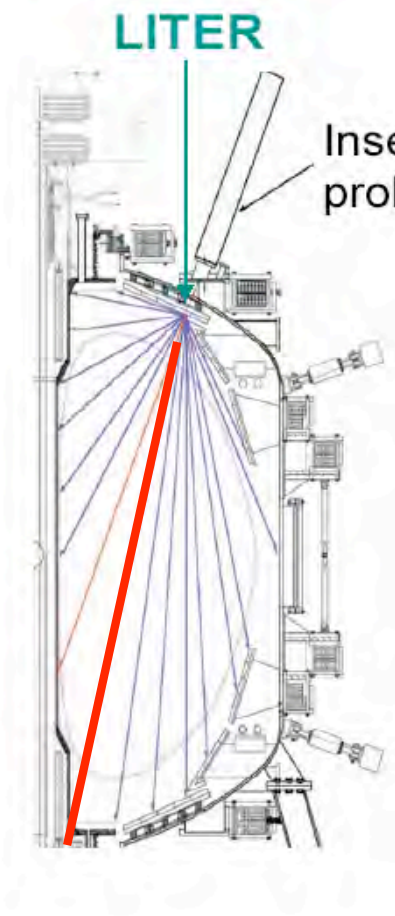
To provide basis to extrapolate high-beta operation to next-step STs

(Ph.D. thesis)

Liquid Lithium Divertor for Particle Control

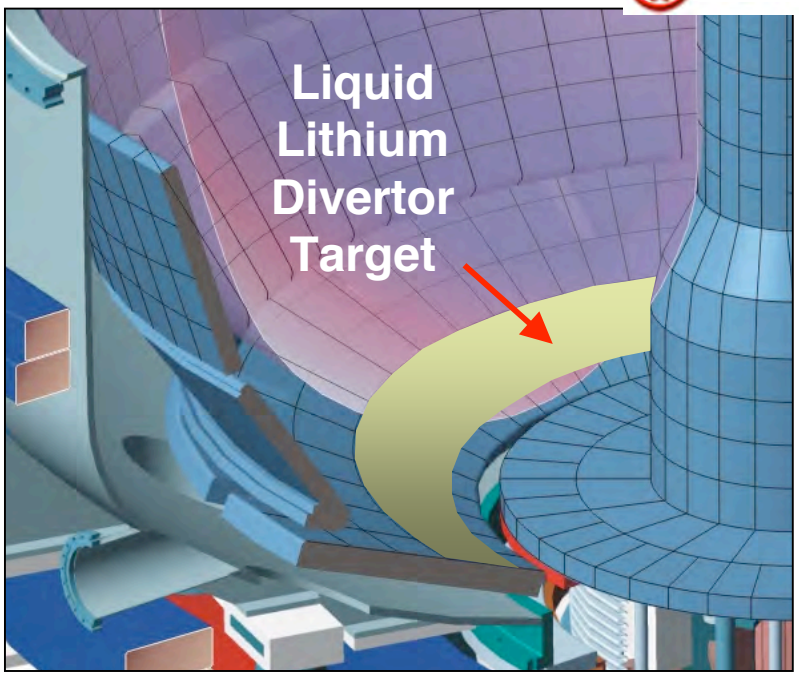
Access to Low Collisionality - High Confinement Regimes

NSTX



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**



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 - Thicker Film for Long-Pulse (mesh under R&D at SNL)

SNL

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

Boundary Physics

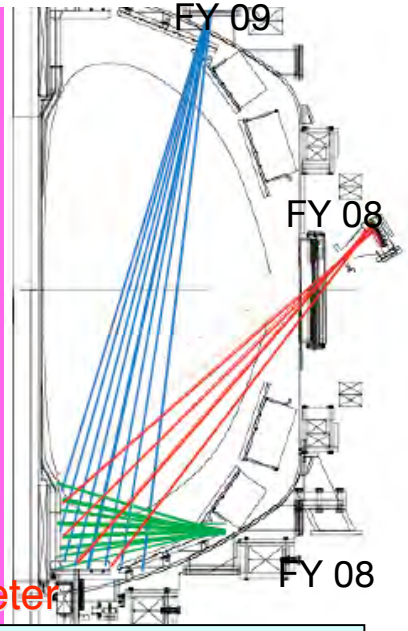
Unique Facility Capability for Divertor Particle Control Using Lithium

NSTX

	FY 08	FY 09	FY 10
Run Weeks Base / Increment	15	11 4 10	11 4 10
Lithium Systems	Second LITER	LLD-I (plates) SNL	LLD-II (Mesh under R&D)
	SGI Upgrade	rt-SGI	rt-ne-bar (FIReTIP)
Edge Tools	LLNL Edge Biasing Probes		
Divertor/Edge Diagnostics	Lithium CHERS	Surface analysis probe	
		Divertor Bolometer (12 ch)	
		Divertor Bolometer (20 ch)	
	Divertor Rogowski Coils		
	Penning Gauge Upgrade	U Washington	
	Fast IR Camera ORNL	Ion Flow Measurement Hiroshima U	Divertor Spectrometer

Increment

Divertor Bolometer



To Support Beam Current Driev, H-mode Confinement, and MHD

HHFW and EBW

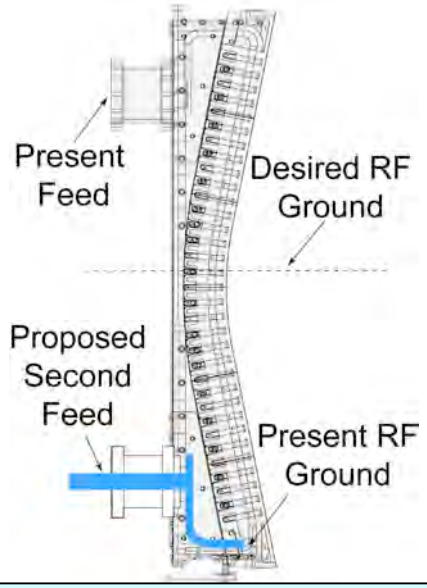
Demonstrate and Understand Non-Inductive Start-up and Ramp-up

NSTX

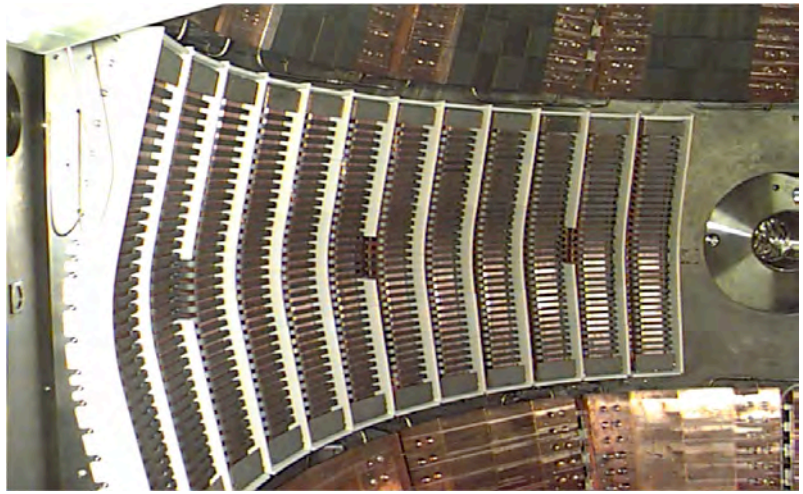
	FY 08	FY 09	FY 10
Run Weeks Base / Increment	15	11 4 10	11 4 10
HHFW		HHFW Antenna Upgrade	HHFW ELM Resilience (ORNL)
EBW	Improved EBW Radiometer *(Ph.D. thesis)*		350 kW EBW/ECH (start-up) (ORNL)

Full Utilz

Double Feed Upgrade to Double Power



HHFW Antenna Upgrade - FY 09



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

Energetic Particles

Increase and Understand Beam-Driven Current at Lower n_e, ν^*

NSTX

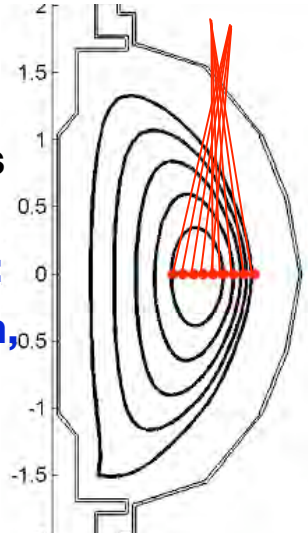
	FY 08	FY 09	FY 10
Run Weeks Base / Increment	15	11 4 10	11 4 10
Energetic Particles	● Fast Ion Dα Camera	UCI	
	● Fast SFLIP		
	● Fast IR Camera		
Energetic Particle Mode	● FIReTIP (3 MHz)	UCD	

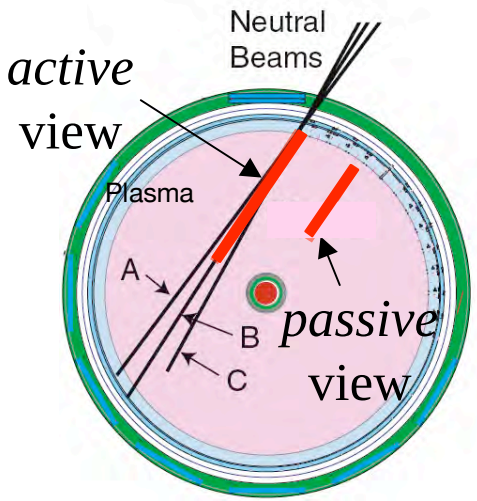
Other EP Diagnostics:
- **Scanning NPA, SS-NPA**
- **MSE-LIF, Neutron detector**

Other EP Mode Diagnostics:
- **High-k scattering, μ– Reflectometer**
- **BES, Magnetic Sensors**

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

Demonstrate and Understand Non-Inductive Start-up

NSTX

	FY 08	FY 09			FY 10		
Run Weeks							
Base / Increment	15	11	4	10	11	4	10
CHI							
● Staged bank firing							
● Absorber control coils							
● CHI + PF-Only							
PF-Only Start-Up							
○ PEGASUS/MST-like plasma guns (under discussion)							
⬢ 350 kW EBW/ECH preionization							

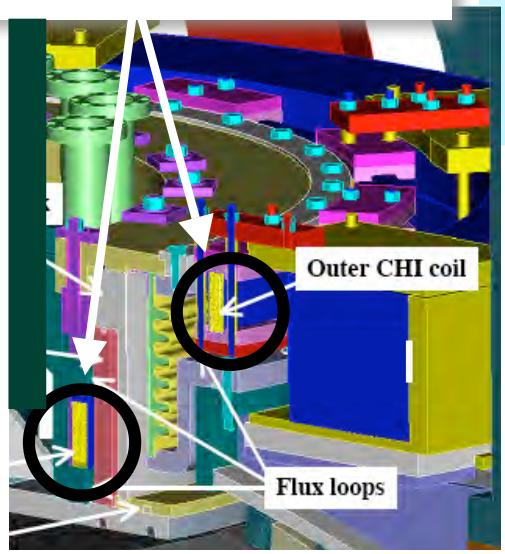
○ Increment
⬢ Full Utilz

U Washington

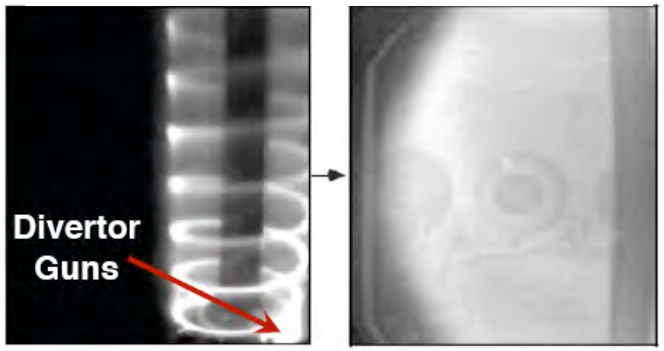
U Wisconsin

ORNL

Absorber control coils



PEGASUS Gun Start-up



Ip ~ 30 kA achieved with one gun

May allow elimination of even slender iron core in ST-CTF

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**

Slide 8

- 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

NSTX

Incremental: + ~ 7%

- Increase operations from 11 to 15 run weeks
- Accelerate key facility/diagnostic upgrades:
  - Plasma gun for start-up in FY 10
  - Divertor Spectrometer to support LLD in FY 09-10
  - High k-θ scattering for improve tubulence measurement in FY 10

Full Utilization : + ~ 17%

- Increase operations from 11 to 25 run weeks
- Accelerate additional key facility/diagnostic upgrades:
  - Non-Magnetic RWM-ID for long-pulse ST-CTF/ITER in FY 10
  - MPTS higher spatial resolution in FY 10
  - Install ECH/EBW System 350 kW for start-up and EBW study in FY10
- Improve facility reliability / availability to achieve full utilization
  - Critical spare parts on hand

10% Budget Cut Case (FY10)

NSTX

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 FTE (15 %) relative to the base case
- Further reduce facility and diagnostic upgrades procurement ~50%
  - Eliminate HHFW ELM resilience hardware
  - Cut preventive maintenance (increase risk)
- 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

NSTX

- 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, FIReTIP, 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)
  - Accelerate key facility and diagnostic upgrades commensurate with increased pace of research