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NSTX

Update meeting for NSTX 5 year plan for FY2009-13

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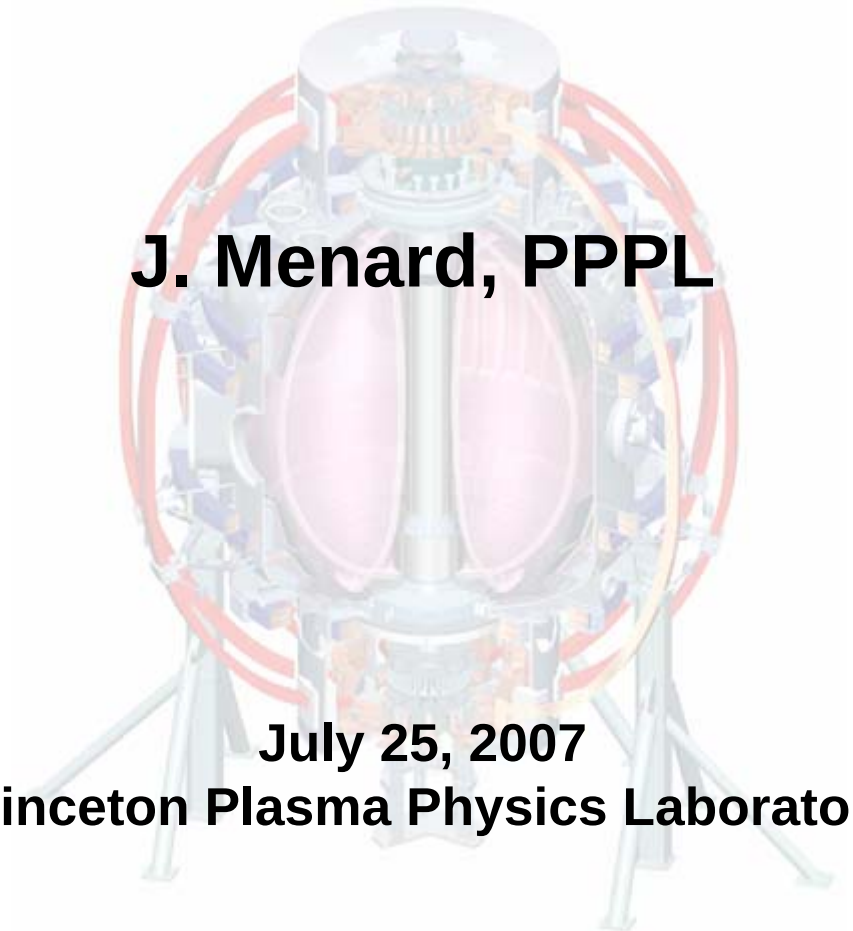

J. Menard, PPPL

July 25, 2007
Princeton Plasma Physics Laboratory

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
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ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Agenda

- Discussion of September workshop
  - Agenda
  - Coordinators, and their responsibilities
    - NSTX coordinators should be proactive in their topical area
    - Gates and Fredrickson will be offered up as 2 leaders
      - Perhaps we can discuss a third…
  - Facilitators, and their responsibilities

- Discussion of 5 year plan
  - Schedule
  - Outline status
  - High-level outline issues
  - Discussion

July 19, 2007

NSTX, C-mod, and DIII-D National Tokamak Planning Workshop
MIT September 17-19, 2007
Agenda

Monday

10 am OFES Perspective

Overview of Tokamak Facility Plans (30min presentation, 5min questions)

10:15 am C-Mod 5- year Plan Overview:E. Marmar
10:50 am DIII-D 5 year Plan Overview: M. Wade
11:25 am NSTX 5-year Plan Overview: M. Ono
12:00 pm *Lunch*

Topical Area Coordination Discussions:

Topical Area contents as outlined in FESAC Priorities Subpanel Report on *"Scientific Challenges, Opportunities, and Priorities for the U.S. Fusion Energy Sciences Program,"* except where noted.
http://www.ofes.fusion.doe.gov/more_html/FESAC/PP_Rpt_Apr05R.pdf

Speakers and Discussion Facilitators are noted.

Integrated Scenario Research

1:15 pm Facility plans (DIII-D: Luce, C-mod: Hubbard, NSTX: Menard)
(15 min presentations, 5 min for clarifying questions)
2:15 pm Summary of preliminary coordination activities (15 min presentation)
(J. Ferron, S. Wolfe, D. Gates)
2:30 pm Discussion: Integrated Scenario Research Plans
(C. Kessel, H. Zohm)
4:30 pm *Break*

Multi-scale Transport Physics Research

(*includes pedestal scaling, L-H transition, and internal barriers)*

4:45 pm Facility plans (C-mod: Greenwald, NSTX: Kaye, DIII-D: Burrell)
(15 min presentations, 5 min for clarifying questions)
5:45 pm Summary of preliminary coordination activities (15 min presentation)
(S. Scott, D. Mikkelson, E. Doyle)
6:00 pm Discussion: Multi-scale Transport Physics Research Plans
(P. Terry, W. Dorland)
7:45 pm *Adjourn*

Tuesday

Macroscopic Plasma Physics Research
(*includes disruption avoidance and mitigation)*

9:30 am Facility plans (NSTX: Sabbagh, DIII-D: Strait, C-mod: Granetz)
(15 min presentations, 5 min for clarifying questions)
10:30 am Summary of preliminary coordination activities (15 min presentation)
(S. Gerhardt, A. Garofalo, I. Hutchinson)
10:45 am Discussion: Macroscopic Plasma Physics Research Plans
(C. Hegna, R. Buttery) (*break included)*
12:15 pm *Lunch*

Research on Waves and Energetic Particles

1:15 pm Facility plans (NSTX: Taylor, C-mod: Wukitch, DIII-D: Nazikian)
(15 min presentations, 5 min for clarifying questions)
2:15 pm Summary of preliminary coordination activities (15 min presentation)
(E. Fredrickson, P. Bonoli, R. Prater)
2:30 pm Discussion: Research Plans for Waves and Energetic Particles
(W. Heidbrink, C. Philips)
4:15 pm *Break*

Research on Plasma Boundary Interfaces
(*includes ELM control such as pellet pacing and RMP)*

4:30 pm Facility plans (C-mod: Lipschultz, DIII-D: Allen, NSTX: Maingi)
(15 min presentations, 5 min for clarifying questions)
5:30 pm Summary of preliminary coordination activities (15 min presentation)
(D. Whyte, P. West, V. Soukhanovskii)
5:45 pm Discussion: Plasma Boundary Interfaces Research Plans
(T. Rognlien, R. Nygren)
7:30 pm *Adjourn*

Wednesday

Summary Reports of Discussions
(15 min presentations, 5 min for questions)

9:30 am Macroscopic Plasma Physics Research (C. Hegna, R. Buttery)
9:50 am Waves and Energetic Particles (W. Heidbrink, C. Philips)
10:10 am Integrated Scenario Research (C. Kessel, H. Zohm)
10:30 am *Break*
10:45 am Plasma Boundary Interfaces (T. Rognlien, R. Nygren)
11:05 am Multi-scale Transport Physics Research (P. Terry, W. Dorland)
11:25 am *Adjourn*

Tokamak Planning Workshop

Science Area	Facility Plan Presentations	Preliminary Coordination	Topical External Facilitators
Program Overview	Marmar (C-mod) Wade (DIII-D) Ono (NSTX)		
Integrated Scenario Research	Hubbard (C-mod) Luce (DIII-D) Menard (NSTX)	Wolfe (C-mod) Ferron (DIII-D) Gates (NSTX)	C. Kessel, G. Sips
Waves and Energetic Particles	Wukitch(C-mod) Nazikian (DIII-D) G. Taylor (NSTX)	Bonoli (C-mod) Prater (DIII-D) Fredrickson (NSTX)	W. Heidbrink, C. Phillips
Macroscopic Research (MHD)	Granetz (C-mod) Strait (DIII-D) Sabbagh (NSTX)	Hutchinson (C-mod) Garofalo (DIII-D) S. Gerhardt (NSTX)	C. Hegna, R. Buttery
Multi-scale Transport Research	Greenwald (C-mod) Burrell (DIII-D) Kaye (NSTX)	S. Scott (C-mod) Doyle (DIII-D) Mikkelson (NSTX)	P. Terry, W. Dorland,
Plasma Boundary Interfaces	Lipschultz (C-mod) Allen (DIII-D) Maingi (NSTX)	Whyte (C-mod) West (DIII-D) Soukhanovskii (NSTX)	T. Rognlien, R. Nygren

Facility Coordinators

(Teams of three, one from each facility)

Deliverables for each area

1. Prior to the Workshop (9/10/2007) produce a 4-5 page paper. Paper should:
   a. Define appropriate subtopics (themes) for coordinated research in their area among the three facilities. Can be joint experiments or complementary experiments followed by integration activies.
   b. Discuss what resources (facility diagnostics, hardware, or analysis capabilities) are involved
   c. Discuss what can be learned (expected outcome of coordinated research)

2. At the Workshop:
   Present summary of writeup in a 15min talk at the Workshop

3. After the Workshop:
   a. Adjust plan based on results of Workshop discussions.
   b. Submit revised plan by October 5, 2007.

Facility Coordinators should communicate with their two counterparts prior to the Workshop to develop plans, divide up work, and prepare their workshop presentation (only one speaker at the Workshop please).

Example page of coordination summary from 3 machines from 2004 coordination activity (E. Synakowski, et al.)

NSTX

Transport Physics (Core)

Research Topic	Specific Coordinated Joint Experiments	Complementary Research Activities	Additional Comments
Thermal transport: underlying physics (turbulence)		**C-Mod:** Upgraded diagnostics (phase contrast imaging) emphasize high k turbulence measurements. Study with direct electron heating (LH) and indirect (ICRF and ion-electron coupling). **DIII-D:** Initial high k turbulence diagnostics deployed for 2004. ECH a tool for ECE for time-dependent analysis. Several run days planned. **NSTX:** Low k turbulence measurements in 2004 into confinement zone. Theory indicates controllable low and high k with NBI and HHFW. High k scattering for 2005	**High relevance to ITER and for predicting beyond it:** Confinement a determining factor in device size requirements. Electron thermal transport identified as a community-wide issue that requires a broad attack. **Complementary physics:** Three devices span electrostatic (DIII-D, C-Mod, NSTX) to electromagnetic (NSTX, $\beta \sim 1$) turbulence realms, allowing tests of gyrokinetic turbulence theory. - NSTX: Merger of thermal and Alfvén velocities with high beta, low B. Theory suggests possible AE damping on ions.
Thermal transport: ITER-like conditions: High performance with $T_e \sim T_i$ (ITPA)		A C-Mod programmatic focus. DIII-D is planning two experiments this year with $T_e \sim T_i$, one in the hybrid scenario, the other in the steady-state scenario.	**Immediate ITER relevance:** Due to high density conditions in C-Mod and expected in ITER. DIII-D, NSTX approach this with combined NBI and wave heating of electrons
Aspect ratio dependence of core confinement (ITPA)	Run time allotted for joint experiment with NSTX and DIII-D in 2004		**NSTX, DIII-D devices ideally suited for cross-comparison:** Poloidal cross sectional shape and size can be matched. Match β_p, but with varying total beta. Same beam heating configuration.
Beta dependence of core confinement (ITPA)		All three programs contribute to database to assess beta dependence of confinement scalings. Of note are recent JET-DIII-D beta scaling experiments.	**ITER relevance high:** Work is aimed at clarifying apparent beta degradation of confinement implicit in some scaling expressions.

Discussion Facilitators

(Two for each area)

Deliverables for each area

1. Prior to the Workshop:
   a. Read the draft coordination plans for their area supplied on Sept 10th by the three facility coordinators.
   b. Prepare brief comments on the coordination plans
   c. Communicate with their co-facilitator on how to organize their discussion time and how they will summarize the discussion during the last session of the Workshop.

2. At the Workshop:
   a. Open the discussion with brief comments on the plan, highlighting what they think are key issues for discussion.
   b. Facilitate the discussion
   c. Present a 15-20 min summary of their discussion, with any suggestions for improving plans. Answer questions (30 min total for summary + Q&A for each topical area)

3. After the Workshop:
   Be available for follow-up Q&A discussion (telephone or e-mail) with program representatives.

Near-term schedule for FY09-13 NSTX 5 Year Plan

We are here

- July 6, 2007 — Budget and upgrade option guidelines issued
- July 13 — Detailed 8-12 page outlines of chapters due
- July 25 — Meet to discuss integrated outlines, and get interim report on chapter writing progress
- July-Aug — Work with fellow coordinators to develop list of possible coordinated research ideas

- August 10 — Draft text of chapters due, circulate to all writers
- August 11-17 — Revise chapters to include coordinated research
- August 17 — Discussion of integrated draft text
- August 20-31 — Edit/revise draft text, circulate for comment

- September 3-7 — Finalize coordination plans with other facilities
- September 7 — Final draft 5 yr plan text due
- September 5-12 — Workshop presentation dry-runs
- September 17-19 — Tokamak Planning Workshop at MIT

Long-term schedule for FY09-13 NSTX 5 Year Plan

- **September 17-19** — **Tokamak Planning Workshop at MIT**
- **Oct. – Dec. 2007** — **Improve the draft plan**
- **January 2008** — **NSTX PAC reviews the draft plan**
- **February 2008** — **Final draft plan ready for review by the team**
- **April 1, 2008** — **Final plan (document) ready**
- **3 wks before review** — **Draft presentation material ready**
- **2 wks before review** — **Dry run of the presentation**
- **1 wk before review** — **Final presentation material ready**
- **~ May 2008 (TBD)** — **New 5 Year Plan Review meeting**

Five Year Plan Write-up Responsibilities

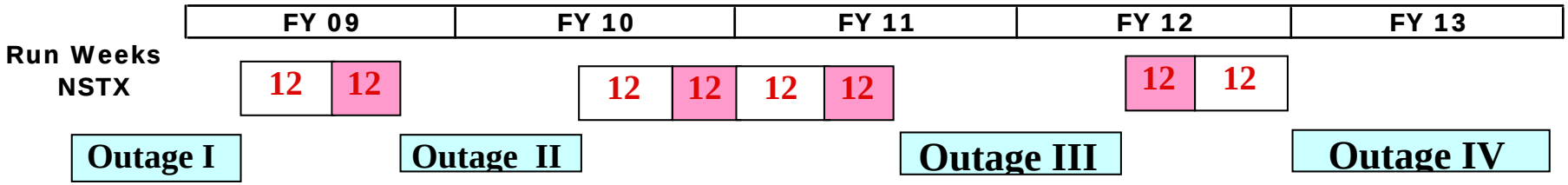
		Lead	Inputs
Chapter 1	Overview/Introduction	M. Ono	J. Menard, S. Kaye, M. Bell, M. Peng
Chapter 2	MHD	S. Sabbagh	J. Menard, D. Gates, J. Manickam
Chapter 3	T&T	S. Kaye	M. Bell, K. Tritz, T.S. Hahm
Chapter 4	Waves & Particles	G. Taylor	J. Hosea, C.K. Phillips, N. Gorelenkov, E. Fredrickson
Chapter 5	Boundary	R. Maingi	H. Kugel, V. Soukhanovskii, R. Majeski, R. Kaita, C. Skinner, D. Stotler
Chapter 6	Integration	J. Menard	C. Kessel, S. Kaye, D. Gates, R. Raman
Chapter 7	NSTX and fusion development	M. Peng	J. Menard, S. Kaye, C. Neumeyer
Chapter 8	Facility/Diagnostics/Control	M. Bell	M. Ono, R. Kaita, C. Neumeyer, B. Stratton, D. Gates
Appendix	NSTX Collaboration Plan	M. Peng	Collaboration Leaders

*Start-up is included in T&T and Integration

Perspectives to include in plan chapters

- Importance to plasma science - comparison to theory & implications
- Importance to burning plasma research = ITER
  - NSTX should recognize, benefit from, influence ITER
- Importance to ST-development: NHTX, ST-CTF, ARIES-ST
    - NHTX info: http://nstx.pppl.gov/DragNDrop/Five%20Year%20Plan%20(FY09-13)/NHTX%20information/
- Expect more emphasis on boundary physics in next 5 years
  - Important in its own right + NHTX relevance
- Make links to new diagnostic requirements/availability
- Emphasize implications of new capabilities
  - Assumes 20-25% increment

NSTX Request Plan (in FY09$) ~ 25% increase



Possible Boundary Joule Milestone

FY 09 Research

Tool Developments for NI advanced regimes:

- Liquid Lithium Divertor
  - Particle control
  - Assess heat control
- EBW heating (200 kW)
  - EBW core heating
- HHFW heating and CD
  - H-mode
  - Start-up an ramp-up
- Solenoid-free start-up
  - CHI absorber null control
  - Plasma gun / PF-only
  - EBW/HHFW assist

FY 10 - 11 Research

Optimization of NI NHTX/CTF relevant regimes

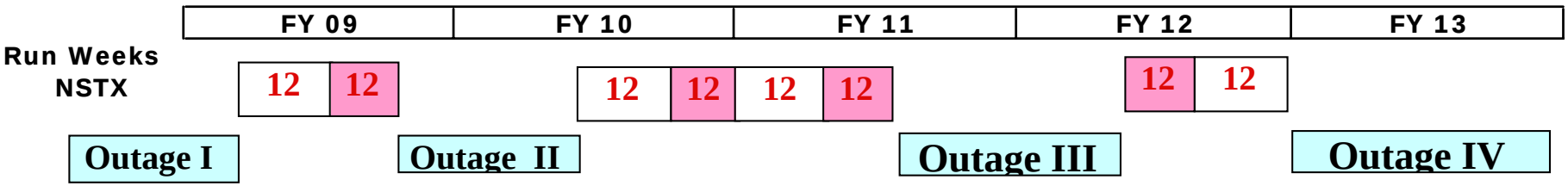
- NBI optimization
  - Assess CD vs radius
  - Assess overall performance vs radius
- Plasma performance with extended pulse length
- Solenoid-free start-up

FY 12 - 13 Research

Demonstration of Long-pulse NI NHTX/CTF relevant regimes

- PFC/Divertor upgrade to handle second NBI for long pulse
- EBW CD (2 MW)
- ELM suppression physics + advanced RWM/EF control

NSTX Request Plan (in FY09$) ~ 25% increase



Outage I Upgrades:
- Liquid Lithium Divertor
- ECH/EBW (200 kW)
- HHFW antenna upgrade
- CHI Absorber null control
- Plasma gun?
- Full P-CHERS
- Real time CHERS
- BES?
- Divertor bolometer
- Fast IR Camera
- Addition 5 ch MPTS

Outage II Upgrades:
- Second NBI (6 MW)
- TF/OH Sub-cooling
- Sol.-free start-up
  - Demonstrate coupling to HHFW and EC/EBW
- Advanced fueling
- MPTS Upgrade
- Divertor Diagnostics

Outage III Upgrades:
- PFC/Divertor upgrade to handle long-pulse
- ECH/EBW (2 MW)
- Divertor Thomson
- Internal RMP/RWM coils

Outage I	Outage II	Outage III
FY 09 budget	FY 09 - 10 budget	FY 11 - 12 budget
$1 M	$13 M	$14 M

Some general guidelines for chapter structure

- Topical chapters of previous 5-yr plan were 30-35 pages
  - Aim for similar length for this 5 year plan
- See last plan for format/structure
- Outline of topical chapters:
  - Overview of chapter – approx 1 page
  - Summarize recent results and new understanding, highlight diagnostics
    - Focus on how results motivate new research in FY09-13 plan
  - State plans for each subtopic of your topical area – 1-2 pages
    - Overall goal of subtopic research plan in 1 sentence
    - Breakdown plan for subtopic in 1-2 year increments – physics, measurements, new capabilities, deliverables
  - Summary – 1 bullet/sentence for each subtopic
  - Graphical timeline of research plan – physics on top, tools on bottom

- DRAFT CHAPTER TEXT due on **August 10, 2007**

The following pages highlight some “high level” issues/comments derived from outlines thus far

Boundary

- Little discussion of L→ H transition physics
  - We have poloidal CHERS and KC Lee's work – can we do more?
- Emphasize ELM stability calcs at low-A, strong shaping, low collisionality, flow/flow-shear more?
  - ELITE + 3D non-linear ELM calcs using M3D/NIMROD?
  - What additional diagnostics are needed for this?
  - Important for understanding how RMP coils impact ELM stability
- What is physical mechanism by which RMP modifies ELMs?
  - Does LITER/LLD offer new insight on density pump-out with RMP?
  - What additional diagnostics might we need to investigate this?

Transport

- Little discussion of role of fast-ion redistribution in interpretation of thermal and/or momentum diffusivities
  - Is this relevant? Need to deal with coupling between EP chapter and transport chapter, if there is coupling…
- ASDEX claims electrostatic turbulence plays a role in fast-ion redistribution/loss for off-axis current drive
  - Can we contribute to this physics with NBI at larger RTAN + our existing and upgraded fluctuation diagnostics?
- Is this better place to put L→H transition physics?

Waves and energetic particles

- Need better justification for HHFW for advanced scenarios
  - Can now heat during NBI at higher BT – can we use this during IP ramp to elevate q?
  - Need simulations of this
- EBW CD shown for target plasma with 40% beta.
  - Need to update this for lower density, 20% beta scenarios in NSTX that extrapolate to CTF/NHTX
  - How much off-axis CD can we get w/ planned 1MW, 28GHz system?
- Can we develop predictive capability for fast-ion redistribution and loss rates for multi-modes using M3D or other?
- *"Exciter and detection system"* for CAE using RMP coils is unrealistic since coils will likely reside behind plates

MHD

- If we implement real-time beta control, can we use real-time spectroscopy to determine ideal stability boundary, and operate just below it?
  - Or can we develop disruption prediction capability
- Emphasize better expt. and theory support for core MHD/TM in advanced scenarios – FY07 highlights importance of such modes at high q_{min}
- Is RMP compatible w/ sustained operation above no-wall limit?
- Need integrated analysis of usage of internal RMP coils
  - ELM stability
  - NTV damping from RMP fields
  - RWM stability with reduced rotation from RMP fields
  - EF control with internal coils
- Impact of disruptions on liquid lithium surface – expt. + theory

Plasma control

- Need to prepare for real-time density measurement and feedback control in prep for successful LLD pumping
  - Need efficient fueling source - (SGI?) under feedback control
- Strike point and beta control next highest priorities?
- Implement “soft-landing” at end of shot?
  - Can we detect when OH flux is nearly completely consumed, then have controlled IP ramp-down (no disruption)
  - May be important for LLD operation and D retention studies
- Enhance shape control to control more moments – off-diagonal control matrix for divertor coil currents?
  - Does squareness control matter for ELM/pedestal control?
- Non-magnetic sensors for shape and RWM/EF control?