FIRE

Burning Plasma Physics Program

Research Proposal for FY- 05/06

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VLT PAC Meeting
UCSD
March 2, 2003

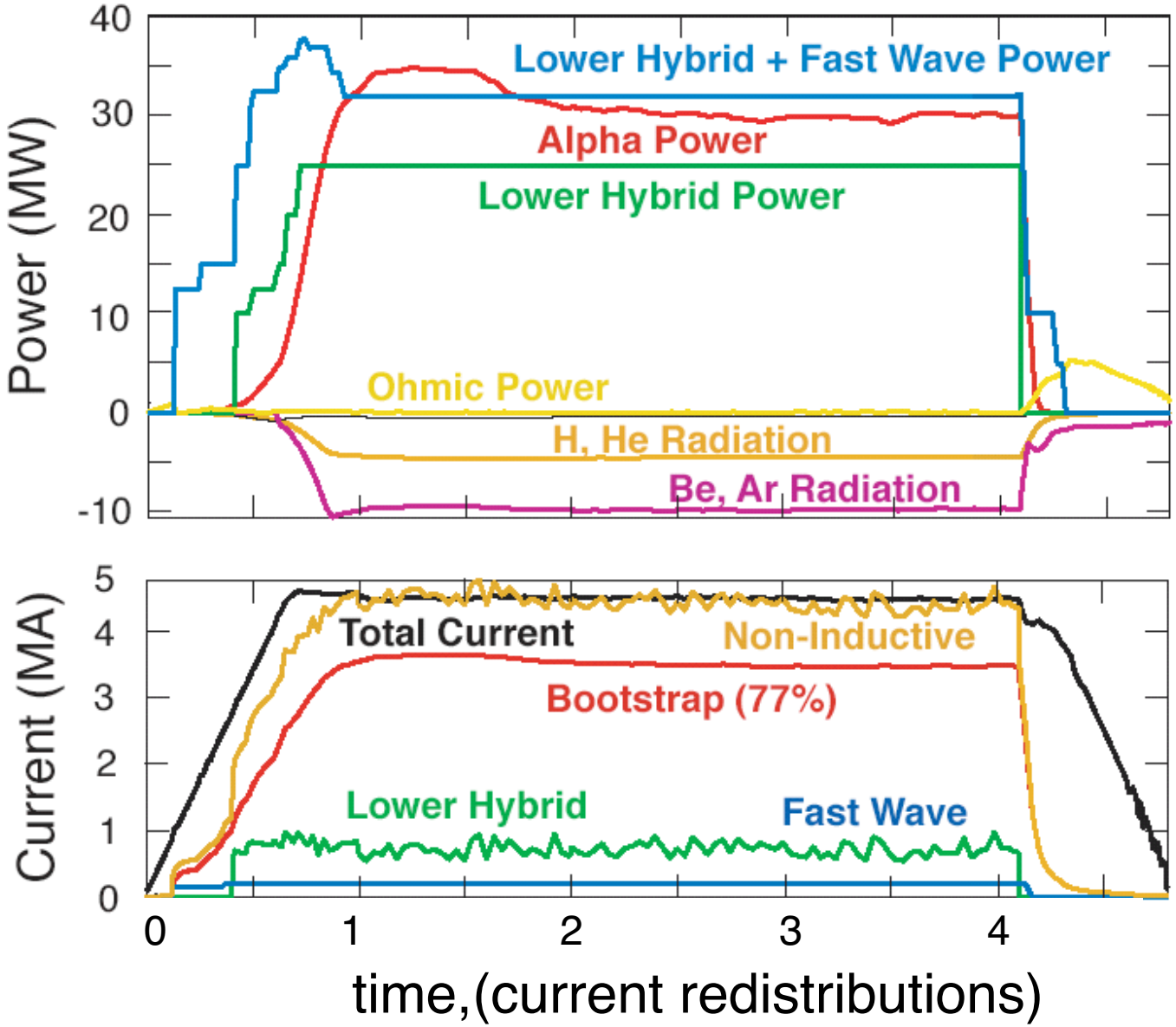
NSO/FIRE Mission/Scope

The purpose of the national Next Step Options (NSO) design studies is to:

- Advance the physics and engineering design of FIRE for the study of burning plasmas to attain, explore, understand an optimize magnetically-confined fusion-dominated plasmas.
- Support the evaluation of candidate fusion program next step options to determine their feasibility, scientific merit and estimated costs as candidates for a new DOE construction project, or for U. S. participation in an international collaboration/cost-shared project.
- Integrate these options into a coordinated multi-element program as input to program planning activities.

The U.S. is presently a participant in the negotiations to decide on a site for the construction of ITER. It is anticipated that a decision on proceeding with ITER will be made by the end of FY04. If the ITER process has not arrived at a decision, then FIRE would be advanced as an alternative to ITER.

"Steady-State" High-β Advanced Tokamak Discharge on FIRE



Q ~ 5

B = 6.5 T

β_N = 4.1

f_{bs} = 77%

H_{98}= 1.7

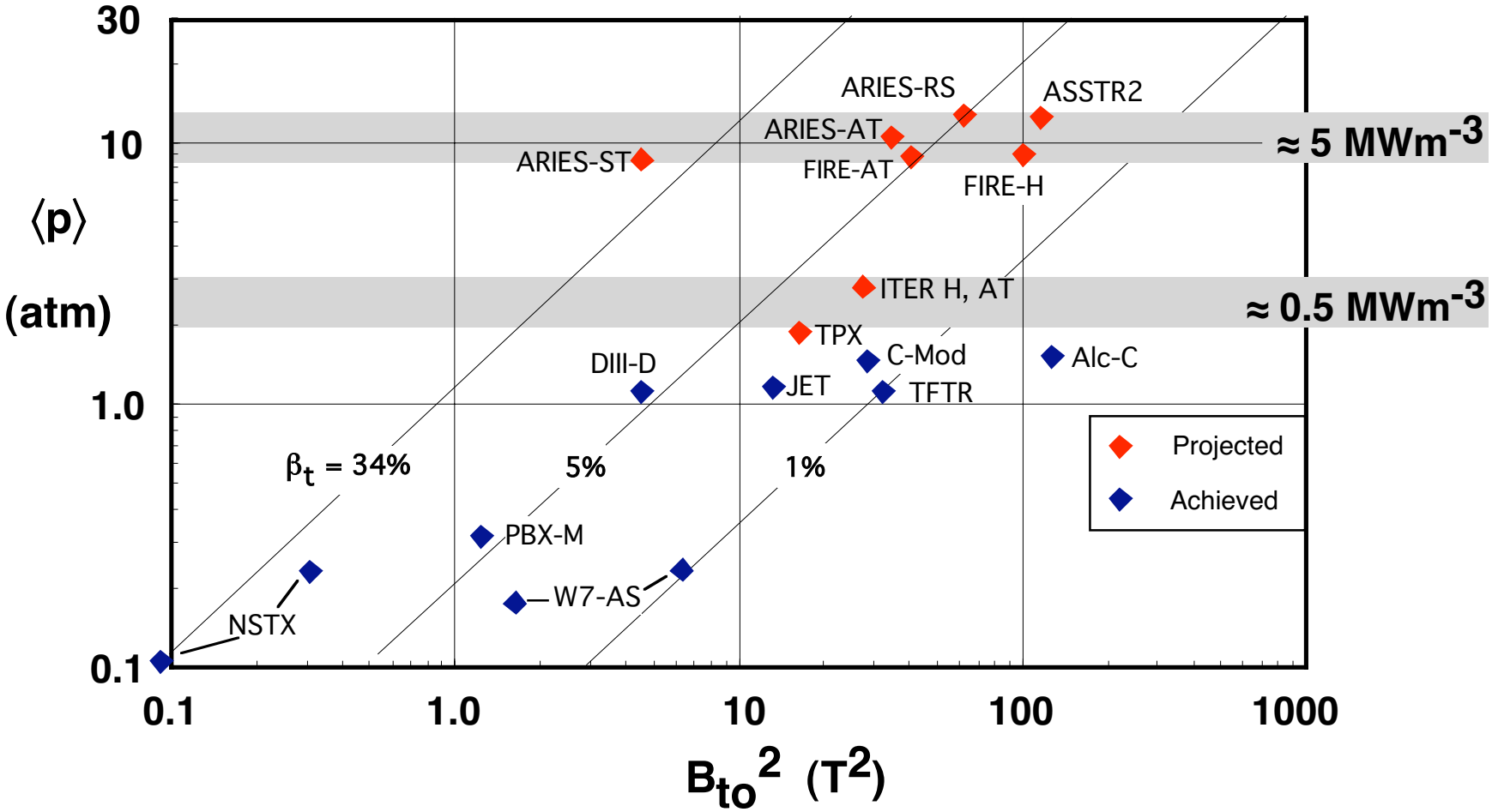
n/n_G = 0.85

τ_E = 0.7s

τ_{He} = 3.5 s

τ_{CR} = 9 s

FIRE Could Explore Fusion Power Density Comparable to a Power Plant (≈ 5 MWm^{-3})



- Plasma pressure must be increased by a factor of 10 while maintaining $\beta \sim 5\%$

Plan A: A Decision is made to Construct ITER

- FIRE activities would be completed ASAP, and NSO activities would be directed toward other areas within its charter.
- The thrust of the NSO activities will be to make progress on **fully exploiting the capability** of ITER (and CTF) with an emphasis on those features required for an attractive tokamak fusion power plant presently envisioned by ARIES-RS. This would include:
  - development and optimization of metallic PFCs,
  - development of RWM technology (insulation, feedback control,..)
  - disruption mitigation techniques under high power density conditions
  - plasma control tools (ICRF, LHCD, Pellets, ..)
  - development of diagnostics for ITER (esp. AT modes)
- An example is the synopses submitted for 20th IAEA FEC

"High-β Steady-State Advanced Tokamak Regimes for ITER and FIRE"

ITER would benefit from Advanced Tokamak Operation

	ITER-AT	PPCS-A(1)	PPCS-C(2)	FIRE-AT	ARIES-RS
R (m), a (m)	6.35,1.85	9.5, 3.2	7.5,2.5	2.14, 0.595	5.52, 1.38
$B_t(R_o)$ (T), I_p (MA)	5.1, 9	7, 30	6, 20	6.5, 4.5	8, 11.3
β_N	3.1	3.5	4	4.1	4.8
f_{bs} (%)	48	45	69	77	88
n/n_{GW}, $\langle n \rangle_{vol}$ (10^{20} m^{-3})	0.8	1.2	1.5	0.85, 2.4	1.7, 2.1
$T_i(0)$, $T_e(0)$	31	30	40	14, 16	27, 28
H98(y,2)	1.6	1.2	1.3	1.7	1.4
Burn Duration/τ_{cr} , s	10, 3000	Steady-state	Steady-state	3.2, 40	Steady-state
$Q = P_{fusion}/(P_{aux} + P_{OH})$	6	20	30	4.8	25
Fusion Power (MW)	360	5000	3400	140	2160
$(P_{loss})/R$ (MW/m)	15	~100	~70	16	80
P_{fus}/Vol (MWm^{-3})	0.45	1.4	1.9	5.5	6.2
Γ neutron (MWm^{-2})	0.5	2.2	2.2	1.7	4

(1) Ian Cook-Symposium on Fusion Engineering –2003
(2) David Campbell Asian Plasma and Fusion Association meeting, Hangchow, China, October 2003

- FY-2005: A specific goal would be to develop an AT scenario (e.g., PPCS-C) for ITER including RWM stability analysis and a feasibility study of closely coupled RWM coils with compatible plasma facing components.
- FY-2006: Extend the development of the AT scenario and hardware required to include conceptual design and international participation.

A national US Burning Plasma Program is needed.

Plan B: No Decision is made to Construct ITER

- An alternative to ITER must be put forward before interest in BPP is lost.
- Put FIRE forward immediately as recommended by:
  - FESAC - FIRE should "be advanced as a U.S.-based burning plasma experiment with strong encouragement of international participation"
  - Energy Policy Act of 2003 - introduced in the Senate on Feb 11, 2004 - "If at any time during the negotiations on ITER, the Secretary determines that construction and operation of ITER is unlikely or infeasible, the Secretary shall send to Congress, as part of the budget request for the following year, a plan for implementing the domestic burning plasma experiment known as FIRE, including costs and schedules for such a plan."
- Similar recommendation has been made for the EU program by Airaghi (2000)
  - "In the same 2-year period(2001-2002), due to the uncertainty over the outcome of the international negotiations, Europe should study an alternative to New-ITER, which would be suitable to be pursued by Europe alone. For example, a copper magnet machine which would still achieve the required objective of demonstrating a burning plasma under reactor conditions even if this would delay the integration of the superconducting technologies."

Plan B: Major Near Term Activities (t_o = July 04)

- Physics Validation Review (update of Snowmass and NSO reviews) Mar 30, 04
- Formation of a national FIRE organization Aug 04
- Initiation of discussions with potential international collaborators Aug 04
- Form FIRE Project Management team Sep 04
- CD-0 Approve Mission Need Oct 04
- Community Workshop on Prep for FIRE Conceptual design Nov 04
- Finalize Plan for FIRE Conceptual Design Nov 04
- Initiate FIRE Conceptual Design (12 -15 months duration) Dec 04
    - Initiate R&D program in support of FIRE CDA
    - Initiate studies of potential construction sites for FIRE
- Completion of FIRE Conceptual Design Jun 06

Budget Implications

NSO/FIRE Budgets: FY02 = $2.1M, FY03 = $1.9M, FY04 = $0.6M, FY05 = 0

Plan A - Fully Exploiting ITER Capability (improving AT capability)

FY-05 and 06 (~1.5FTE) ~$0.5M

Tasks like this should be in the Burning Plasma Program

Plan B - Conceptual Design of FIRE (~$15 M total) and R&D ($2M)

FY-05	CD $7M	
	R&D $1M	
	Total	$8M
FY-06	CD $8M	
	R&D $1M	
	Total	$9M