FIRE Optimization Activities

Response to NSO-PAC1

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Presented to
NSO-PAC2 Meeting
MIT-PSFC, Cambridge, MA

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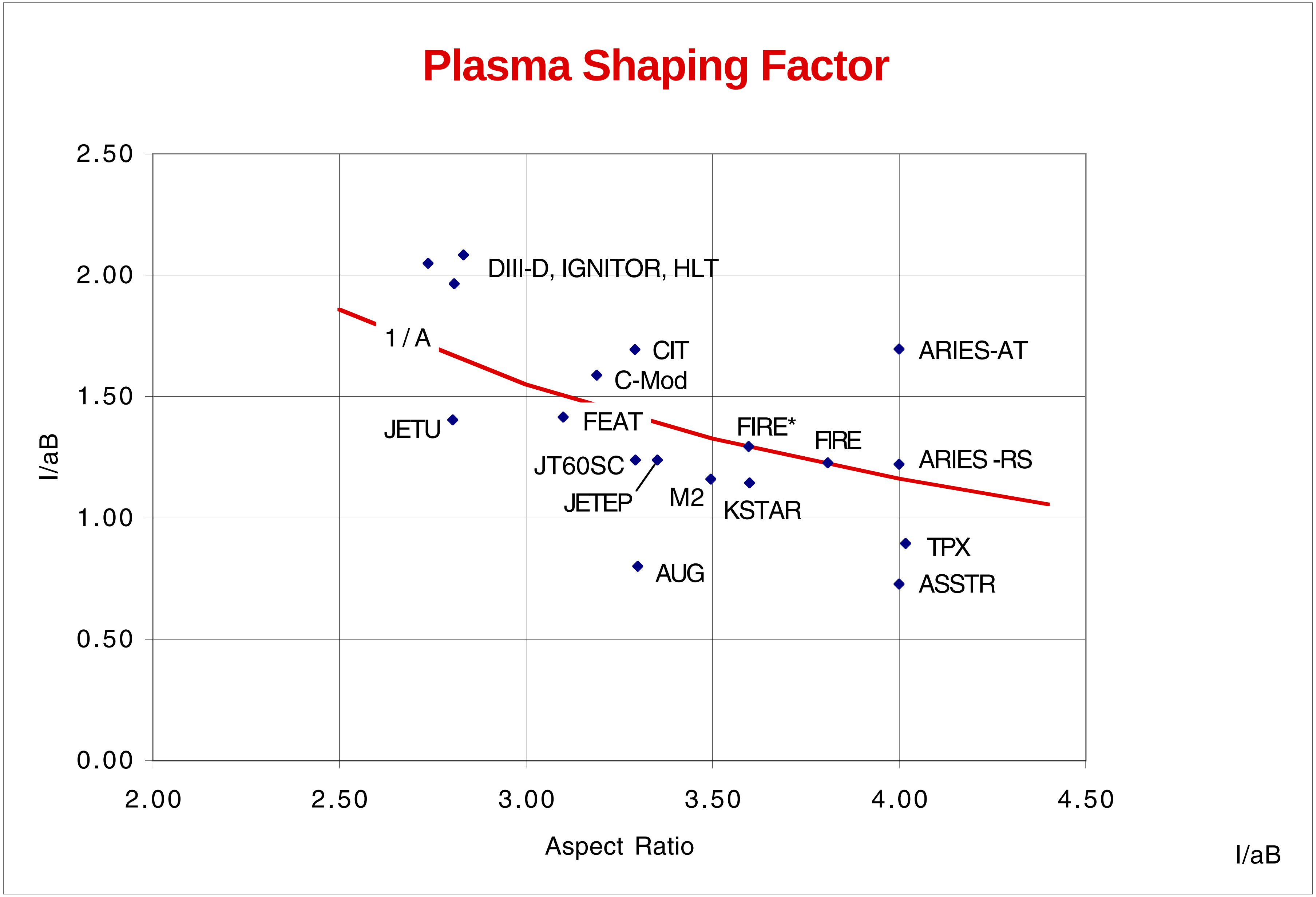
NSO-PAC Recommendations on FIRE Optimization

Finding F1-3: The Committee also endorses the project's focus on "affordability.'' How to maintain a focus on the science of self-heated fusion-dominated plasmas and include advanced toroidal issues while keeping the project affordable was, however, not resolved.

Recommendation R1-6: The Committee recommends that the project clearly show the logic for how the mission statement leads to the design point. The size of the machine, the aspect ratio, the toroidal field, and other design considerations should be better explained on the basis of meeting the objectives of the device. **In particular, the choice of aspect ratio and the size of the device should be further examined with respect to accessibility of physics regimes and the cost of the device.** The PAC requests that the choice of the design point be further discussed at a future meeting.

Recommendation R1-9: The PAC recommends delineating the design implications and quantifying the potential savings as one of the major engineering design efforts for the coming year.



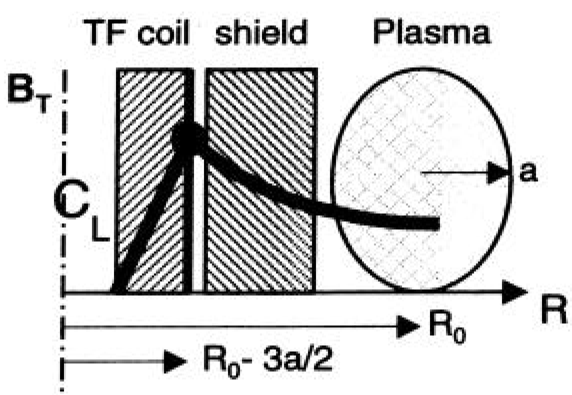
Plasma Shaping Factor
2.50
2.00
1.50
1.00
0.50
0.00
I/aB
DIII-D, IGNITOR, HLT
1 / A
CIT
C-Mod
ARIES-AT
JETU
FEAT
FIRE*
FIRE
ARIES -RS
JT60SC
JETEP
M2
KSTAR
TPX
AUG
ASSTR
2.00
2.50
3.00
3.50
4.00
4.50
Aspect Ratio
I/aB

For superconducting tokamak reactors, It is b/e (*i.e.*,bR_0/a) that is important, not b

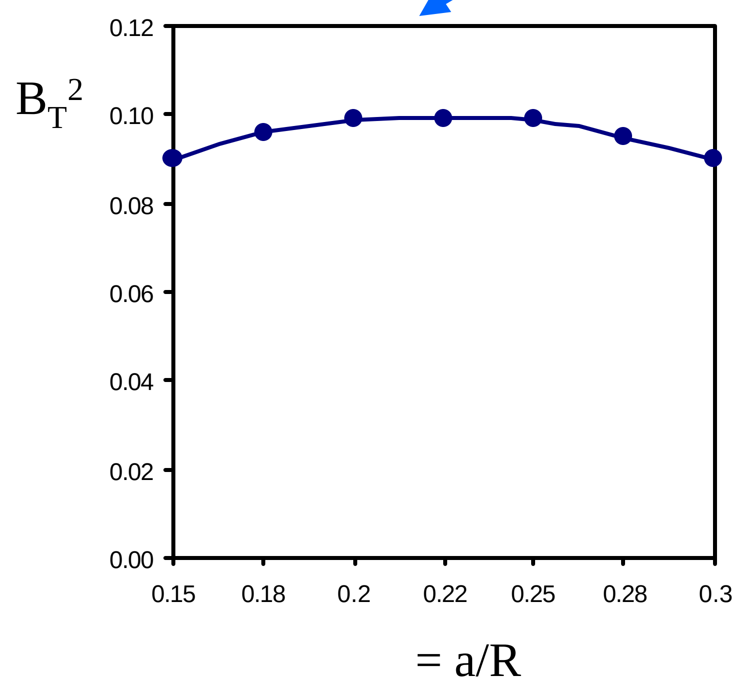
- Fusion power density, P ~ $^{2}B_T^{4}$ = $(\ / \ )^2$ $(\ B_T^{2})^2$

MHD Figure of Merit

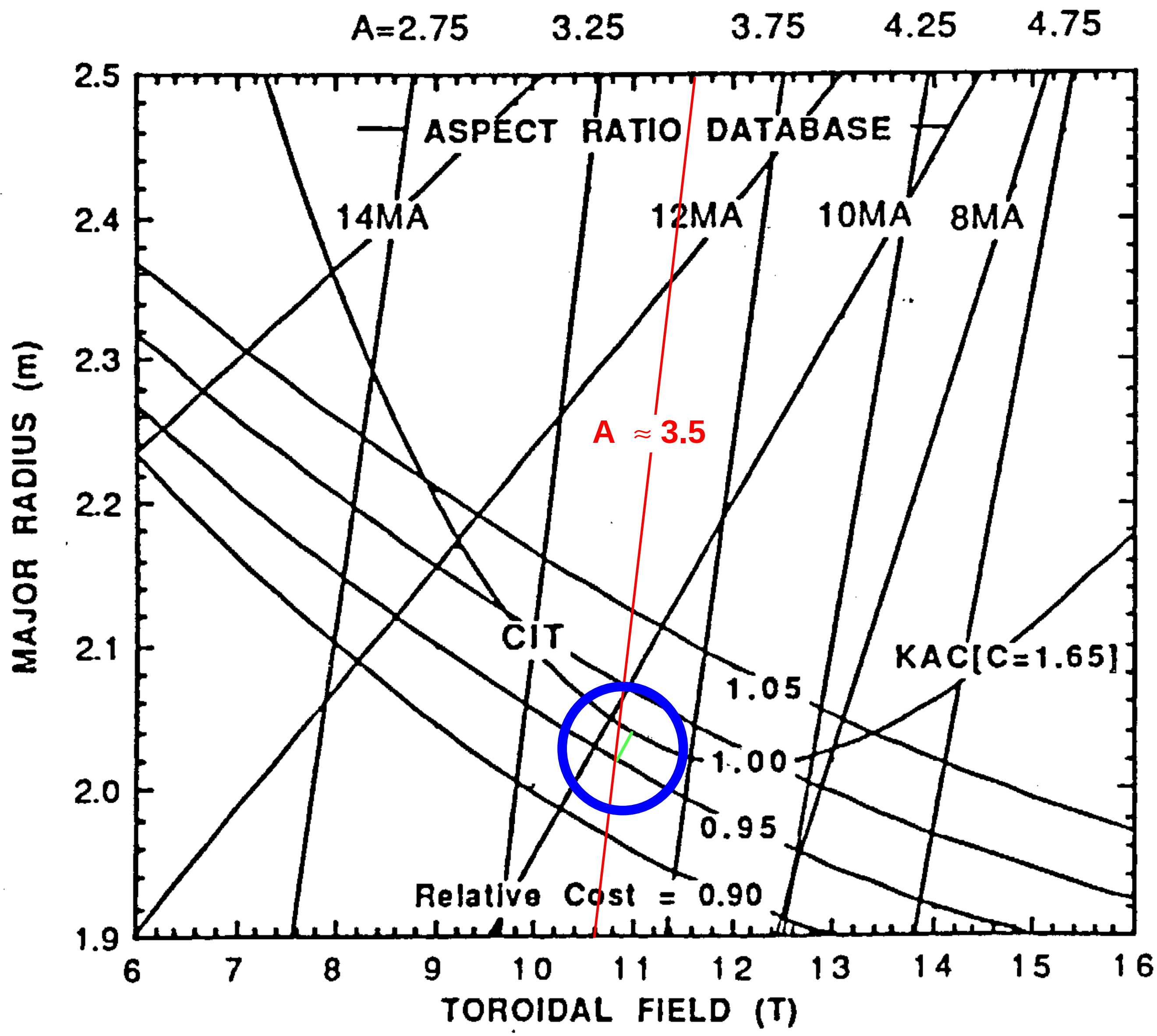
Almost Constant for B_T fixed at the TF coil



From ARIES Group



Systems Code Study of CIT Performance vs Cost



Wedged TF Coil Design

Optimum Aspect Ratio

A ≈ 3.5

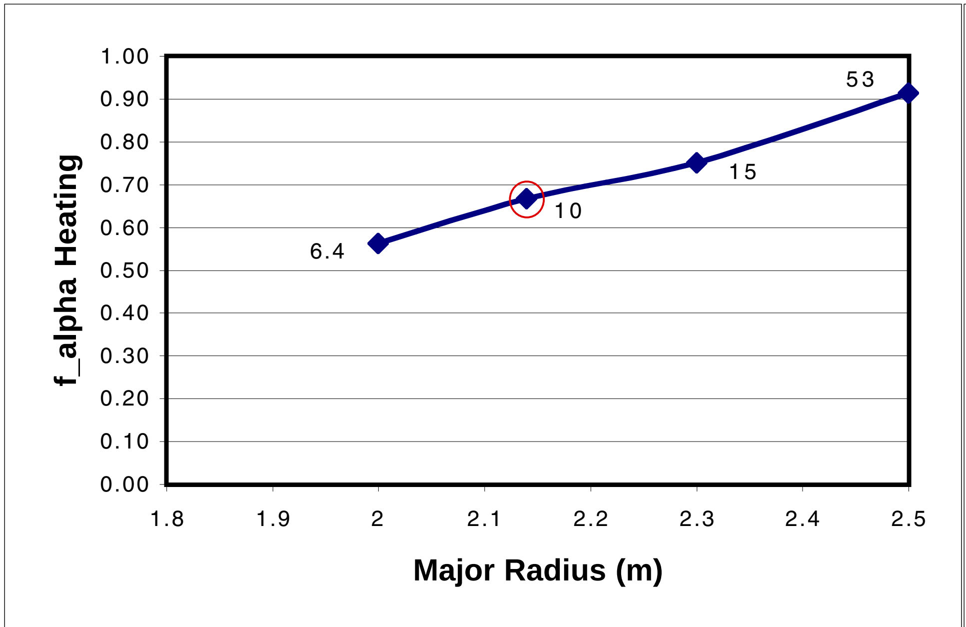
fairly flat optimum.

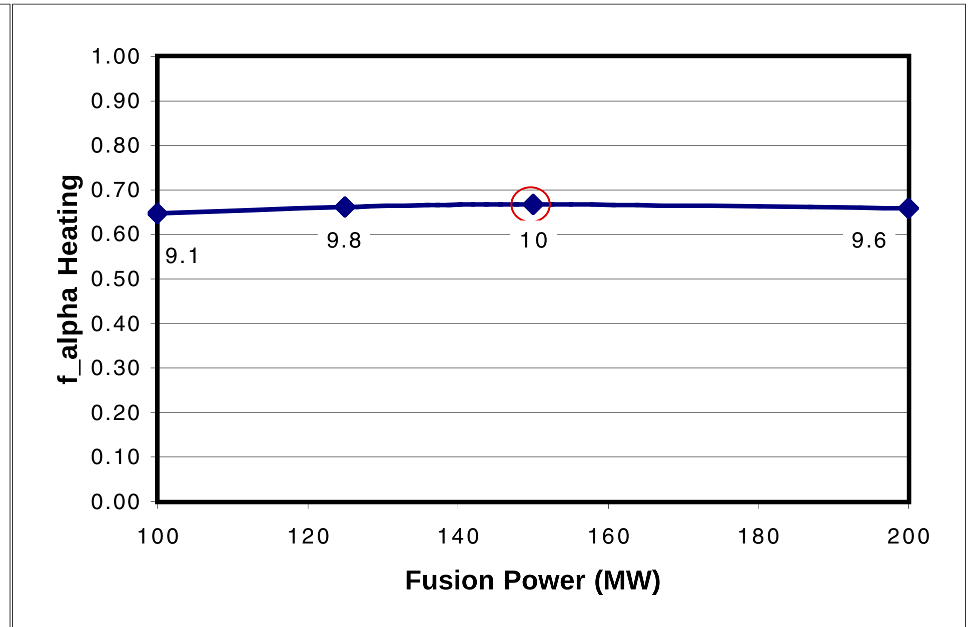
(Reiersen et al-1989)

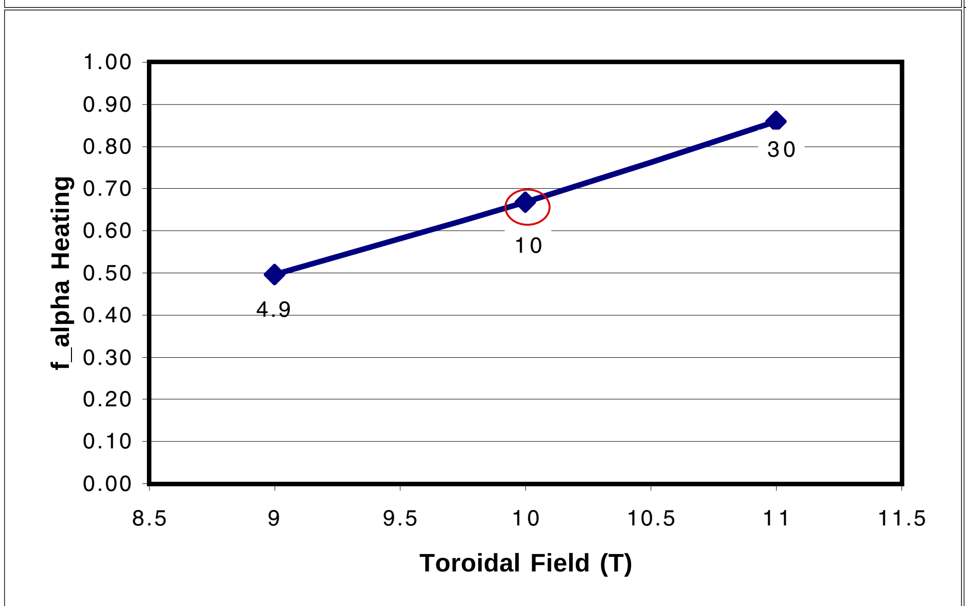
CIT was similar in size to FIRE but had only 5 s flat-top and and slightly different confinement scaling. BPX-AT, also similar in size with a 10 s flat-top, optimized at A = 4.0

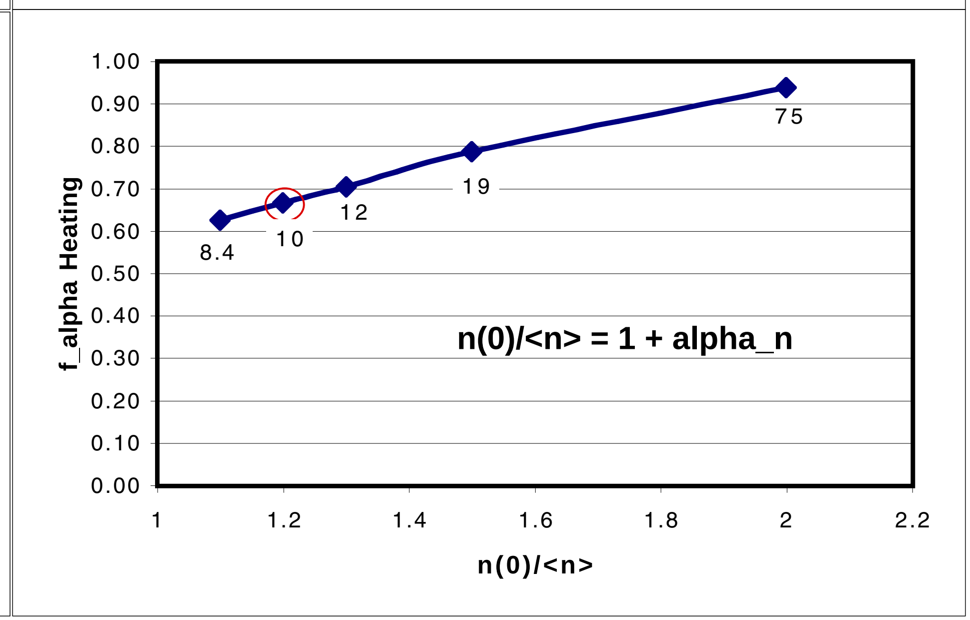
Sensitivity Scans on FIRE*

(A = 3.60, κ95 = 1.77, δ95 = 0.4, ITER98(y,2), H = 1.027, n/nGW = 0.7, nBe = 0.4%)

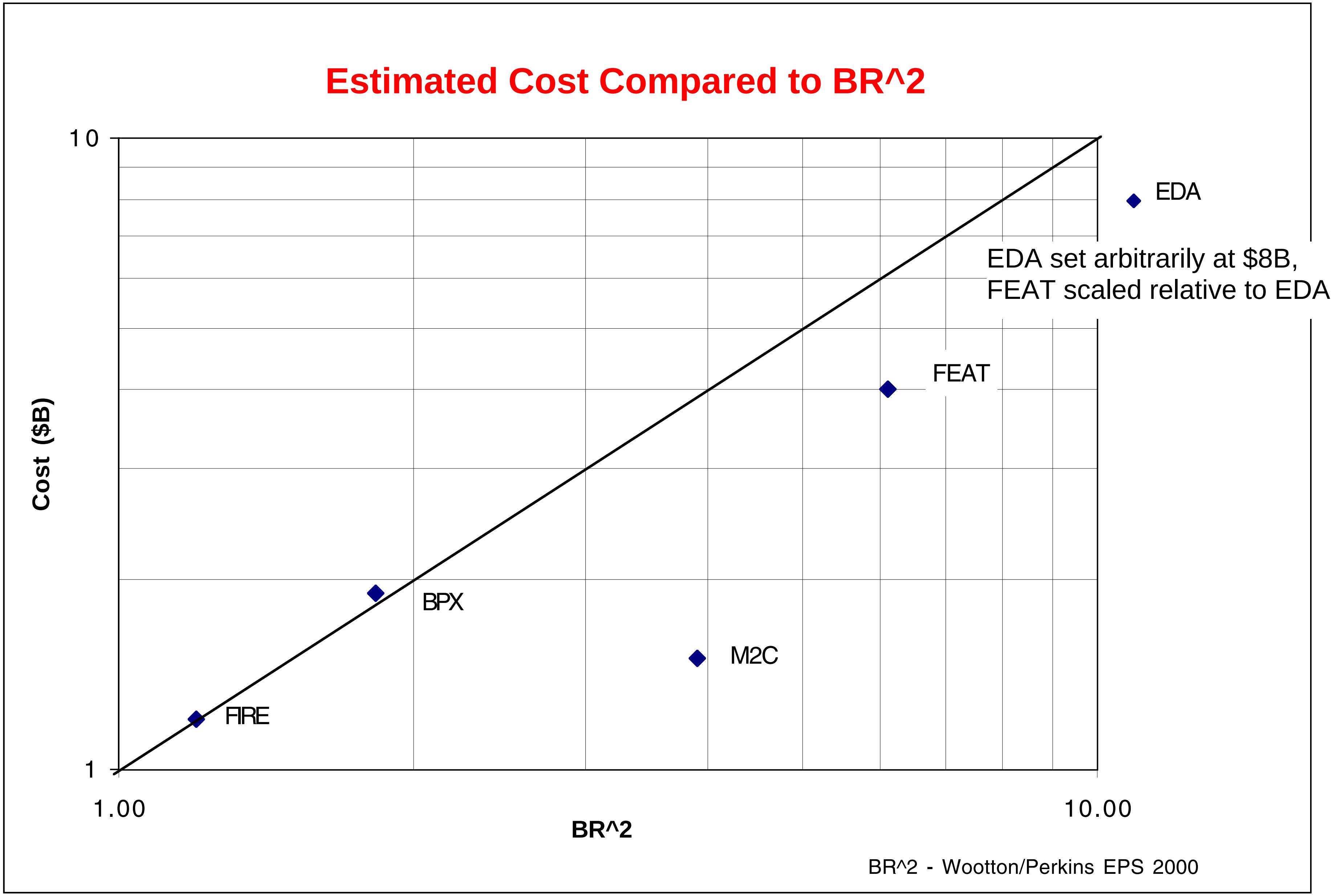






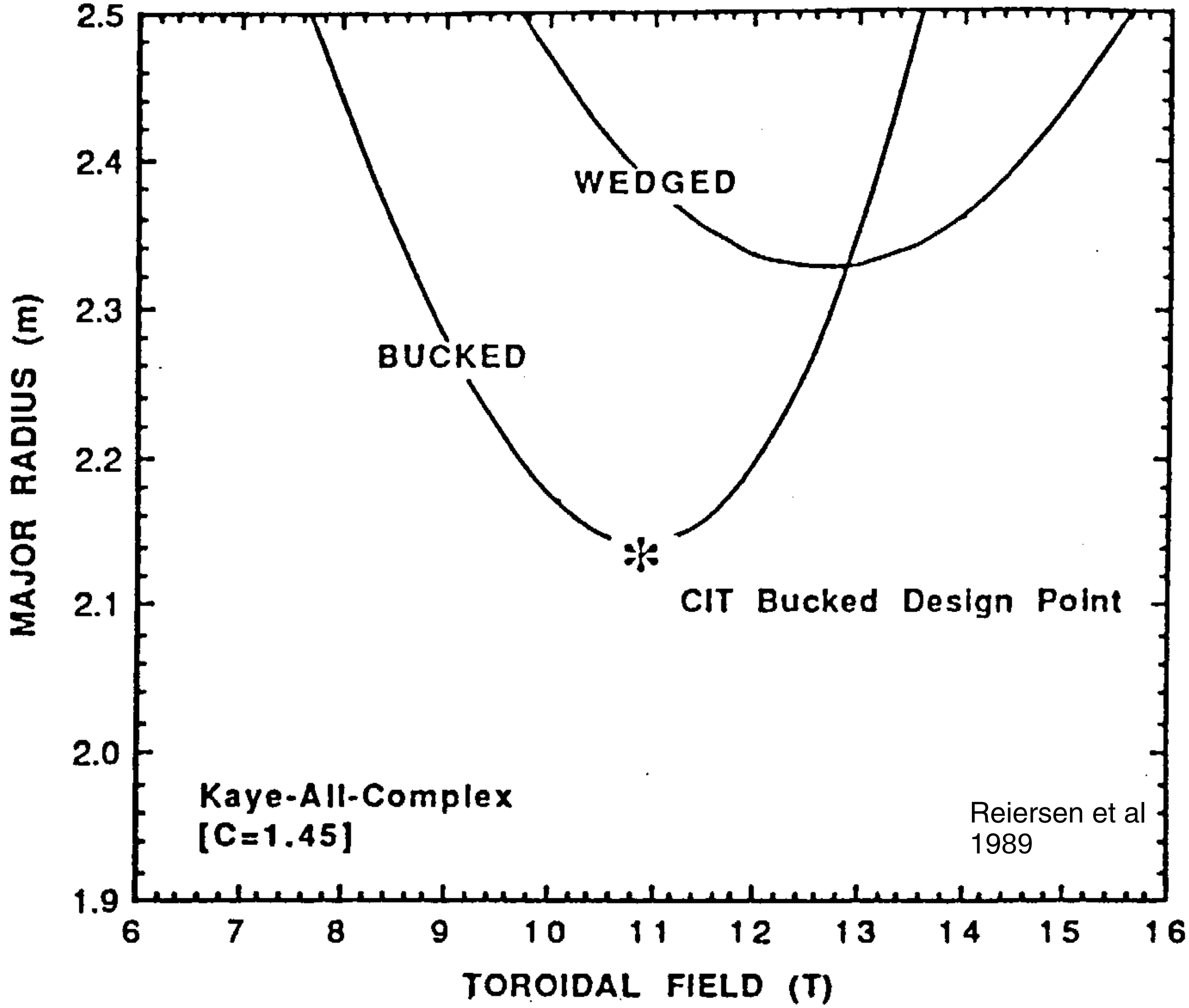


Note: kappa area would make H = 1.01



Estimated Cost Compared to BR^2
10
1
1.00
10.00
Cost ($B)
BR^2
EDA
EDA set arbitrarily at $8B,
FEAT scaled relative to EDA
FEAT
BPX
M2C
FIRE
BR^2 - Wootton/Perkins EPS 2000

Bucked Designs Optimize at Slightly Smaller Size and Field than Wedged Designs



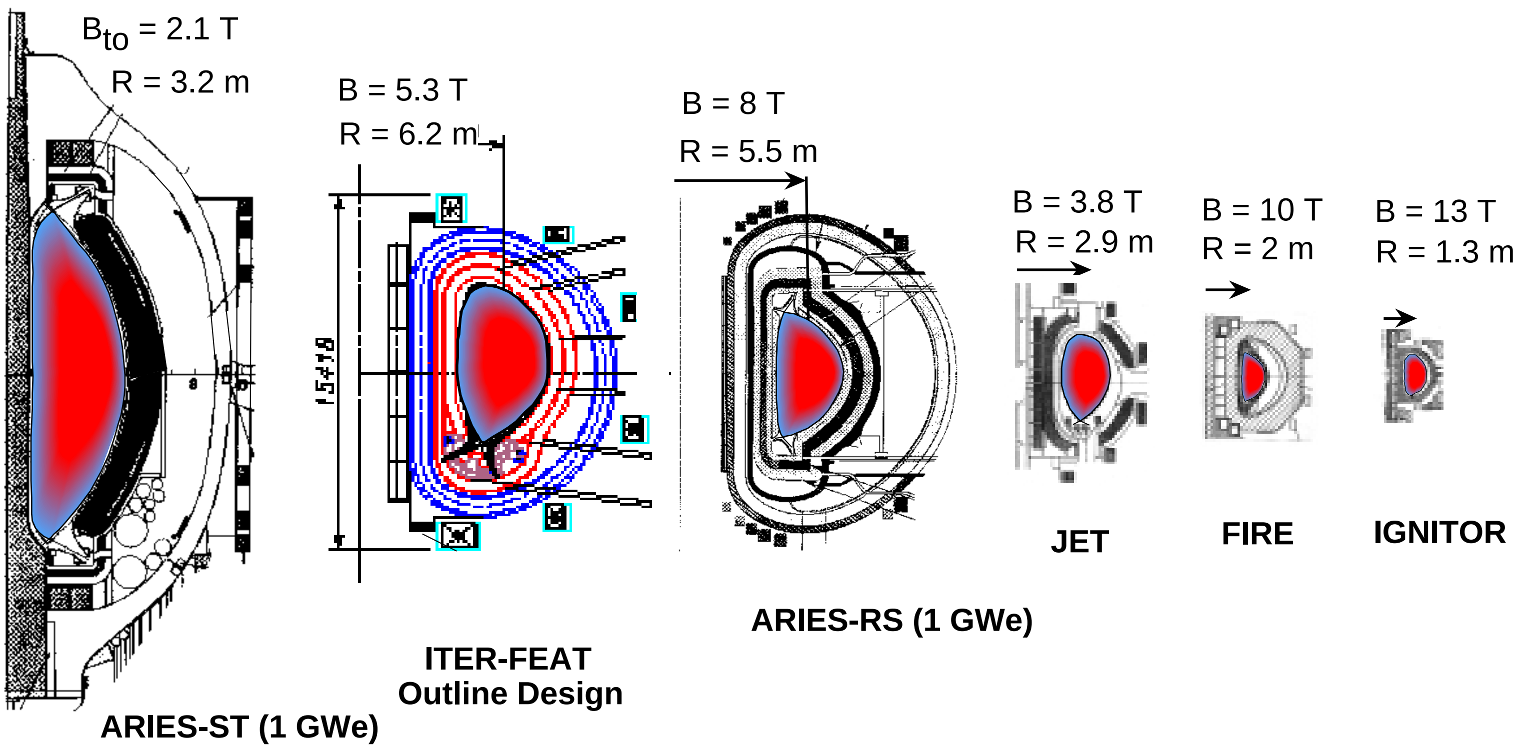
A bucked and wedged design is being evaluated for FIRE.

FIRE Power Requirements for BeCu or CuTF Coils

	10T (20s flattop)		12T (12s flattop)	
BeCu	Peak Power (MW)	Peak Energy (GJ)	Peak Power (MW)	Peak Energy (GJ)
TF	490	11.5	815	11.5
PF	250	2.2	360	3.7
RF	60	1	60	0.6
$\sum$	800	14.7	1235	15.8
Grid	550 (TF&RF)	12.5	600 (TFbase)	10.9
MG	250 (PF)	2.2	635 (TFsupp&PF&RF)	4.9

	10T (45s flattop)		12T (25s flattop)	
Cu	Peak Power (MW)	Peak Energy (GJ)	Peak Power (MW)	Peak Energy (GJ)
TF	267	12.6	345	13.2
PF	250	5	360	4.6
RF	60	2.3	60	1.3
$\sum$	577	19.9	765	19.1
Grid	577 (All Systems)	19.9	404 (TF&RF)	14.5
MG	0	0	360 (PF)	4.6

Potential Next Step Burning Plasma Experiments and Demonstrations in MFE



Cost Drivers	ARIES-ST	ITER-FEAT	ARIES-RS	JET	FIRE	IGNITOR
Plasma Volume (m^3)	810	837	350	95	18	11
Plasma Surface (m^2)	580	678	440	150	60	36
Plasma Current (MA)	28	15	11	4	6.5	12
Magnet Energy (GJ)	29	50	85	2	5	5
Fusion Power (MW)	3000	500	2200	16	200	100
Burn Time (s), inductive	steady	300	steady*	1	20	5

* assumes non-inductive current drive

Preliminary FIRE Cost Estimate (FY99 US$M)

	Estimated Cost	Contingency	Total with Contingency
1.0 Tokamak Core	252.2	75.2	323.0
1.1 Plasma Facing Components	65.0	17.0	
1.2 Vacuum Vessel/In-Vessel Structures	35.2	9.7	
1.3 TF Magnets /Structure	113.8	37.2	
1.4 PF Magnets/Structure	28.4	8.5	
1.5 Cryostat	1.8	0.5	
1.6 Support Structure	7.5	2.2	
2.0 Auxiliary Systems	134.6	39.3	173.9
2.1 Gas and Pellet Injection	7.1	1.4	
2.2 Vacuum Pumping System	13.0	2.0	
2.3 Fuel Recovery/Processing	7.0	1.0	
2.4 ICRF Heating	107.4	34.9	
3.0 Diagnostics (Startup)	22.0	4.9	26.9
4.0 Power Systems	177.3	42.0	219.3
5.0 Instrumentation and Controls	18.9	2.5	21.4
6.0 Site and Facilities	151.4	33.8	185.2
7.0 Machine Assembly and Remote Maintenance	88.3	21.8	110.1
8.0 Project Support and Oversight	100.1	15.0	115.1
9.0 Preparation for Operations/Spares	16.2	2.4	18.6
Preconceptual Cost Estimate (FY99 US$M)	**960.9**	**236.9**	**1193.5**

Assumes a Green Field Site with **No** site credits or significant equipment reuse.

This estimate is work in progress and will be reviewed in the winter 2000.

October 13, 2000

NSO-FIRE Plans for FY2001

- Physics Activities [continue to develop dual mode (BP/AT) capability]
  Broaden confinement analyses, increase interaction with experiments
  Develop AT modes, and experimental requirements

- Plasma Engineering Activities
  More detailed analyses of disruption scenarios

- Engineering Activities
  Improved Wedged TF Design
    Increase plasma current to 7.7 MA while maintaining ≈ 2 tau_skin burn
    Optimization of A subject to fixed performance at 2 tau_skin

  Evaluate pro/cons of Bucked/Wedged design
    potential benefits of 11.5 T for 40 s (no nuc heating), reduced P_{elec}

  Divertor targets, baffles and first wall cooled for ~ 20 - 30 s pulses

- Respond to NSO-PAC, UFA Workshop and FESAC requests.

- Continue proactive outreach activities