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Fusion Power Plants and Related Advanced Technologies with participation of China
March 16-18, 2009 at the University of Tokyo in Kashiwa, JAPAN

Consideration on Design Window for a DEMO Reactor

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Contents

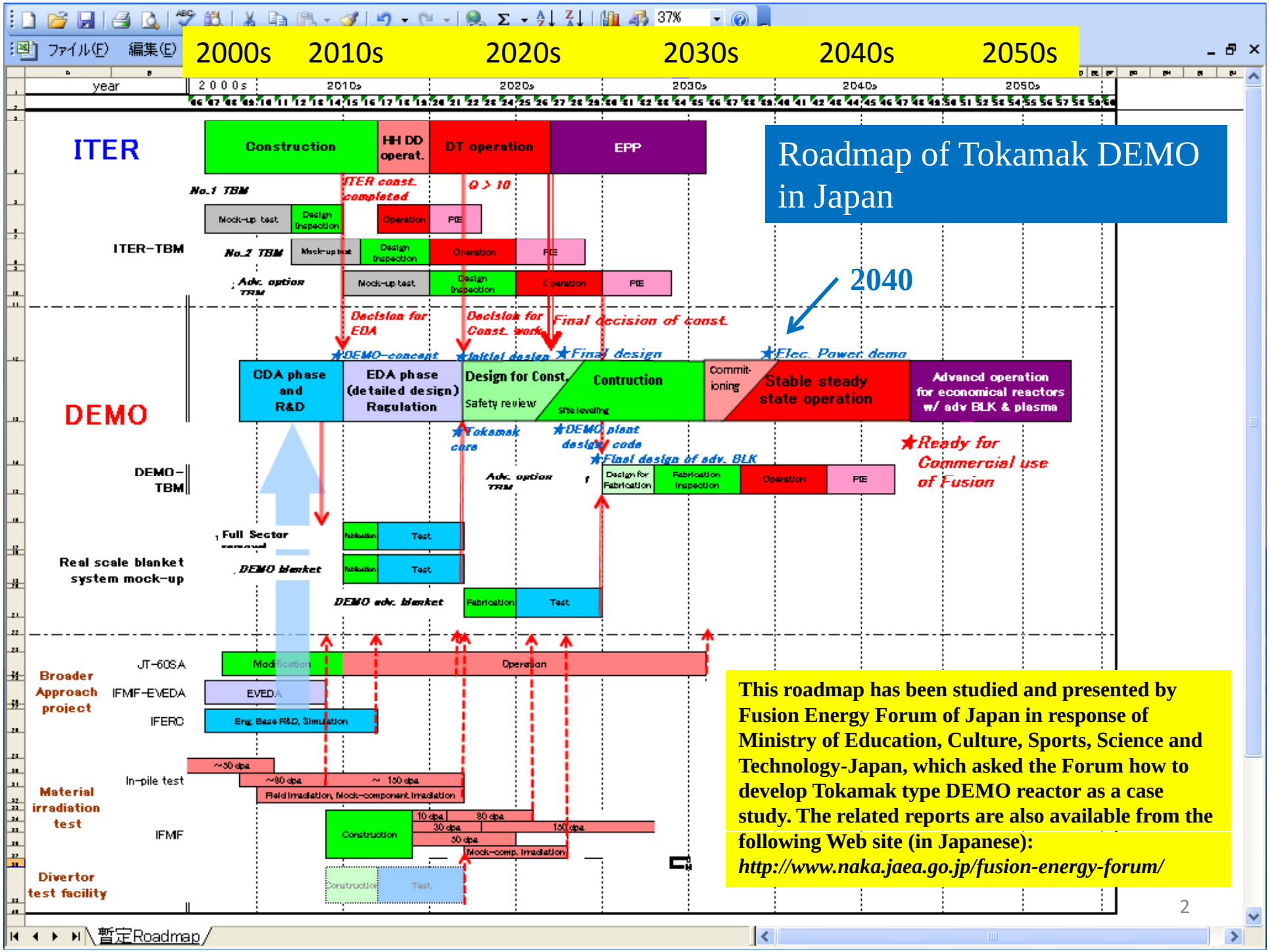
1) Impact of TF coil design

2) Feasibility on pulsed operation

3) Interrelation between plasma parameters

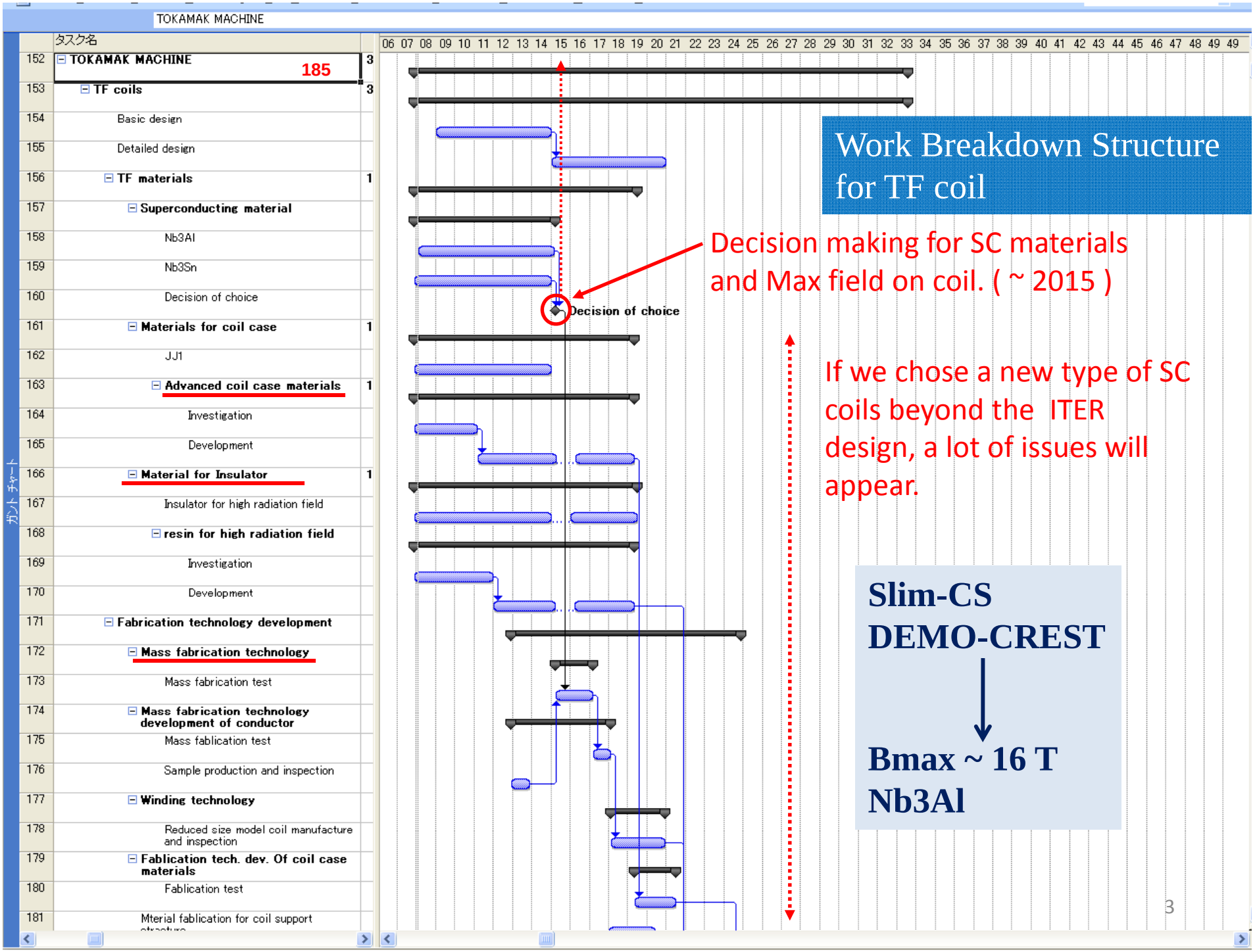
Acknowledgements : Mr. N. Shinji, Mr. S. Okayama and Dr. R. Hiwatari

Roadmap of Tokamak DEMO in Japan



This roadmap has been studied and presented by Fusion Energy Forum of Japan in response of Ministry of Education, Culture, Sports, Science and Technology-Japan, which asked the Forum how to develop Tokamak type DEMO reactor as a case study. The related reports are also available from the following Web site (in Japanese):
http://www.naka.jaea.go.jp/fusion-energy-forum/

Work Breakdown Structure for TF coil



Decision making for SC materials and Max field on coil. (~ 2015)

If we chose a new type of SC coils beyond the ITER design, a lot of issues will appear.

Slim-CS
DEMO-CREST

↓

Bmax ~ 16 T
Nb3Al

Finding by the roadmap & Working breakdown study

Cont.

(ex6) Development of SC coils, if the magnetic field of DEMO exceeds the ITER design parameters (TF: 11.8T, CS: 13T).

Nb3Al for SC conductor is a possible candidate for a higher magnetic field. But, there is no candidate for advanced structure material, over the present JJ1. There is no facility for mass production of Nb3Al. This is another concern.

If the available SC coil technology is similar to the ITER SC coils, the Japanese DEMO design should be re-design.

Based on our roadmap, the time limit for our decision on the SC choice is 2015!!

Demonstration Plant : Demo-CREST

Principles for the Demo-CREST Design

1. to demonstrate electric power generation as soon as possible in a plant scale, with moderate plasma performance which will be achieved in the early stage of the ITER operation, and with foreseeable technologies and materials (**Demonstration Phase OP1~OP4**)
2. to show a possibility of an economical competitiveness with advanced plasma performance and high performance blanket systems, by means of replacing breeding blanket from the basic one to the advanced one (**Development Phase OP4, OPRS**)

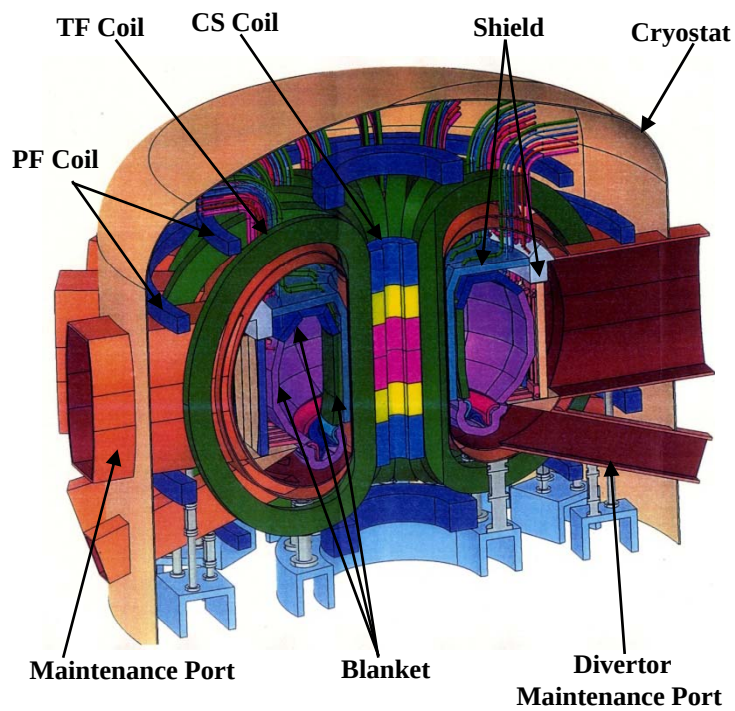
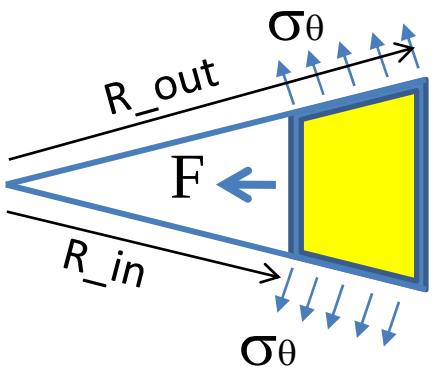


Figure:Bird's-eye of Demo-CREST

		OP1	OP2	OP3	OP4	OPRS
R (m) / A		7.25 / 3.4				
κ/δ		1.85/ 0.35				
q_{min}/q_{95}		-/5.0			-/5.2	3.6 / 6.5
β_N		**1.9**	**2.5**	**3.0**	**3.4**	**4.0**
HH		**0.96**	**1.1**	**1.2**	**1.2**	**1.4**
fn_{GW}		**0.56**	**0.73**	**0.80**	**1.02**	**1.31**
P_b (MW)		188	190	185	191	106
P_f (MW)		1260	1940	2460	2840	2970
P_{enet} (MWe)	**Basic Blanket**	**30**	**230**	**390**	**490**	-
	Advanced Blanket	-	-	-	**850**	**1090**

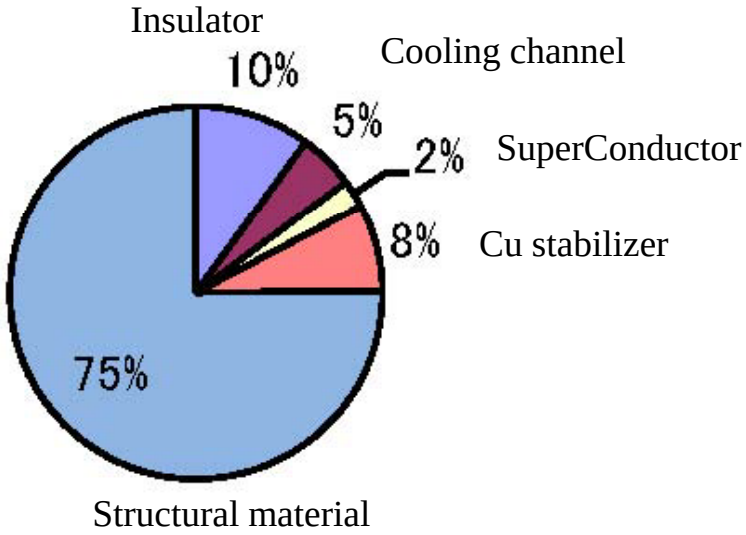
TF Coil Design

Based on the work by S. Nishio



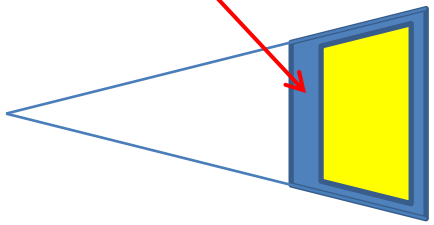
Wedge support

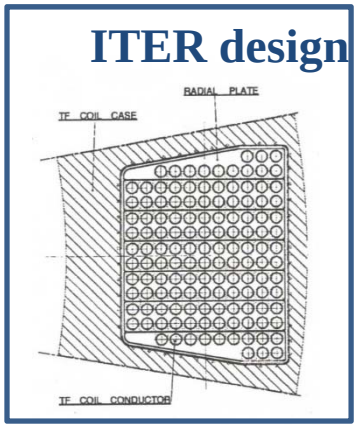
@ Critical current density
@ Mechanical stress
@ thermal stability
@ Induced voltage



➔ Bmax = 16.1 T

Casing of an inner region

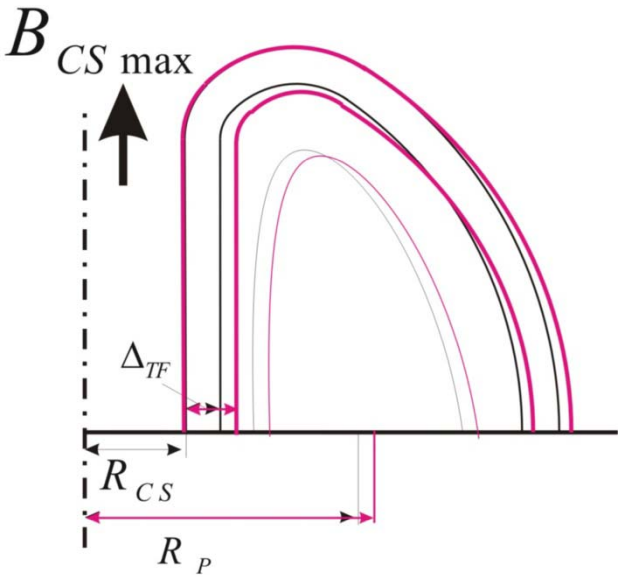




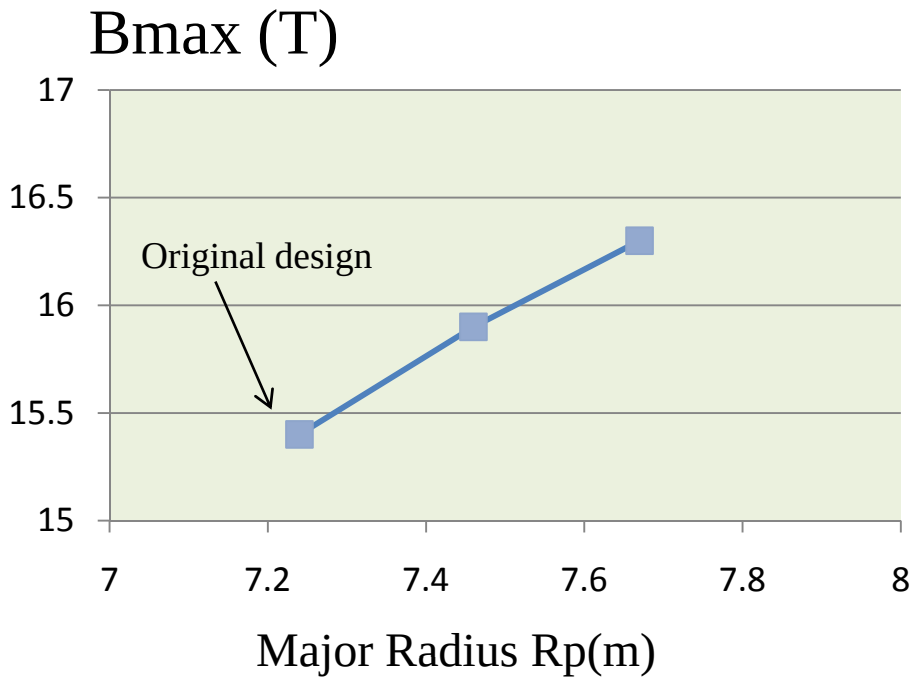
➔ Bmax = 15.4 T

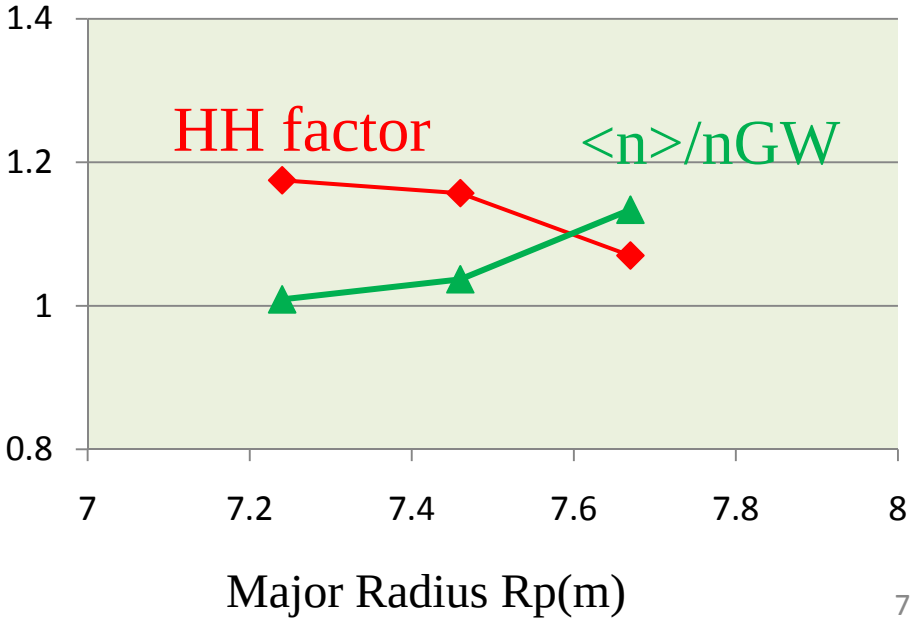
Sensitivity on Major radius

Nb3Al case



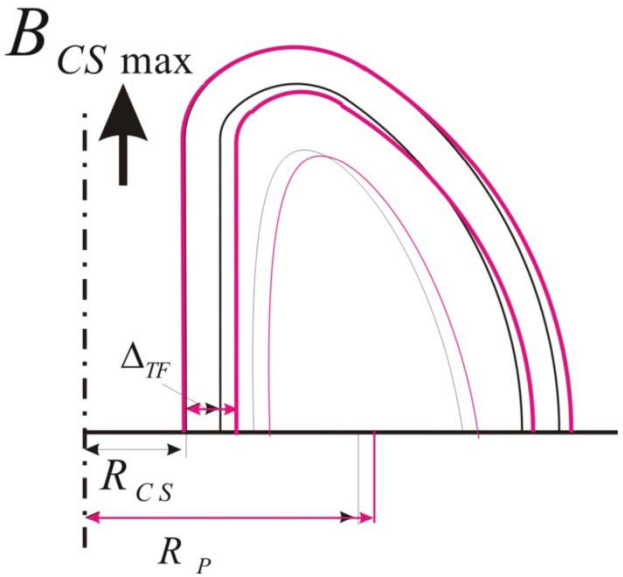
$\Phi p(LpIp)/\Phi cs = 70 \sim 80\ \%$

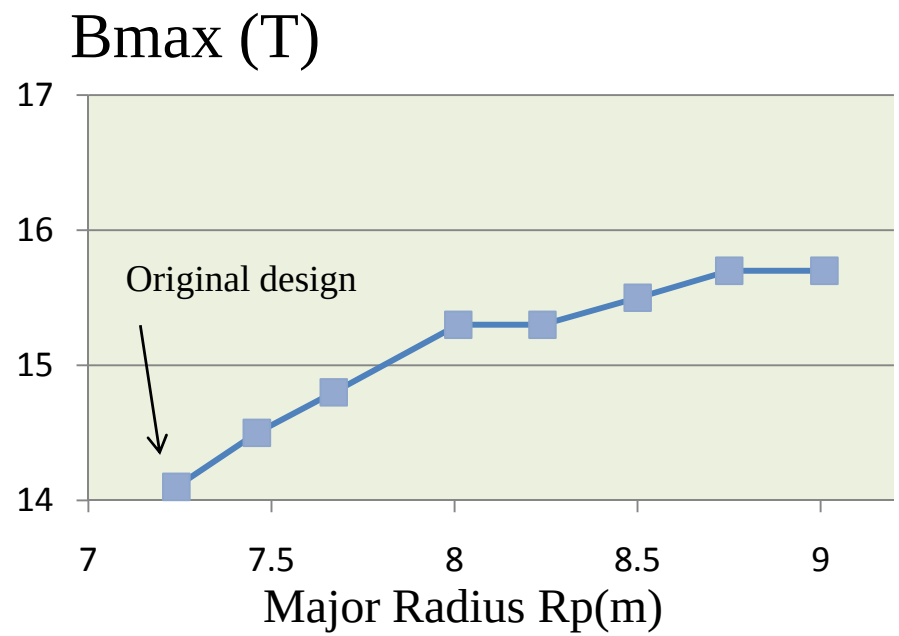


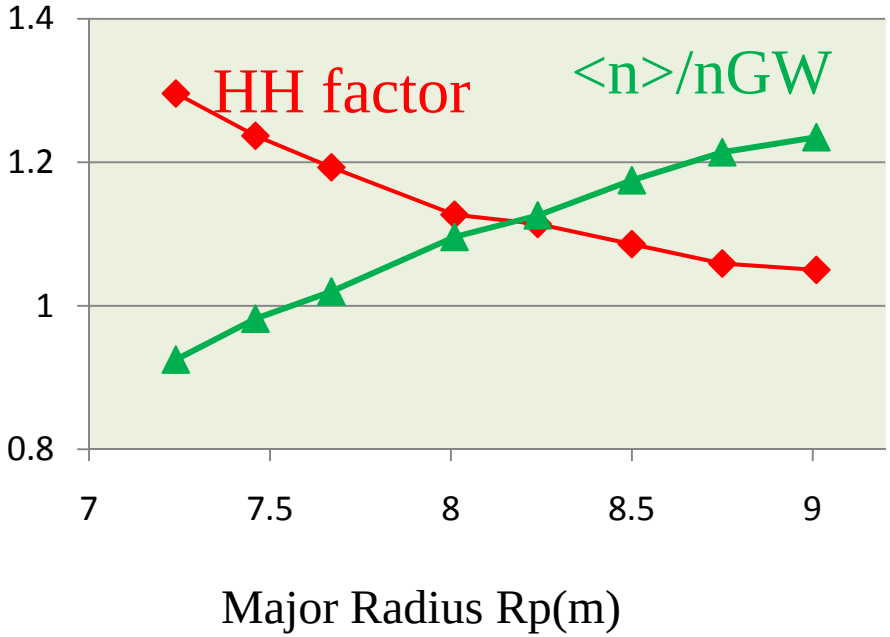


Sensitivity on Major radius

Nb3Sn case

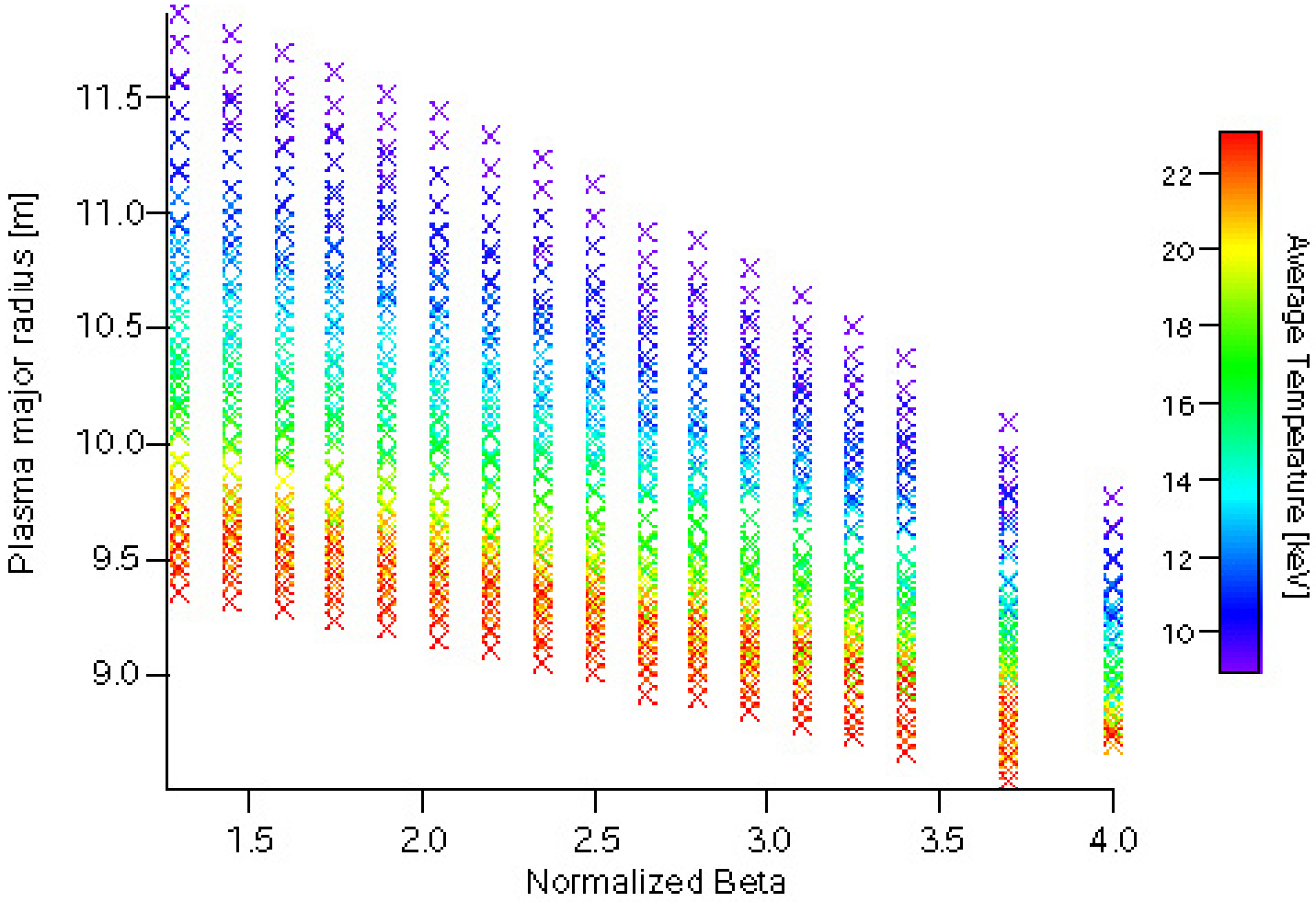




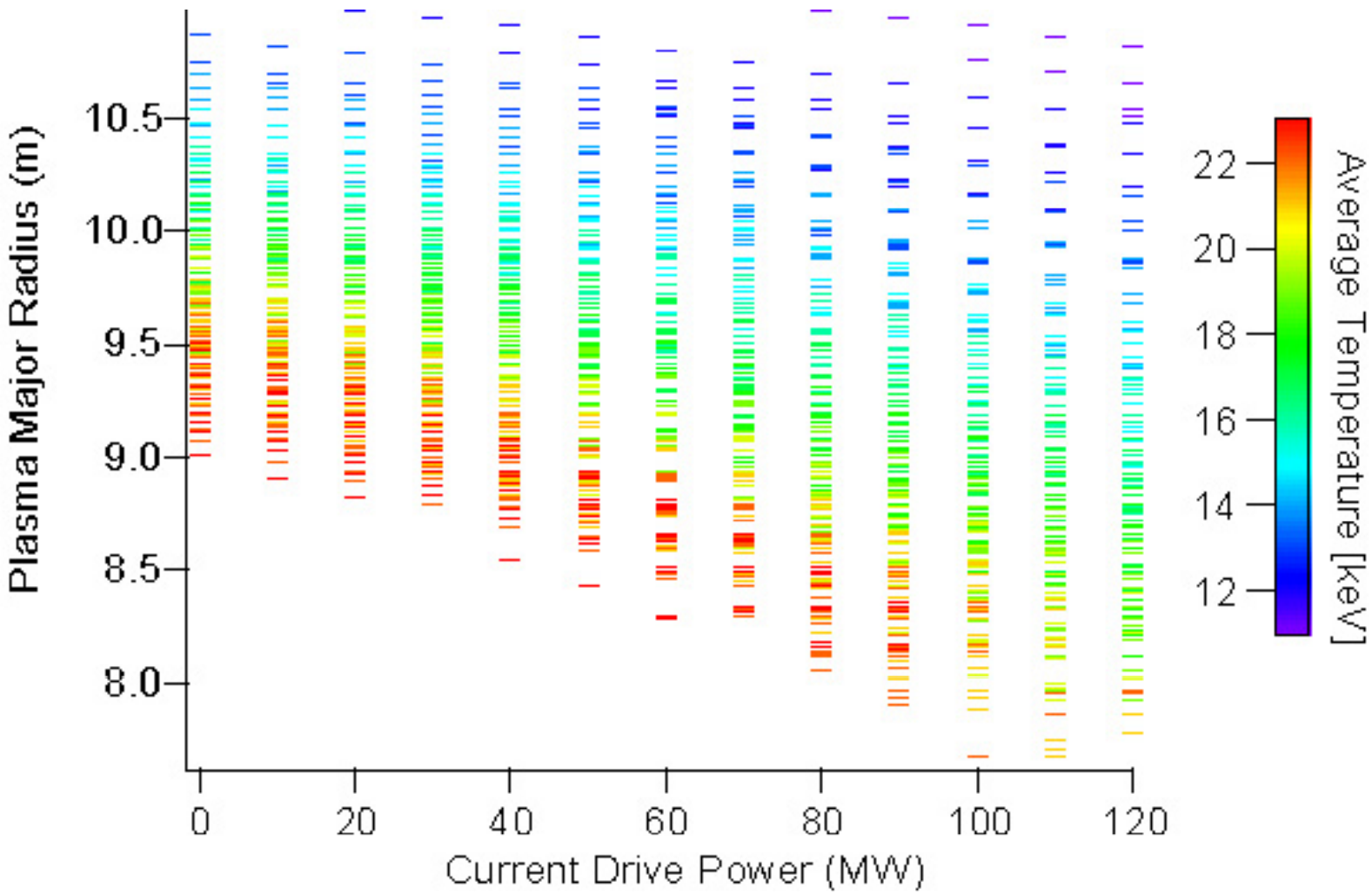


Feasibility of pulse operation

5 hours operation case

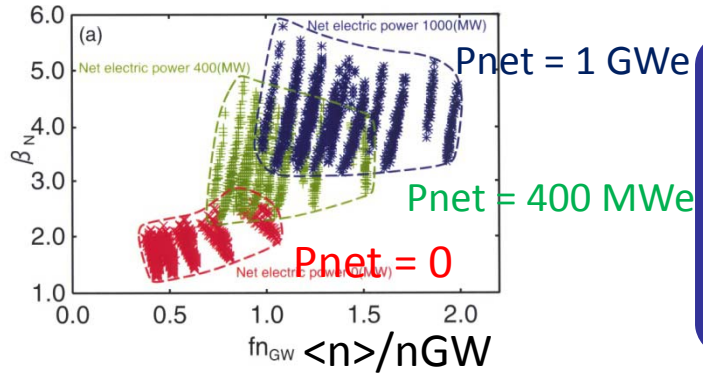


Assist of non-inductive current drive



Correlation between Plasma Performances

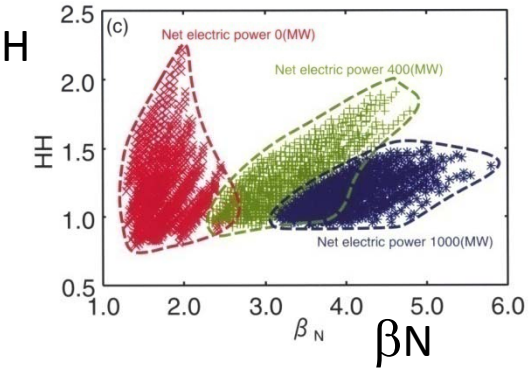
βN



fn_{GW} and β_N

Both fn_{GW} and β_N have to be increased together so as to increase the net electric power

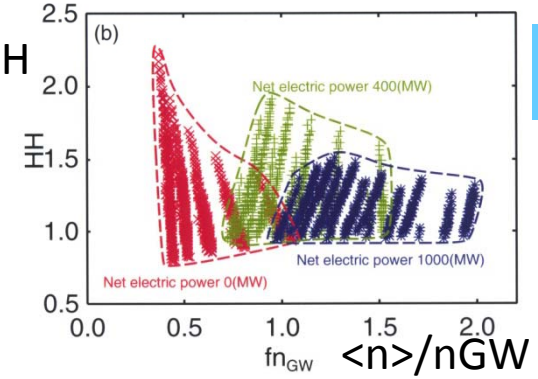
HH



fn_{GW} and HH

No clear relationship

HH



β_N and HH

No clear relationship

There is no operational point under HH≦0.8, of course, which is depending on the ristriction P_{NBI}

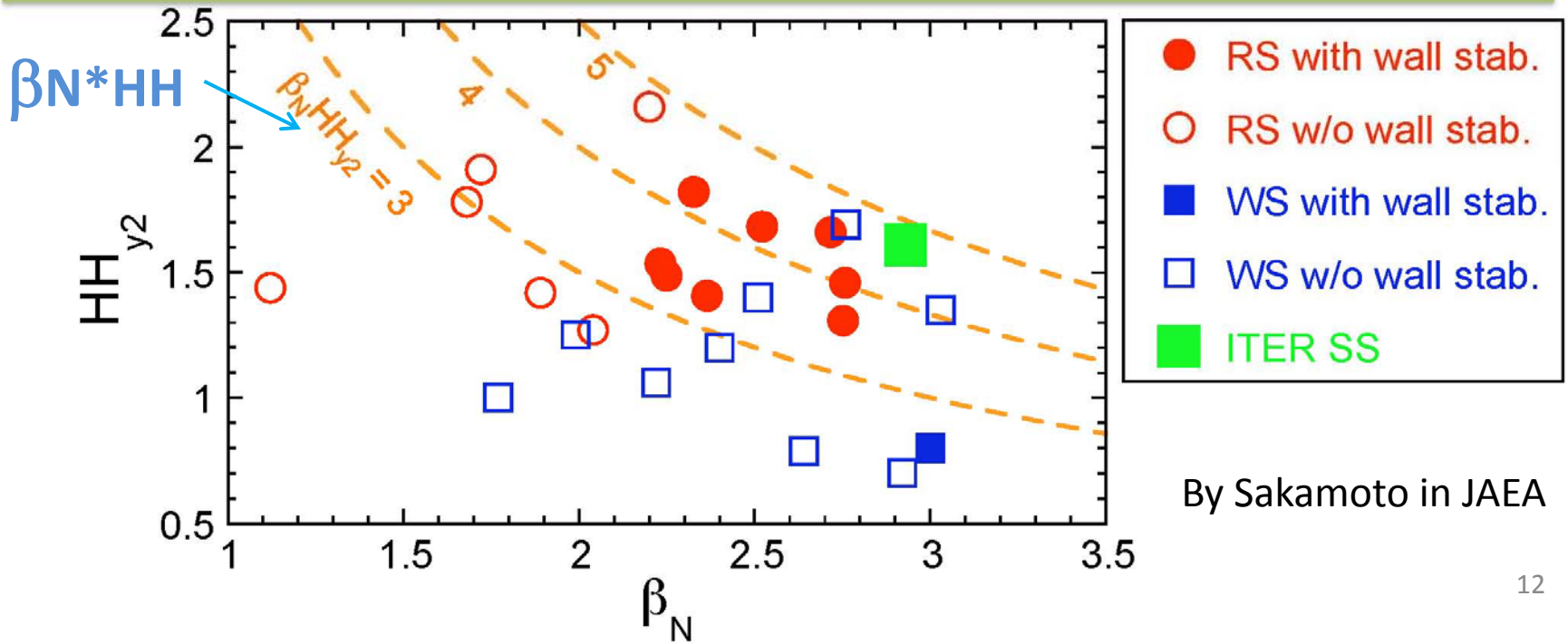
Existence of inevitable HH value

by R. Hiwatari

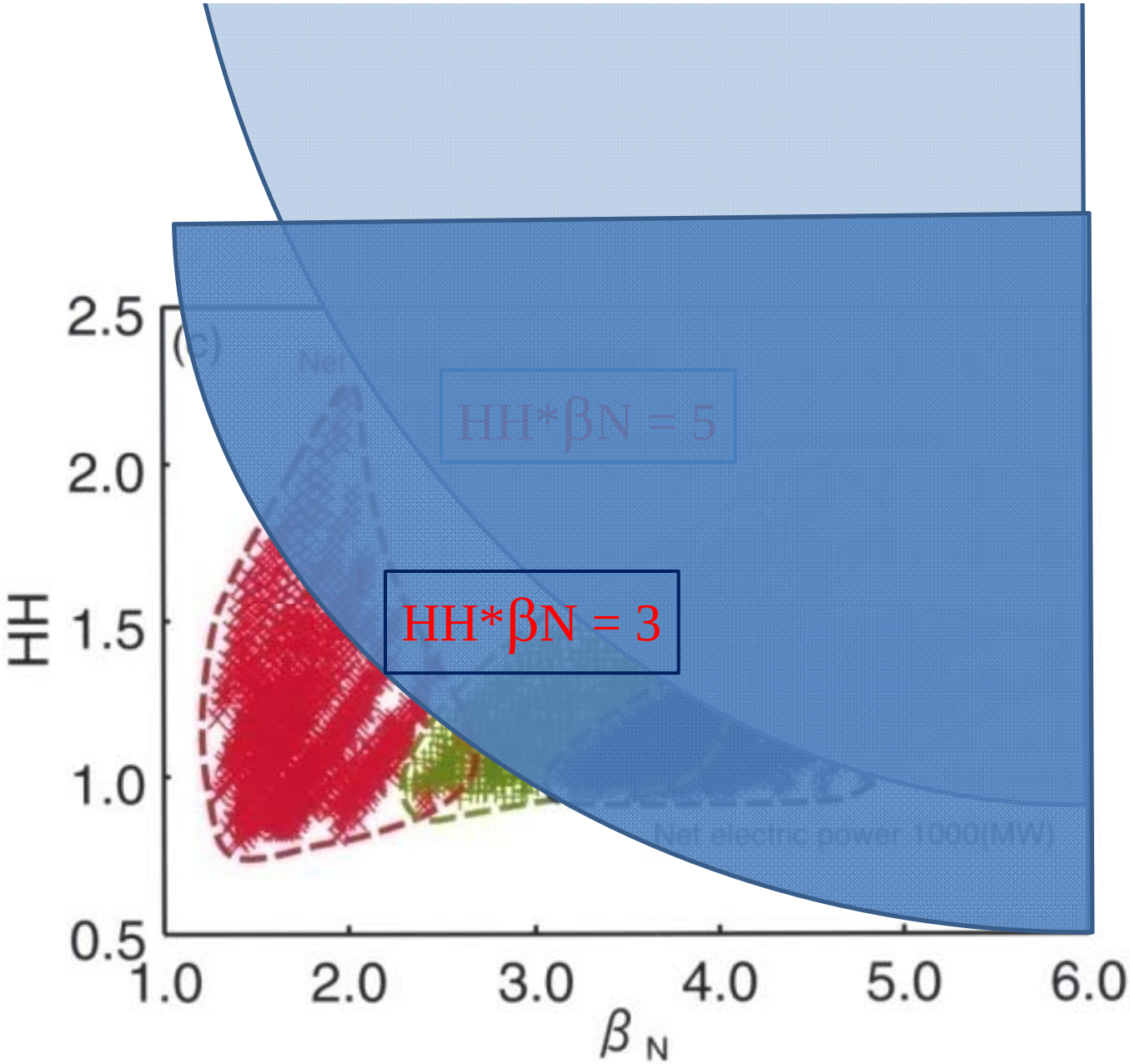
Simultaneous achievement of high beta and high confinement

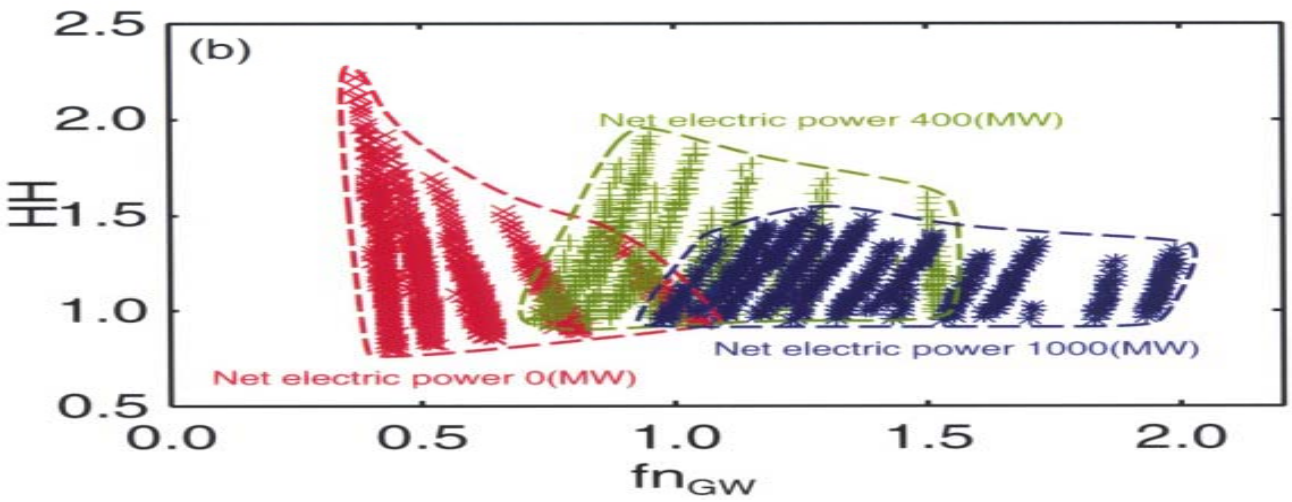
JT-60U

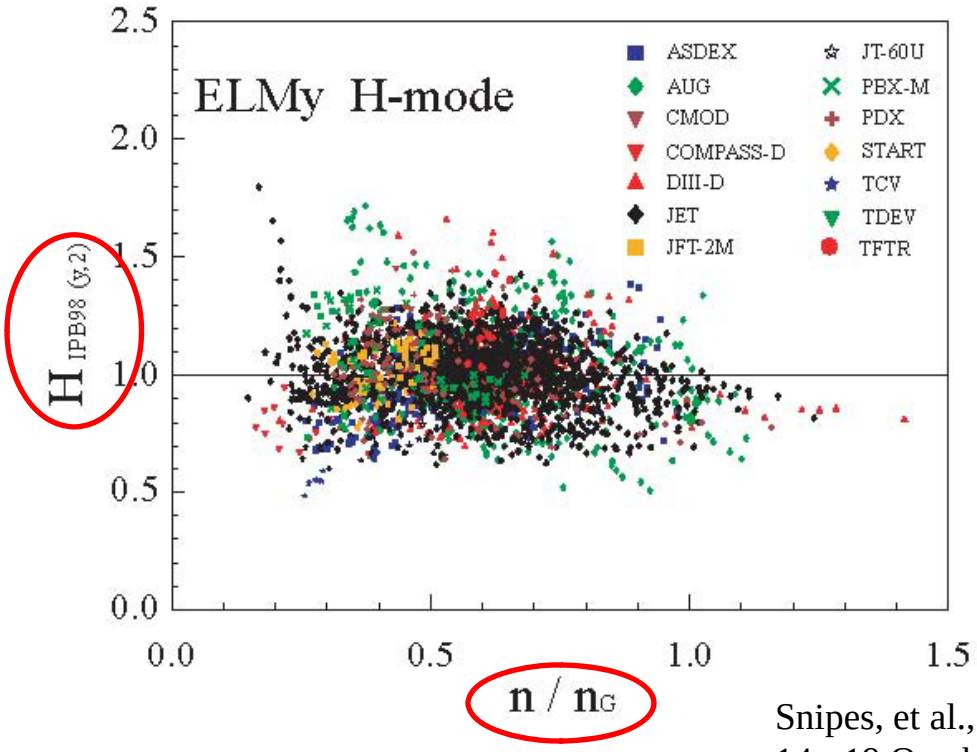
- Beta limit was improved by RWM stabilization, especially in RS plasma with keeping high confinement.
- High β_N expected in ITER was achieved with high confinement.
- In WS plasma, high β_N with high confinement was obtained without wall stabilization.
- Lower confinement in WS plasma with wall stabilization is attributed to the lack of strong central heating.

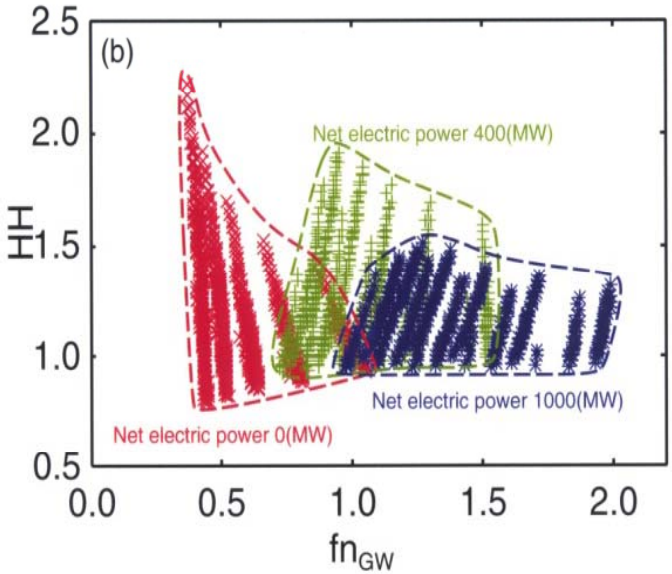


By Sakamoto in JAEA


HH*βN = 5
HH*βN = 3
2.5
2.0
1.5
1.0
0.5
HH
1.0
2.0
3.0
4.0
5.0
6.0
β N







Snipes, et al., 19th Fusion Energy Conference,
14 - 19 October 2002, Lyon, France, CT/P-4

Summary

@ Preliminary study has been carried out for design window of a DEMO reactor.

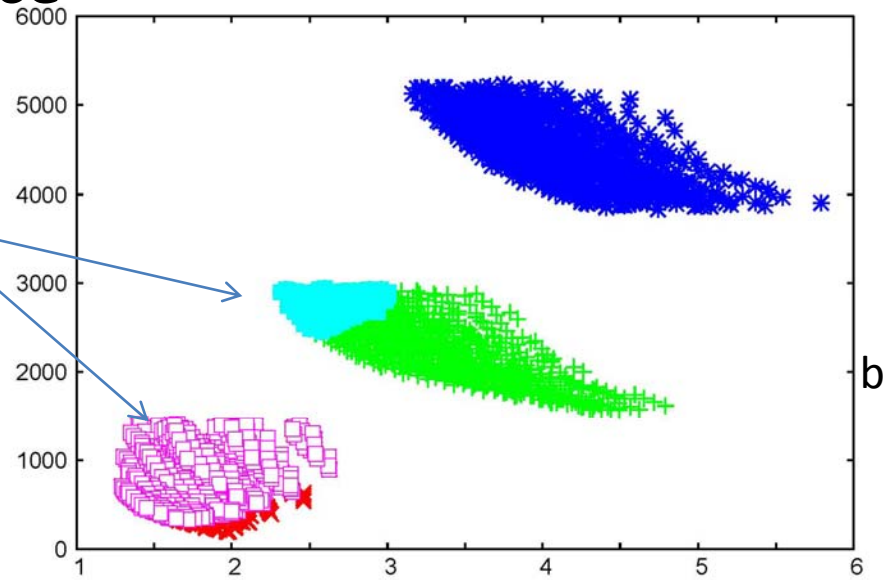
@ The maximum magnetic field strength Bmax strongly affect on the machine size and requirement for plasma performance.

@ A pulsed operation regime has been studied. For example, the device with a major radius of R = 8 ~ 9 m might be feasible for a few-hours inductive operation with a help of an auxiliary current drive power of 60 ~ 100 MW.

@ Inter-relationship between various plasma parameters such as HH, βN and <n>/nGW has been studied. Present experimental data show the strong impact on the design window of the DEMO reactor.

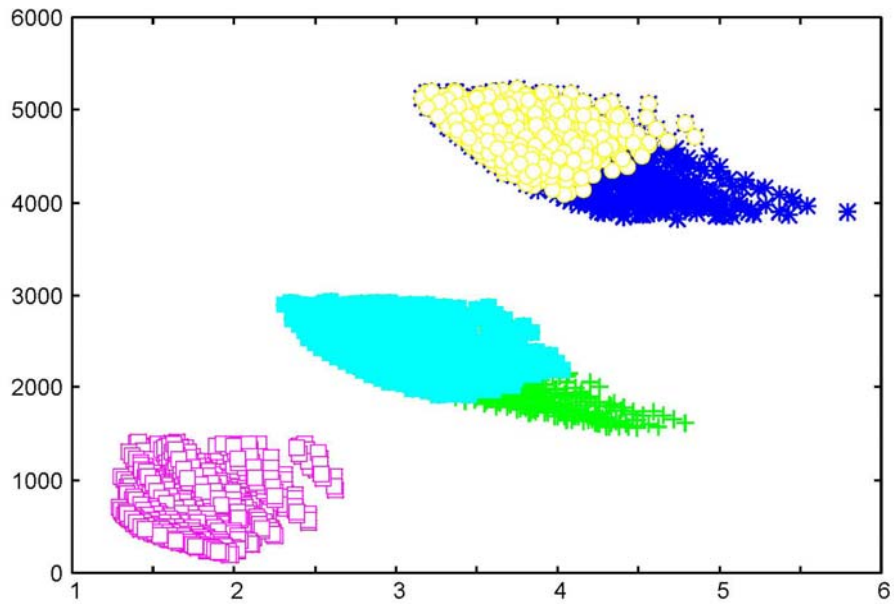
Plasma Performance

Accessible region



bN*HH=3

Fusion Power : Pf



bN*HH=5

Normalized beta : bN