Japan-US Workshop on Fusion Power Plants and Related Advanced
Technologies with participation of EU Jan 11-13, 2005, Tokyo, JAPAN

Parameter Selection of Fusion DEMO Plant at JAERI

M. Sato, S. Nishio, K. Tobita, K. Shinya[1)],
and Demo Plant Team

Japan Atomic Energy research Institute,
[1)]AITEL Corp.,

Contents of my talk

1. Introduction

Compactness and economy

- Fusion DEMO plant design at JAERI directs toward compactness and economy of the reactor with the fusion output of 3 GW level.
- The ratio between fusion power and weight is adapted as the parameter of economy of the reactor.

Low aspect ratio (A) & smaller size of the center solenoid (CS)

- Our parameter survey using a systems code indicates that such a reactor can be envisaged in low aspect ratio (A) region of 2.4-3.
- Smaller size of the center solenoid (CS) has a large impact on reducing the reactor size and weight.

Triangularity (δ)

- High δ is one of key factors to suppress giant ELM as well as to attain high confinement in high plasma density region.
- Is plasma shaping with high triangularity possible with such a reduced CS?

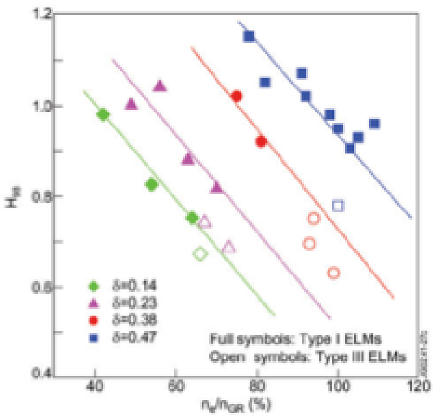
Radial build(Width of scrape-off layer(SOL) etc.)

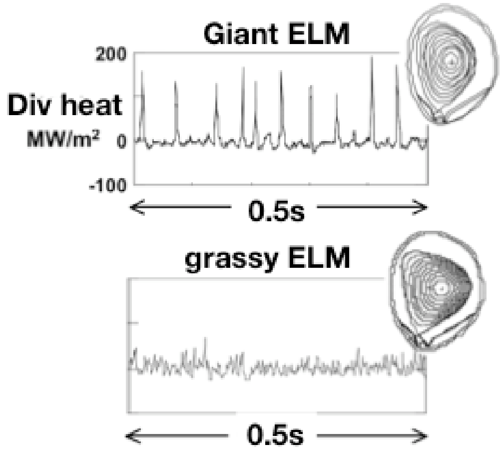
- From the point view of Demo fusion plant design, the SOL width at inboard is important for the radial build.
- The SOL width is estimated based on the MHD equilibrium calculations. It was found that the width must be taken to be wider than previous value (0.1m).

We present the parameter selection of fusion DEMO plant at JAERI and the operation scenario using the system code.

2. Role of CS coil

- High triangularity (δ) is one of key factors to suppress giant ELM as well as to attain high confinement in high plasma density region.





- Three options a ping & Ip ramp up).

	Function of CS coil		
	Aspect ratio (A)	Shaping (Equilibrium)	Ip ramp up/control
CS less(R_{cs}=0m)	~2.4	n	n
slim CS(R_{cs}=0.7m)	~2.6	y	n
full CS(R_{cs}=1.5m)	~3.0	y	y

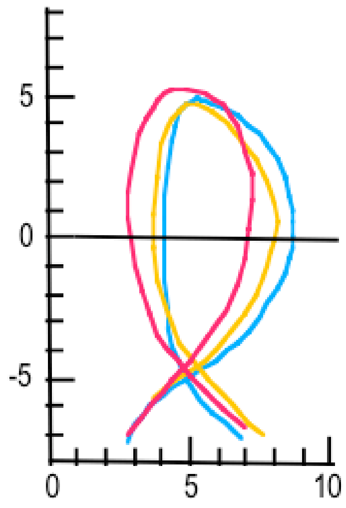
3. Three options of fusion DEMO plant

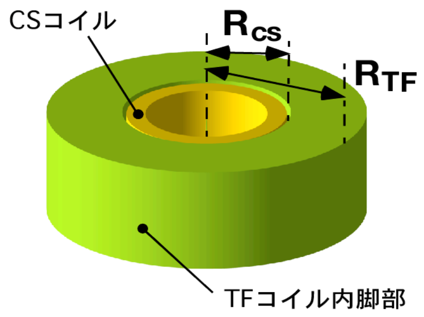
advanced *Focused on roles of CS*

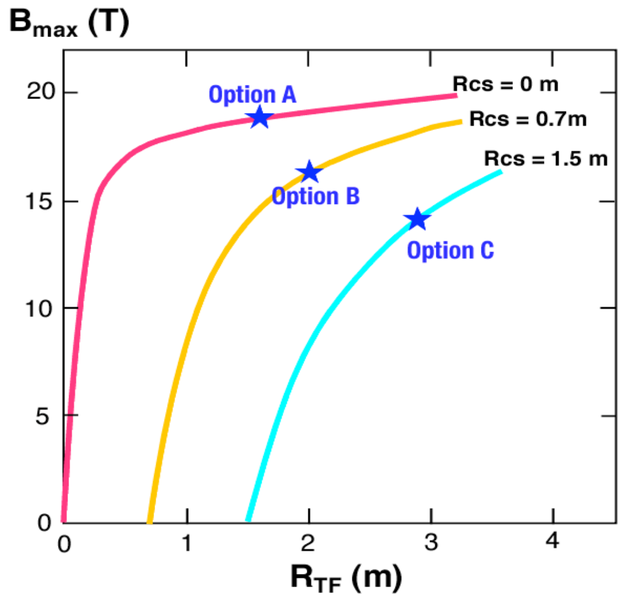
Option A	**CS-less** A ~ 2.3 Rp = 5.1 m, Bmax = 18.2 T weight ~ 15,700 tons
Option B	**Slim CS (10 Vsec)** *CS current enough to get* δ ~ 0.4 A ~ 2.5 Rp = 5.5 m, Bmax = 16 T ~17,300 tons
Option C	**Full CS (30 Vsec)** A ~ 2.8 Rp = 6.3 m, Bmax = 13.8 T ~ 23,700 tons

conservative

cf. SSTR ~ 27,000tons







4. System code
4.1 SOL width

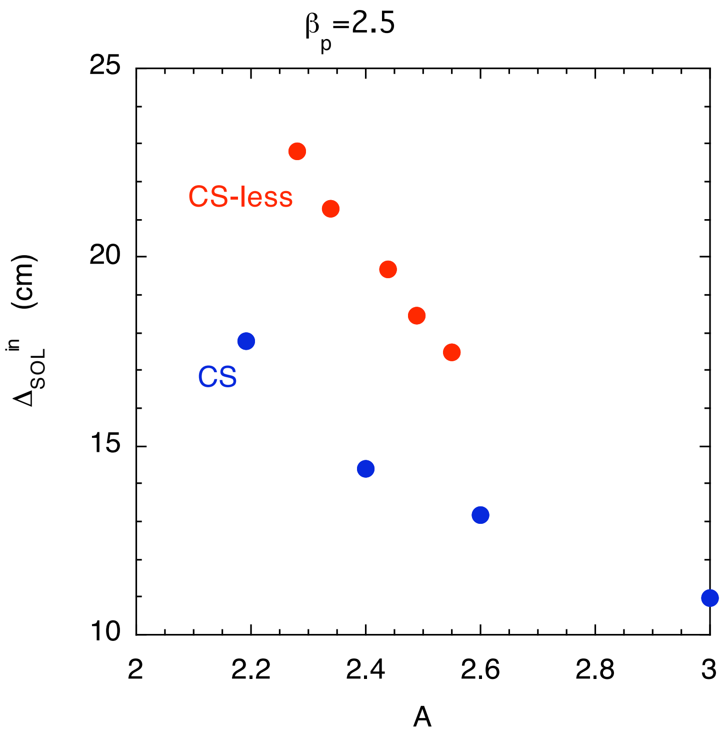
It is important for the radial build in design of Demo fusion plant to evaluate SOL width at inboard.

- **SOL width at inboard (Δ_{sol}^{in}) is determined to the value that corresponds to SOL width of 3cm at outboard.**
- **The Δ_{sol}^{in} is evaluated from results of the equilibrium calculation.**
- **The Δ_{sol}^{in} in the case with CS is shorter than that in the case without CS, because the force due to the CS coil can push the plasma.**
- **The results suggest that following values of Δ_{sol}^{in}.**

  Δ_{sol}^{in} > 20cm in the case of A~2.4 CS less

  Δ_{sol}^{in} > 13cm in the case of A~2.6 slim CS

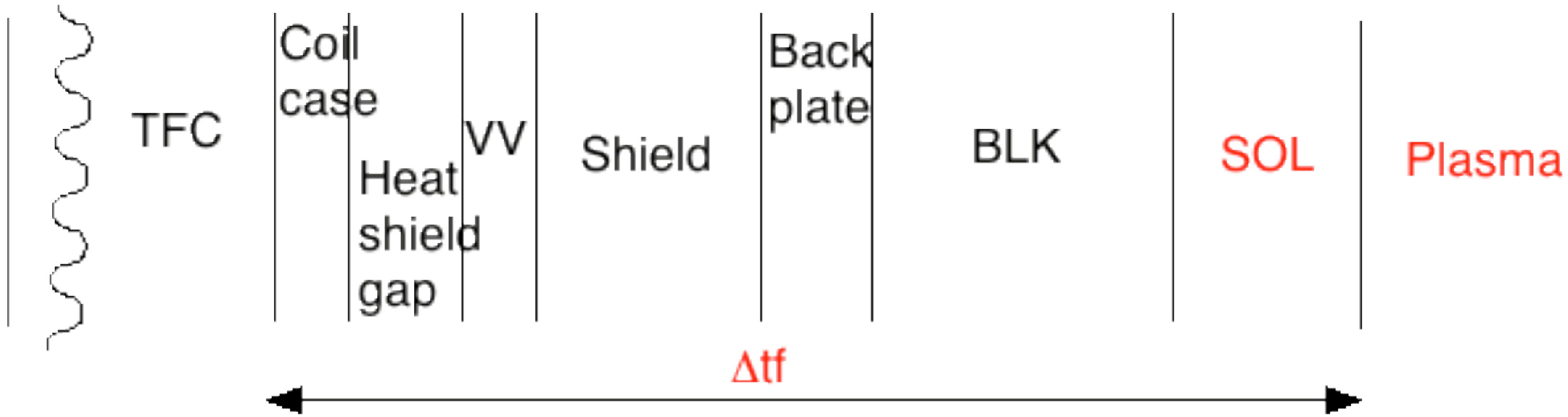
  Δ_{sol}^{in} > 12cm in the case of A~2.9 full CS



Dependence of Δ_{sol}^{in} on A

4.2 Radial build

	A=2.4(CS-less)	A=2.6(slim CS)&2.9(fullCS)
SOL(Δ_{sol}):	25cm	20cm
BLK :	40cm	←
Back plate:	15cm	←
Shield:	30cm	←
Vacuum vessel:	10cm	←
Heat shield,gap:	15cm	←
Coil case:	10cm	←
Total(Δ_{tf}):	145cm	140cm



4.3 Plasma elongation(κ) & normalized beta(β_N)

Assumption

Elongation(κ):Modified Wong's Eq. (~75%)

$$\kappa = (0.05*A+0.55)*\kappa^{Wong}(A)$$

Wong's Eq.:

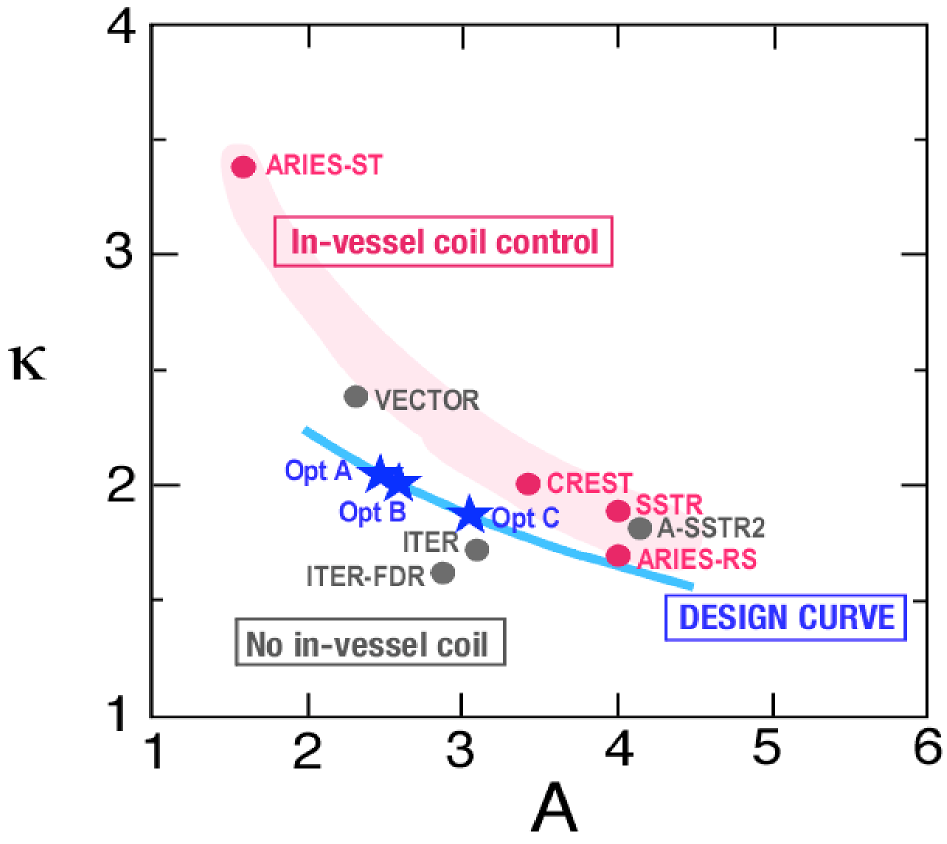
$$\kappa^{Wong}(A) = 0.277+0.9129/A-5.748/A^2$$

A: aspect ratio

Normalized beta(β_N):78% value of Miller-Wong Scaling eq.

Miller-Wong Scaling eq.
:Limit from stability(infinite balooning & low n kink)

$$\beta_N = \left(3.09 + \frac{3.35}{A} + \frac{3.87}{A^{0.5}}\right)\left(\frac{\kappa}{3}\right)^{0.5}$$



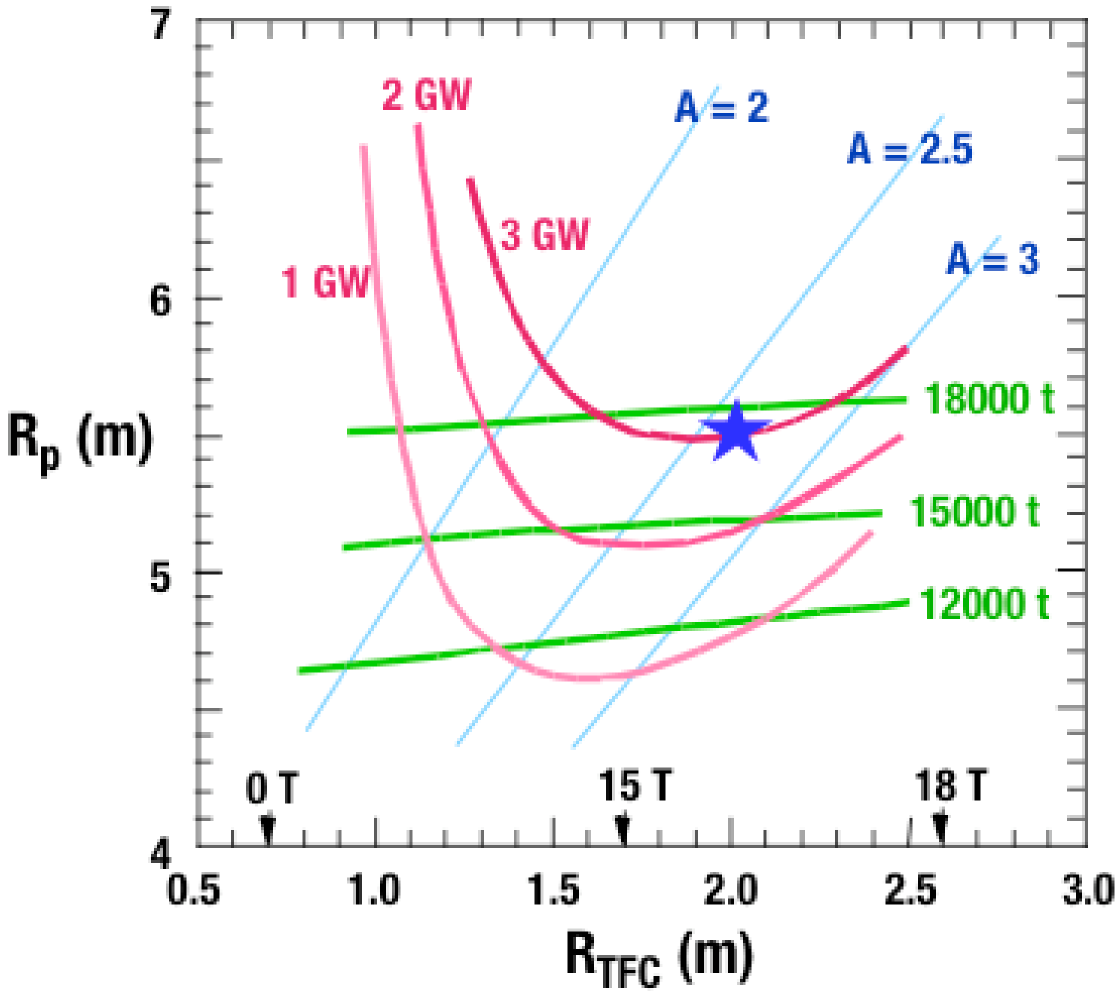
5 System code results
5.1 Selection of DEMO parameters(Option B)

Results of system code

Slim CS

- Pfus～3GW
- HH factor=1.3
- <Te>=17keV
- Lightest parameters

Rtfc=2.0m, Rp=5.5m



5.2 Three cases of DEMO parameters

Results of system code

- Pfus～3GW
- HH factor=1.3
- <Te>=17keV

	CS-less Option A	slim CS Option B	full CS Option C
Rp (m)	5.1	5.5	6.5
a (m)	2.15	2.2	2.3
A	2.3	2.5	2.8
κ	2.08	2.03	1.94
δ	~0.1	~0.4	~0.45
BT (T)	5.35	5.54	5.9
Ip (MA)	18.1	17.5	16.4
q95	5.7	5.5	5.3
βN	4.6	4.4	4.1
HH	1.3	1.3	1.3
n/nGW	0.95	0.98	1.04
Pfus (GW)	3.1	3.1	3.1
Pn (MW/m2)	3.6	3.3	2.7
Q	49	52	60
weight (tons)	15,700	17,300	23,700

Which do you select for the Demo fusion plant?

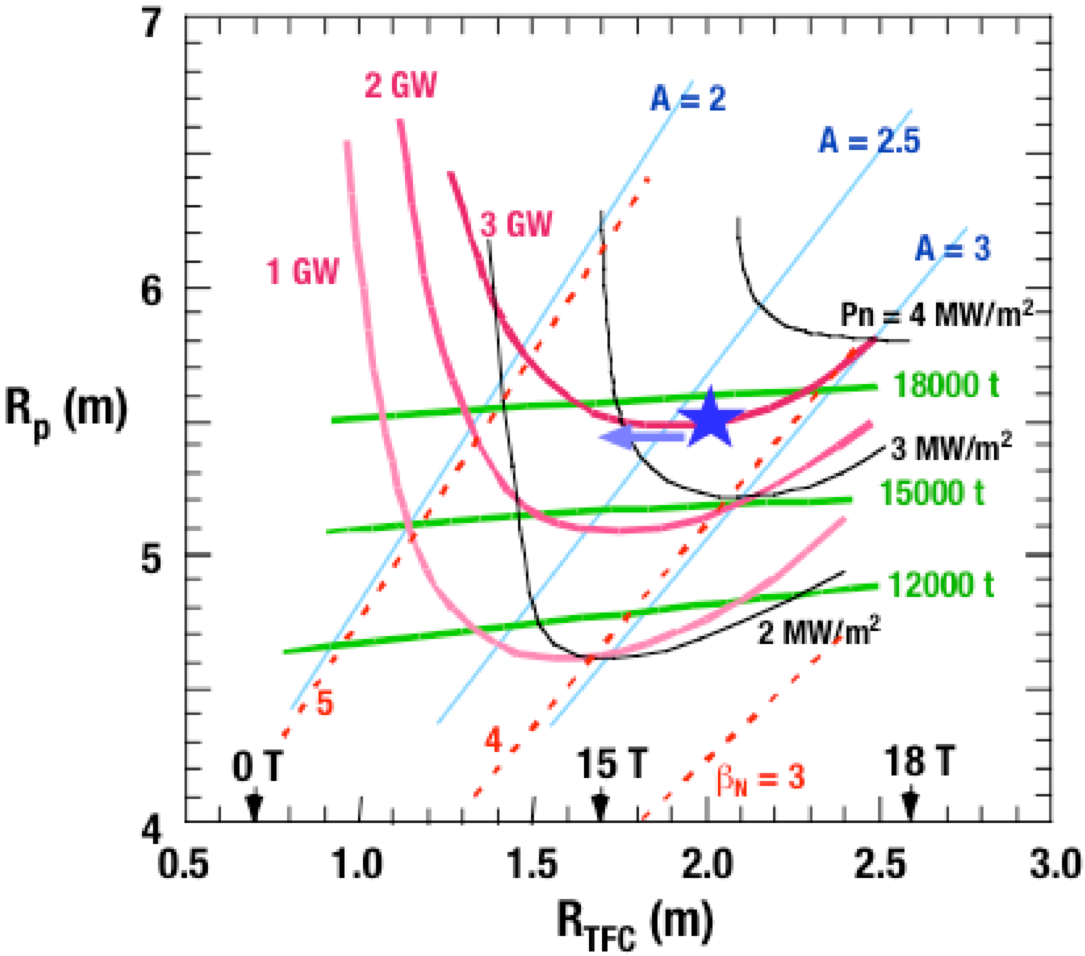
5.3 Selection of DEMO parameters (Option B1)

Results of system code

Slim CS

Lower R_{TFC} may be better to reduce the number of BLK replacement.

- Pfus～3GW
- HH factor=1.3
- <Te>=17keV
- Lightest parameters (Rtfc=2.0m->1.7m, Rp=5.5m)



Operation scenario(preliminary)

Scenario is considered in the case of Option B1.

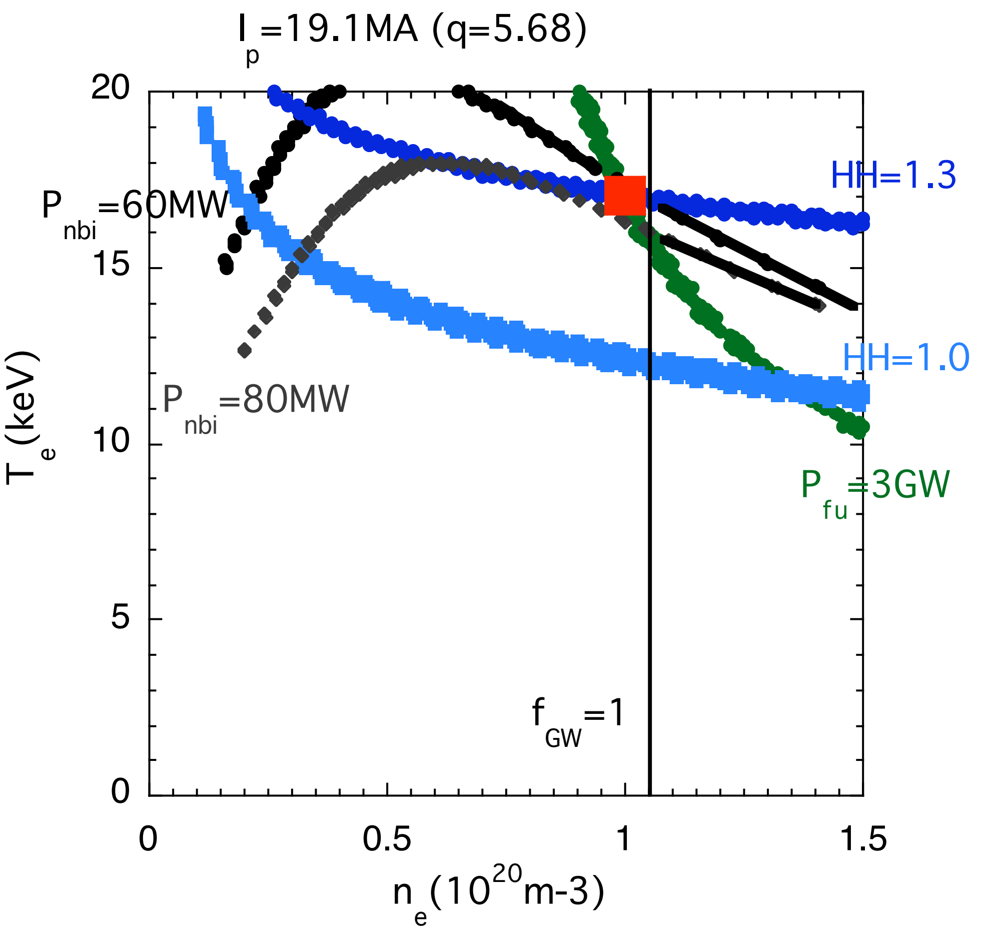
Operation scenario is considered based on the results of system code.

Operation condition

- **HH factor<1.3**
- **n/n_{GW} ($=f_{GW}$) <1.0**
- **P_{nbi} is low as possible as**

At the final state,

- **P_{fusion}~ 3GW**
- **HH=1.3**
- **P_{nbi} ~65MW**

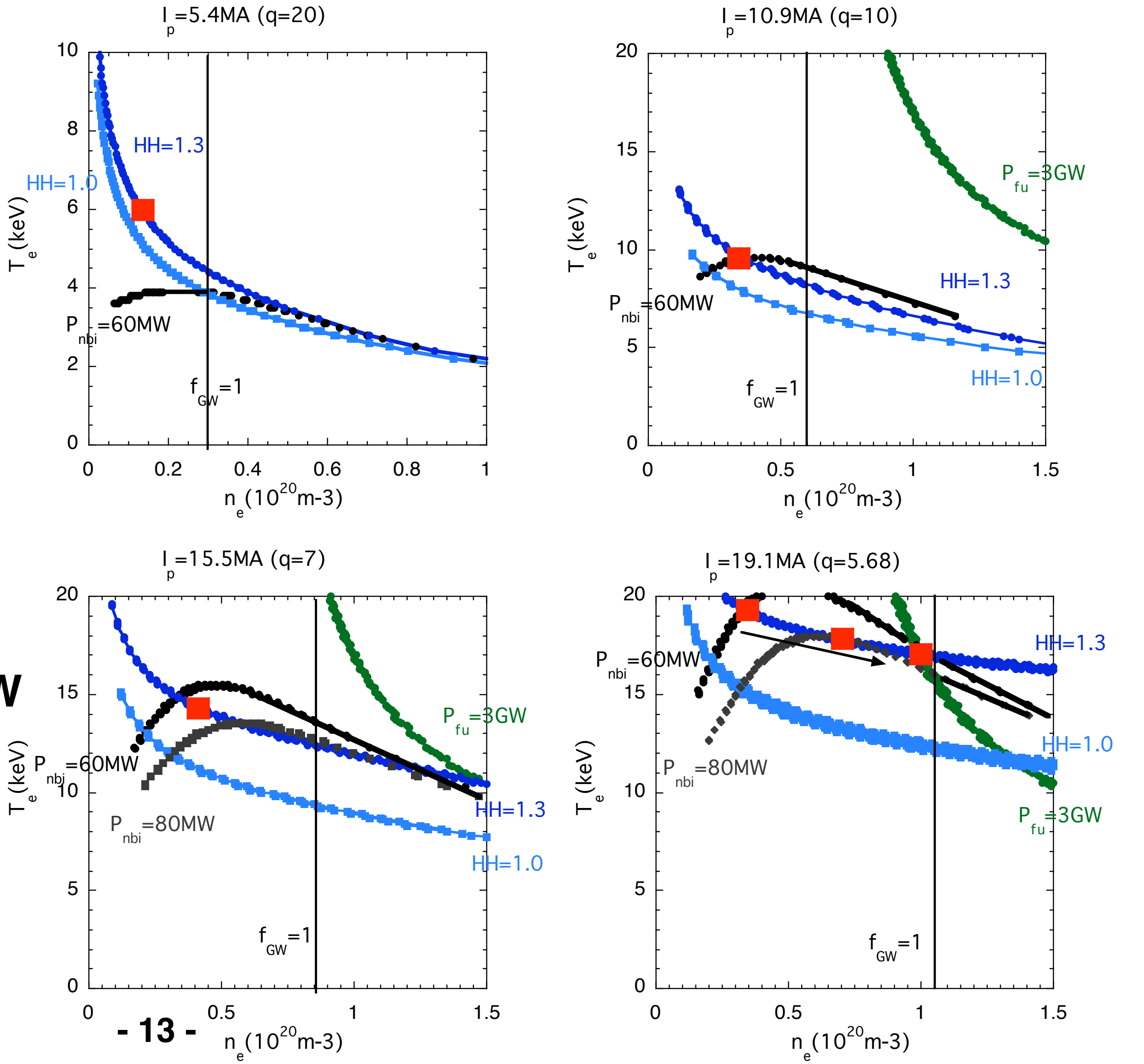


Operation scenario(preliminary)

- Assumption: H mode at 5MA.
- From 5MA to 19MA
HH factor is kept to be 1.3.
- From 5MA to 16MA
$n/n_{GW}\,(=f_{GW}) < 0.6$

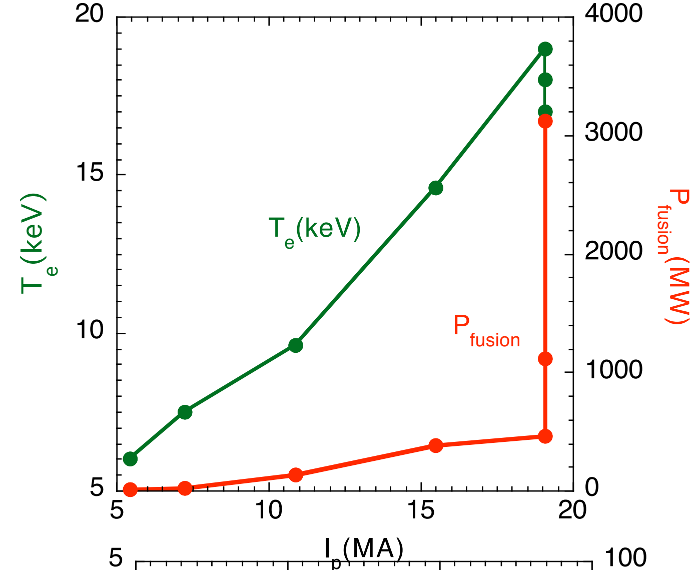
- To reach the final state, the density(n_e) must increase.
However, in the low I_p case,
n_e can not increase due to the condition of $n/n_{GW}\,(=f_{GW}) < 1.0$
On the other hands, in the high I_p case, n_e can increase if P_{nbi} is 80MW

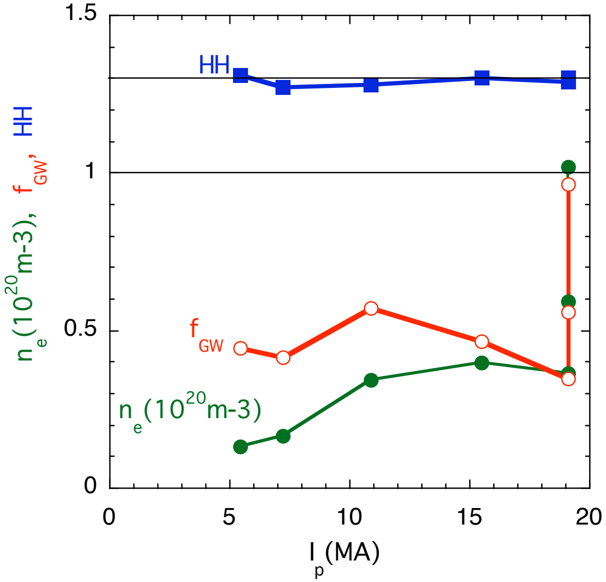
- P_{nbi}=80MW is needed to traverse to final state.

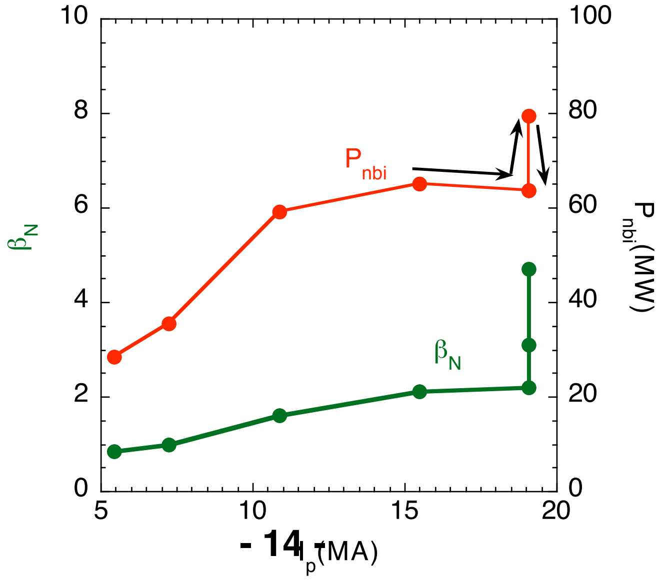


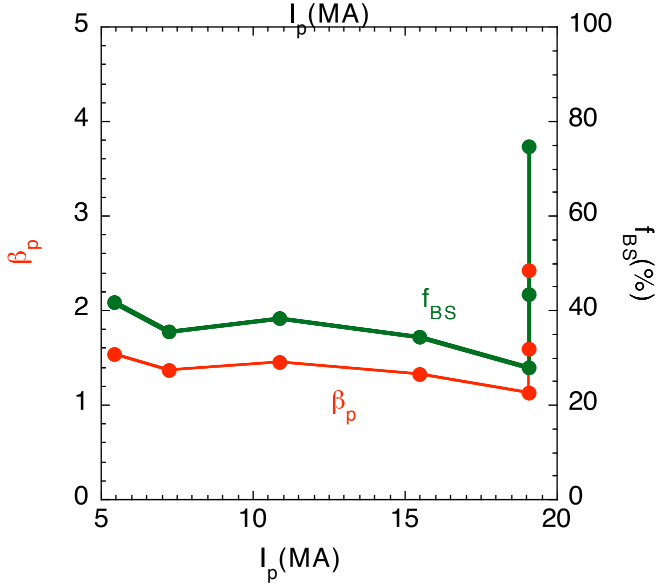
Dependence of parameters on Ip

- **H mode at 5MA.**
- **From 5MA to 19MA: H factor(HH) is kept to be 1.3, and n/n_{GW} $(=f_{GW}) < 1.0$**
- **From 5MA to 16MA: n/n_{GW} $(=f_{GW}) < 0.6$**









Summary

- Fusion DEMO plant design at JAERI directs toward compactness and economy of the reactor with the fusion output of 3 GW level.
- The ratio between fusion power and weight is adapted as the parameter of economy of the reactor.
- The parameter of fusion DEMO plant at JAERI is selected using system code.
- The width of SOL at inboard is estimated based on MHD equilibrium calculations. It was found that the width must be taken to be wider than previous value (0.1m).
- There are three options: CS less, slim CS and full CS.
- For slim CS, high δ_x (≥ 0.43) is obtained and the reactor size and weight become relatively small and light. The role of CS coil is shaping plasma.
- Operation scenario is considered in slim CS case.
  - Plasma is assumed to be H mode at I_p = 5MA.
  - The conditions of HH factor =1.3 & n/n_{GW} (=f_{GW}) < 1.0 is kept during current ramp up.
  - The final state can be reached if P_{nbi} is 80MW.