Divertor Plasma Issues concerning Commissioning Operation for DEMO

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Contents

- Introduction：Operation flexibility and importance of commissioning operation for DEMO
- Overview of Demo-CREST
- Divertor plasma issues concerning commissioning operation for Demo-CREST
  - Issue on divertor heat load
  - Issue on compatibility of divertor configuration
- Summary and future issues

Flexibility of Plasma Operation for DEMO

- DEMO has several plasma operation modes.
  - Commissioning operation mode
  - Usual plasma ramp-up and ramp-down operation mode
  - Rating operation mode
  - Load following operation mode
  - Advanced operation over ITER performance toward 1st (if possible), 2nd and 3rd generation of the commercial power plant.
- How much flexibility is required to install for DEMO ?

  ➔ That depends on the design policy of DEMO.
- More or less, it is necessary for DEMO to keep the flexibility of plasma operation. Especially, commissioning operation mode is important.

Importance of Commissioning Operation

- Commissioning operation is essential to carry out the final verification for all component's performance.
- For example, divertor plasma and blanket system can NOT be demonstrated in the plant scale during the ITER program.
- Divertor:
  - The heat load to the divertor plates becomes huge in comparison with ITER, and some advanced operation method has to be developed through the ITER project.
  - Final demonstration of such advanced divertor operation for DEMO has to be carried out by DEMO itself. Probably, fusion power increases step by step.
- Blanket system:
  - Gradual increase of fusion power results in the wide range of the power load condition of the first wall.

    Is such wide range operation as for the power load possible under the single blanket system ?
  - Under the limited amount of the initial tritium stock, how efficiently the total system (tritium recovery and fueling, power generation) can be examined is important.

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Demonstration Plant：Demo-CREST

Principle for the Demo-CREST Design

- Demonstration Phase：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 (OP1～OP4)
- Development Phase：To show a possibility of an economical competitiveness with advanced plasma performance and high performance blanket systems, by replacing breeding blanket from the basic one to the advanced one (OP4, OPRS)

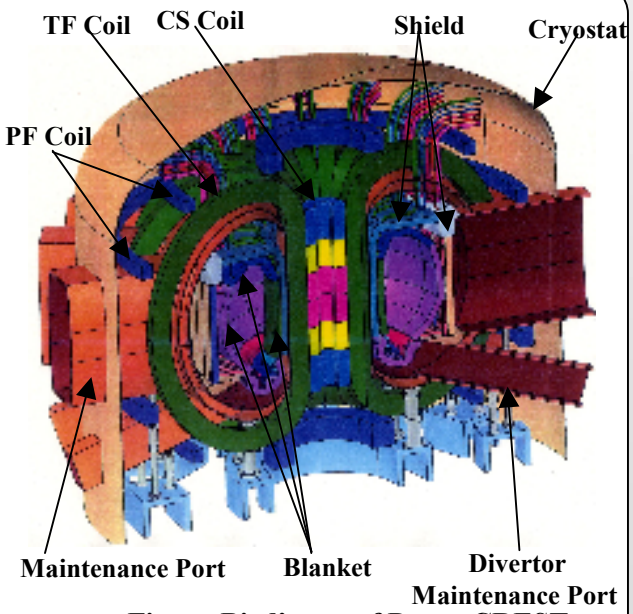
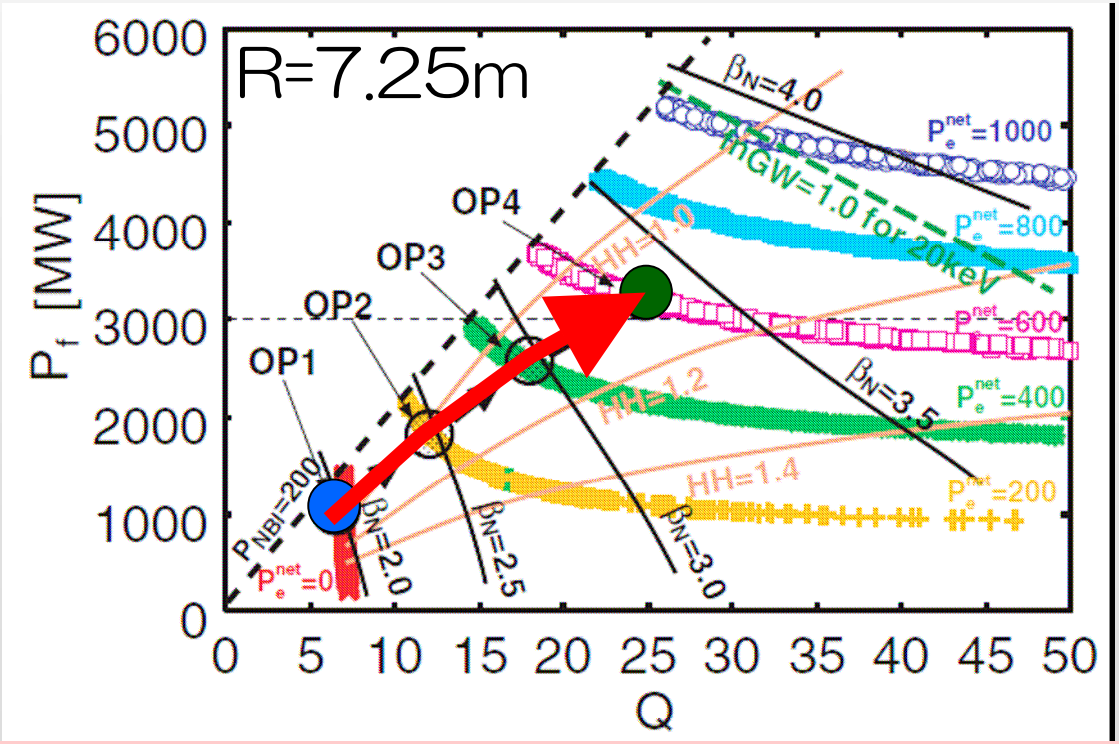


Figure:Bird's-eye of Demo-CREST

		OP1	OP2	OP3	OP4	OPRS
R (m) / A		7.25 / 3.4				
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%)	30	230	390	490	-
	Advanced Blanket(40%)	-	-	-	850	1090

Commissioning Operation Points

- Start with the plasma performance similar to ITER standard operation (OP1:β_N～1.9).
- Final operation point (OP4:β_N～3.4) is based on the ITER advanced operation.
- MHD and current drive for OP1-4 have already been examined.



Consistency with divertor plasma has NOT been examined yet.

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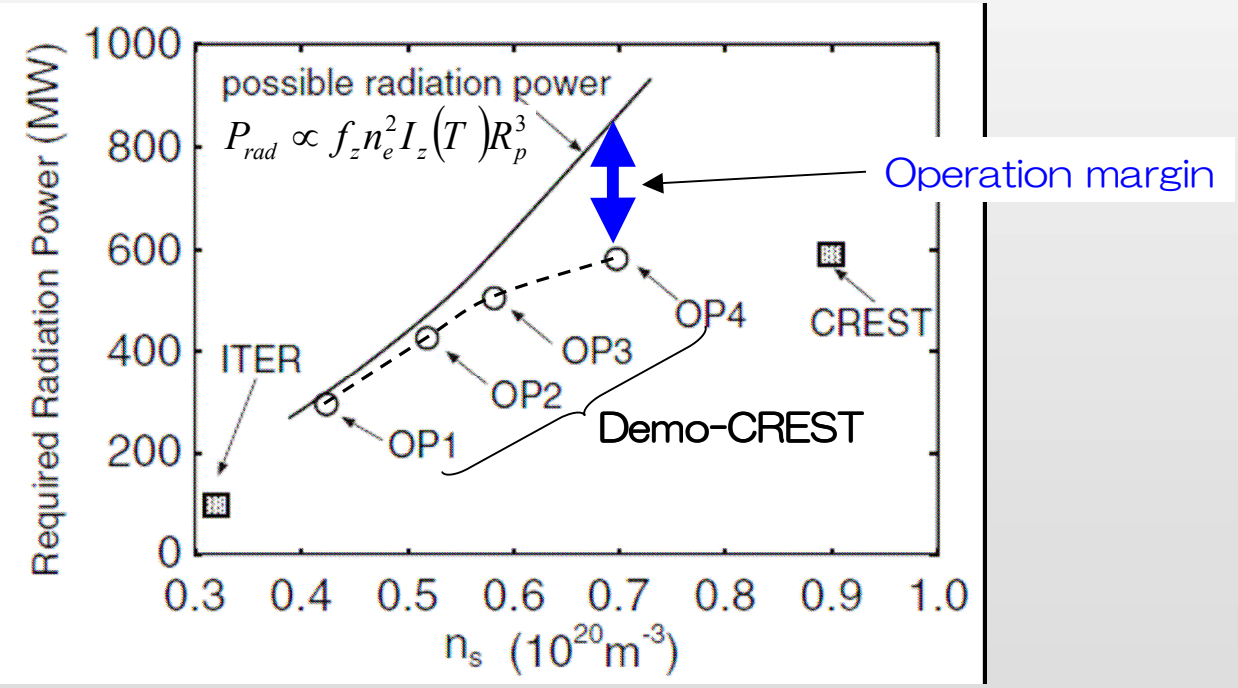
Required Radiation Power for q_{div}<10MW/m^2

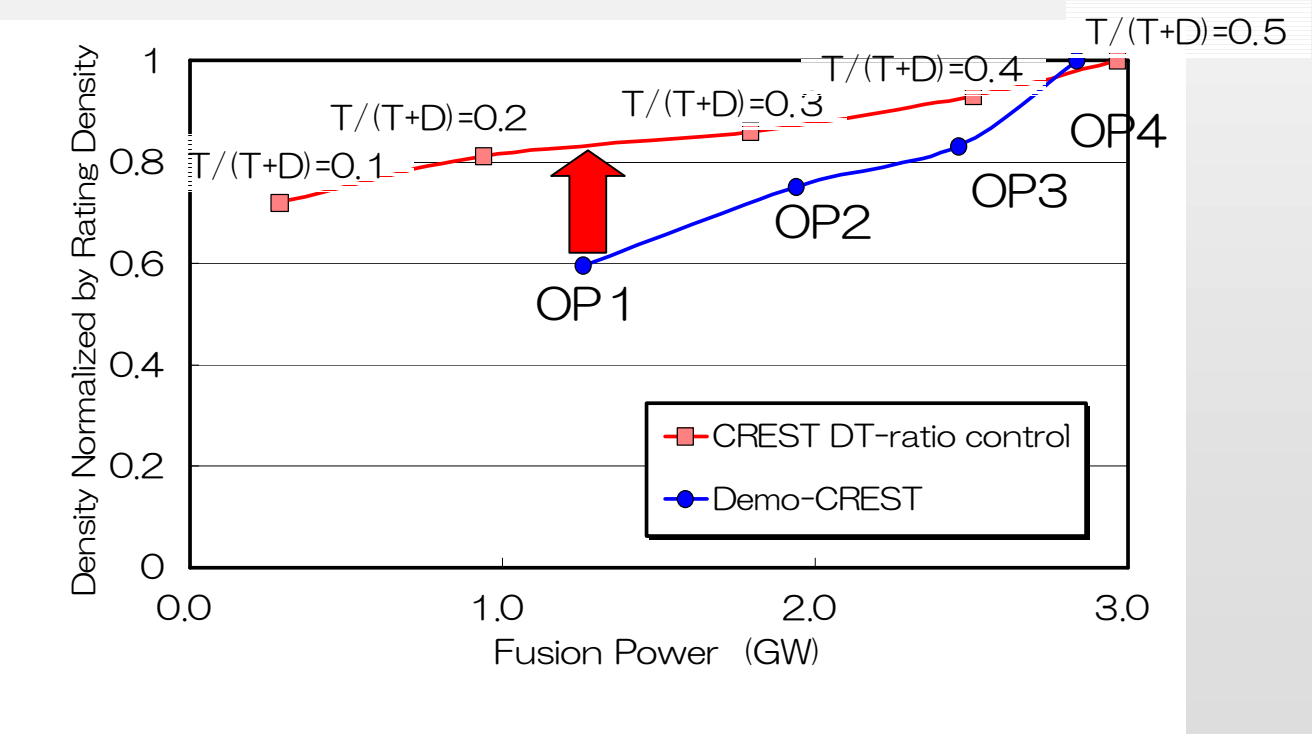
- The radiation power required for q_{div}<10MW/m^2 increases from from OP1 to OP4.
- Possible radiation power P_{rad} : Xe seeding (fz=0.1%) is assumed
- Operation margin for the initial OP1 is smaller than for OP4
- P_f and P_{rad} increase in proportion of ne^2, while there is a constant current drive power 200MW



The higher density is preferable even in the lower fusion power
➔ One of the possibilities is the DT-ratio control

DT-ratio Control Analysis for CREST

- CREST (R=5.4m, β_N=5.5, Pf=3GW, Pcd=100MW)
- Consistency between MHD and current drive has been examined.
- BSC and Ip decrease, then confinement and density are degraded under the limited Pcd.
- DT-ratio control has still possibility for high density operation with low fusion power in comparison with Demo-CREST results



Analysis for Demo-CREST is now under survey.

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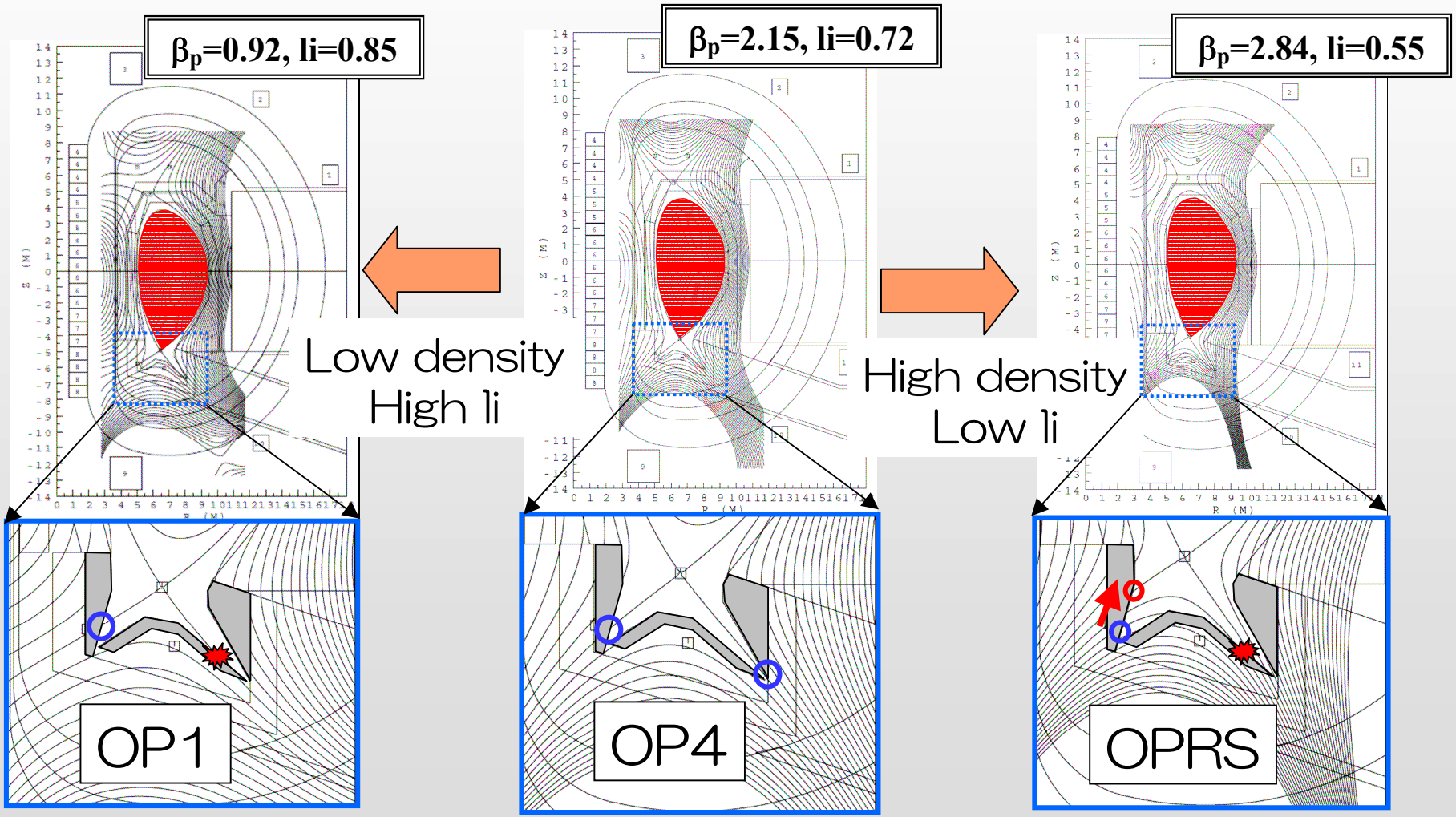
Compatibility of Divertor Configuration

- Equilibrium analysis for Demo-CREST
- Fixed plasma shape of κ_{95}=1.85, δ_{95}=0.25



Equilibrium for Fixed Strike Points

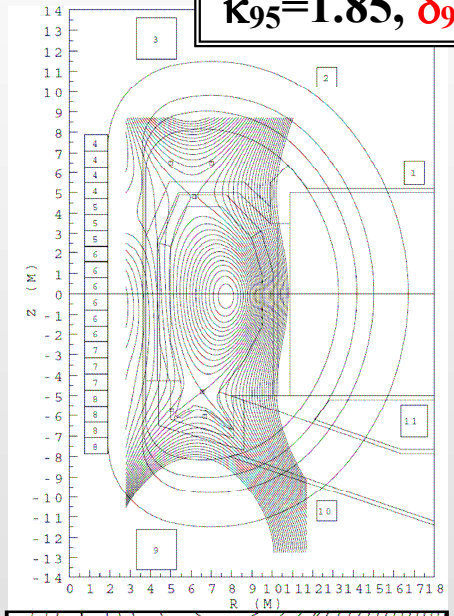
- Elongation becomes large from OP1 to OP4 and OPRS, because X-point moves
- To fix the strike points, plasma elongation has to be increased during the commissioning phase.

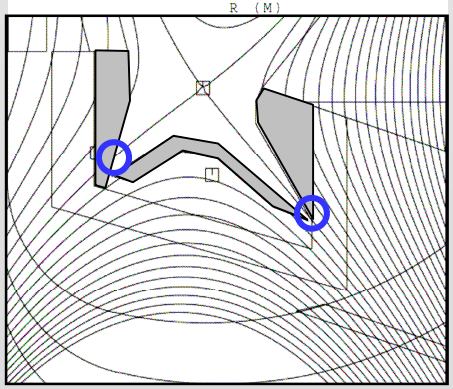
	β_p	l_i	κ_{95}	δ_{95}	κ_X	δ_X	r_X (m)	z_X (m)
OP1	0.92	0.85	1.83	0.23	2.01	0.32	6.57	-4.79
OP4	2.15	0.72	1.86	0.25	2.0	0.31	6.56	-4.72
OPRS	2.84	0.65	1.89	0.23	1.99	0.27	6.65	-4.65

Flexibility for plasma triangularity

- Controllability of δ_{95} is important for high beta operation, but it seems to be difficult with the same location of plates and dome.
- A constant δ_{95} is preferable during the commissioning phase.

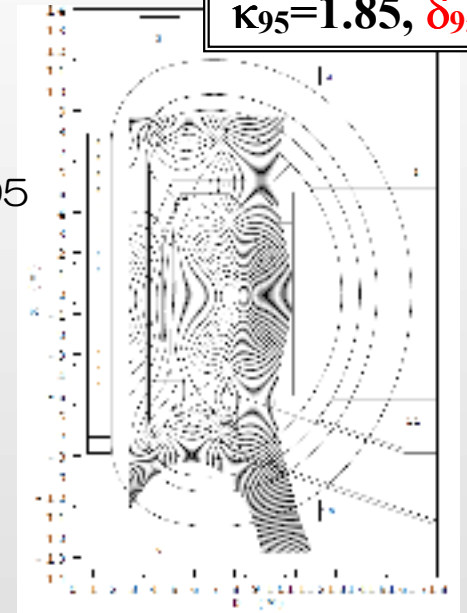
κ_{95}=1.85, δ_{95}=0.25

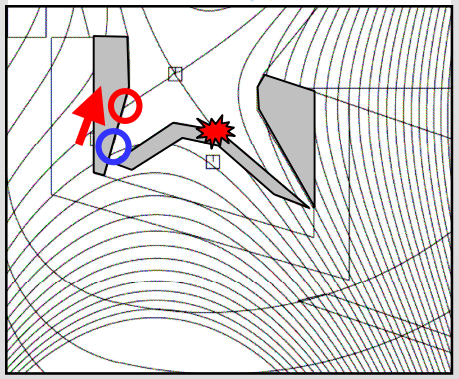




Increase δ_{95}

κ_{95}=1.85, δ_{95}=0.35





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Summary

- For the DEMO design, it is important to consider not only the rating operation point but also all points through commissioning operation.
- As for the divertor heat load of Demo-CREST, the operation condition for the initial operation point of small fusion power and low density is more difficult than that of the full power operation.
- As for the compatibility with the divertor configuration of Demo-CREST, adjustment of elongation is required with increase of fusion power during the normal shear operation. Another divertor configuration (location of plates and dome) is probably required for higher triangularity and reversed shear operation.

Future Issues

- Divertor analysis by 2D divertor transport code SOLPS5(B2-EIRENE) is just started under the collaboration with Keio Univ. and ASIPP.
- Operation points for commissioning operation will be re-assessed under the consideration of the compatibility with divertor heat load and divertor configuration.
- Applicability of DT-ratio control to commissioning operation will be also examined in detail.