Consideration on Physics and Parameters of CFETR

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Mission of CFETR

Consideration:

for What: *fill/bridge gap ?* unable to define precisely features of DEMO

When: *before/parallel with/post ITER ?*

CFETR: part of research activities & one of facilities to fill gap to DEMO ?

Partial Mission (*Nuclear Aspect*):

- *Demonstrating tritium self-sufficiency & other tritium issues*
- *Testing materials & components in integrated fusion nuclear environment*
- *RAMI of components*
- … …

Design goal of the first option of CFETR (Prof. Y.X.Wan)

- A good compliment with ITER
- Demonstration of full cycle of fusion energy with a minim P_f = 50 ~ 200 MW；
- Long pulse or steady-state operation with duty cycle time ≥ 0.3 ~ 0.5；
- Demonstration of full cycle of T self-sustained with TBR ≥ 1.2
- Relay on the existing ITER physical （k<1.8, q>3, H~1) and technical bases (higher B_T , diagnostic, H&CD);
- Exploring options for DEMO blanket & divertor with a easy changeable core by RH；

Requirements of CFETR

- Advanced or conventional tokamak with high feasibility, small-scale and low cost;
- Sufficient running time;
- Being of certain fusion power and neutron wall load required for tritium blanket;
- Integral neutron flux satisfying the requirements of materials and components testing;
- Lower first wall and divertor target heat flux load;

Design Consideration

According to the physical (scaling) law for ITER design and the latest experimental results, balancing major plasma parameters, selecting the core plasma parameters with high feasibility .

- Long pusle operation;
- **Duty factor is 0.3~0.5;**
- **Fusion power is 200 MW~400 MW, Fusion gain is 2~4;**
- **Neutron fluence is 3.0 MWa/m^2 ~ 6.0 MWa/m^2;**
- **Neutron wall load is 0.4 ~ 1.0 MW/m^2;**
- Divertor heat flux under acceptable level;
- Neutral beam and electron cyclotron as heating and current drive;

Consideration of Physics & Parameters

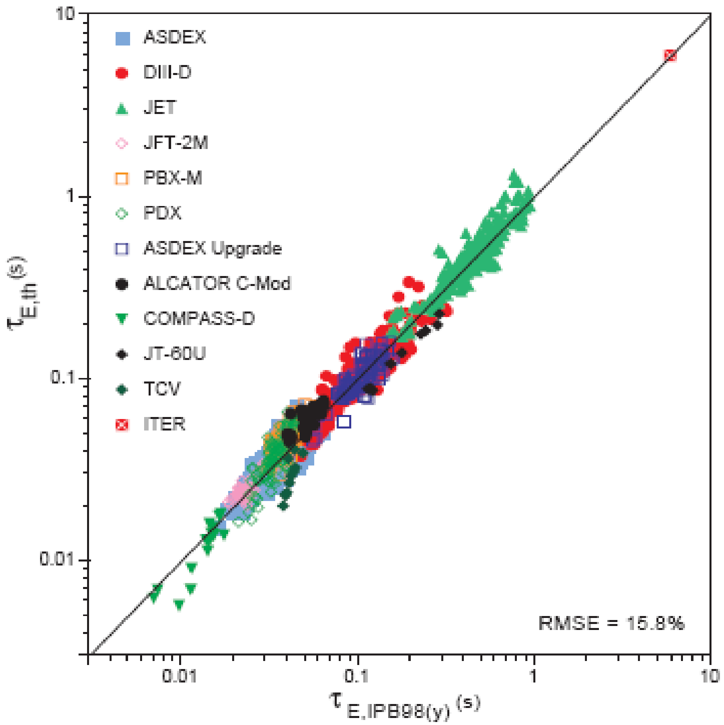
- CFETR should have enough Volt-second to ensure sufficient running time;
- The plasma current has to make sure that the safety factor is greater than 3.0, and will be changed according to the troyon limit, fusion power, running time and so on;

$$q_{95} = \frac{5a^2 B_0}{R_0 I_p} \left(\frac{1.17 - 0.65\varepsilon}{(1-\varepsilon^2)^2} \right) [1 + \kappa^2 (1 + 2\delta^2 - 1.2\delta^3)]$$

Design based on ITER Physics Basis

- The scaling of energy confinement time is IPB98(y,2), Energy confinement time enhancement factor should be designed within reasonable limits, or appropriate extrapolation;

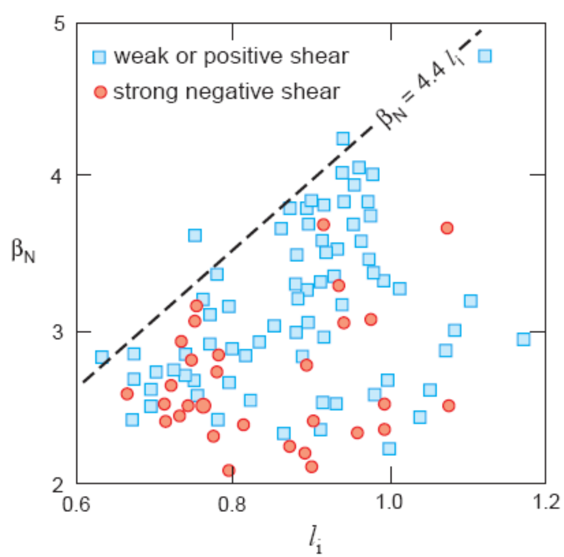
$$\tau_E = 0.00562 H_{H98(Y,2)} I_P^{0.93} R^{1.97} n^{0.41} P^{-0.69} B_T^{0.15} \kappa_a^{0.78} \varepsilon^{0.58} M^{0.19}$$

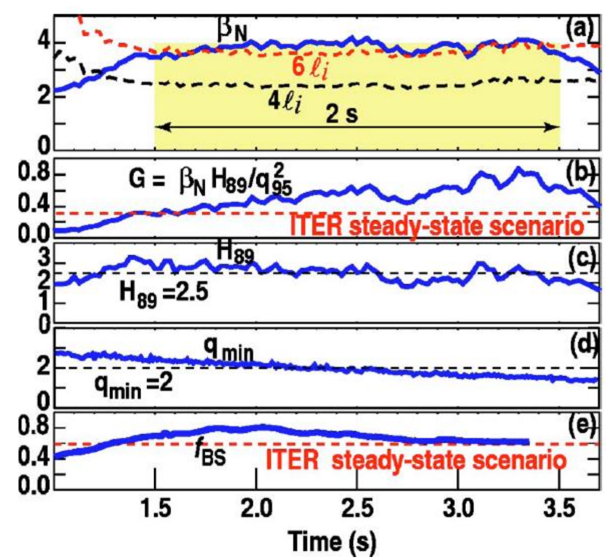


Design based on ITER Physics Basis

- Troyon limit is based on the experimental calibration ratio and empirical formula of the fusion reactor design, and will be adjusted according the fusion power, neutron wall loading, bootstrap current and so on;

$$\beta\% = \beta_N \frac{I_p(\text{MA})}{\text{a(m)B(T)}} \qquad \beta_{N.\max} \approx 4l_i$$





Design based on ITER Physics Basis

- Plasma density is 70%~95% of Greenwald limit, which will be adjusted according to the current drive efficiency, energy confinement time and so on;

$$n_e \leq n_{GW} = \frac{I_p}{\pi a^2}$$

- Fusion gain will be optimized according to the energy confinement time, as well as the current drive power;

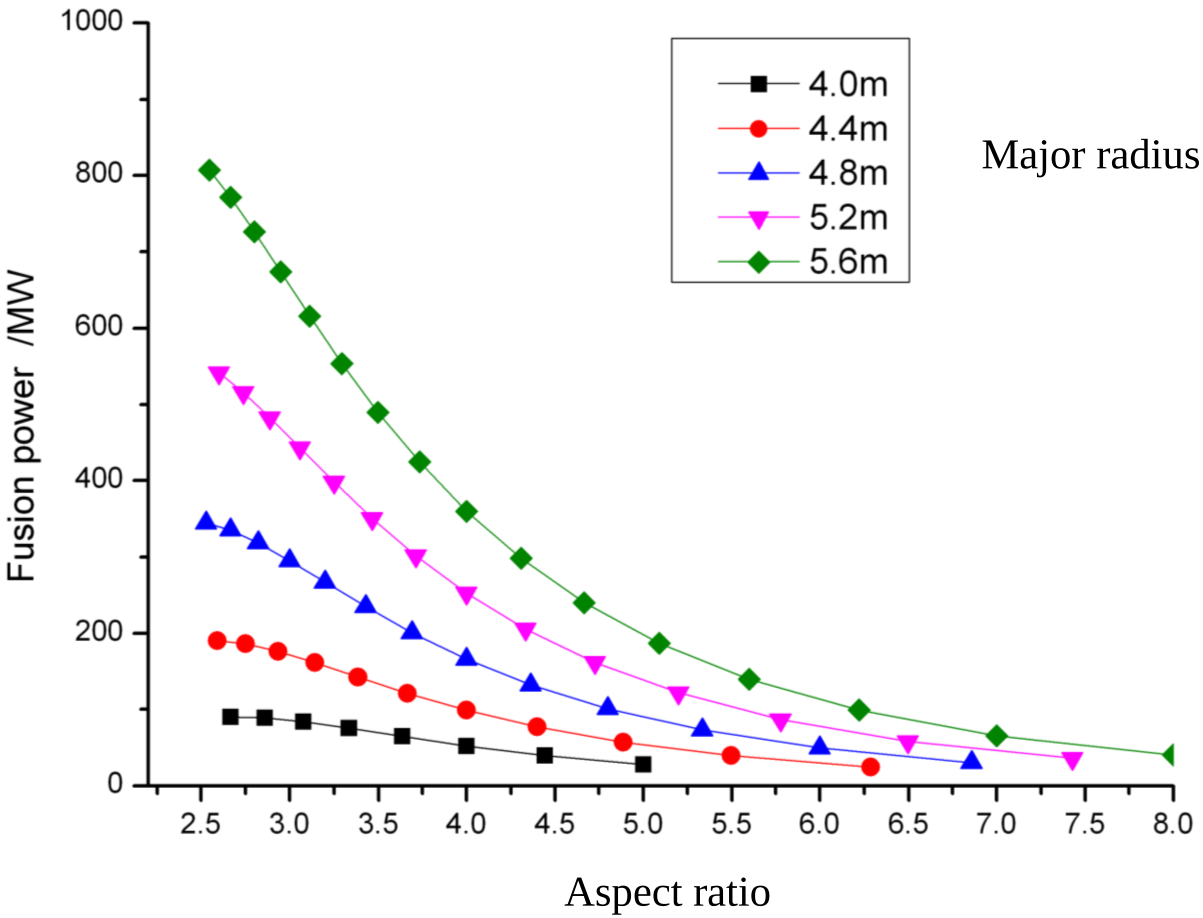
Selecting Parameter

- Using Zero-dimensional calculation, setting temperature & density profile to analyze the fusion power, neutron wall load and running time under the main plasma parameters;
- Setting geometry configuration according to tokamak equilibrium configuration;
- Estimating the thickness of tritium blanket, Shielding blanket and Vacuum vessel according to the neutron wall loading and operation time;

I : Superconductor coils or II: Copper TF coil

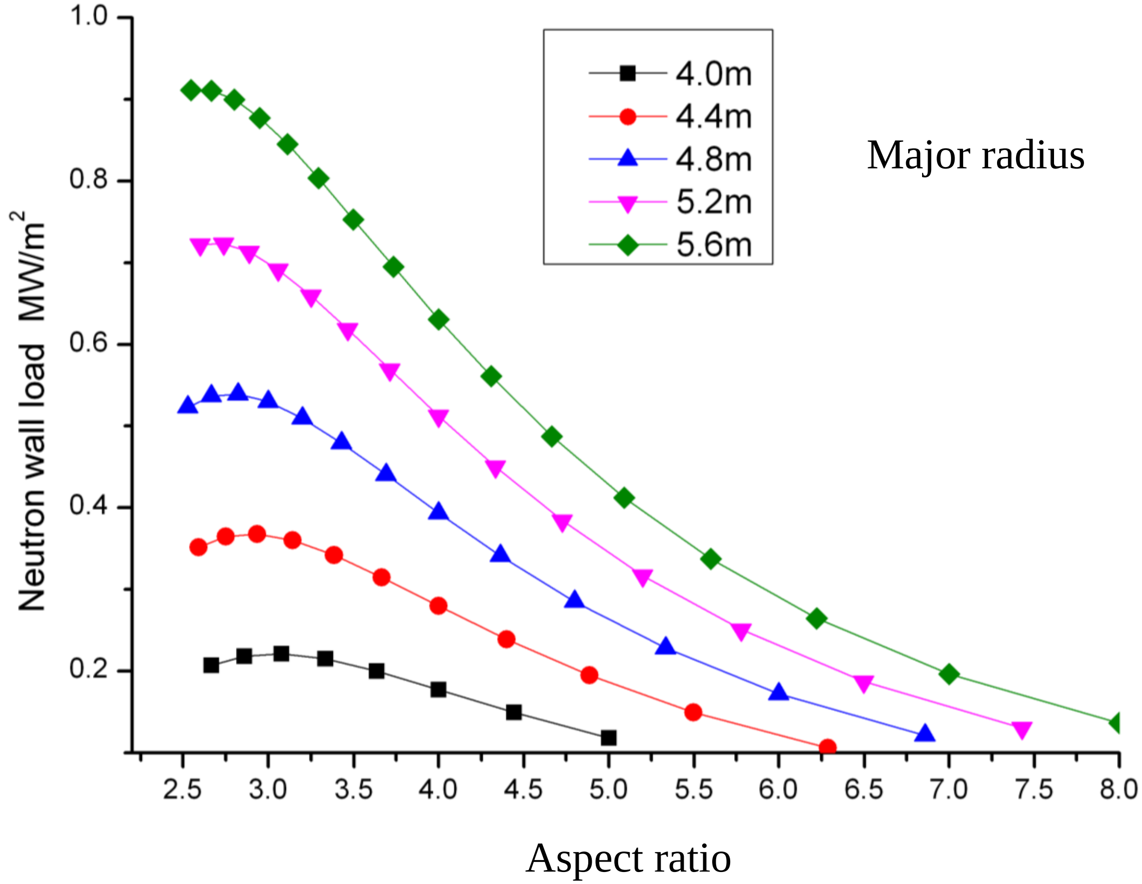
Case I: Superconductor Coils

Fusion power



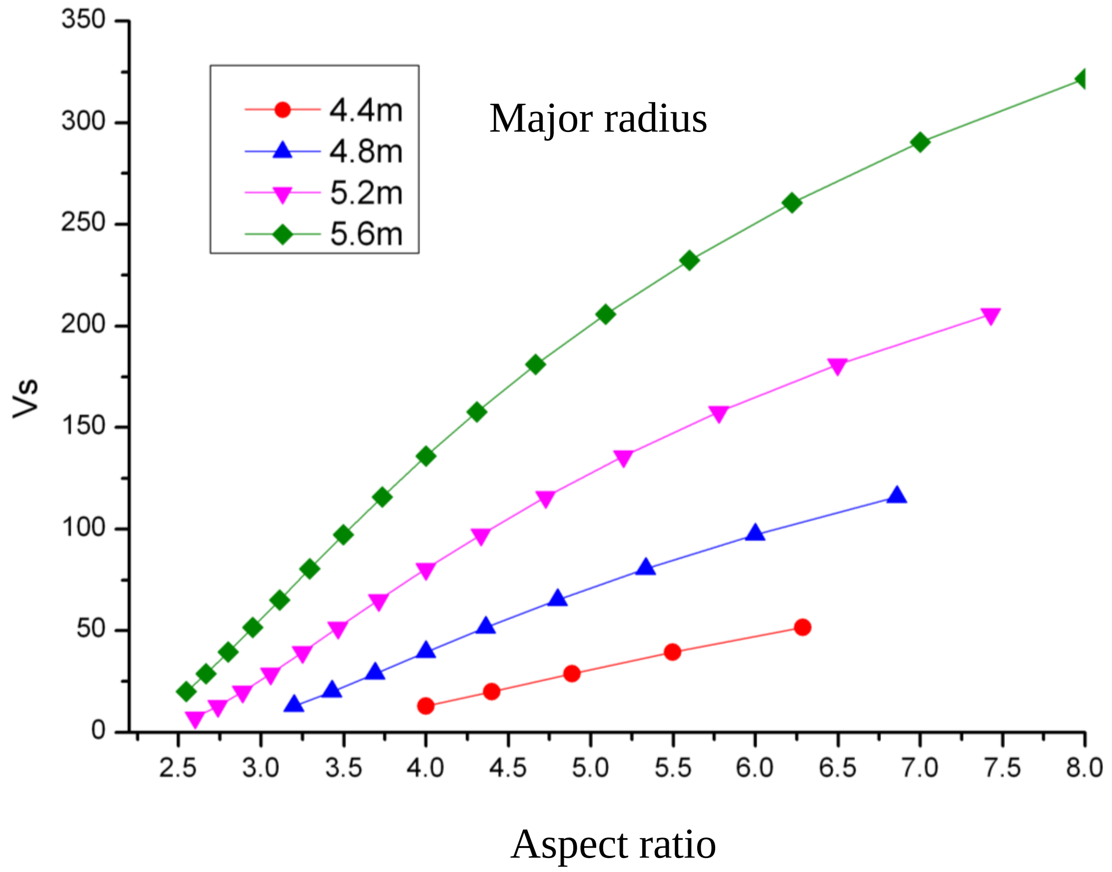
Case I: Superconductor Coils

Neutron wall load



Case I: Superconductor Coils

Volt-second

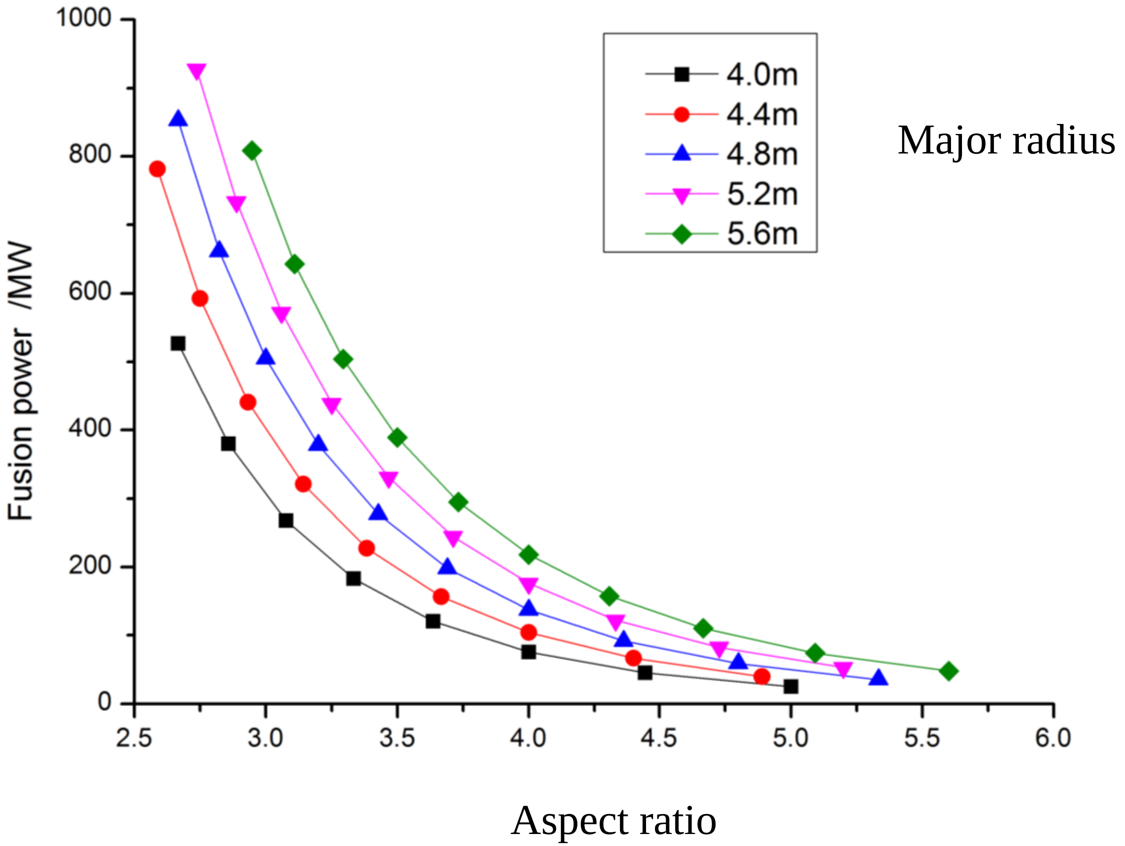


Parameters for Superconductor coils

Major radius is 5.3 m, Minor radius is 1.2 m,
Elongation is 1.75, Triangularity is 0.40,
TF on axis is 6.0 T, Plasma current is 5 MA ~ 8 MA,
Beta N is 2.0 ~ 3.5, Fusion power is 200MW~400MW,
Heating power is 90 MW, Fusion gain is 2.0 ~ 4.0,
Neutron wall load is 0.4 MW/m^2 ~ 0.8 MW/m^2,
Energy confinement time enhancement factor is 1.0 ~ 1.2,
Plasma density is 70% ~ 95% of Greenwald limit,
Volt-second is more than 120 Vs,
Operating times is more than 2000 s, Duty factor is 0.3 ~ 0.5;

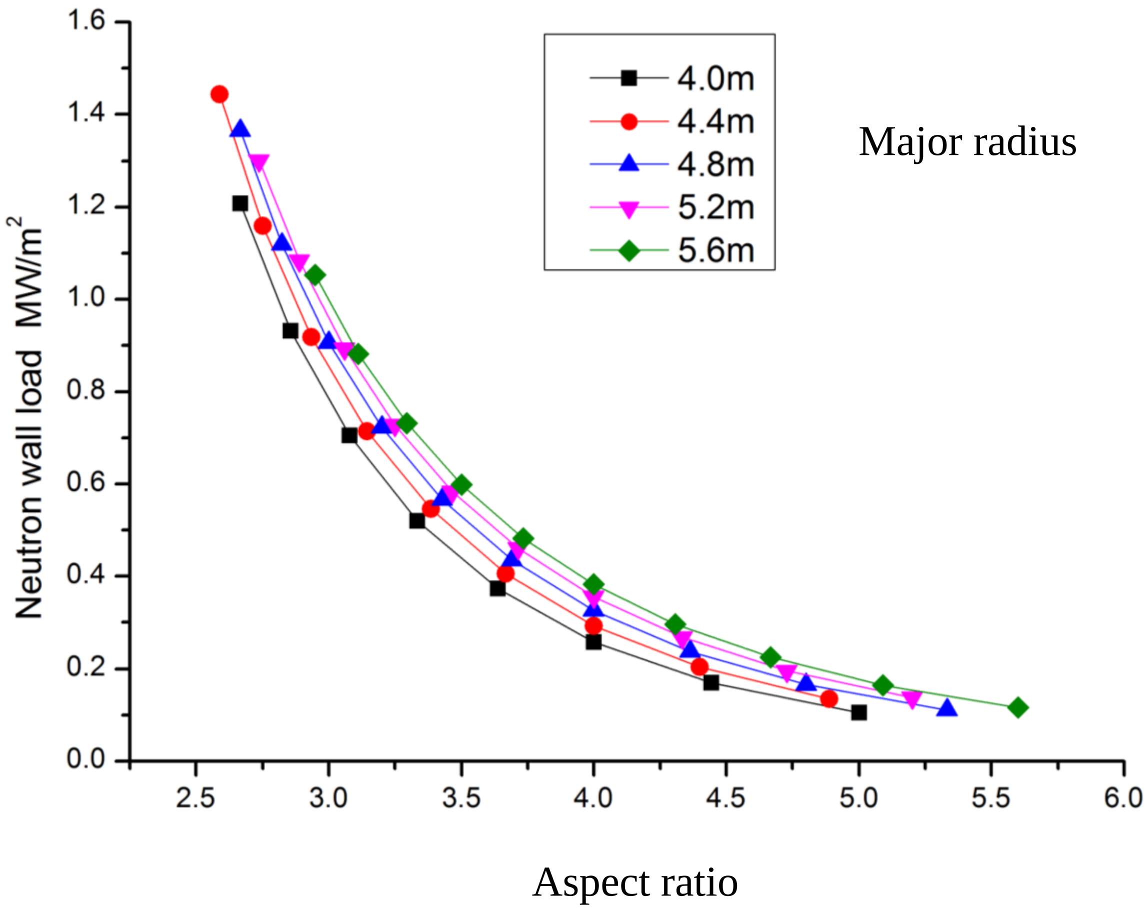
Case II: Copper TF Coil

Fusion power



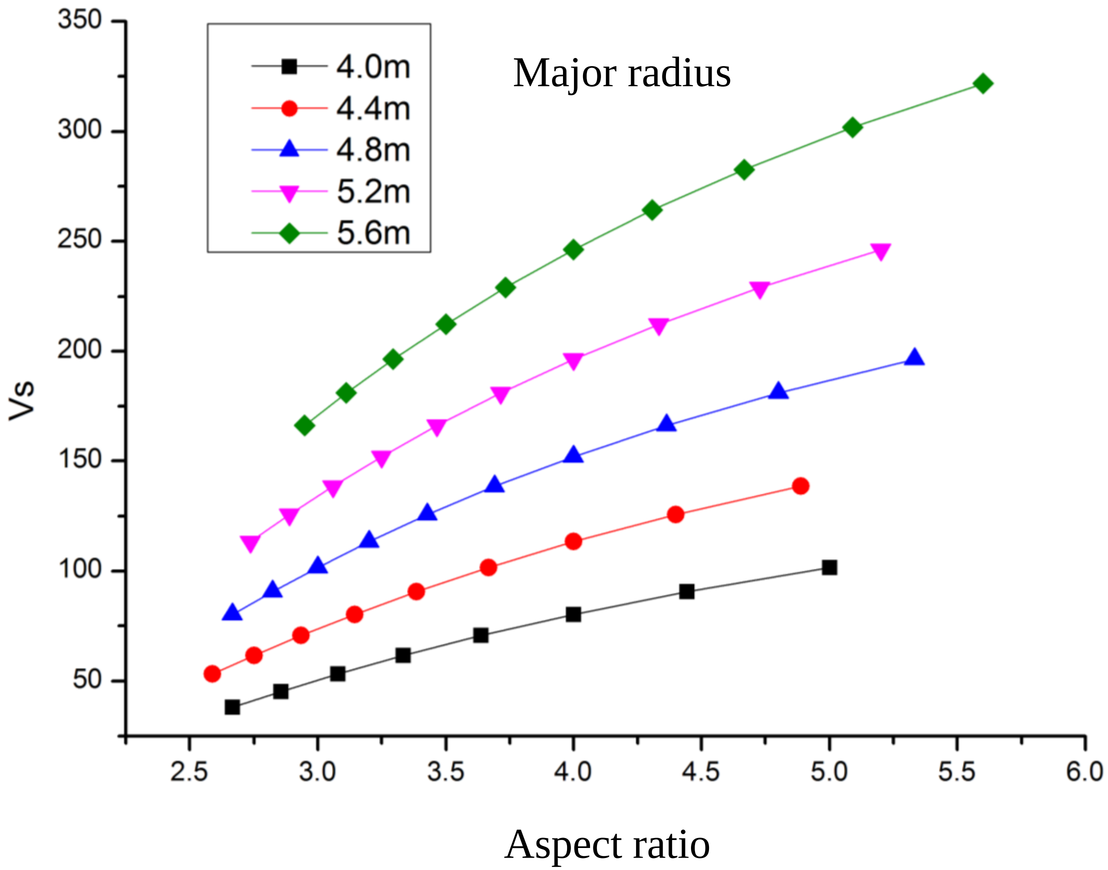
Case II: Copper TF Coil

Neutron wall load



Case II: Copper TF Coil

Volt-second



Parameters for Copper TF Coil

Major radius is 4.9 m, Minor radius is 1.3 m,
Elongation is 1.75, Triangularity is 0.40,
TF on axis is 5.0 T, Plasma current is 6 MA ~ 9 MA,
Beta N is 2.4 ~ 3.5, Fusion power is 200 MW ~ 400 MW,
Heating power is 100 MW, Fusion gain is 2.0 ~ 4.0,
Neutron wall load is 0.4 MW/m^2 ~ 0.8 MW/m^2,
Energy confinement time enhancement factor is 1.0 ~ 1.2,
Plasma density is 70% ~ 95% of Greenwald limit,
Volt-second is more than 150 Vs,
Operating times is more than 1000 s, Duty factor is 0.3 ~ 0.5;

Thanks you！