



Challenge toward Lower Aspect Ratio Tokamak Power Reactor

JAERI

10th International Spherical Torus Workshop
&
US-Japan Exchange Meeting on the Spherical Torus

Sept. 29 – Oct. 1, 2004 at Kyoto Univ, JAPAN

S.NISHIO and Reactor Design Team

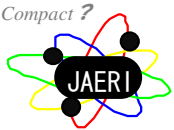
JAERI ; Naka Fusion Research Establishment

Naka-machi, Naka-gun Ibaraki-ken 311-0193, JAPAN

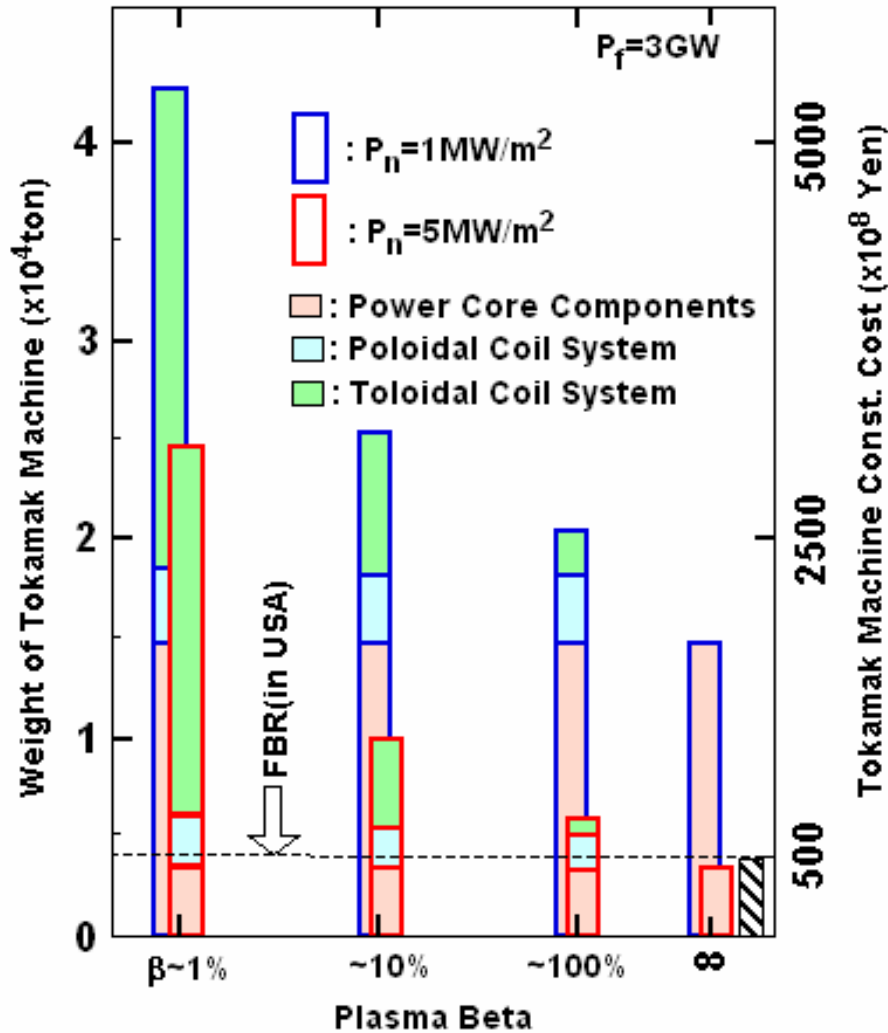
Nishio@naka.jaeri.go.jp

Contents

- (1) ST Plasma, Its Higher Performance**
- (2) Possible Reactor Concepts with ST Plasma**
- (3) Super-conducting Toroidal Field Coil**
- (4) Normal-conducting Toroidal Field Coil**



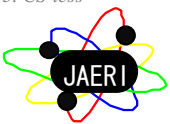
A Craving for Compact & Lightweight



Sensitive Parameters ?

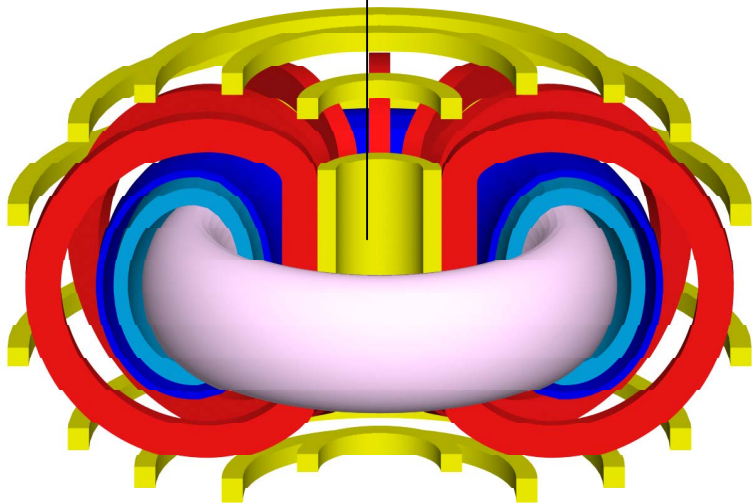
**Neutron Wall Load
&
Power Core Components**

**Plasma Beta
&
Toroidal Coil**



Discard of Center Solenoid Coil

CS Coil



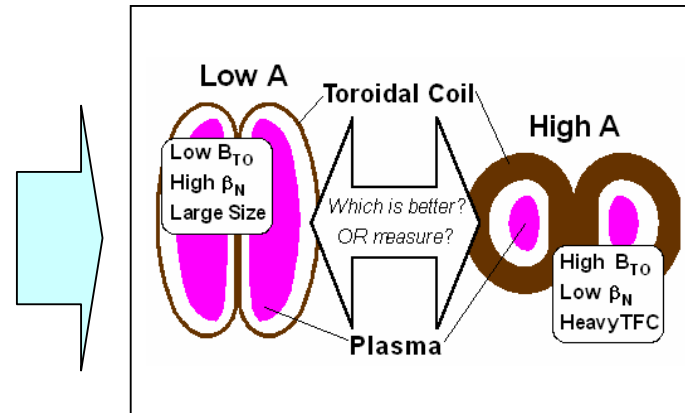
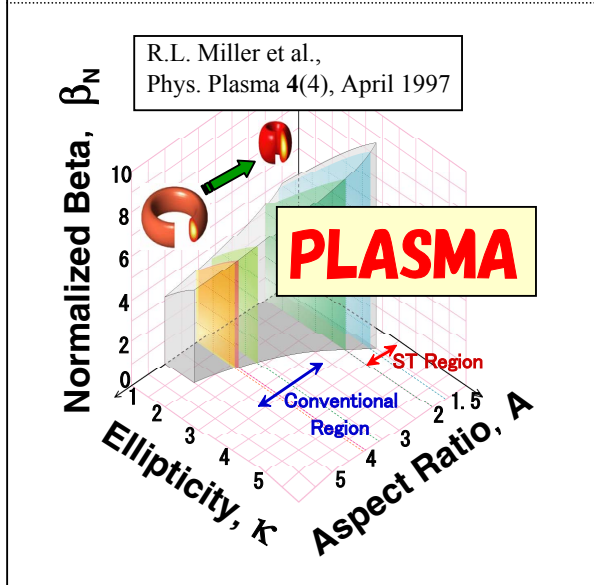
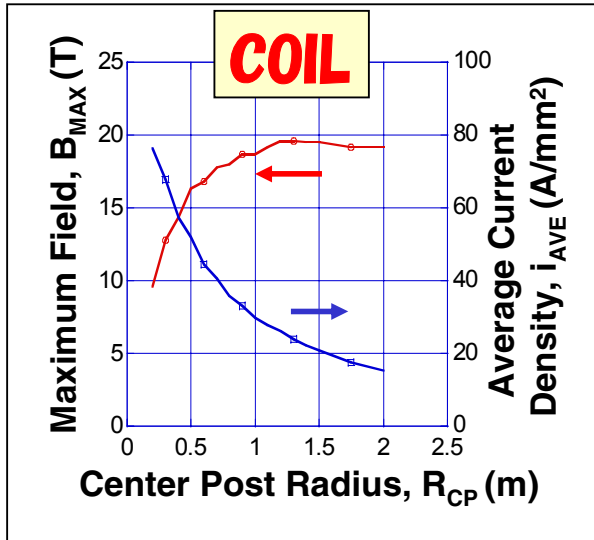
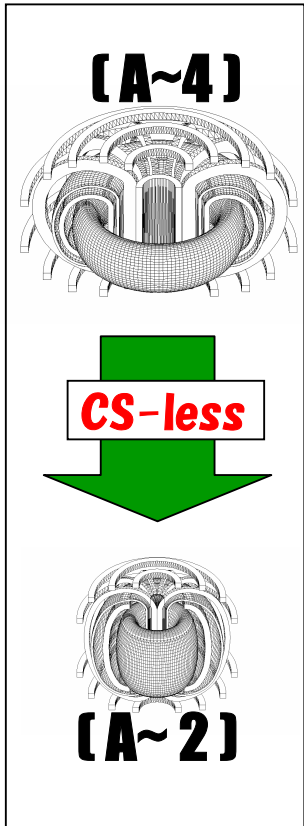
Support Wheel



***In due time,
they fall into disuse !!***



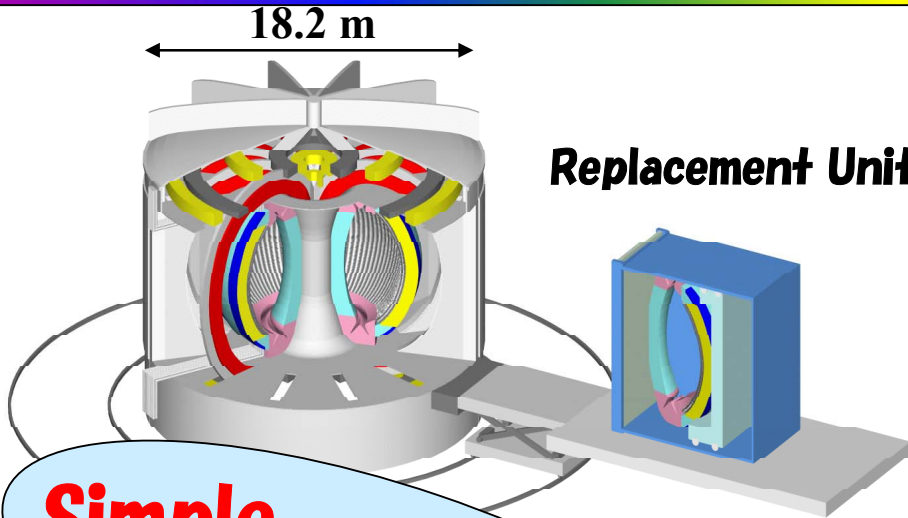
To VECTOR



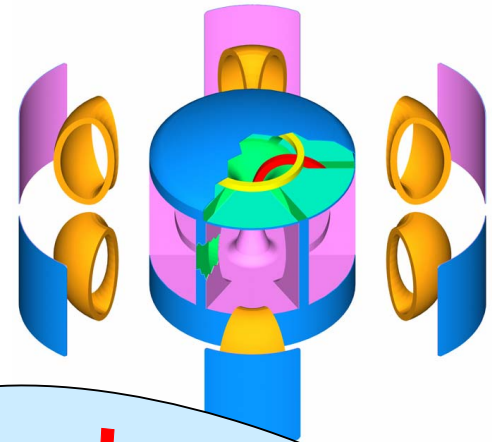
Weight Power Density

VECTOR

This is the VECTOR.



**Simple
Maintenance
Scheme**

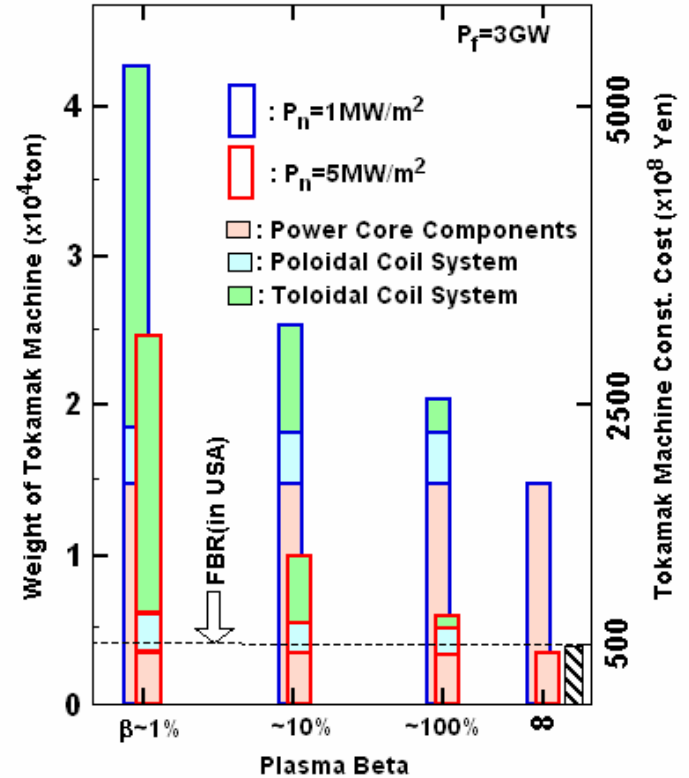
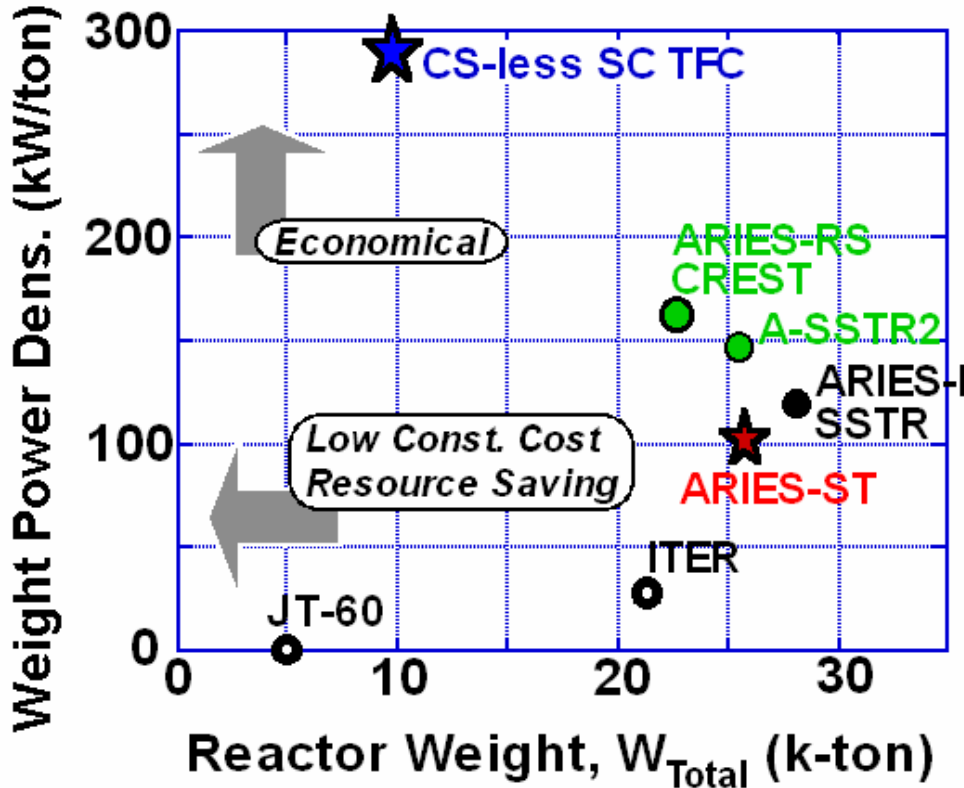
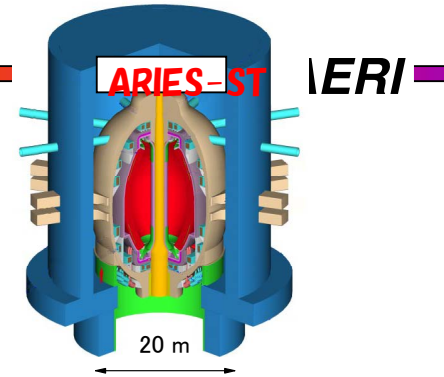
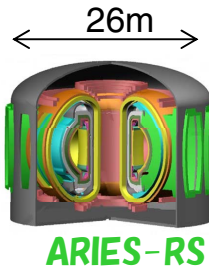
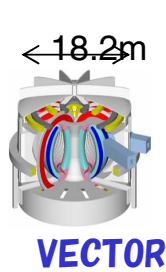
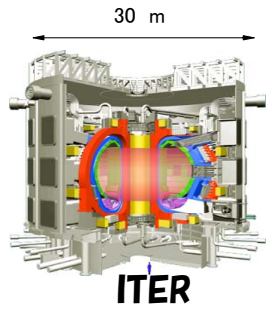


**Simple
Vacuum
Boundary**

Plasma Major Radius : $R_p = 3.2$ m
Plasma Minor Radius : $a_p = 1.4$ m
Plasma Ellipticity : $\kappa = 2.35$
Plasma Current : $I_p = 14$ MA
Normalized Beta : $\beta_N = 5.7$

Fusion Power : $P_F = 2.5$ GW
Neutron Wall Load : $P_n = 5$ MW/m²
Field on axis : $B_0 = 5$ T
Reactor Weight : $W = 8800$ Ton
Weight Power Dens. : $p = 280$ kW/ton

Where is VECTOR ?

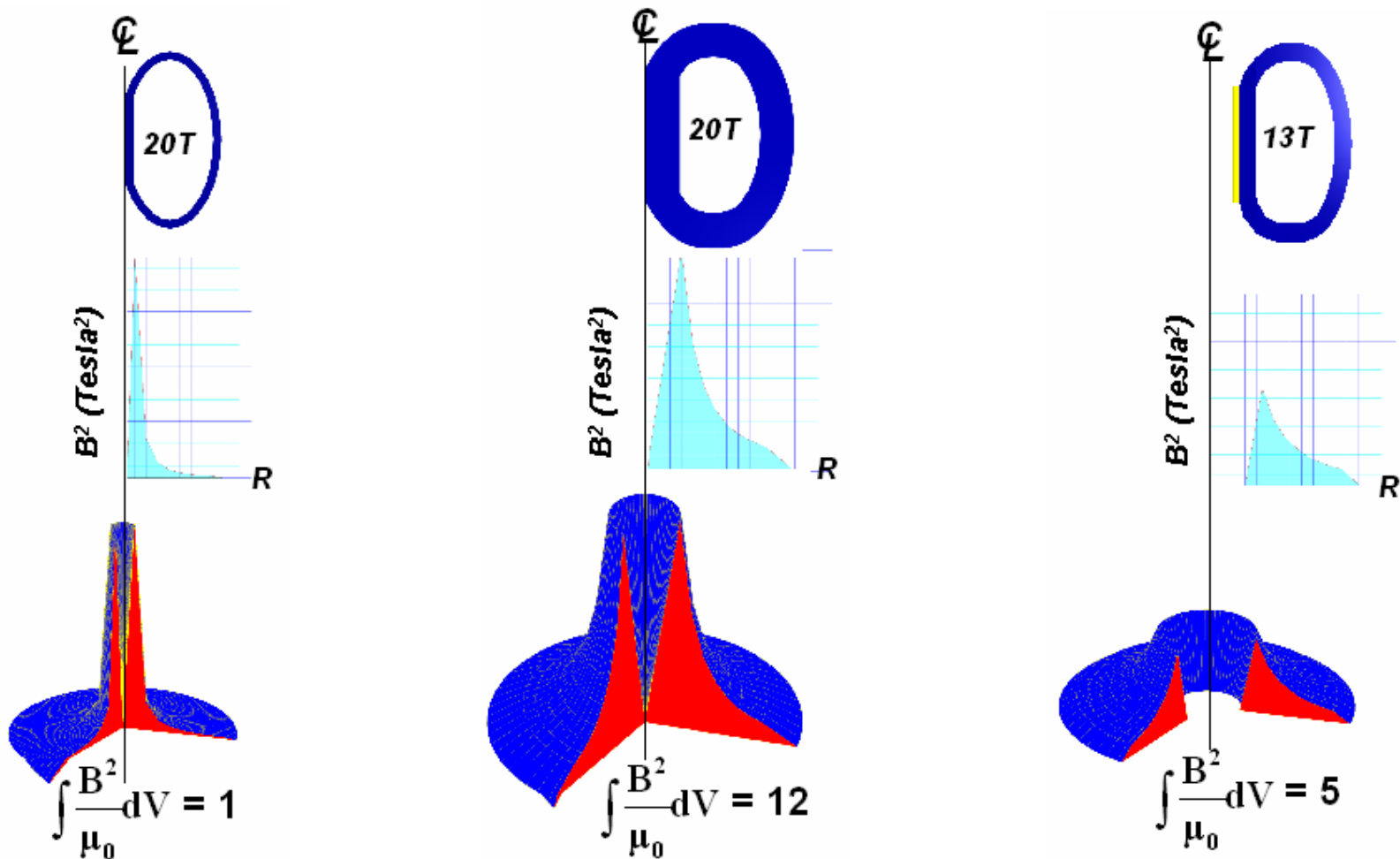




Why CS-less TFC is so lightweight ?

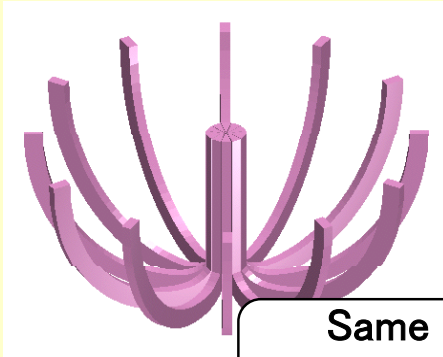
JAERI

TFC weight is in proportion to the stored energy !

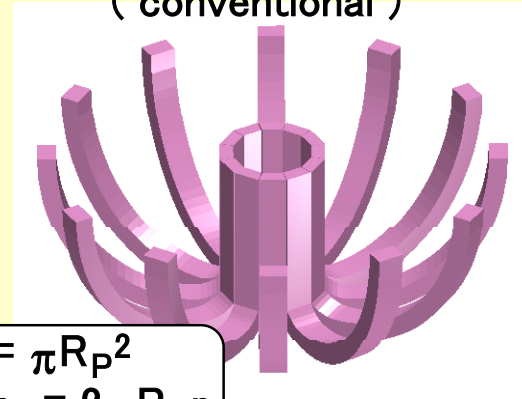


CS-less TFC Concept, Its characteristics.

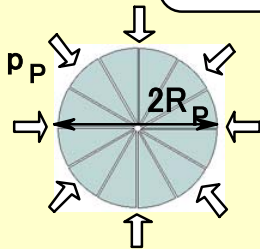
Solid Post Structure
(Apple Shape)



Barrel Structure
(conventional)

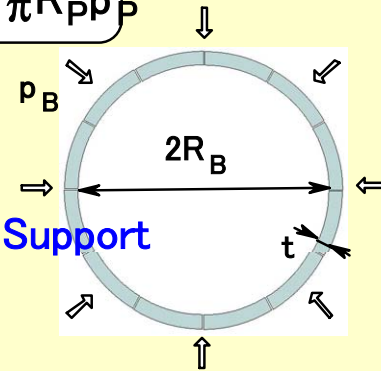


Same Area : $2 \pi R_B t = \pi R_P^2$
 Same Load : $W = 2 \pi R_B p_B = 2 \pi R_P p_P$



Isotropic Support

$$\sigma_r = \sigma_\theta = -p_P$$



Wedge Support

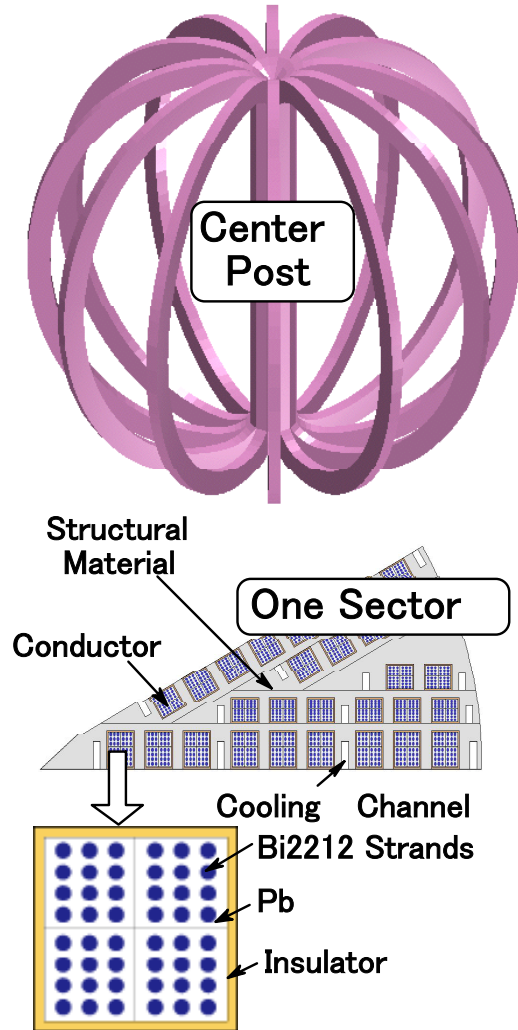
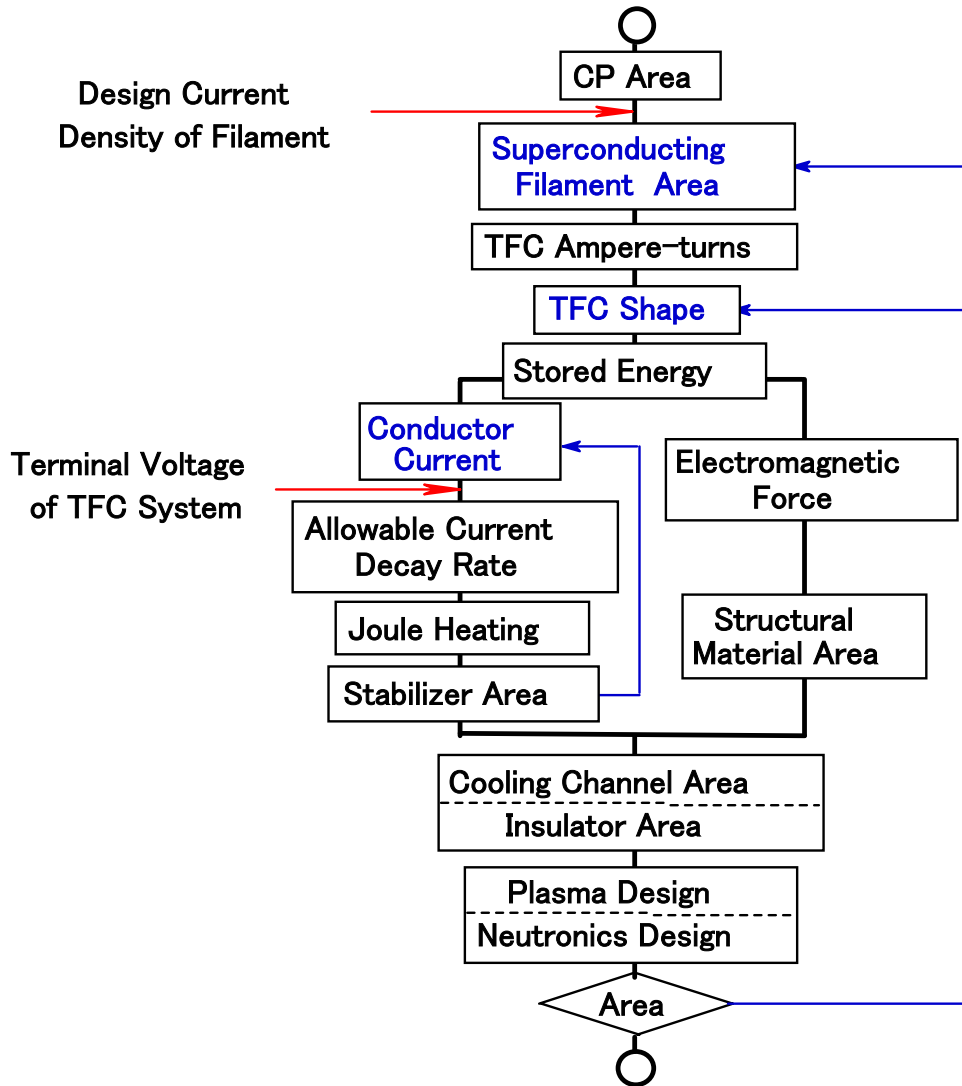
$$\sigma_r \sim 0$$

$$\sigma_\theta = -(R_B/t)p_B$$

The "Solid" is stronger than the "Barrel" by 5 times.

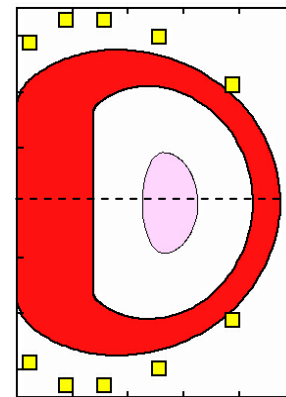
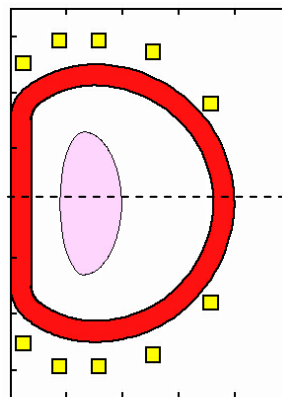
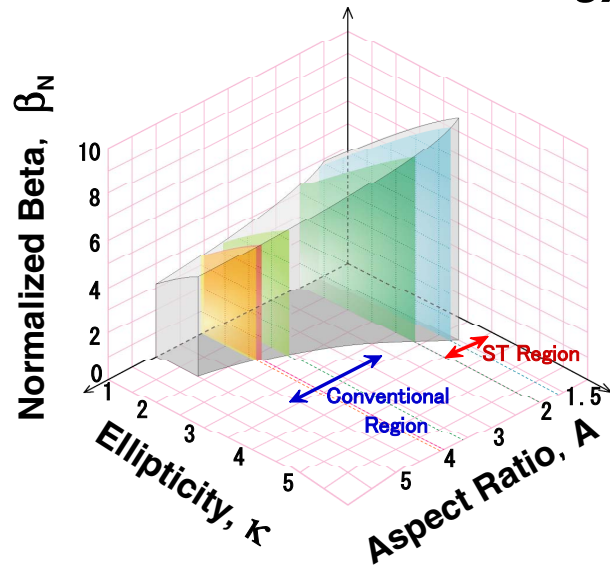
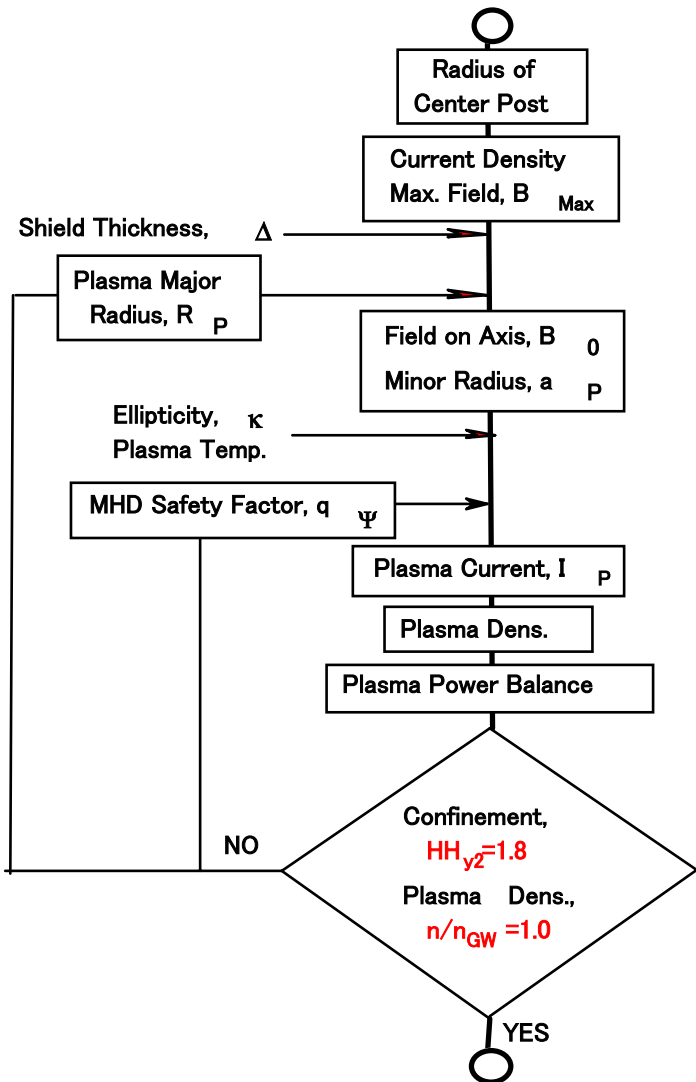
Design Flow of SC-ST TF Coil

Optimization of TFC Material Composition





Plasma Design Flow



Where is optimum point?



Summary

- (i) Heavy tokamak is caused by heavy TFC.**
- (ii) CS-less leads to lightweight tokamak.**
- (iii) ST power reactor with NC TFC is skeptical.**

Urgent Issue

- **High δ plasma equilibrium**
- **Break-down & Current ramp-up**

