US-Japan Workshop on Fusion Power Plants and Related Advanced Technologies
With EU Participation
April 6-7, 2002, Hotel Hyatt Islandia, San Diego, CA

Application of Li_2TiO_3 and $Be_{12}Ti$ in Supercritical water cooled solid blanket for DEMO

Enoeda, Mikio
Japan Atomic Energy Research Institute

Objective and Background

Objective

To clarify the DEMO blanket design which

- can be achieved as soon as possible
- have possibility of economical improvement

, based on the reactor condition similar to SSTR.

Background

A conceptual design of the solid blanket cooled by supercritical water was introduced in the last workshop. The design showed possibility of the blanket concept with reduced activation ferritic steel as the structural material and Li_2O and Be as the breeder and multiplier.

This work

The possibility of the application of Li_2TiO_3, and $Be_{12}Ti$ was shown from the viewpoint of TBR and temperature design.

Blanket Concepts in JAPAN

Background

(1) Solid blankets are regarded as one of candidate designs for near term target of the blanket in DEMO reactor such as SSTR. Because it has potential

- to be achieved as soon as possible
- to have possibility of economical improvement

(2) Liquid blankets have merit of

- better cooling of first wall and divertor
- no radiation damage to breeder.

Thus, it is suitable to higher output density. It is regarded as advanced options.

Concepts

Solid Breeder Blanket (Key organization: JAERI)

- Reference **Water cooled blanket with RAFS = near term target**
- Advance He gas cooling system with SiC/SiC

Liquid Breeder Blanket (Key organization: NIFS and Universities)

- Research on several advanced concepts are on going in parallel ; FLiBe, Li, LiPb,

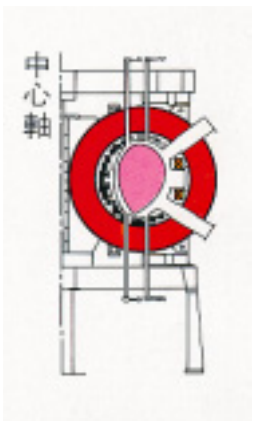
Basic Parameters of Supercritical Water Cooled Solid Blanket

Plasma major, minor radius	¦5.8 m, 1.45m
Plasma current	¦12 MA
Fusion power	¦2300 MW
Neutron wall load	:average 3.5, peak 5 MW/m^2
FW surface heat flux	:average 0.5, peak 1 MW/m^2
Neutron fluence	:7.5 Mwa/m^2 in 2 y

Tritium breeder	:Li_2O or Li_2TiO_3
Neutron multiplier	:Be or $Be_{12}Ti$
6-Li enrichment	:Natural to 90 %
Structural material	:Reduced activation ferritic steel
Coolant	:Supercritical water (25 MPa, 280 – 510 ^oC)
Blanket structure	:Modular structure, front access by remote handling
Dimension	:1 m x 2m, < 4 ton

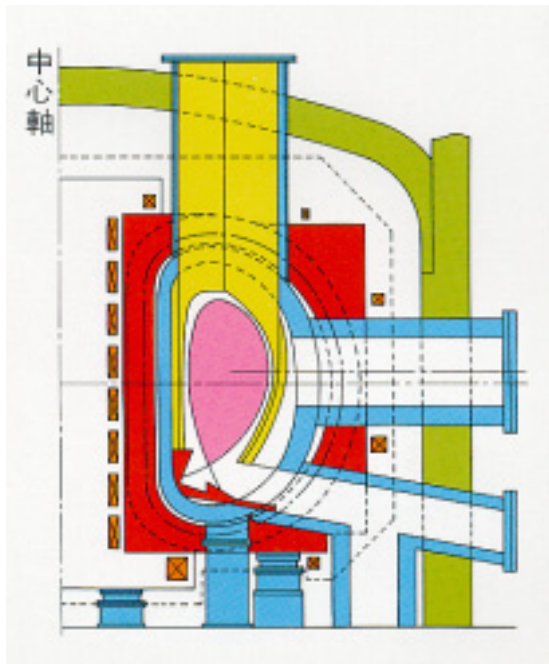
Comparison of the Dimension of Reactors

JT-60U
R = 3.4 m
I_p = 6 MA
V_p = 100 m^3

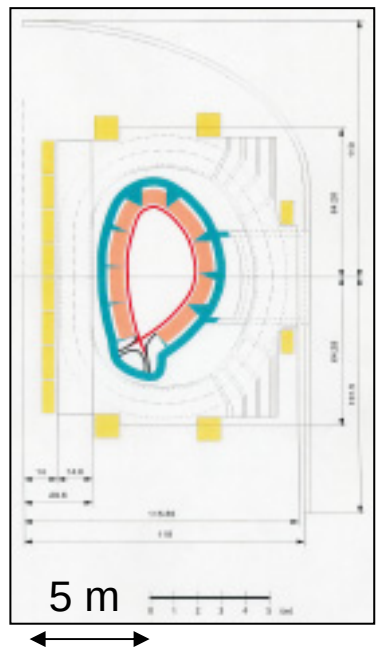


ITER-FEAT (2001)
R = 6.2 m
I_p = 15 MA
V_p = 837 m^3

SSTR (1990)
R = 7.0 m
I_p = 12 MA
V_p = 760 m^3



DEMO (2000) for this study
R = 5.8 m
I_p = 12 MA
V_p = 386 m^3



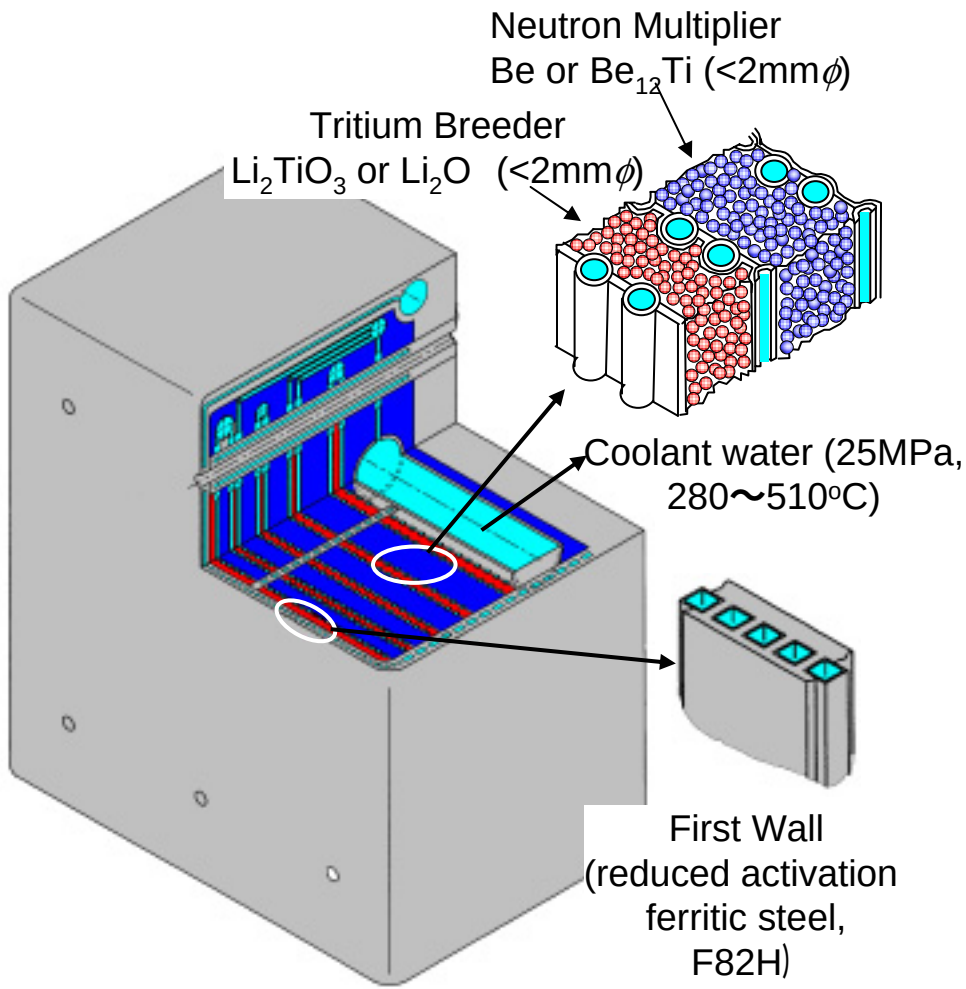
Blanket Structure

- Modular structure
  ; remote handling replacement

- Built-in cooling channels FW
  ; heat removal

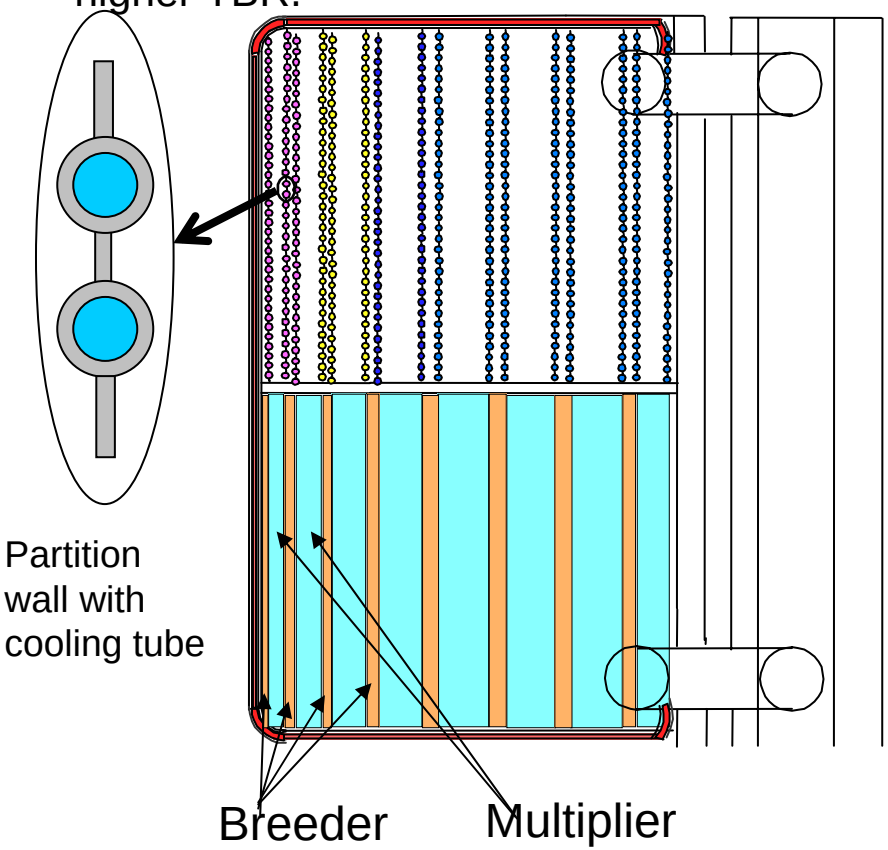
- Pebble bed type of breeder and multiplier
  ; Avoid change of thermal performance due to cracking

- Siries flow path starting from FW to breeder zone
  ; low coolant temperature to relax the load to the FW



Procedure of TBR Estimation

The blanket structure was modeled by 1D layered configuretaion of cooling layer (F82H/H_2O/F82H), breeder layer (Li_2TiO_3), and multiplier layer (Be or $Be_{12}Ti$), contained in the FW and rear wall. Cooling temperature were given at cooling layer and temperature limits were set to breeder and multiplier. Thickness of the layer was adjusted to obtain higher TBR.



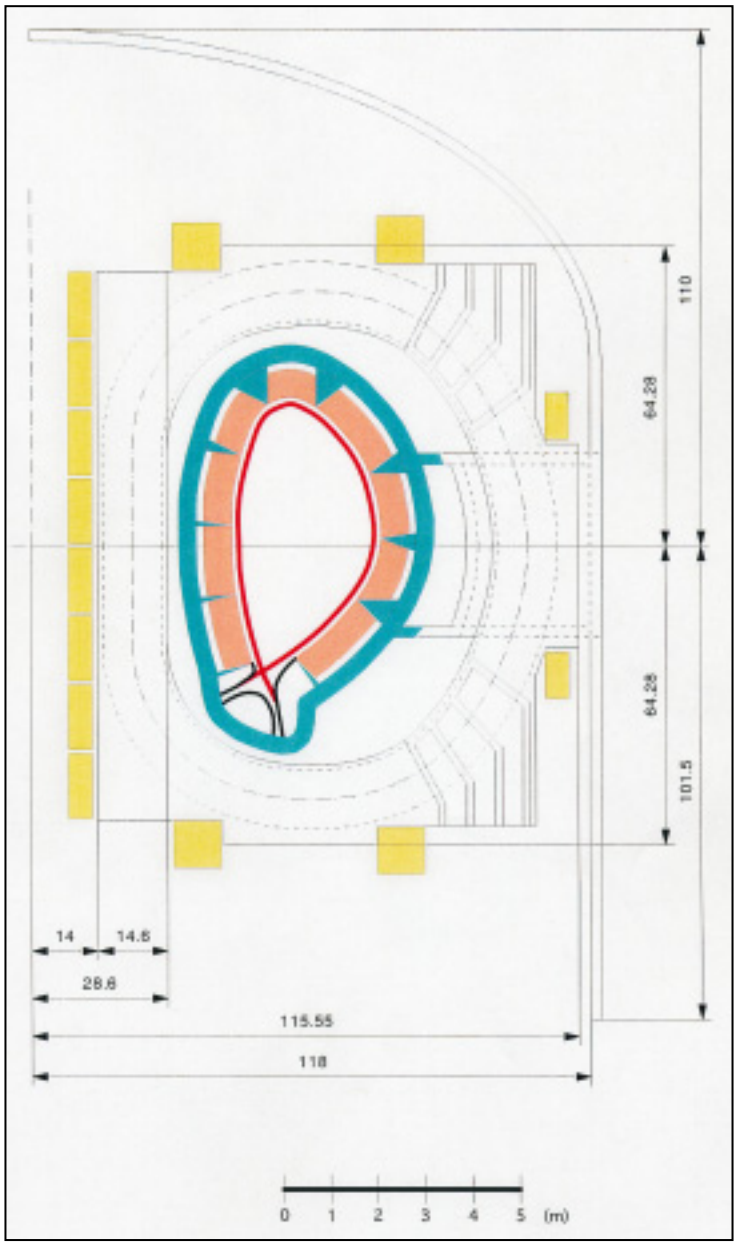
1D modeling of the structure

Calculation methods

(1) Neutron and gamma transport
Calculation code：ANISN
(1D S_N calculation code)
Cross section：FUSION-40
(JENDL3.2)
Neutron 42 groups,
Gamma 21 groups
Calculation parameter：P5-S8

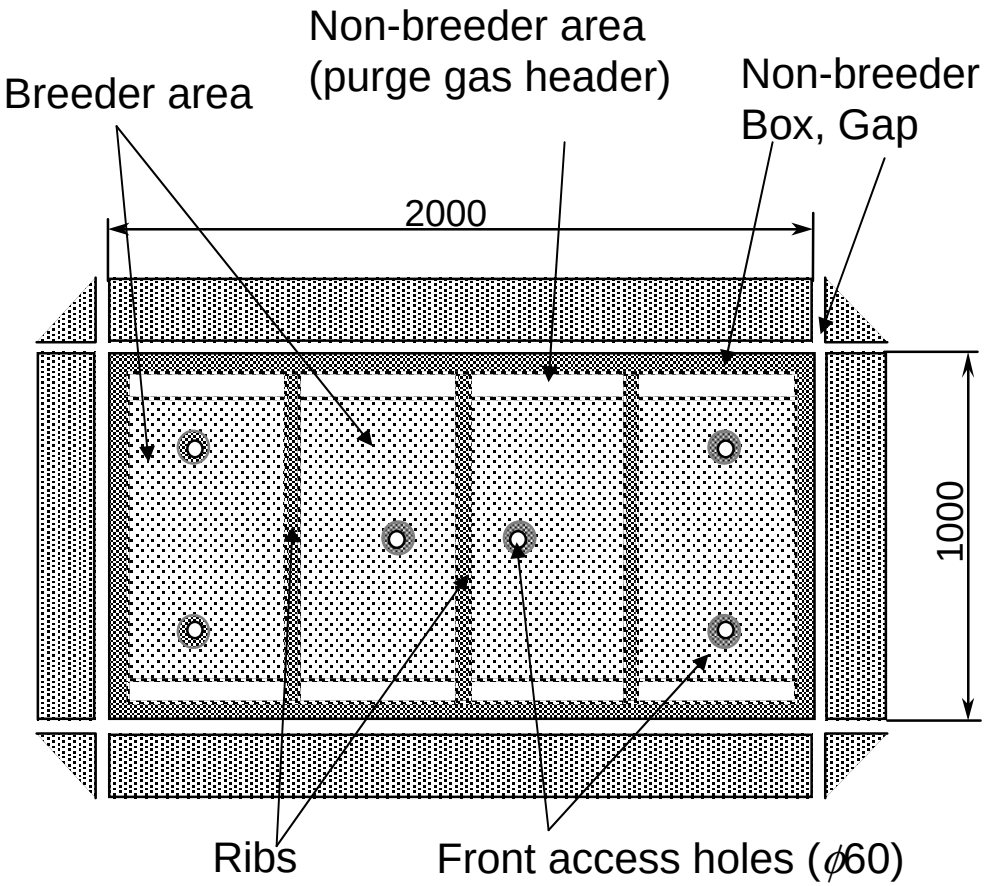
(2) Temperature calculation
：1D heat conduction

Coverage of Plasma Facing Component



Components	Surface area [m^2]
Blanket	420
Blanket (port)	65
NBI port	6
ECH port	1
Divertor	30
Total	522

Coverage in a Module



Cross section of a blanket module

Breeder area

Height of module	2 m
Rib interval	0.5 m

Non-breeder area

Gap between modules	10 mm
Side wall thickness	30 mm
Front access holes	60 mm dia. x 6
Headers	<50mm
thickness of ribs	20 mm

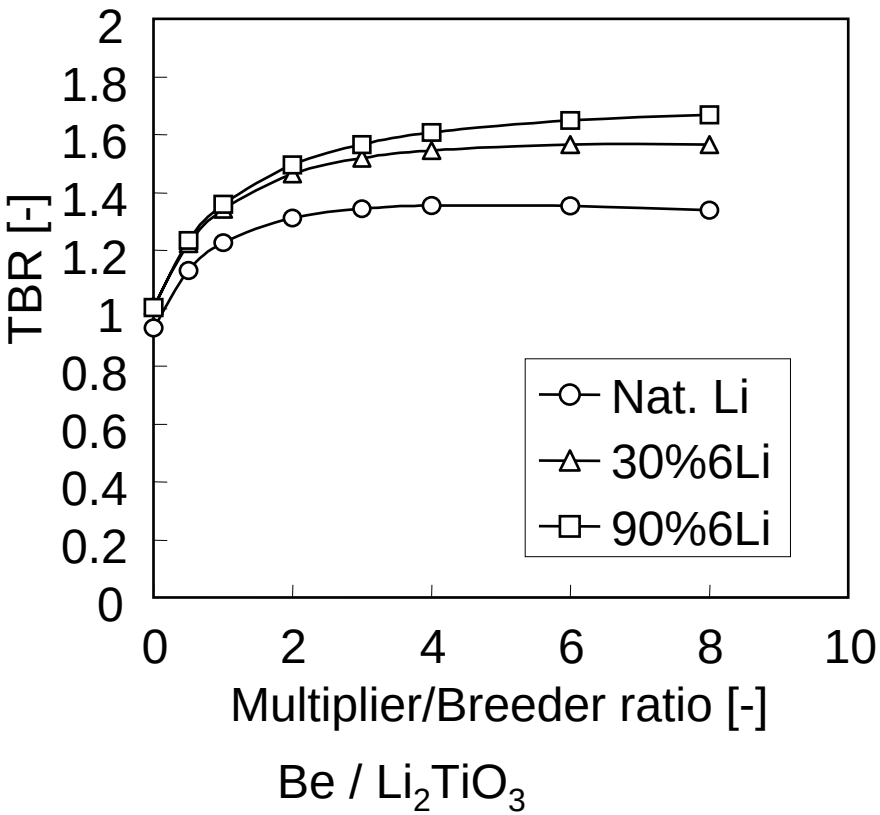
Coverage of Plasma Facing Components and Requirement to Local TBR

Location	Coverage
Gap between modules	1%
Side wall	8%
Header	2 - 9%
Strengthening ribs	3%
Front access holes	1%
Breeder zone	71 - 78 %
Blanket total	93%
Divertors and ports	7%

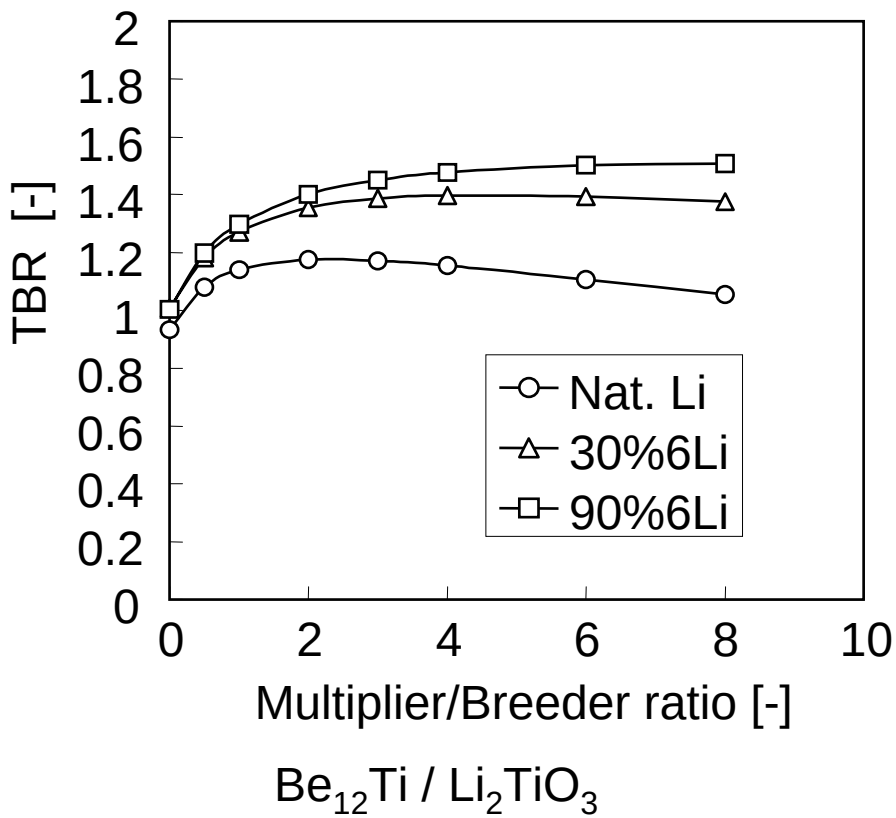
Net TBR	Local TBR
1.00	1.28 -1.41
1.05	1.35 - 1.48
1.10	1.41 - 1.55

Volume Ratio of Multiplier to Breeder

Rough survey by homogenized model of
- cooling layer (F82H + H_2O) + breeder (Li_2TiO_3) + multiplier(Be or $Be_{12}Ti$)



Be / Li_2TiO_3

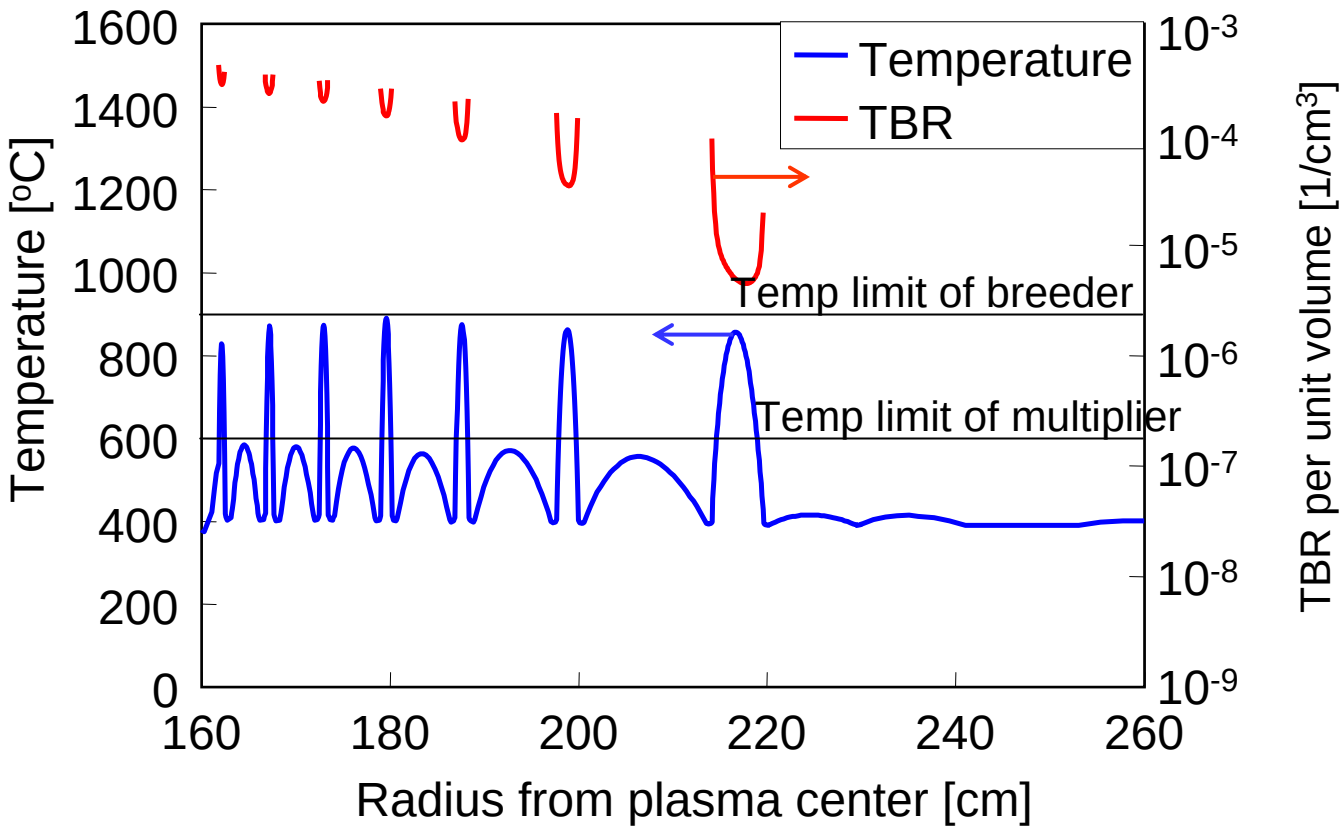


$Be_{12}Ti$ / Li_2TiO_3

TBR leveled off in multiplier/breeder ratio of more than 3 to 4.

Example of TBR and Temperature Calculation

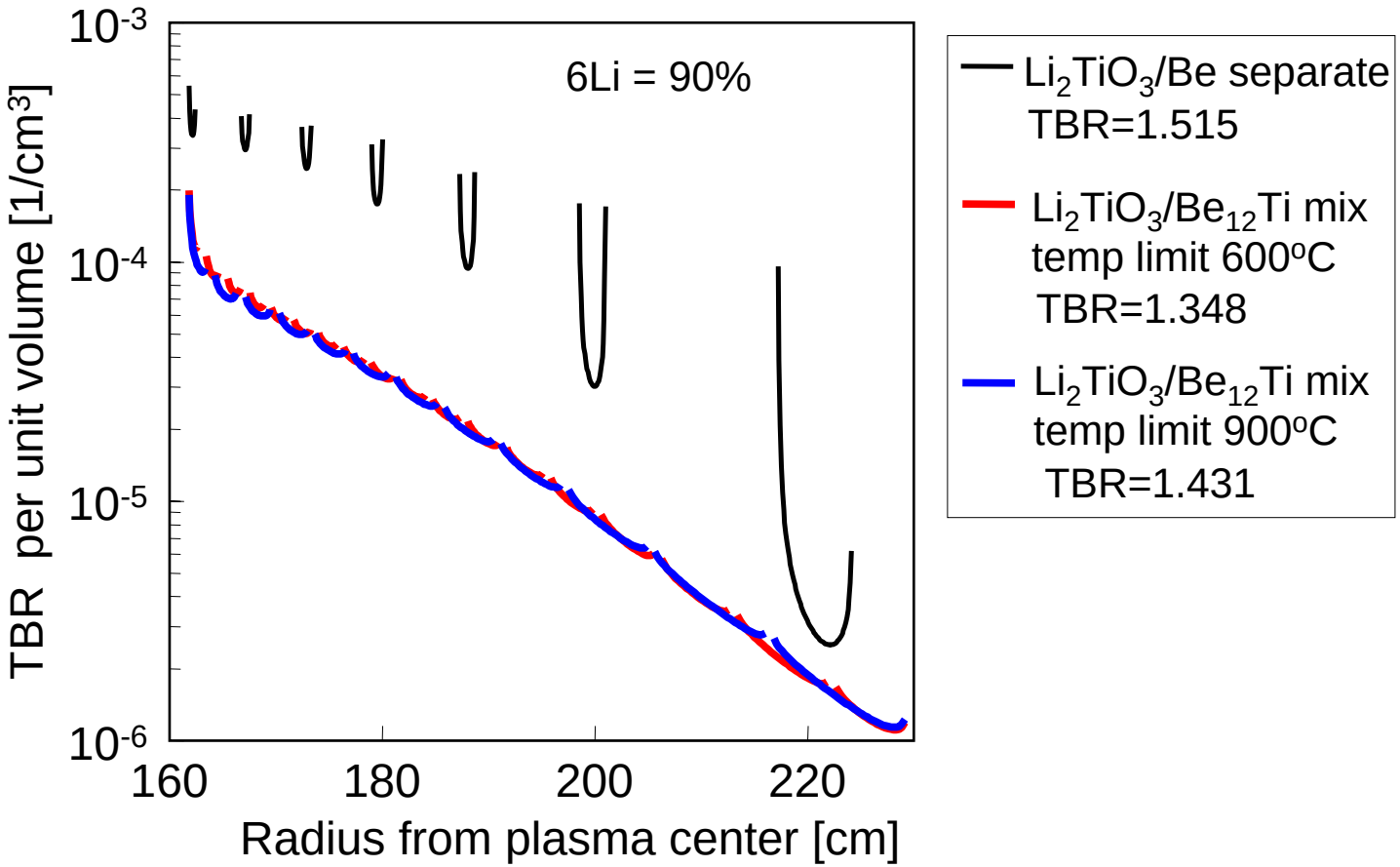
Point of interest
- Applicability of Li_2TiO_3
- Applicability of $Be_{12}Ti$
- Applicability of Mixed packing of Li_2TiO_3 and $Be_{12}Ti$



Li_2TiO_3 / Be separated packing, 6Li enrichment 30%

Result of TBR Calculation

- TBR is 4 – 5 % higher in mixed packing than separate packing
- Mix packing of Li_2TiO_3 and $Be_{12}Ti$ < Separate packing of Li_2TiO_3 and Be



Comparison of TBR distribution

Summary and Evaluation of TBR Calculation Results

Breeder/Multiplier	Li_2TiO_3/Be		$Li_2TiO_3/Be_{12}Ti$				
6Li enrichment	30%	90%	90%	30%	90%	30%	90%
Mix or separate	separate		sep.	mix			
Temp. limit	breeder 900°C		900°C	600°C		900°C	
	multiplier 600°C		900°C				
TBR	1.41	1.52	1.37	1.24	1.35	1.35	1.43
Li_2O/Be case	1.53	1.56					
Judge from TBR point of view	good	good	fare	poor	fare	fare	good

For mix packing, material compatibility is required.

Conclusions

1. Separated packing Li_2TiO_3 and Be was applicable.

2. Mix packing of Li_2TiO_3 and $Be_{12}Ti$ is possible. Further detailed analysis is needed.

3. Separate packing of Li_2TiO_3 and $Be_{12}Ti$ is possible. Further detailed analysis is needed.

4. Detailed structure modeling and analysis by MCNP will be performed. Neutronics experiments are being performed based on this design.