February 22-24, 2011
@NIFS

Recent Design Activities toward DEMO in JAEA

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Design Activity in JAEA

2000 — 2003 — 2010

JAERI | JAEA | JAEA

mid. 2007

BA activity

- *BA DEMO design*
- *Develop design tools*

Studies on various concept. designs

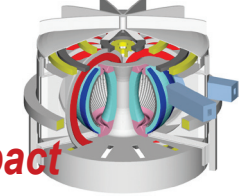
A-SSTR2

High field (23T)

→ CS-free tokamak

DEMO-2001

VECTOR



Supercond. low-A

→ Low-A, compact

SlimCS

Low-A DEMO concept with reduced-size CS

Recent DEMO design activities

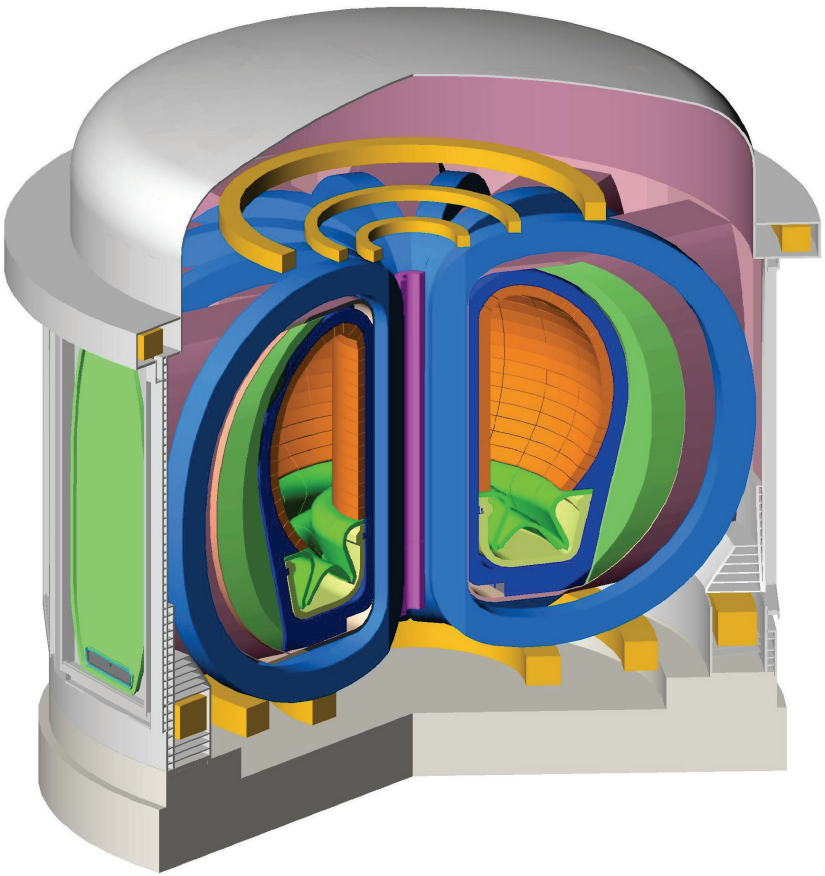
- ★ Modification of blanket concept → *Someya*
- ★ Development of blanket design tool
- Divertor simulation → *Asakura*
- Modification of system code → *Utoh*
- ★ Alternative concept of maintenance

BA DEMO design activities

- ★ Structure and schedule

1. **Modification of blanket concept**
2. **Development of blanket design tool**
3. **Alternative concept of maintenance**
4. **Structure and plan of BA DEMO Design**

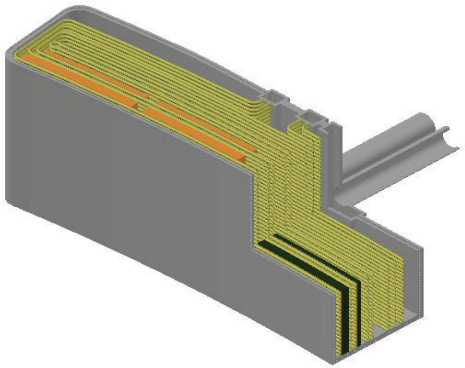
DEMO conceptual design, “SlimCS”



Major radius, R_p	5.5 m
Minor radius, a	2.1 m
Aspect ratio, A	2.6
Plasma current, I_p	16.7 MA
Toroidal field, B_T	6.0 T
Maximum field, B_{max}	16.4 T
Elongation, κ_{95}	2.0
Safety factor, q_{95}	5.4
Normalized beta, β_N	4.3
Density, $\langle n_e \rangle$	1.15×10^{20} m^{-3}
Normalized density, n_e/n_{GW}	1.0
Confinement enhancement, HHy2	1.3
Bootstrap current fraction, f_{BS}	~0.75
Current drive power, P_{CD}	60-100 MW
Fusion output, P_{fus}	2,950 MW
Neutron wall load, P_n	~3 MW/m^2

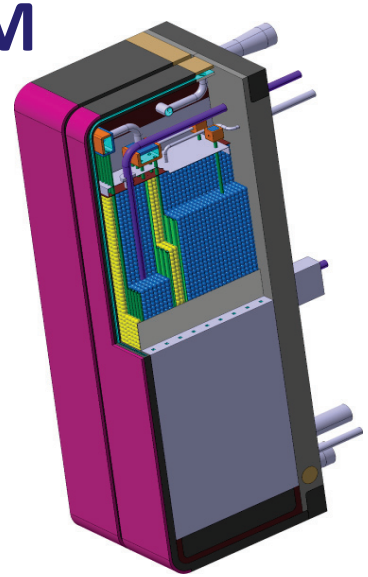
Water-cooled solid breeder blanket

DEMO (SlimCS)



ITER-TBM

JA concept



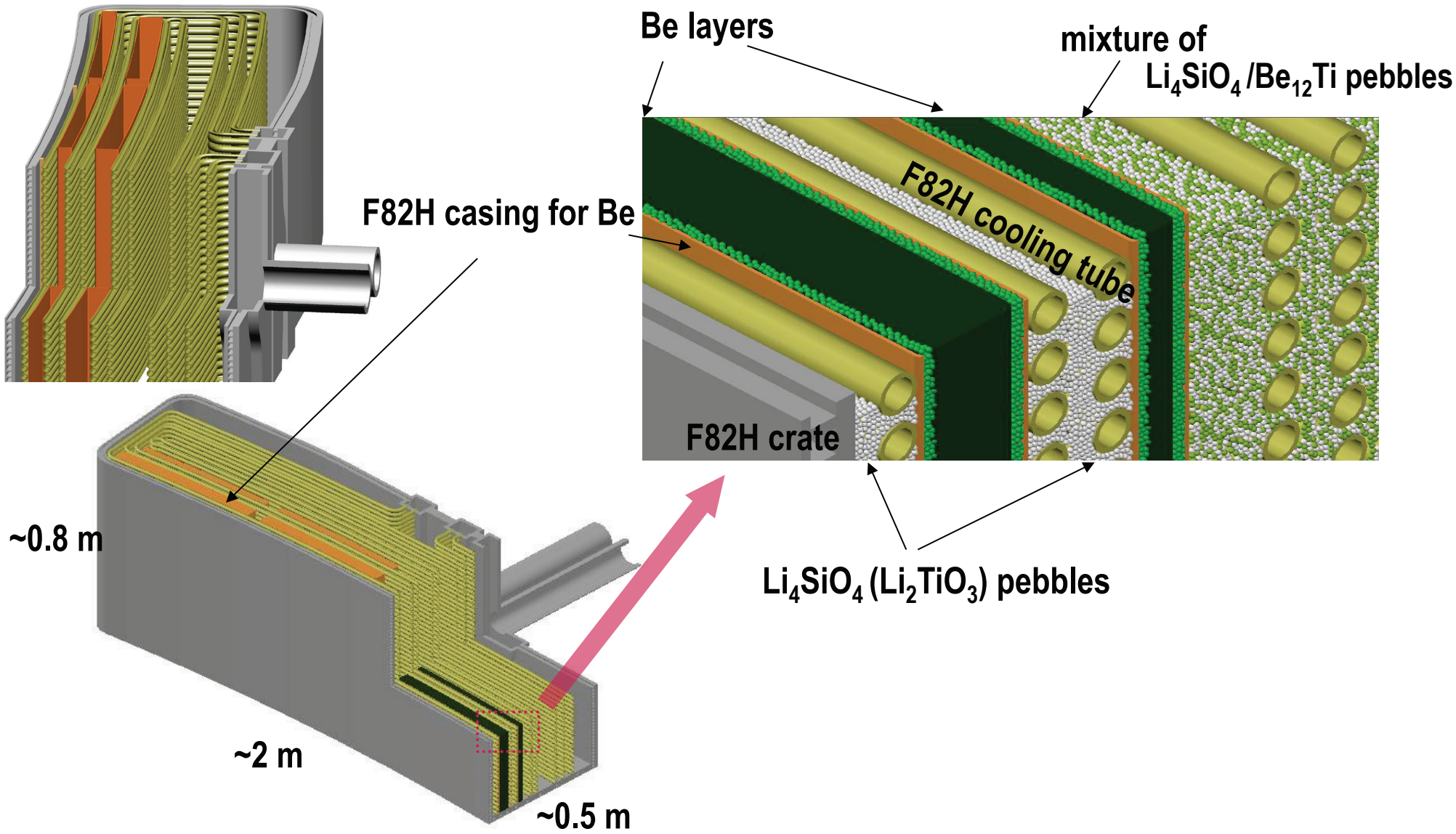
Continuity

Structural material	RAFM (F82H)
Coolant	Water (subcritical) ~23 MPa, 290-360ºC
Neutron multiplier	Be or $Be_{12}Ti$
Tritium breeder	Li_2TiO_3 or other Li ceramics

RAFM (F82H)
Water * 15 MPa, 280-325ºC
Be or $Be_{12}Ti$
Li_2TiO_3 or other Li ceramics

* Another proposal: He gas -- 8 MPa, 300-500ºC

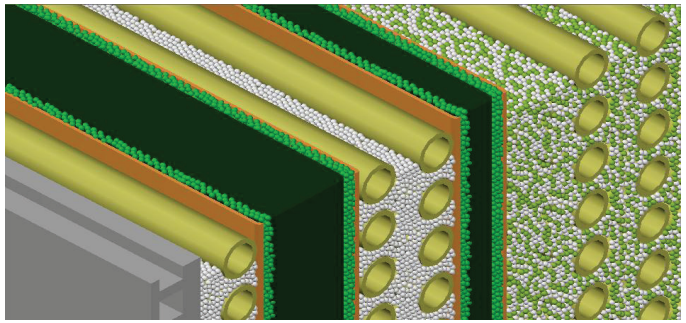
Original interior design



Problems of the blanket design

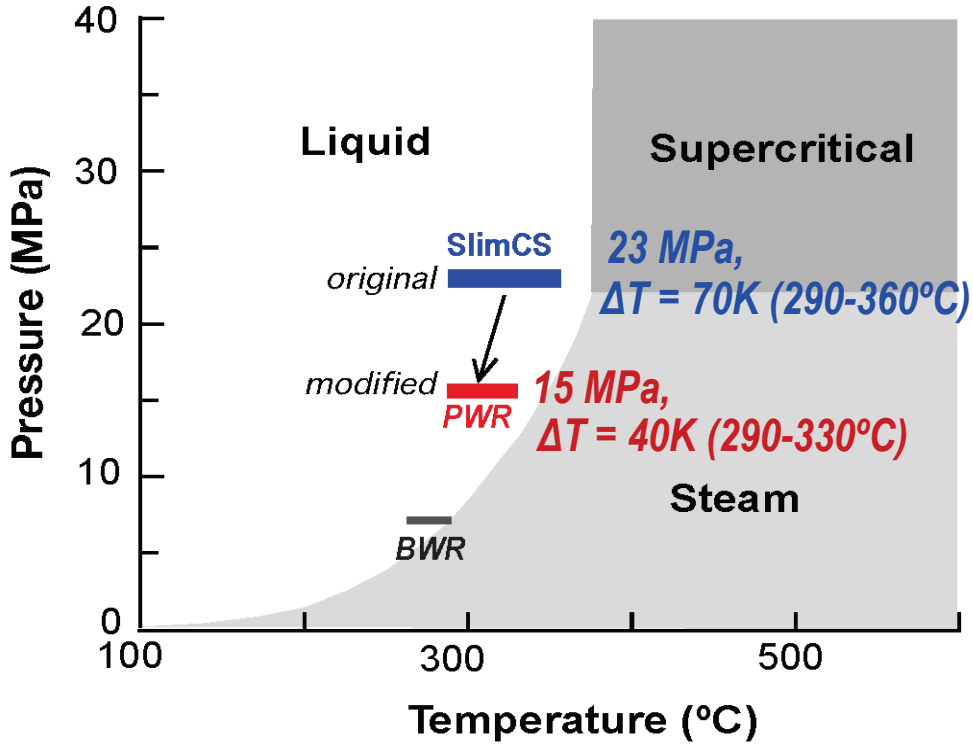
1. Complex interior

- Long welding lines
- Reproducibility of k at welding?
- Reliability of pebble packing?



2. Subcritical water

- Concern on corrosion of F82H tubes by the water



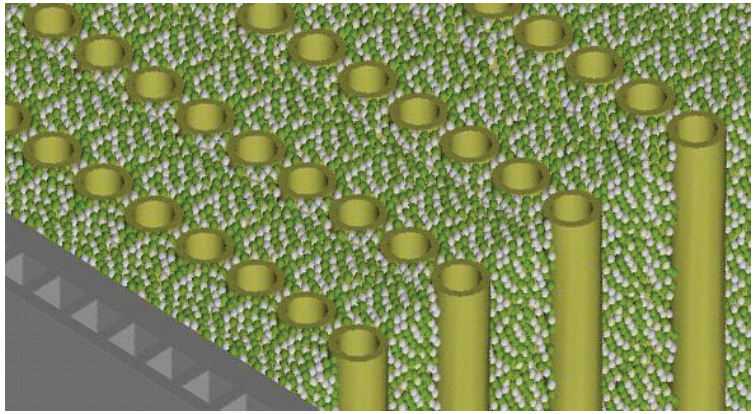
Alternative concept of blanket

Mixed pebbles blanket

- **Mixture of Li_4SiO_4 (Li_2TiO_3) and $Be_{12}Ti$**

  $Be_{12}Ti$, chemically stable ➔ no casing

  ⚠ No experimental evidence on compatibility of Li_4SiO_4 (Li_2TiO_3) and $Be_{12}Ti$ so far



- **Short loop of cooling tubes**

  Toroidal (long dir.) → poloidal (short dir.)

  which allows smaller ΔT between inlet/outlet

➡ **Marginal self-sufficiency of fuel is anticipated.**

➔ **Someya**

1. Modification of blanket concept
2. **Development of blanket design tool**
3. Alternative concept of maintenance
4. Structure and plan of BA DEMO Design

Procedure of blanket interior design

1. To optimize interior arrangement to satisfy the operation temperature of materials

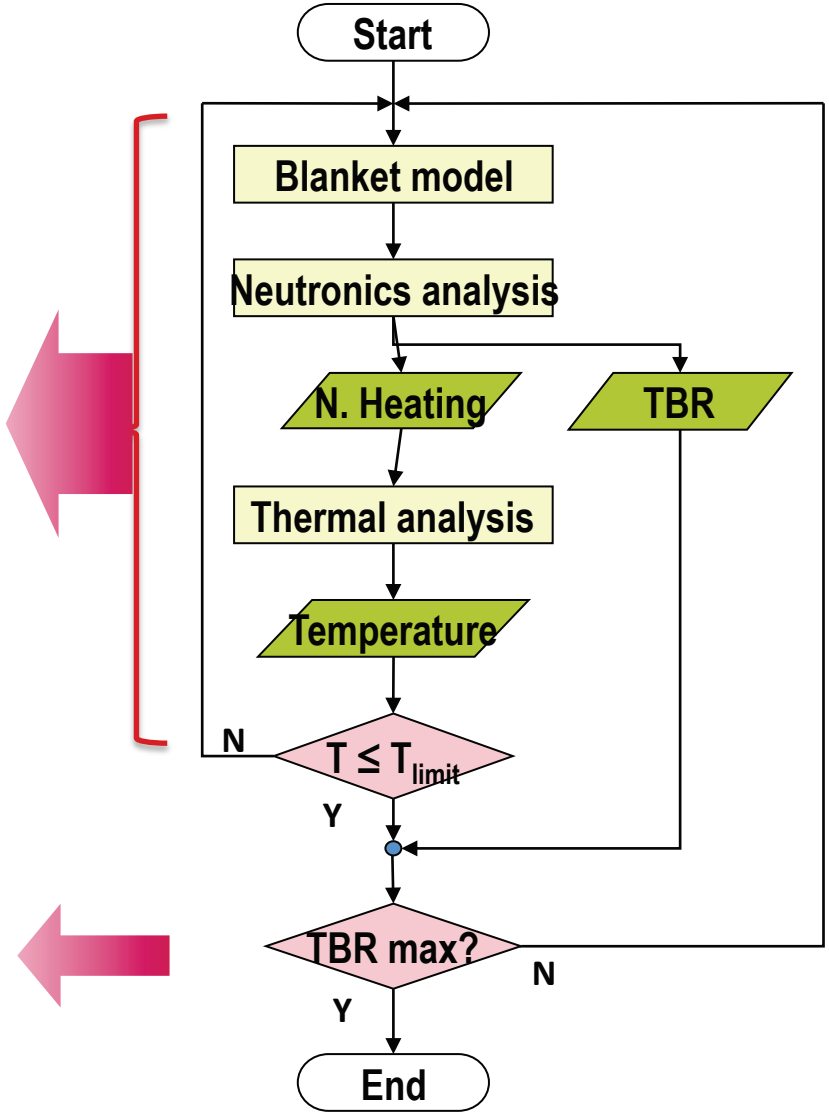
   e.g., Operation temp.

   F82H ≤ 550°C

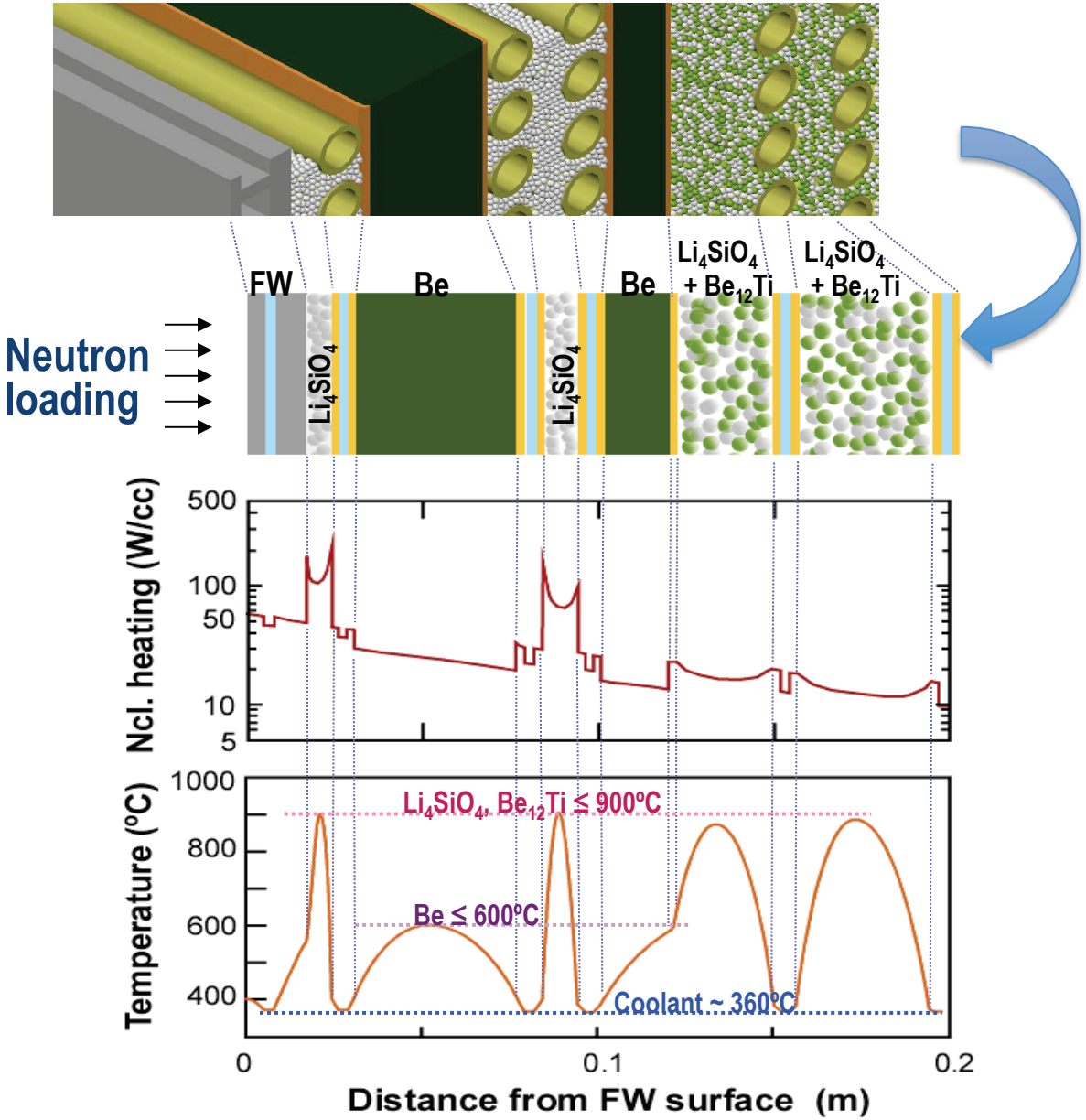
   Be ≤ 600°C

   $Be_{12}Ti$, Li_2TiO_3 ≤ 900°C

2. Furthermore, to maximize TBR



Example of previous optimization



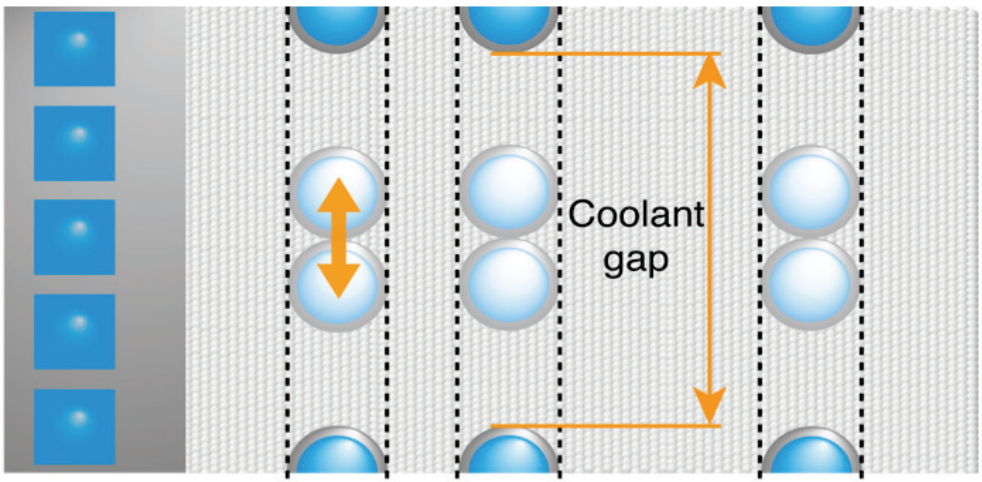
ANISN + HEAT

1-D code "ANIHEAT"

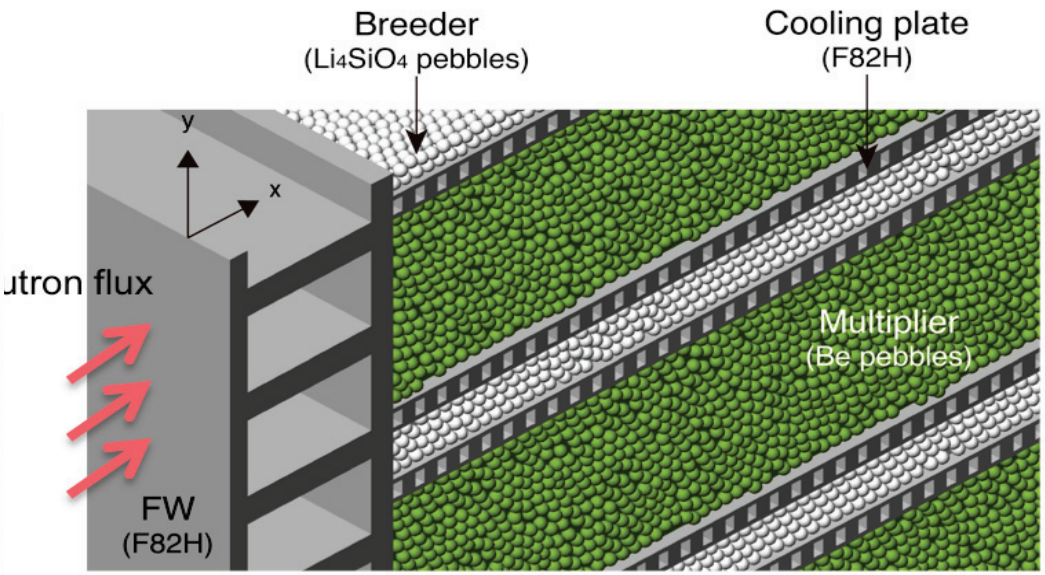
Multi-layered blanket is properly modeled with a 1-D model

Cases that ANIHEAT doesn't work

(1) Extreme case of "multi-layered" with a large gap between cooling



(2) He-cooled pebble bed (EU)



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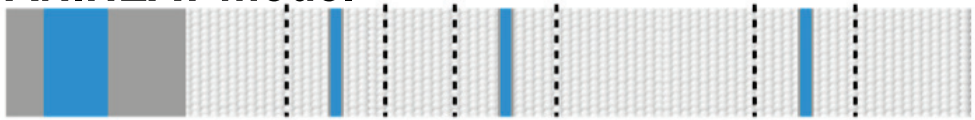
ANIHEAT model

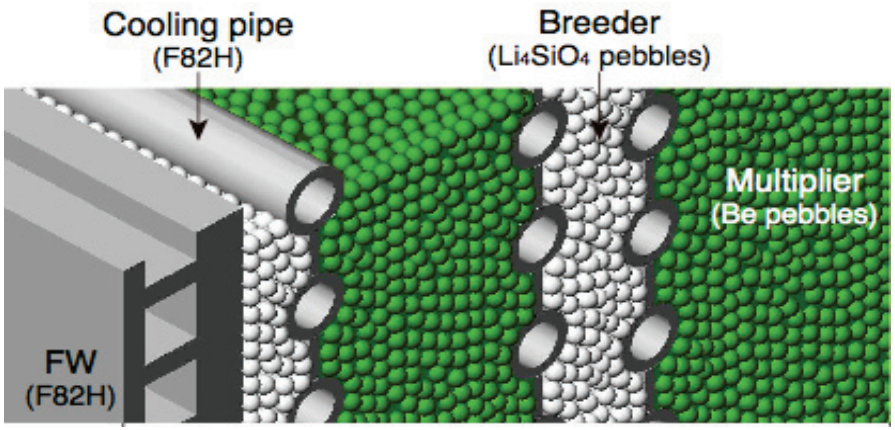


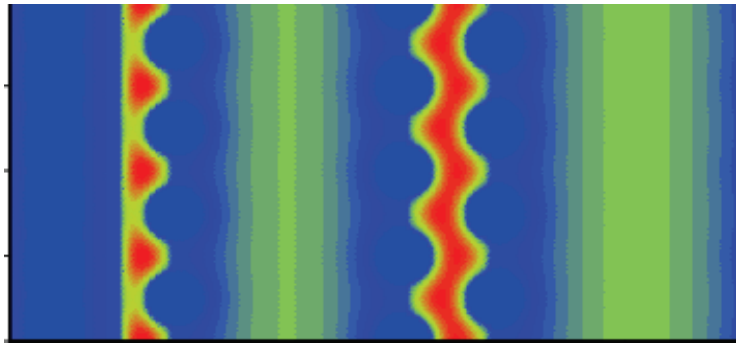
2D code "DOHEAT"

DOT3.5 + HEAT ➔ DOHEAT

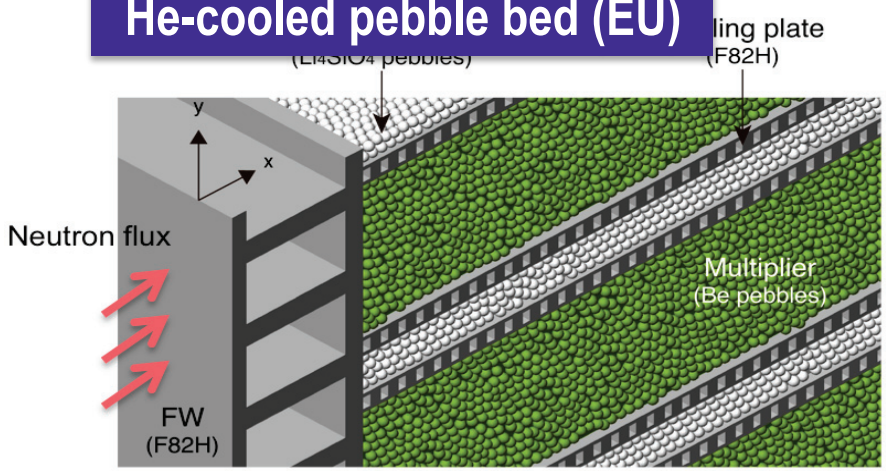
2D n/γ transport 2D heat transfer

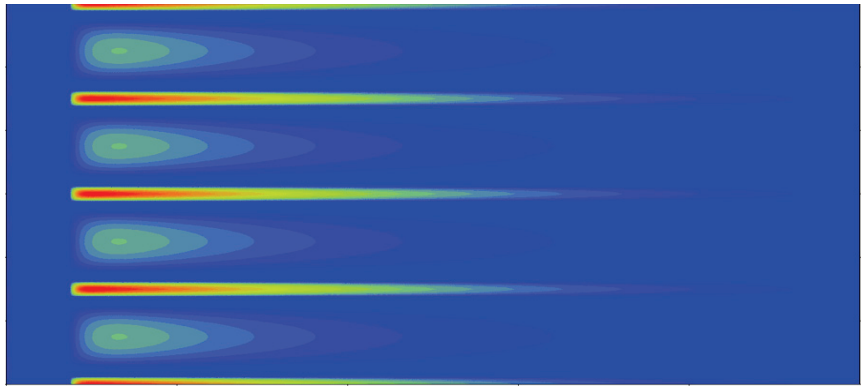
Zigzag alignment of tubes





He-cooled pebble bed (EU)





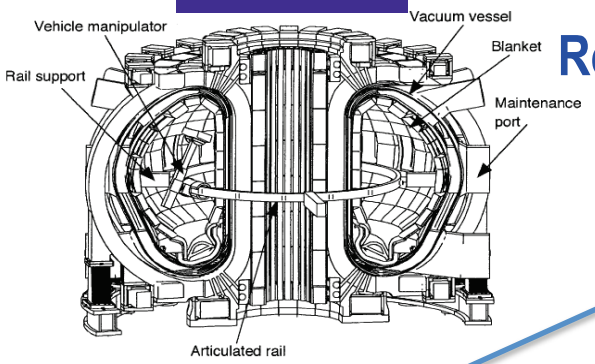
1. Modification of blanket concept
2. Development of blanket design tool
3. **Alternative concept of maintenance**
4. Structure and plan of BA DEMO Design

Various maintenance schemes

“ITER” — to replace a limited number of damaged components

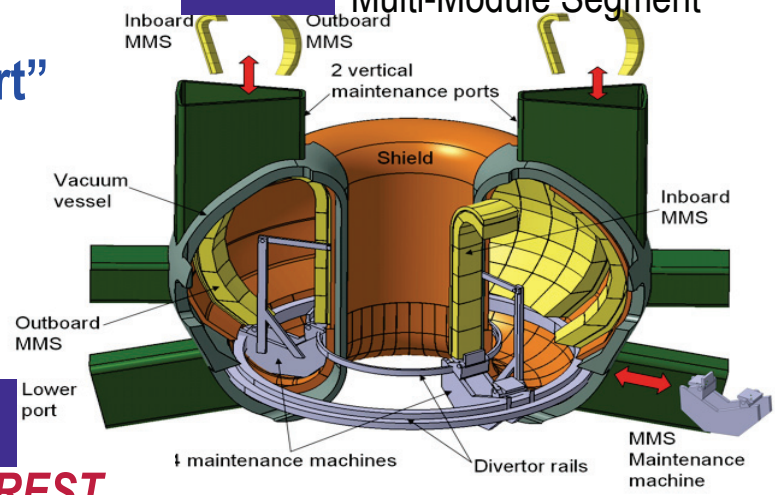
“DEMO” — to replace the whole set of blankets in a short term for demonstrate high plant availability

In-vessel *ITER*

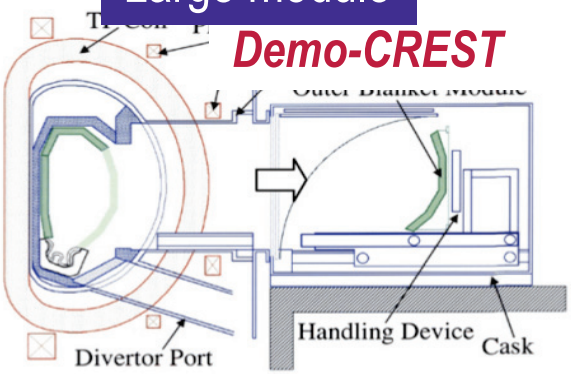


Reality “Art”

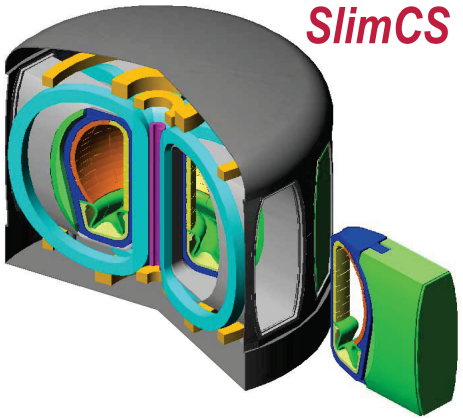
MMS *PPCS* Multi-Module Segment



Large module *Demo-CREST*



Sector transport *SlimCS*



Why “sector” transport maintenance?

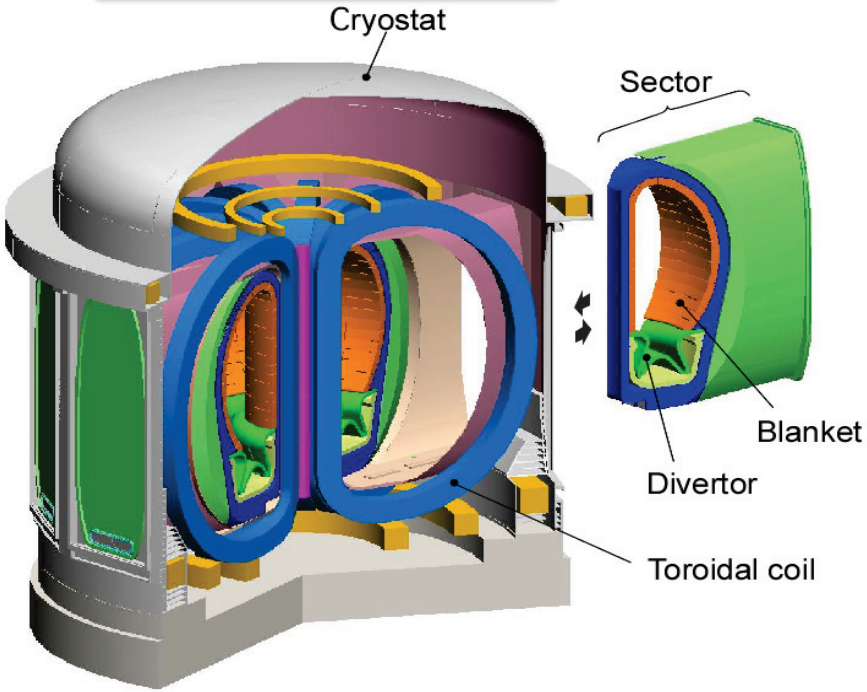
#1. Robust ring structure

➔ Break of the ring deteriorates strength against T-O forces.

#2. To reduce N of manifolds

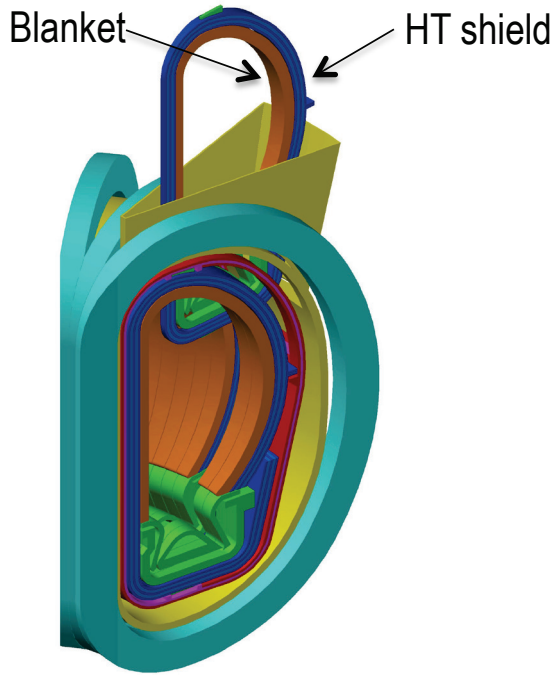
➔ Minimize N of cutting & rewelding points

Horizontal transport



Designed in previous years

Vertical transport



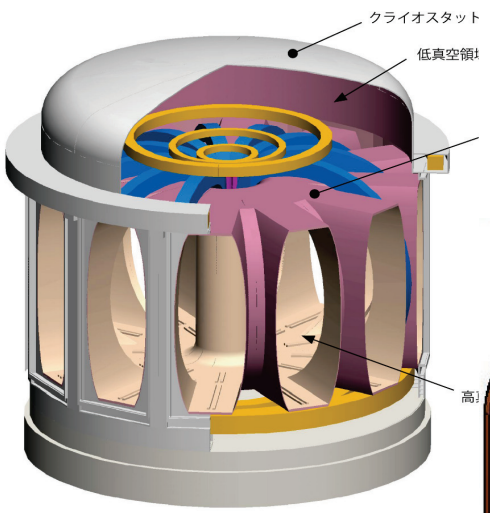
Under study

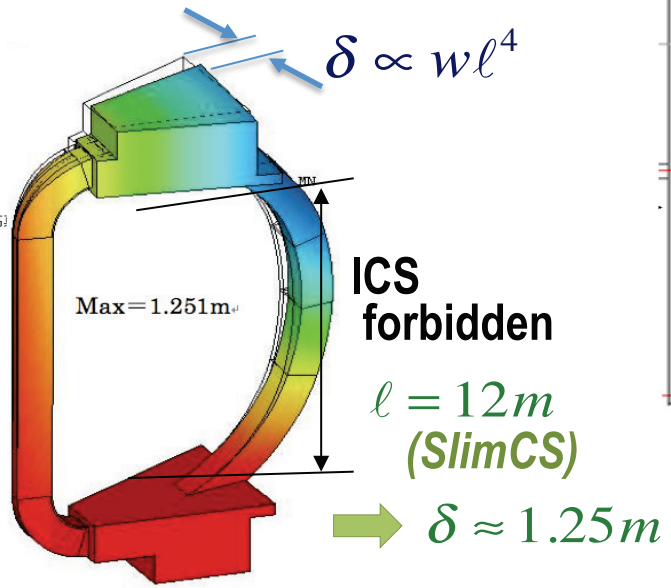
Why “vertical” transport next?

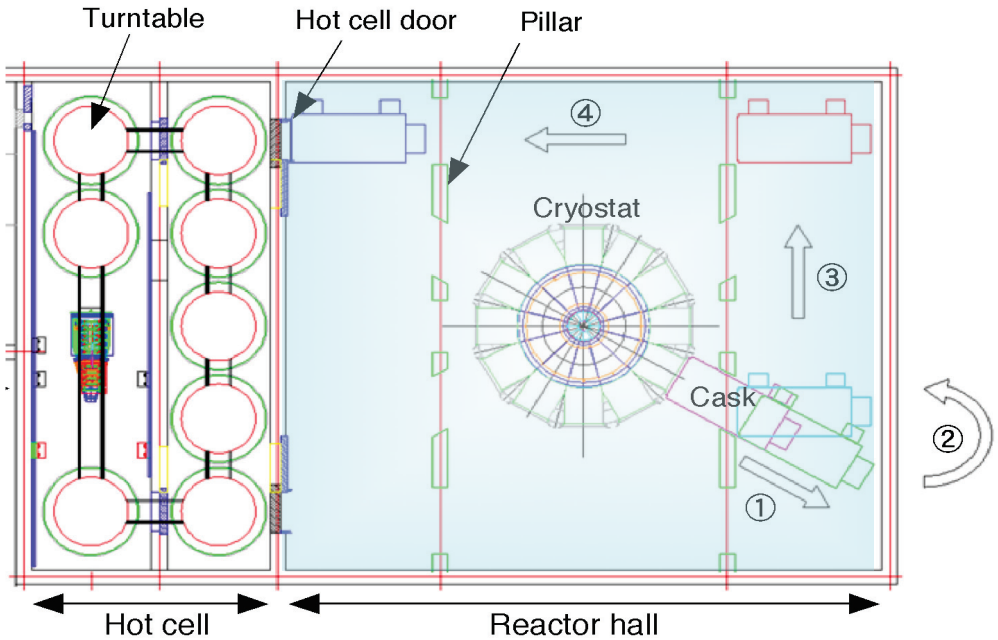
To expand understanding of “sector transport”

- **“Horizontal” transport has difficulties** of
  1) limited support of T-O forces by inter-coil structure
  2) large maintenance space around reactor

- **“Vertical” transport resolves the problems, but may cause diffirent ones.**

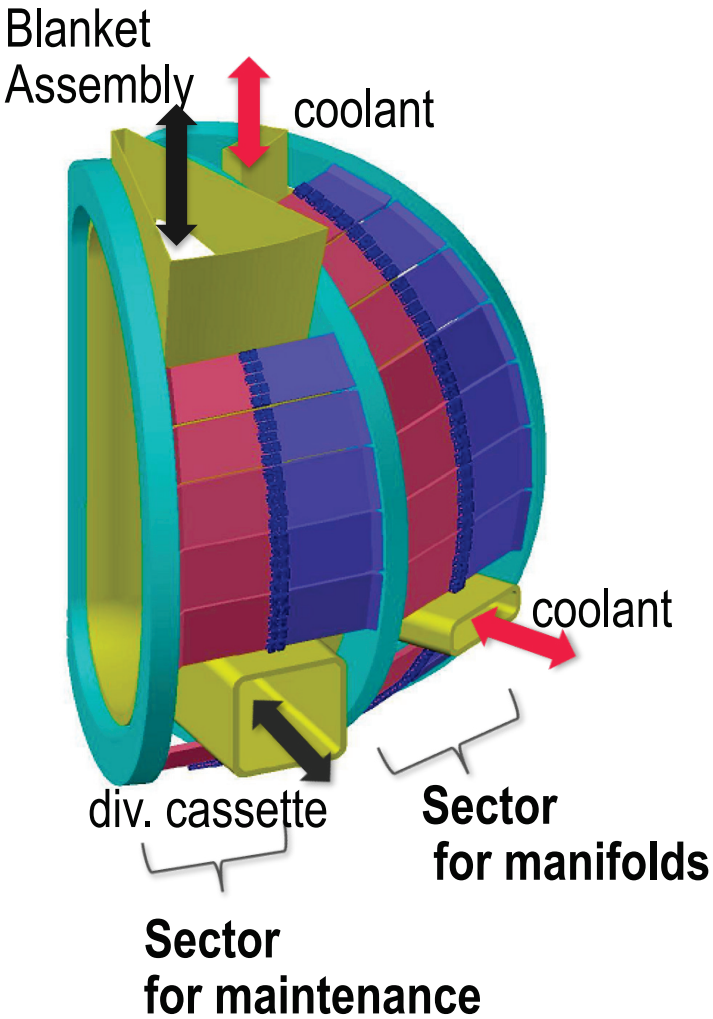




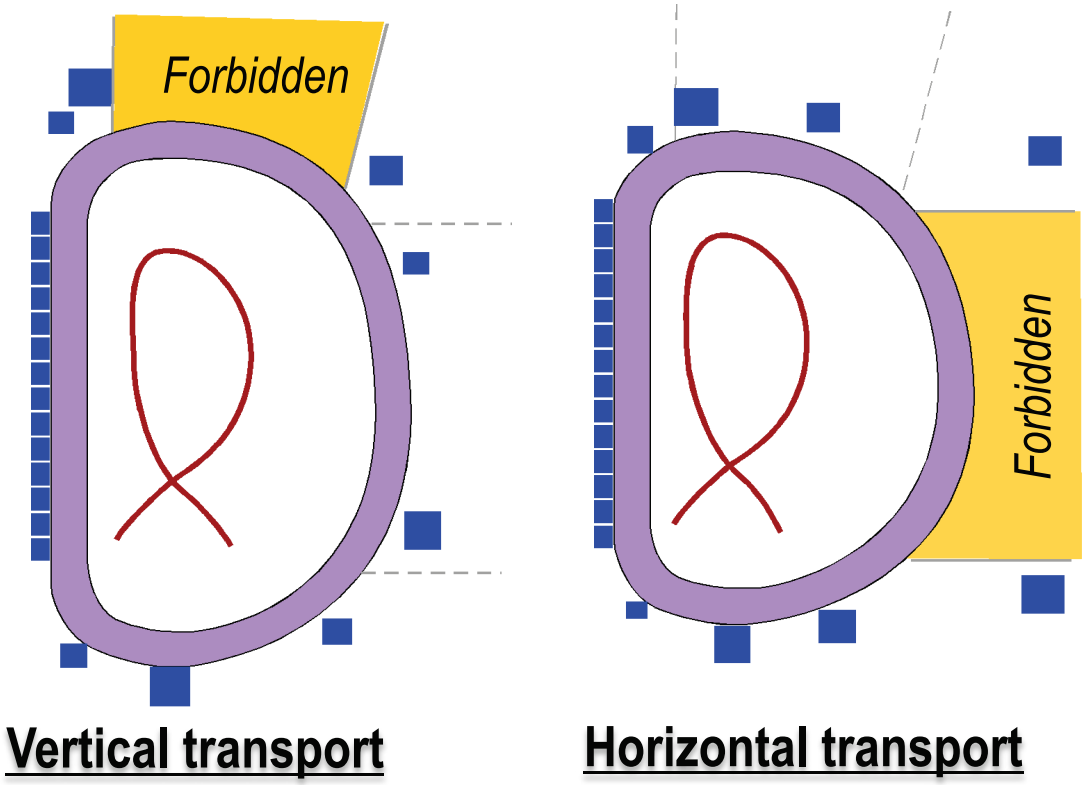


Vertical sector transport

Two different sectors
arranged alternately

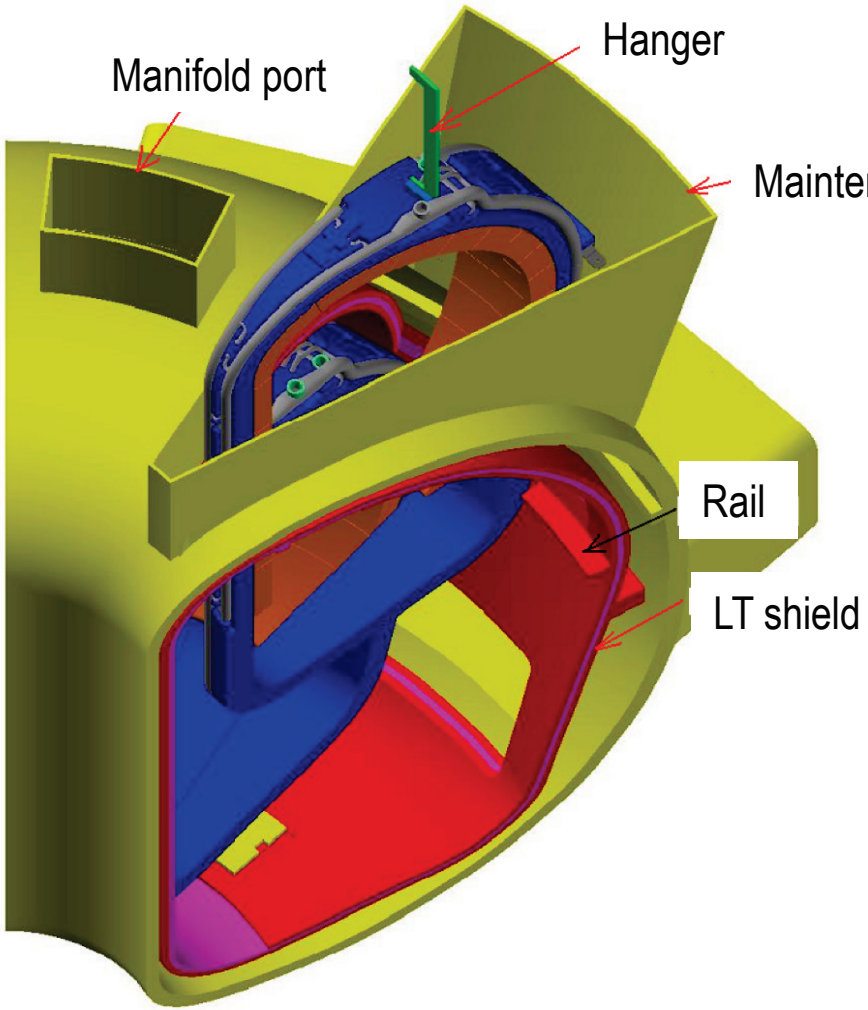


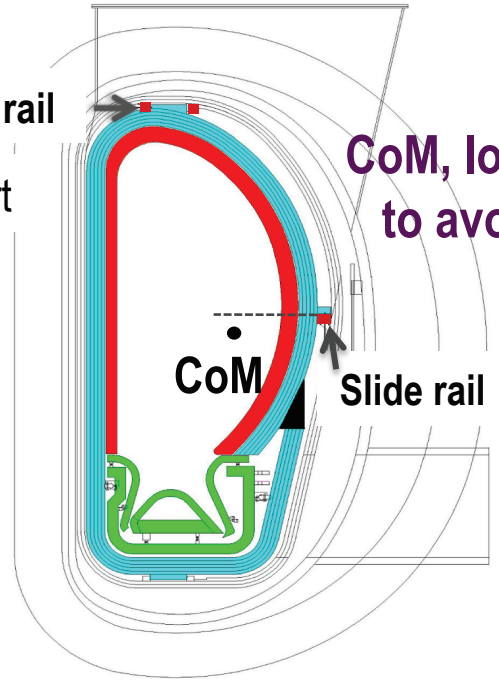
Arrangement PF coils



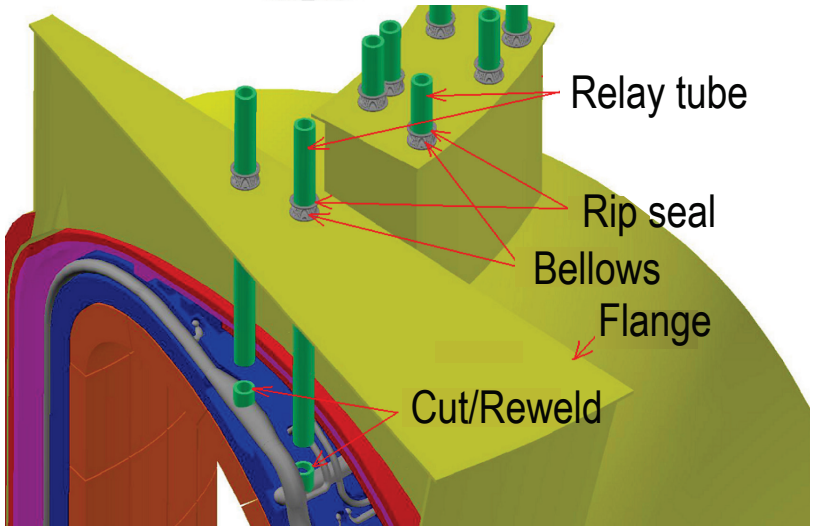
Similar shaped plasma can be obtained
despite of different PF coil arrangement.

Vertical sector transport



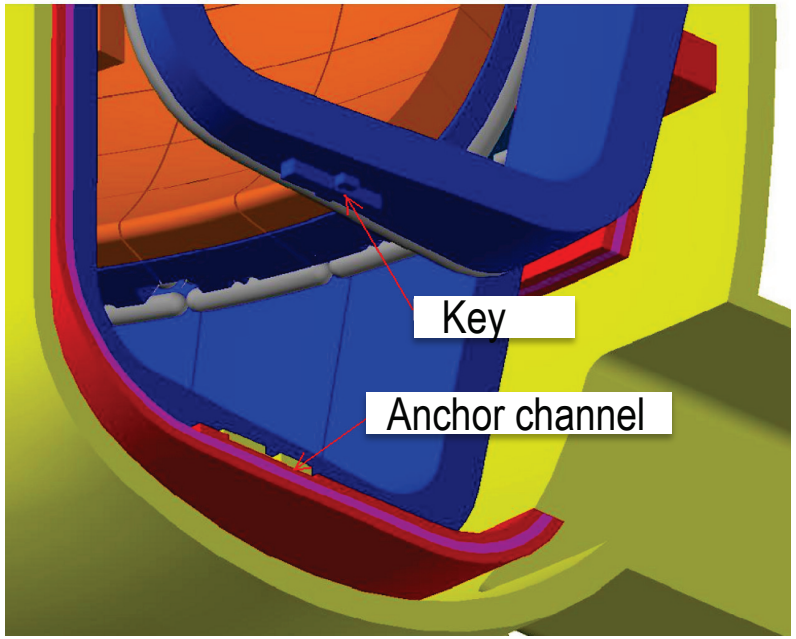


CoM, lower than the slide rail to avoid overturning

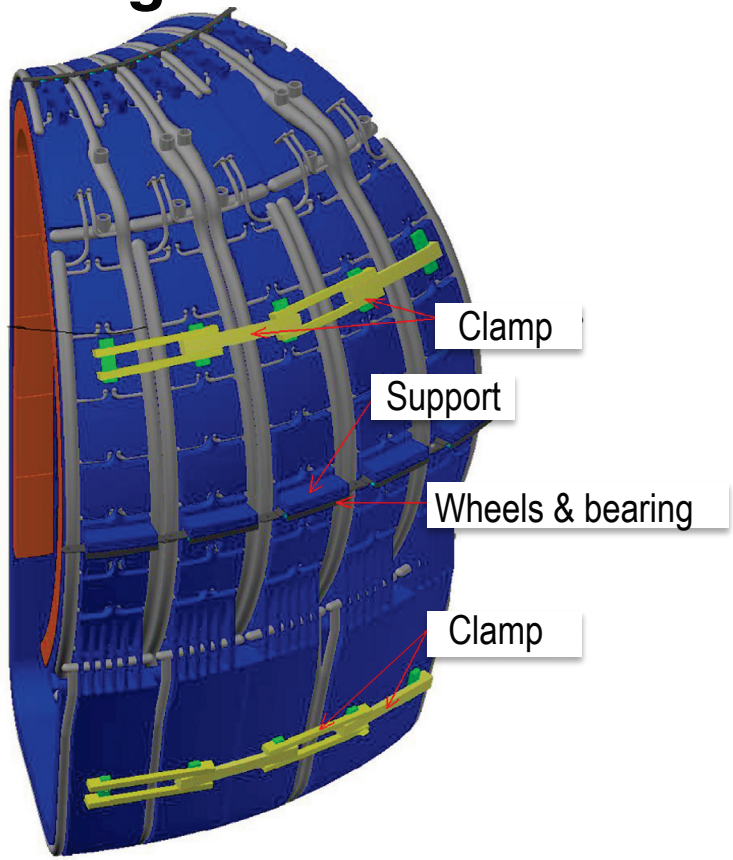


Vertical sector transport

Positioning of sector



Binding of sectors



Future work

- Divertor replacement mechanism
- Transport of removed sectors to the hot cell
- Impacts on building

1. Modification of blanket concept
2. Development of blanket design tool
3. Alternative concept of maintenance
4. **Structure and plan of BA DEMO Design**

DEMO Design under Broader Approach

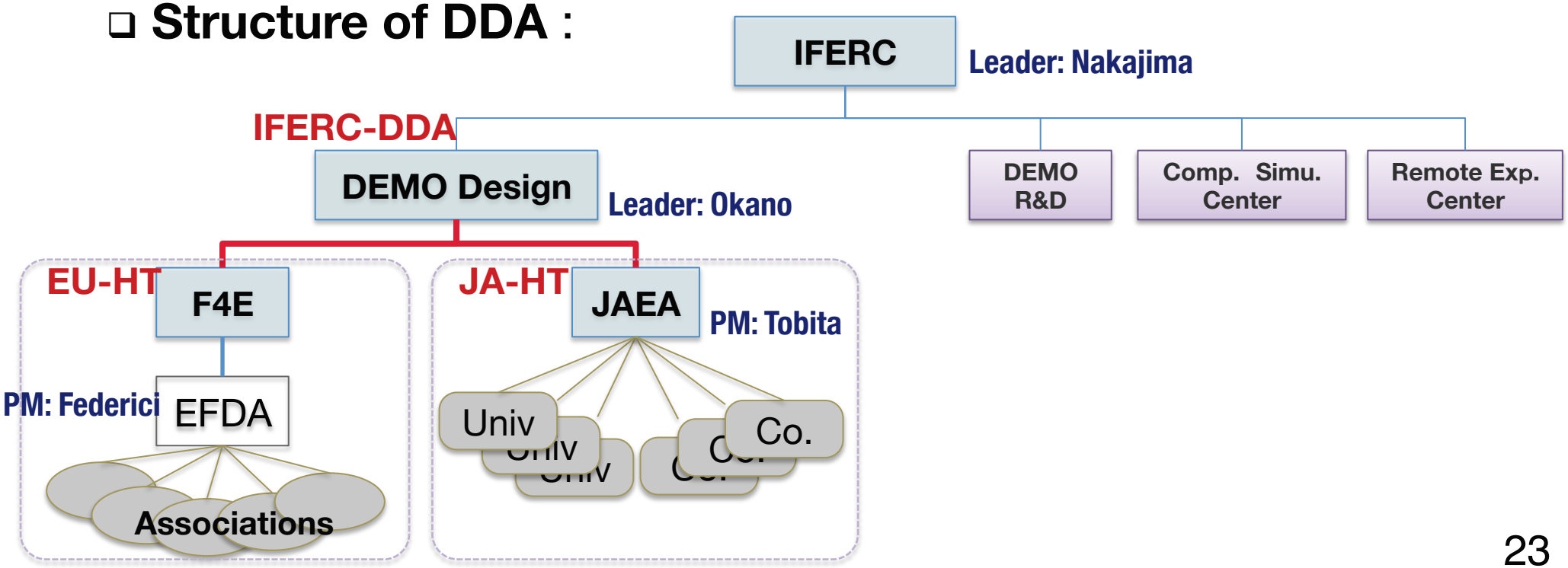
- **Implementing agencies:**

  JAEA — Japan, Fusion for Energy — EU

- **Joint DEMO Design Activities launched in January 2011**

  Preparatory period (2007 mid – 2010)

- **Structure of DDA :**



Plan of BA DEMO Design

- **Small Resource** — two orders smaller than that of ITER-CDA

  → Need to concentrate on limited number of issues

- **Plan of 2011– 2016:**

  Detailed tasks, under discussion

	2011	2012	2013	2014	2015	2016	2017
	Phase 2A		Phase 2B		Phase 2C		
Preliminary design for common design basis			*Survey various DEMO-specific issues and establish common ground for DEMO design*				
Consolidation of the design basis					*Conduct In-depth design and narrow down tech. options*		
Pre-conceptual design	*One or two conceptual designs*						

⌘ ***In Japan, special attention to be paid to foster younger generations***

Summary

- Design study on simplified blanket is under way.
- For blanket design, a 2-D code DOHEAT with an intuitive interface has been developed.
- Vertical sector transport maintenance is under study to provide every possible options for DEMO maintenance.
- BA DEMO design activities embarked on a joint design work in 2011.