# Accomplishment of DEMO R&D Activity of IFERC Project in BA activity

and

# Strategy toward DEMO & Progress of conceptual design study on Japanese DEMO

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# Technical demands on DEMO Design and R&D activity

## *Conceptual design of JA DEMO*

***Fusion Power*** *compatible with divertor heat-handling* *=> $P_f$ = 1.5 - 2.0 GW*

***Device size*** *compatible with operation flexibility including pulse operation* *=> R = 8m class*

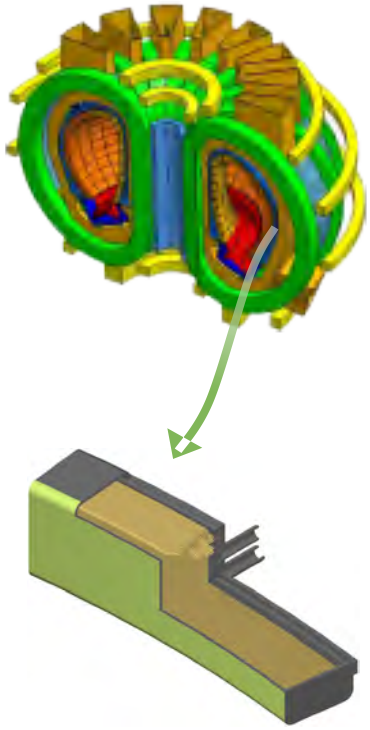
***Breeding Blanket system*** *consisted with the rational combination*

*=> Water Cooled Ceramic Breeder for primary system and advanced option for DEMO-TBM*

**Need to establish basic strategy of safety assurance of fusion system**

### Design challenges to overcome weaknesses in water-cooled DEMO

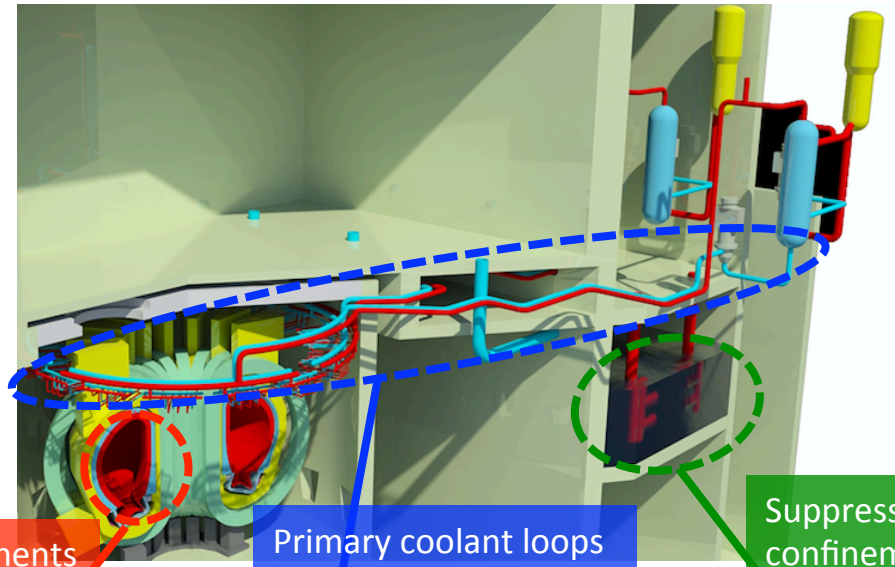
- ✓ T permeation into the primary coolant in in-vessel components
- ✓ T management in the primary coolant loop
- ✓ Confinement concept for T release from the primary coolant loop in a pipe break accident.



### Technical challenges on materials and technologies related to breeding blanket

- ✓Structural material which fulfill the technical demands
- ✓Neutron multiplier and T breeder compatible with water-cooled system
- ✓ Advanced material for functional structure application of dual-coolant liquid metal breed system (DEMO-TBM)
- ✓T handling technologies which form the technical basis of safety and T breeding

# Highlight : DEMO plant concept related to tritium handling in the primary coolant system is developed



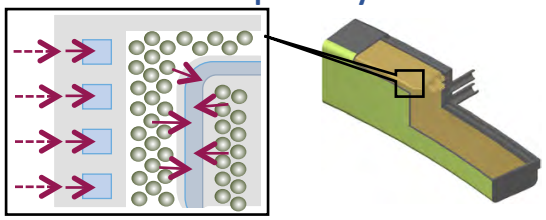
In-vessel components

Primary coolant loops

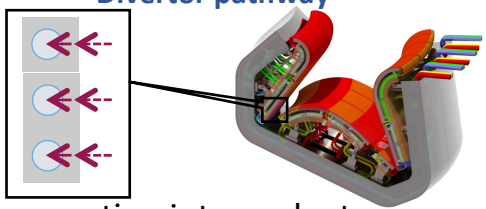
Suppression pool for T confinement concept

## 1. T permeation into coolant

Blanket pathways

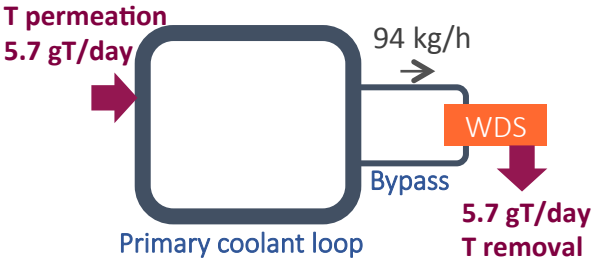


Divertor pathway



T permeation into coolant was estimated to be as low as 5.7 gT/day = 2.5% of produced T

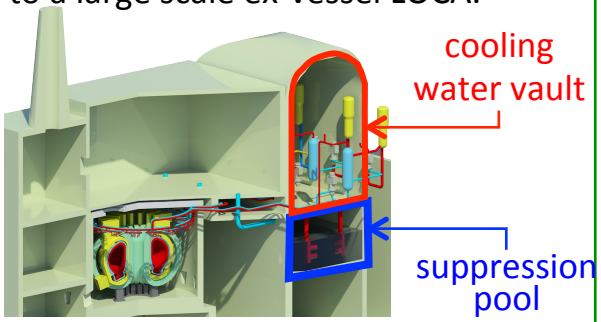
## 2. T extraction from coolant




Management of T concentration in the coolant is viable by applying an existing water detritiation system (WDS) of CANDU.

## 3. Confinement of T at LOCA

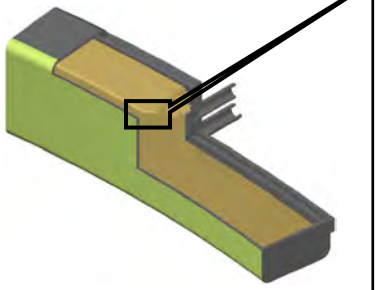
Combination of "cooling water vault" and "suppression pool" is effective to mitigate T environmental release due to a large scale ex-vessel LOCA.

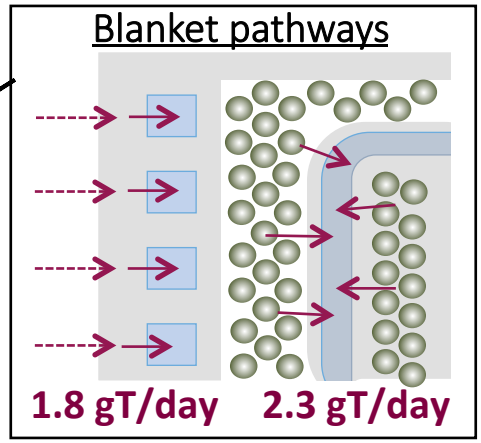


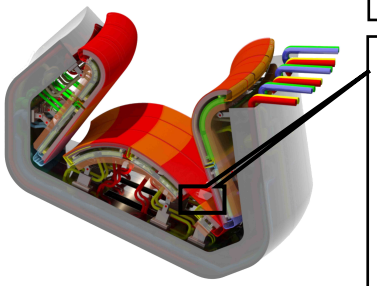

Early public dose: as low as 1.8mSv << 50mSv of no evacuation limit

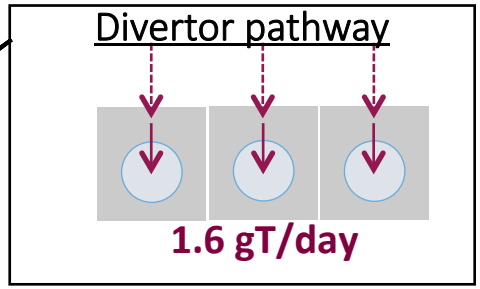
# T permeation into water can be resolved in DEMO

- Tritium permeation was estimated for three pathways via: 1) blanket surface, 2) inside blanket, and 3) divertor surface.








- Tritium permeation was estimated to be as low as **5.7 gT/day** at most.

(K. Katayama et al, Estimation of Tritium Permeation Rate to Cooling Water in Fusion DEMO Condition, 4B-6, Tritium 2016, US)

- For the permeation of **5.7 gT/day**, T concentration in the coolant can be kept at **1 TBq/kg or lower** by applying an existing water detritiation system (WDS) of CANDU.

- Actually, the required water to be processed is 94 kg/h for DEMO, which is satisfied with the specifications WDS in Wolsong (Korea).

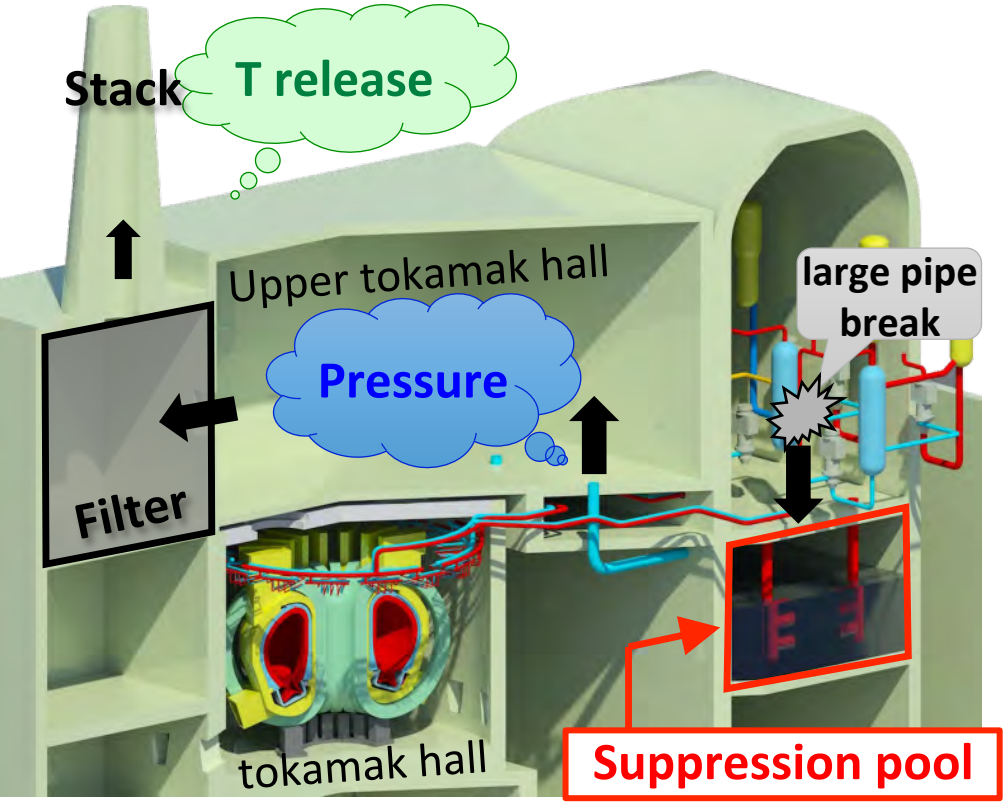

*Water throughput: 100 kg/h*
*T concentration: 0.04 – 2.2 TBq/kg*

# A new concept of T confinement in ex-VV LOCA

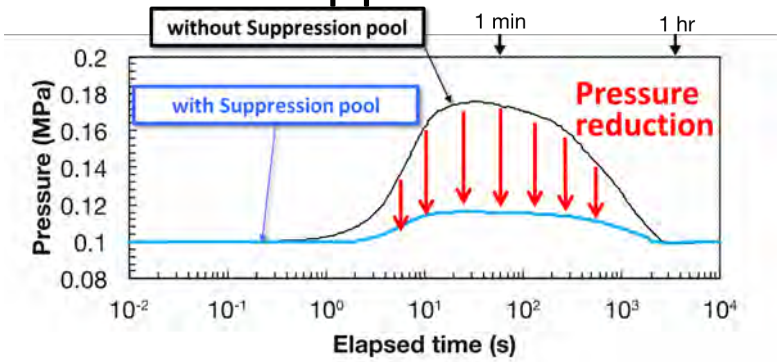
(Y. Someya et al., FEC2016 SEE/P7-5)

- ✓ Ex-VV LOCA discharges the tritiated coolant (1TBq/kg) in the final confinement barrier.
- ✓ Installation of a Suppression Pool (SP) is proposed to mitigate the pressure increase in the Upper Tokamak Hall (UTH), constituting the final barrier.
- ✓ The SP can reduce the pressure in the UTH to less than 0.12 MPa.
- ✓ The resultant release of tritium from UTH can be drastically reduced.

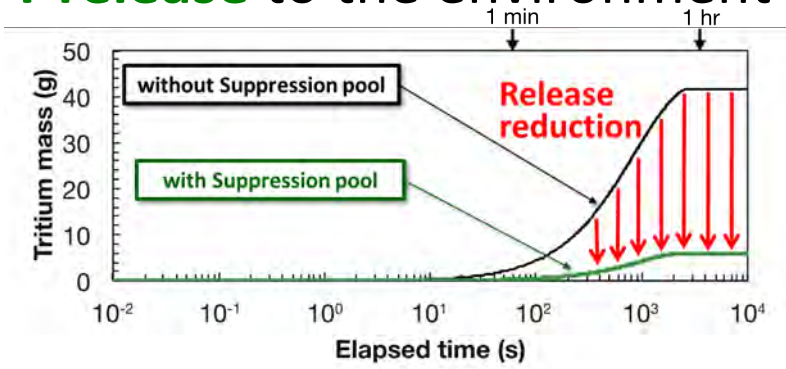
The resultant early dose to the public can be reduced to 1.8mSv << *50mSv.
*("no-evacuation" dose limit recommended by IAEA)




## Pressure in upper tokamak hall




## T release to the environment



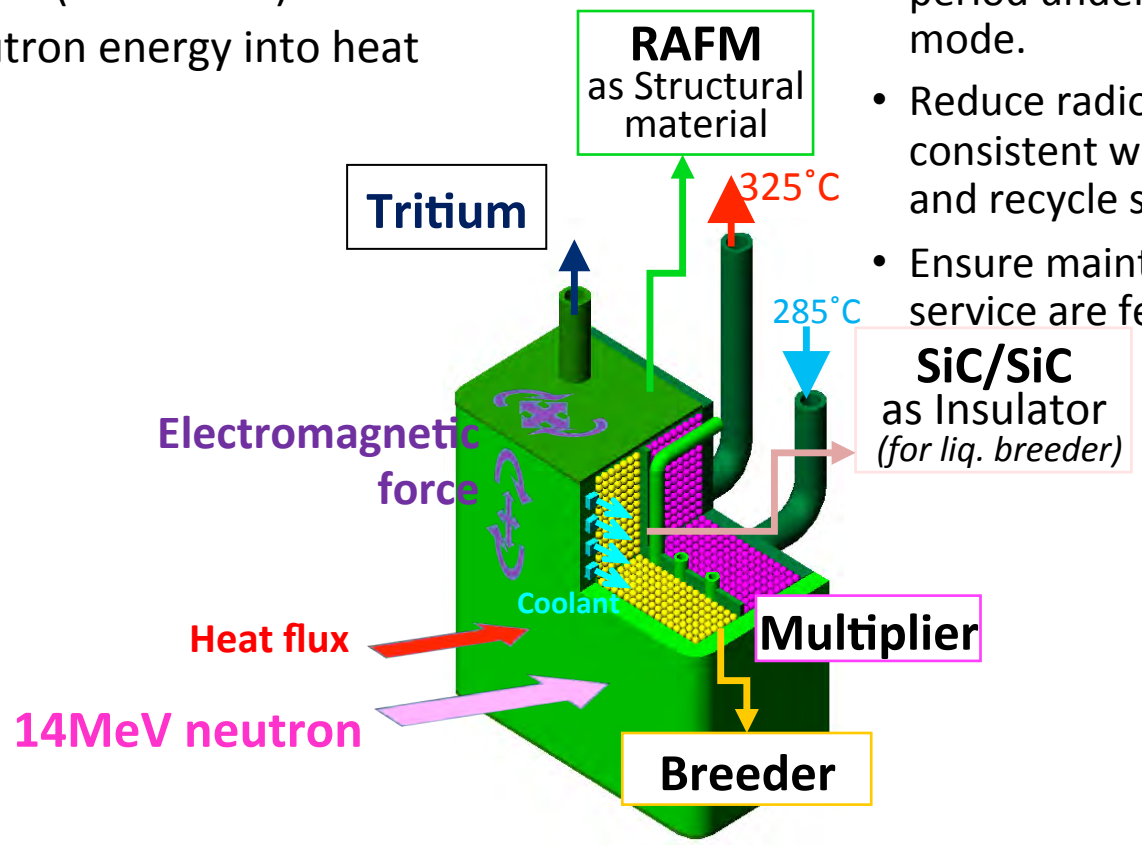
# Requirement for the blanket system

**Required function**

- Shield the high energy fusion neutron
- Breed Tritium (TBR > 1.05)
- Convert neutron energy into heat

**Expected performance**

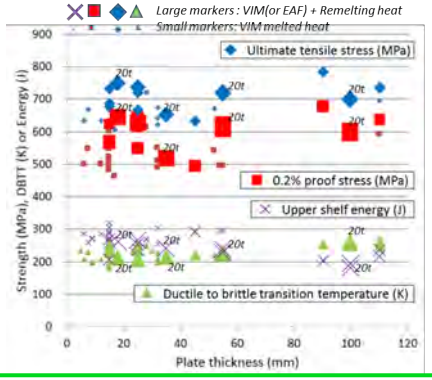
- Assure safety and reliability throughout the assumed service period under the assumed operation mode.
- Reduce radioactive level which is consistent with waste management and recycle strategy.
- Ensure maintenance and inspection service are feasible.




★ **Materials & Tritium technology development for blanket system is expected to provide sound engineering bases for *safety, reliability and feasibility of blanket designs.***

# The highlights of the accomplishment of DEMO R&D

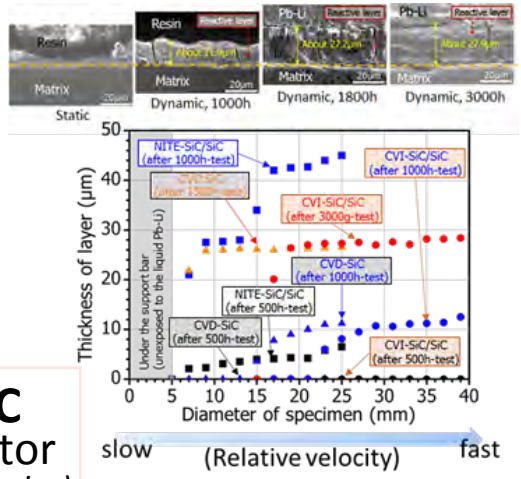
Demonstration of RAFM steel F82H's good reproducibility in DEMO scale production technologies.



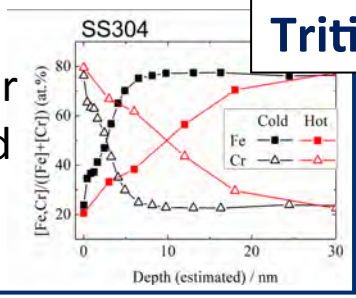


**RAFM**
as Structural material

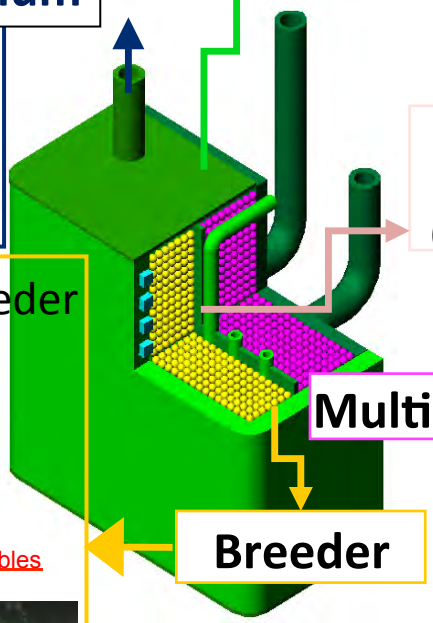
Chemical stability of pure SiC/SiC composite in high temperature liquid Pb-Li




Suppression of passivation behavior of SS304 by tritiated water, but not the case for SS316.




**Tritium**



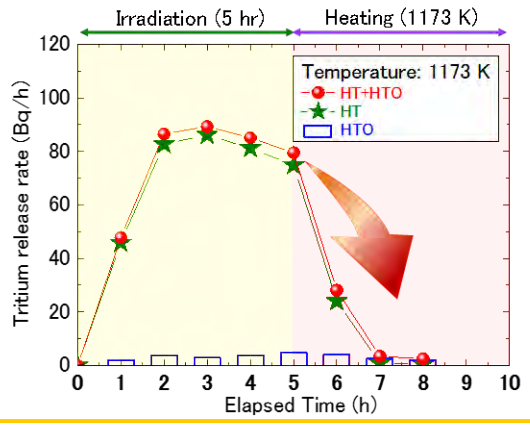
**SiC/SiC**
as Insulator
*(for liq. breeder)*

**Multiplier**

**Breeder**

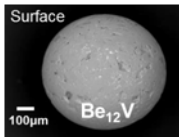
Pebble of super advanced tritium breeder

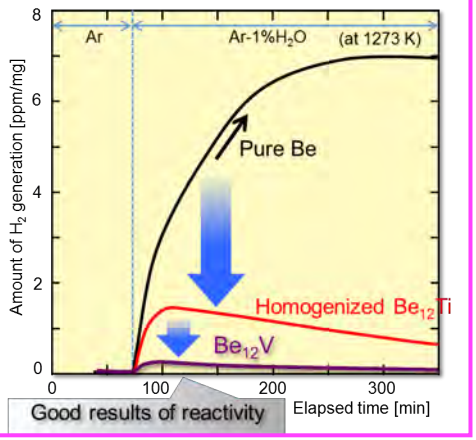
LTZO20 *$Li_{2+x}TiO_{3+y}$ with 20 wt.% $Li_2ZrO_3$*




LTZO20 pebbles

$Be_{12}V$ single phase pebbles as advanced neutron multipliers



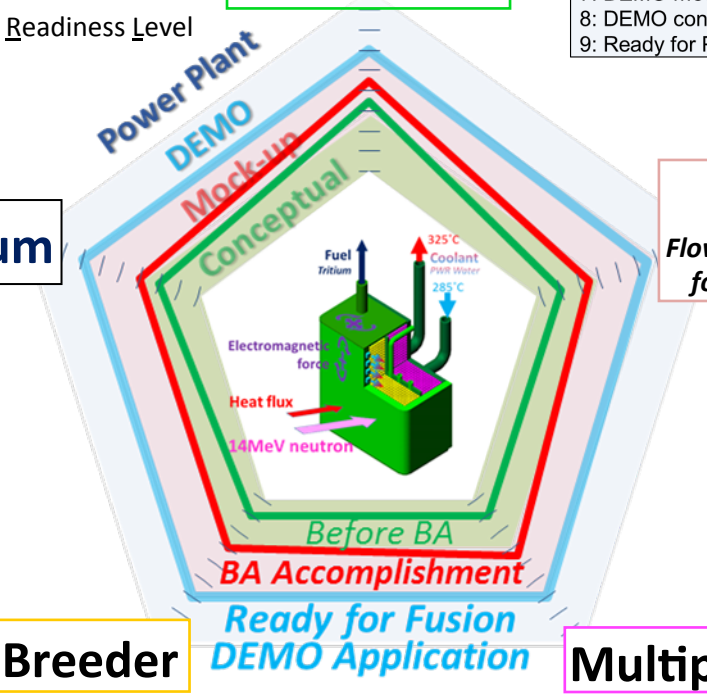



# Strategy toward DEMO beyond BA activity

**Blanket Technologies TRL**
Technical Readiness Level

| |
|---|
| 1:Conceptual idea<br>2:Realization of basic technology<br>3:Proof of technical principle |
| 4: Lab. Scale demonstration<br>5: Industrial level demonstration<br>6: Ready for Fusion application |
| 7: DEMO mockup operation<br>8: DEMO construction / operation<br>9: Ready for Power plant |

**RAFM Steel**
***Structural material***




**Tritium**

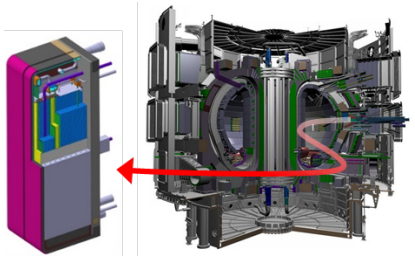
**SiC/SiC**
***Flow channel insert for DEMO-TBM***

**Breeder**

**Multiplier**

***To get ready for Fusion DEMO application.***

Demonstration and endorsement of these developed technologies in industrial level, *under DT fusion in-vessel environment.*



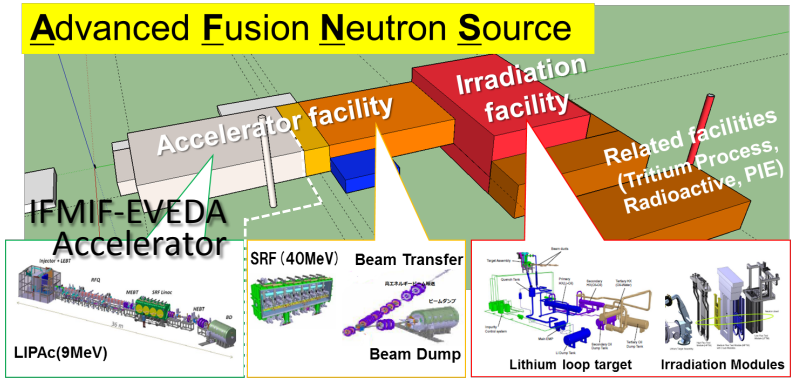
**Operation of ITER-TBM in DT phase**

- ✓ The important demonstration to prove its feasibility ( But, <3dpa)

**An intense fusion neutron source**

*Relatively large volume, constant / high dose fusion n. irradiation facility*

- ✓ Verification of materials and blanket technologies under DEMO-like environment.



# Summary

**Demo concept development**

- ✓ Plant concept related to tritium handling in the primary coolant is developed.
  - ❑ Tritium permeation into the coolant in the in-vessel components is evaluated to be 5.7gT/day.
  - ❑ T management keeping 1TBq/kg in the primary coolant is found to be possible using the existing tritium removal facility of CAMDU.
  - ❑ Confinement concept of T release at ex-vessel LOCA is proposed using suppression pool system, resulting early dose to the public 1.8mSv.

**Demo R&D activity**

- ✓ Five R&D tasks on blanket technologies were conducted in the BA DEMO R&D activity, and the major accomplishments are as follow.
  - ❑ Demonstrate **RAFM steel, F82H,** potential as the DEMO structural material
  - ❑ Prove the stability of **SiC/SiC composite** for functional structure application
  - ❑ Developed **Beryllide ($Be_{12}V$)** as the advanced neutron multiplier
  - ❑ Developed **Li-titanete/Li-Ziroconate ceramic** as the advanced tritium breeder
  - ❑ **Tritium handling technologies**.

**Next step**

- ✓ Need an intense fusion neutron source to demonstrate these technologies.