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*

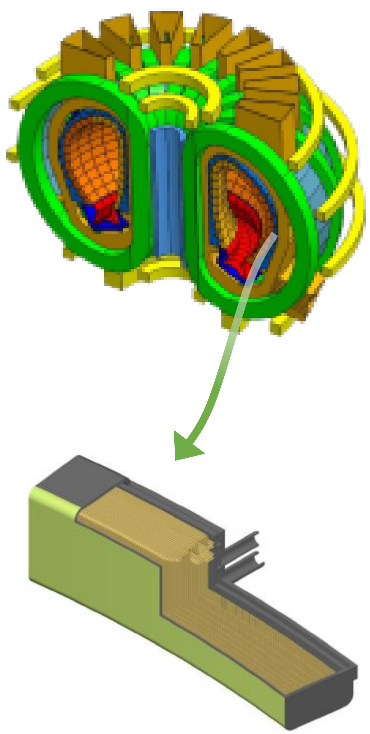
Breeding Blanket system *consisted with the rational combination*

=> 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

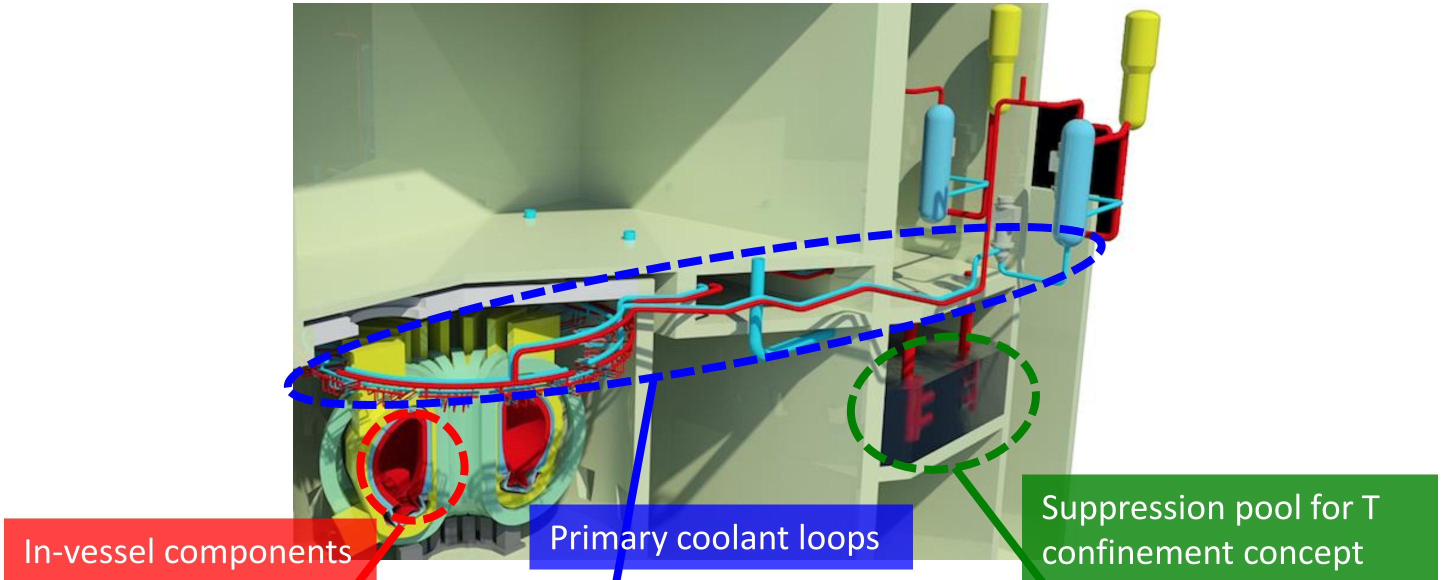
- ✓ T permeation into the primary coolant in in-vessel components
- ✓ T management in the primary coolant loop
- ✓ Confinement concept for T release from the primary coolant loop in a pipe rupture accident.



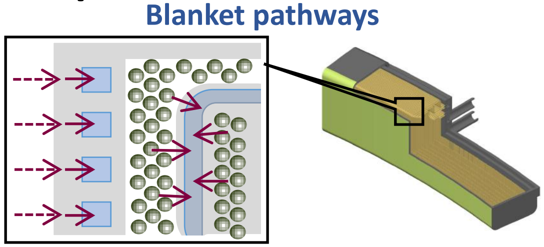
Technical challenges on materials and technologies related to breeding blanket

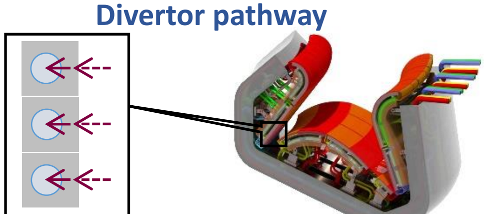
- ✓ Structural material which fulfill the technical demands
- ✓ Neutron multiplier and T breeder compatible with water-cooled system
- ✓ Advanced material for functional structure application (flow channel insert) of dual-coolant liquid metal breeding system (DEMO-TBM)
- ✓ T handling technologies which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

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



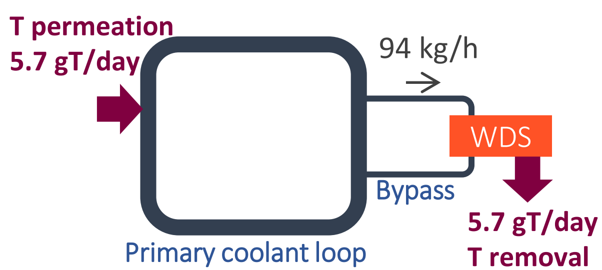
1. T permeation into coolant





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

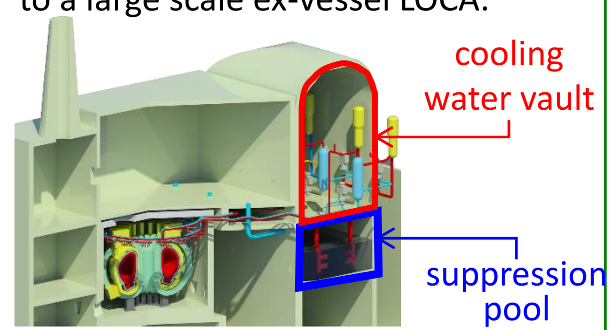
2. T extraction from coolant



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

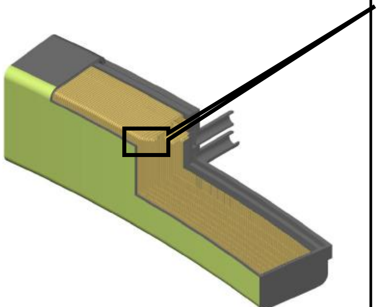
Combination of "cooling water vault" and "suppression pool" is effective to mitigate T environmental release due to a large scale ex-vessel LOCA.

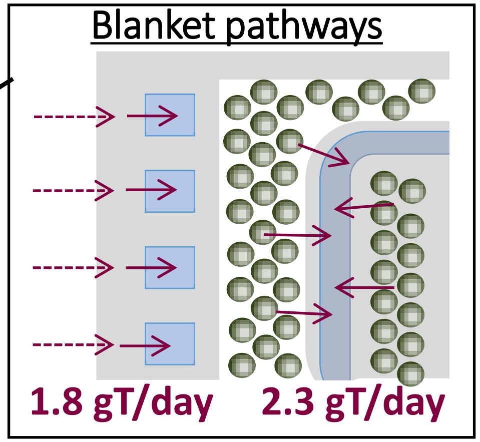


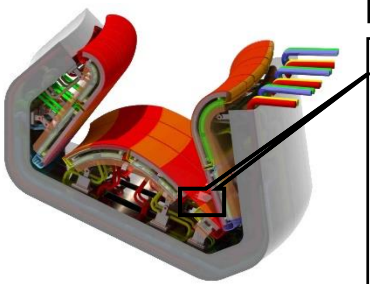
Early public dose: as low as 1.8mSv << 50mSv of no evacuation limit

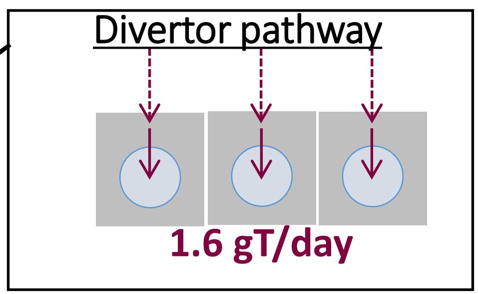
T permeation into water can be resolved in DEMO

- 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).

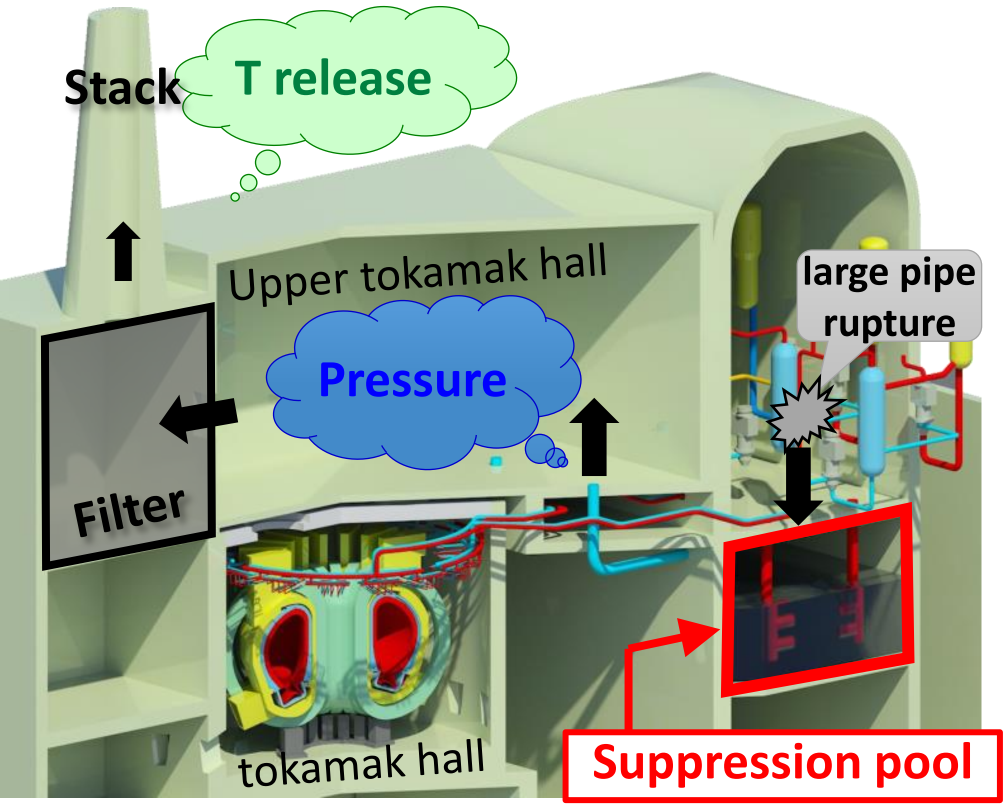
Water throughput: 100 kg/h
T concentration: 0.04 – 2.2 TBq/kg

A new concept of T confinement in ex-VV LOCA

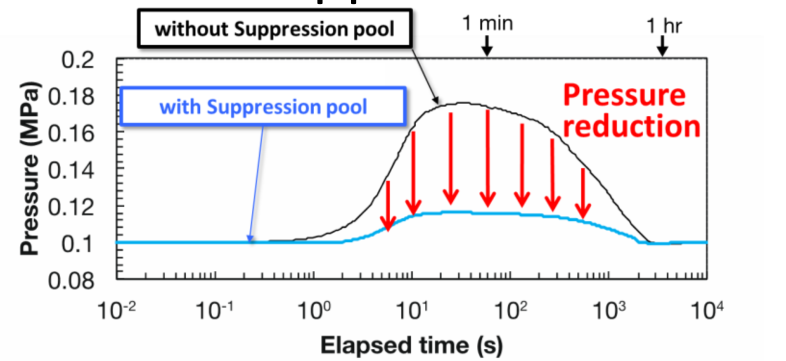
(Y. Someya et al., FEC2016 SEE/P7-5)

- ✓ 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.

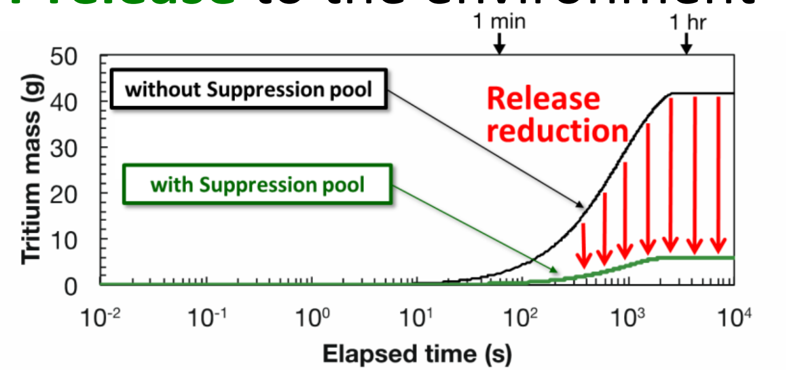
The resultant early dose to the public can be reduced to 1.8mSv << *50mSv.
*(“no-evacuation” dose limit recommended by IAEA)



Pressure in upper tokamak hall



T release to the environment

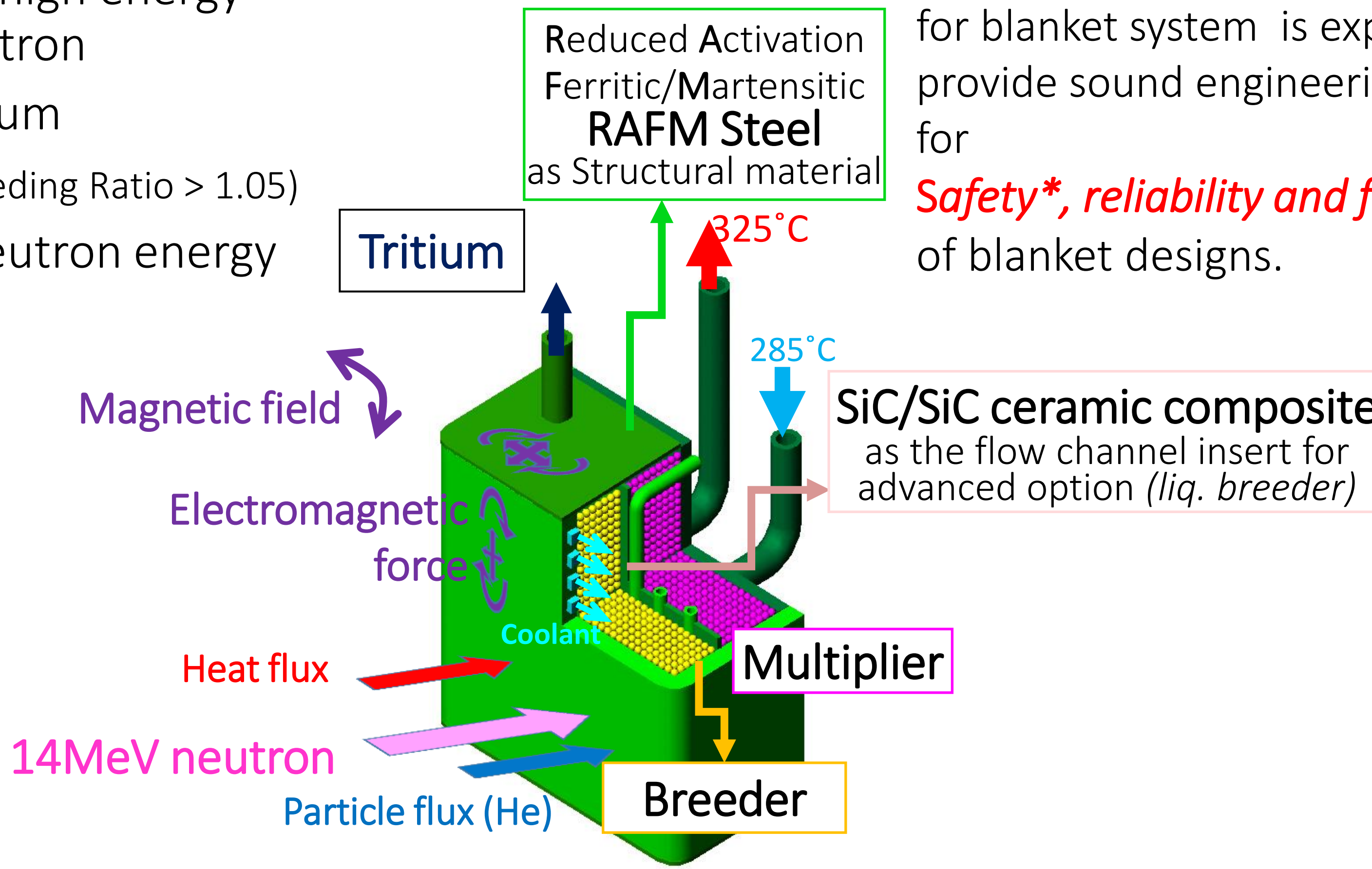


Requirement for the blanket system

Required function

- Shield the high energy fusion neutron
- Breed Tritium

  (Tritium Breeding Ratio > 1.05)
- Convert neutron energy into heat



Expectation to R&D

Materials & tritium technologies for blanket system is expected to provide sound engineering bases for

Safety*, reliability and feasibility

of blanket designs.

** Blanket is not the safety barrier, but is expected not to challenge the integrity of the primary safety barrier, the Vacuum Vessel.*

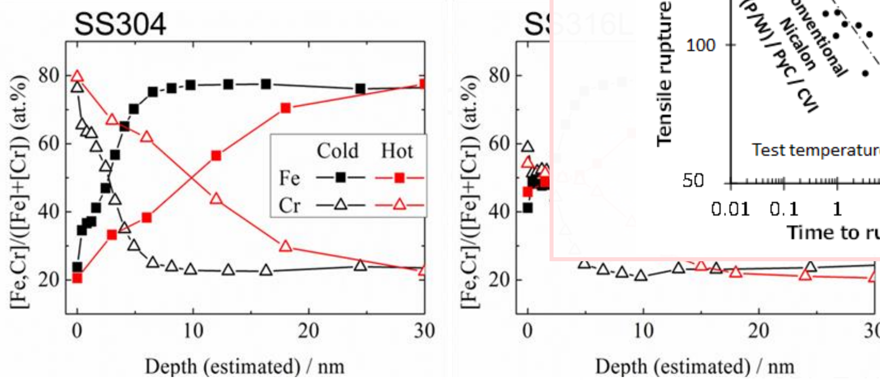
Reduced Activation Ferritic/
as a structural material

Demonstrate JA-RAFM steel F82H
in DEMO scale production techn

Tritium handling technologie

Found suppression of passivati
by tritiated water, but not the c

X-ray Photoelectron Spectroscop
after 1hr corrosion test at RT



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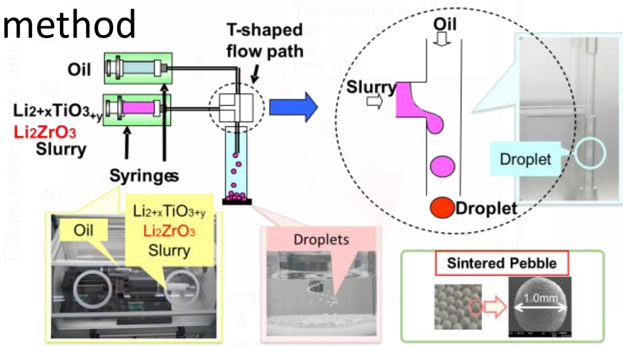
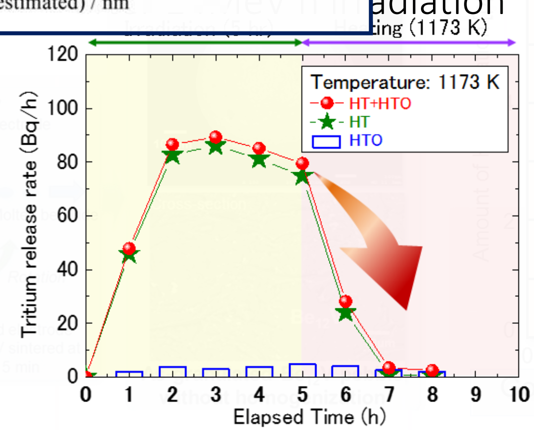
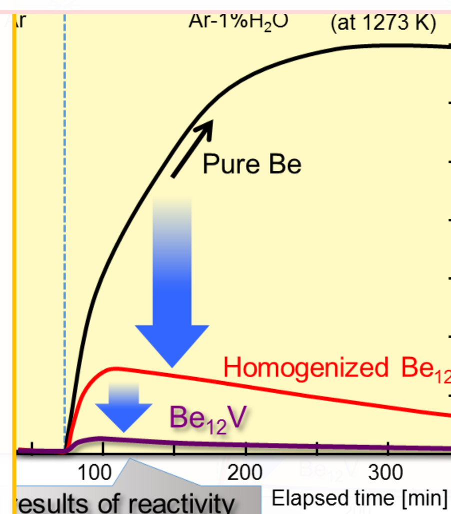
adiation

LIZO pebbles produced by emulsion method



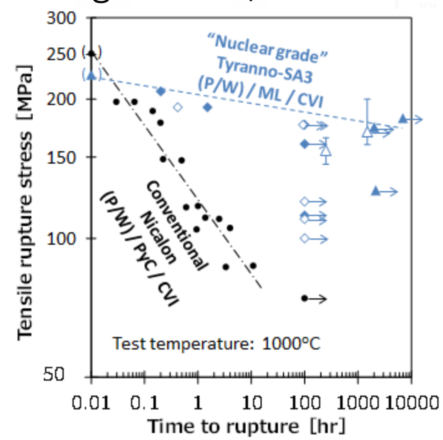




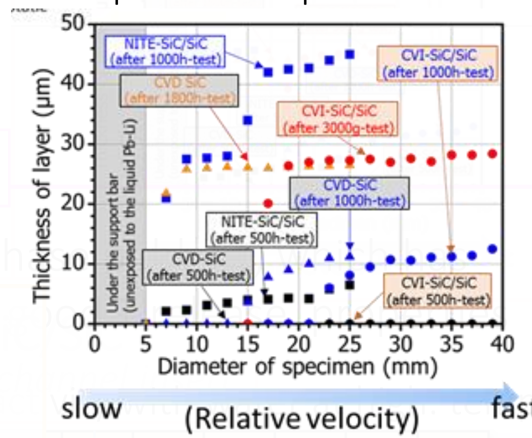
SiC/SiC ceramic composite
as a flow channel insert for advanced option *(liq. breeder)*

Prove the stability of SiC/SiC composite at high temperature for functional structure application

Good high temperature property of new grade SiC/SiC



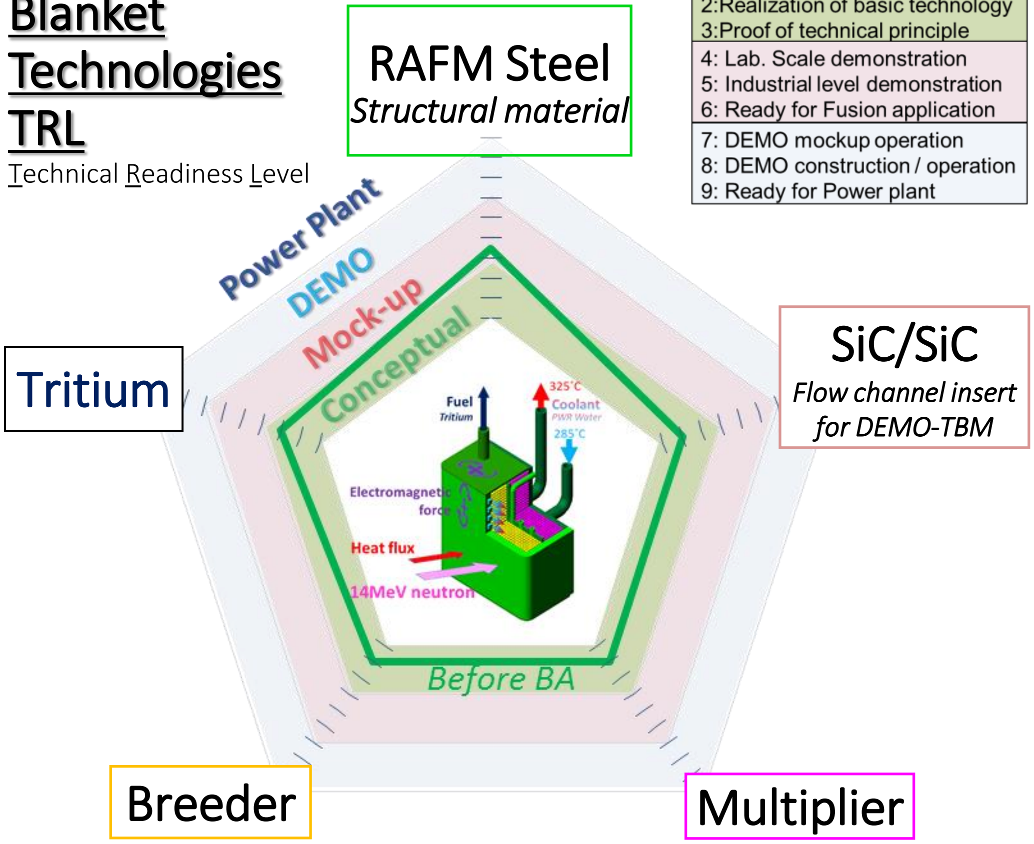
Good compatibility with high temperature liquid Pb-Li



Strategy toward DEMO beyond BA activity

Blanket Technologies TRL

Technical Readiness Level



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

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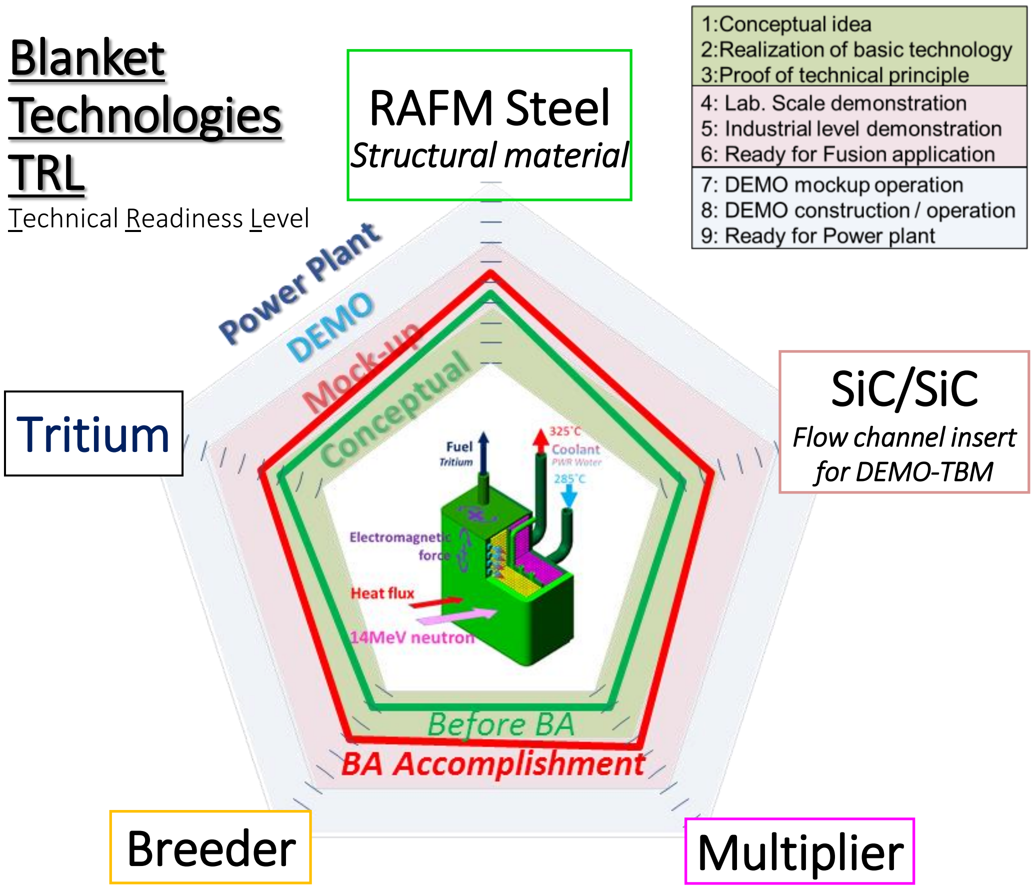

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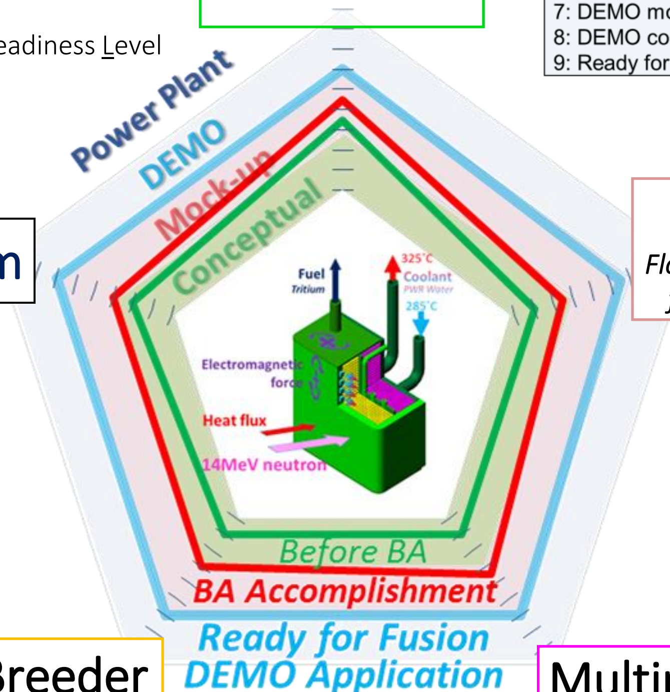
RAFM Steel
Structural material

Tritium

SiC/SiC
Flow channel insert for DEMO-TBM

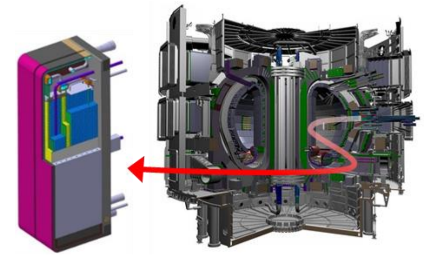


Breeder

Multiplier

To get ready for Fusion DEMO application.

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



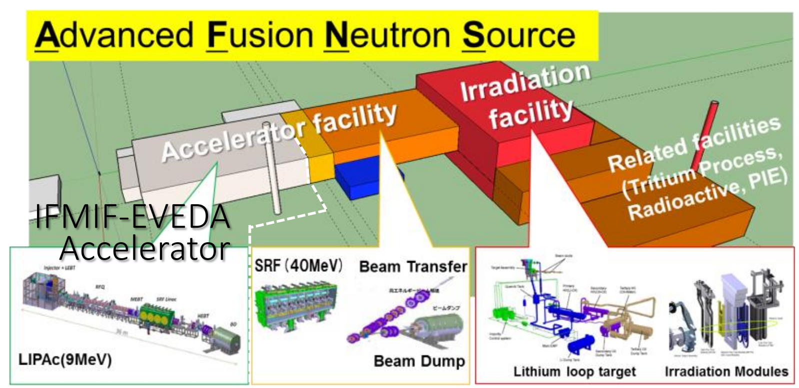
Operation of ITER-TBM in DT phase

- ✓ 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 expertise of 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
  - ❑ Found no T water effects in SS316 in **Tritium handling technologies R&D**

Next step

- ✓ Need an intense fusion neutron source for verification and expertise of these technologies.