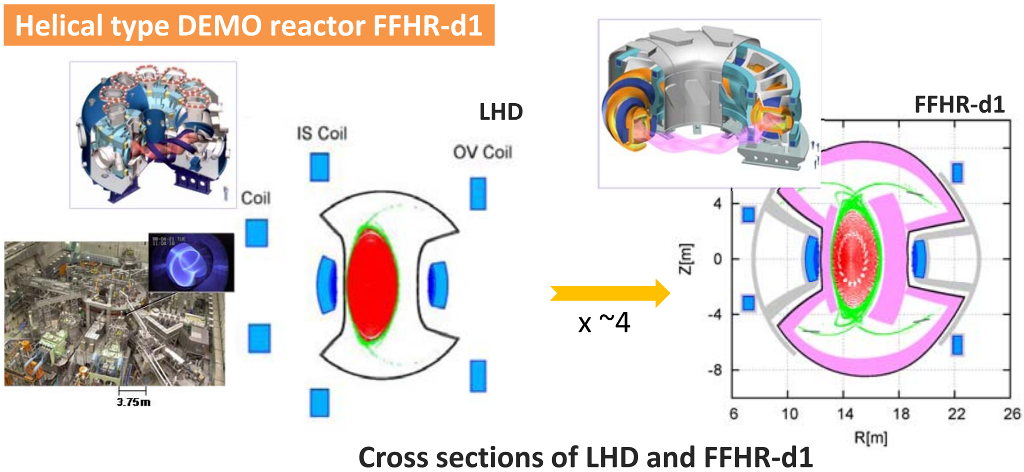
FTP/P7-36

Neutronics Design of Helical Type DEMO Reactor FFHR-d1

T. Tanaka, A. Sagara, T. Goto, N. Yanagi, S. Masuzaki, H. Tamura, J. Miyazawa, T. Muroga, the FFHR Design Group
National Institute for Fusion Science, Japan

Helical type DEMO reactor FFHR-d1

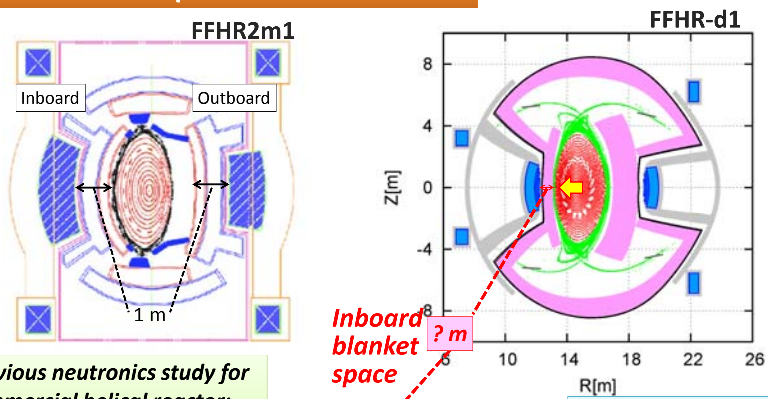


Cross sections of LHD and FFHR-d1

- **Configuration of reactor components and plasma parameters of FFHR-d1*:**
  Enlargement and extrapolation from LHD .**
  ➔ **Enhancement of feasibility, early demonstration.**

*A.Sagara et al., Fusion Engineering and Design 87 (2012) 594–602.
** A. Komori et al., Fusion Science and Technology 58 (2010) 1–11.
** J. Miyazawa et al., Fusion Engineering and Design, 86 (2011) 2879-2885.

Neutronics requirements and issue



Previous neutronics study for commercial helical reactor:
T. Tanaka et al., IAEA-FEC, Chengdu, China, 2006.

Cross sections of FFHR reactors

Present FFHR-d1 DEMO reactor design

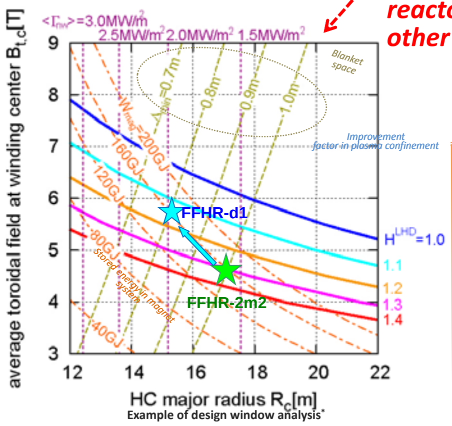
- **Neutronics requirements:**
  (1) Tritium fuel breeding (Tritium Breeding Ratio (TBR) > 1.0)
  (2) Radiation shield for coil systems (Operation for >~10 years)
- ***Issue in FFHR-d1 :***
  Core plasma shifts to inboard side.
  ➔ ***Limited inboard blanket space.***

◆ **Neutronics design study with MCNP5 code and JENDL-3.3 library.**

◆ **Keeping consistency with Plasma, In-vessel, Superconducting coil, Blanket and System Integration designs*.**

* GOTO, T., et al., Plasma and Fusion Research 7 (2012) 2405084

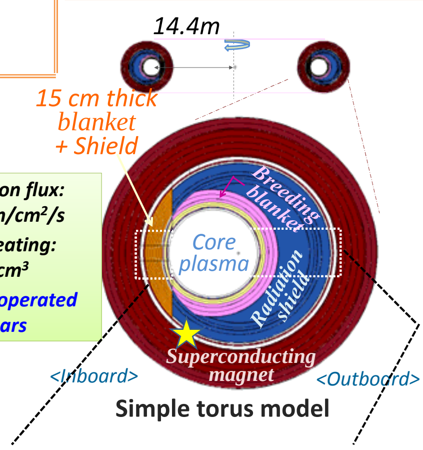
Impacts on reactor size and other design factors



Example of design window analysis*

* GOTO, T., et al., Plasma and Fusion Research 7 (2012) 2405084

Neutronics investigation with torus model (first step)

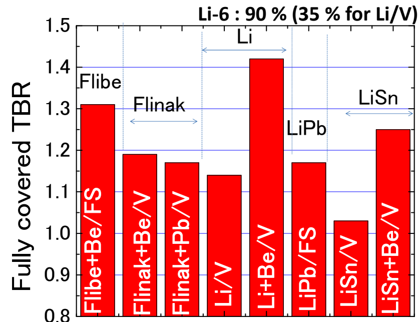


Simple torus model

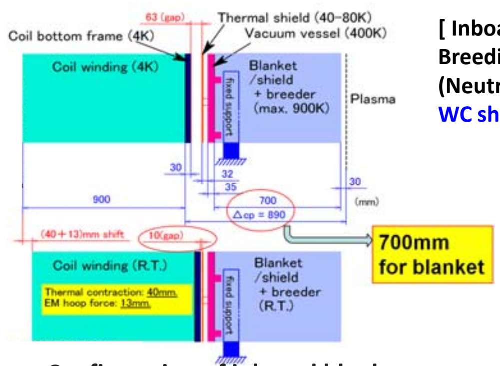
- ✓ *Fast neutron flux: ~1.5×10^{10} n/cm²/s*
- ✓ *Nuclear heating: ~0.5 mW/cm³*
- ➔ *Could be operated for > 10 years*

[Inboard / 15 % of torus]
Breeding blnaket:15 cm
(Neutron multiplier: 10cm)
WC shield: 55 cm

[Outboard]
Breeding blanket: 60cm
(Neutron multiplier: 15cm)
FS+B_4C shield: >50 cm

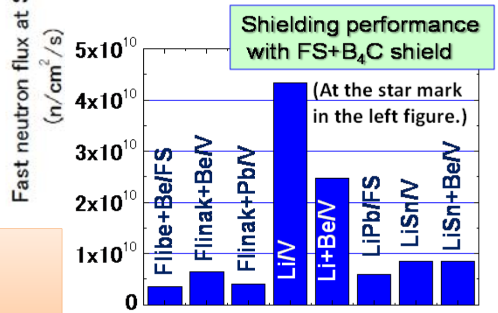


Comparison of tritium breeding performance



Configuration of inboard blanket, shield and helical coil*

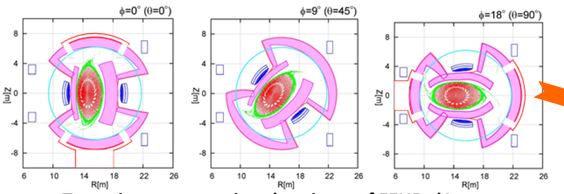
- ✓ ***Inboard blanket space: 70cm***
- ✓ ***First candidate blanket:***
  Flibe+Be/ Ferritic steel (FS)
  (Fully-covered TBR: 1.31)



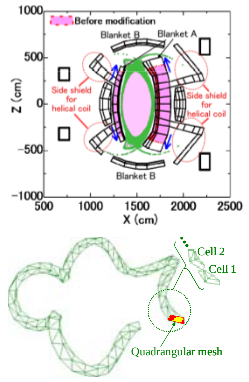
Comparison of neutron shielding performance

* H. Tamura et al., presented at 21st International Toki Conference, Toki, Japan, Nov.28-Dec.1, 2011.

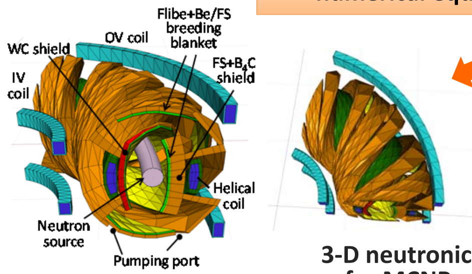
Neutronics evaluation with 3-D model (second step)



Tentative cross section drawings of FFHR-d1



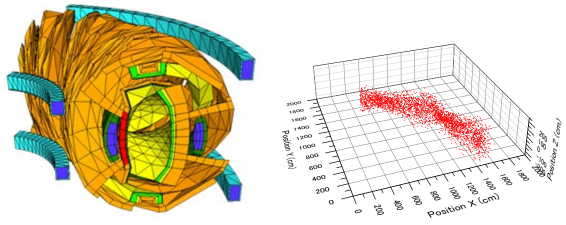
Meshing of cross section
➔3-D model according to numerical equations.



3-D neutronics calculation model for MCNP code (~4,000 cells)

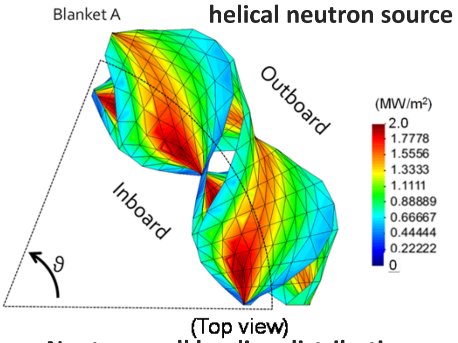
- Repeating modification of blanket dimensions.
- **Keeping connections of magnetic field lines for divertor pumping.**
- ✓ ***Global TBR (Flibe+Be/FS blanket): 1.08***

Neutron wall loading



3-D model

Simulation of helical neutron source

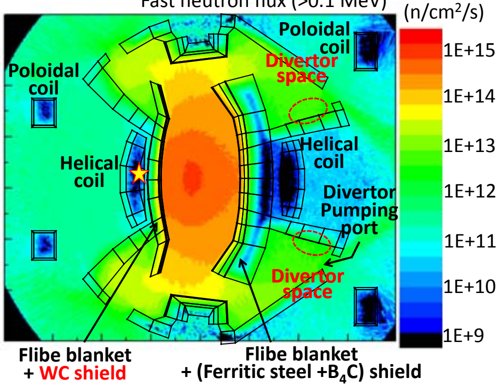


Neutron wall loading distribution

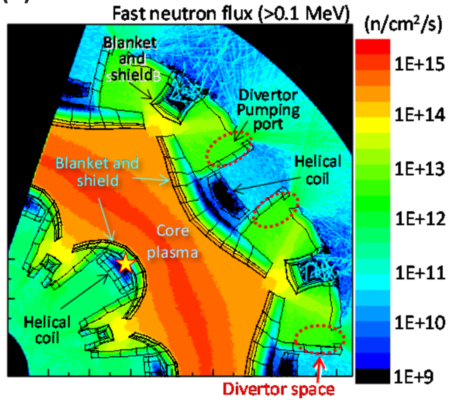
- Design parameters of FFHR-d1
  - Fusion power: 3GW
  - Averaged neutron wall loading: 1.5 MW/m^2
- **Evaluated maximum neutron wall loading:**
  ~2.0 MW/m^2 at inboard
  ~1.5 MW/m^2 at outbpard

Neutron transport and shielding

(a) Vertical distribution



(b) Horizontal distribution

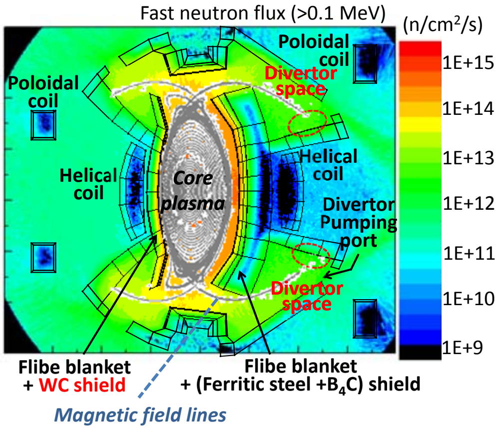


Fast neutron flux distribution

✓ *Fast neutron flux in helical coil at inboard side: ~2 x 10^{10} n/cm²/s.*
(at ☆ mark) Nuclear heating: ~0.6 mW/cm³

➔ **Could be operated for >10 years.**

Divertor placed behind radiation shield



Helical divertor positions

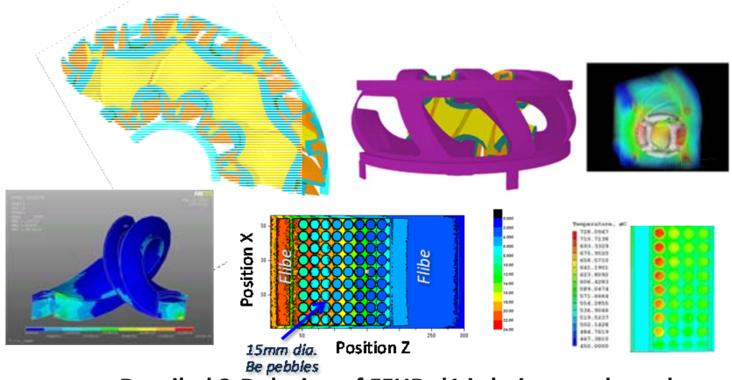
✓ **Helical divertor can be placed behind blanket and shield.**
➔ **Suppression of radioactivity and irradiation damages of divertor materials.**

✓ Coolant ducts from blanket could also be placed behind radiation shield.

Conclusion

- 3-D evaluations of
  - **Tritium breeding with Flibe blanket**
  - **Neutron wall loading**
  - **Radiation shielding**

  indicate that
  the FFHR-d1 design would be feasible from the neutronics point of view.
- Neutronics study is continued for further detailed 3-D design of FFHR-d1.
- Consistency with other design factors is a key point of this study.



Detailed 3-D design of FFHR-d1 is being conducted.