MoD-PMI 2019
18, June 2019

Introduction of National Institute for Fusion Science (NIFS)

Takeo Muroga
Deputy Director General
National Institute for Fusion Science

NIFS Overview

○ Established in May, 1989 as an Interuniversity Research Institute for promoting collaborations with Japanese Universities for plasma science and its application. (30th anniversary celebration carried out in May 2019)
○ Large Helical Device (LHD) was constructed and has been operated as the core facility and activity of NIFS.
○ Presently LHD Project, Numerical Simulation Reactor Research Project, Fusion Engineering Research Project, and international collaboration are promoted.

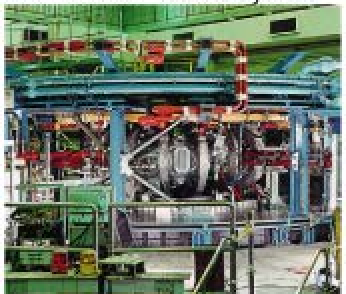
Statistics in 2018

- **Organization structure**
  - 126 researchers, 45 engineers & technicians, 42 administration staff
  - 53 graduate students
  - about 100 of contract employees
- **Budgetary condition**
  - 8,456million yen which includes salary, operational costs of LHD, Supercomputer and other facilities
  - 4,100million yen for LHD operation
- **Collaboration programs**
  - 538 subjects have been approved as collaborative researches in three collaboration programs

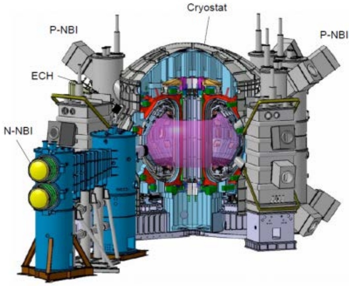
Fusion Research Activities in Japan

for FY 2018

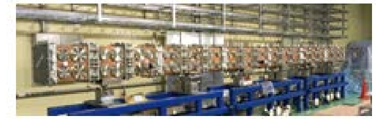
Kyoto Univ.
Heliotron J Helical System



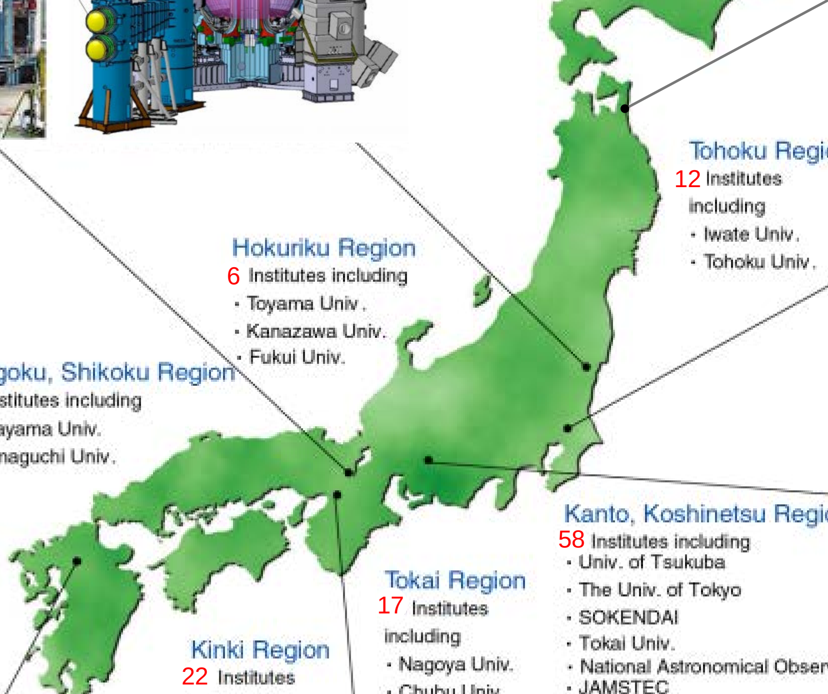
National Institute for Quantum and Radiological Science and Technology (QST) Naka-site
JT-60SA Tokamak



National Institute for Quantum and Radiological Science and Technology (QST) Rokkasho-site



IFMIF-EVEDA



Hokkaido Region
6 Institutes including
- Hokkaido Univ.

Tohoku Region
12 Institutes including
- Iwate Univ.
- Tohoku Univ.

Hokuriku Region
6 Institutes including
- Toyama Univ.
- Kanazawa Univ.
- Fukui Univ.

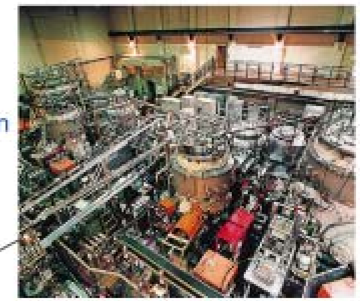
Chugoku, Shikoku Region
17 Institutes including
- Okayama Univ.
- Yamaguchi Univ.

Kyushu Region
16 Institutes including
- Kyushu Univ.
- Saga Univ.
- Kyushu Tokai Univ.

Kinki Region
22 Institutes including
- Kyoto Univ.
- Osaka Univ.

Tokai Region
17 Institutes including
- Nagoya Univ.
- Chubu Univ.

Kanto, Koshinetsu Region
58 Institutes including
- Univ. of Tsukuba
- The Univ. of Tokyo
- SOKENDAI
- Tokai Univ.
- National Astronomical Observatory of Japan
- JAMSTEC
- JAEA

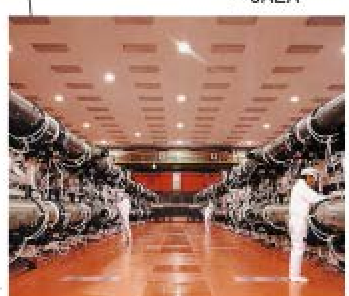


Univ. of Tsukuba
GAMMA 10 Mirror

NIFS LHD

Total numbers of universities and research institutes under collaboration with NIFS: 154

Kyushu Univ.
TRIAM-QUEST ST



Osaka Univ.
GEKKO-XII Laser

International collaborations

Agreements representing the Japanese government

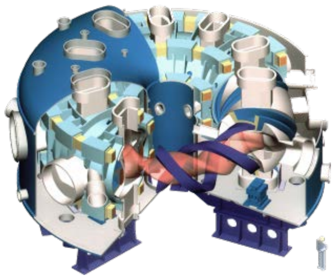
- 6 bilateral agreements (with Australia, China, EU, Korea, Russia, USA)
- 3 multilateral agreements (IEA-Technology Collaboration Programms)

Human exchange by leading programs in 2017

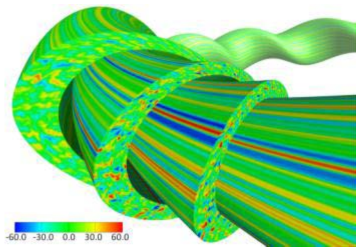
	J/US		J/China		J/Korea		Int. Base	
	man	Day	man	day	man	day	man	day
to NIFS/Japan	81	360	7	61	45	163	6	71
from NIFS/Japan	71	777	41	258	34	157	18	166

NIFS carries out three projects by promoting collaboration with universities

- Large Helical Device Project pursuits to achieve highest performance plasma in Heliotron configuration
  - Enhancement of plasma parameters toward reactor relevant regime
  - Heating, diagnostics, closed divertors, PWI and other technological progress
  - Physics of 3-D plasma and isotope effects



- Numerical Simulation Reactor Research Project develops numerical simulation methods as the basis of numerical research for helical reactors
  - Understanding and systemizing physical mechanisms in fusion plasmas
  - Development of theoretical models for plasma behaviors and their validation
  - Integration of predictive models in a whole machine range



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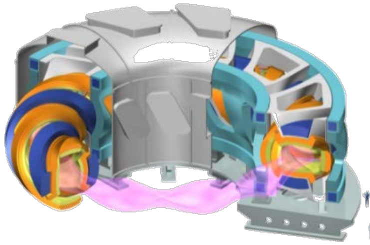
  - Development of superconducting magnet, blanket, low activation materials, divertor / plasma facing components, and tritium control system
  - Helical reactor design studies



Collaboration among the three projects are highly promoted

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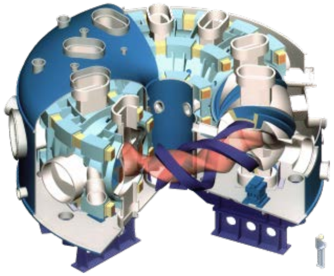

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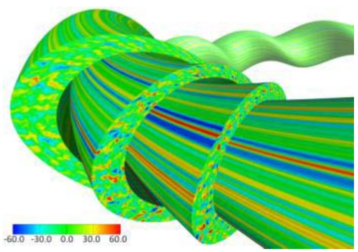

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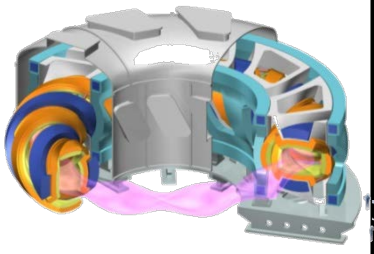
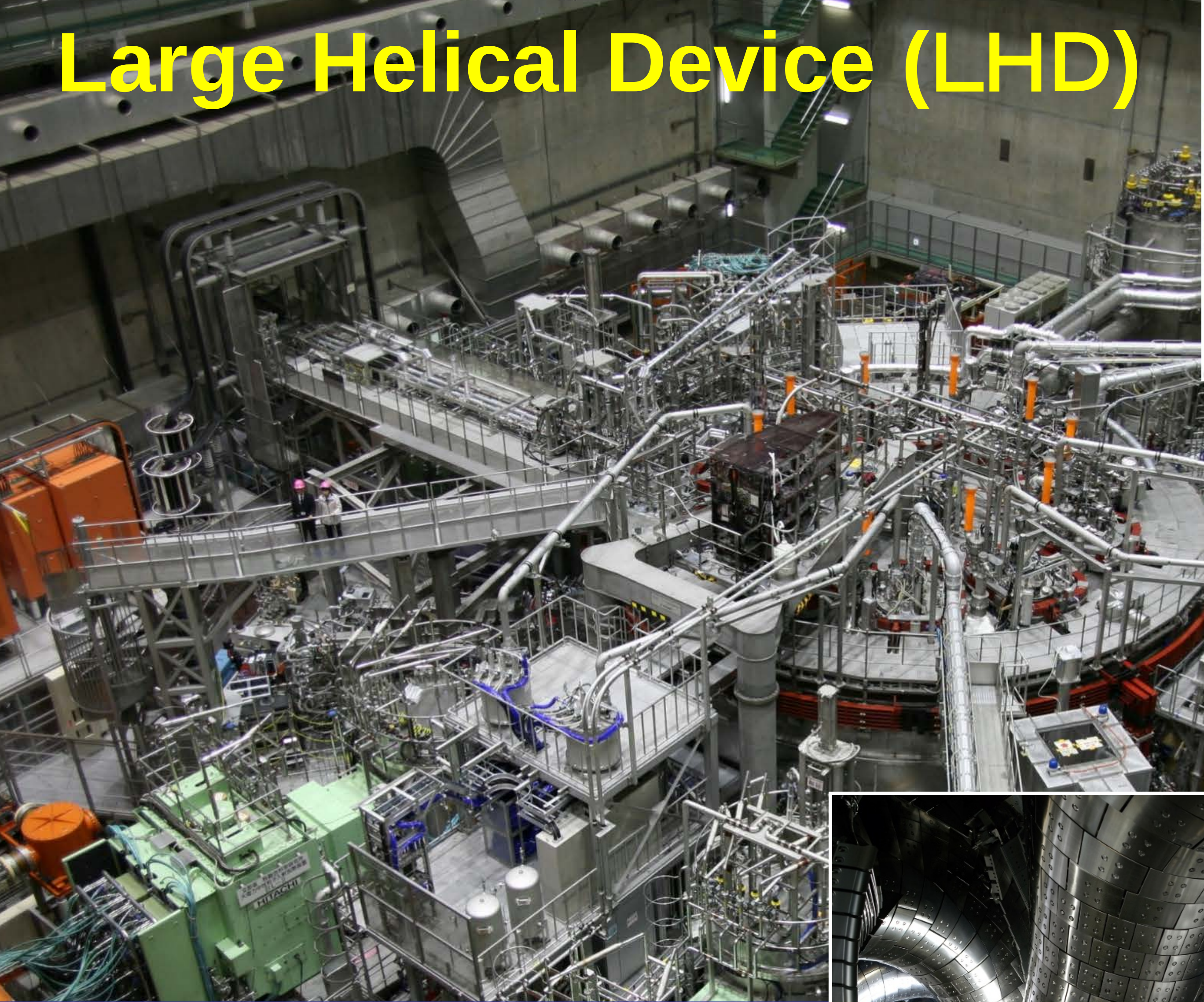
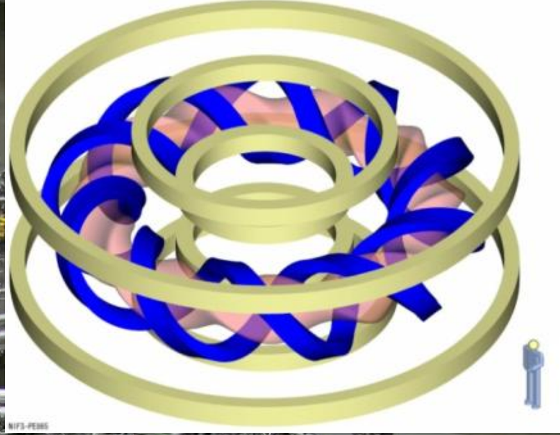


Large Helical Device (LHD)

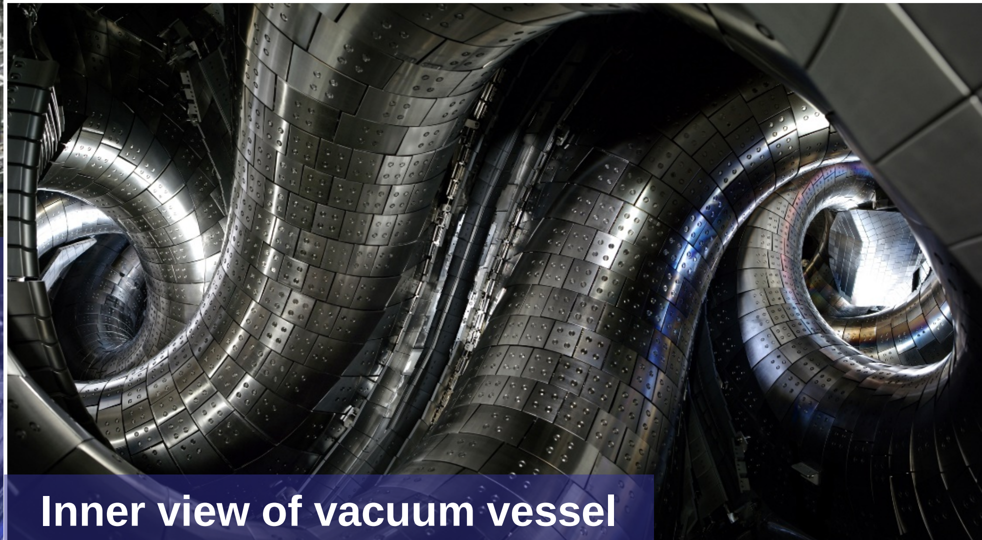




One of the world largest helical devices

- Height: ~ 9 m
- Diameter: ~ 13 m
- Mass: ~ 1500 t

Experiment started in March 1998

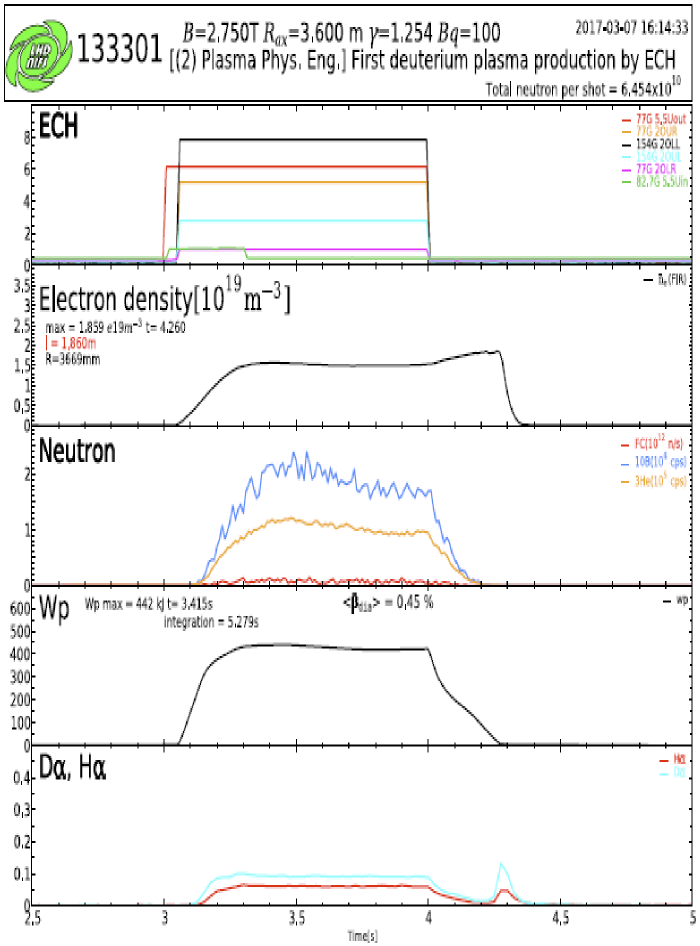


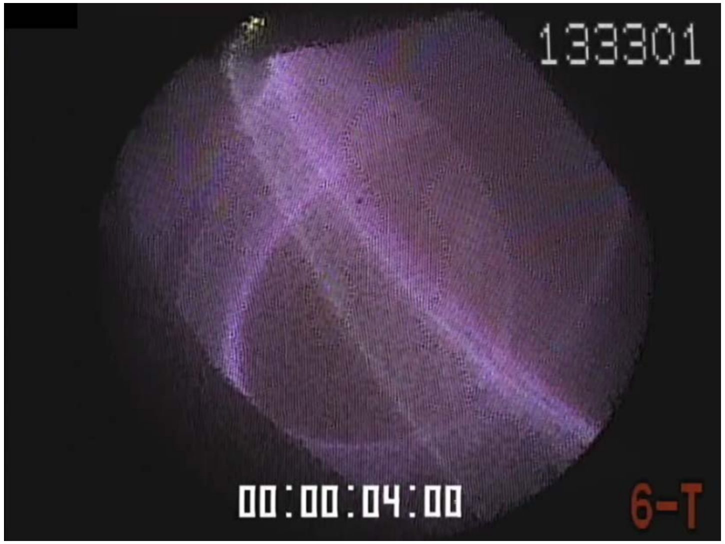
Inner view of vacuum vessel

LHD has proceeded to the new research phase

Deuterium experiment started in March 2017 and will last 9 years

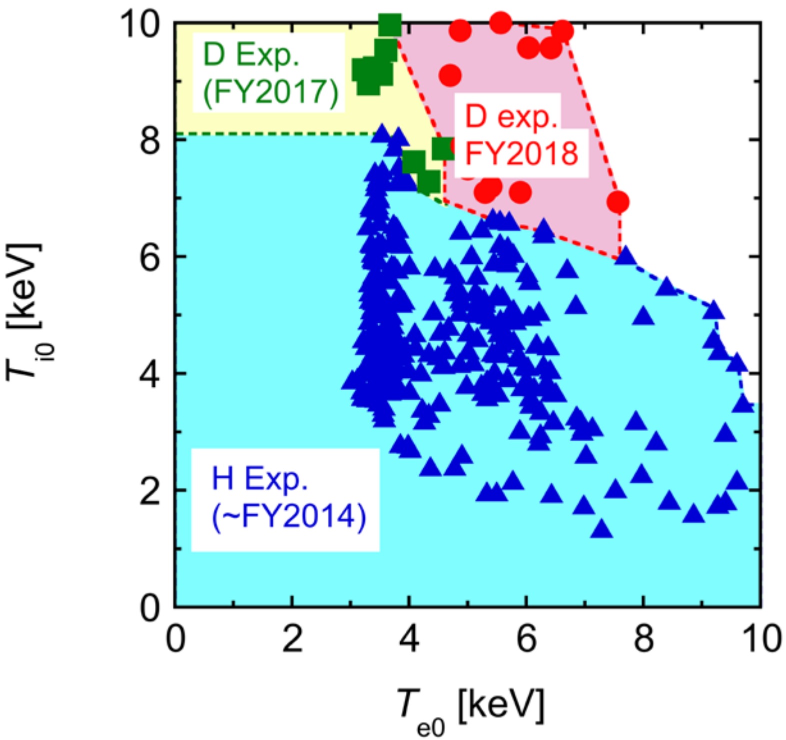
- #133301: P_{ECH}= 5. MW, t_{ECH}= 1 s, n_e= 1.9×10^{19} m^{-3}, T_e= 6.0 keV, T_i= 1.0 keV, W_p= 442 kJ

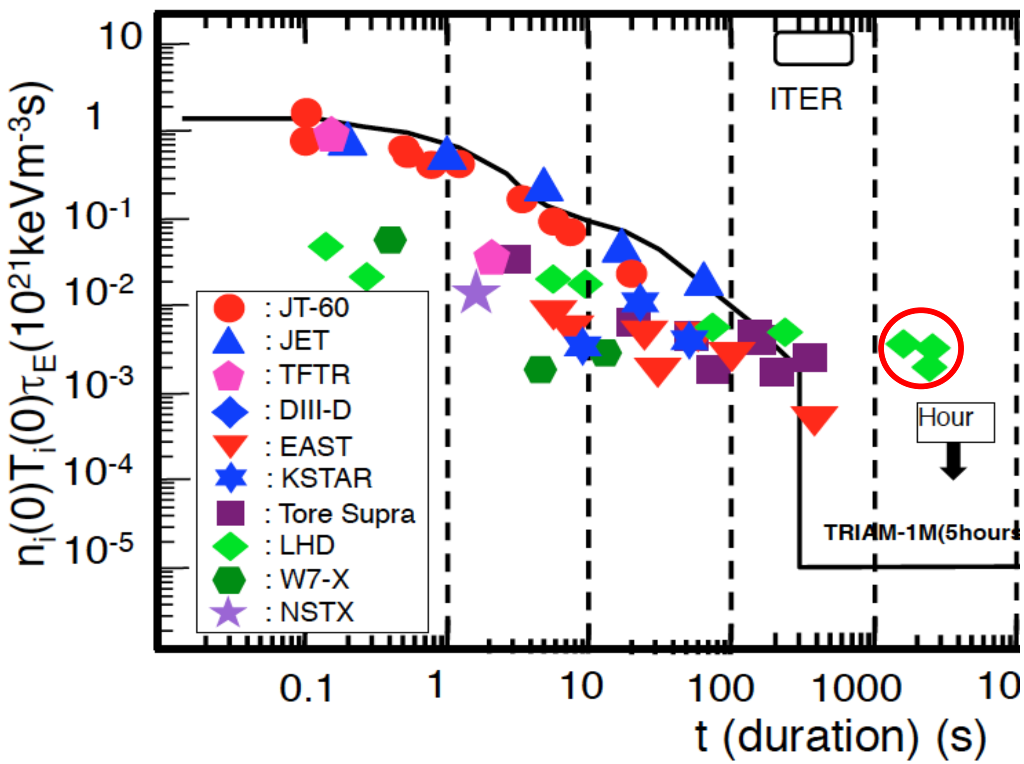




Status Report from LHD

Deuterium experiment (2017~) has extended LHD operational regime



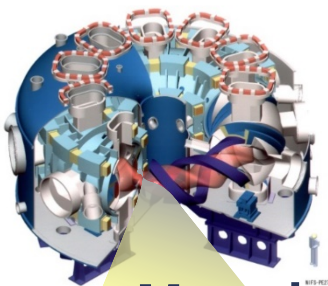


- Fusion-relevant T_i = 10 keV was first achieved in stellarator/heliotron

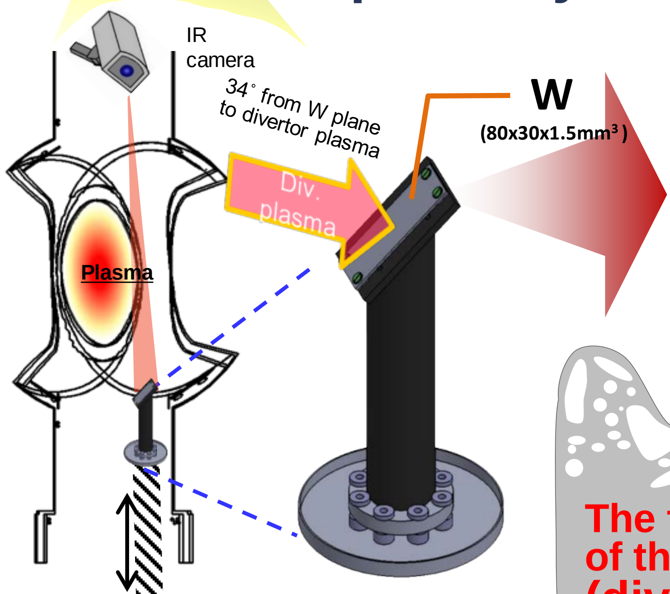
Fusion triple product (by courtesy of M. Kikuchi)

Initial growth phase of the W-fuzz structure was observed in the LHD

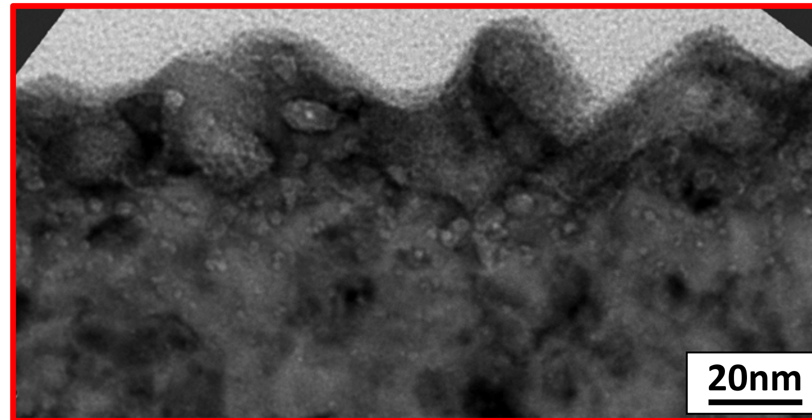
- Total time：10190s (22 shot of He)
- Surface temp.: 1500K-2300K
- Incident He energy: ~100 eV
- He flux : ~5×10^{21} He/m^2s
- He fluence： ~5×10^{25} He/m^2

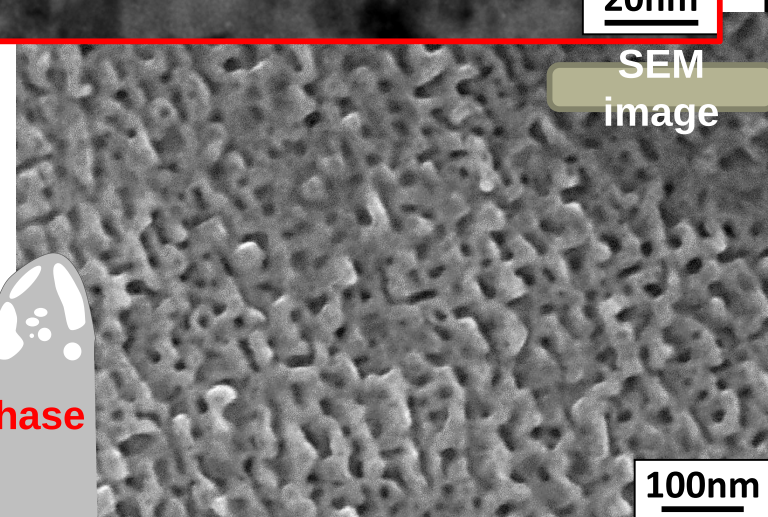


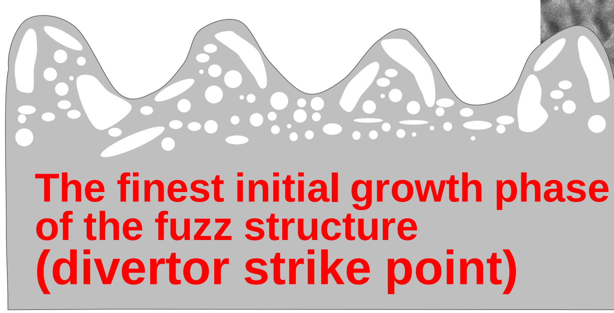
Material probe system



Cross-sectional TEM image







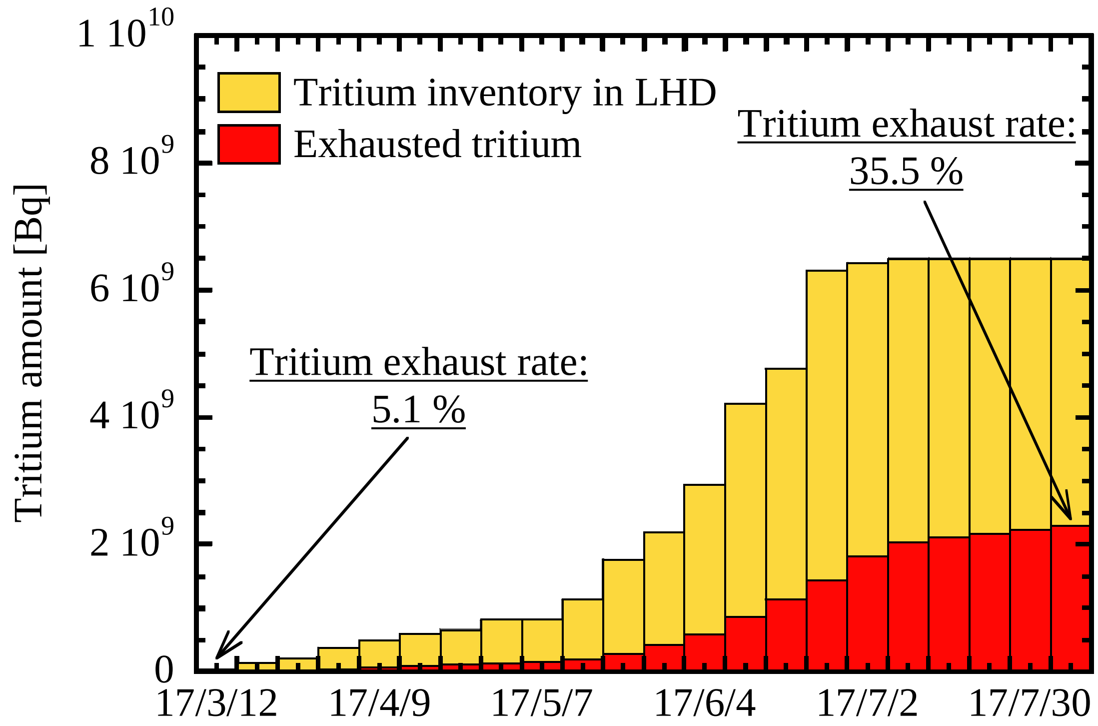
M. Tokitani et al., Nuclear Materials and Energy 12 (2017) 1358–1362

Exhaust Behavior and Mass Balance of Tritium

Exhaust detritiation system with precise detector revealed tritium behavior in LHD (2017)

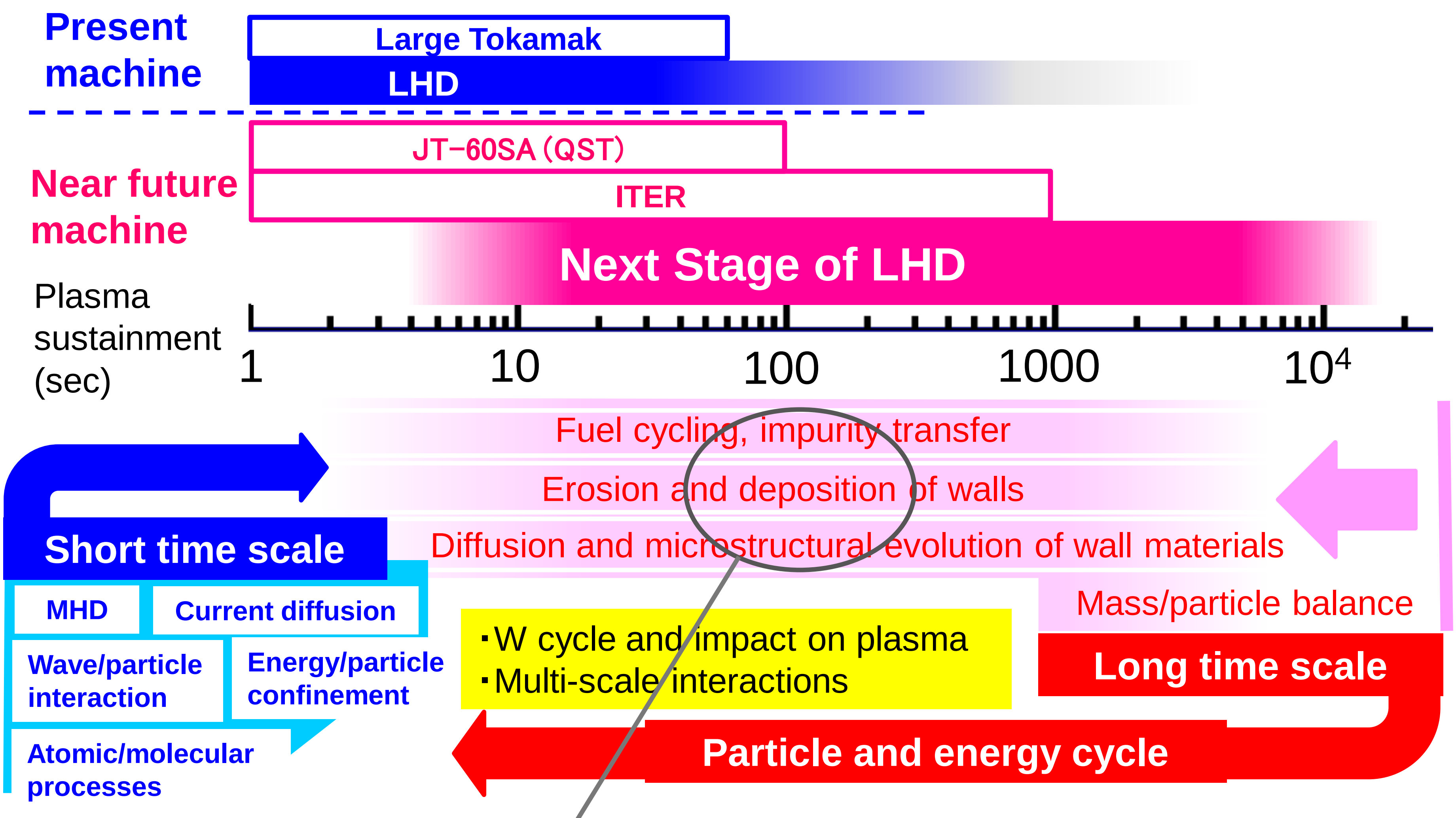
35.5 % of produced tritium was exhausted until the end of the first D-campaign, and 64 % was still retained in vacuum vessel or evacuation system

Out of the retained tritium, half is stored in the divertor plates



Mass balance of tritium during the first deuterium experimental campaign from March 6 to August 7

Next Stage of LHD – Steady State Operation



Plasma-wall interaction is the critical issue for the steady state operation

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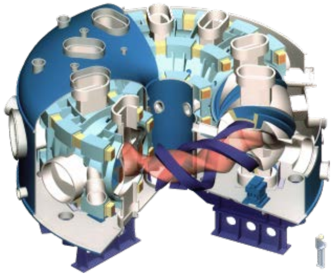

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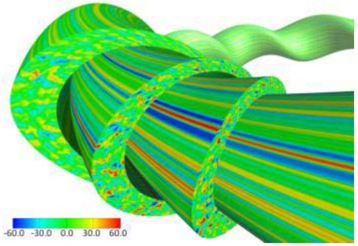

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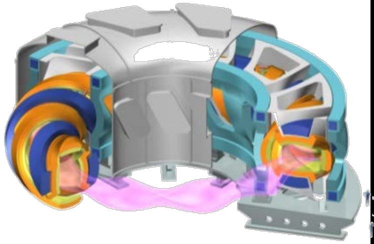
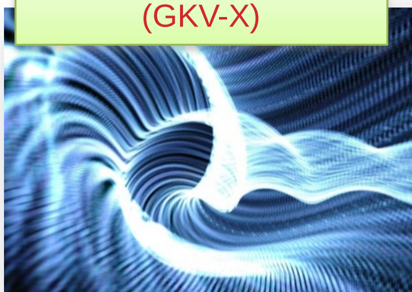


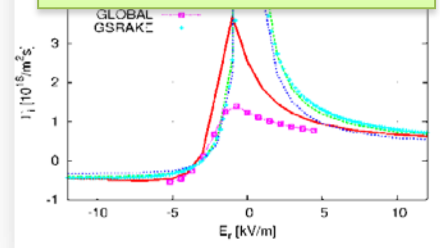
Extensive simulation code developments and comparisons between simulation and experiments towards numerical helical test reactor

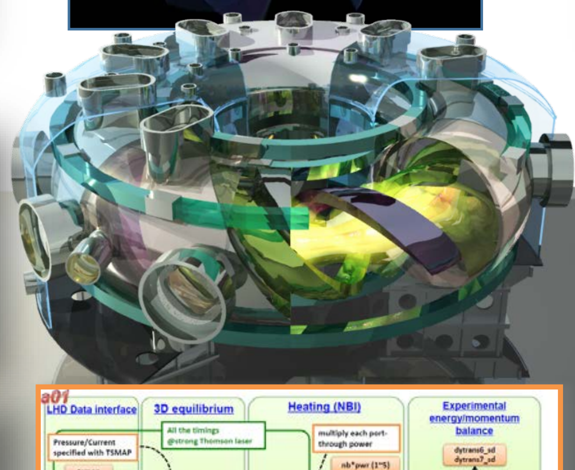
Turbulent transport (GKV-X)



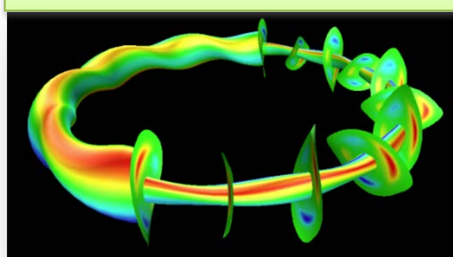
Edge plasma (EMC3-EIRENE)

Neoclassical transport (FORTEC-3D)

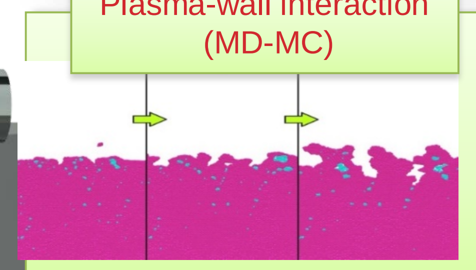


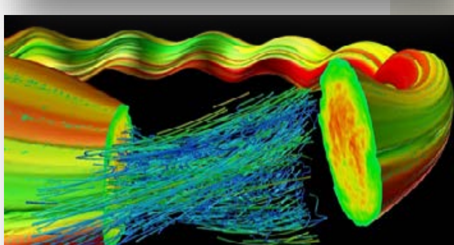


High energy particle (MEGA)

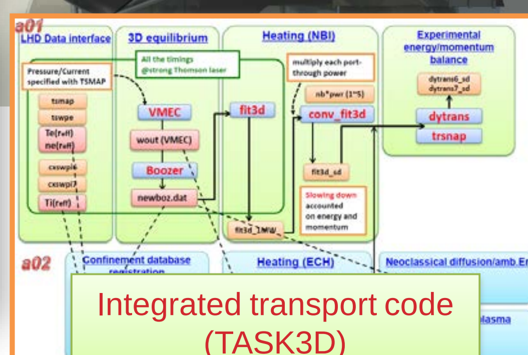


Plasma-wall interaction (MD-MC)

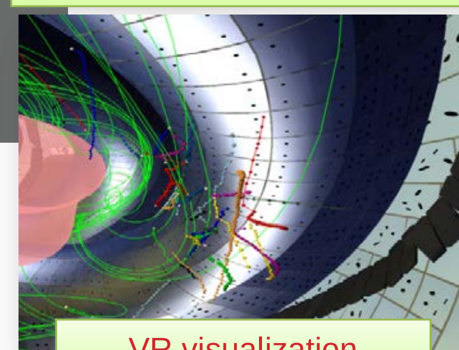




Non-linear MHD (MINOS,MIPS,NORM)



Integrated transport code (TASK3D)



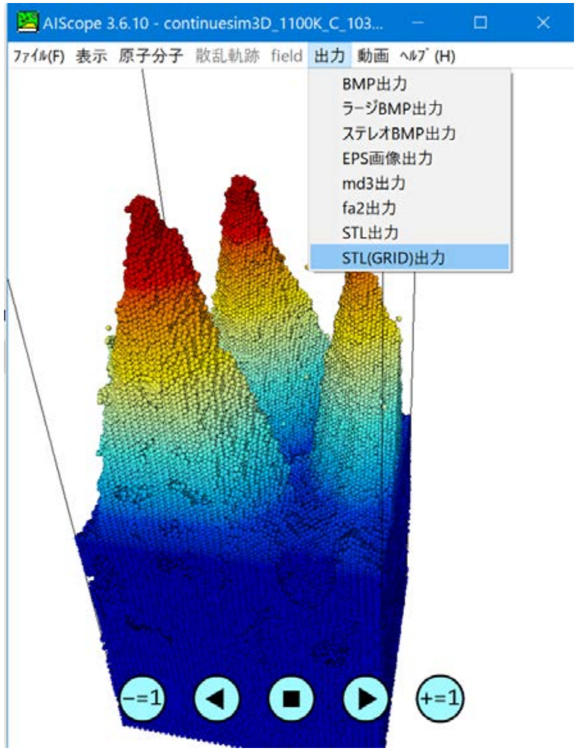
VR visualization

Recent research activities of NSRP for PWI

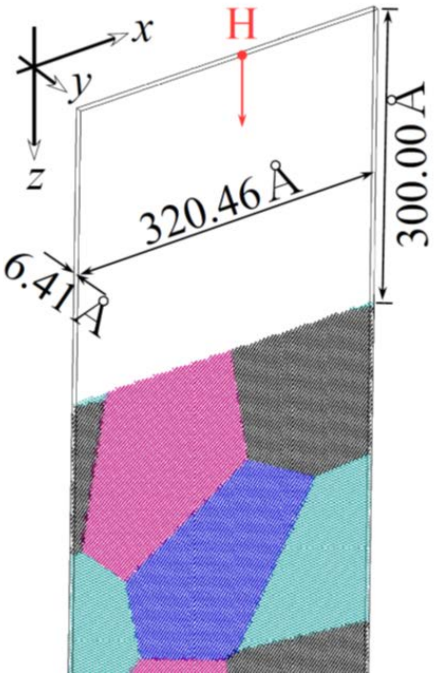
Fuzzy structure formation by BCA-MD-KMC multi-hybrid simulation

Helium injection into polycrystalline W

BCA-MD-KMC multi-hybrid for fuzzy formation solves
- **He injection by BCA (binary collision approx.)**
- **He diffusion by KMC (kinetic Monte-Carlo)**
- **W deformation by MD (molecular dynamics)**



Binary-collision-approximation –based simulation of helium injection into polycrystalline

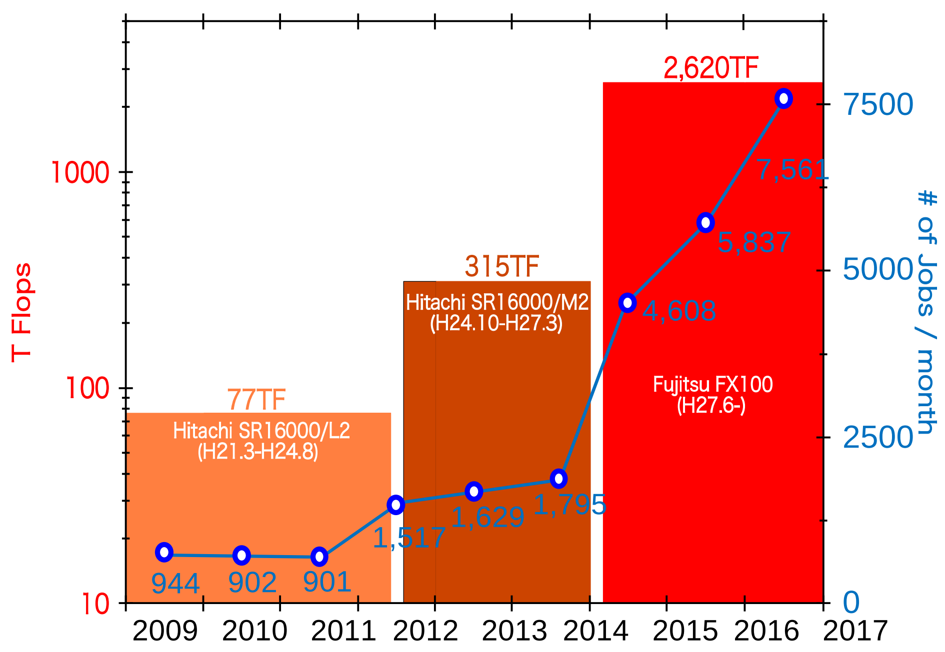


PLASMA SIMULATOR

PLASMA SIMULATOR

- Supercomputer system for numerical simulation research at NIFS ("**Plasma Simulator**") was replaced by Fujitsu PRIMEHPC FX100 with the total peak performance about 2.62 Petaflops, and the total main memory about 81TB in 2015.

(Right): Snapshot of present plasma simulator, FX100,
(peak speed: ~2.62PF,
memory: ~81TB,
period: 2015-2019)



(Left): Peak performances of plasma simulator and numbers of submitted jobs per month in the second mid-term period

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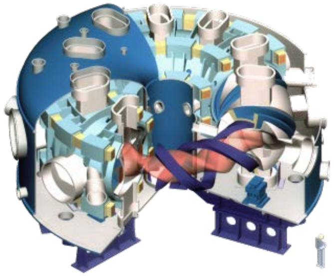

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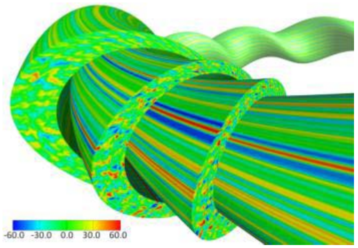

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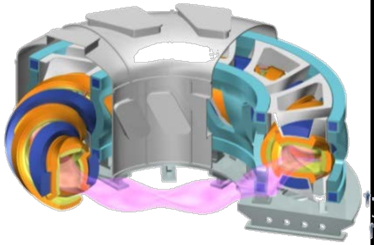
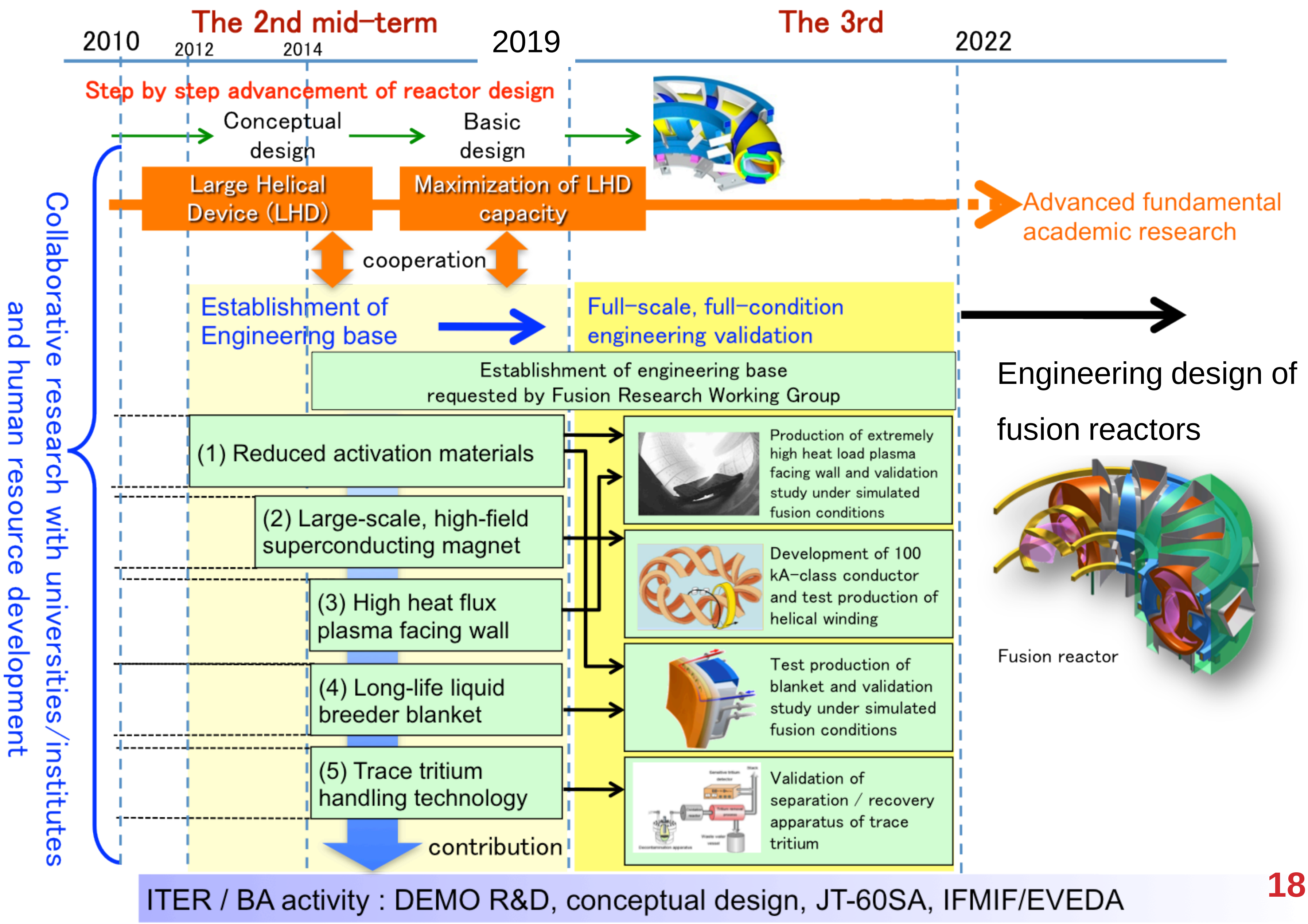
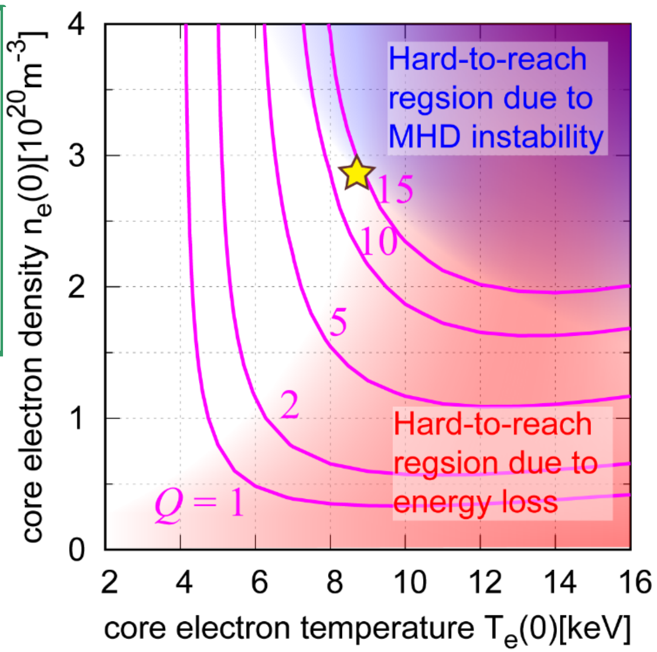


Research Roadmap of FERP

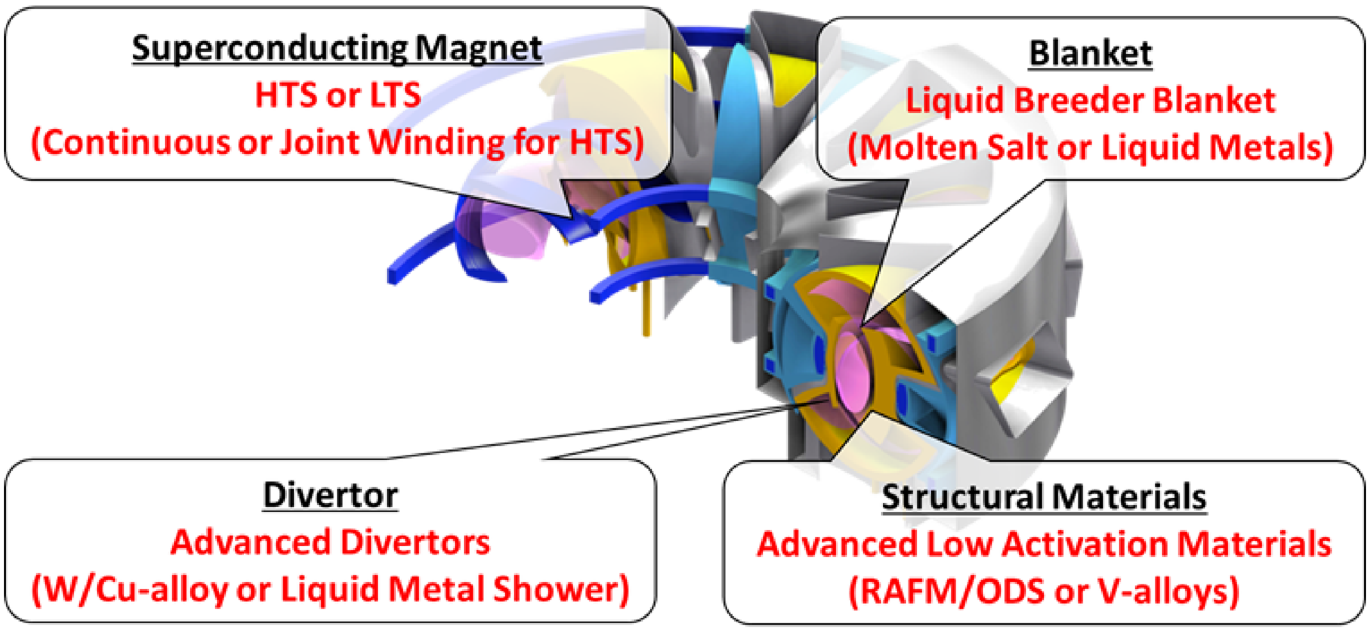


Operation point is explored using systems code "HELIOSCOPE" based on "Direct Profile Extrapolation (DPE)" from LHD experiment data

Fusion Gain of 15 was demonstrated



Innovative ideas have been integrated
(1) to overcome difficulties with 3D structure
(2) to enhance passive safety
(3) to improve plant efficiency

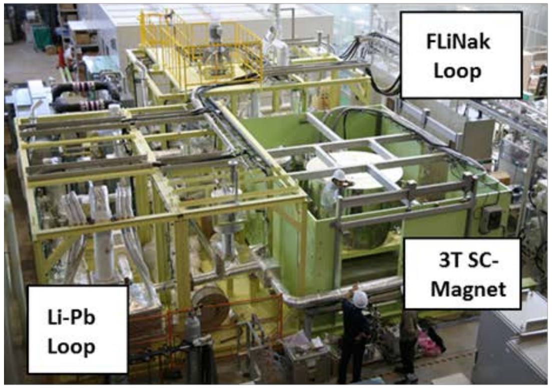


Facilities Installed into NIFS for Collaboration with Universities

13 T, ϕ700 mm Solenoid Coil

Temperature Variable Refrigerator

High T, High Vacuum Creep Test Facilities



Li-Pb/FLiNaK Twin Loops with 3 T Superconducting Magnet (Oroshhi-2)

Hot Isostatic Press (HIP)

Ion Beam Surface Analysis

High Heat Flux Test (ACT2)

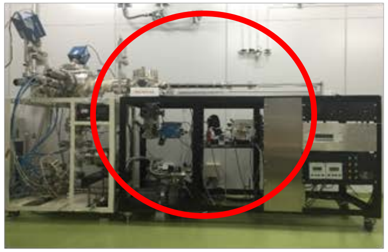
Installed in Radiation Control Area of LHD

FETEM-EDS

FIB

Imaging Plate

GD-OES

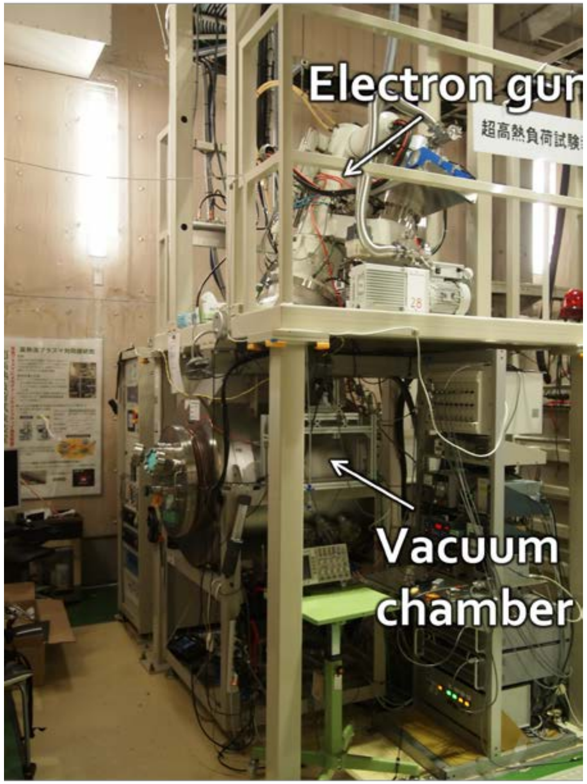


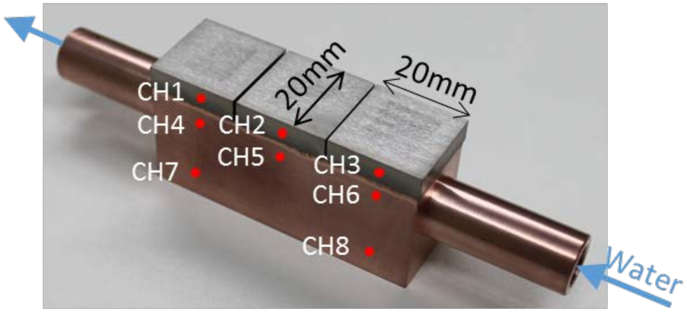
Thermal Desorption Spectrometer

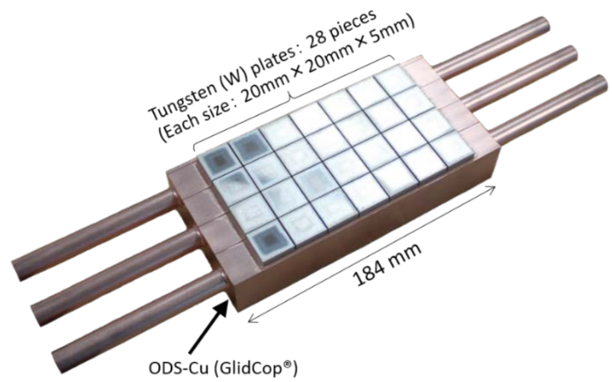
These allows characterizations of the specimens exposed to D-D plasma of LHD

PWI, PFC oriented facilities

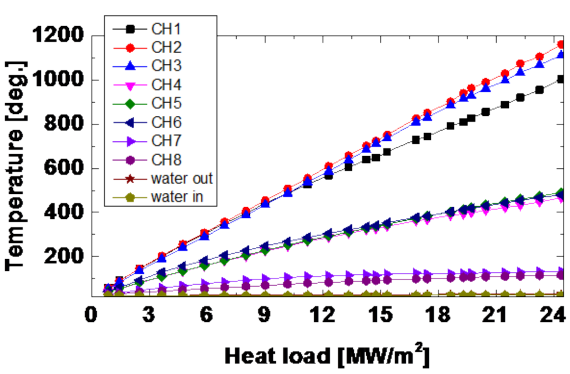
“ACT- 2” 300 kW Electron Beam for Divertor Testing







Divertor component planned to be installed into LHD



Divertor mock-ups (upper: small, lower: large) fabricated by bonding tungsten plates to ODS-Cu block using advanced blazing technique/ (W/BNi-6/GlidCop)

The small divertor test sample showed heat flux resistance to 24 MW/m^2

SUMMARY

- NIFS is an Interuniversity Research Institute promoting collaborations mainly with Universities and international partners for plasma and fusion research.
- Large Helical Device (LHD) is the core facility which entered recently to D-D operation phase, and is planning to enhance steady-state operation research.
- In addition to LHD, Numerical Simulation Reactor Research Project and Fusion Engineering Research Project are carried out.
- For these Project researches, Plasma-Wall Interaction is the critically important research subject.
- Thus, for us, collaboration with PMI Model/Data community is crucially important.