National Institute for Fusion Science (NIFS)

National Institutes of Natural Sciences (NINS)

External Peer Review Reports in FY2013

March, 2014

External Peer Review Committee, NIFS Advisory Committee

Contents

Chapter 1 Background

The National Institute for Fusion Science (hereafter as NIFS) was established in 1989 as an inter-university research institute, with the Large Helical Device (hereafter as LHD) as its principal experimental device, in order to promote fusion research in universities. The planned LHD, bearing the fusion community's consensus and expectations, and characterized by its superconducting Heliotron-type magnetic confinement system, emerged from an idea unique to Japan and has been independently conceived and developed in Japan. Together with generating high-performance helical-type plasmas through its high-power heating system, the LHD is advancing experimental research that aims to clarify physical and engineering issues that stare at the realization of a toroidal magnetic field confinement fusion reactor. On the other hand, parallel to this, utilizing large-scale simulations is essential in analyzing the complexities of fusion plasma. At NIFS, having introduced the newest supercomputer and made it available for collaborative use to fusion theory researchers throughout Japan, we are moving forward with leading-edge research.

Recently, there have been changes to the system for domestic academic research. Since 2004 NIFS has been an institution within the National Institutes of Natural Sciences (hereafter as NINS), and has advanced collaborative use and collaborative research. Since being incorporated, NINS has introduced six-year mid-term goals and mid-term plans, and a system for undergoing annual evaluations of progress. This annual evaluation focuses primarily upon management and operation, and at NIFS receiving evaluations of research results by researchers outside NIFS was deemed to be important. Under the Advisory Committee, the External Peer Review Committee has been established, and it conducts annual research evaluations. The items to be evaluated are decided upon at the Advisory Committee. Adding external members of the Advisory Committee and experts to the Review Committee, the Committee members will conduct evaluations. The Review Committee reports its results to the Advisory Committee, and NIFS, respecting the results of the evaluation, utilizes the results in improving research activities from the next year.

At NIFS, from 2010 began the second period for mid-term goals, and in order to strengthen further the unifying core of NIFS as the Center of Excellence in the plasma and fusion research fields, we composed research projects for the three fields of the LHD, theory simulation, and fusion engineering, and initiated research planning for combining the research results from these fields in moving toward realization of the fusion reactor. For this reason, in 2010 we undertook a restructuring of the research organization within NIFS. In addition to placing all researchers in one research department, we composed a structure that enables researchers to participate independently in projects. Through these changes, coordination among the LHD, theory simulation, and fusion engineering projects became easier, and we have become able to respond to new topics in a timely manner.

In the Advisory Committee, in order to confirm the results of the project system, first, in JFY2011, we implemented an external peer review of the LHD Project and in 2012 of the Numerical Simulation Research Project. Then, in this current year (2013) we decided to implement an external peer review of the Fusion Engineering Research Project (hereafter as FERP), which is in the fusion engineering field. We established an External Peer Review Committee that included the nine members of the Advisory Committee who are not NIFS researchers and the four members from foreign countries, and five other specialists.

In their first meeting held on October 11, 2013, the members discussed the review process and determined the overall objectives and individual items. On November 30, NIFS presented Fusion Engineering Research Project activities in detail using viewgraphs and other materials, and answered the questions from the reviewers. On January 28, 2014, reviewers gathered in subgroups and rated the activities after resolving any outstanding issues. The reviewers then met on February 21 to finalize their review and document this report.

This report consists of three chapters: “Background,” “Reviews and Proposals,” and “In Closing.”

The report will be submitted to the Advisory Committee of NIFS. After gaining the Advisory Committee’s approval, the Director General of NIFS will submit the report to the President of its parental body, NINS. The report will go through NINS to be submitted to the Administrative Council and the Education and Research Council of NINS. After the approval of these councils, this report will be used as an appendix of NINS’s annual reports in “Annual Plan of NINS (JFY2014)” and “Report of Achievements of Business Work in JFY2013” to be submitted to the Ministry of Education, Culture, Sports, Science and Technology. The report will be available to public on the web and in print.

In the evaluation of the Fusion Engineering Research Project, in the mid-term planning stipulated by NINS the basis of the evaluation is the degree of completion of the Fusion Engineering Research Project on which NIFS is advancing, and which has the goals of establishing the fusion reactor design and the engineering base for the reactor, as well as the research standards.

It should be noted that these items of evaluation are based on the proposals from the external evaluation of fusion engineering research, conducted in JFY2009.

1. Whether or not fusion engineering research is developing across the board with the emphasis on helical reactors design
2. Whether or not NIFS is acting as the center for national research on advanced blankets and reduced activation materials as well as taking the leadership in terms of international research
3. Whether or not NIFS continues to develop superconducting coils for fusion reactor development
4. Whether or not efforts are being made to encourage young researchers to participate in the fusion reactor research project
5. Whether or not the fusion engineering research project conducted by NIFS contributes to the establishment of academic fundamentals for helical fusion reactors

The following is a list of this year's evaluation items on the Fusion Engineering Research Project:

[1] Establishment of research system and environment

(1) Whether or not the target of FERP, initiated in JFY2010, is appropriate

(2) Whether or not the organization of FERP is coincident with its target and properly functioning

(3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

[2] Research achievements

Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor

(1) Helical fusion reactor design

(2) R&D toward establishment of the engineering basis

[3] Encouragement of joint activities and collaborative research

(1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes

(2) Whether or not NIFS is contributing to the development of research at universities

(3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others

[4] Human resources development

Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

[5] Future plans

Whether or not the future plan is pointing appropriately toward the medium- to long-term targets

Chapter 2 Reviews and Proposals

Here is a summary of the comments and arguments given by the reviewers. This is followed by proposals which will be important in advancing the FERP research.

2.1 Summary of reviews

[1] Establishment of research system and research environment

(1) Whether or not the target of FERP, initiated in JFY2010, is appropriate

Regarding the important issues of reactor engineering that also are consistent with those for tokamak reactors, as a research center in Japan, together with establishing an engineering base through a helical fusion reactor design and taking into account previous suggestions, NIFS is moving forward with setting objectives while planning the consistency of the reactor design and the engineering bases. **We can say that appropriate objectives are being set as objectives for the Fusion Engineering Research Project, and we rate this highly.**

On the other hand, as research by NIFS and universities, integration as a complete fusion reactor founded upon academic, elemental research is important. And we hope that while paying attention to complementarity and supplementation with tokamak reactors there will be flexible responses to both long-term objectives and short-term objectives and their feasibility.

(2) Whether or not the organization of FERP is coincident with its target and properly functioning

By shifting to a project system NIFS has become able to promote flexible research activities that can be pushed forward while aiming at organic collaboration with numerous related researchers within NIFS. Further, able to proactively advance collaborative research with universities and other institutions, by forming a domestic center, promoting cooperation across projects, allotting topics within the group, and actively placing young leaders, NIFS is constructing a system that considers the development of human resources. Accordingly, **we highly rate this construction of a system that accords with the project’s goals and is functioning appropriately.**

On the other hand, construction of a system for revising each task and feedback from reactor design to experiments and R&D groups are necessary. Further, we hope for the enhancement of researchers moving forward proactively with fusion engineering.

(3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

Through continuous effort including a large-scale supplementary budget, high-level experimental equipment as well as research tools are available. **That an environment in which it is possible to construct an infrastructure for engineering is being appropriately advanced is highly rated.**

Hereafter, it will be important that there be a research structure that includes researchers throughout Japan. Utilizing collaborative research, regarding the maintenance and preservation of equipment that span several fields, through maintaining and increasing technical staff we look forward to the optimization of the operation of equipment as assets of the entire fusion community.

[2] Research achievements

Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor

(1) Helical fusion reactor design

In the design of the helical fusion reactor, which is being emphasized in this project, that taking the conceptual design based upon parameters obtained from the LHD as the standard and linking the design to the Numerical Simulation Research Project indicated a way to self-ignition is of great interest. In particular, this is an advanced conceptual design that incorporated issues confined to the helical device and its strong points, such as the divertor configuration with neutron shielding. This conceptual design is of an extremely high level at the global level. It may be said that this, more so than a comparison with tokamak reactors, is of more significance as reactor design research by extracting engineering issues related to helical fusion reactors. **Accordingly, advancing the design for the helical fusion reactor and providing high-level results at the international level is extremely highly rated.**

By clarifying the process of design changes amid the flow of designs to this point, together with moving forward with establishing the current understandings and issues feedback to the LHD experiments is important. We hope for indications of the direction of engineering research through written descriptions of the detailed examinations of edge plasma modeling, the heat flux to the divertor, and alpha particles, and, further, through evaluation of the calculations obtained from design and measurements obtained from experiments.

(2) R&D toward establishment of the engineering basis

In developing basic equipment in response to the five issues mentioned above, while advancing collaborative research together with outside researchers, research highly rated internationally is being conducted. Further, including the broad linkages with universities and other research institutions, together with the LHD Project and the Numerical Simulation Research Project, NIFS is actively introducing distinctive cutting edge themes. **We highly rate that such research aiming at constructing engineering bases is being conducted, and that researchers are producing research results of high levels internationally.**

From now it may be said that it is necessary to concentrate not only on pioneering and creative research, but also on basic engineering research development and trials and tests. In particular, we look forward to even further advances regarding issues relating to the radiation technologies such as neutrons and tritium necessary for the future fusion reactor, while examining efficient ways of moving forward and planning country-wide linkages within the areas that only NIFS can implement.

[3] Encouragement of joint activities and collaborative research

(1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes

Regarding the diverse research topics relating to reactor engineering, making use of general collaborative research, LHD project collaborative research, and bilateral collaborative research, collaborative research with numerous universities is being organically conducted. Further, regarding international cooperation, such as the Japan-United States collaborative research, the Japan-People’s Republic of China collaborative research, and other forms of international cooperation, international collaborations are being undertaken through linkages with universities with NIFS as the core. Through these activities, **we highly rate the gathering of high-level research abilities present at universities and other institutions and advancing collaborative research appropriately as a Center of Excellence.**

In the future, too, aware of the appraisal of the LHD as an international site, including the exchange of researchers, we look forward to the activities as the Center of Excellence of domestic fusion engineering research. In particular, together with strongly advancing collaborative research in fields such as blankets, with which neutrons and tritium are related, we look forward to NIFS’ role as a Center of Excellence with regard to strengthening society’s acceptance of fusion and the strengthening of safety.

(2) Whether or not NIFS is contributing to the development of research at universities

For undertaking collaborative research as well as research cooperation with numerous universities that are linked to fusion engineering, and for contributing to the expansion of the base of fundamental research in engineering, and for the construction and opening of the database of atomic and molecular processes and plasma-wall interaction, **we highly rate NIFS for greatly contributing to the development of research at universities that aim at advancing academic research.**

In the future, advancing collaborative research on fusion engineering by using the leading edge expert knowledge of researchers at NIFS and utilizing large-scale experiment facilities which are difficult to implement in terms of maintenance, operation, funding, and personnel at the scale of a university laboratory, together with advancing further the germinating and pioneering research at universities, we look forward to the composition of a database that records research results and to the construction of a system that can widely utilize that information.

(3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others

To assist the ITER project and the BA activities, testing of the superconductor coils and NBI performance is being conducted, which shows NIFS's contribution to the ITER project and the BA activities by capitalizing upon the special characteristics of NIFS, which is endowed with specialist research groups and large-scale equipment. Further, reactor engineering researchers at NIFS serve at ITER and actively provide technological assistance in the ITER construction and are contributing to and expanding assistance to the ITER project and the BA activities. Moreover, NIFS has a central role in achieving the planning and implementation of the joint Japan-United States TITAN project and in the execution of the current PHENIX project. And including the contributions to the Atoms and Molecules Database (GENIE), NIFS is providing continuous contributions. Thus, **we highly rate contributions to the ITER project and the BA activities as well as the linkages and contributions to international activities.**

In the future, in the operation and execution of experiments in the LHD device beginning with superconducting coils technology, we look forward to further contributions to the ITER project, including the operation system, the training of operators, the safety system, and others cultivated at NIFS. Further, regarding the BA activities which aimed at a prototype reactor, we anticipate that this Fusion Engineering Research Project, which possesses great technological strength and abundant knowledge, will contribute greatly to research, including technological development and engineering verification, on a significant scale. Moreover, we look forward to the clarification of the relationship with NIFS' helical fusion reactor design, and to the positive contributions of the prototype reactor design joint core team.

[4] Human resource development

Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

As a result of the appointment of young researchers as task leaders, brilliant young researchers who will support fusion research are being nurtured, and numerous exceptional papers are being produced. Further, together with the education guidance that is being provided not only for graduate students at Sōkendai but also for graduate students at Japanese universities and post-doctoral researchers, the introduction of super science high schools (SSH), the implementation of summertime experience enrollment to Sokendai and a steady approach that will educate human resources for the future are moving forward. Through these activities, **we rate highly these contributions to the nurturing of human resources who can participate internationally and support the long-term development of fusion research.**

Regarding the nurturing of human resources, emphasizing the standpoint of general engineering of fusion research, through nurturing broadly human resources that will contribute to developing advanced science and industrial fields through linkages with universities, we greatly look forward to the expansion of the human foundations of fusion research. Further, we strongly hope for the implementation of measures, such as scholarships and the employment of post-doctoral researchers that will seek to increase the research population in fusion. In particular, in the future, it will be necessary to compose a structure for nurturing human resources that follows the roadmap for realizing the fusion reactor and nurturing human resources that support the fusion reactor's safety, which is imperative. Moreover, we hope that NIFS will aim to compose a structure that will make active participation in ITER and other international programs by young researchers (including university researchers) possible.

For the nurturing of human resources, long-term and strategic approaches and indicators for appropriately evaluating results are necessary, and it should be urged to continuously engage in discussions.

[5] Future plans

Whether or not the future plan is pointing appropriately toward the medium- to long-term targets

Appropriate goal-setting regarding each element of technology development currently being planned is being undertaken, and it may be said that a system for that purpose and equipment enhancement, too, is being maintained satisfactorily. With regard to the goals that have been established, from now, too, the capacity to continue undertaking appropriate research development and system maintenance can be readily expected. Accordingly, **the future research plans that aim at goals are appropriate, and we rate highly the future plans which gaze at mid- and long-term prospects.**

On the other hand, it is necessary to clarify the specific road map for aiming toward realization of the helical fusion reactor. Moreover, regarding research and development for the blanket, the divertor, and other important equipment that integrate essential technologies, it will be necessary to clarify further the numerical objectives, the research issues, and the perspective on achievement. At the same time, it will be necessary to also engage in technical issues such as fuel supply, assembly, maintenance, and remote handling. In the above project, a plan based upon an international perspective is indispensable.

Moreover, through active contributions to the prototype reactor design core team, it will be necessary to distinguish among similarities, differences and complementarities in tokamaks and the helical system, and to together search for means for development. It will be necessary to go beyond differences in confinement methods and to pursue engineering similarities and universalities, and to evolve from “technology development” to “engineering bases.” We anticipate that accumulating fundamental experimental data obtained from large-scale equipment at NIFS and developing the database further will contribute to establishing specifications and standards for the fusion reactor.

Through such research activities, we look forward to the nurturing of human resources that will become the axis of advances in the ITER project and development of research on the prototype reactor.

2.2 Proposals

Here is a summary of recommendations given by the panel to the NIFS Fusion Engineering Project for its future operation.

(1) We look forward to the NIFS Fusion Engineering Project strengthening further the linkages between the LHD Project and the Numerical Simulation Research Project, and together with planning refinements in the helical fusion reactor design advances in strengthening collaborative research in the superconducting coils, the divertor, the blanket, and other topics,

fulfilling the role as the Center of Excellence for developing fundamental technologies in the fusion engineering field, and evolving leading technologies that have been developed toward an academic system as engineering.

(2) Nurturing young researchers who will lead the world in the fusion engineering field, including too the ITER project and the BA activities, is an urgent task. We hope that universities and research institutes will construct linkages for realizing new frameworks for the nurturing of human resources and the enhancement of their quality.

(3) We look forward to planning for the introduction of large-size experiment instruments and test equipment in the fusion engineering field, which is difficult at universities, to the preparation of research environments based upon the placement and increase of human resources, and to the construction of their maintenance and management systems, as well as to strongly advancing the efficient application through collaborative use and research by universities and research institutes.

(4) We look forward to the utilization of the technological results and the engineering expertise that have been cultivated at NIFS, active participation in the ITER project and the BA activities, as well as the accumulation of results and knowledge, the standardization of the fusion reactor through the database, and contributions to the formation of standards.

Chapter 3　In Closing

At NIFS, from 2010 the second period for mid-term goals began, and in order to strengthen further the unifying core of NIFS as the Center of Excellence in the plasma and fusion research fields, we composed research projects for the three LHD, theory simulation, and fusion engineering fields, and initiated research planning for combining the research results from these fields in moving toward realization of the fusion reactor. For this reason, in 2010 a restructuring of the research organization within NIFS was undertaken. All researchers were placed in one research department, and a structure was composed that enables researchers to participate independently in projects. Through these changes, linkages among the LHD, theory simulation, and fusion engineering projects are advanced, and timely responses to new topics are anticipated.

In the Advisory Committee, in order to confirm the results of the project system, first, in 2011, we implemented an external peer review of the LHD project and in 2012 the external peer review of the Numerical Simulation Research Project. Then, in this current year (2013) we decided to implement an external peer review of the Fusion Engineering Research Project, which is in the fusion engineering field. We established an External Peer Review Committee that includes the nine members of the Advisory Committee who are not NIFS researchers and the four members from foreign countries, and five other specialists.

At the first meeting of the External Peer Review Committee, which was held on October 11, 2013, we discussed how to advance with this year's external peer review. It was decided to evaluate the points below.

[1] Establishment of research system and environment

(1) Whether or not the target of FERP, initiated in JFY2010, is appropriate

(2) Whether or not the organization of FERP is coincident with its target and properly functioning

(3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

[2] Research achievements

Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor

(1) Helical fusion reactor design

(2) R&D toward establishment of the engineering basis

[3] Encouragement of joint activities and collaborative research

(1) Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes

(2) Whether or not NIFS is contributing to the development of research at universities

(3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others

[4] Human resources development

Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research

[5] Future plans

Whether or not the future plan is pointing appropriately toward the medium- to long-term targets

At their second meeting held on November 30, 2013, the panel was provided by the institute with detailed information on the FERP activities along with the items above. On January 28, 2014, the reviewers gathered in subdivided groups and moved forward with the evaluation process. After all the subgroups completed their proposals, the panel finalized its work in a report at its third meeting held on February 21.

As results of this external peer review evaluation of the Fusion Engineering Research Project, regarding all of the items above, it has been concluded that in general they can be highly rated. In particular, regarding research results relating to the helical fusion reactor design, this advanced conceptual design incorporated strong points and issues unique to the helical system, and can be extremely highly rated. Further, the setting of goals for the Fusion Engineering Research Project and the propulsion system can be said to be appropriate and functioning organically, and this too can be highly rated. Moreover, that high-level experimental instruments and research equipment have been introduced and a research environment is being provided, and that as a Center of Excellence in this field NIFS is contributing to research development at universities too can be highly rated. On the other hand, regarding research aimed at constructing a base for engineering, linkages with the ITER project and the BA activities, and the nurturing of human resources, the constant visibility of effort can be highly rated, though we look forward to still further development. Regarding future plans, there is sound planning, which was well and carefully undertaken based upon achievements to date, and this too can be highly rated. However, we look forward to efforts aimed at advancing academic research that deepens further from “technology development” to “engineering bases.”

Still further, adding to these evaluation results, there are demands for the establishment of a system regarding the efficient application of the experimental instruments and research equipment already provided and for construction of a new framework for nurturing young researchers who will lead the world in the fusion engineering field, and we look forward to the realization of these demands as links with the fusion community.

To conclude, we have summarized below final comments regarding future ways of moving the Fusion Engineering Research Project forward.

(1) We look forward to the NIFS Fusion Engineering Project strengthening further the linkages between the LHD Project and the Numerical Simulation Research Project, and together with planning refinements in the helical fusion reactor design advances in strengthening collaborative research in the superconducting coils, the divertor, the blanket, and other topics, fulfilling the role as the Center of Excellence for developing fundamental technologies in the fusion engineering field, and evolving leading technologies that have been developed toward an academic system as engineering.

(2) Nurturing young researchers who will lead the world in the fusion engineering field, including too the ITER project and the BA activities, is an urgent task. We hope that universities and research institutes will construct linkages for realizing new frameworks for the nurturing of human resources and the enhancement of their quality.

(3) We look forward to planning for the introduction of large-size experiment instruments and test equipment in the fusion engineering field, which is difficult at universities, to the preparation of research environments based upon the placement and increase of human resources, and to the construction of their maintenance and management systems, as well as to strongly advancing the efficient application through collaborative use and research by universities and research institutes.

(4) We look forward to the utilization of the technological results and the engineering expertise that have been cultivated at NIFS, active participation in the ITER project and the BA activities, as well as the accumulation of results and knowledge, the standardization of the fusion reactor through the database, and contributions to the formation of standards.

Based upon these suggestions, one may say that steadily advancing the Fusion Engineering Research Project in the future will greatly contribute to the strengthening of the academic base and the research development systems in the fusion field.

Documents

2013 External Peer Review Presentation Materials

2013 NIFS External Review (Nagoya, Dec. 2013)

Fusion Engineering Research Project in NIFS

FY2010 - 2013

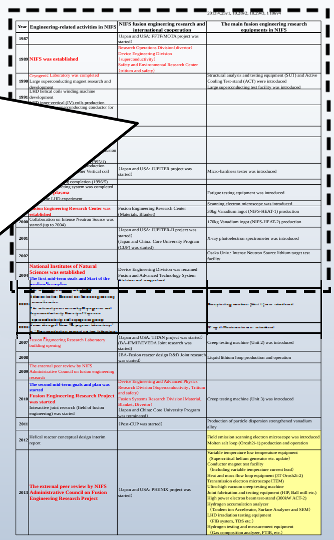
Akio SAGARA

National Institute for Fusion Science

History of Fusion Engineering Study in NIFS (1989 – 2004)

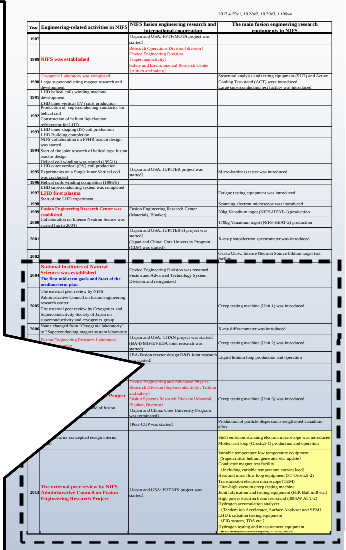
2013.4.25v1, 10.28v2, 10.29v3, 1106v4

Year	Engineering-related activities in NIFS	NIFS fusion engineering research and international cooperation	The main fusion engineering research equipments in NIFS
1987		(Japan and USA: FFTF/MOTA project was started)	
1989	**NIFS was established**	Research Operations Division (divertor) Device Engineering Division (superconductivity) Safety and Environmental Research Center (tritium and safety)	
1990	Cryogenic Laboratory was completed Large superconducting magnet research and development		Structural analysis and testing equipment (SUT) and Active Cooling Test-stand (ACT) were introduced Large superconducting test facility was introduced
1991	LHD helical coils winding machine development LHD inner vertical (IV) coils production		
1992	Production of superconducting conductor for helical coil Construction of helium liquefaction refrigerator for LHD		
1993	LHD inner shaping (IS) coil production LHD Building completion		
1994	NIFS collaboration on FFHR reactor design was started Start of the joint research of helical type fusion reactor design Helical coil winding was started (1995/1)		
1995	LHD outer vertical (OV) coil production Experiments on a Single Inner Vertical coil was conducted	(Japan and USA: JUPITER project was started)	Micro-hardness tester was introduced
1996	Helical coils winding completion (1996/5)		
1997	LHD superconducting system was completed **LHD first plasma** Start of the LHD experiment		Fatigue testing equipment was introduced
1998			Scanning electron microscope was introduced
1999	**Fusion Engineering Research Center was established**	Fusion Engineering Research Center (Materials, Blanket)	30kg Vanadium ingot (NIFS-HEAT-1) production
2000	Collaboration on Intense Neutron Source was started (up to 2004)		170kg Vanadium ingot (NIFS-HEAT-2) production
2001		(Japan and USA: JUPITER-II project was started) (Japan and China: Core University Program (CUP) was started)	X-ray photoelectron spectrometer was introduced
2002			Osaka Univ.: Intense Neutron Source lithium target test facility
2004	**National Institutes of Natural Sciences was established** **The first mid-term goals and Start of the medium-term plan**	Device Engineering Division was renamed Fusion and Advanced Technology System Division and reorganized	



History of Fusion Engineering Study in NIFS (2004 – 2013)

2004	**National Institutes of Natural Sciences was established** **The first mid-term goals and Start of the medium-term plan**	Device Engineering Division was renamed Fusion and Advanced Technology System Division and reorganized	
2005	The external peer review by NIFS Administrative Council on fusion engineering research center The external peer review by Cryogenics and Superconductivity Society of Japan on superconductivity and cryogenics group		Creep testing machine (Unit 1) was introduced
2006	Name changed from "Cryogenic laboratoriy" to "Superconducting magnet system laboratory		X-ray diffractometer was introduced
2007	Fusion Engineering Research Laboratory building opening	（Japan and USA: TITAN project was started） (BA-IFMIF/EVEDA Joint research was started)	Creep testing machine (Unit 2) was introduced
2008		（BA-Fusion reactor design R&D Joint research was started）	Liquid lithium loop production and operation
2009	The external peer review by NIFS Administrative Council on fusion engineering research		
2010	**The second mid-term goals and plan was started** **Fusion Engineering Research Project was started** Interactive joint research (field of fusion engineering) was started	Device Engineering and Advanced Physics Research Division（Superconductivity、Tritium and safety） Fusion Systems Research Division（Material, Blanket, Divertor） （Japan and China: Core University Program was terminated）	Creep testing machine (Unit 3) was introduced
2011		（Post-CUP was started）	Production of particle dispersion strengthened vanadium alloy
2012	Helical reactor conceptual design interim report		FY2012 supplementary budget Field emission scanning electron microscope was introduced Molten salt loop (Orosh2i-1) production and operation
2013	**The external peer review by NIFS Administrative Council on Fusion Engineering Research Project**	（Japan and USA: PHENIX project was started）	Variable temperature low temperature equipment （Supercritical helium generator etc. update） Conductor magnet test facility （Including variable temperature current lead） Heat and mass flow loop equipment (3T Orosh2i-2) Transmission electron microscope（TEM) Ultra-high vacuum creep testing machine Joint fabrication and testing equipment (HIP, Ball mill etc.) High power electron beam test-stand (300kW ACT-2) Hydrogen accumulation analyzer （Tandem ion Accelerator, Surface Analyzer and SEM） LHD irradiation testing equipment （FIB system, TDS etc.） Hydrogen testing and measurement equipment （Gas composition analyzer, FTIR, etc.）



Points of Evaluation

[1] Establishment of Research System and Environment

研究環境の整備

[2] Research Achievements ~ Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor

研究成果 ～ヘリカル型核融合炉の研究を進めることにより、国際的に高いレベルの成果を上げているか

[3] Encouragement of Joint Activities and Collaborative Research

共同利用・共同研究の推進

[4] Human Resource Development ~ Whether or not FERP is bringing up young researchers who can support long-range growth of international fusion study

人材育成 ～核融合研究の長期的な発展を支える国際的に活躍できる人材の育成に貢献しているか

[5] Future Plans ~ Whether or not the future plan is appropriately pointing at the medium- to long-term target

将来計画 ～目標に向けた今後の研究計画は適切か。特に、中長期的展望を見据えたものとなっているか

[1] Establishment of Research System and Environment

研究環境の整備

(1-1) Whether or not the target of FERP, initiated in FY2010, is appropriate

平成２２年度にプロジェクトとして位置付けられた核融合工学研究プロジェクトの目標設定は適切か

(1-2) Whether or not the organization of FERP is coincident with its target and properly functioning?

推進体制は目標に合致し、適切に機能しているか

(1-3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

工学基盤の構築を可能とする研究環境の整備は適切に進められているか

(1-1) Target of FERP

FERP has been launched since 2010
With the target of
Promotion of conceptual and baseline designs toward realization of a steady-state helical fusion reactor and construction of engineering basis that enables real-scale and real-environment R&D
定常ヘリカル型核融合炉実現に向けての概念及び基本設計の推進と、実規模・実環境試験を可能にする基幹工学基盤の構築

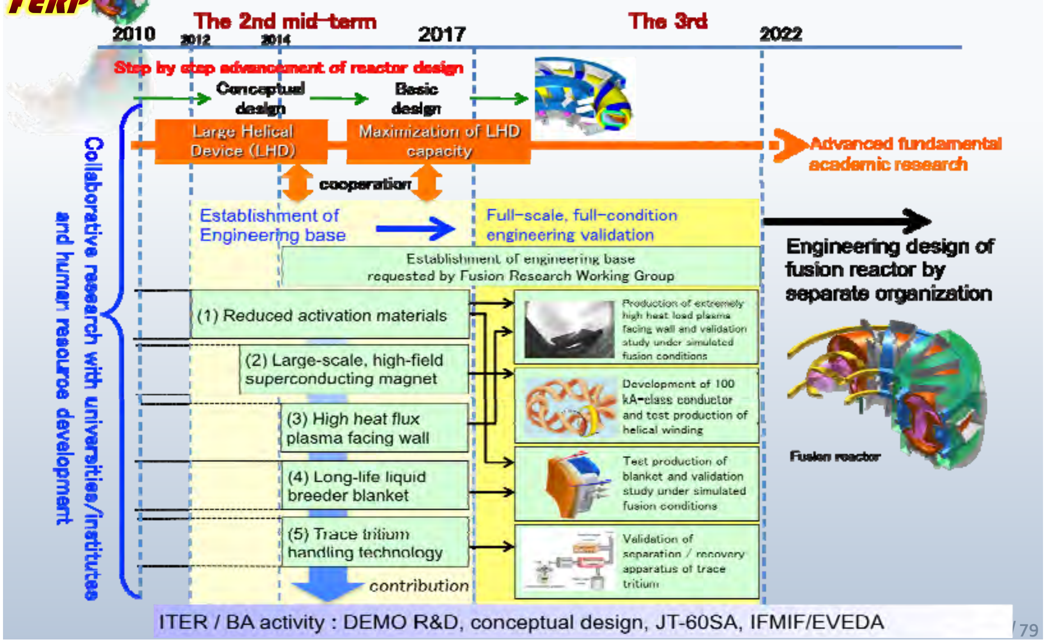
Two keywords:
- ✓ Conceptual design of helical reactor ➔ Reactor Design
- ✓ Construction of engineering basis ➔ R&D

Any researcher can participate in FERP, although the main body is the former '**Fusion Engineering Research Center (FERC)**'

FERP as a 'PROJECT' of NIFS

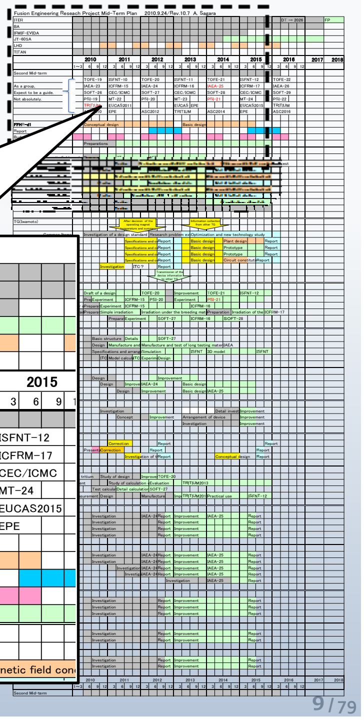
Objectives and plans for the 2nd mid-term Objectives to increase the quality of research and education in NINS	"As one of the nation's centers of excellence, NIFS intends to organize the academic activities concerning fusion sciences and related fields at universities and other research institutes. To achieve controlled thermonuclear fusion, meant to be environmentally safe, NIFS will promote all fusion-related research collaborations, including internationally coordinated activities towards nuclear fusion experiments, based on the use of large experimental devices and computers."
Action to achieve the objectives	"Research should be conducted for the development of blankets and superconducting coils along with efficient reactor design activities, intending the establishment of academic fundamentals." / . . . / …
Promotion of PROJECTs in NIFS	**FERP** *Fusion Engineering Research Project* / LHD Large Helical Device Project / NSRP Num. Sim. Res. Project

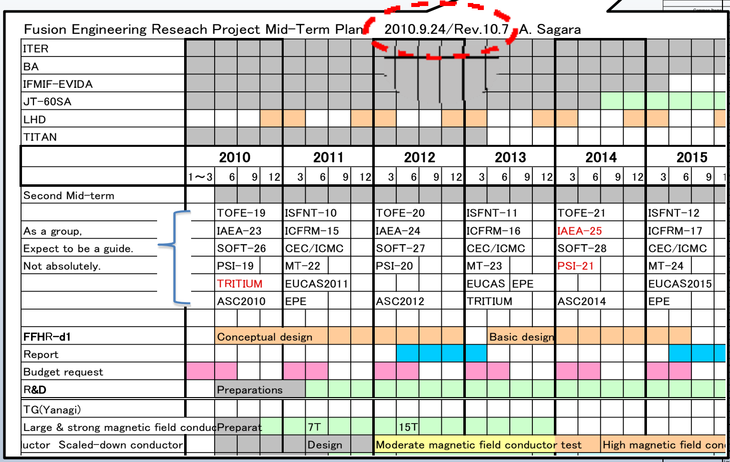
Roadmap of FERP



Mid- Term Schedule

- ✓ The work plan was already determined at the start-up phase of FERP
- ✓ International conferences concerned





Tasks for FERP (1)

Red: Reactor Design
Green: R&D

Superconducting Magnet Group (International Conference: 27, Publications: 17)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[SC Magnet] ● Conductor development ● Coil winding ● Cooling	Large-scale high-field conductor testing facility	□ Upgrade to 15 T - 680 mm bore, 75 kA sample current, 4 - 50 K temp. for sample coil	✓Design and order of new conductor testing facility	■ New facility with 13 T - 680 mm bore, 50 kA sample current, 4 - 50 K temp. for sample coil	
	CIC conductor & winding	□ 100 kA@4.5 K, 12 T conductor □ Design of HC with continuous winding	✓Testing of JT-60SA conductor/joint/model-coil and ITER joint ✓1-D thermal analysis of CIC	■ Examination of twist strain of Nb_3Sn and Nb_3Al CIC strands	ITER BA
	Indirect -cooling LTS conductor & winding	□ 100 kA@4.5 K, 12 T conductor □ Design of HC with continuous winding	✓Nb_3Sn Rutherford-type conductor with Al-alloy jacket with FSW welding ✓20 kA@4.5 K, 12 T	■ Examination of strand element for 100 kA@4.5 K, 12 T (200 kA critical current)	
	HTS conductor & winding	□ 100 kA@20 K, 15 T conductor and joint □ Design of HC with jointed-winding	✓103 kA@20 K, 5.3 T with a mechanically-jointed one-turn HTS coil sample ✓Proposal of new winding concept	■ 100 kA@ 20 K, 6 T ■ Examination of fabrication process with joint, internal insulation, gas cooling	Tohoku Univ.
	EM force support structure	□ Optimized design of robust and minimum-weight support structure	✓Design with 3-D FEM calculation ✓660 MPa stress and further optimization	■ Further optimization in accordance with maintenance scenario	
[Cryogenic] ● Cryogenic system ● Coil power supply system	Cryogenic system	□ Optimized design for FFHR	✓Examination of ITER system ✓Development of dynamic simulator	■ Improvement of dynamic simulator ■ Design of optimized refrigerator	ITER
	Bus-line and current-lead	□ Optimized design for FFHR	✓Examination of ITER system	■ Design of new HTS or MgB_2 bus-line for FFHR	ASIPP ITER
	Coil power supply system	□ Optimized design for FFHR	✓Examination of series excitation of the whole magnet coils	■ Design of quench protection system	

Tasks for FERP (2)

Red: Reactor Design
Green: R&D

In-Vessel Component Group -1-

(International conference: 67, Publications: 119)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[Blanket] ●Blanket system development ● Blanket design	Radiation shield	□ Property evaluation of shielding materials □ Material selection for long-term performance retention	✓Data of thermal conductivities ✓Evaluation of neutronics environment	■ Evaluation of high temperature stability ■ Investigation of irradiation effects	AIST, Osaka Univ.
	Breeding blanket	□ Performance enhancement of vanadium alloy □ Performance enhancement of low activation ferritic steel □ Development of large area ceramic coting □ Acquisition of chemical property of coolant □ Blanket design for FFHR-d1	✓Property evaluation of electron beam welding section / Dissimilar welding test / Fabrication of Y doped high Cr alloy ✓No performance degradation in 12Cr ODS at >900 °C / Fabrication of high Cr ODS ✓Multilayer oxide coating and nitride coating by large area coating techniquies / Hydrogen permeation reduction:~1/200 ✓Accurate evaluation of hydrogen solubility and diffusibility in Li-Pb / Construction of LiPb corrosion test loop with ferritic steel ✓Evaluation of fuel breeding and shielding performances by 3-D neutronics calculation	■ Optimization of heat treatment process / Irradiation test ■ Irradiation test / Comparison of 9Cr-ODS and 12Cr-ODS ■ Optimization of coating fabrication process / Coating test on tube and duct ■ Understanding of hydrogen transport in LiPb flow / Acquisition of corrosion data in LiPb flow with temperature gradient ■ Investigation of heat removal	Tohoku Univ. Ehime Univ., Hokkaido Univ. Kyoto Univ. Tokai Univ. Toyama Univ.
	Heat, hydrogen isotopes recovery system	□ Data acquisition and modeling of hydrogen isotope transport	✓Design and construction of Flinak loop Orosh^{2}i-1 ✓Successful circulation control ✓Development of hydrogen recovery tube.	■ Construction of new FLiNaK and LiPb test loops with 3 T magnet ■ Thermal recovery under magnetic field	Kyushu Univ. Tokai Univ. Kyoto Univ.
	First wall	□ Data acquisition and modeling of hydrogen isotope transport	✓Data acquisition of plasma driven and gas driven hydrogen permeation. ✓Hydrogen retention data after	■ Data acquisition of bidirectional hydrogen transport from plasma and coolant	Hokkaido Univ.

Tasks for FERP (3)

Red: Reactor Design
Green: R&D

In-Vessel Component Group -2-

(International conference: 67, Publications: 119)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[In-Vessel Components] ●In-vessel component development ● Structural design ● Maintenance	Vacuum vessel	□ Manufacture of a sector mock up	✓Basic geometry using numerical equations ✓Structure of radial build component ✓Access ports with large aperture	■ Optimization in accordance with maintenance scenario	
	Divertor	□ Manufacture of a divertor module	✓R&D of a short sample made of W and RAFM pipe ✓Examination of specifications and arrangements	■ Test under high heat load	Okayama Univ. of Science
	Remote maintenance	□ Demonstration of maintenance process	✓Research of maintenance condition and machinery ✓Development of autonomous mobile robot	■ Visualization of maintenance scenario	JAEA Tokai Univ.

Tasks for FERP (4)

Red: Reactor Design
Green: R&D

Reactor System Design Group -1-

(International conference: 56, Publications: 81)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[Design Integration]	Task setting and project management	☐ Publish a conceptual design report of helical reactor FFHR-d1 ☐ Planning of real-scale and real-environment test	✓Interim report on FFHR-d1 conceptual design was published ✓Managed a large supplementary budget	■ Collaboration with IFERC ■ Operation of large R&D devices equipped by the supplementary budget	JAEA (BA-DDA) Universities
	Conceptual design of helical fusion reactor	☐ Establishment of consistent and feasible design concept	✓Development of system design code ✓Basic 3-D shape design of in-vessel components	■ Feedback of the result of detailed analysis ■ Cost and waste evaluation	JAEA (BA-DDA)
[Building Layout]	Layout design and construction process	☐ Site layout design ☐ Establishment of concept of construction process	✓Listing of buildings ✓Listing of necessary task at the construction	■ Determine the location of buildings ■ Estimation of the amount of time of each task	
	Reactor building design	☐ 3D CAD design of reactor building	✓Estimation of the floor space ✓Evaluation of leakage field profile	■ Layout design of equipment in the building	
[Power Supply] ● Power supply ● Generator	Generator and power supply system	☐ Design report based on steam turbine generator ☐ Estimation of power flow and design of start up procedure	✓Conceptual design based on steam turbine generator ✓Conceptual design of start up scenario and dc power system of SC coils	■ Adjustment of thermal source and heat exchanger design ■ Feed back of the design results of other components	Osaka Univ. Tokai Univ. Meiji Univ.
	Transmission and hydrogen production	☐ Integration design of hydrogen production plant ☐ Development of MgB_2 cable for SC transmission line	✓Conceptual design of hydrogen production was published ✓ Conceptual design of hybrid energy transmission line was published	■ Component design of hydrogen production plant ■ Development of MgB_2 cable with high current capacity	ASIPP

Tasks for FERP (5)

Red: Reactor Design
Green: R&D

Reactor System Design Group -2-

(International conference: 56, Publications: 81)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[Tritium]	Tritium fuel balance	☐ Estimation of tritium inventory, particle balance and required tritium decontamination factor [DF]	✓Demonstration of tritium fuel balance using simple mass balance model and estimation of required throughput and DF, etc	■ Consideration and proposal of advanced tritium processing system based on the fuel balance model	
	Tritium safety handling	☐ Development of high throughput (> 1000 m^3/h) tritium removal system and its system code	✓Demonstration of preliminary integrated tritium removal system code combined with catalyst and membrane separator	■ Verification and validation of integrated tritium removal system code using middle scale tritium removal system	Akita Univ. Nagoya Univ.
	Tritium decontamination	☐Clarification of tritium decontamination in/on the metal materials	✓Understanding of hydrogen isotope behaviors in/on a stainless steel by glow discharge cleaning	■ Development of simple tritium decontamination system by atmospheric pressure plasma	Univ. of Toyama (HRC)
	Tritium monitoring	☐ Demonstration of low level tritium monitoring : $2x10^{-4}$ Bq/cm^3-gas 6 Bq/cm^3-water @10 min.	✓Tritium gas: performance optimization ✓Tritiated water : few Bq/cm^3 @ 180 min.	■ Tritium measurement and demonstration of $2x10^{-4}$ Bq/cm^3 ■ Shorter counting time toward 6 Bq/cm^3-water @10 min	Kyoto Univ. (RIC) Nagoya Univ.
[Operation Control]	Safety analysis and control system	☐ Conduct safety analysis ☐ Conceptual design of control system	✓Review of safety analysis ✓Consideration of safer blanket design	■ Preparation of safety analysis code	
	Burn control	☐ Establishment of plasma operation scenario	✓Demonstration of ignition-access by quasi-1D calculation	■ Detailed physics analysis on the simulated profiles	Tokai Univ.

Tasks for FERP (6)

Red: Reactor Design
Green: R&D

Reactor System Design Group -3- (International conference: 56, Publications: 81)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[Core Plasma]	Plasma experiment	□ Obtain the radial profile data extrapolatable to the reactor w/o enhancing β	✓Self-ignition in FFHR-d1A with P_{fusion} ~ 3 GW @ f_β ~ 3 (β_o ~ 10 %) ✓Sub-ignition in FFHR-d1B with Q ~ 20 @ f_β = 1 (β_o ~ 2.4 % and P_{aux} ~ 30 MW)	■ Sub-ignition in FFHR-d1B with Q > 30 @ f_β =1 ■ Exploration of the better magnetic configuration (e.g., vertical elongation at γ_c = 1.20)	LHD
	MHD equilibrium and stability	□ Mitigation of the Shafranov shift at high-beta □ Definition of the beta limit	✓HINT2 and VMEC have been applied ✓High-aspect ratio and B_v control are effective ✓Confinement is not largely deteriorated at D_I ~ 0.2	■ Analysis of the profiles during the start-up and sustainment phases predicted by HELIOSCOPE	LHD NSRP
	Neoclassical transport	□ Evaluation of the neoclassical transport	✓FORTEC-3D and GSRAKE have been applied ✓Neoclassical thermal loss can be compatible with α heating	■ (same as above)	LHD NSRP
	Alpha heating	□ Evaluation of the direct loss and the heating power of alpha particles	✓GNET and MORH have been applied Direct loss of α particles can be ~15 %, or less	■ (same as above)	Kyoto Univ. LHD NSRP
	Anomalous transport	□ Evaluation of the anomalous transport	✓Application of GKV-X is considered	■ (same as above)	NSRP
	Plasma operation scenario	□ Development of 1D core plasma simulation code □ Establishment of the plasma operation scenario □ Find out the detachment scenario	✓NGS and DPE are included to HELIOSCOPE ✓Self- and sub-ignition scenarios in FFHR-d1B are developed ✓Detachment exp. in LHD	■ Integration of TASK-3Da into HELIPSCOPE	LHD NSRP

Tasks for FERP (7)

Red: Reactor Design
Green: R&D

Reactor System Design Group -4- (International conference: 56, Publications: 81)

Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[Plasma Heating]	NBI	□Fundamental experiment on photo-neutralizer □ Design of 1.5-2.0 MeV beam accelerator □ Design of neutron shield	✓6.9 MW@ 190 KeV for 1.5 sec. per NBI ✓more than 16 MW injection with 3 beamlines ✓4 MW for 10 sec. pulse	■ Production of perfect ion-ion plasma including less than 1/1000 of electron / H- ion ratio ■ Beam trajectory simulation	JAEA, RFX Group (Padova, Italy), Tohoku Univ. Keio Univ.
	ECH	□ Demonstration of 1 MW 60 minutes injection □ Demonstration of high efficiency OXB heating □ Find high efficiency OXB in FFHR	✓0.4 MW 20 minutes achieved ✓16 % OXB heating efficiency @77 GHz ✓Ray tracing environment in FFHR established	■ 1MW 20 minutes ■ High OXB heating efficiency @154 GHz ■ Ray tracing with mode conversion in FFHR	Univ. of Tsukuba Kyoto Univ. Kyushu Univ.
	ICRF	□ Development of fast wave simulation-framework with actual geometrical model	✓Cold plasma model with three dimensional calculation	■ Antenna with Faraday shield and protector ■ Hot plasma model	Tokyo Univ. MIT
[Fueling]	Pellet	□ Optimization of pellet injection condition taking into account ablation and plasmoid homogenization	✓Modeling completed based on the experimental results in LHD	■ Exploration of the possibility for the very high speed pellet injection beyond 10 km/s	

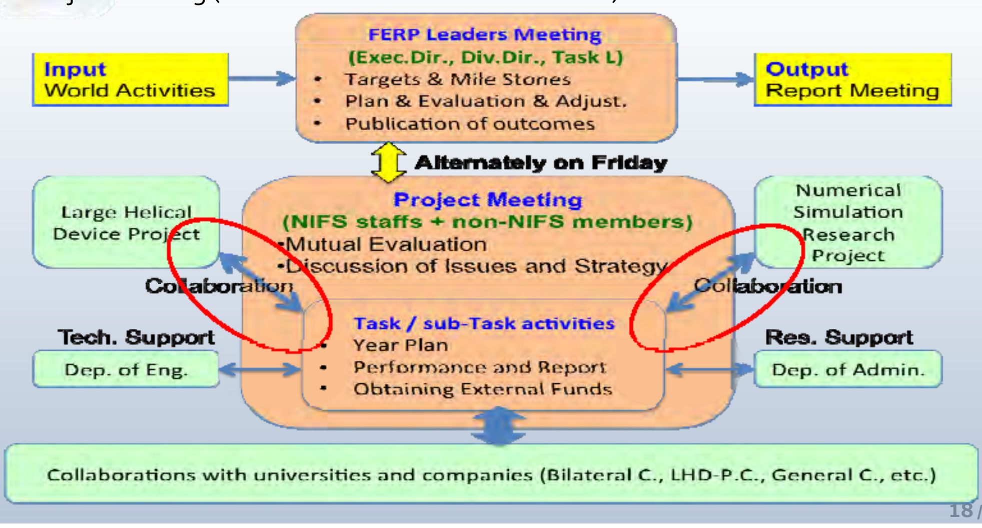
Tasks for FERP (8)

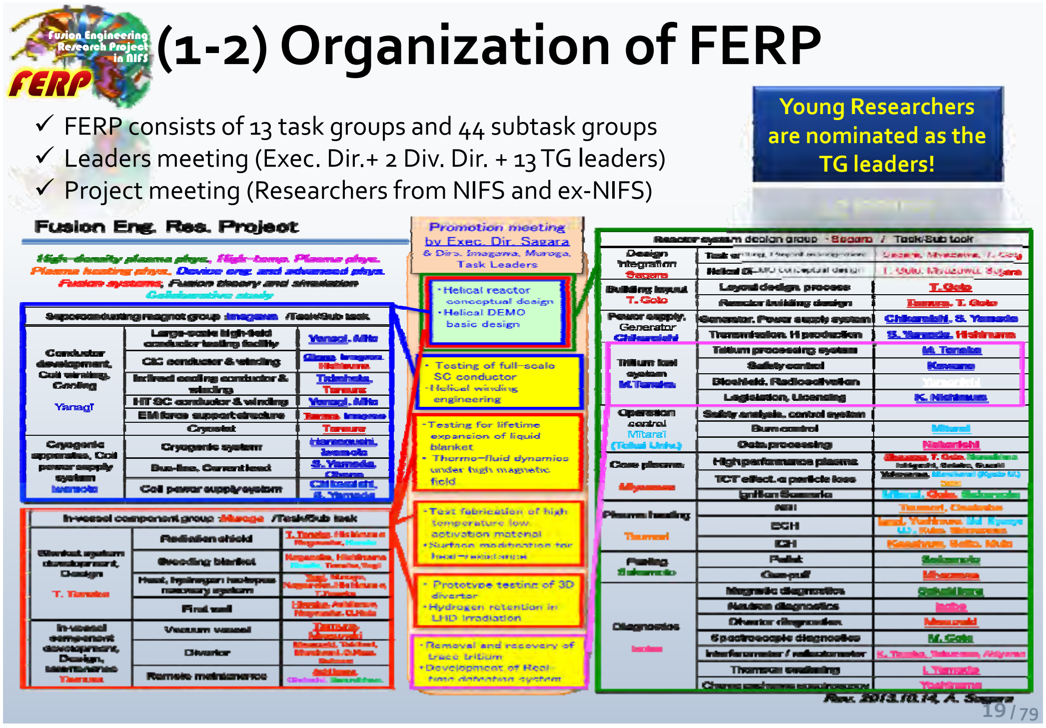
Red: Reactor Design
Green: R&D

Reactor System Design Group -5-		(International conference: 56, Publications: 81)			
Task	Subject	Mid-Term Goal	Achievement	Next Move	Collaboration
[Diagnostics]	Investigation of available diagnostics	☐ Selection of diagnostics ☐ Put diagnostic devices in CAD	✓Initial consideration results submitted to PFR	■ Arrangement of diagnostic ports	Tokyo Institute of Tech. JAEA
	Neutron diagnostics	☐ Design of the device	✓Feasibility check of existing neutron flux monitor and spectrometer for DEMO	■ Survey of diagnostic port available for neutron diagnostics	Nagoya Univ.
	Spectroscopic diagnostics	☐ Design of the device	✓Particle source profile measurement with single line-of-sight	■ Spatial profile measurement of impurity lines in EUV range	Kyoto Univ. Shinshu Univ.
	Interferometer / reflectmeter	☐ Design of the device ☐ Demonstration of high-resolution measurement at high-density in LHD	✓Measurement test with a proto-type (CO_2 laser) system has begun on LHD	■ Bench tests of a shorter wavelength (Nd:YAG laser) system	Kyushu Univ. Shimane Univ. Chubu Univ.
	Thomson scattering	☐ Design of the LIDAR system.	✓Feasibility check on the high-power laser for LIDAR	■ R&D on the high-power laser	Osaka Univ. Institute for Molecular Science

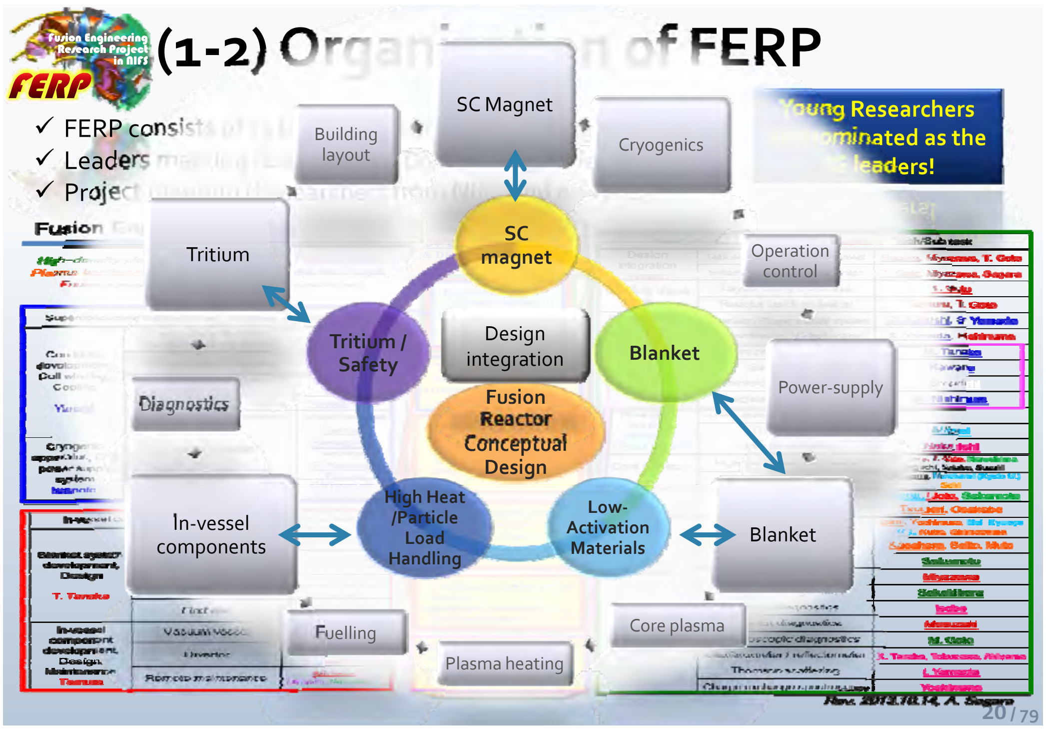
(1-2) Organization of FERP

- ✓ FERP consists of 13 task groups and 44 subtask groups
- ✓ Leaders meeting (Exec. Dir.+ 2 Div. Dir. + 13 TG leaders)
- ✓ Project meeting (Researchers from NIFS and ex-NIFS)

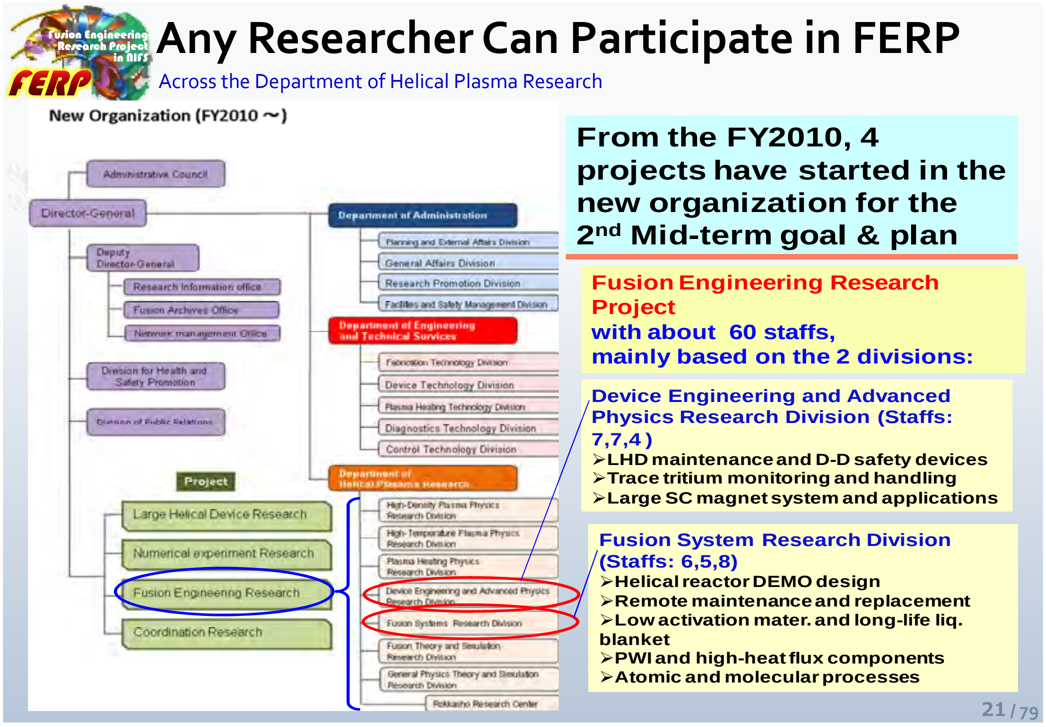




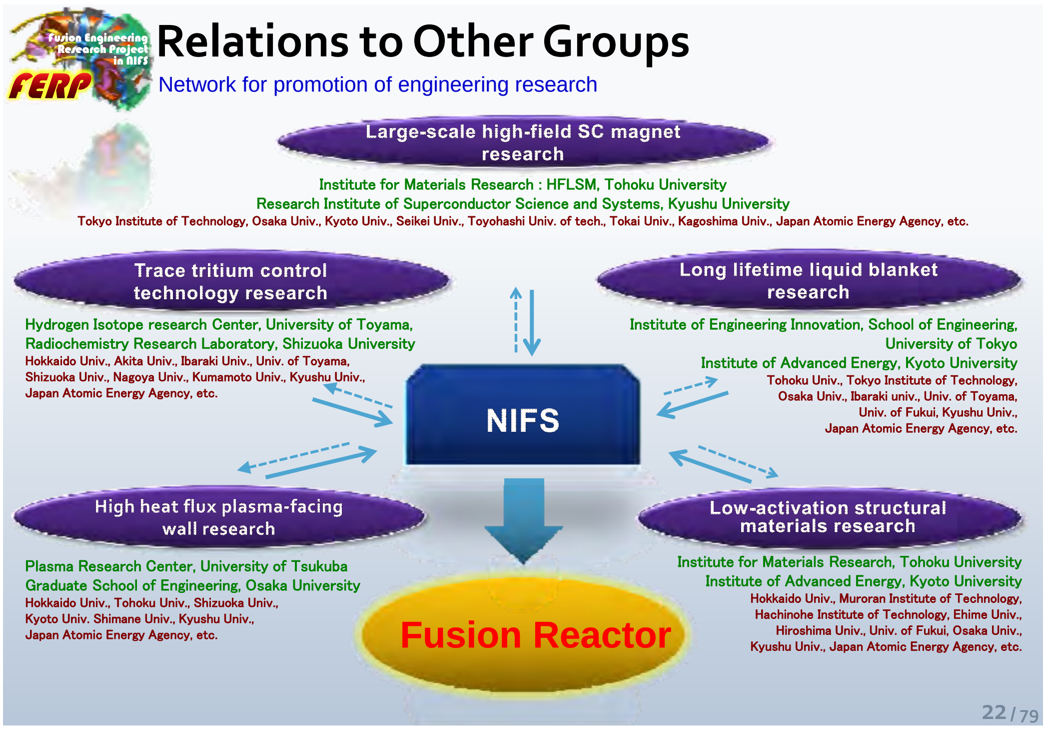
(1-2) Organization of FERP
Fusion Engineering Research Project in NIFS
FERP
✓ FERP consists of 13 task groups and 44 subtask groups
✓ Leaders meeting (Exec. Dir.+ 2 Div. Dir. + 13 TG leaders)
✓ Project meeting (Researchers from NIFS and ex-NIFS)
Young Researchers are nominated as the TG leaders!
Fusion Eng. Res. Project
Promotion meeting by Exec. Dir. Sagara
Task Leaders
·Helical reactor conceptual design
·Helical DEMO basic design
·Testing of full-scale SC conductor
·Helical winding engineering
·Testing for lifetime expansion of liquid blanket
·Thermo-fluid dynamics under high magnetic field
·Test fabrication of high temperature low activation material
·Prototype testing of 3D divertor
·Hydrogen retention in LHD irradiation
·Removal and recovery of trace tritium
Rev. 2013.10.14, A. Sagara
19 / 79



(1-2) Organization of FERP
FERP
SC Magnet
Building layout
Cryogenics
SC magnet
Tritium
Operation control
Tritium / Safety
Design integration
Blanket
Power-supply
Fusion Reactor Conceptual Design
Diagnostics
In-vessel components
High Heat /Particle Load Handling
Low-Activation Materials
Blanket
Fuelling
Plasma heating
Core plasma
Young Researchers
Rev. 2013.10.14, A. Sagara
20 / 79



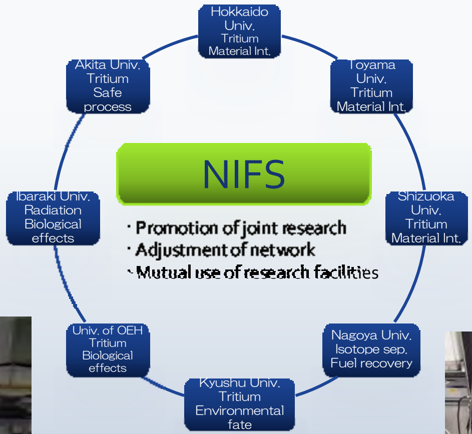
Any Researcher Can Participate in FERP
Across the Department of Helical Plasma Research
New Organization (FY2010 ～)
Administrative Council
Director-General
Deputy Director-General
Research Information office
Fusion Archives Office
Network management Office
Division for Health and Safety Promotion
Division of Public Relations
Project
Large Helical Device Research
Numerical experiment Research
Fusion Engineering Research
Coordination Research
Department of Administration
Planning and External Affairs Division
General Affairs Division
Research Promotion Division
Facilities and Safety Management Division
Department of Engineering and Technical Services
Fabrication Technology Division
Device Technology Division
Plasma Heating Technology Division
Diagnostics Technology Division
Control Technology Division
Department of Helical Plasma Research
High-Density Plasma Physics Research Division
High-Temperature Plasma Physics Research Division
Plasma Heating Physics Research Division
Device Engineering and Advanced Physics Research Division
Fusion Systems Research Division
Fusion Theory and Simulation Research Division
General Physics Theory and Simulation Research Division
Rokkasho Research Center
From the FY2010, 4 projects have started in the new organization for the 2nd Mid-term goal & plan
Fusion Engineering Research Project with about 60 staffs, mainly based on the 2 divisions:
Device Engineering and Advanced Physics Research Division (Staffs: 7,7,4)
➢LHD maintenance and D-D safety devices
➢Trace tritium monitoring and handling
➢Large SC magnet system and applications
Fusion System Research Division (Staffs: 6,5,8)
➢Helical reactor DEMO design
➢Remote maintenance and replacement
➢Low activation mater. and long-life liq. blanket
➢PWI and high-heat flux components
➢Atomic and molecular processes
21 / 79



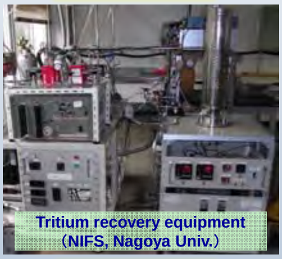
Relations to Other Groups
Network for promotion of engineering research
Large-scale high-field SC magnet research
Institute for Materials Research : HFLSM, Tohoku University
Research Institute of Superconductor Science and Systems, Kyushu University
Tokyo Institute of Technology, Osaka Univ., Kyoto Univ., Seikei Univ., Toyohashi Univ. of tech., Tokai Univ., Kagoshima Univ., Japan Atomic Energy Agency, etc.
Trace tritium control technology research
Hydrogen Isotope research Center, University of Toyama, Radiochemistry Research Laboratory, Shizuoka University
Hokkaido Univ., Akita Univ., Ibaraki Univ., Univ. of Toyama, Shizuoka Univ., Nagoya Univ., Kumamoto Univ., Kyushu Univ., Japan Atomic Energy Agency, etc.
Long lifetime liquid blanket research
Institute of Engineering Innovation, School of Engineering, University of Tokyo
Institute of Advanced Energy, Kyoto University
Tohoku Univ., Tokyo Institute of Technology, Osaka Univ., Ibaraki univ., Univ. of Toyama, Univ. of Fukui, Kyushu Univ., Japan Atomic Energy Agency, etc.
NIFS
High heat flux plasma-facing wall research
Plasma Research Center, University of Tsukuba
Graduate School of Engineering, Osaka University
Hokkaido Univ., Tohoku Univ., Shizuoka Univ., Kyoto Univ. Shimane Univ., Kyushu Univ., Japan Atomic Energy Agency, etc.
Low-activation structural materials research
Institute for Materials Research, Tohoku University
Institute of Advanced Energy, Kyoto University
Hokkaido Univ., Muroran Institute of Technology, Hachinohe Institute of Technology, Ehime Univ., Hiroshima Univ., Univ. of Fukui, Osaka Univ., Kyushu Univ., Japan Atomic Energy Agency, etc.
Fusion Reactor
22 / 79

Tritium Science and Technology

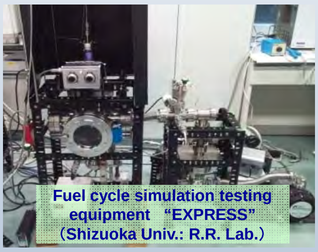
General joint research (Kyushu Univ.)



Interactive joint research



General joint research (Nagoya Univ.)



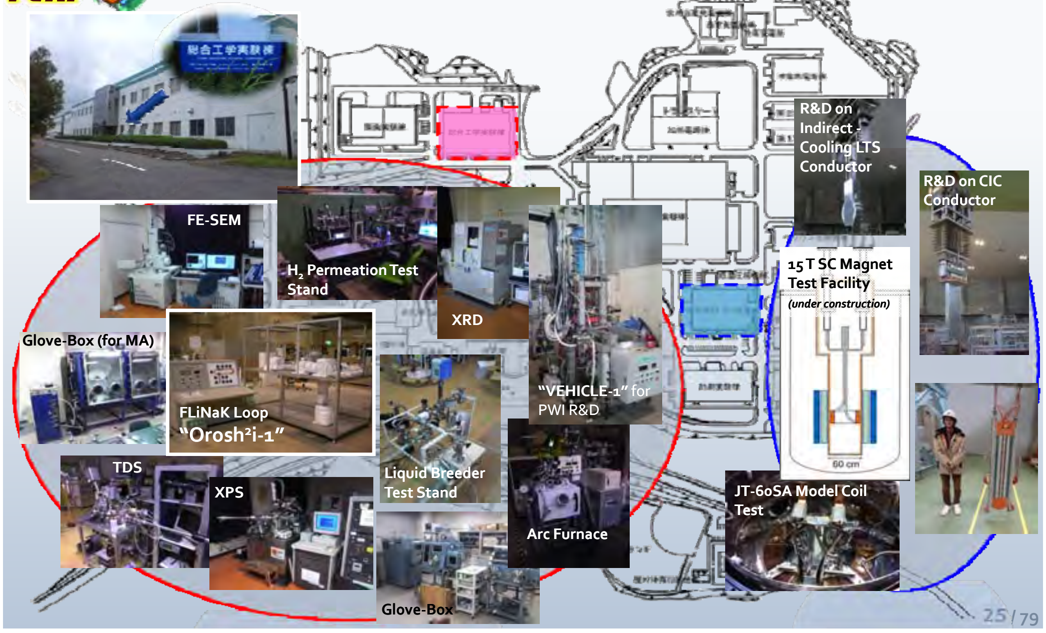
LHD plan joint research

(1-3) Research Environment

Devices for engineering research in NIFS since 1989

Year	The main fusion engineering research equipment in NIFS	Events
1989		NIFS established
1990	Surface analysis and testing equipment (SUT) and Active Cooling Test-stand (ACT) were introduced Large superconducting test facility was introduced	
1995	Micro-hardness tester was introduced	
1997	Fatigue testing equipment was introduced	LHD first plasma
1998	Scanning electron microscope was introduced	
1999	30 kg Vanadium ingot (NIFS-HEAT-1) production	Fusion Engineering Research Center established
2000	170 kg Vanadium ingot (NIFS-HEAT-2) production	
2001	X-ray photoelectron spectrometer was introduced	
2002	Osaka Univ. : Powerful neutron source lithium target test facility	
2005	Creep testing machine (Unit 1) was introduced	
2006	X-ray diffractometer was introduced	
2007	Creep testing machine (Unit 2) was introduced	
2008	Liquid lithium loop production and operation	
2009		External evaluation on engineering research
2010	Creep testing machine (Unit 3) was introduced	FERP launched
2011	Production of particle dispersion strengthened vanadium alloy	
2012	Field emission scanning electron microscope was introduced Molten salt loop (Orosh2i-1) production and operation	Large supplementary budget secured
2013	Variable temperature low temperature equipment (Supercritical helium generator etc. update) Conductor magnet test facility (Including variable temperature current lead) Heat and mass flow loop equipment (Orosh2i-2) Transmission electron microscope (TEM) Ultra-high vacuum creep testing machine Bond testing equipment (HIP, Ball mill etc.) Active Cooling Test-stand (ACT-2) Hydrogen accumulation analyzer (Pelletron Accelerator Surface Analyzer and SEM) ＬＨＤ irradiation testing equipment (Focused ion beam system, TDS etc.) Hydrogen testing and measurement equipment (Gas composition analyzer, FTIR, etc.) Electron beam processing machine	External evaluation

(1-3) Research Environment



Large Supplementary Budget of 2.4 Billion JPY in FY2012

(1) SC Magnet

- 13 T SC magnet test facility, …

(2) Blanket

- Twin loop with 3T SC magnet, …

(3) Low-Activation Material

- HIP device, TEM, creep test device, …

(4) Divertor

- High heat load test device of 10 MW/m², pelletron tandem accelerator of 1 MV, …

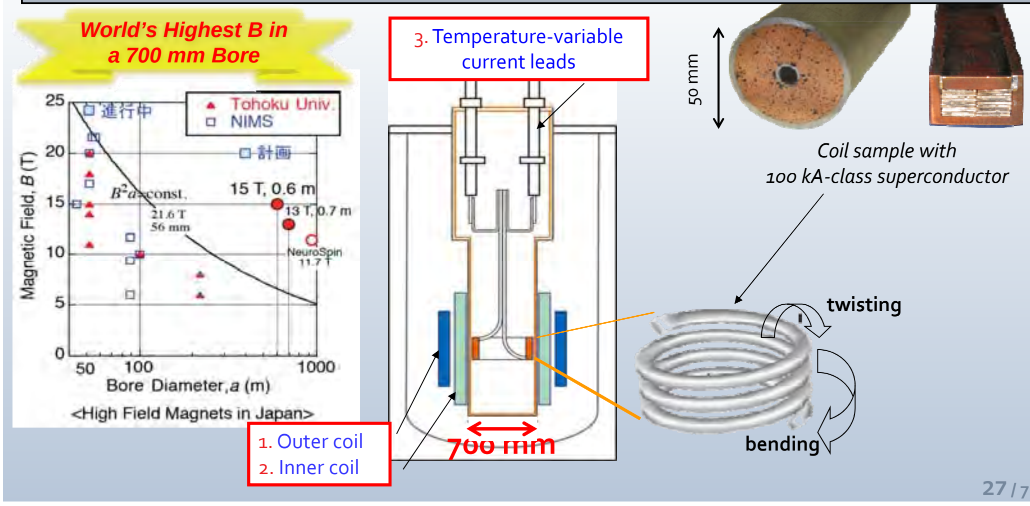
(5) Tritium

- Gas / liquid analyzer, …

15 T SC Magnet Facility

R&D by SC magnet TG

The superconductor testing facility at "Superconducting Magnet Systems Research Laboratory" will be upgraded (after 25 years operation) to increase the bias magnetic field from 9 T to 15 T so that 100 kA-class conductor samples will be tested at temperature 4 – 50 K

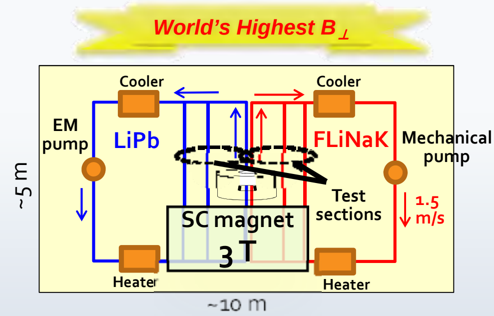


Twin Loops with 3T SC Magnet

R&D by Blanket TG

✓ Orosh²i-2

- Operational Recovery Of Seperated Hydrogen and Heat Inquiry
- Forced circulation loops of FLiNaK (~500 ℃) and LiPb (~300 ℃)
- Integrated test stand with a SC magnet of 3 T



Basic configuration of ***Orosh²i-2***

Specifications of Orosh²i-2

- ***Pipe diameter*** *: 1 inch*
- ***Normal operation temp.*** *: FLiNaK 500 ℃, LiPb 300 ℃*
- ***Maximum flow velocity*** *: ~1.5 m/s* ***Inventory*** *: ~100 L*
- ***Magnetic field*** *: max. ~3 T (CS magnet), 50 cm Φ x 15 cm*

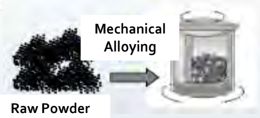
✓ Simulation of temperature and flow velocity in fusion blanket

✓ Integrated tests of MHD pressure drop, control of laminar and turbulence flow, hydrogen and heat recovery, corrosion behavior etc. under intense magnet field.

✓ Test stand for elemental technologies developed in collaborative studies.

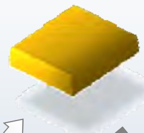
HIP Device, TEM, Creep Test

R&D on low-activation materials by Blanket TG



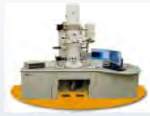
- ☐ Planetary ball milling

Nano-particle dispersion strengthened materials



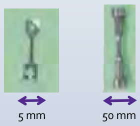
Surface morphology and composition

- ■ Field Emission SEM (existing)



- ☐ TEM
- ☐ EDS

HIP
(Hot Isostatic Press)



Miniature size *Standard size*

- ☐ High temperature isostatic sintering and joining test system (Fabrication of medium size test pieces)
- ☐ High temperature creep test facility
- ☐ High speed impact test facility

✓Characterization of nano-particle dispersion

✓Evaluation of high temperature strength and low temperature ductility

Target (non-irradiation)
- Yield stress: 300 MPa <
- Thermal creep: < 1 % at 100 khr
- DBTT: < RT

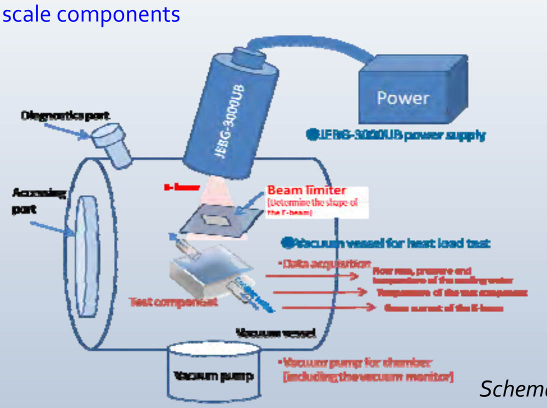
✓Establishing fabrication technology

High Heat Load Test Device

R&D by In-Vessel Components TG

✓ACT-2
- Ultra high heat flux test stand
- 10 MW/m^2 of heat loading by 300 kW electron gun
- Large vacuum vessel
- R&D on material, cooling media, and bonding technique
- Realistic scale components

300 kW electron gun

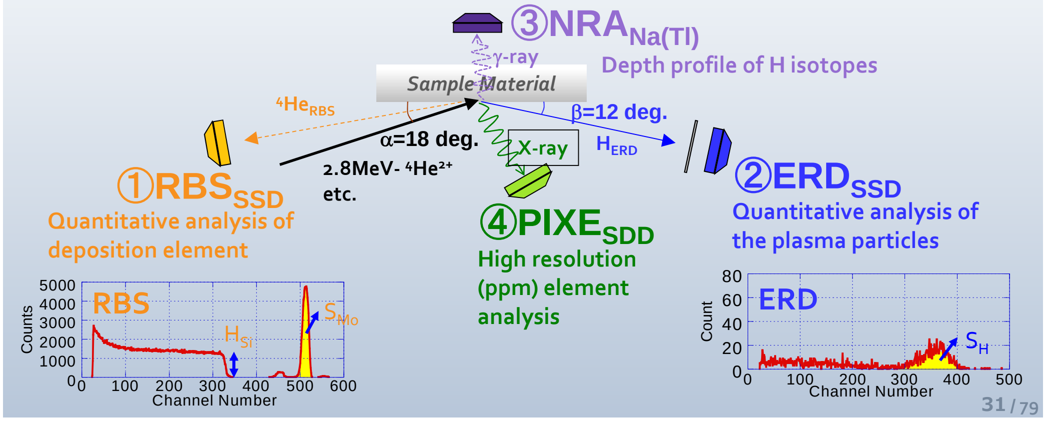


Schematic of ***ACT-2***

Accelerator for Material Test

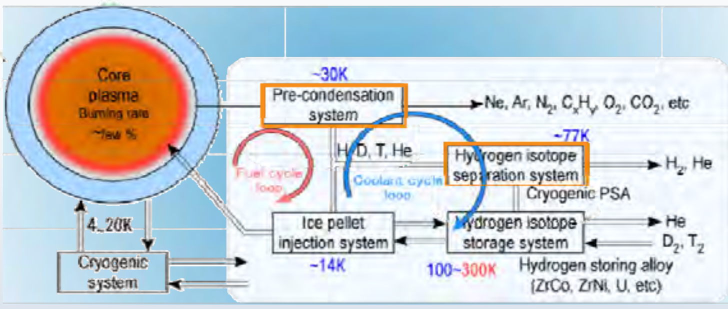
R&D by In-Vessel Components and Blanket TGs

✓ Non-destructive analysis
- By 1 MV pelletron tandem accelerator
- Quantification of the retained H
- Multiple analysis of RBS, ERD, NRA, and PIXE



Advanced fuel cycle system

R&D by Tritium TG



✓ Proposal of a simplified fuel cycle system
- toward low tritium inventory

Feasibility studies of a low temperature processing

Fuel purification processing by **three stage cryogenic condensation system**
[Supported by Dr. Iwamoto (NIFS)]

Hydrogen isotope separation by **cryogenic pressure swing absorption system**
[Kyushu Univ., Dr. Kotoh]

Proposal of tritiated water processing

Tritiated water processing by **dual temperature and dual pressure type CECE system**
[Nagoya Univ., Dr. Sugiyama]

Highly tritiated water processing by **gas phase processing system**
[Univ. of Toyama, bidirectional Collab.]

Support by gas and liquid analyzers

Advanced gas phase tritium analyzer
(Proportional counter with a pulse shape discriminator)
[Nagoya Univ., Kyoto Univ.]

Advanced tritiated water analyzer
(Solid scintillator type)
[OHYO KOKEN KOGYO CO., LTD]

Stable Isotope analyzer
(FTIR spectrometer, Gas / liquid / solid surface)

Gas chromatograph/ mass spectrometer
(Analyzer in operation)

Summary of [1] Development of Research System and Environment [1] 研究環境の整備

	Points of Evaluation	Facts
1-1	Whether or not the target of FERP, initiated in FY2010, is appropriate 平成２２年度にプロジェクトとして位置付けられた核融合工学研究プロジェクトの目標設定は適切か	The target of FERP ("*Promotion of conceptual and baseline designs toward realization of a steady-state helical fusion reactor and construction of engineering basis that enables real-scale and real-environment R&D*") is appropriate: ✓ FERP has successfully launched as the PROJECT of NIFS ✓ Roadmap and tasks to do are defined with five fundamental R&Ds
1-2	Whether or not the organization of FERP is coincident with its target and properly functioning? 推進体制は目標に合致し、適切に機能しているか	The organization of FERP coincide with the target and properly functioning: ✓ 13 TGs are organized based on the tasks defined by the target ✓ The leaders meeting is properly leading the project ✓ The project meeting of more than 70 times has been held ✓ Collaborations with other groups are being carried out successfully
1-3	Whether or not an appropriate research environment is provided for the establishment of academic fundamentals 工学基盤の構築を可能とする研究環境の整備は適切に進められているか	The research environment in NIFS is being provided appropriately: ✓ Five fundamental R&Ds are going on successfully ✓ Collaborations with other groups are being carried out successfully ✓ The research environment is now widely improving with the large supplementary budget in FY2012

[2] Research Achievements

~ Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor

研究成果 ～ヘリカル型核融合炉の研究を進めることにより、国際的に高いレベルの成果を上げているか

(2-1) Helical fusion reactor design

ヘリカル型核融合炉の設計

(2-2) R&D toward establishment of the engineering basis

工学基盤構築に向けた研究

(2-1) Helical Fusion Reactor Design

- ✓ Conceptual design of FFHR-d1
- ✓ The newest version of FFHR series
- ✓ Phased design activity
- ✓ Each consideration stage is called the '**Round**'

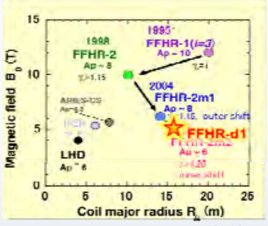


Figure from A. Sagara et al., Fusion Eng. Des. 85 (2010) 1336.

- **Round 1** (FY 2010 – 2011)
  - Determination of basic device parameters of FFHR-d1

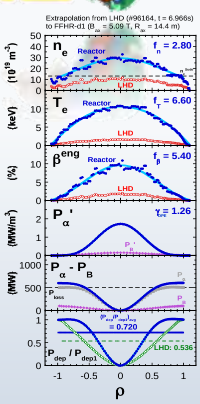
Core plasma TG — *Radial profiles*
In-vessel components TG — *Radial build*
Design Integration TG — *Design window*
Blanket TG — *Neutronics (TBR)*
Superconducting coil TG — *Cooling capability*

- **Round 2** (FY 2011 –)
  - Design of in-vessel components
  - Collaboration with LHD / Numerical Simulation Research projects

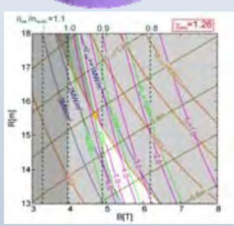
Blanket TG — *3D blanket design, 3D neutronics*
Design Integration TG — *Consistency check, Numerical model*
In-vessel components TG — *Divertor design, Pumping*
Core plasma TG — *Direct Profile Extrapolation*
LHD project — *Experiment*
Num. Sim. Res. project — *Physics analysis*

1st Round

FFHR-d1 design parameters are determined

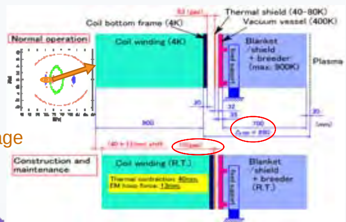


1 Estimate radial profiles in FFHR-d1 by extrapolating the profile data obtained in LHD (DPE: Direct Profile Extrapolation)



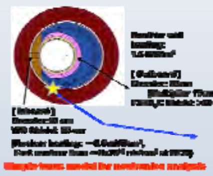
2 Identify the design window by an integration code HELIOSCOPE

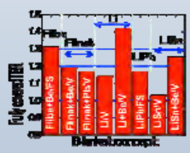
3 Determine the radial build by taking into account the shrinkage of cooled devices



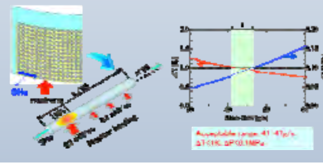
Core plasma TG — *Radial profiles*
In-vessel components TG — *Radial build*
Design Integration TG — *Design window*
Blanket TG — *Neutronics (TBR)*
Superconducting coil TG — *Cooling capability*

4 TBR estimation by neutronics calculation of the breed and shield blankets





5 Cooling simulation of SC helical coils to determine the tolerable nuclear heating



Design Parameters of FFHR-d1

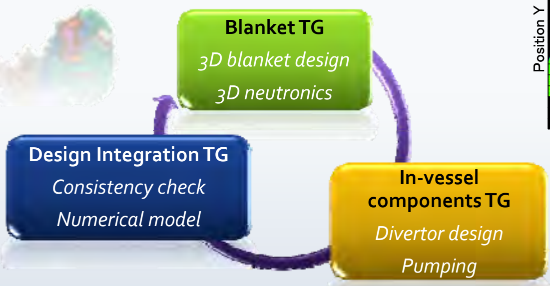
ISFNT 2011

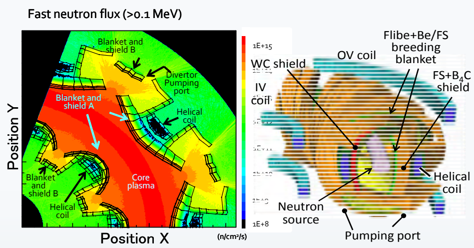
A. Sagara et al., Fusion Eng. Des. **87**, 594 (2012)

			LHD	FFHR2	FFHR2m1	FFHR2m2		FFHR-d1
						Standard	SDC	
Coil pitch parameter	γ_c		1.25	1.15	1.15	1.2		1.25
Coil major radius	R_c	m	3.9	10	14.0	17.3		15.6
Plasma major radius	R_p	m	3.75	10	14.0	16.0		14.4
Plasma minor radius	a_p	m	0.61	1.24	1.73	2.35		2.54
Plasma volume	V_p	m^3	30	303	827	1744		1878
Blanket space	Δ	m	0.12	0.7	1.1	1.05		0.765
Magnetic field	B_0	T	4	10	6.18	4.84		4.7
Magnetic energy	W_{mag}	GJ	1.64	147	133	160		160
Fusion power	P_{fus}	GW		1	1.9	3		3
Neutron wall load	Γ_n	MW/m^2		1.5	1.5	1.5		1.5
H factor of ISS95	H^{ISS95}			2.40	1.92	1.92	1.64	2
Plasma beta (evaluated with B_{ax})	$<\beta>$	%		1.6	3.0	4.4	3.35	5
Divertor heat load (Δ 0.1m) (on average)	Γ_{div}	MW/m^2			5	7.2	1.9	8.1
Total capital cost		G$(2003)		4.6	5.6	7.0		
COE		mill/kWh		155	106	93		

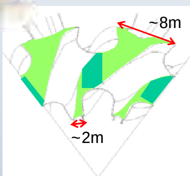
2nd Round

Design of in-vessel components

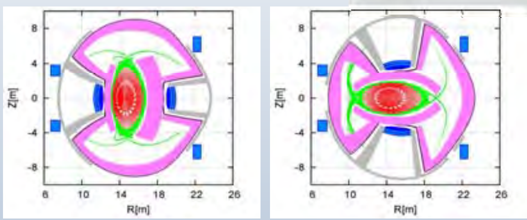


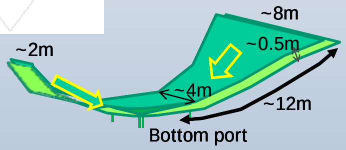


Estimation of the neutron flux distribution by the 3D simulation code MCNP【Blanket TG】



Design of the pumping ducts to realize a high-conductance【In-vessel components TG】





Numerical modeling of the blanket poloidal shape being consistent with plasma and divertor legs at arbitrary toroidal angle ϕ【Design integration TG】

Structural Analysis with 3D-CAD

Large maintenance ports are applicable with tolerable EM stress

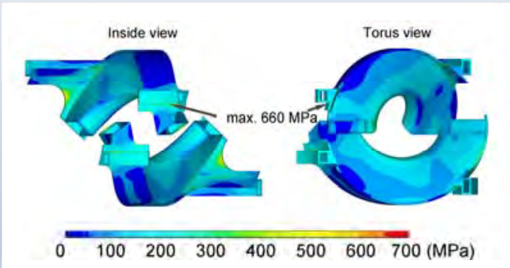
ISFNT 2013

R_c = 15.6 m, B_c = 4.7 T, P_{fusion} ~ 3 GW

Upper port
(6 m x 10 m x 11 m)

Outer port
(bottom 8.5 m x height 7.5 m)

- ✓Numerical modeling of in-vessel components
  - Make modification of the design and translation between CAD softs easy
- ✓3D structural analysis
  - Von Mises stress < 660 MPa with 250 mm thick helical coil case
- ✓Maintenance scenario
  - Parallel maintenance from large 10 ports

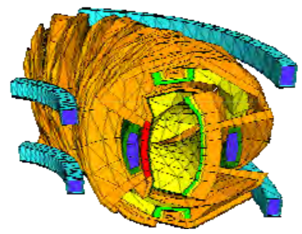


Results of structural analysis

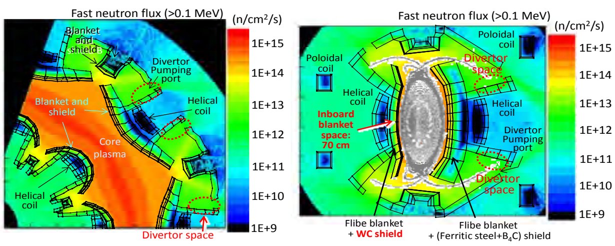
3D Neutronics Analysis

ISFNT 2013

Neutron flux can be reduced at divertor set behind the blanket



3-D neutronics calculation model keeping consistency with core plasma, magnet, in-vessel component designs.



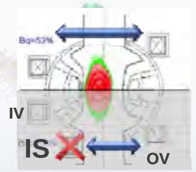
Fast neutron flux distribution calculated by MCNP code

- ✓3-D neutronics analysis
  - Sufficient radiation shielding and tritium breeding (TBR: ~1.08) performances of the FLiBe blanket have been shown by MCNP
  - Irradiation damages on divertors set behind the radiation shield will be ~1/10 (1.0-1.6 dpa/y) at inboard and ~1/100 (0.06 dpa/y) at outboard compared with those at the first wall
  - Possibility of applying copper alloy for divertor cooling emerges

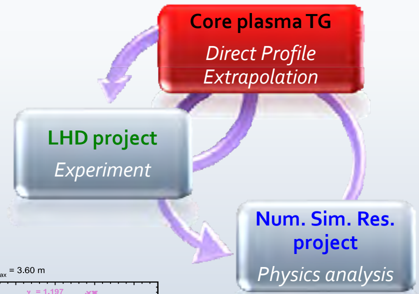
Inter-Project Collaboration

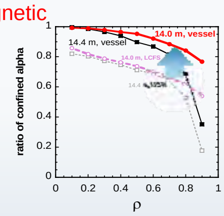
With the LHD project and the Numerical Simulation Research Project

1 Proposal of experiments in LHD using the similar magnetic configurations as FFHR-d1



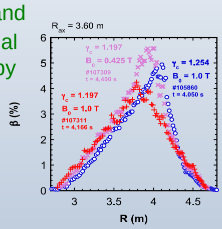
The number of poloidal coils is reduced from 6 in LHD to 4 in FFHR-d1 to secure large maintenance ports





Both of the alpha re-entering effect and the plasma position control is effective to reduce the alpha loss 【MORH】

2 Plasma experiment and estimation of the radial profiles in FFHR-d1 by DPE (Direct Profile Extrapolation)

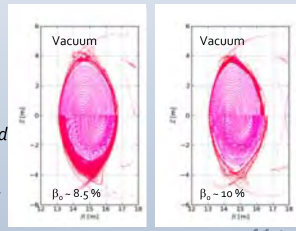


Shafranov shift is mitigated in the high aspect ratio configuration (red and magenta) compared with the standard configuration (blue)

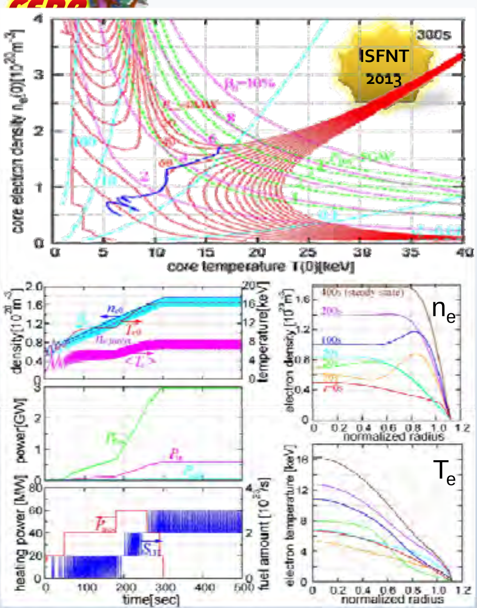
3 Identification of the MHD equilibrium in FFHR-d1 using HINT2 and VMEC

Magnetic surfaces are destructed at high-beta (left) can be restoration by the plasma position control (right) 【HINT2】

4 Detailed physics analysis



Operation Scenario is Being Established



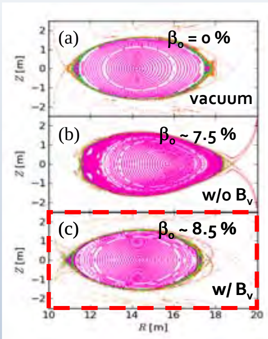
Results of core plasma simulation

✓Quasi 1D plasma simulation

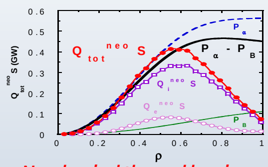
- Profile effect is taken into account based on NGS (Neutral Gas Shielding model) and DPE (Direct Profile Extrapolation method)

✓Detailed physics analyses

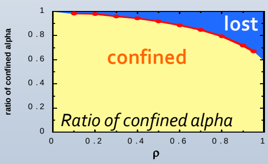
- Shafranov shift mitigation is possible
- Neoclassical loss and alpha loss are tolerable



Magnetic surfaces similar to those in vacuum are obtained at high beta by applying B_v



Neoclassical thermal loss is compatible with the α heating



Direct loss of alpha particles is tolerable

(2-2) R&D

Five fundamental engineering studies are ongoing

SC Magnet

R&D on three kinds of SC Magnet

- Demonstration of 100 kA in HTS coil

Tritium / Safety

R&D on hydrogen isotope processing

Blanket

R&D on elemental technologies for liquid blanket

- Demonstration of FLiNaK circulation in Orosh²i-1

LHD

Collaboration with LHD

- ✓ FFHR configuration
- ✓ Material test
- ✓ EBW
- ✓ Hydrogen isotope processing
- ✓ Neutron diagnostics

High Heat / Particle Load Handling

R&D on the divertor device

- Bonding of W and Cu / RAFM
- Detachment exp. In LHD

Low-Activation Materials

R&D on V-alloy and coating

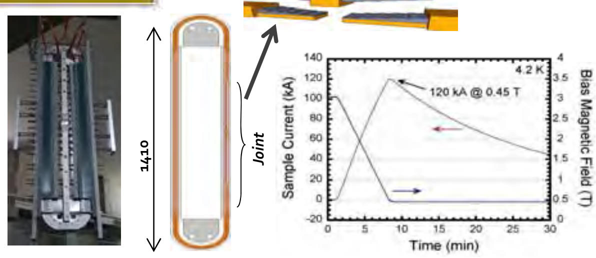
- Improved characteristics of V-alloy at ~700 °C
- Double layer ceramic coating

R&D on SC Magnet

Three types of SC conductor have been developed

High–Temperature Superconductor

Collaboration with Tohoku Univ.



- ✓ High-Temperature Superconductor (HTS) with GdBCO has achieved 100kA@20 K, 5 T and 120 kA@4.2 K, 0.4 T
- ✓ Mechanical lap-joint developed by Tohoku Univ. has satisfied required joint resistance

CIC Conductor Testing

Collaboration with ITER and BA

- ✓ Short-sample conductors and CS model coil were tested for JT-60SA
- ✓ Conductor joint test is being carried out for ITER-TF

Indirectly-cooled Nb_3Sn conductor

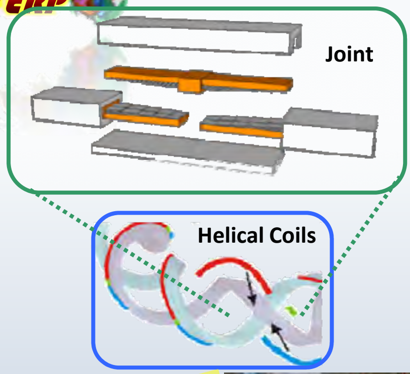
- ✓ Indirectly-cooled Nb_3Sn conductor with Rutherford cable and Al-alloy jacket with Friction Stir Welding is being developed
- ✓ 5 kA@12 T-class sample was tested as a three-turn coil
- ✓ 20 kA@12 T-class & 100 kA@12 T-class samples were fabricated

Progress in the HTS Option of Helical Coils

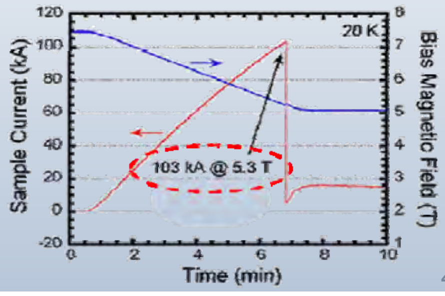
✓HTS: High Temperature Superconductor
- High cryogenic stability (no worry of quench)
- High mechanical strength with YBCO

✓Segmented-fabrication (jointed-winding) of helical coils
- Accelerate the manufacturing process
- No need of large winding machine

✓R&D on the jointed HTS coil
- One turn HTS coil sample with a mechanical joint
- 100 kA coil current has been achieved @20 K, 5 T

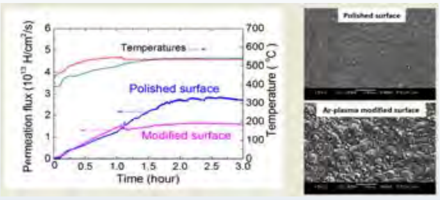


Collaboration with TOHOKU Univ.

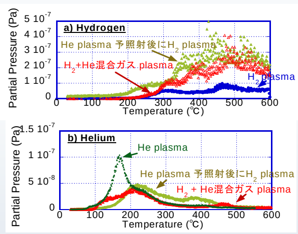


R&D on Blanket

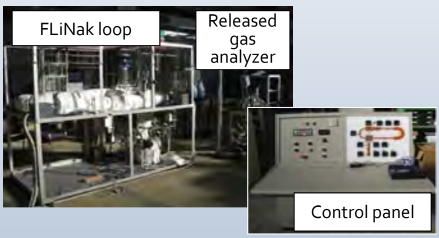
Elemental technologies for liquid blanket have been developed



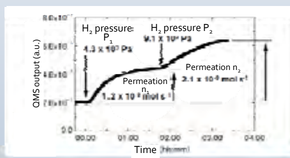
Data acquisition of plasma driven hydrogen permeation through F82H at 520 °C



Analysis of hydrogen retention in F82H after He plasma pre-irradiation



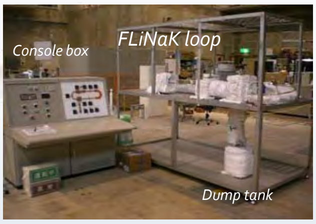
Completion of construction of FLiNaK loop Orosh²i-1 and start of operation.



Development of electrically insulated hydrogen recovery unit for molten salt coolant

FLiNaK Circulation

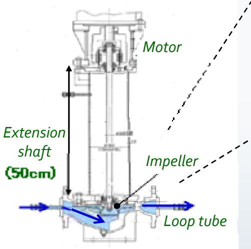
Experiment in Orosh^{2}i-1



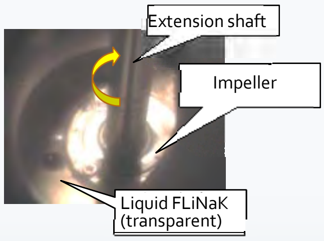
FLiNaK circulation loop system

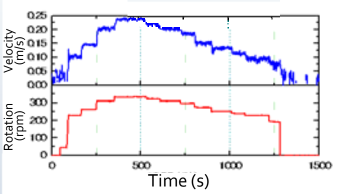
"Orosh²i-1"

Operational Recovery Of Separated Hydrogen and Heat Inquiry



Development of centrifugal pump for high temperature molten salt loop





Specification of Orosh²i-1

- *Pipe diameter : 1/2 inch*
- *Maximum temperature : 600 °C*
- *Maximum flow velocity : ~0.5 m/s*
- *Inventory : ~3 L*

✓The world's first integrated molten salt loop system for study of separate recovery of hydrogen and heat

✓Successful control of FLiNaK circulation and velocity measurement at 500 °C

- Operation of centrifugal pump for high temperature molten salt has been demonstrated

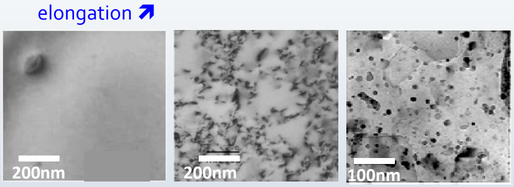
✓Development and experience accumulation on

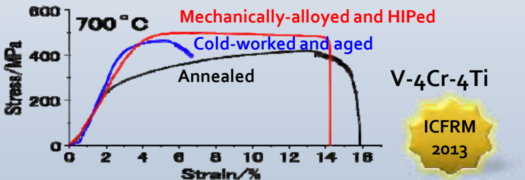
- Circulation control of high temp. molten salt
- Velocity measurement
- Hydrogen charge and recovery
- Handling of molten salt etc.

R&D on Vanadium Alloys and Ceramic Coating

✓V-alloys are promising low activation structural material

- Microstructural control => high-T strength ↗
- Mechanical-alloying and HIP => both strength and elongation ↗





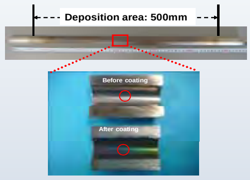
ICFRM 2013

Microstructure and tensile properties of standard and strengthened V-4Cr-4Ti

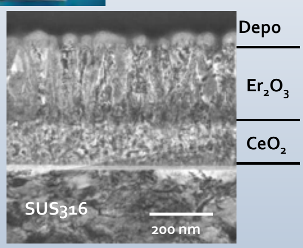
✓Ceramic coating is essential to breeding blankets

ICFRM 2013

- For electrical insulation, and
- Reduction of the tritium permeation
- Double layer Er_2O_3 coating technique on the tube interior has been developed



Er_2O_3 coating on the tube interior

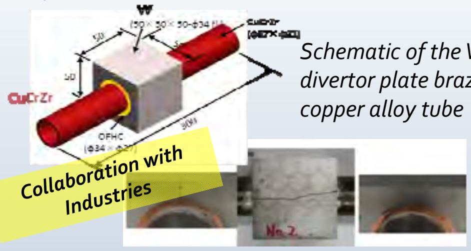


Cross section of the double-layer coating

R&D and Related Researches on Divertor

✓Bonding of tungsten with other metals

- Brazing of tungsten mono-block with copper alloy tube
- Bonding of tungsten mono-block with F82H tube by HIP

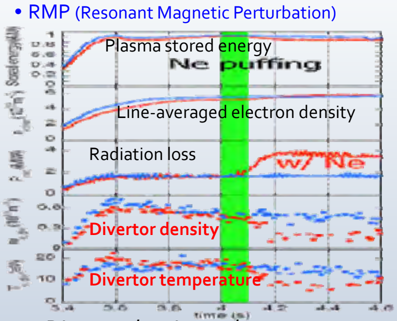


Schematic of the W divertor plate brazed with copper alloy tube

Optimizations of the heat treatment and the sizes of the block and tube are necessary

✓Divertor detachment for heat load reduction

- Detachment experiments in LHD, by
  - Impurity gas puffing
  - Edge density limit at high density
  - RMP (Resonant Magnetic Perturbation)



Divertor density and temperature was reduced by Ne puffing

✓Various researches are also ongoing

- Evaluation of the enhanced radiation loss by Ne
- Spectroscopic study on W
- Interaction between W and hydrogen
- Plasma irradiation test of PFC materials
- Neutral particle simulation (EIRENE)
- MD simulation on C and W
- Configuration optimization for asymmetry mitigation
- Strike-point sweeping for erosion mitigation

Summary of [2] Research Achievements and Environment

[2] 研究成果

	Points of Evaluation	Facts
2	**Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor** ヘリカル型核融合炉の研究を進めることにより、国際的に高いレベルの成果を上げているか	**Many research results have been achieved throughout the reactor design activity and related R&Ds in FERP:** ✓ 150 presentations in total have been given in the international conferences (invited: 14, oral: 26) ✓ 217 papers in total have been published
2-1	**Helical fusion reactor design** ヘリカル型核融合炉の設計	**Conceptual design of the helical reactor FFHR-d1 is proceeding:** ✓ Considerations on plasma, SC magnet, blanket, divertor, in-vessel components, structure, neutronics, etc. ✓ 37 presentations related to the FFHR-d1 design have been given in the international conferences (invited: 4, oral: 3) ✓ 81 papers related to the FFHR-d1 design have been published
2-2	**R&D toward establishment of the engineering basis** 工学基盤構築に向けた研究	**R&Ds on SC magnet, blanket, low-activation materials, divertor, and tritium have been conducted:** ✓ In collaboration with universities ✓ 113 presentations on these R&Ds have been given in the international conferences (invited: 10, oral: 23) ✓ 136 papers on these R&Ds have been published

[3] Encouragement of Joint Activities and Collaborative Research

共同利用・共同研究の推進

(3-1) Whether or not NIFS is promoting collaboration as COE, concentrating the high research ability of universities and others

大学等が有する高い研究能力を結集して、COEとして共同研究を適切に進めているか

(3-2) Whether or not NIFS is contributing to the development of research at universities

大学の研究発展に寄与しているか

(3-3) Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others?

ITER計画やBAなど国際的な活動との連携、貢献を図っているか

(3-1) Collaboration

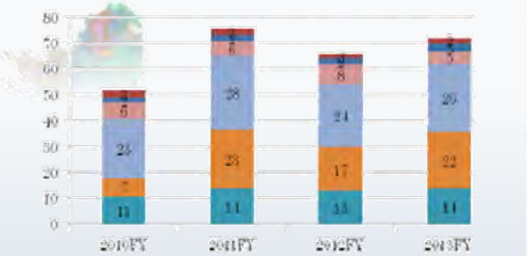
Whether or not NIFS is promoting collaboration as COE, concentrating the high research ability of universities and others

大学等が有する高い研究能力を結集して、COEとして共同研究を適切に進めているか

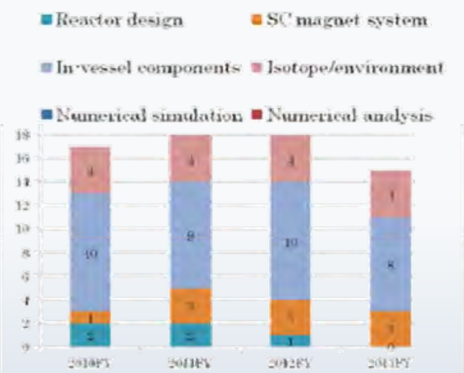
Collaborations on Fusion Engineering in 2010-2013: 542 in Total

- ✓266 under NIFS collaborations
  - 52 on reactor design
  - 69 on SC magnet system
  - 101 on in-vessel components
  - 25 on isotope / environment
  - 19 on numerical simulation / analysis
- ✓64 under LHD project collaborations
- ✓91 under bilateral collaborations
- ✓40 with private companies
- ✓81 by external funds (71 by grant-in-aid of MEXT)

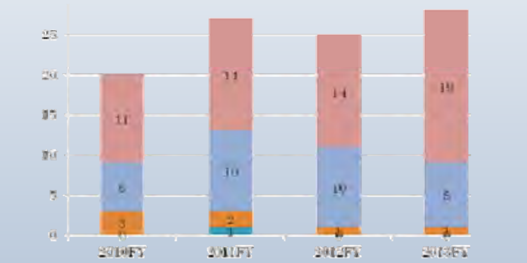
Statistics of Collaboration



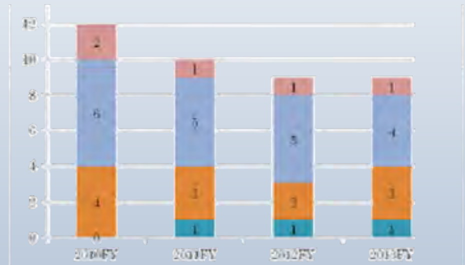
General joint research collaborations



LHD project research collaborations



Bilateral research collaborations



Research collaborations with private companies

(3-2) Research at Universities

Whether or not NIFS is contributing to the development of research at universities

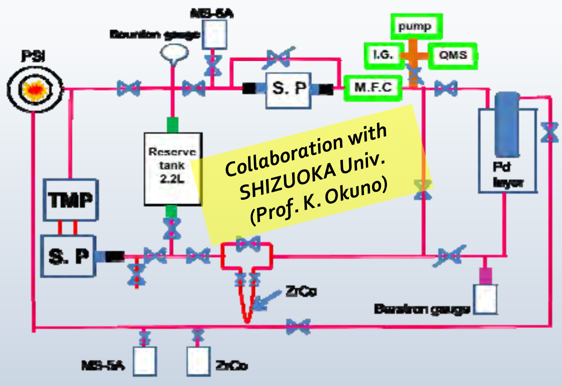
大学の研究発展に寄与しているか

- ✓Tokai University
  - Plasma operation scenario
  - HTS (YBCO) current lead
- ✓The University of Tokyo
  - System code
  - Application of HTS in Mini-RT
  - Material study for liquid blankets
- ✓Tohoku University
  - HTS (YBCO) mechanical joint
  - MHD pressure loss mitigation
  - Fatigue life evaluation
  - Heat removal in FLiBe blanket
  - W alloy
- ✓Kyushu University
  - Tritium balance
  - Hydrogen isotope separation
  - Neutron irradiation effect on SC magnet
  - Environmental dynamics of OBT
- ✓Kagoshima University
  - Stability of HTS (MgB_2) conductor
- ✓Sophia University
  - Current inhomogeneity in CIC conductor
- ✓Toyohashi University of Technology
  - Detection of partial discharge in SC magnet
- ✓Hokkaido University
  - Plasma irradiation effect on H/He retention
- ✓Nagano National College of Technology
  - Hydrogen isotope oxidation
- ✓Kyoto University
  - W coating on low activation materials
  - Energy conversion in divertor
- ✓Akita University
  - Hydrogen isotope trapping
- ✓**Shizuoka University**
  - **Dynamics of hydrogen transport**
- ✓Osaka University
  - PWI study using laser / ion beam induced plume
- ✓Kanazawa University
  - Graphite divertor tile
- ✓The University of Electro-Communications
  - Spectroscopic study of W by EBIT
- ✓Niigata University
  - Charge exchange between W and H
- ✓Nagoya University
  - Neutron measurement system
  - ^{6}Li isotope separation
- ✓University of Occupational and Environmental Health
  - Biological effect of T
- ✓Akita University
  - Hydrogen isotope trapping

… and so on

Example of Cooperative Activities in the NIFS Fusion Engineering Research Project

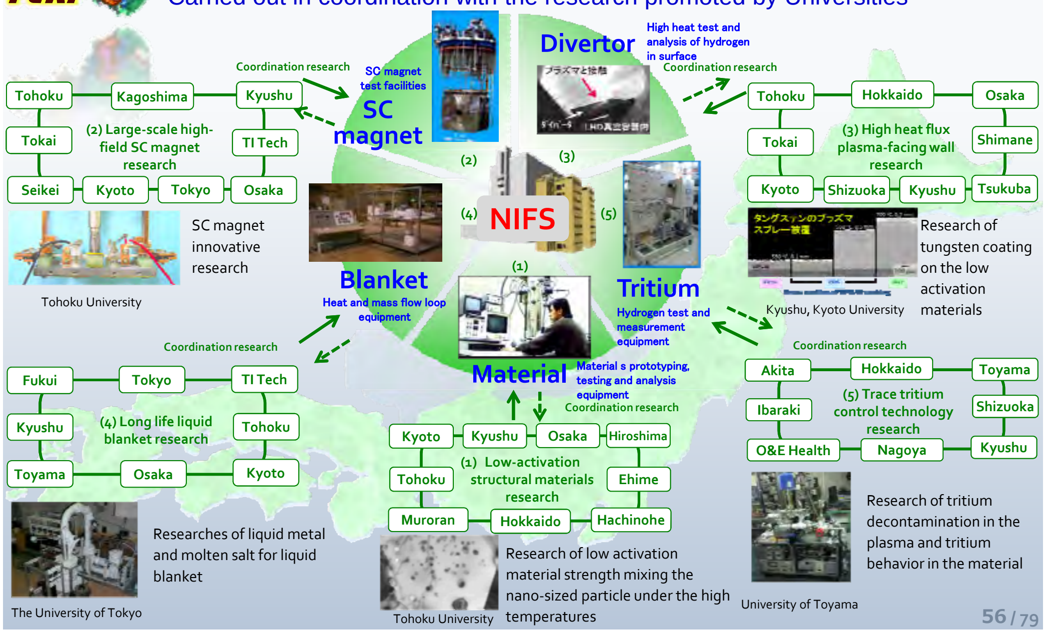
- ✓e.g., Recovery efficiency of hydrogen isotope
  - Important to elucidate the tritium transport in fusion reactor
- ✓Lab. scale experiment of hydrogen circulation in Shizuoka Univ.
  - Named "EXPRESS"
  - Consists of plasma formation system, gas purification system, and gas stock



Schematic of "EXPRESS" in Shizuoka Univ.

Collaboration Network

Carried out in coordination with the research promoted by Universities



(3-3) International Activities

Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others?

ITER計画やBAなど国際的な活動との連携、貢献を図っているか

✓ITER

- SC magnet: ITER-TF coil, cryo system
- NBI: beam simulation, experiments

✓BA

- JT-60SA: SC magnet
- IFERC DEMO R&D: RAFM, SiC, PWI exp. in JET
- IFERC DEMO Design: cost model
- IFMIF-EVEDA: fatigue life evaluation

✓TITAN

- Permeability test of Er_2O_3 coated RAFM in Idaho National Laboratory (INL)
- MHD pressure loss experiment in UCLA (with Tohoku university)
- Irradiation effect on jointing materials (with Osaka university)

✓GENIE

- Provision of atomic and molecular database

Collaboration with ITER

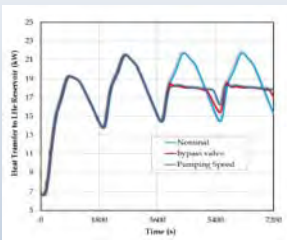
✓SC magnet and cryo system

- ITER-TF coil testing
- Cryo system simulation code C-PREST

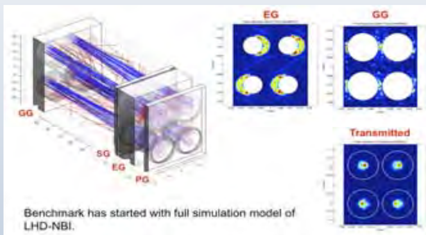
✓Neutral Beam Injection (NBI)

- Beam simulation
- Experiments in NIFS test stand

Performance test of the ITER-TF connection part in NIFS



Simulation results of the heat transfer to LHe reservoir, by C-PREST made in NIFS



3D-beamlet simulation including secondary charged particles

Collaboration with BA

✓JT-60SA

- SC magnet testing

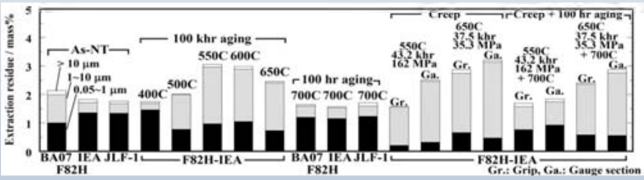
✓IFERC

- Precipitation behavior of F82H-BA07 during aging and creep
- Electrical conductivity and hydrogen permeability of SiC materials under irradiation
- Cost model
- PWI experiment in JET

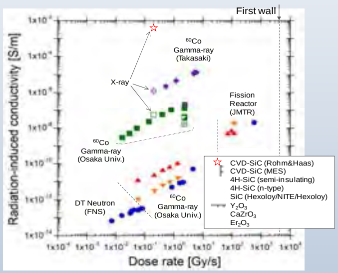
✓IFMIF-EVEDA

- Fatigue life evaluation using small specimen

Performance test of the JT-60SA CS model coil in NIFS



The extraction residue of RAFM (Reduced Activation Ferrite Materials) and the particle size distribution (in each bar)

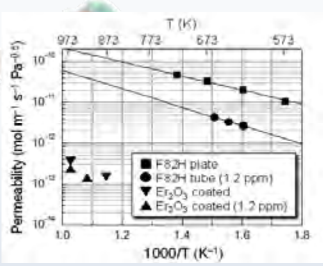


The radiation-induced conductivity in various ceramic materials

Collaboration on TITAN

✓ Japan-US collaboration on Tritium, Irradiation and Thermofluid

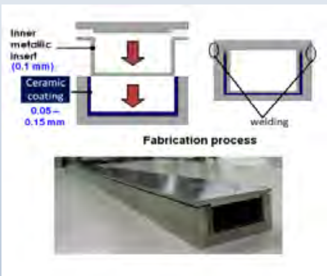
- Following JUPITER and JUPITER-II

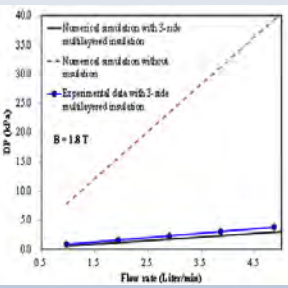


Permeability of F82H with and w/o Er_2O_3 coating

✓Recent Topics

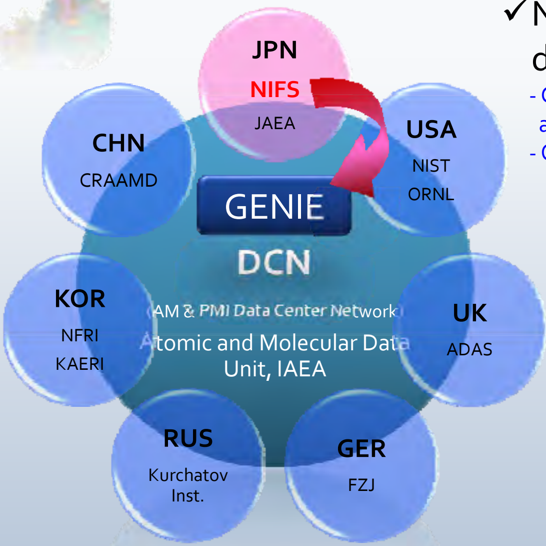
- Permeability test of Er_2O_3 coated F82H using tritium in Idaho National Laboratory
- Mitigation of MHD pressure loss by partial electrical isolation (with Tohoku University)
- Irradiation effect on jointing materials (with Osaka Univ.)





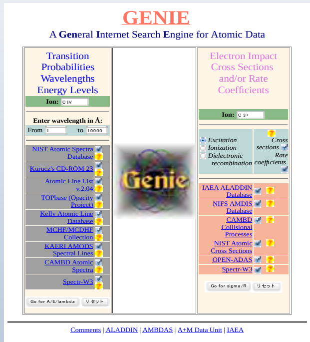
Pressure loss dependence on the flow velocity of Li-Pb in a channel with electrical isolation on three-sides

Collaboration on Atomic and Molecular Database



✓NIFS is Providing the largest database to GENIE

- GENIE is the worldwide search engine of atomic and molecular database
- Organized by DCN (IAEA)



http://www-amdis.iaea.org/GENIE/

Summary of [3] Encouragement of Joint Activities and Collaborative Research

[3] 共同利用・共同研究の推進

	Points of Evaluation	Facts
3-1	Whether or not NIFS is promoting collaboration as COE, concentrating the high research ability of universities and others 大学等が有する高い研究能力を結集して、COEとして共同研究を適切に進めているか	542 collaborations have been performed on the engineering issues of ✓ SC magnet, cryo system, reduced activation material, blanket, divertor, tritium, reactor design, and so on
3-2	Whether or not NIFS is contributing to the development of research at universities 大学の研究発展に寄与しているか	A lot of important researches have been performed at universities, under collaboration with NIFS
3-3	Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others? ITER計画やBAなど国際的な活動との連携、貢献を図っているか	FERP is contributing to ITER, BA, TITAN, atomic and molecular database, by closely cooperating with them

[4] Human Resource Development

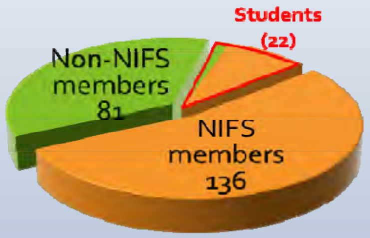
~ Whether or not FERP is bringing up young researchers who can support long-range growth of international fusion study

人材育成 ～核融合研究の長期的な発展を支える国際的に活躍できる人材の育成に貢献しているか

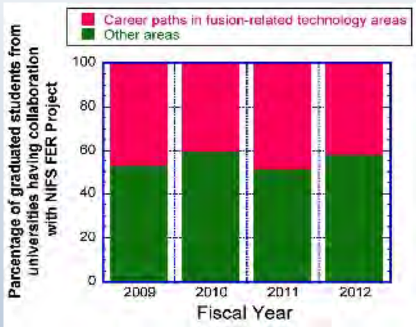
✓ **22** papers have been written by the students grown up through the collaboration with FERP

✓ **A half** of the students are now working in fusion-related technology fields

- Graduated from universities collaborating with FERP
- ~420 collaborations have been carried out by FERP and universities in these 4 years



Breakdown of published papers

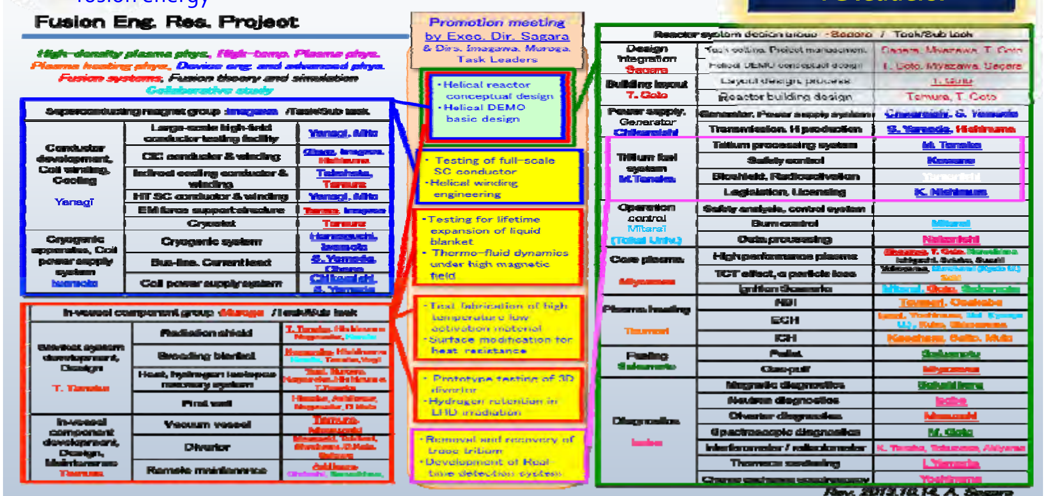


TG Leaders of FERP are YOUNG

✓ Most of them are the thirties or forties

- Each of them is aware of his/her responsibility for realizing the fusion energy

Young Researchers are nominated as the TG leaders!



[5] Future Plan

~ Whether or not the future plan is appropriately pointing at the medium- to long-term target

将来計画 ～目標に向けた今後の研究計画は適切か。特に、中長期的展望を見据えたものとなっているか

✓Next Move on Reactor Design

- New approach
- 3^{rd} round
- Starting peer review with JAEA

✓Next Move on R&D

- Promotion of the 5 major R&Ds toward real-scale and real-environment test in the 3^{rd} mid term

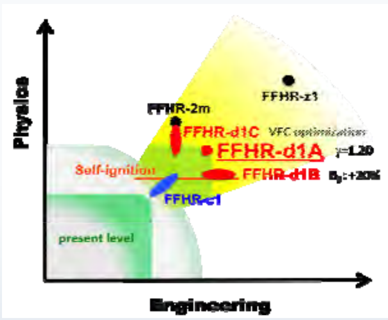
New Approach

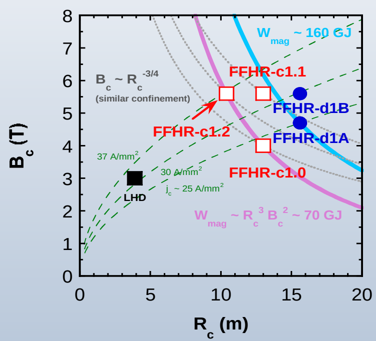
Starting discussion on FFHR-d1A, d1B, d1C, and c1

- ✓ FFHR-d1A is the base for 3D designs with a modified Aspect ratio by reducing the Shafranov shift
- ✓ FFHR-d1B is a flexible design for the ignition core with the magnetic (B) field enhanced by 20%
- ✓ FFHR-d1C is another flexible design with Configuration optimization of vertical field coils
- ✓ FFHR-c1 is a sub-ignition version as "before-demo, compact and component-test"

	FFHR-d1	FFHR-d1A	FFHR-d1B		FFHR-c1.0	FFHR-c1.1	FFHR-c1.2
R_c (m)	15.6	←	←	←	13.0	←	10.4
$V_{p,max}$ (m^3)	1,877	1,421	←	←	823	823	419
B_c (T)	4.7	←	5.6	←	4.0	5.6	←
W_{mag} (GJ)	162.5	←	223.5	←	67.5	125.1	61.4
[illegible]	1.25	1.20	←	←	←	←	←
[illegible]	1.0	0.85	←	←	←	←	←
f_n	5.1	3.7	1.9	1	←	←	←
[illegible]	9.1	9.1	4.5	2.4	←	←	←
P_{aux} (MW)	0	←	←	27	53	40	49
P_{fusion} (GW)	2.7	3.0	1.5	0.43	0.065	0.25	0.13
Q	∞	←	←	16	1.2	6.2	2.6
Γ_n (MW/m^2)	≤ 1.5	1.5	0.73	0.21	0.05	0.18	0.14

~0.5 dpa ~ 2 dpa/year is possible



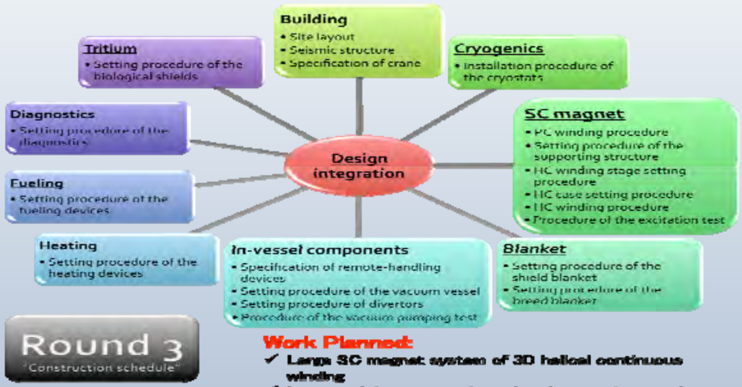


3rd Round

Just started since FY2013

✓ Maintenance method and construction process are being discussed in the 3rd round

- What are the concrete problems in the construction process?
- How do we maintain the in-vessel components? ← **also applicable for construction**
- How can we fabricate the large helical coils?



Work Planned:

✓ Large SC magnet system of 3D helical continuous winding

✓ Large maintenance ports and replacement scenarios

Starting Peer Review with JAEA

Renewal of the collaboration style with JAEA

1994: Collaboration on FFHR design started

2013: All Japan combined team for DEMO development planning launched

➔ Reinforcement of collaboration with JAEA

[Schedule]

25-27 Nov. 2013: 1st Meeting @ Rokkasho

Feb./Mar. 2014: 2nd @Toki

May/Jun. 2014: 3rd @Rokkasho

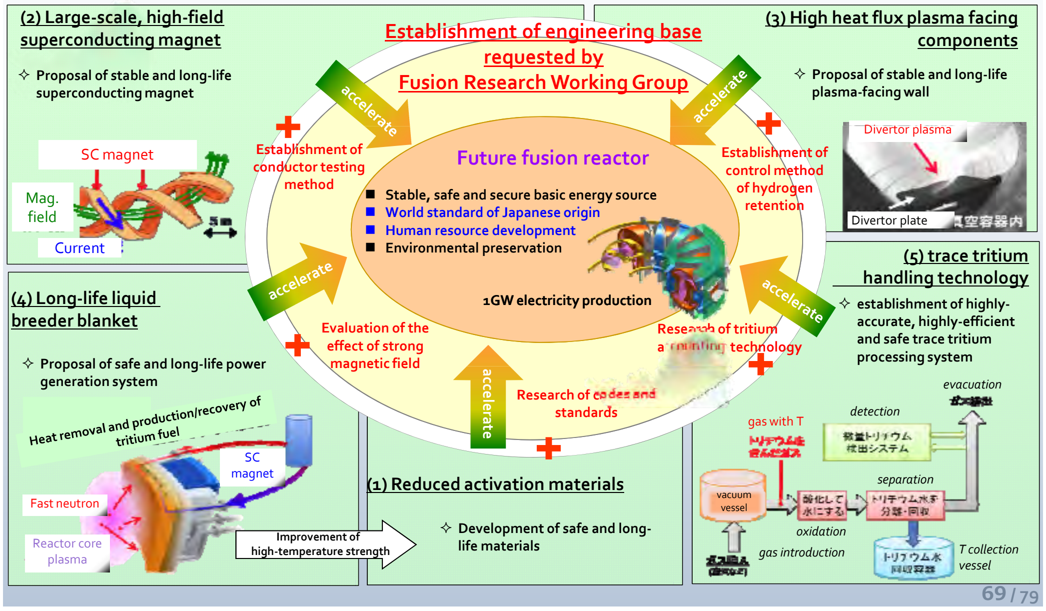
2014: 4th @Toki

✓ Problem-solving by peer review

- Helical reactor design by NIFS (FERP)
- Tokamak reactor design by JAEA

Next Move on R&D

Toward real-scale and real-environment test in the 3rd mid term



Summary of [4] Human Resource Development and [5] Future Plan

[4] 人材育成　[5] 将来計画

	Points of Evaluation	Facts
4	**Whether or not FERP is bringing up young researchers who can support long-range growth of international fusion study** 核融合研究の長期的な発展を支える国際的に活躍できる人材の育成に貢献しているか	**FERP is bringing up young researchers:** ✓ 22 papers have been written by students who collaborated with FERP ✓ A half of the students found their jobs in the fusion-related technology fields ✓ Most of the TG leaders of FERP are 30ies or 40ies who are actively playing important roles in the international fusion community
5	**Whether or not the future plan is appropriately pointing at the medium- to long-term target** 目標に向けた今後の研究計画は適切か。特に、中長期的展望を見据えたものとなっているか	**The future plan of FERP is appropriate:** ✓ Reactor design will proceed to the next step, to draw a concrete view of the helical fusion reactor ✓ R&Ds and collaborations with universities will be accelerated by operating the devices provided by the large supplementary budget in FY2012

Points of Evaluation based on Proposals from the External Evaluation in FY2009

1. **Whether or not fusion engineering research is developed across the board with the emphasis on helical reactors design**
   ヘリカル炉設計を軸に組織横断的に核融合工学研究を発展させているか
2. **Whether or not NIFS is acting as the center for national research on advanced blankets and reduced activation materials as well as taking the leadership from the international research point of view**
   核融合科学研究所が先進ブランケット及び低放射化材料研究の国内拠点となり、国際的にも研究の主導的立場を確保しているか
3. **Whether or not NIFS continues to develop superconducting coils for fusion reactor development**
   核融合炉開発に向けた超伝導コイル研究を推進しているか
4. **Whether or not efforts are being made to encourage young researchers to participate in the fusion rector research project**
   核融合炉研究プロジェクトを担う若手研究者を育成しているか
5. **Whether or not the fusion engineering research project conducted by NIFS contributes to the establishment of academic fundamentals for helical fusion reactors**
   核融合科学研究所の進める核融合工学研究の発展がヘリカル核融合炉実現のための学術体系の構築に大きく貢献しているか

Tasks have been Taken Over

Researches before 2010 are continued with additional tasks in FERP since 2010

	Subject
LHD	(1) Higher field by subcooling
	(2) Dynamic control of plasma axis
	(3) High reliability of LHD SC system
R&D for Reactor	(4) Nb_3Sn, Nb_3Al conductor/coil
	(5) HTS, MgB_2 development
	(6) Thermoacoustic applications
	(7) Cryotarget
	(8) SC power line
	(9) Neutron irradiation effect
	(10) New SC wires
	(11) Conduction cooled magnet
Material	Radiation effects on V-alloy weld joints
	W coating on V-alloys
	Thermal creep of RAFM and V-alloys
Corrosion	Corrosion of RAFM in Flibe and Flinak
	Corrosion of RAFM and V-alloys in Li
Coating	Fabrication of insulator and T-barrier coating
H-monitor	H-monitoring system in liquid breeder
Neutronics	Tritium Breeding Ratio for FFHR
	Experimental check
Maintenance	Long-life blanket
	Wide ports
Reactor size	Blanket space
	Magnetic energy
Ignition access	Heating power
	New regime for SDC
Neutronics	Neutron economy
SC magnet	Large helical coils
	Cooling
	Support post
Tritium Monitor	Hydrogen Pump
	Separation of Hydrogen and Tritium
	High sensitive T gas monitor
Tritium Recovery	H/T separation with CECE
	Low loss oxidation material
	Compact & high efficient dehumidifier
	Compact T recovering system
	Develop H/T separation with ZrNi
Prepare for Deuterium Experiments in LHD	T retention, desorption and removing
	Measuring T in concrete
	High sensitive H analyzer
	Design of RI monitoring cart
	Biological effect
	Environmental effect of tritium

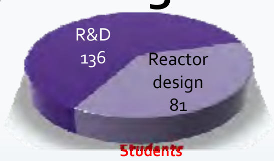
Task	Subject
[SC Magnet] ● Conductor development ● Coil winding ● Cooling	Large-scale high-field conductor testing facility
	CIC conductor & winding
	Indirect -cooling LTS conductor & winding
	HTS conductor & winding
	EM force support structure
[Cryogenic] ● Cryogenic system ● Coil power supply system	Cryogenic system
	Bus-line and current-lead
	Coil power supply system
[Blanket] ● Blanket system development ● Blanket design	Radiation shield
	Breeding blanket
	Heat, hydrogen isotopes recovery system
	First wall
[In-Vessel Components] ● In-vessel component development ● Structural design ● Maintenance	Vacuum vessel
	Divertor
	Remote maintenance
[Design Integration]	Task setting and project management
	Conceptual design of helical fusion reactor
[Building Layout]	Layout design and construction process
	Reactor building design
[Power Supply] ● Power supply ● Generator	Generator and power supply system
	Transmission and hydrogen production
[Tritium]	Tritium fuel balance
	Tritium safety handling
	Tritium decontamination
	Tritium monitoring
[Operation Control]	Safety analysis and control system
	Burn control
[Core Plasma]	Plasma experiment
	MHD equilibrium and stability
	Neoclassical transport
	Alpha heating
	Anomalous transport
	Plasma operation scenario
[Plasma Heating]	NBI
	ECH
	ICRF
[Fueling]	Pellet
[Diagnostics]	Investigation of available diagnostics
	Neutron diagnostics
	Spectroscopic diagnostics
	Interferometer / reflectmeter
	Thomson scattering

Points of Evaluation based on Proposals from the External Evaluation in FY2009

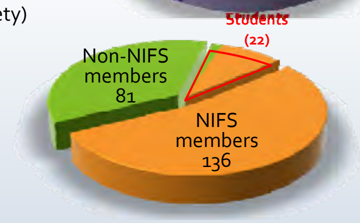
	FY2009	FY2013
1	Whether or not fusion engineering research is developed across the board with the emphasis on helical reactors design	**FERP is developing the fusion engineering research:** ✓ With the researchers from various scientific fields ✓ Collaboration with LHD project / Num. Sim. Res. Project on FFHR-d1 is successfully ongoing
2	Whether or not NIFS is acting as the center for national research on advanced blankets and reduced activation materials as well as taking the leadership from the international research point of view	**FERP is internationally leading the study on advanced blanket and reduced activation materials:** ✓ Especially on the FLiBe blanket and V alloy ✓ Twin loops for molten salt / LiPb circulation test with 3 T magnetic field will be the "only one" in the world
3	Whether or not NIFS continues to develop superconducting coils for fusion reactor development	**FERP is continuing to develop three types of SC magnet for fusion reactor:** ✓ Collaboration with ITER and BA (JT-60SA) ✓ Jointed winding of HTS helical coil is the new original idea
4	Whether or not efforts are being made to encourage young researchers to participate in the fusion rector research project	**FERP is encouraging young researchers to join:** ✓ Young researchers are nominated as TG leaders ✓ Important issues are assigned to young researchers
5	Whether or not the fusion engineering research project conducted by NIFS contributes to the establishment of academic fundamentals for helical fusion reactors	YES, we think so! **HOW about you?**

Summary of Publications and Collaborations on Fusion Engineering

1. Publications in 2010-2013: 217 in total

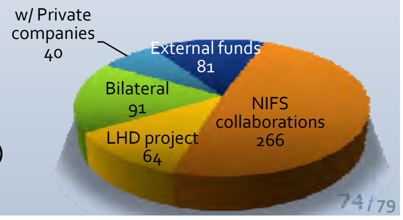


- ✓136 on R&D
  (17 on SC magnet & Cryogenics, 25 on Low activation materials, 62 on Blanket & First wall, 46 on Divertor, 56 on Tritium & Safety)
- ✓81 on Reactor Design
  (28 on Concept & System design, 21 on Core plasma control, 11 on Plant equipment & related technology)
- ✓81 written by non-NIFS staffs
- ✓22 written by students



2. Collaborations in 2010-2013: 542 in Total

- ✓266 under NIFS collaborations
  (52 on reactor design, 69 on SC magnet system, 101 on in-vessel components, 25 on isotope / environment, 19 on numerical simulation / analysis)
- ✓64 under LHD project collaborations
- ✓91 under bilateral collaborations
- ✓40 with private companies
- ✓81 by external funds (71 by grant-in-aid of MEXT)



"Interim Report on the Conceptual Design of the FFHR-d1 Helical Fusion Reactor" has Come Out

✓Reduced version was published in Journal of Plasma and Fusion Research

http://www.jspf.or.jp/Journal/PDF_JSPF/jspf2013_06/jspf2013_06-359.pdf

(1-2) Whether or not the organization of FERP is coincident with its target and properly functioning?

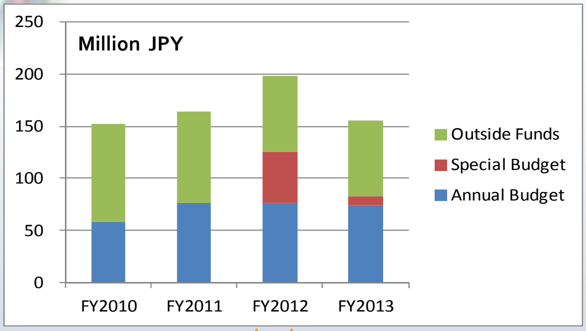
NIFS Fusion Engineering Research Project member				December, 2013	
	Name	Division or University	Title	TASK (including design and R&D)	Group Leader / Task L / Sub TL
1	Sakamoto	High-Density Plasma Physics	Aso. P	Fueling	TL
2	Morisaki	High-Density Plasma Physics	Prof.	In-vessel component	
3	Sakakibara	High-Density Plasma Physics	Aso. P	Diagnostics	STL
4	Ohdachi	High-Density Plasma Physics	Aso. P	In-vessel component	
5	Goto, M	High-Density Plasma Physics	Aso. P	Diagnostics	STL
6	Narusima	High-Density Plasma Physics	Asi. P	In-vessel component	
7	Tanaka, K	High-Temperature Plasma Physics	Aso. P	Diagnostics	STL
8	Isobe	High-Temperature Plasma Physics	Aso. P	Diagnostics	TL
9	Yamada, I	High-Temperature Plasma Physics	Aso. P	Diagnostics	STL
10	Nakanisi	High-Temperature Plasma Physics	Aso. P	Operation control	STL
11	Tokuzawa	High-Temperature Plasma Physics	Aso. P	Diagnostics	
12	Akiyama	High-Temperature Plasma Physics	Asi. P	Diagnostics	
13	Yoshinuma	High-Temperature Plasma Physics	Asi. P	Diagnostics	STL
14	Shimozuma	Plasma Heating Physics	Prof.	Plasma heating	
15	Mutoh	Plasma Heating Physics	Prof.	Plasma heating	
16	Tsumori	Plasma Heating Physics	Aso. P	Plasma heating	TL
17	Saito	Plasma Heating Physics	Aso. P	Plasma heating	
18	Osakabe	Plasma Heating Physics	Prof.	Plasma heating	
19	Yoshimura	Plasma Heating Physics	Aso. P	Plasma heating	
20	Igami	Plasma Heating Physics	Asi. P	Plasma heating	STL
21	Kasahara	Plasma Heating Physics	Asi. P	Plasma heating	STL
22	Seki	Plasma Heating Physics	Asi. P	Core plasma	
23	Mito	Device Engineering and Advanced Physics	Prof.	Coil	
24	Takahata	Device Engineering and Advanced Physics	Prof.	Coil	STL
25	Imagawa	Device Engineering and Advanced Physics	Prof. Div.Dir	Coil	GL of SC magnet
26	Sato	Device Engineering and Advanced Physics	Emeritus		
27	Nisimura, K	Device Engineering and Advanced Physics	Prof.	Tritium	STL
28	Uda	Device Engineering and Advanced Physics	Emeritus	Operation control	
29	Yamada, S	Device Engineering and Advanced Physics	Aso. P	Cryogenics	STL
30	Yanagi	Device Engineering and Advanced Physics	Aso. P	Coil	TL
31	Chikaraishi	Device Engineering and Advanced Physics	Aso. P	Power supply / Cryogenics	TL
32	Takayama	Device Engineering and Advanced Physics	Aso. P		
33	Kawano	Device Engineering and Advanced Physics	Aso. P	Tritium fuel system	STL
34	Iwamoto	Device Engineering and Advanced Physics	Aso. P	Cryogenics	TL
35	Tanaka, M	Device Engineering and Advanced Physics	Aso. P	Tritium	TL
36	Hamaguchi	Device Engineering and Advanced Physics	Asi. P	Cryogenics	STL
37	Obana	Device Engineering and Advanced Physics	Asi. P	Coil	STL
38	Natsume	Device Engineering and Advanced Physics	COE	Coil / Cryogenics	
39	Sagara	Fusion Systems	Prof. Exc.Dir	Design Integration and R&D cordination	GL of Design Imtegration
40	Muroga	Fusion Systems	Prof. Div.Dir	Blanket	GL of In-vessel
41	Hirooka	Fusion Systems	Prof.	Blanket	STL
42	Murakami, I	Fusion Systems	Prof.	In-vessel components	
43	Miyazawa	Fusion Systems	Aso. P	Core plasma / Design Integration / Fueling	TL
44	Tanaka, T	Fusion Systems	Aso. P	Blanket	TL
45	Nagasaka	Fusion Systems	Aso. P	Blanket	STL
46	Tamura	Fusion Systems	Aso. P	In-vessel components / Coil / Buliding layout	TL
47	Masuzaki	Fusion Systems	Aso. P	In-vessel components / Diagnostics	STL
48	Goto, T	Fusion Systems	Asi. P	Buliding layout/Design Integration /Core plasma	TL
49	Hishinuma	Fusion Systems	Asi. P	Coil / Cryogenics / Power supply	
50	Ashikawa	Fusion Systems	Asi. P	Blanket / In-vessel components	STL
51	Sakaue	Fusion Systems	Asi. P	In-vessel components	
52	Kato	Fusion Systems	Asi. P	Blanket / In-vessel components	
53	Tokitani	Fusion Systems	Asi. P	In-vessel components	
54	Yagi	Fusion Systems	Asi. P	Blanket	STL
55	Watanabe	Fusion Systems	COE	Blanket	
56	Yokoyama	Fusion Theory and Simulation	Aso. P	Core plasma	STL
57	Satake	Fusion Theory and Simulation	Aso. P	Core plasma	
58	Suzuki	Fusion Theory and Simulation	Asi. P	Core plasma	
59	Mitarai	Tokai Univ.	Prof.	Operation control / Core plasma	TL
60	Murakami, S	Kyoto Univ.	Aso. P	Core plasma	
61	Kondo	Tokai Univ.	Lecturer	Blanket	STL
62	Idei	Kyushu Univ.	Aso. P	Plasma heating	
63	Kozaki	Osaka Univ.	Visiting P		
64	Banzai				Secretary

Supplement

Supplement

(1-3) Whether or not an appropriate research environment is provided for the establishment of academic fundamentals

Budget for Fusion Engineering Research Project



- NIFS facility budget is 4.8 Billion JPY in FY2013.
- Annual budget for NIFS collaboration related to fusion engineering is about 100 Million JPY, which is mainly used in universities.

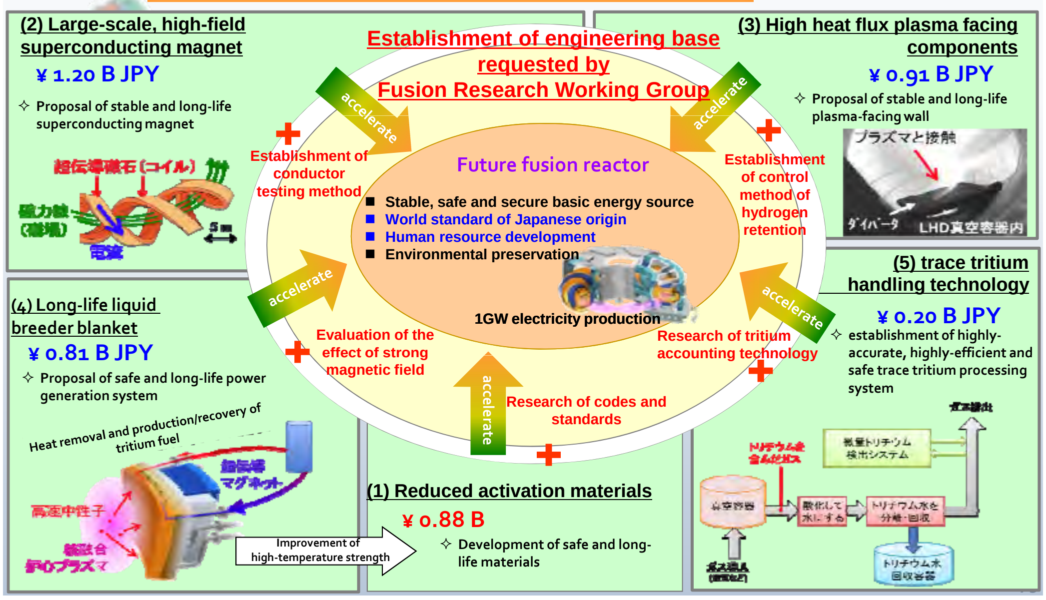
Supplementary budget of 2.4 Billion JPY for facility

Requested for FERP	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	
Special Budget (Facility + Operation)	0.93	0.87	0.77	0.63	0.50	0.32	4.00	Billion JPY

Supplement

Establishment of fusion engineering area by 5 large-scale experimental researches

FERP requested the total 4 Billion JPY in 6 years for facility and operation



Supplement

[2] Research Achievements

~ Whether or not FERP is achieving internationally evaluated results throughout the study on helical fusion reactor

Year	International Conference	Presentations by FERP and collaborations	Presentations Total	Ratio	Reference
2010	26th Symposium on Fusion Technology (SOFT 2010)	12	547	2.2%	FED Vol.86 Issues 6-8, 9-11
2010	9th International Conference on Tritium Science and Technology (TRITIUM2010)	17	170	10.0%	FST Vol.60 No.3,4
2010	19th ANS Topical Meeting on the Technology of Fusion Energy (TOFE 2010)	13	145	9.0%	FST Vol.60 No.1,2
2011	10th International Symposium on Fusion Nuclear Technology (ISFNT-10)	12	215	5.6%	FED Vol.87 Issues 5-6, 7-8
2011	15th International Conference on Fusion Reactor Materals (ICFRM-15)	22	222	9.9%	JNM Vol.442 Supplement 1 / FST Vol.61 No.1
2012	20th International Conference on Plasma Surface Interactions in Fusion Devices (PSI-20)	22	238	9.2%	JNM Vol.438 Supplement
2012	20th ANS Topical Meeting on the Technology of Fusion Energy (TOFE2012)	9	161	5.6%	FST Vol.64 No.2,3 (3/94) + Book of Abstract
2012	27th Symposium on Fusion Technology (SOFT2012)	11	510	2.2%	FED Vol.88 Issues 6-8, 9-10
2013	11th International Symposium on Fusion Nuclear Technology (ISFNT-11)	16	525	3.0%	ISFNT-11 Book of Abstract

Results of FERP Evaluation 2013

Number of persons

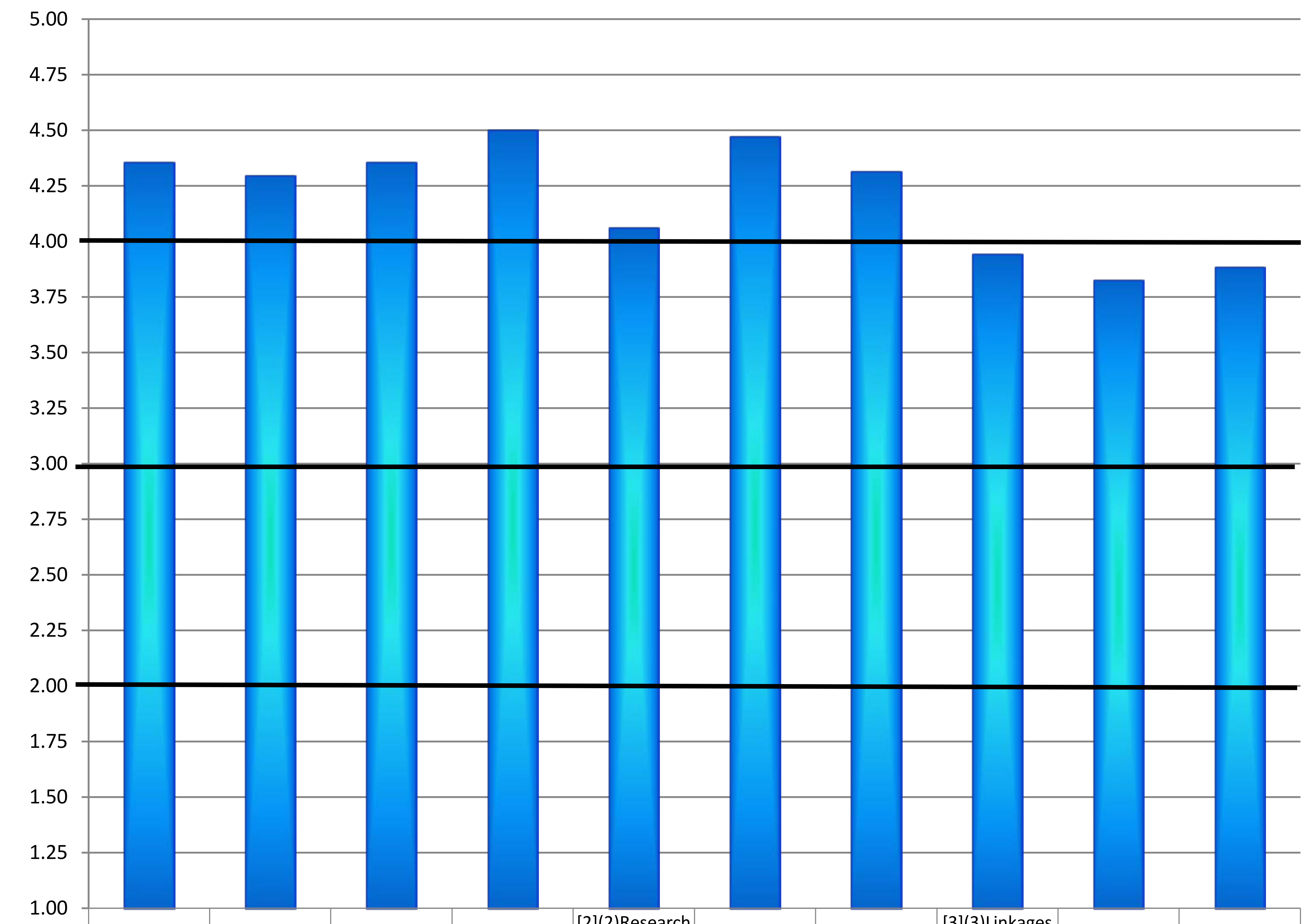
Items	[1](1)Setting of Objectives	[1](2)Research System	[1](3)Research Infrastructure	[2](1)Helical Fusion Reactor Design	[2](2)Research Aimed at Constructing an Engineering Foundation	[3](1)Role as COE	[3](2)Commitment to Universities	[3](3)Linkages with ITER Project, BA Activities, and International Activities	[4] Human Resources Development	[5] Future Plans
S	7	6	7	10	4	8	5	3	4	1
A	9	10	9	5	10	9	11	10	6	13
B	1	1	1	2	3	0	0	4	7	3
C	0	0	0	0	0	0	0	0	0	0
Average scores	4.35	4.29	4.35	4.50	4.06	4.47	4.31	3.94	3.82	3.88

Evaluation Scoring		
S	Extremely highly commendable	5
A	Highly commendable	4
B	Commendable	3
C	Adequate	2
D	Inadequate	1

※ This table contains all the scores given by both Japanese and foreign reviewers. Total numbers vary by item because some were left blank.

Items	Evaluation Items
[1]	(Establishment of research system and environment)
[1](1)	Whether or not the target of FERP, initiated in JFY2010, is appropriate
[1](2)	Whether or not the organization of FERP is coincident with its target and properly functioning
[1](3)	Whether or not an appropriate research environment is provided for the establishment of academic fundamentals
[2]	(Research achievements) Whether or not FERP is achieving internationally praised results through the study of the helical fusion reactor
[2](1)	Helical fusion reactor design
[2](2)	R&D toward establishment of the engineering basis
[3]	(Encouragement of joint activities and collaborative research)
[3](1)	Whether or not NIFS is promoting collaboration as a COE, focusing the high-level research abilities of universities and research institutes
[3](2)	Whether or not NIFS is contributing to the development of research at universities
[3](3)	Whether or not FERP is collaborating with and contributing to international activities of ITER, BA, and others
[4]	(Human resources development) Whether or not FERP is nurturing young researchers who will support the long-term growth of international fusion research
[5]	(Future plans) Whether or not the future plan is pointing appropriately toward the medium- to long-term targets

Item-by-item average scores



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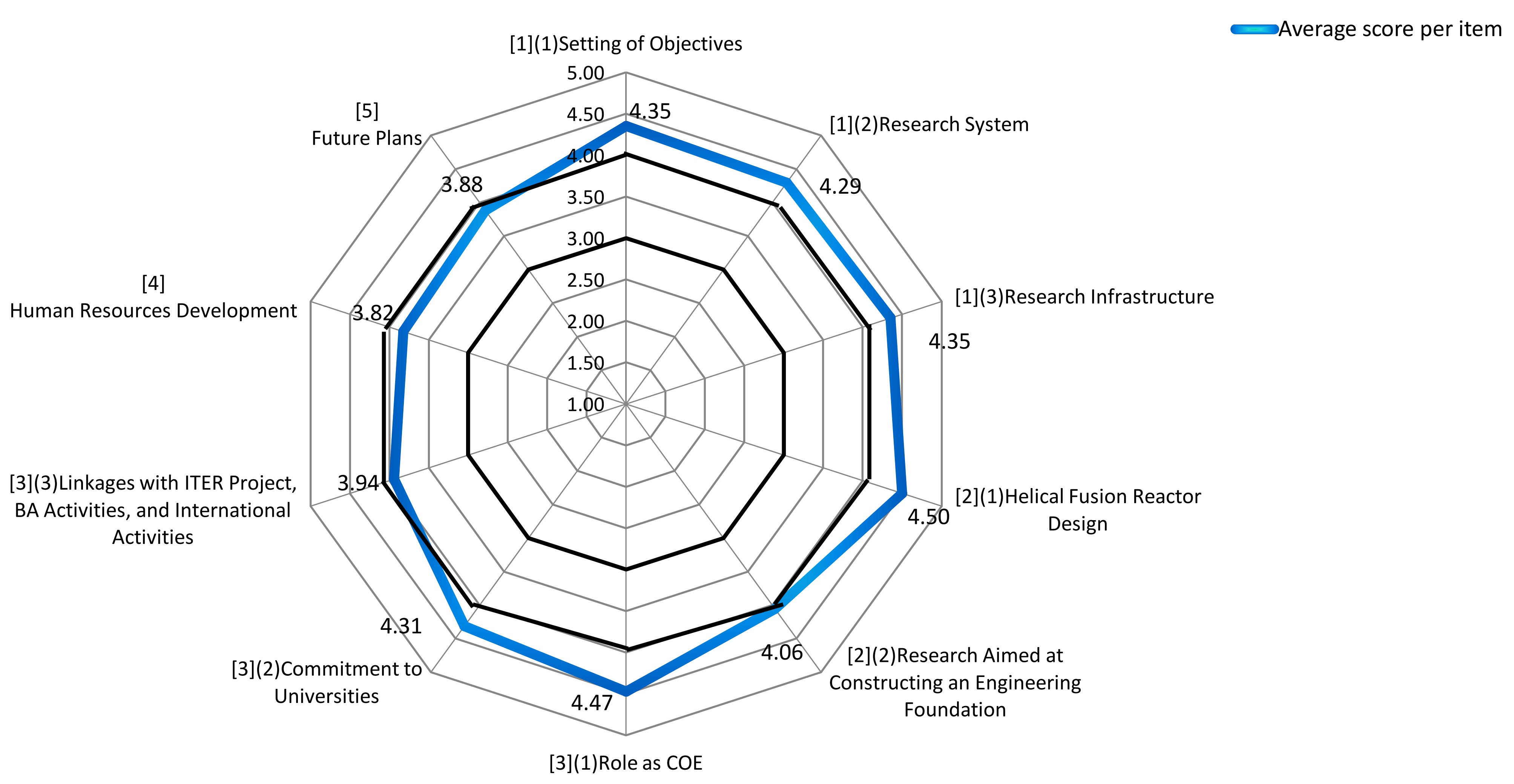

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