Interdisciplinary Development of Advanced Fusion and Antimatter Science Using Superconducting Dipole Fields

Project manager

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Summary of the project

We aim to realize a neutron source enabling multifaceted utilization of fusion energy, based on plasma confinement in a dipole magnetic field—an approach fundamentally different from existing tokamak and helical configurations—and to develop interdisciplinary applications in antimatter science.

- A dipole magnetic field generated by high-temperature superconducting technology provides a natural confinement configuration analogous to planetary magnetospheres, enabling the stable generation and sustainment of high-performance plasmas suitable for advanced fusion using a relatively simple device structure.
- By employing a high-magnetic-field superconducting dipole device, the project will demonstrate the feasibility of ion heating and neutron production, thereby establishing the engineering foundation for a fusion-based neutron source.
- Utilizing the fusion neutrons thus obtained, the project will advance applications in materials and physical sciences, including the development of high-intensity positron sources and research on antimatter plasmas and advanced materials diagnostics. Through this interdisciplinary expansion, the project will contribute to diversified utilization of fusion energy and to progress toward future advanced-fusion systems.

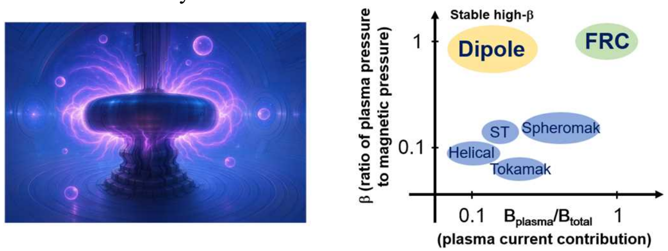

Fig. 1. Characteristics of the dipole confinement method and comparison with existing approaches.

Milestone by 2034

- To carry out demonstration operation of a fusion-neutron source based on a superconducting dipole and clarify its engineering feasibility as a steady, continuously usable volumetric neutron source.
- To advance research and development in antimatter science utilizing the neutron source and establish the foundational platform for interdisciplinary technologies involving positrons and positronium.

Milestone by 2029

- To optimize ion heating using a scaled-up, high-magnetic-field dipole device and to demonstrate neutron production.
- To conduct an integrated evaluation of multiple ion-heating mechanisms—including electron-to-ion energy transfer, anomalous heating caused by turbulence and fluctuations, and direct ion heating—and to quantify the reactor conditions required for operation as a neutron source. Based on these results, the fundamental parameters necessary for conceptual design of a fusion neutron source and dipole fusion reactor will be organized.
- To initiate research and development on positrons and positronium, and to advance the demonstration of the associated technological components.

Project structure

We will establish and operate an integrated research and development framework—linking device design and fabrication, heating experiments, and theory/simulation—to demonstrate ion heating in a dipole magnetic configuration and to acquire the information necessary for the design of future devices.

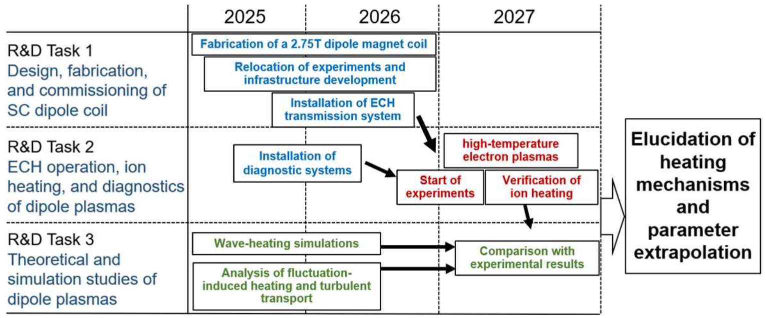

Fig. 2. R&D framework and activities planned through November 2027.