

Innovative Muon-Catalyzed Fusion Technology for Practical Applications

Project manager

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R&D institutions

Chubu University

Leader's institution

Tohoku University,
High Energy Accelerator
Research Organization (KEK)

Summary of the project

Muon-catalyzed fusion (μ CF) is a technology in which fusion reactions are induced by muons—an elementary particle. Unlike conventional fusion approaches, μ CF does not require extreme reactor core conditions such as ultra-high temperatures or pressures, and is instead highly compatible with existing technological infrastructures (Fig. 1).

This project aims to establish the scientific foundation for Advanced μ CF, a high-efficiency form of muon-catalyzed fusion capable of achieving a net-positive energy balance, by dramatically enhancing the fusion-reaction efficiency mediated by muons. By 2050, the project envisions contributing to a sustainable society in harmony with the global environment through decentralized power sources, neutron-source applications, and other diversified uses.

Unlike other fusion methods, μ CF does not require plasma states; instead, it realizes fusion in low-temperature, high-density regimes. Leveraging these unique characteristics to the fullest, the project aims to enable practical societal deployment of fusion energy.

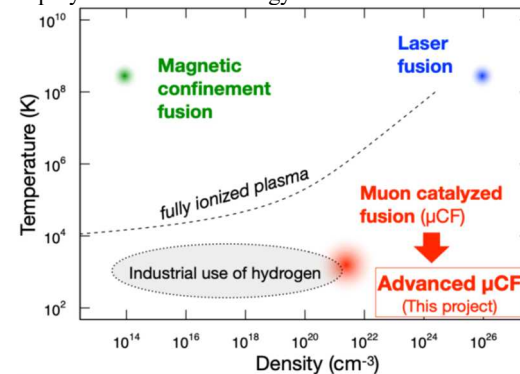


Fig. 1. Comparison of temperature–density regimes for different fusion approaches.

Milestone by 2034

By 2034, the project will demonstrate the feasibility of achieving a net-positive energy balance through Advanced μ CF and will scientifically clarify the physical conditions and control techniques required for the efficient production, capture, and transport of muons.

In addition, engineering considerations will be incorporated to complete the conceptual design of a compact μ CF reactor. A roadmap for applications such as decentralized power sources and neutron-source systems will also be

presented, enabling the project to reach a stage at which development of a prototype reactor can begin.

Milestone by 2029

By 2029, the project will elucidate, through both theoretical and experimental approaches, the physical conditions and reaction mechanisms required to enhance the reaction efficiency of Advanced μ CF. A system for handling deuterium and tritium, together with the associated safety-operation requirements, will be established to provide the foundation for demonstration experiments. Using high-precision X-ray detection techniques, the quantum processes accompanying μ CF reactions will be directly observed, enabling experimental validation of the reaction model and confirming the validity of the reaction mechanisms.

Through these achievements, the project will extract the key physical and engineering parameters necessary for future studies of an Advanced μ CF reactor and will establish the foundation for integrated reactor design beyond 2034.

Project structure

This project was launched under the leadership of Chubu University, in collaboration with Tohoku University and KEK, including the Institute of Materials Structure Science and the Institute of Particle and Nuclear Studies.

The project began with a research framework (Fig. 2) in which atomic and molecular physics serves as the foundation, and multiple fields—including particle and nuclear physics, radiation chemistry, accelerator science, cryogenic and superconducting technology, hydrogen-isotope engineering, and laser science—work together. Within this framework, the project is pursuing the elucidation and demonstration of the μ CF reaction mechanisms necessary for realizing Advanced μ CF.

R&D Project : Innovative Muon-Catalyzed Fusion Technology for Practical Applications

[Comprehensive Study of Reaction Mechanisms and Experimental Foundations for Realizing Advanced μ CF]

- 1) Theoretical framework and condition analysis of reaction mechanisms toward the realization of Advanced μ CF
- 2) Evaluation of required beam parameters and feasibility for Advanced μ CF
- 3) Conceptual design of Advanced μ CF experiments and examination of validation methodologies
- 4) Preliminary study of tritium control system design requirements and safe operation, with a view toward future demonstration

Fig. 2. R&D framework.