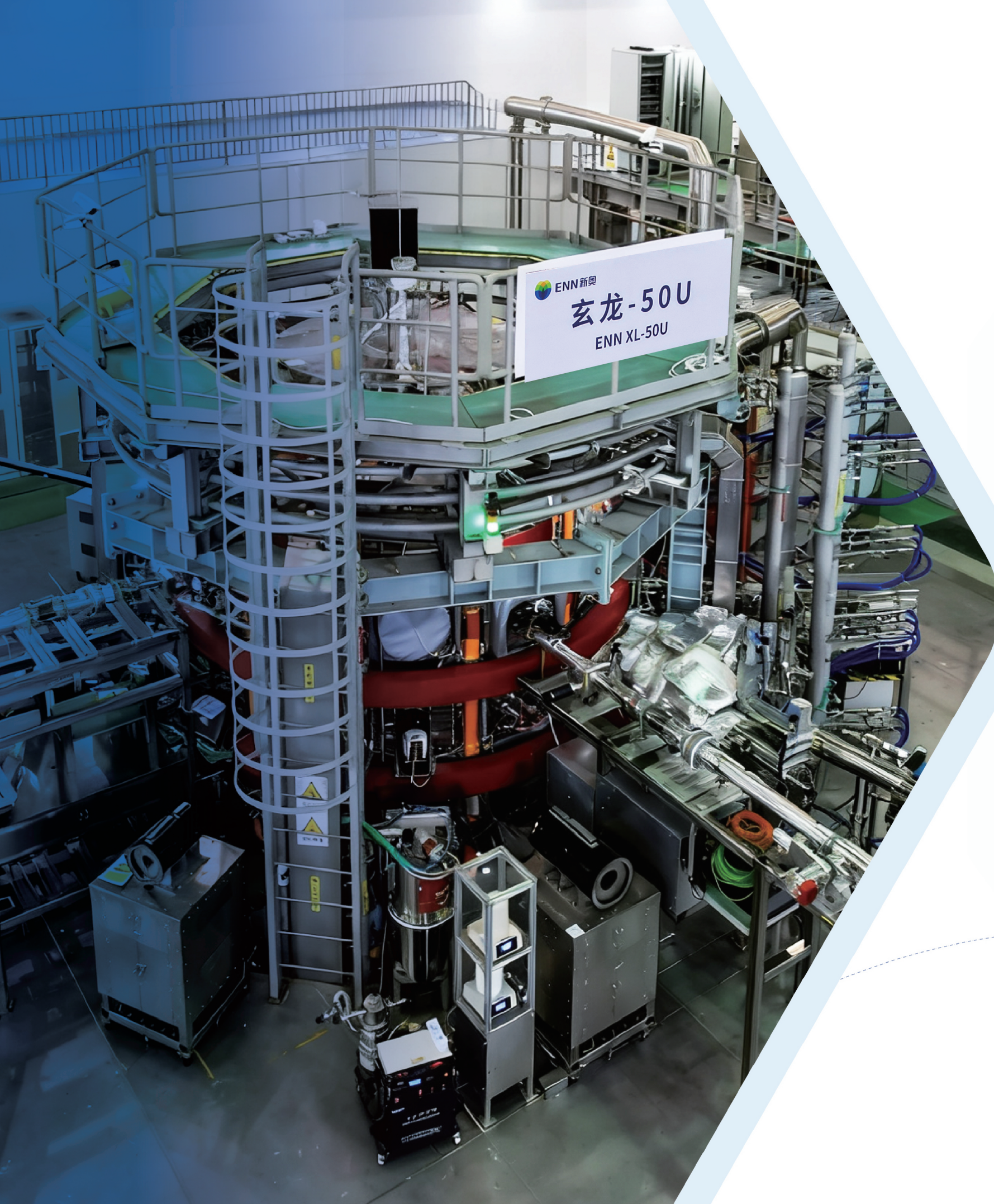




ENN COMMERCIAL FUSION POWER



Powering a better future



Staff Members

40000+

Residential Users

32 million+

Industrial Users

293000+

ENN——China's first private pioneer in commercial fusion energy

ENN Group is a Chinese conglomerate that was established in Langfang, Hebei Province in 1989 with a clear mission to create a modern energy system and enhance people's quality of life. Initially focused on urban gas provision, ENN has since expanded its operations to encompass the entire natural gas industry, including production, distribution, trade, storage, and engineering. ENN has also diversified into other sectors, such as real estate, tourism, culture, and health, to provide premium living experiences.



ENN Energy
(02688.HK)



ENN Natural Gas
(600803.SH)



ENC Digital Technology
(603869.SH)



Tibet Tourism
(600749.SH)

As a subsidiary of ENN Group, ENN Science and Technology Development Co., Ltd, (ENN Energy Research Institute), develops sustainable and commercially viable energy solutions. Founded in 2006, it has achieved breakthroughs in coal-based low-carbon technologies and ubiquitous energy network, now leads R&D in compact fusion—a transformative approach to clean energy.

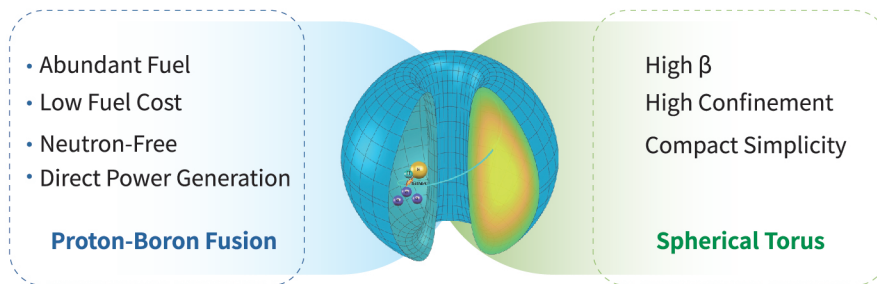
ENN pioneered commercial fusion energy development in China, initiating its fusion technology R&D program in 2017.



Pioneering the Path to Commercial Fusion Energy

Controlled nuclear fusion, with its near-limitless potential, is widely regarded as the ultimate solution to global energy needs. The realization of this vision must fulfill the core requirements of commercial energy: safety, cleanliness, and low cost.

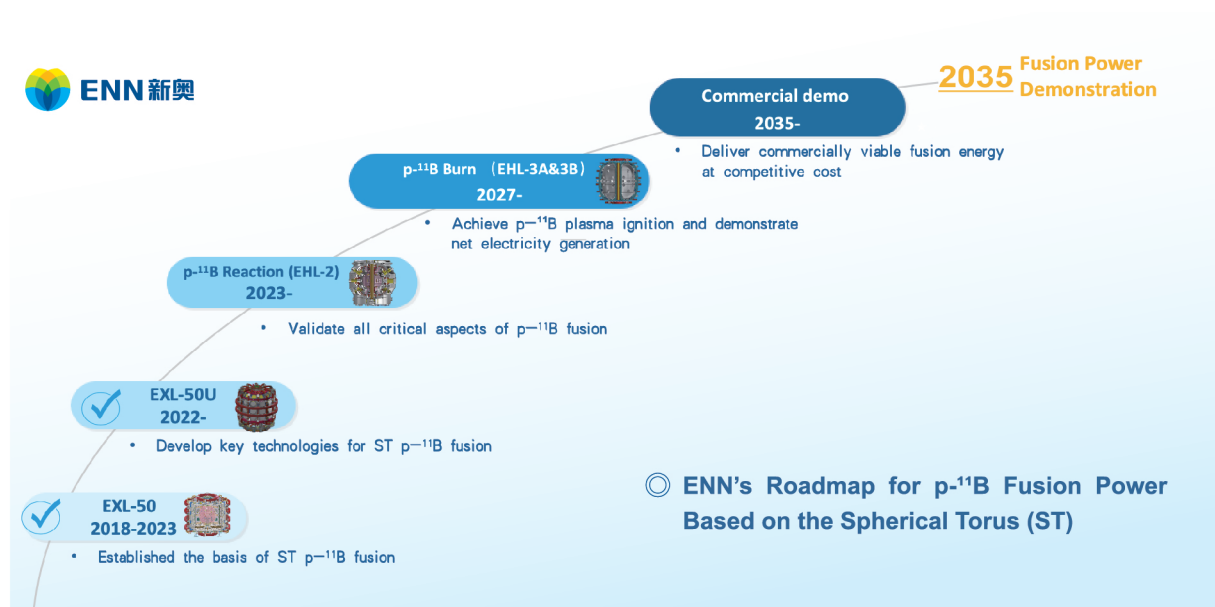
The spherical torus proton-boron fusion pathway chosen by ENN leverages inherent advantages such as abundant fuel reserves, inherent safety, minimal environmental impact, and high energy conversion efficiency. This alignment with the essential criteria for future commercial energy production establishes it as a groundbreaking and commercially viable technical route.



Spherical Torus Proton-Boron Fusion: A Novel Path to Commercialization

Our Objectives: Demonstrating Fusion Power Generation by 2035

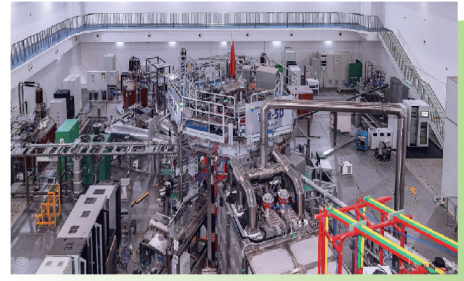
With a focus on commercial deployment, ENN is using backward planning from our 2035 goal to anticipate and resolve core scientific and engineering challenges in advance, while leveraging AI to accelerate R&D.



Agile Steps, Major Leaps in Fusion Core Competency

● EXL-50

ENN achieved a major milestone in August 2019 with the completion of China's first medium-scale spherical torus device, the EXL-50. Over four years of stable operation, the device conducted more than 20,000 physics experiments and achieved a plasma current of 170 kA—setting a world record for electron cyclotron resonance heating (ECRH) non-inductive current drive.



● EXL-50U

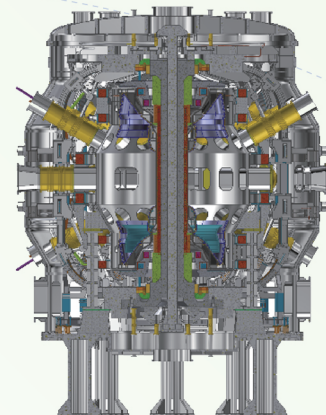
In 2023, the device was upgraded to EXL-50U. Just one year after its first plasma, in 2025, it reached a central magnetic field of 1.2 T sustained for seconds, a hydrogen-boron plasma current of 1 MA, and a temperature of 40 million degrees Celsius—exceeding its original design targets and positioning it among the world's leading spherical torus devices. As China's first and only MA-class spherical torus, the EXL-50U has filled a critical gap in the country's fusion roadmap.



● EHL-2

To overcome critical scientific and technological hurdles in $p\text{-}^{11}\text{B}$ fusion, ENN is developing the EHL-2, a spherical torus device designed with world-leading parameters. The project is scheduled for completion in 2027.

Thirteen peer-reviewed papers detailing the physics design of EHL-2 were published in a special issue of Plasma Science and Technology in February 2025. The engineering design and critical testing phases for the device have been completed.



"Theory-Engineering" Dual-Wheel Drive Enables High-Efficiency R&D

● Close Integration of Theoretical Innovation and Engineering Technology

Theoretical research comprehensively spans the entire R&D chain—from technical route planning, nuclear reaction mechanisms, physical design to experimental validation and analysis—providing a theoretical foundation and directional guidance for fusion device development. Engineering efforts realize the implementation of key technologies, including the main vessel systems, heating and current drive, plasma control, and magnet engineering, thereby efficiently supporting the requirements of physical experimental validation.

● Physics Theory & Experimental Research

Focusing on the core physics of enhancing fusion reaction gain and discharge duration, 11 major research initiatives have been conducted.



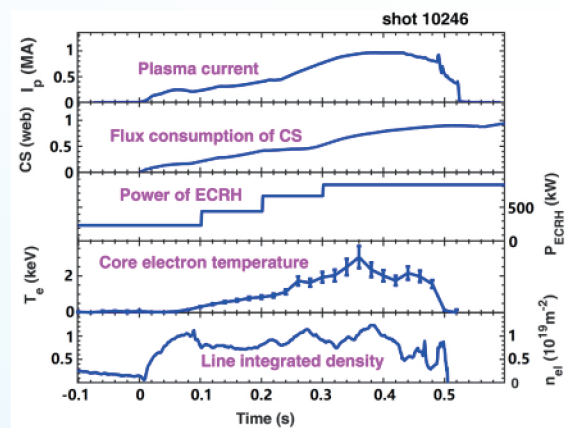
Achievement of **MA** Level
Plasma Current



Development and
Open-Sourcing of Programs:
BO, BORAY, and ETSC



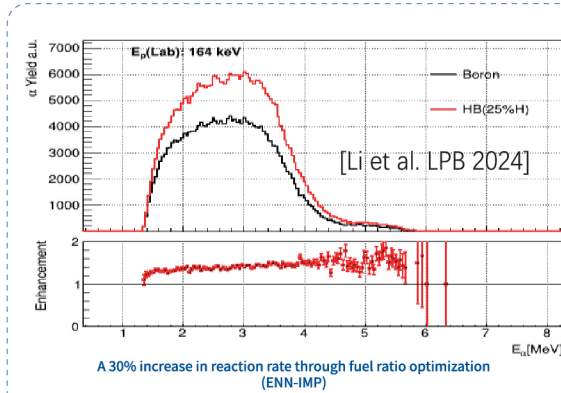
107 papers were published,
104 of which are SCI-indexed



Experimental Data of 1 MA Plasma Current

● Multiscale Proton-Boron ($p\text{-}^{11}\text{B}$) Fusion

With the goal of enhancing the reaction rate, establish a multi-scale, multi-level research framework for $p\text{-}^{11}\text{B}$ fusion that bridges nuclear physics and plasma physics.



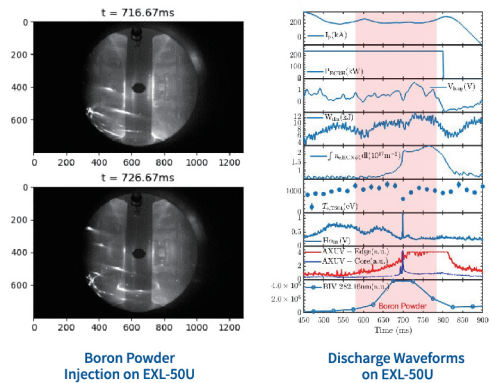
- Cross-section measurements
- 30% increase in reaction rate through fuel optimization
- "Net energy gain window" identified through optimization of non-equilibrium parameters

● Research on $p\text{-}^{11}\text{B}$ Plasma Properties

Experiments confirm that boron powder injection effectively enhances plasma performance. This provides a solid foundation for studying boron transport physics and exploring active control methods for achieving peaked boron density profiles.

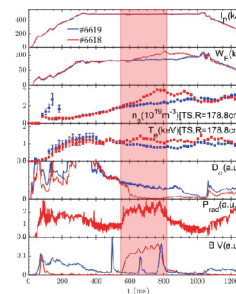
In EXL-50U, boron powder was injected at 5 mg/s, leading to several key improvements:

- ~4x increase in electron density.
- Significant reduction in particle recycling.
- Substantial increase in plasma stored energy.

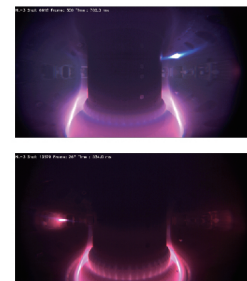


The HL-3 tokamak utilizes two methods for boron delivery: powder injection and laser blow-off.

- Effective real-time wall conditioning through boronization and reduced impurity levels.
- Using powder injection, a significant boost in both electron temperature and density compared to the reference discharge.



Comparison of Discharge Waveforms in HL-3: With (#6618) vs. Without (#6619)

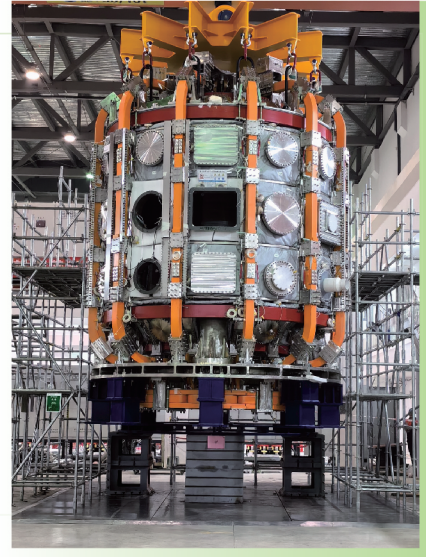


Boron Powder Injection HL-3 (SWIP)
Figure above: Boron Powder Injection
Figure below: laser-guided gas puffing

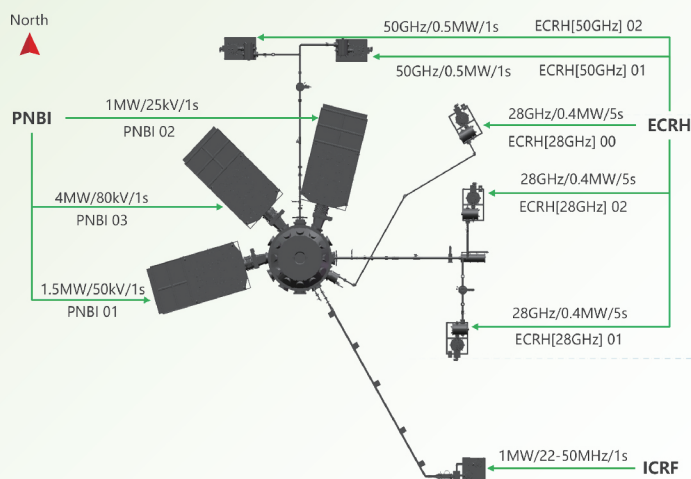
● Rapid Iteration and Engineering Implementation of Fusion Devices

The team possesses the capability to design, construct, and upgrade medium-to-large spherical torus, compressing the typical global development and construction timeline of 5-10 years down to one year or even six months.

- The medium-scale spherical torus device EXL-50 was built within 10 months, from design to commissioning.
- The high parameter device EXL-50U was upgraded within only 3 months.
- Complete the engineering design of EHL-2 and the testing work of key components.



● Heating and Current Drive (H&CD) System



- The H&CD system on EXL-50U is capable of delivering a total power of 10 MW.
- The arc discharge ion source of the Neutral Beam Injection (NBI) system is capable of extracting ion beams at 25 kV/20 A and 50 kV/40 A.
- A 3MW/200kV/3s NBI system, featuring radio-frequency driven negative ion sources, has completed physical design.

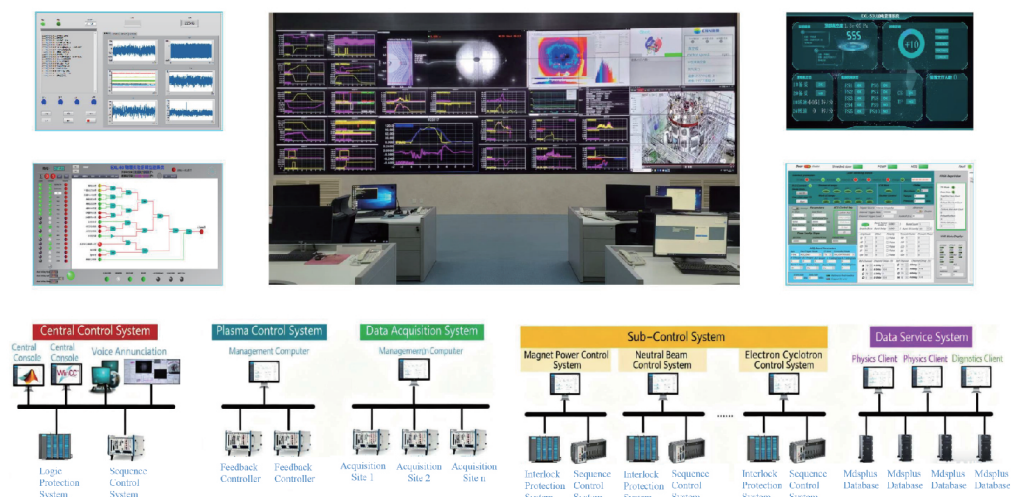
● New Generation MMDDC-Based Magnet Power Supply

- ▶ EXL-50U: $I_{TF} = 150$ kA, $B_t = 1.2$ T@R=0.6 m has been achieved.
- ▶ EHL-2 will adopt the new-generation MMDDC-based magnet power-supply technology; a 20 kA prototype has already been validated.
- ▶ Exploration of inverter-type high-voltage power supply technology at 200 kV and above is under way.



● Fully Digital & Intelligent Control System

- ▶ Independently developed the Central Control System (CCS), Plasma Control System (PCS), and Data Acquisition System (DAS).
- ▶ Closed-loop control at the sub-millisecond level and efficient multi-system coordination.
- ▶ The comprehensive digital platform accelerates the iterative validation of advanced control algorithms and intelligent controllers.
- ▶ An open, distributed, and self-organizing control system architecture.



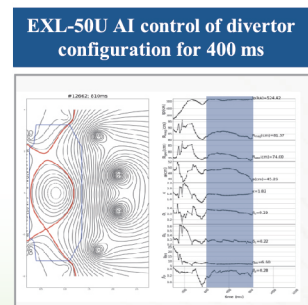
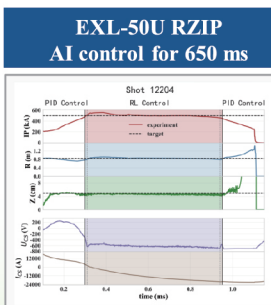
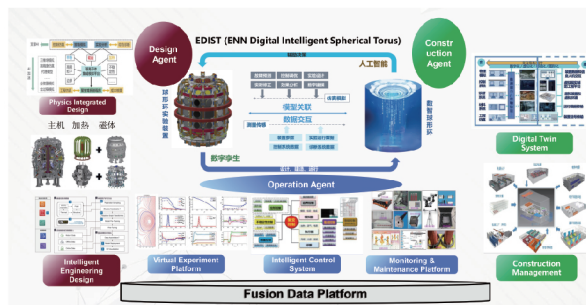
AI Accelerates Fusion R&D

With the fusion data platform as the core foundation, AI team focuses on scenarios including intelligent plasma control, fusion agent development, and device fault monitoring.

650 ms RZIP
intelligent
Control.

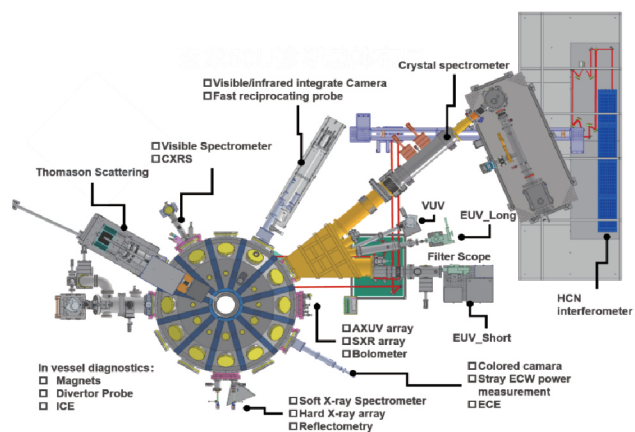
400 ms intelligent
control of divertor
configuration.

The developed digital twin system enhances the computational speed of multi-physics coupling simulations for the main engine by over four orders of magnitude.



High-Precision Diagnostic System

- Comprehensive Diagnostic Systems: magnetics, laser diagnostics, microwave diagnostics, spectroscopies, nuclear measurements and probes.
- The profile data integration: synthesizes outputs from microwave reflectometry, Thomson scattering, and HCN interferometry systems to deliver comprehensive physical distribution profiles.
- Future priorities include advancing diagnostics for high-energy particles and fusion products.



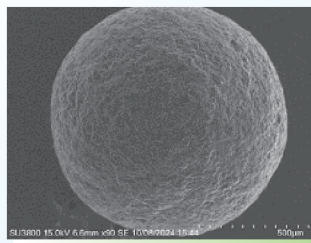
● Fusion-Grade HTS Magnets at Meter Scale

- ▶ Meter-scale D-shaped high-field HTS coil achieves $B_{\max}$ 12.2 T and B_0 7.3T@20K, 5.3kA.
- ▶ Over 200 experiments conducted under both normal and quench conditions.
- ▶ First validation of multi-coil 12 T coupled operation.
- ▶ A 160 W@18 K, 20 kA testing platform for magnet systems (including excitation operation, quench protection, overcurrent testing, insulation testing, thermal cycling assessment, and joint performance evaluation).



● Efficient Fueling and Target Fabrication

- ▶ Developed a boron pellet injection system capable of low-field-side injection at 280 m/s.
- ▶ Achieved spherical boron pellets with density $\geq 80\%$, sphericity $\geq 90\%$, and mechanical strength >100 N.
- ▶ Capable of fabricating pure boron and hydrogen boron targets (0.1–10 μm ; hydrogen content tunable up to 40 at%), with precise boron control in carbon hydrogen boron composites.



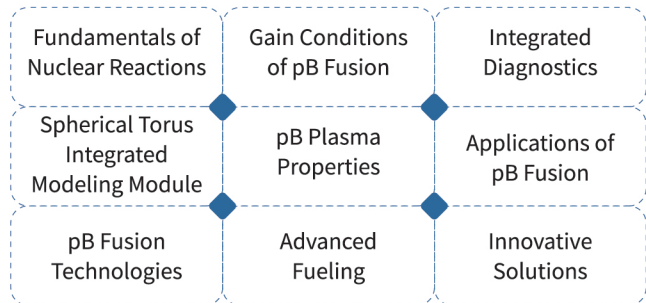
Boron Fuel Pellet with $d = 1.0$ mm



Nanometer-thick self-supporting ^{11}B target with $\phi = 10.0$ mm

Open Collaboration and Shared Success

ENN has launched the **Proton-Boron Fusion Research and Applications Workshop** and the **ENN Fusion Research Fund** to foster cross-disciplinary collaboration. The Fund's first call in May 2025 awarded 18 projects, all now active. Future calls will expand to wider research areas—we welcome continued participation from the global academic community.



© ENN Fusion Research Fund



By engaging with the global fusion community and contributing to key international forums, ENN shares valuable perspectives, putting its commitment to future energy into action.



December 2023

Joined the Controlled Nuclear Fusion Innovation Consortium



April 2024

ITER Inaugural Private Sector Fusion Workshop



November 2024

Inaugural ministerial meeting of the IAEA WFEG

ENN builds a platform for future fusion talent through scholarships and open days, fulfilling our social responsibility and cultivating tomorrow's fusion leaders.



© Scholarship Award Ceremony

© Fusion Talent Open Day



We invite experts, industry partners, and graduates passionate about fusion research to join ENN in advancing commercial fusion technology!



Website



WeChat



EXL-50U VR

Powering a better future

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