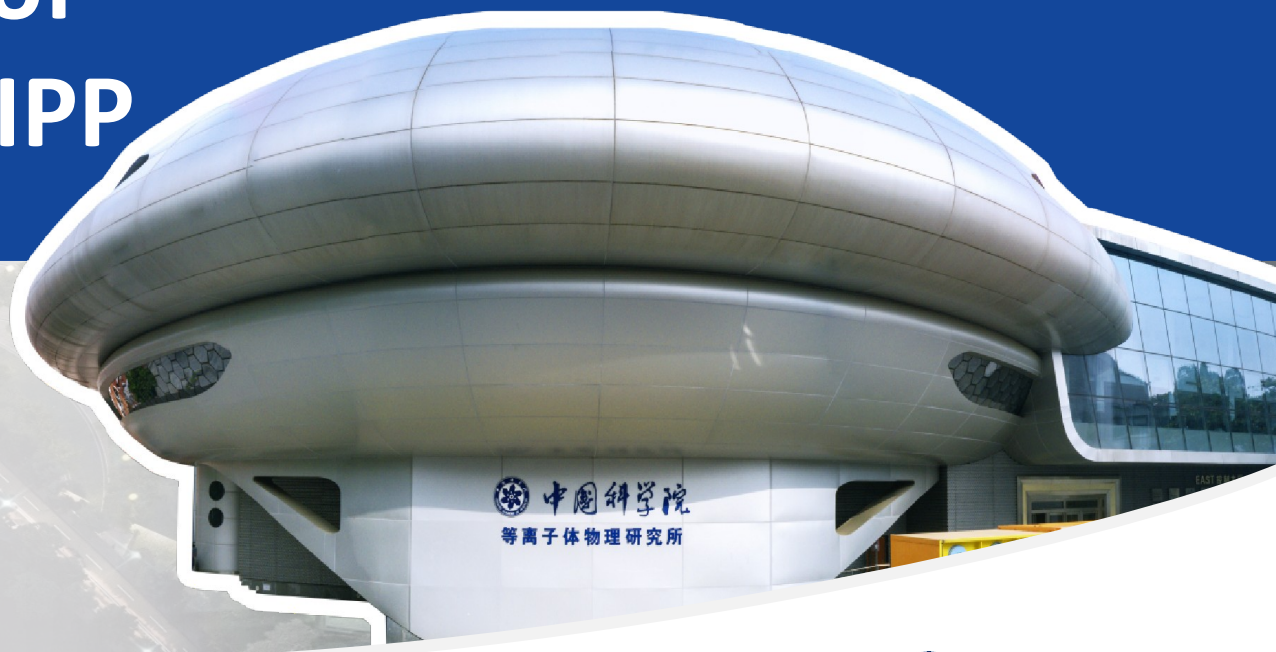
Recent research in the field of thermonuclear energy at ASIPP



Saklakova Viktoria

26.08.2025

ASIPP

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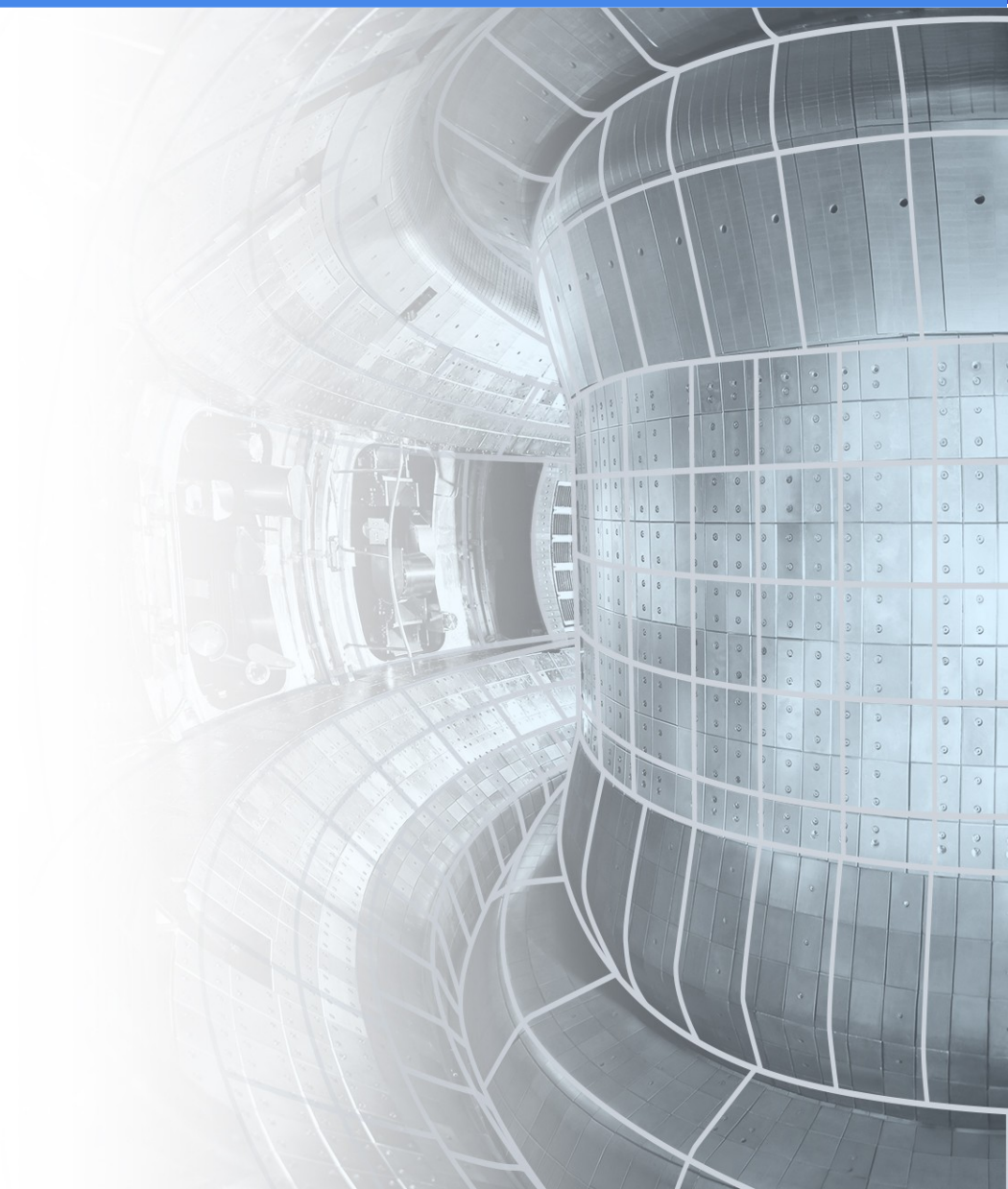


ASIPP - Institute of Plasma Physics, Chinese Academy of Sciences, founded in Sept. 1978 in Hefei, Anhui Province.

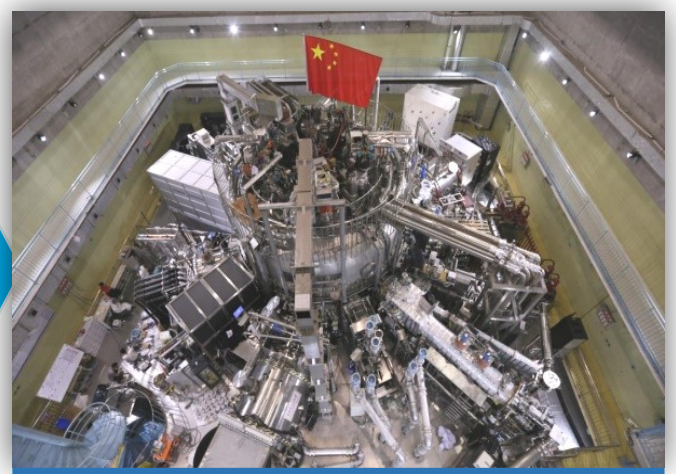
Mission of ASIPP

The research of fusion energy based on the tokamak approach

Main Research Activities:

- Fusion Plasma physics
- Fusion engineering and technologies
- Reactor design
- Low temperature plasma & application

Four generations of Tokamak at ASIPP

HT-6B	HT-6M	HT-7	EAST
			
1978 - 1992	1985 - 2002	1994 - 2012	1998 -

- **HT-6B & HT-6M:** Conventional non–superconducting tokamak
- **HT-7:** The **Chinese first superconducting** tokamak
- **EAST (Experimental Advanced Superconducting Tokamak):** The **world's first full superconducting** tokamak with a non-circle cross-section.

Facts and Figures

Science Island

New Energy Research Center

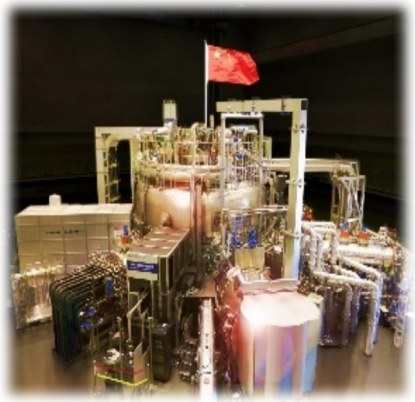
- Staff: 700+
- Graduate students: 500
- Contracted Employee: 300+
- Orgnization:

  14 Divisions, 2 Research Centers,20+ high-tech Companies

CRAFT Campus

Our Fusion Strategy

- ✓ R&D towards a clean, safe, low-carbon energy
- ✓ A full chain of research facilities



EAST

Operating

Plasma physics, steady-state operation

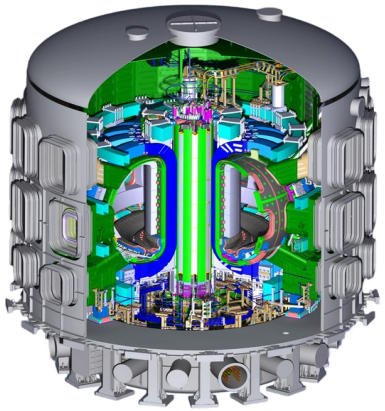
CRAFT

Constructing

14 key sub. systems

R&D For BEST, CFEDR

Non nuclear

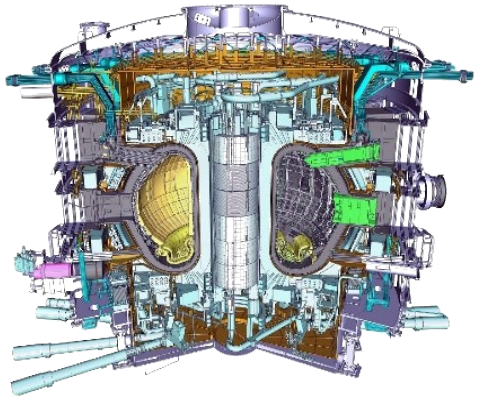


BEST

Constructing

DT operation

supporting ITER



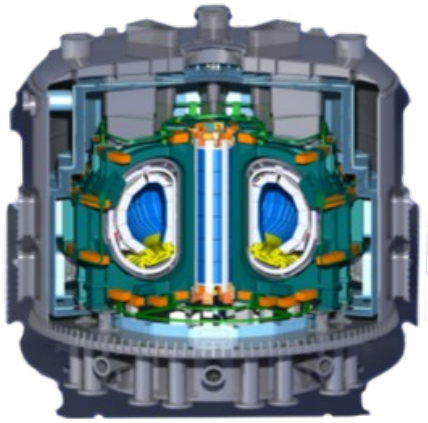
ITER

Joining

DT

400s Q=10

3000s Q=5



CFEDR

Designing

<500MW

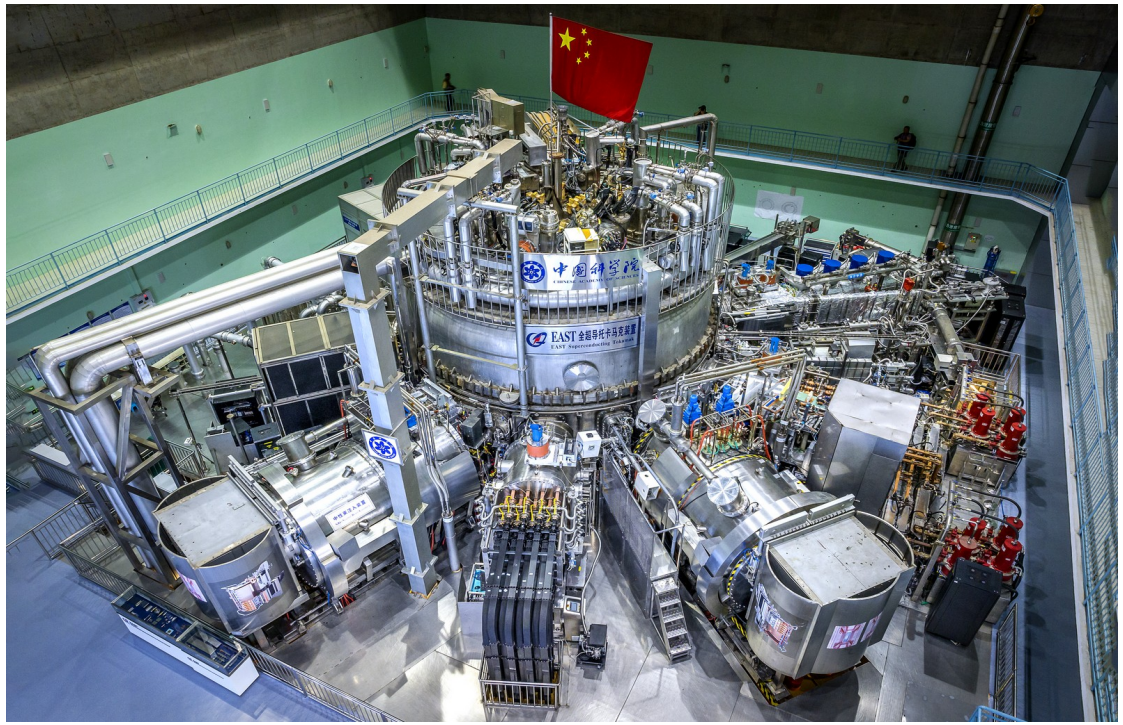
Q=5~30

TBR > 1, 5y

EAST

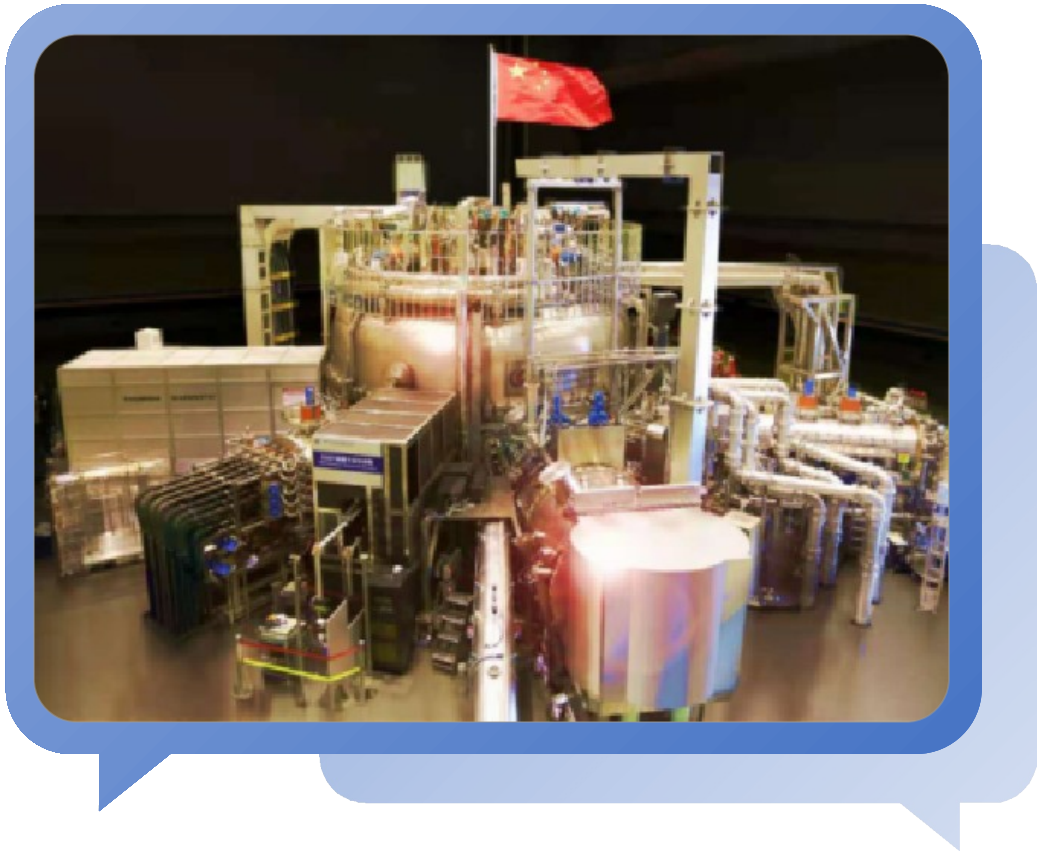
“Artificial Sun” - Experimental Advanced Superconducting Tokamak

- The First fully superconducting tokamak in the world.



- Mission of EAST project is to establish scientific and technical basis for future fusion reactors.

EAST fully superconducting Tokamak



Main Scientific Goals :

1 MA Current	100 Million K	1000 s

To realize the advanced long pulse steady-state operation (SSO) and provide scientific basis for the design, construction and experimental operation of ITER and CFEDR.

An open platform for steady-state high performance plasma operation.

1996	2000	2006	2024
Proposal	Start of construction	First plasma	130000th discharge

EAST Experiment Milestones

Several new records for H-mode and steady-state operation

2008
First H-mode

2010
1MA H-mode

2012
400s 20million C L-mode

2012
30s Steady state H-mode
H_{98}~0.85
Record

2016
100s 50million C L-mode

2016
60s steady state H-mode
H_{98}≥1

2017
100s steady state H-mode
H_{98}>1.1
Record

2018
20s H-mode
H_{98}>1.3

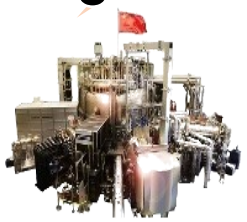
2020
60s H-mode
H_{98}>1.3

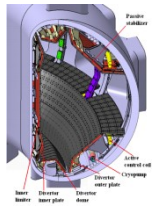
2021
Electrons 120 million C 101 seconds
1056 second long pulse

2023
403s H-mode
Record

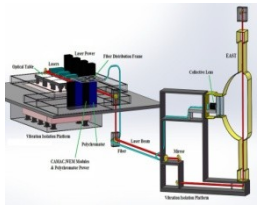
2025
1066s H-mode
H_{98} > 1.3
Record

- Active water cooled all metal wall
- Low momentum heating and driving
- ……

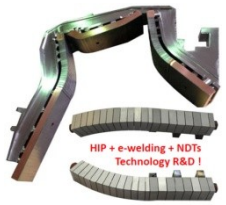




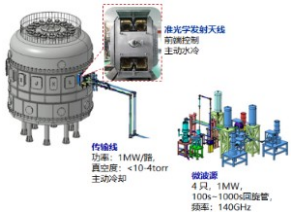
Graphite FW



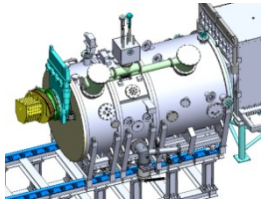
Advanced diagnostic



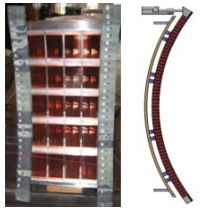
Upper W divertor



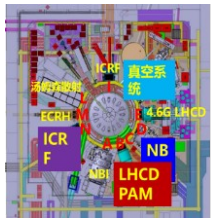
ECRH



Heating upgrade



Limiter modification



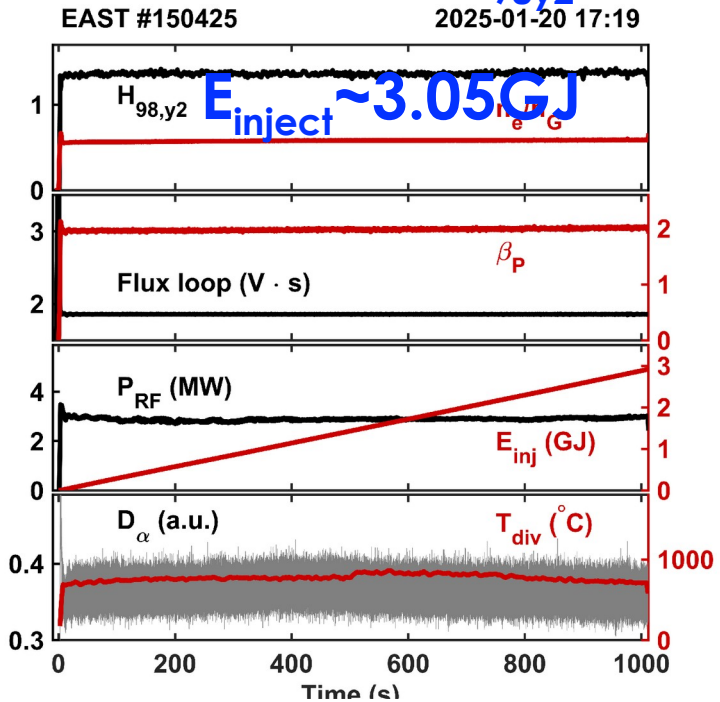
Heating upgrade

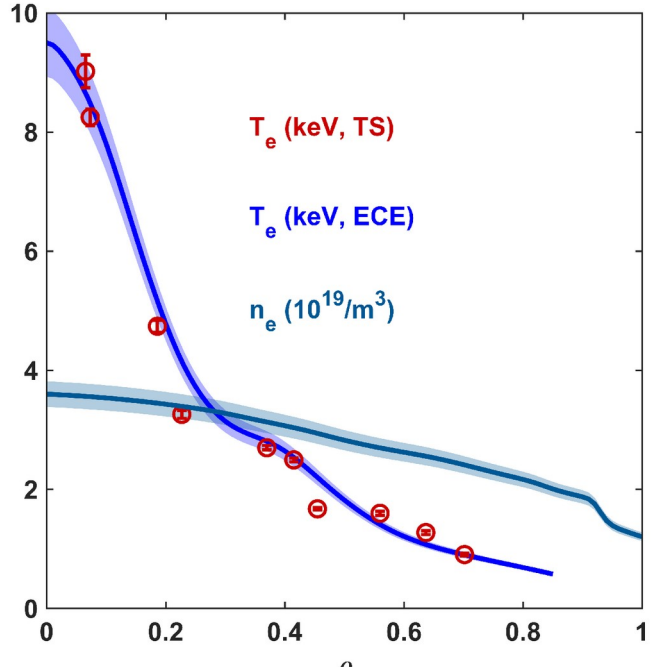
Lower W divertor

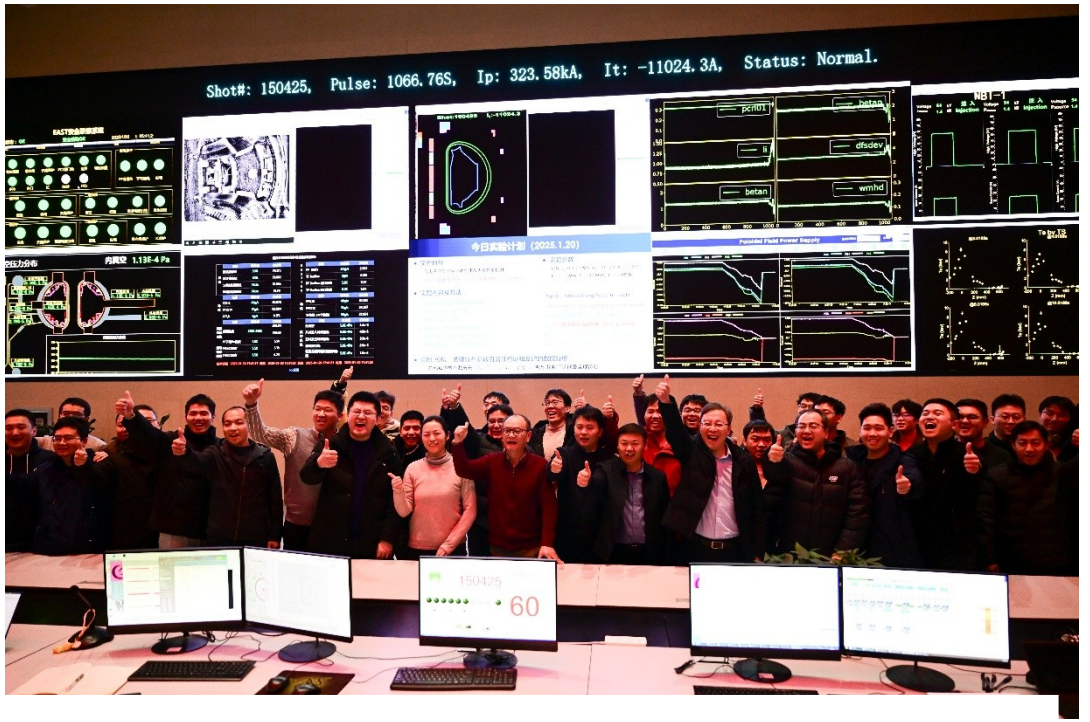
2008 | 2010 | 2014 | 2015 | 2017 | 2020-2025

H-mode plasma over 1000s on EAST

– Bt~2.5T, H_{98y2}~1.35, n_e/n_G ~0.6, f_{BS} ~50%, T_e (core) ~10keV,



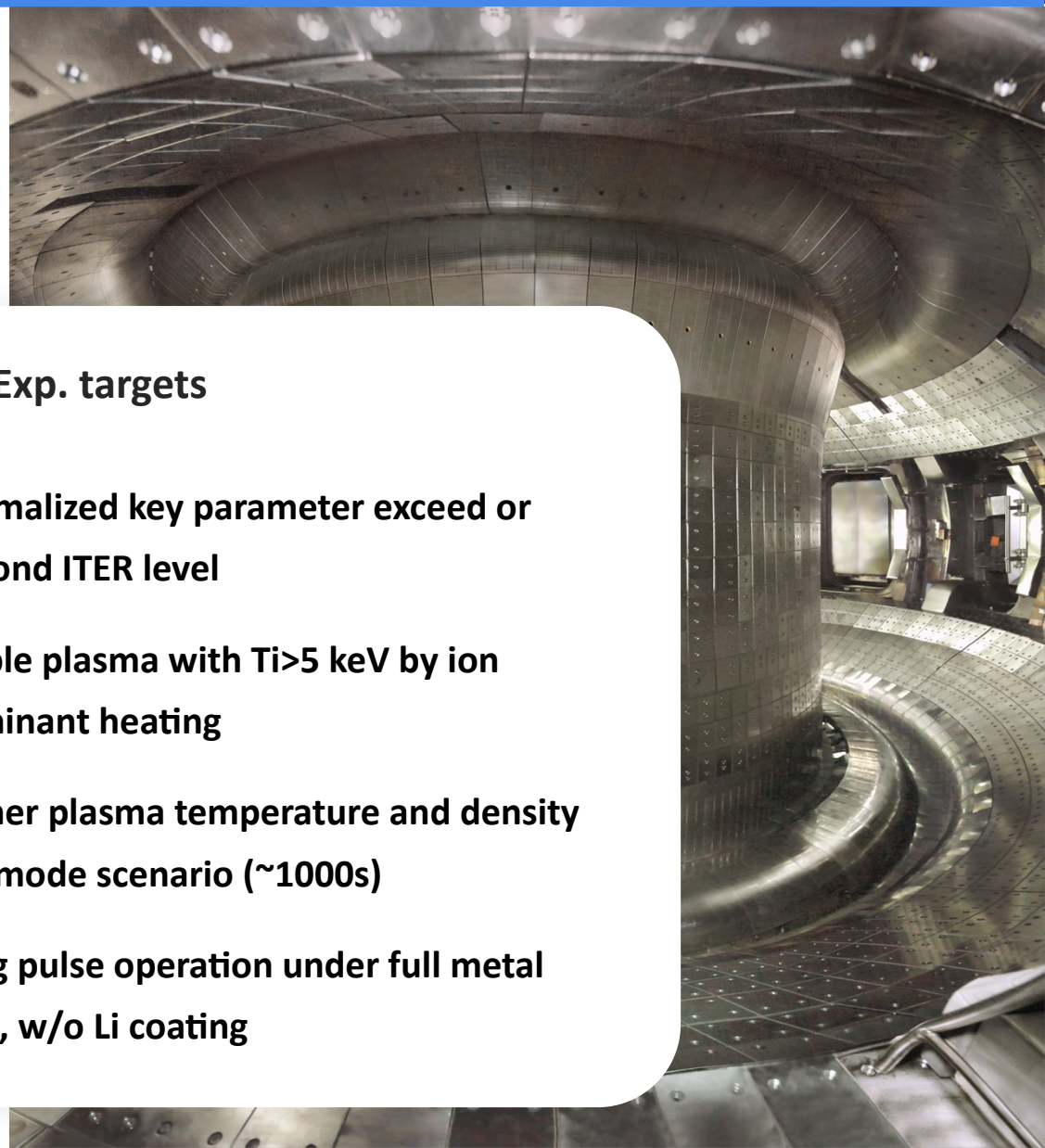




- P_{LHCD} =1.1 MW, P_{ECRH}=1.9 MW, H_{98y2} >1.3 with e-ITB, β_P = 2.0, T_{div}~600-800°C
- A grassy ELM regime on the horizontal target, facilitating efficient RF power coupling and reducing W sputtering/erosion.
- Low Z materials wall coating and real-time powder injections to improve particle control.

Key physics issues for EAST near future

Cutting-edge physical research related to future plasma scenarios, focusing on solving key scientific and technical issues in support of ITER/CFEDR



Scientific issues

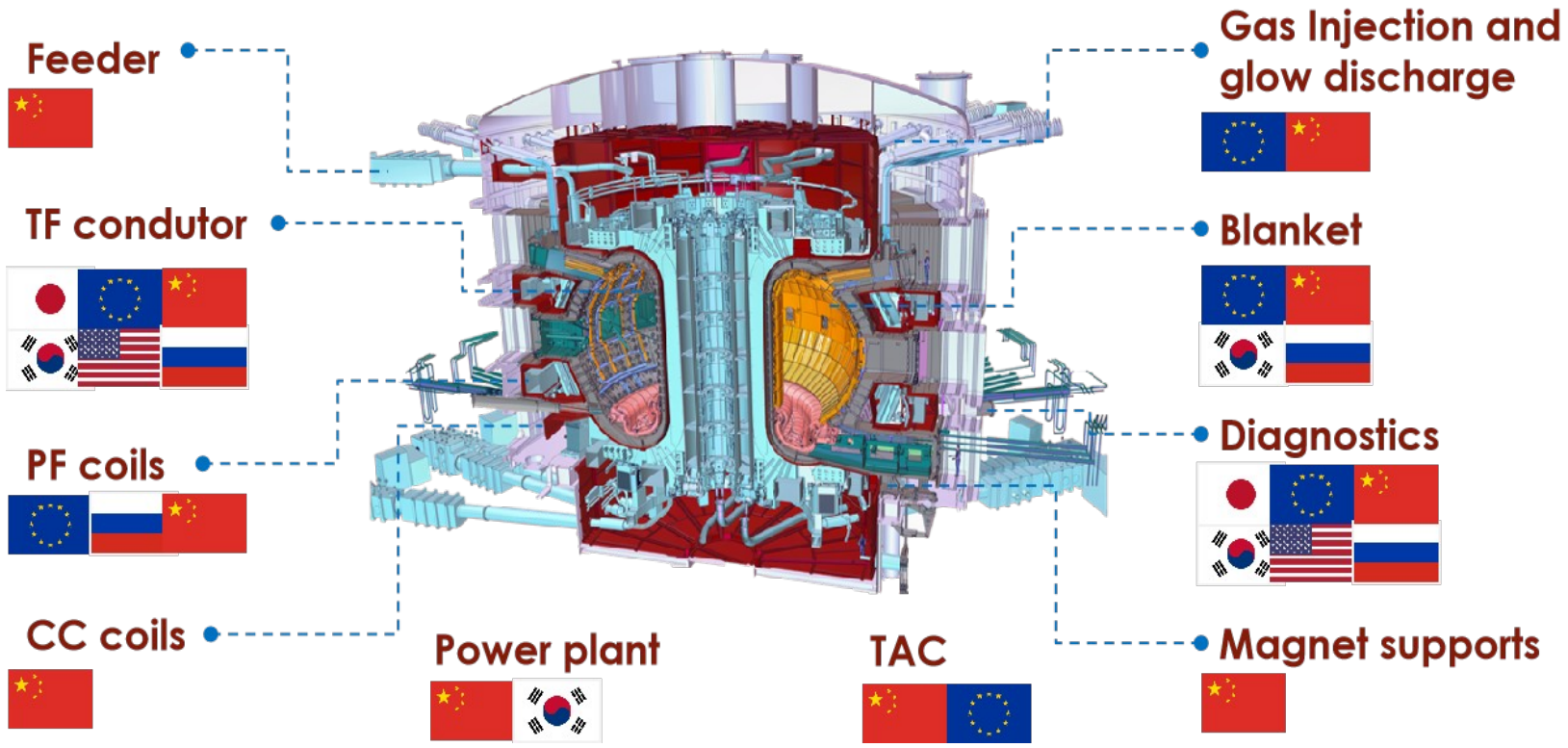
- Plasma current drive and profile control
- Energetic particle physics, with a focus on studying the nonlinear interaction between waves and energetic particles, interaction with NBI and ICRH coupling
- The confinement and transport of high beta_N plasma, the mechanism of internal transport barriers under electrical dominant heating
- The physical integration from the plasma boundary to the core, with full metal wall

Exp. targets

- Normalized key parameter exceed or beyond ITER level
- Stable plasma with Ti>5 keV by ion dominant heating
- Higher plasma temperature and density in I-mode scenario (~1000s)
- Long pulse operation under full metal wall, w/o Li coating

A Most Valuable Partner to ITER

A major ITER contributor in China ：



- ASIPP undertakes more than 73% of ITER Procurement Package in China
- Taking ITER contracts like PF6, TAC1, bellows…
- Supporting human resource to ITER: IPAs, Visiting Scientists…

ASIPP Contribution to ITER – PAs

Conductors

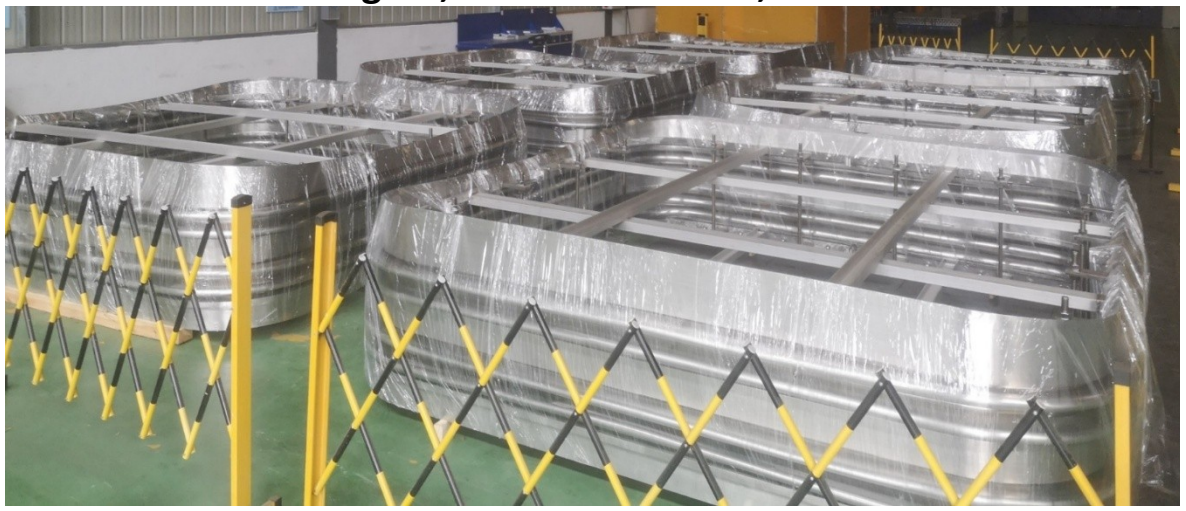
AC/DC

CCs

Feeder

ASIPP Contribution to ITER – Contracts

PF6 magnet, 12 m in diameter, ~400 tons



Large cross section (3m*4m) rectangular bellows

ITER Assembly (TAC1)

ASIPP Contribution to ITER – Assembly

- **“China is the most valuable partner for ITER”**

—— B. Bigot (ITER Director General)

习近平向国际热核聚变实验堆计划重大工程安装启动仪式致贺信

国际热核聚变实验堆（ITER）计划重大工程安装启动仪式7月28日在法国该组织总部举行。国家主席习近平致贺信。

习近平指出，科学无国界，创新无止境。国际科技合作对于应对人类面临的全球性挑战具有重要意义。国际热核聚变实验堆计划承载着人类和平利用核聚变能的美好愿望，计划实施以来，中方始终恪守国际承诺，中国企业和科研人员勇挑重担，与国际同行齐心协力，为计划的顺利推进贡献了中国智慧和中国力量。十多年来的积极探索和实践充分证明，开放交流是探索科学前沿的关键路径。

习近平强调，当前，全球正面临新冠肺炎疫情带来的严峻挑战，人类比以往任何时候都更需要携手前行、共克时艰。中方愿继续同各方加强科研交流合作，合力突破重大关键科学和技术，推进全球科技创新，为增进各国人民福祉、实现全球可持续发展不断作出新贡献。

国际热核聚变实验堆计划是当今世界规模最大、影响最深远的国际大科学工程，我国于2006年正式签约加入该计划。

新华社发

ITER International Contracts

PF6 ： 100% completed ， In cash procurement from EU F4E

As CNPE consortium member, implemented the installation of major components of ITER

Installation of coil

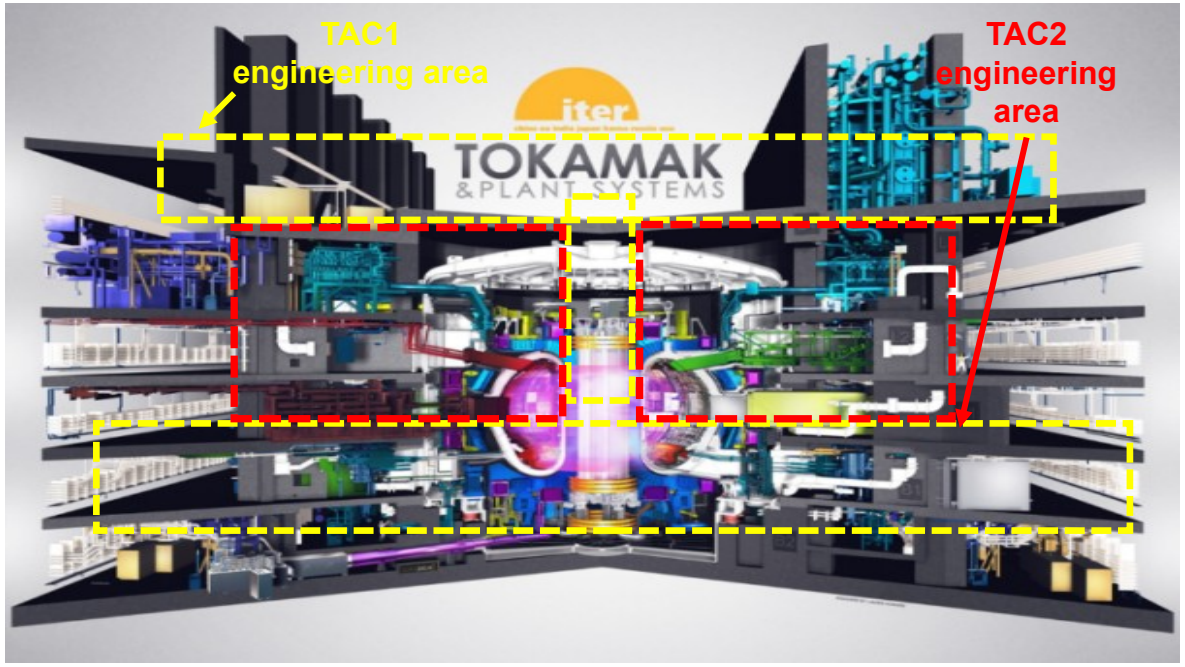
>95% in PIT >50% Feeder Placement have been finished

ITER Tokamak Assembly Contract (TAC1)

CN consortium has successfully implemented the installation of major components of ITER, and has become the most trusted contractor for IO

>95% in ITER PIT and >50% of Feeder Placement have been finished.

The TAC1 was signed in September 2019



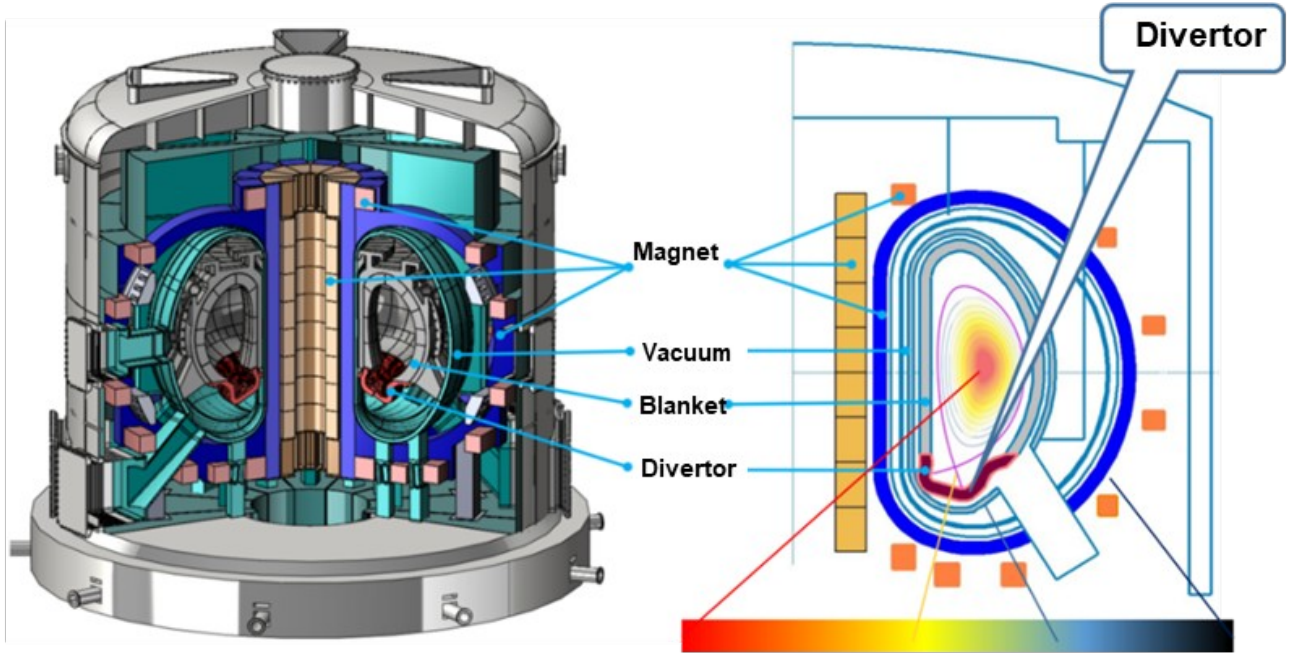
Contribution to ITER staff & site construction

- **ASIPP have sent over 100 people to support ITER On-site.**

(Including IPA \ TAC1 personnel \ Visiting Scientists…)

CRAFT: Comprehensive Research Facility for Fusion Technology

- Explore and master fusion DEMO level key technologies
- **Establish the method and standard** for manufacture the key material, components and system for CFEDR



Large complex superconducting magnet system

Divertor system under extreme conditions

project durations 5 years and 8 months

CRAFT

Two main platforms and related R&D works:

Superconducting magnet research system

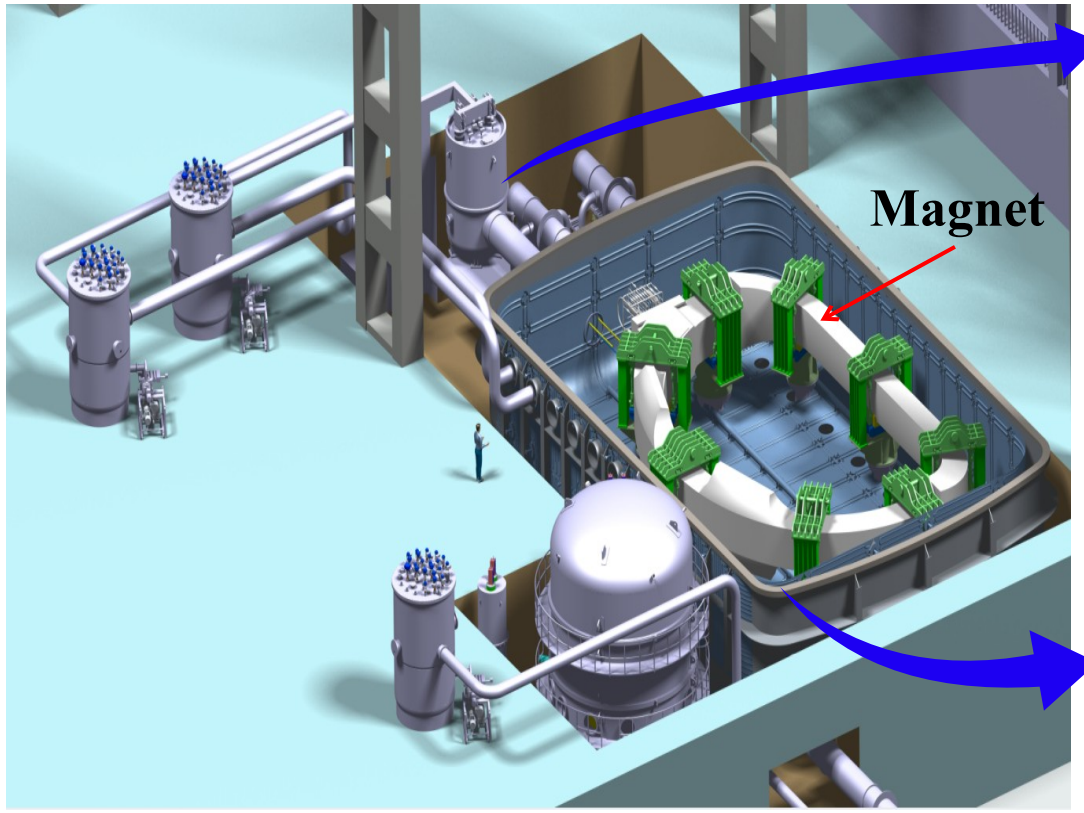
1. SC Material testing facility
2. SC Conductor testing facility
3. SC magnets testing facility
4. CFEDR CSMC and testing facility
5. CFEDR HTS coil and testing
6. CFEDR TF coil and testing
7. Cryogenic system
8. Power supply system

Divertor research system

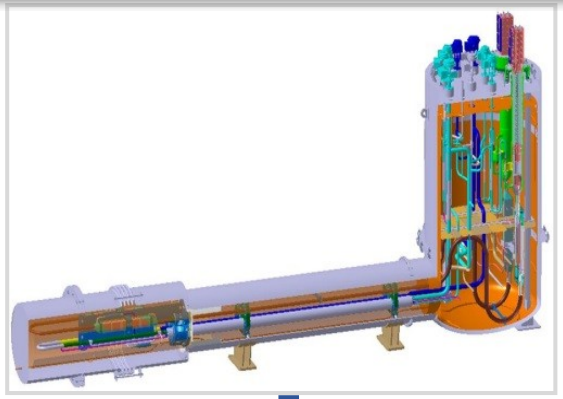
9. Large Linear plasma testing facility
10. CFEDR divertor development
11. CFEDR divertor testing facility
12. EAST divertor upgrade
13. NNBI system
14. ECRH system
15. LHCD system
16. ICRF system
17. RH testing facility
18. VV and installing testing facility
19. Mater Control facility

CRAFT: SC magnet test facility

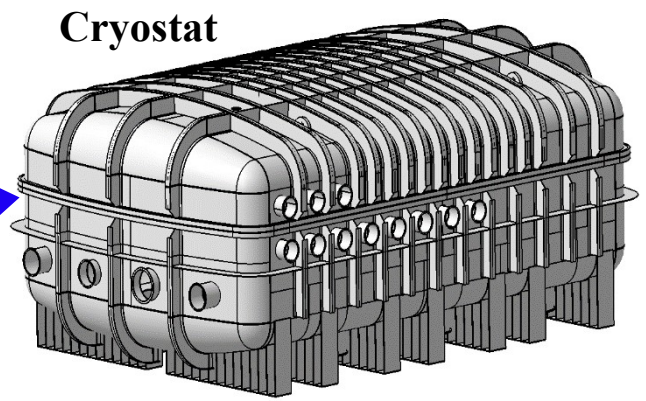
To master scientific and the intrinsic physical properties and service behavior of materials for superconducting magnets in complex and extreme environments, and to carry out engineering application research.



Large-scale Magnet Performance Research



- Quench detection system
- Protection system
- Cryogenic system
- Fast discharge
- Vacuum system

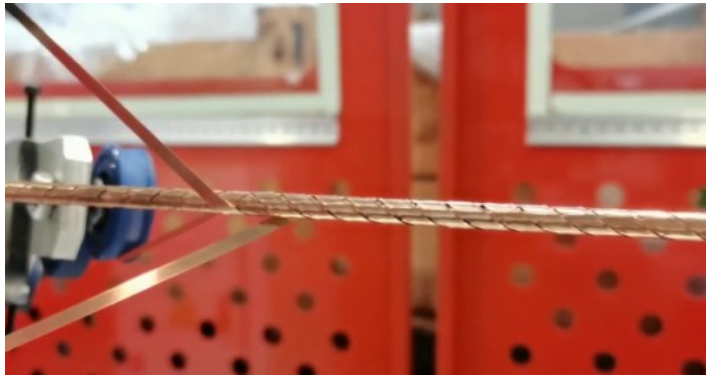


Item	Description
Cryostat main dimension	Length~25.5m ; Width~15.5m ; Height~10m
Operation temperature	4.5K
Current leads operation current	100kA/60kA
SHe pressure	3-6 Bar
SHe massflow	>500 g/s

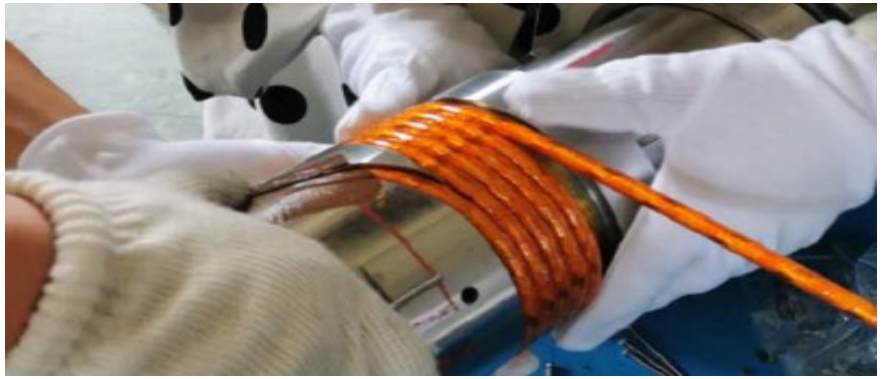
CRAFT: HTS coil development

- Develop automatic cabling machine
- low resistance HTS joint
- Long cable manufacturing

Insert coil:
Maximum field: 21.1T (back field18.5T)
Operating current: 6.5kA

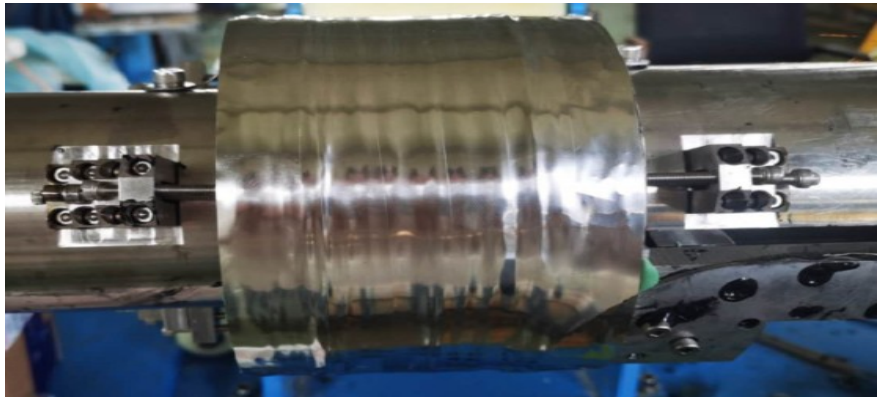


Cabling



Coil winding

Curing



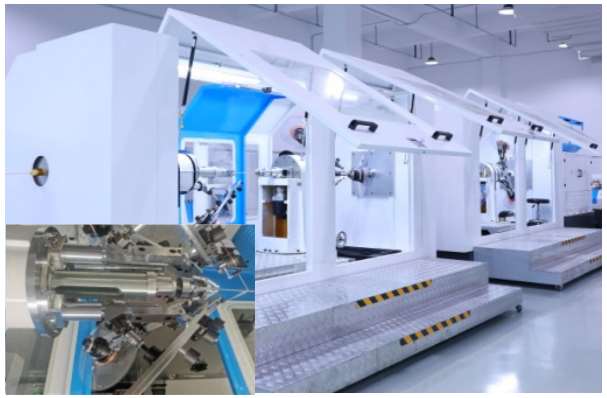
Pre-loading

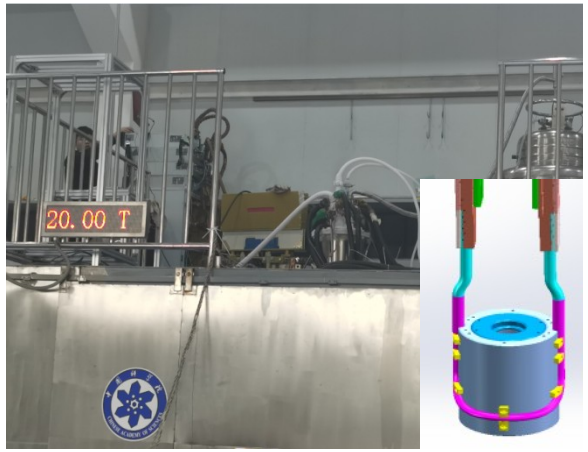
Testing

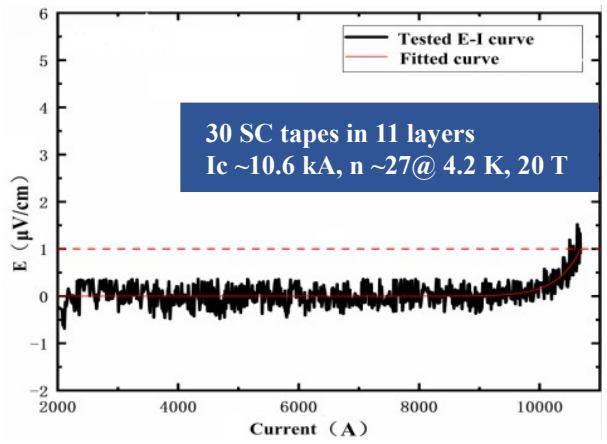
CRAFT: HTS magnet development

Sub-cable:

- Develop automatic cabling machine
- Sample performance → I_c=10.6kA@20T, 4.2K
- Long cable manufacturing → L=110.6m

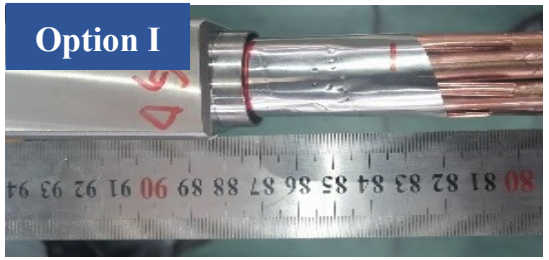


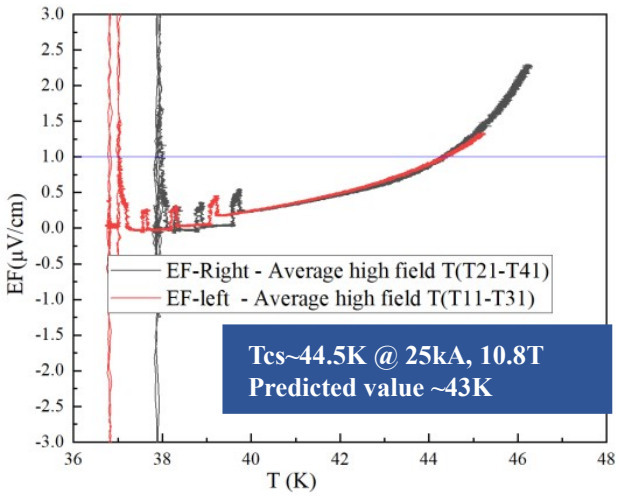




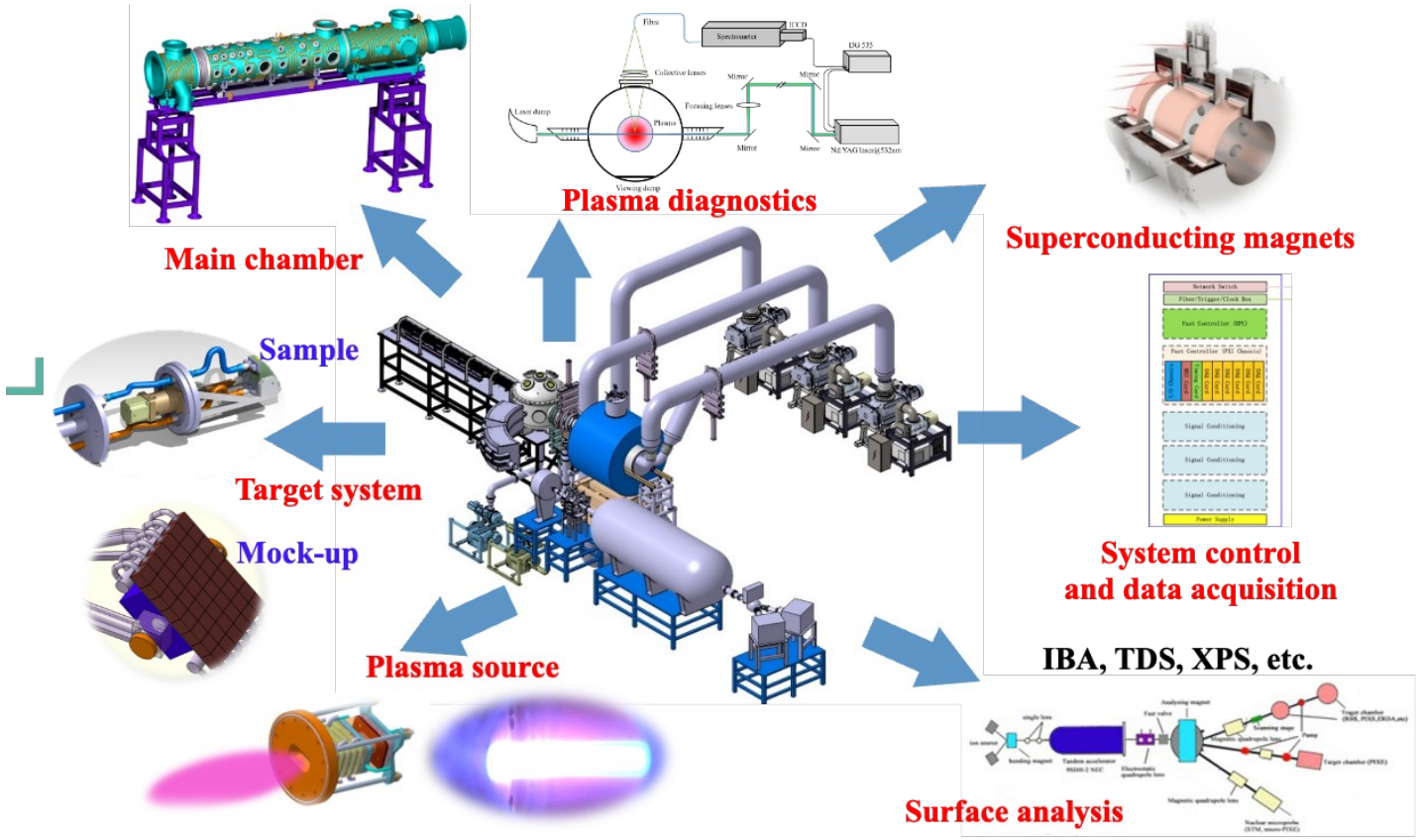
Full size conductor:

- Two samples were prepared → **2.7m per sample**
- Sample performance → **47kA@10.8T, 4.2K, stable**
- New optimized samples expected to finish in October



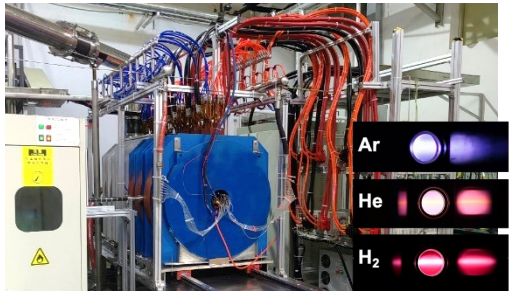


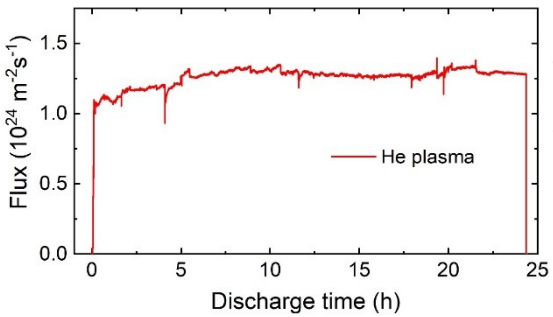
CRAFT: Large linear plasma testing facility



Shot length	~1000 s - hours
Magnetic field	~3 T
Particle flux	10^{24} -10^{25} $m^{-2}s^{-1}$
Plasma dimension	30-100 mm
Max. Sample/mock-up size	250×250 mm

Pilot machine, >1024 $m^{-2}s^{-1}$ flux for >24 hours



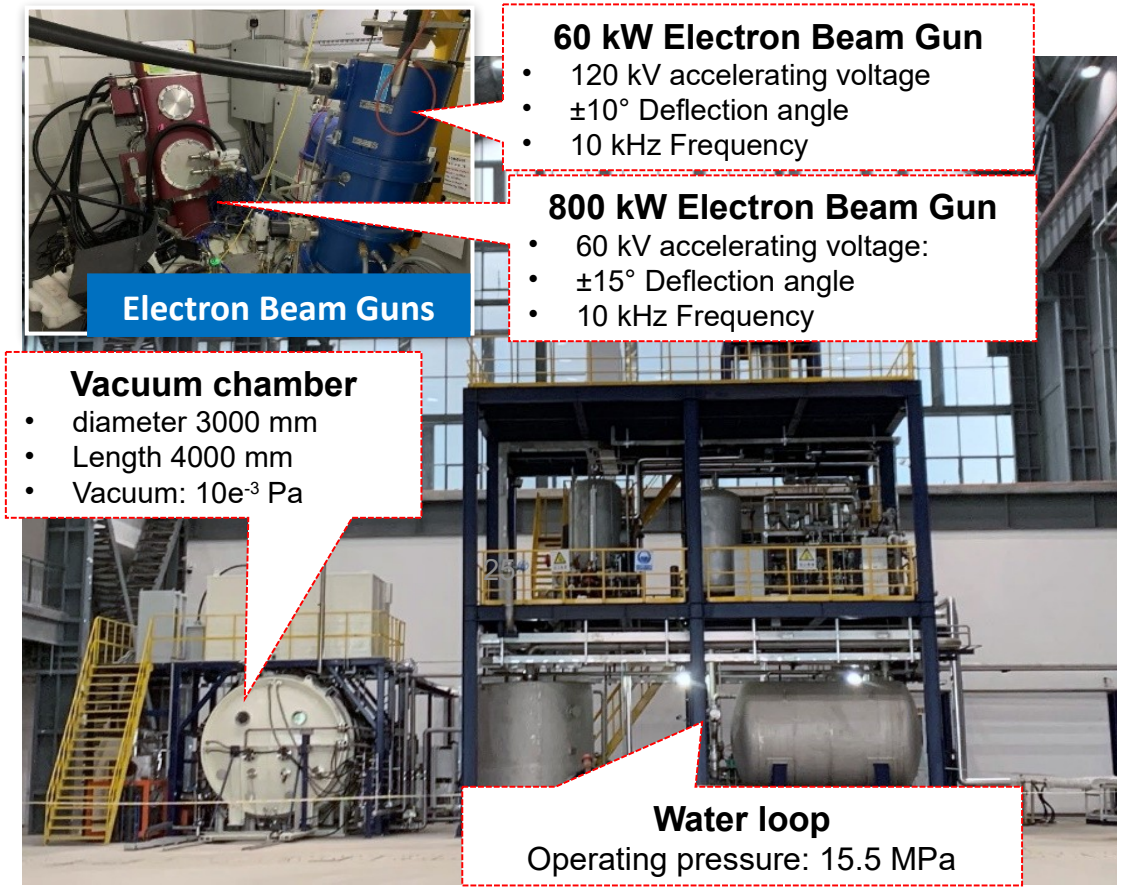


Will be finished on end of 2024

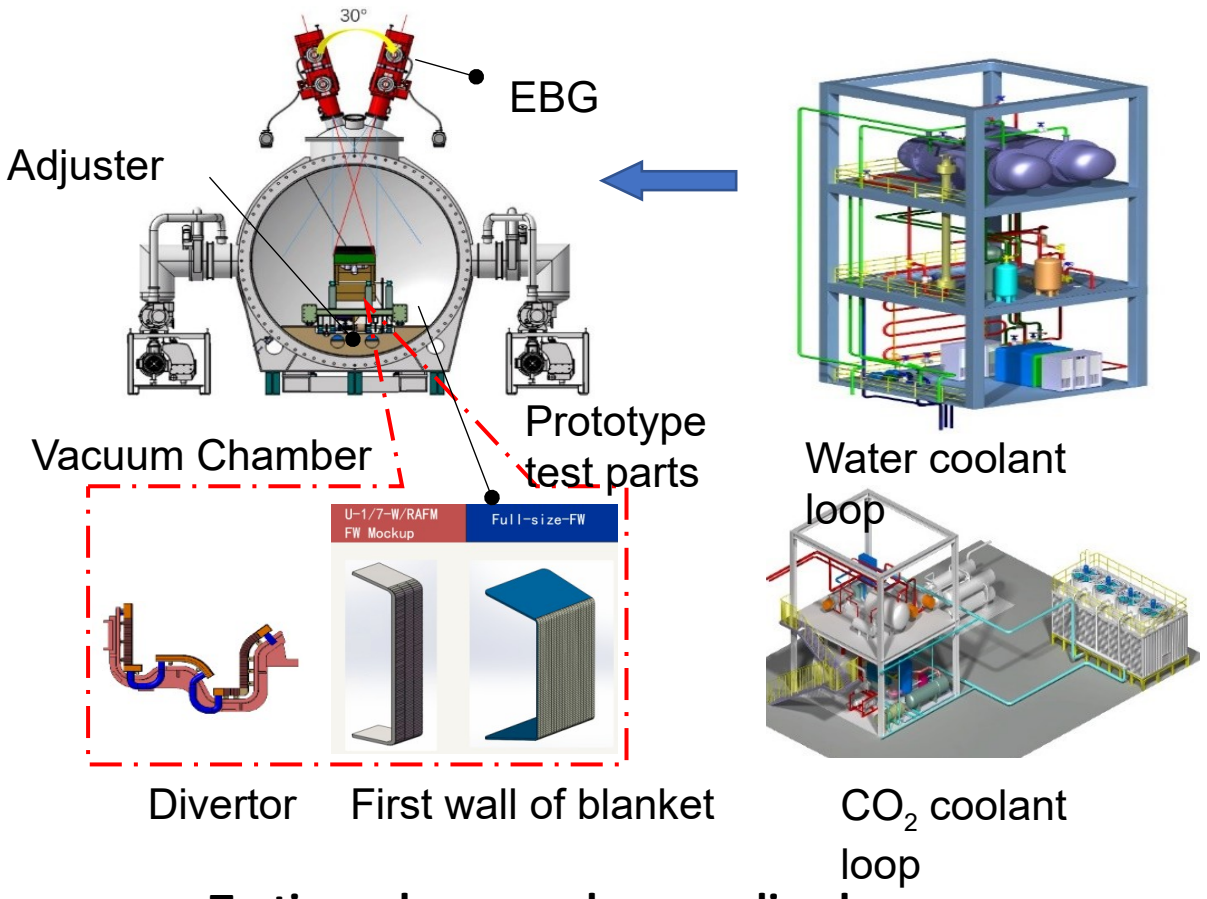
CRAFT: Divertor/Blanket test facility

The construction and commissioning of the main machine and water loop was finished

20MW/m2 heat load, Water/CO2 cooling, components acceptance test or accident test



Main device and water loop

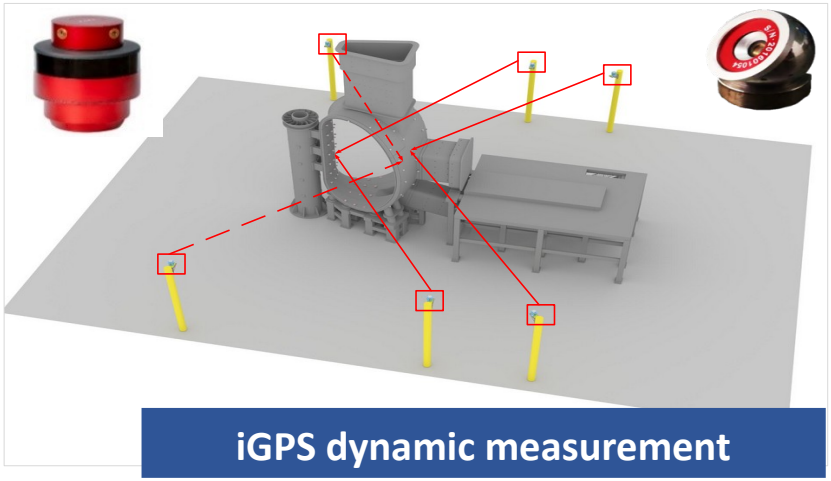


Testing scheme and gas cooling loop

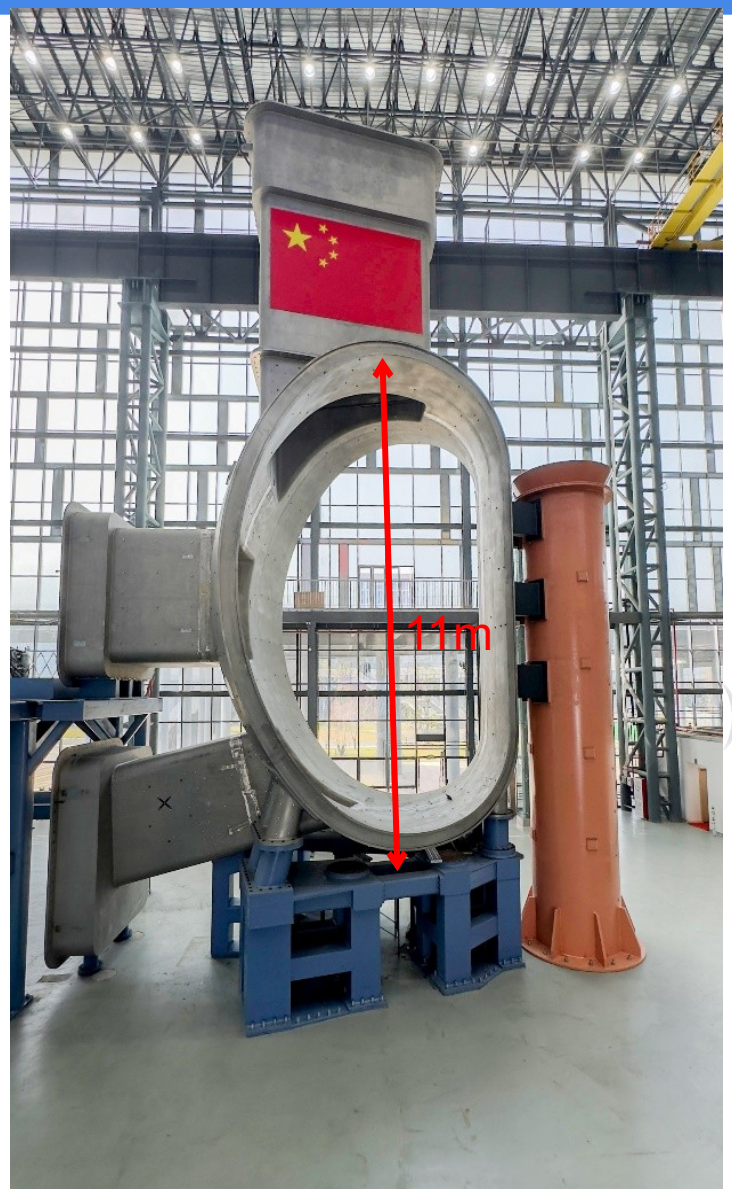
CRAFT: 1/8 VV and Assembly Test Platform

Manufacturing completion

- ✓ Based on precision measurement and reverse engineering , Assembly accuracy ≤ 1mm
- ✓ In-site weld length : ~190m
- ✓ Groove type: 50mm full penetration
- ✓ Welding quality: ISO-5817 level B
- ✓ Surface deviation ≤ ±8mm

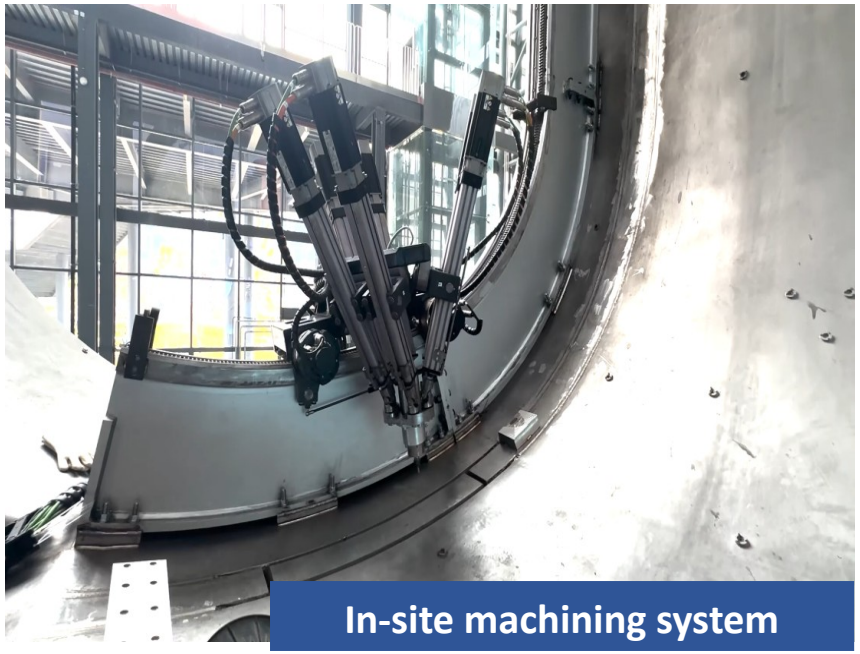


iGPS dynamic measurement



Completion of automation system

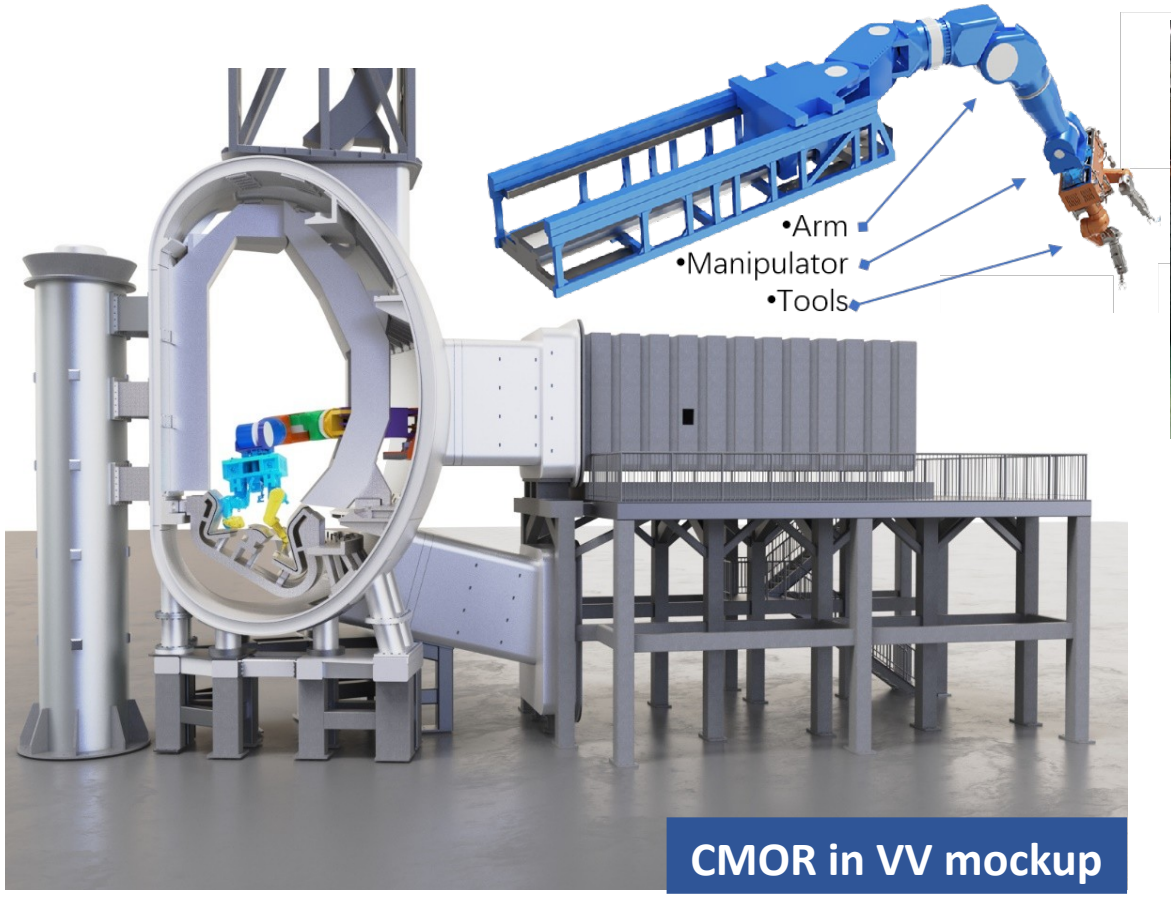
- ✓ In-site automatic machining, Narrow Gap Tungsten Inert Gas Welding, automatic Phased Array Ultrasonic Testing have been built and applied in the assembly process of sectors.



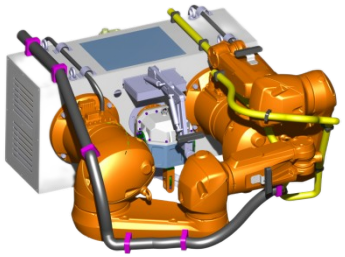
In-site machining system

CRAFT: Remote handling system

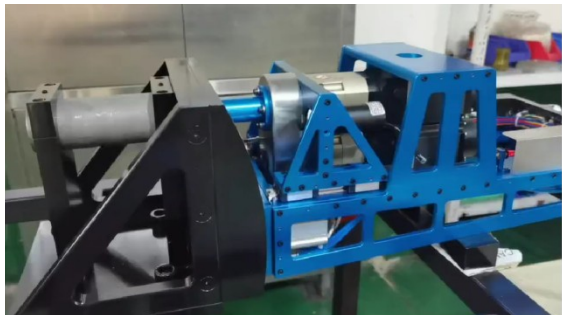
CFEDR Multipurpose Overload Robot would be used for maintenance the first wall components with 10 meters long and 2.5 tones capacity



CMOR in VV mockup



- Dexterous manipulator being assembled
- 30kg per arm, 100kg for crane

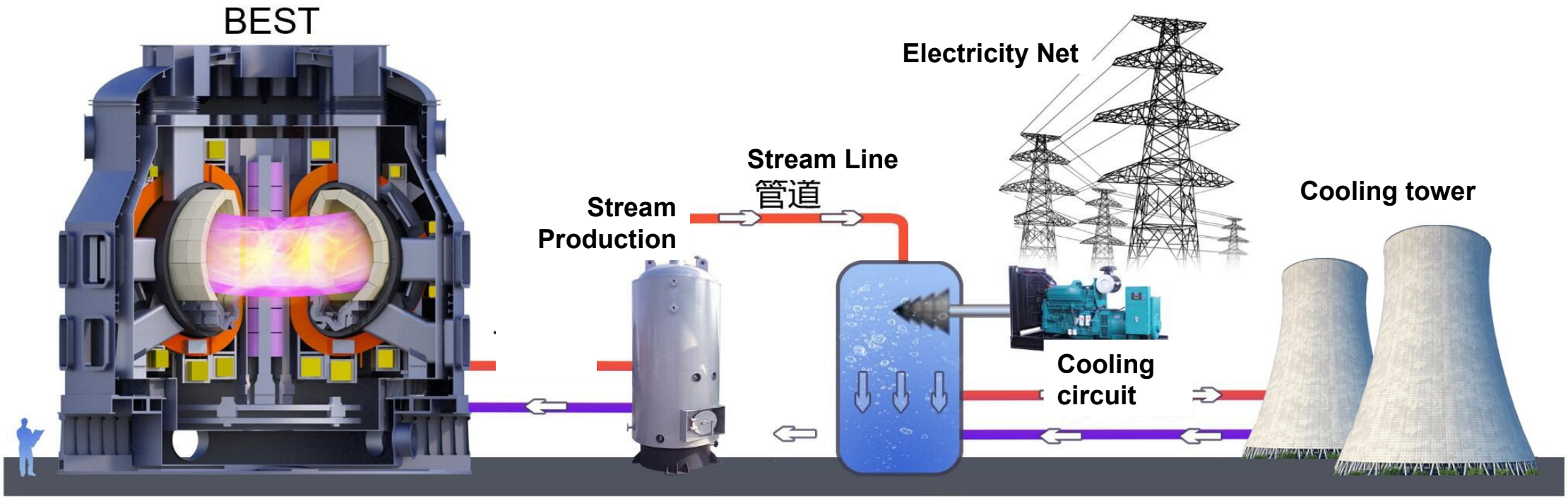


- Qualified in-bore cutting tool for divertor
- ø51mm with 3mm thickness

BEST: Burning plasma Experimental Superconducting Tokamak

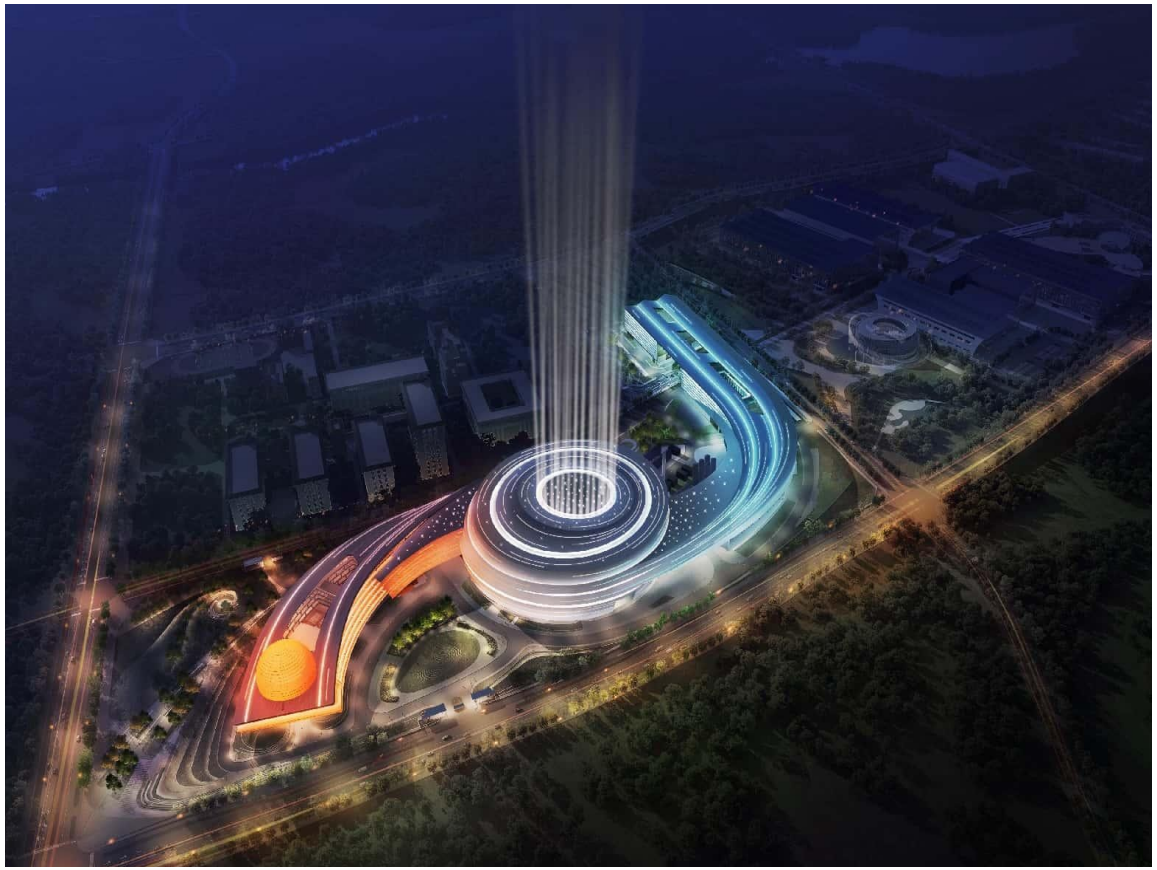
Scientific objective

- Fusion power of 20-200 MW, Q=1-5, alpha particle heating and the burning plasma confinement and transportation
- Long pulse steady state safe control of burning plasma
- Realization of real-time T production, extraction and cycling



BEST Campus Starts its Construction

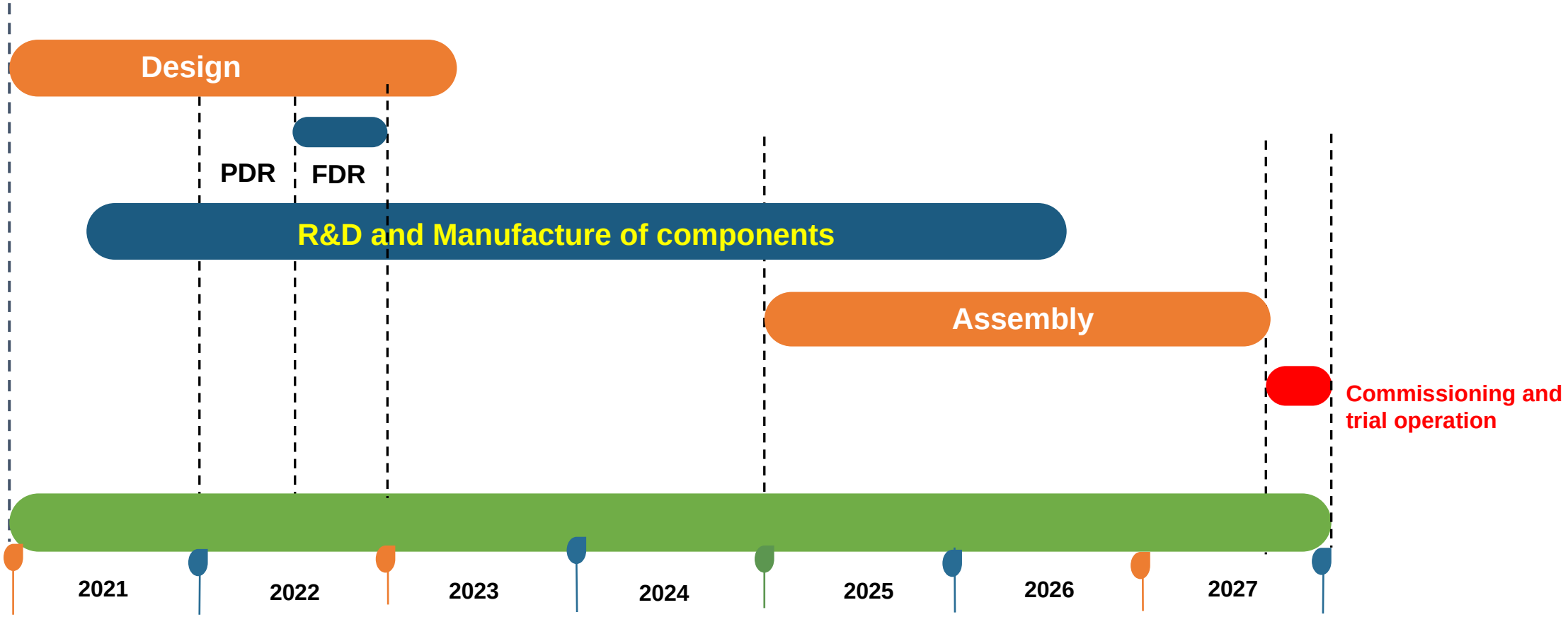
The construction of BEST main building will be finished in a couple of months



Overall schedule of BEST

It is planned to have the first plasma on December 2027

DT Q~1 long (>1000s) :2029-2030, Q~5 (5-10s) 2030-2035



BEST started its fabrication

Three production lines TF coil

Production line for conductor

TF Winding Test

Superconducting Joints Fabrication

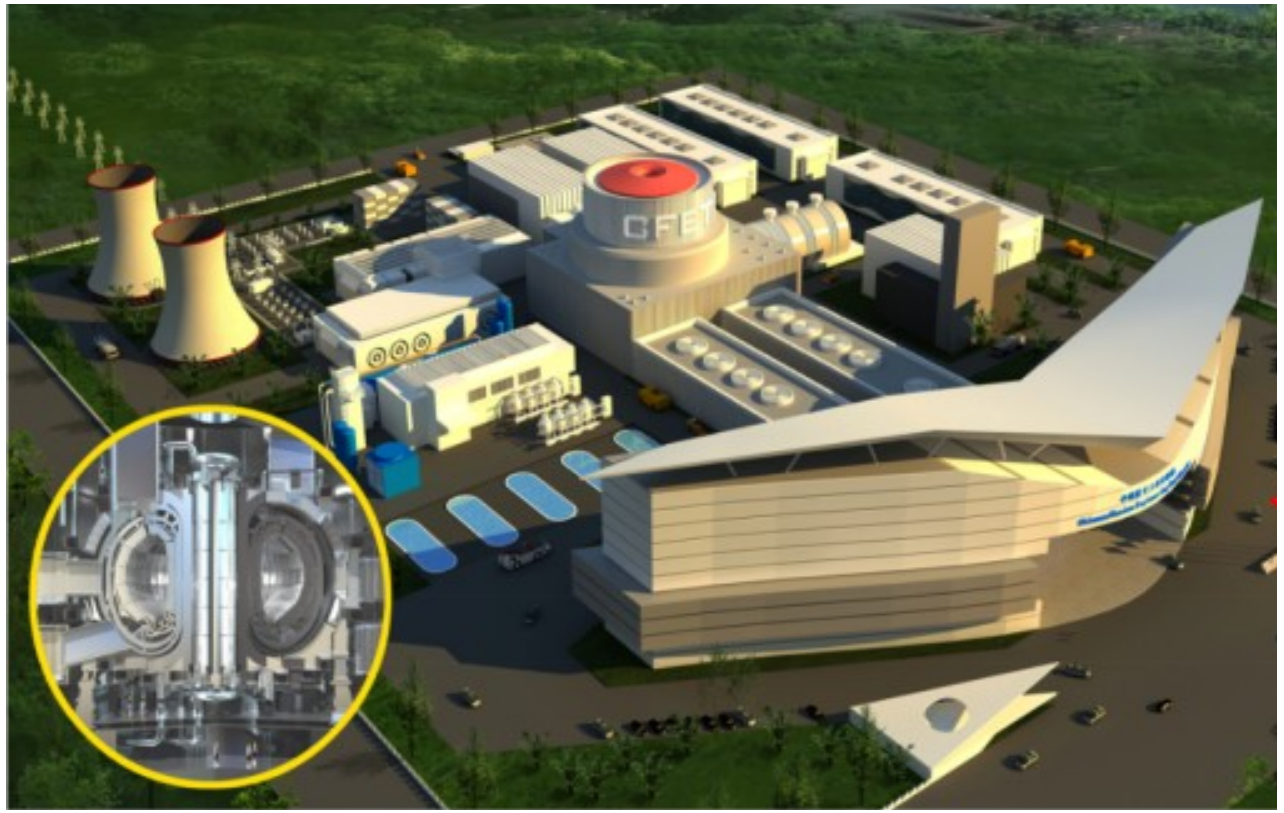
Superconducting Cable

CFEDR: Chinese Fusion Engineering DEMO Reactor

Aiming 1.5-3.0 GW net electrical power generation

Achieve steady-state self-sustainable burning with Q=20-30

Systematic R&D works for the Engineering Verification based on CRAFT



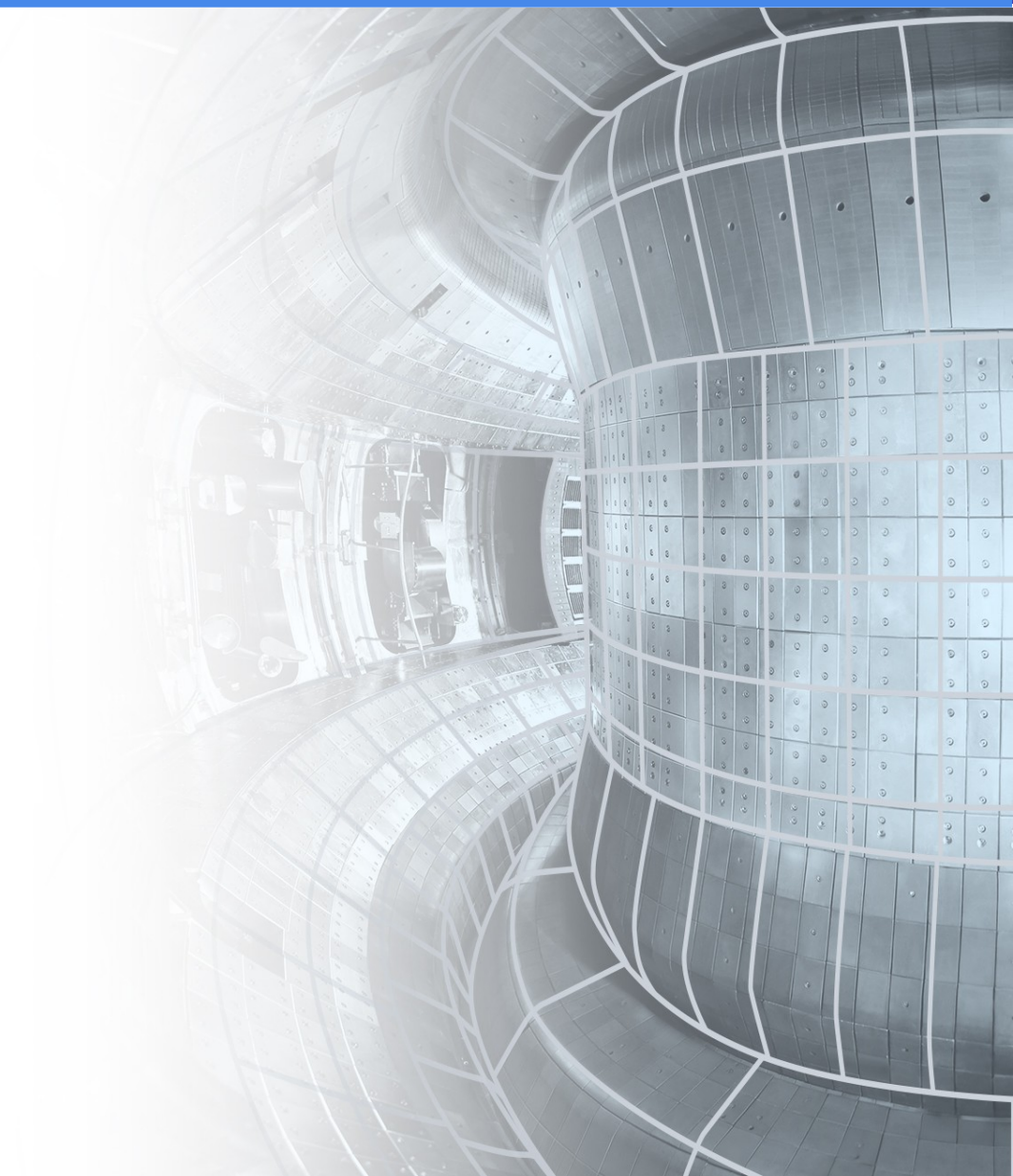
- ✓ **R&D works are being carried out**
  - TF magnet
  - Divertor
  - 1/8 vacuum vessel
  - NBI system
  - RH system
- ✓ **Large-scale testing facility under constructed**
  - Magnet Performance Research facility
  - Linear plasma testing facility

Contents

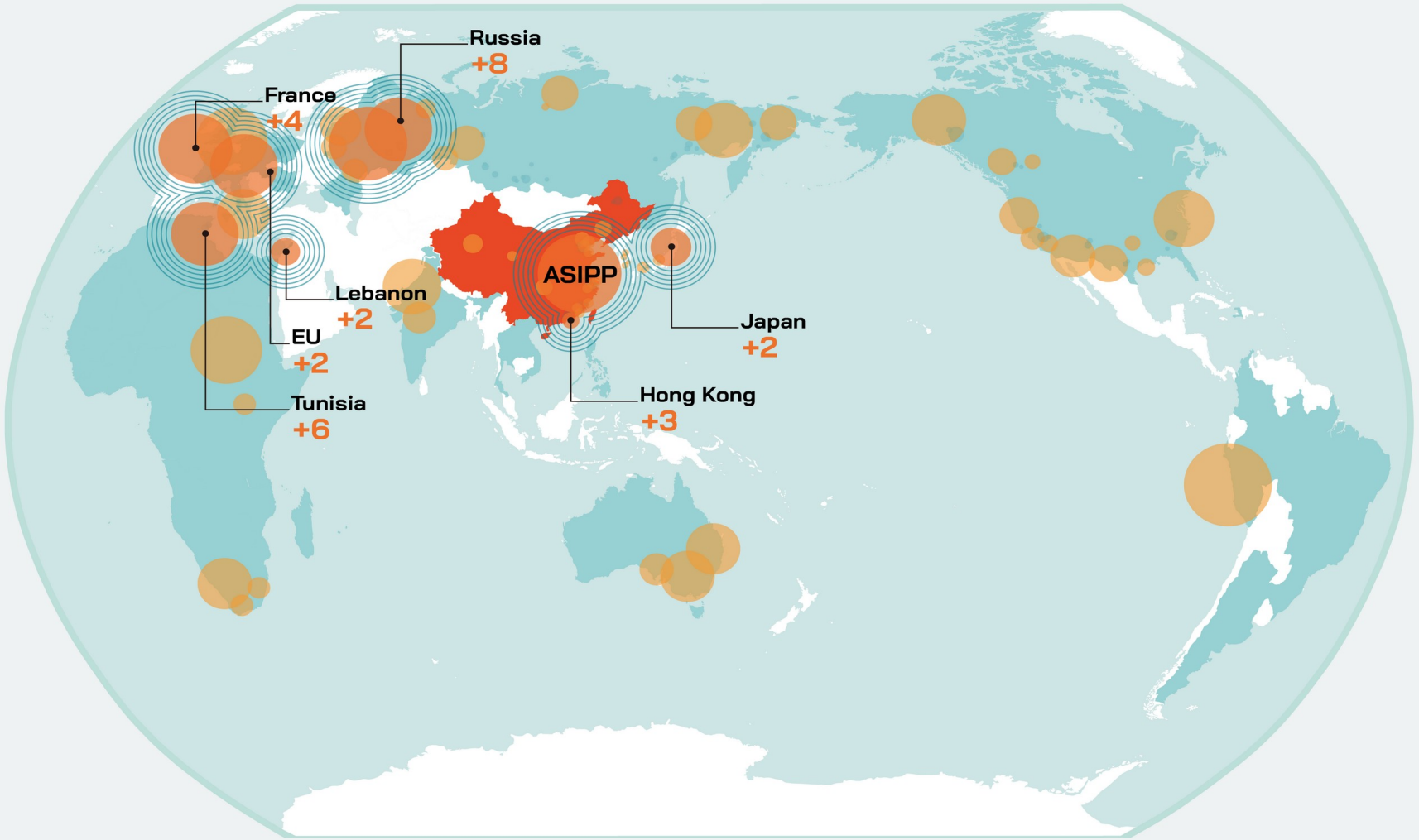
ASIPP Introduction

International Cooperation

Summary



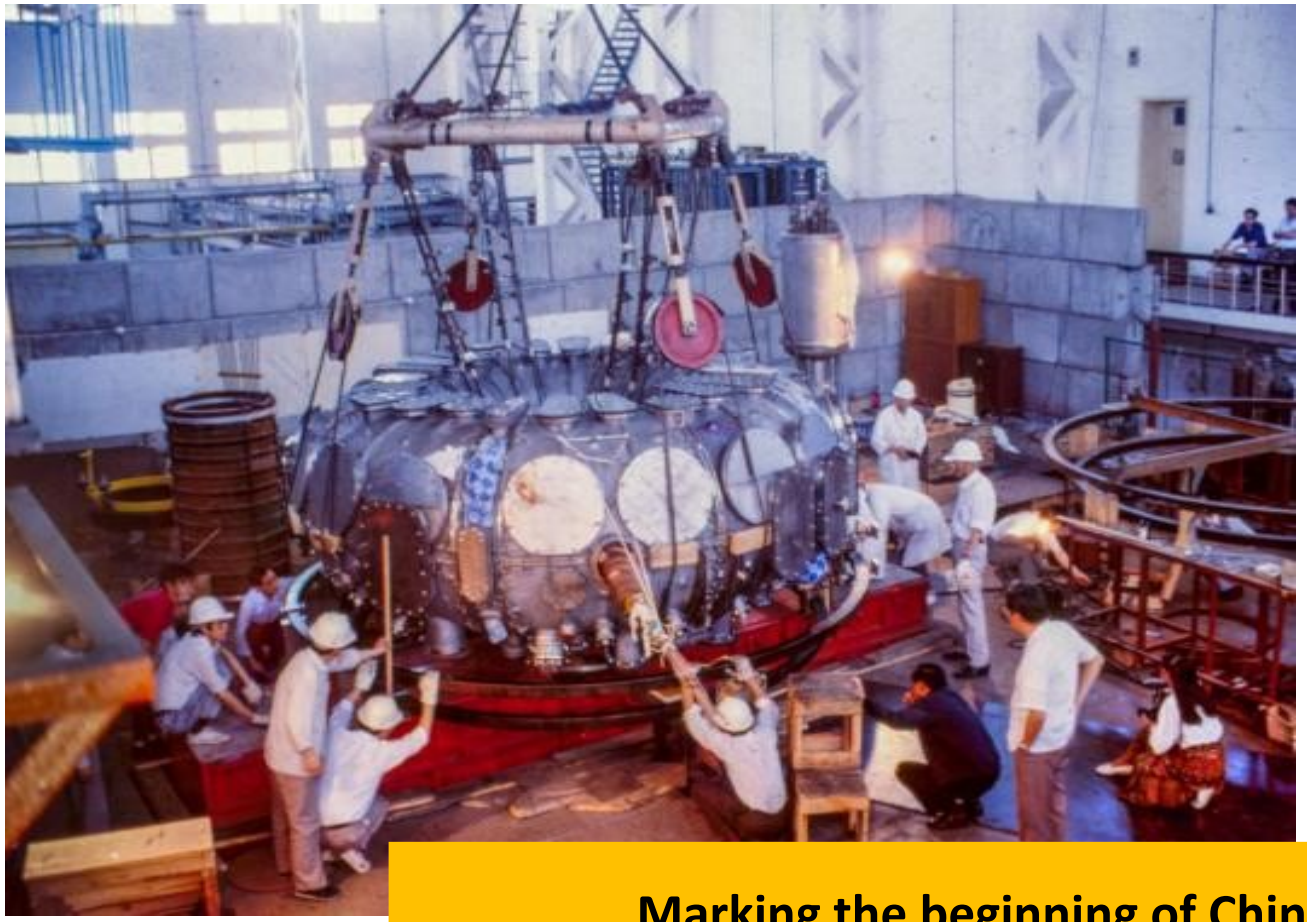
Worldwide collaboration network



Established cooperative relations with **120+** key fusion research institutions and **50+** countries and regions.

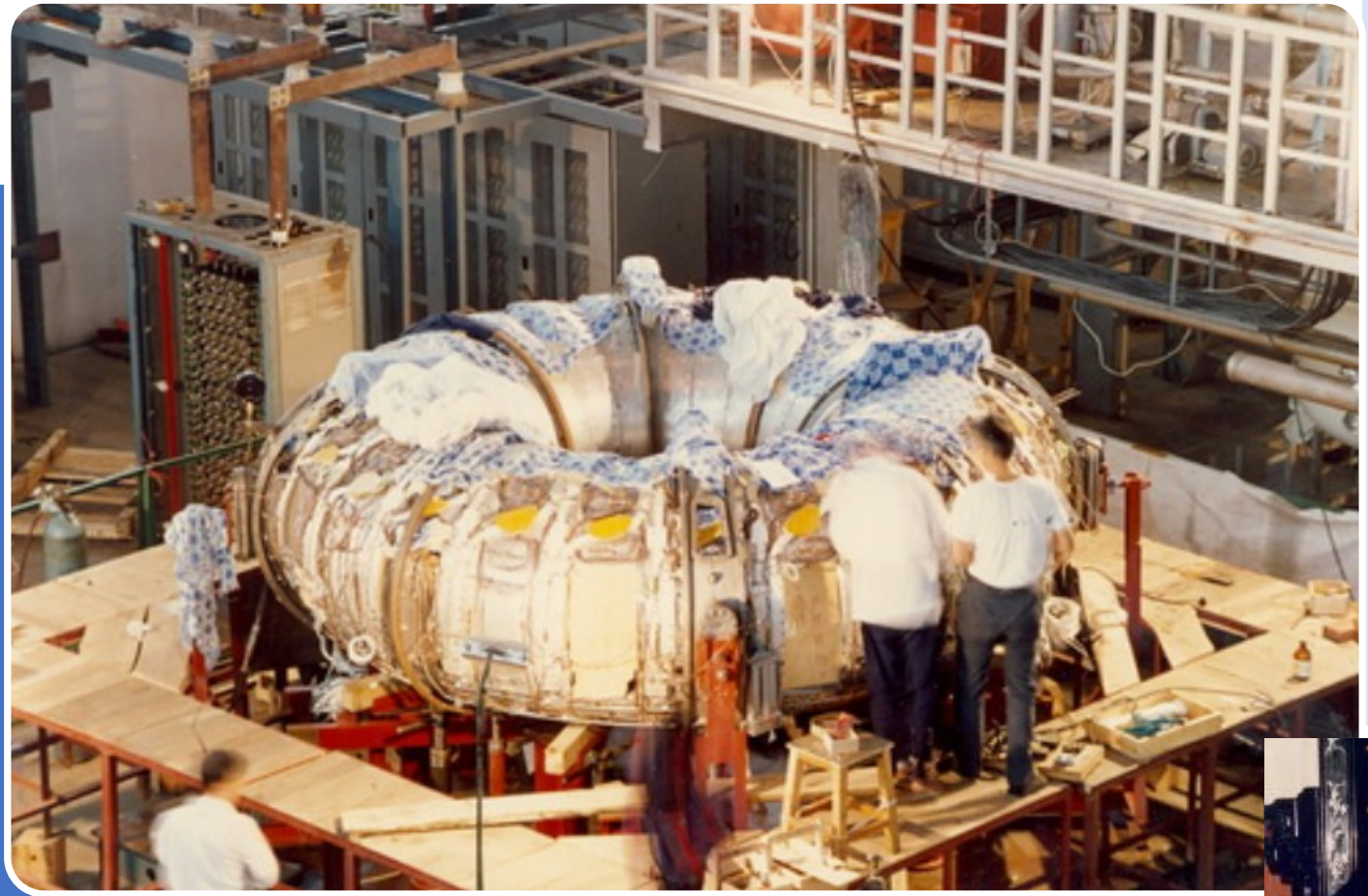
35-year History of Sino-Russian Fusion Development

In 1992, the NRC “ Kurchatov Institute” donated the world's first superconducting tokamak T-7 to ASIPP, and spent 2 years assisting ASIPP in its installation, upgrade, and reconstruction into China's first superconducting tokamak device—the Hefei Tokamak-7 （ HT-7)



Marking the beginning of China-Russia fusion cooperation

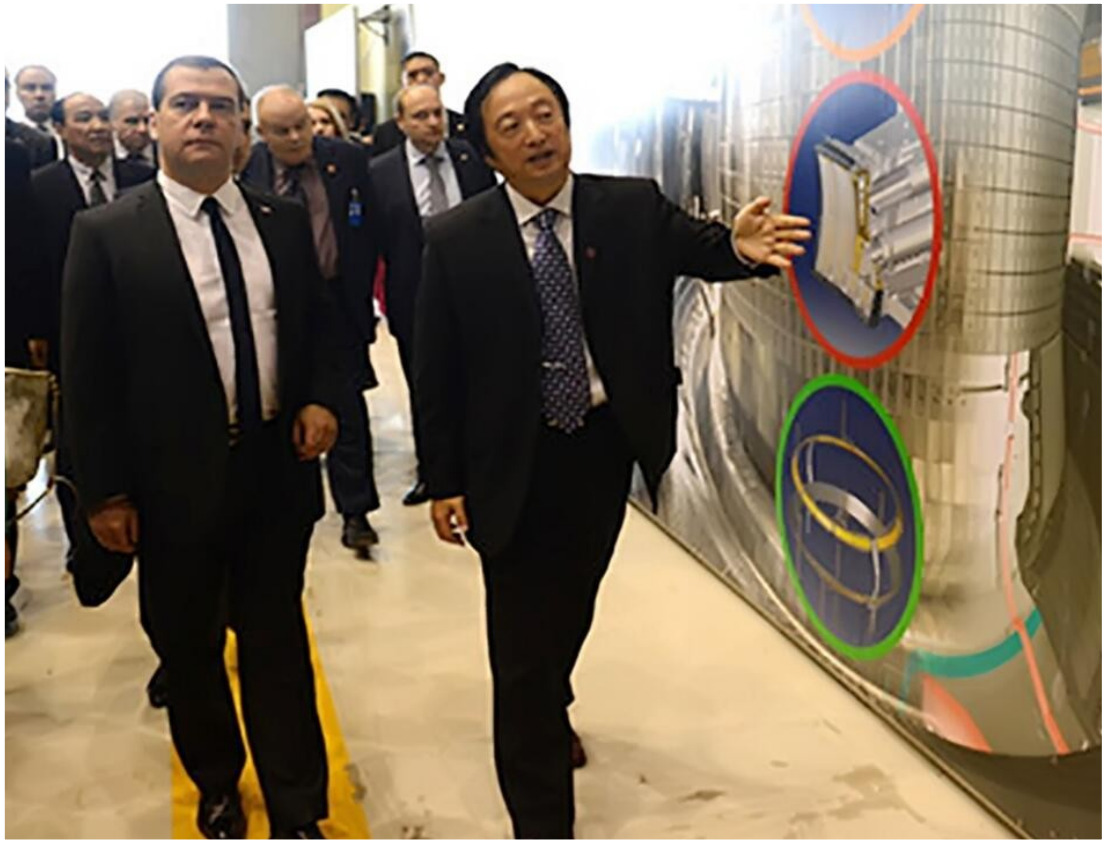
China's First Superconducting Tokamak Device — HT-7

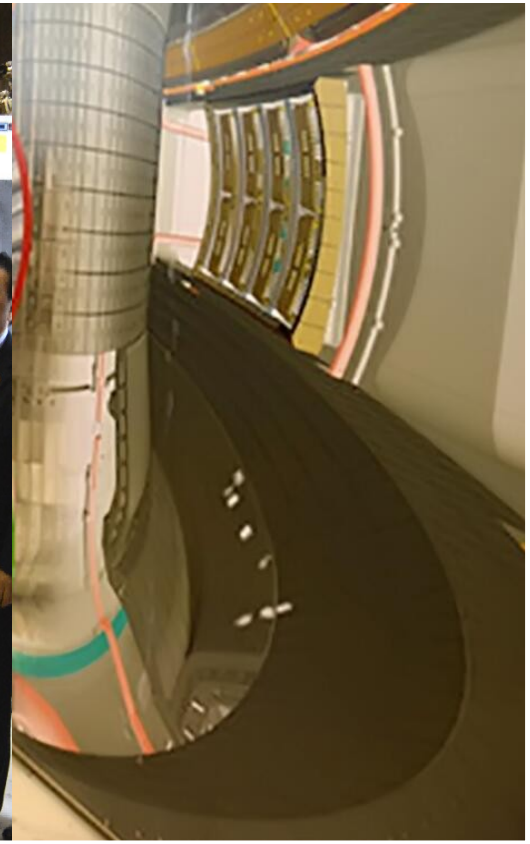


Major Results

- Realize 400s plasma discharge
- Nurture an exceptional engineering, scientific research and management team
- Establish amicable and cooperative relations with Russia

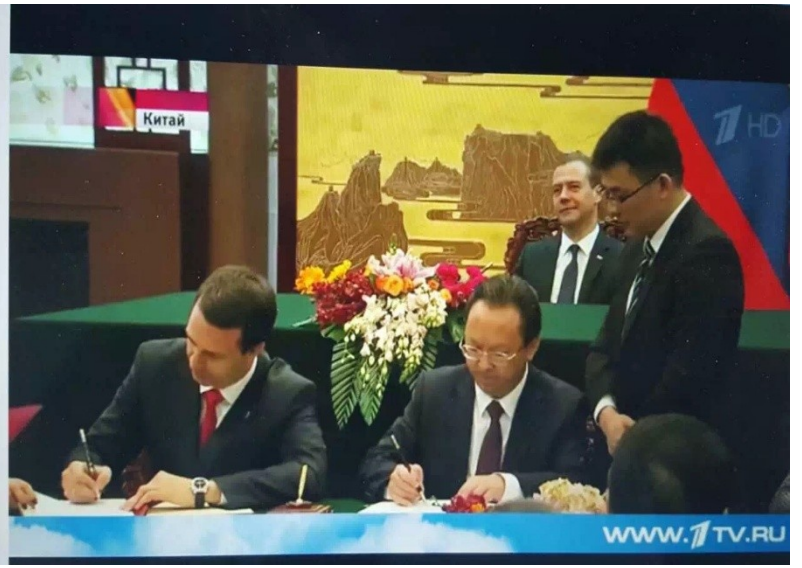
Strong Support from Two Governments





Dmitry Medvedev highly praises the in-depth cooperation in the fields of nuclear fusion and Large Scientific Infrastructures (2013)

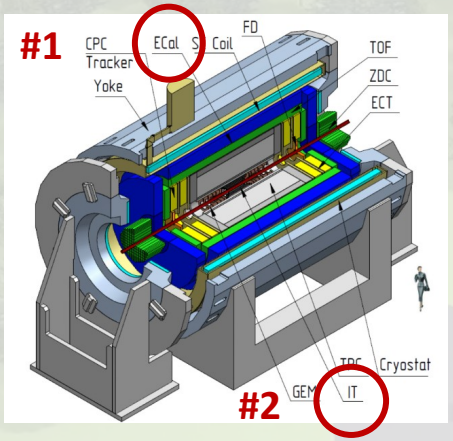
In-depth Collaboration on Large Scientific Infrastructures



01 The Ministry of Science and Technology strongly supports the NICA project with a funding of 130 million CNY

02 ASIPP designs and manufactures the Magnet Energy Storage system for NICA project

Collaborations on the NICA Project



Key Technical Research Collaborations of NICA

Topic #1
Collaborative Research on Key Technologies of the NICA-MPD Novel Electromagnetic Calorimeter

*Tsinghua University
- Shandong University
- Fudan University
- Huzhou University
- Nanhua University

Topic #2
Joint Development of a Silicon Pixel-Based Inner Tracking Detector

*Central China Normal University
- University of Science and Technology of China
- Institute of High Energy Physics, CAS
- Institute of Modern Physics, CAS
- Huzhou University

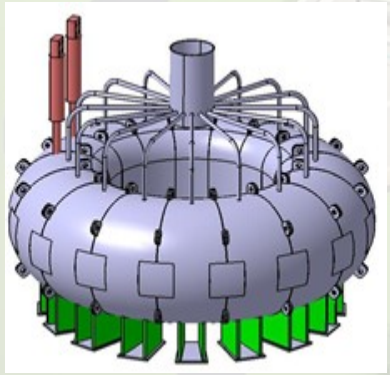
Topic #3
Collaborative Research on the MJ-Class High-Temperature Superconducting Energy Storage Magnet System

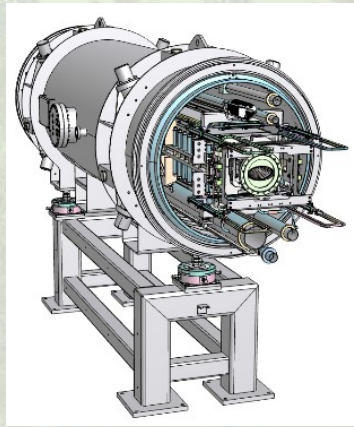
*Institute of Plasma Physics, CAS (ASIPP)

Topic #4
Joint Development of Key Components for the Next-Generation Heavy-Ion Accelerator

*Institute of Modern Physics & Institute of High Energy Physics, CAS

Project Duration
2020.6~2024.5
Total Budget:
129.44 million CNY


#3


#4

Sino-Russian Superconducting Proton Joint Research Center

The Center was officially established in Hefei.

JINR and ASIPP jointly developed the SC200 advanced superconducting proton cyclotron.

Significant Achievements of Superconducting Proton Therapy

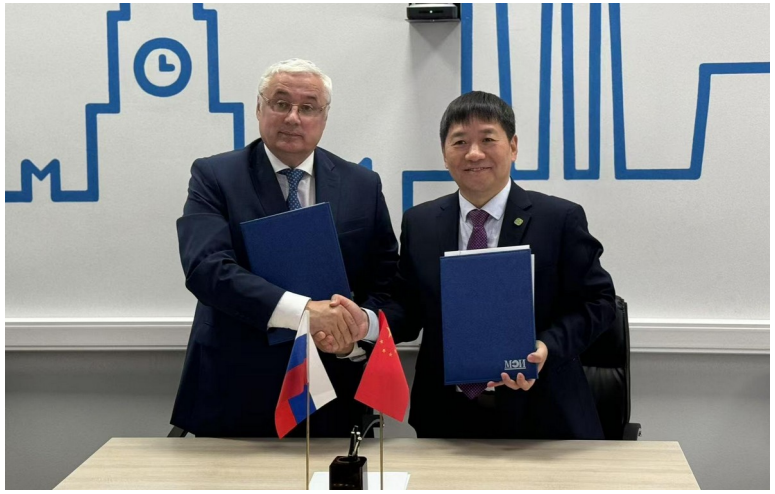
The superconducting Proton Therapy System features **high accuracy, customized software interface, high efficiency, compact structure, and flexible configuration.**

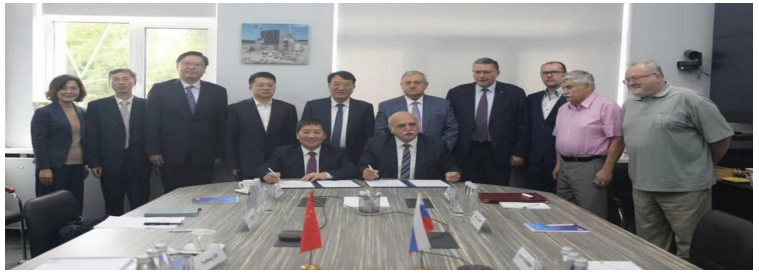
360° Rotating Frame
Rotational accuracy : ±0.1°
Isocentric accuracy : ±0.5mm

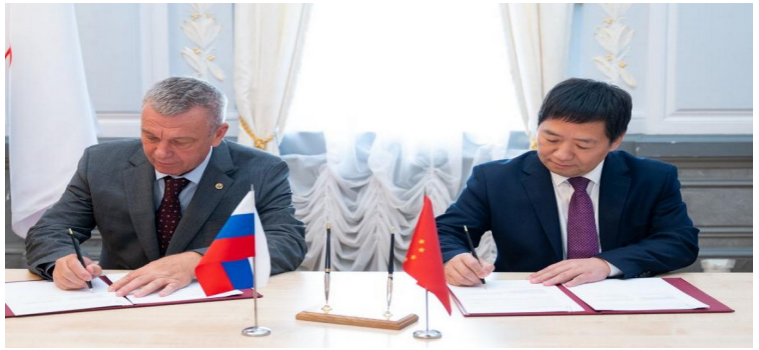
Maximum energy: 240 MeV
Energy range : 70-220 MeV
Beam intensity: ≥ 800 nA

Deepening Collaboration on ITER Project

- Regular Technical Exchanges
- Signing of Multiple Cooperation Agreements
- Joint Research & Development



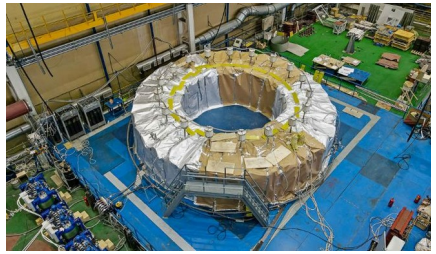




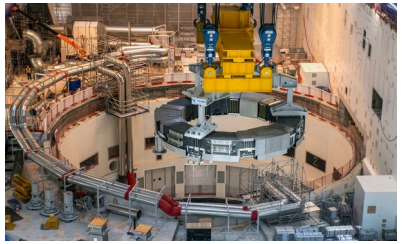
From participation to co-leadership –
building the future of fusion together ！

Knowledge Sharing & Technical Breakthroughs

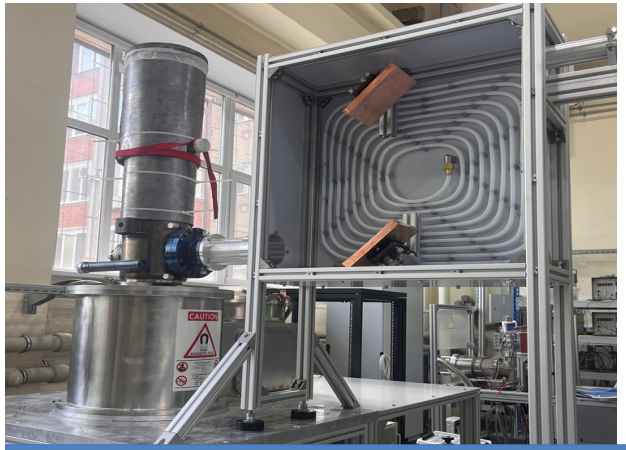
Technology Collaboration: Shared Expertise and Key Component Development



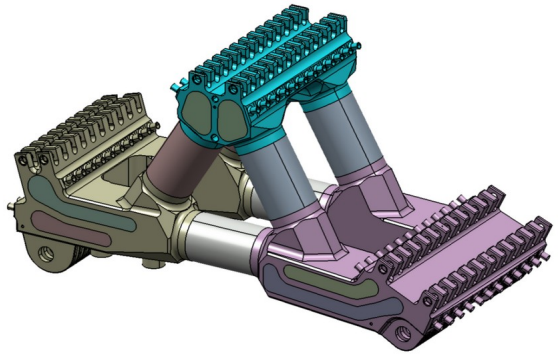
PF1



PF6



High-Power Gyrotron R&D and Expert Collaboration



Engineering Design of the Divertor System

Pictures are kindly provided by our collaborators

Mutual Support in International Organizations

Participate and promote the BRICS scientific and technological activities, strengthen the openning & sharing of Large Scientific Infrastructures

Successfully organized the BRICS Fusion Week

Jointly promote scientific and technological innovation activities

Talent Development & Exchange Programs

Fostering the next generation: joint training and mobility

Students at the ASIPP Summer Camp

Scientists share knowledge at Science Island

Over 300+ individuals trained or exchanged since 2020

Significant Recognition by National Government

- 6 national awards of international collaboration and friendship
- Several CAS/Provincial awards of international collaboration

K. Gentle

2004, US

V. Chan

2009, US

E. Velikhov

2015, Russia

B. Bigot

2019, France

A. Becoulet

2020, France

G. Trubnikov

2020, Russia

Strong Support from CAS and other agencies

- Many domestic projects from CAS, MOST, Anhui Province, Hefei City.
- 40+ international experts benefited from those programs to ASIPP for collaborations

New Pilot Programme for Open Innovation (PPOI)

President's International Fellowship Initiative
国际交流计划

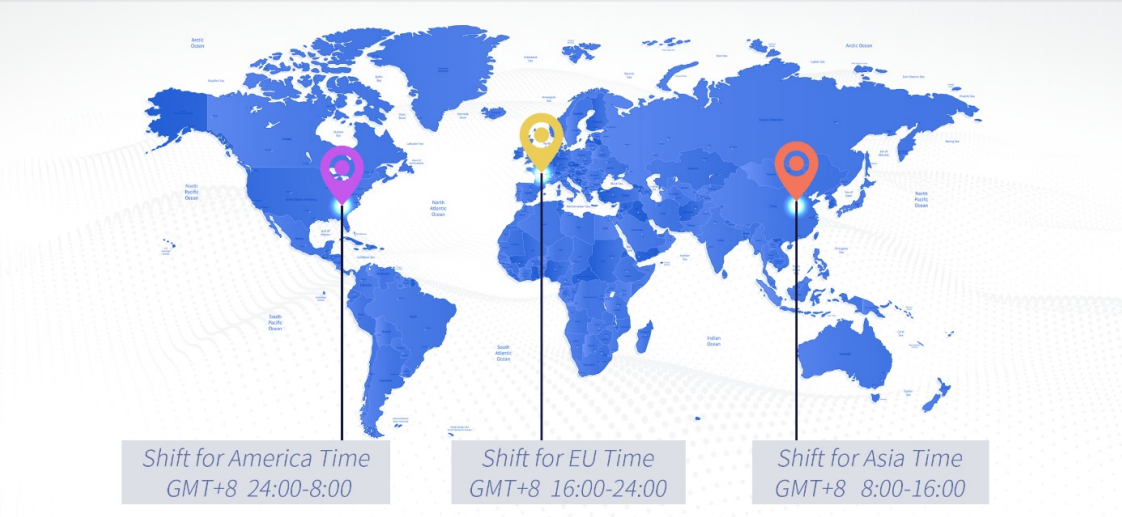
100+ countries

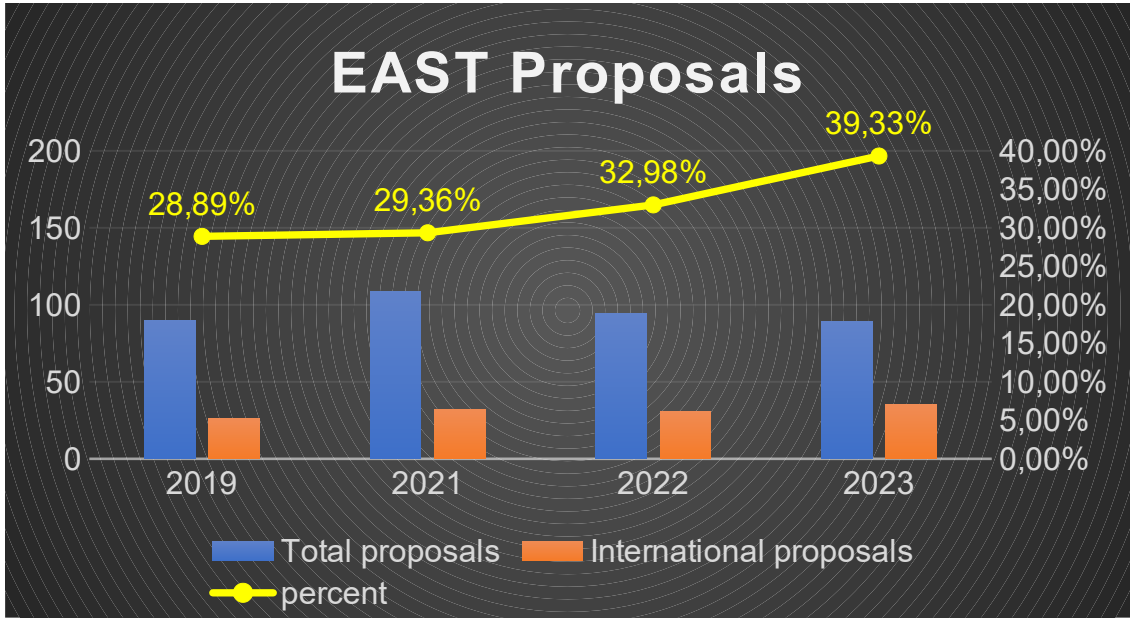
5,000+ PIFI Fellows sponsored

"一带一路"国际科学组织联盟
Alliance of International Science Organizations

Visiting Fellowship	Duration	Funding
for Early-Career Scientists	3-9 month	RMB 20,000/month (pre-tax)+ Round-trip travel allowance
for Senior Scientists	2-3 months	RMB 30,000/month (pre-tax)+ Round-trip allowance (Associate professors or equivalent-level experts)
		RMB 40,000/month (pre-tax)+ Round-trip travel allowance (Professors or equivalent-level experts)

Recent Collaboration on EAST experiments





EAST is a **shared and open** experiment platform to the world

~30% international proposals was carried out in recent 3 years;

3-shifts joint experiments for different time zones

Units: **ITER**、 **GA**、 **ENEA**、 **MIT**、 **PPPL**、 **NIFS**、 **FZJ**、 **IPP**、 **CEA**、 **Lehigh University**、 **LLNL**、 **UCLA**、 **UC3M**、 **UCLA**、 **SPbPU**、 **CREATE**、 **Kyushu University……**

Summary and outlook

01

ASIPP **focuses** on discovering the ultimate energy source for humanity using EAST-CRAFT-BEST-CFEDR facilities.

02

ASIPP's robust efforts and steady operations support **ITER** progress and **future fusion reactor performance**.

03

Committed to openness and sharing, ASIPP will deepen collaboration with the global fusion community.


Thank you!