International Atomic Energy Agency

Overview of Thailand's Tokamak-1 and Experimental Studies

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2nd Technical Meeting on the Collisional-Radiative Properties of Tungsten and Hydrogen in Edge Plasma of Fusion Devices
28 November – 1 December 2023

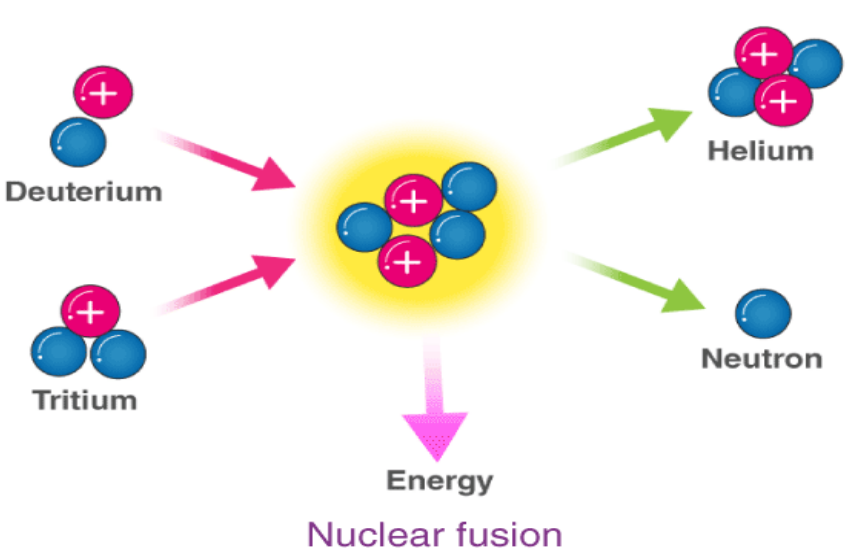
Overview of Thailand's Tokamak-1 Experimental Studies

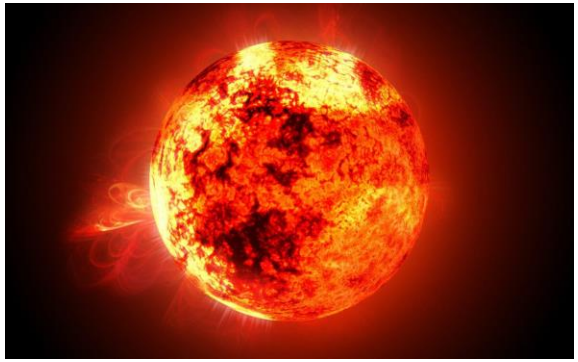
- Introduction
- Overview of Thailand Tokamak-1
- Global Timeline
- Future plan of Thailand Tokamak-1
- Challenges for RD section
- Problem & Expected support from the IAEA

Introduction

- What is Fusion?

$$D + T \longrightarrow {}^{4}_{2}He\ (3.5\ MeV) + n\ (14.1\ MeV)$$





Two light nuclei fuse together, become heavier nucleus, and release energy.

TT-1 Project Timeline

HT-6M tokamak Donation ceremony from ASIPP to TINT with H.R.H Sirindhorn presided the ceremony.

15 Jul 2018

TT-1 Building : Foundation Stone Laying ceremony

23 Nov 2020

Thailand Team Onsite @ ASIPP

Jun -Sep 2022

Grand Opening

25 July 2023

Plasma Technology and Fusion Collaboration MOU signing ceremony between TINT and EGAT

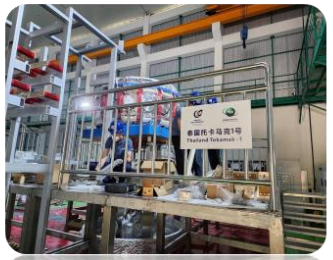
24 Apr 2019

TINT-ASIPP TT-1 Reconstruction of Supporting Ceremony Contract Signing Ceremony

7 Jun 2021

TT-1 arrived TINT Ongkharak

17 Jan 2023



TT-1 Installation @ TINT Ongkharak

Feb-Jun 2023

Initial phase of the construction plan for TT-1

2020 - 2025

Design and Fabricated in Thailand

1. Soft x-ray array	2. Optical Diagnostic
3. AXUV Diagnostics	4. HXR Diagnostics
5. LP Diagnostics	6. SXPHA Diagnostic
7. ECE Diagnostic	8. Thomson Scattering

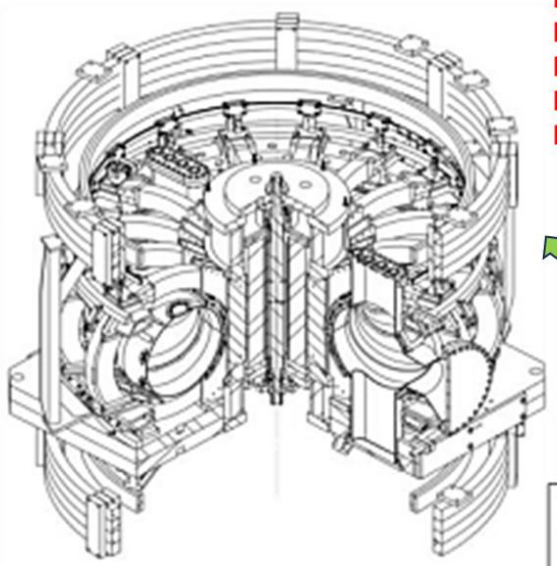
Install in 2023

2020 - 2021

Design and Fabricated in ASIPP

1. Magnetic Probe
2. HCN Interferometer
3. CCD Diagnostic

Move to Thailand in 2022



Toroidal Field (TF)	**16 coils**
1. Toroidal field (B_T)	1.52 Tesla
2. Max. Ripple (δ)	6.53 %
3. Turn current (I_{TF})	7.64 kA
4. Flat top time(τ)	100 ms

Poloidal Field (PF)	**7 coils**
1. Central Solenoid coils (CS	1 pieces
2. Ohmic Heating coils (HF)	4 coils
3. Vertical Field (VF)	2 coils

Vacuum Chamber	
Main Radius (R)	0.65 m
Minor Radius (a)	0.2 m

A. Tamman et.al; 2020

Thailand Tokamak-1

Main machine

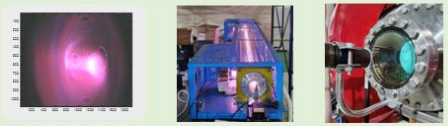
Vacuum Chamber:
- Major Radius : 0.65 m
- Minor Radius : 0.20-0.25 m
- Material : SS 306L

Magnet Coils:

Toroidal Field :	16 coils
Ohmic Heating Field:	5 coils
Vertical Field:	2 coils
Feedback Coils:	1 coils

Diagnostics

- Magnetic Measurement
  - 12x2 Toroidal Positions
  - 12x2 Poloidal Positions
- HCN laser 3 channels
- Hα
- CCD Camera



Power Supply

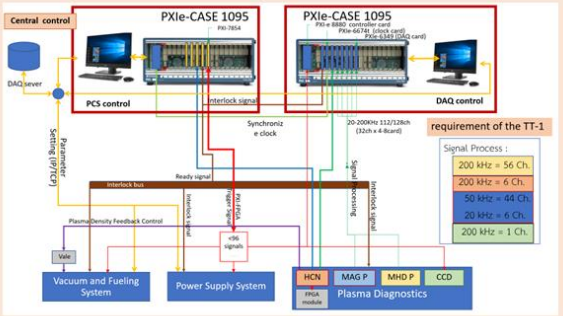
Toroidal Field Magnet Coil	7.6 kA
Ohmic Heating	17 kA
Vertical Field Magnet Coil:	4.8 kA
Feedback Coils:	230 A

Vacuum System

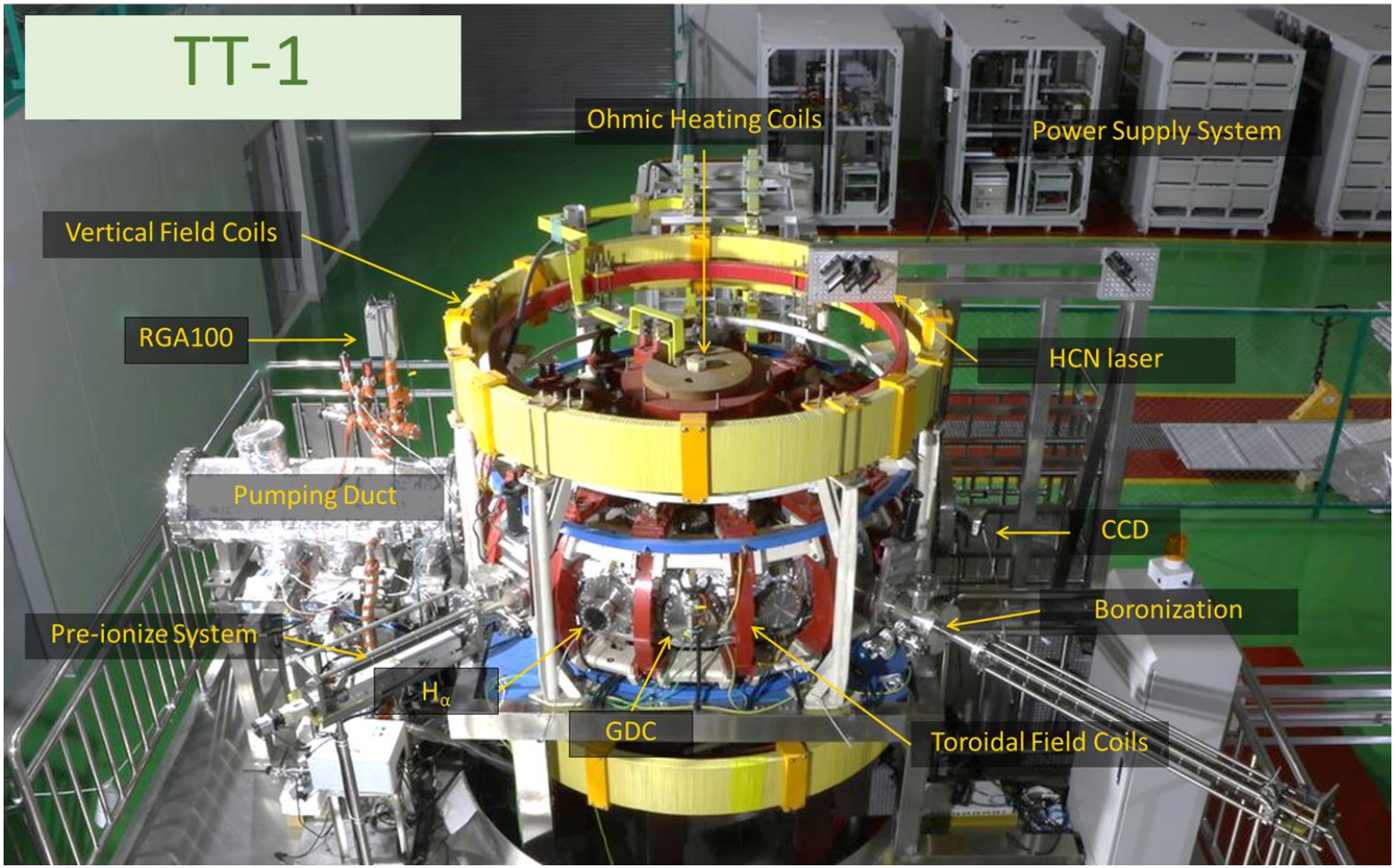
- Pumping [1x10^{-6} Pa]
  - 2xTMP + 2 Root
  - 1xIon pump
- GIS piezo-electric
- Pre-ionization
- 2xGDC
- Baking
- Boronization
- 2xRGA

Data Acquisition

- PXIe / 128 Ch. / 500 kHz

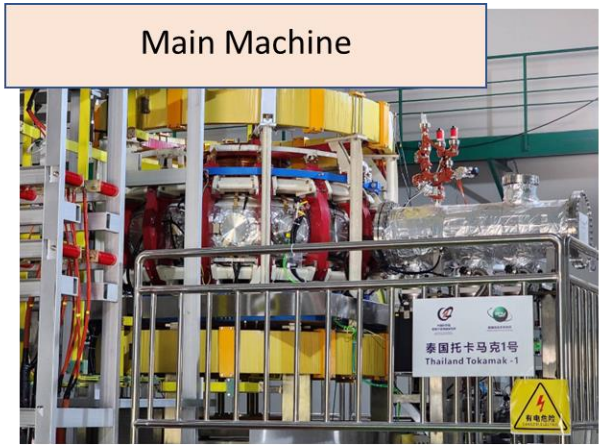


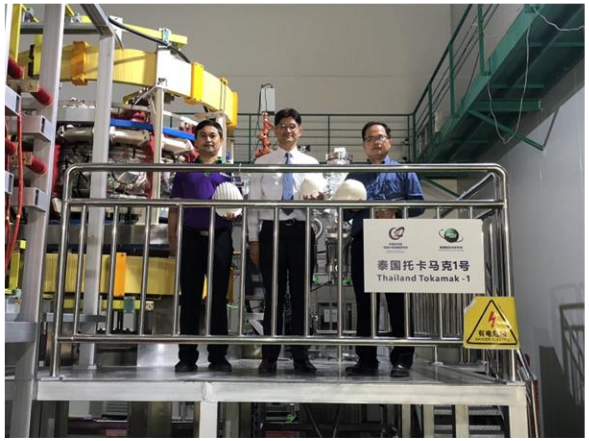
Thailand Tokamak-1



Installation @ TINT Ongkharak

Main Machine





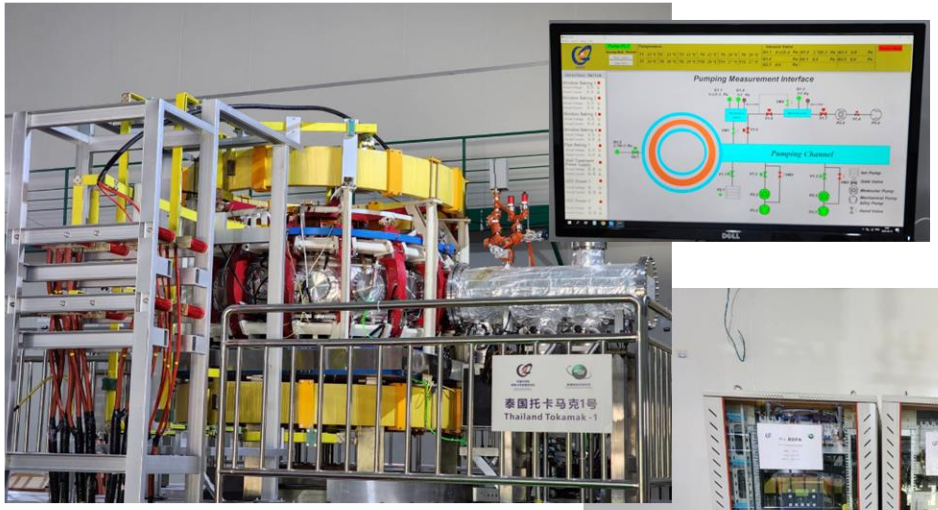
Power Supply

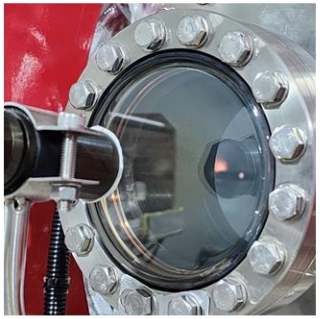
Installation @ TINT Ongkharak

DAQ

- The data will be collected using the Data Acquisition System (DAQ).
- Each experiment takes only 100 ms from start to finish

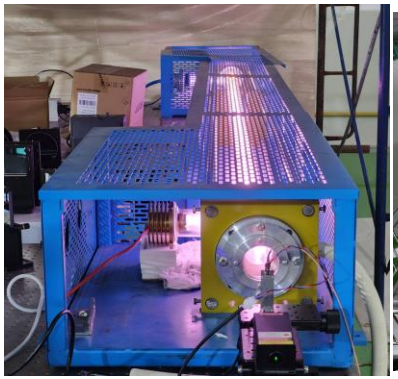
Vacuum



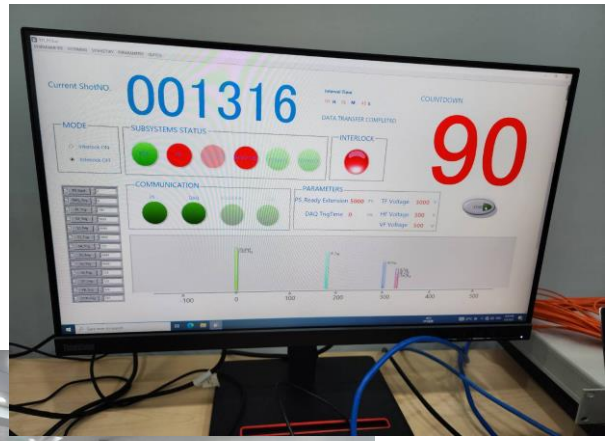


Installation @ TINT Ongkharak

HCN



PCS



- Far-infrared Hydrogen Cyanide (HCN) Laser Interferometer. It consists of a far-field infrared laser with a wavelength of 0.337 mm.
- The laser beam is transmitted through the plasma in the machine. To measure the electron density in the plasma.

Diagnostic system installation

For the TT- 1 developed in Thailand. The diagnostic system installation is divided into 3 groups:

1) Magnetic sensors system

Emphasis is placed on measuring the specific properties of the plasma that result in its release or change magnetic field of the machine

2) HCN Laser Interferometer measuring system

For measuring the density of the plasma generated in order to use such data for controlling the plasma density in the machine.

3) The high-speed imaging system focuses on investigating the operation of the poloidal plasma size limiting device. To control the plasma inside the machine.

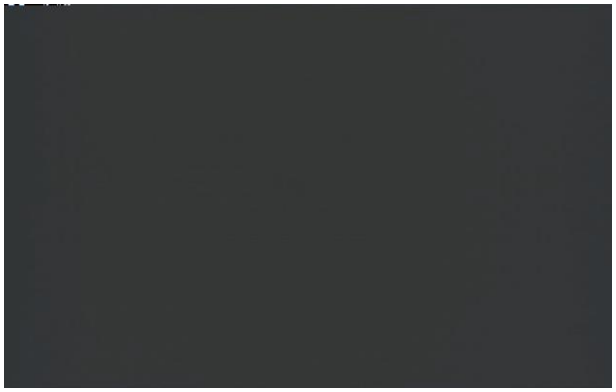
TT-1 Current status

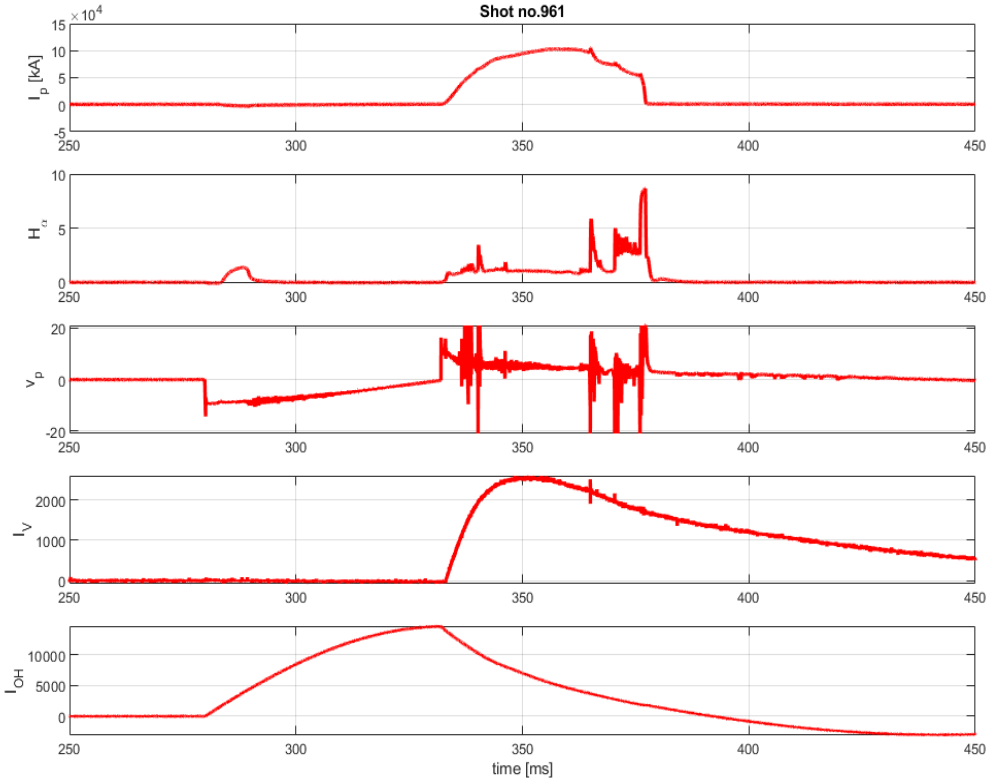
TT-1 Current status (100 kA@ASIPP)

Plasma current = 71.7 kA

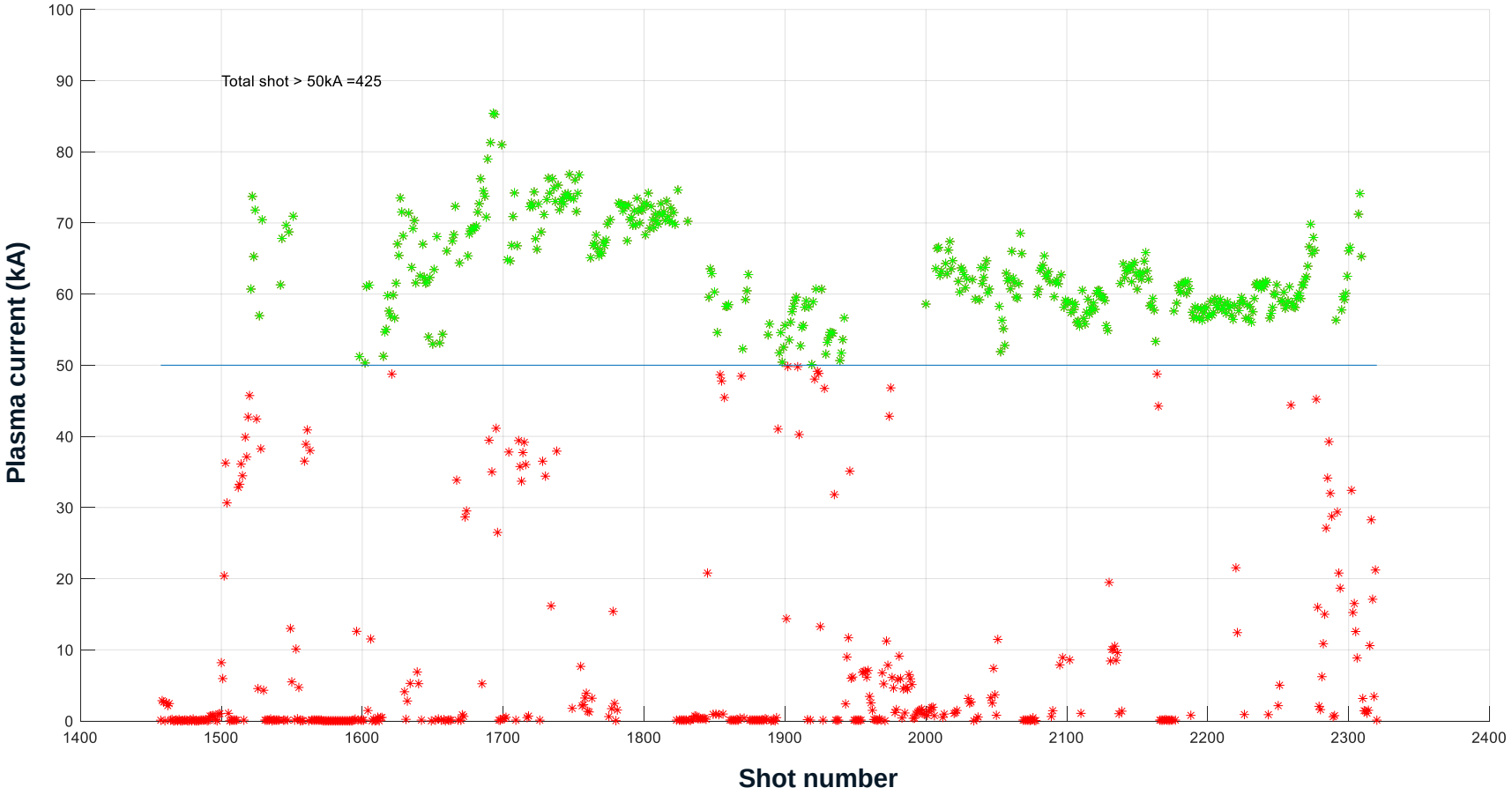
Plasma temperature = 375, 150 °C

Time = 88.1 ms

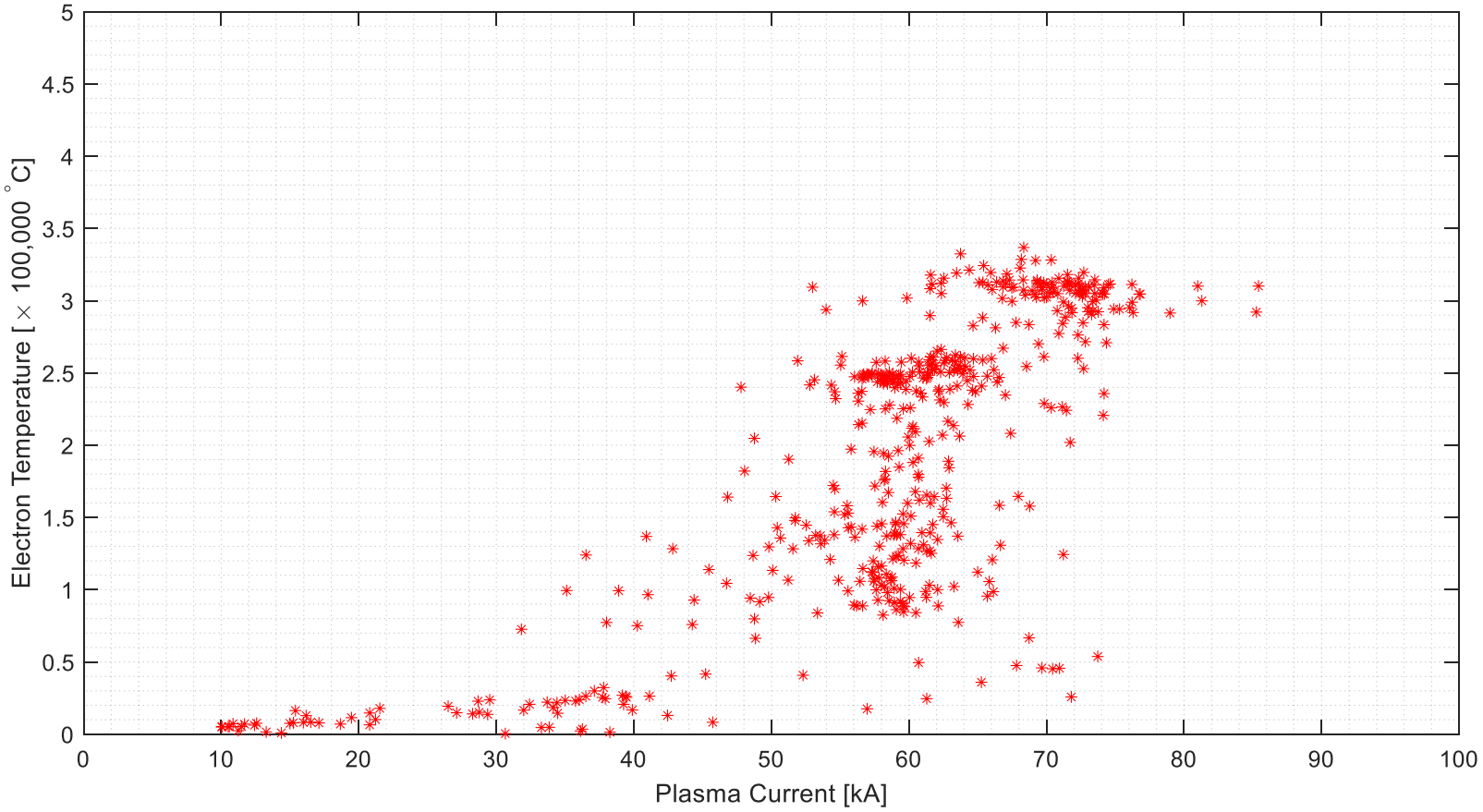




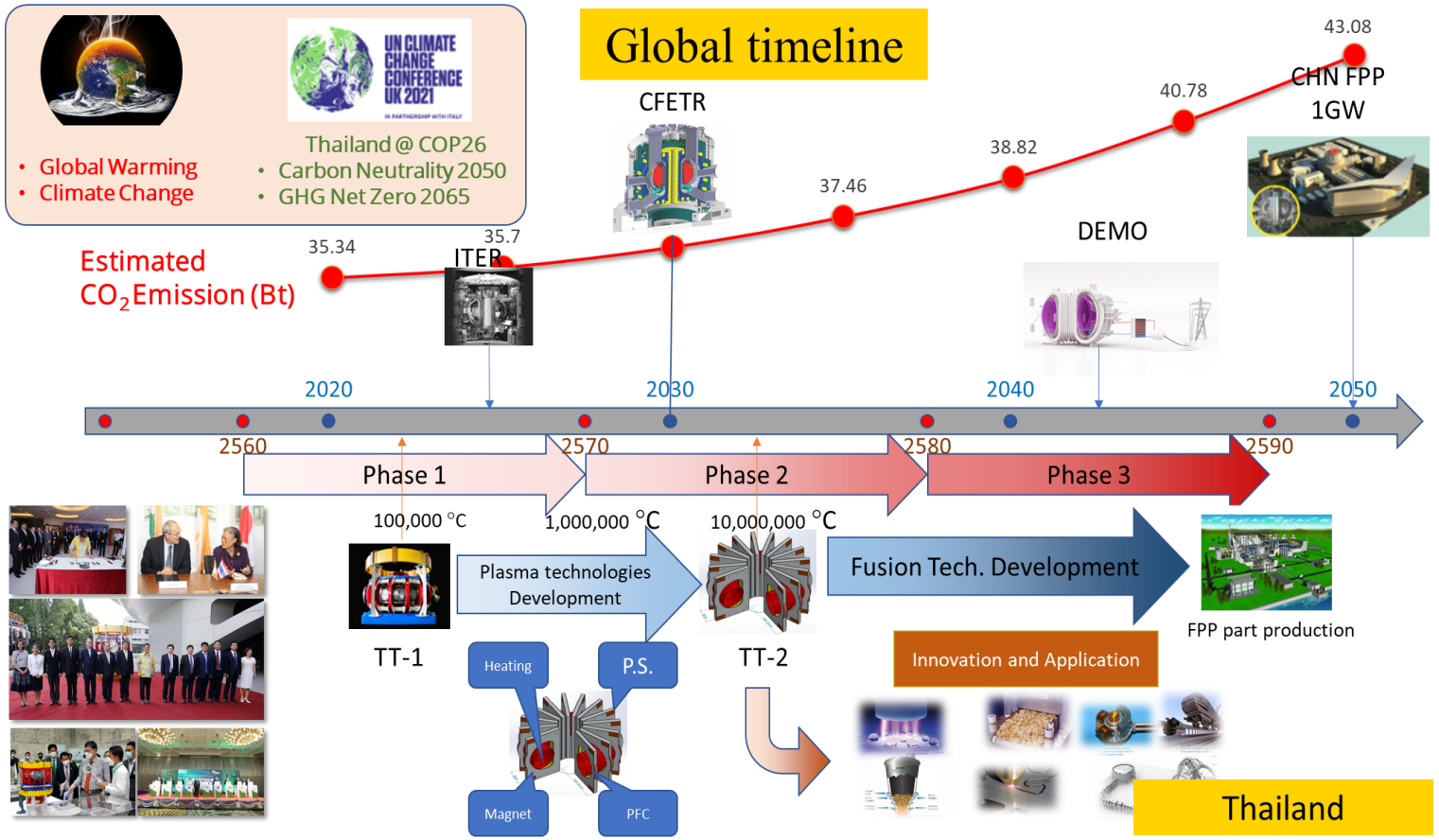
TT-1 Current status Cont. (THA)



TT-1 Current status Cont. (THA)



Global Timeline



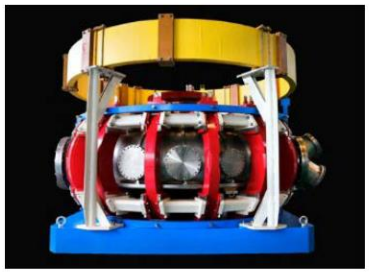
- In 2025, the ITER tokamak will be completed and put into operation.

- China's CFETR tokamak is targeted to be completed and operational in 2030, and another fusion power plant will emerge in the next 20 years

- Energy problems are the biggest energy challenges facing humanity. We all know that fossil fuels are not clean and are running out. Renewable energy is currently not able to step up as a main source of energy.
- One solution that solves both problems is fusion technology. Although it has been developed for a long time, there is continuity, which shows the possibility that it can actually happen.

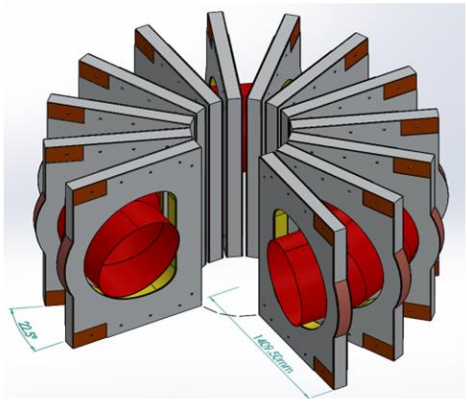
Future plan of Thailand Tokamak-1

Phase 1 (2017-2026)



- The first engineering and fusion technology learning infrastructure in the ASEAN region.

Phase 2 (2027-2036)

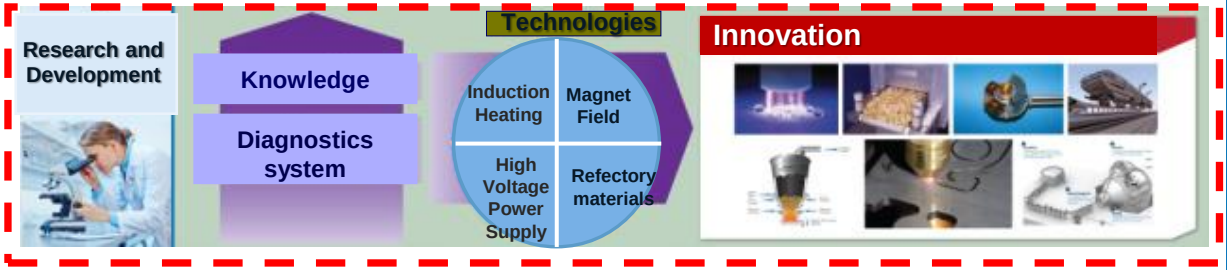


- Development TT-1 is to be used for research into high-temperature plasma and fusion energy, which may drive electricity generation in the future.
- Superconducting tokamak will be designed and developed by a Thai Researcher within the next 10 years

Phase 3 (2037-2589)

The Next 30 Years, Thailand will have the key technology to produce some parts of fusion power plants.

Challenges for RD section



Technology for producing some parts of fusion power plants

Output

- 10 innovation
- 1,000 researchers and engineers
- 100,000 contributors and funding

Challenges for RD section

- Design for the first Wall and Blanket of the new Thai tokamak-2
- The materials (Refractory metals) that need to be developed for the first wall and other structural elements of the new Thai tokamak-2
  - copper alloys for the heat sink
  - beryllium for facing the plasma.
  - tungsten (W) for the wall sections
- superconducting toroidal and poloidal magnets.

Conclusions and Recommendations

- Thai Tokamak-1device is ready to start operations for fusion energy research in July, after a successful trial on April 21st, according to Thailand's Institute of Nuclear Technology (TINT).

- From first plasma operation in China, we got the results are Plasma current = 71.7 kA Plasma temperature = 375, 150 ^{o}C with Time = 88.1 ms. TINT plans to develop a supplementary heating system for plasma using electromagnetic wave heating to raise the temperature of the plasma to 1 million degrees Celsius.

- Tokamak technology can also be applied to industrial, agricultural and medical science uses.

- TINT is expected to design and build its own tokamak machine for domestic use, with an aim to make Thailand ASEAN's hub of fusion technology development center.

Conclusions and Recommendations

Problem

- Lack of human resources with knowledge in superconducting, magnet coil, and materials for use in TT-1

Expected

- Advisory on developing materials part use in the aspects of first wall component, superconducting including magnet coil of TT-1.

- Budget/Project to contribute for training course (ASPNF) of researchers who have interested in Thailand in terms of fusion experimentalists utilizing plasma and magnetic fusion devices.

Thank you