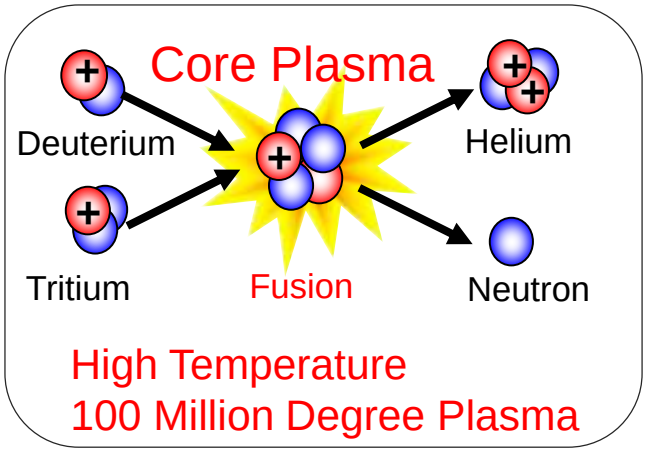
Symposium 2019 on the ITER/BA Activities
Fusion Energy Forum of Japan

Progress of ITER Procurement Activities and JT-60SA Construction

QST Naka Fusion Institute　Yutaka Kamada

ITER BA成果報告会、2019年12月19日、東京大学伊藤国際学術センター

Fusion Power Generation System



High Temperature
100 Million Degree Plasma

Superconducting Coils

Fuel Plasma

Vacuum Vessel

Fuel Supply System

ITER
Q=10

Blanket

- heat extraction from fusion neutrons
- tritium breeding using neutrons

Coolant

Plasma Heating & Current Drive System

中性子

Electric Output

Heating Power

Divertor

Hot Coolant

Heat Exchanger

Fusion Output

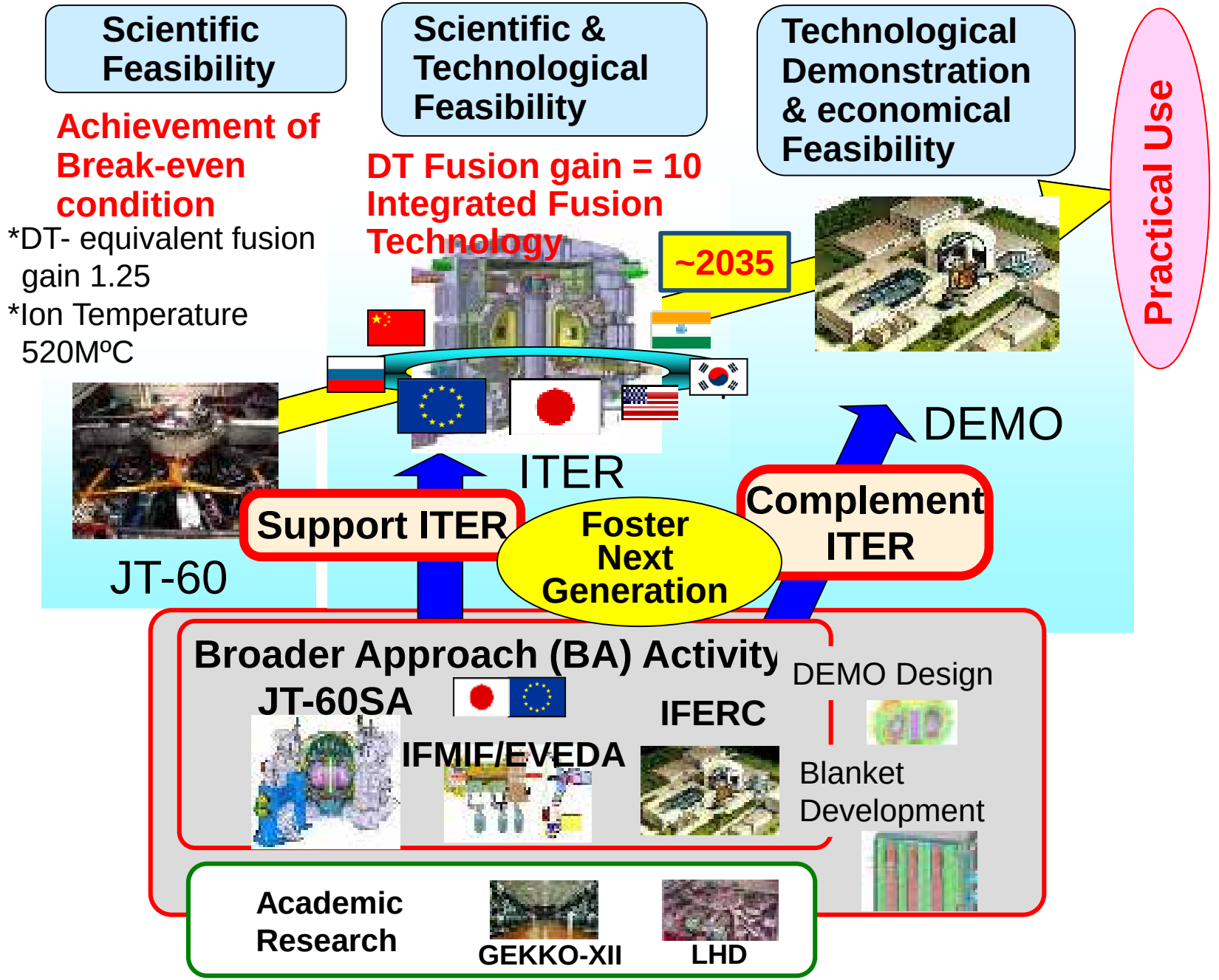
Turbine Generator

Tritium Handling facility

$$\text{Fusion Energy Gain } Q = \frac{\text{Fusion Output}}{\text{Heating Power}}$$

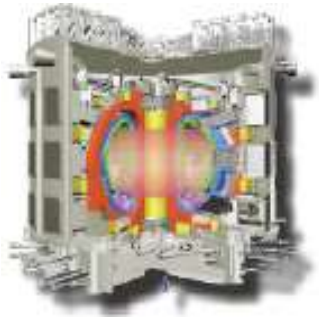
30~50 necessary for Demo

Japanese Strategy of Fusion Energy Development



ITER(Burning Plasma)+JT-60SA(High Pressure Plasma)=DEMO
Japan can study Fusion with 'ITER + JT-60SA'

Key Points of Fusion Plasma Research



ITER

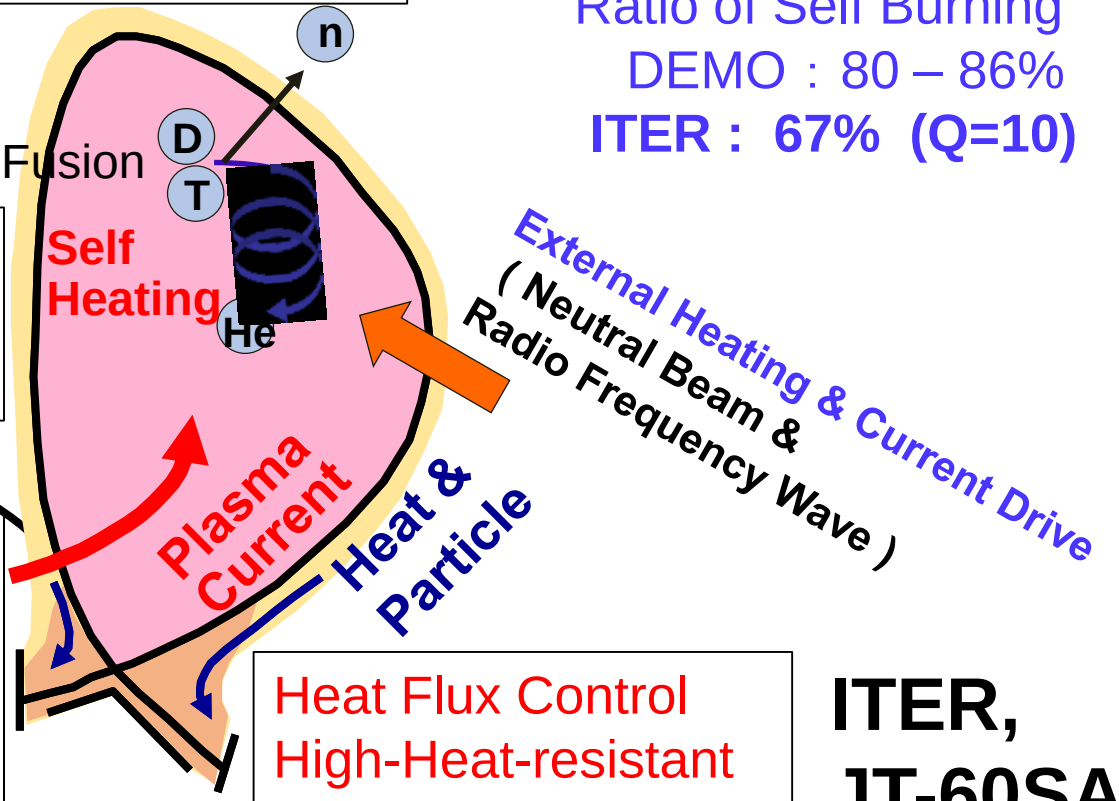
Self Heating = Burning Plasma
（High Temperature & Density
by high confinement Efficiency）

20% of Fusion Power
= Self heating

Ratio of Self Burning
DEMO : 80 – 86%
ITER : 67% (Q=10)

JT-60SA

High Power Density
（High Plasma
Pressure）



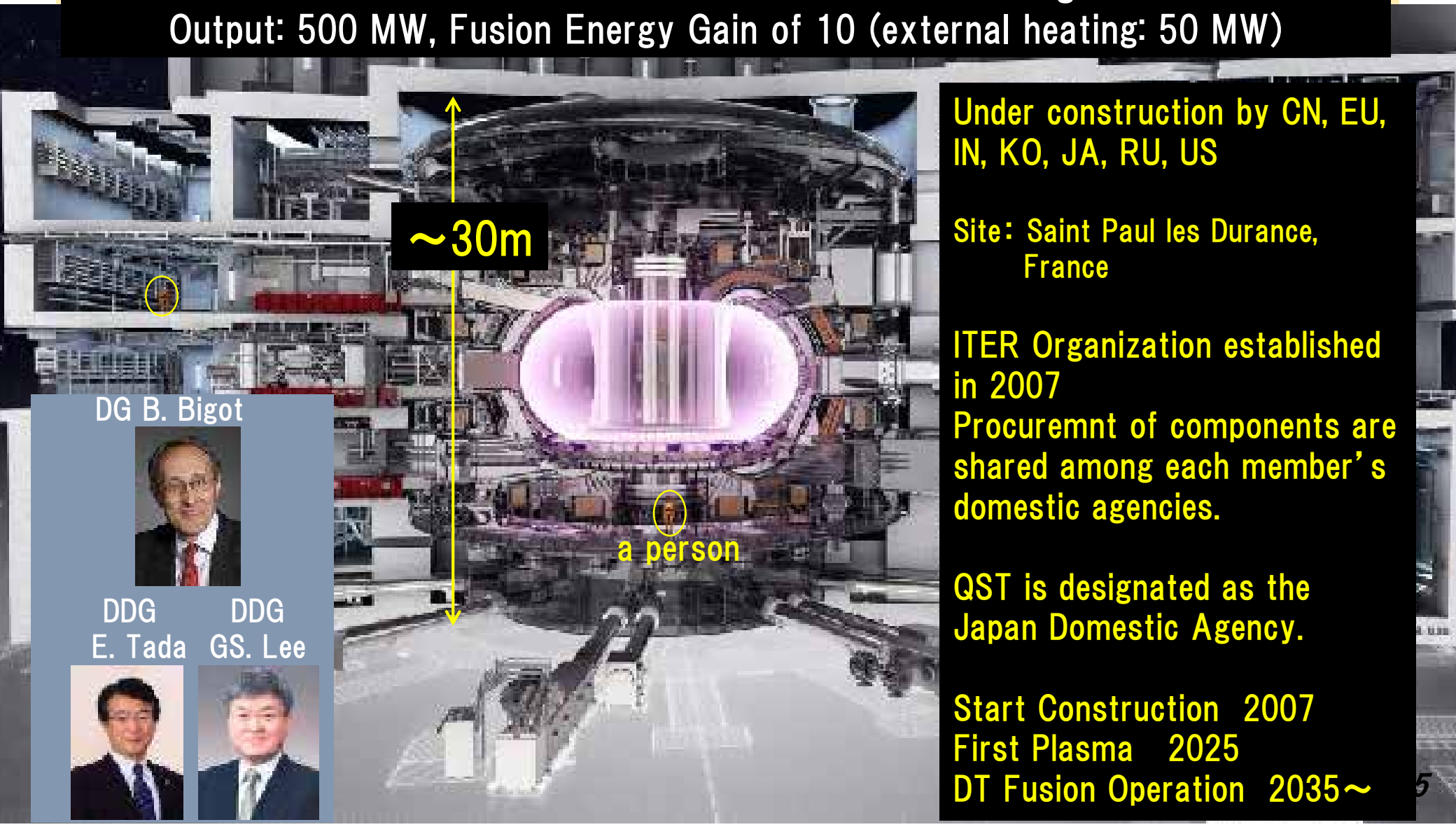
Steady-state Sustainment
of Whole plasma current
non-inductively（ High
Plasma Pressure ）

Heat Flux Control
High-Heat-resistant
Divertor

**ITER,
JT-60SA**

ITER: World Wide Joint Project of 7 Parties

Demonstration of continuous fusion burning
Output: 500 MW, Fusion Energy Gain of 10 (external heating: 50 MW)



DG B. Bigot

DDG E. Tada

DDG GS. Lee

Under construction by CN, EU, IN, KO, JA, RU, US

Site: Saint Paul les Durance, France

ITER Organization established in 2007
Procuremnt of components are shared among each member's domestic agencies.

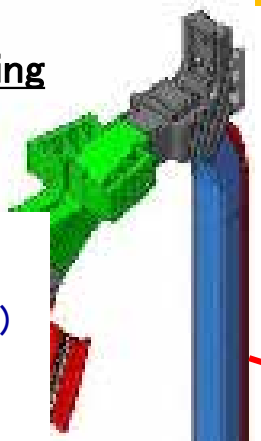
QST is designated as the Japan Domestic Agency.

Start Construction 2007
First Plasma 2025
DT Fusion Operation 2035~

State-of-the-art Main Body Components Shared by Japan

Naka Fusion Institute

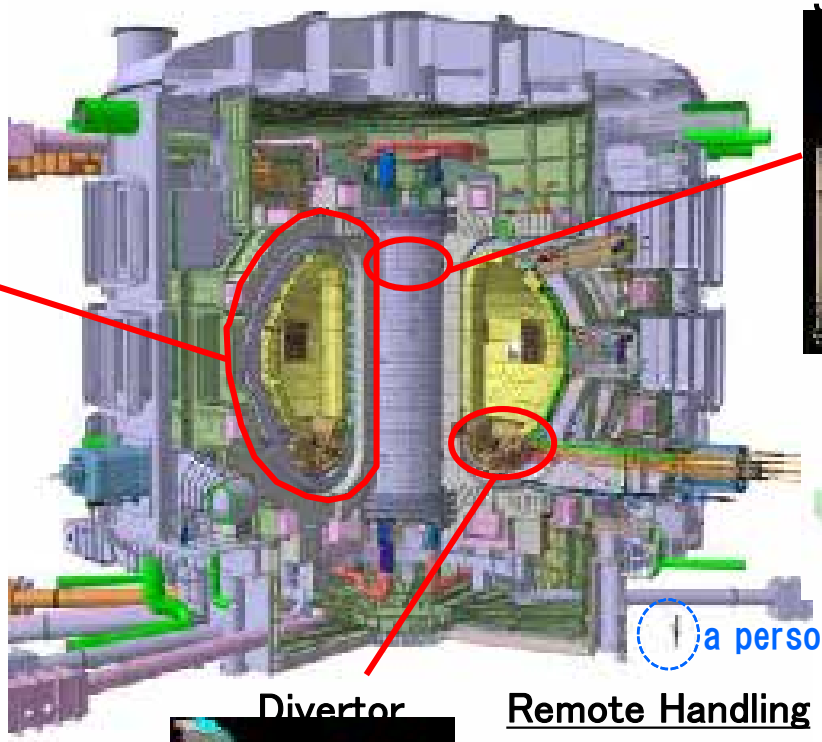
Superconducting Toroidal Field Coil



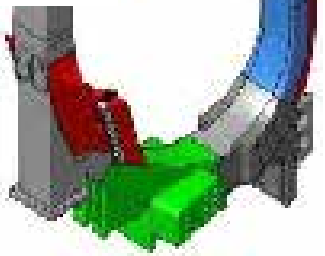
- 33 Conductors (about 33%)
- 19 Structures (All)
- 9 Windings / Integrations (about 50%)

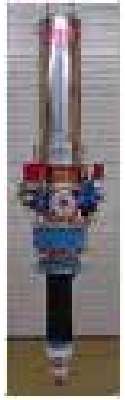
Superconducting Central Solenoid Conductor

- 49 Conductors (All)



Radio Frequency Heating System



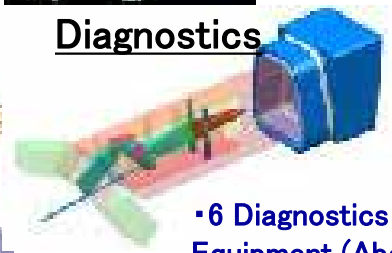


- 8 Gyrotrons (about 33%)
- Equatorial Launcher (All)

Neutral Beam Injector

- 3 1MeV Power Supply High Voltage Parts (All)
- 3 HV Bushings (All)
- 1 Accelerator (About 33%)

Diagnostics



- 6 Diagnostics Equipment (About 15%)

Divertor

Outer Target (All)

Remote Handling Equipment

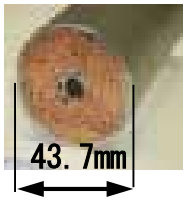
Blanket Remote Handling Equipment (All)

Tritium Removal Plant

Tritium Removal System (50%)

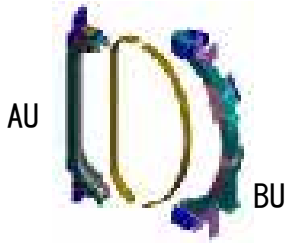
Progress of Superconducting Toroidal Field (TF) coil

Conductor (33 unit length)



Winding Pack (WP) (for 9 TF coils)

Structure(19 sets)

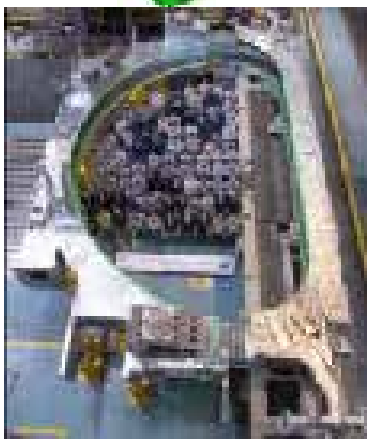


Assembly (9 sets)

WP for 1st TF coil before cold test (Mitubishi)

Double pancake for 3rd TF coil (Toshiba)

TF structure for 1st JA portion



TF structure for 1st EU portion

WP fabrication status (1st + 2nd fabrication factory)

JA/EU	JA									EU									
号機	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10
AU	■	■	■	■			■			■	■	■	■	■	■	■			
BU	■	■		■		■				■	■	■	■	■	■				
出荷	■	■		■						■	■			■	■				

TF structure fabrication status

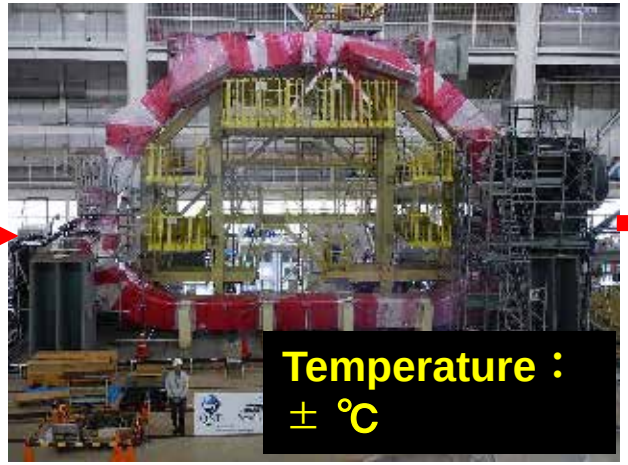
Green : Completion

1st TF Coil near Completion with High Accuracy

Confirmation of alignment between upper & lower structure (Jan. 2018)

Cold Test of the Winding Pack (Nov. 2018)

Integration of winding pack & structure: Started Mar. 2019



Resin Impregnation (Completed Sep. 2019)

Final Machining Completed in Dec.2019

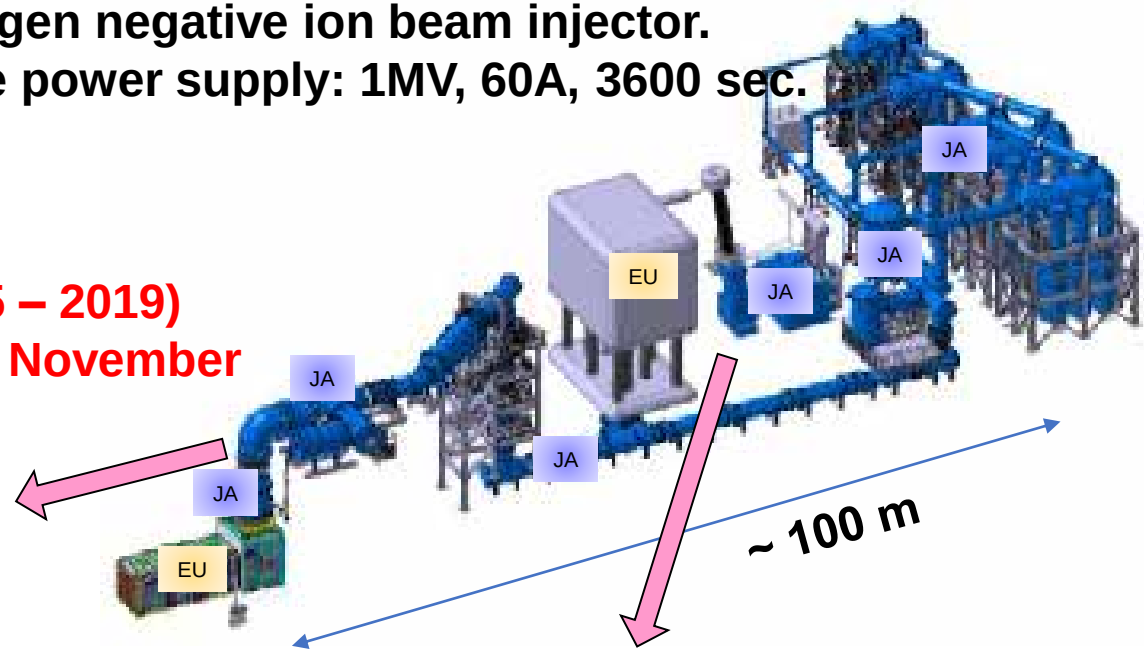
Jan. 2020 Completion

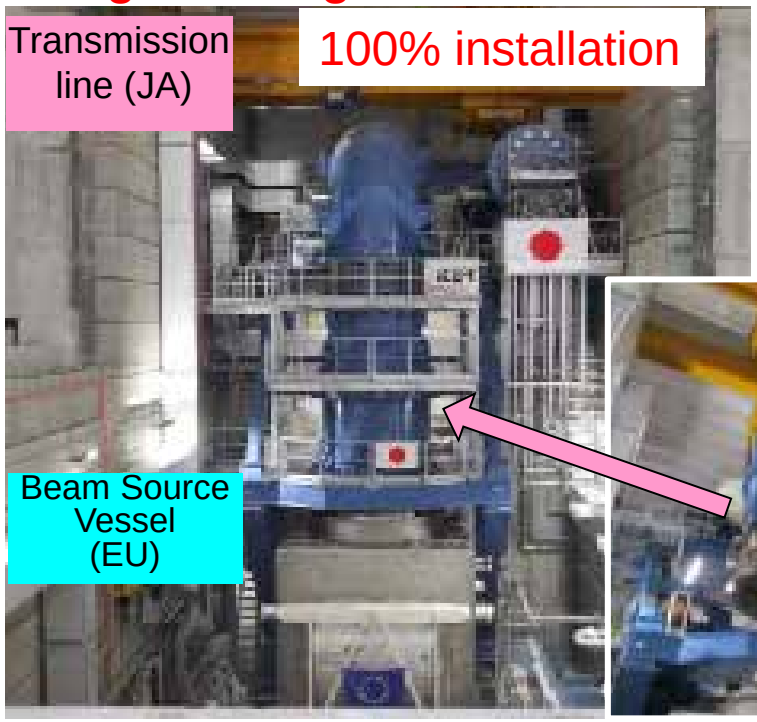
Completion of High Voltage Power Supply Syatem for the Neutral Beam Injector

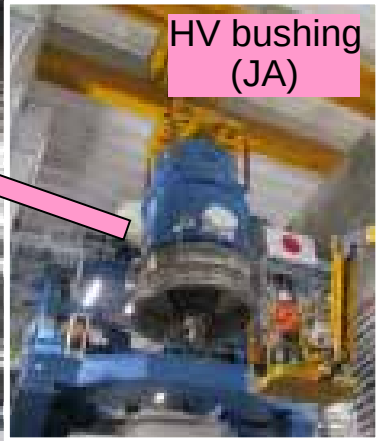
Neutral Beam Test Facility (NBTF) is under construction in Padova in advance of ITER for full scale R&D of 1 MV, 40 A hydrogen negative ion beam injector.
JA procures the DC ultra high-voltage power supply: 1MV, 60A, 3600 sec.

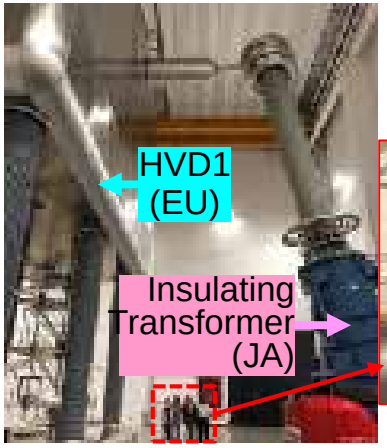
JA Completed

- **manufacturing of all component**
- **installation of all component (2015 – 2019)**
- **voltage holding test of at 1.2 MV in November**









JA, EU, RFX, IO

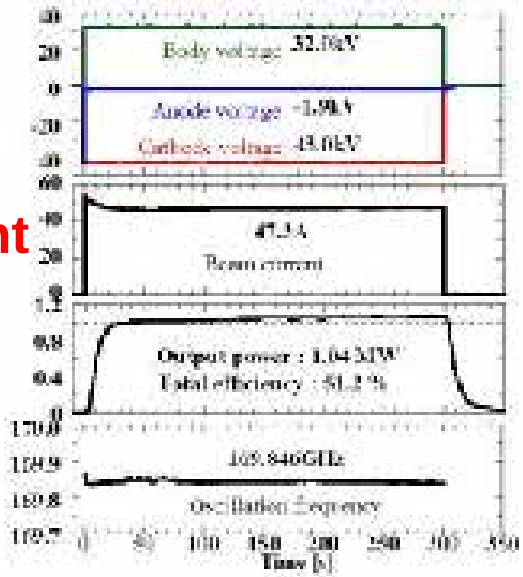
Progress of Radio Frequency Heating System

High-power mm-wave oscillator: GYROTRON

JA procures 8 Gyrotron out of all 24 sets.

4 Gyrotron: manufacture completed

2 of them has been tested => satisfied the requirement

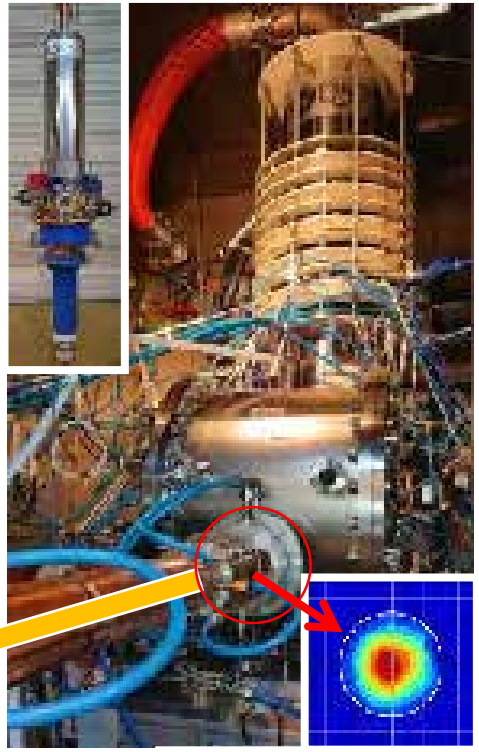


1.04 MW, 51.2% Efficiency
300 sec pulse length was confirmed for the 2nd Gyrotron

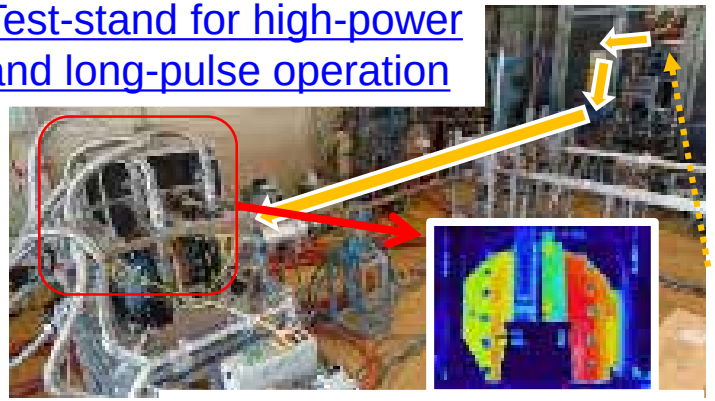
[Requirements of factory acceptance test (FAT)]

- **Frequency/Power/Efficiency:**
  170GHz/ ≧ 1MW/ ≧ 50%
- **Full-power modulation:**
  1～5kHz/ ≧ 60sec
- **Duration time: ≧ 300sec**
- **Operation reliability: ≧ 95%**

JA-GYROTRON system



Test-stand for high-power and long-pulse operation



1MW power CW-injection

Output beam

Output beam

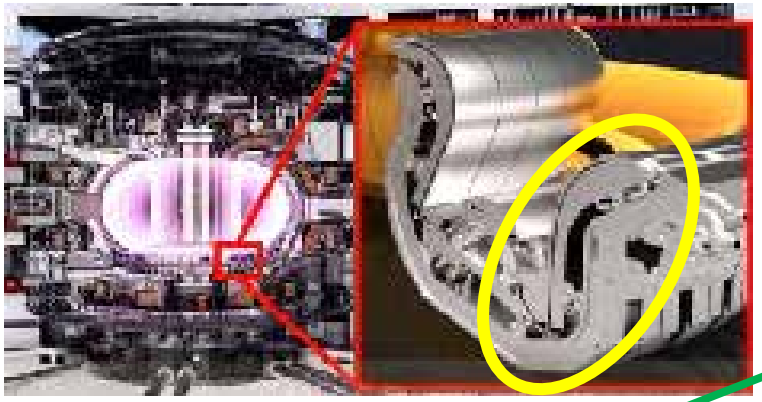
1st , 3rd, 4th Gyrotron

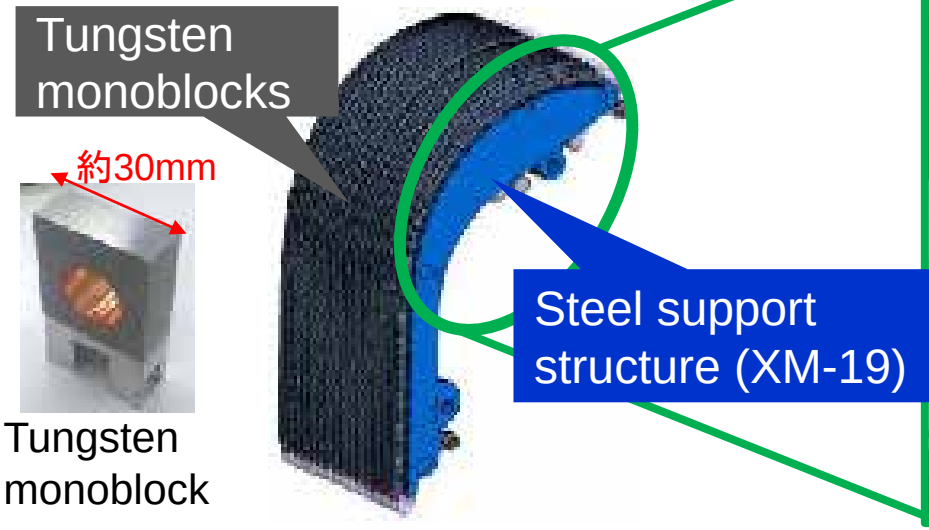
Progress of divertor outer vertical target

Plasma-facing material: Tungsten
Actively cooled by water
Heat flux: 20 MW/m^2

Manufacturing of full-scale prototype on going

<u>Tungsten monoblocks</u>
Manufacture of 3,600 tungsten monoblocks have been completed.
<u>Stainless-steel forgings</u>
XM-19 forging material is being manufactured.
<u>Cooling Pipe</u>
Manufacture of CuCrZr cooling pipe completed

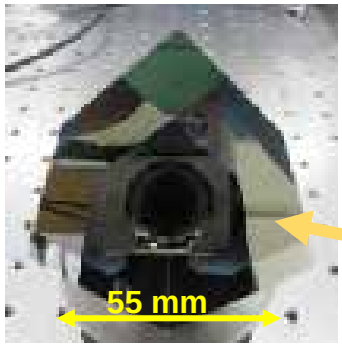




Progress of Plasma Diagnostics

Among five diagnostics procured by Japan, Poloidal Polarimeter and Edge Thomson Scattering systems are at the final design stage through prototyping of major components

Layout of Poloidal Polarimeter



Retroreflector made by grinding tungsten material

fire resistance test

Laser transmission line with the actual length.

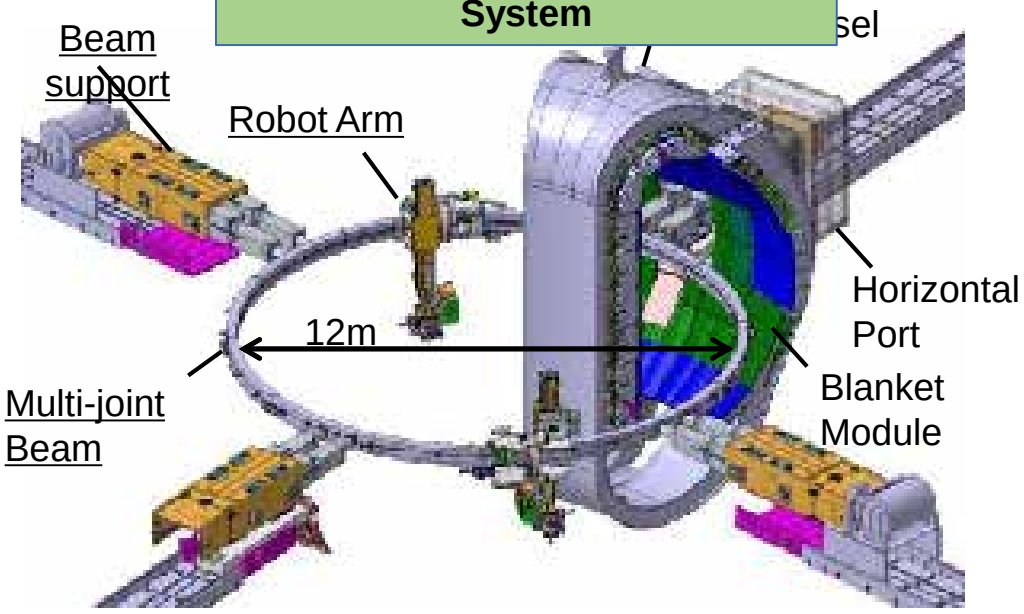
Automatic Adjustment of Laser Alignment

FIR laser prototype

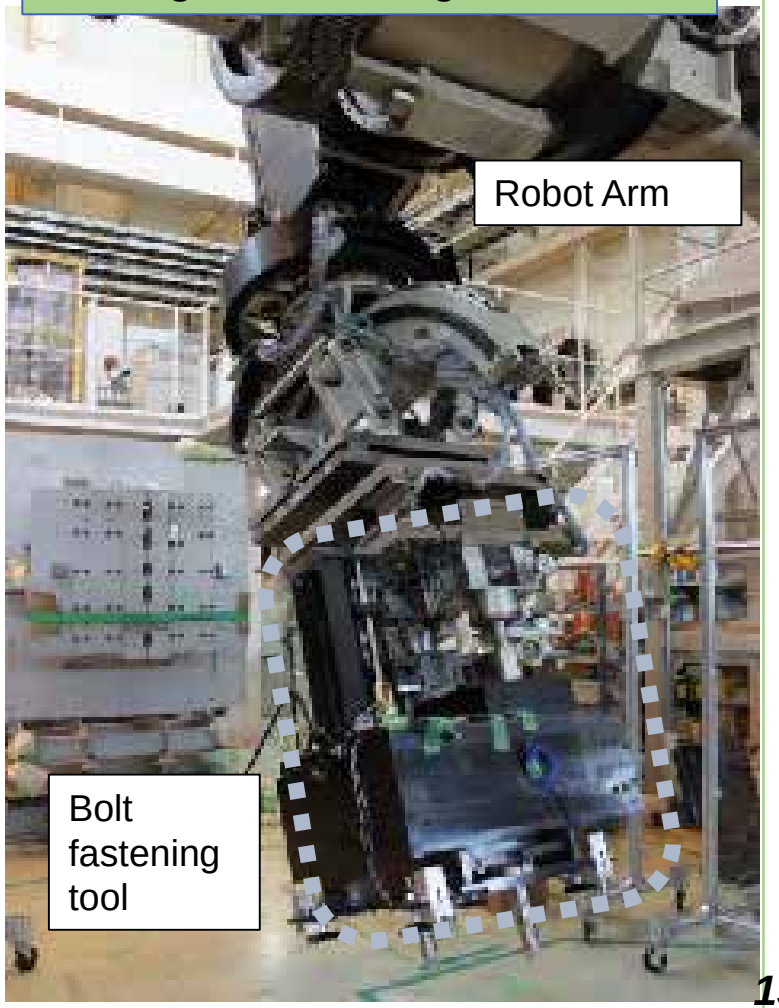
Progress of Blanket Remote Handling System

- **A large robot arm to handle a Blanket module (max. 4 tons) with high accuracy**
- Challenges :
  - ➢ Developping Various tools
    - ✓ Large torque (10kNm) fastening tool
    - ✓ Remote access weld / cut / inspection tool for 43mm diameter tube
  - ➢ Precise Positioning method
    - Gap between Blanket Module and the Vacuum vessel is 0.5mm
  - ➢ Radiation resistant devices

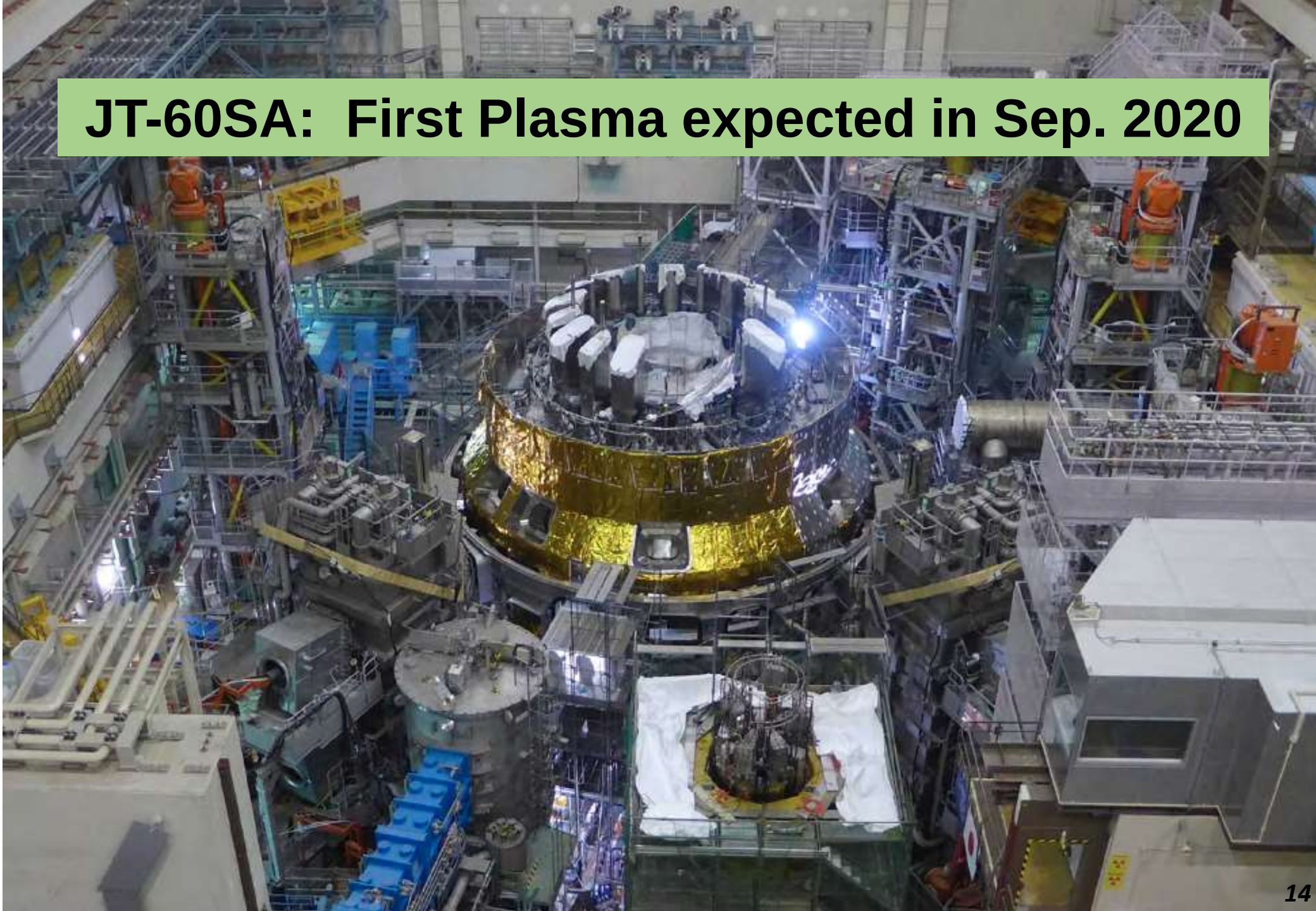
Blanlet Remote Handling System



Bolt fastening tool for large torque (10kNm) tolerates strong electro magnetic force



JT-60SA: First Plasma expected in Sep. 2020



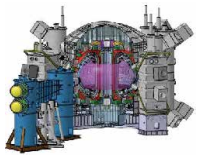
JT-60SA Project Mission

Large Super Conducting Tokamak with
‘ Plasma Shape suitable for high pressure plasma stability’

ITER
Burning Plasma

DEMO

Economically Attractive

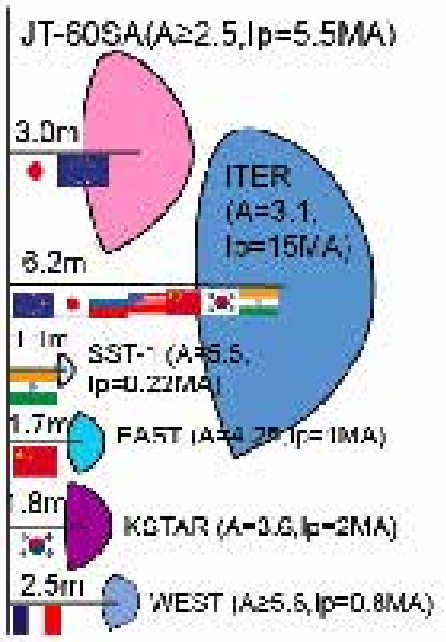


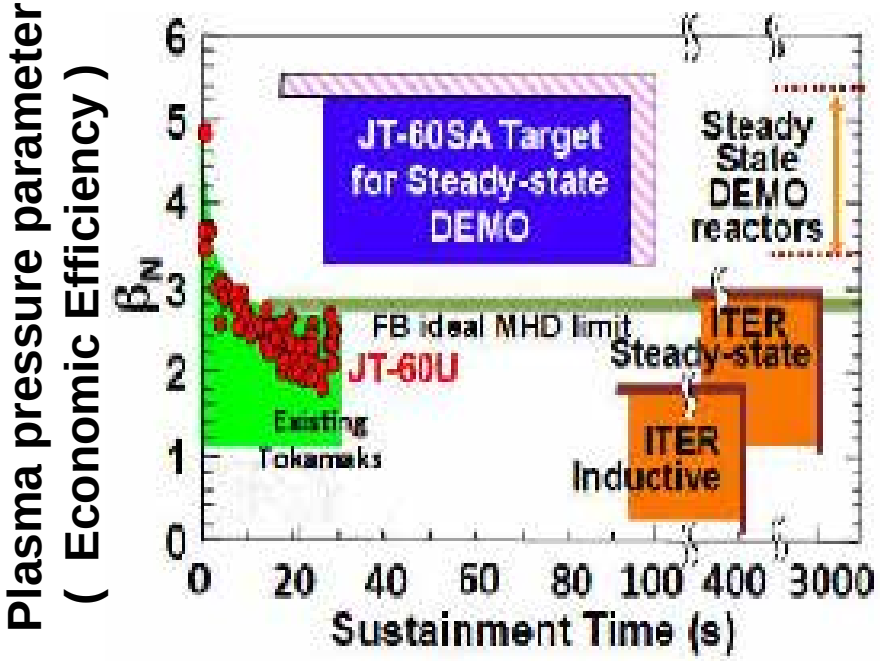
JT-60SA
High Pressure Plasma

1. Support ITER
⇒ ‘Risk Mitigation & Efficient Operation of ITER’
using break-even-equivalent class high temperature D-plasmas

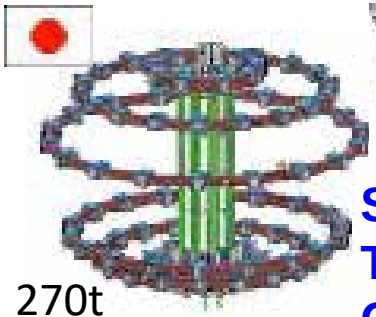
2. Complement ITER toward DEMO
with long sustainment (~100s) of high pressure steady-state plasmas necessary in DEMO

3. Foster Next Generation leading ITER & DEMO

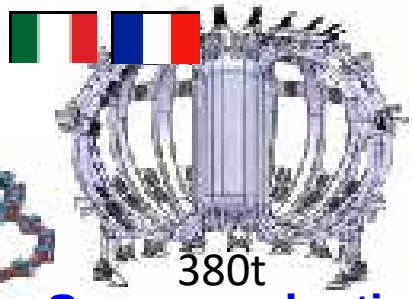




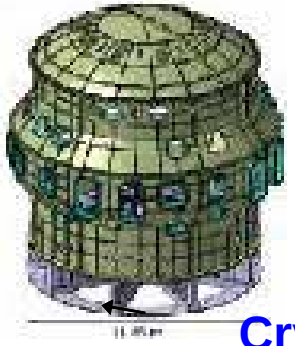
EU & JA Share Procurements of JT-60SA Components


270t

Superconducting Poloidal Field Coils

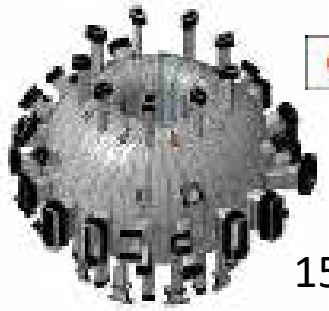

380t

Superconductin Toroidal Field Coils

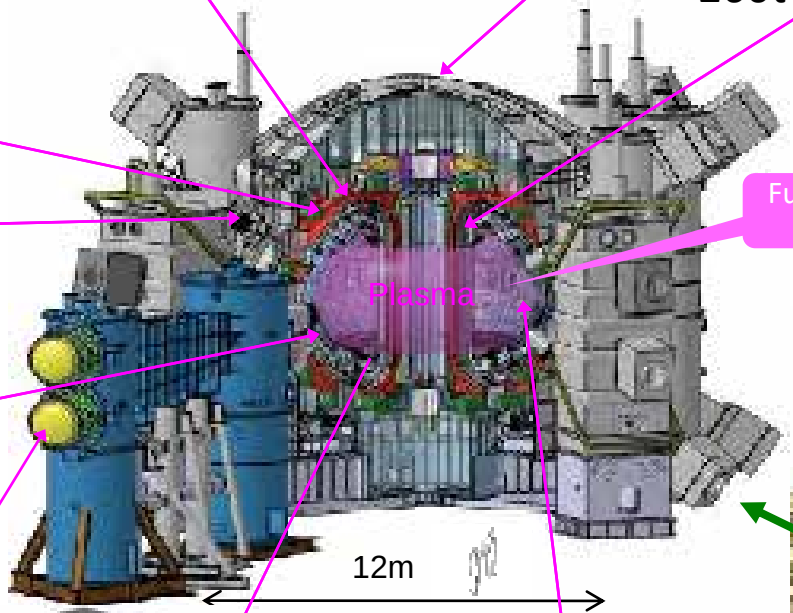


Cryostat body 220t

Cryostat base 260t


150t

Vacuum Vessel



Fusion reaction here

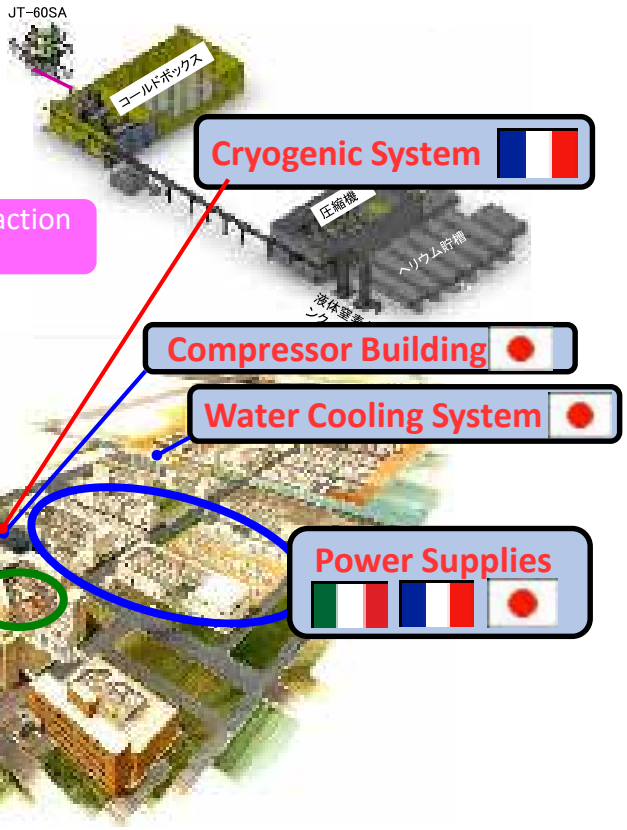
ECRF Heating System

In-vessel Components

Neutral Beam Injector

Divertor

Plasma Diagnostics



Cryogenic System

Compressor Building

Water Cooling System

Power Supplies

JT-60SA Assembly is on schedule

Assembly Completion March 2020 & First Plasma September 2020

Cryostat Base

Lower Poloidal Field Coils

Vacuum Vessel

VV thermal shield

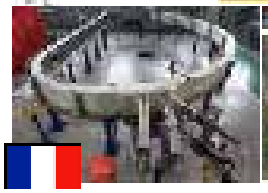
TF Coils

Upper Poloidal Field Coils and Central Solenoid

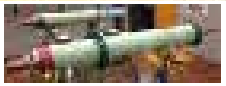
Cryostat

TF Coil Cold Test Facility

Cryostat



TF Coils

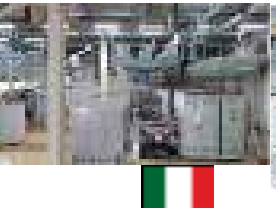


Current Lead

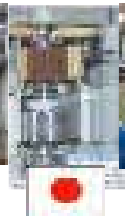
First Plasma Sep. 2020

power supplies

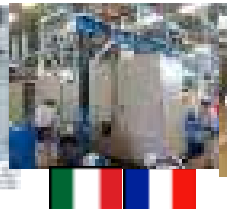
QPC



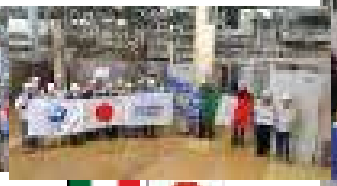
MG



SCMPS



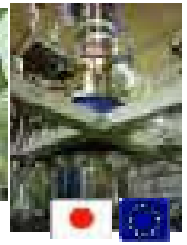
SNU



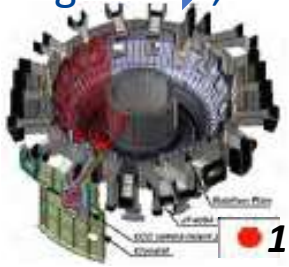
cryoplant

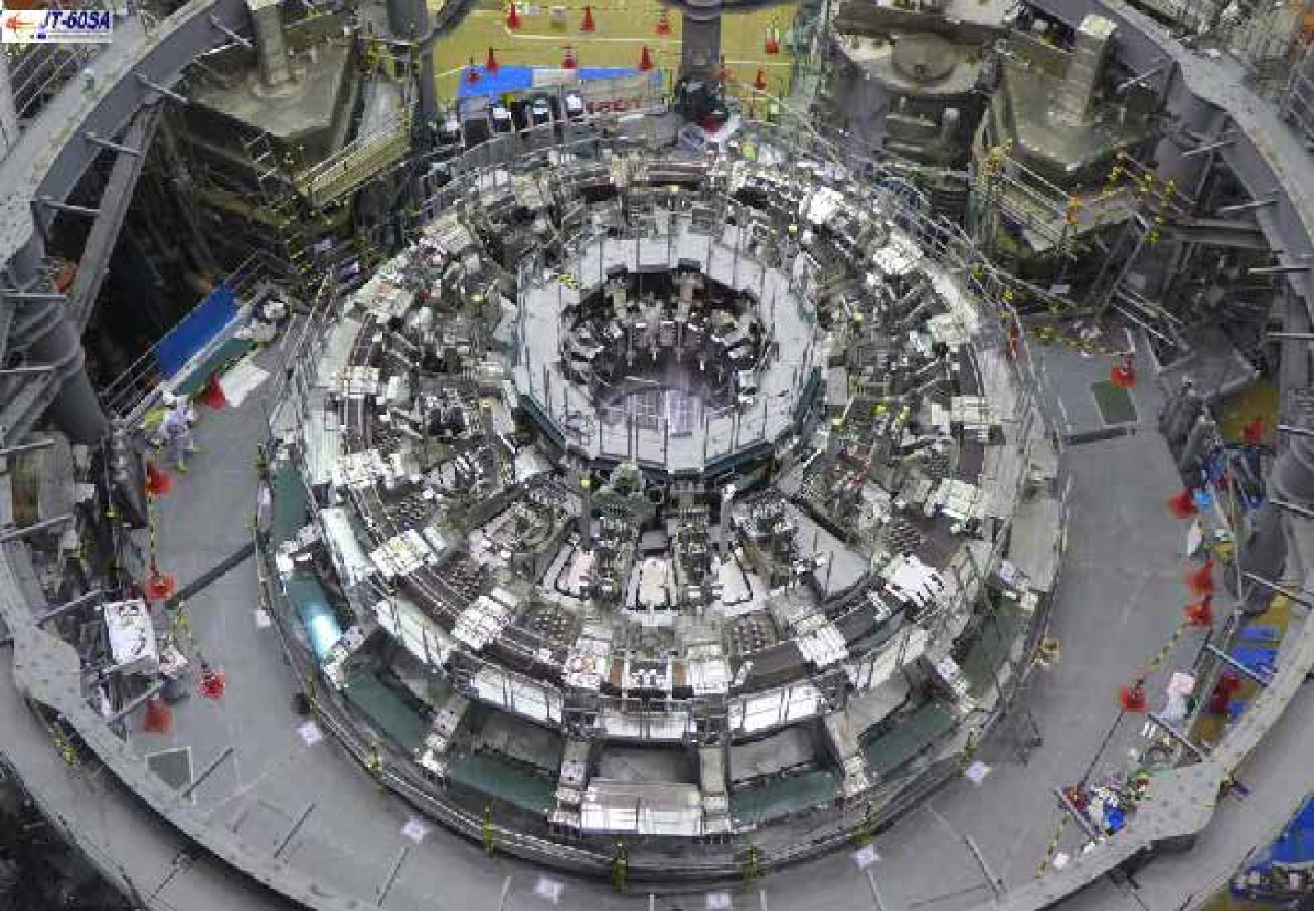
NBI

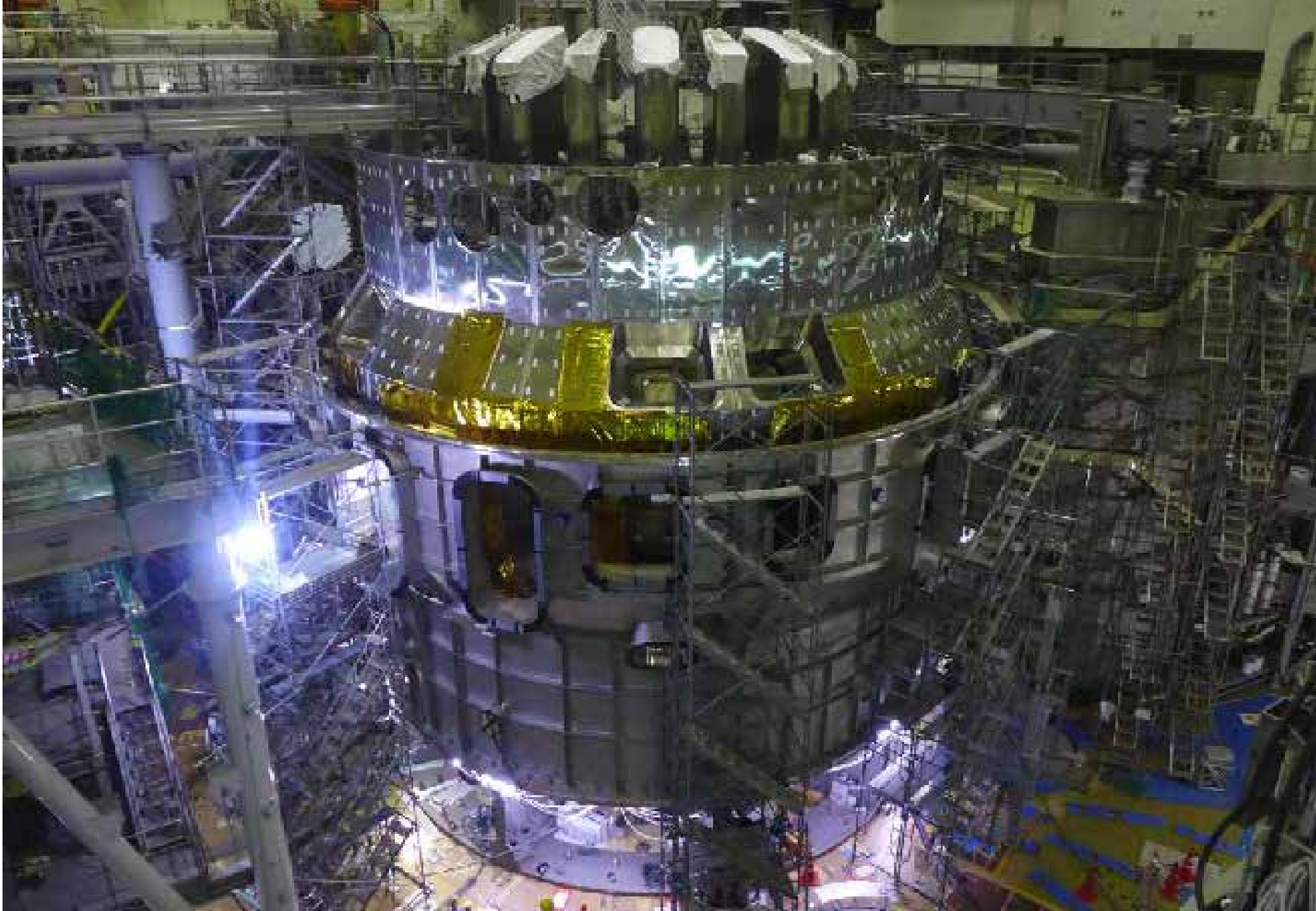
ECRF

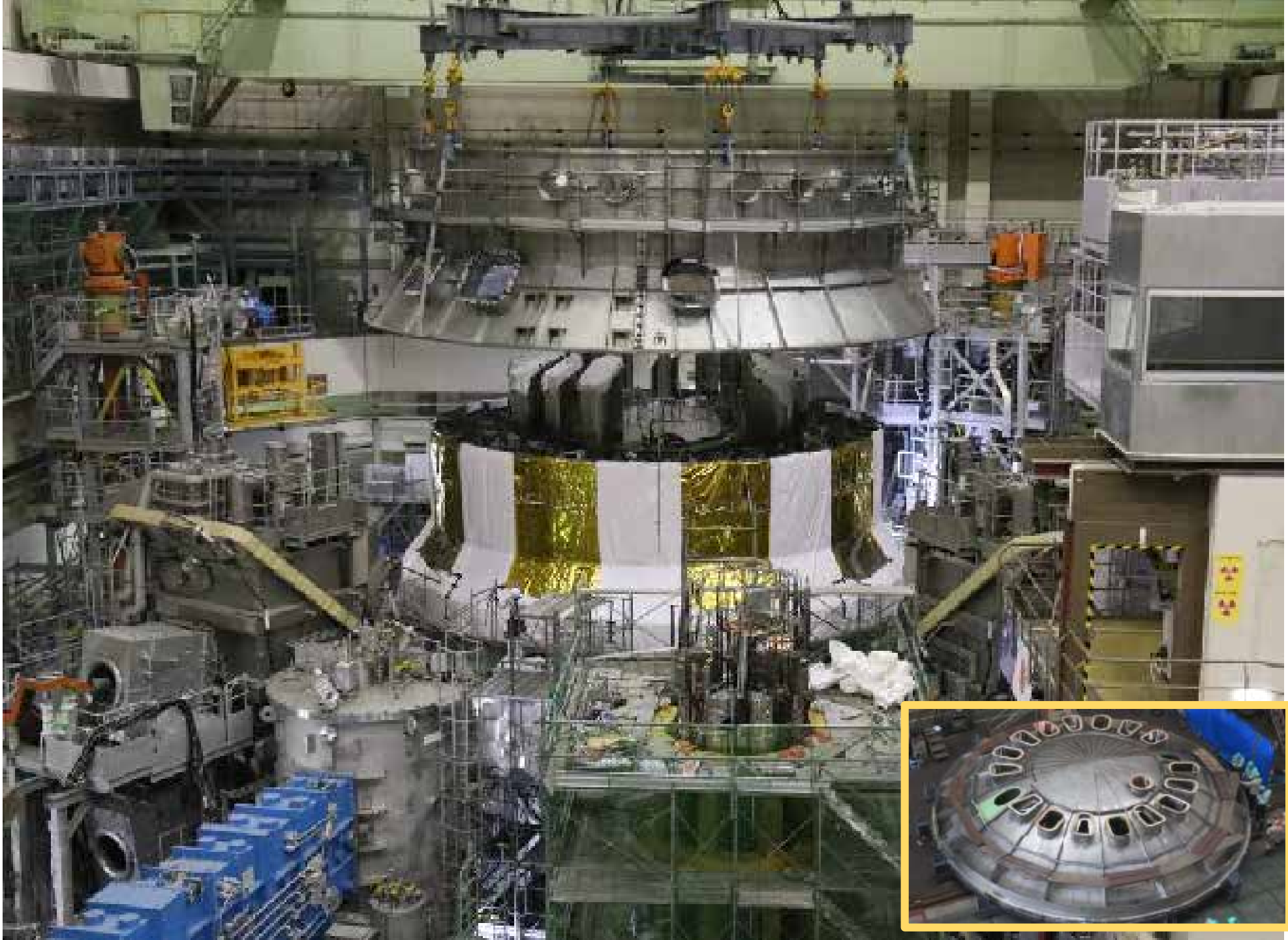


diagnostics, etc




JT-60SA



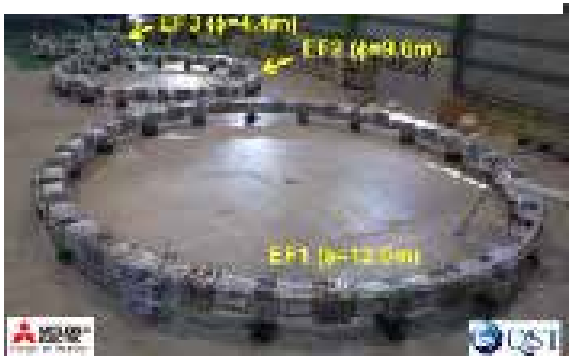


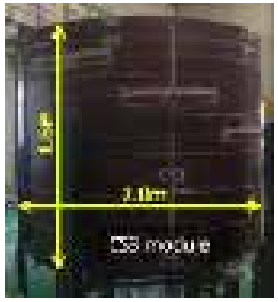
Excellent Accuracy of Manufacture and Assembly

Allowable magnetic field error : ～10^{-4}
=> Manufacture & assembly accuracy is ~ mm ⇨ **Achieved**

CB, surface flatness 0.6mm

EF, Deviation from exact Circle 0.3-1.3mm

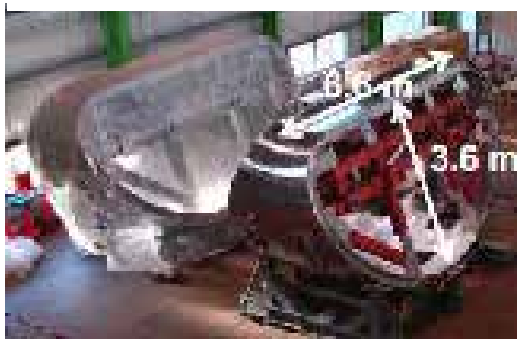




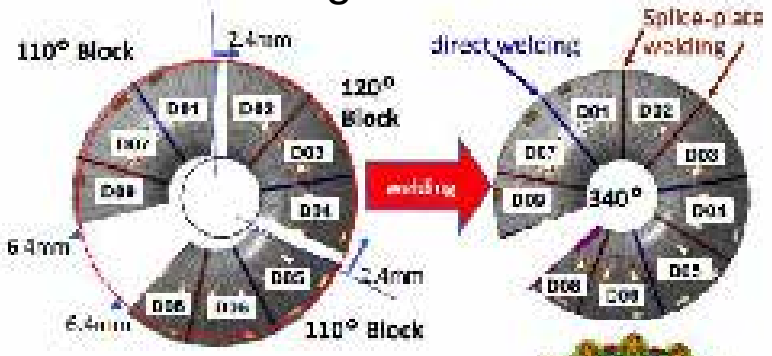
CS, Deviation from exact Circle 0.3-0.4mm

TF, Deviation of Current center 2 mm

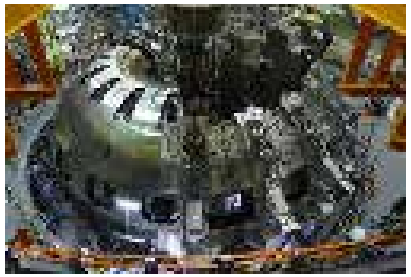
VV ±2 - 5 mm

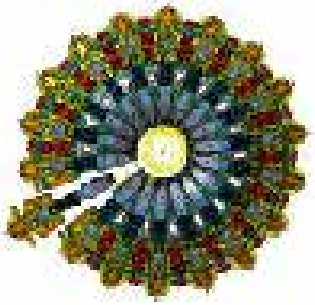


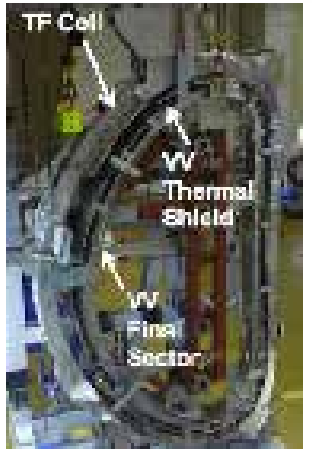
VV welding : ±4 - 8 mm



TF assembly : ±1 mm







Laser tracker

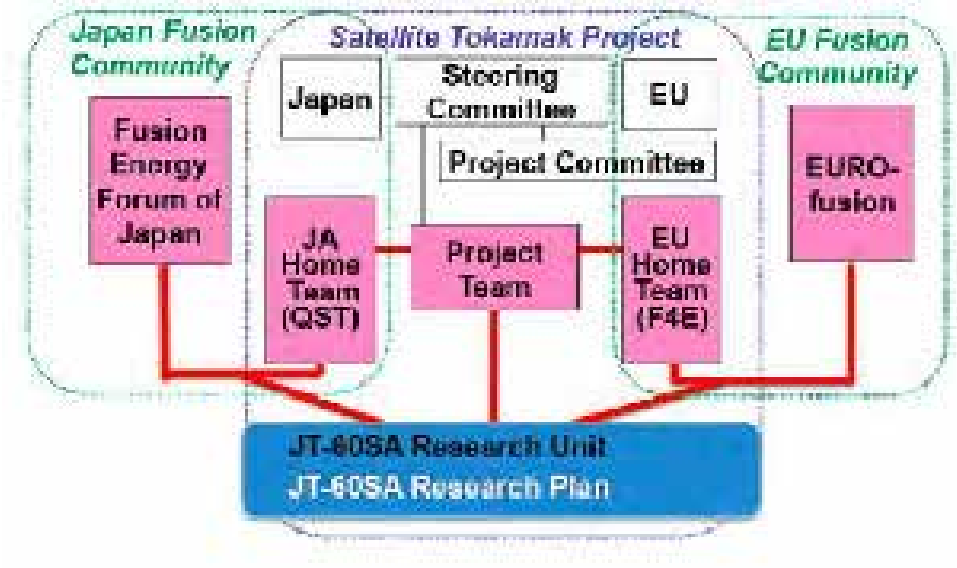
JT-60SA Research Plan

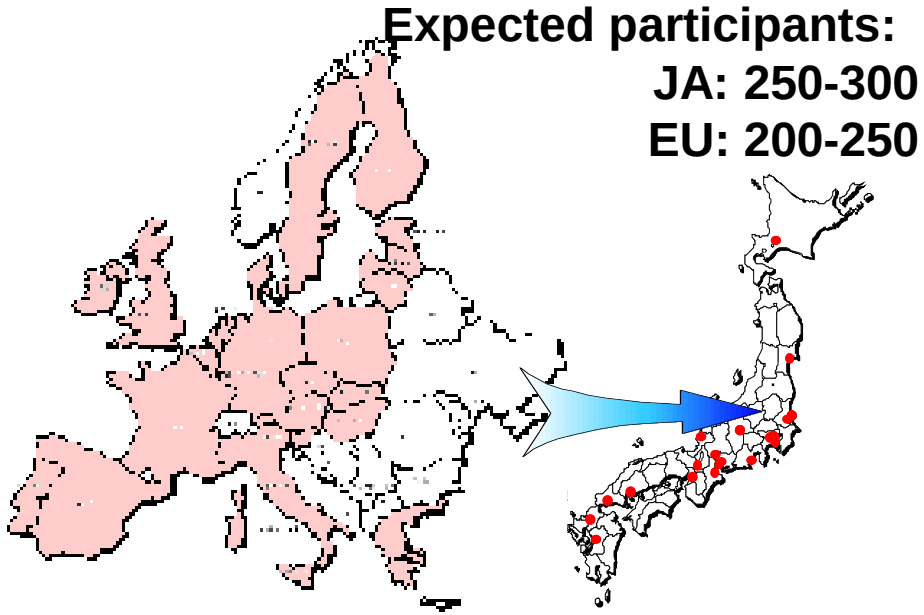
JA-EU JT-60SA Research Unit organized in 2009 with the JA and EU fusion community.
Research Plan Activity operated by young generation.

v.1 Home Team 2009, May → v.2 JA Univ. 2010 Jan → v.3 EU and JA 2011, Dec. → v3.1, 3.2, 3.3 2013-2016 → v.4.0: 2018, Sep

Experiment Team

JT-60SA Research Plan Ver. 4.0 was documented in Sep. 2018 by 435 co-authors, JA 174 (18 institutes), EU 261 (14 countries, 33 institutes)





Live

Naka Fusion Institute
JT-60SA Central Control Room

'JT-60SA Discharge Sequence'

Director, Dep. Advanced Plasma Research
S. Ide

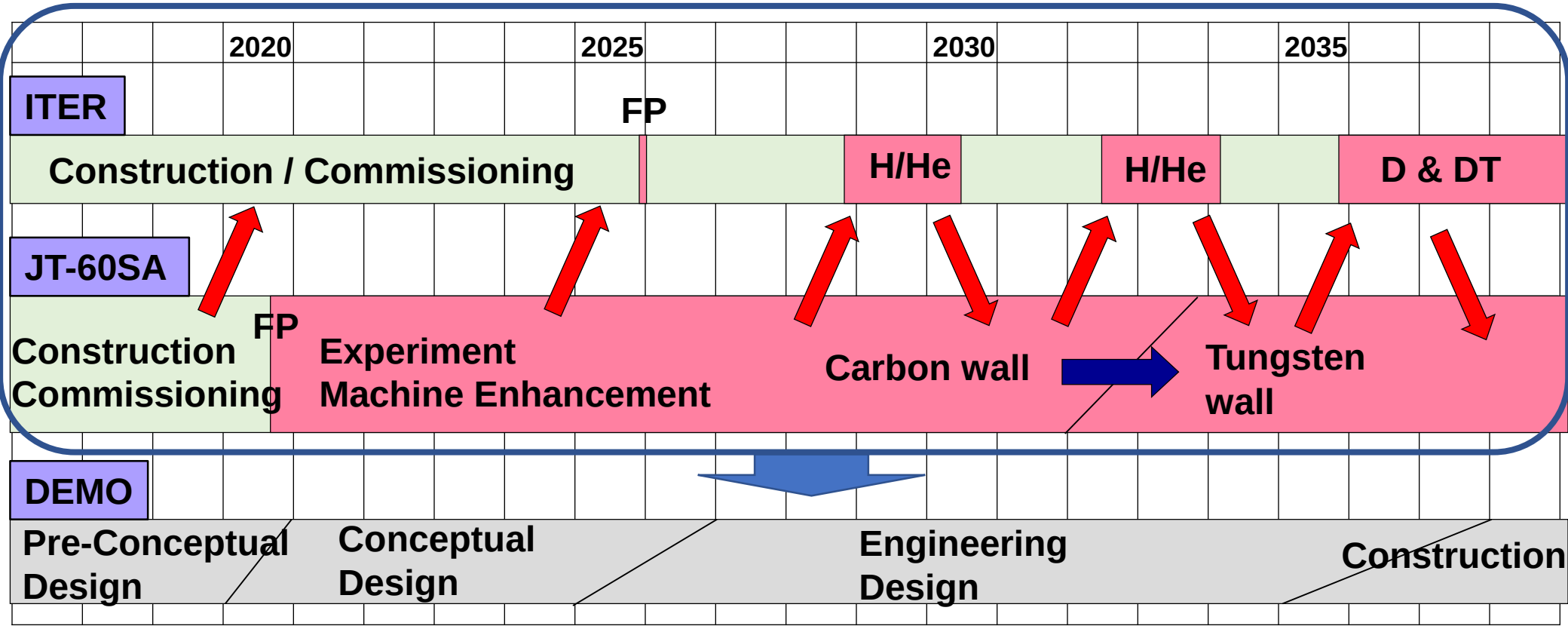
Schedule of JT-60SA & ITER Collaboration

Manufacture / Assembly /System Evaluation
Experiments/ Analyses/ Modeling

=> ITER

ITER & JT-60SA Collaboration Arrangement Signed on 20th Nov.

JA & EU University ' On-site Laboratory' at QST Naka



Thank You for Your Attention