

The assembly and commissioning progress of HL-2M Tokamak

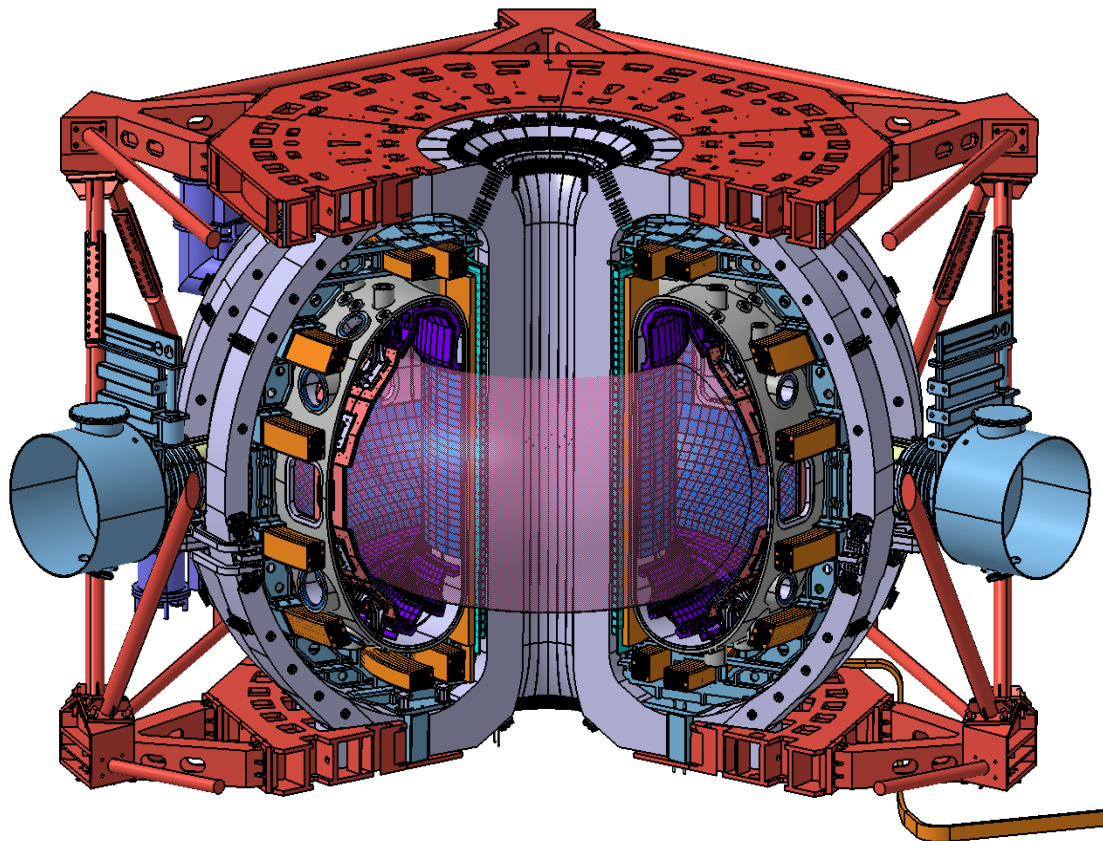
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10th US-PRC Magnetic Fusion Collaboration Workshop (MFCW 2020) , US: March 22-26, 2021 / PRC: March 23-27, 2021, Virtual-WebEx: <https://pls.llnl.gov/resources/events/MFCW>



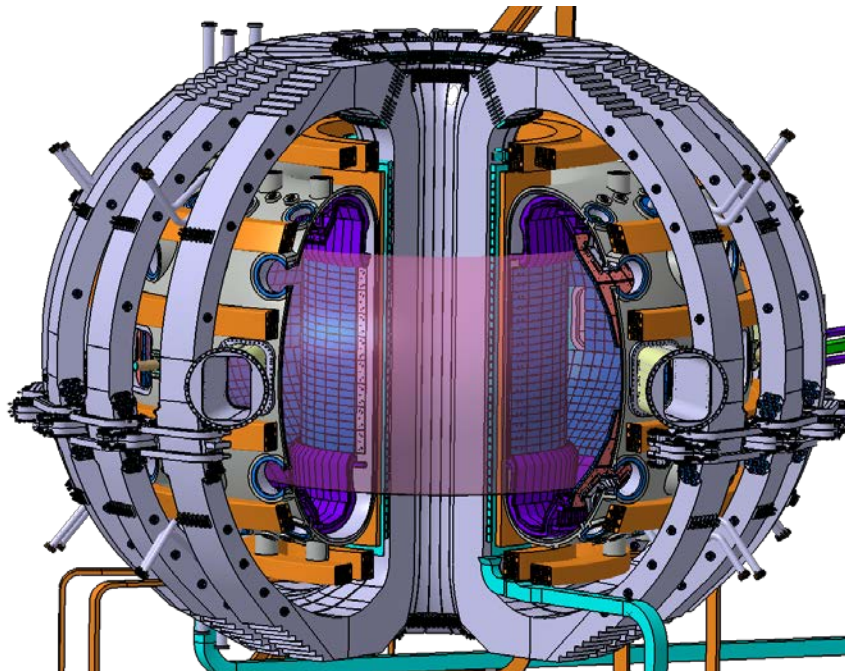
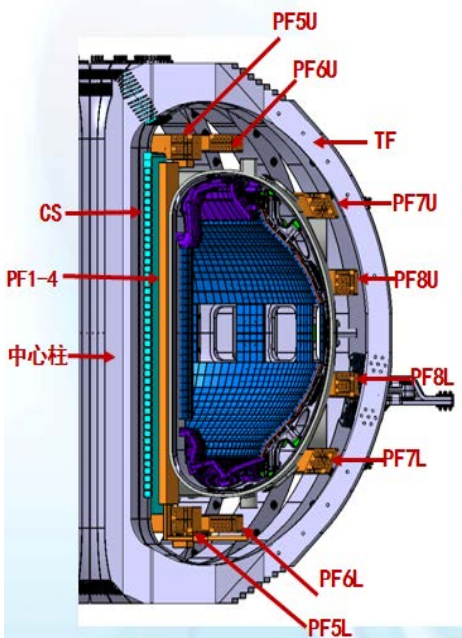
HL-2M is a middle-sized copper tokamak



	HL-2A	HL-2M
R	1.65m	1.78m
a	0.4m	0.65m
A	4.1	2.8
I_p	0.45MA	2.5~3MA
Bt	2.8T	2.2~3T
Plasma volume	5.2m ³	14.8m ³
Flux-swing	5	>14
κ	<1.3	2
δ	<0.5	>0.5
null	sn	Sn and dn



HL-2M uses demountable TFC



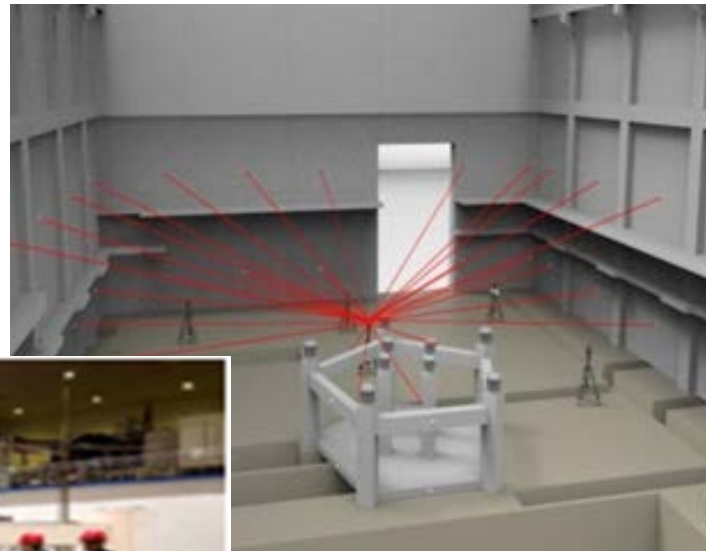
TF Coil	20 coils, 140 turns
B_t	2.2 T (1.78m)
I_t	140 kA
N_t	140 turns
CS	A/B parallel, 48 turns
I_{CS}	220 kA
N_{CS}	48 turns
PF Coil	16 coils
I_{PF}	14.5~40 kA
N_{PF}	26~28 turns





Main progress of assembly and commissioning of HL-2M

March 2019,
The site measurement started.



The size of VV were measured and remarked



For later installation of thermal shielding, magnetic measurements and engineering measurements, e.g., temperature, stress, displacement, etc.



VV was transferred to SWIP site in April 2019



A series of tasks were sequentially performed, e.g., cleaning, support installation, size measurement, vacuum pumping, and leakage detection, etc.

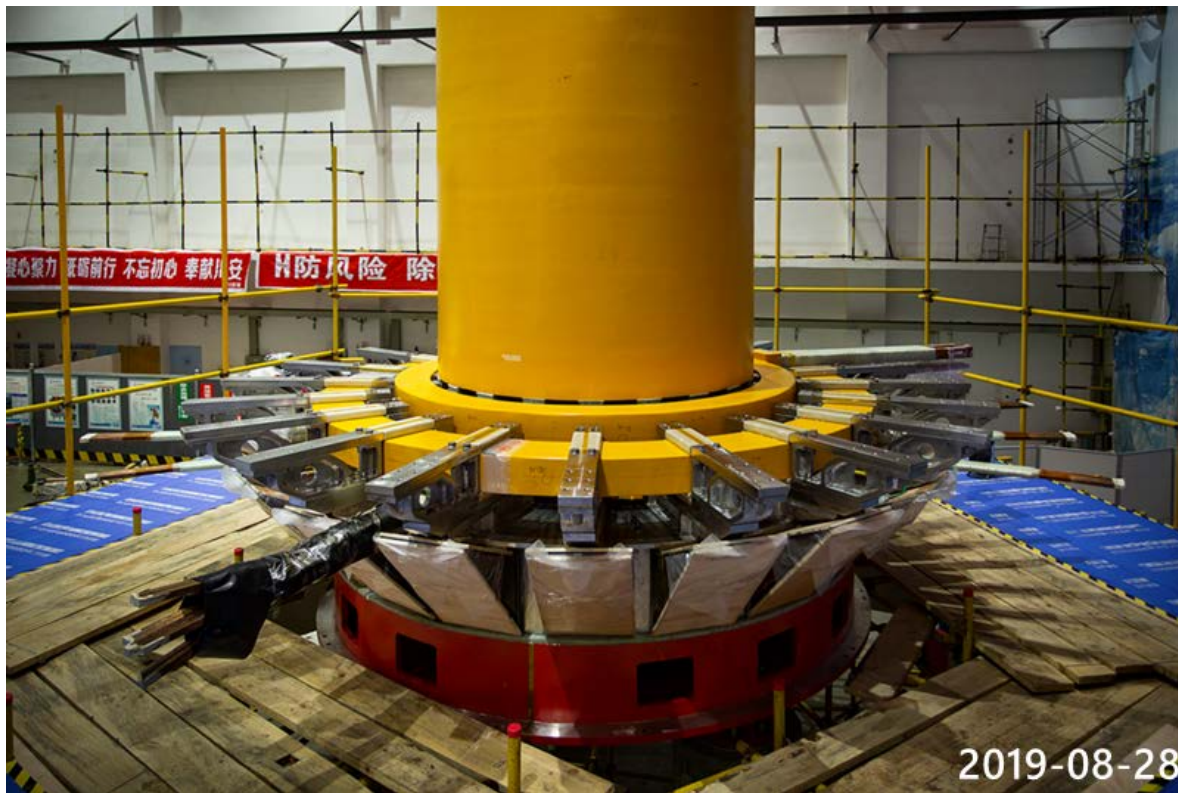


The gravity support was installed



The TFC central stack with CS coil was installed





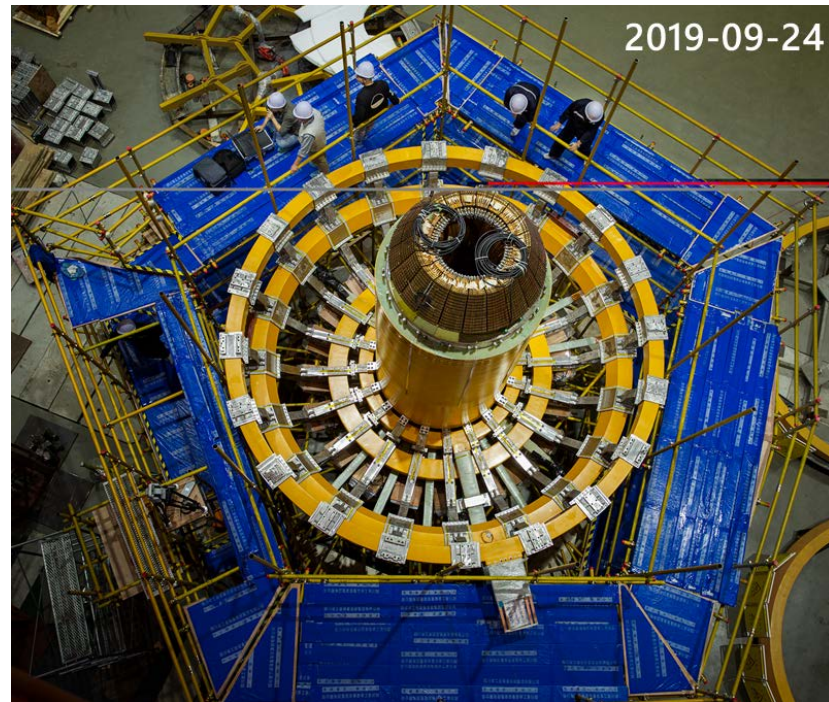
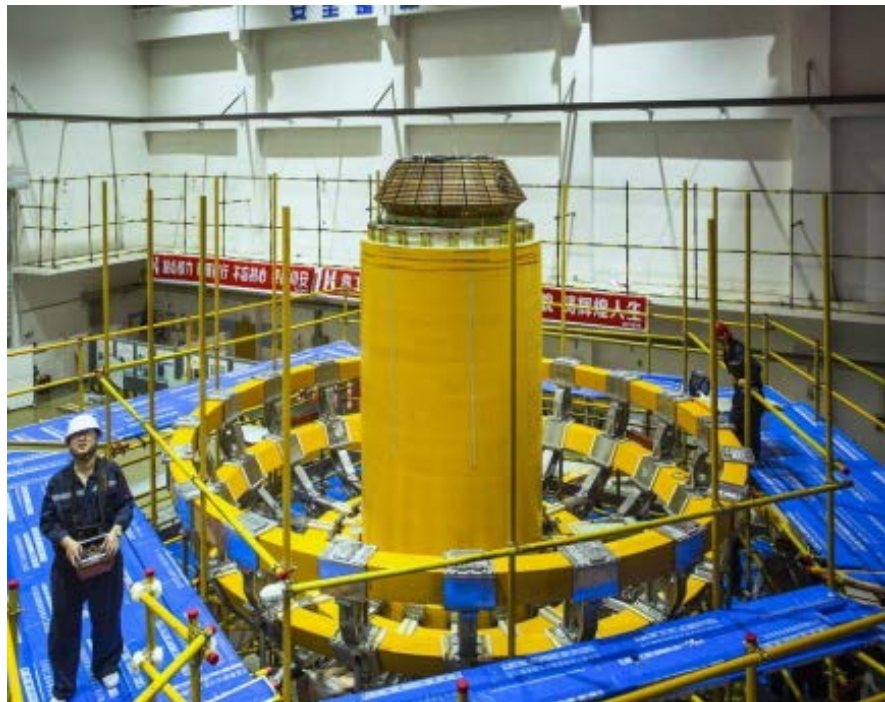
The thermal shield was installed for VV



The inner coil stack PF1-4 was installed

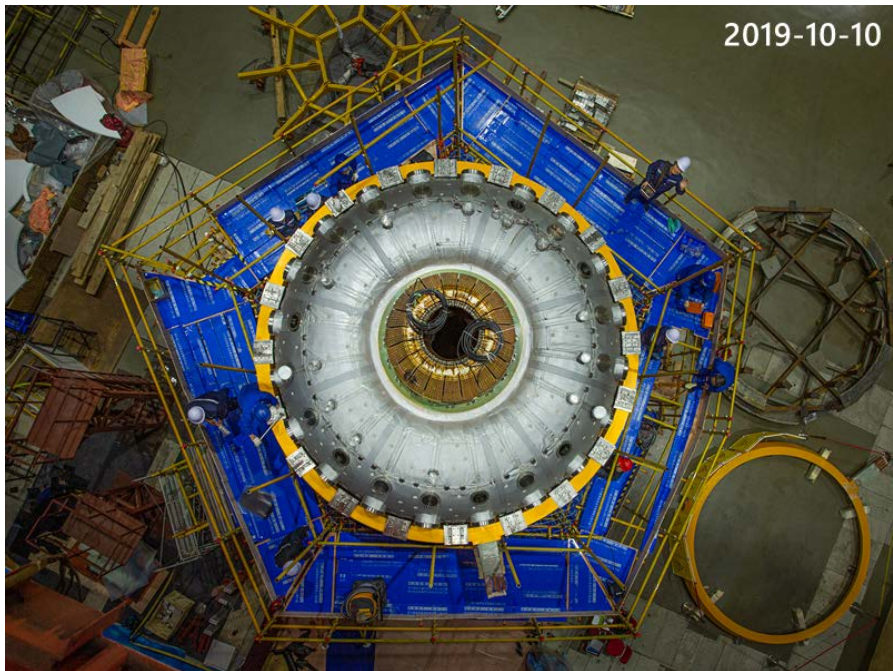


Installation of lower PF coils and PF1-4 stack finished





Installation of upper PF coils



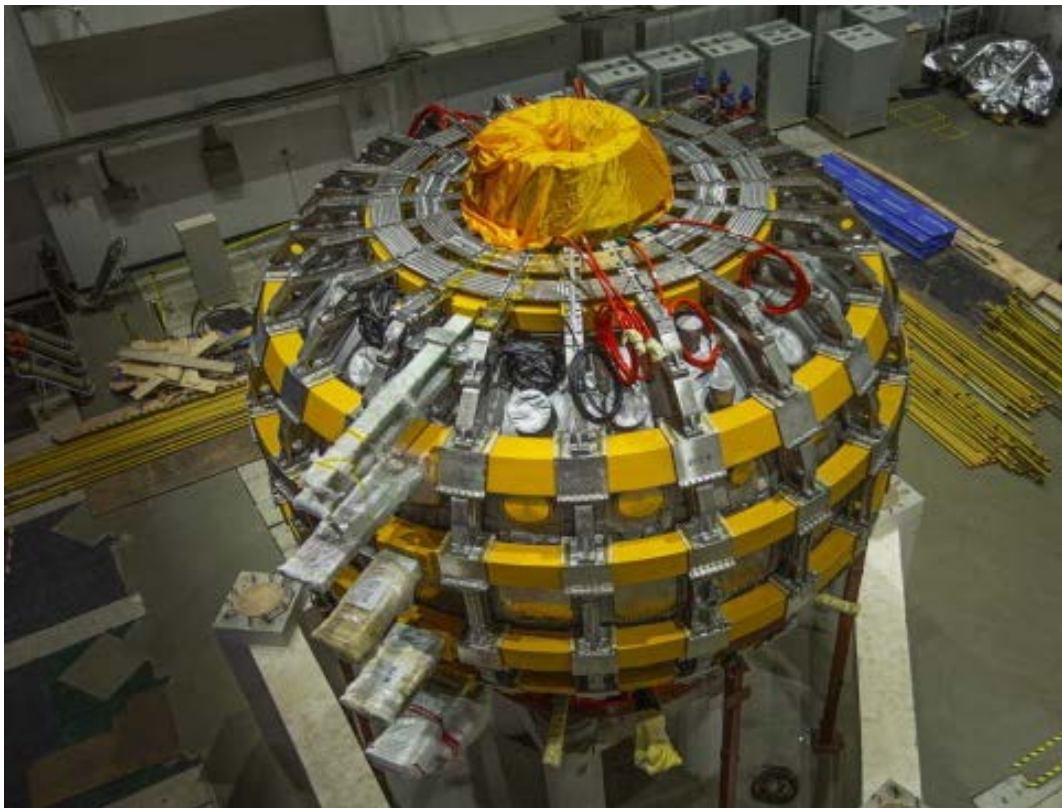




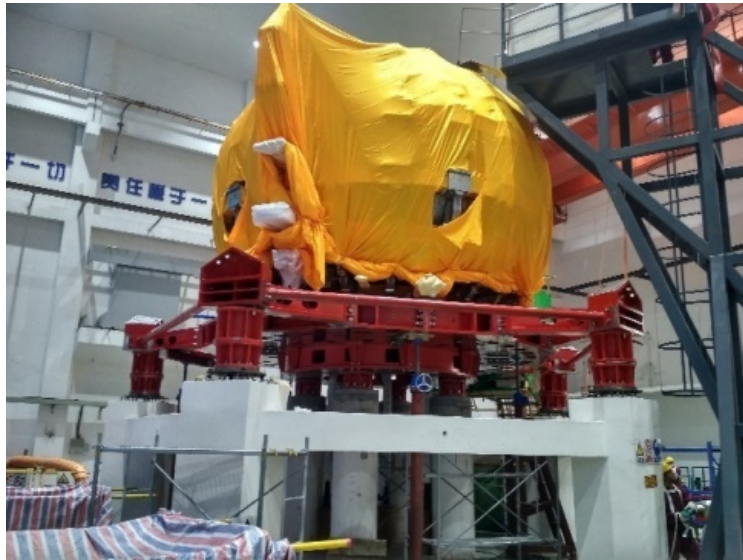
PF coils and their support were to be finished



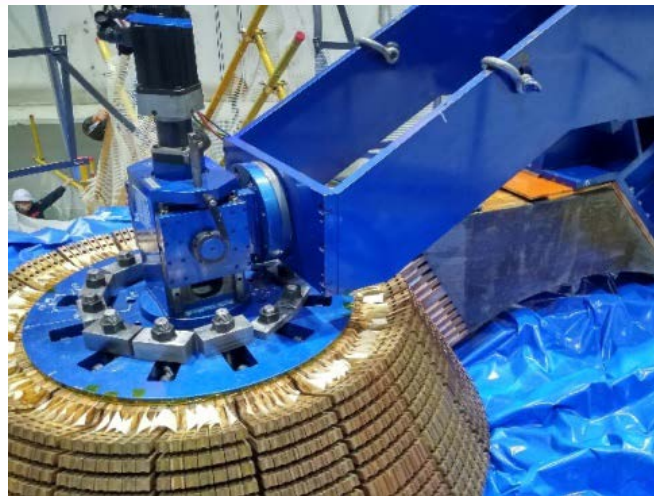
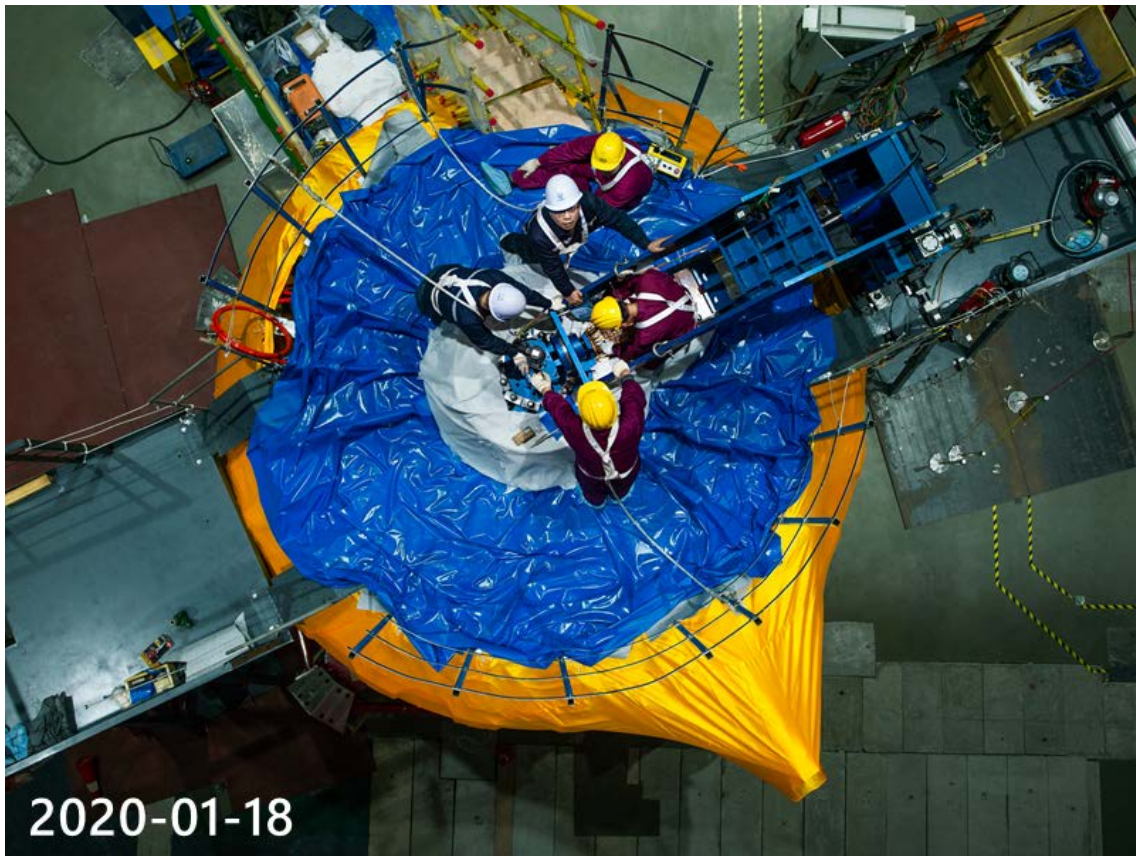
PF coils and their support were installed



After PFC were installed, the lower platform were installed. Surroundings were removed for TFC connection.



The upper sections of TFC were installed



After PFC were installed, the TFC would be connected.

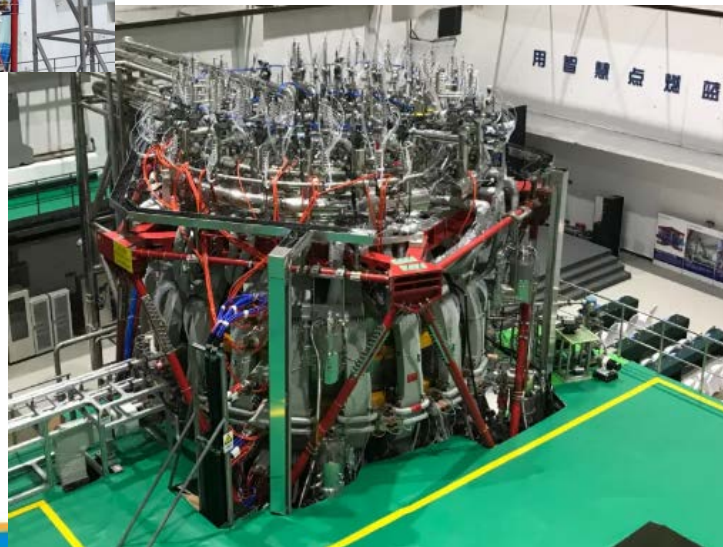
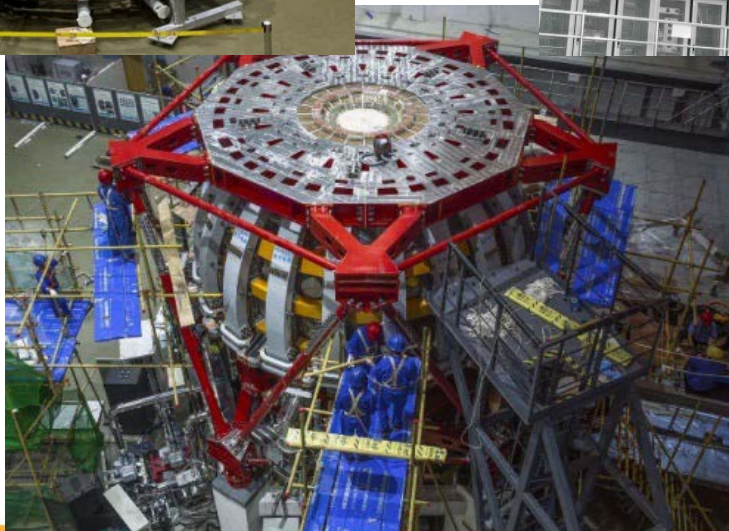
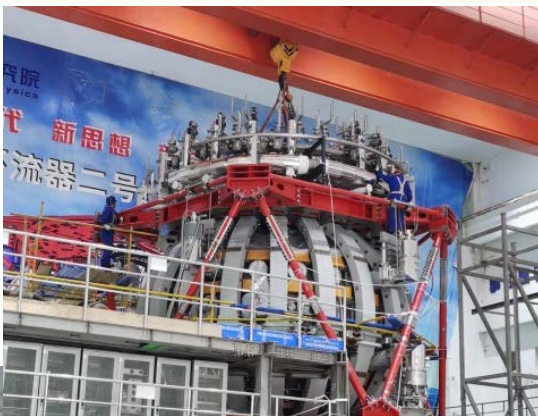
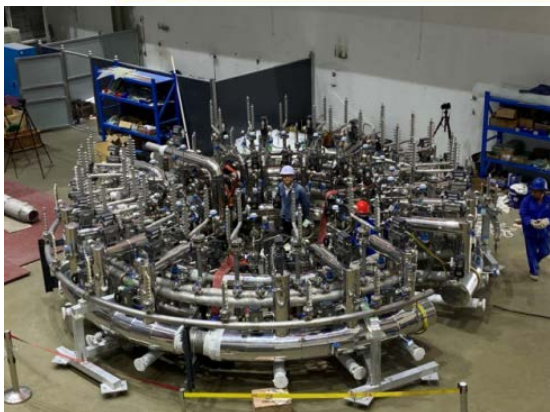


The outer sections of TFC were installed

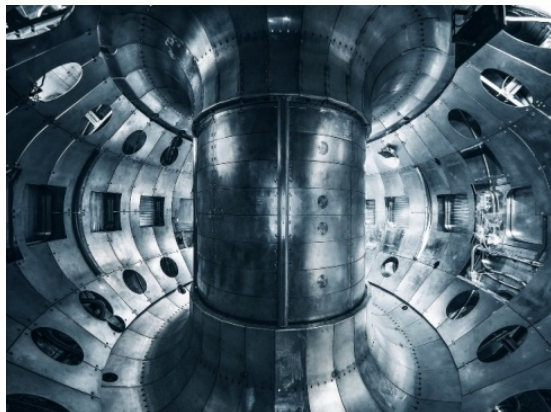
After all upper sections of the TFC were installed, upper platform were installed.



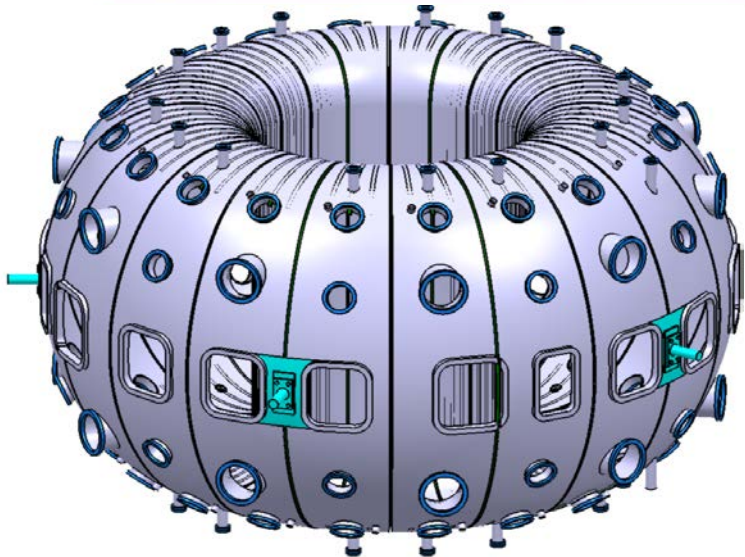
All components were installed in Oct. 2020



There were mass of tasks for 1st plasma discharge

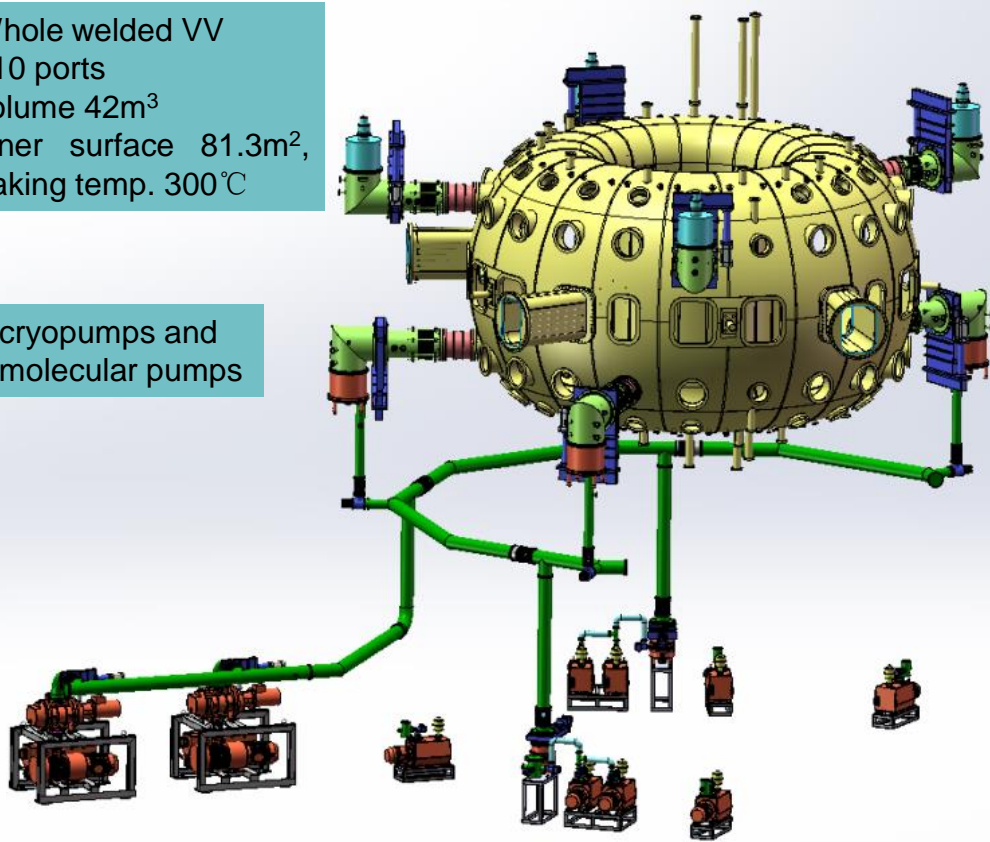


Vacuum pumping system



Whole welded VV
210 ports
volume 42m³
inner surface 81.3m²,
baking temp. 300°C

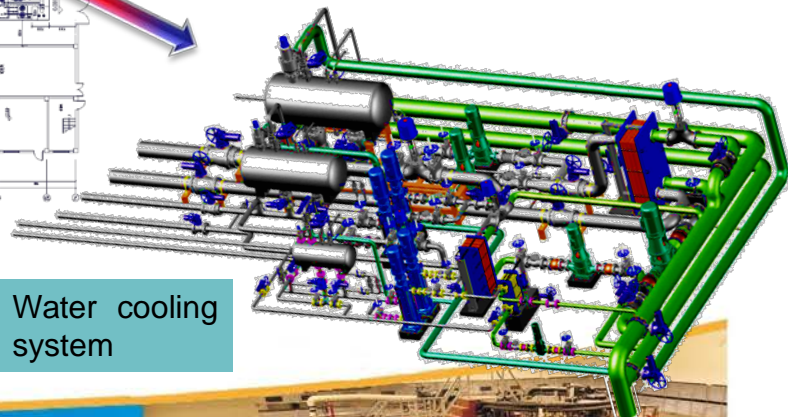
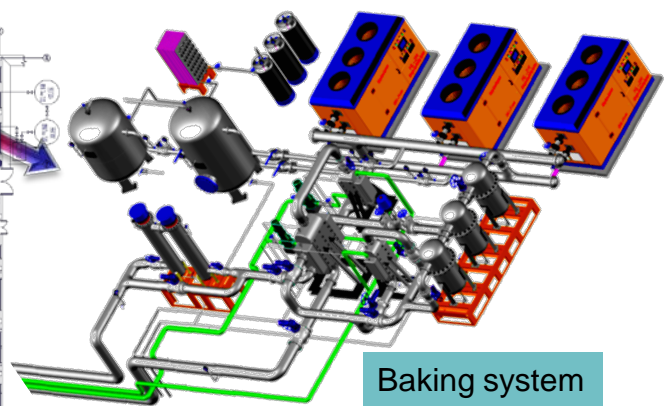
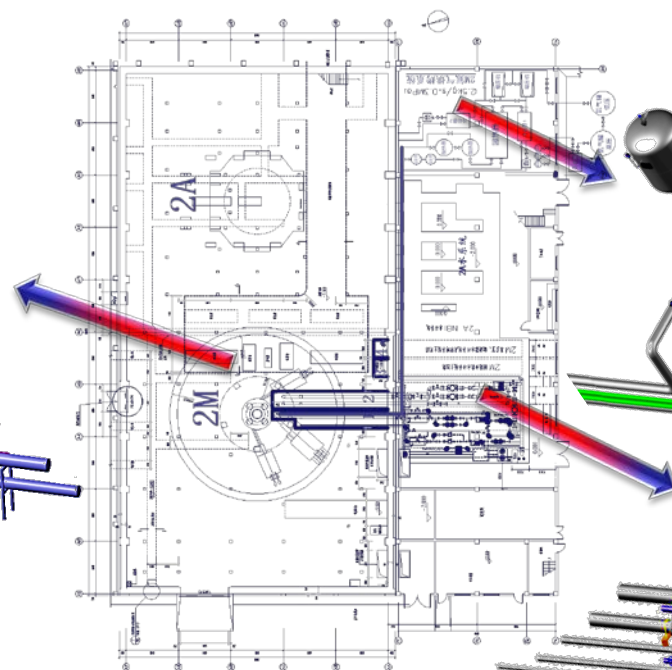
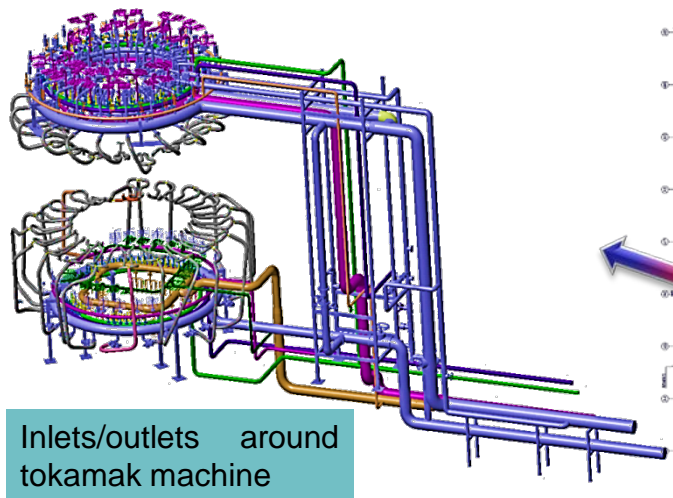
4 cryopumps and
4 molecular pumps



Ultimate vacuum /Pa	< 3.0×10⁻⁶
Total leakage /Pa·m ³ ·s ⁻¹	< 5.0×10⁻⁷
Leakage rete for single welding or port /Pa·m ³ ·s ⁻¹	< 9.0×10⁻¹⁰

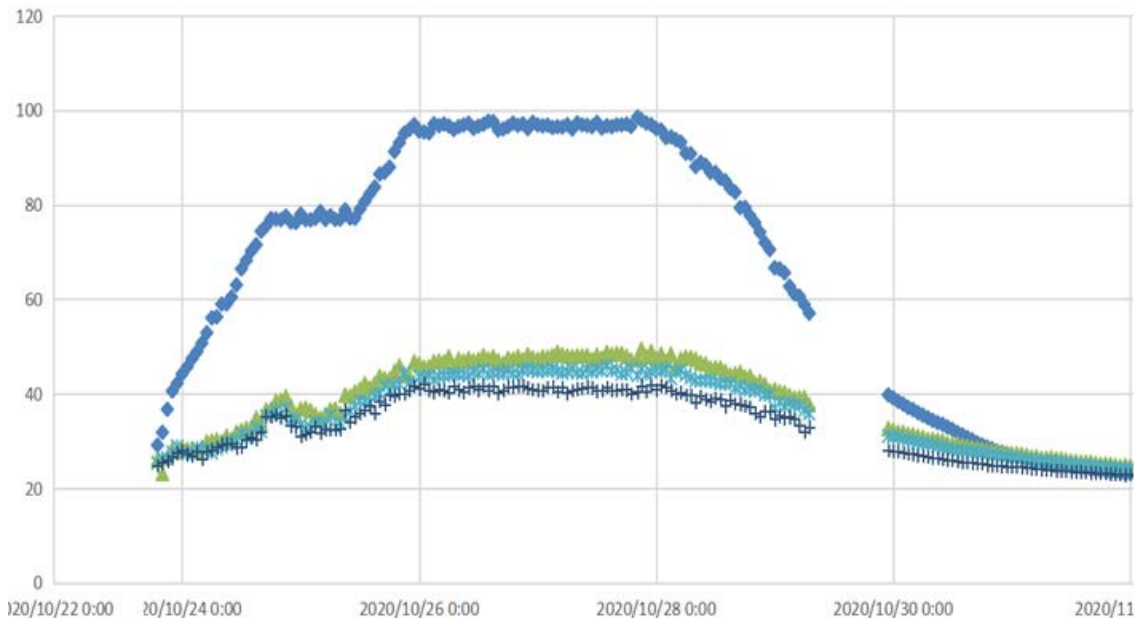


Water cooling system and baking system

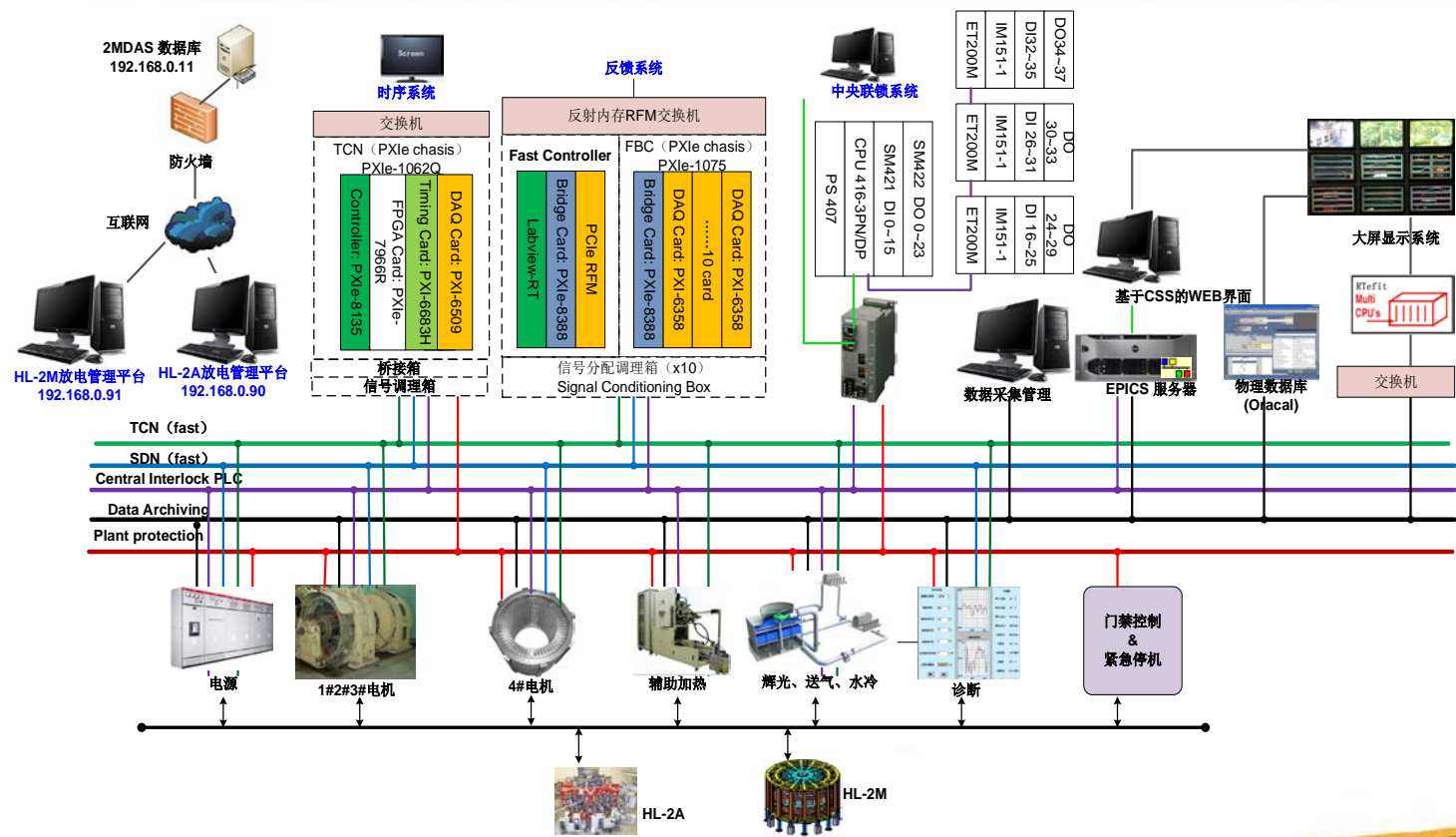


VV baking with 100°C for 2 days

For the first time of baking, the temperature and its change rate were reduced. The temp. distribution is carefully checked.



Hardware of the control system has been built

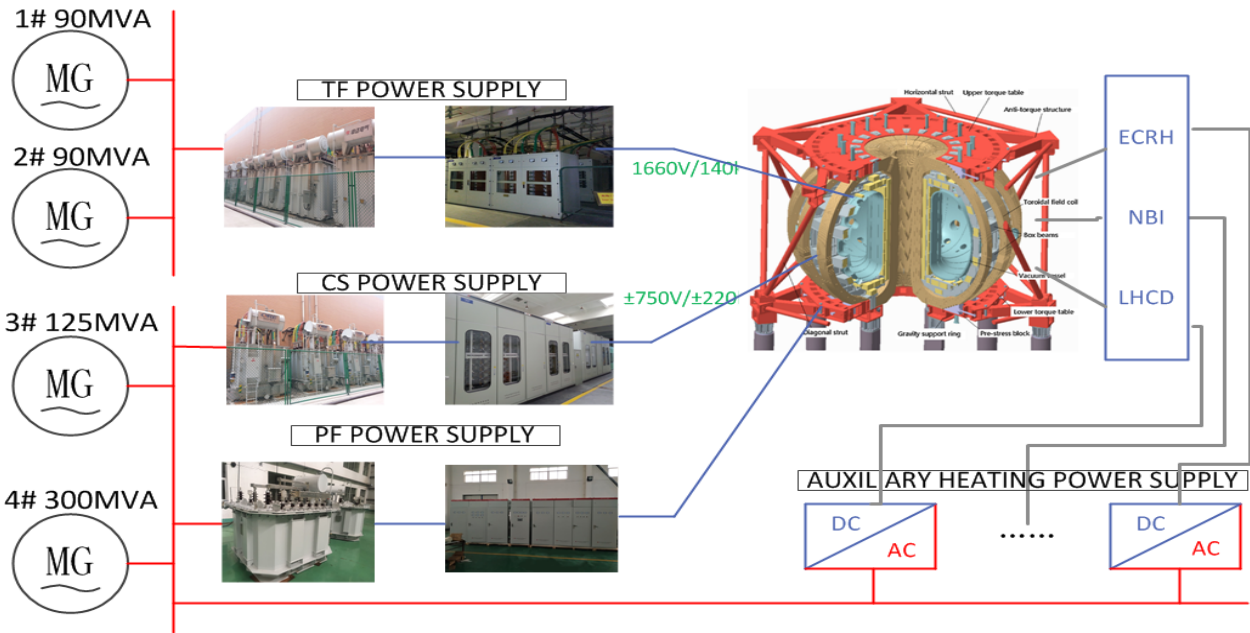


- Discharge management
- Plasma feedback control
- Timing
- Interlock and protection
- Data acquisition and database
- Engineering monitoring
- Network
- Display



Power supplies are able to run normal discharges

The power supply systems and MG had been gradually designed, constructed and tested. Since Oct. 2020, they are connected to relevant coils of HL-2M.

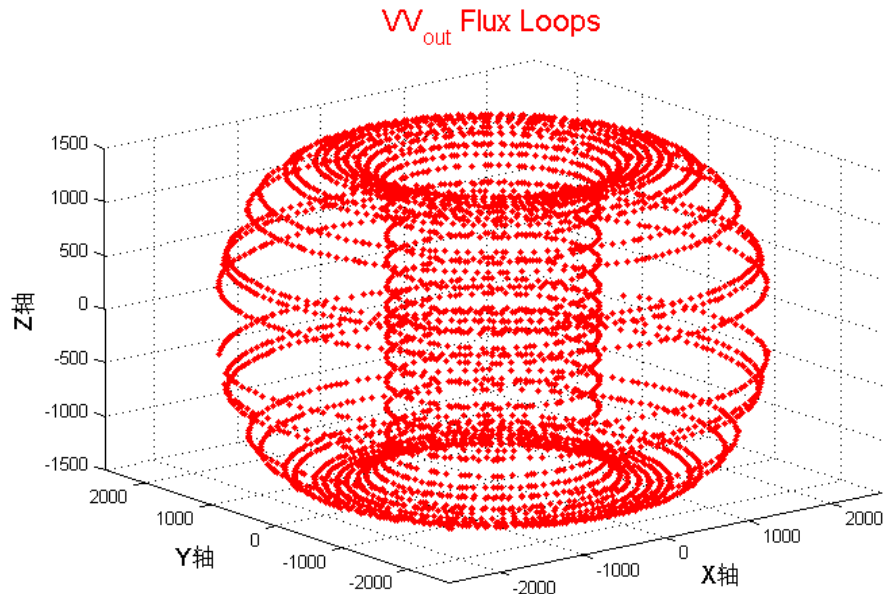
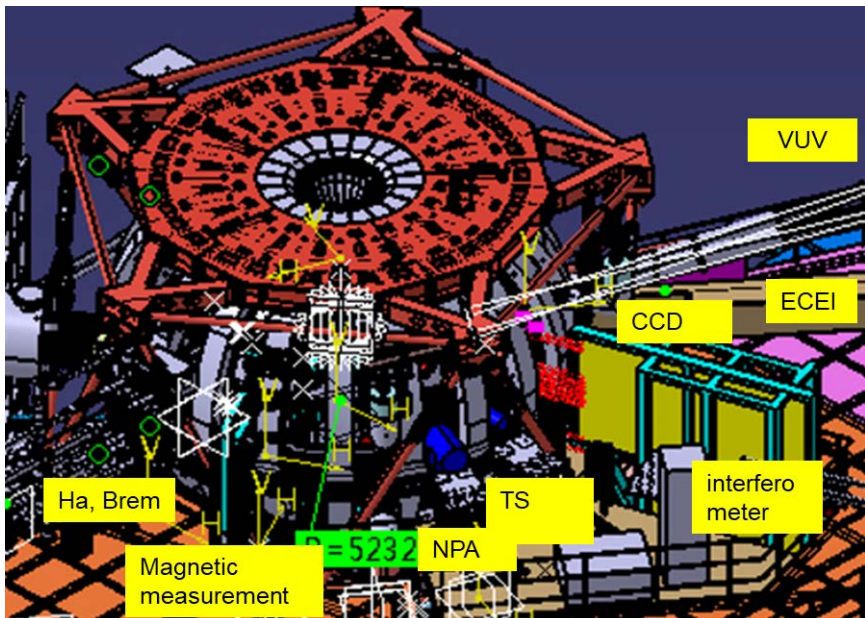


TFC Power supply	1660 V / 140 kA
CS power supply	± 750 V / ± 220 kA
PF1U / PF1L	± 650 V / ± 15 kA
PF2U / PF3L	± 650 V / ± 15 kA
PF3U / PF3L	± 650 V / ± 15 kA
PF4U / PF4L	± 650 V / ± 15 kA
PF5U / PF5L	± 650 V / ± 38 kA
PF6U / PF6L	± 650 V / ± 38 kA
PF7U / PF7L	± 750 V / +6 (-40) kA
PF8U / PF8L	± 750 V / +6 (-40) kA



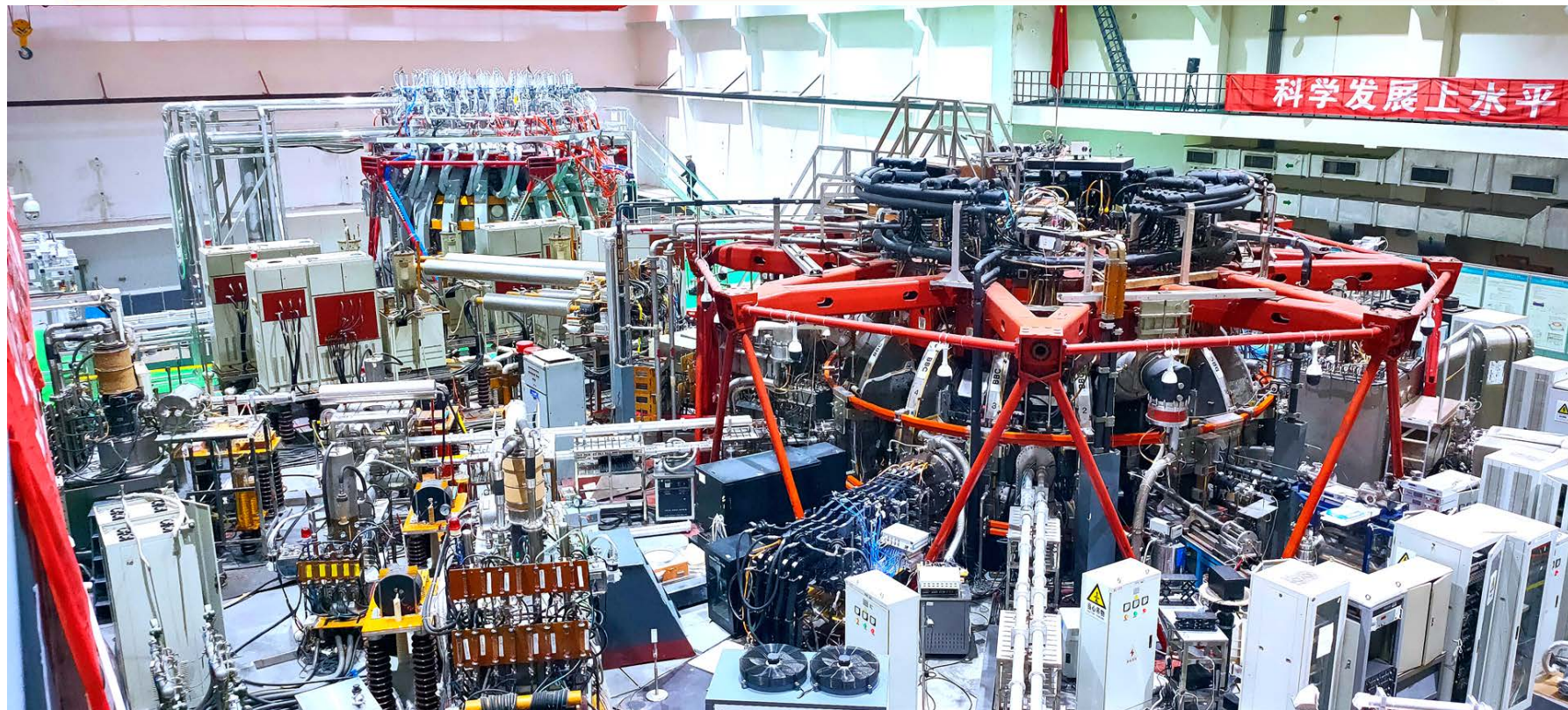
8 kinds of 16 sets diagnostics installed on HL-2M

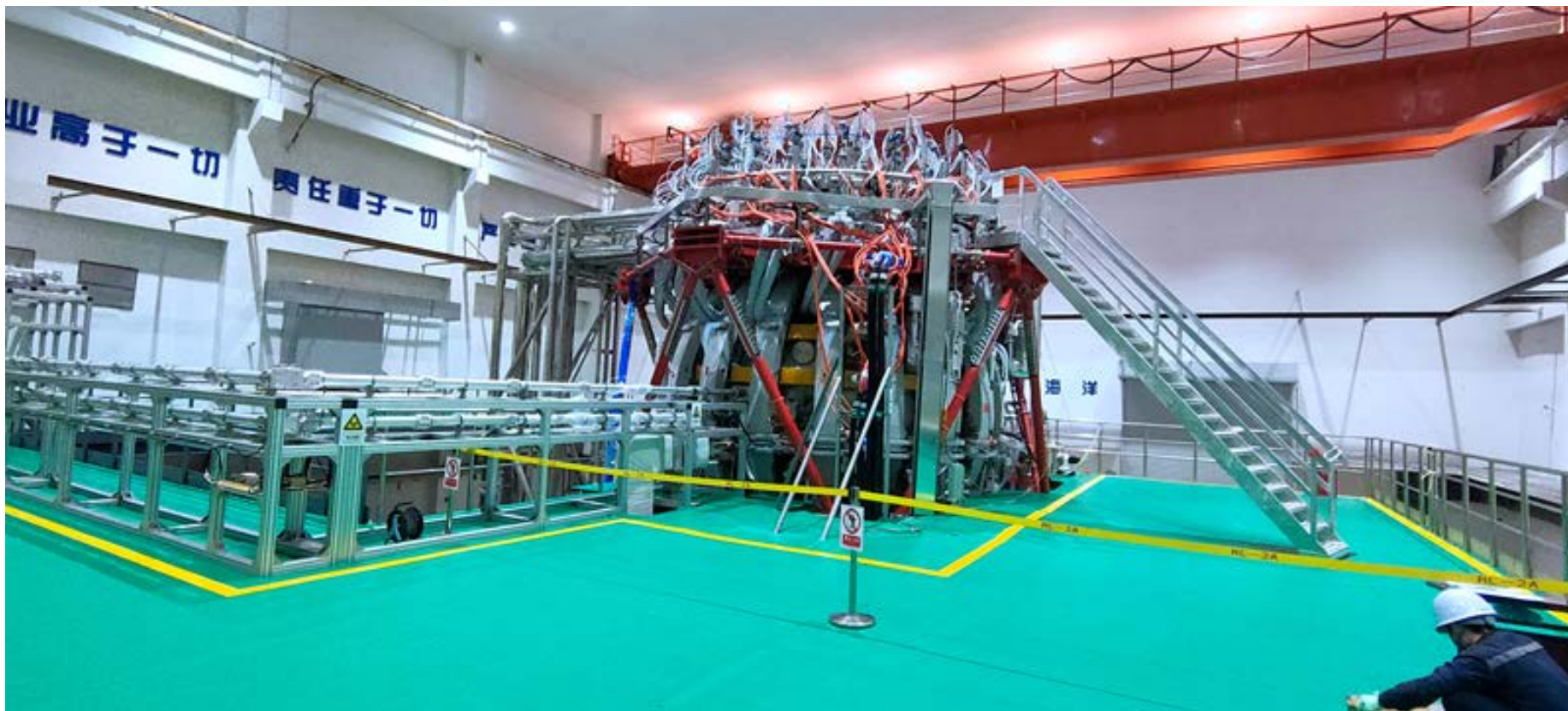
The 1st plasma diagnostics were mainly focused on plasma basic aspects, e.g., current, density, position, temperature, visible light, impurity, etc.

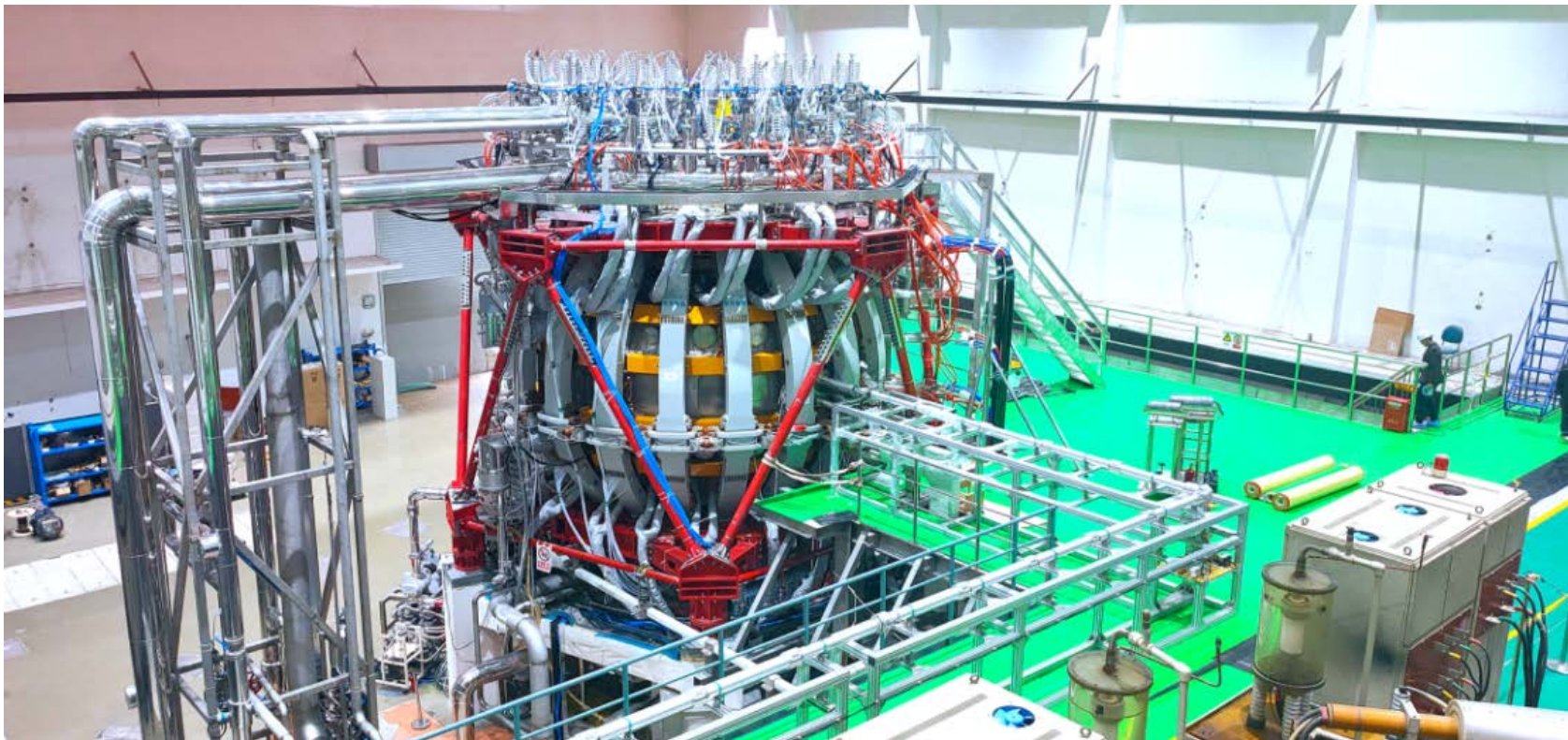


Magnetic measurement was designed, the one outside VV has been totally commissioned.









First break-down of gas on Nov.19, 2020

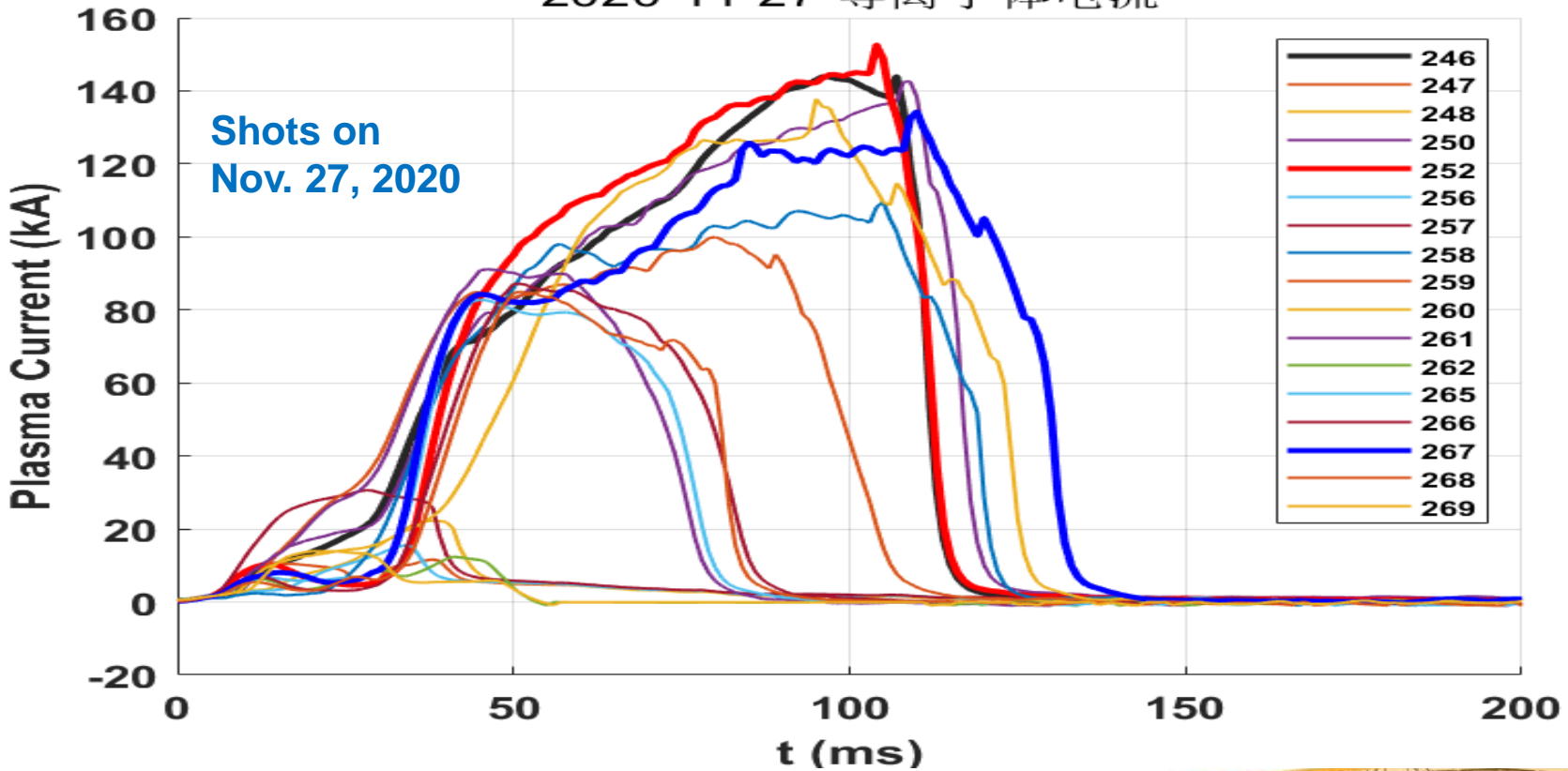


The first plasma breakdown took place on Nov.19, 2020, with the first feed of gas.



Repeatable break-down and plasma current

2020-11-27 等离子体电流





First plasma witness ceremony on Dec. 4, 2020



First plasma witness ceremony on Dec. 4, 2020



The 1st plasma is to show that the tokamak machine, components, and all of the subsystems can run and work together, and the plasma can be achieved and controlled.

- The baking temperature are still low in contrast to designed.
- The coil currents are limited due to reduction of heat removal capability, hence the flux swing is decreased below 1.5Vs and $I_p < 300$ kA.
- The inner wall of VV was covered by a SS shell, without divertor installation. The number of the diagnostics are reduced.
- The TFC current is reduced with $B_t < 0.7T$ (rated 3T), while the mechanical and thermal properties are carefully checked.
- Only CS coil, PF8, PF6 are used, in which PF8U and PF8L are fed in series, so does PF6U and PF6L. CS coil works with only one-direction current about half of rated value.



**HL-2M already has a start,
but it is just at the beginning of scientific studies
towards fusion energy development.**

Next HL-2M will enhance its experimental capability.

**We are looking forward to collaborations with
scientists during its coming experiments, as the way
we have experienced during its construction.**



Thank you for your attention.

