Overview progress and future plan

of

EAST project

Yuanxi Wan,Jiangang Li, Peide Weng
for
EAST, GA and PPPL Team

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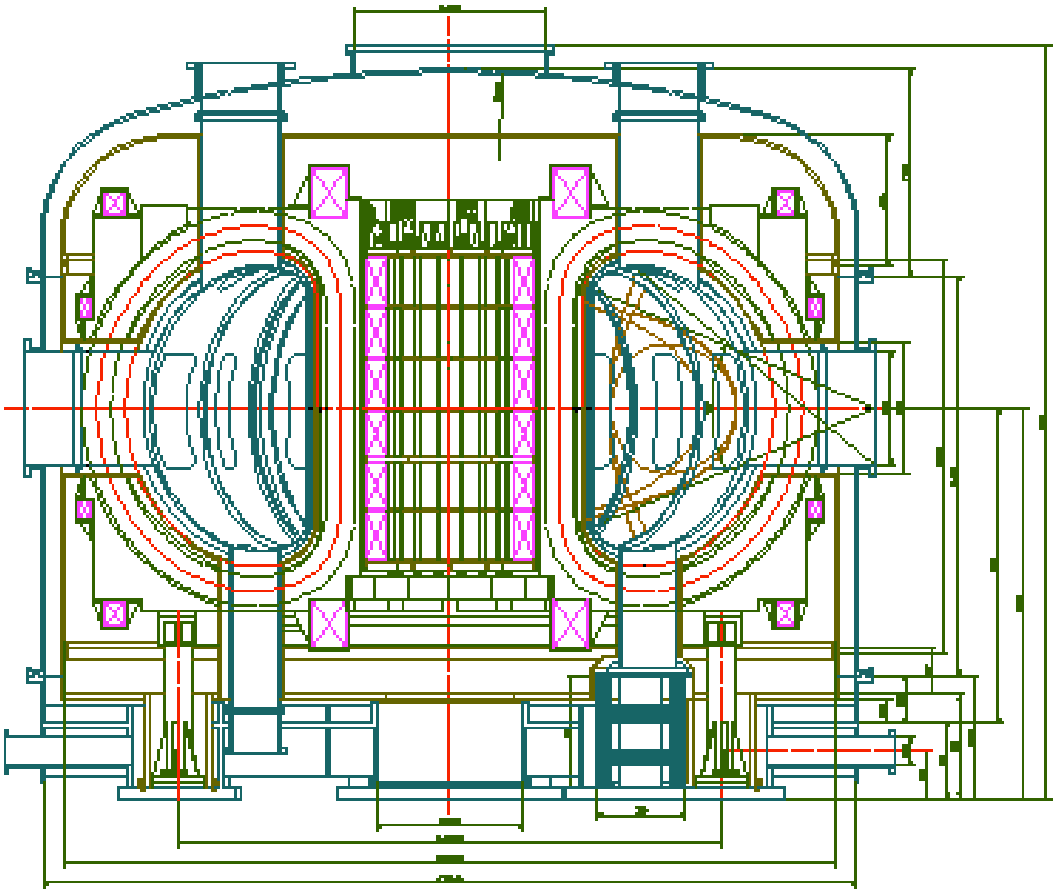
EAST is an Ex. Advanced Superconducting Tokamak

EAST Tokamak



Main Parameters

(First Phase)

Toroidal Field, B_o	3.5 T
Plasma Current, I_P	1 MA
Major Radius, R_o	1.7 m
Minor Radius, a	0.4 m
Aspect Ratio, R/a	4.25
Elongation, K_x	1.6 - 2
Triangularity, δ_x	0.6 - 0.8

Heating and Current Driving :

ICRH	3 - 3.5 MW
LHCD	3.5 MW
ECRH	0.5 MW
Pulse length	1000 s

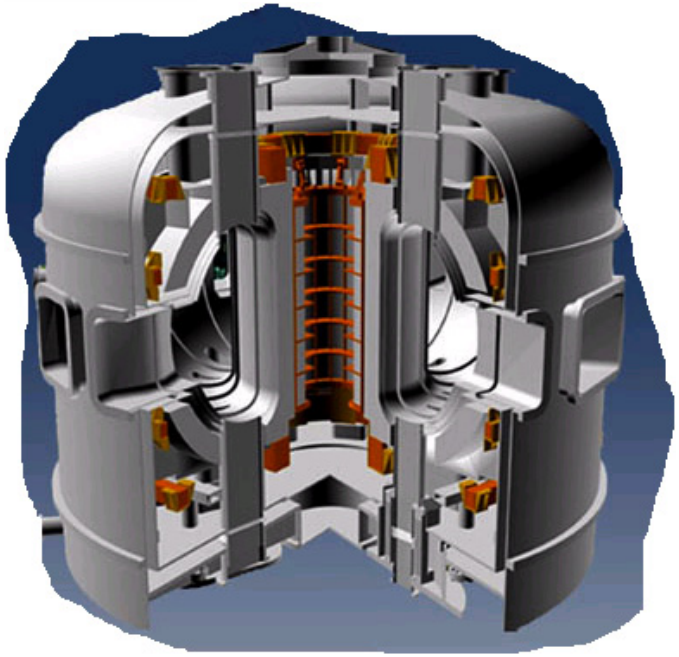
After hard working over 8 Years

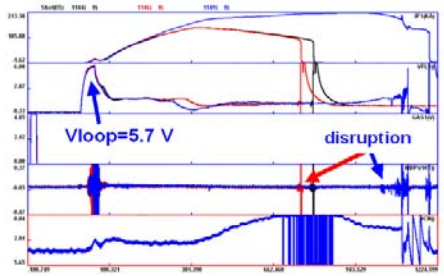
the first plasma discharges

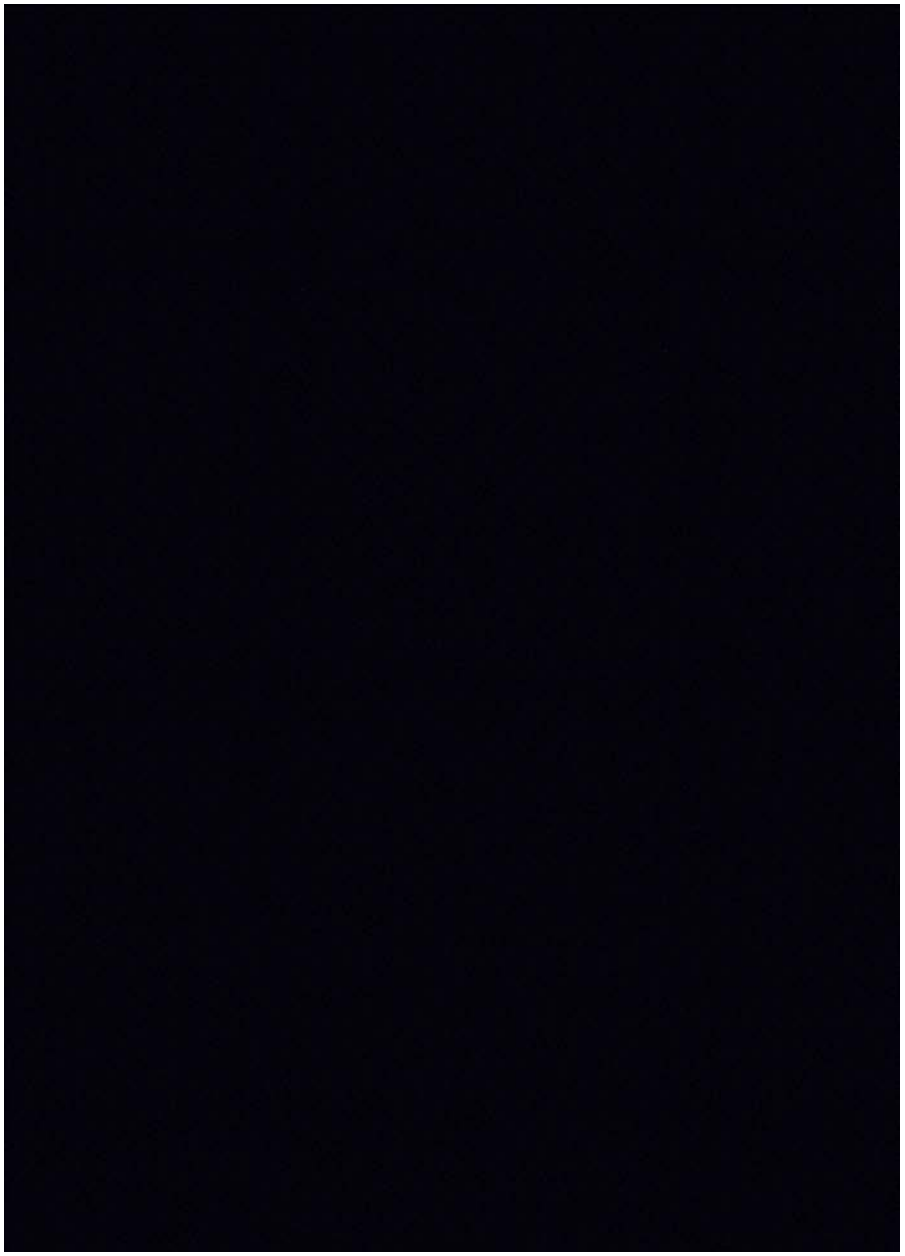
were successfully obtained

at September 26 2006 !

EAST Shot: 1149# by CCD







The EAST First Plasma discharges
Sept. 26 ,2006

Content

I. Overview progress

II. Unique Characteristic

III. Future plan

milestone

- 1997 The project approved by government **as MPSR**
- 1998-2000 Many evaluations of the proposal, the conceptual and preliminary engineering design, budget plan etc;
- 2001-2005 R&D, fabrication, tests of all SC magnets and assembly;
- 2006
  - ➢ Feb.- Mar. First engineering commissioning was success
  - ➢ April - July All in-vessel components and diagnostics assembled
  - ➢ Sept.22 **Rated B_T = 3.5 T at 1.7 m** and $\Delta\Phi$ ~ 13 vs achieved
  - ¬ Sept.26 **The first plasma discharges obtained successfully!**
  - ¬ Sept.28 Passed the evaluation **with very good comments** given by the experts committee

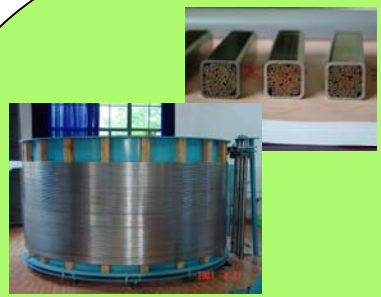
The experimental campaign begun formally from Sept 26. 2006 !

Important progress

1. All TF,PF SC magnets were fabricated, tested before assembly

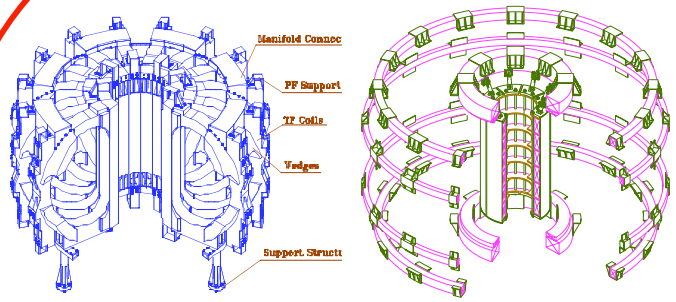
- Four workshops for CICC, winding,VPI, milling and the test facility were set up around 2000;
- and 35 Km CICC, 16 TF magnets,12 PF coils produced by the workshops with good quality;
- All magnets has been tested successfully by cooling and charging, which indicate: the quality of the design and fabrication for all magnets by our workshop is satisfied before the final assembly !

5.Test Facility



1.CICC

2.Winding



TF&PF systems of EAST

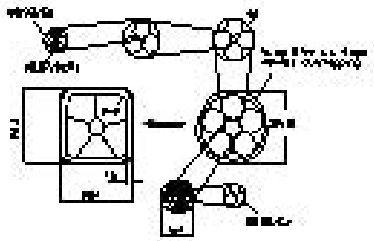
4.Milling

3.VPI

The most important components of EAST tokamak:

28 superconducting magnets were fabricated and tested by ASIPP

Important progress



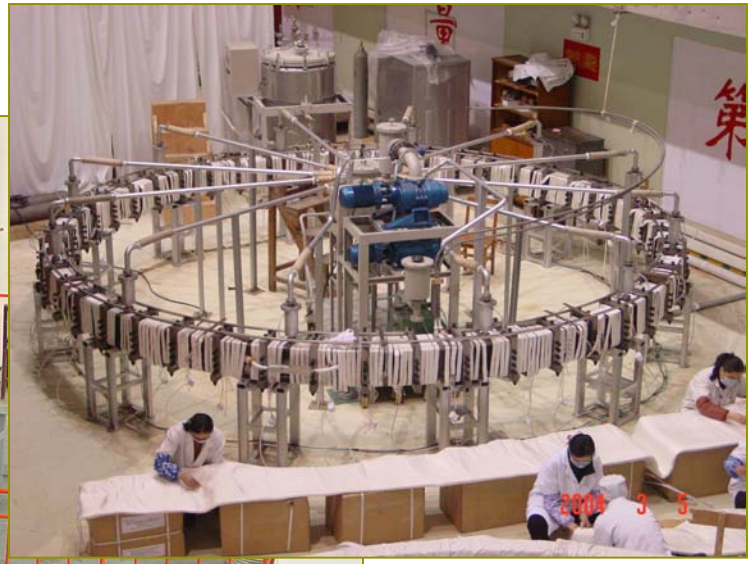
Configuration of CICC

The jacketing line of Cable In Conduit Conductor (CICC)

Important progress

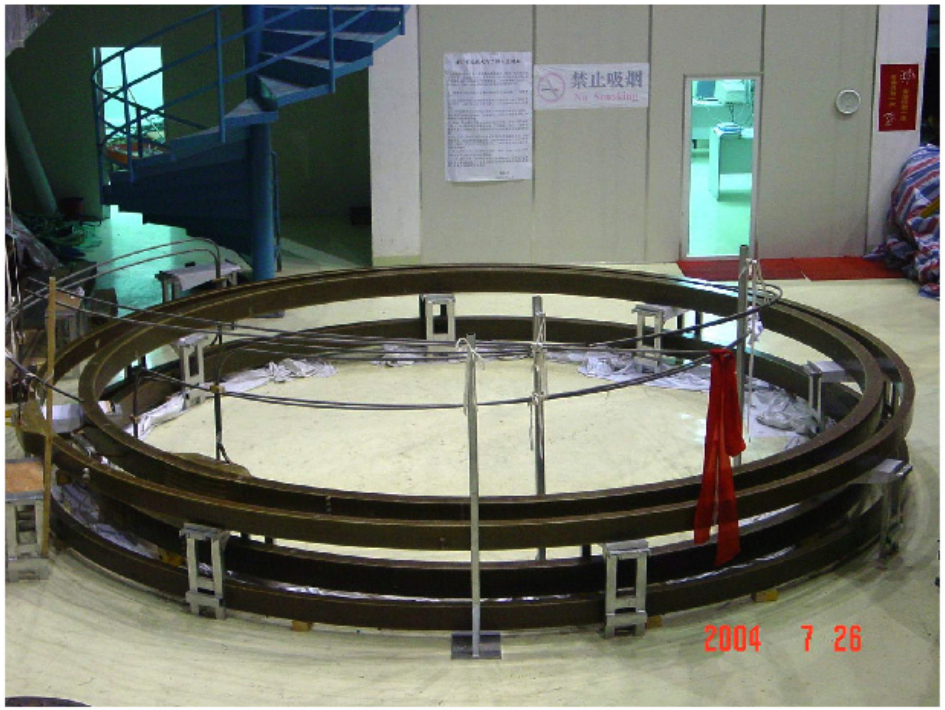
Three Winding machines are working

Important progress



The largest PF coil is under VPI

Vacuum impregnation workshop(VPI) for TF and PF coils



All PF coils have been ready for final assembly

Important progress

TF coil case is under machining by NC-milling machine

The TF magnets were ready for the final assembly

Important progress

The cryogenic test facility set up in ASIPP to test the performances of all SC coils before installation.

Cryostat with CLs:

Diameter	3.4 m
Height	6.7 m
Vacuum	1 °¡10^{-5} τ
Current leads	2 pairs
	20-30 kA

Power Supply:
24 kA/0-100V(CW)
100kA/0_800V(5s)

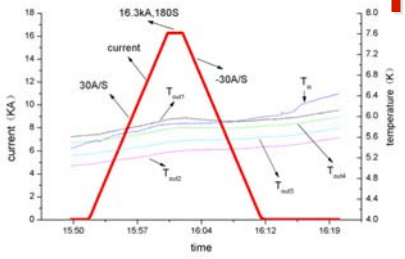
Cryogenic test facility system

Control and Data Collection System

Refrigerator: 500 W/4.5 k

Important progress

The test results of all TF magnets



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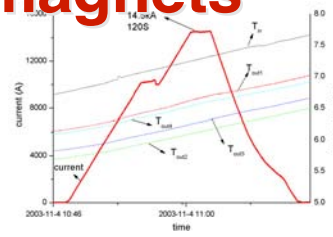

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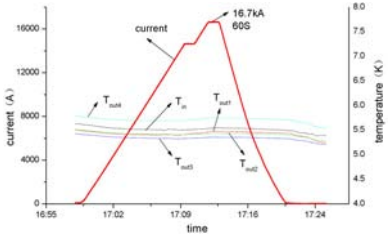
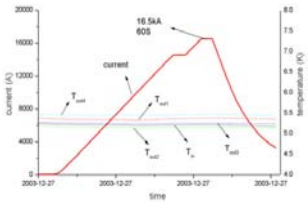
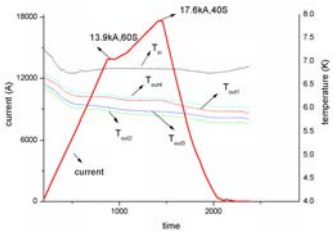


3#TF



4#TF



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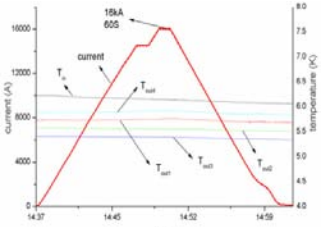
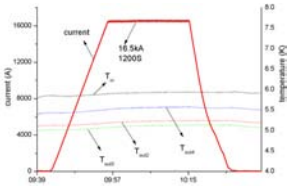


6#TF



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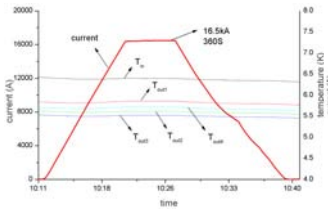

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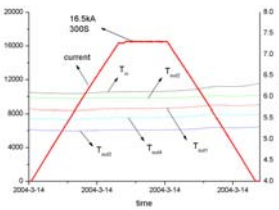

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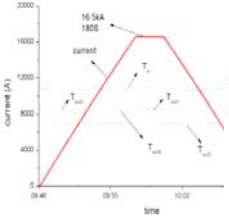

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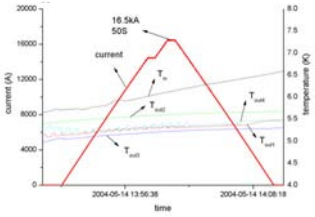

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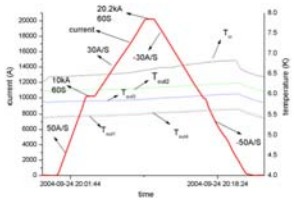

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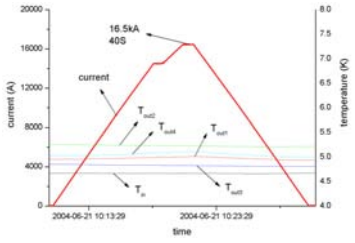

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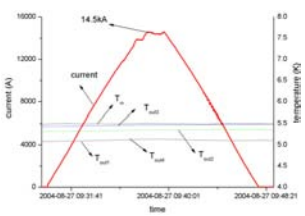

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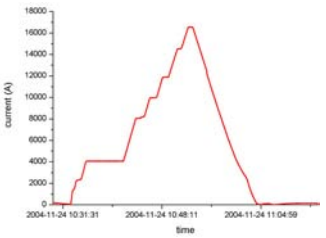

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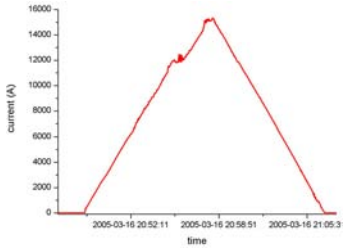
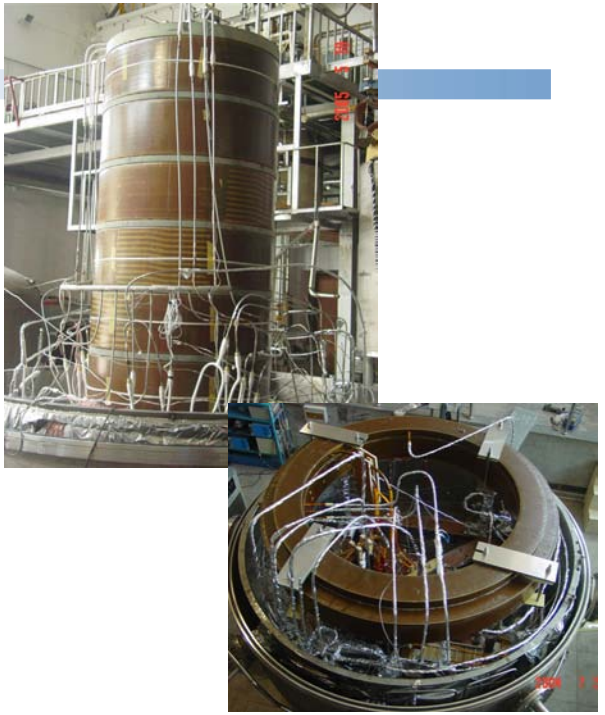
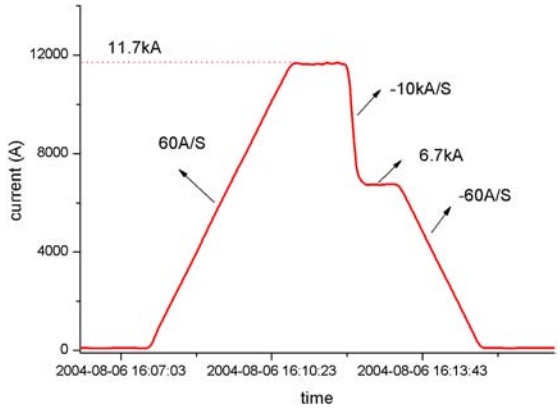


16#TF

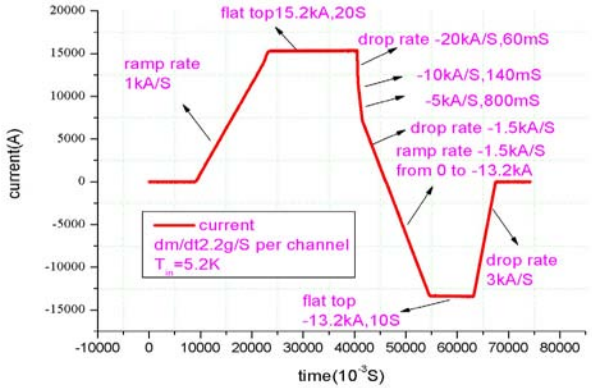
Important progress

The all test results for PF coils

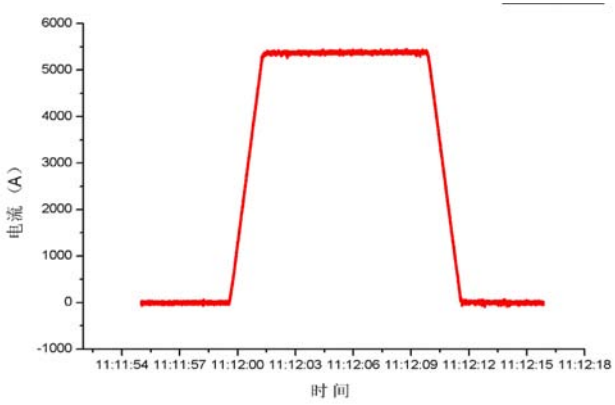




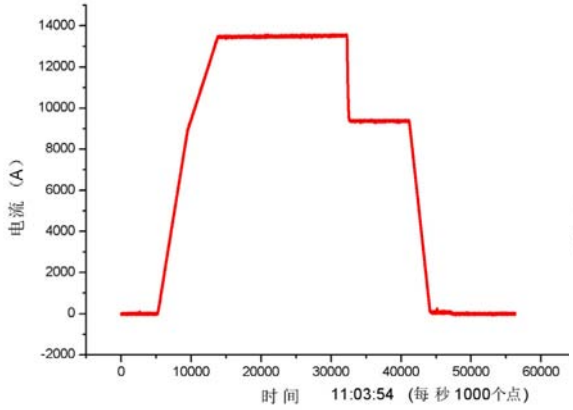
Diverter coil



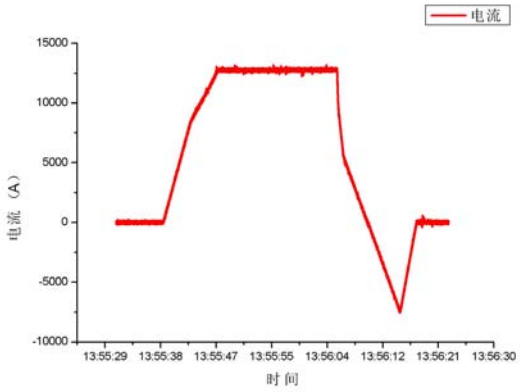
Central Solenoid



Fast dI/dt (A)



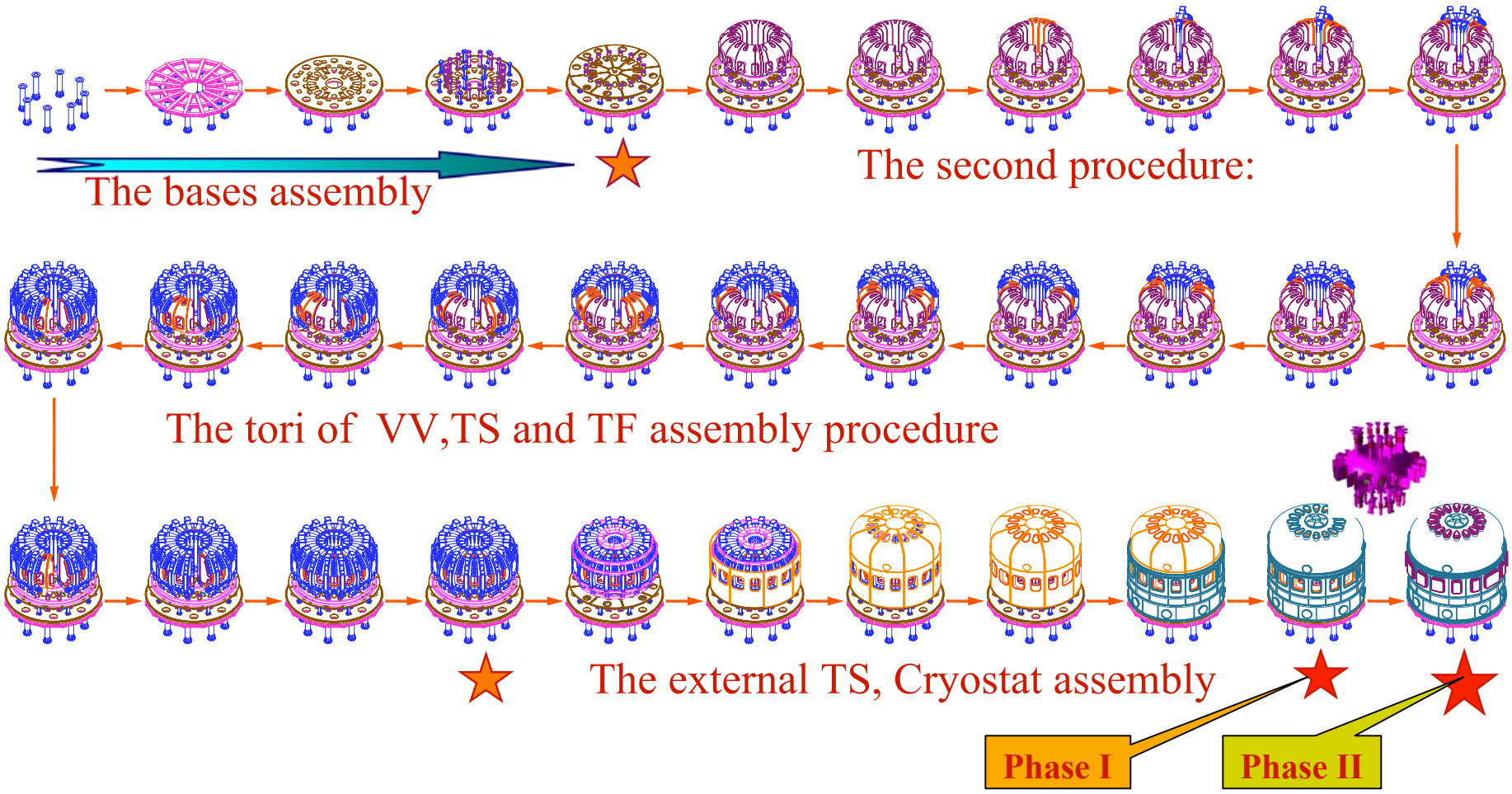
Fast dI/dt (B)



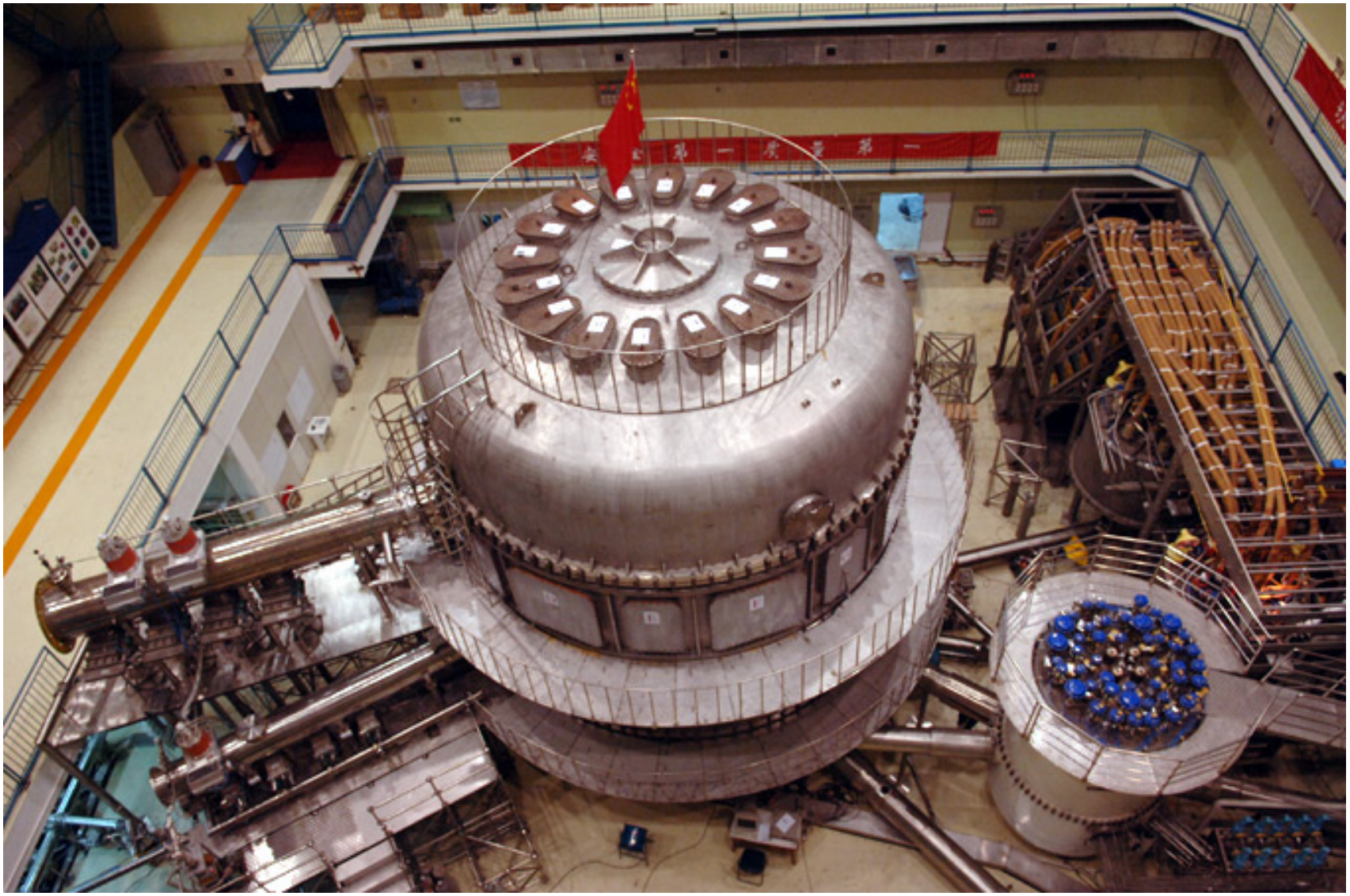
Fast dI/dt (D)

Important progress

The final assembly of EAST begun at middle of 2003, which consists of four main sub-procedures.



Important progress

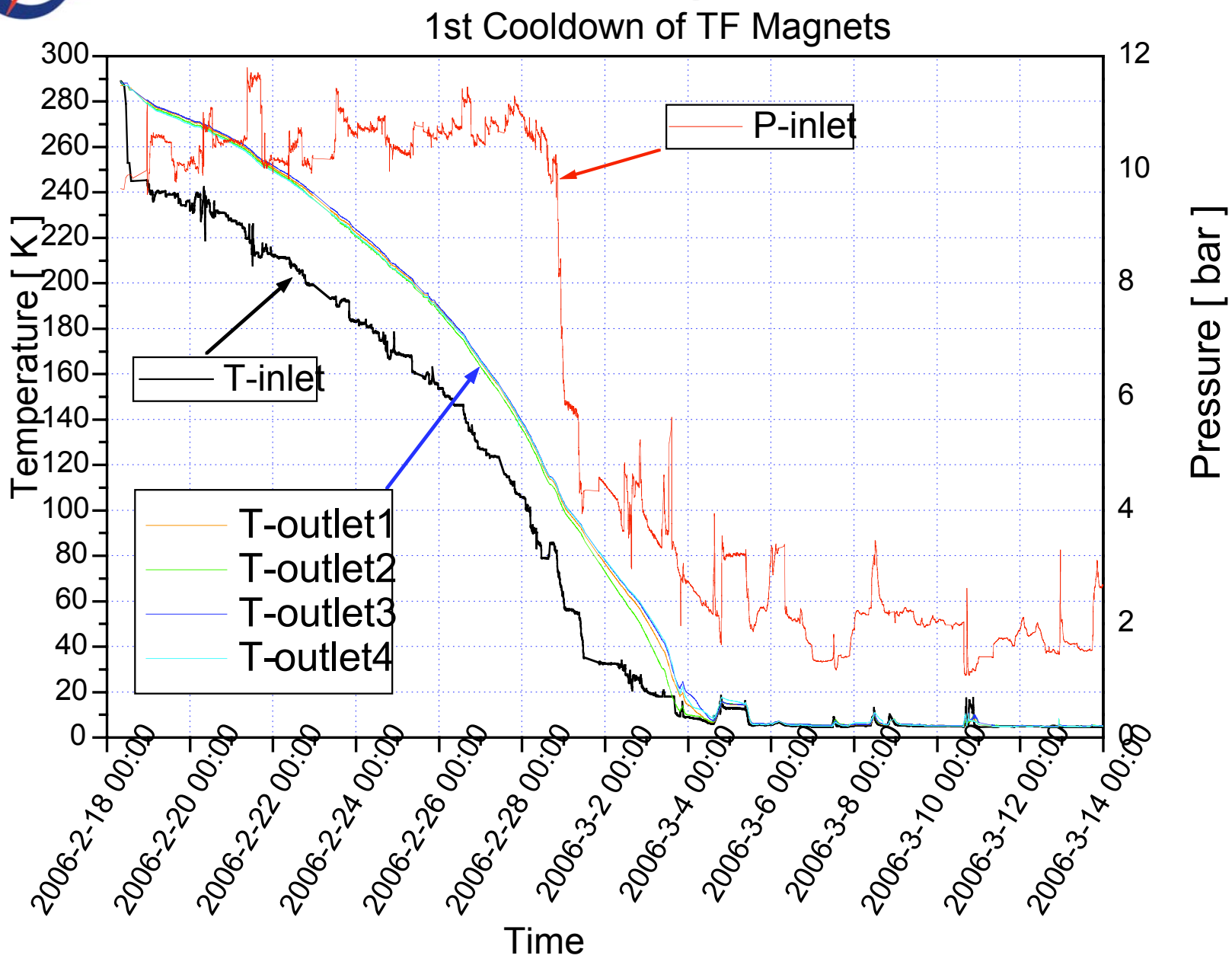


Bird view of EAST in the first commissioning (Phase I)

2. The first engineering commissioning was very success

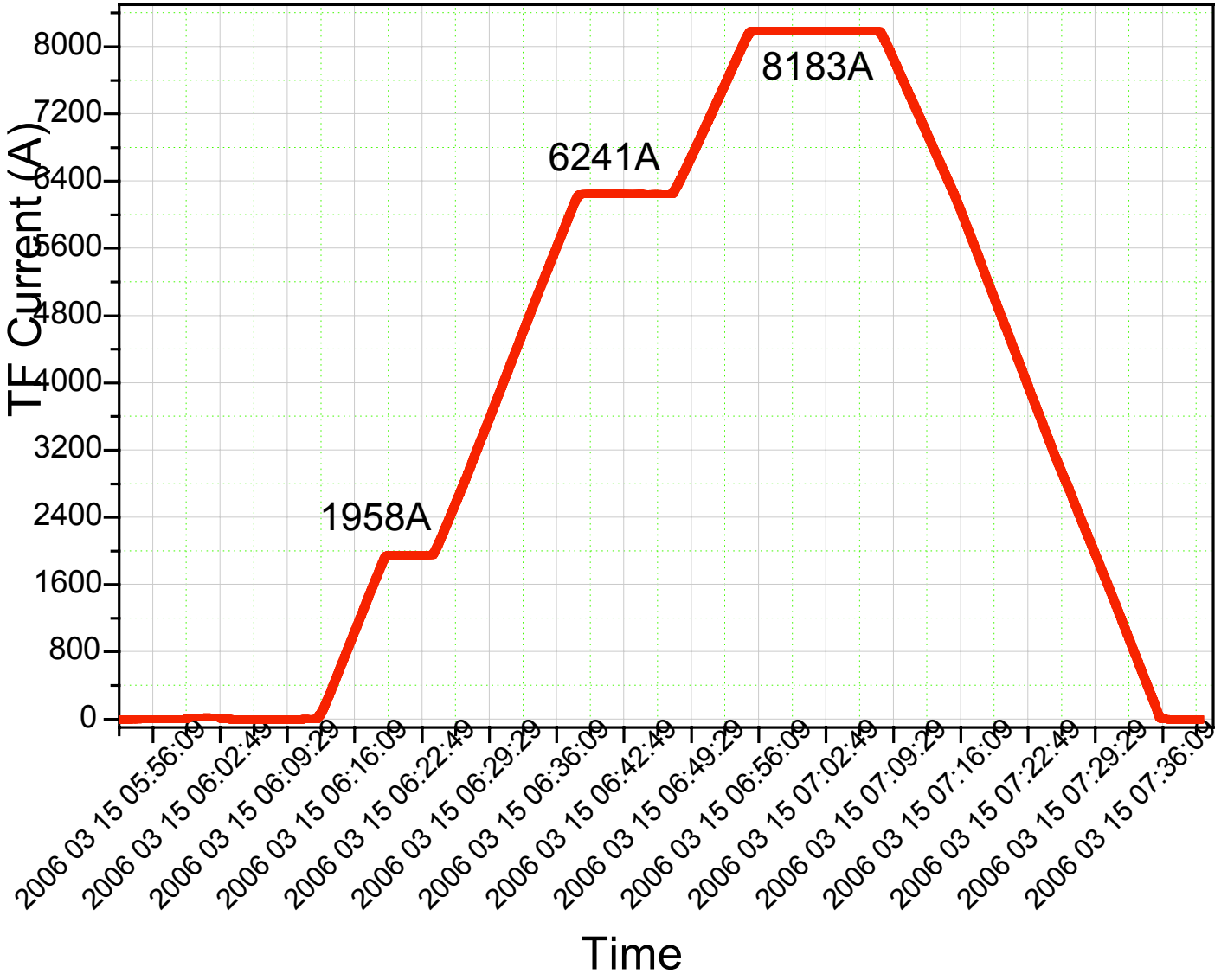
- Just taken three days the vacuum of cryostat can be pumped to the level for cooling down ;
- Only taken 18 days all SC magnets were cooled down to~4.5 K
- TF system has been excited to 8 KA (2.0 T at 1.7 m);
- All PF coils have been charged with few KA;
- All sub-systems such is pumping system; cryogenic system; TF and PF power supplies; control and dada acquisition system are quit stable and satisfy the operation requirement
- The High T_c current leads which is first to be used on tokamak worked quit well;
- About 700 insulators produced by our team have good quality to insure the safety of operation

Important progress



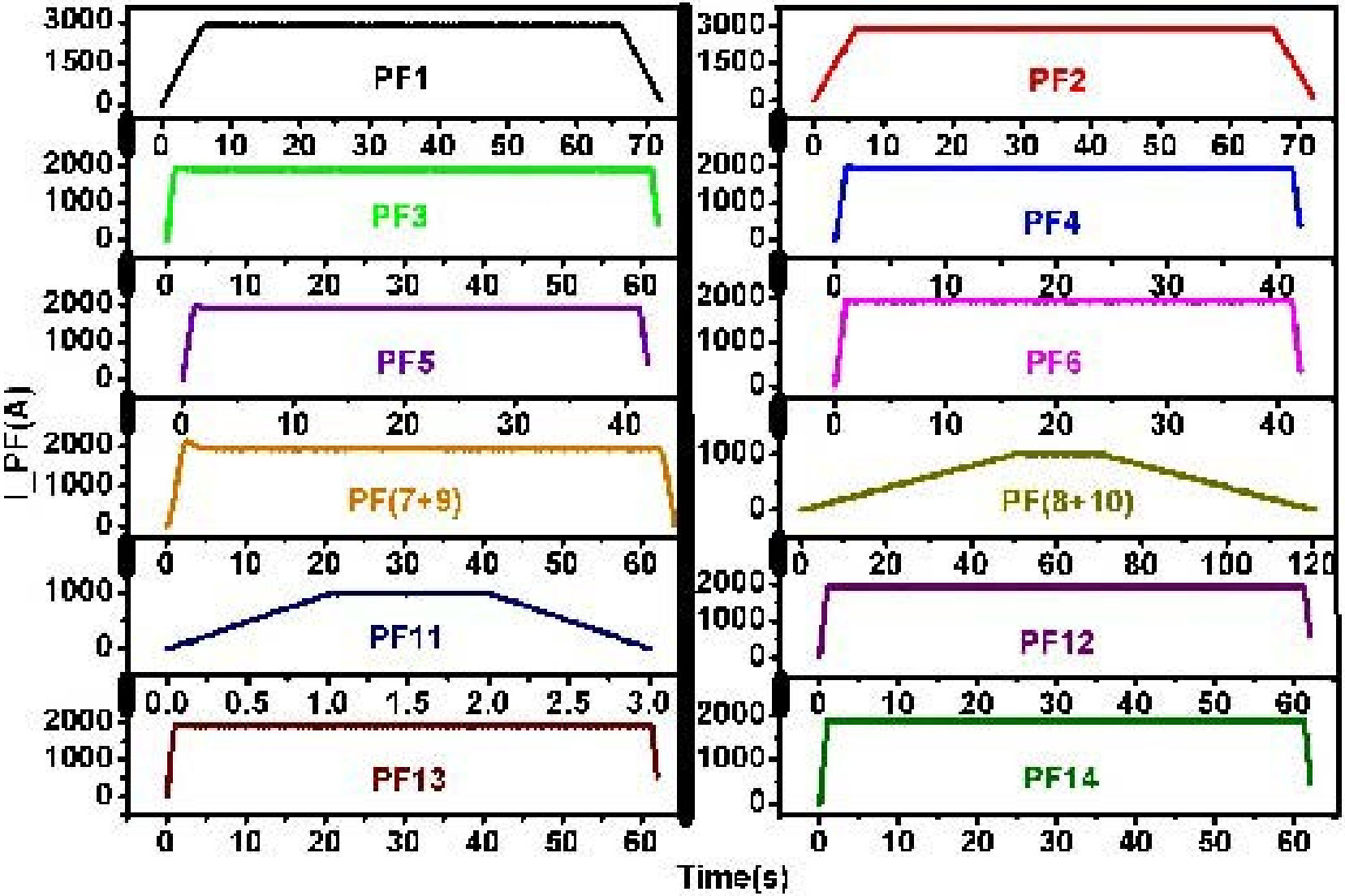
Important progress

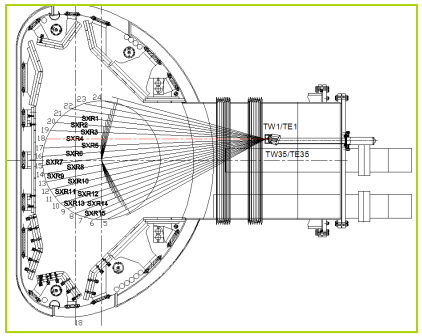
The TF system of EAST successfully excited to 8000A (2T)



Important progress

All PF coils of EAST successfully charged to few KA



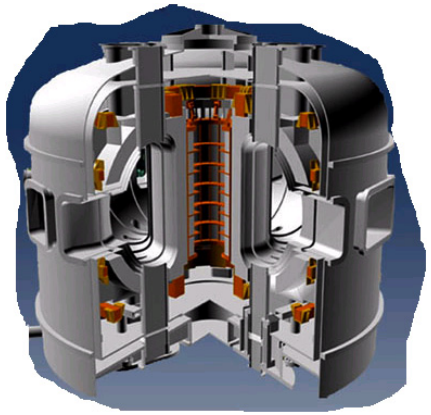


7 Diagnostics

8 Control & Dada system

9 Power station & water cooling

5 LHCD system



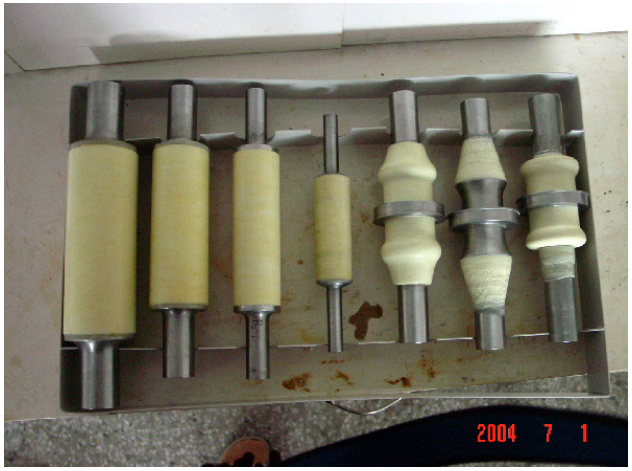
1 EAST Tokamak

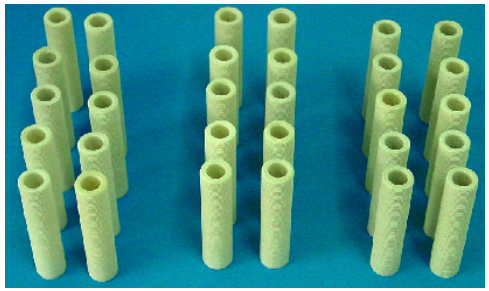
6 ICRH system

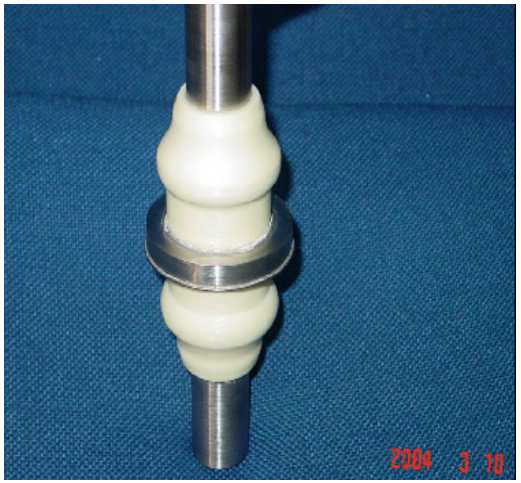
2 Cryogenic

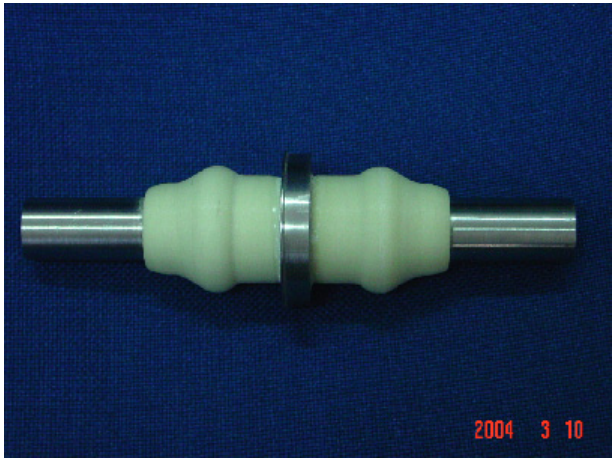
3 TF,PF powers

4 Pumping system





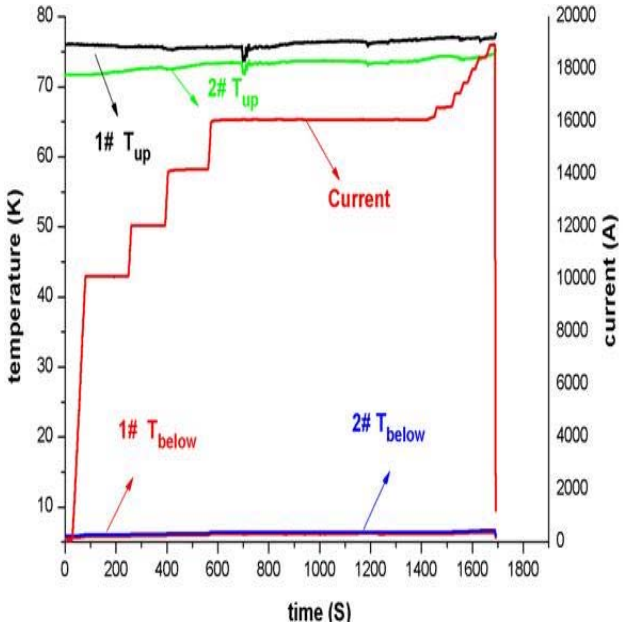


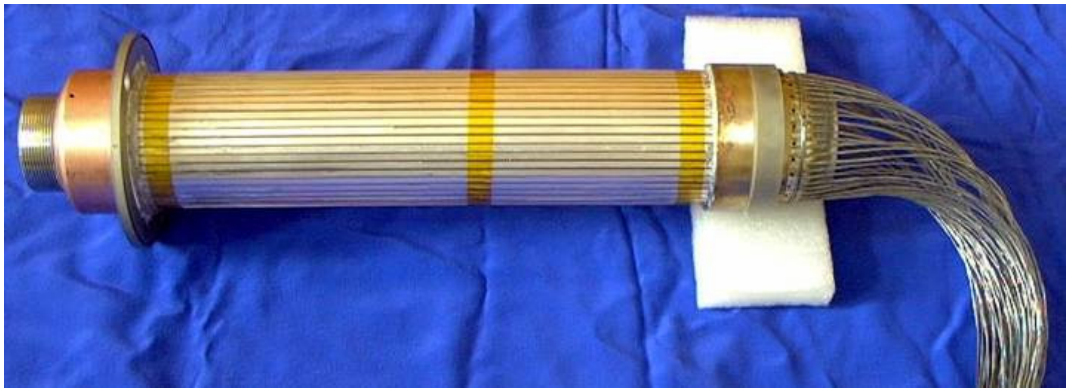


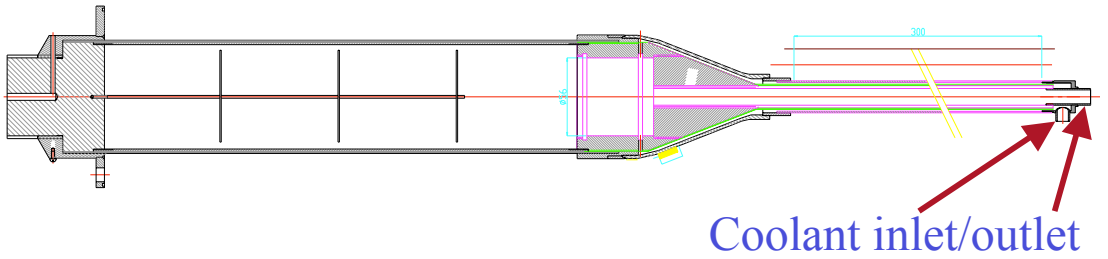
The quality of hundreds of insulators on EAST is quit good

HTc Current Leads

- To reduce the cryogenic consuming, EAST uses 5 pairs HTc current leads at the first operation stage.
- 13 pairs of HTc current leads have been tested with LN and at the same operation condition from 15kA to 20kA.

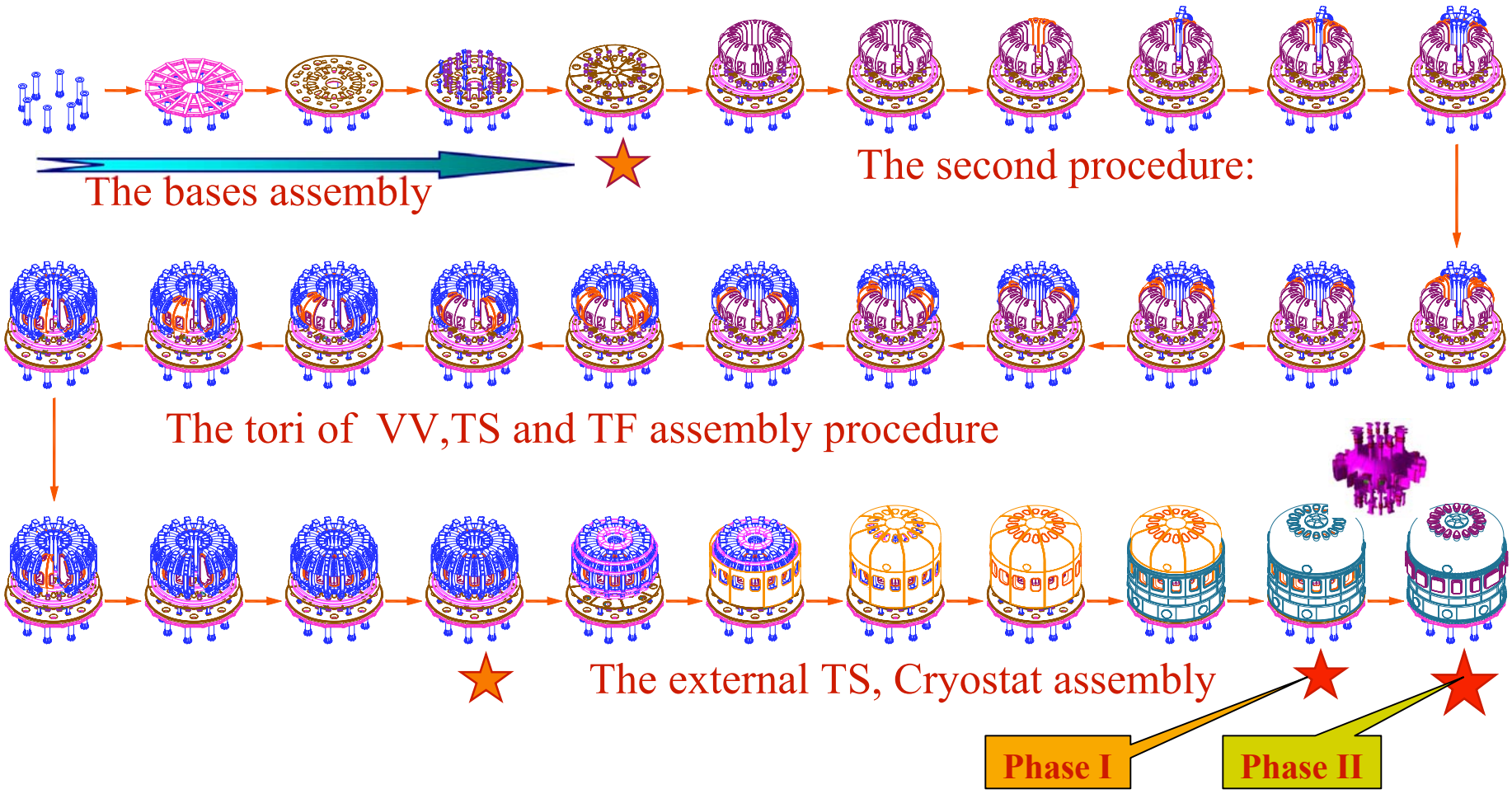






Important progress

The final assembly of EAST begun at middle of 2003, which consists of four main sub-procedures.

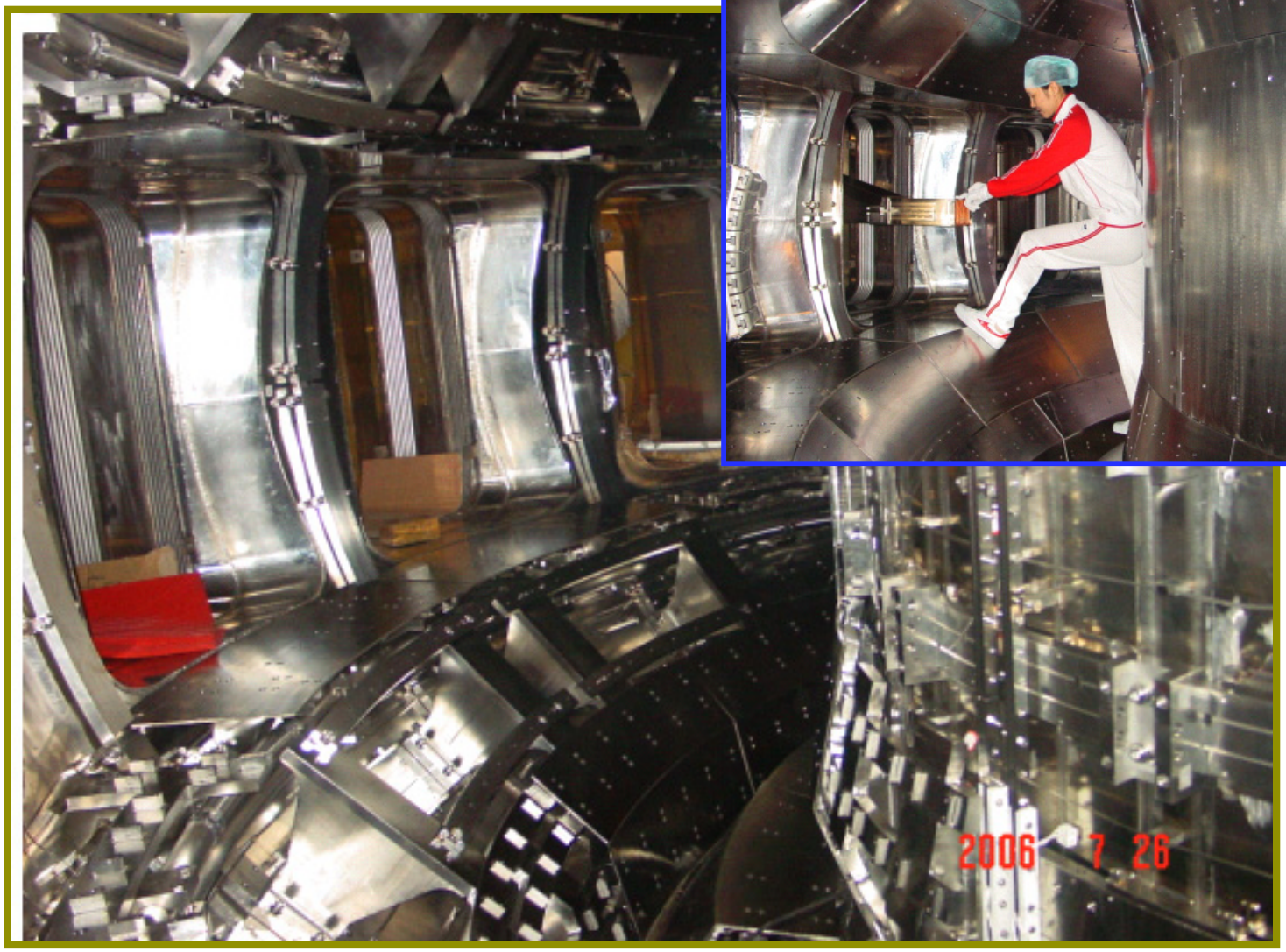


3. The all in-vessel components were assembled successfully before discharges

In-vessel components Include in :

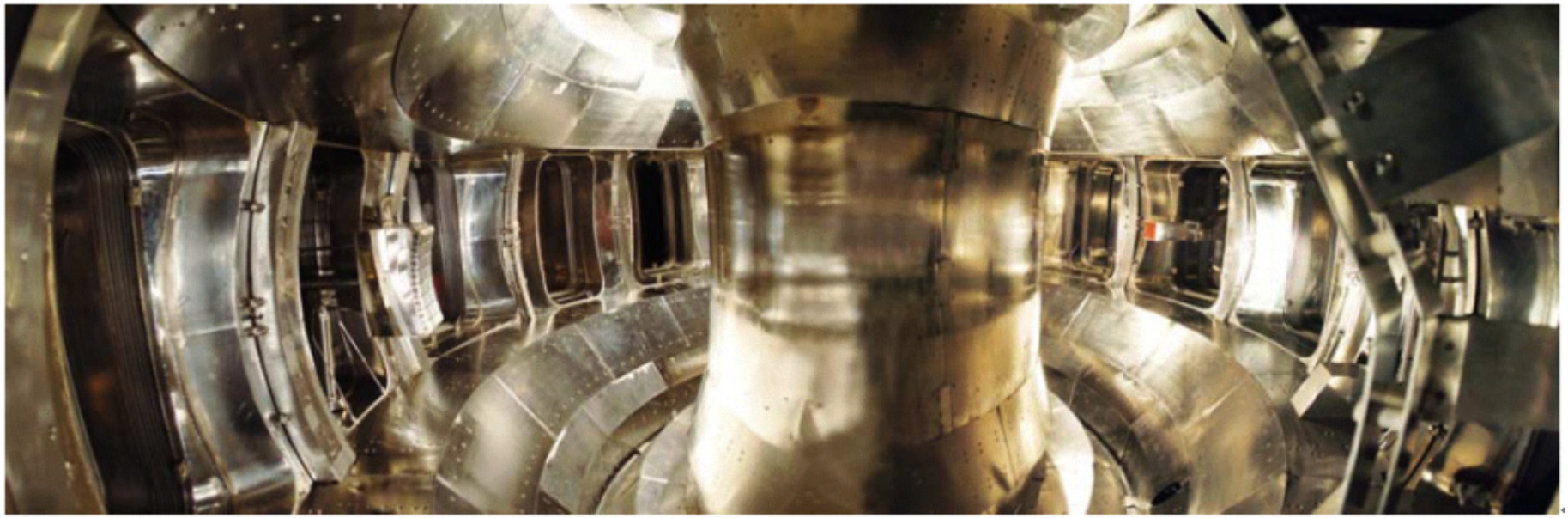
- Electromagnetic diagnostics: Rogowski coils for I_p and Halo current, Mirnov coils, Probes,Diamagnetic loop, Single ring for flux, etc.
- Fast feedback control coils;
- Antennas both for LHCD and ICRH;
- Movable limiters;
- Baking systems with the many temperature sensors;
- Diverter and protect plates;
- Pumping system for vacuum vessel;
- Diagnostics: HCN,CCD,OSMA,ECE,PHA,SX,AXUV,IR etc.

Important progress



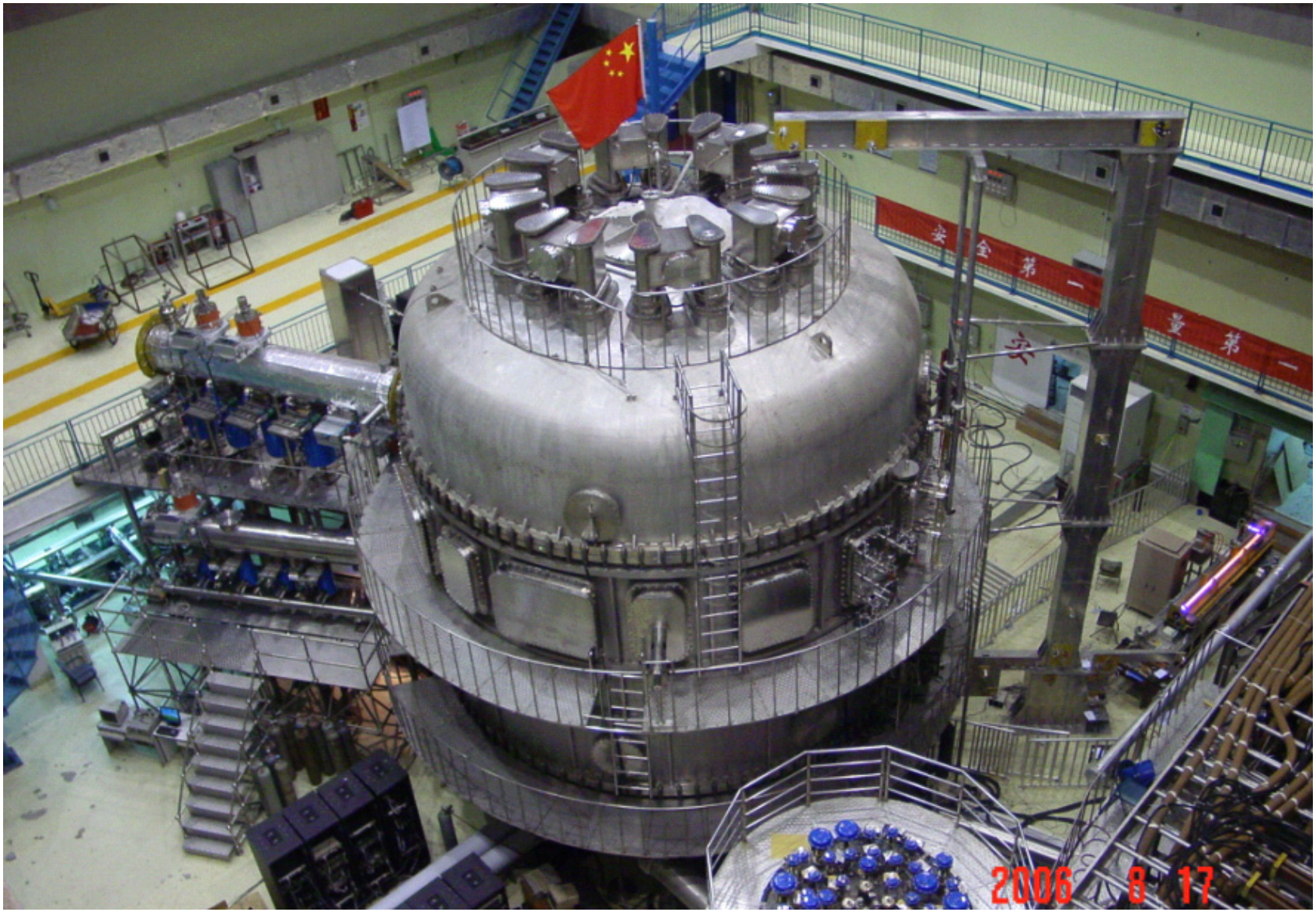
In-vessel components were assembling

Important progress



View inside the vacuum vessel of the EAST

Important progress



Bird view of EAST after assembly completed (Phase II)

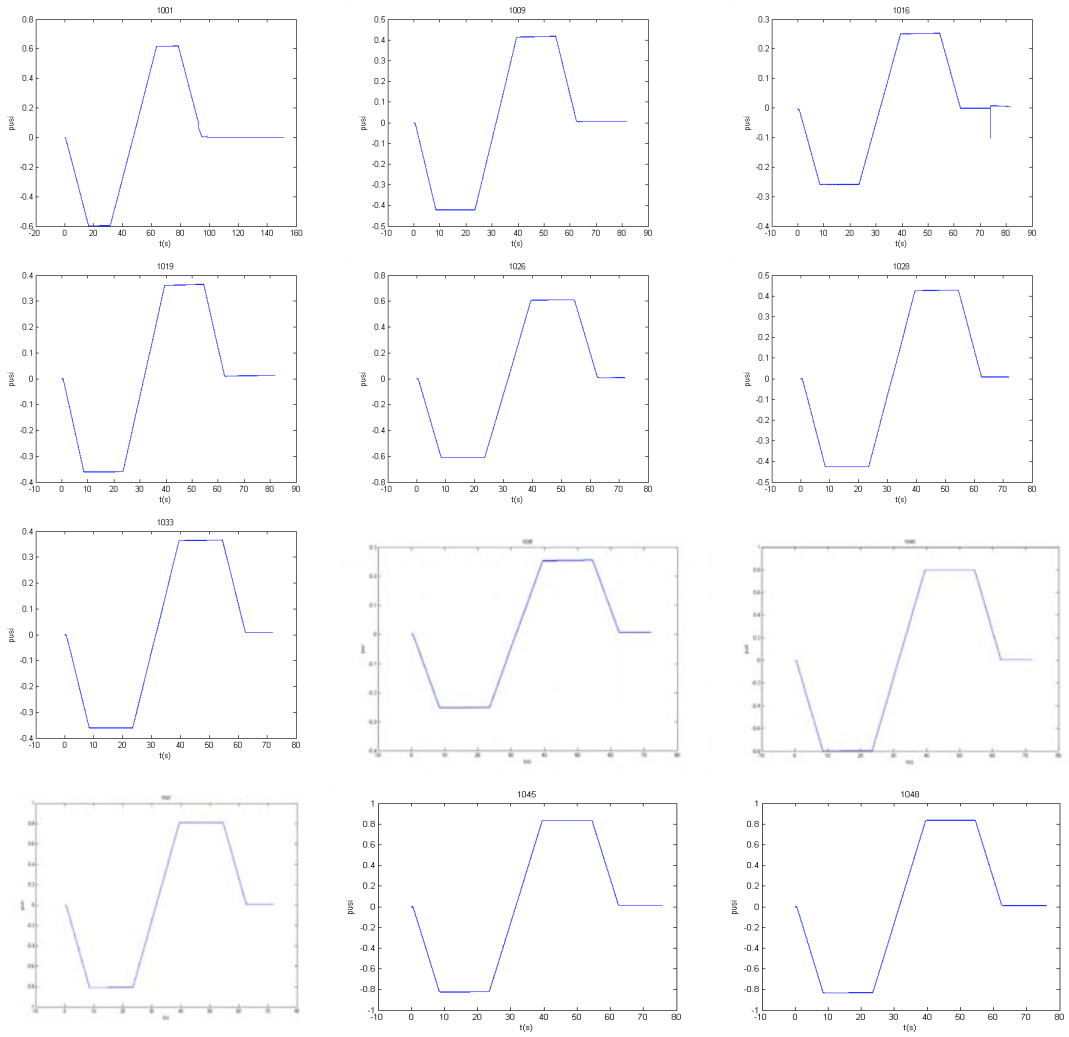
4. The rated B_T = 3.55 T has been achieved

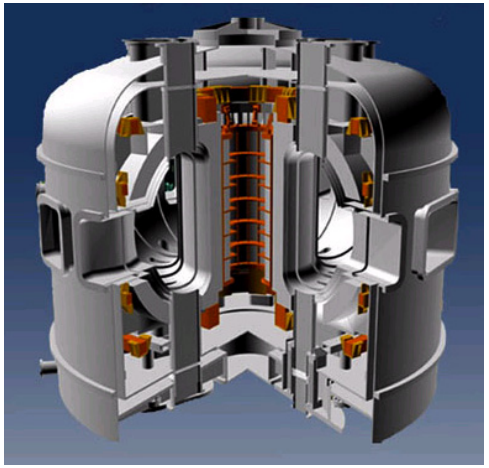
- EAST project should passe the evaluation by the national expert committee
- So the TF system of EAST has been excited successfully to the rated level B_T=3.55 T (I_T = 14.55 KA) at Sept. 22
- And each of PF coils was excited to +8 KA to –8 KA to simulate the plasma initiation, ramp-up and maintain the flattop.

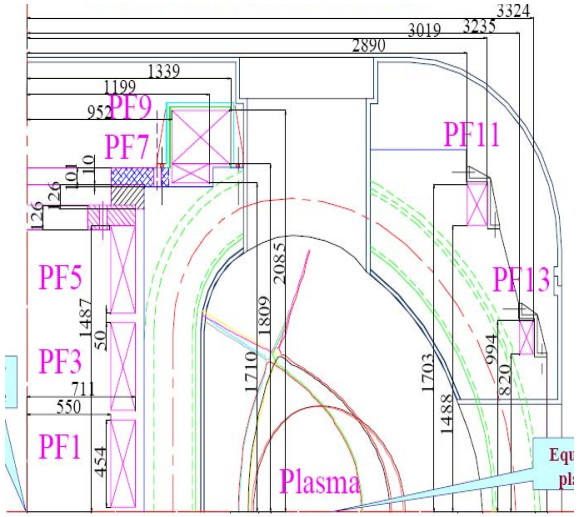
The total flux changes measured has been achieved 13 VS

The conclusion given by the committee is : *The construction phase of EAST has been completed with high quality*

Important progress

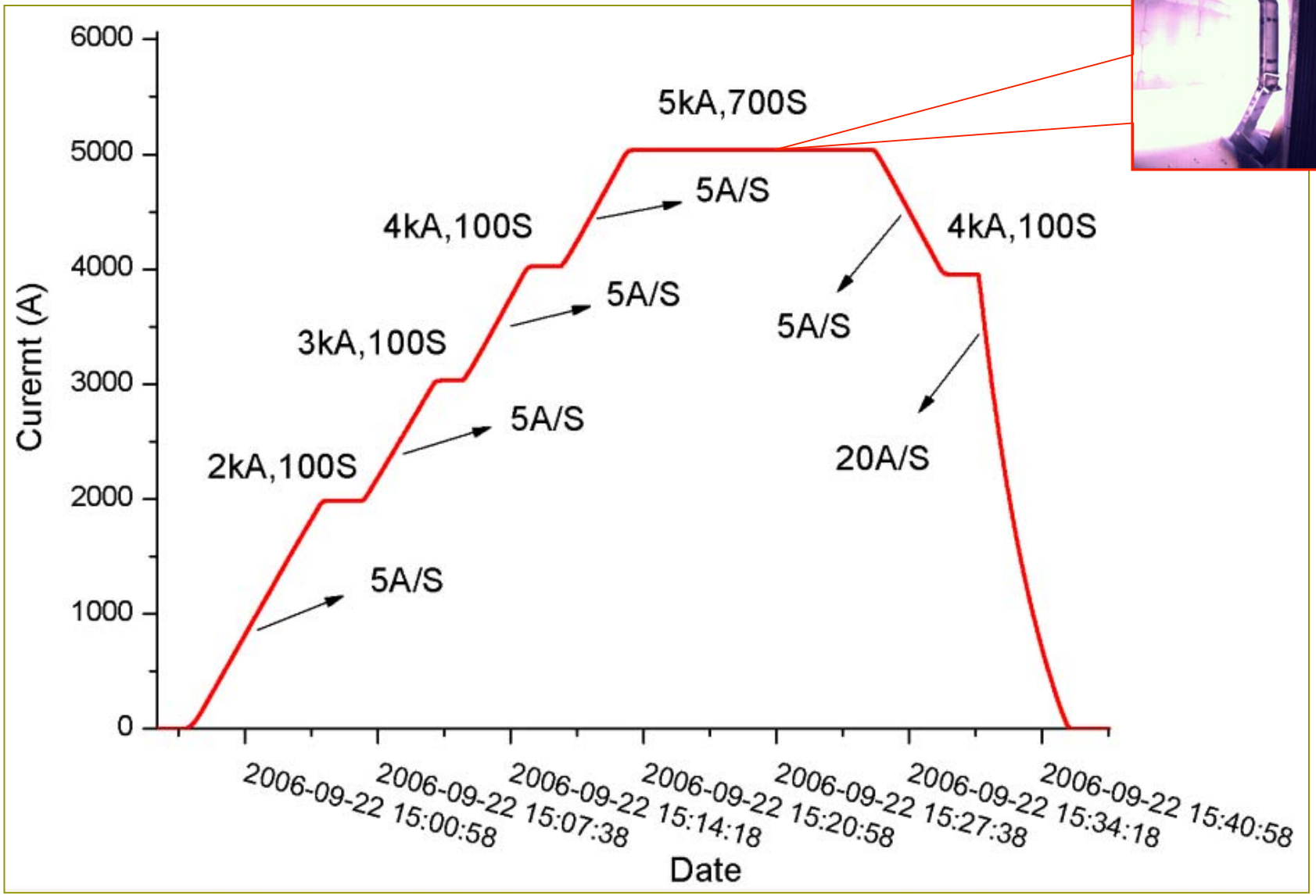






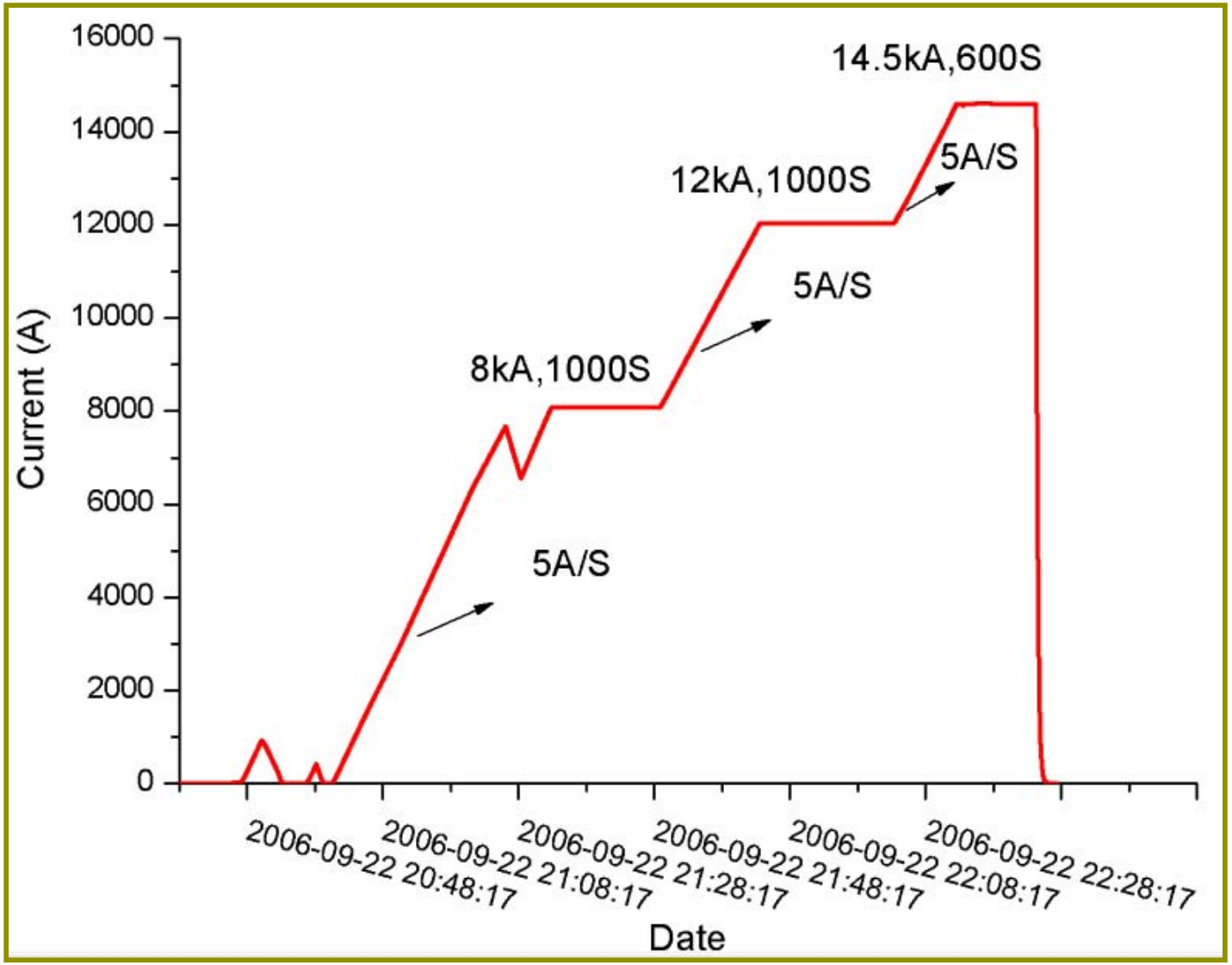
12 PF coils charged from(-8 kA) to (+8 kA) and provide 13.18 VS

Important progress



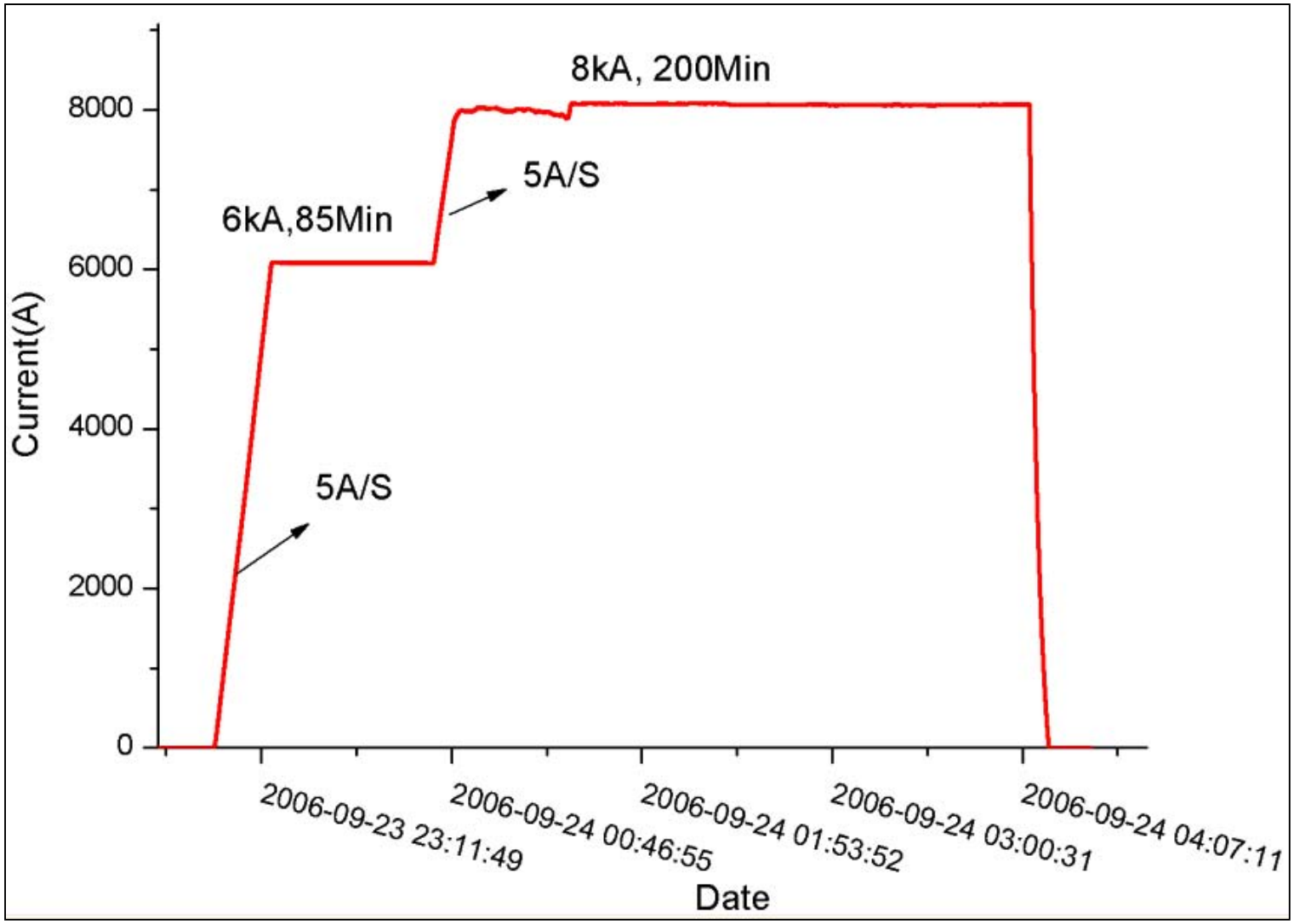
5000 A ~ 2500 Seconds for TF

Important progress



14500 A ~ 100 minutes for TF

Important progress



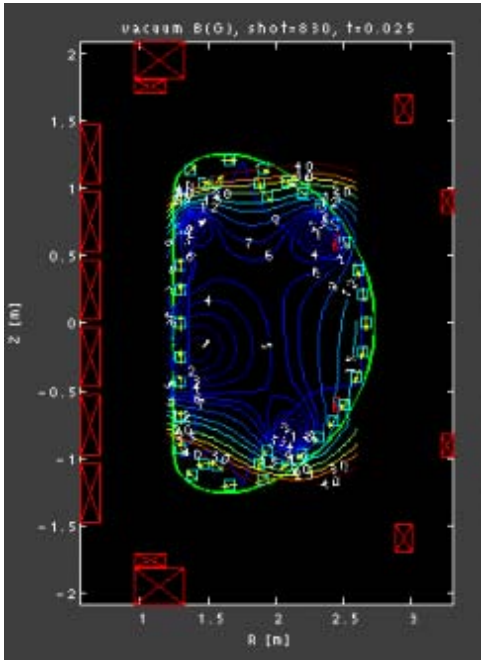
8000A ~ 5 hours for TF

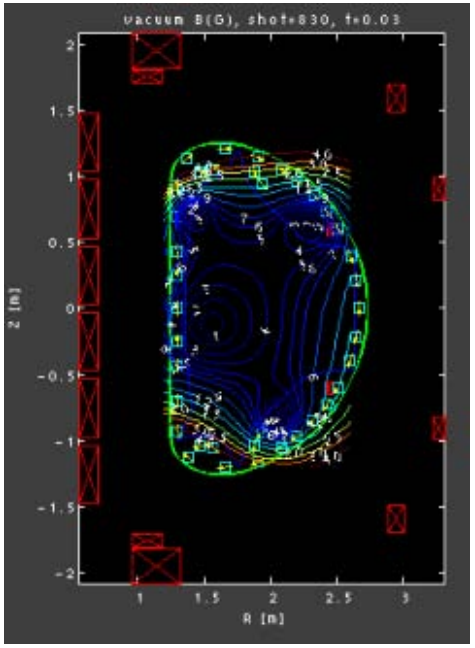
5. The first plasma discharges have been obtained

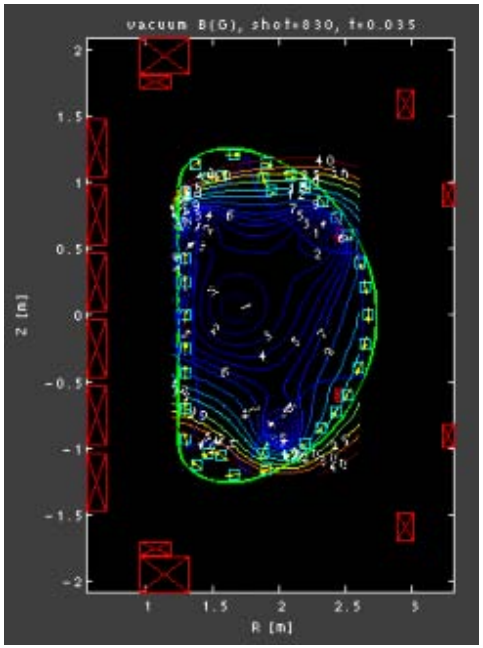
- A lot of investigation have been done at 60~80 K for quench protection PCS, PF power control, electromagnetic measurements and the good zero stray field configuration in discharge chamber has been obtained
- The He GDC plasma, ICRH plasma and the He plasma discharge have been obtained

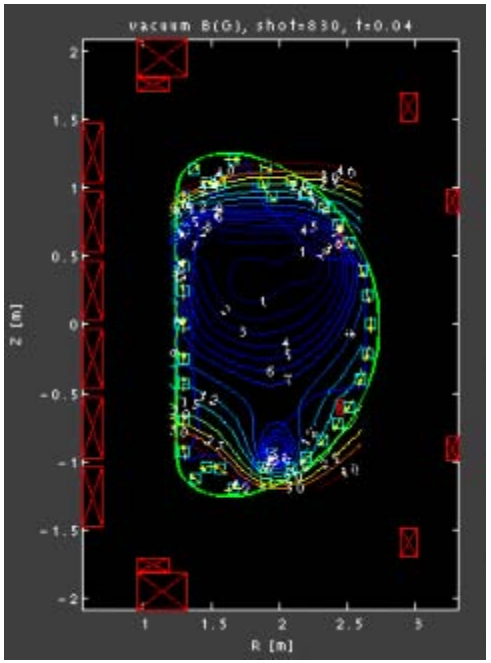
  All above are good preparation for the first plasma discharges;
- **The first plasma discharges achieved successfully at 26 Sept. under the strong collaboration with GA and PPPL experts !!!**

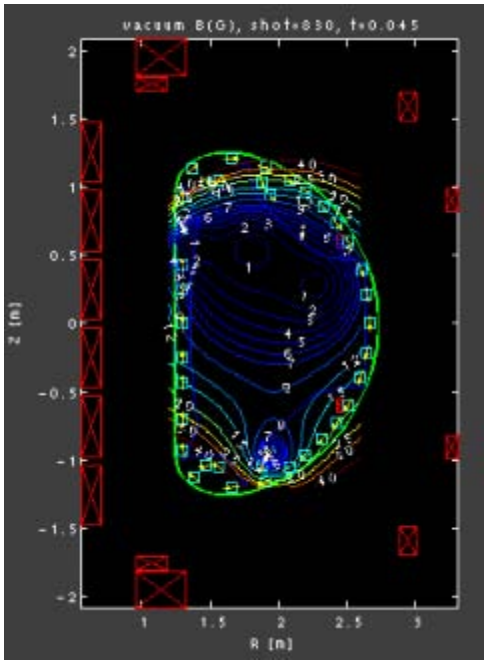
Looking for the good zero stray field configuration in discharge chamber has been obtained











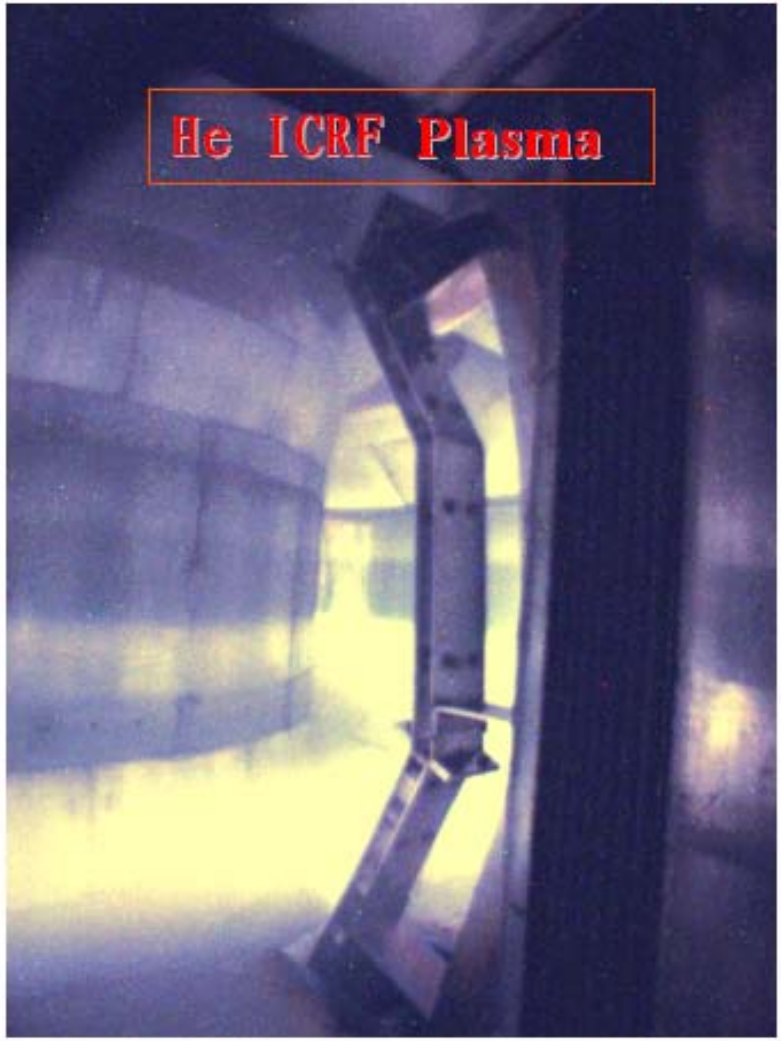
RF Plasma (I)

ASIPP

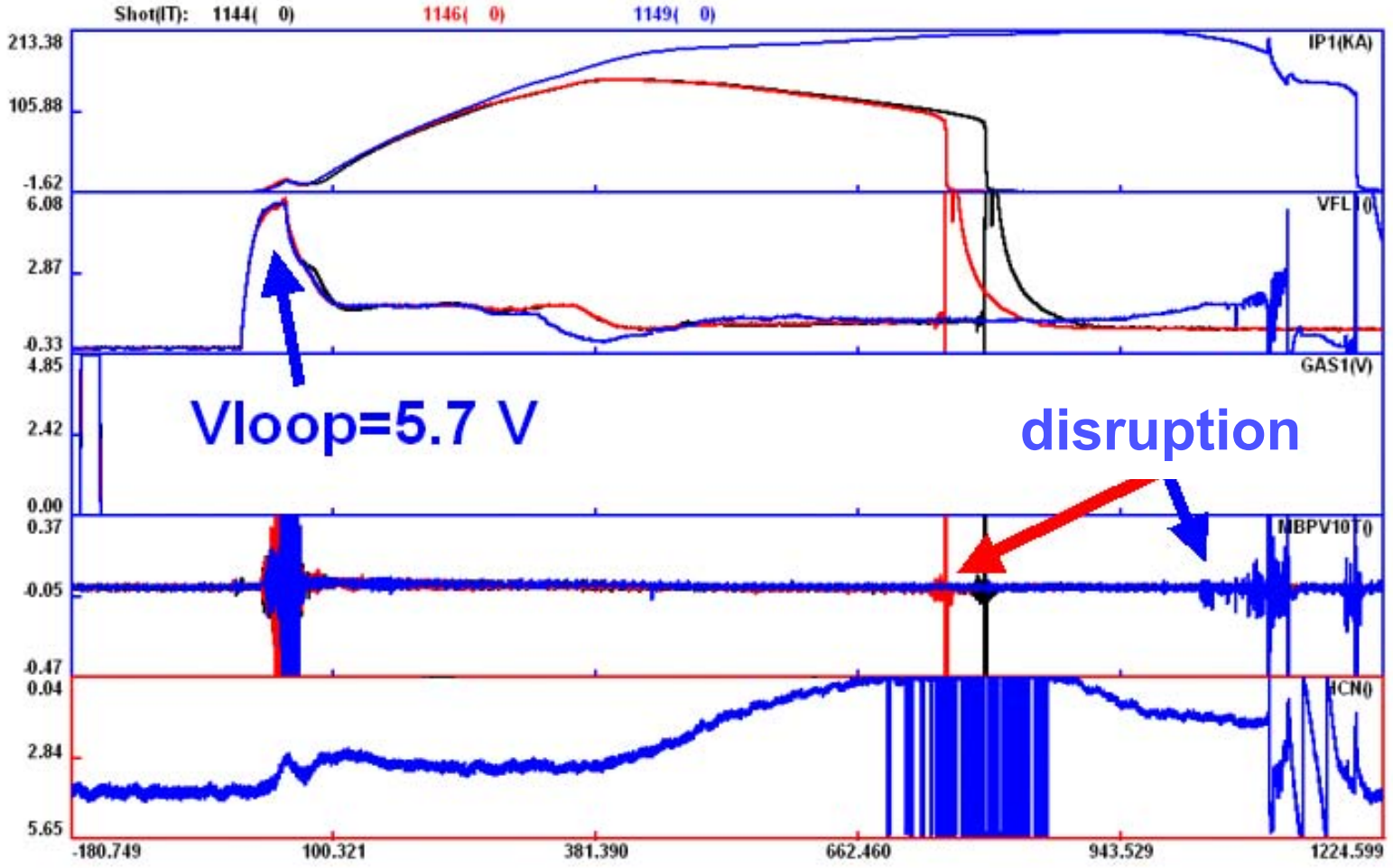
EAST

(*By Y.Yang*)

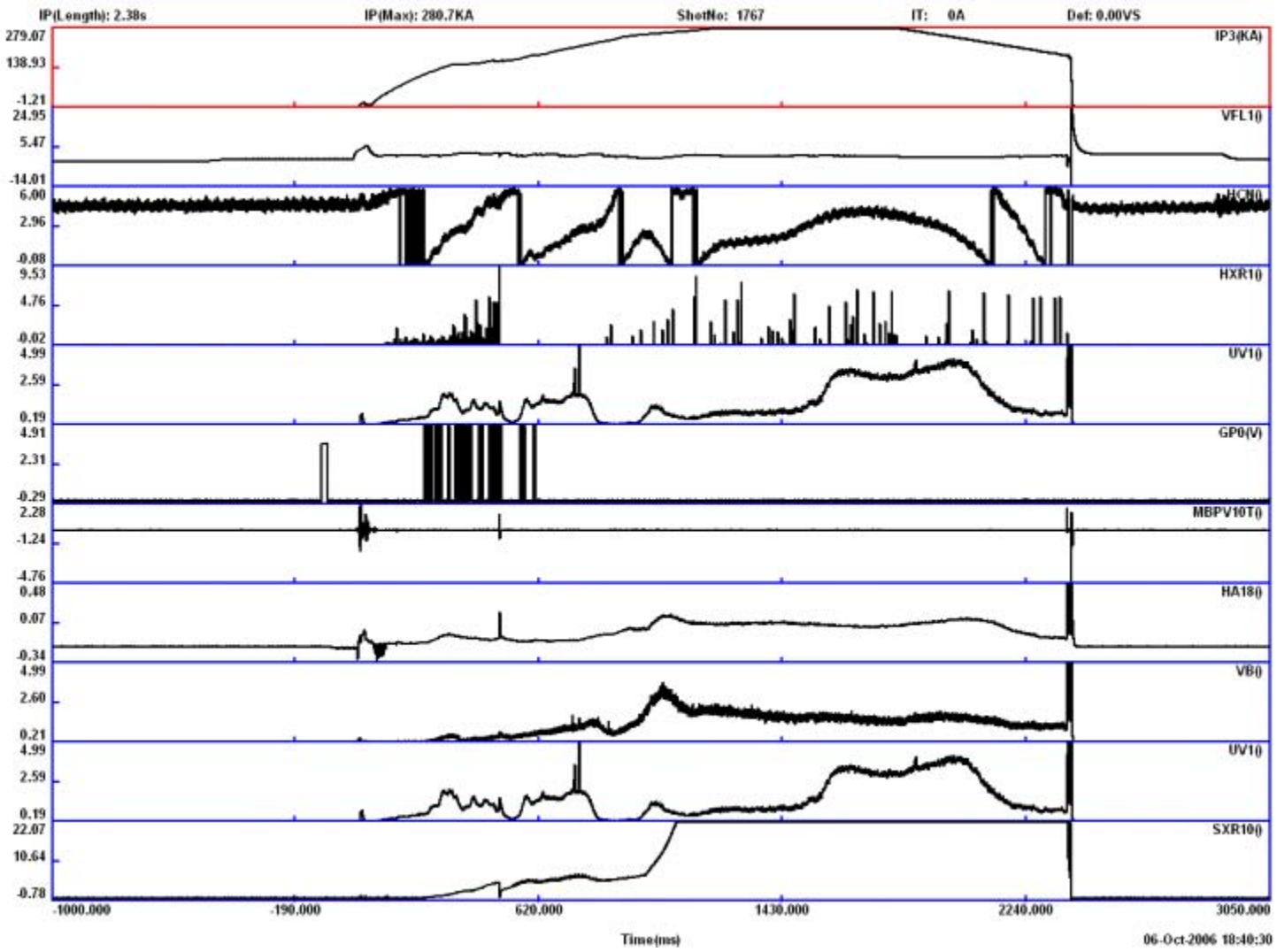
CW puff gas P ~ 4.8E-3Pa
Prf ~ 20KW
0.3s on /1.0s off
It ~ 500A



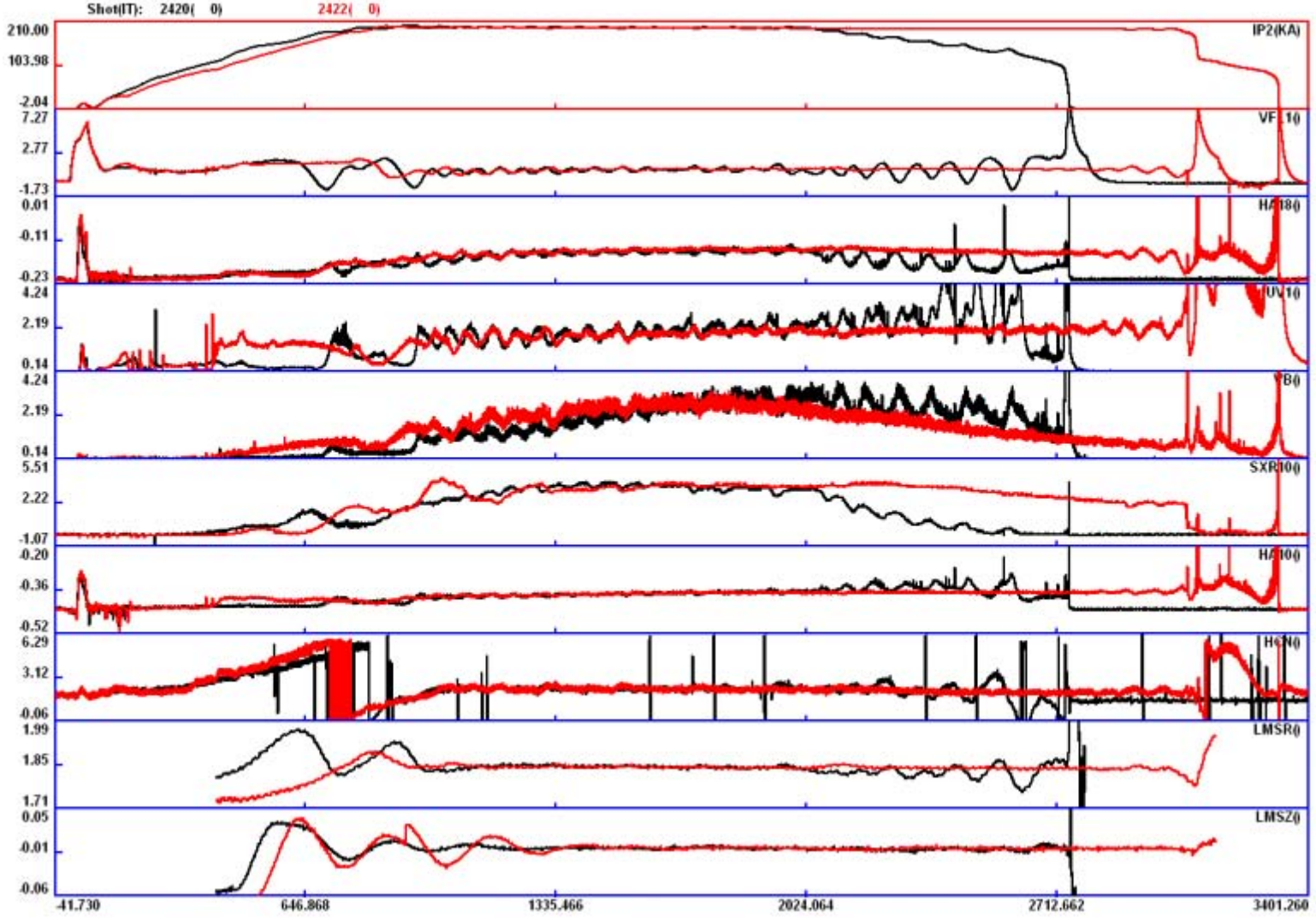
Ip=150-220kA, Bt=2T, t=0.5-1.2s, <ne>=0.68xE19/m3 @ L=0.8m



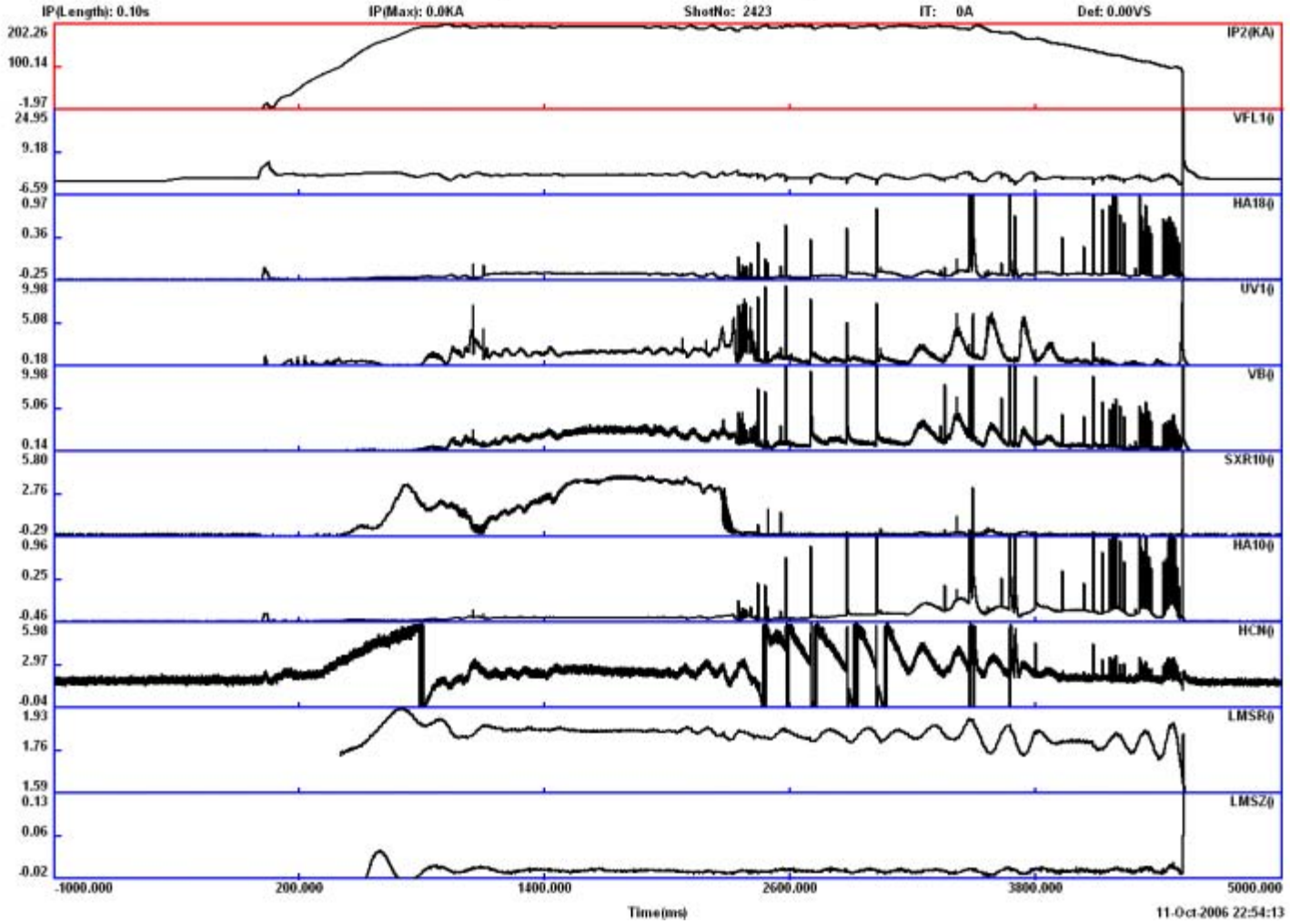
Shot 1767: T(0) ~ 500 eV nel ~ 1.8



Repeatable 200kA with more than 2s flattop for plasma shaping

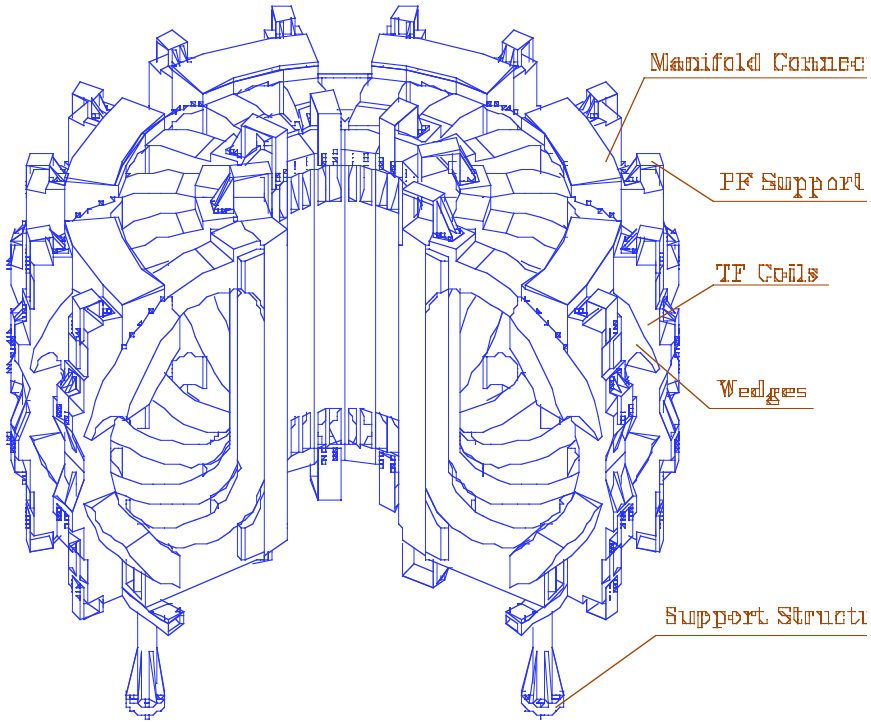


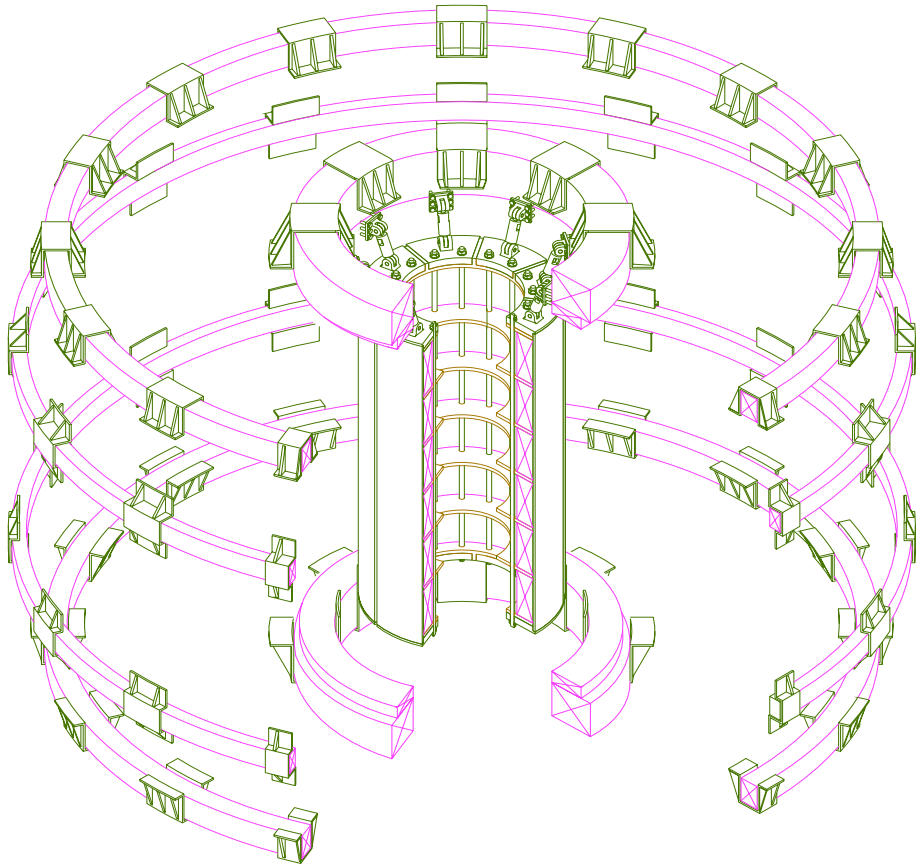
Longest shot: 200kA/4.5s,3s flattop



Characteristic & Mission

Both TF and all PF are SC magnets



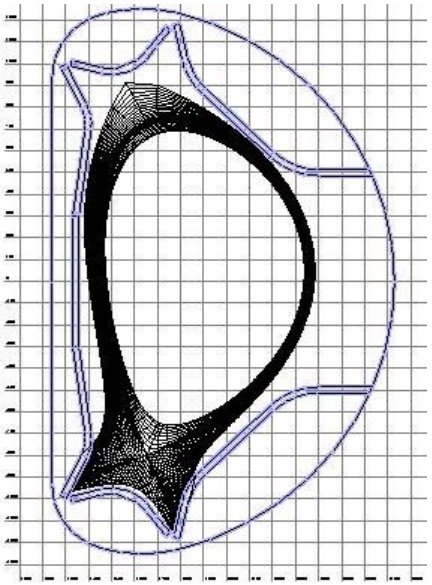


16 ‘D’ shape TF magnets

12 PF coils with individual power supply

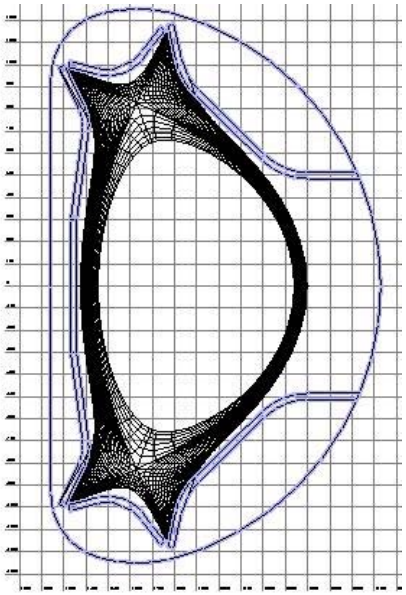
Characteristic & Mission

With the Flexible Diverter configurations



B2-EIRENE

Simulation shows acceptable SN and DN configurations.

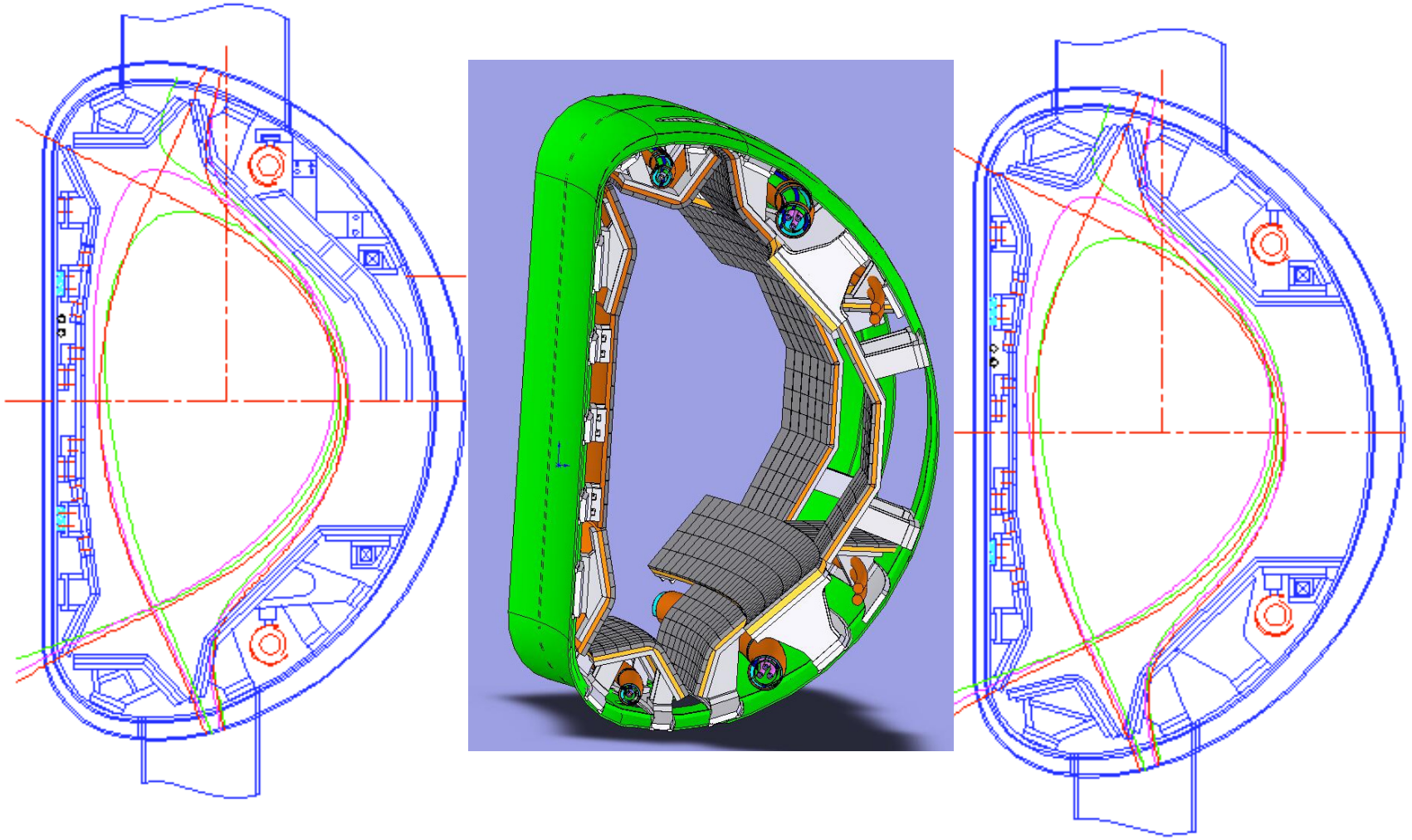


Major parameters of the SN configuration	
Major radius, R (m)	1.94
Minor radius, a (m)	0.46
Elongation at separatrix, κ_x	1.69
Upper triangularity at separatrix, δ_{xu}	0.32
Lower triangularity at separatrix, δ_{xl}	0.54
Plasma volume, V_p (m^3)	11.9

Major parameters of the CDN configuration	
Major radius, R (m)	1.94
Minor radius, a (m)	0.47
Elongation at separatrix, κ_x	1.76
Upper triangularity at separatrix, δ_{xu}	0.56
Lower triangularity at separatrix, δ_{xl}	0.56
Plasma volume, V_p (m^3)	12.5

Characteristic & Mission

With the Changeable and active cooled In-Vessel Components



Characteristic & Mission

The Mission of EAST Project

- Investigation and developing of the engineering and technologies for the full superconducding tokamak;
- Steady- state operation with higher plasma performance;
- Power and particle handle under steady-state operation condition
- Investigation of Advanced Tokamak physics, especially, under the steady-state operation condition;

It is hoped that EAST will make some contribution to the bases of both physics and technology for Steady- State Advanced Tokamak Reactor (SSATR) !

Future plan

1. Go to long pulse or SSO

- It should be the basic requirement for any SC Tokamak especially for the one, both TF and PF coils of which are SC magnet;
- Other necessary conditions for SSO of EAST are :
  - CW LHCD with 3-5 MWs power to driven 0.5~1MA physics and technologies development;
  - CW ICRH with 3-5 MWs power input to heat the LHCD plasma to few Kev level (development of relevant technology and physics)
  - To develop the control system which suitable the requirement of SS operation

2. Shaping to diverter configuration with long pulse or SSO

- Both particle and energy balance by the control of edge plasma will be second most important issue for SS operation:
- So the experiment to shape the plasma from circle ,elongation and many kind of diverter configuration with relative high performance plasma are second investigation experimental area; the condition needed are:
  - increase the pumping system;
  - fast feedback control system
  - Again to develop suitable plasma control system

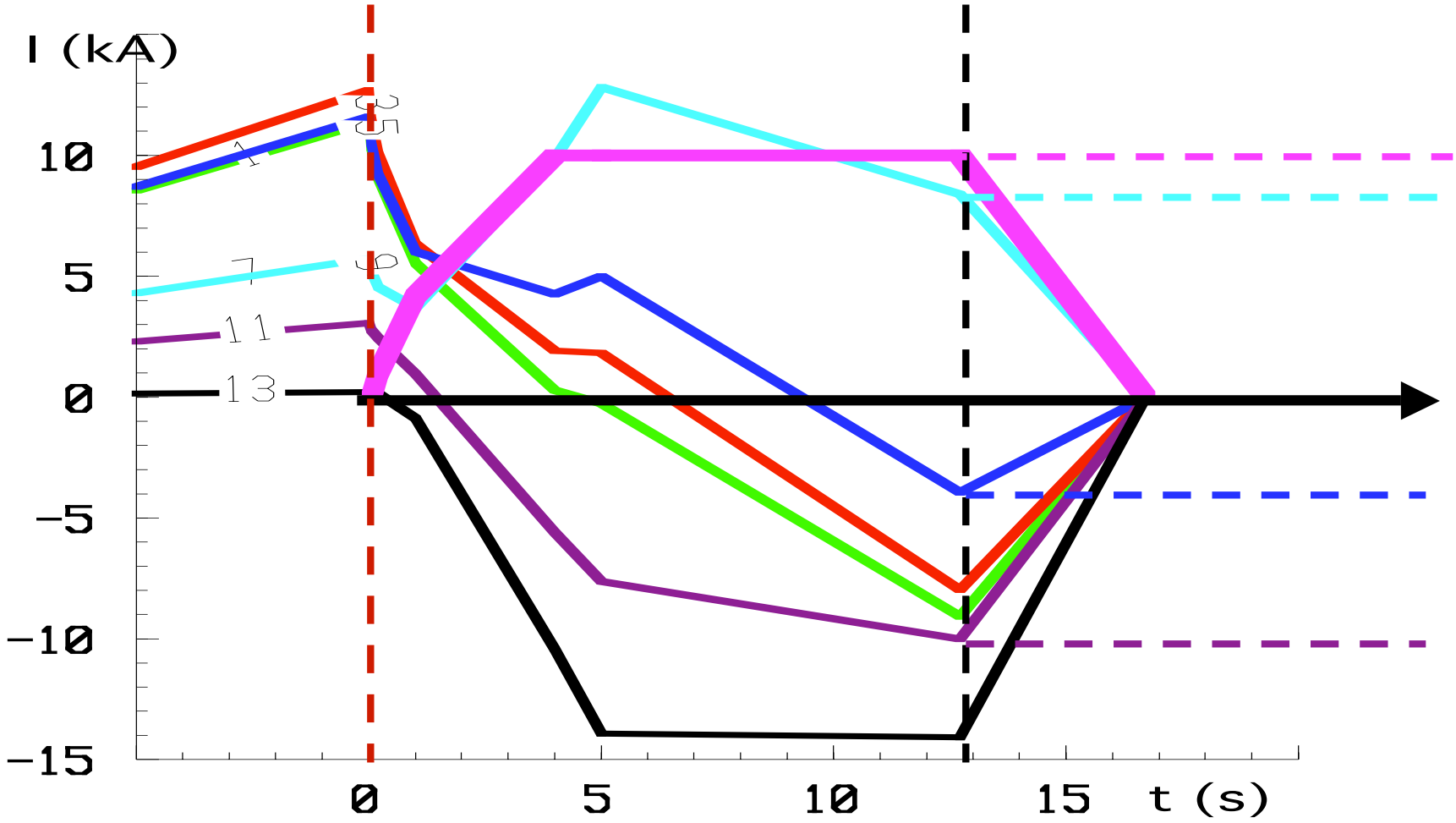
Future plan suggestion

3. Go to advanced plasma performance under SS operation

- Improve the confinement by shaping, profile control, synergetic effect of LHCD and ICRF and isotopic effect;
- Increase the β value by shaping, decrease B_T, and high heating power
- But the emphasize should be on:
  - Can go to SS operation with the improved confinement model ?
  - Can increase and stabilize the bootstrap current for SS operation

Future plan suggestion

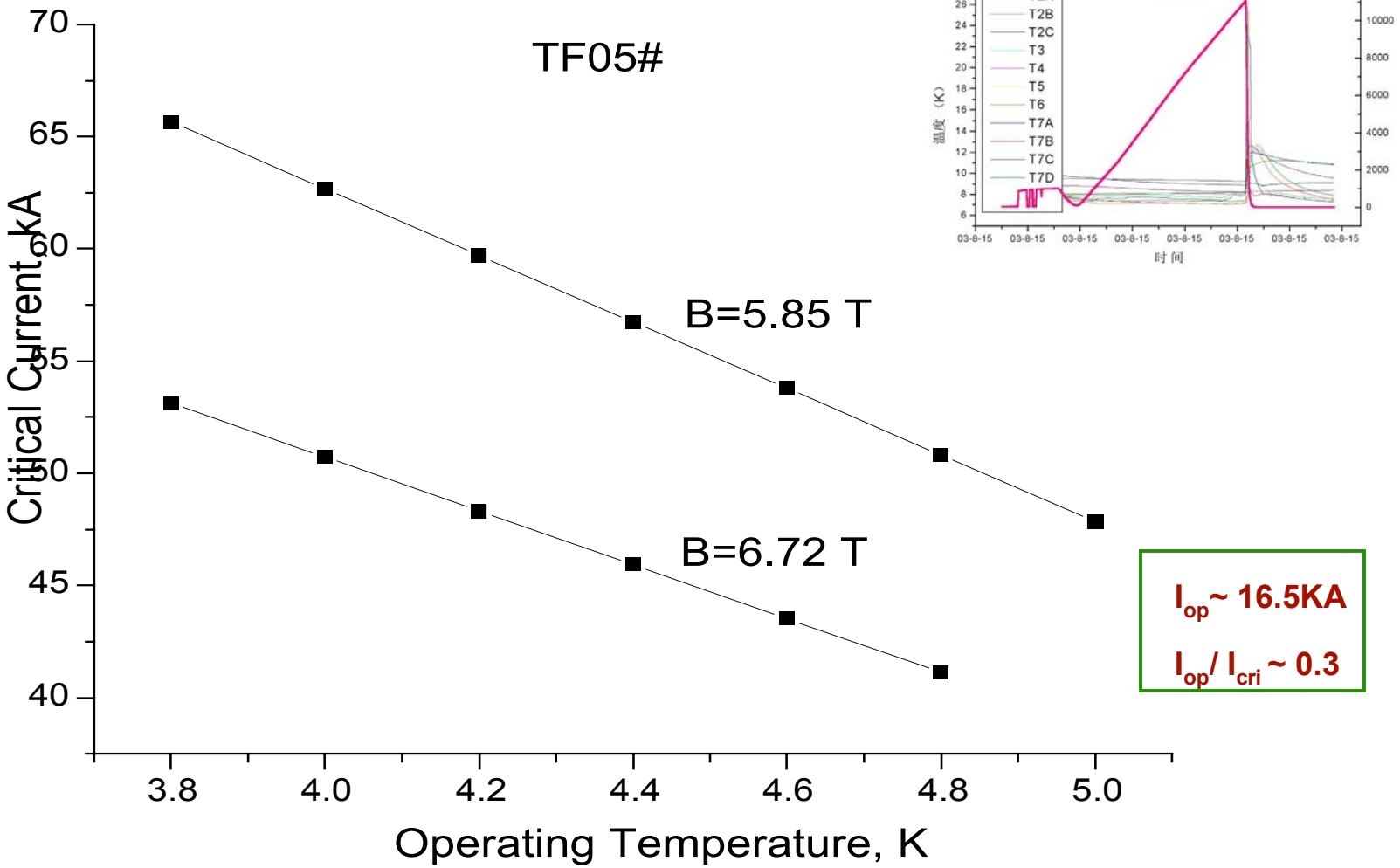
3. investigate more safe operation models for SC tokamak



4. Try to go to EAST's second phase

- SS operation will face more challenge when the parameters of plasma are more high. So EAST will try to go to it'second phase:
  - Working temperature on SC magnets decrease from 4.5 K to 3.8 K
  - $B_T = 4.0$ T at R= 1.7m
  - I_P = 1.5 MA
  - Working gas will be Deuterium
  - Will increase addition heating power from (6 - 7) to 15 MW
- Repeat SS operation with the diverter configuration and higher parameters

Important progress



I_{op}~ 16.5KA

I_{op}/ I_{cri} ~ 0.3

The TF magnet is possible to operate in second phase at 3.8 K

Role of EAST project

- It will great strengthen fusion research in China within next 10 ~ 20 years at least.
- It will benefit ITER project.
- But more important is it will benefit the next national fusion research project (maybe Tokamak Test Reactor) in China.

China is facing serious energy problems

and needs to get fusion energy as early as possible.

Summary

- The construction phase of EAST has been successfully completed.
- The nominated B_T=3.55 T,°£X10 VS and dI/dt _10-20 kA/S of EAST have been achieved.
- The first plasma discharges have been obtained under the close international collaboration with GA and PPPL.
- All progress and success above indicates:EAST is ready for operation and it will provide fusion community a very good international research facility for steady state diverter plasma research.
- The progress and future experiments of EAST will also certainly benefit to both the ITER project and the consideration of next national fusion research project in China.

Thanks

To all collaborators !

In China

1. Institute of Plasma Physics, CAS, Hefei
2. Hefei University of Technology
3. Donghua University, Shanghai
4. South West Institute of Physics, Chengdu
5. Tsinghua University, Beijing
6. USTC. Hefei,
7. Tianjin University, Tianjin
8. Thermal Power Research Institute Co., Ltd, Suzhou
9. Jialong Co.,Ltd, Shanghai
10. Wuhu Shipyard,China State Shipbuilding Co
11. Wuhu Boiler Works
12 Shanghai Boiler Works Co.,Ltd.
13. Shanghai No.5 Steel Co.,Ltd .
14. Nuclear Non-Destructive Testing Centre

International cooperator

15. General Atomic
16. FRC, UT at Austin
17. PPPL
18. Washington University
19. NIFS, Toki
20. CEA Cadarache
21. R.&D.Institute for Cable industry, Russian
22. Institute for High Energy Physics, Russian
23. "Kurchatov institute",
24. D.V.Efremov Institute of Electrophysical Apparatus
25. Nuclear Fusion Institute,"Kurchatov institute"
26. Bochvar Institute of Inorganic materials, Russian
27. CRPP, Swiss
28. Forschungszentrum Karsruhe Institute

Dr. Jiangang Li will take the full responsibility in Charge of EAST project from now!

End

and

Thanks