FPA-34th

CFETR
the Next Step for FE in China beyond ITER

Yuanxi Wan

E-mail: wanyx@ipp.ac.cn
wanyx@ustc.edu.cn

OUTLINE

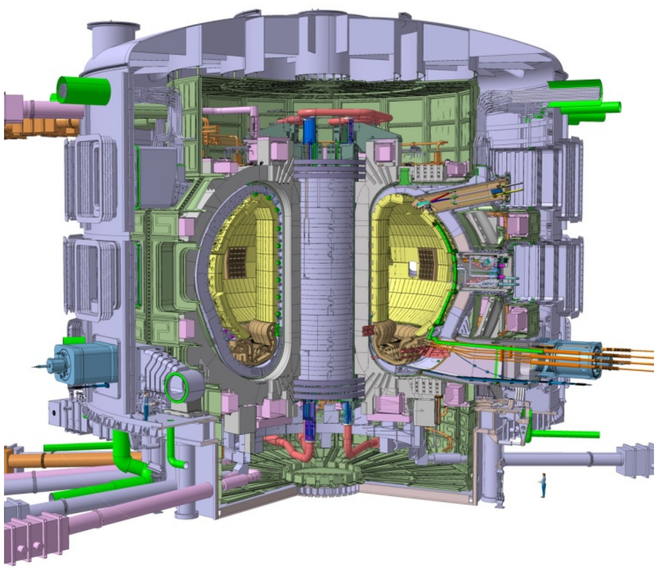
1. CFETR

   - Missions and some considerations of CFETR
   - Progress of integration design of CFETR
   - Progress and plan of R&D for CFETR
   - Working schedule

2. Summary

Fusion research in China

12 CN PAs in kind



Total is 0.6 billion US dollars

Enhanced domestic MF research

- **Upgrade EAST, HL-2M etc.**
- **Theory and education;**
- **Fusion materials;**
- **Development for key tech.**
- **Design and R&D for next reactor**

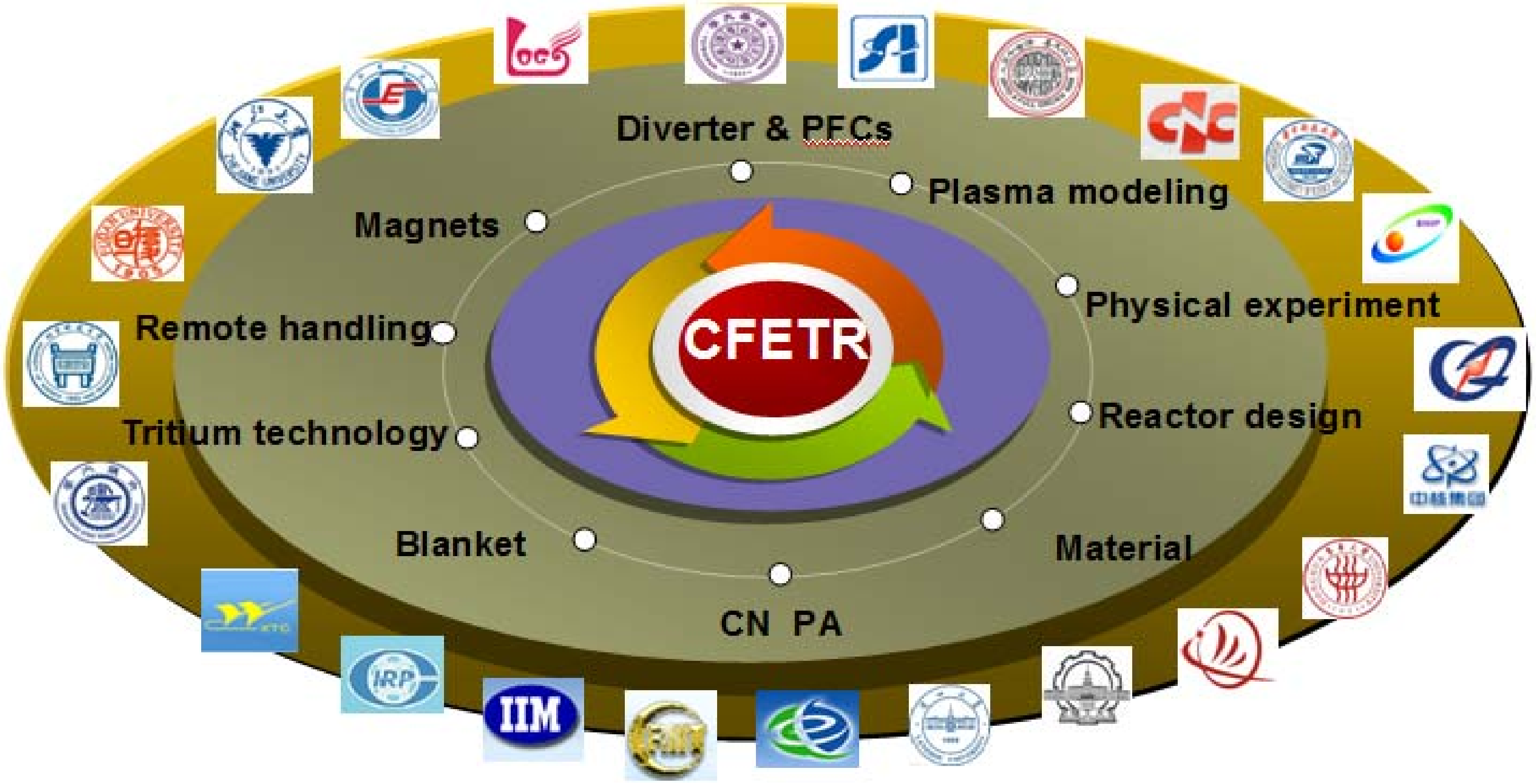
~ (70-80%) 0.6 billion US dollars

Budget for ITER-CN (10 years)

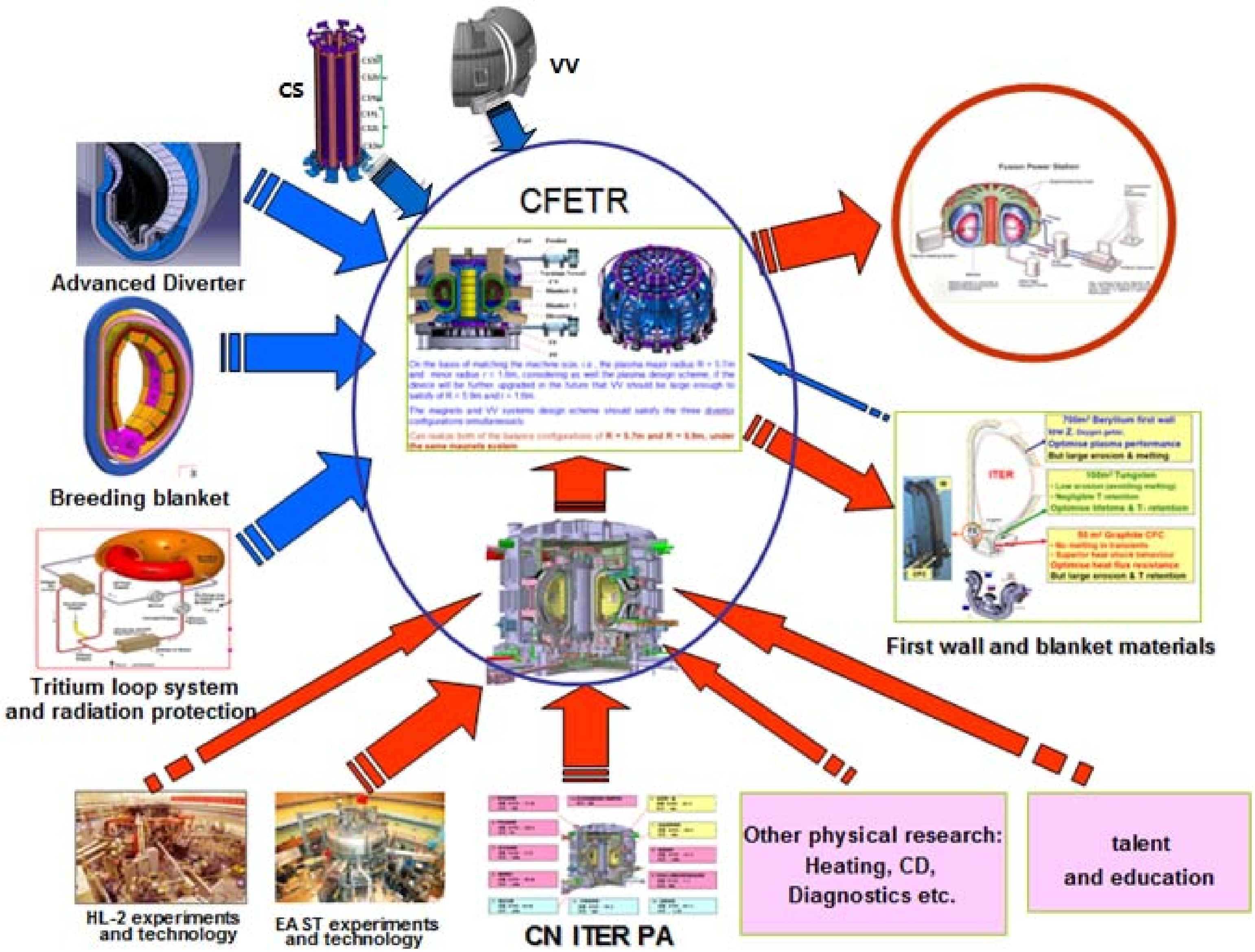
Enhanced domestic MF research

with CN PAs is making important contribution to CFETR R&D

66 projects (~350 M$) were supported by MOST since 2008. About 20 institutes and universities are responsible for them and more than 50 affiliations were already involved.



The strategy for development of FE in China now :



Missions of CFETR

- A good complementary with ITER
- Demonstration of the fusion energy with a minim $P_f = 50 \sim 200MW$；
- Long pulse or steady-state operation with duty cycle time ⩾0.3 ~ 0.5
- Demonstration of full cycle of T self-sustained with TBR ~ 1.2
- Relay on existing ITER physical（k~1. 8-2, q > 3, H~1) and technical bases but there is the potential for further upgrade .
- Exploring the options of easy changeable blanket & divertor for DEMO by RH

The goal of our design is to try to build the engineering testing reactor for fusion energy as early as possible !!

Some Considerations on CFETR strategy

- **The CFETR should base on but beyond ITER;**

- **CFETR should directly face to the challenges of pure FE reactor at first: namely SSO burning plasma; Tritium breeding, processing and self sustainable; Hybrid is not CFETR option,**

- **CFETR can not wait the material which is suitable for DEMO or FPP. CFETR will be one of the best test facility to develop the suitable materials for DEMO or FPP under the real fusion reactor condition, which should be one of the most important mission of CFETR.**

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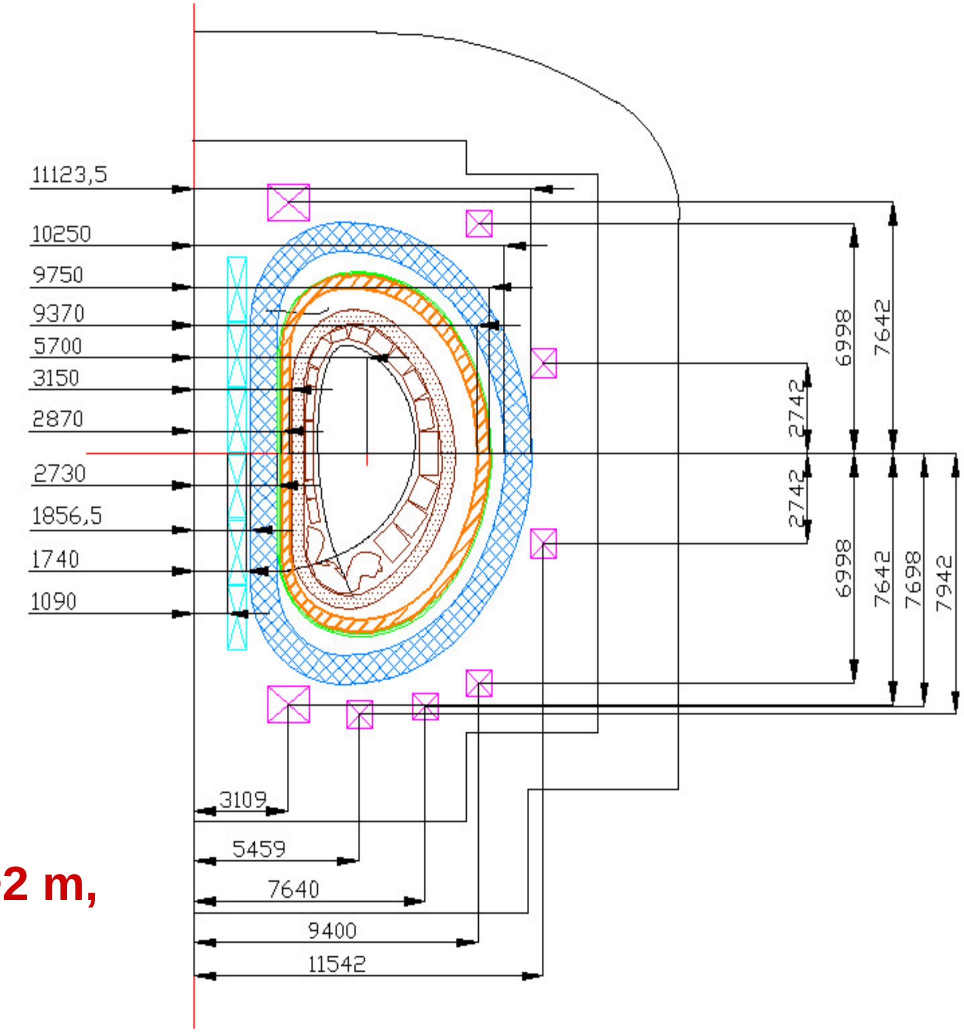
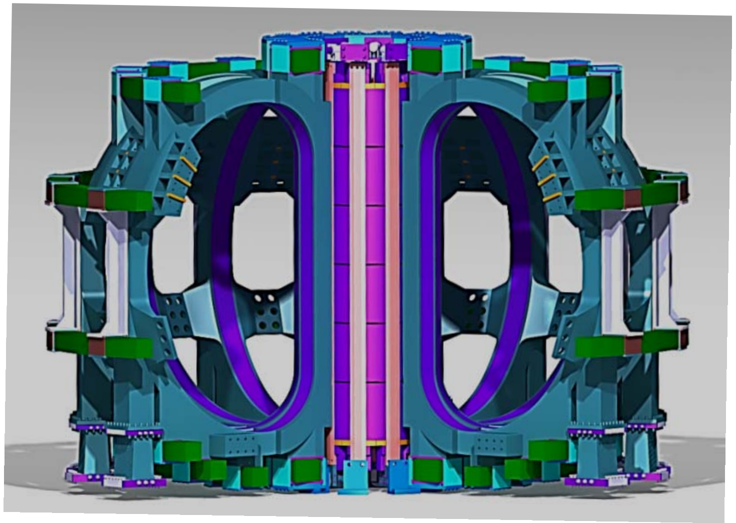
CFETR Machine Configuration

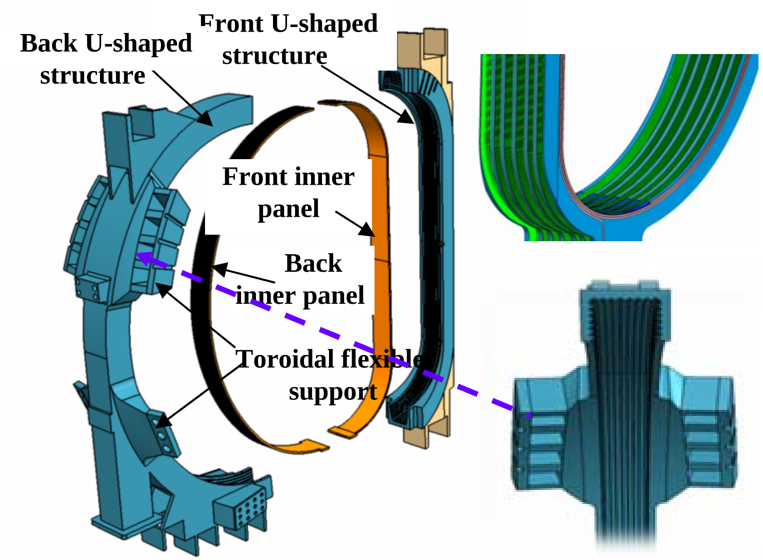
- B_t= 4.5 -5T;
- I_p= 8-10MA;
- R = 5.7m;
- a = 1.6m;
- κ = a/b=1.8～2.0；
- β_N ～2.0； $q_{95} \geqslant 3$；
- Triangularity δ = 0.4-0.8；
- Single-null diverter；
- Neutron wall loading ≈0.5MW/m²;
- Duty cycle time = 0.3-0.5；
- TBR ～ 1.2
- Possible upgrade to R~5.9 m, a~2 m, B_t= 5T, I_p~14 MA

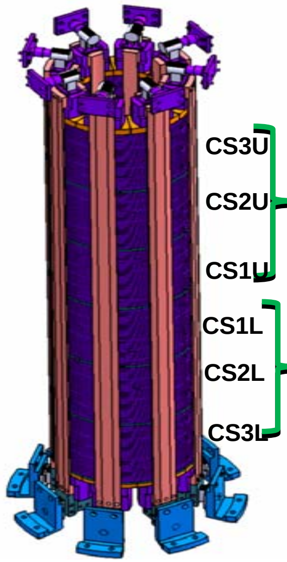


CFETR Magnet System

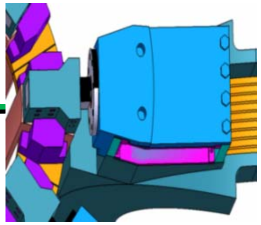


CFETR main parameters (ITER-Like/Super-X/Snowflake)				
Parameter	ITER-Like	Super-X	Snowflake	ITER
Number of TF coils	16	16	16	18
Plasma current (MA)	10	10	10	15
Central magnetic field(T)	5.0	5.0	5.0	5.3
Maximum current of TF coil (kA/turn)	67.4	67.4	67.4	68
Major radius(m)	5.7	5.7	5.7	6.2
Minor radius(m)	1.6	1.6	1.48	2.0
Ohm field coil center radius(m)	1.415	1.415	1.415	2.055
Maximum Volt second	160	160	160	240-250
Elongation	1.8/2.0	1.8/2.0	2.17/2.14	1.70/1.85
Number of PF coils	6	8	8	6

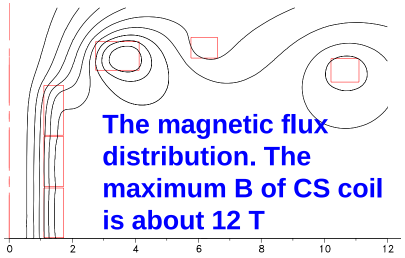


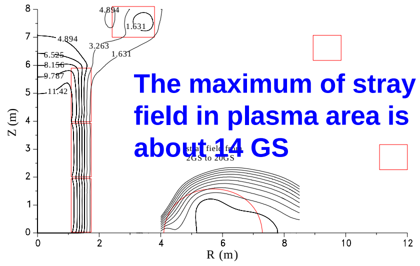


Tightening Tie Plate block



Bottom support structure



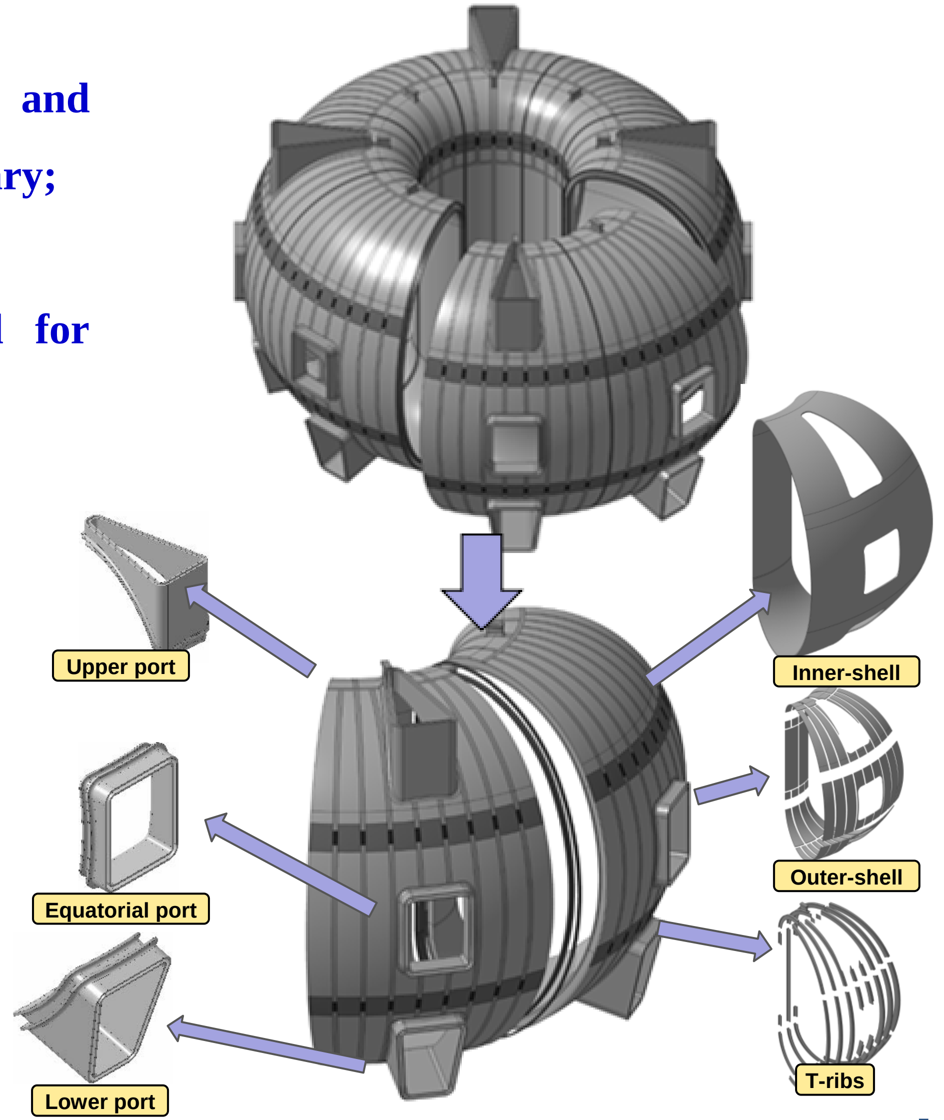


CFETR Vacuum Vessel

- A torus shaped double wall structure;
- To provide high vacuum for plasma and primary radiation confinement boundary;
- To support in-vessel components
- Important space of the Vacuum Vessel for plasma;
- First safety barrier;

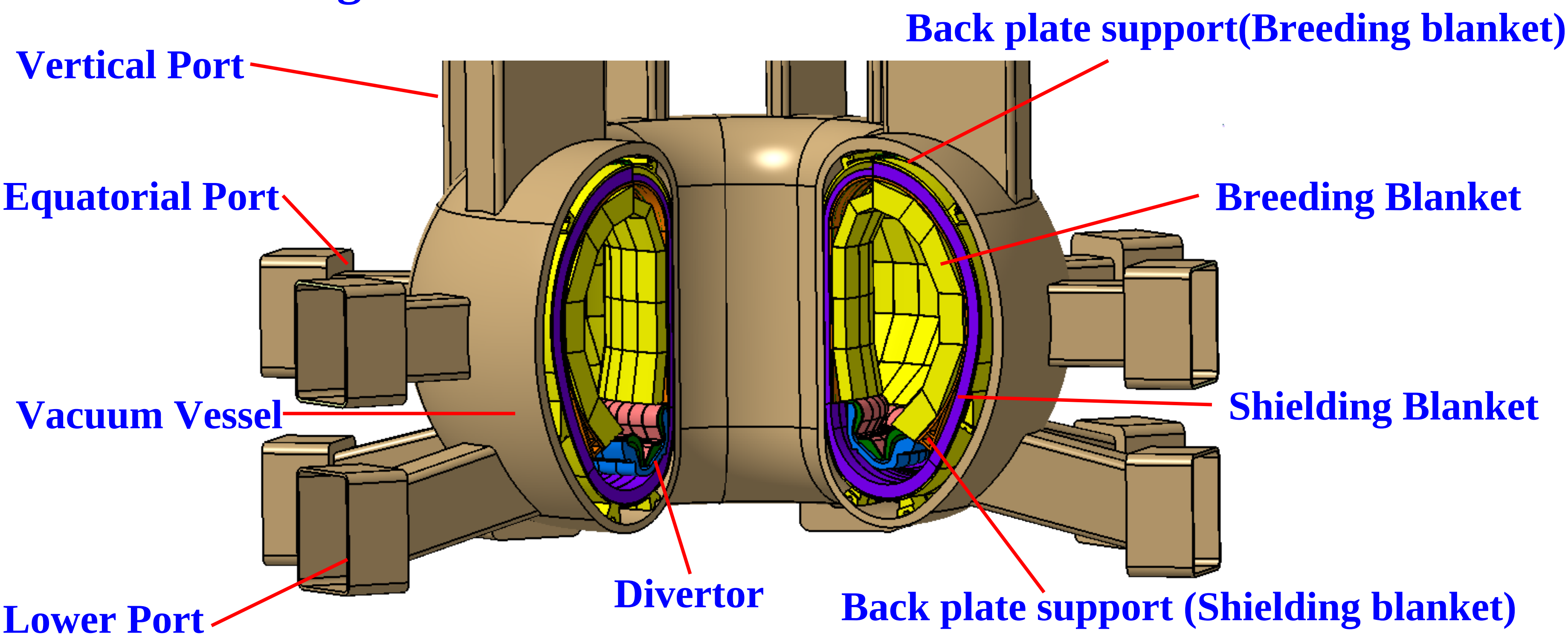
The vacuum vessel:
4 upper ports
8 equatorial ports
8 lower ports.

These ports are used for equipment installation, vacuum pumping, maintenance, etc.



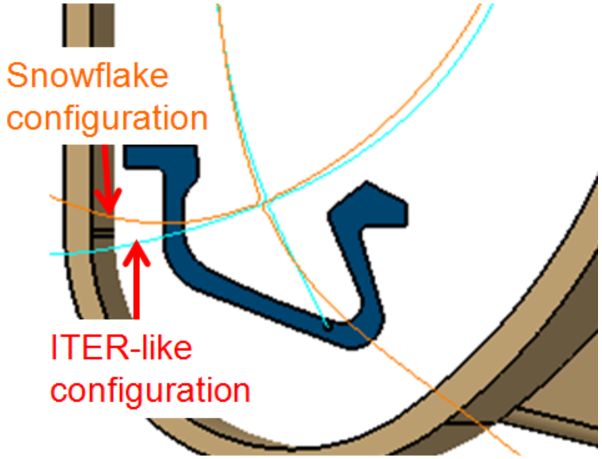
CFETR Blanket

◆ Blanket configuration

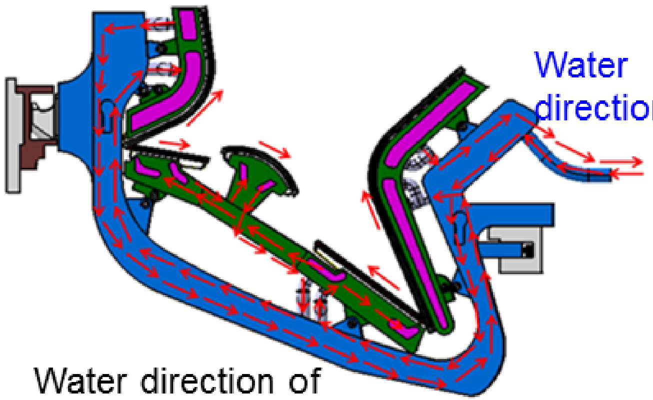


The CFETR blanket system composed of tritium breeding blanket and shielding blanket.

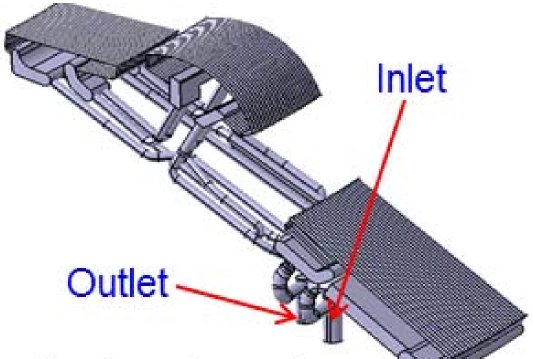
CFETR Divertor



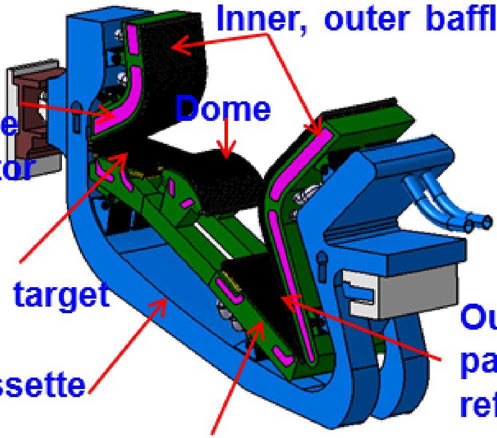
Divertor plasma configuration



Water direction of snowflake divertor



Cooling channel model



Snowflake divertor design

- **Three configurations: ITER-Like, Snowflake and Super X.**
- **New structure with 'vertical reflector': inner baffle, inner particle reflector, inner target, dome, outer target, out particle reflector and outer baffle.**
- **Cassette structure for easier RH handling. Shared cassette between snowflake and ITER-like divertor.**
- **Small incident angle ~16° .**
- **Closed 'V' shape configuration.**
- **Pumping gap between dome and targets.**
- **Divertor cooling scheme was developed.**
- **Support design compatible with RH was finished.**

CFETR Remote Handling

- Duty time : 0.3-0.5
- Fusion power: 50-200MW
- High dosage of neutron: 2-3 orders of magnitude than ITER Tokamak
- To meet CFETR design parameters
- Prevention of diffusion of Radioactive dust

⇨

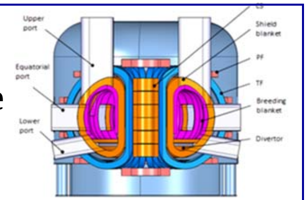
- Big modules(divertor, blanket ,etc)
- High decay heat need to removed
- Reduce the quantity of middle port
- High magnetic field intensity of CS (max:13T)
- Radiation resistance of RH devices

⇨

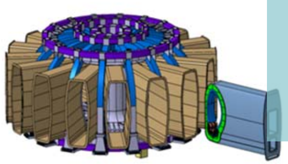
- High load for RH and less maintenance time
- Need forced cooling after SD
- High utilization of port (diagnostic integration, reduce maintenance port)
- New superconducting material for magnet
- High safety and availability requirement

Conceptual design of CFETR

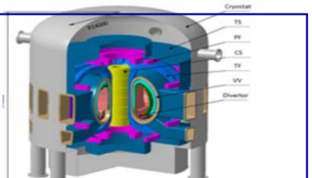
ITER-like

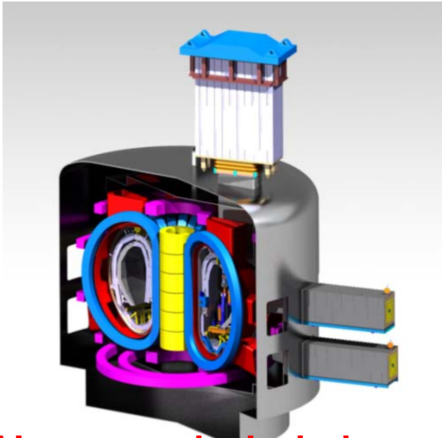


Overall large window



Large middle window





A new design of large- vertical window scheme was selected by discussing the disadvantages and advantages of the three conceptual CFETR design.

CFETR-ASSEMBLY (1).mov

- **Integration Assembly with all Magnets, VV, shielding, diverter, blanket etc.**
- **Blanket RH**
- **Diverter RH**

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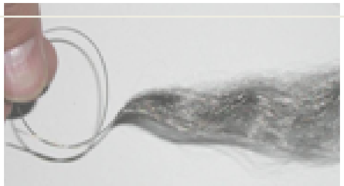
Progresses of CN PA for CFETR R&D

Strands manufacture

by Western Superconducting Technologies Co., Ltd.

Φ 0.820mm:
5000~10000m
NbTi filaments



NbTi & Nb_3Sn superconducting strands manufactory line

Progresses of CN PA for CFETR R&D

Progress of Conductor PA

- 3 jacketing lines and conductor integrating facility were set up in ASIPP.
- 2 parallel buildings were set up for conductor integrating, NDE, cabling, acceptance test.
- All conductors produced by CN DA were accepted with their first tests.
- The first ITER oversized components, PF5 conductor, arrived at ITER site in June.

900m CICC jacket line

Conductor fabrication process

Ceremony for 1st shipping

TF conductor arriving Italia

TF conductor arriving Japan

PF conductor arriving ITER site

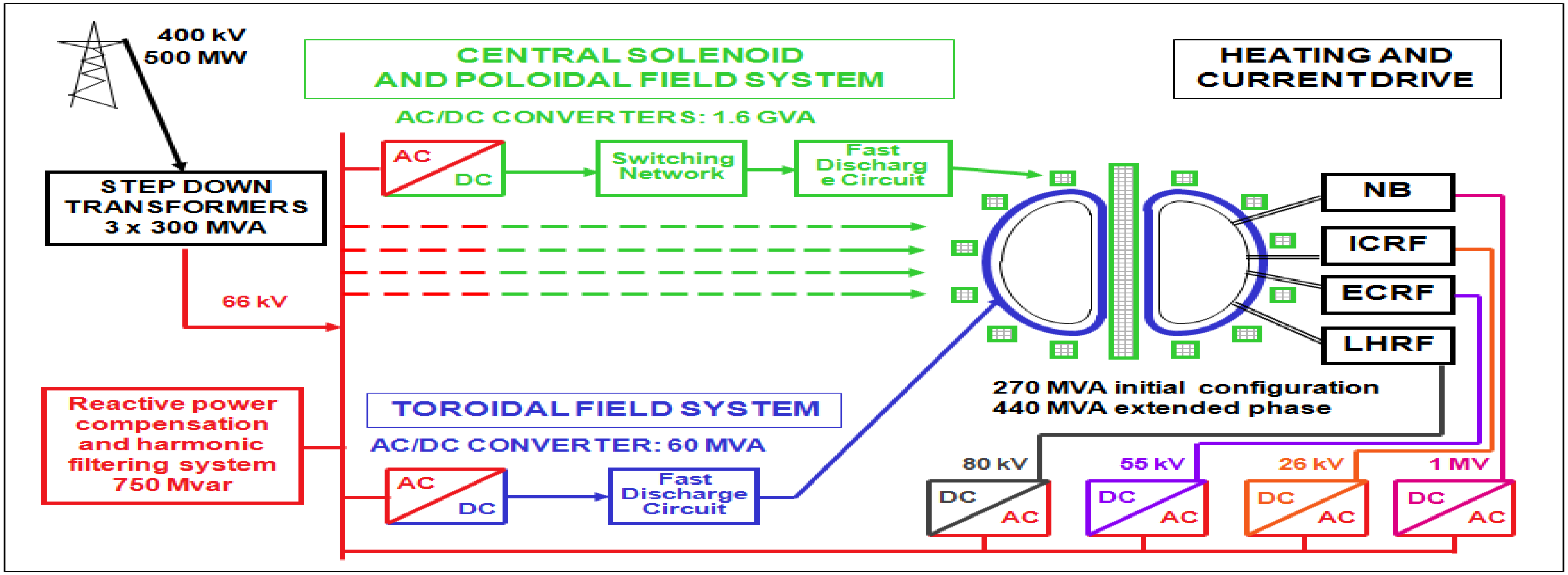
Progresses of CN PA for CFETR R&D

ITER Magnet Power Supply :

- **Pulsed power electrical network (PPEN) (CN 100%)**
- **AC/DC converter (CN 55%; KO 45%)** (107kiuA, phase 2/35kiuA)
- **Reactive power compensation & harmonic filter (RPC) (CN 100%)**
- **SNU&FDU** (RU 100%)

Progress of power supply PA

- **Complete local controller in hardware and test**
- **A new substation 300MVA / 110kV completed**
- **PS test facility has been completed in Dec. 2012**
- **Preliminary design was be completed in July 2012**
- **The prototype manufacture was just finished.**



CN PAs to ITER

1. Poloidal Magnet Conductors
74.25 (kIUA)
CN: 69%

10.Conductor of CC & FEEDER
CN: 50%

6. Blanket-First Wall
87.0:(kIUA)
CN : 10%

2. TF Magnet Conductor
215.0 (kIUA)
CN: 7%

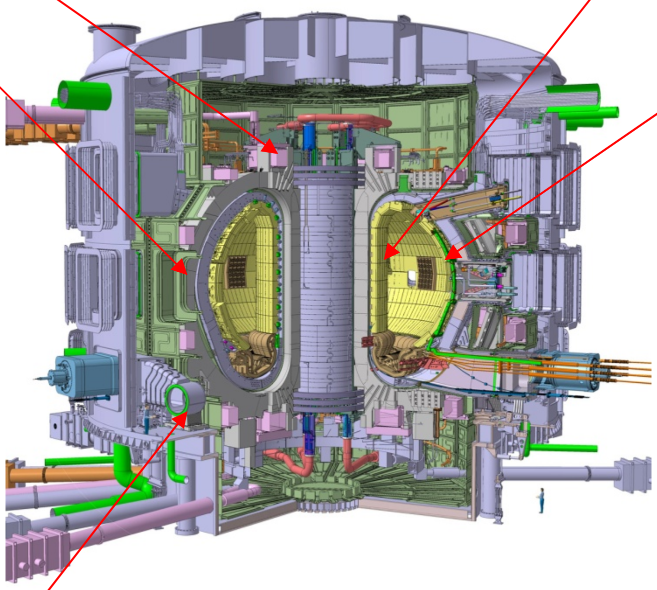
7. Blanket-Shield Block
58.0:(kIUA)
CN : 40%

3. Correction Coils
5.51:(kIUA)
CN : 100%

8. High Voltage Substation Materials
21.0: (kIUA)
CN : 100%

4. Feeders
48.38: (kIUA)
CN : ~100%

9. Gas Injector Valve Boxes + Glow Discharge Cleaning Conditioning
7.7: (kIUA)
CN : 88%

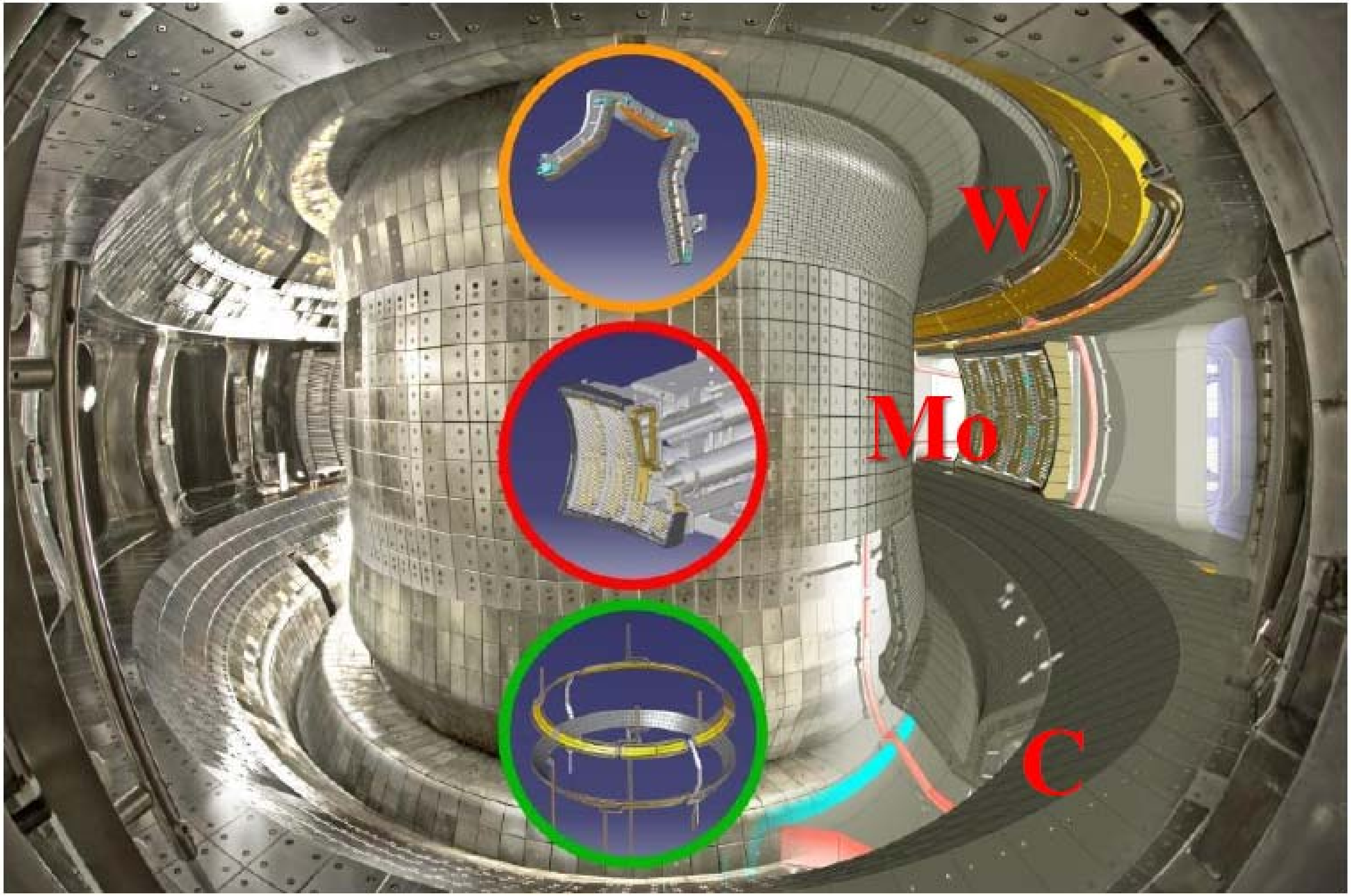


5. Magnet Supports
22.85:(kIUA)
CN : 100%

11. AC/DC Converters
82.2: (kIUA)
CN : 62%

12. Diagnostics
137.5: (kIUA)
CN : 3.3%

Important Upgrade on EAST for CFETR R&D

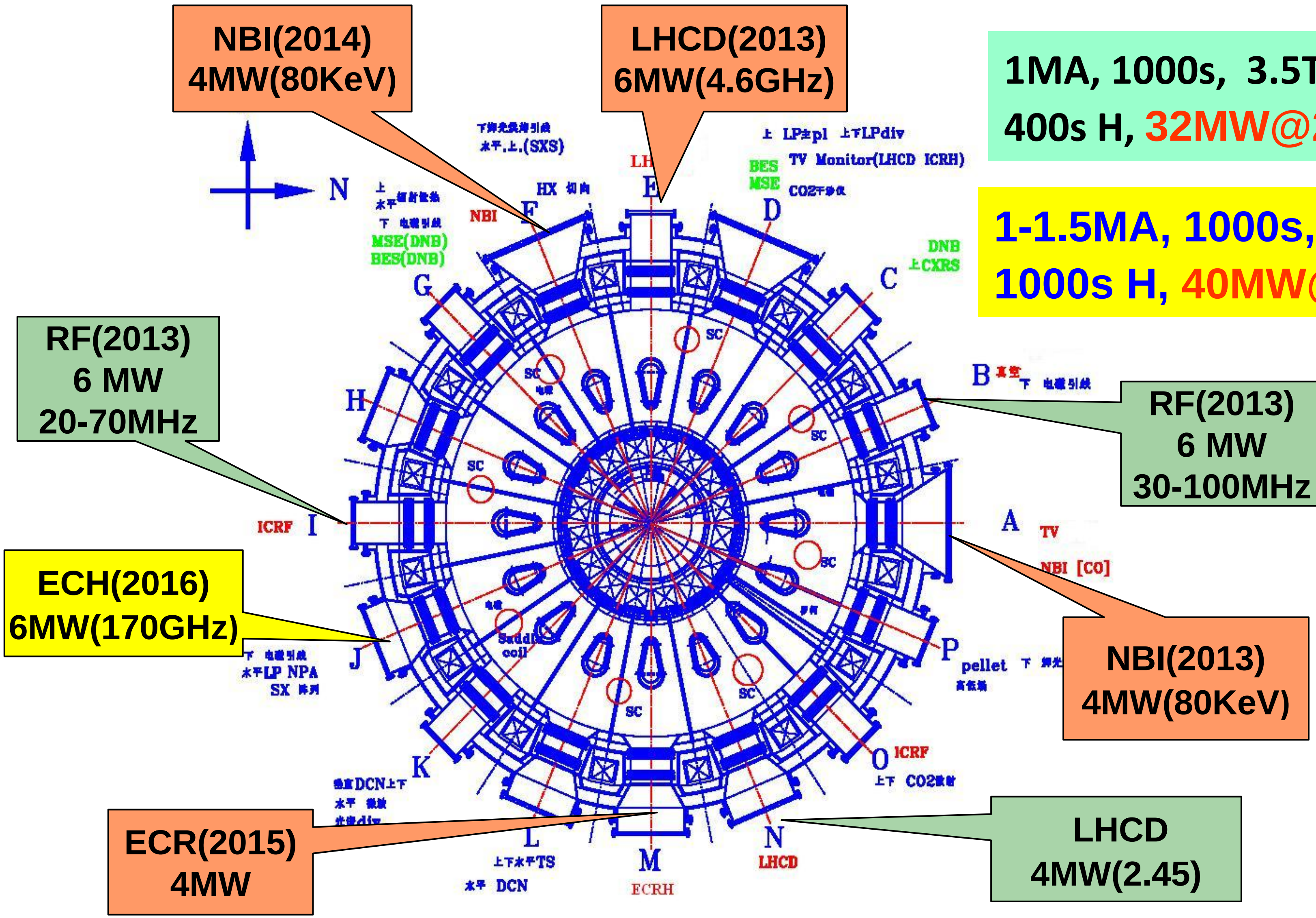


divertor scenarios compatible with high performance core plasma for SSO

Important Upgrade on EAST for CFETR R&D

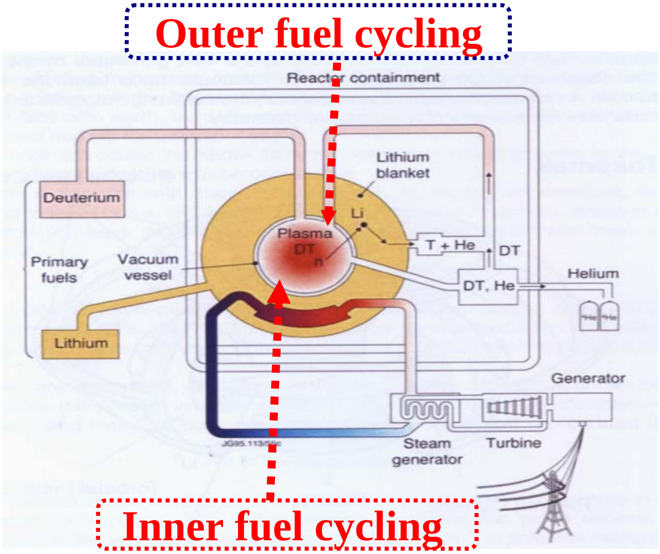
1MA, 1000s, 3.5T， 70Dia.
400s H, 32MW@2014

1-1.5MA, 1000s, 3.5-4T,
1000s H, 40MW@2016



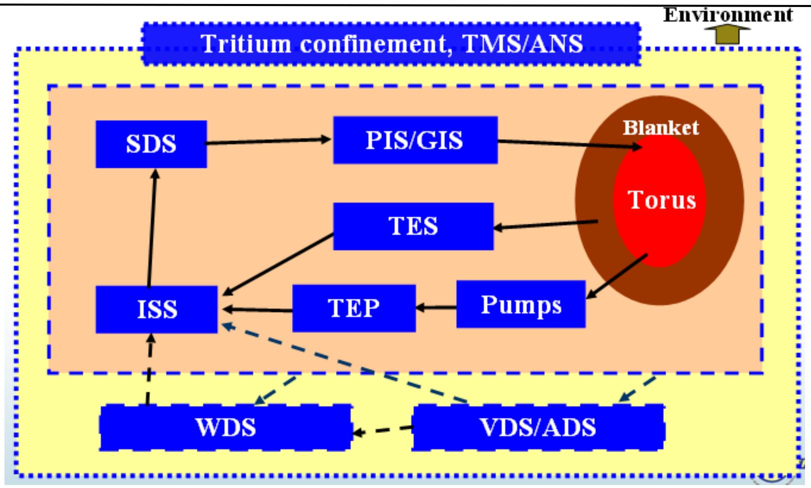
Progress on T-plant technologies

- **Concept design of T-plant for China Fusion Engineering Test Reactor (CFETR)**
  - Have been supported in 2012
  - Key issues
  - Start-up tritium preparation?
  - Plant breakdown structure (PBS)?
  - Technological principle, parameters for each PBS?
  - Tritium safety measures?
  - Preliminary safety analysis?
  - R&D scheme?



- **Preliminary fuel recycling for CFETR**

The conceptual design of the main processes (TES,TEP,ISS, WDS,VDS and ADS) have been finished.



Progress on the materials related with Tritium

Progress of preparation of solid tritium breeder

CAEP independently developed a frozen- wet preparation technology of solid tritium breeder, currently has a preparation capability of kilograms in lab.

Li_4SiO_4 pebble

Preparation level of Kg class

Compressive strength(a.v.) >20 N

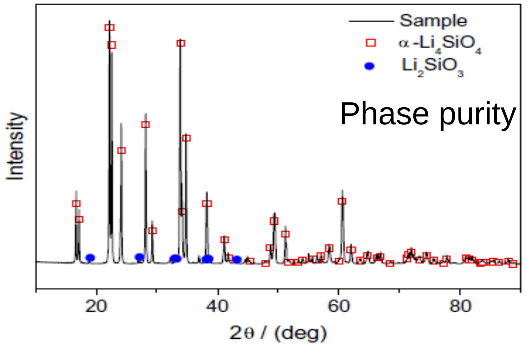


Fig. 4. XRD pattern of the powder.

Characteristics	Value
Diameter (mm)	0.63 ± 0.02
Density (% TD)	>80
Sphericity	≤1.02
Packing density (g cm^{-3})	1.2
Surface area (m^2 g^{-1})	60.57
Li content (%)	22.75
T_m (°C)	1224
Grain size (μm)	3–5
Crush load (a.v) (N)	20

D.Zhu, et al. J. Nucl. Mater, 2010

X. Gao, et al. J. Nucl. Mater, 2012

Tritium permeation barrier

- Formation of tritium permeation barrier (TPB) on vessels and pipes for tritium confinement is the first choice to minimize tritium loss and its environmental radiological risk.
- A series of oxides, aluminides, carbides and nitrides of TPB have been studied, and high tritium permeation reduction factor (PRF) can be obtained.

TPB type	Oxides	Carbides and nitrides	Compounds
Materials	Al_2O_3，Cr_2O_3，Er_2O_3，$(Ar,Cr)_2O_3$	TiN，TiC，SiC	Al_2O_3/FeAl，Er_2O_3/SiC，SiC/TiC@Al-Cr-O
Process	chemical and physical process	physical process	chemical and physical process
PRF	400~10000	>1000	300~3000

Progress on Materials research

China Low Activation Martensitic steel (CLAM)

Production and properties

- Nominal compositions: 9Cr1.5W0.2V0.15Ta0.45Mn0.1C
- 4.5 ton smelting with good control of main compositions

Irradiation properties and TBM Fabrication

- High-dose neutron irradiation experiments
  (Spallation source ~20dpa)
  (High Fluence Engineering Test Reactor ~2dpa)
- Fabrication of test blanket module (TBM)
  (1/3 scale P91 TBM, 1/3 scale CLAM first wall)

1/3 CLAM FW

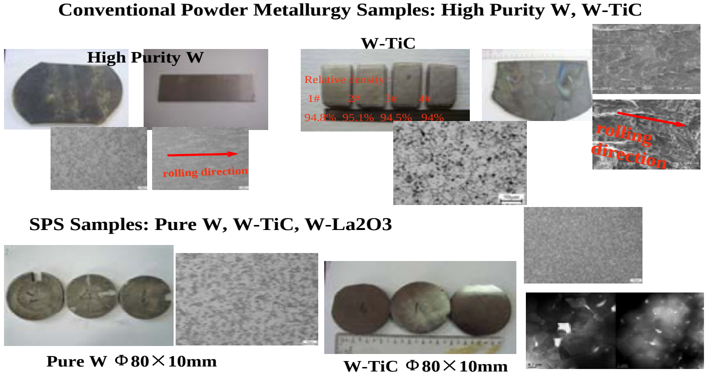
1/3 P91 TBM

Properties of CLAM steel is comparable with those of the other RAFMs, e.g. Eurofer97, JLF-1.

Plasma-facing materials: W

W material study scope: W alloy; W coating; W/Cu component

High heat-flux test facility



Status of CFETR Design and R&D

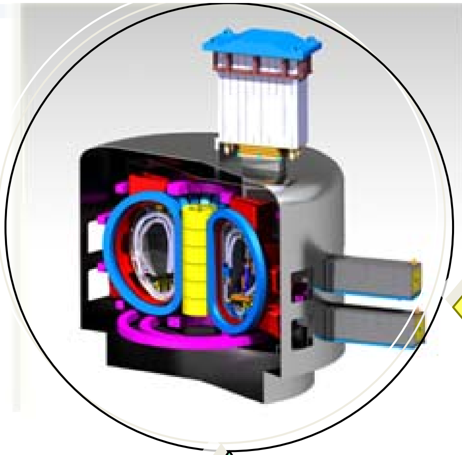
Integration design

Conceptual design

integration simulation

Engineering design

By EDP& I-collaborations



Key components R&D :

- **CS (60 M ￥)**
- **one section of VV**
- **Neutron source (~10^{14}/cm²)**
- **HR & R&D**
- **Breeding blanket**
- **Advanced Divertor**

Tritium related

T- Plant
T- breeding Materials
Fueling
Safety

By EDP

SSO experiments & related technologies

ICRH (CW)
ECRH (CW)
4.6 GH LHCD (CW)
NBI (LP)
W diverter
Diagnostics & COODAC on EAST,HL-2M,J-TEXT

By EDP

SC magnets related

Strands
Feeders
CICC
Magnets
Support system
Cryogenics
Quench protection

By CN PA and EAST

Power supply systems

Shielding blanket

TBM

First wall

By CN PA

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Working schedule

- **2012- 2014: provide two options of engineering concept design of CFETR** (SC option will be more in detail)

- **Complete two proposals in 2015 :**

  1. more key R&D items for CFETR

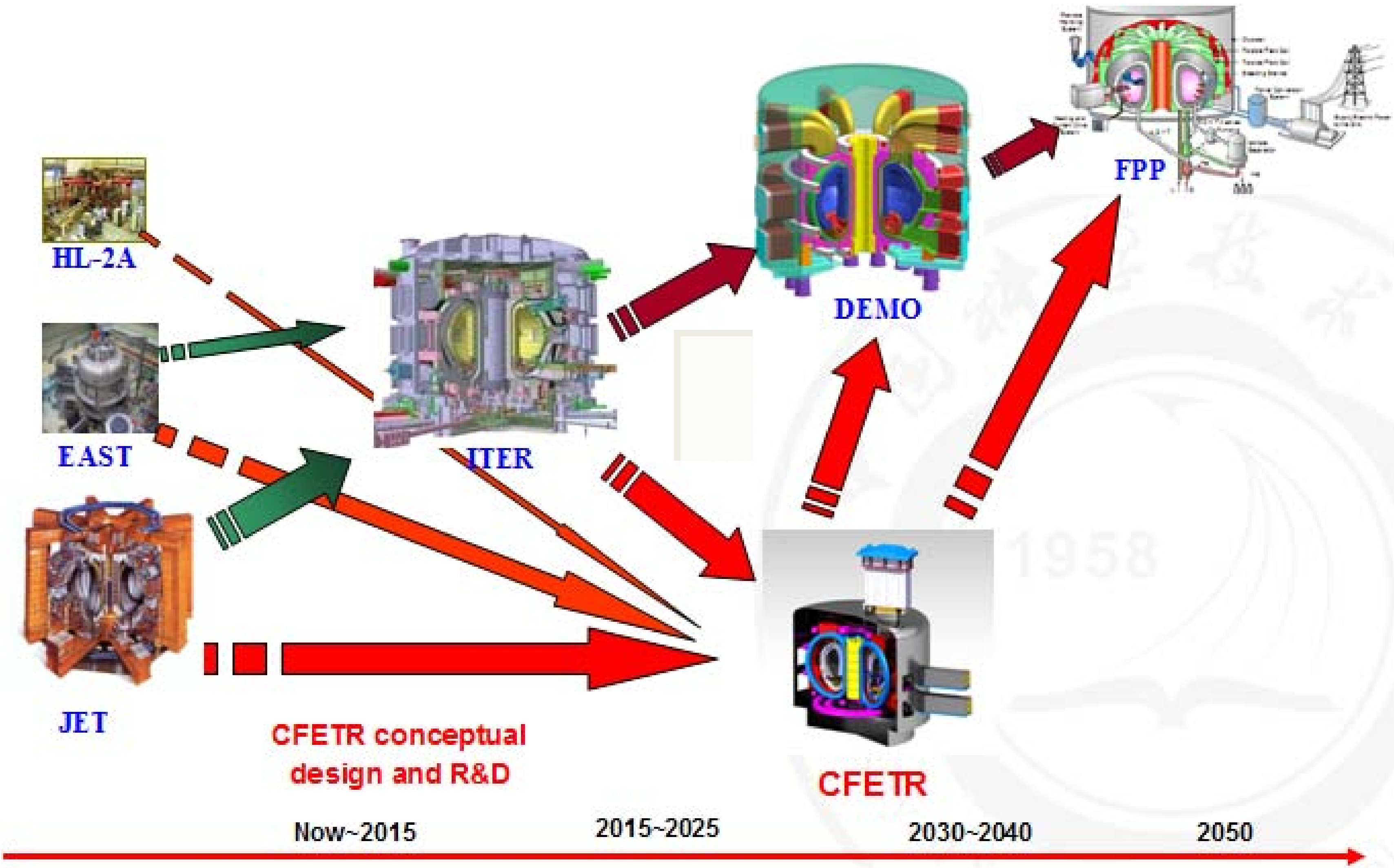
  2. Construction proposal for CFETR

It is hope that CFETR

can be constructed around 2030

Summary

Possible Roadmap for FE research in China



Thanks for your attention !

CFETR-HR.mov