Strategy for Chinese MFE

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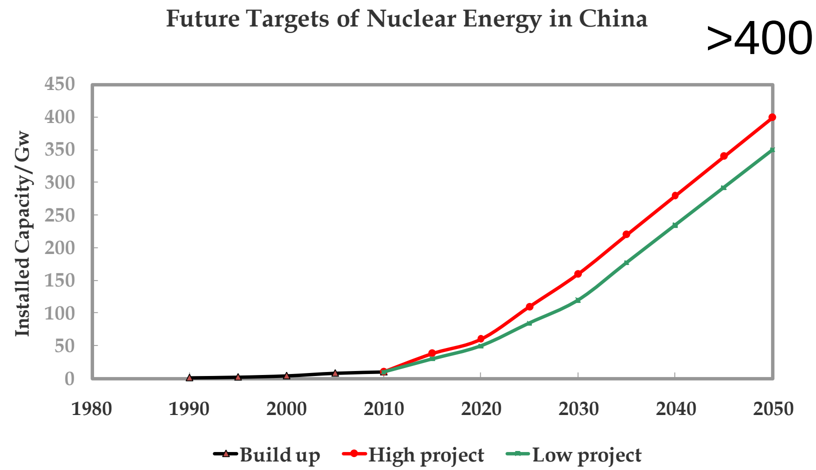
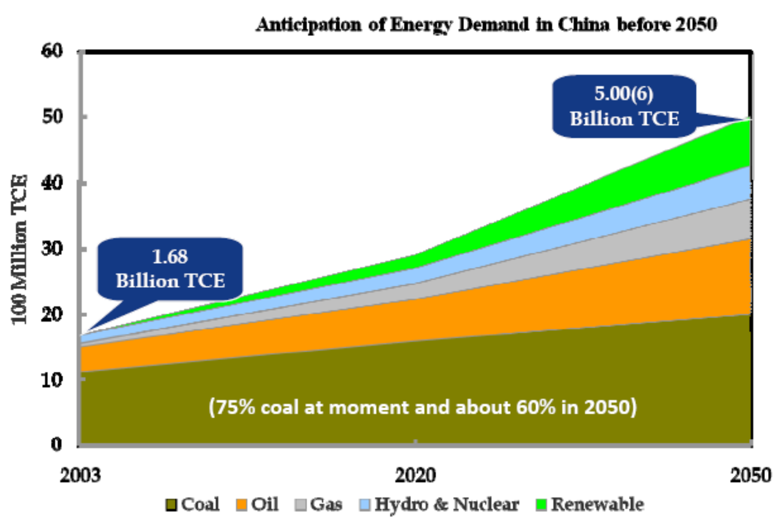
Energy Needs in China

World average 2.4 kW per person
USA : 10.5k W
UK: 5.2kW
JP: 6.3kW
China:1.6kW (growing 10% /y)
India: 0.7kW
Bangladesh: 210 Watts

>400 GW



Energy Needs in China



IEA2005

Renewable and nuclear energy were promoted significantly in China for reducing CO_2 of 40% in 2020.

Fukushima Nuclear accident make a strong impact to nuclear energy

More urgent need for fusion energy.

Need 100 GW fusion plant in 2100

GAP Analysis: > 50 years to Power Plant

	Issue	Approved devices	ITER	IFMIF	DEMO Phase 1	DEMO Phase 2	Power Plant
Plasma performance	Disruption avoidance	2	3		R	R	R
	Steady -state operation	2	3		r	r	r
	Divertor performance	1	3		R	R	R
	Burning plasma (Q>10)		3		R	R	R
	Start up	1	3		R	R	R
	Power plant plasma performance	1	3		r	R	R
Enabling technologies	Superconducting machine	2	3		R	R	R
	Heating, current drive and fuelling	1	2		3	R	R
	Power plant diagnostics & control	1	2		r	R	R
	Tritium inventory control & processing	1	3		R	R	R
	Remote ha ndling	1	2		R	R	R
Materials, Component performance & lifetime	Materials characterisation			3	R	R	R
	Plasma -facing surface	1	2		3	4	R
	FW/blanket/divertor materials		1	1	3	4	R
	FW/blanket/divertor components		1	1	2	3	R
	T self sufficiency		1		3	R	R
Final Goal	Licensing for power plant	1	2	1	3	4	R
	Electricity generation at high availability				1	3	R

10 year	10 years	10 years	10 years	10 years
Build ITER + IFMIF	Run ITER +IFMIF	Build DEMO	Run DEMO	Build proto-type

A Glance at MCF Road Map

- US: ITER—IFMIF+CTF(FNF)--DEMO--Power Plant (~ 50 years)
- EU&JP: ITER--IFMIF-- DEMO--Power Plant
- KO: KSTAR--ITER--DEMO(30)--Power Plant(40)

Increase size+Increase performance+Ruduce risks

Risks are always there.

No single device can solve all S&T problems.

Learning by Doing.

Make a real Next Step forward is most important

Ordering 0 Issues for Next Step

– **Demonstrating and exploring the burning plasma state**

– **Creating predictable, high-performance steady-state plasmas**

– **Taming the plasma-material interface**

– **Harnessing fusion power**

Issues with poor bases

- ➢**SS operability of a fusion nuclear facility**
- ➢**Electricity generation.**
- ➢**Complete T fuel cycle.**
- ➢**Material &component Validation**
- ➢**Power and particle handling.**
- ➢**Necessary date for safety & licensing of power plant.**
- ➢**Large industrial involvement.**

CN-MCF Near Term Plan (2020)

Deliver quantified PA on time

- ASIPP: Feeders (100%), Correction Coils (100%), TF Conductors (7%) , PF Conductors (69%), Transfer Cask System(50%), HV Substation Materials (100%), AC-DC Converter (62%)
- SWIP: Blanket FW (10%) &Shield (50%), Gas Injection Valve Boxes+ GDC Conditioning System (88%), Magnetic Supports (100%),
- Diagnostics (3.3%)

+

Enhance Domestic MCF

Upgrade EAST, HL-2A

ITER technology

TBM (Solid, DCLL)

University program

DEMO design

DEMO Material

Education program(2000)

Can start construct CN pilot power plant before 2020

Options for China next Step

Electricity generation with reduced mission

- Start small, but viable
- Have a credible, sensible approach including step by step development path
- Avoid High Cost from beginning
- With a very attractive, deliverables milestone.
- With commercial power plant potential.
- Running for a few hours to SSO

Based on existing technologies:

Option 1: Pure Fusion

A FDF-class with SC coils

A ST-type compact device

Option 2: Fusion –Fission hybrid

Fusion: Q=1-3, Pth=100-200MW

Fission: M= 20-30, Pth = 2-5GW

Option3: ITER-type machine with FFH blanket: Pt =5GW, Pe=1.5GW

Option 4 : A multi-function machine with a changeable core.

Competitions to Fusion in China

G-IV Reactor:

Fast Breeder

65MW (now)

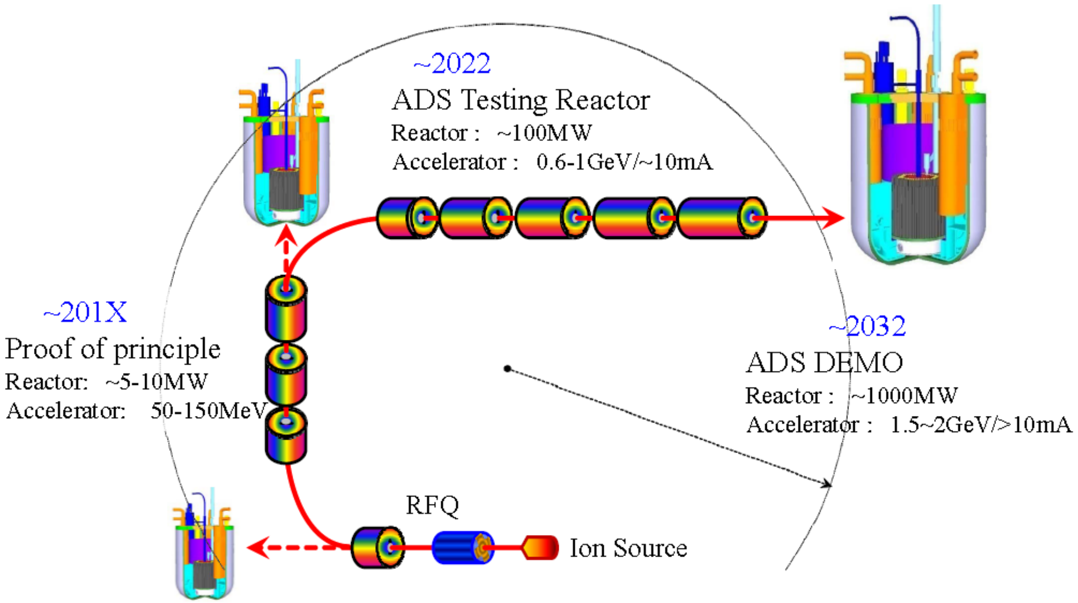
→800MW(2015)

HTGR

10MW (now)

→200MW (2015)

ADS-NWT Road Map



ADS starts for NWT

Melt-salt fission (100MW at 2020)

Z-pinch and Laser hybrid reactor configurations also proposed

China Fusion Engineering Testing Reactor

Step 1: ITER-SS-H mode

R=4-5m； a=1-1.5m； k=1.75；
$T=4.5K$, $B_T=5T$； Ip=8MA；
$ne=1\text{-}4 \times 10^{20} m^{-3}$；
Beta N : 2.5
Pth: 100MW-200MW

Q=2-5 , t> 2 hours to SSO

Material &Component testing,

T breading (TBR>1),

T fuel recycling, RH validation

RAMI validation

FFH blanket testing (SFB, TM)

Step 2: AT H-mode

R=4-5m； a=1-1.5m； k=1.75；
T=3.6K or T=1.8K, $B_T=6\text{-}7T$；
Ip=10-14MA；
$ne=2\text{-}4 \times 10^{20} m^{-3}$；
Beta N : 4-5
Pth: ~1GW

Q=10-20, t > 2 hours to SSO

Material &Component testing

T breading (TBR>1),

Pure fusion TBM configuration

RH validation, RAMI validation

Close fuel cycle

Planning for Next Step

- CN-Design team（18）

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Phy. Design, 13 sub-groups

2 options within 3 years (ECD1)

- Eng. Design （4-6 Y）
- Key R&D （3-10 Y）
  - Diagnostic
  - Blanket (TBM, FFHM)
  - Magnet
  - T-plant
  - RH
- Personnel (10 years)

2016-2025 Construction

Rank No.1 in 2016- 5Y plan

Operation:

5-years, H_2, He (D_2)

6-8 Y DT-1 operation

6-8 Y DT-2 operation

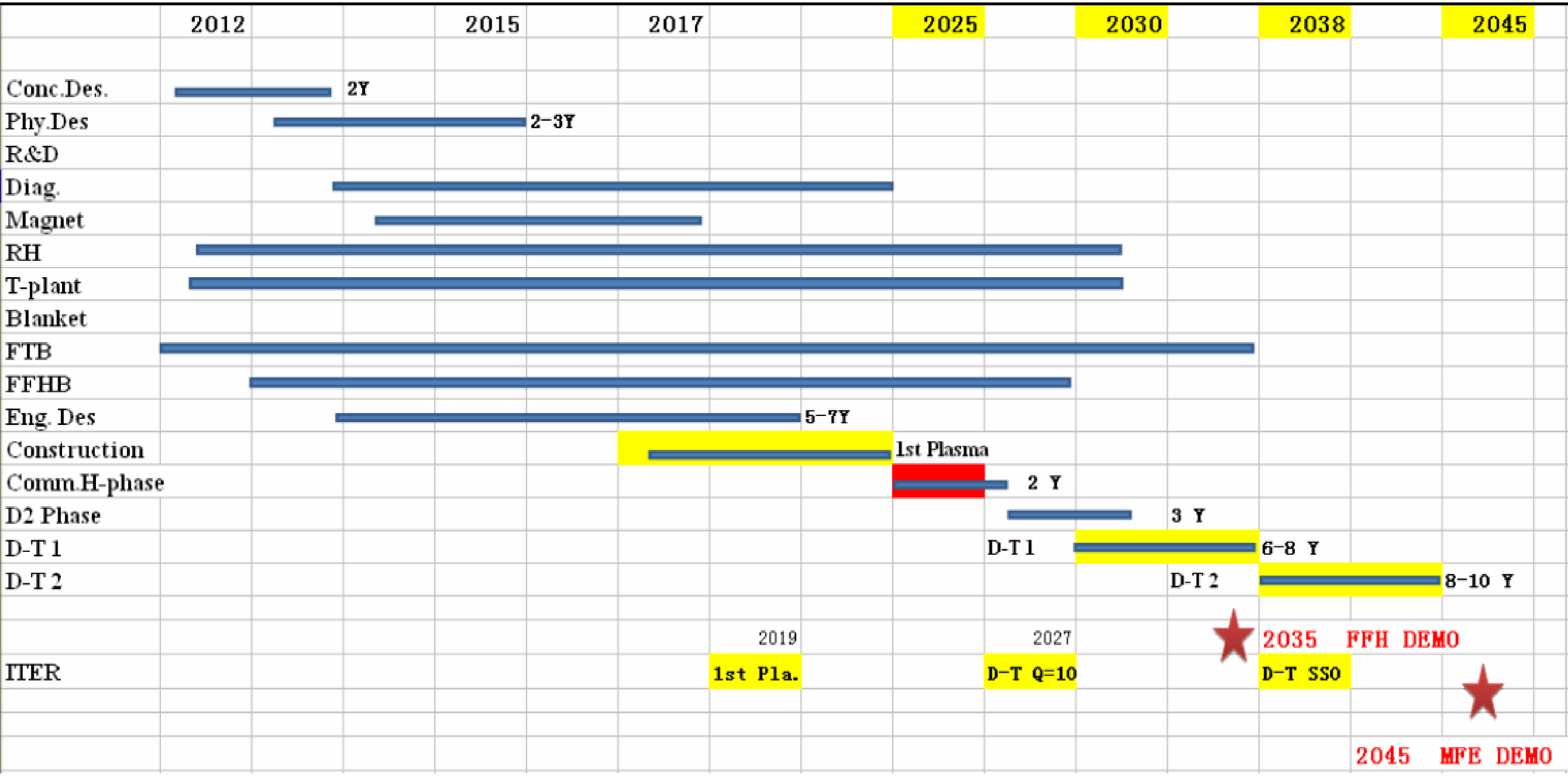
ITER

2019: 1st Plasma

2027: DT-1, Q=10, 400s

2037: DT-2, Q=5, 3000s

Plan and Schedule



Plasma Performance Estimation

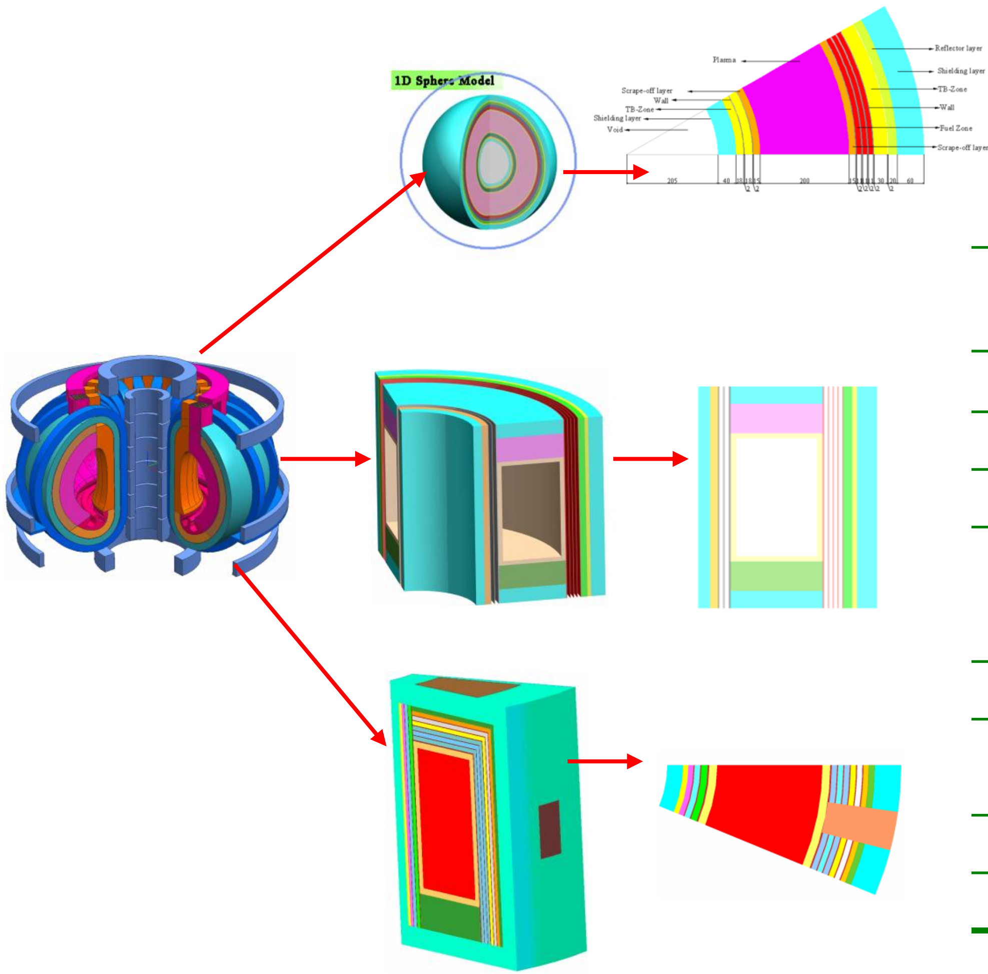
- 0D Estimation
- 1D (FDF) estimation
- Using existing exp.Data
- Step 1: 100-200MW
- Step 2: 1000MW

Case	A1	A2	A2	A4	A5	B1	B2	B3	B4
Beta N	2.5	3.1	3.6	4.0	4.4	2.5	3.0	3.6	3.9
P (MW)	268	367	426	480	526	152	204	248	276

R(m)=5, a(m)=1.5, B(Tesla)=5, κ=1.75, δ=0.4, Vp (m^3)=389

	A q_{95} =3.5	B q_{95} =3.5	C q_{95} =3.0	D q_{95} =3.0	E q_{95} =4.55
Ip (MA)	9.1	9.1	10.5	10.5	7
Paux (MW)	80	50	80	50	50
q_{95}	3.5	3.5	3.0	3.0	4.55
Fusion power (MW)	198	149	316	244	192
Q	2.47	2.98	3.95	4.87	3.84
$n_{20}T_{10}$ (10keV*$10^{20}/m^3$)	0.912	0.792	1.15	1.01	0.90
$T_i(0)$ (keV)	13.9	12.1	15.2	13.4	17.8
n(0) ($10^{20}/m^3$)	1.64	1.64	1.89	1.89	1.26
n_l ($10^{20}/m^3$)	1.29	1.29	1.49	1.49	0.99
β_T	2.66	2.31	3.36	2.95	2.62
β_N	2.19	1.90	2.40	2.11	2.81
β_P	0.92	0.80	0.87	0.77	1.53
f_{bs} (%)	30.1	26.2	28.6	25.1	50.2
τ_{E_98Y2} (s)	1.38	1.82	1.47	1.90	1.19
Pn/Awall (MW/m^2)	0.48	0.36	0.76	0.59	0.46
Brems power (MW)	12.0	8.0	14.3	9.9	8.8
Peak Heat flux (MW/m^2)	4.13	2.7	4.9	3.4	3.1
P_{th} (MW)	31	31	34	34	27

Neutronics Models (1D, 2D, 3D)
TBR>1, spent fuel burner, transmulator



Zones	Material component (%)	Thickness (cm)
Inboard blanket		
FW	RAFM steel (50) +H_2O (50)	**2**
Tritium breeding zone	LiPb (^{6}Li:90%) (100)	**18×2**
Structural walls	RAFM steel (50) +H_2O (50)	**2**
Shield layer	RAFM steel (50) +H_2O (50)	**40**
Outboard blanket		
FW	RAFM steel (50) +H_2O (50)	**2**
Fuel zone	**UO_2 (43.31)+PuO_2 (14.9)+MAO_2 (1.79)+Zr (10)+H_2O (30)**	**13**
Structural walls	RAFM steel (50) +H_2O (50)	**2×2**
Tritium breeding zone	**LiPb (^{6}Li:90%) (100)**	**30**
Reflector layer	C (100)	**20**
Shield layer	RAFM steel (50) +H_2O (50)	**60**

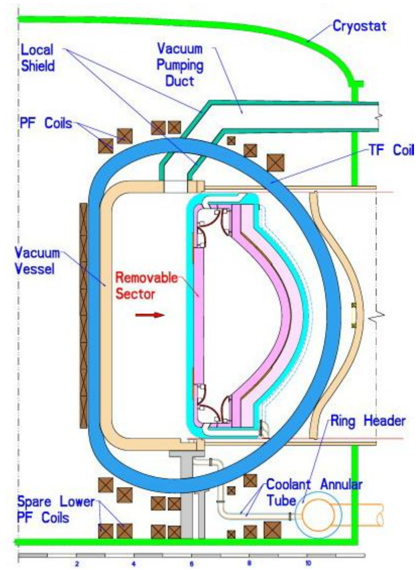
H_2O-Cooled:The total thickness of outboard blanket of EM/FB is ~129cm（43cm(Fuel zone+T zone)+20cm(Reflector layer)+60cm(Shield layer))
He-Cooled:The total thickness of outboard blanket of EM/FB is ~176cm（90cm(Fuel zone+T zone)+20cm(Reflector layer)+60cm(Shield layer))

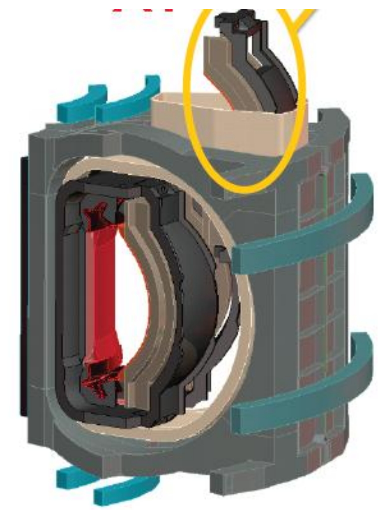
One Option: Deep Spent Fuel Burner

Years	Keff	TBR	Fuel Inventory(SNF) (t HM)	Pth (GW)	Pdmax (MW/m3)	M	Burnup(MW. d/t HM)	BSR	TSR_{MA}
0	0. 91	2. 13	113. 26	8. 94	99. 88	74. 38	28. 81	–	–
1	0.89	1. 96	110.29	7. 82	81. 94	65. 03	54.01	4.43	3.14
2	0.87	1. 75	107.90	6. 79	67. 55	56. 52	75.89	8.64	4.71
3	0.86	1. 64	105.93	6. 24	59. 34	51. 89	96.00	12.34	5.54
4	0.85	1. 55	104.21	5. 84	59. 28	48. 55	114.82	15.72	6.04
5	0.84	1. 53	102.66	5. 67	49. 76	47. 21	133.10	18.90	6.36
6	0.83	1. 44	101.23	5. 32	44. 93	44. 23	150.24	21.93	6.61
7	0.83	1. 39	99.91	5. 08	41. 50	42. 28	166.61	24.82	6.83
8	0.82	1. 39	98.67	5. 04	39. 70	41. 90	182.85	27.62	7.04
9	0.81	1. 36	97.51	4. 94	37. 65	41. 12	198.77	30.33	7.26
10	0.81	1. 36	96.40	4. 91	36. 24	40. 90	214.60	32.95	7.46

Key Issues for this Approach

- Design: Construction such device will be technically ready but Start RAMI for power plant potential.
- T-plant & Fuel cycle
- Two diagnostics options for DT-1 and DT-2 phase
- New technology for RH





Theory & Simulation

Fusion energy integrated modeling

Validate codes in exiting devices, especially under SSO

- Validating in ITER+DT-1

Efforts Made-Education

Present state:

- ASIPP: HT-7/EAST (150 students), ITER (80 students)
- SWIP (60)
- School of Physics (USTC, 25)
- School of Nuclear Science (USTC-ASIPP, >50)
- CN-MOE-MCF center (10 top universities) 50

Total about 450 students, 150/y, 20-30% remain in fusion

Targets and efforts

➢2000 fusion talents in 2020

➢MOST, MOE, CAS, CNNC

have lunched a national fusion training program for next 10 years.

Basic training in 10 top univ.

Join EAST/HL-2A experiments

Small facilities in Univ.

Foreign Labs& Univ.

Annual summer school, workshop

Efforts Made- R&D (MOST)

Present state

- 5 year-MCF plan
- 10-year MCF plan

2009

Solid TBM concept design

DCLL TBM concept design

PWI

ITER design

ITER-ICRF

MCF-talent (8, exp.)

2010

Hybrid concept design

TBM-T system design

DEMO-FW(W)

MCF-basic simulation

MCF-talent (9, ITPA)

2011

CN-MCF Reactor design

ITER-W-diverter

High But (NbAl3,YBCO) magnet

T-plant design

RFP

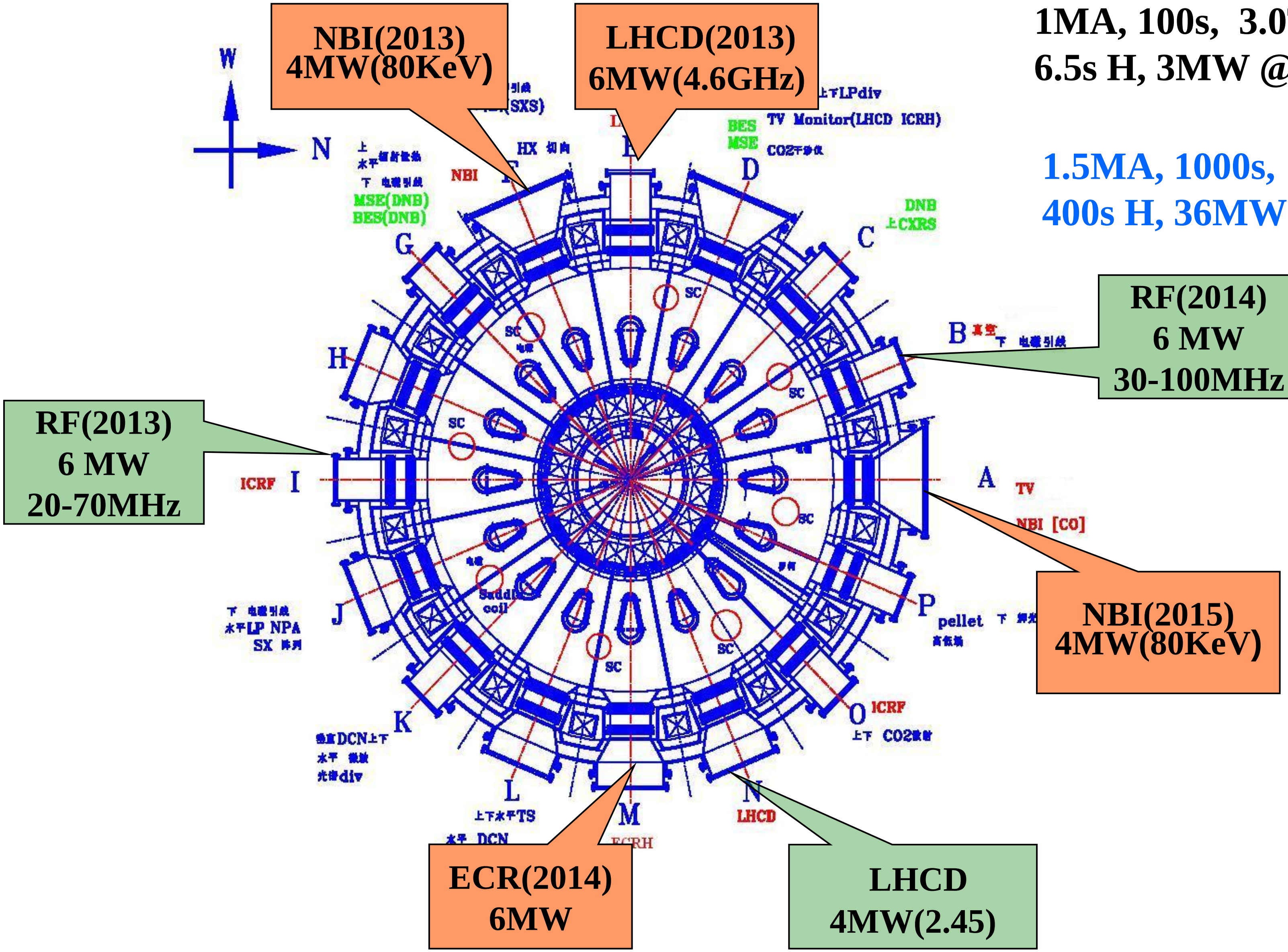
MCF-talent (5, simulation)

MCF-talent (11, material)

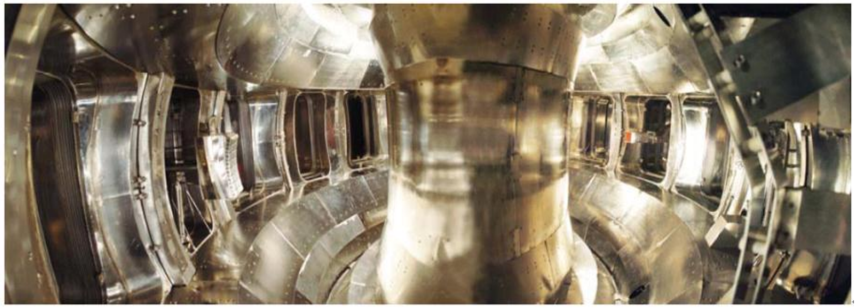
Efforts Made- EAST ATSSO

1MA, 100s, 3.0T
6.5s H, 3MW @2010

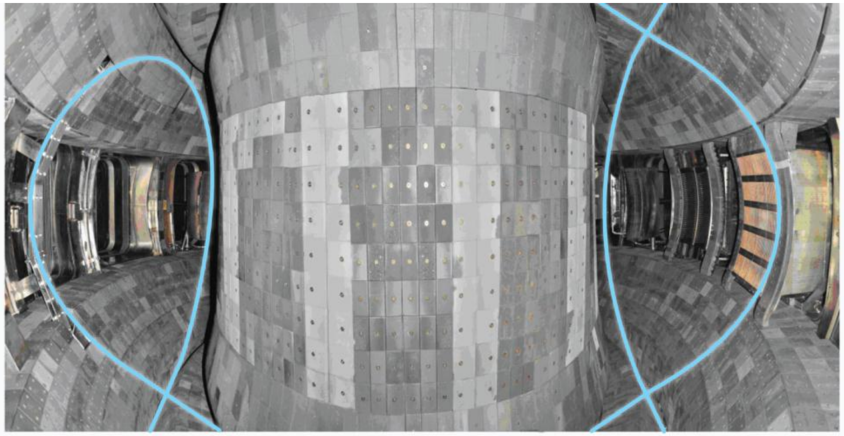
1.5MA, 1000s, 4.0T
400s H, 36MW@2015



Efforts Made- EAST PFC Strategy



Initial phase (2006-2007)



First phase (2008-2013) 200C

HT-7 Full Metal PFC + LL limiter

Low Recycling regime

Plasma-facing Materials and Components (PFMC)

- **Initial phase (2006-2007)**
  PFM ⇨ SS plates bolted directly to the support without active cooling
- **First phase (2008-2013) 200C**
  PFM ⇨ SiC-coated C tiles
  heat flux capability ~2MW/m²
- **Second phase (2014-2016) 300C**
  PFC ⇨ Actively-cooled W/Cu
  heat flux capability of 10MW/m²
- **Last phase (2014-2016) > 400C**
  Full W wall , diverter 10MW/m²
  + possibility of LL Divertor

Low Recycling regime

Very Strong Support from Top Leaders and Public (10,000 visitors to EAST)

Summary

- **China needs fusion more urgent**
- **Starting a small E-DEMO type nuclear device with step by step approach will speed up fusion energy development**
- **Efforts have been made towards this goal**
- **Wide international cooperation is need and your advice and participating are valuable**