Preliminary Consideration on next CFETR

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Ordering 0 issues for next step

Physics:

- **Demonstrating and exploring the burning plasma state**
- **Creating predictable, high-performance steady-state plasmas**
- **Taming the plasma-material interface**
- **Harnessing fusion power**

Engineering:

- **Electricity generation.**
- **Complete T fuel cycle.**
- **SSO or long pulse**
- **Material Validation**
- **Component Validation (As CTF，blanket, divertor)**
- **RAMI for power plant**
- **Necessary date for safety & licensing of power plant.**

Possible Options for CFETR

Electricity generation with reduced mission

- Using JET, JT-60 experiences, complement to ITER
- Have a credible, sensible approach including step by step development path
- Avoid High Cost from beginning
- With a very attractive, derivable milestone.
- With commercial power plant potential.
- 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=100-300MW
- Fission: M= 20-30, Pt = 0.5-2.5GW

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

Option 4 : Same machine with Op.1&2 but with a changeable core.

Option 1：

Step 1: ITER-Hybrid-H mode

R=5m； a=1.5m； k=1.75；

T=4.5K, BT=5T； Ip=8MA；

ne=1-4x$10^{20}$$m^{-3}$；

Beta N : 2.5

Pth: 150MW-300MW

Q=2-5 , t> 8 hour, 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 or High Bt

R=5m； a=1.5m； k=1.75；

T=3.6K, BT=6-10T；

Ip=10-15MA；

ne=2-4x$10^{20}$$m^{-3}$；

Beta N : 3- 4, or 2-3

Pth: 1-1.5GW

T> 8 hour, SSO

Material &Component testing

T breading (TBR>1),

Pure fusion TBM configuration

RH validation, RAMI validation

Close fuel cycle

Plasma performance estimation

- 0D Estimation
- 1D (FDF) estimation
- Using existing exp.data
- Step 1: 150-300MW

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

High field approach (Nb_3Al)

Present normal DIIID data (not best one), relative conservative assumptions

Betan=2，0.8 n_GW. q0~1, q95≥3

Bt0 (Tesla)	6	7	8	10
Ip （MA）	10	11	13	15
Power (MW)	401	626	1085	1859

Betan=3，0.8 n_GW. q0~1, q95≥3

Bt0 (Tesla)	6	7	8	10
Ip （MA）	10	11	13	15
Power (MW)	584	1019	1612	2010

- Better stability
- Qeng will be over unity(Prec~ 350-400MW)
- SSO is still remained (AT， Ip AC or long pulse heat storage approach)

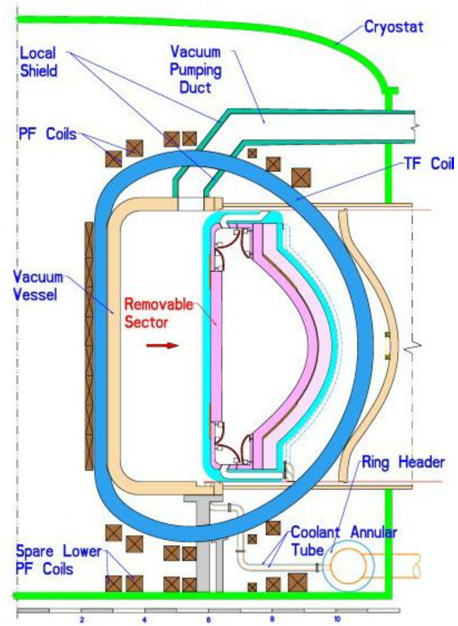
What We Can Do? Bottom up

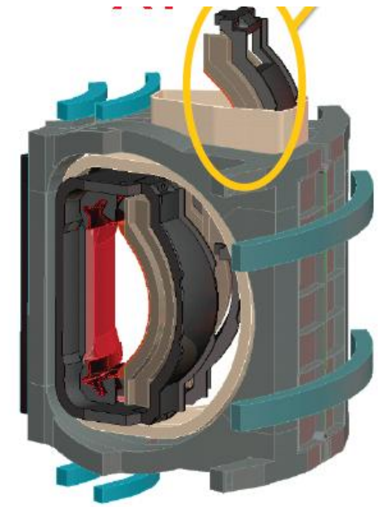
	EAST	JT-60SA	ITER	CFETR	DEMO
Disruption avoidance	**P**	P	MS	5-10 Y	Y
steady-state operation	**P**	P	MS	5-10 Y	Y
divertor performance	**P**	P	P	10-15 Y	Y
burning plasma Q>10	**no**	no	Y	15-20 Y	Y
power plant plasma performance	**P**	P	MS	15-20 Y	Y
T self-sufficiency	**no**	no	no	15-20 Y	Y
materials characterisation	**no**	no	no	20-30 Y	Y
plasma-facing surface interaction	**P**	P	P	10-20 Y	Y
FW/blancket/divertor materials lifetime	**no**	no	no	20 Y	Y
FW/blancket/ components lifetime	**no**	P	P	20 Y	Y
H/CD systems performance	**P**	P	Y	10-20 Y	Y
electricity generation at high availability	**no**	no	no	> 20 Y	Y
superconducting machine	**Y**	Y	Y	5-6 Y	Y
tritium issues	**no**	no	Y	10-20Y	Y
remote handling	**no**	P	Y	10-20 Y	Y
DEMO diagnostics	**no**	P	P	10-20 Y	Y
	2007	2017	2020	025-2030	?
Can we do it? how long?	**yes, now**	2-3Y	5-10 Y	5-10 Y for cons	
				20 years for op	

Built a superconducting R=5/a=1.5 tokamak is one of choice within 5-8 years

Key Technical Issues for this Approach

- **Design: Construction such device will be technically ready but Start RAMI for power plant potential from beginning.**
- **T-plant & Fuel cycle**
- **Two diagnostics options for DT-1 and DT-2 phase**
- **New mythology and technology for RH(blanket, divertor)**
- **High field magnets (CS & TF)**
- **DEMO-like divertor**
- **Blankets (a few options)**
- **VV proto-type**





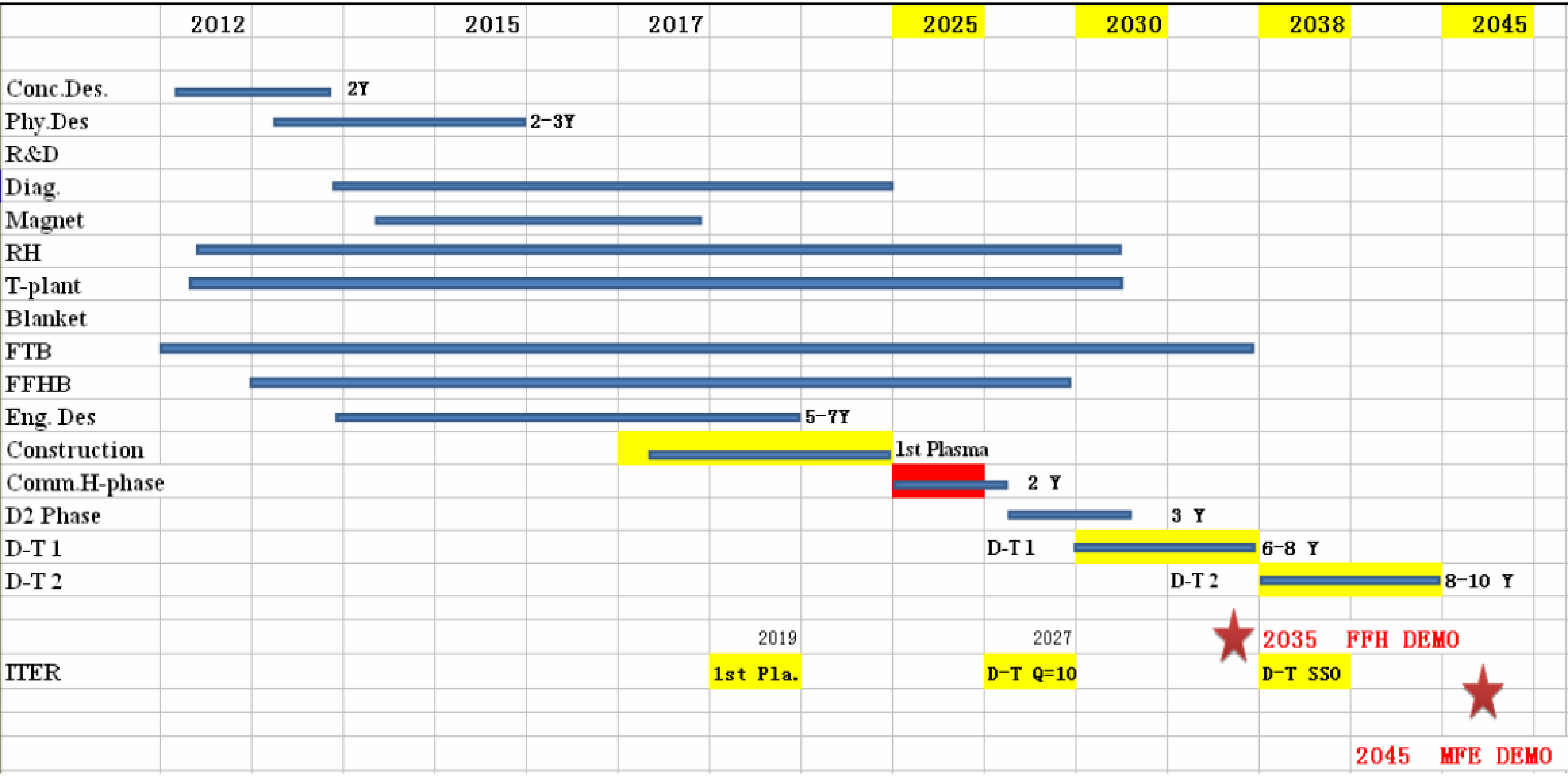
Theory & Simulation

Fusion energy integrate modeling

Validate codes in existing devices, especially under SSO

- Validate in ITER+DT-1

Possible Plan and Schedule



Summary

- **Fusion energy generation, full tritium cycling and power plant potential are key requirements for Chinese next step MFE device.**
- **Built a superconducting 5/1.5 tokomak is foreseeable within 5-8 years**
- **To built such device together with ITER will certainly speed up CN MFE development.**