EAST 5 year physics plan

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Unique features of EAST

- Full superconducting magnets.
- Actively cooled plasma facing components.
- D shape plasma with strong shaping capacity (Limiter, SN, CDN).
- Changeable internal structure for handling steady-state power and particle loads.

→ **Could provide a good facility for international fusion community before ITER starts operation.**

Physics Objective of EAST

- Long sustainment of Full CD hot plasma (~60s) at Ip =1MA.
- Realization of H-mode operation with reasonably high performance (β_N>2, H_{89}>2) for pulse length up to 30s.
- Long sustainment of high beta (β_N>3) plasma for 20s (wall saturation time).
- Divertor optimization (compatibility with high δ and β, Doped C PFC, actively cooled PFC, long particle exhaust).

Two phases of operation

	phase I 2007-2009	phase II 2010-2011
B_0	2-3.5	3.5
I_P(MA)	0.5-1	1
R_0(m)	1.90	1.90
a(m)	0.45	0.45
K_x	1.2-1.5	1.5-1.7
δ_x	0.2-0.3	0.3-0.7
ICRH(MW) CW	1.5(30-110) 4.5（20-55）	4.5(30-110MHz) 4.5(20-50MHz)
LHCD(MW) CW	2(2.45GHz) 4 (3.7GHz)	2(2.45GHz) 4(3.7GHz) 4(4.6GHz)
NBI(MW) >100s	0	4(40-80keV)
pulse length(S)	1-60	10-100
Configuration:	limiter, DN,SN	Internal cryo-pump DN, SN

EAST 5 Year Operation Program

	2007	2008	2009	2010	2011
Hardware and tool development					
RF	30-110MHz/1.5MW	----------	30-110MHz/4.5MW	----------	
		20-55MHz/4.5MW	----------		
LH	2.45GHz/2MW	----------			
			3.7GHz/4MW	----------	
				4.6GHz/4MW	
NBI				40-80kV/5MW	
Diagnostics:					
For operation and protection			For physics understanding		
Full Metal PFC		Full C PFC with actively cooling & internal cry-pump			
Shaping & real-time EFIT					
Density, impurity and temperature control					
		Integration&sustainment		Performance optimization	
SSO Demonstration Ip=0.5-1.0MA, t = 30s			t = 60s	t = 100s	
Scenarios Development		$\beta_N H_{89}$~ 2-3	$\beta_N H_{89}$~ 3-4	$\beta_N H_{89}$~ 4-6	

Providing useful information for ITER --Plasma Control

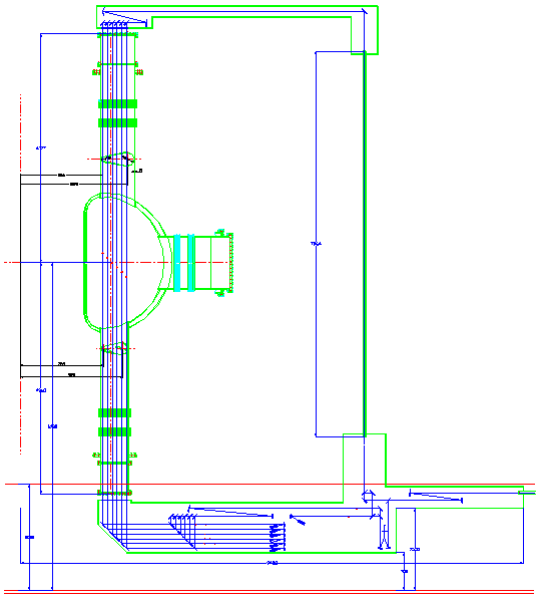
- **Equilibrium, shape and position for SC tokamak in close cooperation with GA PCS group.**
- **By using PF coils+ internal fast feedback coil, develop state-of-the-art simulations and models for real-time and steady-state condition with external heating.**
- **Real time data acquisition for steady-state condition.**
- **Toroidal field ripple and fast particle losses:**

  Ferromagnetic material with ripple 2.7% to less than 1%.
- **MHD Instabilities: tailoring J(r) by LHW,IBW, NBI, RF.**
- **Disruption mitigation: Ar, Ne puff (GP, MBI), killer pellets**
- **Profile controls**

  n_e: NBI, ICRF, IBW, pellet, SMB

  $T_e(T_i)$: LHCD, IBW, NBI, ECRH, MCCD, ICRF

Steady-state Diagnostics(I)
Machine operation and protection



DCN laser interferometer/polarimetry:
Laser Output power: > 200mW
Continuous operation: > 15 days
6 channels
First interferometer for density control
Later upgrade to polarimetry for current density control

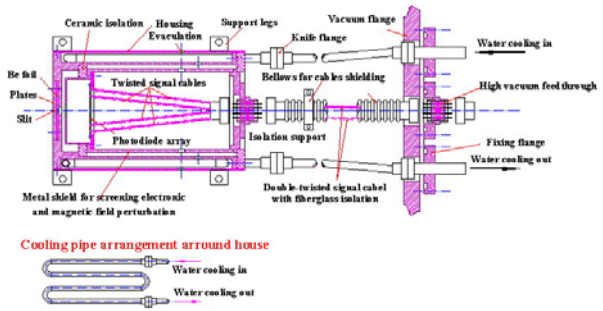
For machine operation & protection:

- **Magnetics**
- **FIR interferometer**
- **Vis TV**
- **IR TV**
- **H_α/ D_α monitors**
- **UV-vis monochromators**
- **Thermocouple**
- **Vacuum gauges**
- **HXR**

Steady-state Diagnostics(II)
Physics understanding

Main plasma parameters:

- **Magnetics (I_p, β_P, li…)**
- **FIR(HCN) interferometer**
- **YAG laser TS**
- **CER**
- **bolometers**
- **Zeff (VB array)**
- **Visible-VUV spectroscopy**
- **Diverter diagnostics (Langmuir probe arrays, bolometry, IRCCD, fast gauge etc)**



Actively cooled SXR array for SSO

For Physics Understanding:

- **ECE (Heterodyne radiometer)**
- **μW reflectrometer**
- **ECE imaging**
- **Fast moving probes**
- **Manual moving probes**
- **μW reflectometer**
- **Neutron**
- **HX-PHA arrays**
- **SX-arrays**
- **CO2 collective scattering**
- **Hα/ Dα spectroscopy**
- **Fast Hα/ Dα fluctuation**
- **Fast loss ion monitor**

All diagnostics should meet long pulse operation requirements

Typical long pulse operation scenarios

- **Hybrid(30s):**
- **Ip=1.0MA, D Plasma, B_T=3.5T; q*=3.4, ne=5x10^{19}, H=2, R=1.95m, a=0.45m, κ=1.6, δ =0.6,**
- **4MW LH, 4MW RF**
- **f_b (I_b / Ip) ~0.28**
- **β_N ~1.56**
- **W (MJ) ~1.02**

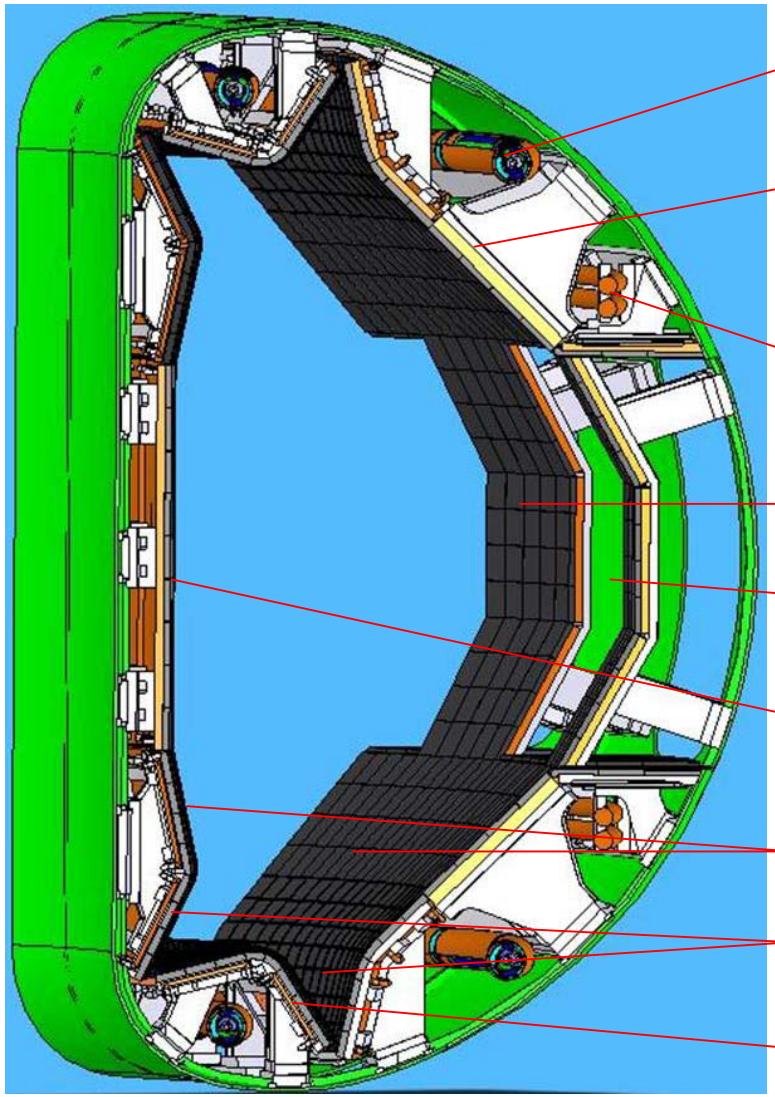
- **Steady-state(60s):**
- **Ip=0.5MA, D Plasma, B_T =2T; q*=3.4, ne=3x10^{19}(~0.56n_{GW}), H=2, R=1.95m, a=0.45m, κ=1.6, δ =0.6,**
- **4MW LH, 4MW RF**
- **f_b (I_b / Ip) ~0.9**
- **β_N ~ 4.3**
- **W (MJ) ~0.3**

Advanced Tokamak Research Thrusts

- **Extend pulse length to steady-state condition with fully non-inductive current drive (LHCD + Bootstrap).**
- **Profile Control via LHCD, IBW,MCCD, ICRH at the time scale well beyond wall saturate time.**
- **Understanding, control and sustainment of Internal Transport Barriers, with Ti ~Te and no momentum input.**
- **Divertor optimization by large plasma shaping, with good power and particle handling structure.**
- **Advanced PFM and Wall conditioning technique for tokamak reactor.**
- **Advanced diagnostics.**

Actively cooled PFC

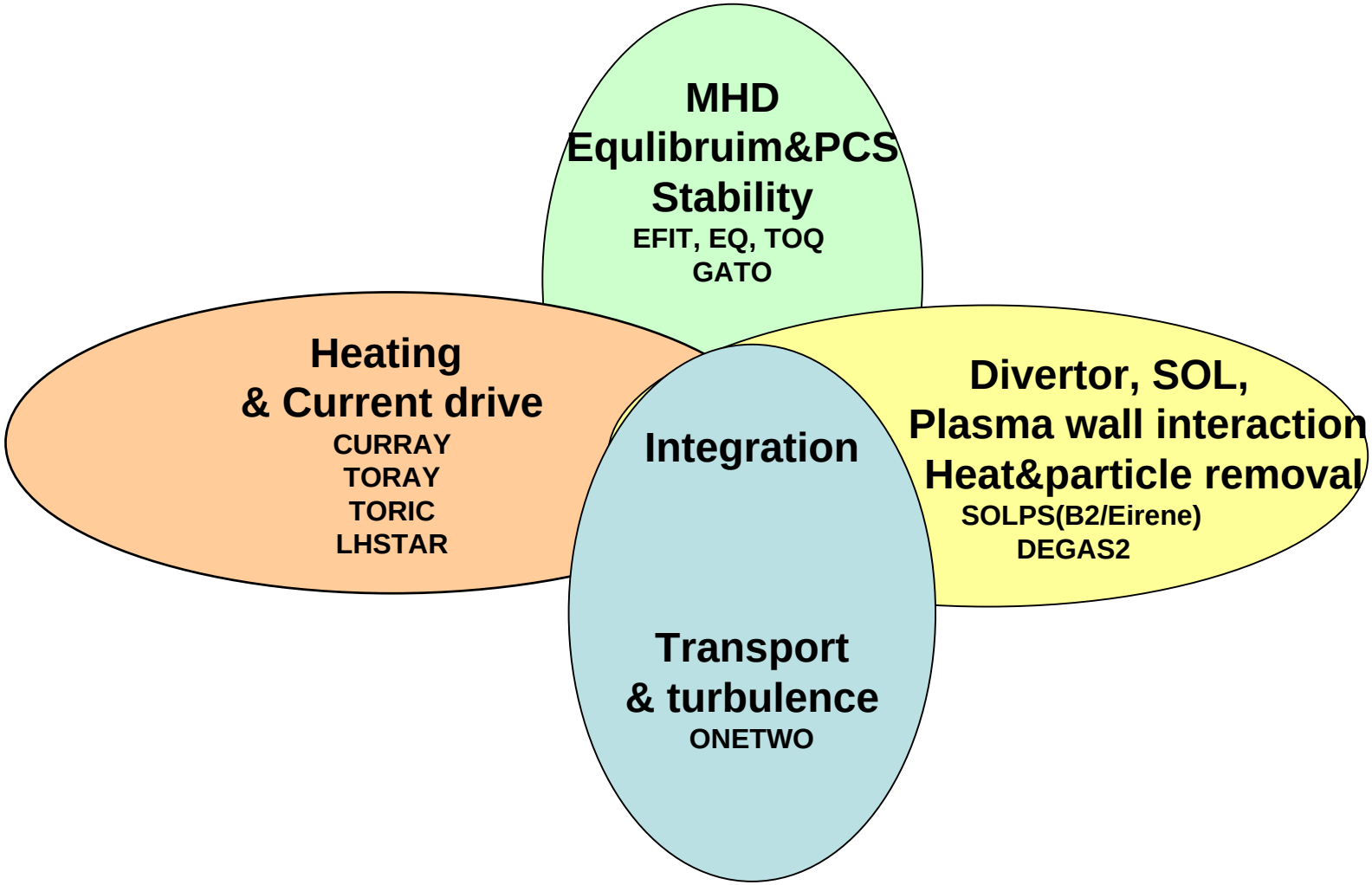
- For different phases of EAST, different PFMs will be selected.
- In the present, initial phase (-2006), PFM is SS plate bolted to the support.
- In the first phase (2007-2008) with nominal heating (max. heat flux onto divertor ~ 3.5 MW/m^2), PFMs will be mainly SiC-coated doped graphite bolted to Cu heat sink .
- In the second phase (2009-) with upgraded heating (max. heat flux onto divertor ~ 7 MW/m^2), PFCs will be W/Cu and, possibly, partial W/Fe.



Plasma wall interaction in Long Pulse AT operation

- **Understand flows and exchanges of fuel and impurity particles between plasma and facing materials for fuel and impurity control.**
- **RF wall conditioning techniques in divertor devices for ITER (cleaning, isotopic control, boronization).**
- **Develop RF Tritium removal techniques that could be applicable to ITER.**
- **Steady-state erosion and redeposition.**
- **In-situ control of T-codeposition and migration by surface temperature control.**
- **Life time of graphite and W under SSAT operation.**

Try to build a close coupling between theory and experiments



Challenges

- Safely operating full superconducting magnets.
- Continuous heating and current drive techniques.
- Steady-state operation and real-time control.
- Heat and particle removal in steady-state condition.
- Achieving steady state H-mode operation.
- Good prediction for experiments and experimental data analysis.

Wide international cooperation needed

EAST could provide a unique opportunity for the world-wide fusion community :

- **Evolution of current profile on the time scale much longer than the resistive time in MA tokamak plasma.**
- **Behavior of transport barriers in the steady-state operation mode.**
- **MHD stability on the steady-state base .**
- **A wide international cooperation is urgently needed for plasma control, diagnostics, heating & current drive, theory and simulation, physics understanding.**

Education of young generation

- There are nearly 140 young stuff scientists and 250 students who are under 35 years old.
- We are lack of experienced advisers.
- We are going to send many good young persons to foreign labs for further education.
- Establish a international advisory group for training students via internet.
- Assign good and interesting topics to young stuff and students.

Summary

- EAST starts operation after successfully completing the construction and commissioning.
- With full superconducting coils, actively cooled PFC and D shape plasma, EAST could provide a unique facility for world fusion community.
- Wide range cooperation is needed for providing important research results for future ITER operation.
- Helps and supports from world fusion community are welcome and highly appreciated.

Thanks