EAST Current Status and Future Plans

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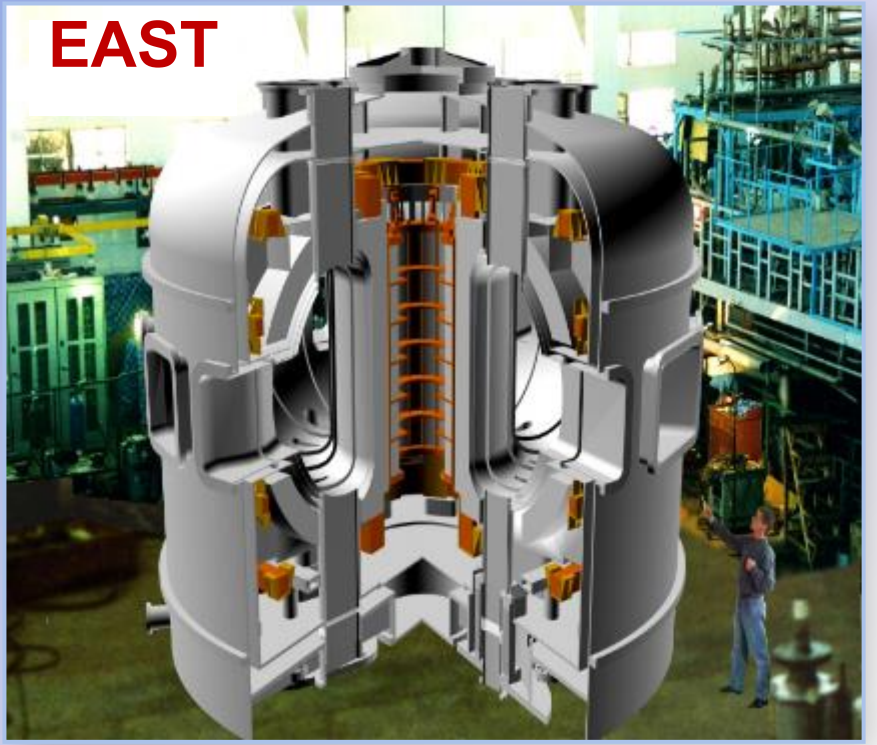
(for Jiangang Li)

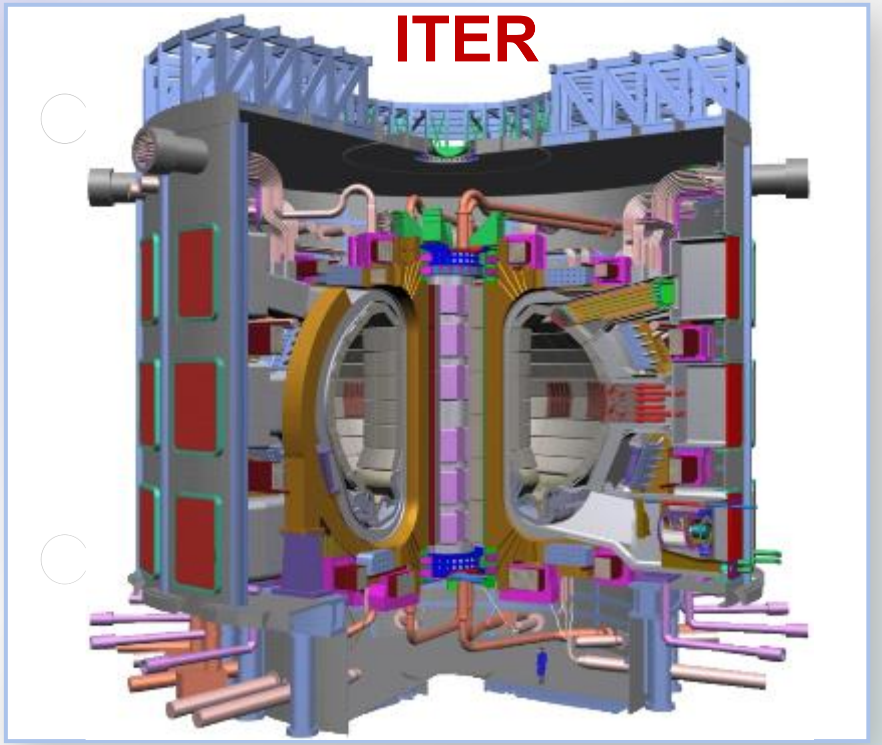
FESAC Strategic Planning Meeting,
July 8-10, 2014, Gaithersburg, MD

Outline

- Introduction of EAST
  (Experimental Advanced Superconducting Tokamak)
- Recent Progress on Long Pulse Operation
- EAST Capabilities & Future Plans

EAST Has ITER-Like Configuration and Heating Scheme



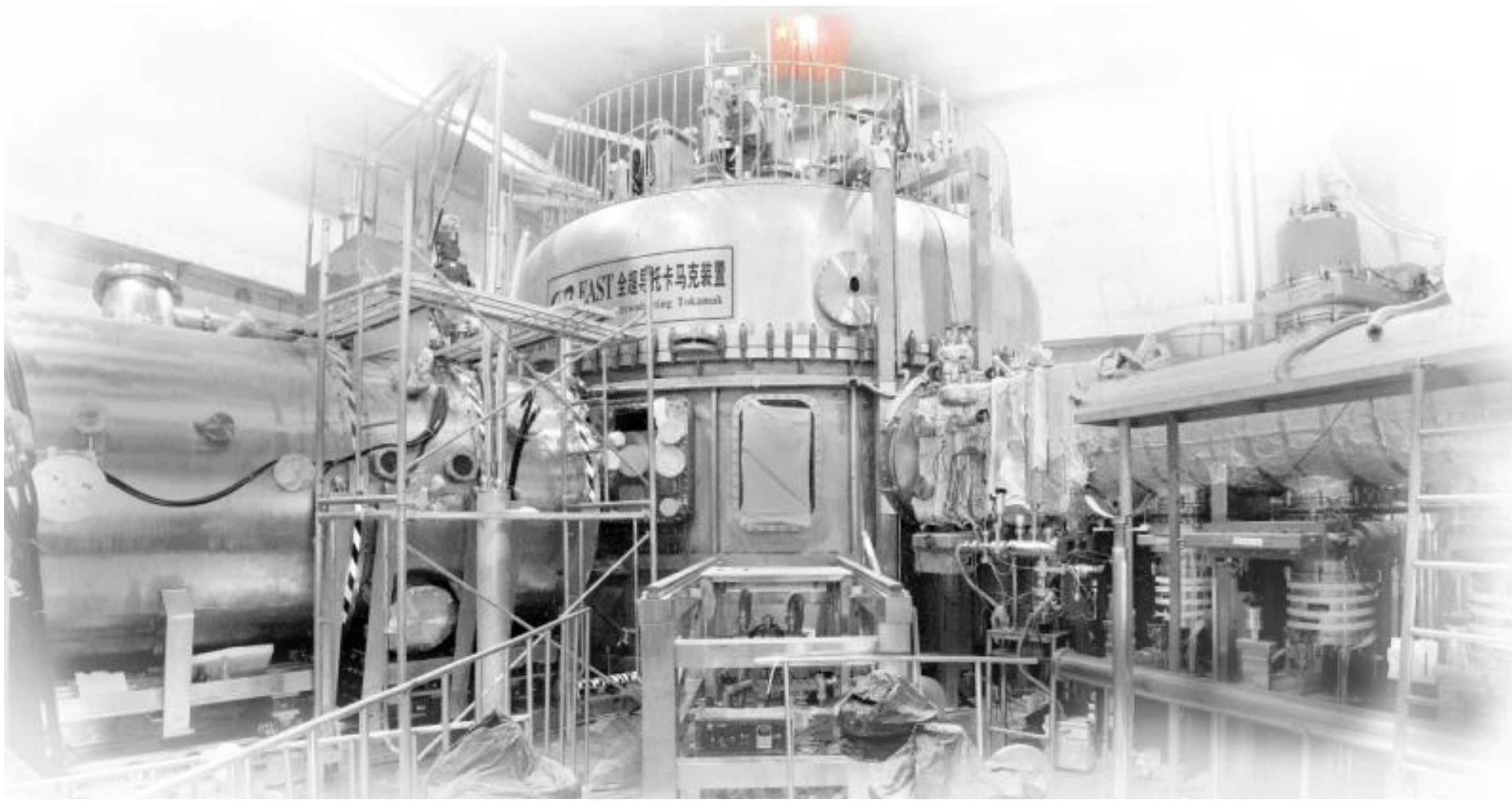


R = 1.9 m, a = 0.5 m, t = 1000 s
I_p = 1 (1.5) MA, B_T = 3.5 (4) T
Single /Double null

R = 6.2 m, a = 2 m, t = 400 s
I_p = ~15 MA, B_T = 5.3 T
Single null

Mission of EAST

- Demonstrate high power, long pulse plasma operation.
- Understand advanced SS plasma physics.
- Contribute to physics & engineering basis for ITER & CFETR



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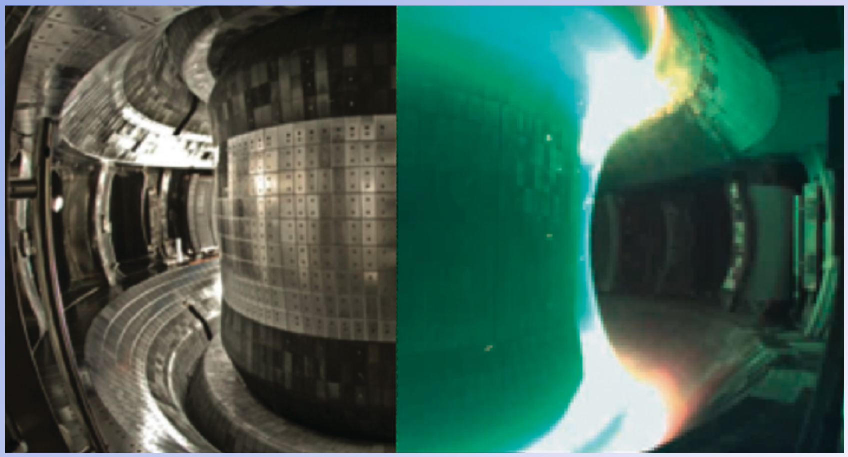
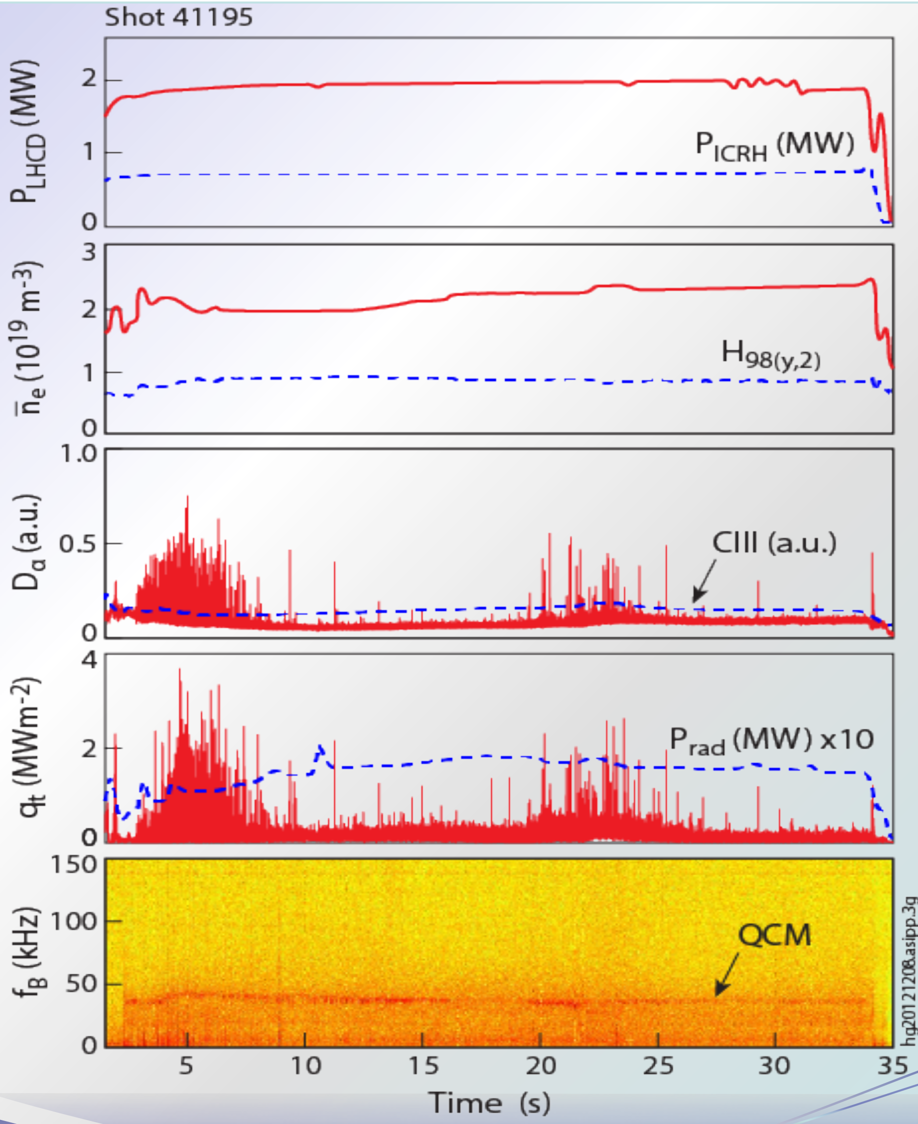
Achieved a New Long Pulse H-mode with Predominant LHCD





- Enabled by Lithium coating and LHCD.
- Small ELMs with good confinement (H_{98}~0.9).
- Target heat load is largely below 2 MW/m^2.

J. Li et al., Nature Phys. **9**, 817 (2013)

Achieved a New Long Pulse H-mode with Predominant LHCD

nature physics

ARTICLES

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A long-pulse high-confinement plasma regime in the Experimental Advanced Superconducting Tokamak

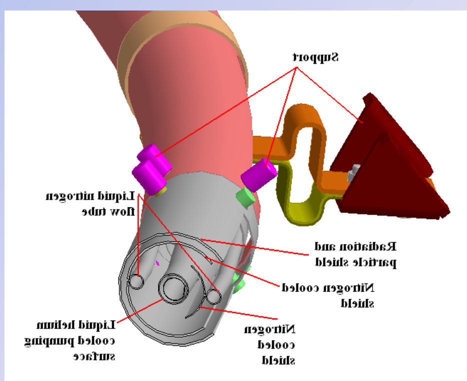
J. Li[1], H. Y. Guo[1,2]*, B. N. Wan[1], X. Z. Gong[1], Y. F. Liang[1,3], G. S. Xu[1], K. F. Gan[1], J. S. Hu[1], H. Q. Wang[1], L. Wang[1], L. Zeng[1], Y. P. Zhao[1], P. Denner[3], G. L. Jackson[4], A. Loarte[5], R. Maingi[6,7], J. E. Menard[6], M. Rack[3] and X. L. Zou[8]

High-performance and long-pulse operation is a crucial goal of current magnetic fusion research. Here, we demonstrate a high-confinement plasma regime known as an H-mode with a record pulse length of over 30 s in the Experimental Advanced Superconducting Tokamak sustained by lower hybrid wave current drive (LHCD) with advanced lithium wall conditioning. We find that LHCD provides a flexible boundary control for a ubiquitous edge instability in H-mode plasmas known as an edge-localized mode, which leads to a marked reduction in the heat load on the vessel wall compared with standard edge-localized modes. LHCD also induces edge plasma ergodization that broadens the heat deposition footprint. The heat transport caused by this ergodization can be actively controlled by regulating the edge plasma conditions. This potentially offers a new means for heat-flux control, which is a key issue for next-step fusion development.

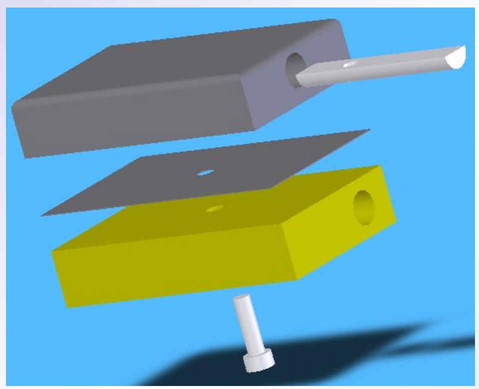
With international collaborators from Germany, USA, France and the ITER Organization.

Achieved Long Pulse Operation over 400s with LHCD

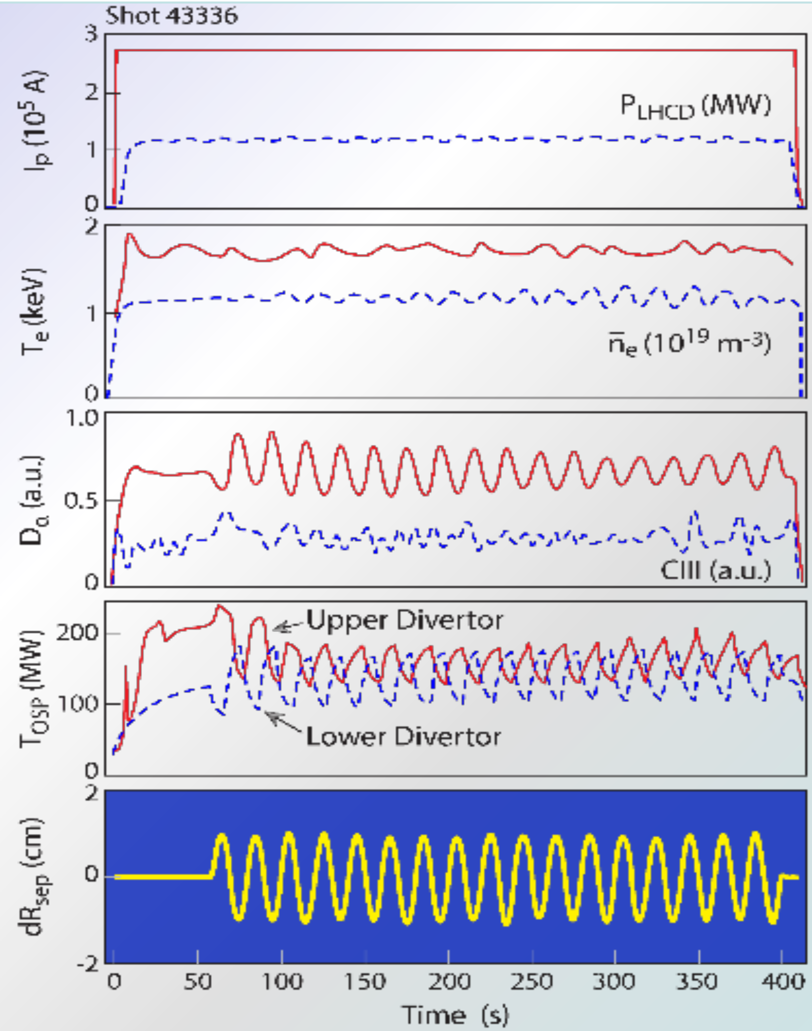
- **Control recycling**: Li coating.
- **Particle exhaust**: divertor pumping.
- **Power exhaust**:
  - Active water cooling,
  - Alternating divertor configurations,
  - Strike point sweeping.



Divertor cryopump (~76 m^3/s for D_2)

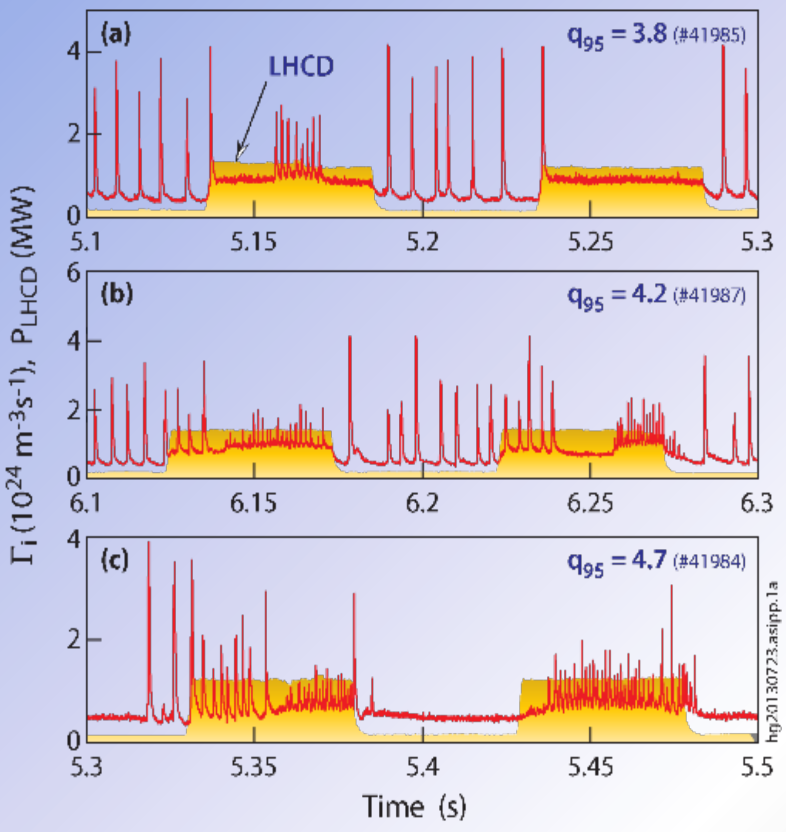


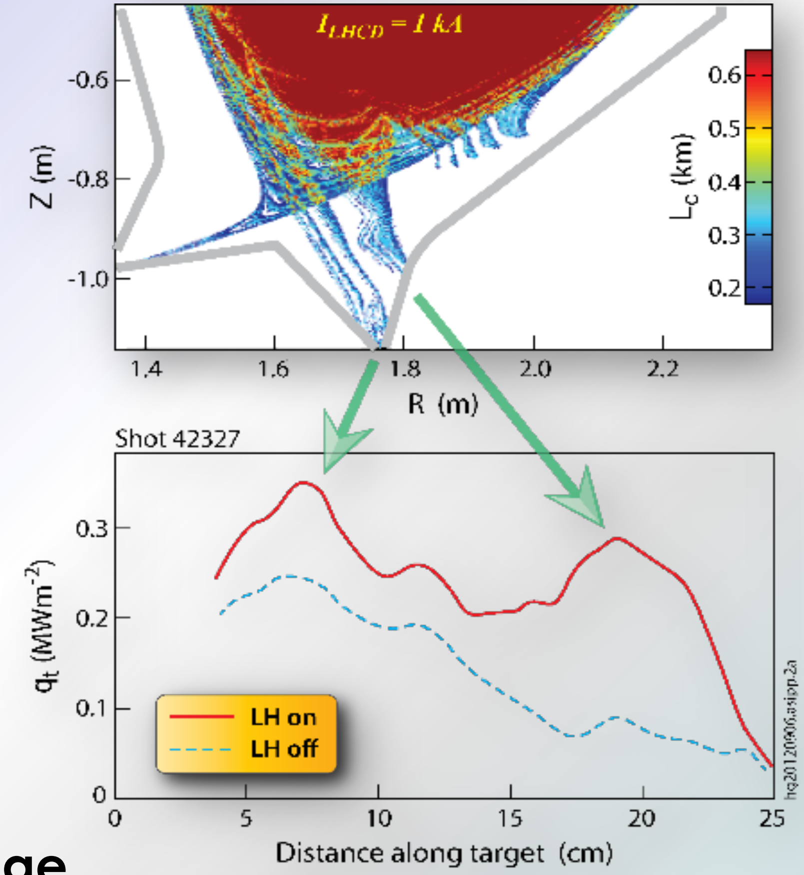
Actively cooled PFC (SS heat flux 2MW/m^2)



H. Y. Guo et al., Nucl. Fusion **54**, 013002 (2014)

Achieved ELM mitigation with LHCD-RMP over a wide range of q_{95}



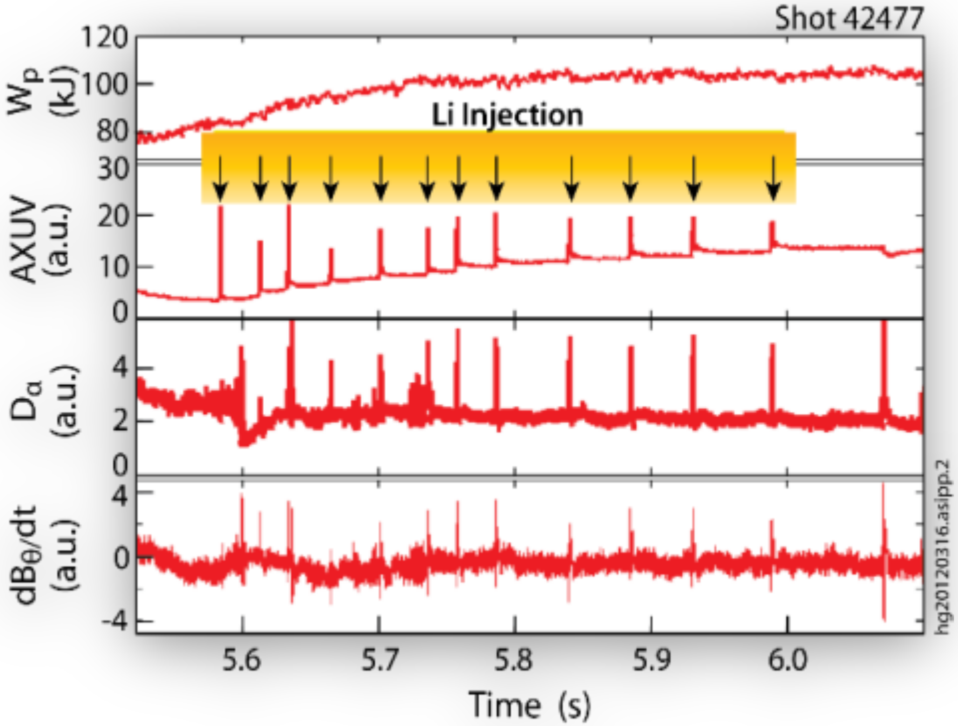


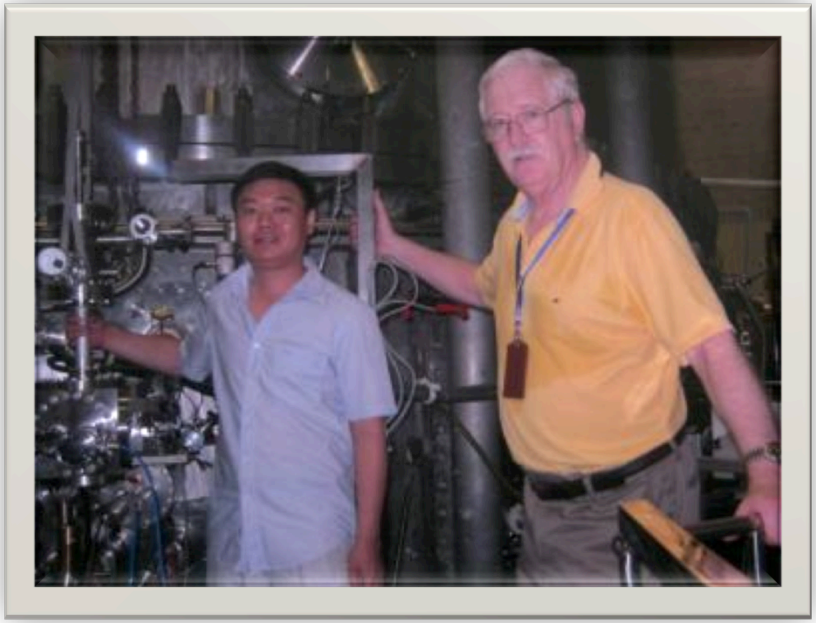
- LHCD drives n=1 helical currents at edge, leading to 3D distortion of magnetic topology, similar to RMP.
- Also facilitates steady-state heat control by broadening heat deposition.

Y.F. Liang et al., Phys. Rev. Lett. 110, 235002 (2013)

Demonstrated for the 1st time ELM Pacing by Innovative Li-pellet Injection

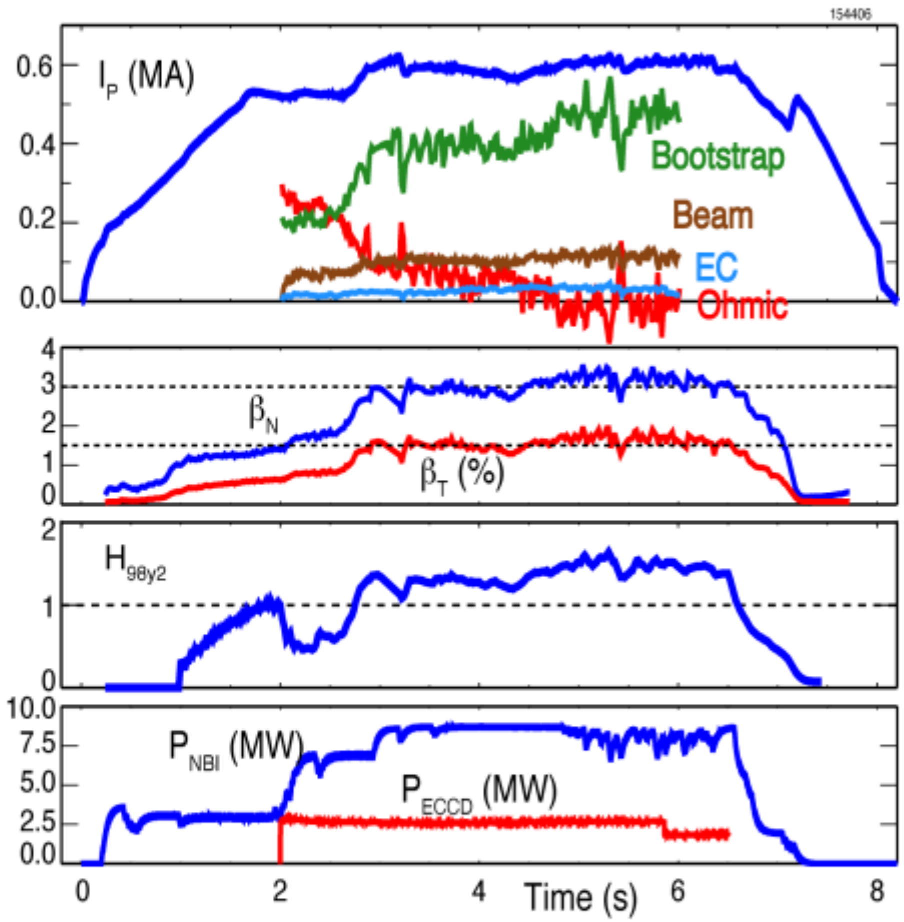
D. Mansfield et al., Nucl. Fusion **53**, 113023 (2013).





- Triggering ELMs (~25 Hz) with 0.7 mm Li Granules @ ~45 m/s.
- Each pellet triggers an ELM during ELM free phase after L-H transition.

Joint DIII-D/EAST Experiment Developed Fully Non-inductive Scenarios for Steady-state H-mode Operation on EAST



- **High bootstrap fraction >80% with β_N ≥3 and q_{95} ~10.**
- **Excellent energy confinement quality H_{98y2}~1.5.**

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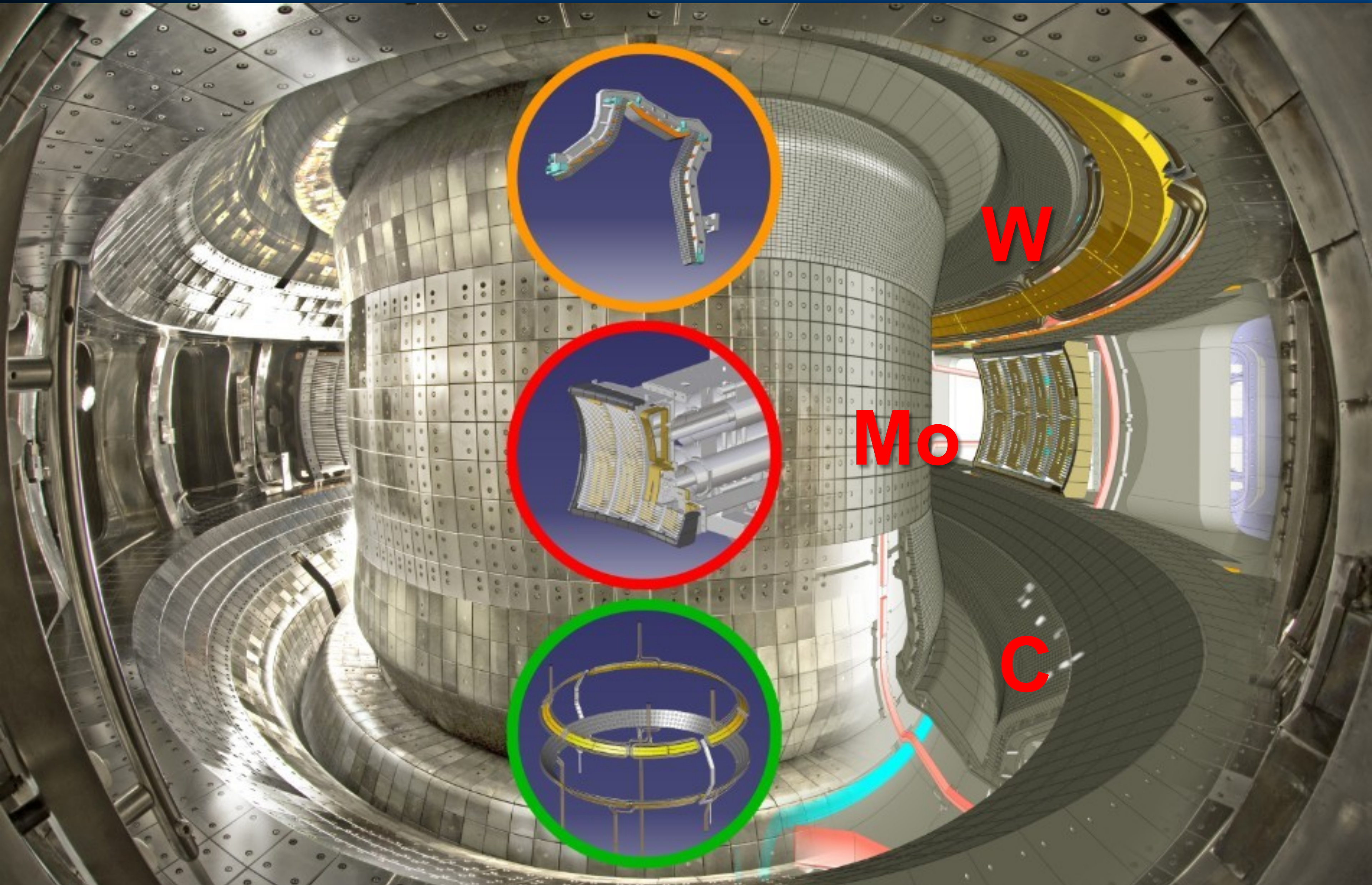
Newly Upgraded PFCs



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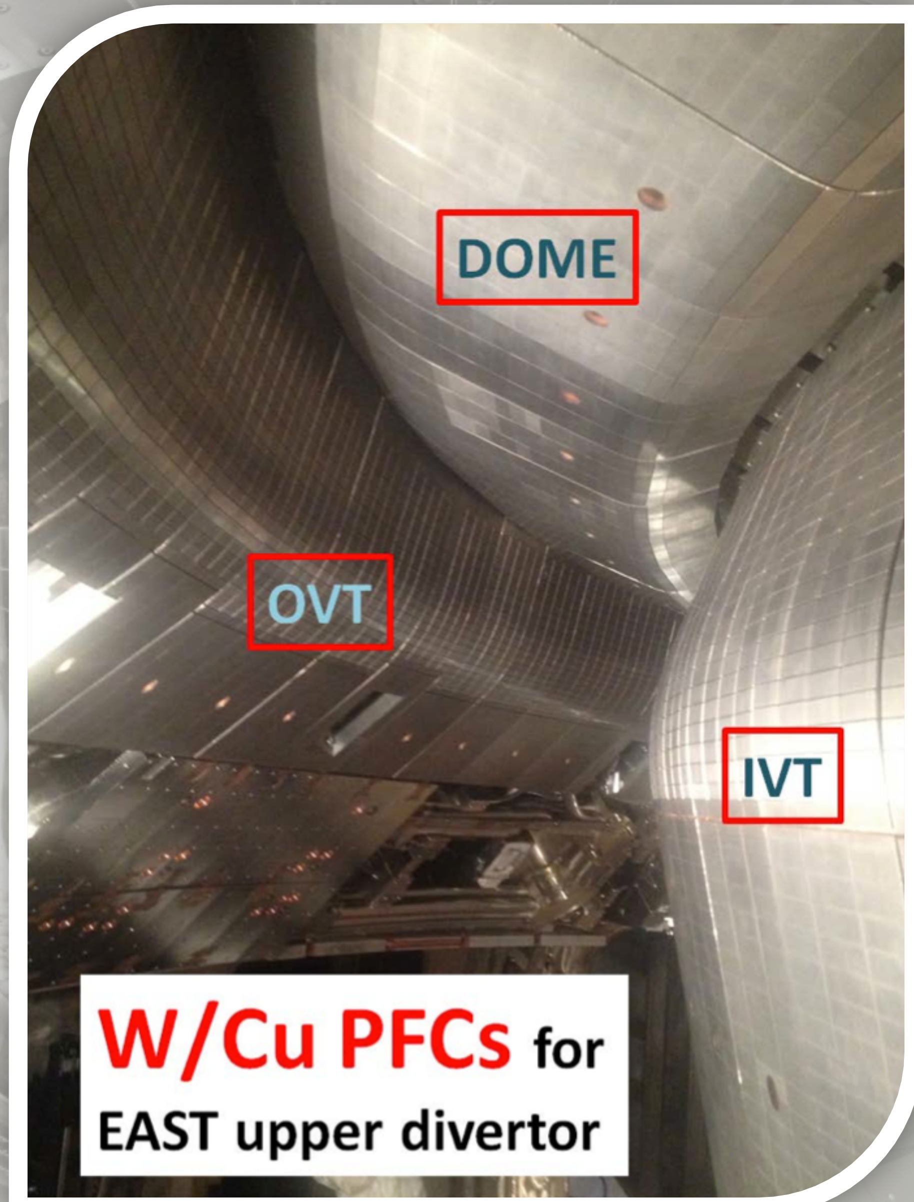
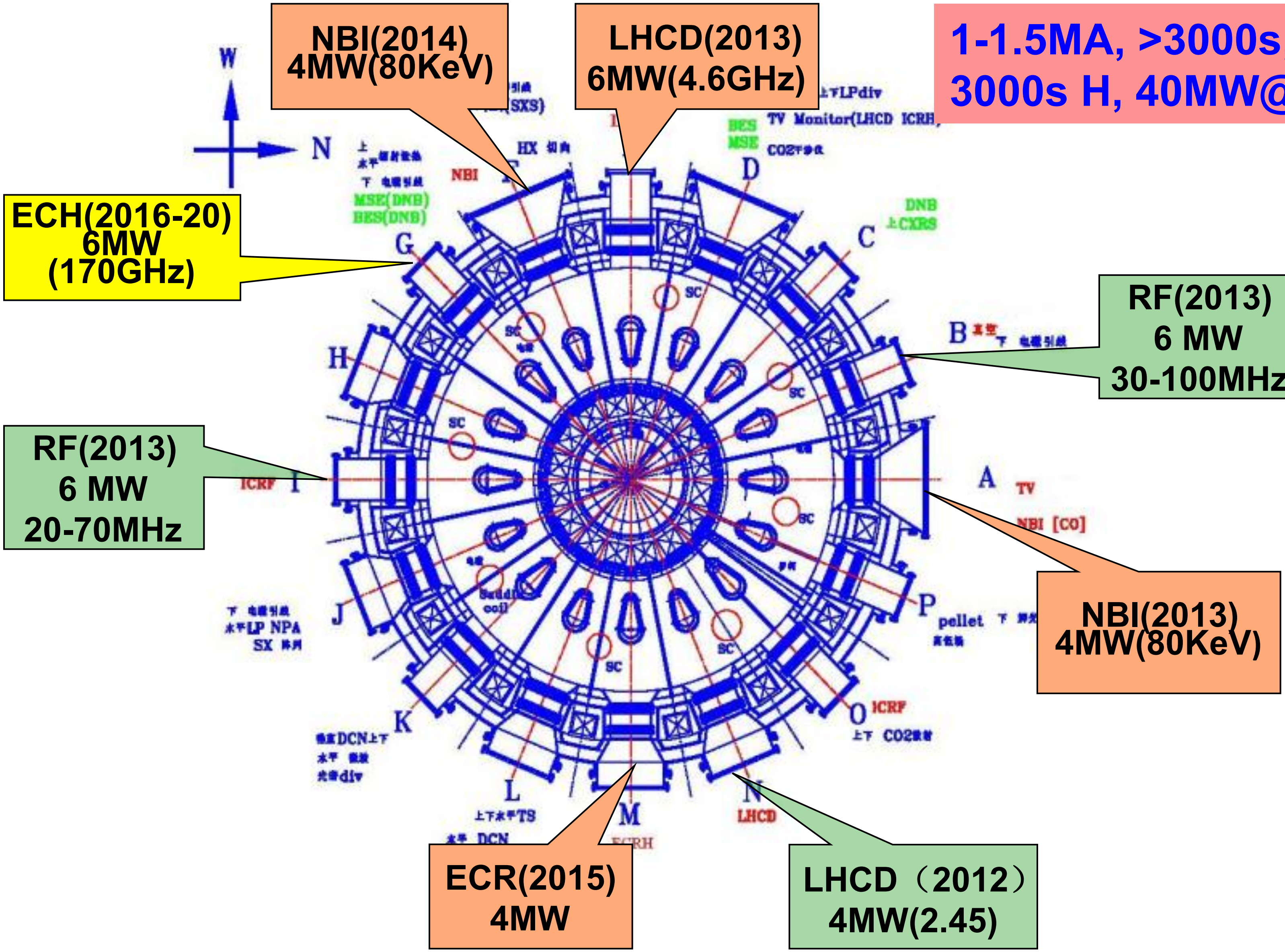


Current Drive and Heating



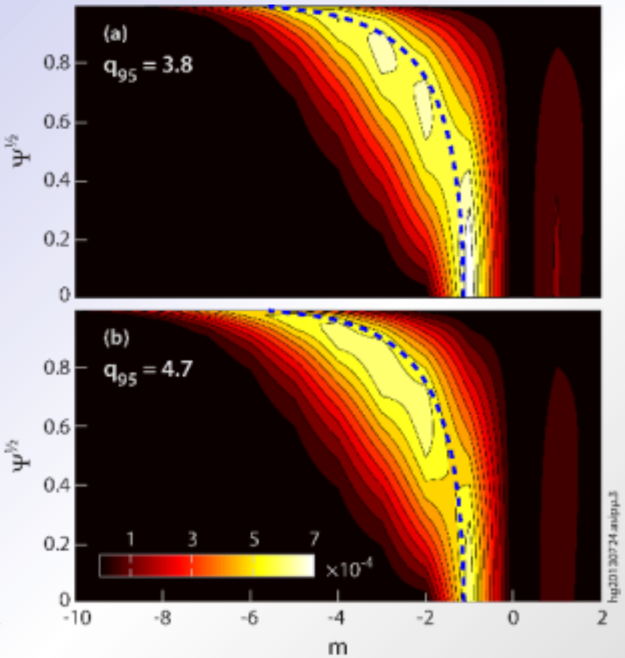
1-1.5MA, >3000s, 3.5-4T, 3000s H, 40MW@2018

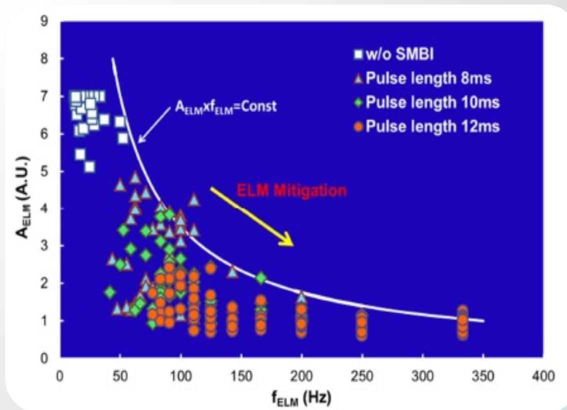
Diagnostics (total 78)

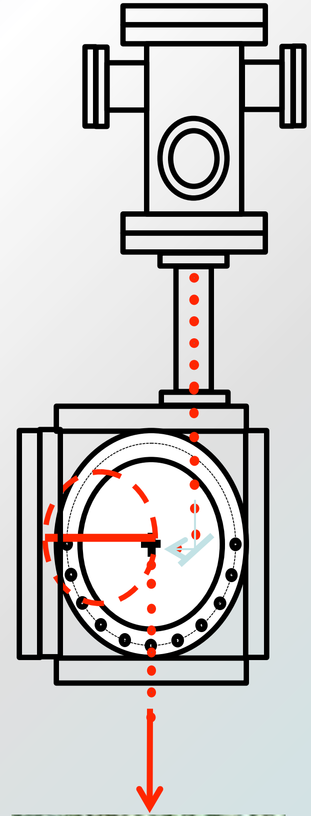
Function	Plasma specification
Plasma rotation profile	Core: XCS (solid D), CXRS Edge: Hot-He beam (5mm, 50kHz,Ti>20eV, >1km/s); ERD(P&T), Edge-CXRS reciprocating probe
q profile/ j relaxation	P: 3 beam Polarimetry-Interferometry System (9ch. H); MSE (2014) B: SXR+EFIT reconstruction
Fusion product Neutron flux spectrum	3He + BF3, Fission chamber BC501 array (3ch)+
Lost ions	sFLIP, H-NPA, FIDA (active and passive, S&f,4cm)
Fluctuation (Te & Ne, V)	Core: CO2 laser scattering (CTS), ECEI (Te, 16ch×26ch, 2.5-2.8T) Polarimetry-interferometry (Ne), Poloidal and radial correlation reflectormeter Edge: Li-BES (Ne/r2cm,p1cm); DBS reflectormeter(Ne/V_E); GPI (Ne, 2mm, 400k); Hot He –beam (100K); Fast CCD; MW reflectormeter; ME-SXR (Te, slow); Reciprocating probe+HFS probe
MHD instability Lock mode (MHD)	ECEI (16ch×16ch, 2.5-2.8T), 2D T-SXR camera, Mirnov coil SXR camera, Tang. SXR, Saddle coil
Runaway behaviors	Midplane: BGO + NaI (Forward+backward), IR camera NaI array (5ch) + CdTe + BGO array (4ch)
Edge plasma parameters RF sheath behavior	Reciprocating probe, Bolometer, Tri-probe, Mach probe, Ha/Da, GPI Katusmata probe, Microwave reflectormetre

ELM Control Tools

- **RMP Coils**
- **LHCD–RMP**
- **Pellet pacing**
- **Slow speed Li injector**
- **Supersonic gas injection**







Plans for Next 5 Years

	2014	2015	2016	2017	2018
Ip(MA)	1	1	1	1.5	1.5
LHCD (MW), 2.45 GHz	4	4	4	4	4
LHCD (MW), 4.6 GHz	6	6	6	6	6
ICRF (MW), 25-70MHz	12	12	12	12	12
NBI (MW), 80 KeV	8	8	8	8	8
ECRH (MW)	1	2	4	6	10
Diagnostics	60	80	80	80	80
Duration (s)	400	1000	1000	1000	1000
H-mode (s)	100	400	400	1000	1000
β_N	2	2-3	2-3	2-3.5	2-3.5

With over 30MW CW power and 80 diagnostics, EAST will play a key role in the quest for long pulse advanced high performance plasmas for ITER within next 5 years.

Challenges for Next 5 Years

- Control of ELMy-H modes >400s (profile , RMP, wall control).
- Power handling (>10MW/m^2) and particle control.
- Integration of PMI and high performance core plasmas.

EAST – Tested for ITER

Summary

- EAST has made significant progress on both physics and engineering fronts towards high power, long pulse operation, in collaboration with the world fusion community.
- EAST 2014 campaign aims at high performance long pulse (~ 400s) discharges with >20 MW CW H&CD, ITER-like mono-block divertor with power handling capability of >10 MW/m^2.
- EAST will face major challenges in ELM control and PMI under long-pulse (400-3000s), ITER-relevant conditions within next few years.
- EAST has built productive and exciting partnerships with the US fusion community, will continue and promote further collaborations in the future.

Thank You!

谢谢！