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Development of Quiescent H-mode Scenario with ITER Like Tungsten Divertor in EAST

J. Qian[1], A. Garofalo[2], X. Gong[1], B. Zhang[1], T. Shi[1], L. Zeng[1], Q. Ma[1], L. Xu[1], J. Huang[1], C. Holcomb[3], D. Weisberg[2], M. Wu[1], J. Chen[1], L. Zhao[1], S. Ding[1], Q. Zang[1], B. Lyu[1], H. Liu[1] and Y. Sun[1]
[1]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China
[2]General Atomics, San Diego, California, USA
[3]Lawrence Livermore National Laboratory, Livermore, California, USA
Email: jpqian@ipp.ac.cn

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ABSTRACT

- For the first time, EAST experiments have achieved stationary quiescent H-mode scenario under the condition of low torque and pure RF injection (true zero torque) with ITER like tungsten divertor.
- Stationary QH-mode over 50-80 energy confinement time or 3-6 current relaxation time with the energy confinement close the standard ELMy H-mode confinement scaling (H_{98y2} ~1.0) by using counter neutral beams.
- Experiments also shows this ELM-free regime can be operated using more balanced neutral beam injection at lower torque ($T_{in\ j}$~ -0.5 Nm).
- Using the n=2 non-axisymmetric fields, EAST recently achieved the QH-mode with the RF only heating, where ELMs completely disappeared and were replaced by the quasi-coherent/broadband MHD fluctuations.

BACKGROUND

- The high confinement mode (H-mode) is associated with a formation of an edge transport barrier (ETB). Plasmas operating in this regime may drive large edge localized mode (ELM) with the burst of heat load and particles to the divertor periodically.
- Quiescent H-mode operates H-mode confinement, controlled density, without ELMs, thus a promising scenario for future devices.
- The additional particle transport driven by the edge harmonic oscillations (EHO)/broadband allows the plasma edge to reach a transport equilibrium at edge pressure and current density below the ELM stability boundary.
- The QH-mode is usually obtained with the counter neutral beam injection (NBI) torque or sing non-axisymmetric fields (NRMFs) to generate large edge plasma rotation and rotation shear for creating and sustaining the EHO.

DEVELOPMENT OF QH-MODE WITH NEUTRAL BEAMS

- An example of QH-mode by using two counter NBs was obtained with ITER-like tungsten divertor.
- The ELM-free sustained around 3 seconds, more than five times the current profile relaxation timescale.
- The energy confinement factor, H_{98y2} is close the standard ELMy H-mode.
- The fundamental EHO frequency (~60kHz n=-1) and the upper frequency (~120kHz n=-2) are clearly seen.
- The divertor heat flux confirms the plasma accessed the ELM-free regime.

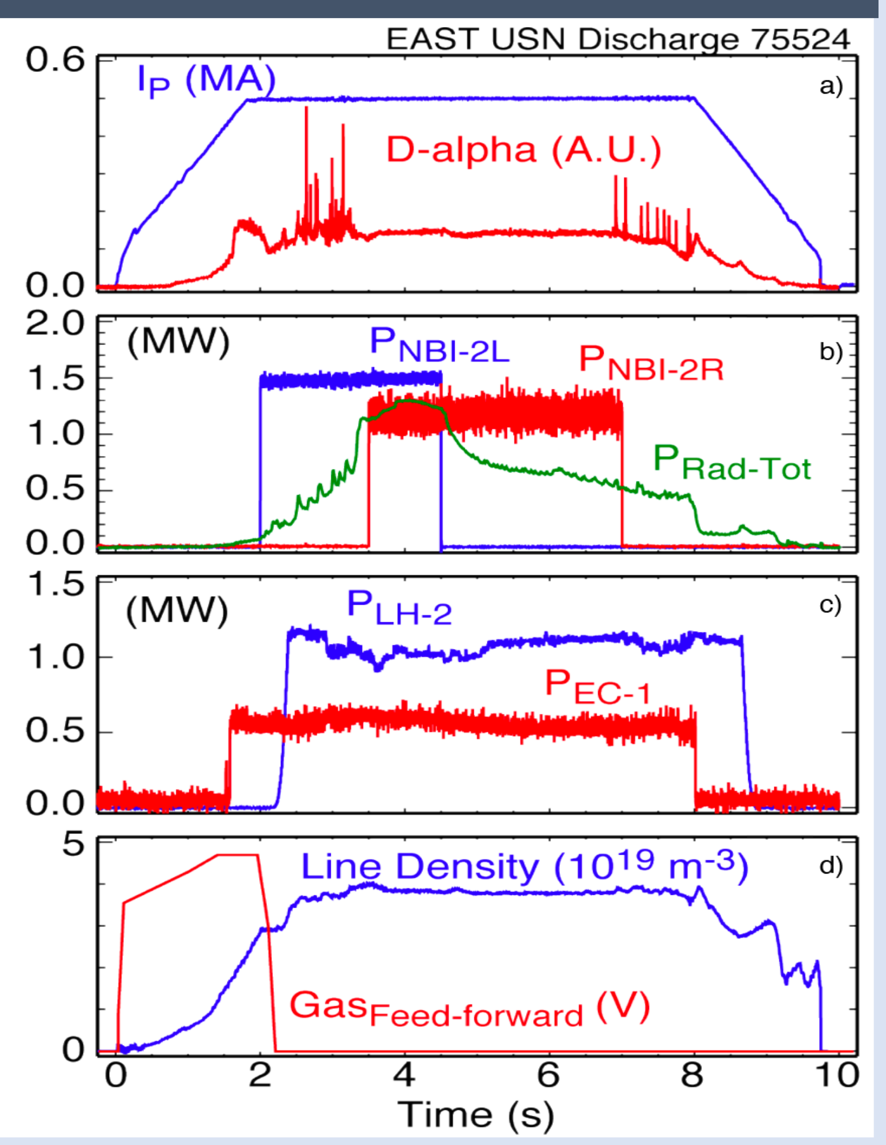
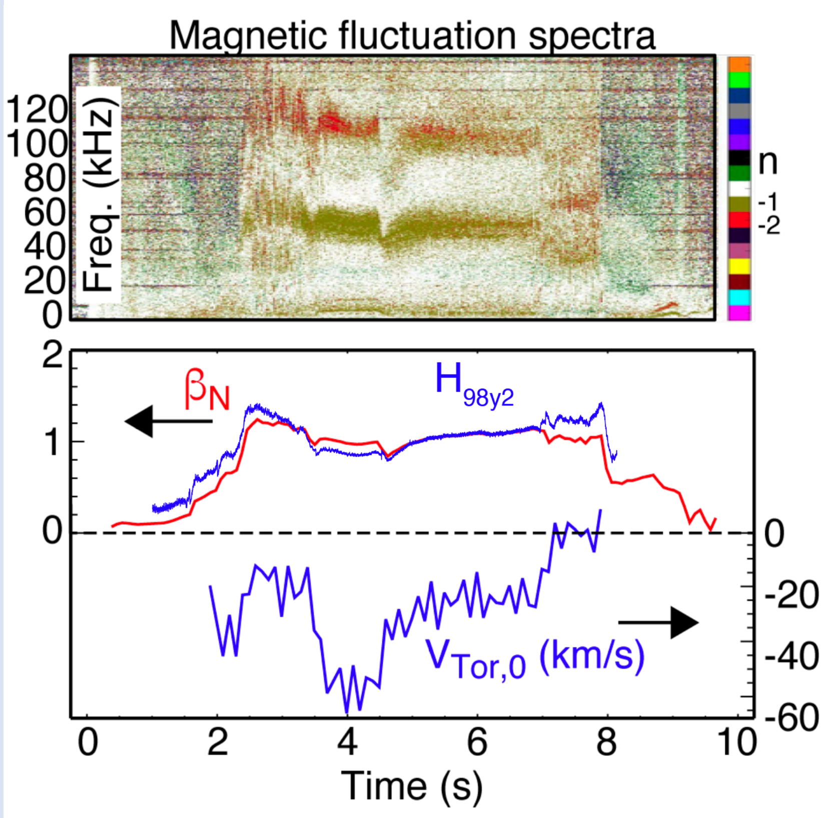
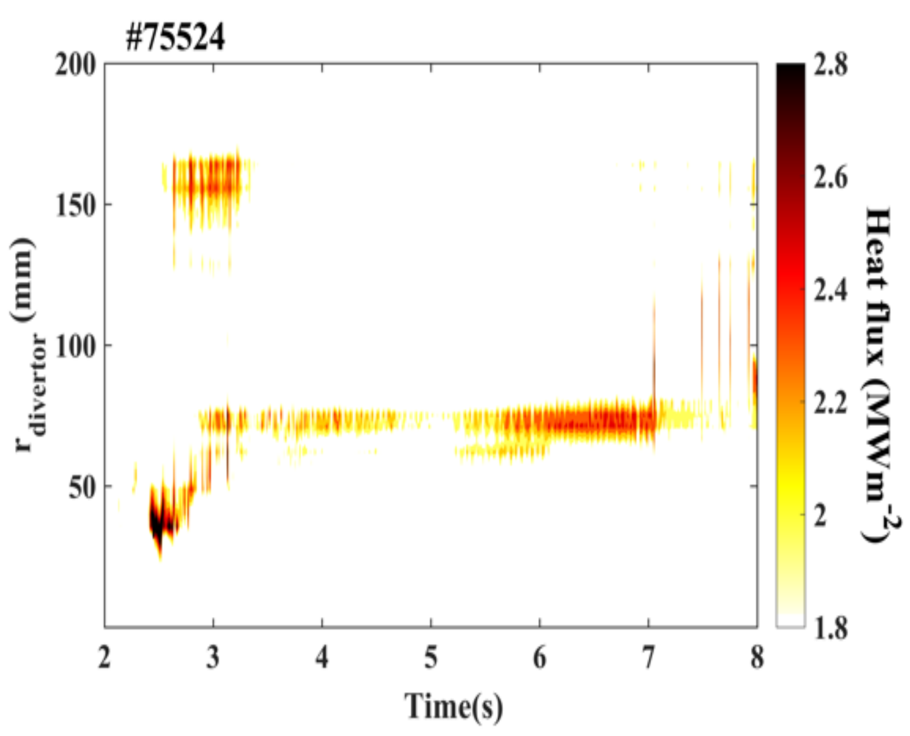
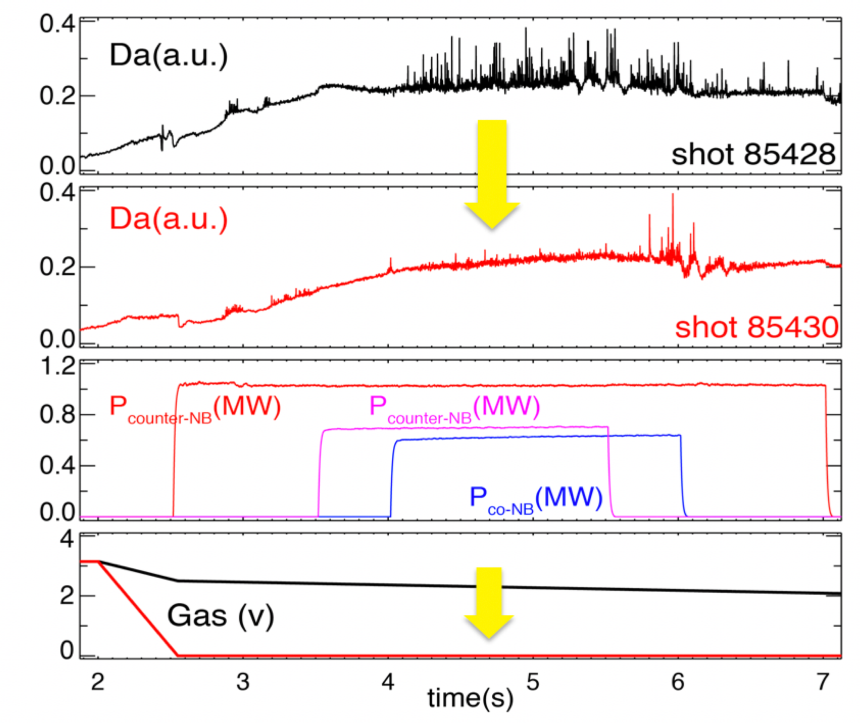


Figure 1 Time histories of several parameters of QH mode discharge by using counter neutral beam in EAST.





EFFECT OF GAS PUFFING AND TORQUE ON QH-MODE ACCESS



- ✓ ELM disappears when cutting gas feed forward to zero, where a broadband MHD modes are observed

Figure 4 Comparison of two discharges with (black) and without (red) gas feed forward

- ✓ QH-mode obtained in more balanced NB injection.
- ✓ The ELM occurs as the plasma heating is shifted from balanced neutral beam injection to the co-Ip NB injection.
  - ➢ The counter neutral beam torque reduced from -0.9Nm to -0.5Nm

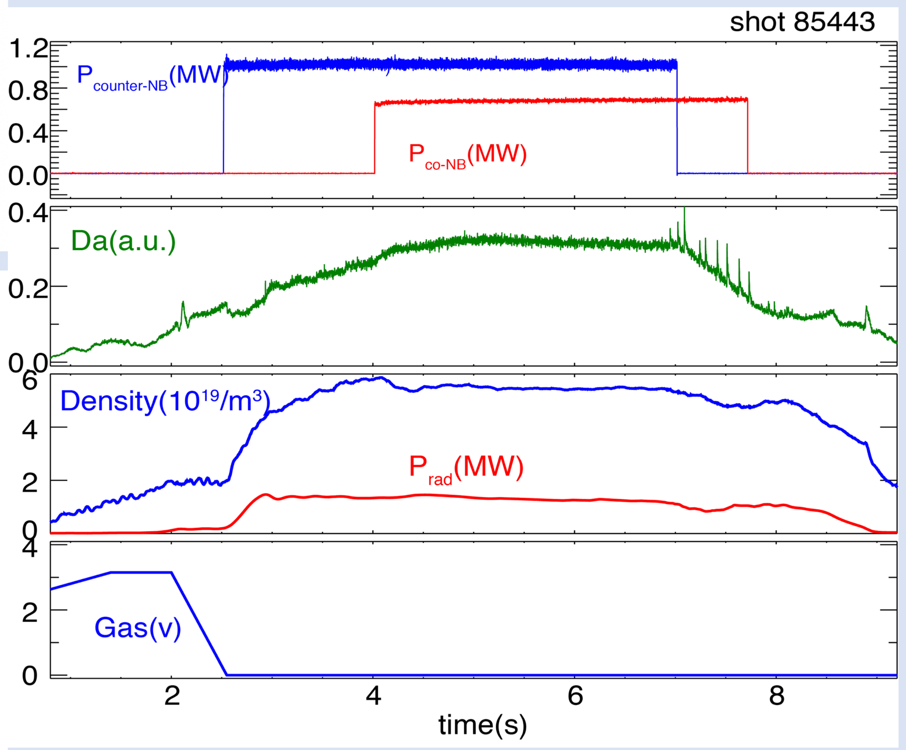


Figure 5. Time histories of several parameters of QH mode discharge by using Crt &Co neutral beam in EAST.

EXTENSION OF QH-MODE WITH PURE RF POWER

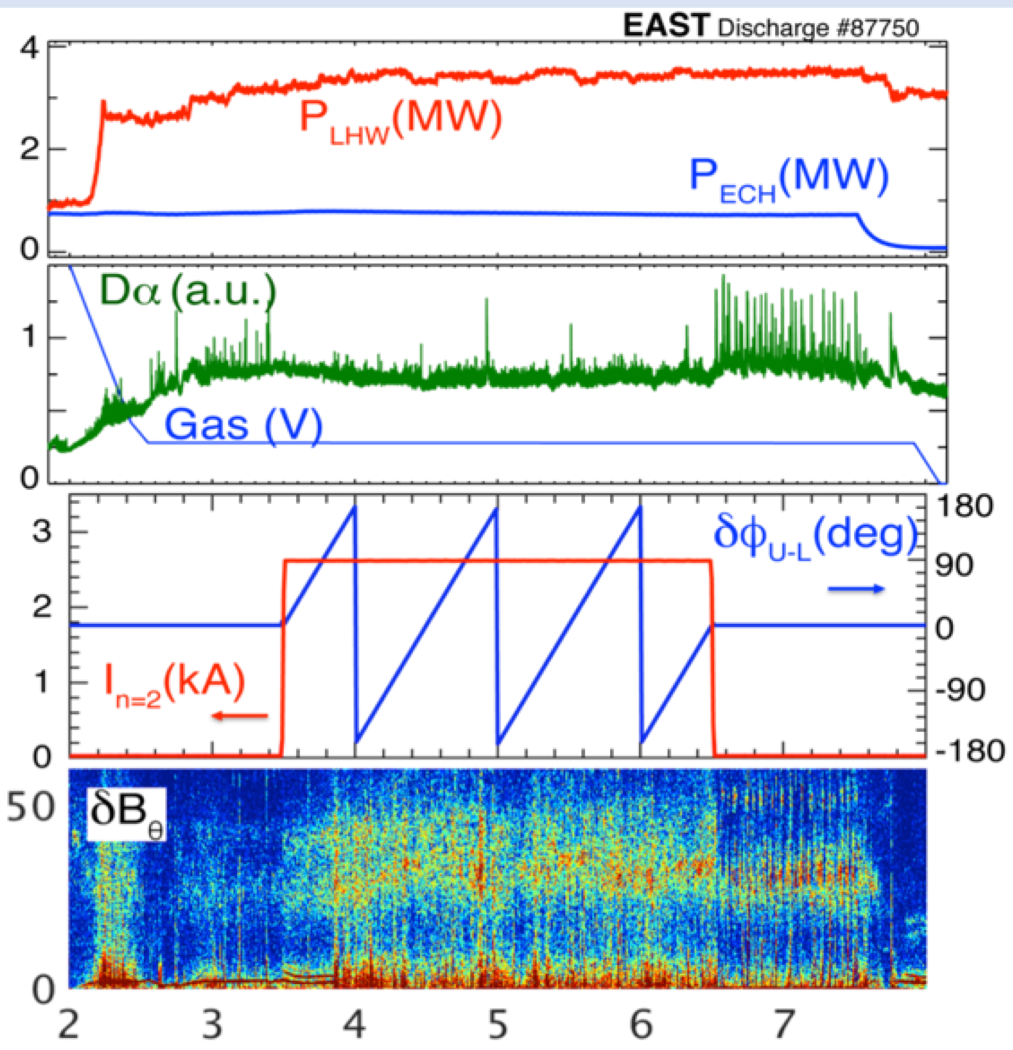


Figure 6 Time histories of several parameters of QH mode discharge by using pure RF and NRMF. From top to bottom, the injected power of LHW and EC, Da, feed-forward gas puff, n=2 NRMF and magnetic fluctuation spectra by Mirnov probe.

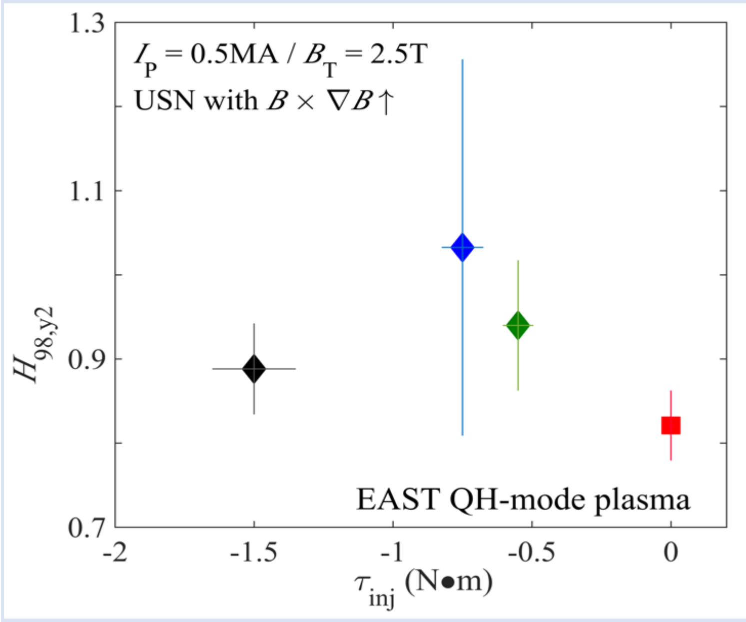


Figure. 8. energy confinement against external input torque for QH-mode plasma on EAST.

- ✓ QH-mode achieved with 3D fields (n=2 NRMFs).
- ✓ ELMs completely disappeared and were replaced by the quasi-coherent/broadband MHD
- ✓ Energy confinement $H_{98,y2}$ nearly stayed constant with reduced torque.

CONCLUSION

- EAST experiments have produced stationary quiescent H-mode scenario under the conditions of low torque and pure RF injection with ITER like tungsten divertor.
- The energy confinement $H_{98,y2}$ stayed constant with the torque range from -1.5 to 0 Nm.
- Further exploration of QH-mode will be carried out toward higher β_N and lower q_{95}.

ACKNOWLEDGEMENTS

Work supported by National MCF Energy R&D Program (2019YFE03040000, 2019YFE03020004), National Natural Science Foundation of China Under Grant (11975274, 11975276), users with excellence program of Hefei Science Center CAS 2019HSC-UE013, Anhui Provincial Natural Science Foundation No. 2008085j04.