DEVELOPMENT OF STEADY-SATE OPERATION SCENARIOS WITH FULL TUNGSTEN LIMITER/DIVERTOR IN ITER-RELEVANT CONFIGURATION ON EAST

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The major goal of EAST is to demonstrate long-pulse high-performance regime with tungsten wall for scientific understanding in support of future fusion device. The revised ITER baseline has been proposed together with its associated new research plan [1, 2]. In support of the R&D required for the new ITER baseline, EAST has successfully demonstrated long pulse fully non-inductive H-modes up to 100s at $T_e(0)$ > 8.5keV with type II ELMs under both boronized and uncoated metal wall with zero torque injection by RF-only heating shown in Figure 1. Energy confinement in these conditions remains high (H_{98y2} > 1.1) and is independent of the tungsten source from the main limiter and heating mix, thanks to the efficient W exhaust by type II ELMs and low core inwards neoclassical transport with no central fuelling by NBI and low rotation, as expected in ITER. Operation with higher plasma density (f_{GW} > 0.6) can significantly reduce the edge electron temperature and the influx of medium and high-Z impurities leading to similar radiative fractions that low densities with higher impurity influxes.

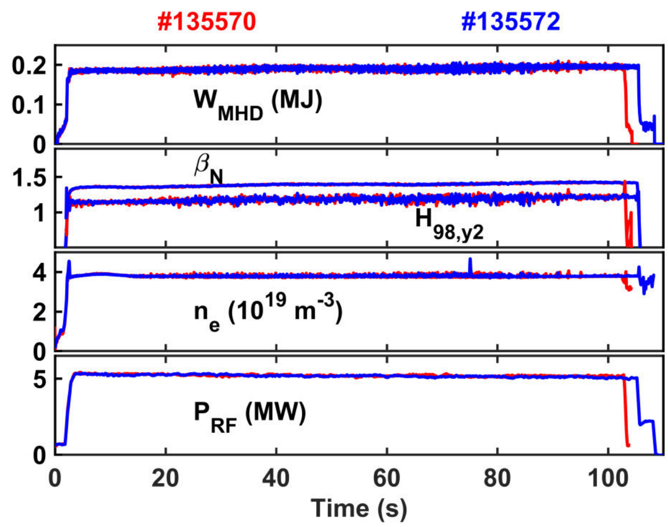

Figure 1 Time history of stationary ~100s H-mode plasma on full metal wall with P_{EC} ~ 3.0MW, P_{LH} ~ 2.2MW with optimization of heating and current driven coupling and well controlled high Z impurity .

To support ITER new research plan, a dedicated set of joint ITER-EAST experiments have been performed on three topics: optimization and characterization of boronization, plasma start-up on the tungsten limiter [3], and the impact of W on the H-mode operational space with and without boron coatings [2]. The related key technical and scientific challenges have been addressed. For wall conditions with boron coating, to improve the uniformity and quality of the boron film, optimization and characterization of boronisation using ICWC and GDC has been investigated. For plasma initiation, ECW assisted start-up has been carried out and robust breakdown and plasma initiation at low toroidal electric fields has been demonstrated with optimized magnetic field configurations in a large range of prefill gas pressure. For assessment of the impact of tugsten as first wall material on plasma performance, the H-mode experiments have been implemented by ECH and NBI. The impacts of ELM type, separatrix-to-W limiter gap on plasma performance are summarized in Figure 2. The impact of different wall conditions (lithium-coating, boron-coating, non-coating) on energy confinement, H&CD efficiency, particle control, etc. will be illustrated in detail in the presentation. Furthermore, a high poloidal beta (β_p) scenario has been developed in boron wall at $q_{95} \sim 6.2$, a range attractive for ITER steady-state operation, with high energy confinement quality ($H_{98y2} \sim 1.25/\beta_N \sim 1.8$) by dominant electron heating.

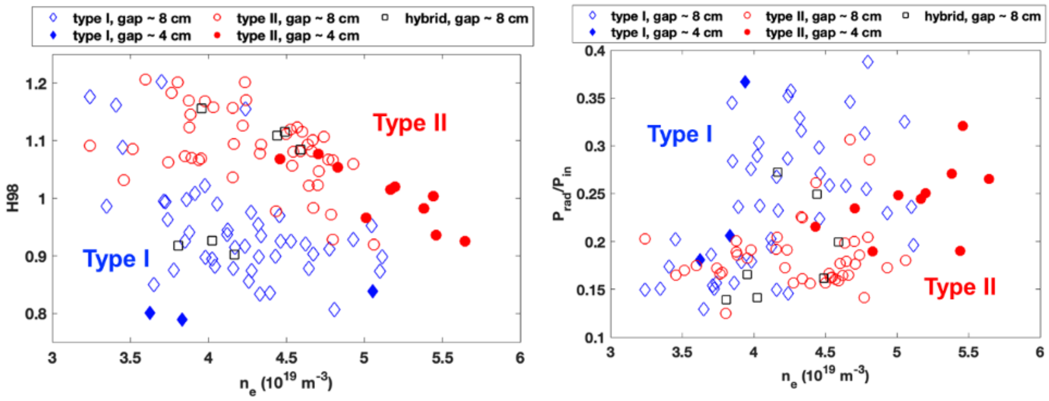

Figure 2 Left: H_{98} versus plasma density, right: radiated power fraction versus plasma density for EAST H-mode experiments in boron wall for two separatrix-W-limiter gaps and ELM types (I, II and hybrid-I-II) with no impurity seeding. These results showed the higher performance and the lower impact or the separatrix-limiter gap that can be achieved with type II ELMs for the same density as type I ELMs.

To account for the ITER heating and current mix, we have also explored a fully non-inductive high β_p regime without lower hybrid wave systems shown in Figure 3. All the ITER H&CD systems were used and found suitable for high β_p plasmas in a LSN configuration. High performance has been achieved with $\beta_p \sim 2.3$, $\beta_N \sim 1.8$, $H_{98y2} \sim 1.2$ at $I_p \sim 400$kA, $\langle n_e \rangle \sim 4.0 \times 10^{19}$m^{-3}, $P_{EC} \sim 1.4$MW, $P_{IC} \sim 1.5$MW, $P_{NB} \sim 2$MW. The preliminary results for contributors to current drive analyzed by TRANSPT show that: $f_{NI} \sim 70\%$, $f_{BS} \sim 38\%$. The target q-profile was pre-shaped by NBI or ICRF at an early phase of the discharge. This included the application of a suitable voltage for early NBI heating and optimized density and gap to improve ICRF coupling. With the enhanced EAST capabilities, e.g. ECH power upgraded to 8 MW, we are planning to extend the performance to the lower collisionality with boron wall expected in ITER-relevant configuration, which can offer unique contributions in support of the ITER new research plan.

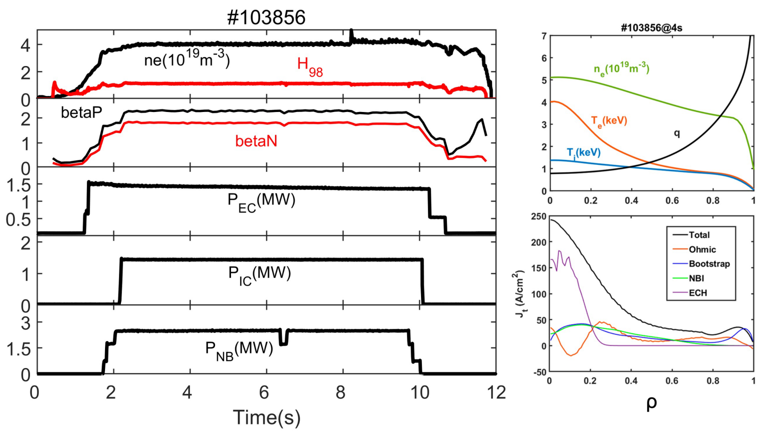

Figure 3. High β_p plasmas in ITER heating scheme for #103856 with $\beta_p \sim 2.3$, $\beta_N \sim 1.8$, $H_{98y2} \sim 1.2$, at $I_p \sim 400$kA, $\langle n_e \rangle \sim 4.0 \times 10^{19}$m^{-3}, $P_{EC} \sim 1.4$MW, $P_{IC} \sim 1.5$MW, $P_{NB} \sim 2$MW, experimental profiles (n_e, T_e, T_i, q) at 4s and total current density profile with bootstrap, ohmic, beam, EC driven current components.

ACKNOWLEDGEMENTS

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