# High-$\beta_N$ Experiments and Corresponding MHD Activities in the HL-2A Tokamak

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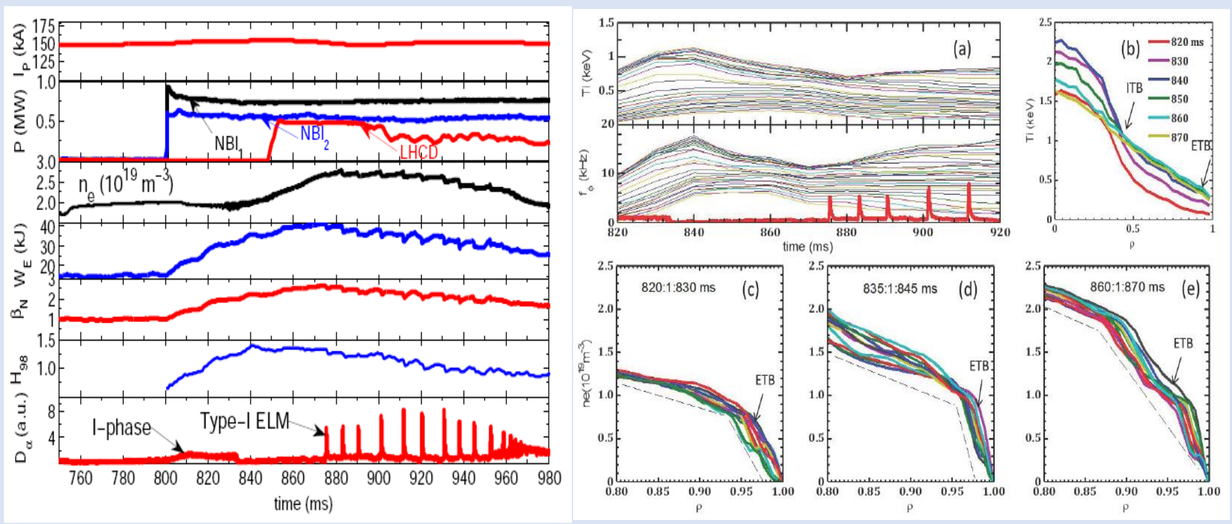
## ABSTRACT

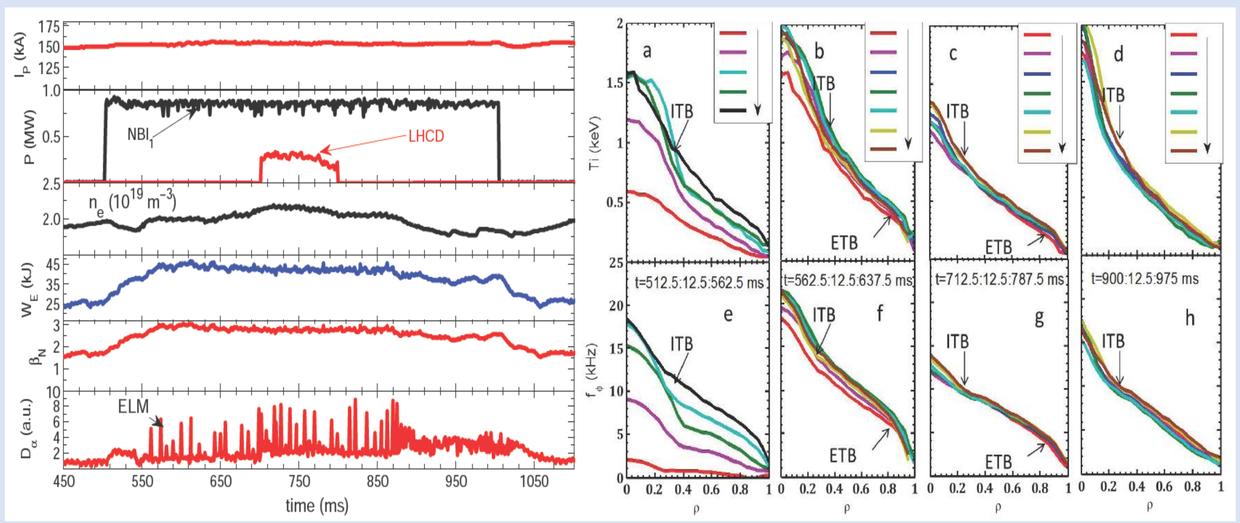
• High-$\beta_N$ experiments have been carried out on HL-2A in recent several years. The high- $\beta_N$ is realized by double transport barriers (DTBs) under the circumstance of hybrid scenarios. A stationary high-$\beta_N$ (>2) scenario is obtained by the pure NBI heating. The transient high performance is also achieved, and corresponding $\beta_N$ >3, ne/ne$_G$~0.6, $H_{98}$~1.5, $f_{bs}$~30, $q_{95}$~4.0 and G~0.4. In high-$\beta_N$ plasmas, there are abundant MHD instabilities, including low-frequency global MHD oscillation with n=1 and high-frequency coherent mode (HCM) in the edge, and neoclassical tearing mode (NTM) and Alfvenic modes in the core. In some high-$\beta_N$ discharges, it is observed that the NTMs with m/n=3/2 limit the growth of the plasma energy and decrease $\beta_N$. The low-n global MHD oscillation consistent with the coupling of destabilized internal (m/n=1/1) and external (m/n=3/1 or 4/1) modes, and it plays a crucial role in the triggering onset of ELMs. Achieving high-$\beta_N$ on HL-2A suggests the core-edge interplay is key important for the plasma confinement enhancement mechanism. The experiments of enhancing-$\beta_N$ can contribute to the future plasma operation, such as ITER.

## High-$\beta_N$ realization on HL-2A




High-$\beta_N$ realization by double transport barriers (DTBs) under circumstance of hybrid scenarios on HL-2A.

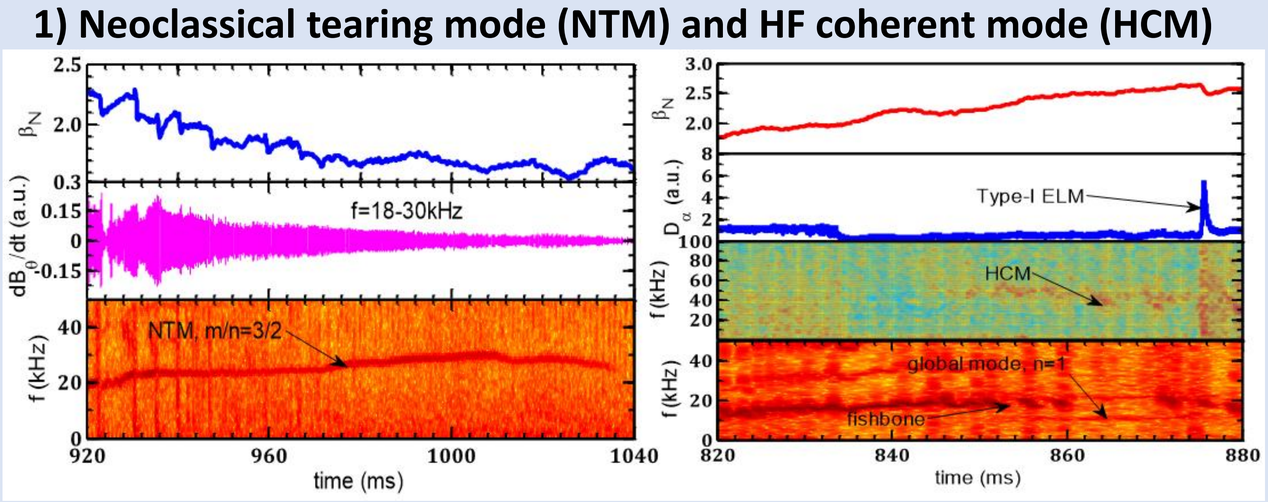
## Stationary high- $\beta_N$ scenario on HL-2A




$\beta_N$ >3, ne/ne$_G$~0.6, $H_{98}$~1.5, $f_{bs}$~30, $q_{95}$~4.0 and G~0.4 at t~590 ms.

## MHD stabilities in high-$\beta_N$ plasmas

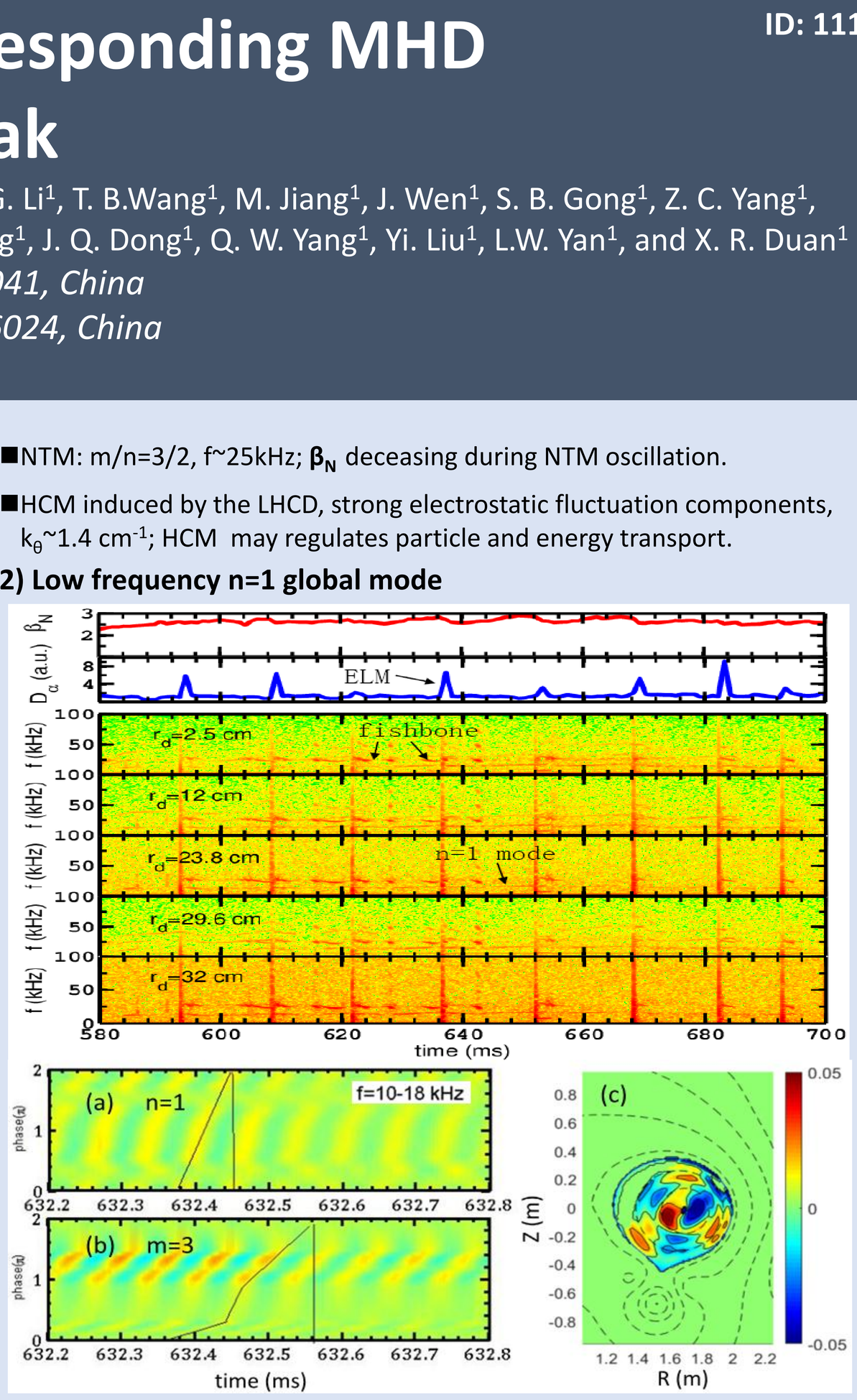
### 1) Neoclassical tearing mode (NTM) and HF coherent mode (HCM)




■NTM: m/n=3/2, f~25kHz; $\beta_N$ deceasing during NTM oscillation.

■HCM induced by the LHCD, strong electrostatic fluctuation components, $k_\theta$~1.4 cm$^{-1}$; HCM may regulates particle and energy transport.

### 2) Low frequency n=1 global mode

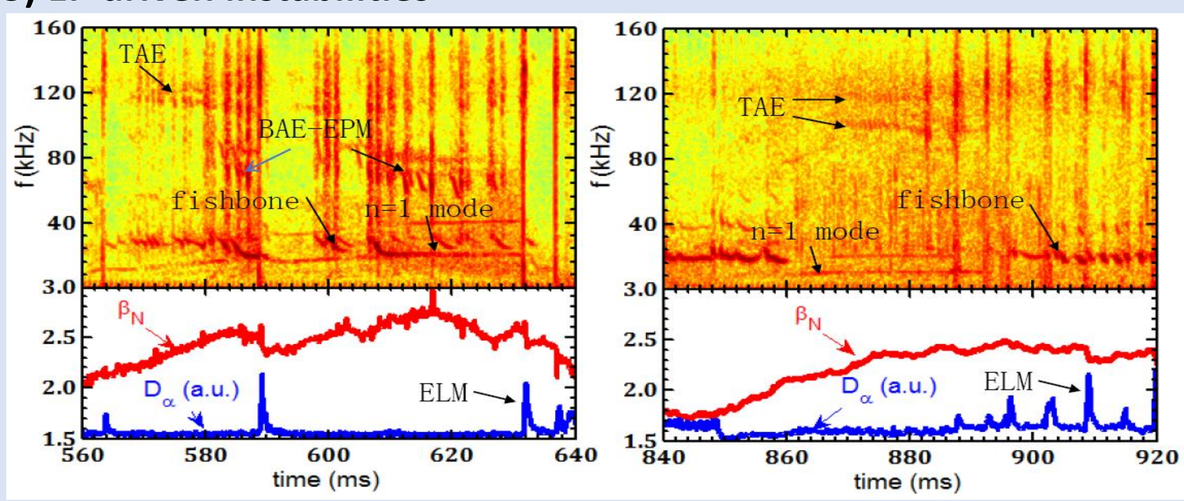



Low frequency global mode:

■coupling of destabilized internal and external modes with m/n=1/1 and m/n=3/1, respectively.

■The mode plays a crucial role in the triggering onset of ELMs.

### 3) EP driven instabilities




■Alfvenic modes&energetic-ion redistribution: an important influence on the pedestal evolution.

## Discussion and conclusion

- A stationary high-$\beta_N$ scenario ($\beta_N$ >2, t~15$\tau_E$ ) is obtained on HL-2A. The transient high performance is also realized, and corresponding $\beta_N$ >3, ne/ne$_G$~0.6, $H_{98}$~1.5, $f_{bs}$~30, $q_{95}$~4.0 and G~0.4. In high-$\beta_N$ H-mode plasmas, there are many kind MHD instabilities, including global n=1 MHD oscillation, HCM, NTM and Alfvenic modes. In some high-$\beta_N$ discharges, the NTMs degrade the plasma confinement and decrease $\beta_N$. The low-n global MHD mode plays a crucial role in the triggering onset of ELMs. The Alfvenic modes and energetic-ion transport may affect the pedestal evolution.
- Some crucial physics problems need to be resolved on HL-2A, namely how control MHD instabilities and sustain transport barrier to achieve higher steady-state $\beta_N$. The study of improving-$\beta_N$ , by expanding ITB foot outward, controlling MHD activities and enhancing synergic effects between ITB and ETB, would be important for the future plasma operation, such as ITER and CFETR.