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# Sustainable Internal Transport Barrier Discharges in KSTAR


J. Chung, S. -H. Hahn, H. Han, J. Kang, H. S. Kim, Y. M. Jeon, J. Ko, K. D. Lee, W. H. Ko, S. H. Seo, J. H. Lee, J. W. Juhn, M. H. Woo and S. W. Yoon

Korea Institute of Fusion Energy (KFE)

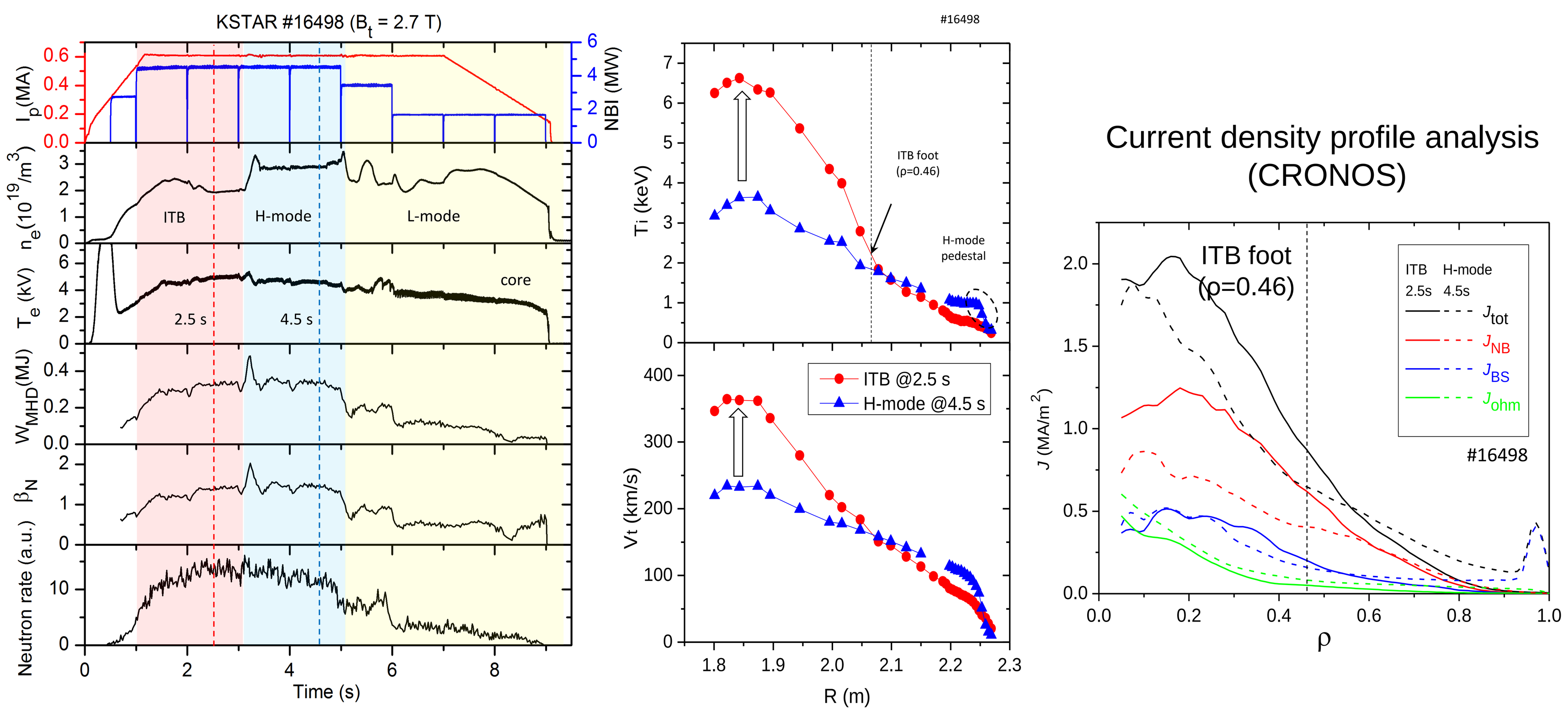
jinil@kfe.re.kr


## ABSTRACT


- It has been exploring the inboard-limited ITB (Internal Transport Barrier) as an alternative advanced operation scenario for KSTAR.
- Experiment were conducted to access the ITB using the upper single null (USN) - unfavorable condition for H-mode transition.
- The key control parameters of the experiment were the vertical position and the location of outboard striking point of the plasma.
- The shape control attempted to divert the plasma to a vertically shifted USN with a marginal touch of the inboard limiter.
- The striking point control was effective in maintaining ITB performance for a longer period of time (~10 s).


## INTRODUCTION

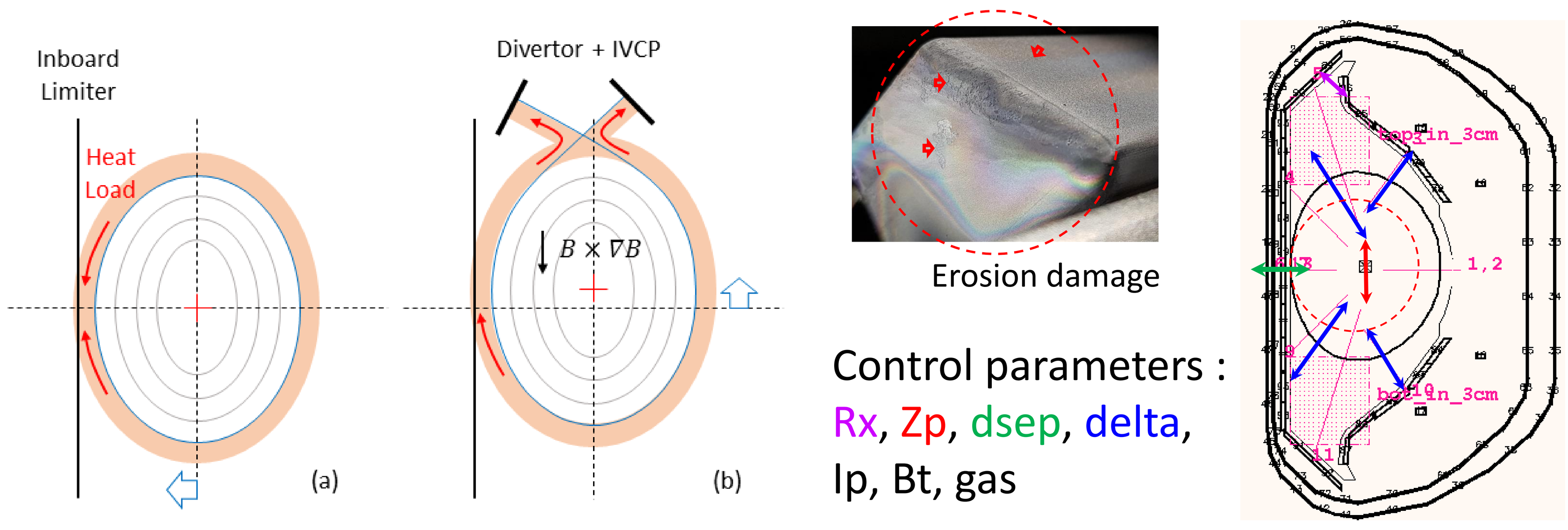
- Previously, an early injection of big enough (> 4 MW) neutral beam injection (NBI) power under a limited L-mode was a key of the ITB access and was observed in both ion and electron thermal channels.



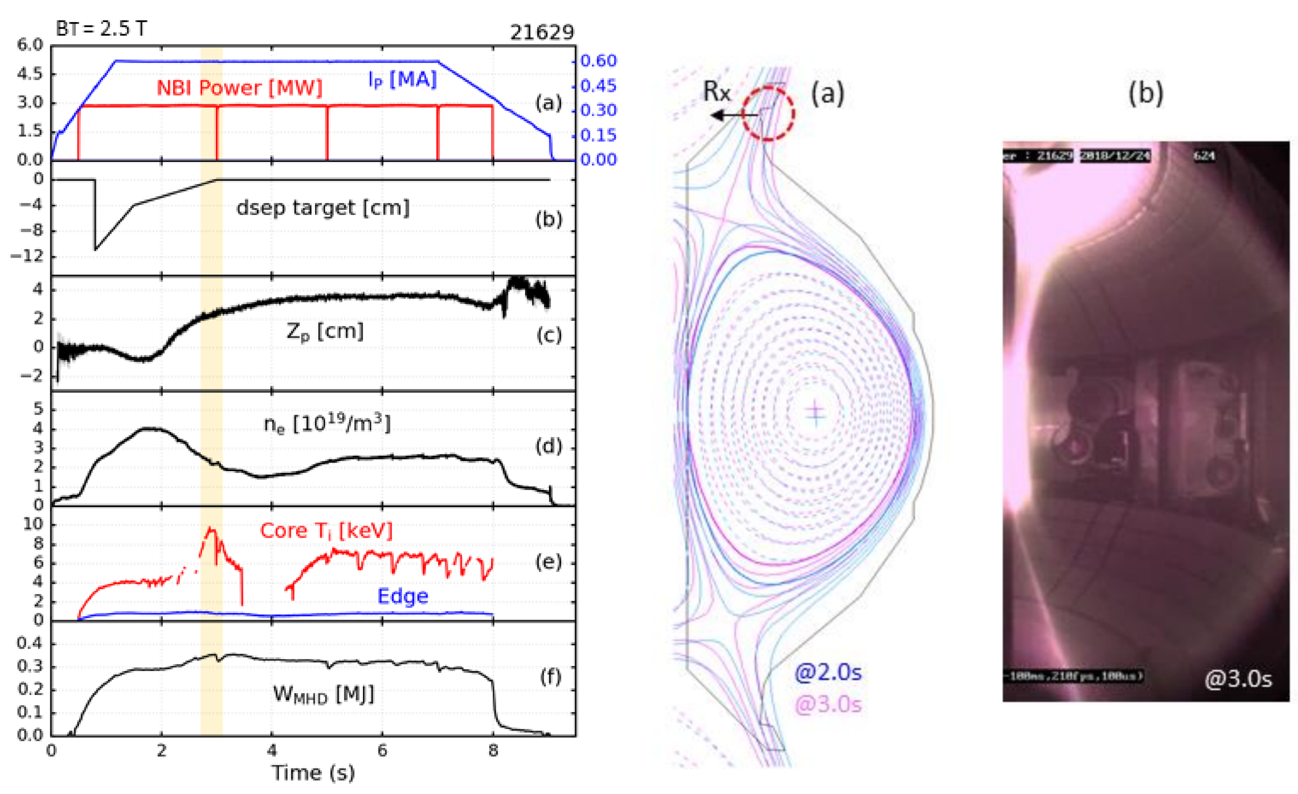

*The first ITB result in KSTAR (J. Chung et. al., NF 58 016019, 2018)*

## EXTENSION OF ACCESS CONDITION USING PLASMA SHAPING

- The upper single null (USN) configuration (unfavourable for H-mode) reduces the heat load on the inboard limiter and can be applied to effective particle pumping through the upper divertor gap.



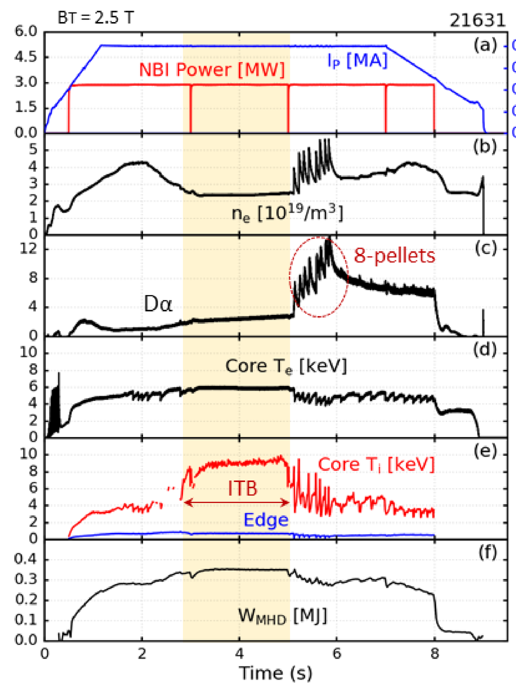

*Concepts of the shaped ITB. (a) Inboard-limited on-axis (b) diverted off-axis for impurity control and reducing the erosion damage.*



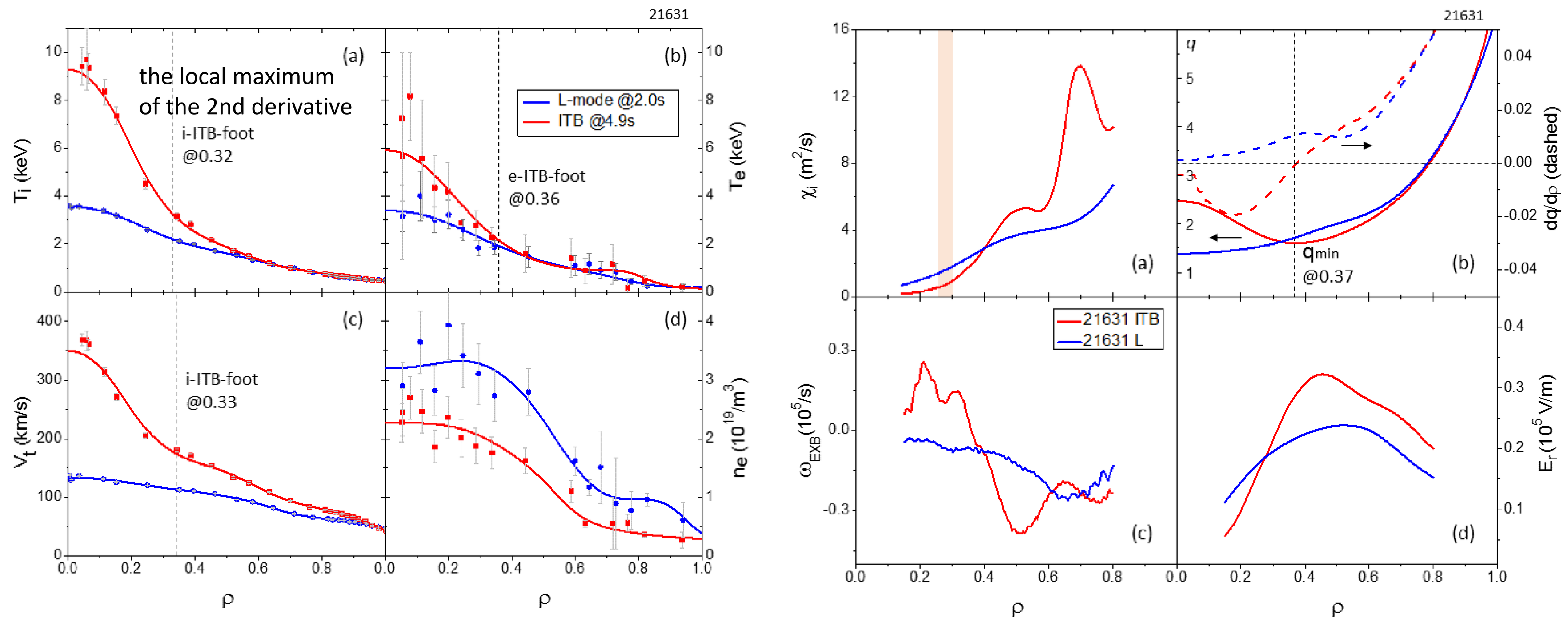

*Time trace parameters of the first shaped ITB discharge at BT=2.5T (Left) and its plasma shape. (Right)*

- The first result of the USN-like ITB and its appearance. The ITB was successfully accessed with a low heating power of about 3.0 MW.

## ANALYSIS OF PROFILES IN A STABLE ITB



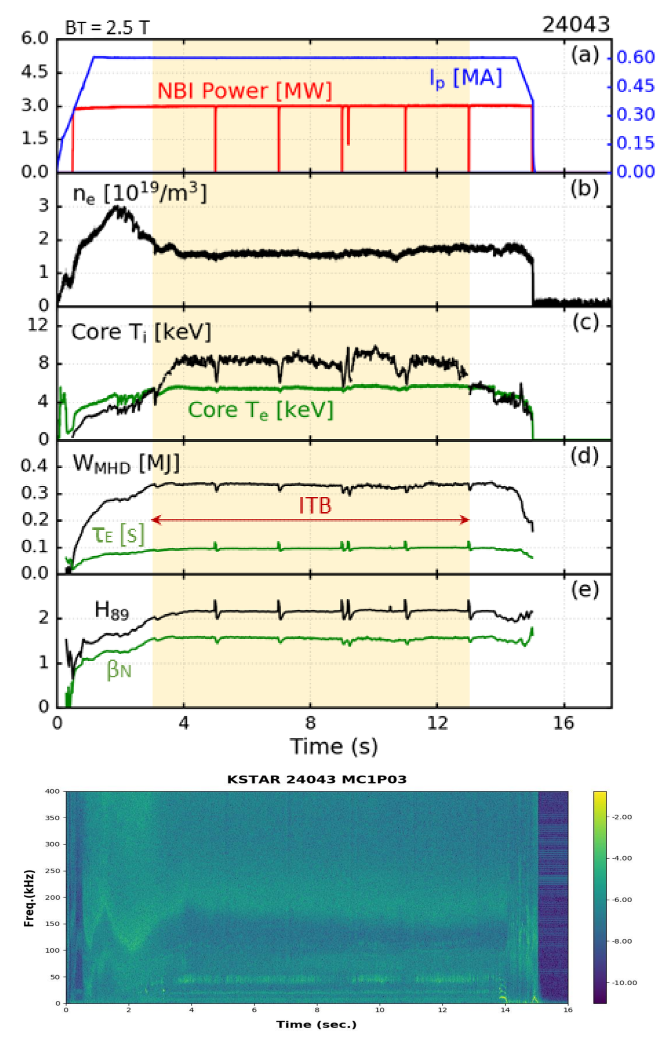

- The advantage of the ITB with L-mode edge can be observed (ELM-free) with an improvement of confinement.
- The ion heat diffusivity goes down to the neoclassical heat diffusivity level at ρ = 0.25.
- The q-profile during the ITB is weakly reversed.
- Observed a clear $\omega_{E\times B}$ layer structure where the $E_r$ has a steep gradient near the $q_{min}$.




*(Left) Profiles of the discharge #21631 measured from the CES and the Thomson (Right) Results of TRANSP/NUBEAM analysis (a) ion heat diffusivity (b) safety factor (c) E×B shearing rate (d) radial electric field.*

## MAINTAINING PERFORMANCE IN A LONG-PULSE DISCHARGE

- The ITB formed during plasma shaping at 3.0 s and lasted for about 10 s (100τE).
- Parameters indicating plasma performance were maintained stable.
- Different edge and diverter conditions in the suggested USN-like configuration could significantly change the recycling.
- The control is important to minimize the inflow of impurities because the direction of the force of B × ∇B is directed downward.
- This MHD-resistant characteristic can be thought of as making the ITB discharge robust, resulting in high energy confinement efficiency.




*Time evolution of a long-pulse ITB discharge*

## SUMMARY AND CONCLUSION

- The ITB scenario enhances the discharge performance in a robust way and is reproducible in a wide range of experimental conditions.
- The ITB operation window has been also extended by upshifted plasma shaping under a marginal NBI power up to 3.0 MW.
- The shaping may reduce the ITB power threshold and enables vertically off-axis beam deposition.
- This experiment allowed the KSTAR to access the ITB in the range of 2.9 - 5.0 MW of NBI heating capacity, and successfully demonstrated that it can maintain the performance for about 10 s, equivalent to 100 τE.

## ACKNOWLEDGEMENTS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