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Disruption Avoidance after NBCD Turn-off in Fully Non-inductive, Reversed Shear Discharges

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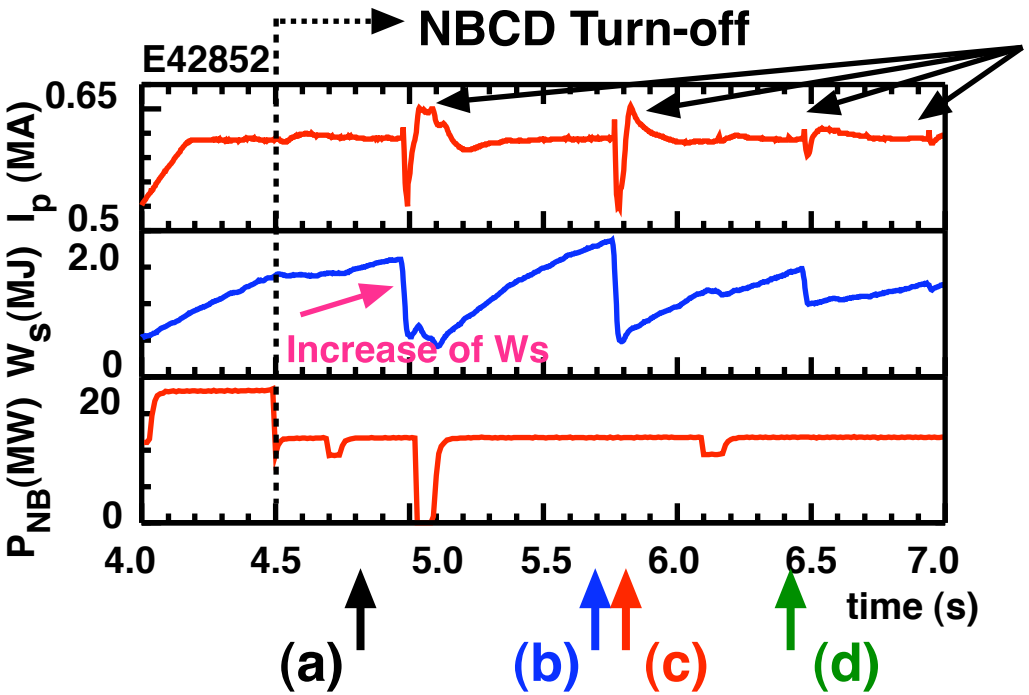
Outline

Reactor Grade, SS Tokamak Plasma

- Self-burn w/o NB Heating
  - → Burn-control, Thermal Instability, Fueling etc.
- High β
  - → Disruption, MHD Stability etc.
- Steady State Operation
  - → Non-inductive Current Drive
- Reversed Magnetic Shear (RS)
  - → High BS Current + External CD Means w/o CS.

Intermittent β collapses after NBCD turn-off were studied on high β, fully non-inductive, RS discharge of JT-60U (E42852).

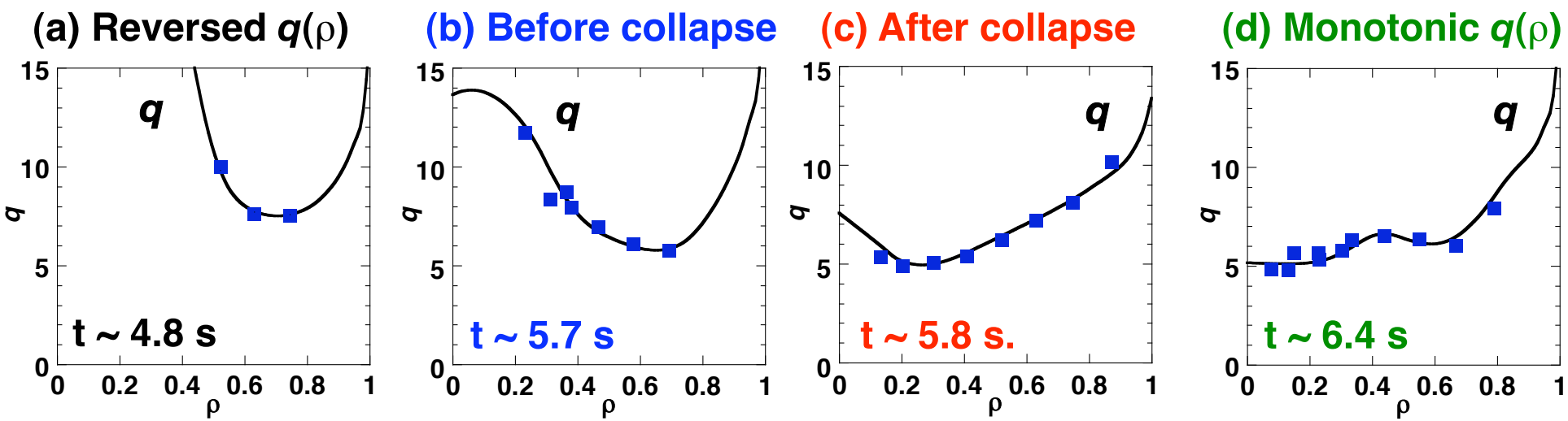
Intermittent β Collapse after NBCD Turn-off (E42852)



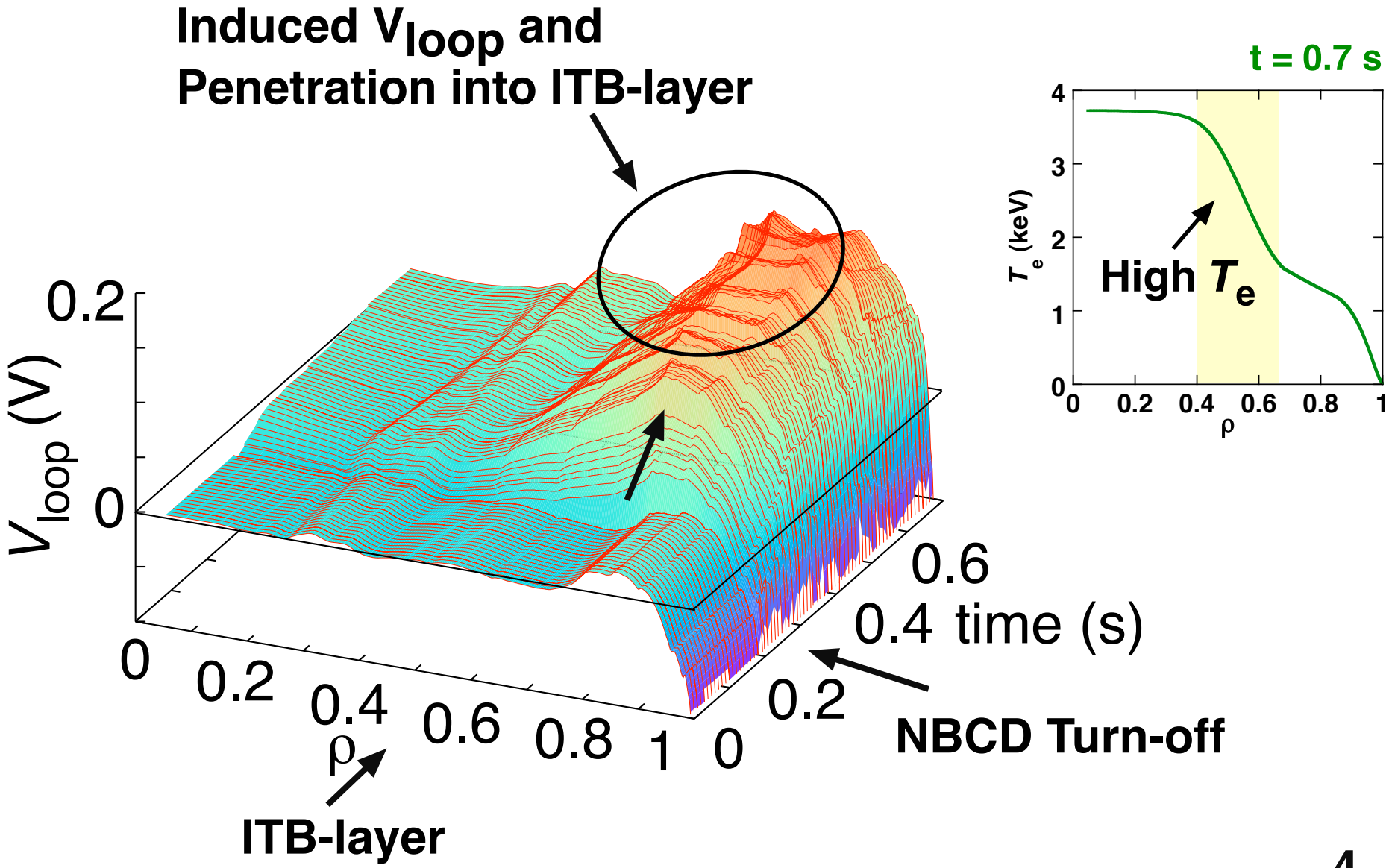
- **Intermittent Collapses**

$$I_p = I_{BS}(0.3\ \text{MA}) + I_{NB}(0.3\ \text{MA})$$

- **Why NBCD turn-off triggers the collapse?**
- **Why not major disruption? Why the collapse repeats?**



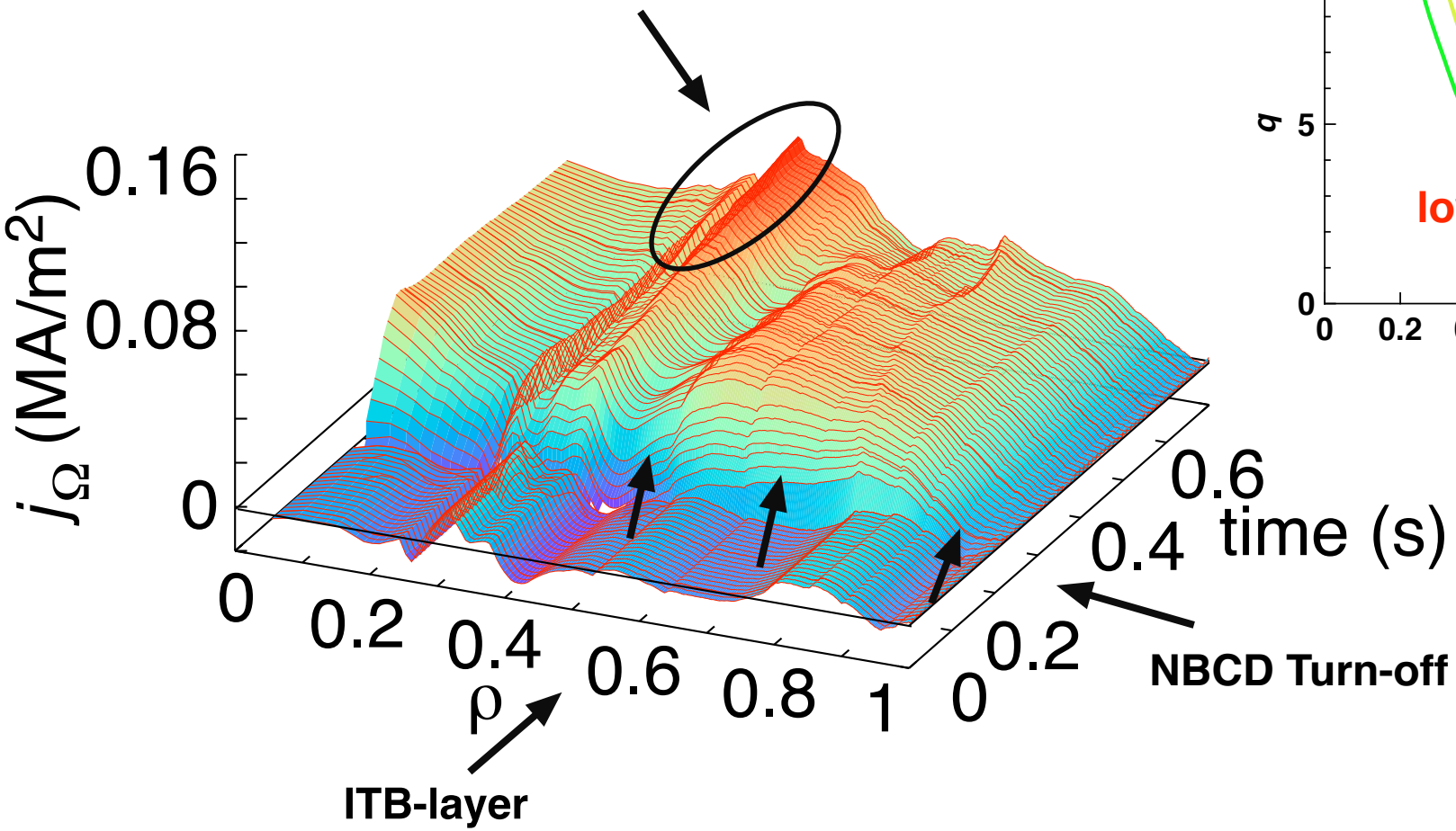
Induced V_{loop} after NBCD Turn-off and Penetration into ITB-layer

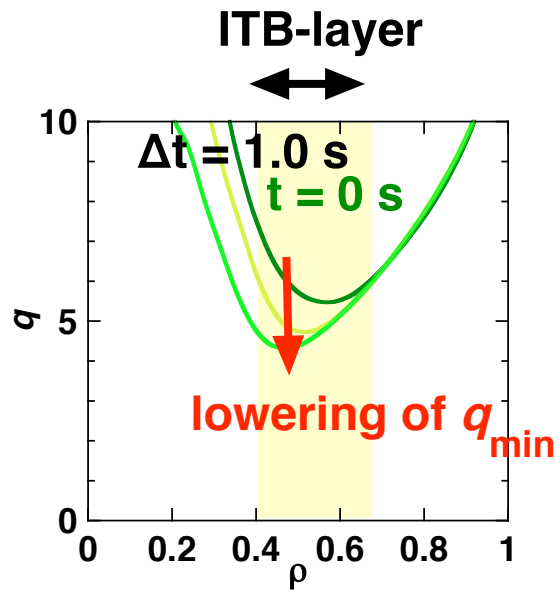


Accumulation of "Return Current" j_Ω at ITB-layer

j_{NB} replaced by "return current"

$$j_\Omega \propto T_e^{3/2} \bullet V_{loop}$$





MHD Instability of High-*q* RS Discharge

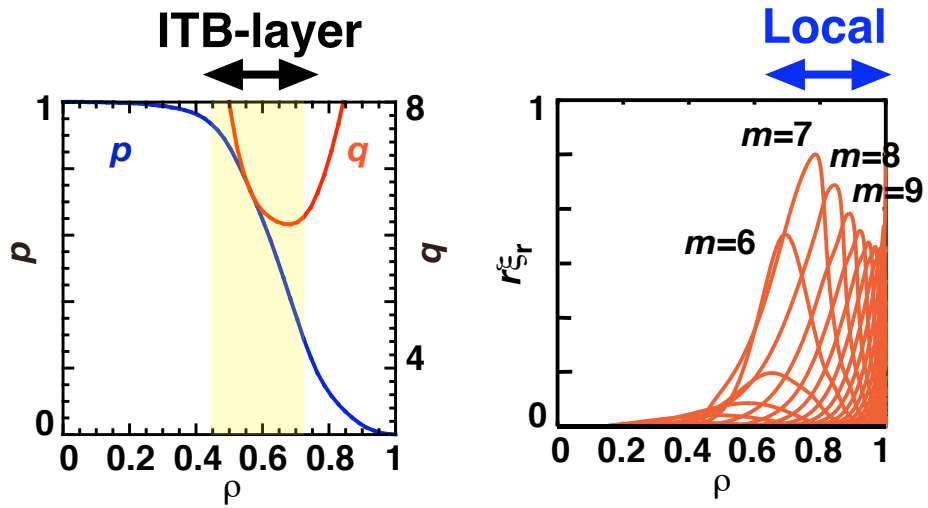
n **= 1 kink-ballooning mode becomes unstable with β_N ~ 1.7 % mT/MA.**

Mode Structure

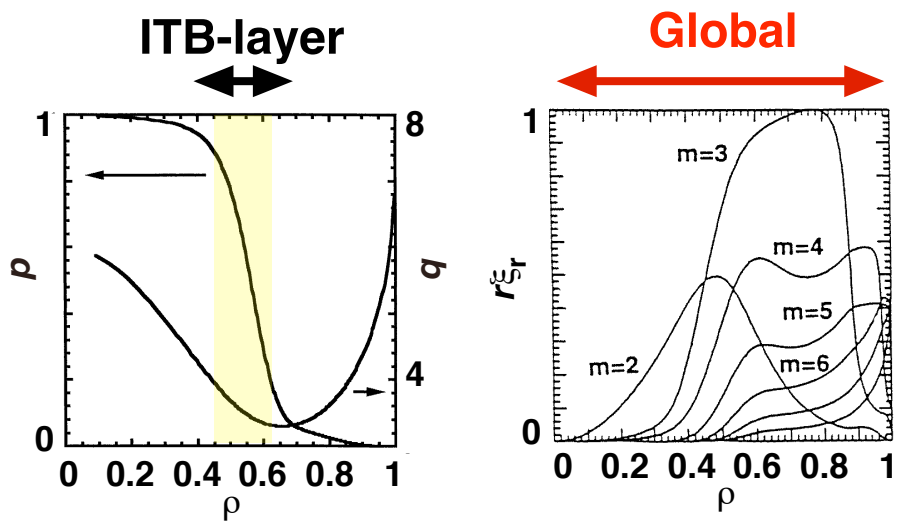
- **When q_{min} > 6, *m* = 2, 3, 4 modes are absent.**
- ***m*** **= 6, 7, 8, … modes are localized around ITB.**

n **= 1 K-B mode never destroies core-region of high q_{min}, RS plasmas.**

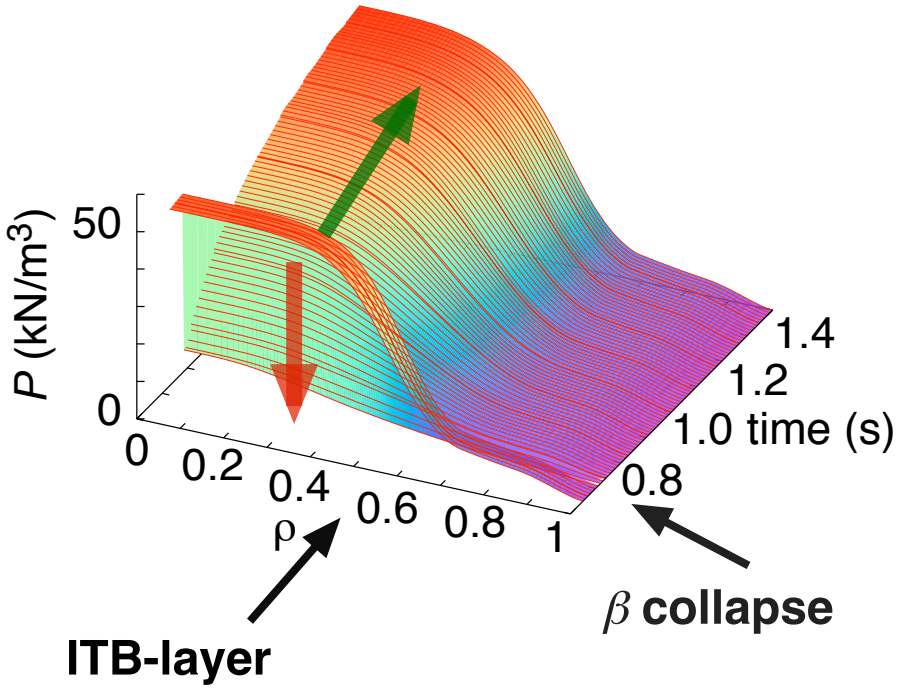
High-*q* Discharge

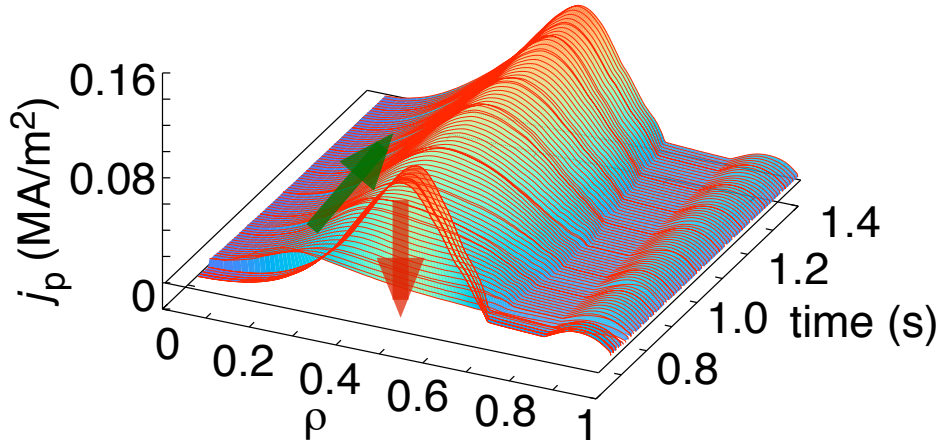


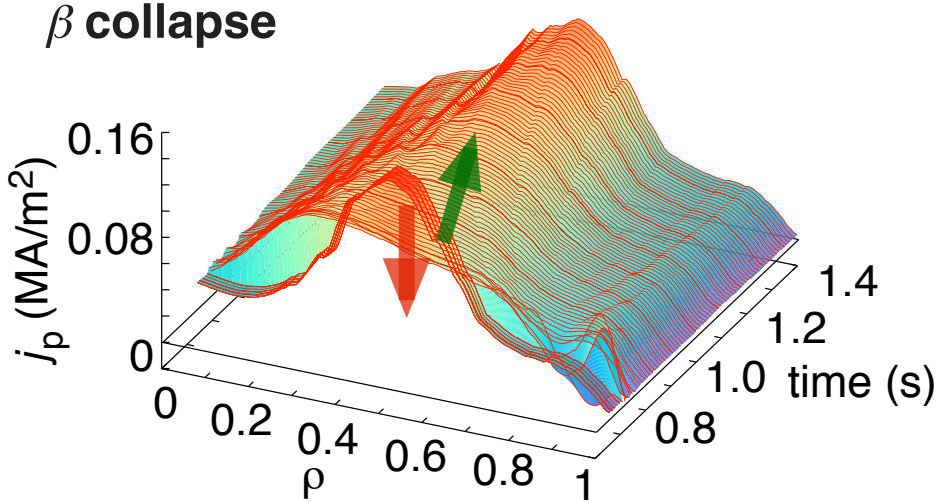
Low-*q* Discharge



Simulation of Recoveries after Collapse



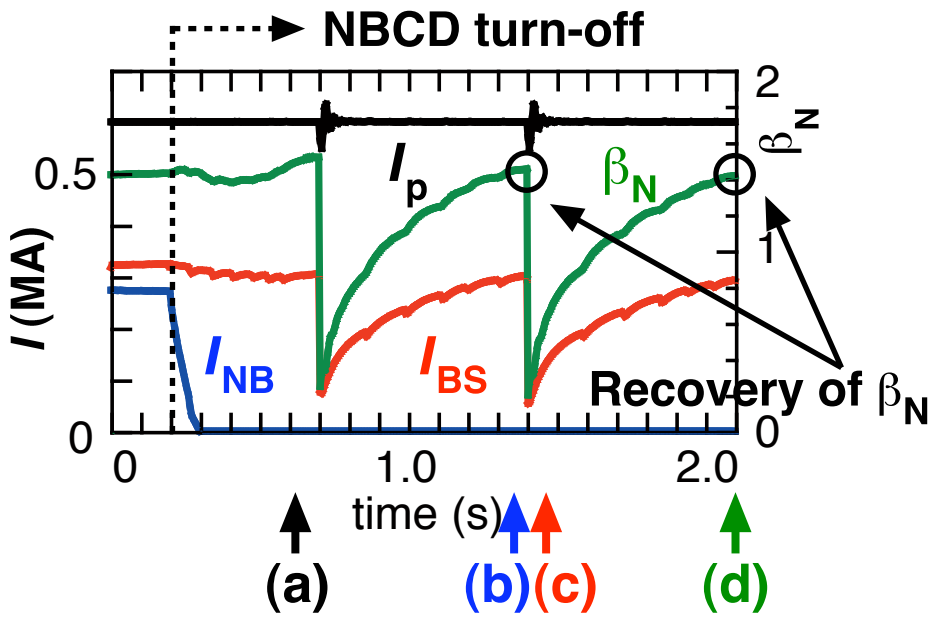




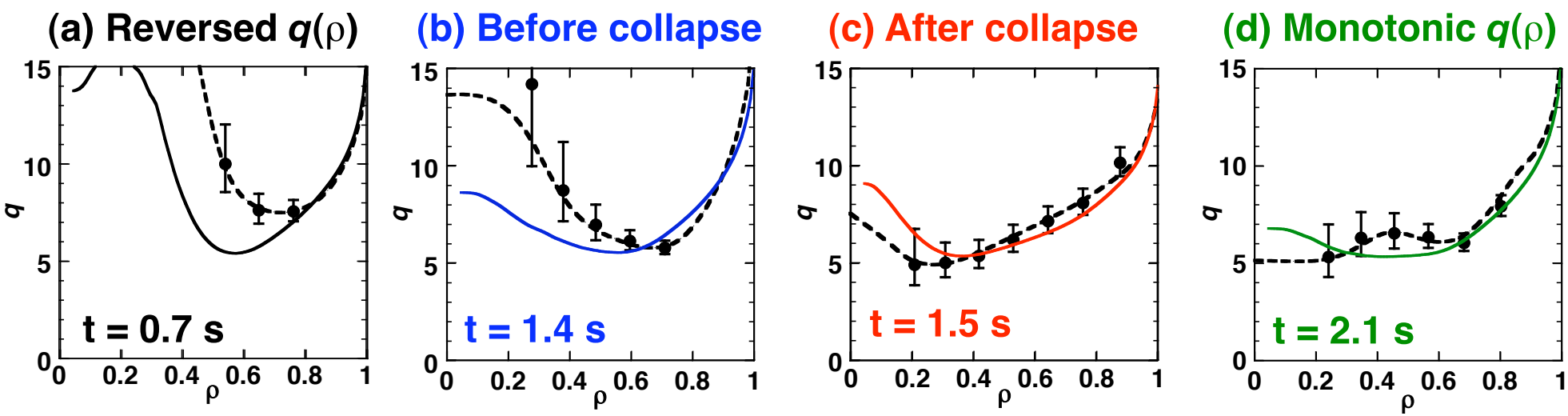
Collapse

Recovery

TSC Simulation of Intermittent β Collapse



TSC simulation has successfully reproduced Intermittent β collapse & recovery process of high β, fully non-inductive, RS discharge of JT-60U (E42852).



Conclusion

We studied characteristics for intermittent β collapses after NBCD turn-off in JT-60U non-inductive, RS discharge.

- Self-consistent transport simulations and linear MHD stability analysis have clarified such as:
  - Redistribution of "Return Current" induced after NBCD turn-off lowers q_{min} further.

    → Onset of $n = 1$ kink-balloning mode localized around ITB.
  - Increase of BS current under continuous NB heating can lead to ITB reconstruction.

    → Cause of subsequent β collapses