

○ ● ● Suppression of Islands and Disruption Experiments in HYBTOK-II

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Outline

1. Experimental Objectives of MHD Studies in HYBTOK-II
2. Experimental Devices and Operation
3. Dynamic Ergodic Divertor(DED) Experiments
4. Disruption Experiments
5. Summary

○ ● ● MHD Studies in a Small Tokamak HYBTOK-II

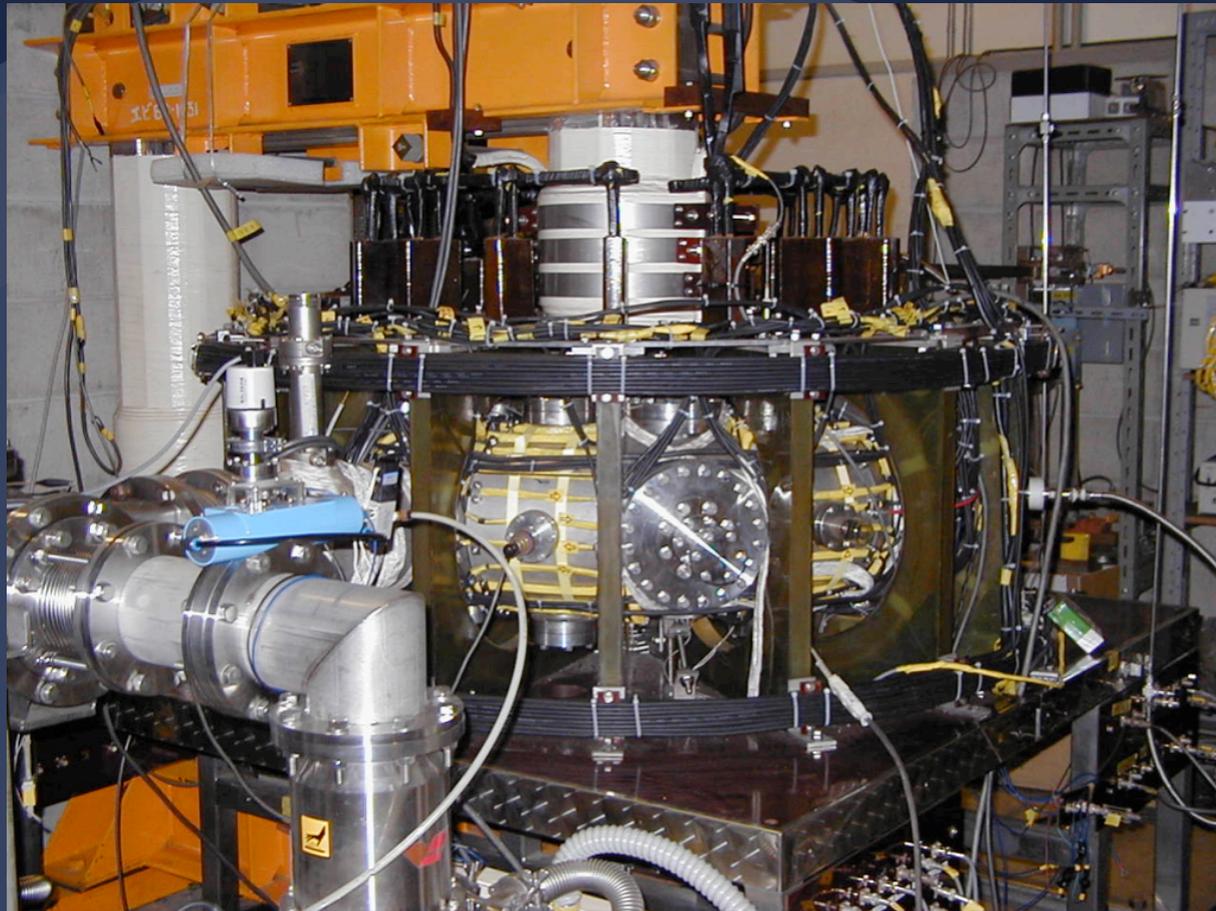
Experimental Objectives

1. Control of Tokamak Edge Plasmas by Rotating Helical Magnetic Perturbation (Dynamic Ergodic Divertor)
 - Island Formation and Ergodization
 - Rotation Drive by Rotating Helical Magnetic Field
 - Improvement of Plasma Properties
2. Studies on MHD Control
 - Island Suppression by Plasma Current Modulation
3. Studies on Disruption Properties
 - Dynamics of Internal Magnetic Structure
 - Key Mechanisms to Determine Thermal and Current Decay Times

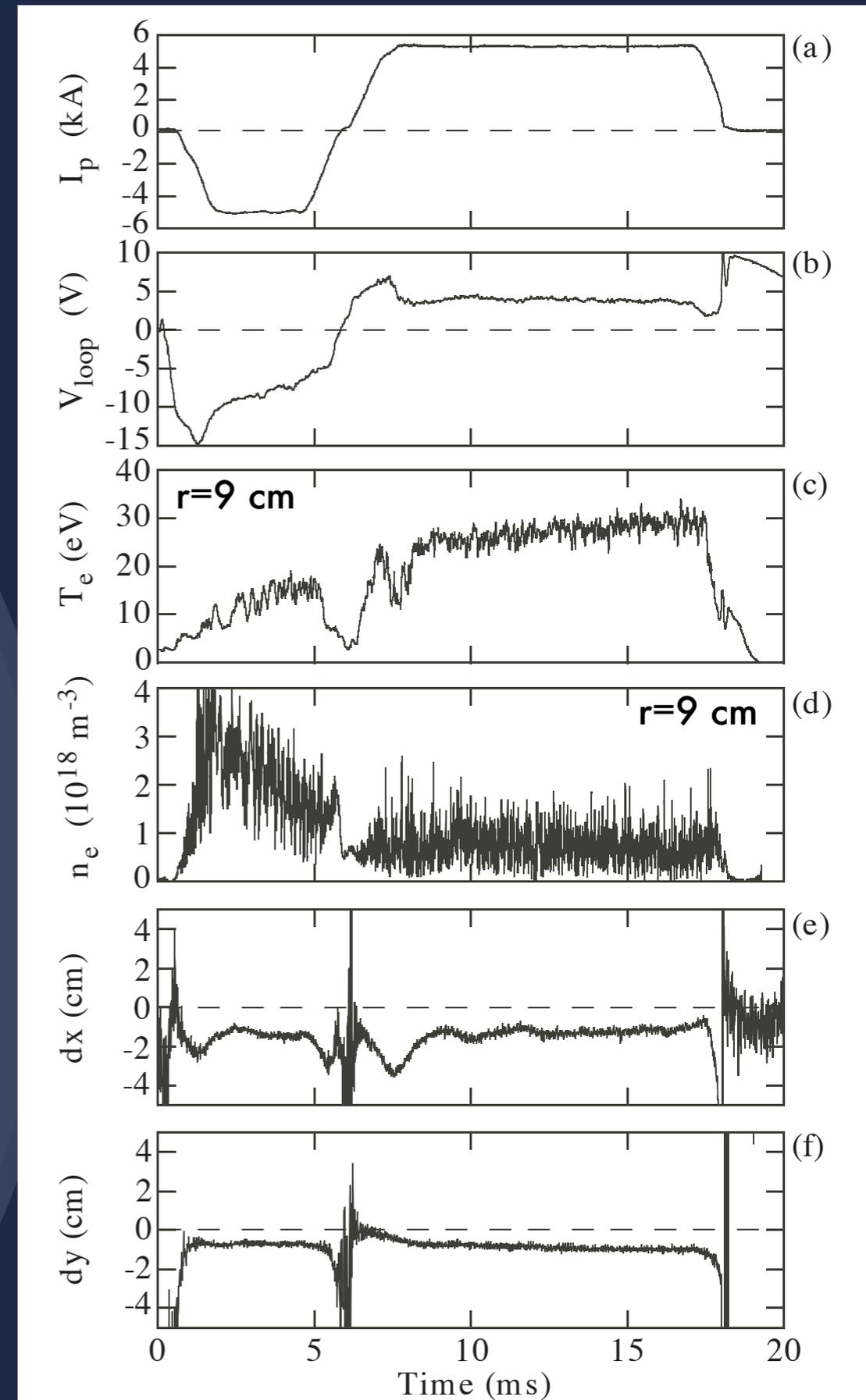


HYBTOK-II Tokamak

HYBTOK-II Tokamak

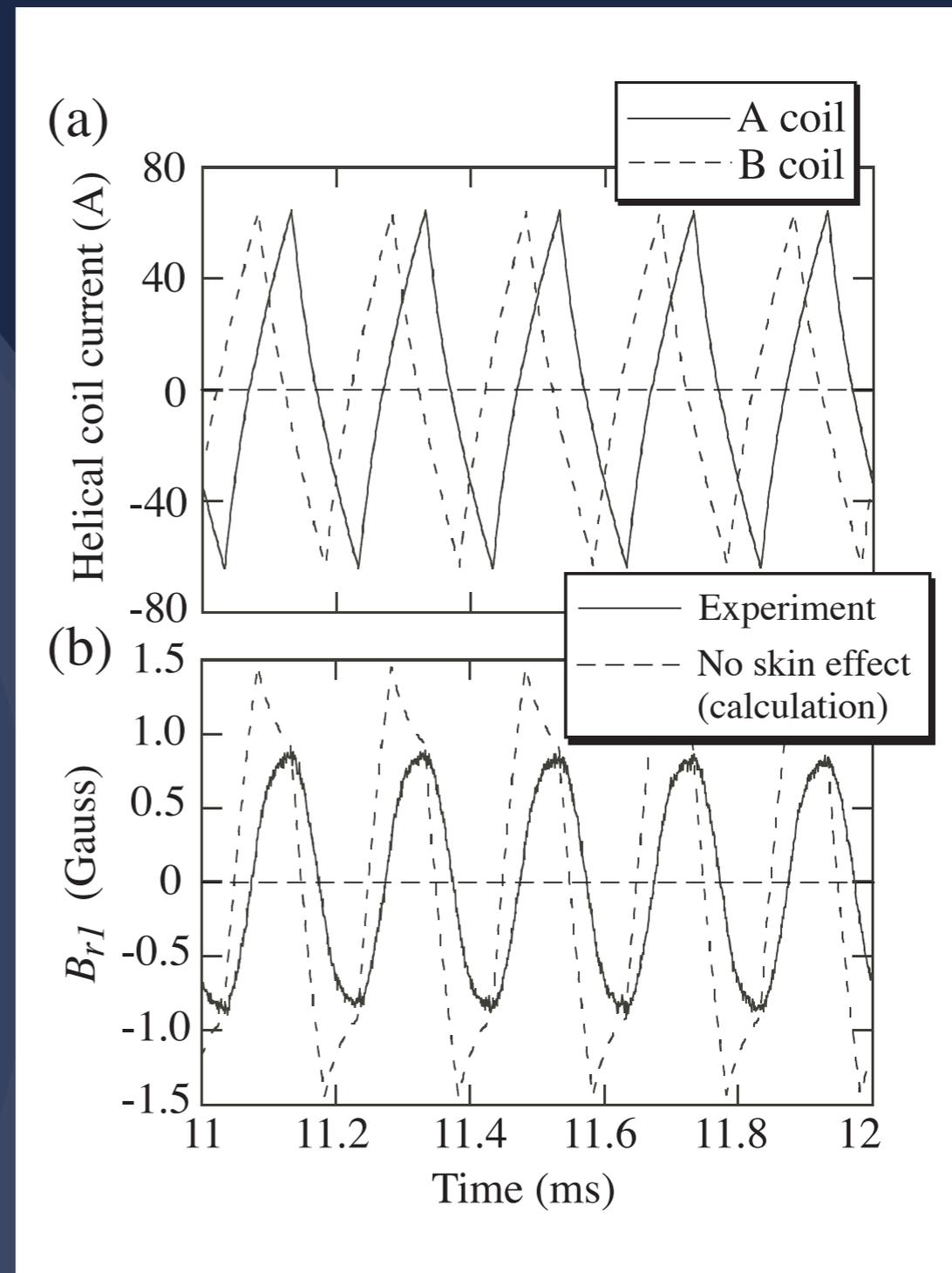
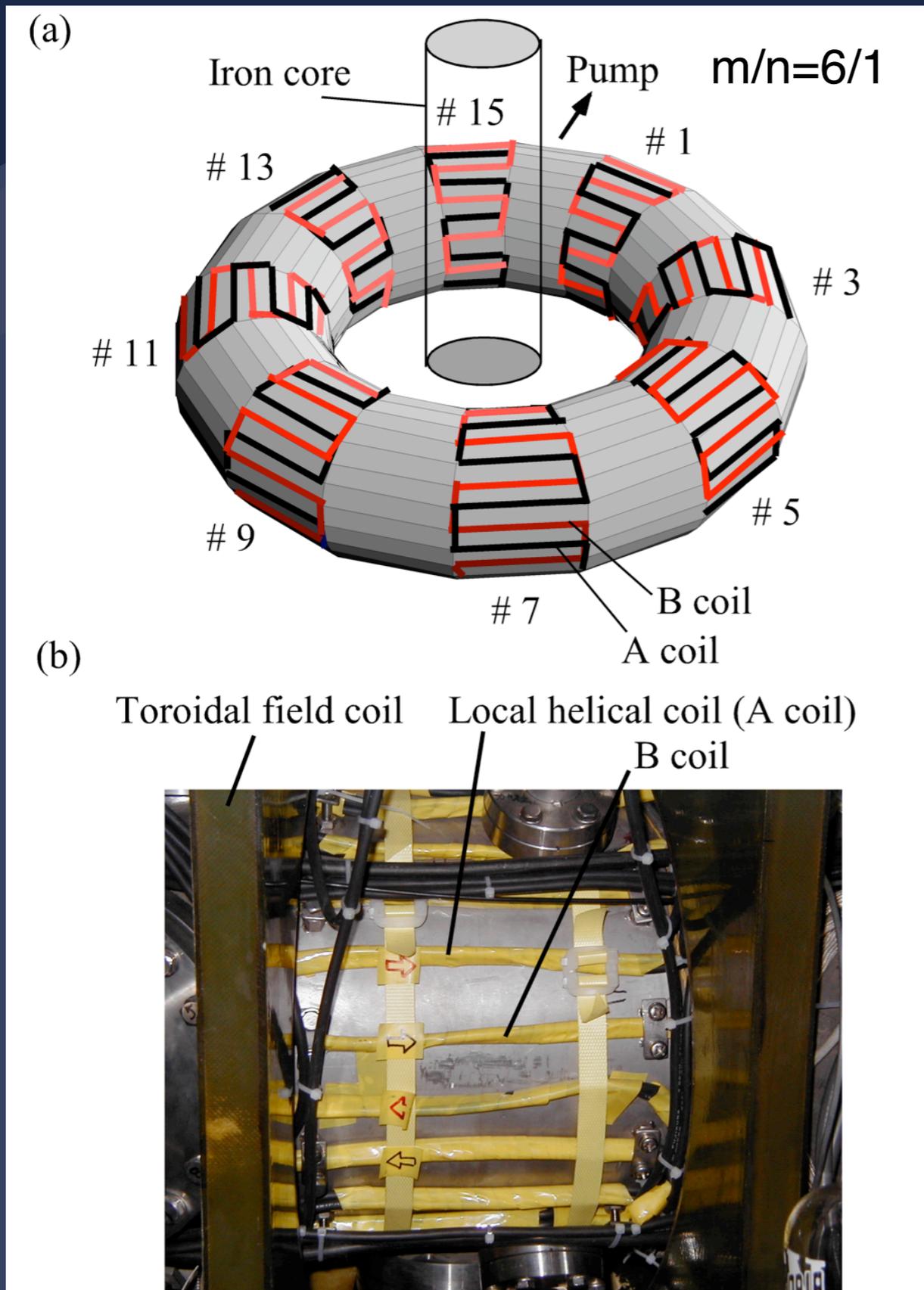


Major Radius : 0.4 m
Minor Radius : 0.11 m
Plasma Current : 15 kA
Toroidal Field : 0.5 T
RF Heating : 200 MHz, 10 kW





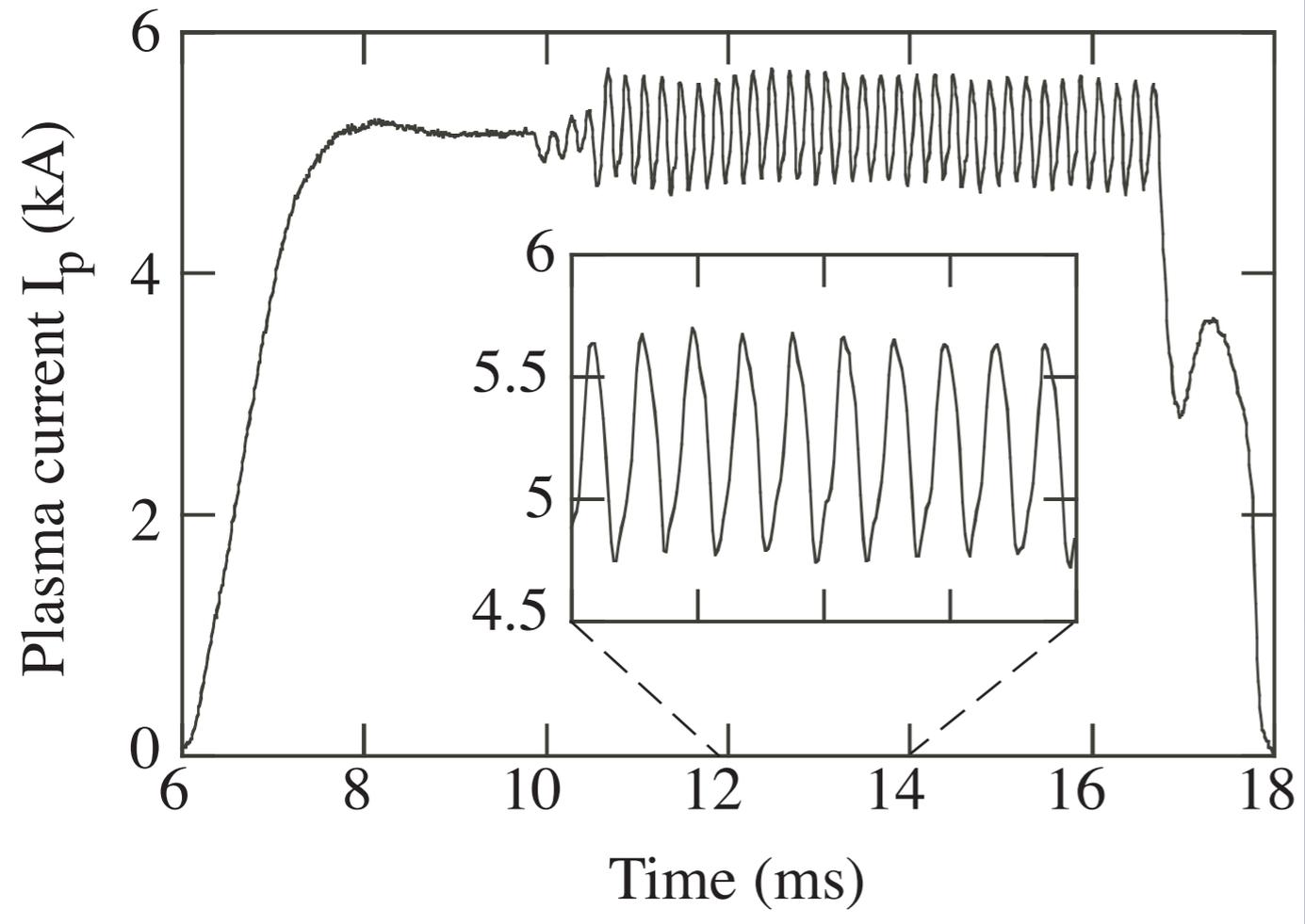
Local Helical Coil for DED



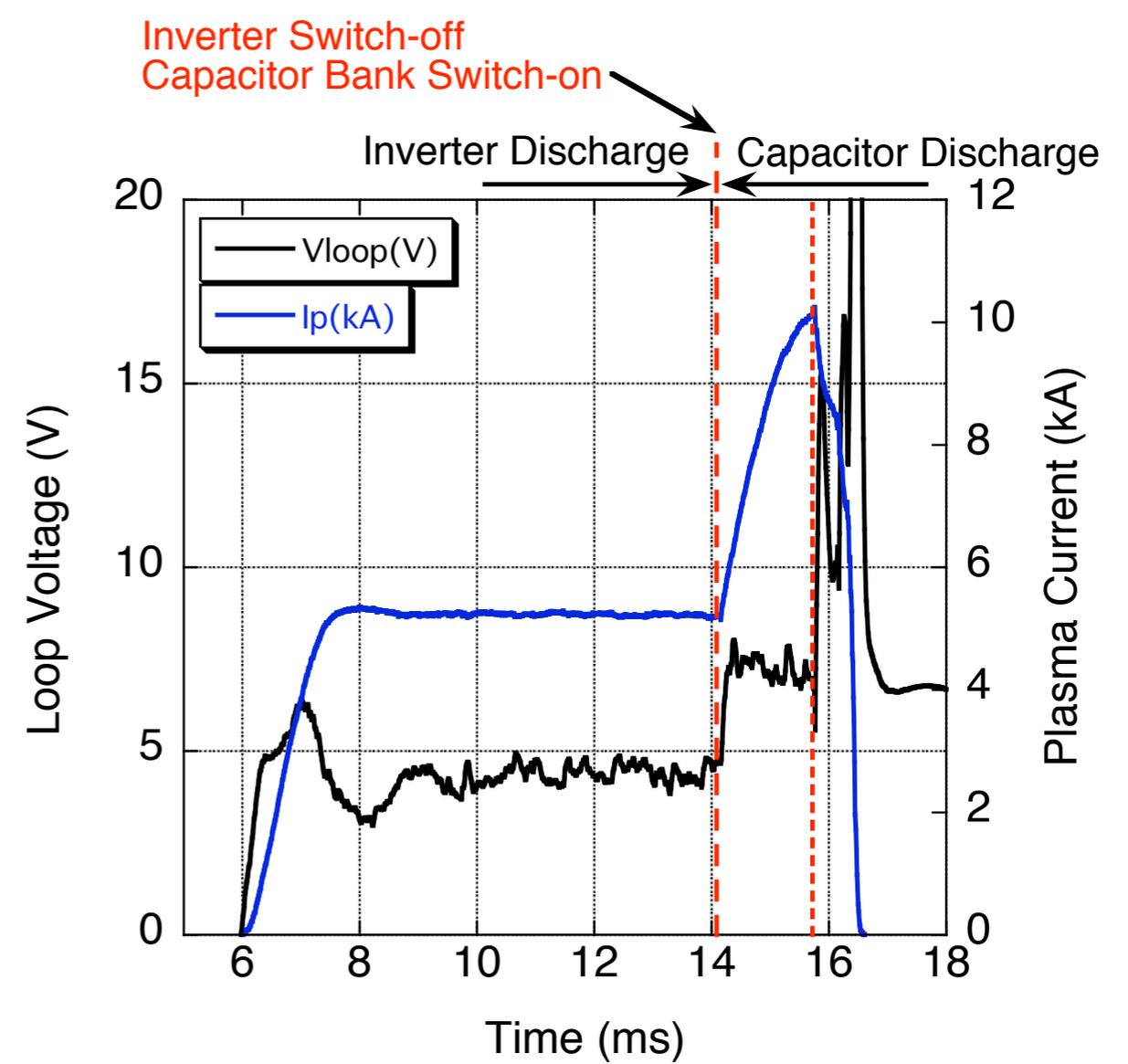
DSP Controlled Power Supplies

- Fast IGBT Inverters for Joule and Vertical Coils
- Fast Current Control by DSP
- Hybrid Operation Combined with Capacitor Bank Discharge

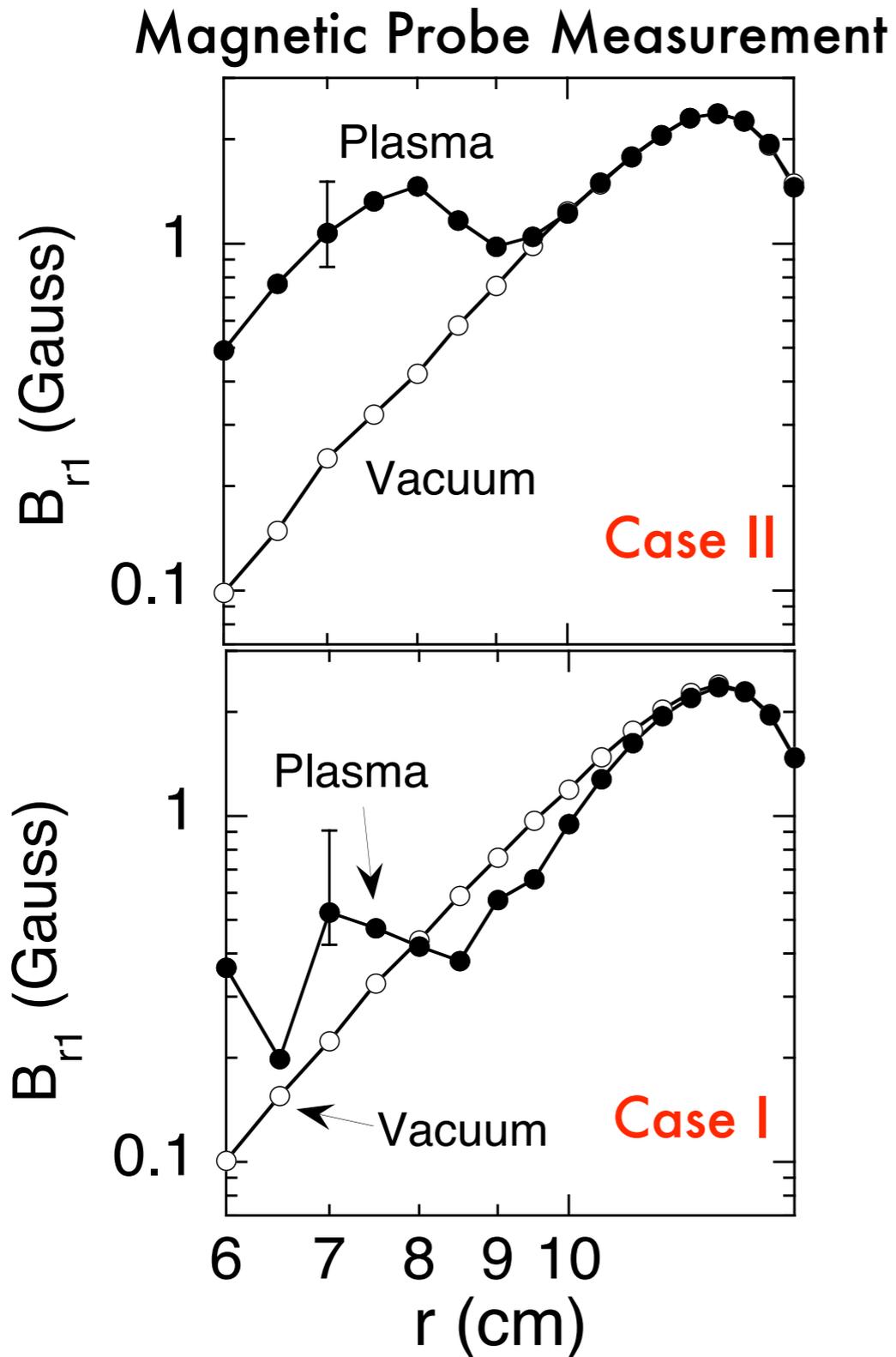
Plasma Current Modulation at $f_{mod}=5$ kHz



Hybrid Operation of Joule Coil



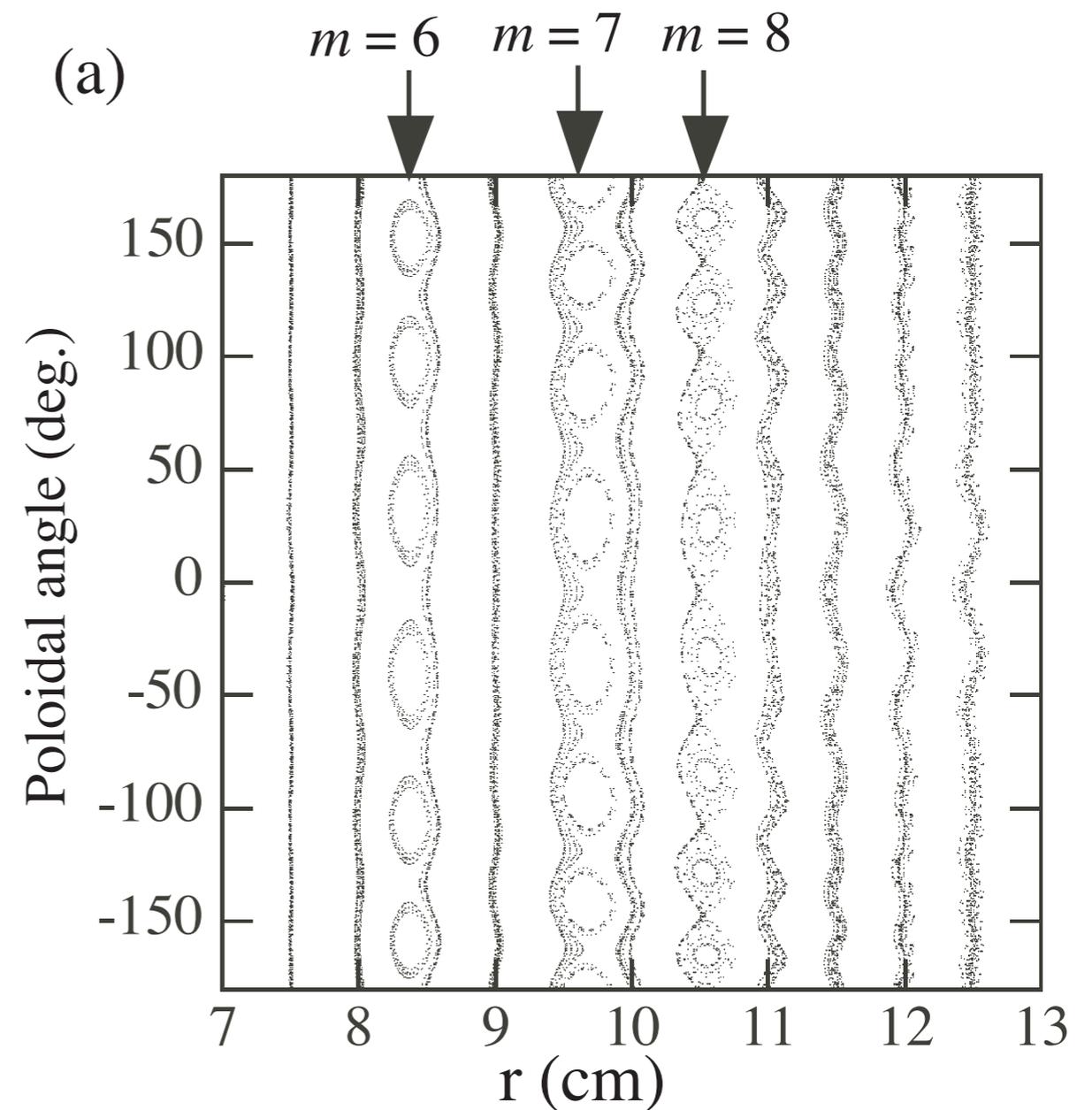
DED Experiments: Penetration of RHMP and Ergodization 1



Direction of RHMP

Case I : Ion Diamagnetic Direction

Case II : Electron Diamagnetic Direction

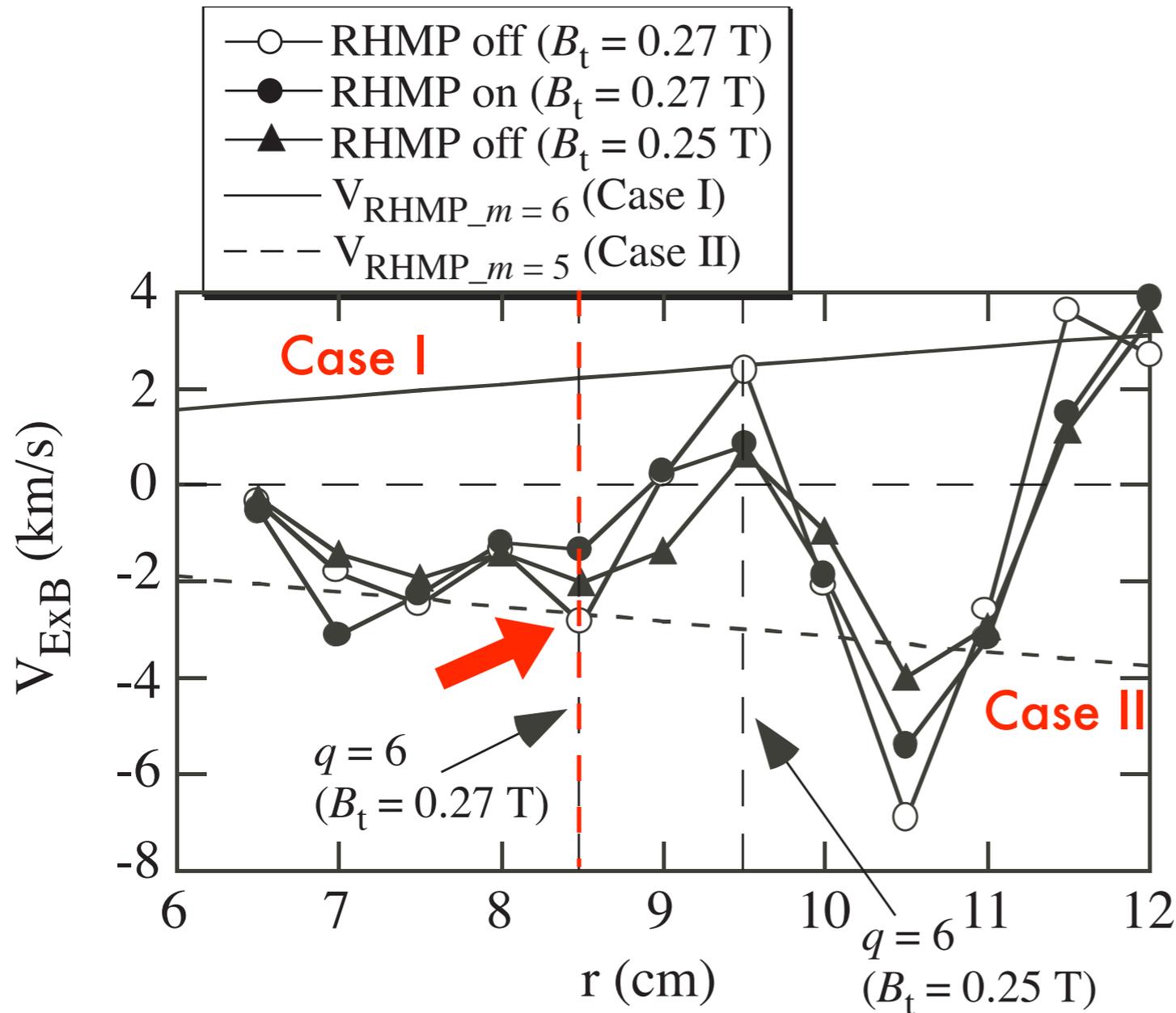


Poloidal angle (deg.)



DED Experiments: Penetration of RHMP and Ergodization 2

ExB Plasma Rotation and Rotation Velocity of RHMP



Direction of RHMP

Case I : Ion Diamagnetic Direction

High Doppler Shifted Frequency
=> Strong Damping of RHMP
=> Small Island Formation

Case II : Electron Diamagnetic Direction

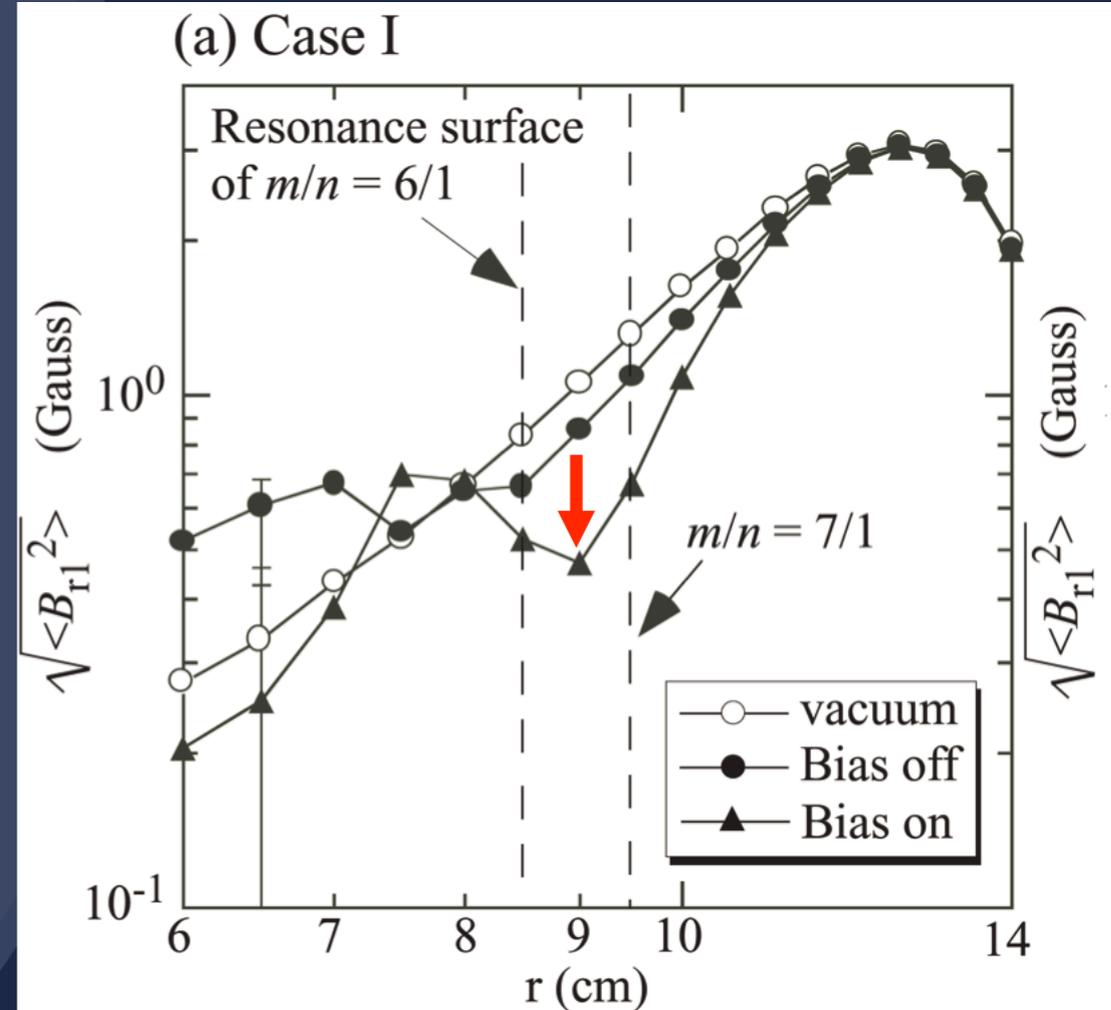
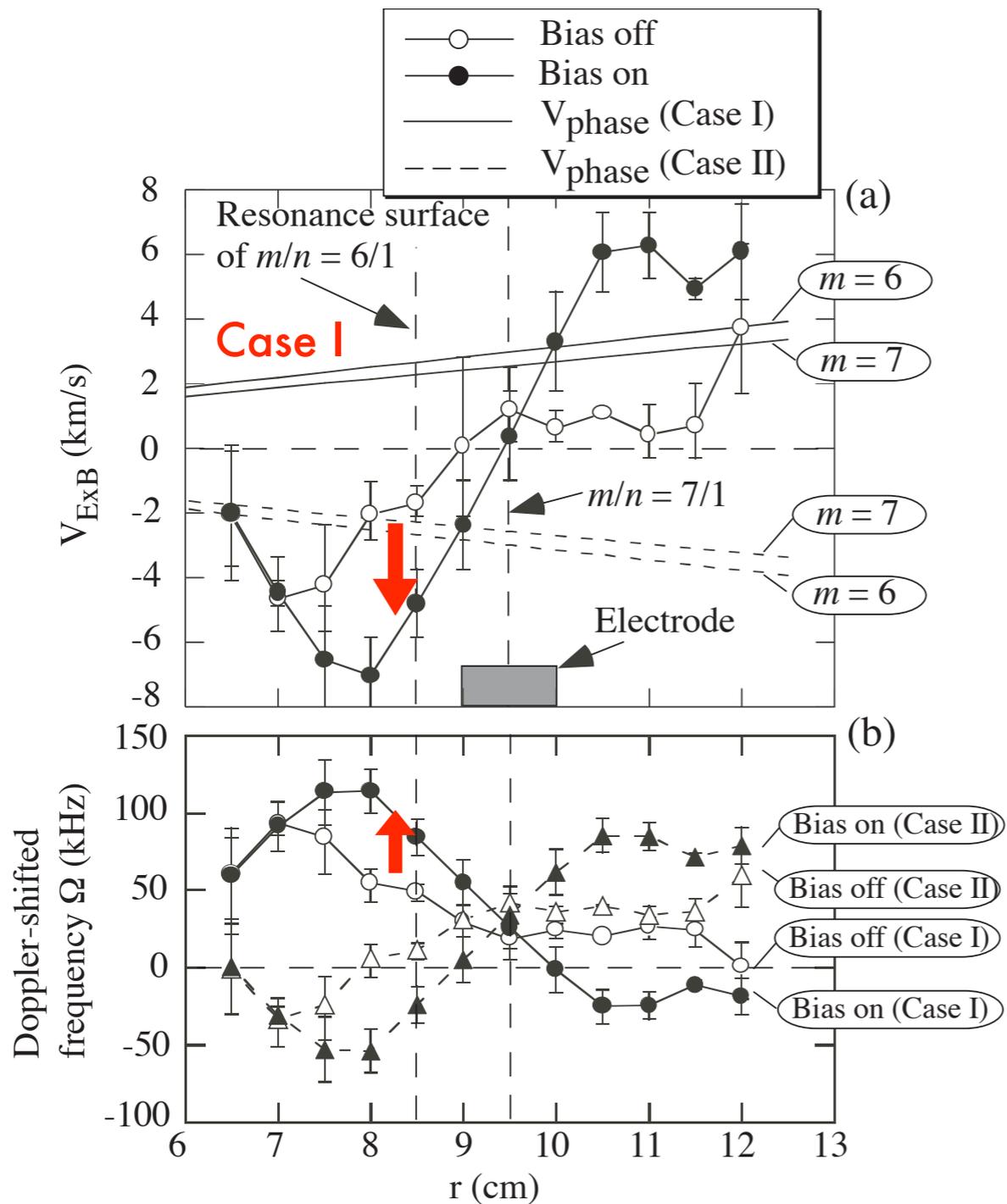
Low Doppler Shifted Frequency
=> Weak Damping of RHMP
=> Large Island Formation
=> Modification of I_p Distribution
=> Amplification of B_{r1}

DED Experiments: Control of RHMP Penetration by Biasing

Electrode Biasing changes
ExB rotation velocity

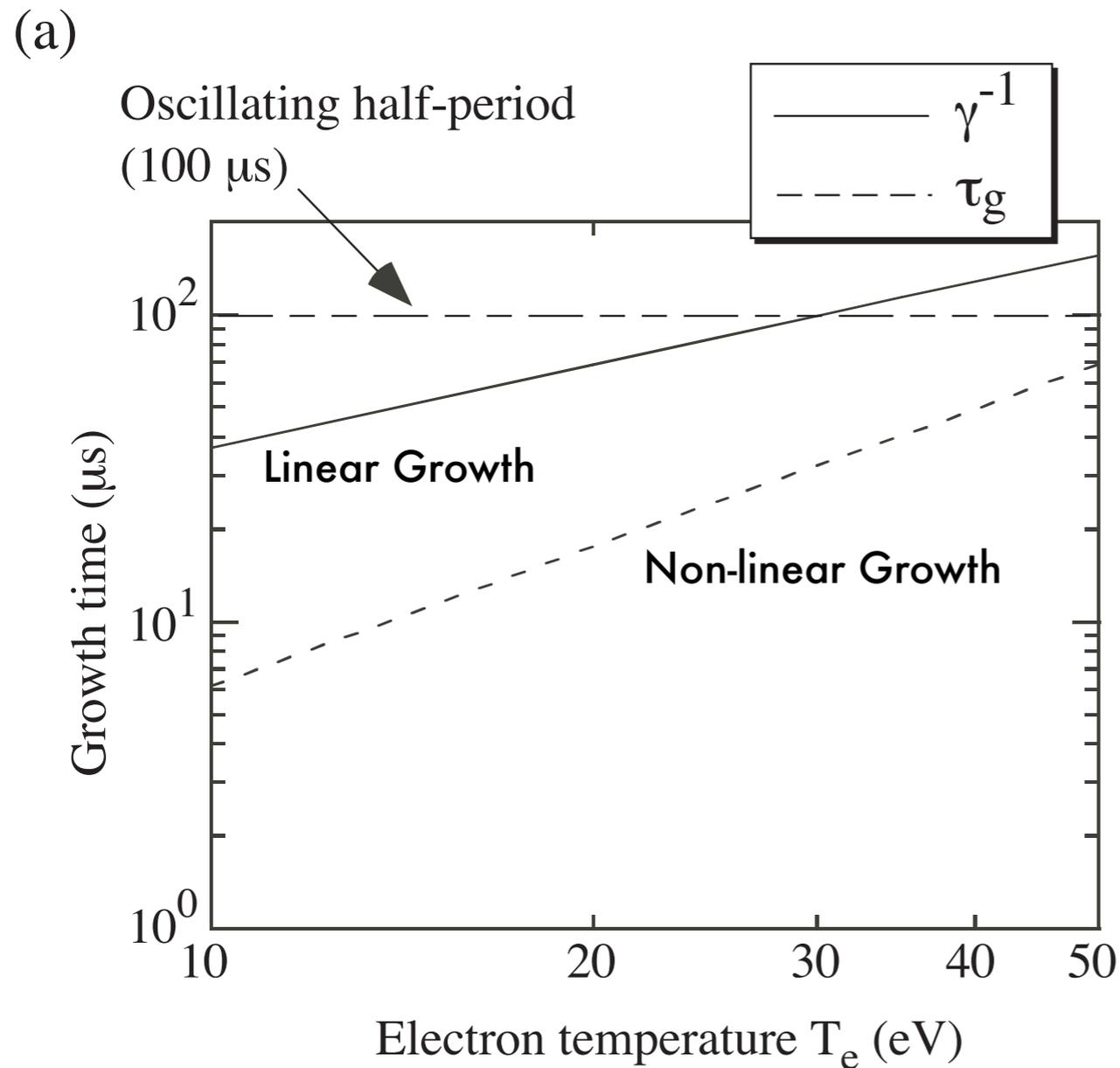
Case I : Increase of Doppler Shifted
Frequency => **Strong Damping**

$$\Omega \sim 48 \text{ kHz} \Rightarrow \sim 83 \text{ kHz}$$

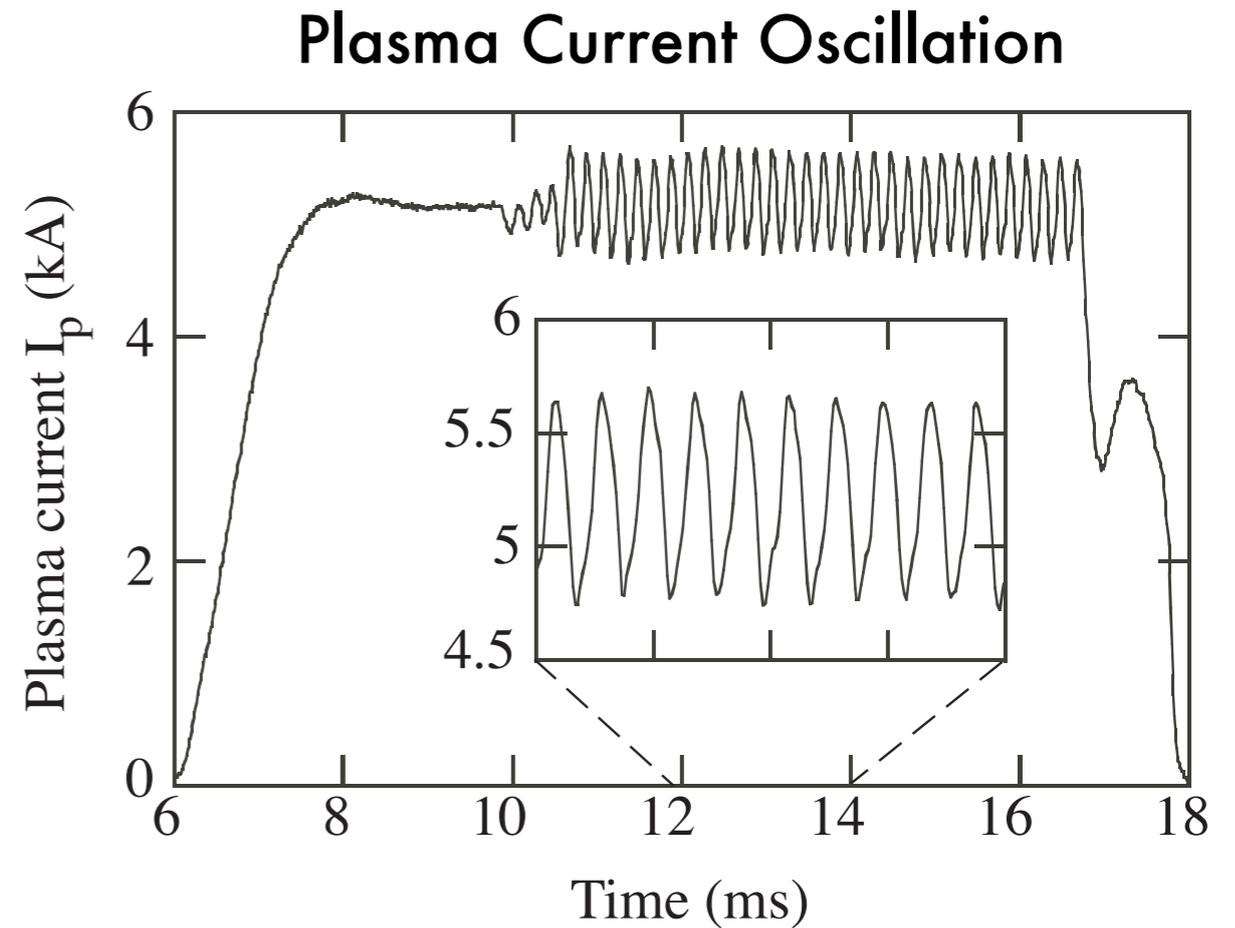


DED Experiments: Suppression of Island by Resonance Surface Oscillation 1

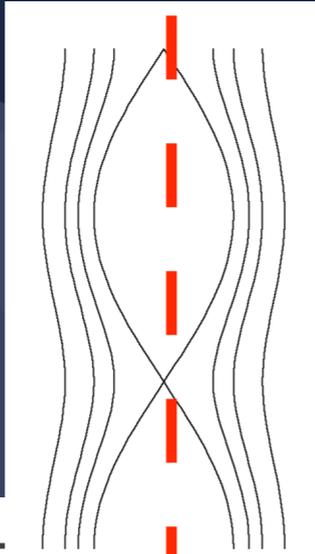
Growth Time of Resistive Tearing Modes



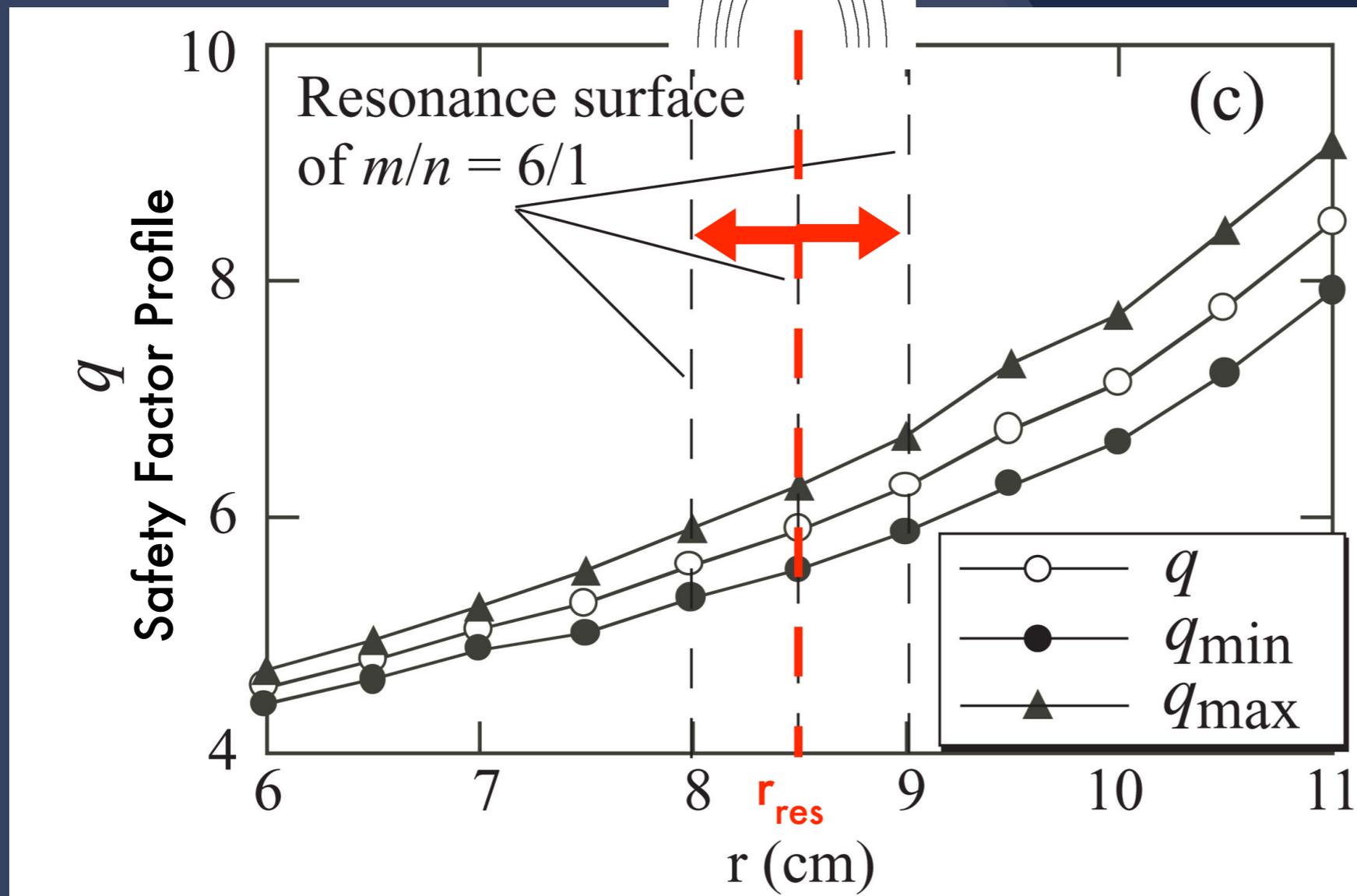
(b)



DED Experiments: Suppression of Island by Resonance Surface Oscillation 2



Oscillation of Resonance Surface and Growth of Resistive Tearing Mode

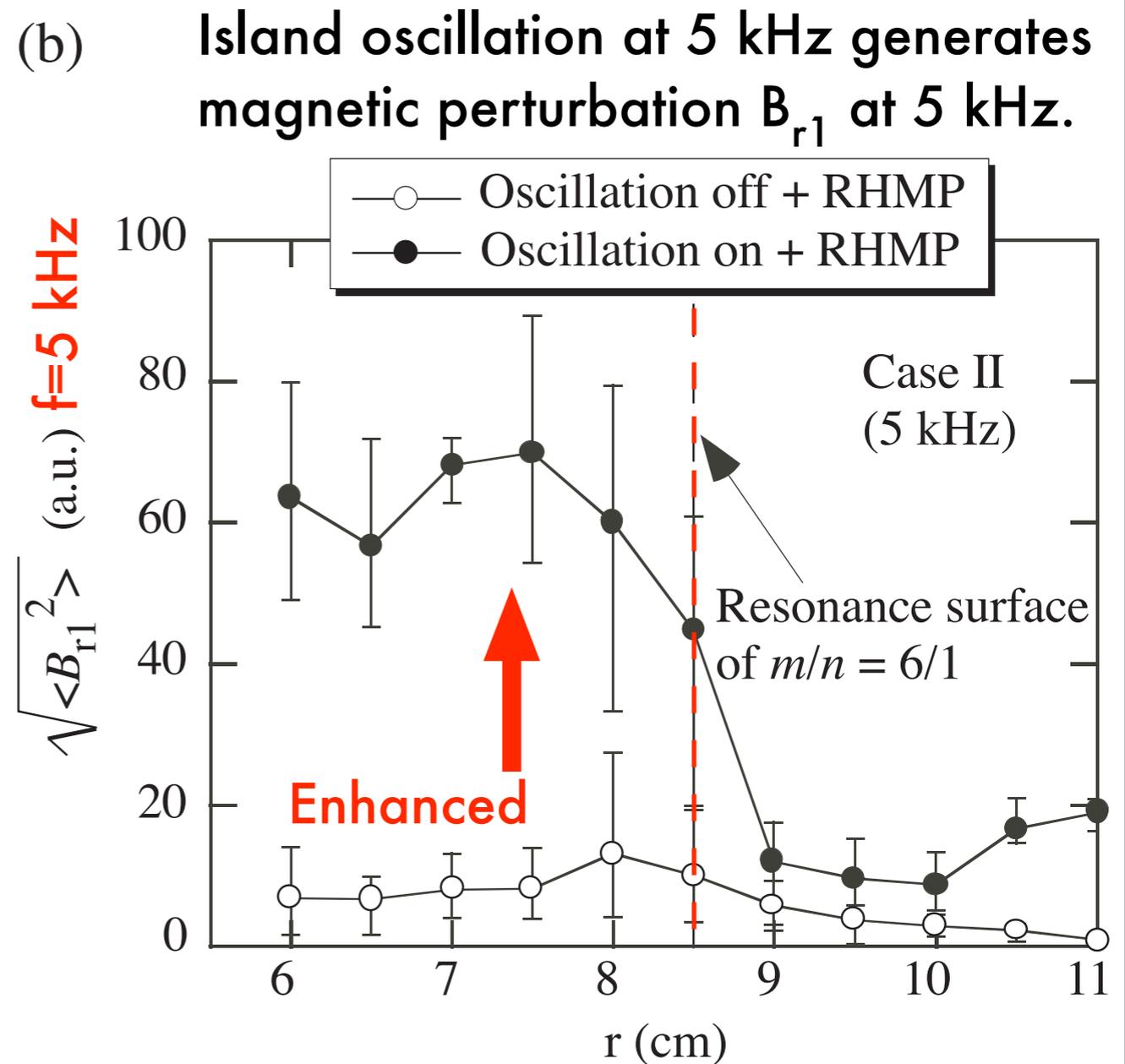
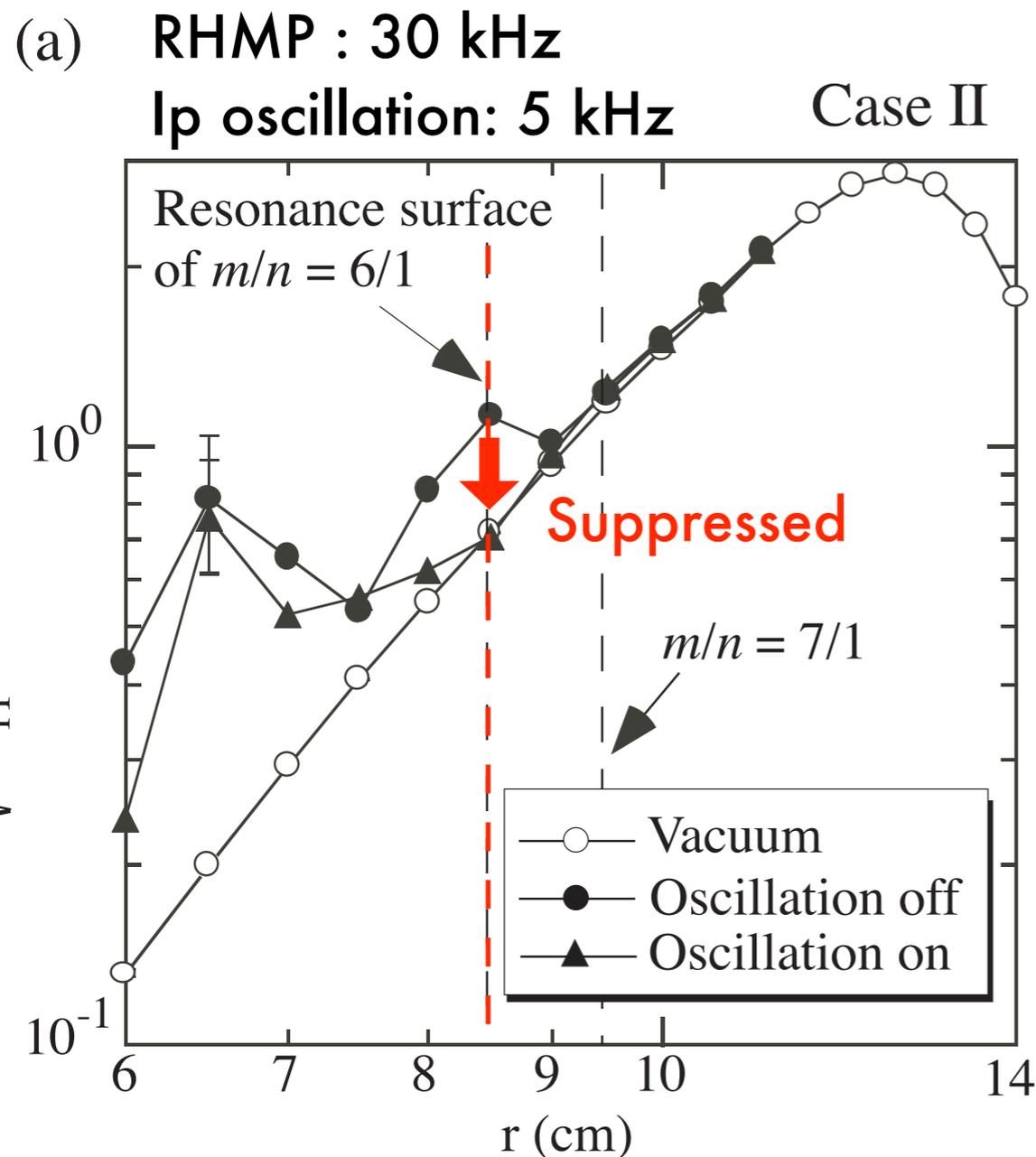


If oscillation of r_{res} is faster than γ ,

Island growth is suppressed?



DED Experiments: Suppression of Island by Resonance Surface Oscillation 3

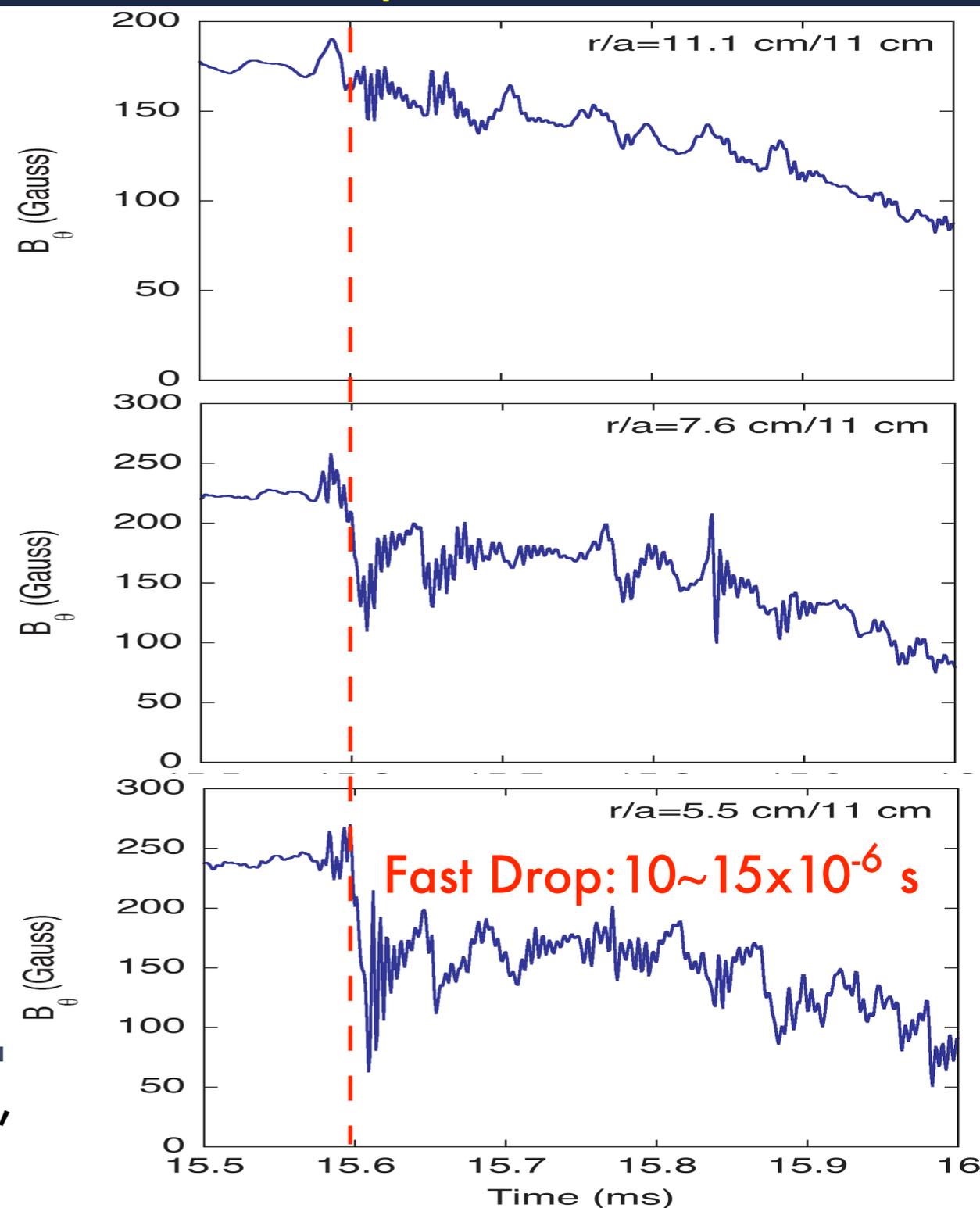
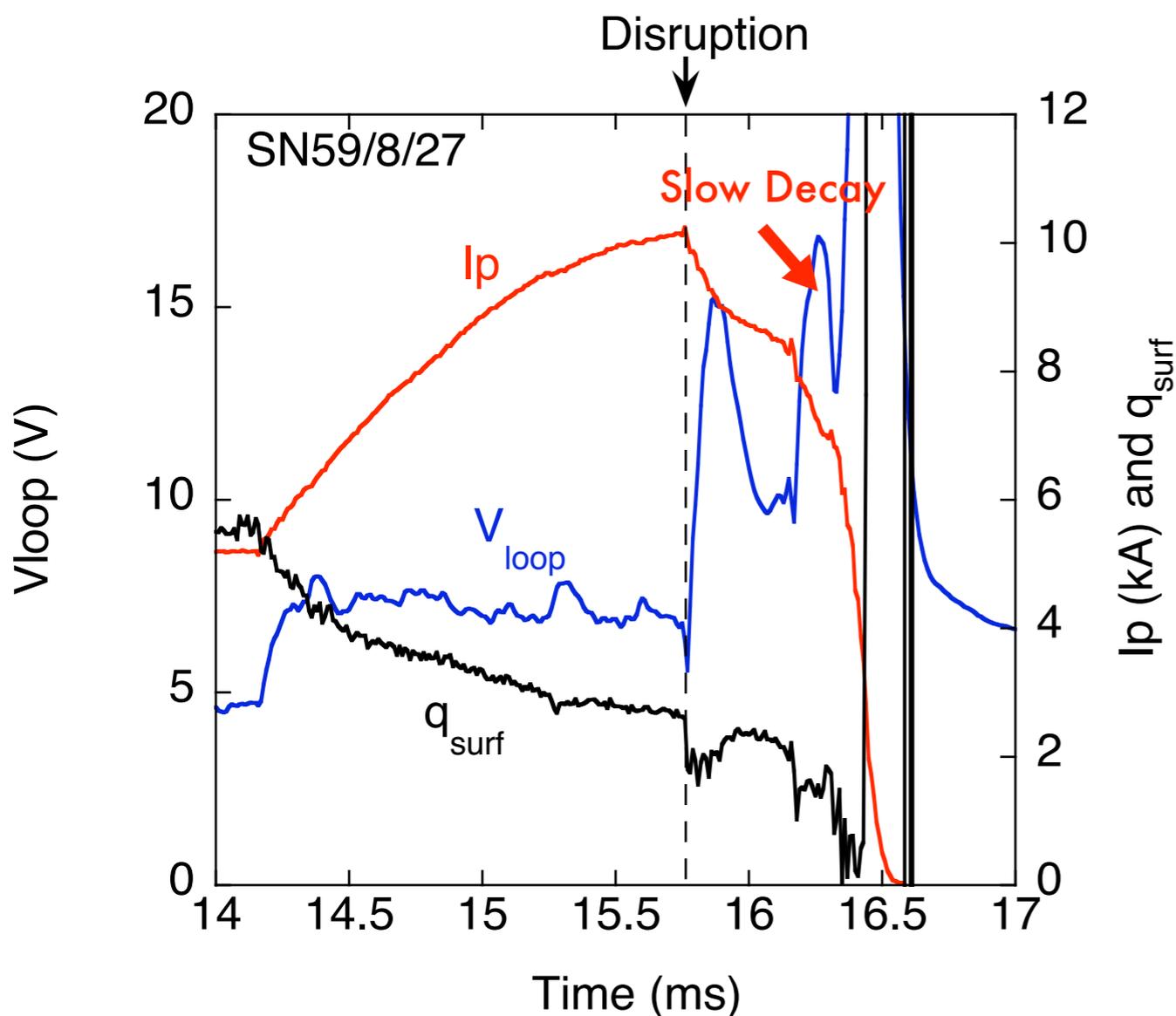




Disruption Experiments: Disruption Phenomena in a Small Tokamak

Disrupted

Typical Waveforms of Disruptive Shot

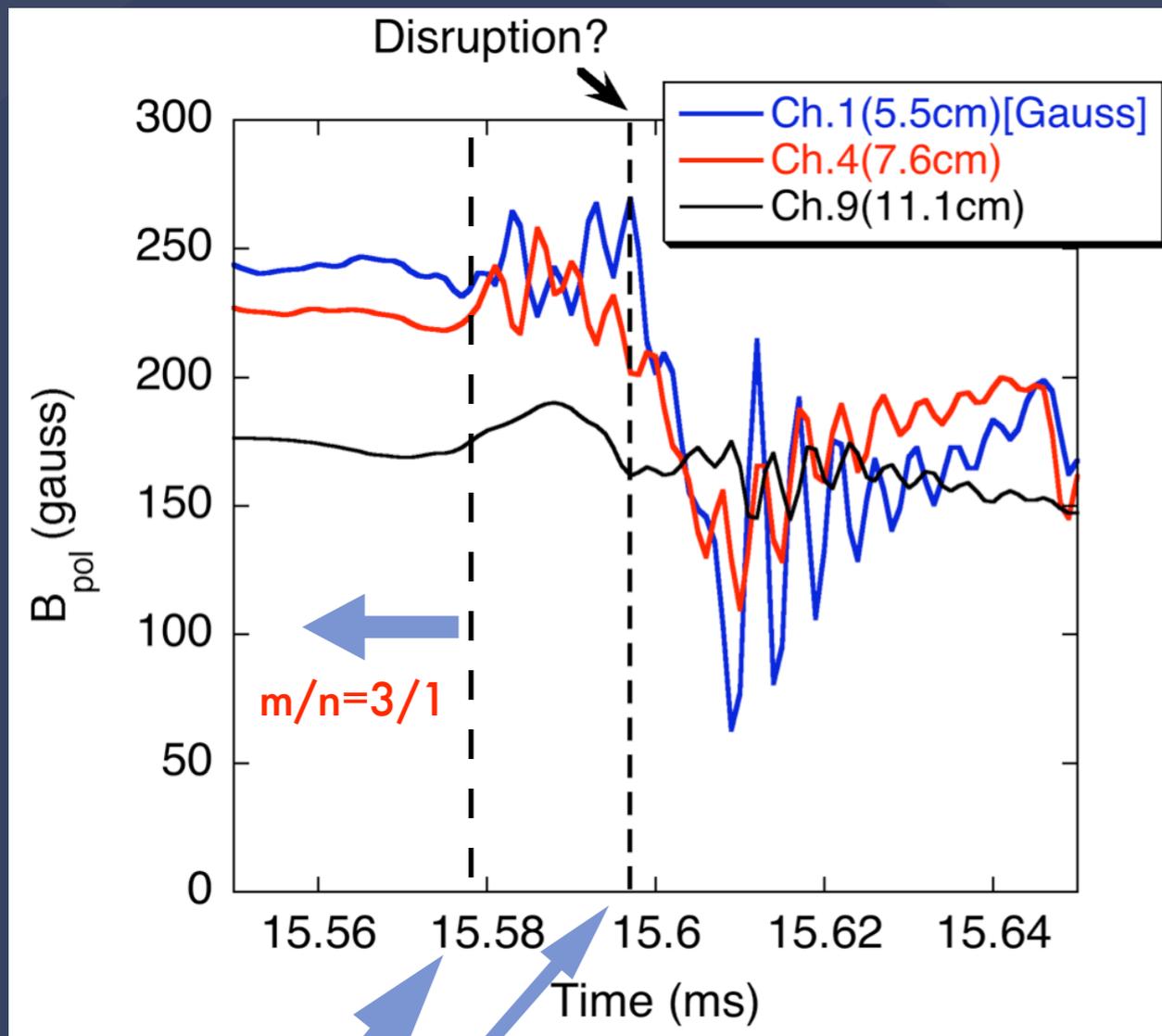


Internal poloidal magnetic field drops very fast,
 $10\sim 15 \times 10^{-6}$ s : $S = \tau_R / \tau_A \sim 3 \text{ ms} / 0.5 \mu\text{s}$



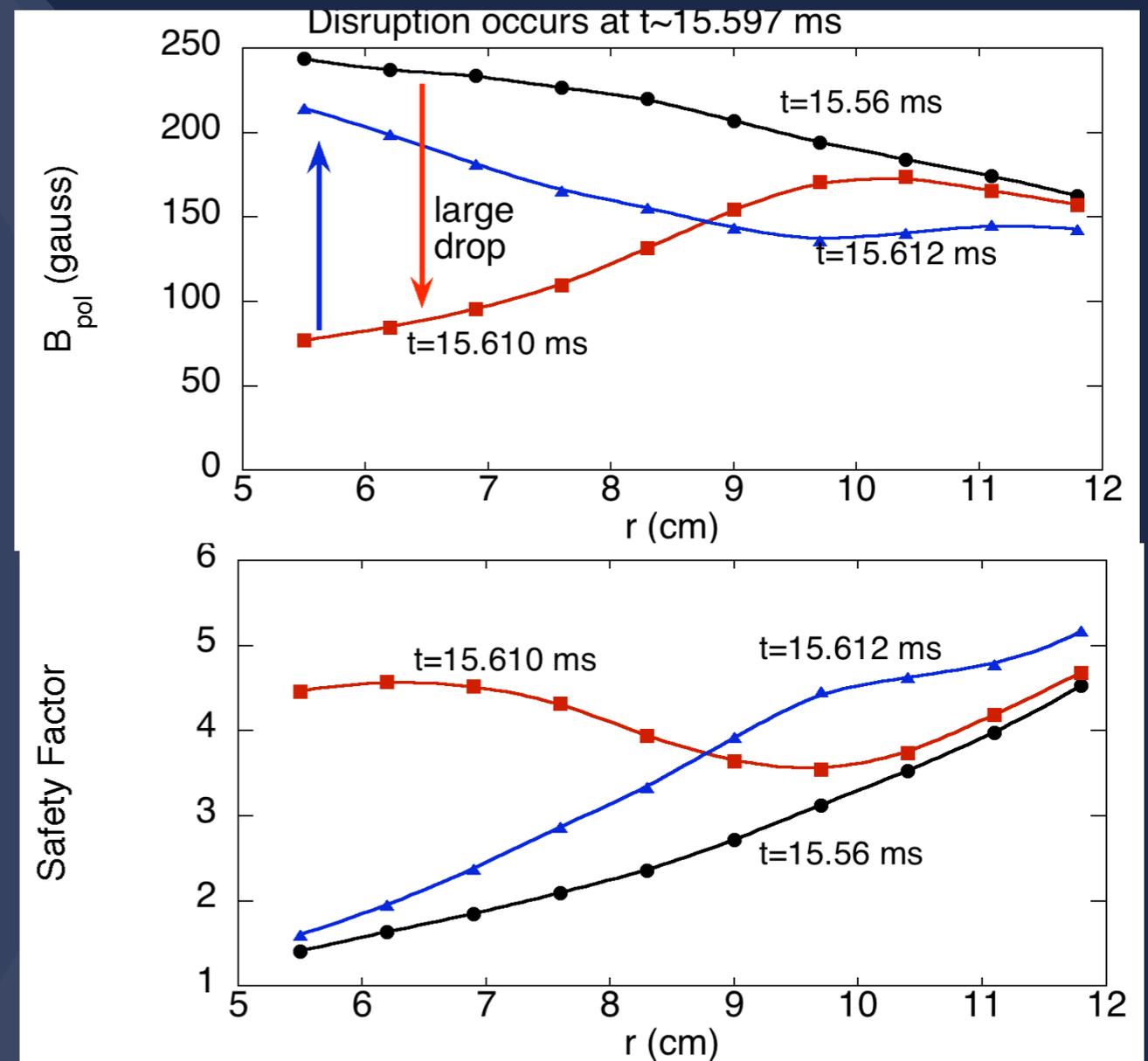
Disruption Experiments: Rapid Change of Plasma Current Profile/ q Profile

Precursor can be seen just before disruption, then internal magnetic field ($q < 2 \sim 3$) drops, followed by large amplitude oscillations.



develops to $q \sim 3$, and then disrupted.

High frequency oscillation starts inside $q \sim 2$.





Summary

1. DED Experiments

- Penetration of RHMP induced by local helical coils are studied.
- Doppler shifted RHMP frequency has an important role for penetration of RHMP.

Doppler shifted RHMP frequency high

=> strong damping of RHMP and weak island formation.

Doppler shifted RHMP frequency low

=> damping of RHMP is weak, large island formation and resultant current profile modification leads RHMP amplification.

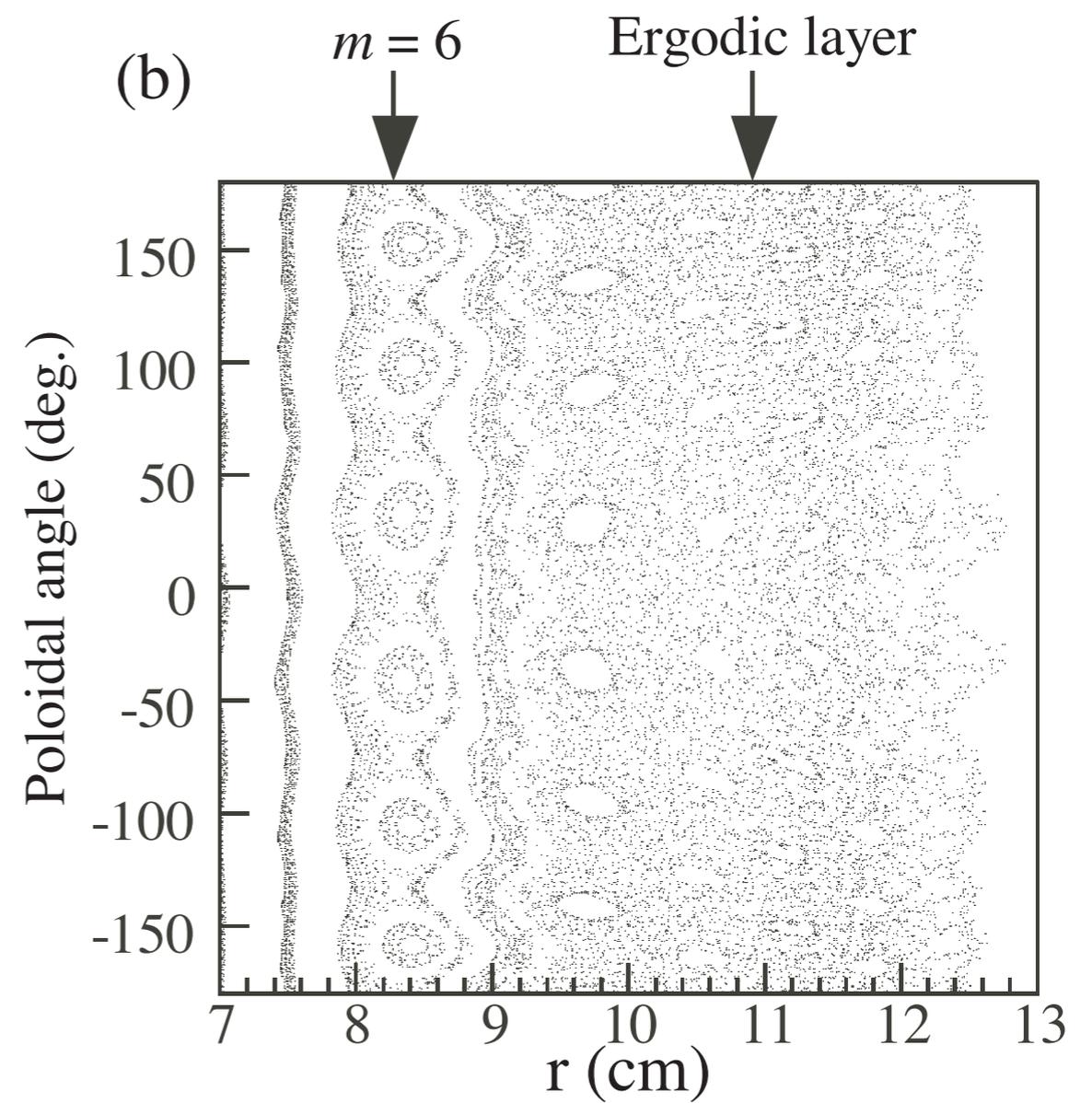
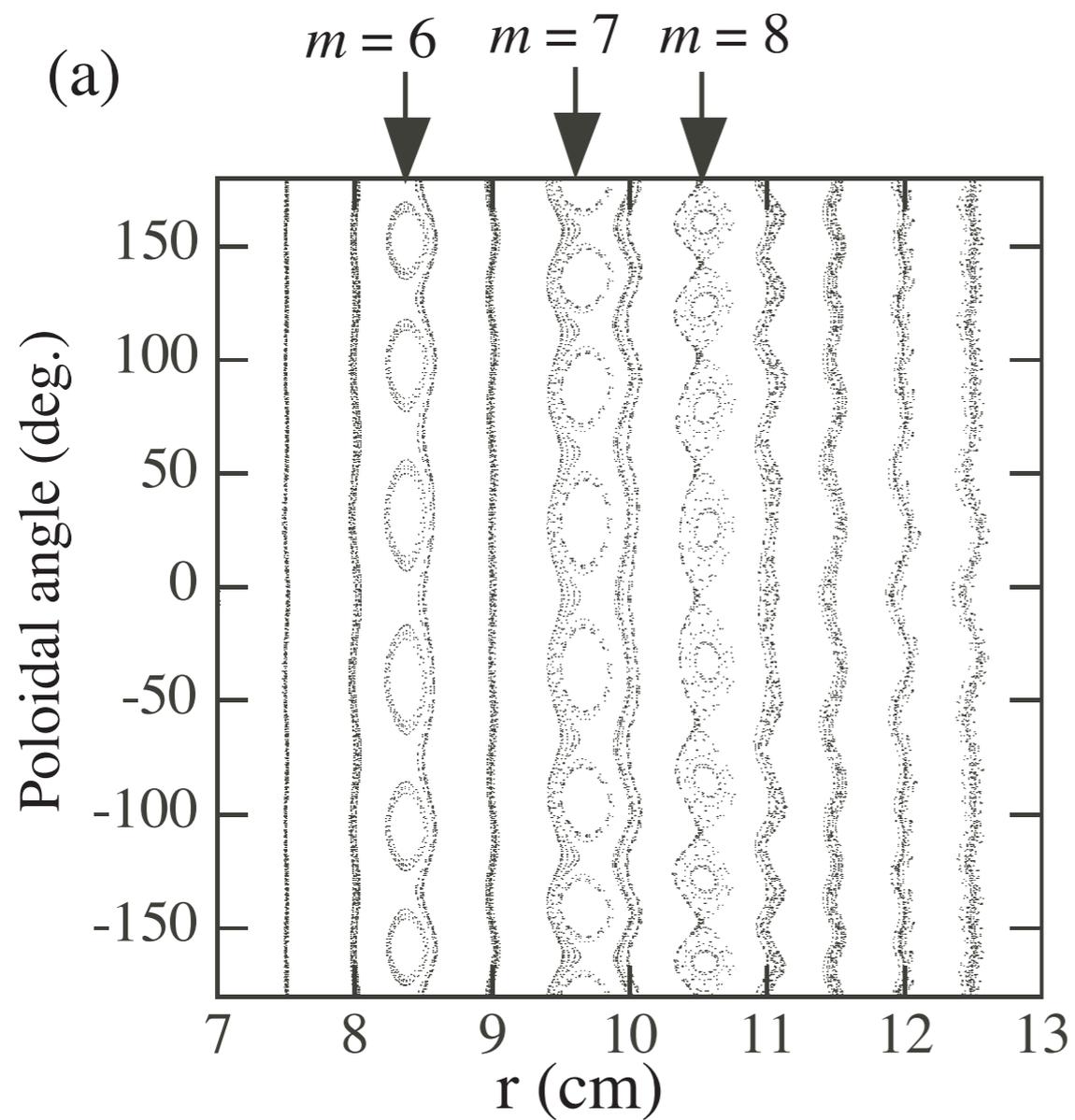
2. Island Suppression

- Resonant surface oscillations induced by I_p oscillation can suppress externally excited islands, but it is not clear to suppress self-excited islands in low q discharges, $q_{\text{surf}} \sim 3$.

3. Disruption Experiments

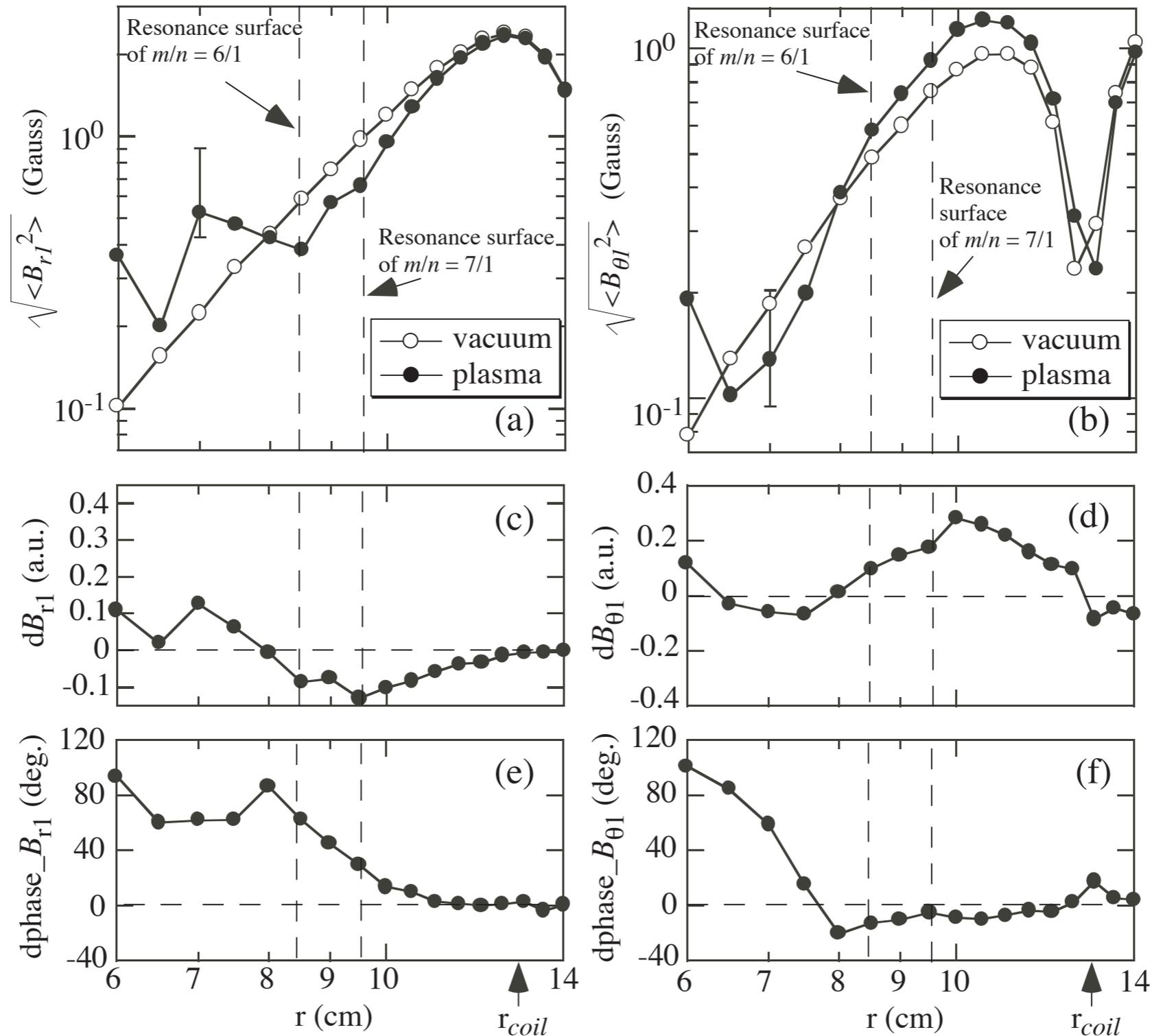
- Internal magnetic structures during disruptions are measured. Fast current drop inside $q \sim 3$ and current flattening occurs within $t \sim 15 \mu\text{s}$. Detailed analysis is under way.

DED Experiments: Island Formation and Ergodization



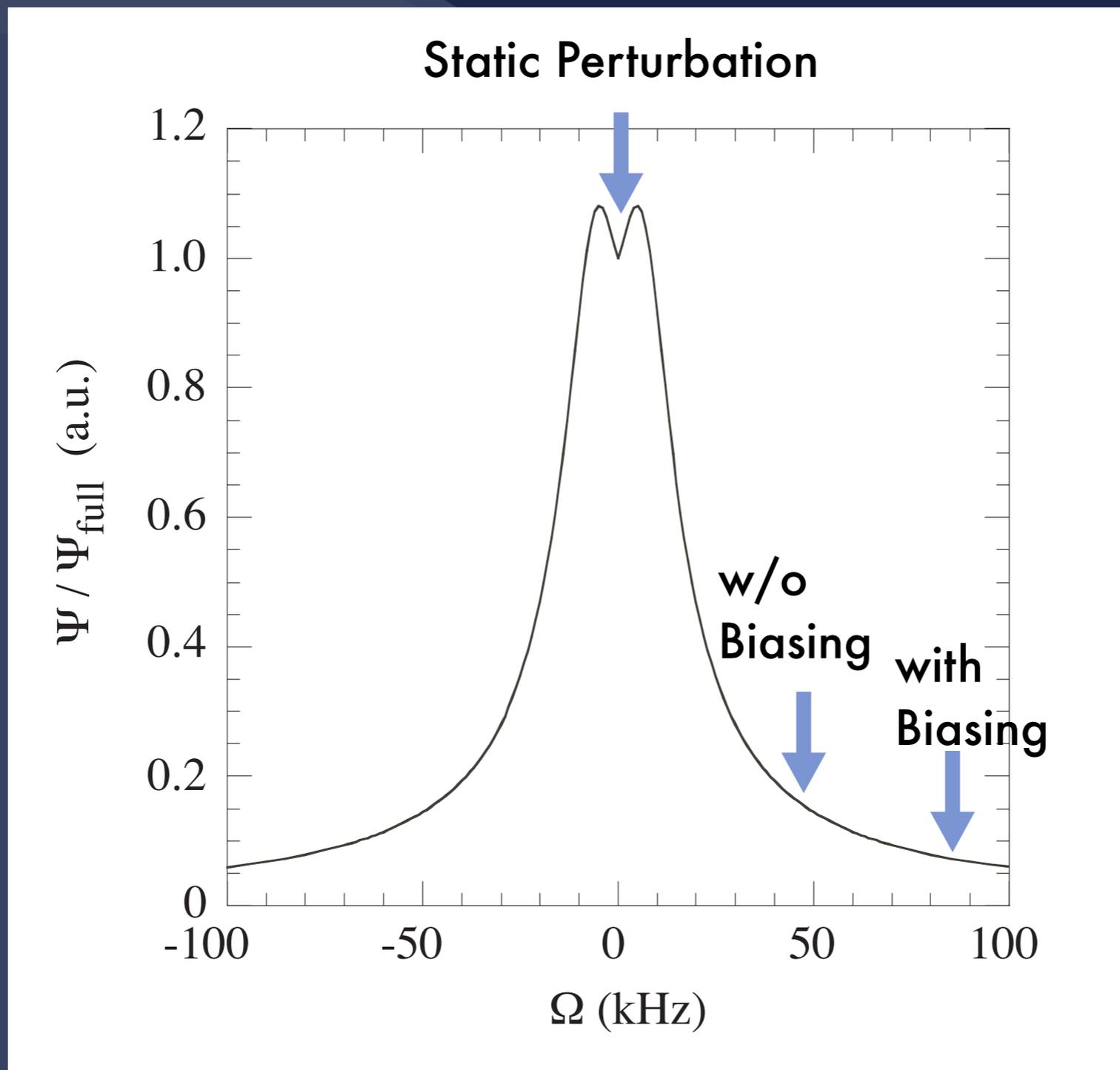
DED Experiments: Penetration of RHMP and Ergodization 3

Case I



DED Experiments: Suppression of Island by Helical Shielding Current

Change of Perturbed Flux Function



DED Experiments: Penetration of RHMP and Ergodization 4

Case II

