

Driven ExB rotation and its effect on external kinks

David A Maurer



Columbia University

22nd November 2004
9th Workshop on MHD Stability & Control
“Control of MHD Stability: Back to the Basics”
Princeton, New Jersey

Outline

- Motivation
- Experimental setup
- Initial experiments
- Theoretical modeling
- Future work

Work in progress

Basic Motivation

- Plasma rotation strongly effects the behavior of resistive wall modes (RWMs) and tearing modes (TMs)
- It is important to understand the effects of plasma rotation on MHD modes in order to be able to better understand and control MHD on present and future fusion devices.
- Question: Can we find a suitable way to perturb plasma rotation and measure its effect on MHD systematically?

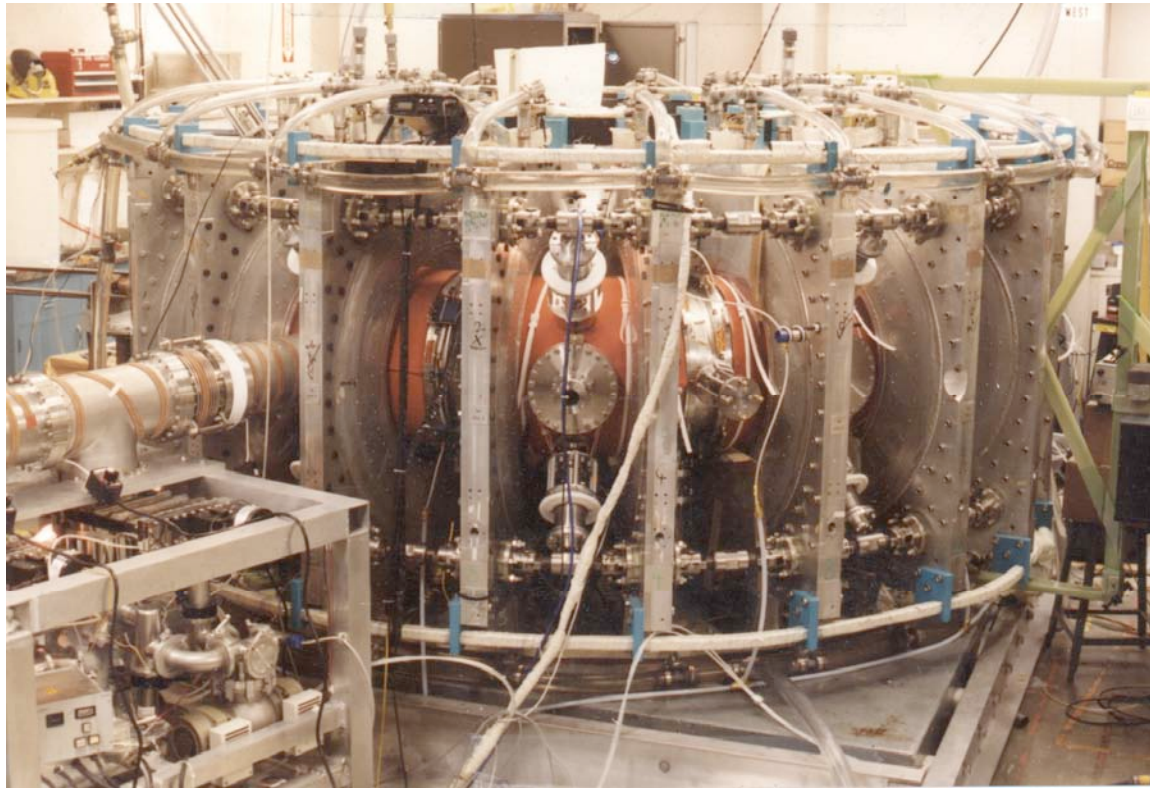
Spectroscopic Analogy

- MHD spectroscopy has recently been shown to be a useful tool in exploring stable kink mode behavior in tokamaks (Shilov HBT-EP, Reimerdes DIII-D)
- MHD Spectroscopy: Apply resonant magnetic perturbation and measure the plasma kink response
- Driven ExB rotation: Apply $J_r \times B$ torque that changes plasma and mode rotation and measure plasma kink response

Use biased electrode J_r to torque plasma

- Offers another “knob” to poke and prod the plasma with to investigate kink dispersion characteristics by directly changing plasma rotation
- Easy to implement using an insertable electrode
- Localized in radius
- Use a “modest” bias voltage so as not to induce confinement changes (H-modes)

HBT-EP Tokamak Parameters

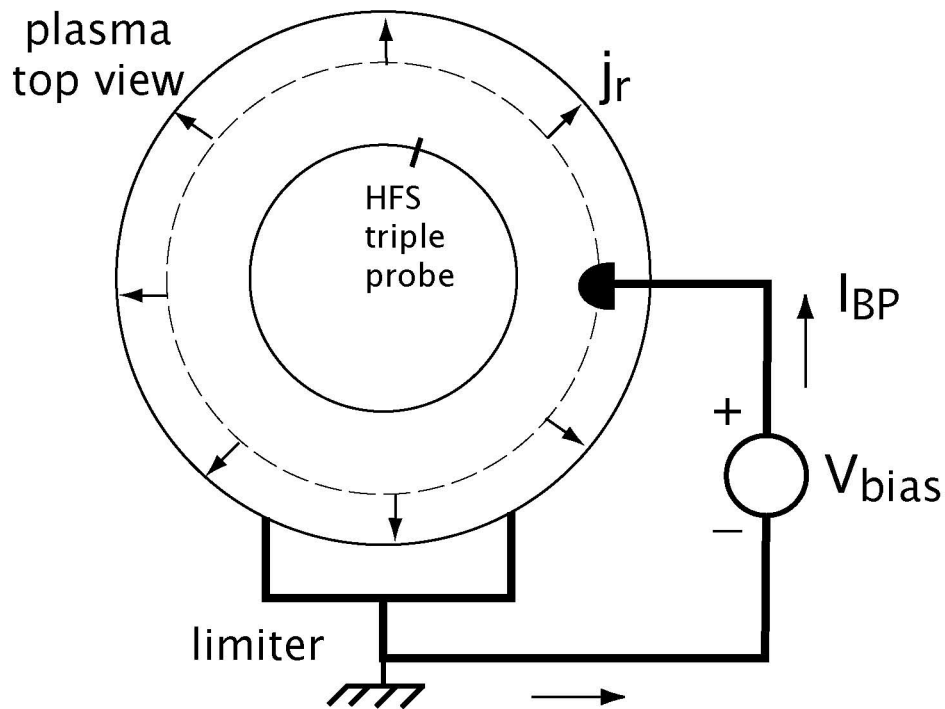


Major radius: $R_0 = 0.92-0.97$ Minor radius: $a = 0.15-0.19$ m

Plasma current: $I_p \leq 25$ kA Toroidal field: $B_T \leq 3.3$ kG

Temperature: $\langle T_e \rangle \sim 80$ eV Density: $\langle n_e \rangle \sim 1 \times 10^{19}$ m⁻³

Biased Probe Edge Driven Rotation for Kink Studies



Charging of interior magnetic surface drives radial current to limiter. Rotation induced by $j_r \times B$ torque.

Initial measurements made with HFS triple probe and external magnetics for mode detection.



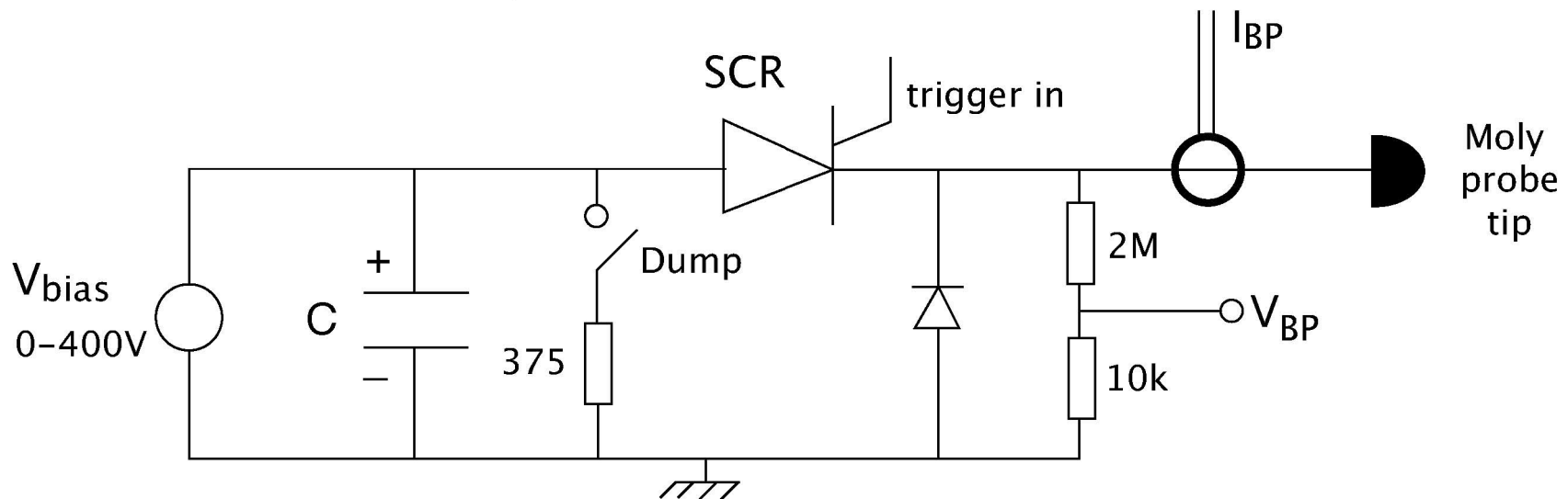
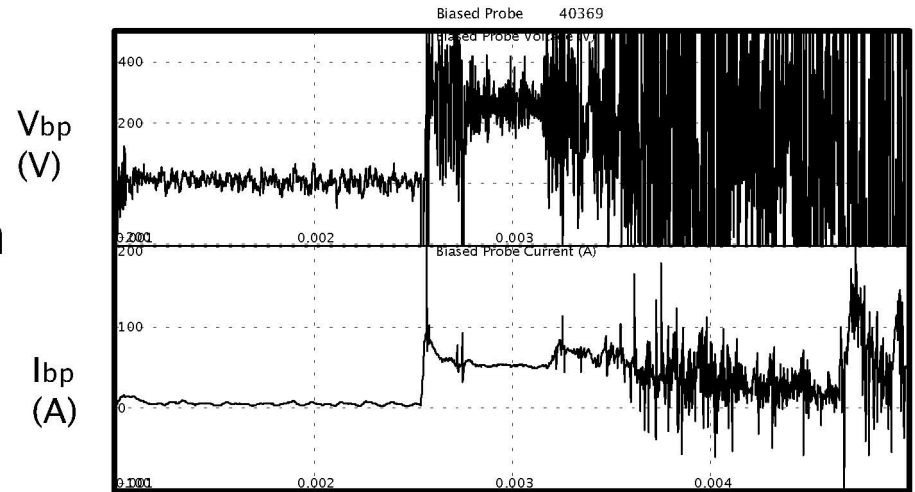
Biased Probe Edge Driven Rotation for Kink Studies

BP biased into electron saturation.

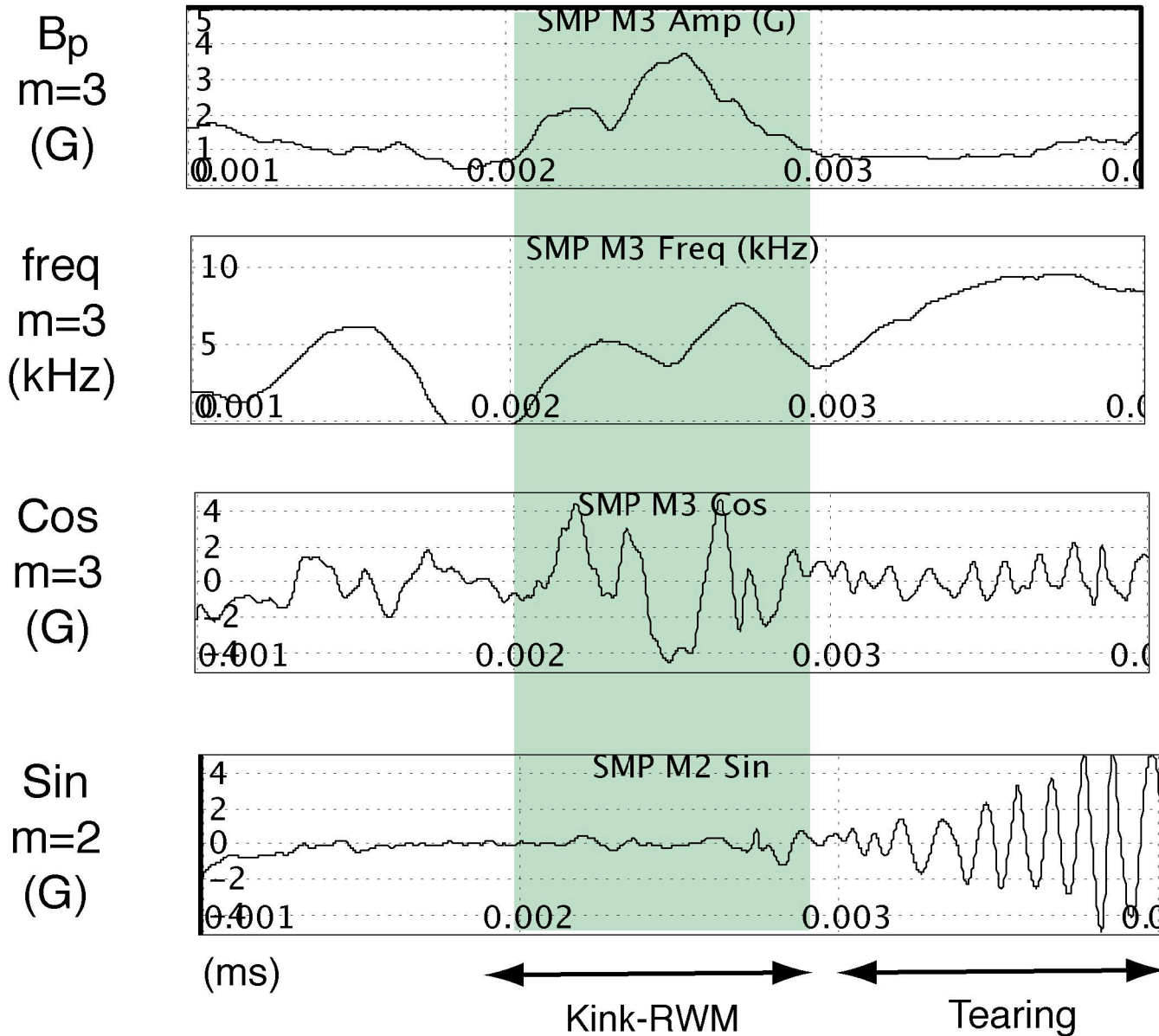
Induces rotation in the opposite direction to natural mode propagation

Typical currents are ~ 10 to 50 A

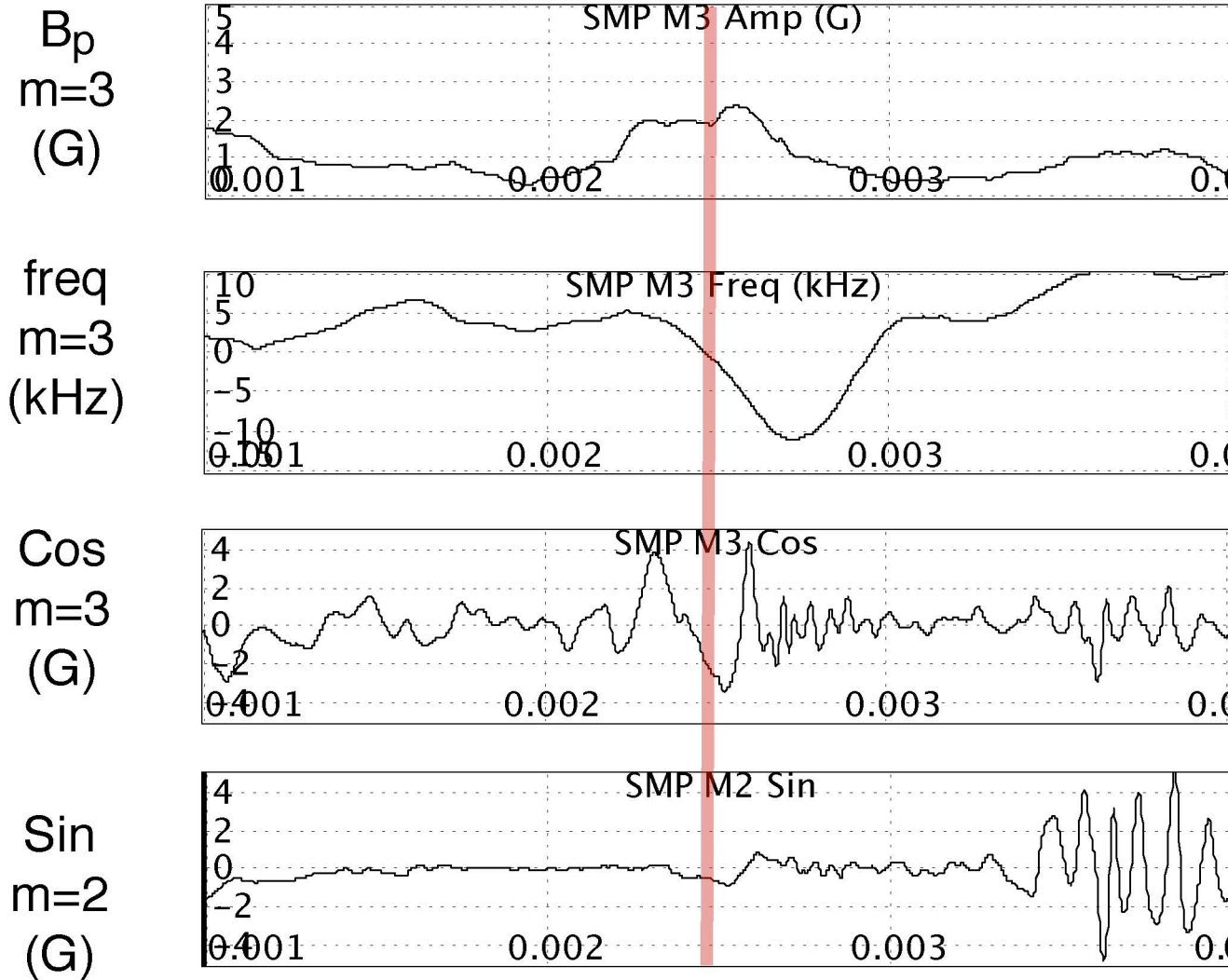
Once energized the voltage is on the probe for the rest of the pulse



Kink excited as evolving edge q approaches 3

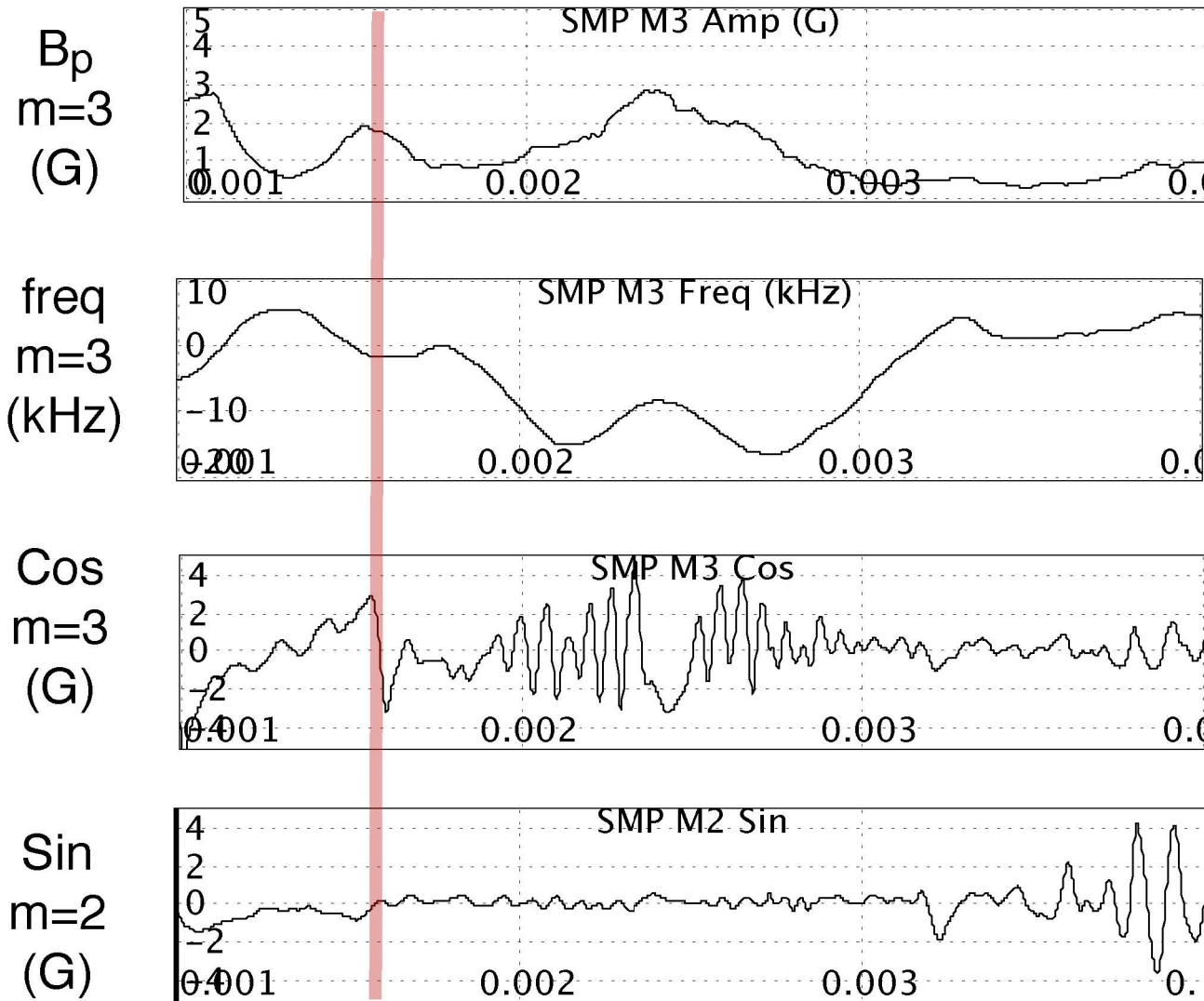


BP energized during kink unstable phase



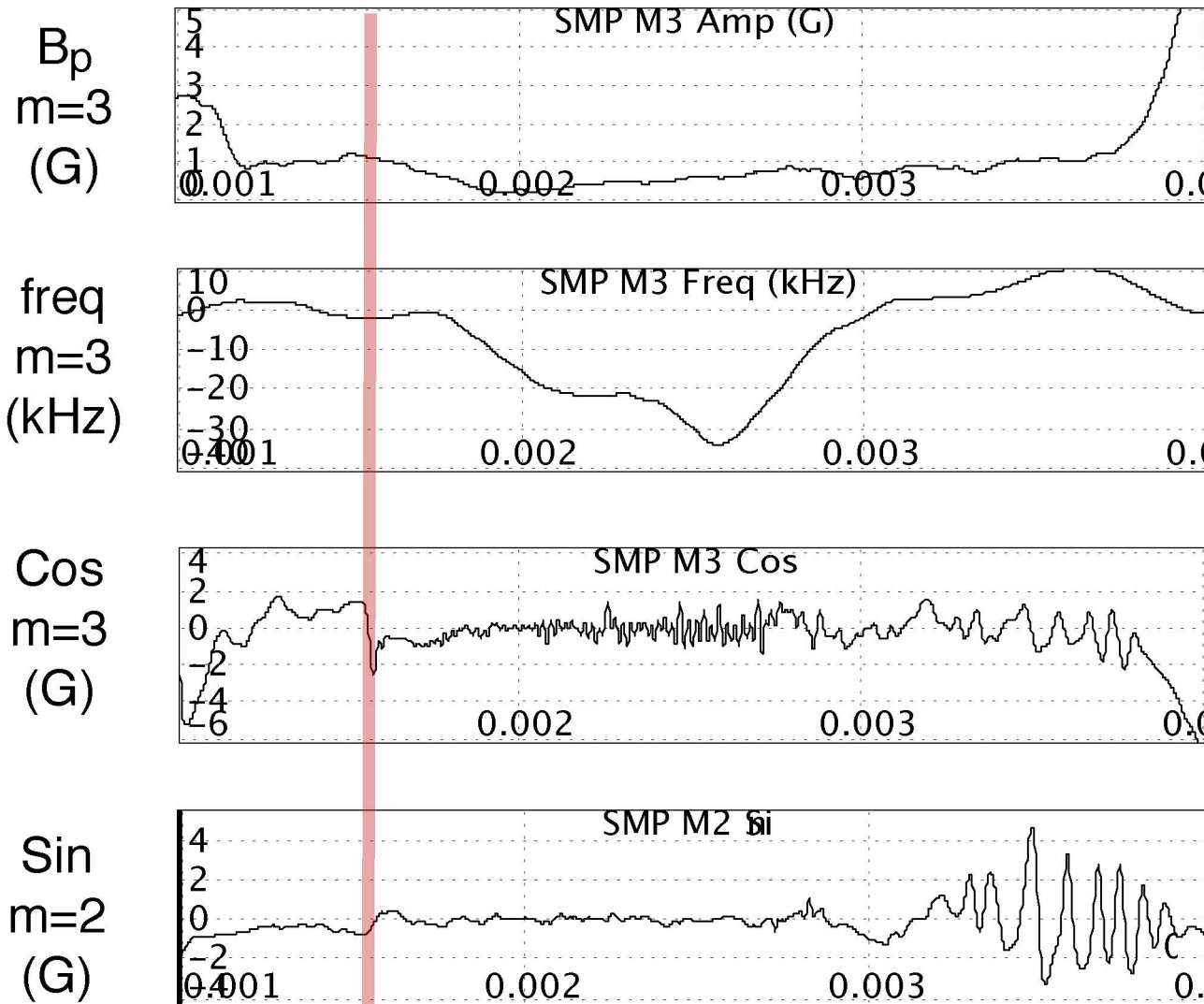
BP energized at 75V

BP energized prior to kink unstable window



BP energized at 75V

BP energized with higher bias voltage prior to unstable window



BP energized at 150V

Adding Electrode Torque to Kink Dynamical Models

- Start with Fitzpatrick-Aydemir model equations
- Keep plasma-kink mode frequency evolution equation with wall torque and viscous restoring torque
- Add appropriate $J_r \times B$ torque

Modified F-A Model

In the viscous regime appropriate for HBT-EP these are...

Plasma flux:
$$-\frac{\bar{\alpha}}{\Omega} \frac{d\Psi_a}{dt} + [1 - \bar{s} + i\bar{\alpha}] \Psi_a = \frac{1}{\sqrt{c}} \Psi_w$$

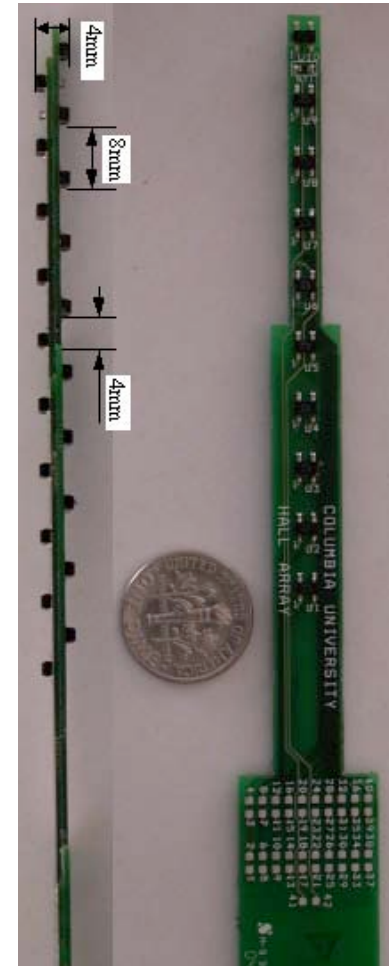
Wall flux:
$$\frac{d}{dt} \Psi_w + \frac{\gamma_w}{1-c} (\Psi_w - \sqrt{c} \Psi_a) = 0$$

Torque balance:
$$\frac{d}{dt} \Omega + \nu_d (\Omega - \Omega_o) = a_1 \Gamma_w + a_2 \Gamma_{BP}$$

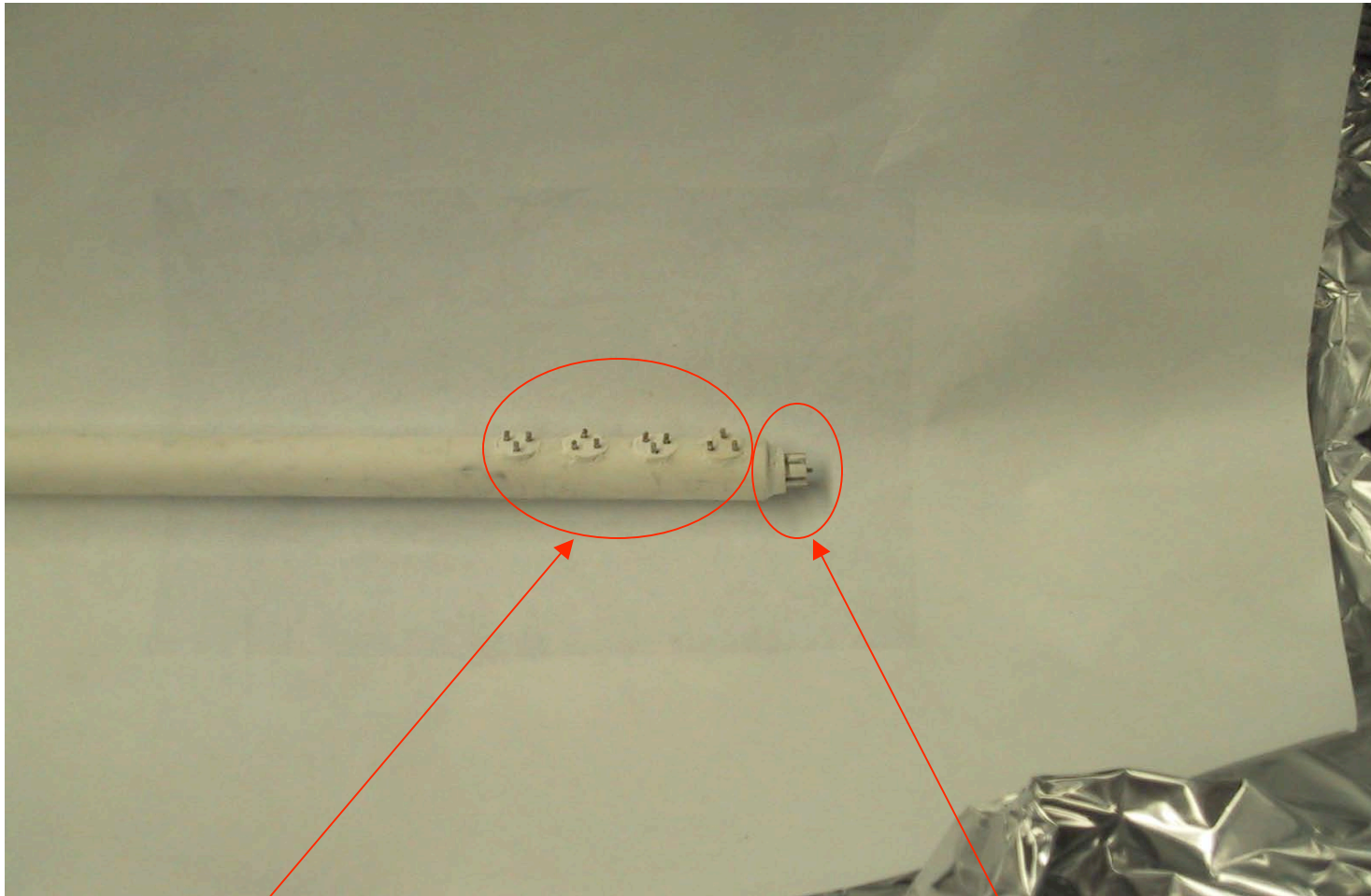
Observation of linear $m=3$ frequency increase is consistent with a constant electrode torque

Multi-Element Hall Probe

- High resolution
- Edge measurement of poloidal field improves accuracy of equilibrium reconstruction
- Magnitude and phase of perturbed kink oscillations



New edge Langmuir probe array



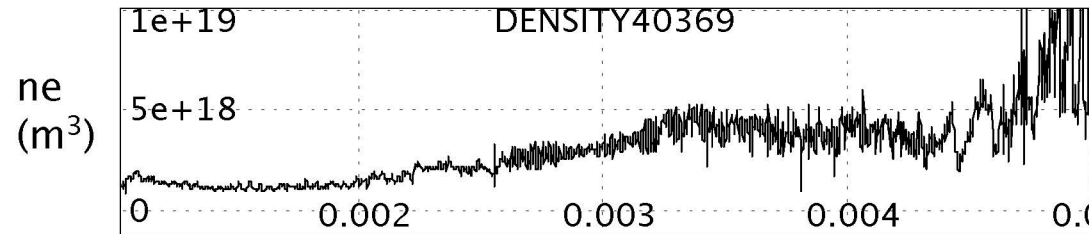
Triple Probe Array.
Each triple probe is
12 mm center to
center apart.

Multi-pin Mach Probe.

Summary

- Electrode bias has been shown to have a large effect on kink modes in HBT-EP. Kinks have been accelerated and mode amplitude has been suppressed while changing plasma rotation
- A simple prescription has been proposed to modify the torque equation in the F-A model.
- Future measurements provided by the Hall, Mach and Triple probes will enable close comparison to theory

HFS triple probe measurements during biasing



density rise due
to plasma drifting
into probe

