Generation and Evolution of Plasma Flow in the MST Reversed Field Pinch

Darren Craig and MST Group

University of Wisconsin - Madison

Motivation

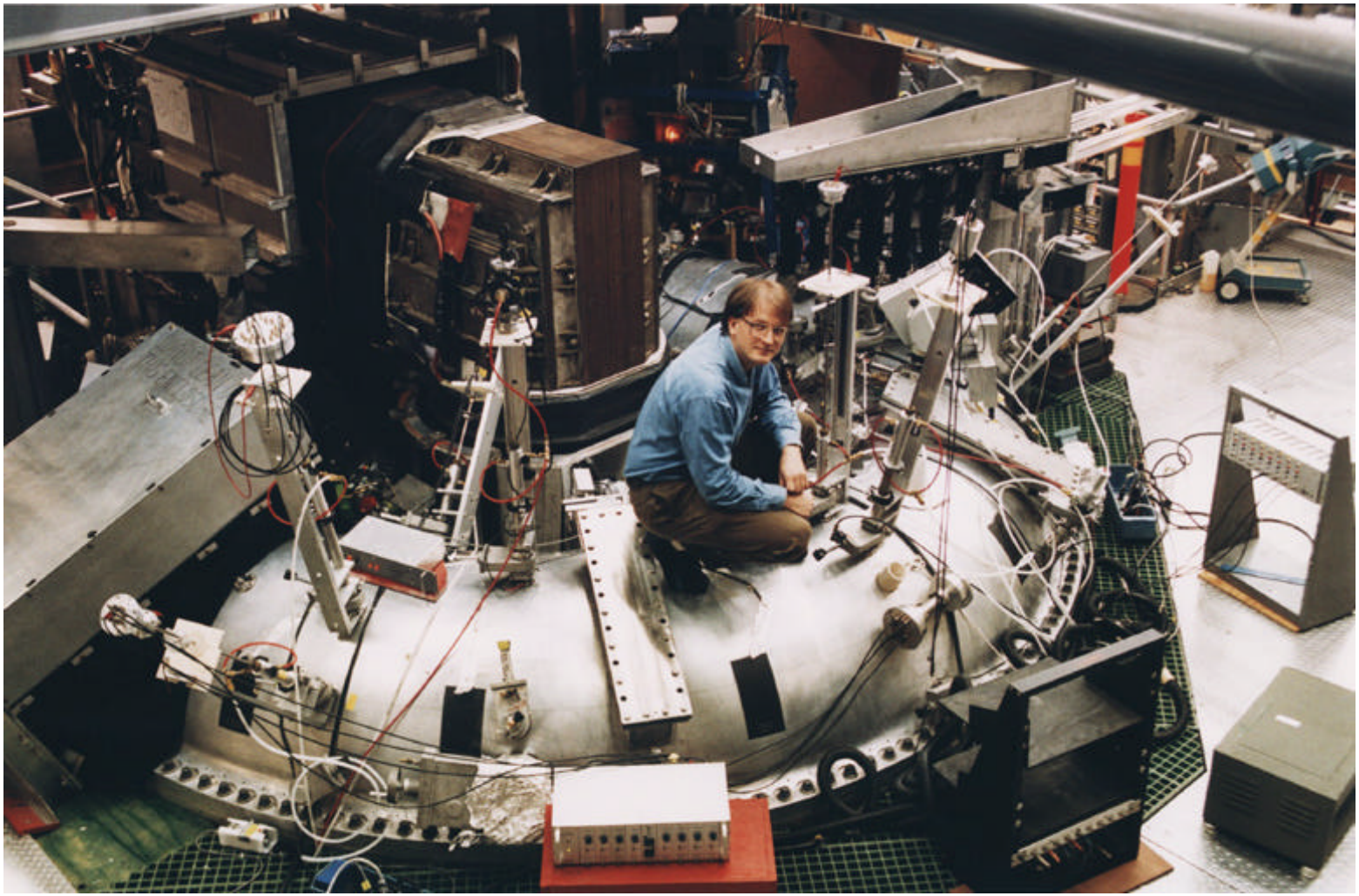
- Plasma flows and MHD mode rotation can play an important role in the success of many magnetic confinement concepts.
  - -Particularly true for RFP where locked modes can produce localized plasma-wall interaction.

- It is important to develop both an understanding of how plasma flows evolve and the means to control them in a variety of configurations.

Outline

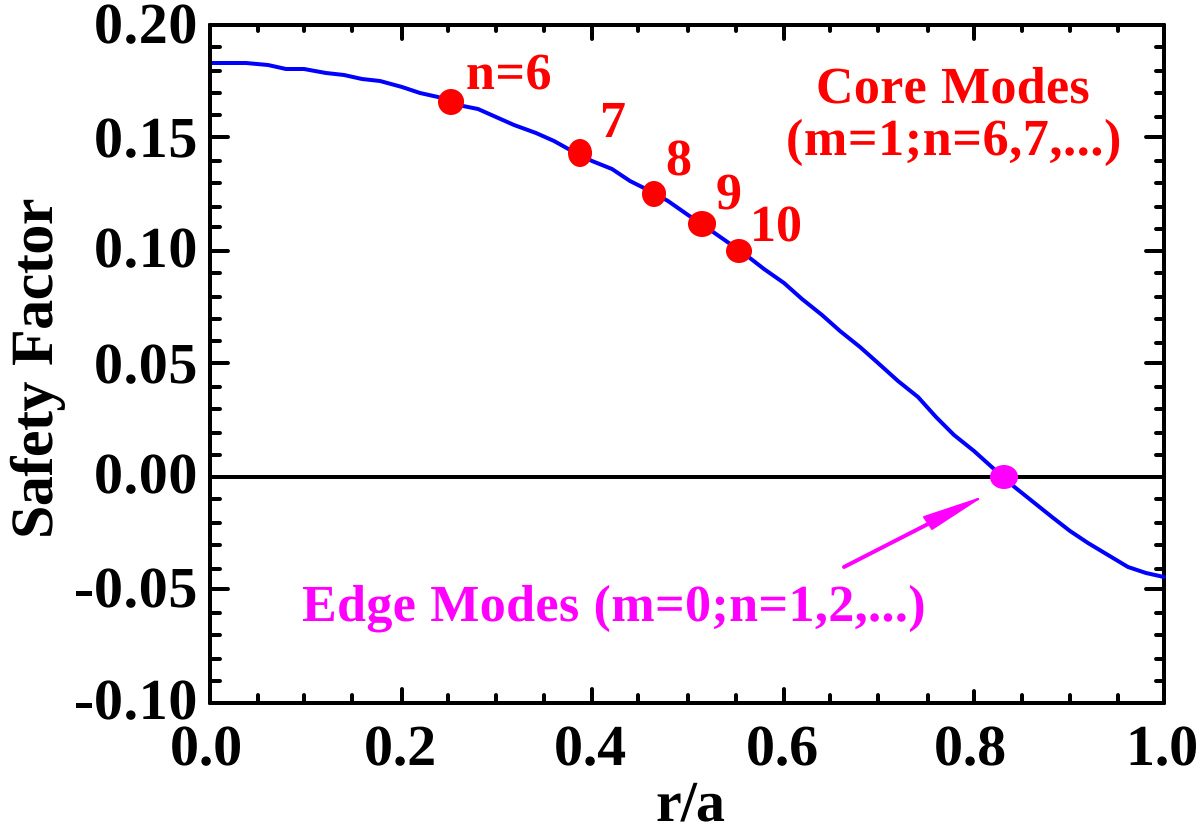
- Mode rotation dynamics in the RFP
  - Nonlinear torques between coupled modes
- Flow damping measurements
- Future plans and diagnostic upgrade status

The Madison Symmetric Torus



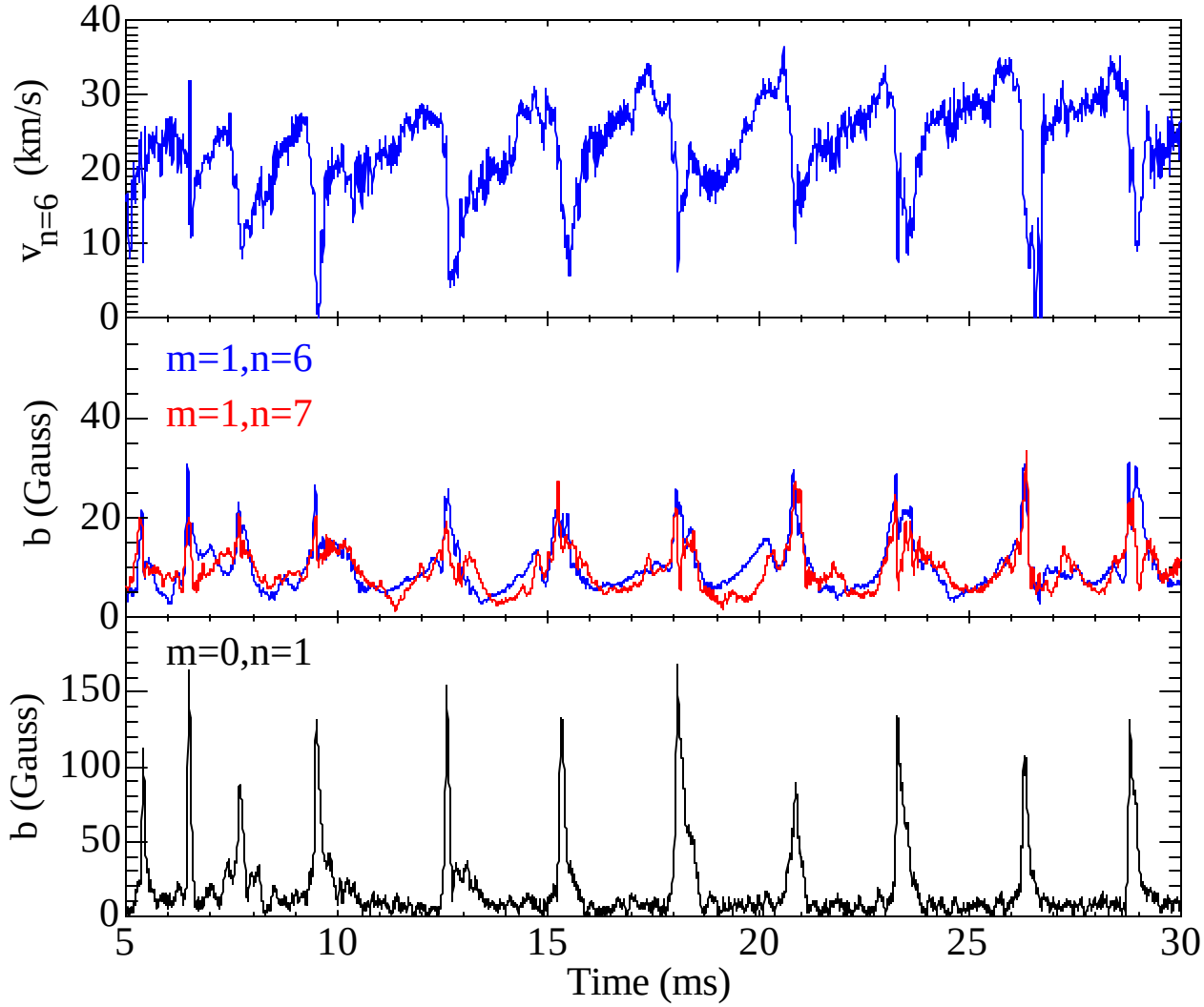
RFP Modes

- "Core Modes" -- m=1 modes resonant in core
- "Edge Modes" -- m=0 modes resonant in edge
- Edge and Core nonlinearly coupled



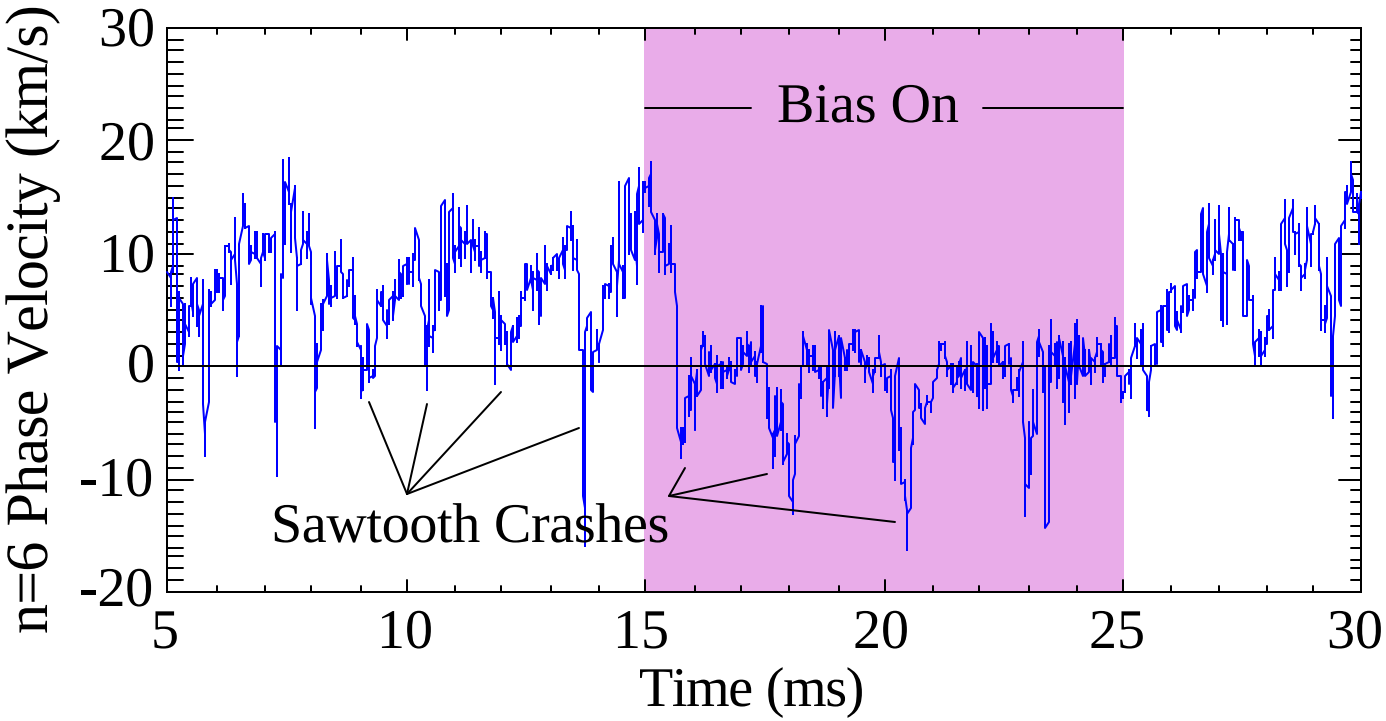
Core Modes Decelerate During Sawtooth Events

- Core and edge mode amplitudes burst during sawtooth events and rotation slows down.



Sawtooth Flow Changes Not Simple Locking

- Edge Biasing -- Negative Edge Rotation
- Core modes *unlock* and rotate negatively at crashes
- Indicates core-edge coupling at sawtooth



Nonlinear Torque

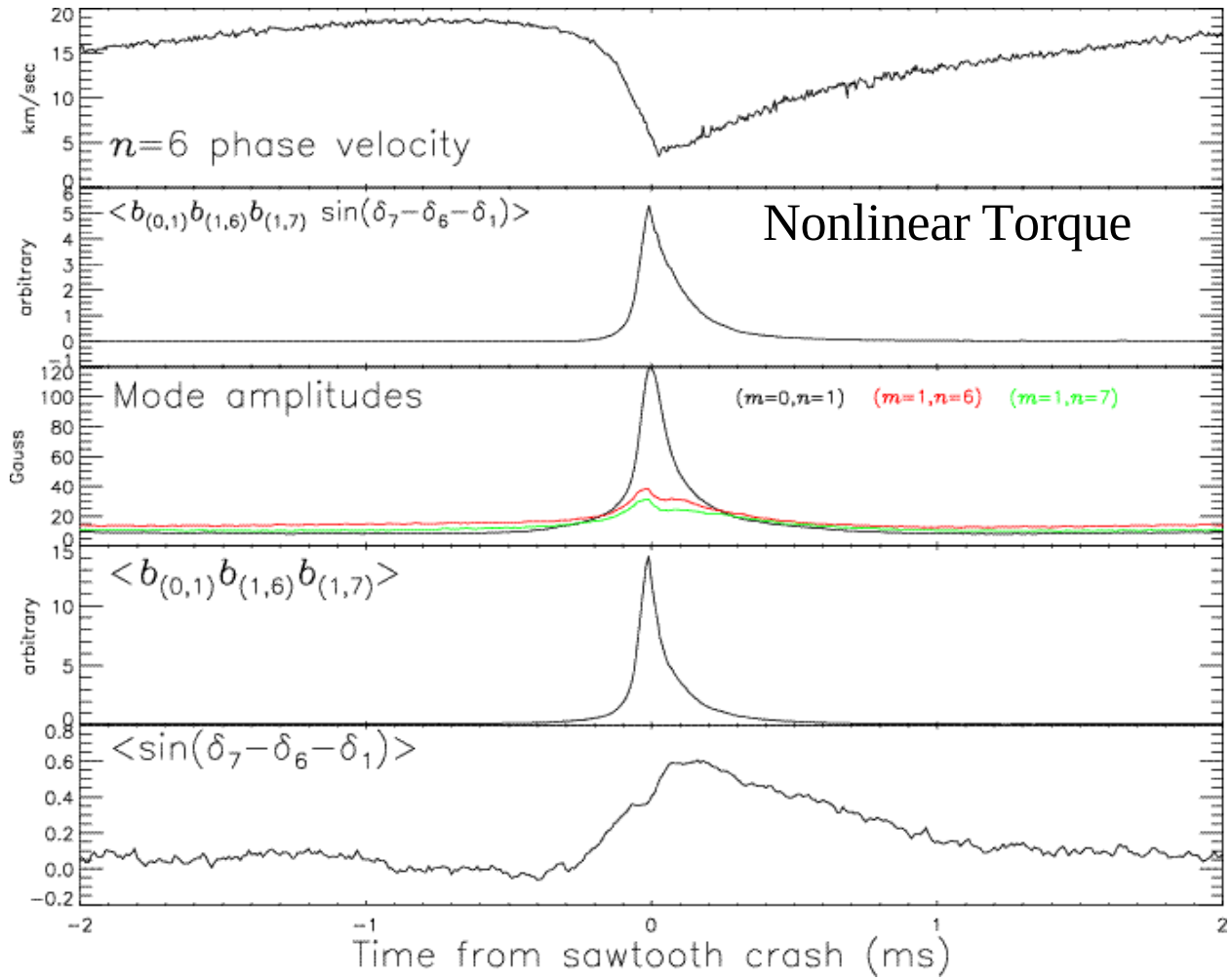
- Linear Torque: Field error induces J at resonant surface, JxB forces lock mode. Torque ~ mode amplitude.
- Nonlinear Torque: Two modes nonlinearly produce a third mode, JxB forces lock this mode to it's resonant surface, velocity relationship established between modes. Torque ~ product of mode amplitudes.
- Application to MST: Two adjacent core modes (e.g. n=6 and n=7) generate m=0 mode (n=1) which locks to reversal surface (moving at edge flow speed).
  - Requires $\omega_7-\omega_6= \omega_1$ i.e. $7v_7-6v_6 = v_{edge}$
  - If core viscosity is high enough, then $v_7=v_6$
    - only solution is flat velocity profile with $v_7=v_6=v_{edge}$

2 Experimental Results Support Nonlinear Torque Picture

1. Mode amplitudes and phases combine to give maximum torque at sawtooth crash.

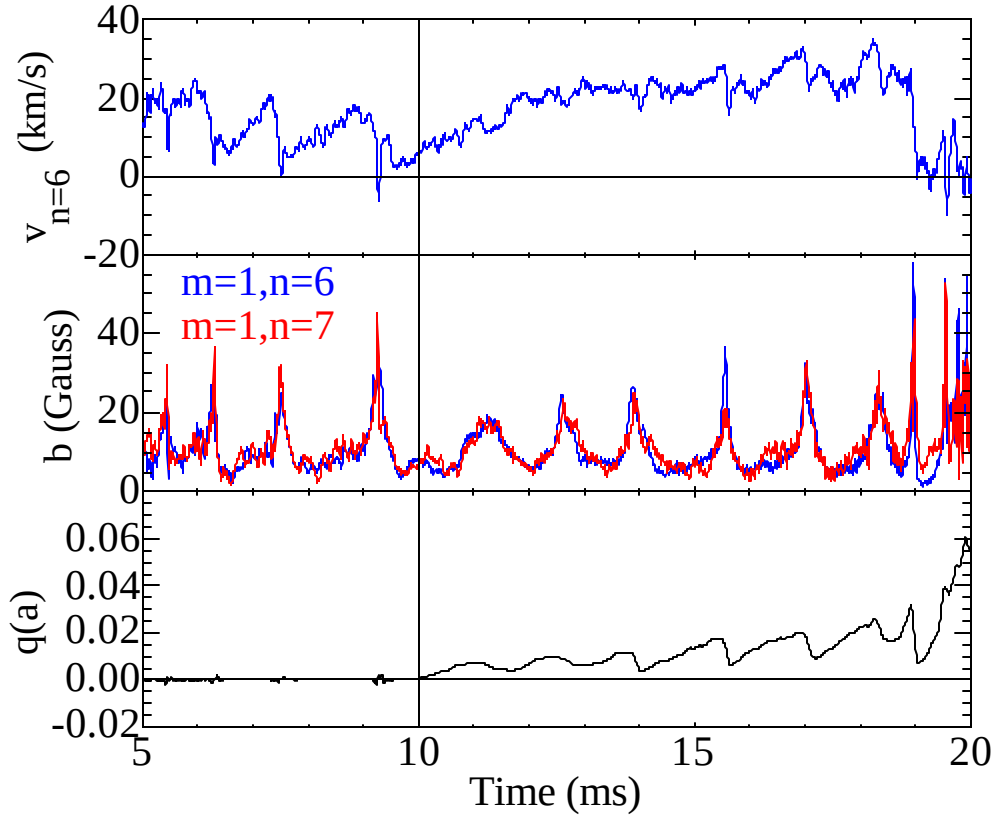
2. Core mode rotation does not change much at sawtooth when q=0 surface is removed from plasma.

Mode Amplitudes and Phases Combine To Give Maximum Nonlinear Torque at Crash



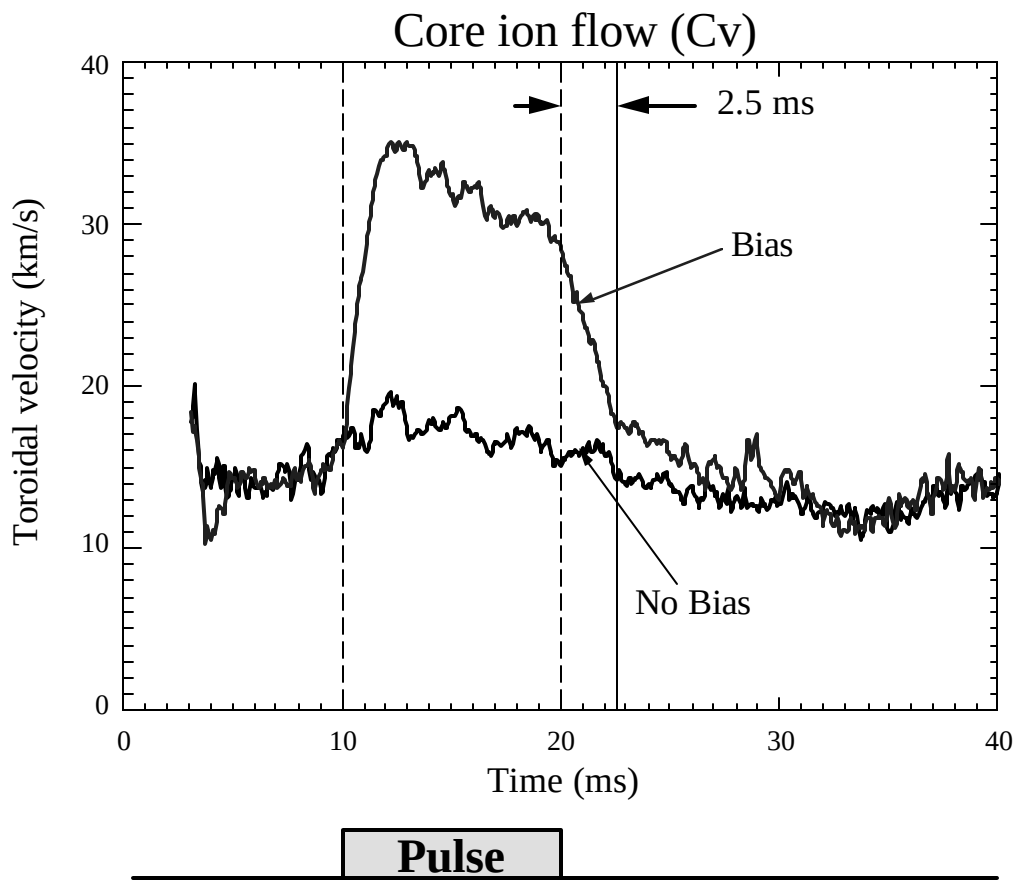
No Sudden Deceleration Without q=0 Surface

- By forcing q(a) > 0, can exclude q=0 surface from plasma.



Flow Damping Experiments

- Using biased probes, create square pulse of high speed edge flow.
- Measure damping time of core flow.



Flow Damping Results

- Classical viscosity too small to explain damping.
- Damping independent of density (not classical).
- Damping time consistent with particle and energy confinement times.
- Damping weaker in high confinement, low magnetic fluctuation discharges.
- Damping consistent with estimates of momentum diffusion caused by magnetic fluctuations.

Summary of Experimental Results

- Flow evolution in the RFP is strongly influenced by magnetic fluctuations.

- Nonlinear torques between coupled modes cause sudden changes in mode rotation at sawtooth events.

- Momentum diffusion is much greater than classical estimates and is probably due to stochasticity in B.

Future Plans

- Understand flow generation
  - Direct Reynolds Stress Measurements
- Understand effect of flow profile on fluctuations, confinement, relaxation,…
- Control mode rotation with rotating external perturbations
  - RFX has had success with rotating m=0
  - MST plans to apply two differentially rotating m=1 perturbations (different n)
  - What is the effect of breaking up mode coupling on global confinement?

Diagnostic Upgrades

- 2 diagnostic neutral beams now installed on MST
  - 30 keV, 4A Hydrogen
  - 20 keV, 4A Helium
- Charge Exchange Recombination Spectroscopy (CHERS)
  - Evaluating different emission lines and designing high throughput spectrometer
- Rutherford Scattering
  - Observed scattered signal
  - Now working on reducing noise and error bars