STRUCTURE OF RESISTIVE WALL MODES IN DIII–D

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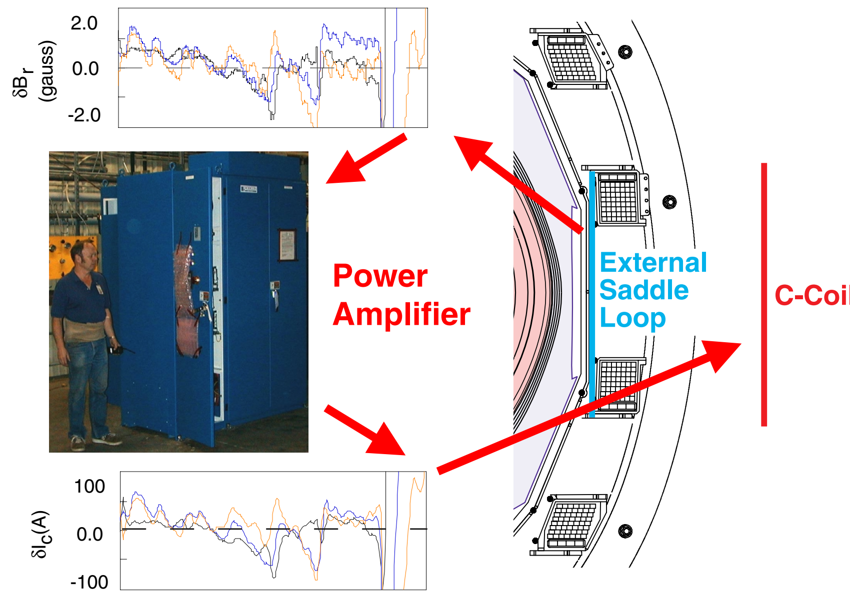
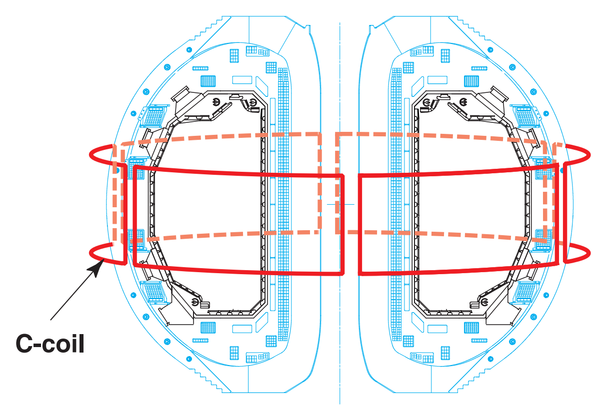
ABSTRACT

- Resistive wall modes limit the performance of DIII-D discharges when beta exceeds the no-wall ideal stability limit. These slowly rotating, n=1 modes are normally detected on DIII-D by a six-coil toroidal array of large-area sensor loops, each covering a 60 degree arc on the midplane.
- Two new 12-loop arrays of external saddle loops above and below the midplane are now acquiring data routinely. The combined array of 30 saddle loops provides information about both the poloidal and toroidal structure of RWMs.
- Chord-by-chord comparisons of three identical soft x-ray cameras distributed in a toroidal array confirm the expected kink-like internal structure.
- The observed poloidal and internal structure will be compared with code predictions.

DETECTION AND ACTIVE FEEDBACK STABILIZATION OF RWM

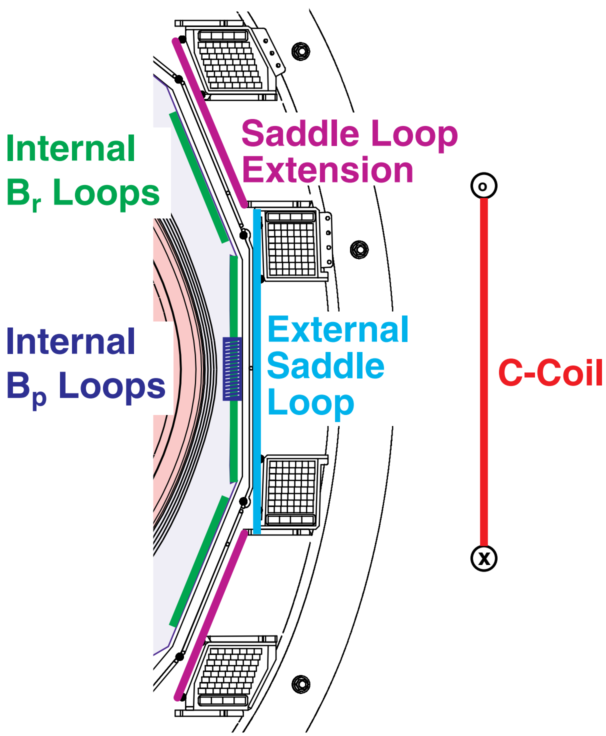
- Resistive wall modes (RWM) have been under study on DIII-D for several years.
- Experiments on active magnetic feedback stabilization of these modes began in 1999.
  - Six picture-frame "saddle" loops, arranged in a toroidal array, detect slowly rotating magnetic perturbations.
  - Feedback stabilization commands are generated from the saddle loop data, using a variety of algorithms, and sent to three power amplifiers.
  - Each amplifier energizes a pair of correction coils (C-coils) with the proper current and phase for controlling growth of the mode.

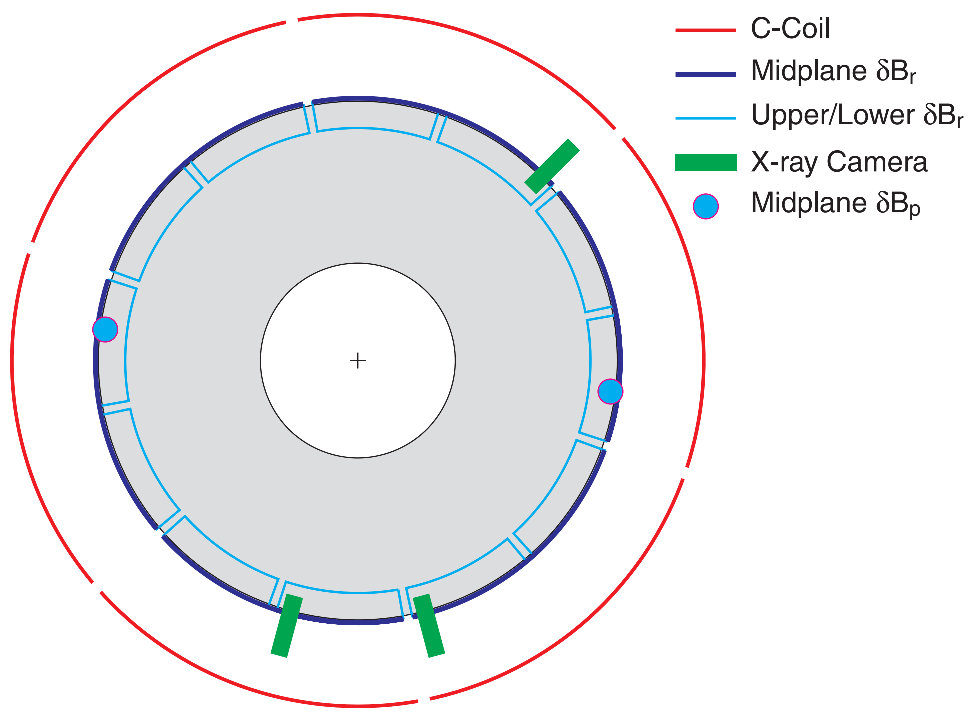




RESISTIVE WALL MODE DIAGNOSTICS FOR DIII-D

- Thirty external δB_r loops measure RWM toroidal and poloidal structure.
  - Twelve picture-frame δB_r loops were added above and twelve below the original six-coil equatorial array for the CY2000 experiments.
- Identical x-ray cameras at three toroidal locations show RWM internal structure.
- Two diametrically opposed internal midplane probes provide δB_p measurements.
- Additional δB_r and δB_p loops are now being installed inside the vacuum vessel to improve detection and control capabilities for the 2001 experiments.



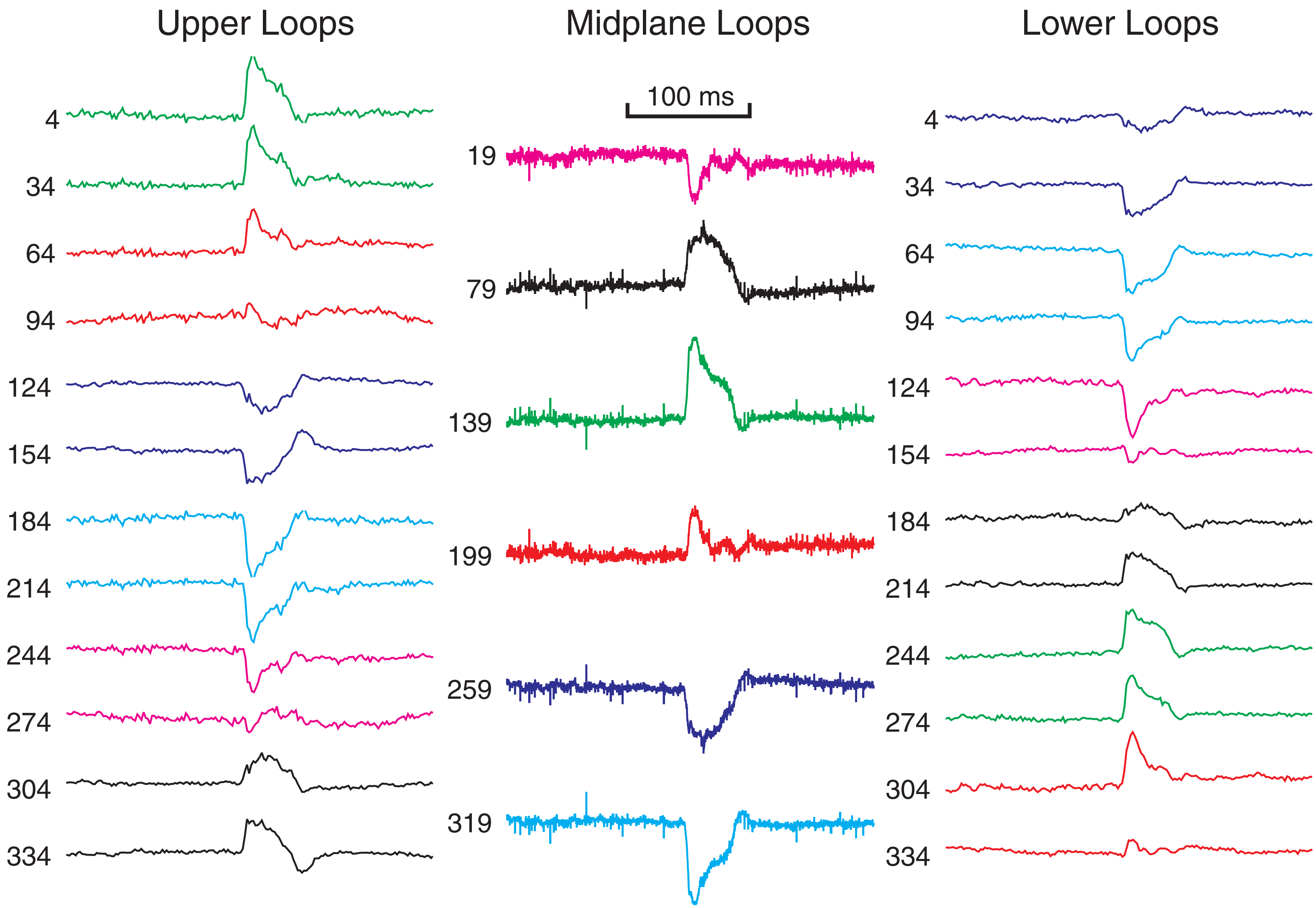


SADDLE LOOPS DETECT SLOWLY ROTATING n=1 MODES

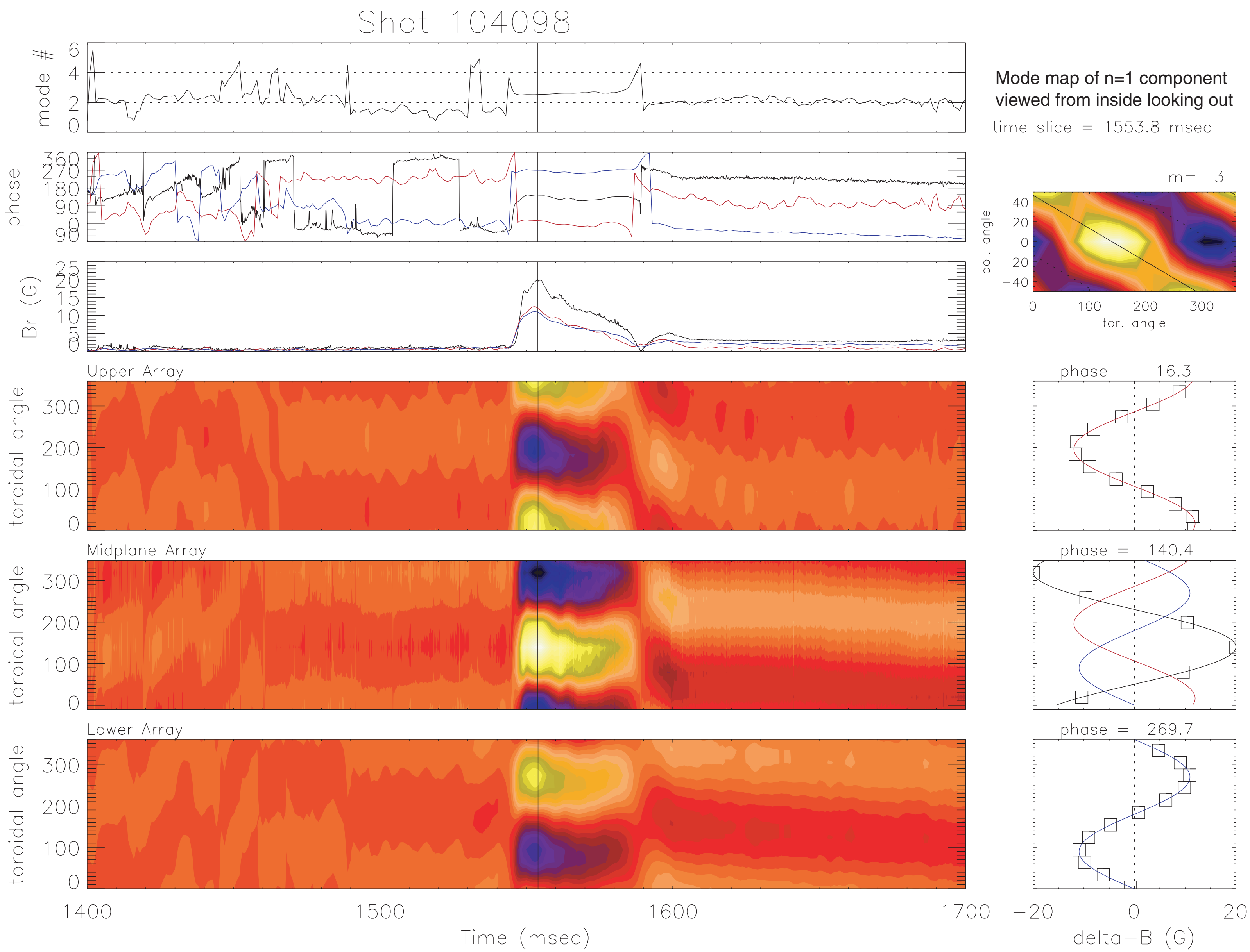
- Each midplane saddle loop covers a 60° toroidal segment of the vacuum vessel, corresponding to the toroidal configuration of the C-coils.
- Each of the 24 new external loops covers a 30° toroidal segment.
- The loops are arranged in opposing pairs to help discriminate against axi-symmetric stray fields from poloidal field coils.
- Loop pair differences from each of the three toroidal arrays can be used to determine the amplitude and phase of a slowly growing, slowly rotating n=1 magnetic perturbation, such as that expected from a resistive wall mode.

RWM SENSOR LOOP DATA (NO FEEDBACK)

#104098

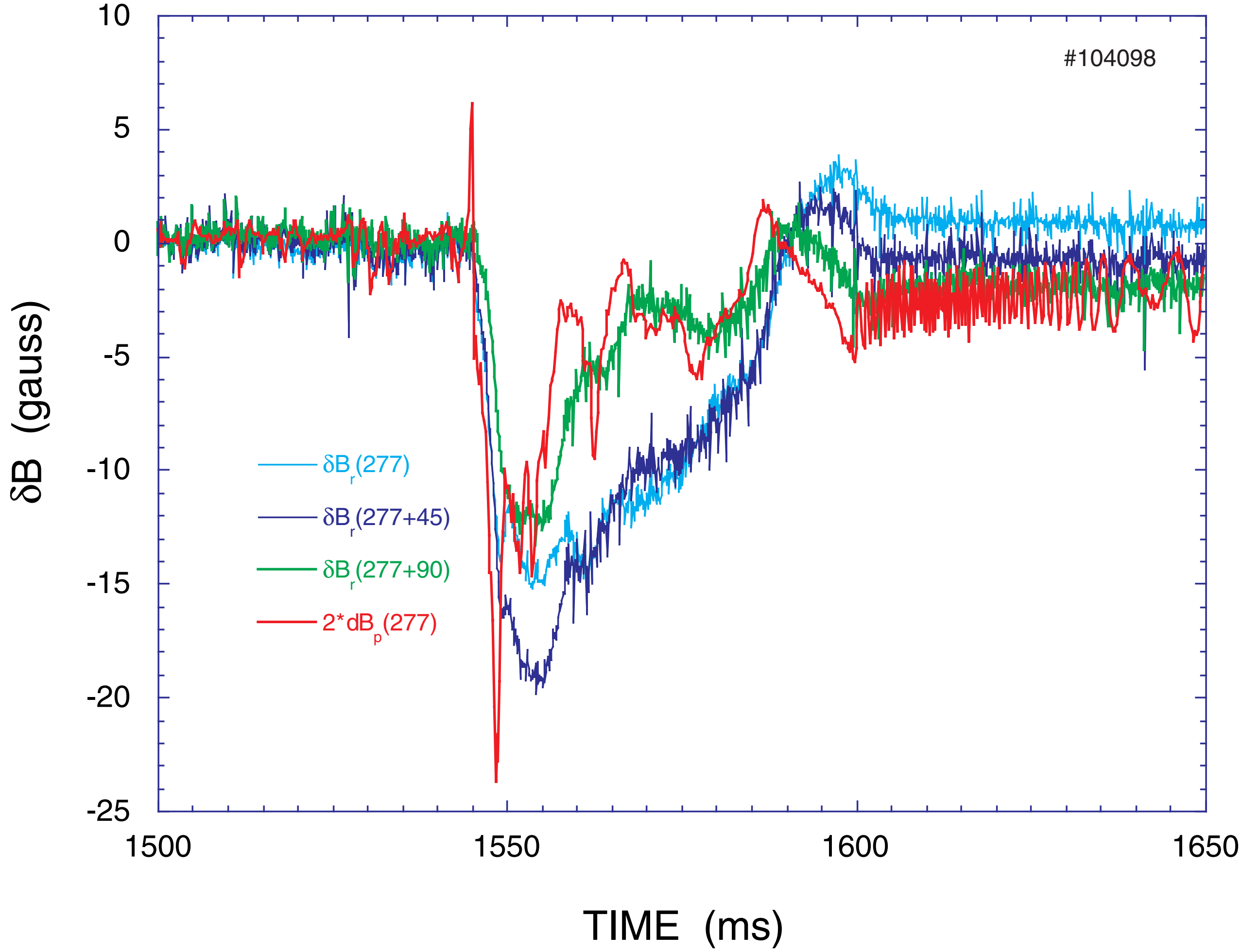


RWM MODE ANALYSIS FROM SENSOR LOOP DATA (NO FEEDBACK)



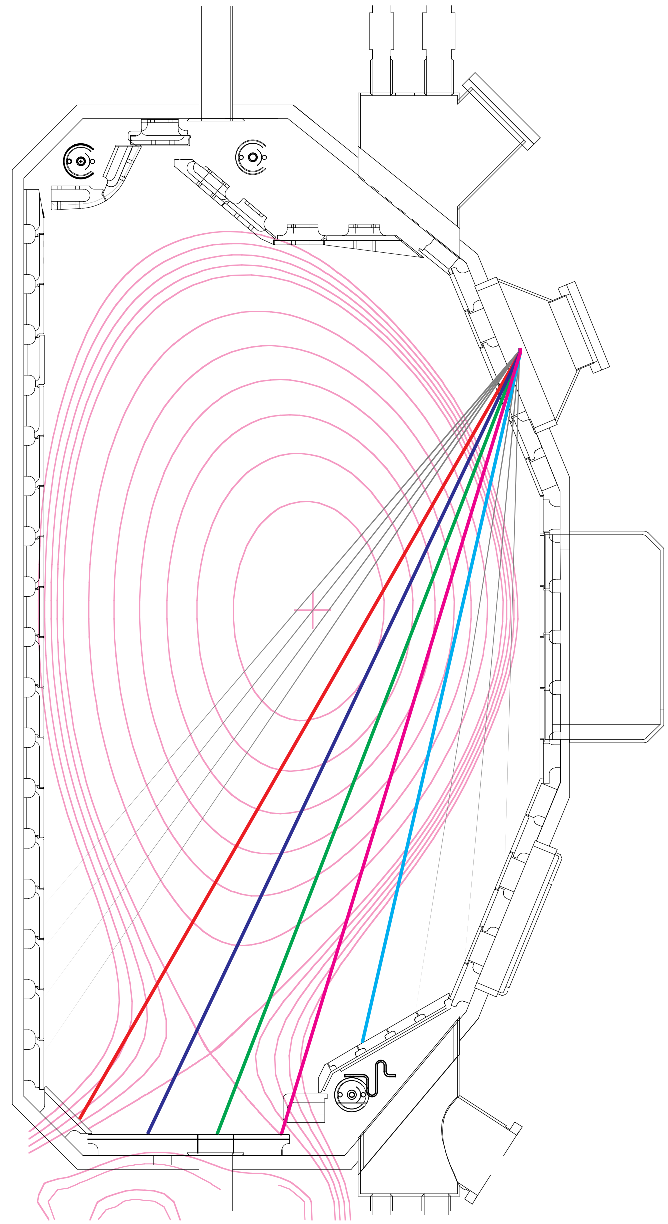
δB_p AND δB_r DATA SHOW EXPECTED PHASE RELATION

- A pair of diametrically opposed B_p probes inside the DIII-D vacuum vessel, at toroidal locations of 97° and 277° on the plasma midplane, measure δB_p during Resistive Wall Modes.
- Maximum δB_r is expected to be 90° clockwise (viewed from above) from maximum δB_p.
- δB_r at various toroidal locations is determined from the amplitude and phase deduced from saddle loop data.
- Results confirm expected 90° toroidal phase difference.

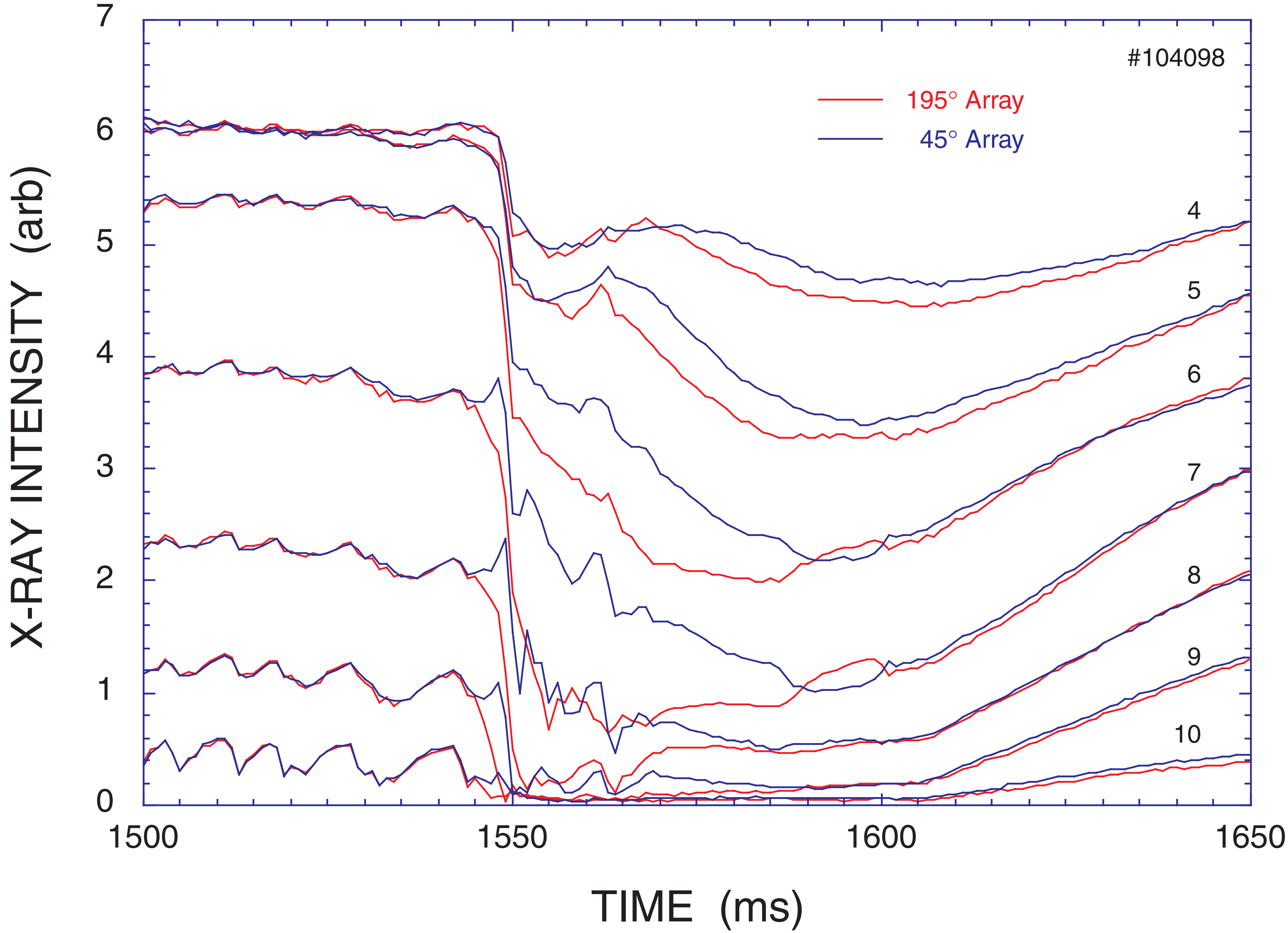


SOFT X-RAY DATA SHOW n=1 MODE BEHAVIOR

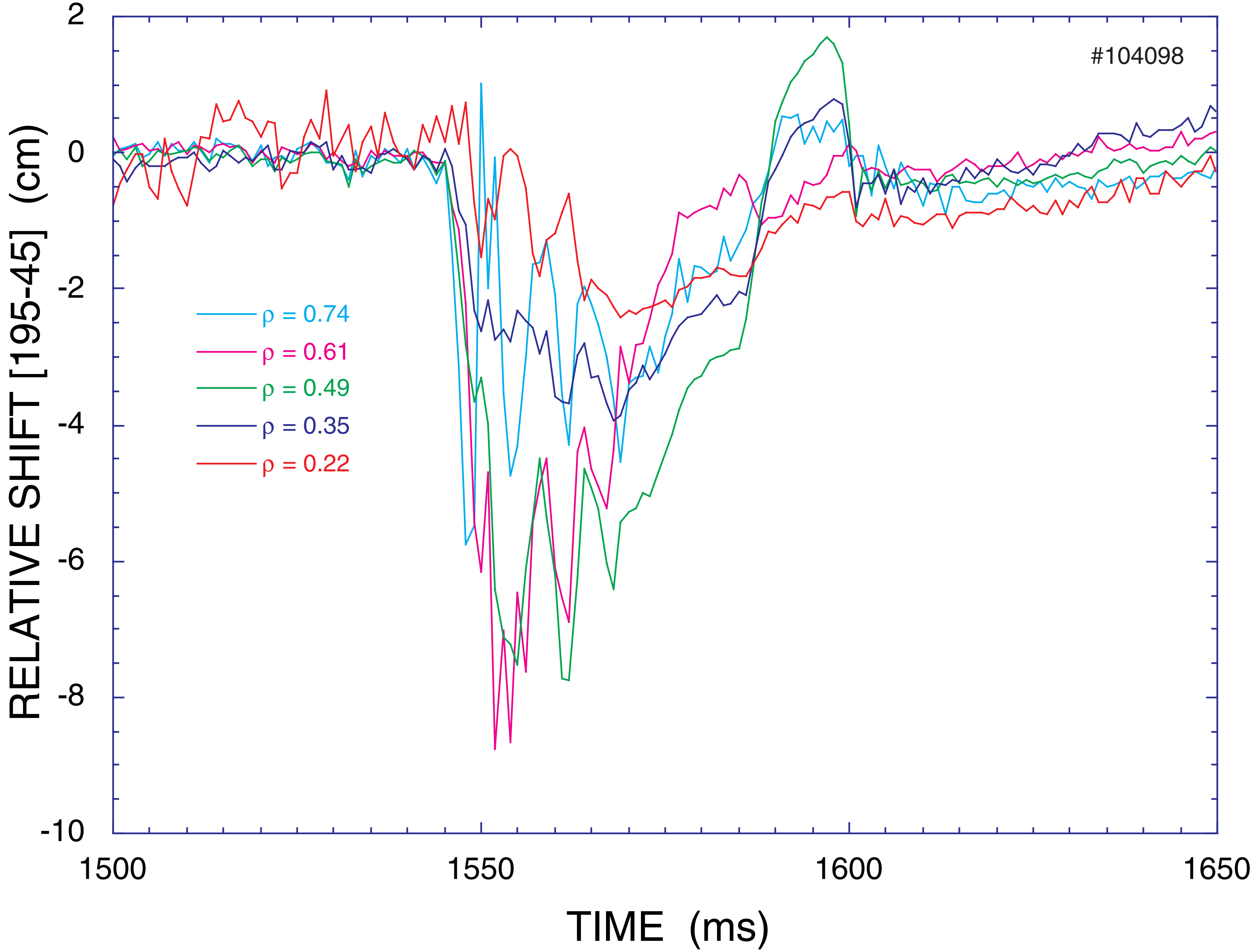
- DIII-D has three nominally identical soft x-ray poloidal arrays at toroidal angles of 45°, 165° and 195°.
- Data from the arrays are compared chord-by-chord to look for differences ascribable to toroidal variations.
- Flux surface geometry and poloidal x-ray profiles are used to convert toroidal differences to relative radial displacements of flux surfaces.



X-RAY ARRAYS AT 45° and 195° DIFFER DURING RWM

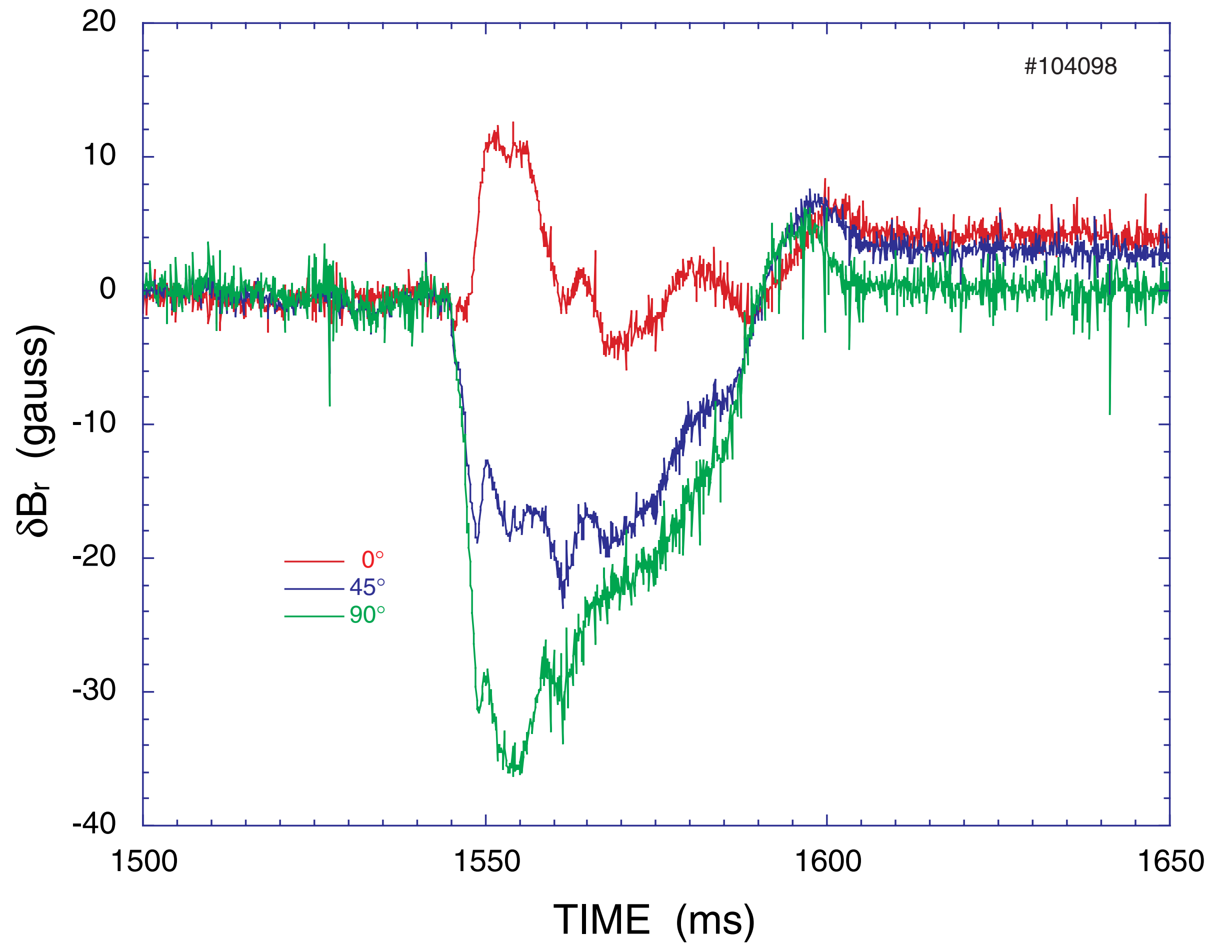


RELATIVE SHIFTS (195°-45°) DEDUCED FROM X-RAY DATA

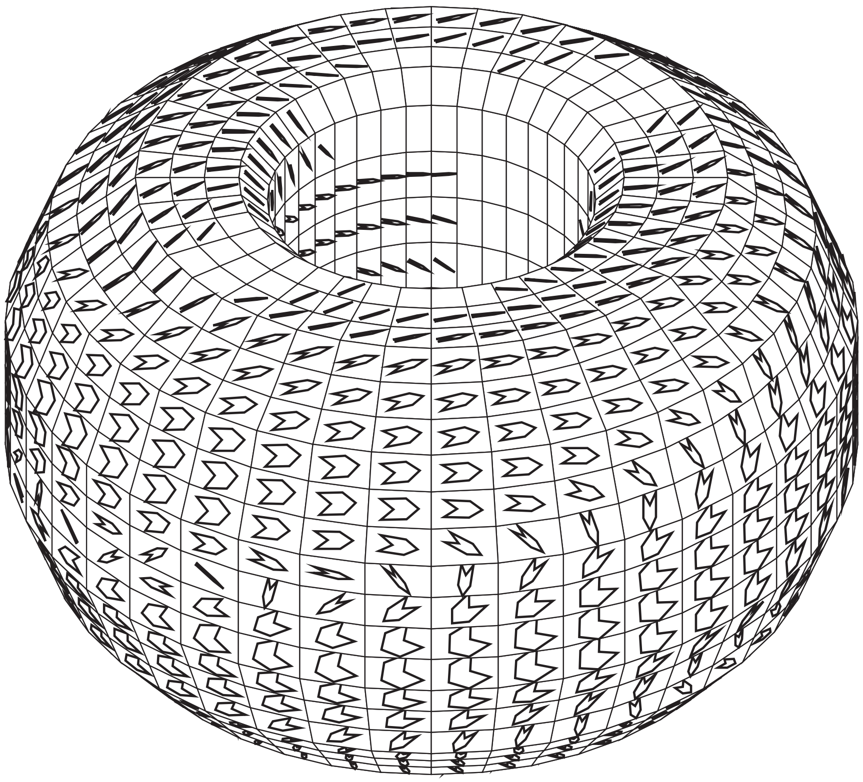


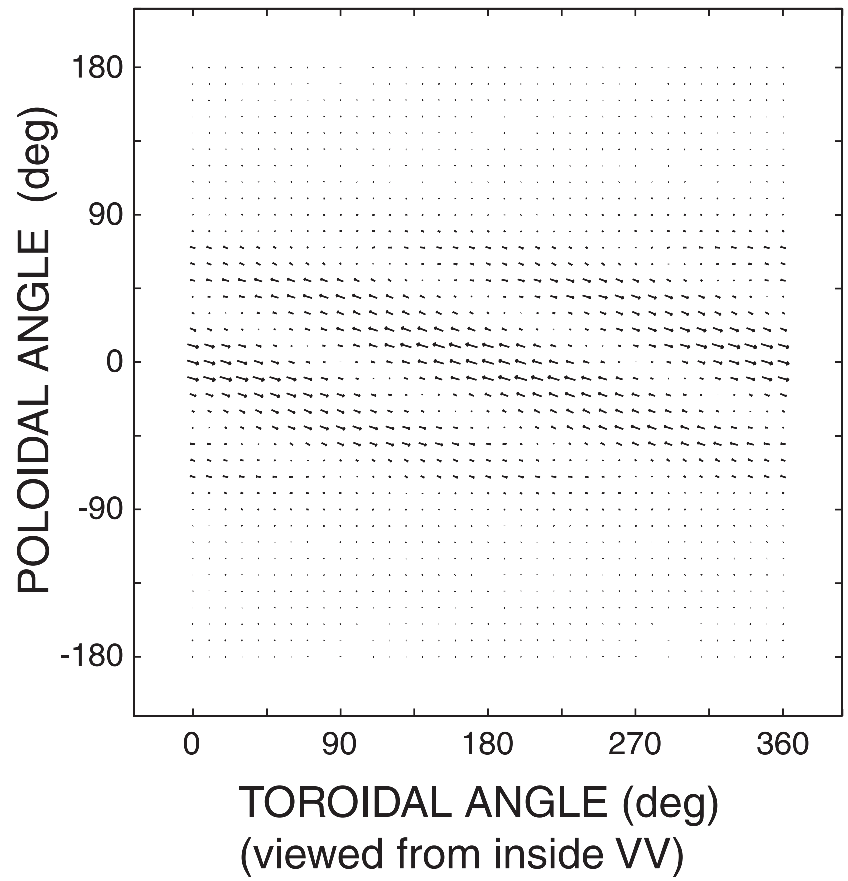
X-RAY AND δB_r DATA SHOW EXPECTED PHASE RELATION

- Amplitude and phase of δB_r from midplane saddle loops are used to find relative difference in δB_r between 195° and 45° toroidal locations for comparison with relative displacements deduced from x-ray arrays.
- Maximum δB_r is expected to be 90° clockwise (viewed from above) from maximum radial displacement.
- Results confirm expected 90° toroidal phase difference.



CODES PREDICT INDUCED CURRENTS IN CONDUCTING WALL





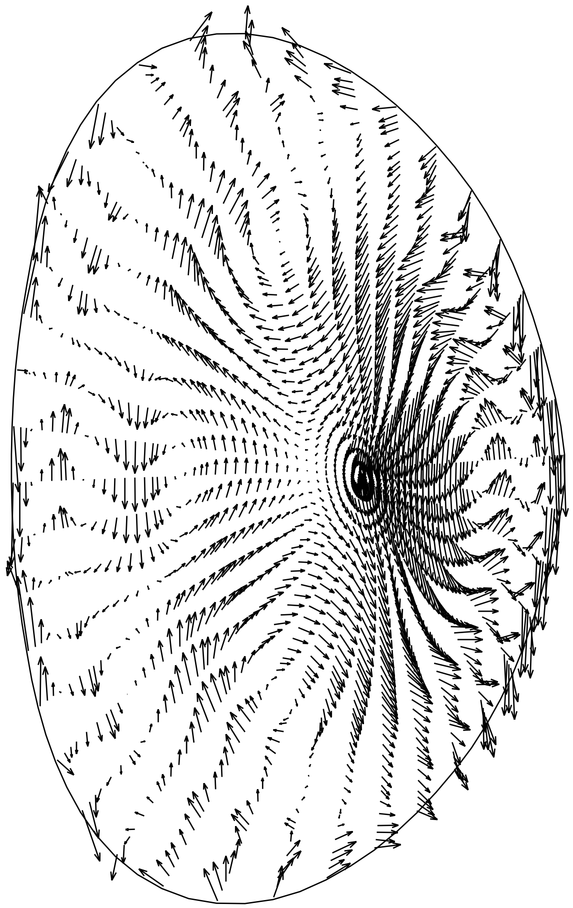
GATO-VALEN

J. Bialek et al.

GATO-VACUUM

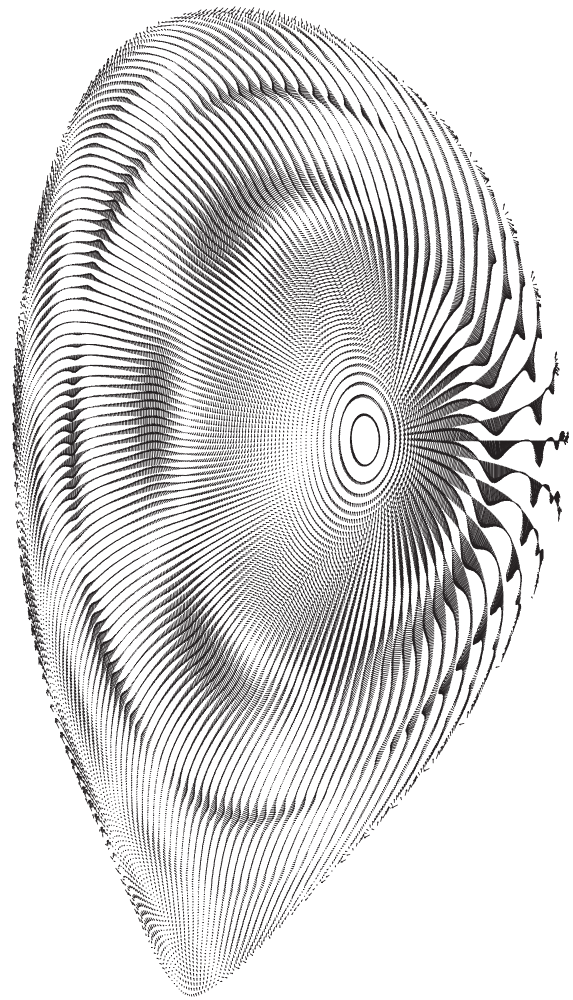
M. Chance et al.

CODE-PREDICTED INTERNAL STRUCTURE FOR #92544



GATO

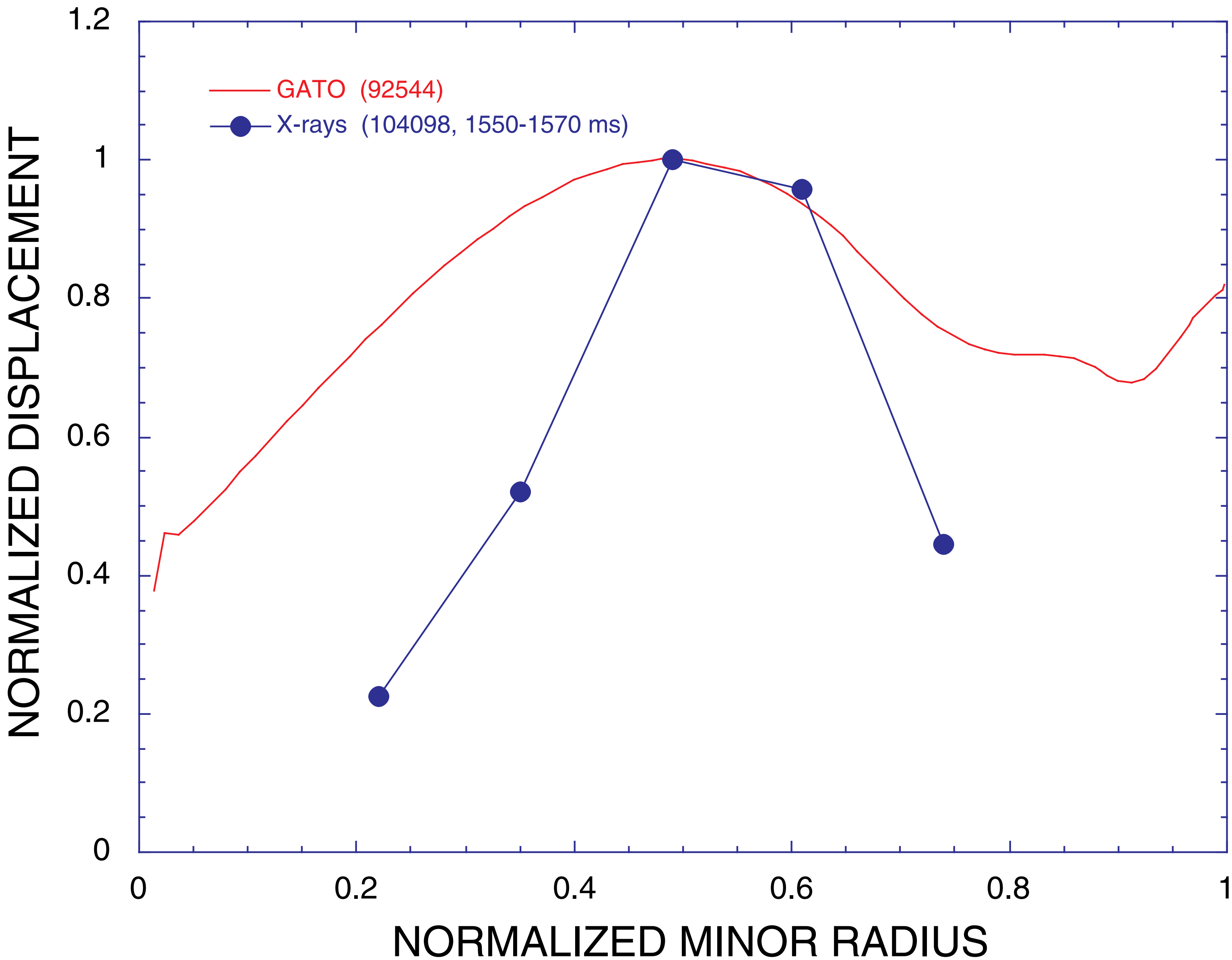
M. Chu et al.



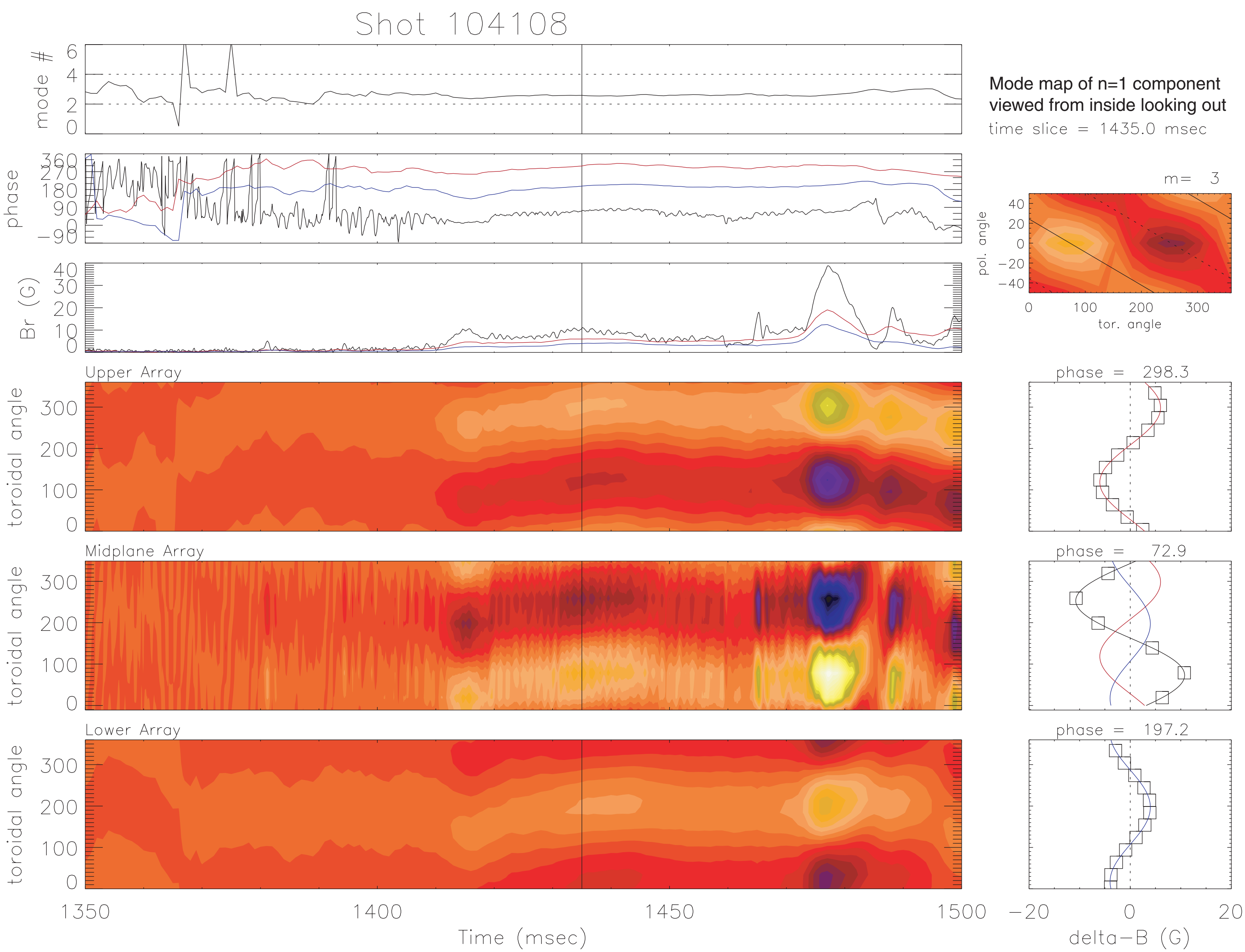
PEST

J. Manickam

INTERNAL STRUCTURE FROM X-RAYS AGREES WITH GATO

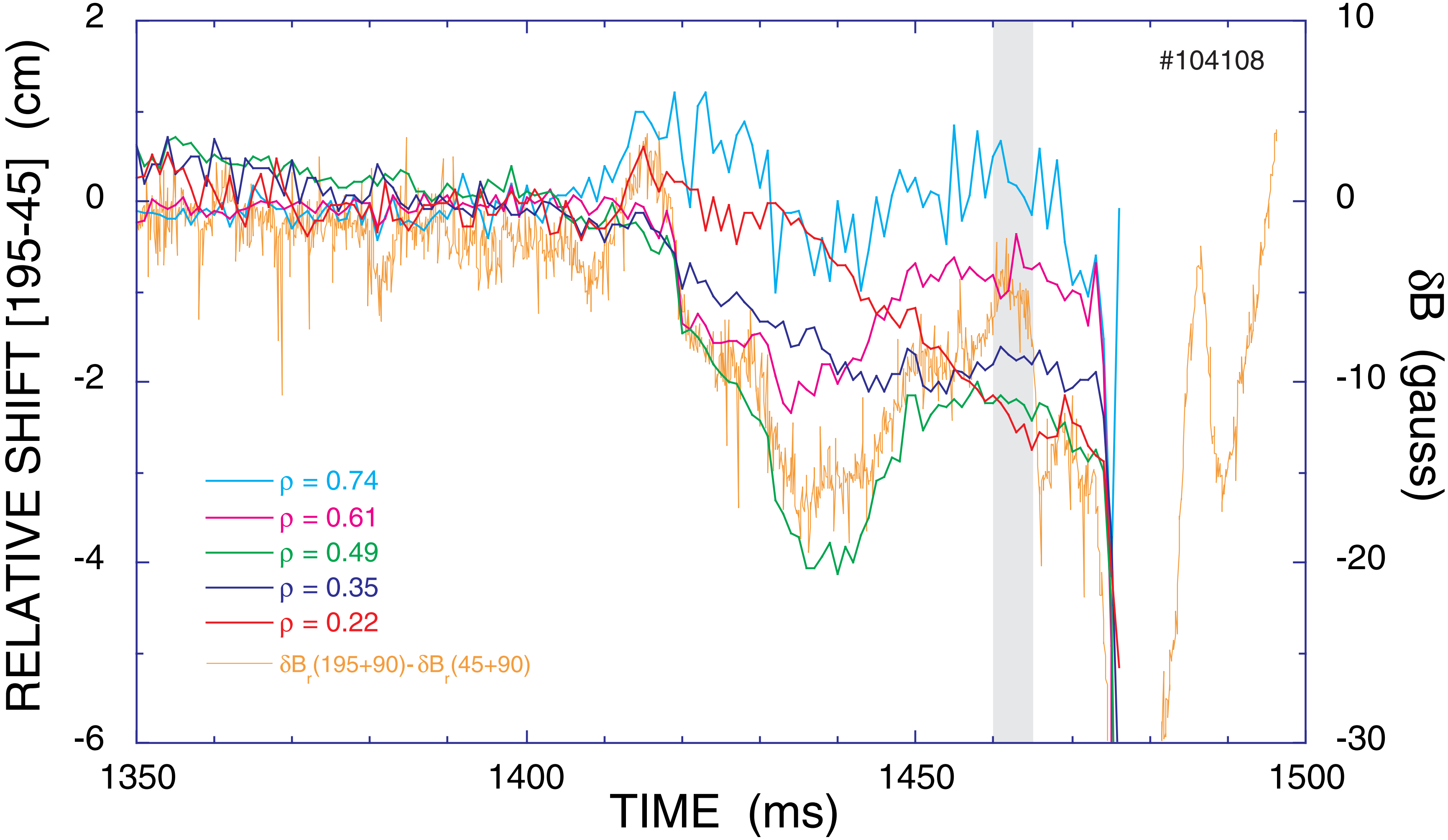


RWM MODE ANALYSIS FOR SHOT WITH SMART SHELL FEEDBACK



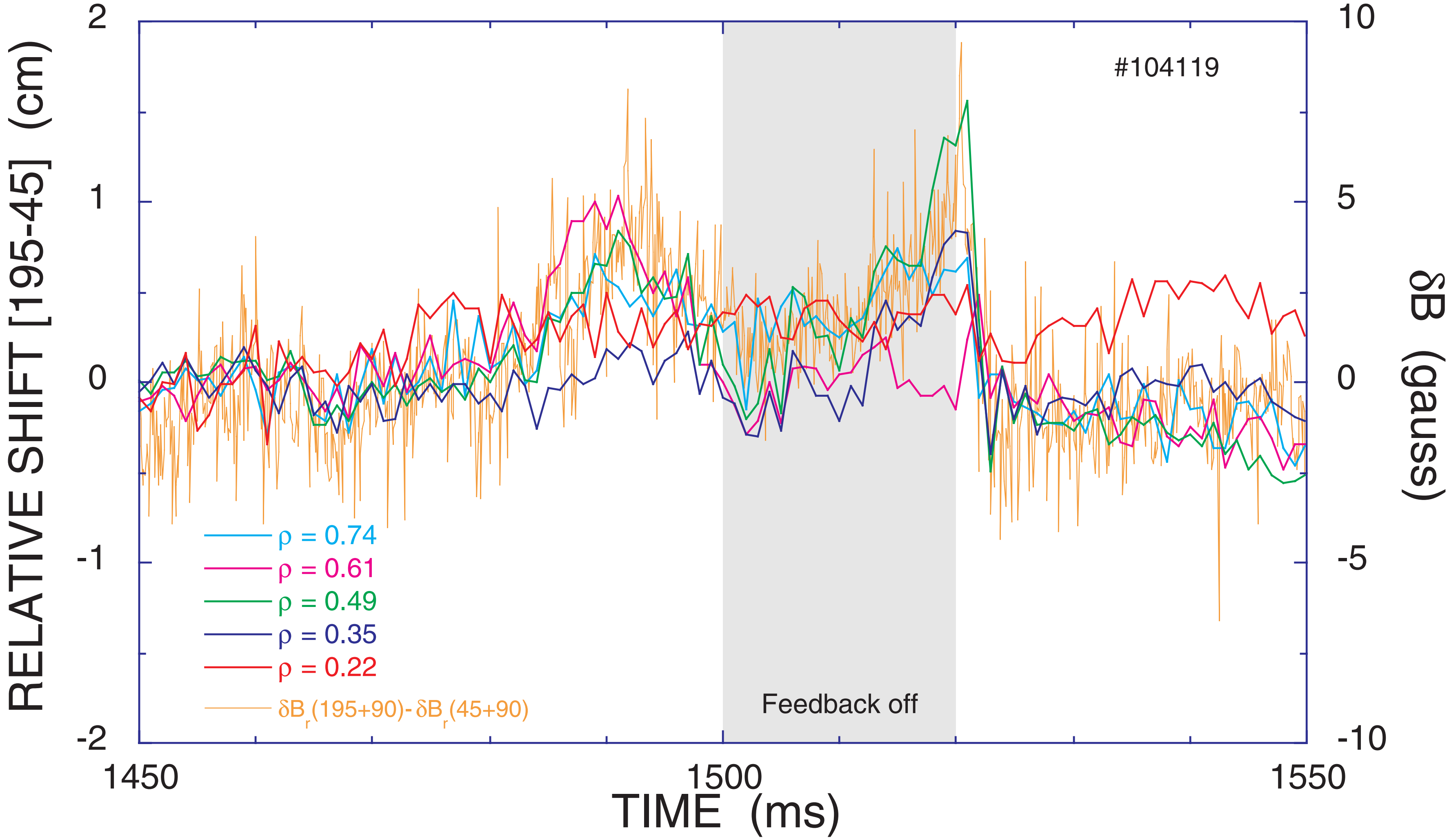
RELATIVE SHIFTS FOR SHOT WITH SMART SHELL FEEDBACK

- With Smart Shell feedback, RWM mode amplitude is held at moderate level until feedback is gated off for 5 ms at t = 1460 ms.
- Internal radial displacement is well correlated with external magnetic perturbation.



MODE AMPLITUDE GROWS WHEN FEEDBACK IS GATED OFF

- Mode is controlled until feedback is gated off, then grows.
- Control is re-established when feedback is switched back on.



SUMMARY

- Twenty-four new picture-frame δB_r loops, together with the original six-loop equatorial array, have measured the helical structure of Resistive Wall Modes during the CY2000 DIII-D experimental campaign and have confirmed the expected n = 1, m £ 3 characteristics.
- A pair of diametrically opposed δB_p probes have measured the perturbed poloidal field at one toroidal location and have confirmed the expected phase relationship with respect to the δB_r measurements.
- Chord-by-chord comparisons of toroidally distributed soft x-ray cameras have measured relative radial displacements at the camera locations. The measurements agree with the internal mode structure predicted by MHD codes and confirm the expected phase relationships with respect to δB_r and δB_p measurements.
- The measurements show that active feedback stabilization can delay or suppress RWMs and that the mode can grow when feedback stabilization is removed.
- During feedback stabilization, the amplitude of RWMs is reduced, but the structure of the modes appears to be unchanged.