Global Structure of a Stable, Driven Kink Mode: DIII-D Measurements and Model Validation

By
M.J. Lanctot[1]

In collaboration with
H. Reimerdes[1], A.M. Garofalo[2], M.S. Chu[2], Y.Q. Liu[3], E.J. Strait[2], J.-K. Park[4], M.J. Schaffer[2], N. Bogatu[5], J. M. Hanson[1,6], E. M. Hollmann[7], Y. In[5], G.L. Jackson[2], R.J. La Haye[2], S. Mordijck[7], M. Okabayashi[4], and T.H. Osborne[2]

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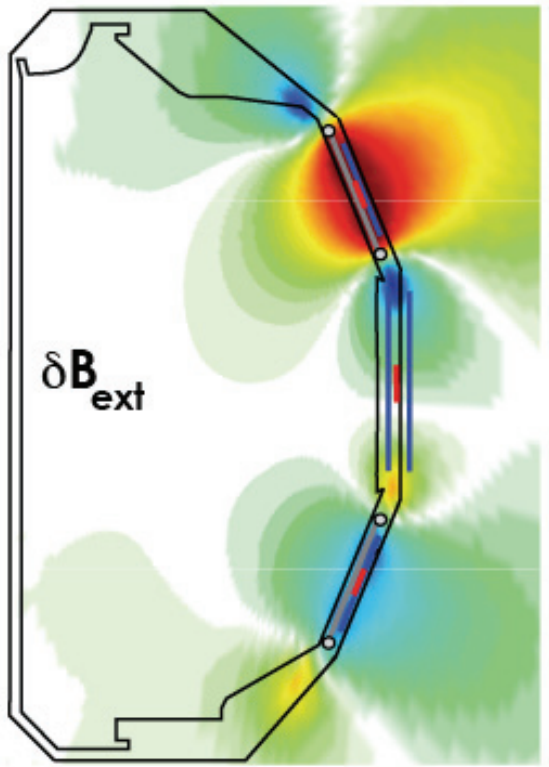
COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

Validation of perturbed equilibrium models lays foundation for improved control using non-axisymmetric fields

- **Background**
  - **Non-axisymmetric magnetic fields have adverse and beneficial effects**
    - **Locked modes and disruptions, ELM suppression, Drive toroidal rotation**
  - **Urgent need exists for quantitative models that explain these observations**



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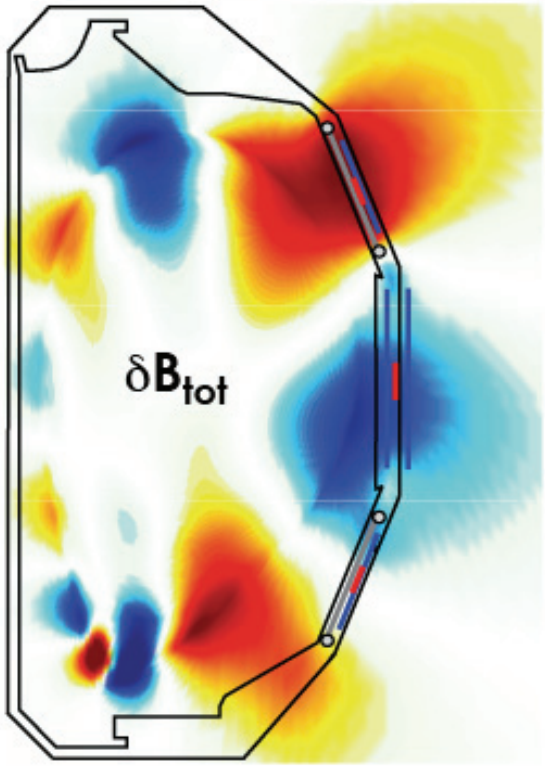
    - PR field results from plasma currents that maintain a stable perturbed equilibrium



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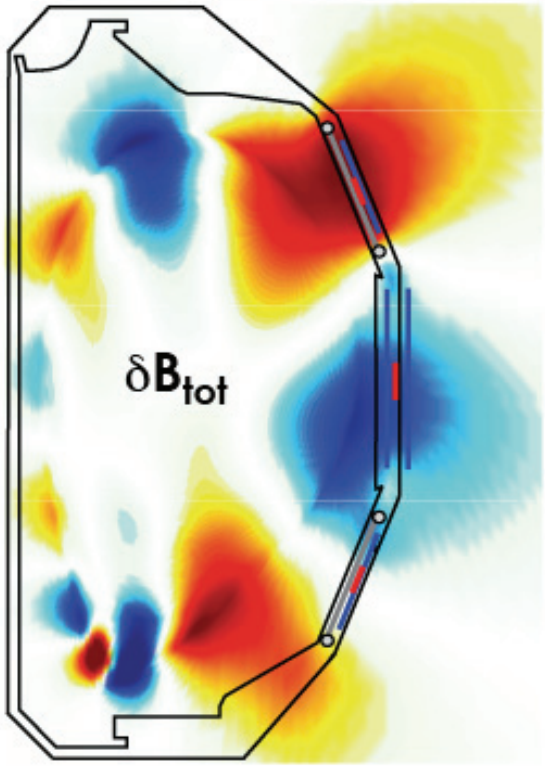
- **Main Results**
  - Ideal MHD gives a quantitative description of the external plasma response well below the no-wall limit
  - External fields that match kink mode eigenfunction determine the strength of the plasma response
  - Ideal MHD plasma approximation fails as plasma approaches marginal stability



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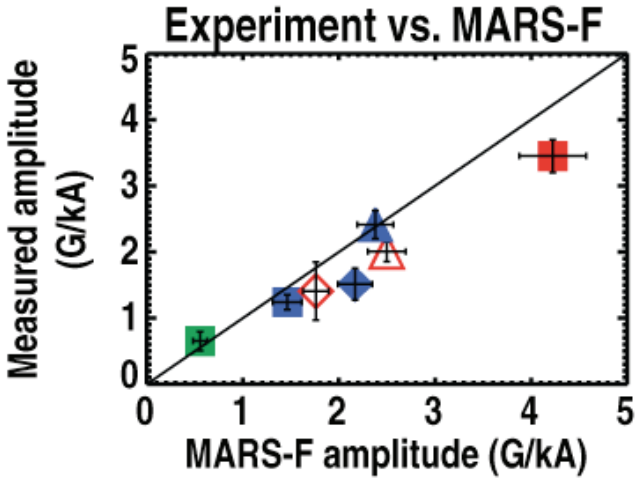
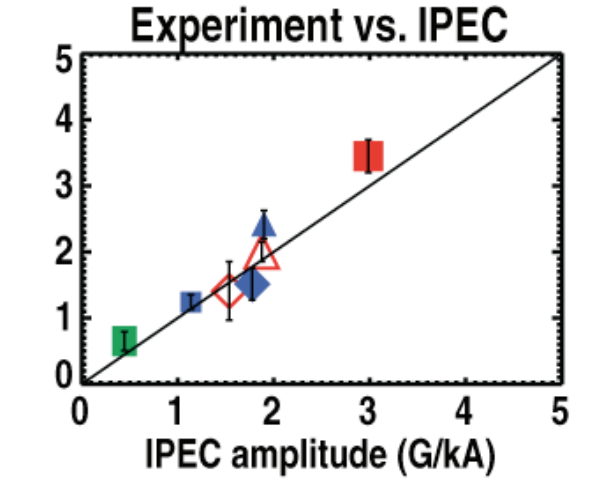
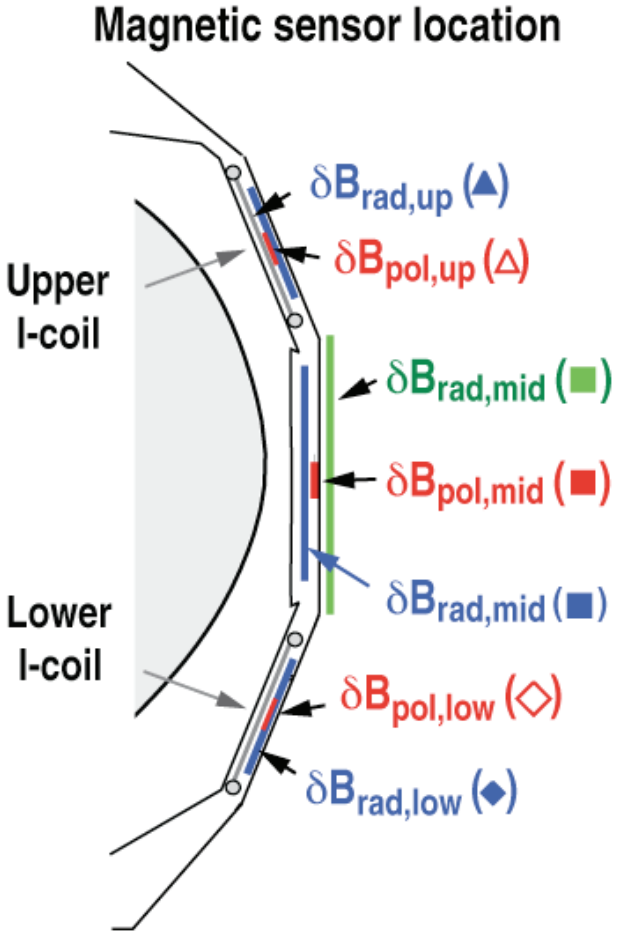
Quantitative agreement is found between external magnetic field measurements and ideal MHD theory

- **Modeling of plasma response with IPEC[1] and MARS-F[2] recreates measurements of perturbed radial and poloidal field at β_N = 1.4**
  - **No free parameters employed in the modeling**





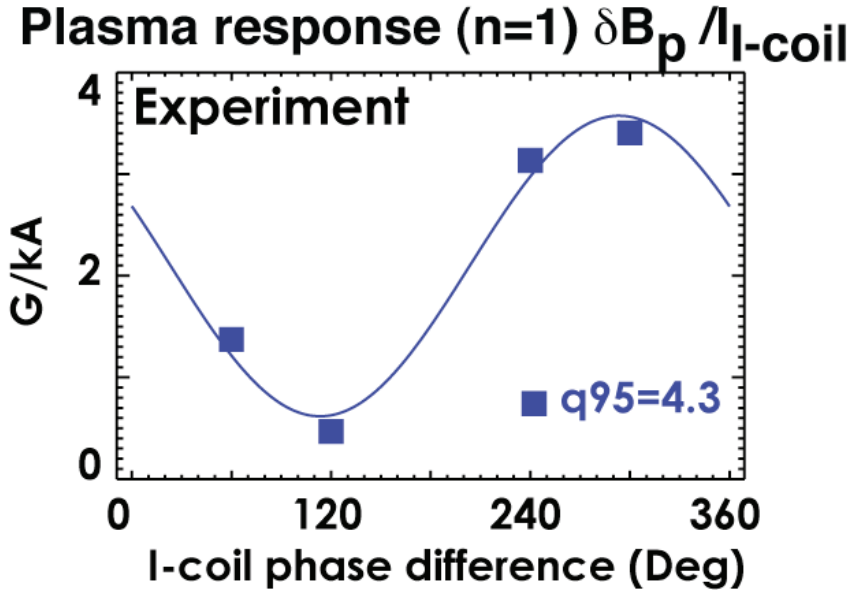


DIII-D 135761@t=1800ms (β_N=1.43)

1. J.-K. Park *et al.*, Phys. Plasmas 16, 056115 (2009).
2. Y.Q. Liu *et al.*, Phys. Plasmas **7**, 3681 (2000).

Plasma response depends on alignment of the applied field to the kink mode structure

- Scan I-coil phase difference at fixed pressure



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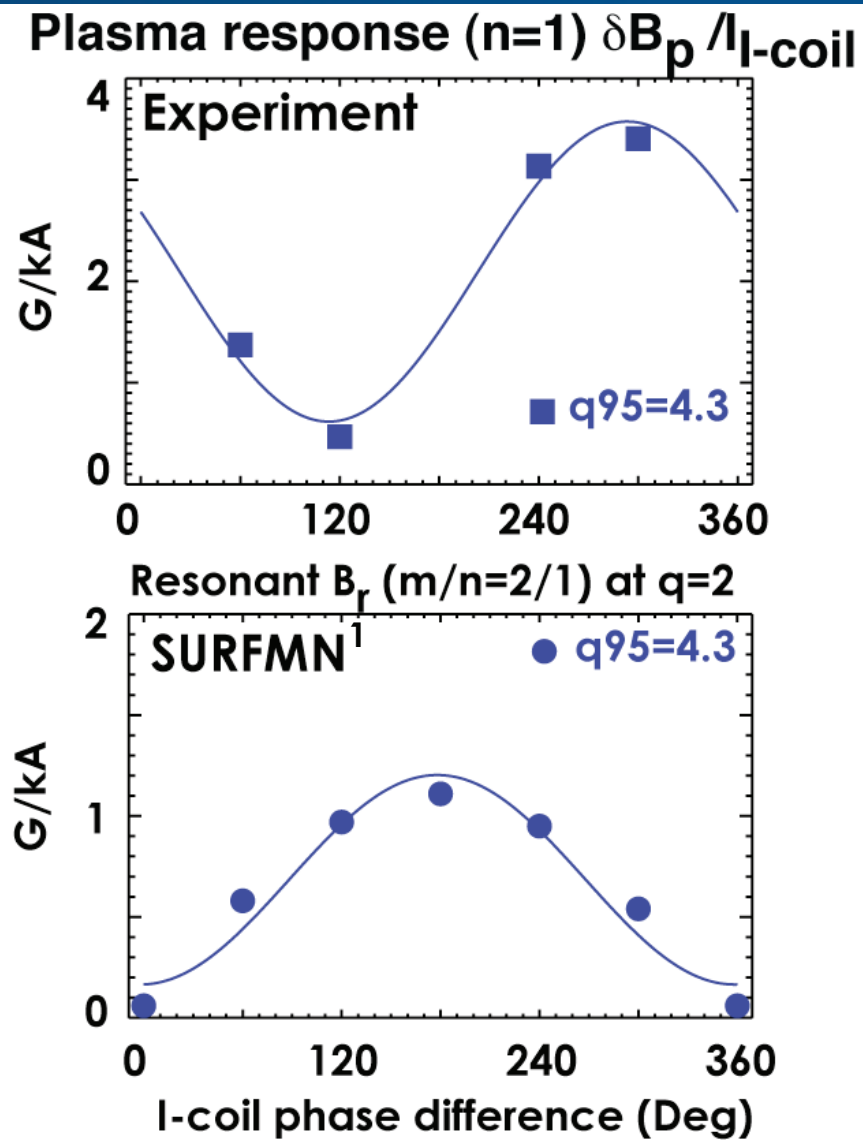

1. M.J. Schaffer *et al.*, Nucl. Fusion 48, 024004 (2008)

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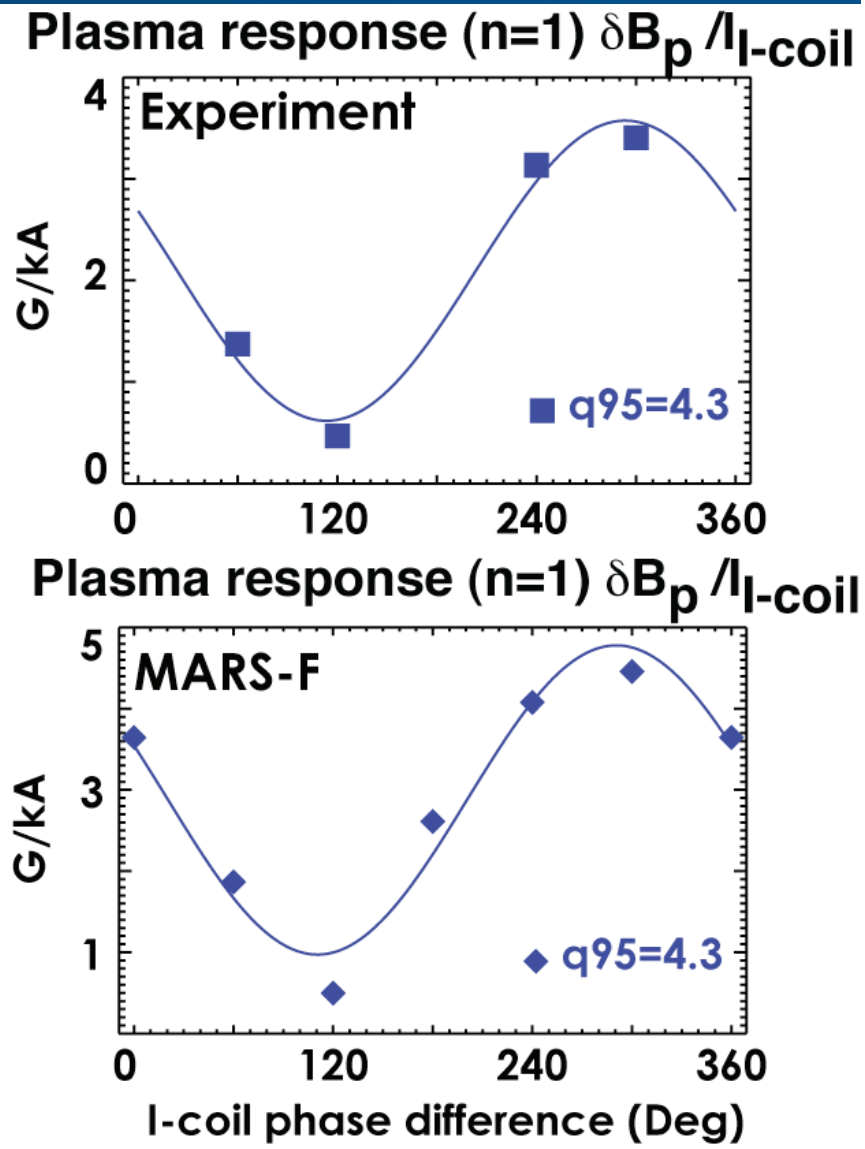

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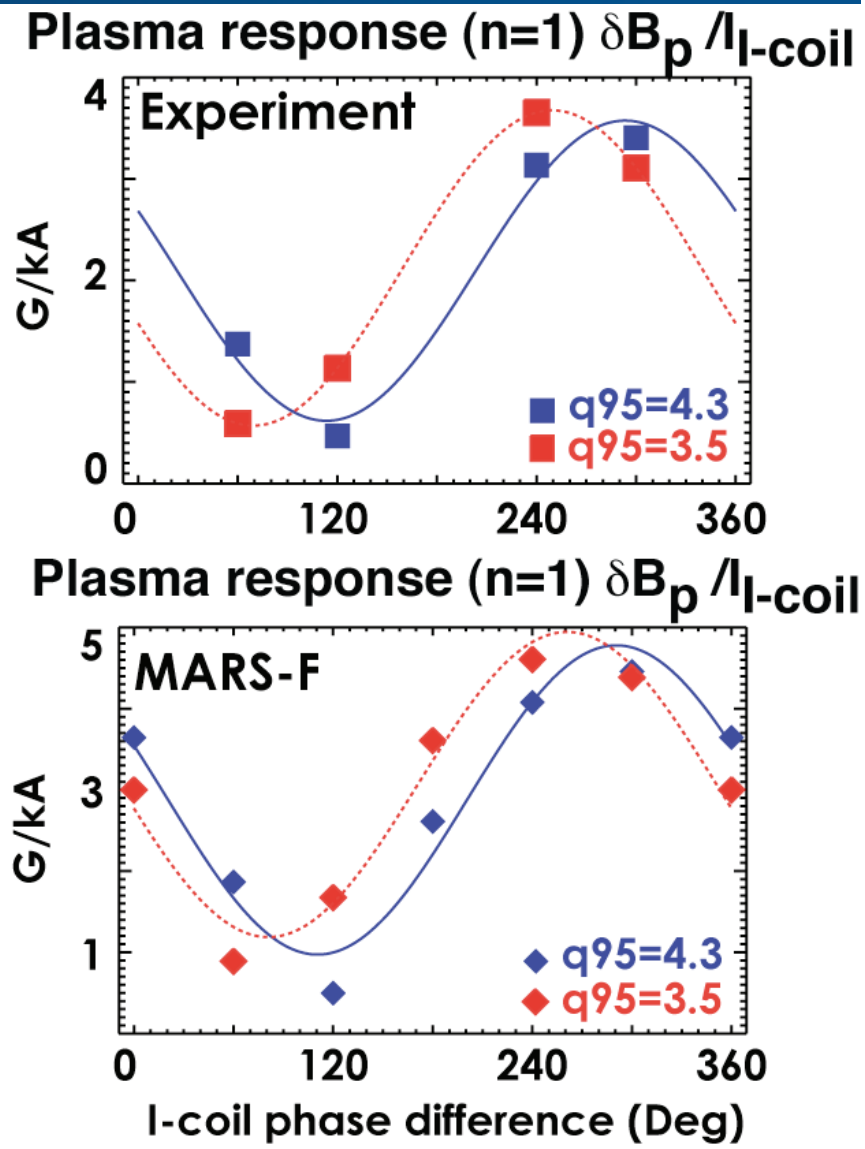

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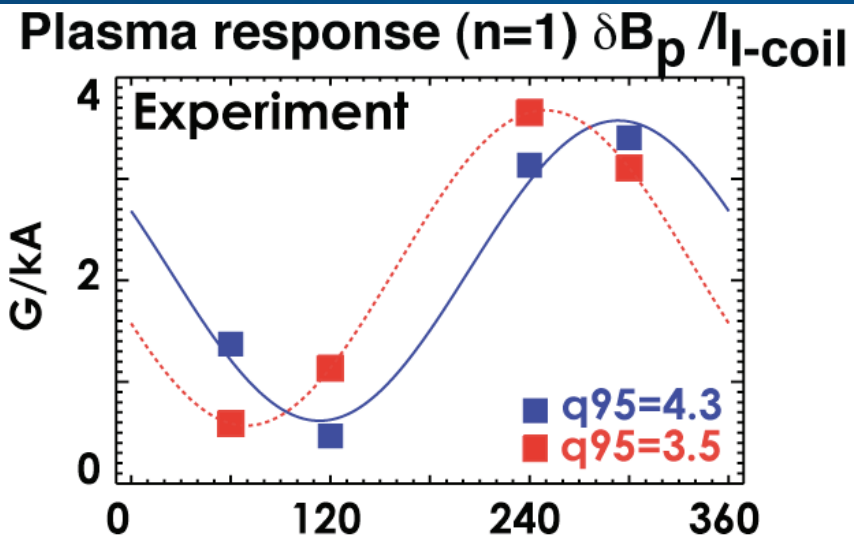
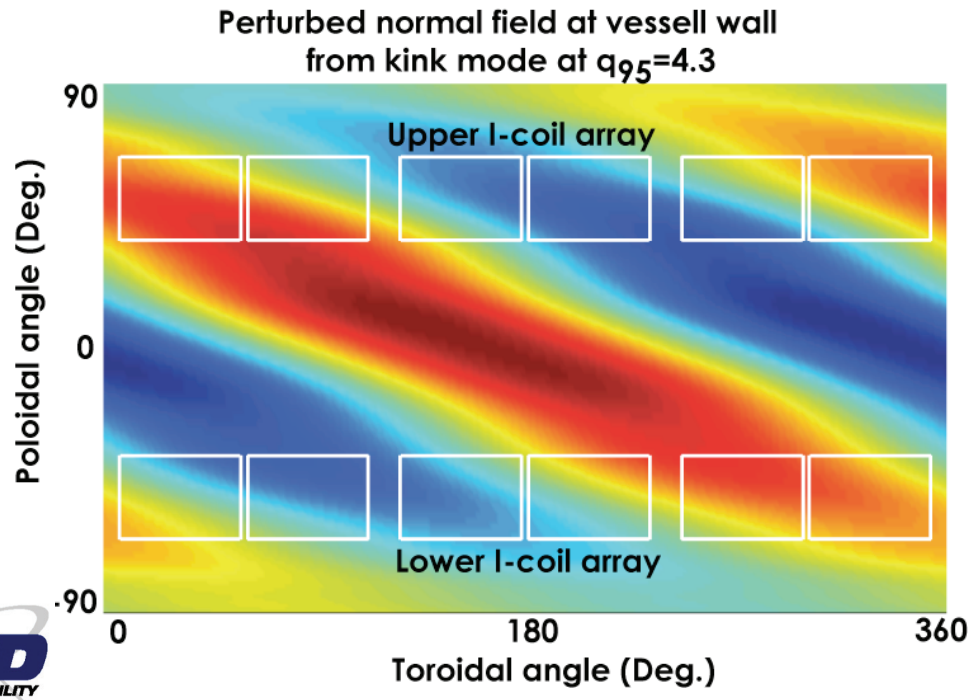
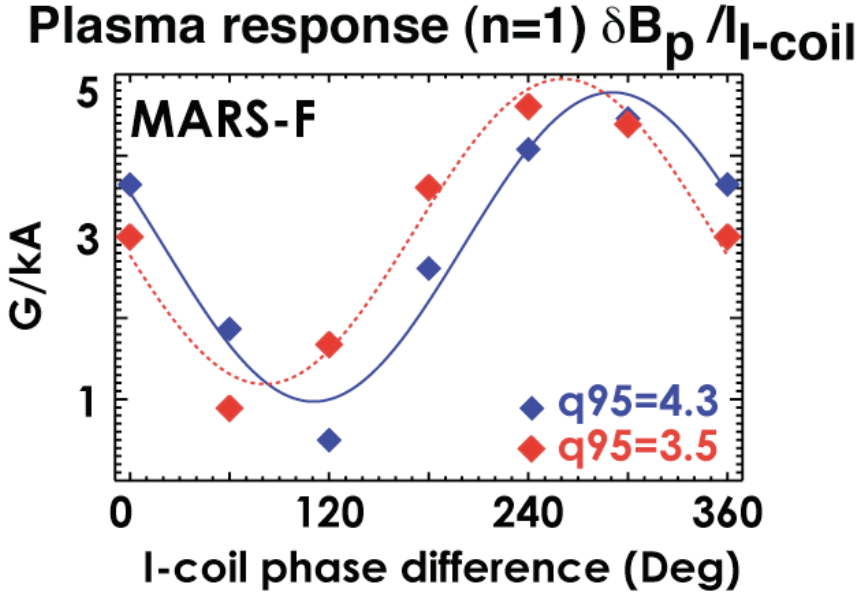
- Strongest plasma response occurs when the applied field matches the kink eigenfunction







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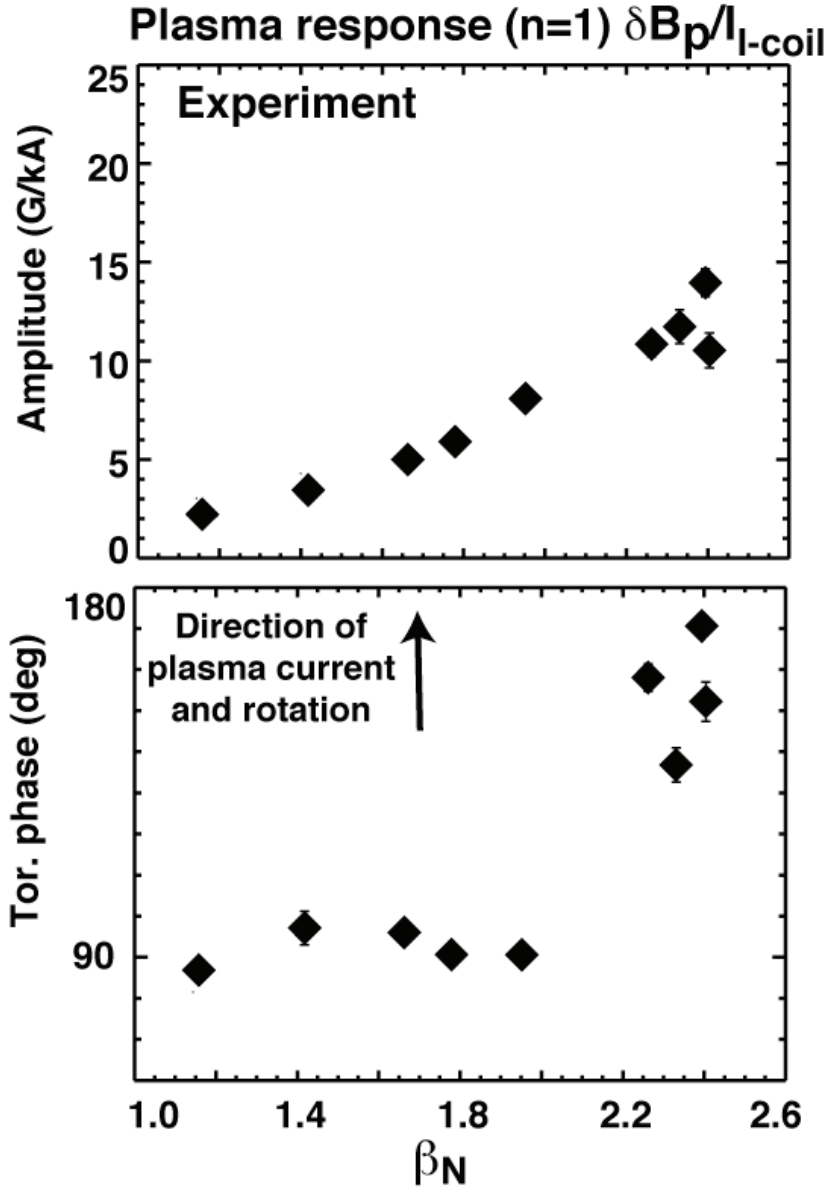
Linear ideal MHD theory describes measured *n*=1 plasma response for values of β_N up to 80% of no-wall stability limit

- **Plasma response was measured in NBI heated H-mode discharges over a wide range of β_N**



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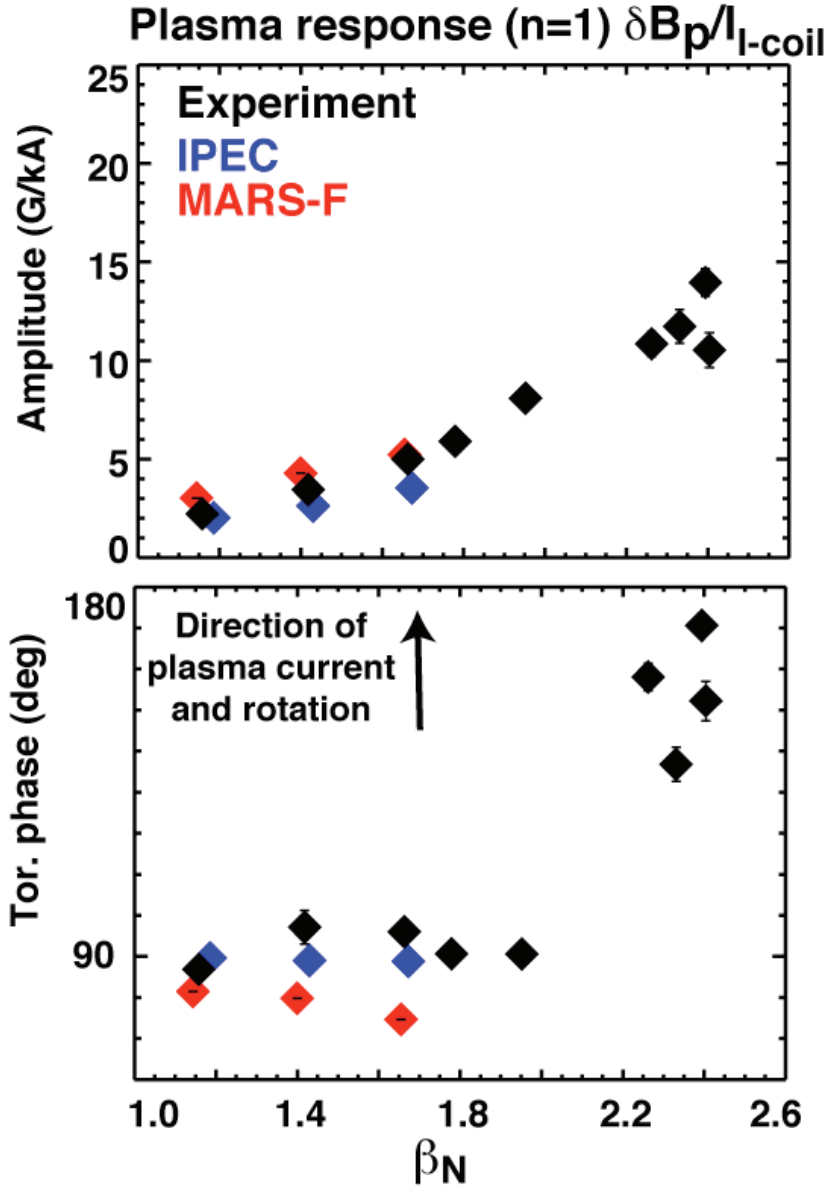

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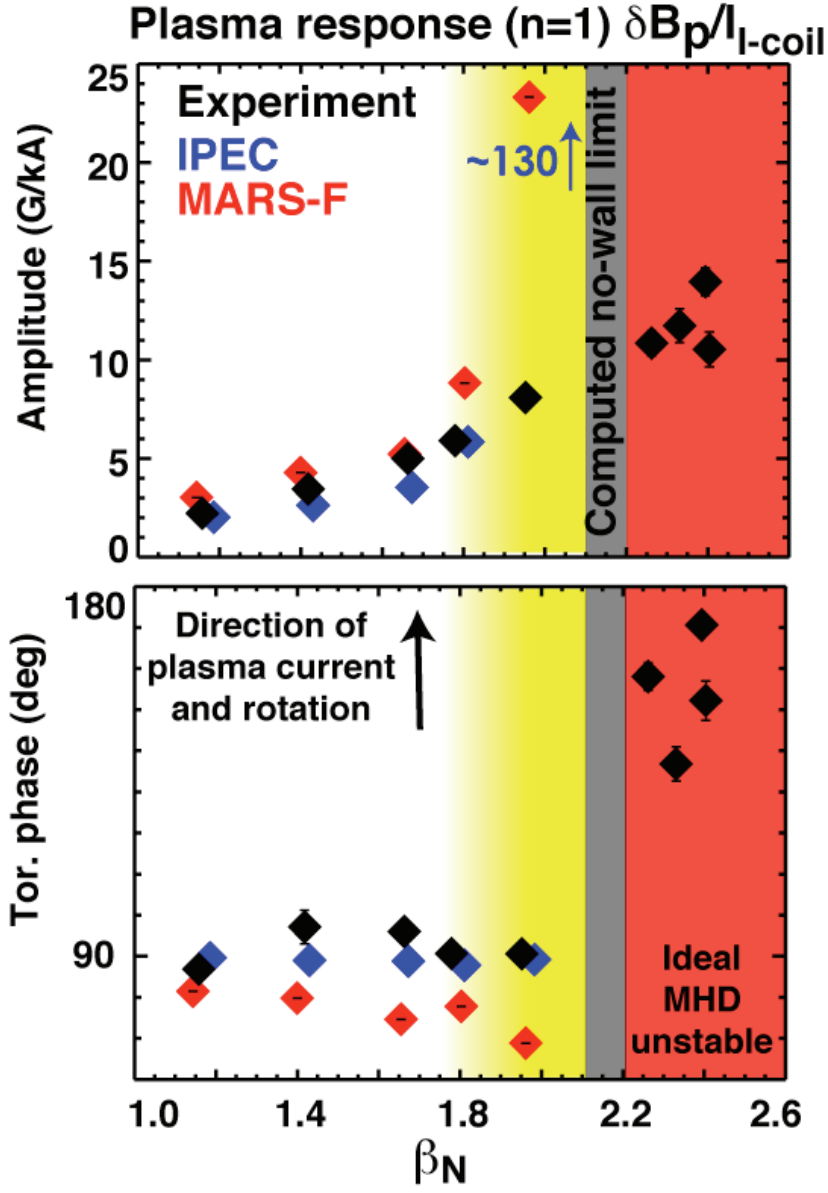

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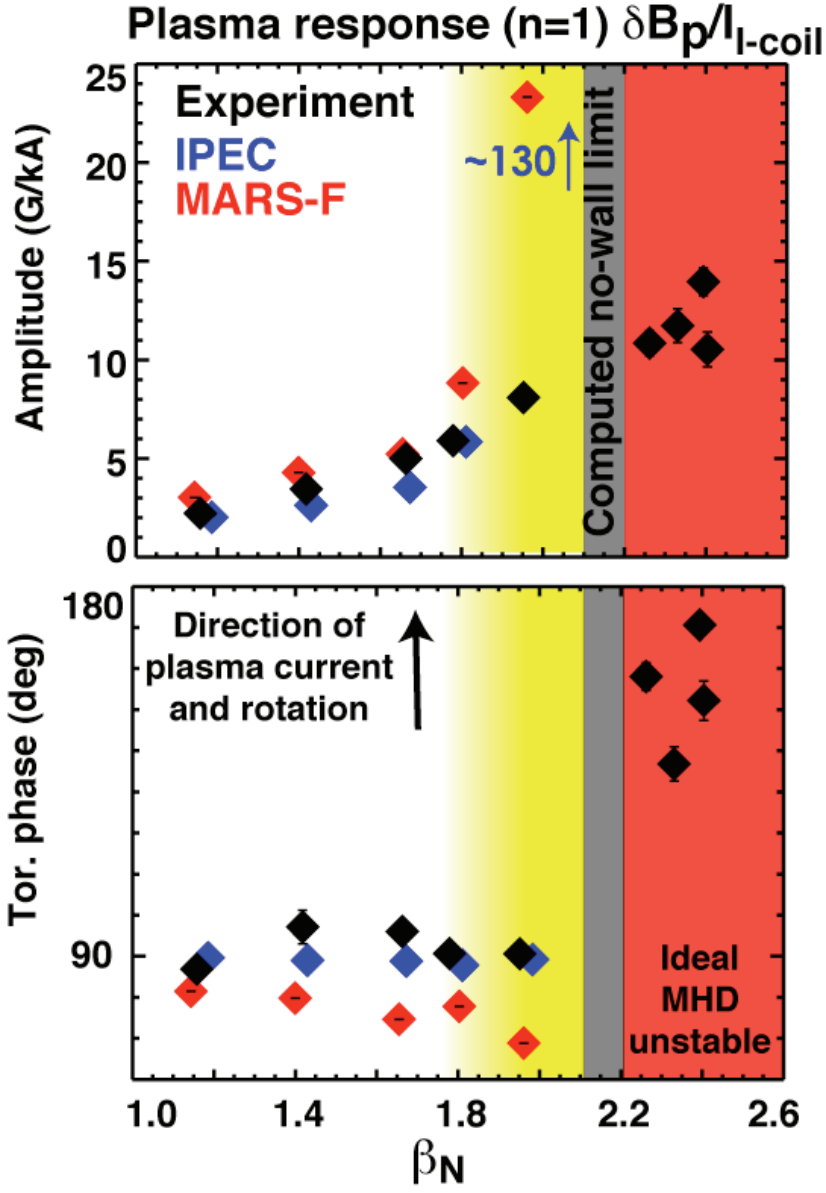
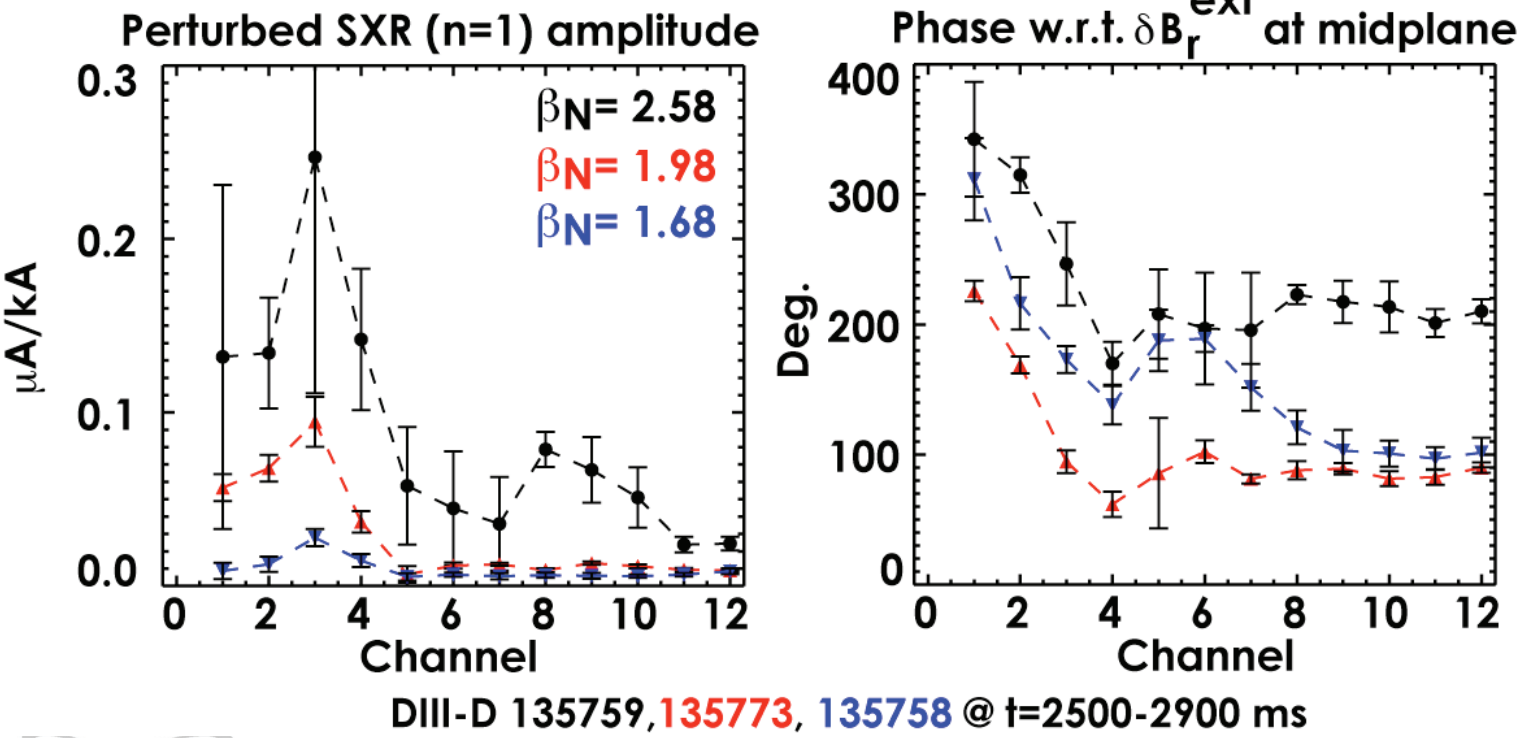
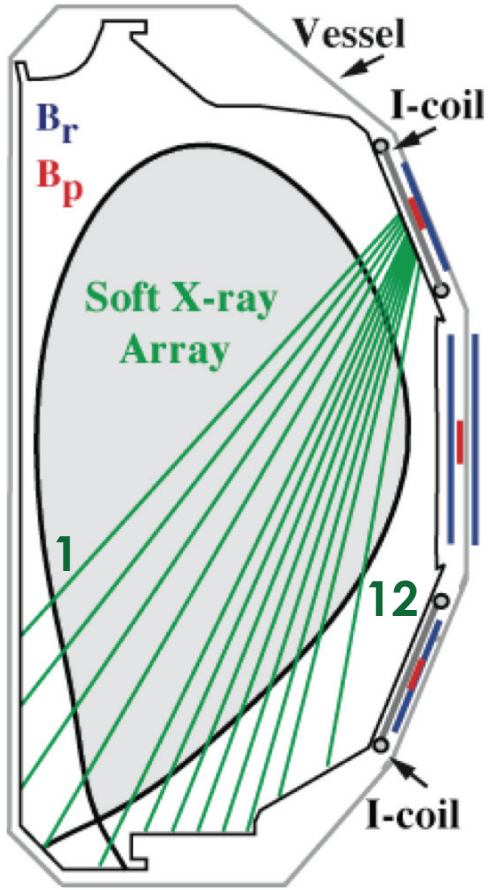
➔ Results establish limits of validity for linear ideal MHD models of the plasma response



Measurements of the perturbed (n=1) soft x-ray (SXR) emissivity show many similarities with magnetic data

- Edge SXR perturbation is always in phase with perturbed poloidal field
- Amplitude of perturbed SXR increases with β_N especially near rational surfaces
- Phase of internal perturbation shifts in direction of rotation as β_N increases





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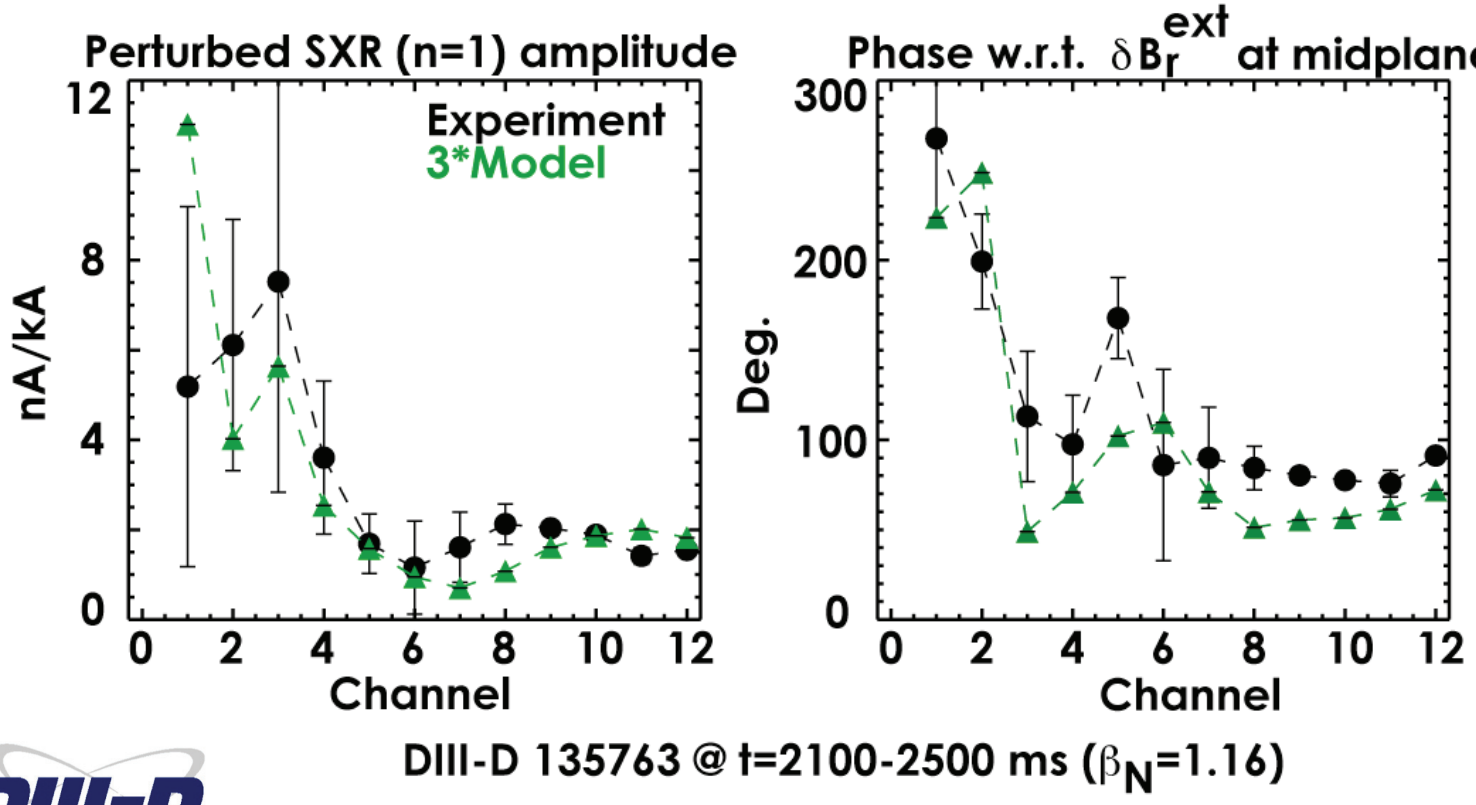
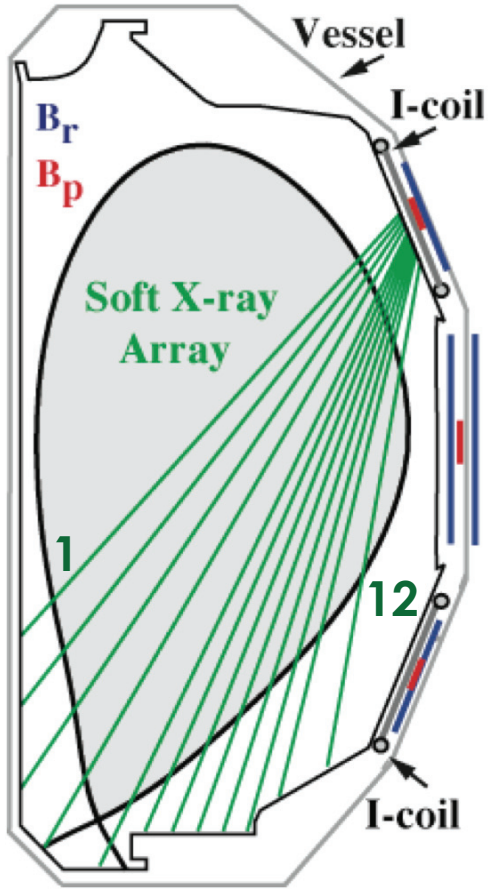
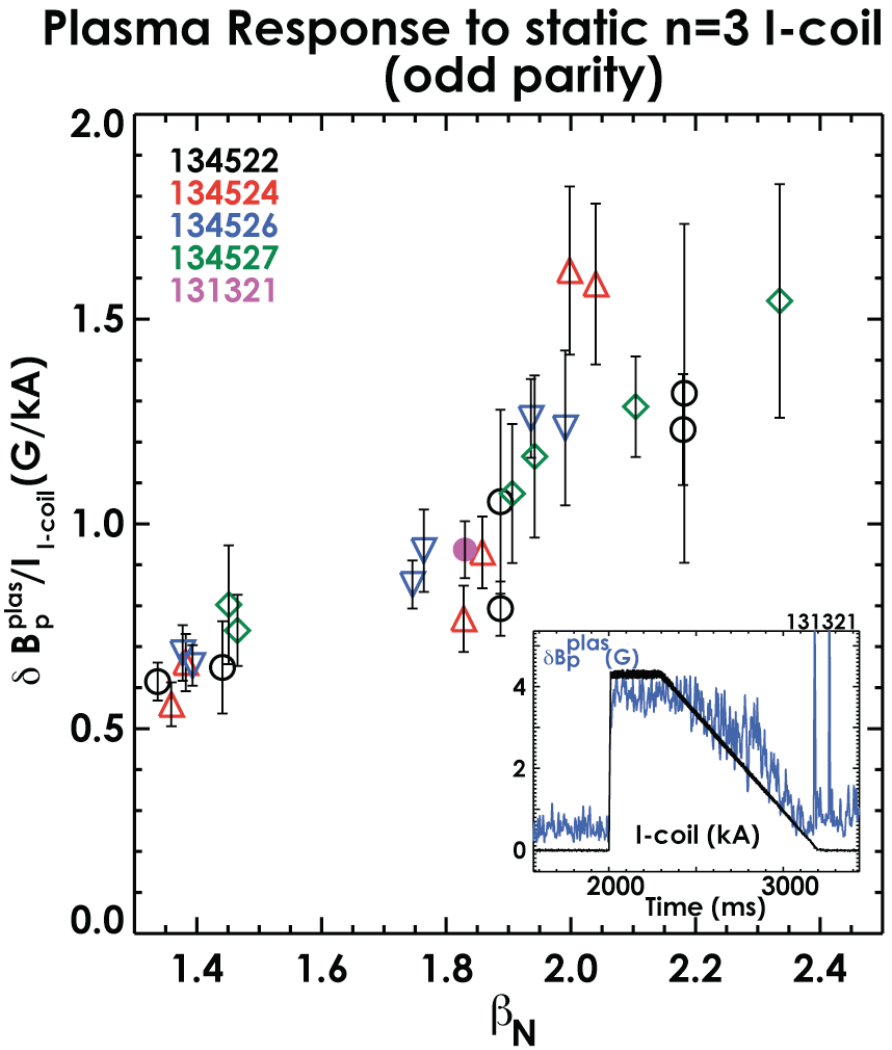
Modeling of SXR measurements at low β_N shows qualitative agreement with ideal MHD mode structure

- **Modeling of perturbed SXR based on thermal continuum emission and ideal MHD mode structure matches the measured profile, phase, and β_N dependence of PR but underestimates amplitude by factor of 3**
  - Disagreement in absolute magnitude likely due to simple model of SXR emission





Ideal MHD modeling of plasma response to n=3 magnetic braking field also in good agreement with measurements



[Garofalo et al. Phys. Plasmas 16, 2009]

- I-coil pulses used to probe n=3 PR well below the n=3 no-wall limit (~ 2.76)
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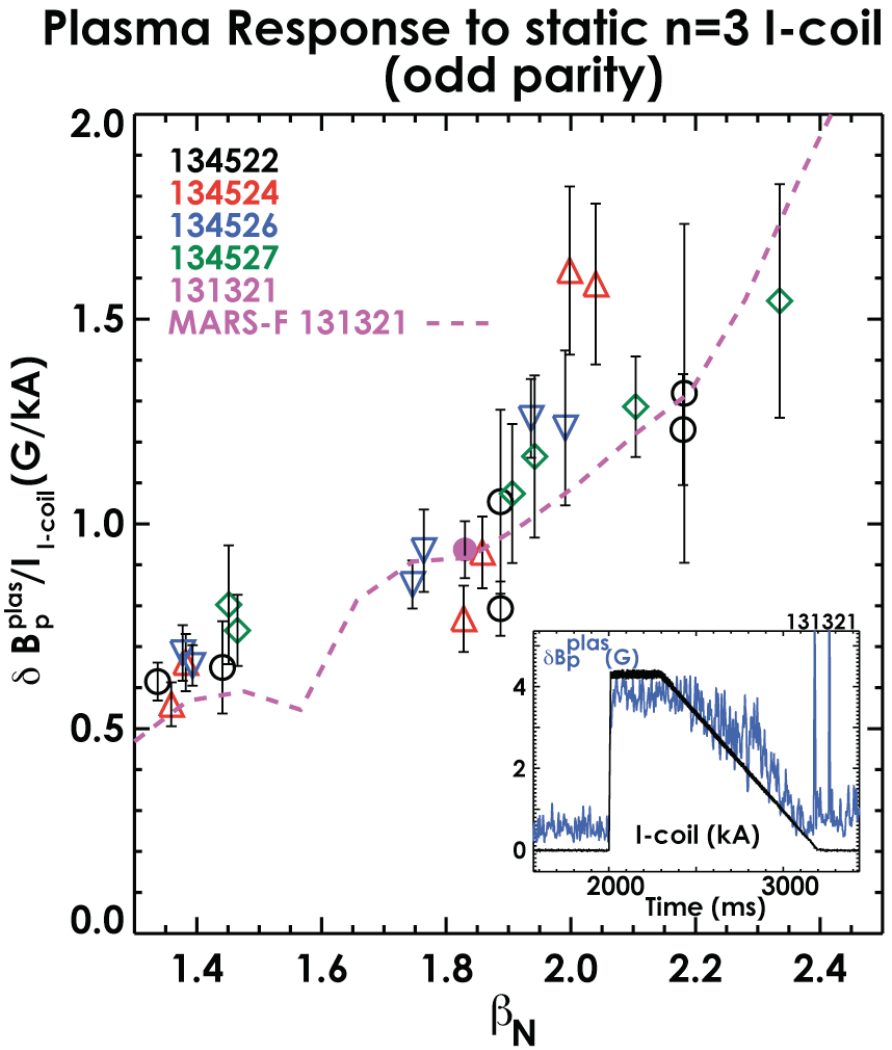

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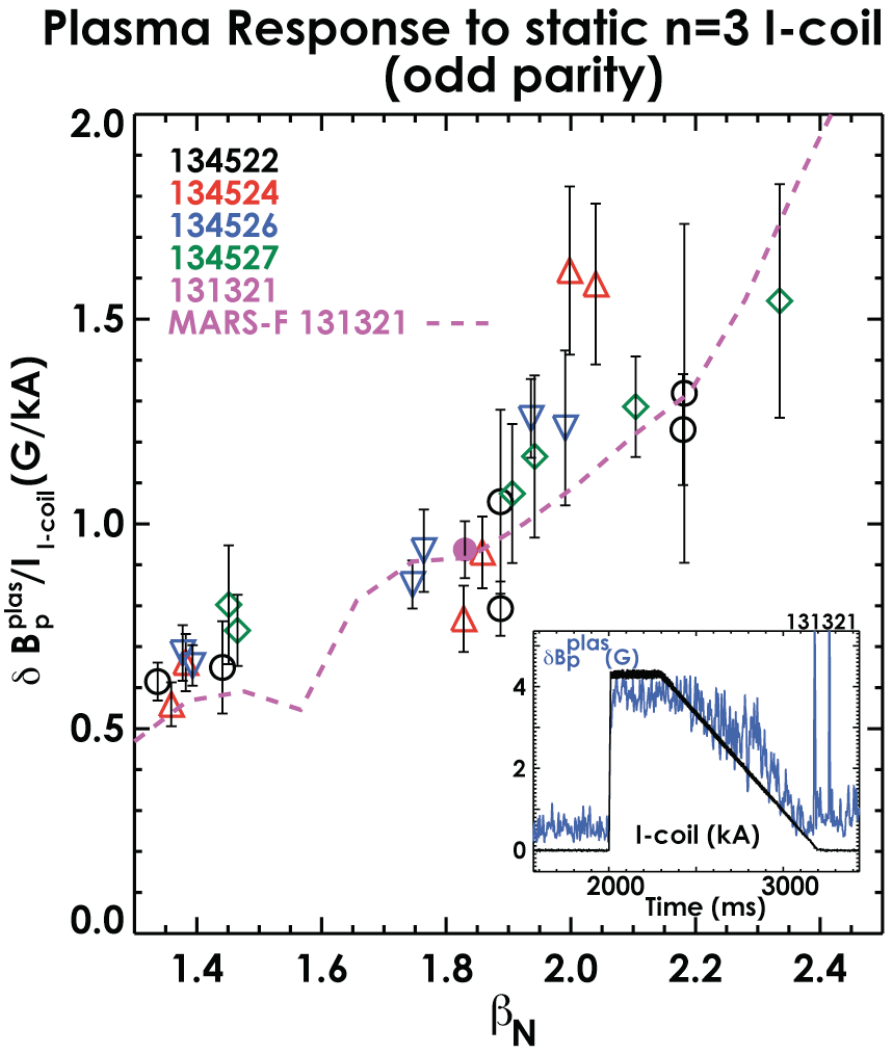

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- Recent work shows β_N dependence of n=3 PR depends on external field structure
  - See poster by H. Reimerdes Tuesday PM

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Summary

- Ideal MHD gives a quantitative description of the external n=1 and n=3 plasma response well below the no-wall limits
- Ongoing modeling of the internal structure of the n=1 plasma response shows qualitative agreement with SXR measurements
- External fields that match kink mode structure determine the strength of the plasma response
- Ideal MHD plasma approximation fails as plasma approaches marginal stability

- Work in progress
  - Continued modeling of SXR emission
  - Modeling of non-ideal effects on the plasma response above the no-wall limit with MARS-K

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