I-COIL PERTURBATIVE EXPERIMENT TO INVESTIGATE EFFECTS OF 3D ERROR FIELDS ON MAGNETIC SURFACES

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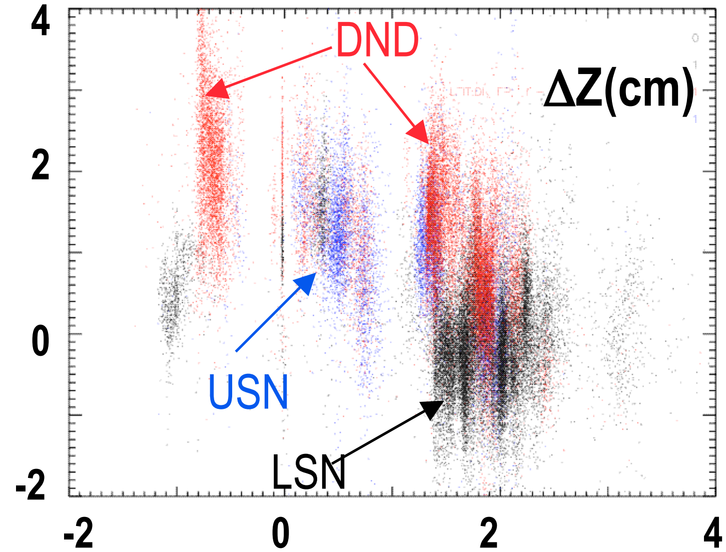
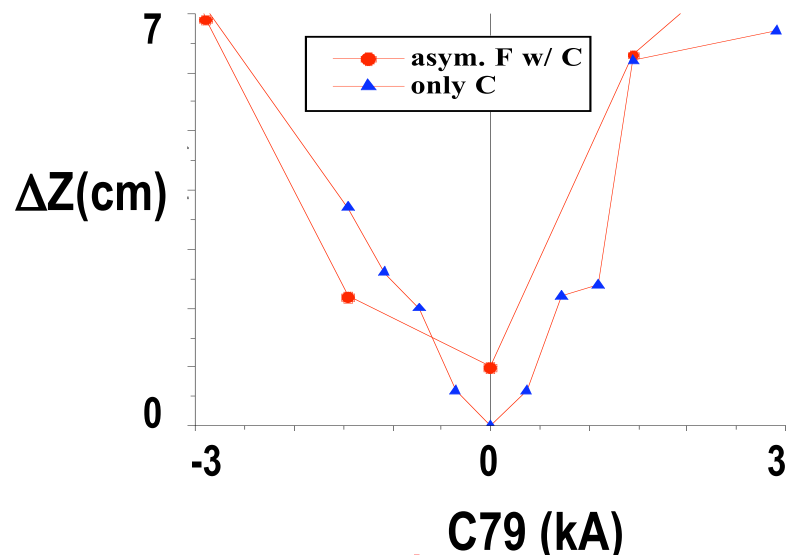
46th Annual APS Division of Plasma Physics Meeting
Savannah, GA
November 15 - November 19, 2004

BACKGROUND

- Accurate determination of the edge separatrix location is crucial for proper interpretation and understanding of the physical processes governing H-mode discharges
  - Pedestal widths are very narrow
- Need to resolve 1-4 cm vertical separatrix difference between magnetics and Thomson T_e seen in some DIII-D discharges
  - Modeling suggests plasma response important
- Need systematic data to guide development of plasma response model and 3D reconstruction tools
  - I-Coil perturbation experiments





I-COIL PERTURBATIVE EXPERIMENTS

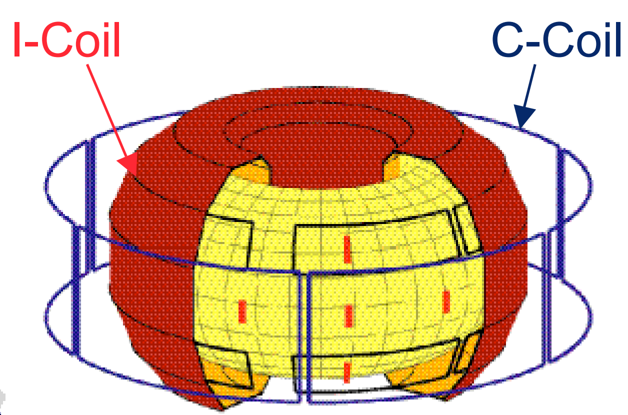
- **Apply slowly rotating *n* = 1 traveling waves at 5 Hz and various amplitudes (0.1 - 0.3% of the poloidal equilibrium field) by pre-programming the I-coil currents to perturb the edge magnetic surfaces**

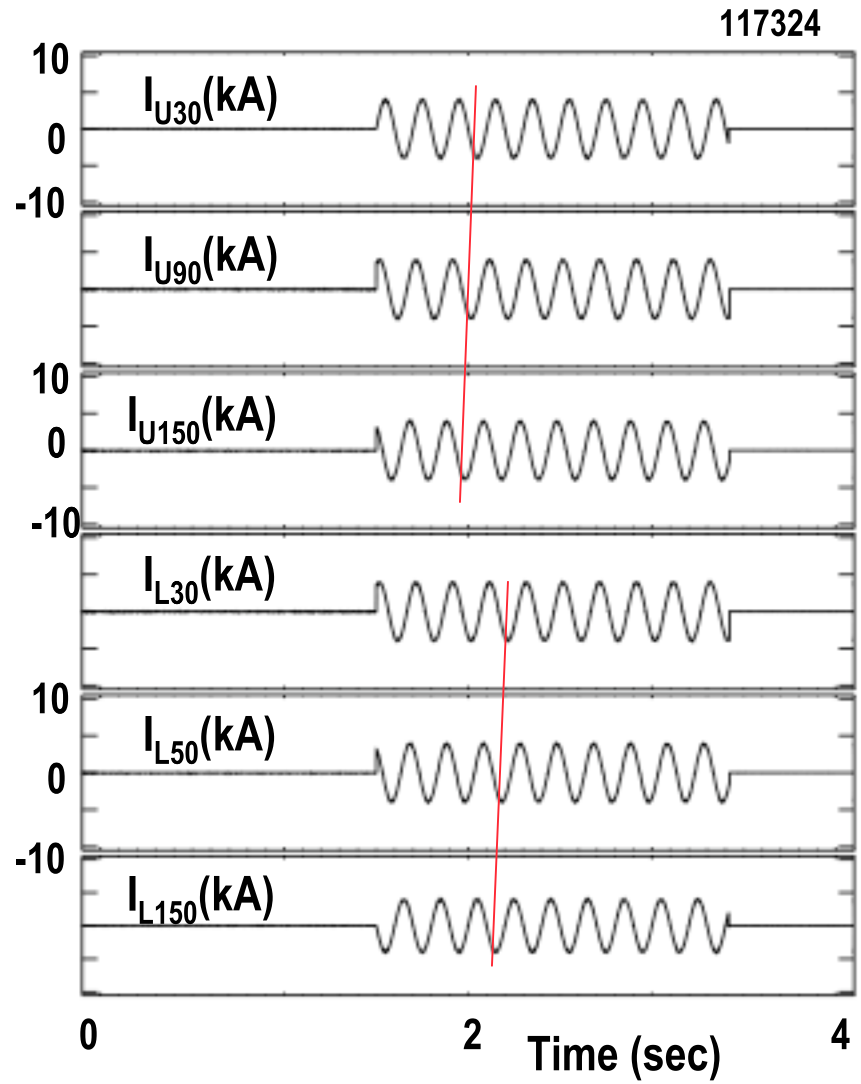
$$IU030 - IU210 = I_0 \cos\left(\frac{2\pi\Delta t}{\tau}\right)$$

$$IU090 - IU270 = I_0 \cos\left(\frac{2\pi\Delta t}{\tau} - \frac{\pi}{3}\right)$$

$$IU150 - IU330 = I_0 \cos\left(\frac{2\pi\Delta t}{\tau} - \frac{2\pi}{3}\right)$$

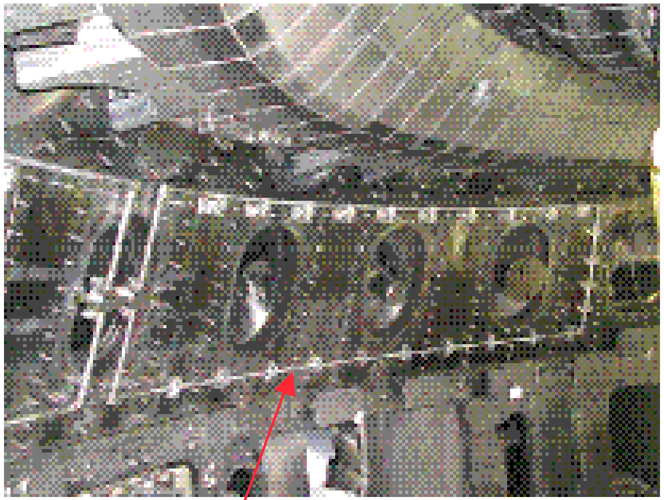
- **Document effects on Thomson separatrix location**





OUTLINE / SUMMARY

- At 0.1% perturbation, the vertical separatrix location difference between magnetic reconstructions and Thomson T_e measurements responds in phase to the applied perturbed field with an amplitude $\Delta Z \sim 2$ cm
- At 0.3% perturbation, the amplitude of the separatrix location difference grows in time leading to an early discharge termination due to appearance of a locked mode
- Analyses suggest plasma response likely important
  - With I-coil perturbation only $\Delta Z \sim 0.5$ cm

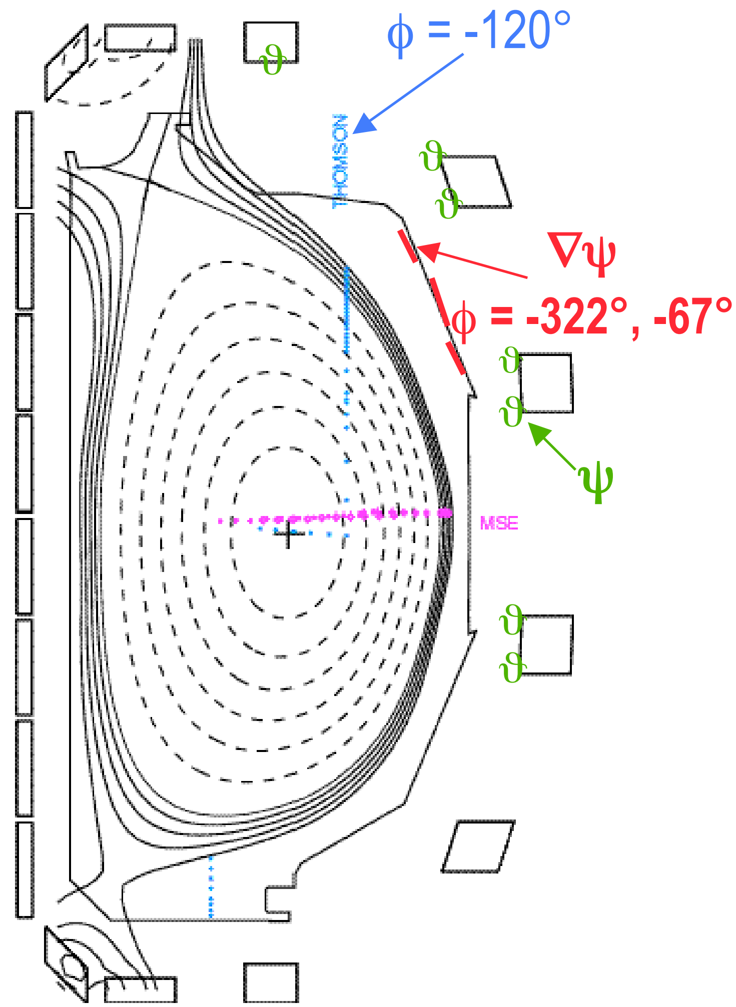


DIII-D NATIONAL FUSION FACILITY SAN DIEGO

GENERAL ATOMICS

SEPARATRIX LOCATION IS DETERMINED BY EXTRAPOLATING EXTERNAL MAGNETIC MEASUREMENTS INWARD

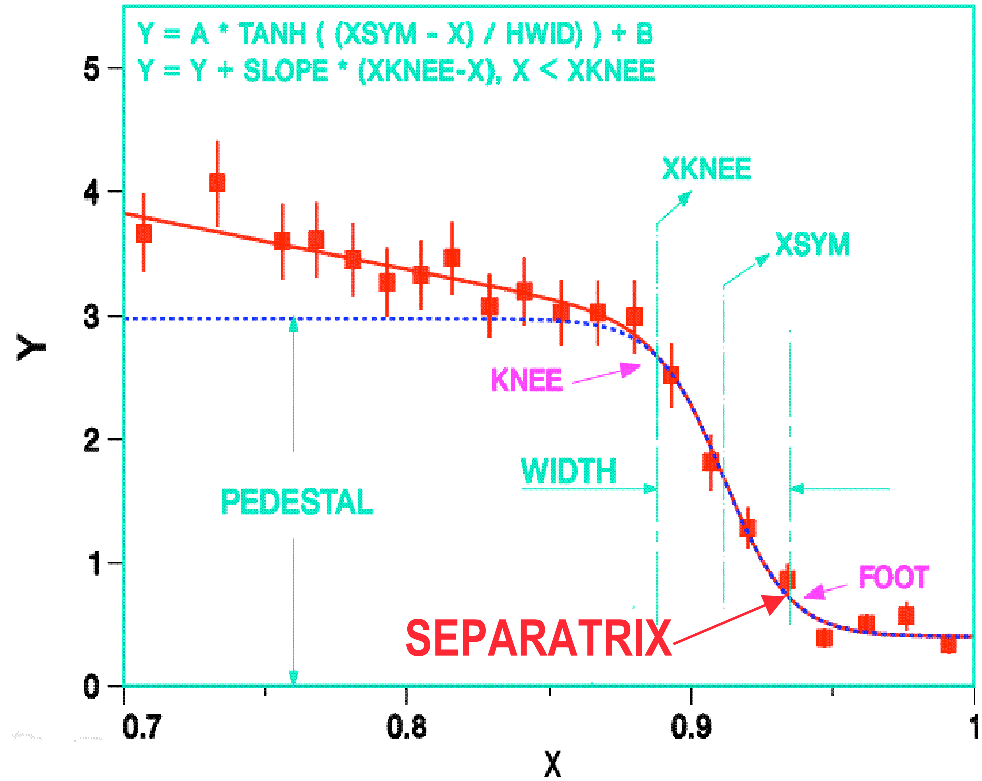
- EFIT extrapolates magnetic measurements inward assumed discharge in a 2-D equilibrium state
  - ~ 41 flux loops: ψ, ~ 73 magnetic probes: $\nabla\psi$
  - Equilibrium relates 2nd derivatives to ψ and $\nabla\psi$
  - Separatrix location defined by largest closed flux surface enclosed by limiter
  - More accurately determined if separatrix is closer to magnetic loops
- Main magnetic probes are at ϕ = -322°, some at -67°
  - Separatrix location largely represents magnetic topology at ϕ = -322°
- Thomson measurements are at ϕ = -120°



SEPARATRIX LOCATION CAN ALSO BE INFERRED FROM HYPERBOLIC TANGENT FIT TO THOMSON T_e PROFILE

- H-mode discharges only
- 3 parameters amplitude, radius, and width Tanh fit to T_e
- $Z_{TS} = Z_{SYN} + 0.5\ \Delta Z_{WIDTH}$
- Previous analyses indicate some consistency with UEDGE divertor heat flux solution with this approach [1]
- Thomson measurements are located at the poloidal plane $\phi = -120°$

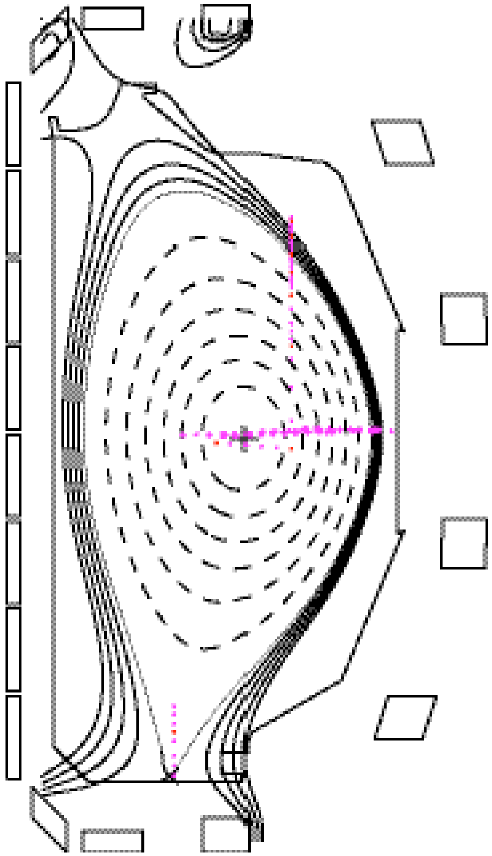
TANH Fit to Thomson T_e



[1] Porter, 1998 Phys. Plasmas **5** 1410

ΔZ RESPONDS IN PHASE WITH AN AMPLITUDE ~ 2 cm AT 0.1% I-COIL PERTURBATION

- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93, Z_{TS}= 67.5 cm



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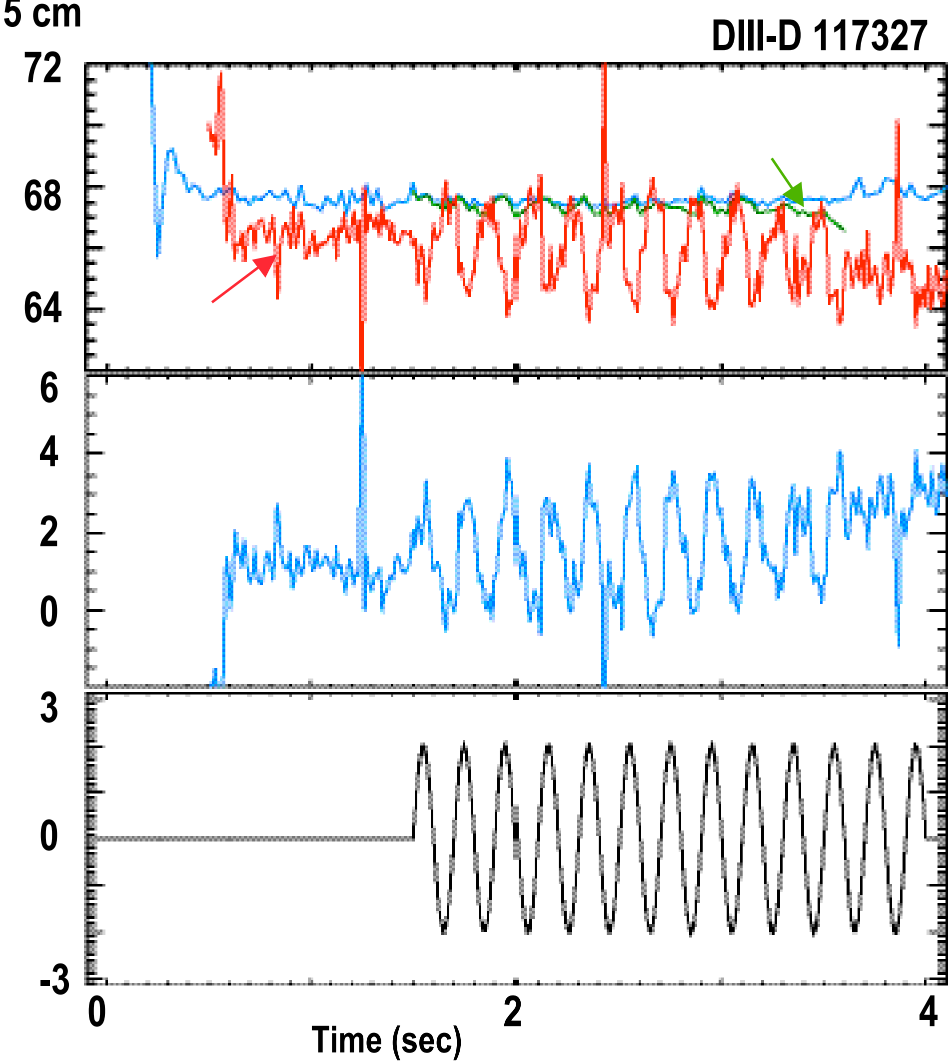

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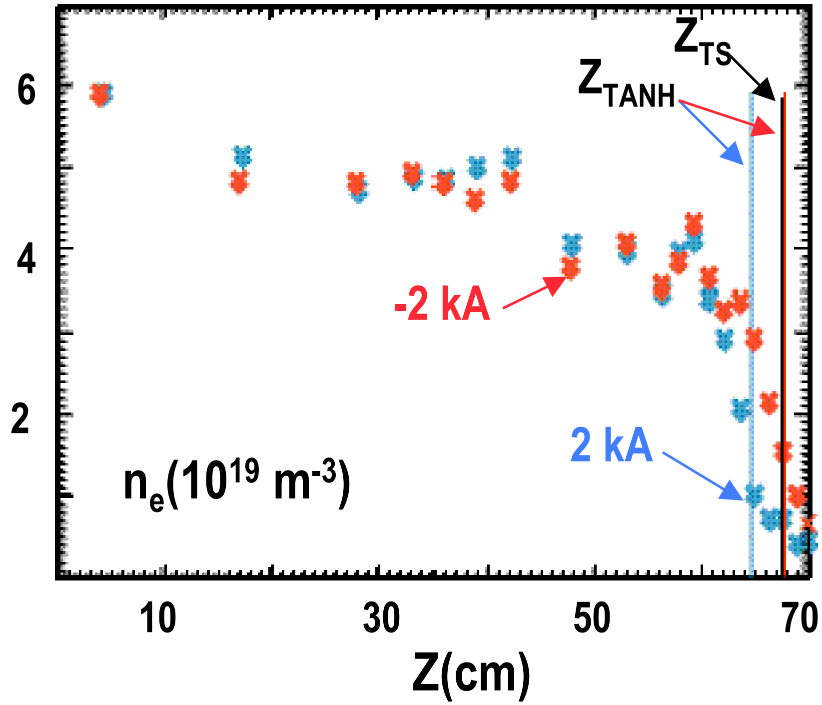
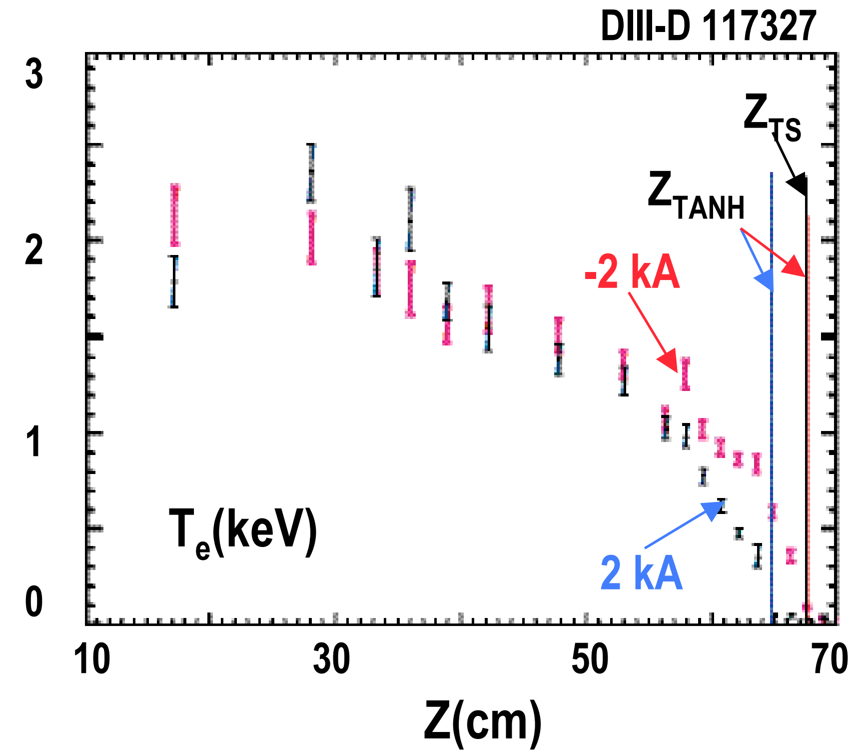
GENERAL ATOMICS

EDGE ELECTRON PROFILES ARE MODULATED BY I-COIL PERTURBATIONS

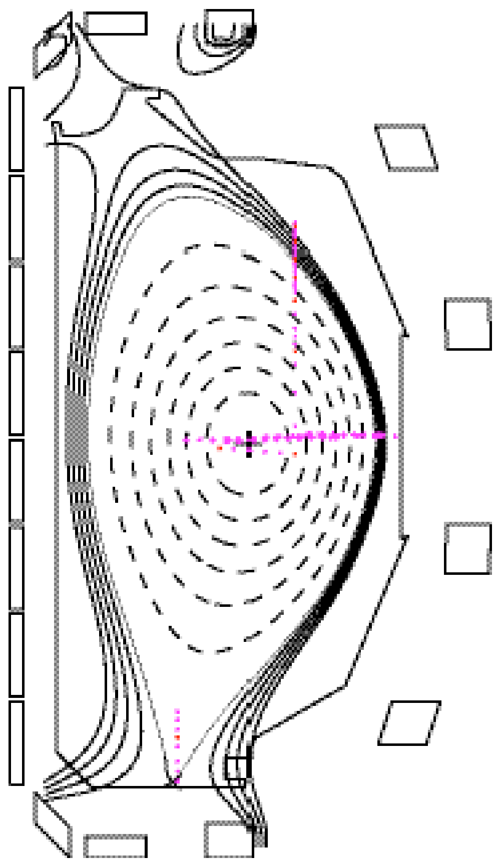
- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93
- Similar magnetic Z_{TS}= 67.5 cm at both I-coil currents





AT 0.3% PERTURBATION ΔZ GROWS IN TIME AND DISCHARGE TERMINATES EARLY

- 1.12 MA, -1.99 T, β_N = 2.00, l_i = 1.00, Z_{TS}= 67.5 cm



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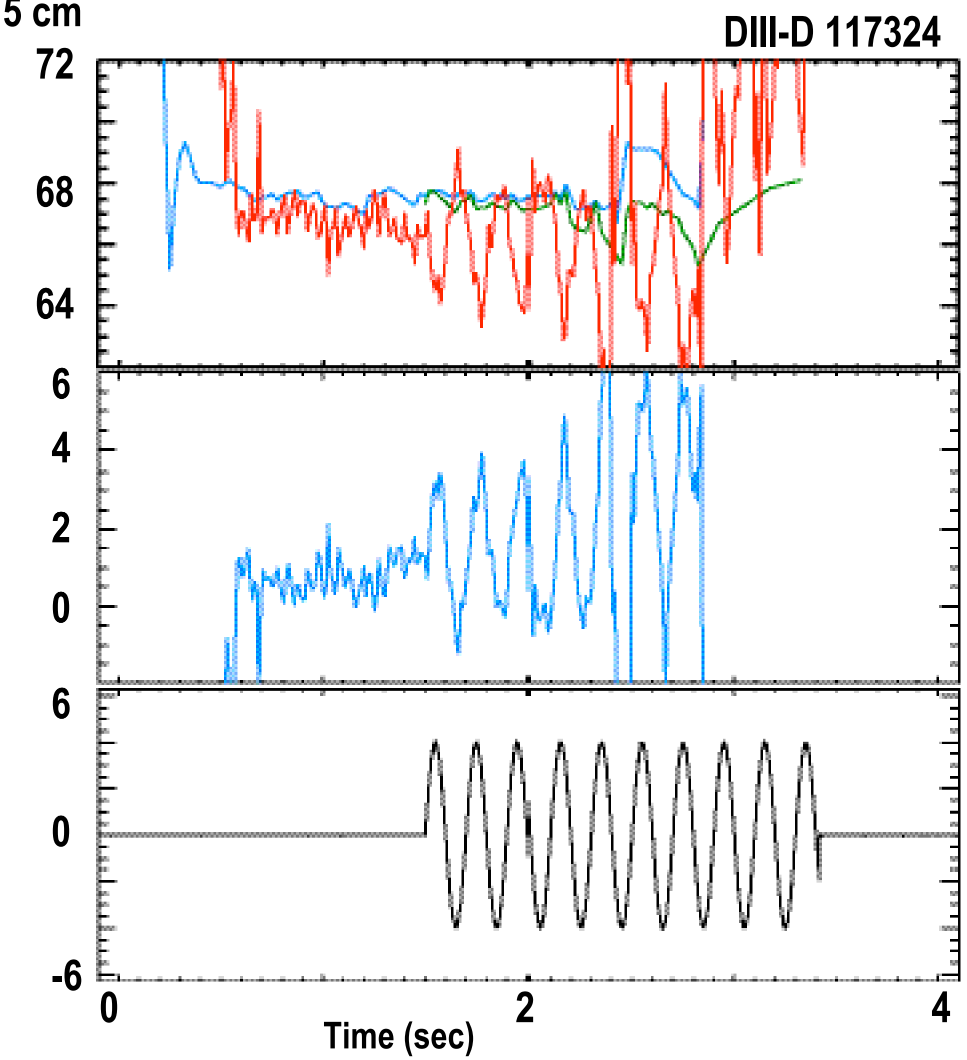

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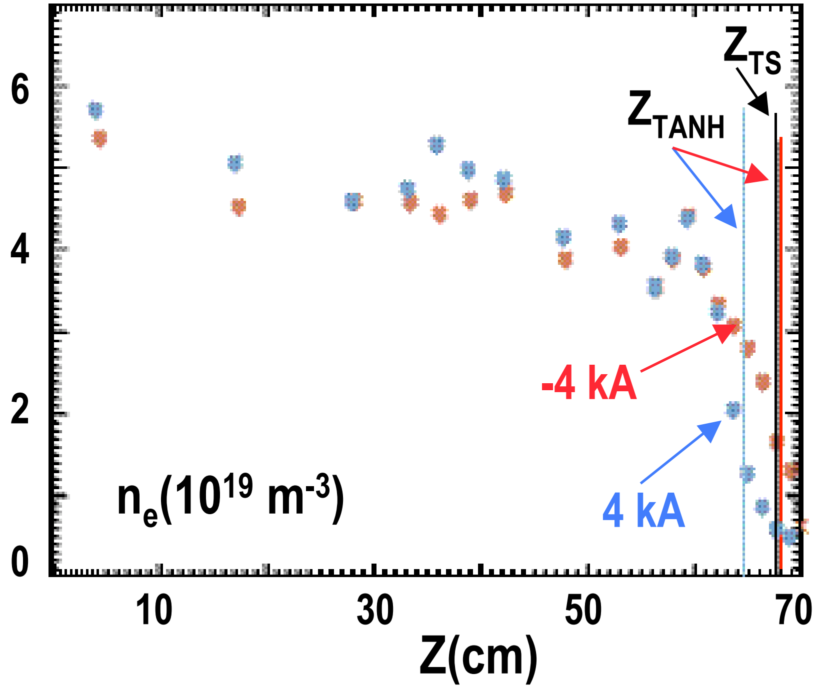

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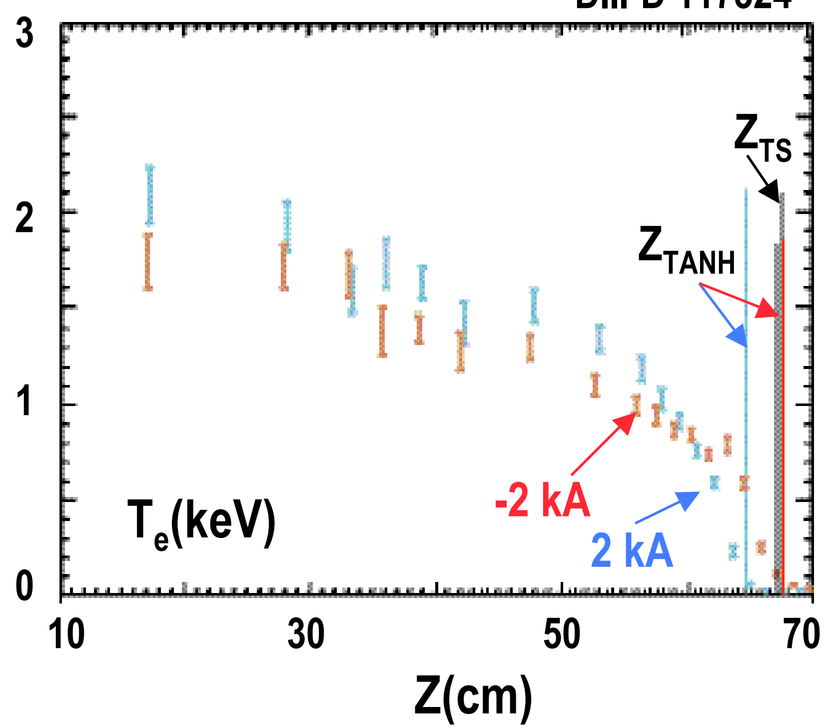

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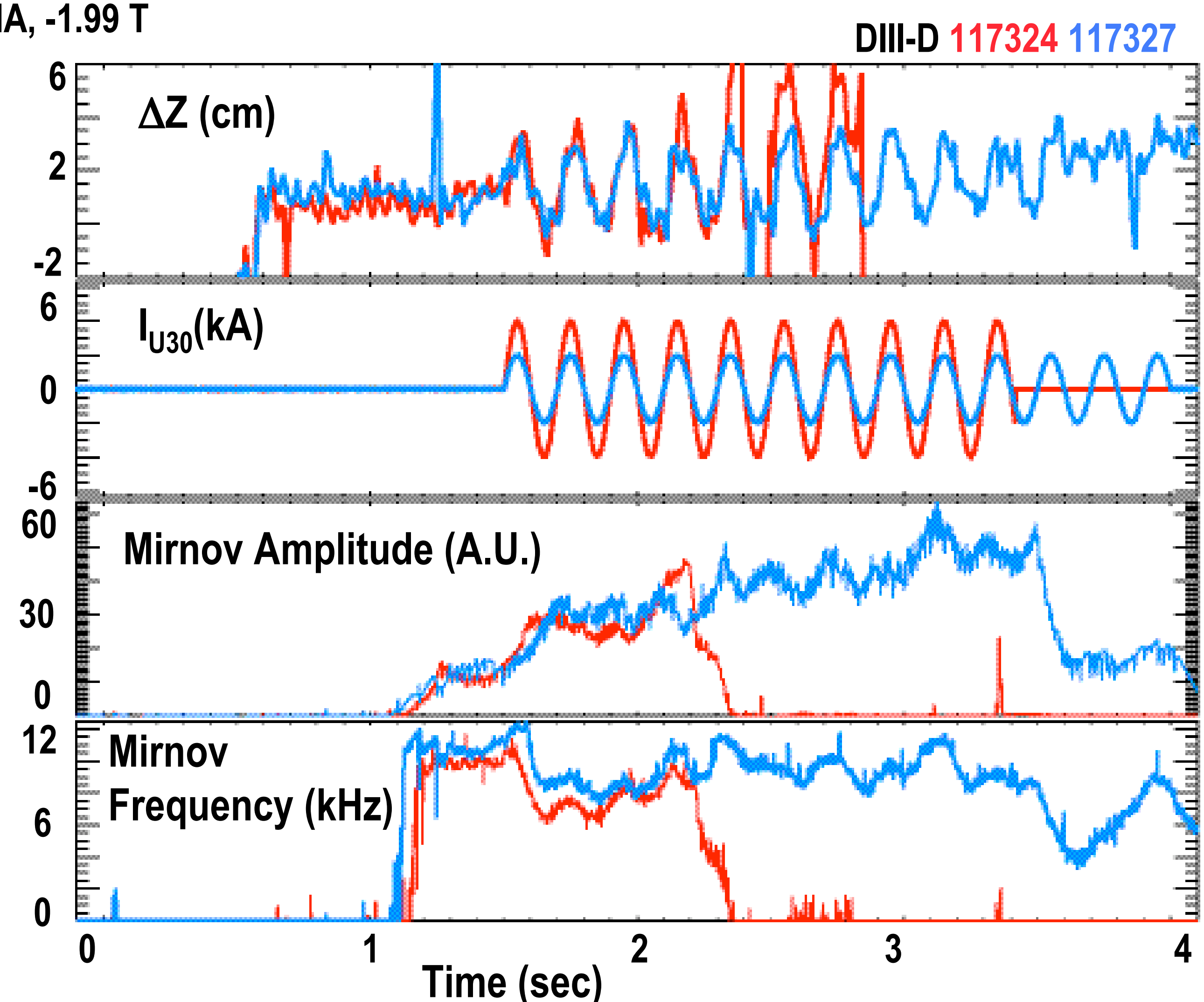
GENERAL ATOMICS

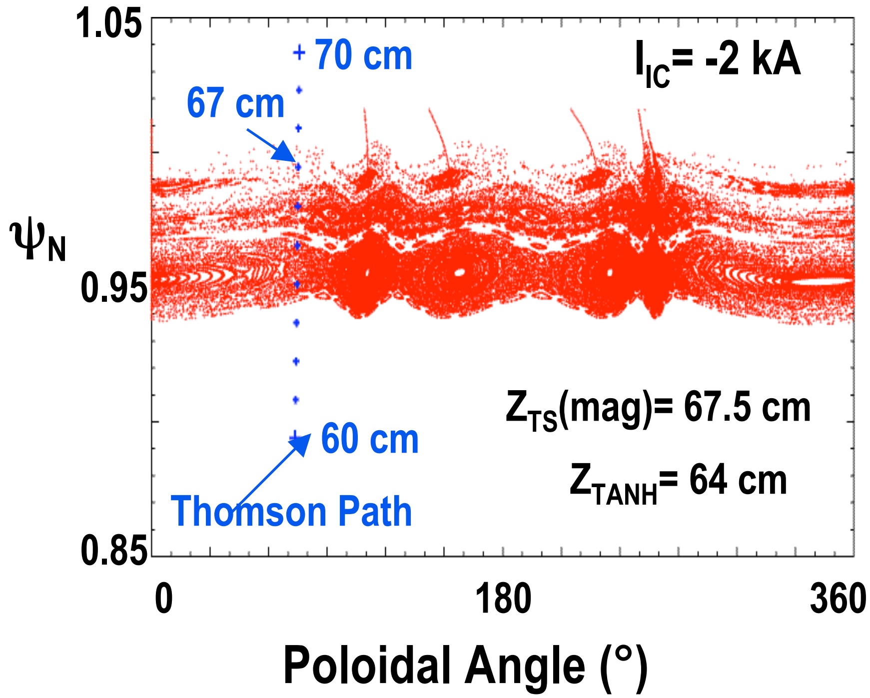
DISCHARGE WITH 0.3% PERTURBATION TERMINATES EARLY DUE TO A LOCKED MODE

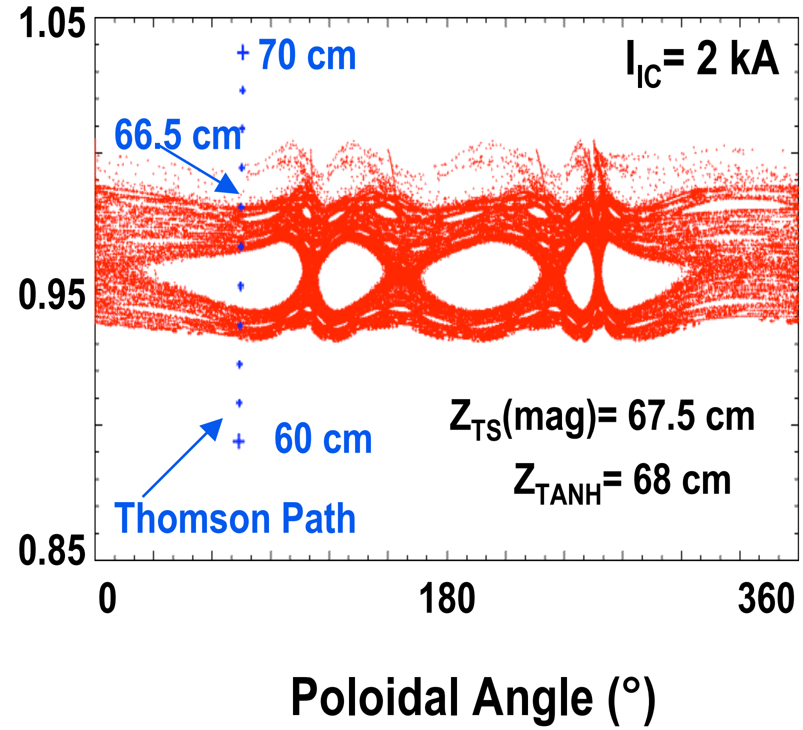
- 1.12 MA, -1.99 T



PERTURBATION FROM I-COIL ALONE CANNOT EXPLAIN THE OBSERVED LARGE ΔZ

- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93
- Plasma response important





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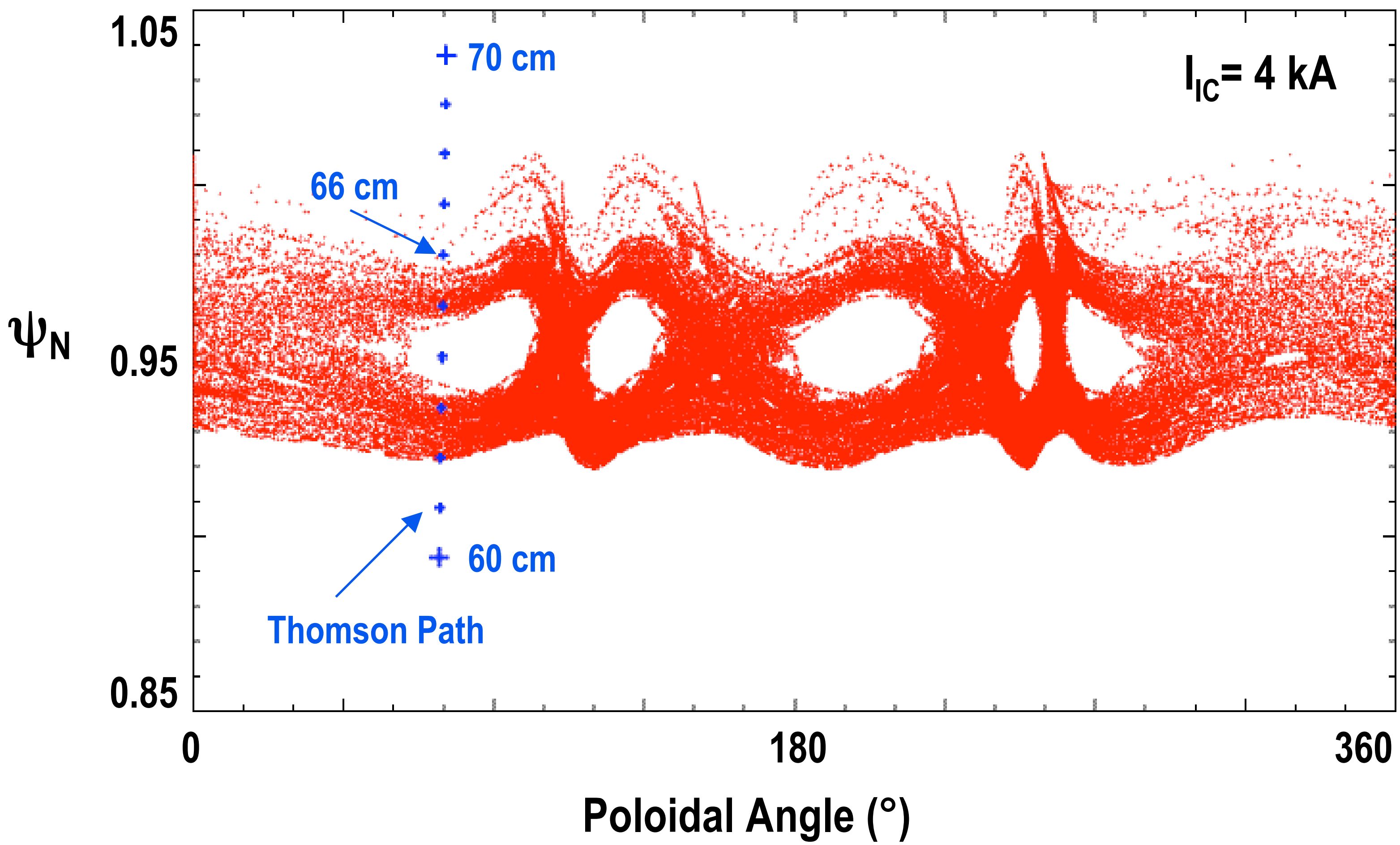
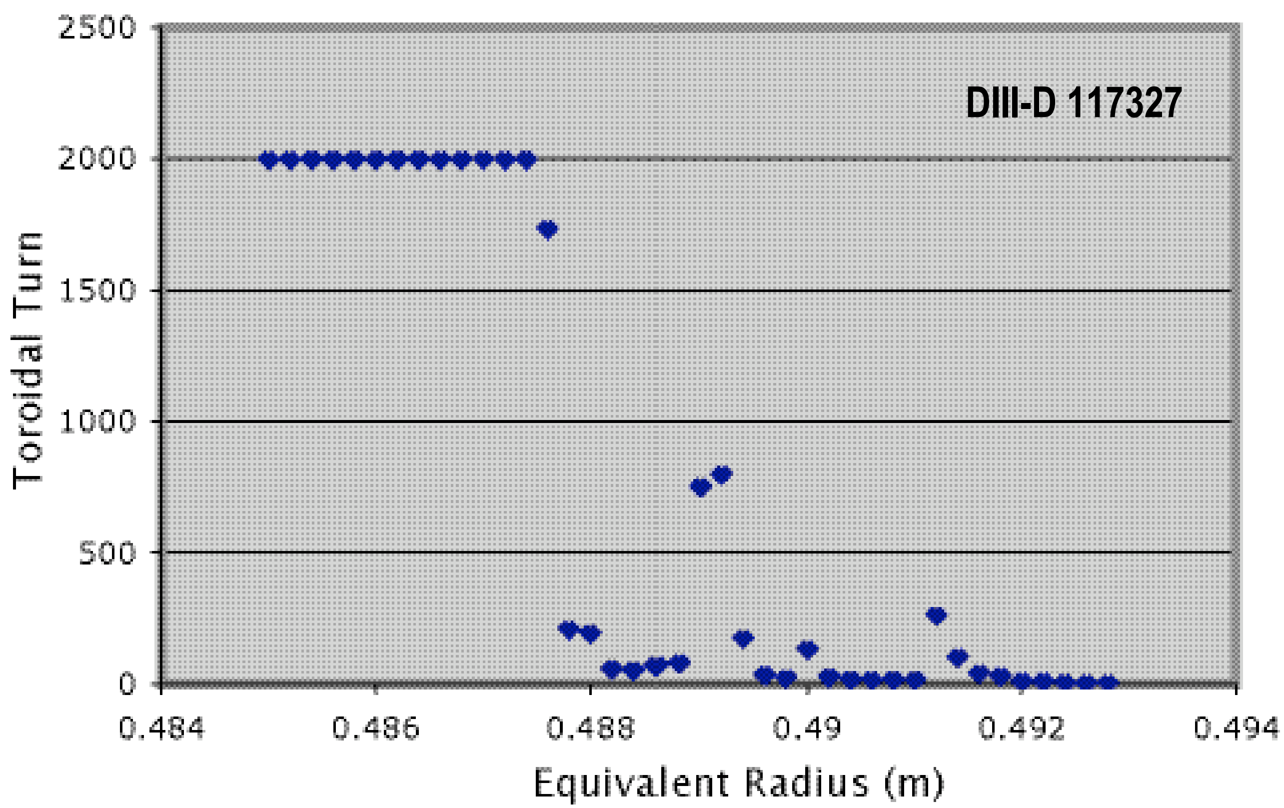


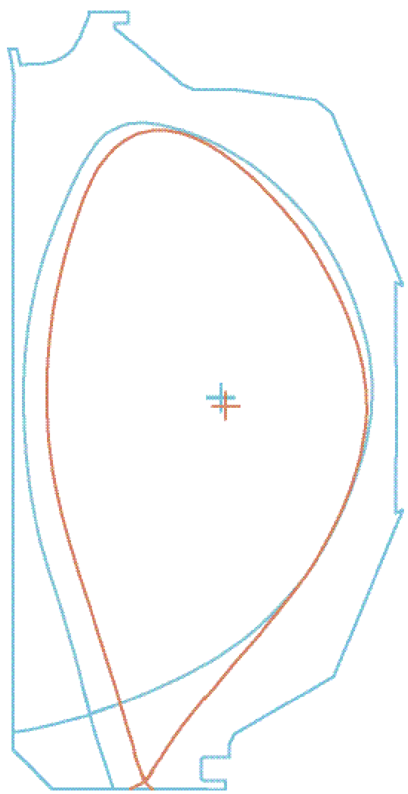
MAGNETIC FIELD LINE LENGTH MAY PROVIDE AN USEFUL MEAN TO CHARACTERIZE PLASMA BOUNDARY

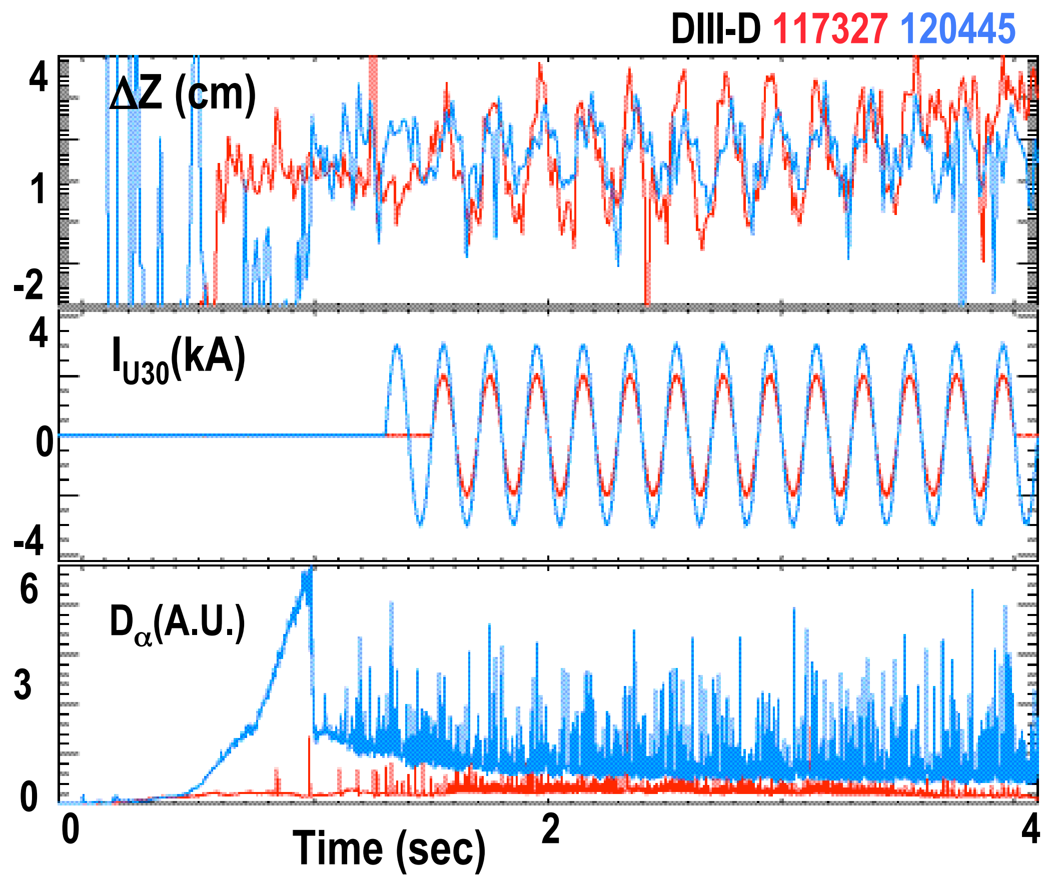
- **1.12 MA, -1.99 T, β_N = 2.00, ℓ_i = 1.00**



ΔZ VARIES WITH PLASMA SHAPE AND UPPER AND LOWER I-COIL PHASING

- 1.12 MA, -1.99 T





SUMMARY

- Experimental results are consistent with the conjecture that the observed separatrix location differences between magnetic and Thomson T_e measurements in some DIII-D discharges are due to the small toroidal asymmetry of the external shaping coil locations
- Plasma response important
- Experiments provide a good set of data to develop and benchmark plasma response model and 3D reconstruction tools