EFFECTS OF 3D TOROIDALLY ASYMMETRIC MAGNETIC FIELD ON MAGNETIC SURFACES

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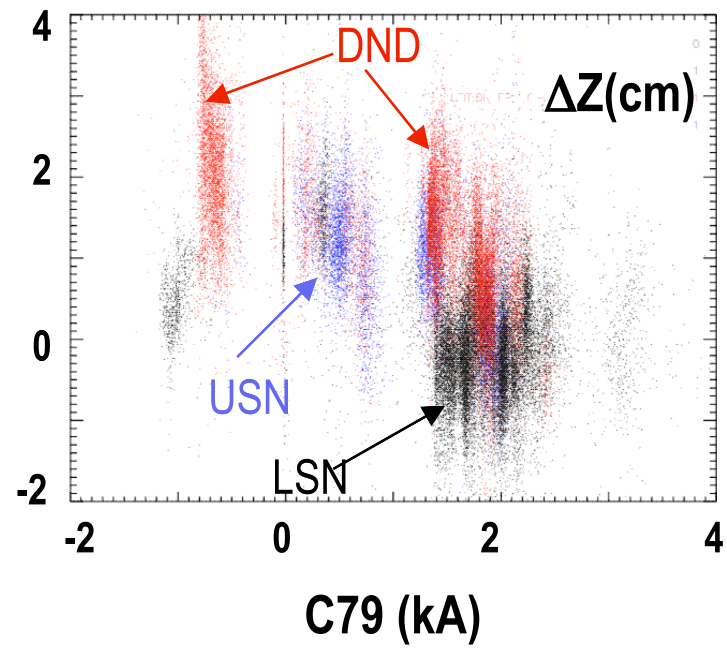
DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

BACKGROUND

- **Accurate determination of edge separatrix location crucial for interpretation of H-mode pedestal data**
  - Pedestal widths very narrow
- **1-4 cm vertical separatrix difference between magnetics and Thomson T_e seen in some DIII-D discharges**
  - Correlate with C-coil error field correction current
  - Modeling indicates plasma response important
- **Need systematic data to guide development of plasma response model and resolve difference**
  - I-Coil perturbation experiments

$\Delta Z = Z_{JT}$ (magnetics) - Z_{TS} (Thomson)



I-COIL MAGNETIC SURFACE PERTURBATION EXPERIMENT

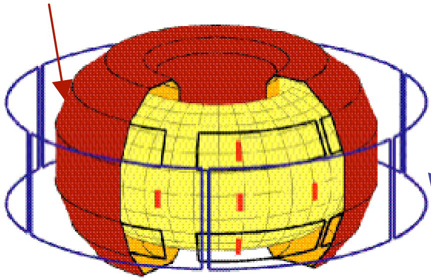
- **Apply slowly rotating *n* = 1 traveling waves at 5 Hz and various amplitudes (0.1 - 0.3% poloidal equilibrium field) using I-coil to perturb the edge magnetic surfaces**

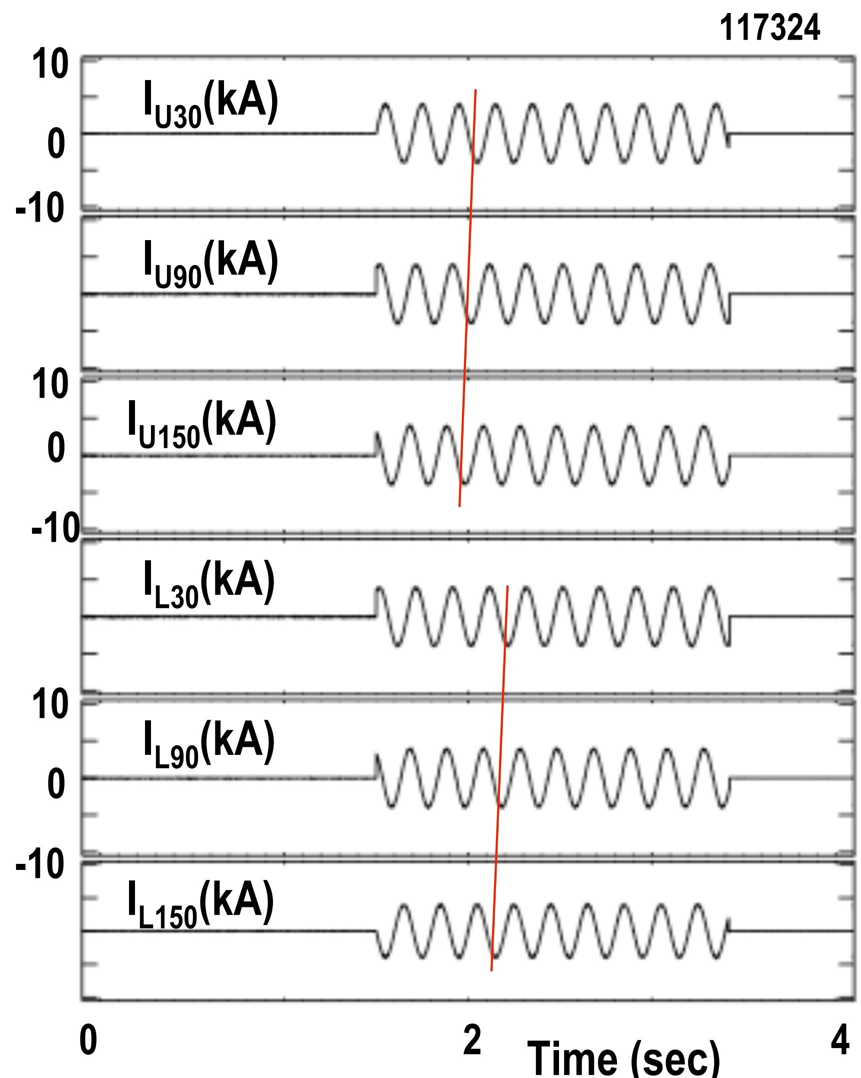
$$IU030 - IU210 = I_0 \cos\left(\frac{2\pi\Delta t}{\tau}\right)$$

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

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

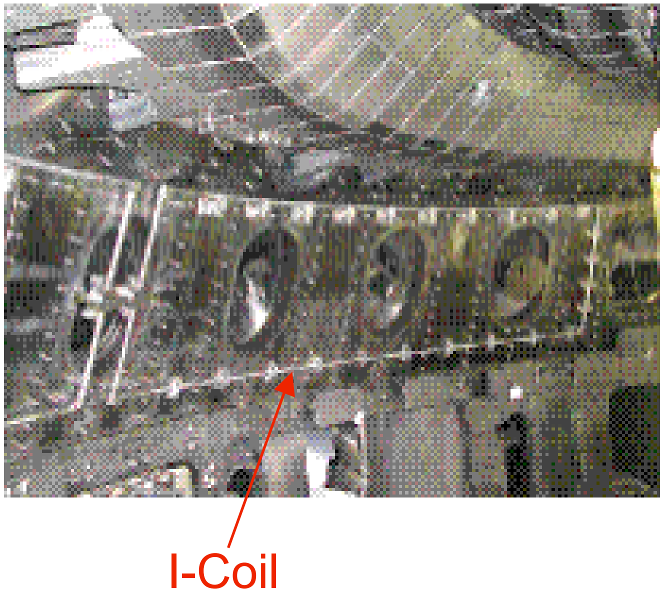
- **Document effects on Thomson separatrix location**





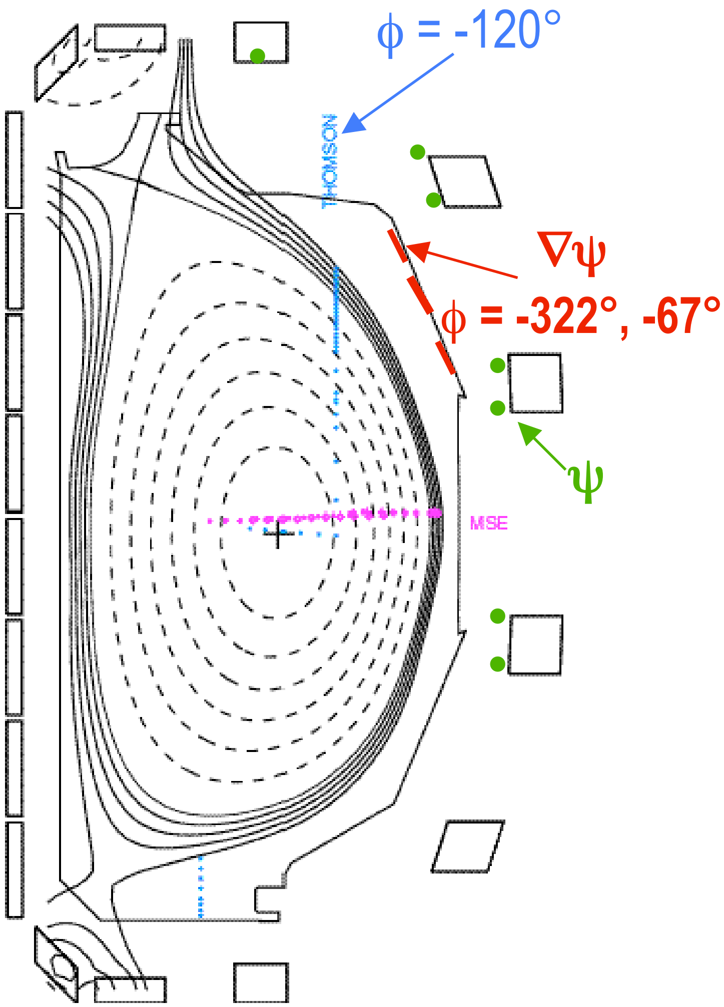
OUTLINE / SUMMARY

- **At 0.15% perturbation, amplitude of separatrix location difference between magnetic reconstructions and Thomson T_e responds with fixed amplitude ΔZ ~ 2 cm**
- **At 0.30% perturbation, amplitude of the separatrix difference grows in time leading to early discharge termination due to locked mode**
- **Magnetics, Thomson, ECE, and SXR indicate a "balloon"-like response**
- **Analyses confirm plasma contribution to response important**
  - With I-coil perturbation only ΔZ ~ 0.5 cm



SEPARATRIX LOCATION DETERMINED MAGNETICALLY BY EXTRAPOLATING MAGNETIC MEASUREMENTS INWARD

- **EFIT extrapolates magnetic measurements inward assumed 2-D equilibrium**
  - 41 flux loops: ψ, 73 magnetic probes: $\nabla\psi$
  - Equilibrium relates 2nd derivatives to ψ and $\nabla\psi$
  - More accurately determined if separatrix closer to magnetic loops
- **Magnetic probes at ϕ = -322°, some at -67°**
  - Separatrix location largely represents magnetic topology at ϕ = -322°
- **Thomson measurements at ϕ = -120°**

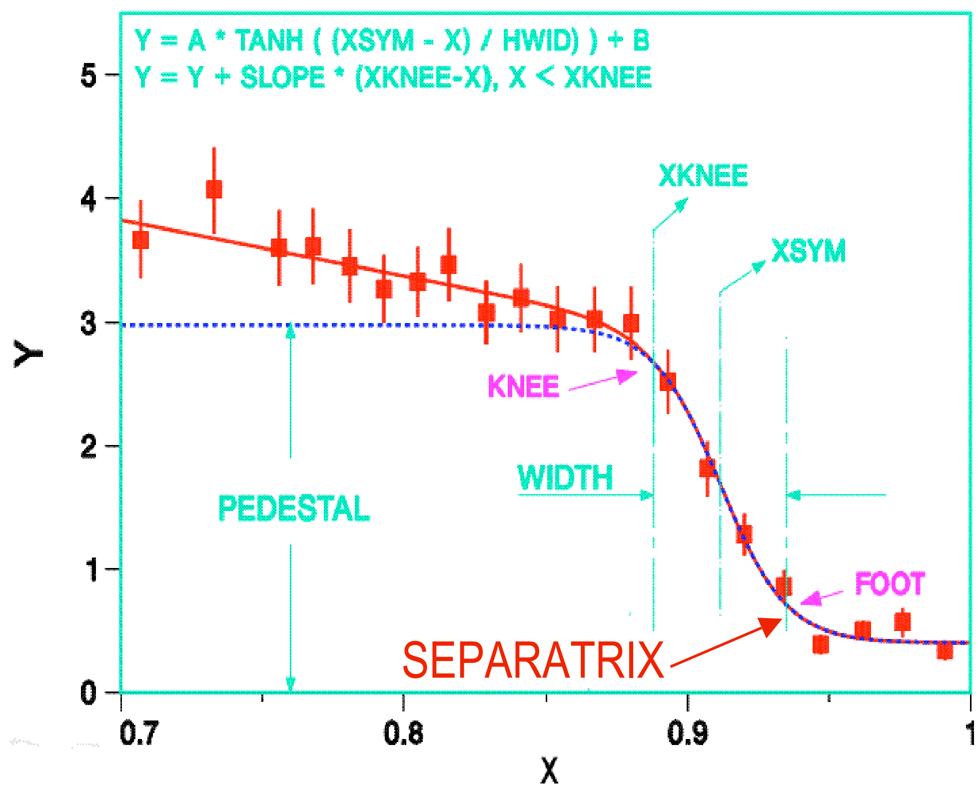


SEPARATRIX LOCATION CAN ALSO BE INFERRED FROM THOMSON T_e PROFILE

- H-mode discharges only
- 3 parameters (amplitude, radius, width) TANH fit to T_e

  $Z_{TS} = Z_{SYM} + 0.5\ \Delta Z_{WIDTH}$
- Previous analyses indicate some consistency with UEDGE divertor heat flux solution
- Thomson located at $\phi = -120°$

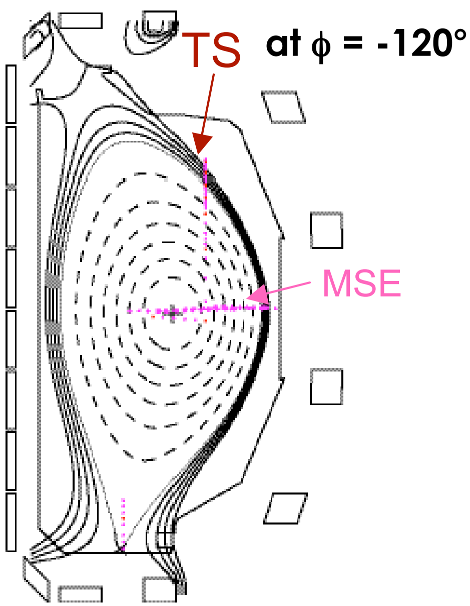
TANH Fit to Thomson T_e



Porter, Phys. Plasmas **5,** 1410 (1998)

ΔZ RESPONDS WITH FIXED AMPLITUDE ~ 2 cm AT 0.15% I-COIL PERTURBATION

- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93, Z_{TS}= 67.5 cm
- Slowly rotating *n* =1 traveling wave at 5 Hz
- $\Delta Z = Z_{JT}$ (magnetics) - Z_{TS} (Thomson)



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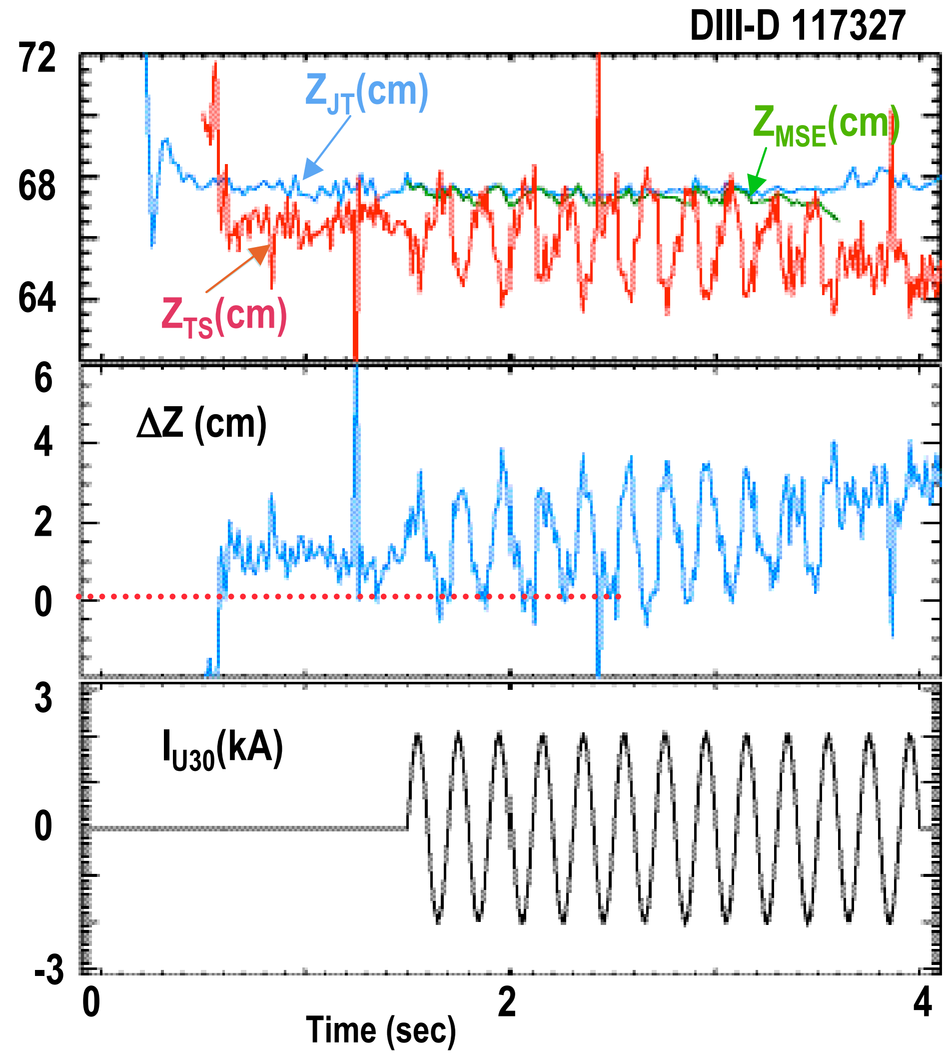

EDGE ELECTRON PROFILES ARE MODULATED BY I-COIL PERTURBATION

- 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

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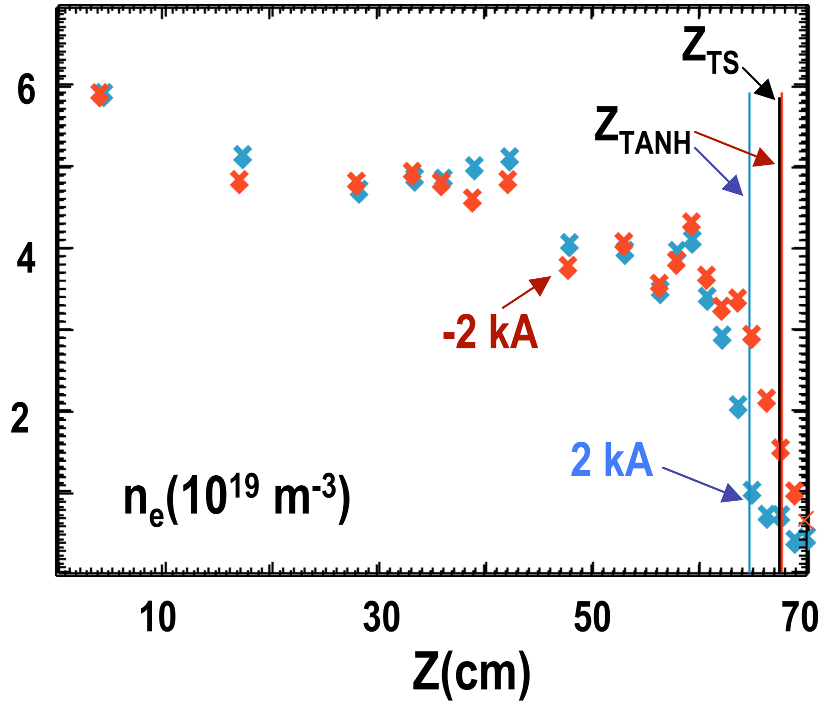
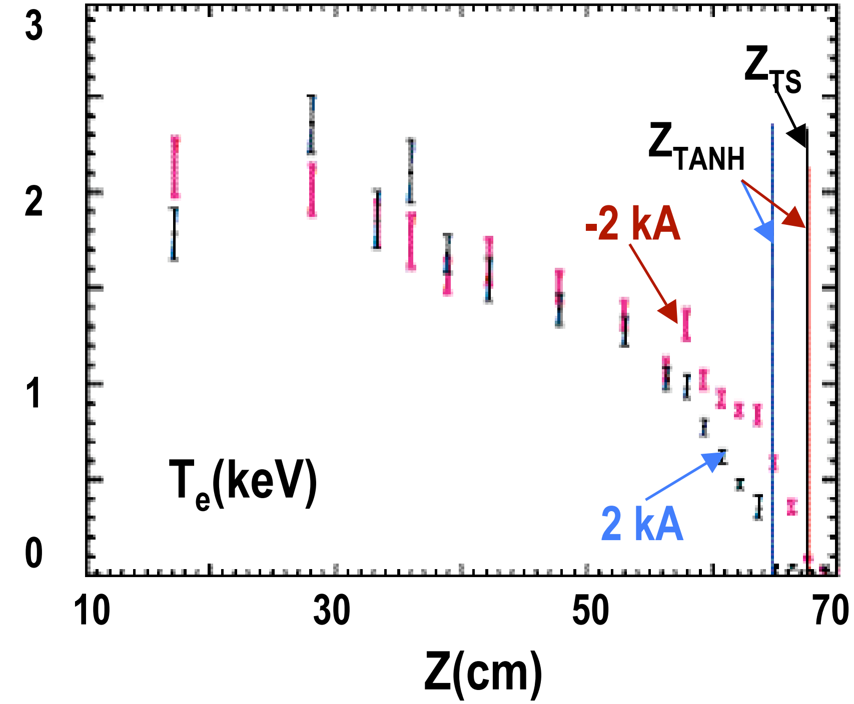
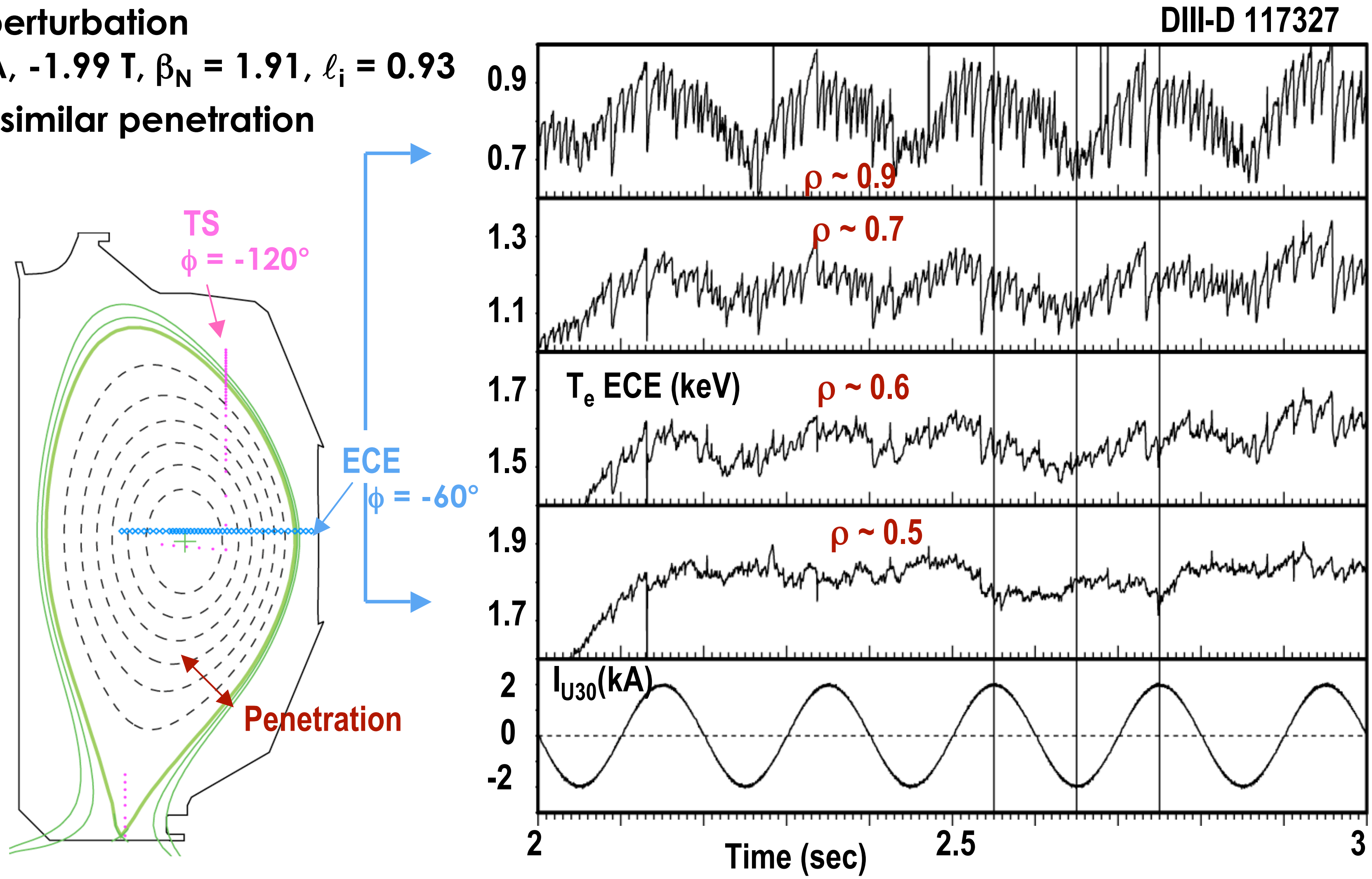




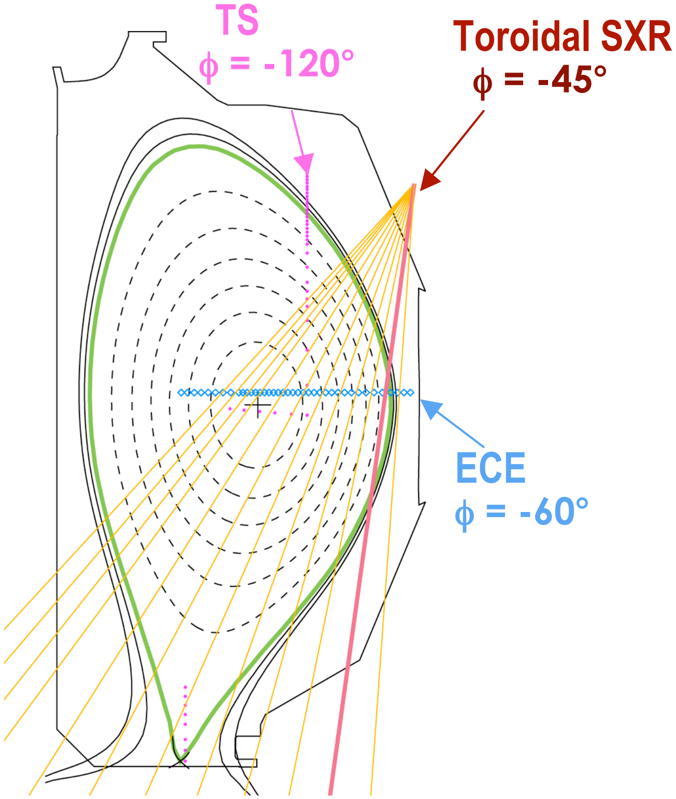
I-COIL PERTURBATION PENETRATES WELL INTO PLASMA OUTER REGION

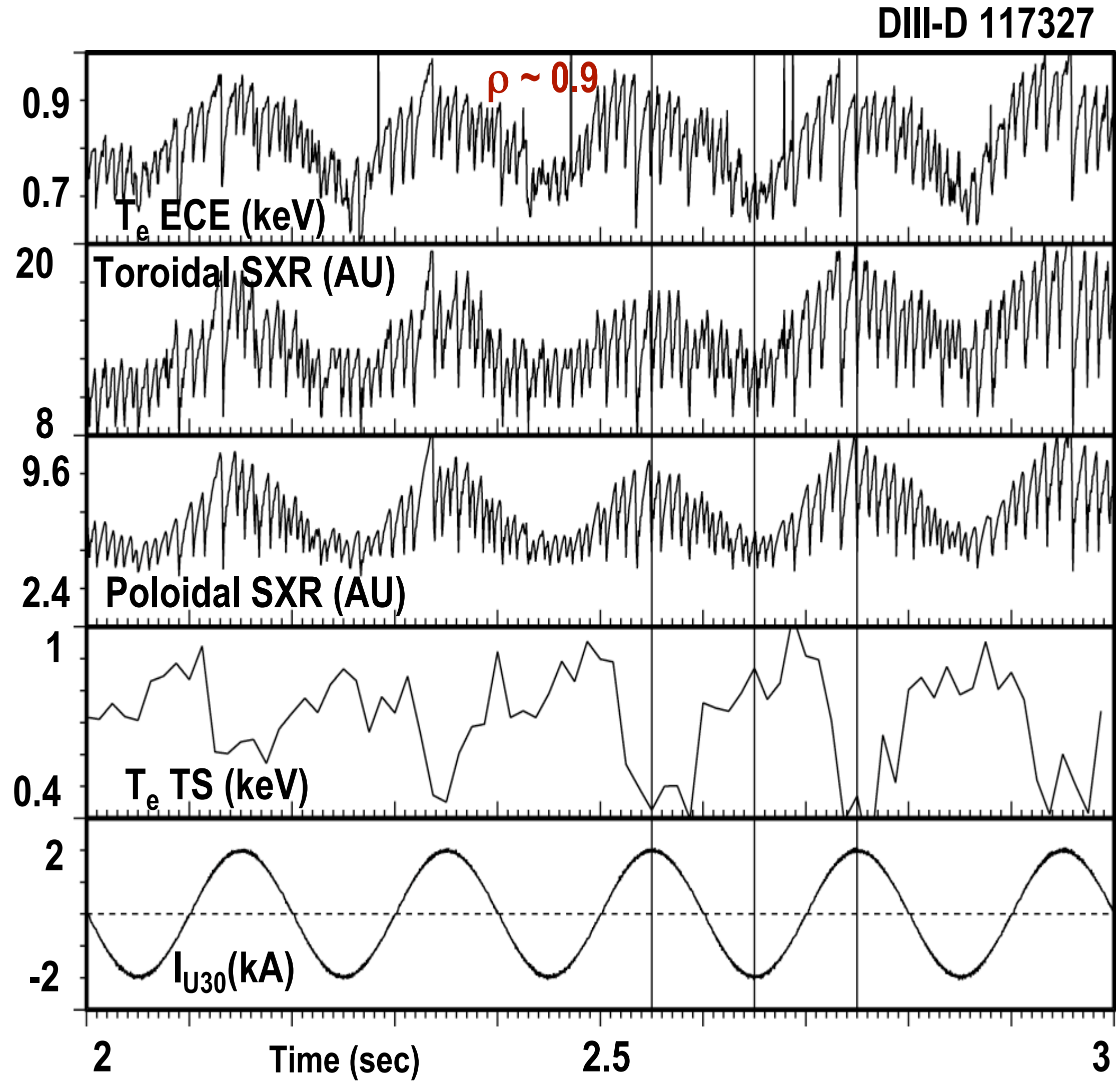
- 0.15% perturbation
- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93
- TS sees similar penetration



ECE, SXR, AND THOMSON DATA INDICATE A "BALLOON"-LIKE RESPONSE

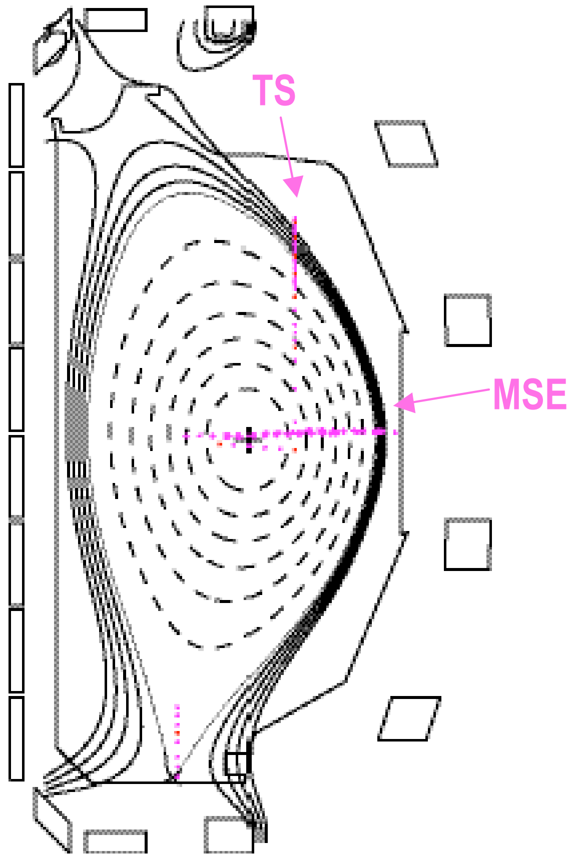
- 0.15% perturbation
- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93
- TS out of phase with ECE, SXR
- Magnetics *n* = 1

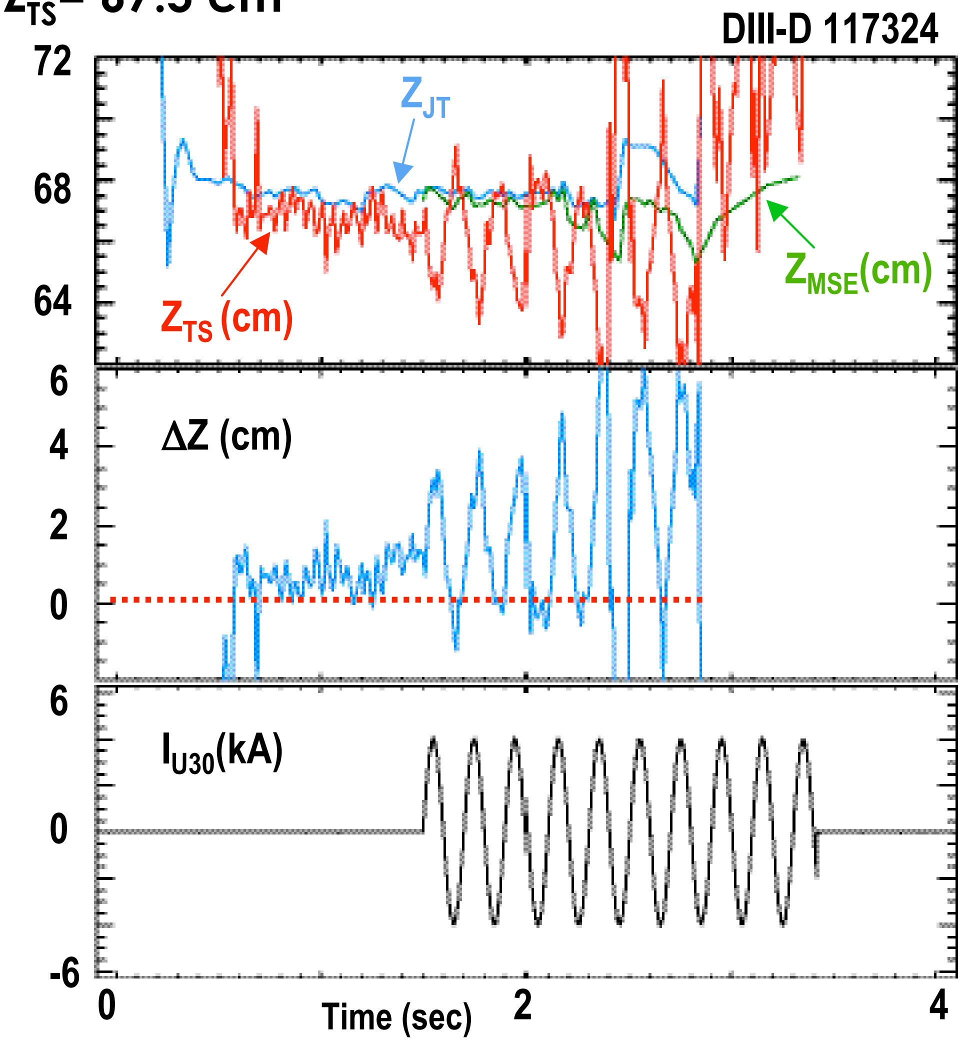




AT 0.3% PERTURBATION ΔZ GROWS IN TIME AND DISCHARGE TERMINATES EARLY

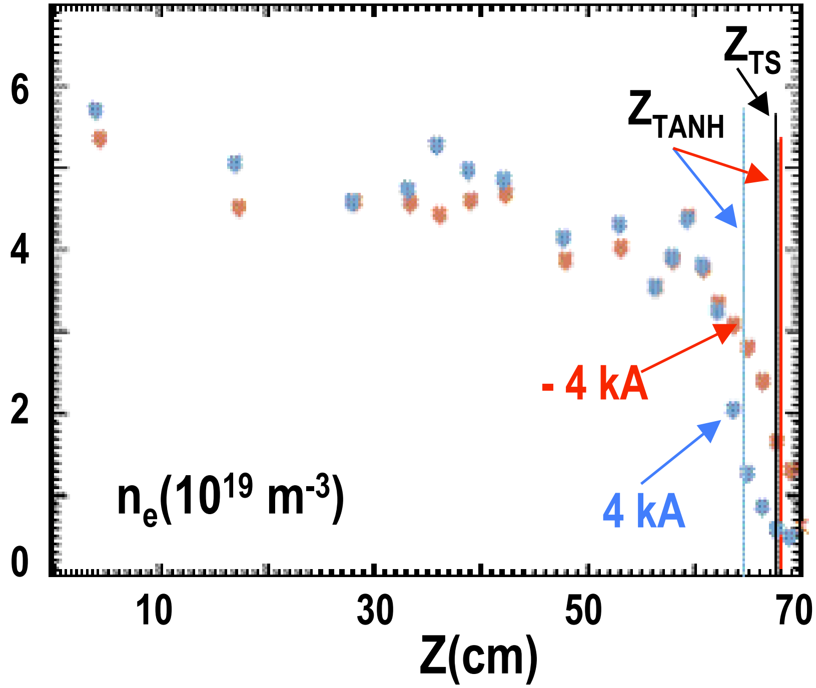
- 1.12 MA, -1.99 T, β_N = 2.00, ℓ_i = 1.00, Z_{TS}= 67.5 cm

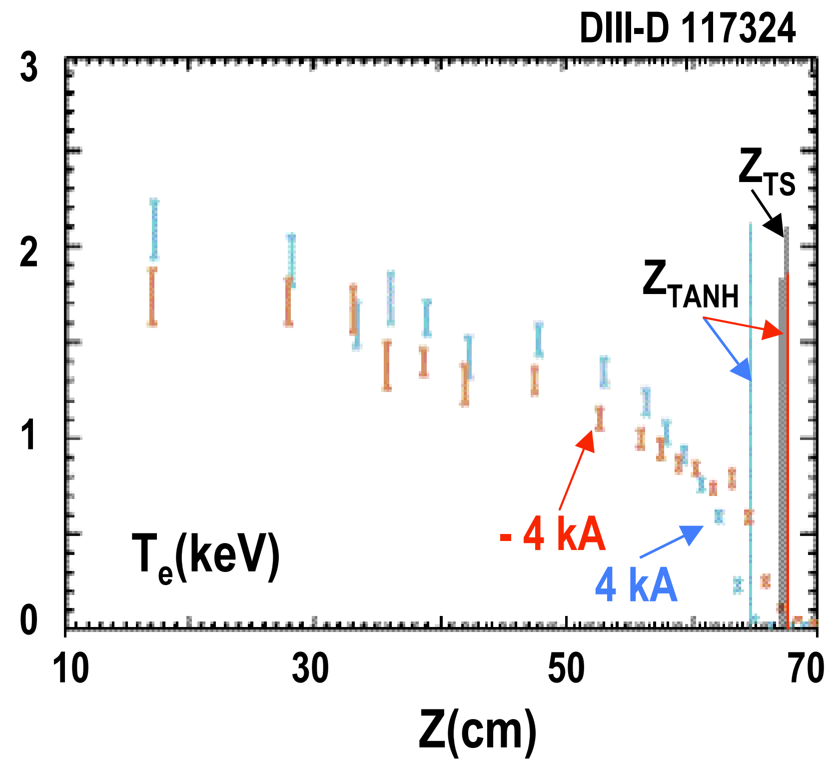




PERTURBATION PENETRATES DEEPER INTO PLASMA CORE AT HIGHER I-COIL CURRENT

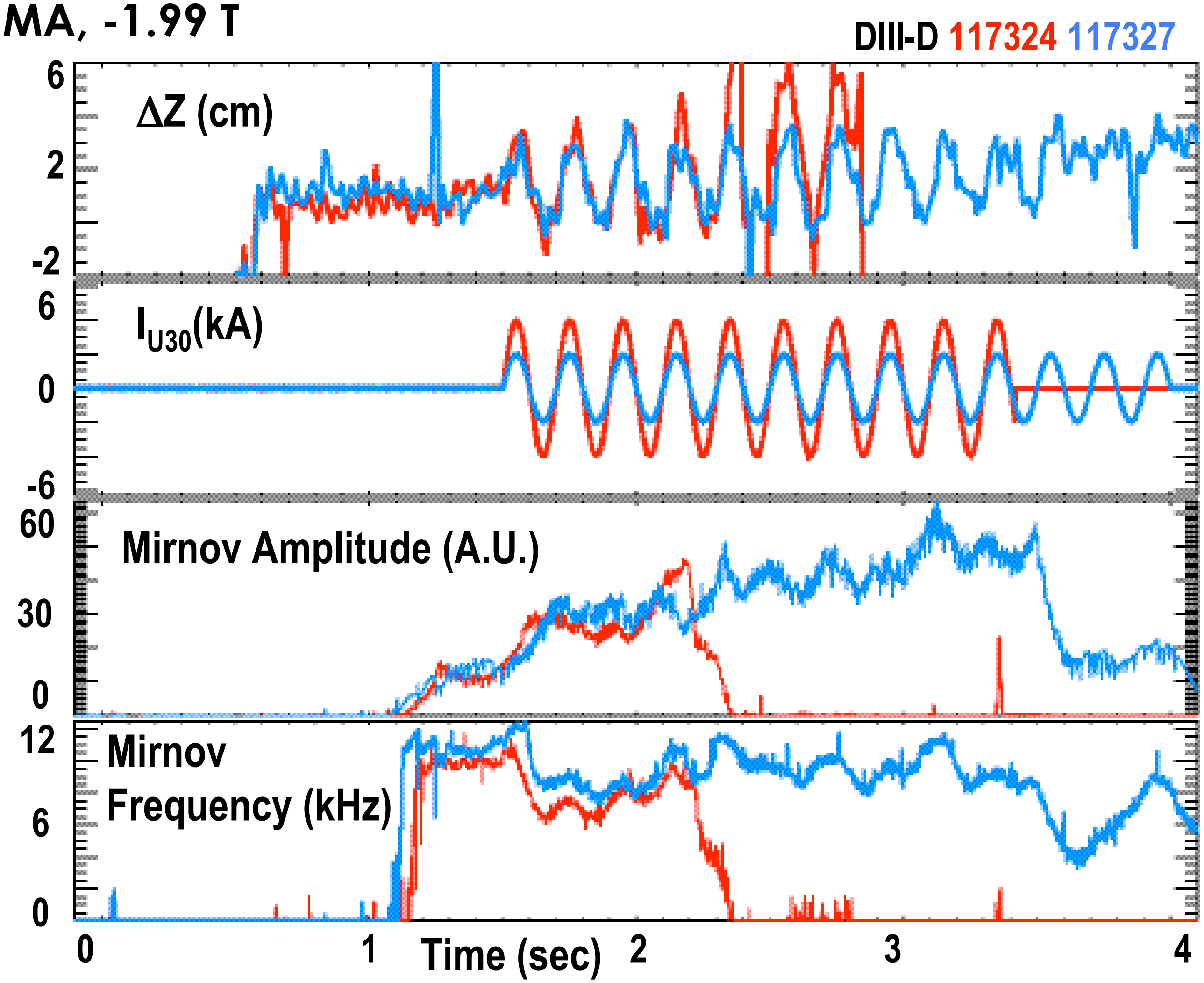
- **0.3% perturbation, 1.12 MA, -1.99 T, β_N = 2.00, ℓ_i = 1.00**
- **Similar magnetic Z_{TS}= 67.5 cm at both I-coil currents**





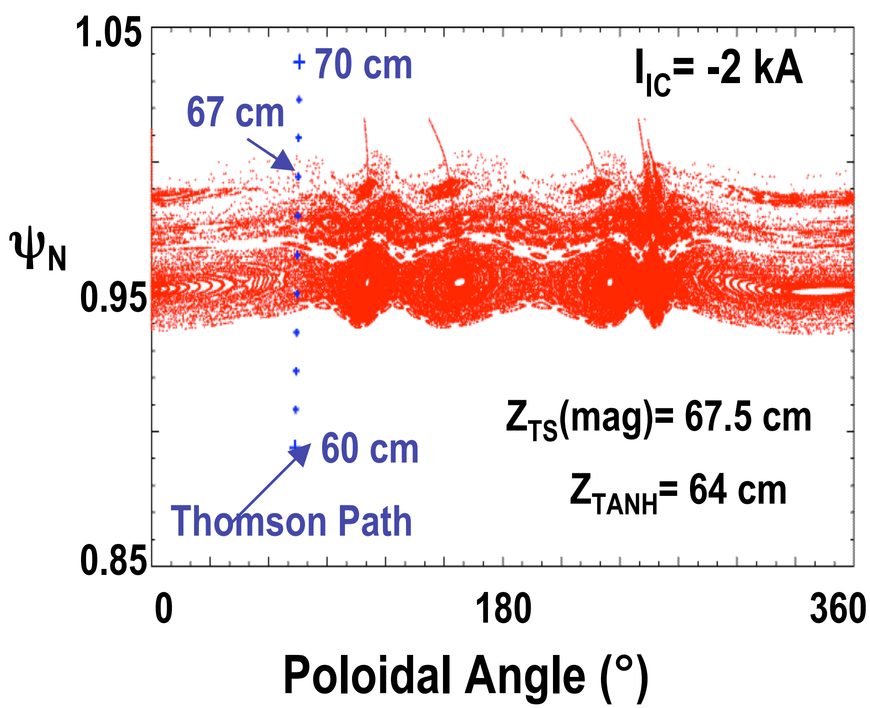
DISCHARGE WITH 0.3% PERTURBATION TERMINATES EARLY DUE TO A LOCKED MODE

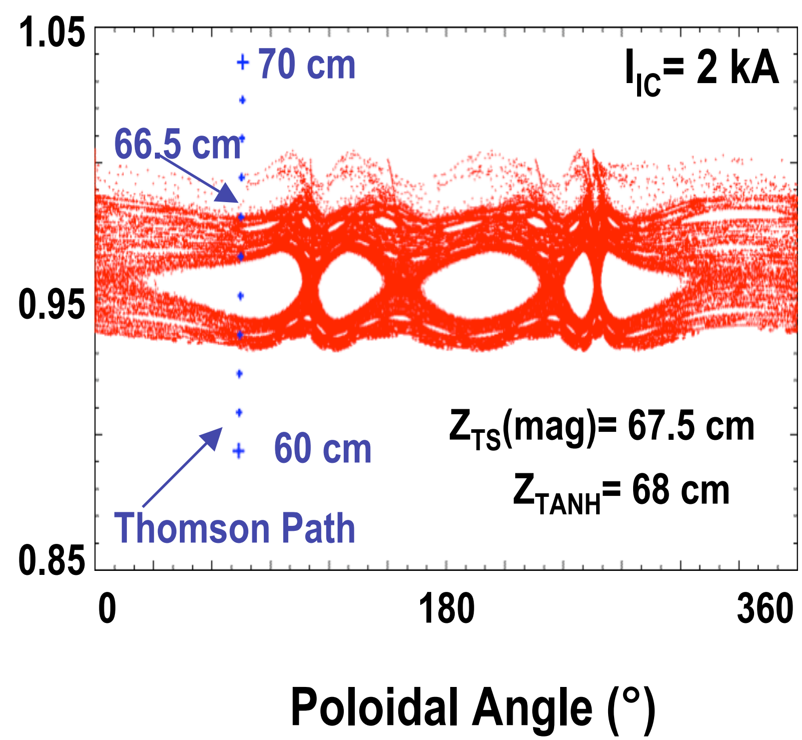
- **1.12 MA, -1.99 T**



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

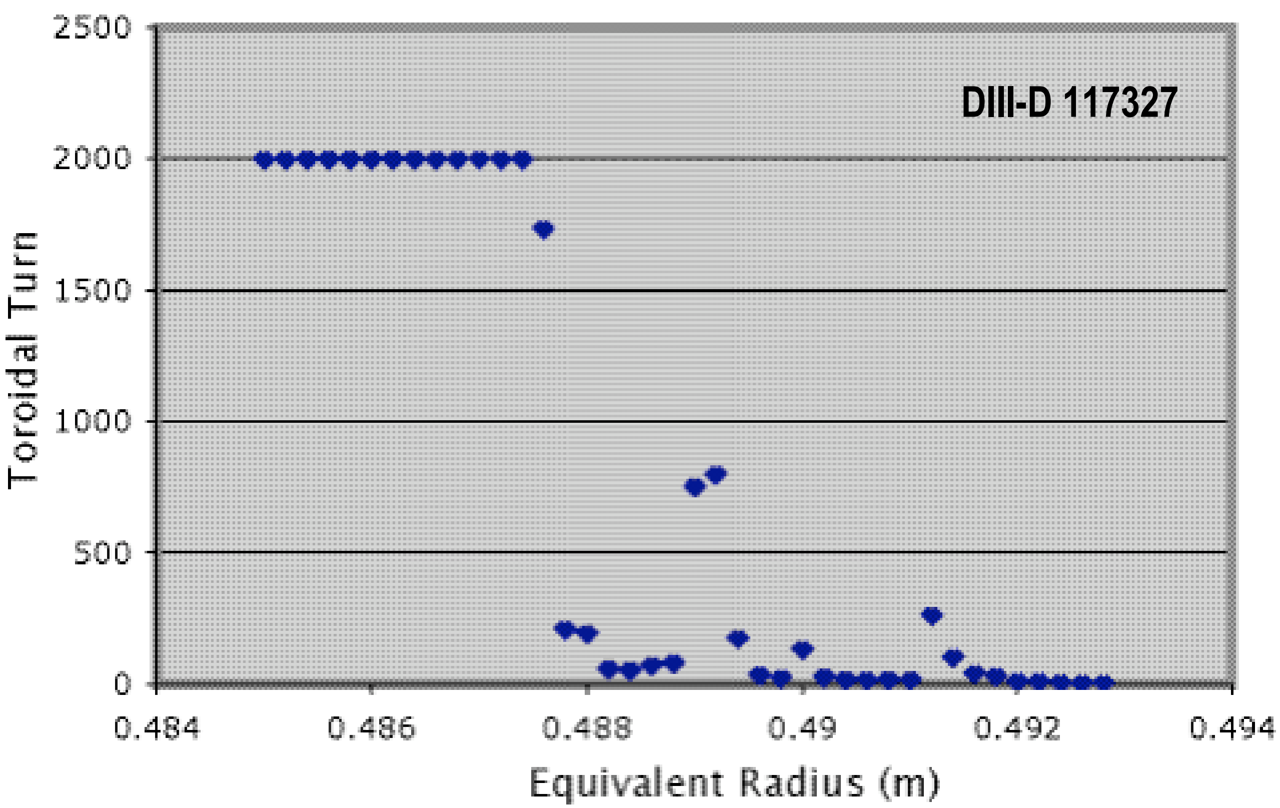
- 1.12 MA, -1.99 T, β_N = 1.91, ℓ_i = 0.93
- Plasma contribution to response important





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**



SUMMARY

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