Test Blanket Module Mockup Experiments in DIII-D

by

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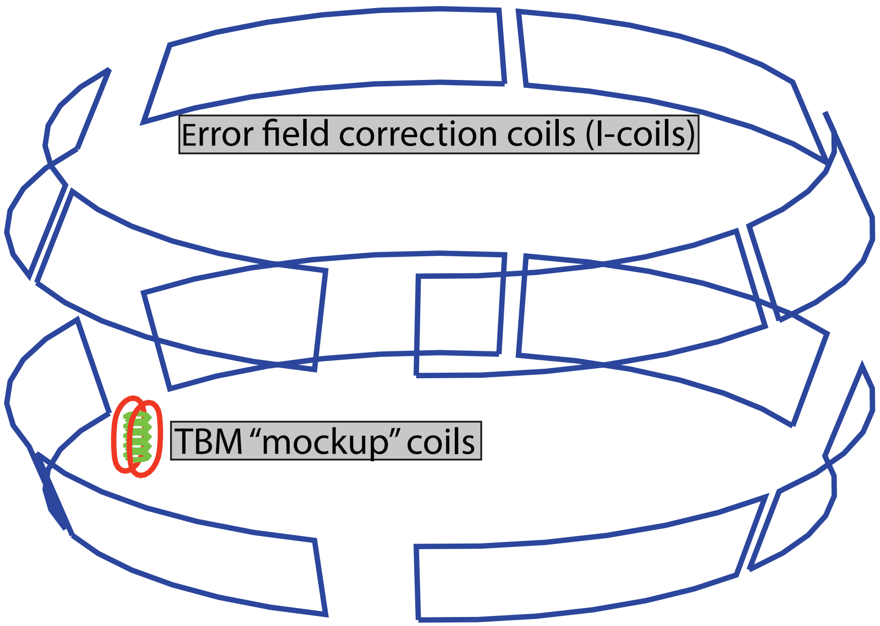

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GENERAL ATOMICS

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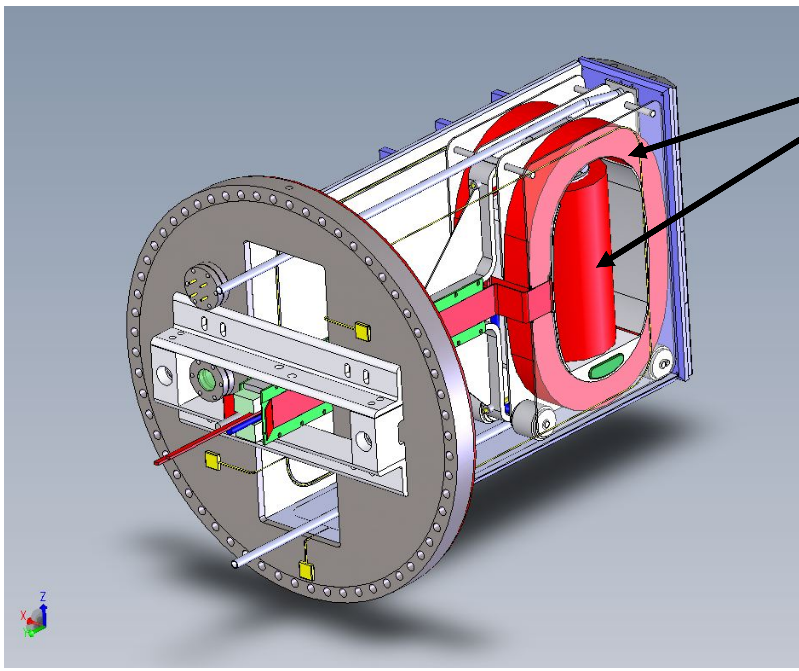
How Will the Magnetization of the Test Blanket Modules Affect ITER's Performance?

- **DIII-D experiments test the effects of a localized error field on energy confinement, fast ion confinement, …**



- **TBM "mockup" coils approximate the magnetization of two ITER TBMs in one ITER port**
- **Matches ITER TBM's far field well**
- **Mockup is capable of ~3x ITER's $\Delta B/B_0$**
  - Approximate the total amplitude of ITER's 3 TBM ports

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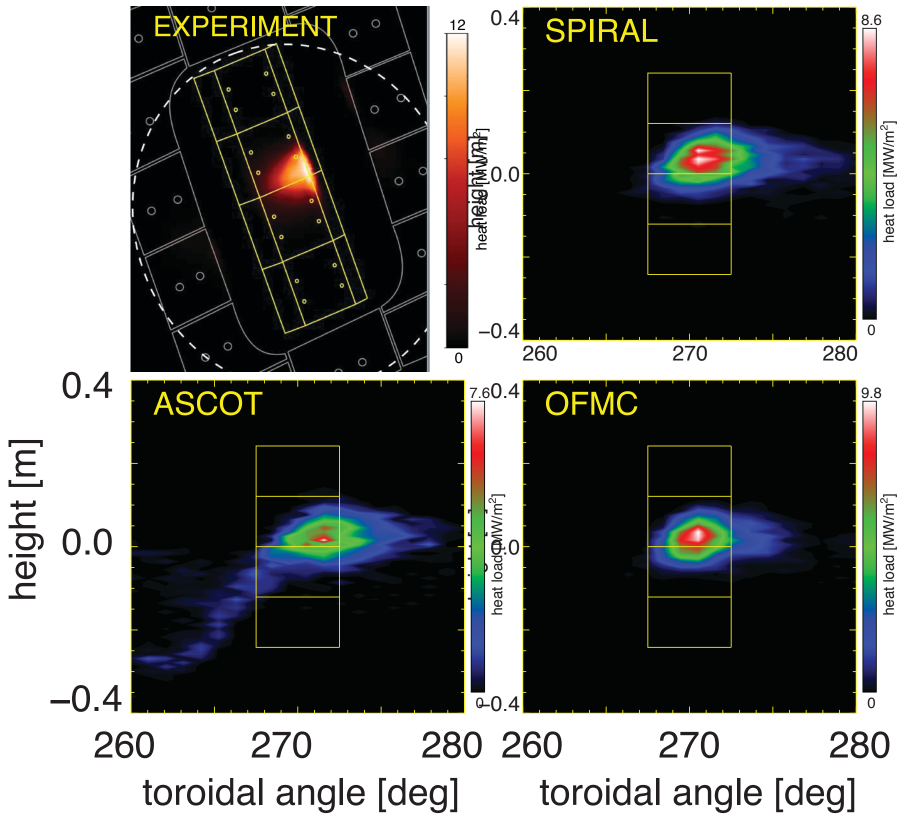
Direct Measurement of Local Heat Loads at the TBM Allows Benchmarking of of Fast Ion Loss Models for ITER

- **Infrared imaging measures fast ion heat loads with:**
  - Co and counter NBI
  - "Parallel" and "perpendicular" NBI

- **Compare to simulations of fast-ion loss caused by 3D fields:**
  - ASCOT & SPIRAL – full gyro-orbit codes
  - OFMC - guiding center code

- **Codes agree well on location of heat deposition and peak heat loads**



G.J. Kramer: APS poster GP8.00097
IAEA 2012 (ITR/P1–32)

New Experiments Test the Correction of TBM Error Field in H-mode Plasma

- **Previous experiments (2009) found that the TBM field reduced**
  - Plasma rotation
  - Energy and particle confinement
  - Error field tolerance in L- and H-mode

- **n=1 correction of TBM error field in Ohmic plasmas successfully restored the locked mode resistance**

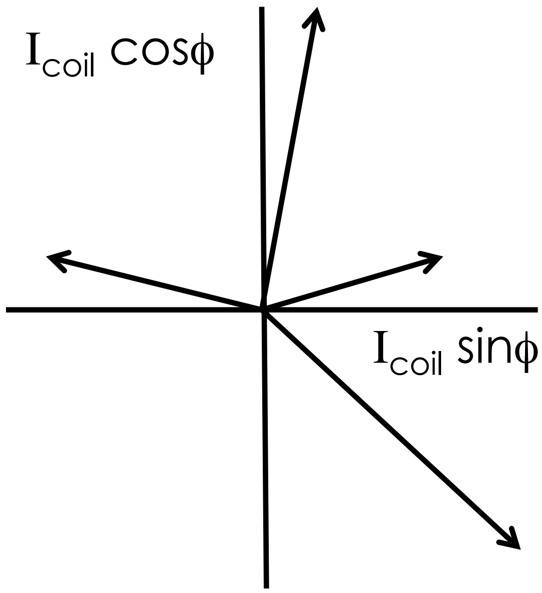
- **2011 experiments:**

  test n=1 correction of the TBM error for H-mode plasmas

H. Reimerdes, IAEA 2012 (EX/P4–09)

Non-disruptive Technique Optimizes Error Field Correction by Maximizing the Plasma Rotation

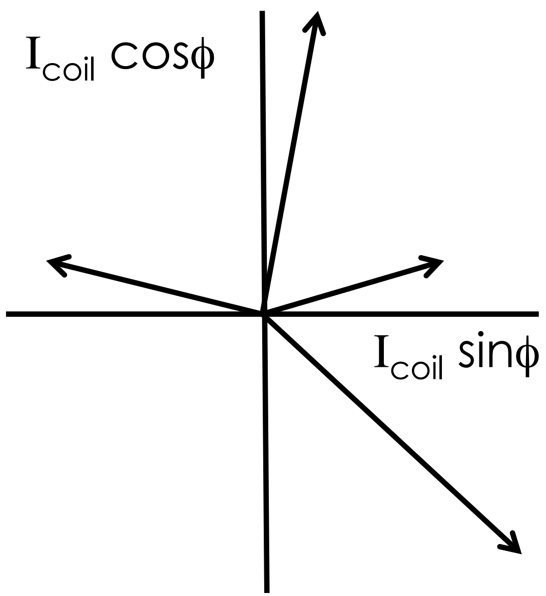
- **Vary correction field n=1 amplitude and phase**



Represent amplitude and toroidal phase of coil currents as vector in the x-y plane

Non-disruptive Technique Optimizes Error Field Correction by Maximizing the Angular Momentum

- **Vary correction field n=1 amplitude and phase**
- **2D parabolic fit → I-coil currents for maximum angular momentum**



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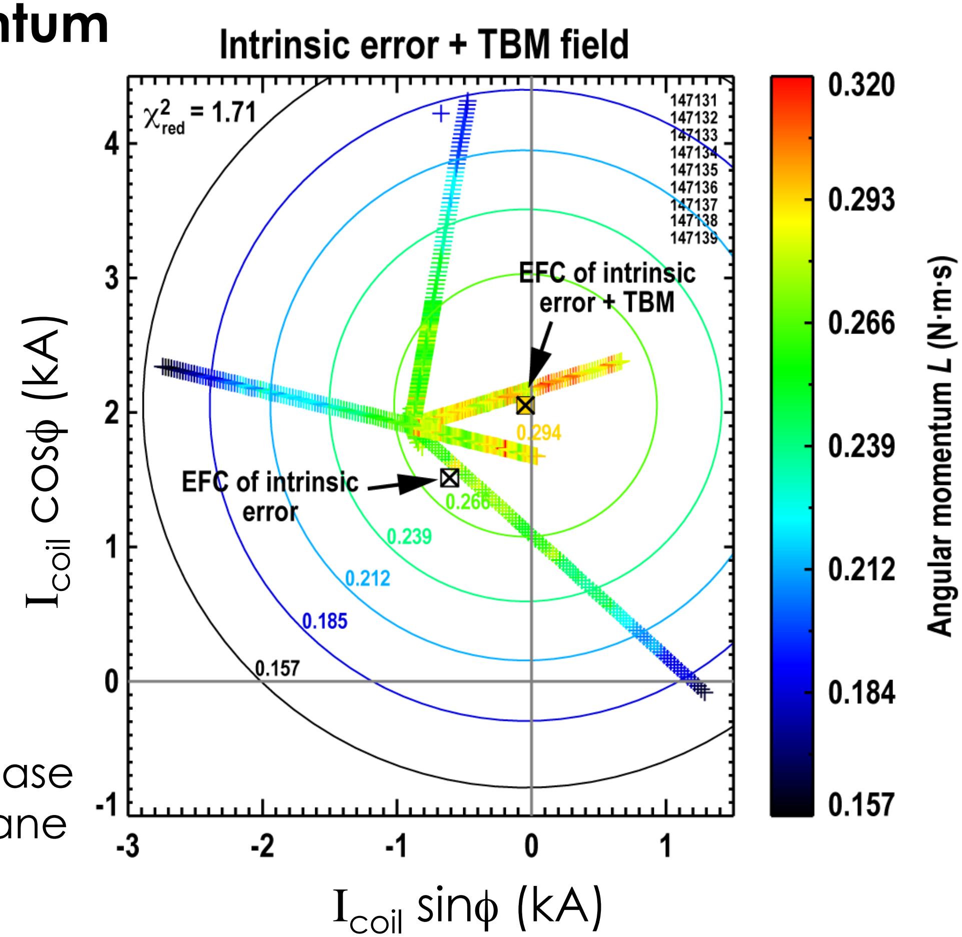

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E.J. Strait/APS-DPP/Oct. 2012
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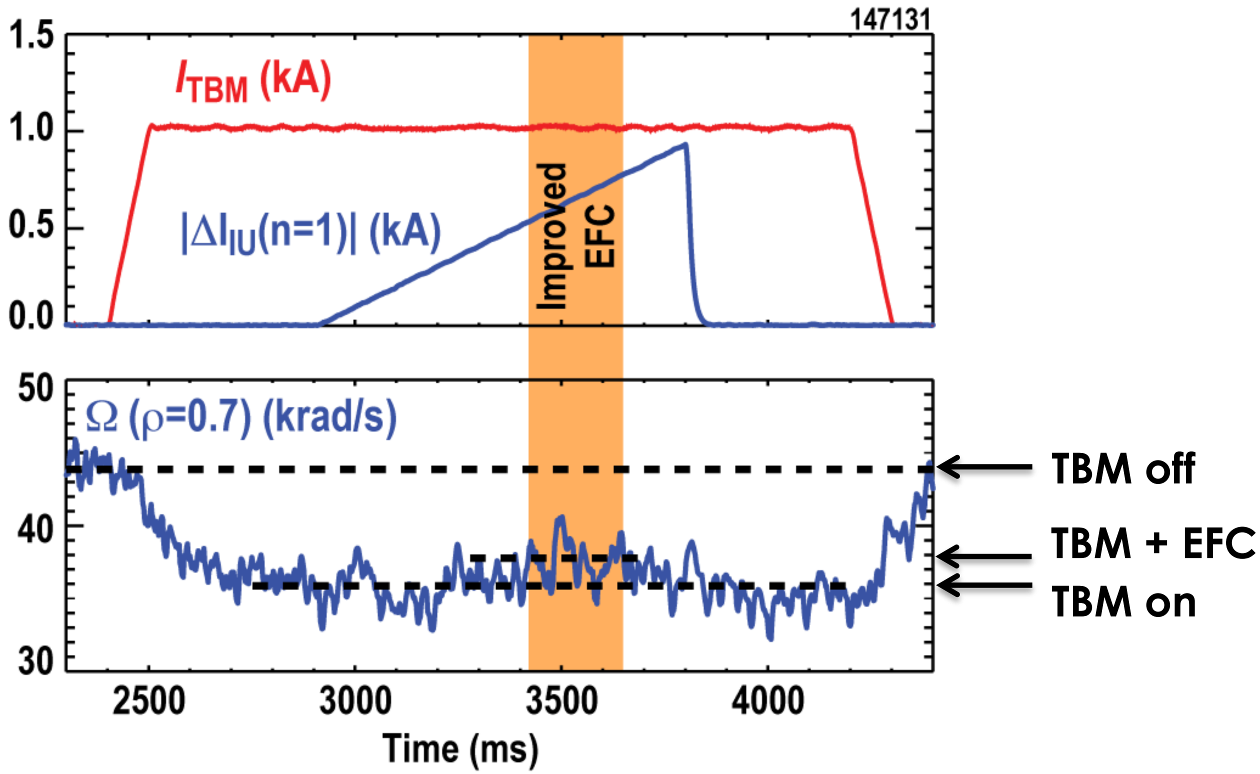
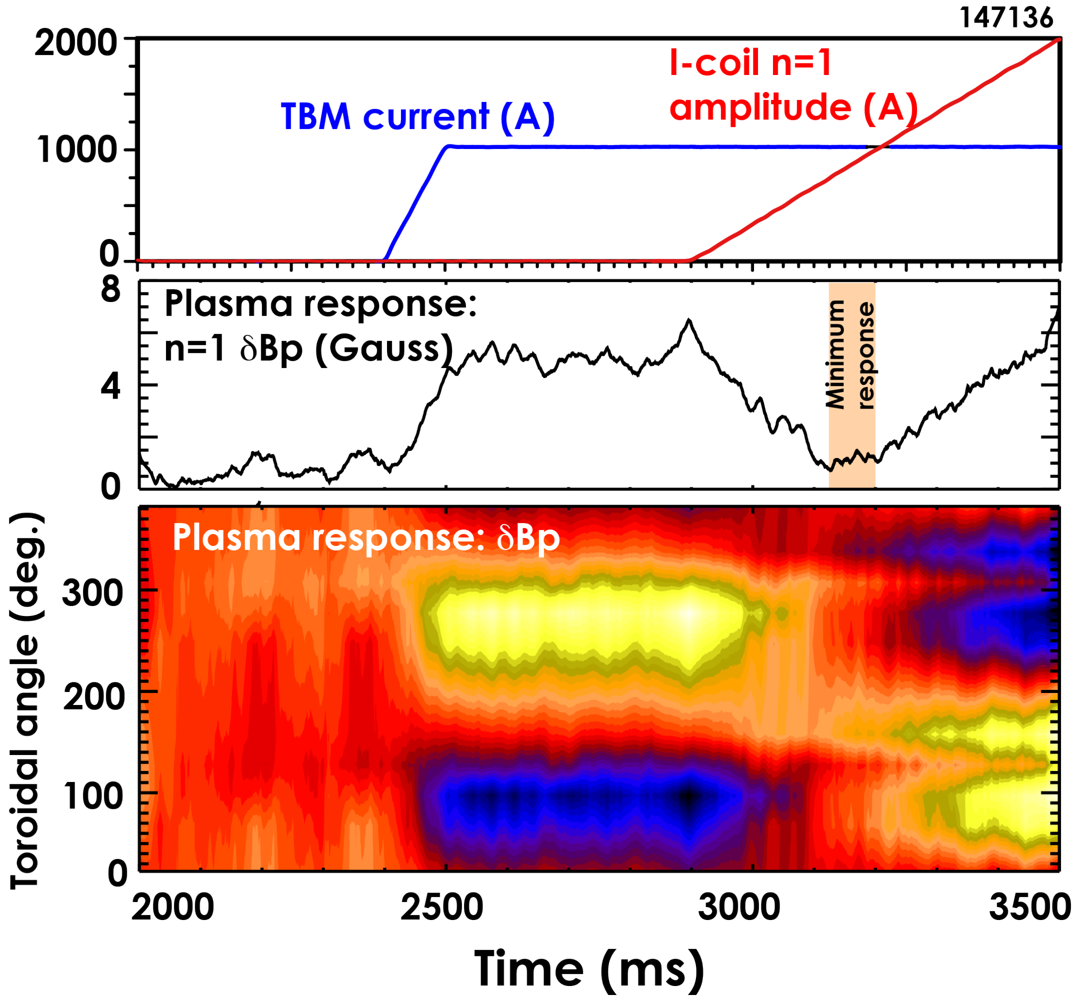
n=1 Error Field Correction Achieves Only Partial Recovery of Momentum Confinement Degradation

- **TBM magnetic field error reduces rotation by ~20%**
  - In rapidly rotating ELMy H-mode
- **n=1 error field correction recovers at best only a small fraction (~¼) of the rotation loss**



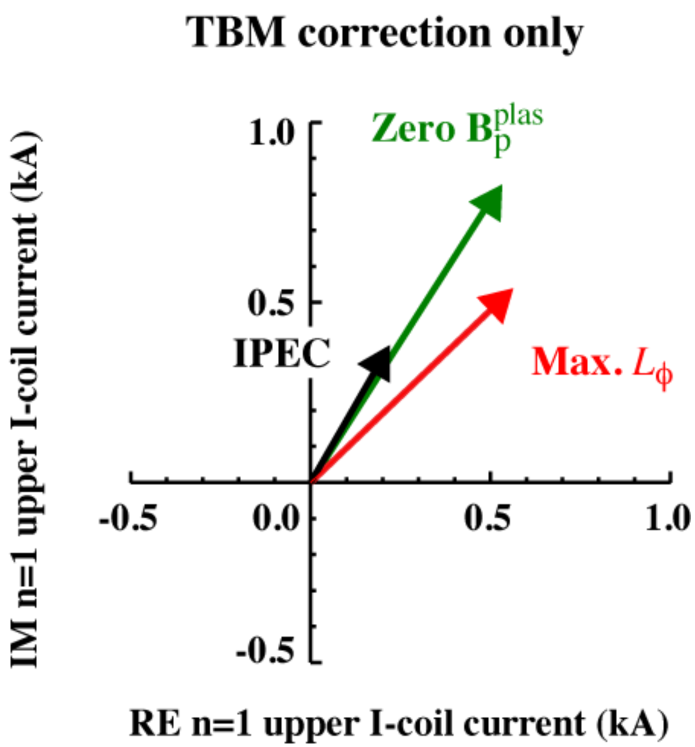
Alternative Strategy: Minimize the n=1 Kink-resonant Response

- **Minimize the n=1 "resonant field amplification"**
  - Vary n=1 correction field phase and amplitude
  - Linear fit → I-coil currents for minimum magnetic response
- **Coil current ramp at optimum phase confirms minimum magnetic response**



Two Methods of Optimizing n=1 Error Field Correction Are in Reasonable Agreement

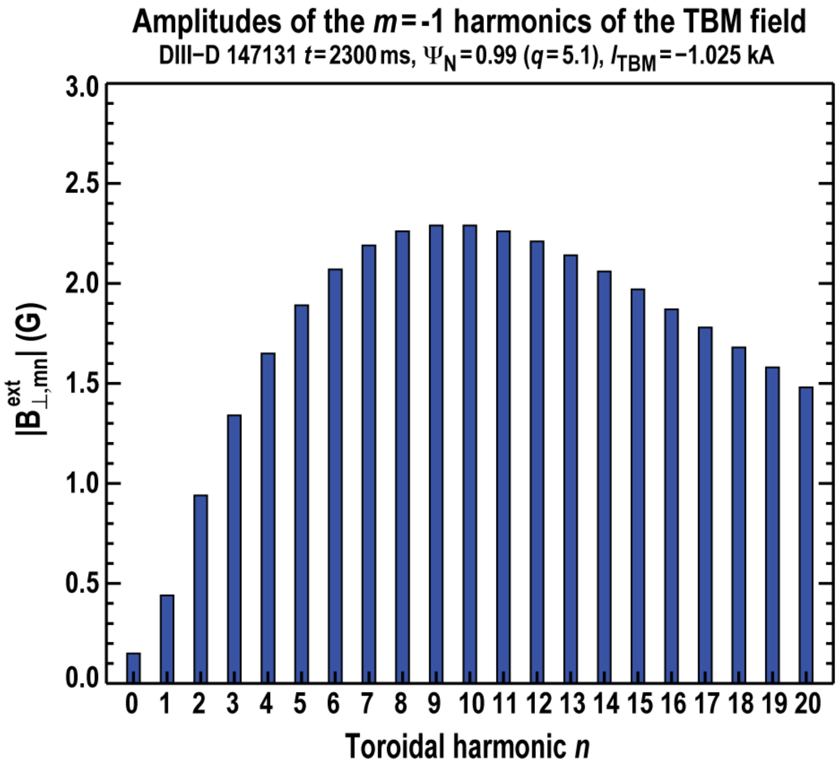
- Minimize the braking of plasma rotation
- Minimize the n=1 magnetic response of the plasma
- IPEC model prediction agrees on the toroidal phase
  - Amplitude is within a factor ~2 of experimental values



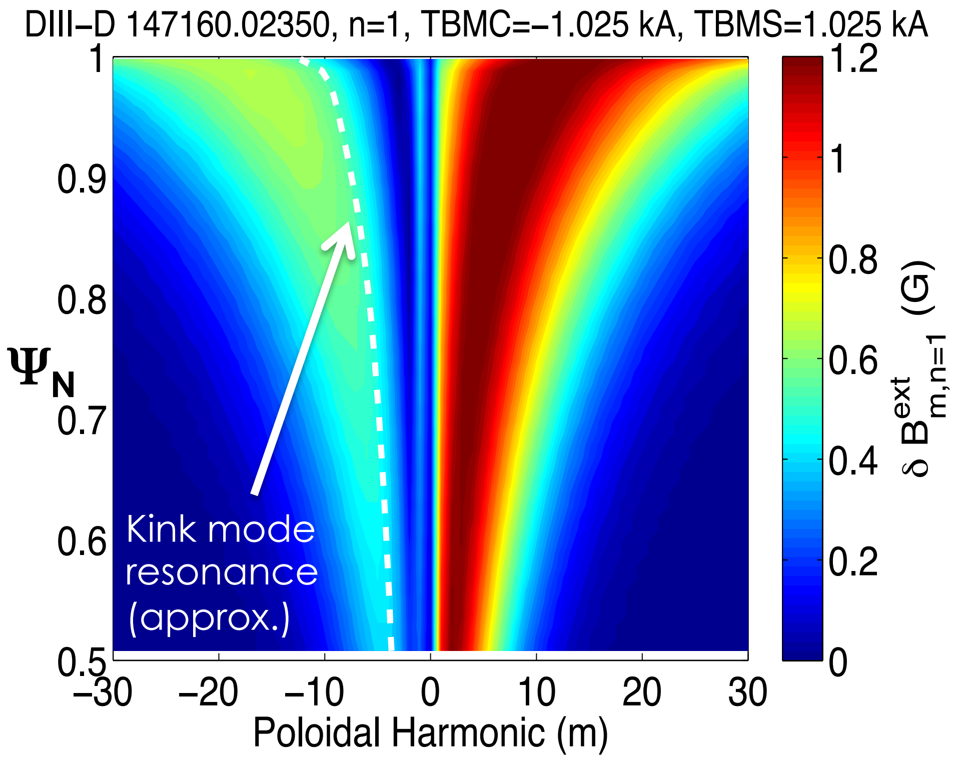
- The small difference between the two minimizations may be a consequence of non-resonant braking

TBM Has a Broad, Non-resonant Spectrum

- **Toroidal mode spectrum peaks at *n*≈10**



- **n=1 kink mode-resonant components are small**



➔ **Full correction may require multiple n or local correction coils**

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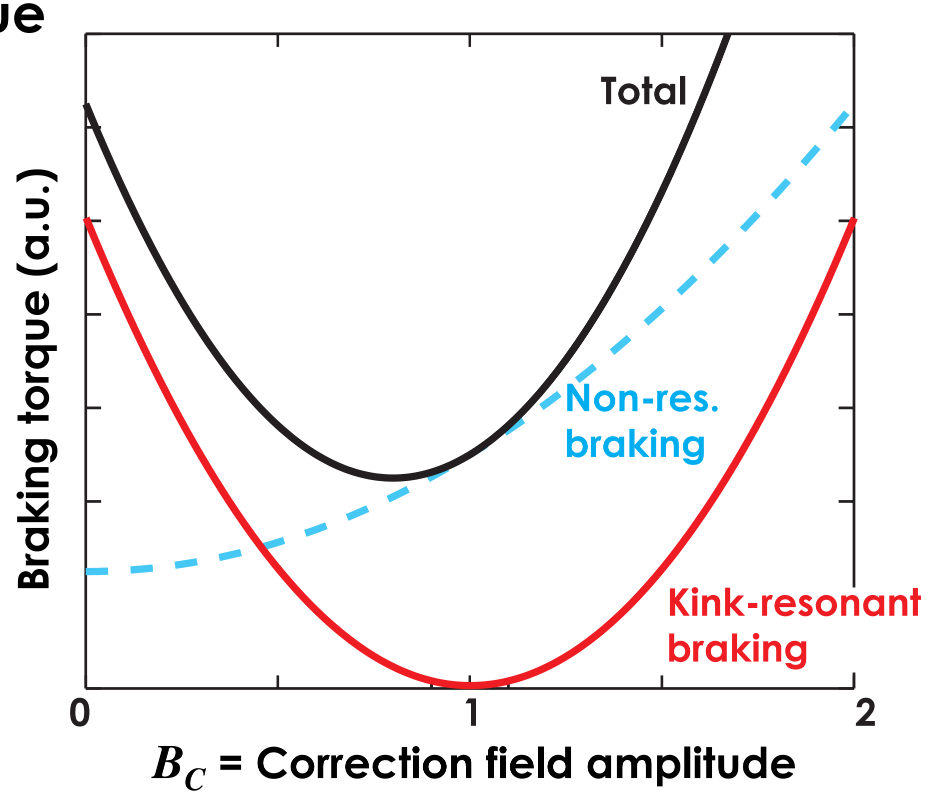
TBM Results Suggest a Significant Non-resonant Contribution to Braking of Rotation

- **Simple model for braking torque of error field B_E and correction field B_C:**

$$T = \left(a_K B_E - b_K B_C\right)^2 + a_{NR}^2 \mathbf{B}_E^2 + b_{NR}^2 \mathbf{B}_C^2$$

Kink-resonant (n=1) contribution	Non-resonant contributions

- **Non-resonant terms prevent complete cancellation of error field braking**



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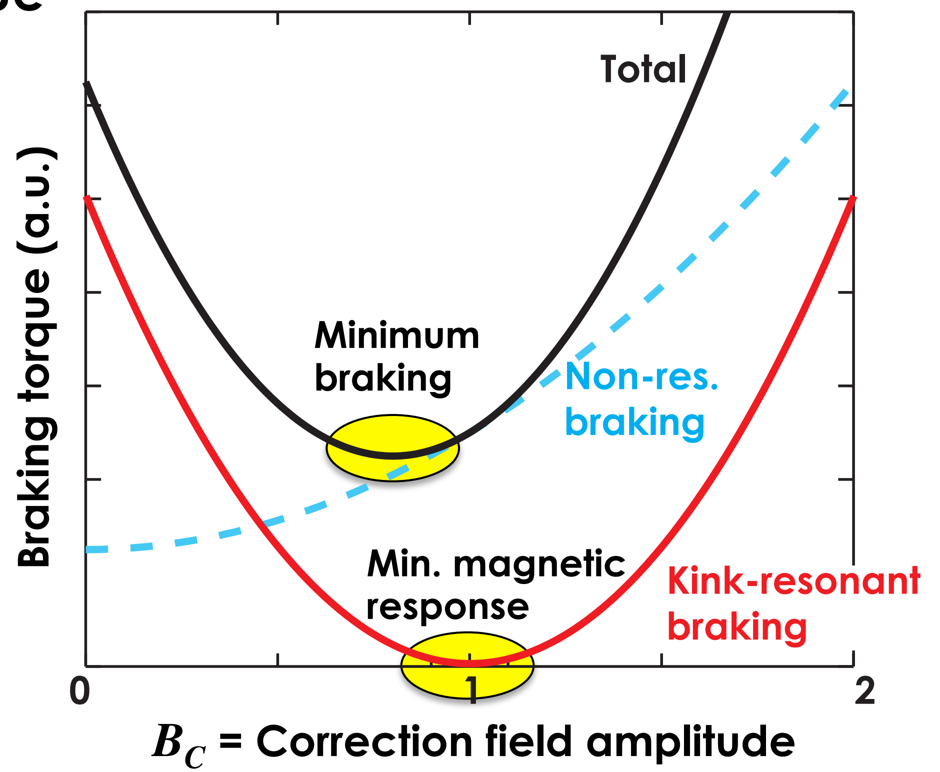

- **Non-resonant terms prevent complete cancellation of error field braking**

- **Minimum braking requires smaller correction field than minimum kink resonance**
  - Consistent with TBM experiment?

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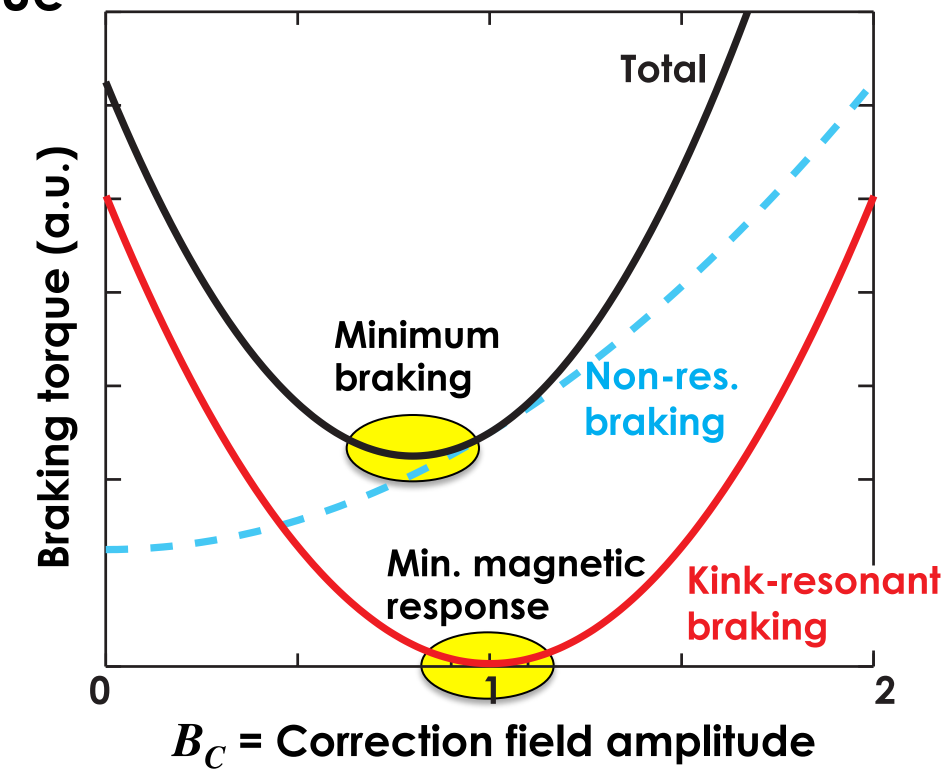
Fit TBM results to this model:

- **Correction field has moderate non-resonant braking ratio: $b_{NR}/b_K \sim 0.5$**
- **TBM error field has larger non-resonant braking ratio: $a_{NR}/a_K \sim 2$**



Summary

- **DIII-D results suggest an important role of magnetic braking by n >1 and/or non-resonant fields (in H-mode plasmas)**

➔ **Compensation by n=1 fields alone may have limited effect against TBM-induced braking of ITER plasmas with rotation**

  – But n=1 compensation is still important for avoiding resonant error field penetration at low rotation