

Kink-Resonance of NTV Torque: Optimizing the Poloidal Spectrum

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Role of 3D field poloidal spectrum on NTV torque

What role does the poloidal spectrum have in 3D fields driving NTV?

Coupling to the kink-response dominates δB , and thus NTV ($T \sim \delta B^2$)

- ▶ Is there a 3D field that drives 0 NTV? What is the Maximum?
- ▶ Is the single mode model valid? Which mode?

Motivation: modeling shows clear peak in torque at peak kink-response

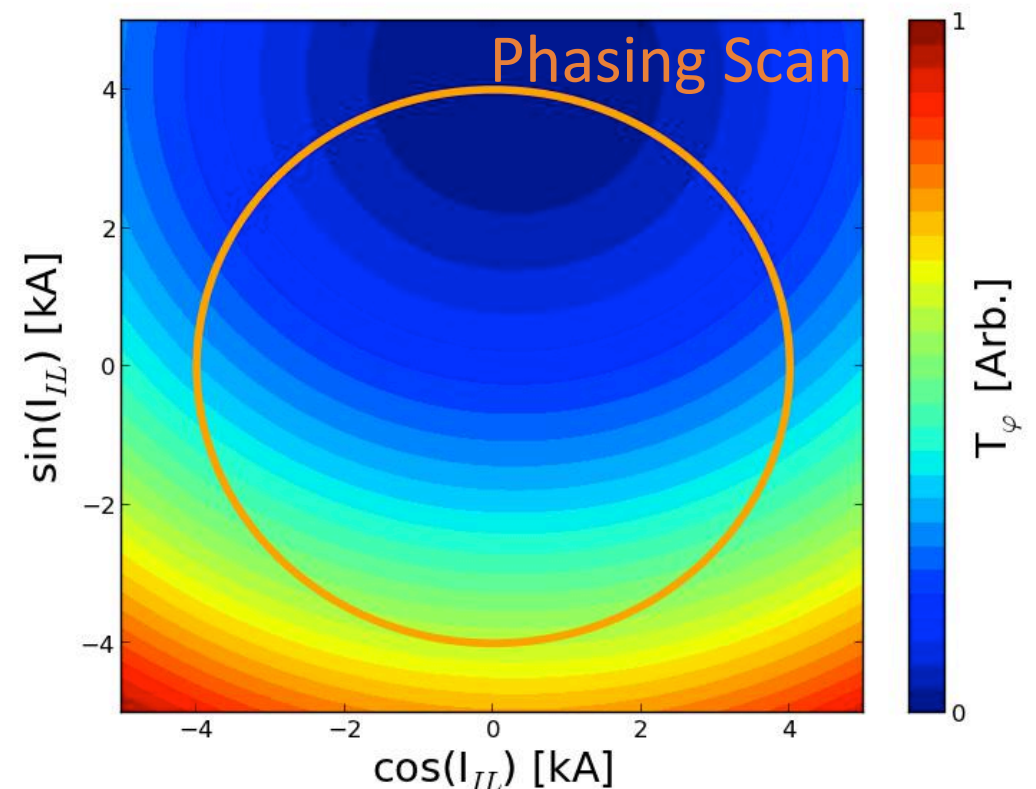
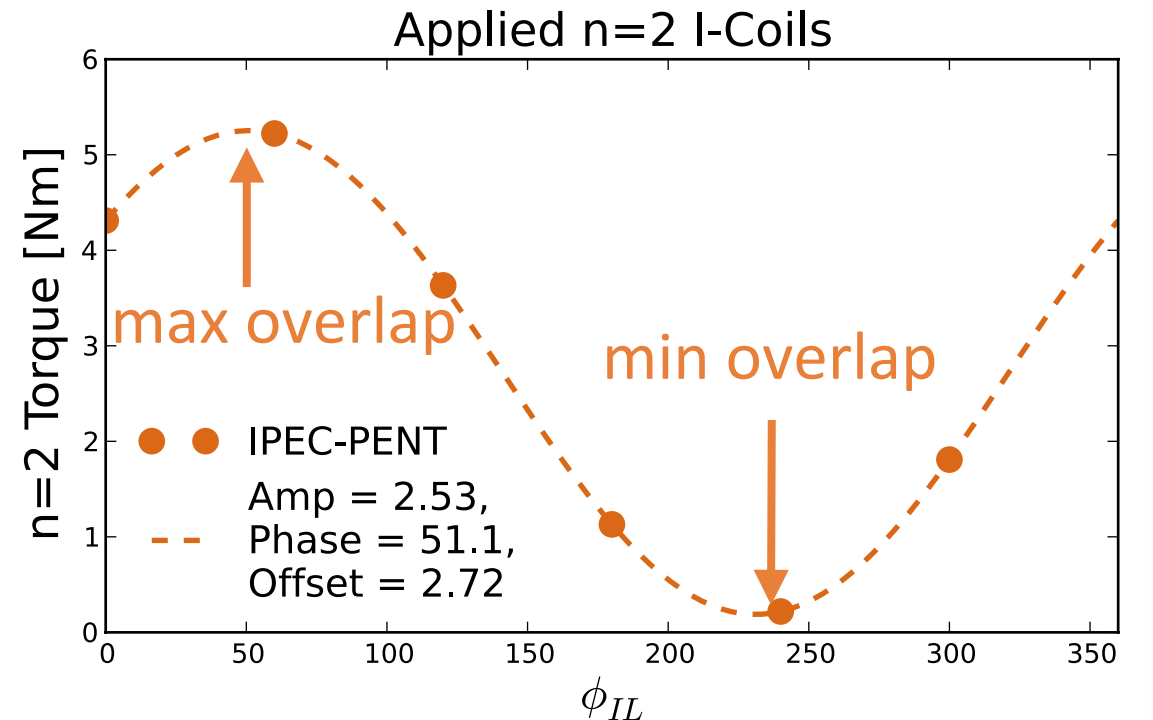
Peak corresponds to maximum overlap metric with IPEC “dominant mode”

- ▶ A SVD of coupling between mode applied on plasma surface and δB^2 on rotational surfaces

NTV calculated using Perturbed Equilibrium Nonambipolar Transport (PENT) code

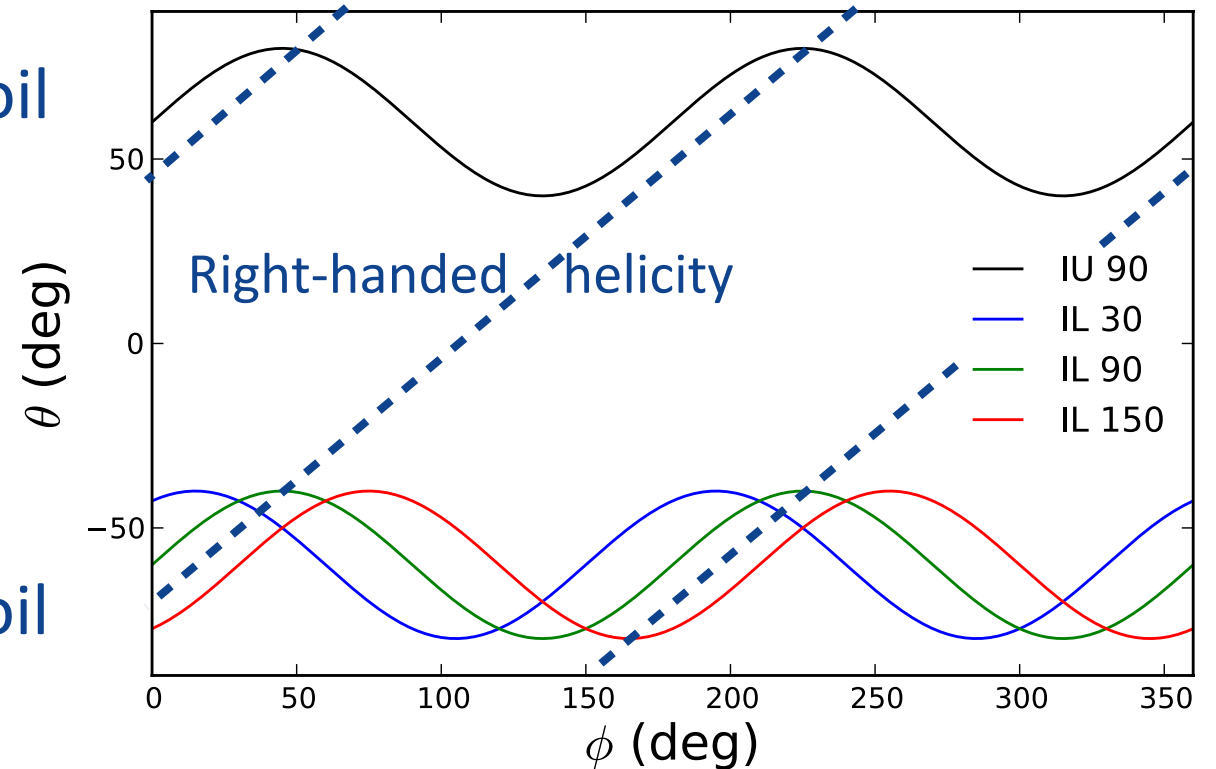
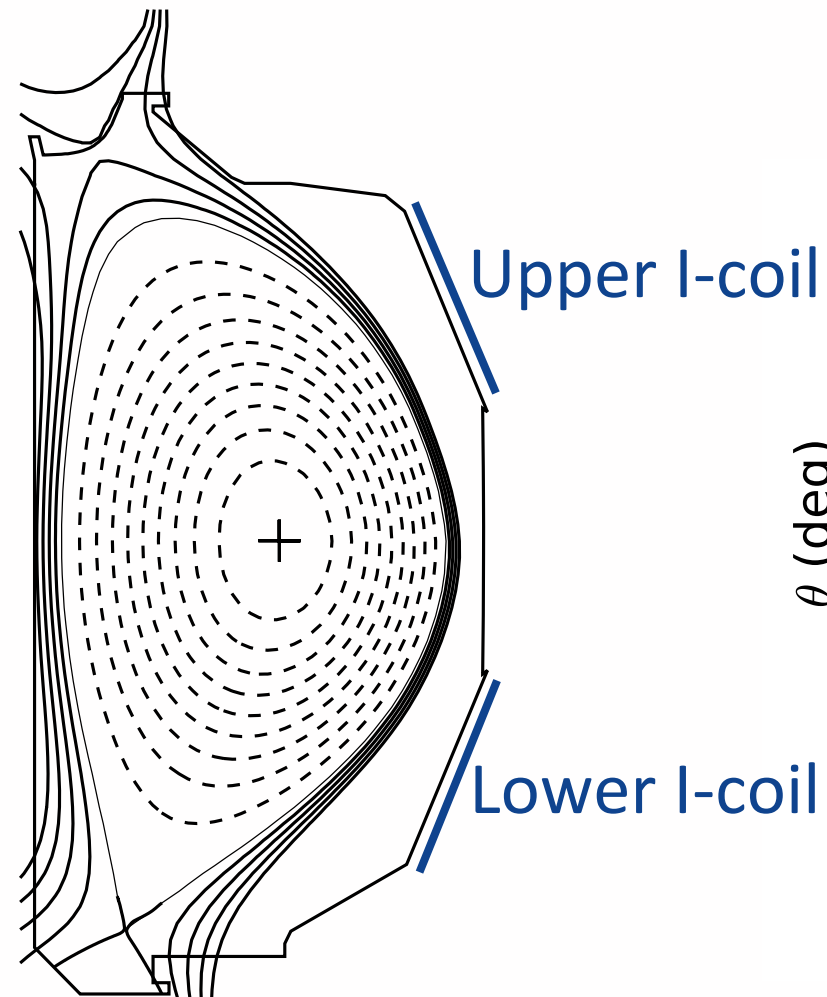
- ▶ Ideal MHD δB , $\nabla \cdot \xi$ from IPEC
- ▶ Zero-orbit width drift-kinetic eq. solved in general geometry

Near perfect sinusoid confirms circular NTV contour in phase space (dominant mode)



Relative phasing of applied n=2 I-Coil fields changes kink mode coupling in experiment

B_T 1.9
 q_{95} 5.3
 β_N 2.0, 2.3
 I_p -1.1MA
Beam heated,
QH mode,
reverse I_p for
 T_{NBI} ramp (next
slide)



Vary phase of lower I-Coil n=2 field and look for ordering of NTV torque with Kink overlap

Set upper I-coil to phasing with 0 current in IU90 to avoid sidebands

Approach utilizes bifurcation in torque-rotation space

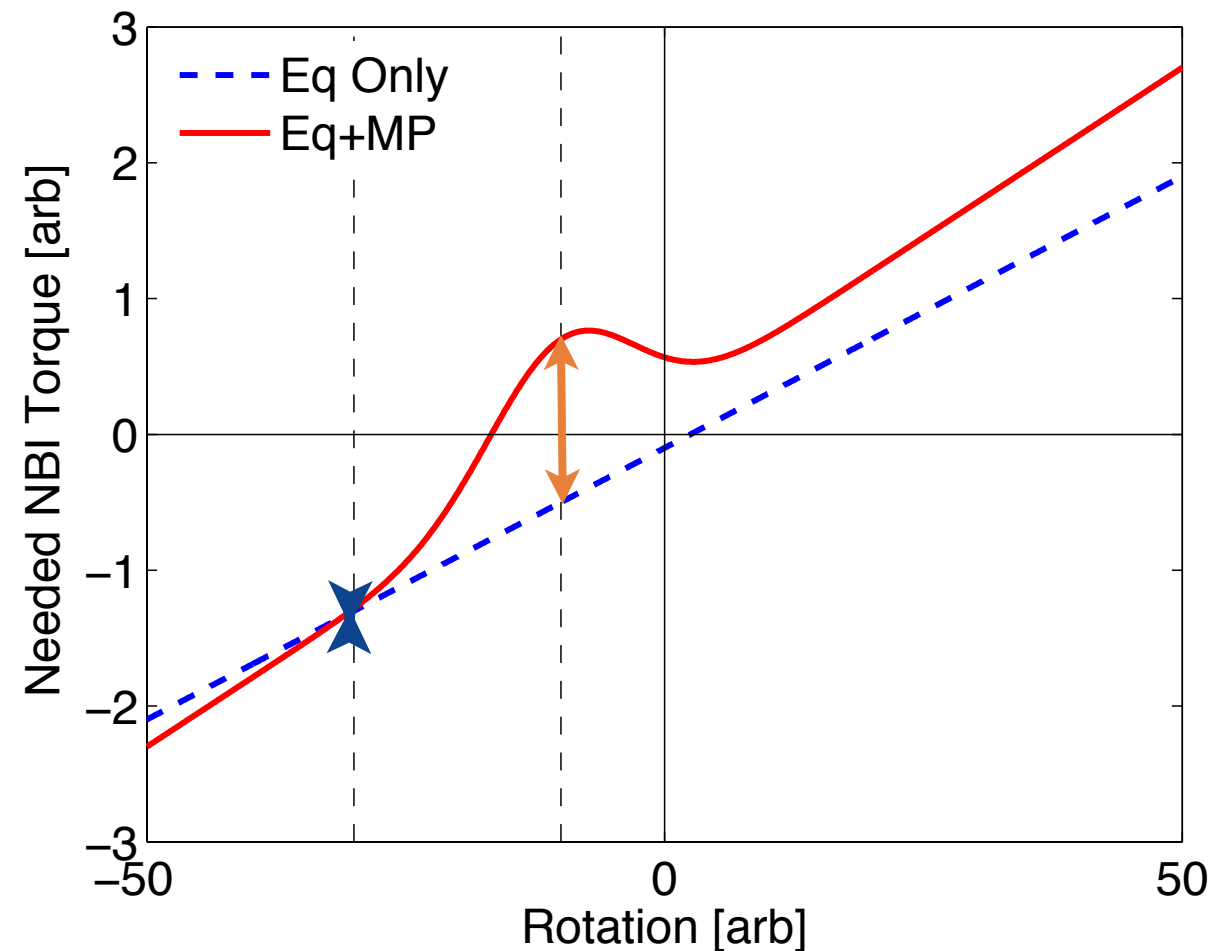
NTV goes like rotation... except near kinetic resonances

$$\Re[\mathcal{R}_{T\ell}] \propto -\frac{\nu \left[\omega_{\varphi} + \omega_{*T} \left(\varepsilon - \frac{5}{2} \right) \right]}{\left[\ell \omega_b + n (\omega_E + \omega_D) \right]^2 + \nu^2}$$

Resonant torque goes like the inverse of rotation

Experiment utilized “torque ramp-down”, moving towards co-Ip injection until rotation bifurcation and locking

- Compare rampdown at each phasing to no 3D field baseline



Approach utilizes bifurcation in torque-rotation space

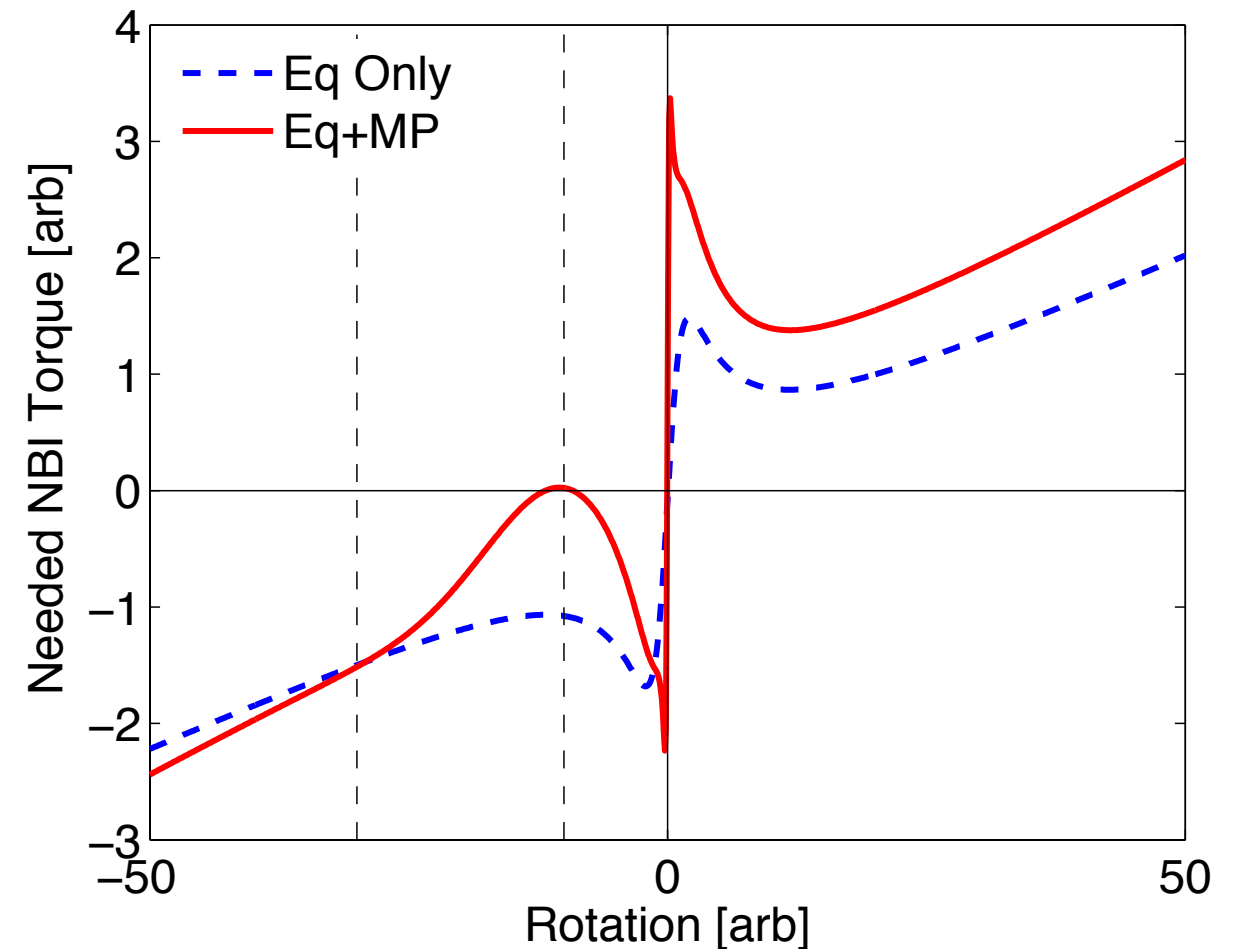
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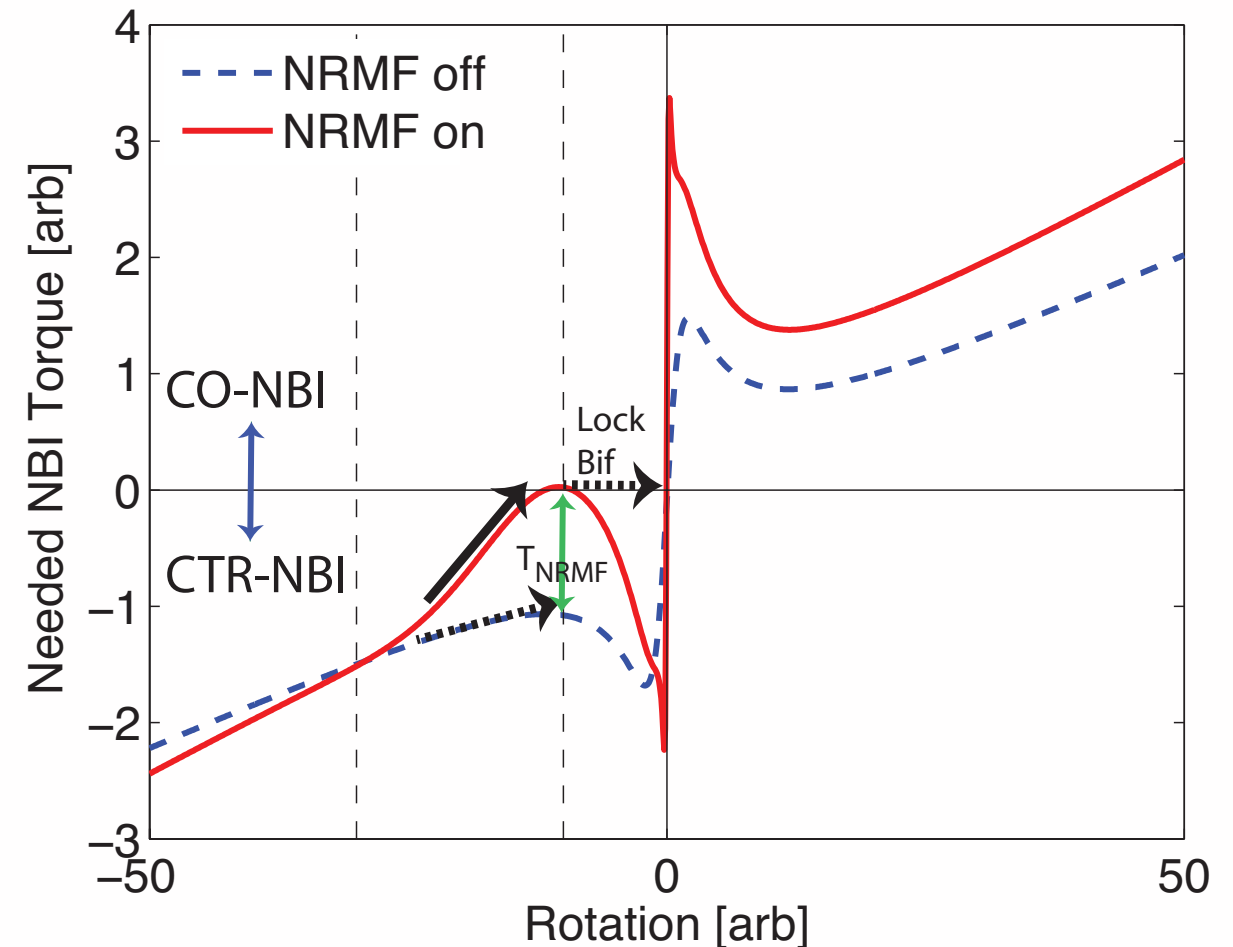
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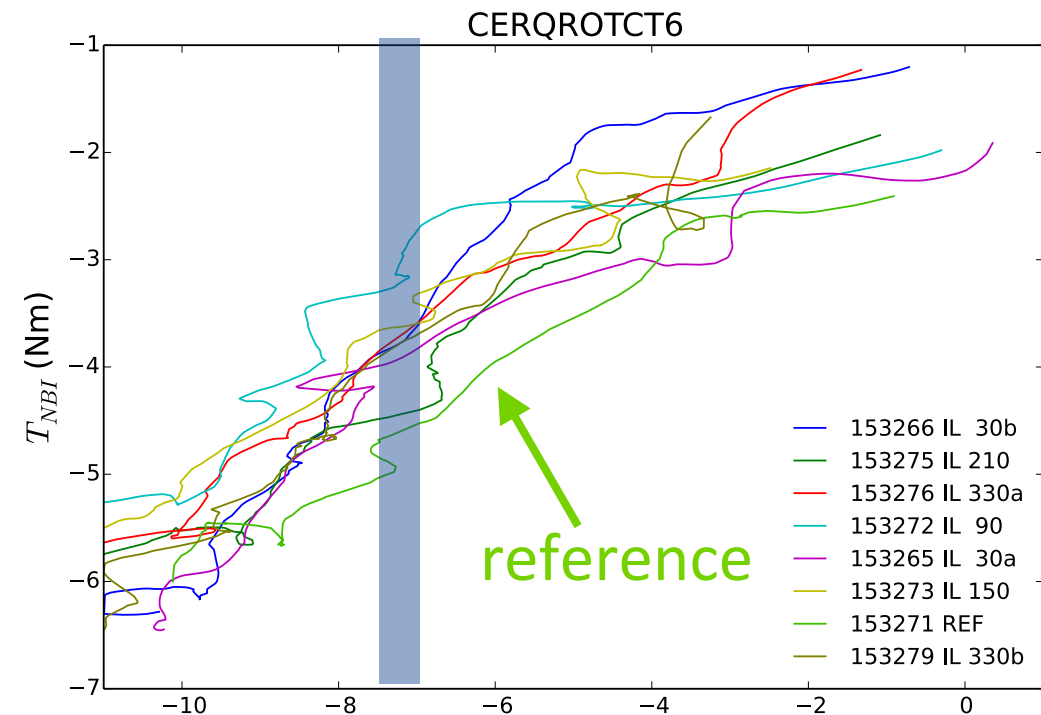
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Experiment showed NTV poloidal spectrum dependence

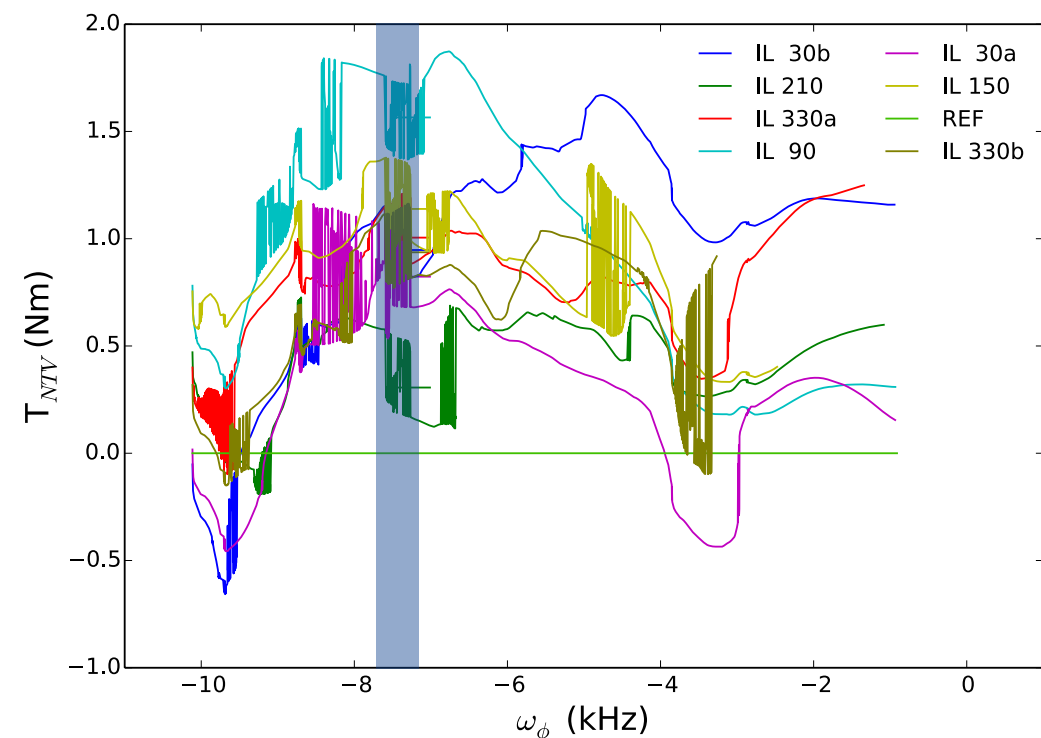
Each discharge mapped to T - ω_ϕ space

- ▶ Ends show spread bifurcation
- T_{NBI}

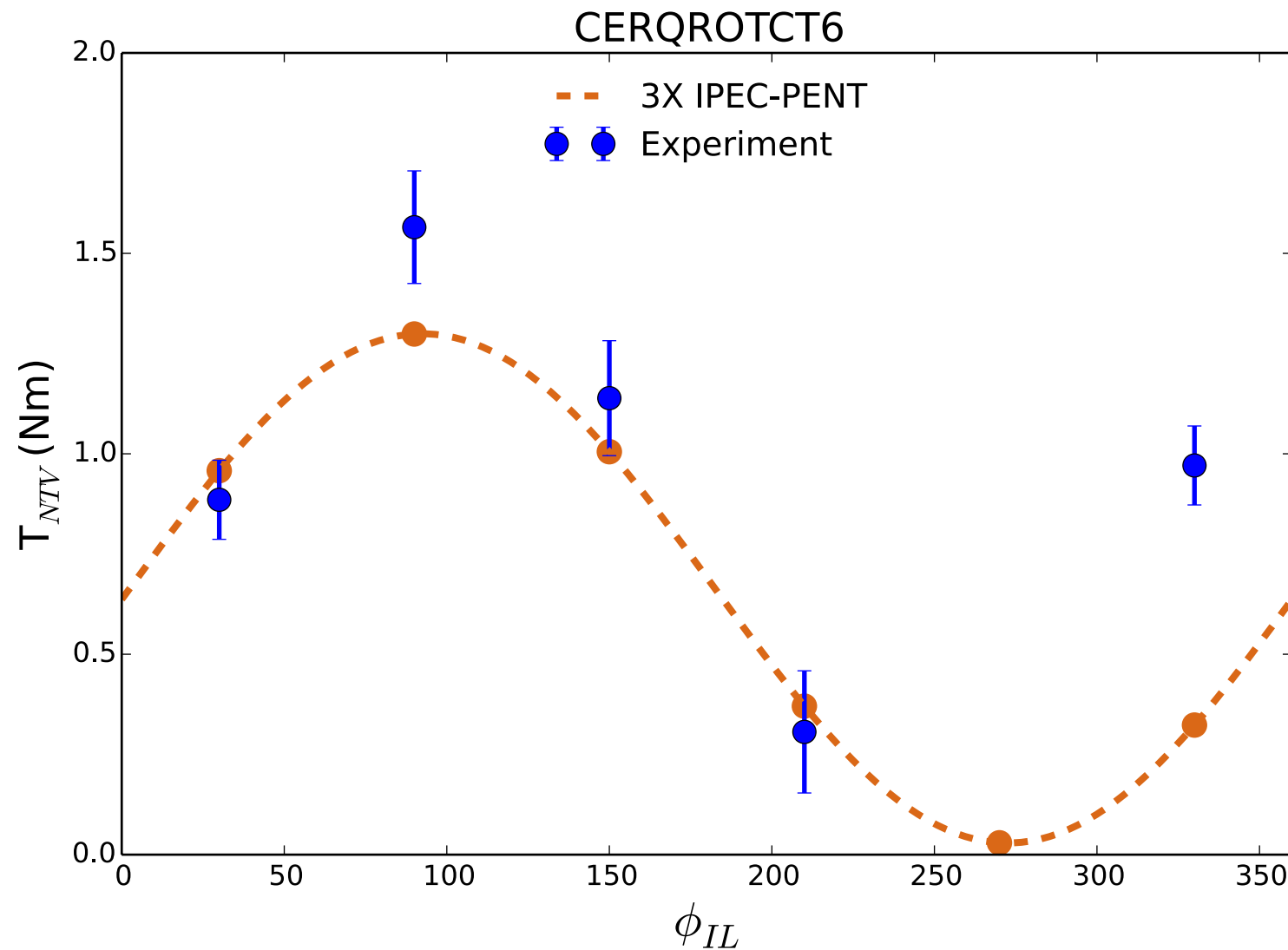


“NTV” is difference between a given trajectory and the reference

- ▶ Compare $T_{NTV}|_\omega \rightarrow$ need ω before any bifurcation



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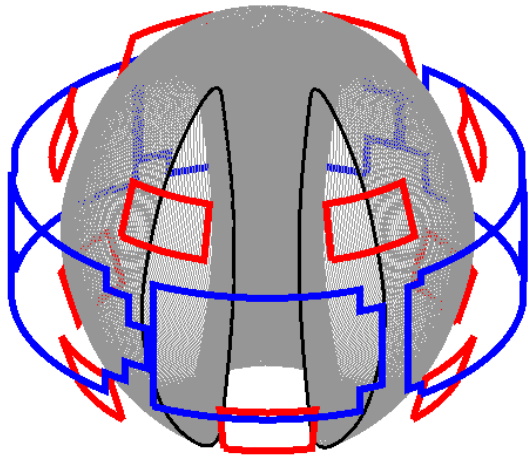
Variation on the order of 1 Nm ($\pm 50\%$)

- Seen in both T_{bif} and $T_{NTV} = \Delta T_{NBI}$

PENT currently predicting too low a torque

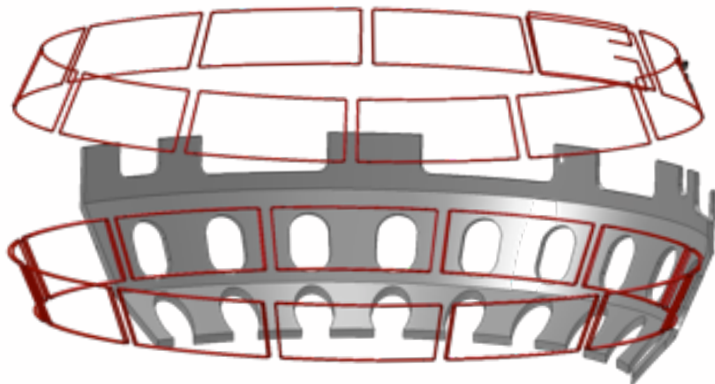
- Improving kinetic EFITS

Summary and implications



Coupling to the kink-response dominates δB , and thus NTV ($T \propto \delta B^2$)

- ▶ Single mode model validated in DIII-D PENT modeling and experiments



Efficiency of NTV drive for current *and future* coil sets completely determined by dominant mode coupling

- ▶ 2 poloidal positions enough to couple to or decouple from single dominant mode
- ▶ Mode determined by linear SVD analysis
 - Fast and available now
 - Theory will be tested with large scale 3D optimization study with S. Lazerson in support of NCC at PPPL

