U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

Tearing Mode Simulation in NSTX-U L-Mode Plasmas

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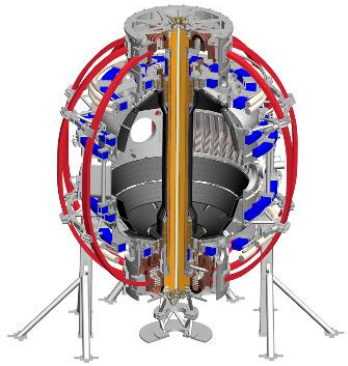
NSTX-U Results Review
PPPL
September 21-22, 2016

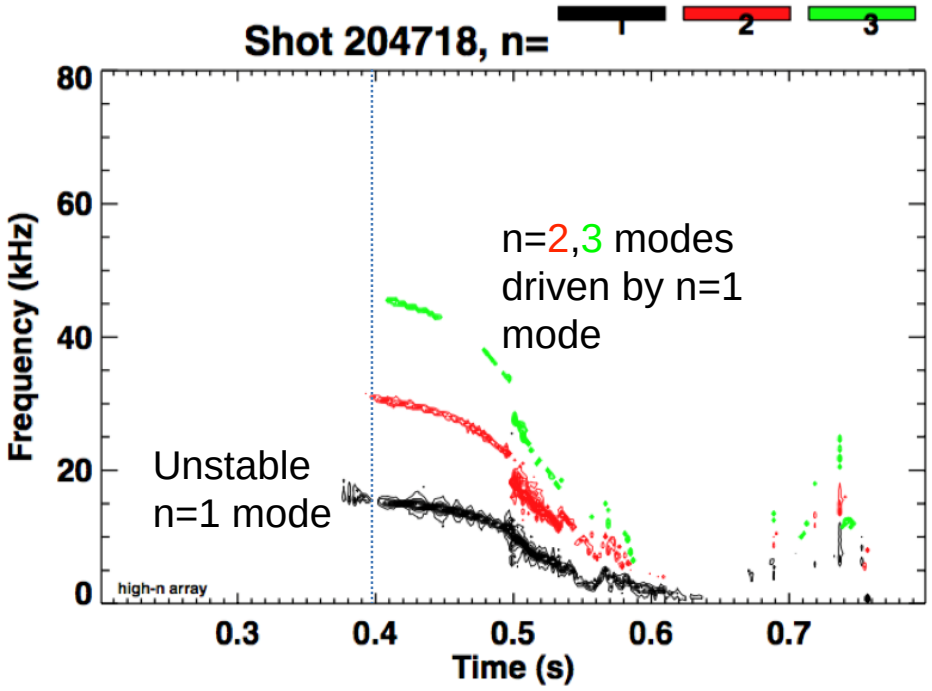
PPPL



MARS-F and New Developed Resistive DCON Predict Unstable Tearing Mode as Observed in NSTX-U Expreiments

Unstable n=1 tearing mode is observed in L mode NSTX-U discharge (204718). Resistive DCON and MARS-F predict unstable n=1 tearing modes at q>2 singular surfaces.

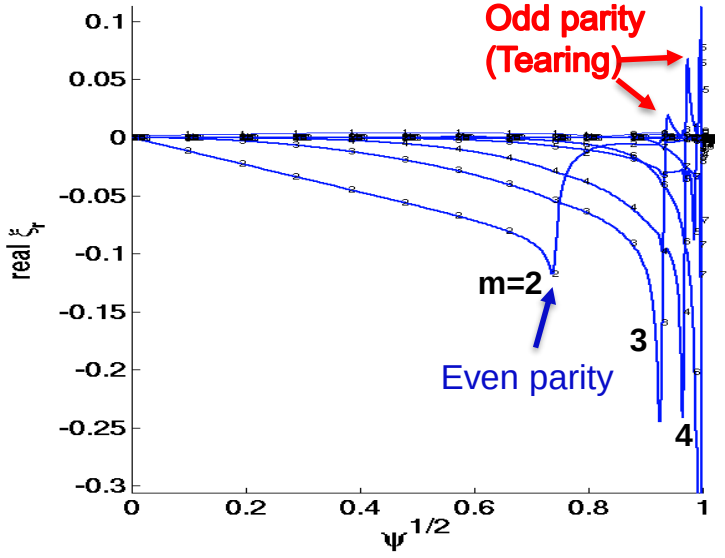
NSTX-U experiment observes n=1 unstable mode which drives n=2, 3 modes later



Diagonal terms of Δ' matrix solved by DCON (outer region) is positive at q=3 and 4 surfaces

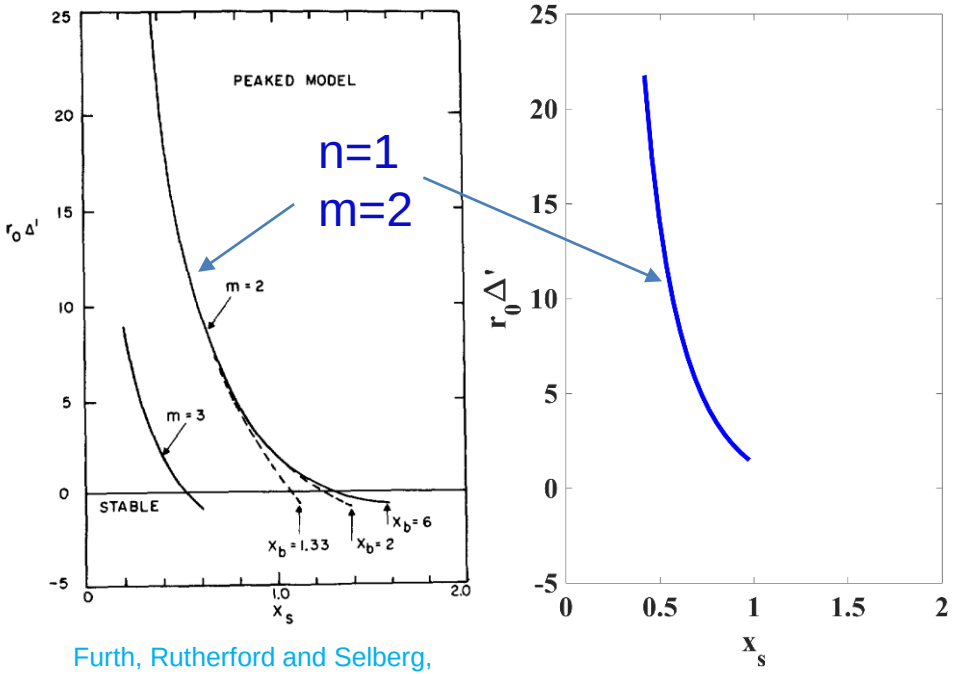
Δ'(q=2)	-4.29
Δ'(q=3)	10.0
Δ'(q=4)	3.18

MARS-F finds unstable tearing mode at zero rotation, growth rate $\gamma = 1.7 \times 10^{-3}\omega_A$



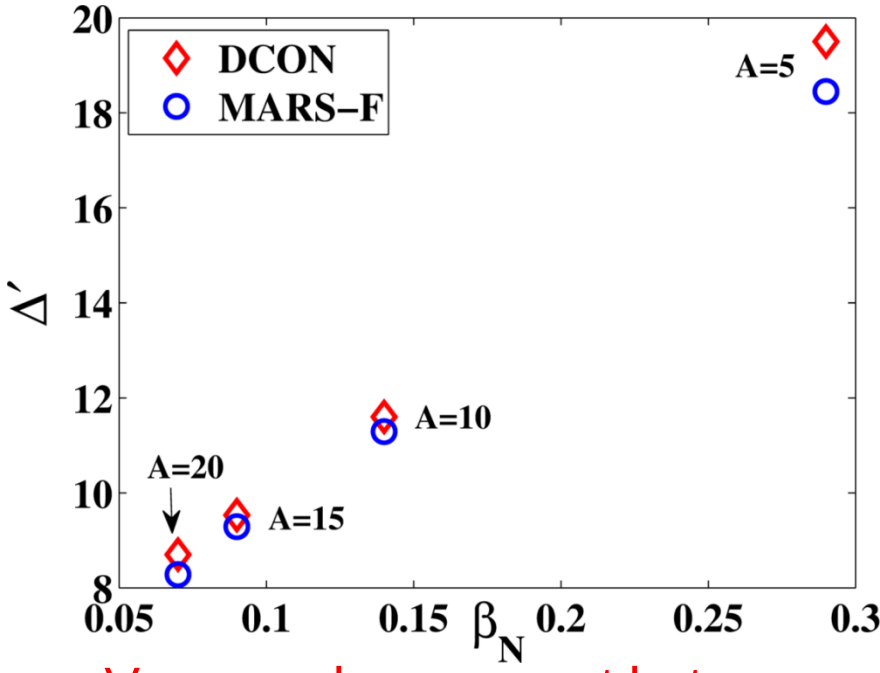
Successful Δ' Benchmark Indicates Reliability of Resistive DCON Outer Region Solution

Resistive DCON repeats analytical Δ' behavior in FRS equilibrium.



Furth, Rutherford and Selberg, Phys. Fluids 16, 1054(1973)

MARS-F calculates Δ' from computed eigenvalue and GGJ model.

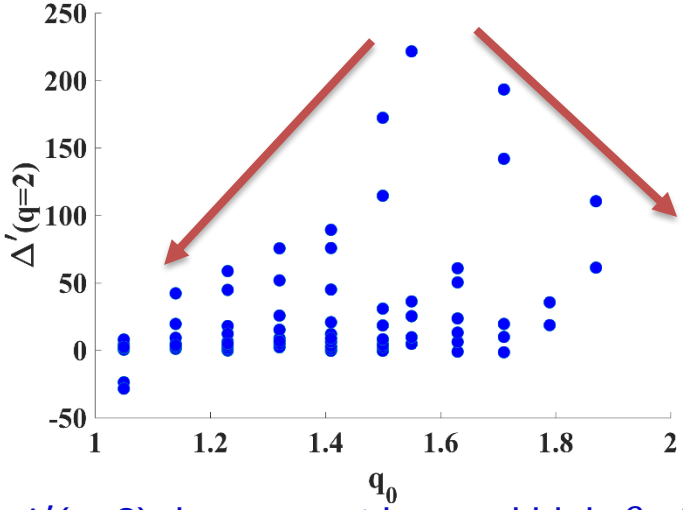


Very good agreement between DCON and MARS-F

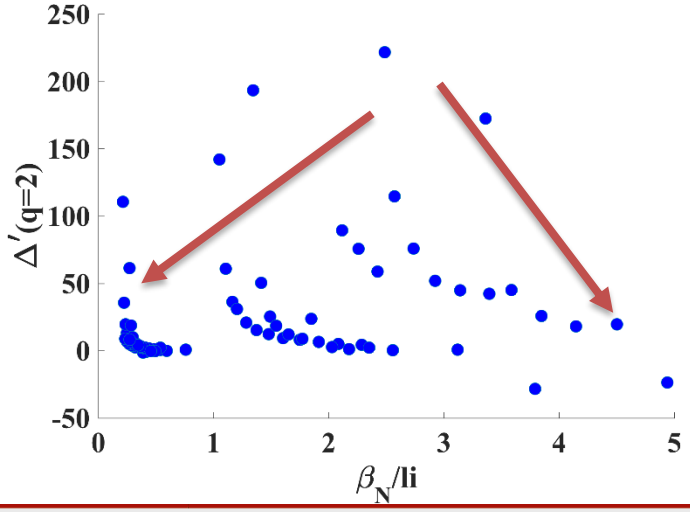
First resistive DCON paper (Glasser, Wang and Park) has been submitted to PoP.

Δ' Optimization of L-Mode Discharge to Avoid n=1 Tearing Instability ($\Delta' \downarrow$ when $q_0 \downarrow$ and $\beta_N/l_i \uparrow$)

Δ'(q=2) decrease while q_0 approaches to q=1 and q=2 surfaces.



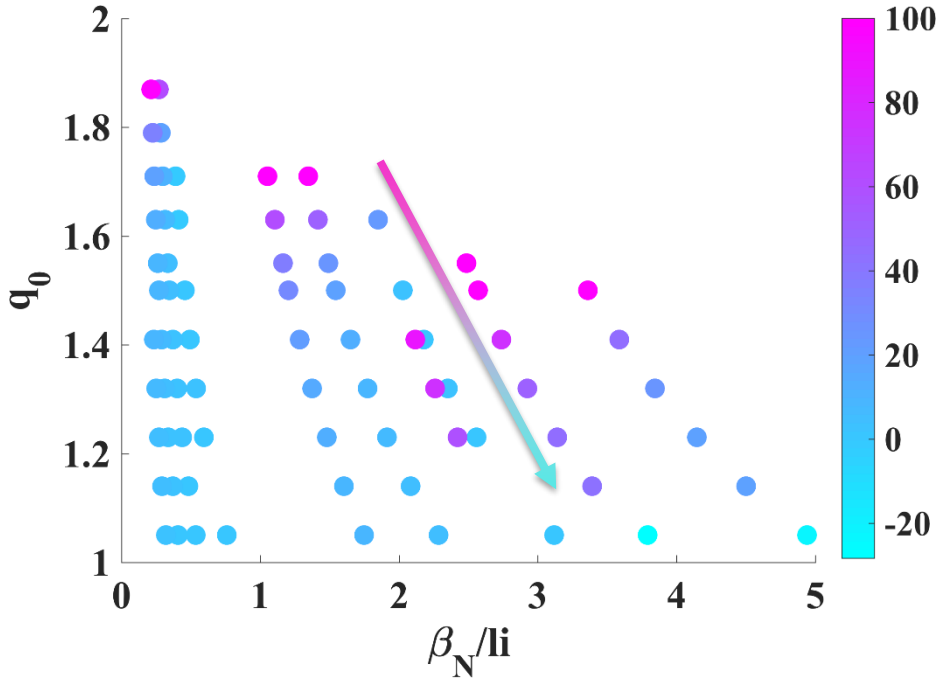
Δ'(q=2) decrease at low and high β_N/l_i.



Current and pressure profiles are scanned by CHEASE.

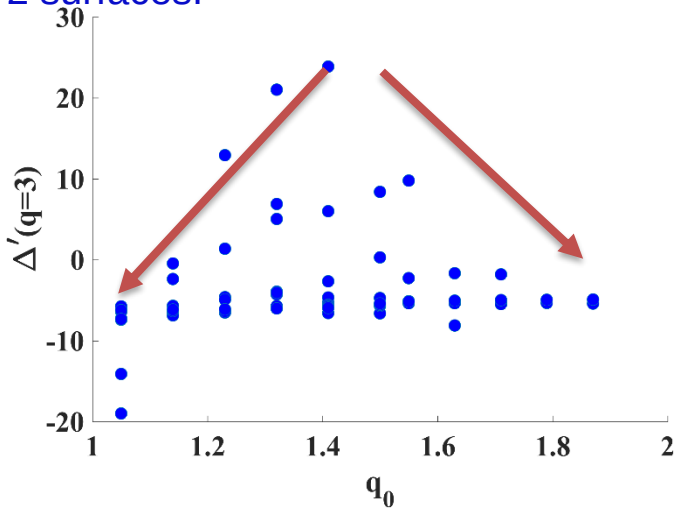
Outer region Δ' is solved by Resistive DCON in full toroidal geometry.

Δ'(q=2) decrease while $q_0 \downarrow$ and $\beta_N/l_i \uparrow$

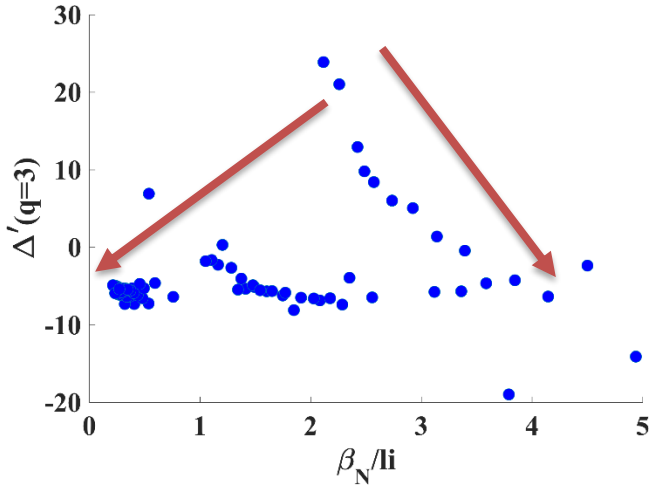


Δ′ Optimization of L-Mode Discharge to Avoid n=1 Tearing Instability (Δ′ ↓ when q_0 ↓ and β_N/l_i ↑)

Δ′(q=3) decrease while q_0 approaches to q=1 and q=2 surfaces.



Δ′(q=3) decrease at low and high β_N/l_i.



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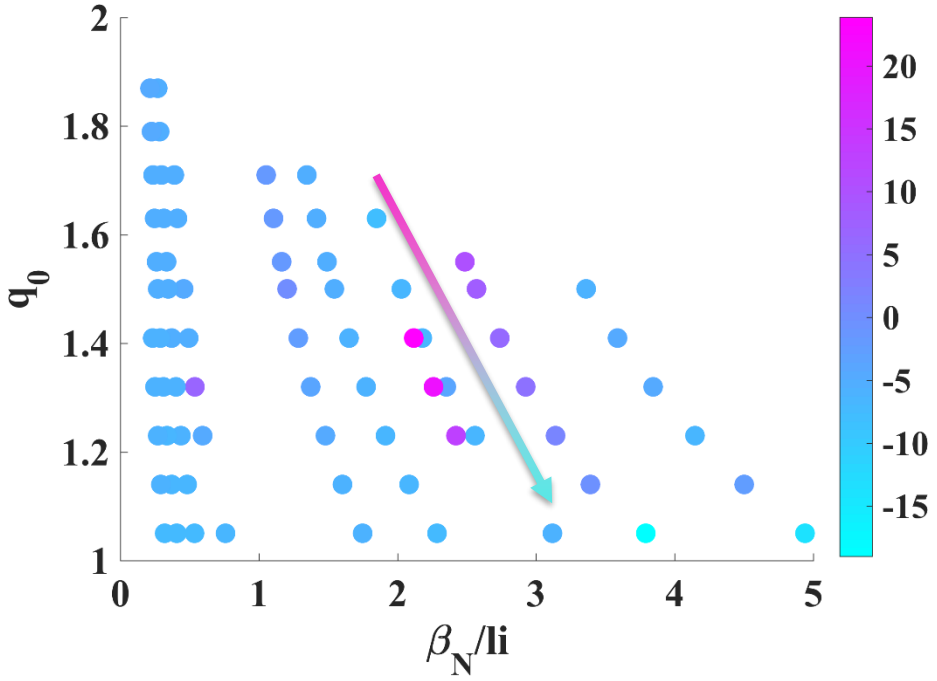
Outer region Δ′ is solved by Resistive DCON in full toroidal geometry.

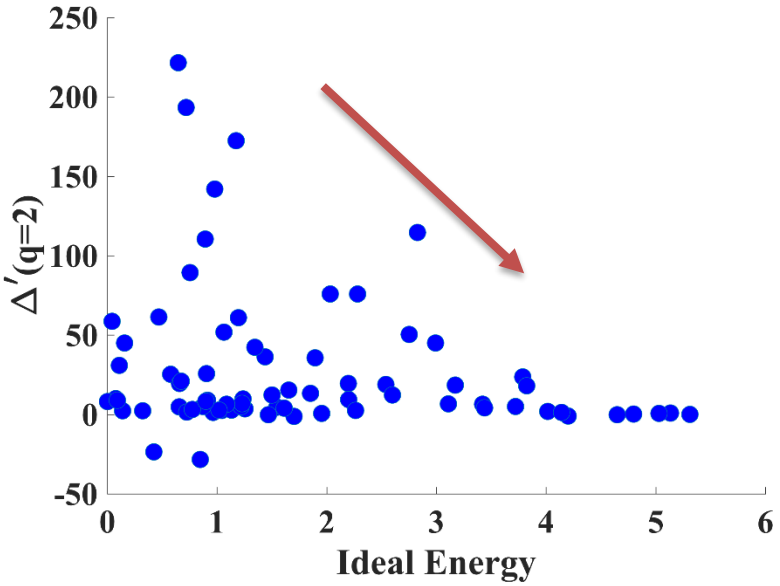
Δ′(q=3) decrease while q_0 ↓ and β_N/l_i ↑

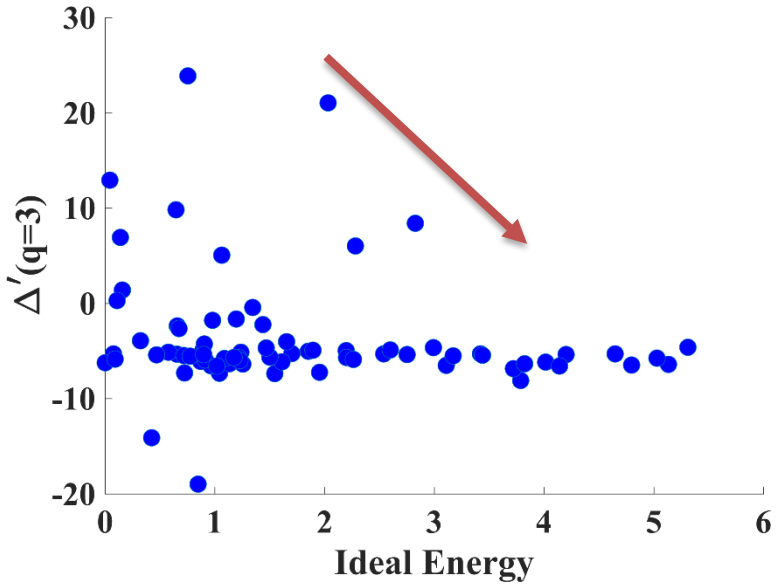


Outer Region Free Energy Decrease (More Positive Ideal Energy) → Δ′ Decrease

Δ’ behavior directly relates to the ideal energy (Outer region energy).

More stable idea MHD stability corresponds to smaller Δ′.





Real-time ideal DCON may important to both ideal and resistive MHD instabilities.

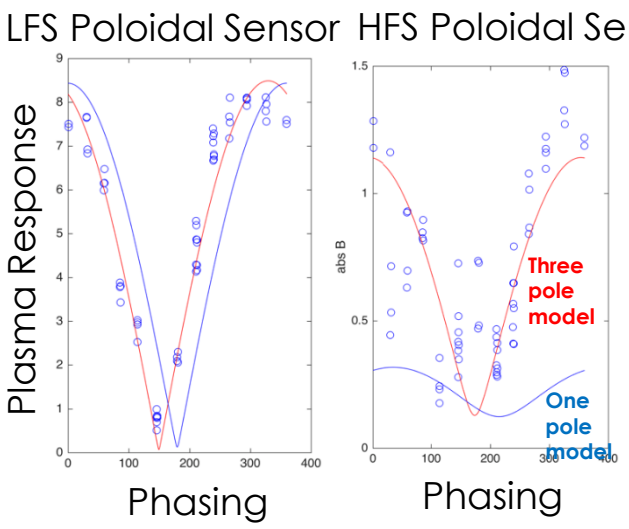
Nyquist MHD Spectroscopy is Developed to Detect MHD Modes by Extracting Plasma Transfer Function

- Low frequency MHD spectroscopy can identify multi-mode response and mode stability
- Approach:
  - Scan I-coil frequency with each given coil frequency
  - Direct extraction of Muli-mode transfer function (γ_1, γ_1, ...γ_m)

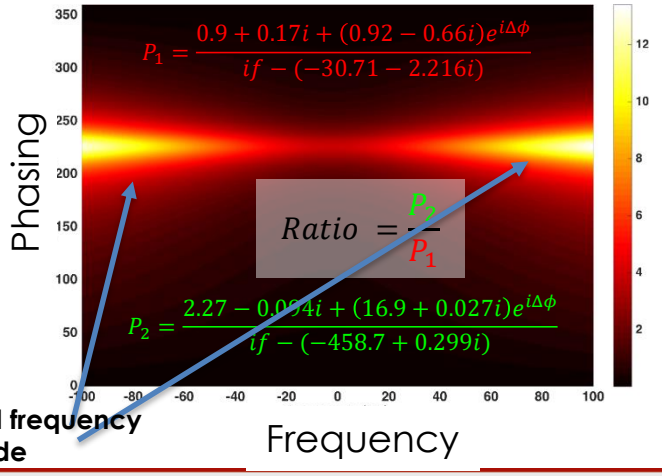
$$P_j(\Delta\phi, f) = \sum_{i=1}^{N} \frac{a_i^j + b_i^j e^{-i\Delta\phi}}{f + \gamma_i}$$

- Advance of new method :
  - Extend NCC (NSTX-U) and I-coil (DIII-D, EAST) capability to directly detect MHD eigenmodes
  - Measured damping rate provides direct, fundamental test of ideal, kinetic and resistive 3D models
- Impact: Identify the underlying tearing, ideal MHD governing stability. TM/Global stability warning. Optimize coil phase and frequency amplifying secondary mode for ELM suppression.
- Nyquist MHD Spectroscopy will be tested in DIII-D and EAST experiments.

DIII-D experiments fitting (f=0)



MARS-F n=1 EAST plasma response simulation



Good coil phase and frequency for amplifying P_2 mode