3D magnetic response modeling and synthetic diagnostics with GPEC/MARS

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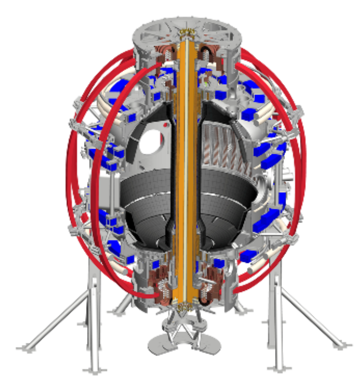


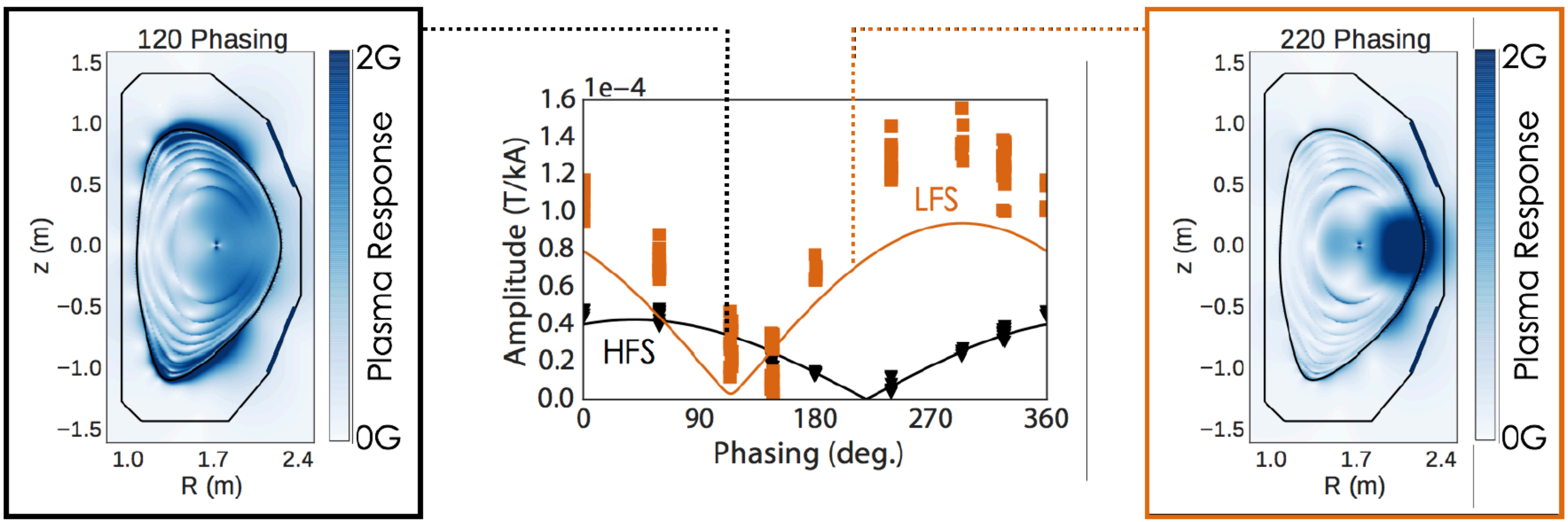
GPEC/MARS can be used to address capability of 3D magnetic sensors for multi-modes and field penetration

- Multi-modes and bifurcation in 3D magnetic response are important topics in error field, NTV, RMP ELM control
  - DIII-D highlighted the importance of optimal sensor locations to resolve subdominant modes and/or response bifurcation by field penetration
- GPEC can address sensor capability for linear/static response, by synthetic diagnostics and systematic mode decomposition
  - Synthetic diagnostics: PYPEC
  - Mode decomposition: SVD of matrix between sensors and reluctance
  - Bifurcation by layer penetration: RPEC
- MARS can address dynamic sensor capability and response change by field penetration in linear regime
  - Frequency characteristics and Nyquist contour for multi-modes
  - Linear resistive response by MARS-F

Synthetic diagnostics in IPEC (N. Logan) allow direct comparison with experiment for static 3D response

- IPEC diagnostics have been successfully used to validate 3D response codes, and to identify multi-mode characteristics in DIII-D
- Recent study shows that the modes can be decomposed best by reluctance matrix, which can be possibly coupled to sensors and coils for multi-mode response measurement and control

DIII-D n=2 response to I-coil (Logan, APS 2015)



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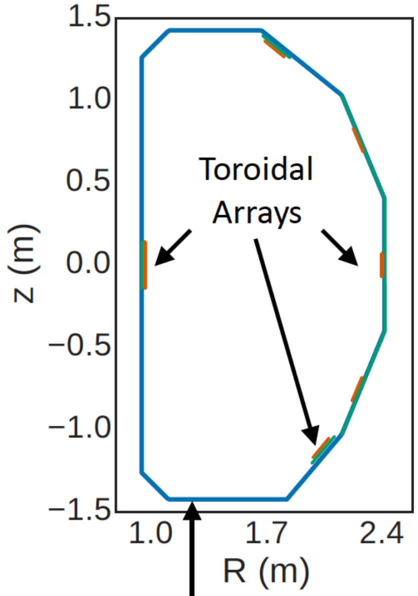
Extensive magnetic synthetics have been developed for DIII-D



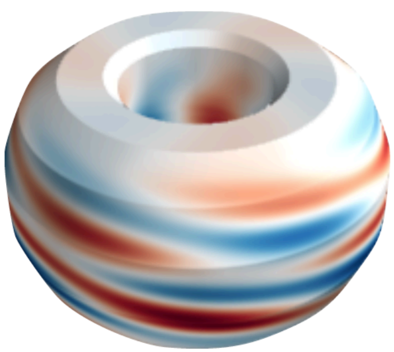
Synthetics include toroidal arrays of sensors for both the radial and poloidal field

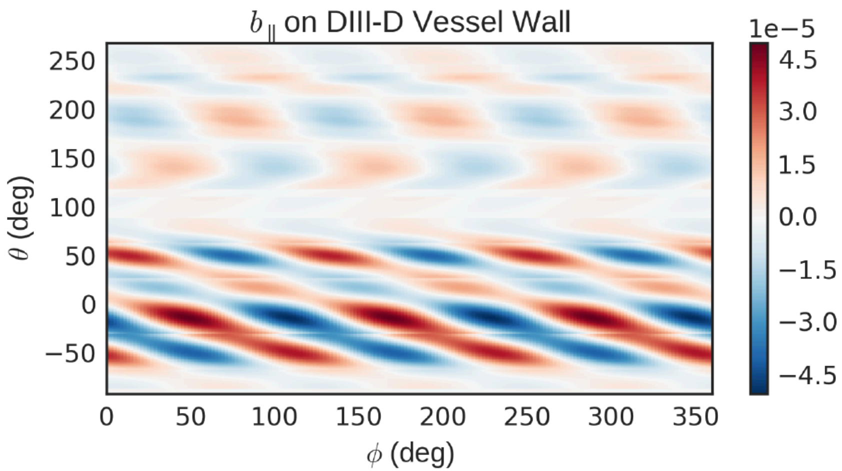
- Field projected to true length,tilt to calculate average flux

Full vessel wall provides arbitrarily fine diagnostic

- Shows structures averaged over by finite sensor lengths
- Upgrade used this to project to previously un-diagnosed regions (HFS)

Arbitrary accuracy "diagnostic" at the wall





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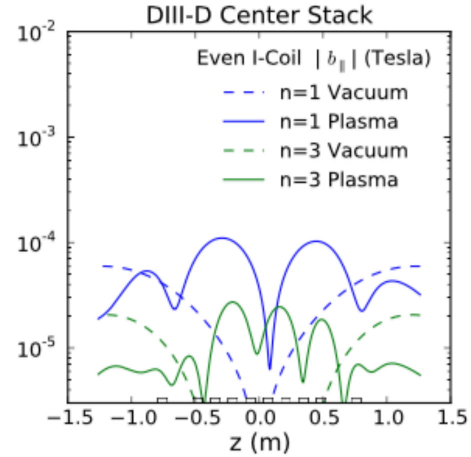
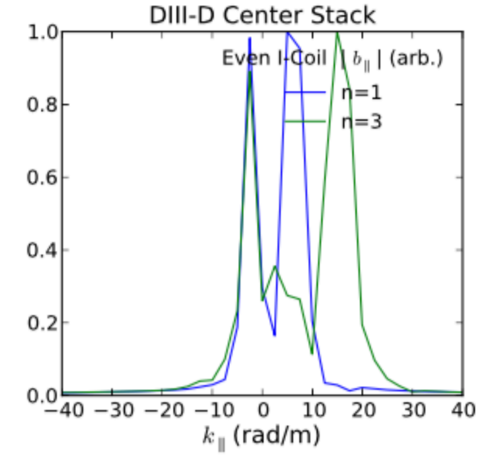
IPEC synthetics played a major role in guiding the DIII-D 3D magnetics upgrade

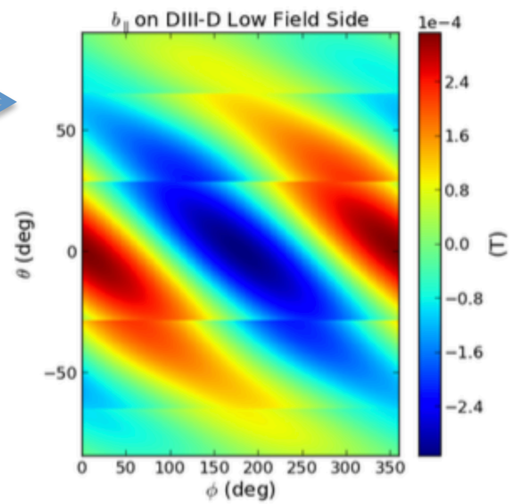
- Scale lengths were used to determine necessary sensor size/ spacing

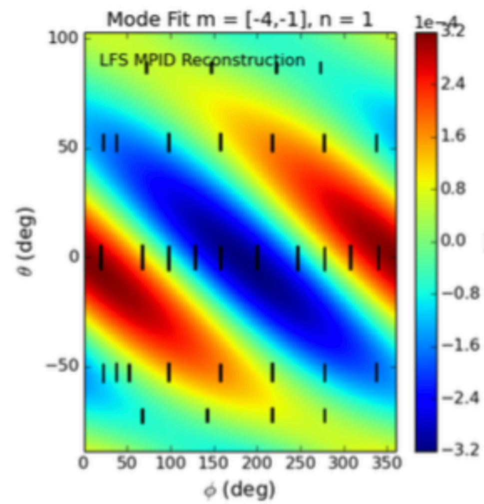




- Geometry variations estimated positioning sensitivity/errors

- Reconstructions using discrete sensor distributions were tested for robustness in constraining multiple types of plasma response





- **IPEC synthetics can be readily implemented for NSTX-U (with sensor geometry/locations) and can be utilized as done for DIII-D**

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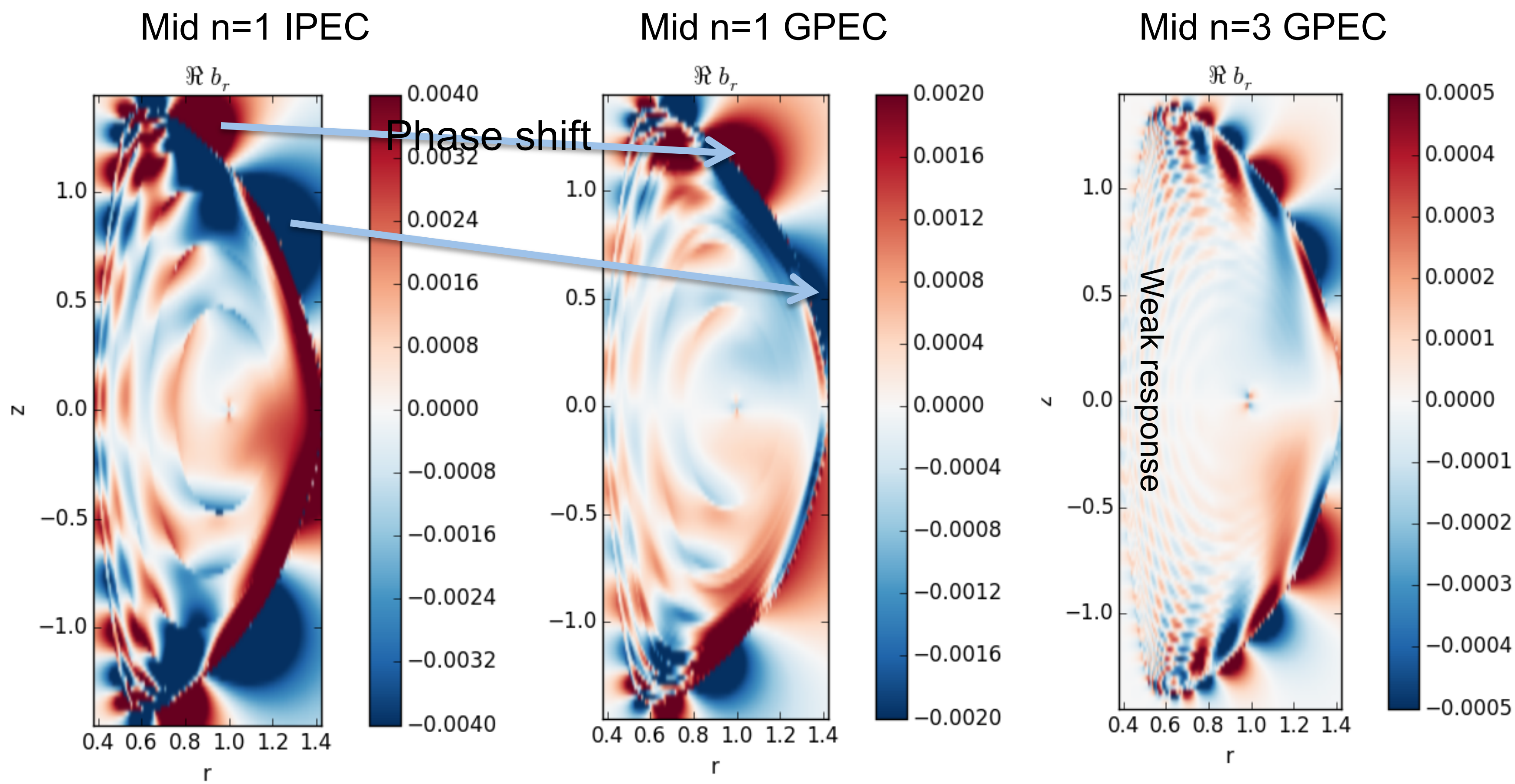
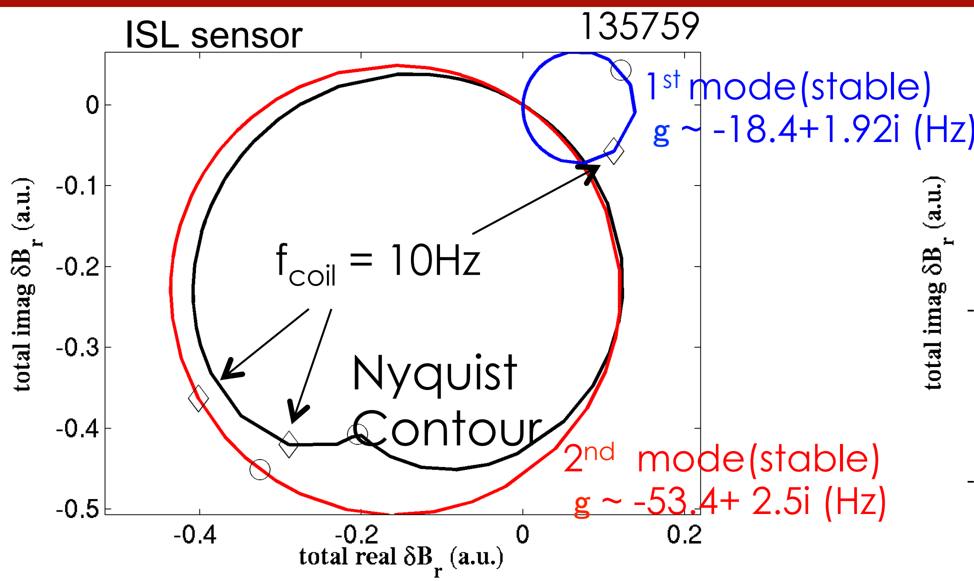
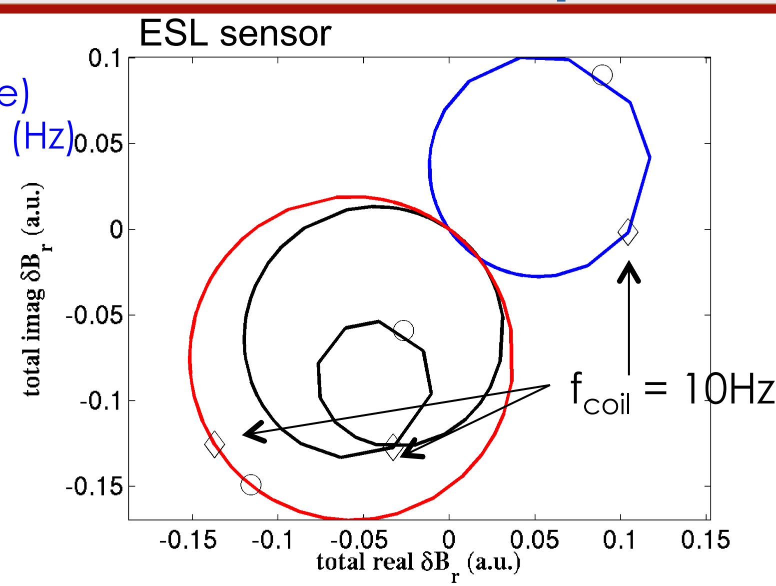
GPEC can also be used to improve synthetic diagnostics and address kinetic response in NSTX-U

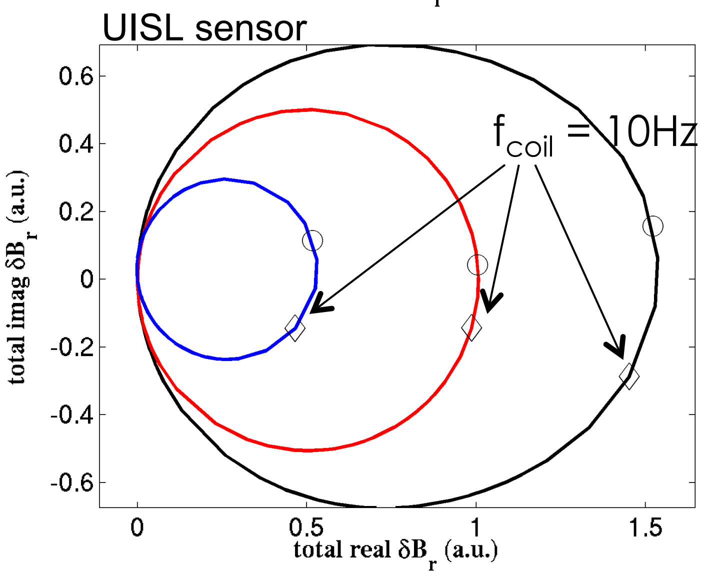
- GPEC can be used with NSTX-U synthetic magnetics
- NSTX-U can be very different from DIII-D due to large difference in HFS vs. LFS, requiring careful exercise with sensors and different modeling



MARS can be used to address sensor capability of dynamic multi-mode responses







- Padé approximation indicates two modes contribute to fluid response
- Second least stable mode also dominates n=2 fluid plasma response
- Good sensors (UISL in the example) can better resolve the two modes – can be tested for NSTX-U sensors

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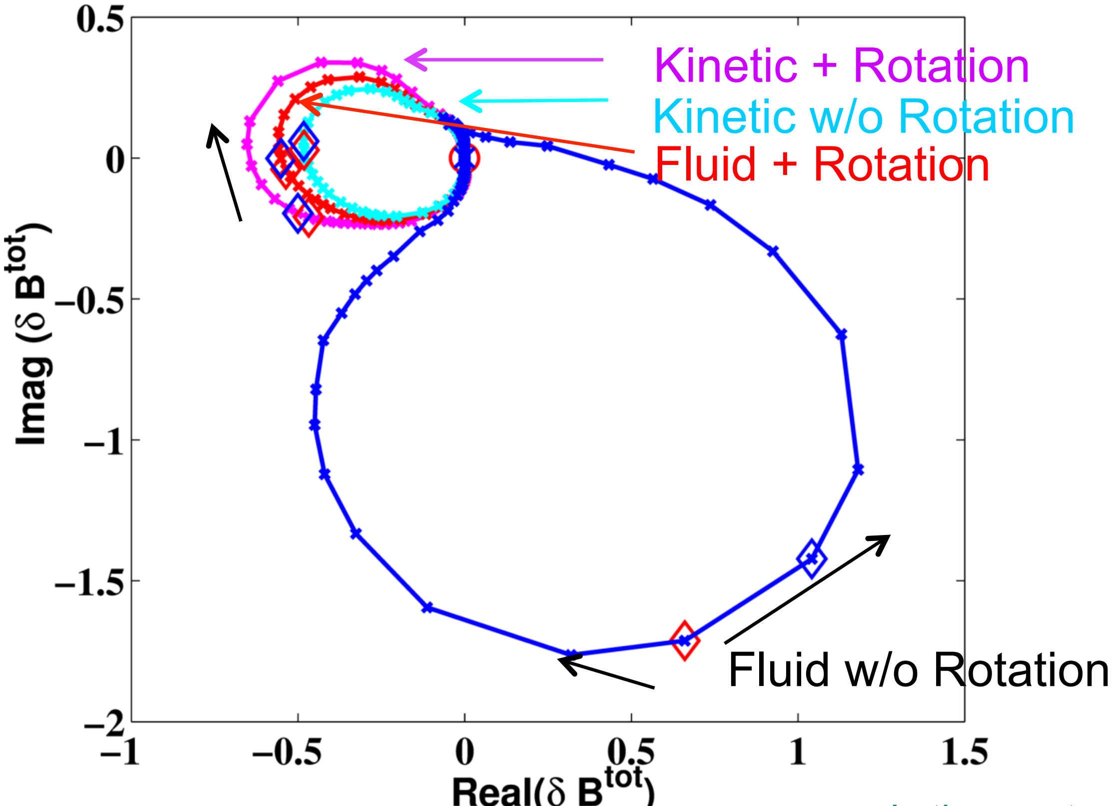
MARS Nyquist contour can be tested with different design of NSTX-U sensors to validate physics model and multi-modes

- MARS shows clear separation of Nyquist contour in frequency response depending on physics model
- With validated model, MARS can be used to test capability of designed sensors to discriminate secondary or higher order mode responses

NSTX high-β response to midplane n=1 at the upper Br sensor



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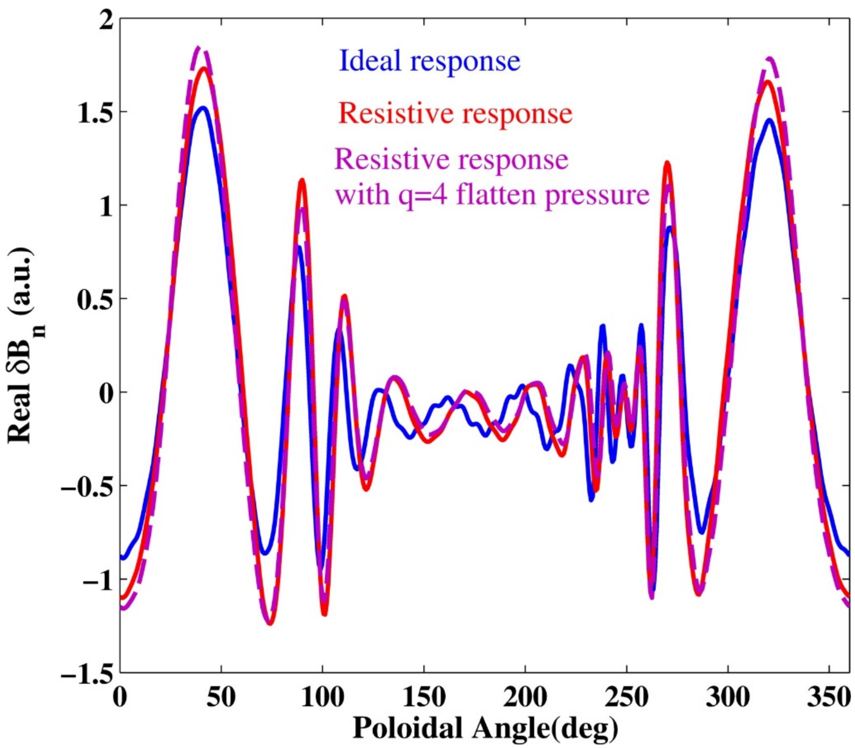
MARS can be used to address sensor capability for ideal vs. resistive response for NSTX-U, as shown in DIII-D

- In recent DIII-D experiments, 90 deg phase change at HFS has been observed at the transition of ELM suppression in the presence of n=2 external perturbation (Nazikian)
- MARS resistive simulation shows a quantitative agreement with experimental observation
  - Resistive response show ~90 deg phase difference compared to ideal response at HFS
- For NSTX-U, MARS can be used to locate sensors to amplify difference of resistive response vs. ideal response



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