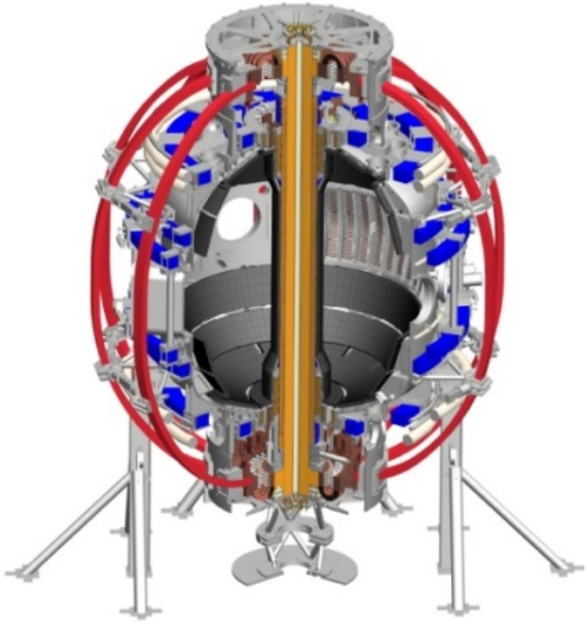
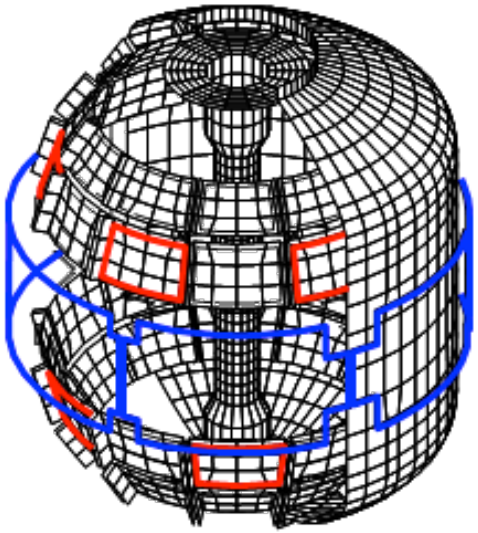
Updates for NCC Working Group

Jong-Kyu Park
For NCC Working Group

NSTX-U NCC WG Meeting

March 23rd, 2015





Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
NFRI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

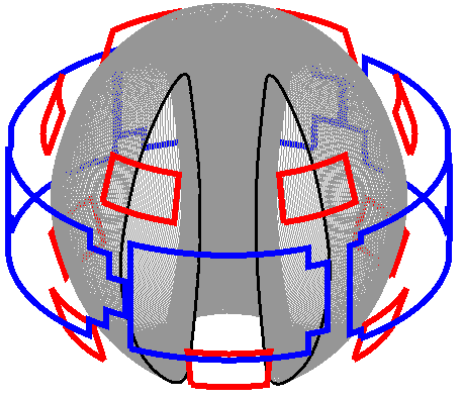
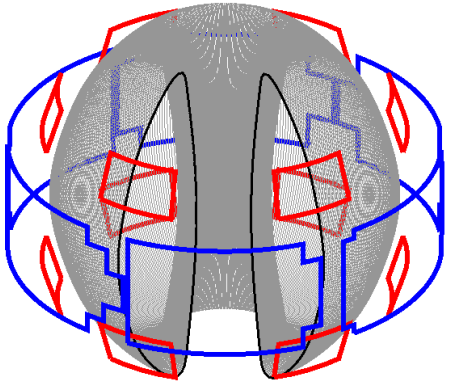
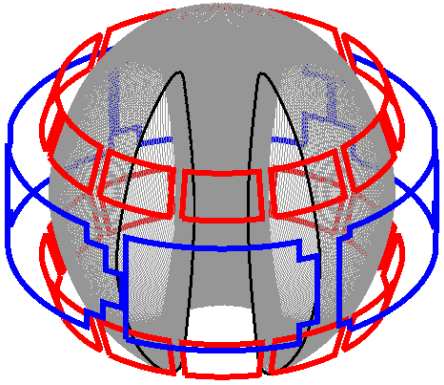
NCC WG goals and deliverables

- Deliverables (by April 2015):
  - Give presentation making recommendations on NCC and SPA performance requirements, gather and incorporate team input
  - Generate written report (5-20pp Word file) documenting NCC and SPA requirements for use in developing engineering requirements document (GRD) to drive engineering design

- Charges:
  - Specify required coil current, frequency, and location for NCC
    - Consider full set (24 coils) and partial set (12 coils)
    - Consider range of applications: NTV, EFC, RWM, RMP, ELM pacing, etc...
  - Specify required number of independent SPA channels vs. applications and requested capabilities

Key questions

- Partial NCC odd vs. even vs. Full NCC

- 1 turn vs. 2 turns (3kAt or 6kAt?)
  - 1 turn is much more preferred in engineering
- # of SPAs recommended
- Answers can be different whether
  - NCC is considered alone and compared to midplane coil
  - NCC + midplane is fully considered for optimization

Physics analysis with partial/full NCC options

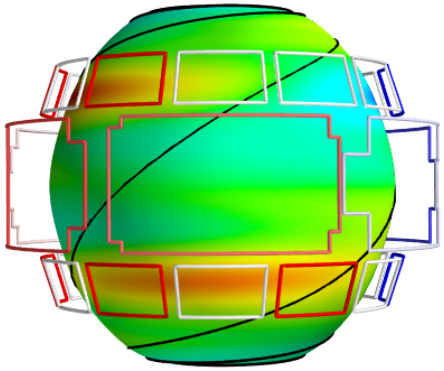
- Two equilibrium targets + TRANSP kinetic profiles were used
- Figures of merit were defined for EF, RWM, NTV, RMP, and analyzed using readily available tools (IPEC, PENT, VALEN3D, TRIP3D, POCA) for NCC alone, compared to midplane alone

Figures of Merit	Favorable values	MID	12U	2x6-Odd	2x12
EF (n=1) $F_{N-R} \equiv \frac{T_{NTV}}{\sum_{\psi_N<0.85} \delta B_{mn}^2}$	High F_{N-R}	0.07	0.13	1.24	1.24
RWM (n=1) $F_{\beta} \equiv \frac{\beta_{active}}{\beta_{no-wall}}$	High F_{β}	1.25	1.54	1.61	1.70
NTV (n≥3) $\Delta\left(F_{N-N} \equiv \frac{T_{NTV}(\psi_N<0.5)}{T_{NTV}(\psi_N<1)}\right)$	Wide ΔF_{N-N}	1.00	1.44~6.08	1.75~11.33	6.38~59.4
RMP (n≥3) $F_{N-C} \equiv \frac{\left(C_{vacuum,\psi_N=0.85}\right)^4}{T_{NTV}}$	High F_{N-C}	0.25~0.30	0.31~1.04	0.43~0.77	1.18~3.53
	Wide ΔF_{N-C}	1.00	2.20~12.3	10.4~17.4	888~14400

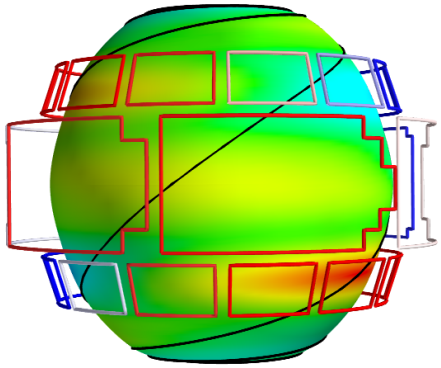
For n=1 NTV/RMP: Roughly Partial 2 turns = Full 1 turn

- Partial NCC can drive the same n=1 field as full NCC if coil currents are doubled

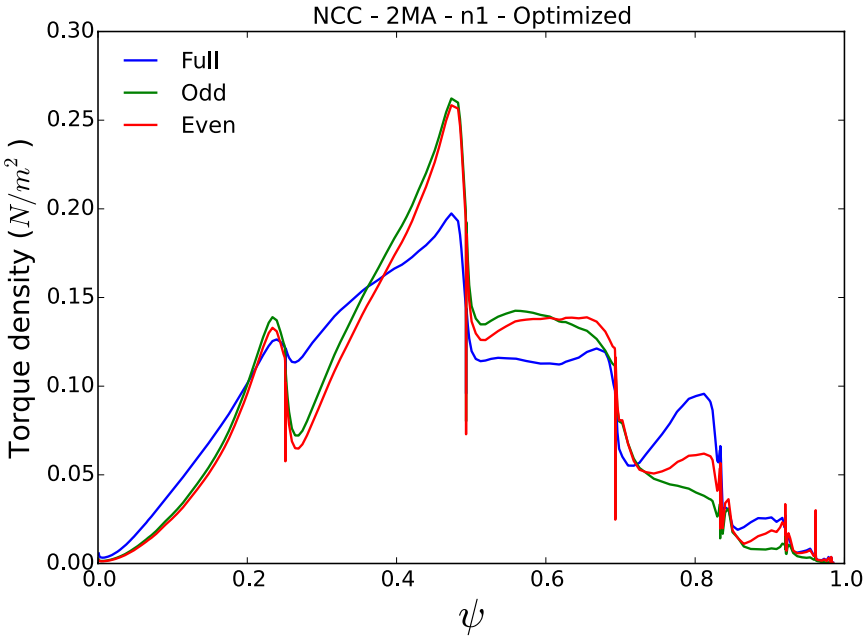
Partial (Even)



Full NCC



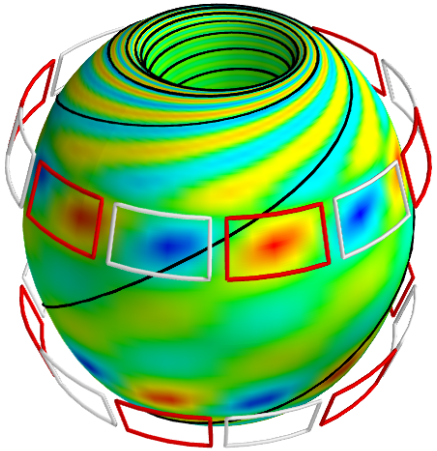
- ***Full NCC 1 turn < 1 Nm***
- ***Upper/Mid/Lower ~ 3:2:3***
- ***Partial NCC 1 turn < 0.3 Nm***
- ***Upper/Mid/Lower ~ 6:2:6***



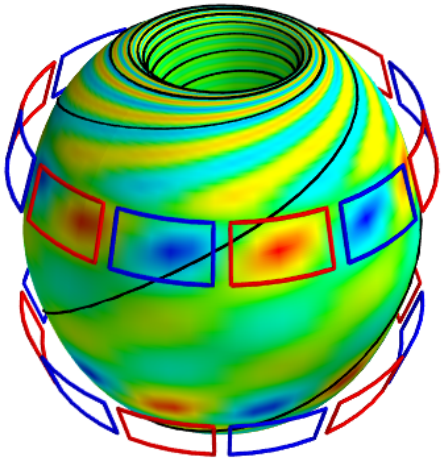
For n=6 NTV/RMP: Partial 2 turns = Full 1 turn

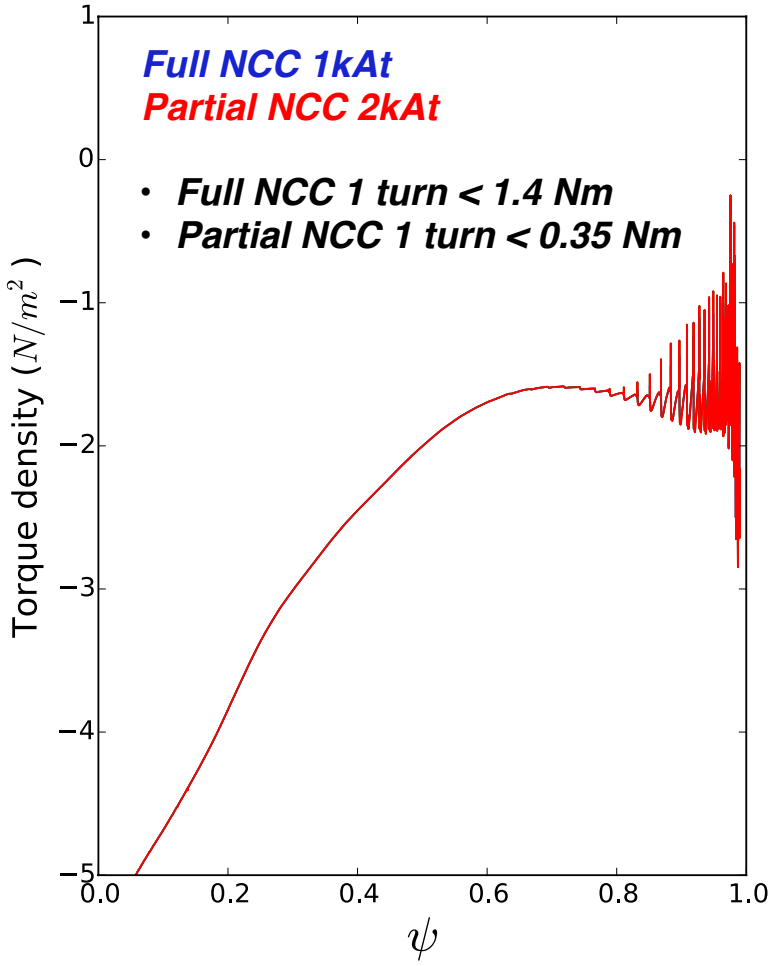
- Partial NCC can drive the same n=6 field as full NCC if coil currents are doubled

Partial (Odd)



Full NCC

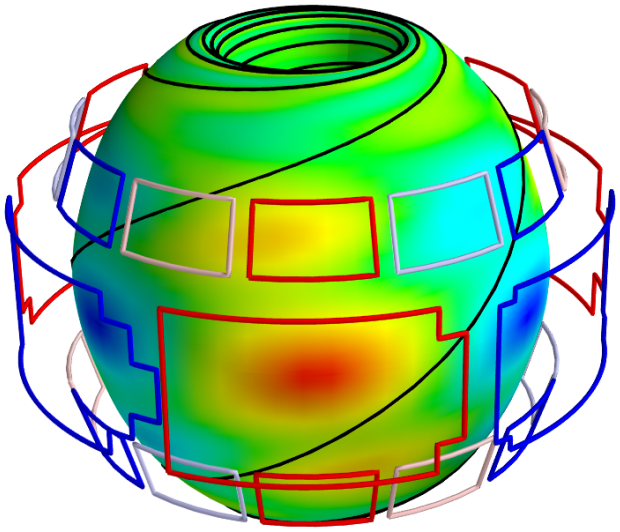




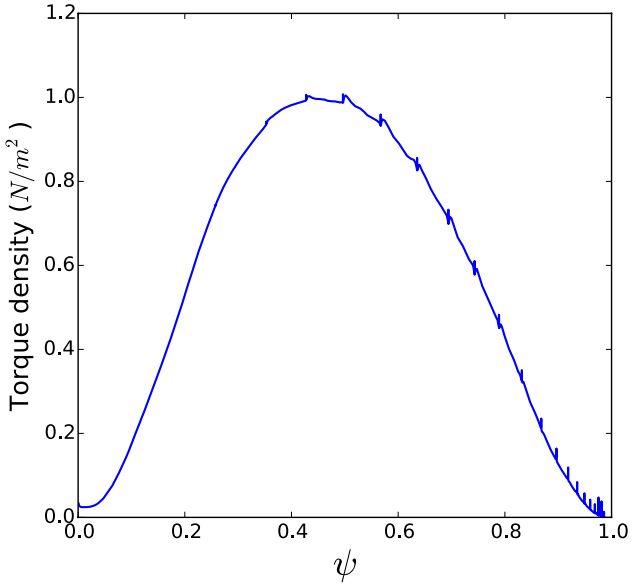
For n=3 NTV : Full NCC provides great capability for core NTV while minimizing all the resonant fields

- IPECOPT shows full NCC can be optimized to drive core NTV while minimizing all the resonant fields at the rational surfaces
  - Optimized field is almost orthogonal to field lines
  - Plasma is almost transparent to this field

Full NCC



NTV profiles



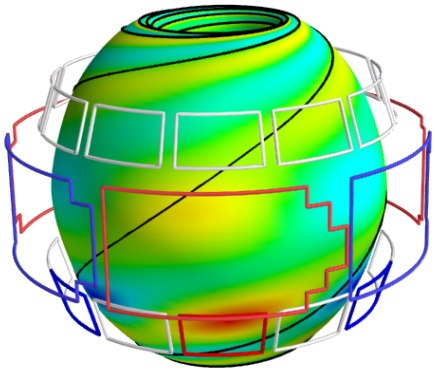
- ***Full NCC 1 turn < 6 Nm***
- ***Upper/Mid/Lower ~ 1:2:1***

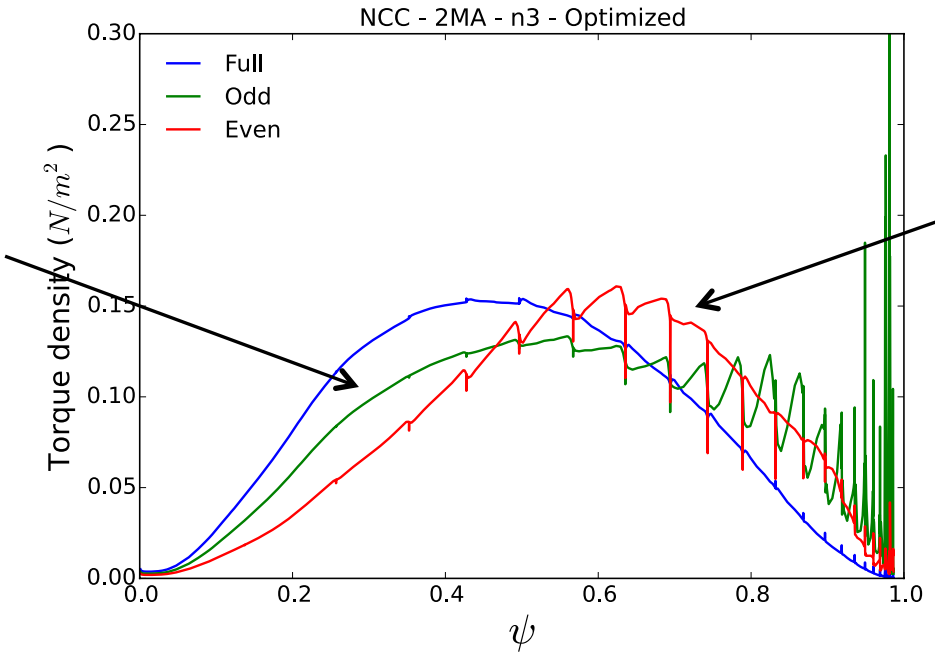
For n=3 NTV : Partial NCC can also provide good core NTV but with 4 times greater coil currents

- In the optimization of partial NCC, not all three array of coils are well utilized
  - With ‘odd’ option: Upper (or lower) coils are not used
  - With ‘even’ option: Midplane coils are weakly used

- ***Odd NCC 1 turn < 1 Nm***
- ***Upper/Mid/Lower ~ 0:2:3***

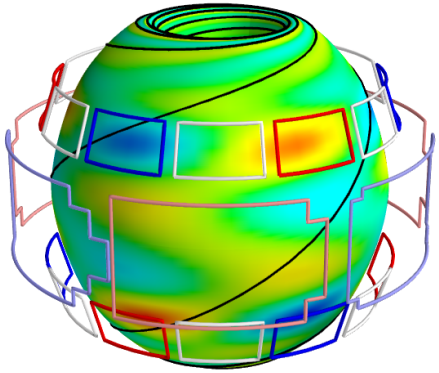
Partial (Odd)





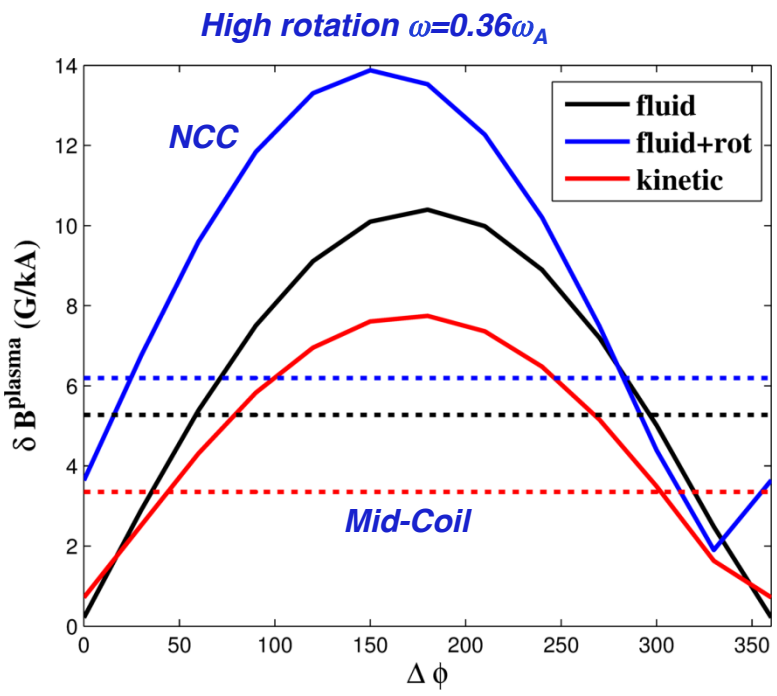
- ***Even NCC 1 turn < 1 Nm***
- ***Upper/Mid/Lower ~ 3:2:3***

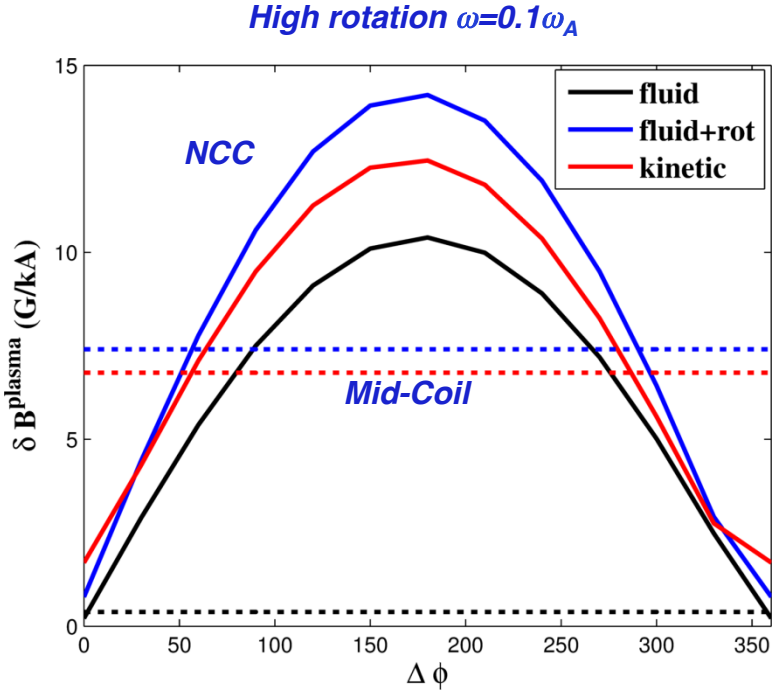
Partial (Even)



Kinetic plasma response is coupling characteristics similar to fluid response for n=1

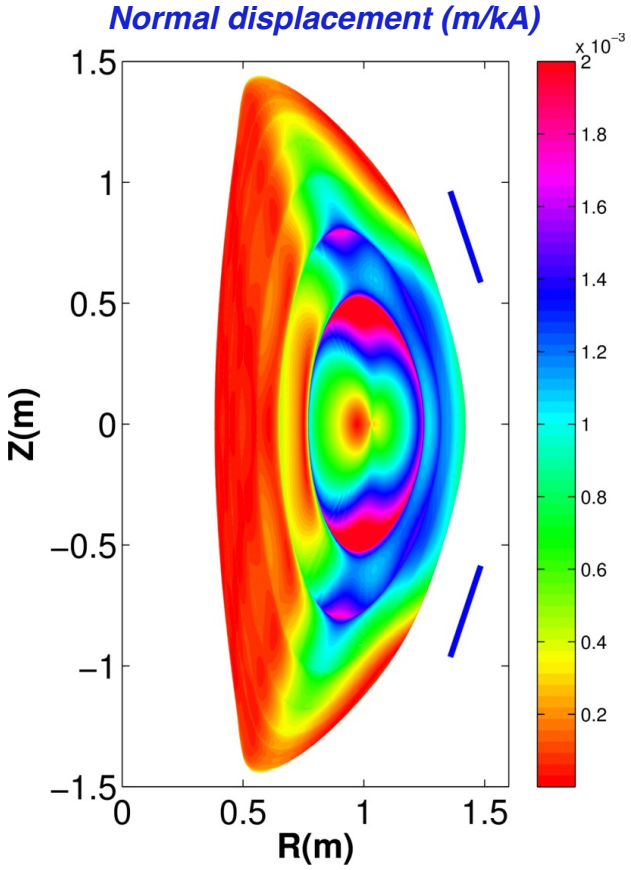
- MARSK applications show the similar characteristics on
  - Relative change in the response compared to midplane coil
  - Coupling vs. phase remains similar
- NCC utility analysis based on ideal MHD may be a reasonably good approximation

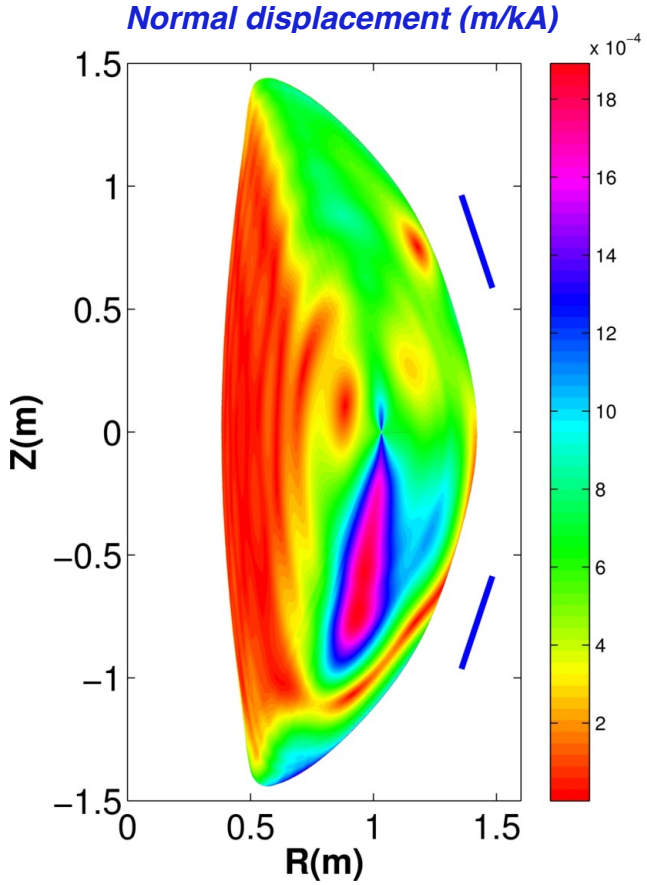




Kinetic response is however richer for internal structure especially when NCC is used

- MARSK shows up-down asymmetric structure for internal displacements when NCC is used, differently from midplane coil
  - Partial or full NCC can be used to study this interesting predictions





Discussion and plans

- Need inputs by April 3rd to finalize "draft of recommendation"
  - Partial NCC odd vs. even vs. Full NCC
  - Maximum currents, or threshold/currents required
    - NTV (Nm/kA), RMP (Chirikov/kA), Stability (Ballooning region/kA)
  - # of SPAs if any

- J.-K will collect analysis from group, and present summary of physics analysis activity and draft of recommendation in the week after April 3rd
  - Gather feedback from group and team
  - Write the written report for GRD (or paper)