Plasma Response to RMP in DIII-D Discharge 142603

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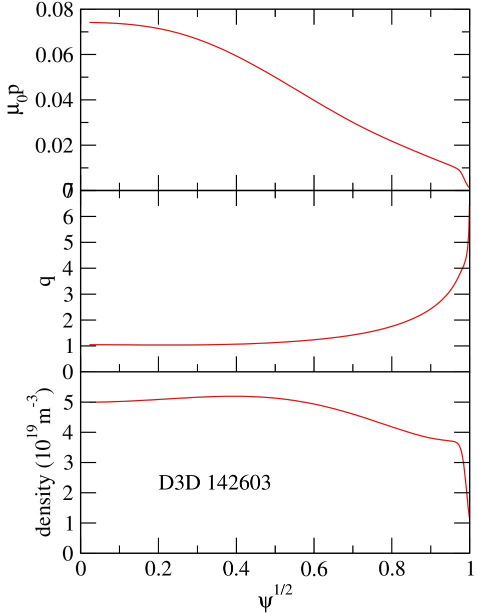
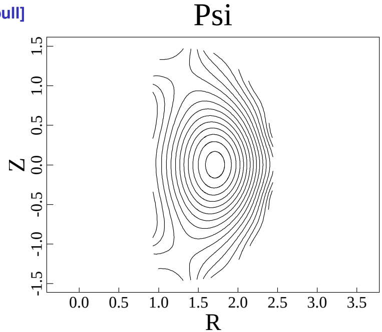
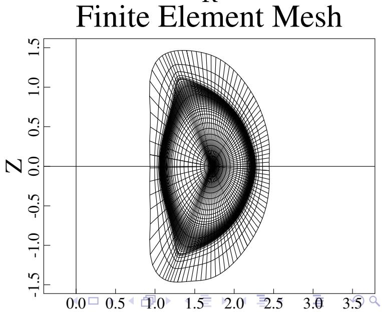
This study is part of the effort to benchmark calculations of plasma response to RMP from several commonly used codes

- Previously, NIMROD code was applied to investigating the "RMP enhanced transport and rotational screening in simulations of DIII-D (#113317) plasmas" [Izzo and Joseph (2008)].
- Present study starts with resistive MHD model and Spitzer resistivity profile where $S_{\rm core} \sim 10^8$ and $S_{\rm edge} \sim 10^6$; No other physical dissipations are assumed in this first attempt.
- `48x96` finite elements with polynomials of order 4 in poloidal domain, 11 toroidal Fourier components are included in the calculations.
- Linear plasma response from a static equilibrium (i.e. no rotation) will be discussed here.

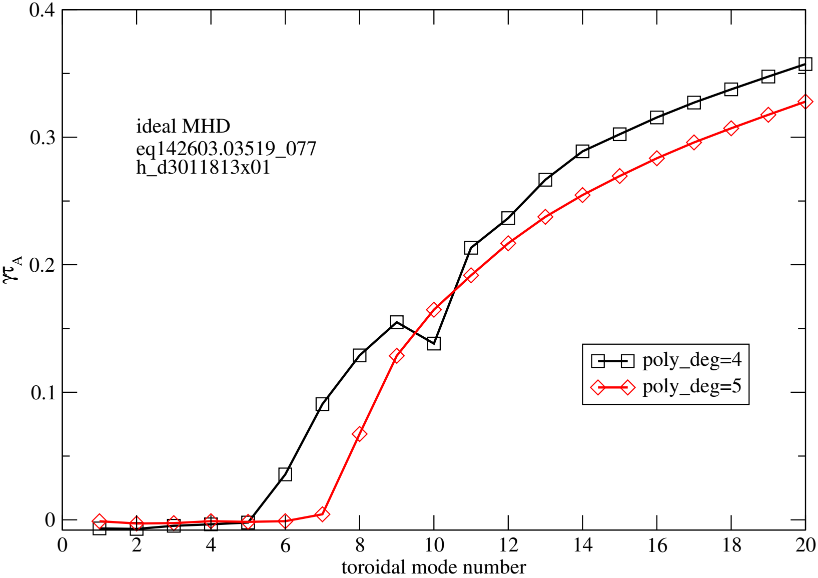
DIII-D discharge 142603 has been subject of several RMP studies [Courtesy of Turnbull]



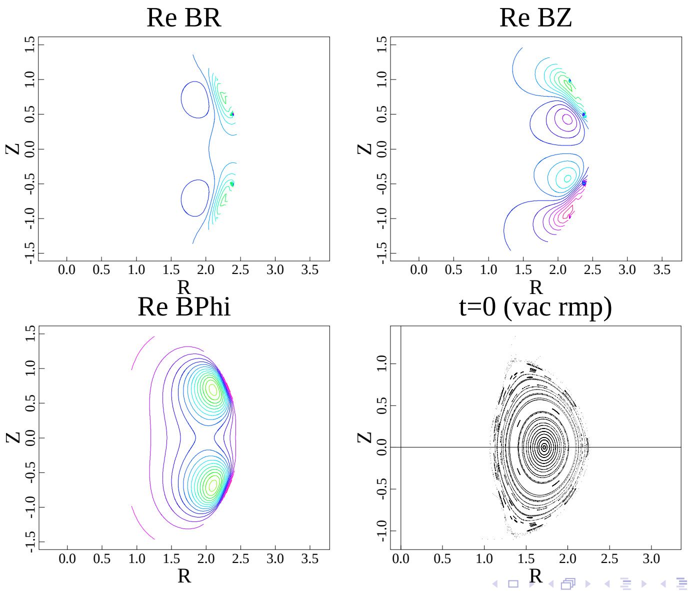




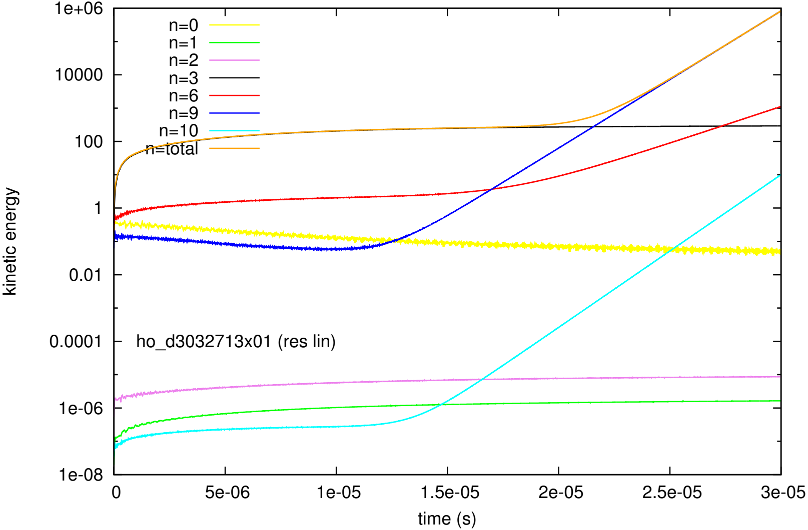
Equilibrium is unstable to ideal MHD edge localized modes for $n > 5$



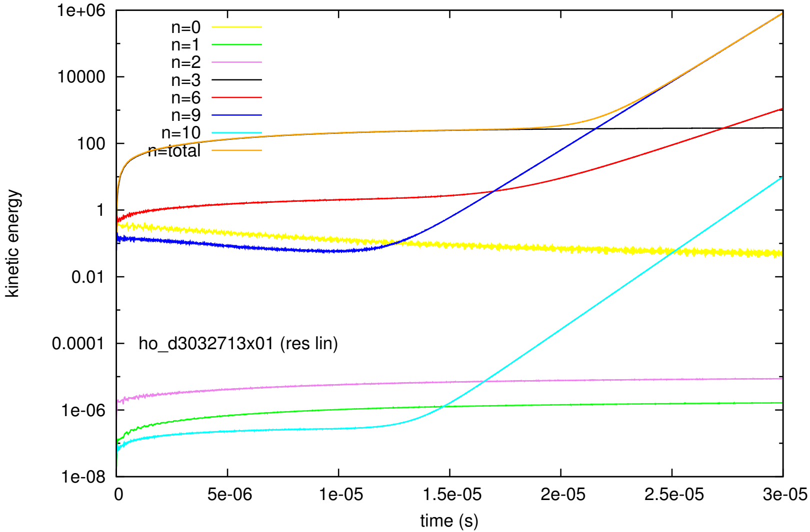
I-coil vacuum field is imposed as initial and boundary conditions ($n_{\mathrm{rmp}} = 3$, even parity) [Courtesy of Izzo]



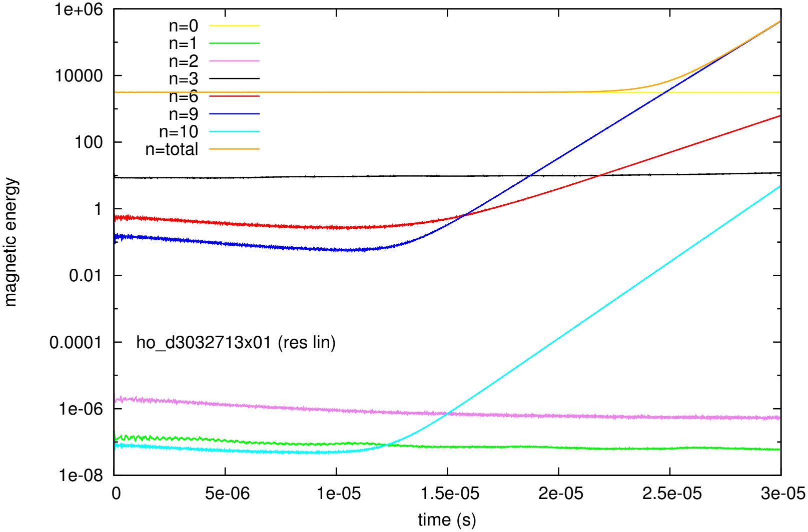
Linear resistive response of static plasma is mainly in the RMP toroidal harmonics ($n = 3, 6, 9$)



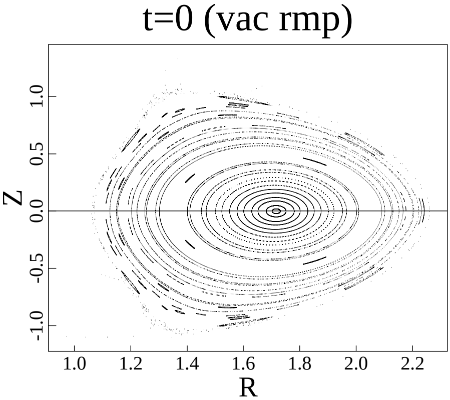
Low-*n* response reaches steady state; high *n* response turns into instability

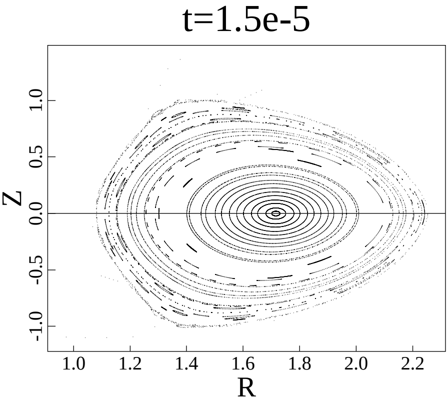


Magnetic energy of primary RMP toroidal component ($n = 3$) remains nearly constant while higher-n harmonics grow in time



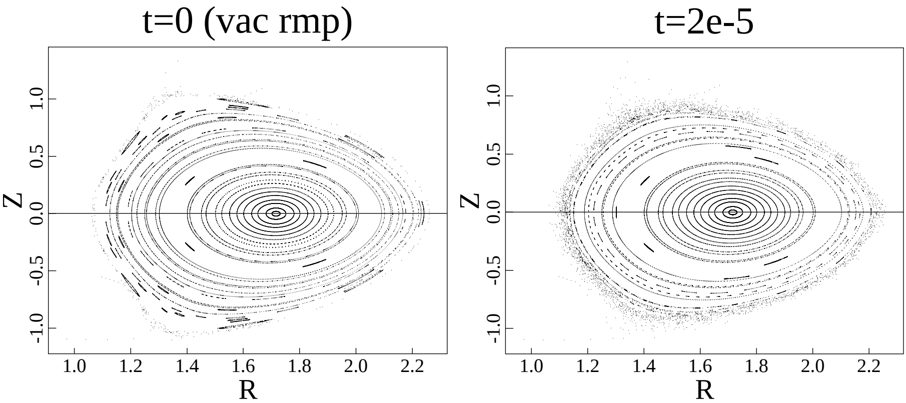
First stage of magnetic response after saturation of $n = 3$ component is similar to vacuum RMP field





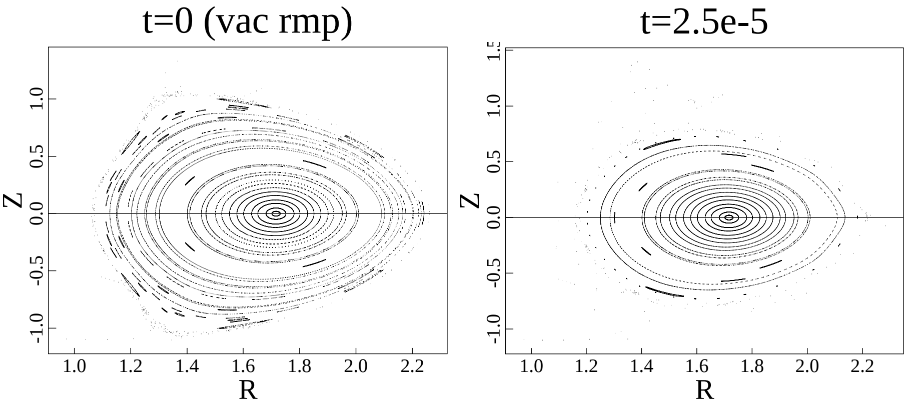
Islands and perturbed flux surfaces are mostly localized at edge pedestal region inside separatrix.

Magnetic response enters second stage as edge pedestal region becomes more stochastic due to higher-*n* growth



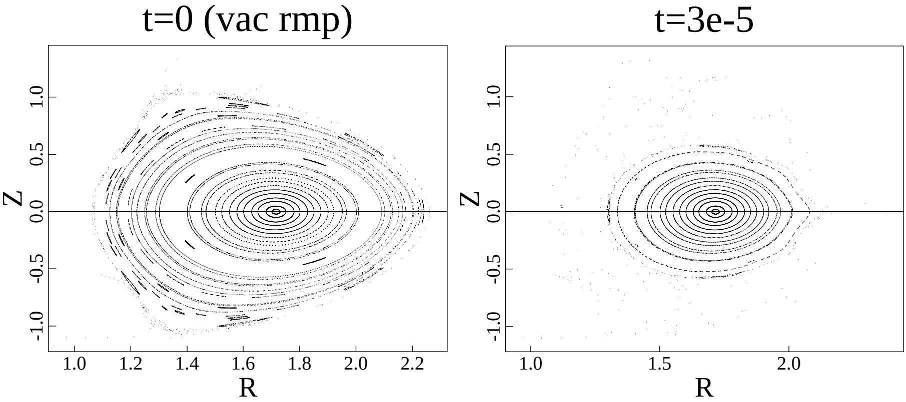
Stochastic region is localized in edge pedestal region.

In third stage the field lines in edge pedestal region become open as growing higher-*n* components start to dominate



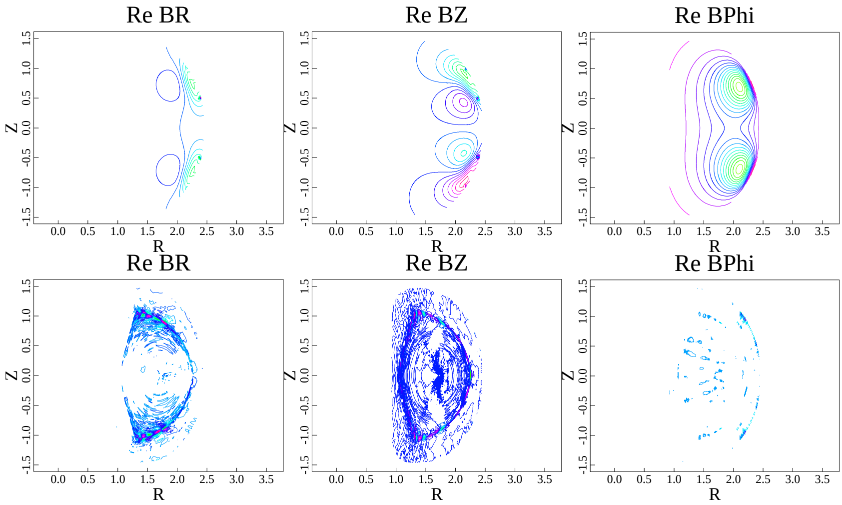
Magnetic structures inside edge pedestal remain similar to vacuum field.

Growing edge localized modes eventually deplete flux surfaces in pedestal region

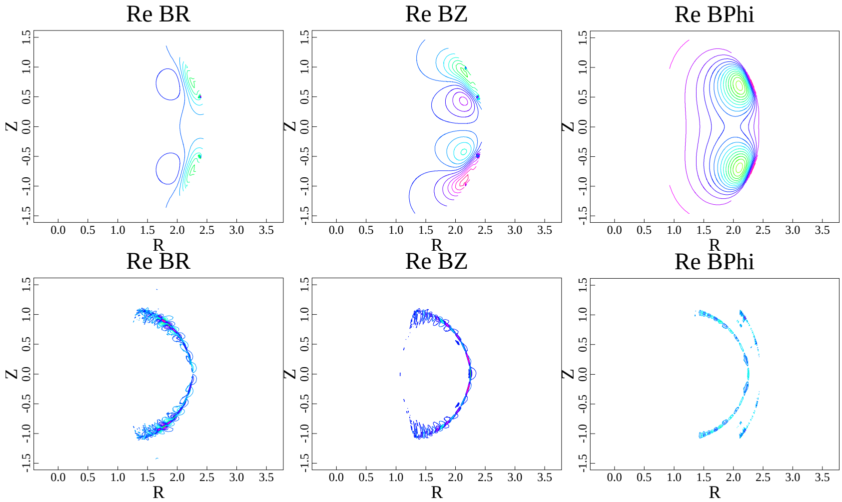


Field lines in pedestal region escape to outside of separatrix.

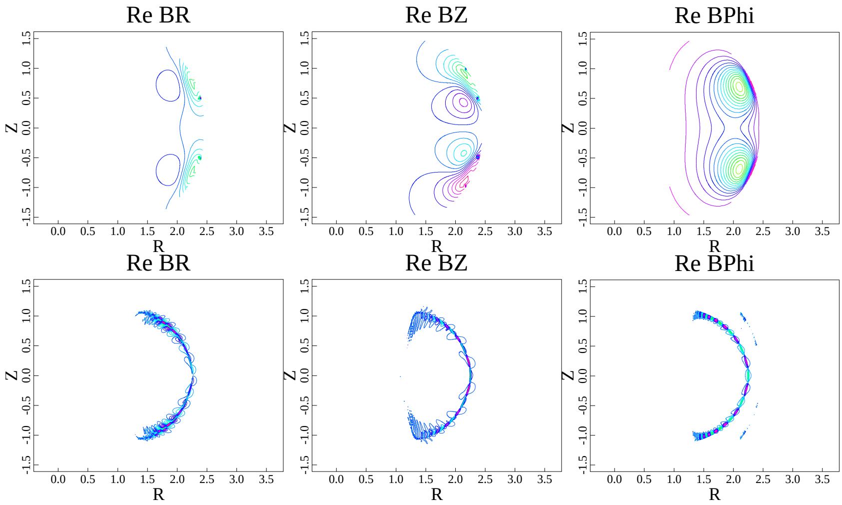
Unlike Poincare plots, contour structure of first stage resonant magnetic response very different from vacuum field



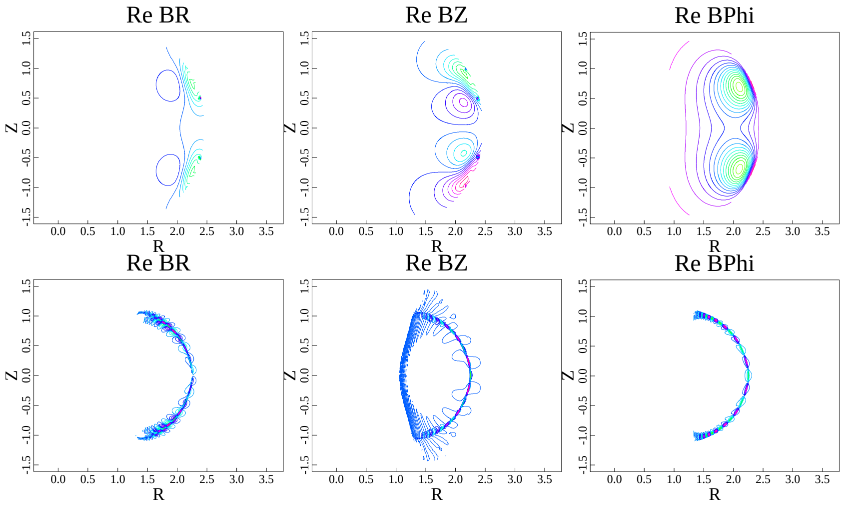
In second stage of response edge localized mode structure transitions to that of high-*n* ballooning



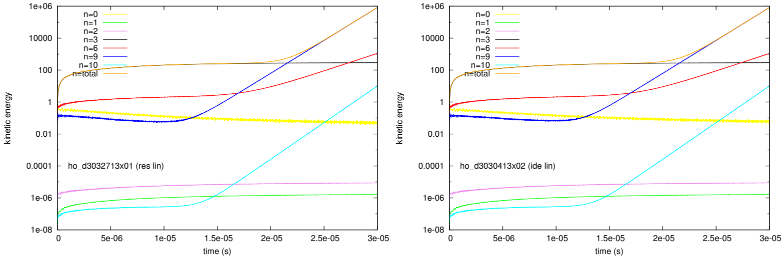
Contours of mode structure show final stage of response is dominated by high-*n* edge localized ballooning mode



Structure of final response not visually different from an intrinsically growing high-*n* edge localized ballooning in absence of RMP

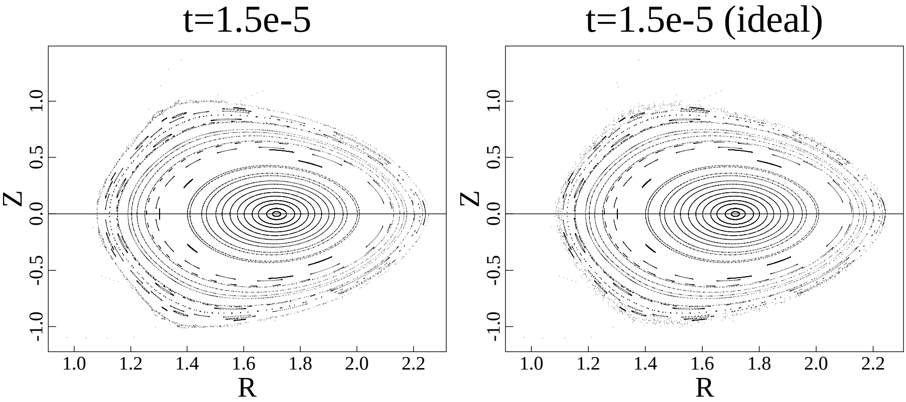


In experimental resistivity regime the plasma response to RMP is nearly ideal



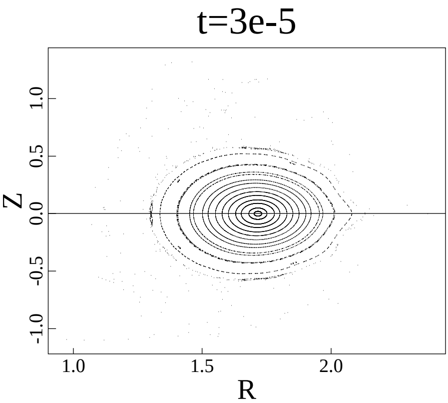
Left: Spitzer resistivity; Right: ideal MHD

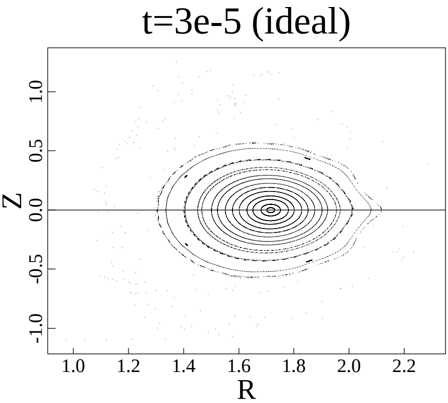
During initial stage, structures of resistive and ideal magnetic response appear similar



Resonant responses form near edge region inside separatrix.

During final stage, good flux surfaces are better preserved in ideal response than in resistive response





In both cases flux surfaces in edge pedestal region are lost.

Summary and discussion

- Initial efforts have started to model plasma response to RMP in a DIII-D discharge (# 142603).
- Primary (low-n) RMP component tends to make edge pedestal region stochastic.
- High-n RMP component can drive edge localized ballooning instability and deplete good flux surfaces in edge pedestal region.
- In experimental resistivity regime, ideal and resistive response appear similar.
- Benchmark studies with other code calculations are planned.