Plasma Response to RMP in Unstable Pedestal

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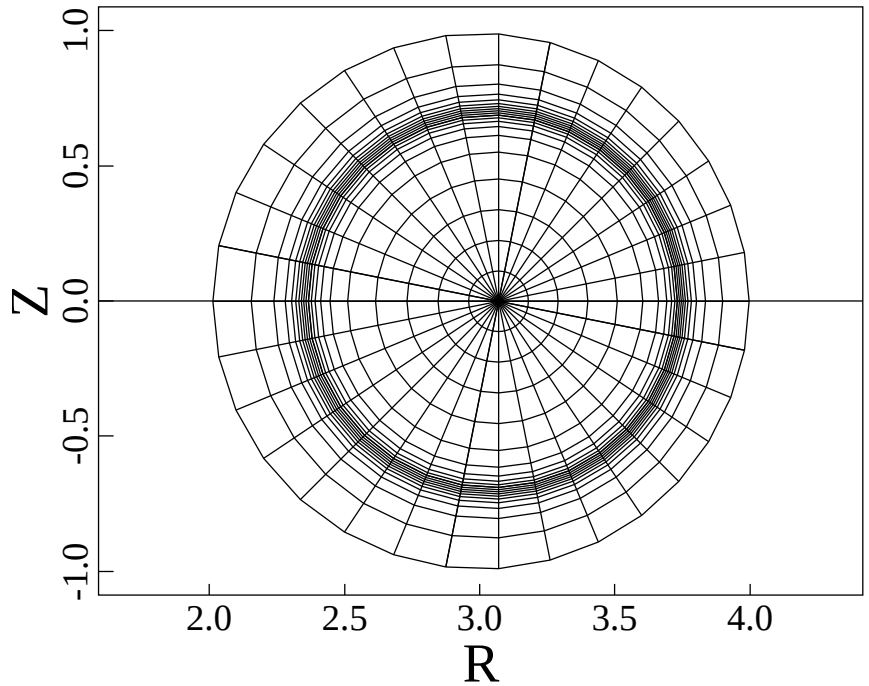
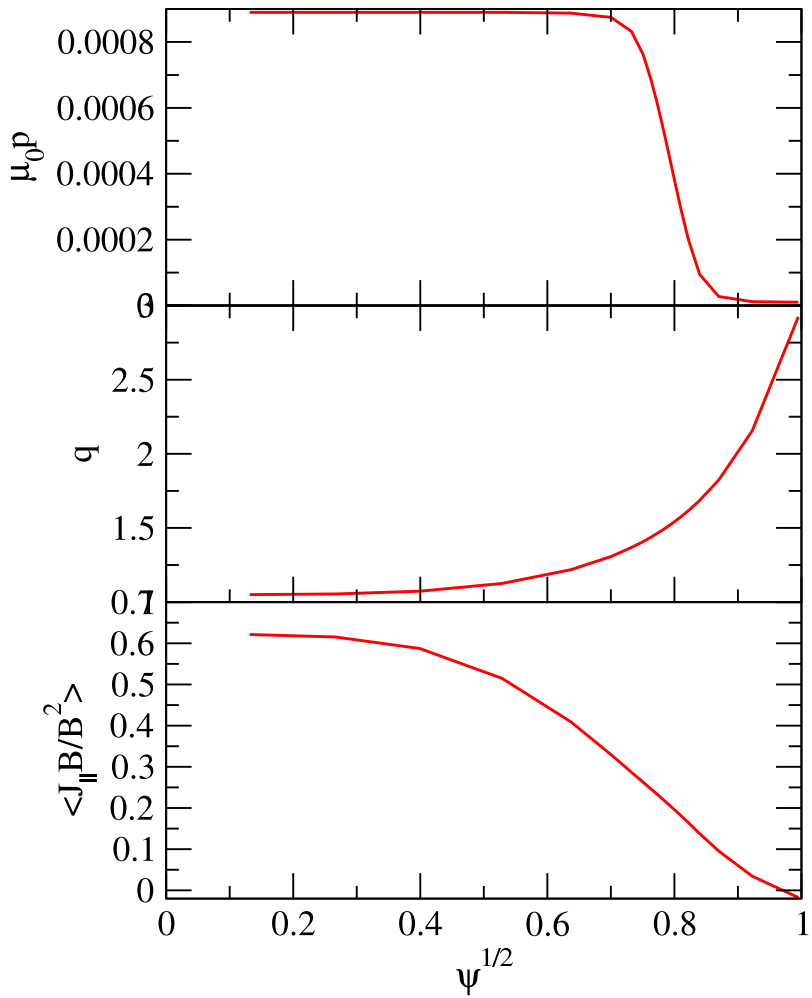
How would the plasma in an unstable edge pedestal respond to RMP?

- In experiments RMPs are believed to change properties of the unstable H-mode edge pedestal.
- Low β stable edge pedestal
  - Linear response
  - Nonlinear response
- High β unstable edge pedestal
  - Linear response
  - Nonlinear response
- Resistive MHD model with $\eta = 25$ ($S \sim 10^5$), $D = 25$, $\mu_{\text{kin}} = 25$, $\chi_\perp = 1$, $\chi_\parallel = 10^8$.
- `20x32, poly=5`, 22 toroidal Fourier components are included in the nonlinear simulations.
- Summary and discussion

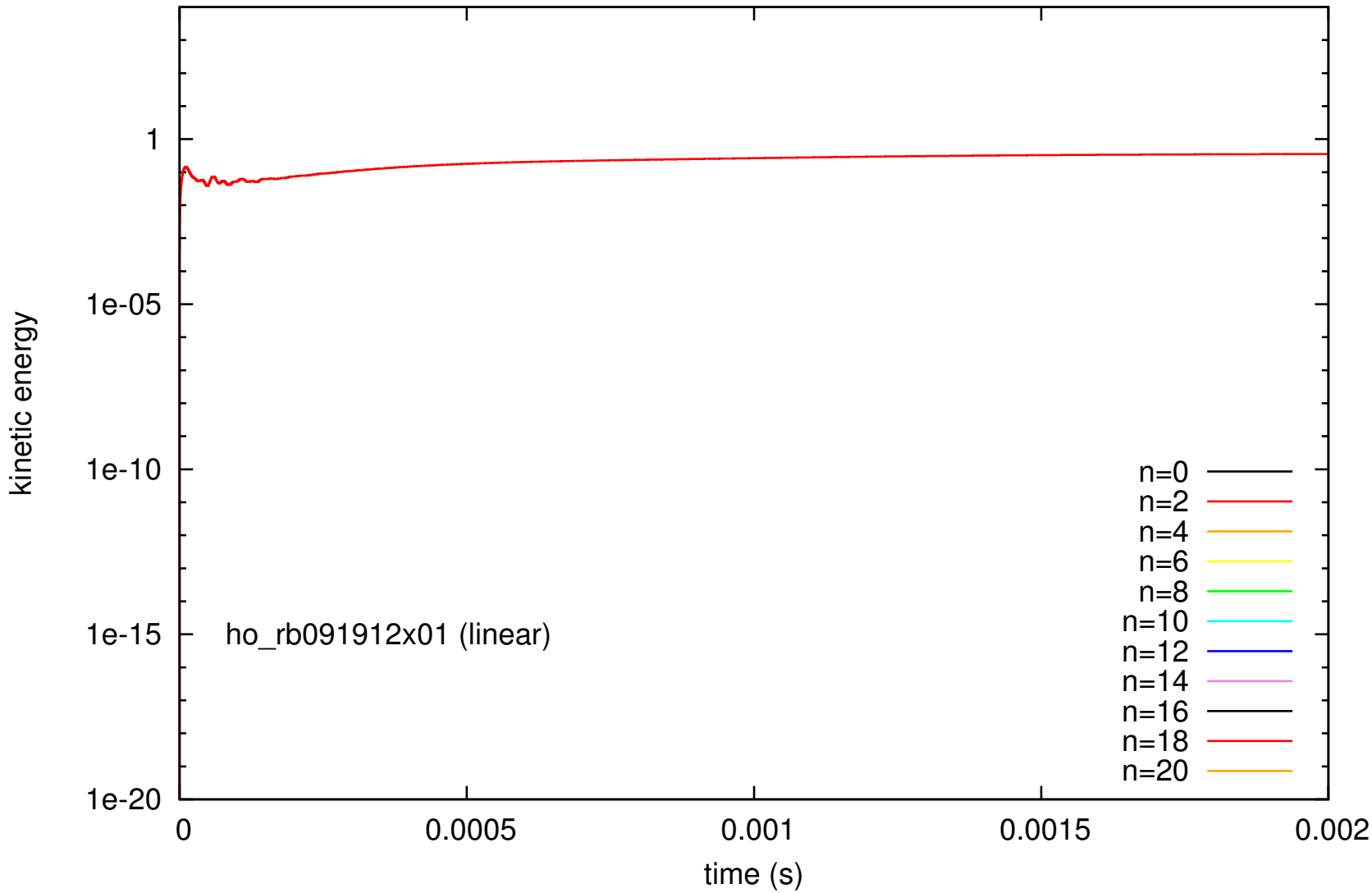
A circular-shaped limiter equilibrium with low β is stable to all toroidal modes $n > 0$



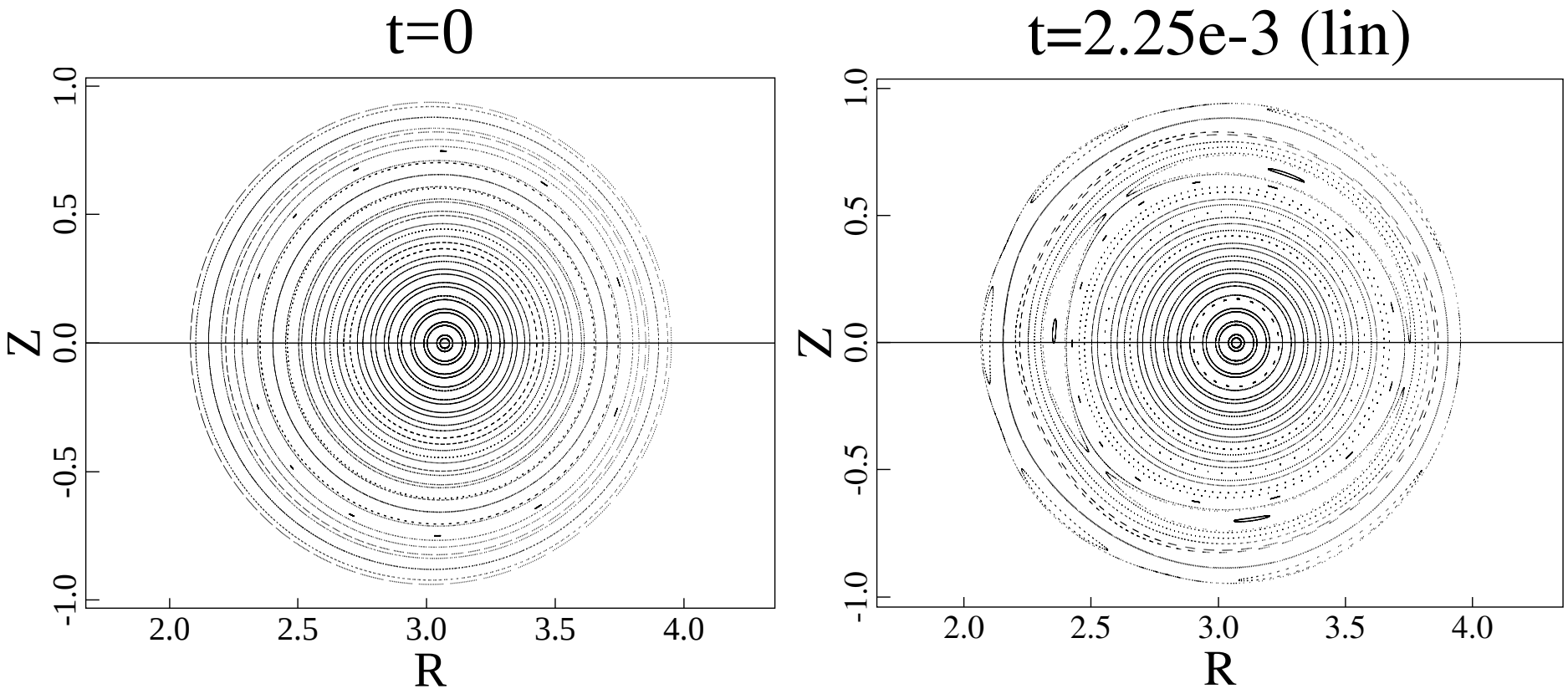
- $\beta \sim 0.1\%$ at pedestal top
- $m/n = 3/2$ RMP imposed as B.C.
- $q = 1.5$ in pedestal center.



Linear resistive response of stable edge pedestal is solely in the RMP toroidal harmonic ($n = 2$)

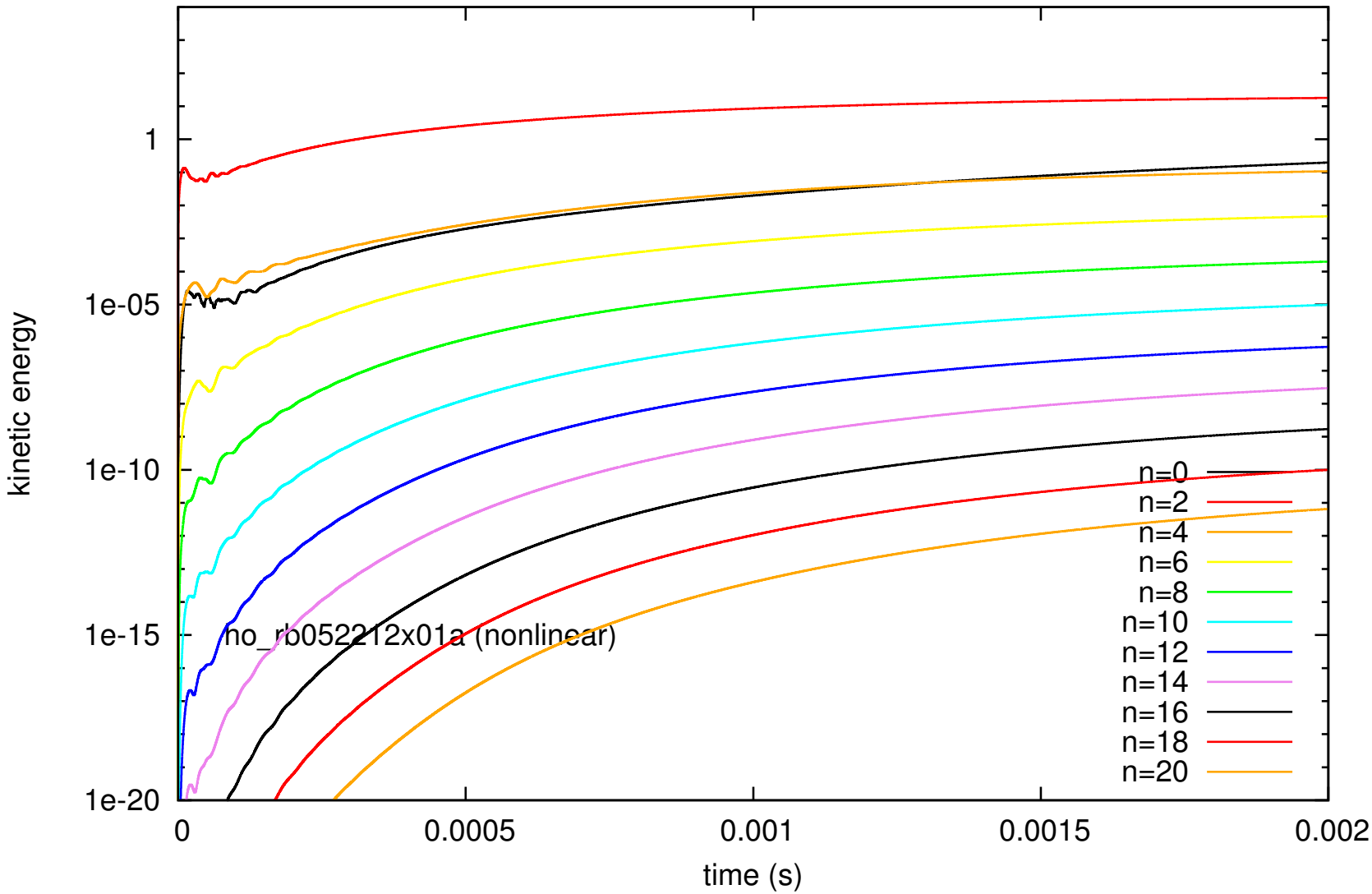


Regular island structures are clearly formed at resonant surfaces in saturated state

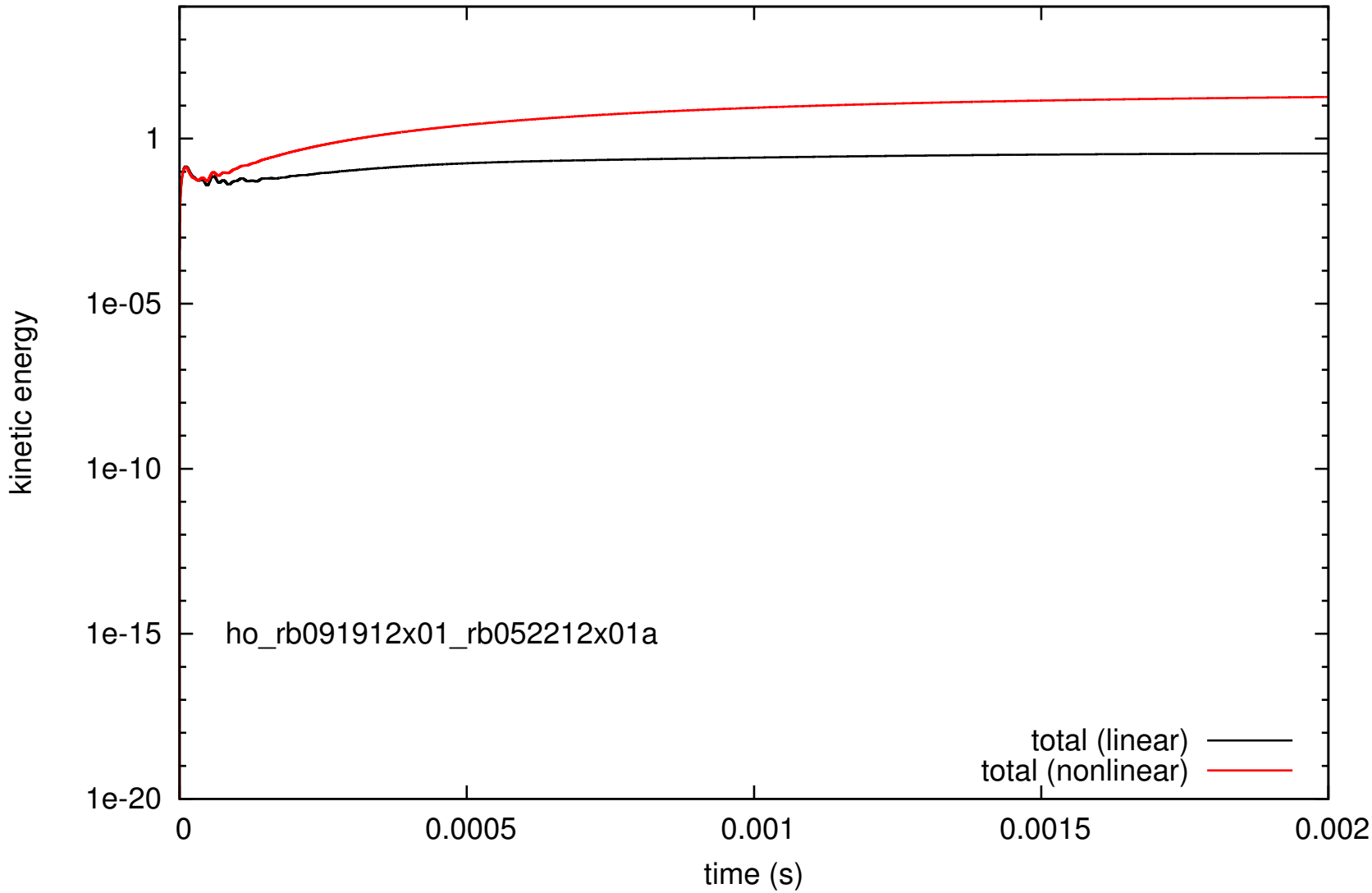


$m = 3, 4, 5$ islands form in response to $n = 2$ RMP B.C.

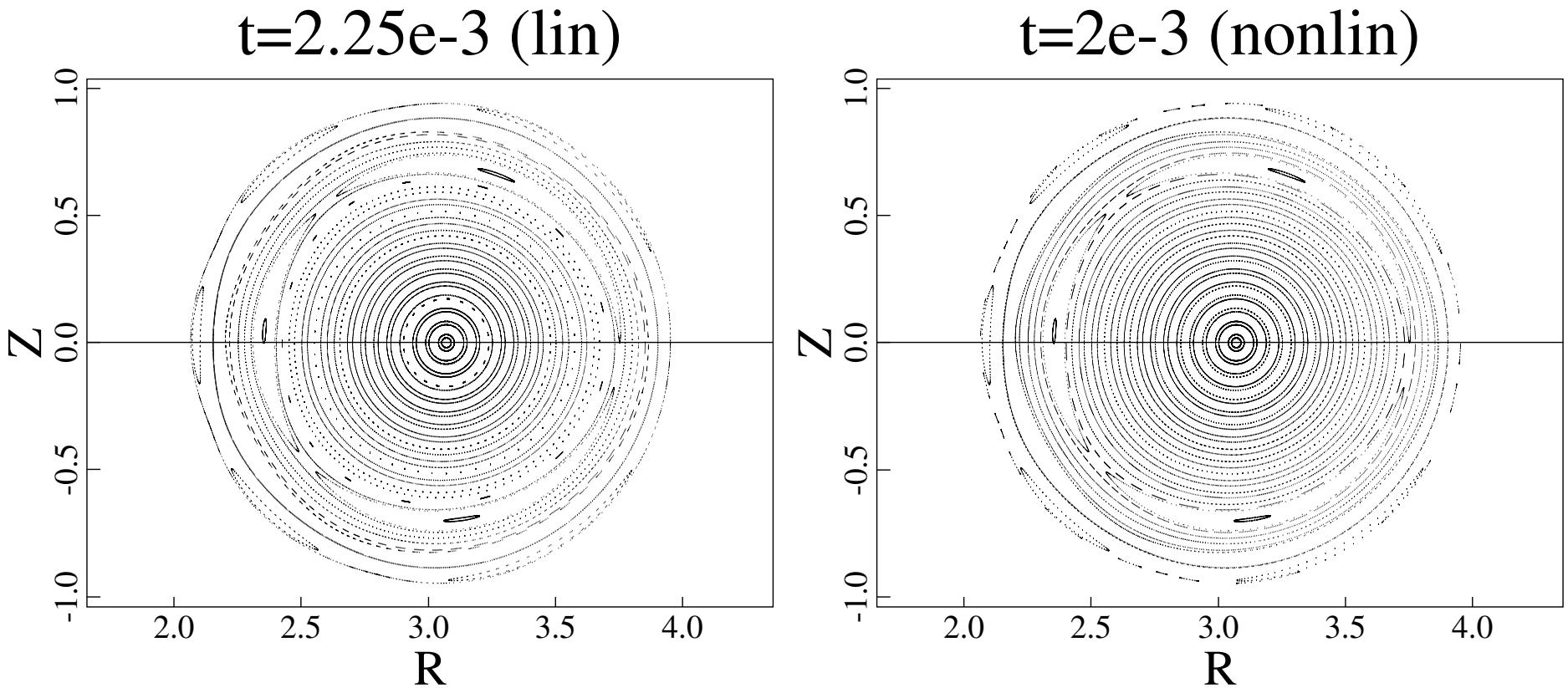
Nonlinear resistive response of stable equilibrium dominated by RMP toroidal harmonic ($n = 2$)



Saturated plasma flow in nonlinear response is significantly (10 times) stronger than in linear response

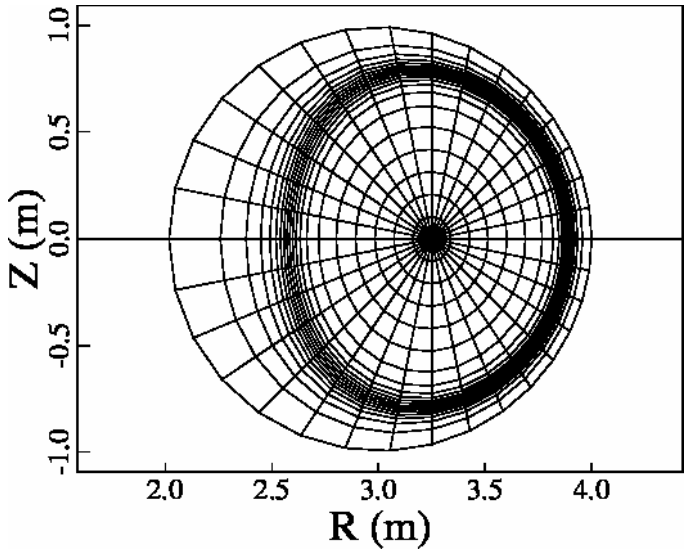


Island structures due to linear and nonlinear responses to RMP in stable pedestal are similar

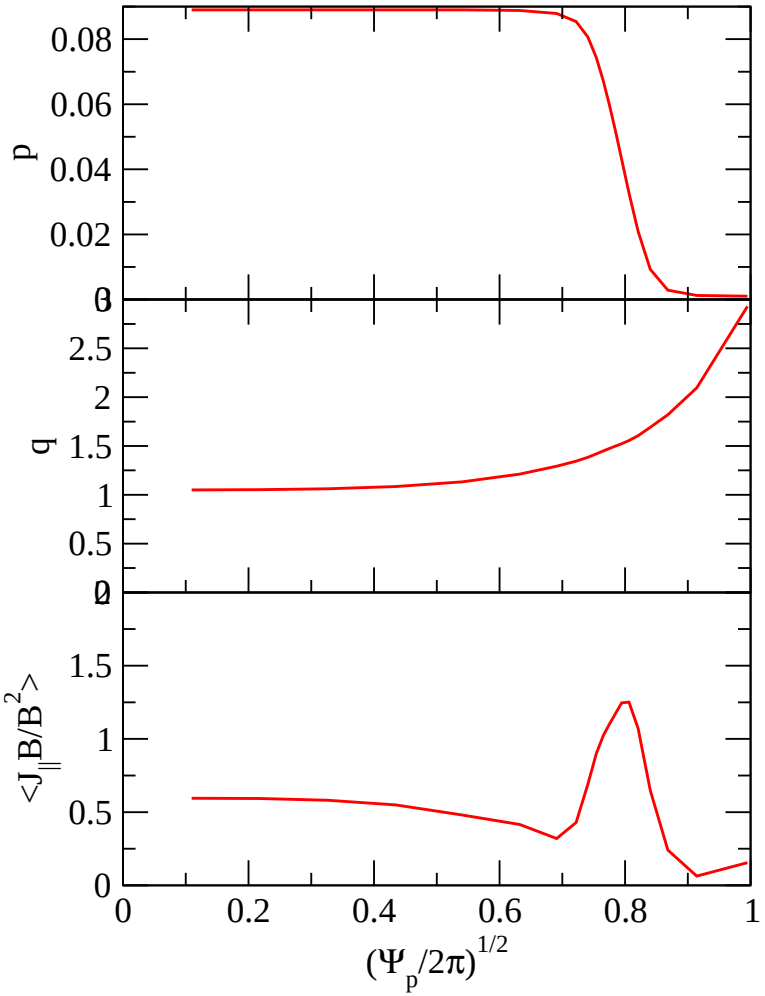


$m = 3, 4, 5$ islands form in response to $n = 2$ RMP B.C.

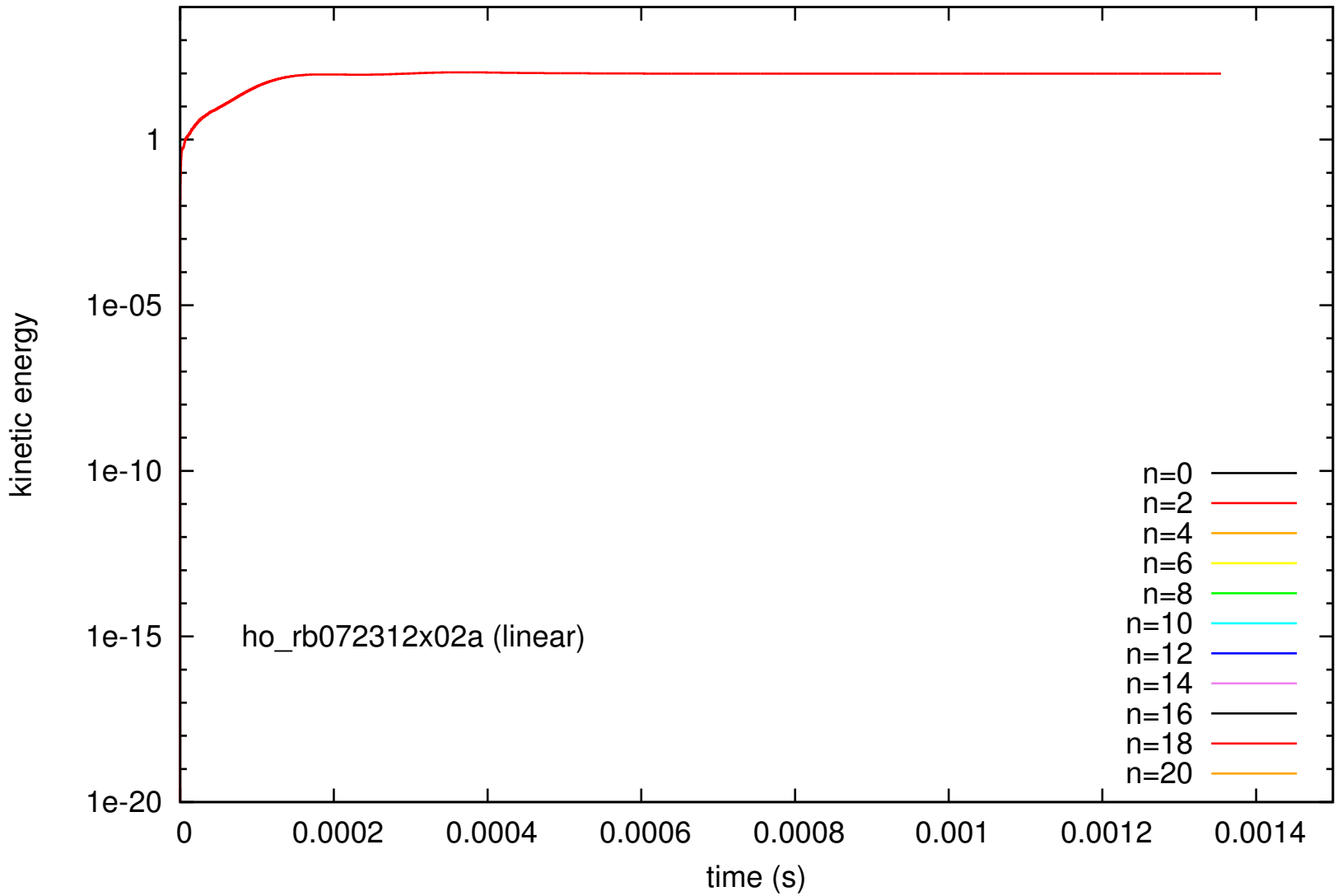
At higher β equilibrium becomes unstable to most edge localized modes



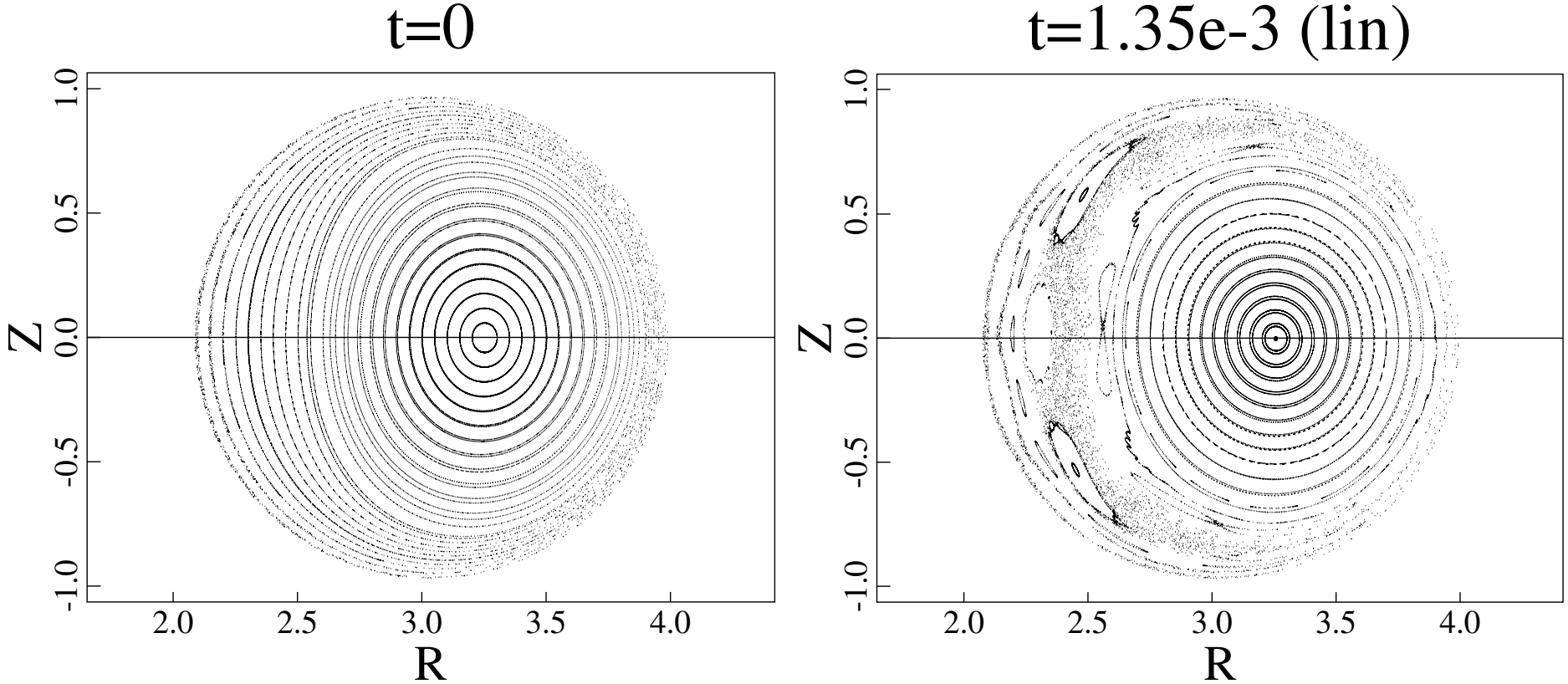
- $\beta \sim 9\%$ at pedestal top
- $n \gtrsim 3$ modes unstable



For unstable pedestal linear plasma response is also solely in the RMP toroidal harmonic ($n = 2$)

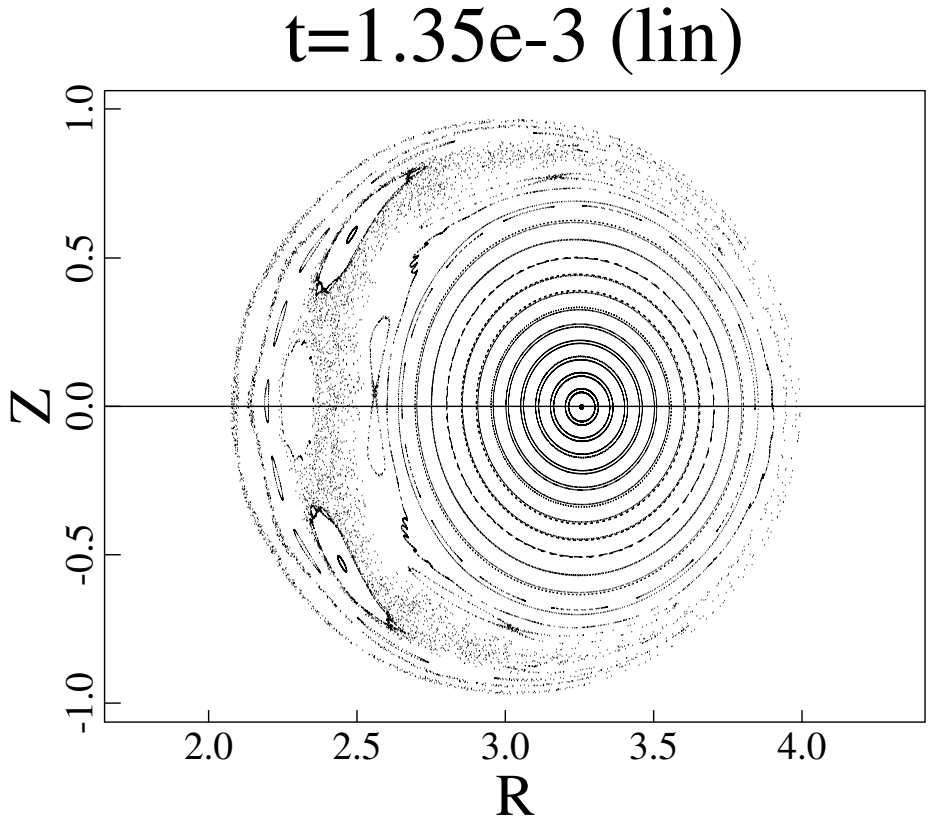


In unstable pedestal helical magnetic structures due to linear plasma response become more complicated than in stable pedestal

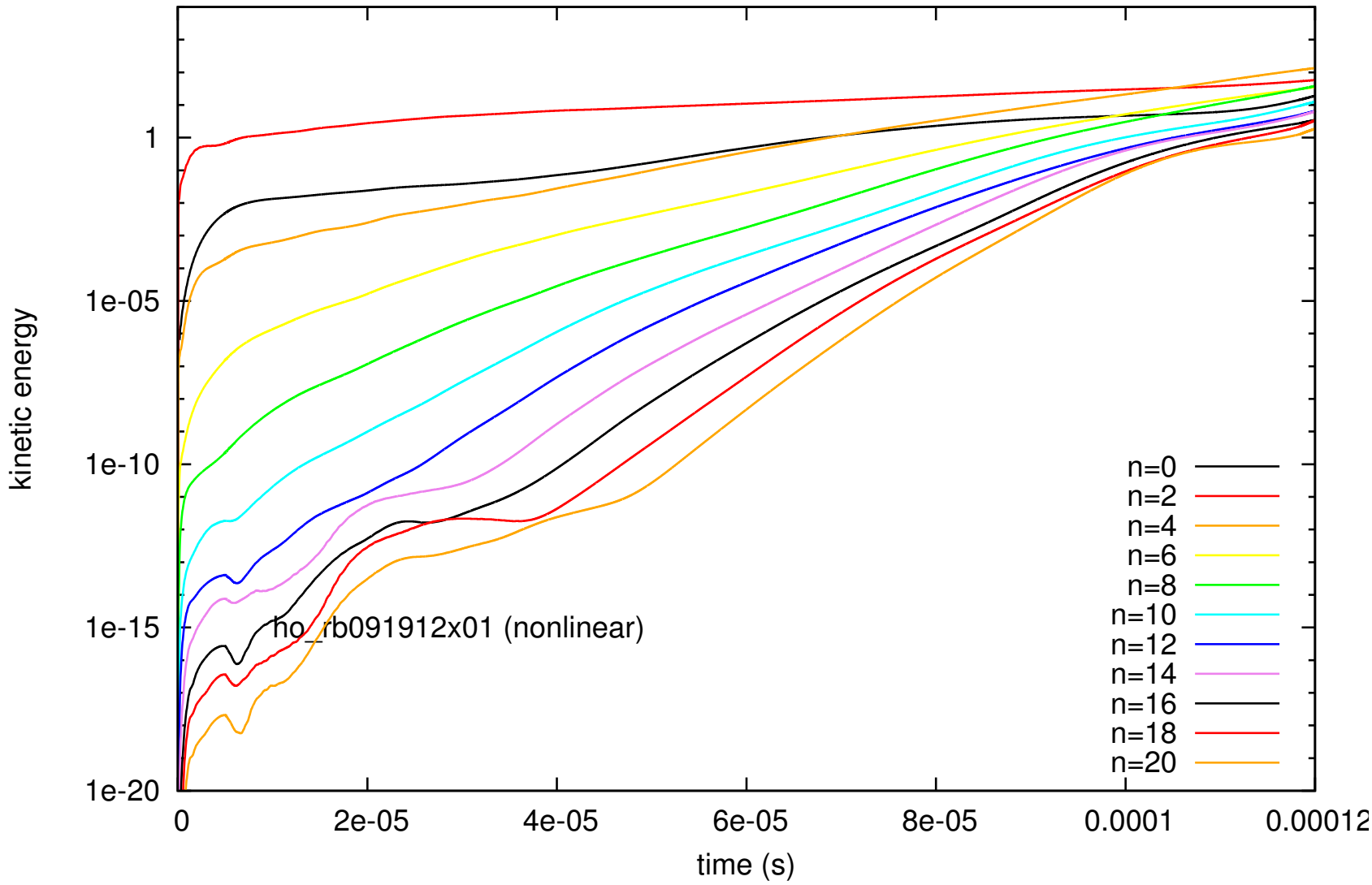


In unstable pedestal helical magnetic structures due to linear plasma response become more complicated than in stable pedestal

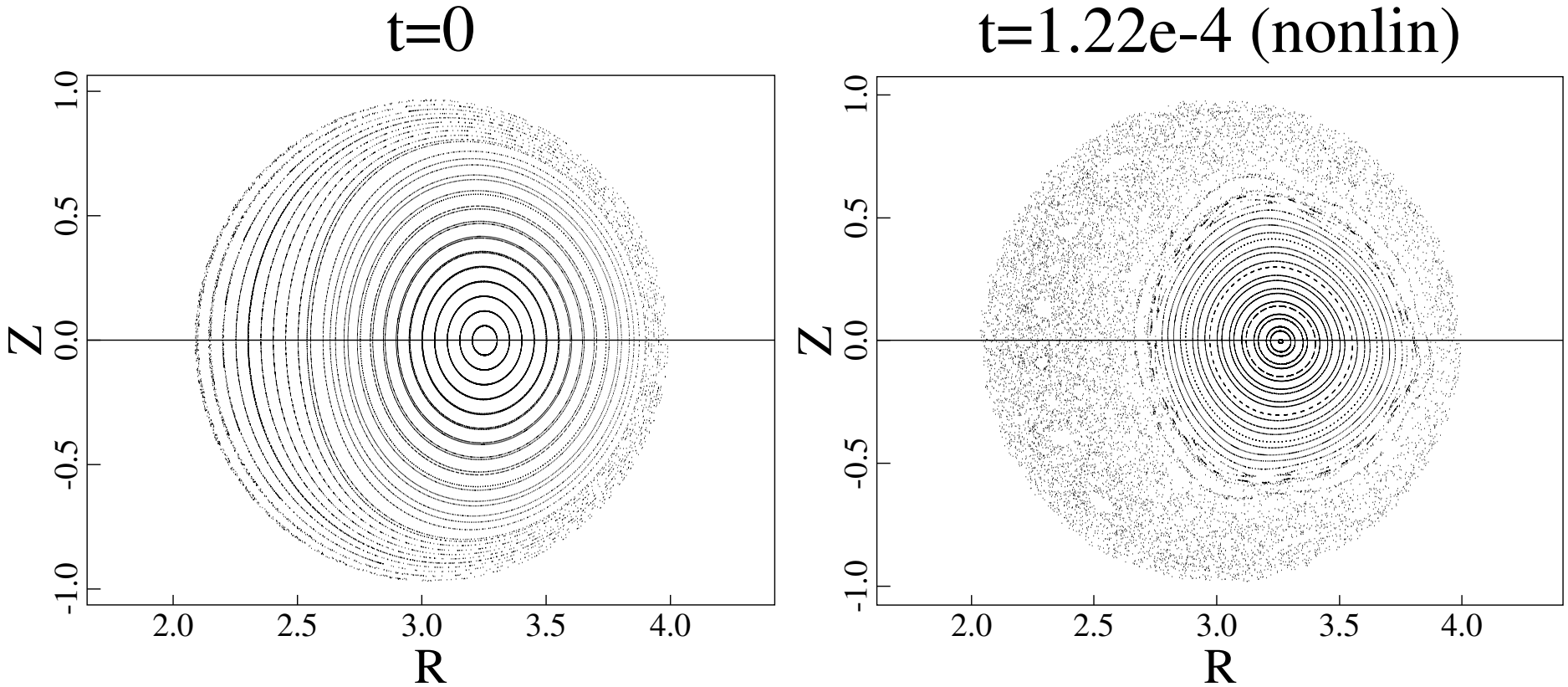
- Intervening islands and stochastic layers form in edge pedestal region due to linear response to $n = 2$ RMP.
- How different/important would be the nonlinear response of this unstable edge pedestal?



For unstable edge pedestal, nonlinear response is dominated by higher-n toroidal harmonics ($n > 2$)



In unstable pedestal nonlinear response makes entire edge region magnetically stochastic and much different from the linear response



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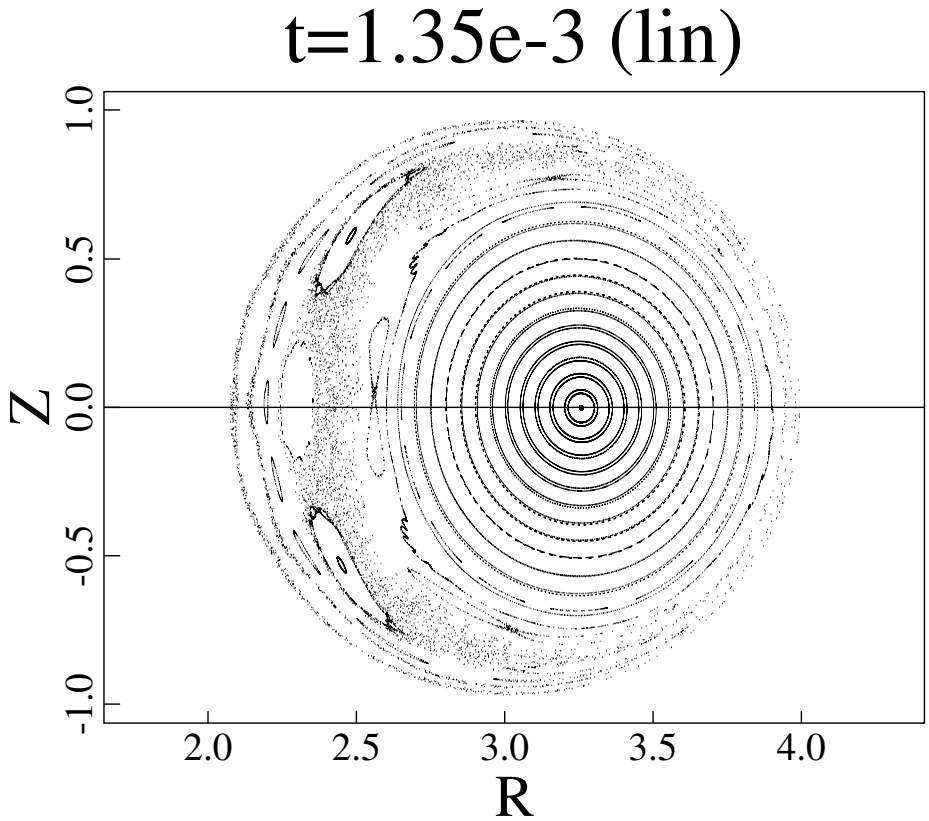

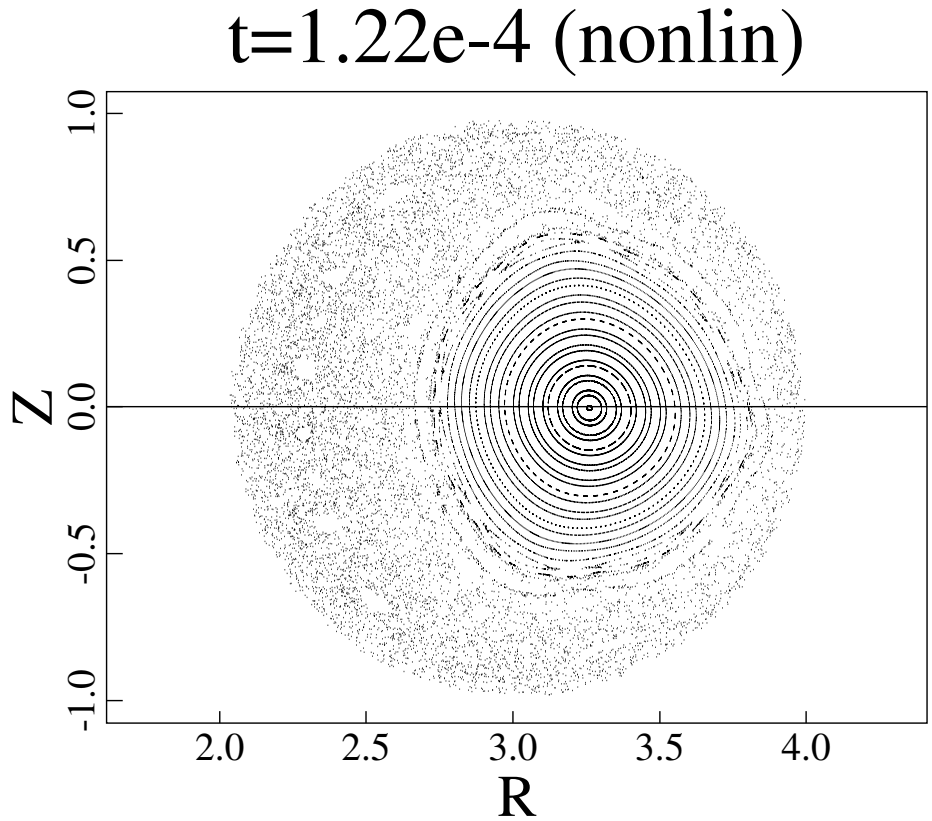

Is the development of instability part of the nonlinear plasma response to RMP in unstable pedestal?

- In dynamic MHD simulations, nonlinear responses are mixed with development of instability of the unstable equilibrium.
- 3D equilibrium solver (such as HINT2) has been used to obtain generic 3D equilibrium either stable or unstable.
- HINT2 has been applied to solving for nonlinear response to RMP in tokamak systems.
- Nonlinear plasma response from NIMROD simulations are being compared with HINT2 solutions (in collaboration with Y. Suzuki from NIFS).

Summary and discussion

- In experiments RMPs are believed to change properties of the unstable H-mode edge pedestal.
- Plasma responses to RMP are different in stable and unstable pedestal.
- RMP induced magnetic structures are more complicated in unstable pedestal.
- Linear and nonlinear plasma responses seem very different in unstable pedestal.
- Is the development of instability part of the nonlinear plasma response to RMP in unstable pedestal?