

# Ideal MHD Stability of NCSX

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# Outline

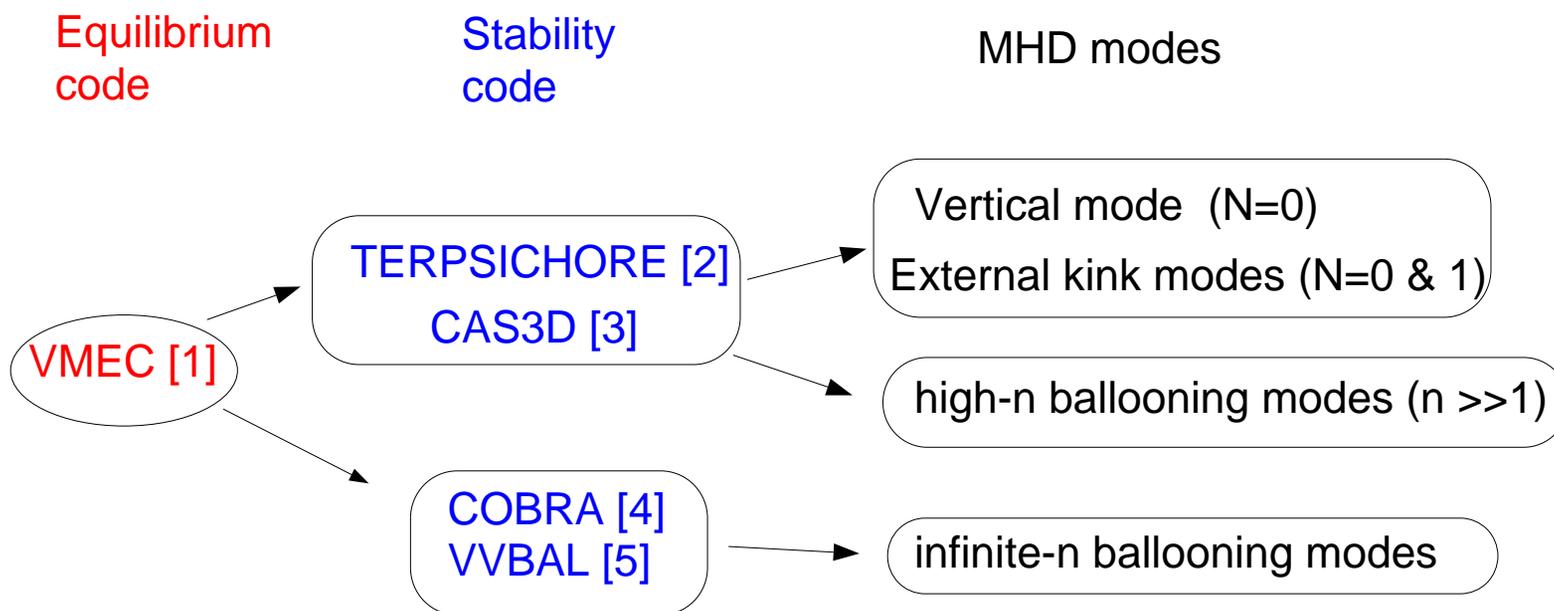
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- We present the physics basis for ideal MHD stability in NCSX.
- We have
  - validated** the 3D MHD stability codes used in the design of NCSX;
  - achieved** a good understanding of stabilization effects of 3D shaping;
  - analyzed** the MHD stability property of the NCSX configurations.
- The NCSX reference configuration is stable to moderate- $n$  MHD modes at  $\beta = 4.08\%$ .

# Stability Codes and Their Validation

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[1] Hirshman S. P. and Whitson, J. C., Phys. Fluids **26** (1983) 3553.

[2] Anderson, D. V. *et al.*, Scient. Comp. Supercomputer II, (1990) 159.

[3] Nührenberg, C., Phys. Plas. **3**, (1996) 2401.

[4] Sanchez, R. *et al.*, J. Comp. Physics **161**, (2000) 576.

[5] Cooper, W. A., Phys. Plasmas **3**, 275(1996)

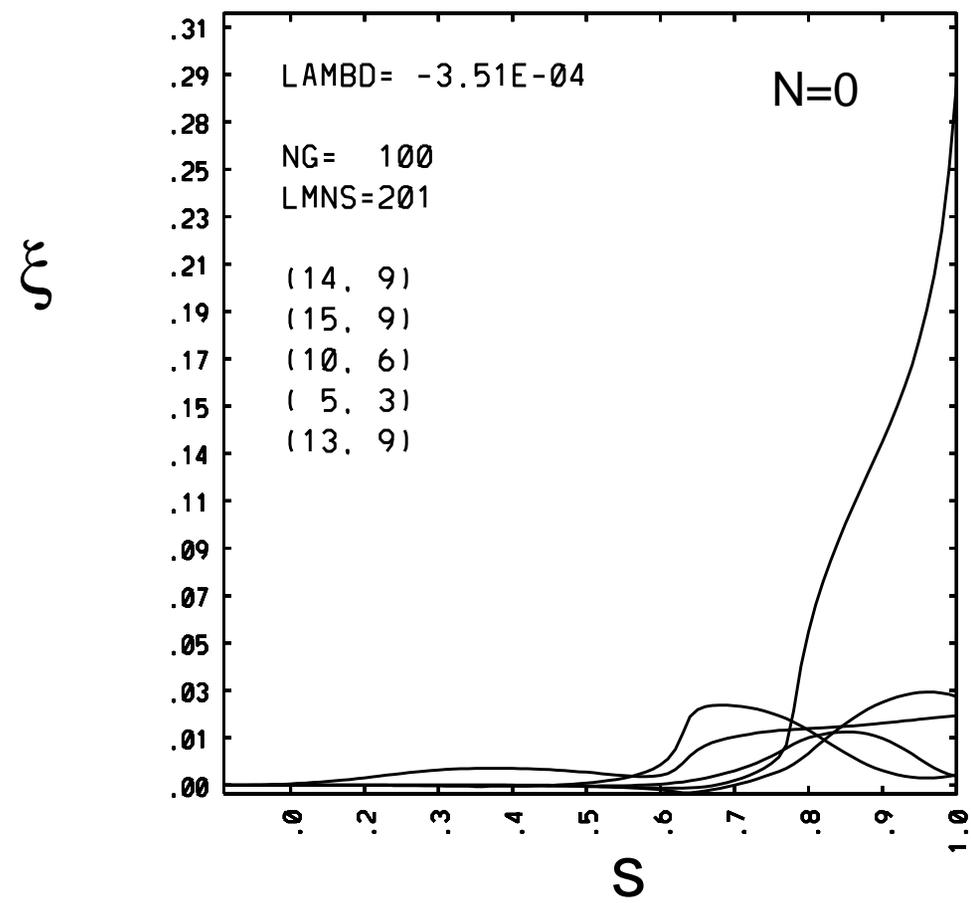
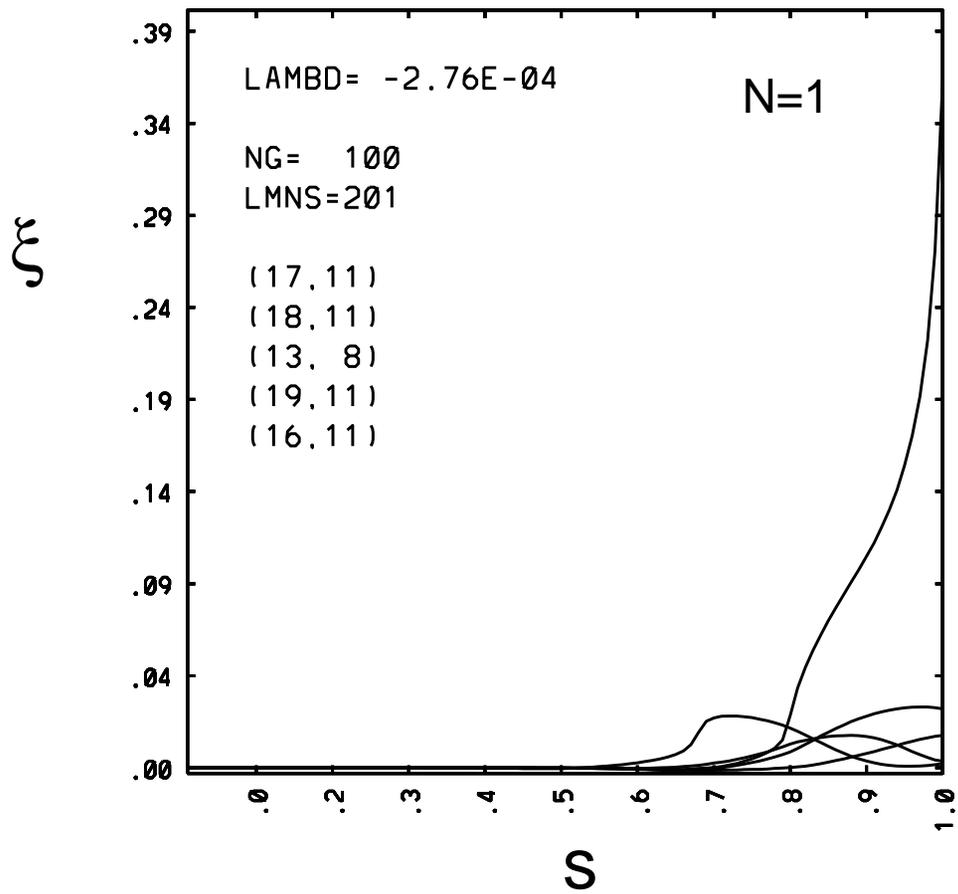
## Stability of NCSX: External Kink Modes

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- The NCSX reference configuration was optimized to be marginal stable to external kink modes using reasonable numerical resolutions (typically 49 surfaces and 91 perturbation modes with  $n$  up to 8).
- Recent convergence study reveals weak high- $n$  external kink modes by using much higher resolutions (100 surfaces and 201 perturbation modes with  $n$  up to 17). This level of resolution is too costly for configuration optimization.
- These high- $n$  modes can be stabilized by a small modification to the 3D shape.

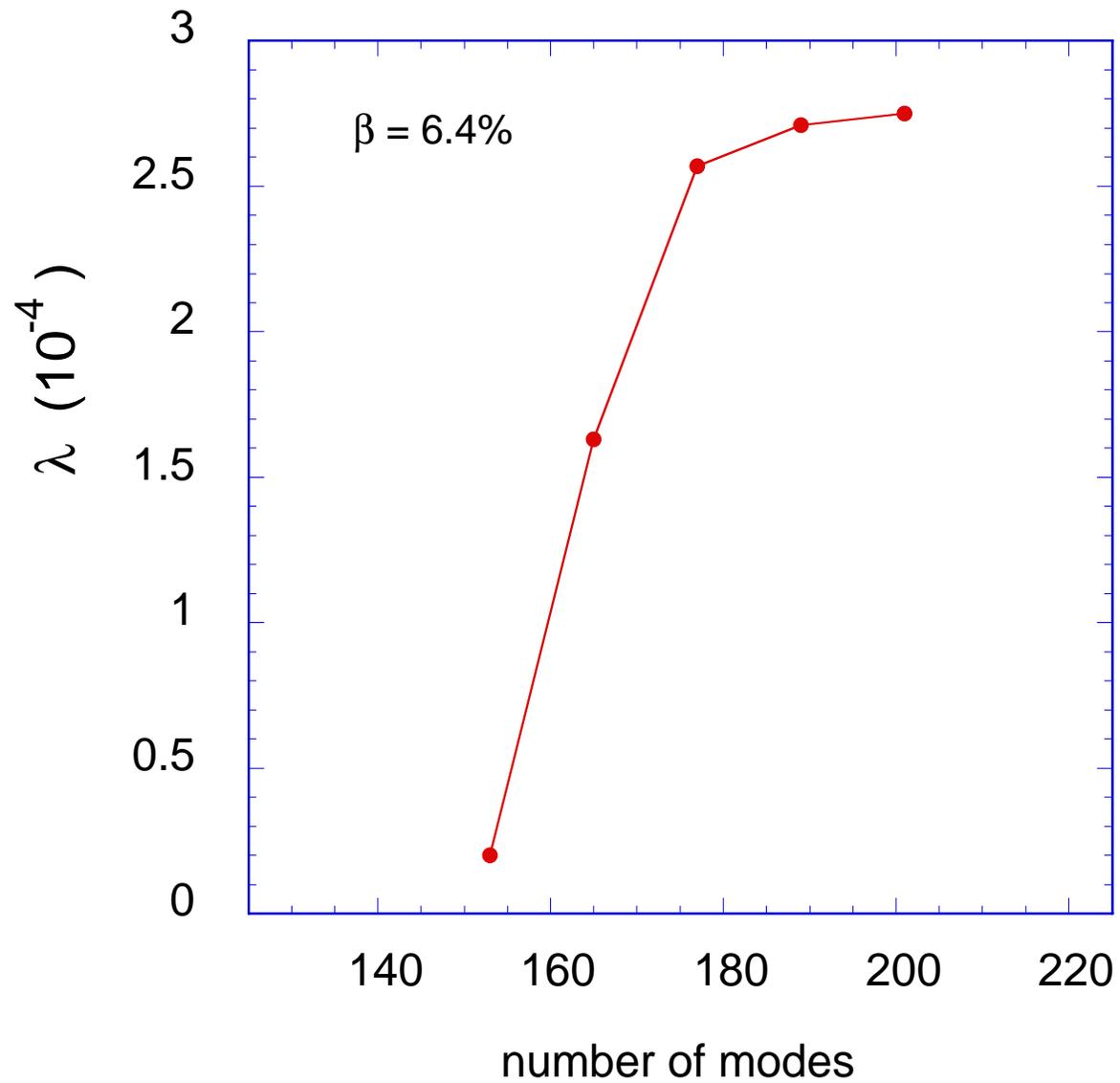
# High-n External Kink Modes are Edge-localized

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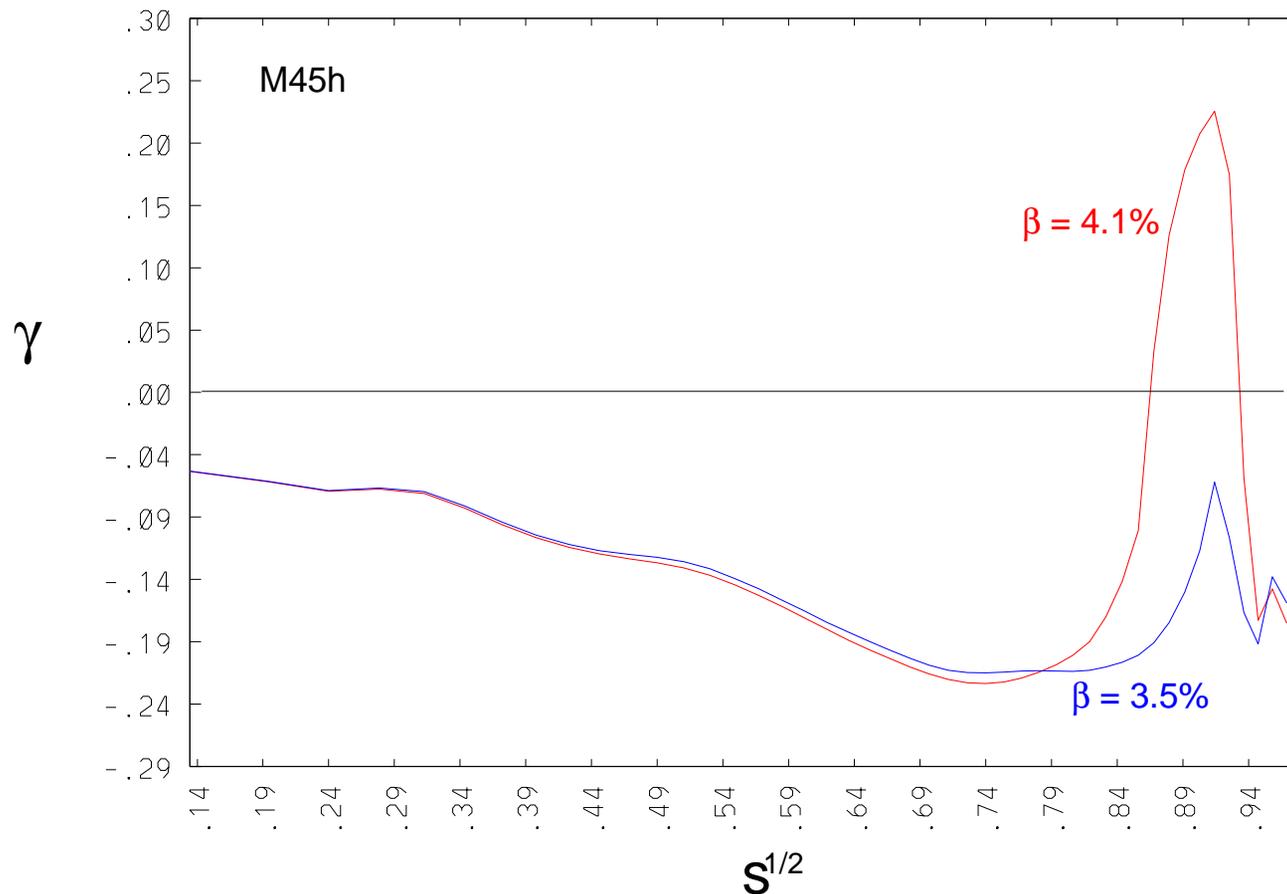


# The High-n External Kink Mode Converges in Number of Modes

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- The ballooning stability was not considered in optimization of the reference configuration with healed magnetic islands. As a result, the configuration is unstable to infinite-n ballooning modes in a narrow radial region near the edge (about 7% of the minor radius).
- The corresponding critical beta is around 3.6%.



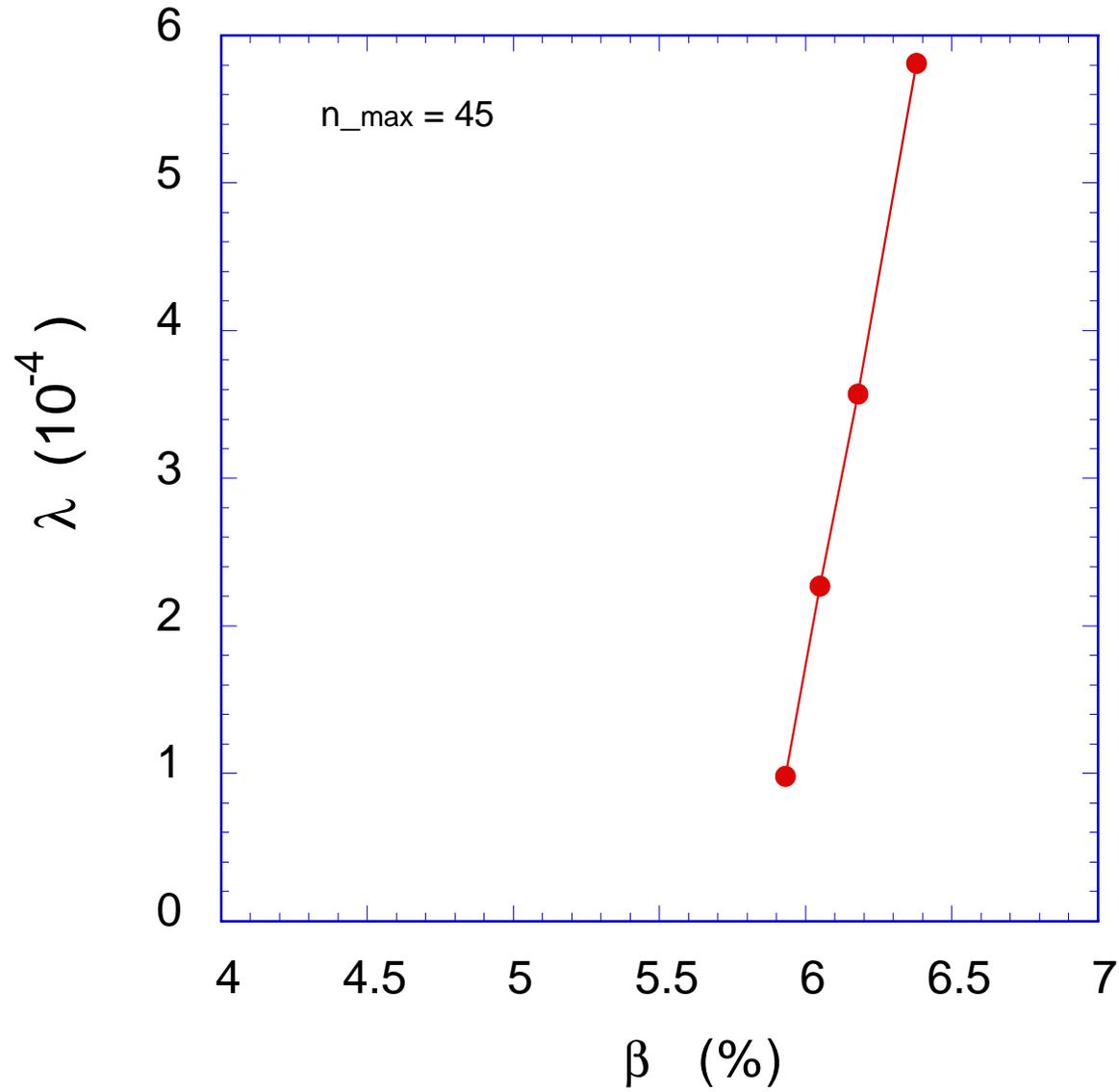
## Stability of NCSX: Finite-n Ballooning Modes

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- In a real plasma, FLR stabilization can heal the infinite-n modes. Then, what is beta limit due to finite-n modes ?
- Using the global Terpsichore code, we were able to determine the stability of high-n ballooning modes for n as high as 45.
- The calculated beta limit of finite-n ballooning modes is significantly higher than the infinite-n limit ( $\beta_{crit} \sim 5.8\%$  for  $n \leq 45$ ).

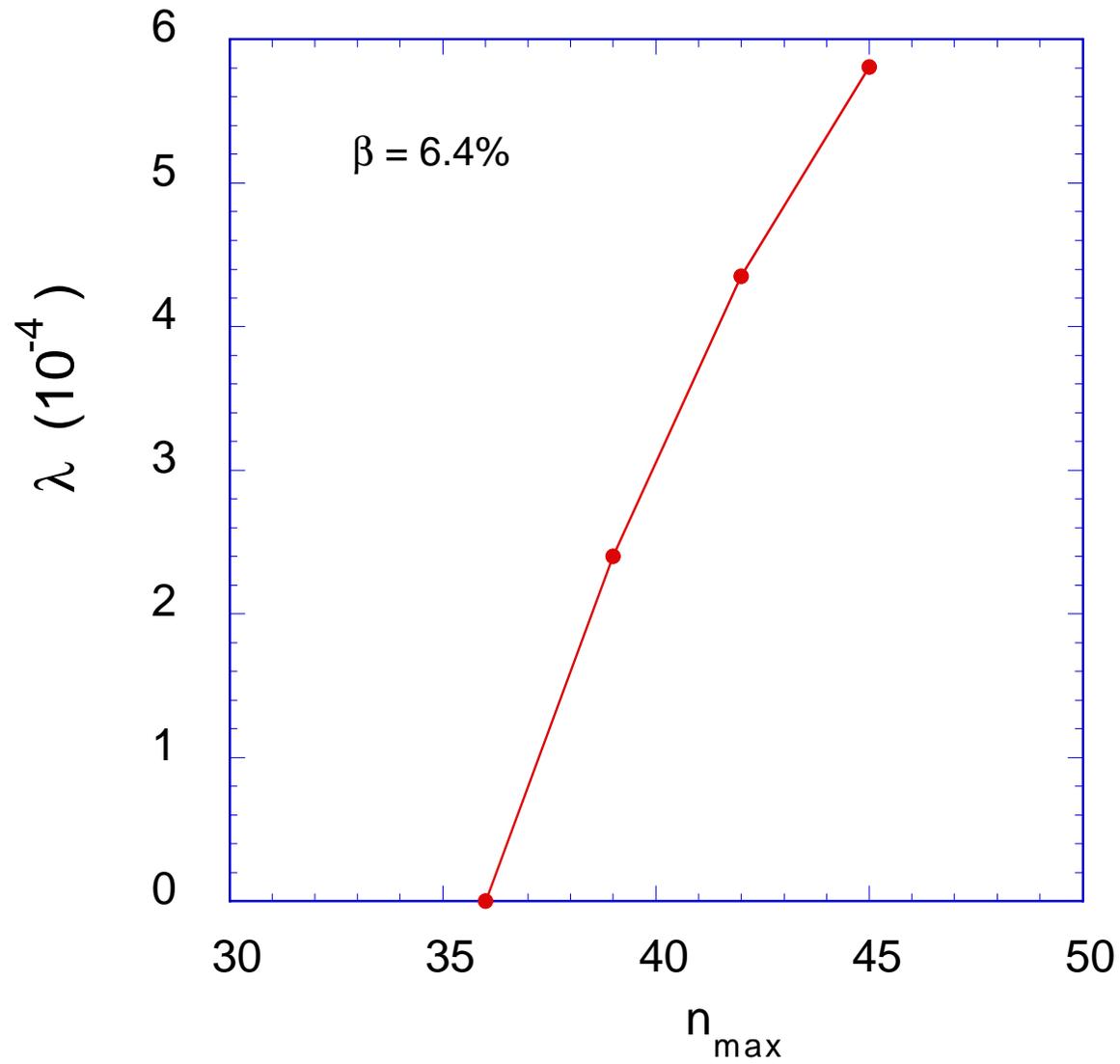
# The Beta Limit of Finite-n Modes is High

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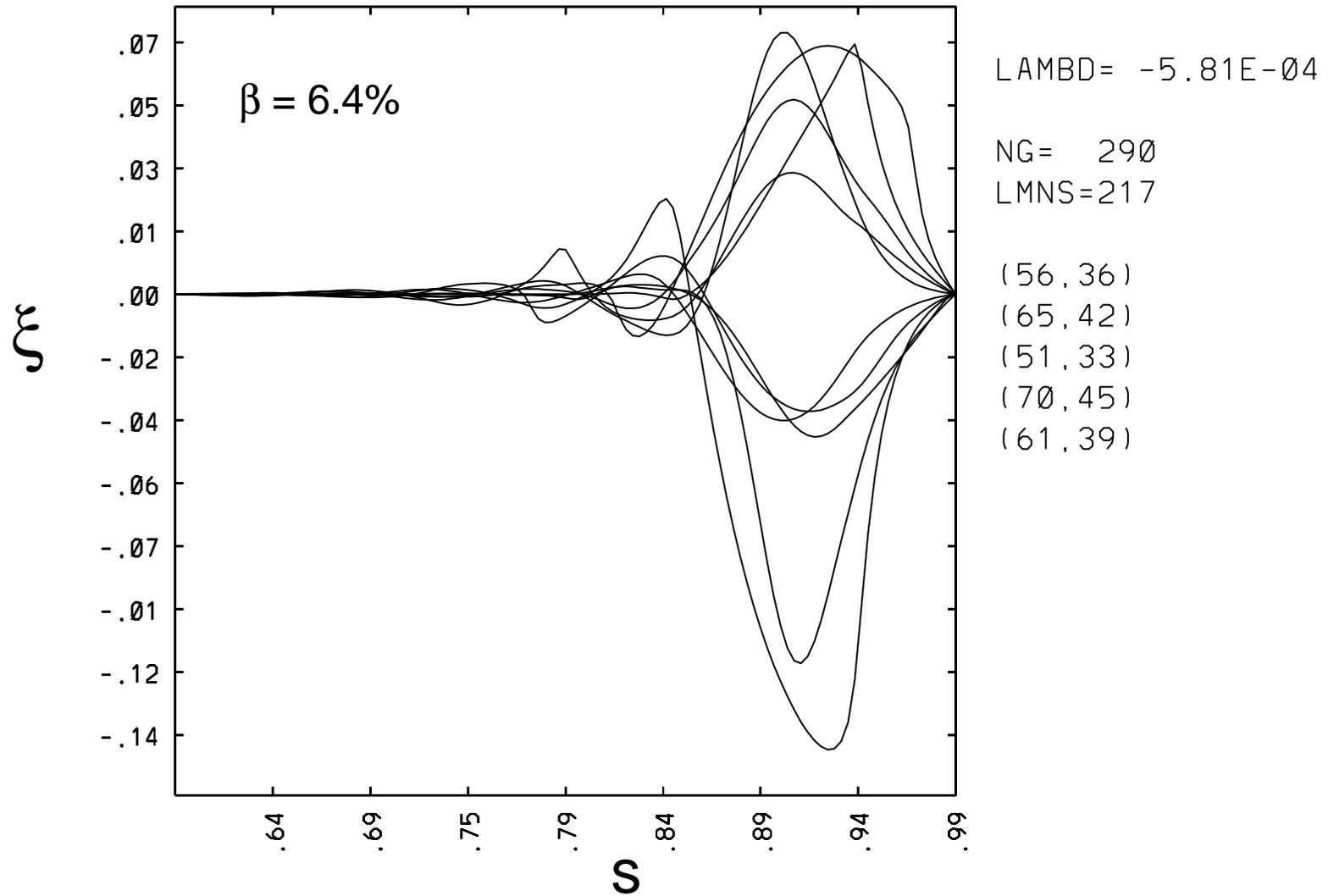
# The Finite-n Ballooning Modes become Unstable at High-n

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# Eigenfunctions of Finite-n Ballooning Mode

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# Conclusions

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- The MHD stability of current-carrying compact stellarators is investigated using most advanced MHD codes.
- The NCSX configuration is stable to moderate- $n$  MHD modes ( $n \leq 8$ ).
- The finite- $n$  beta limits are much higher than the infinite- $n$  threshold. Thus, the external kink modes are probably the limiting instabilities rather than ballooning modes.