

MHD Simulations of ELMs on KSTAR and EAST

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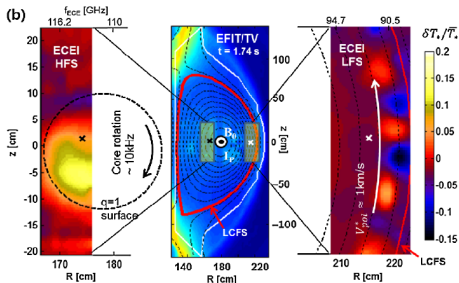
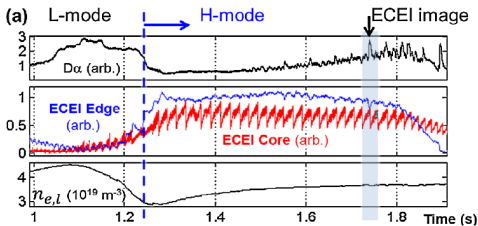
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Acknowledgment

- ▶ KSTAR collaborators:
 - ▶ H.-S Han, G.-Y. Park, J.-Y. Kim
- ▶ EAST collaborator(s):
 - ▶ Y.-W. Sun

KSTAR ECEI system observed signatures of ballooning filaments in ELM experiment [G. S. Yun *et al.* 2011]

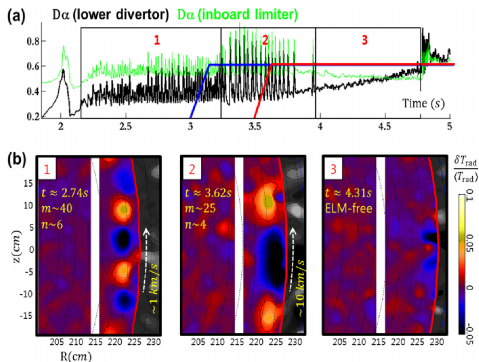
- ▶ Initial linear growth phase
- ▶ Saturation phase
- ▶ Final crash phase



KSTAR RMPs were observed to change ballooning filaments and suppress ELMs

- ▶ KSTAR ECEI system observed disappearance of ballooning filaments in ELM experiment with application of $n = 1$ RMP

[G. S. Yun *et al.* 2012].

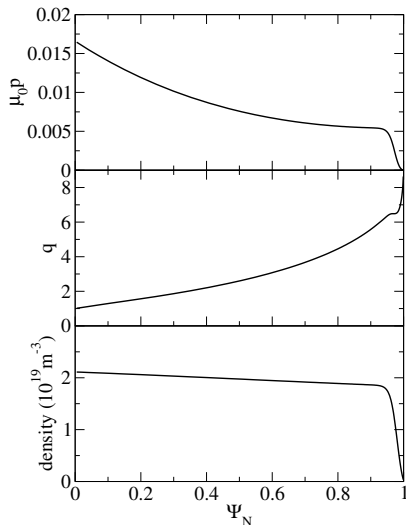


Equilibrium reconstruction from experimental data involves many unknowns and assumptions [Han and Kim

2012]

- ▶ Temperature ($T_i = T_e$) profile was fitted from CES diagnostics to a combination of hyperbolic tangential function and Heaviside step function.
- ▶ Density profile was determined from the measured line integrated density ($2.45 \times 10^{19} m^{-3}$) and an assumed pedestal width based on the EPED1 model.
- ▶ Current profile was based on combination of Ohmic relaxed profile in core and bootstrap current profile at edge.
- ▶ TEQ code was used to obtain a free boundary equilibrium.

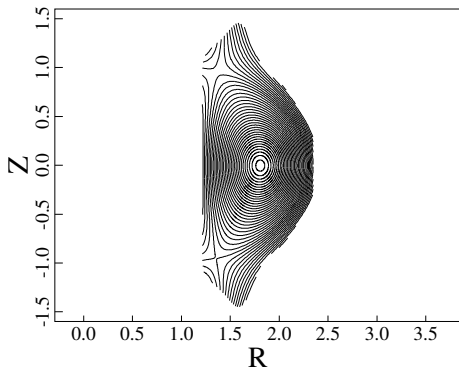
Radial profiles of reconstructed equilibrium have edge pedestal in both pressure and density inside separatrix



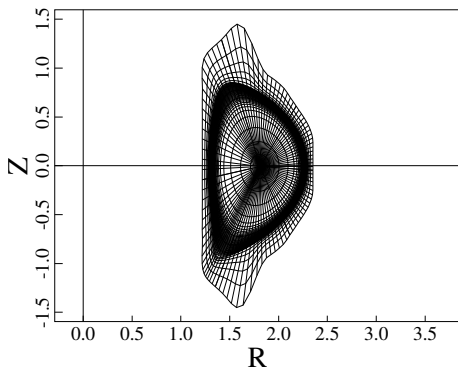
- ▶ Edge current density leads to a zero shear edge region.
- ▶ Spitzer resistivity model with $S_{\text{max}} = 10^6$ at magnetic axis was used in simulations .
- ▶ Weak viscosity and anisotropic thermal diffusivities.

Finite element mesh conforms with magnetic flux surfaces inside separatrix and is packed at edge and near x point

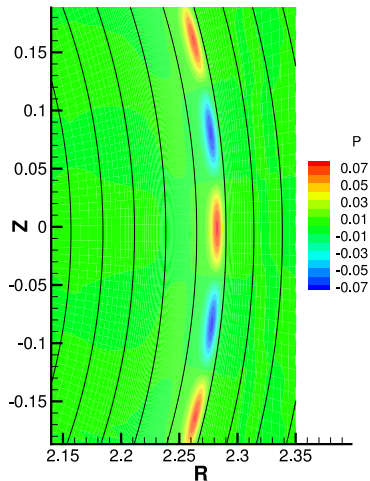
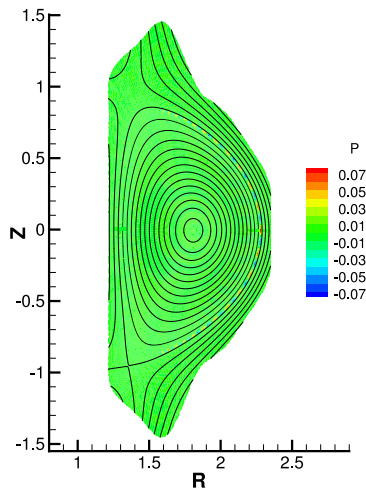
PSI



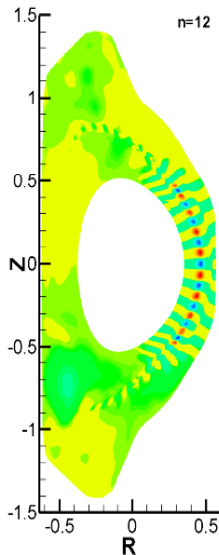
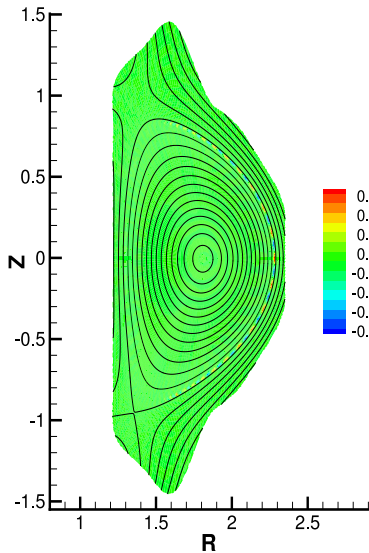
Finite Element Mesh



$n = 11$ edge mode structure is localized right inside the separatrix

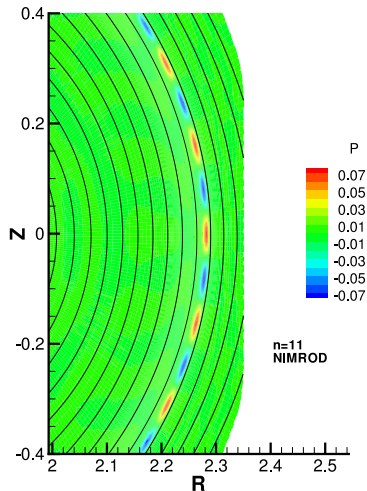


Comparison between NIMROD (left) and M3D (right) computation results for linear mode structure shows agreement

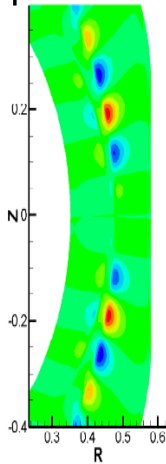


[Han and Kim 2012]

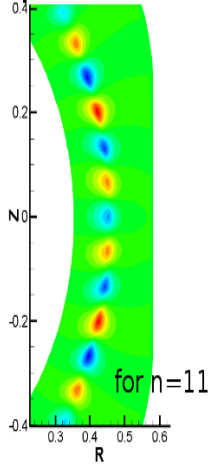
$n = 11$ mode structure for pressure from NIMROD appears to be match more with vector potential rather than pressure field from M3D



perturbed P

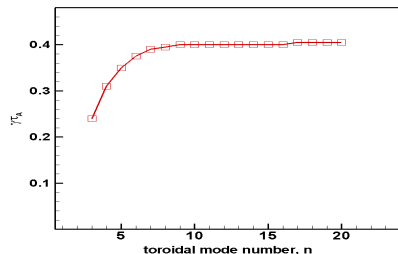
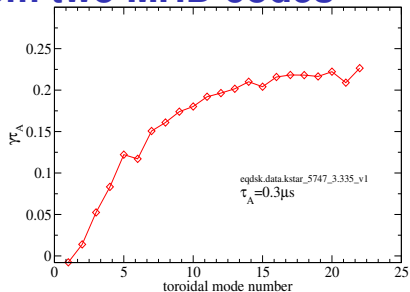


perturbed a



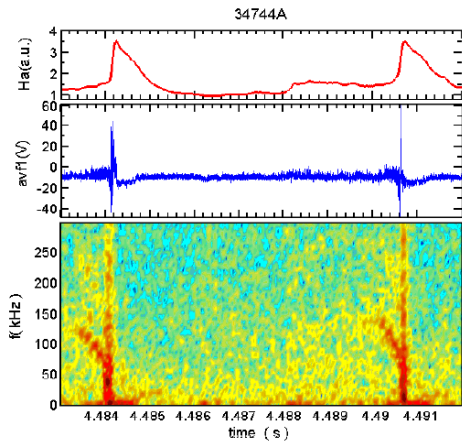
[Han and Kim 2012]

Linear growth rates as function of toroidal mode number qualitatively agree between calculation from two MHD codes



- ▶ NIMROD results in upper panel.
- ▶ M3D results in lower panel [Han and Kim 2012].
- ▶ Remaining discrepancies may be due to
 - ▶ difference in computation domains
 - ▶ difference in normalization (Alfvénic time)
 - ▶

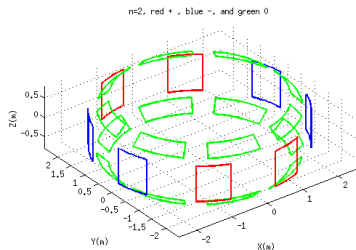
MHD activities have been identified prior to ELM onsets on EAST H-mode experiments



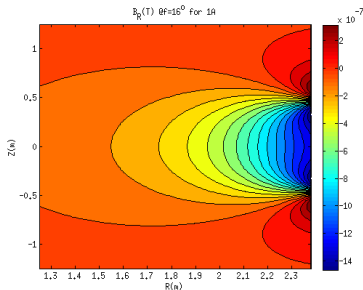
- ▶ EAST reciprocating probes were used to detect MHD precursors in pedestal region in ELM experiments

[Liu *et al.* 2011].

EAST RMP coil system is being designed using a code previously developed for the design of in-vessel coils on JET [Y.-W. Sun 2012]

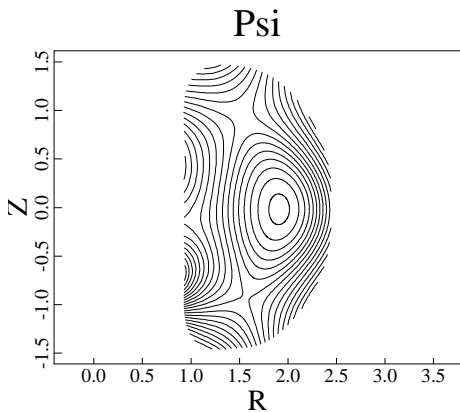
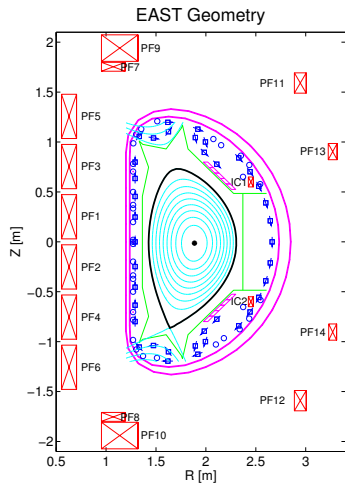


- ▶ EAST in-vessel coil configuration



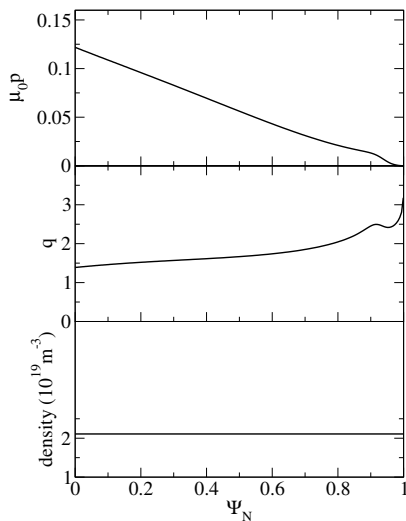
- ▶ A vacuum $n = 2$ RMP field distribution in poloidal plane

EAST geometry and equilibrium flux surface are used to set up the computation domain



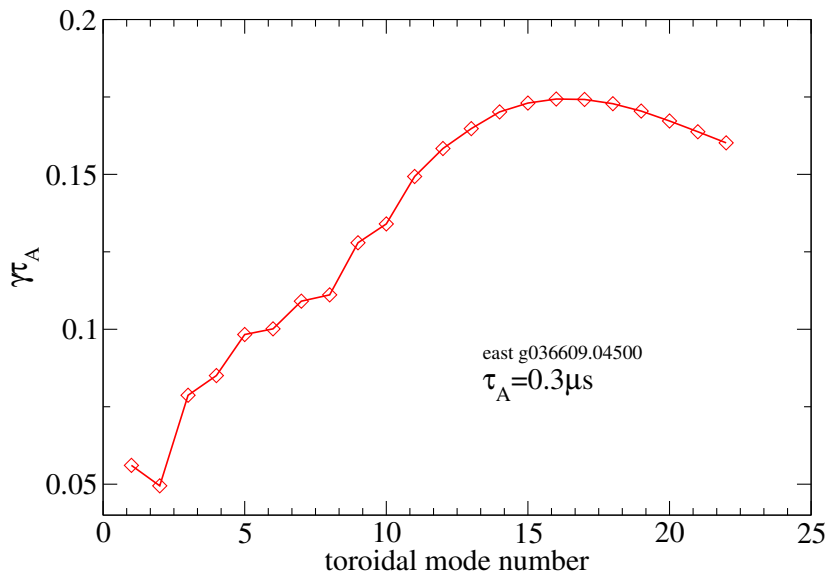
[Y.-W. Sun 2012]

For initial testing purpose, an artificially high β configuration is assumed

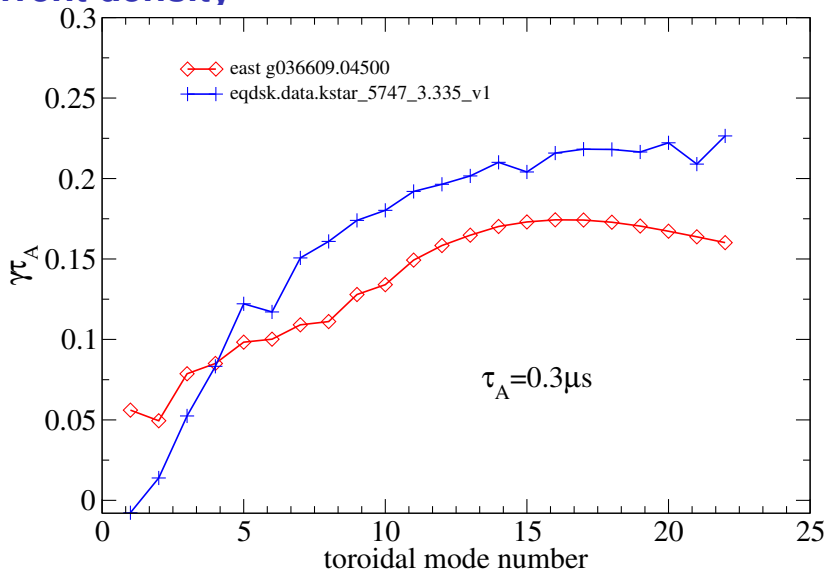


- ▶ Flat number density profile.
- ▶ Stronger edge current leads to a reversed shear in edge region.
- ▶ Spitzer resistivity model with $S_{\max} = 7.8e8$.
- ▶ Weak viscosity and anisotropic thermal diffusivities.

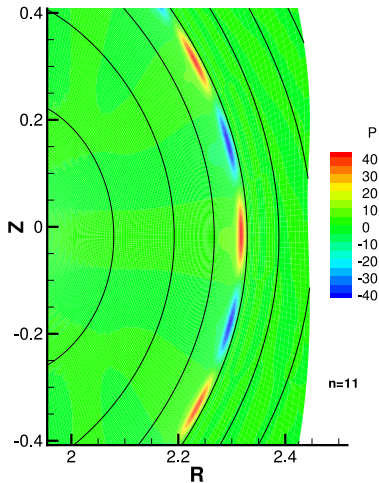
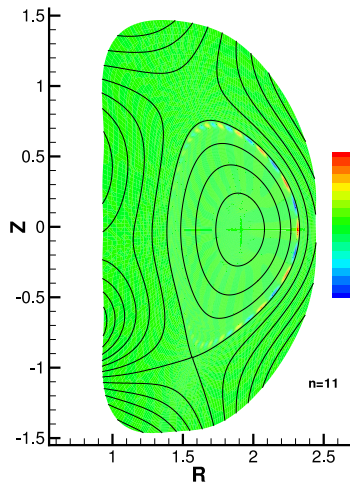
Edge pedestal is unstable to all n modes and $n = 16$ has a local maximum growth rate



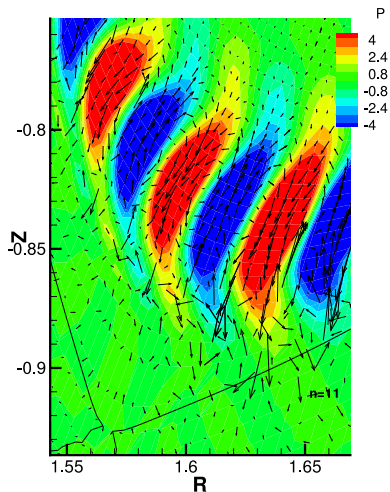
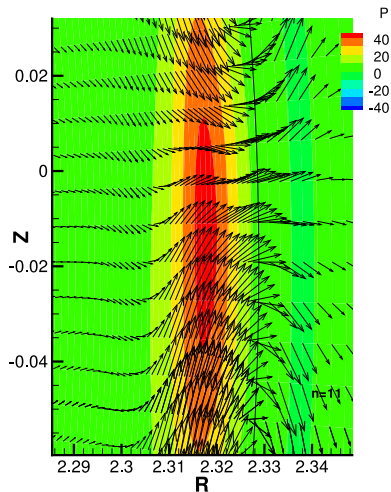
Higher β configuration can be less unstable due to effects of (lower) resistivity and (higher) edge current density



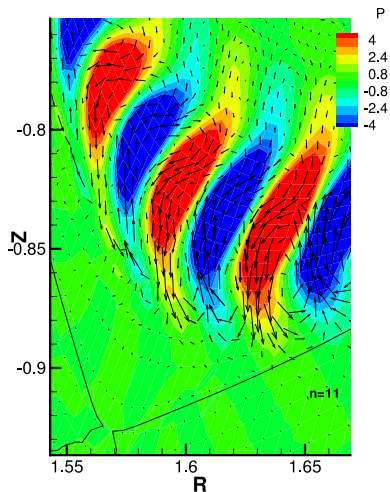
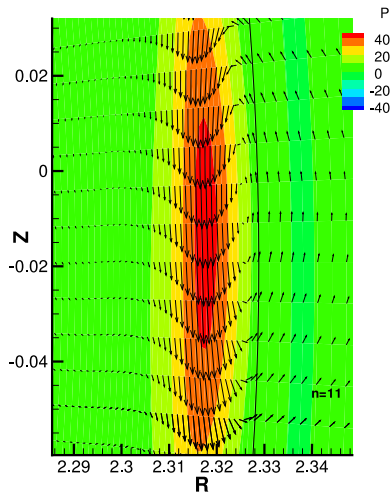
$n = 11$ mode structure of perturbed pressure is localized adjacent to the inside of separatrix



Mode structures (flow vectors) are different in outboard mid-plane and near X-point



Mode structures (perturbed B vectors) are different in outboard mid-plane and near X-point



Summary

- ▶ Collaborations on ELM modeling have started with KSTAR and EAST teams.
- ▶ For experimental ELM analysis and modeling, the major challenge is to achieve accurate reconstruction of equilibriums.
- ▶ For both KSTAR-like and EAST-like H-mode equilibrium configurations, NIMROD simulations have been able to reproduce filamentary structures adjacent to the inside of separatrix, similar to those observed in experiments.
- ▶ Next step is to use NIMROD code in simulations to study edge response to RMP for these experiment-based configurations.