3D nonlinear modeling of Resonant Magnetic Perturbation on EAST

J. Huang[1)], Y. Suzuki[1, 2)], Y. F. Liang[3,4)], Y. W. Sun[3)], M. N. Jia[3)], N. Chu[3)], M. Q. Wu[3)] and EAST team[3)]

[1)] *National Institute for Fusion Science, Toki 509-5292, Japan*
[2)] *The Graduate University for Advanced Studies, SOKENDAI, Toki 509-5292, Japan*
[3)] *Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China*
[4)] *Institute for Energy and Climate Research–Plasma Physics, Forschungszentrum Juelich, Association EURATOM-FZJ, Trilateral Euregio Cluster, 52425 Juelich, Germany*

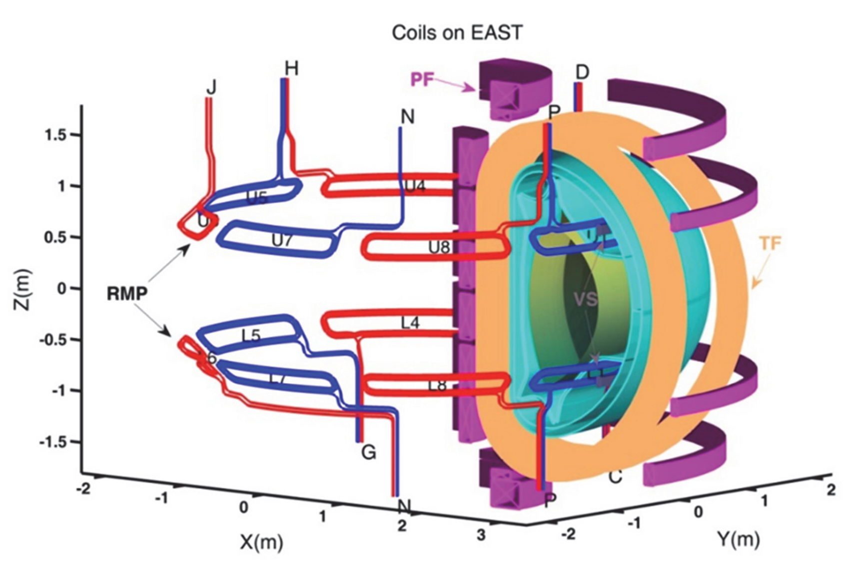
Email: huang.jie@ nifs.ac.jp

ABSTRACT

- 3D MHD equilibrium under RMP is solved on EAST by the nonlinear resistive HINT code [1].
- The pedestal pressure is flatted from modeling result in the RMP penetration phase.
- self-consistent plasma flow is introduced to simulate the nonlinear interaction between RMP field and plasma rotation, resulting in plasma response in RMP shielding phase.

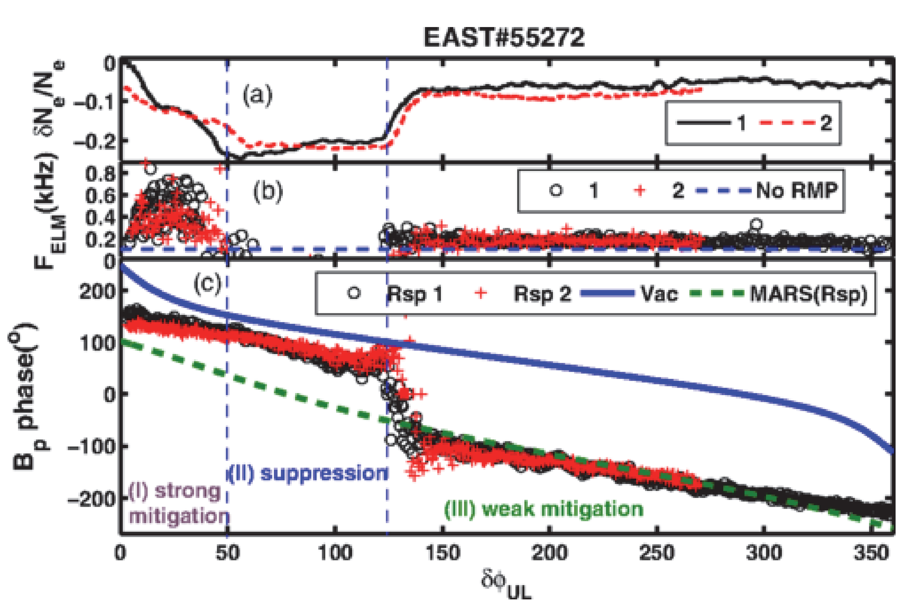
BACKGROUND

- EAST has been equipped with RMP coil system, asking for 3D equilibrium reconstruction.
- Nonlinear transition between ELM suppression and mitigation is observed with RMP on EAST [2].



RMP coil system

- 8(U)+8(L)=16 coils.
- I ~ 10 (kAt), V ~600V.
- 4 (8) power supplies.
- n=1−3 rotating and n=1-4 non-rotating.



Nonlinear transition experimental observation

- RF dominant heating plasma.
- I~10(kAt), n=1 RMP.
- $\delta\phi_{UL}$ continuous change from t=4.0s, $f_{\delta\phi_{UL}}$~0.5Hz.
- Repeatable bifurcation.

METHODS

- The 3D tokamak equilibrium is calculated by the HINT code based on the relaxation method.
- Initial plasma flow is introduced to simulate the nonlinear interaction between RMP field and plasma rotation in the step B :

$$\frac{\partial \mathbf{v}}{\partial t} = -\nabla p + \mathbf{J}_1 \times (\mathbf{B}_0 + \mathbf{B}_1) + \nu \Delta \mathbf{v}$$

$$\frac{\partial \mathbf{B}_1}{\partial t} = \nabla \times [(\mathbf{v} - \mathbf{v}_0) \times (\mathbf{B}_0 + \mathbf{B}_1) + \mathbf{v}_0 \times \mathbf{B}_{RMP} - \eta(\mathbf{J}_1 + \mathbf{J}_{net})] + \kappa_{divB} \nabla\nabla \cdot \mathbf{B}_1$$

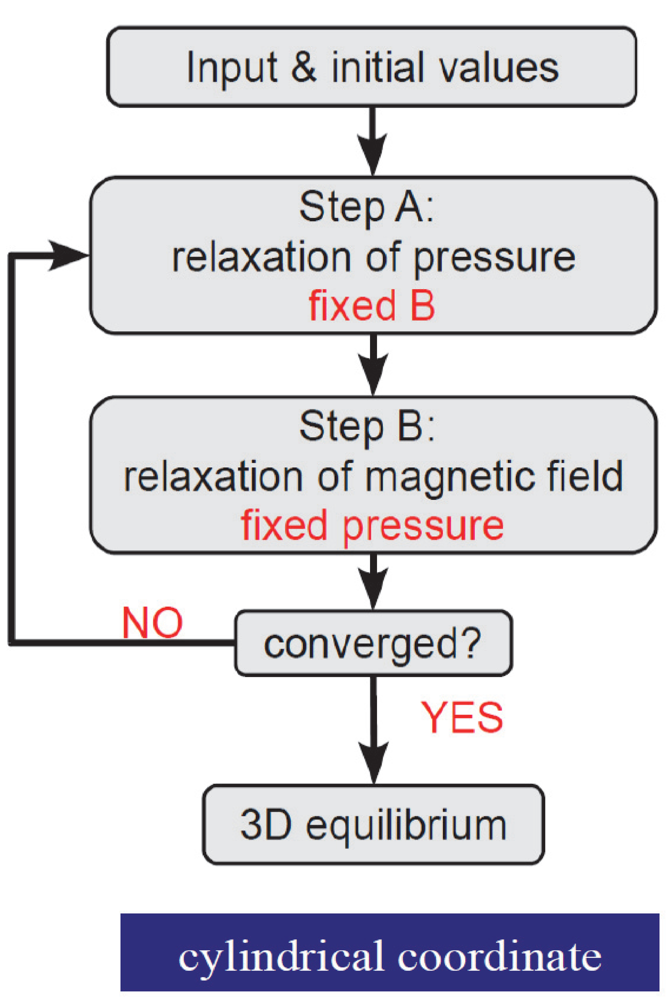
$$\mathbf{J}_1 = \nabla \times \mathbf{B}_1$$

- The initial values are given by 2D EFIT equilibrium with RMP field.
- The initial velocity: $\mathbf{v}_0 = \mathbf{v}_{\perp 0} + \mathbf{v}_{\parallel 0}$

$$\mathbf{v}_{\perp 0} \cdot \mathbf{B}_{eq0} = 0$$

$$\mathbf{v}_{\perp 0} \cdot (\mathbf{B}_{peq0} \times \mathbf{B}_{\phi eq0}) = 0$$

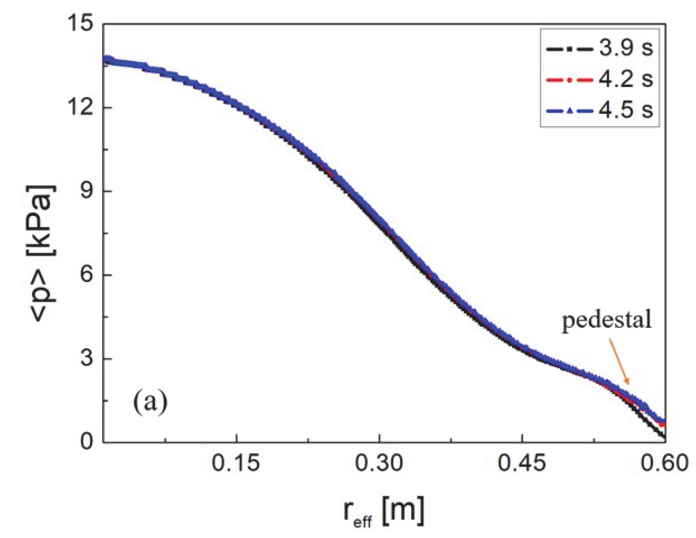
$$|\mathbf{v}_{\perp 0}| = v_{\perp 0} \qquad \Omega_{\perp 0} = \Omega_{\perp axis}(1 - s^2)$$



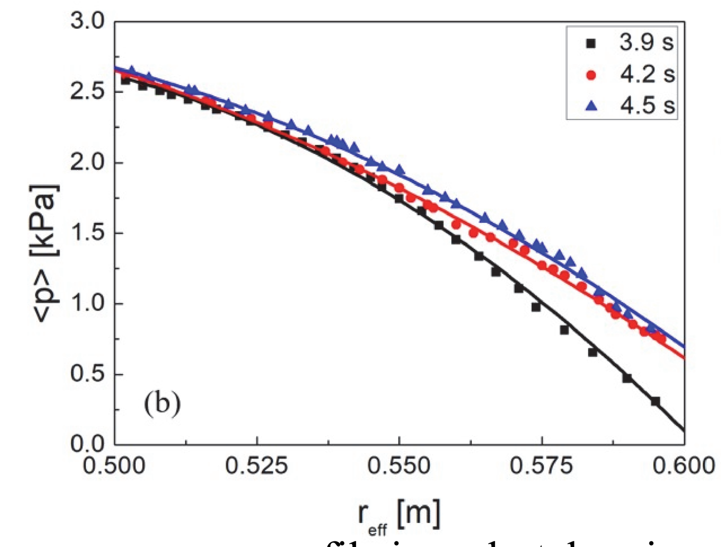
Flow chart of HINT

OUTCOME

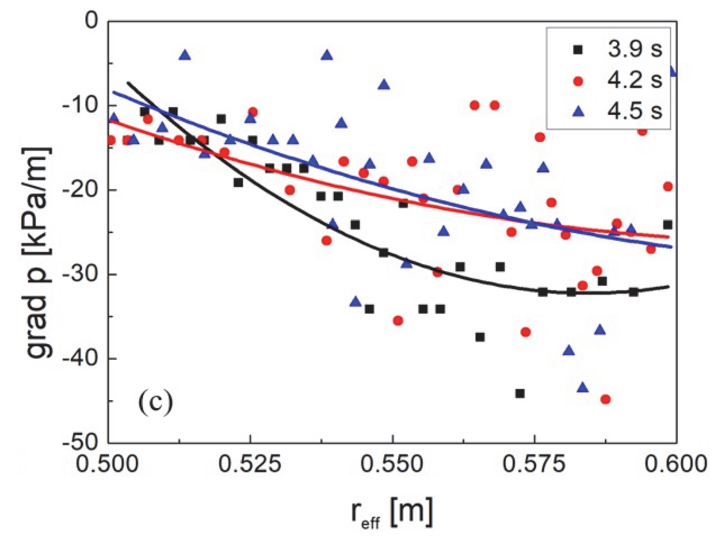
3D equilibrium reconstruction in RMP penetration phase



pressure profile



pressure profile in pedestal region

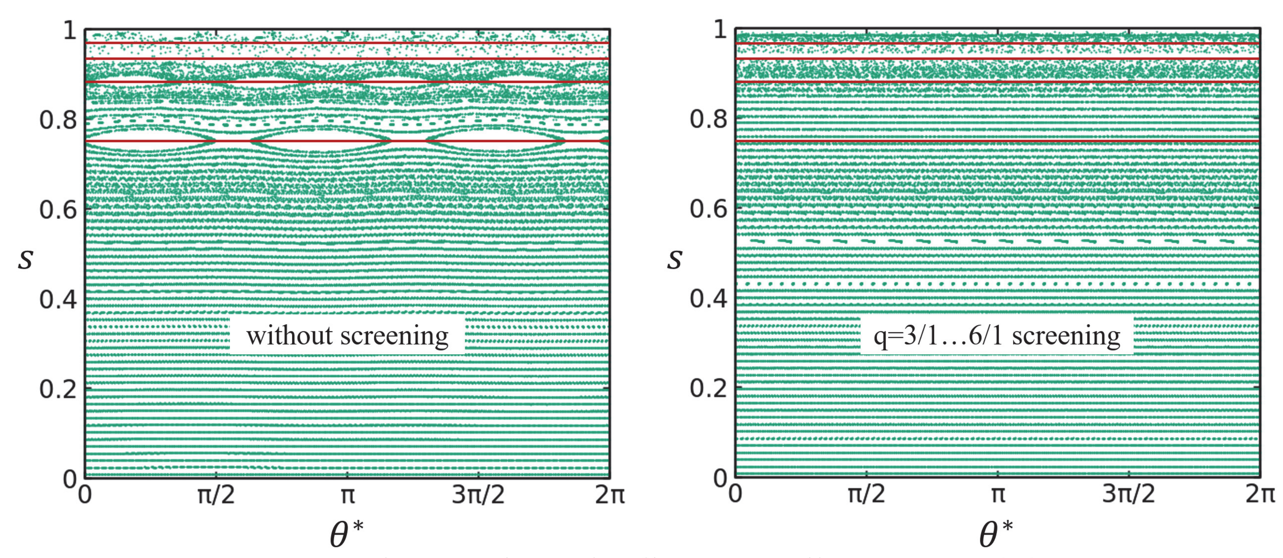


pressure gradient

- t=3.9s: no RMP;
  t=4.2s: strong ELM mitigation;
  t=4.5s: ELM suppression.
- Almost identical in core region.
- Flatted in the pedestal with RMP.

3D equilibrium reconstruction in RMP shielding phase

local ideal plasma response



magnetic topology in flux coordinate at t=4.8s

t=4.8s: weak ELM mitigation

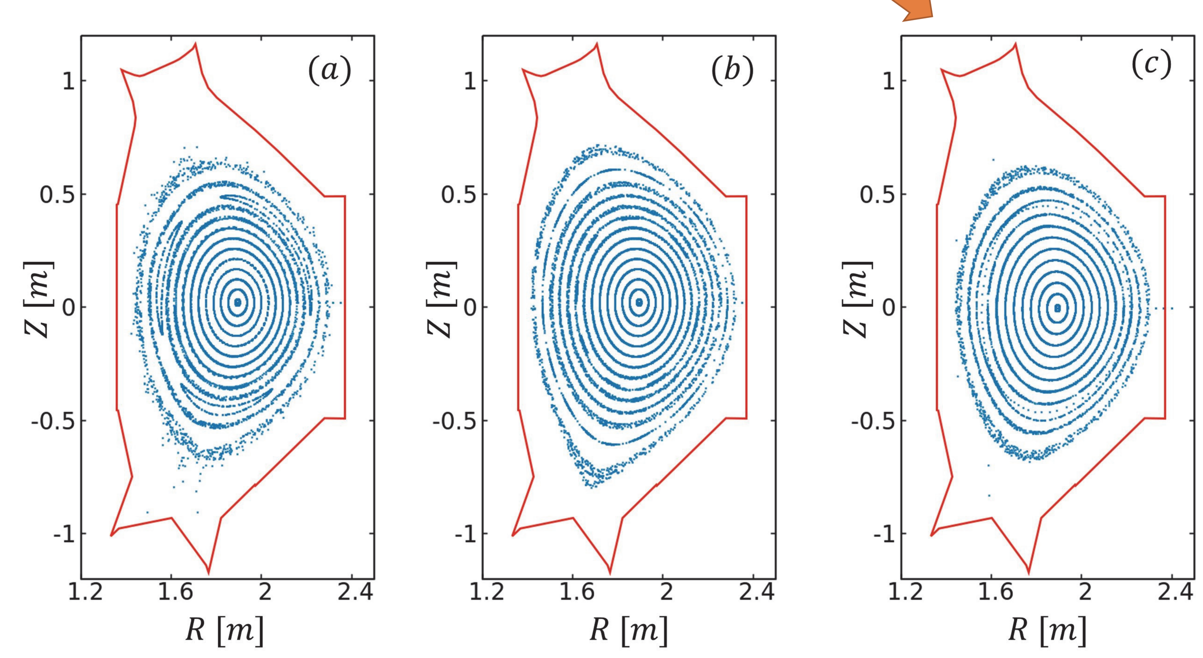
- Localized on flux surface.
- Divergence free.
- Parallel to magnetic field line.

$$\mathbf{J}^{scr} = \sum_{m,n} J_{m,n} \delta(\Psi - \Psi_{m,n}) e^{i(m\theta^* - n(\varphi - \varphi_0))} \hat{\mathbf{b}}_{eq}$$

HINT code: $\mathbf{v}_{\perp 0} \times \mathbf{B}_{RMP}$

$E_{\parallel 0}$

RMP field partially shielded by flow



magnetic topology calculated by HINT at t=4.8s

(a): no response

(b): with local ideal plasma response

(c): with $\mathbf{v}_{\perp 0}$ $\Omega_{\perp axis} = 15\ krad/s$

CONCLUSION

To suppress or mitigate ELM strongly, the depth penetration of RMP field or the relevant edge topological change resulting from the nonlinear interaction between RMP field and plasma flow is the key factor from the modeling.

REFERENCES

[1] Y. Suzuki (2017) Plasma Phys. Control. Fusion 59 054008

[2] Y. Sun et al. (2016) Phys. Rev. Lett. 117 115001