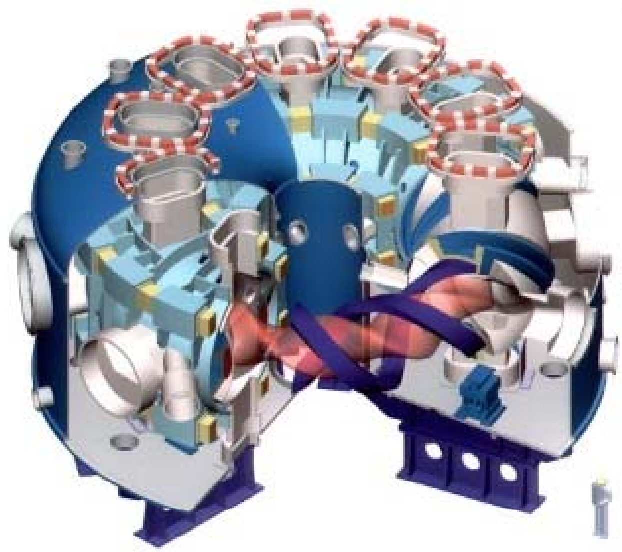
Formation and termination of particle transport barrier in LHD

S. Ohdachi, K. Tanaka, R. Sakamoto, T. Morisaki, J. Miyazawa, K. Y. Watanabe and LHD Experiment Group

National Institute for Fusion Science

Outline

- Peaked density/pressure plasmas observed in the Large Helical Device
- Build-up process
- MHD property of LHD
- Collapse event and ballooning mode
- Summary

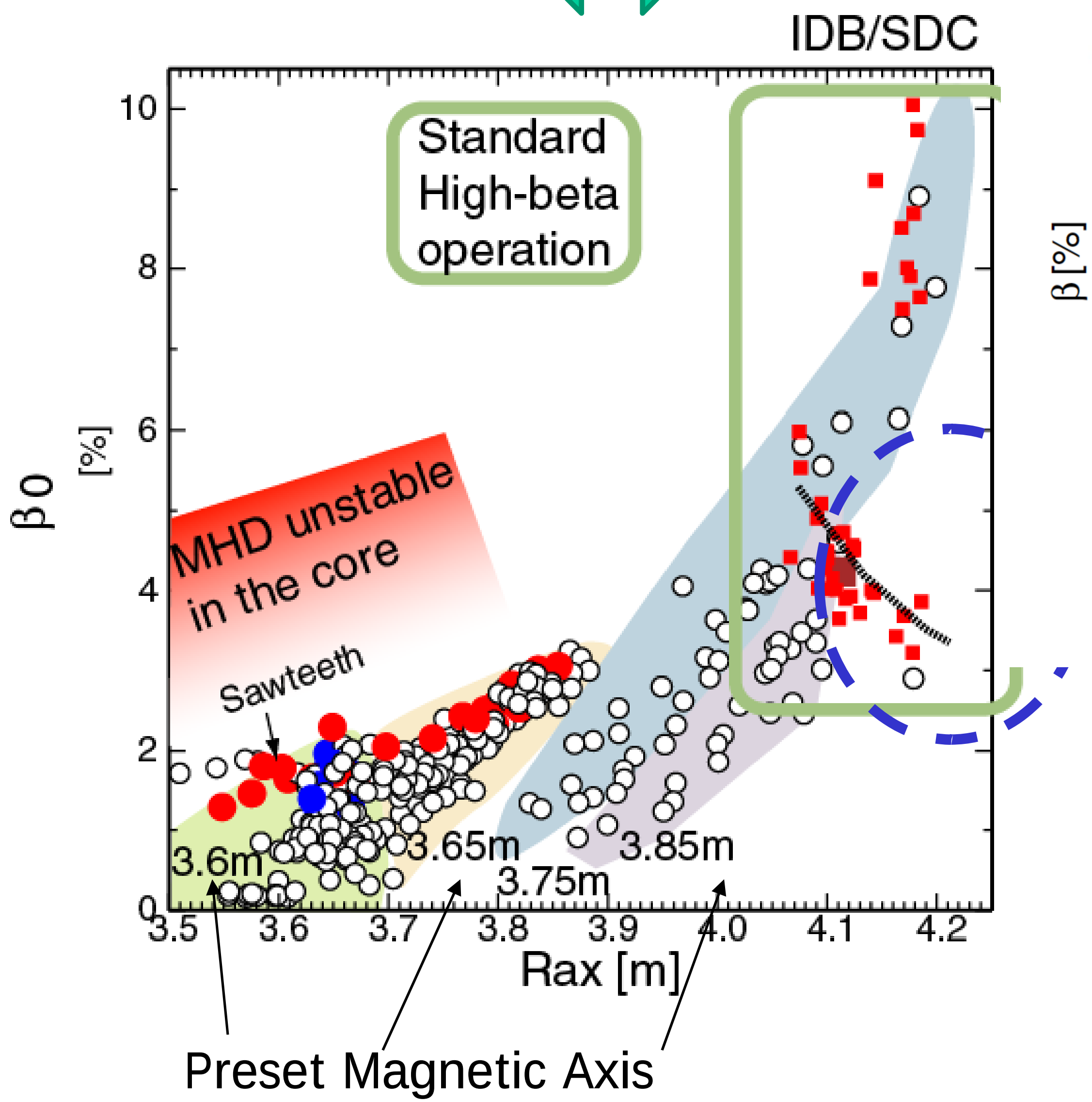


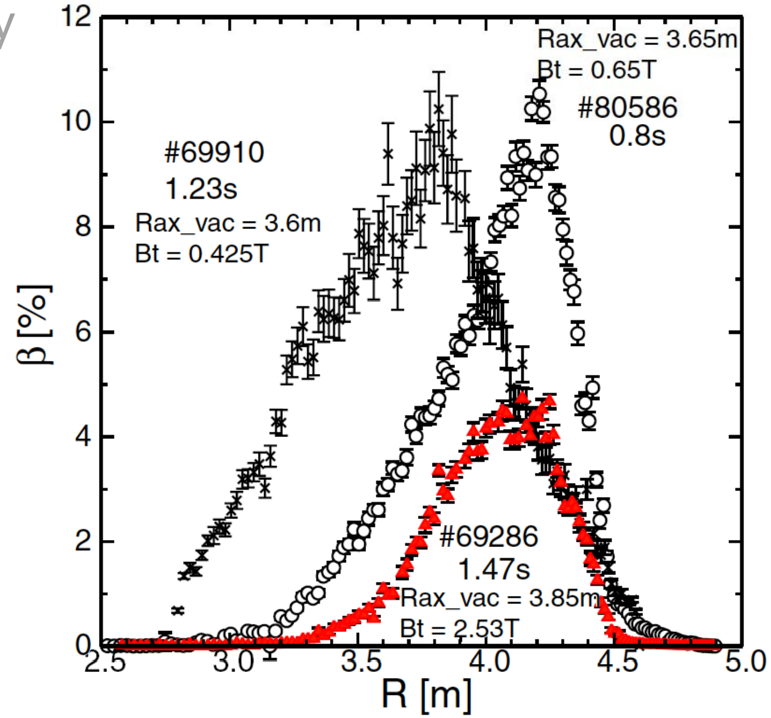
L = 2, m=10 Heliotron type device
R = 3.5 - 3.9m, a ~ 0.6m

NBI(tangential) ~ 15MW

MHD instabilities and high-β operational regime

Better Confinement ⇔ MHD Stablity





10%) plasmas.

- In outward shifted case, we achieve a peaked pressure profile. We discuss the beta limit in this kind of discharges.

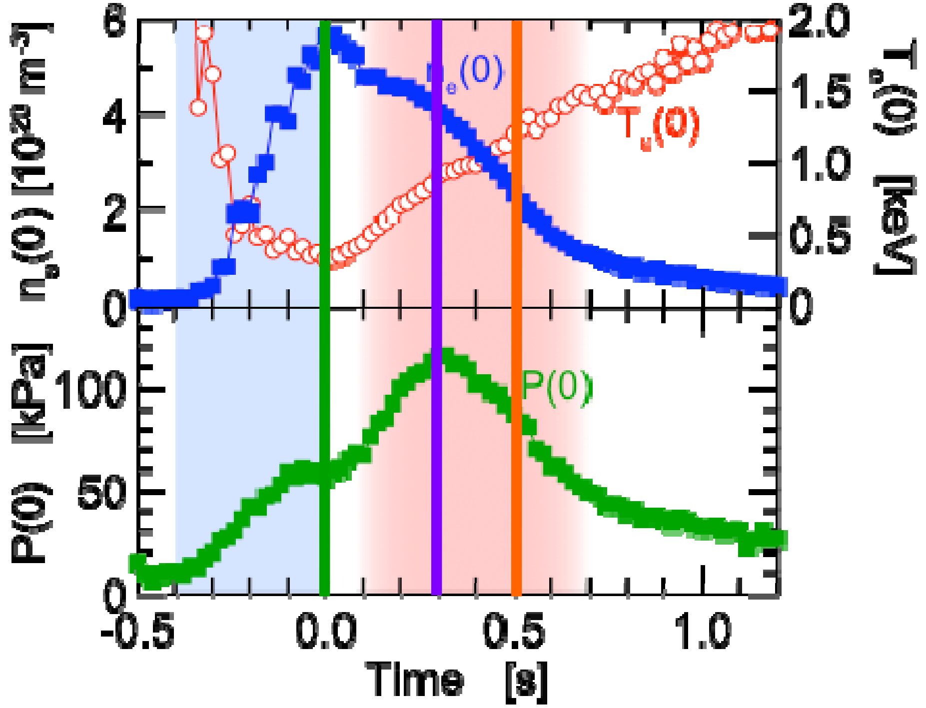
How to make the Peaked Profile

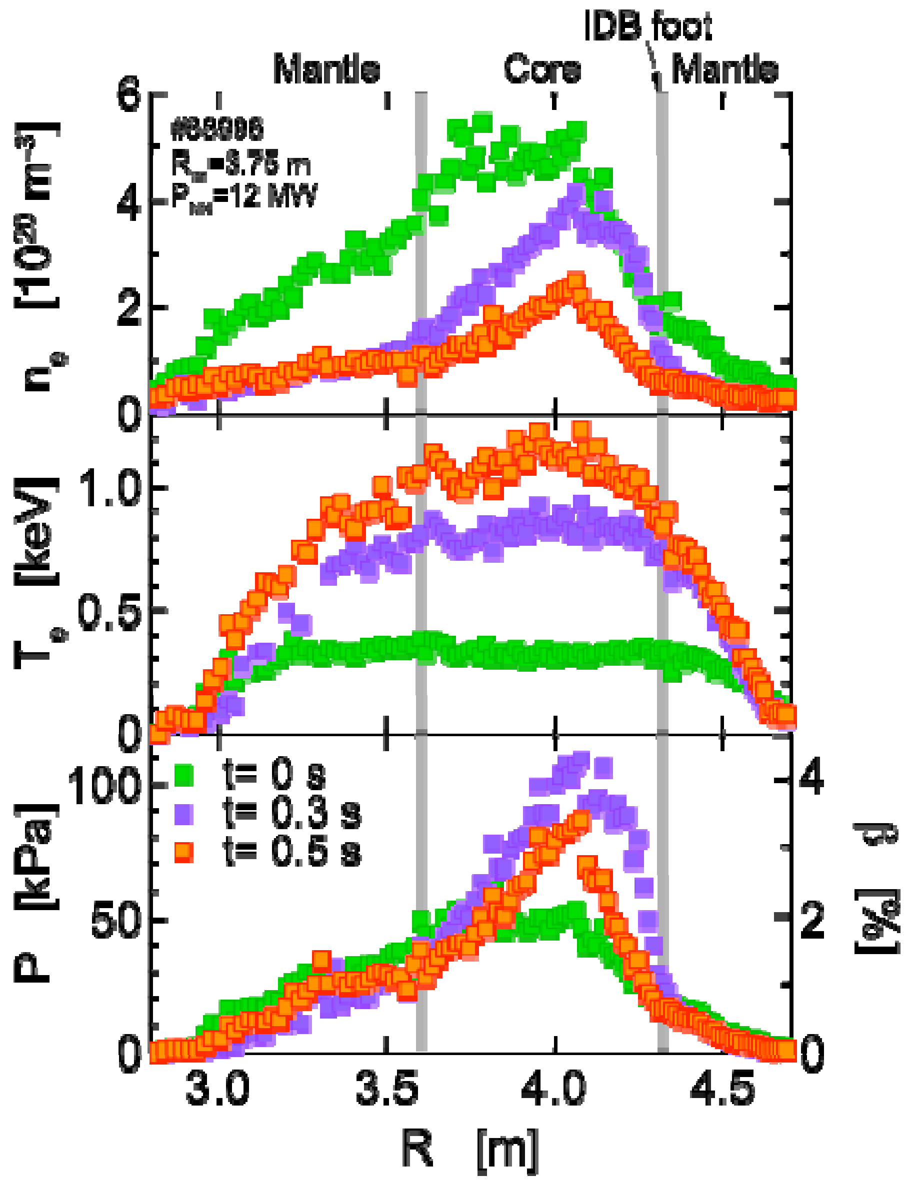
- Intensive multi-pellet injection
- IDB (diffusion barrier) formation in Density decay phase

Temperature recovery rate

↓

Core density decay rate





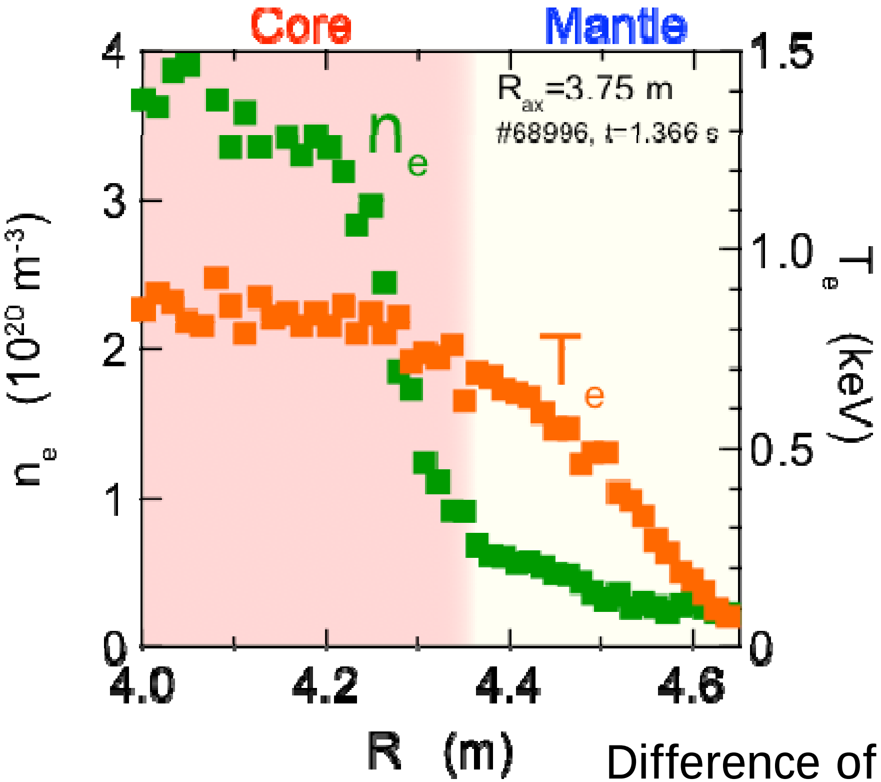
R. Sakamoto, Nucl. Fusion **49**(2009) 085002

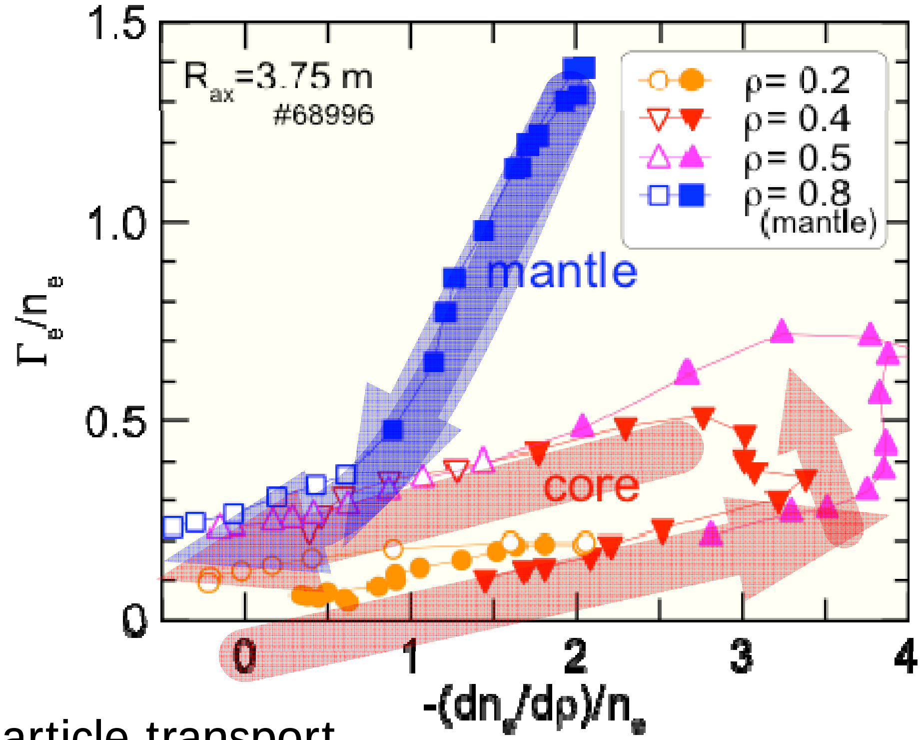
Particle Transport Property of IDB Plasmas

- Particle transport coefficient of IDB plasma is estimated from relationship between time evolution and gradient of density profiles.

$$\Gamma_e = -D_e \frac{\partial n_e}{\partial \rho} + n_e v_e$$
$$Y = D_e X + v_e$$

$$\text{where} \begin{cases} X = -\dfrac{1}{n_e}\dfrac{\partial n_e}{\partial \rho} \\ Y = \dfrac{\Gamma_e}{n_e} = \dfrac{\int \left(S_e - \frac{\partial n_e}{\partial t}\right) dV}{n_e A} \end{cases}$$





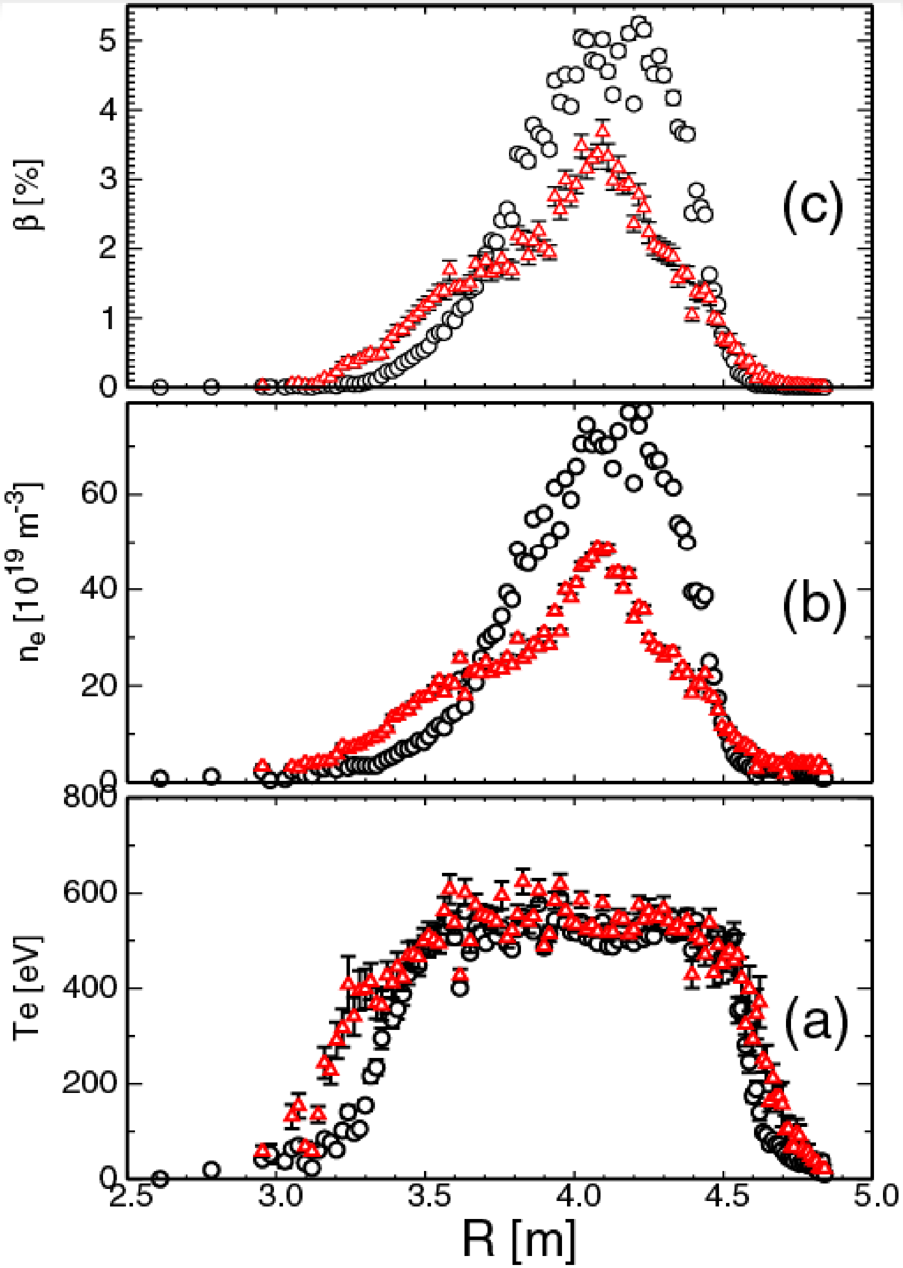
Difference of particle transport
in Core/Edge sustain sustain the peaked density profile

Increase of the central beta is limited by CDC

- Increase of the β_0 is disturbed by a collapse event, (so-called core density collapse(CDC)). CDC is an abrupt event where the core density is collapsed within 1 ms. (much faster than other MHD relaxation events in the LHD)

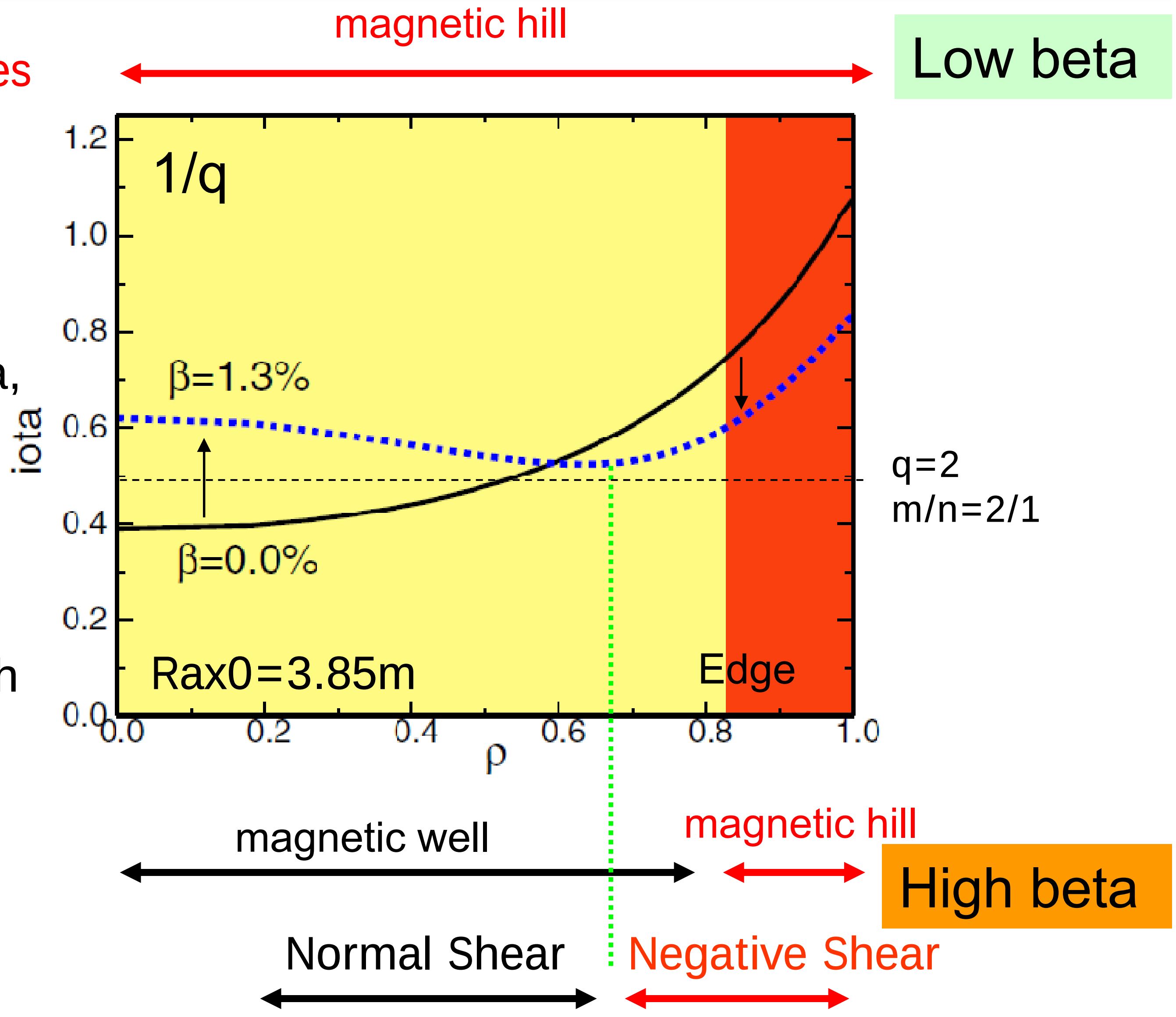
- By CDC, central beta is decreased by ~50%.

- MHD events is a candidate since the process is very fast.



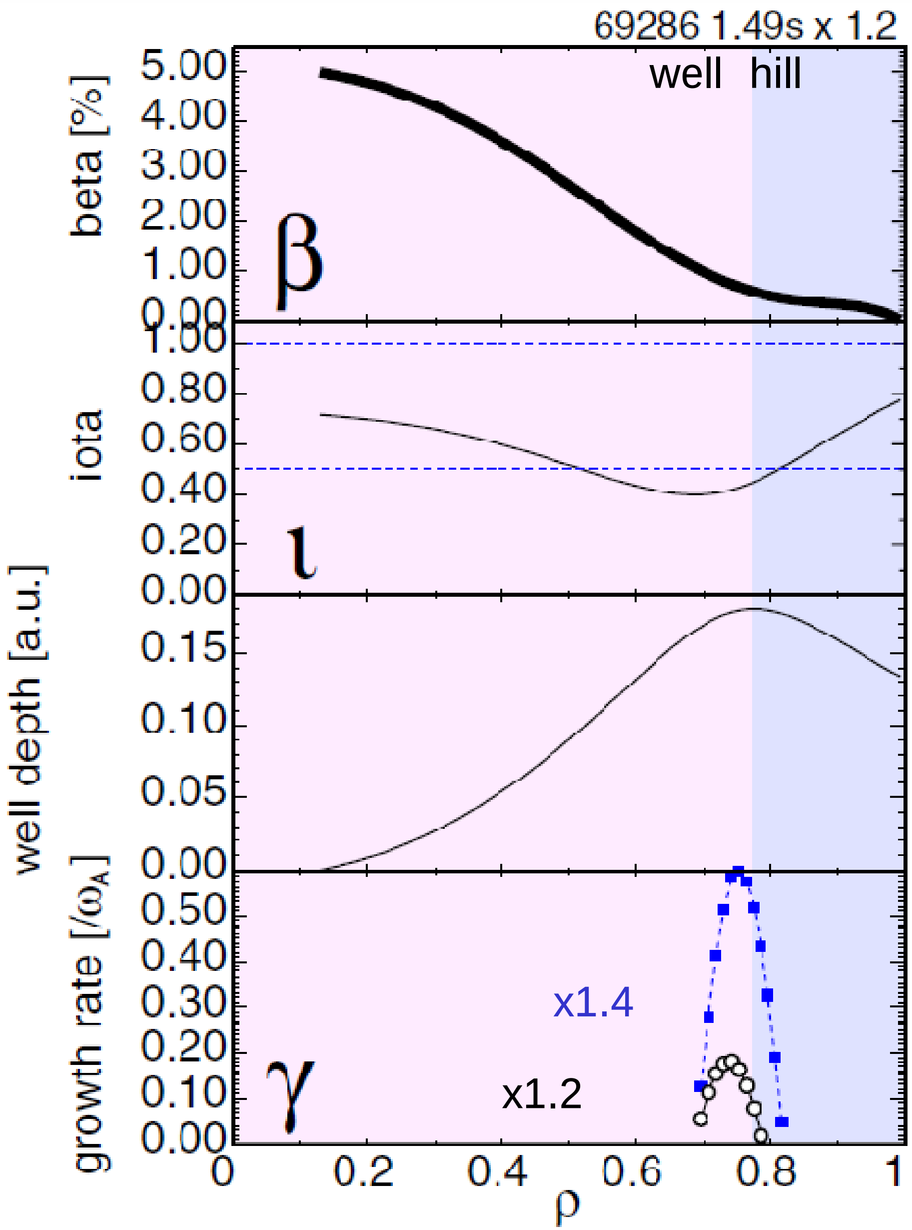
Typical Iota profile and well/Hill boundary

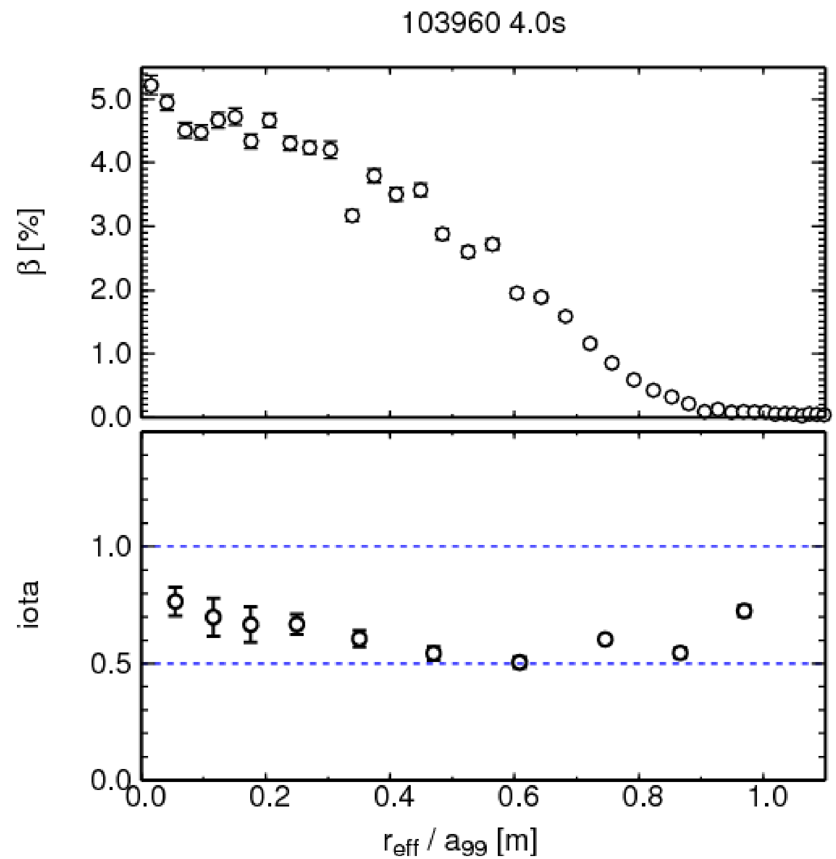
- In LHD, pressure gradient driven modes are important; stability depends on magnetic well depth.
- With increase of beta, the well region expands. (core instabilities vanish.)
- Ballooning mode both in Tokamak-like normal-shear region and negative-shear region is expected with steep pressure gradient.



N. Nakajima Phys. Plasmas **3** 4545,4556(1996)

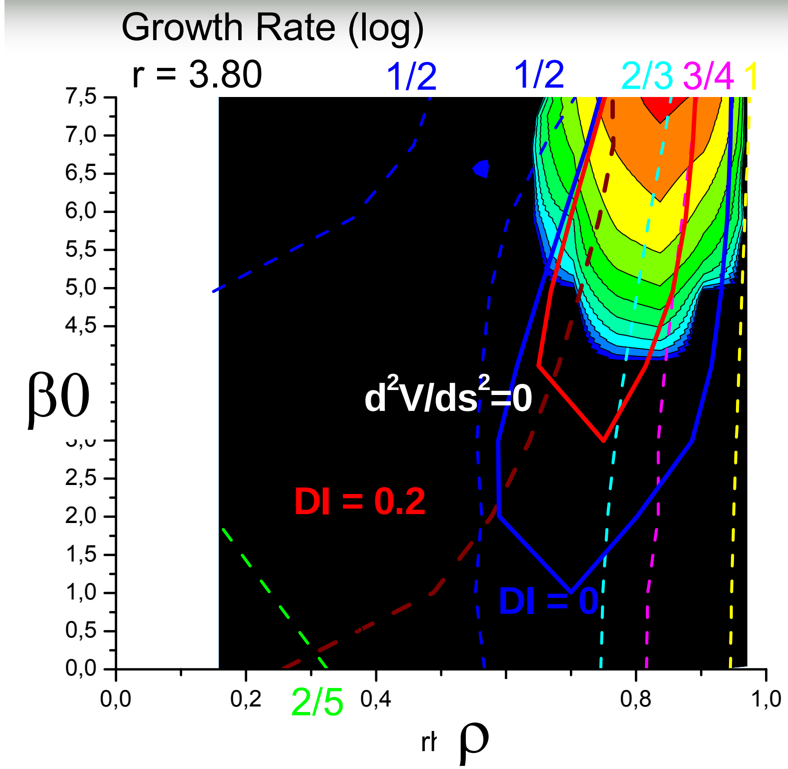
Growth-rate is calculated by Hn-Bal code



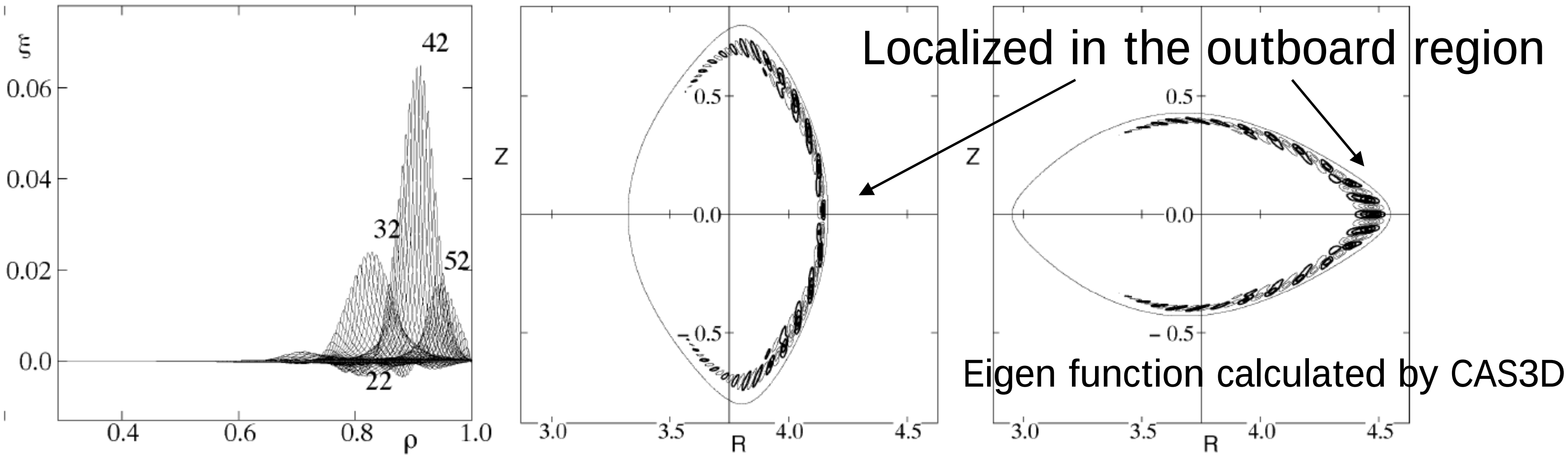


- The magnetic shear there is negative. ⇒ Helical type ballooning modes (3D effect).

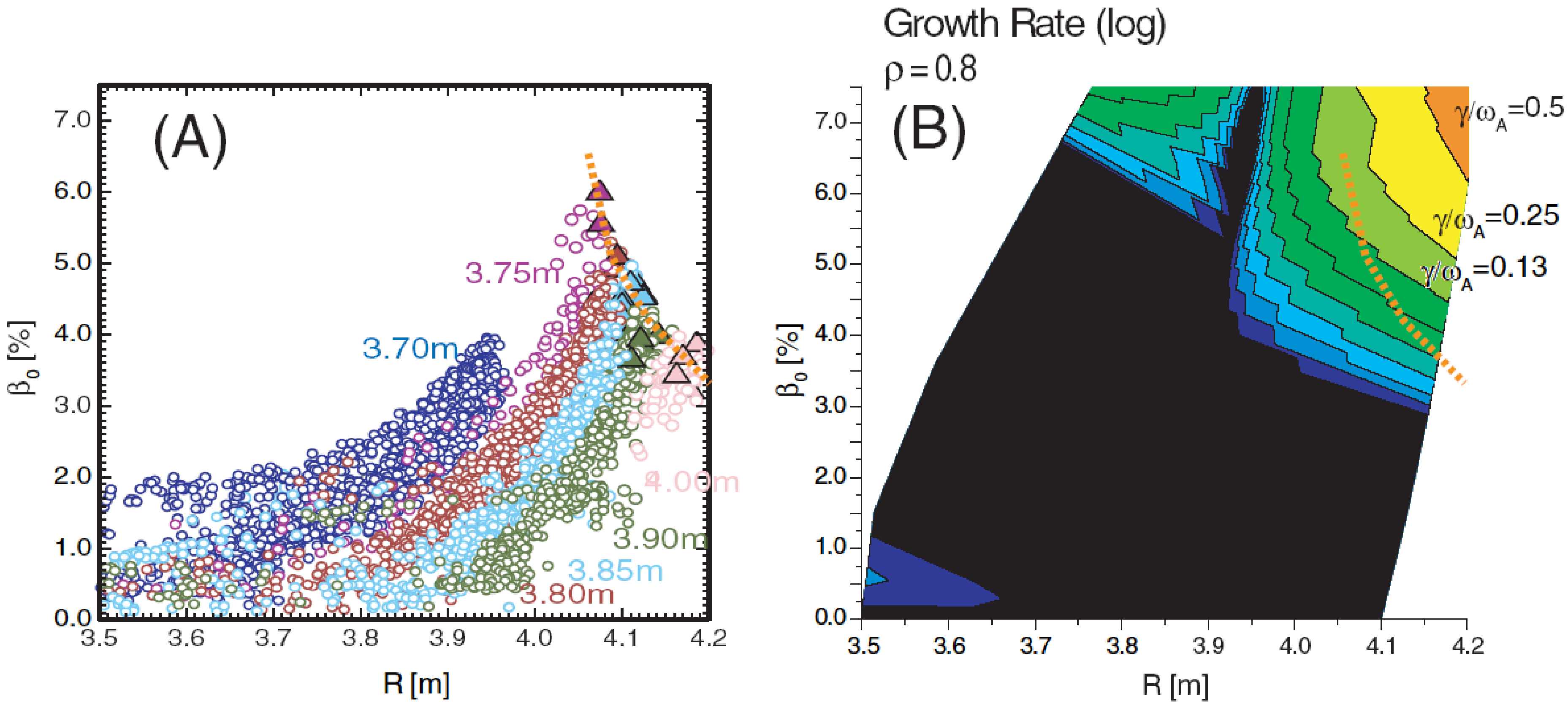
Systematic survey of High-n ballooning mode



- Growth rate are calculated increasing the central beta value.
- High-n ballooning mode is destabilized in Magnetic hill region when central beta is increased.
- Growth rate is estimated in the outboard side of horizontally elongated section. We expect mode structure even in the vertically elongated section.



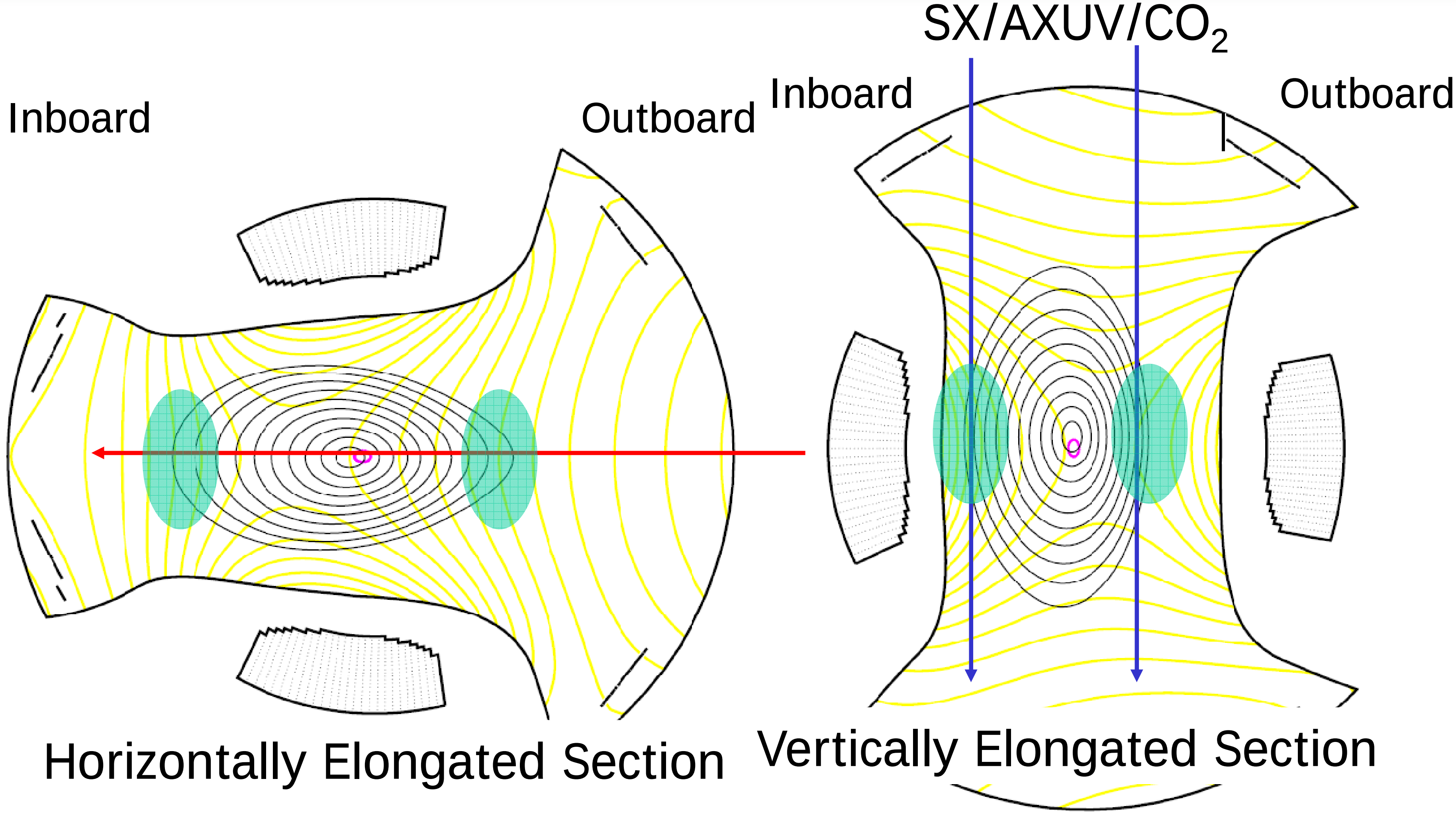
CDC region and Ballooning unstable region



- Experimental data(A) is organized by magnetic axis position and the central beta.

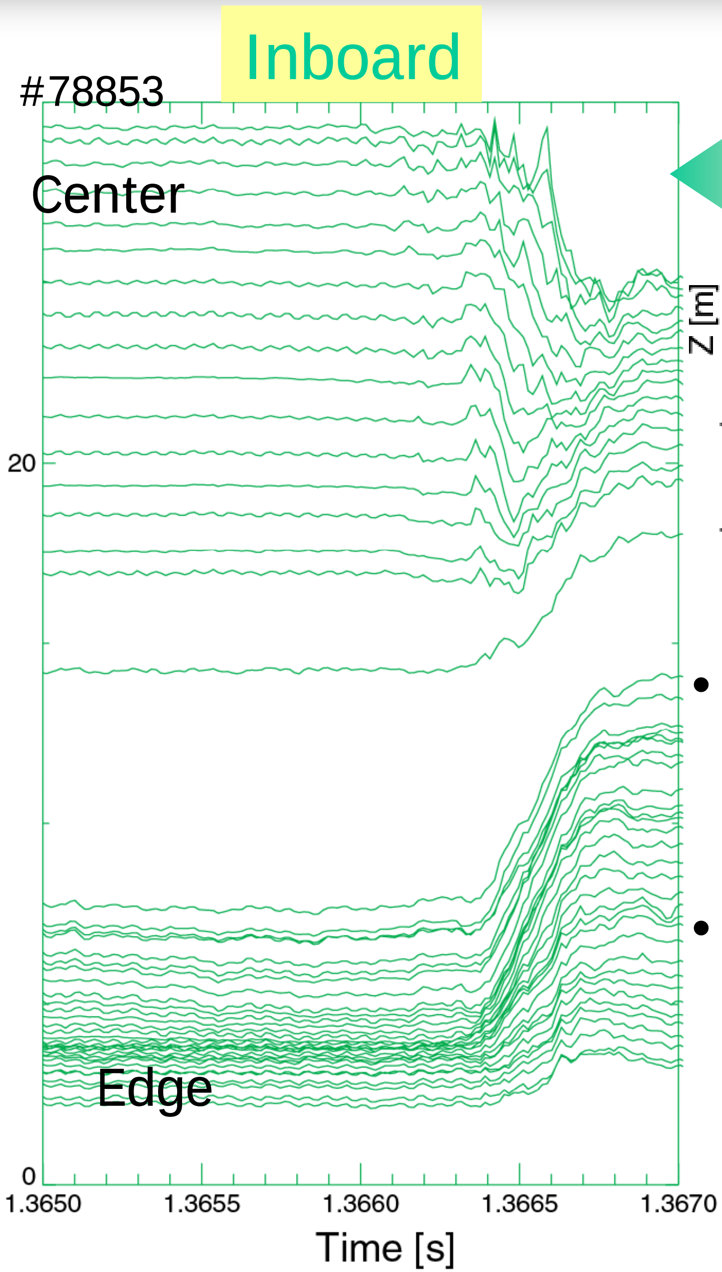
- CDC appears where growth rate is rapidly increasing.

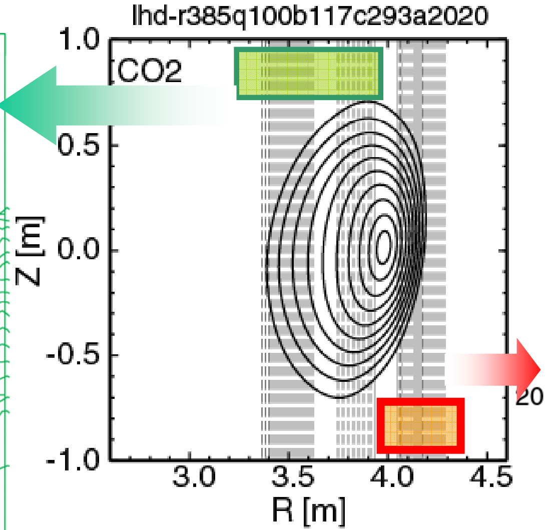
Magnetic field and diagnostics in LHD



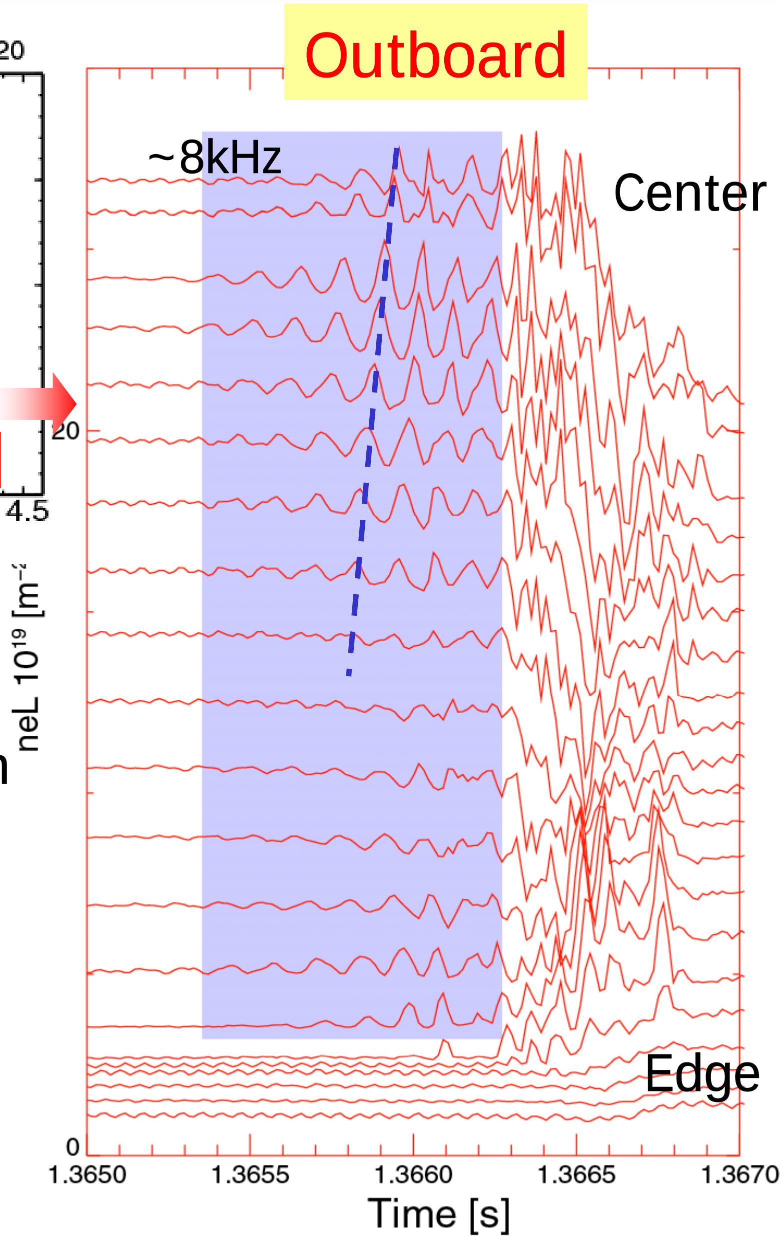
- Most of the fluctuation diagnostics in LHD is line-integrated ones.
- We use vertically elongated section to compare in/out asymmetry.

Pre-cursor observed in CO2 interferometer

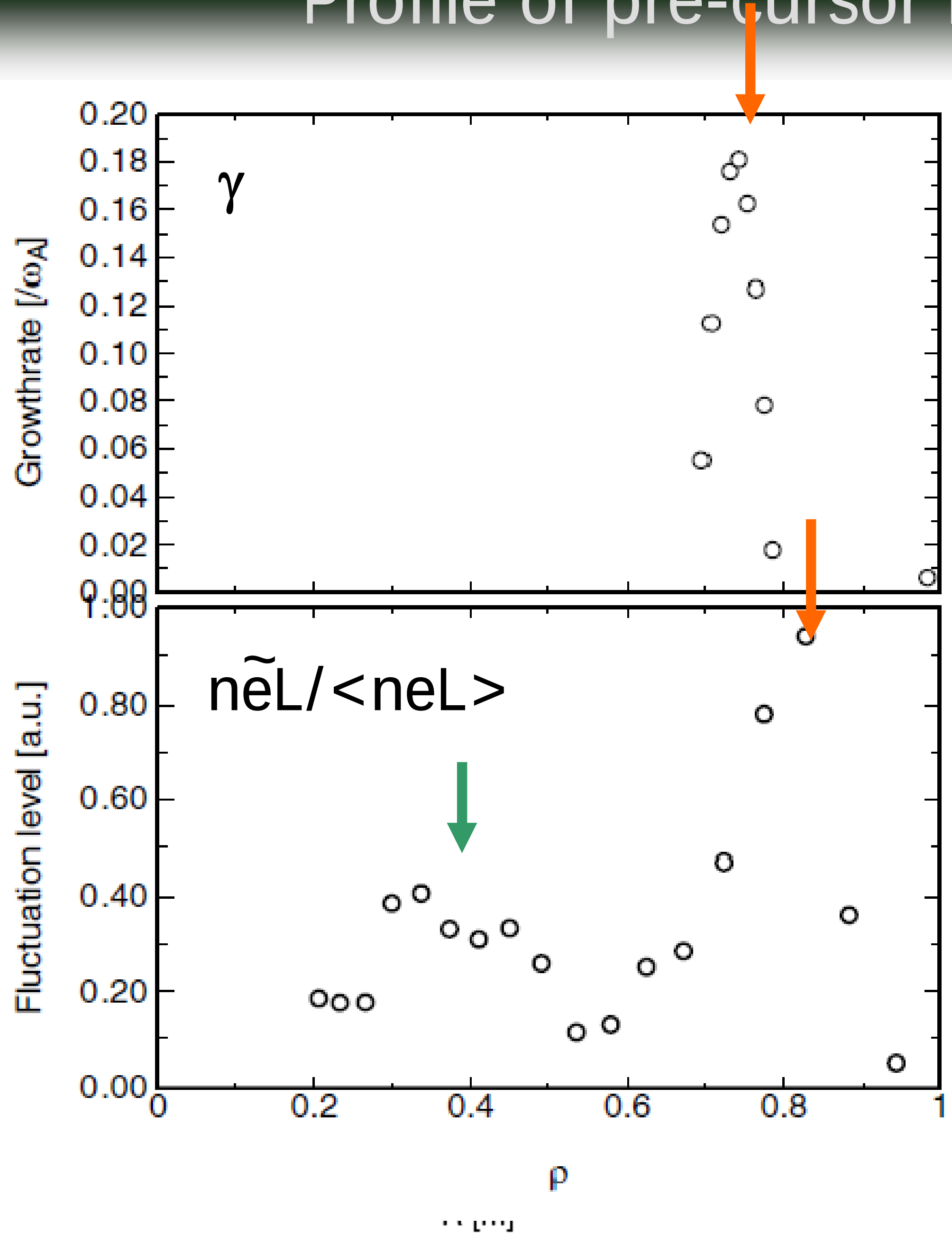


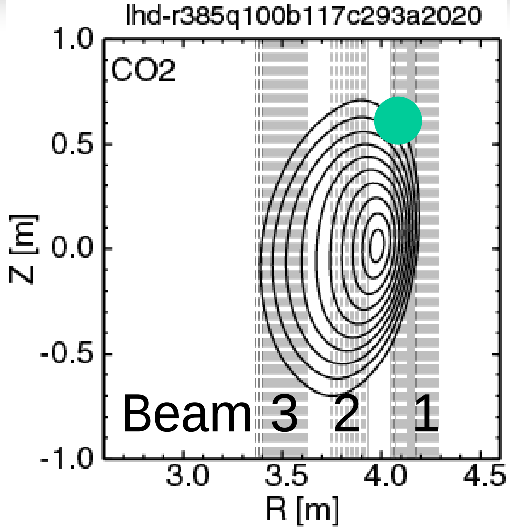


- Oscillations just before CDC is observed only in outboard side.
- Pre-cursor is distinguished in relatively low Bt (2.0T) experiments.



Profile of pre-cursor like oscillations



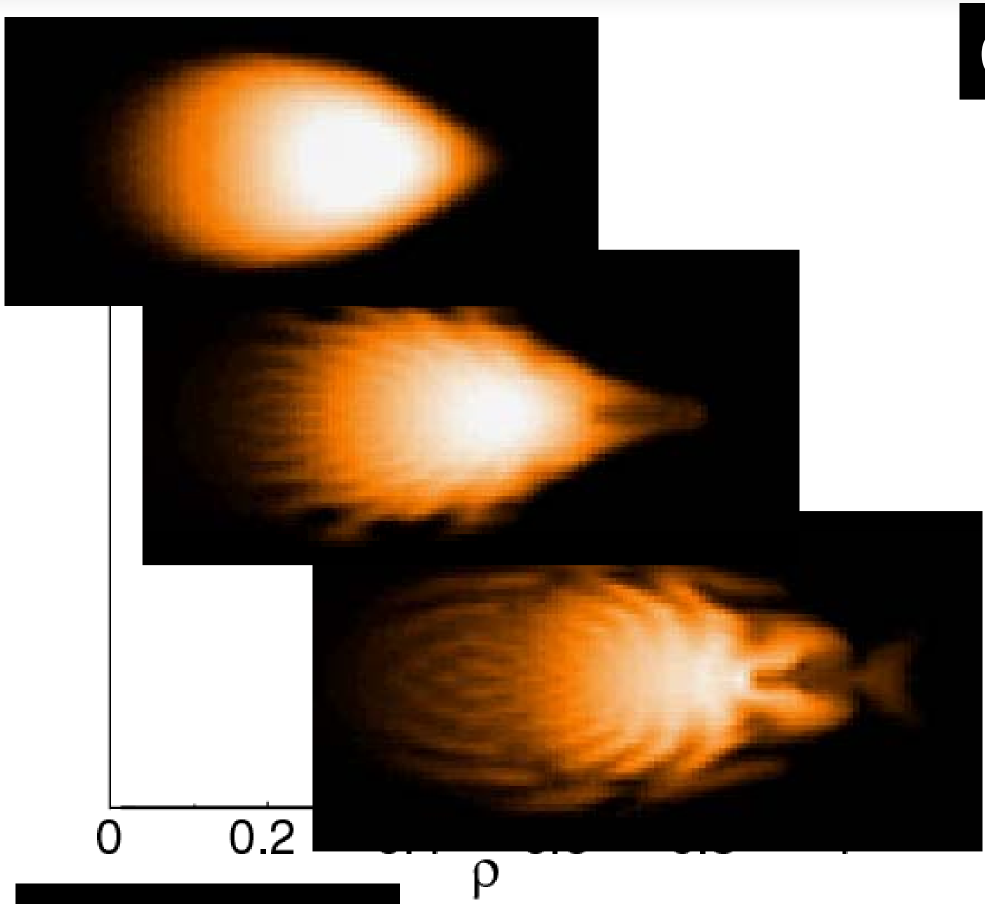


Location of the fluctuations are consistent with the calculation of Hn-bal code.

Error in the estimation of ρ is not small (Δρ~0.2) since the distance of the flux surfaces are quite small in the outboard side.

Inner peak (ρ~0.3-0.5) might be caused by the line-integration effect.

Why radially narrow mode affects the whole profile?

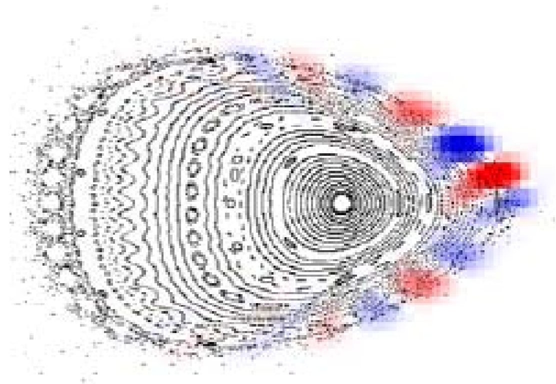


Candidate 1

- At the beginning, flattening of the edge region (ρ~0.8) is observed.
- The stability at inner area becomes worse after the flattening.
- Large scale MHD instability are triggered by this.

Candidate 2

- Ergodization of the magnetic field is expected from the non-linear simulation. (N. Mizuguchi *et al Nucl. Fusion* **49**(2009) 095023)
- Particle flux is enhaced due to the parallel particle flux.



Summary

- Fairly peaked density/pressure profile is observed with multiple pellet injection in LHD. The limit of the pressure gradient is determined by MHD collapse events.

- This collpase is related with the high-n ballooning mode.
  - Collapse appears where the ballooning mode is unstable.
  - Precursors, localized in the code predicted region, are sometimes observed.

Mistery to be studied

- Though the mode structure and precursors are well localized ($\Delta\rho < 0.2$), whole plasma is affected by this event. Different from ELM events in tokamak H-mode.
- Core localized MHD instabilities (m=1?) might be related with this.