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Characteristics of MHD in the high central density plasma in LHD

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Thanks to
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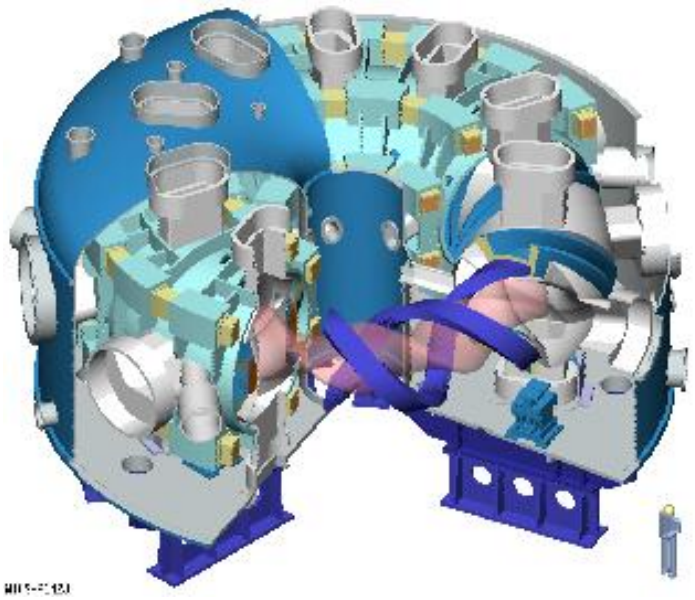
NAKAJIMA, Noriyoshi / SUZUKI, Yasuhiro
SAKAKIBARA, Satoru

Large Helical Device (LHD)



Major radius R_0 = 3.5~4.1[m]
Minor radius a ~ 0.6[m]
Aspect ratio A_p = 5.8~6.8
Magnetic field B_t £ 3[T]
Super conductor coils
A pair of helical coils L/M = 2/10
3 pairs of poloidal coils
Heating
NBI, ECH, ICRF
Fueling
Gas puff, Pellet injection

Current-FREE plasma
- **Current drive is not necessary**
- **No current driven MHD instability**

Outline

- **Back ground**
- **High central density plasma**
- **MHD stability**
- **Core Density Collapse event**
- **Summary**

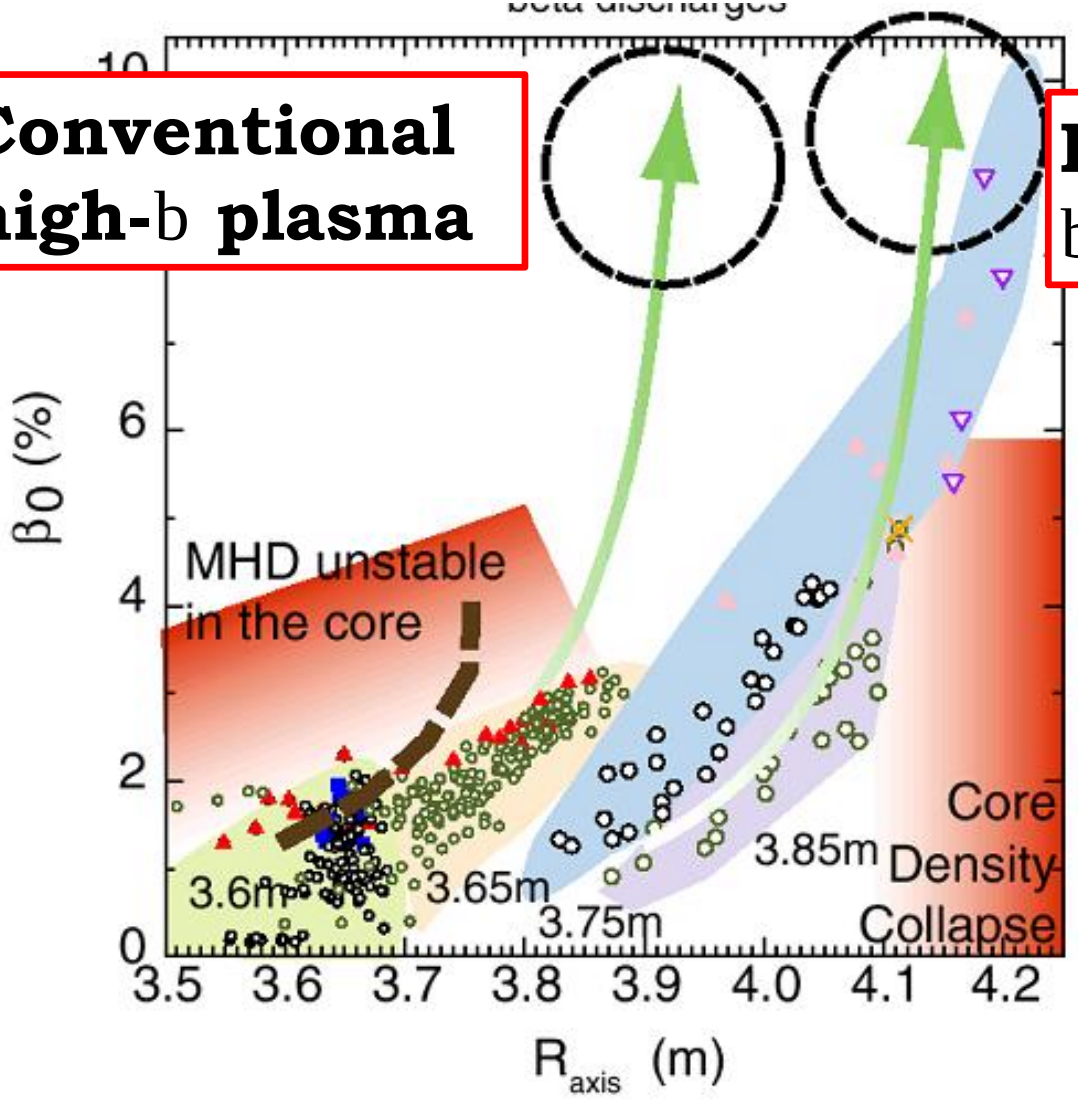
Back ground

Two approaches to the high-b plasmas

by S. Ohdachi

Conventional high-b plasma

High central b plasma



Study of MHD stability is important

Back ground

Comparison of plasmas

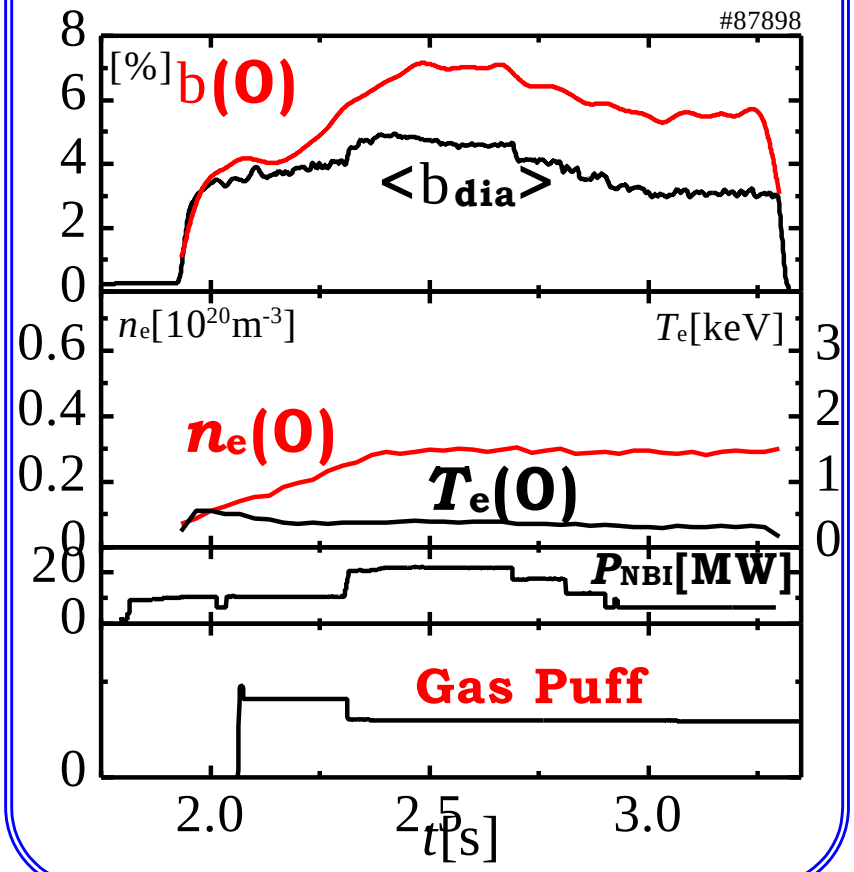
Conventional high-b

$n_e(0) = 0.3\times10^{20}[m^{-3}]$

$\langle b_{dia}\rangle = 5[\%]$, $b(0) = 7.2[\%]$

$R^v_{ax} = 3.6[m]$, $B_t = 0.425[T]$

Fuelling : Gas puffing



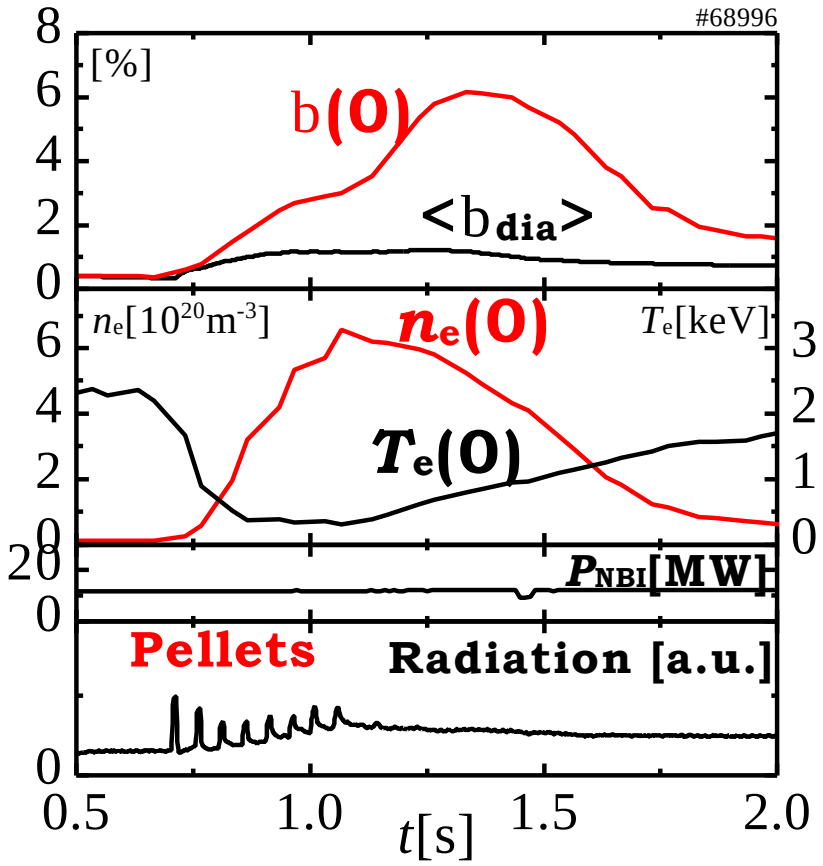
High central density

$n_e(0) = 6.5\times10^{20}[m^{-3}]$

$\langle b_{dia}\rangle = 1.2[\%]$, $b(0) = 6.2[\%]$

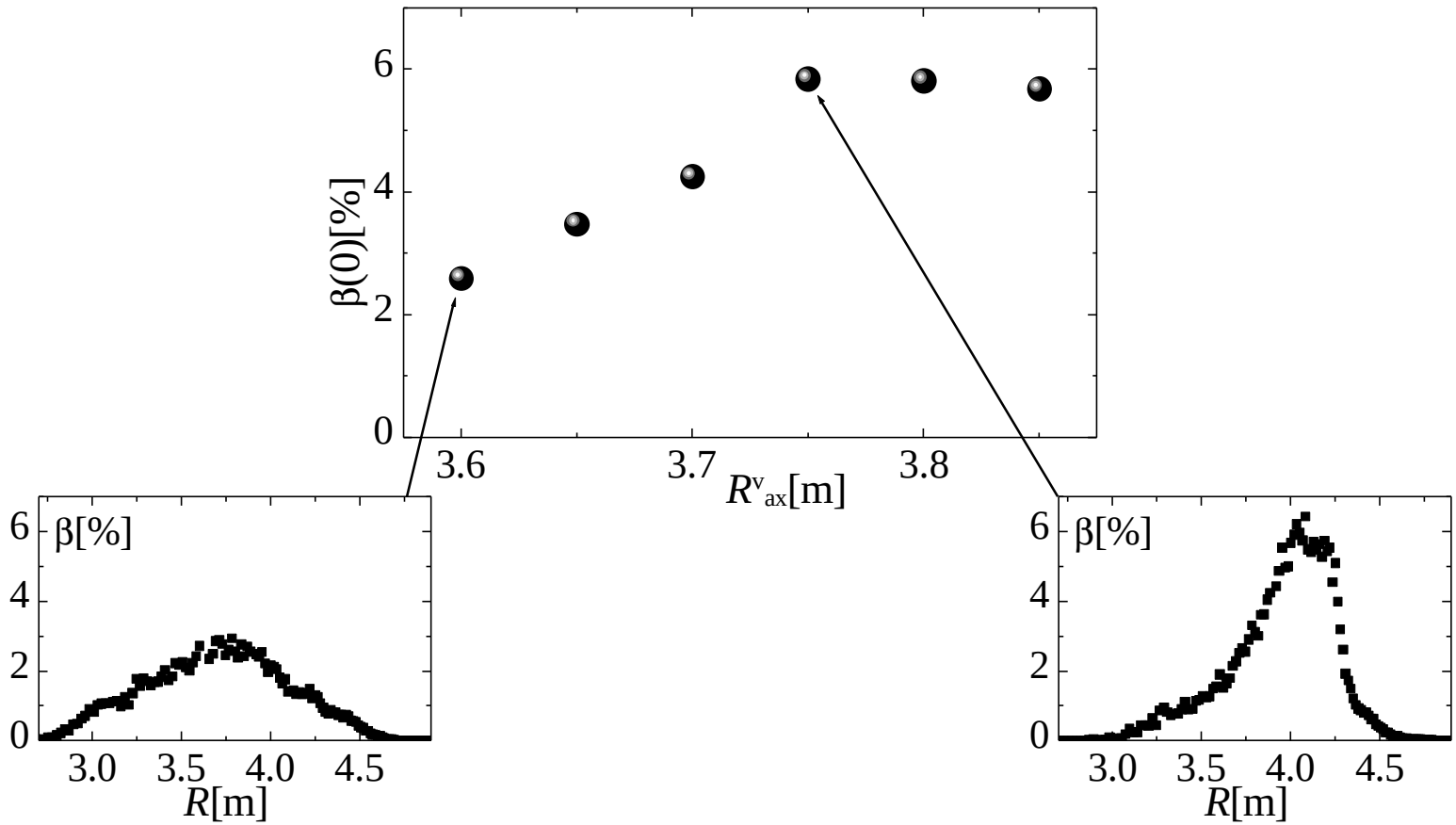
$R^v_{ax} = 3.75[m]$, $B_t = 2.75[T]$

Fuelling : Pellet injection



High central density plasma

Attainable central beta b(0)



b(0) depends on R^{v}_{ax}

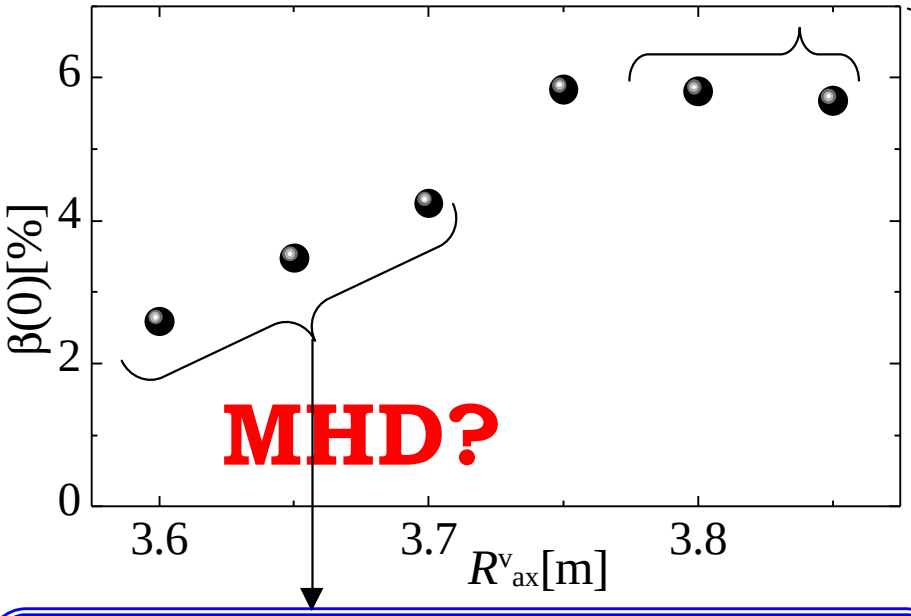
(R^{v}_{ax} : preset magnetic axis position)

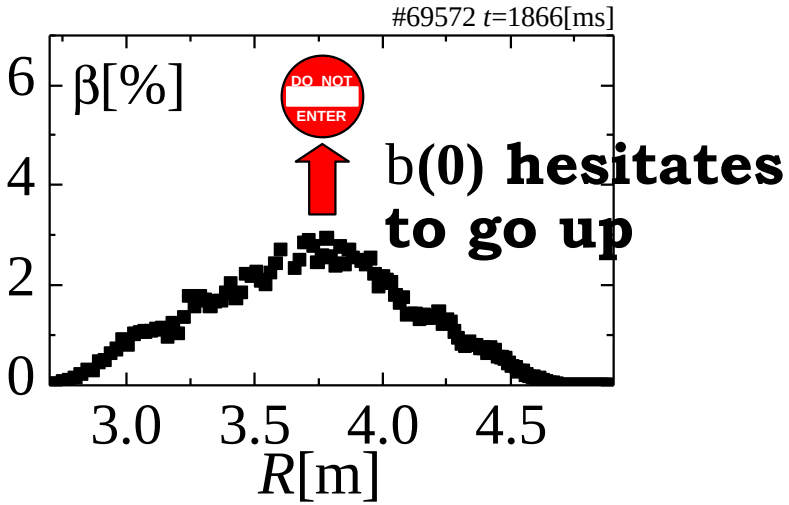
What suppresses b(0) ?

High central density plasma

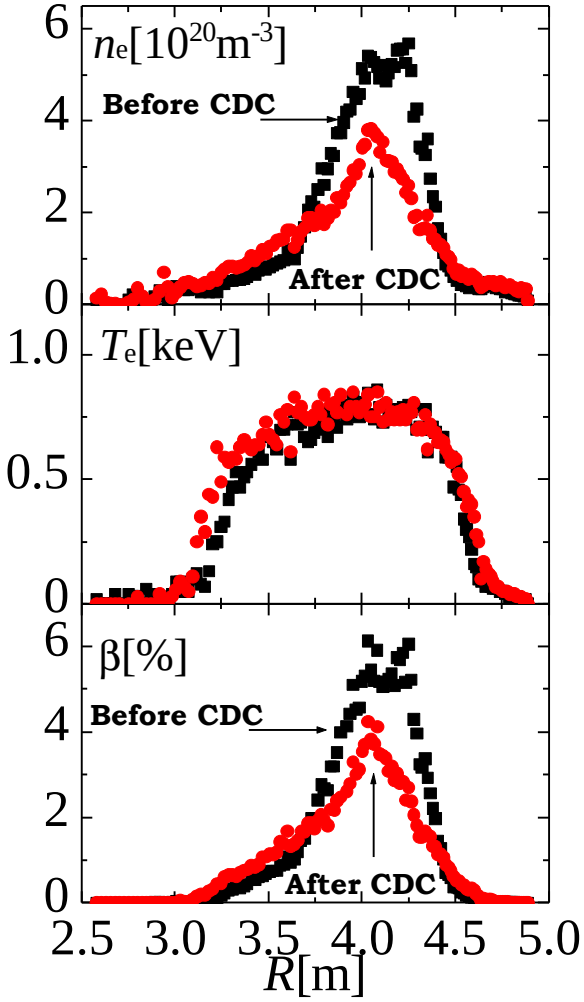
From experimental observation, b(0) seems to be suppressed by …

CDC





Core Density Collapse event



Open questions

- **How is b(0) suppressed?**

  (R^{v}_{ax} < ~3.7[m])

- **What is cause of CDC?**

  (R^{v}_{ax} > 3.75[m])

We try to explain them from the viewpoint of MHD

Open questions

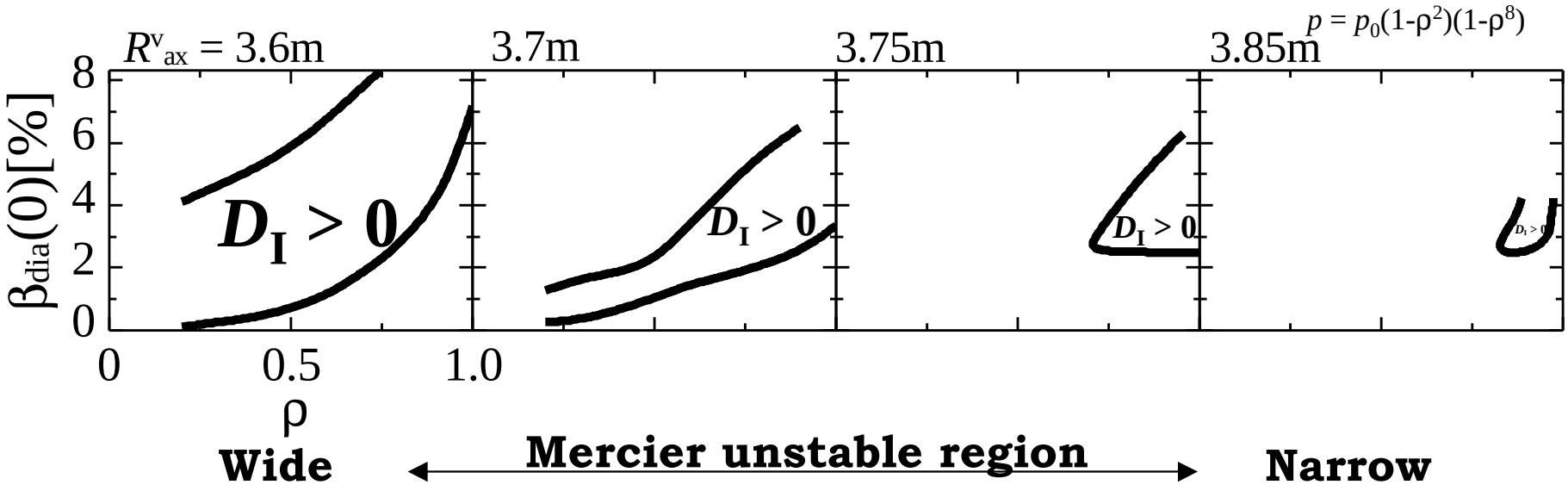
How is b(0) suppressed?

(R^v_{ax} < ~3.7[m])

- **General MHD properties of LHD plasmas**
- **Region of experimental results**

How is b(0) suppressed? (R^v_{ax} < ~3.7[m])

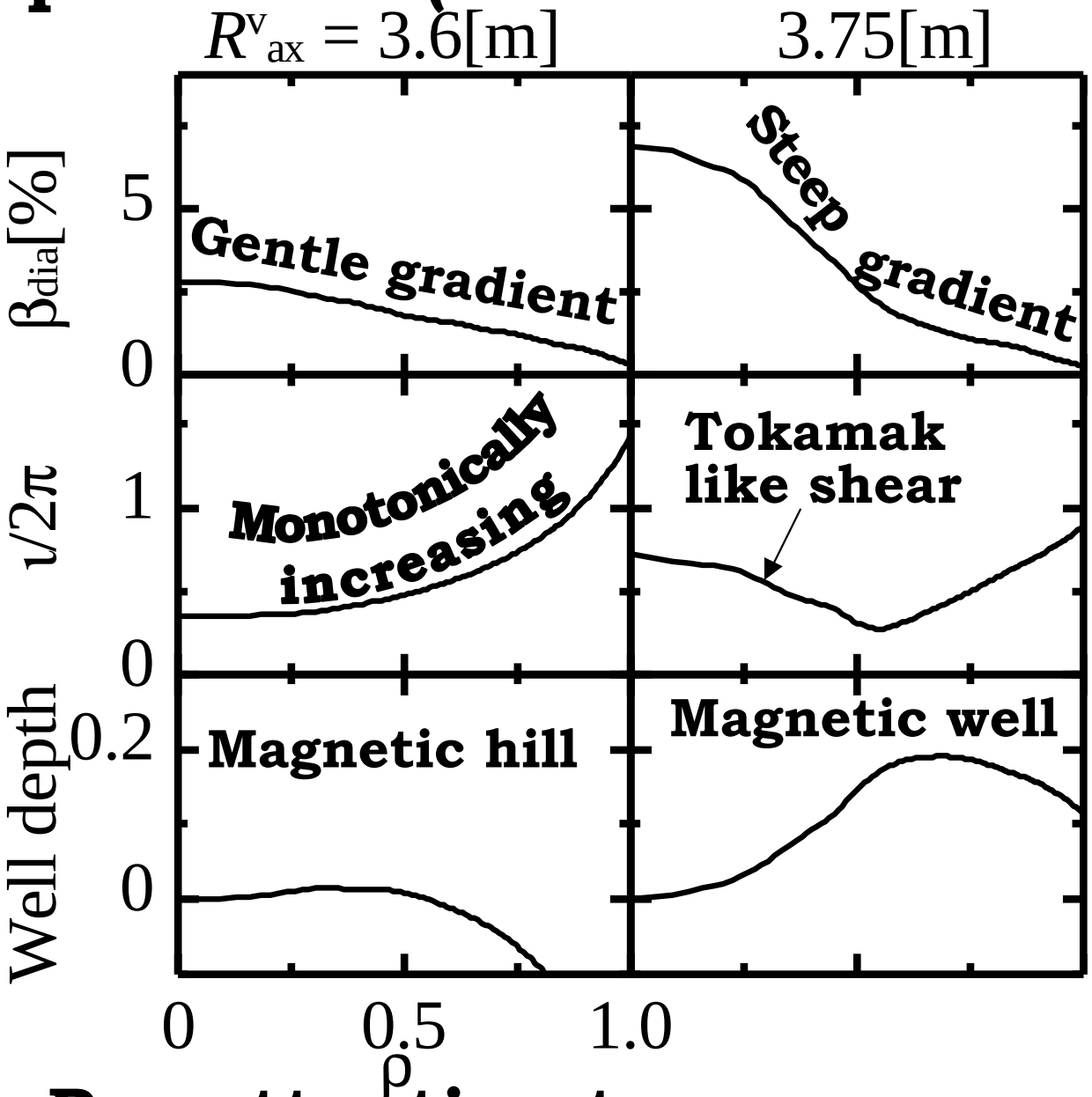
General MHD properties of LHD plasma



Mercier unstable region narrows with R^v_{ax}

How is b(0) suppressed? (R^v_{ax} < ~3.7[m])

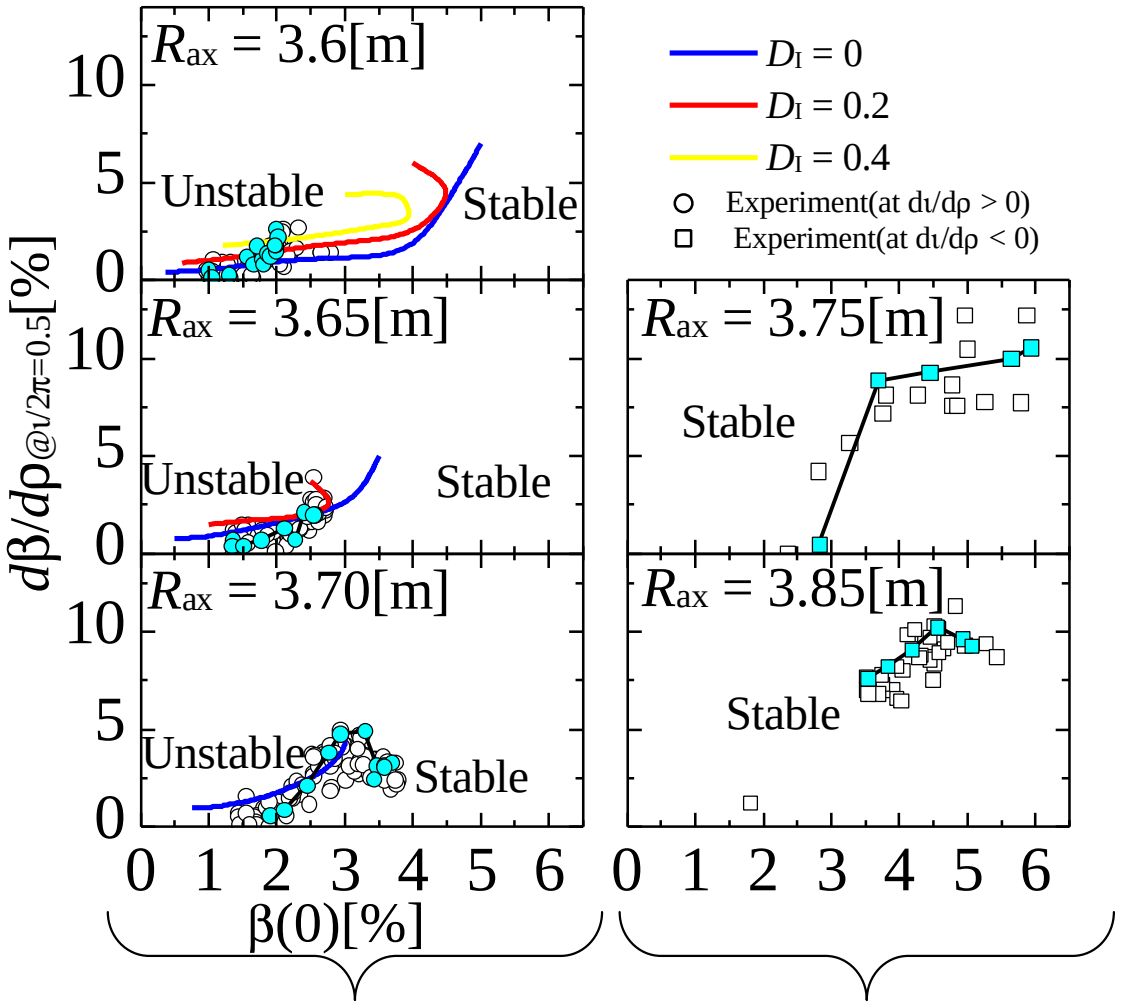
Equilibrium (when Maximum b(0))



Pay attention to pressure gradient at core (i/2p = 0.5)

How is b(0) suppressed? (R^v_{ax} < ~3.7[m])

Region of experimental results

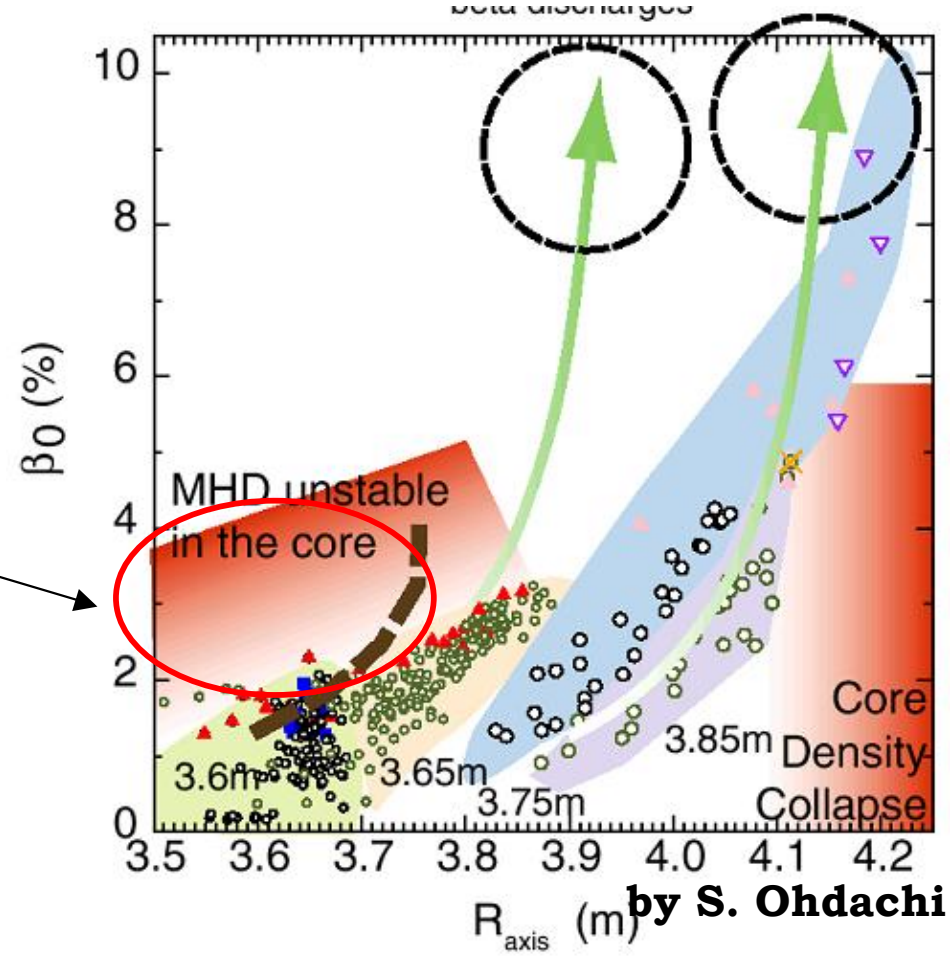


- **Mercier stable region expands with R^v_{ax}**
- **The $d\beta/dr$ reaches to 5[%]**
- **$d\beta/dr$ seems to be suppressed by ideal local mode**

- **No Mercier unstable region**
- **The $d\beta/dr$ attains to 12[%]**
- **Pressure gradient increases with β without restriction**

How is b(0) suppressed? (R^{v}_{ax} < ~3.7[m])

MHD unstable



- **Pressure gradient seems to be suppressed by ideal local mode**
- **b(0) hesitates to go up**

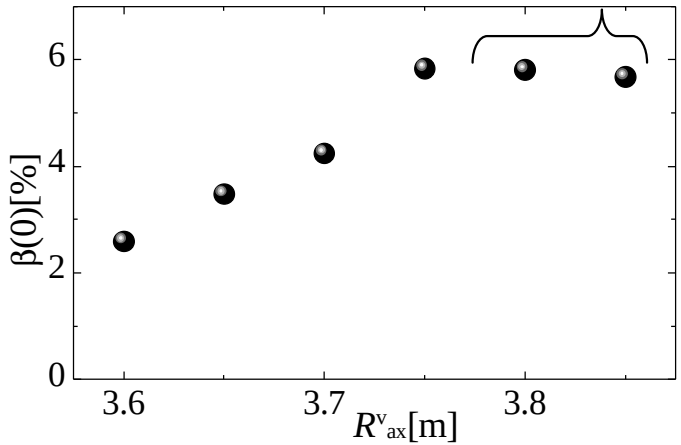
Open question

What is cause of CDC?

($R^v_{ax} > 3.75$[m])

- Details of experimental observation
- MHD analysis

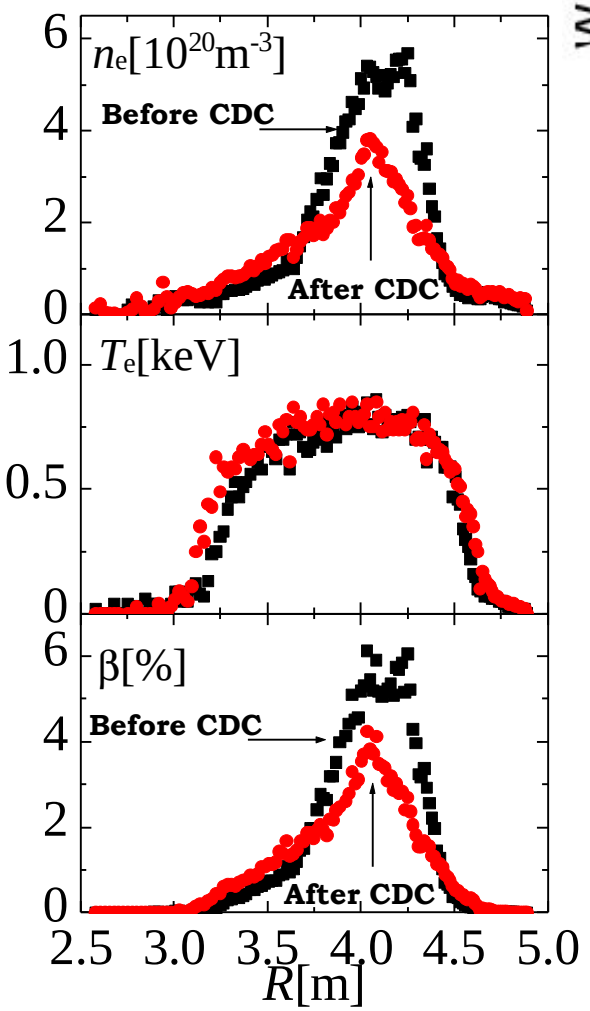
CDC event (**C**ore **D**ensity **C**ollapse event)

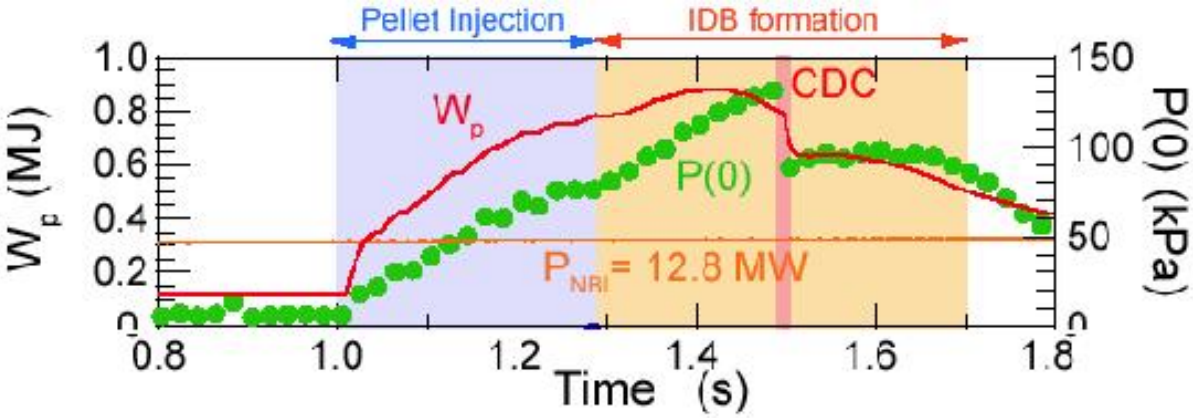


What is cause of CDC? ($R^v_{ax} > 3.75$[m])

Details of experimental observation

Observed for $R^v_{ax} > 3.75$[m]



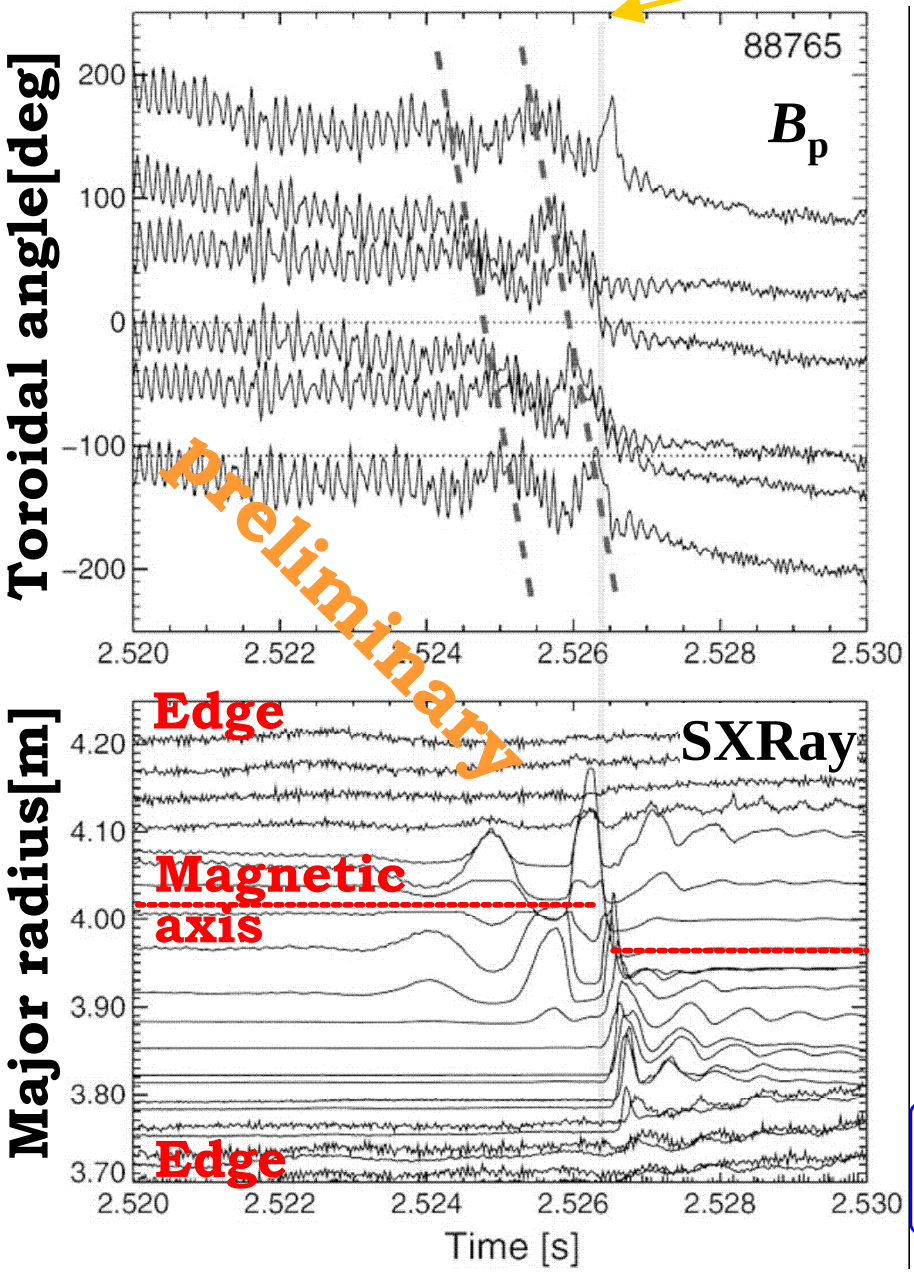


- n_e drops at core
- T_e is sustained
- b_{dia} decreases

What is cause of CDC? ($R^v_{ax} > 3.75$[m])

Details of experimental observation

Precursor of CDC (by S. Ohdachi)



$n = 1$ is observed in B_p

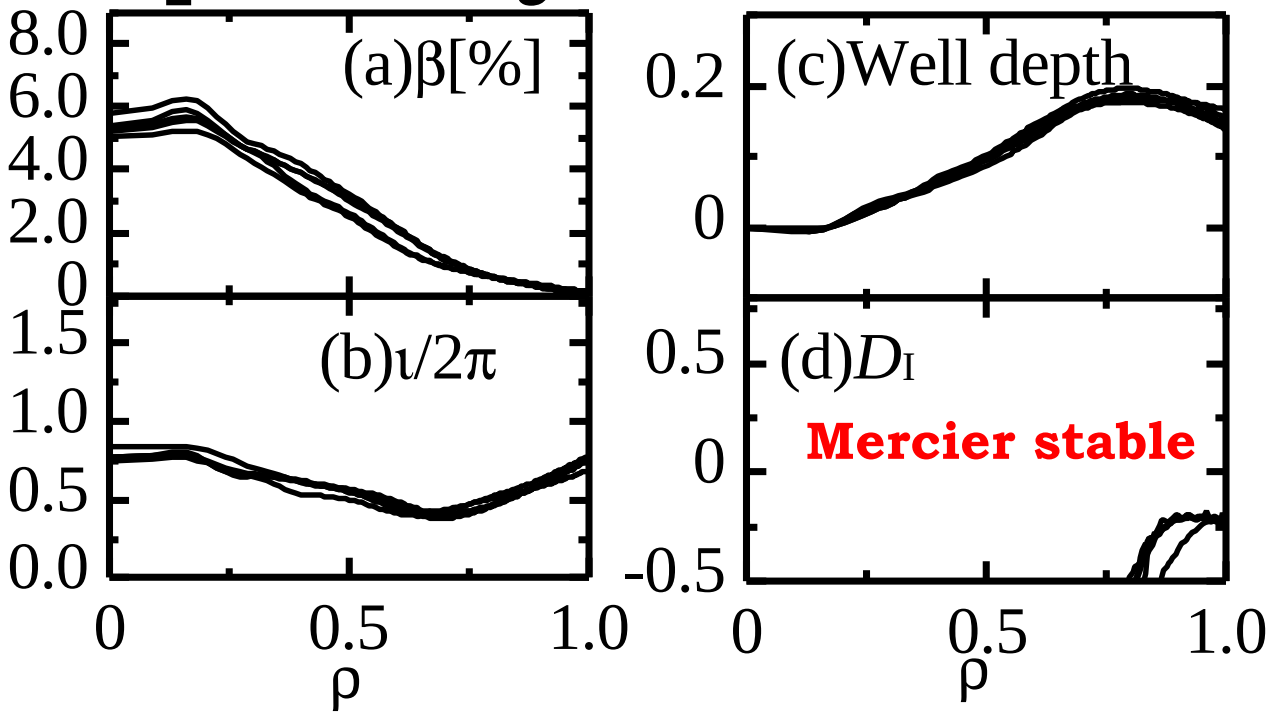
Soft X-Ray Precursor (2[ms]) at core with odd mode (Odd poloidal mode?)

How about MHD?

What is cause of CDC? ($R^{v}_{ax} > 3.75$[m])

MHD analysis

Equilibria just before CDC



- **Steep pressure gradient**
- **Reversed** i/2p **gradient**
- **Deep & wide magnetic well-depth**
- **Mercier stable**

Low-*n* (1~4) global ideal mode is stable

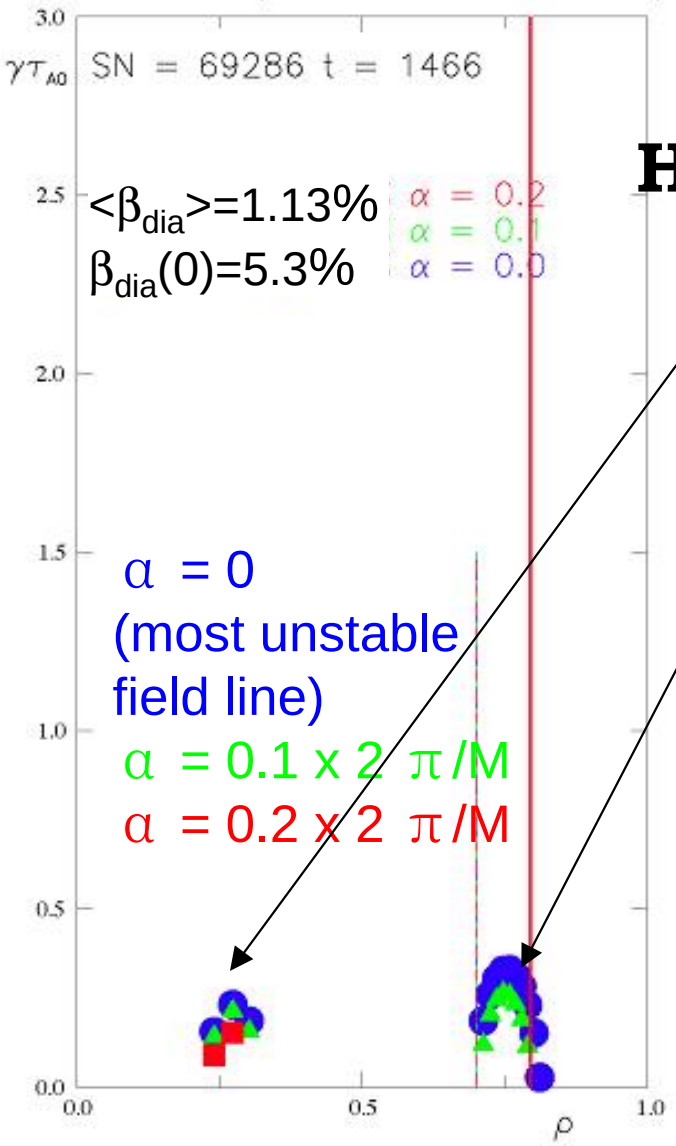
(TERPSICHORE / W.A. Cooper PPCF Vol. 34, p1011 (1992))

What is cause of CDC? ($R^{v}_{ax} > 3.75$[m])

MHD analysis

Ballooning mode (Hn_bal code)

(N.Nakajima, PoP Vol.3 (1996) pp.4545-4555 and pp.4556-4567)



Helical-like ballooning modes

Core :
tokamak-like shear

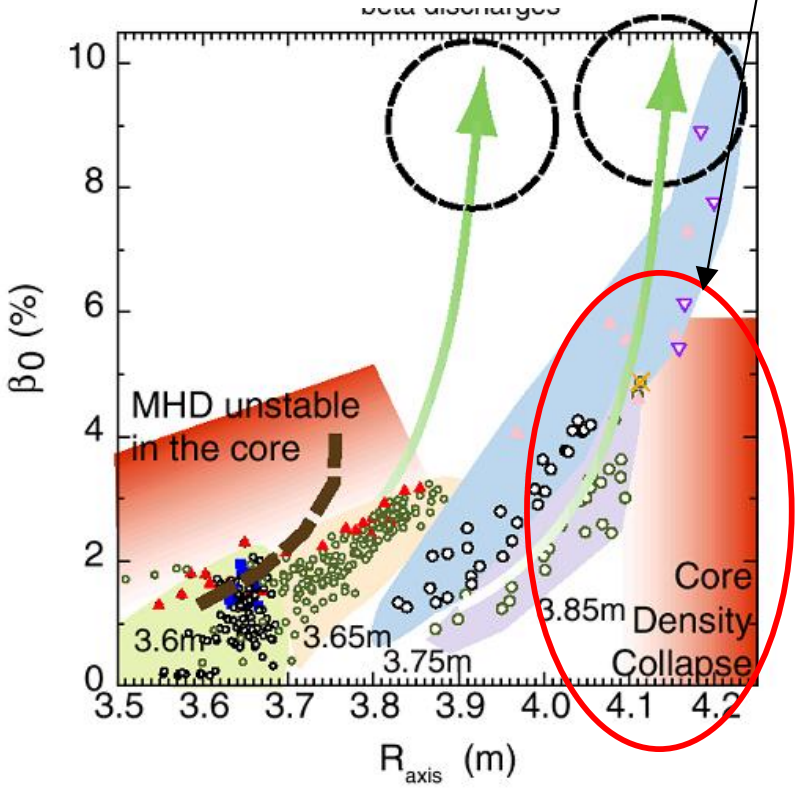
Periphery :
helical-like shear

High-*n* ballooning modes in the core region might lead to CDC???

More exact checks are required

What is cause of CDC? ($R^{v}_{ax} > 3.75$[m])

CDC event



Experiment
- **Core-localized phenomena**

Numerical Calculations
- **Mercier stable**
- **Low-n stable**
- **Ballooning unstable???**

MHD study is being continued to clarify physics of CDC event

Summary

- **MHD stability of LHD plasmas with high central density are analyzed**

- **Attainable b(0) depends on R^{v}_{ax}**

- **In $R^{v}_{ax} < 3.75$[m], pressure gradient seems to be suppressed by ideal local mode**

- **In $R^{v}_{ax} > 3.75$[m], b(0) is suppressed by CDC event**
- **MHD study is being continued to clarify physics of CDC event**