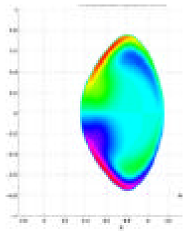
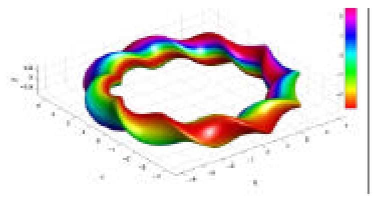
Low-*n* Ideal Mode Driven by Large Toroidal Current in LHD





NARUSHIMA, **Y**oshiro (NY)

LHD experimental group

narusima@LHD.nifs.ac.jp

National Institute for Fusion Science, 322-6 Oroshi-cho, Toki, Gifu 509-5292, Japan

Out line

1. Background and purpose
2. Large Helical Device (LHD)
    1. Experimental setup
    2. Equilibrium
3. MHD analysis by **TERPSICHORE** -code (W.A.Cooper)
    1. Mode structures
    2. Growth rate and toroidal current
    3. Various current density profiles
4. Conclusion
    1. Summary
    2. Proposal to experiment

Background

- Toroidal current is **NOT** necessary to produce **a Heliotron plasma**. Therefore, this type of plasma is **NOT** destabilized by the current driven MHD mode **in principle**.

- In LHD experiment, the pressure driven MHD modes have been studied. This studies show that **the toroidal current** has a role to modify the characteristics of the pressure driven instabilities via **the rotational transform.**

- In the other devices such as Heliotron-E and CHS, the studies about the current driven instabilities have been done. In that experiment, the target plasma is resistive plasma due to low temperature.

- Ideal MHD phenomena of the current driven modes are able to investigate by LHD with high temperature plasma. Furthermore, **Heliotron plasma**'s magnetic field is not annihilated by the disruption like a **Tokamak**, so that the effect of the current driven mode is clearly observed.

Purpose

1. To drive the large toroidal current in LHD plasma.

and

2. To find the characteristics of the current driven MHD instabilities experimentally.

Before the experiment

The low-*n* ideal MHD analysis is performed on the LHD plasma using the 3-dimensional stability code of **TERPSICHORE.** (W.A.Cooper)

↓

The experiment will be done.

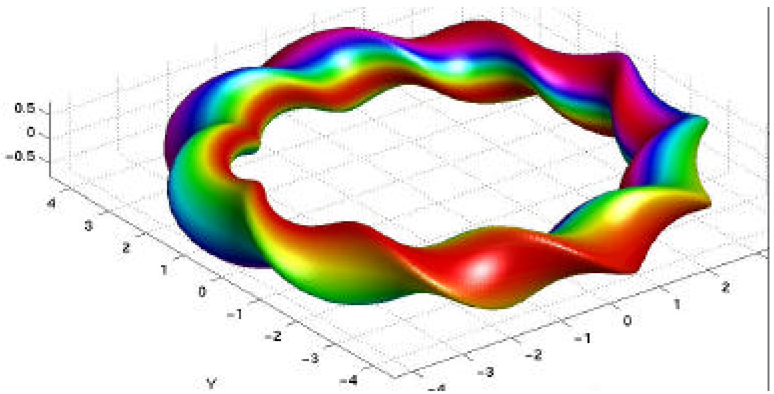
21/Nov/2002 02:00~7:30 (EST)

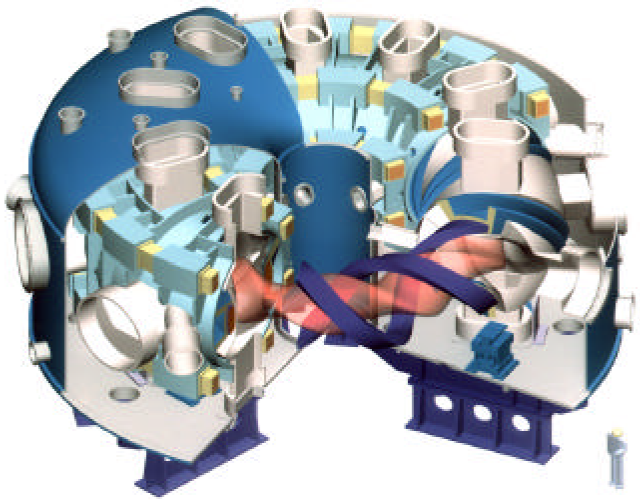
21/Nov/2002 16:00~21:30(JST)

Large Helical Device (LHD)

Experimental setup

- l=2/m=10 Continuous Helical Coils and Three Pairs of Poloidal Coils
- Major and Averaged Minor Radii are 3.9 m and 0.5~0.65 m, respectively
- Aspect Ratio A_p is 6~7 (CHS : 5, Heliotron-E : 11)
- Magnetic Axis Position R_{ax} = 3.5 ~ 3.9 m
- Available Magnetic Field B_t < 3.0 T
- **One co.-NBI and two ctr.-NBIs are equipped.**



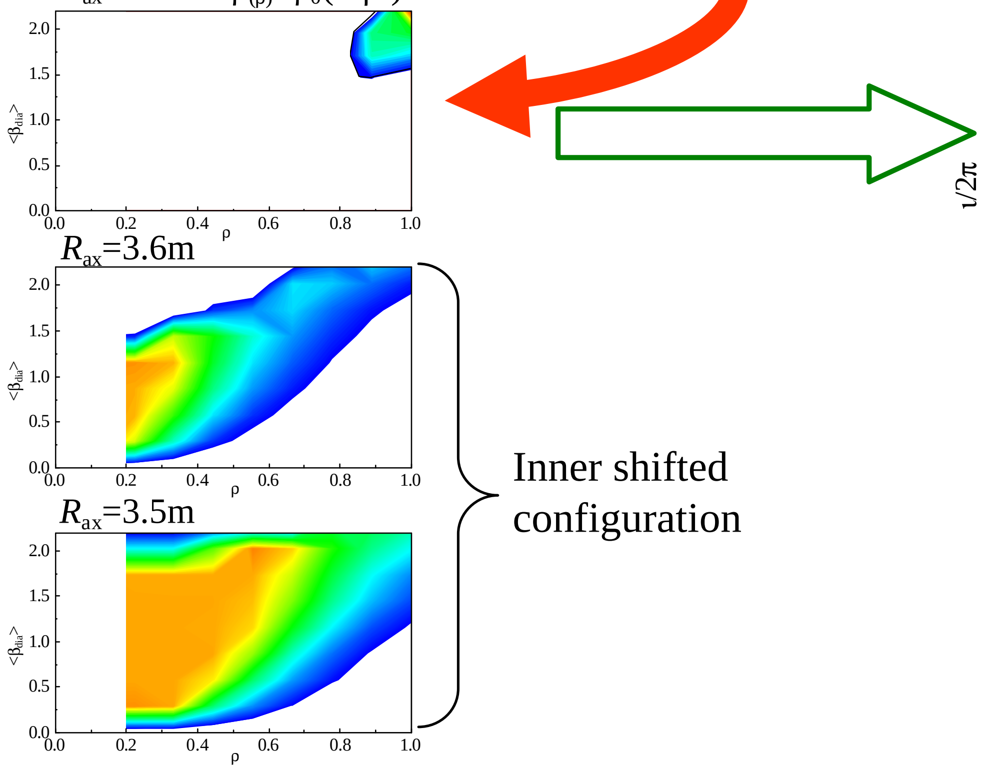


Equilibrium (current free)

Magnetic axis R_{ax}=3.75m

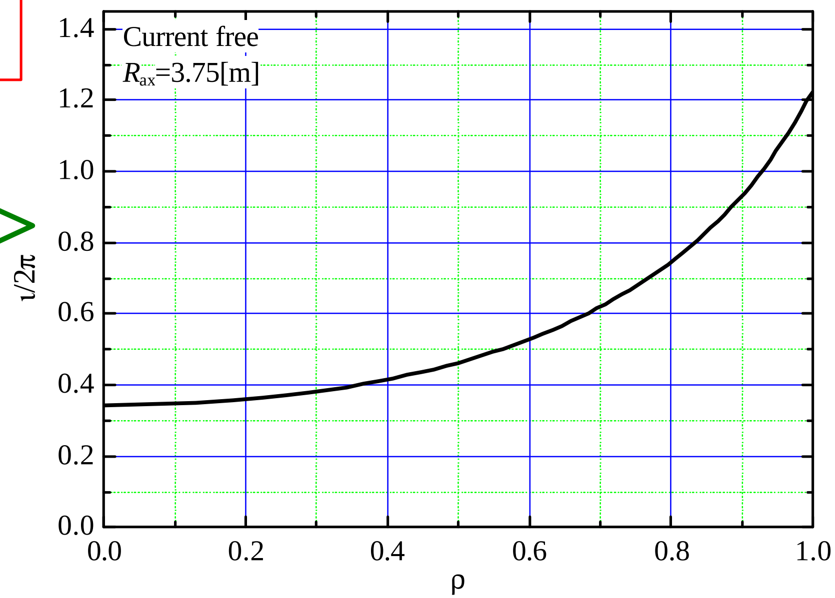
~Pressure driven mode is stable at low β~

Mercier unstable region



Vacuum field (β~0[%])

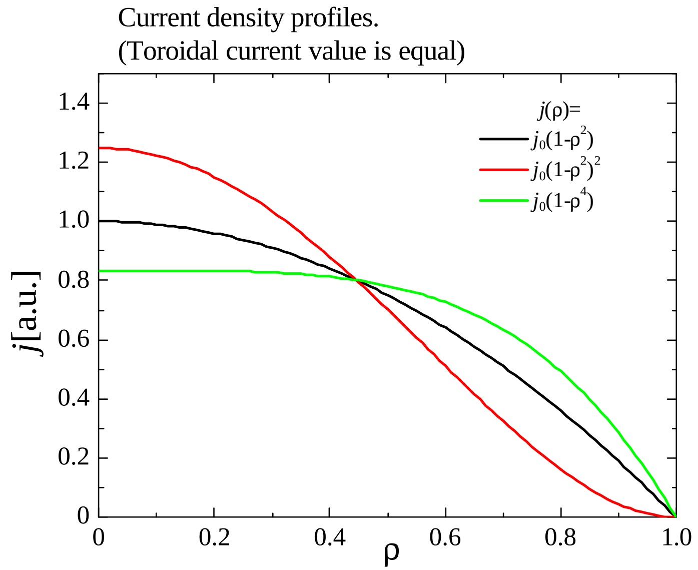
To check the influence of the toroidal current.



ι/2π profile $\iota_{(0)}/2\pi$=0.35, $\iota_{(1)}/2\pi$ =1.20

Equilibrium (current-carrying plasma)

Current density profiles



Three kinds of current density profiles are assumed.

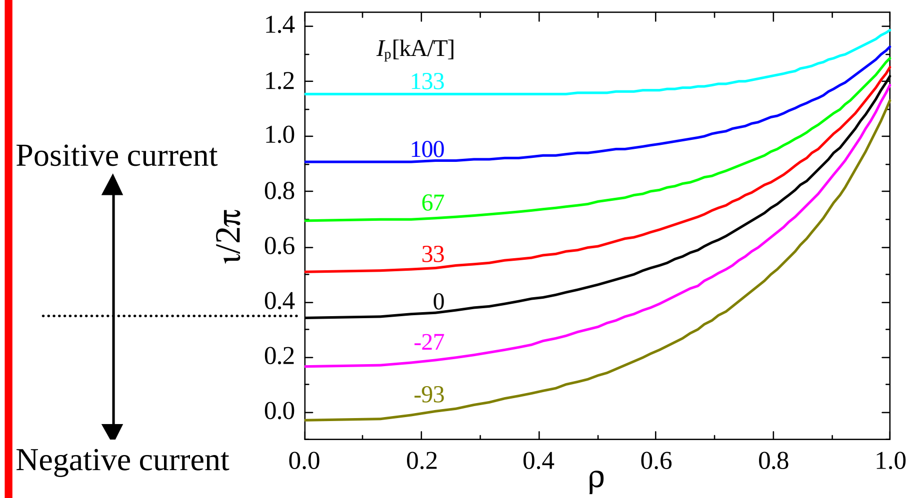
$j=j_0(1-\rho^2)$ [parabolic]

$j_0(1-\rho)^2$ [peaky]

$j_0(1-\rho^4)$ [broad]

Change of ι/2π profiles

R_{ax}=3.75m, β_0=0% $j=j_0(1-\rho^2)$



Positive current makes the ι/2π profile go up.

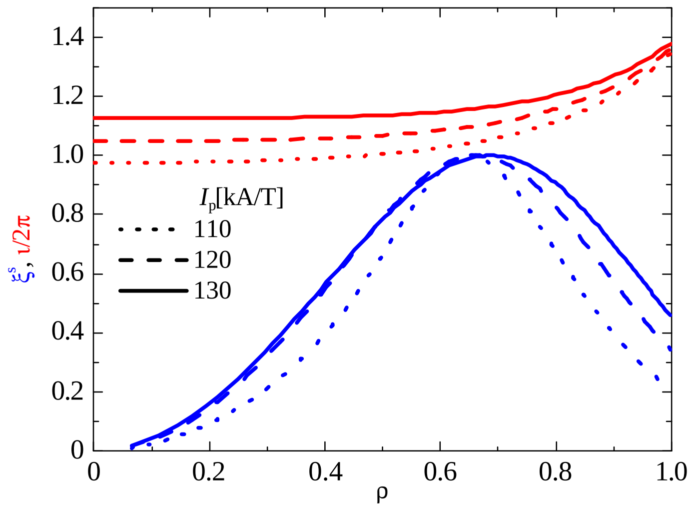
We pay attention to the equilibrium with **positive** current I_p<133[kA/T].

In the case of negative current, any instabilities do not appears in the analysis.

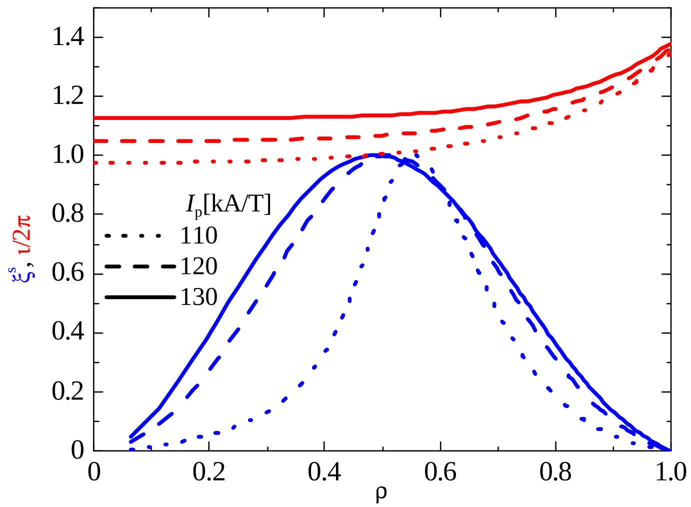
Mode structures ~Total current dependence~ PARABOLIC

The mode with m/n=1/1 becomes unstable.

Free boundary mode



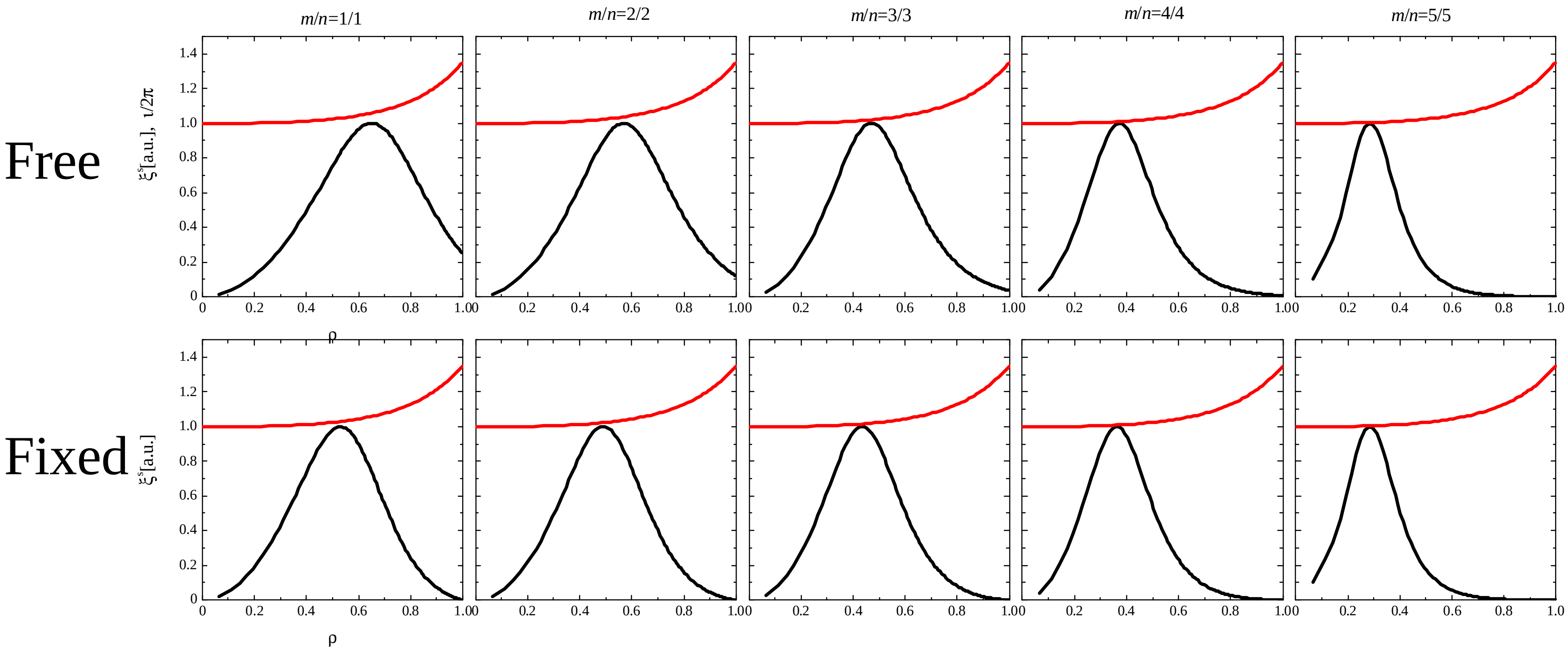
Fixed boundary mode



- The plasma is stable at I_p<105 [kA/T].
- Mode width becomes broader with the increase of the toroidal current.
- The mode structure remains even in the equilibrium without the resonant surface of $\iota/2\pi$=1.0. (I_p>120[kA/T])

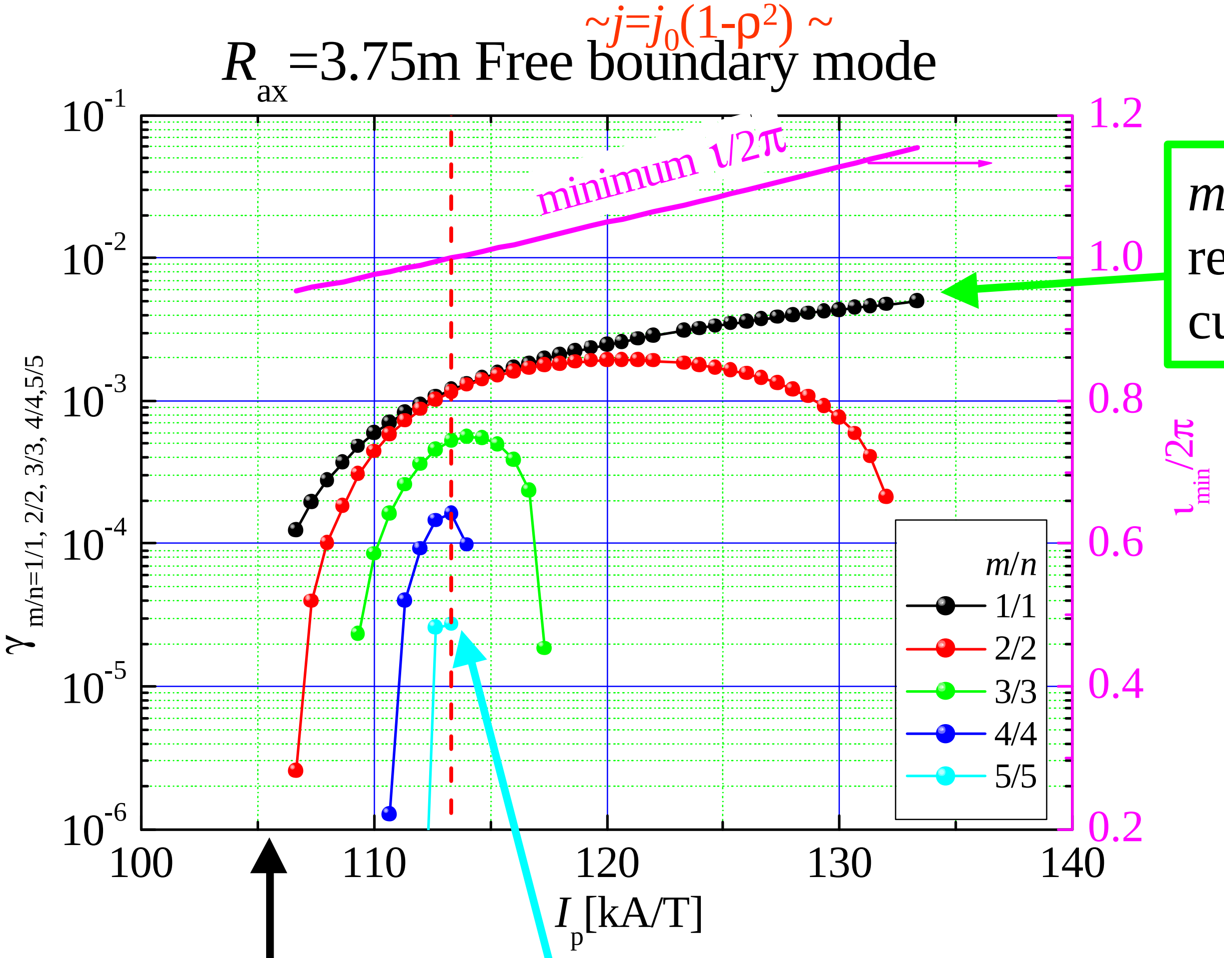
Mode structures (m/n=1/1, 2/2, 3/3, 4/4, 5/5)

R_{ax}=3.75m, $j=j_0(1-\rho^2)$, I_p=113[kA/T]



The higher modes(n=2,3,4,5) also appear.

Growth rate and toroidal current

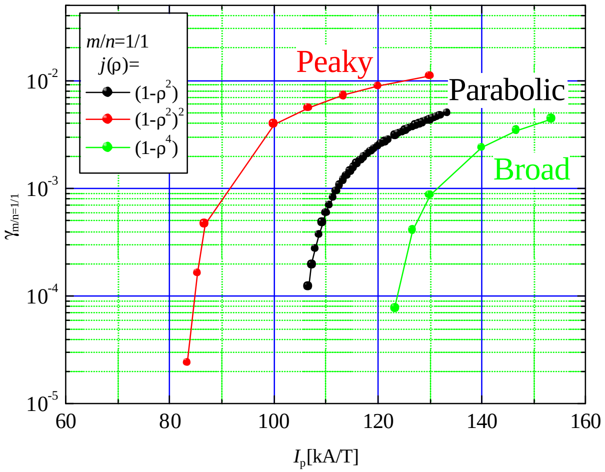


m/*n*=1/1 mode remains in the large current region.

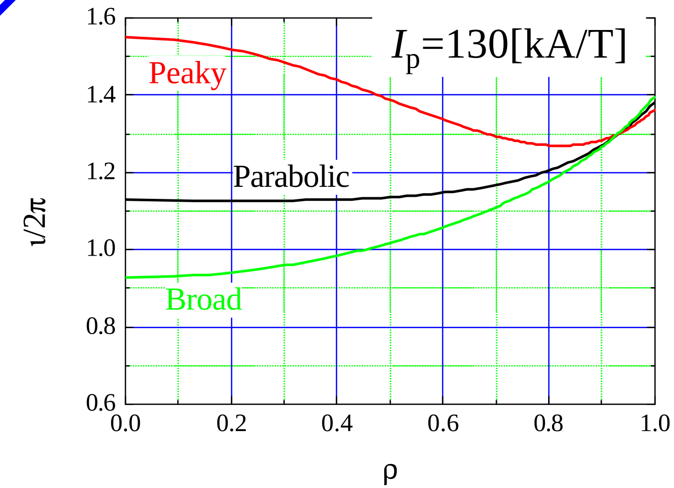
Plasma is destabilized at I_p>105[kA/T]

Higher modes (especially 5/5) disappears in the minimum ι/2π>1.0.

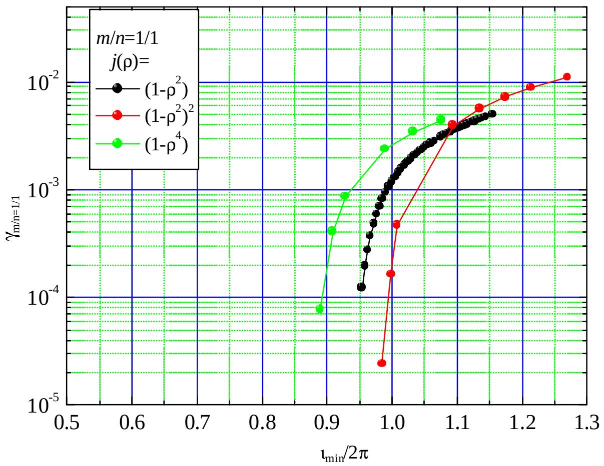
Growth rate under the condition of various current density profiles.



The plasma is destabilized at lower I_p in the peaky current density profile rather than the case of the broad one.



The peaky current profile pushes up the iota at the plasma center.



It seems that the plasma is destabilized in the region of $\iota/2\pi > 1.0$ even in the different current density profiles.

Conclusion

Summary

- Low-*n* ideal MHD analysis by **TERPSICHORE** shows

  1. LHD Plasma is destabilized by the large (I_p>105[kA/T]) toroidal current and *m/n*=1/1 mode is a main component.
  2. The *m*/*n*=1/1 mode clearly appears in the equilibrium without the rational surface of ι/2π=1.0.
  3. On the other hand, the higher modes disappear in that equilibrium.

Proposal to experiment

- MHD stable configuration (R_{ax}=3.75[m]) is used to observe the current driven mode.
- NBIs drive the toroidal current of I_p>100[kA/T].
- Low density and high temperature plasma allows us to investigate the ideal MHD phenomena.

Recent experiment

The large negative toroidal current (-95[kA/T]) have been obtained in recent experiment.

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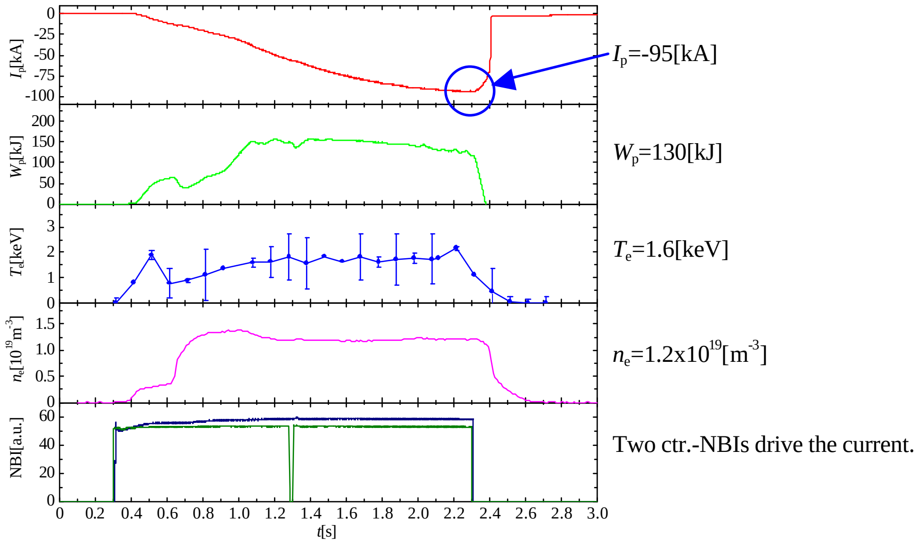
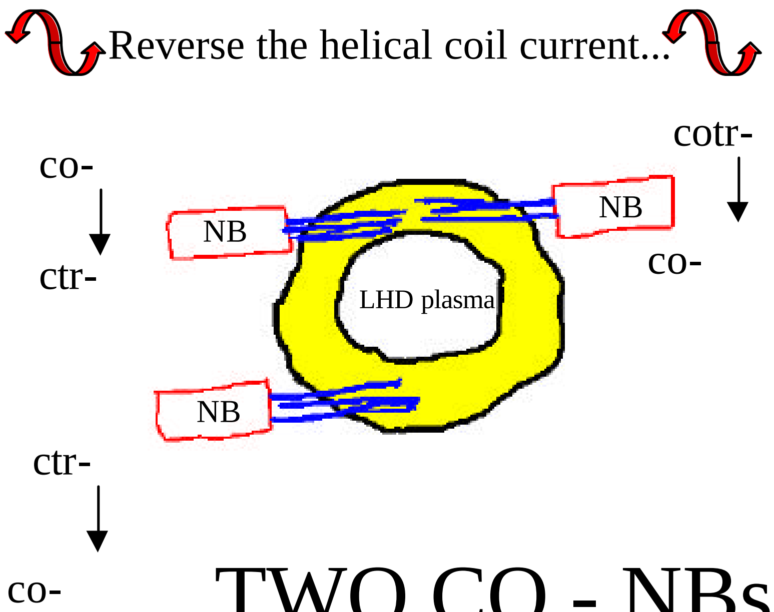
R_{ax}=3.6[m] B_t=1.0[T]



How to drive the positive current?

The positive current-carrying plasmas are able to be produced under the condition of reversed helical coil current. It is equivalent to situation of the two co.-NBs.

Reverse the helical coil current...



TWO CO.- NBs