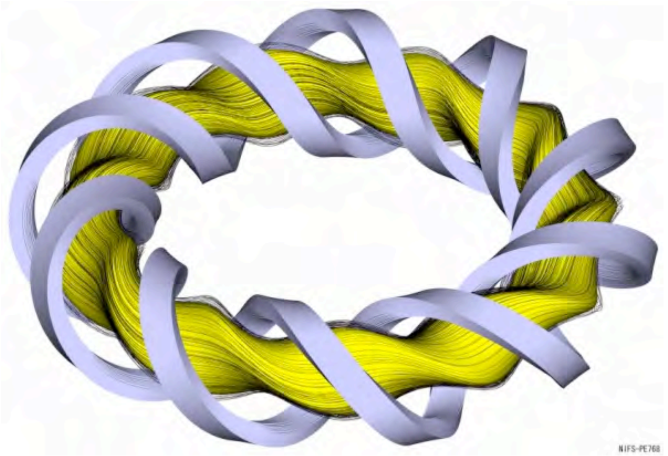
I-08

17th ISHW Oct. 12, 2009, Princeton, NJ, USA

Effect of Nonaxisymmetric Perturbation on Profile Formation

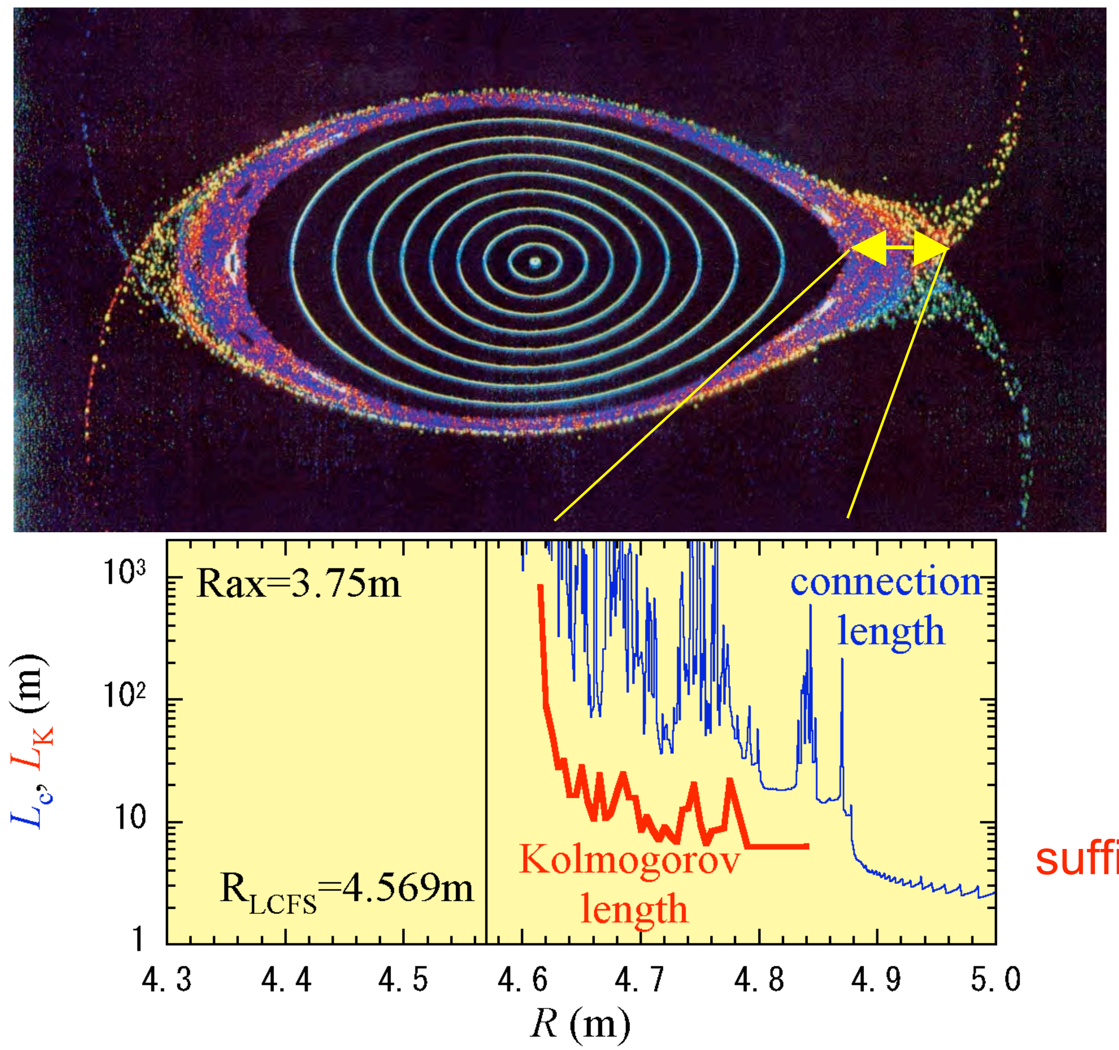
National Institute for Fusion Science

<u>T. Morisaki</u>, Y. Suzuki, J. Miyazawa, M. Kobayashi, S. Masuzaki, M. Goto, R. Sakamoto, H. Funaba, N. Ohyabu, H. Yamada,
A. Komori and LHD Experiment Group



Contents
- ***intrinsic*** edge stochasticity - *introduction* -
- ***enhanced*** stochasticity by plasma itself and external perturbation field
  - *particle transport (density pump out)* -

Introduction - *edge stochastic region in LHD -*

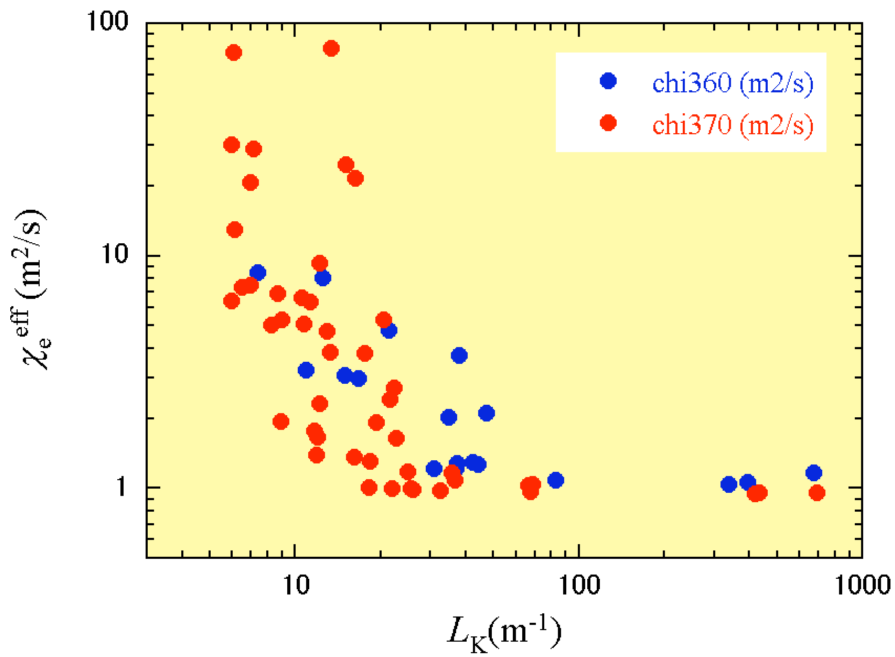


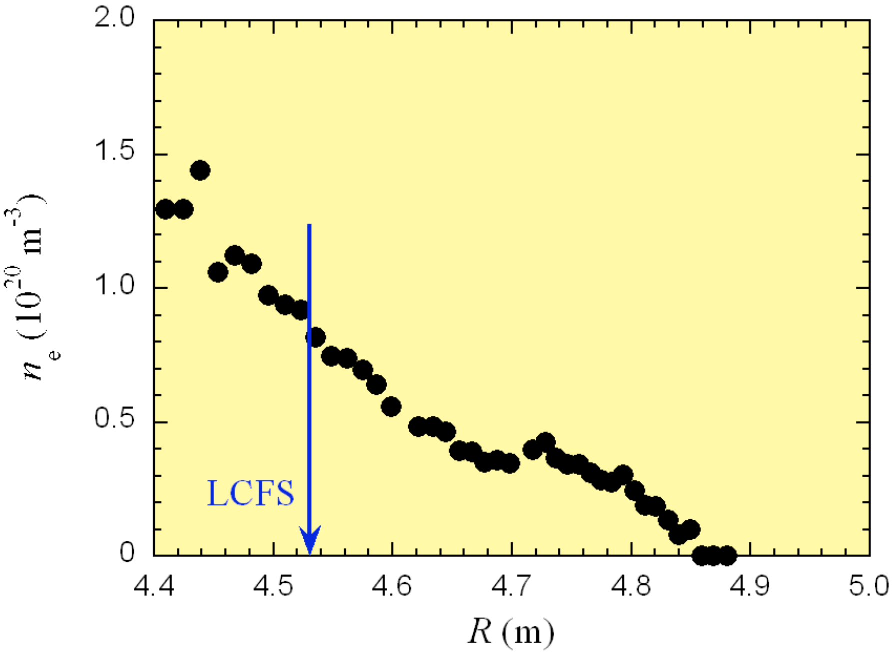
$L_K < L_c$

sufficiently stochastic

Heliotron configuration intrinsically has stochastic region

Motivation - *what about transport in stochastic region ? -*





χ_e rapidly increases where L_K < ~ 50m

- independent of magnetic configuration -

Energy flow seems to reflect the magnetic field topology

On the other hand…..

- No clear gradient change is seen
- Relatively high n_e region spreads across LCFS

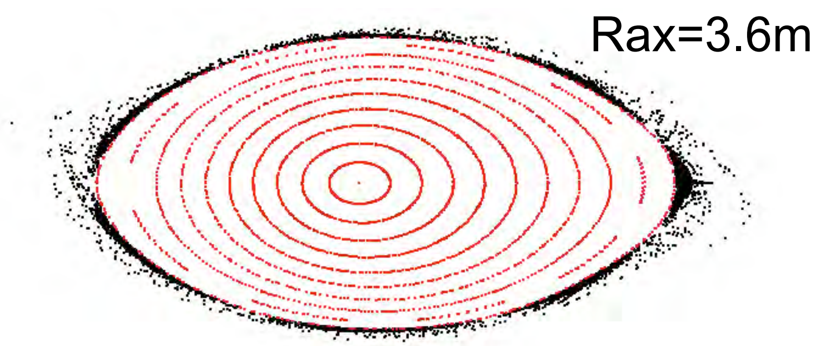
Particles feel magnetic structure ?

To see this in detail,

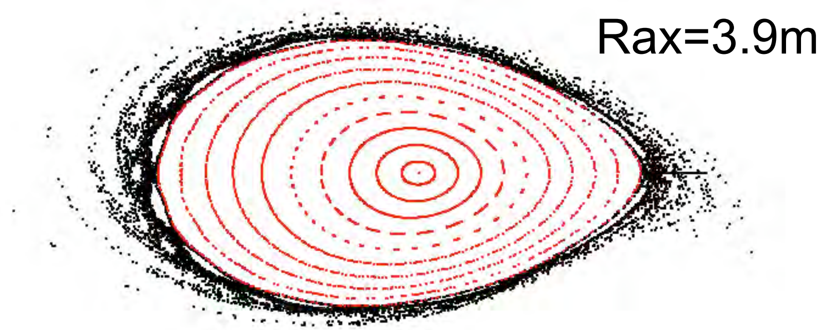
experiments in various edge topology are necessary

Edge magnetic topology can be varied

(1) by changing magnetic axis

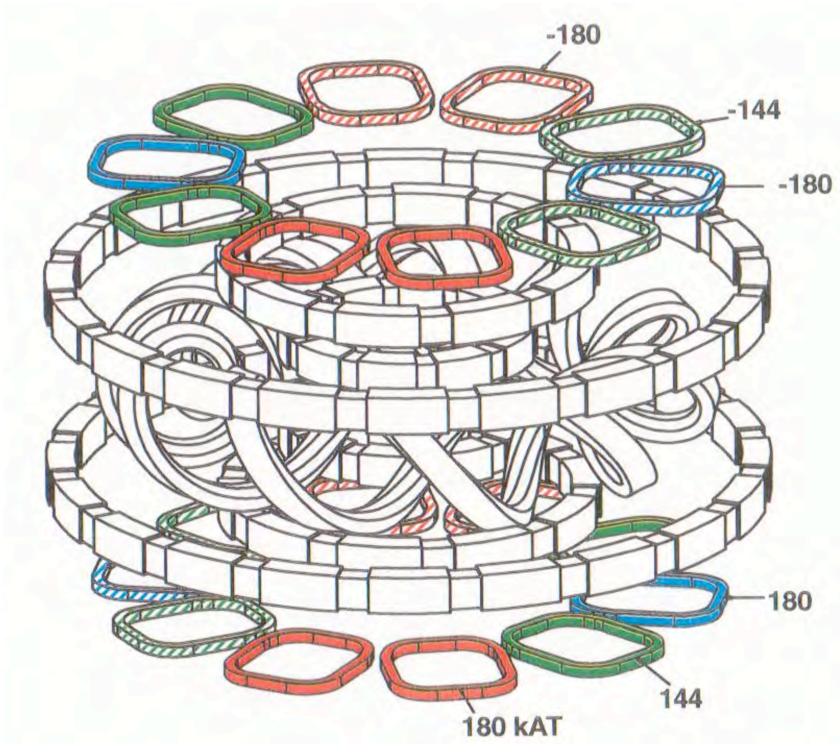


outward shift



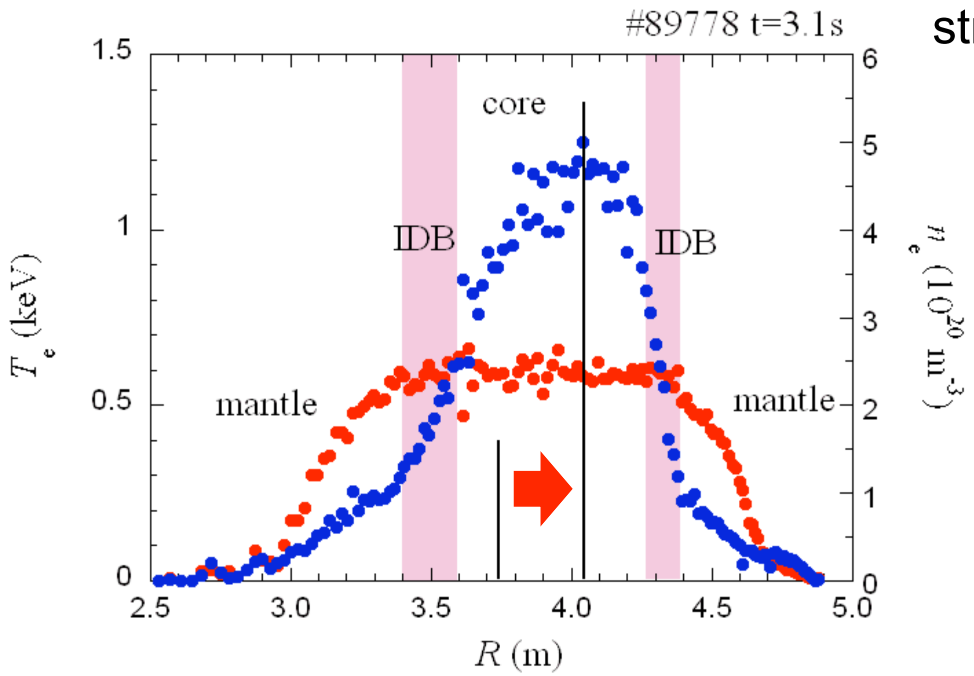
Stochastic region spreads over
in outward shifted configuration

(2) by external magnetic perturbation



10 pairs of normal conducting coils can apply m/n=1/1 and 2/1 perturbations

Stochastization is enhanced in SDC plasma



strong edge pumping + central fuelling

Super**D**ense **C**ore plasma
with **I**nternal **D**iffusion **B**arrier
(**IDB-SDC** plasma)

* $n_e(0) \sim 1\times10^{21}$ m^{-3}
* $Te(0) \sim 0.4$ keV
* $P(0) \sim 140$kPa
* $W_{dia} \sim 1$MJ
* $\beta(0) \sim 4.7\%$

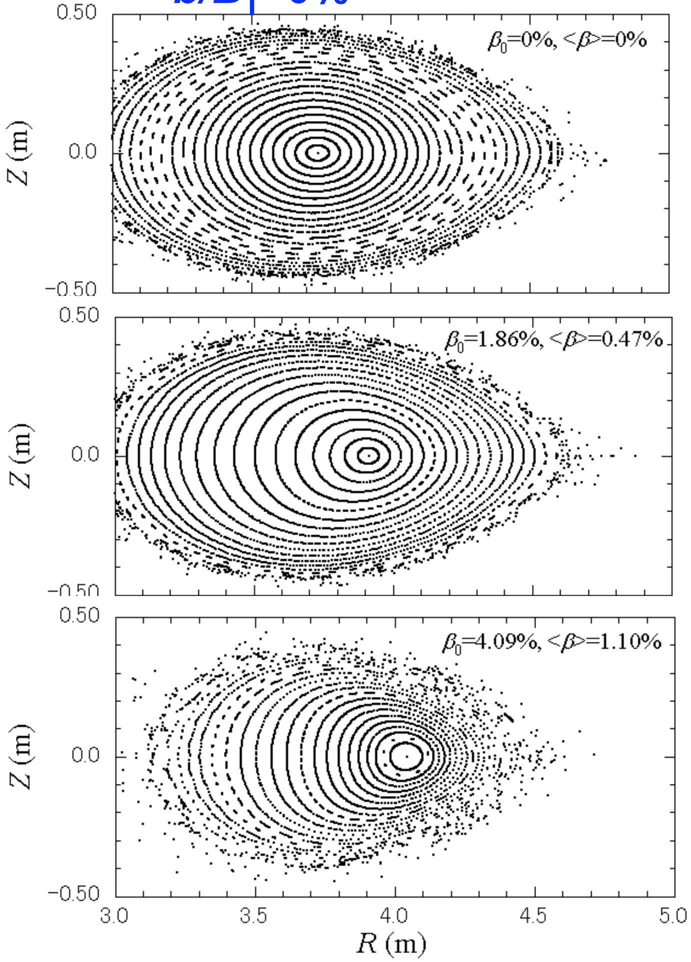
high pressure core region ==> - large Shafranov shift
steep gradient at IDB ==> - spontaneous current , e.g. bootstrap
- destabilization of MHD activities

Edge stochasticity is enhanced
(Furthermore, what if perturbation is applied to SDC plasma ?)

As β_0 increases .... HINT2 code predictions

(*HINT2 can calculate 3D equilibrium even in the stochastic region*)

b/B_T=0%

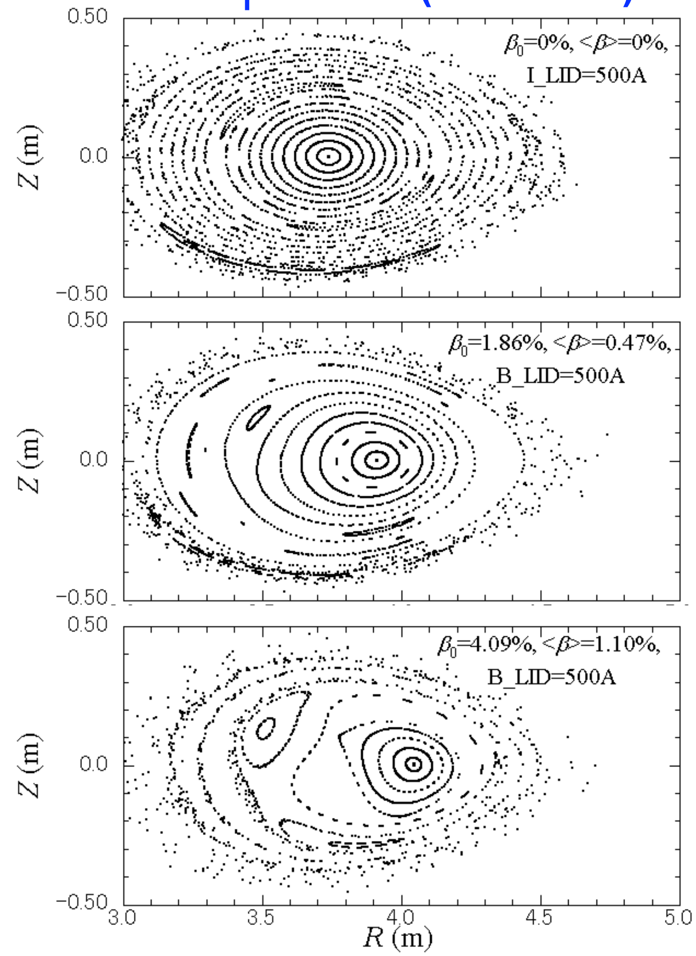


β_0=0%

1.86%

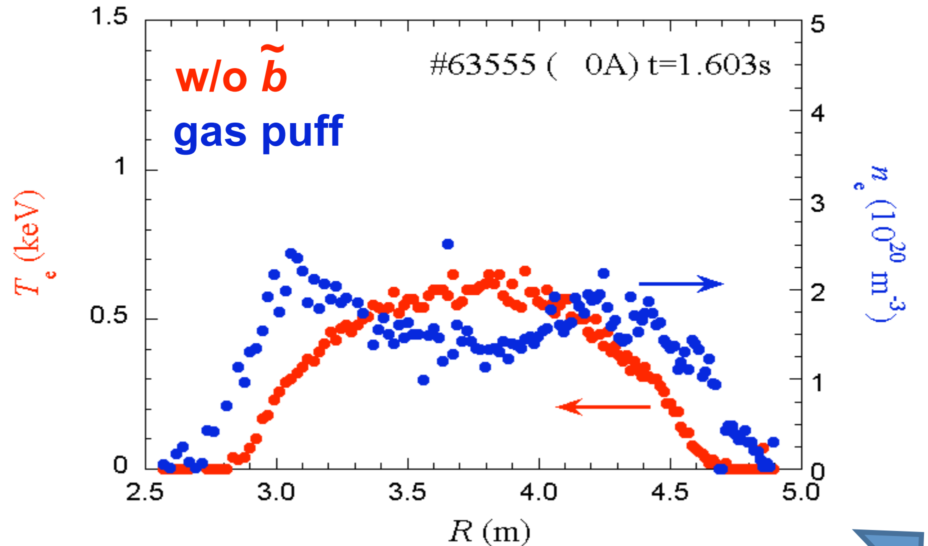
4.09%

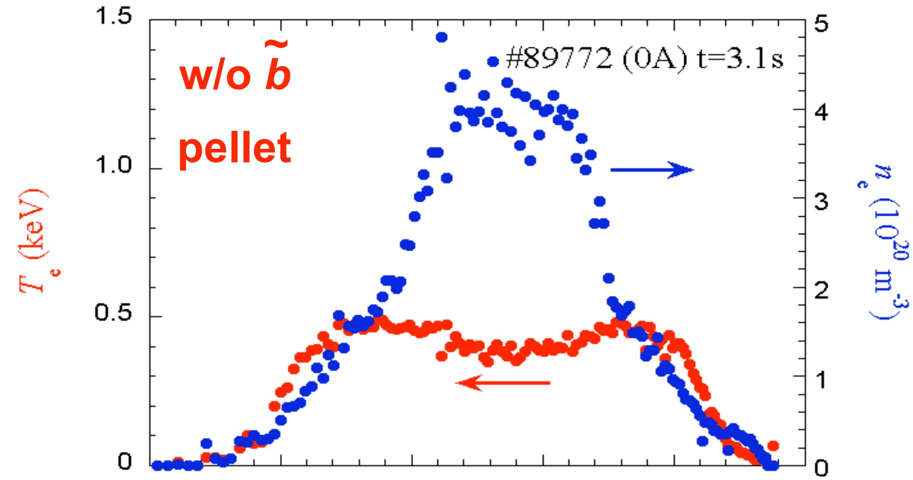
b/B_T=0.02% (m/n = 1/1)



Flux surfaces are sensitive to external perturbation, especially in high beta regime

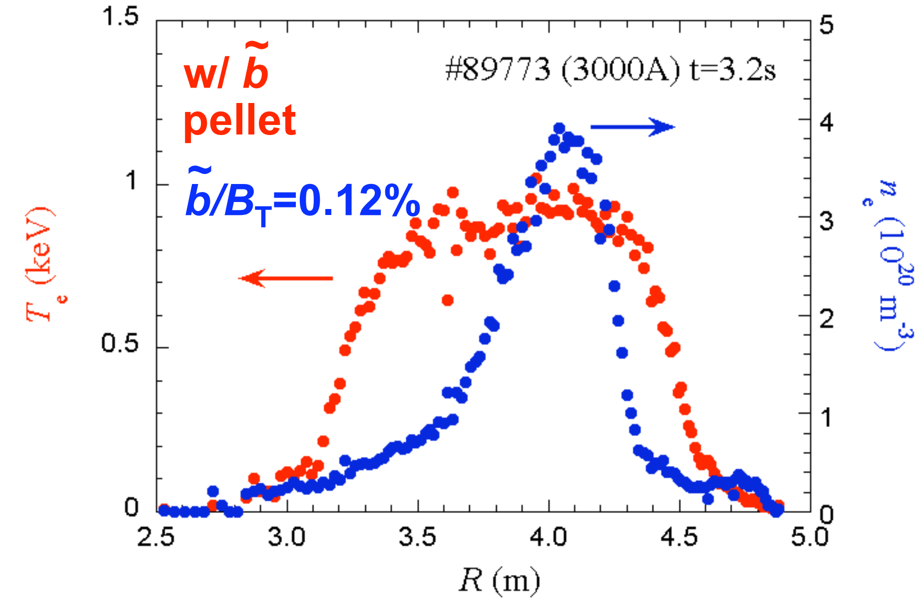
Effect of external perturbation on n_e, T_e profiles





pump + pellet,

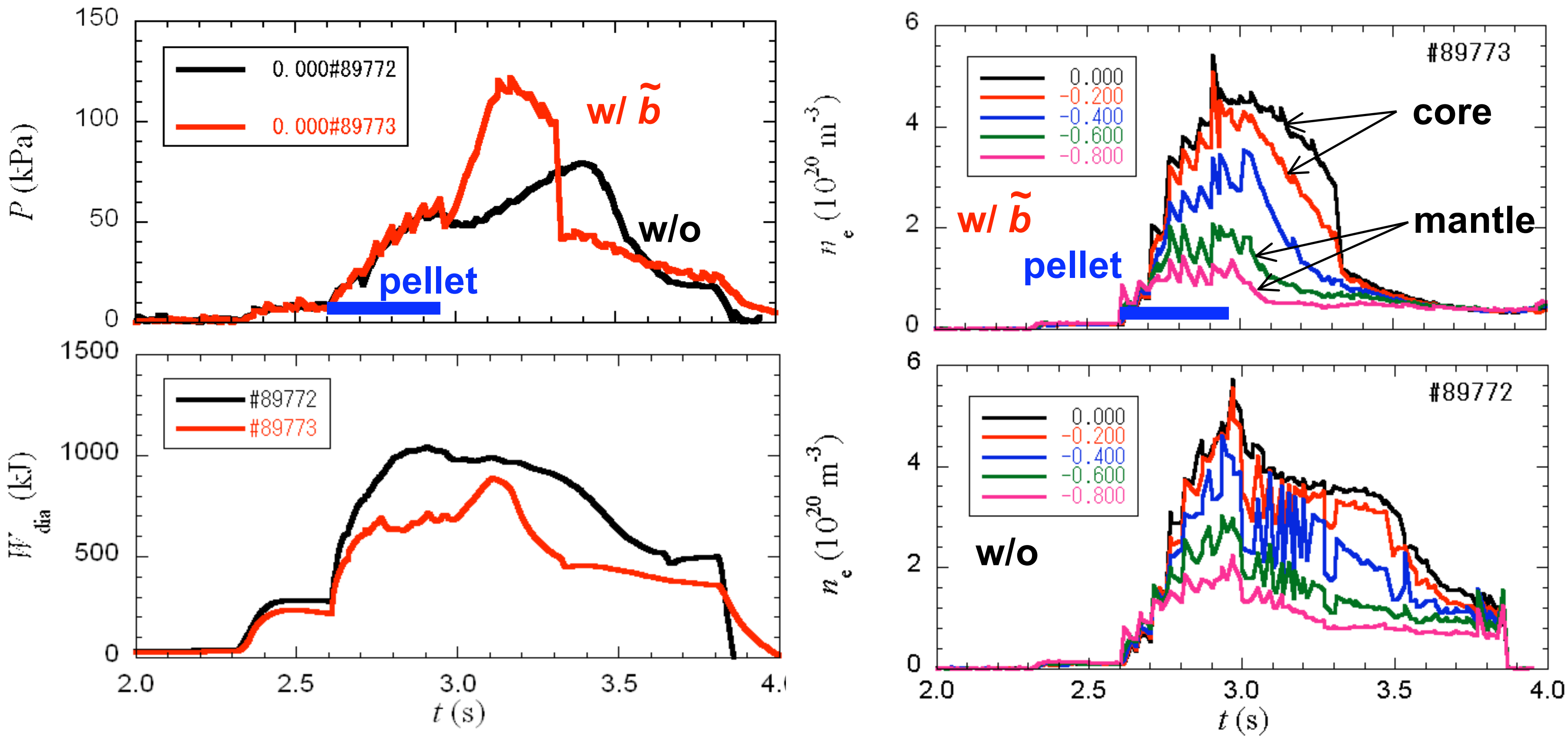
- IDB-SDC plasma
- n_e at edge decreases
- edge stochasticitization



Applying *m*/*n*=1/1 perturbation,

- n_e in stochastic region is **pumped out**
- T_e at core region increases
- enhanced stochasticity (HINT2)

Temporal behavior of IDB-SDC plasma with strong perturbation



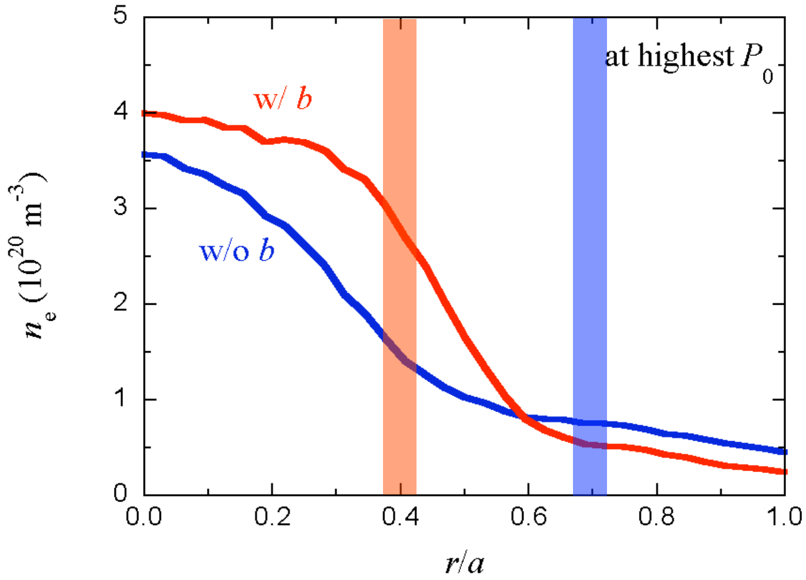
- With perturbation,
  - higher P_0 is obtained
  - smaller W_{dia} due to reduction of edge n_e
- Sudden decrease of P_0 ~ 0.2 s after its peak
  - Core Density Collapse (CDC) -

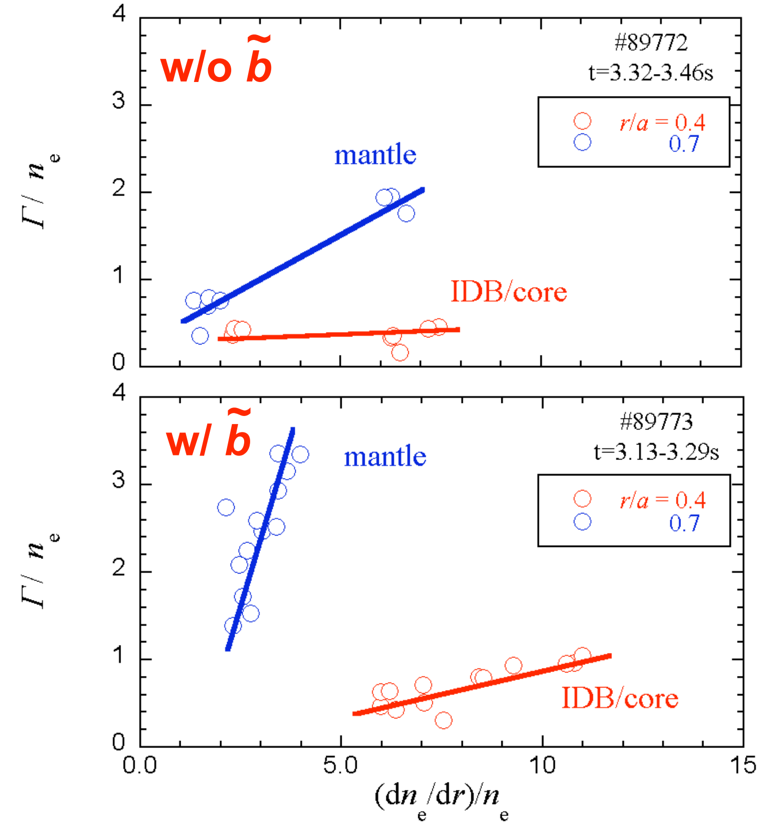
w/*b* • n_e in mantle rapidly decreases soon after the final pellet (convex downward)
• n_e in core stays for a while

==> suggesting different transport between core and mantle

w/o *b* • n_e in whole region gradually decreases

Effect of perturbation on particle transport



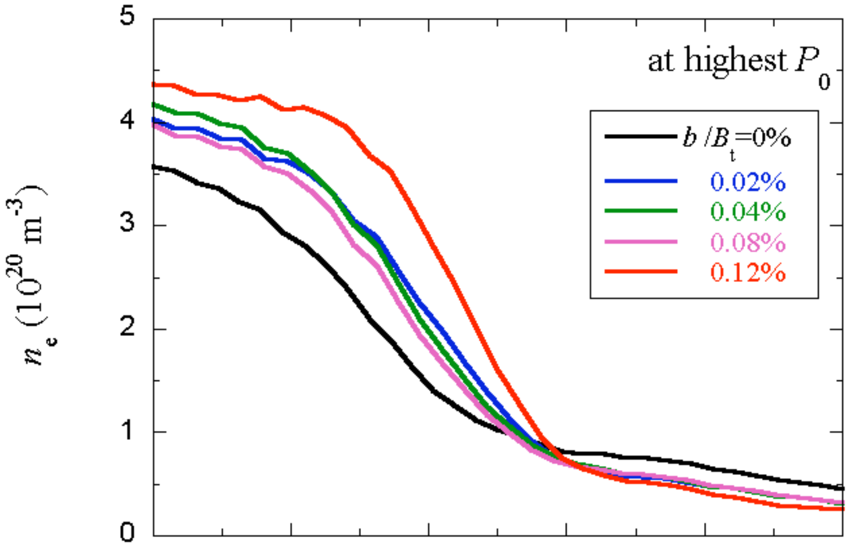


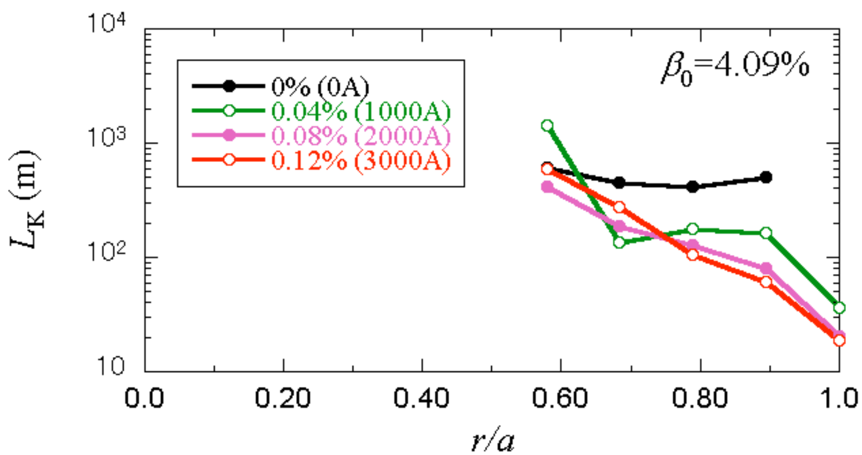
1D particle transport analyses

$$\Gamma = \frac{1}{r}\int_0^r r\left(S - \frac{\partial n_e}{\partial t}\right)dr \qquad \frac{\Gamma}{n_e} = -D\frac{1}{n_e}\frac{\partial n_e}{\partial r} + v$$

Strong perturbation enhances edge particle transport (not so in core)
which is due to **enhanced stochasticity** in mantle with external perturbation
(consistent with HINT2 prediction)

Effect of perturbation on particle transport





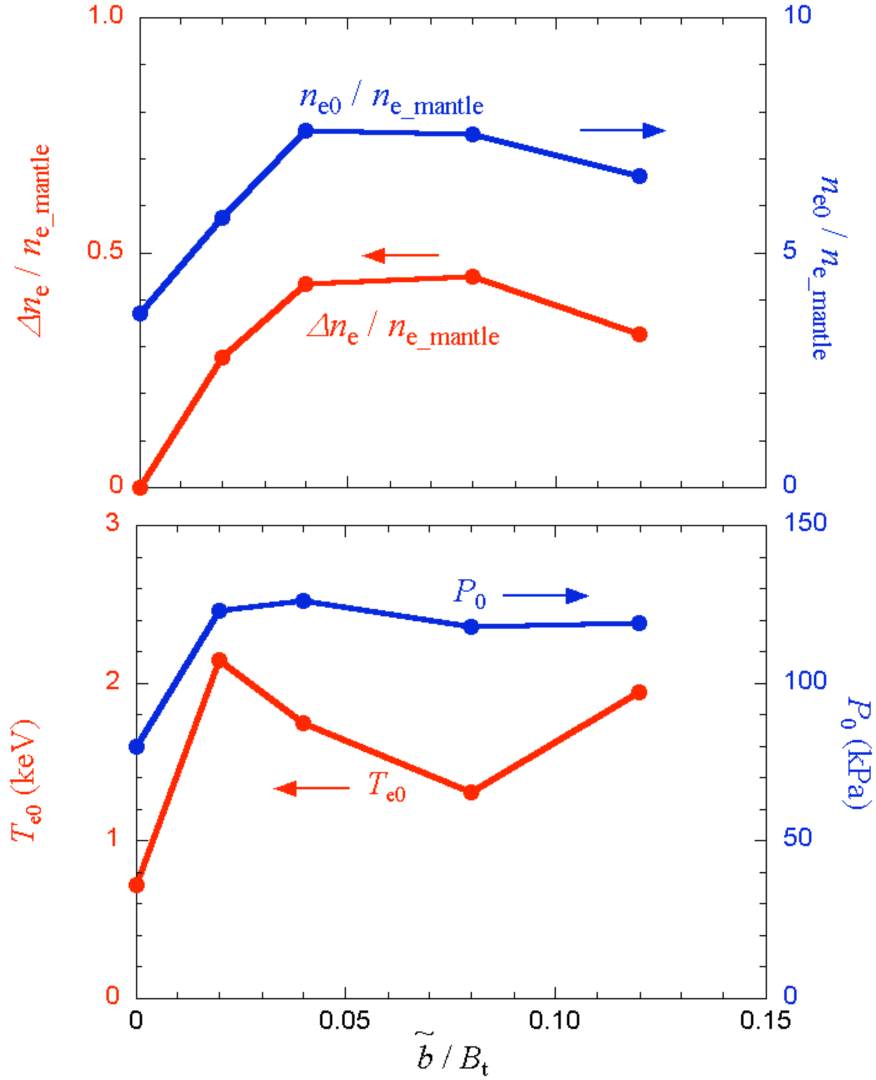
Applying perturbation,

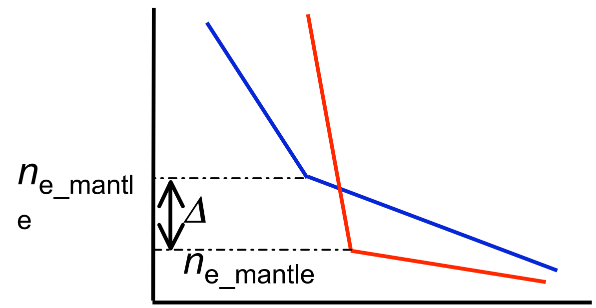
- grad n_e becomes steep with *b*
- foot point is at r/a ~ 0.55 - 0.60
- pump out effect is strong with strong *b* (detailed analysis is on going)

From L_K calculation with HINT2 equilibria,

- stochasticity increases with b
- even a small *b* results in strong stochastization

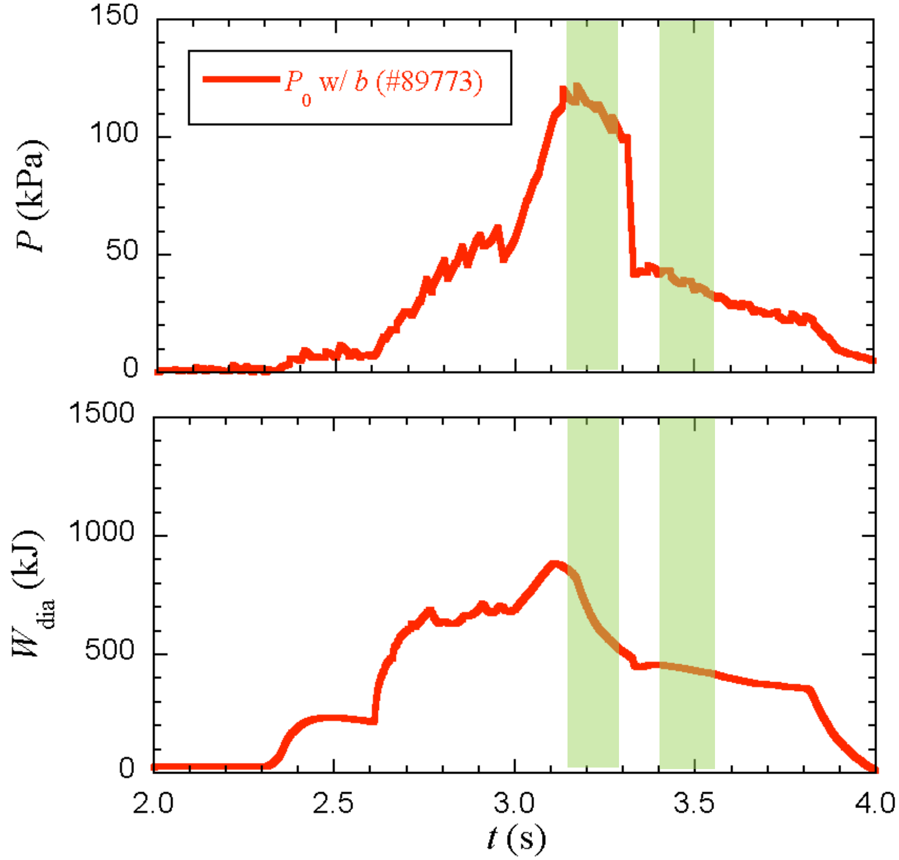
n_e pump out dependence on perturbation field strength

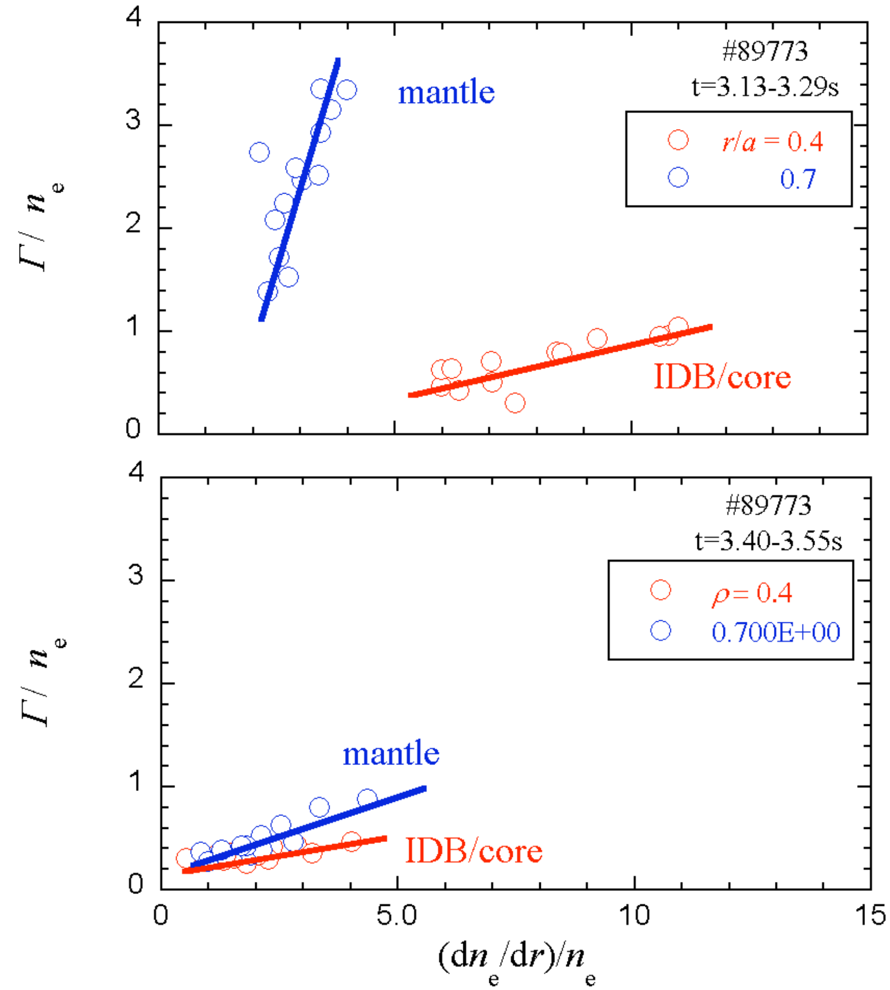




- Even a small perturbation can pump out particles in mantle
- Accordingly central pressure increase
- suggesting that magnetic field in mantle is sensitive to external perturbation in SDC plasma (consistent with HINT2 calculation)

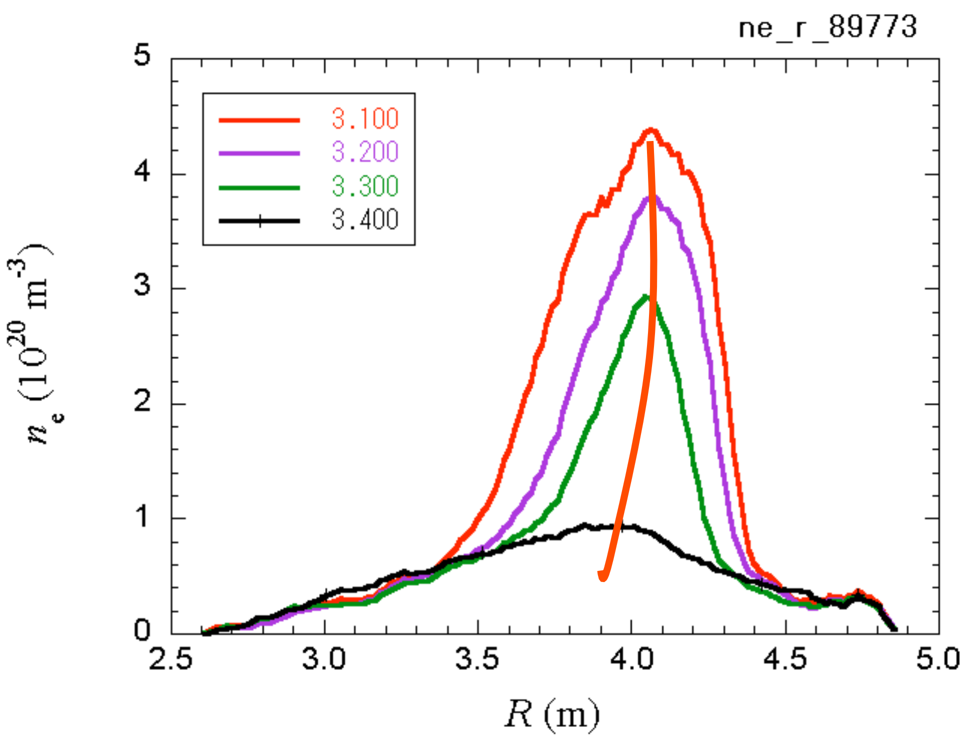
Recovery of *D* in mantle

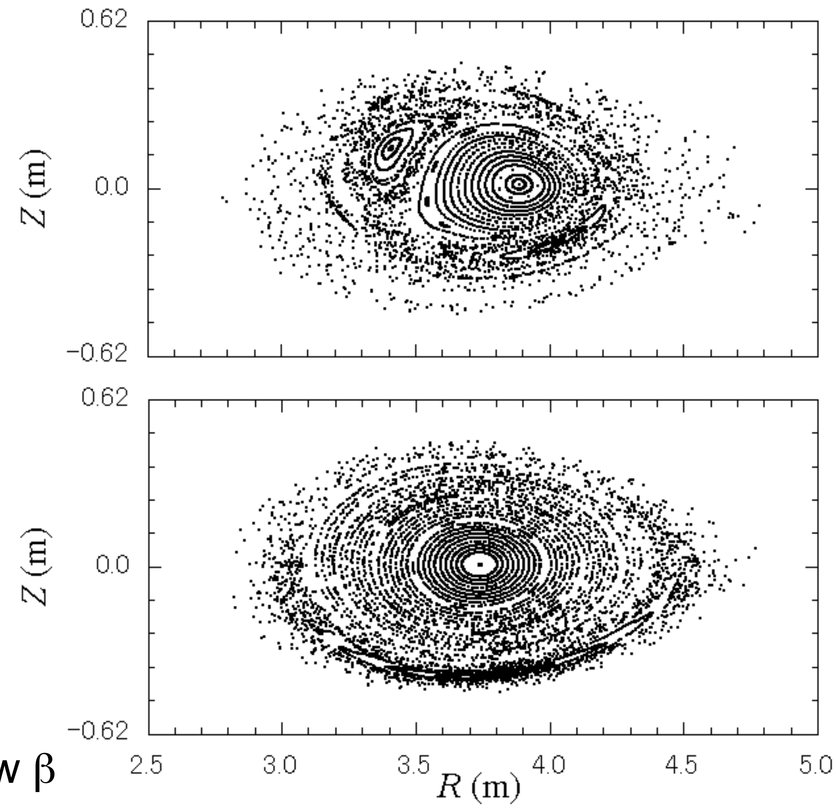




- At highest P_0, *D* in mantle is high
- After P_0 drop,
  - *D* in mantle improves, suggesting the restoration of ergodized region
  - *D* in core still keeps low

Recovery of *D* in mantle





Drop of P0 returns the plasma back to the low β regime with relatively "peaceful" magnetic flux surfaces

Recovery of D in mantle

Summary

Effect of externally applied low *m*/*n* magnetic perturbation on high density plasma with peaked pressure profile is numerically and experimentally investigated.

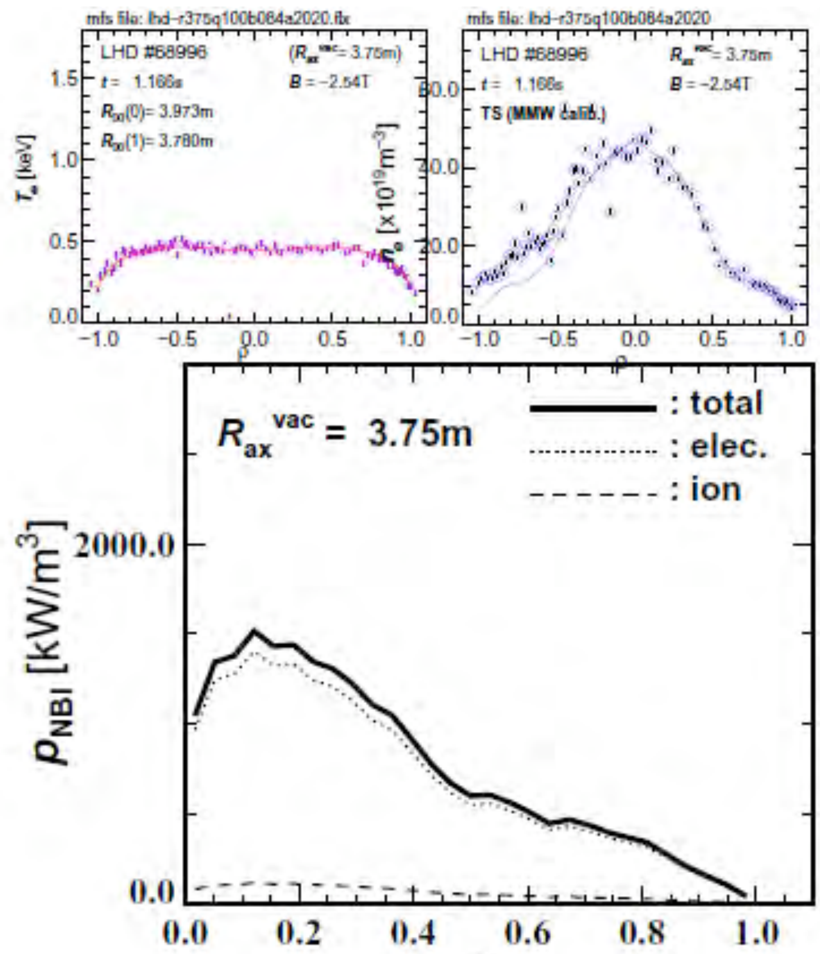
- Even with a small perturbation, magnetic surfaces are strongly deformed,
  - which enlarges magnetic islands.
  - which enhances the edge stochastization.

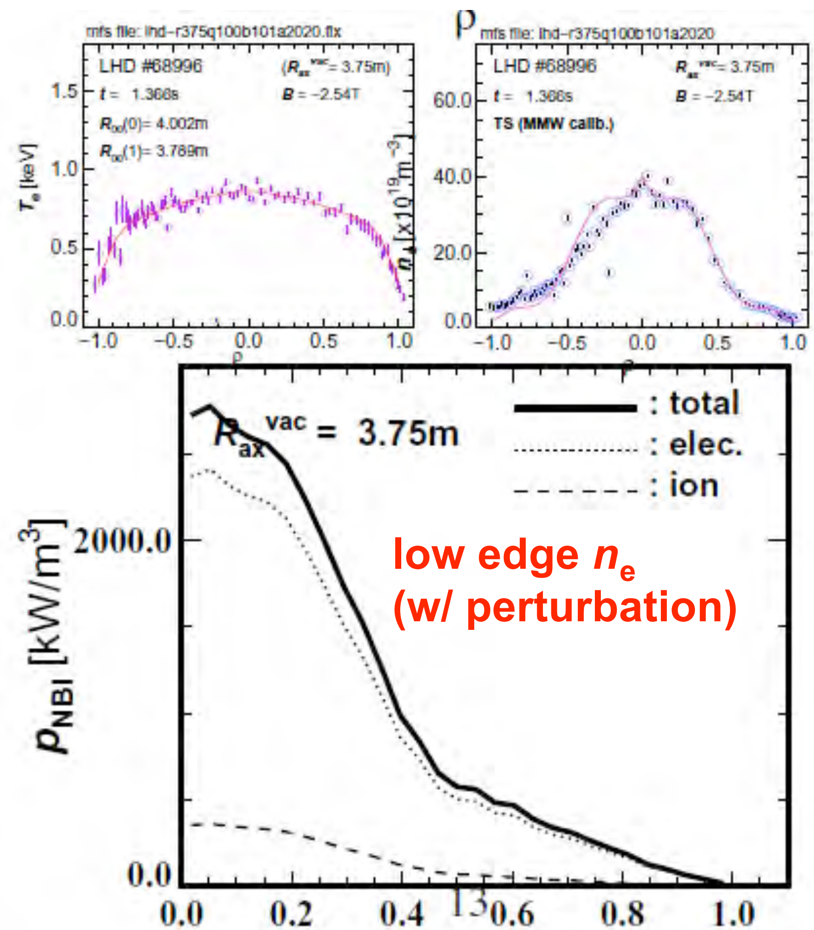
- With strong perturbation, density pump out is observed in the mantle (edge) region, together with the increase of core T_e (or P),
  - degradation of particle transport (D) in the mantle, but not in the core.

- Even a small perturbation can affect the profile formation

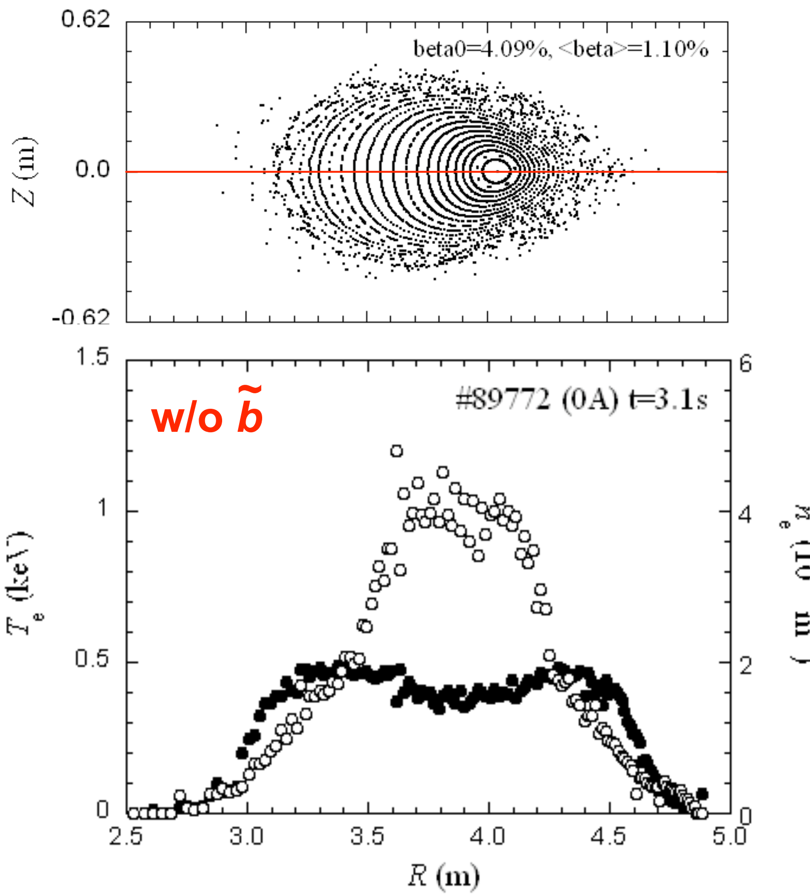
- After the P_0 drop, stochastized mantle is restored and D recoves

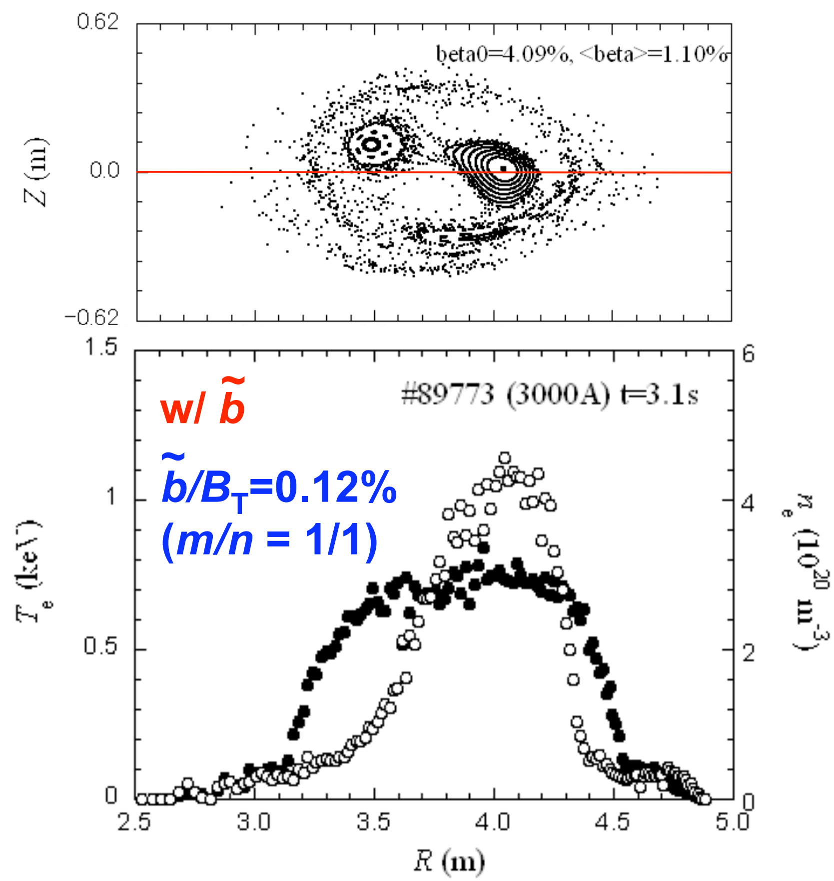
Power deposition profiles with and without perturbation





Effect of external perturbation on n_e, T_e profiles



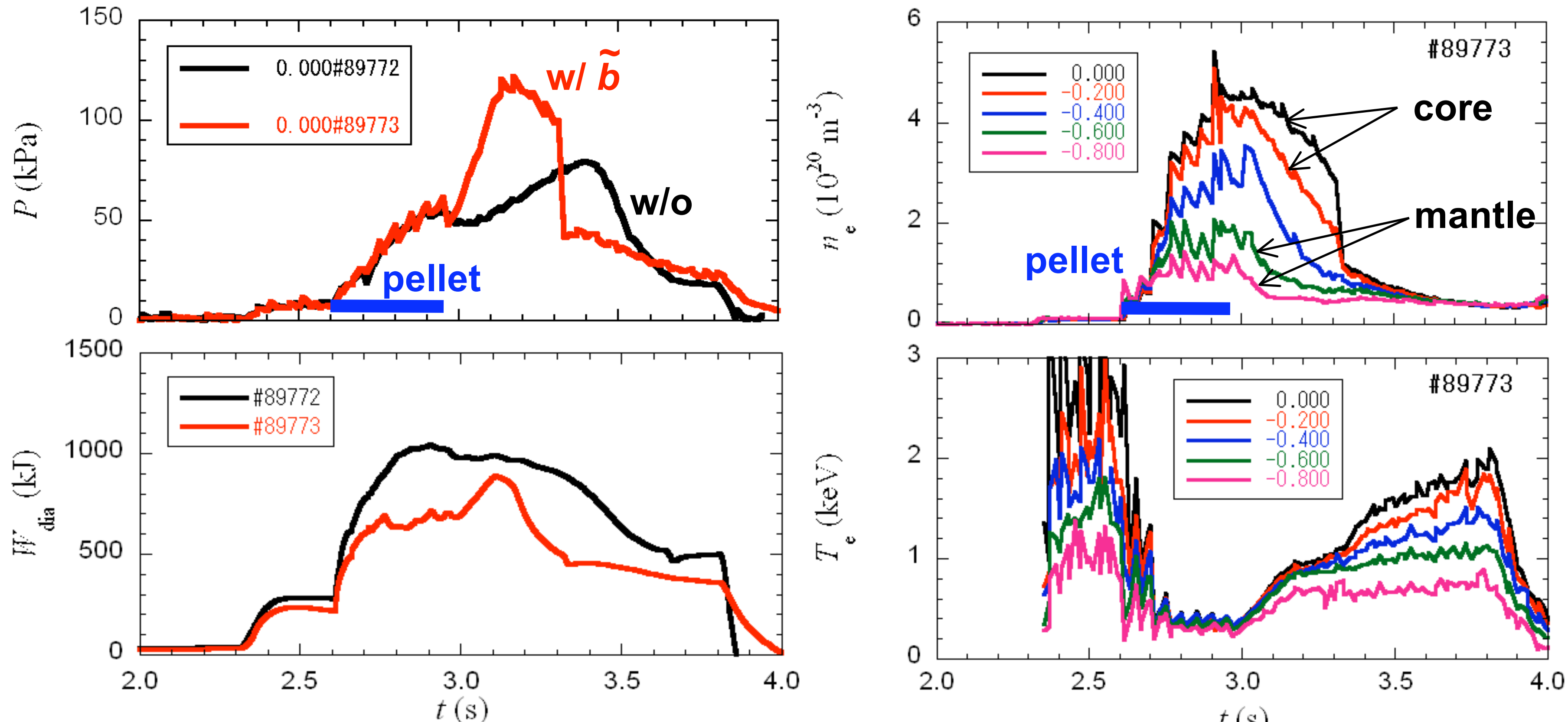


According to HINT2 calculation, edge region is **ergodized** in SDC

Applying *m*/*n*=1/1 perturbation,

- n_e in stochastic region is pumped out
- T_e at core region increases
- edge stochasticity ***increases*** (HINT2)

Temporal behavior of IDB-SDC plasma with strong perturbation



- With perturbation,
  - higher P_0 is obtained
  - smaller W_{dia} due to reduction of edge n_e
- Sudden decrease of P_0 ~ 0.2 s after its peak

  - Core Density Collapse (CDC) -

- n_e in mantle rapidly decreases soon after the final pellet (convex downward)
- n_e in core stays for a while

  suggesting different transport between core and mantle