Progress in LHD experiments in 2002 - 03

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J-US WS on HHFC/PSI

Workshop Agenda

Large Helical Device / *National Institute for Fusion Science*

Experimental plan of 7th campaign (Sep. 2003 - Jan. 2004)

Target parameters :

Electron density	2×10^{20}m^{-3}
β value	3.5 %
Pulse length	5 min

Achieved parameters :

Electron density	1.6×10^{20}m^{-3}
β value	3.2 %
Pulse length	2.5 min
Electron temperature	10 keV
Ion temperature	7 keV
Energy confinement time	0.36 s

Main objectives:

- Stability of high-β plasmas in the inward-shifted configurations,
- Edge plasma control by Local Island Divertor (LID) with aim of improvement of plasma confinement.

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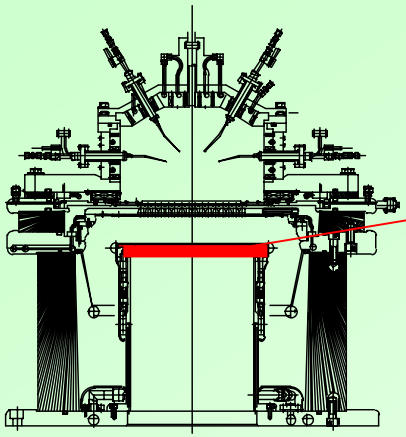
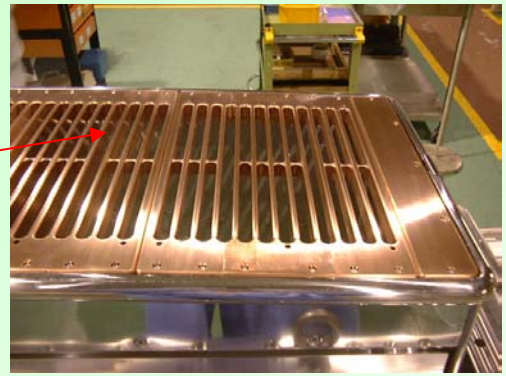
Demonstration of LID functions

- Formation of electric fields and its effect on particle transport,
- Effect of plasma currents on stability and confinement.

Development of negative ion source





Electrode

multi-aperture type

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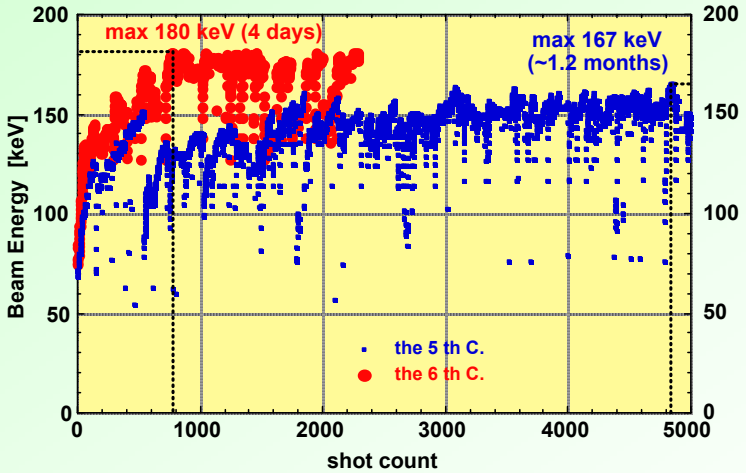
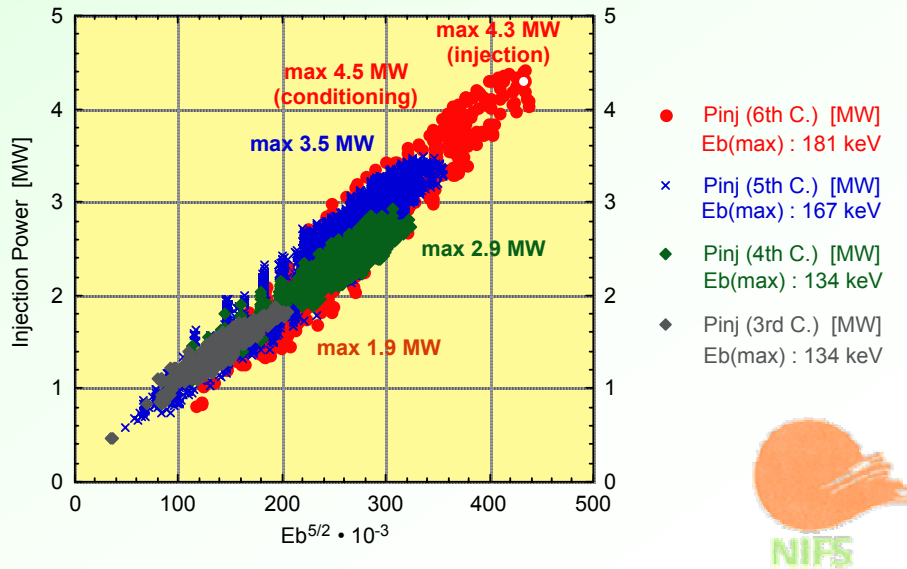
multi-slit type

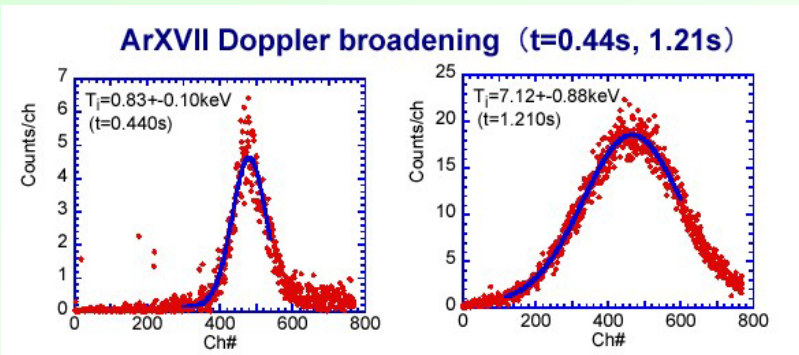
shorter conditioning
higher voltage

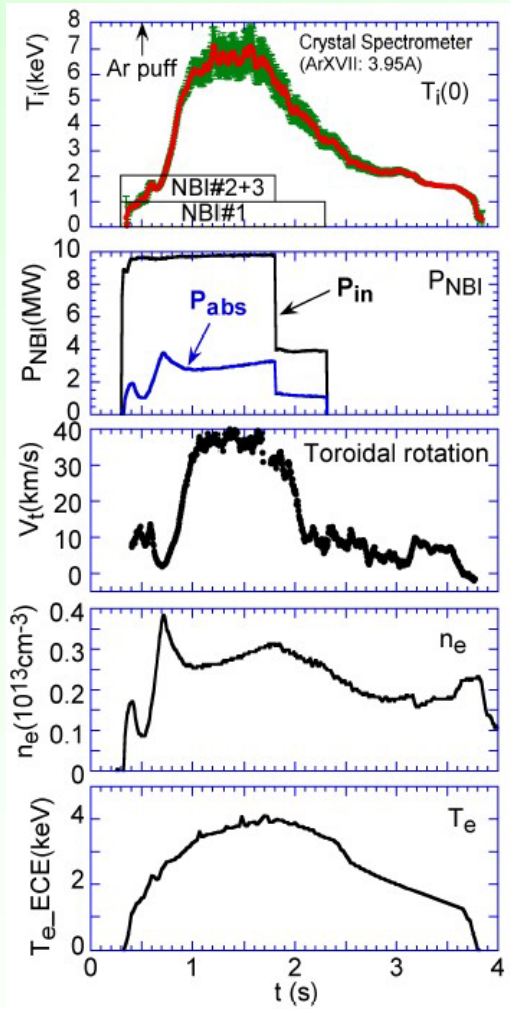




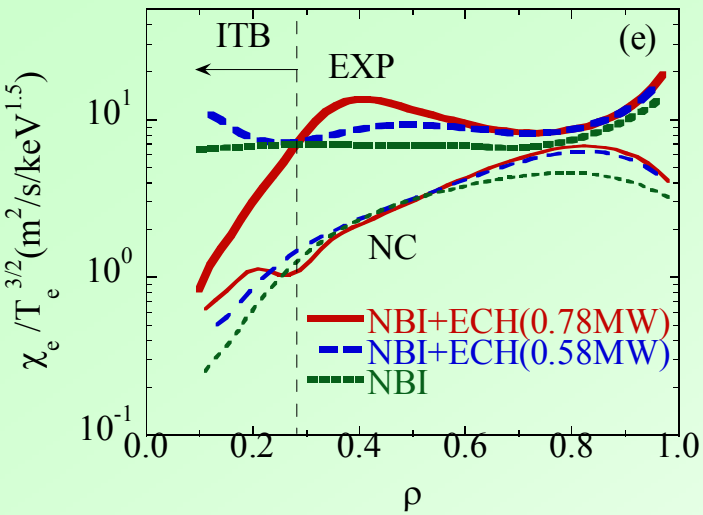
Achievement of $T_i(0)$ = 7 keV

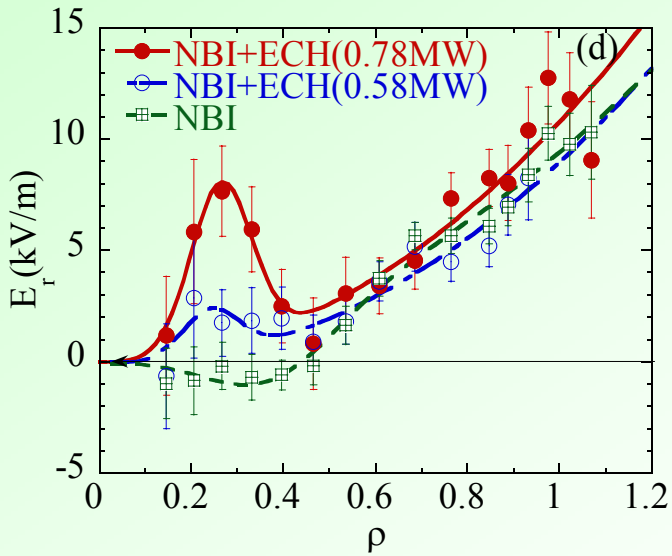
- Achieved Ti(0) increased with n_e by Ar puff
- Ne glow DC was effective
- n_e=0.3 x 10^{19}/m^3, n_i<0.1 x 10^{19}/m^3
  Dominant ion : argon
- Good correlation between Ti(0) increase and $V_t(0)$ acceleration is suggested
- Slowing down time is longer than 1 sec.

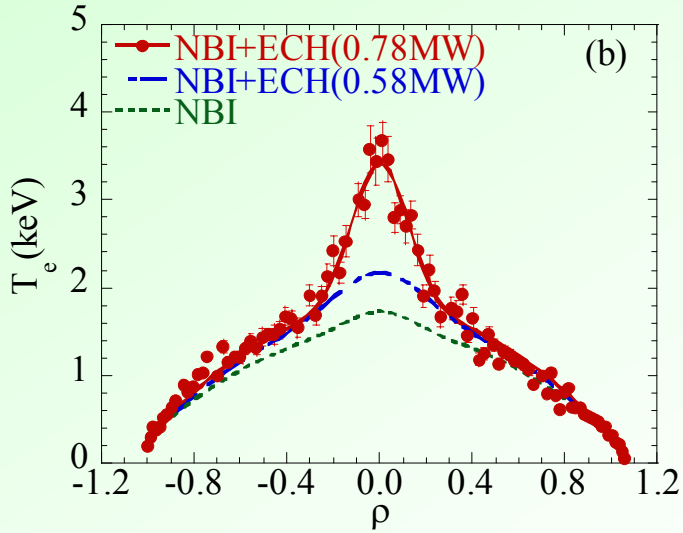




ITB in LHD



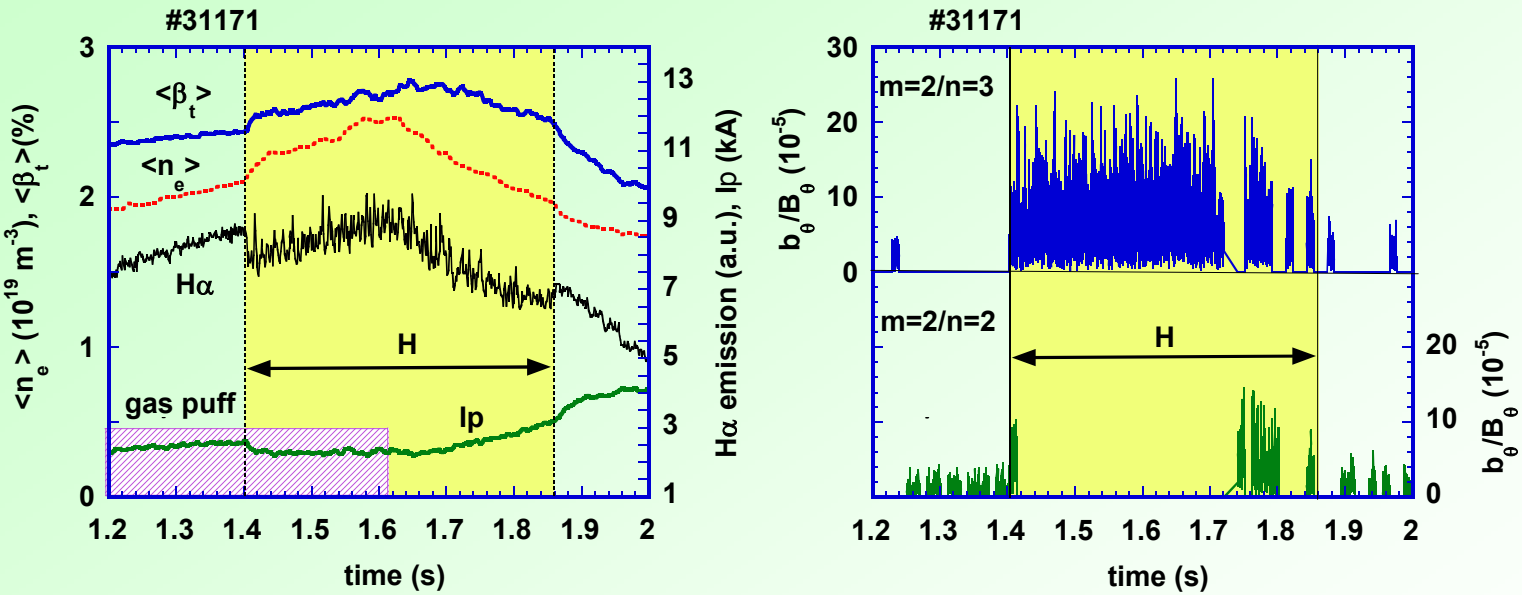




no change of magnetic shear

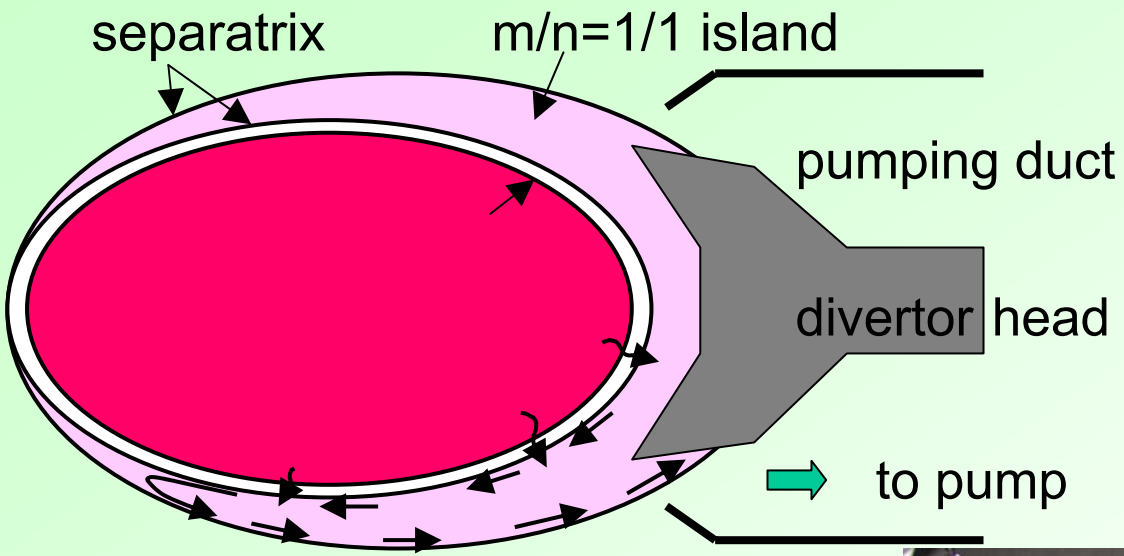
ITB formation associated with the transition of Er and appearance of Er shear

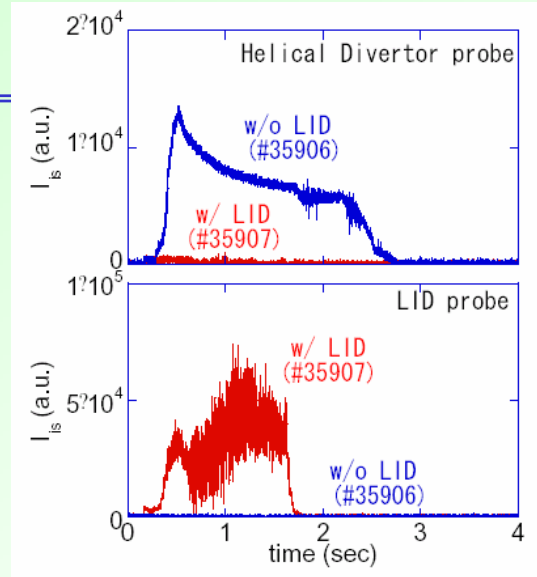
Typical Shot with L-H Transition



- Rapid density rise and Hα-drop: Improvement of particle conf.
- Enhanced Hα-fluc. with short quiescent phase
- Formation of edge transport barriers in the magnetic hill
  1. Rapid enhancement of edge MHD modes such as m=2/n=3
  2. Quick saturation of Wp or $<\beta_t>$ due to these MHD modes

Concept of Local Island Divertor (LID)

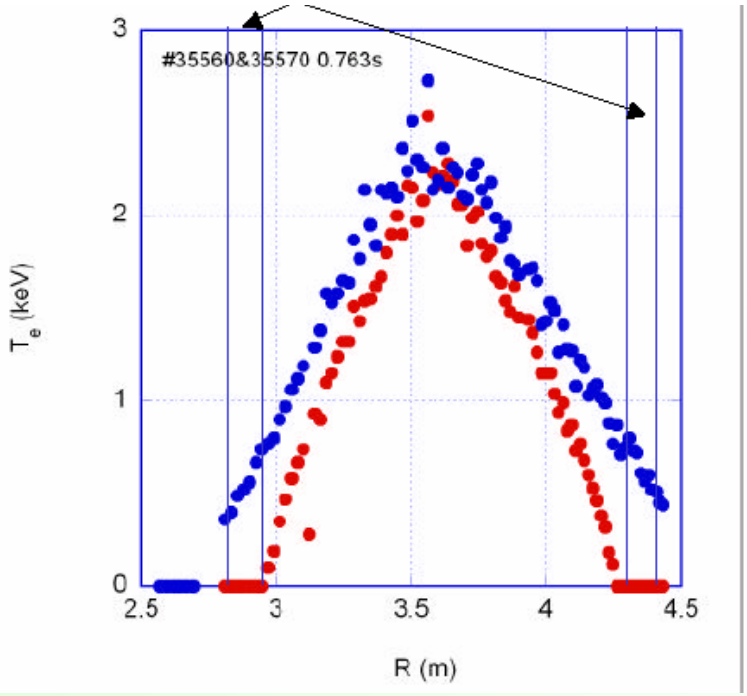


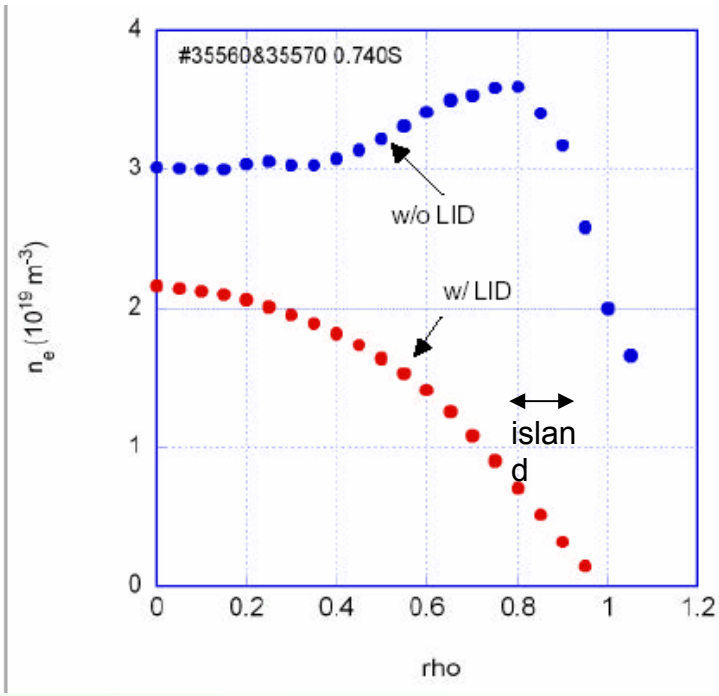


Ion-saturation current

- **Carbon head is inserted into an m/n = 1/1 island**
- **Heat &particle flux guided to the backside of the head**

Effect of LID on edge n_e and T_e profiles (NBI plasma)

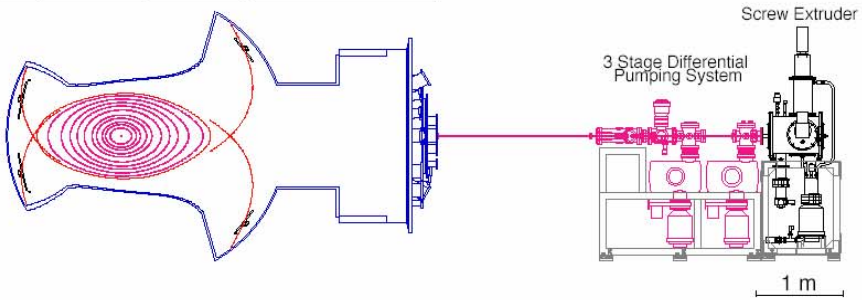




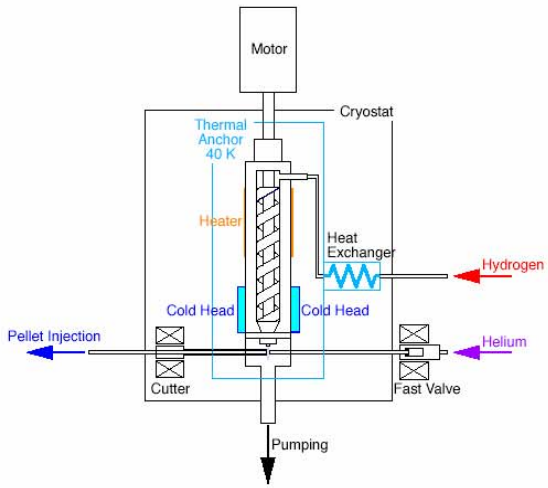
Steepening in edge T_e and peaked profile in n_e

Repetitive Pellet Injection Experiments in LHD

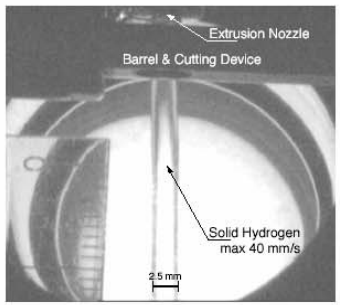
Repetitive pellet injector and LHD



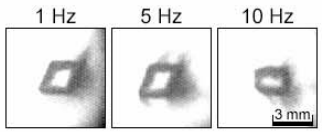
Schematic view of "Screw Extruder"



Extruded solid hydrogen



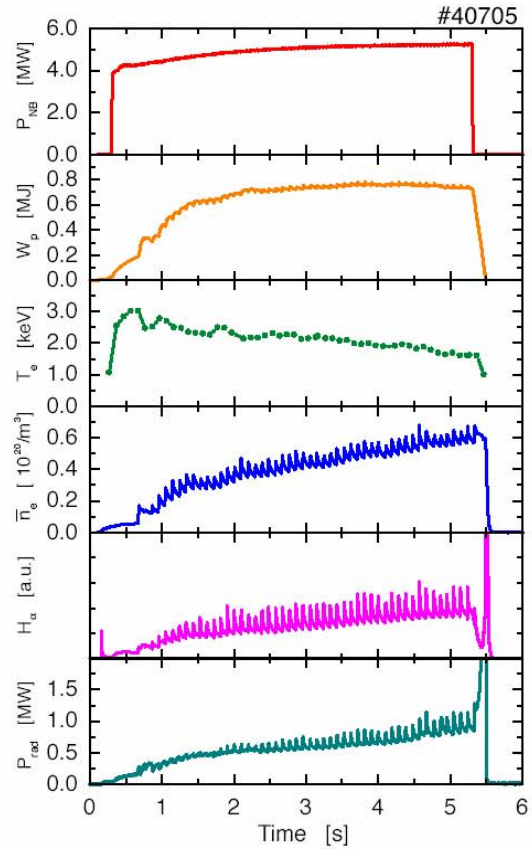
Pellet shadow-graph



- Extruded speed: 35 mm/s for 2.5 mm nozzle
- Solid hydrogen is accelerated by He gas after cutting from extruded solid hydrogen rod.
- Injection frequency: max 11 Hz
- Injection velocity range: 200 - 550 m/s

- No limitation on operational duration
  - +10,000 shot injection test was carried out at 11 Hz.
  - +Characteristics do not change with the repetitive frequency .
  - +reliability: more than 99%

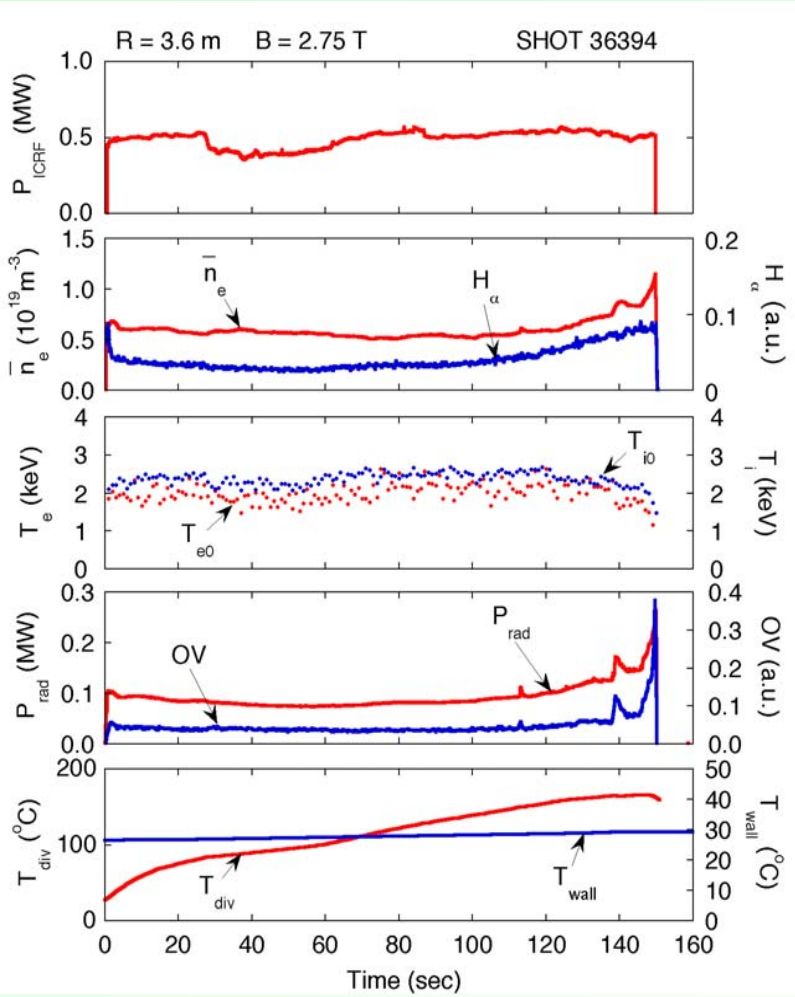
Plasma experiment



- 50 pellets were injected with 10.5 Hz repetitive rate to NBI heated plasma.
- Density rise per pellet meet the requirements, and the density may be controlled by repetitive rate and/or pellet size.

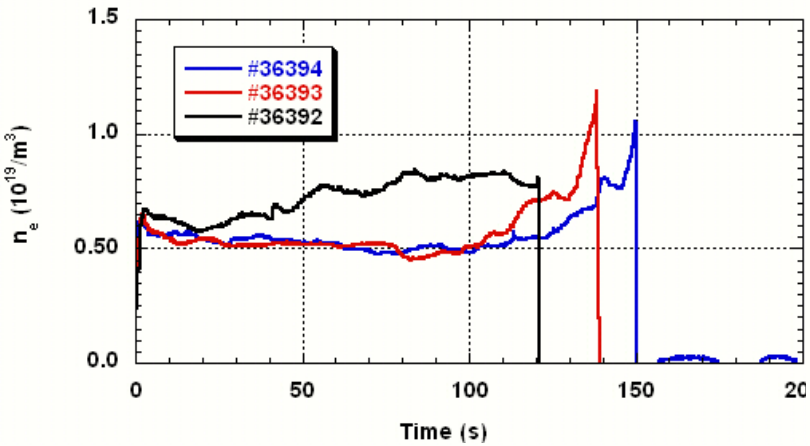
Long-Pulse Discharge with ICRF

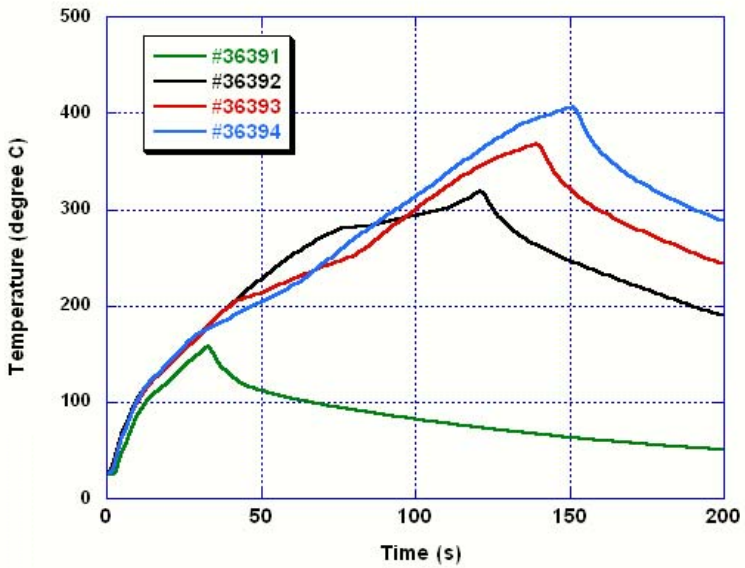
movie (2.5 min.)

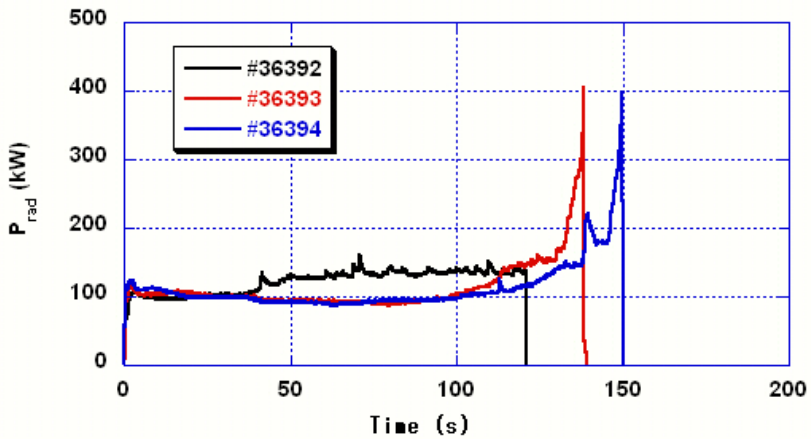


- 150 s ICRF discharge with ~ 0.5 MW
- $\langle n_e \rangle \sim 0.6 \times 10^{19}$ m^{-3}
  $T_{e0} \sim T_{i0} \sim 2$ keV
- Gradual increase of n_e, H_α, P_{rad} after 100 s
  → Local heating ?
- Temperature increase
  $\Delta T_{div} \sim 150$ ℃ - 400 ℃
  $\Delta T_{wall} \sim 3$ ℃

ICRF 150 sec (Oct. 2002)

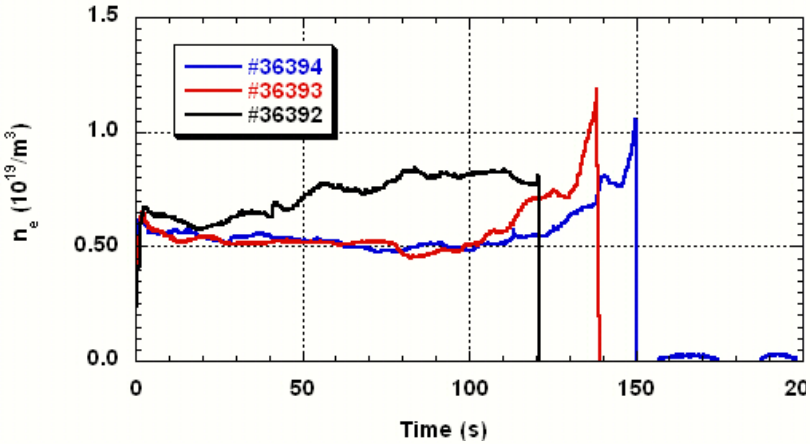


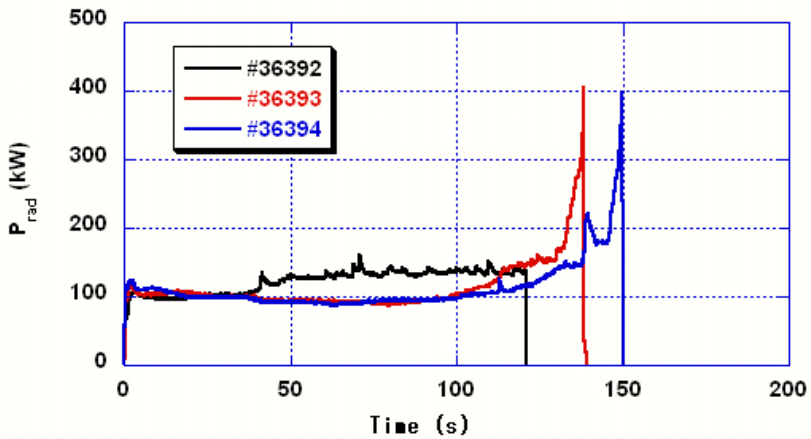


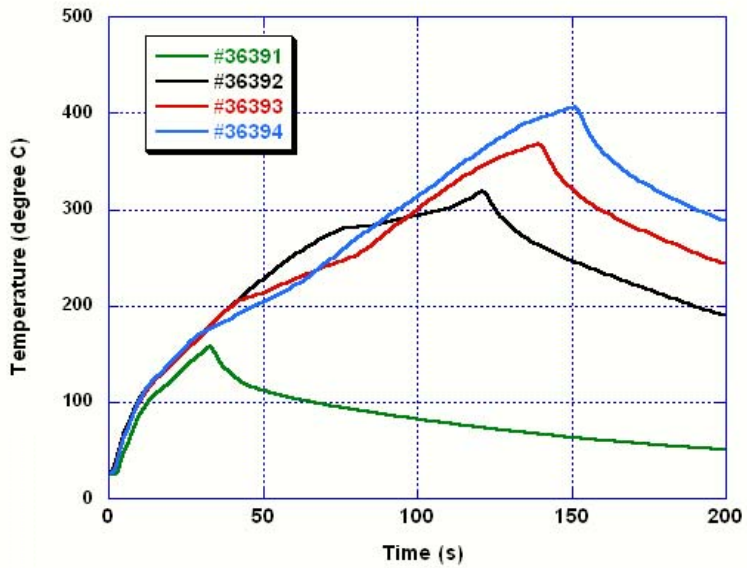


Density builds up without gas puffing
→ Collapse

ICRF 150 sec (Oct. 2002)



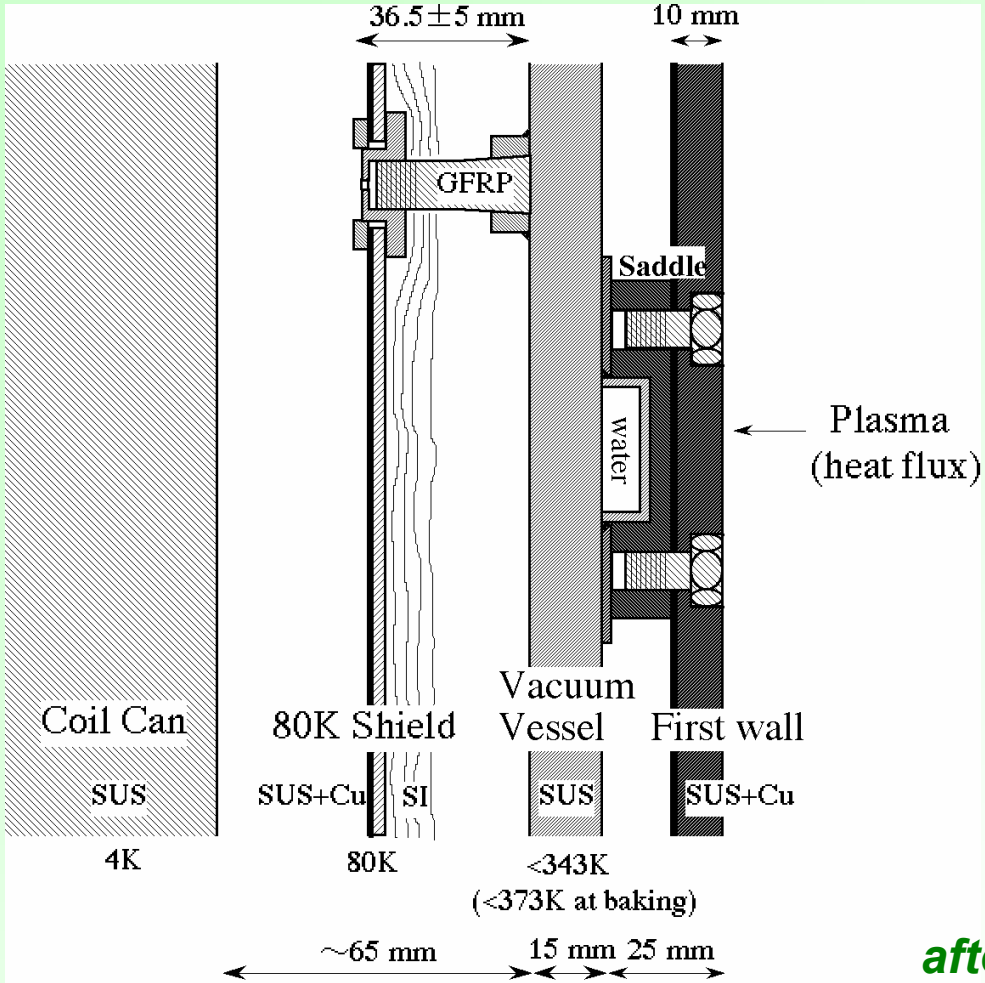




Temperature of the tiles exceeds baking temp.

Higher n_e – larger P_{rad} lower T_{tile} – no collapse

Schematic view of LHD first wall

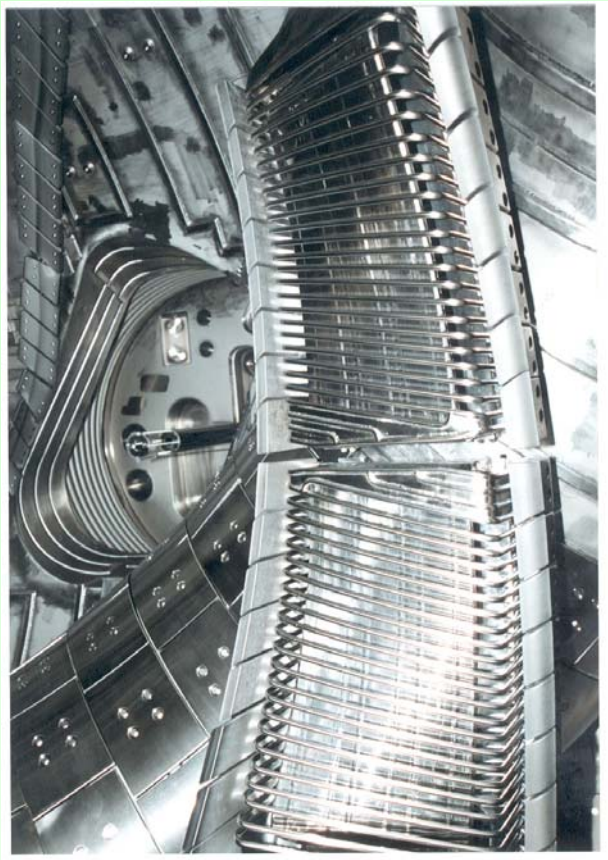


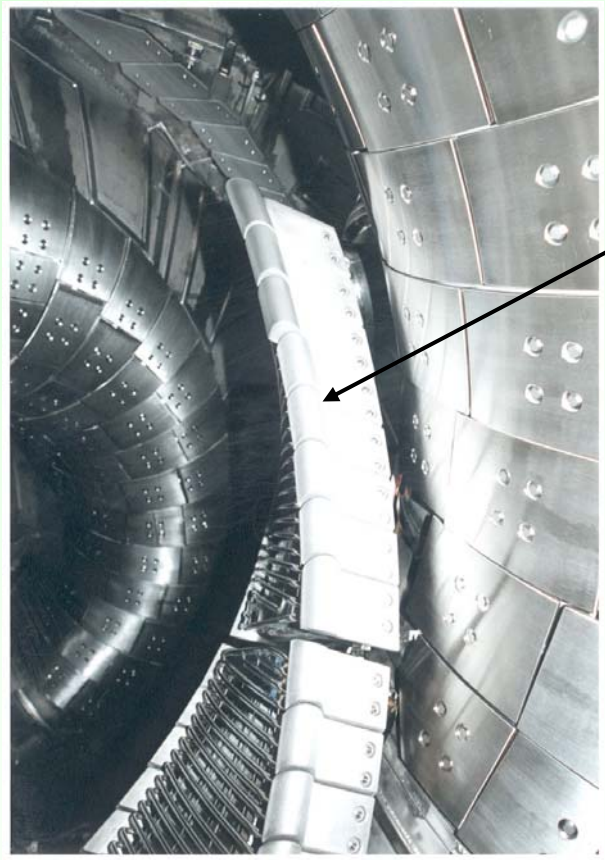
- Radial build of the first wall to coil can
- Cooling channels are directly welded to VV
- First wall panels are fixed on the channel

after N. Inoue & A. Komori

RF antenna

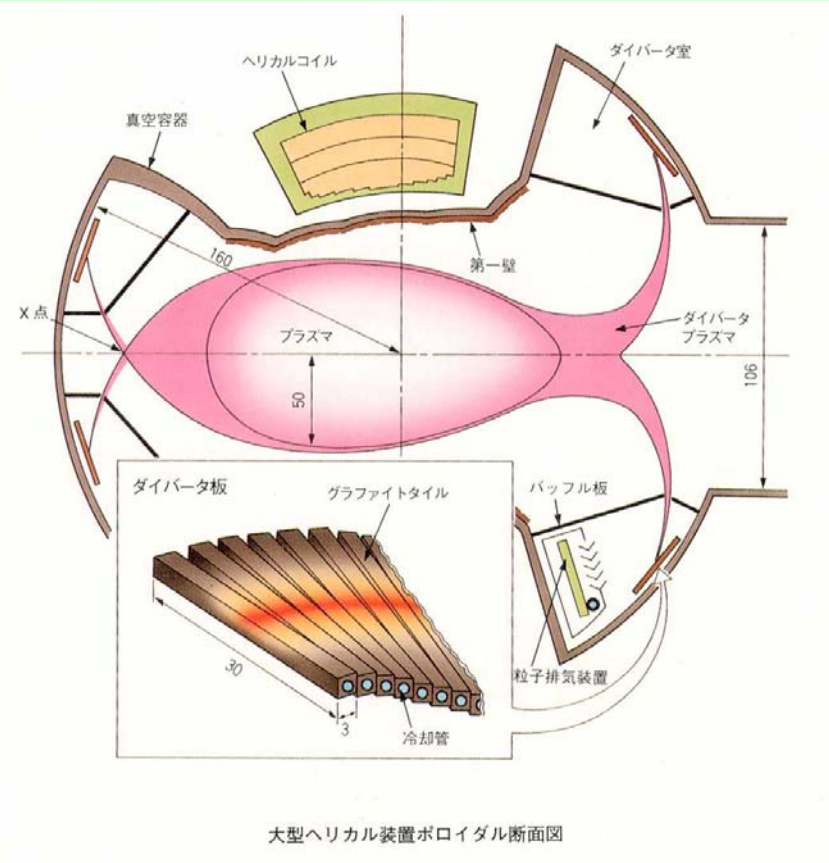
2 x ¼ turn, high field side, water cooled, radially movable





carbon protector

Features & requirements for LHD divertor



大型ヘリカル装置ポロイダル断面図

-Double null, 4 legs
-Helically running,
3-dimensional
-Direction of mag. field lines
at striking point is poloidal
→ Discrete bar array

-Heat load
10s pulse 5 MW/m^2
steady state 0.75 MW/m^2

Wider and more intensive collaborations are going on with universities and JAERI

at the LHD Control Room

Members of the JT-60 group joined to high-power NBI experiments after boronization and long-pulse experiments

Summary

- Maximum achieved parameters
- Achievement of $T_i(0) = 7$ keV
- Development of negative ion source
- Physics of ITB in LHD
- Typical Shot with L-H Transition
- Long-Pulse Discharge with ICRF
- Local Island Divertor
  Effect of LID on edge n_e and T_e profiles
- Repetitive Pellet Injection (>50 pellets)
- Collaboration with university groups and JAERI
- LHD experiments : 7th Cycle Plan

LHD Experiments / 7th Cycle Plan

- Pump down / Cool down Aug. – Sept. 2003
- Experiments
  end of Sept. 2003 – end of Jan. 2004
- Subjects
  - Higher performance, transport, stability
  - Long pulse discharge,
    recycling / impurity analyses
  - LID (Local Island Divertor)
  - Divertor/edge plasma analyses and PSI
  - High energy particles, heating
  - Others

Workshop Agenda