ITC-12/APFA'01
Ceratopia Toki, Toki
11-14, Dec. 2001

Global Particle Balance of Long Duration Discharges on TRIAM-1M

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- Introduction
- Wall pumping rates of low and high density discharges
- Static and dynamic properties of wall recycling
- Global particle balance of the ultra-long discharge (τ_D ~ 3 hours)
- Summary

Introduction

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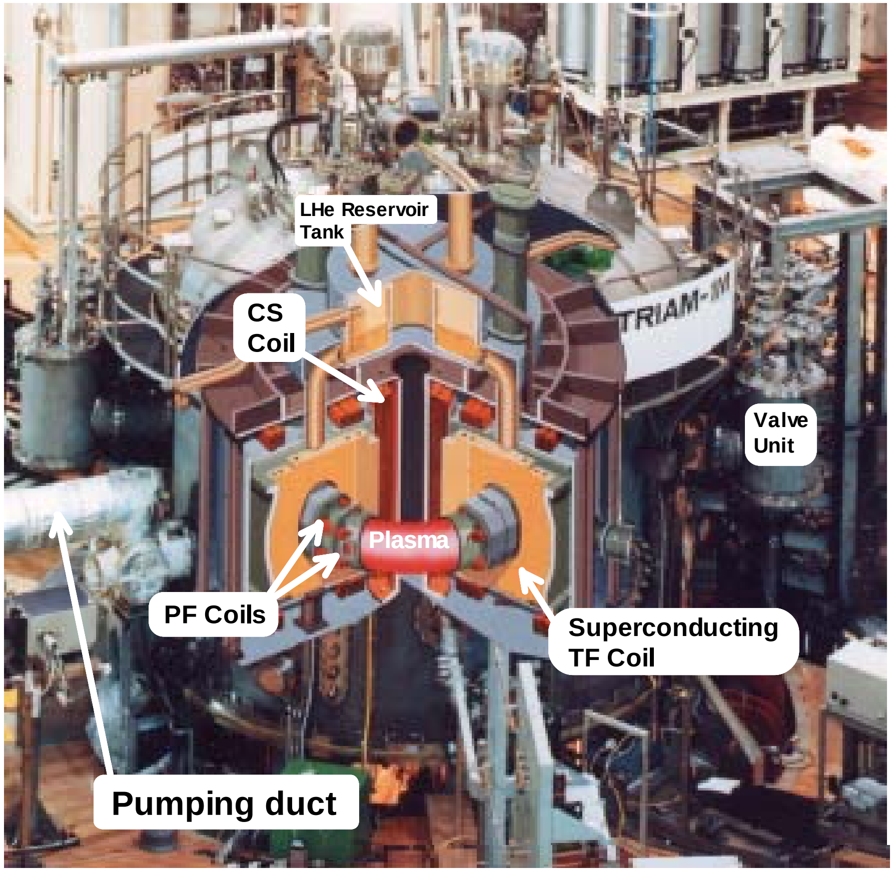


Bird's-eye view of TRIAM-1M

Major radius	**0.84 m**
Minor radius	**0.12 m**
Toroidal field	**8 T (Steady State)**

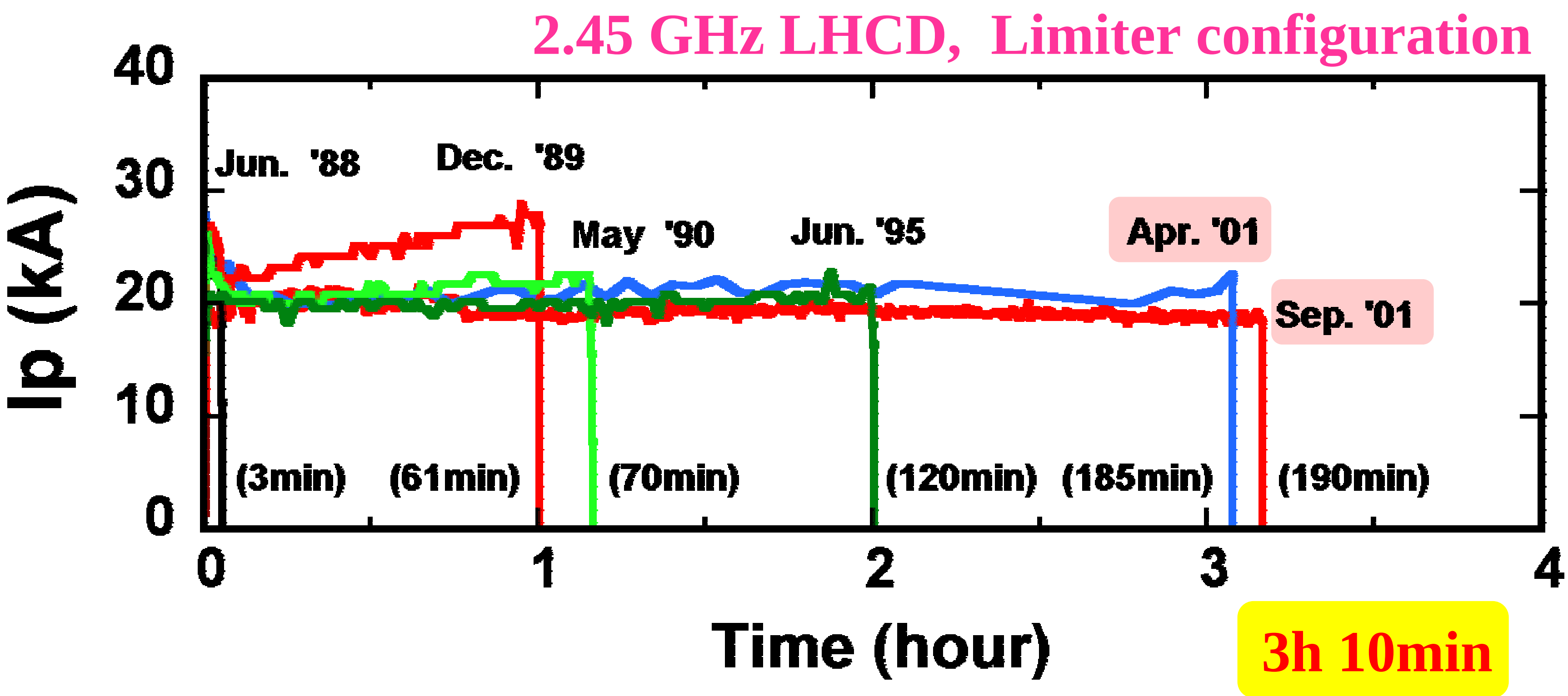
TF coils : Nb_3Sn (superconductor)

PF coils : Cu (normal conductor)

Plasma facing components: High Z
- vacuum vessel : stainless steel
- Limiter : Molybdenum
- Divertor : Molybdenum

Without low Z material and coating

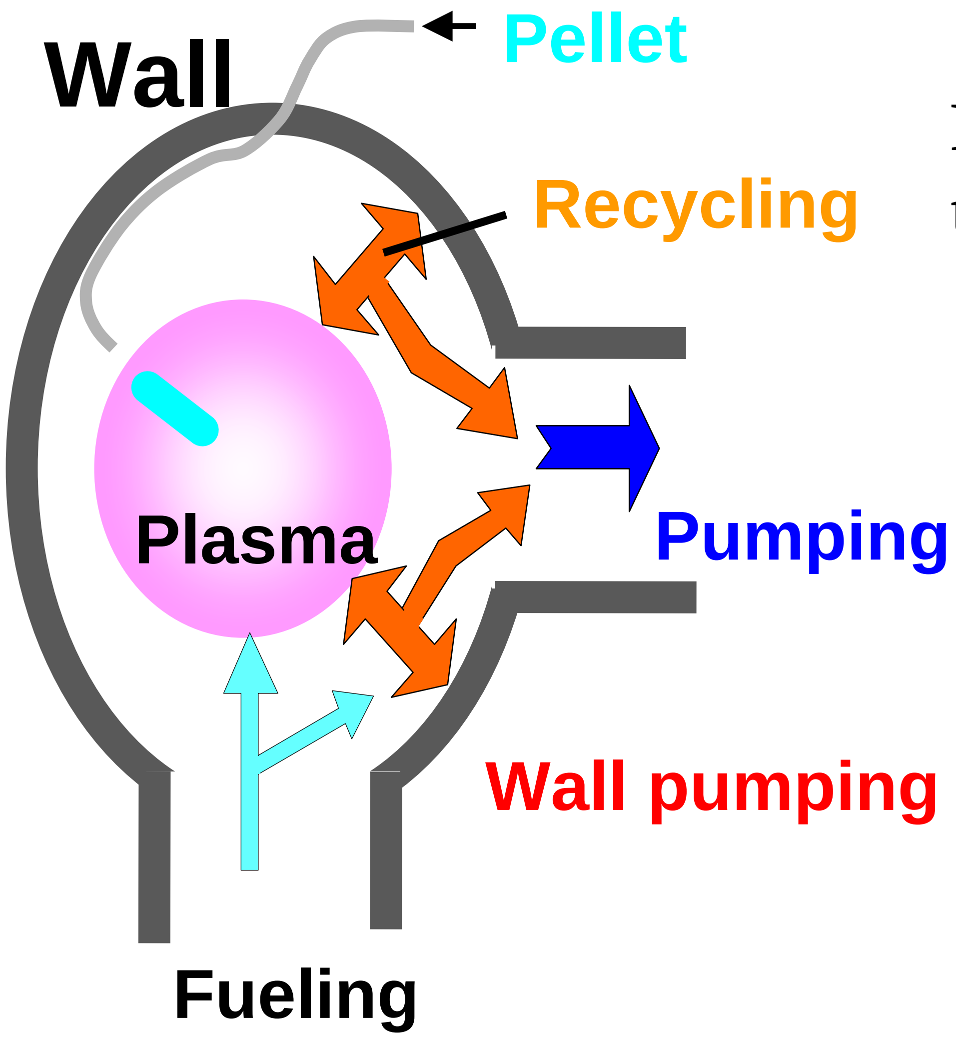
Progress of long tokamak operation



In TRIAM-1M, the study and development of the long pulse operation have actively been carried out.

Particle control is one of key issues for long pulse operation.

Particle balance inside the vacuum vessel (I)



Particles supplied in the vacuum vessel

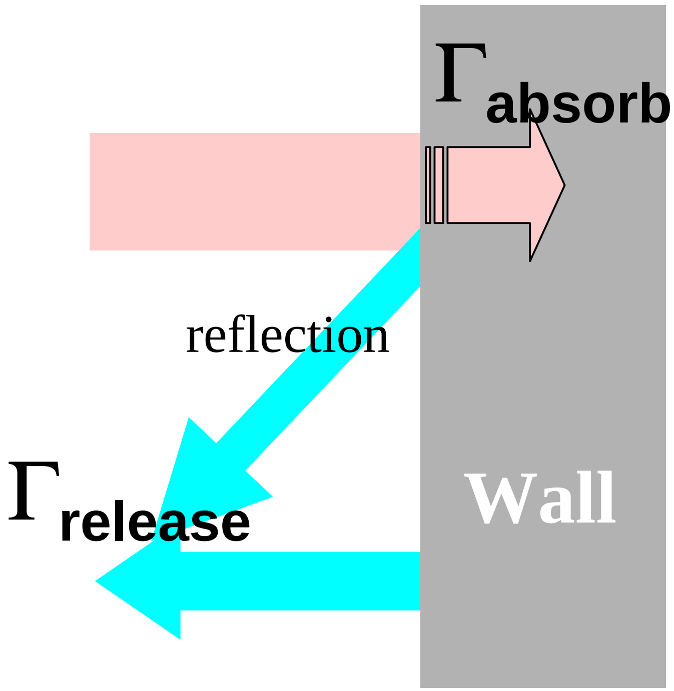
- **External pump**
- **Wall pumping**

This depends on the plasma condition.

Particle balance inside the vacuum vessel（II）

In the vacuum vessel

$$dN_p / dt \;+\; dN_0 / dt \;=\; \Gamma_{fuel} - \Gamma_{pump} - \Gamma_{wall}$$



Γ_{fuel} : fueling rate

Γ_{pump} : pumping rate

Γ_{wall} : net wall pumping rate

$$\Gamma_{wall} = \Gamma_{absorb} - \Gamma_{release}$$

Positive : Sink

Negative : Source

$\Gamma_{wall} = 0$ looks like wall saturation

Comparison of Γ_{wall} between low and high density discharges

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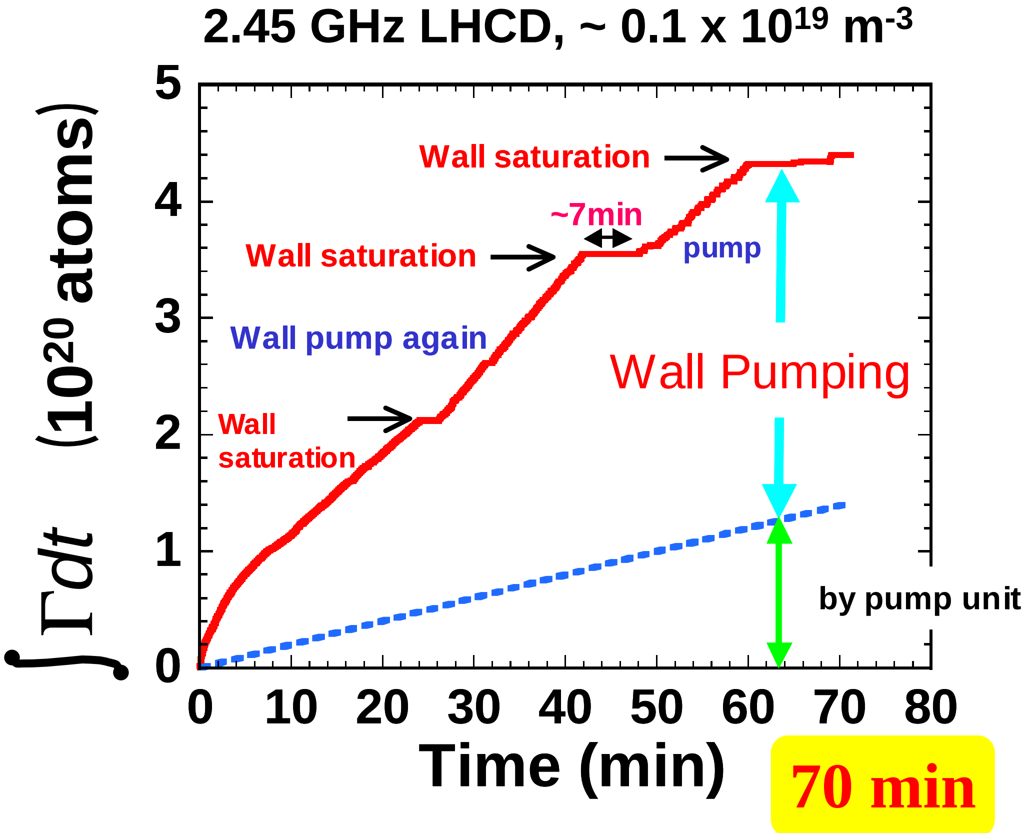

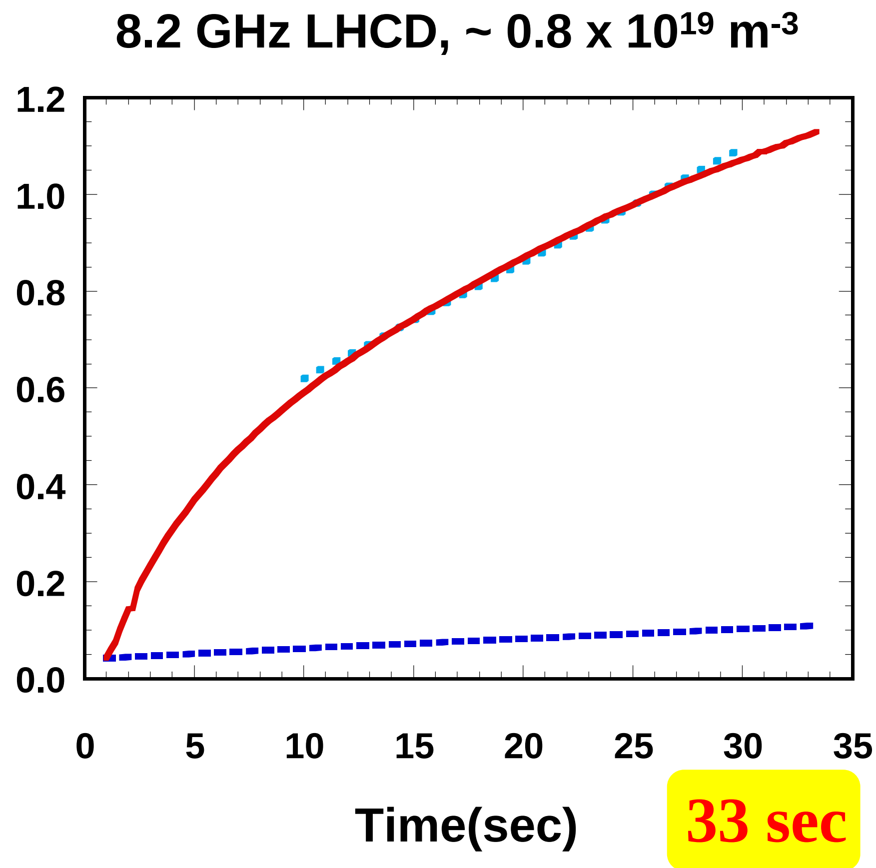

The wall repeats the process of being saturated and refreshed.

$$\Gamma_{wall} = \Gamma_{fuel} - \Gamma_{pump}$$

Ref: M.Sakamoto et al., NF **42** (in press)

Comparison of Γ_{wall} between low and high density discharges

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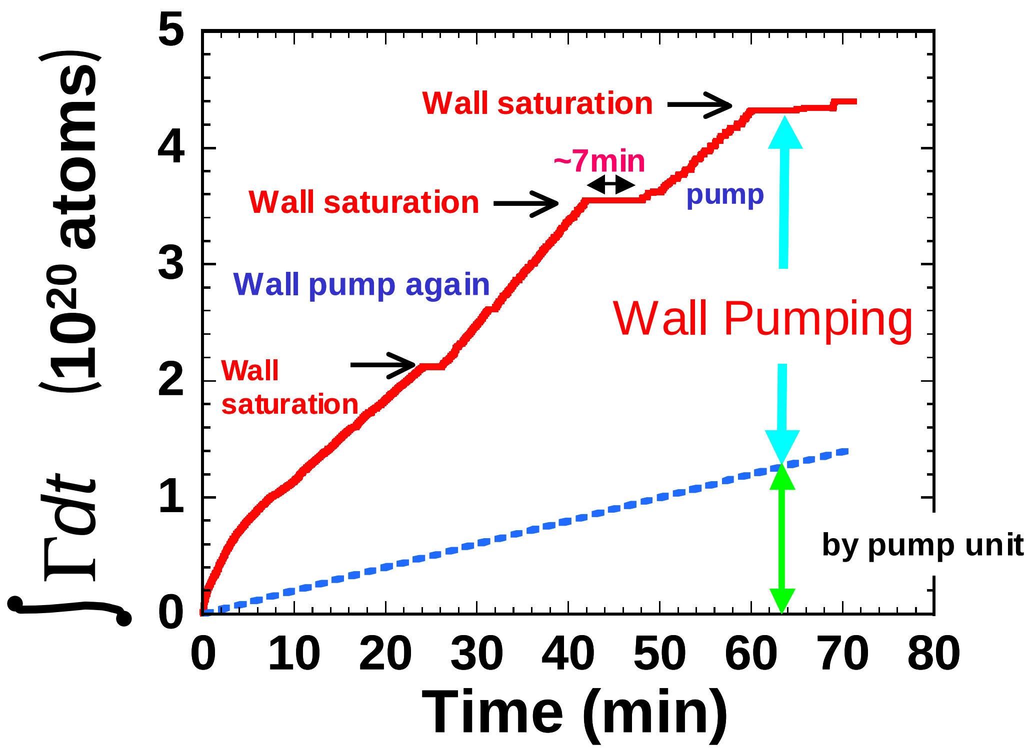
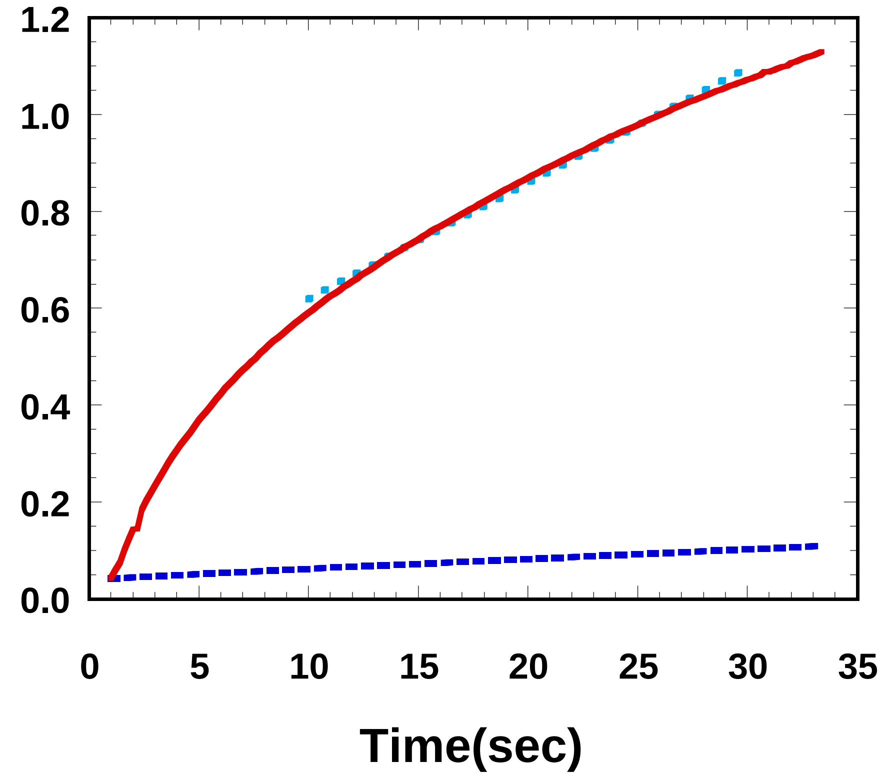
2.45 GHz LHCD, ~ 0.1 x 10^{19} m^{-3}



8.2 GHz LHCD, ~ 0.8 x 10^{19} m^{-3}



Γ_{wall} ~ 1.5×10^{16} atoms m^{-2} s^{-1}

Γ_{wall} ~ 4×10^{17} atoms m^{-2} s^{-1}

Γ_{wall} of high density discharge is ~ 30 times higher than that of low density discharge.

Γ_{wall} seems to depend on the particle flux to the wall.

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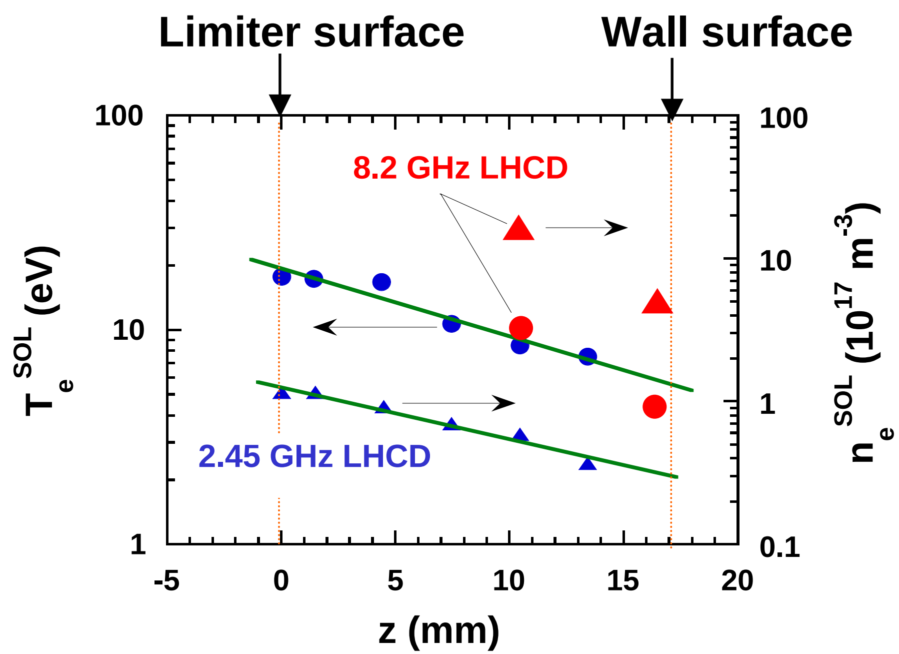
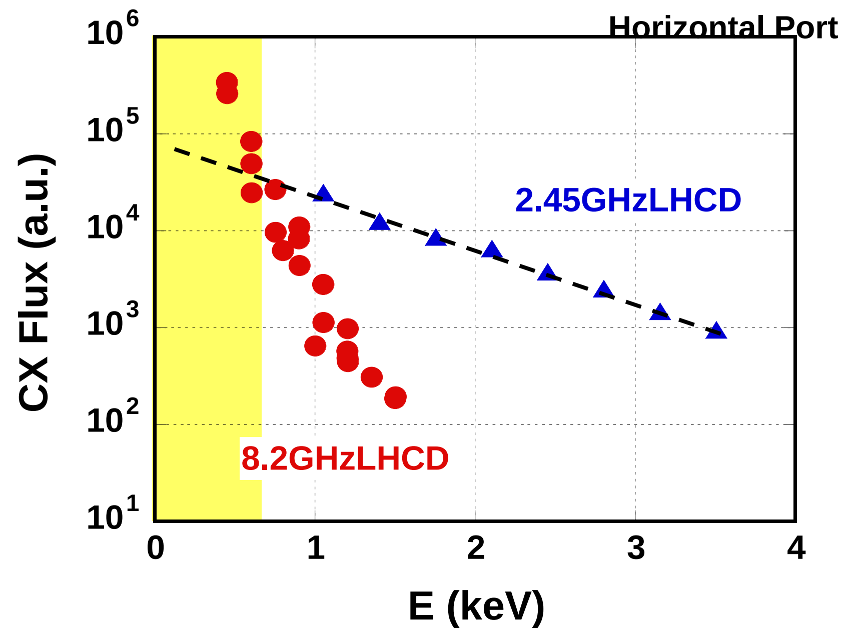
Diffused flux



CX neutral flux



- T_e^{SOL} (8.2GHz) ~ T_e^{SOL} (2.45GHz)
- n_e^{SOL} (8.2GHz) > 10 n_e^{SOL} (2.45GHz)

The difference of wall pumping rates between low and high density plasmas seems to be caused by the difference of the total amount of the diffused flux and/or the CX neutral flux with the energy of < ~0.7 keV.

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Effective particle confinement time in the static condition

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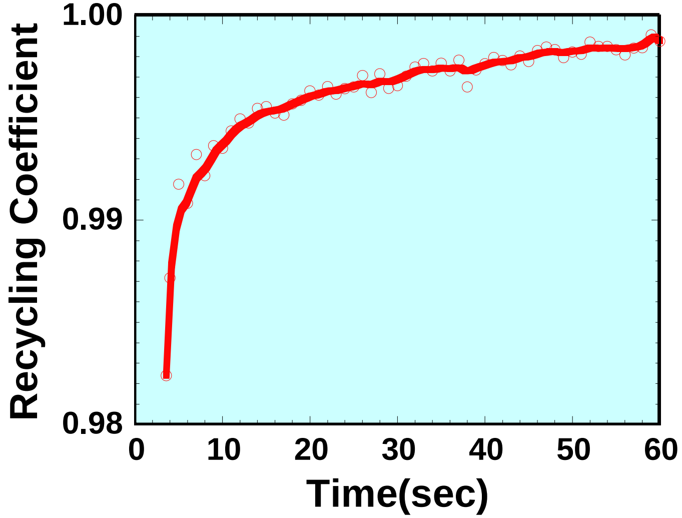
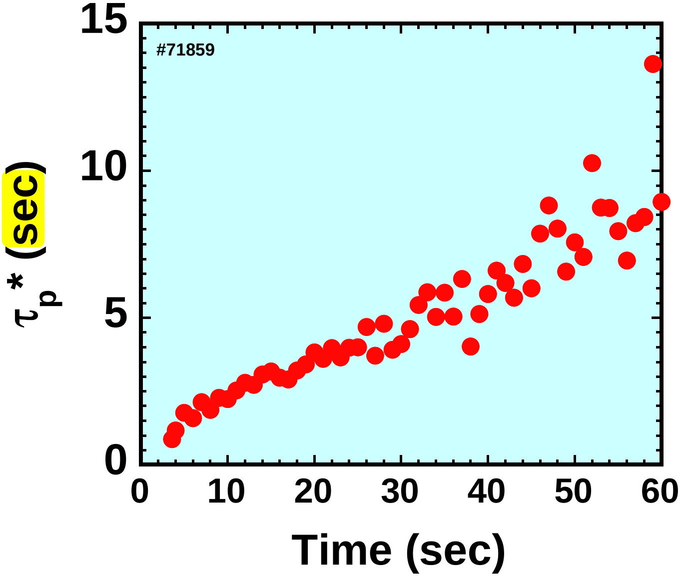


Particle balance equation inside the plasma

$$dN_e / dt = \eta \Gamma_{gas} + R\, N_e / \tau_p - N_e / \tau_p$$

Recycling coefficient increases with time and approaches to 1.



Effective particle confinement time

$$\tau_p^* = \frac{\tau_p}{(1-R)}$$

τ_p^* : 1~10 sec

$\tau_p{}^*$ in the dynamic condition

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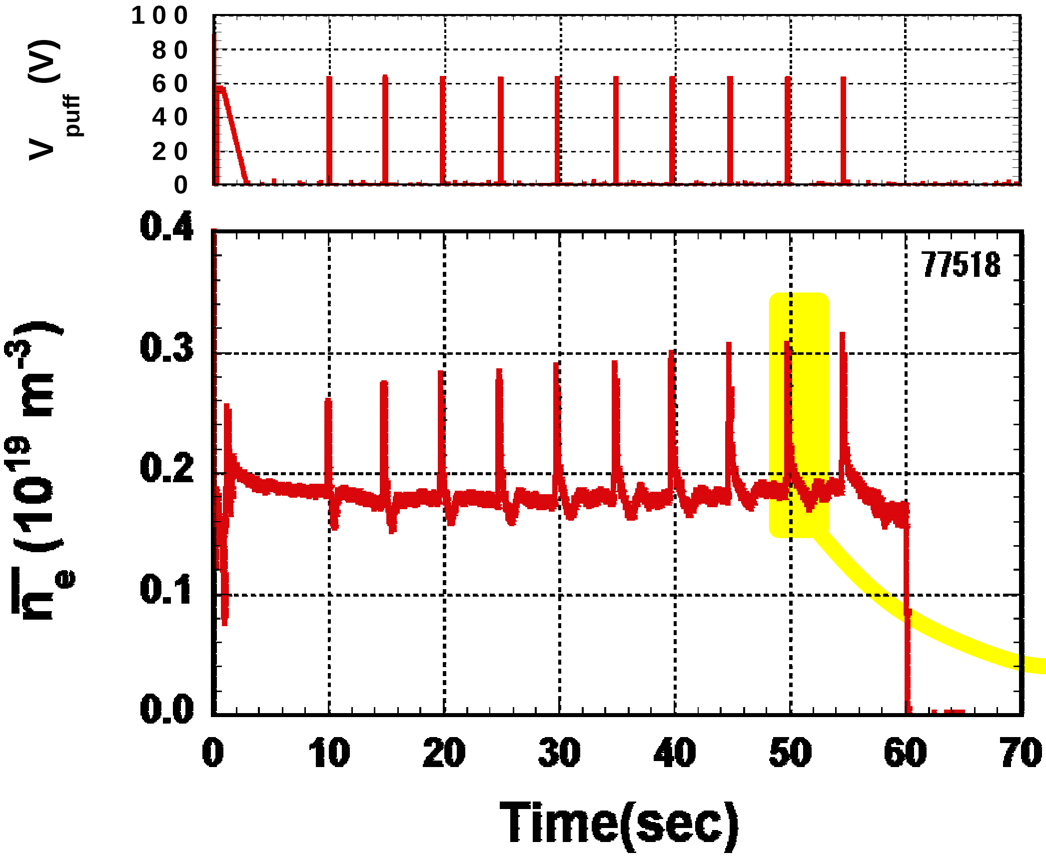
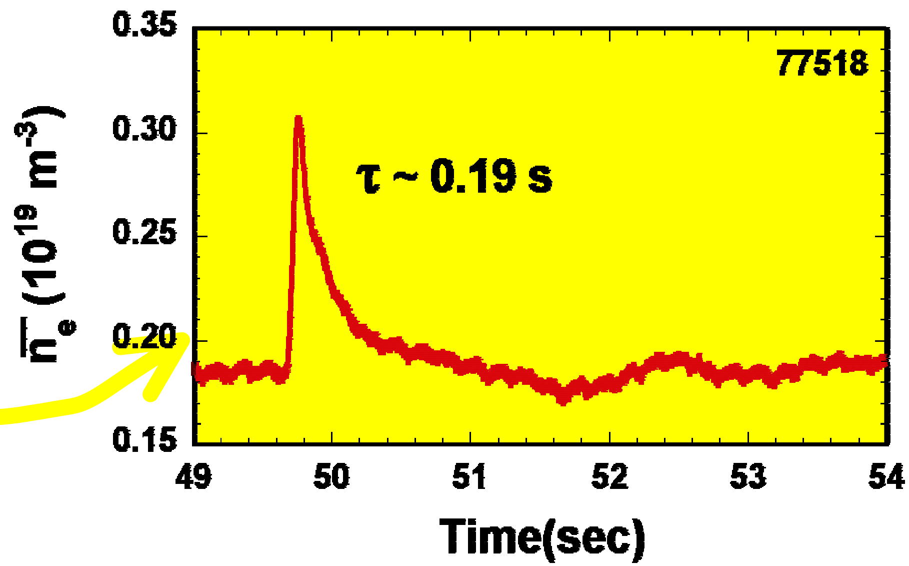


Gas puff was carried out at intervals of 5 s.



Decay time of $\bar{n}_e$ is only ~ 0.2 s.

Comparison of τ_p^* between in the static and the dynamic conditions

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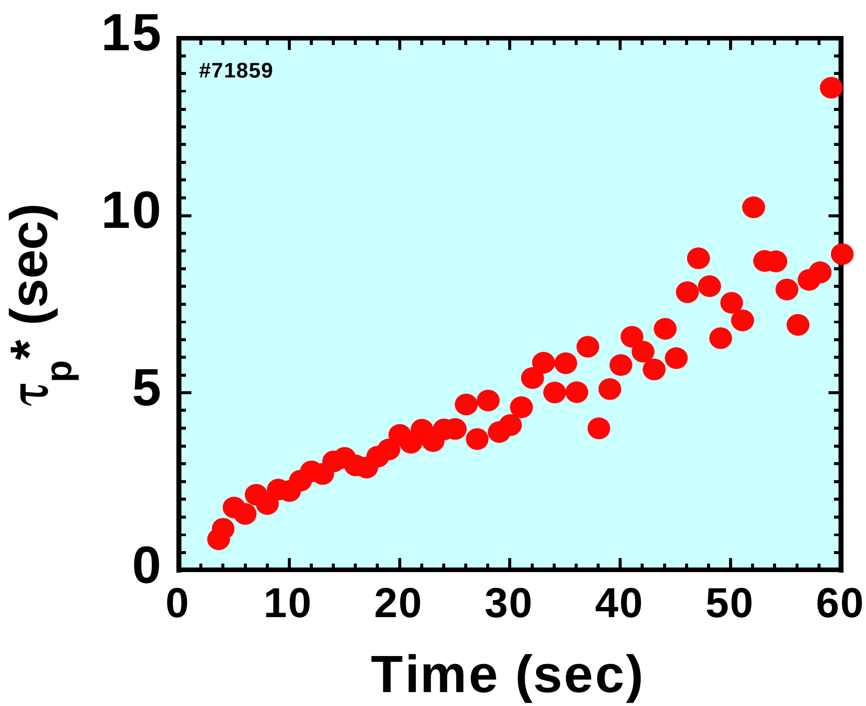
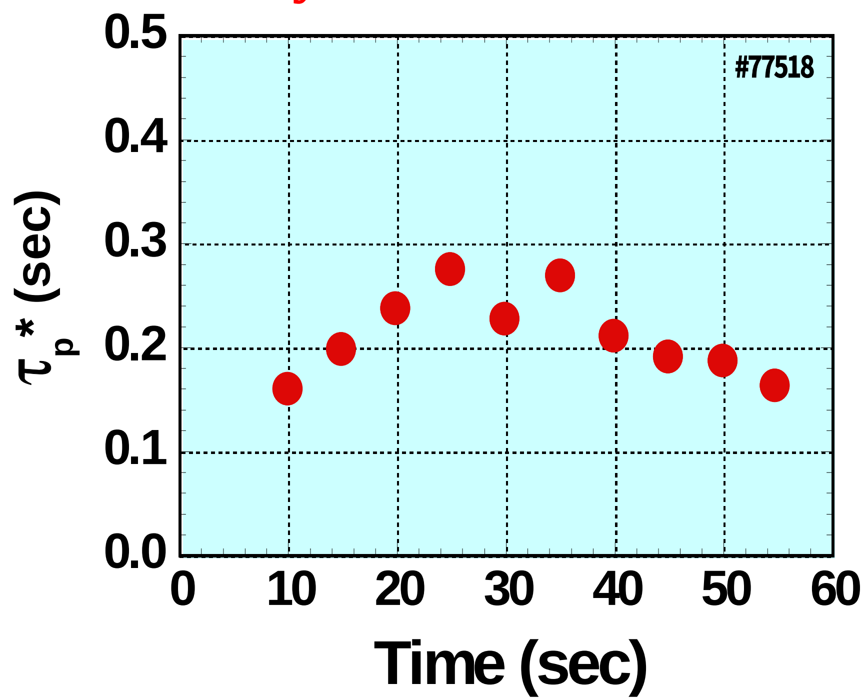
Static condition

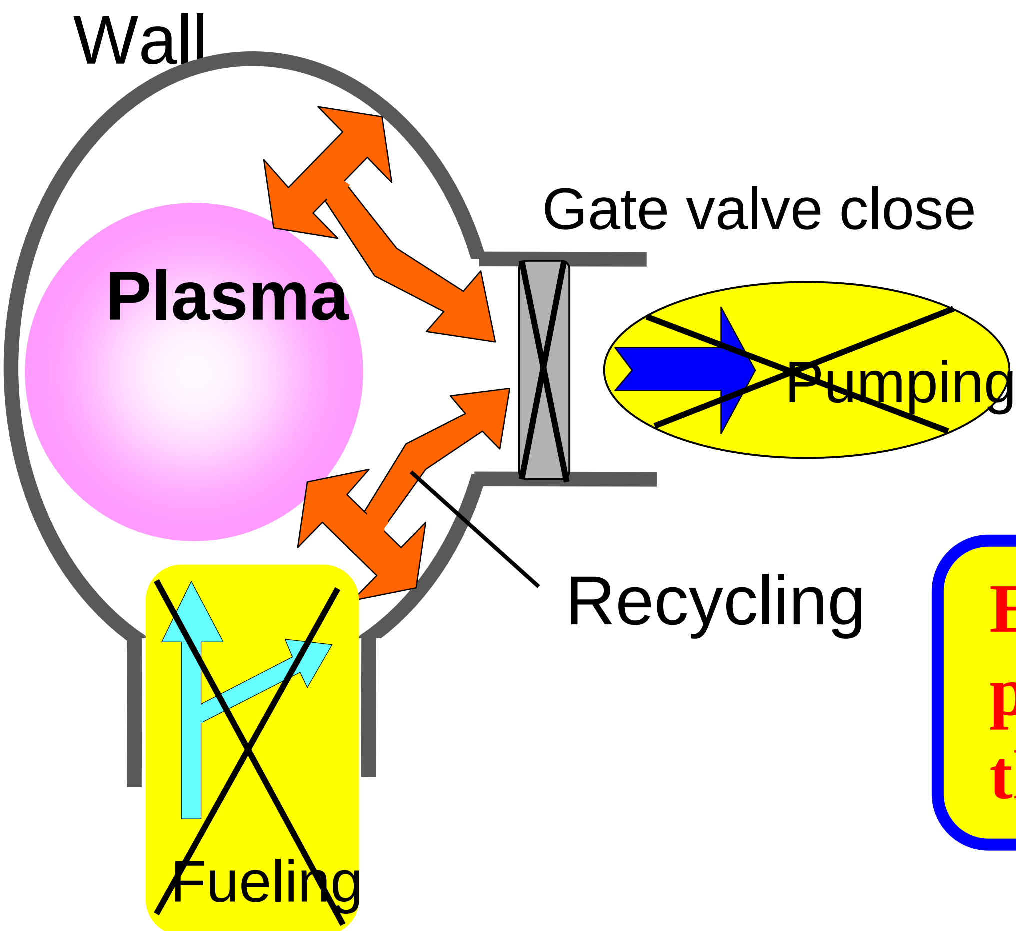


Dynamic condition



This suggests that the wall pumping rate is enhanced by the additional gas puff.

Another example for the static and dynamic conditions



Particles in the vacuum vessel
(1) are ionized,
(2) stay as neutrals,
(3) are wall-pumped,
(4) are evacuated by the pump unit.

Experiment on stopping the pumping and the fueling during the long duration discharge.

Pumping and fueling termination during the discharge

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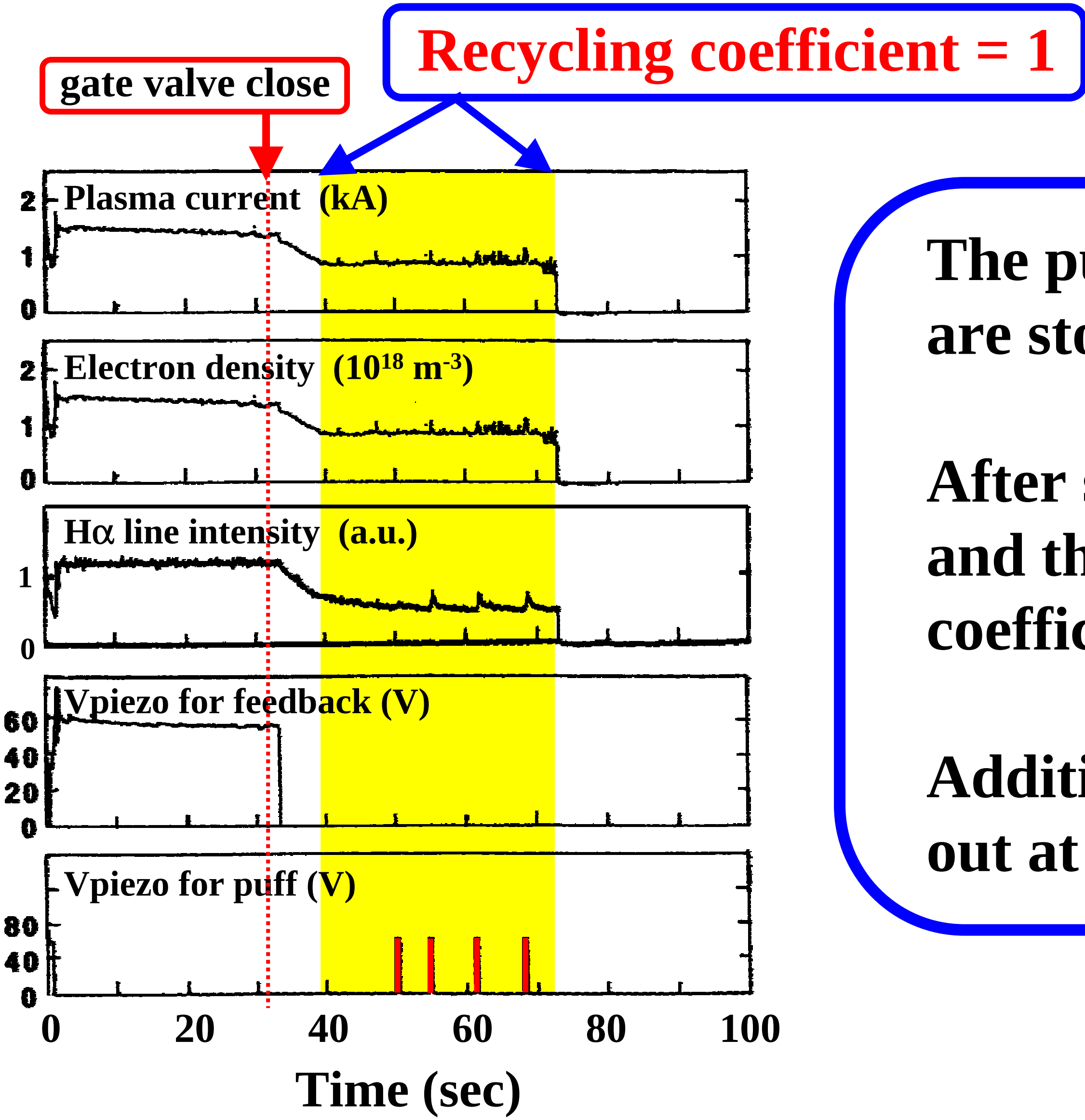

The pumping and the fueling are stopped at t~ 33 sec.

After stopping the pumping and the fueling, recycling coefficient must be unity.

Additional gas puff is carried out at 50, 54.5, 61, 68 sec.

Wall pumping is enhanced by the additional gas-puff

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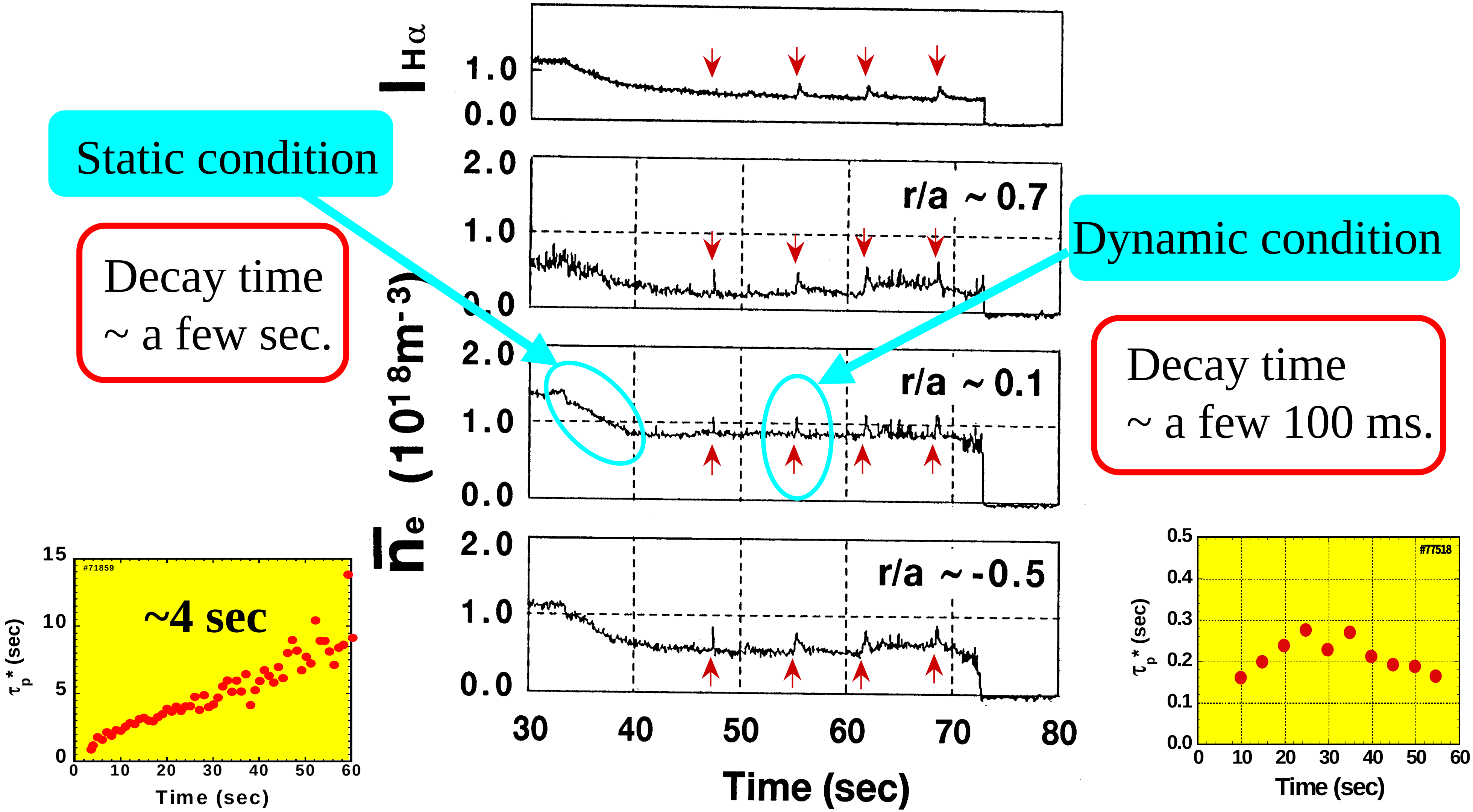

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Particle balance in 3 hours discharge

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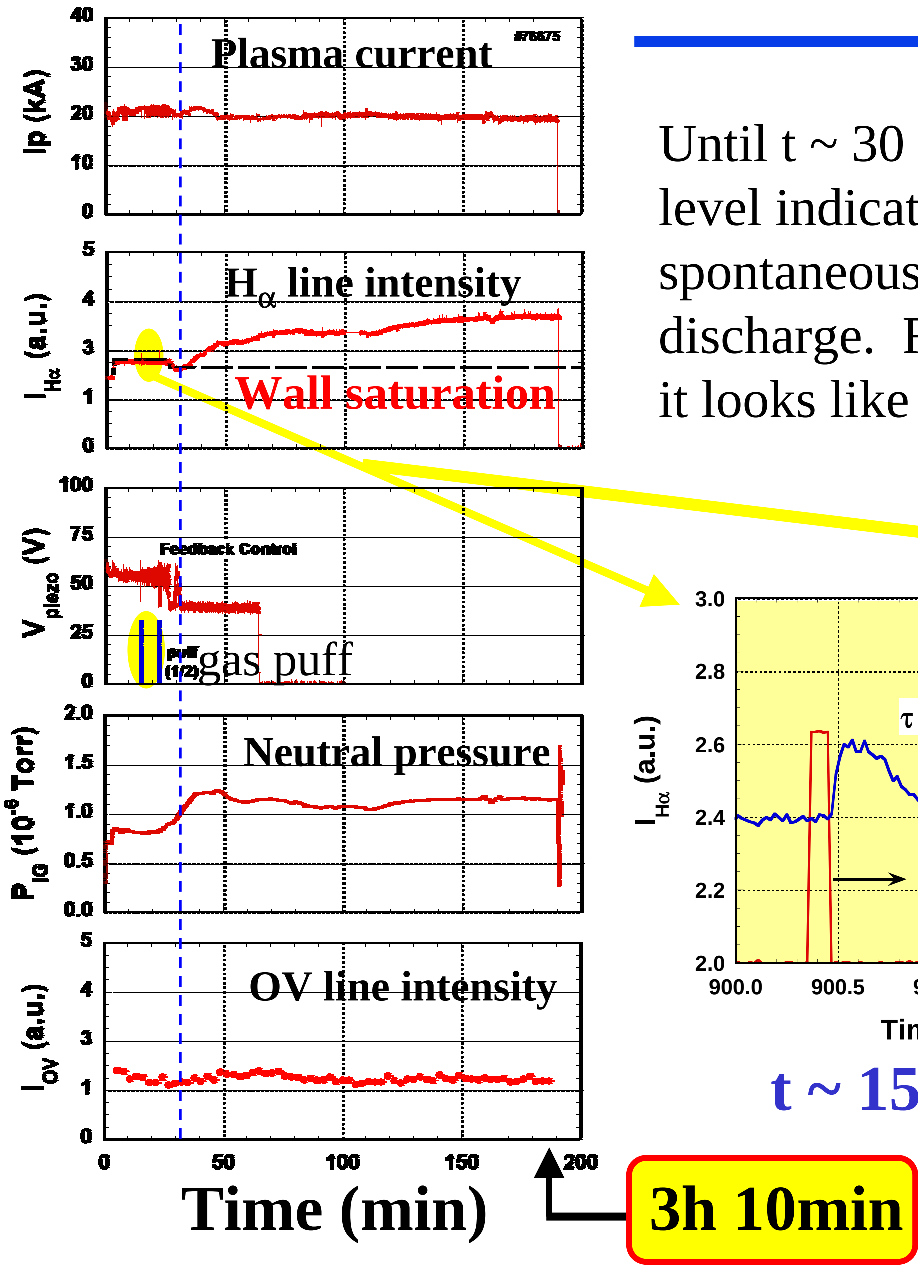
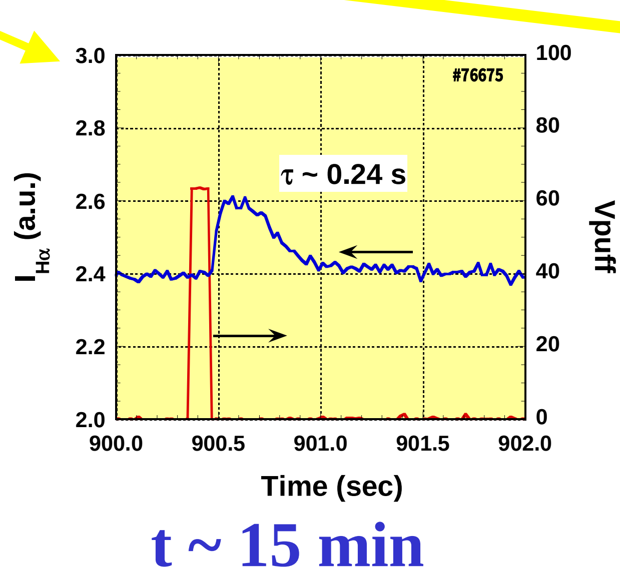
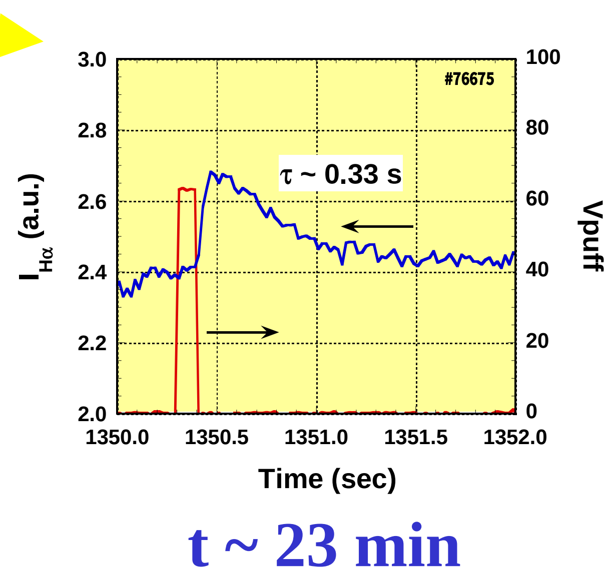
Until t ~ 30 min, the H_α line intensity followed the reference level indicated by the chain line. After that, it increased spontaneously and no particle control until the end of the discharge. From the viewpoint of the global particle balance, it looks like wall saturation.







Global particle behavior during the 3 hours discharge

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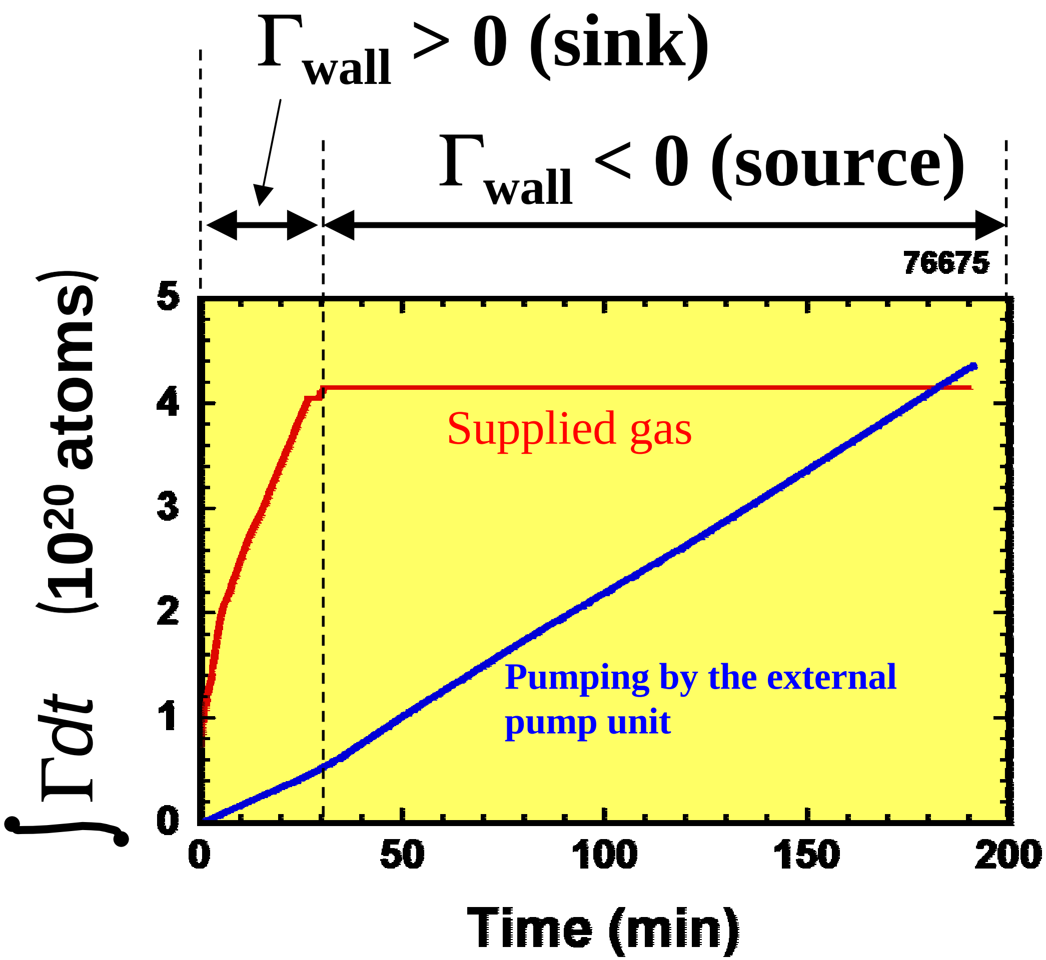
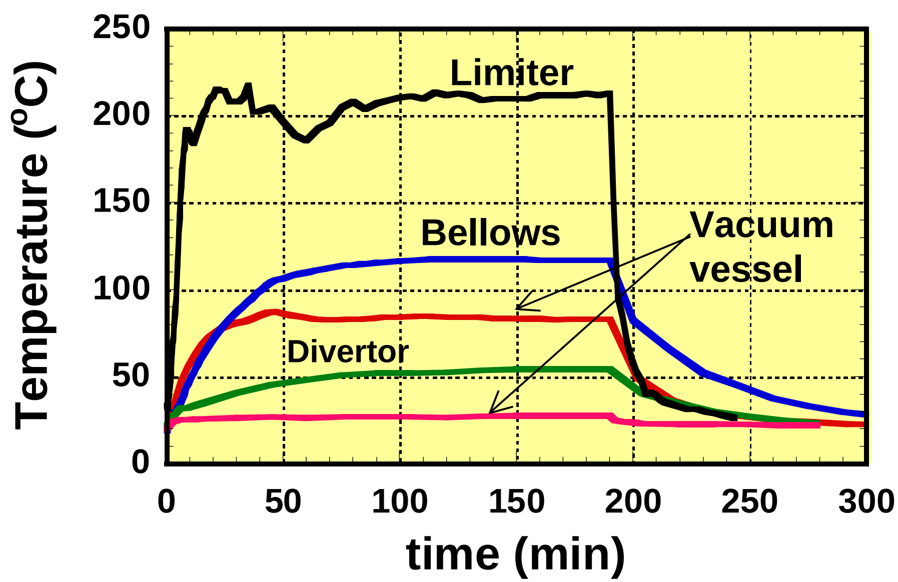


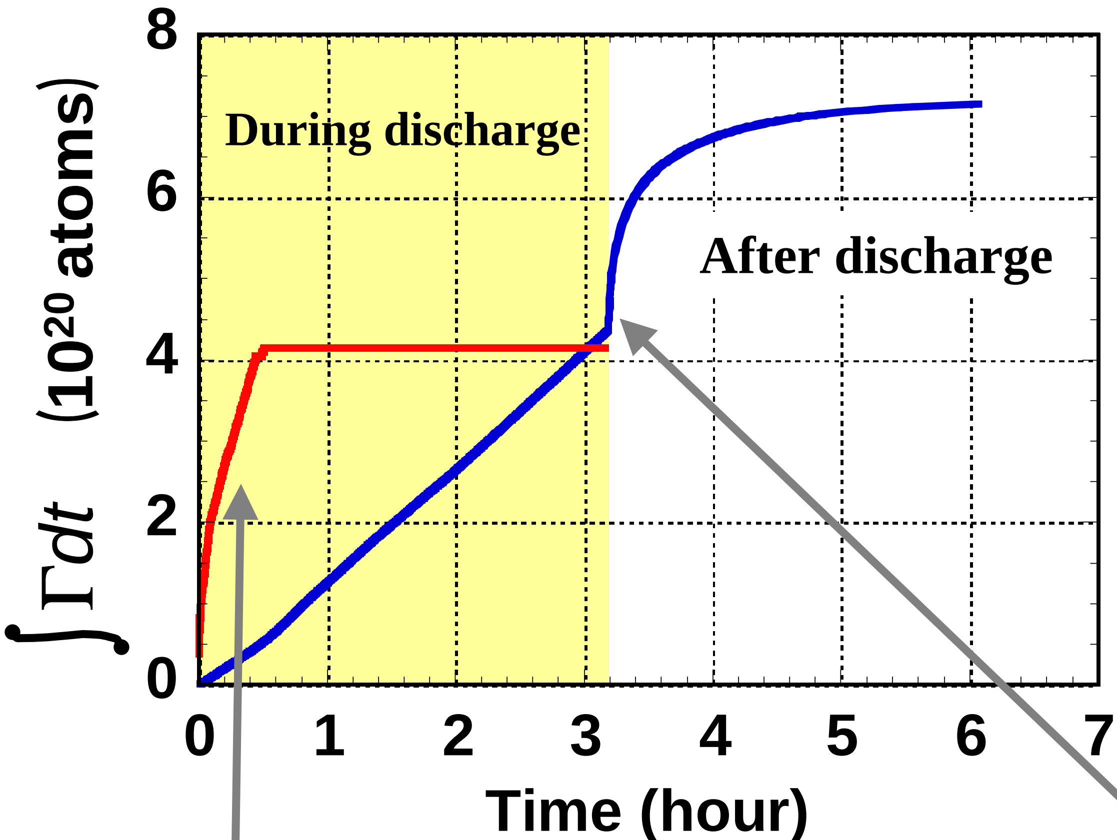
Hydrogen atoms pumped by the wall were released from the wall until the end of the discharge.

$T_{limiter}$: < 5min

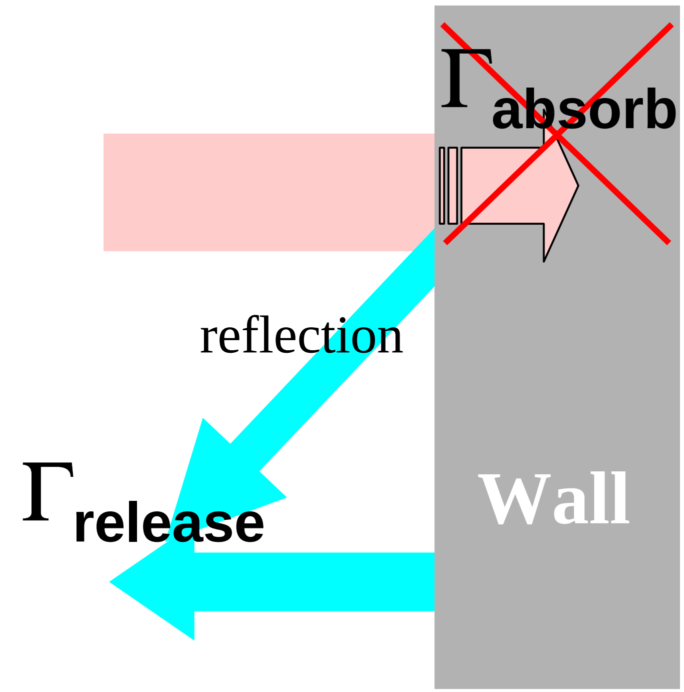
$T_{chamber}$: 30~60 min



Estimation of absorption rate from the comparison between before and after the plasma termination



Just after the plasma termination



Γ_{wall} ~

2.4 x 10^{16} atoms m^{-2} s^{-1}

Preliminary

$$\Gamma_{absorb} = \Gamma_{wall}^{before} - \Gamma_{wall}^{after}$$

order of >10^{18}

Summary

The study of the global particle balance has been carried out in the long discharge of the superconducting tokamak TRIAM-1M.

- The wall pumping rate depends on the particle fluxes, i.e. diffused flux and CX neutral flux (E<0.7keV).

- The wall recycling properties in the static and dynamic conditions are quite different. The wall pumping is enhanced by the additional gas puff. The difference of the effective particle confinement time between static and dynamic conditions is more than one order of magnitude.

  □τ_p^* : 1~10 sec in the static condition

  □τ_p^* : ~0.2 sec in the dynamic condition

- 3 hours discharges ware achieved. Around t~30min, the wall seems to be saturated from a viewpoint of global particle balance. One candidate is increase in hydrogen release from the main chamber due to the temperature increase.