Impact of nearly-saturated divertor plates on particle control in long and high-power-heated discharges in JT-60U

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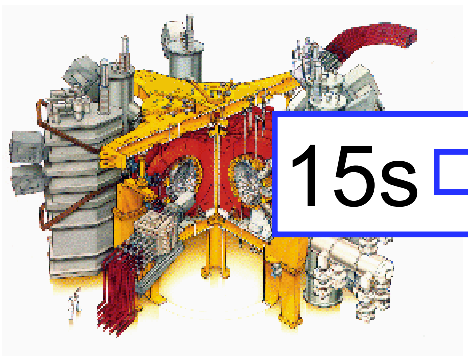
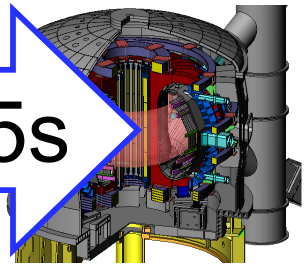
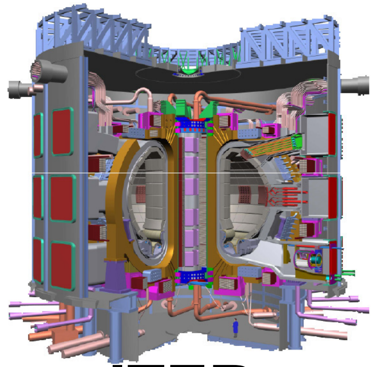
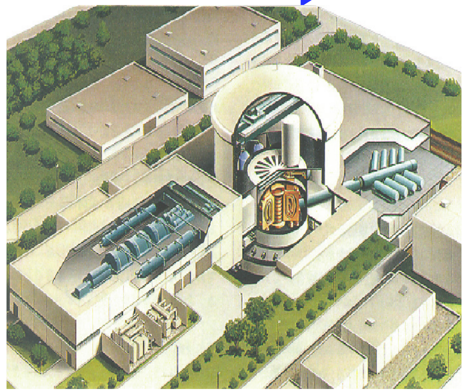
Background

□ □ Long pulse, steady-state operation









15s ⇒ 65s

JT-60	JT-60NCT	ITER	DEMO
Sec.	Min.	Min.~ Hour	Day - Year

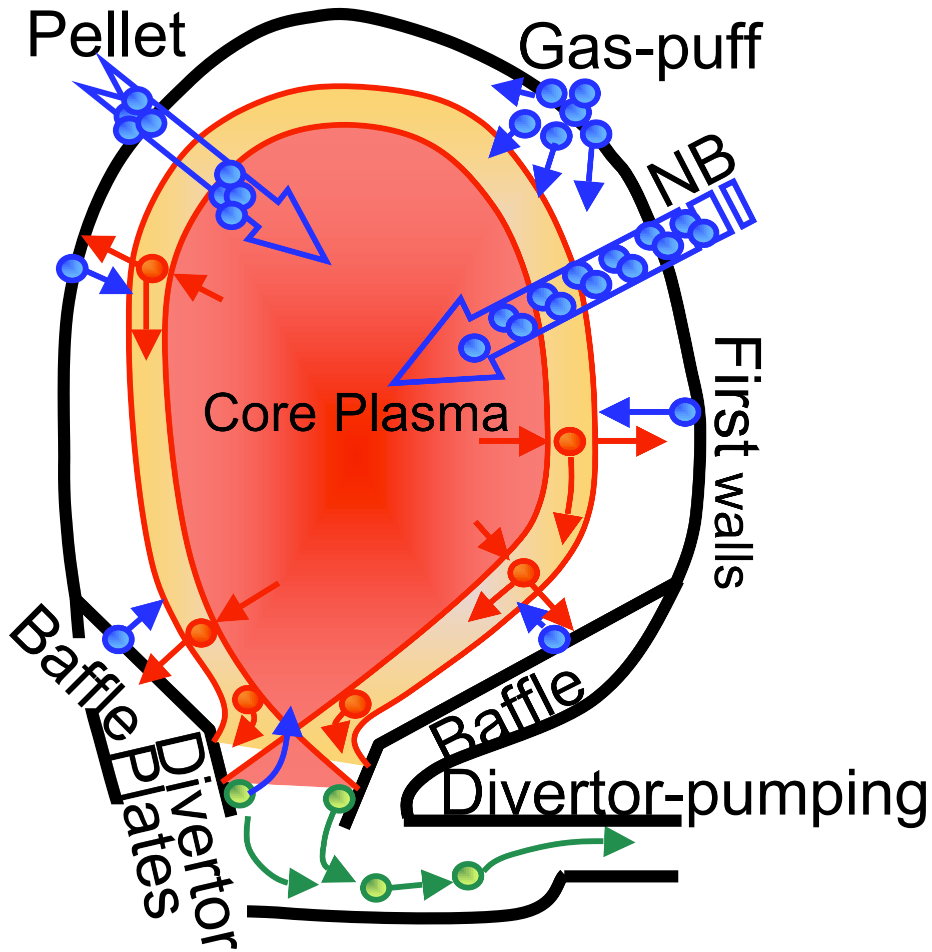
τ_{wall}

Conditioned
$R_{recycling}$ < 1

Unconditioned
$R_{recycling}$ ~ 1 or >1
(Wall saturation)

ISSUE: Experience and knowledge of operation with $R_{recycling}$ ~ 1

Introduction



Particle control;
For a constant density
Fueled = Pumped

Short pulse:
Divertor-pumping
+
Wall-pumping

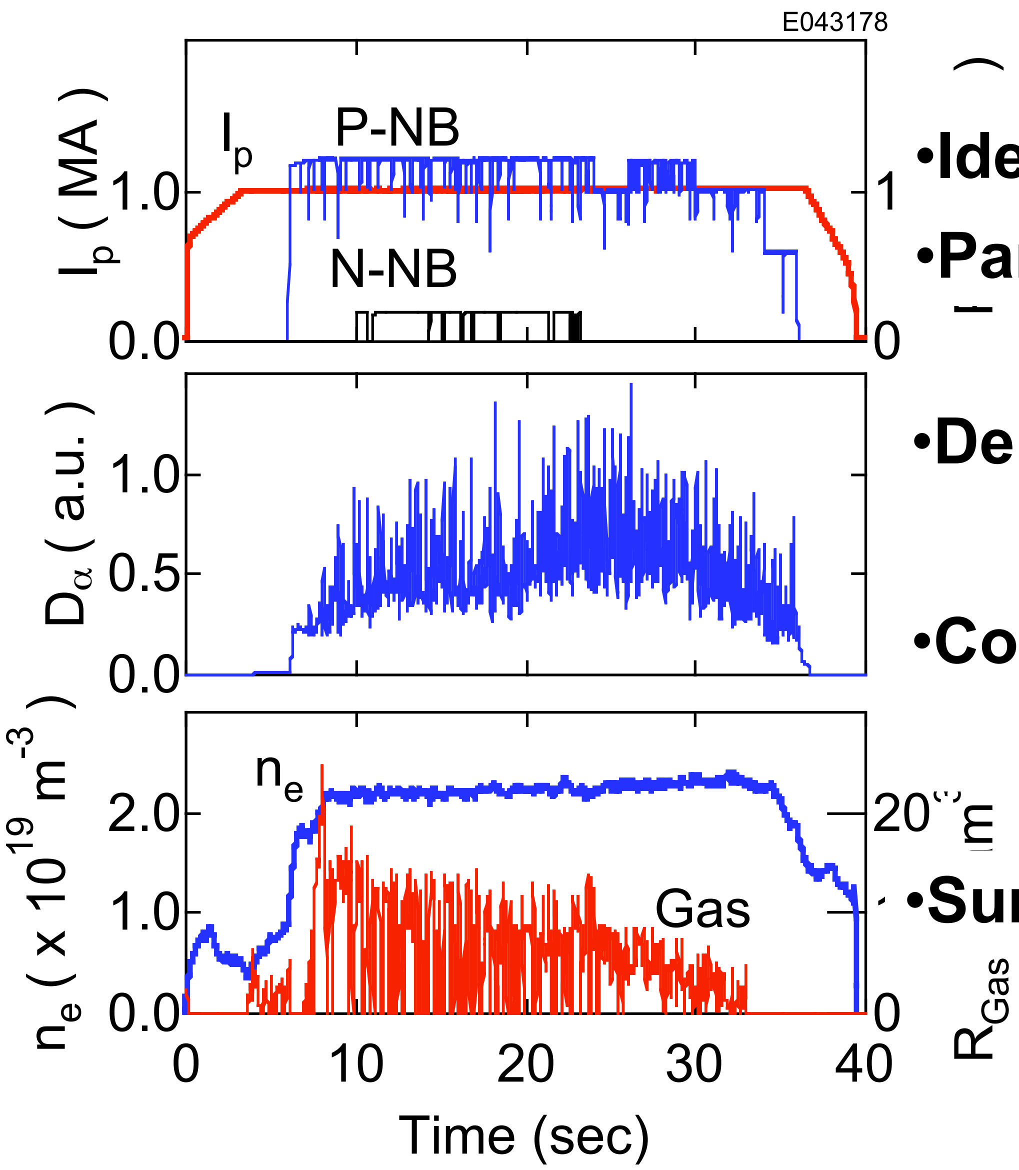
Long pulse:
Divertor-pumping
+
(Co-deposition?)

Long pulse in JT-60
P_{heat}~12 MW, 30s

⇨

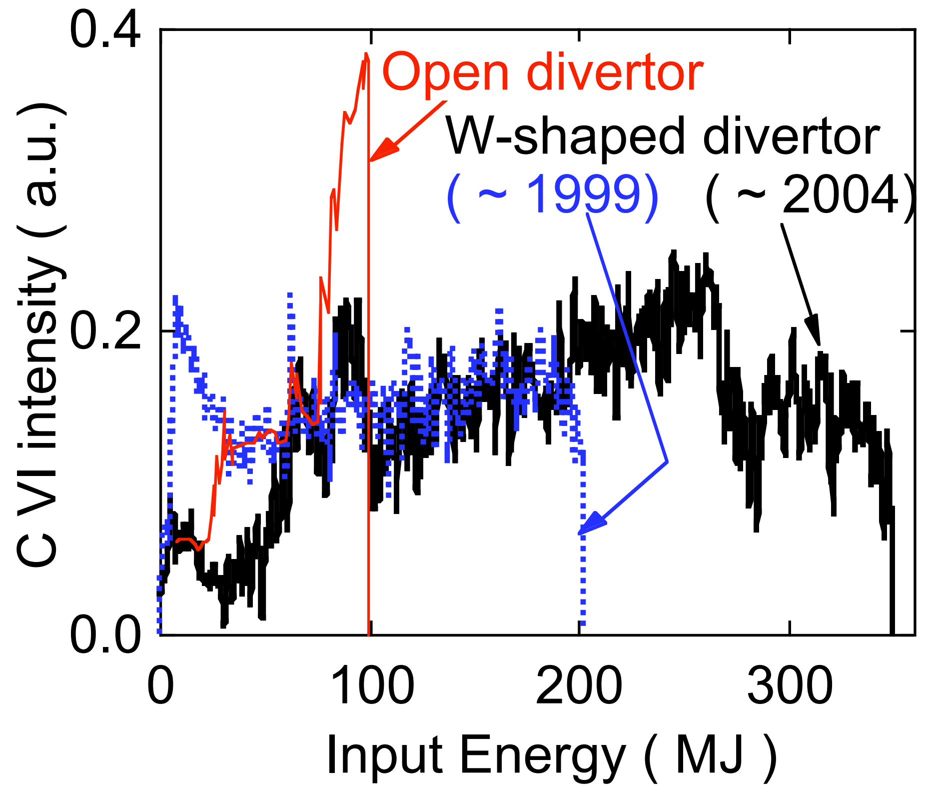
Particle control
Wall/Divertor saturated

Outline



- Identification of wall saturation
- Particle source
- Density controllability with at wall saturation
- Controllability of detachment (predictive simulation)
- Summary

No carbon bloom

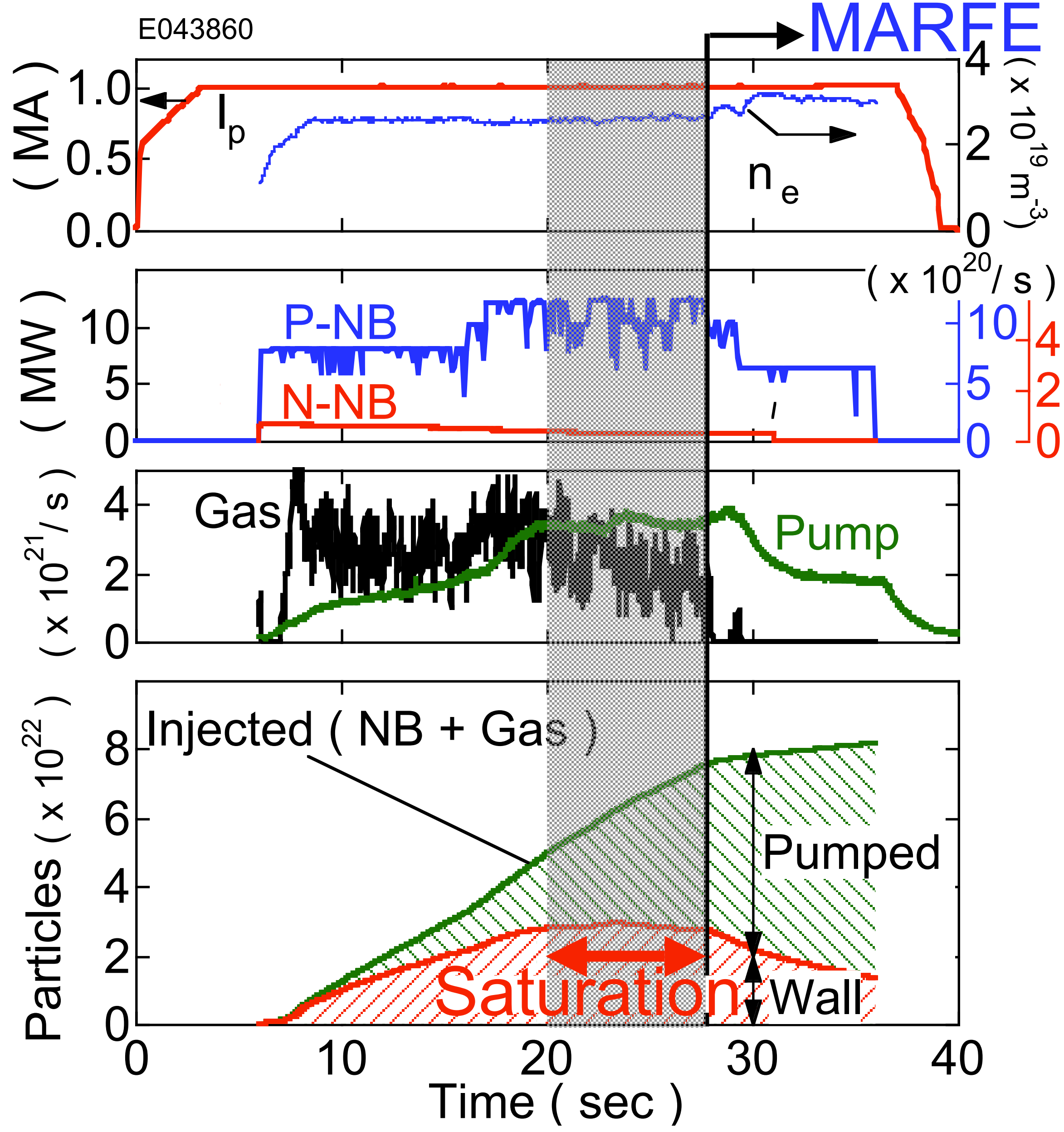


Energy Input : 350 MJ

Wall temperature : ~ 1300 K

Identification of Wall Saturation

Wall Saturation identified in long pulse operation



Quasi-steady-state,

$V_p\, dn_p/dt \sim 0,$

$V_n\, dnD_0/dt \sim 0,$

$R_{wall} = R_{P\text{-}NB} + R_{N\text{-}NB} + R_{Gas} - R_{pump}$

t = 20 - 27s,

constant wall retention

⇒ Wall saturation

⇒ ELMy H-mode

⇒ Z_{eff} ~3, H_{89PL} ~1.7

Then,

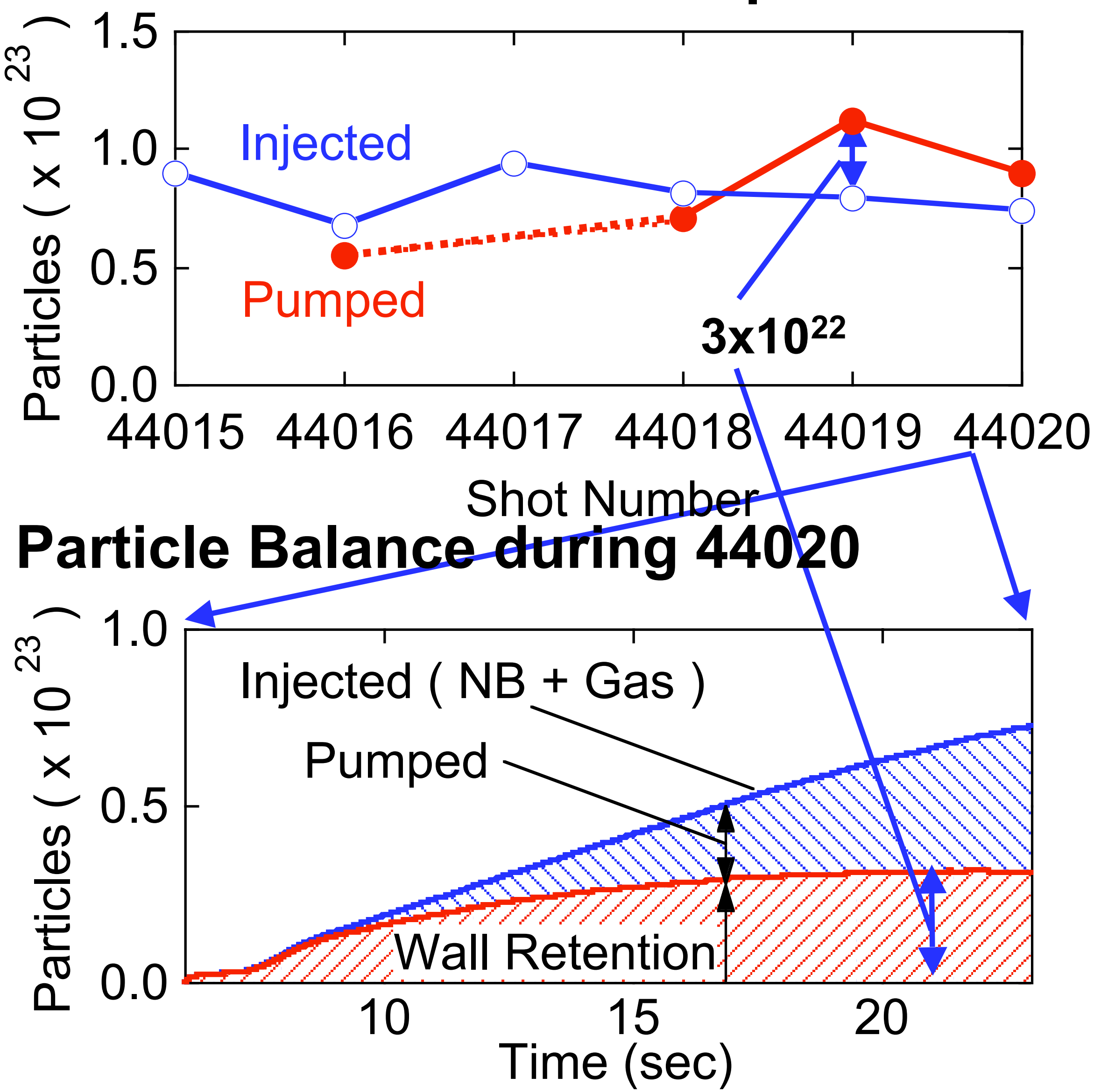
⇒ MARFE (detach)

Saturation Area, Wider than Divertor plates

JT-60U

Particle Balance between pulses

Particle Balance during 44020



- **Until 44018,** **Wall retention increases**
- **Wall saturation**
- **After 44019,** **3×10^{22} are released.**

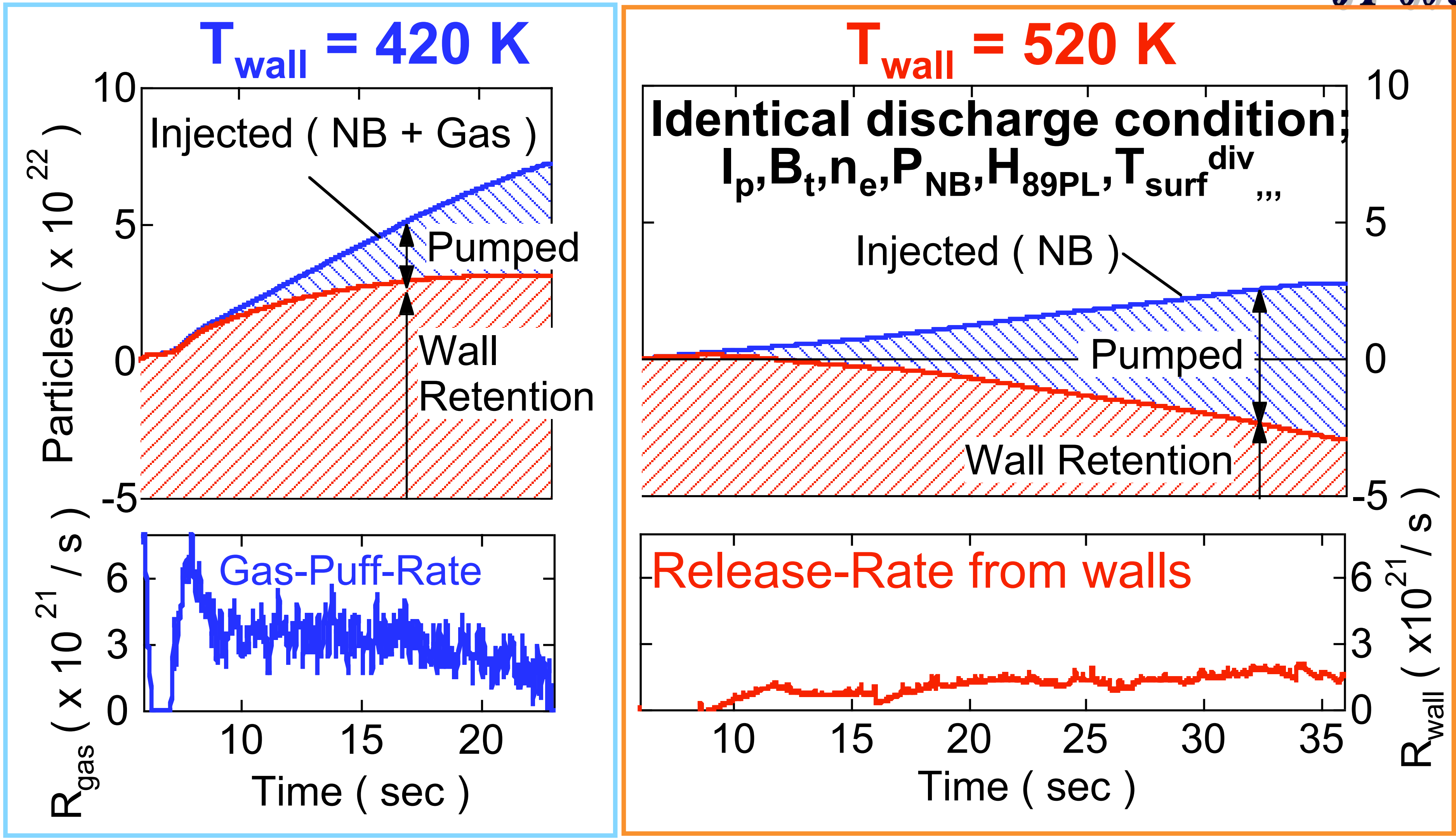
- **During 44020,** **3×10^{22} retained in walls.**

⇒Active wall-pumping capacity ~ 3×10^{22}

Saturation level of
D^+ to C tile at 300eV
$= 1\times10^{21} m^{-2}$

Saturation area (Minimum)
$= 3\times10^{22} / 1\times10^{21} m^{-2}$
$= 30\ m^2$
> Divertor plates (20 m^2)

Significant Particle Release at T_{wall} = 520 K



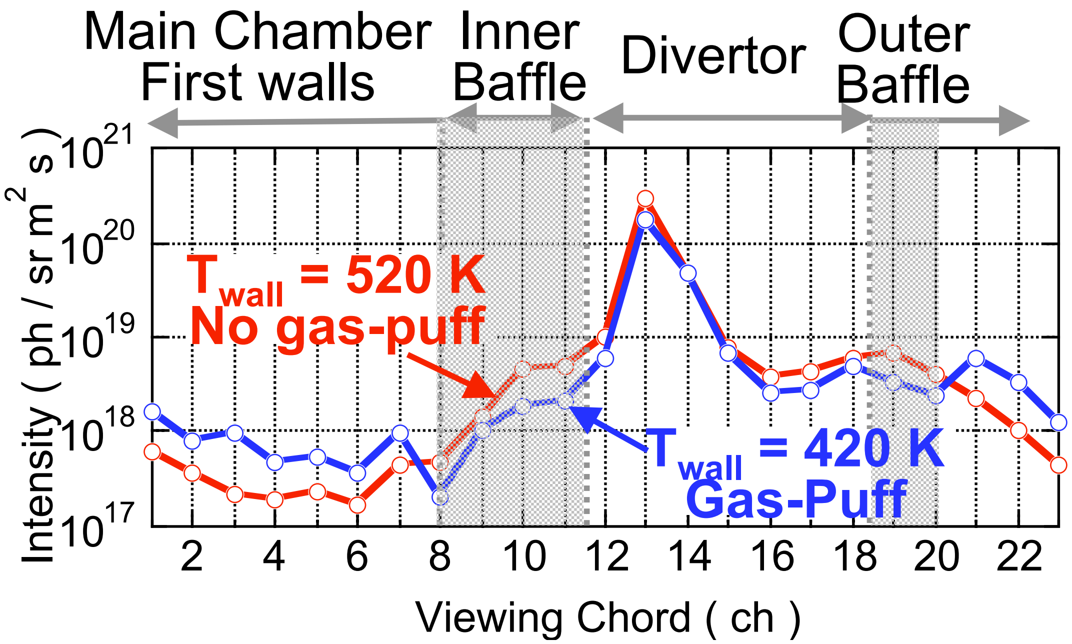
The only difference : first-wall-temperature

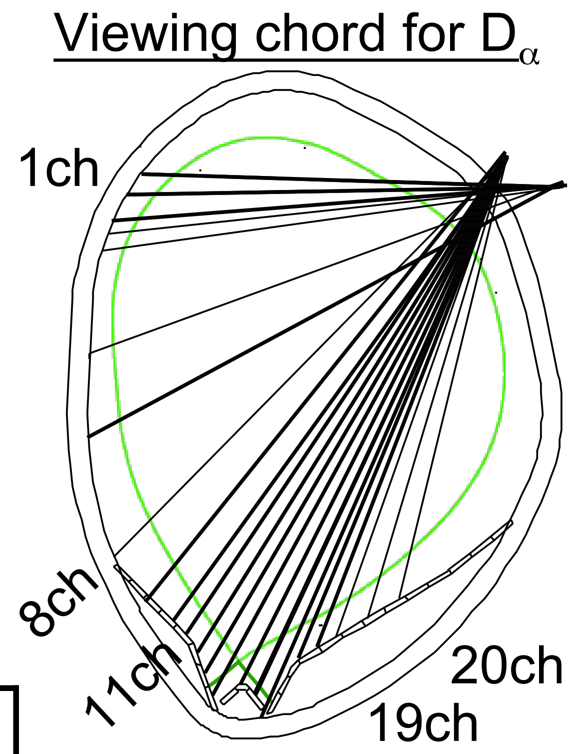
⇒ Suggests particle release from first wall / Baffle plates

Source of particles, Baffle Plates

JT-60U

D_α Brightness

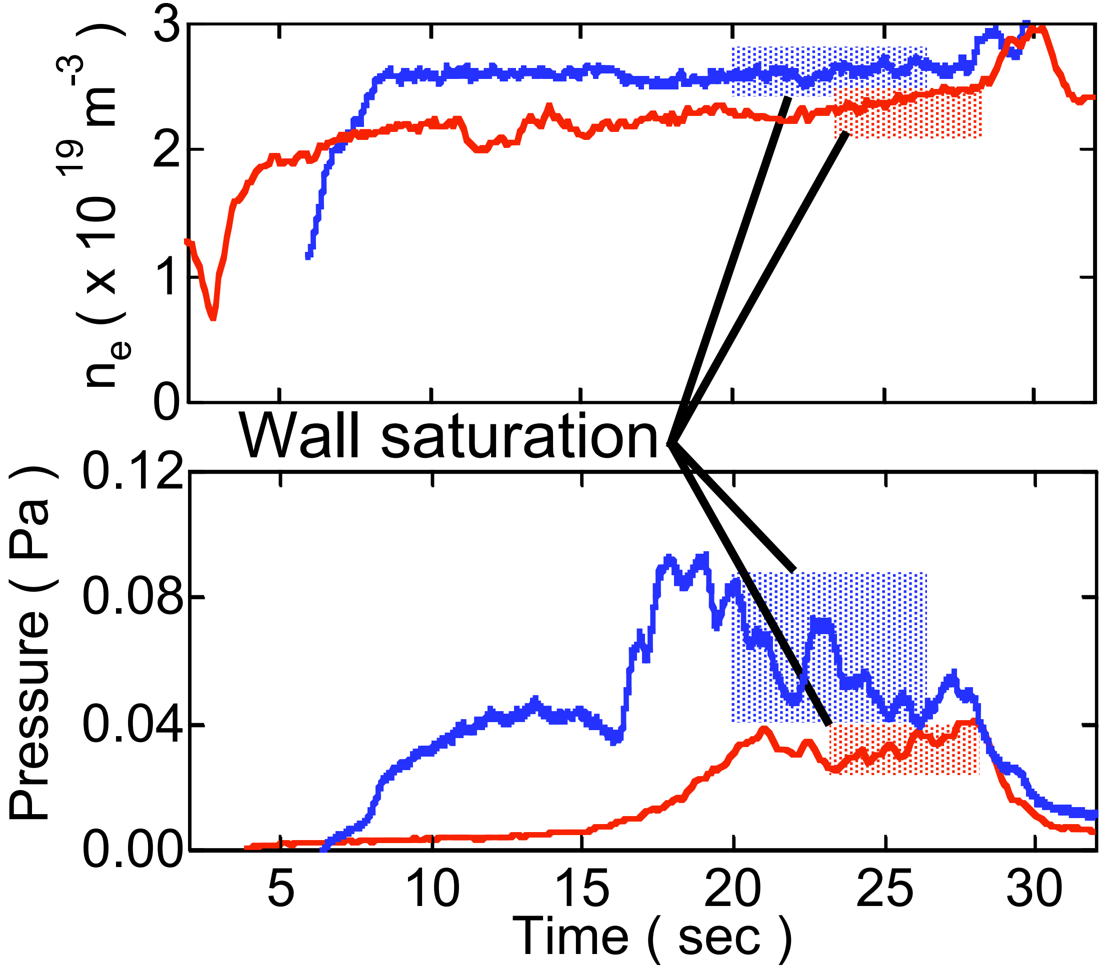


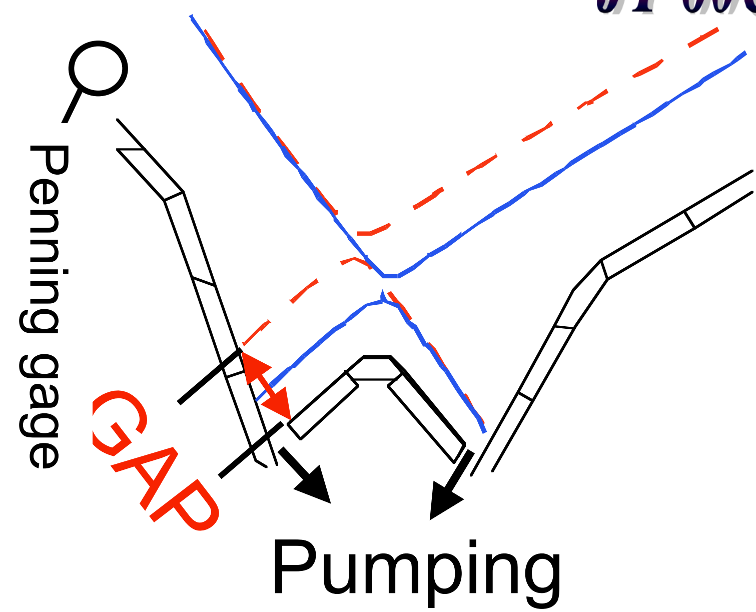


	T_{wall}= 420 K	T_{wall}= 520 K
Divertor	similar	
First wall	>	
Baffle	<	

Density controllability by Active divertor-pumping at wall saturation

Density controllability of divertor-pumping





GAP	9.5 cm	4.5 cm
ΔP_0	+	~ 0, -
Δn_e	>	

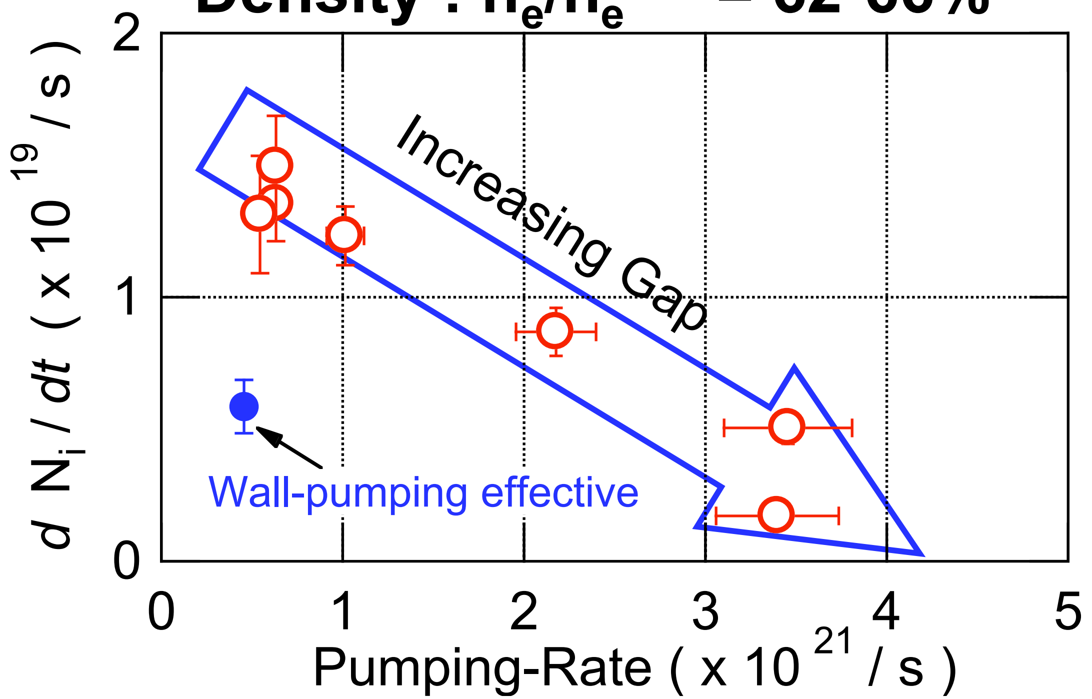
Suggests;

Large GAP ⇨ Increase of P_0 ⇨ Increase of n_e

High pumping-rate suppresses increase of plasma particles

Condition : wall saturation

Density : n_e/n_e^{GW} = 62-66%

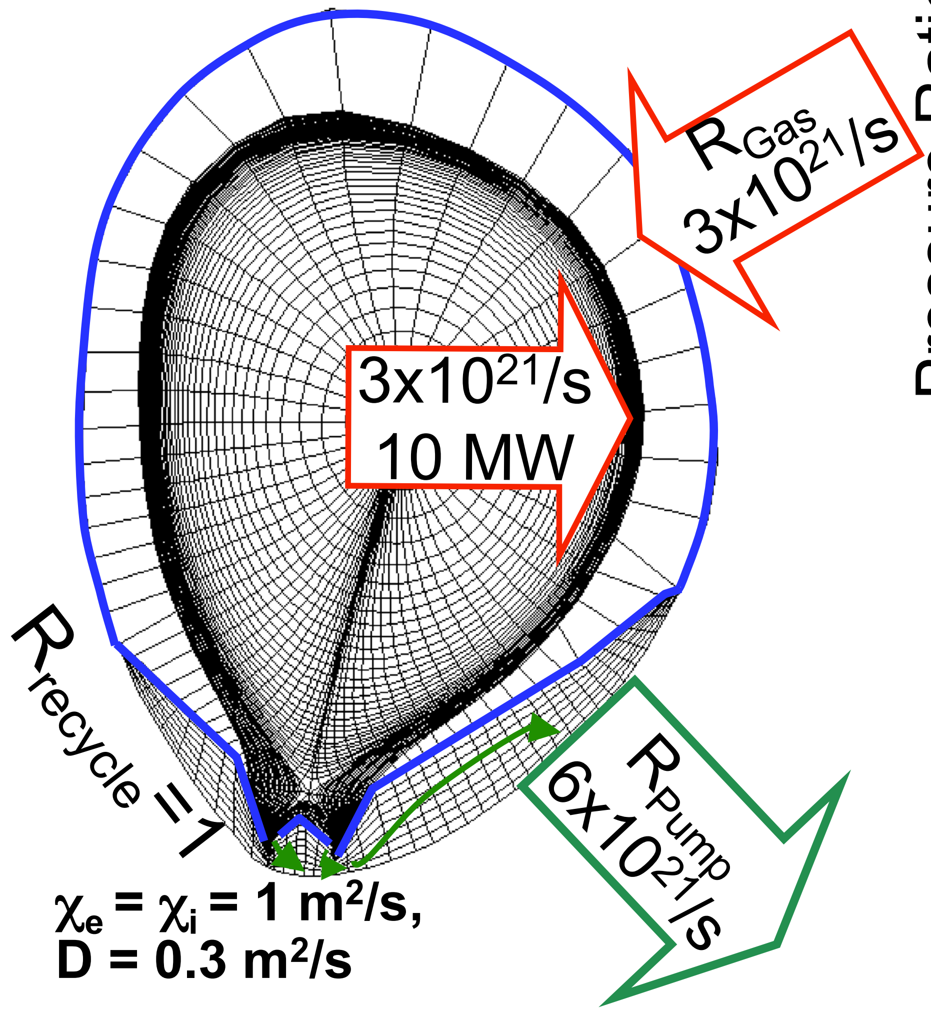


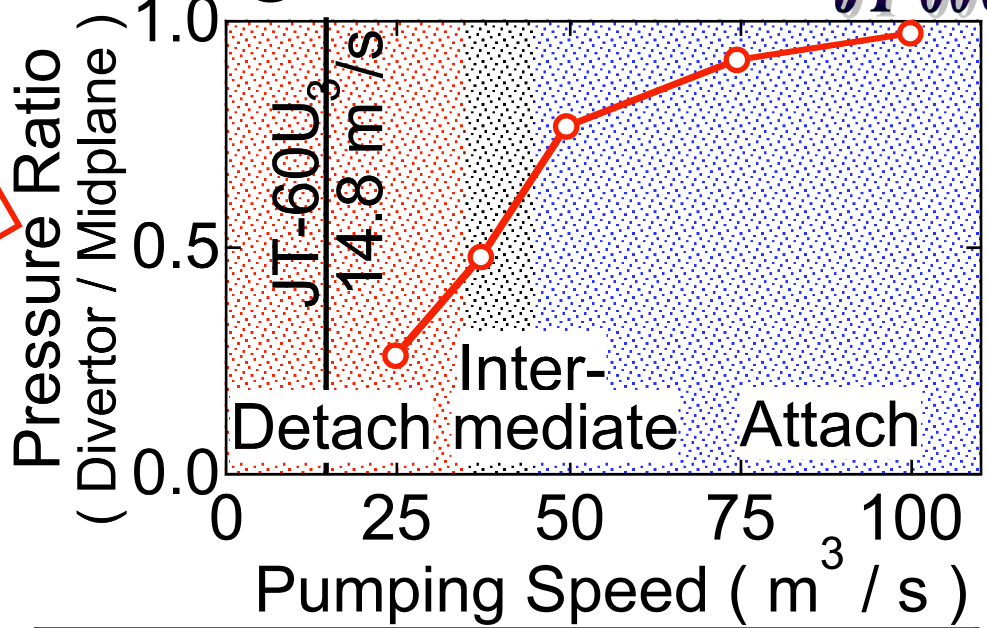
Difficult to prevent undesirable density rise of high δ plasmas (Large GAP)

⇒ Limited period of high β_n; ex. 22.3 s for β_n = 2.2

Higher pumping-rate is required even for low δ plasmas (Small GAP)

Controllability of detachment by divertor-puming at R = 1





Pumping speed	$25 m^3/s$	$50 m^3/s$
P_0^{OutDiv}	2.0 Pa	1.2 Pa
n_e^{OutDiv}	$4 \times 10^{20} m^{-3}$	$2 \times 10^{20} m^{-3}$
T_e^{OutDiv}	0.8 eV	9.7 eV

Indicates higher pumping speed by a factor of 2 - 3 can avoid MARFE at the end of long pulse discharges.

Summary

- ELMy H-mode plasma (~ 12MW, ~ 30 s, 350 MJ)
- No carbon bloom
- Wall saturation was identified
  (Minor role of co-deposition)
  divertor plates
  walls/baffle plates <= important particle source
- No sudden changes of plasma
- Increase of plasma density => detachment
- Higher divertor-pumping efficiency required
  to avoid MARFE