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

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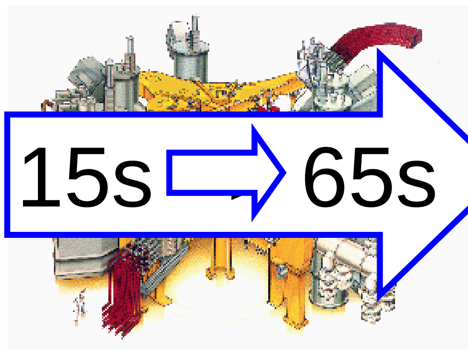
Background

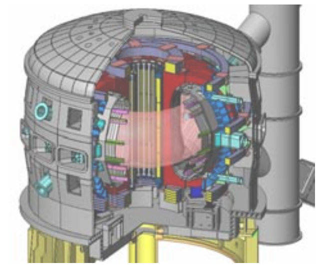
Long pulse, steady-state operation



15s → 65s

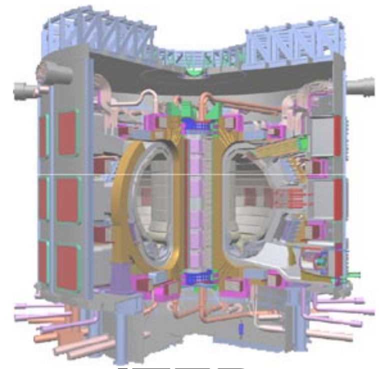
JT-60

Sec.



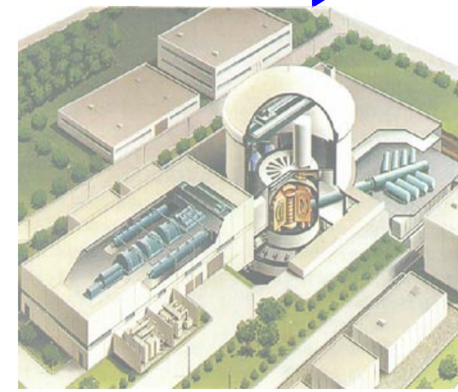
JT-60NCT

Min.



ITER

Min.~ Hour



DEMO

Day - Year

τ_{wall}

Conditioned

$R_{recycling}$ < 1

Unconditioned

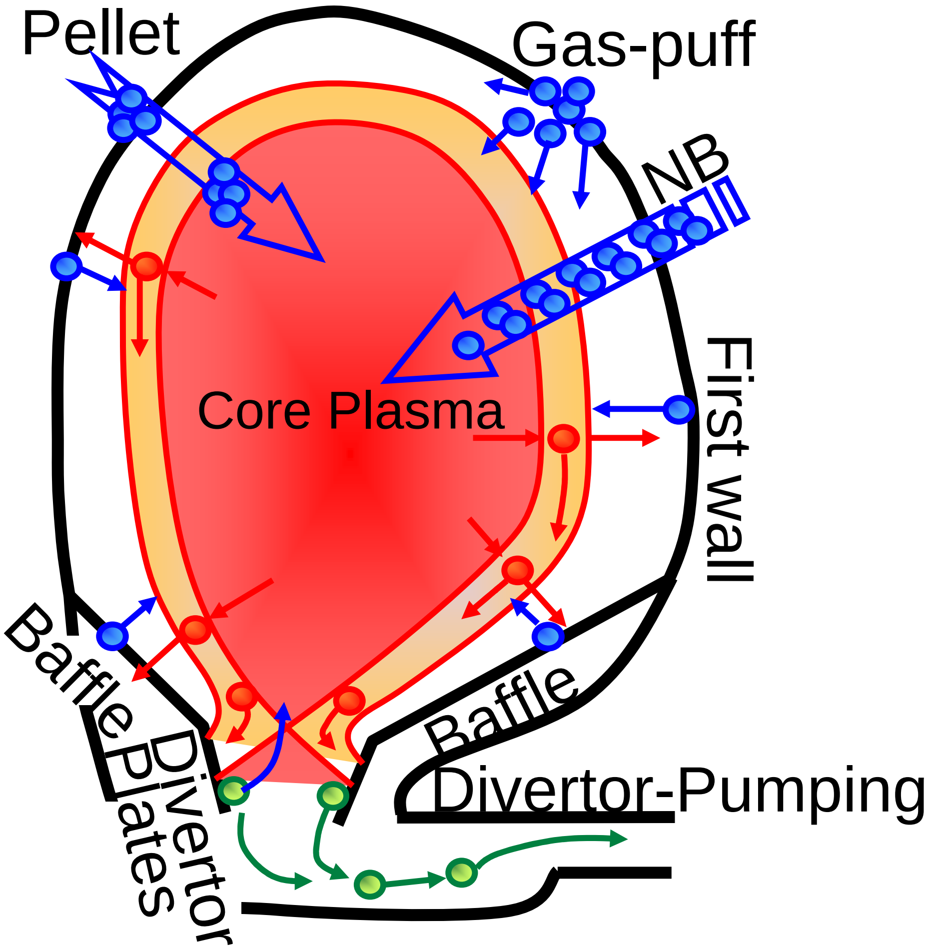
$R_{recycling}$ ~ 1 or >1

(Wall saturation)

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

Introduction

JT-60U



Particle control;

For a constant density

Fueled = Pumped

Short pulse:

Divertor-pumping

+

Wall-pumping

Long pulse:

Divertor-pumping

+

(Co-deposition?)

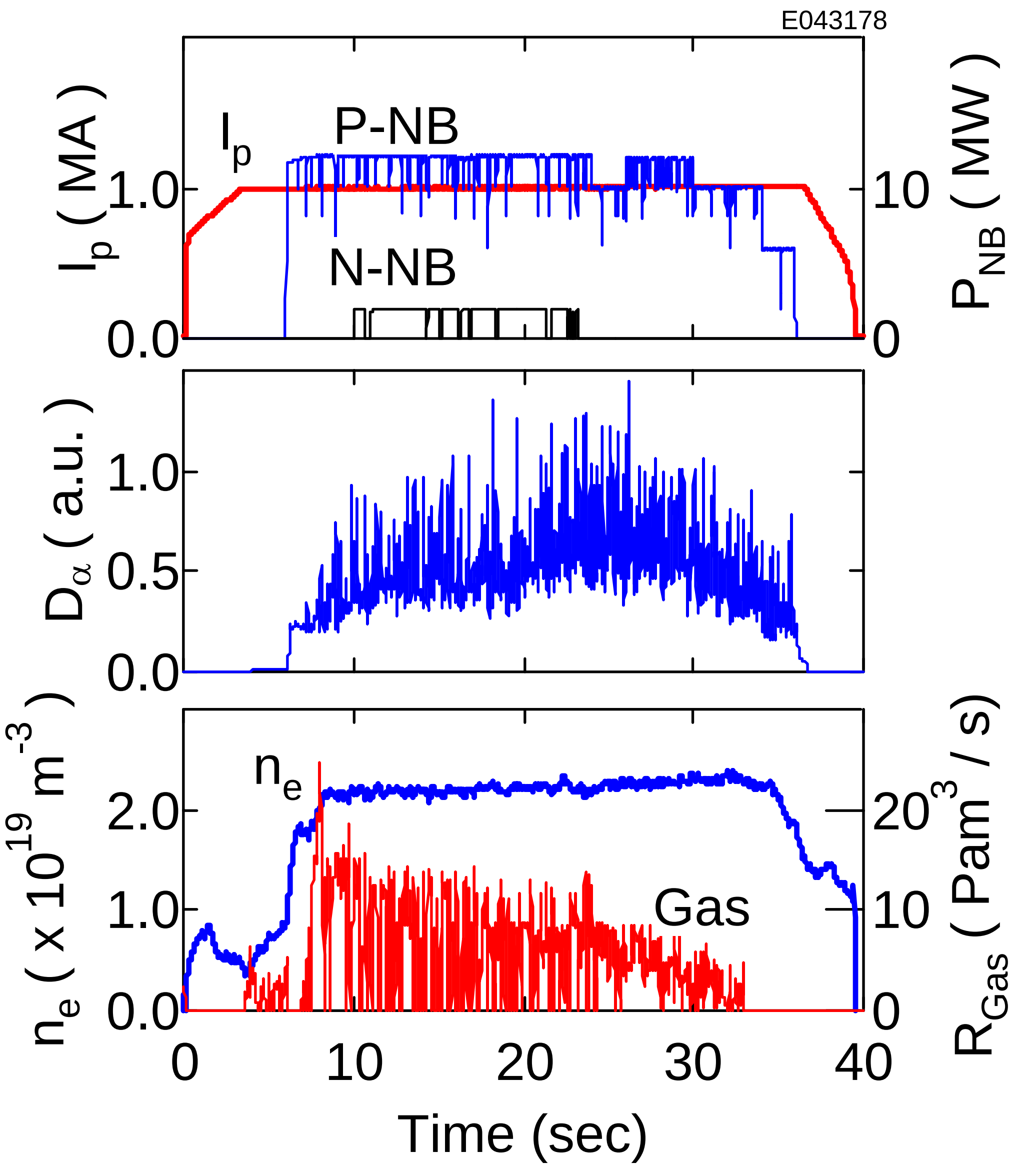
Long pulse in JT-60

P_{heat}~12 MW, 30s

⇨

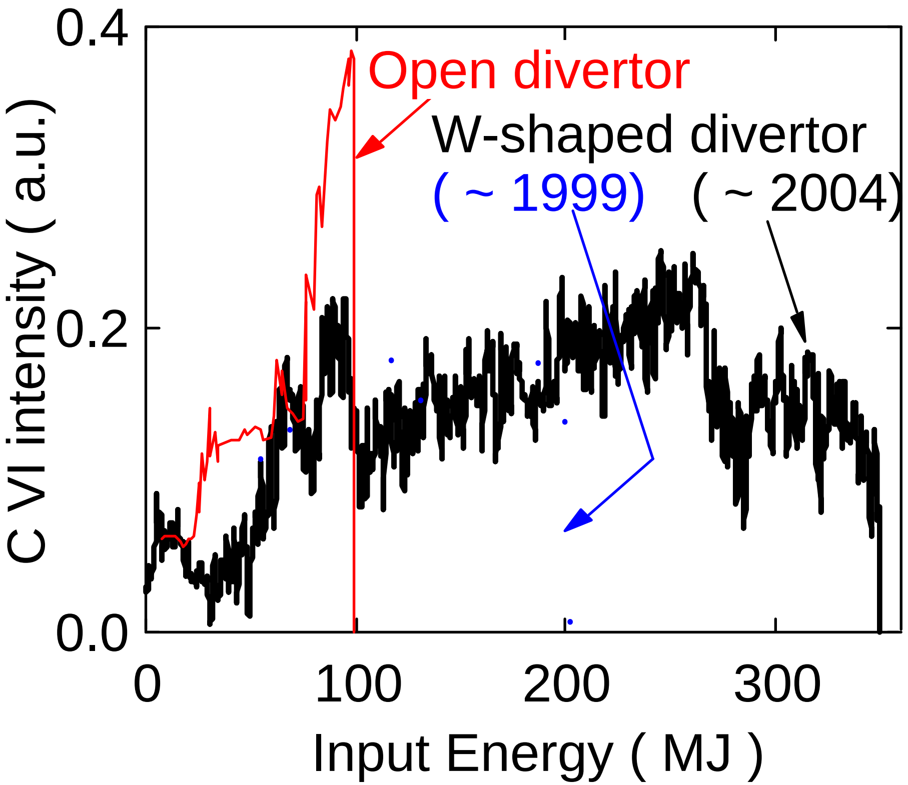
Particle control at wall saturated

Outline



- **Identification of wall saturation**
- **Density controllability at wall saturation**
- **Summary**

No “carbon bloom”

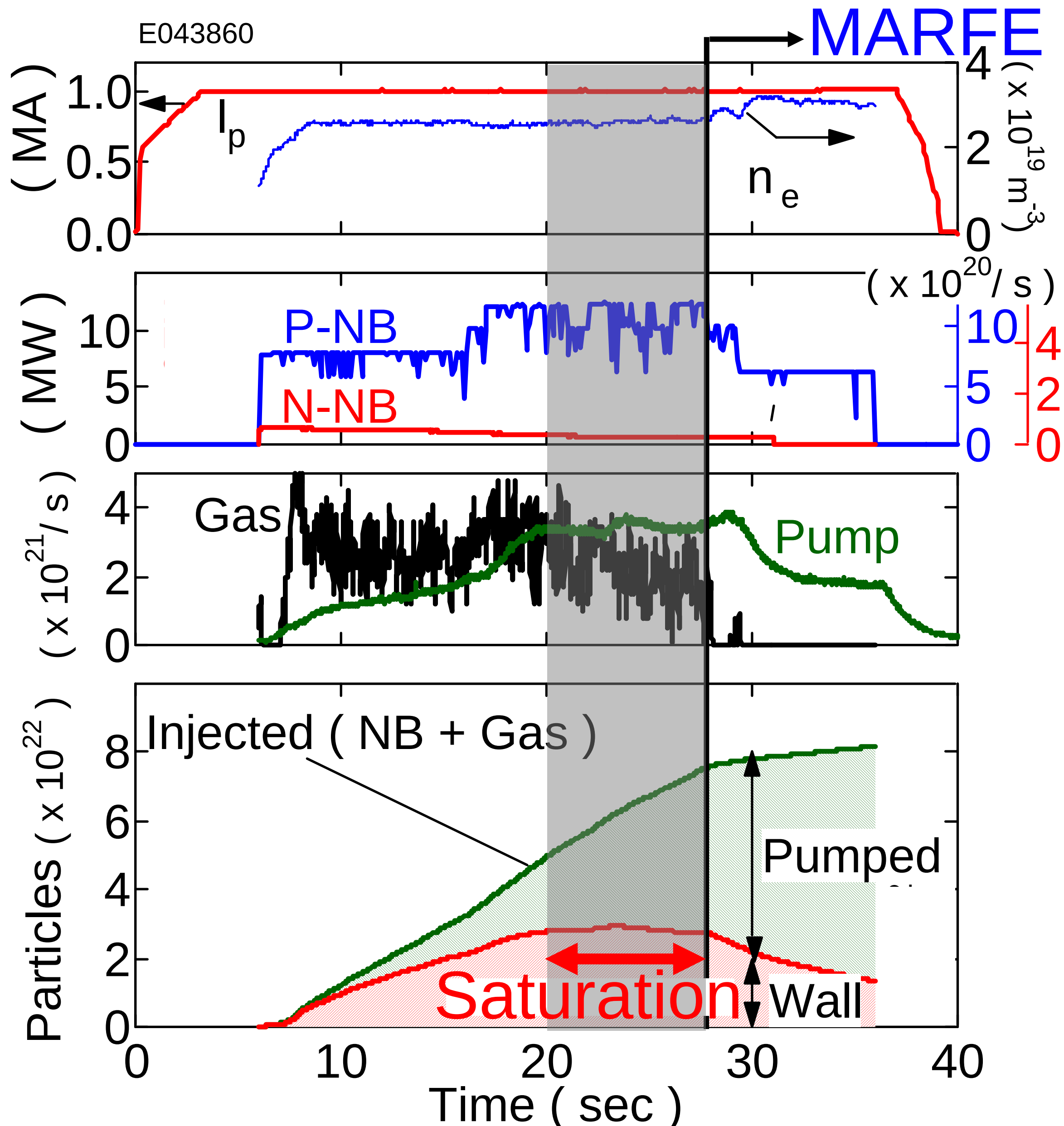


Energy Input : 350 MJ

Div. surface temperature : ~ 1300 K

Identification of Wall Saturation

Wall Saturation identified in long pulse operation



Quasi-steady-state,

$V_p\, d\mathbf{n_p}/dt \sim 0,$

$V_n\, dn\mathbf{D_0}/dt \sim 0,$

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

t = 20 - 27s,

constant wall retention

⇒ Wall saturation

⇒ ELMy H-mode

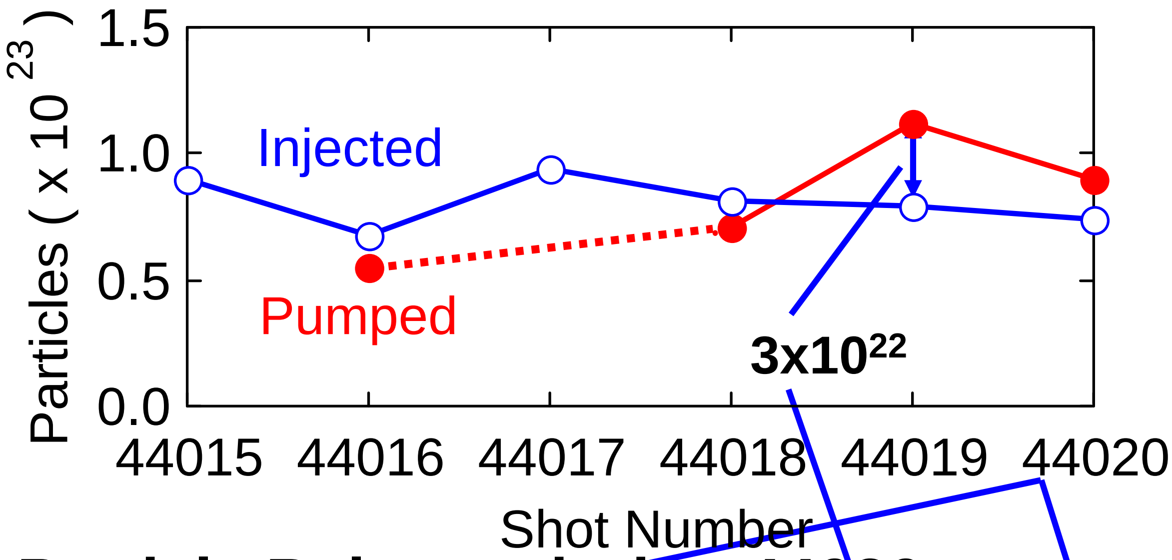
⇒ Z_{eff}~3,H_{89PL}~1.7

Then,

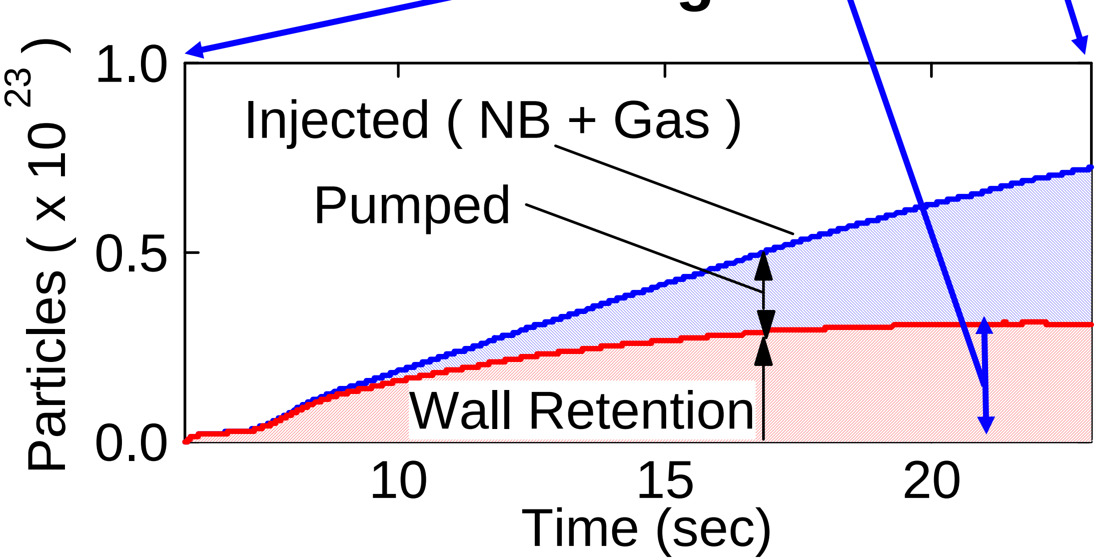
⇒ MARFE (detach)

Saturation Area, Wider than Divertor plates

Particle Balance between pulses



Particle Balance during 44020



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

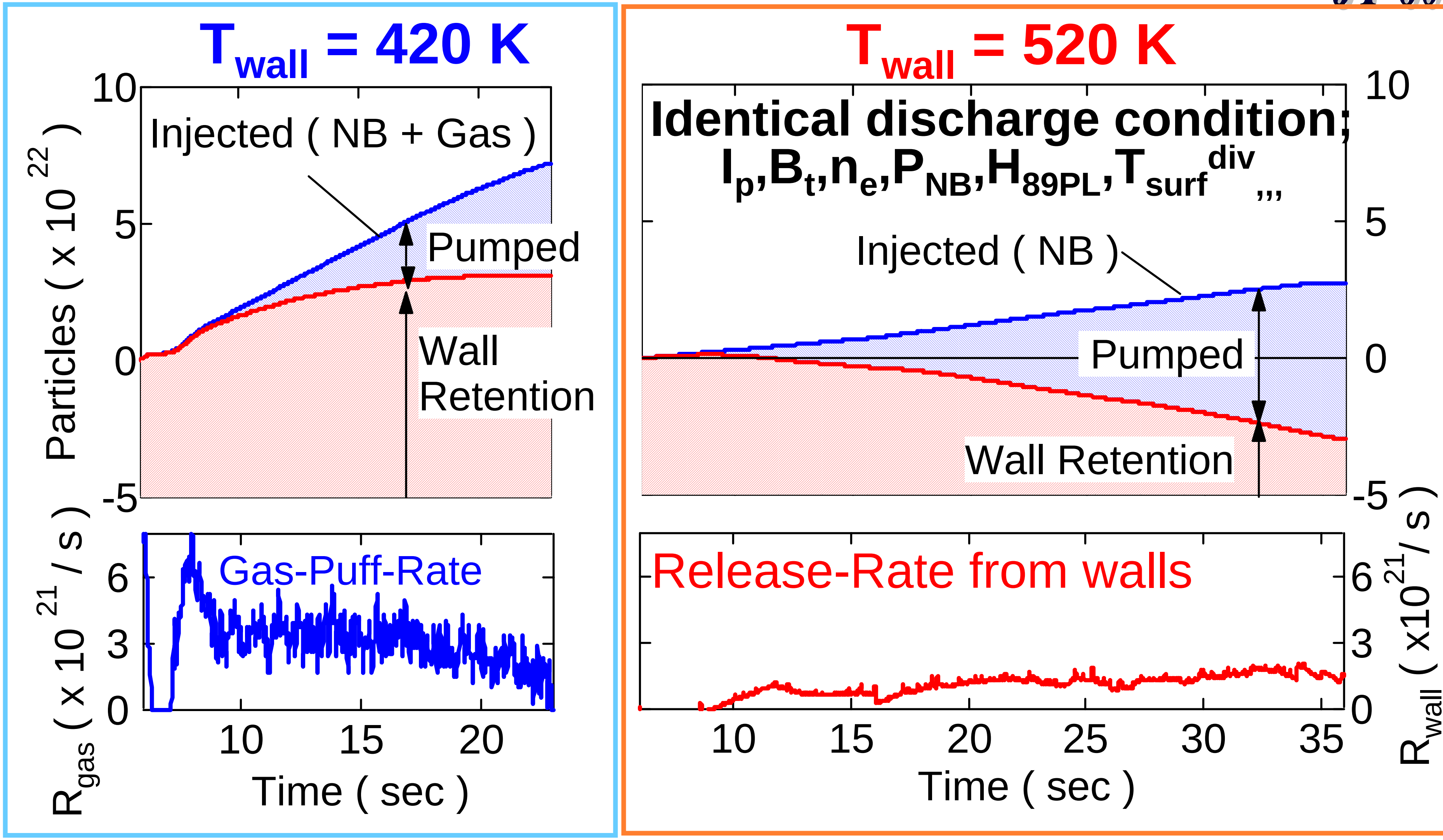
- **During 44020,**
  3×10^{22} retained in walls.

⇒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



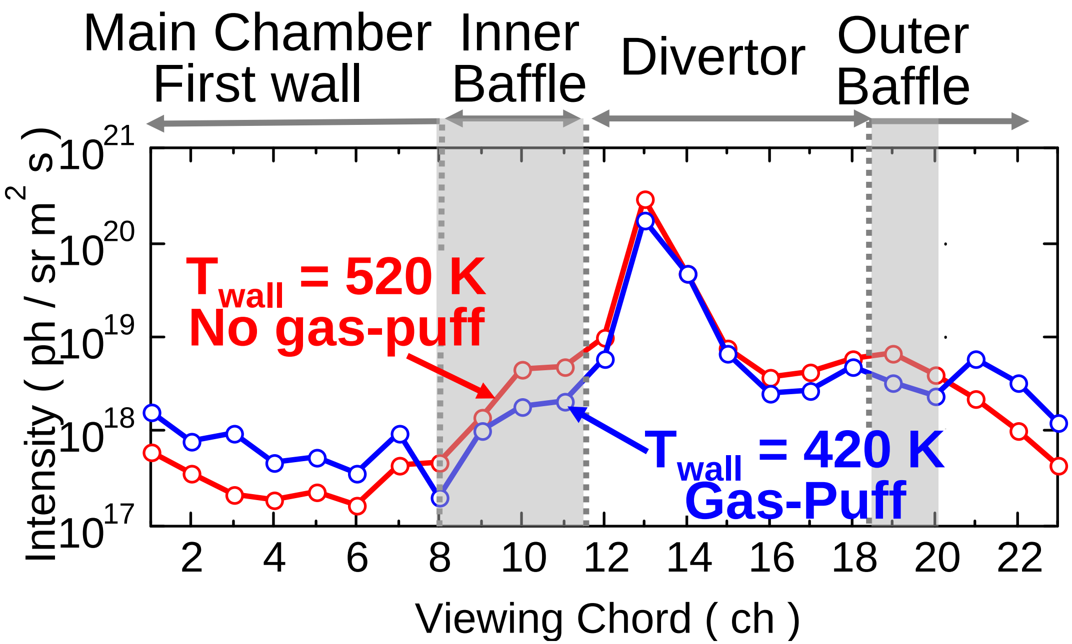
The only difference : first-wall-temperature

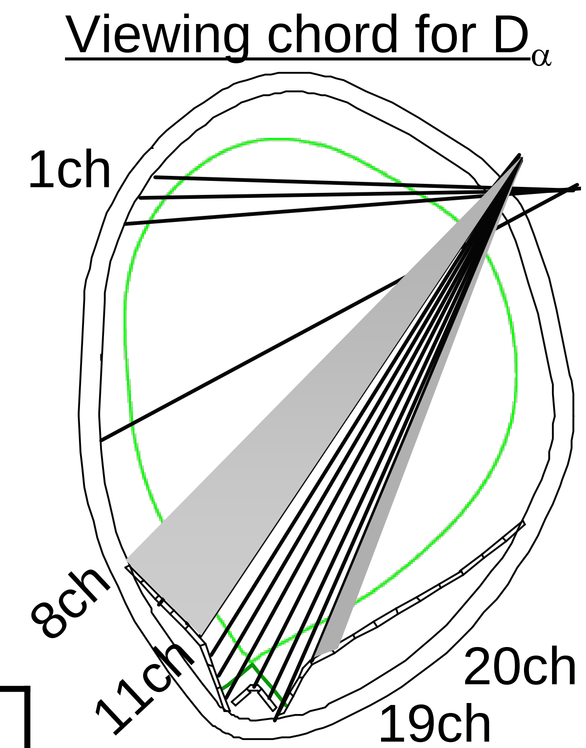
⇒ Suggests particle release from first wall / Baffle plates

Source of particles, Baffle Plates

JT-60U

D_α Brightness



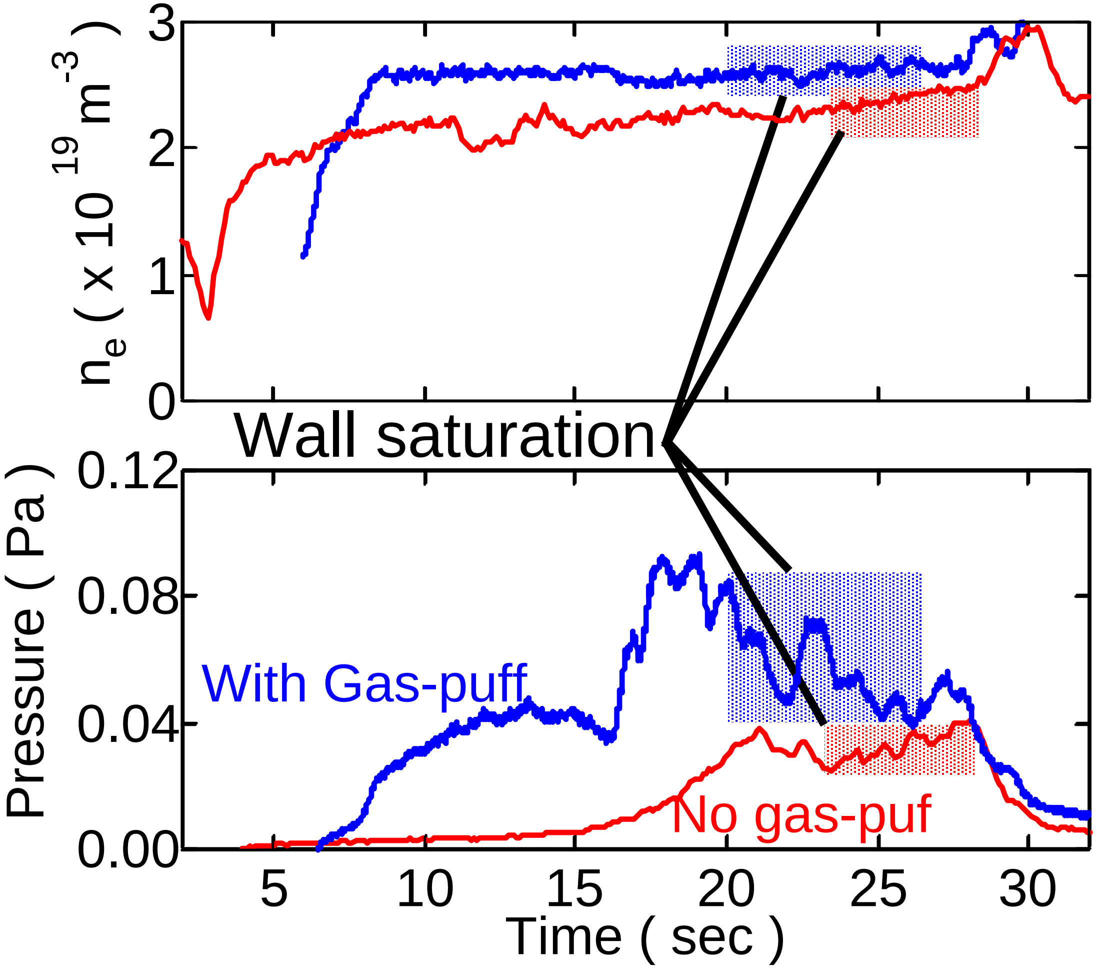


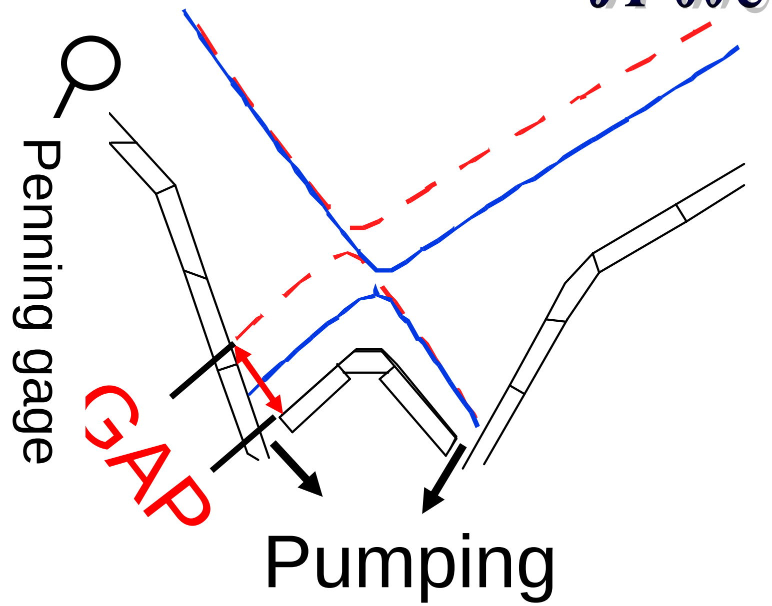
	T_{wall}= 420 K	T_{wall}= 520 K
Divertor	**similar**	
First wall	**>**	
Baffle	**<**	

Density Controllability by Active Divertor-Pumping at Wall Saturation

Density controllability of divertor-pumping

JT-60U





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

Suggests;

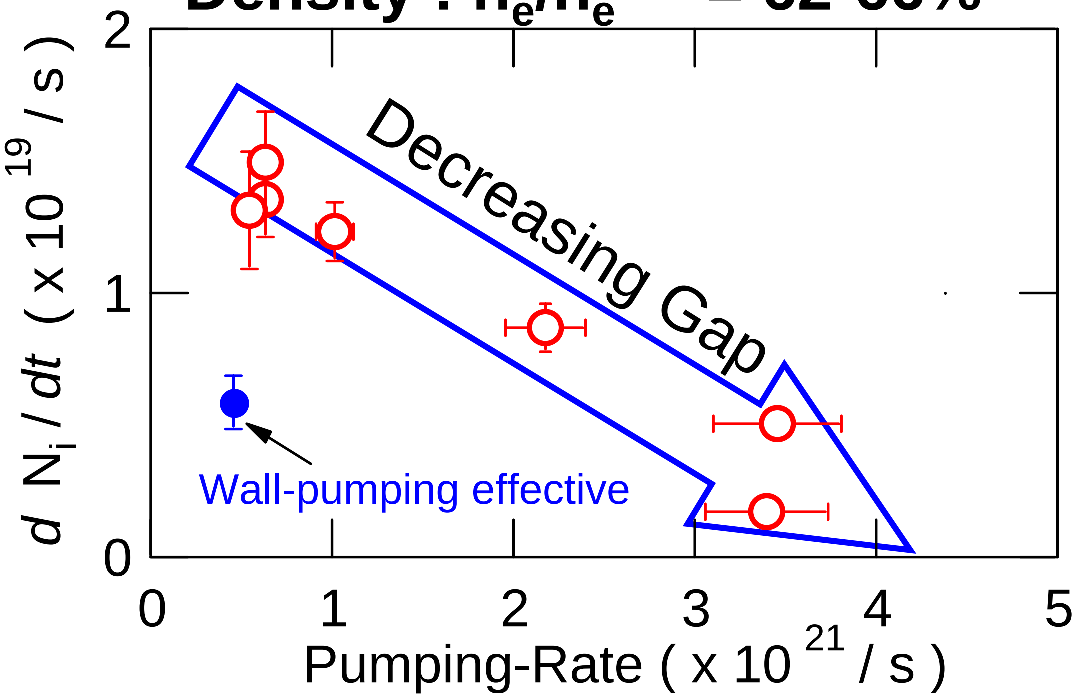
Large GAP ⇨ Increase of P_0 ⇨ Increase of n_e

High pumping-rate suppresses increase of plasma particles

JT-60U

Condition : wall saturation

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



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

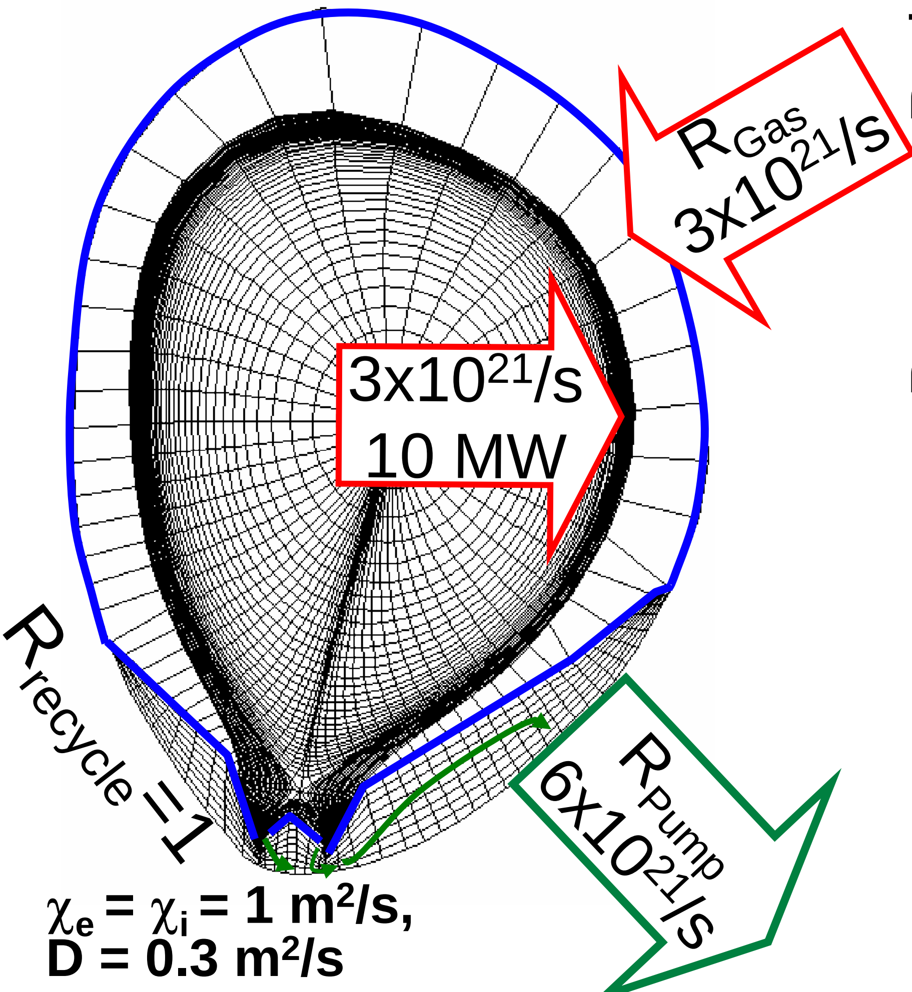
⇒ Limited period of high β_N; ex. 22.3 s for β_N = 2.3

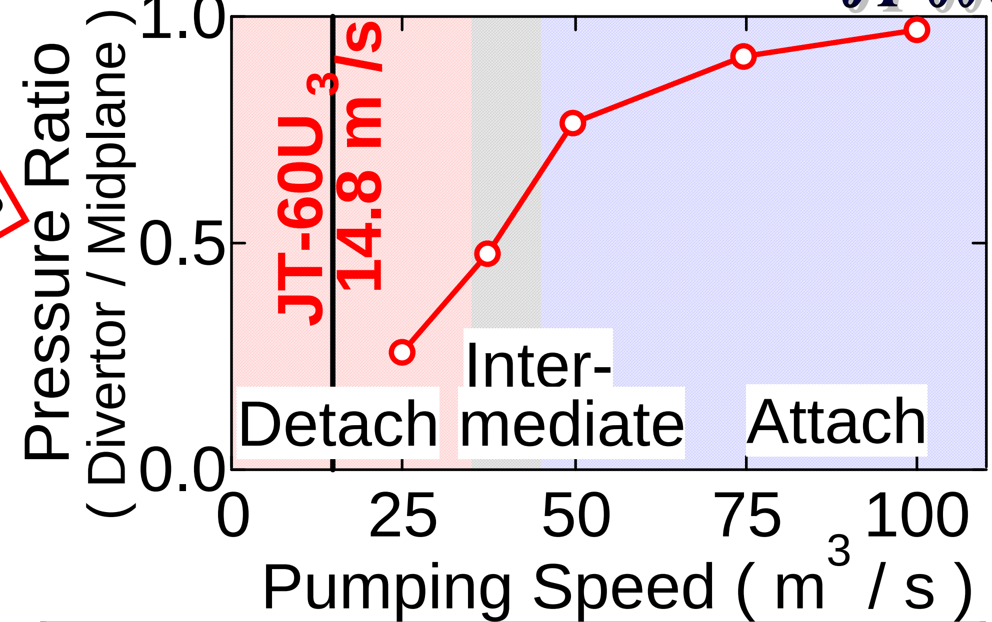
Higher pumping-rate is required even for low δ plasmas (Small GAP)

Controllability of detachment by divertor-puming at R = 1

JT-60U

SOLDOR simulation





Pumping speed	$25 m^3/s$	$50 m^3/s$
P_0^{OutDiv}	2.0 Pa	1.2 Pa
n_e^{OutDiv}	$4x10^{20} m^{-3}$	$2x10^{20} m^{-3}$
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

JT-60U

- Modification for Long Pulse Operation, 15 sec => 65 sec
  NB 10 sec => 30 sec
- ELMy H-mode plasma
  (~30 s ,~ 12 MW, 350 MJ, No “carbon bloom”)
- Wall saturation was identified
  (Minor role of co-deposition)
  Divertor plates
  Wall/baffle plates ⇐ important particle source at $R_{recy} > 1$
- No sudden changes of plasma (Z_{eff}, H_{89PL})
- Undesirable increase of plasma density
  ⇒ Confinement Degradation, MARFE
- Higher divertor-pumping efficiency (x 2 - 3)
  required to avoid MARFE