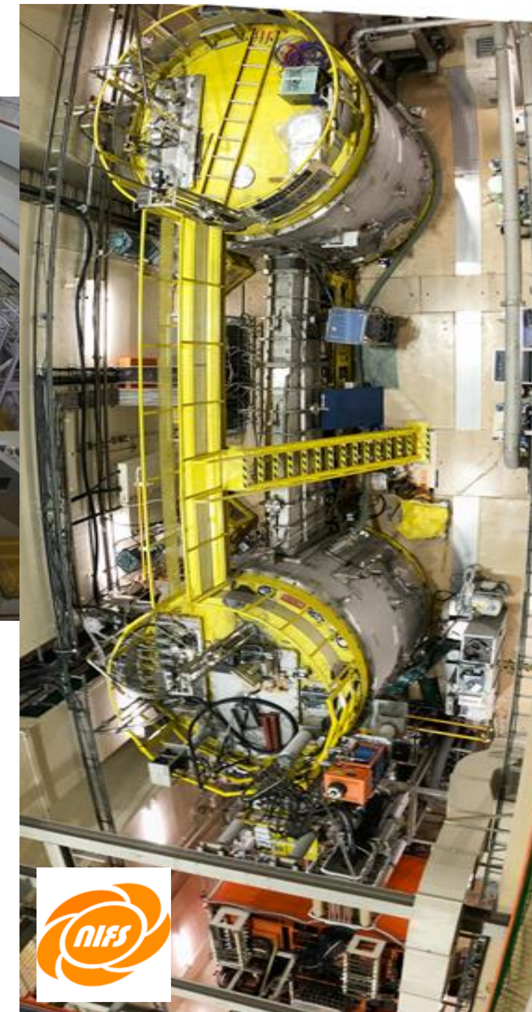
#1175 : 100 seconds negative ion accelerations for JT-60SA negative-ion based NBI

M. Kashiwagi and QST NB group, Japan

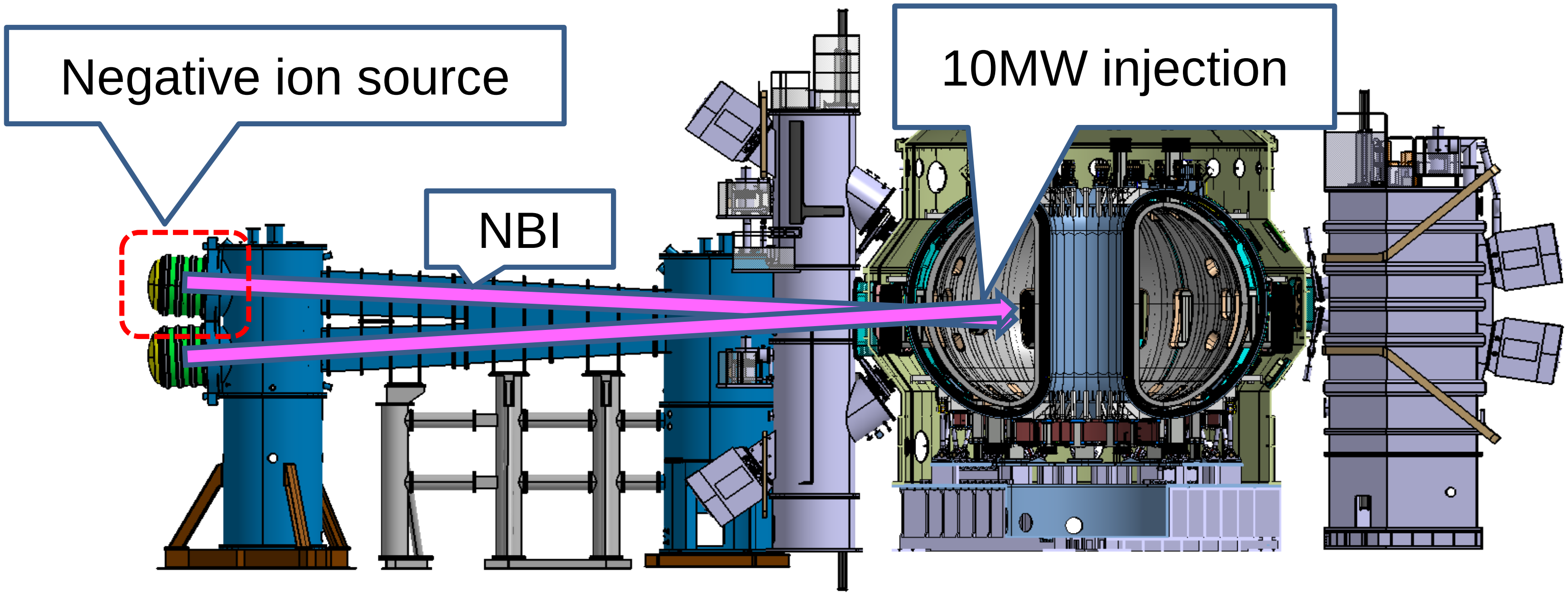


#763 : Challenges toward Improvement of Deuterium Injection Power in LHD Negative-Ion-Based NBIs

K. Tsumori and NIFS NB group, Japan

JT-60SA NBI is upgrading from 10 s (JT-60U) to 100 s.

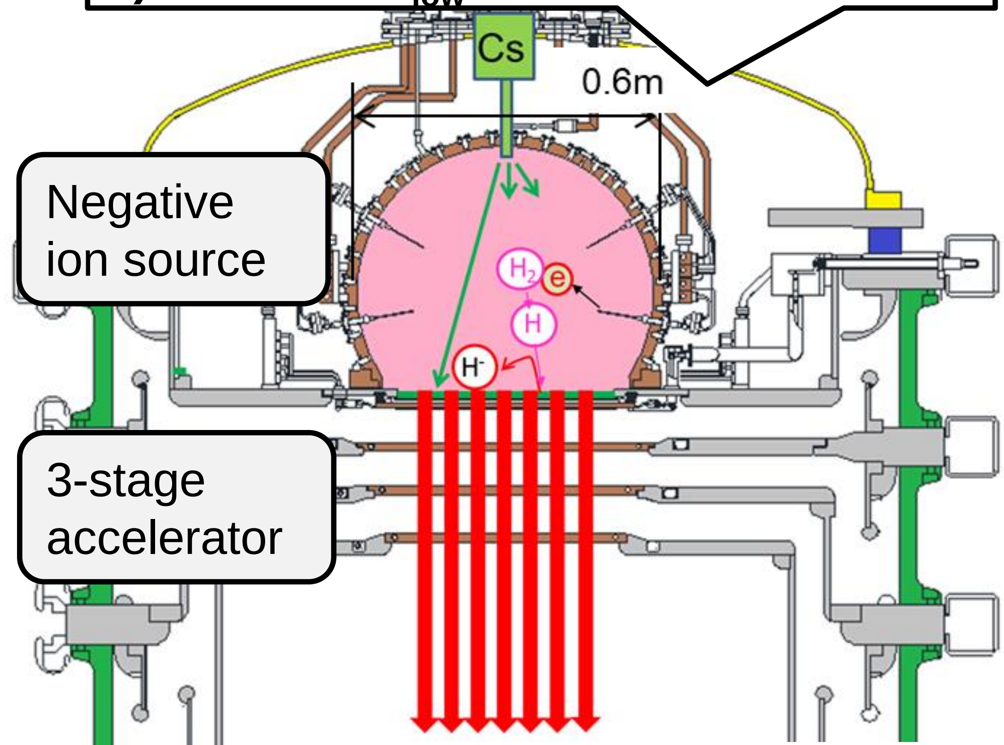
Realization of stable beam acceleration is important for the ITER NBI.

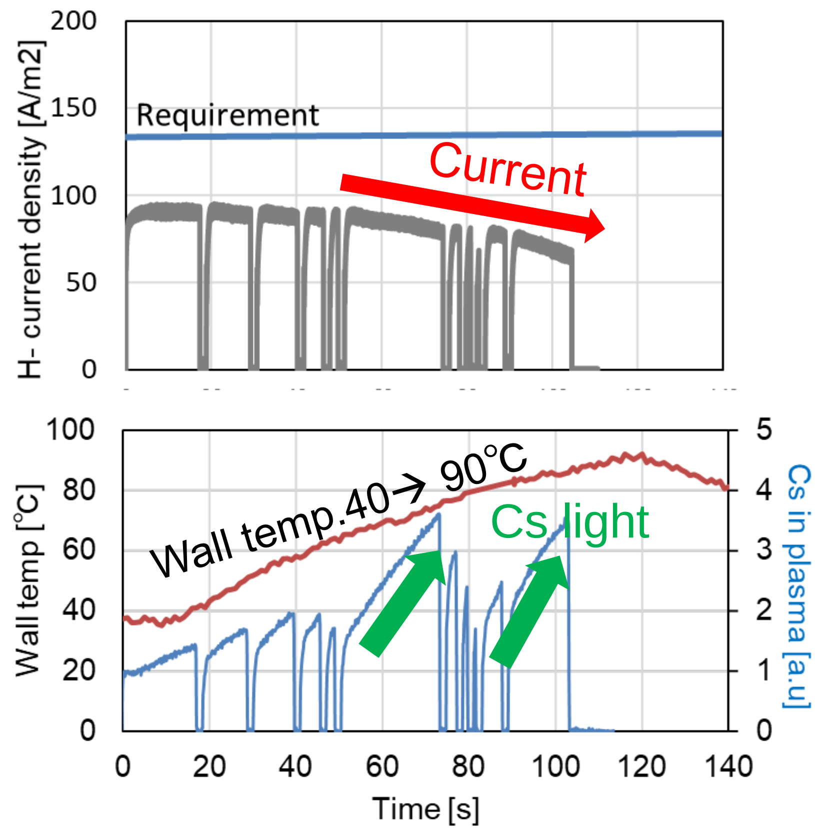


	Requirement	JT-60U	2016 (only extraction)		This achievement
Beam energy (keV)	500	340	10	10	500
D- / H- Current (A)	22	17	32	15	0.3
Current density (A/m^2)	130	102	190	90	154
Pulse (s)	100	30	1	100	118

Issues to achieve 500 keV, 130 A/m^2 for 100 s

1) $e_f + H_2 \rightarrow H^0 + H^+ + e_f$
2) Cs on PG (>200℃) →
Low work function(WF_{low}) surface
3) $H^0/H^+ + WF_{low} \rightarrow H^-$





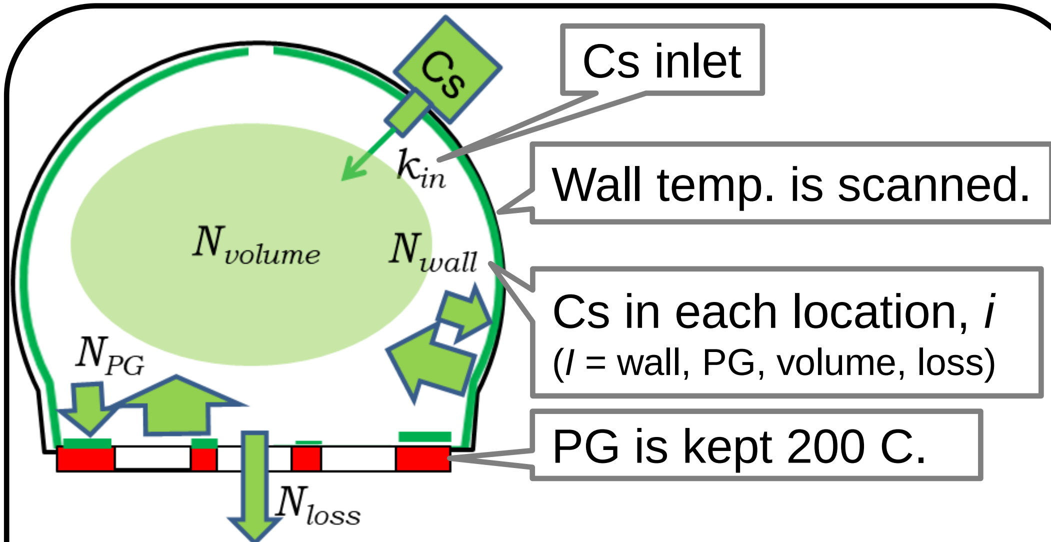
Issues

(A) Gradual decrease of negative ion current after 50 s.
(B) Demonstration of stable beam acceleration over 100 s.

1/8 ion source and the three-stage accelerator was utilized for this test due to facility limitation.

(A) : Degradation of current is influenced by Cs behavior.

Balance equations to solve Cs behavior



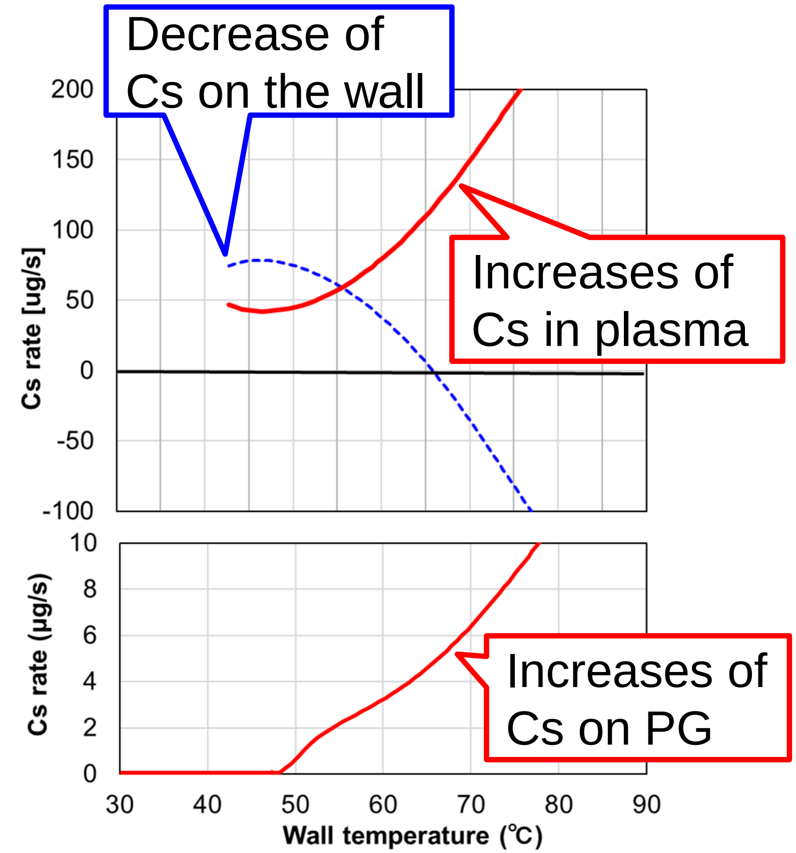
$$kin = \sum_i \frac{dNi}{dt}$$

$$\frac{dNi}{dt} = a_i \frac{S_i}{S_{total}} N_i^{neutral} - (\beta_i - 1)\frac{S_i}{S_{total}} N_i^{ion} - \gamma_i N_i$$

(α=absorption yield, β=sppeterring yield, γ=desorption yield)

These values were obtained in the sample test by using Cs.

Cs against wall temperature

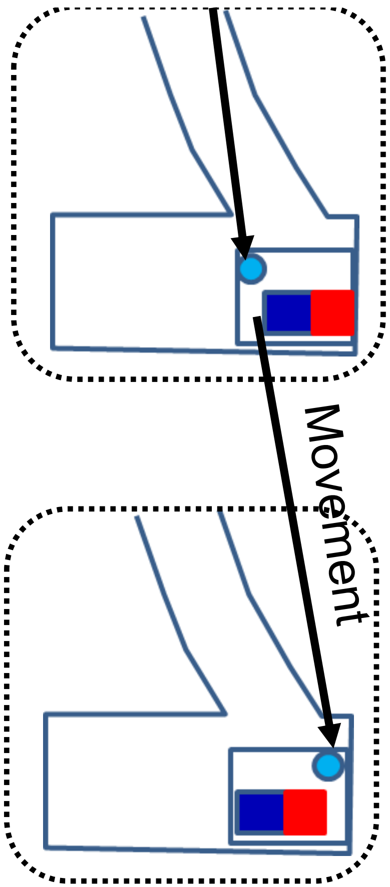


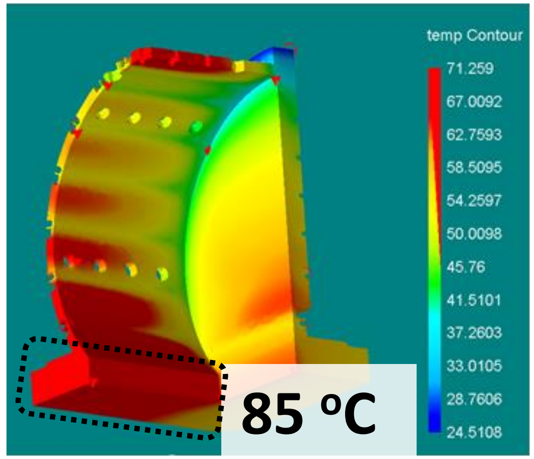
Increases of Cs on PG will change the work function on PG.
This will be a cause of the degradation of the negative ion current.
Temperature during operation should be maintained be to Wall < 50℃, PG > 200℃.

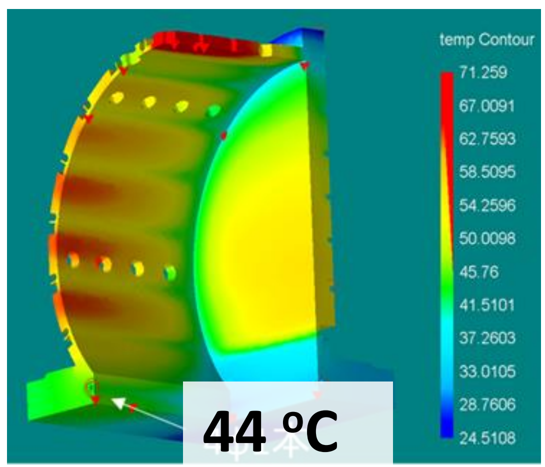
Modification of ion source to keep < 50 ℃ at wall

①Movement of water channel

Water channel

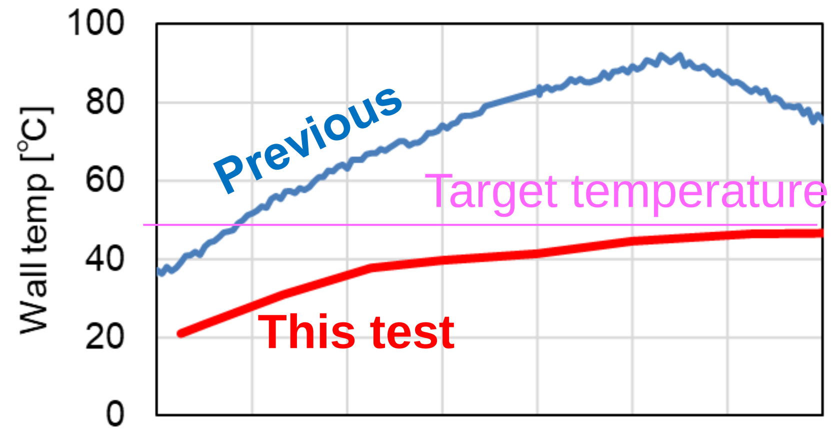


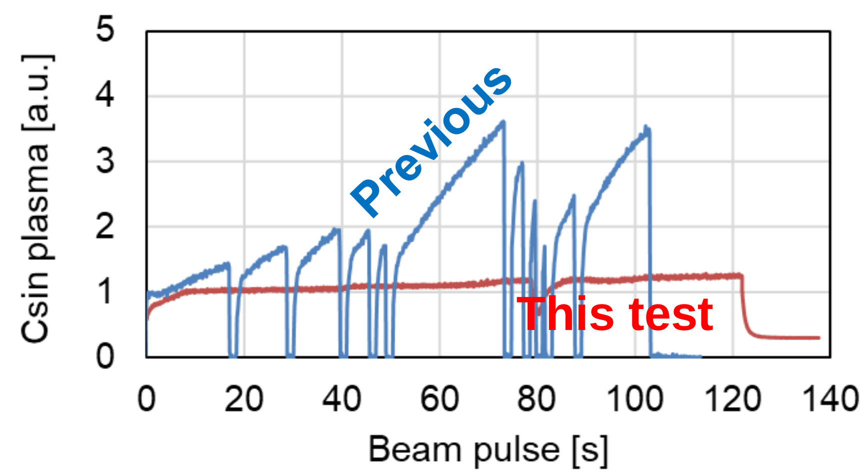




②Water flow rate : 10 L/min to 30 L/min.

Experimental results

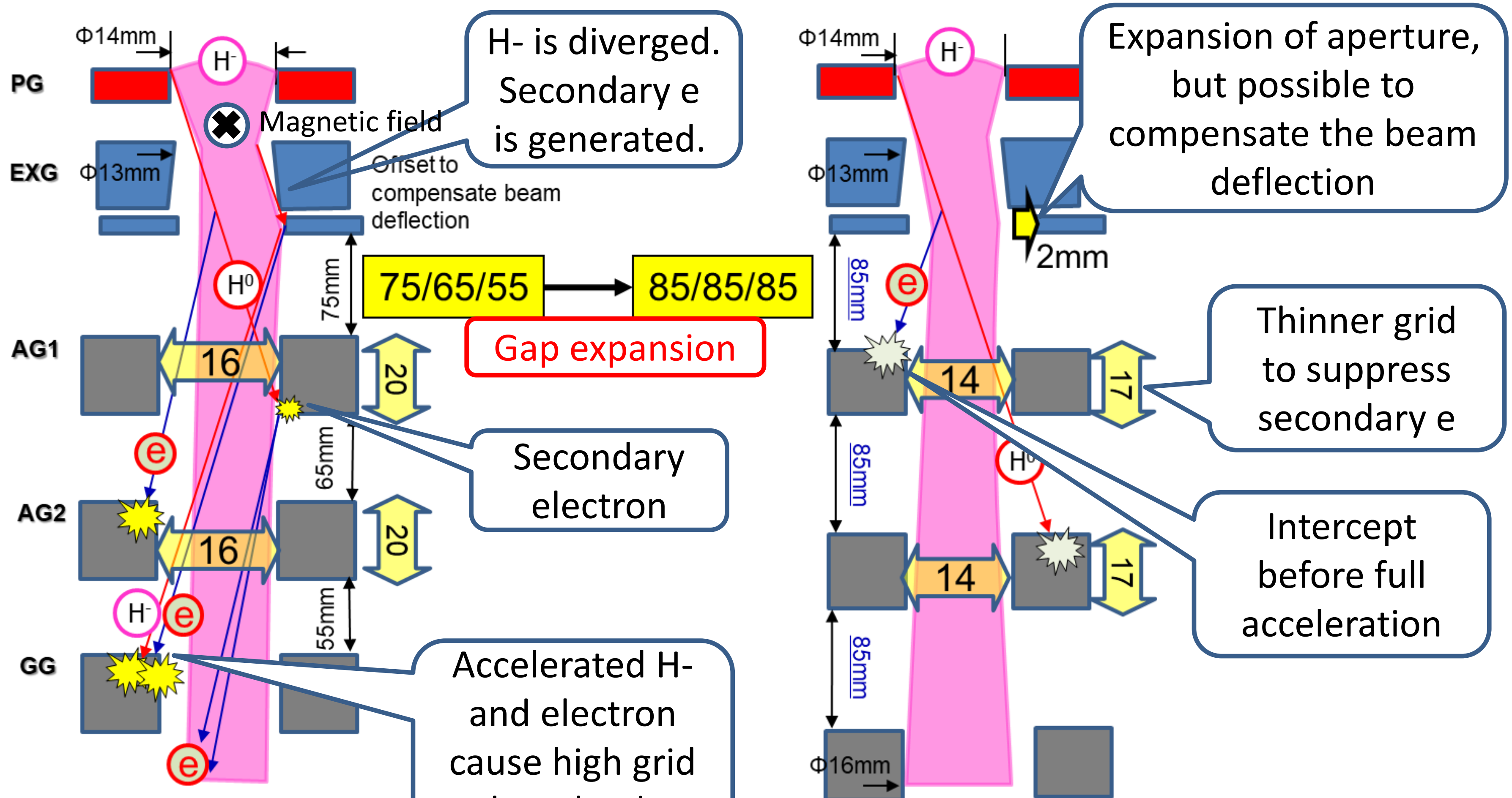




Wall temperature < 50 ℃
Cs in plasma : Reduced and stable

(B) Demonstration of 500 keV beam

Insufficient voltage holding has been improved to expand the acceleration gap.
To reduce the grid heat load less than allowable value 15 % of the total beam power, following techniques developed for the stable beam were applied to this test.

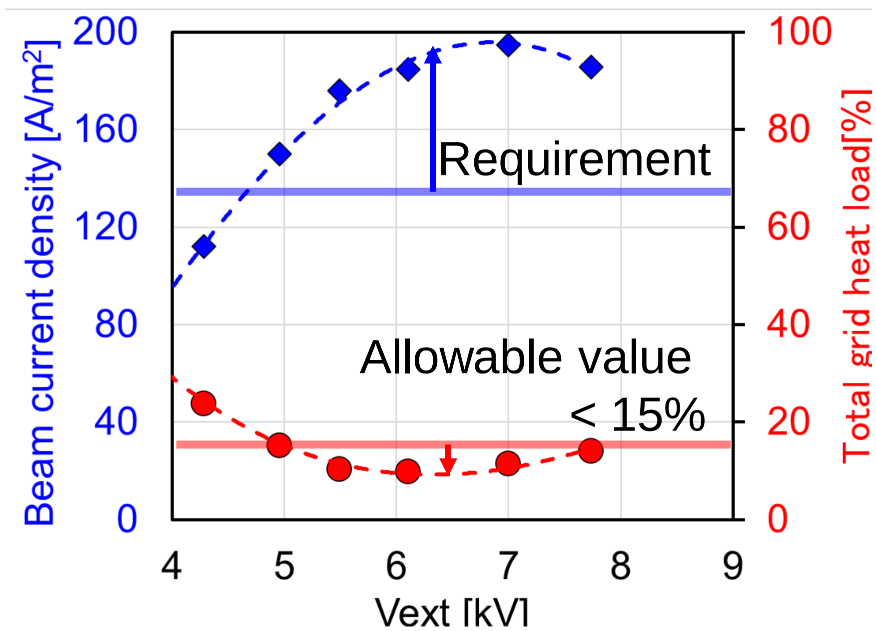


(a) Original

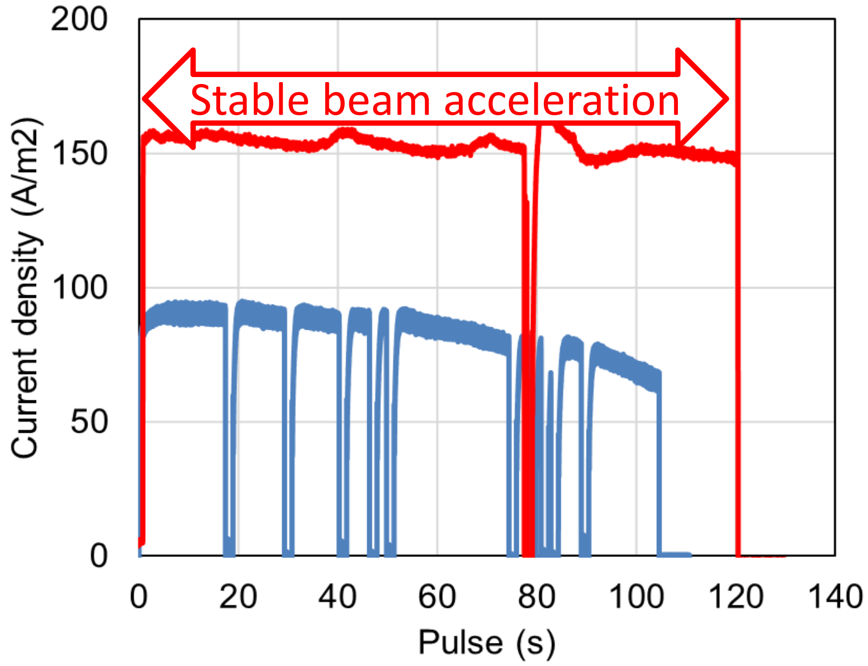
(b) Modification

Long pulse beam exceeded the requirement

Grid heat load and current density



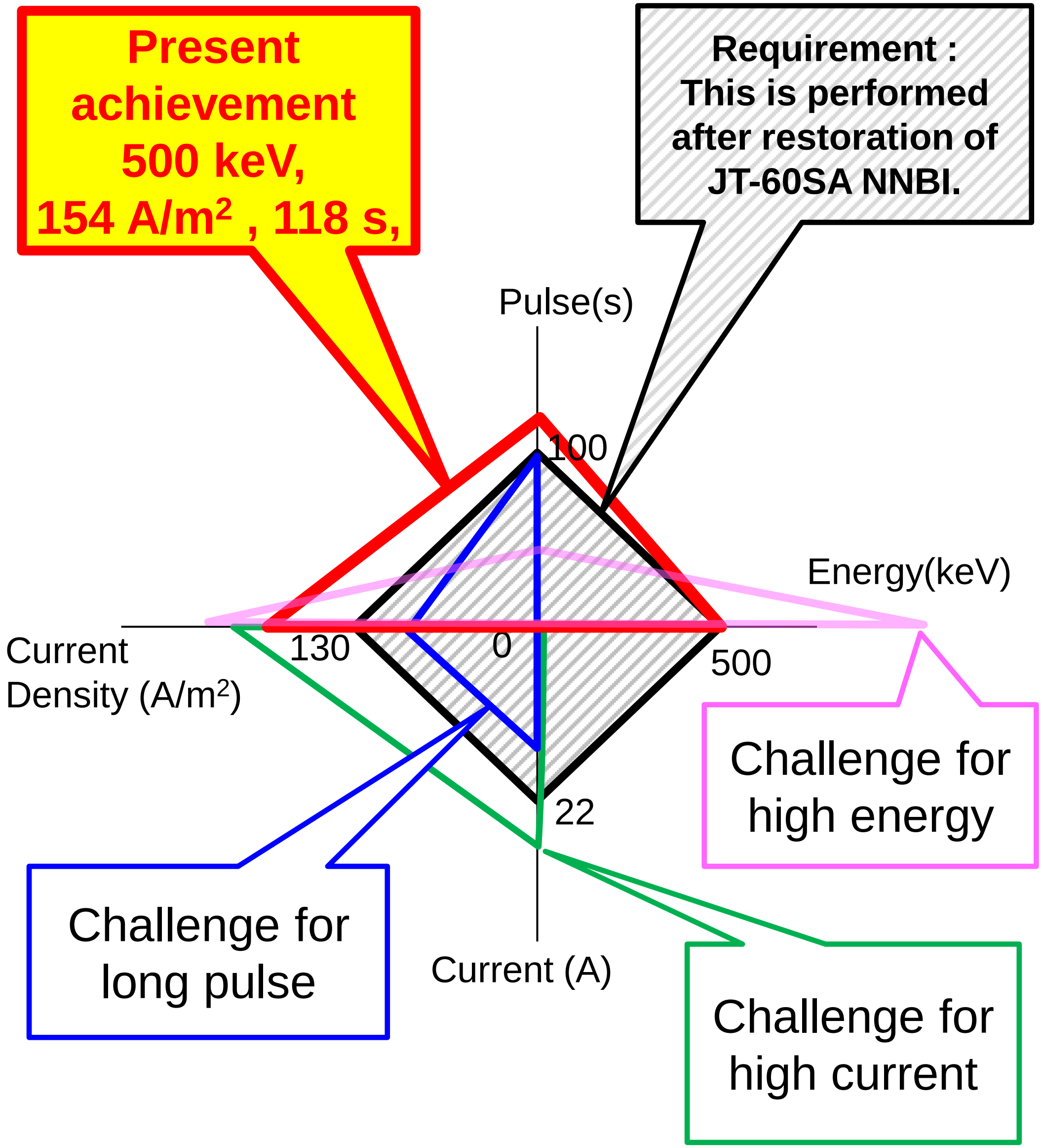
Long pulse operation



500 keV, 154 A/m^2 for 118 s, which exceeds the requirement of JT-60SA has been successfully demonstrated.

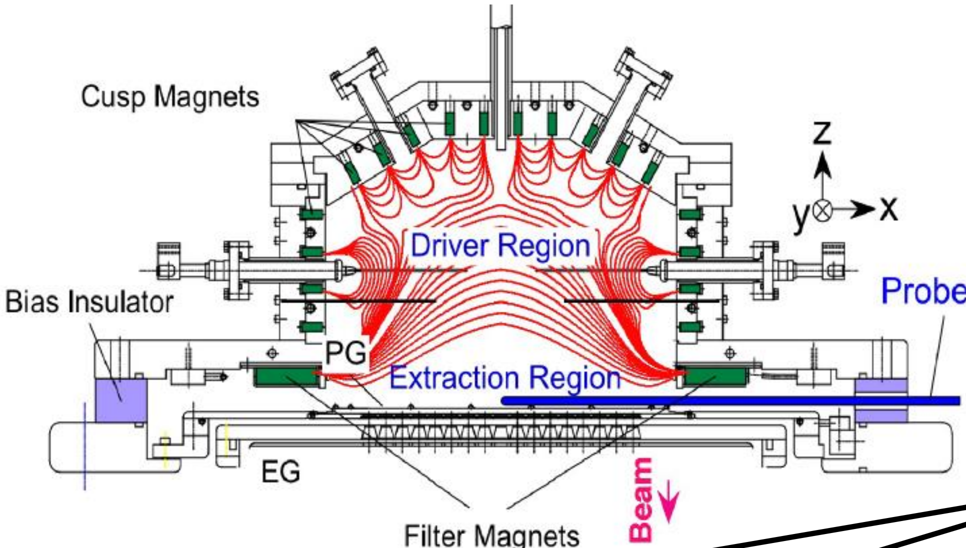
Summary : Stable 500 keV beam acceleration

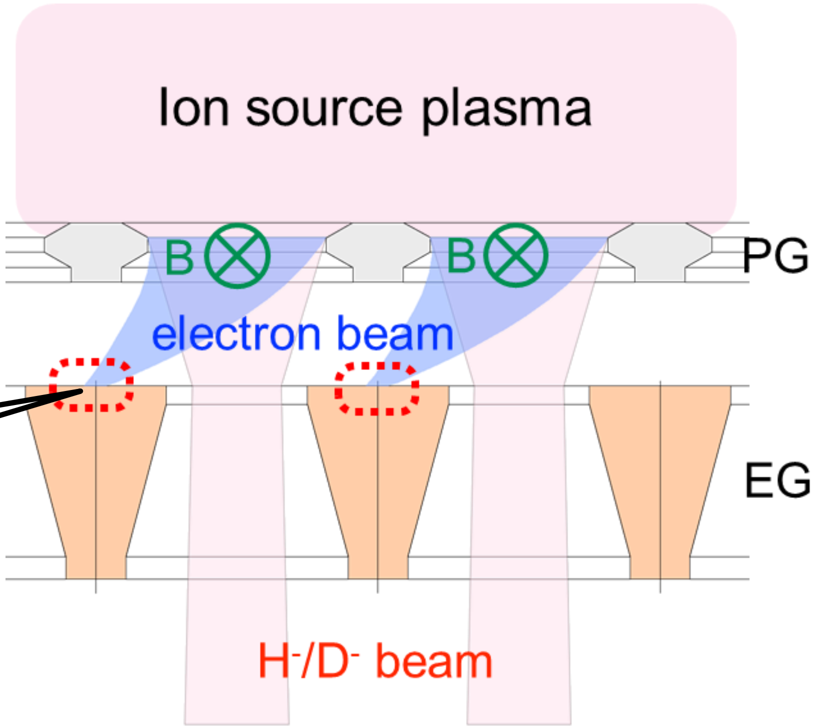
- 500 keV, 154 A/m^2 for 118 s H$^-$ beam has been successfully demonstrated.
- This satisfied the requirement of JT-60SA NNBI.
- Temperature control of the ion source and modification of the accelerator to decrease grid heat load were keys to achieve this achievement.



#763 Improvement of Deuterium Injection Power in LHD Negative-Ion-Based NBIs

Deuterium beam (D) since 2017, D power was 1/3 –1/2 of H power, which was lower than expected value (mass ratio: $\sqrt{(m_H/m_D)} = 1/1.4$).





Extracted electrons with D beam become larger than that with H beam.
-Breakdowns at extraction gap
-Damage on Extraction Grid (EG)

Electron reduction is the most important to reduce heat load on extractor and to increase H^-/D^-. This is common issue for the ITER NBI.

Large electron current in D operation

Measurement inside plasma

Negative-ion density:

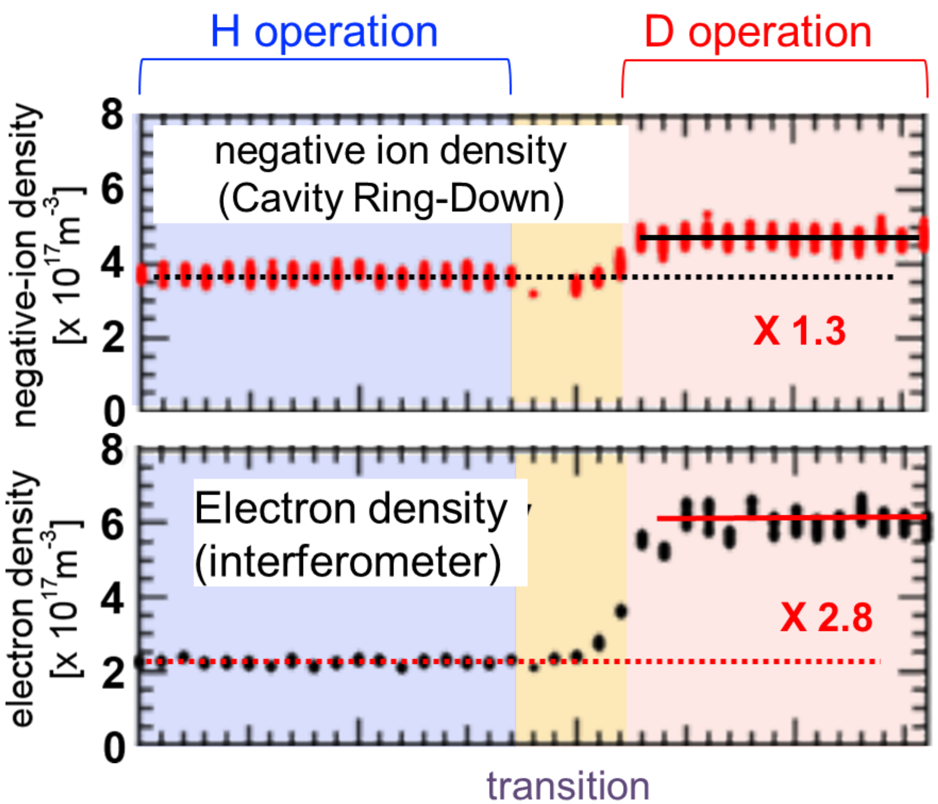
D$^-$ density was 1.3 times lager.

Electron density (ion density):

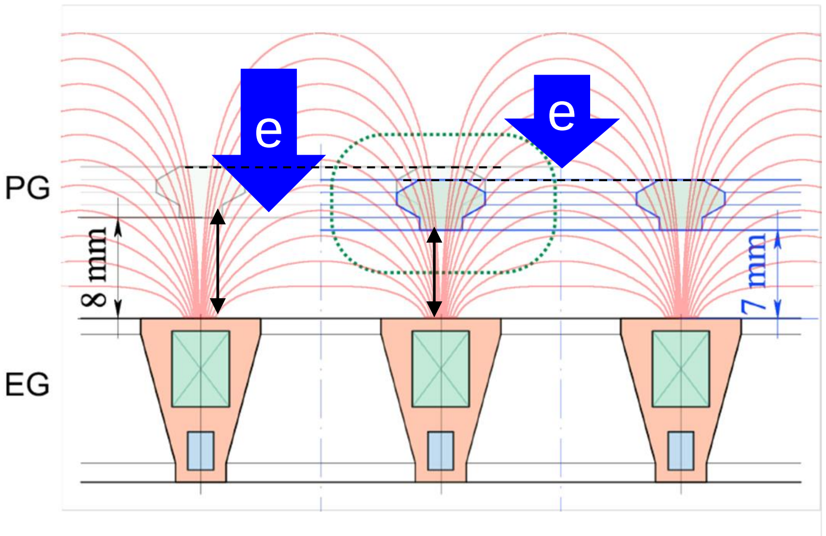
~3 times larger! in D_2 discharge.

Electrons diffuse together with D$^+$ ions form driver to beam extraction region (ambipolar).

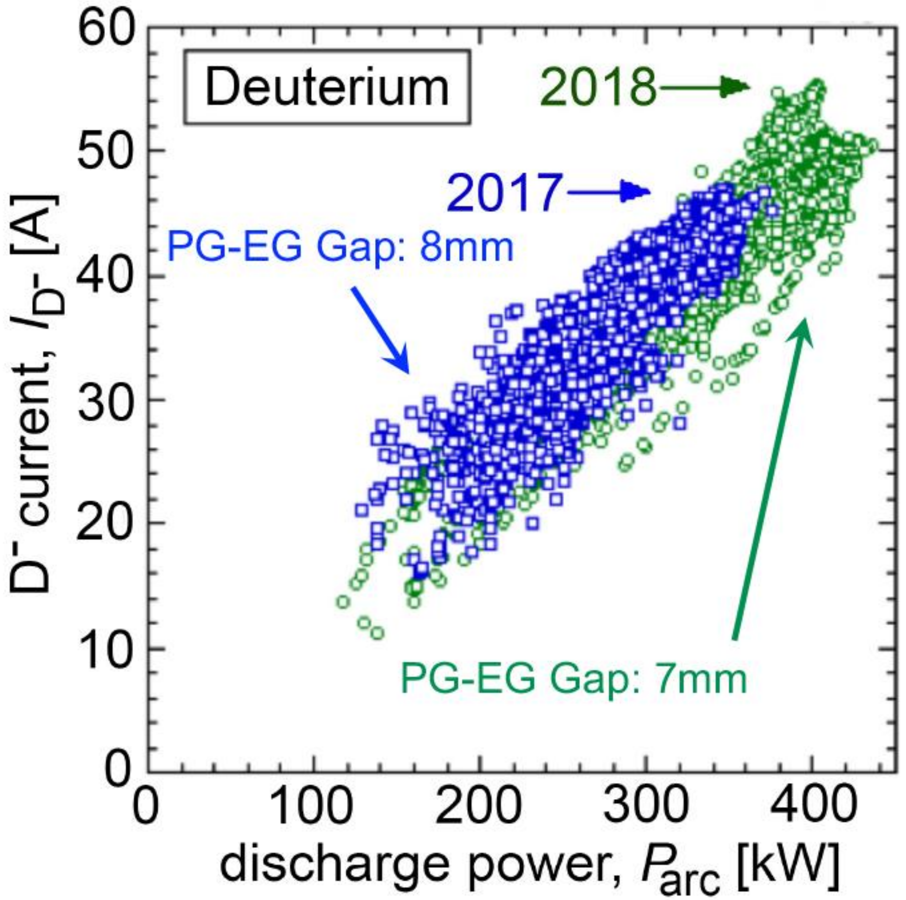
Electrons flow to the PG should be suppressed before the extraction.



Countermeasure 1 : Enhancement of magnetic field on PG

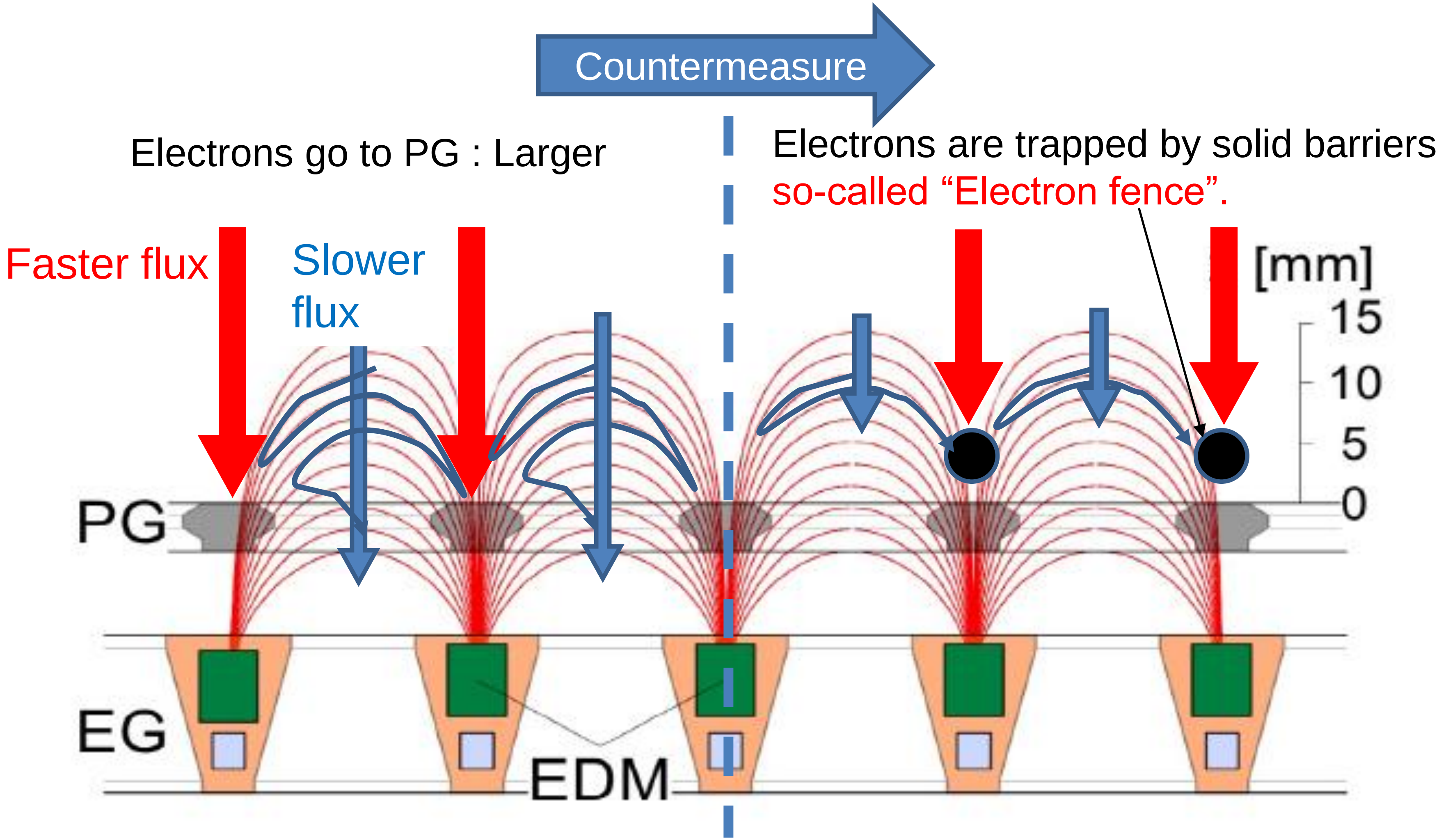


Cusp magnetic field over the PG was increased by moving the PG to the EG in order to suppress electrons flow to the PG.



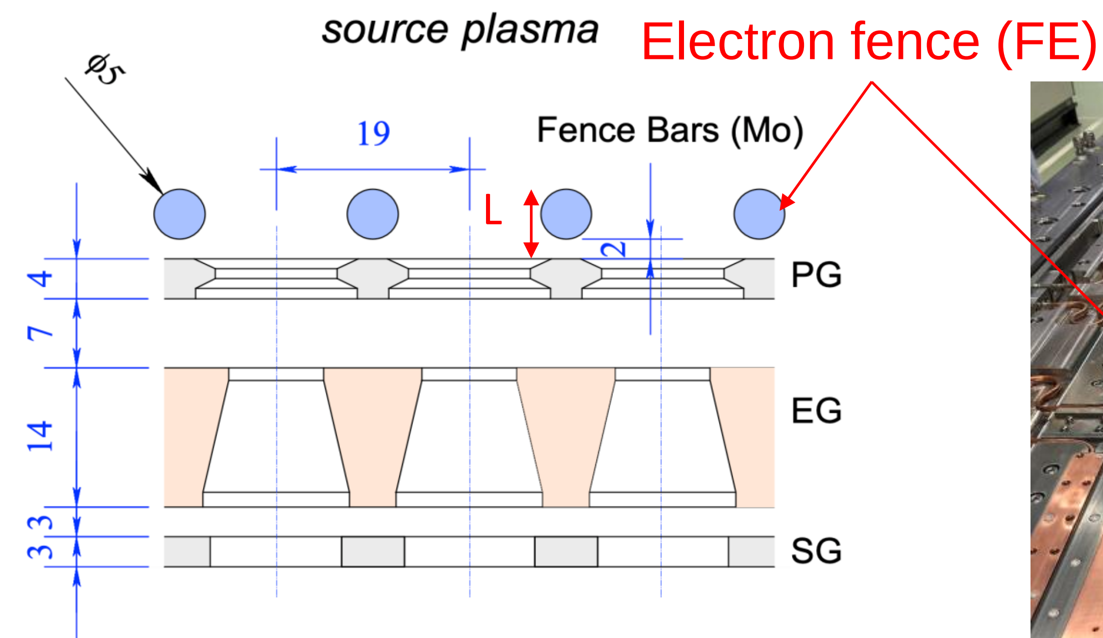
As the result, electron current suppressed and D^- current increased by 20 %.

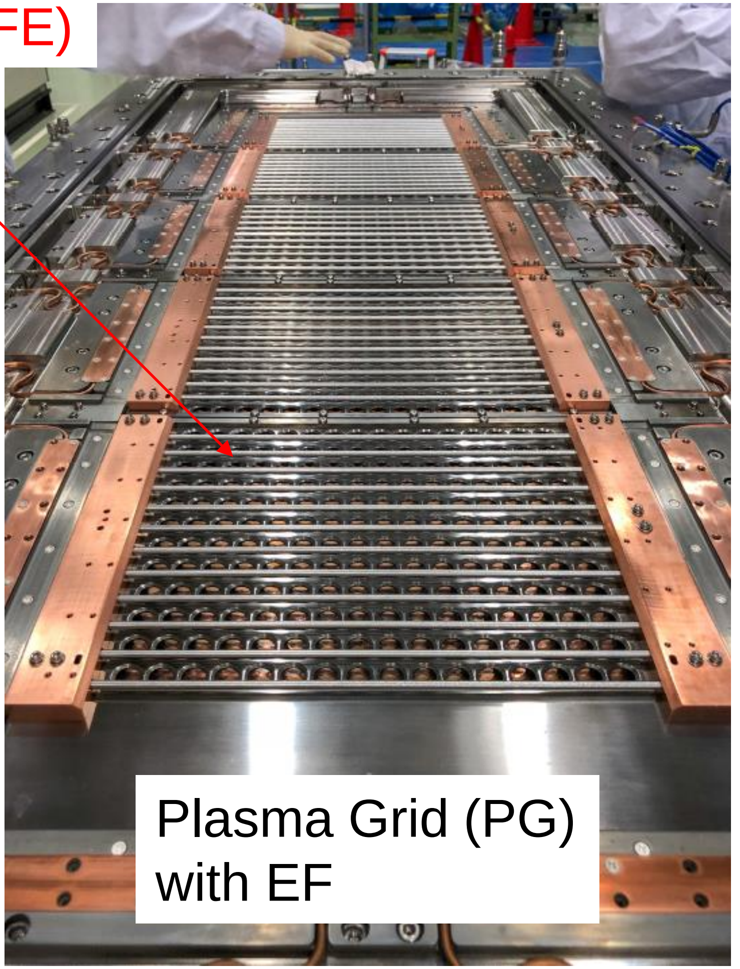
Countermeasure 2. Electron fence to reduce electrons



Solid barriers on the way of cusp lines could be effective to reduce diffusion of electrons.

Design of electron fence (FE)

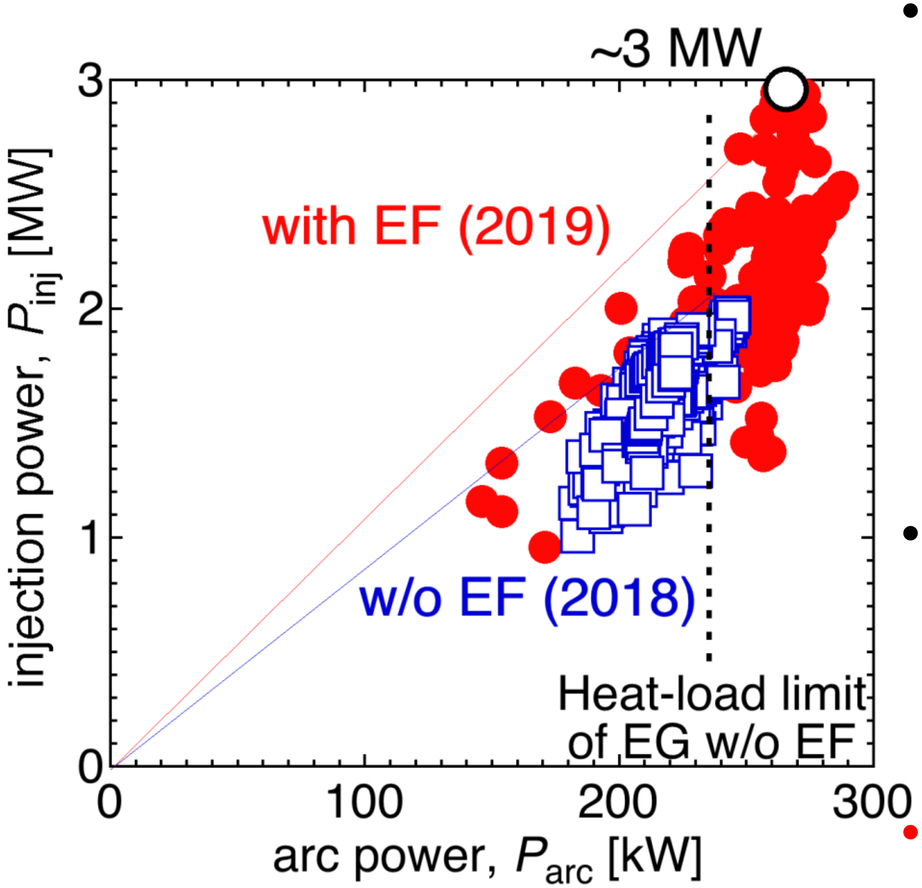




Height from PG "L"
Designed to pass ions and block electrons in using the difference of their gyro radii.
H-/D- (5 mm) and electron (1mm).
→ L is around 5 - 7 mm.

Molybdenum rods of the EF is arranged between neighboring the rows PG apertures.
Electron current decreased less than 50 %.

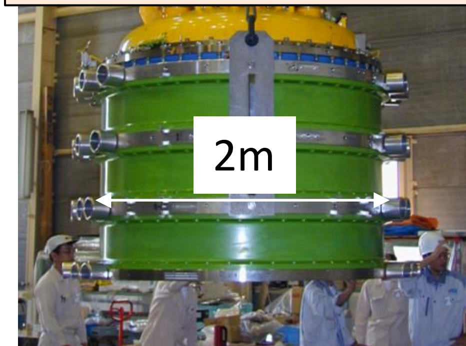
Summary : Improvement of D power



- The EF is designed to pass ions and block electrons in ion source plasma using the difference of their gyro radii. Electron current becomes less than 50 % by attaching the EF.
- Because of the electron reduction, D injection power increased from 2 MW to 3 MW.
- The Electron Fence is applicable to ITER.

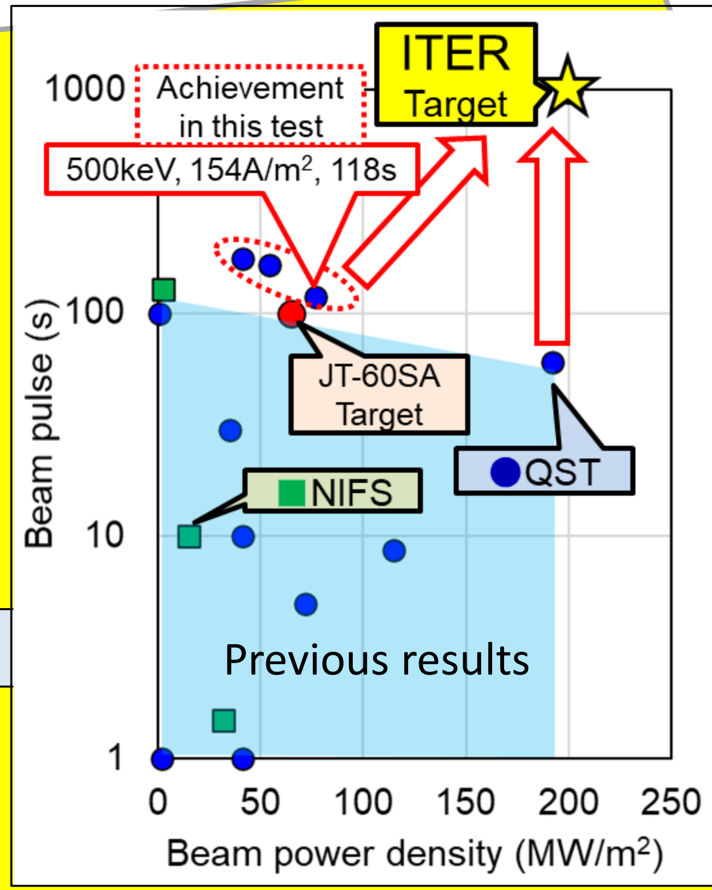
The way to the ITER NBI

Ion source for JT-60SA

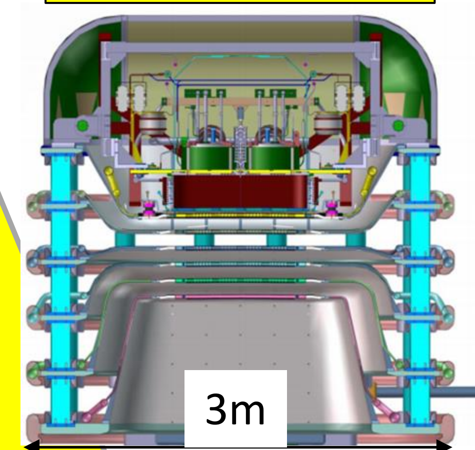


Ion source for LHD

1MeV accelerator



ITER beam source



NBTF MITICA

NBTF SPIDER

IPP ELISE