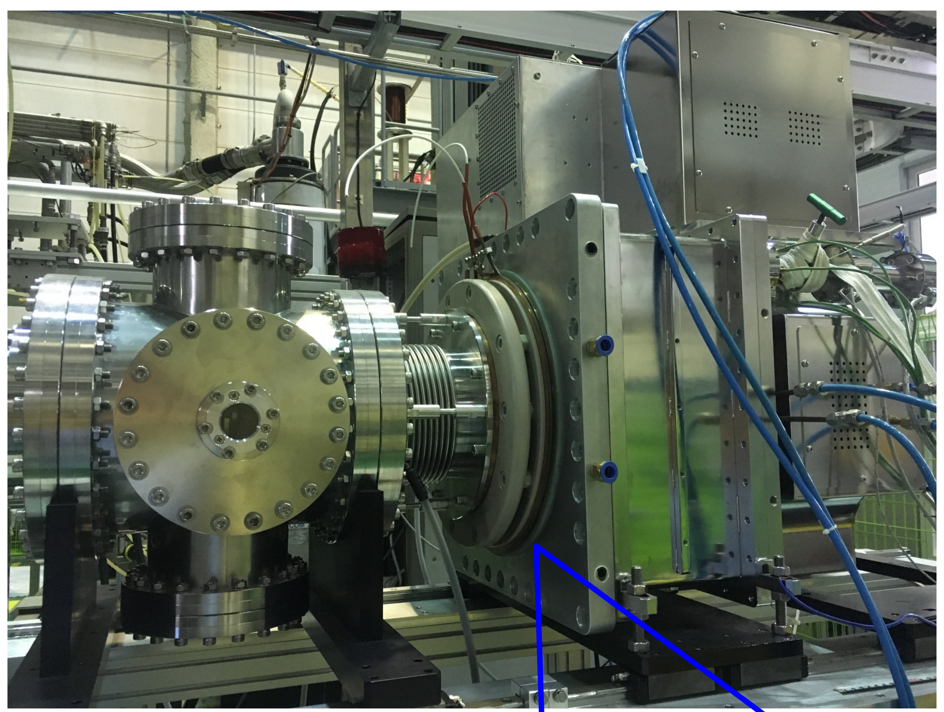
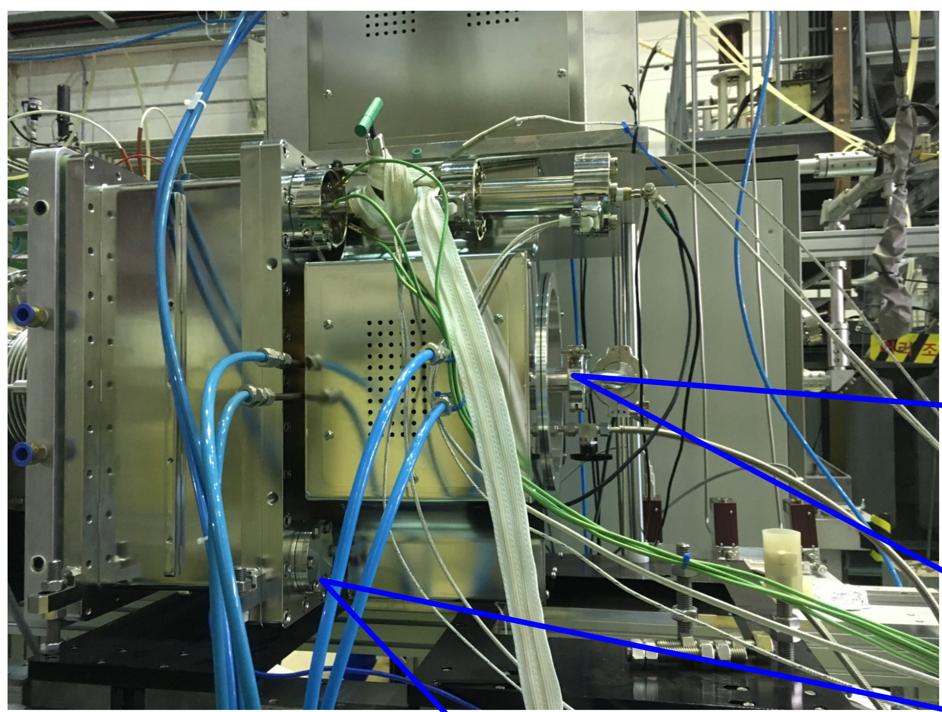
Negative ion beam extraction in an RF hydrogen plasma with Cs seeding

*Min Park[1], ByungKeun Na[1], Tae-seong Kim[2], Seung Ho Jeong[2] and Jong-Gu Kwak[1]
[1]National Fusion Research Institute (NFRI)
[2]Korea Atomic Energy Research Institute (KAERI), Republic of Korea
E-mail : mpark@nfri.re.kr

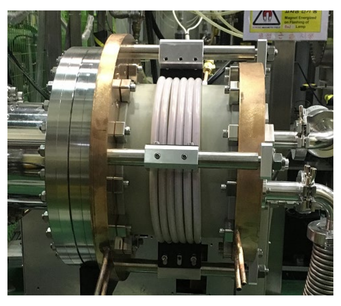
ABSTRACT

A negative ion beam source of 200 keV / 0.5 A has been under development at National Fusion Research Institute (NFRI). Recently, a Cs dispenser was equipped to feed the Cs to enhance the source performance. To see the Cs seeding effect, preliminary short-pulse beam extraction experiments were carried out with 50 keV accelerator prior to the installation of 200 keV accelerator. It was confirmed that the performance of Cs dispenser was maintained for more than 2 hours and the beam currents were increased by about 2 times. The co-extracted electron currents were drastically decreased. It is necessary to find optimum operational conditions such as the current waveform of Cs dispenser to control the Cs evaporation rate and particularly the plasma grid (PG) temperature which is the main factor for the deposition rate or the thickness of Cs on the PG surface.

I. RF negative ion beam source

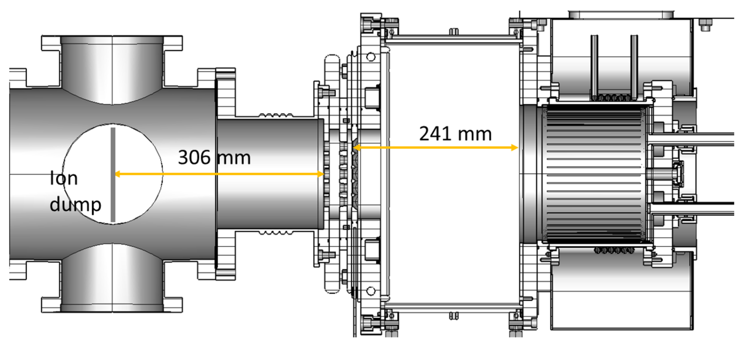



▪ RF ICP plasma source

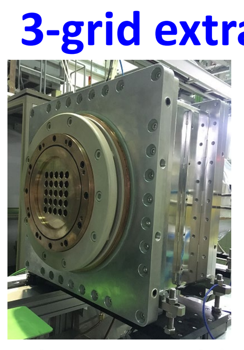
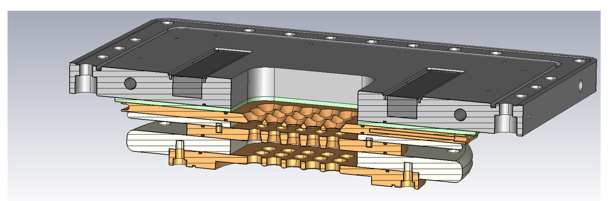


- **Aluminum nitride(AlN)**
- High heat conductivity (140-180 W/m°K)
- I.D : 200 mm
- H : 150 mm
- T : 5 mm
- **6- turn RF antenna fed by 2MHz (Max. 8kW)**
- Covered with a Teflon tube for H.V insulation
- Cu tube O.D : 6 mm
- Teflon thickness : 1 mm
- **Copper Faraday shield**
- 0.5 mm thickness, not water-cooled

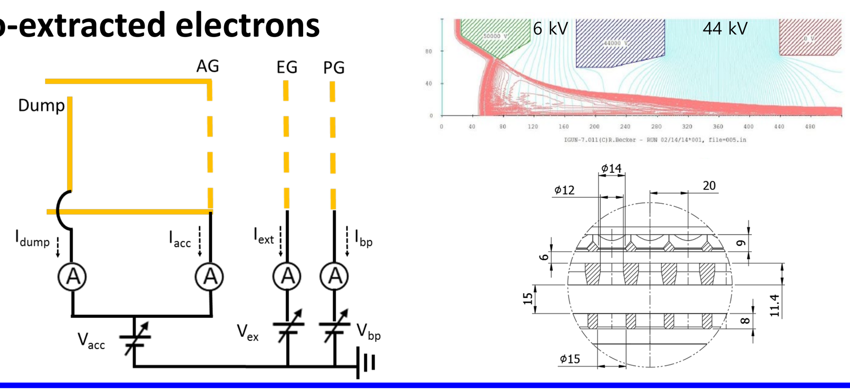
▪ System cross-section view



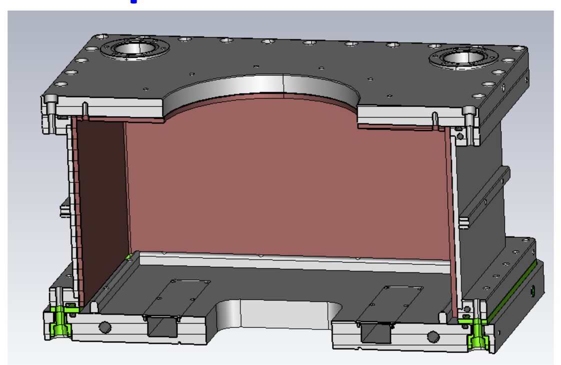
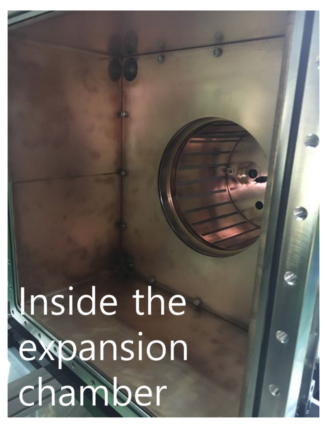
▪ 3-grid extraction and acceleration system

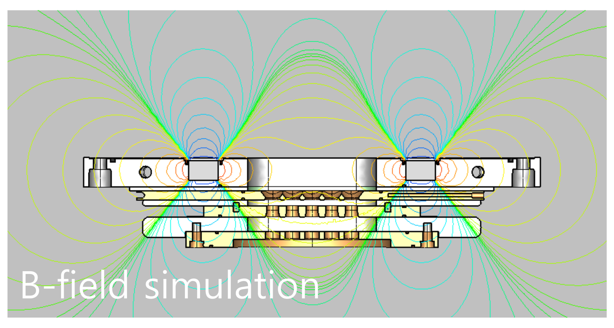
- **Plasma Grid (PG) : 38.5 cm² extraction area**
- **Extraction Grid (EG) w/ electron deflection magnets (EDMs) : up to 10 kV**
- **Acceleration Grid (AG) : up to 40 kV**
- **Bias Plate (BP) + PG : up to 60 V to suppress co-extracted electrons**

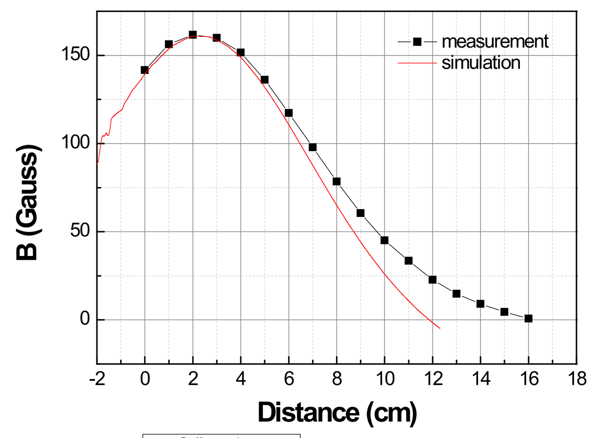


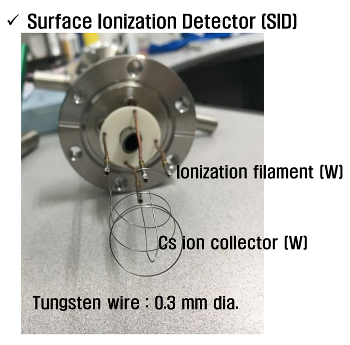
▪ Expansion chamber

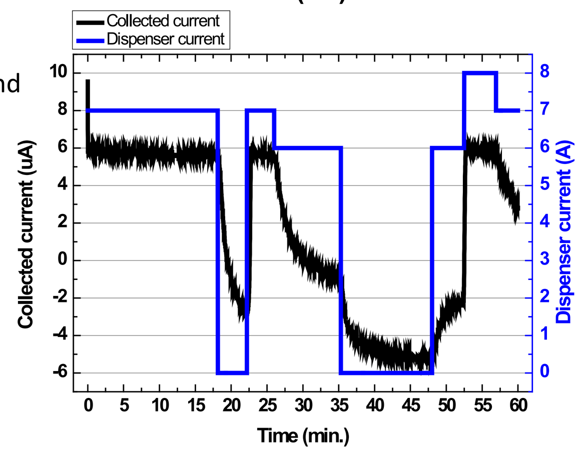
- 375 x 375 x 200 (mm³)
- Copper shield inside (T : 5 mm) for uniform temperature distribution
- w/ Cs dispenser oven
- w/ Filter magnet for high energy electron suppression



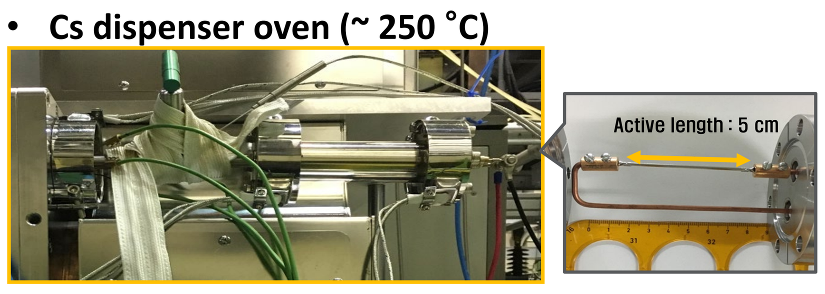




- Surface Ionization Detector (SID)
- 3 [A] for heating of the ionization and collector filaments
- 50 [V] biasing the ionization filament w.r.t the Cs collector filament



- **Cs dispenser oven (~ 250 °C)**



✓ Current of 6.5 [A] through Cs dispenser for one hour will provide 2.3 [mg/cm] x 5 [cm] =11.5 [mg] of Cs. (total 22 mg contained in a Cs dispenser)
✓ The area of inner wall surfaces is about 6000 cm², requiring only 0.64 mg when covered with one monolayer of Cs. (1 monolayer =4.8 x 10^{14} atoms /cm²)

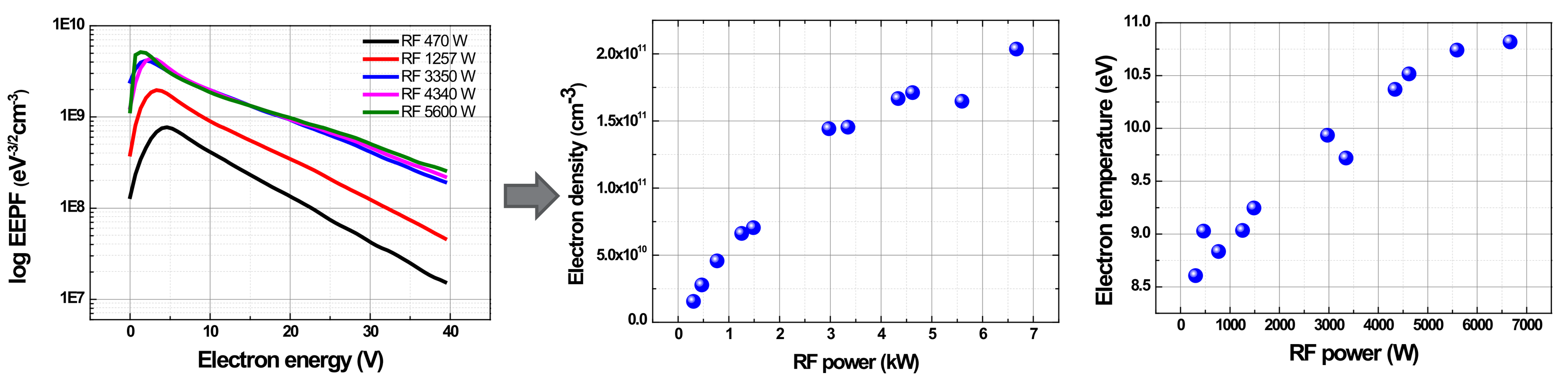
II. RF ion source performance

▪ Hydrogen Plasma Characteristics (in the plasma source region)

- **Pressure : 0.6 Pa H_2**
- **RF 2 MHz, up to 7 kW**
- **Ne : ~ 2 x 10^{11} cm³**
- **Te : 8 ~ 11 eV**

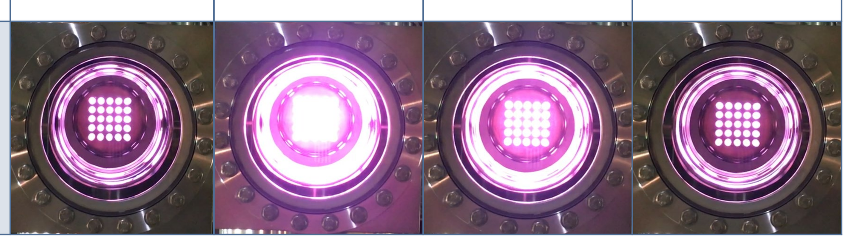
✓ short-tip probe (r=0.05 mm / l=3mm) with RF choke filters and compressed air cooling
✓ Used for EEPFs measurement

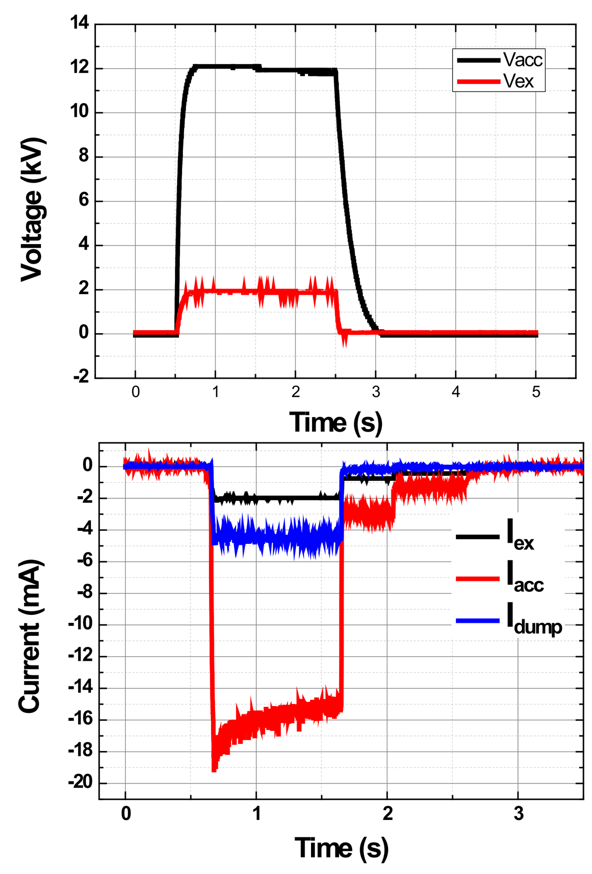
✓ Maxwellian Electron Energy Probability Functions (EEPFs) obtained by 2nd derivative of the probe IV curve (Druyvesteyn's method)



▪ Beam extraction with RF and HVDC pulsed operation

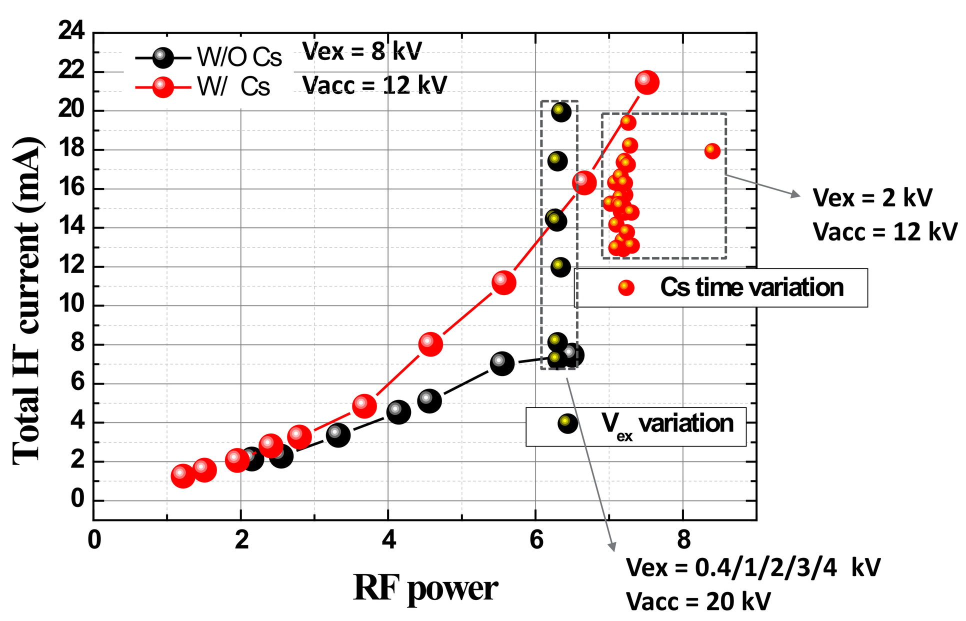
✓ Because the faraday shield inside the AlN is not water-cooled, plasma operation at high RF power is pulsed to protect the AlN from the plasma heat load.

RF power pulse operation				
Power (kW)	0.8	7	1.5	0.8
Duration (sec)	CW	1	0.5	CW
				



▪ Cs feeding effect on the negative ion beam extraction

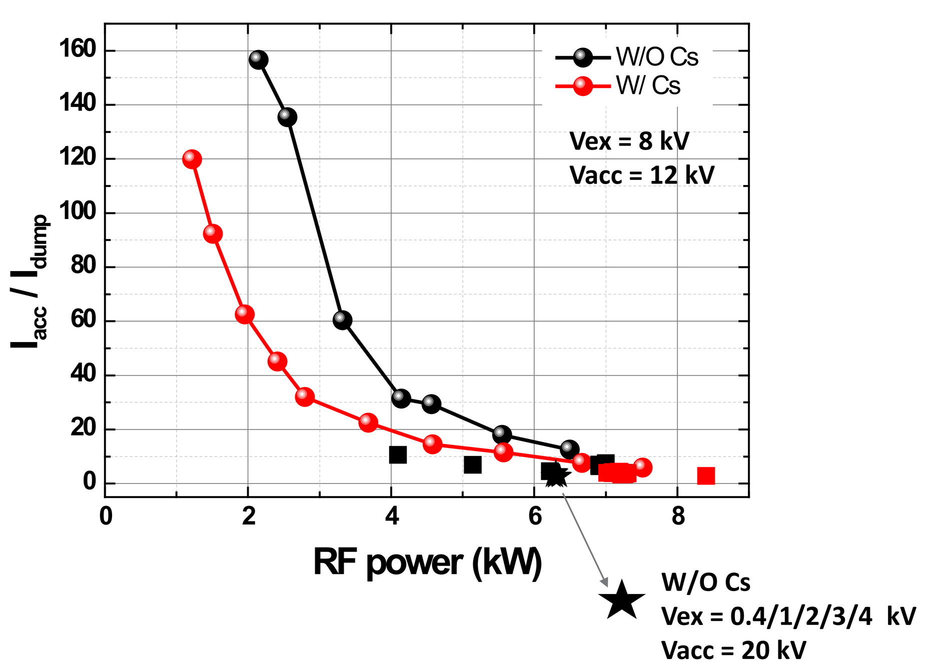
✓ Cs feeding drastically enhances the extracted negative ion currents.



✓ The input RF power seems too low for high current beam extraction
✓ Even without Cs seeding, higher H- current could be obtained with different extraction and acceleration voltage configurations.

▪ Beam optics estimation

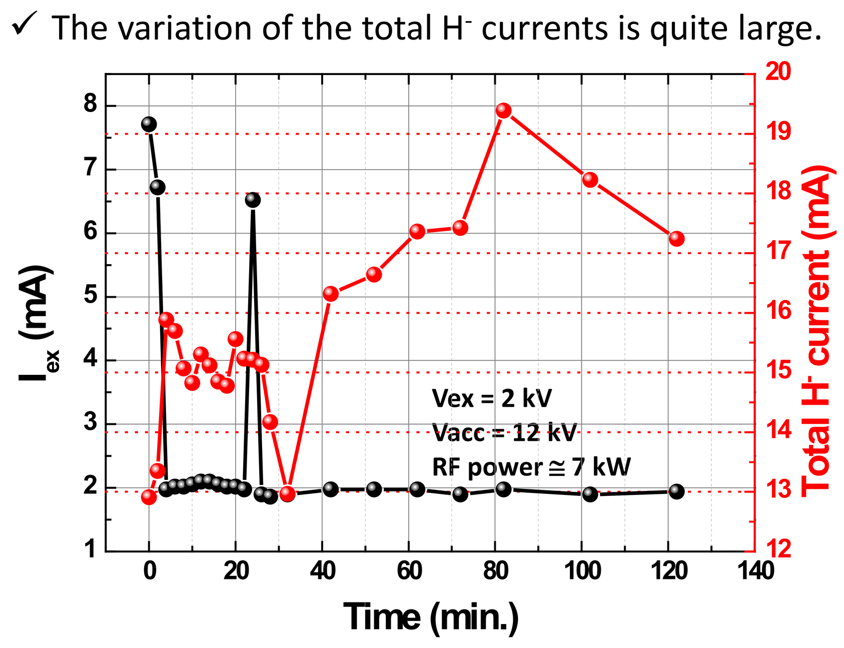
✓ The better beam optics could be obtained with lower Vex with similar total H⁻ current. (low H⁻ density due to low RF power)



▪ Cs feeding effect on the extraction grid current (corresponding to the co-extracted electron current)

✓ About 4 minutes after the Cs injection, the extraction grid current drastically decreased and maintained for 2 hours.

✓ The variation of the total H⁻ currents is quite large.



The negative ion beam extraction has been conducted and the effect of the Cs seeding was confirmed. In the experiments, the Max. RF power was too low to achieve better performance of the beam source. The extraction grid current corresponding to the co-extracted electron current can be a clear indicator for the Cs condition on the plasma grid(PG). Maintaining higher PG temperature (~250 °C) is necessary for the stable beam extraction. Now, a new RF power up to 50 kW (~ 400 kHz) has been installed. The preliminary beam extraction result with the new RF power is presented by Dr. Na *("Recent progress in the RF Hydrogen Negative Ion Source in NFRI")*.