

Integrated Modeling of the Beam Formation and Extraction in the Linac4 Hydrogen Negative Ion Source

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 S. Nishioka¹, S. Abe¹, S. Mattei², J. B. Lallement², T. Kalvas³, A. Hatayama¹, and J. Lettry²
¹Graduate school of Science and Technology, Keio University, Yokohama, Japan

²CERN, 1211 Geneva 23, Switzerland

³Department of Physics, University of Jyväskylä, Jyväskylä 40500, Finland.

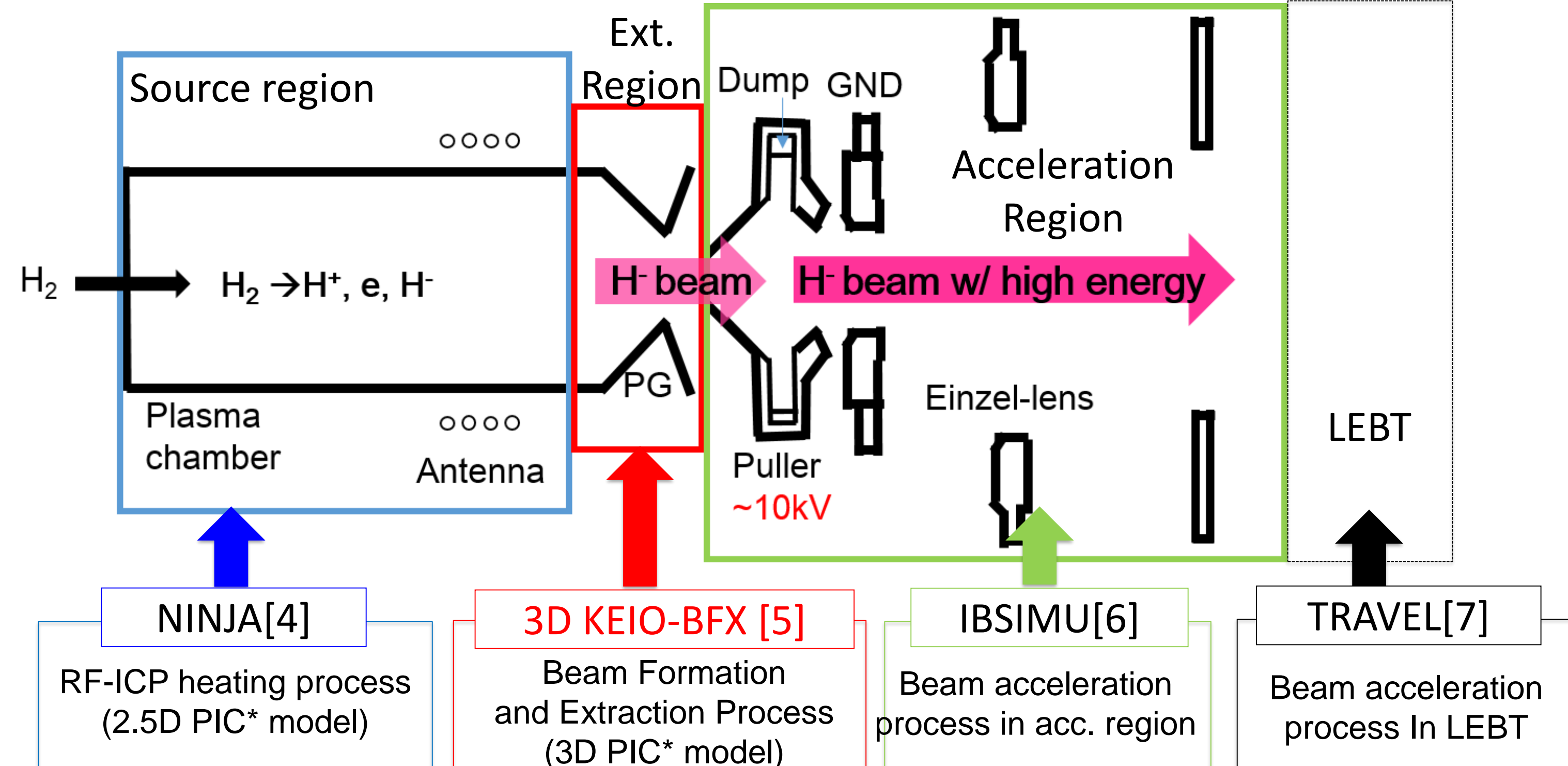
Email : nishioka@ppl.appi.keio.ac.jp

Abstract

Linac4 H⁻ ion source is required to deliver 50 mA of H⁻ ion beam within a transverse rms emittance of 0.25π mm·mrad[1]. In order to demonstrate the feasibility of these requirements, it is indispensable to study the H⁻ beam formation and extraction processes in the vicinity of the beam extraction hole (extraction region). Recently, the effects of the operation parameters on the H⁻ beam formation and extraction have been investigated by the 2D Particle in Cell (PIC) model² and the 3D PIC model³. In Ref. 2, it has been shown that the 2D PIC code is useful to understand the basic physics of the H⁻ extraction in the qualitative sense.

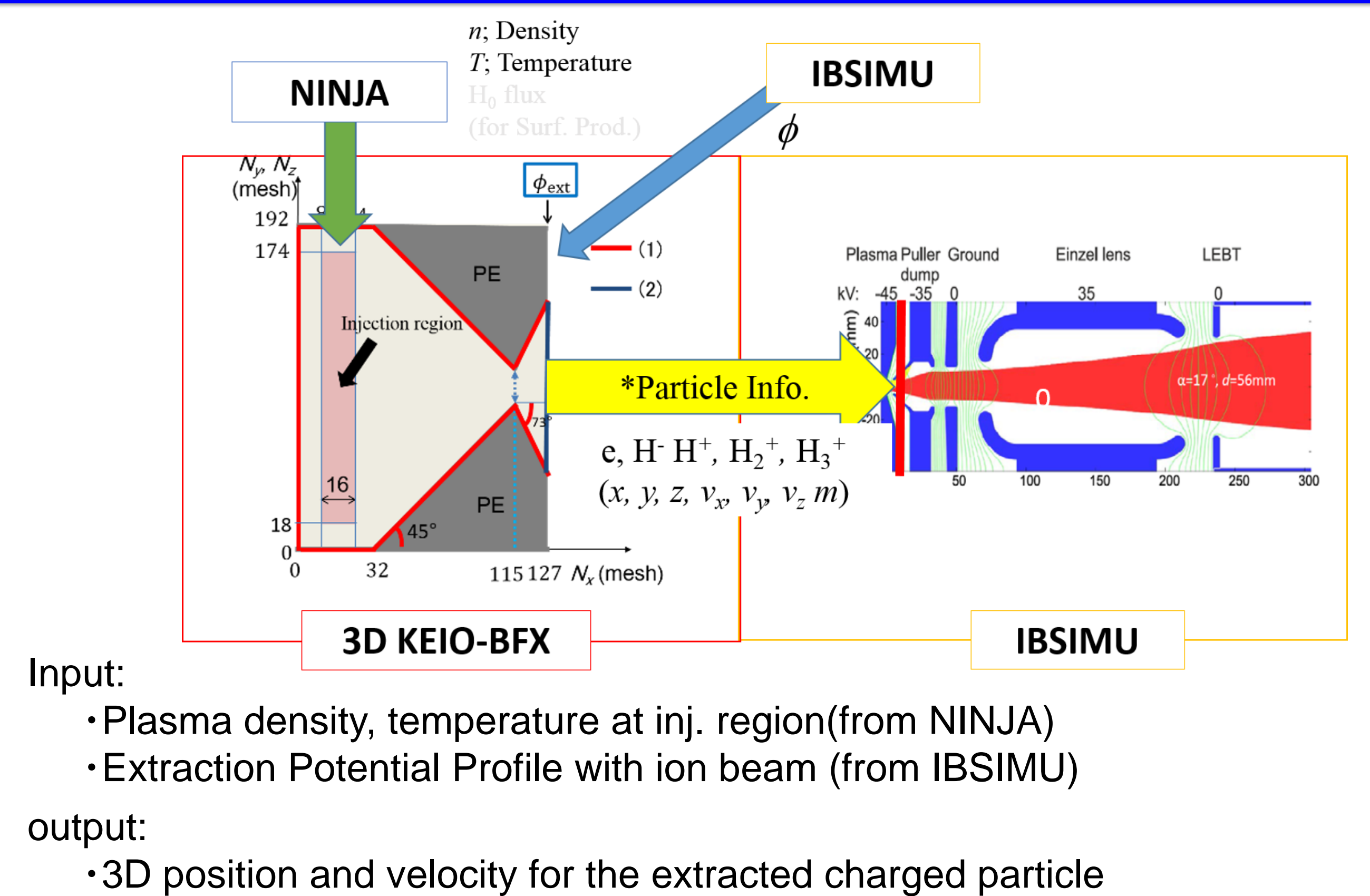
In order to make the predictive simulation tools for the extracted beam current and emittance in the Linac4 H⁻ ion source, we have launched the development of the integrated model for the H⁻ ion beam formation and extraction process. More specifically, our 3D KEIO-Beam Formation and eXtraction (3D KEIO-BFX) is coupled with the NINJA, IBSIMU and TRAVEL. We have performed the case of the H⁻ ion extraction w/o the Cs, the extracted H⁻ ion beam current and co-extracted electron current obtained by the integrated model have then shown reasonable agreement with the experiments.

Background

 Schematic view of the Coupling existing software package For Linac4 H⁻ ion source[1]


Our 3D KEIO-BFX code is coupled with NINJA, IBSIMU and TRAVEL.

Coupling Scheme for 3D KEIO-BFX



Input:

- Plasma density, temperature at inj. region (from NINJA)
- Extraction Potential Profile with ion beam (from IBSIMU)

output:

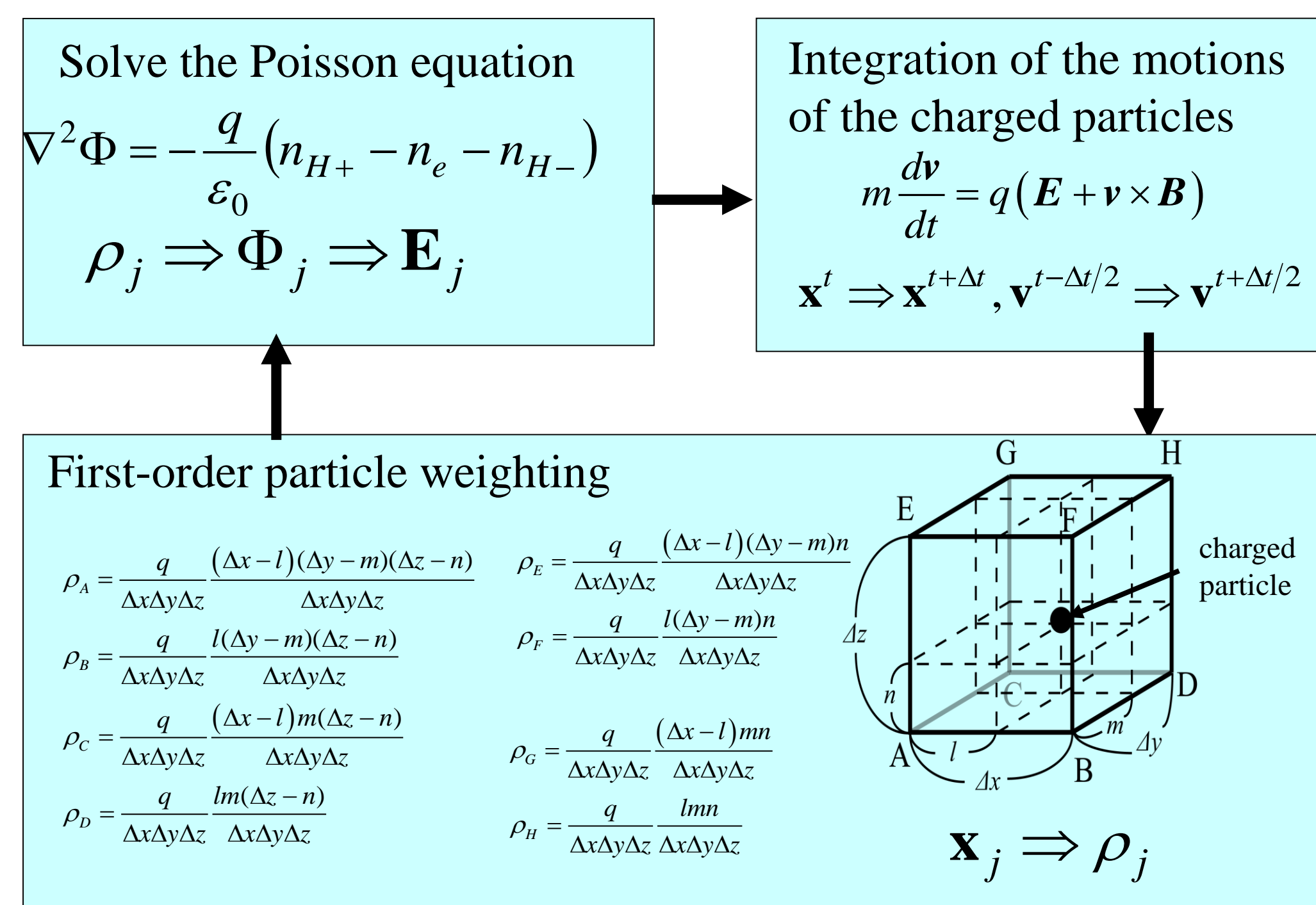
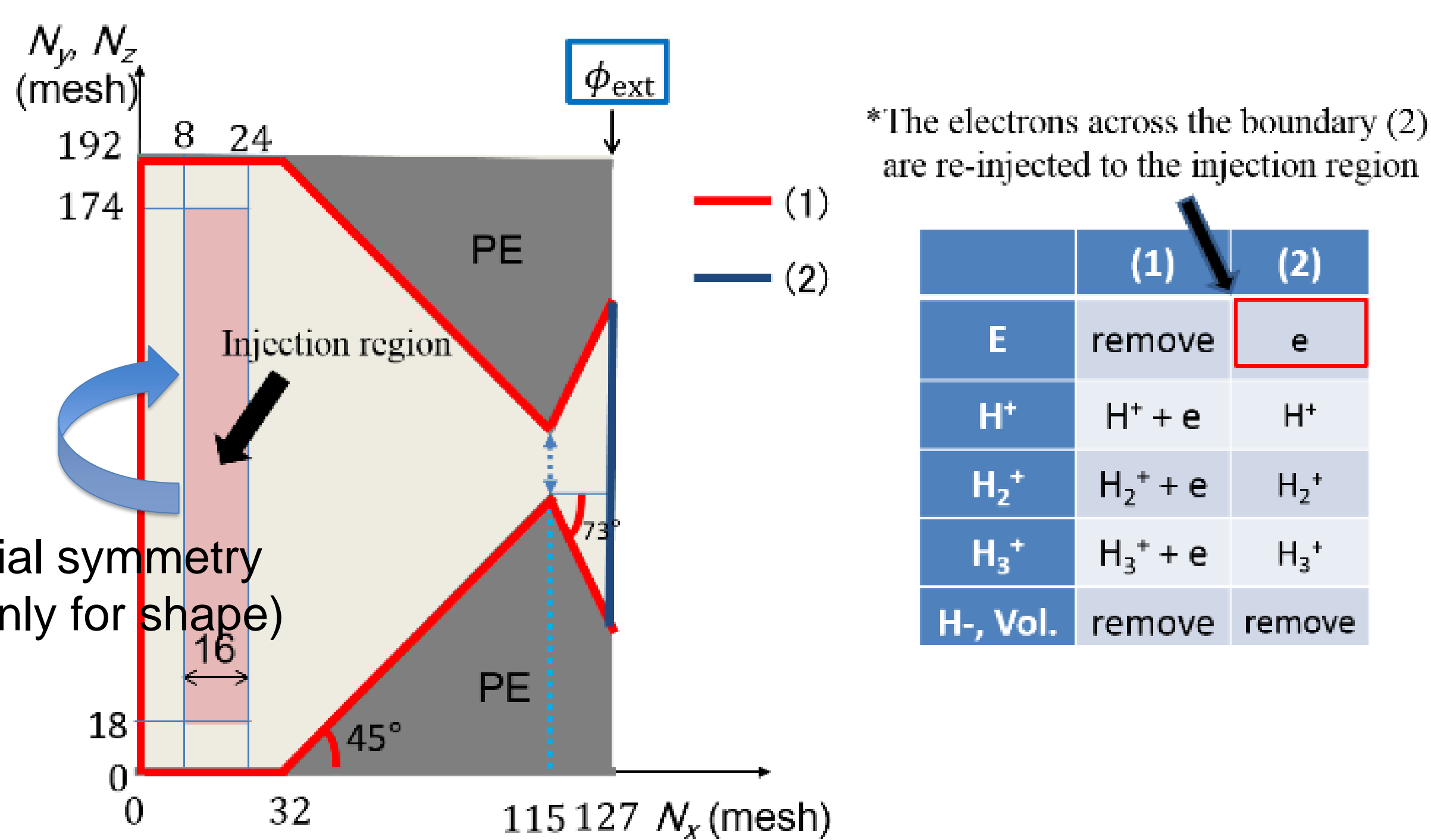
- 3D position and velocity for the extracted charged particle

3D KEIO-BFX model

 Extraction region in Linac4 H⁻ ion source is modeled by 3D PIC scheme

Trajectories of the charged particle is solved by following method in PIC scheme

Input Parameters



Physical Parameters	Symbol	Value
Temperature	T_j	$T_{H^+} = 3.6 \text{ eV}$
		$T_{H^+} = 2.0 \text{ eV}$
		$T_{H_2^+} = 1.8 \text{ eV}$
		$T_{H_3^+} = 1.6 \text{ eV}$
Electron Density	n_e	$4.0 \times 10^{18} \text{ m}^{-3}$
	n_{H^+}	$1.6 \times 10^{18} \text{ m}^{-3}$
	$\sum_{v=0}^{13} n_{H2(v)}$	$6.2 \times 10^{18} \text{ m}^{-3}$
Ratio for dens.	$n_e : n_{H^+} : n_{H_2^+} : n_{H_3^+}$	40:30:3:7

Mesh size : $0.625 \lambda_{De}$ ($\lambda_{De} = 7.1 \times 10^{-6} \text{ m}$)
 Scaling factor : 1.75×10^{-2}
 Mesh : $128 \times 193 \times 193$
 Real size : $31.75 \text{ mm} \times 48 \text{ mm} \times 48 \text{ mm}$
 Time step : $0.4 \omega_p = 1.8 \times 10^{-10} \text{ rad/s}$
 Full 3D magnetic field is specified from Ref. [8]
 Collision: DA, AD, ED, H2ED are taken into account by null collision

Results; case of the H⁻ extraction w/o Cs (only volume produced H⁻)

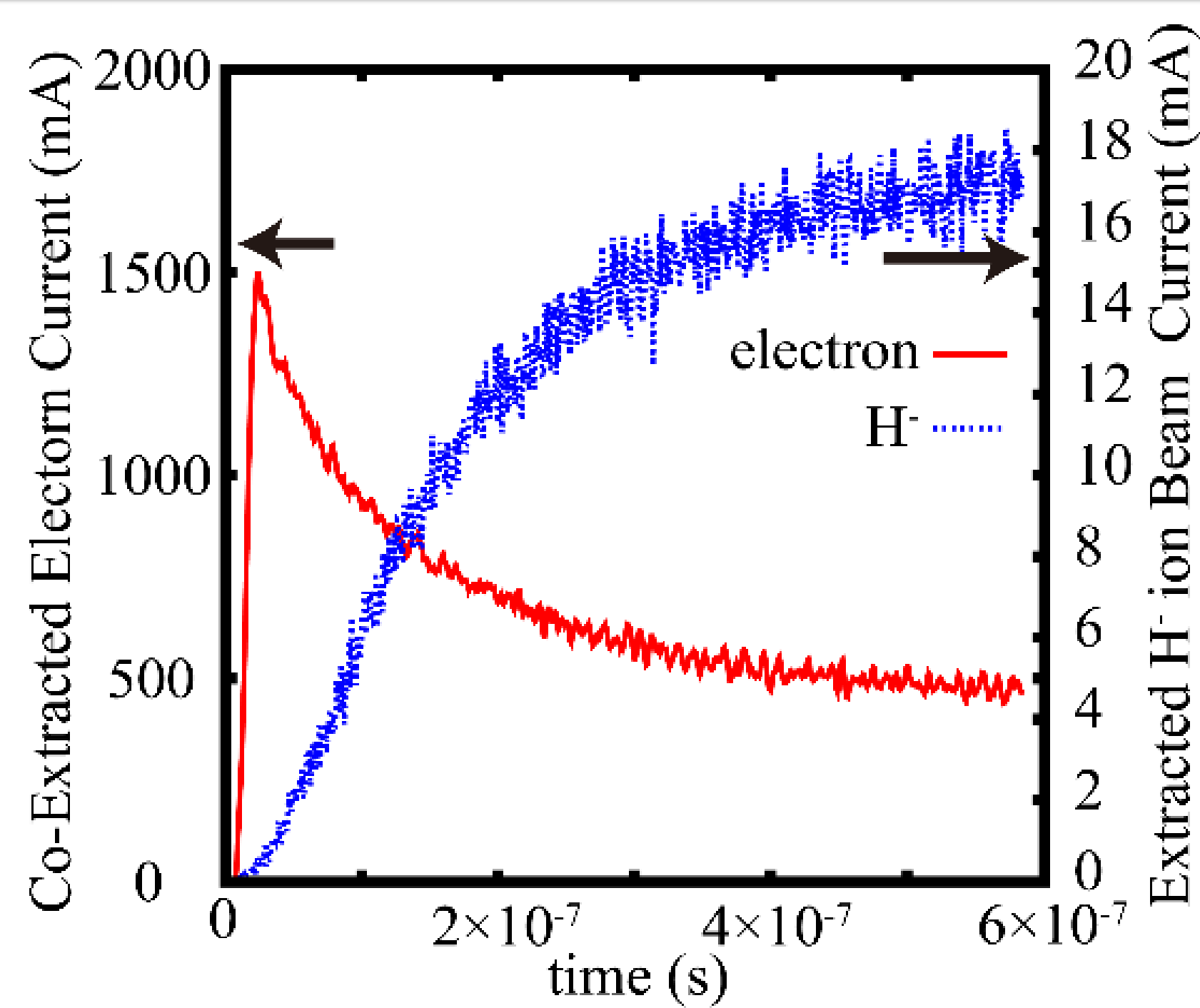


Fig. Time evolution of the extracted electron current density by each code

- $j_{H^-, \text{ext}}$: 17.2 mA
- $j_{e, \text{ext}}/j_{H^-, \text{ext}}$: 28.5

→ reasonable agreements with experiments (20~30mA, 20~30)

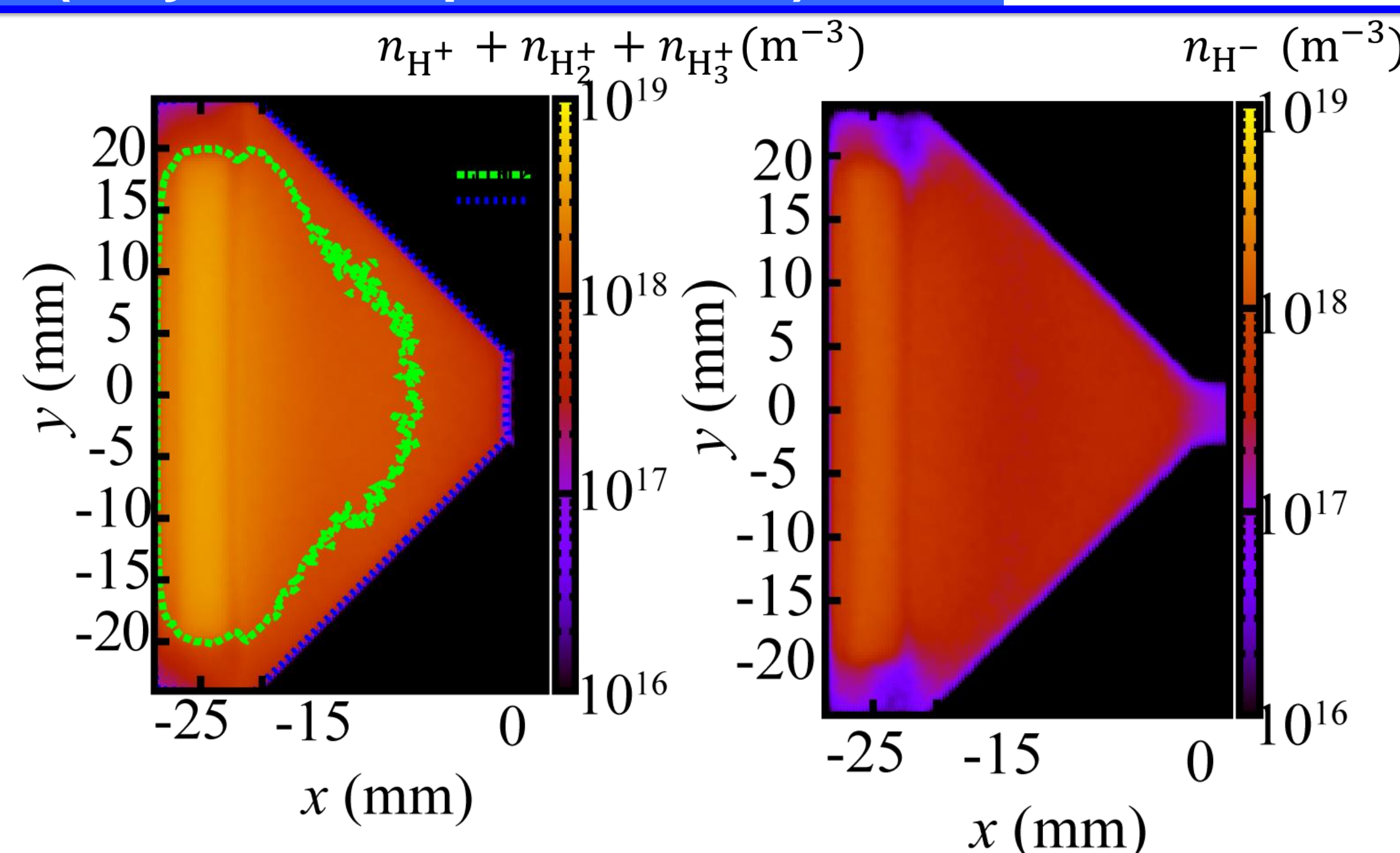
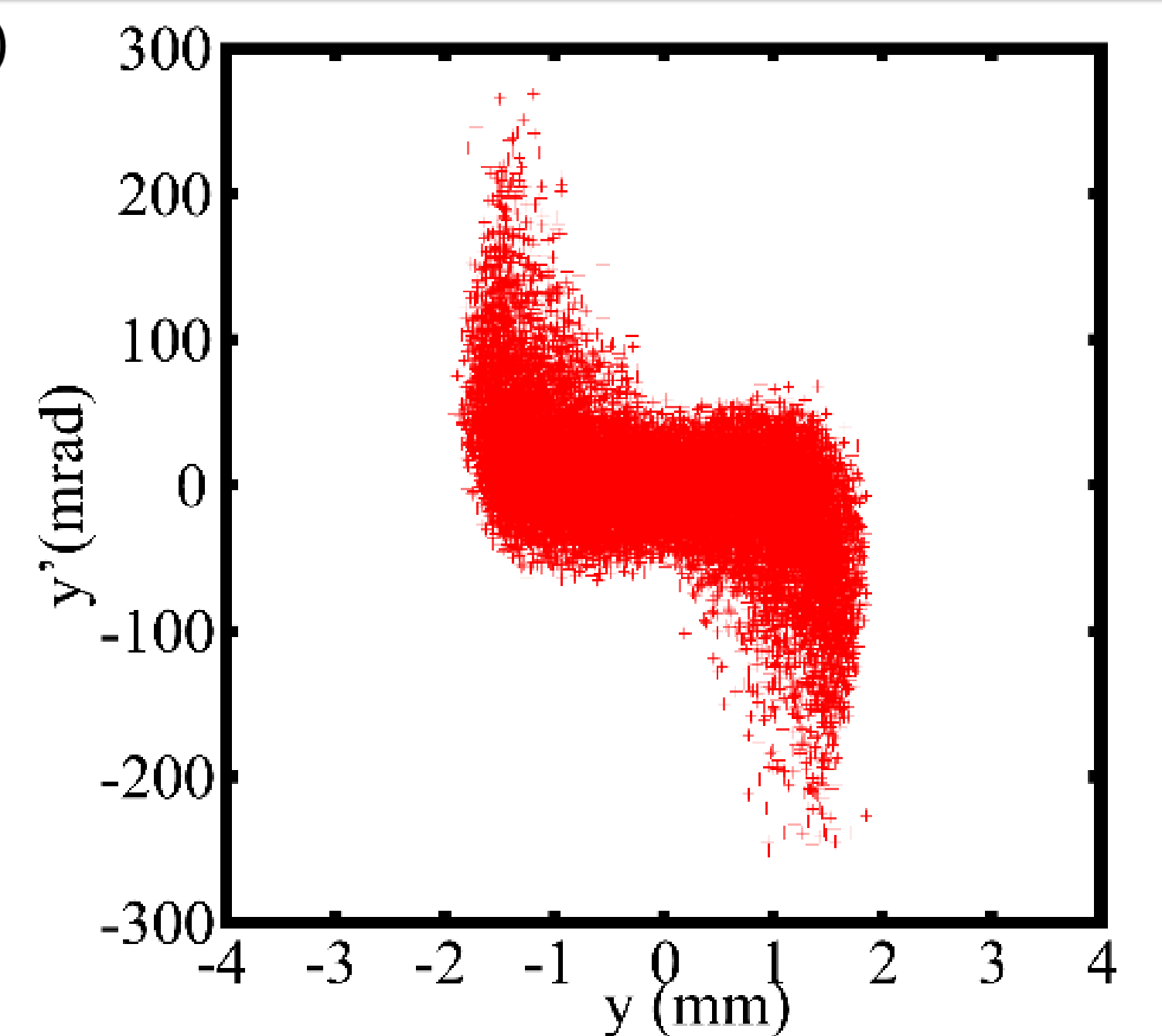


Fig. 2D density profile for in the x-y mid-plane which is parallel to the magnetic field.


 Fig. Emittance diagram at $x = x_{\text{max}}$ along y direction

 $\epsilon_{\text{norm, rms}} : 0.08 \pi \text{ mm} \cdot \text{mrad}$

→ Based on this emittance diagram, the emittance growth in acceleration region and LEBT will be calculated by IBSIMU and TRAVEL

Conclusion

(1) Extracted H⁻ ion beam current and the ratio of the co-extracted electron current to the H⁻ ion beam current are estimated from the integrated model to be 17.2 mA and 28.5, respectively.

→ these results are in reasonable agreement with the experiments (20~30 mA, 20~30)

(2) Normalized emittance at $x = x_{\text{max}}$ along the y direction is estimated to be $0.08 \pi \text{ mm} \cdot \text{mrad}$

→ Emittance growth during the beam acceleration will be calculated by the IBSIMU and TRAVEL.

References

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