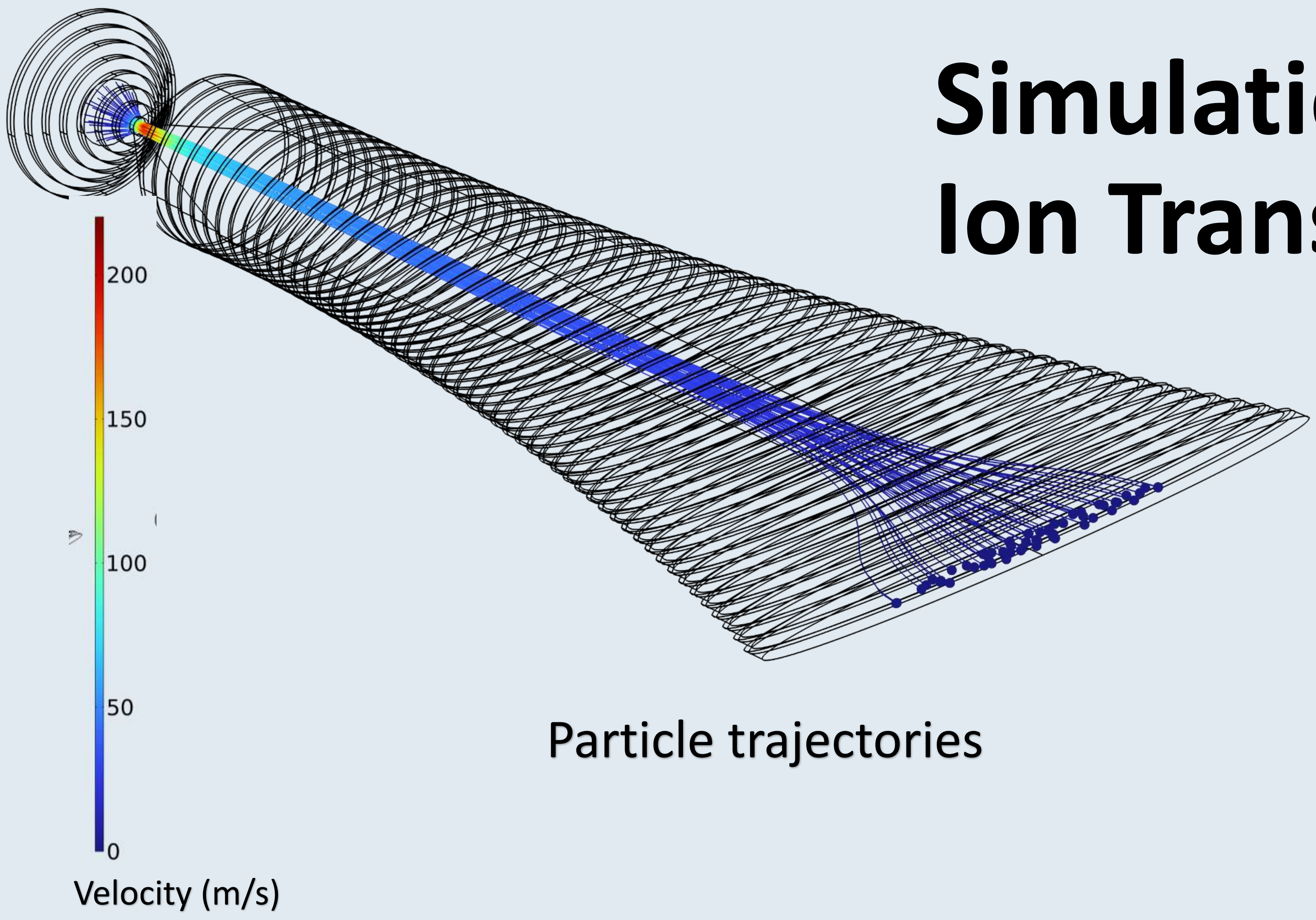
Simulation Studies on a High-Pressure Ion Transfer by Gas Flow (ITGF) Device



Particle trajectories

The interface between a round gas cell exit and a rectangular detector channel requires the effective transport of ions driven by the gas flow.

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Introduction & Goals

The synthesis of the superheavy elements and investigations of their nuclear, atomic, and chemical properties are at the scientific forefront. Experiments are challenging due to the extremely low production rates down to a single atom per day and short half-lives [1]. A new universal high-density gas stopping cell (Unicell) [2] setup for the study of gas-phase chemistry and nuclear properties of superheavy elements is under construction, allowing highly-efficient and fast ion beam bunching and extraction into high vacuum. For this, an Ion Transfer by Gas Flow (ITGF) device was proposed by us, as an interface between the gas stopping cell and a setup for chemical separation and detection. The ITGF device is a 20 mm long gas channel, along which the cross section changes smoothly from circular to slit-like. This offers exciting prospects in different scientific research applications.

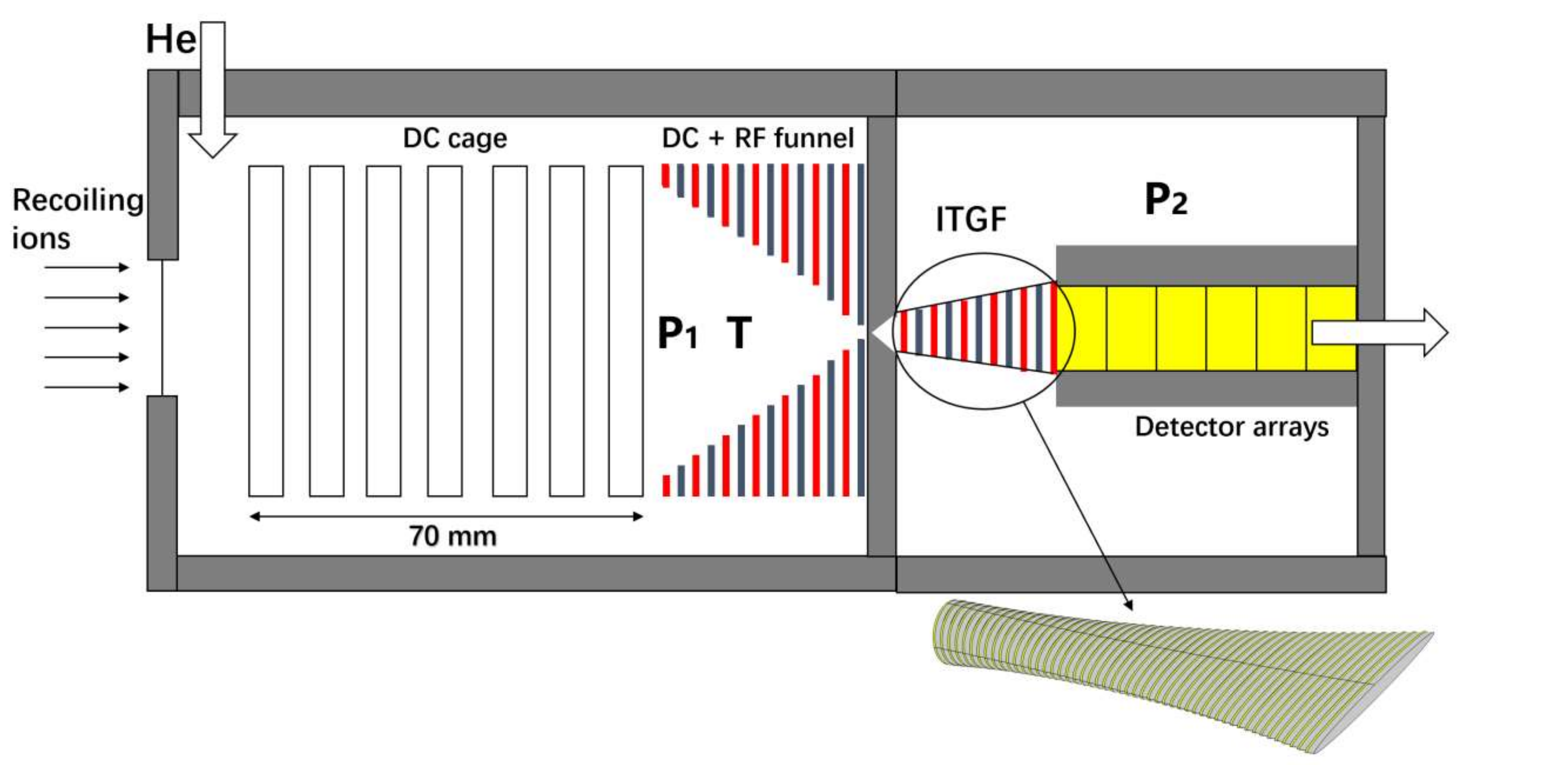

FIGURE 1. The schematic of Unicell setup for the study of chemistry experiments. The 3D model of ITGF setup.

Methodology

The entire gas cell and ITGF are modeled using COMSOL® in 3D. The coupling of the three interfaces "Laminar Flow, Electric Currents, and Particle tracing for fluid flow" is not only used for gas flow simulation in ITGF but also for the simulation of ion trajectories under the combined action of electric field and gas flow in ITGF. Here, "Compressible flow (Ma < 0.3)" is selected as the compressibility of the helium gas flow. The boundary condition of the wall is "freeze", which means that if ions collide with the wall, they will be lost. The "electric field (ec)" and "electric field (es)" are used as the electric force, at the same time, the "Stokes law" is the drag force in this model. The trajectories of 100 (Mass = 293, charge +1, +2) ions were simulated in each run. Their initial position was chosen within the Unicell volume, following a preceding simulation of recoil thermalization.

Results

1. If different gas flow rates are provided (as shown in table 1), then the velocity distribution is also different, which means that the maximum velocity in the nozzle is different.
2. Since the gas velocity in nozzle is very large, the ions are driven only by the helium gas flow and pass through the ITGF device quickly. The extraction efficiency will be very high (nearly 100%). As gas flow rate increases, transport times decrease to 1 ms or less. This allows ions from the gas cell to stably enter the subsequent detector arrays.
3. The radial confinement of ions within the ITGF by RF fields was originally considered but is not required for their efficient transport at the required flow rates.

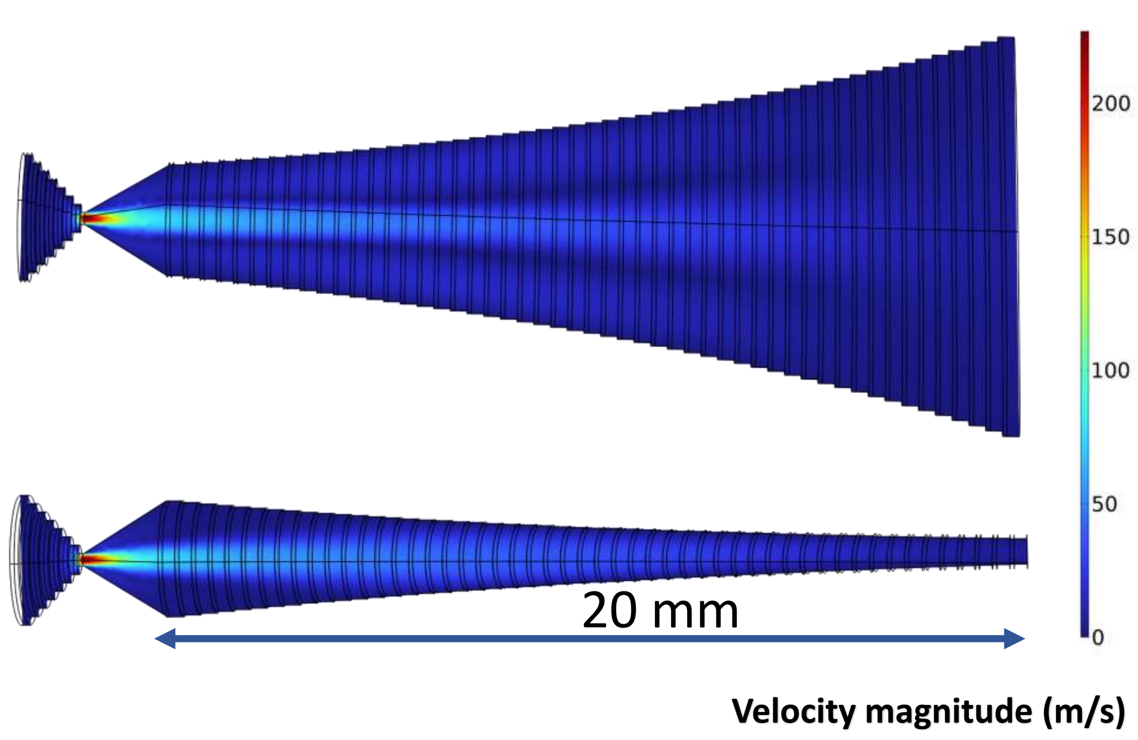

FIGURE 2. Simulated gas flow distribution in vertical and horizontal plane in ITGF device.

TABLE 1. The calculated values of the gas flow velocity in the nozzle (Vmax) and the flow-through time in the ITGF (t) for different flow rates.

Helium flow rate (cm^3/s)	Vmax (m/s)	t (ms)	Extraction Efficiency
2	48	29	100%
6	126	4.5	100%
10	212	1.3	100%
15	350	0.5	100%
20	502	0.3	100%

REFERENCES

[1] Yu.Ts. Oganessian and V.K. Utyonkov, Rep. Prog. Phys. 78, 036301(2015).
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