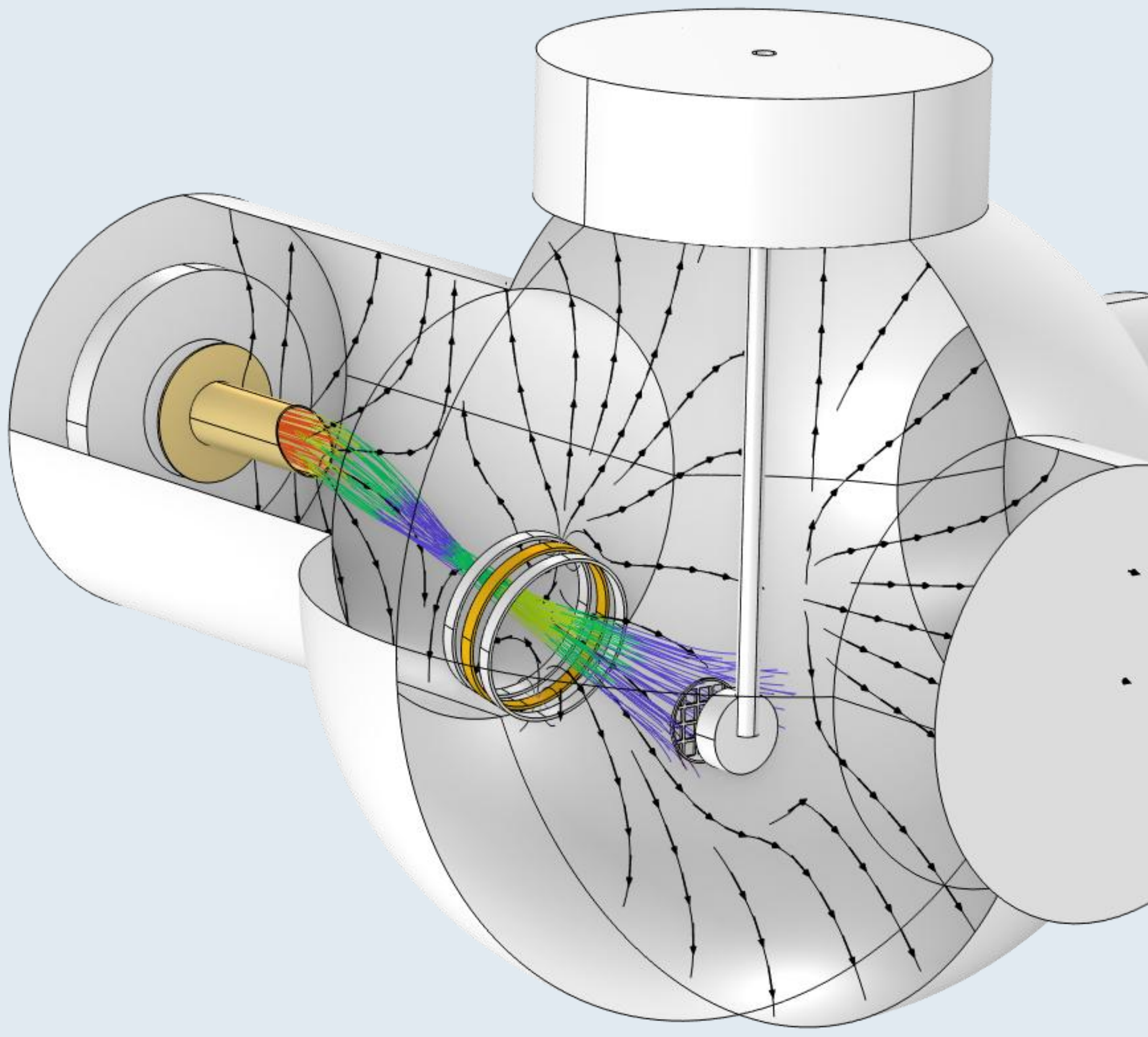




# Efficient Charged Cluster Beam Transport

Improve the transport and delivery of size-selected nanoclusters by revealing how electrostatic fields, cluster energy, and particle size govern beam focusing and transmission.

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## Abstract

During commissioning of the size-selected cluster source at beamline B07 in Diamond light source, very low cluster current was measured at the sample holder when using the original four-plate electrostatic deflector. When the deflector was removed, the current increased, but the beam spread across the deposition chamber. COMSOL Multiphysics® simulations showed that the original geometry produced strong transverse electric field components, causing beam divergence and inefficient transport.

Based on these results, a cylindrical tube deflector was designed and implemented, leading to improved beam steering and successful localized deposition of size-selected Pd clusters. Further simulations indicated that small, low-energy clusters remained particularly sensitive to electrostatic perturbations. An Einzel lens-inspired focusing geometry was therefore developed to improve beam confinement and transport for low-energy cluster deposition.

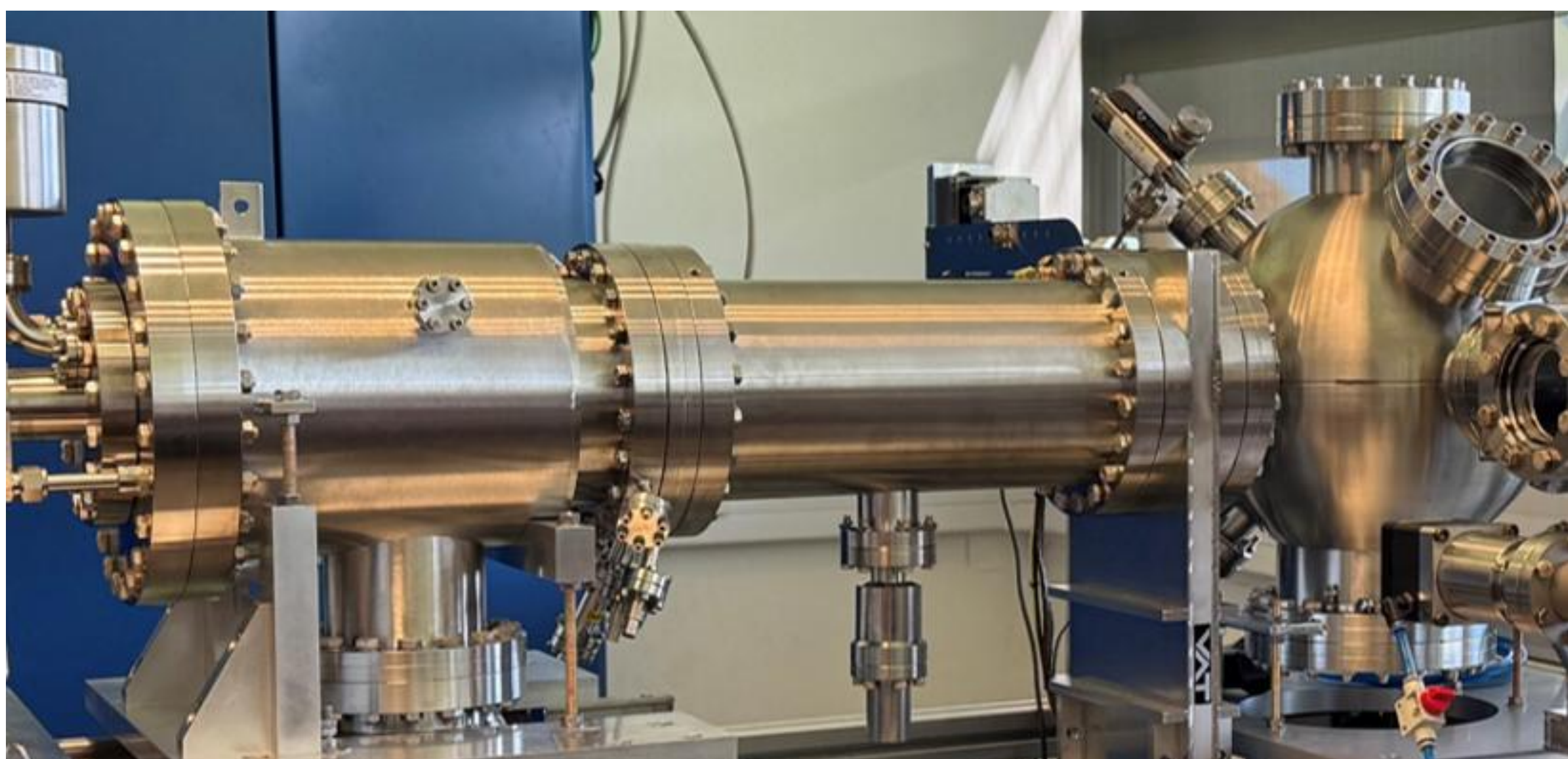


FIGURE 1. DLS-B07 size-selected cluster source and deposition system used for nanocluster beam generation, filtering, transport and deposition.

## Methodology

The electrostatic field and charged cluster transport are modelled in three dimension (3D) using COMSOL Multiphysics®. The model includes all the possible elements to reproduce the electric-field environment experienced by the charged clusters. The electric field and Cluster trajectories are obtained from the electrostatic potential and forces:

$$\nabla \cdot (\epsilon_0 \epsilon_r \nabla V) = 0, E = -\nabla V, m \frac{dv}{dt} = qE.$$

Initial cluster velocity is defined from the experimentally measured cluster kinetic-energy distribution obtained using a Retarding Field Analyzer (RFA) method by measuring current-voltage at QMF grid position.

## Results

For Pd<sub>78</sub> clusters with an experimentally measured kinetic energy of 0.8 eV, the simulations show pronounced beam divergence when no additional focusing optics are used, resulting in poor confinement across the deposition chamber. Introducing the asymmetric electrostatic lens improves beam steering and shifts the trajectories toward the sample region, although a fraction of the beam remains divergent. The addition of the Einzel lens provides further focusing and confines the trajectories more effectively around the target position. This simulation trend is supported by the experimental spatial current scan, where application of the focusing voltage produces a substantially stronger and more localized cluster-current peak within the sample region. Together, the results demonstrate that combining asymmetric steering with additional electrostatic focusing can significantly improve the delivery of low-energy size-selected clusters to the substrate.

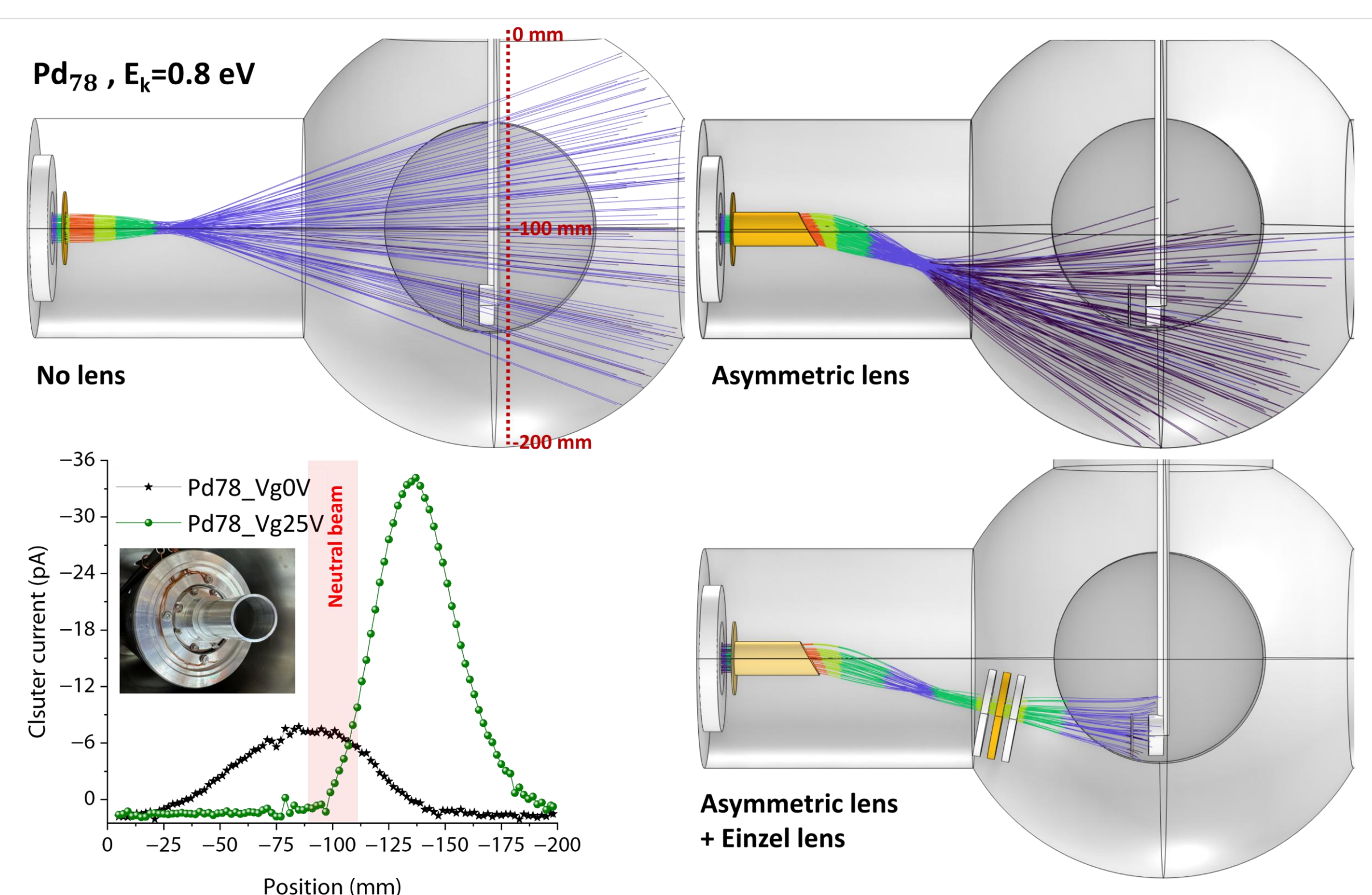


FIGURE 2. COMSOL Multiphysics® simulations of Pd<sub>78</sub> cluster transport ( $E_k = 0.8\text{ eV}$ ) comparing no focusing optics, an asymmetric electrostatic lens, and an asymmetric + Einzel lens configuration. The measured spatial cluster-current profile confirms improved beam localization when the focusing voltage is applied.

## REFERENCES

A. Large., et al. "Operando XPS studies of precisely size-selected Pd nano-catalysts for methane oxidation." *Faraday discussions* (2026).

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