

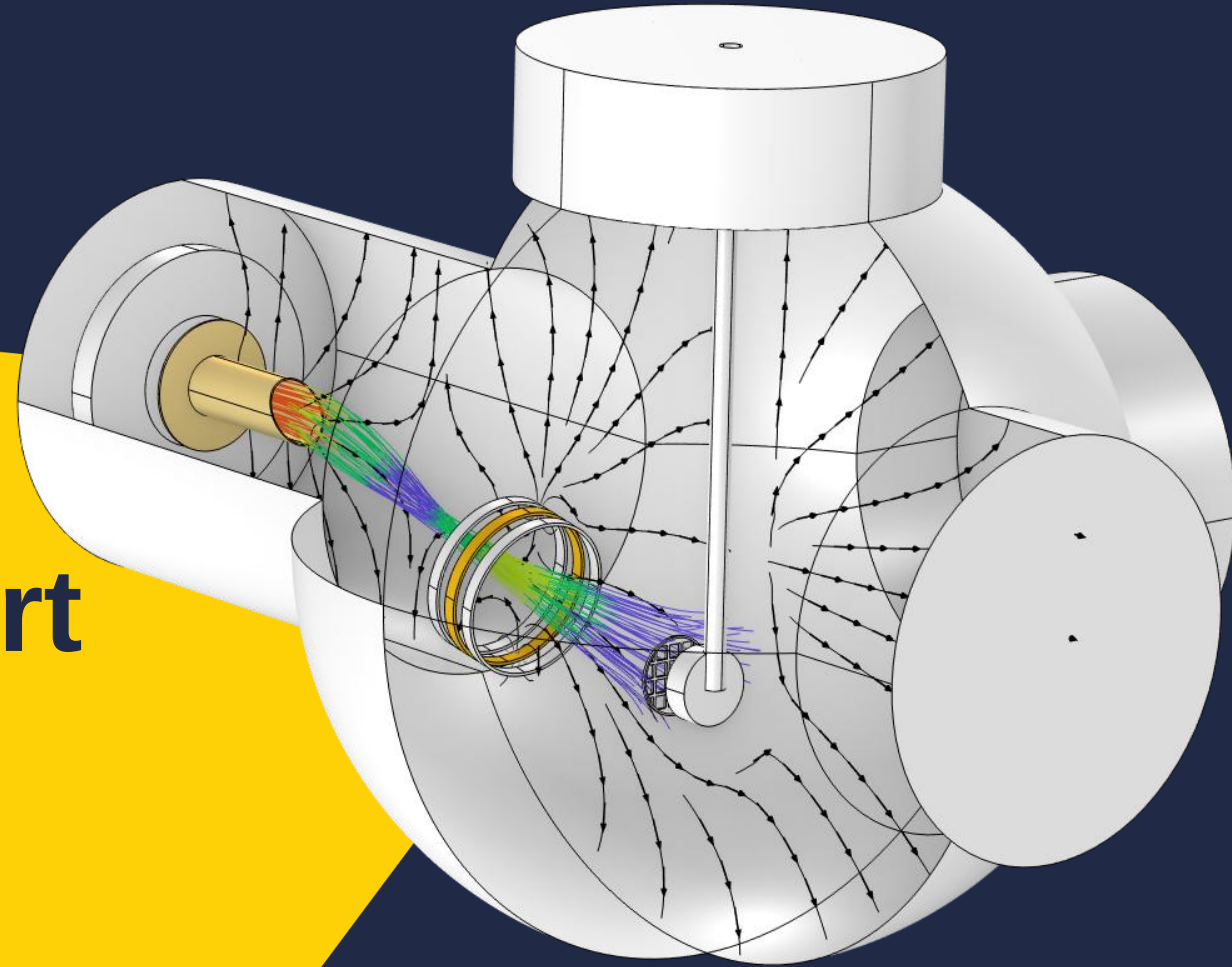
Efficient Charged Cluster Beam Transport

Ali Khatibi, Matthijs van Spronsen, Georg Held

Diamond Light Source, UK

COMSOL Conference | 2026 Cambridge

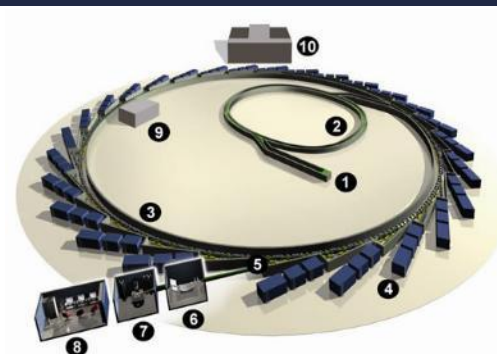
Ali.khatibi@diamond.ac.uk



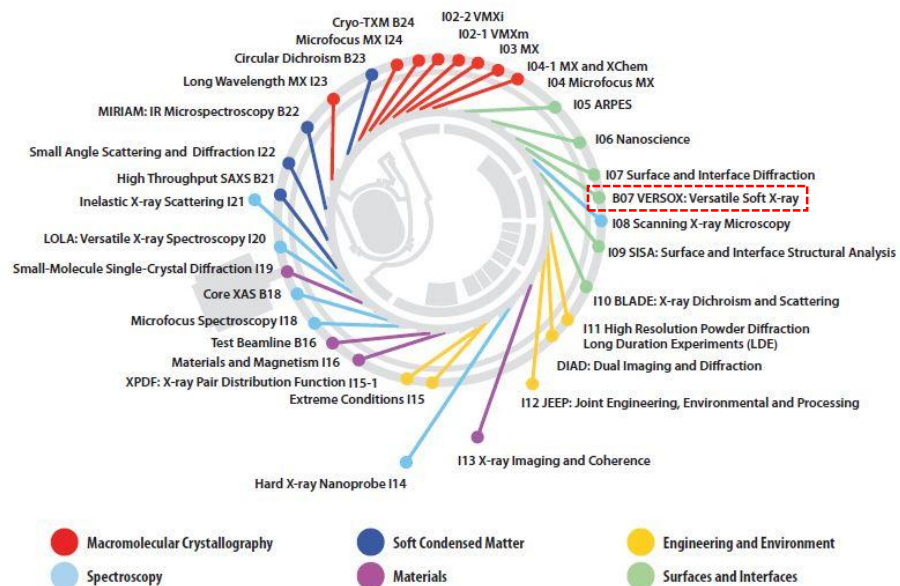


Introduction: Diamond Light Source - Beamline B07

- UK National Synchrotron Radiation Facility In operation since 2007
- > 4000 scientists (universities and industry) visit every year
- Fundamental and applied research in many fields...

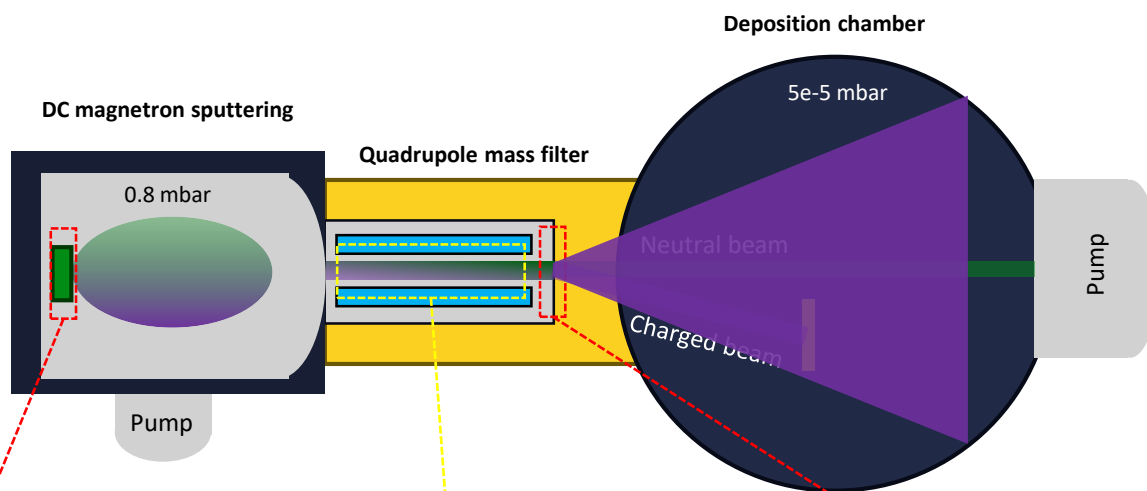


Advancing UK
science
goals



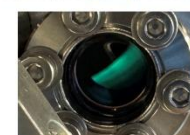


Introduction: DLS-B07 size-selected cluster source



Sputtering source

Sputtering Metal vapors from targets surface by an argon/helium plasma and forming nanoparticles in aggregation zone.



In-situ plasma spectroscopy

Real-time plasma spectroscopy of process to detect gaseous species, impurity Monitoring target sputtering



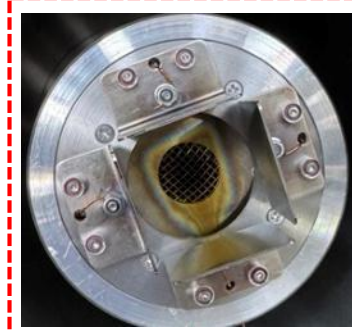
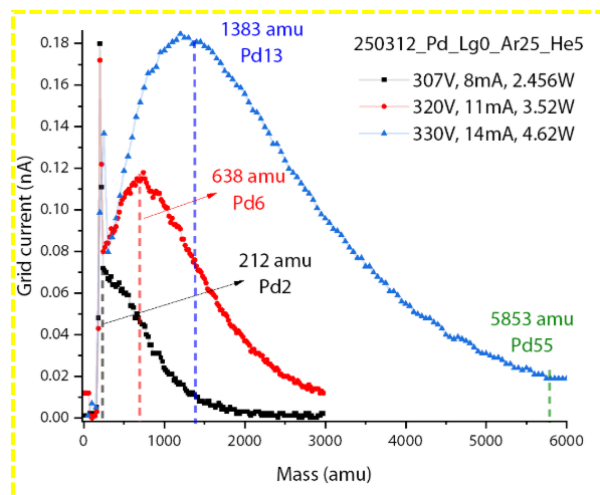
In-line Quadrupole Mass Filter

Real-time scanning or filtering of clusters by mass (amu) or diameter (nm) Monitoring cluster current and energy on grid

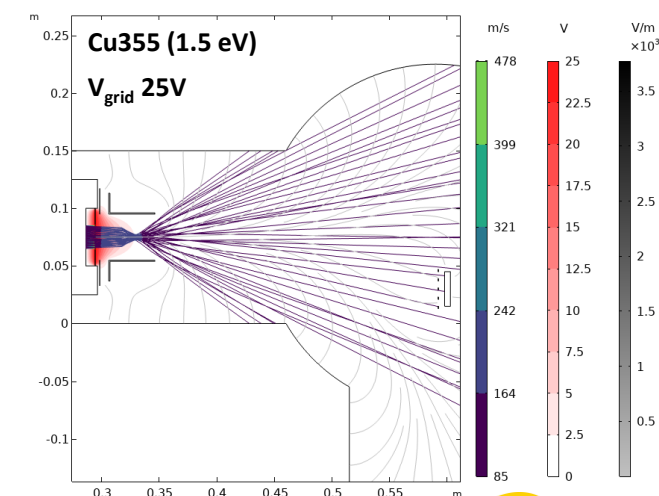
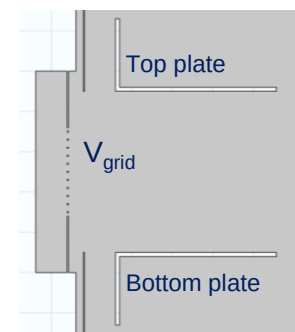


Automated sample holder

Monitoring cluster current Individually controlling cluster coverage and kinetic energy



Comsol 2D case

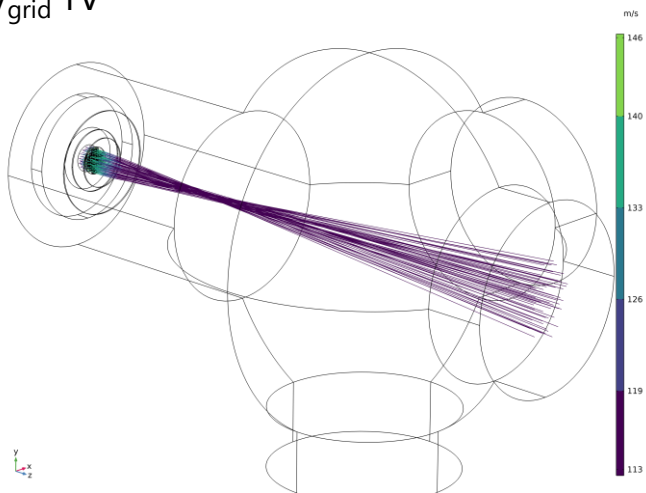




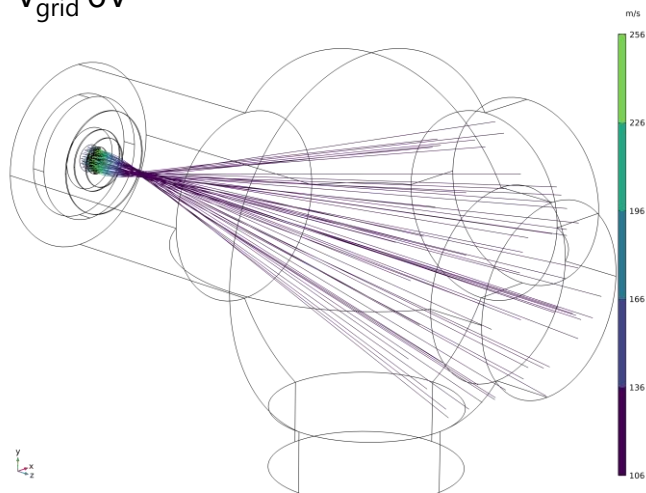


Results: Cluster beam divergent

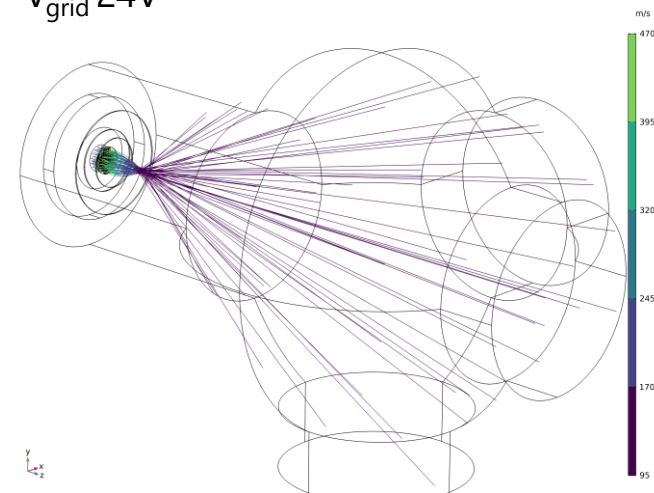
$V_{\text{grid}} 1\text{V}$



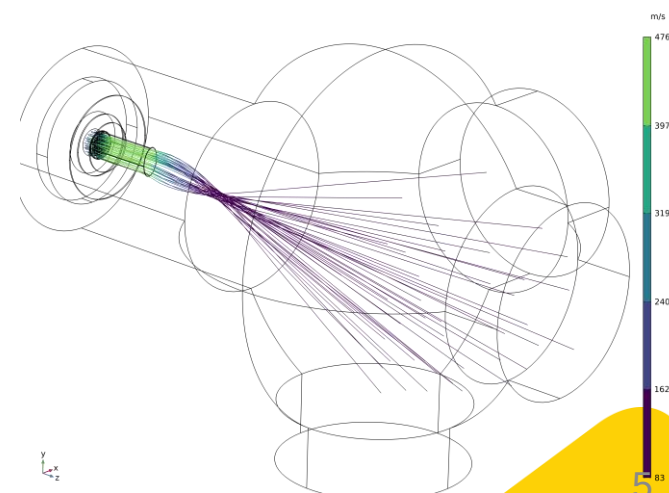
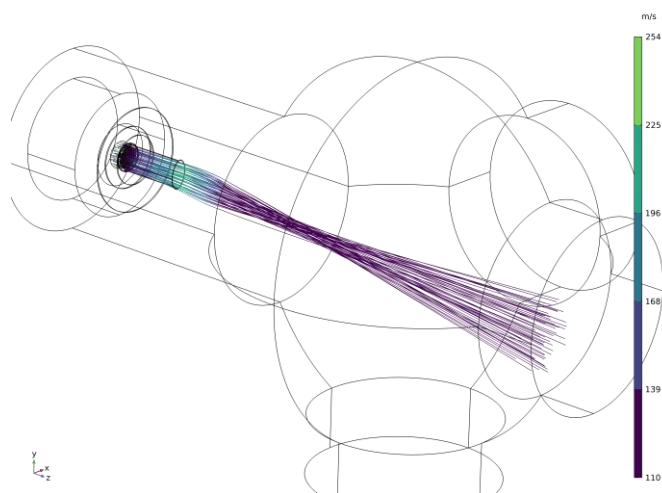
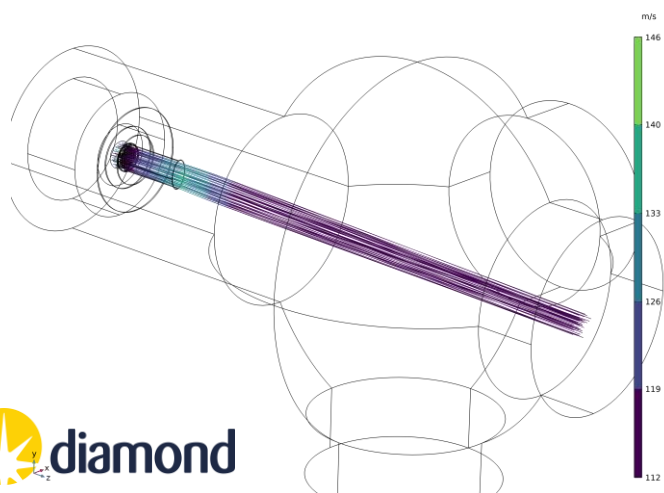
$V_{\text{grid}} 6\text{V}$



$V_{\text{grid}} 24\text{V}$



Cu355 (1.1eV)

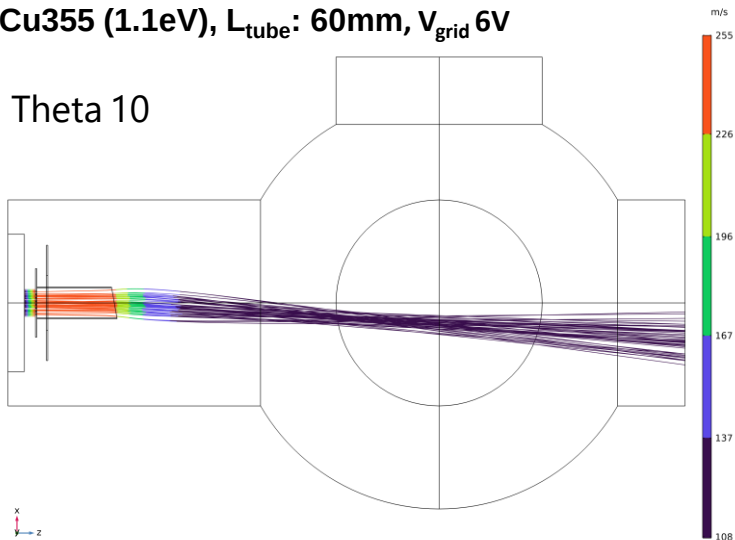




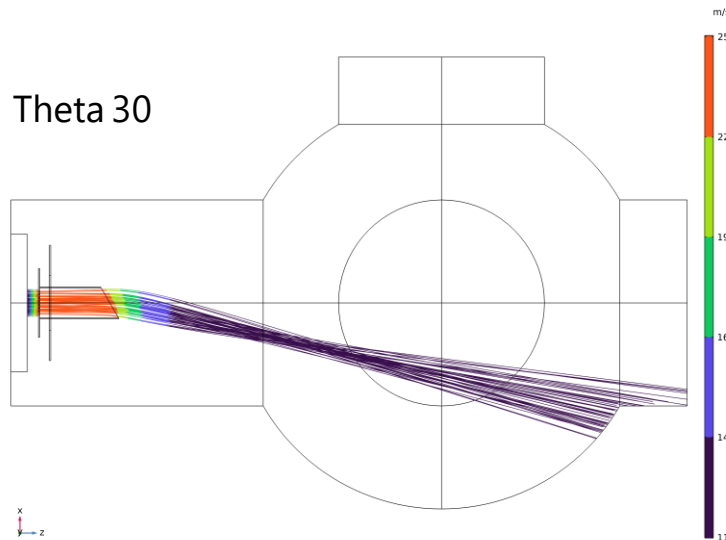
Results: Asymmetric tube

Cu355 (1.1eV), L_{tube} : 60mm, V_{grid} 6V

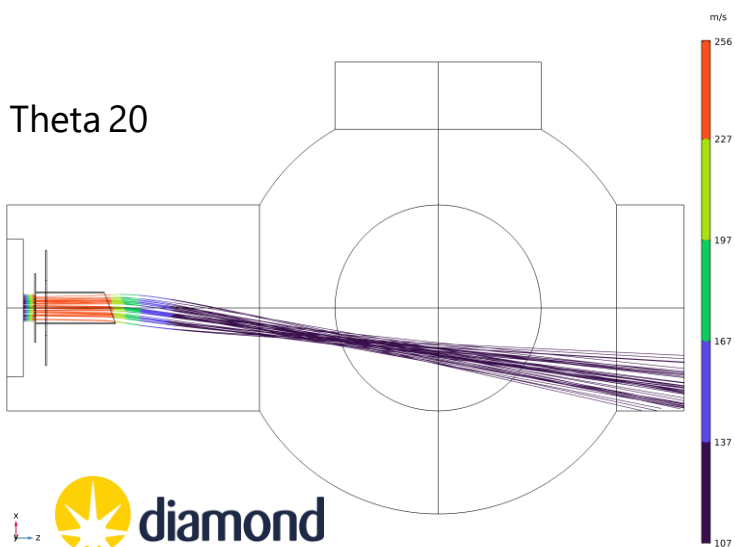
Theta 10



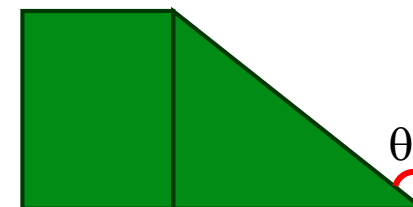
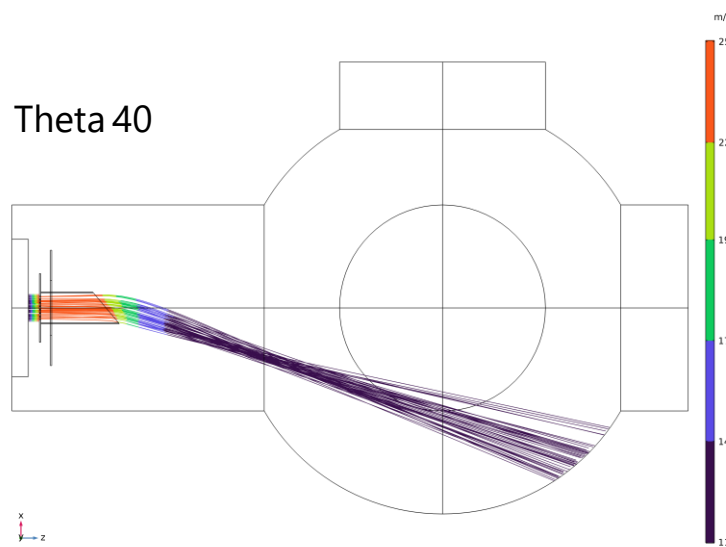
Theta 30



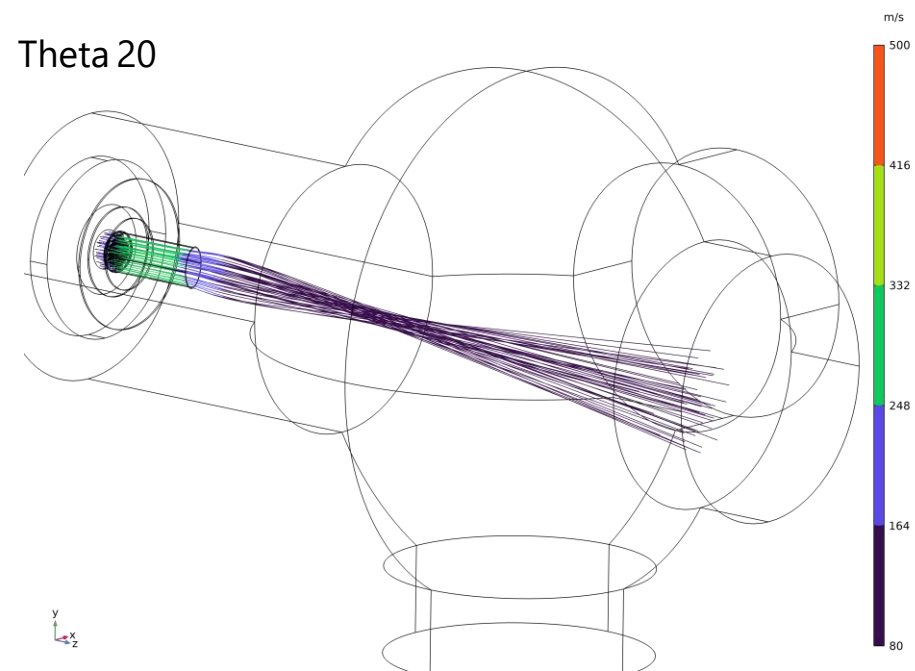
Theta 20



Theta 40



Theta 20

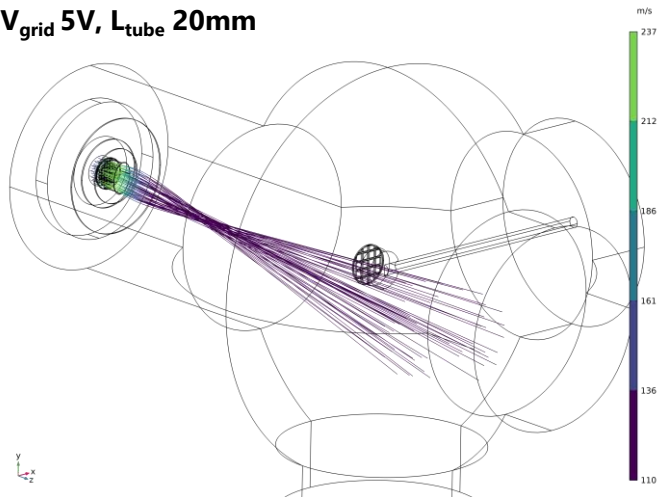




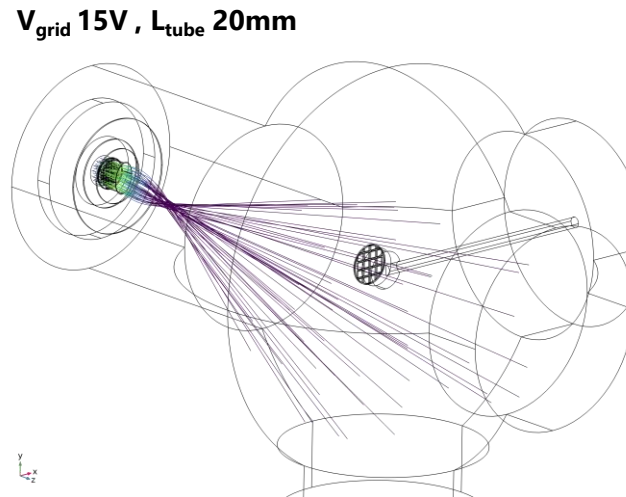
Results: Asymmetric tube

Cu355
(1.1eV)

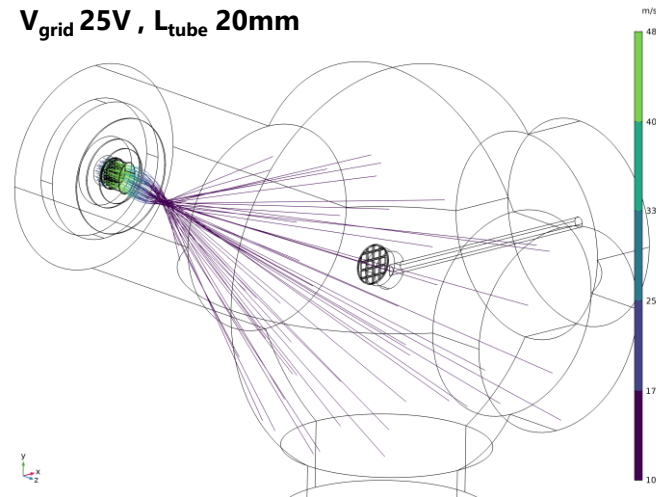
$V_{\text{grid}} 5\text{V}, L_{\text{tube}} 20\text{mm}$



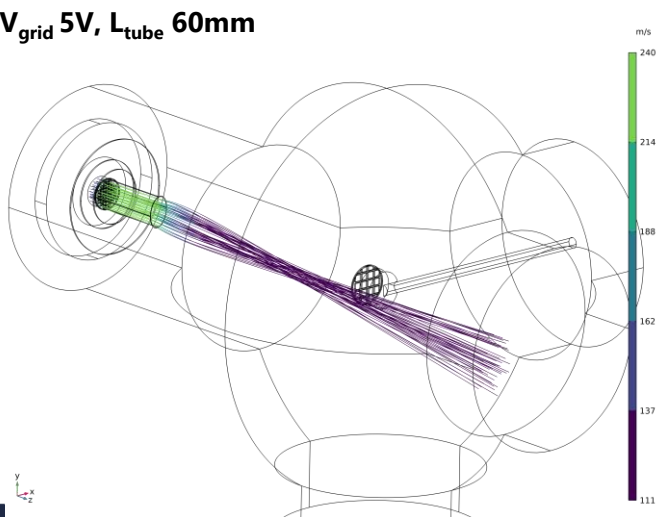
$V_{\text{grid}} 15\text{V}, L_{\text{tube}} 20\text{mm}$



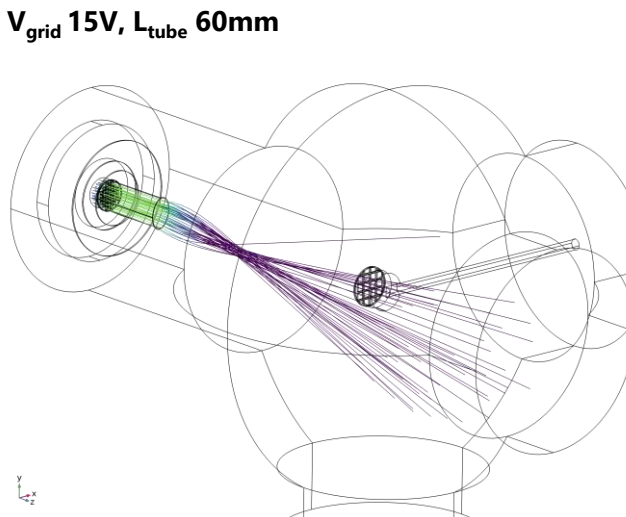
$V_{\text{grid}} 25\text{V}, L_{\text{tube}} 20\text{mm}$



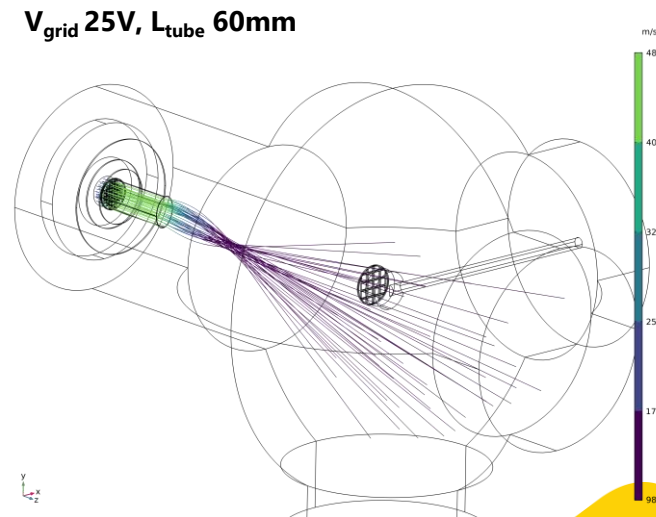
$V_{\text{grid}} 5\text{V}, L_{\text{tube}} 60\text{mm}$



$V_{\text{grid}} 15\text{V}, L_{\text{tube}} 60\text{mm}$

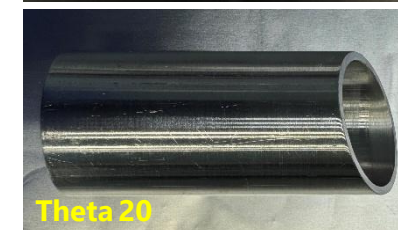
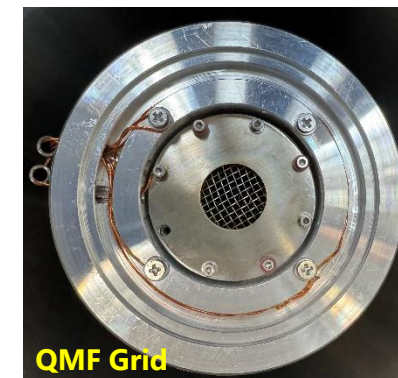
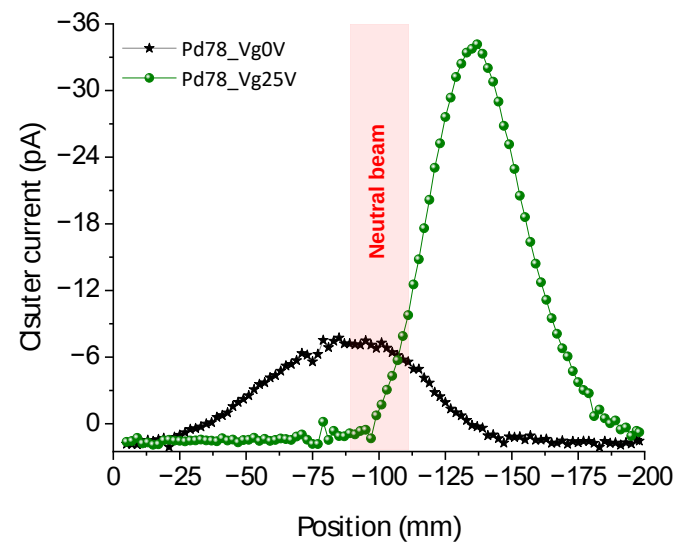
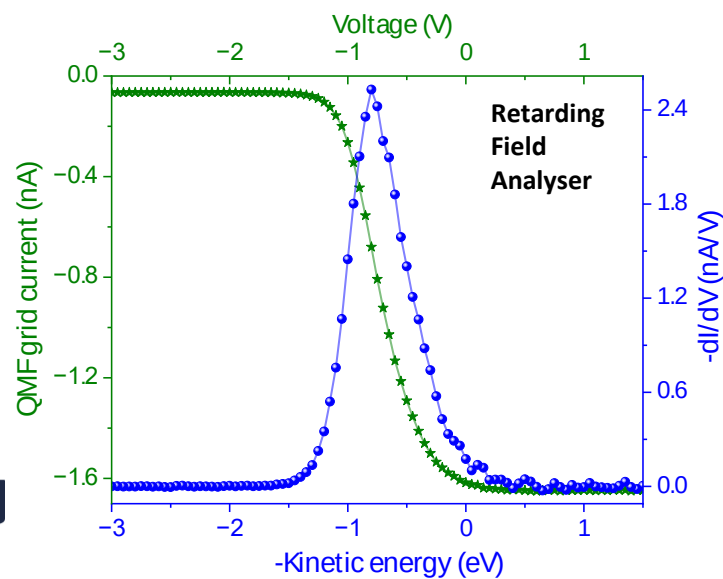
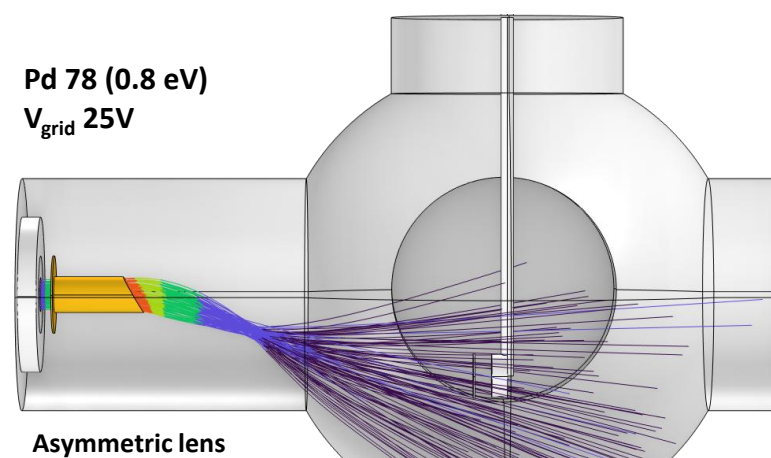
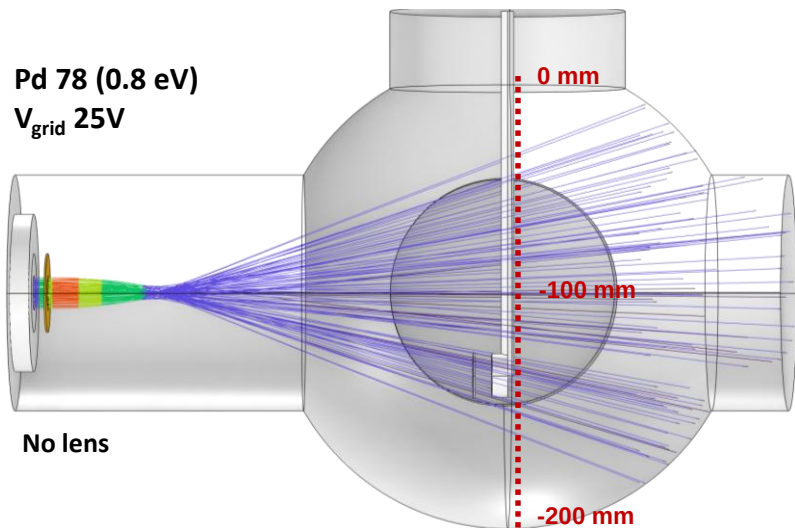


$V_{\text{grid}} 25\text{V}, L_{\text{tube}} 60\text{mm}$



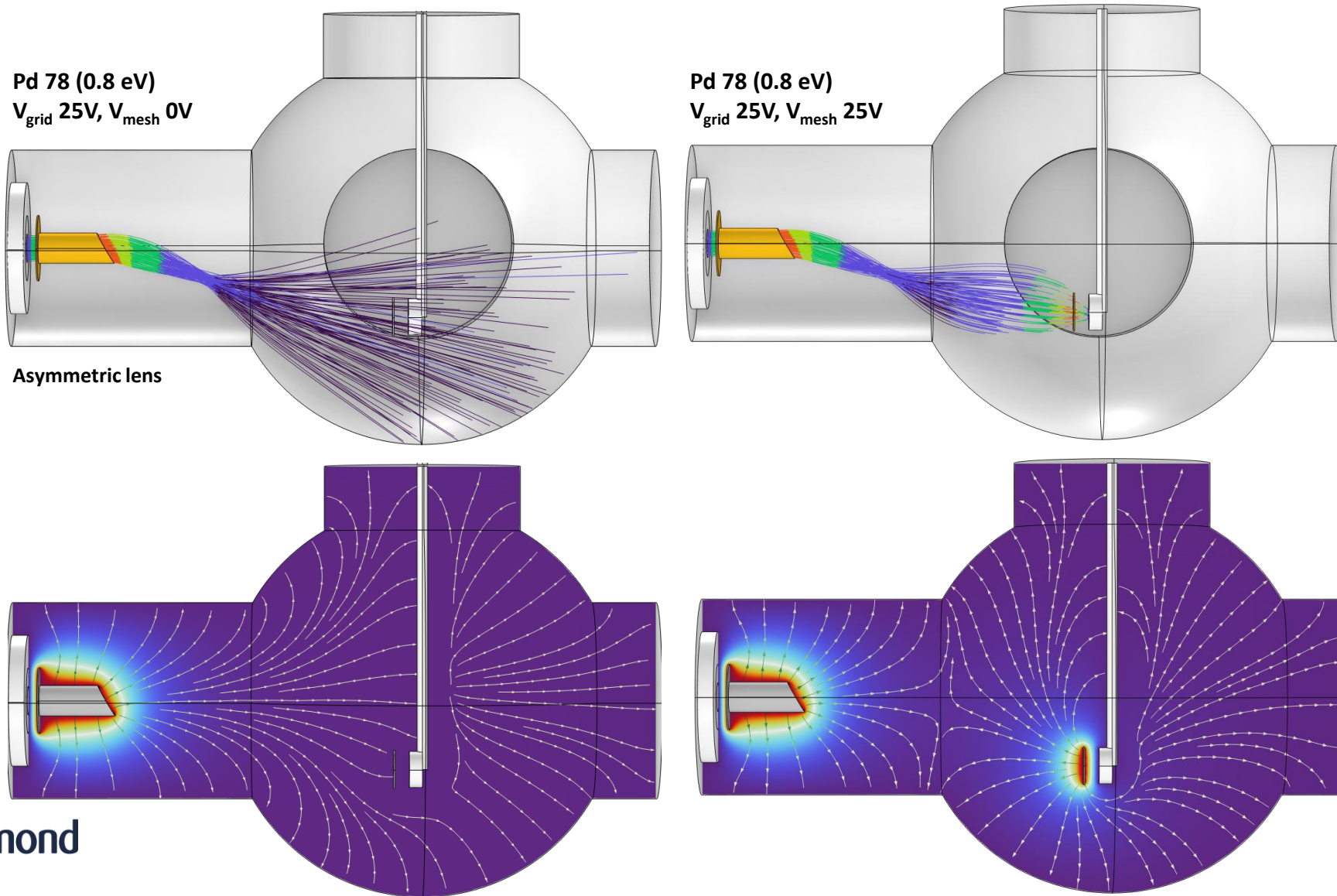


Results: Charged cluster beam deflection

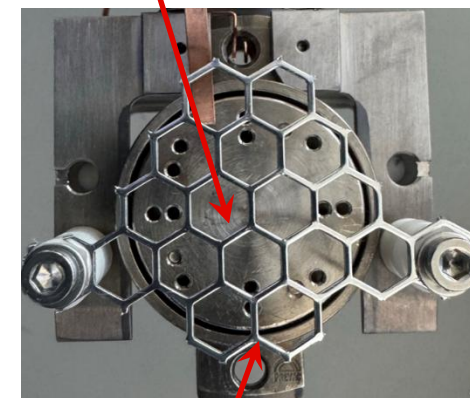




Results: Charged cluster beam deflection



Sample holder

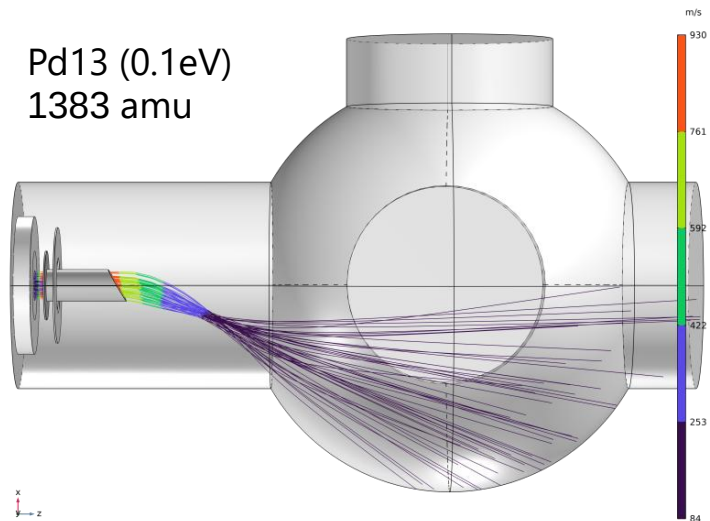


Mesh

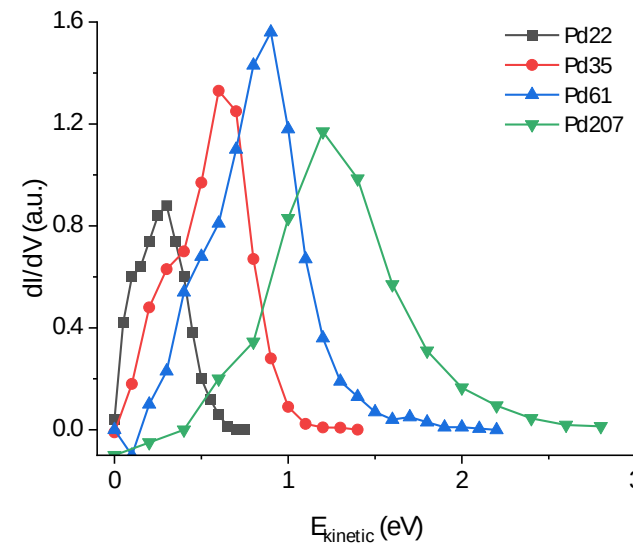
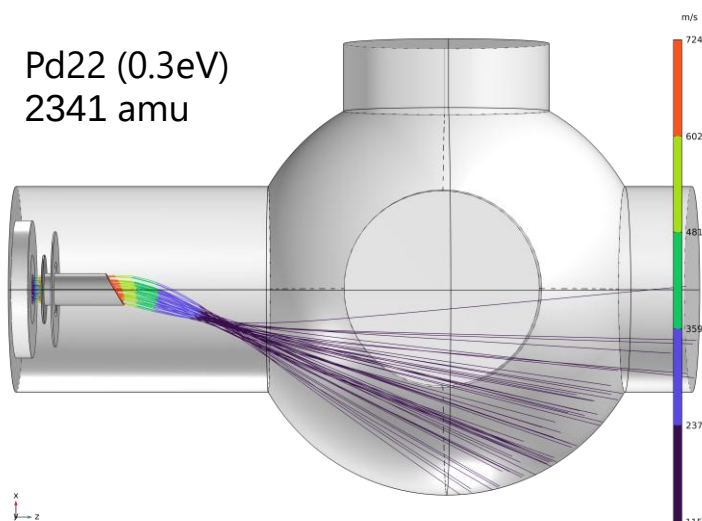


Results: Pd clusters

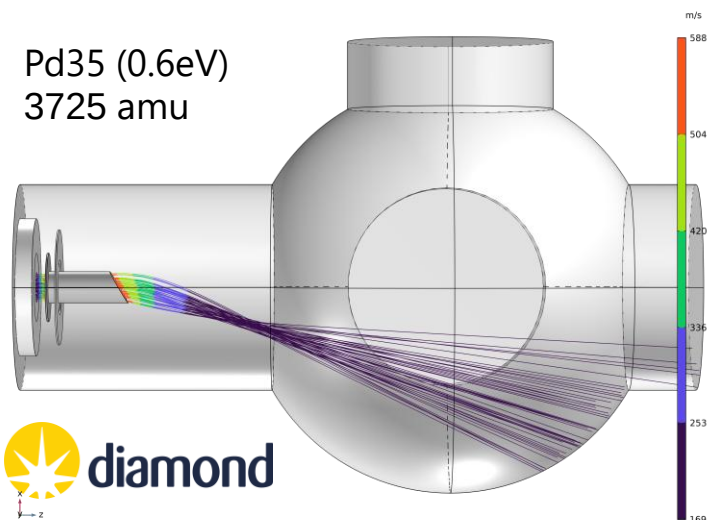
Pd13 (0.1eV)
1383 amu



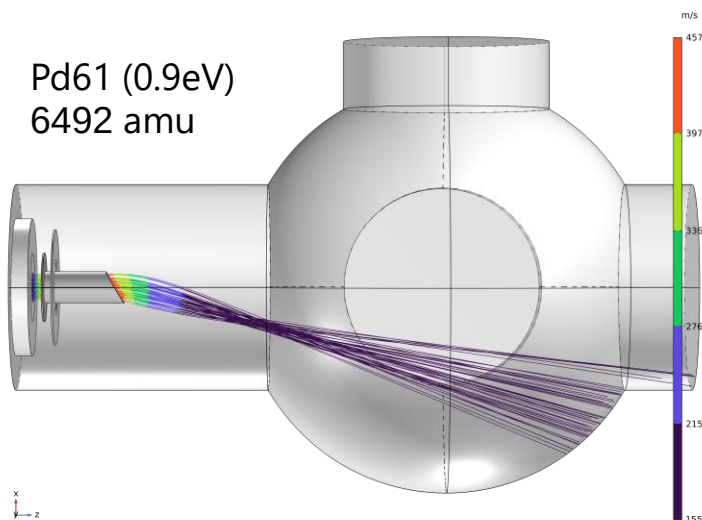
Pd22 (0.3eV)
2341 amu



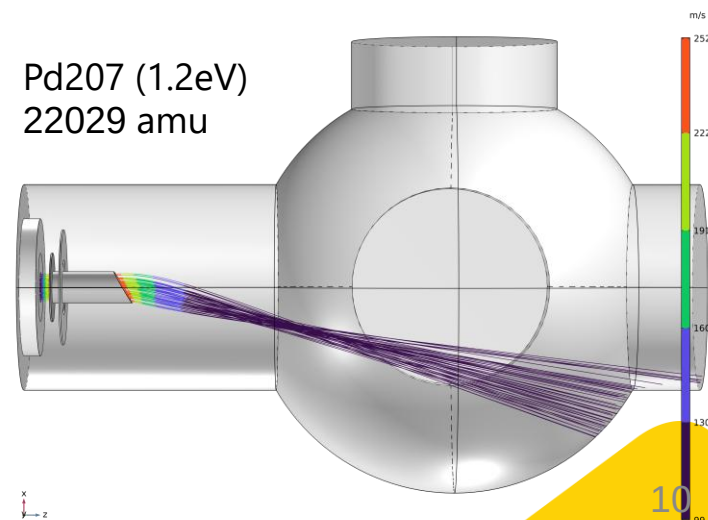
Pd35 (0.6eV)
3725 amu



Pd61 (0.9eV)
6492 amu



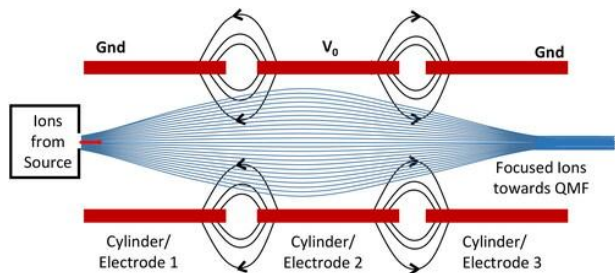
Pd207 (1.2eV)
22029 amu



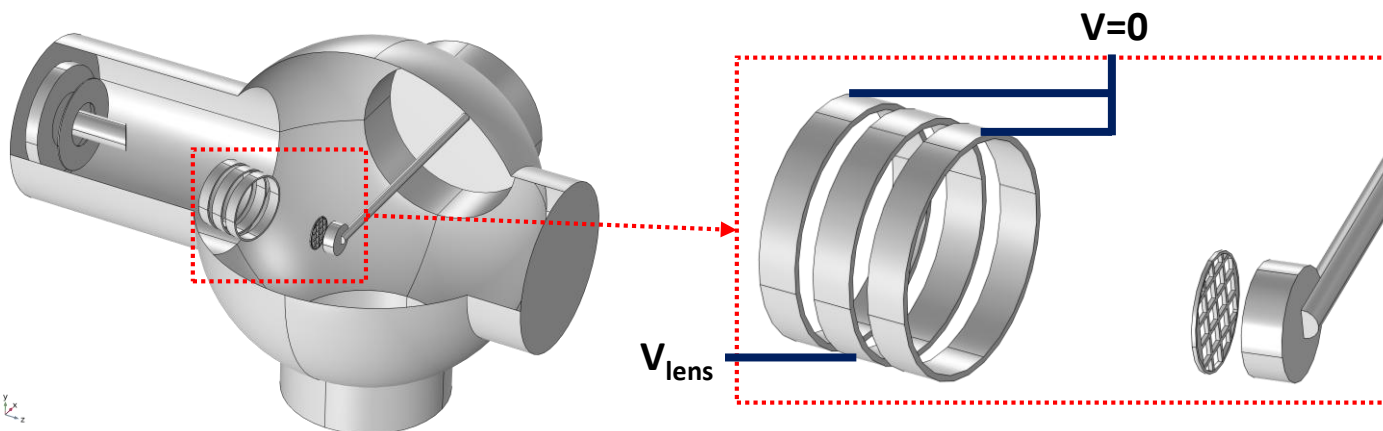


Results: Small clusters divergent

Using Einzel lens to confine cluster beam

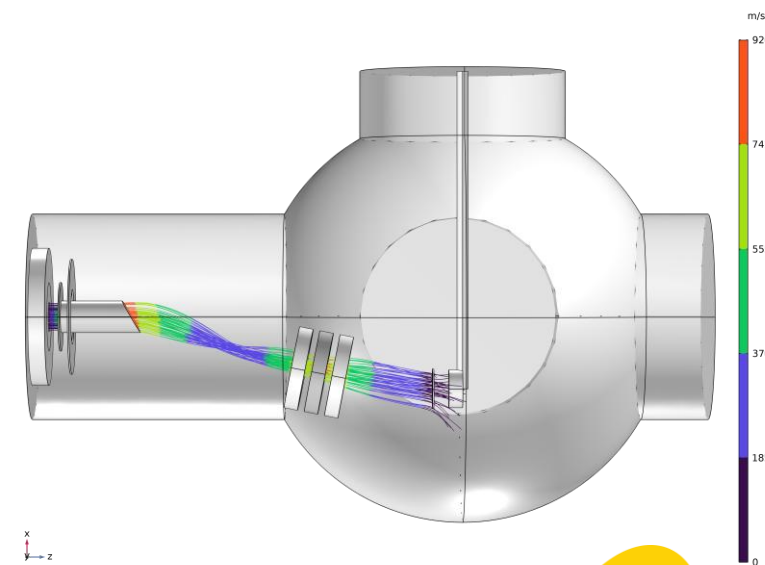
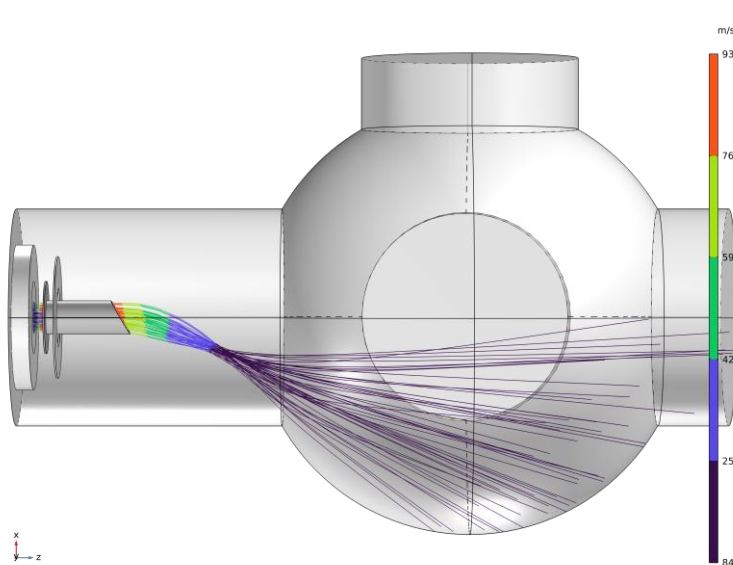
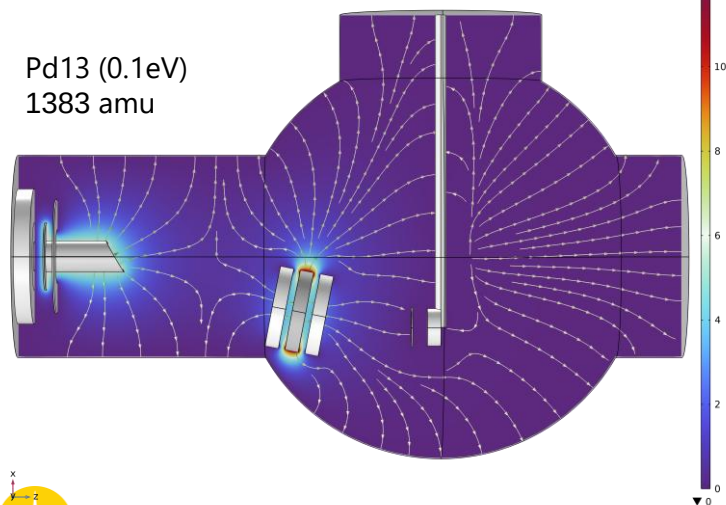


Mehta, K. et al. (2024), *Instrumentation Science & Technology*, 53(3), pp. 351–362.



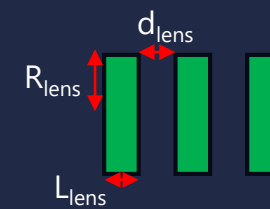
$R_{\text{lens}}: 3\text{cm}$, $L_{\text{lens}}: 1\text{cm}$, $d_{\text{lens}}: 1.5\text{cm}$, $V_{\text{lens}} = 2V_{\text{grid}}$

Pd13 (0.1eV)
1383 amu

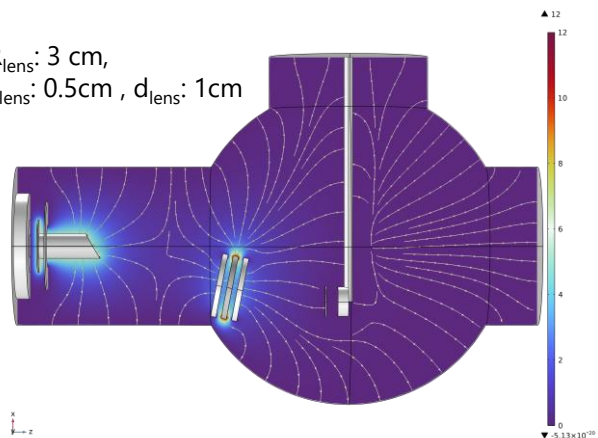




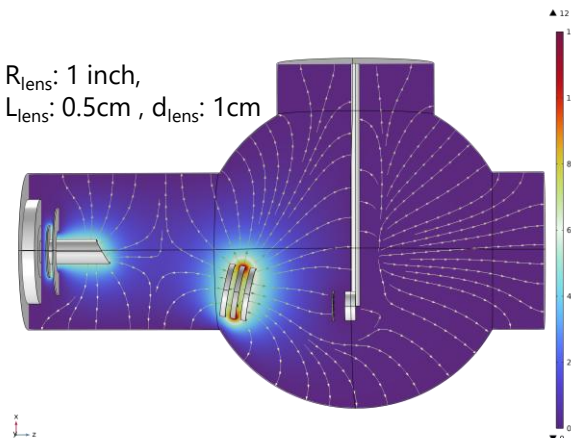
Results: Einzel lens



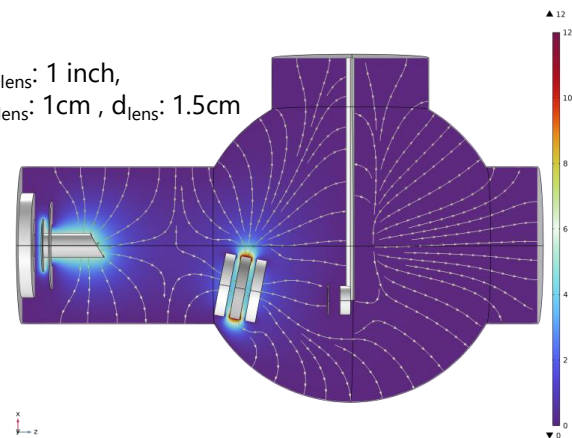
$R_{\text{lens}}: 3 \text{ cm},$
 $L_{\text{lens}}: 0.5 \text{ cm}, d_{\text{lens}}: 1 \text{ cm}$



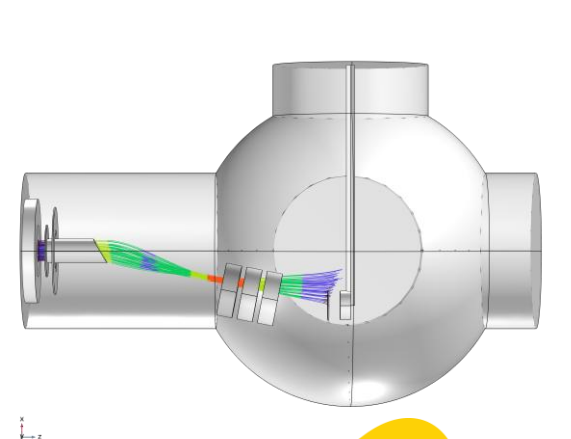
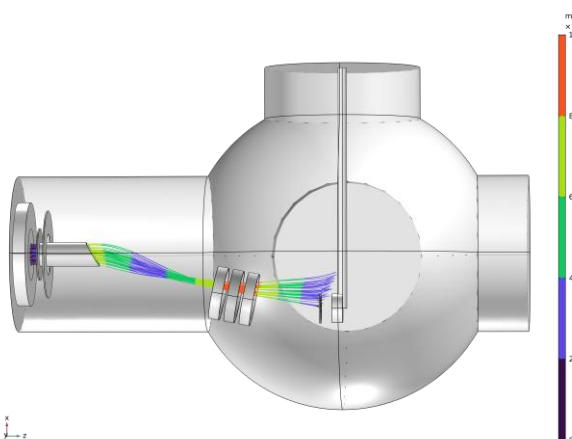
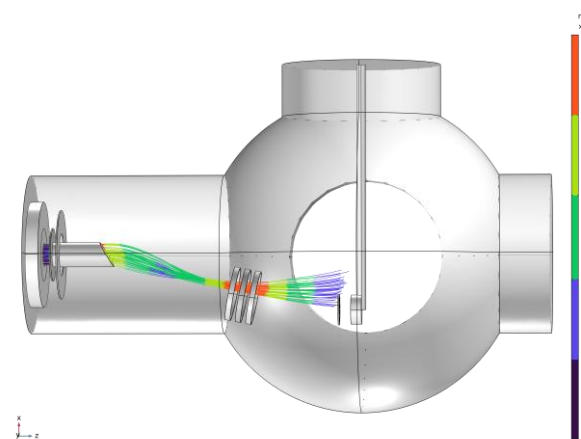
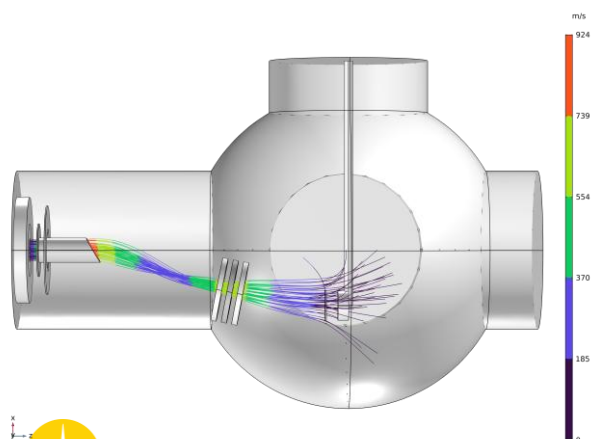
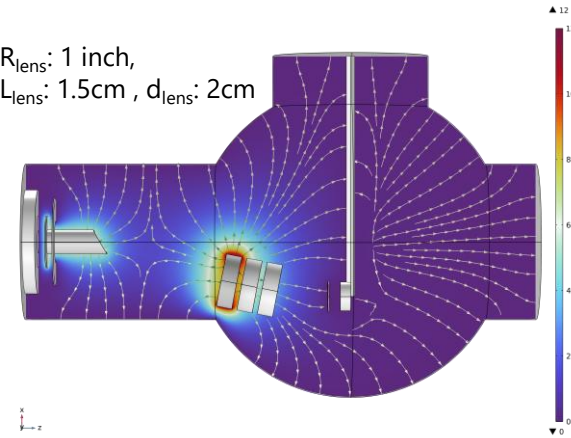
$R_{\text{lens}}: 1 \text{ inch},$
 $L_{\text{lens}}: 0.5 \text{ cm}, d_{\text{lens}}: 1 \text{ cm}$



$R_{\text{lens}}: 1 \text{ inch},$
 $L_{\text{lens}}: 1 \text{ cm}, d_{\text{lens}}: 1.5 \text{ cm}$

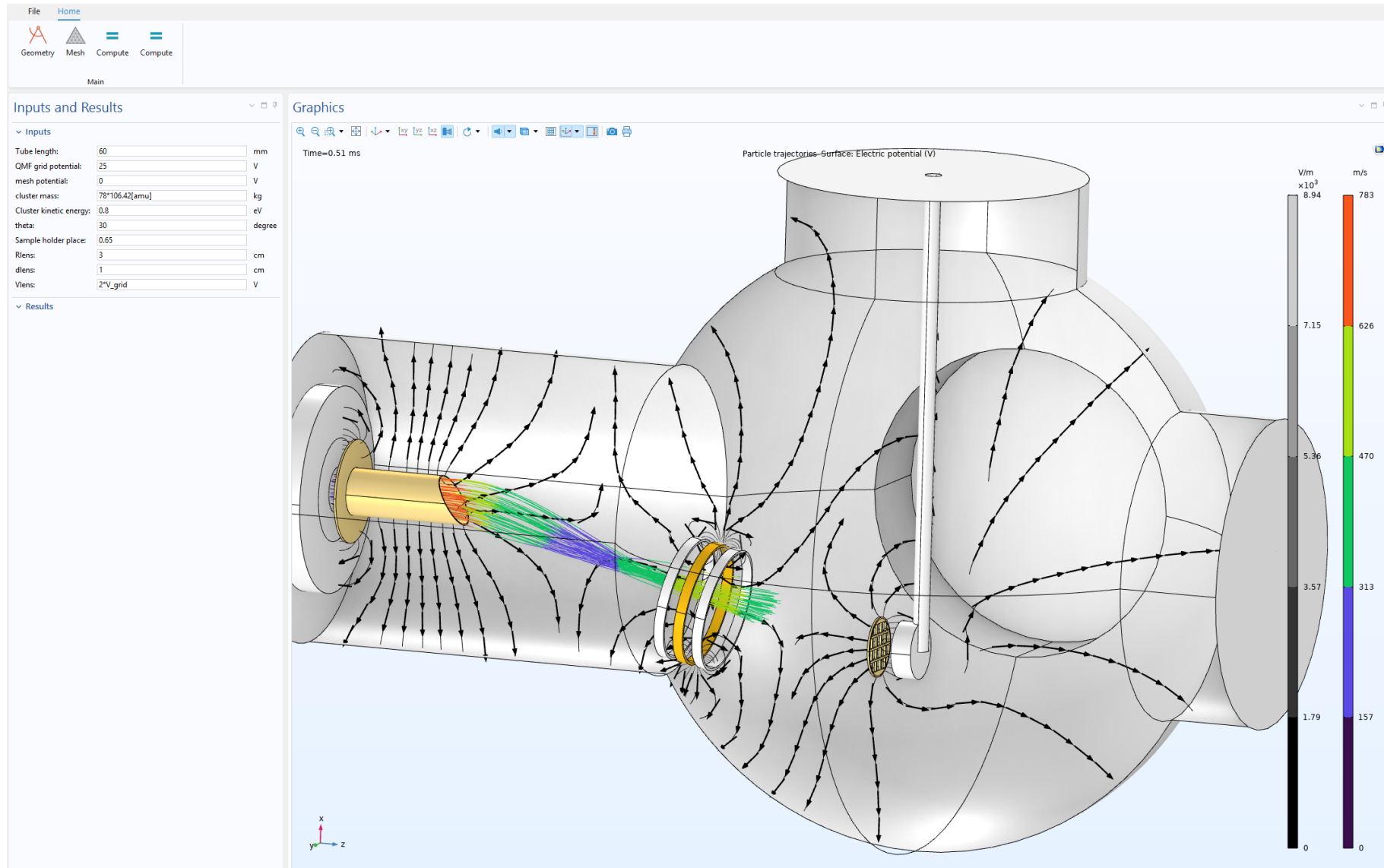


$R_{\text{lens}}: 1 \text{ inch},$
 $L_{\text{lens}}: 1.5 \text{ cm}, d_{\text{lens}}: 2 \text{ cm}$





Results: Application builder





Thanks for your attention

B07 Staff

Georg Held

Matthijs van Spronsen

Andrew Watts

David Grinter

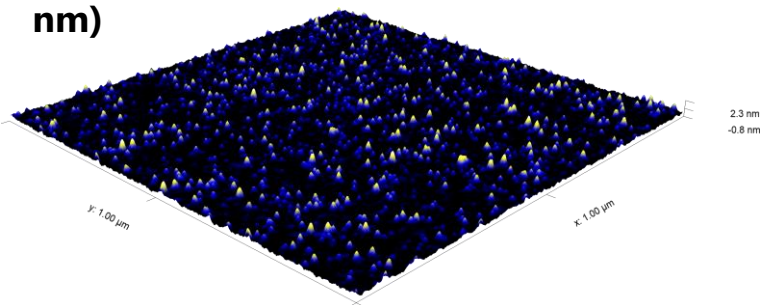
Matthew Cox



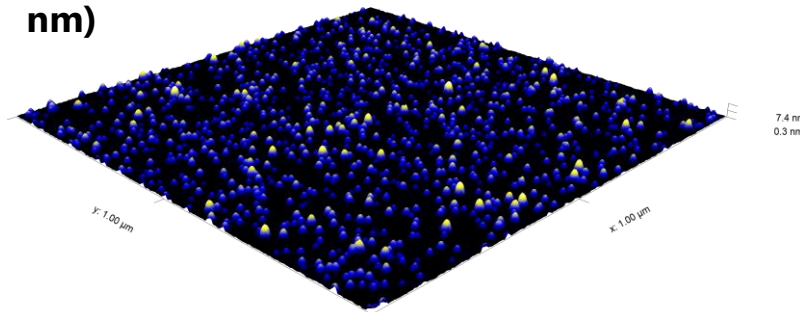


Size selected Pd clusters (1.5nm, 2.5nm, 4.5nm)

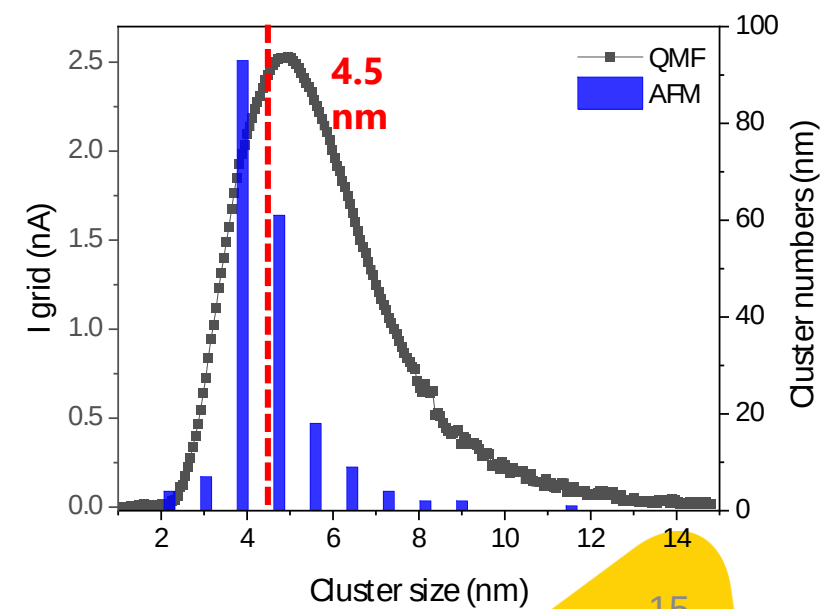
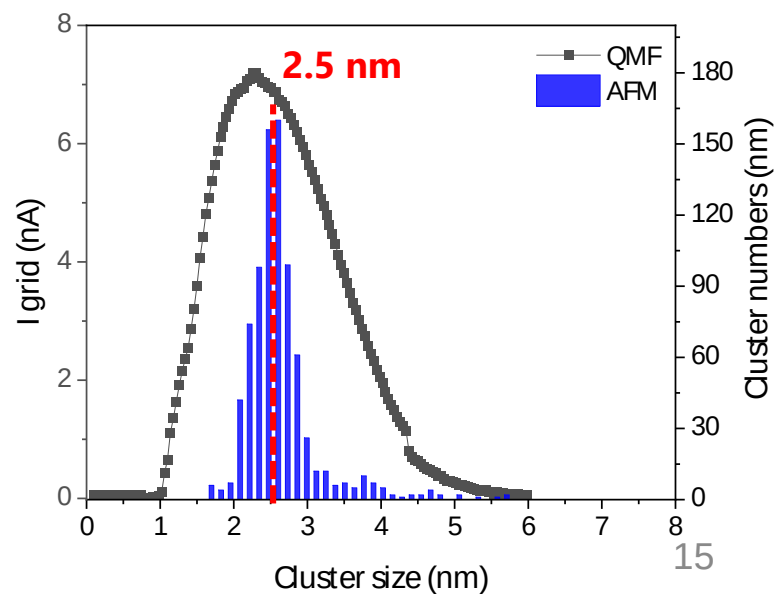
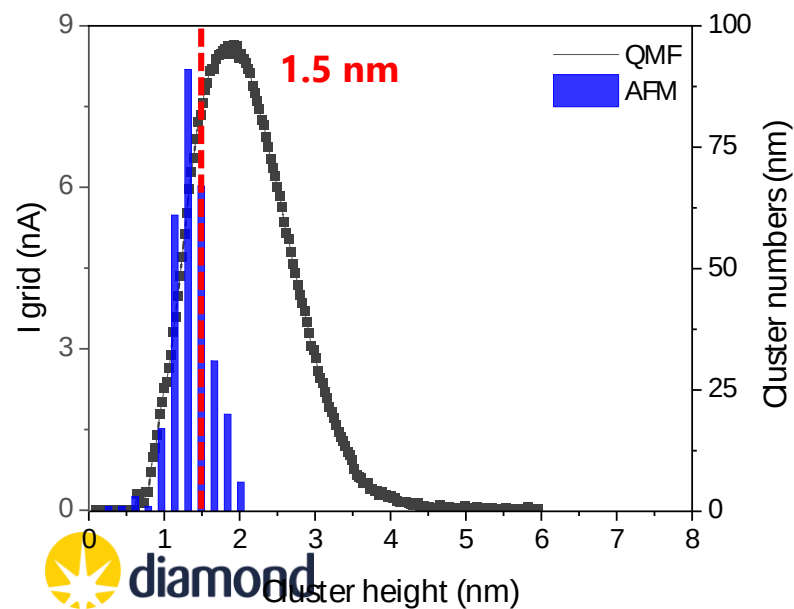
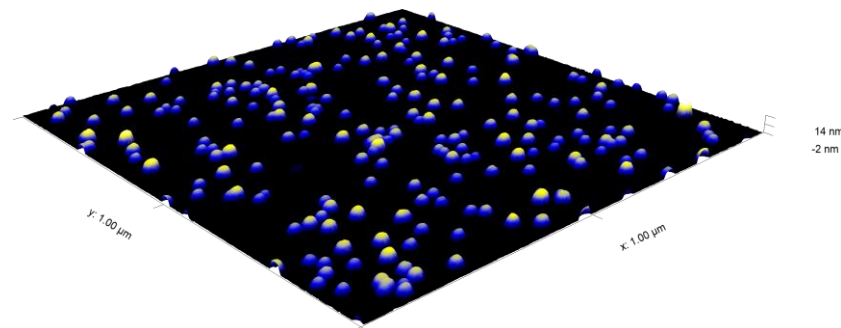
Pd120 (1.5 nm)



Pd556 (2.5 nm)

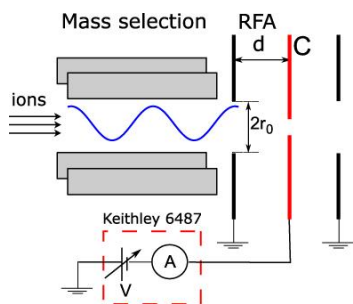


Pd3241 (4.5 nm)





Retarding Field Analyzer (RFA), Cluster kinetic energy



$$\frac{dI(V)}{dV} = \frac{e^2}{M} f(v) \quad v = \sqrt{[2eV/M]}$$

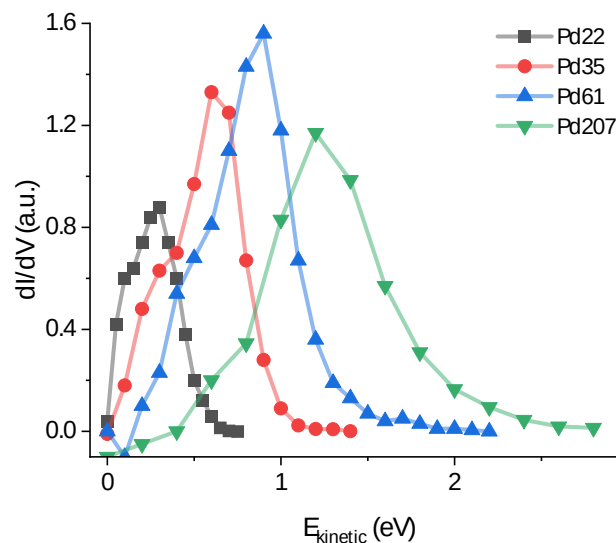
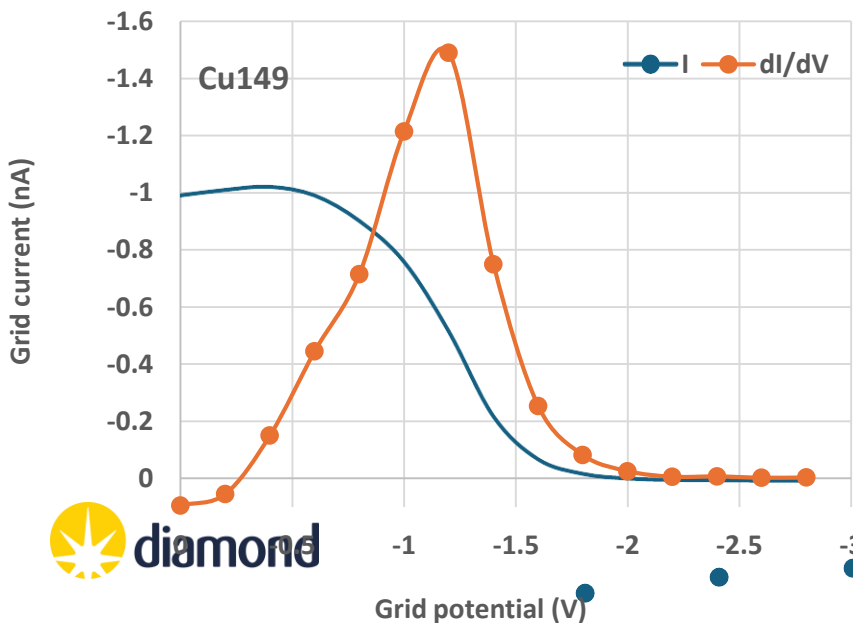
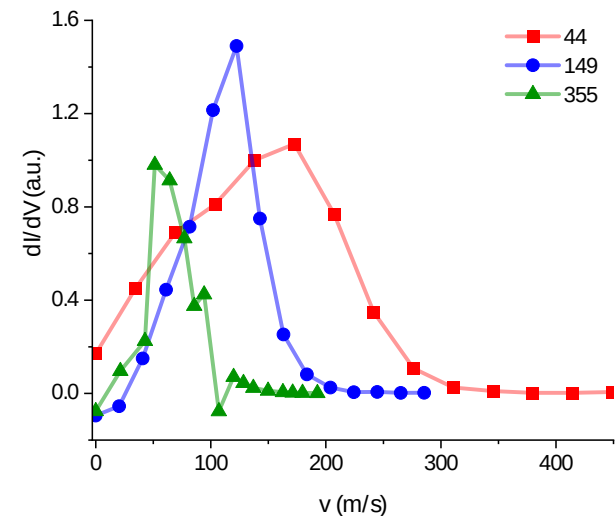
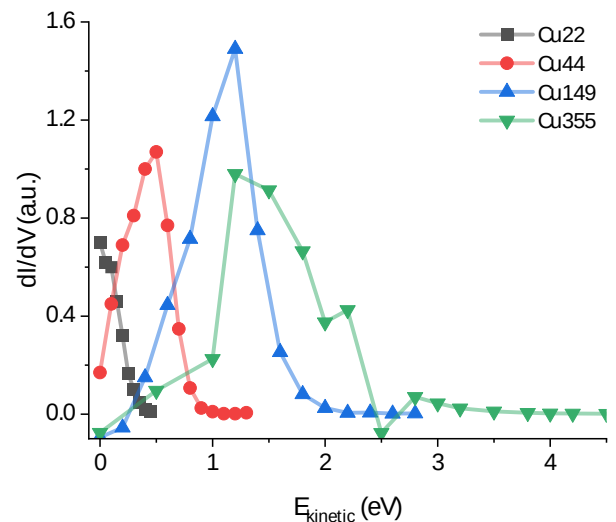
Ganeva, Marina, et al." *Plasma Sources Science and Technology* 22.4 (2013): 045011.



I_{grid}, V_{grid}



Keithley 6487



Pd cluster	E_k per atom	Cu cluster	E_k per atom
22	9 meV	22	-
35	14 meV	44	11 meV
61	13 meV	149	7 meV
207	5 meV	355	4 meV