Stability of ionization-injection-based laser-plasma accelerators.

Experimental results on long-term stability at PLASMED X

PRAB 25 031301, 2022

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DESY.

Overview of DESY Campus

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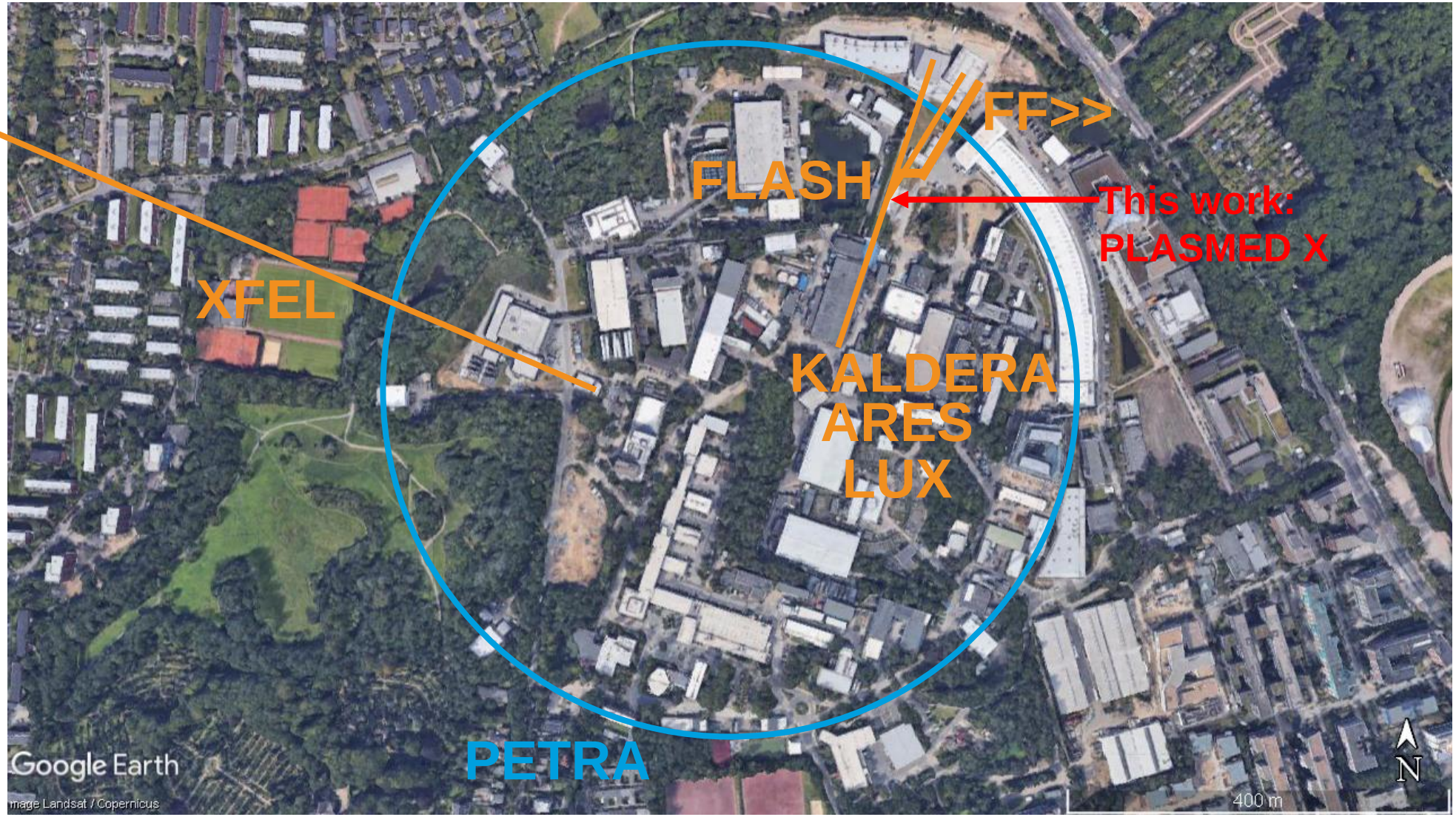

MPA4: Laser-Driven Plasmas & Applications

Fundamentals of LPAs and industrial and medical applications

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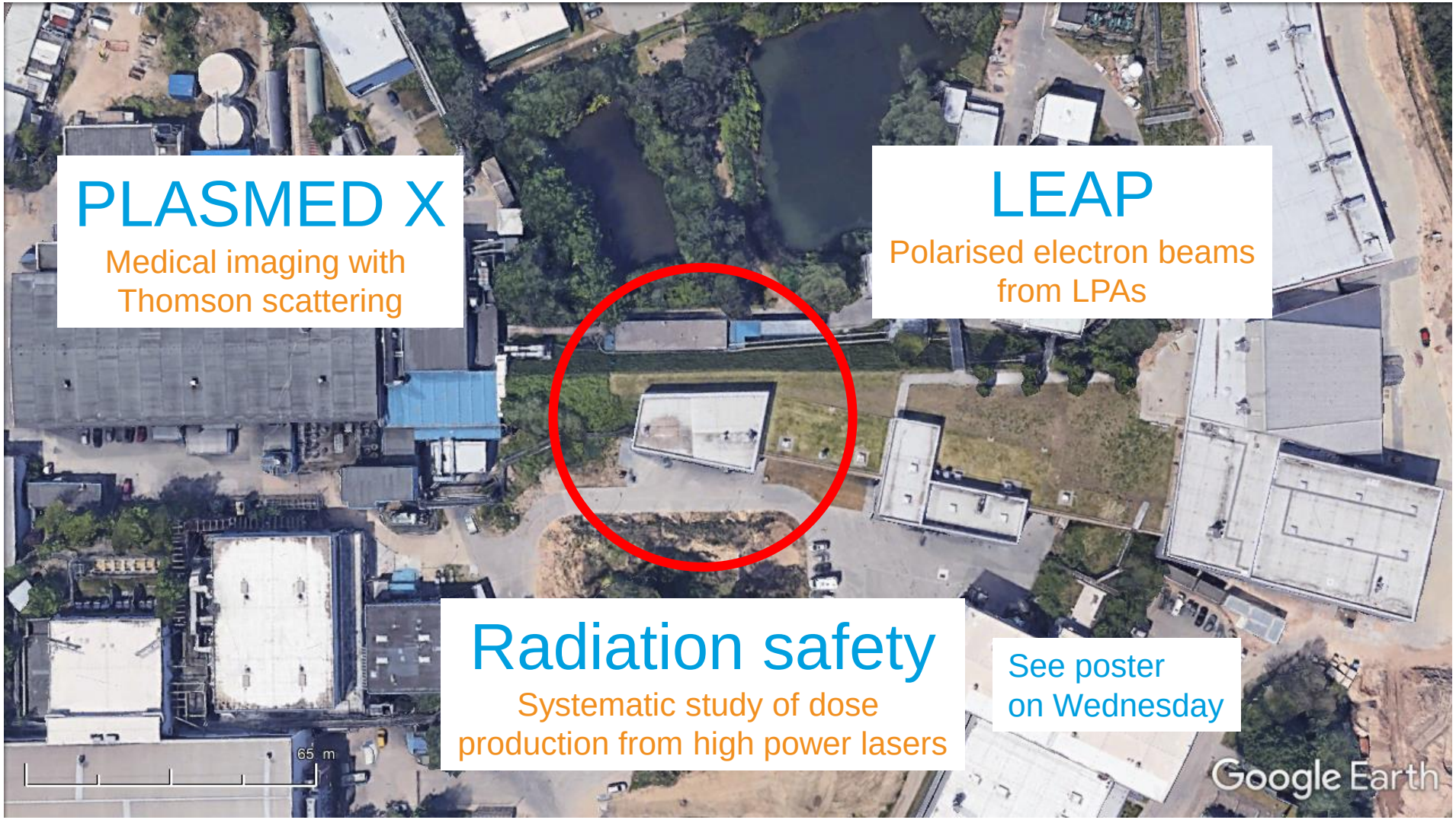

60 second labtour

Overview of the experimental laboratories

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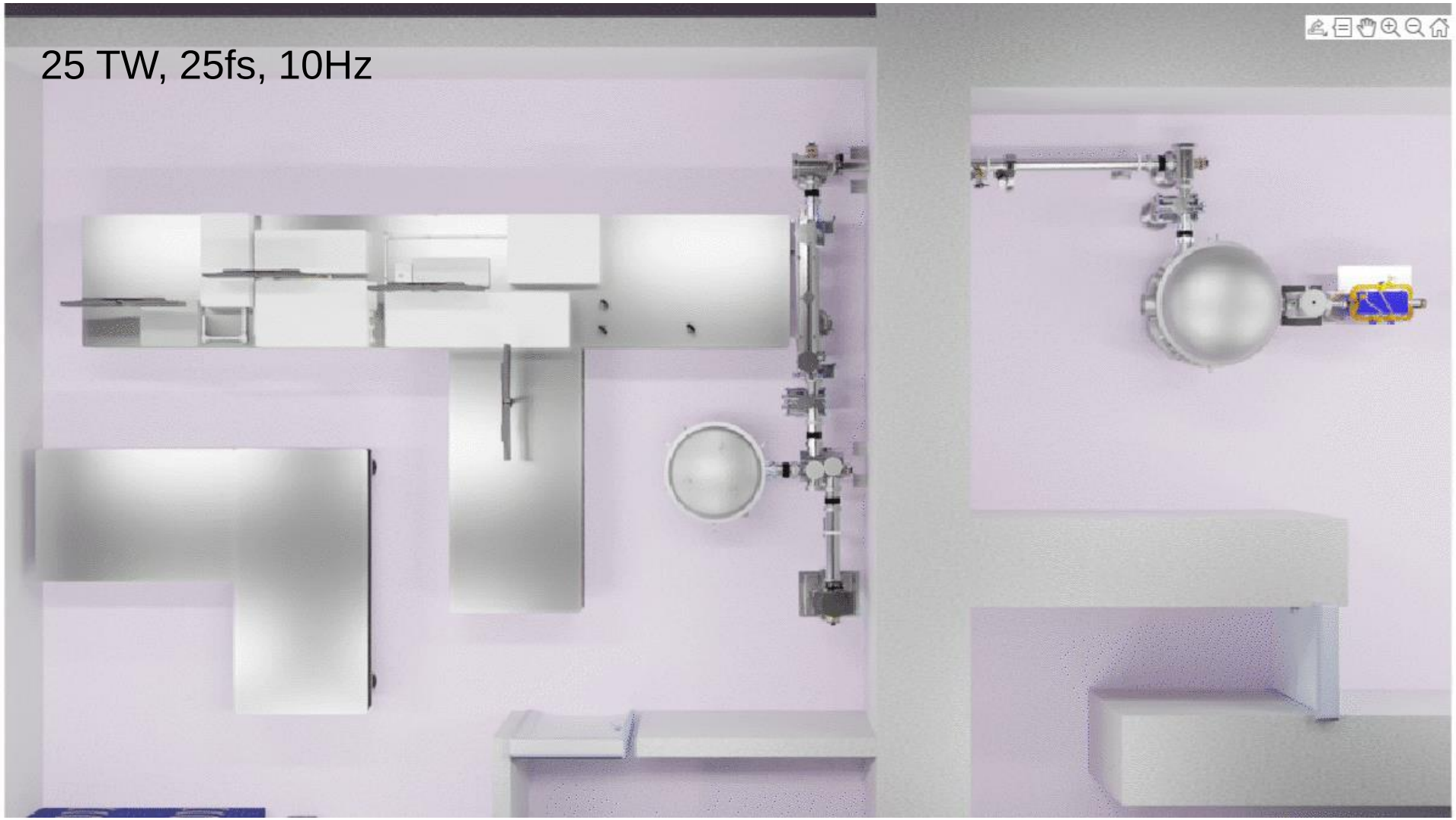

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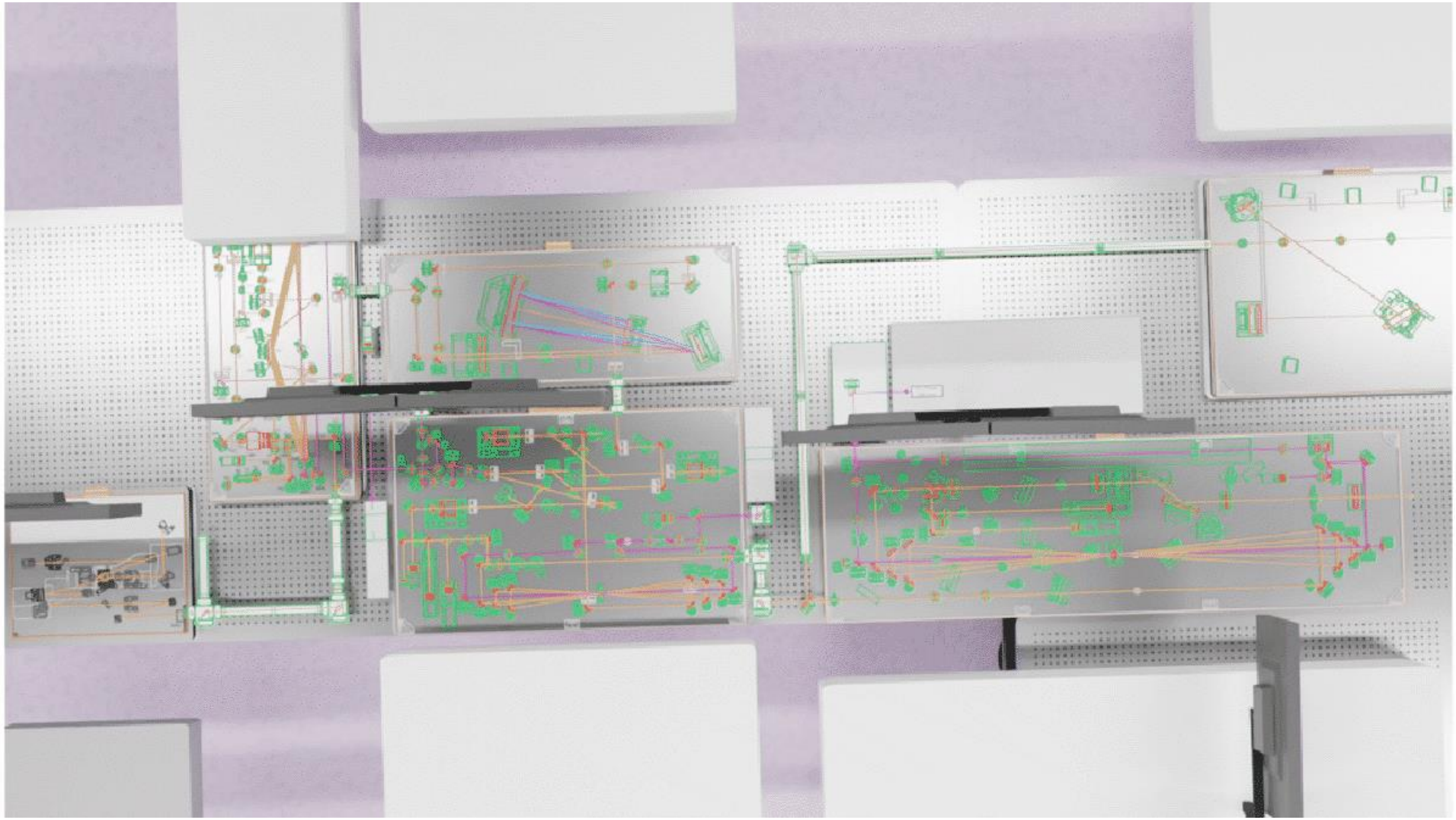

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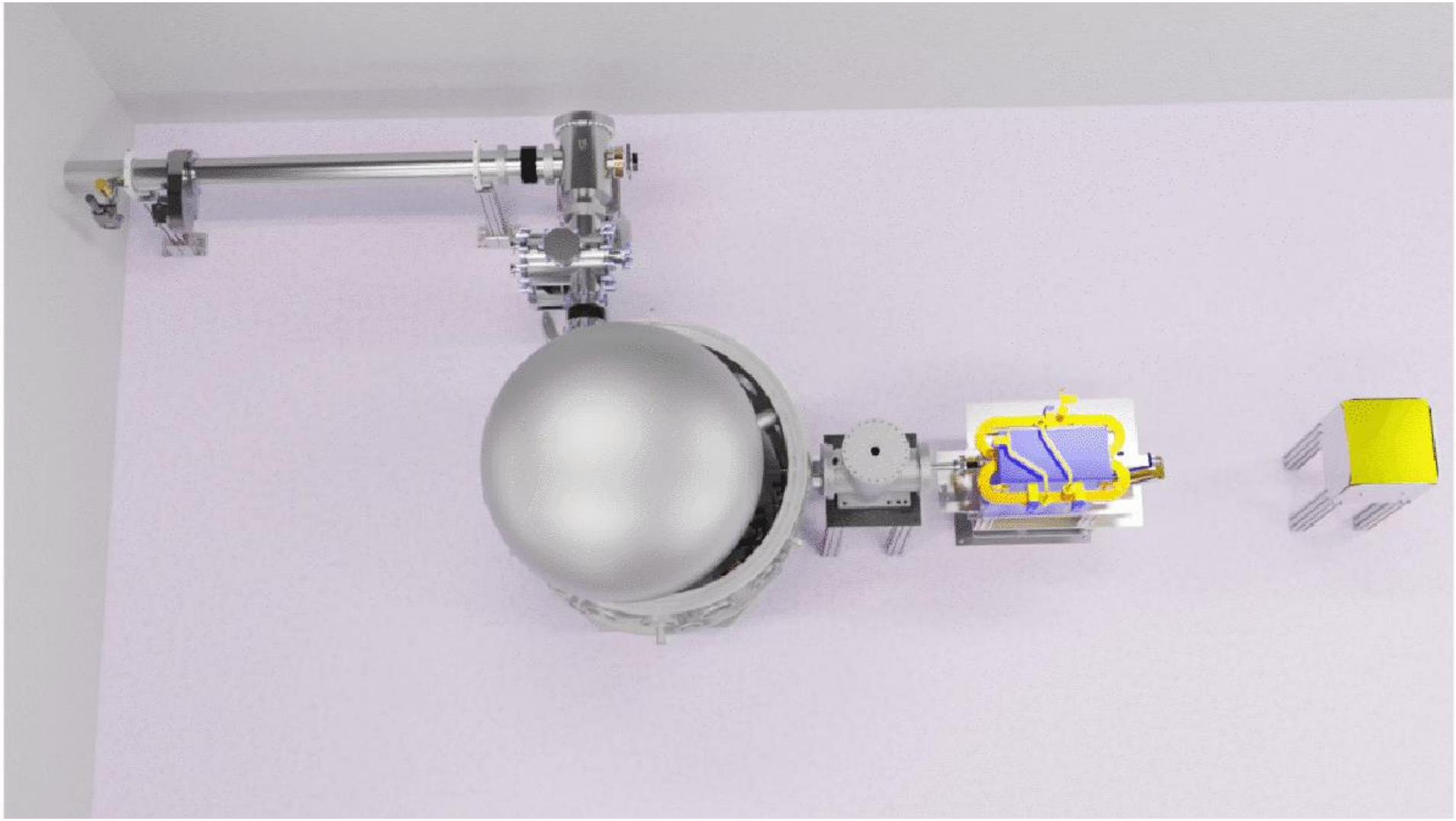

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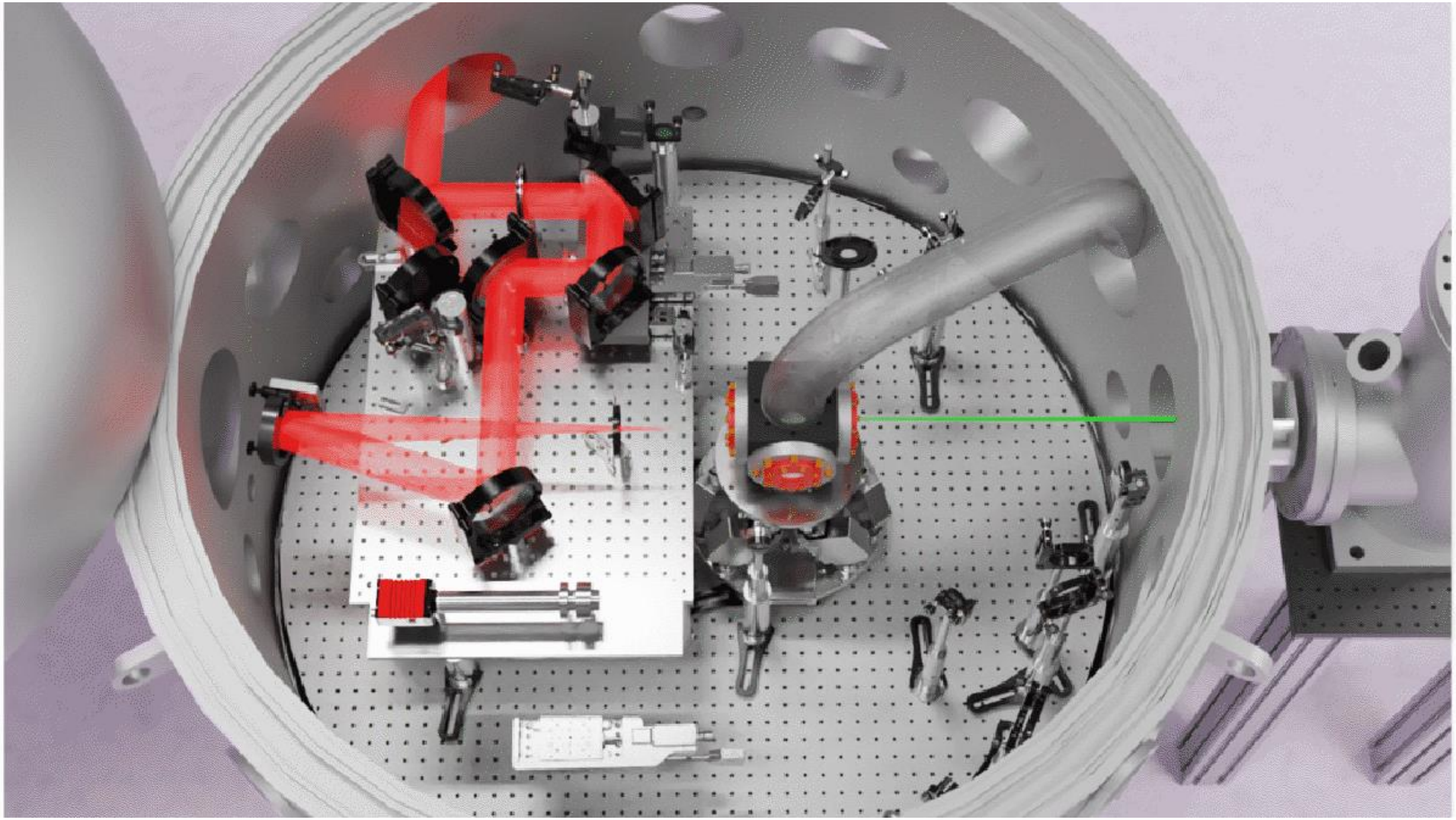

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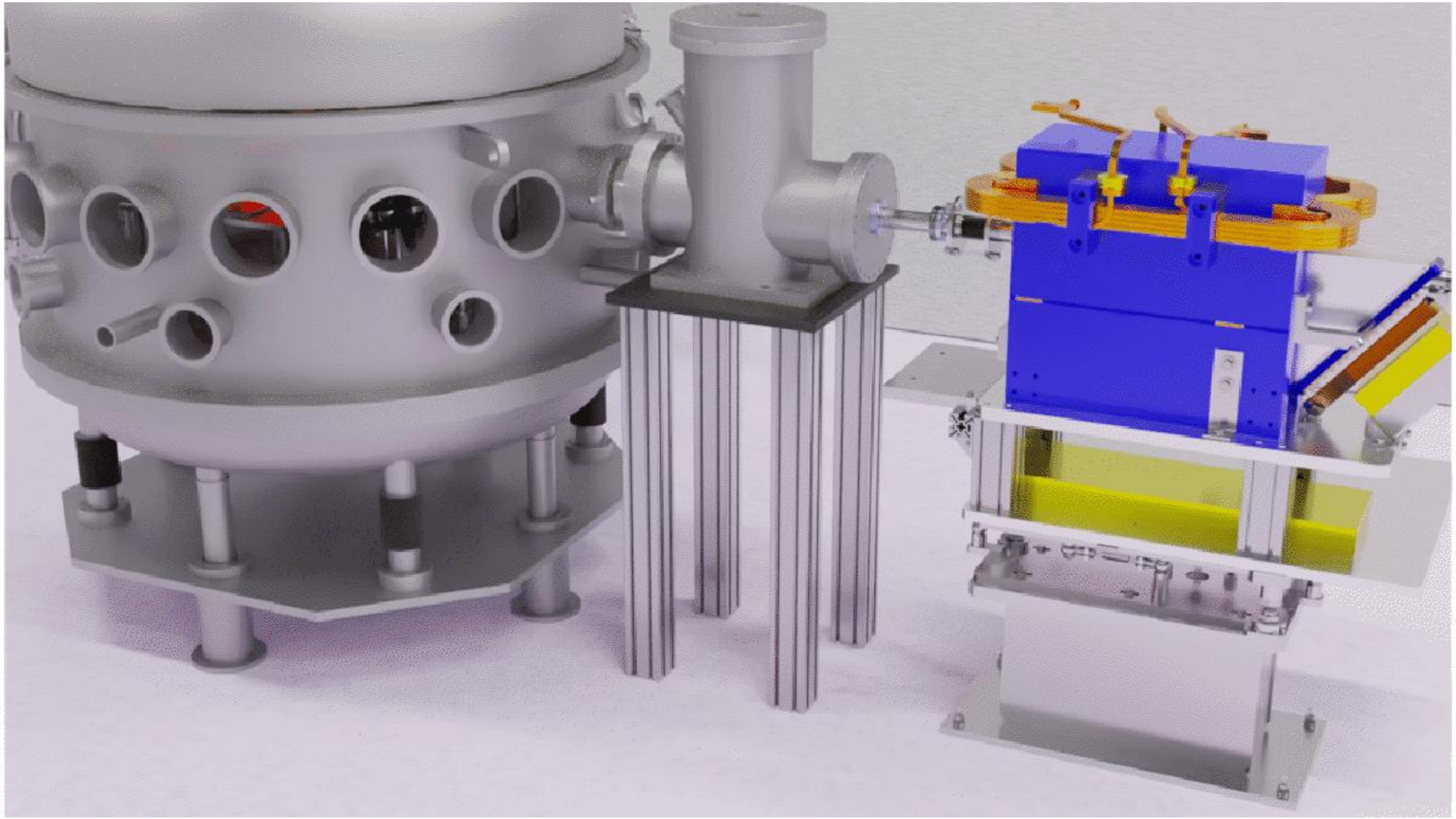

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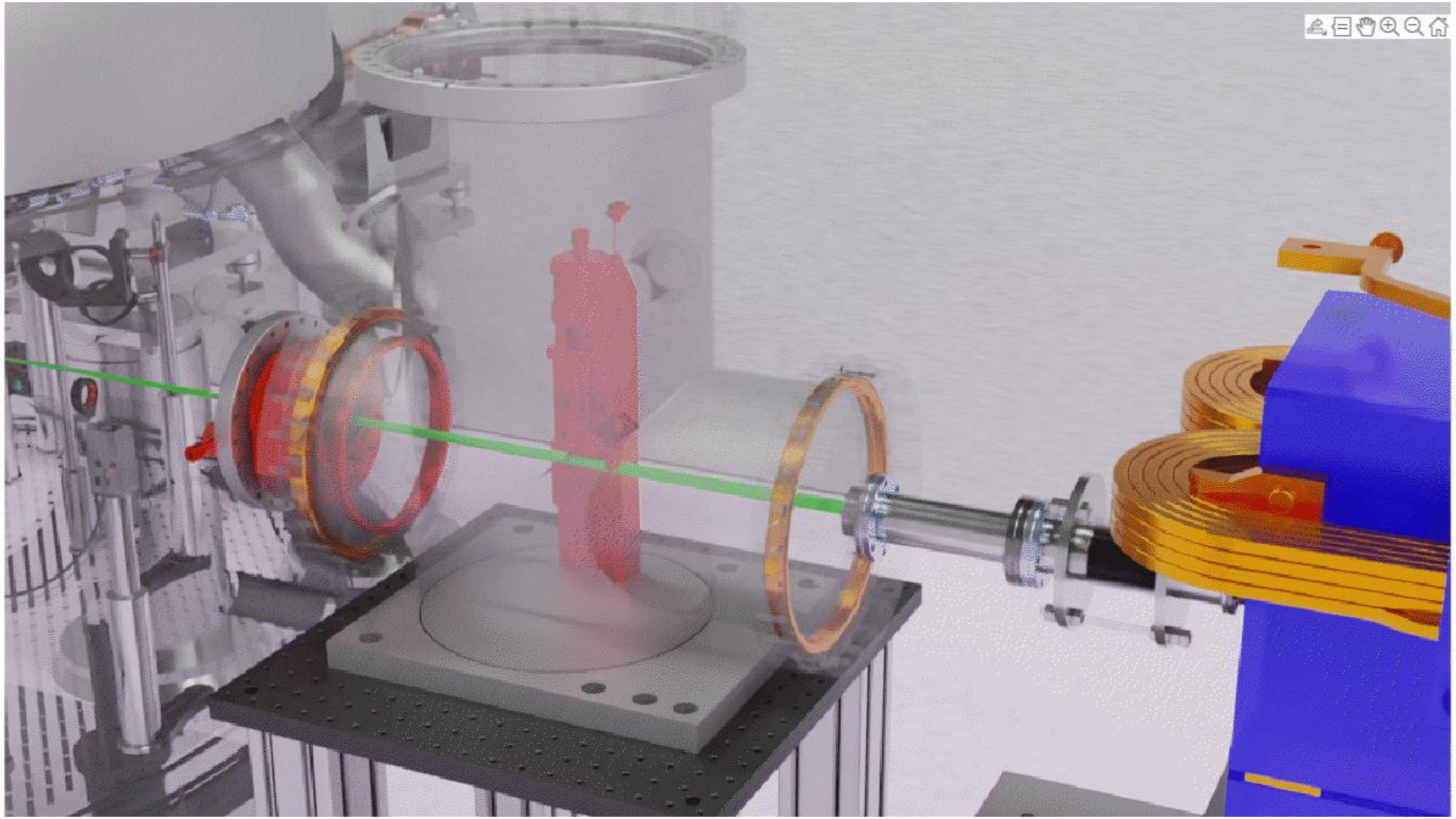
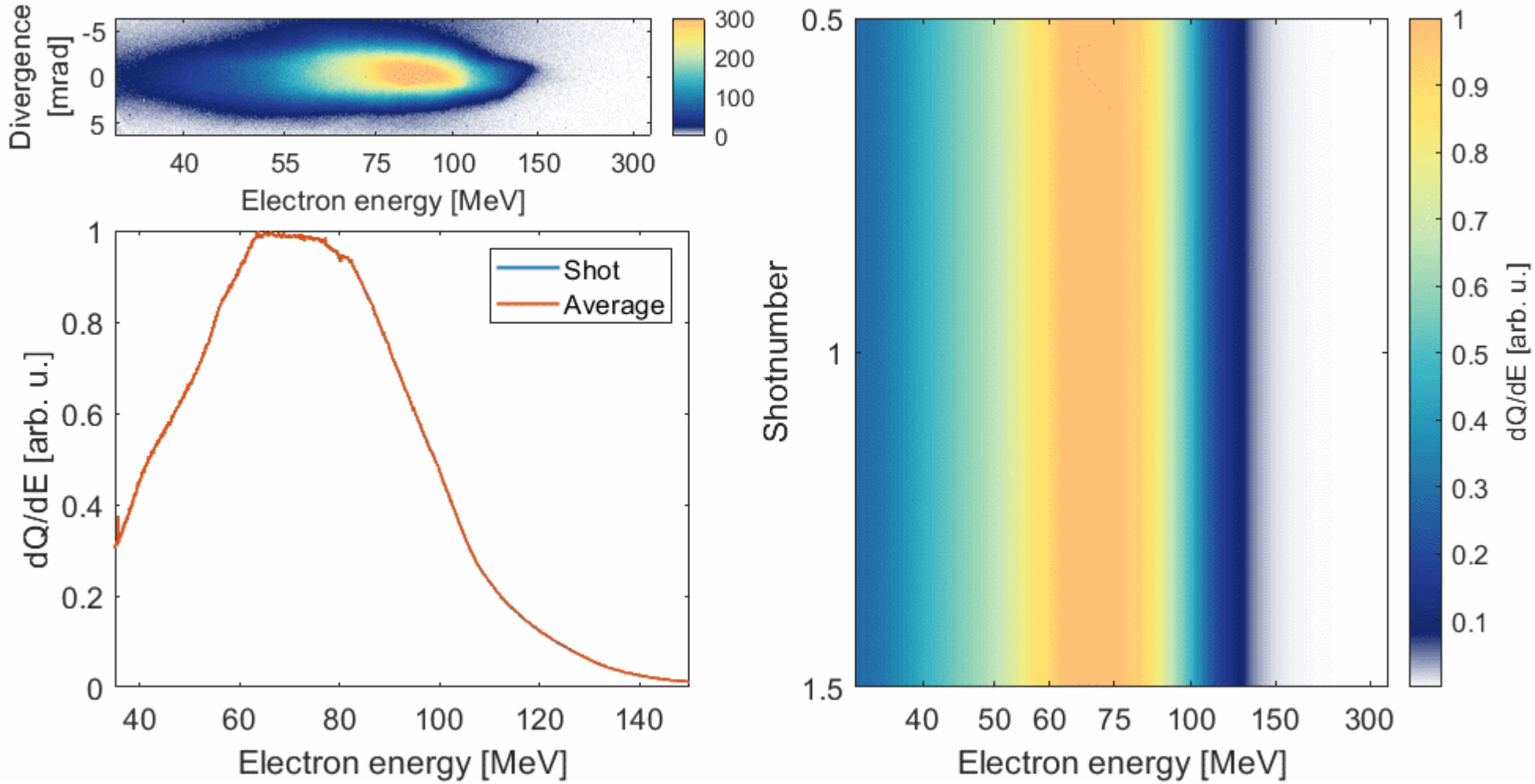


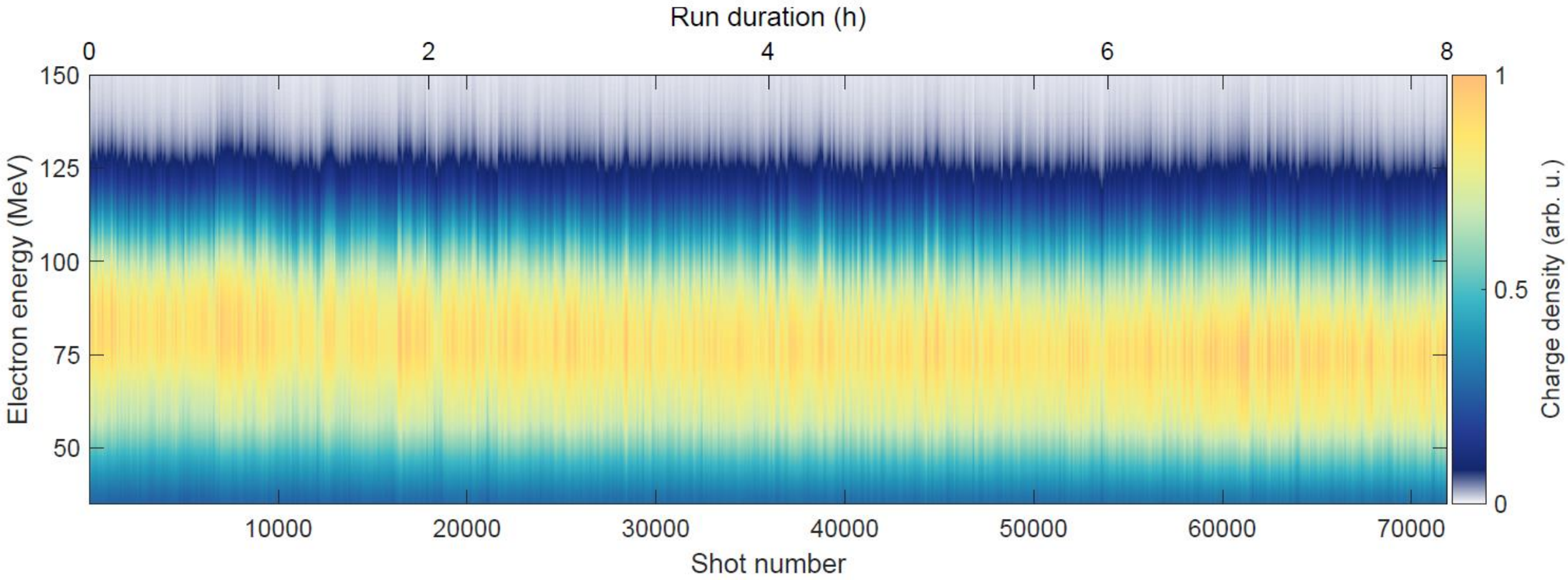
Stable electron beams with ionisation injection

Spectral stability at actual repetition rate of 2.5 Hz



Stable electron beams with ionisation injection

Electron peak energy decreases by 4.7 MeV, probably due to heating of gratings



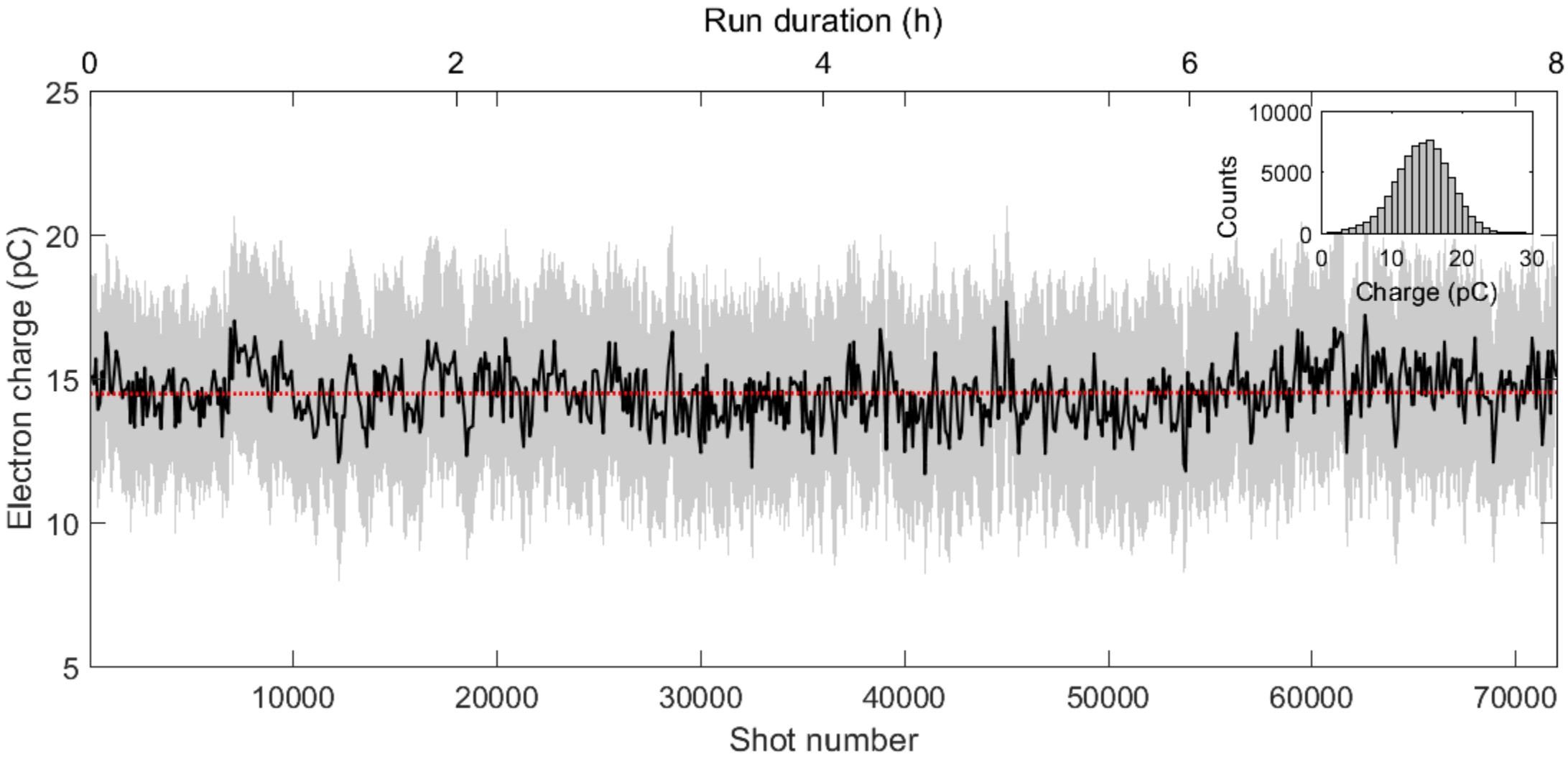
Drop of energy also at LOA
L. Rovige et al., PRAB 23, 093401 (2020)

Potential source: grating heating
S. Fourmaux et al., Opt. Express 17, 178 (2009)
V. Leroux et al., Opt. Express 26, 13061 (2018).

Stable operation at 1 Hz possible
A. Maier et al., PRX 10, 031039 (2020)

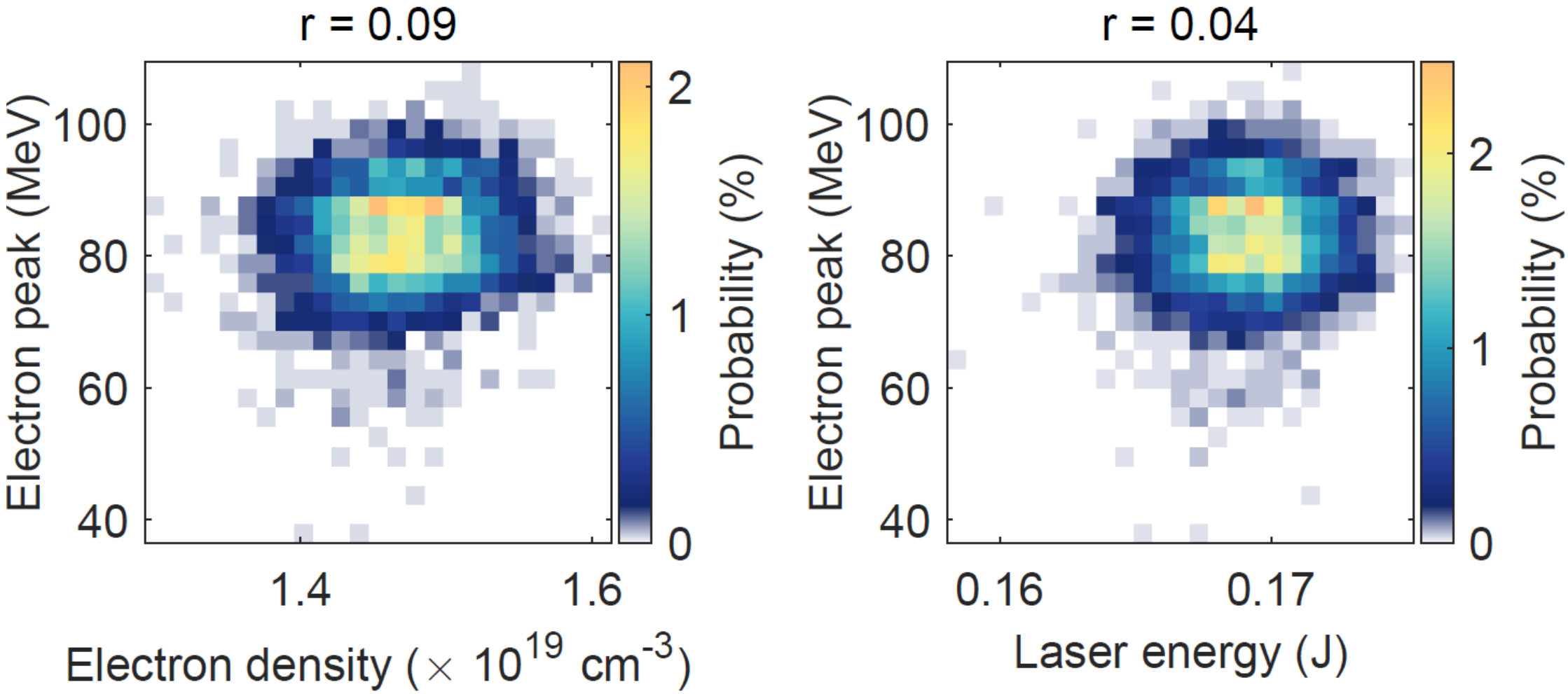
Stable electron beams with ionisation injection

Average charge: $14.5 \pm 3.8\ pC$; constant over 8 hours, 100% injection



Learning from correlations

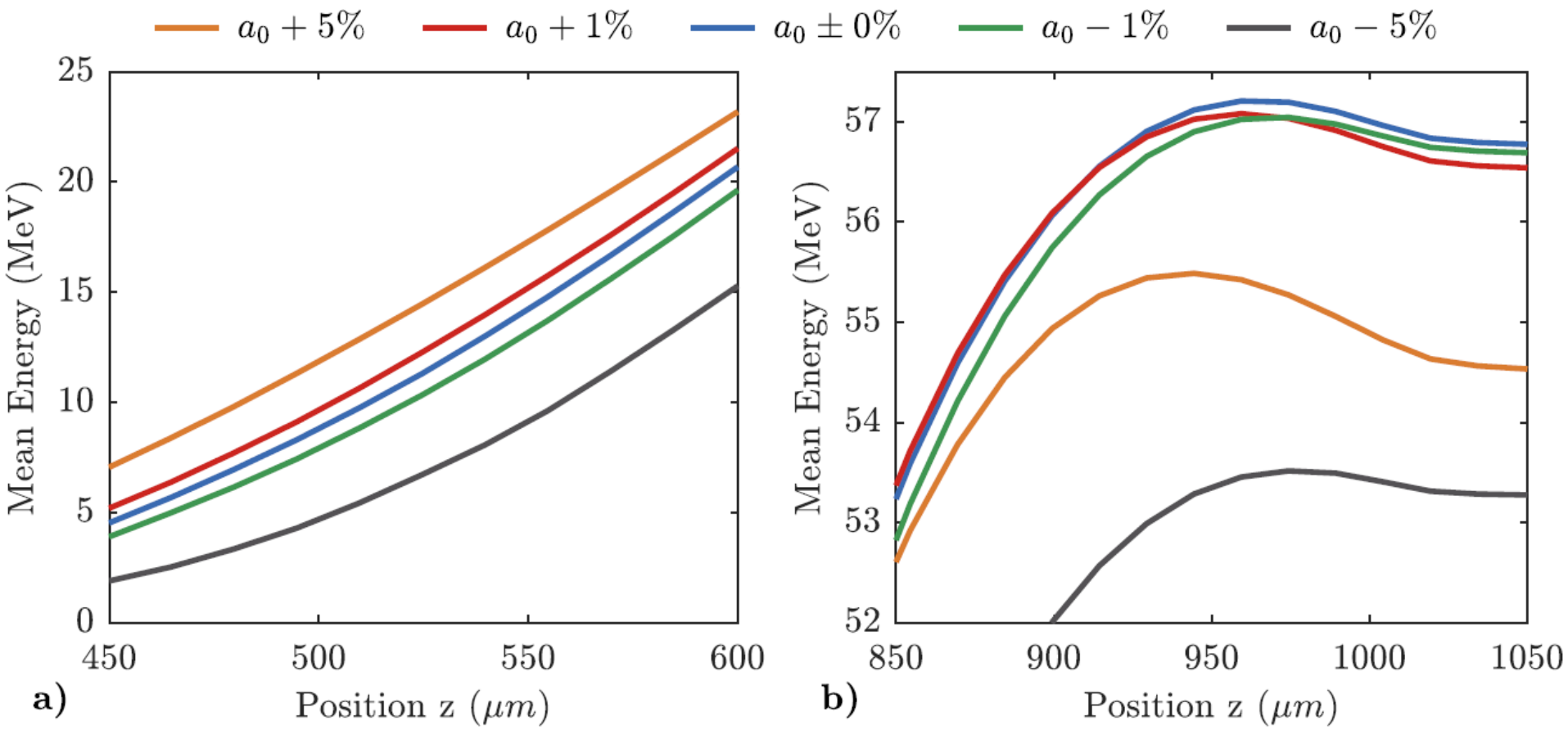
Electron energy as a function of density and energy



Self-stabilization at dephasing limit

Electron energy can be stabilized by operating close to dephasing limit

Scan of normalized laser potential



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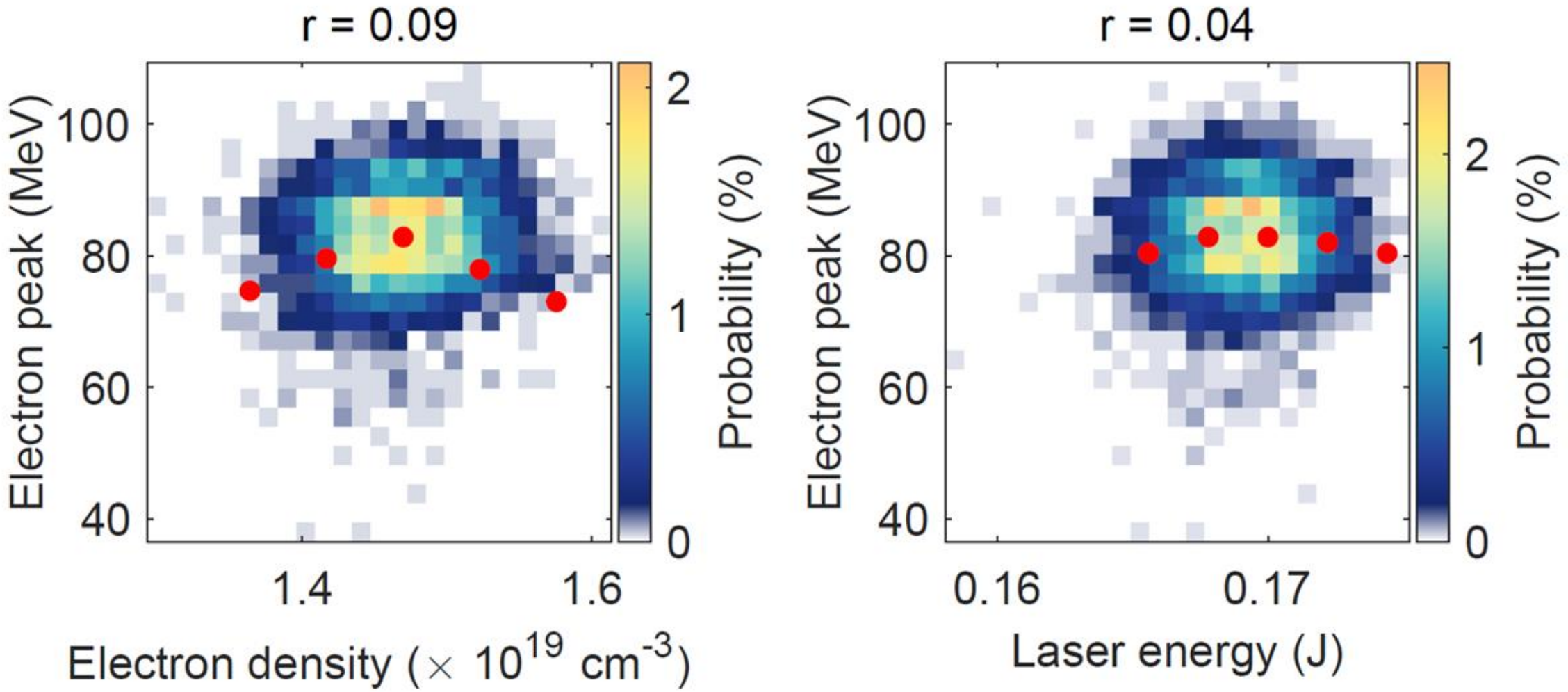

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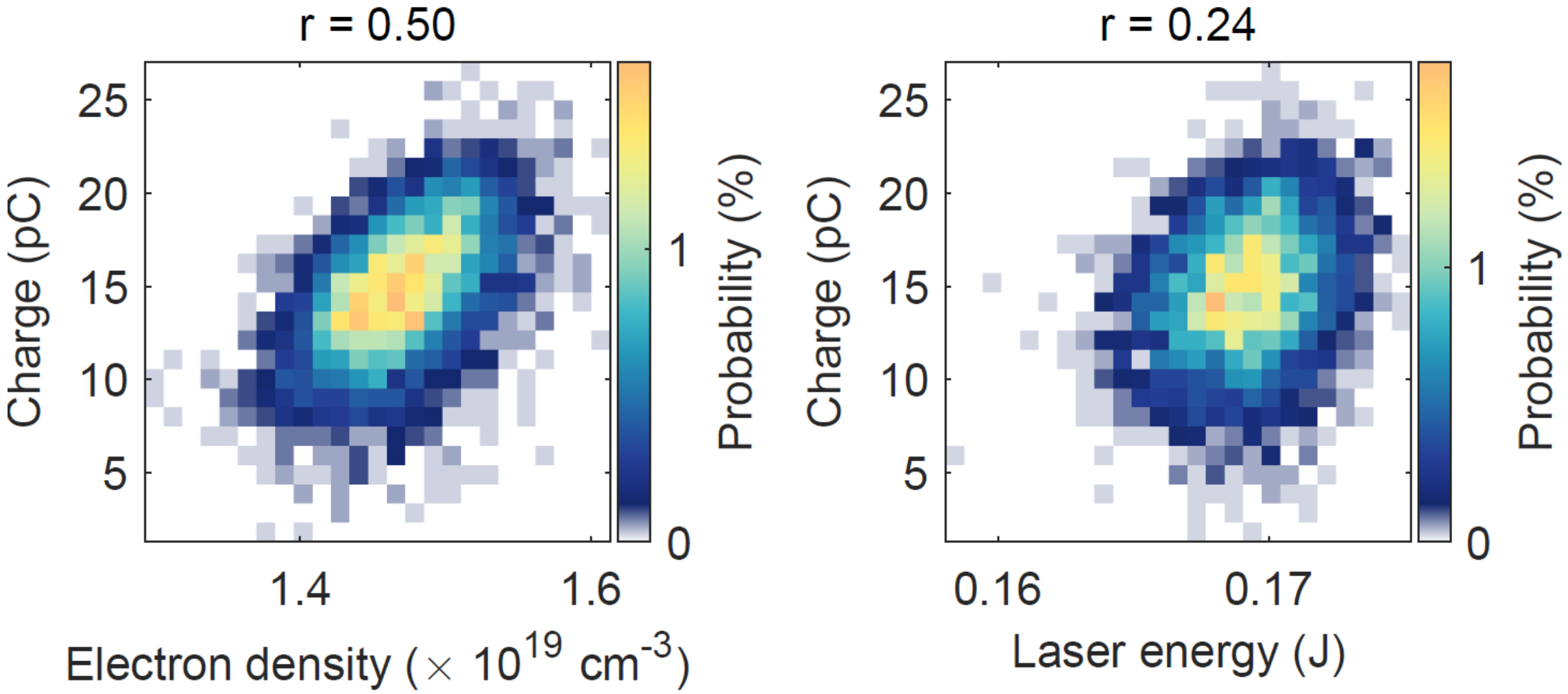
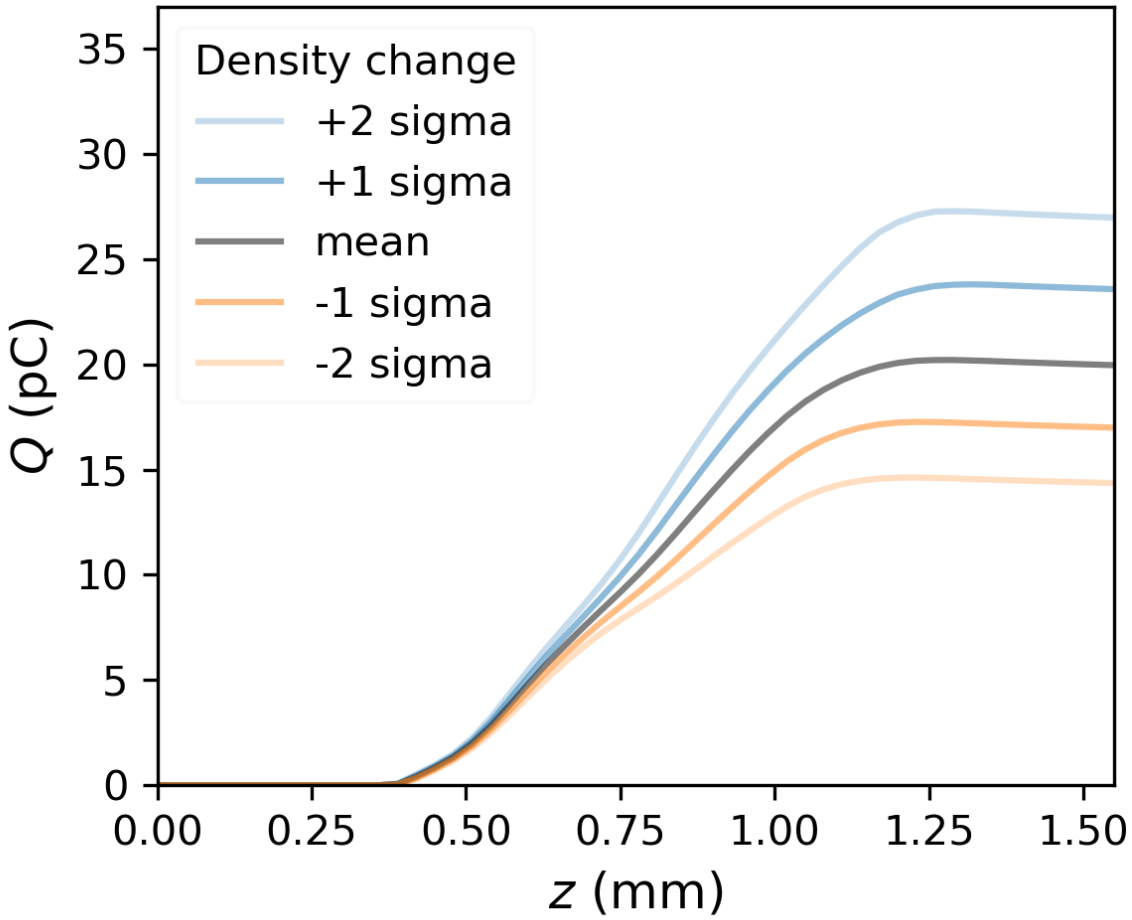
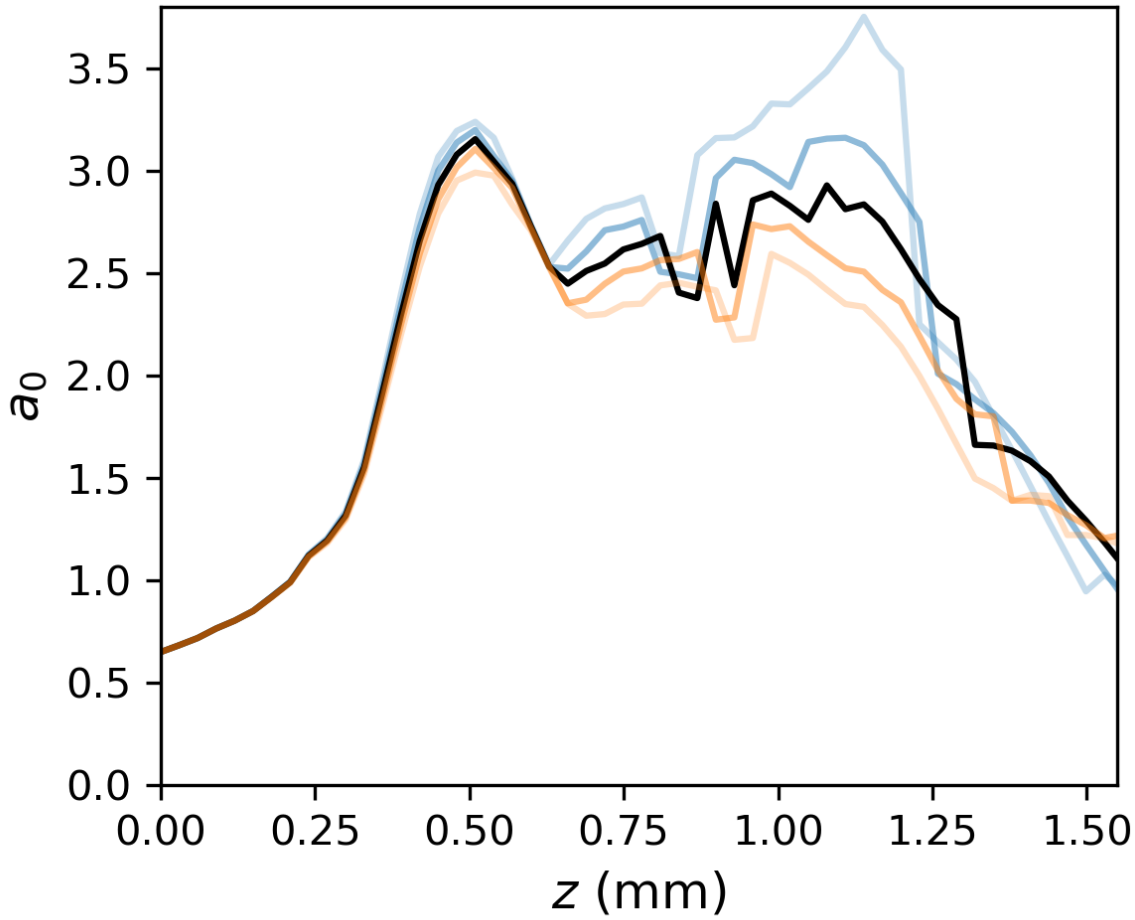


Plasma density strongly influences charge

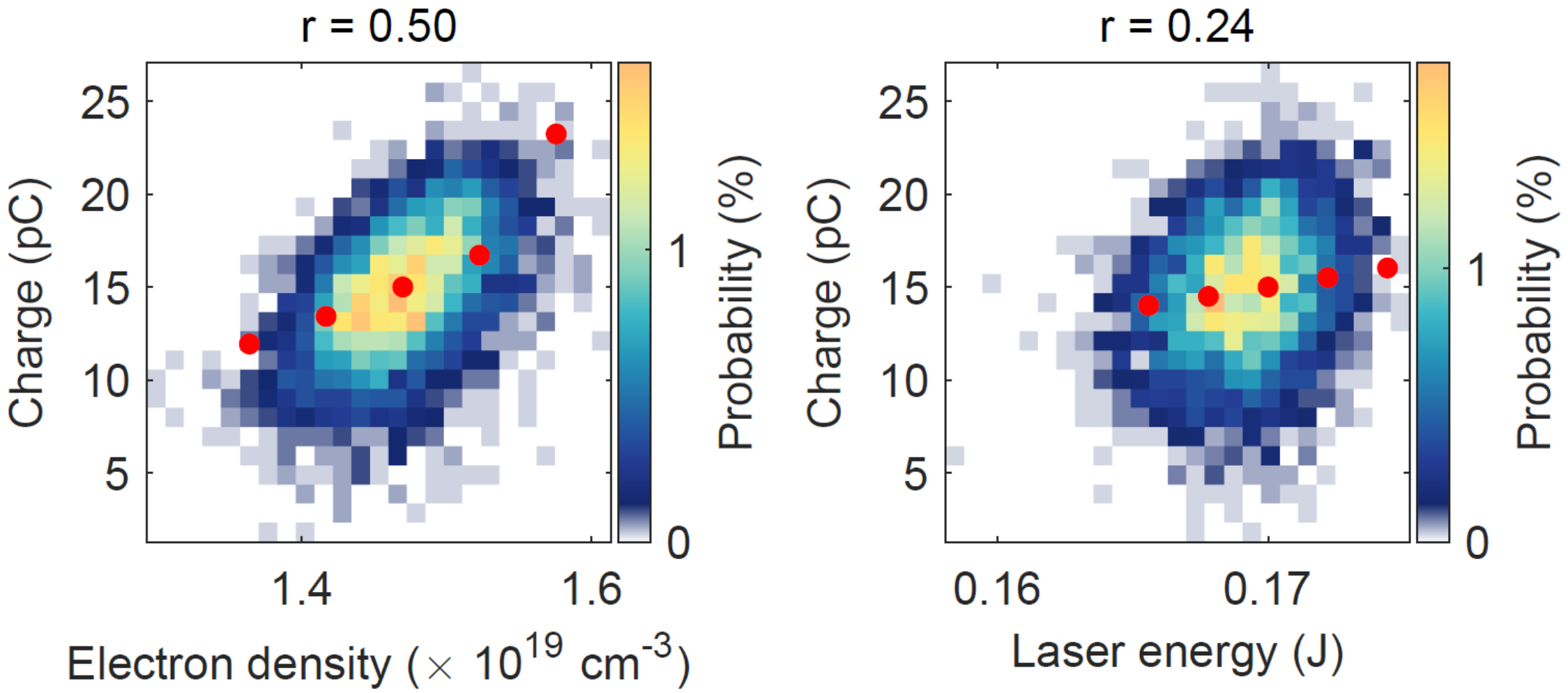
Self-focusing significantly alters injection





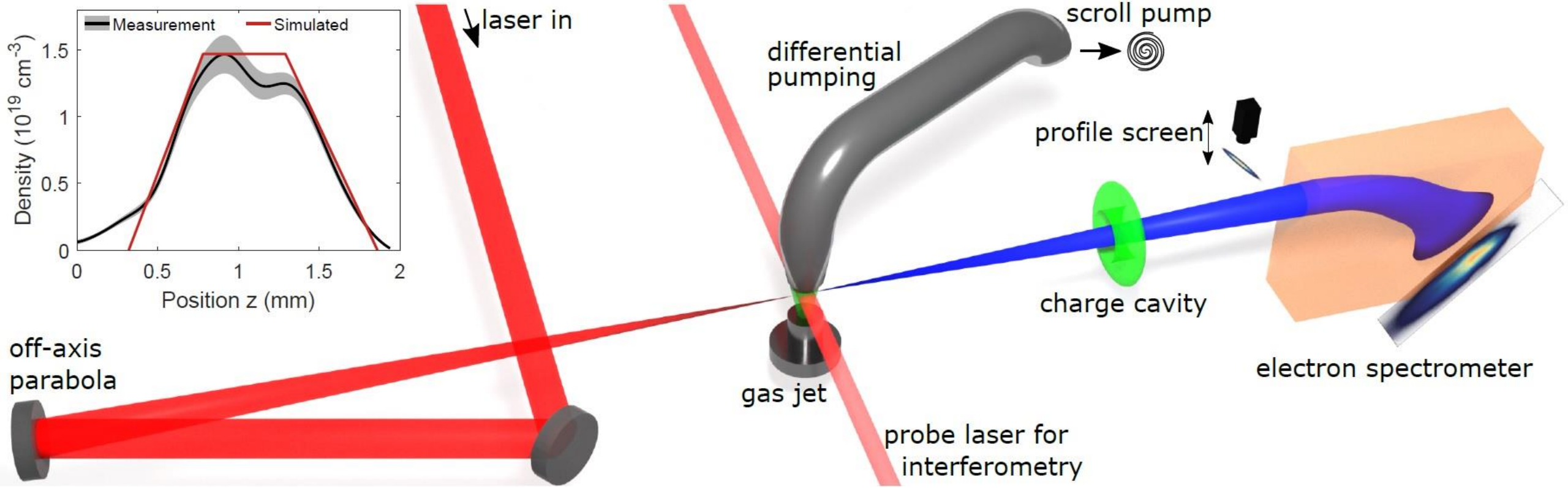
Plasma density strongly influences charge

Fluctuations 3 times higher than expected from increase in particle number



Overlap inside the plasma possible

Information of the Thomson beam can be transported out of the plasma



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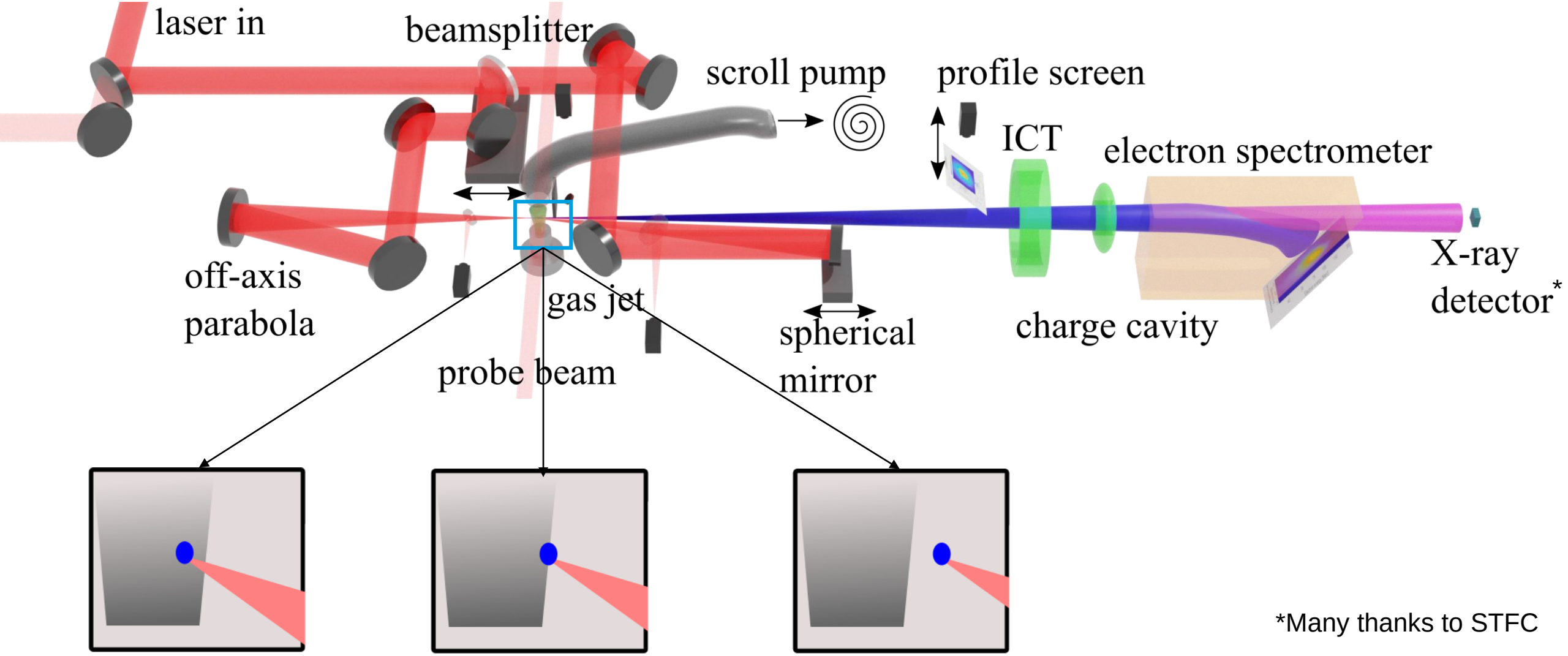
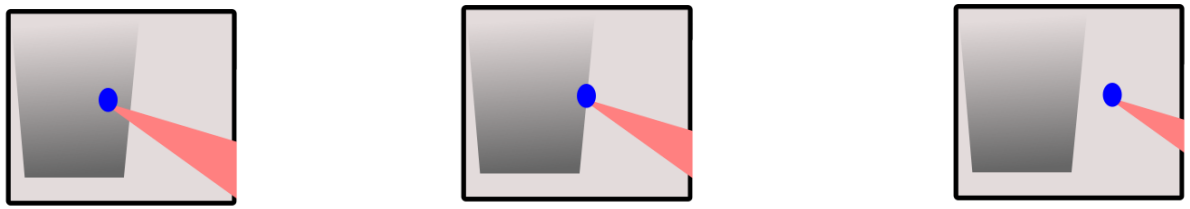


*Many thanks to STFC

Measurement of the electron energy evolution in the plasma

Thomson scattering enables non-invasive measurement of the electron energy

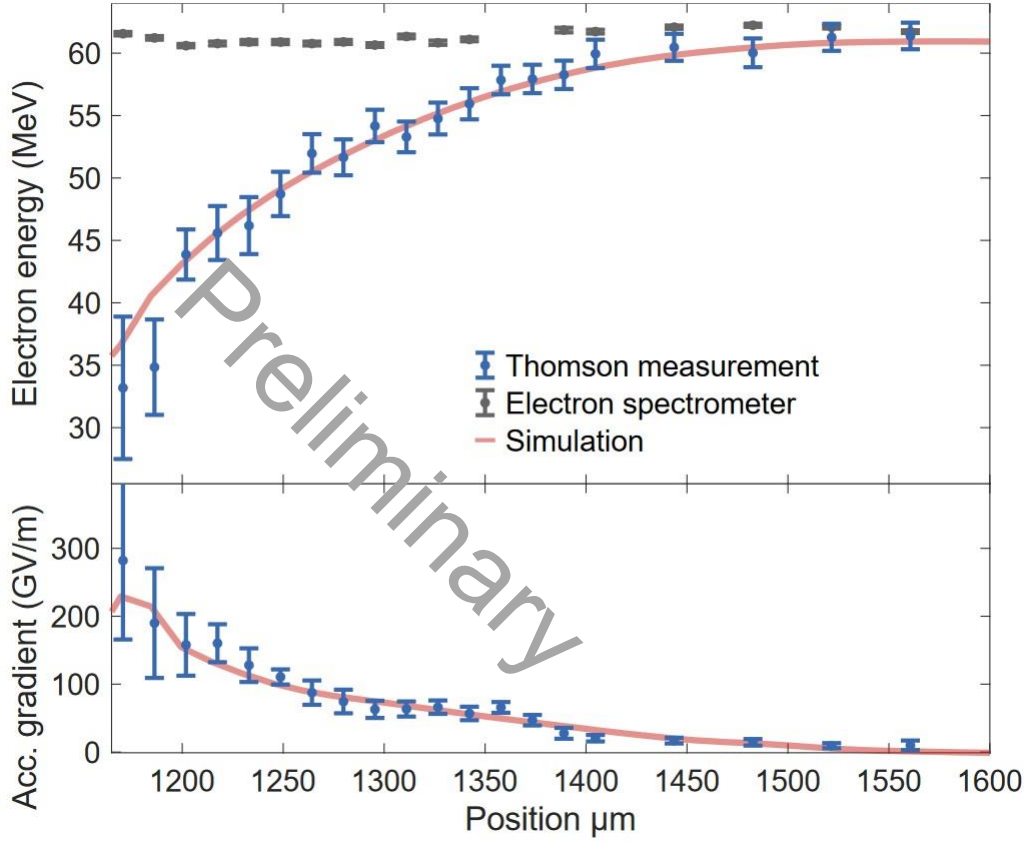


Energy of scattered photons:

$E_\gamma \approx 4\gamma_e^2 * E_{Laser} * \Lambda$ [1]

[1] J. M. *Krämer et. Al., Scientific Reports* **8**: 1398 (2018)

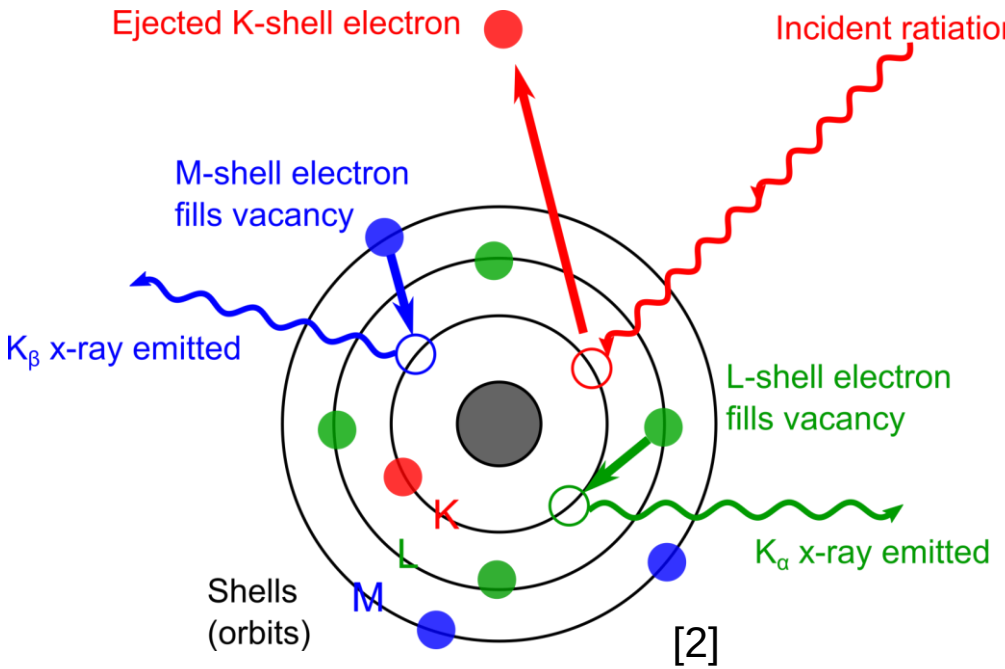
In-situ measurements enable experimental study and optimization of processes inside plasma wakefield



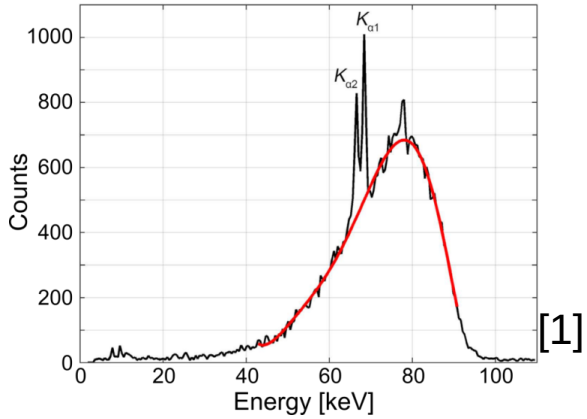
S. Bohlen et al., submitted (2022)

Applications: X-Ray Fluorescence Imaging (XFI*).

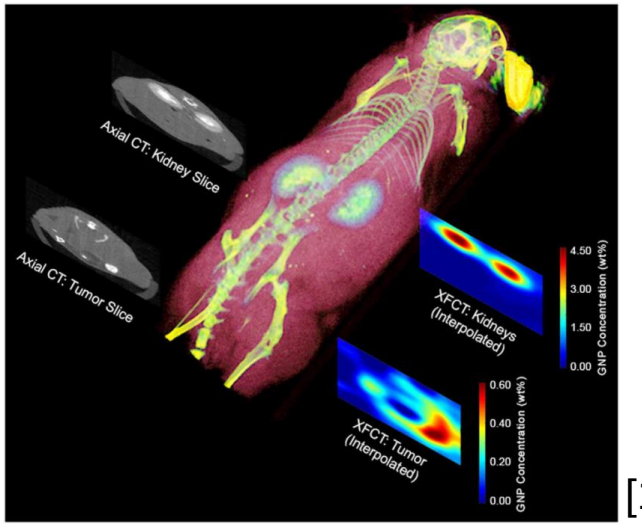
Scanning of a body with X-rays to detect Gold Nanoparticles (GNPs)



[2]



[1]



[1]

Possible applications:

- Imaging of cancer cells
- Pharmacokinetics (tracking of medical drugs)

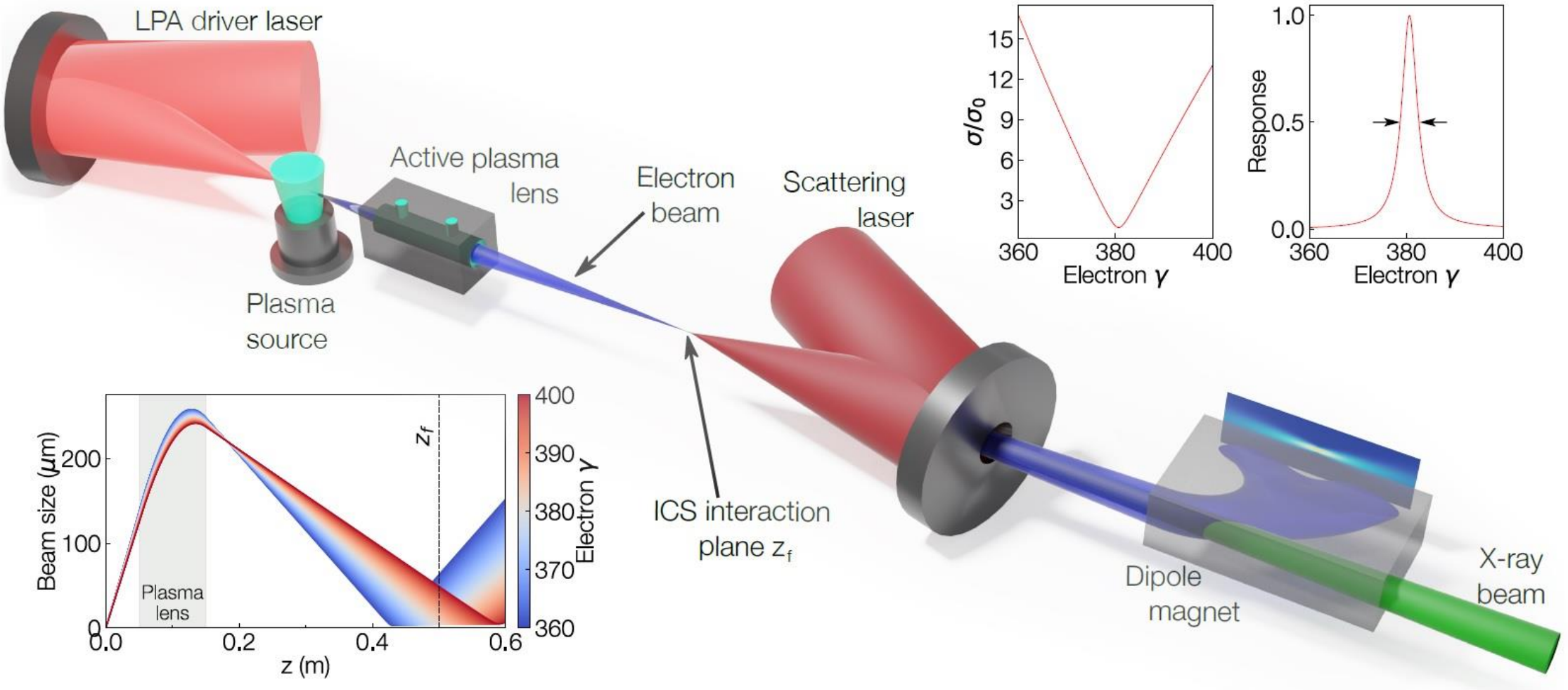
*Collaboration with University of Hamburg

[1] Manohar et al. (2016), Sci. Rep., 6: 22079

[2] image from www.bruker.com: How XRF works

Precision-tunable narrowband x-ray source

New design using active-plasma lens recently accepted in Scientific Reports



T. Brümmer et al., *Compact all-optical precision-tunable narrowband hard Compton X-ray source*, accepted in Scientific Reports

Summary

Stability of LPAs using ionisation-injection.

- Robust system for generation of electron beams at 2.5 Hz and charge constant over run of 8 hours and 72.000 shots
- Energy stabilization by operation close to dephasing limit
- Fluctuations of charge predominantly from shot-to-shot fluctuations of gas density
- New diagnostic: in-situ measurement of longitudinal evolution of beam energy and local acceleration gradient
- Developed new concept for tunable narrowband collimated x-ray source