Plasma, Laser, Action

First Shots from PALLAS
Laser Plasma Accelerator at IJCLab

Jana Serhal.
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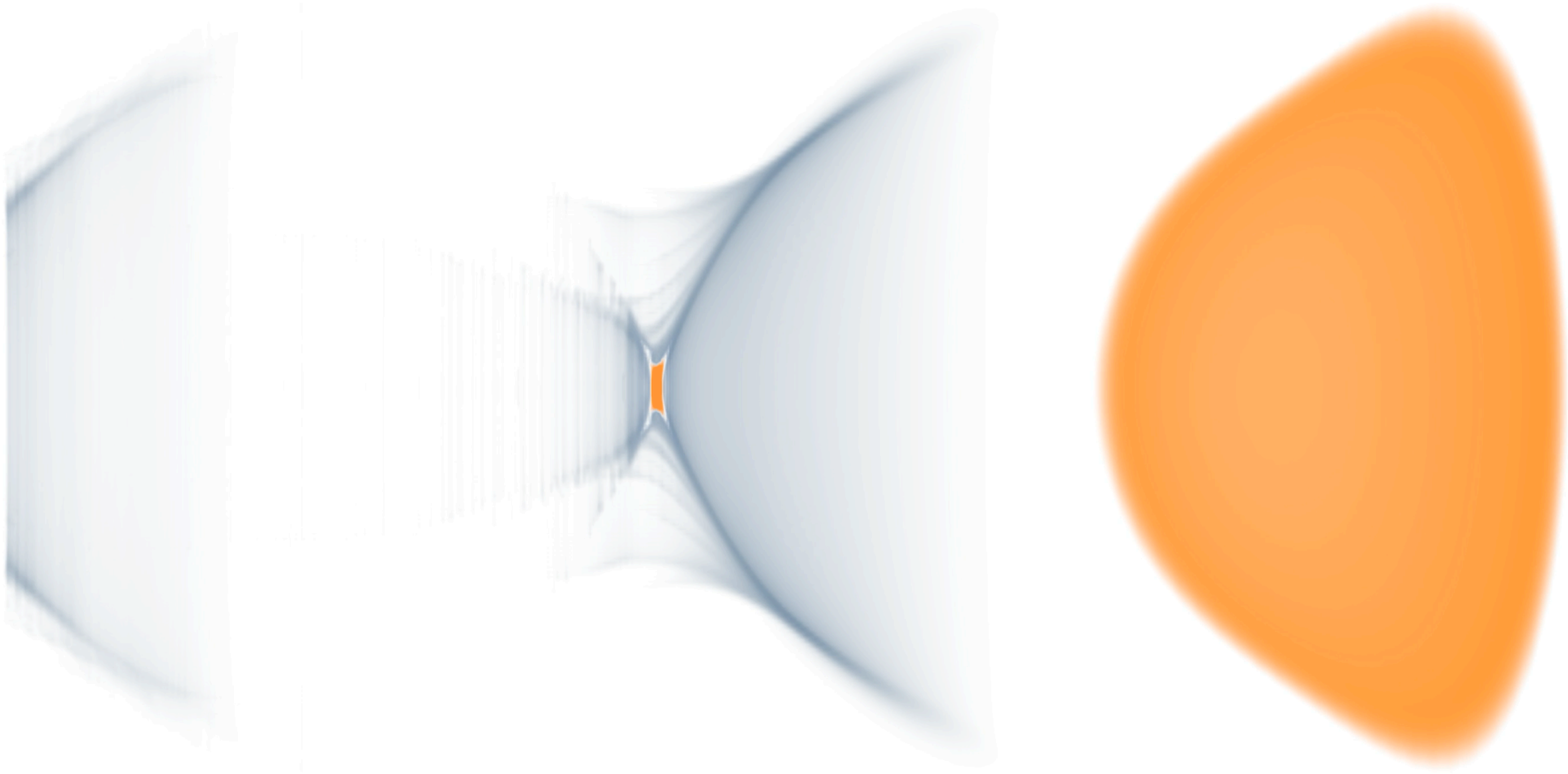
PALLAS
cnrs
IJCLab Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

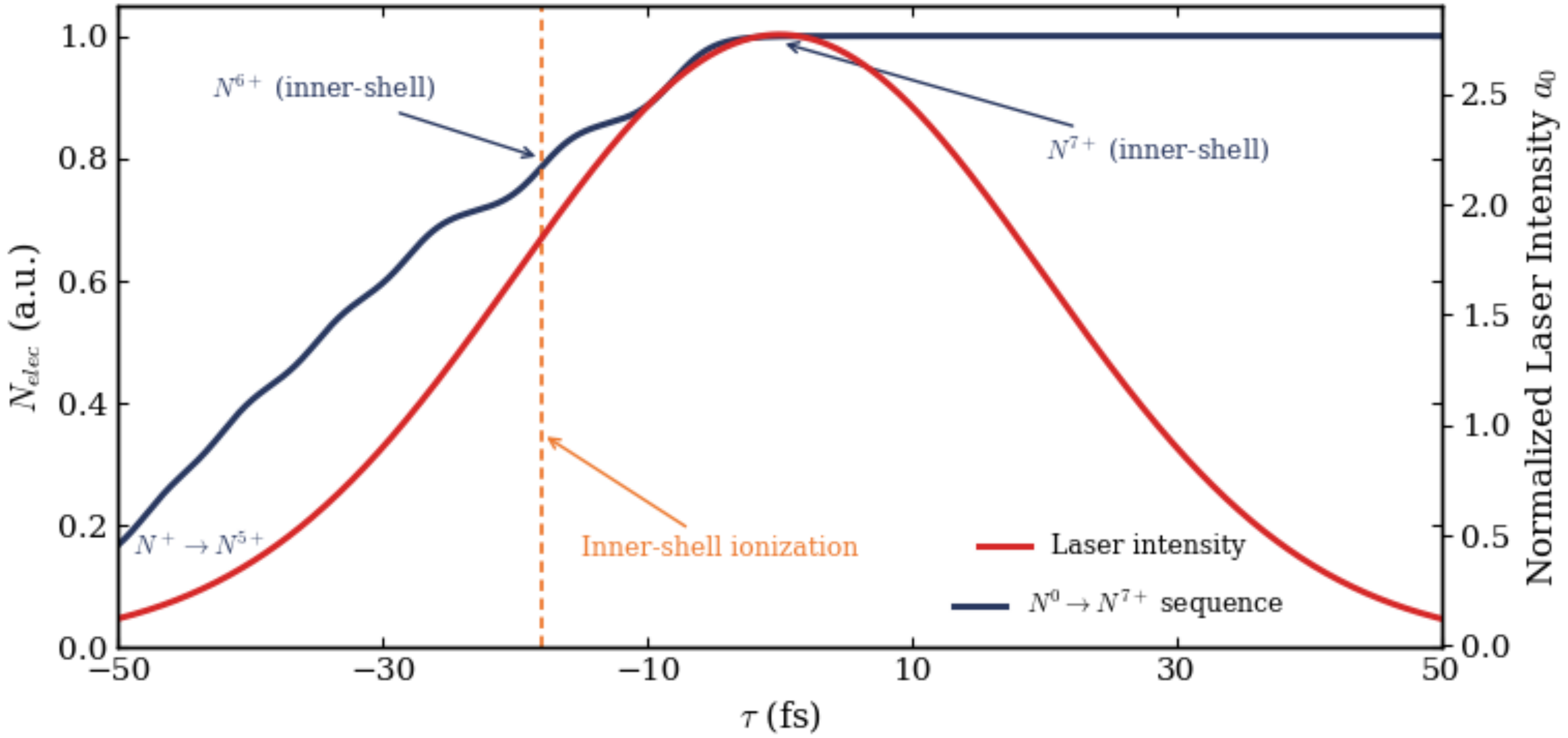
Laser Plasma Acceleration: Concept and Mechanism

- High-intensity laser beam ($\cong 1.10^{18} W/cm^2$)
- Drives a plasma wakefield in a gas target.
- Electrons can be trapped and accelerated in this wake.
- Gradient: **~100 GV/m** → 1000× conventional accelerators.



How to Inject Electrons into the Wakefield?

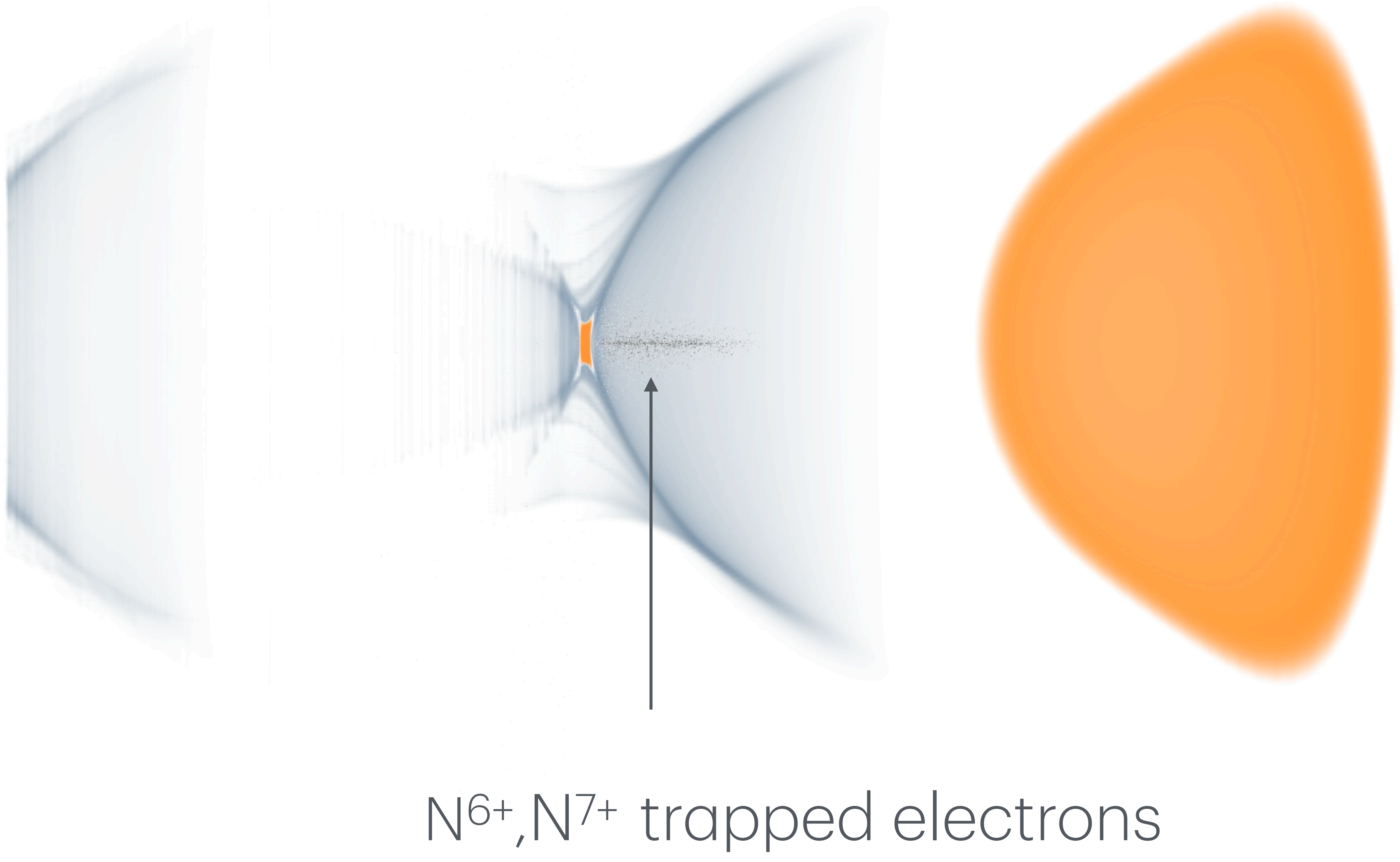
- Ionization injection: high-Z dopant (N_2) in low-Z gas (He).
- Electrons born inside the wake are automatically trapped and accelerated to high energies.



How to Inject Electrons into the Wakefield?

Only electrons moving close to the wake's phase velocity can be trapped and accelerated.

$$v_{electron} = v_{phase,wakefield}$$



PALLAS: Laser-Plasma Injector

🎯 Core Objectives:

Aiming for "high-quality beam" laser-plasma injector (LPI) facility working in Continuous 10 Hz operation

⚡ Precision Laser Control

Improve beam stability: pointing, energy, wavefront

Increase system uptime and reduce operator dependence

⚙️ Target Systems

Develop structured gas cells for reliable electron injection

Focus on material robustness and power handling at 10 Hz operation

💥 Electron Beam Studies

Baseline beam characterisation and first control tests

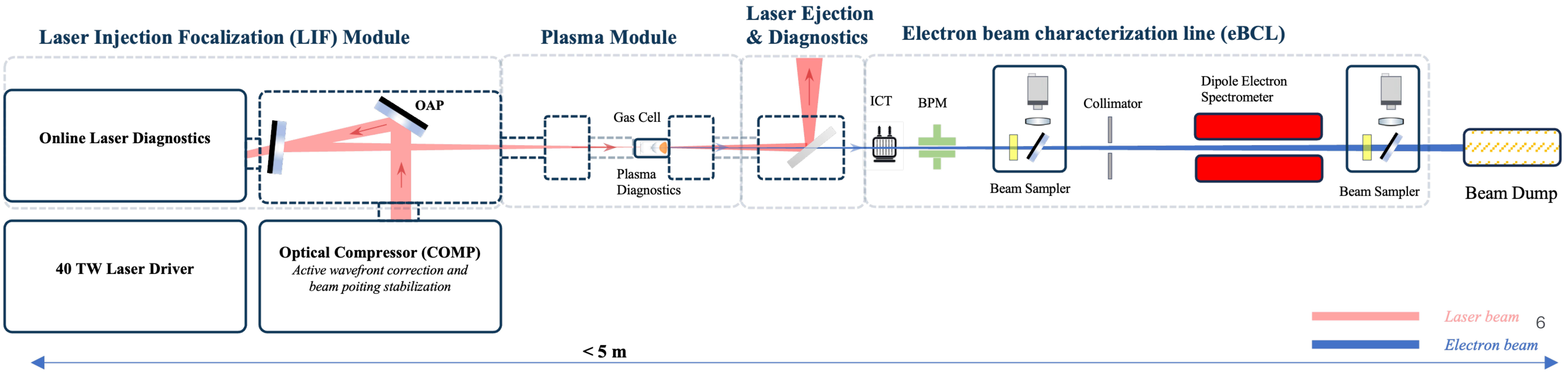
PALLAS: Laser-Plasma Injector

Current Laser System:

- 40 TW, 1.4–1.6 J, 45 fs
- 1 Hz rep rate
- Stability: 11–13 μrad (PV)

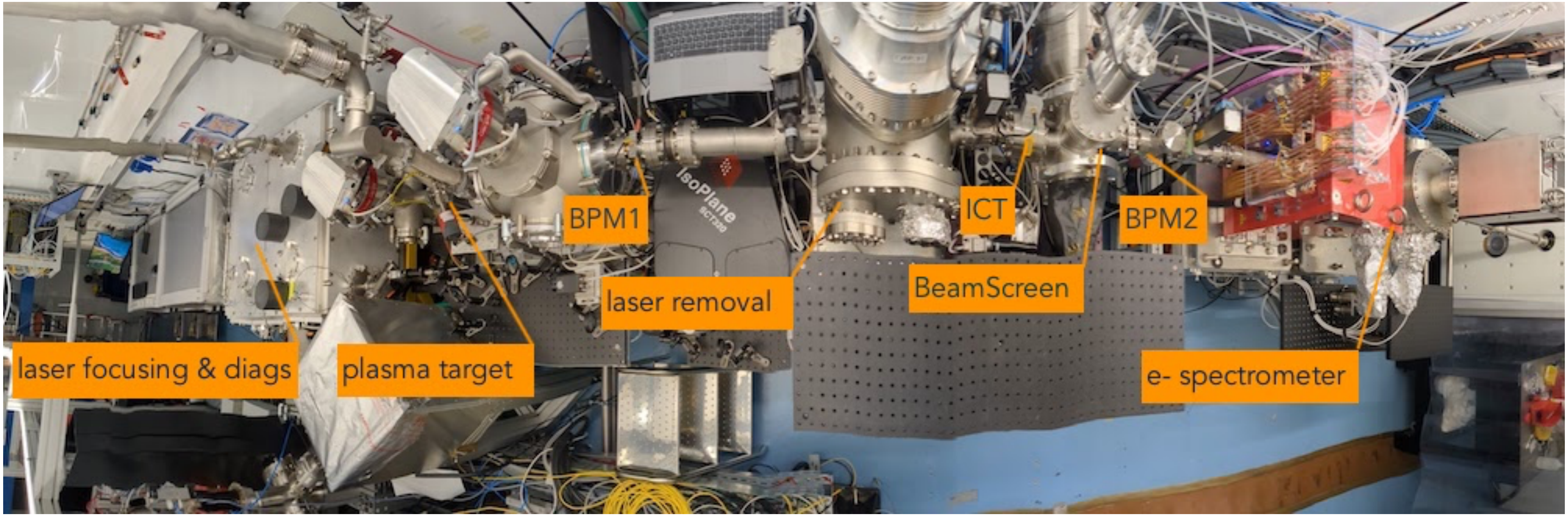
Targer Laser System:

- 3J, 40 fs
- 10 Hz rep rate
- Stability < 1 μrad (PV)



PALLAS: Laser-Plasma Injector

The Setup

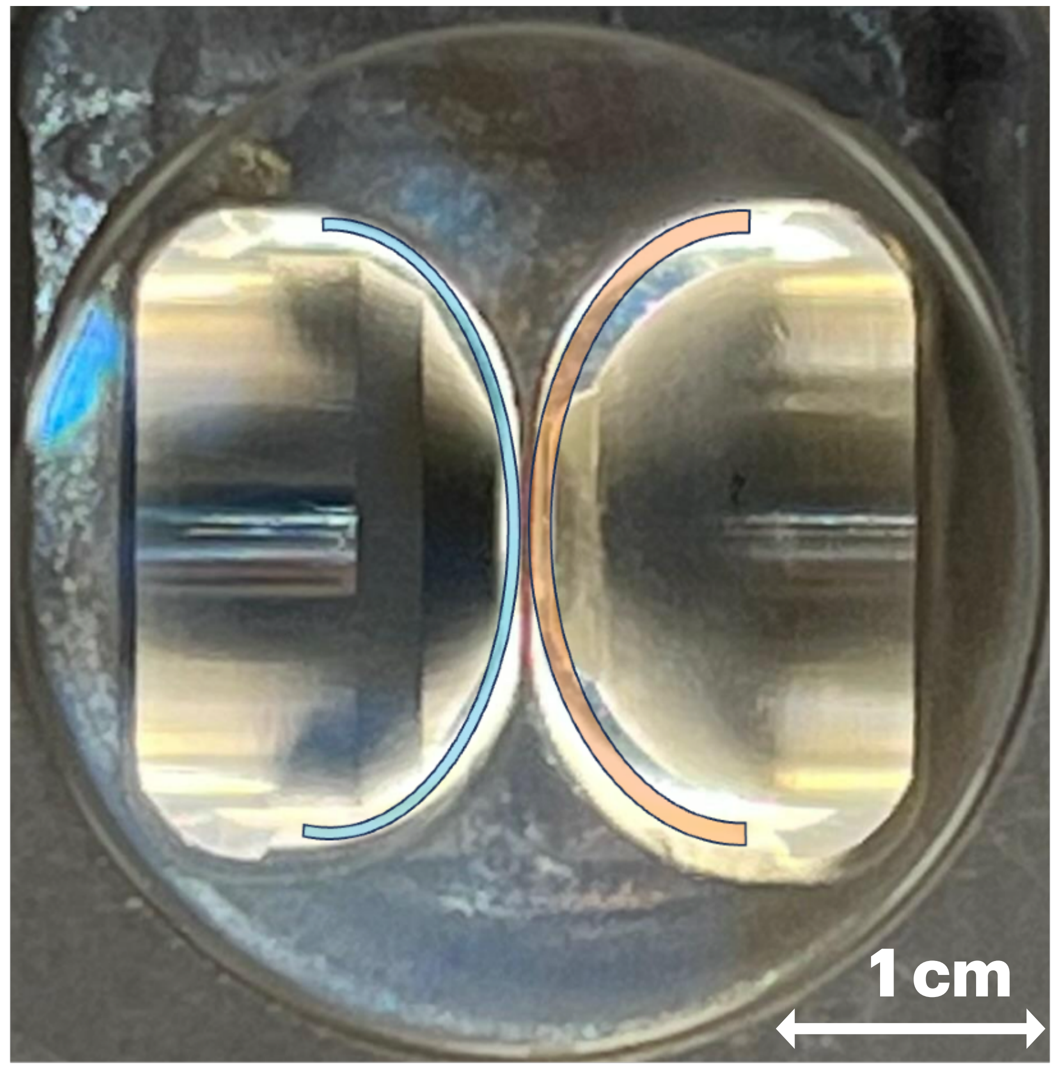


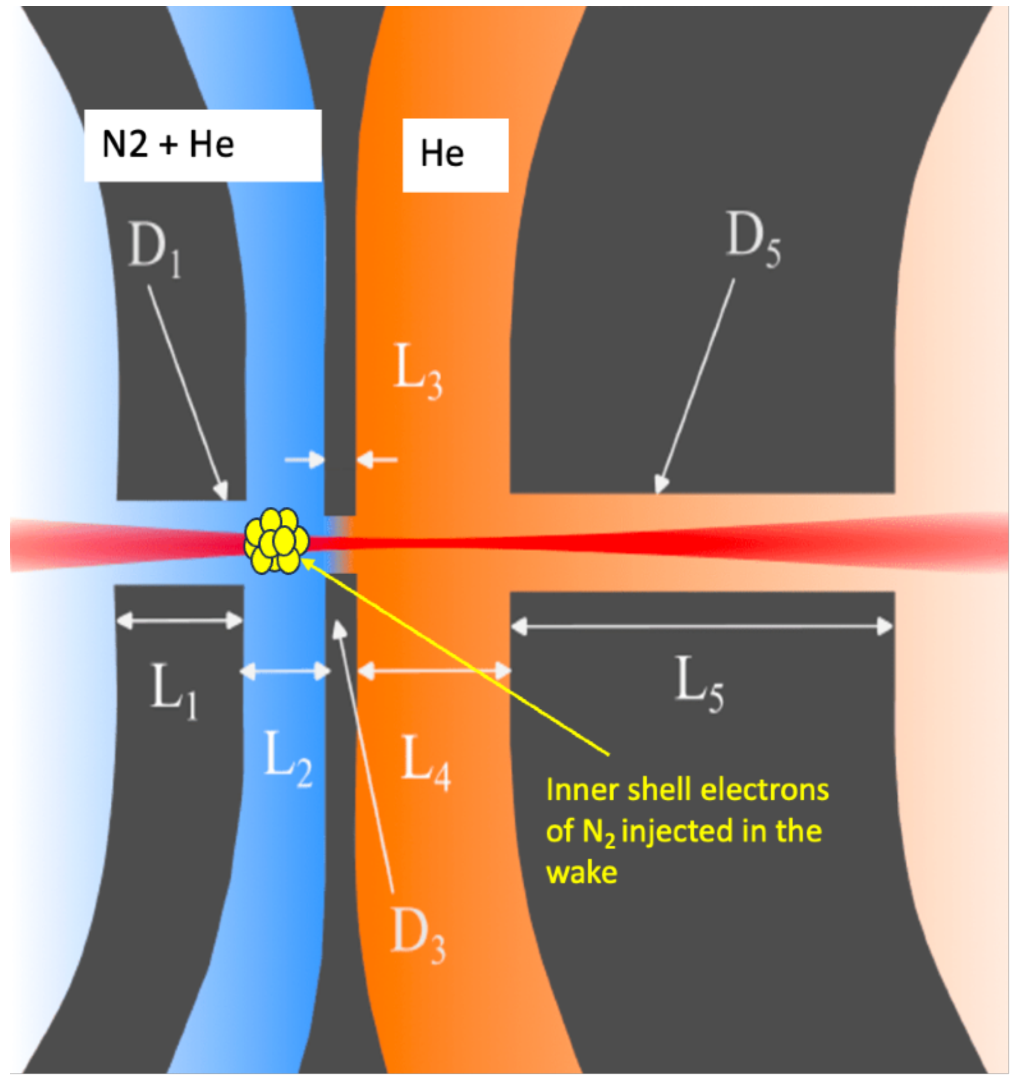
Two-Chamber Gas Cell: Injection & Acceleration

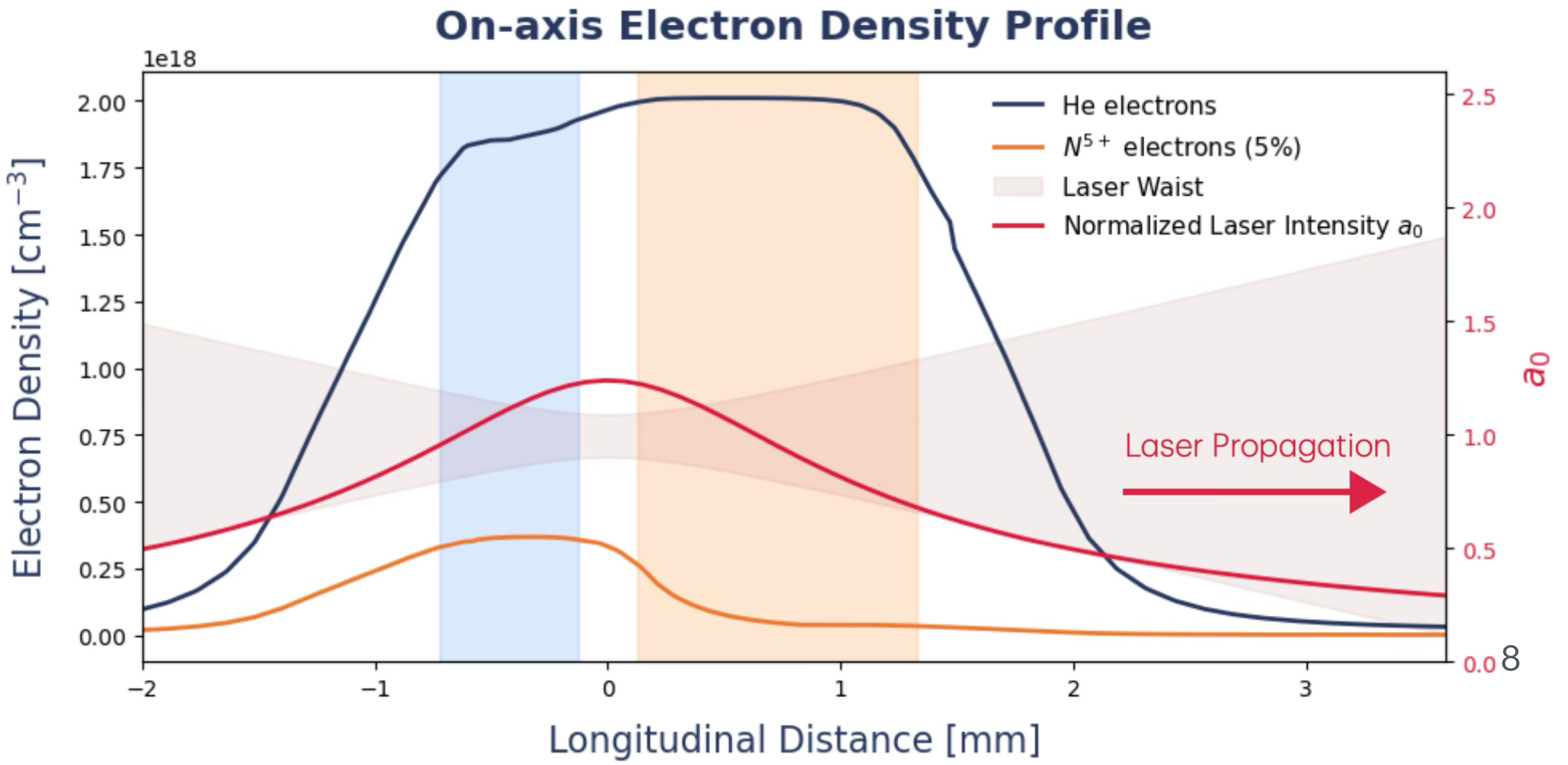
- **Injection chamber (blue):** N_2/He mixture → ionisation injection
- **Acceleration chamber (orange):** pure He for energy gain
- **Gas profiles:** validated with computational fluid dynamics simulations

Plasma diagnostics:

- Probe beam for electron density
- Spectral diagnostics for dopant localisation via spectral emission lines

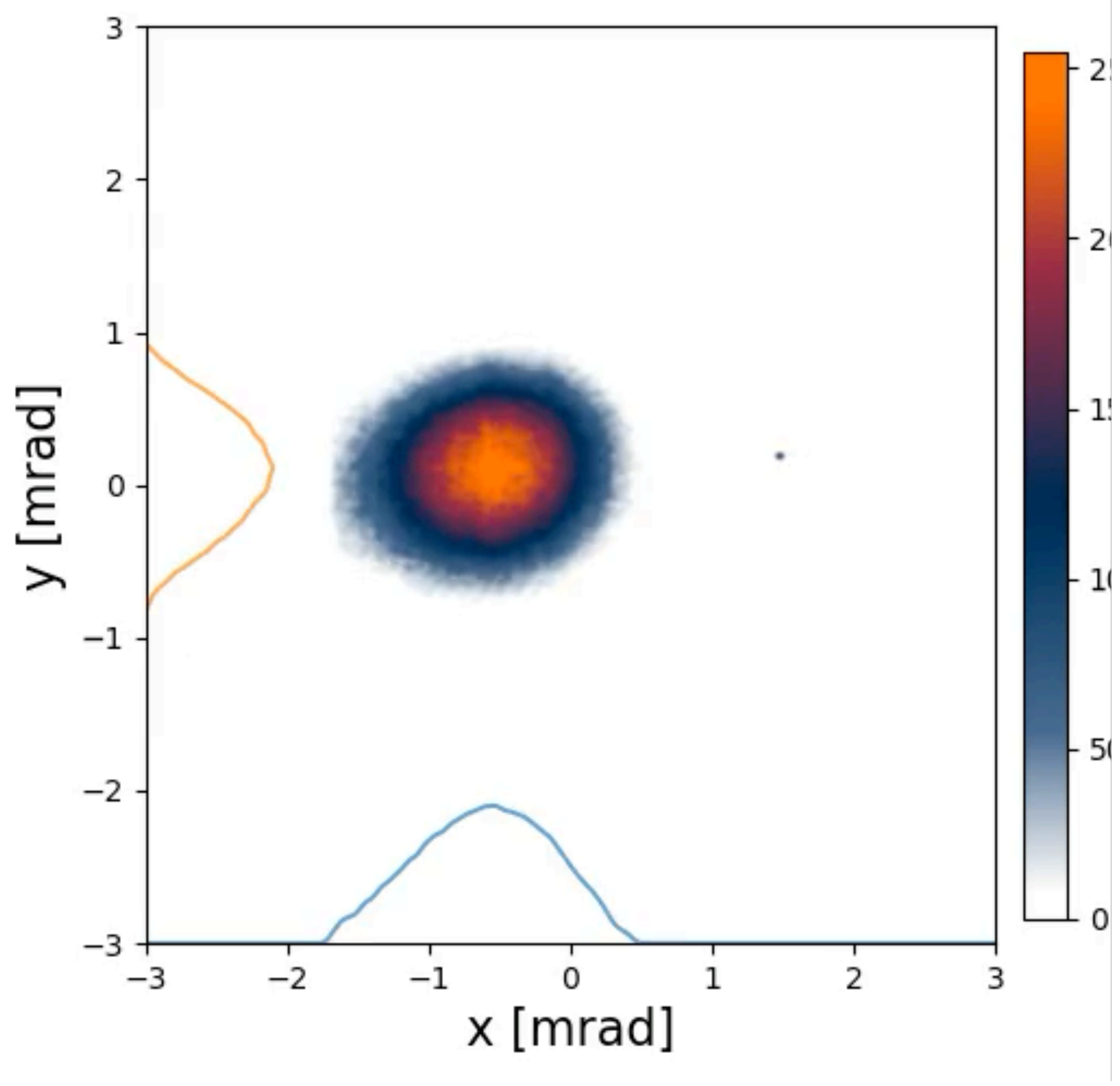


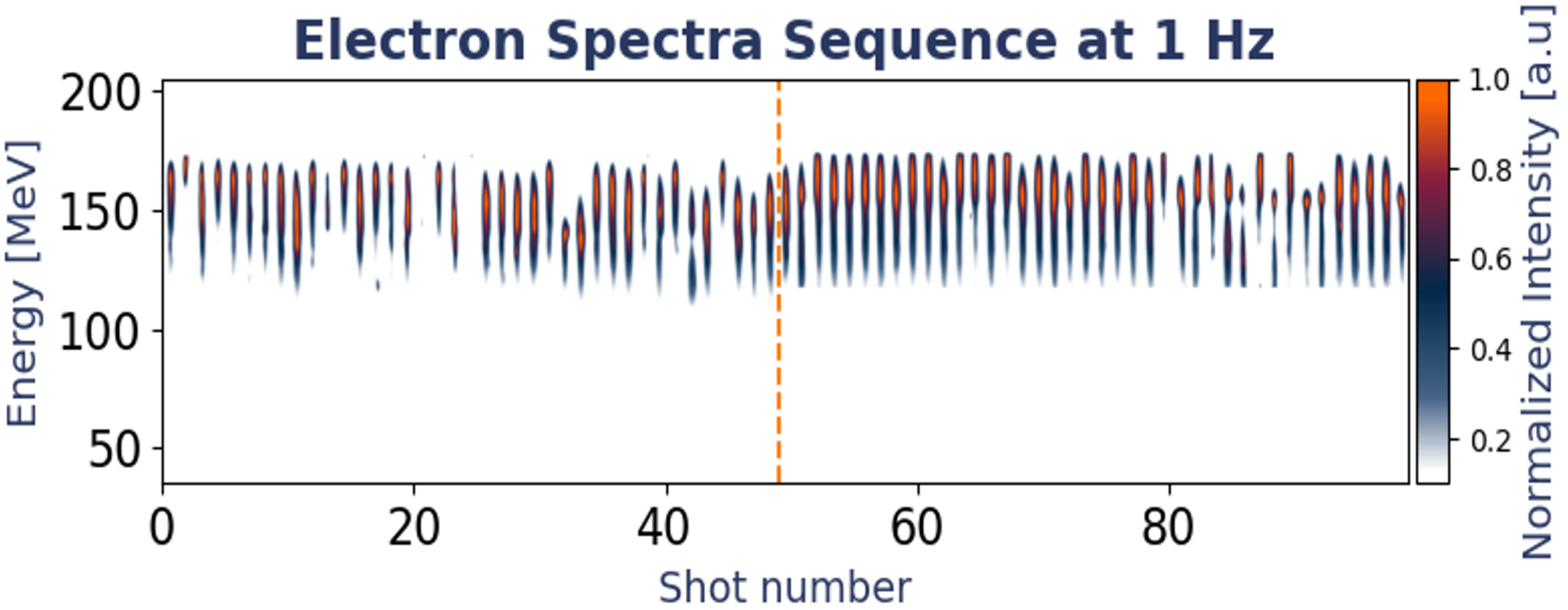




Electron Beam: First Results

First electron beams observed at 1 Hz operation with pressure P=75 mbar and N_2 concentration $c_{N2} = 35\ \%$.





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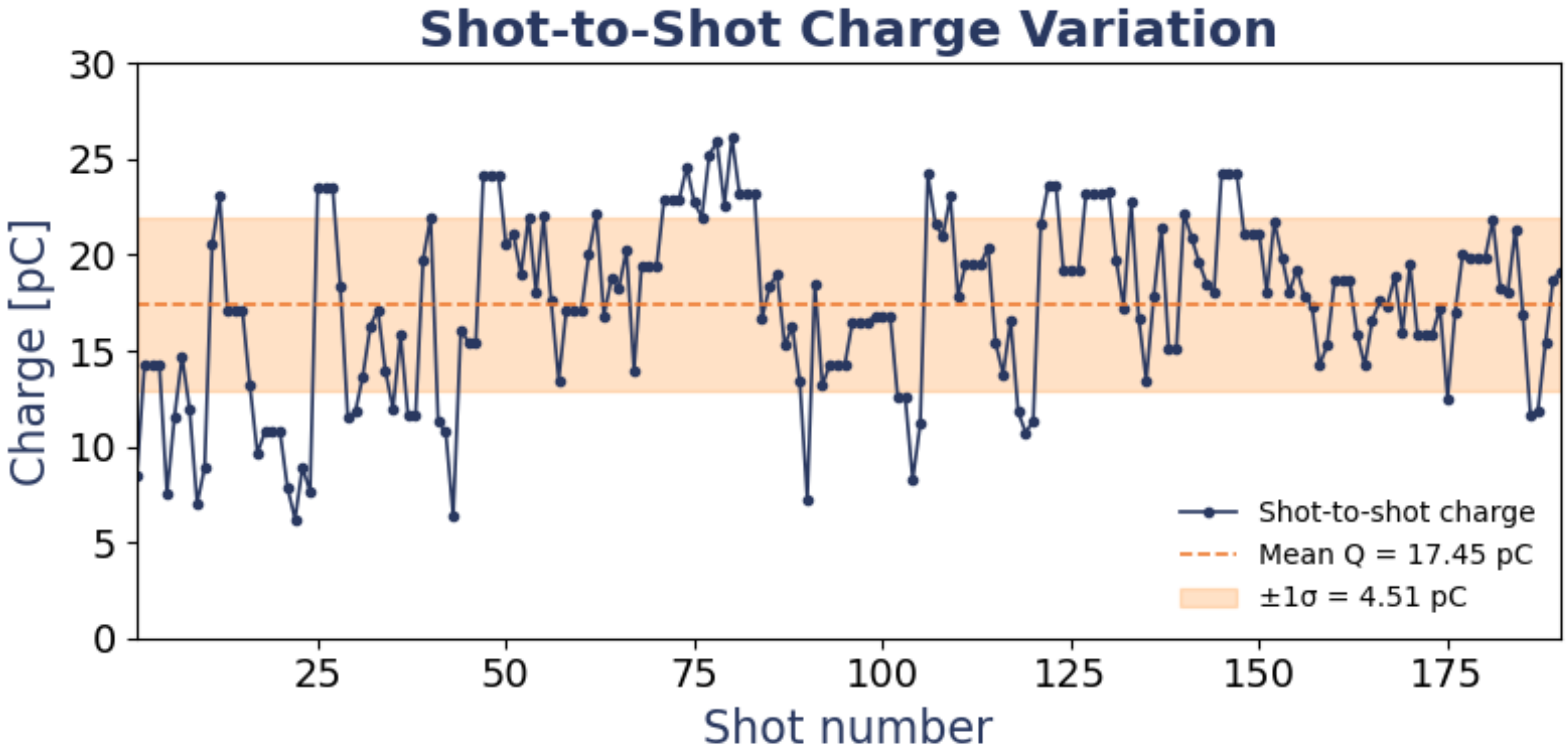

Electron Beam: First Results

Key Takeaway

- First beams observed at 1 Hz commissioning
- 140–160 MeV, 10–25 pC, divergence <2 mrad
- Stability 15–23%, energy spread broad (no focusing yet)
- • Next steps: higher laser energy on target, pointing stabilisation, 10 Hz operation…

Parameter		Goal	Achieved
Energy (E_{med})	[MeV]	150	140-160
Energy Spread (σ_E)	[MeV]	<7.5	18-100 (+)
Charge (Q)	[pC]	15-30	10 -25
Divergence (θ)	[mrad]	<5	0.8 x 1.2
Stability	[%]	5	15 -23

The Team

Baynard, Elsa
Beck, Arnaud
Cassou, Kevin
Cayla, Jean Noel
Coacolo, Jean Louis
Douillet, Denis
Gonnin, Alexandre
Huber Arnaud
Iaquaniello, Gregory
Kane, Gueladio
Kazamias, Sophie
Lenivenko, Mykyta
Lucas, Bruno
Malkinski Konrad
Neveu, Olivier
Peinaud, Yann
Pintonato Marceau
Pittman, Moana
Serhal, Jana
Specka, Arnd
Swain, Kalyani