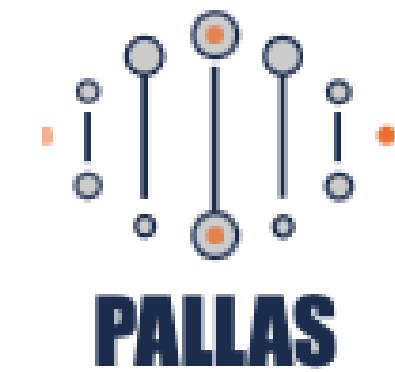


From PALLAS to DESY

Plasma targets for high-repetition-rate laser-plasma accelerators



Jana Serhal
22/10/2026

Laser Plasma Acceleration:

the concept & mechanism

1

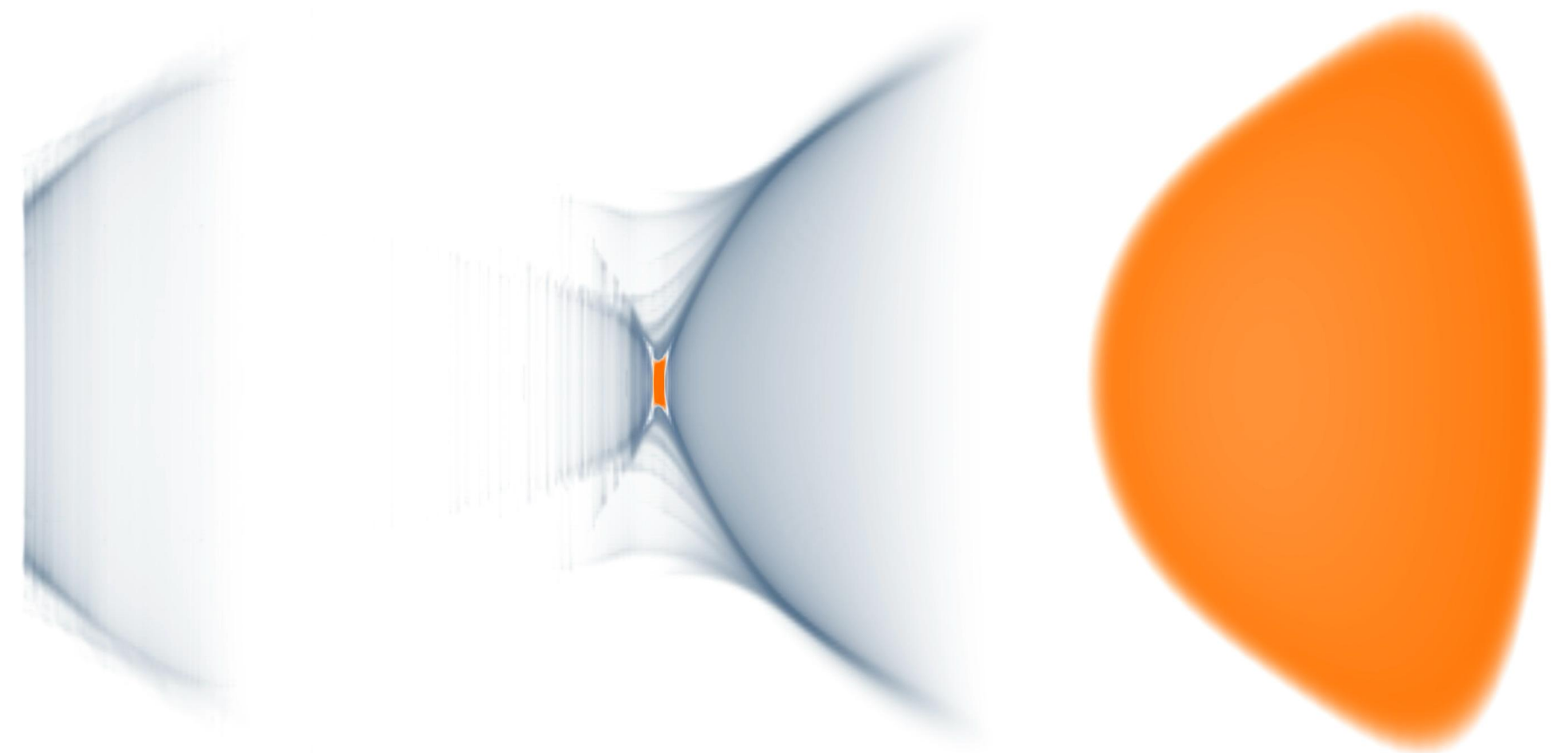
An intense laser pulse ($\cong 1.10^{18} W/cm^2$) is shot at a gas target

2

The pulse ionises the gas $\rightarrow$ plasma
It then drives a **wave** in the plasma.

3

Electrons surf the wave and gain energy over few millimetres



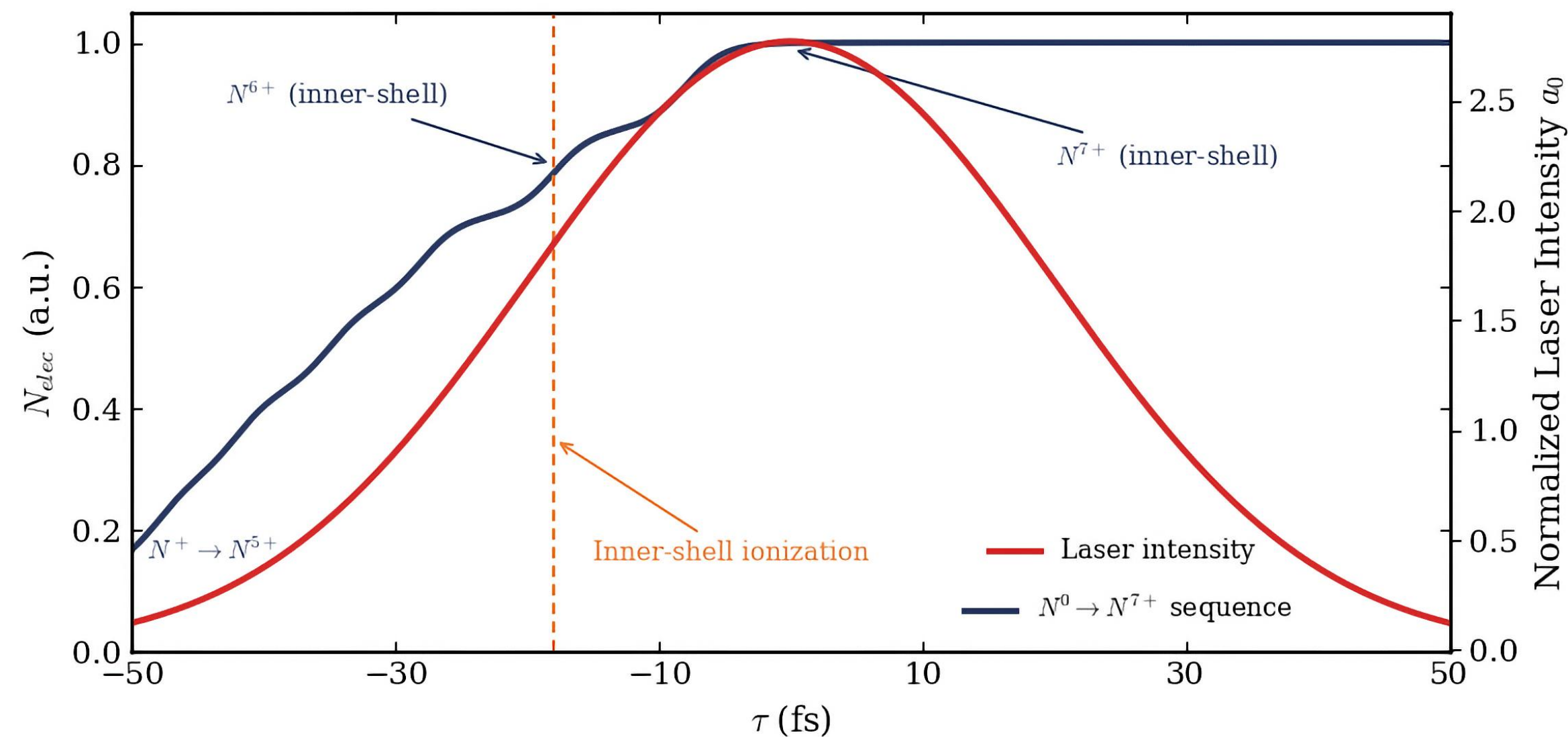
Simulation: the laser pulse (orange) drives a plasma wave (blue) behind it

100 GV/m
accelerating gradient

X 1000
RF cavities

Catching the electrons

ionisation injection



1

Add dopant

A little bit of nitrogen N2 in Helium

2

Outer electrons leave early

Freed by the front of the pulse, helps to the formation of the wave

3

Inner shell electrons leave later

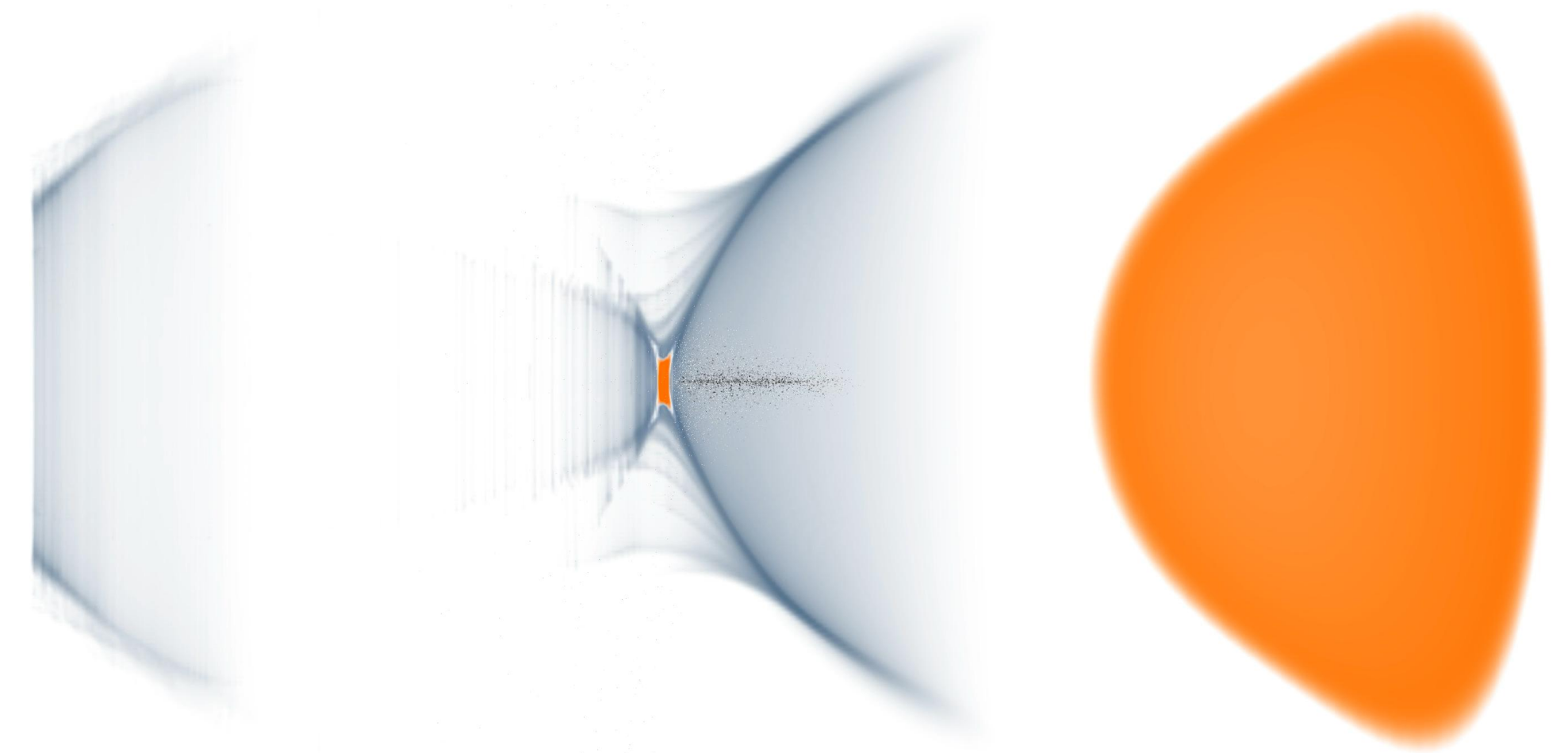
$N^{5+} \rightarrow N^{6+}, N^{7+}$ only at peak intensity, inside the wave $\rightarrow$ trapped

Only fast electrons are trapped

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

The challenge: injection

Put electrons in the right place, at the right moment.



Simulation: a bunch of trapped electrons rides at the back of the wave

PALLAS : Laser-Plasma Injector at IJCLab

3 J . 45 fs

Laser pulse

1 —> 10 Hz

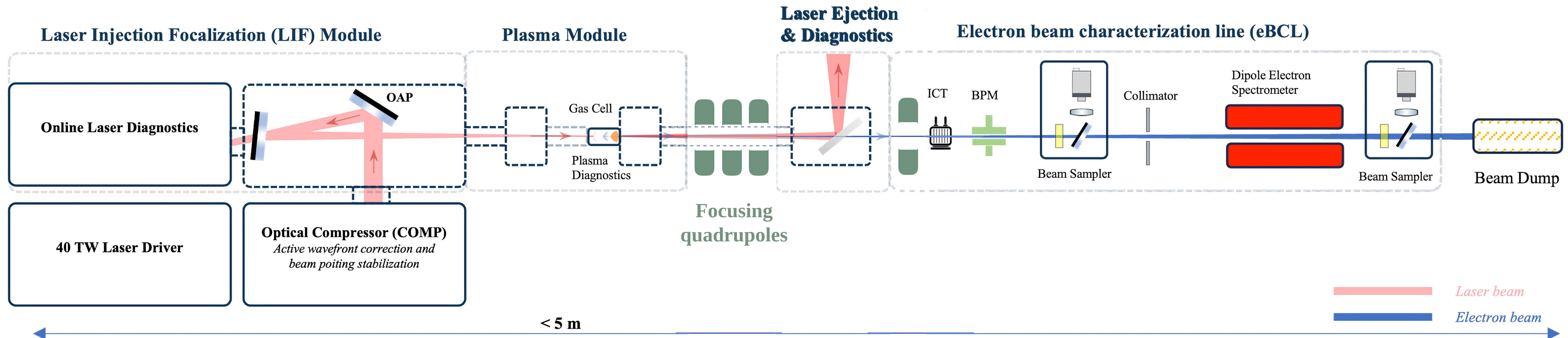
Repetition rate

12 μ rad —> <1 μ rad

Pointing stability

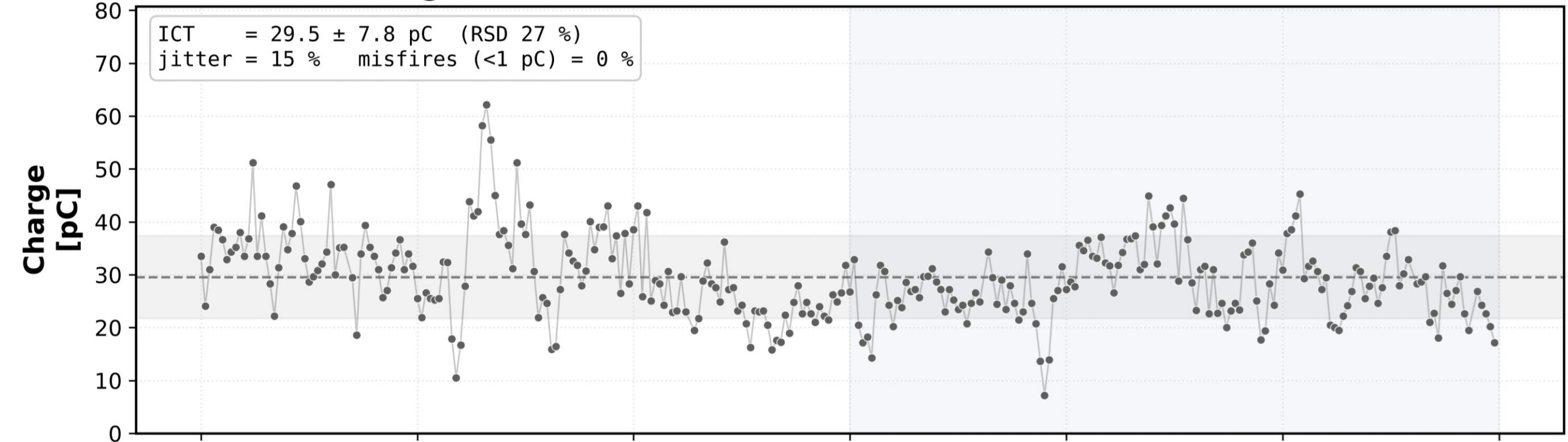
<5 m

Beamline

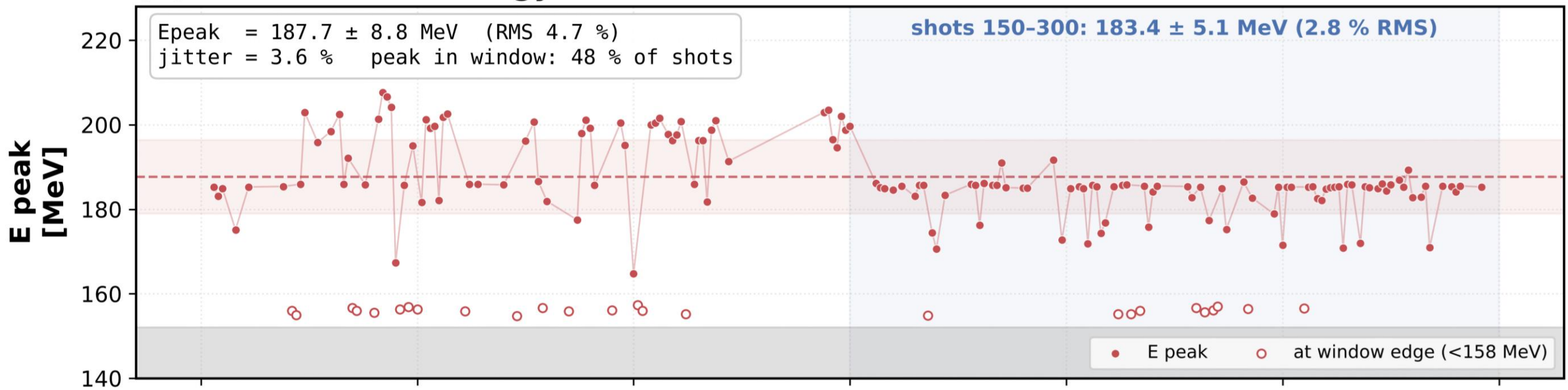


Recent Beams from PALLAS

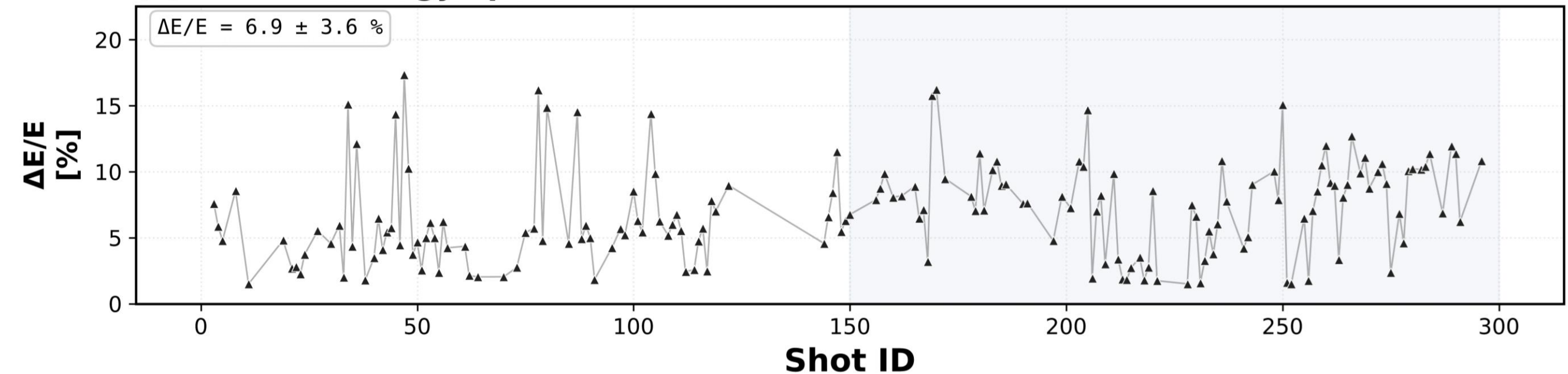
(a) Electron Charge



(b) Electron Peak Energy

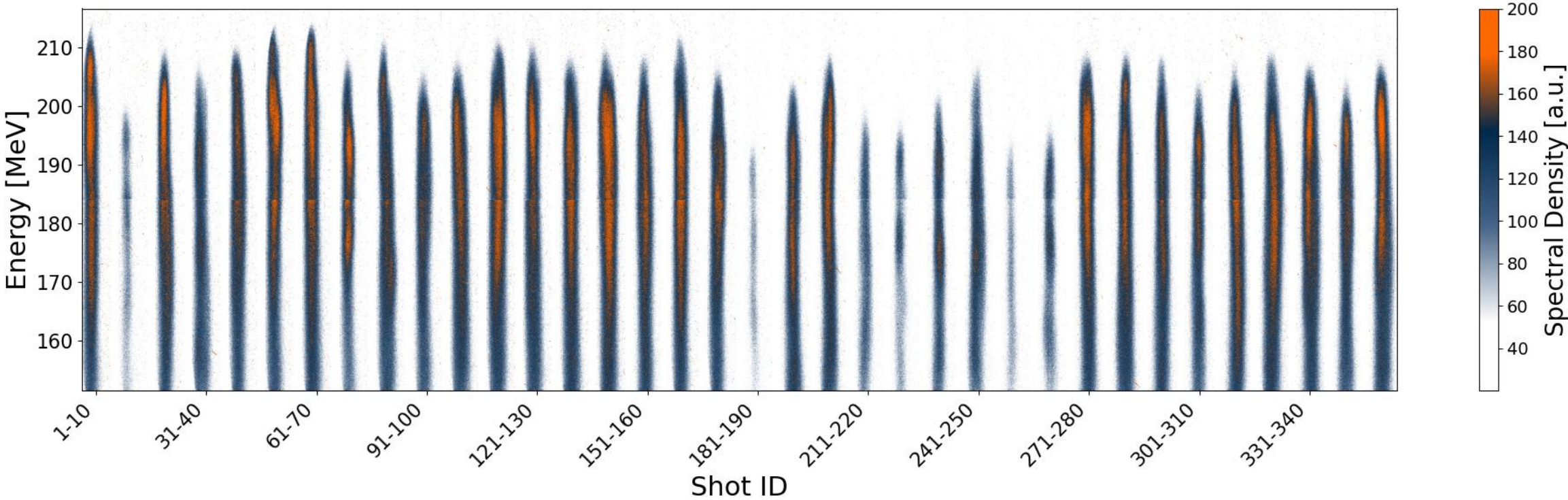


(c) Relative Energy Spread



29.5 pC
Charge

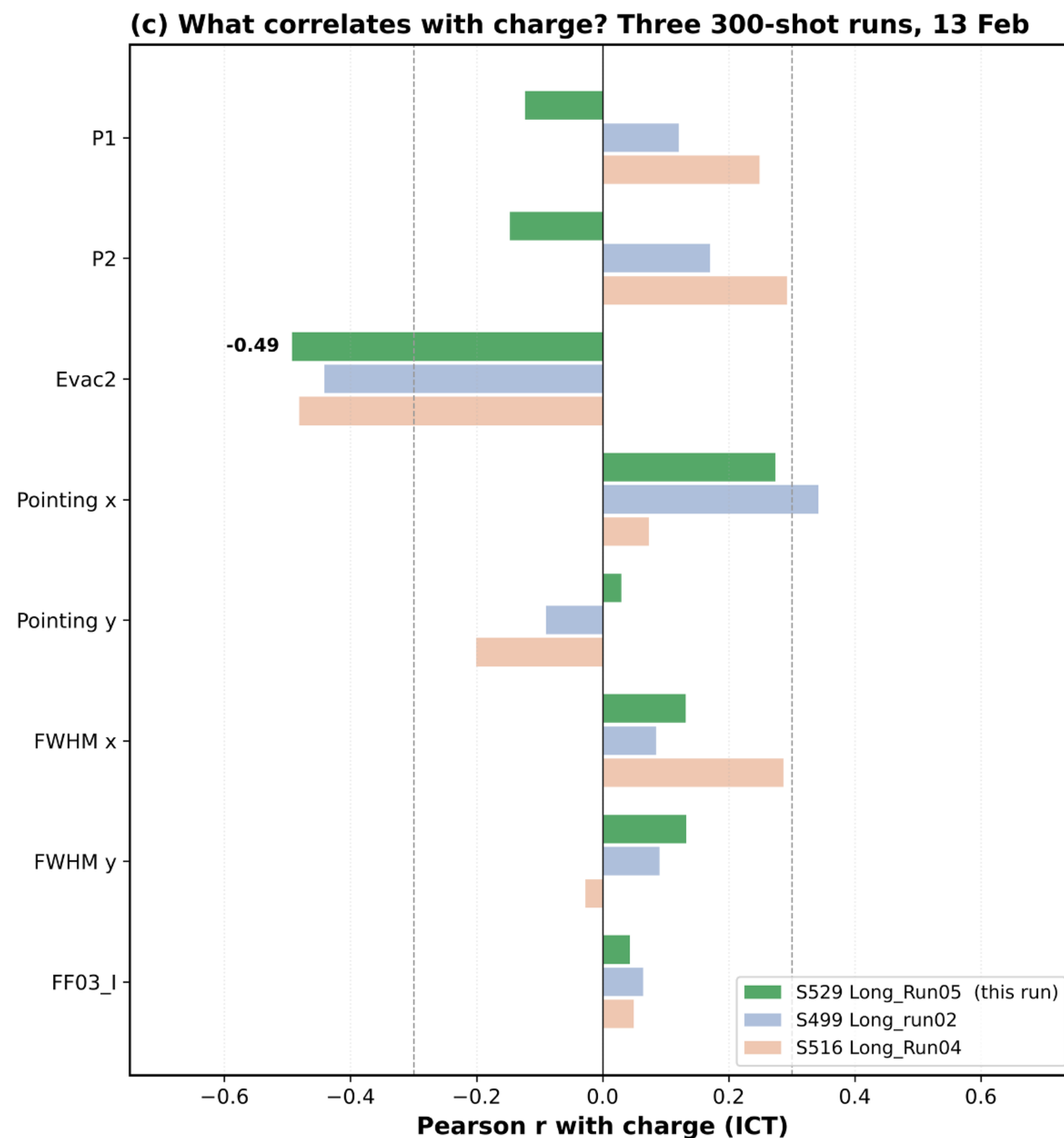
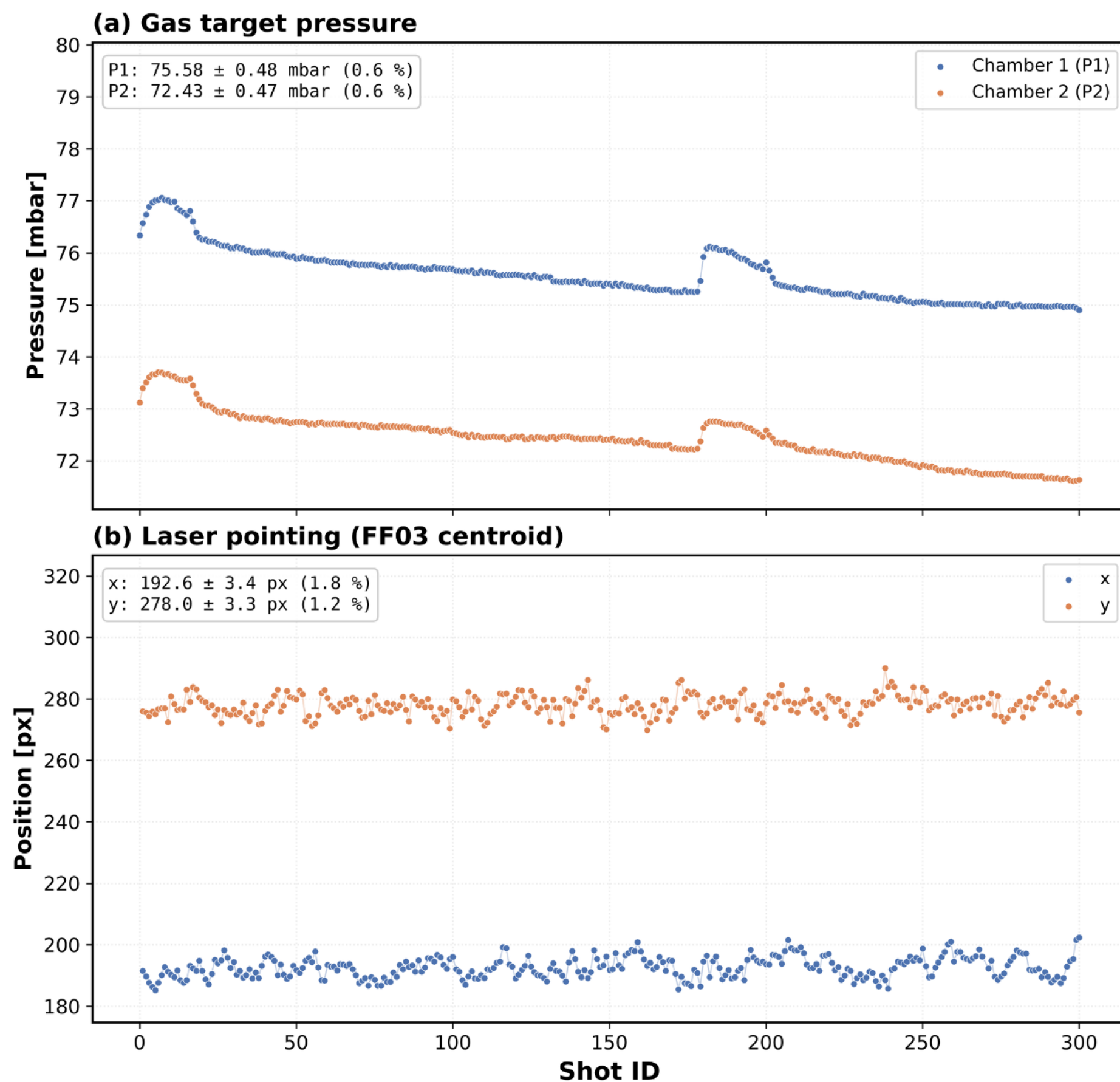
187 MeV
Peak energy



Spectra averaged over groups of 10 shots, from a ~350-shot long run of the February campaign.

Understanding the correlations

Laser & target conditions



Stable gas target
Pressure in both chambers
held to 0.6 % over 300 shots.

Charge follows the
vacuum.

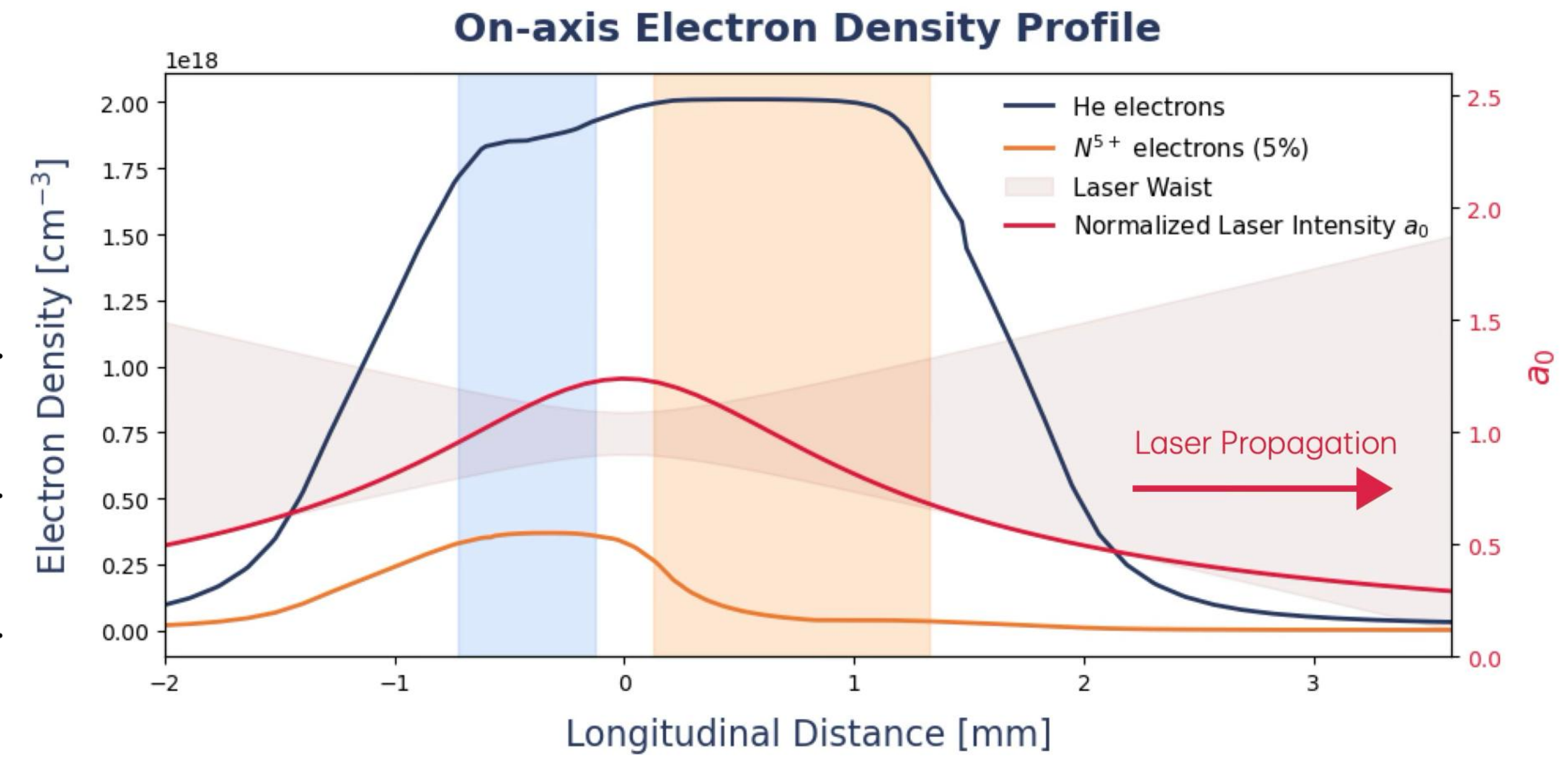
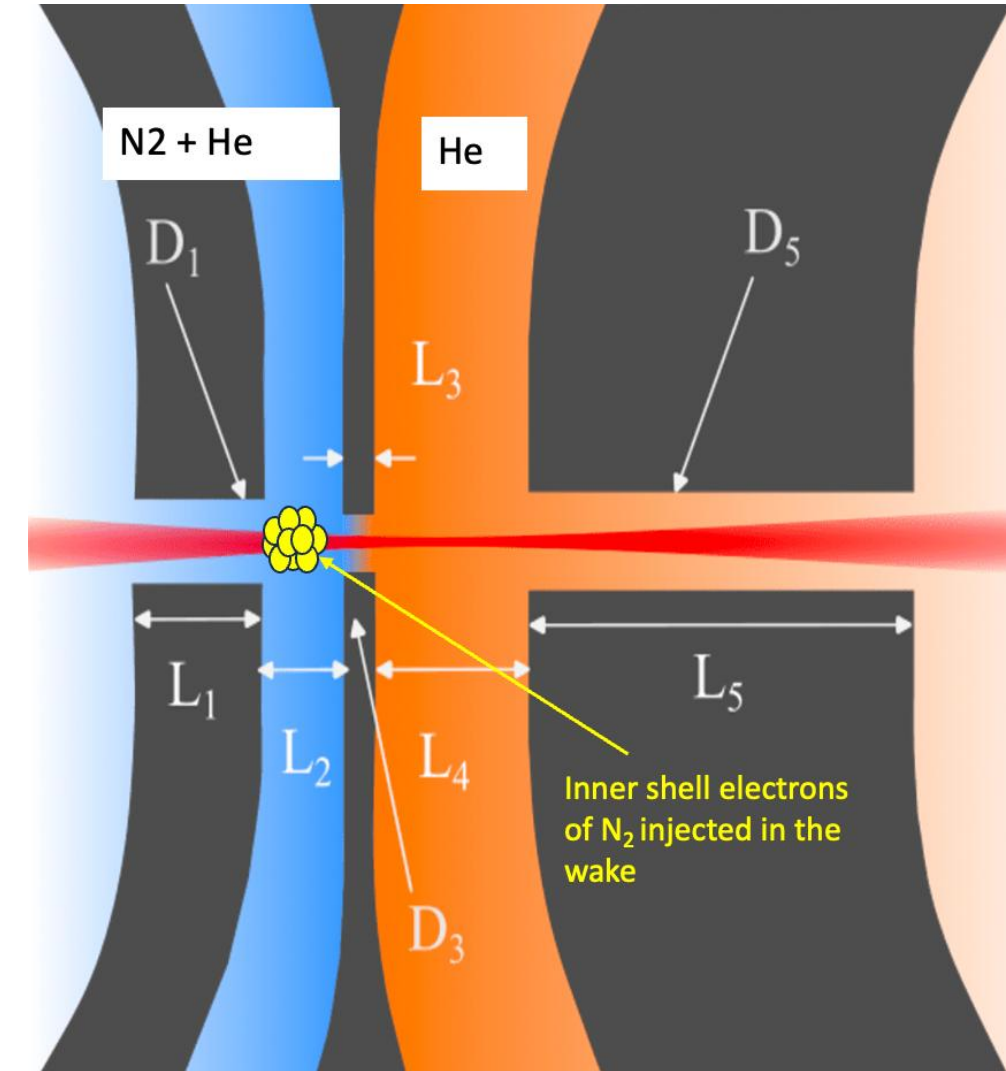
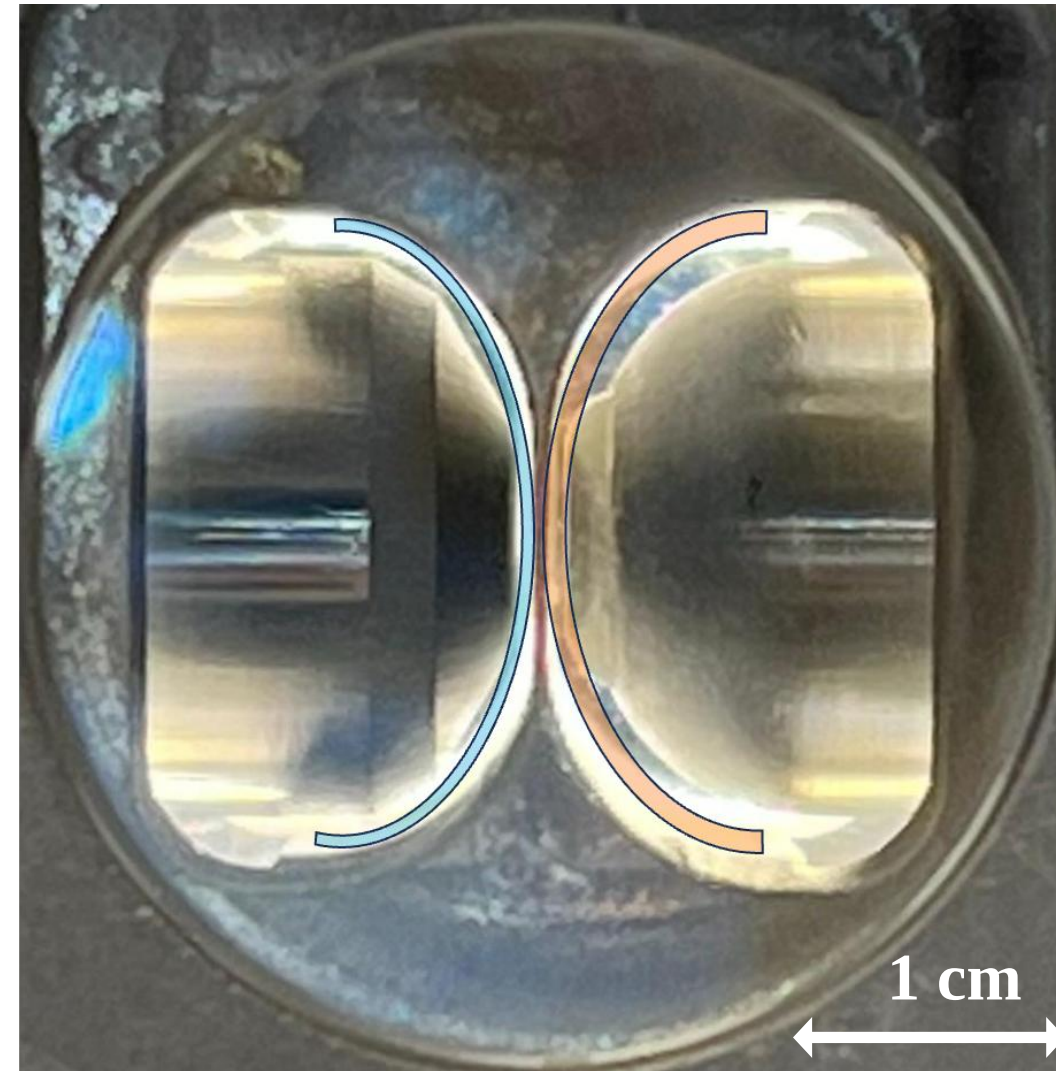
Laser pointing matters:
Horizontal laser pointing
correlates with charge.

How to counteract energy spread?

Through the *injection* process

DIANA : Two Chamber Gas Cell

The injector



Injection Chamber

N_2 / He mixture $\rightarrow$ ionisation injection



Acceleration Chamber

Pure He $\rightarrow$ energy gain

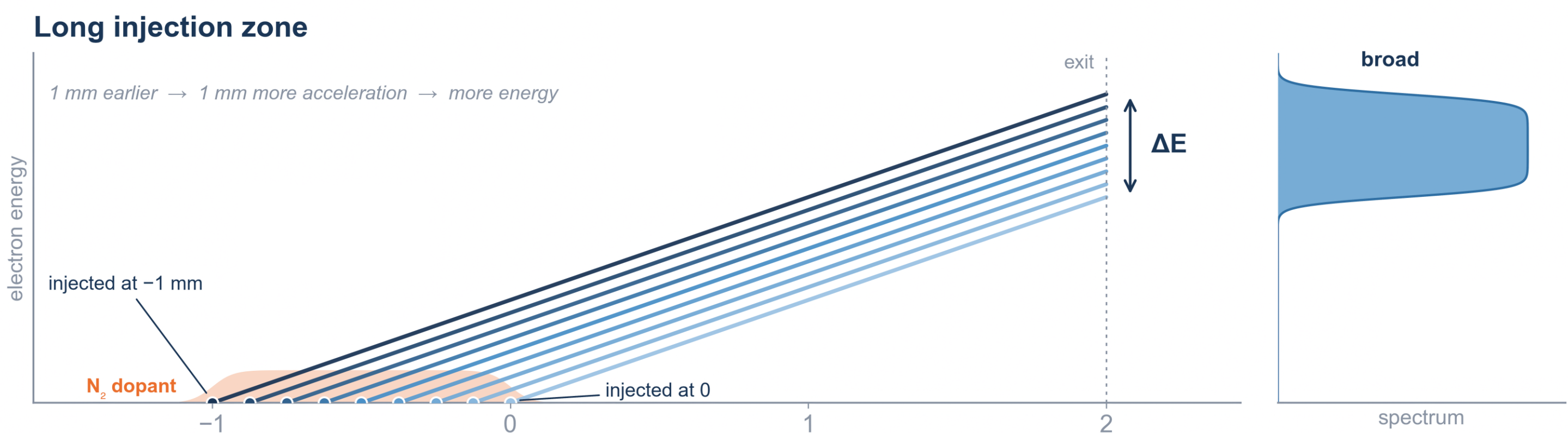


Diagnostic

Probe beam for density · emission lines for dopant localisation

What about Energy Spread?

Cause 1 : A long injection zone



1

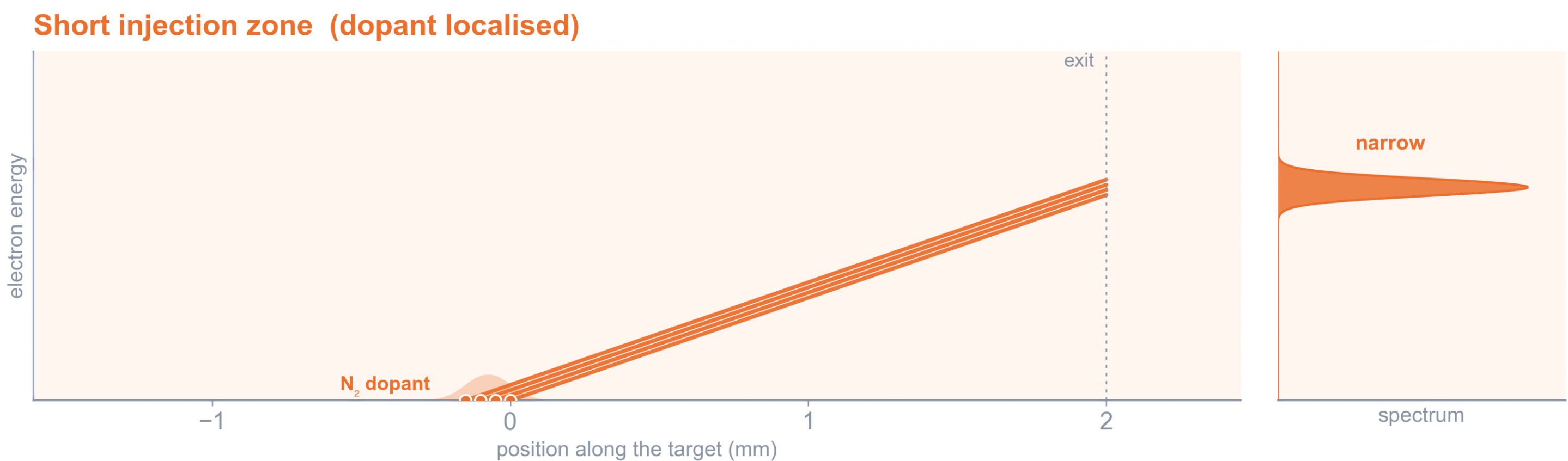
Electrons are born where the dopant is:

A long dopant region injects over a long distance.

2

Born earlier, accelerated longer

Injected at -1 mm vs 0: one extra millimetre in the wave, so more energy.

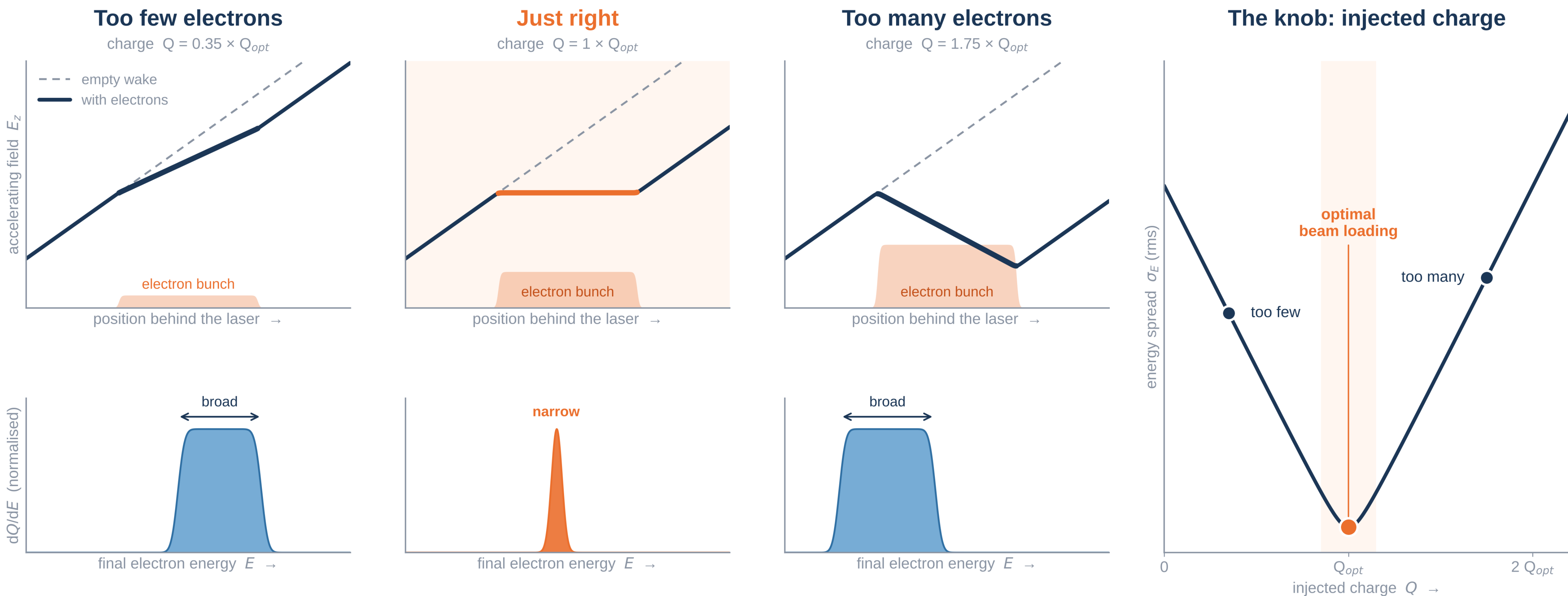


Short injection → narrow spectrum

What about Energy Spread?

Cause 2 : Beam Loading

The electron beam drives its own wakefield which superimposes that of the laser.

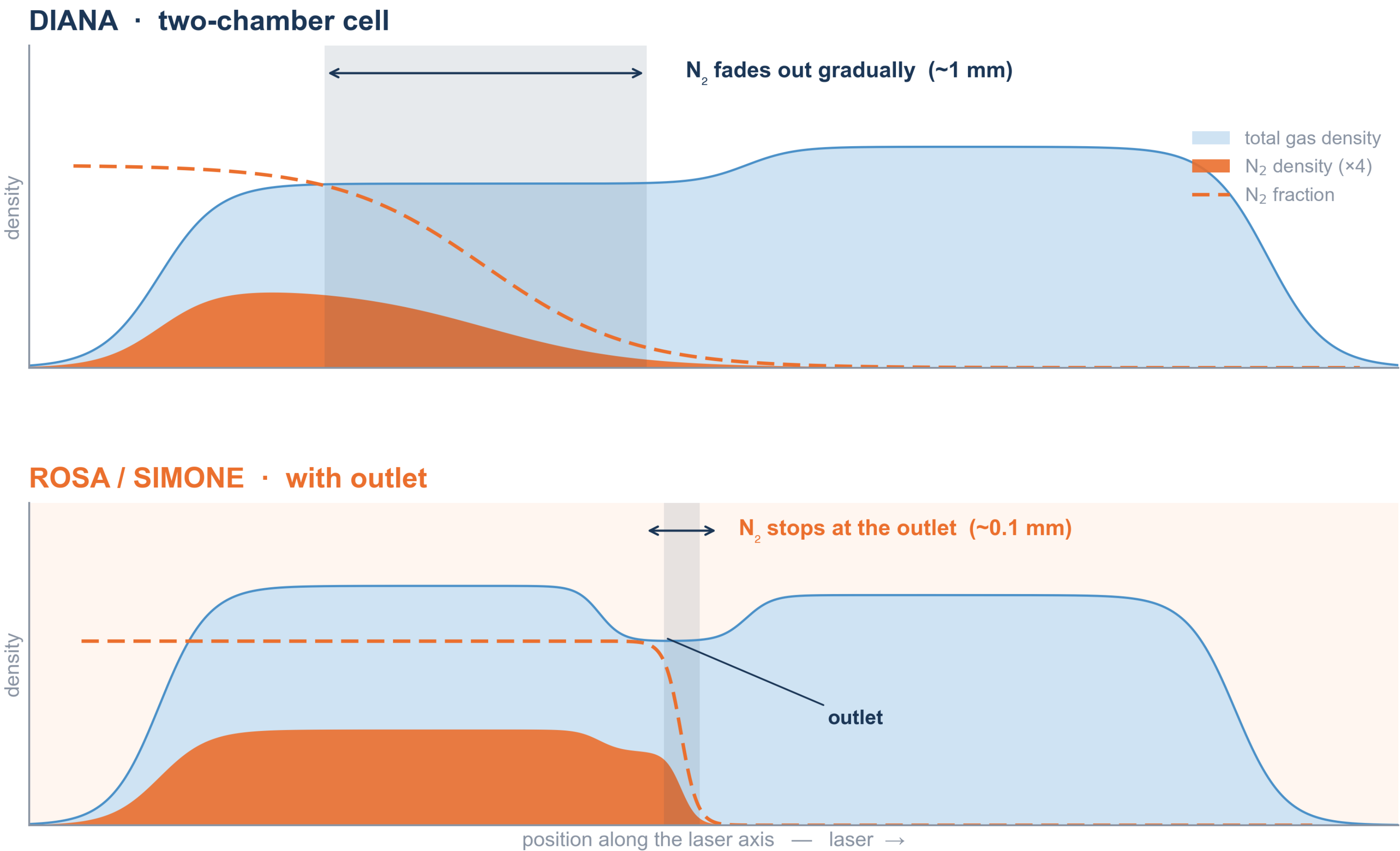


After DIANA :

ROSA and SIMONE localise the dopant

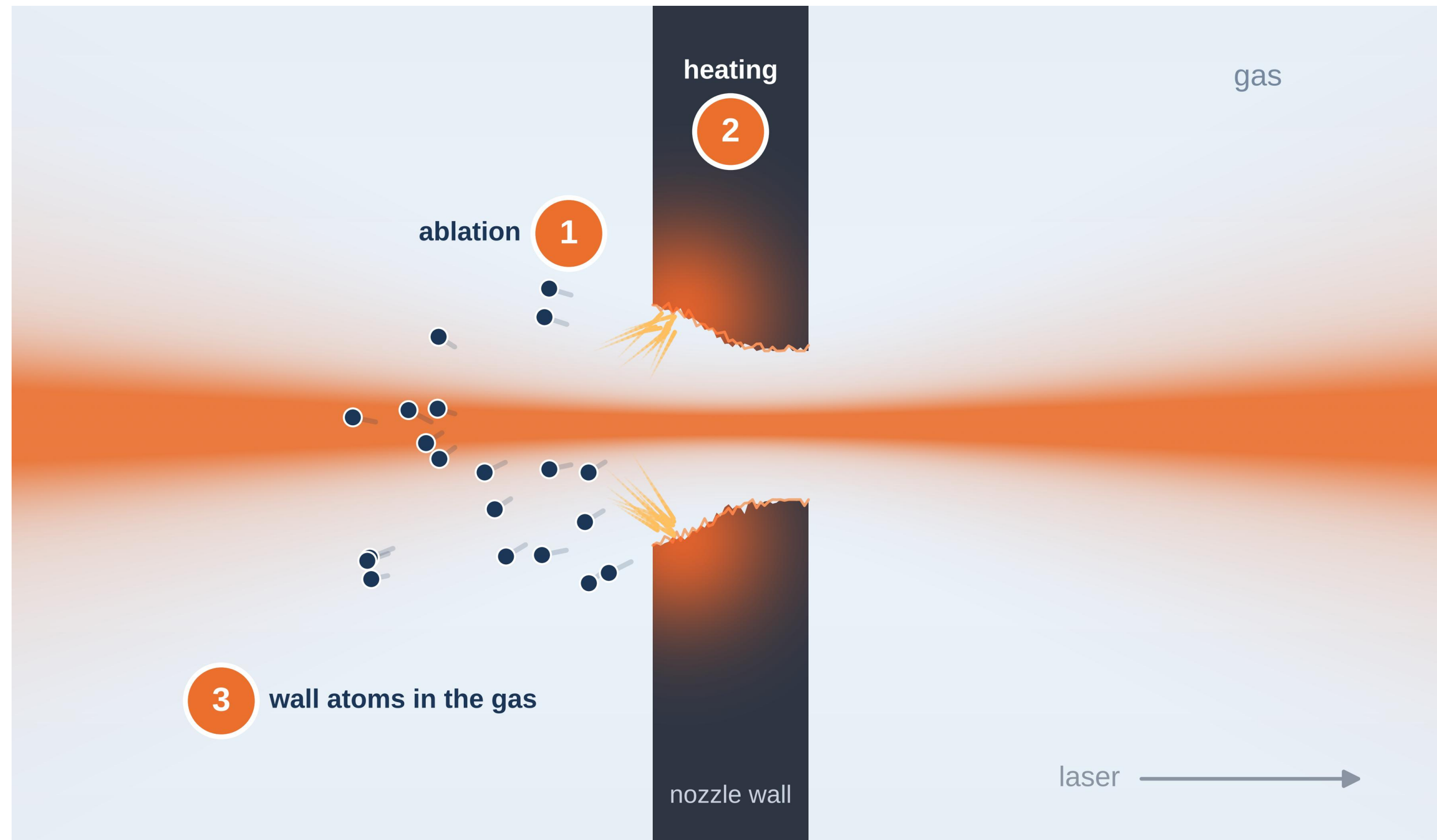
Controlled injection

Lower energy spread



**Towards Higher
Repetition Rates:**

Every Shot Leaves a Mark



1 Ablation

The laser erodes the material

2 Heating

Heat is absorbed to the walls

3 Contamination/Debris

Solid atoms enter the gas and vacuum chambers.

Change in geometry

—> Change in gas profile

—> Affect electron beam's quality and stability

What the laser does to a nozzle at 1 Hz



x 2

Hole diameter : 0.5 -> 1 mm

x 4

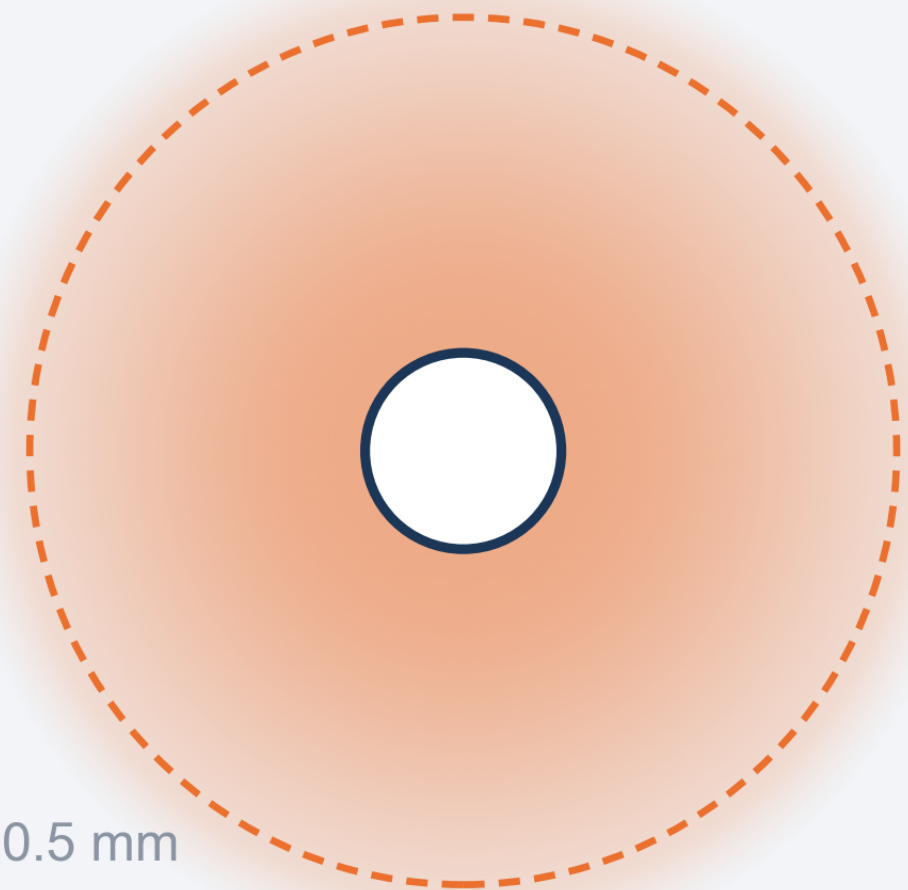
Open area : more gas escapes

Going to Higher Repetition Rates:

Less time to cool down : stronger thermal load to manage

1 Hz

time between shots: 1 s

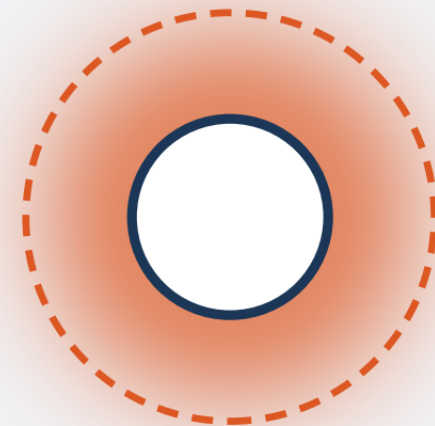


0.85 mm

heat spread before the next shot

10 Hz

time between shots: 100 ms

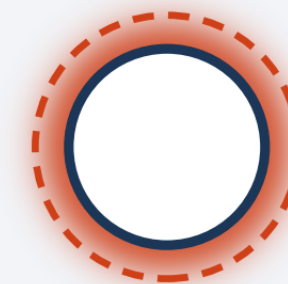


0.27 mm

heat spread before the next shot

100 Hz

time between shots: 10 ms



0.085 mm

heat spread before the next shot

1 kHz

time between shots: 1 ms



0.027 mm

heat spread before the next shot

Thank you, *to both teams*

