Beam manipulation through plasma density modulation

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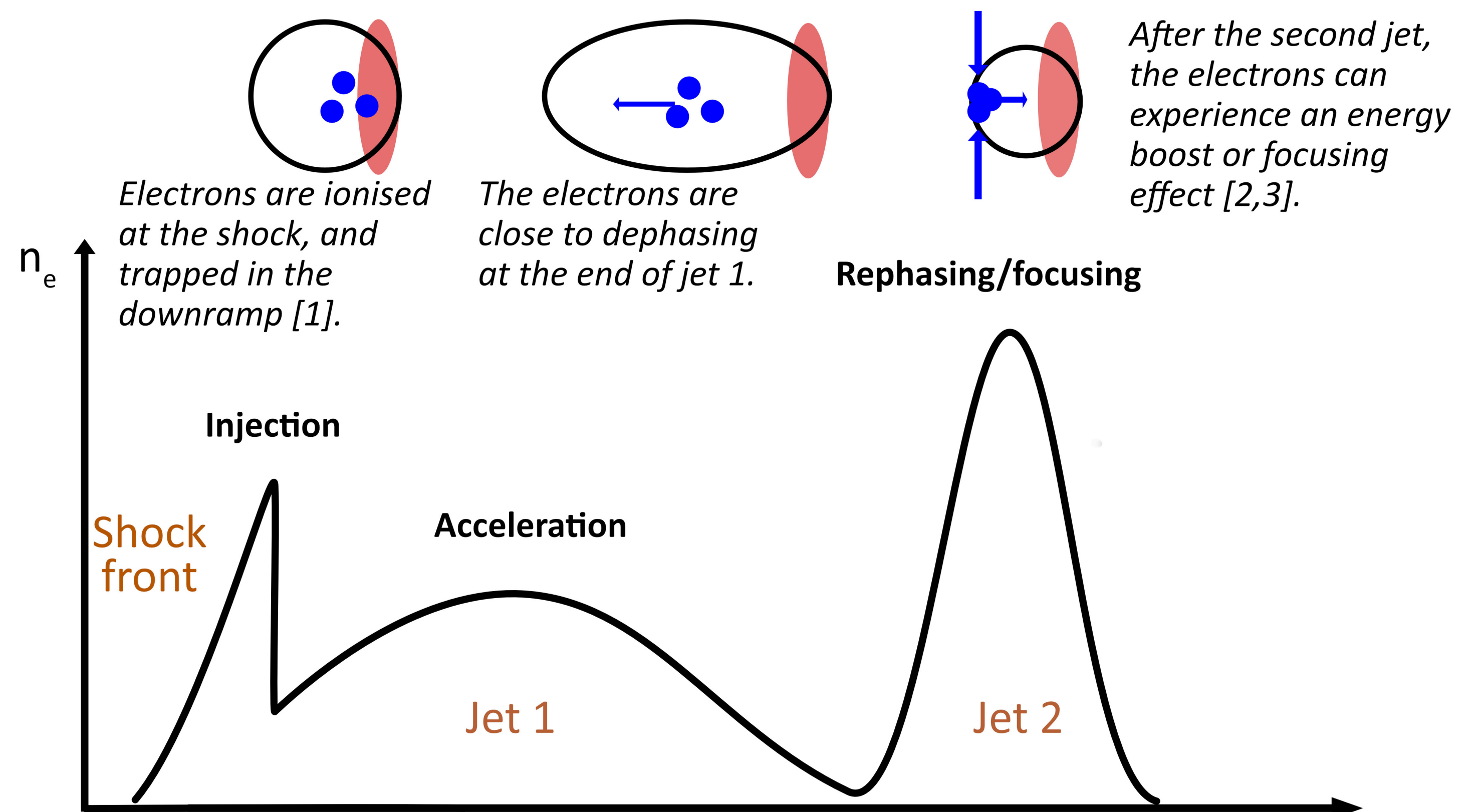
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Summary

By tailoring the density profile seen by the laser, more control over the injection and the electron bunch properties from a LWFA can be obtained. Here, the density profile is modulated by the use of a razor blade and two supersonic gas jets. It is found that the divergence can be significantly reduced, and an optimum can be found with respect to jet separation which is insensitive to density changes. A boost in energy gain can be obtained, which both depend strongly on the separation between the two jets and density in jet 2.
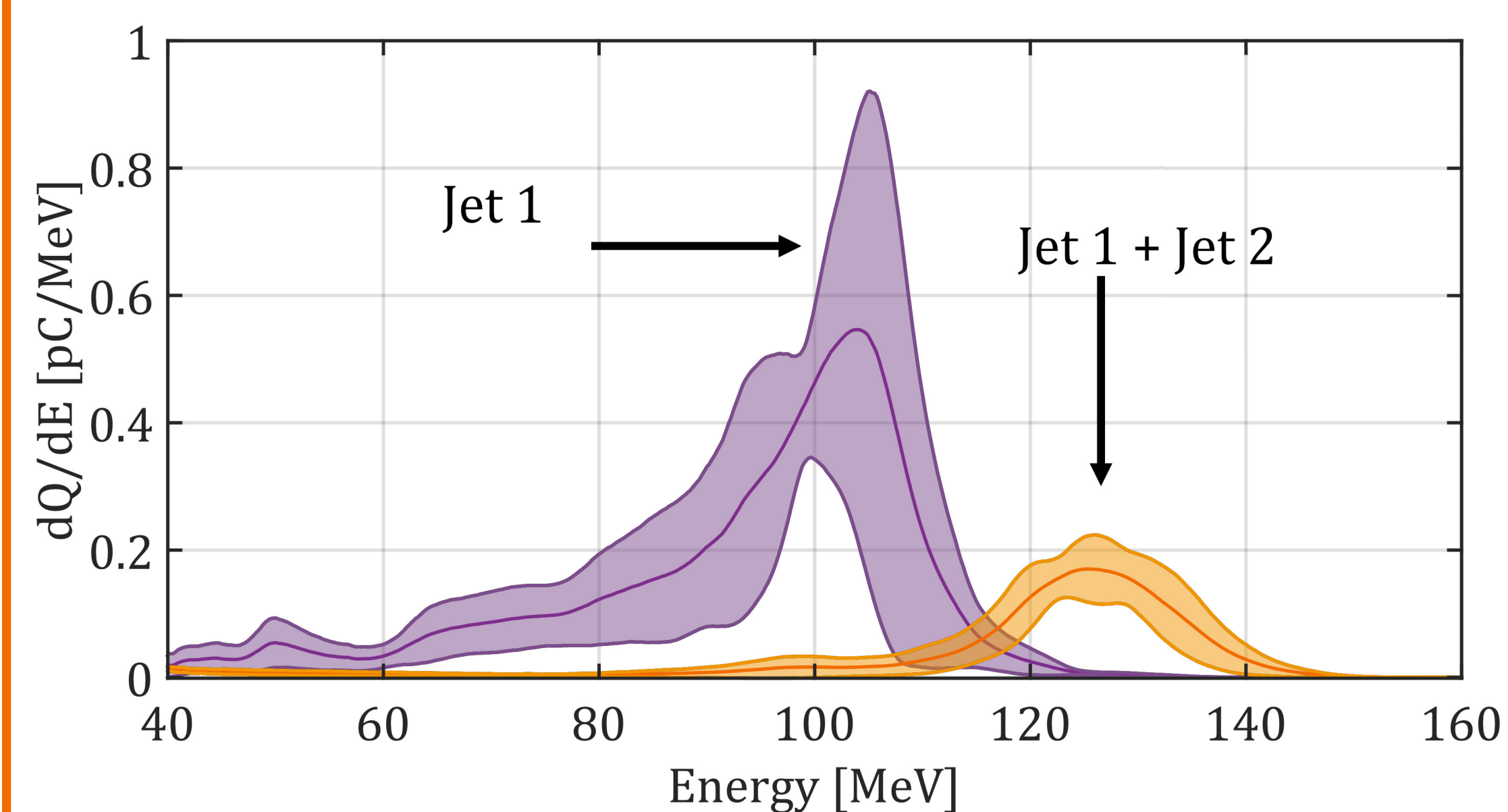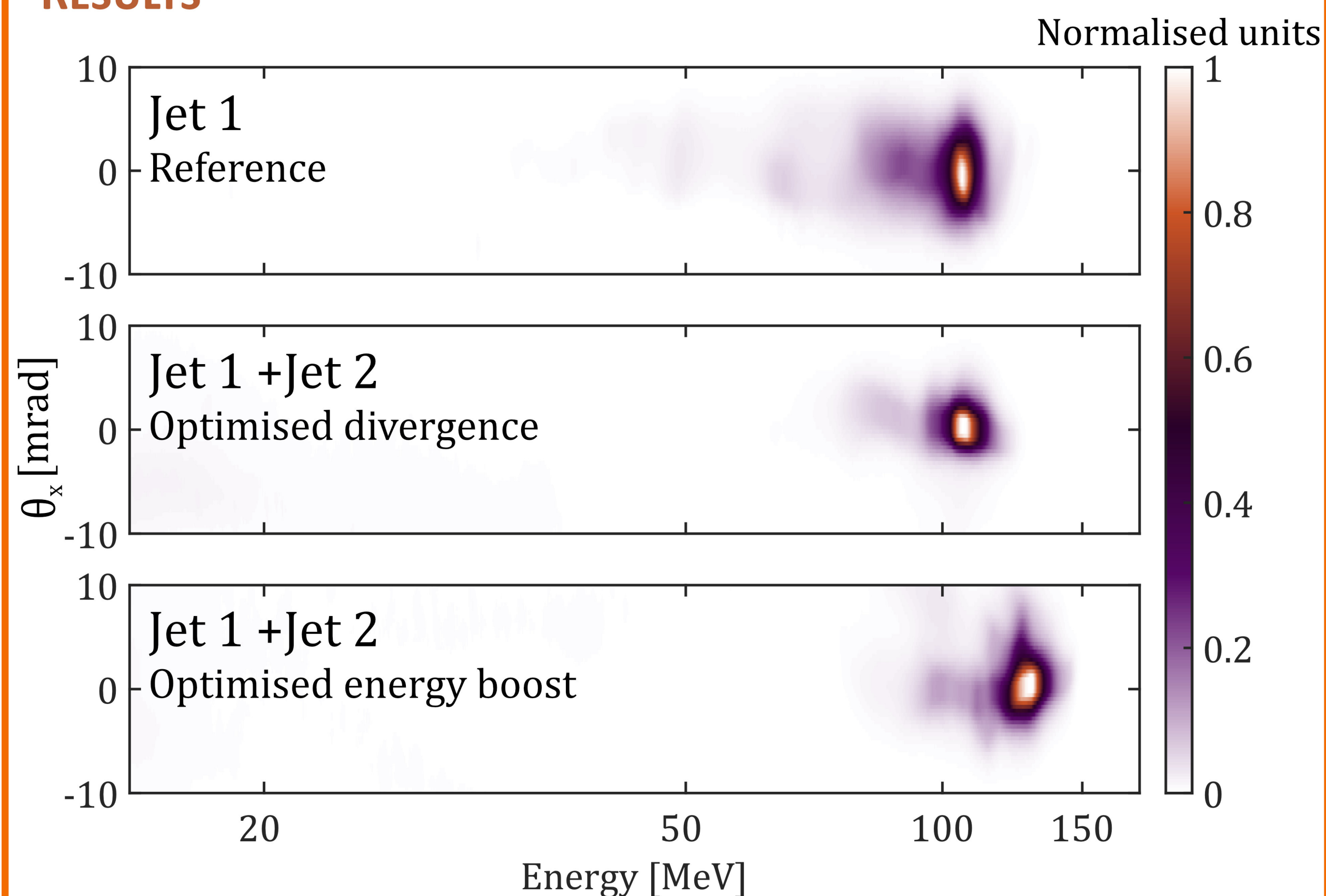
The experimental setup

1 J, 38 fs, 800 nm — Shock front — He + 1% N_2 — Jet 2 — He — Jet 1 — Δs
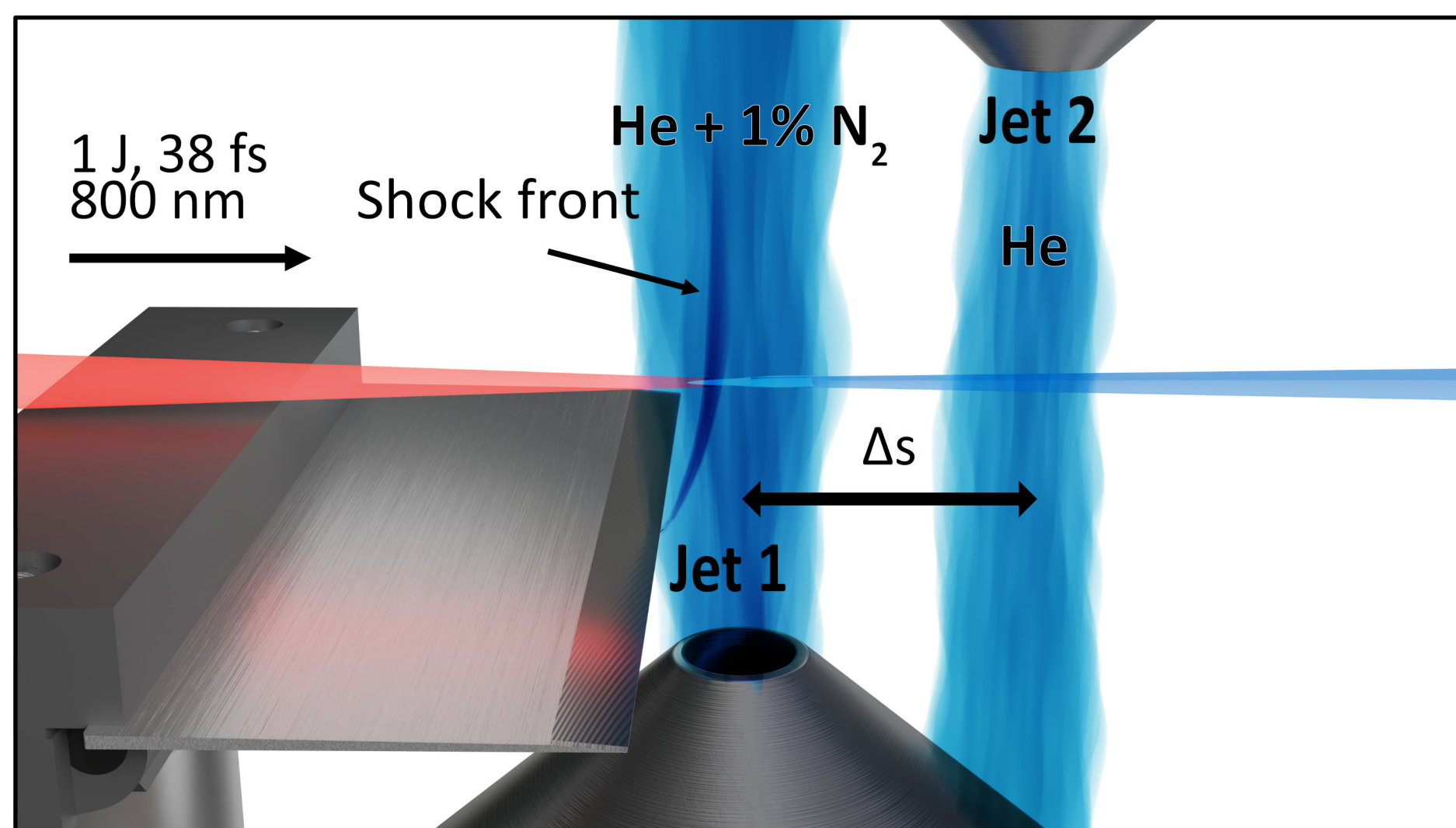
The razor position and density in jet 1 are kept constant, such that plateau density is $3 \cdot 10^{18}$ cm^{-3}, and the fraction in density between the shock and plateau is 1.5. The density and position of jet 2 are varied.

Electrons are ionised at the shock, and trapped in the downramp [1].

The electrons are close to dephasing at the end of jet 1.

After the second jet, the electrons can experience an energy boost or focusing effect [2,3].

n_e — Injection — Shock front — Acceleration — Jet 1 — Rephasing/focusing — Jet 2

Results

Jet 1 Reference

Jet 1 + Jet 2 Optimised divergence

Jet 1 + Jet 2 Optimised energy boost

θ_x [mrad] — Energy [MeV] — Normalised units

dQ/dE [pC/MeV] — Energy [MeV] — Jet 1 — Jet 1 + Jet 2
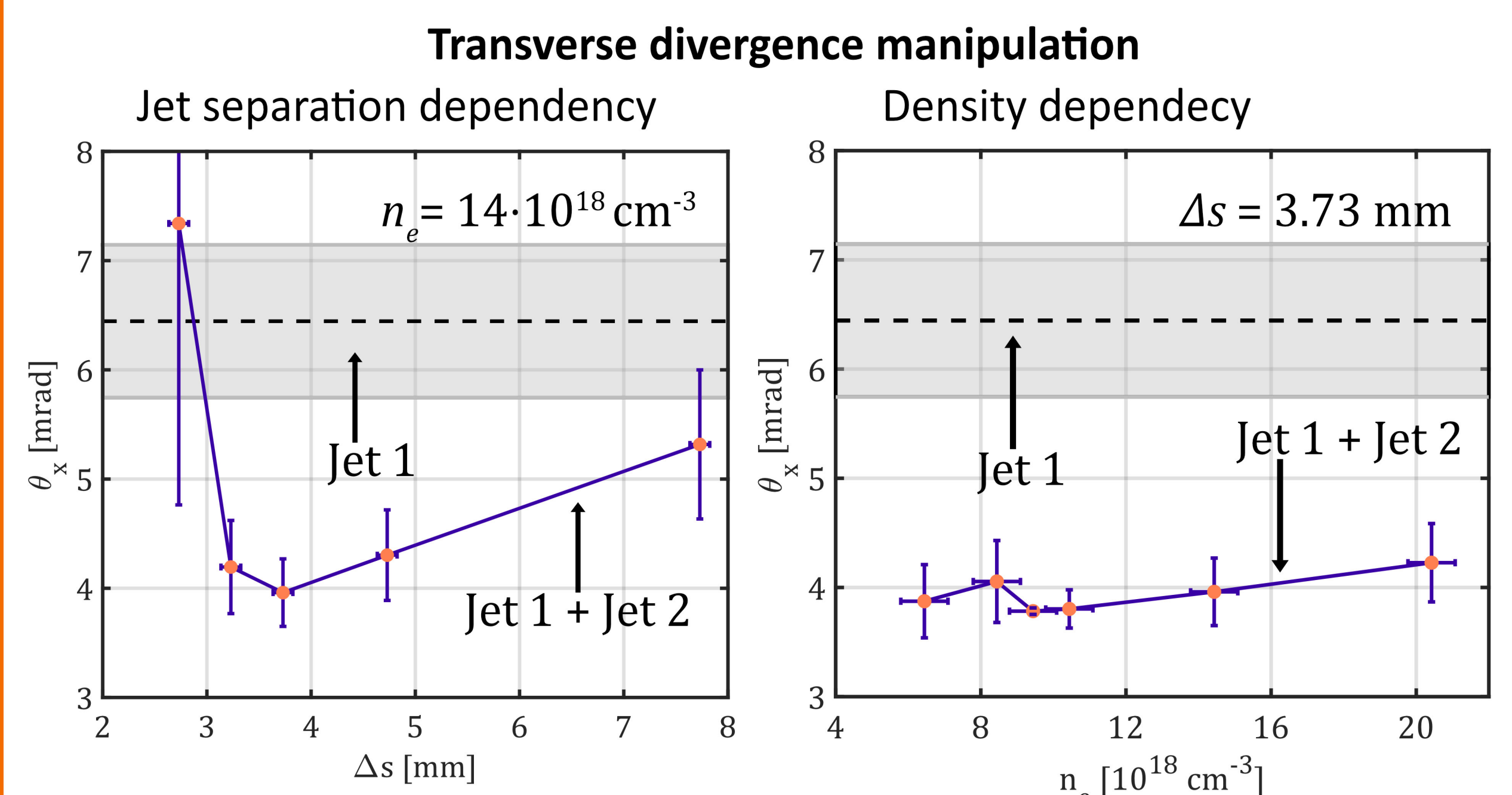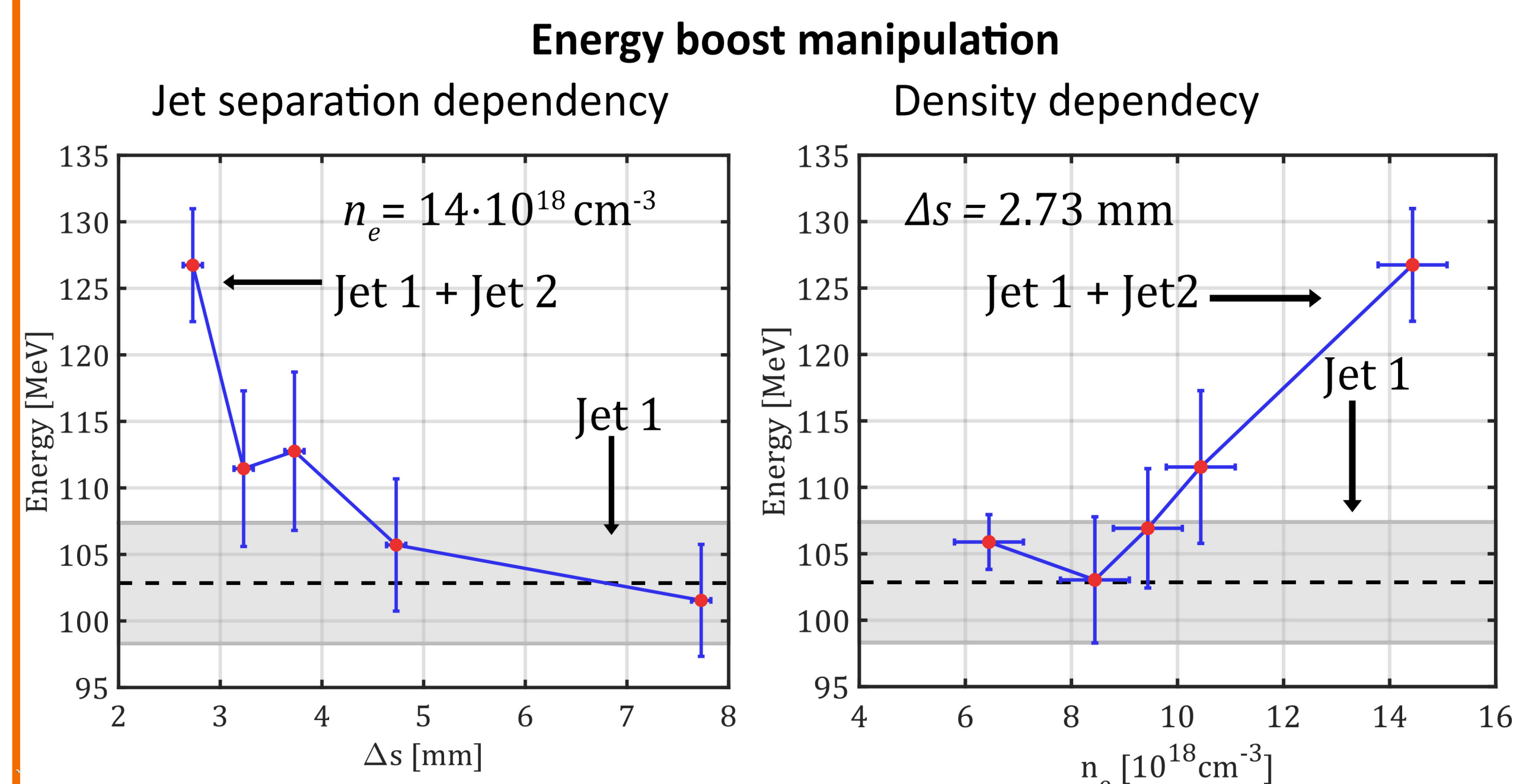
The detected typical spectrum (top) and charge calibrated spectrum (bottom) of five consecutive shots. In the bottom image, the shaded area represents the rms deviation from the mean (solid line).

Controlling the divergence and energy boost

Transverse divergence manipulation

Jet separation dependency — $n_e = 14 \cdot 10^{18}$ cm^{-3} — Jet 1 — Jet 1 + Jet 2 — θ_x [mrad] — Δs [mm]

Density dependecy — $\Delta s = 3.73$ mm — Jet 1 — Jet 1 + Jet 2 — θ_x [mrad] — n_e [10^{18} cm^{-3}]

The divergence dependency with respect to the distance between the two jets and background density in jet 2 is plotted. The horizontal error bars are the motor accuracy and the error from the retrieved density of the interferograms respectively, while the vertical error bars are the respective rms deviation.

Energy boost manipulation

Jet separation dependency — $n_e = 14 \cdot 10^{18}$ cm^{-3} — Jet 1 + Jet 2 — Jet 1 — Energy [MeV] — Δs [mm]

Density dependecy — $\Delta s = 2.73$ mm — Jet 1 + Jet2 — Jet 1 — Energy [MeV] — n_e [10^{18} cm^{-3}]

The energy boost dependency on the jet separation (left) and background density in jet 2 (right). The horizontal error bars denotes the same as above.

[1] C. Taury et al. *Sci Rep* **5**, 16310 (2015).
[2] A. Döpp et al. *Phys. Plasmas* **23,** 056702 (2016).
[3] S. Kuschel et al. *Phys. Rev. Accel. Beams* **19**, 071301 (2016).

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