Demonstration of Divergence Reduction of Laser Driven Wakefield Electron Beams Using a Compact Plasma Lens Generator

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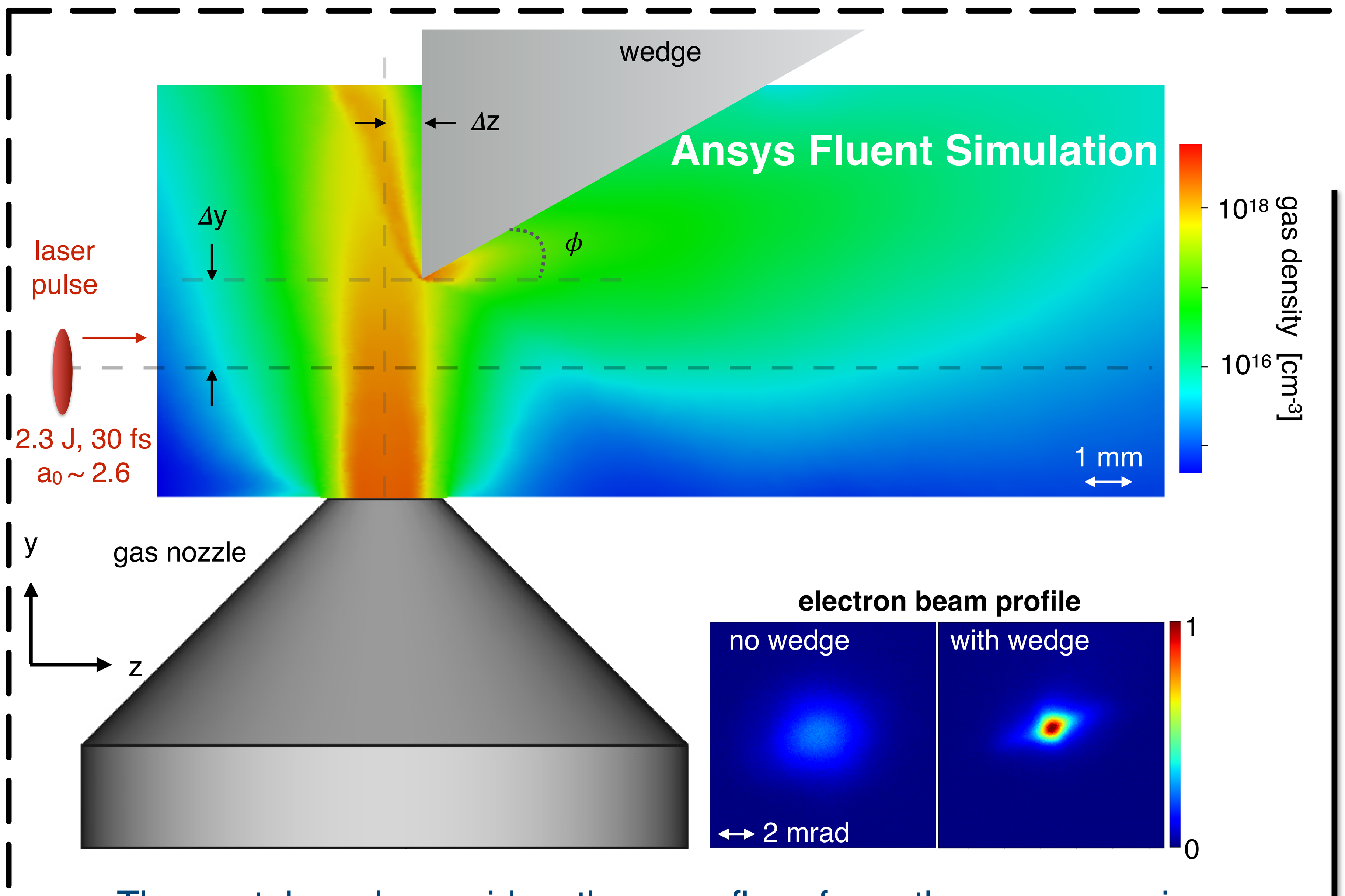
Motivation

Reduce the divergence of the electron beams from **a compact plasma accelerator** to improve the transportability for further applications such as **free-electron lasers (FELs)**

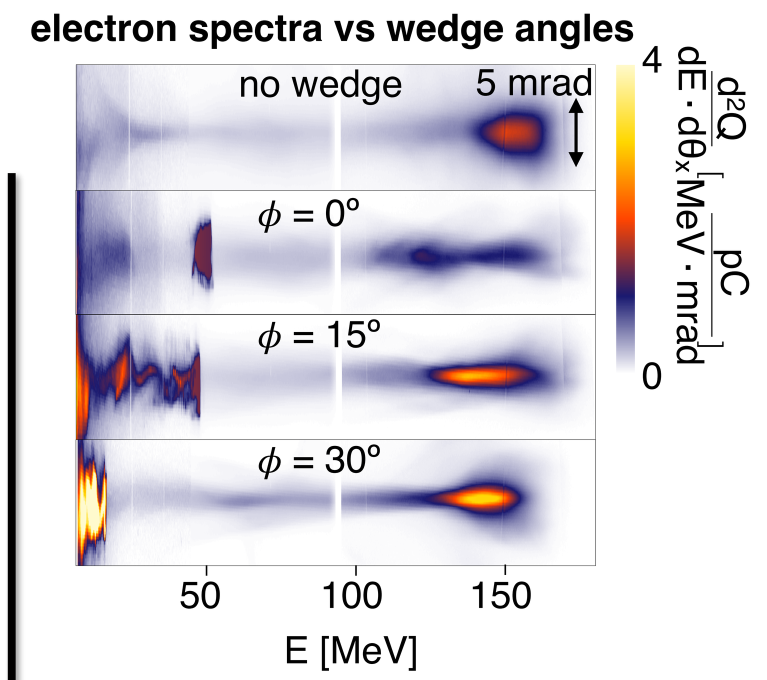
Method: Compact Plasma Lens Generator

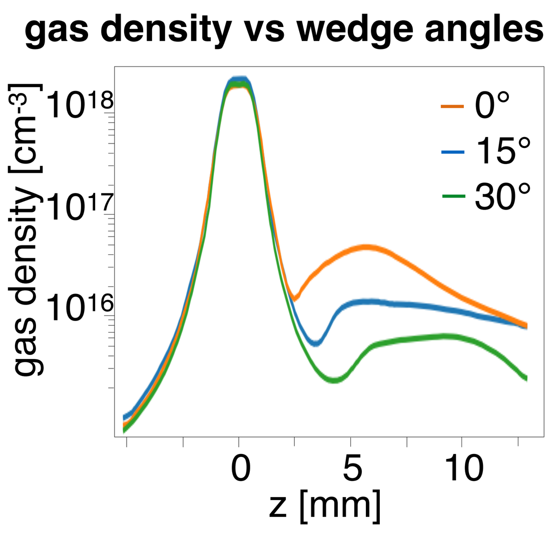
Utilise a metal wedge that guides the gas flow from the nozzle to create a shallow density bump which serves as **a passive plasma lens** behind the **laser-driven plasma accelerator**

Demonstration of Compact Plasma Lens Generator

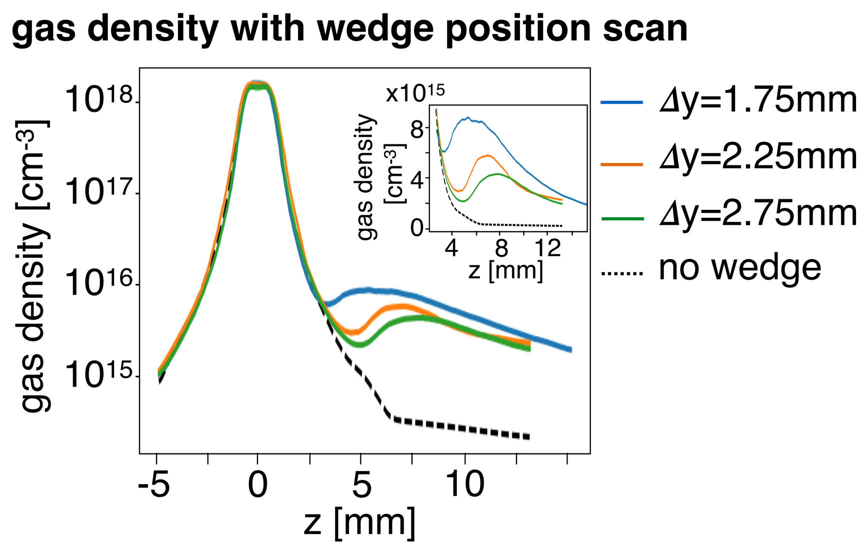


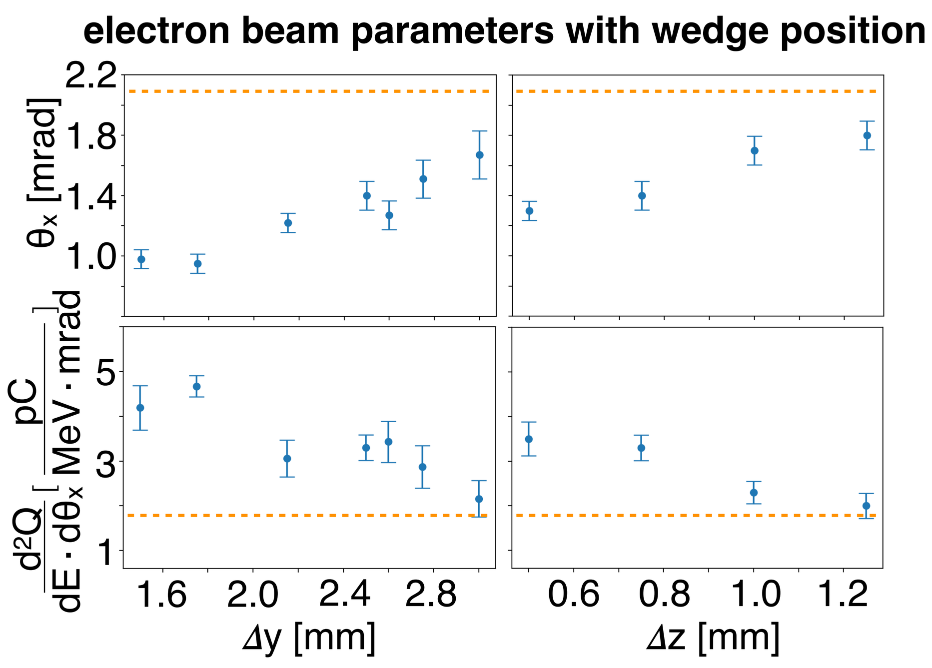
- The metal wedge guides the gas flow from the super sonic nozzle and generates **a shallow second density bump** behind the Laser driven wakefield accelerator which serves as a **passive plasma lens** to focus the accelerated electron beams.
- The gas density profile is obtained by performing **hydrodynamic simulations** using Ansys Fluent.





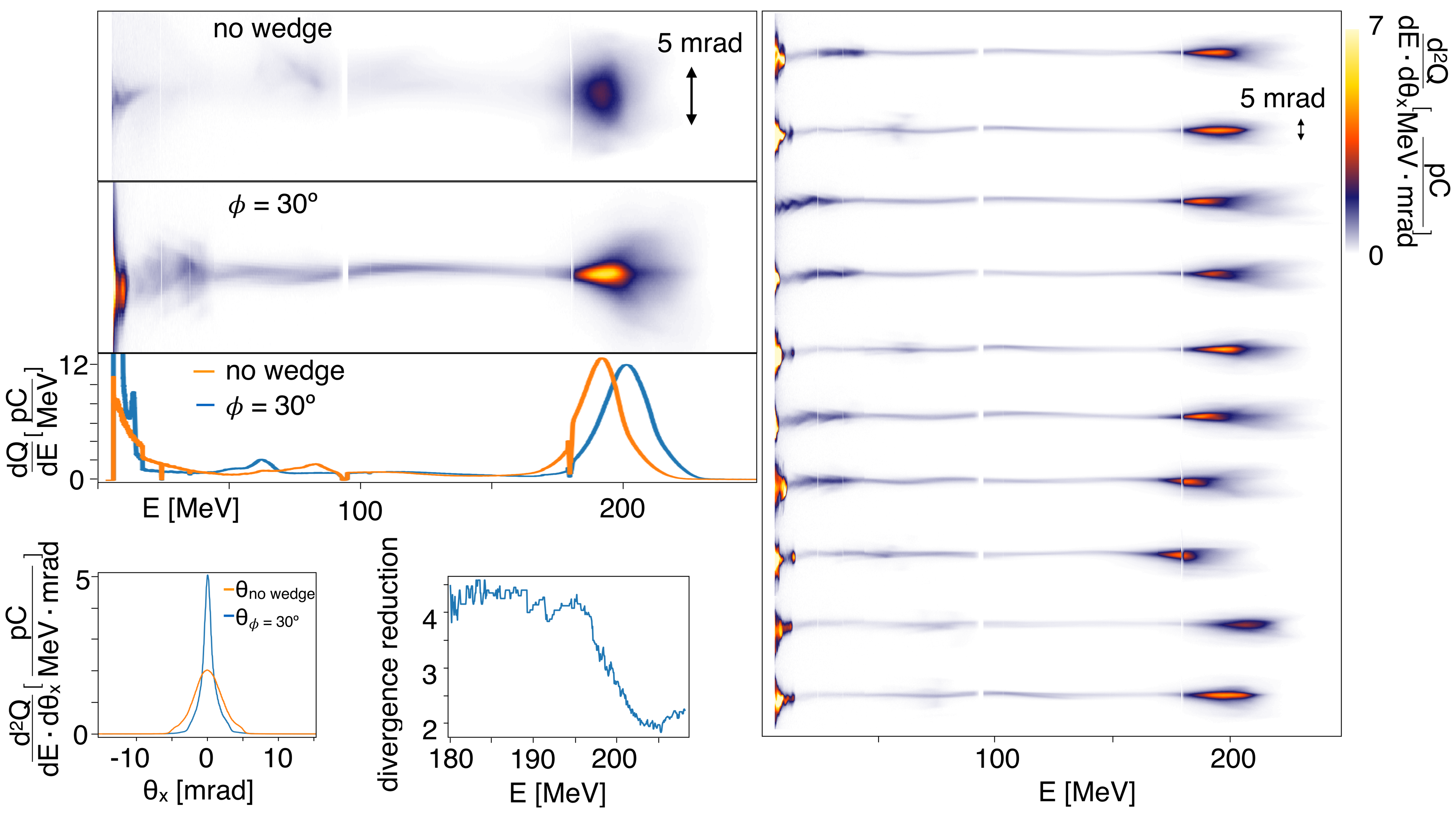
- One can optimise the plasma lens by changing the **wedge angle**.
- The best charge density was achieved when the wedge angle ϕ **= 30°**.





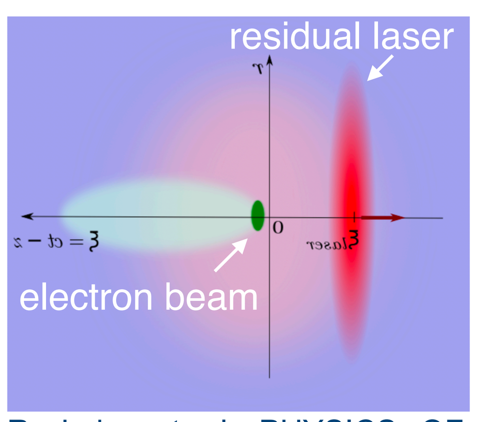
- After determining the wedge angle (ϕ **= 30°**), we scan the position of the wedge to optimise the electron beam.

Optimised Electron Beam Parameters and Discussion



	divergence [mrad]	peak Q density [pC/(MeV*mrad)]	peak energy [MeV]	Q over 100 MeV [pC]
no wedge	2.15±0.4	1.77±0.7	203.2±19	285±90
ϕ = 30°	0.95±0.2	4.7±0.8	194.5±7.5	312.1±31

- The electron beam is optimised when Δz = 0.75 mm and Δy = 1.75 mm.
- The **divergence of the beams is reduced for more than two fold** while the peak energy and the total charge of the beams is within the statistics error, which means that the **peak current of the electron beams remains high** after propagating through the plasma lens.
- The **peak charge density improves drastically** when the beam is optimised.



R. Lehe et al. PHYSICS OF PLASMAS 21, 043104 (2014)

- The **focusing effect is dominated by the ion cavity generated by the intense electron beams.**
- The residual drive laser diverges quickly after exiting the nozzle and generates **linear wakefield with weaker focusing field.**

Passive plasma lens

$$x'' = -k_\beta^2 x,$$

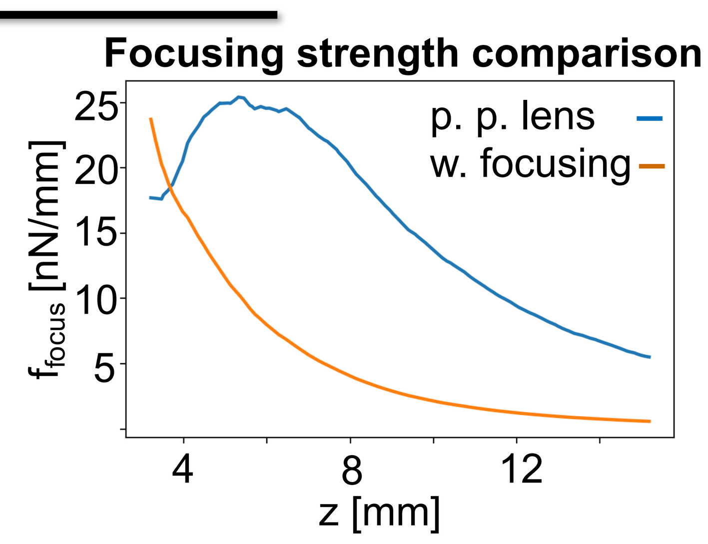
$$k_\beta = \frac{2\pi}{\sqrt{2\gamma}\lambda_p}$$

Wakefield focusing

$$x'' = -\frac{k_{foc}^2 Z_R^2}{z^2}x,$$

$$k_{foc}^2 = \frac{\eta a_0(0)^2}{\gamma w(0)^2}\sin(k_p d)$$

Z_R = 0.9 mm
γ = 400
$a_0(0)$ = 5
$w(0)$ = 15 μm



- With the compact plasma lens, we successfully transported the electron beams and generate seeded FEL: https://www.researchsquare.com/article/rs-1692828/v1

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