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LASER WAKEFIELD ACCELERATOR DESIGN FOR THE EXTREME PHOTONICS APPLICATIONS CENTRE (EPAC)

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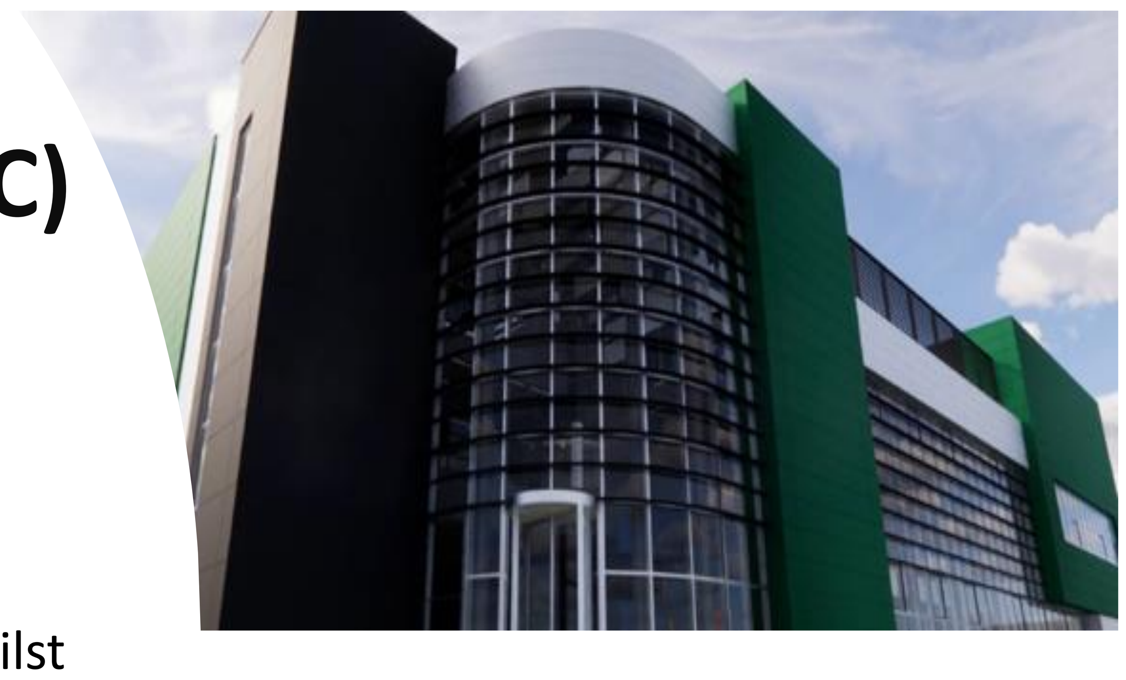
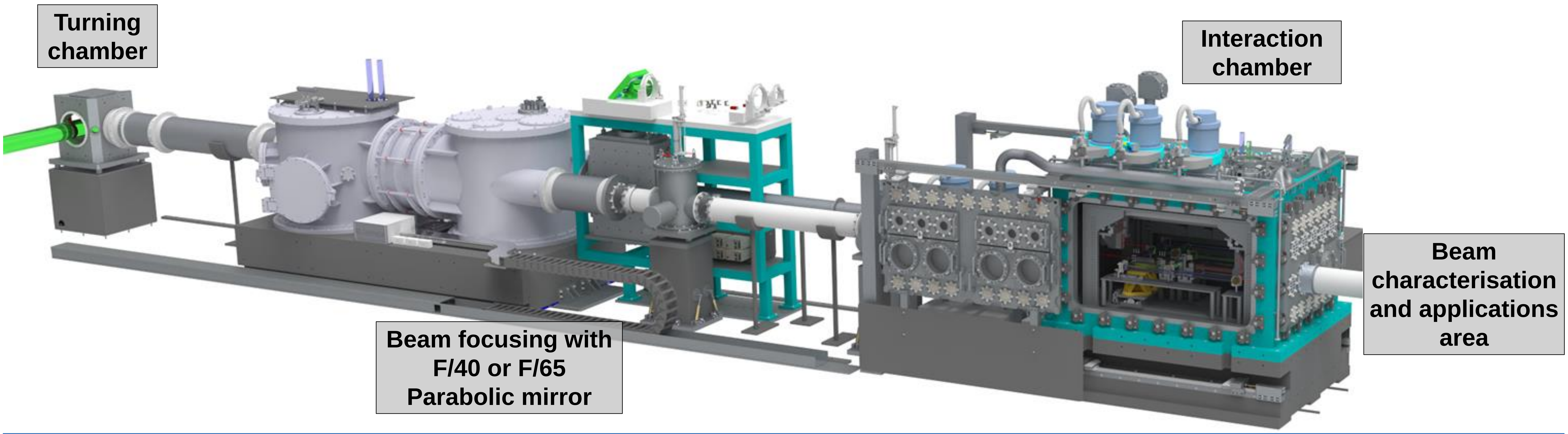


The EPAC laser will deliver **1 PW** at **10 Hz** (**30 J** in **30 fs**) and will be available for academic and industrial users. Experimental area 1 will predominantly be used for gas target experiments whilst experimental area 2 will support more solid target interaction experiments. We plan to be operational by the end of 2025.

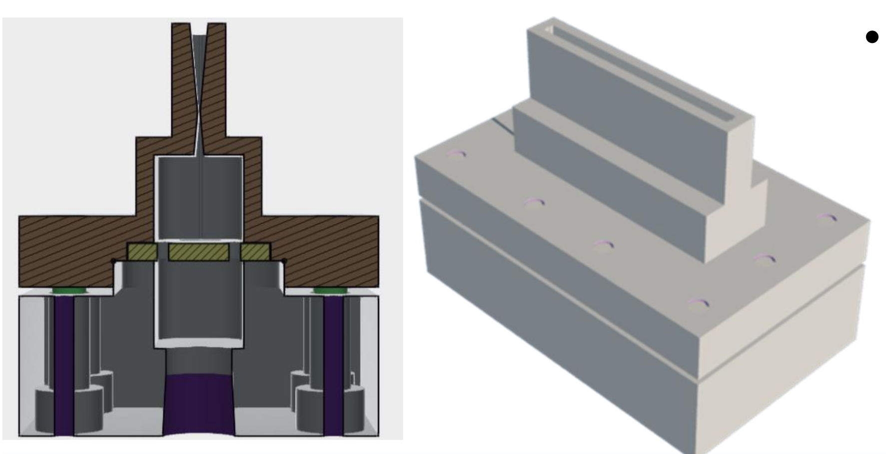
EPAC Experimental Area 1



Gas Jet Design and Characterisation

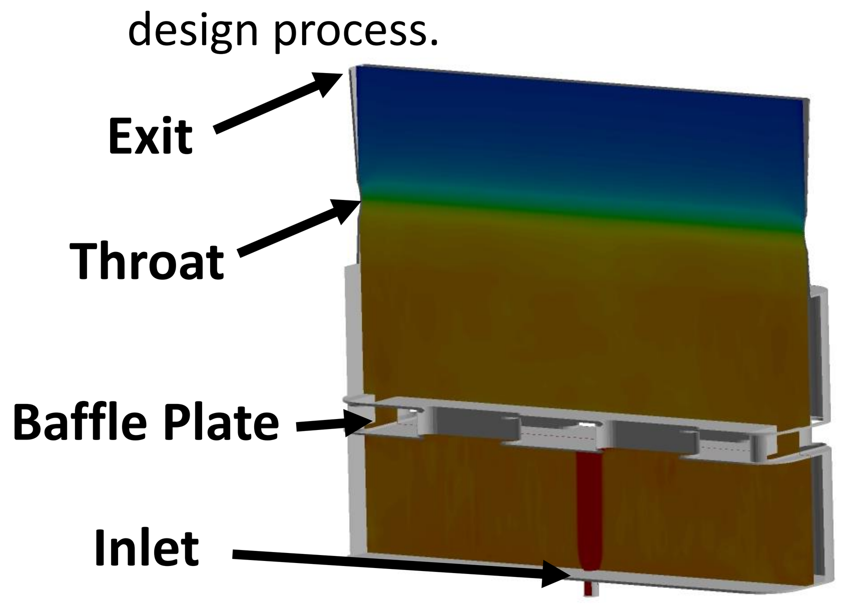
Motivation

- Thorough gas target design is crucial to operating a stable, high quality electron accelerator via LWFA.
- We will supply several different facility-maintained gas target options designed for various experimental requirements.
- The priority is a slot shaped gas nozzle.



Fluid Modelling

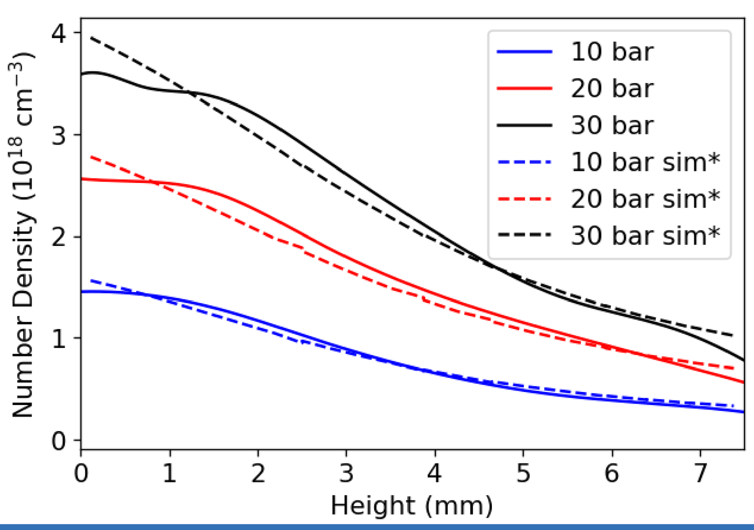
- 3D fluid simulations were performed using Code-Saturne [1] to aid the design process.

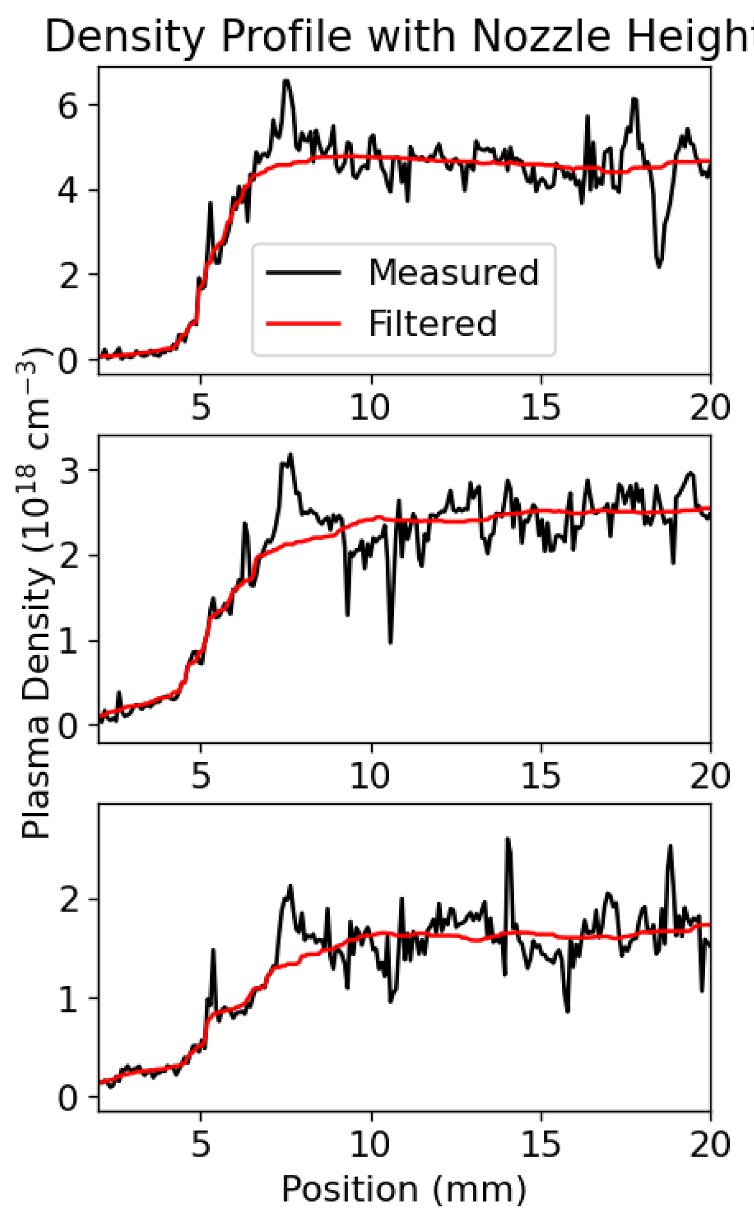


- The current design has a converging-diverging section in the axis perpendicular to the laser direction to accelerate the flow, and a baffle plate above the valve inlet to homogenise the gas density in the lower region, as shown above.

Experimental Characterisation of Slot Nozzle

- A neutral gas density characterisation setup, capable of 2 or 4 passes through the jet, has been established [2].
- Plot below shows gas density at the centre of the jet as a function of height. Simulation data is scaled to reflect inefficiency in gas system.



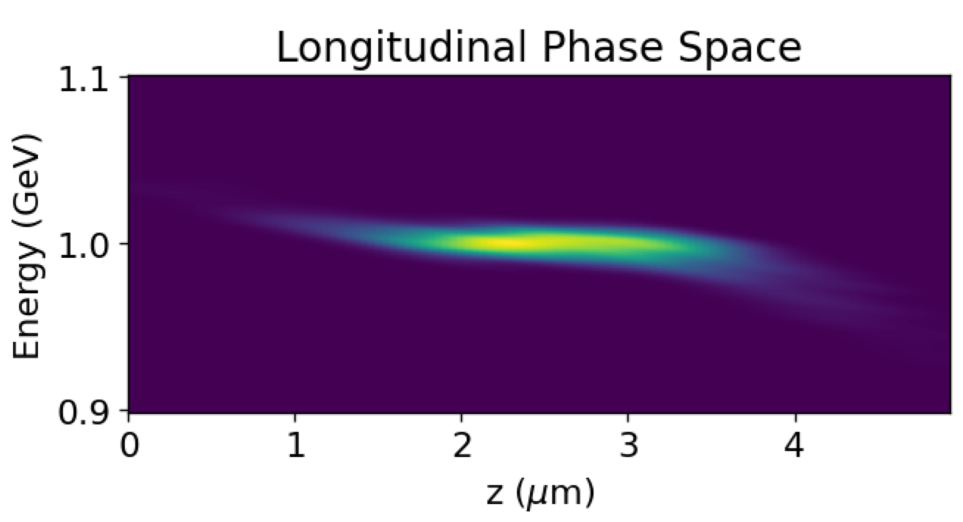


- This nozzle design has been successfully used for experiments at the Gemini laser facility.
- Plots on the left show plasma density measurements taken using a wavefront sensor.
- Structure in profile thought to be measurement noise rather than real fluctuations.

Plasma Accelerator Simulation and Electron Beam Transport

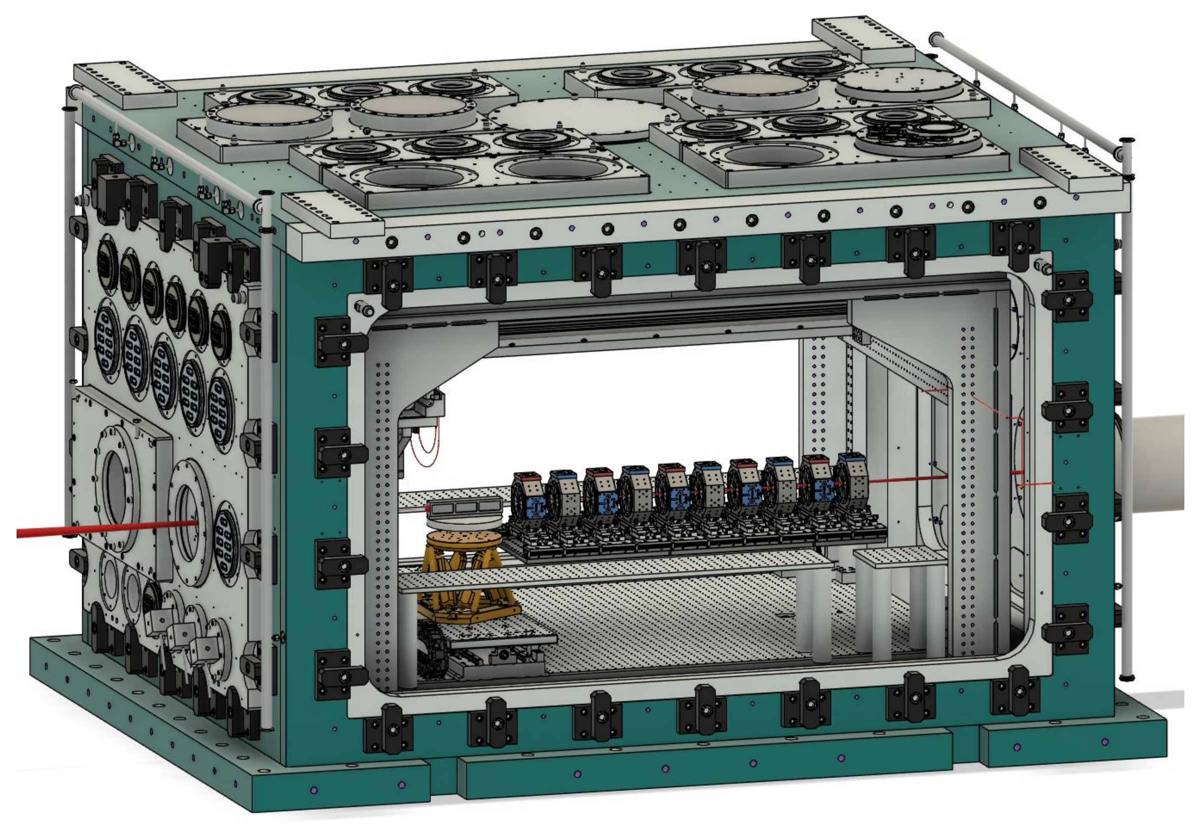
PIC Simulations

- Simulations have been performed in FBPIC [3], led by Bayesian Optimisation, as in [4].
- The longitudinal phase space for an optimised, 1 GeV beam that has been fed into tracking sims is plotted below.
- Median Energy = 1 GeV.
- Energy Spread = 0.76% rms.
- Charge = 22.5 pC.



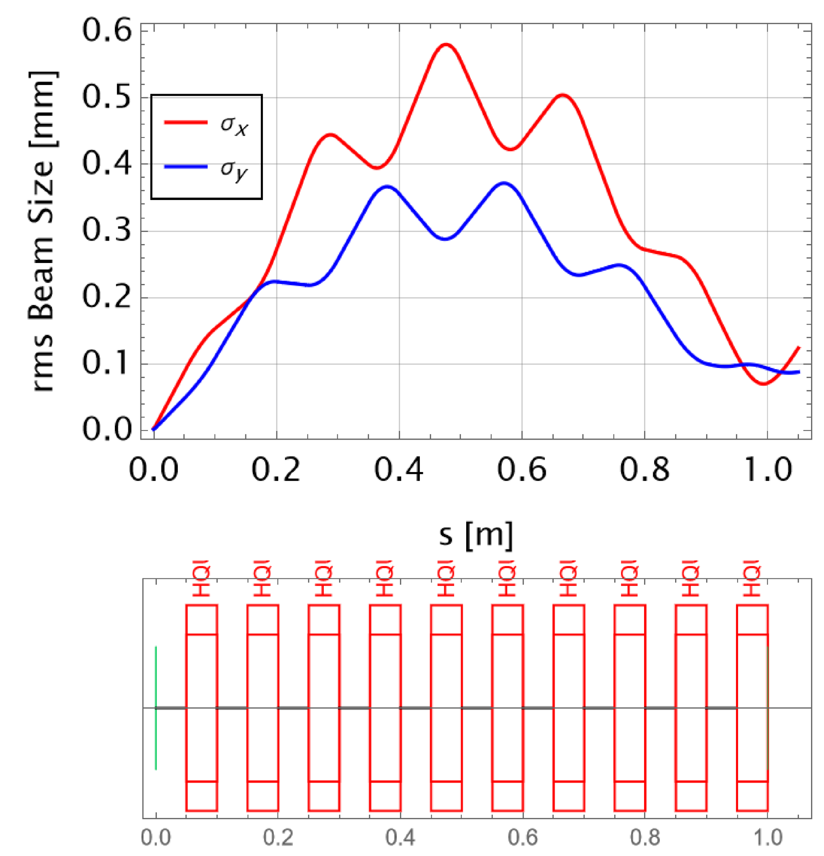
1 GeV, 1 m Focus Case Study

- An array of permanent quadrupole magnets has been designed to focus a 1 GeV electron bunch, 1 m from the source i.e., at the end of the main interaction chamber.
- The design is drawn below, with quads 1-4, 5-8 and 9-10 grouped on precision stages for alignment.



Tracking Results

- Tracking simulations have been performed in Elegant [5] to transport the electron beam from FBPIC through the 10 PMQ array.
- A focal spot size of approximately 80 µm rms can be achieved at a distance of 1 m from the source.
- Further work is required to reduce the electron beam energy spread, emittance and divergence at the source to maximise the brightness of the electron beam at the interaction point.



References

[1] https://www.code-saturne.org/cms/web/
[2] S. Karatodorov et al. Sci Rep 11, 15072 (2021)
[3] R. Lehe et al. Computer Physics Communications, (2016)
[4] S.Jalas et al. Phys. Rev. Lett. (2021)
[5] M. Borland, doi:10.2172/761286, (2000)