Development of a LWFA gas target for fine electron injection control

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MEFT Boosting the Future

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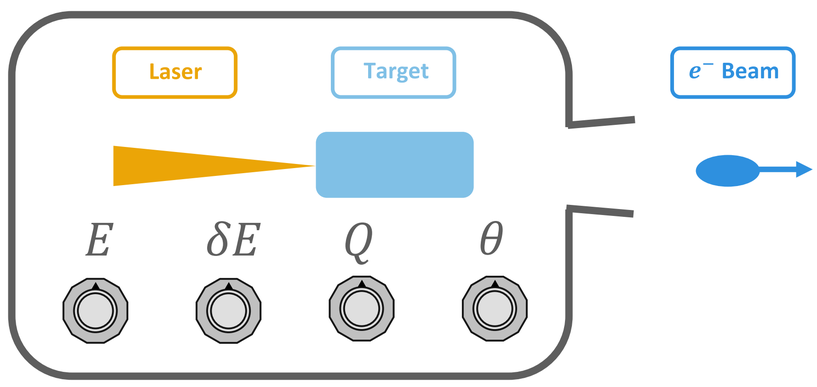
Background

- Ultimate **goal** of LWFA
  - Produce high-quality particle beams **tailored** to specific applications with reproducibility at $\geq 10\ Hz$
- Relevant particle **beam parameters**:

Energy – E	Energy Spread – δE
Charge – Q	Emittance – θ

- State of the art targets:
  - Gas Jets
  - Discharge Cells

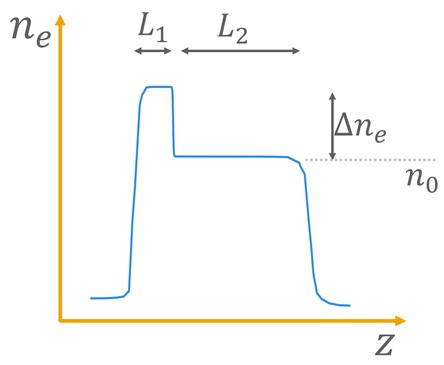
Final Goal



Density Profile

Reliable and tunable injection by density down-ramp scheme [1].

- **Density step** controls beam **charge**
- **Length of the 2nd plateau** controls beam **energy**
- Baseline density matched to laser parameters

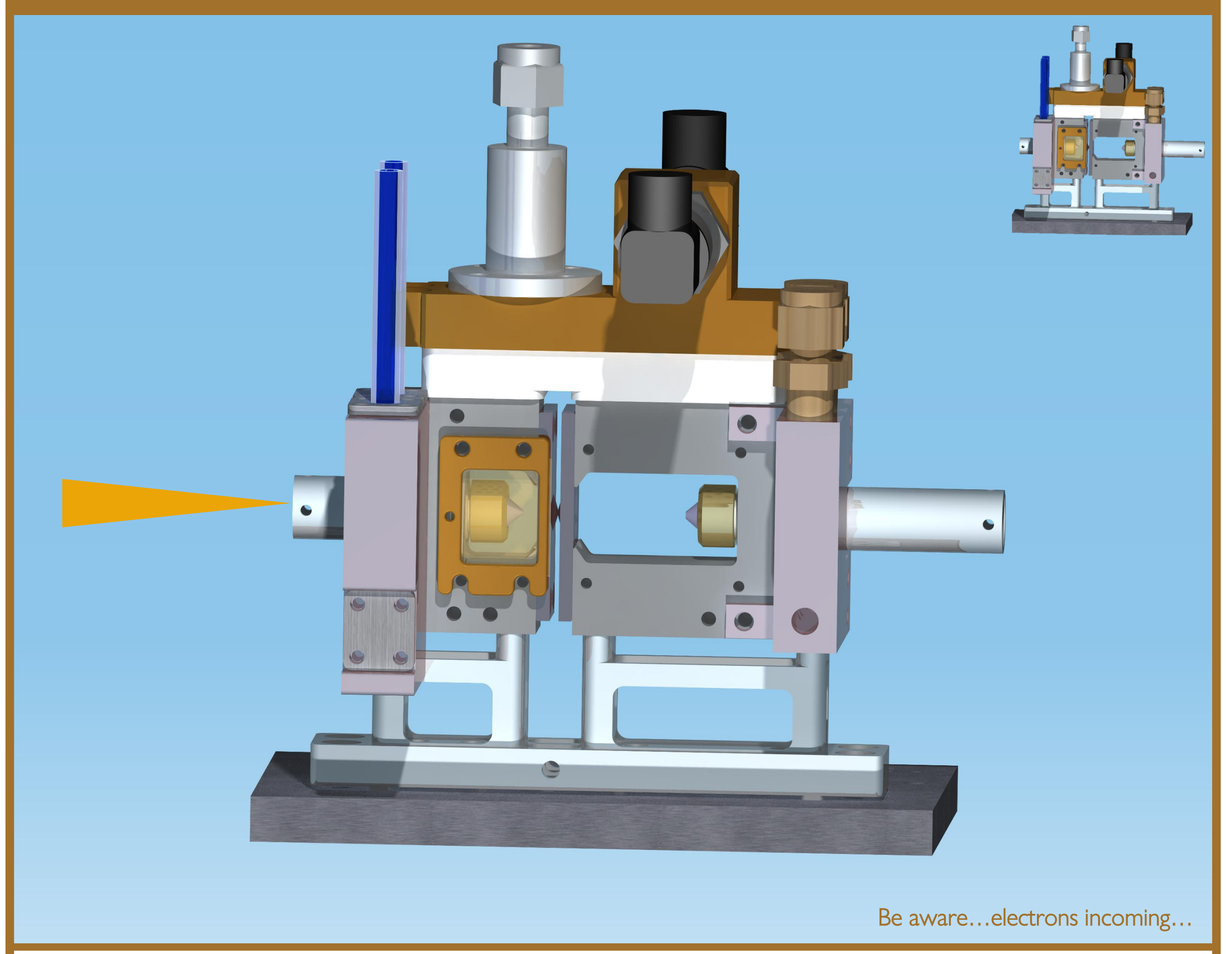


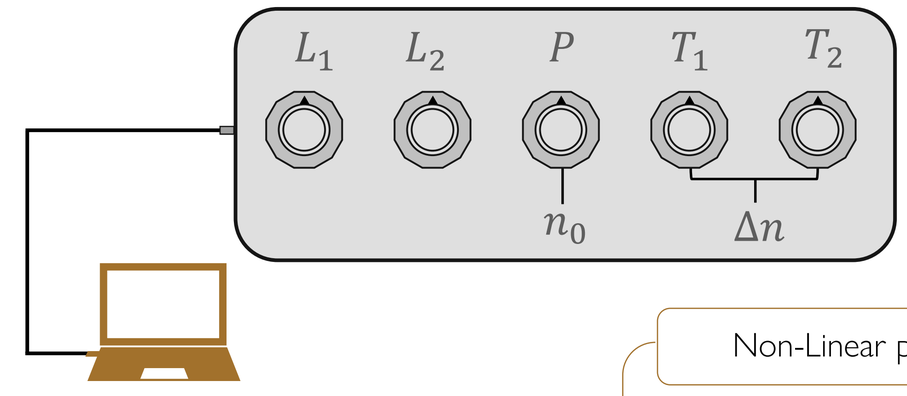
Gas Target Design

To achieve the desired density profile (N. Lopes):

- 2 free parameters to vary density of a gas → $n \propto \frac{P}{T}$
- **Pressure fixed** to avoid undesired flow in the sharp gradient (injection) region.
  - The gas is injected from the top using a fast valve - actuation time ~ 10 ms
  - Cycle time controls the pressure of the injected gas
  - This is the control on the baseline density – n_0
- 2 chambers with **controlled temperature** but **thermally isolated** from each other
  - The temperature difference controls the density step – Δn
  - Separated by small distance – 20 μm – to ensure sharp density gradient
- 2 **sliding cylinders**
  - Allow for effective length control of the chambers – L_1 and L_2

A novel **tunable** gas target for an electron LWFA





Adaptive Control via **Machine Learning** → Bayesian Optimization [2][3] → Non-Linear problems; Sample-efficient optimization; Multiple-objective optimization; Incorporates uncertainty

Research Objectives

1) Validate gas target design through CFD simulations ☑ OpenFOAM

2) Simulation based optimization of the density profile using a BO approach ☑ [4] Osiris

3) Test target in an **experimental** setting

See it in action!

Future Directions

- Bright, hard and tunable Betatron X-rays for low-dose applications
- High intensity/rep-rate/quality GeV electron beams

References & Acknowledgements

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