# Single-Stage Laser-Driven Plasma **Acceleration with External Injection for EuPRAXIA**



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The EuPRAXIA (European Particle Research Accelerator with eXcellence In Applications) project aims at producing a conceptual design for the worldwide plasmabased accelerator facility, capable of delivering multi-GeV electron beams with high quality. The EuPRAXIA accelerator facility will be used for various user applications such as Free-Electron-Laser (FEL), high-energy physics (HEP) detector tests, photon science etc [1].

EuPRAXIA includes studies of different approaches to plasma acceleration techniques. Laser-driven plasma wakefield acceleration (LWFA) with external injection of an electron beam from an RF linac is one of the basic research directions of the EuPRAXIA.

## **SIMULATION PARAMETERS**

#### $\diamond$ **Plasma**:

- parabolic plasma channel of shape  $n(r) = n_0 + \Delta n (r/r_{ch})^2$ ,
- with on axis density  $n_0 = 10^{17} \text{ cm}^3$ ;  $\Delta n = 2.21 n_0$  and channel width  $r_{ch} = 50 \mu \text{m}$ ;
- plasma up-ramp:  $f(z) = (1 (z z_0)/l_{opt})^{-2}$ ; plasma down-ramp:  $f(z) = (1 + z/l_{opt})^{-2}$ .

♦ Laser pulse:

- $-a_0 = 2.5; \lambda_1 = 800 \text{ nm.}$
- pulse length 70 fs (FWHM); spot size 59 µm (FWHM).

**High charge electron beam** [4]

Parameters	at the plasma	after acceleration

### ♦ Plasma:

2D PIC simulation with the code OSIRIS [2]

- density  $n_0 = 10^{17} \text{ cm}^{-3}$ ;
- plasma up-ramp has a shape close to cubic polynomial function;

# **♦** Laser pulse:

-  $a_0 = 3.1; \lambda_1 = 800$  nm.

- pulse length 100 fs (FWHM); spot size 64 (FWHM);

## **ARES electron beam** [3]

Parameters	at the plasma entrance	after acceleration
Charge [pC]	0.74	0.74
Energy [MeV]	83.5	2372
Rel. energy spread [%]	0.45	0.196
$\sigma_{z}$ (RMS) [ $\mu$ m]	0.26	0.277
$\sigma_{r}$ (RMS) [ $\mu$ m]	2.28	0.152
Norm. transv. emittance, $\varepsilon_{n,x}$ [µm]	0.14	0.358
Long. box size	201.7 μm	
Propagation distance [cm]	7.2	





	entrance	
Charge [pC]	30	30
Energy [MeV]	548	1080
Rel. energy spread [%]	0.06	16
$\sigma_{z}$ (RMS) [ $\mu$ m]	3.552	3.555
$\sigma_r (RMS) [\mu m]$	0.97	0.471
Norm. transv. emittance, $\varepsilon_{n,x}$ [µm]	0.4	0.487
Long. box size	185 µm	
Propagation distance [cm]	3.2	













Evolution of the externally injected electron beam properties during acceleration process: relative energy spread (a), absolute energy spread (b), normalized transverse emittance (c), beta function (d), bunch width (e) and longitudinal bunch length (f). Offset between the electron beam center and the laser pulse center =  $88.3 \mu m$ . Plasma ramp length:  $L_{uramp} = L_{dramp} = 0.1$  mm.

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Evolution of the externally injected electron beam properties during acceleration process: relative energy spread (a), absolute energy spread (b), normalized transverse emittance (c), beta function (d), bunch width (e) and longitudinal bunch length (f). Offset between the electron beam center and the laser pulse center =  $88.2 \mu m$ . Plasma ramp length:  $L_{uramp} = 0.1$  mm.



Longitudinal momentum distribution of the ARES electron beam (a) and high charge electron beam (b) at the plasma exit.

#### References

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