Doctoral Network

COMPARATIVE STUDY OF ELECTRON BEAM CAPTURE FOR LASER-PLASMA ACCELERATOR BASED EUV-FEL

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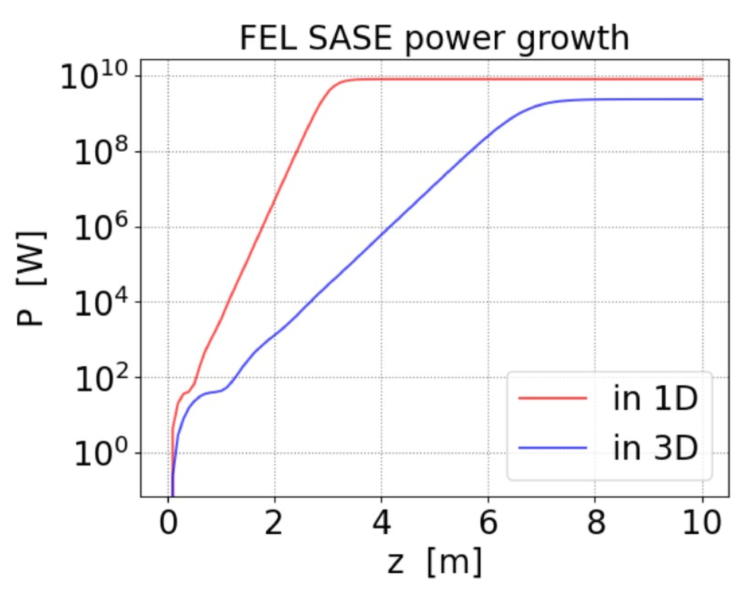
In the frame of this presentation, we explore the development of a novel compact Laser-Plasma Accelerator (LPA) based Free Electron Laser (FEL) operating in the extreme ultraviolet (EUV) range of the radiation spectrum. Achieving the desired electron beam parameters within a single-unit Swiss-FEL type undulator (as a commercially available option) presents a significant challenge. The presentation covers requirements of the LPA-based electron beam parameters for the LPA-based FEL and various options for capturing electron beams from a compact laser-plasma accelerator to reach the saturation of the FEL power.

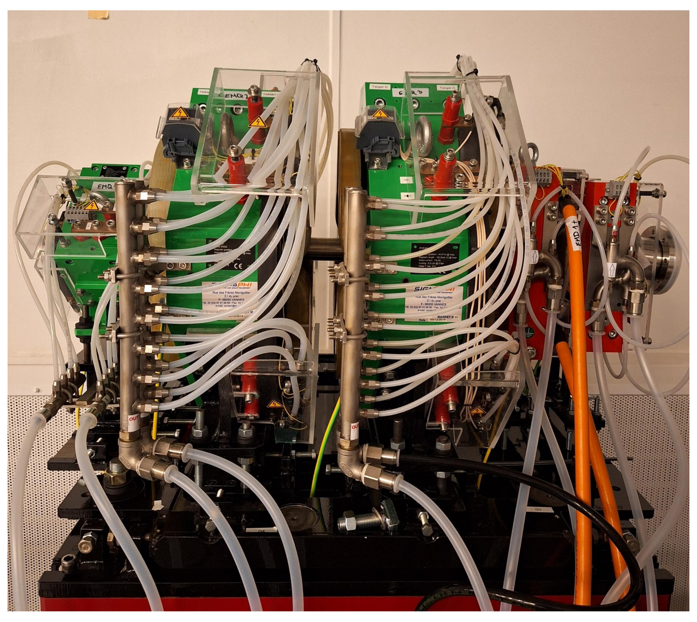
ADDRESING REQUIREMENTS FOR EUV-FEL

Undulator parameter	1.1
Undulator period	15 mm
Undulator gap size	4 mm
Undulator length	4 m
Undulator peak magnetic field	0.79 T
Energy	400 MeV
Normalized slice emittance	0.5 π mm mrad
RMS transverse beam size	38.79 μm
Relative slice energy spread	0.25 %
Photon wavelength (h=1)	19.64 nm
Photon energy (h=1)	63.21 eV
Gain Length 1D	13.91 cm
Saturation Power 1D	7.93 GW
Saturation Length 1D	3.03 m
Gain Length 3D	32.52 cm
Saturation Power 3D	2.23 GW
Saturation Length 3D	6.69 m

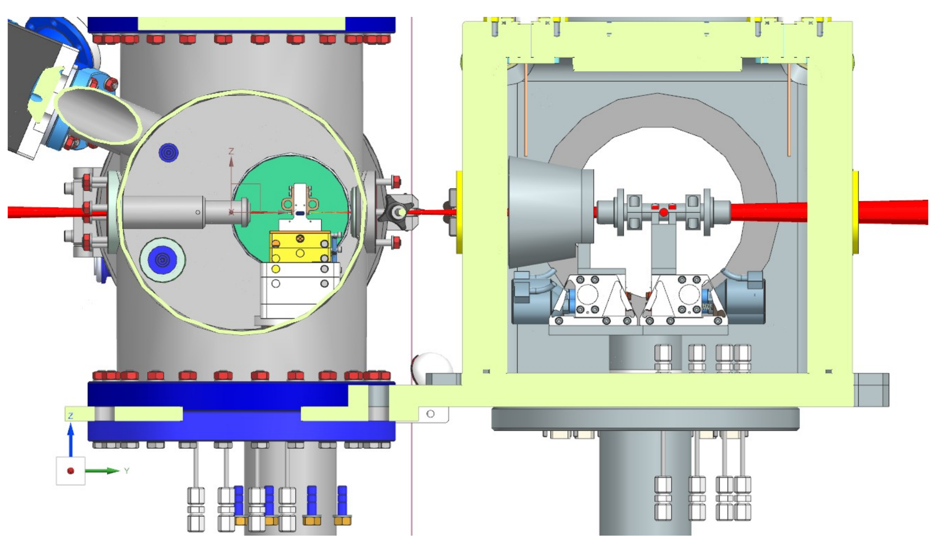


EFFECTIVE BEAM FOCUSING TECHNOLOGIES

Three electro-quadrupole magnets setup

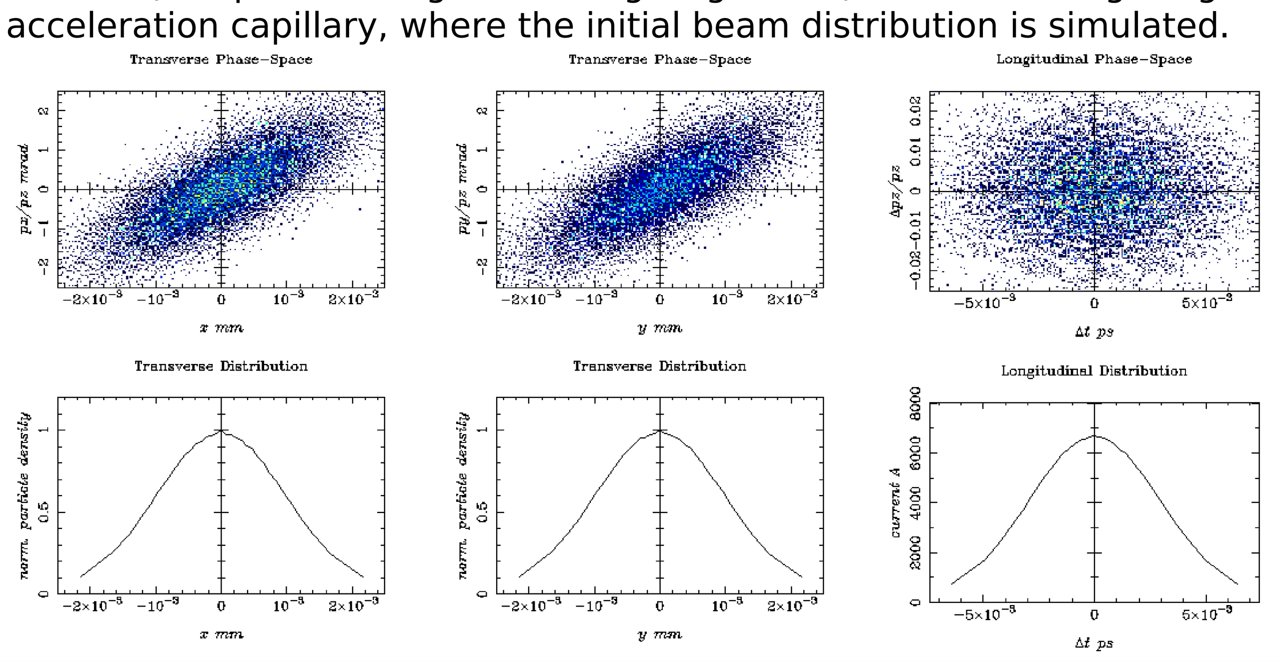


Active plasma lens setup



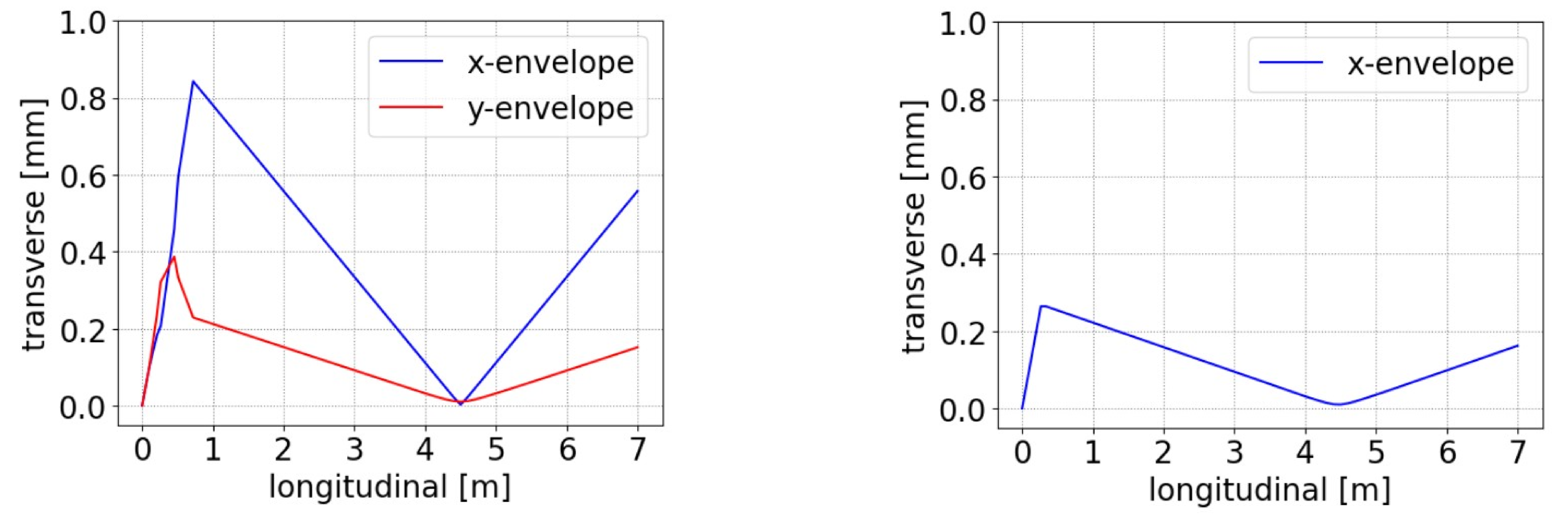
MULTI-PARTICLE TRACKING WITH ASTRA

The multi-particel tracking simulation using an **ideal electron beam** was preformed using ASRTA (A Space Charge Tracking Algorithm). The tracking begins immediately after the acceleration capillary, where the initial beam distribution is simulated.

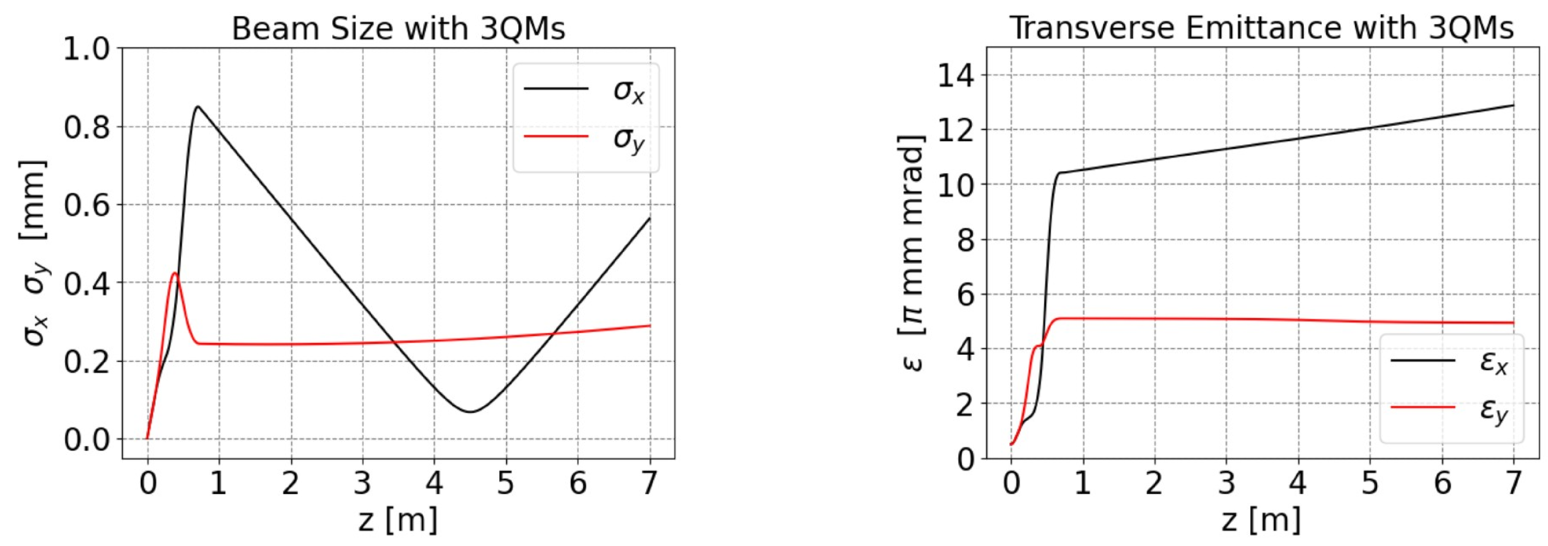


Energy	400 MeV
Normalized emittance	0.5 π mm mrad
RMS transverse beam size	10^{-3} mm
RMS divergence	1 mrad
Bunch length	3 fs
Relative energy spread	1 %
Total charge	50 pC

Sigma matrix formalism in order to find the optimal settings for the quadrupole magnets and APL, namely the current values required to achieve a focused beam at the center of the undulator.

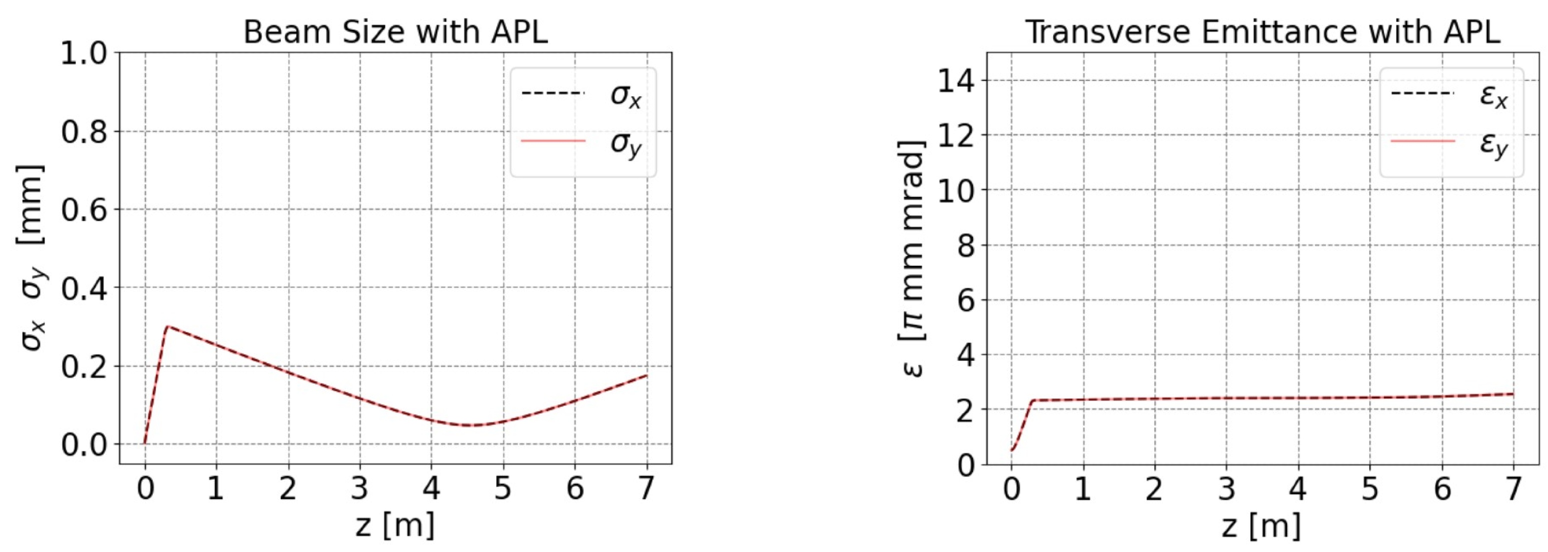


- **Evolution of the Beam Size and Emittance in the Beamline setup with three Electro-Quadrupole Magnets**



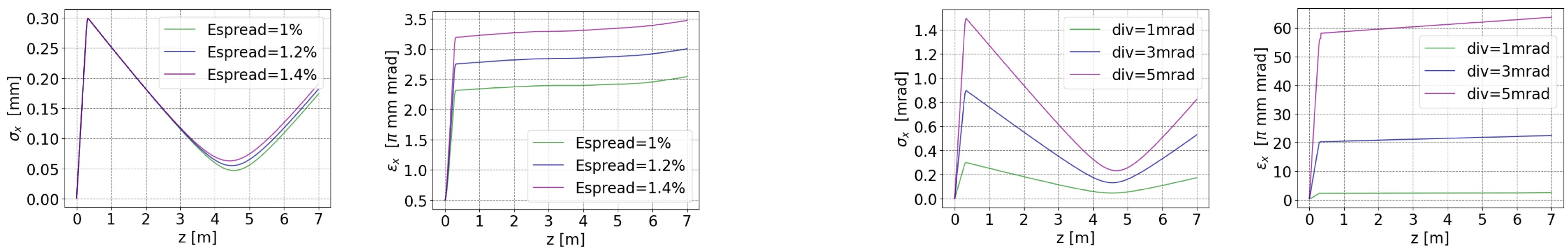
Inverse relationship between the focusing of the beam in the horizontal and vertical plane. Large degradation of beam emittance, up to 10 π mm mrad, due to intrinsic emittance growth and chromatic aberration.

- **Evolution of the Beam Size and Emittance in the Beamline setup with Active Plasma Lens (Argon gas)**



Both the vertical and horizontal planes exhibit focused behavior. Still increasing in the beam size but it is notably smaller than in the previous setup. Degradation of beam emittance remains significantly low, around 2 π mm mrad, due to intrinsic emittance growth and chromatic aberration.

CONCLUSION



From this observations, active plasma lenses show higher potential for effectively capturing and focusing electron beams in EUV FEL applications. It is clear that active plasma lens provide kT/m focusing fields, orders of magnitude stronger focusing compare to conventional quadrupole magnets. Furthermore, the aberration is fully suppressed by using a heavier gas species like Argon. Moreover, the highly diverging beam produced from the laser-plasma interaction which combined with high energy spread leads to minorer beam size and emittance growth in case of the active plasma lens. However, further optimizations and analysis as well as reducing the distance between the LPA and the APL, are necessary to fully achieve electron beam parameters in the required range.

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