Characterization of self-injected electron beams from LWFA experiments at SPARC_LAB

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WHAT WE WANT TO DO:

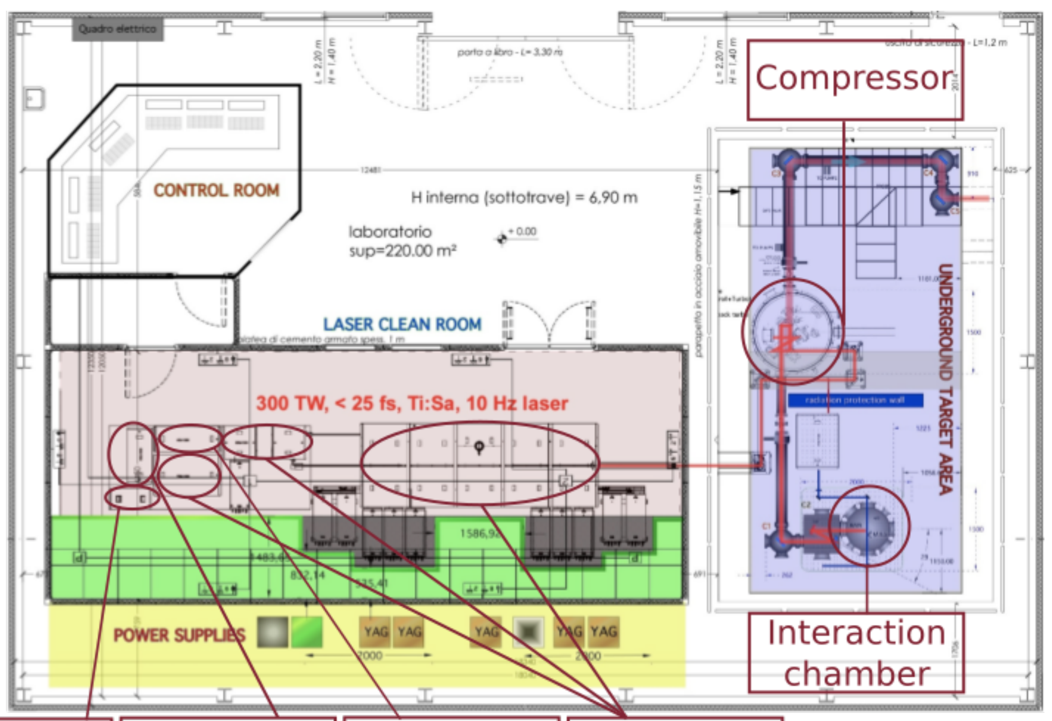
LWFA bubble regime

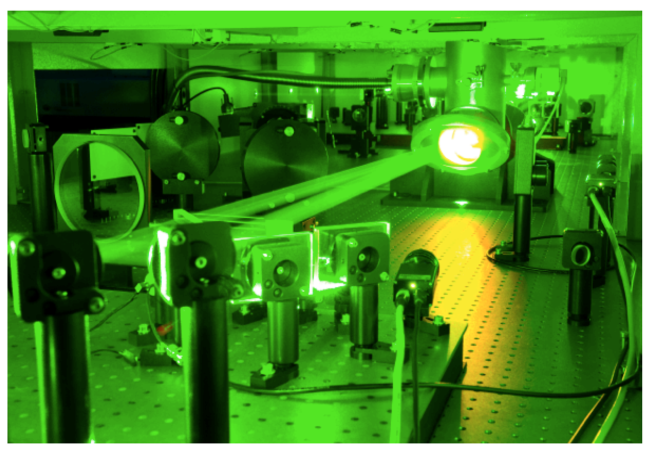
In the strongly non-linear regime, thus using high laser intensities, the wakefield accelerating structure for the electrons is bubble-like and the electrons are self-injected from the rear of the bubble inside the accelerating and focusing region, completely depleted from electrons by the strong ponderomotive laser potential at its passage through the underdense plasma.
It occurs for a normalized laser intensity $a_0 = eE_0/m_e\omega_0 c \gg 1$, that is for laser pulses shorter than the plasma wavelength $\lambda_p = 2\pi c/\omega_p$ where $\omega_p = e(n_0/\varepsilon_0 m_e)^{1/2}$ is the plasma frequency.

WHAT WE SET-UP:

250 TW FLAME Laser System

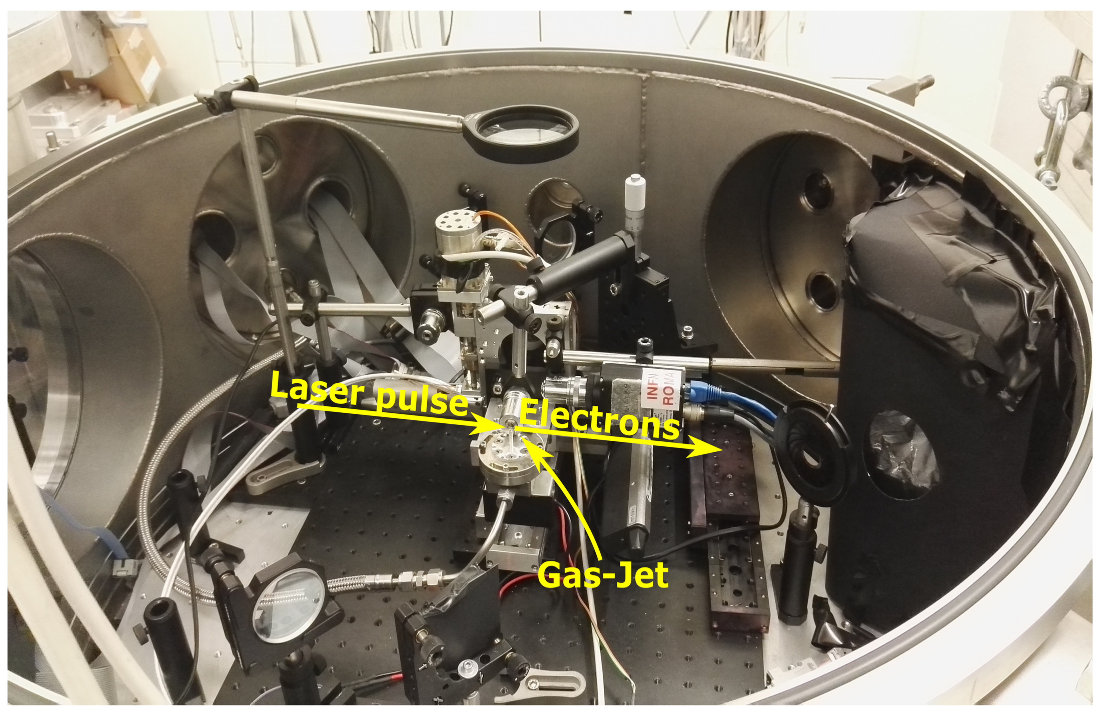
based on Ti:Sa CPA technique, 10 Hz R.Rate, 800 nm wavelength



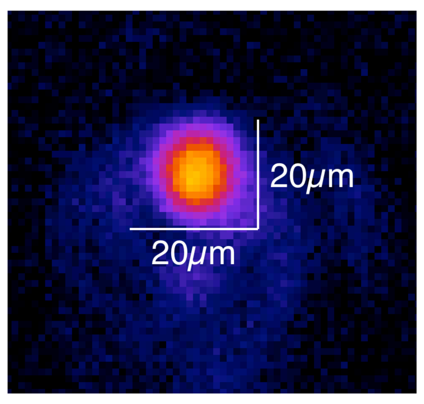


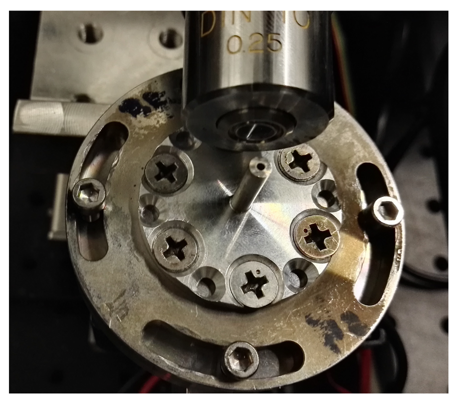
Energy (on focus)	1 J
Temporal length (FWHM)	40 fs
Focal spot (diameter 1/e²)	20 μm
Spectral width (FWHM)	60 nm

The main laser beam is focused in middle of the interaction chamber (vacuum 10^{-6} mbar) on an He target, by means of an OAP mirror with focal length 1m.



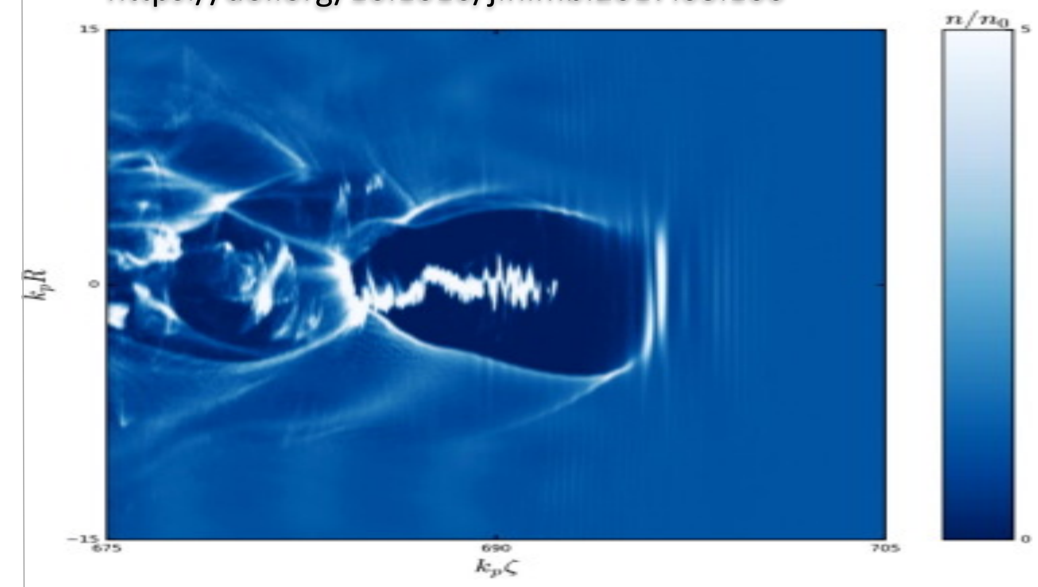
The gas, transported by the gas-jet, is synchronously injected with the laser pulse, that stimulates the plasma wakefield, so that an electron bunch in the same direction of the laser is generated.



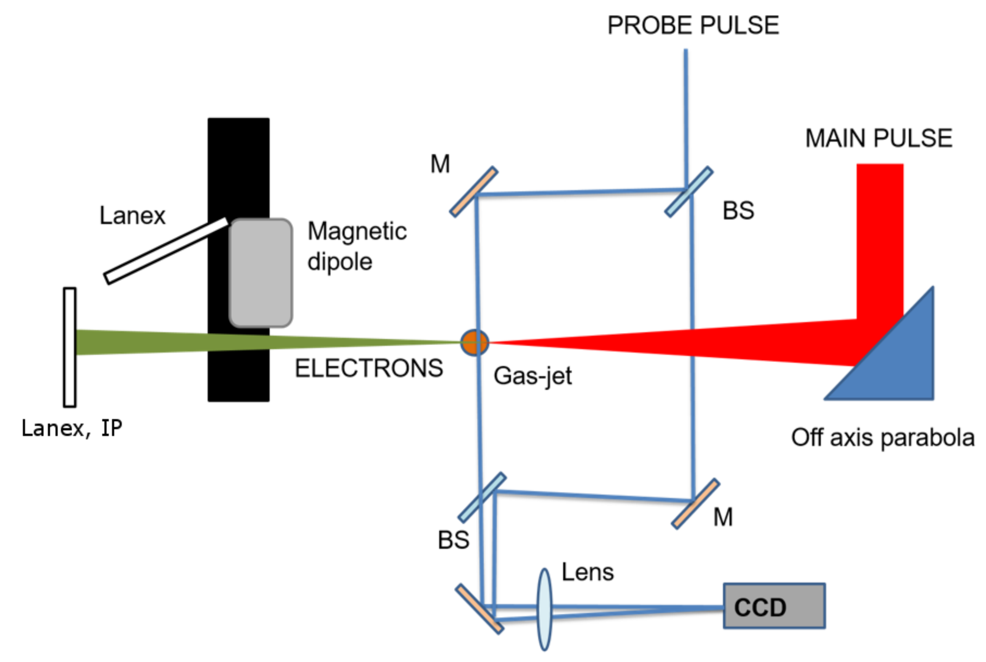


Simulations

2D plasma density plot from PIC Code ALaDyn simulations
https://doi.org/10.1016/j.nimb.2017.03.106



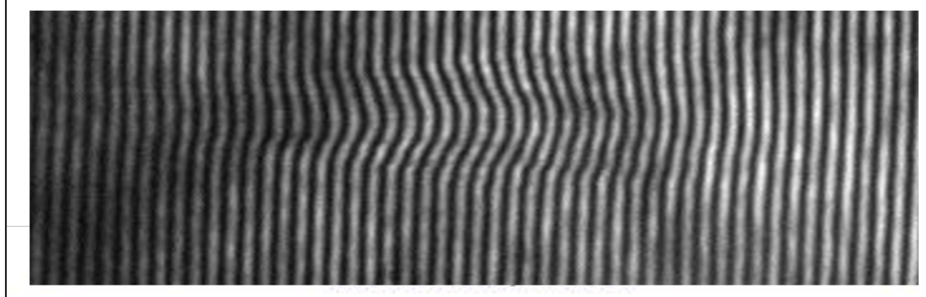
Electron beam diagnostics

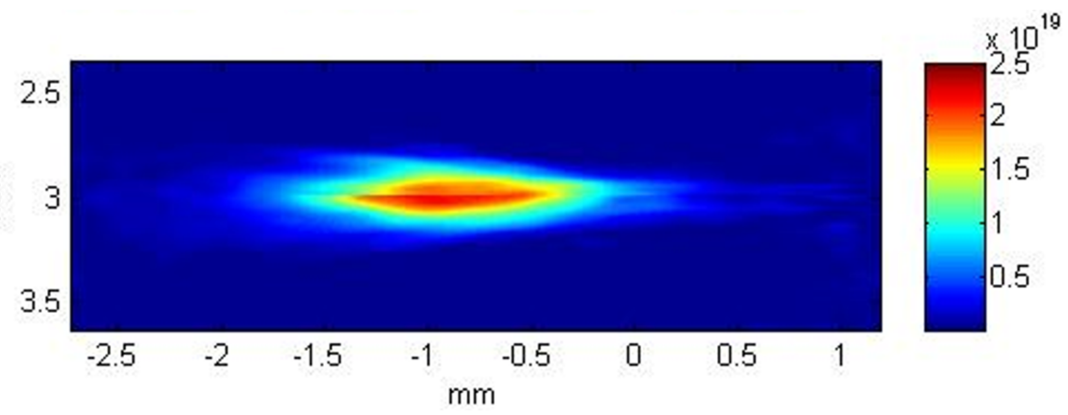


WHAT WE OBTAINED:

Electron plasma density

Mach-Zehnder interferometer, probe laser. Plasma refractive index $\eta = \sqrt{1 - n_e/n_c}$ detected by measuring the dephasing of the probe beam caused by the different phase velocity propagating through the plasma. Data analysis made by a Matlab GUI.



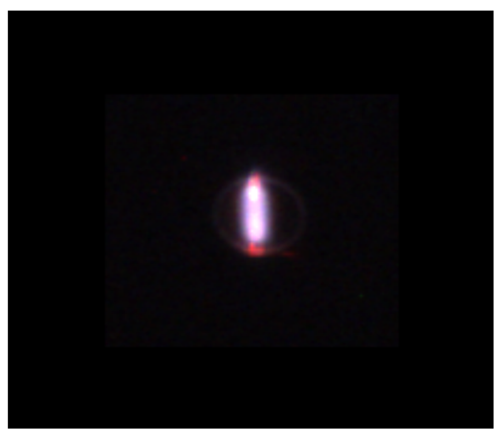


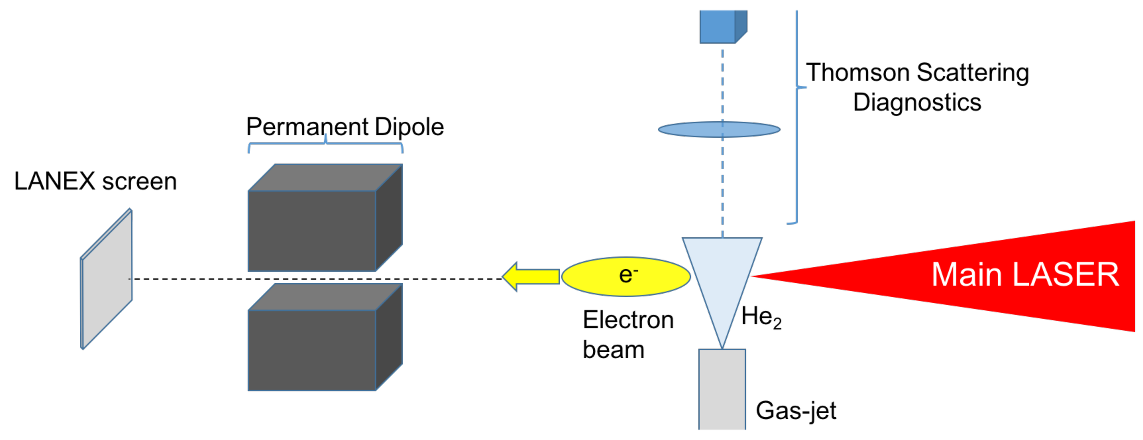
1 x 10¹⁹ cm⁻³

$E_0 \approx 96\sqrt{n_0} \approx 300\ GeV/m$

Plasma channel length

90° Thomson Scattering diagnostic: 200 mm focal length lens, 35 mm objective. Electron-photon collisions between laser and plasma during the interaction.



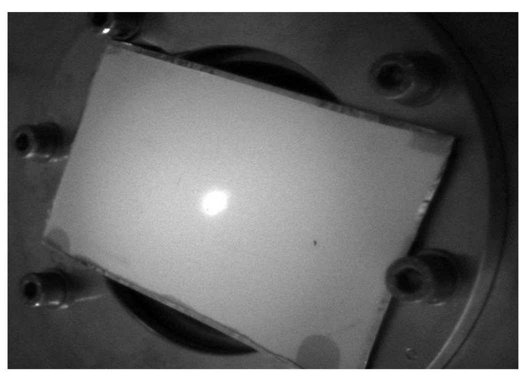


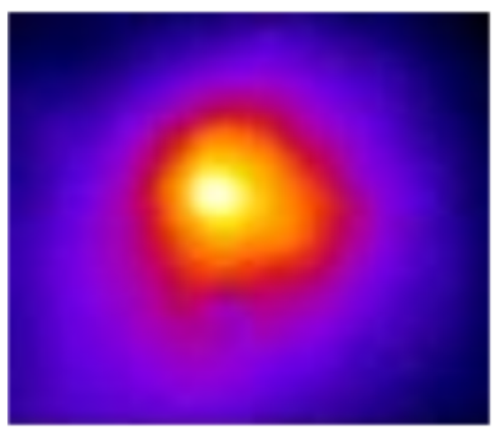
2.6 mm

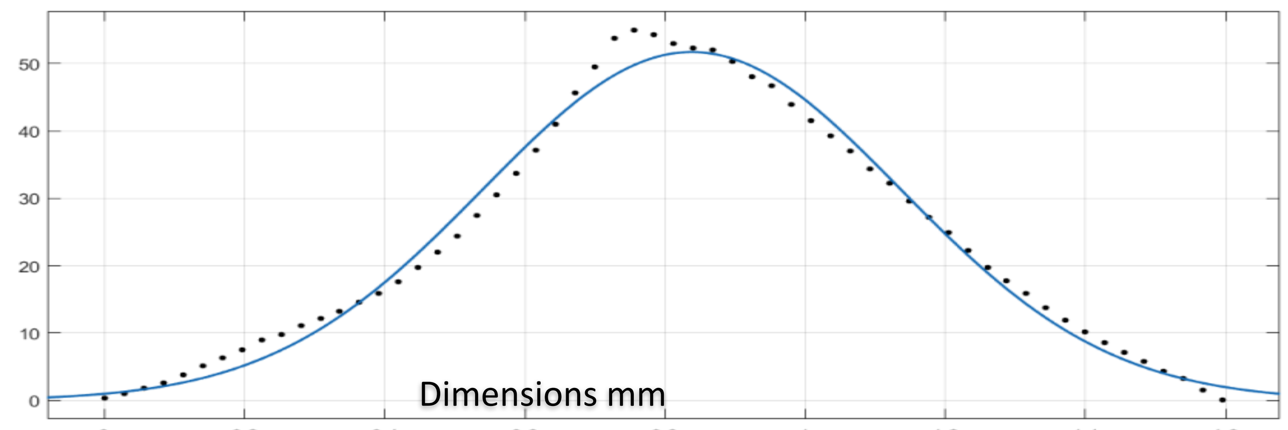
Agreement Mach-Zehnder measurement

Electron beam transversal dimensions (rms)

Lanex scintillator at 90°





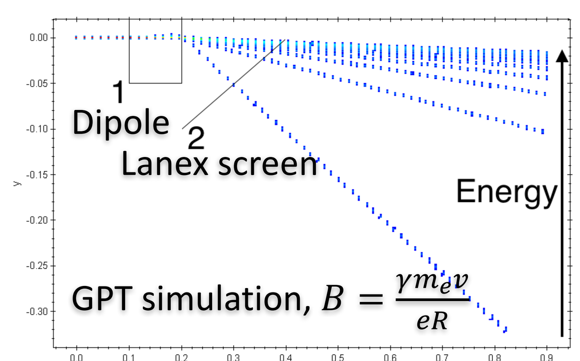


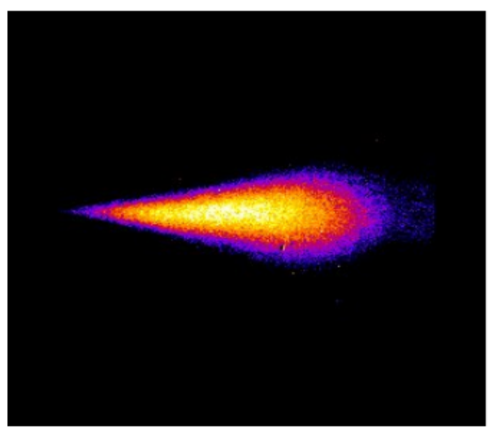
(5 – 15) mm

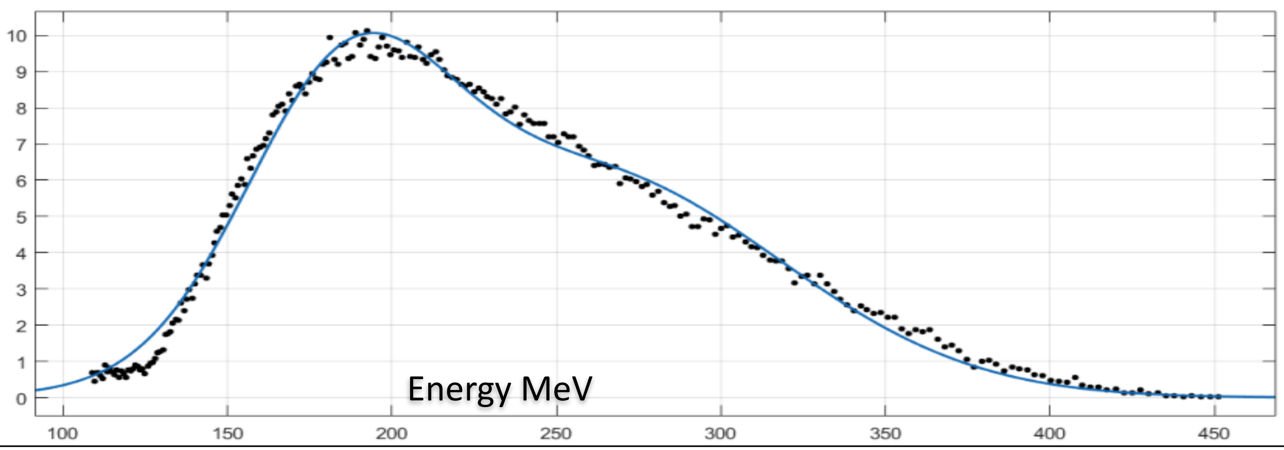
Divergence (2-8) mrad

Electron energy spectrum

1T permanent dipole, lanex scintillator at 60°





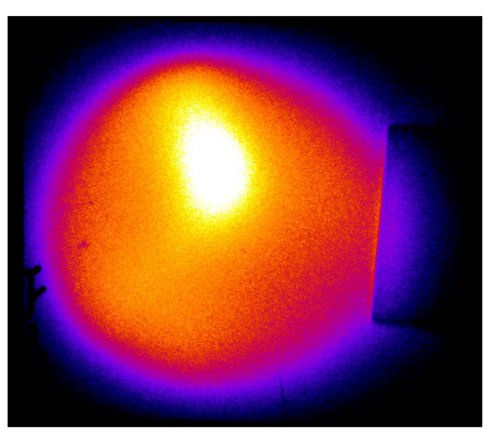


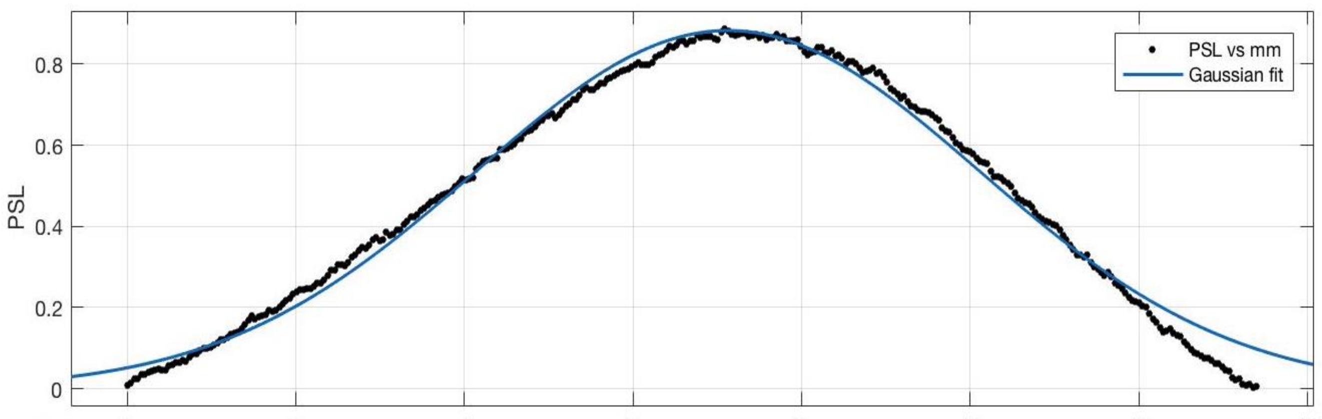
(150-350)MeV

Energy Spread (10-30)%

Absolute beam charge

Fuji BAS Imaging Plates, DURR scanner. The number of photons emitted in the read-out process (PLS) is proportional to the total absorbed radiation energy. Off-line measurement.





~100 pC

Agreement dimension measurement

FUTURE DEVELOPEMENTS

To keep only the energetic core of the whole electron charge spectrum an energy selector will be installed. The problem of the divergence of the electron beam arises when it exits from the plasma channel where it was confined, and it is related to the charge of the beam and to its energy. A magnetic quadrupole can help cut down to a tolerable value of few mrad the divergence of high energy electron beams, achievable in such a short accelerating cavity, and the high energy spread obtained can be reduced by means of an optimization of the injection. New methods to measure the beam charge will be implemented, such as the installation of a toroid.