SPARC LAB

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

The FLAME laser at SPARC_LAB

Maria Pia Anania

On behalf of SPARC_LAB collaboration

Outline

FLAME @ SPARC_LAB

- ***FLAME itself***

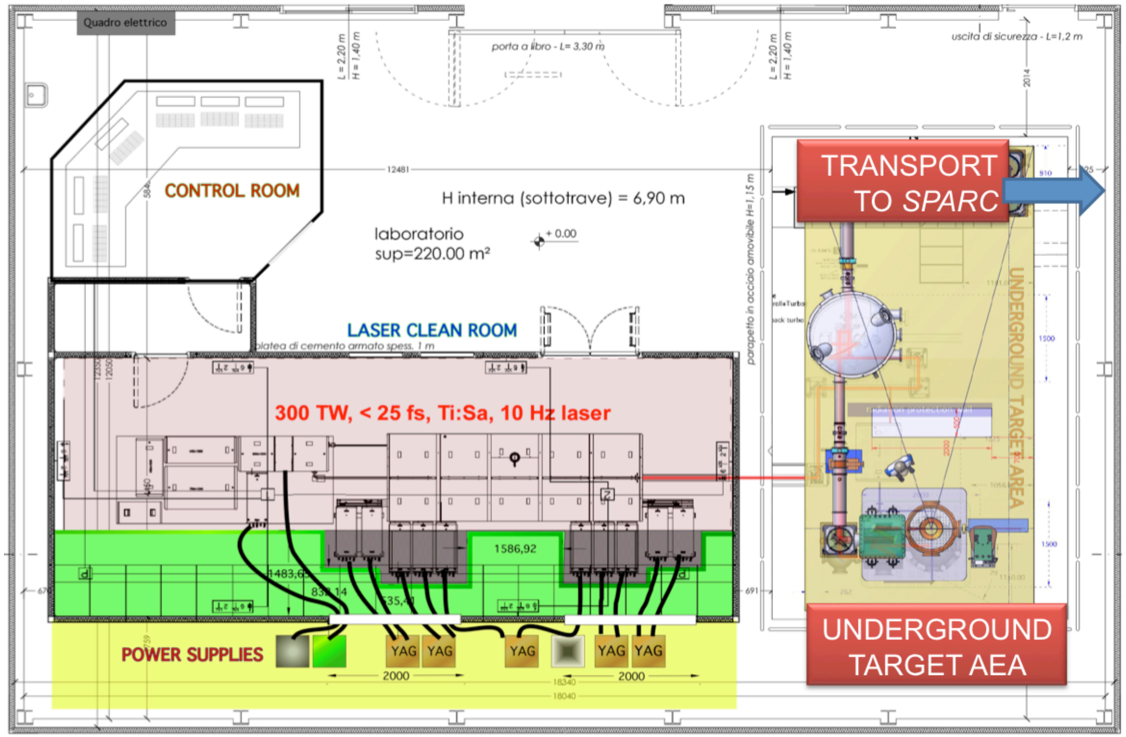
a. Electron acceleration by self injection
b. Light ion acceleration by TNSA
c. Air propagation by LIDAR

- ***FLAME + SPARC***

a. Compton scattering
b. Electron acceleration by external injection

Summary

Layout of the FLAME laser.



Max energy: 7J

Max energy on target: ~ 5J

Min bunch duration: 23 fs

Wavelength: 800 nm

Bandwidth: 60/80 nm

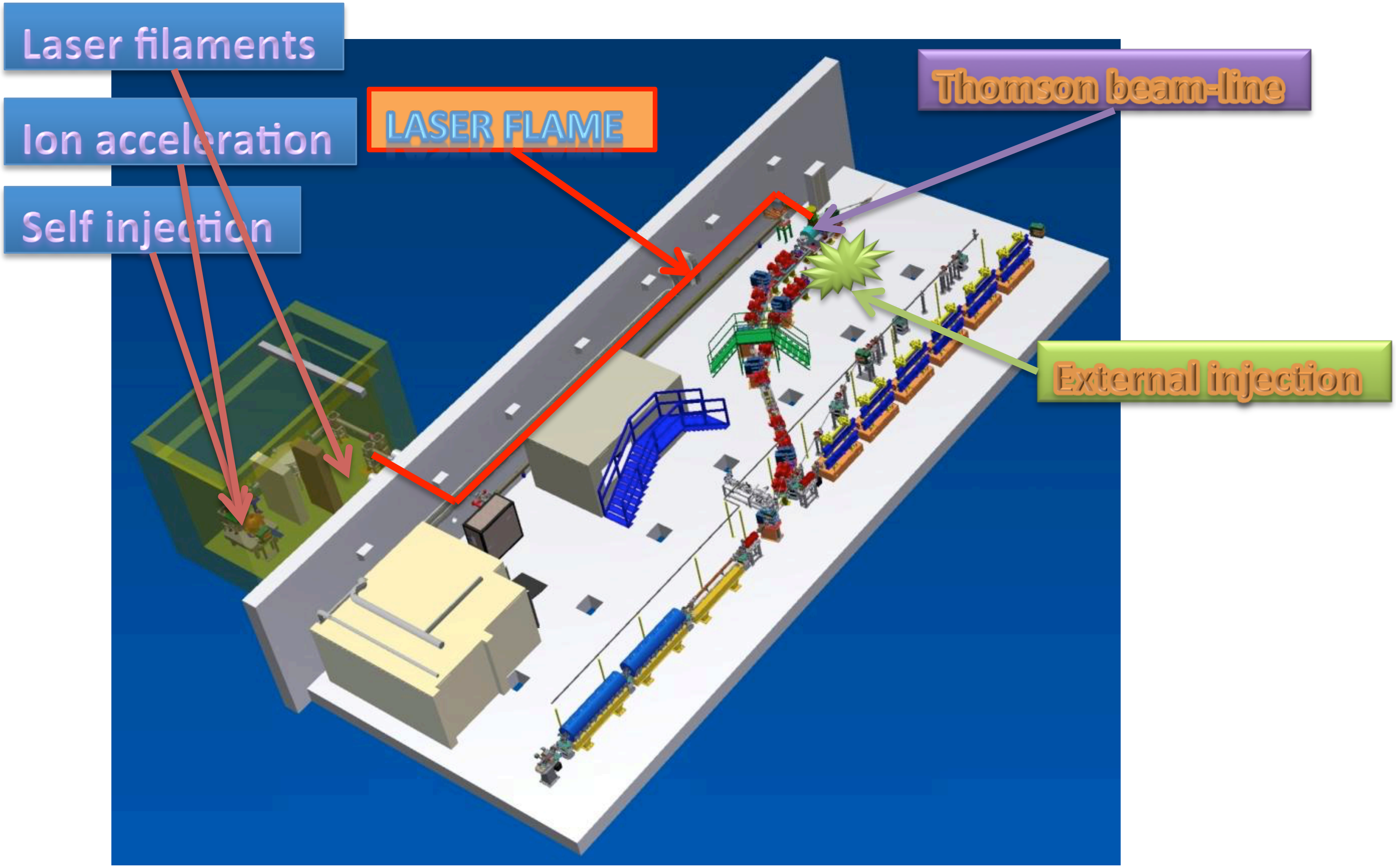
Spot-size @ focus: 10 µm

Max power: ~ 300 TW

Contrast ratio: 10^{10}

FLAME @ SPARC_LAB

SPARC_LAB is a multi-disciplinary test facility composed by a high brightness LINAC and a high power laser.



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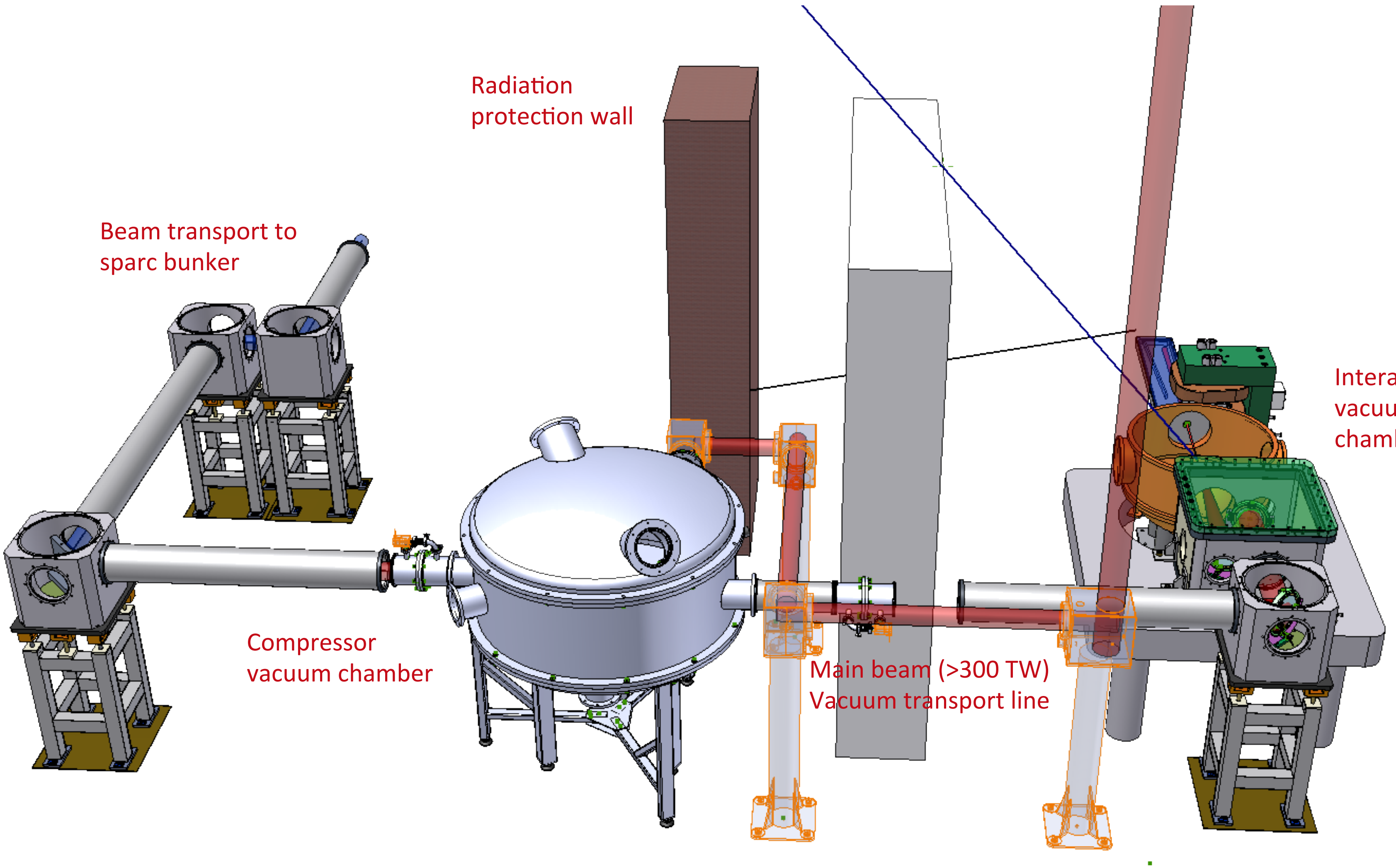
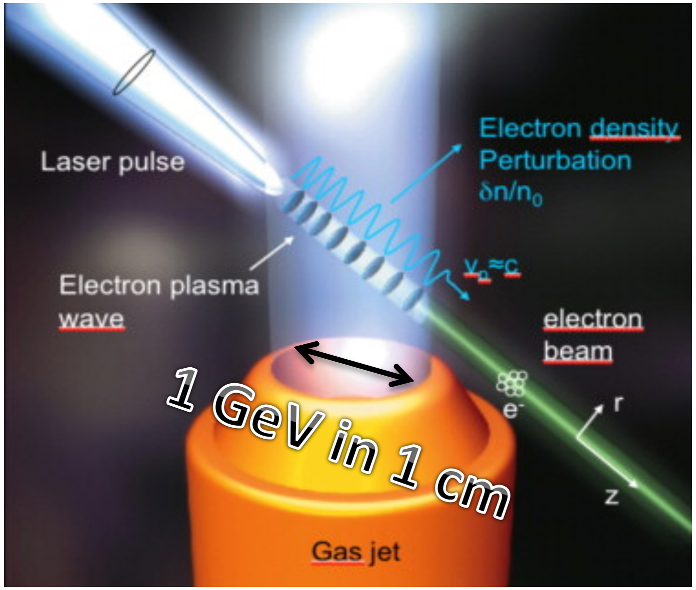
FLAME bunker



Laser wakefield acceleration

Laser wakefield accelerators (LWFA) are a novel type of accelerators capable to produce accelerating field up to 100 GV/m. This feature gives the possibility to have very compact accelerators able to accelerate electrons to GeV energies in few **centimetres**.



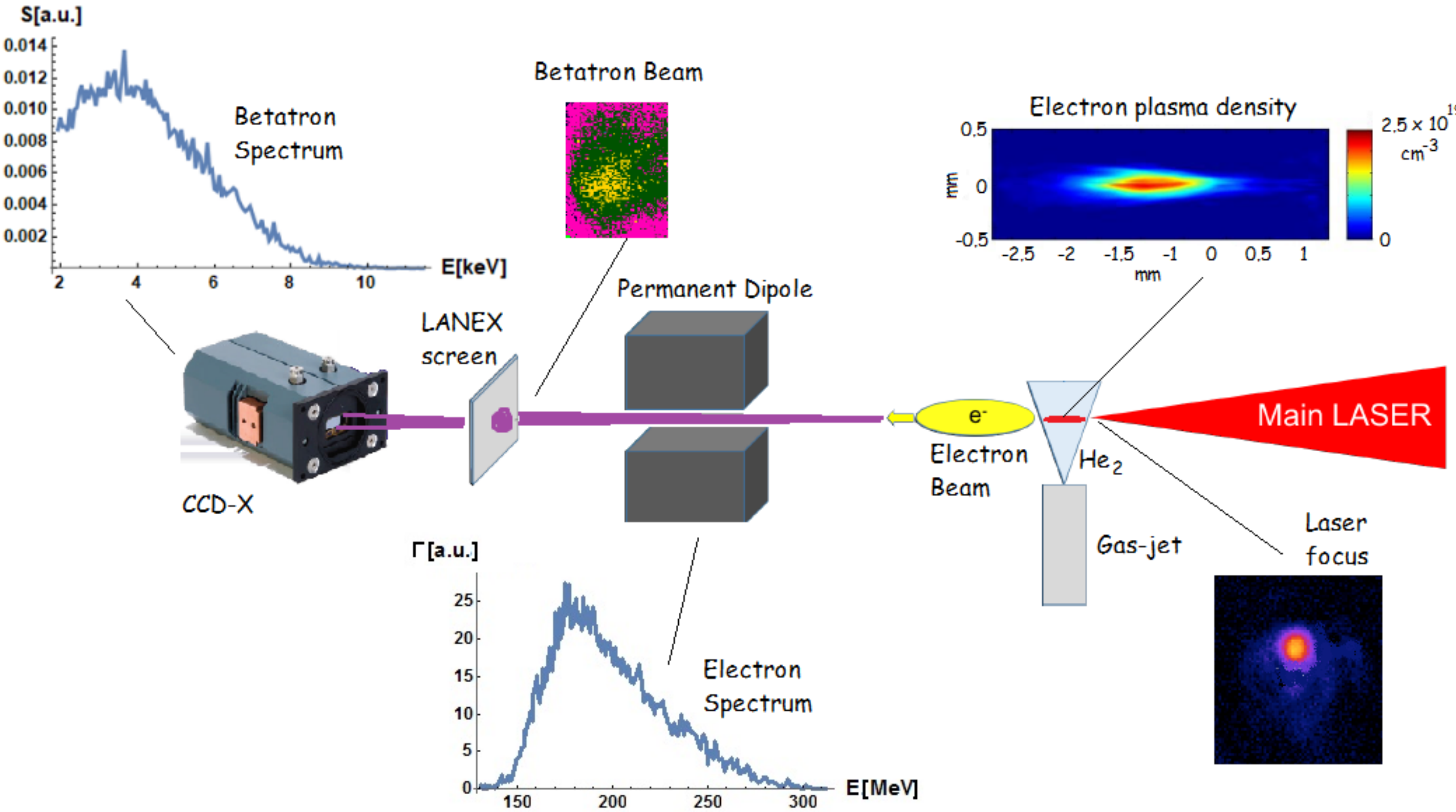
PROS:

1. Costs of the facilities;
2. Compactness: key-word is TABLE TOP!

CONS:

1. Instability of the electron bunches;
2. Quality of the electron bunched are not yet comparable to that of conventional accelerators.

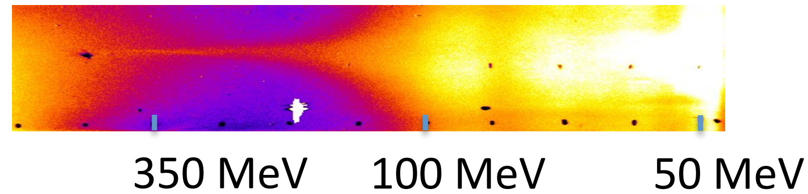
LWFA experiments: the set-up

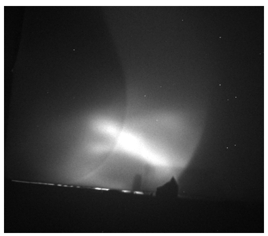


LWFA experimental results

Full electron beam characterization:

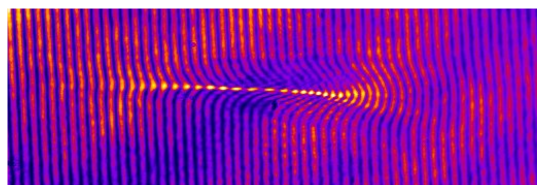
1. Electron beam energy;

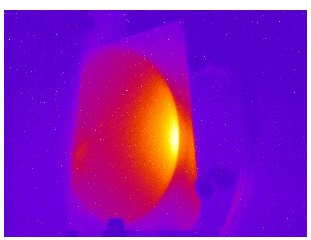




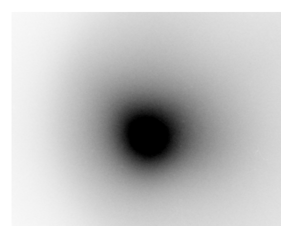
2. Electron beam divergence;

3. Plasma density;



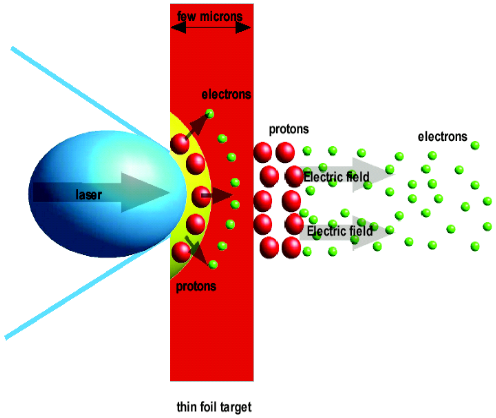


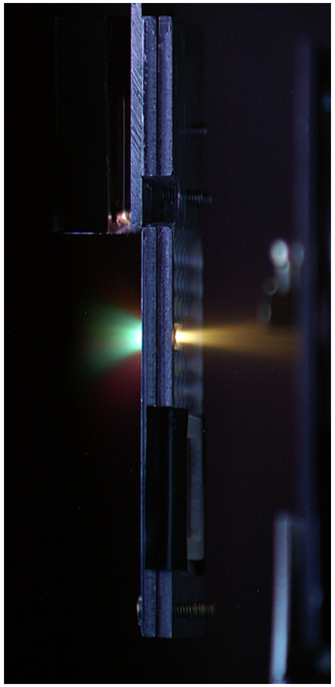
4. Betatron radiation → electron beam emittance;



5. Electron beam charge;

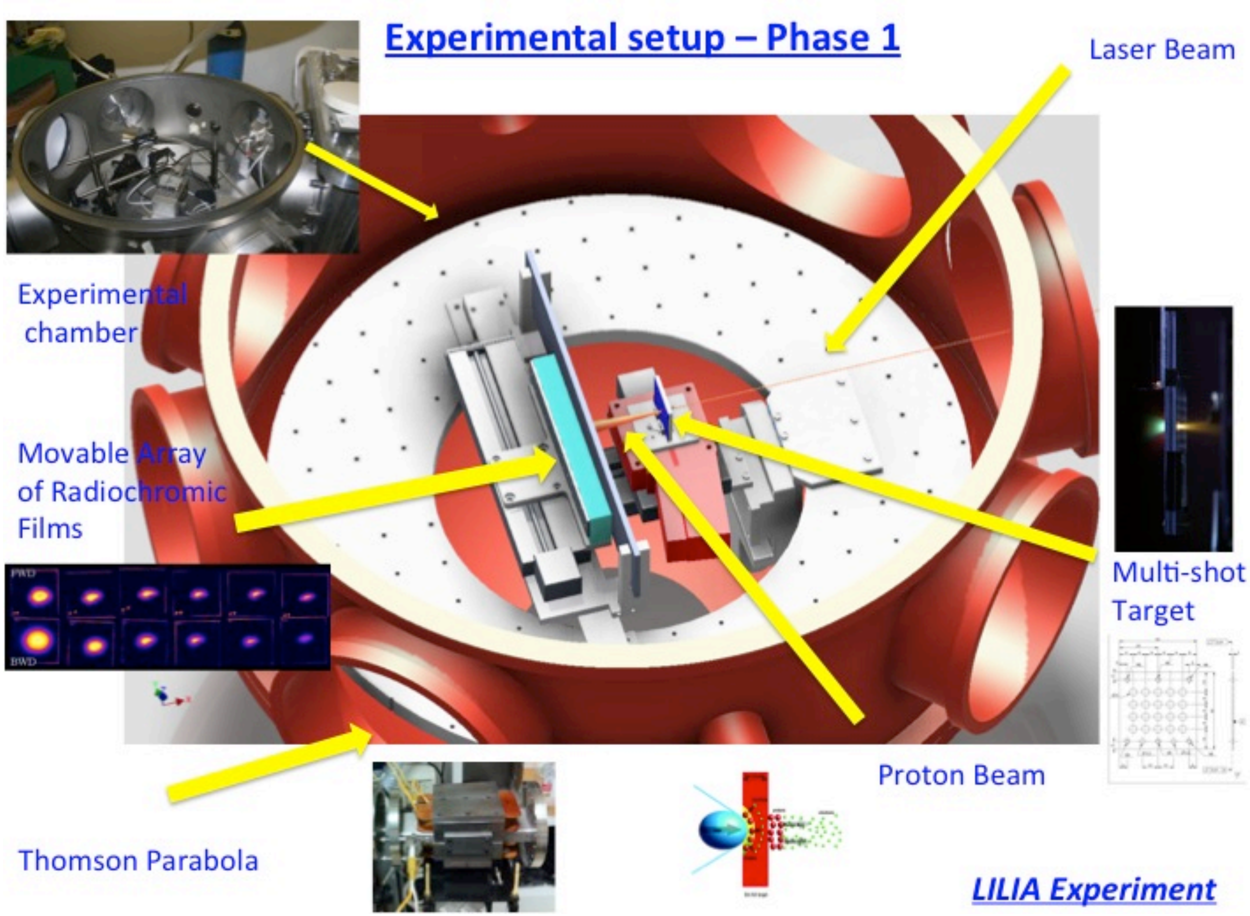
Light ion acceleration by TNSA

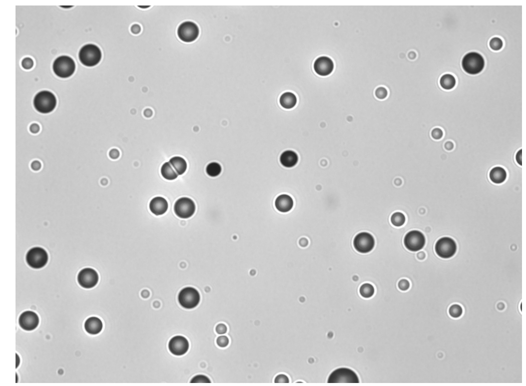


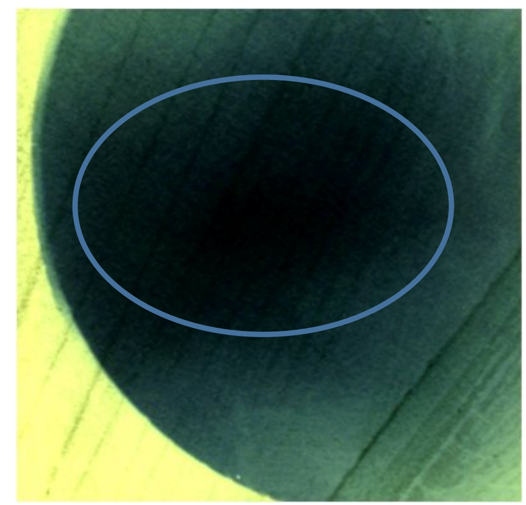


The principle of work of proton acceleration by thin metal target (TNSA) is to focus a high intensity laser on a thin metal target in order to generate a plasma on the surface of the target. This process generates a burst of MeV fast electrons contained in the target (by the very strong electrostatic field generated by charge separation). These some field also act to accelerate protons at the target surface out into the vacuum.

Light ion acceleration by TNSA

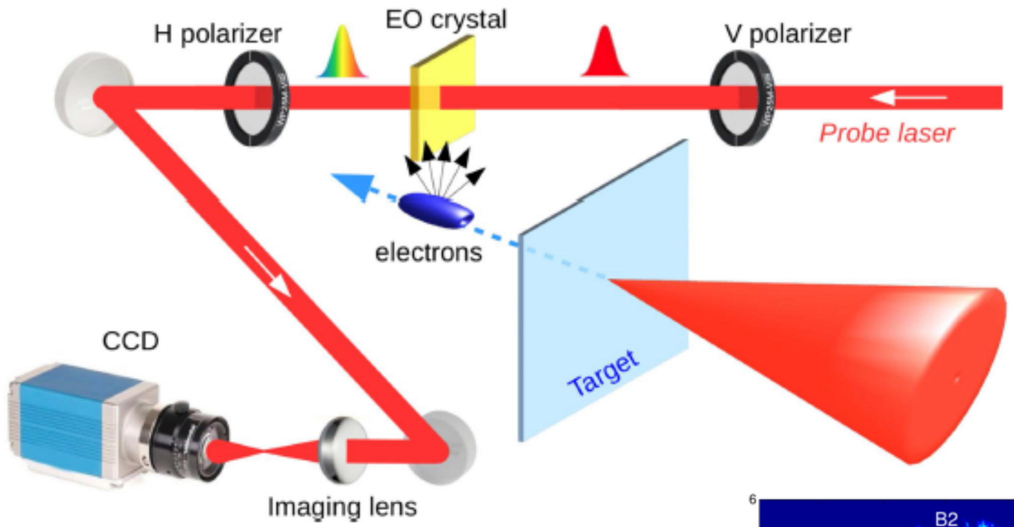






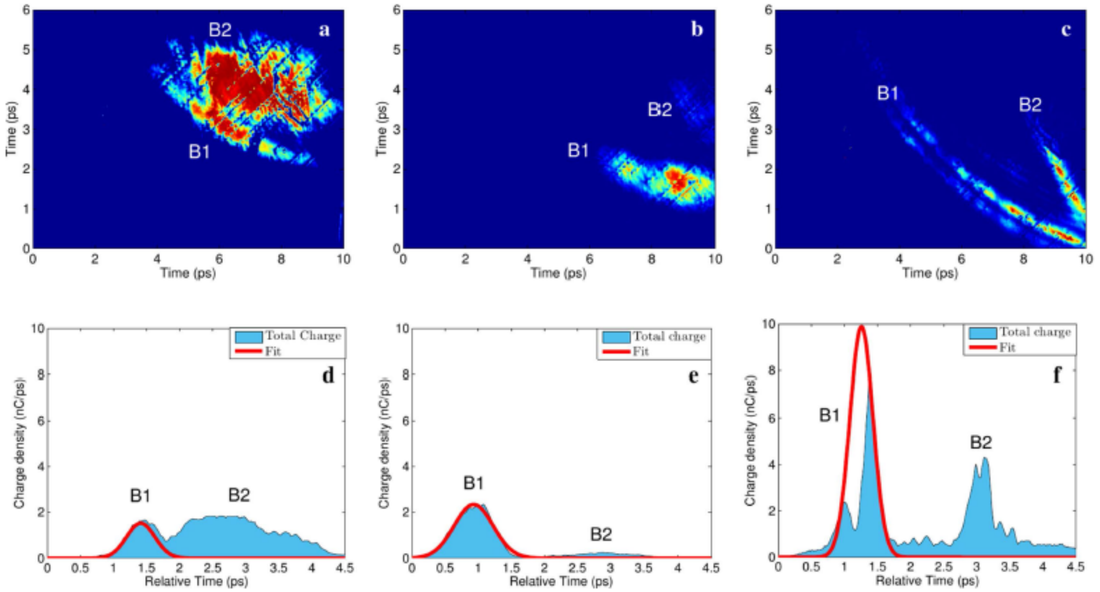
CR39 and gafchromic films to measure first protons accelerated.

Light ion acceleration by TNSA



EOS diagnostic is non-intercepting and single-shot → perfect for TNSA!

Shaping properly the solid target, emitted electrons and ions can be “enhanced” → target are then more impactive than laser power!



Pompili, R., et al., Scientific Reports 6 (2016).
Pompili, R., et al., *Optics express* 24.26 (2016): 29512-29520.

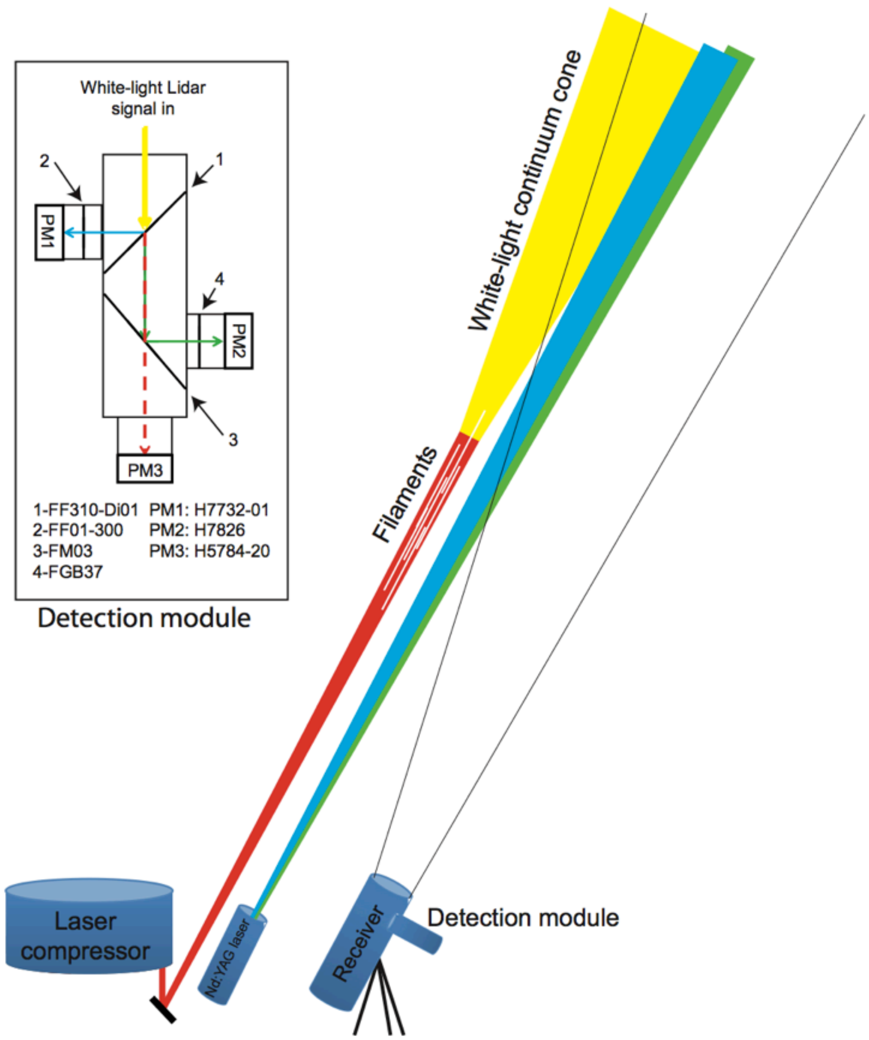
LIDAR experiments

LIDAR – *Light Detection and Ranging*) → to measure atmospheric parameters: height, layering and densities of clouds, cloud particle properties, temperature, pressure, wind, humidity, trace gas concentration, etc.

High power lasers propagating in air → multiple plasma lines (filaments due to Kerr lens) → propagate in atmosphere for hundreds of meters by controlling chirp and duration of laser.

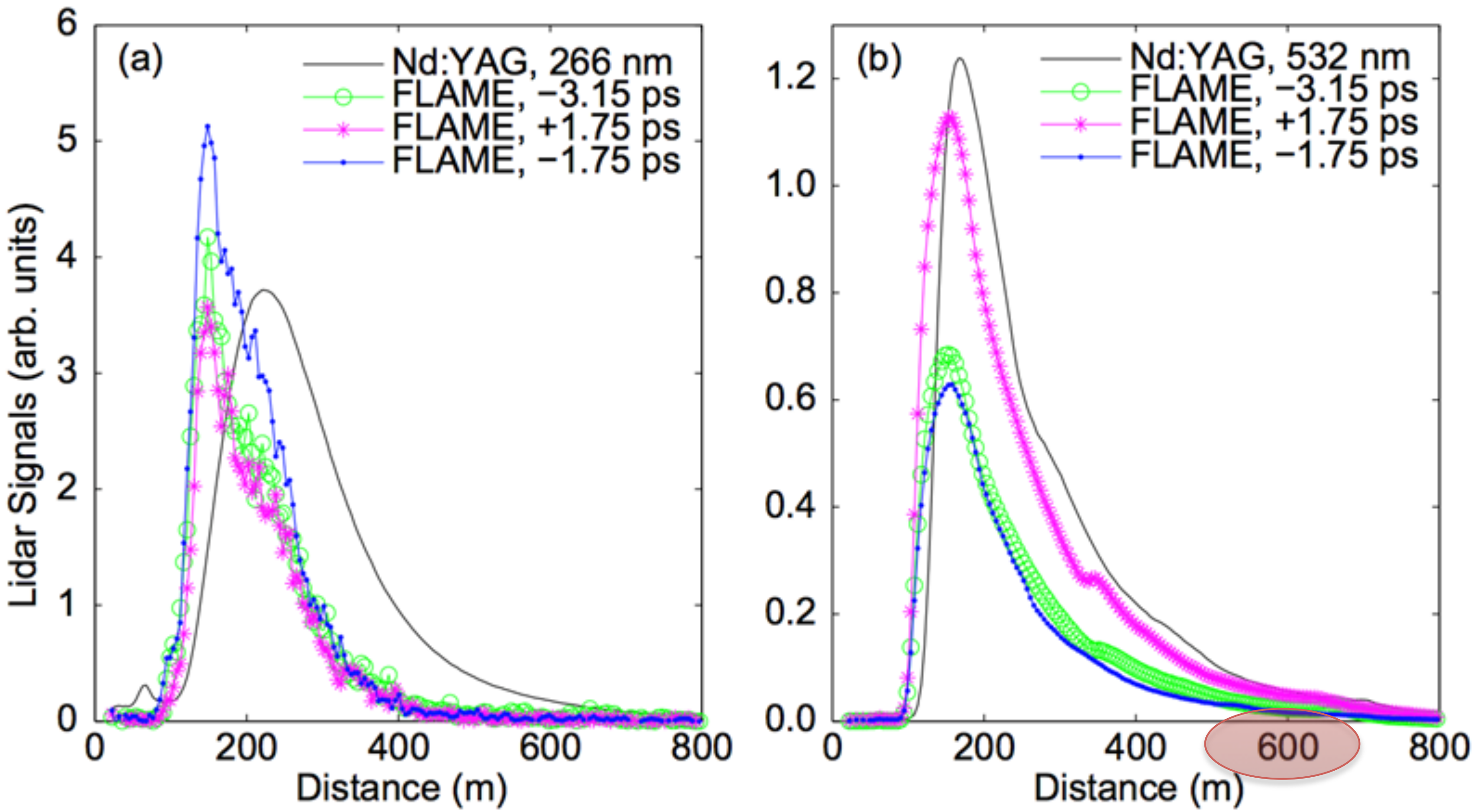
Analyzing the light emitted by the plasma filaments, different species can be detected and analyzed → industrial incidents, leakages, fires, as well as unknown aerosols → does not require any priori knowledge of the species present in air.

Air propagation: LIDAR experiments



LIDAR experiments

Backscattering light (LIDAR signal) from the plasma filaments.



M. Petrarca et al., **Appl. Phys. B**, 114, pp 319-325 (2014)

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a. Compton scattering
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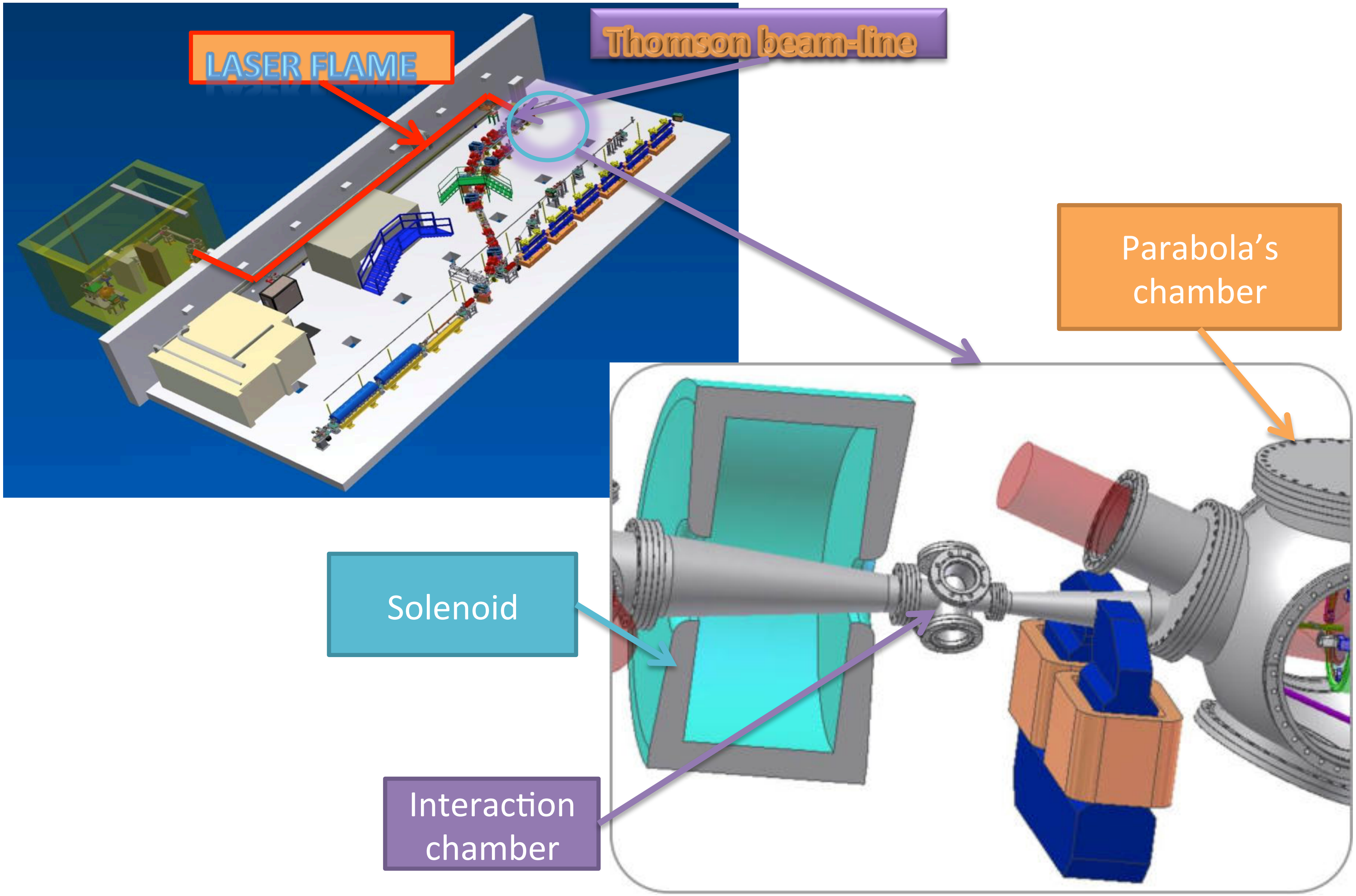
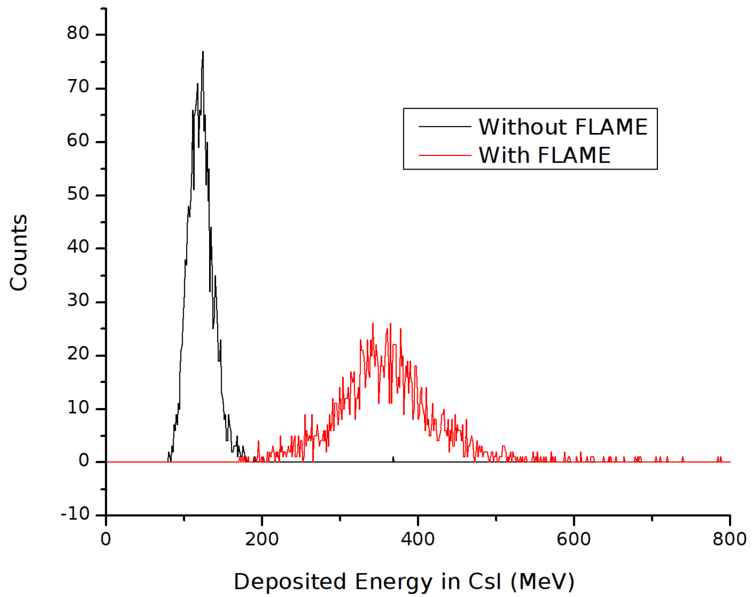
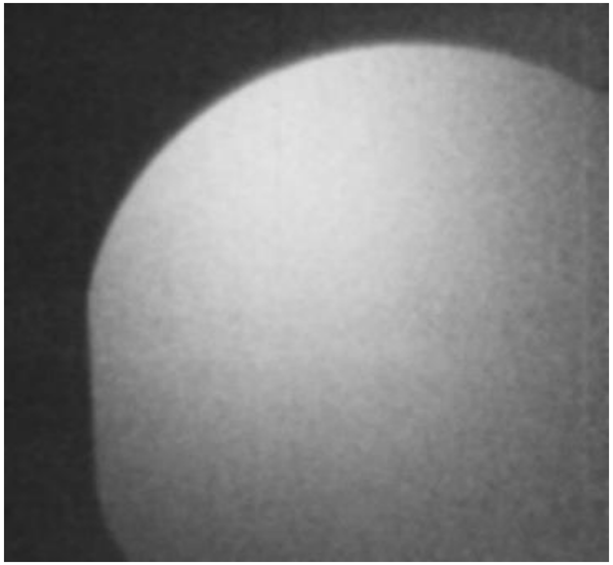
Compton scattering experiments



Compton scattering experiments





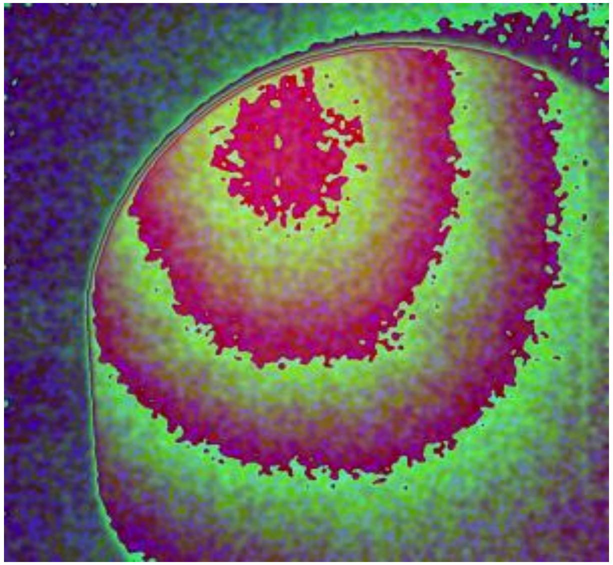
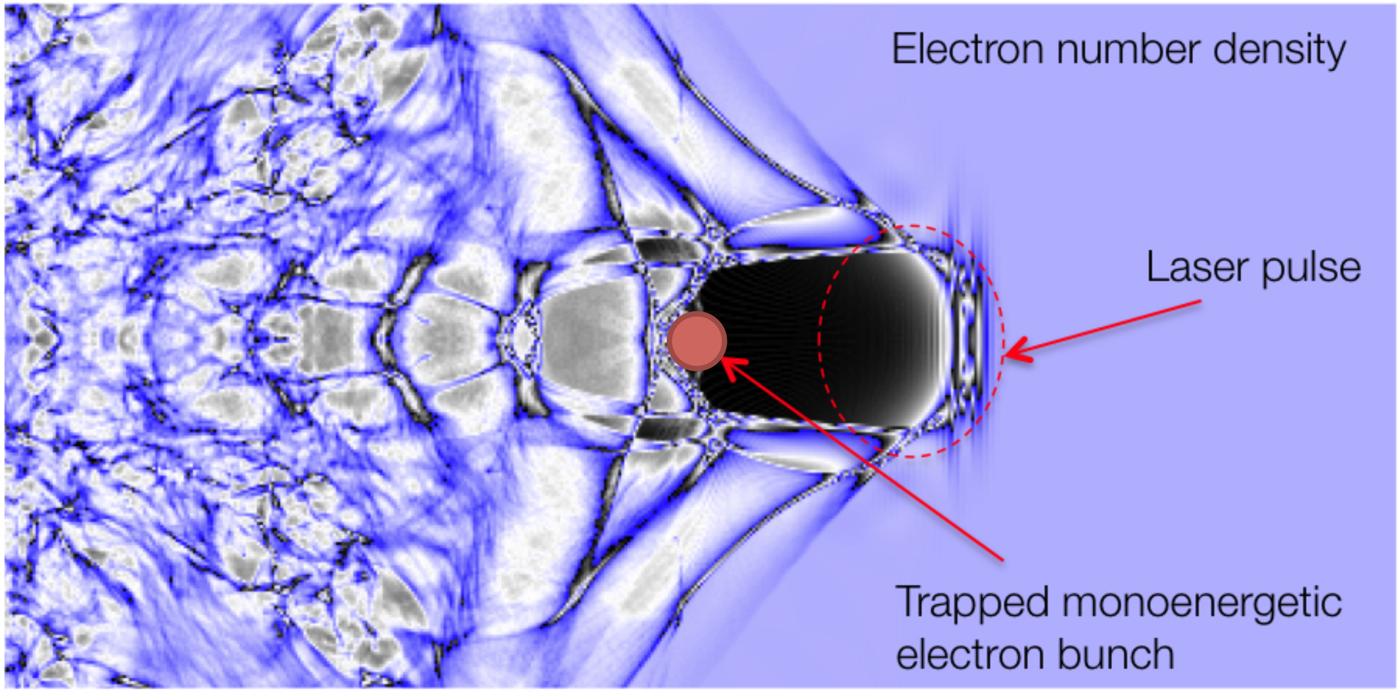


Image of the radiation taken with Hamamatsu imager Flat Panel C9728DK-10 (1s acquisition time).
Capable to produce stable and high energy X-rays (up to ~ 1MeV) with both FLAME and SPARC at full performances.

C. Vaccarezza et al, Proceedings of IPAC (2014)

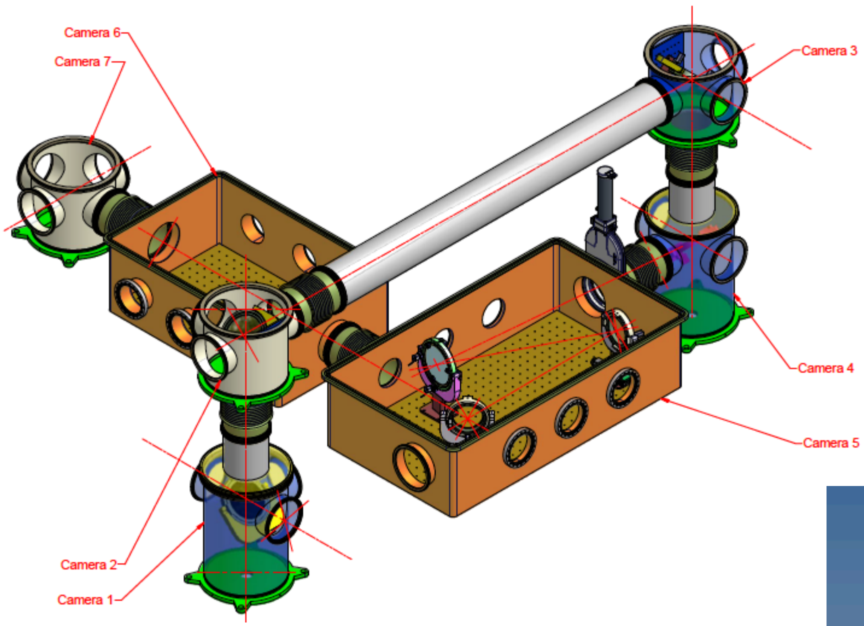
External injection



Electrons accelerated by the linac injected with the right phase on the creast of the wakefield to be further accelerated.

Expected electrons at the plasma exit with a higher energy and a quality comparable to that of incoming electron beam.

External injection



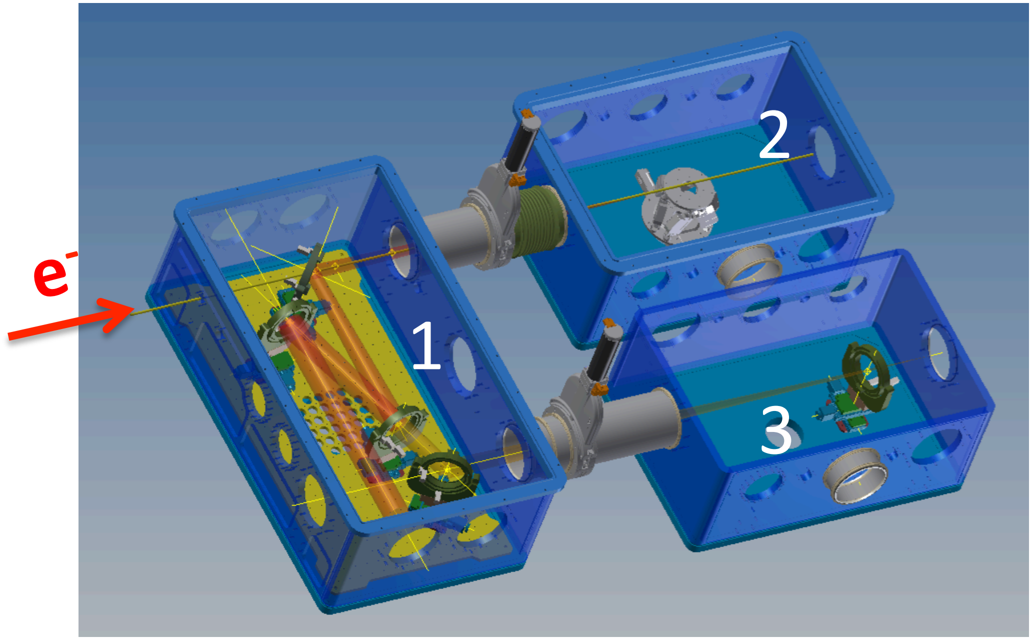
Design of the vacuum chamber for the laser transport.

1st chamber is for mirrors and 3 m focal length off-axis parabola,

2nd chamber is for interaction and 3rd chamber is for diagnostics.

Movements of the capillary (filled with H2) will be made with hexapod.

Synchronization: needs to be at the fs level.



Summary

SPARC_LAB: multi-disciplinary test facility which have the unique possibility to have the combination of a high power laser and a high brightness Linac.

- ***FLAME itself***

a. Electron acceleration by self injection
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c. Air propagation by LIDAR

- ***FLAME + SPARC***

a. Compton scattering
b. Electron acceleration by external injection

For more details…

More details about FLAME experiments will be find on the following talks/poster:

LWFA: Gemma Costa (poster);

Diagnostics: Fabrizio Bisesto (talk)

Betatron radiation: Alessandro Curcio (talk)

TNSA: Prof. Arie Zigler and Fabrizio Bisesto (talks)

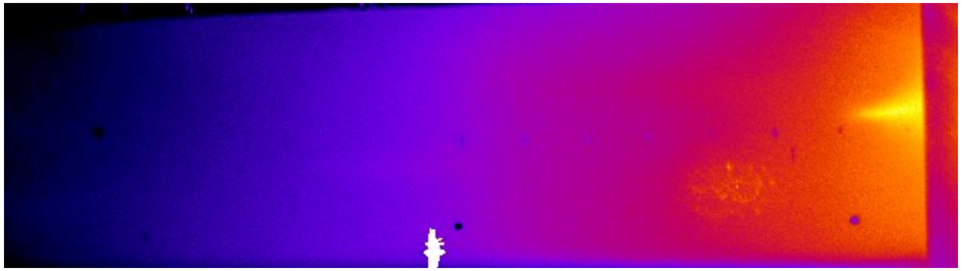
THANK YOU!

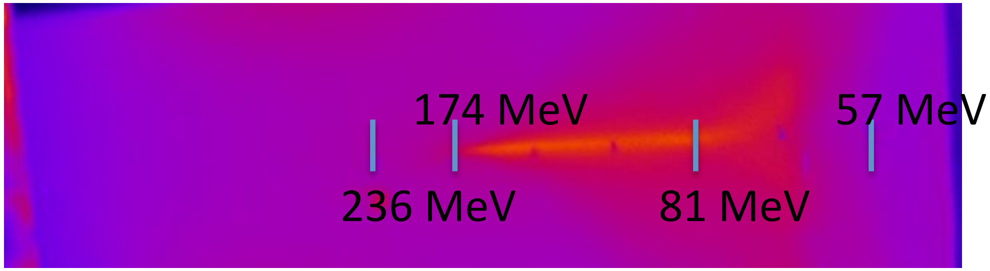
LWFA experimental results

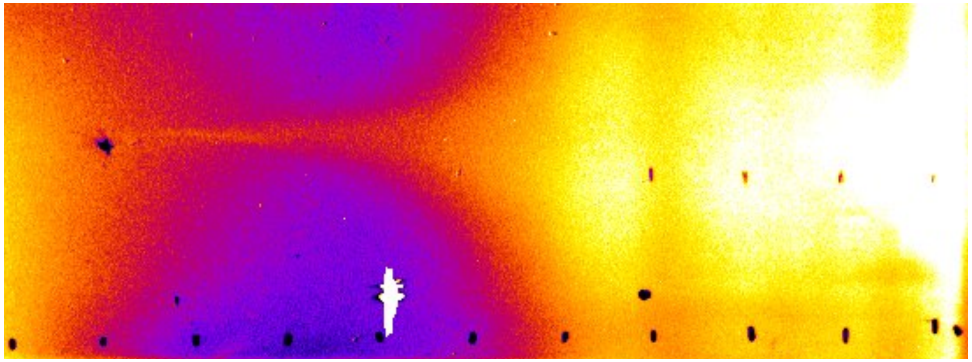
Source optimization and parametric study of the laser and plasma parameters is undergoing.

So for example by scanning the plasma density, electron energy has been varied from 50 MeV, to 175 MeV and up to 300 MeV.

Also by tuning plasma density, energy spread has been reduced from 100% to 20%.

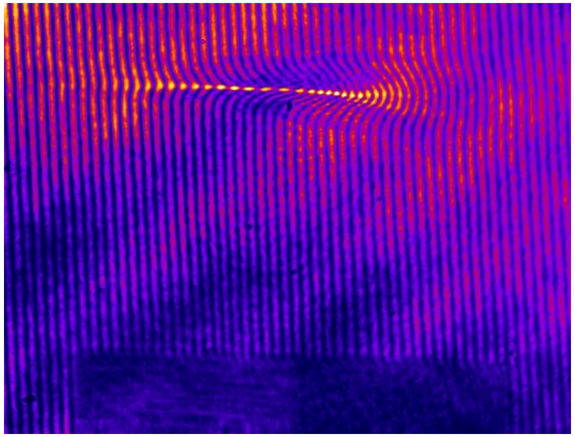




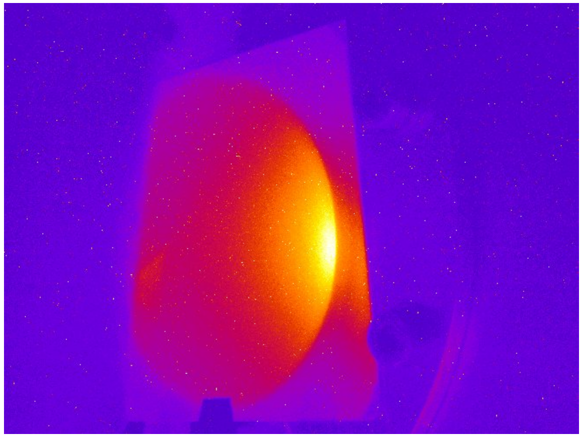


LWFA experimental results

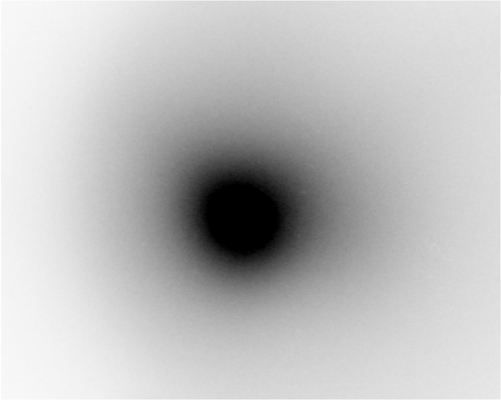
- Diagnostics



Plasma density (varied from ≈$5*10^{18}$ to ≈$2*10^{19}$).



Betatron radiation (up to 20 KeV).



Charge (up to 10 pC in the core).

Compton scattering experiments

Electron beam

Energy: 50.6±0.2 MeV

Energy spread: 0.39±0.025%

Emittance: 4.82 mm mrad

Charge: 200±20 pC

Duration: 3.1 ps

Spot-size: 89.1±2.6 µm in x
88.3±3.2 µm in y

Laser beam

Energy: 2 J on target

Spot-size: 20 µm

Duration: 300 fs

Wavelength: 800 nm

Bandwidth: 60 nm

Contrast: 10^8