Innovative single shot diagnostics for electrons from laser-plasma interaction at SPARC_LAB

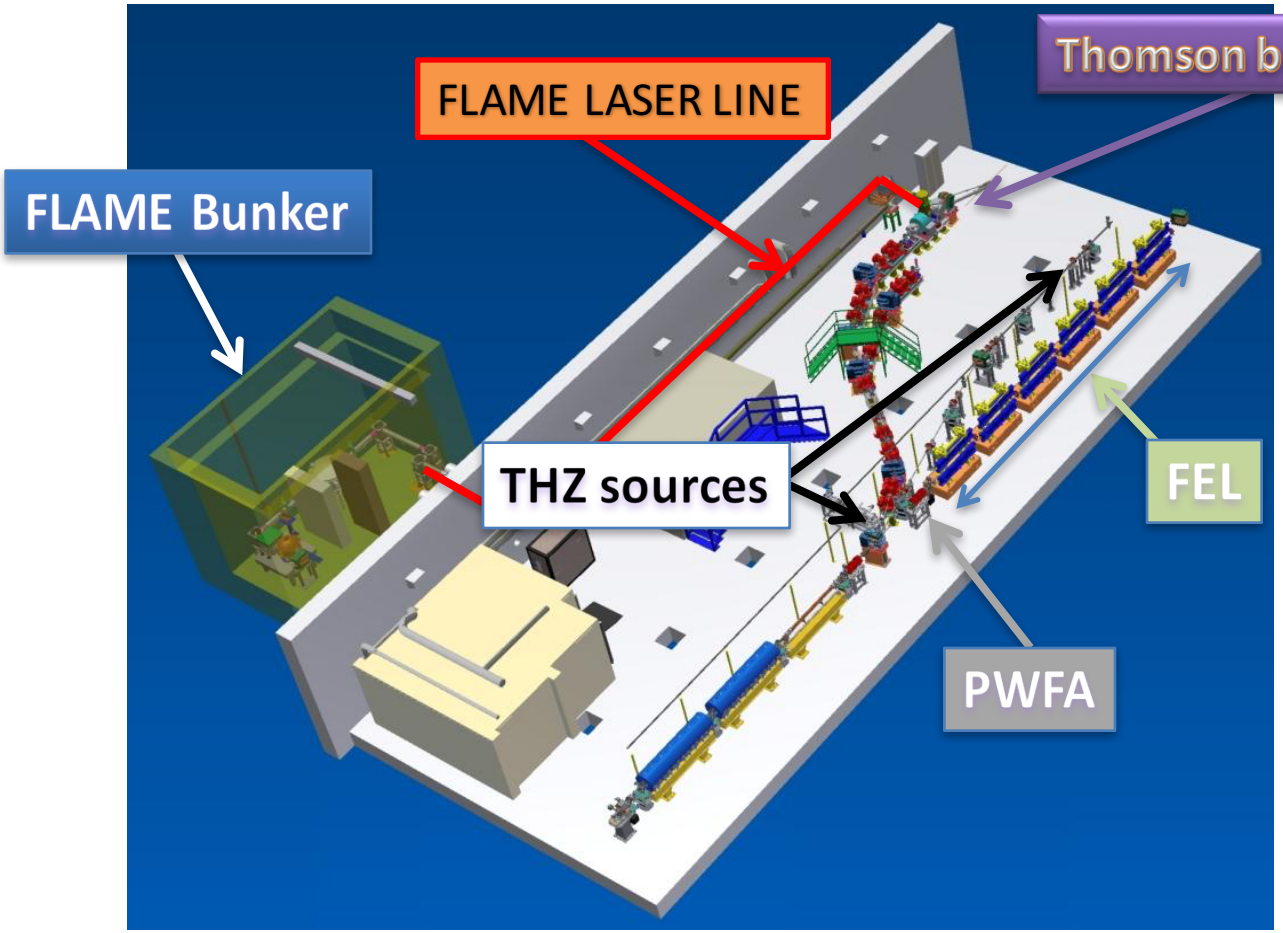
F. Bisesto

On behalf of SPARC_LAB collaboration

Outline

- SPARC_LAB Facility and the FLAME laser
- Single shot emittance measurements based on incoherent optical transition radiation (OTR)
- Electro optical sampling (EOS) diagnostics for fs resolution temporal measurements on fast electrons from laser-matter interactions
- Conclusions

SPARC_LAB Facility

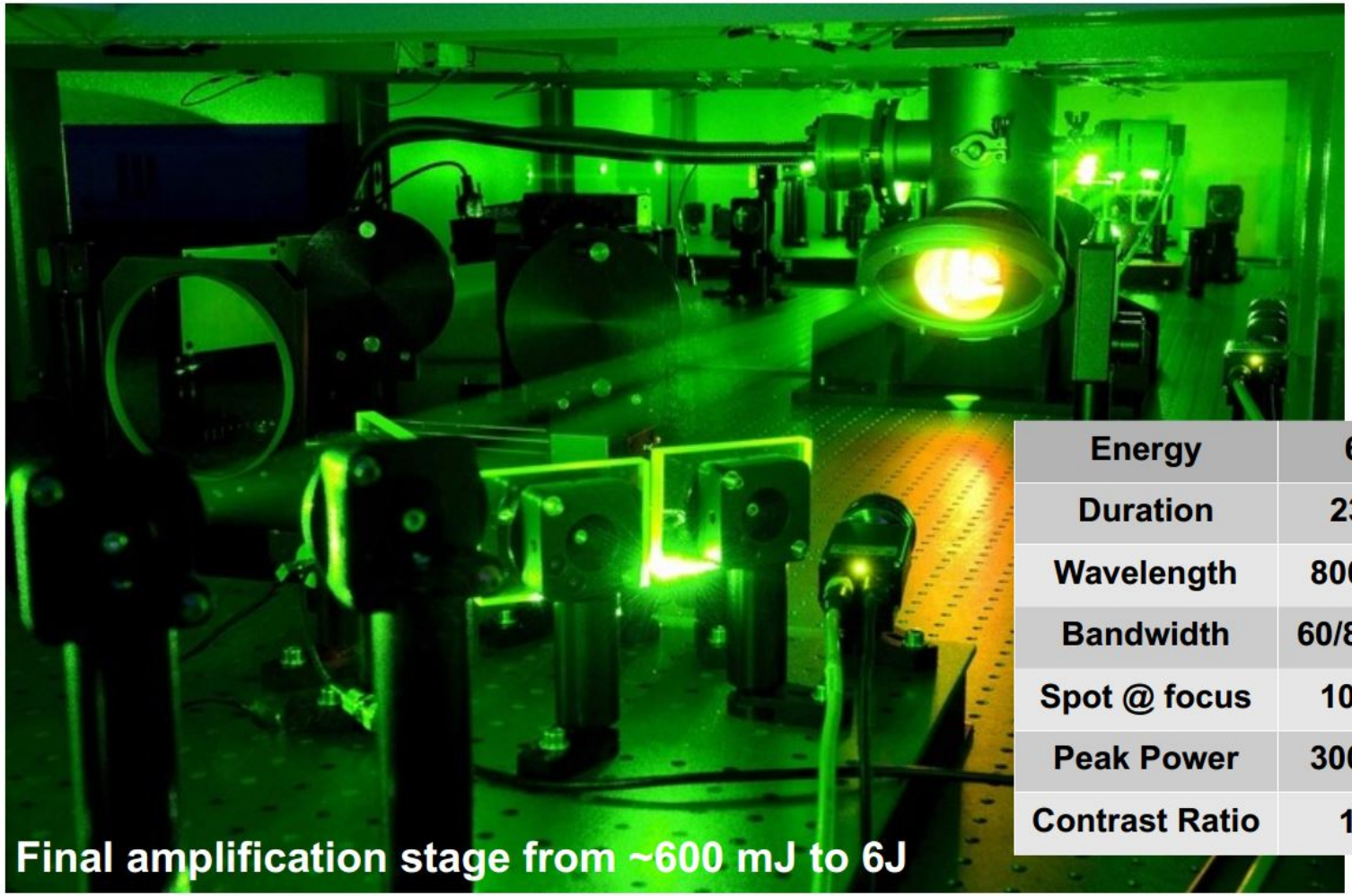


Sources for **P**lasma **A**ccelerators and **R**adiation **C**ompton with **L**asers and **B**eams

SPARC_LAB is a multi-disciplinary TEST Facility composed by a high brightness LINAC and the high power laser FLAME: this characteristic makes it unique.

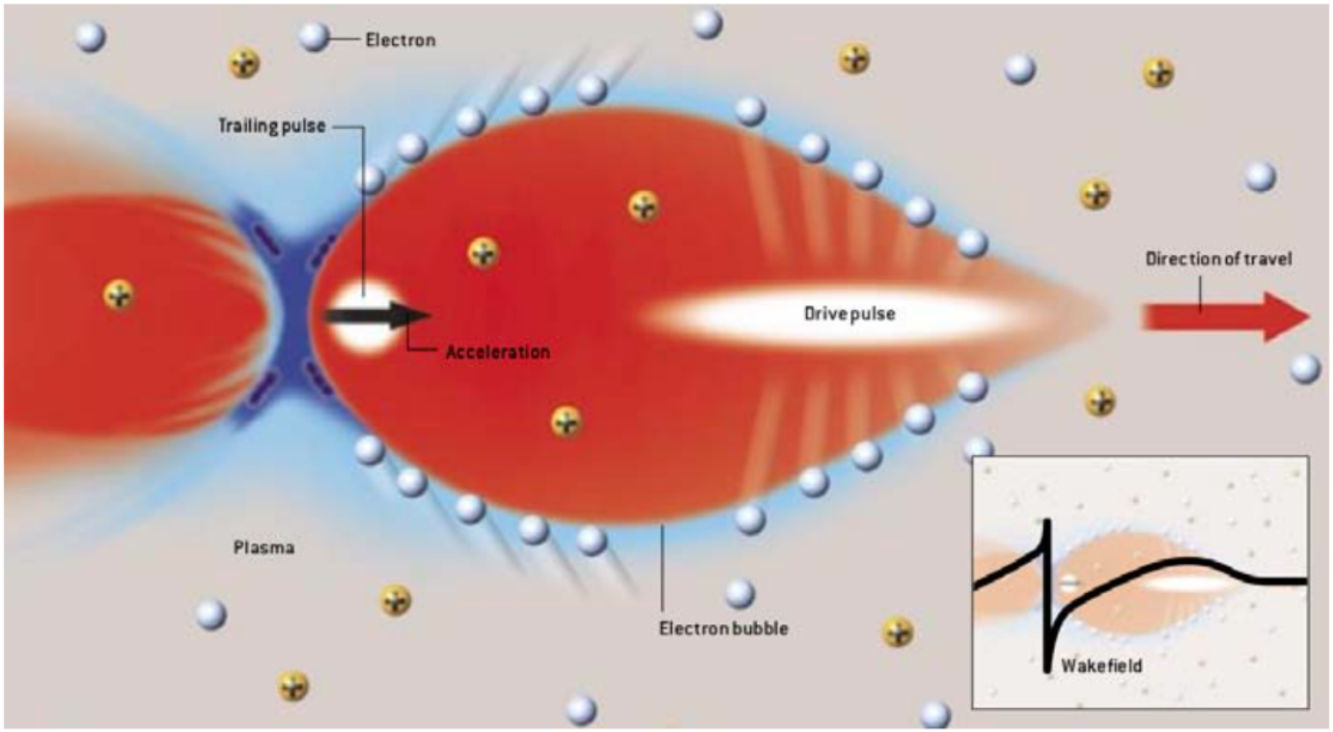
Ferrario, M., et al. "SPARC_LAB present and future." NIMB 309 (2013): 183-188

FLAME laser



Energy	6 J
Duration	23 fs
Wavelength	800 nm
Bandwidth	60/80 nm
Spot @ focus	10 μm
Peak Power	300 TW
Contrast Ratio	10^{10}

Plasma Acceleration



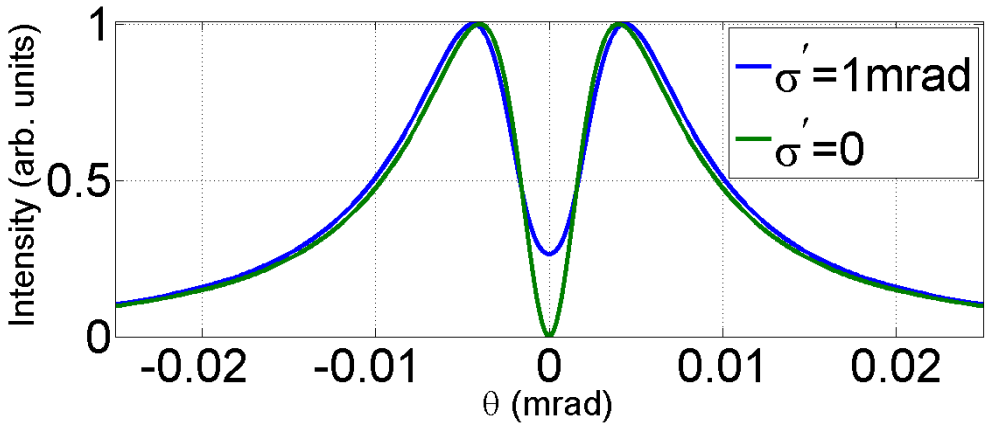
Accelerating field $E_0[\frac{V}{m}] = \frac{m_e c}{e}\omega_p \simeq 96\sqrt{n_0[cm^{-3}]}$

From 100 MV/m of RF structure (limited by breakdown) to >100GV/m!!!

Importance of single shot diagnostics

- Electron beams from plasma are still characterized by:
  - Relatively large energy spread (~5%);
  - Shot-to-shot instabilities.
- Single shot diagnostics are very helpful to properly characterize plasma beams.
- Emittance measurement: development of a scheme based on incoherent **Optical Transition Radiation** (OTR).

Single shot emittance measurements based on incoherent OTR



The angular distribution of incoherent TR is **sensitive to beam divergence**: the central minimum is not zero.

Emittance:

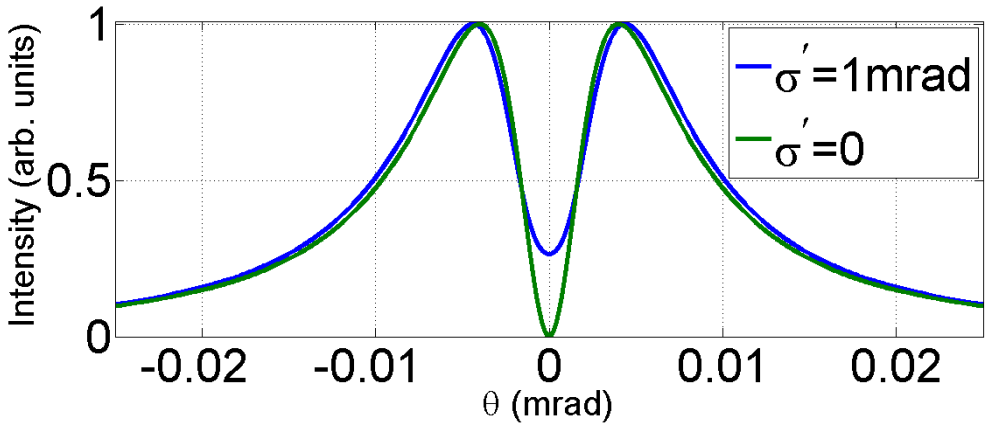
$$\varepsilon = \sqrt{< x^2 >< x'^2 > - < xx' >^2}$$

?

From spot size

From angular distribution

Single shot emittance measurements based on incoherent OTR



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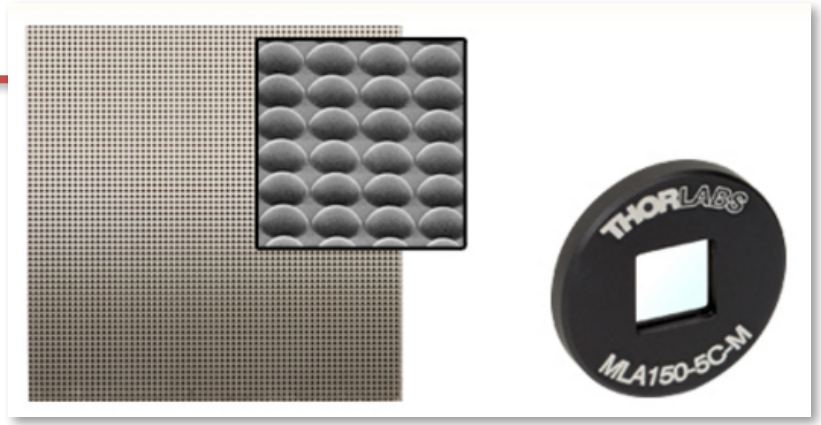
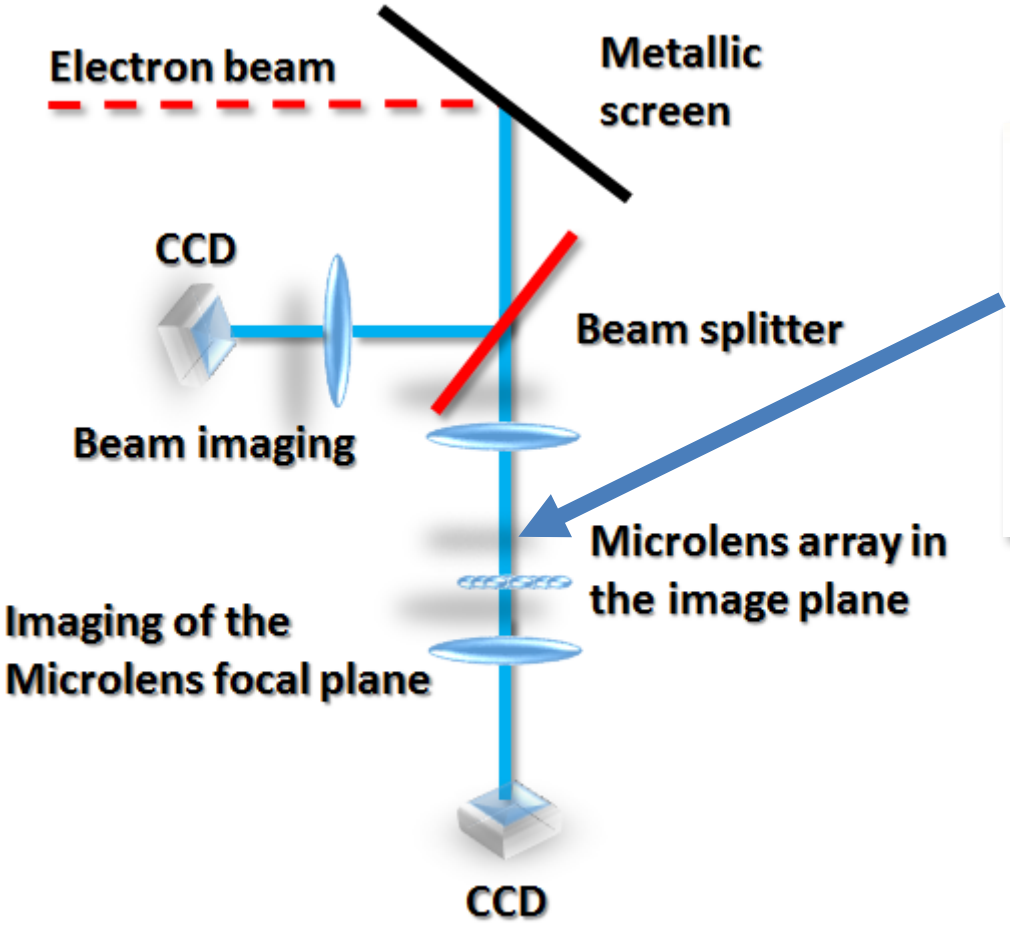
From spot size

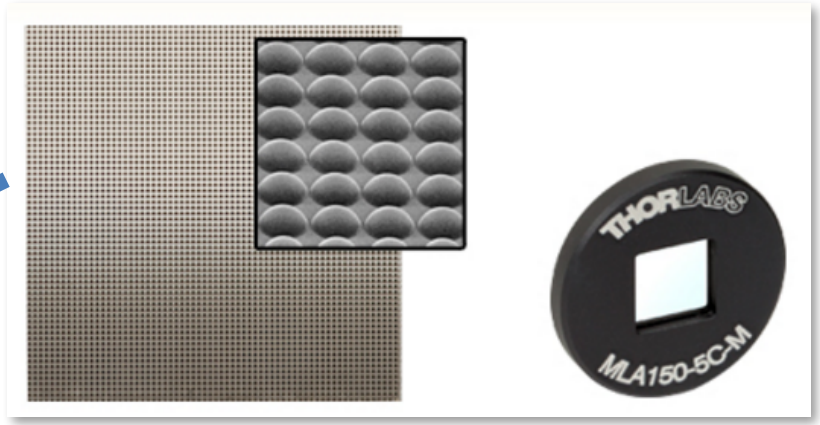
From angular distribution

IDEA: Microlens array!



Experimental setup



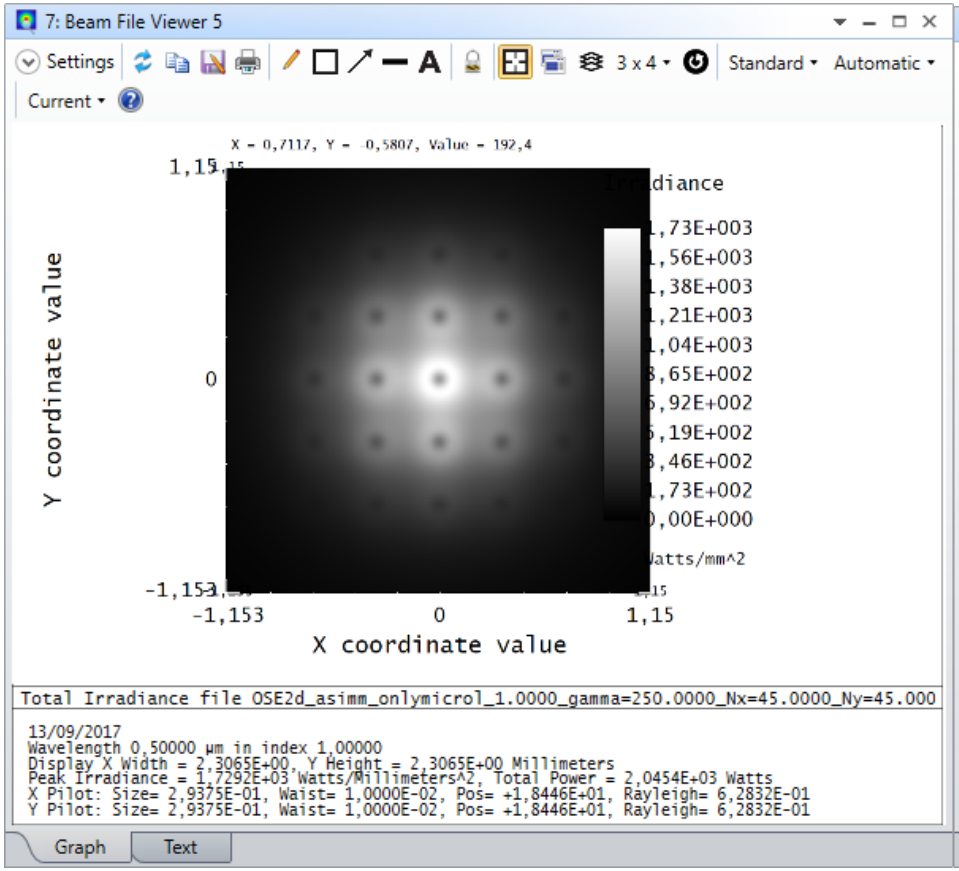


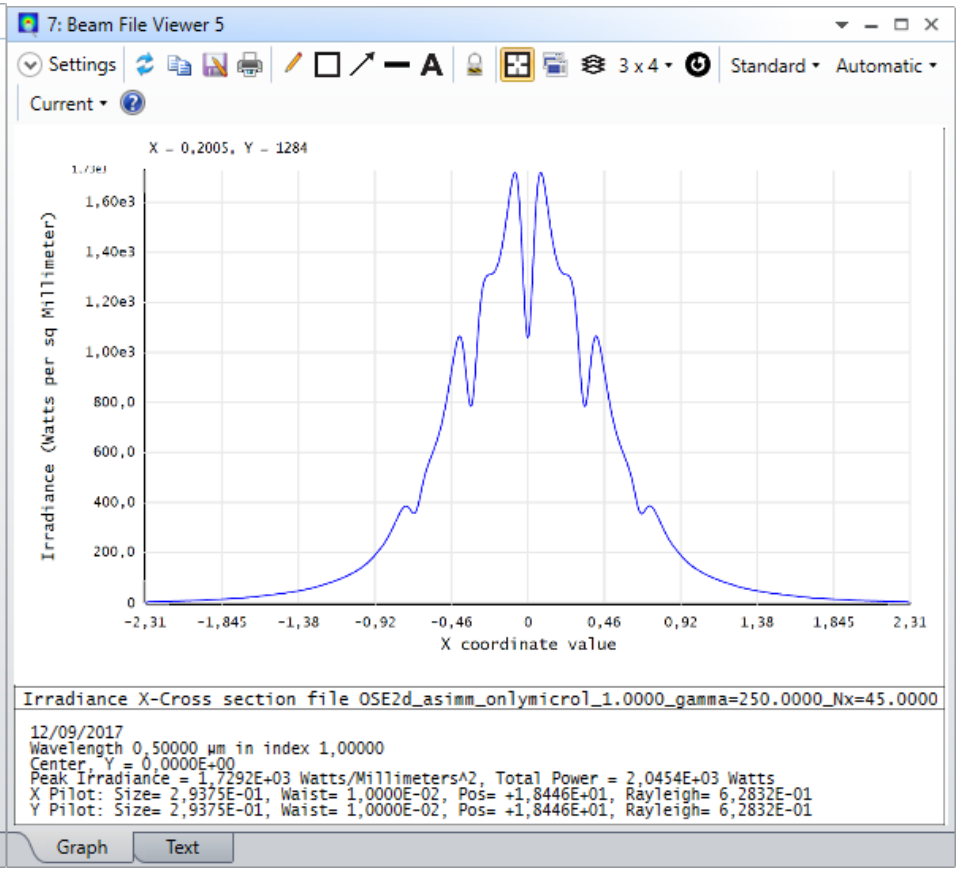
9x9mm array, 300um pitch, 18.5mm focal length

Cianchi, A., Bisesto, F. et al. "Transverse emittance diagnostics for high brightness electron beams." NIMA (2016)

ZEMAX Simulations

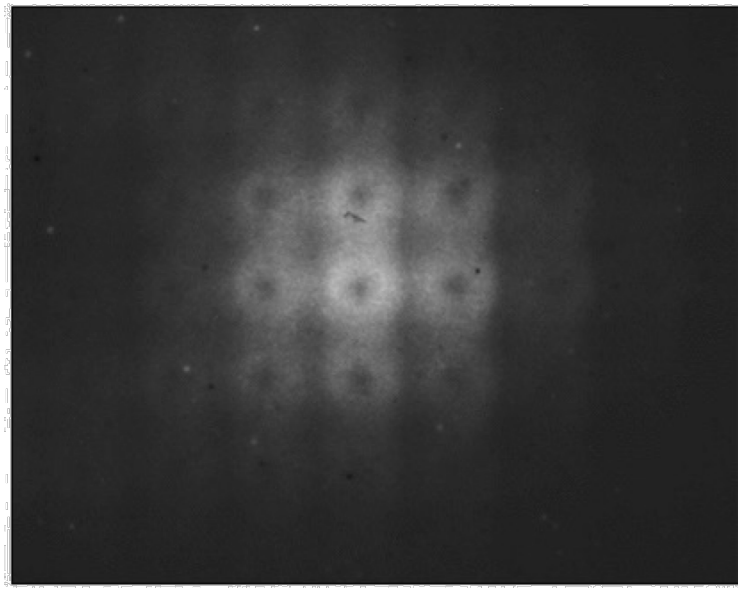
$$\gamma = 250,\ \sigma = 300\mu m,\ \sigma' = 2mrad$$

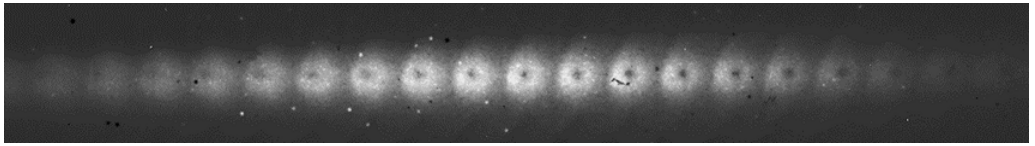




Bisesto F. et al., paper to be submitted

Preliminary results



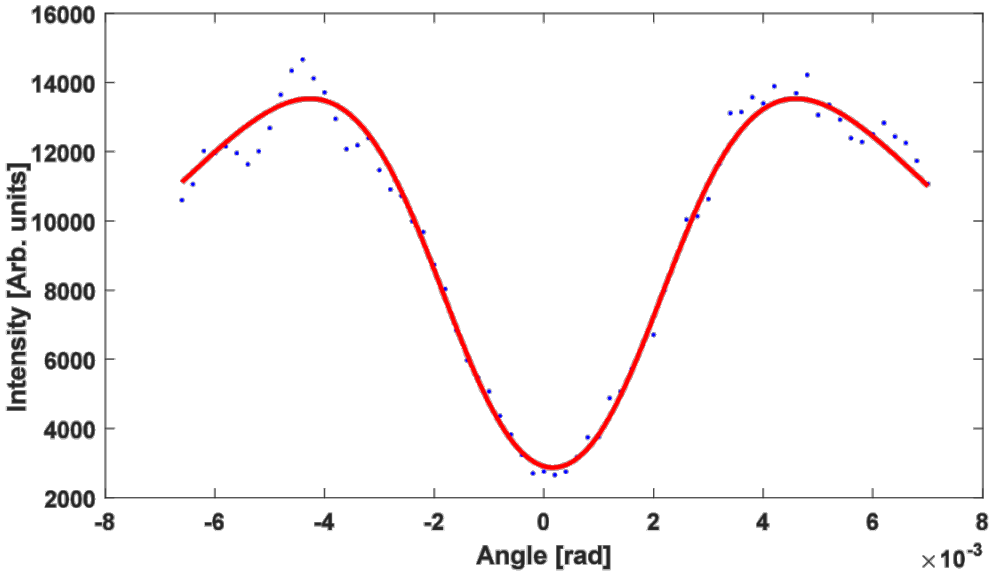


Measurement with focused beam in y-direction.

Experiment performed at SPARC_LAB.

Beam parameters:

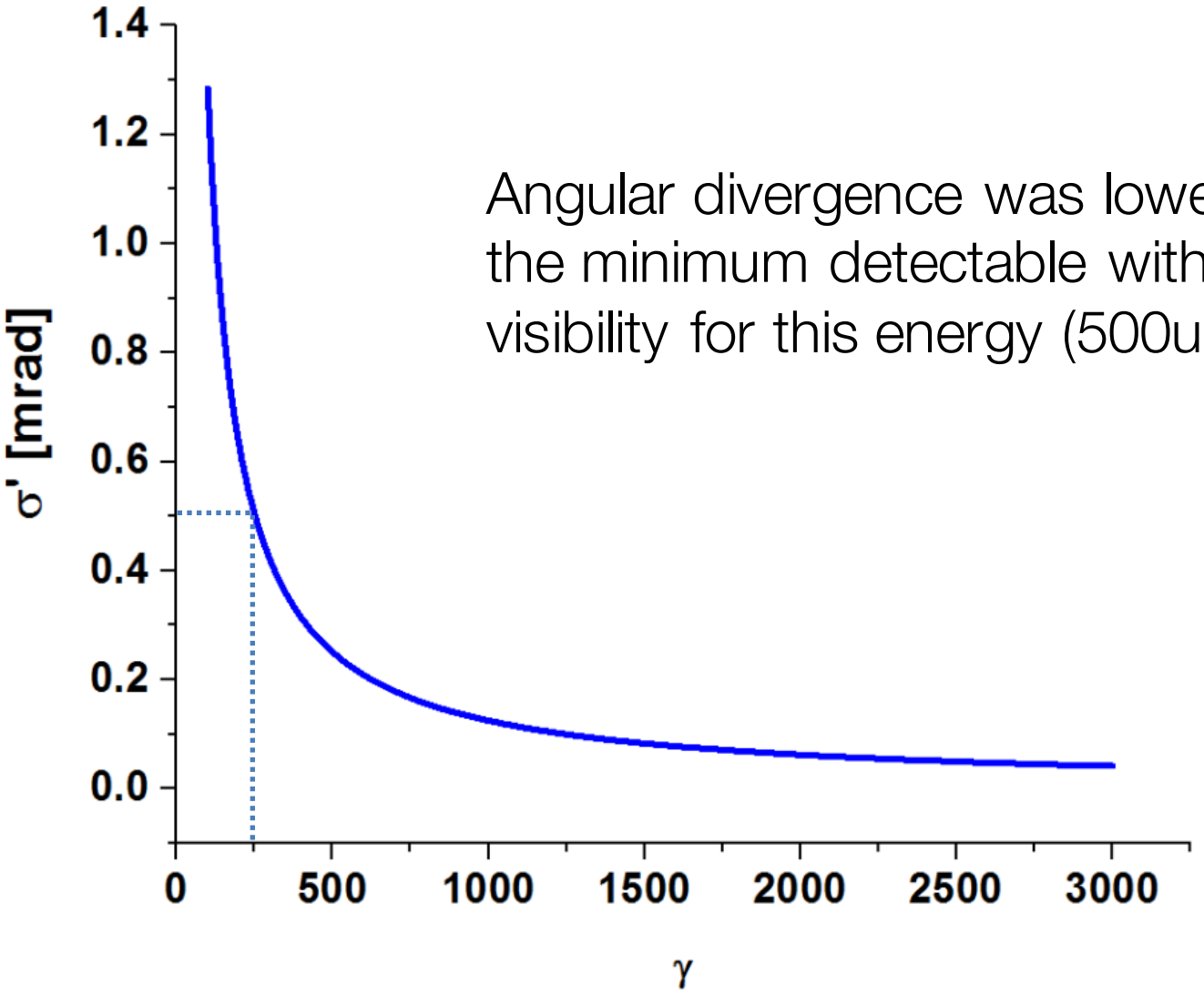
- **Energy** = 125 MeV
- **Spot size** = 600 um
- **Beam divergence** = 250 urad
- **Temporal length** = 1 ps



Line profile of central microlens.

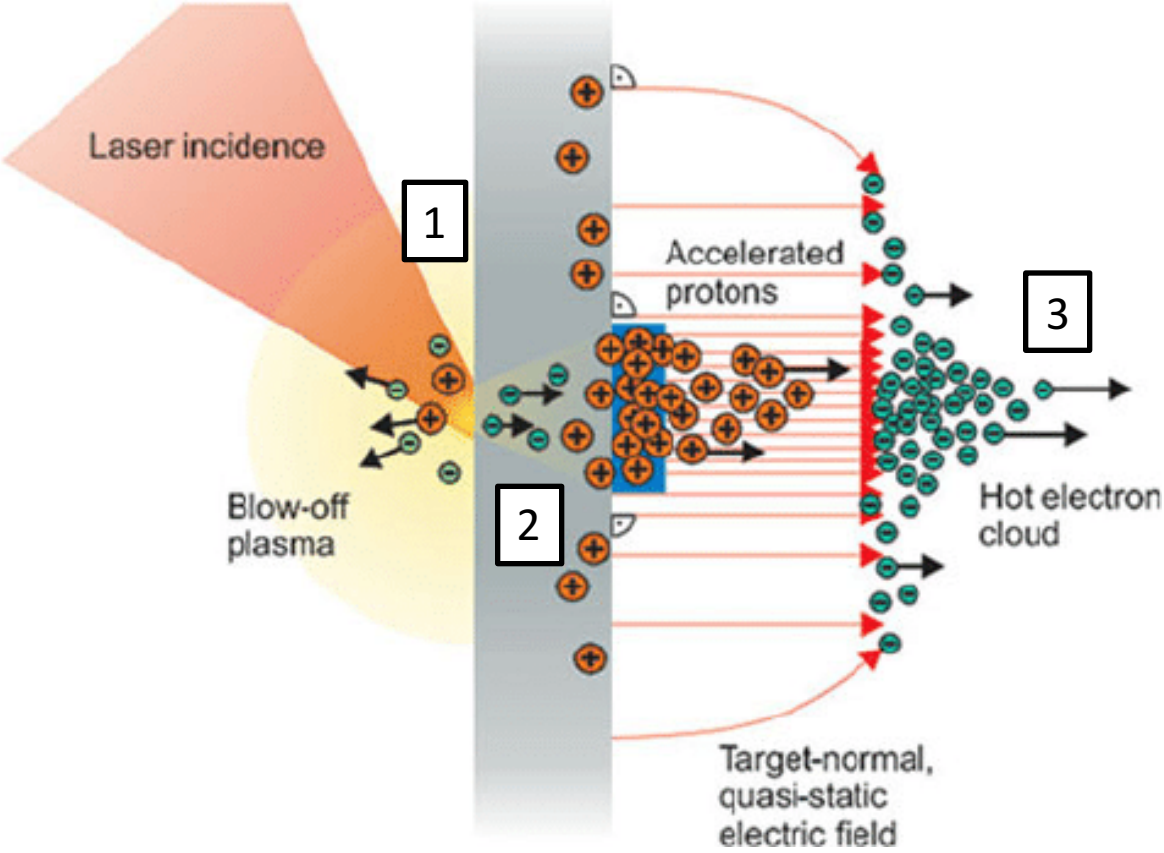
Cianchi A., Bisesto F. et al. "Transverse emittance diagnostics for high brightness electron beams." NIMA (2016)

Visibility



Angular divergence was lower than the minimum detectable with good visibility for this energy (500urad).

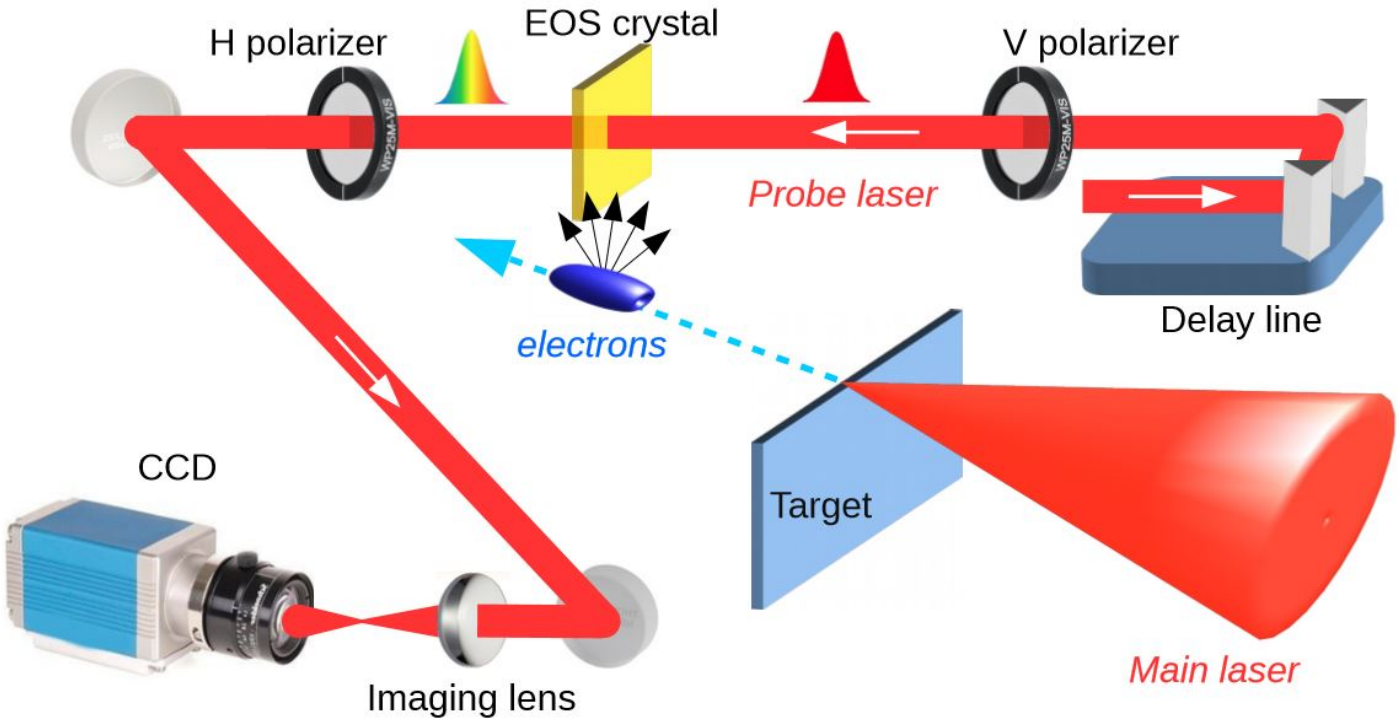
Fast electron fs-dynamics detection



1) Laser interacts with target.
2) Electron acceleration and positive charge left on target.
3) Most energetic electrons (**fast electrons**) escape and their electric field causes ion acceleration.

H. Schwoerer et al., *Nature* 439, 445-448 (2006)

Experimental Setup

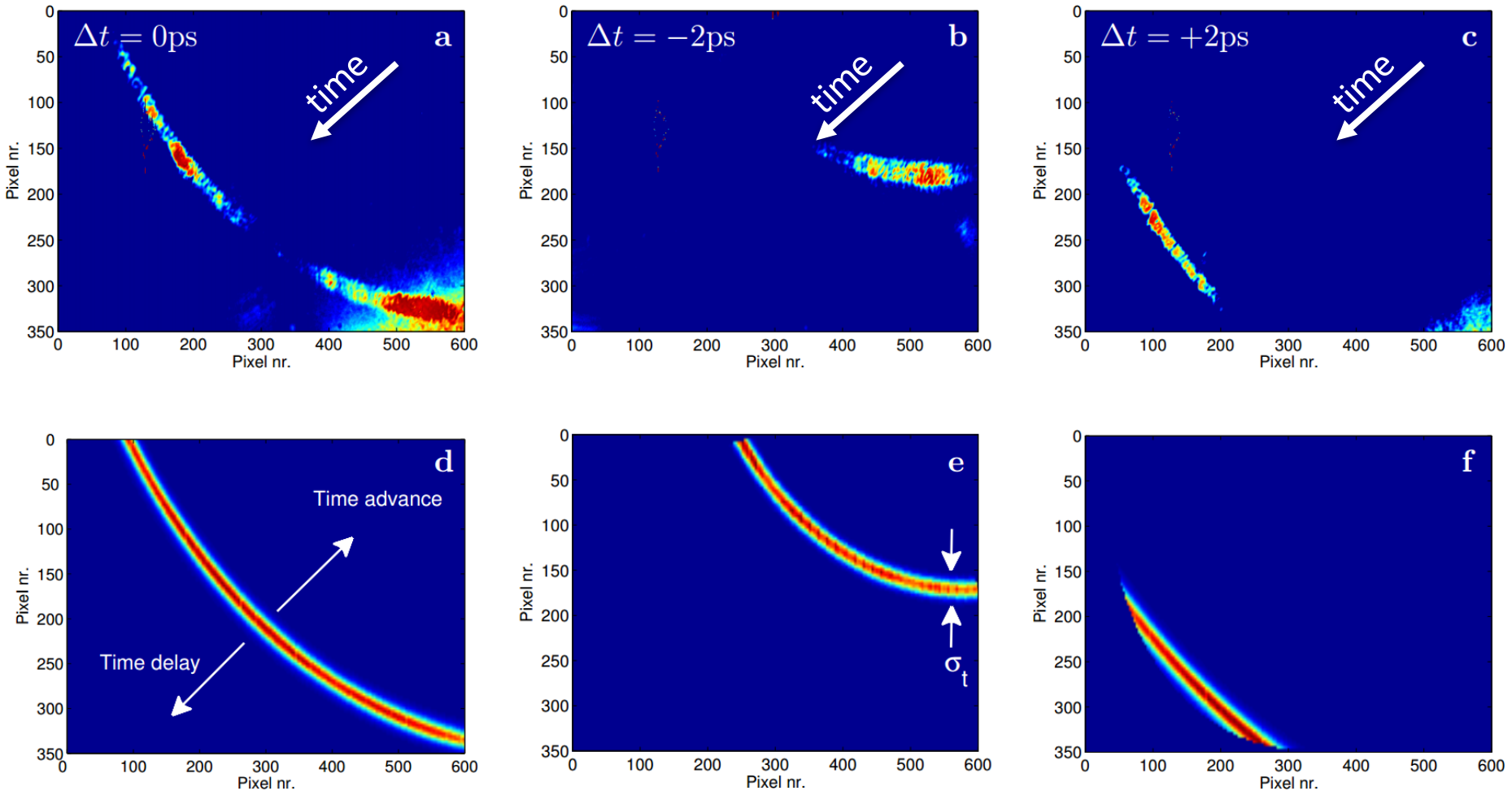


LASER PARAMETERS (on target):

- Energy 4J
- 35fs FWHM
- w_0=30µm

Pompili, R., et al. "Sub-picosecond snapshots of fast electrons from high intensity laser-matter interactions ." Opt.Exp. 24 (2016)

Experimental results



Temporal window: 10 ps.

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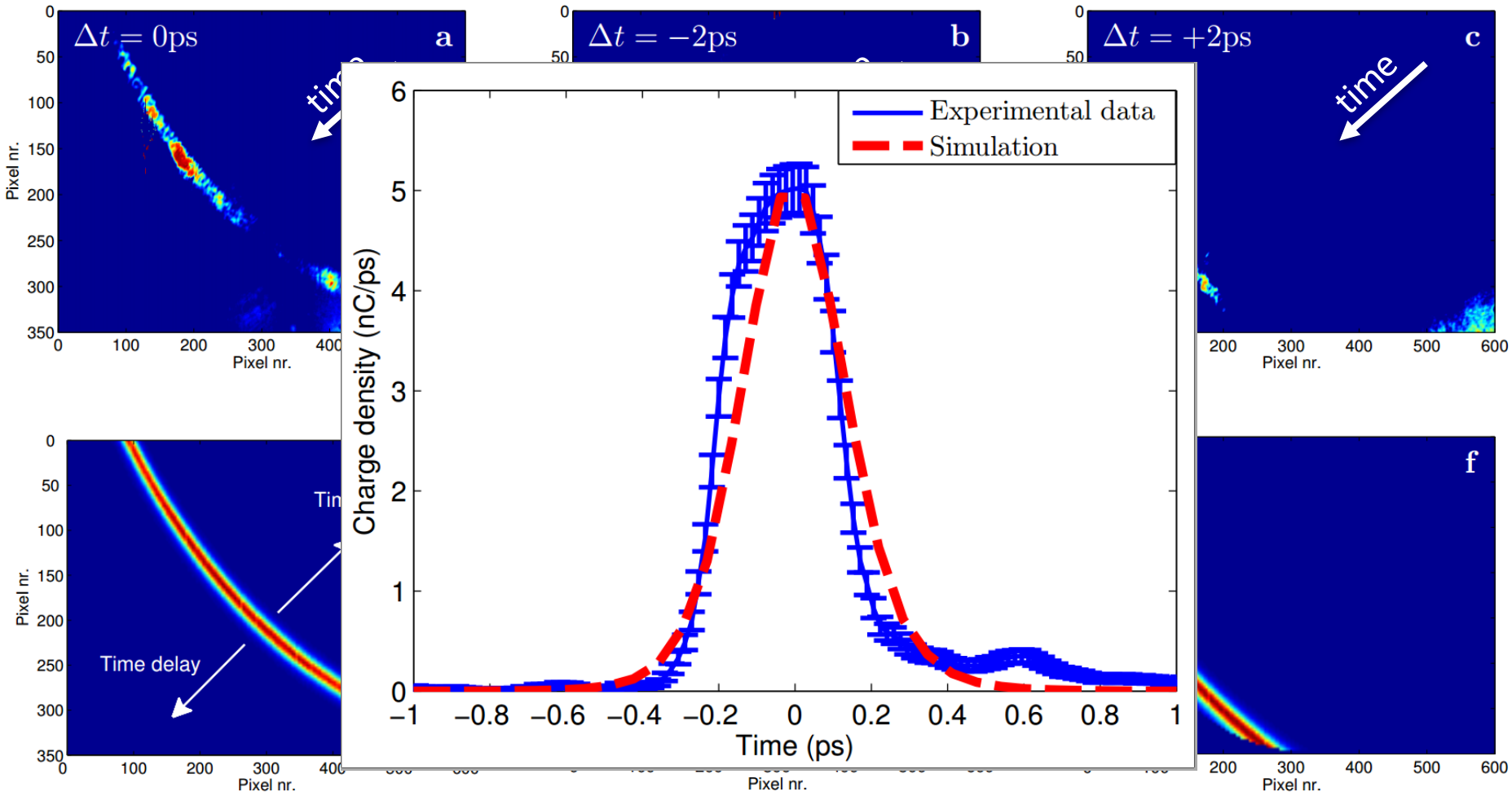

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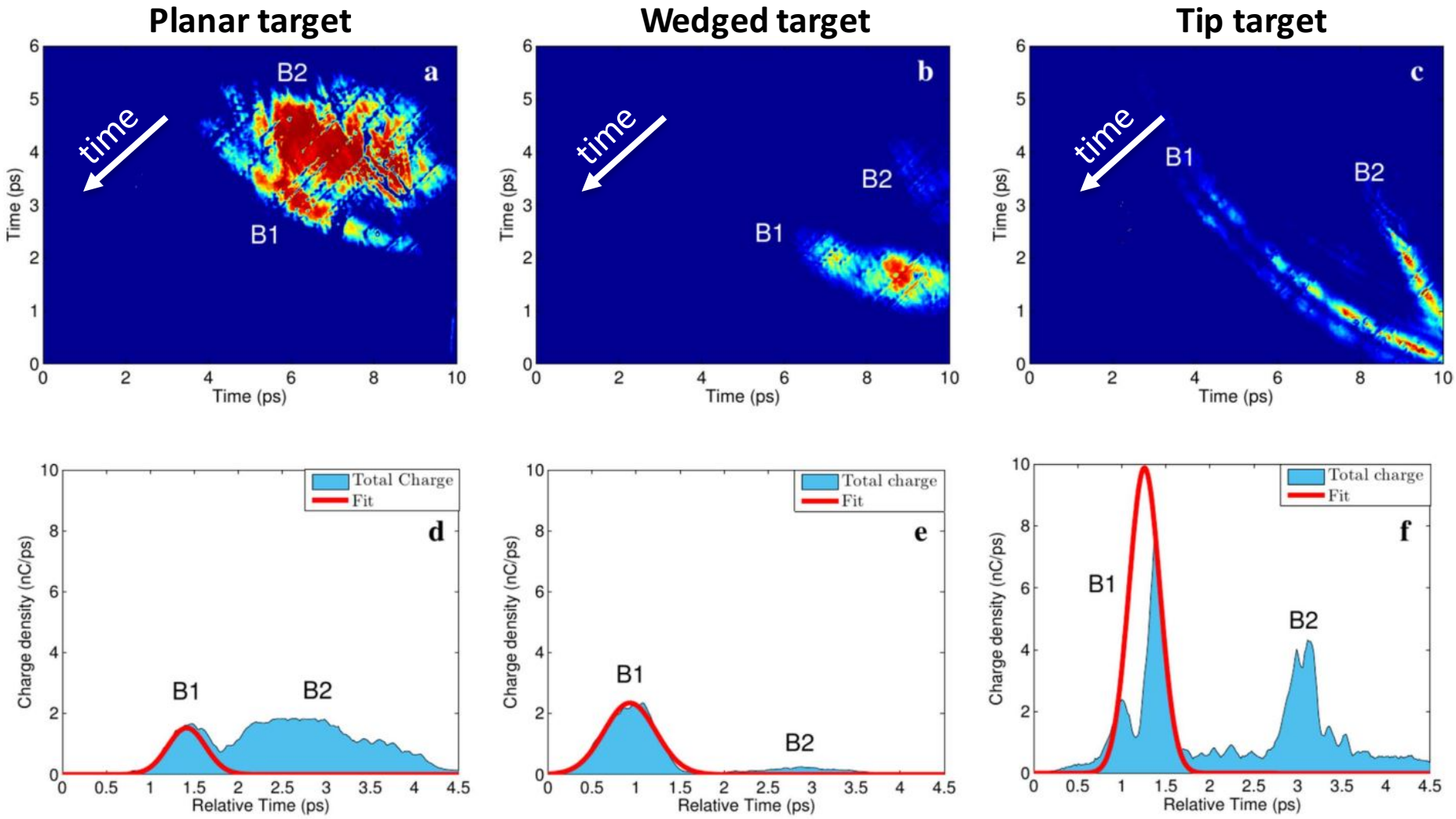
Influence of target shape



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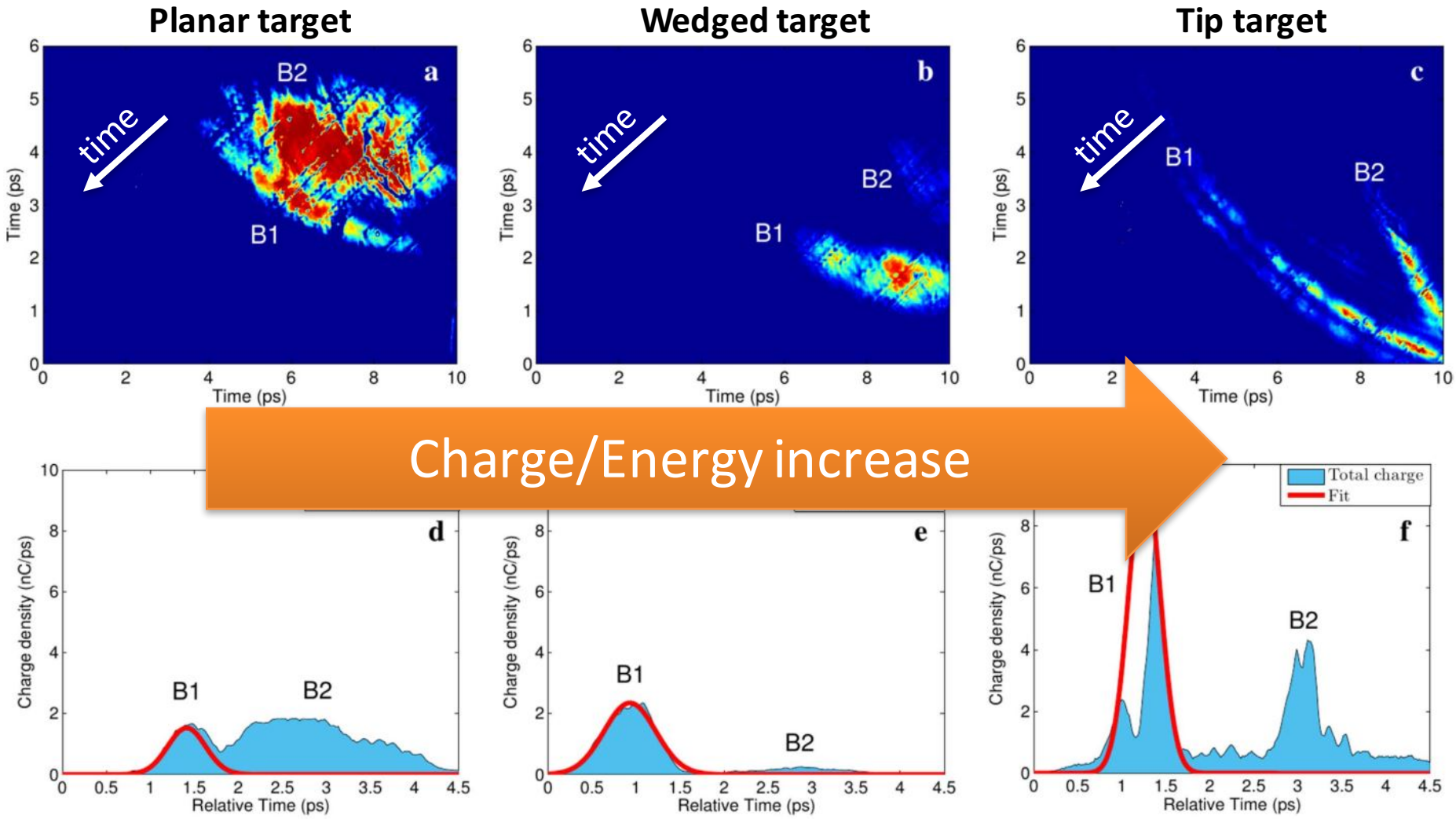
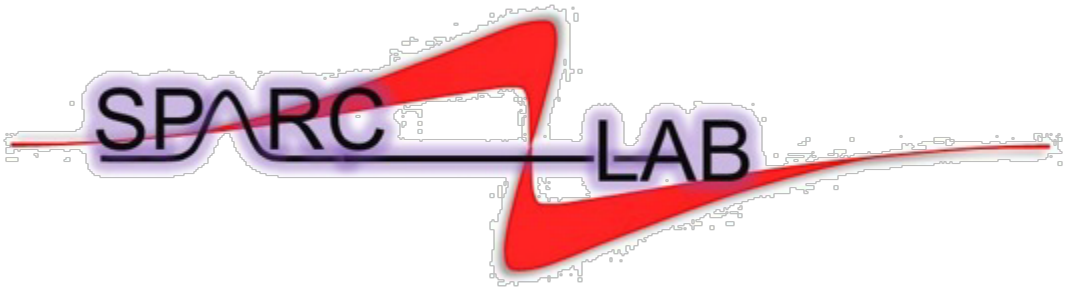


Pompili, R., et al. "Femtosecond dynamics of energetic electrons in high intensity laser-matter interactions." Sci.Rep. 6 (2016)

Conclusions

- A novel scheme for **single shot emittance** measurements based on incoherent OTR has been reported.
  - First tests on RF LINAC have represented a **proof of principle** of this system.
  - A new experimental run is foreseen in the next future.
- We presented the **first time-resolved measurements** probing the emitted **fast electrons** based on EOS technique.
  - We studied the influence of target shape: a field enhancement has been measured.
  - A new experimental run has started.



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On behalf of SPARC_LAB collaboration