Laboratoire d'Optique Appliquée

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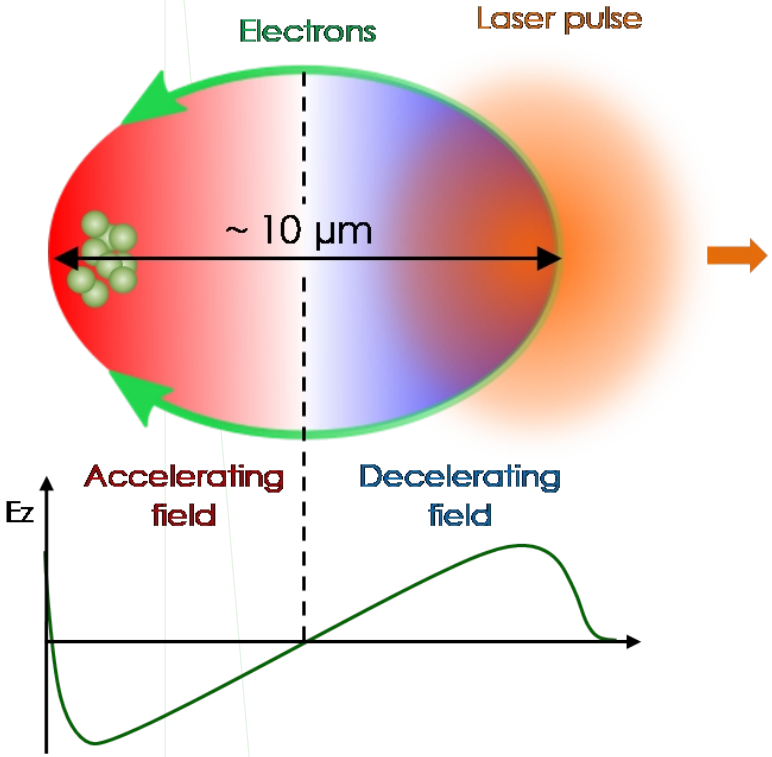
Increase of the energy gain in a laser-plasma accelerator stage

C. Thaury, K. Oubrerie, A. Leblanc, L. Kononenko, R. Lahaye, C. Caizergues, J. Gautier, J-P. Goddet, K. Ta Phuoc, S. Smartsev, A. Tafzi

LOA - IPP

2nd Townhall Meeting High Gradient Accelerator Plasma/Laser
05/2021

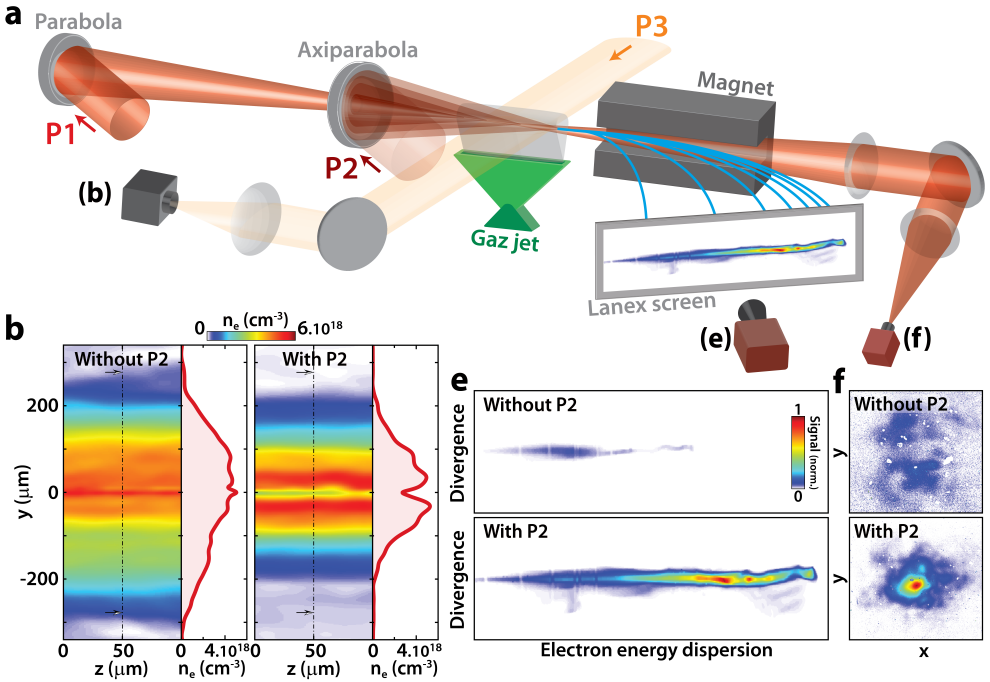
High energy challenge

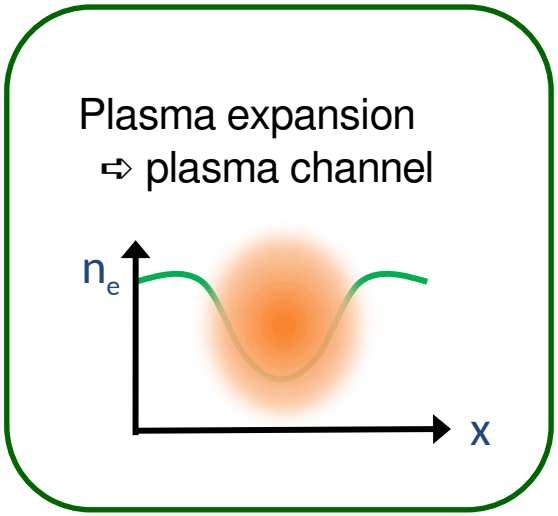


Extracting most of the laser energy and reaching high-energy requires to sustain a high amplitude electric field over a long distance

➪ need for laser guiding

Laser-plasma wave-guide

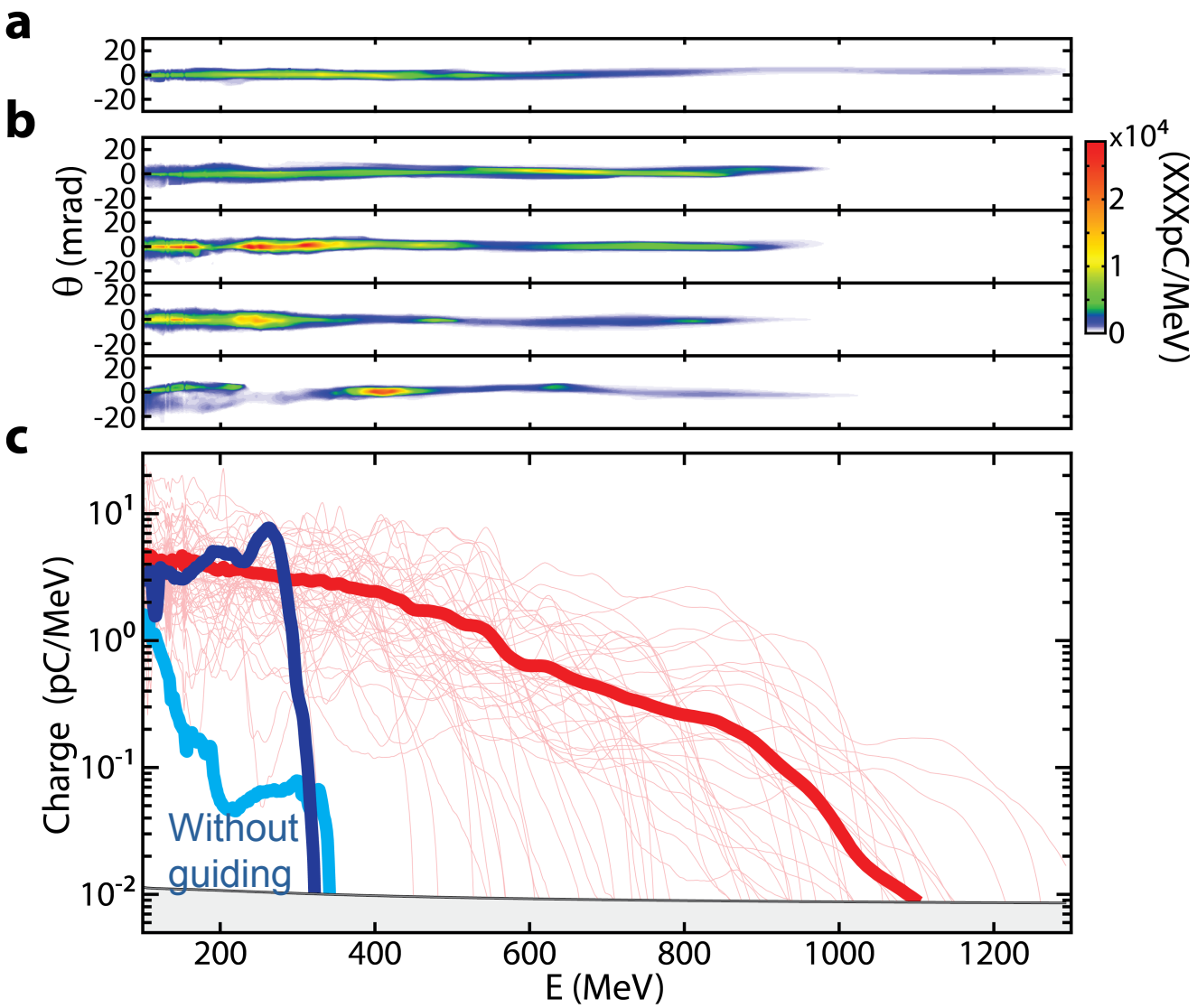




- Above threshold ionization
  - ➪ efficiency does not depend on the plasma density
- Fully optical technique – plasma wave-guide (no damage)
  - ➪ high laser power
  - ➪ high rep. rate
- Ease of plasma shaping and possibility to use several beams
  - ➪ compatible with all controlled injection techniques
  - ➪ compatible with plasma tapering → rephasing

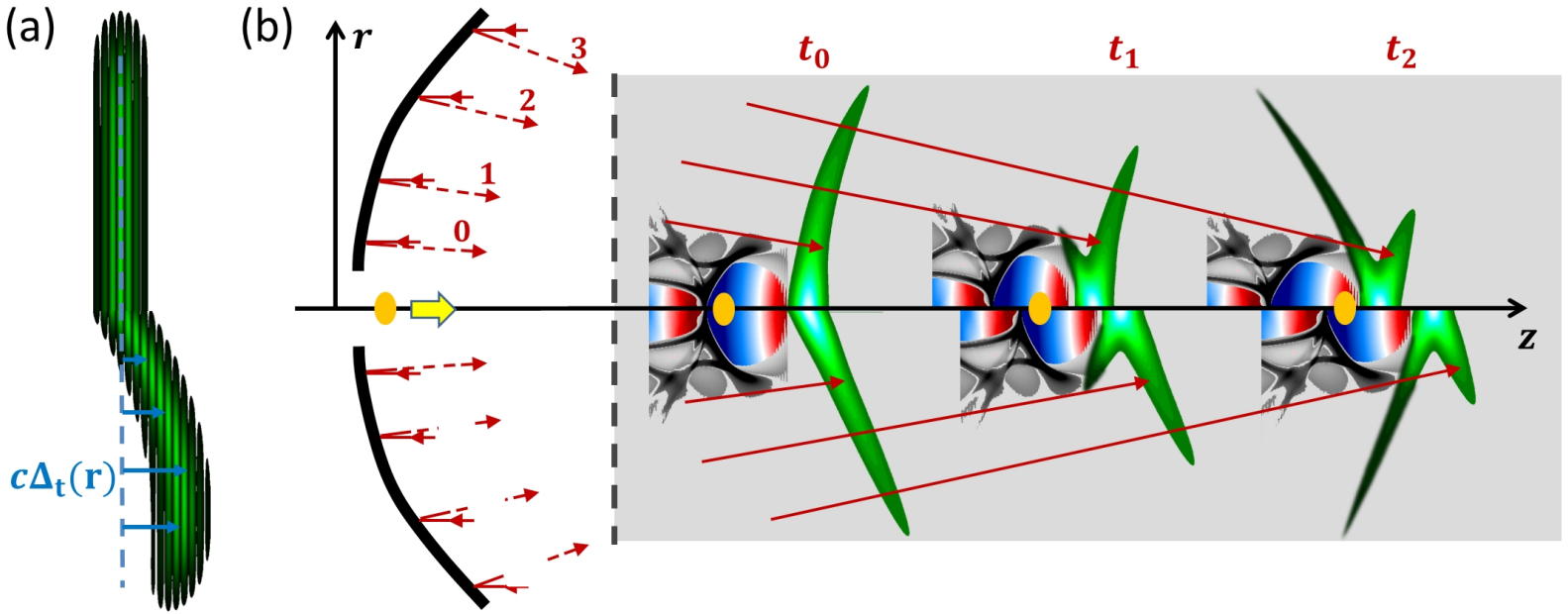
Wave-guide and ionization injection

- 60 TW laser
- 15 mm gas jet
- Up to 1.1 GeV



Dephasing-less acceleration

- Acceleration with a diffraction-free superluminal laser beam.
- Overcoming diffraction, dephasing and depletion.



Up to 50 GeV energy gain with a 1 PW, 15fs laser pulse

C. Caizergues et al., Nature Photonics **14**, 475–479 (2020)

Questions for the community Part I

I.2) What intermediate physics applications/steps do you see until a HEP linear collider?

→ FEL with 5-10 GeV electron beams

I.4) What is the role of your work here?

→ Demonstrate techniques allowing for the generation of high quality, multi-GeV electron beams

Questions for the community Part II

II.1) What are the important milestones for the next 10 years to get there from today?

→ Increase of the average power of PW-class lasers
→ Improvement of the stability of laser parameters (pointing, energy...)

→ Demonstration of efficient staging
→ Demonstration of high-quality, efficient 10 GeV stage

II.3) What should be proposed as deliverables until 2026?

→ Accelerator driven by a laser with an average power > 100 W.

→ A 5 GeV gain stage with a relative energy spread < 10^{-3}, stability in energy <3 %, stability in charge < 10 %, and transfer efficiency >15%.

→ Efficient coupling of two acceleration stages, with negligible charge loss, and preservation of beam parameters.

II.4) Is the R&D work for each of those deliverables already funded and, if not, what additional resources would be needed

→ For the high-quality,10 GeV stage: regular access to PW facility, post-docs, PhD students...

Questions for the community Part III

III.1) What key R&D needs can be achieved in existing R&D facilities?

→ At short-medium term laser-plasma R&D can be achieved with existing or planned facilities. R&D on laser is required before planning new facilities.

III.2) What is the role of the already planned future facilities in Europe and world-wide?

→ LAPLACE project at LOA: increase average power (→ 100 W) + center devoted to R&D on laser-plasma acceleration.

→ Largest facilities: upscale laser-plasma accelerator to higher energies.

III4) Is a completely new facility needed?

→ Not at medium term.

III.5) Are additional structures needed beyond existing networks and projects, e.g. a design study for a collider or an advanced accelerator stage?

→ No.