International Beam Instrumentation Conference IBIC

11 - 15 September 2016 Barcelona

Electro-Optical Methods for Multipurpose Diagnostics

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on behalf of the SPARC_LAB collaboration

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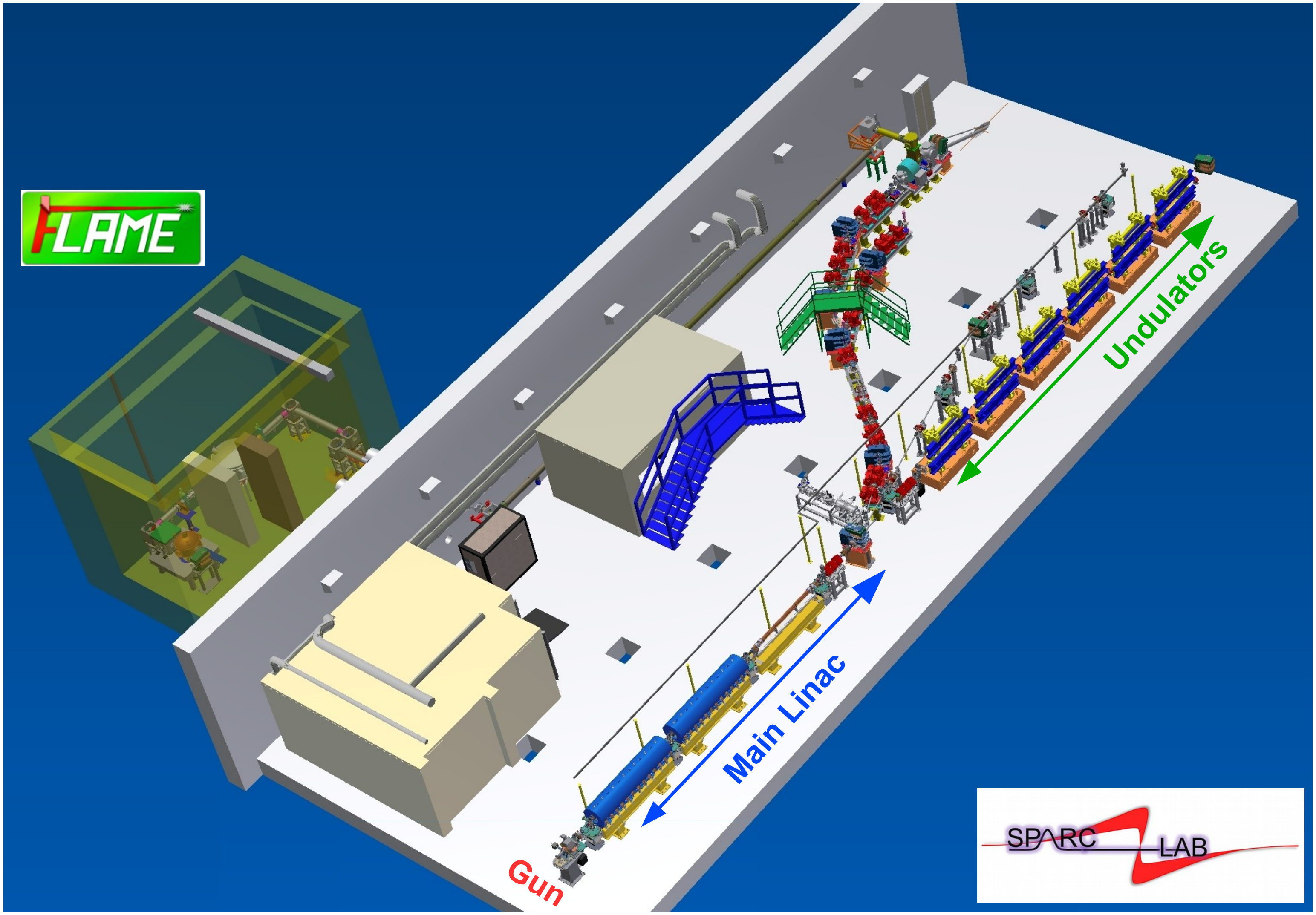
SPARC LAB

Outline

- The SPARC_LAB test-facility
- Electro-Optical Sampling technique with spatial encoding
- Measurement of comb-like beams for Plasma Wakefield Acceleration
- Validation of timing-jitter reduction between lasers and ultra-short bunches
- Probe the Target Normal Sheath Acceleration for protons/ions with measurements in harsh environment

SPARC_LAB test-facility



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

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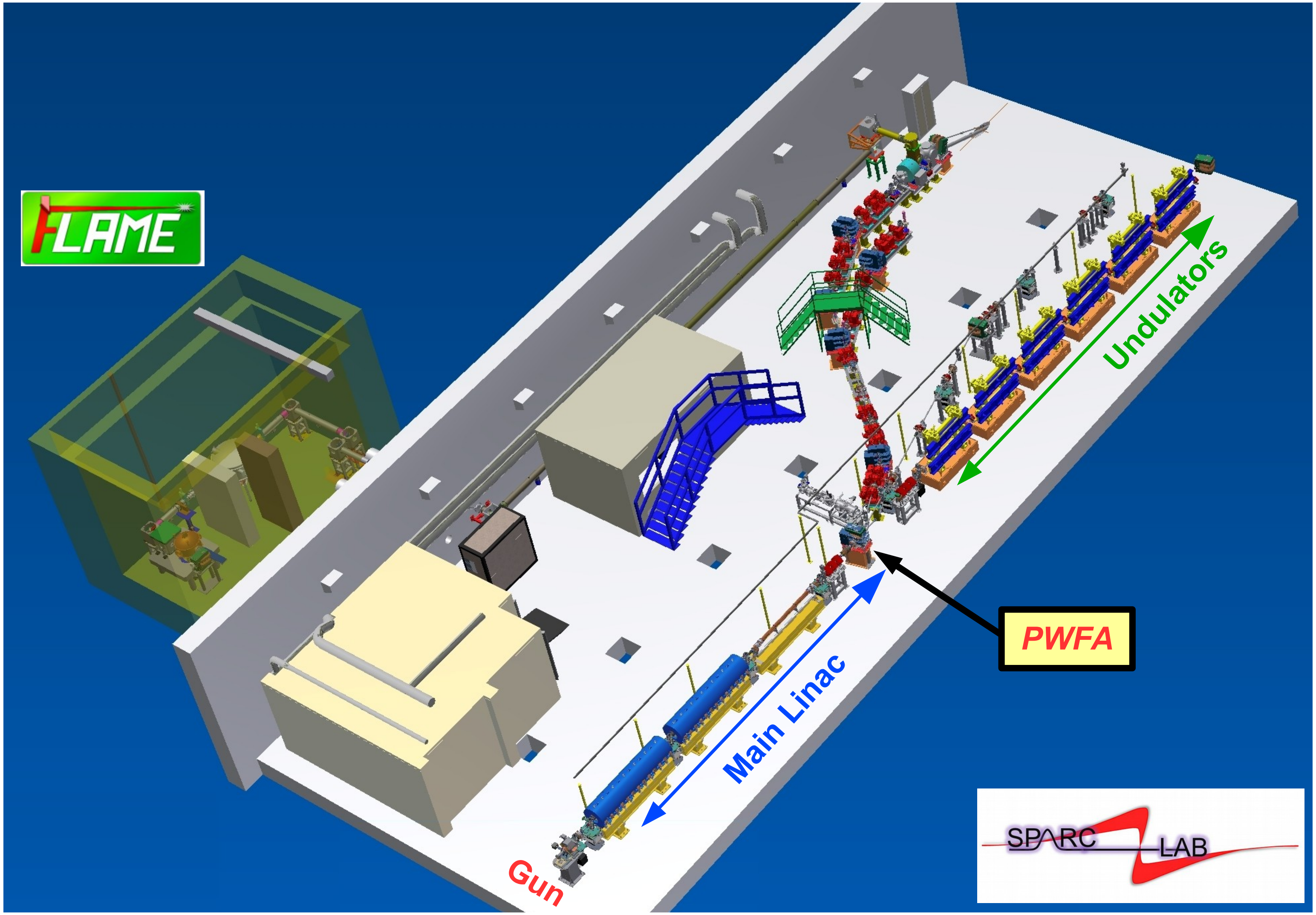

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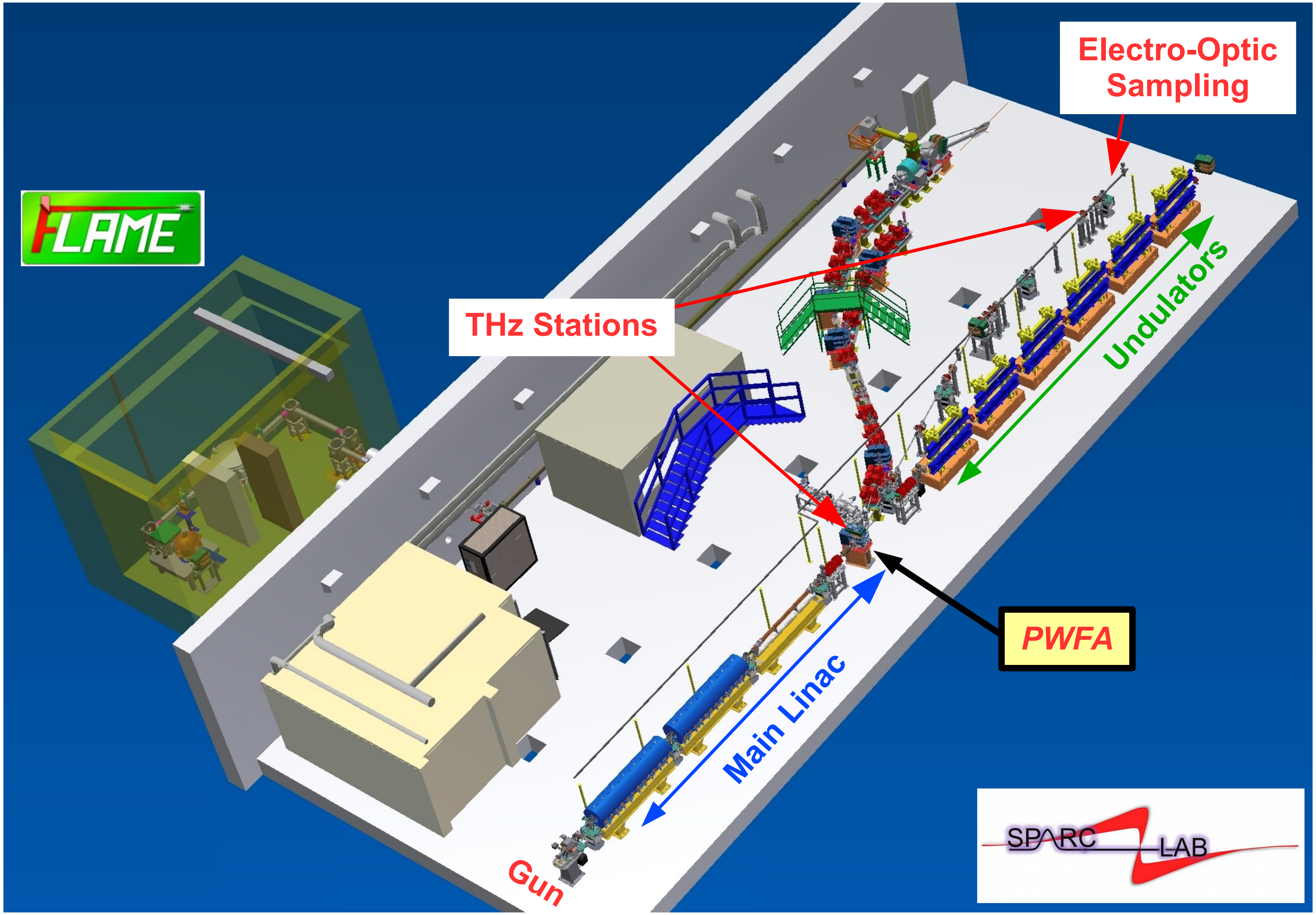

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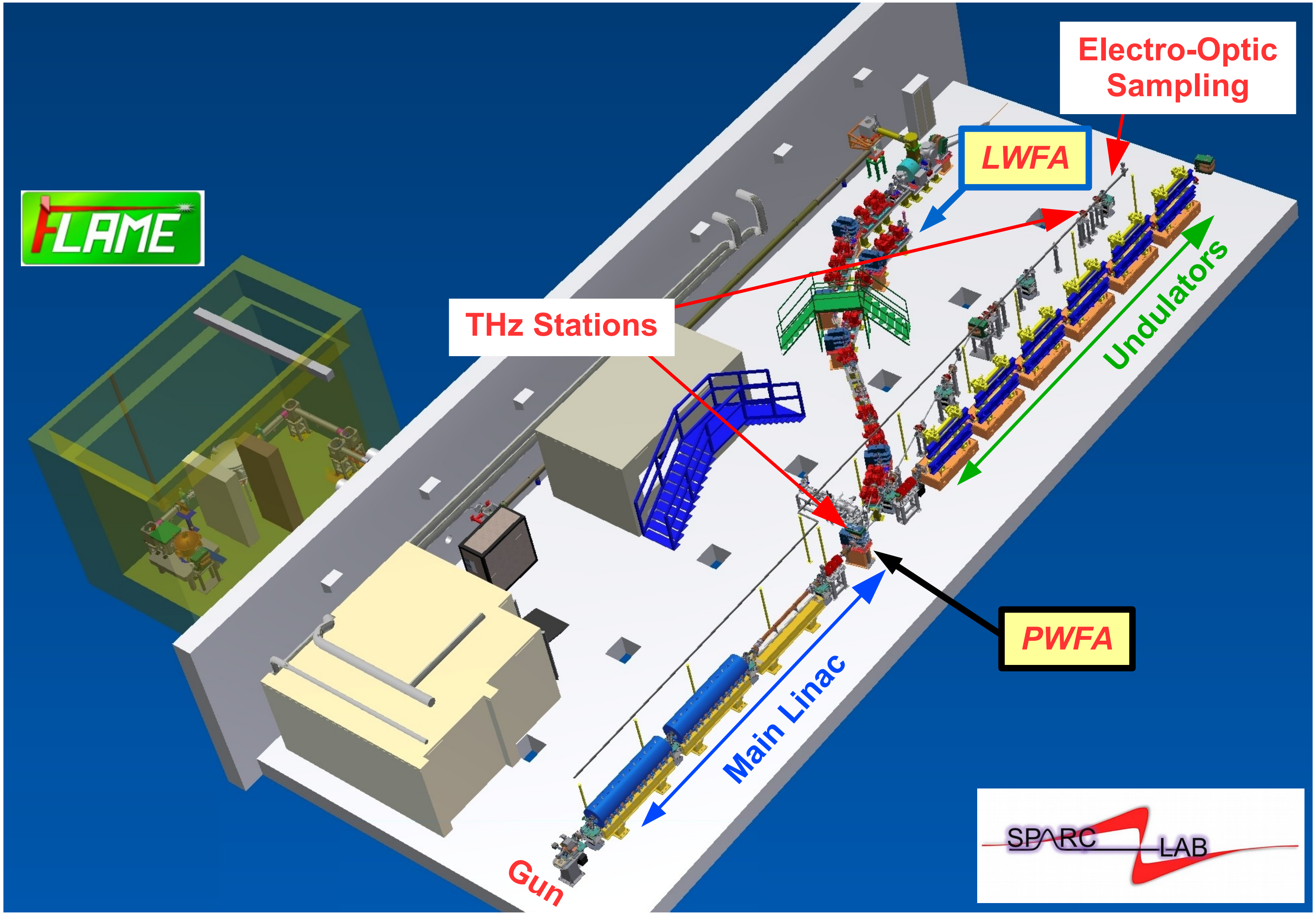

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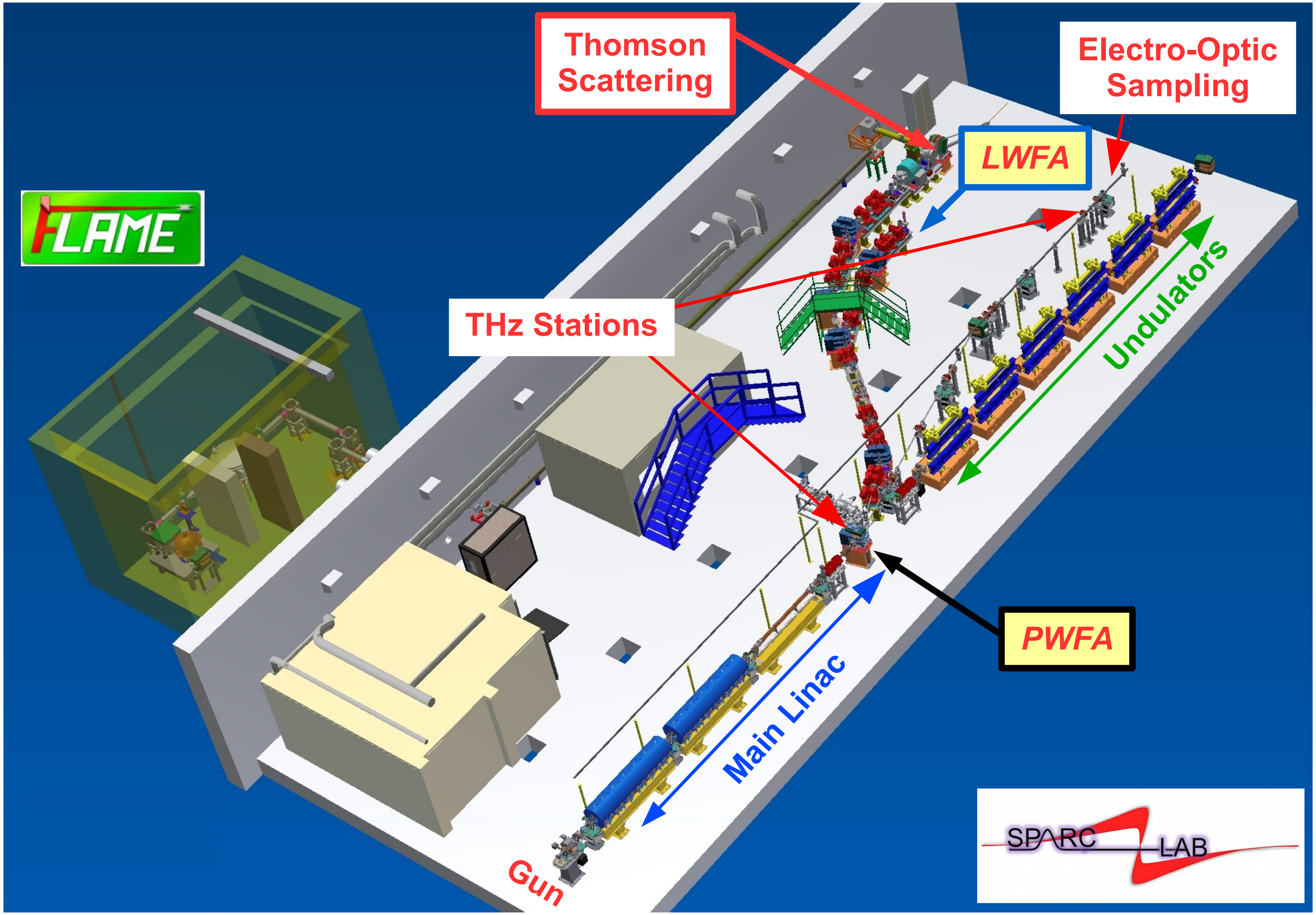

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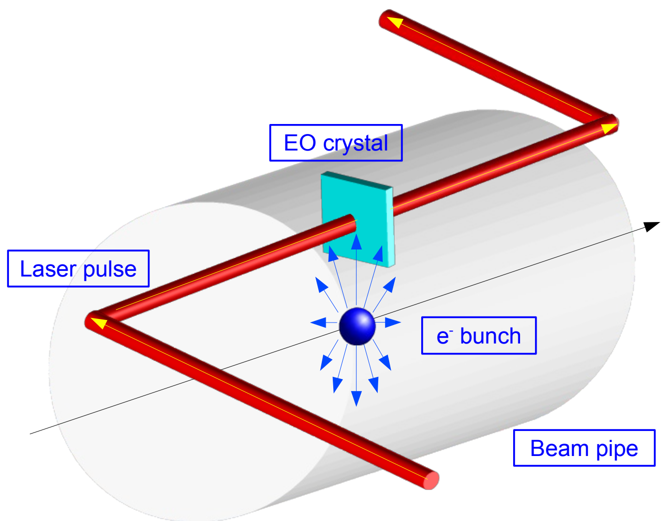
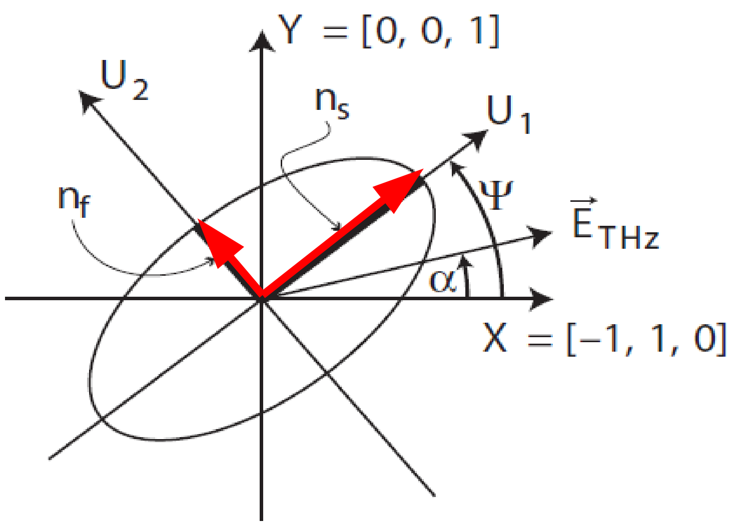
Electro-Optical Sampling





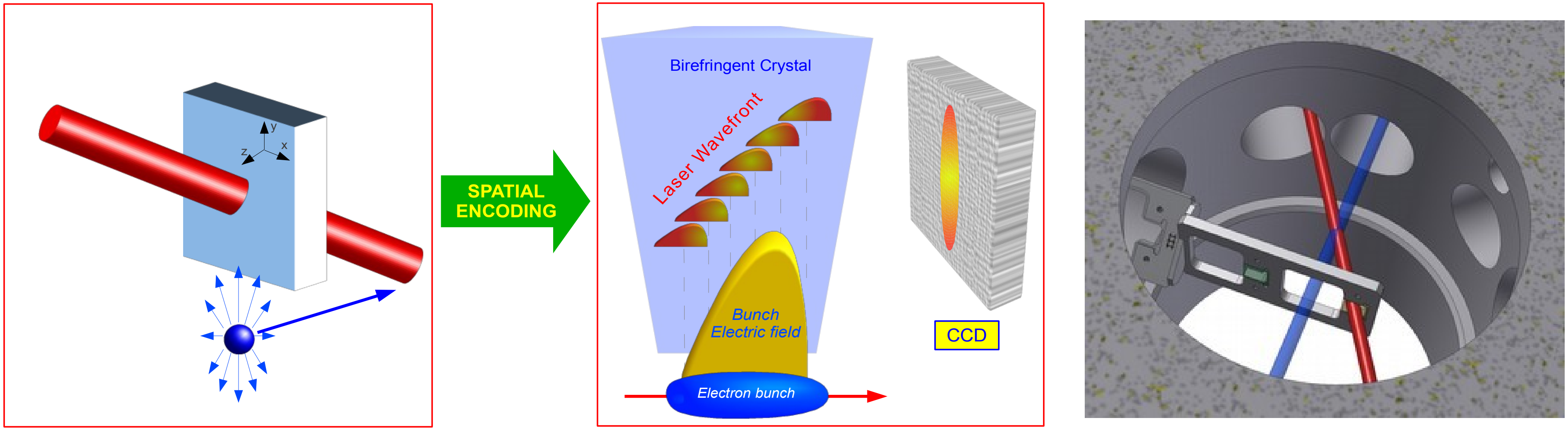
- Induced phase-delay by the electro-optic effect

$$\Gamma(t)=\frac{\omega d}{c}(n_1-n_2)=\frac{\omega d}{2c}n_0^3 r_{41} E_{bunch}(t)\sqrt{1+3\cos^2\alpha}$$

- Single shot, non-intercepting, 50 fs (rms) resolution

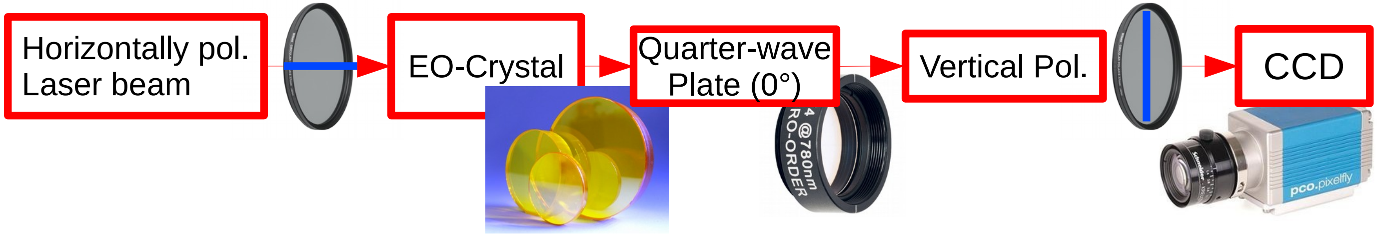
B. Steffen et al., Physical Review Special Topics-Accelerators and Beams 12, 032802 (2009).

Spatial encoding



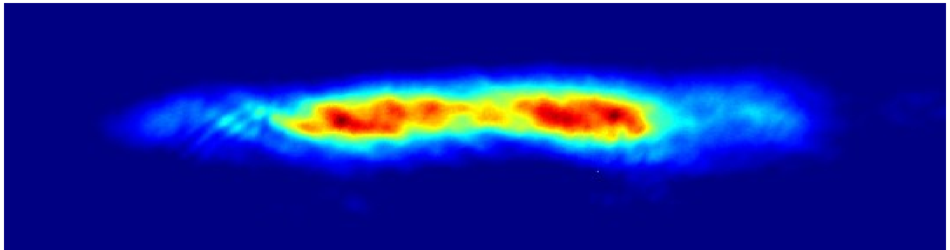
- **Laser crosses the crystal with an angle (30°)**
- **Polarization modulation → transferred to intensity modulation by means of linear polarizer**

$$I_{det} = I_{laser} \sin^2 \Gamma \propto E^2_{THz}$$

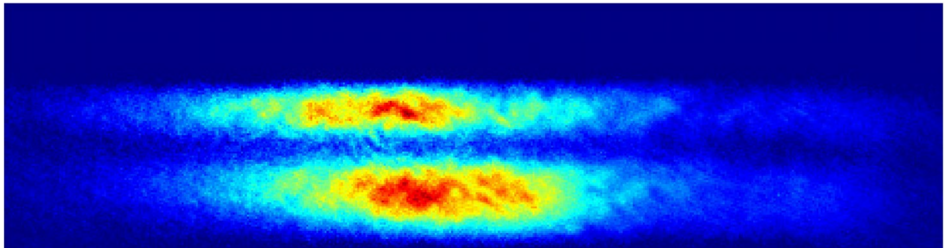


Cavalieri, Adrian L., et al. "Clocking femtosecond X rays." Physical review letters 94.11 (2005): 114801.

Multi-bunch trains with THz separation

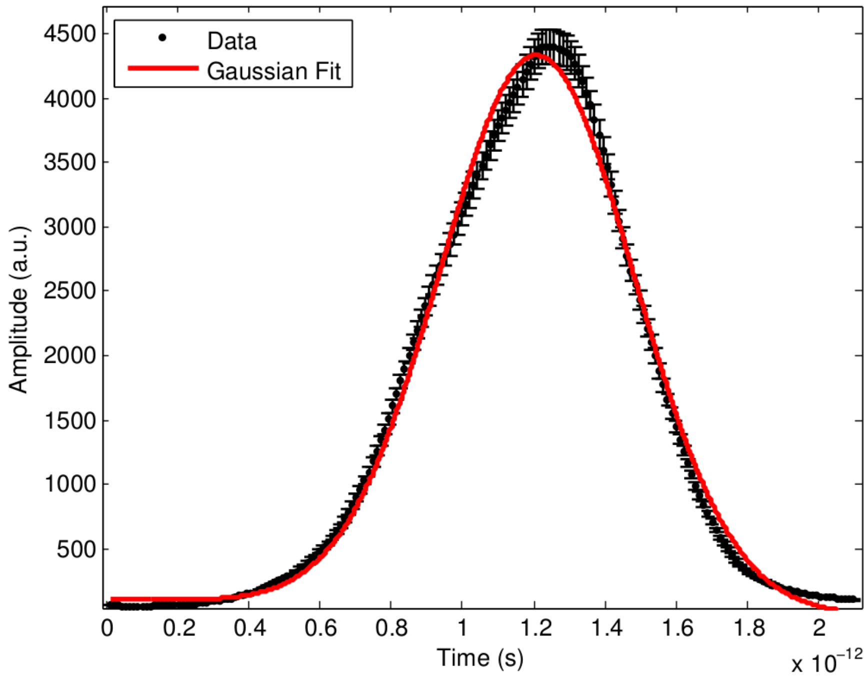


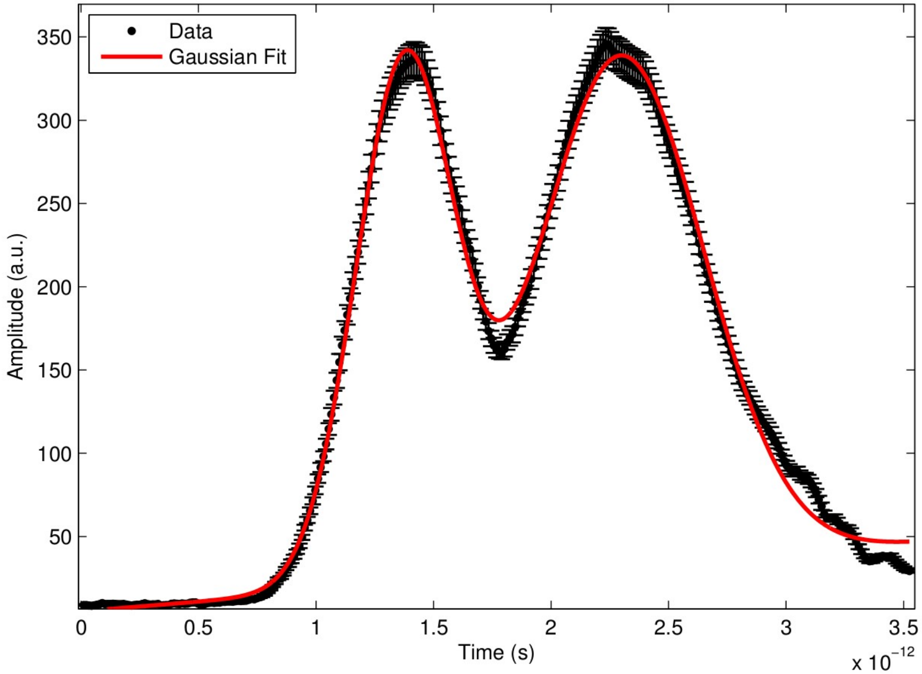
ZnTe (400μm), single bunch 510 fs



GaP (100μm), comb beam (160 and 200 fs, 800 fs distance)

80 fs temporal resolution





R. Pompili, et al., Nuclear Instruments and Methods in Physics Research Section A: Accelerators. 740, 216 (2014).

Bunch compression and timing-jitter

- Ultra-short bunches with ultra-low jitter wrt laser pulses
  - **Seeded FELs**
  - **External injection in laser-driven plasmas**

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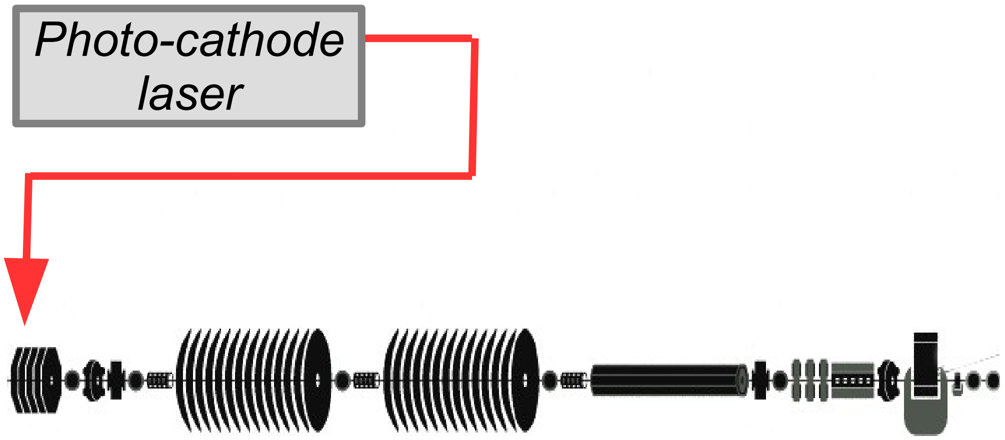

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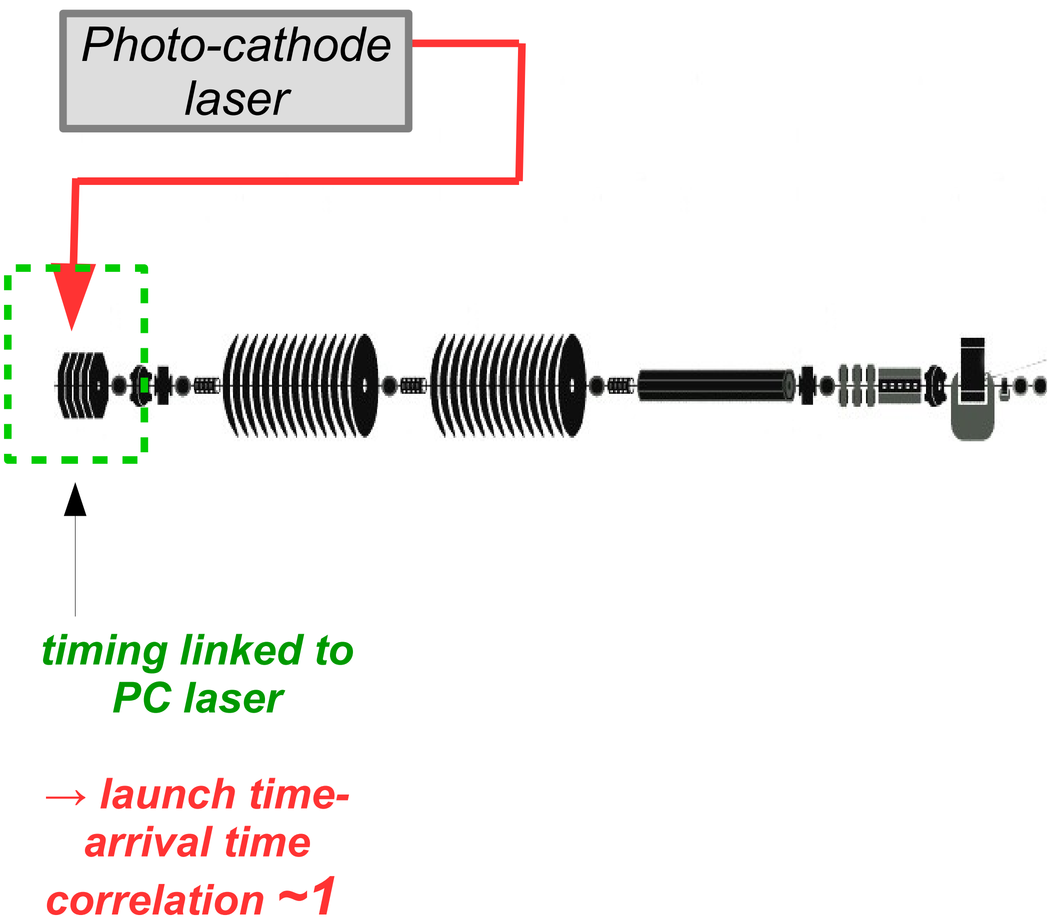

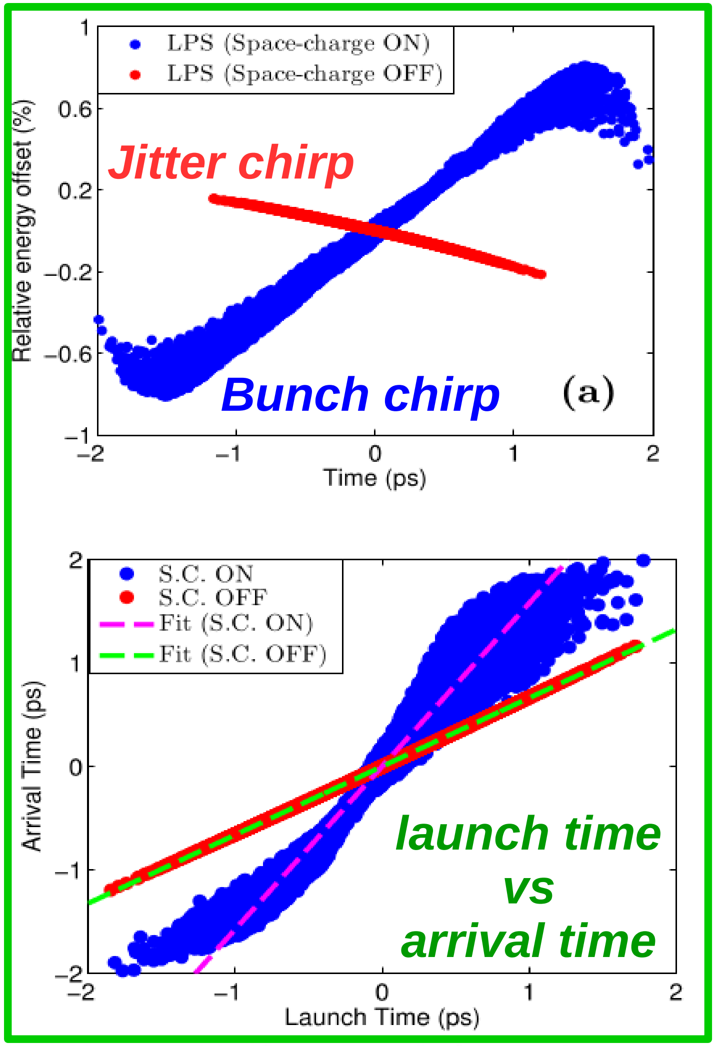

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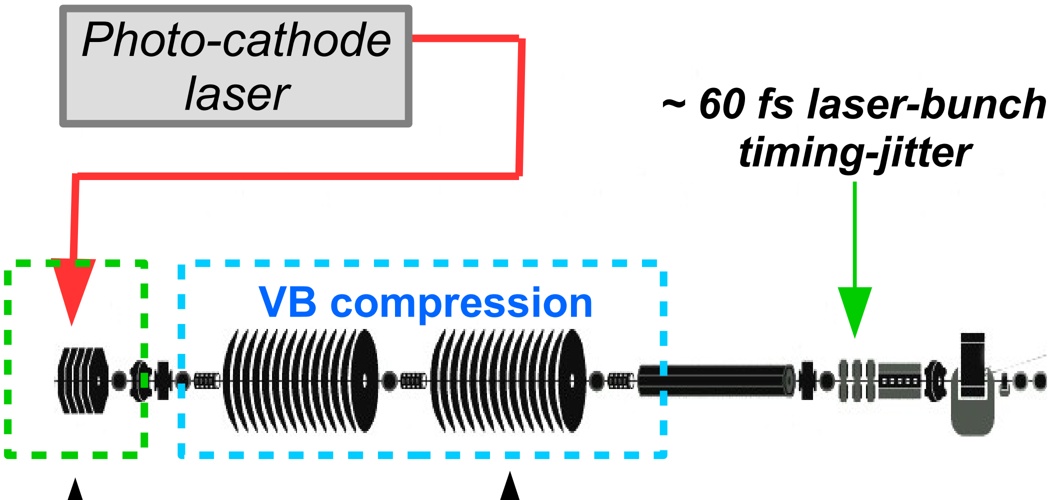
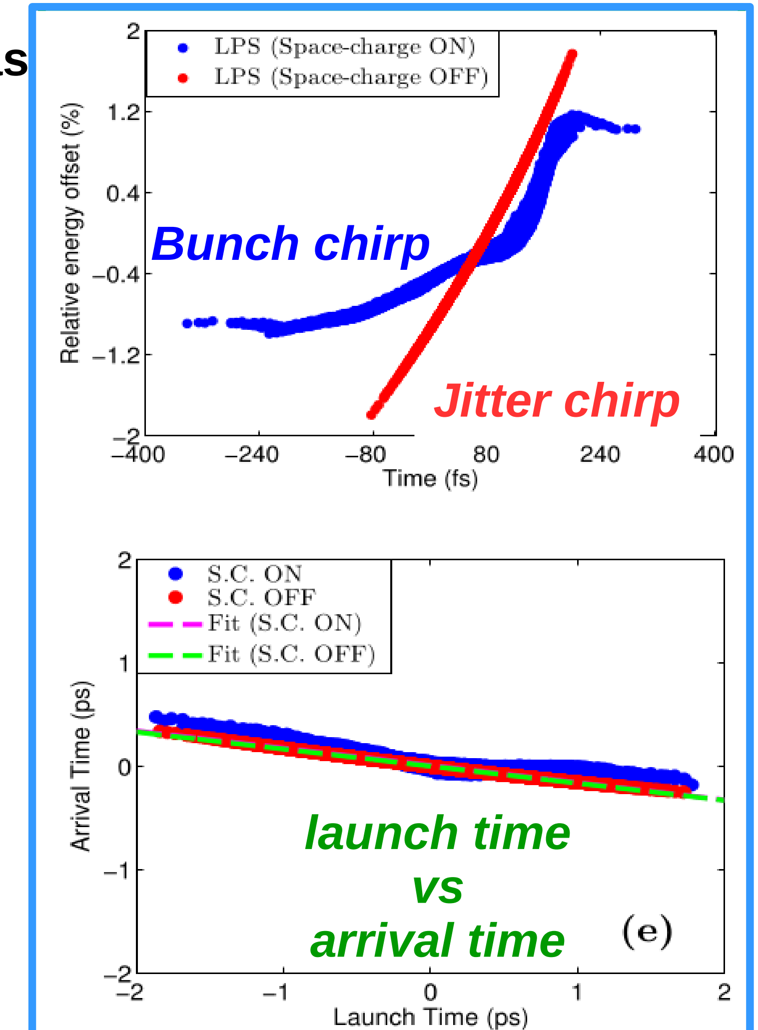


timing linked to PC laser

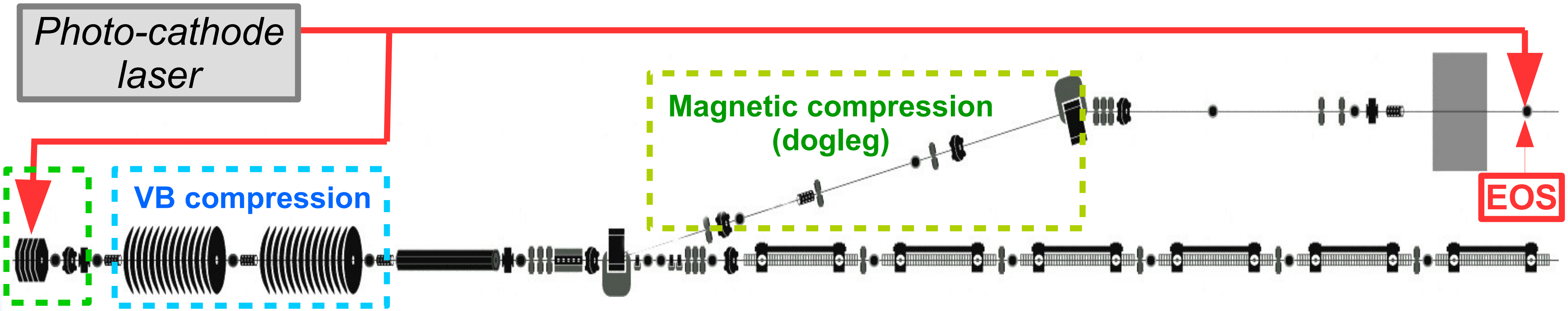
→ launch time-arrival time correlation ~1

timing linked to compressor (RF)

→ launch time-arrival time correlation ~0



Jitter reduction by hybrid compression



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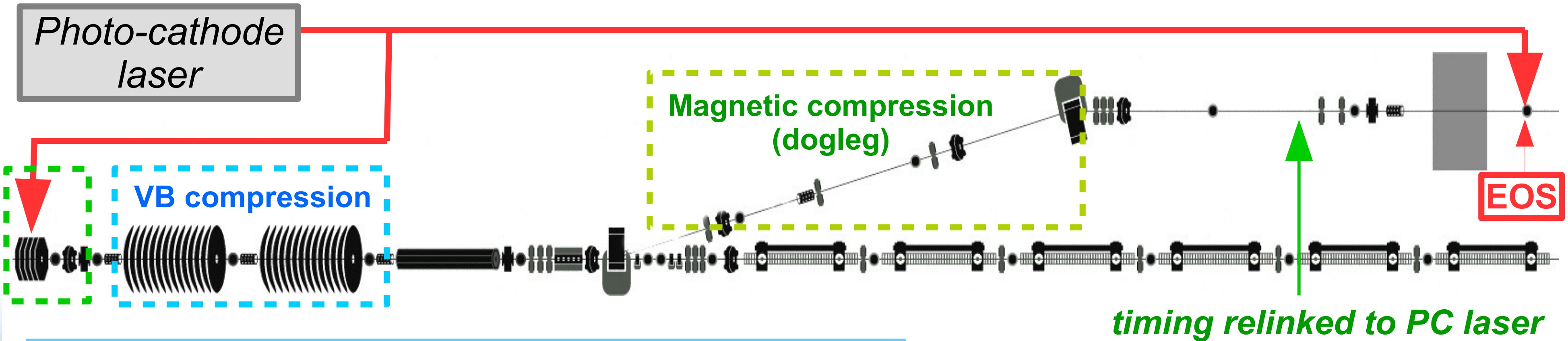

Hybrid compression: *bunch shortening by* ***VB****, relative ATJ reduction by* ***magnetic compression***

Pompili, R., et al. "Femtosecond timing-jitter between photo-cathode laser and ultra-short electron bunches by means of hybrid compression." New Journal of Physics 18.8 (2016): 083033.

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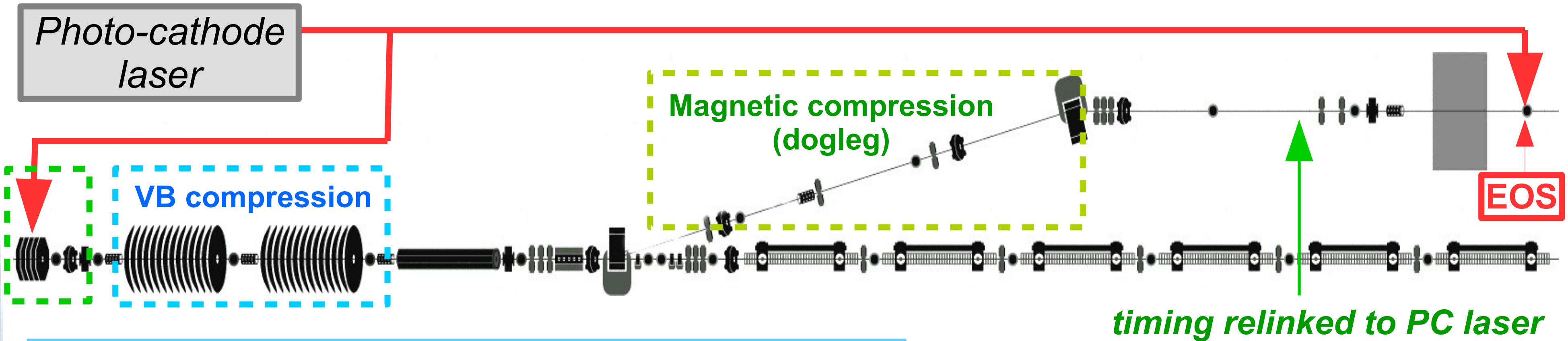

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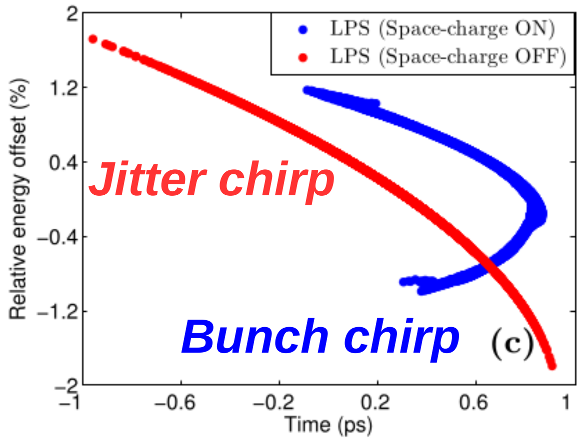

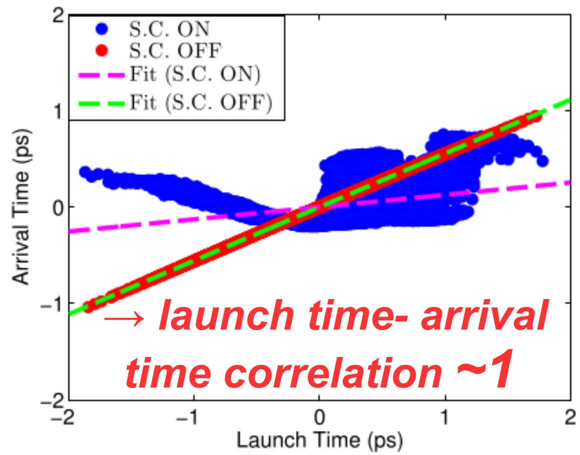

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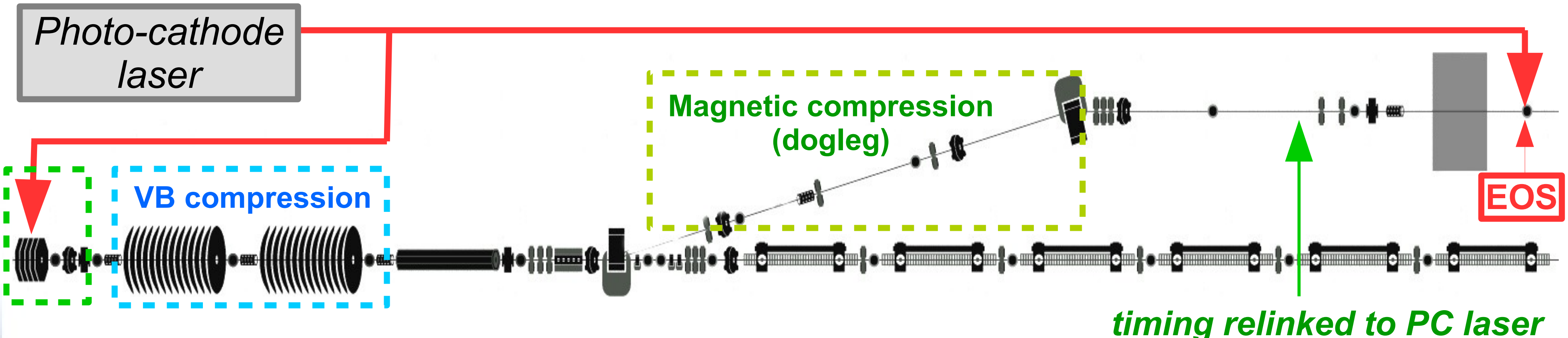

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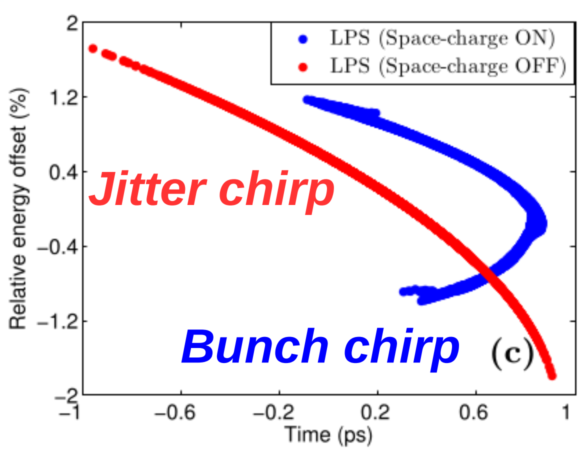
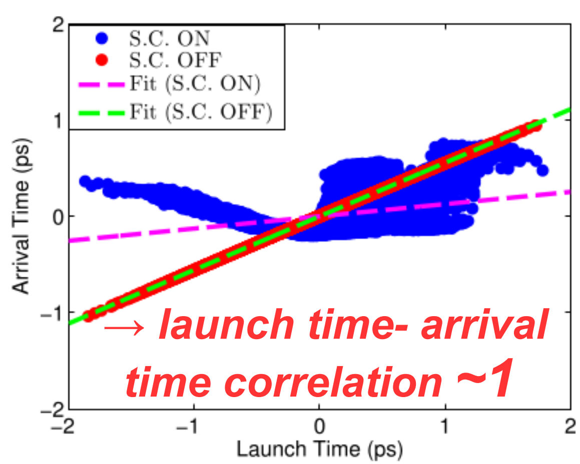
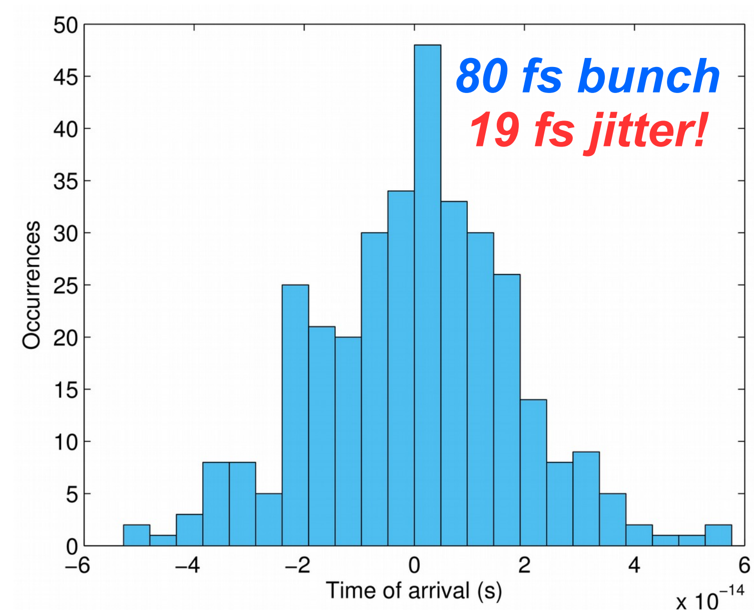
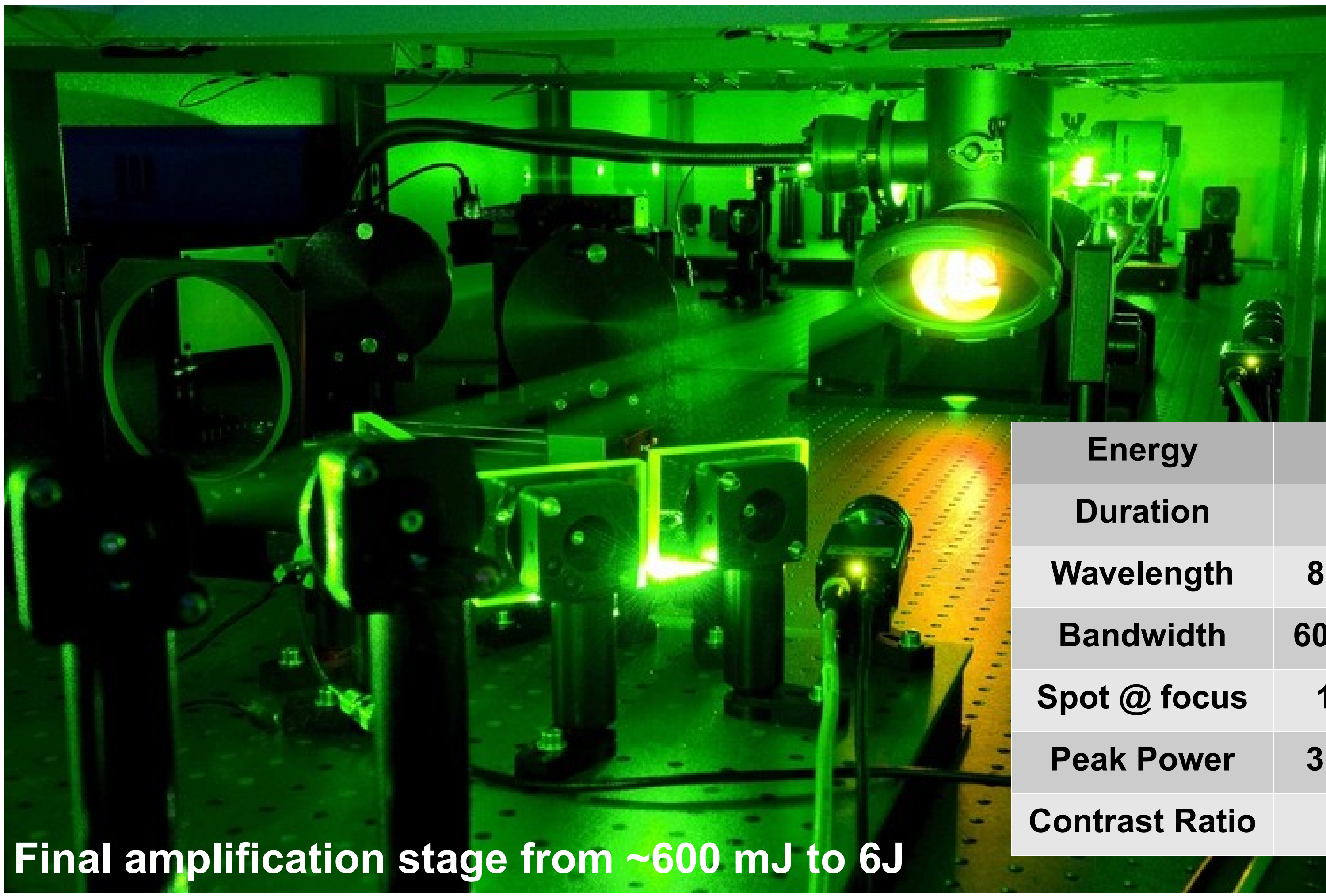




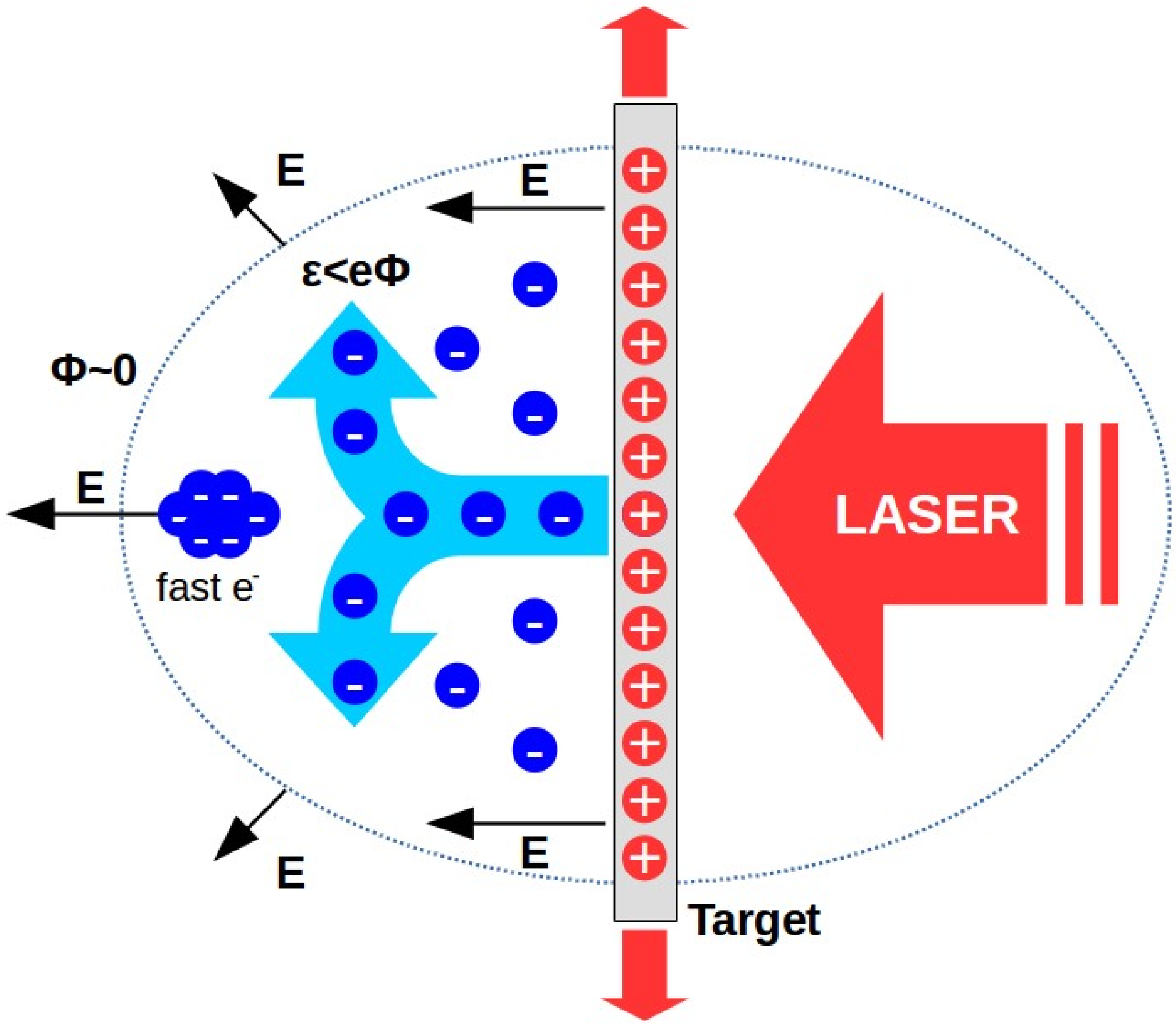


FLAME laser facility



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}

TNSA process



Dubois, J-L., et al. "Target charging in short-pulse-laser–plasma experiments." Physical Review E 89.1 (2014): 013102.

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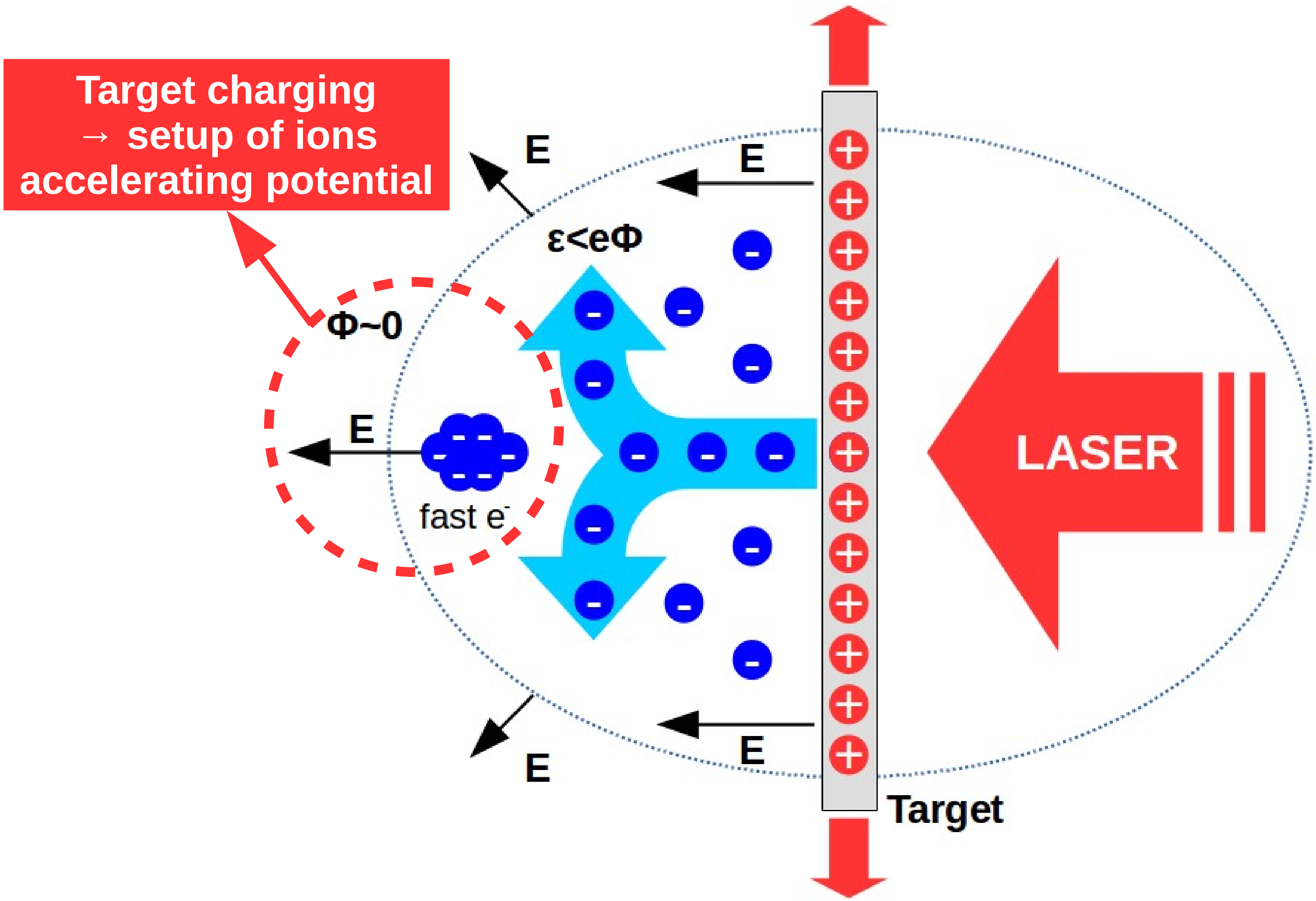

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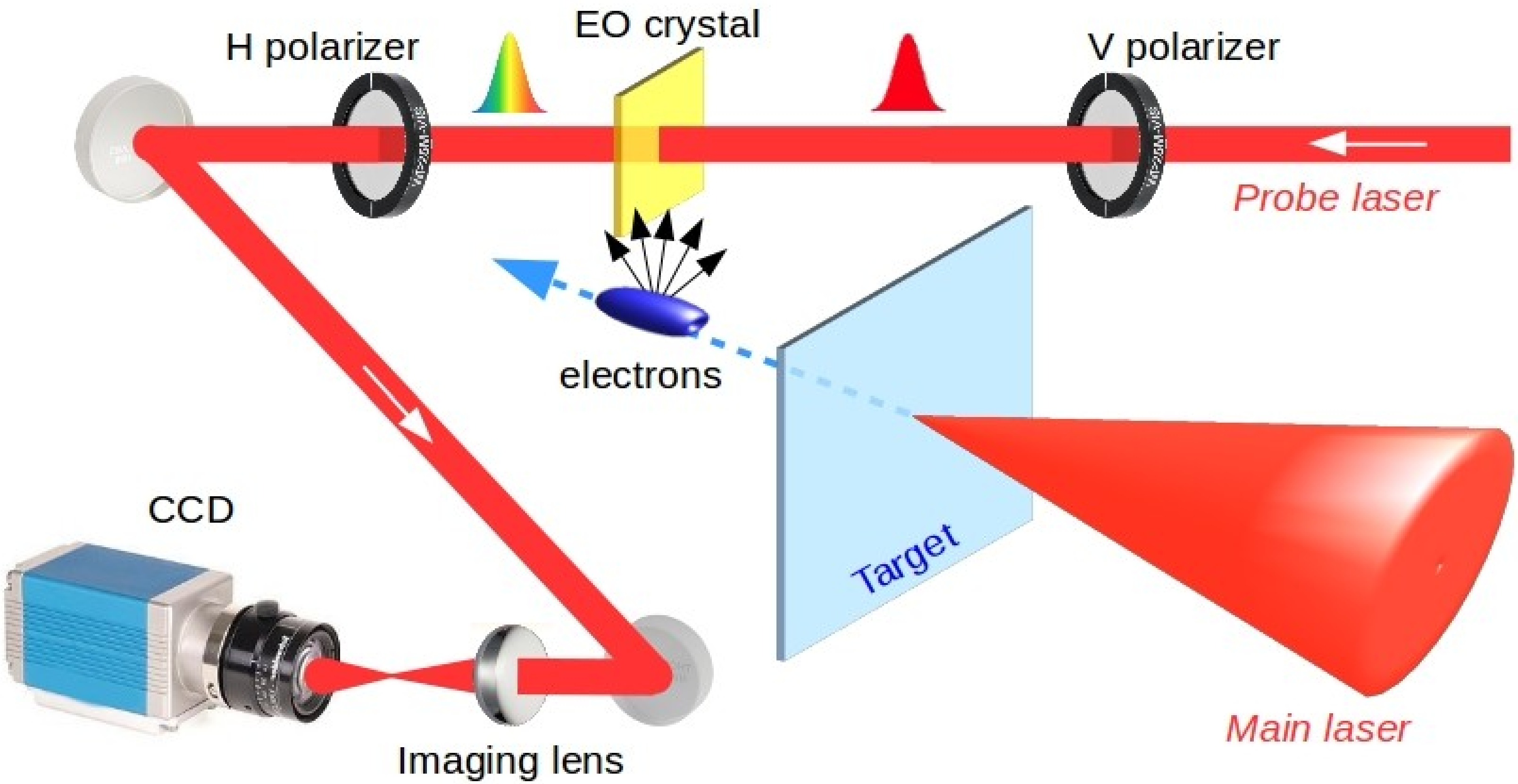
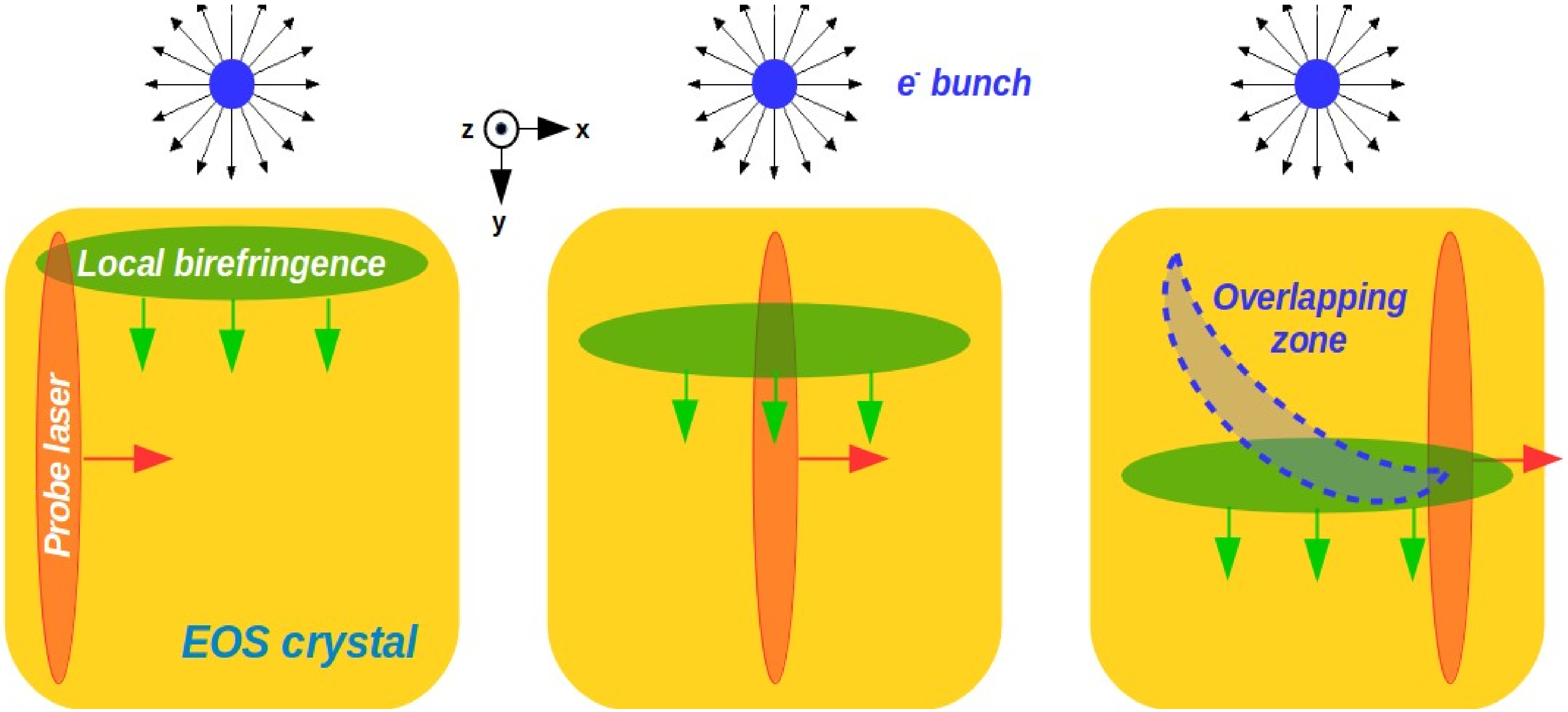
Experimental setup



Detection of electro-optic signals

- Picosecond time-window → particle selection by changing the probe delay
  - *Detection only of emitted fast electrons (no protons/ions, gammas, late electrons)*
- Encoding process results in curved signals



Results

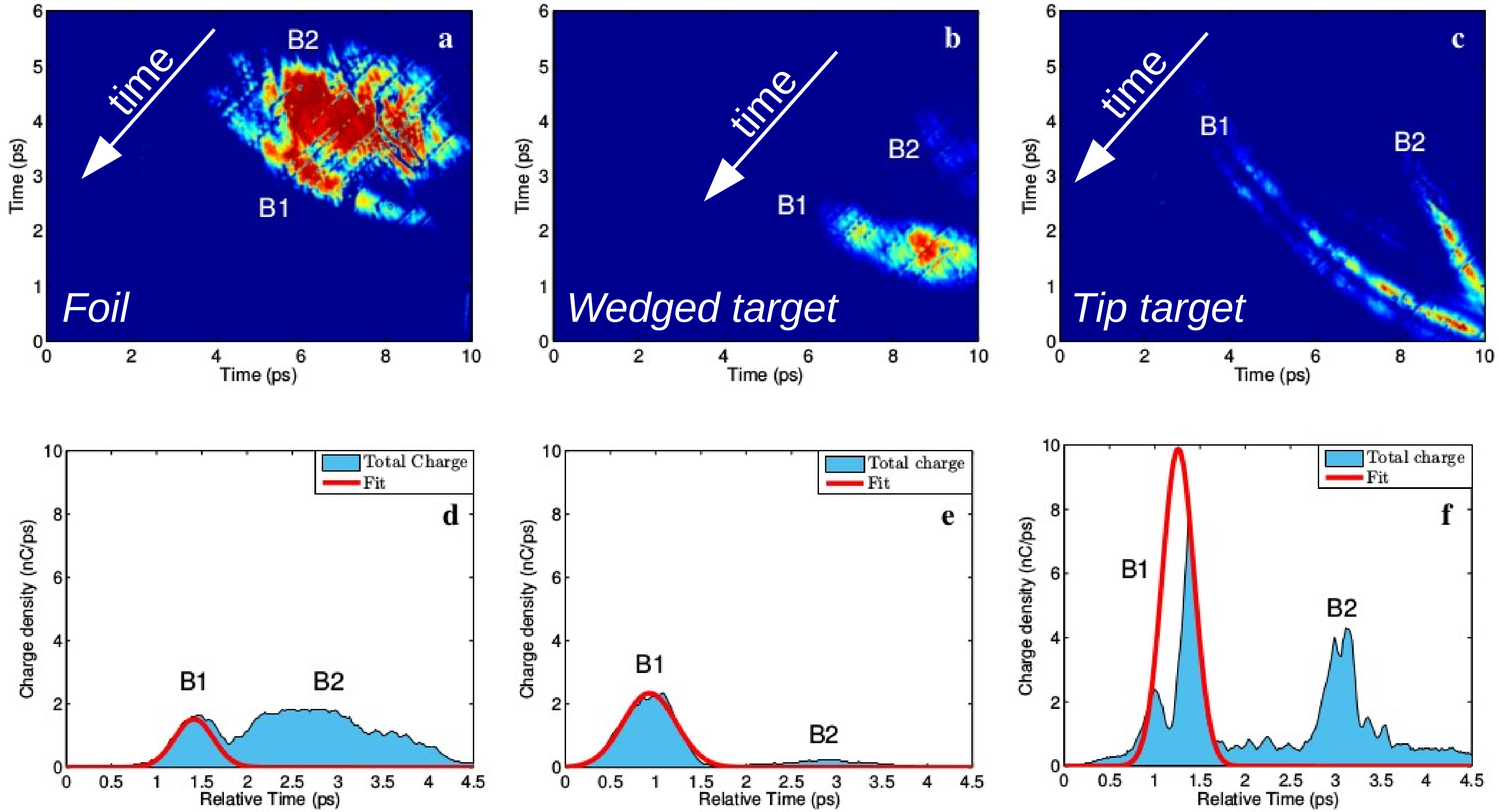


Figure 2. Snapshots with different target shapes. Signatures of the escaping electrons from (a) planar, (b) wedged and (c) tipped targets. The emitted charges are, respectively, (a) 1.2 nC (B1) and 3 nC (B2); (b) 2 nC (B1) and 0.3 nC (B2); (c) 7 nC (B1) and 3 nC (B2). The gaussian envelopes represent the extrapolated charge profiles of each bunch. (d-f) Corresponding longitudinal charge profiles. A 10^2 neutral density filter has been used in (b) and (c) to avoid saturation of the CCD camera.

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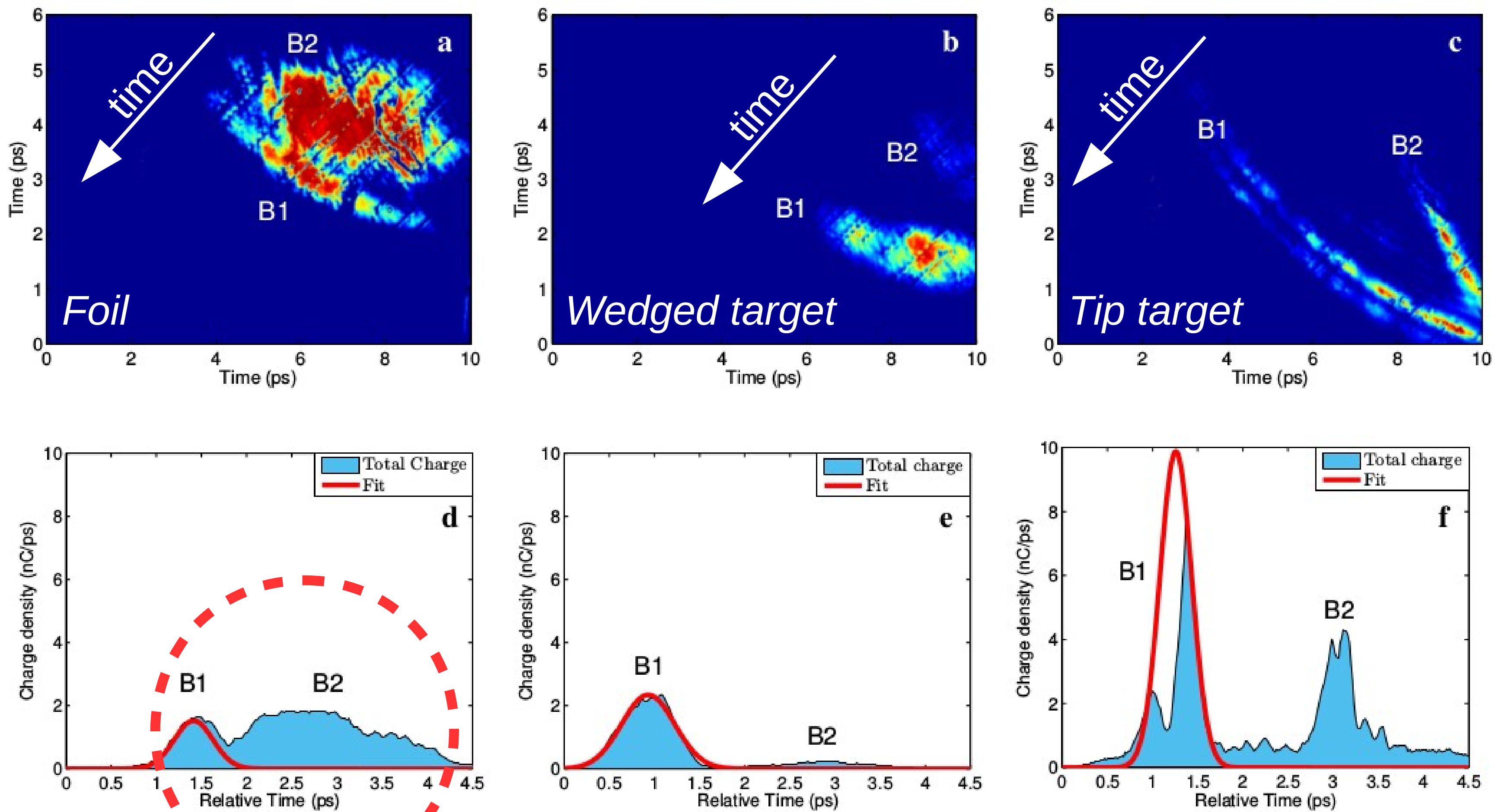

Temporal evolution of the TNSA electrostatic potential

Figure 2. Snapshots with different target sh … (a) planar, (b) wedged and (c) tipped targets. The emitted charges are, respect … B1) and 0.3 nC (B2); (c) 7 nC (B1) and 3 nC (B2). The gaussian envelopes represent the extrapolated charge profiles of each bunch. (d-f) Corresponding longitudinal charge profiles. A 10^2 neutral density filter has been used in (b) and (c) to avoid saturation of the CCD camera.

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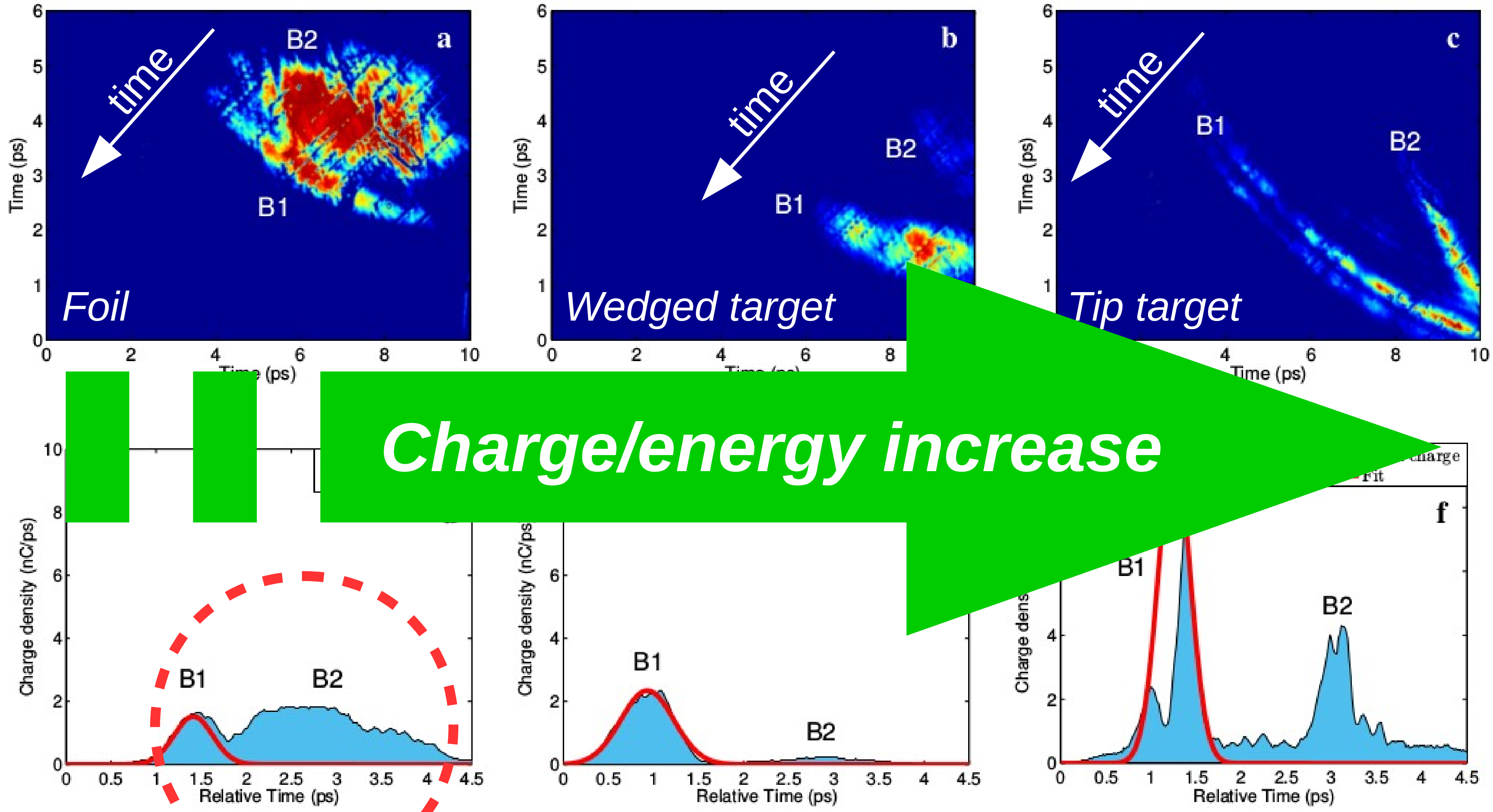

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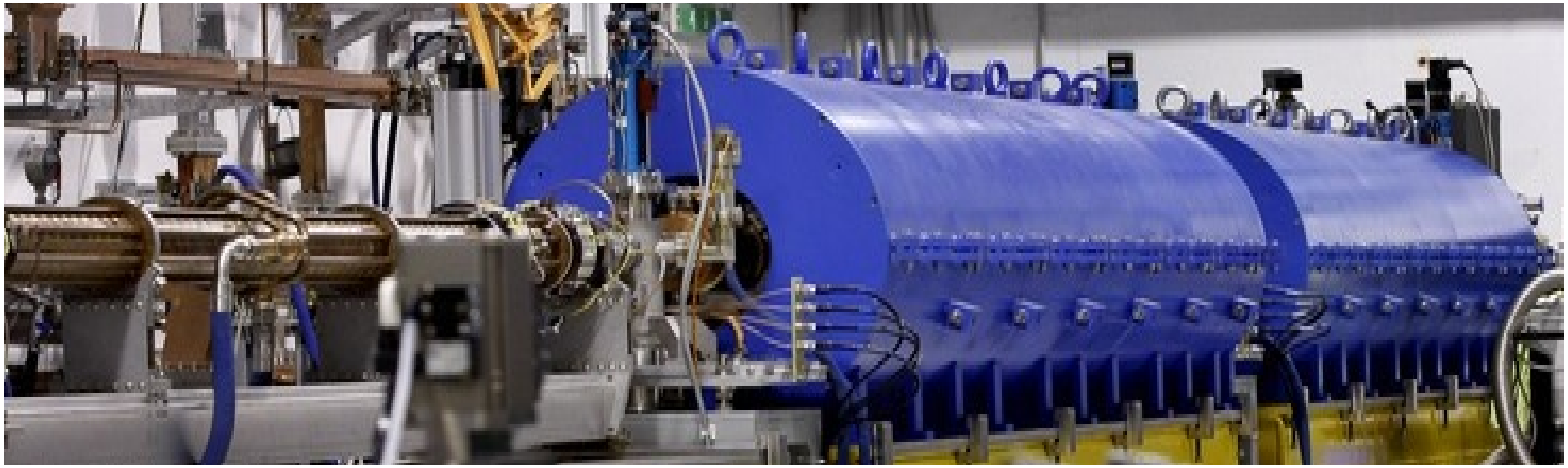
Conclusions

- We presented results about the use of EOS technique for several kind of experimental activities
- Accelerator facilities
  - *Longitudinal beam monitor for THz-spaced bunch trains*
  - *Time-of-arrival monitor used to demonstrate the hybrid compression scheme for ultra-short bunches with ultra-low timing-jitters with respect to the PC laser system*
- Laser-target interactions
  - *Test of the field enhancement conjecture*
  - *Probe the temporal evolution of proton/ion acceleration*
  - *First time-resolved measurements ever done probing the emitted fast electrons*
  - *Experimental evidence of nonlinear temporal evolution of the induced accelerating potential in TNSA processes*

Acknowledgments



- *M.P. Anania, M. Bellaveglia, E. Chiadroni, D. Di Giovenale, M. Ferrario, V. Lollo, G. Di Pirro, V. Shpakov, F. Villa (INFN, Frascati, Italy)*
- *A. Cianchi (Tor Vergata University of Rome, Italy)*
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- *A. Zigler (Racah Institute of Physics, Hebrew University, Jerusalem, Israel)*

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