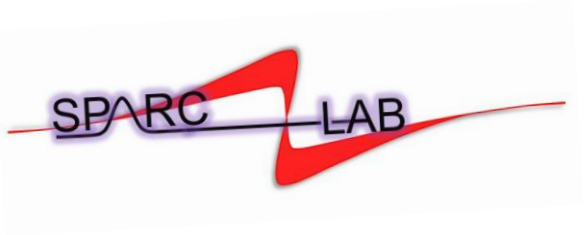
Laser pulse shaping for high gradient accelerators

F. Villa
on behalf of SPARC_LAB collaboration

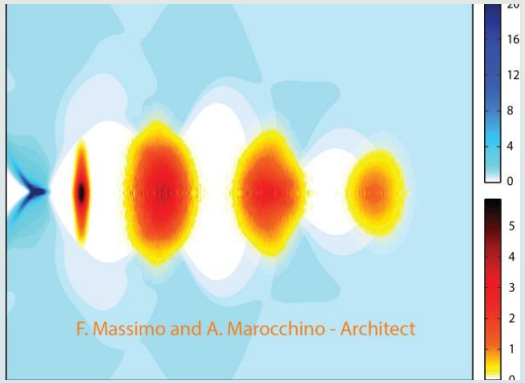


Outline

- Introduction
- Pulse shaping
- Multibunch configurations
- Hollow beams
- Conclusions

PWFA with comb beam and velocity bunching

- Laser-comb: multiple electron bunches produced directly at the cathode
  - *Accurate laser pulses delay and duration is fundamental*
  - *Easy setup, (un)balancing (charge ramps…)*



- Velocity bunching for bunch compression

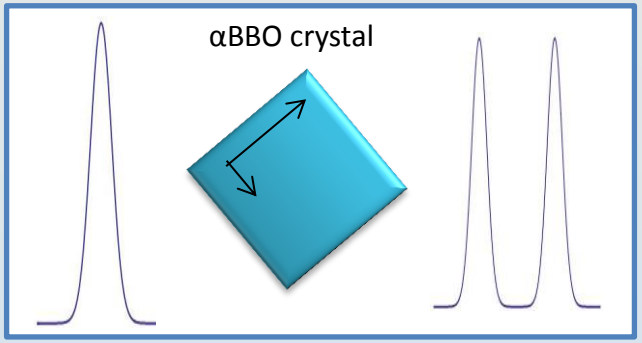
  Distance and duration tuning by moving linac 1st section phase
  Different approach with respect to other multi-bunches schemes

Ferrario, M., et al "Laser comb with velocity bunching: Preliminary results at SPARC." NIM 637.1 2011 S43-S46.

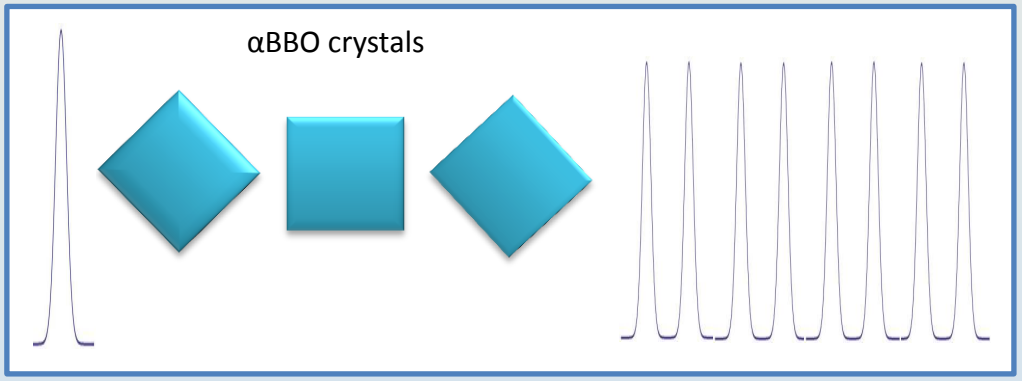
Pulse shaping with birefirngence

- Birefringent crystal technique:
  - Fast/slow axes different time propagation $\Delta T = (n_e - n_o)\, L/c$

1 crystal => 2 pulses



n crystals = 2^n pulses



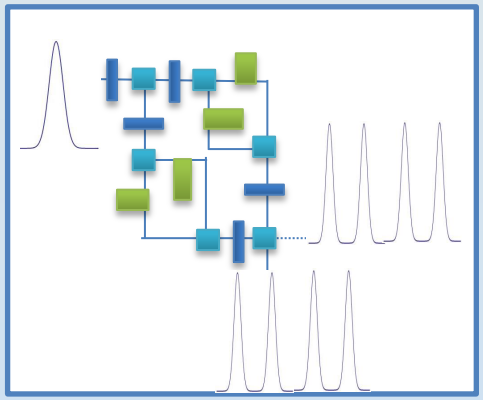
  - Pros
  - Easy and reliable
  - Easy to stack

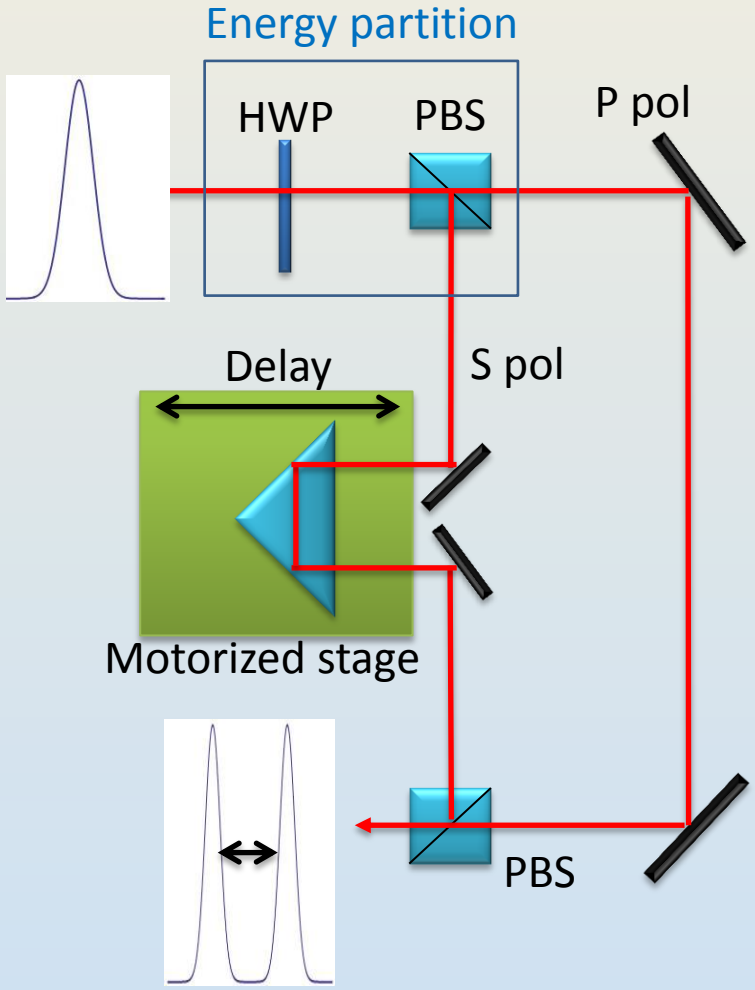
Cons:
Fixed delays
Pulse pairing

A. K. Sharma et al., *Phys. Rev. ST Acc. Beam,* n. 12, p. 033501, 2009
C. Jing et al., *Phys. Rev. ST Acc. Beam,* vol. 14, p. 021302, 2011

Pulse shaping with splitting

- Interferometer configuration:
  - Pros:
    - Very flexible
  - Cons:
    - Transverse alignment
    - Complex setup for more than 2 pulses

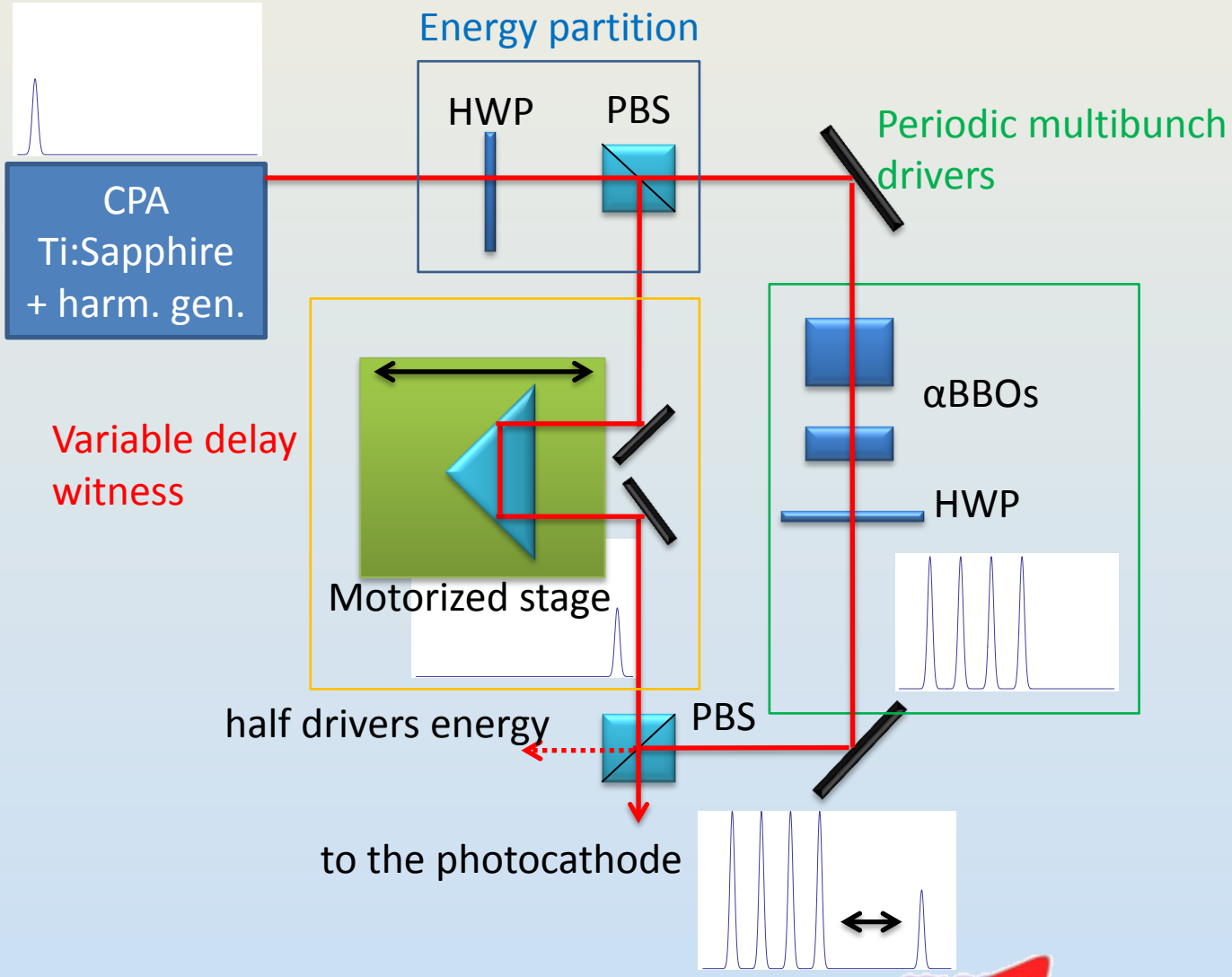




C. W. Siders et al., *Appl. Opt.,* vol. 37, n. 22, p. 5302, 1998
Y. Ding et al., *Phys. Rev. ST Acc. Beam,* vol. 13, p. 060703, 2010

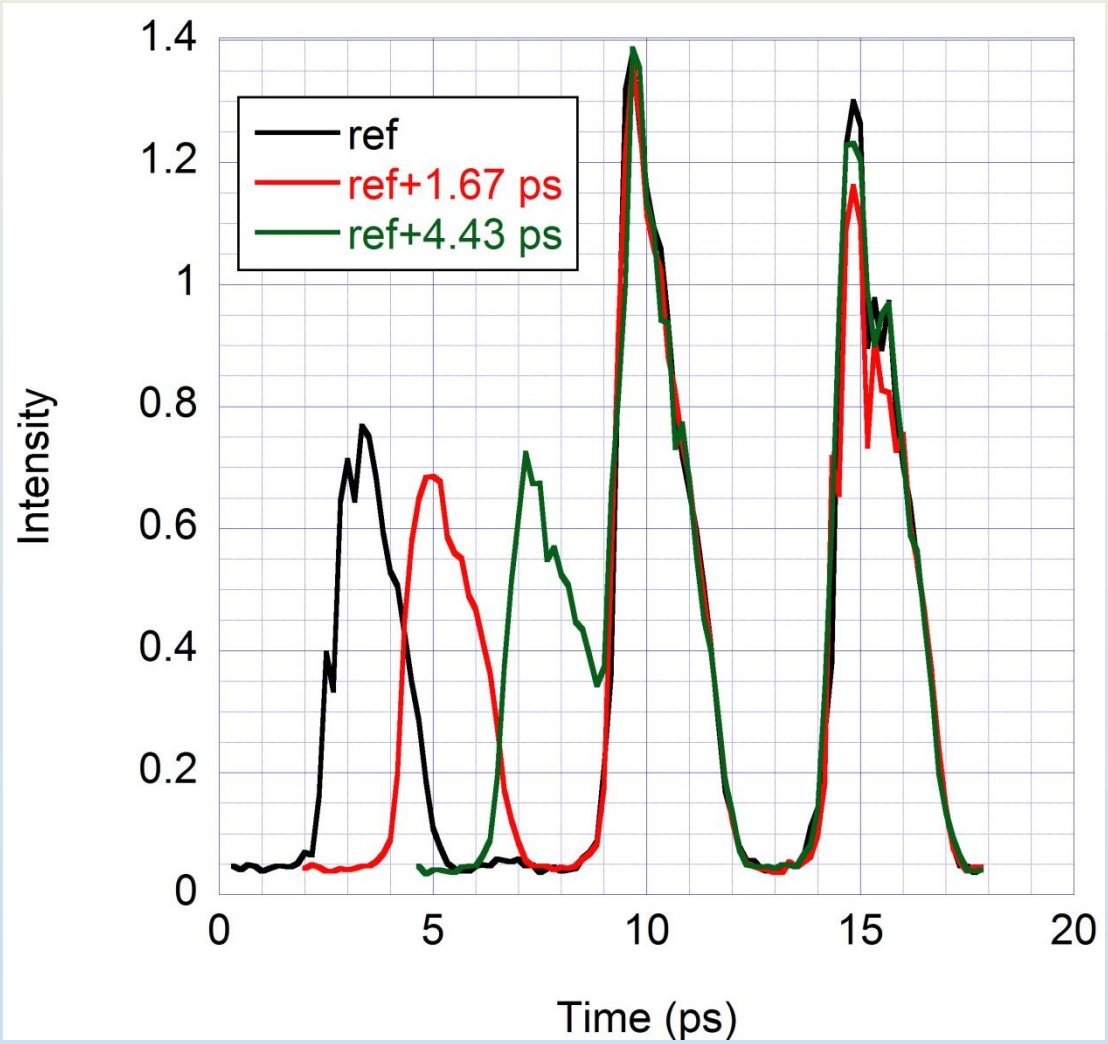
Flexible pulse shaping

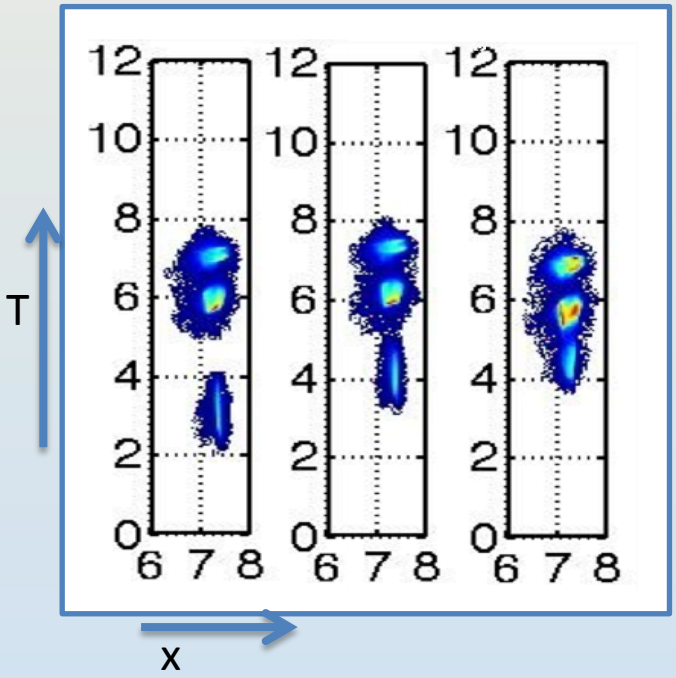
- Witness with variable delay
- Many drivers



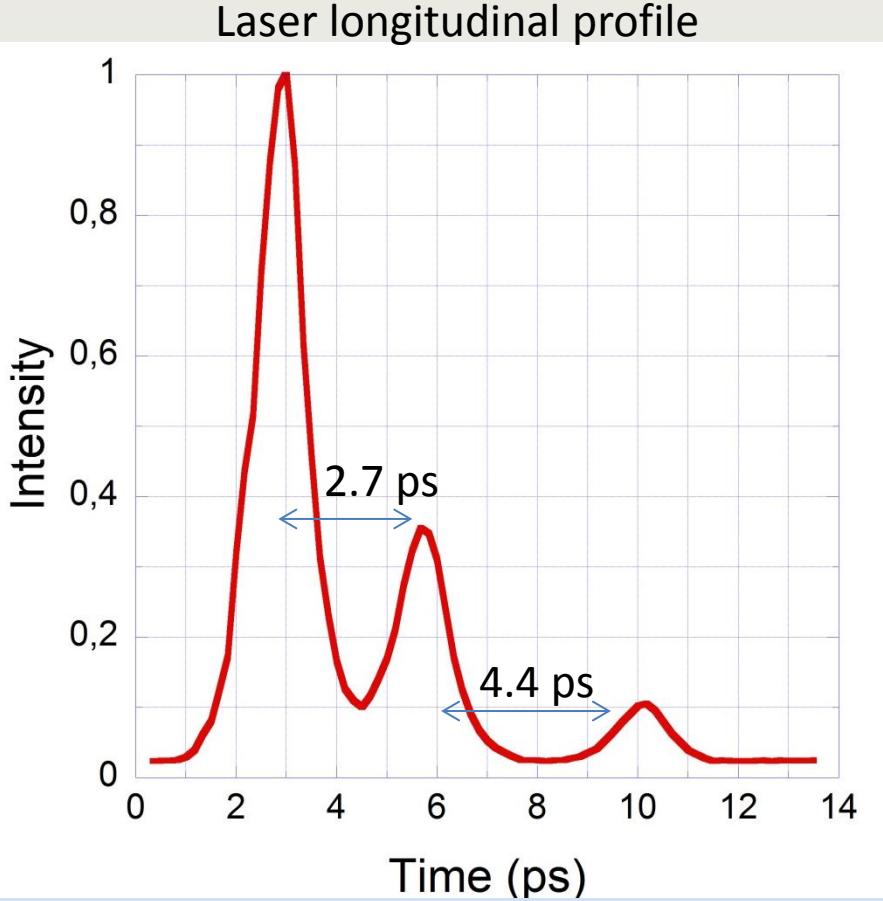
Witness delay fine tuning

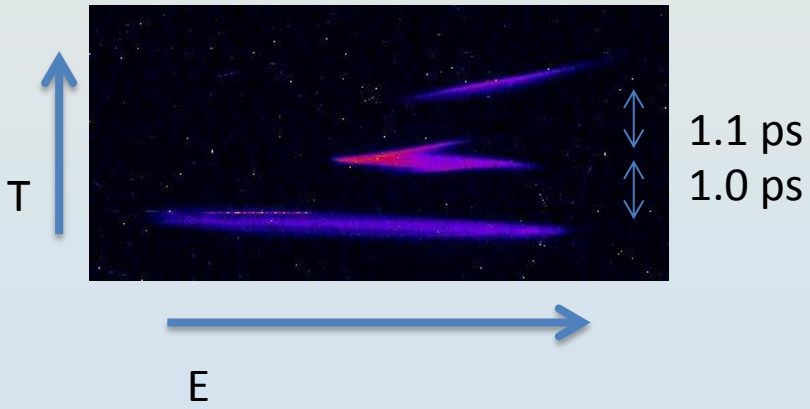
Laser longitudinal profile





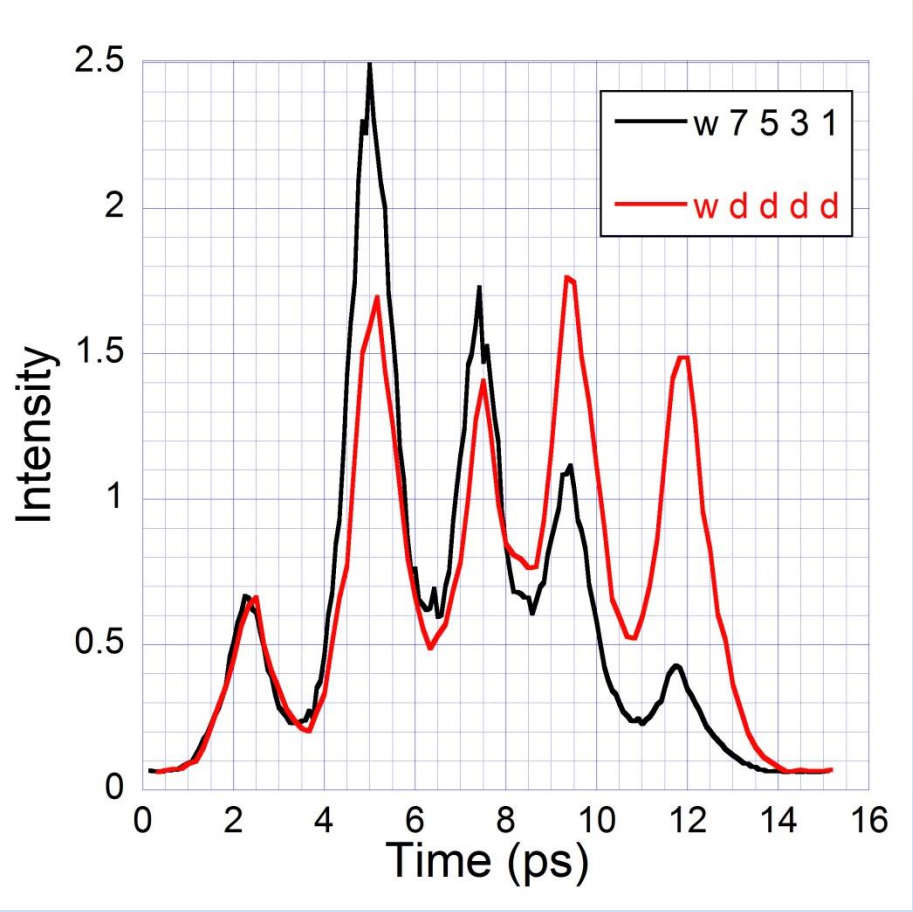
Equal pulse separations

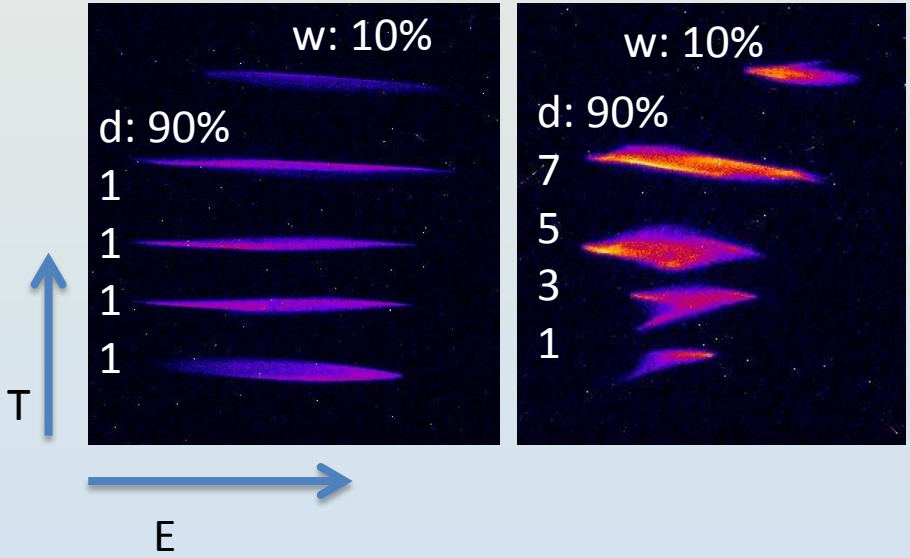




Ramped beams

Laser longitudinal profile



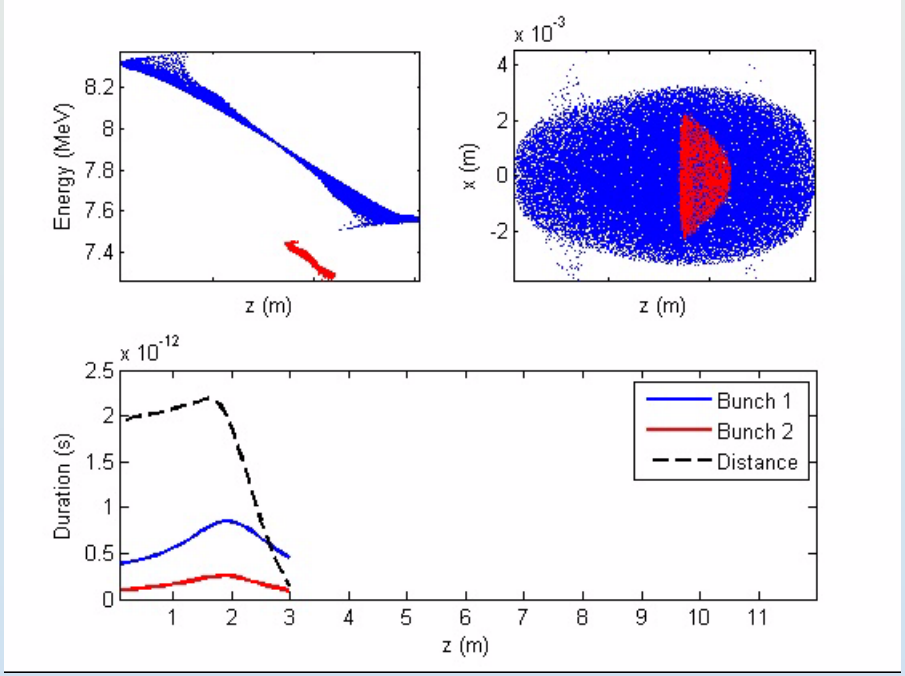


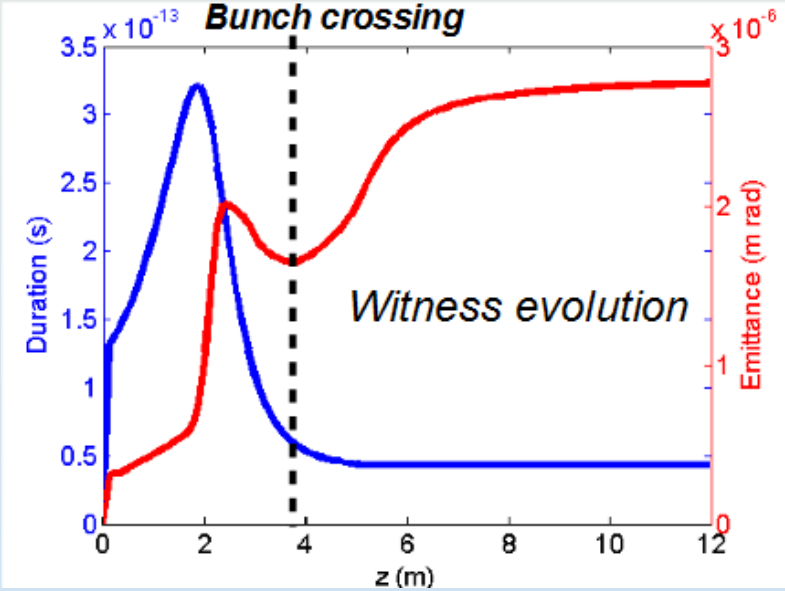
A. Cianchi et al., Phys. Rev. ST Acc. Beam, vol. 18, p. 082804, 2015.

A. Mostacci et al., SPIE Optics + Optoelectronics, Prague, 2015.

Hollow beam: Why hollow?

- Witness cross the driver during compression:
  - Larger emittance and longer compressed pulse





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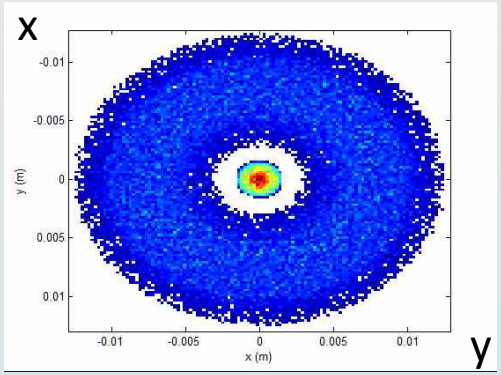
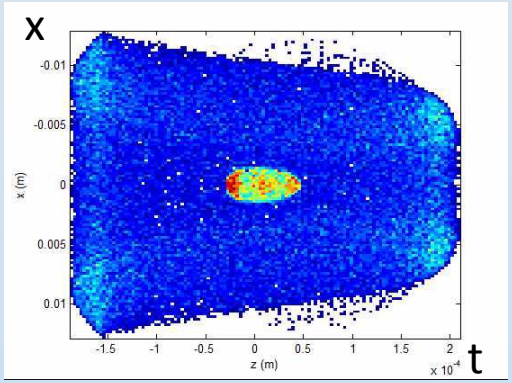
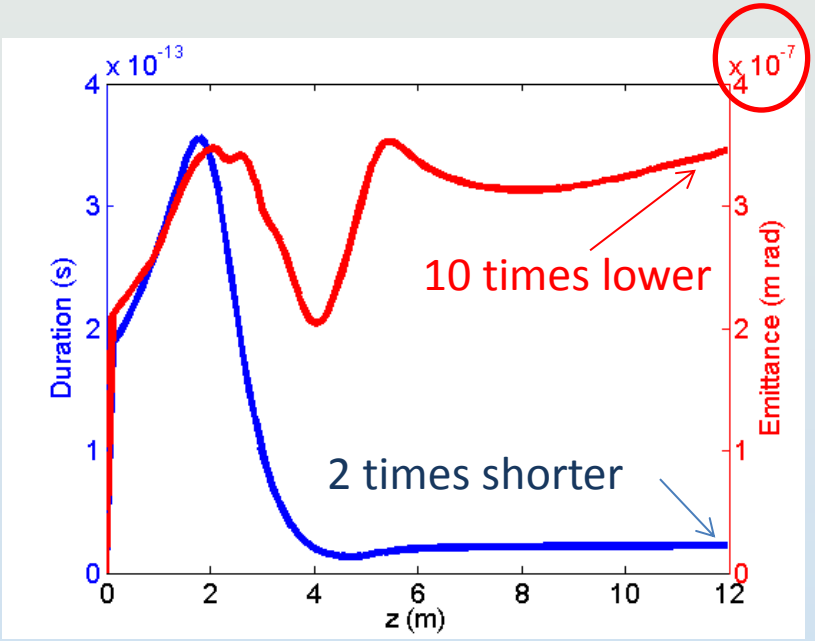
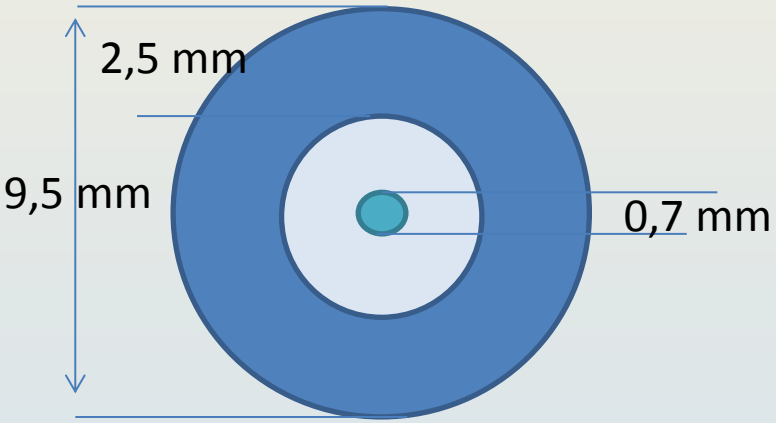




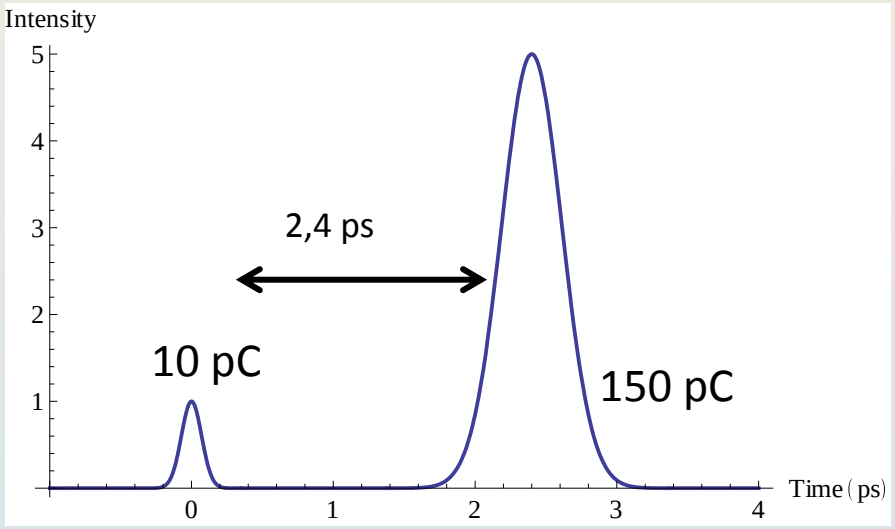


Hollow beam requirements

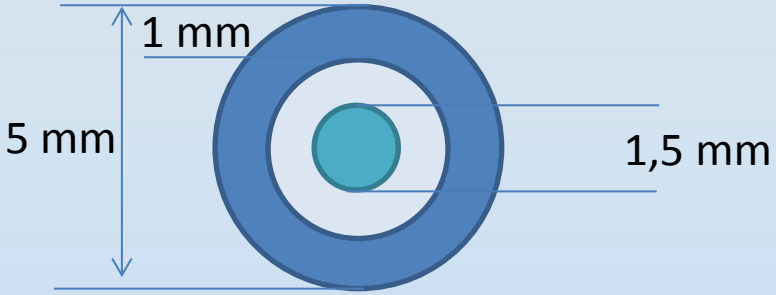
Single driver transverse profiles



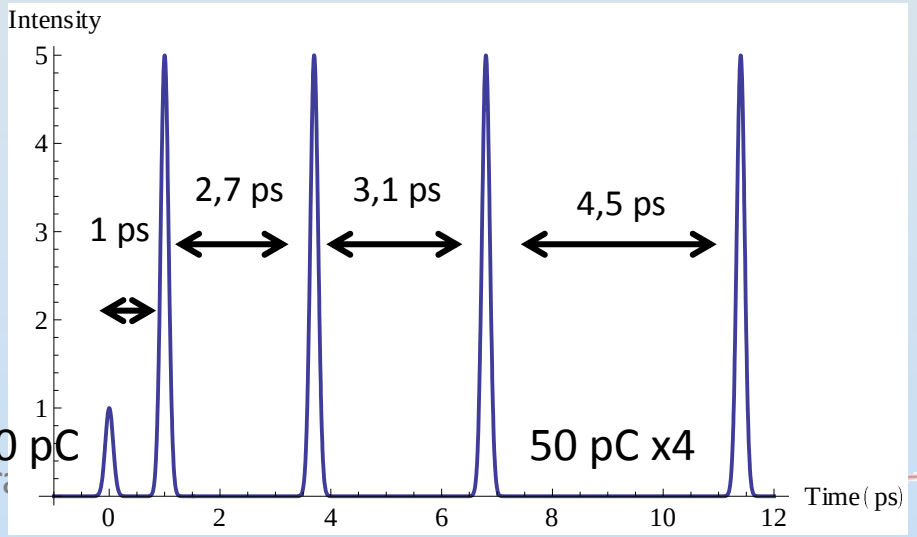
Single driver longitudinal profiles



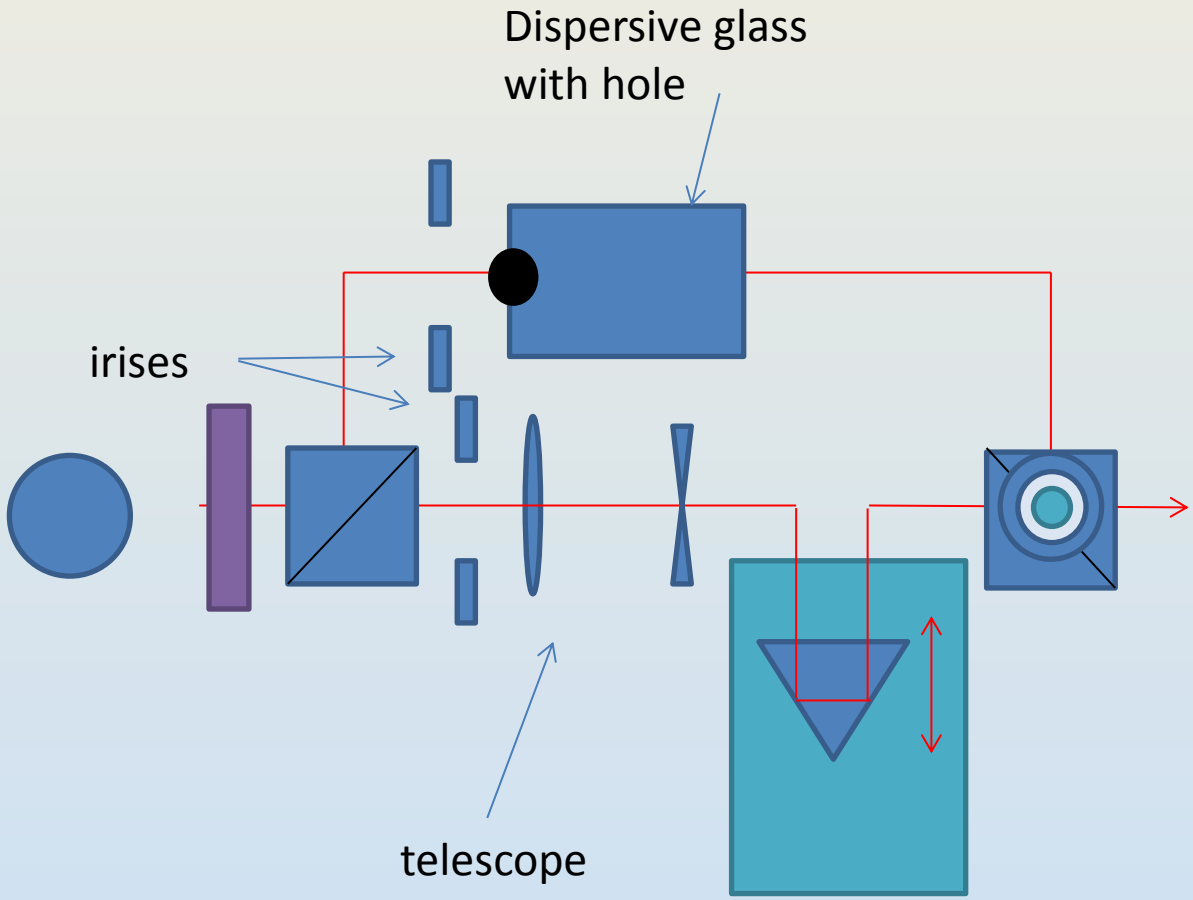
Multi-driver transverse profiles



Multi-driver longitudinal profiles



Hollow beam laser shaping scheme



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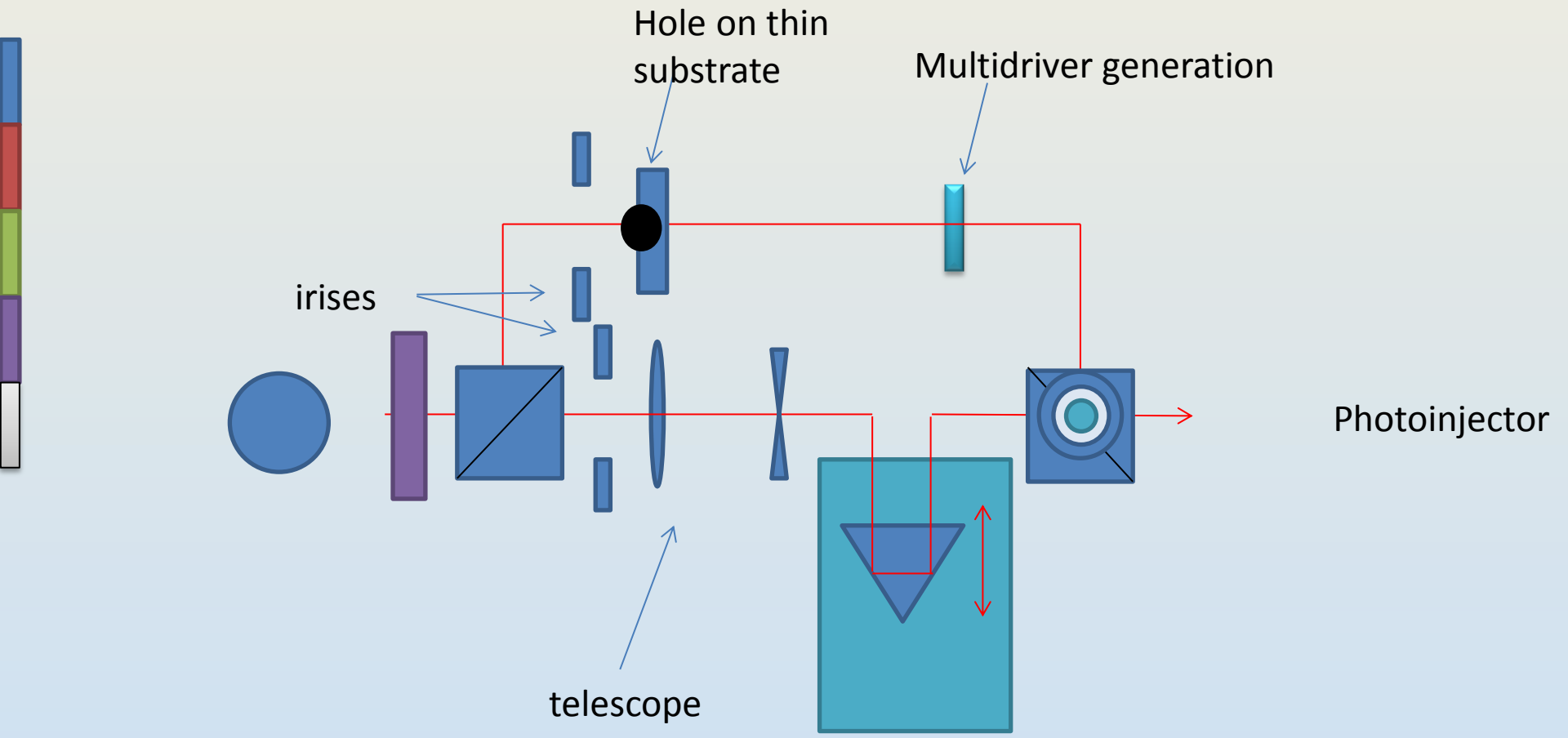

Conclusion

- Pulse shaping:
  - Control of delays between pulses
  - Fine tuning of each pulse amplitude (charge)
  - Flexibility for different configurations
- Hollow beams:
  - new possibilities for PWFA

Thank you!

- Sparc_lab collaboration
  - D. Alesini, M.P. Anania, M. Bellaveglia, A. Biagioni, F. Bisesto, M. Castellano, E. Chiadroni, M. Croia, D. Di Giovenale, M. Ferrario, G. Di Pirro, R. Pompili, S. Romeo, J. Scifo, V. Shpakov, B. Spataro, C. Vaccarezza (INFN, Frascati)
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