EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

WP12
Acc. Prototyping & Exp. Test Facilities

Coordinators
Rajeev Pattathil - STFC Rutherford Appleton Laboratory
Andrea Mostacci - Sapienza Univ. within SPARC_LAB

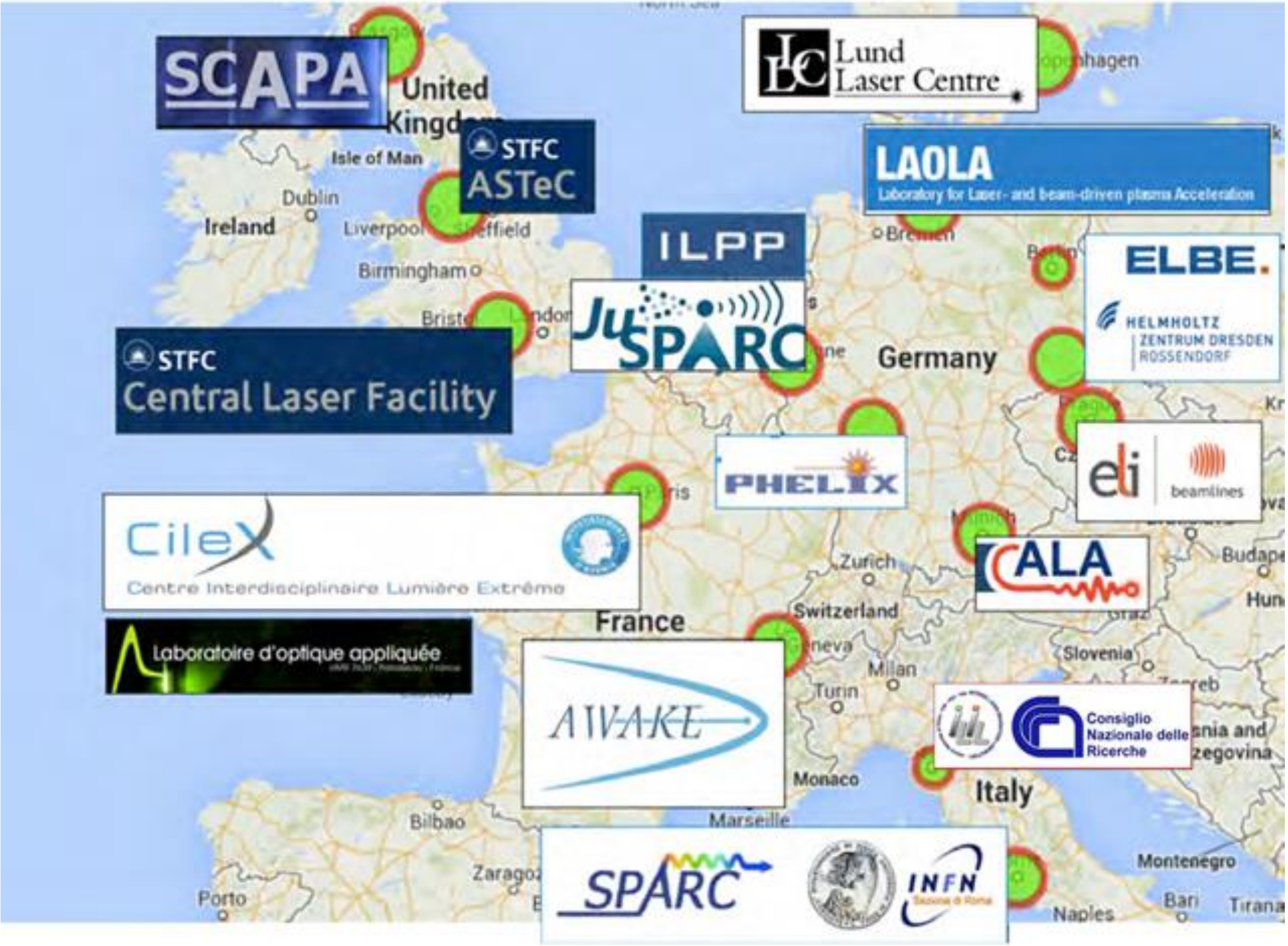
Yearly meeting and 2nd Collaboration Week, 20-24 November, 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

Outline

- WP12 progress in brief
- Review of the experiments useful to EuPRAXIA design study
- Review of facilities and facility access

Facilities involved in Eupraxia



WP12 progress in brief

Objectives

- **Facilitate tests for concepts** and prototypes developed in other work packages in various facilities
- **Survey of the experimental results** of the proof-of-principle tests and accelerator prototyping studies

Key Tasks

- Gather information regarding **potential experimental facilities** where tests can be conducted
- Describe capabilities of these facilities and access mechanisms
- Gather information regarding **concepts that need testing/prototyping** in consultation with other WP's and understanding priorieties.
- **Feed back relevant results into the EuPRAXIA design study**

Deliverable Report

D (12.2) Program for tests including schedules and teams

List of experiments

Few schedules

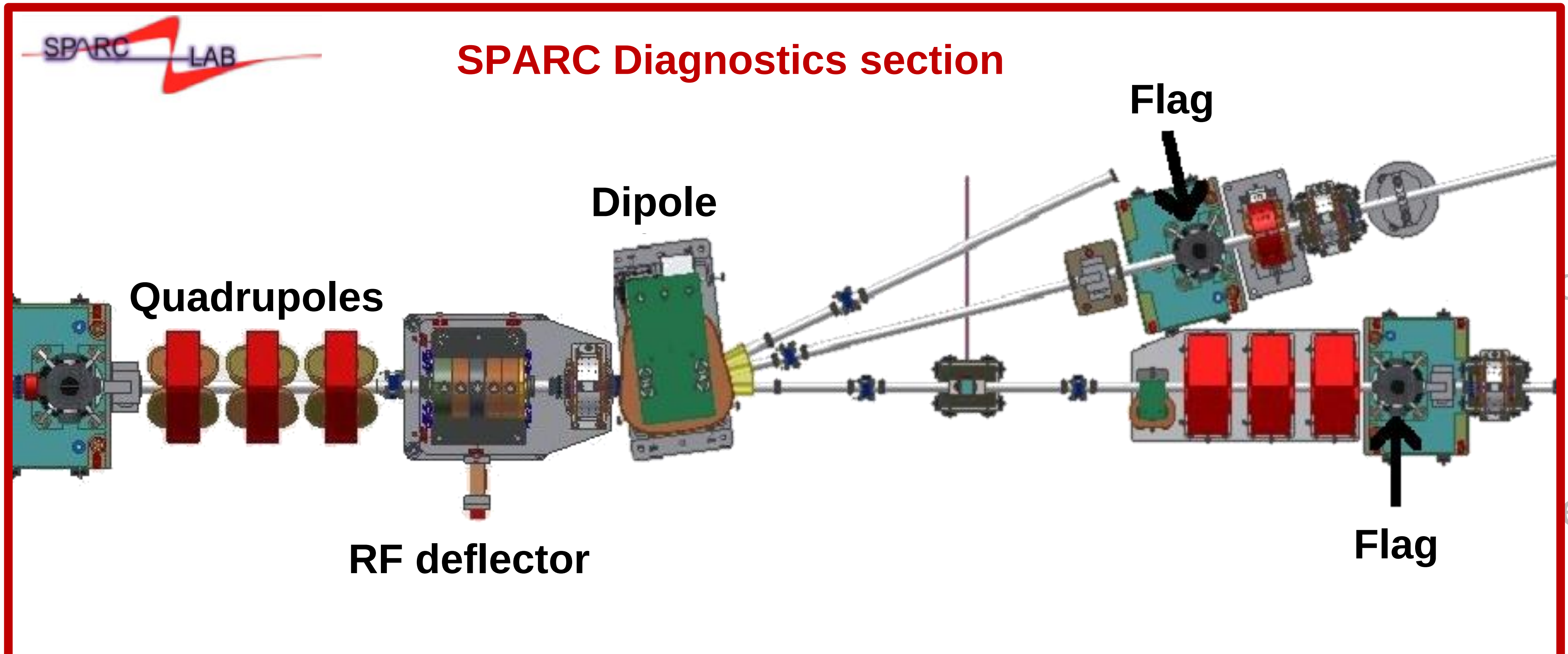
Few teams

Needed experiments

- Slice energy spread of plasma accelerated beam (~3fs slice for 1nm radiation)
- Schemes for selected issues (e.g. driver removal, resonant multiple laser pulses)
- Plasma based beam dump
- Switching options for driver and witness at low energy, preserving beam qualities.
- Compact advanced diagnostics and new ideas
- Stability of different schemes for plasma injectors (pointing stability of laser, plasma oscillations)
- High charge (higher than few tens of pC) in Plasma Injectors
- Synchronization for external injections
- Advanced devices (e.g. de-chirper for passive streaking)
- Feedback control (pointing, temporal, phase..)

Needed experiments

- Slice energy spread of plasma accelerated beam (~3fs slice for 1nm radiation)
- ... pulses)
- ... qualities.
- ... er, plasma



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- High (
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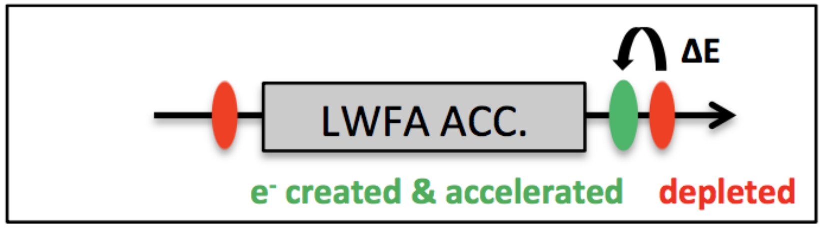
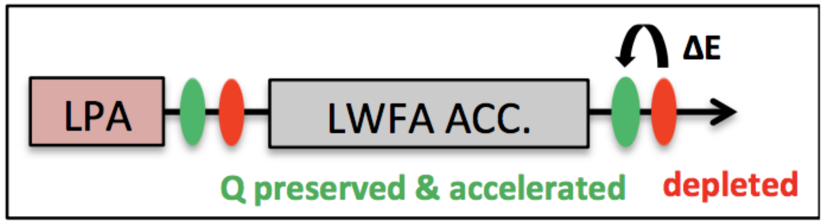
- Feedb

Courtesy of E. Chiadroni – WP5

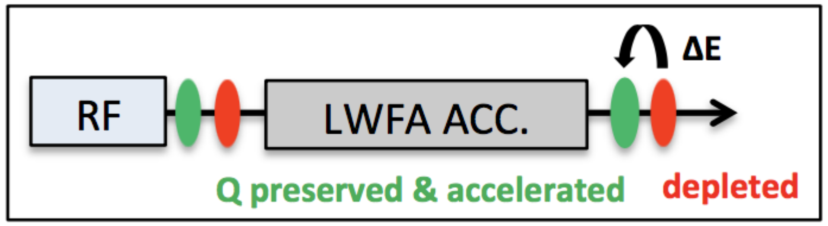
1. Laser Plasma Accelerator (LPA) with internal injection



2. LPA with external injection from Laser Plasma Injector (LPI)



3. LPA with external injection from RF injector



4. Beam-driven Plasma Accelerator (BPA) with external injection from RF injector

Laser beam Electron beam

P. A. Walker *et al.*, Horizon 2020 EuPRAXIA design study, *J. Phys.: Conf. Ser.* **874**, 012029 (2017)

Needed experiments

- Slice energy spread of plasma accelerated beam (~3fs slice for 1nm radiation)
- Schemes for selected issues (e.g. **driver removal**, resonant multiple laser pulses)
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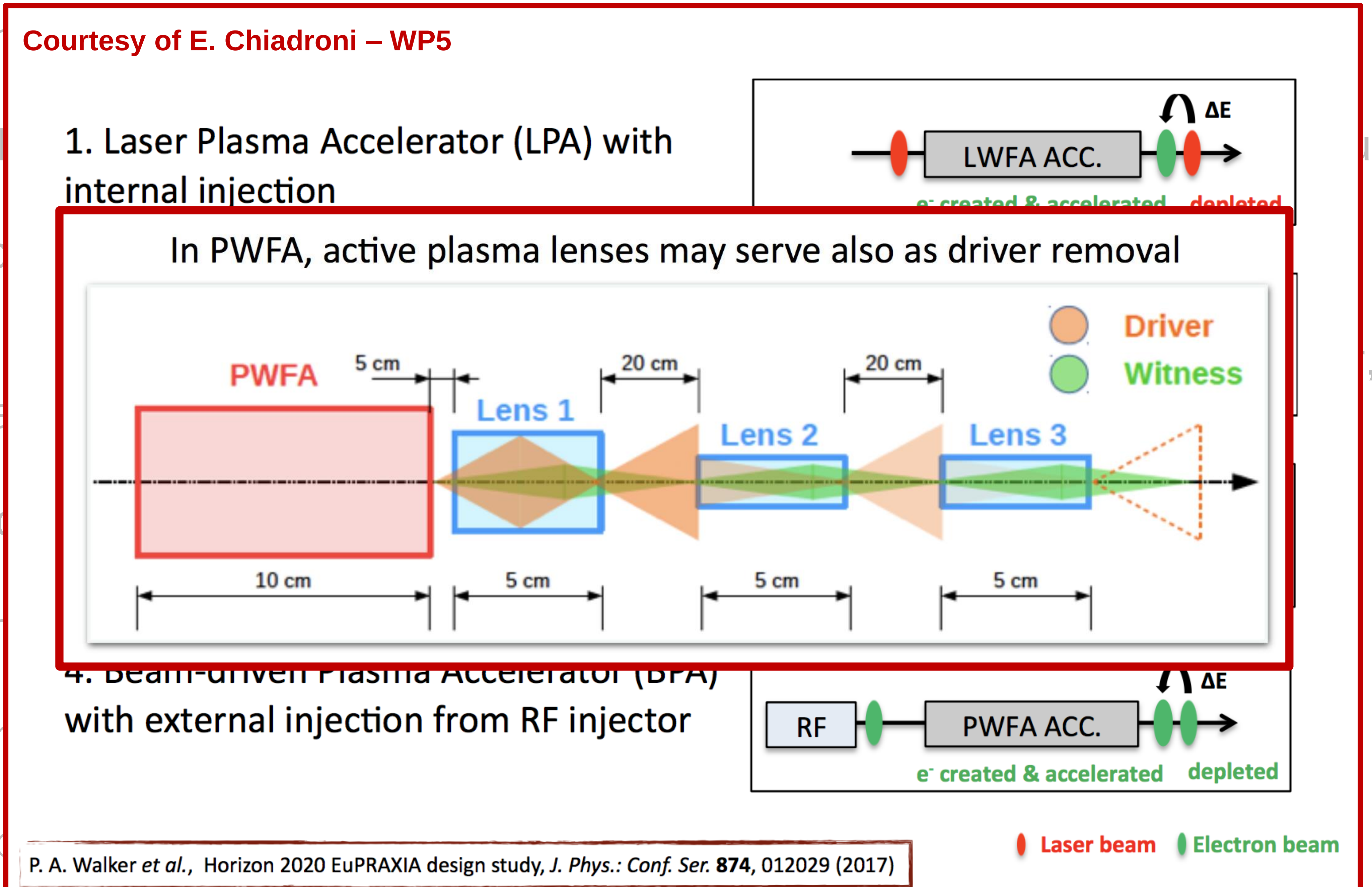

Needed experiments

- Slice energy spread of plasma accelerated beam (~3fs slice for 1nm radiation)
- Schemes for selected issues (e.g. driver removal, **resonant multiple laser pulses**)
-
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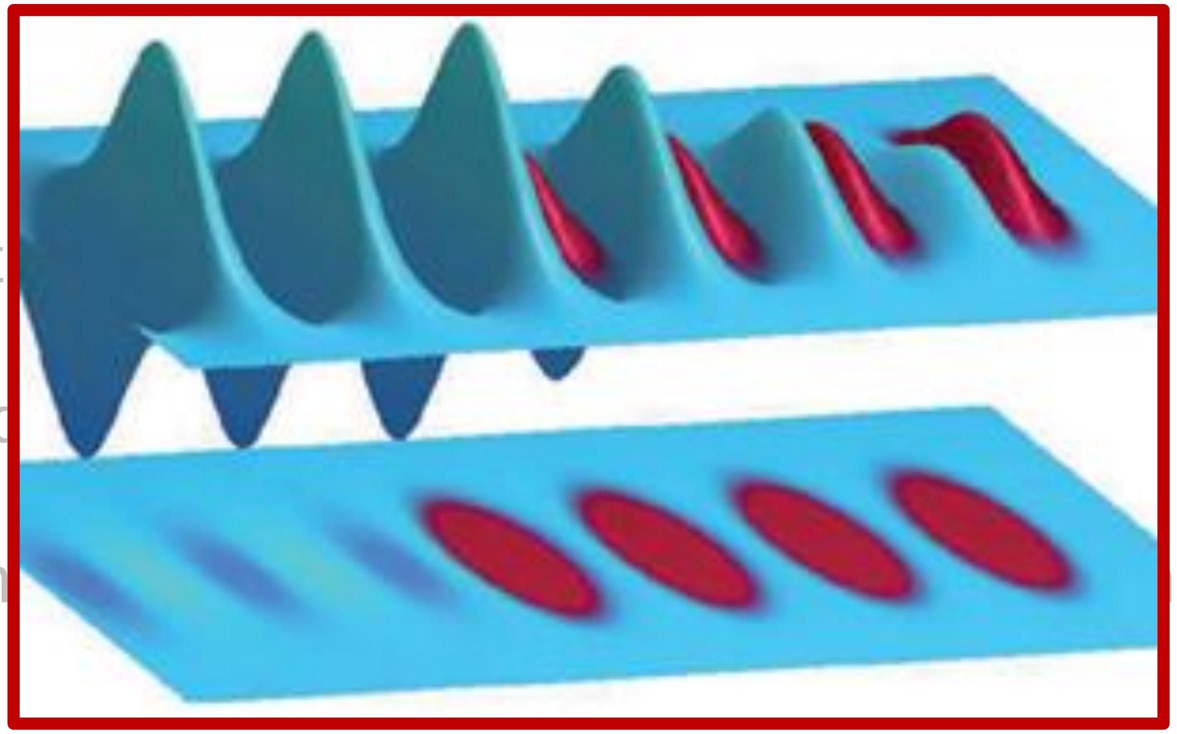
-
- Advanced devices (e.g. de-chirper for passive streaking)
- Feedback control (pointing, temporal, phase..)

Multi-pulse Wakefield Acceleration: **Oxford experiment with CLF's Astra laser**

Typically, nonlinear wakefield excitation requires a **single, high intensity laser pulse** from a sub-PW-class laser.

This work demonstrated that plasma wakefields can be driven by a **train of correctly spaced, low energy (10s mJ), short (~50 fs) laser pulses**.

This discovery could facilitate the use of emerging laser technologies, offering the prospect of plasma accelerators operating at multi-kHz repetition rates



Phys. Rev. Lett, **119**, 044802 (2017)

Needed experiments

- Slice energy spread of plasma accelerated beam (~3
- Schemes for selected issues (e.g. driver removal, res

Eli-beamlines group will test CTR bunch length measurement at SPARC-LAB

- Switching options for driver and witness at low energ
- **Compact advanced diagnostics and new ideas**
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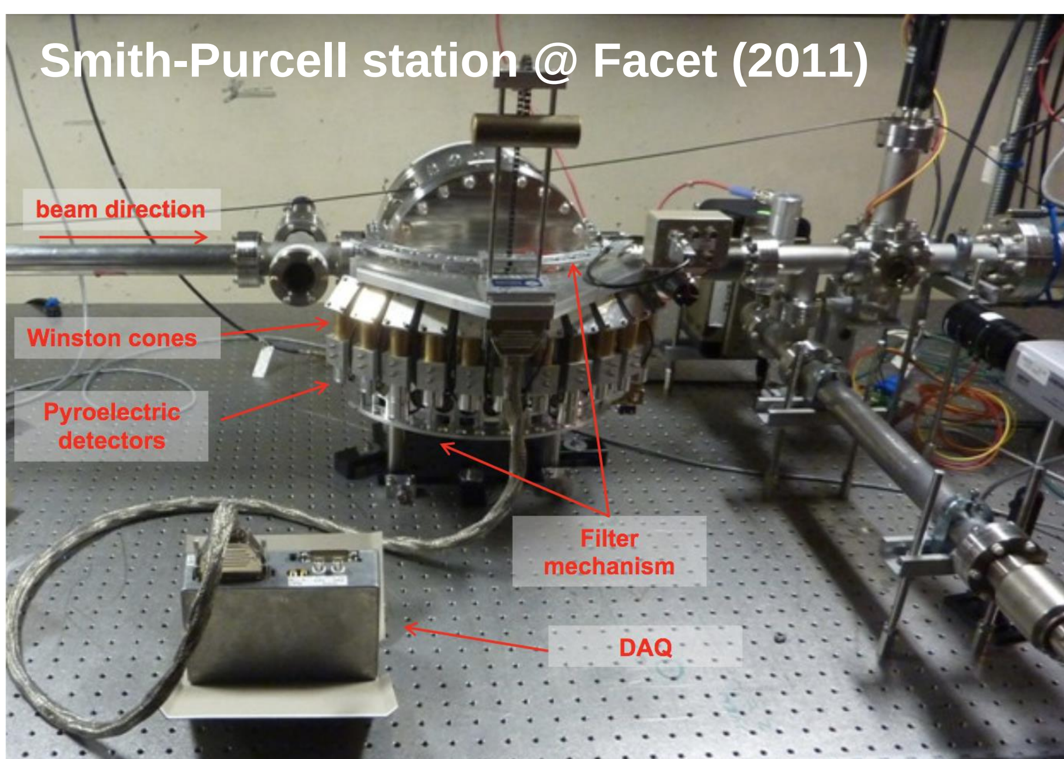
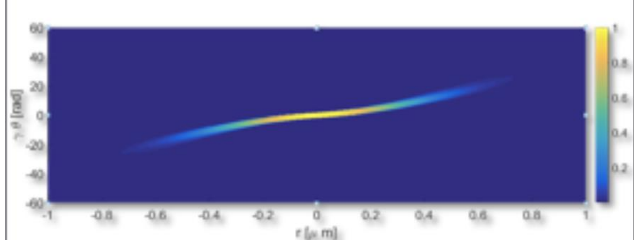
- or pas
- Feedback control (pointing, temporal, phase..)



betatron radiation

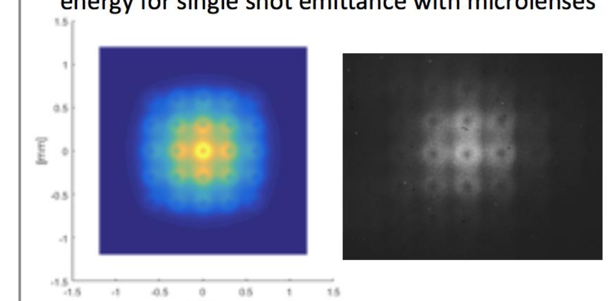
- Phase space reconstruction by means of Betatron radiation + simultaneous measurement of electron energy spectrum
- Normalized rms emittance (correlated): 0.6 mm mrad
- Normalized rms emittance (non correlated, upper limit): 1.6 mm mrad

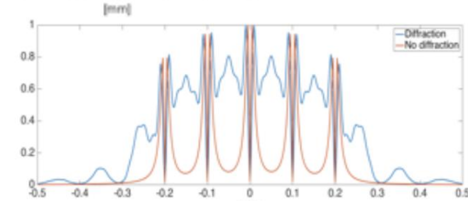


Curcio, A., et al. “

diffraction radiation

- Improving side effects computations
- Considering also diffraction contributions at high energy for single shot emittance with microlenses





Cianchi, A., et al. "*Transverse emittance diagnostics for high brightness electron beams.*" Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **865** (2017): 63-66.

Courtesy of E. Chiadroni – WP5

Needed experiments

- Slice energy spread of plasma accelerated beam (~3fs slice for 1nm radiation)
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- …nje
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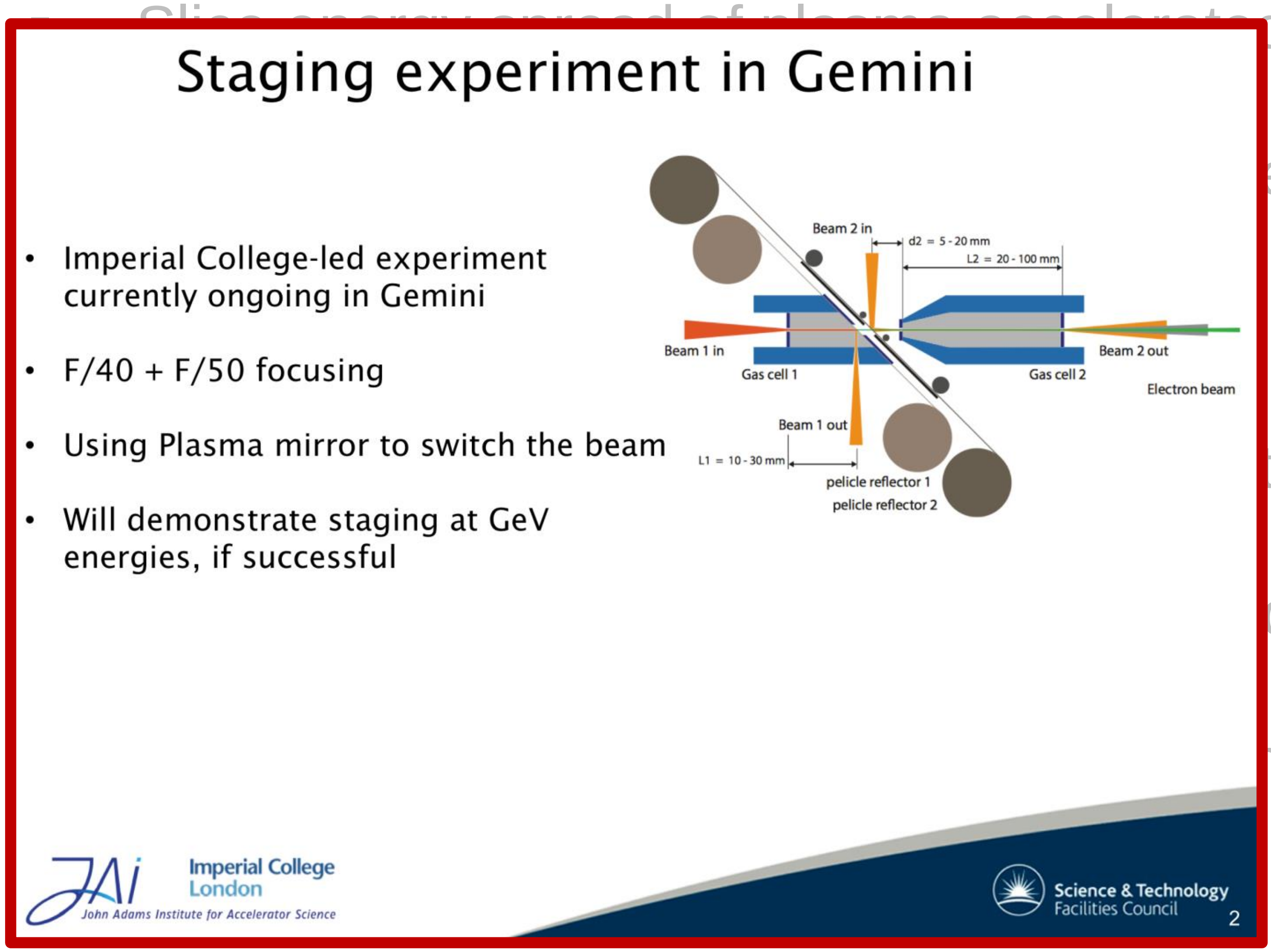
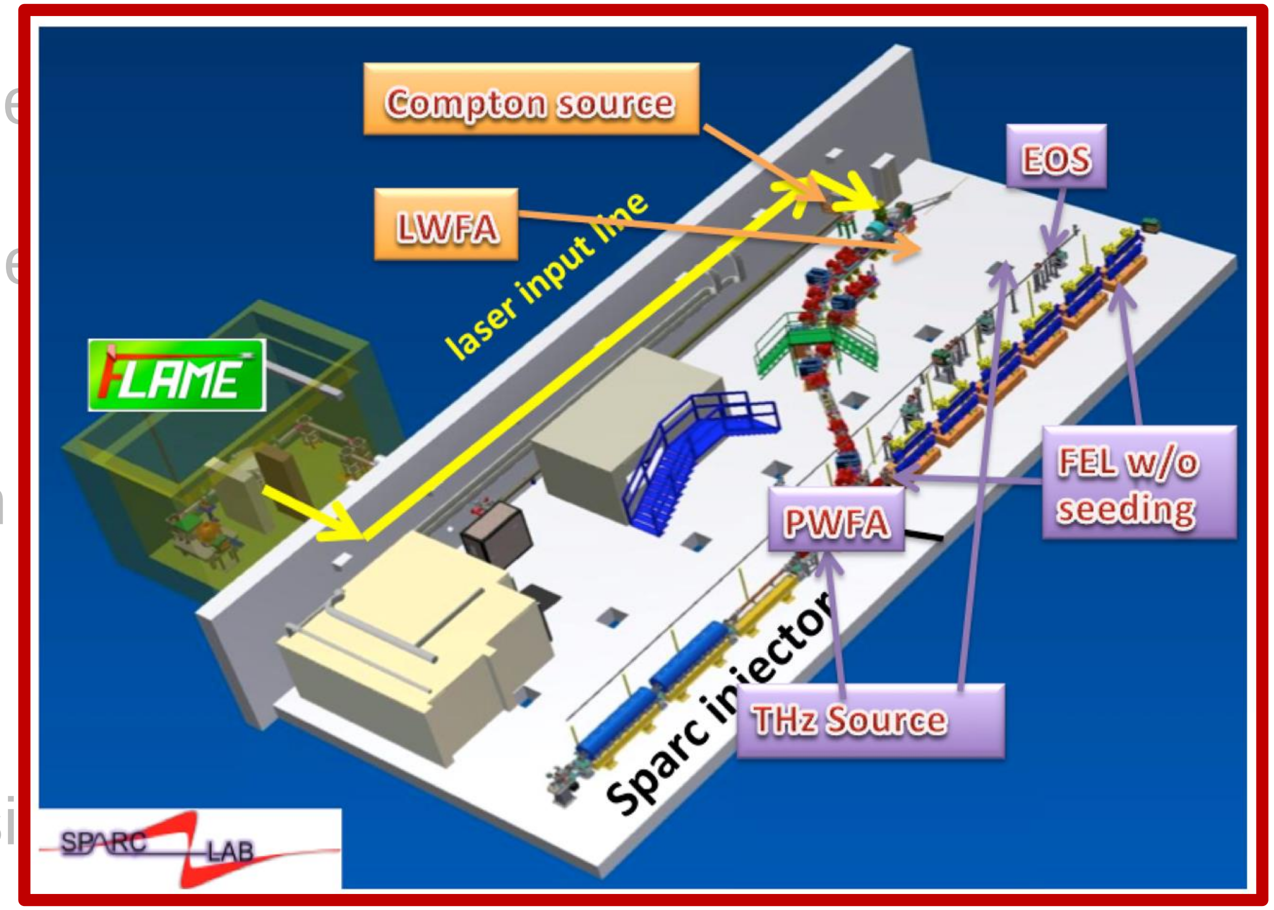




Needed experiments

Courtesy of P. Krejcik – IBIC17

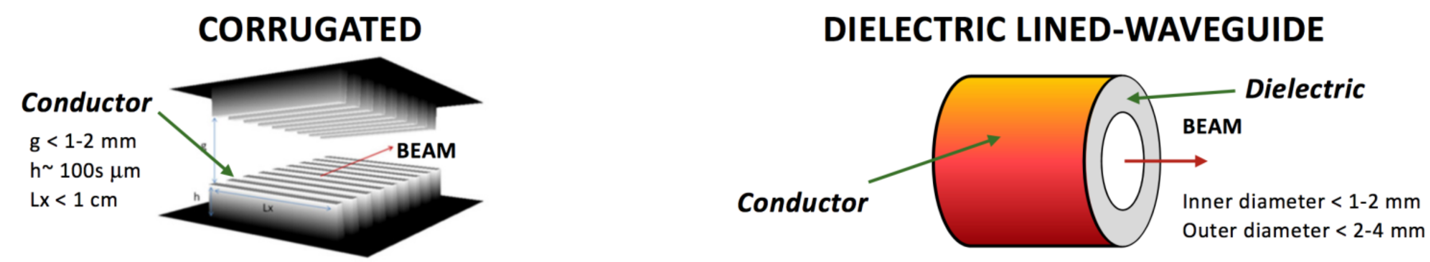
d beam (~3fs slice for 1nm radiation)

emoval, resonant multiple laser pulses)

low energy, preserving beam qualities.

deas

- Stability of different schemes for p oscillations)



- High charge (higher than few tens

Courtesy of S. Bettoni – IPAC17

- Synchronization for external inject

More typically corrugated →

Flat	Round
Easily tunable	More difficult to tune
Reduced amplitude (by $\pi^2/16$)	Maximum amplitude

← More typically dielectric lined

- **Advanced devices (e.g. de-chirper for passive streaking)**
- Feedback control (pointing, temporal, phase..)

Needed experiments

- Slice … ation)
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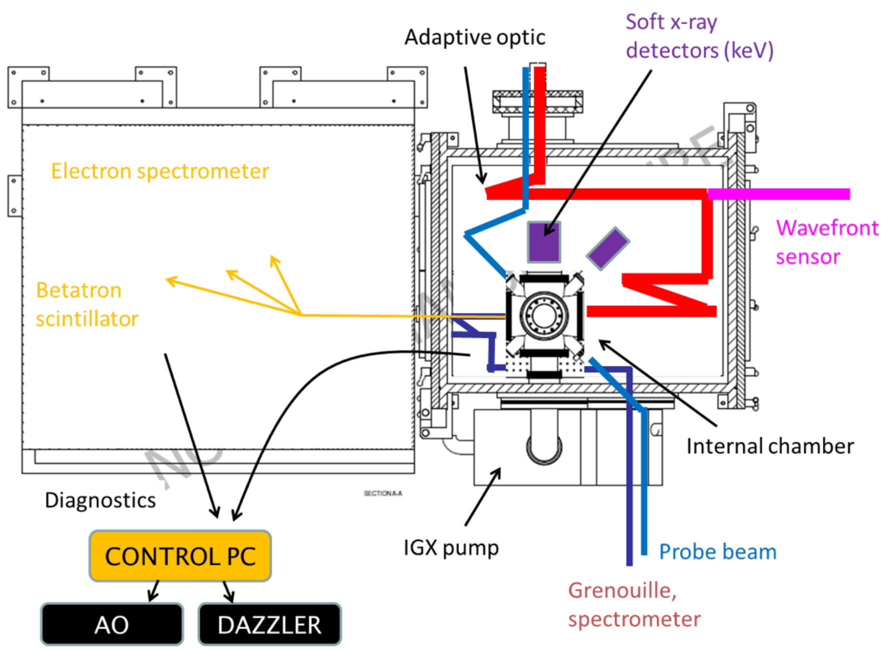
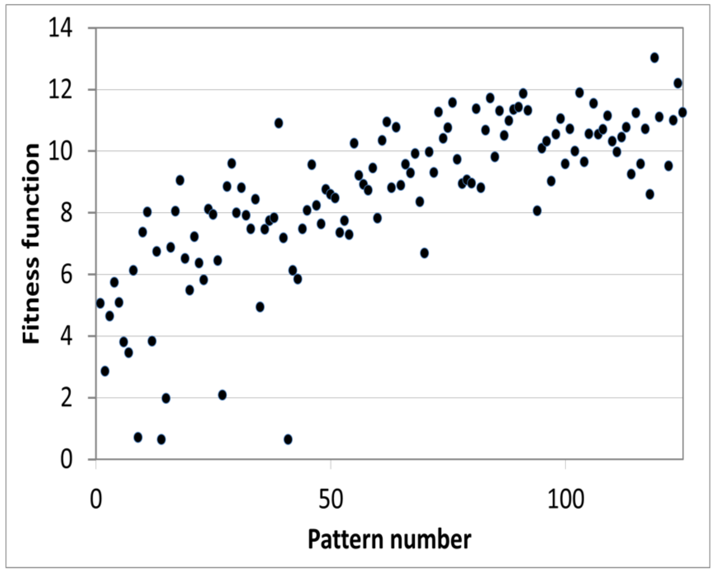
- Sync
- Adva

Testing Feedback control of electron acceleration at 5Hz

- Experiment with a 15TW laser (Astra)
- Genetic algorithm feedback to control spatio-temporal properties of the driving laser pulse
- Optimising x-ray and 100 MeV electron generation





- Fitness function defined to maximise th signal in an energy “bucket” 90 – 110 MeV
- Overall increase in beam charge

http://www.clf.stfc.ac.uk/

Science & Technology Facilities Council

- Feedback control (pointing, temporal, phase..)

Needed experiments

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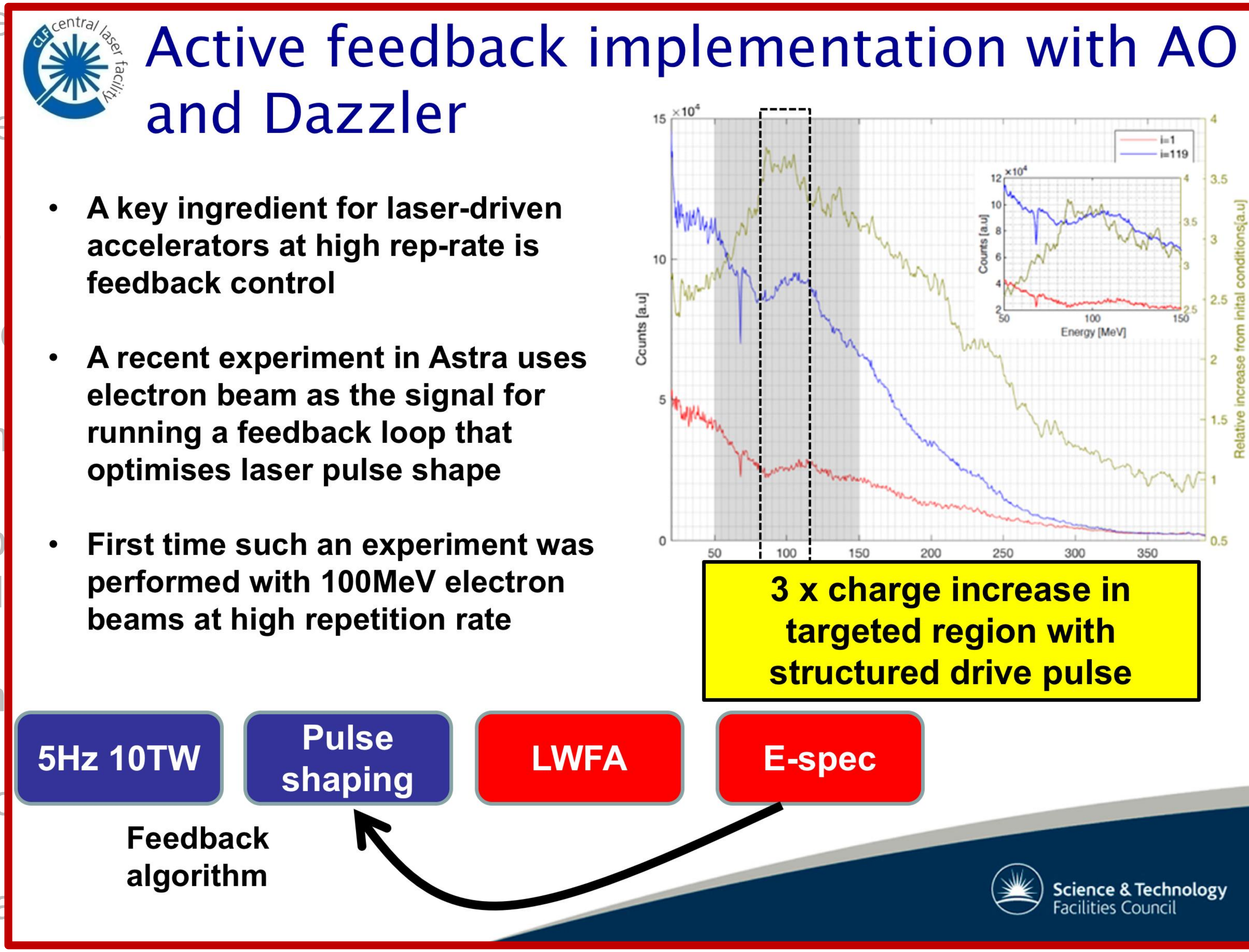

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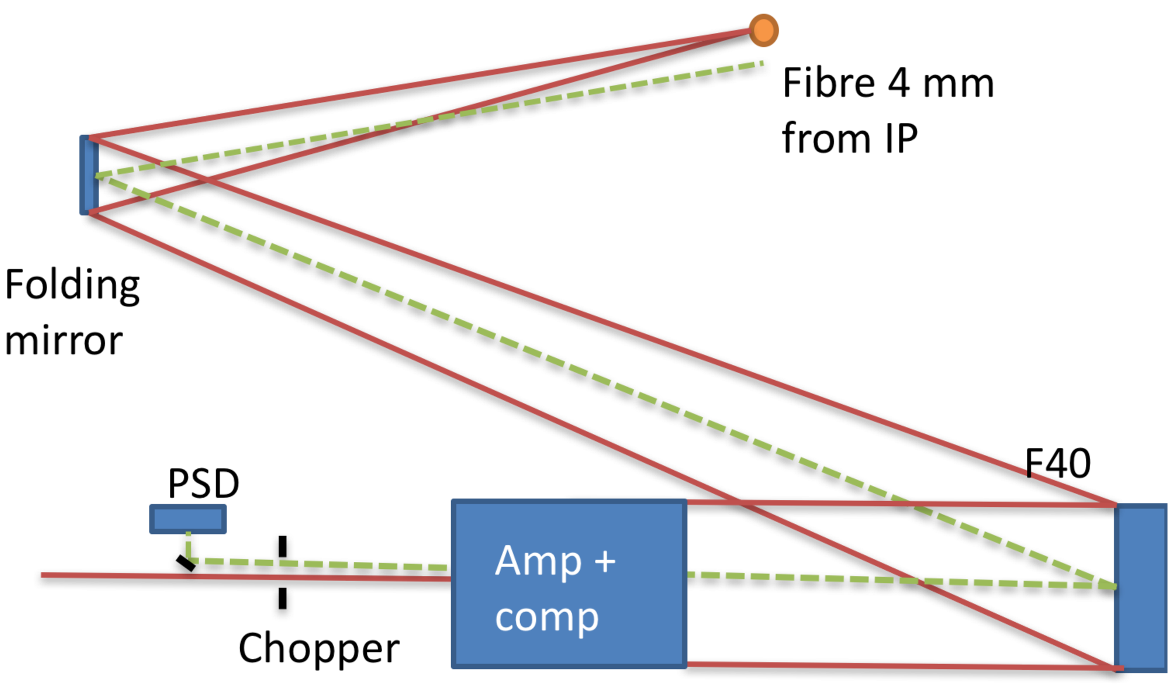
Beam-stabilisation update

- Focus of each Gemini beam moves up to approximately 10 focal spot diameters. We aim to get to 0.1 focal spot diameters
- Scheme is to use a pilot CW laser to monitor vibrations in the laser chain, and correct for these with a piezo driven mirror.
- Proposed scheme will use counter propagating laser.



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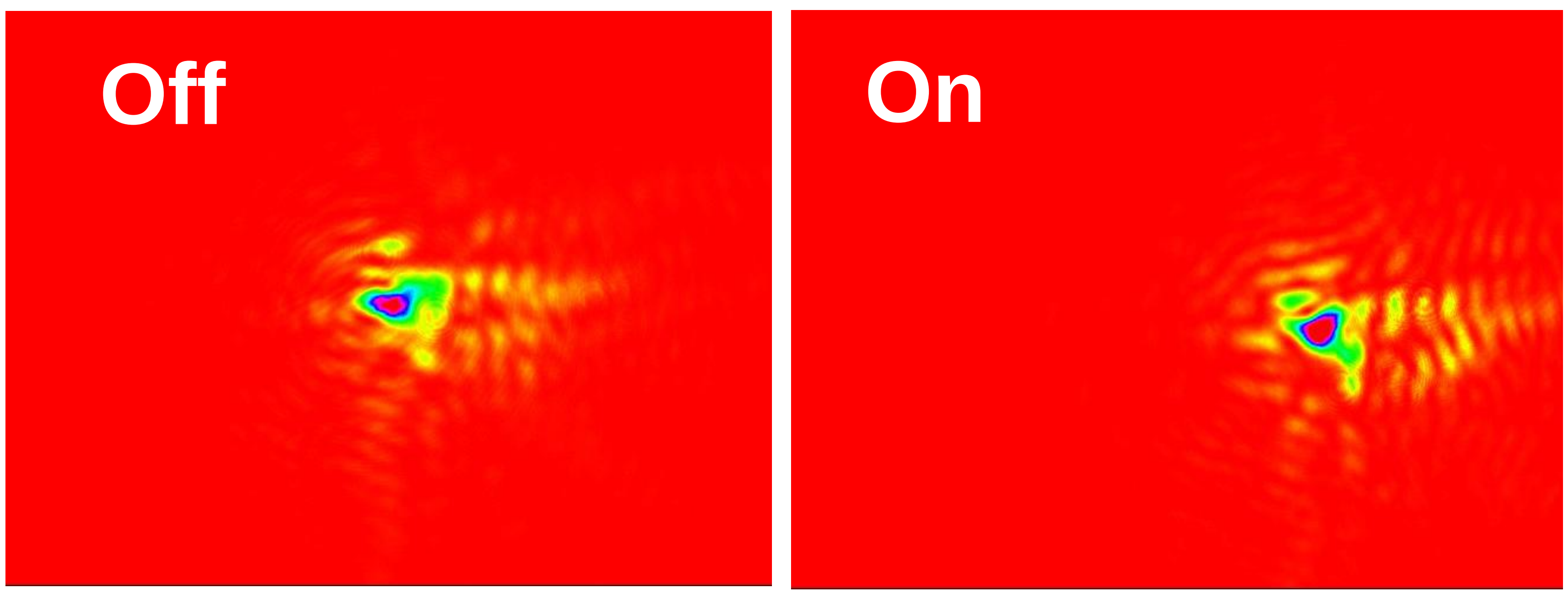
- Adva…

Stabilisation with counter-propagating beam originating 4 mm offset from interaction point

3-4 focal spots

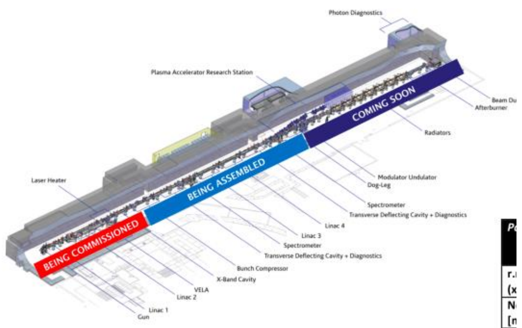


Tests are ongoing currently.
Looking to implement in January

- Feedback control (pointing, temporal, phase..)

vocal-external.liv.ac.uk/sites/eupraxia

- CLARA is a purpose built dedicated flexible FEL Test Facility
- A scaled down version of an X-ray FEL containing all of the key technical components, where all lessons learnt can be directly applied to any future UK XFEL.



Accelerator Research and Innovation for European Science and Society

High Brightness Electron Photo-injector
research facility with high brightness electron beams (particle driven particle acceleration, FEL, Compton Source, THz source, advanced diagnostics …)

Energy	30-180 MeV
Energy Spread	< ~ 0.1%
charge	10 pC - 1nC
bunch length	10 fs -10 ps
Rep rate	10 Hz

plasma interaction chamber installed on the beam line
FEL undulators aligned with the plasma chamber
Compton interaction point
External injection text stand in construction
Ongoing activities
PWFA, active plasma lens, THz source, advanced diagnostics

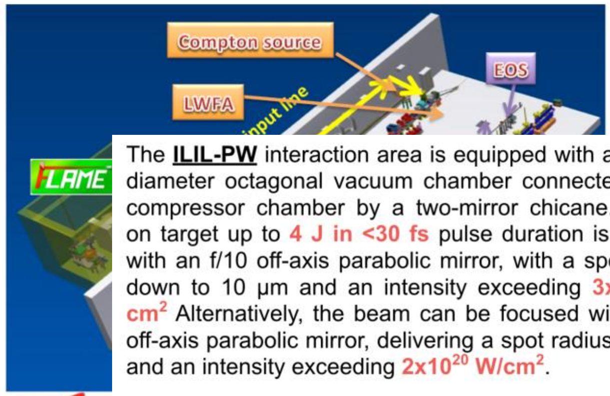
300 TW class laser
self injection electron beam, betatron radiation

Rep rate	10 Hz
Wavelength	800 nm
Energy (after compression)	7J
Pulse duration	~25fs
Synchronisation with Linac	~50 fs
Beam quality	M2<1.5
Energy stability	<1.5%

Ongoing activities
LWFA, TNSA, advanced diagnostics

SPARC LAB INFN

Access: collaboration



The ILIL-PW interaction area is equipped with a 140 cm diameter octagonal vacuum chamber connected to the compressor chamber by a two-mirror chicane. Energy on target up to 4 J in <30 fs pulse duration is focused with an f/10 off-axis parabolic mirror, with a spot radius down to 10 μm and an intensity exceeding 3×10^{19} W/cm^2 Alternatively, the beam can be focused with an f/3 off-axis parabolic mirror, delivering a spot radius of 3 μm and an intensity exceeding 2×10^{20} W/cm^2.

The ILIL-TW interaction area is equipped with two 80 cm diameter interaction vacuum chambers. One of th interaction chamber is configured with an f/10 off-ax parabolic mirror, with an energy on target of 400mJ in 35 fs pulse duration and a focal spot radius of 10 μ for an intensity of 3×10^{18} W/cm^2. The set up is optimize for repetitive operation (1Hz) of LWFA in the multi ten of MeV electron energy for applications, gamma-ra generation and detector tests and development. Th other chamber is configured with an f/3 off-axis parabo mirror, with an energy on target of 400mJ in a 35 pulse duration and a focal spot radius of 3 μm, for a intensity of 2×10^{19} W/cm^2.

Intense laser Irradiation Laboratory (ILIL)
Istituto Nazionale di Ottica
CNR
Pisa, Italy

Petawatt lasers at 10 – 100 Hz

hilase

- 100J, 10Hz system; delivered for the Czech "Hilase" project
- "Delivering another to the European XFEL in Hamburg - will be installed in 2017
- Upgrading Gemini using DiPOLE technology under consideration
- A 10J, 100Hz laser under development for Widespread Teaming

Science & Technology Facilities Council

Please review or send information in the website

List of the available facilities

	Contact name	Contact email
STFC-RAL (Gemini)	Dan Symes	dan.symes@stfc.ac.uk
LULI (Elfie)	Arnd Specka	specka@llr.in2p3.fr
CILEX (APOLLON*)	Arnd Specka	specka@llr.in2p3.fr
ELI-BEAMS*	Georg Korn	georg.korn@eli-beams.eu
ELI-ALPS*	Karoly Osvay	osvay@physx.u-szeged.hu
HI-JENA (JETI)	Matt Zepf	m.zepf@uni-jena.de
LLC-LUND	Claes-Göran Wahlström	claes-goran.wahlstrom@fysik.lth.se
LOA	Victor Malka	victor.Malka@ensta.fr
SLIC	Pascal d'Oliveira	pascal.doliveira@cea.fr
CELIA	Stéphane Petit	stephane.petit@celia.u-bordeaux.fr
SCAPA	Mark Wiggins	mark.wiggins@strath.ac.uk
Oxford University	Simon Hooker	Simon.Hooker@physics.ox.ac.uk
Imperial College London	Zulfikar Najmudin	z.najmudin@imperial.ac.uk
ILIL Pisa	Leo Gizzi	la.gizzi@ino.it
LMU/MPQ	Stefan Karsch	stefan.karsch@mpq.mpg.de
HZDR Dresden	Ulrich Schramm	u.schramm@hzdr.de
LUX	Andreas Maier	andreas.maier@desy.de
SINBAD*	Urlich Dorda	ulrich.dorda@desy.de
SPARC_LAB	Massimo Ferrario	massimo.Ferrario@lnf.infn.it

vocal-external.liv.ac.uk/sites/eupraxia

Access to facility

User facilities Direct application	Laserlab facilities Laserlab application	Other facilities Collaborative agreement
STFC-RAL	HI-JENA	SCAPA
LULI	LLC-LUND	ICL
STFC-DL	LOA	OXF
	SLIC	QUB
	CELIA	CNR-PISA
		SPARC_LAB (INFN)
		LUX
		MPQ
		HZDR-DRESDEN

Problem

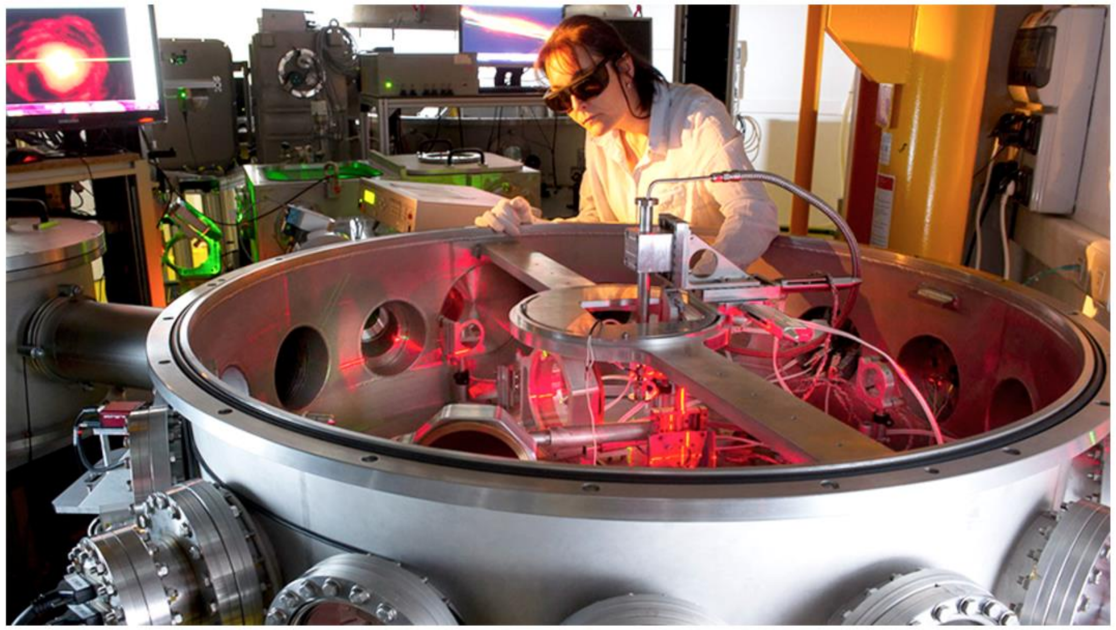
The experiments useful for Eupraxia may not be eligible

ARIES

Accelerator Research and Innovation for European Science and Society

FLASHForward

WP13: Plasma beam testing



The LPA-UHI100 versatile and user friendly environment for Laser Plasma Acceleration studies at LIDYL (Image: Ph. Stroppa)

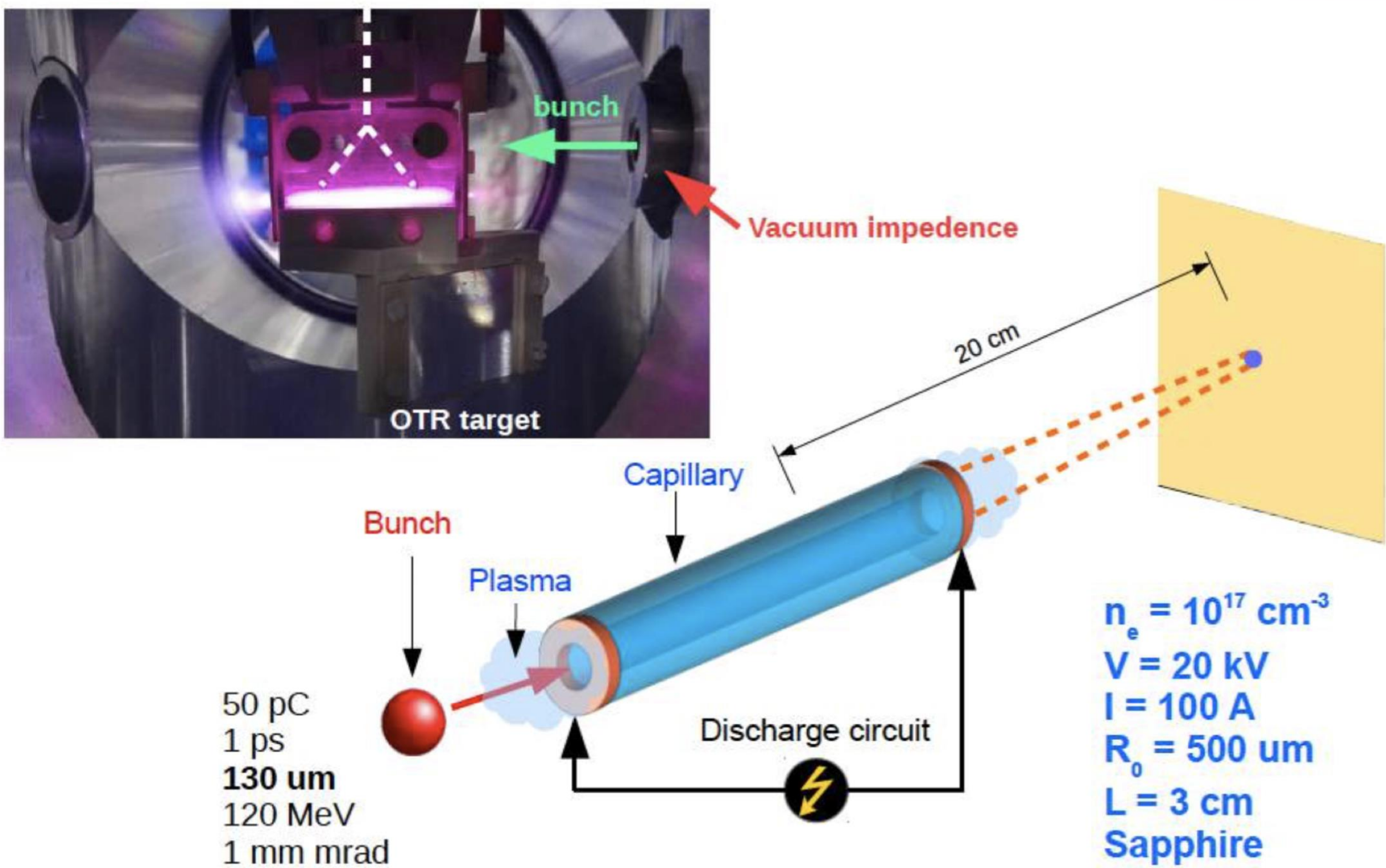
Objectives

- Coordinate and monitor WP13 activities
- To provide transnational access to plasma beam testing facilities
  - APOLLON at
  - LPA-UHI100 at
  - LULAL at Lund

Tasks

Task #	Task name	Task leader
13.1	APOLLON	Brigitte Cros (CNRS)
13.2	LPA-UHI100	Brigitte Cros (CNRS) Sandrine Dobosz Dufrenoy (CEA)
13.3	LULAL	Olle Lundh (Lund University)

Plasma lens



A. Marocchino et al., *Experimental characterization of the effects induced by passive plasma lens on high brightness electron bunches*, APPLIED PHYSICS LETTERS 111, 184101 (2017)

Plasma lens

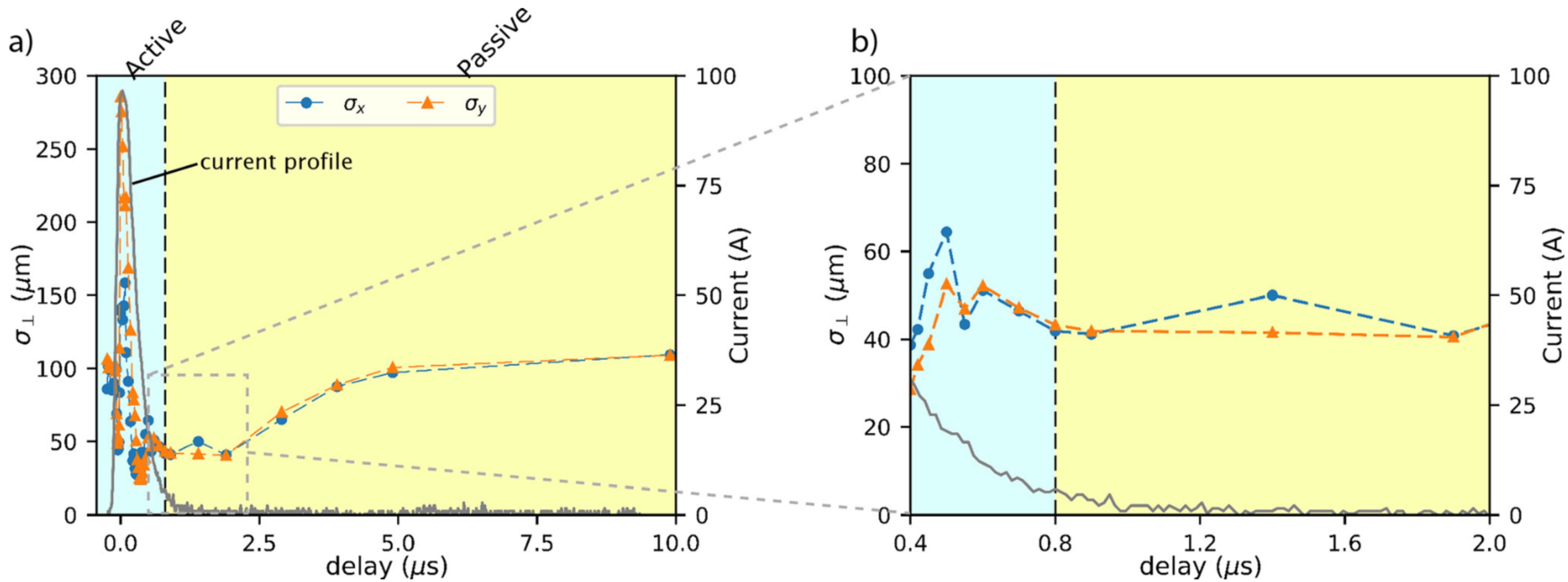


FIG. 2. Measurements of the transverse bunch rms-dimension as a function of the current delay time. Blue circles correspond to σ_x, dark yellow triangles to σ_y, while the current profile is overimposed in gray color. Sub-figure (a) plots the entire experimental scan, and subsection (b) focuses on the delay of 0.4–2.0 μs, the early phase of the active lens, characterized by a constant focusing gradient. Rms-dimensions were measured at the first screen, 17.5 cm from the capillary center. Background colors have been used to identify the *Active lens*, light blue, and *Passive lens*, light yellow. Subplot (b) is a zoom-in image for the time-interval (0.4 μs, 2 μs).

A. Marocchino et al., *Experimental characterization of the effects induced by passive plasma lens on high brightness electron bunches*, APPLIED PHYSICS LETTERS 111, 184101 (2017)

Plasma lens

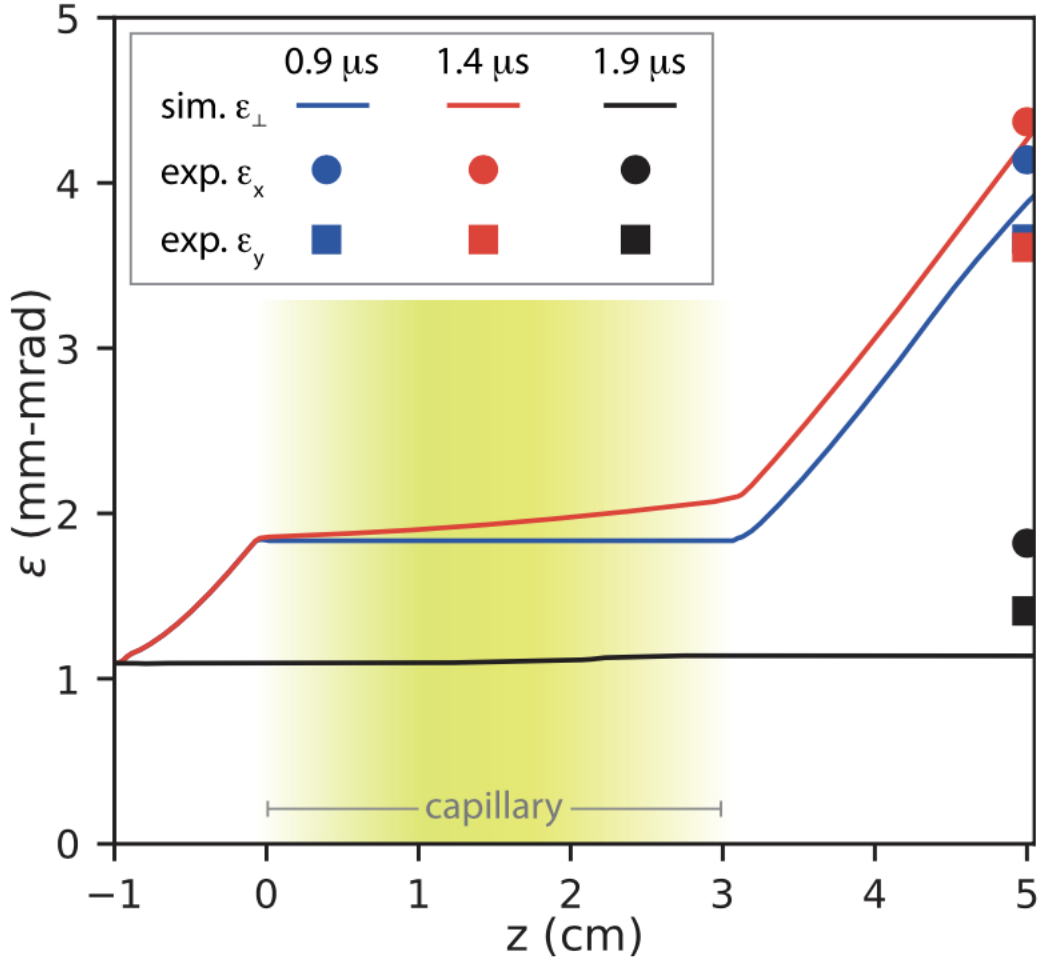
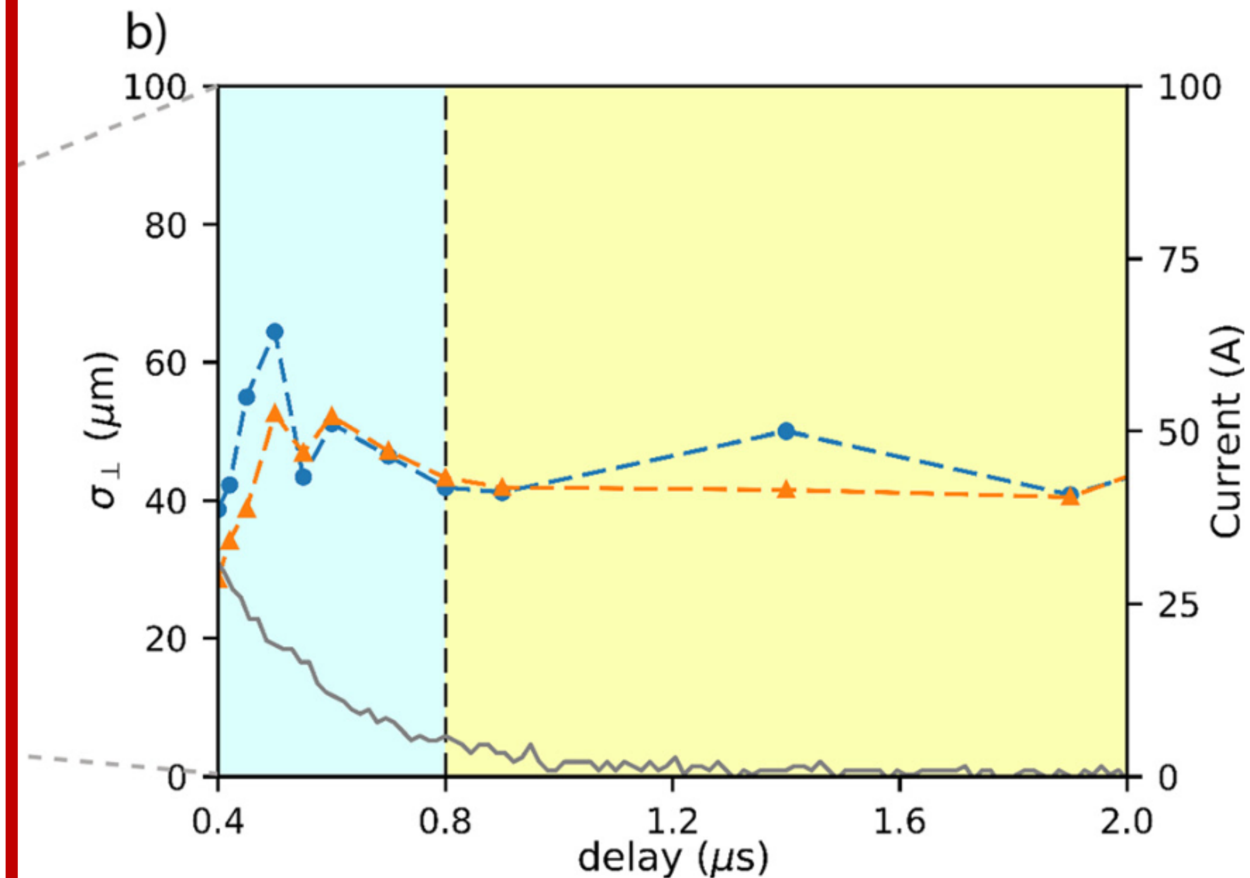


FIG. 5. Plot of the normalized transverse rms-emittance as a function of z. The numerically computed emittance is plotted with a solid line, and the experimental values are reported on the right edge. The ε_x experimentally measured quantities are reported with a circle and ε_y with a square.



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A. Marocchino et al., *Experimental characterization of the effects induced by passive plasma lens on high brightness electron bunches*, APPLIED PHYSICS LETTERS 111, 184101 (2017)

Conclusions

- **Experimental program** in EuPRAXIA partners is interesting and **can be very useful** in the assessment of the EuPRAXIA design study
- WP12 is progressing. The main difficulties are due to the **planning of experiments** that must take into account hosting laboratories priorities.
- **Benchmarking code against measurements** is starting
- Master students?

Thank you for your attention

- Slice energy spread of plasma accelerated beam (~3fs slice for 1nm radiation)
- Schemes for selected issues (e.g. driver removal, resonant multiple laser pulses)
- Plasma based beam dump
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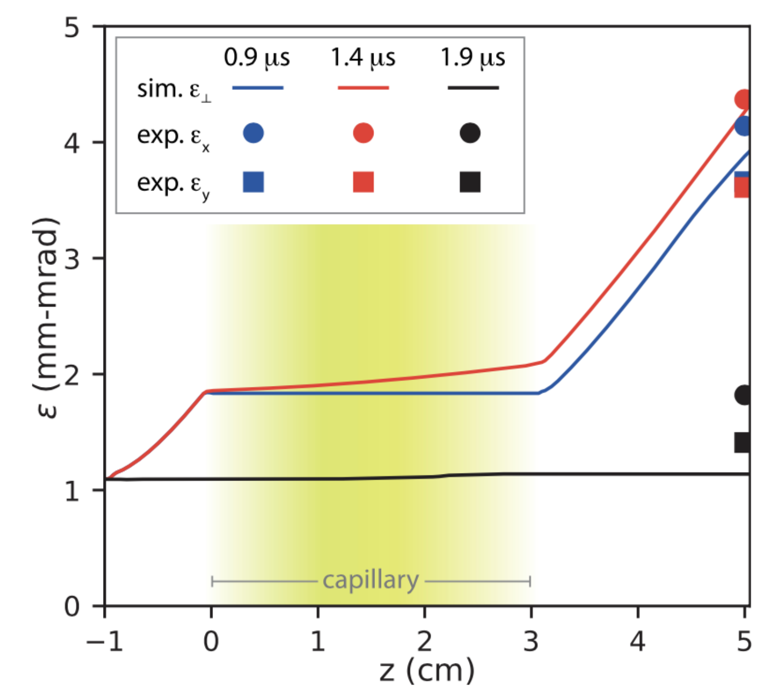

FIG. 5. Plot of the normalized transverse rms-emittance as a function of z. The numerically computed emittance is plotted with a solid line, and the experimental values are reported on the right edge. The ε_x experimentally measured quantities are reported with a circle and ε_y with a square.