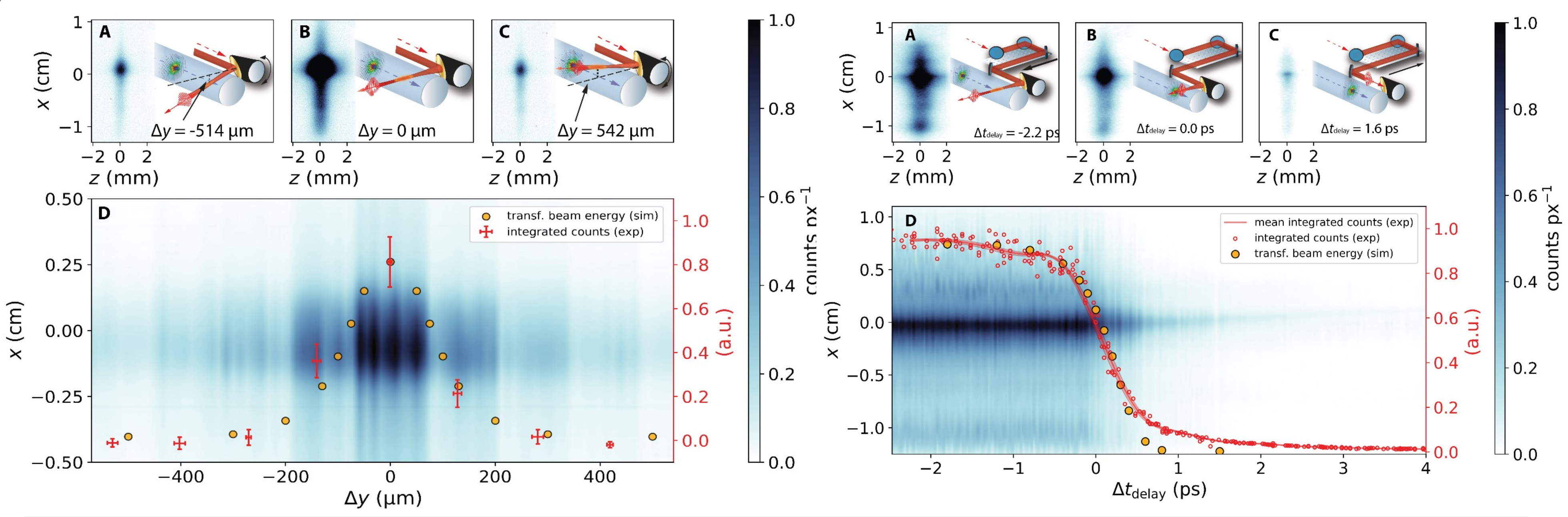
Plasma afterglow metrology at CLARA

A.J. Nutter[1,2,3], D. Angal-Kalinin[4], O. Apsimon[3,5], L. Boulton[1,3,6], A. Gleeson[4], T. Heinemann[1,6,7], H. Jones[3,8], G.G. Manahan[1], A. Matrallain[1], T. Pacey[4], L. Reid[3,8], P. Scherkl[1,3], E. Snedden[4], A. Sutherland[1,9], D. Walsh[4], D. Ullmann[1,3], A. Knetsch[6], L. Corner[3,8], A. Irman[2], U. Schramm[2,10], J. Cary[11], M. Hogan[12], V. Yakimenko[12], J. B. Rosenzweig[9], B. Hidding[1,3]

[1] University of Strathclyde
[2] Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
[3] The Cockcroft Institute
[4] Science and Technology Facilities Council ASTeC
[5] University of Manchester
[6] Deutsches Elektronen-Synchrotron (DESY)
[7] University of Hamburg
[8] University of Liverpool
[9] University of California, Los Angeles (UCLA)
[10] Technische Universität Dresden
[11] University of Colorado Boulder
[12] SLAC National Accelerator Laboratory

Motivation and the E210 Campaign

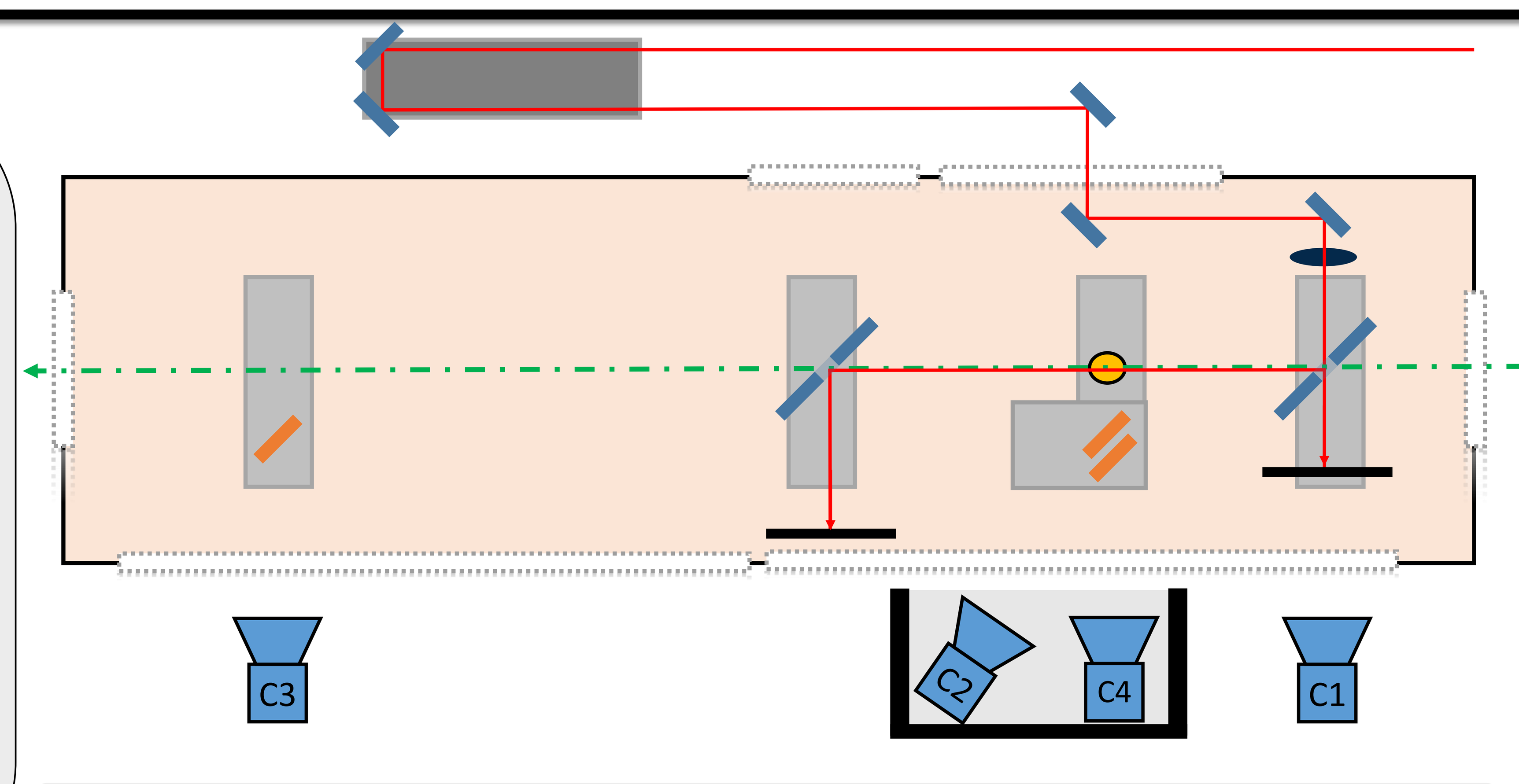


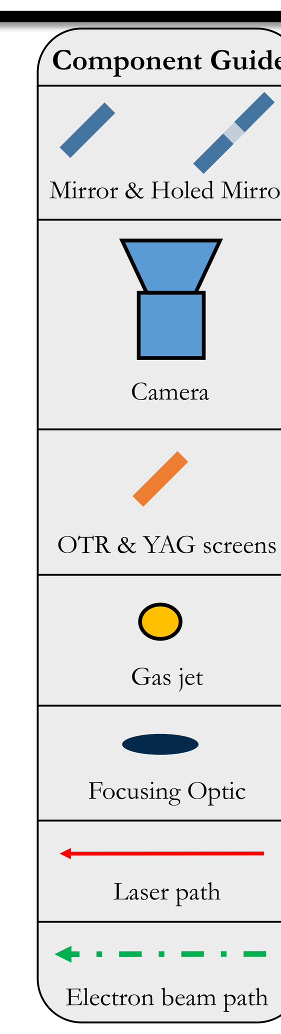
Results from the spatial and temporal misalignment scans conducted during the E210 campaign.

Plasma afterglow metrology offers a novel spatiotemporal diagnostic tool for the alignment of laser and electron beams. Measurements of the integrated intensity of the plasma afterglow allow phenomena on the femtosecond-micrometer scale to be observed over microsecond-millimetres. Successful experimental demonstration was achieved as part of the E210 campaign at SLAC [1]. Misalignment scans were conducted by varying the laser pointing and arrival time, allowing spatiotemporal alignment of femtosecond-micrometer precision to be achieved between laser and electron beam. This degree of precision is key for a number of potential applications, notably the underdense plasma photocathode "Trojan Horse" injection scheme for PWFA [2].

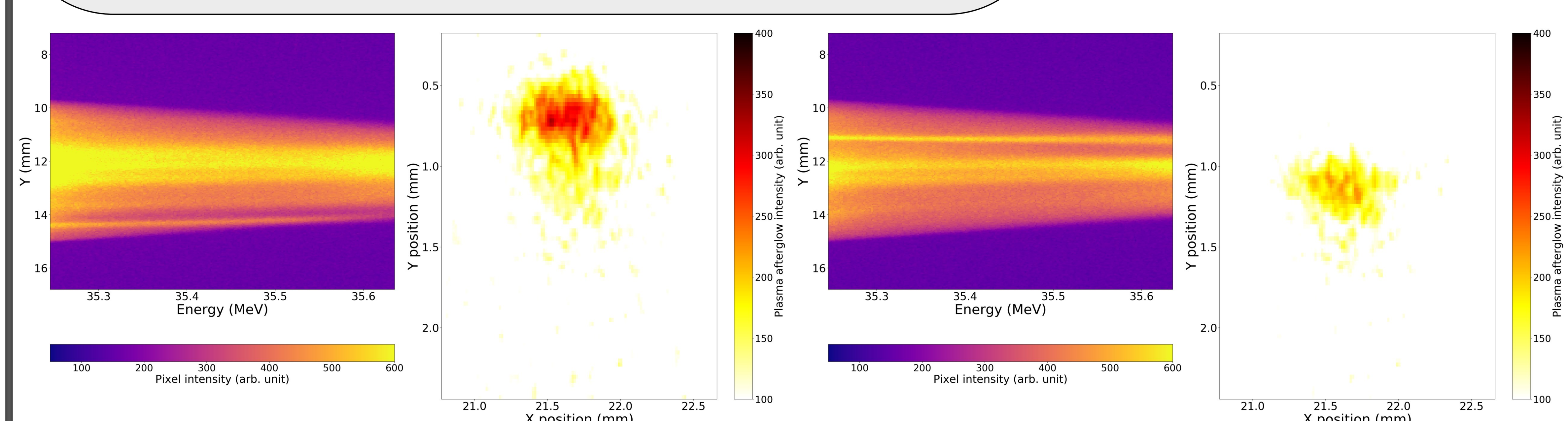
The CLARA experimental campaign

Recent results from the CLARA facility, part of the Daresbury Laboratory, have continued this work on plasma afterglow metrology. The setup is seen to the right, and features co-propagating beams with the Argon gas jet positioned at 90° to both. The pointing of the laser pulse was varied by tilting the first holed mirror, allowing the plasma position to be altered. A horizontal high intensity filament was observed within the downstream electron spectrometer images, indicating partial plasma lensing, the position of which was dependant upon the position of the plasma. Additionally, the presence of a low intensity tail within the plasma afterglow signal has shown potential for application as a plasma lifetime diagnostic. Work is ongoing to confirm both of these results with simulations, and to assess their scope for future investigation.

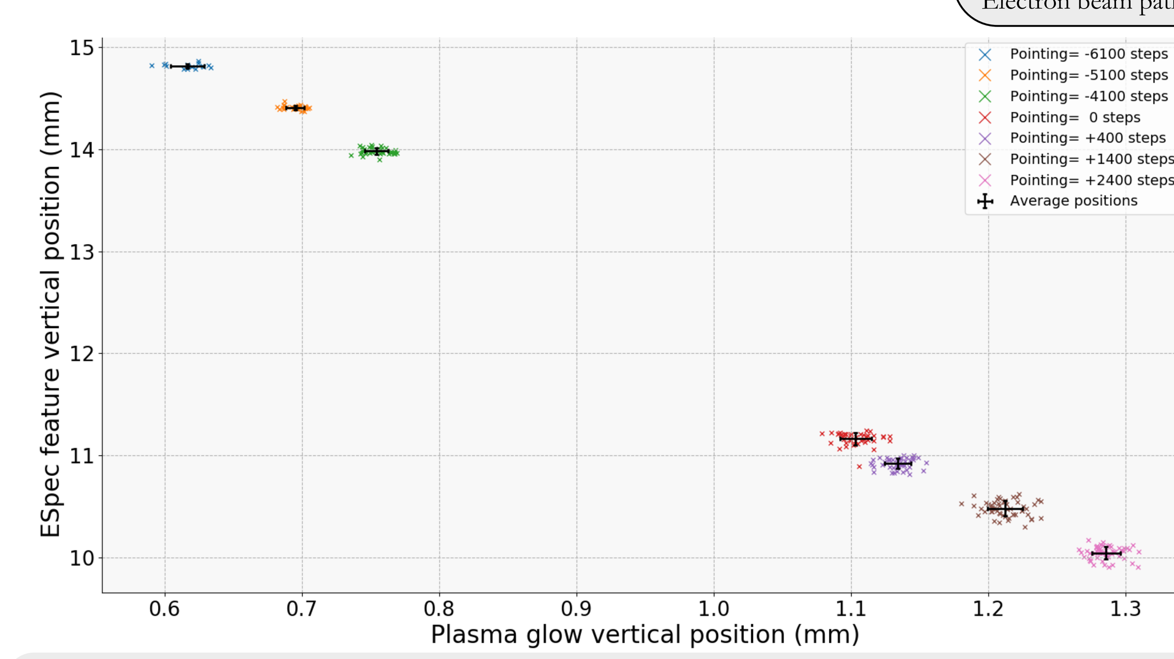




Overview of the experimental setup used during the CLARA experimental campaign.



The plasma lensing feature appears as the horizontal high intensity filament seen within the electron spectrometer images, alongside the plasma afterglow.



Correlation between the positions of both the lensing feature and the plasma afterglow.

Upcoming experiments and Future work

VARIOUS FACILITIES [3][4][5]

Facility	Beam energy	Beam charge	RMS Beam dimensions
ASTeC	35 MeV	100pC	100 x 120 x 100 μm
HZDR / Helmholtz Zentrum Dresden Rossendorf	200 - 300 MeV	100 - 500pC	1 x 5 x 5 μm
SLAC	10 GeV	2nC	16 x 16 x 16 μm

A number of upcoming experiments aim to continue the development of plasma afterglow metrology. Plans for the first implementation of this diagnostic within a hybrid laser-plasma wakefield acceleration (LPWFA) experiment are currently ongoing at the HZDR facility. The recently commissioned FACET II facility at SLAC will host the E315 experiment, which will build upon the previous work done there. Additions to the setup will aim to extend the capabilities of the diagnostic to more than the spatiotemporal alignment demonstrated during E210. Experimental work will also continue in 2020 at the CLARA facility, where further investigation into the previously discussed results will be done. The disparity between these three experimental facilities and their capabilities demonstrates the eventual goal of wide applicability for plasma afterglow as a metrological tool.

References

[1] P.Scherkl et al. (2019). arXiv:1908.09263
[2] A.Deng & O.Karger et al. (2019). *Nature Physics.*
[3] J. Couperus et al. (2017). *Nature Communications*, 8(1).
[4] T. Heinemann et al. *IPAC'17*. Paper TUPIK010.
[5] (2016). Technical Design Report for the FACET-II Project at SLAC National Accelerator Laboratory

Contact details

University of Strathclyde, Department of Physics
107 Rottenrow E, Glasgow G4 0NG
Alastair Nutter, alastair.nutter@strath.ac.uk

FACET-II Facility for Advanced Accelerator Experimental Tests