WG5: Plasma devices, plasma and beam diagnostics

N. Delerue & R. D’Arcy
on behalf of all WG5 speakers

WG5 topics

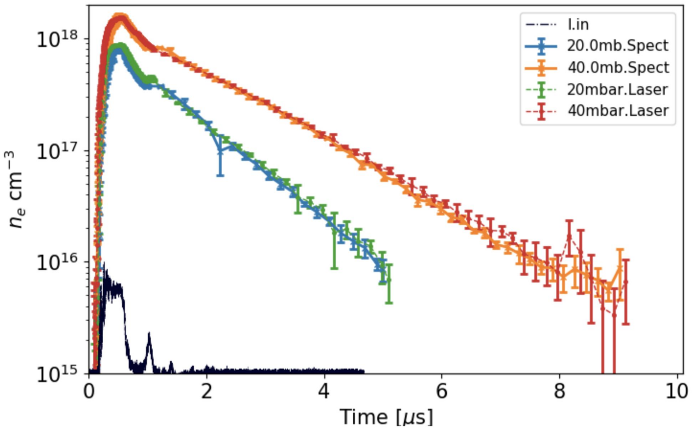
- Plasma diagnostics
    - Cold plasma
    - Wakefield characterisation
    - Plasma optimisation
    - Post-plasma characterisation
- Beam diagnostics
    - Charge and energy
    - Transverse diagnostics
    - Longitudinal diagnostics
    - Machine learning
- Plasma applications

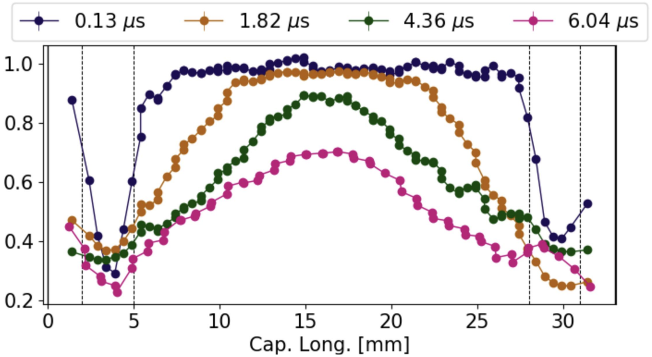
Cold plasma characterisation

FLASHForward

- Plasma density and evolution diagnosed with two methods: Two colour laser interferometry and atomic emission spectroscopy
- Excellent agreement between two methods
- Spectroscopy used to image the temporal evolution of the longitudinal profile, essential for high impact publications

(thanks J. Garland)

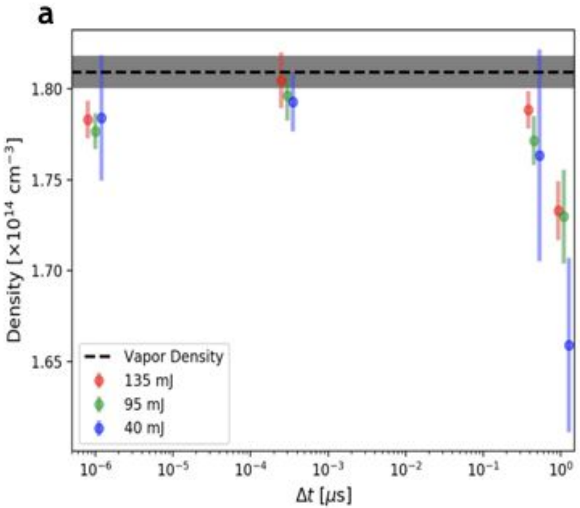


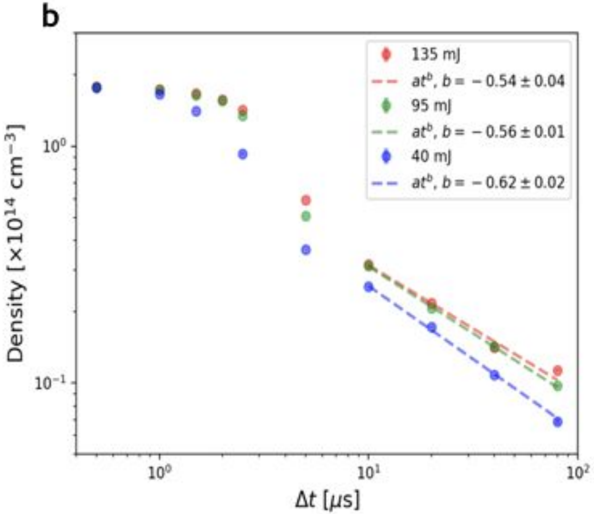


> Profiles here are normalised and scaled to illustrate profile change

Cold plasma characterisation

- Self-modulation of the long AWAKE proton bunch can be used to infer the plasma wavelength
- By varying the arrival of the proton beam relative to the seed laser the evolution of the plasma column be inferred from the variation in modulation
- Comparison to analytic formalisms are as expected, with density decaying as t^{-1/2}



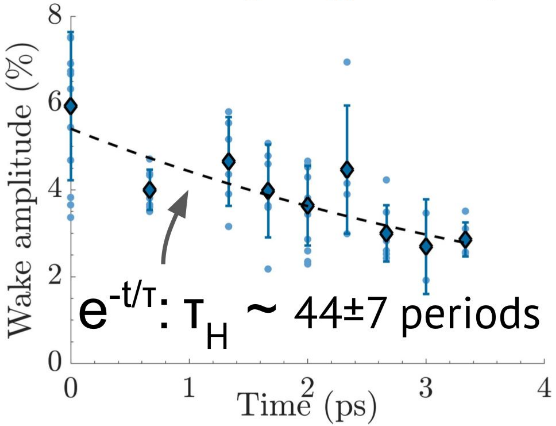


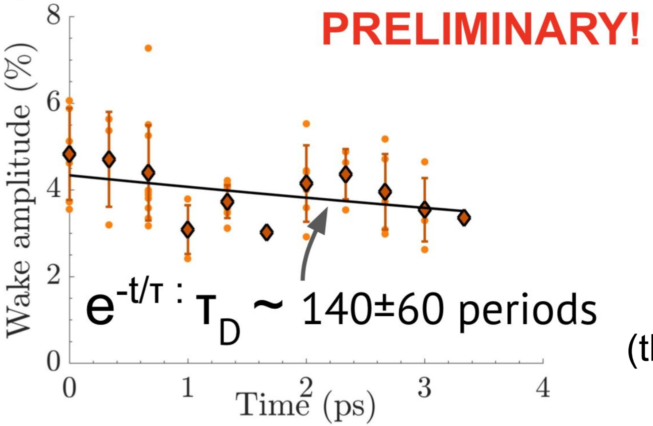
(thanks Simon van der Meer laureate)

Wakefield characterisation

- Multi pulse laser system used to perform frequency domain holography on a temporally evolving plasma.
- Pressure is varied with the temporally encoded spectral shifting extracted, resulting in a timing scan.
- Comparison of results for Hydrogen and Deuterium are preliminary but give an indication of the lifetime of ion motion — important for high rep. rate.

Hydrogen (20 mbar) Deuterium



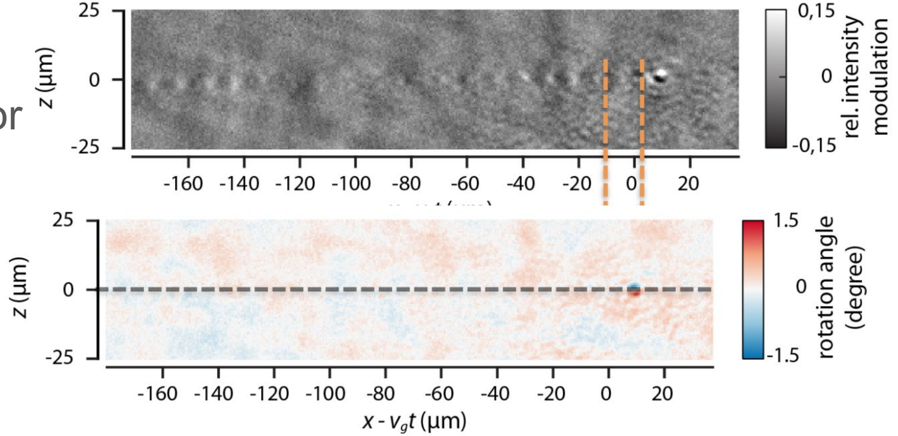


(thanks J. Jonnerby)

Wakefield characterisation

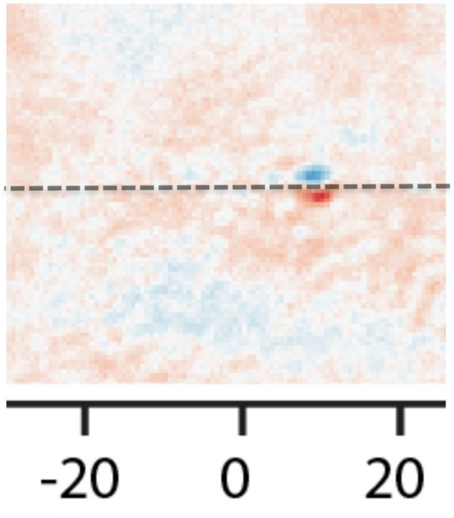
- Rotate the laser polarisation to two different values. The laser then undergoes an additional rotation from the azimuthal magnetic fields of the electron bunch/bubble… then subtract
- Evolution of the LWFA process can be recorded by delaying the arrival time of the laser

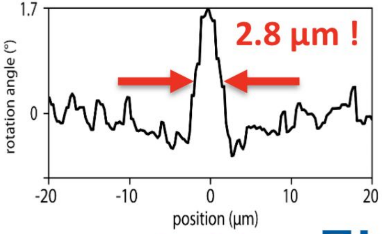
first plasma period (bubble)



- Non-invasive method gives online feedback for optimisation

(thanks A. Sävert)



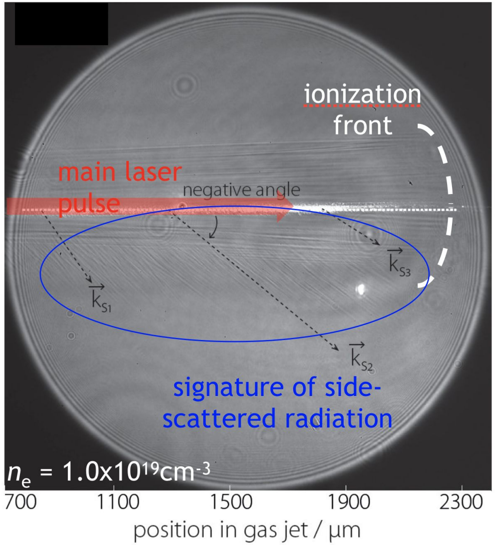


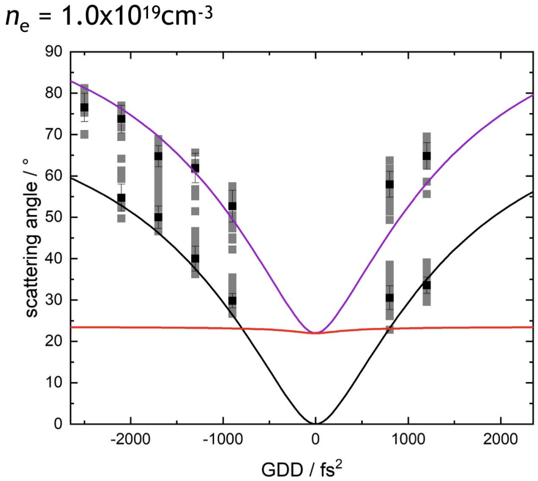
$\tau_{rot} \approx 9.5$ fs

Wakefield characterisation

HI JENA
Helmholtz Institute Jena

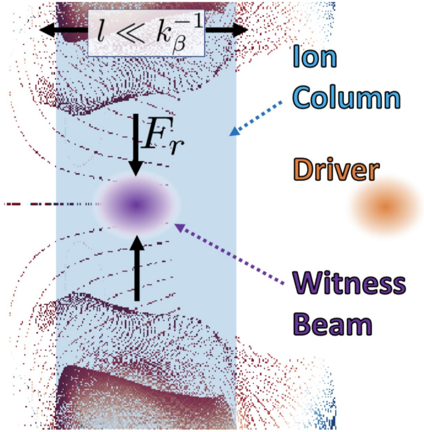
- This technique can also lead to unexpected results…
- Asymmetric Raman scattering with interesting modulations observed, with the magnitude and direction seemingly dependent on the chirp of the laser
- Incorporating the chirp-based tilted phase front into the analytical formalisms looks like it could explain the observations. More results to come...



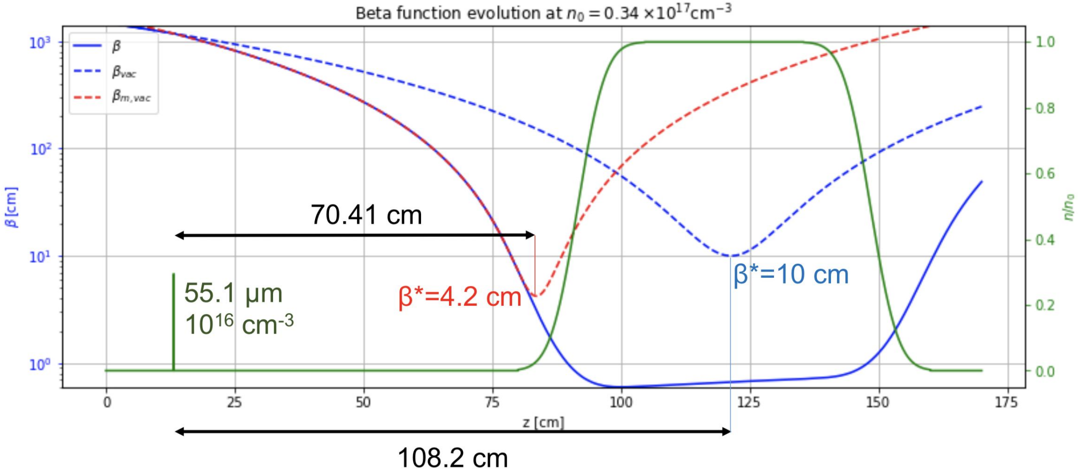


(thanks M. Kaluza)

Plasma process optimisation

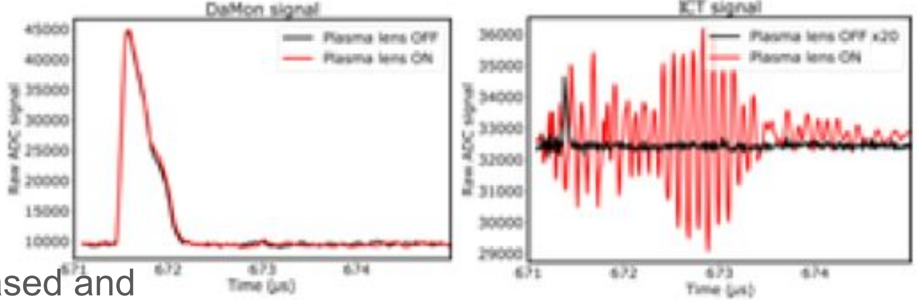


- It's not just the plasma acceleration length requiring attention. Beam quality (emittance) will be degraded if the beam isn't transversely matched to the plasma.
- These matched values are incredibly small so why not use a plasma ramp in the blowout regime as a passive plasma lens to focus the beam down further
- Proposed to be used at FACET-II with promising simulation results demonstrated



(thanks M. Litos)

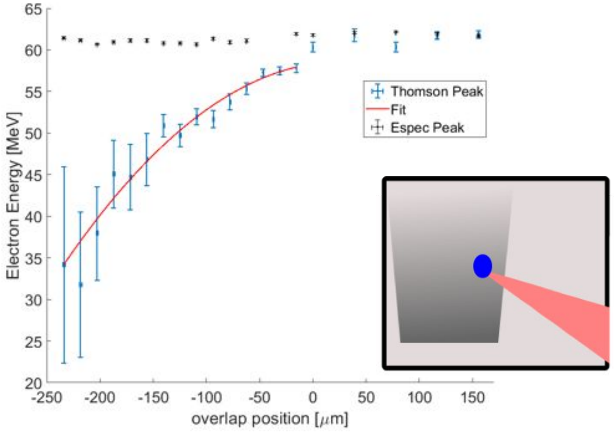
Charge and Energy



S. Bohlen reported on comparisons between ICT-based and cavity-based charge measurements, showing that cavity based measurements are less sensitive to EMP.

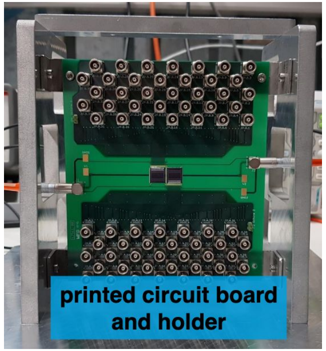
(thanks S. Bohlen)

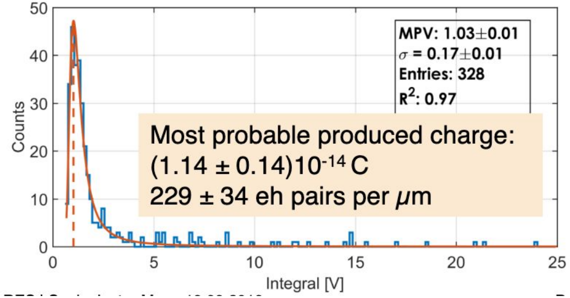
He also reported on energy measurements based on Thomson scattering.



(thanks S. Bohlen)

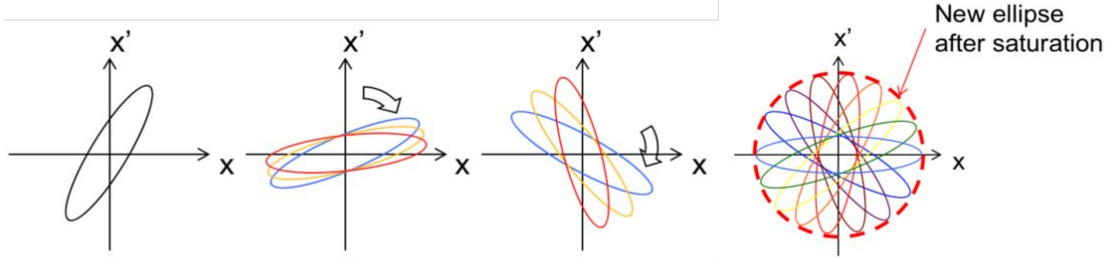
S. Jaster-Merz reported on that application of ATLAS' silicon strips detectors for a spectrometer.



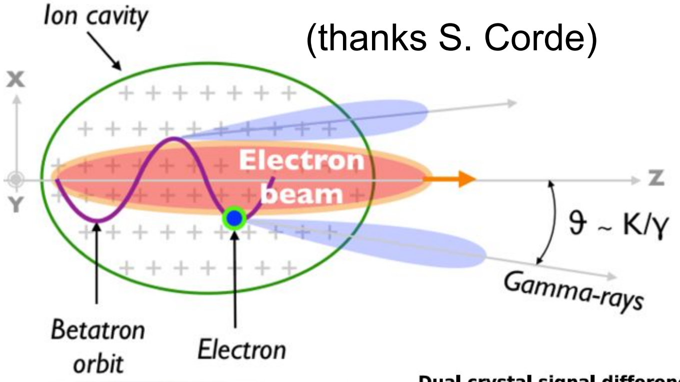


(thanks S. Jaster-Merz)

Transverse diagnostics



(thanks S. Corde)

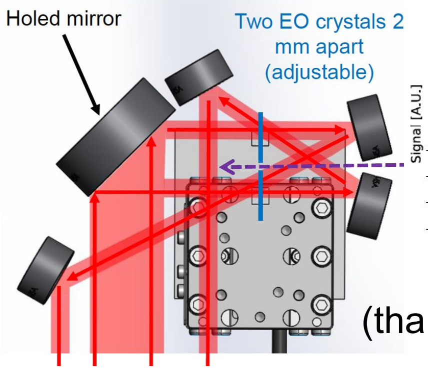


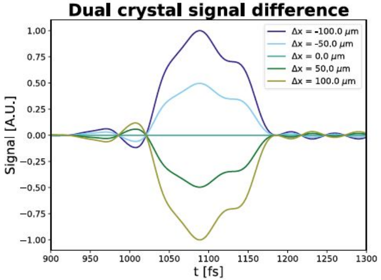
(thanks S. Corde)

Several speakers reported that mismatched beams may lead to emittance blow up and filamentation.

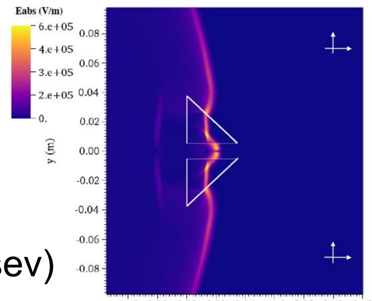
Solutions to measure this mismatch have been presented.

- S. Corde proposed to use gamma-rays to measure this.
- K. Hunt-Stone proposed an EOS based BPM.
- A. Curcio reported on Cerenkov diffraction based BPM.



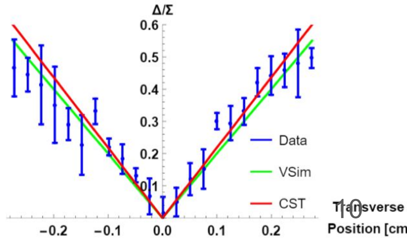


(thanks K. Hunt-Stone)



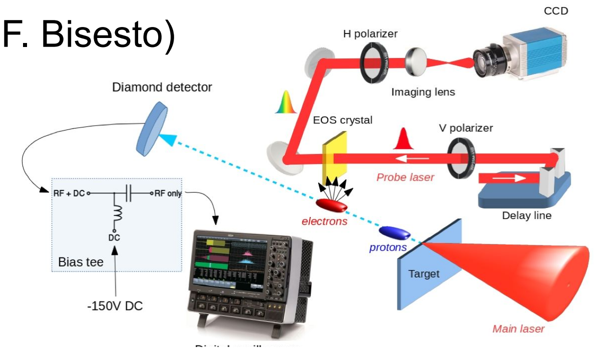
(Courtesy K. Lekomtsev)

(thanks A. Curcio)



Longitudinal diagnostics (1/2)

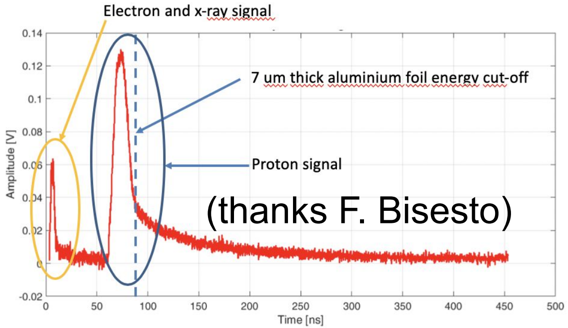
(thanks F. Bisesto)



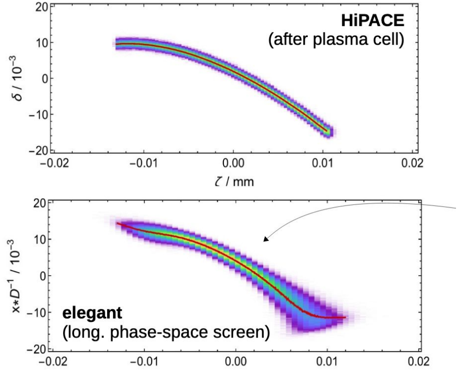
F. Bisesto reported on the use of EOS to distinguish protons from fast electrons.

K. Hunt-Stone also reported that EOS BPMs give information on the longitudinal profile.

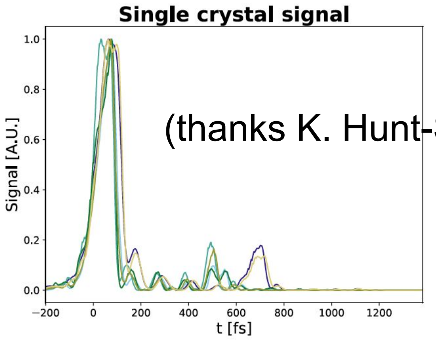
P. Gonzalez reported on a 12Ghz TDS being commissioned.



(thanks F. Bisesto)



(thanks P.Gonzalez)

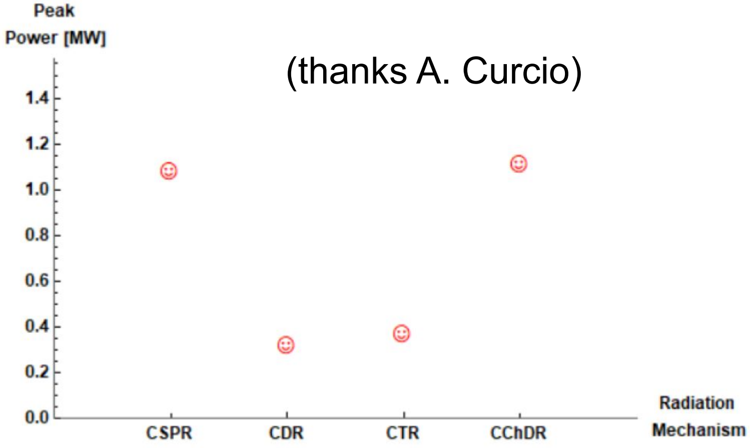


(thanks K. Hunt-Stone)

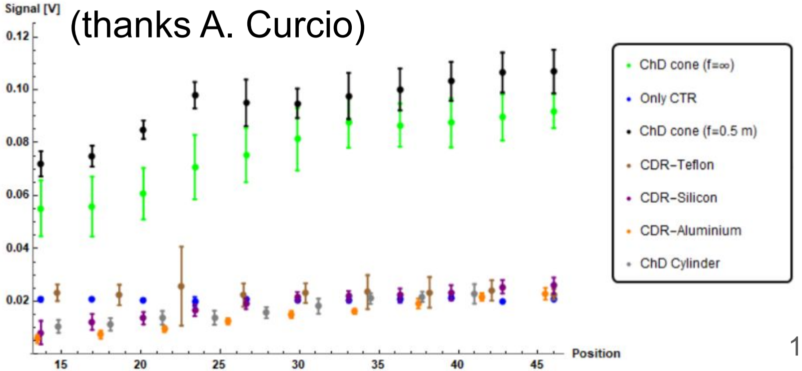
Longitudinal diagnostics (2/2)

O. Zarini used CTR to diagnose ultra-short bunches (FWHM = 22 fs) from various injection methods. Sub-fs structures can be resolved. Microbunching observed. Combined with point spread function measurement, could be used for 3D reconstruction.

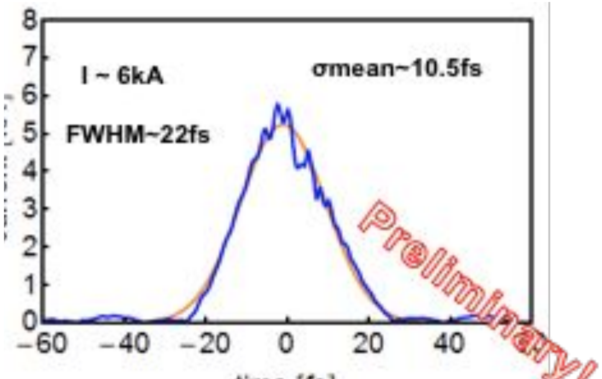
A. Curcio reported on a study of several coherent radiation phenomena at CLEAR.
Studies show that EM shadowing was not observed despite the position been well between the formation length.



(thanks A. Curcio)



(thanks A. Curcio)

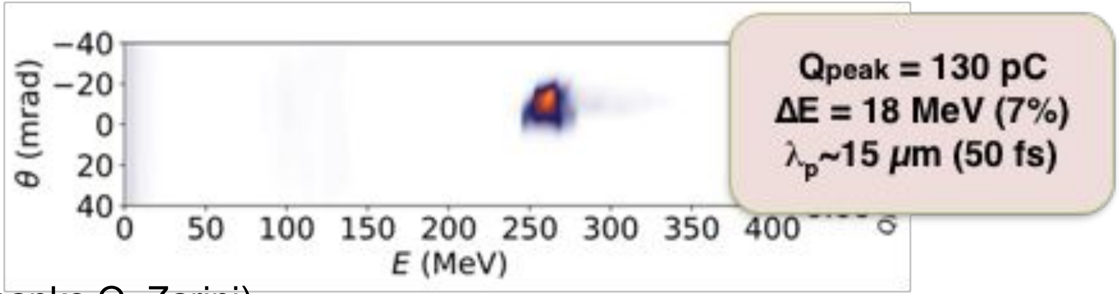


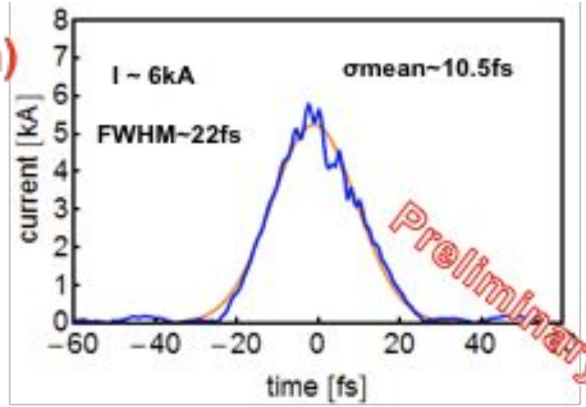
(thanks O. Zarini)

Coherent transition radiation

- Ultra-short bunches can be, and are, generated from PWFA methods. These bunches need to be diagnosed, ideally in a non-invasive way.
- Coherent transition radiation (CTR) — a well understood diagnostic technique — was implemented at HZDR to diagnose ultra-short bunches (FWHM = 22 fs) from various injection methods. Sub-fs structures can be resolved. Microbunching observed.
- Combined with point spread function measurement, could be used for 3D reconstruction.

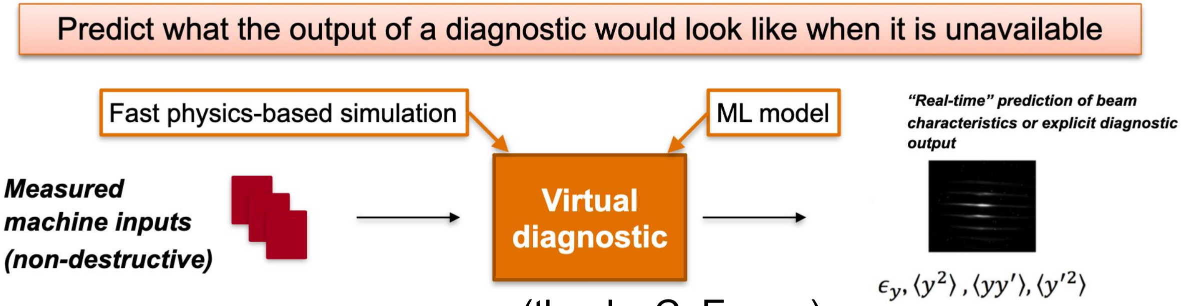
Shock front injection (100% He + density modulation)



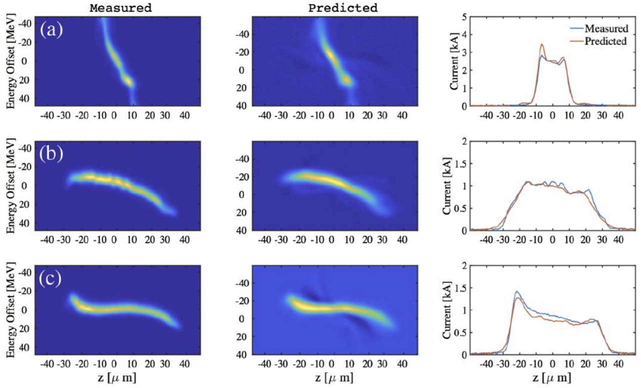


(thanks O. Zarini)

Machine Learning



(thanks C. Emma)



(thanks C. Emma)

M. Hogan on behalf of C. Emma introduced the concept of virtual diagnostics where beam properties are inferred by machine learning. And it works!

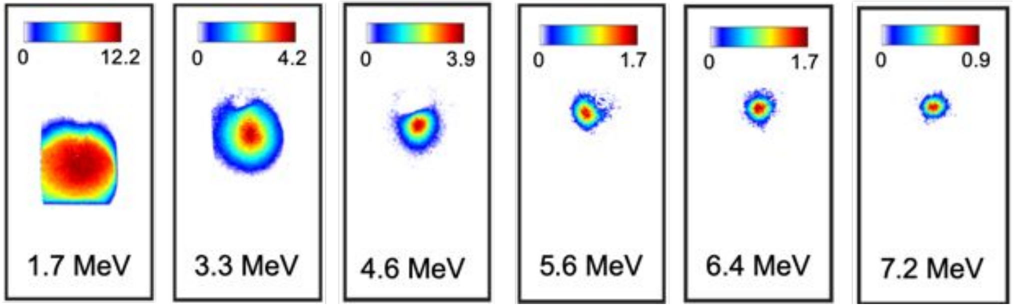
Does ML know more than us about the beam?

Active Plasma lenses

E. Adli reported on studies of aberrations in active plasma lenses and suggested a model to explain non-linearities. Ultimate goal is to build a lattice of active plasma lenses.

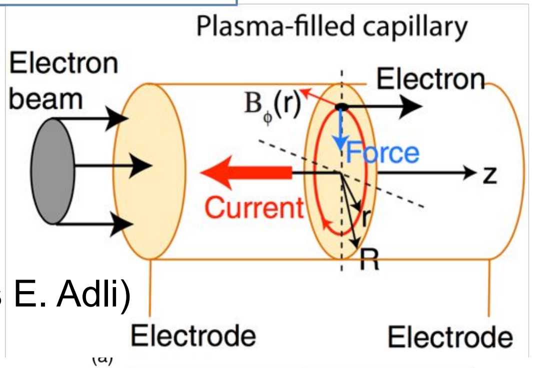
J. Bin reported on the use of plasma lenses to focus protons.

(Thanks J.Bin)

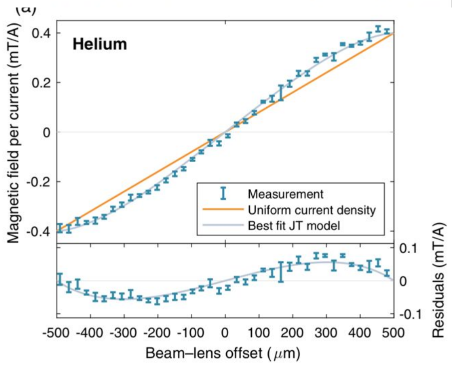


Active plasma lens principle

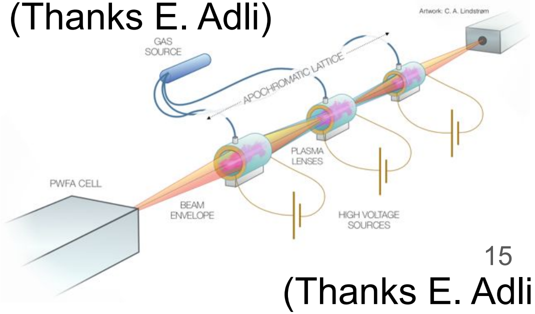
Figure: J. van Tilborg et al.



(Thanks E. Adli)



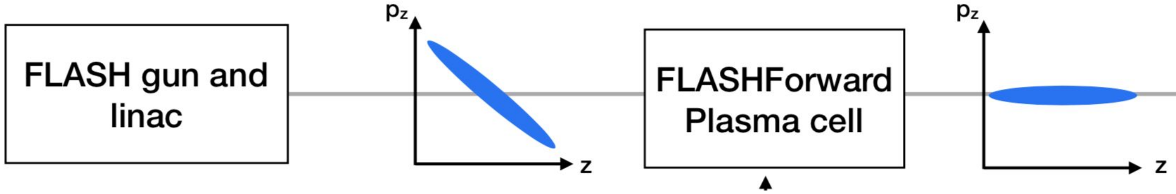
(Thanks E. Adli)



(Thanks E. Adli)

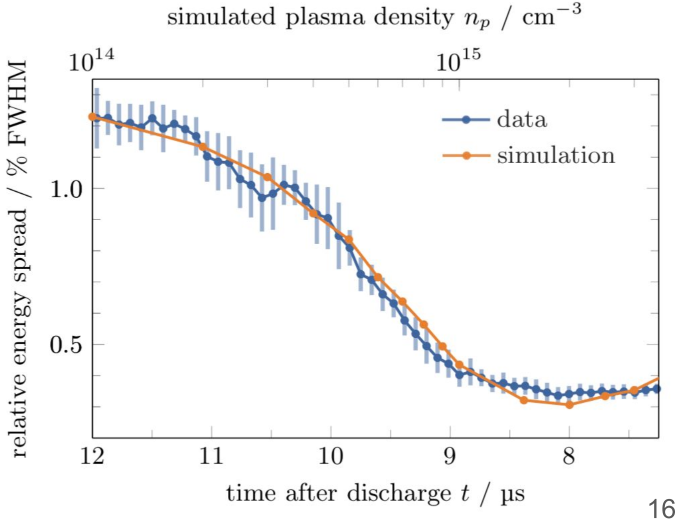
Plasma applications

FLASHForward



(thanks R. D'Arcy)

- Once these plasma sources are understood and optimised their ultra-high gradients can be leveraged for novel applications
- As well as plasma lenses, strong focus has been placed on plasma dechirpers (three PRLs this year)
- Decelerating phase of the wakefield can be used to remove a large correlated energy spread at unprecedented levels, essential for e.g. the chirp developed in a non-beam loaded PWFA scheme



Thanks to Alessandro, the organisation committee, and everyone who contributed to WG5*!

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