Measurement of the decay rate of laser-driven linear wakefields

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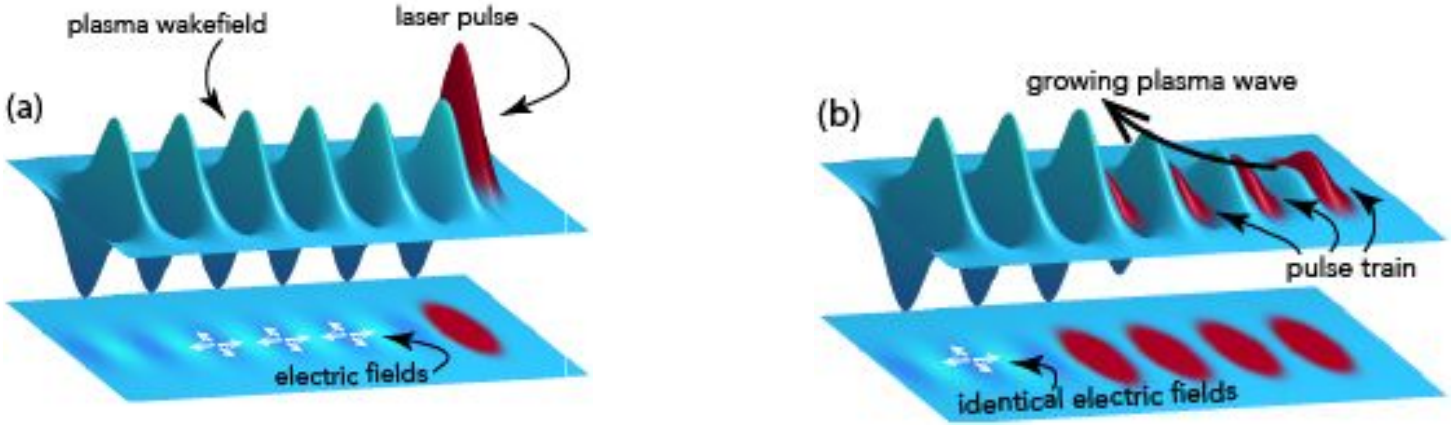
[3]Central Laser Facility, Rutherford Appleton Laboratory

* *Now at: John Adams Institute for Accelerator Science, Imperial College London*
** *Now at: York Plasma Institute, University of York*

Multi-pulse LWFA



- Increase repetition rate of LWFAs to kHz range
- Resonant excitation by *N* pulses
- Could enable commercial laser systems as drivers

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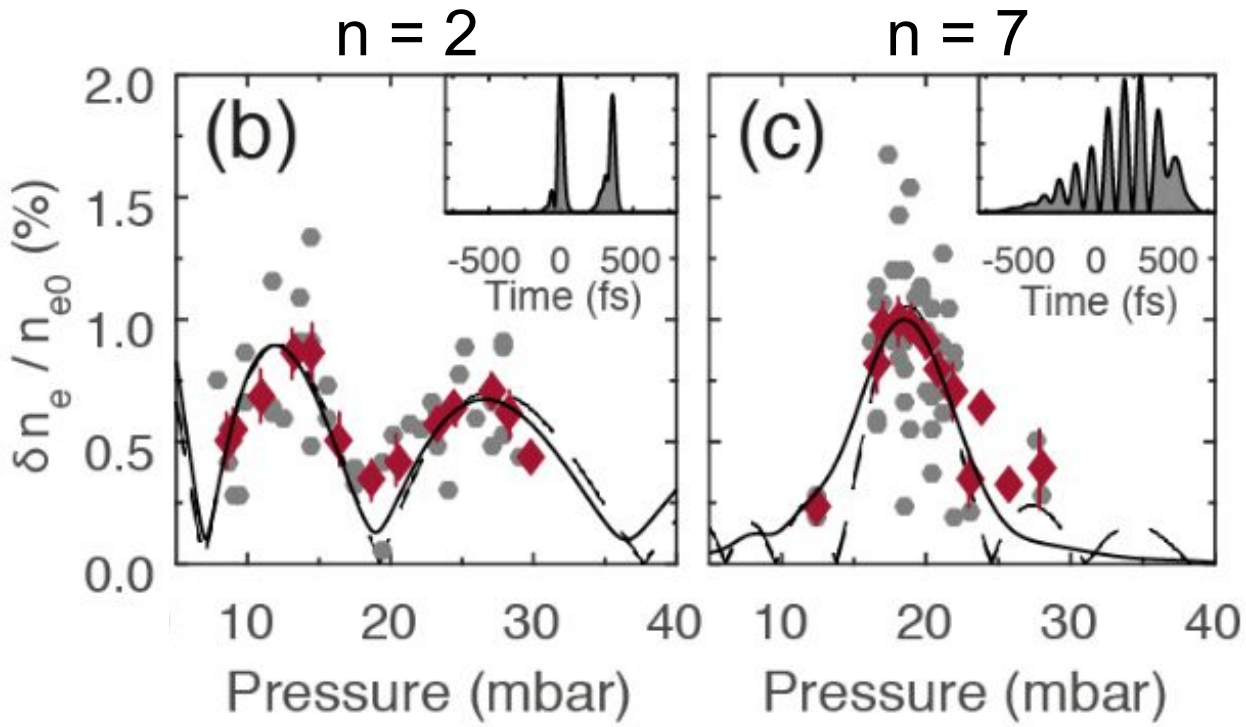
Multi-pulse LWFA



J. Cowley et al, 71 Phys. Rev. Lett. (2017)

Wakefield decay

- Decay mechanisms:
  - Landau damping
  - Collisional damping
  - Interaction with ions - including ion motion

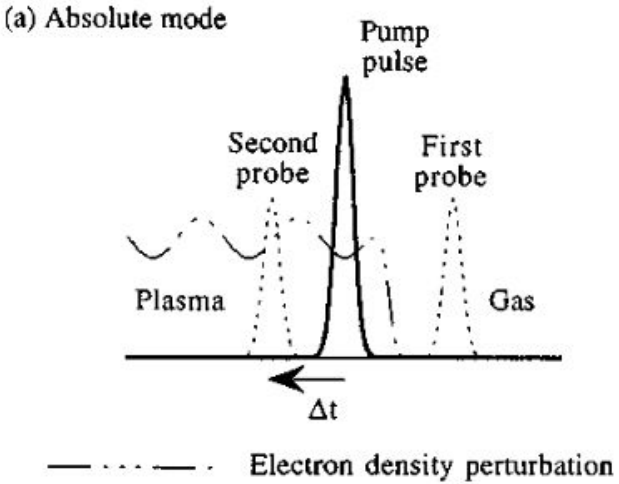
- Ion motion timescale: $\tau = \omega_i^{-1}$ ~ 60 periods (H)
  ~ 85 periods (D)

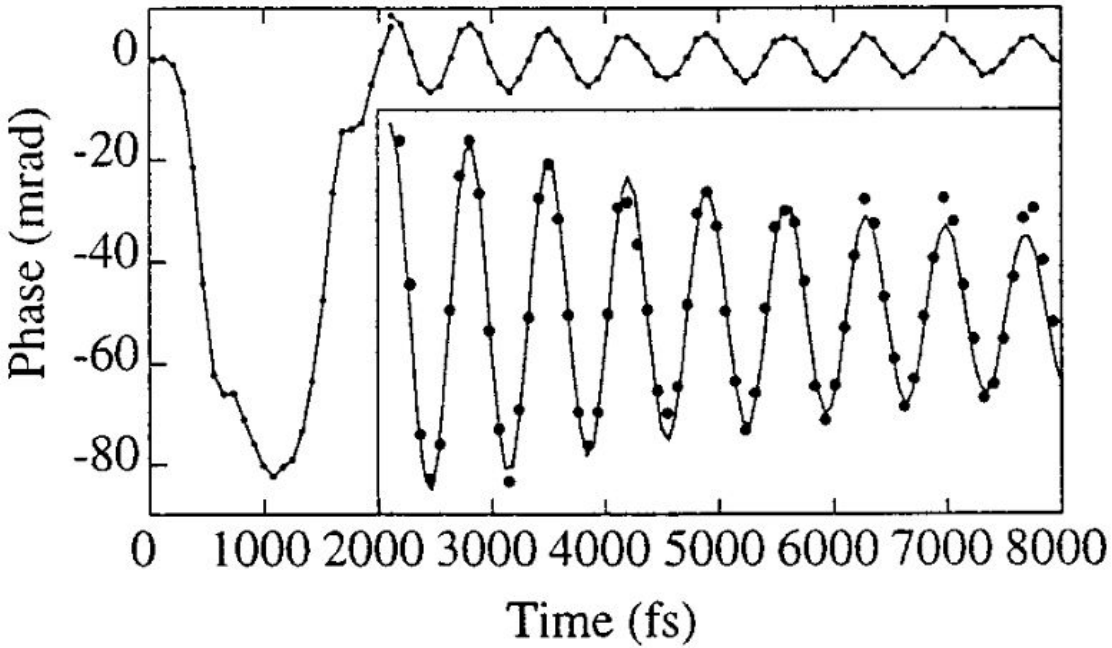
$$\frac{\tau_H}{\tau_D} = \frac{1}{\sqrt{2}}$$

Previous studies

Study	Method	a_0	Density	Decay time (plasma periods)
Marques, J. et al, Phys. Plasmas (1998)	Frequency domain interferometry	0.16	5×10^{15} - 1×10^{17} cm^{-3} (He)	2 - 50
Kotaki, H. et al, Phys. Plasmas (2002)	Frequency domain interferometry (Gas jet)	0.6	$7.4*10^{17}$ cm^{-3} (He)	8
Ting A. et al, Phys. Rev. Lett. (1996)	Coherent Thomson scattering (SM - LWFA)	0.78	$1 * 10^{19}$ cm^{-3} (He & H)	~140

Frequency domain interferometry (FDI)

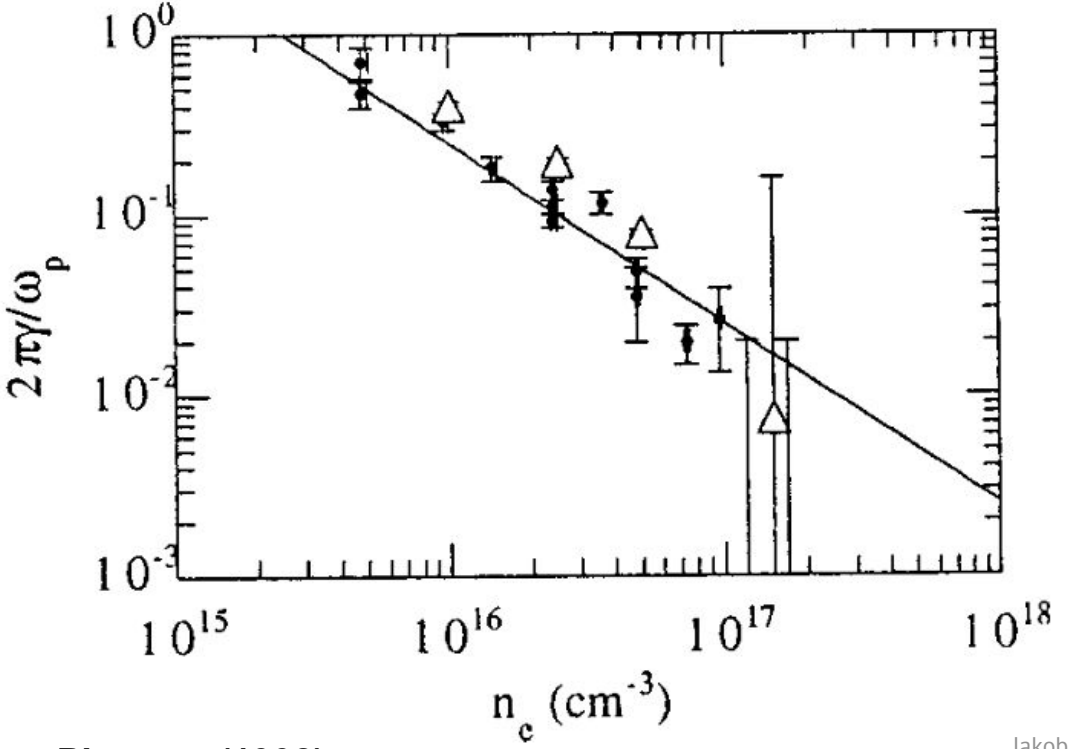




Marques, J. et al, Phys. Plasmas (1998)

Frequency domain interferometry (FDI)

Wake decay versus density



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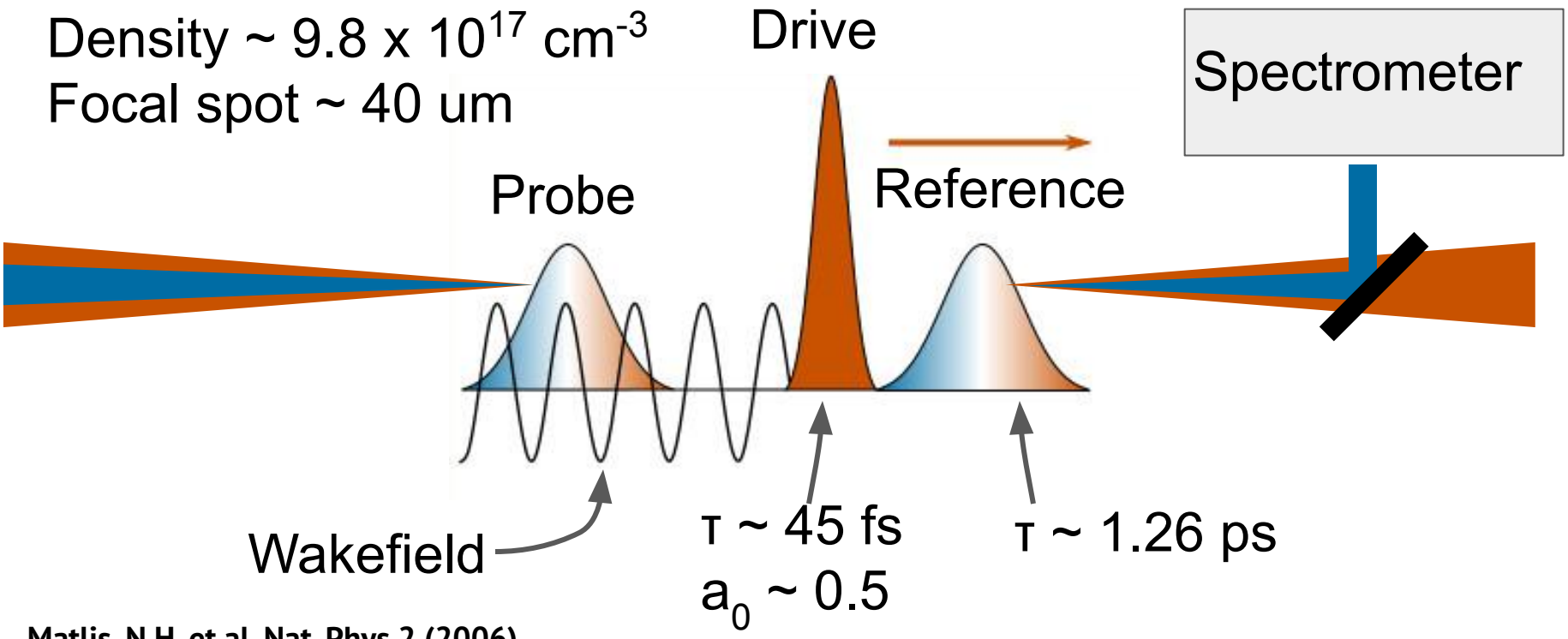
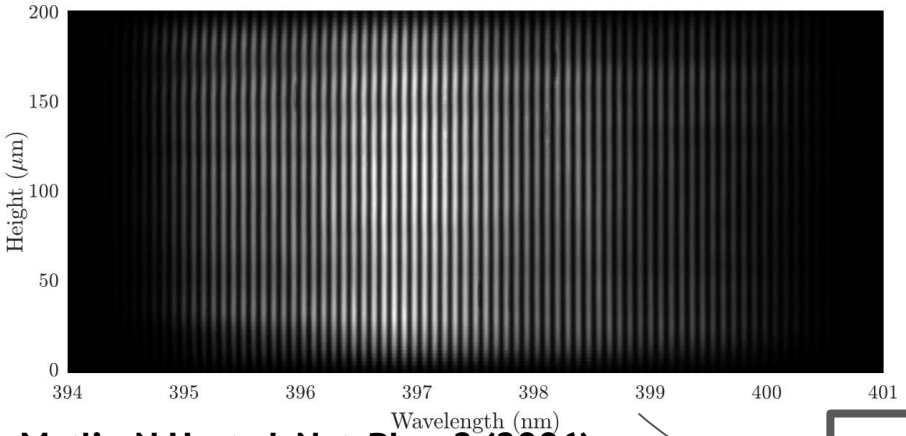
Frequency domain holography (FDH)



Matlis, N.H. et al, Nat. Phys 2 (2006)
Matlis, N.H. et al, Opt. Lett. 41 (2016)
Arran, C. et al, Phys. Rev. Accel. Beams 21 (2018)

Temporally encoded spectral shifting (TESS)



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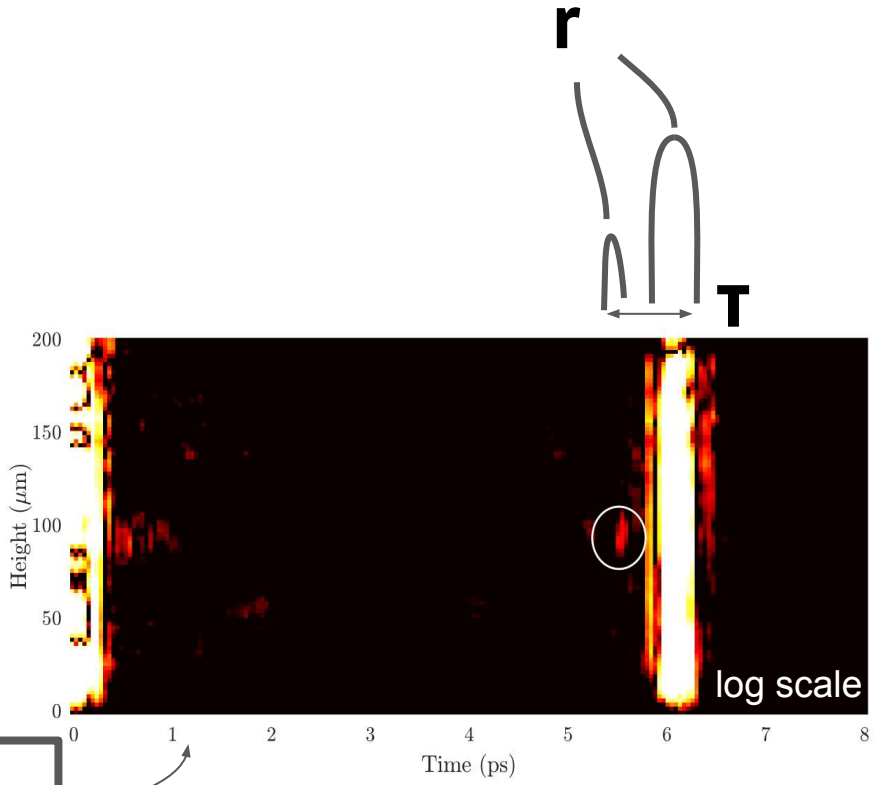

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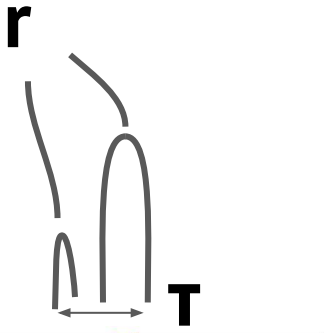
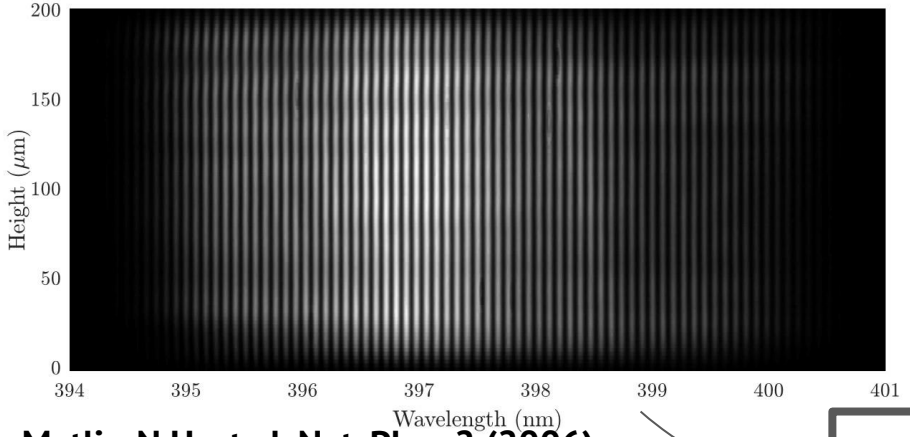
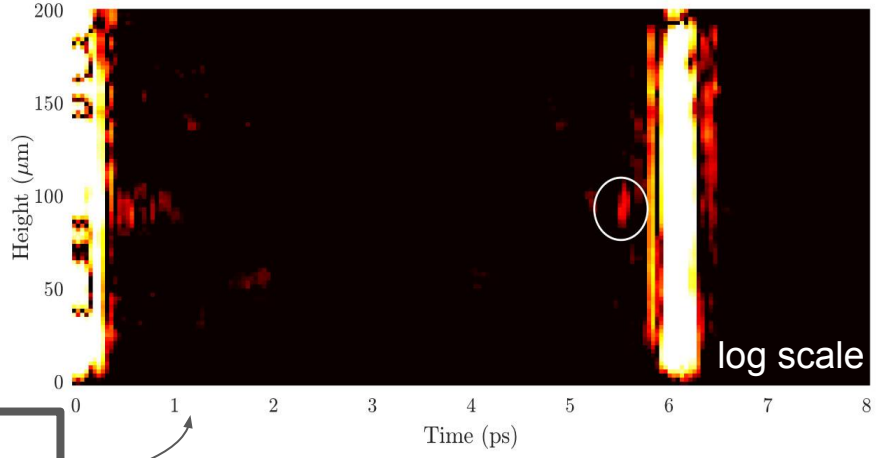
Temporally encoded spectral shifting (TESS)

$$r = F(\omega_p)\frac{J_1(\phi)}{J_0(\phi)} \qquad \frac{\delta n}{n} = -\frac{2\omega_0 c\phi}{\omega_p L}$$

$$\tau = \varphi^{(2)}\omega_p$$







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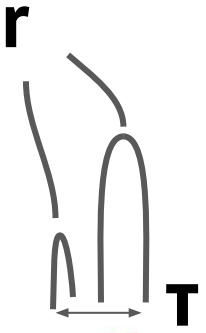

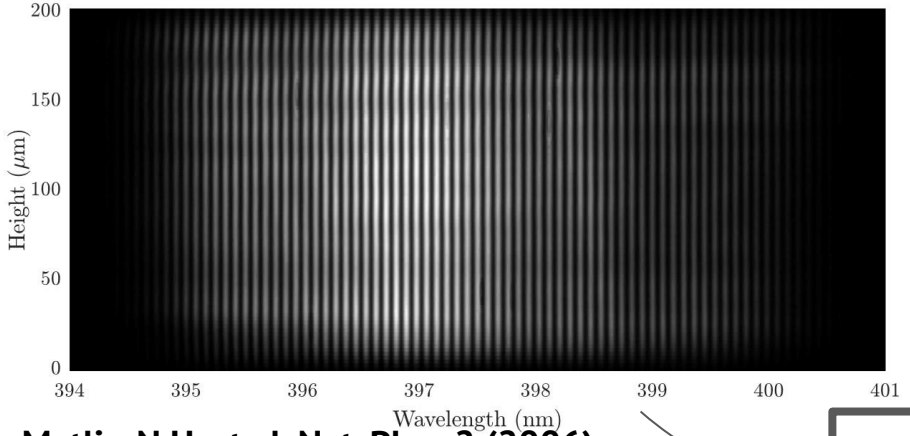

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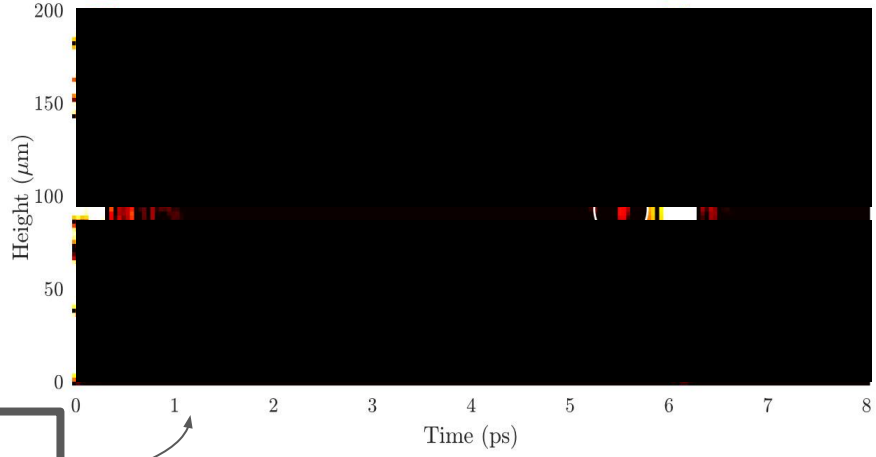

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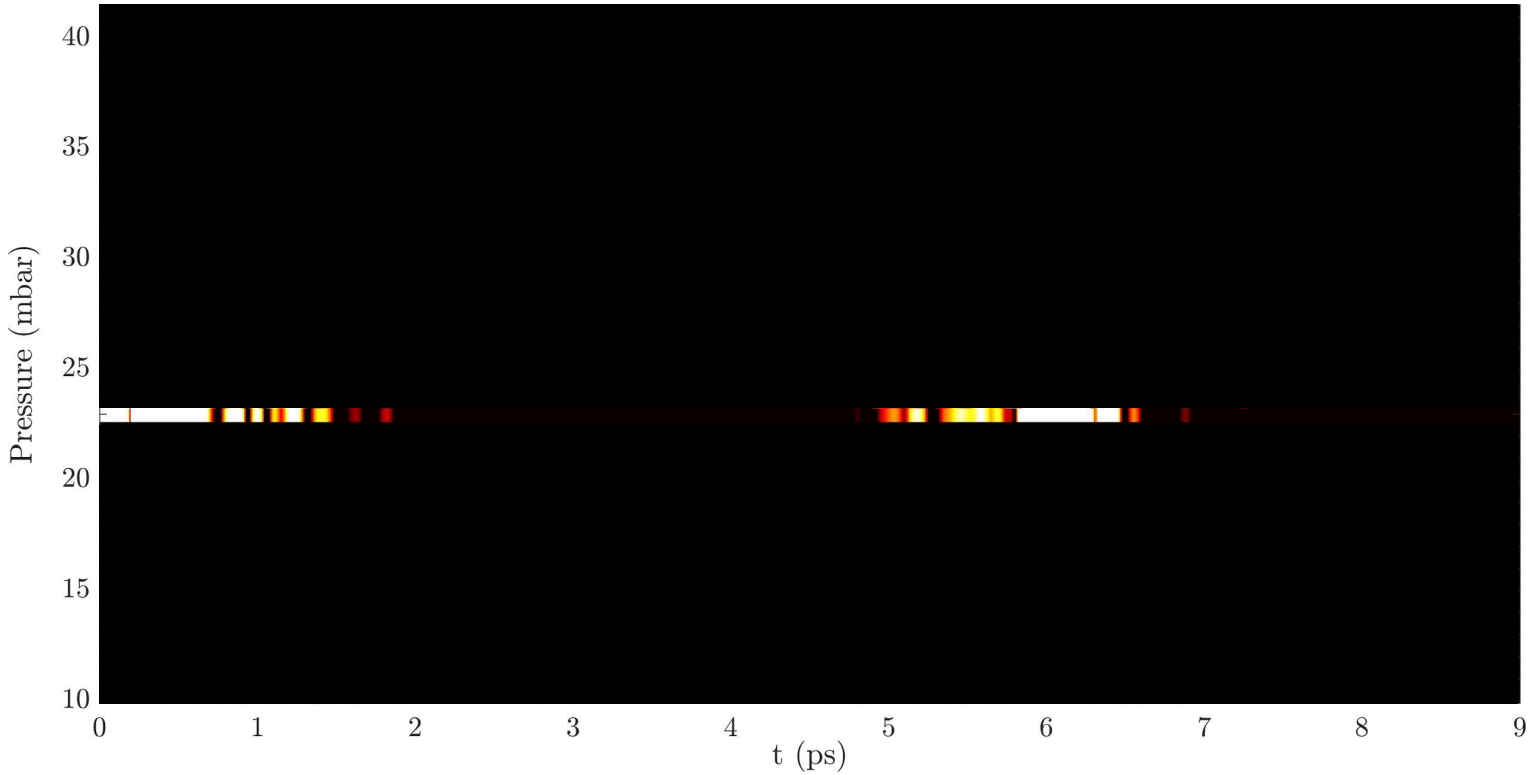
Pressure scan



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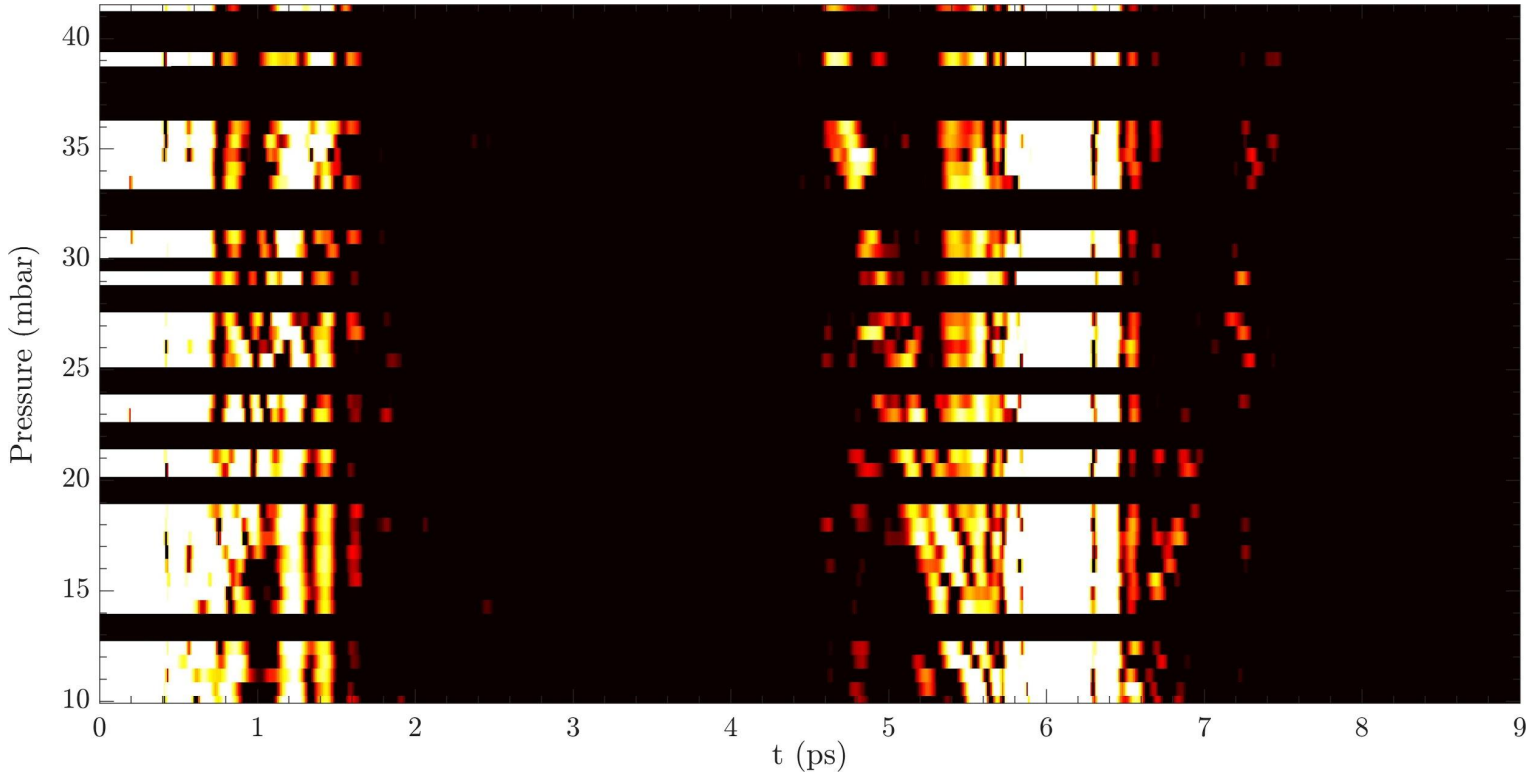

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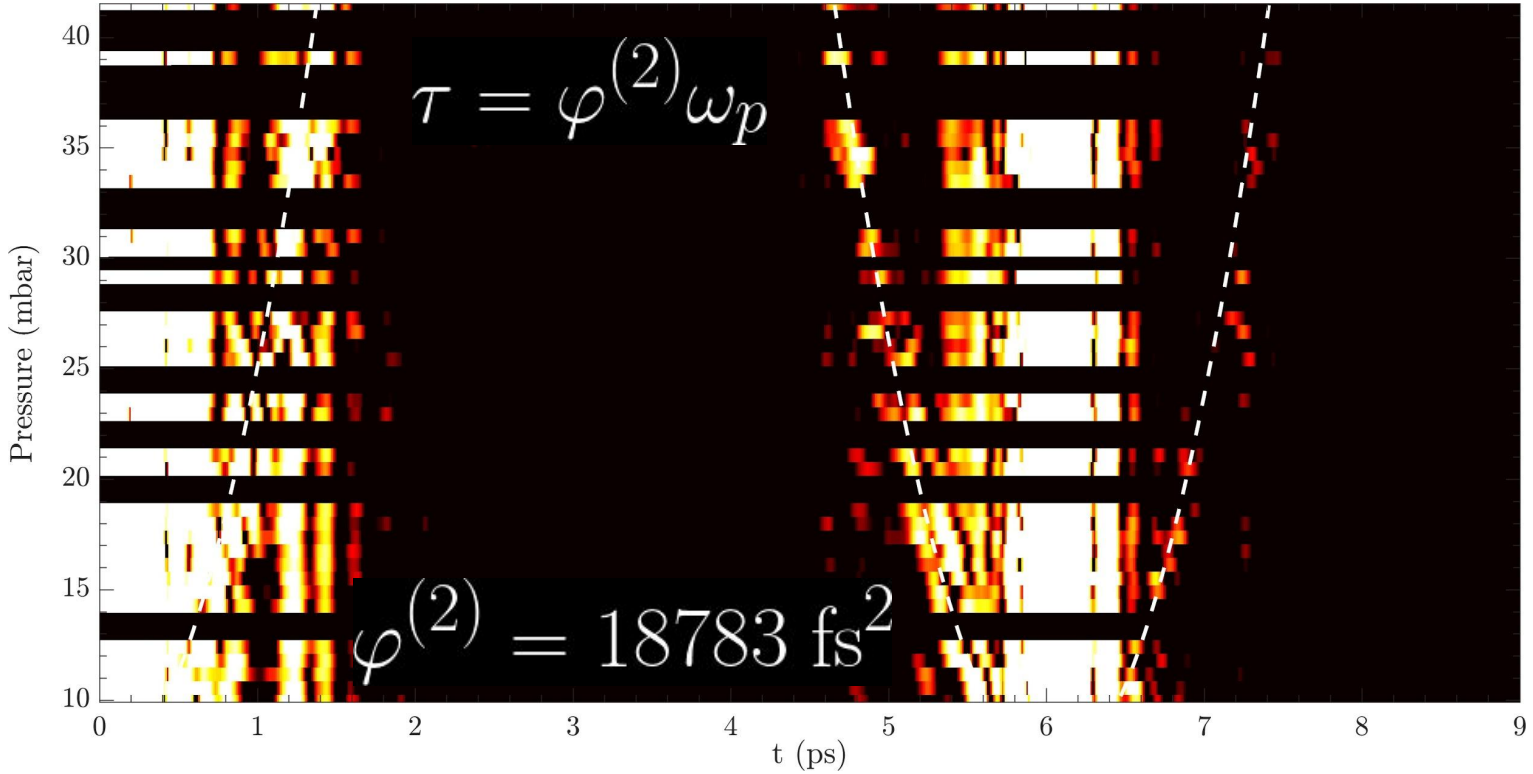

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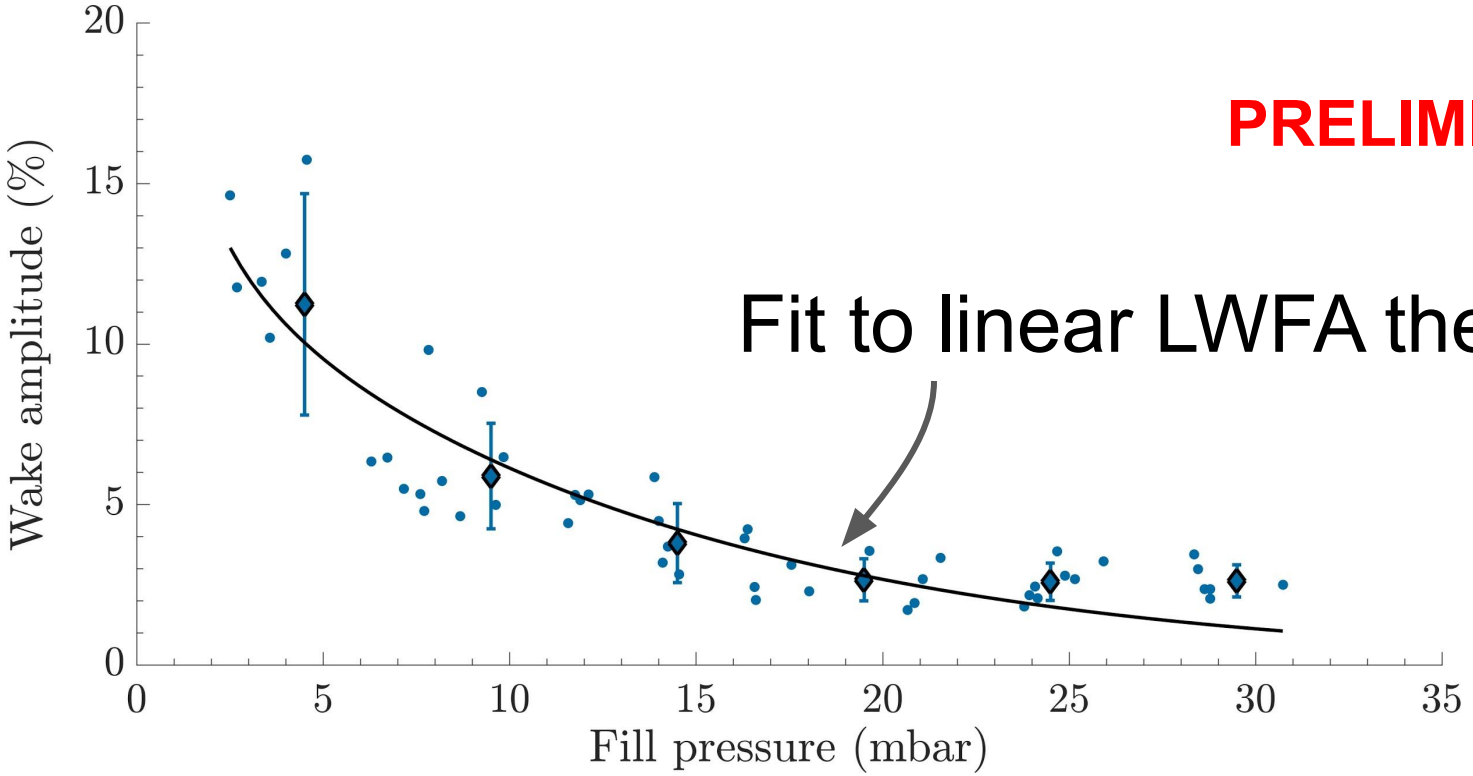
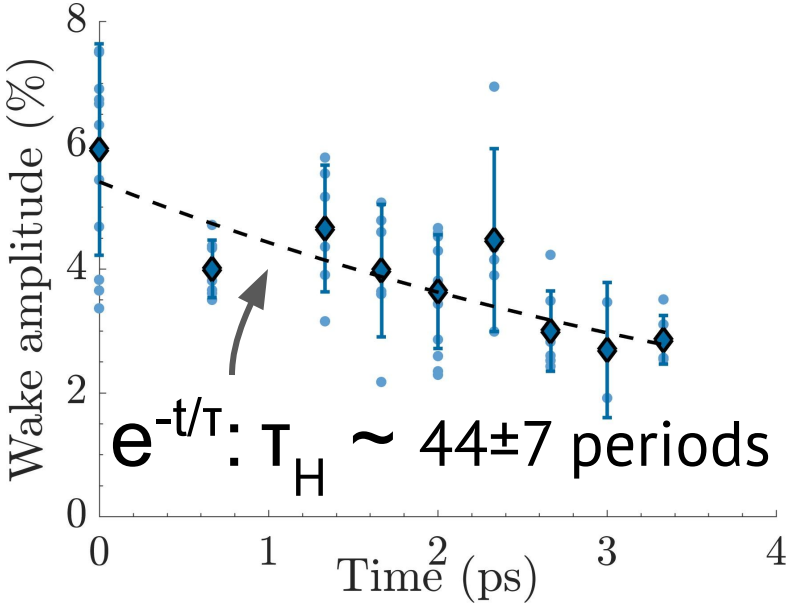


PRELIMINARY!

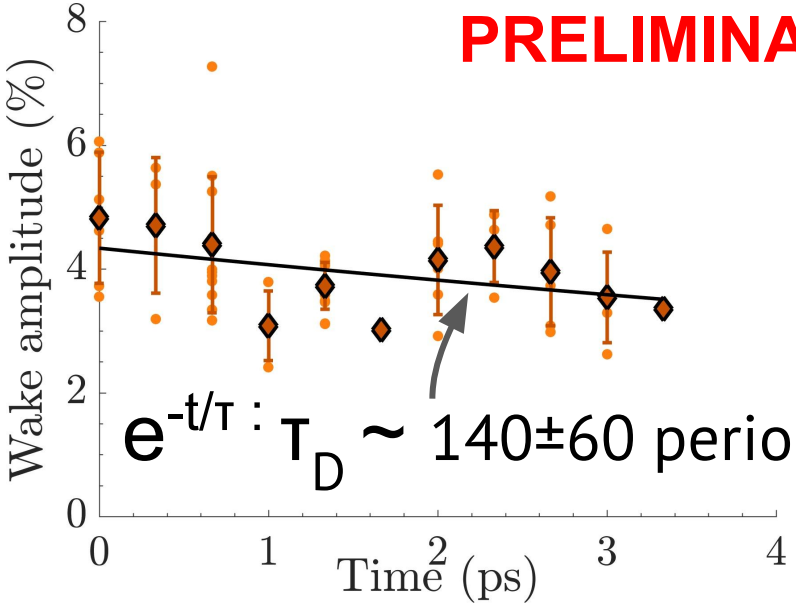
Temporal evolution

Hydrogen (20 mbar)



Deuterium

PRELIMINARY!



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Temporal evolution

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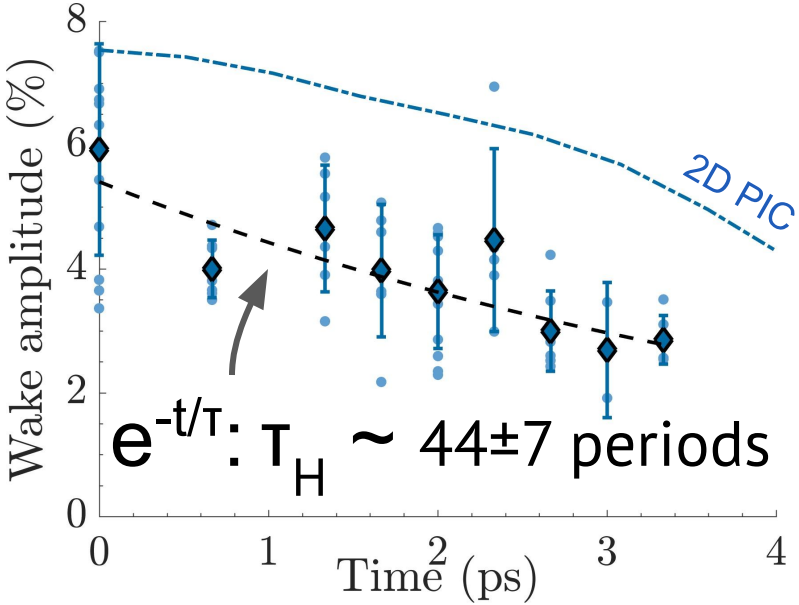

Deuterium

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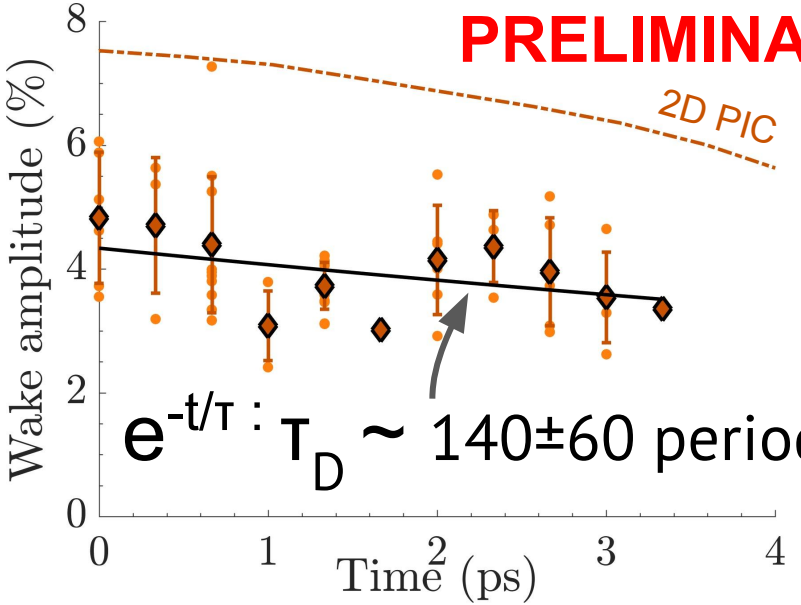
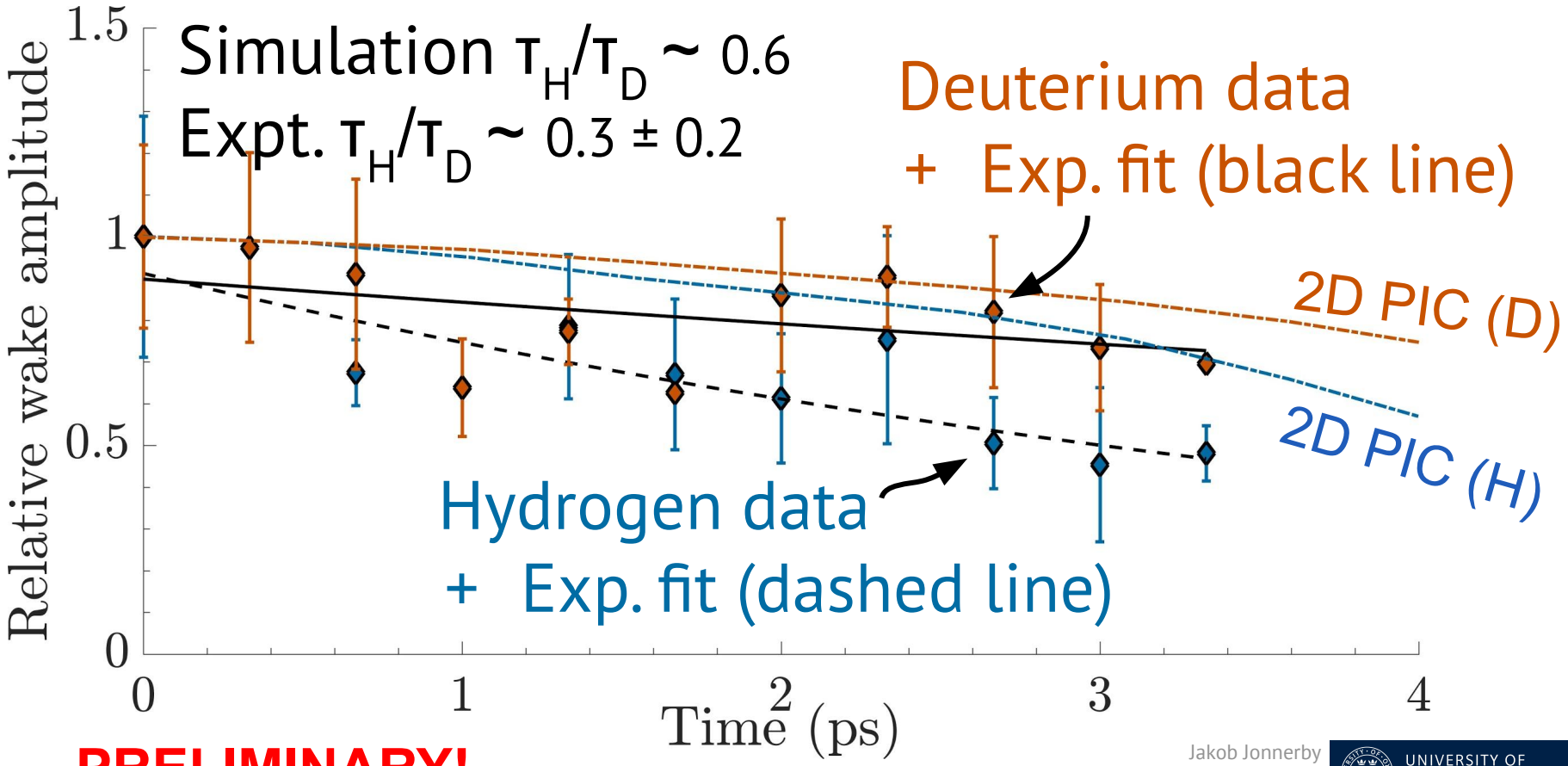


Simulation: 2D PIC (SMILEI), same design parameters as experiment (no free parameters!). *4 particles per cell*

Credits: Alexander v. Boetticher

Relative decay rate



PRELIMINARY!

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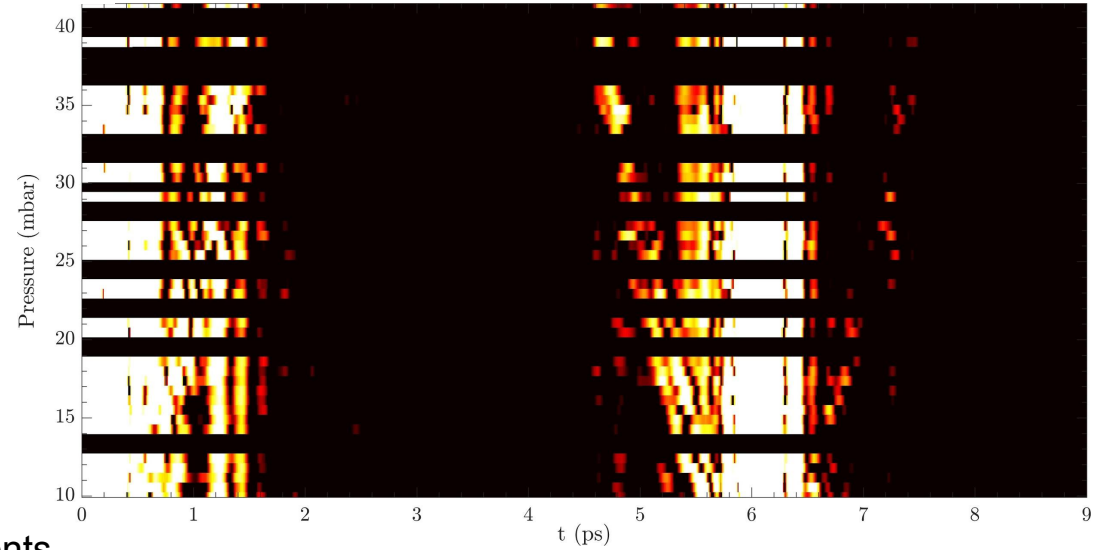
Conclusions

- MP-LWFA could be used to reach **kHz repetition** rate LWFAs
- Wake lifetime measured for the first time using FDH/TESS
- Results suggests that MP-LWFA can sustain ~ 40 (H) - 100 (D) pulses
- τ_H ~ **44±7** plasma periods, τ_D ~ **140±60** plasma periods
- **Suggests wakefield decay not a showstopper for MP-LWFA!**

Thank you!



Acknowledgements

Work supported by the UK Science and Technology Facilities Council (STFC UK) [grant numbers ST/N504233/1, ST/R505006/1, ST/M50371X/1]; the Engineering and Physical Sciences Research Council [Studentship No. EP/N509711/1]; the Helmholtz Association of German Research Centres [Grant number VH- VI-503]; JAI rolling grant 01/04/2017 - 31/03/2018: ST/P002048/1. This material is based upon work supported by the Air Force Office of Scientific Research under award numbers FA8655-13-1-2141 and FA9550-18-1-7005. This work was supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 653782. This work was supported by the plasma HEC Consortium EPSRC grant number EP/R029148/1 and ARCHER UK National Supercomputing Service. The author acknowledges the support of the EAAC 2019 student grant.