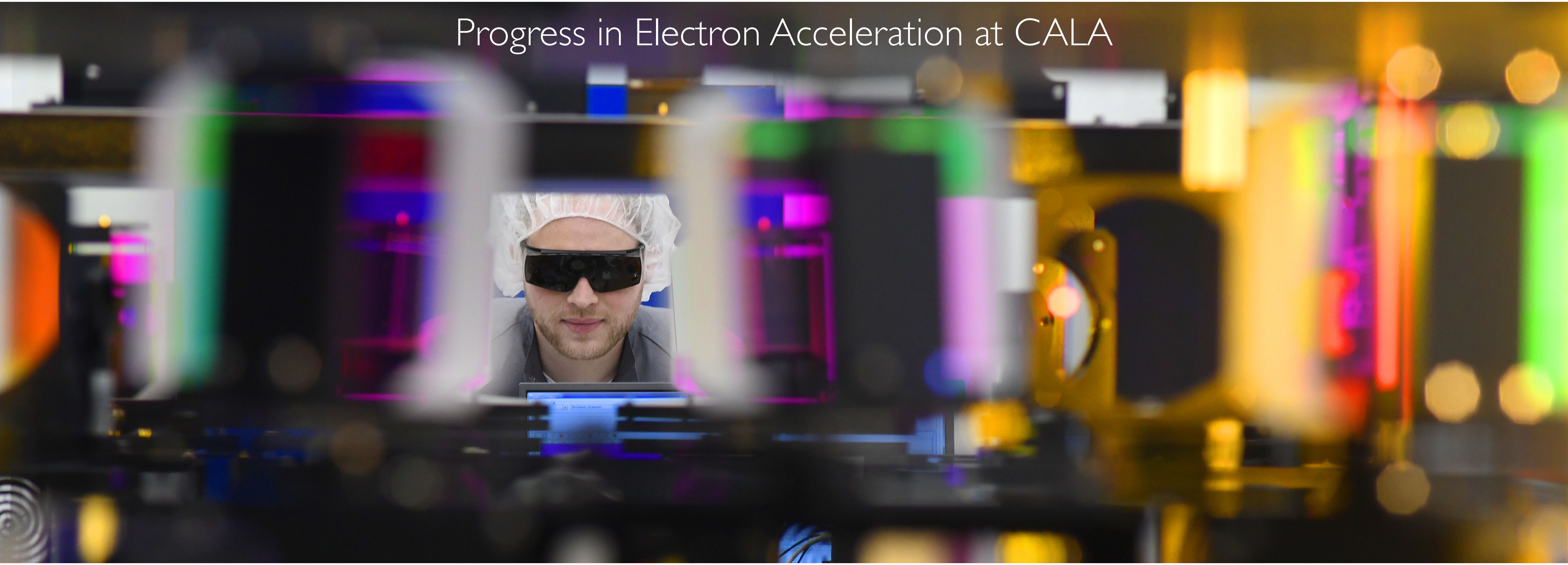
Progress in Electron Acceleration at CALA

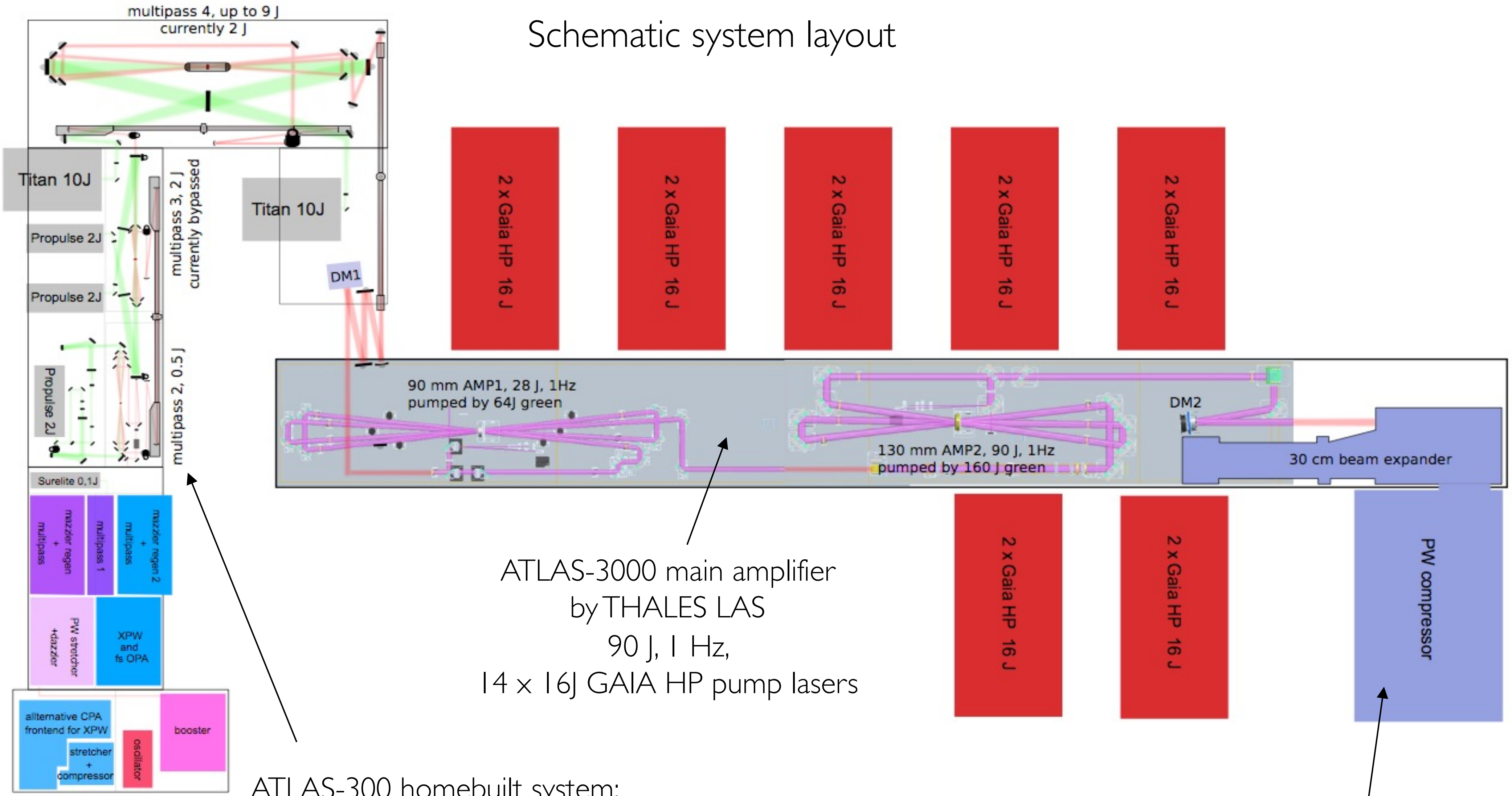


Stefan Karsch
Ludwig-Maximilians-Universität München
Garching, Germany

Internet: www.pulse.physik.uni-muenchen.de

ATLAS-3000 @ CALA

Schematic system layout



ATLAS-3000 main amplifier
by THALES LAS
90 J, 1 Hz,
14 x 16J GAIA HP pump lasers

ATLAS-300 homebuilt system:
up to 300 TW, 25 fs, 5 Hz Ti:Sa laser

Homebuilt beam expander
& compressor

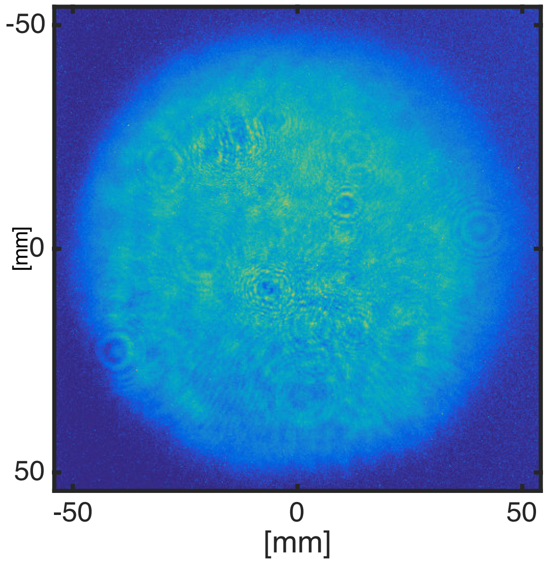
ATLAS-3000 performance

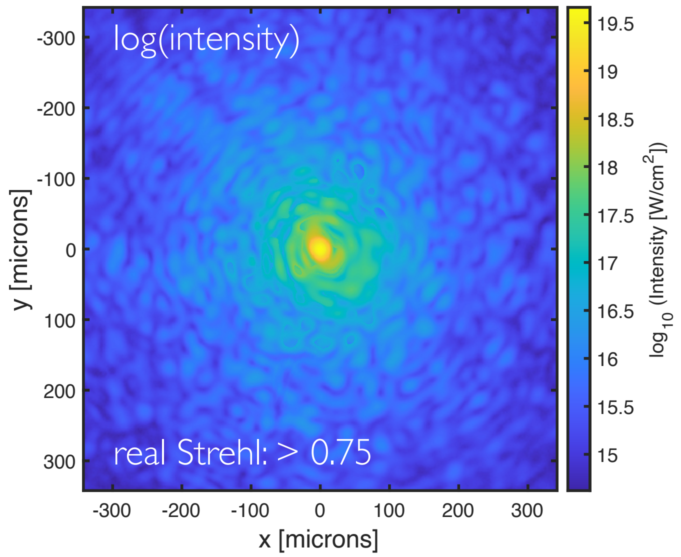
near field

far field

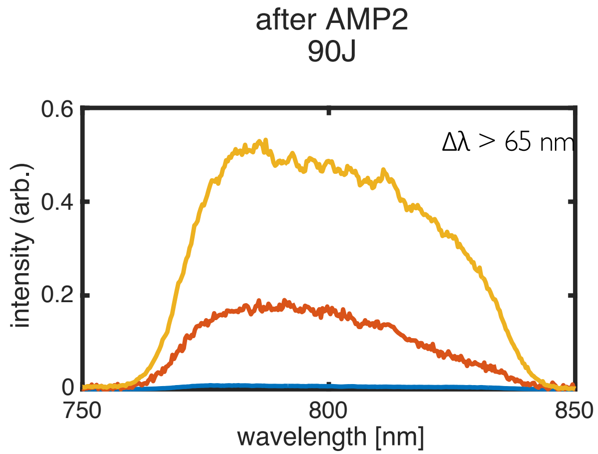
contrast

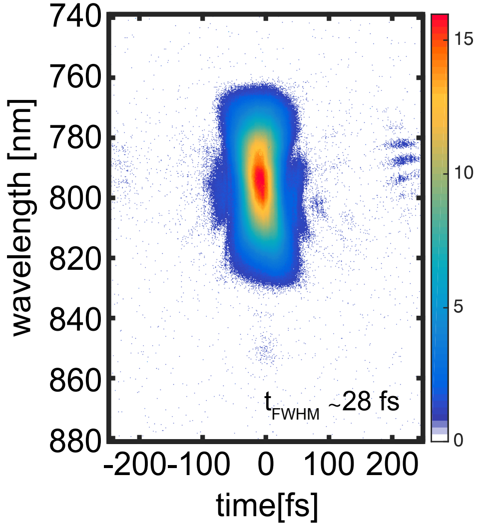
spatial

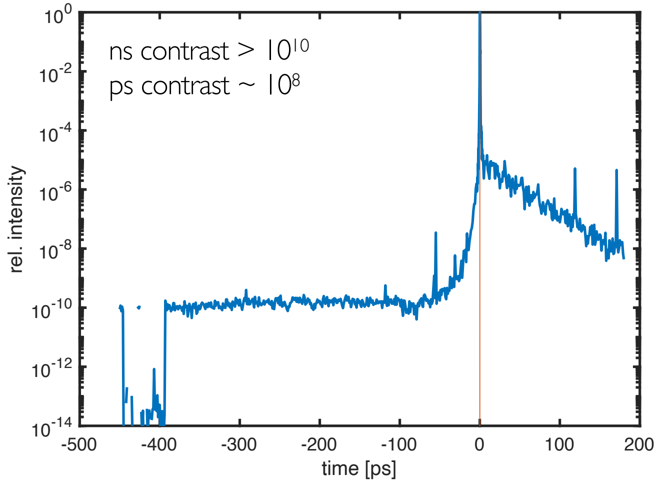




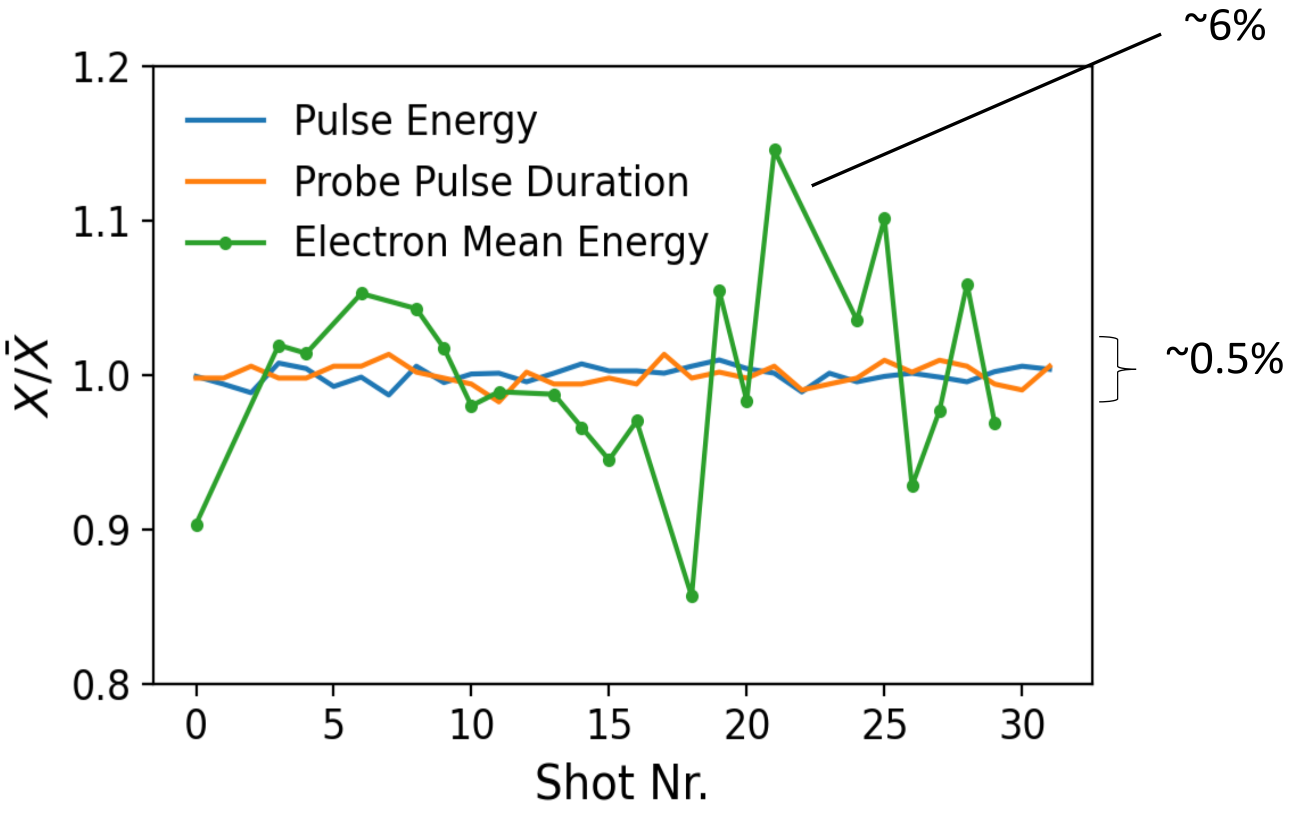
spectro-
temp.





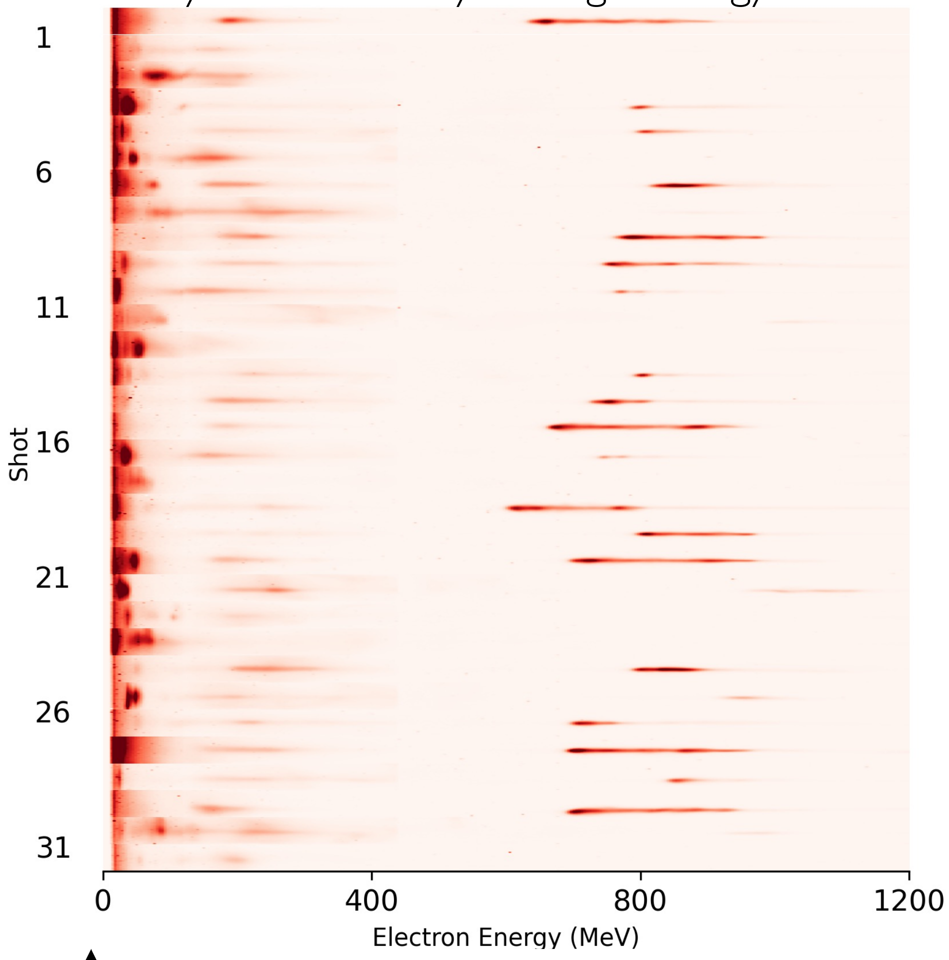


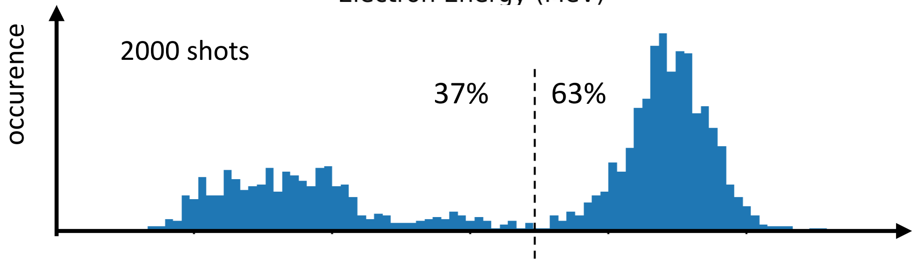
ATLAS-3000 is quite stable…



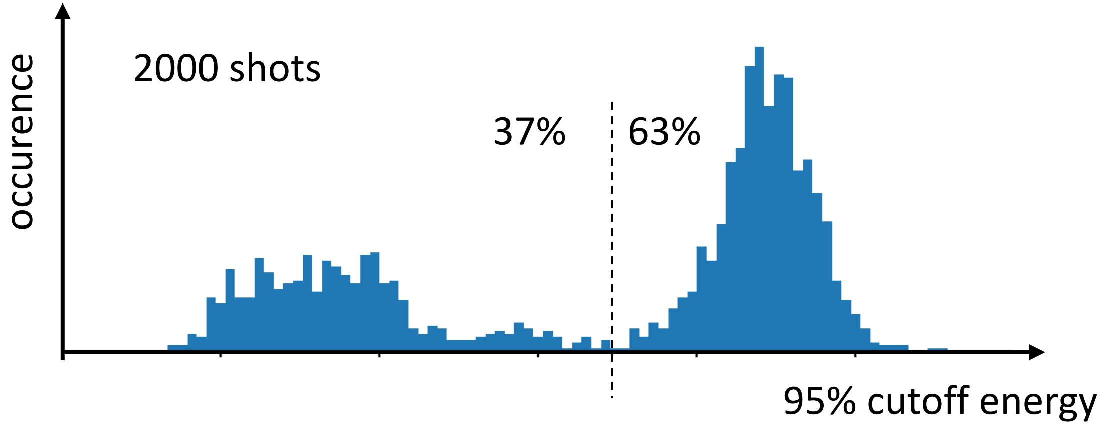
Comparable to: -Bella (~0.5%)
-Angus (~1%)

… however, electrons aren't always:

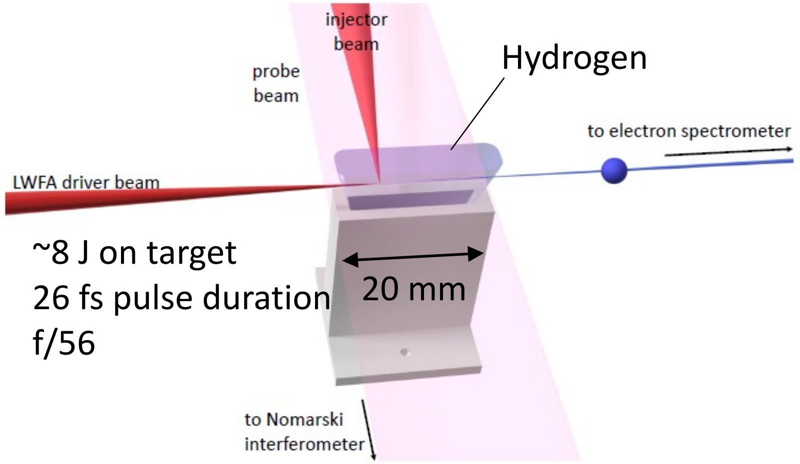




Which laser parameters cause fluctuations?



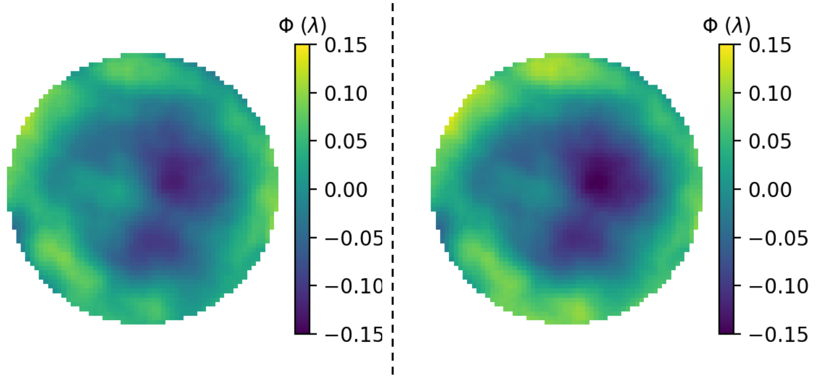
LWFA with slit nozzle and optical injection



→ see Johannes Zirkelbach's talk (next in this session)

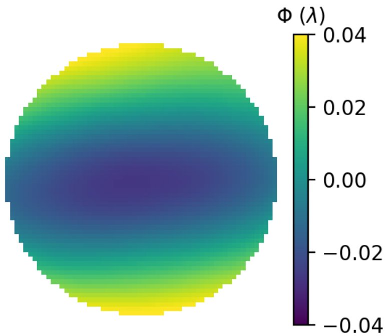
Average wavefront at the laser output:

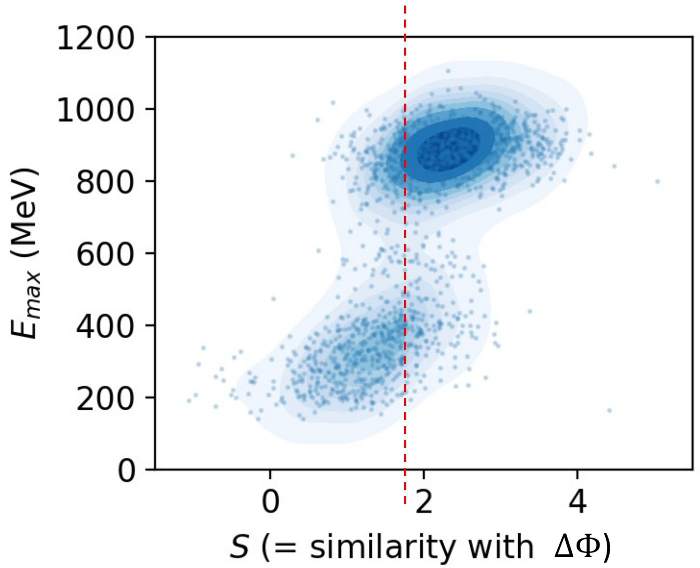
$E_{max} < 700\ MeV$ $E_{max} > 700\ MeV$



$S = \int \Phi \cdot \Delta\Phi \cdot dA$

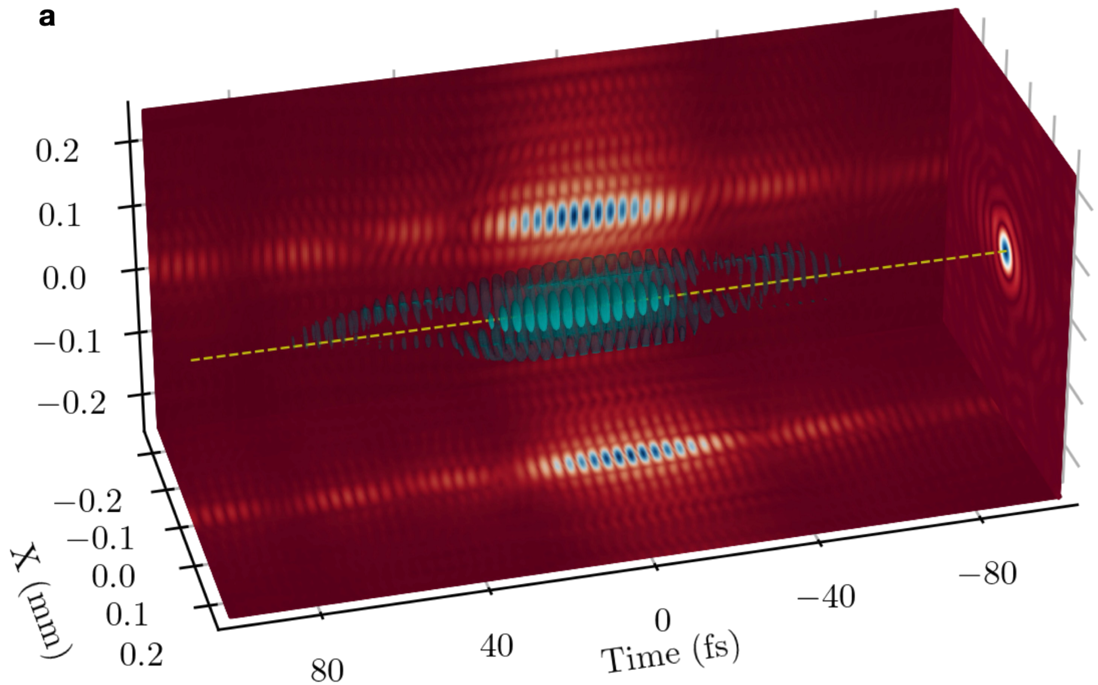
$\Delta\Phi$





New single-shot diagnostics

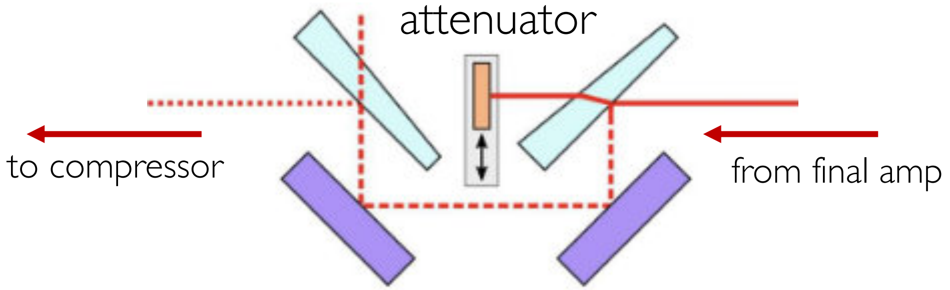
Real-time Acquisition of Vectorial Electro-magnetic Near-fields (RAVEN) – single shot vector field measurement

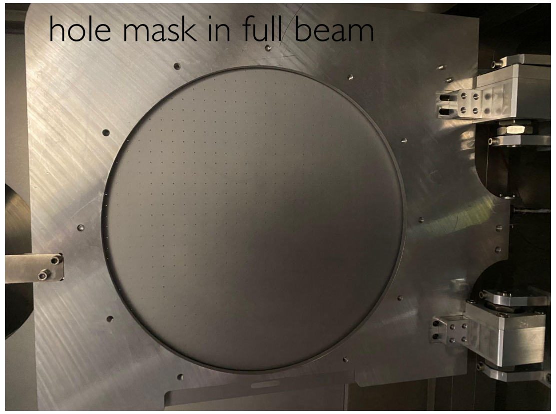


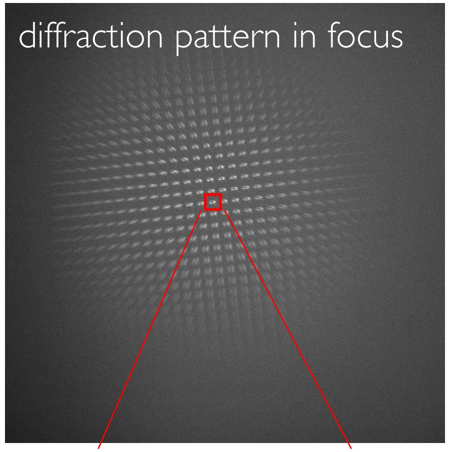
for more details:

➞ see Andreas Döpp's invited talk, Thursday, 11:00 am.

Full-energy focus measurement of a PW laser





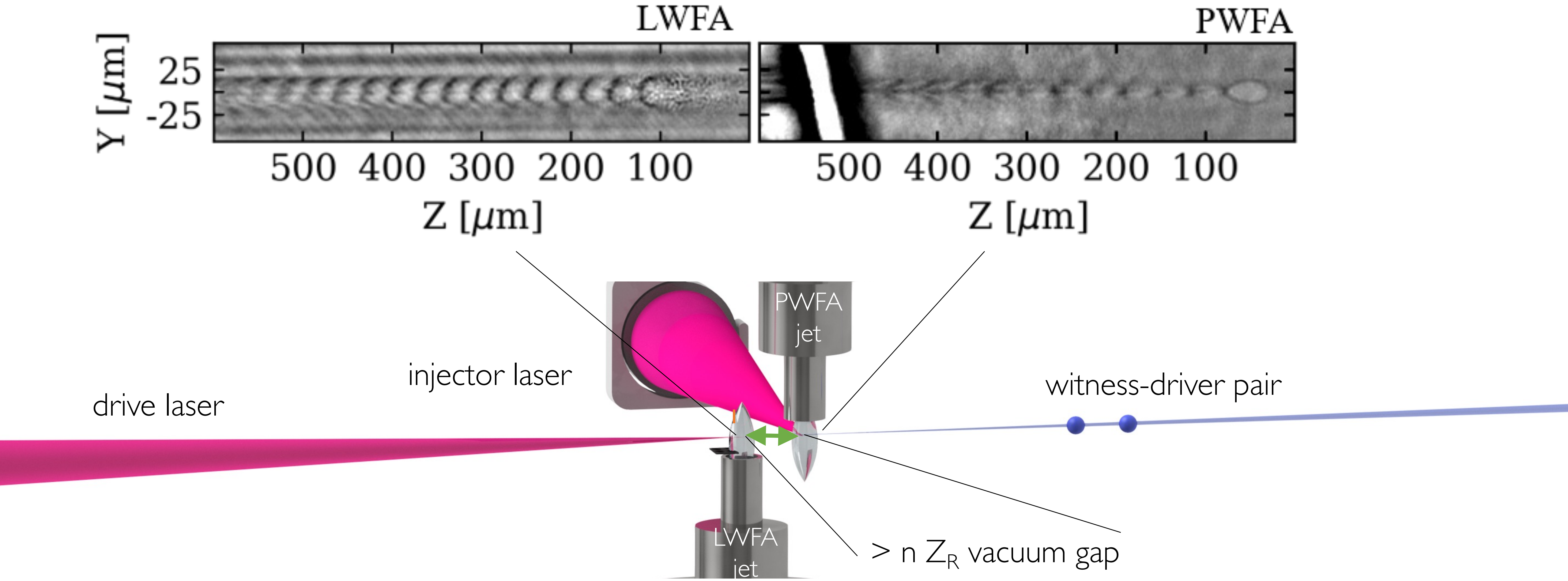


atten. changes focus, mask doesn't

Hybrid laser-plasma wakefield acceleration (LPWFA)

- how do we achieve ultracold electron beams for future wakefield accelerators and compact light sources?
- how can we study basic PWFA physics with high accessibility in a scalable toy model?

Idea: Drive a PWFA with electrons from an LWFA



Hybrid LPWFA milestones

First experimental clues (ca. 2010):

Mode
Colle

Hybrid accelerator & plasma photocathode concept

B. Hi
B. Hi

Strong drivers: nC LWFA electron bunches

J. Co
J. Gö

Plasma waves driven by LWFA electrons

M. G
S. Sc

Driver-witness pairs: Dual bunches from a single LWFA

J. We

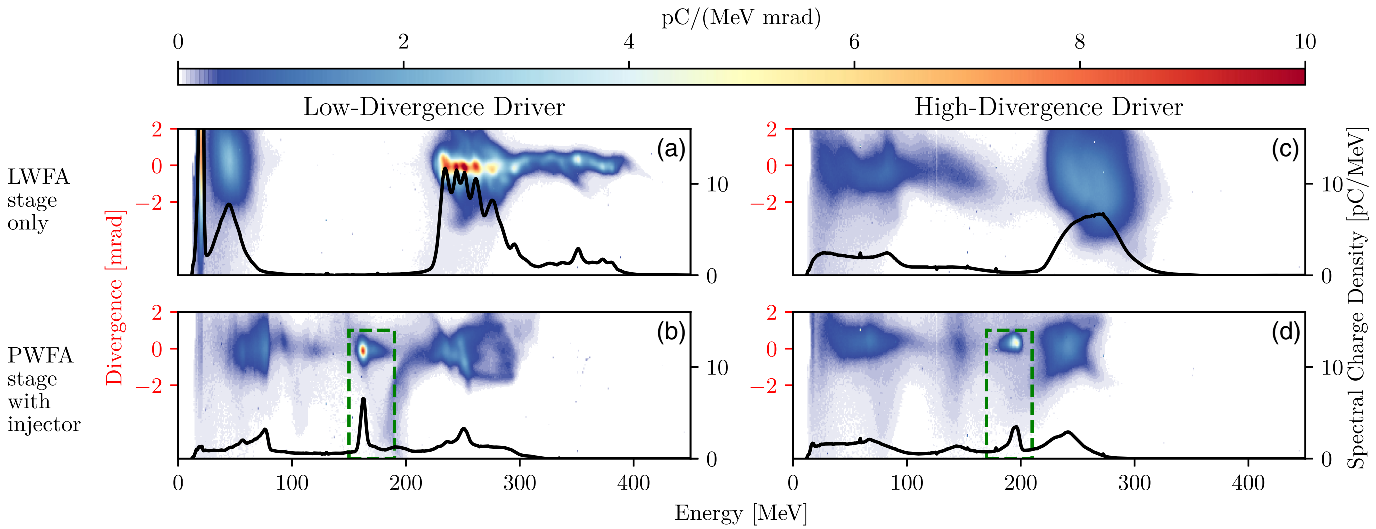
Hybrid proof-of concept: External injection of witness beam

T. K

Towards cold beams: Internal injection of witness beam

J.

High stability and beam quality from hybrid accelerator

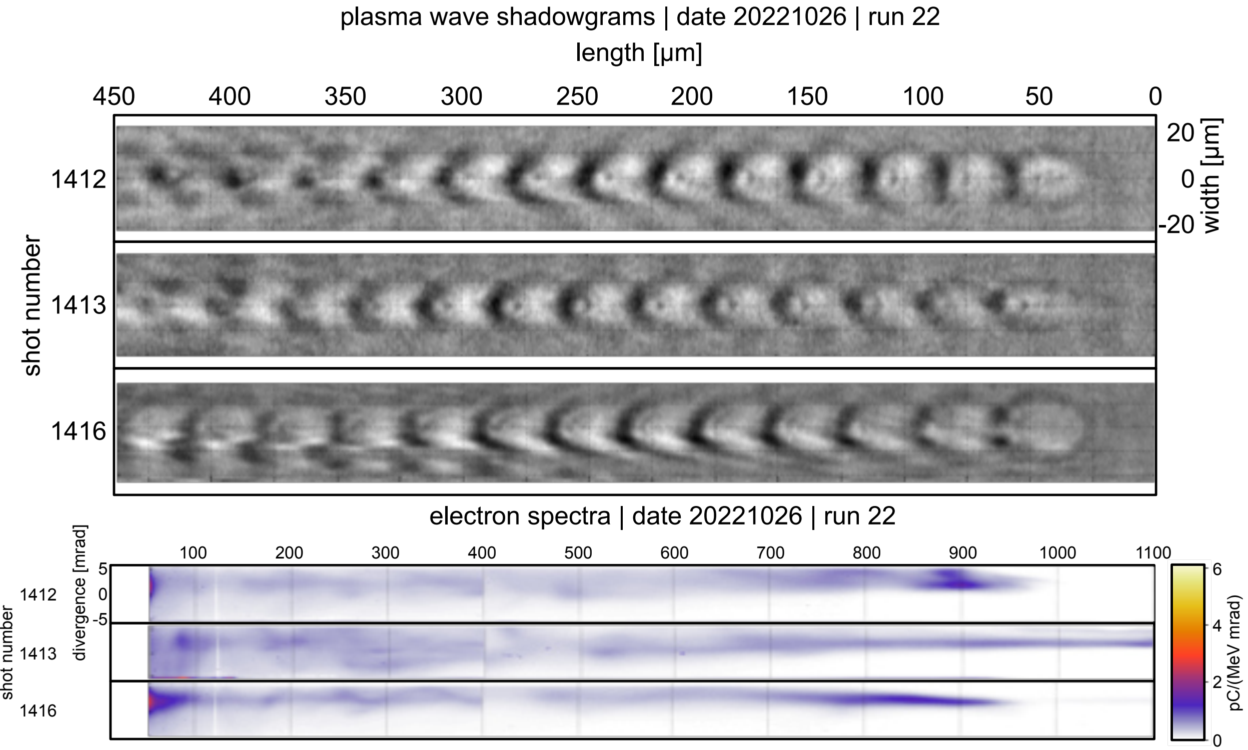


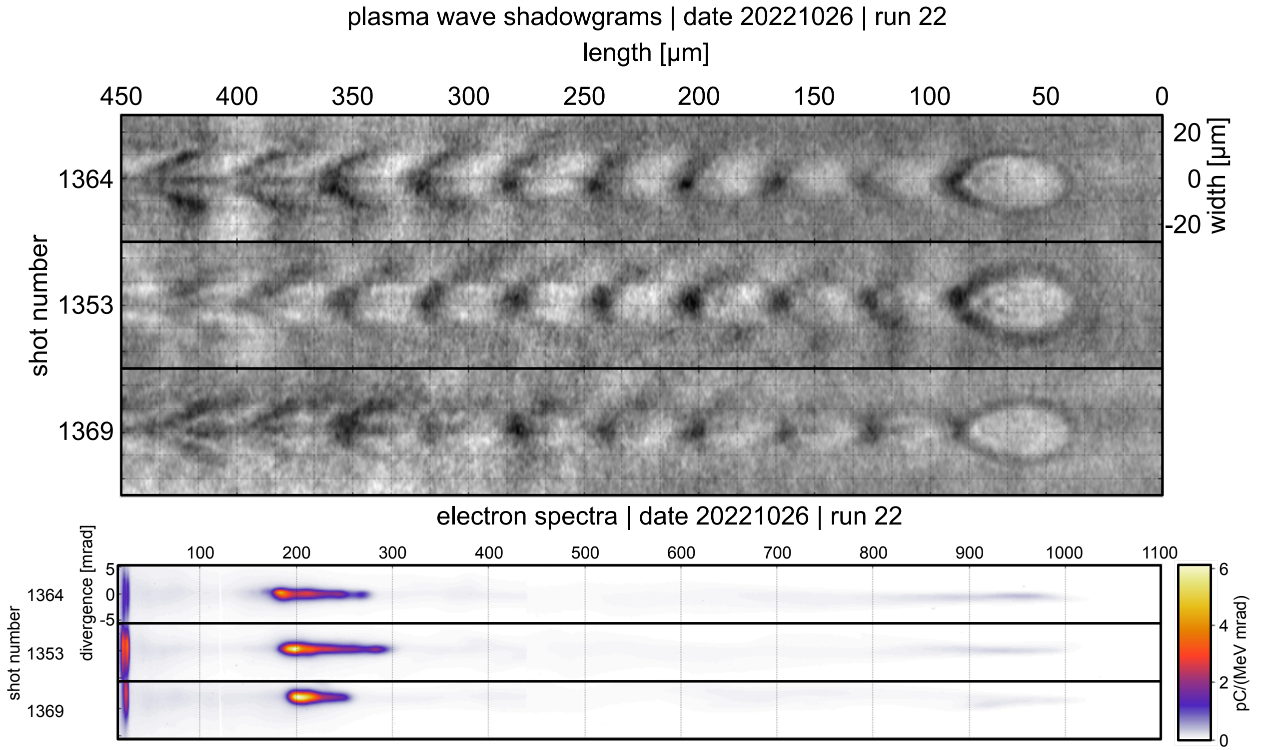
M. Foerster et al. Phys.Rev.X **12**, 041016 (2022)

Hybrid collaboration (since 2017)

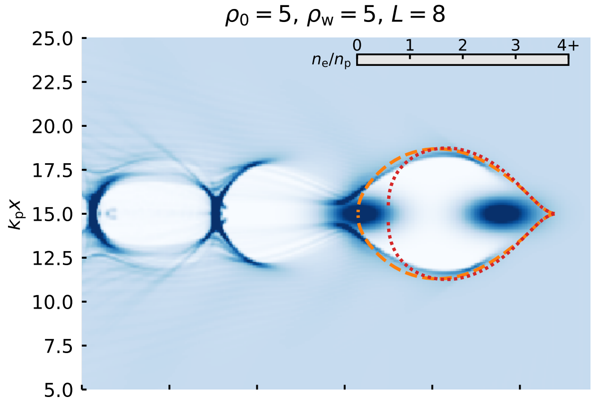
LMU
HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF
loa
University of Strathclyde Glasgow
DESY.
hhu Heinrich Heine Universität Düsseldorf
WEIZMANN INSTITUTE OF SCIENCE

Plasma Wave Shadowgraphy: Elongated first bubble





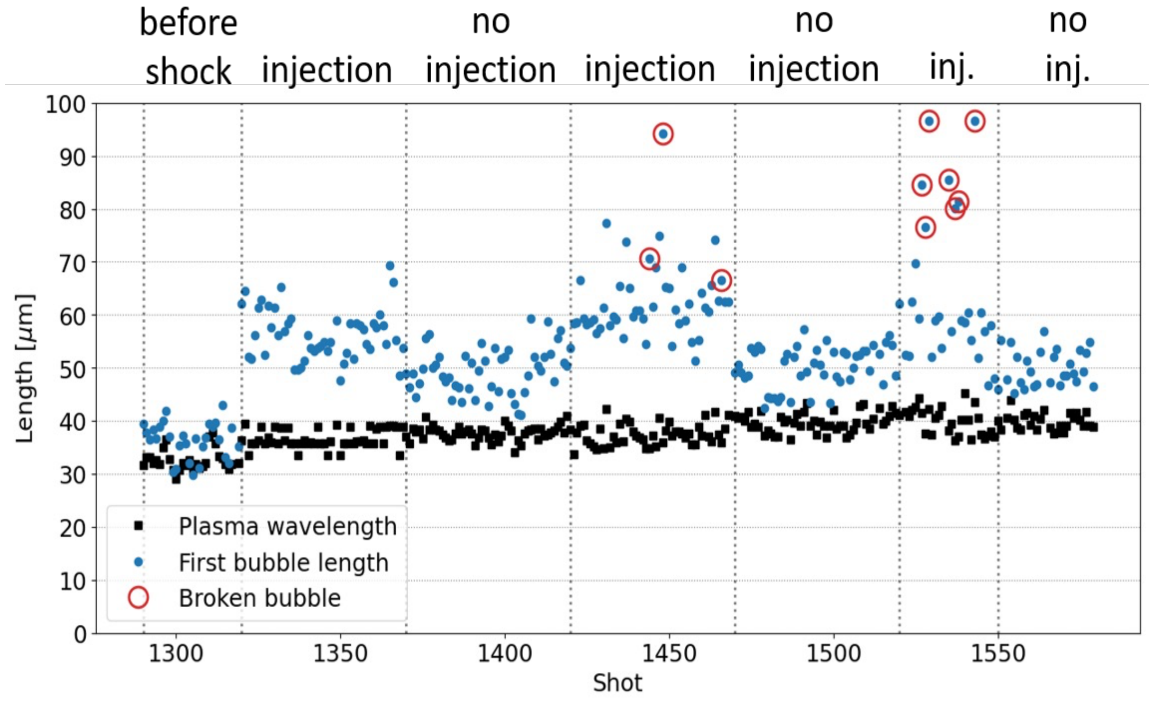
no witness injection

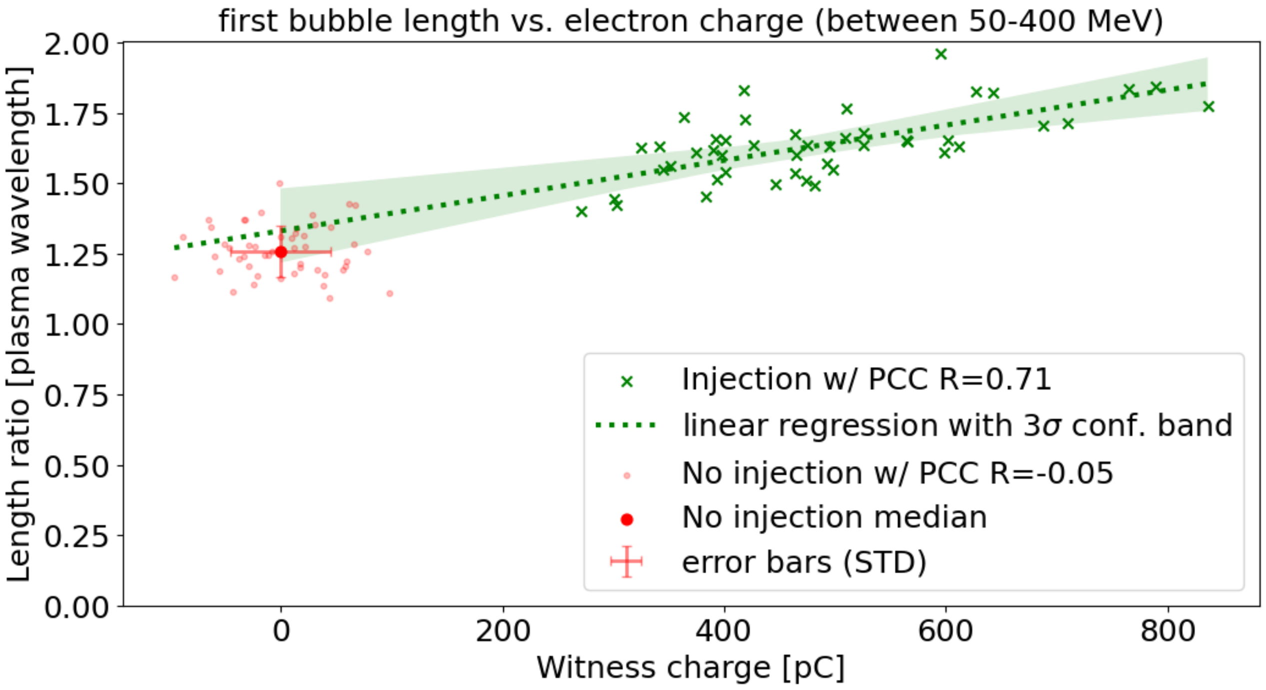


quasi-monochromatic witness injection

Plasma Wave Shadowgraphy: Elongated first bubble

trigger injection with shock in PWFA:

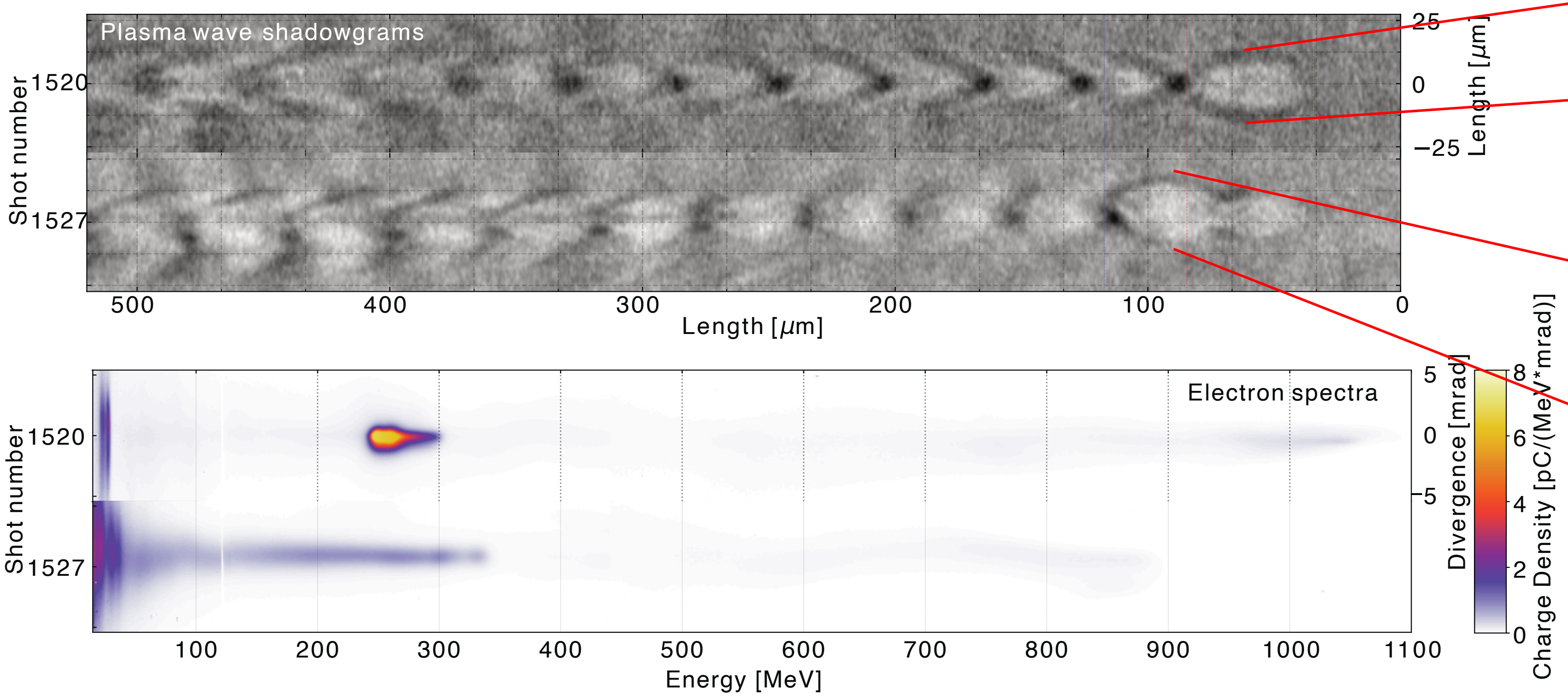


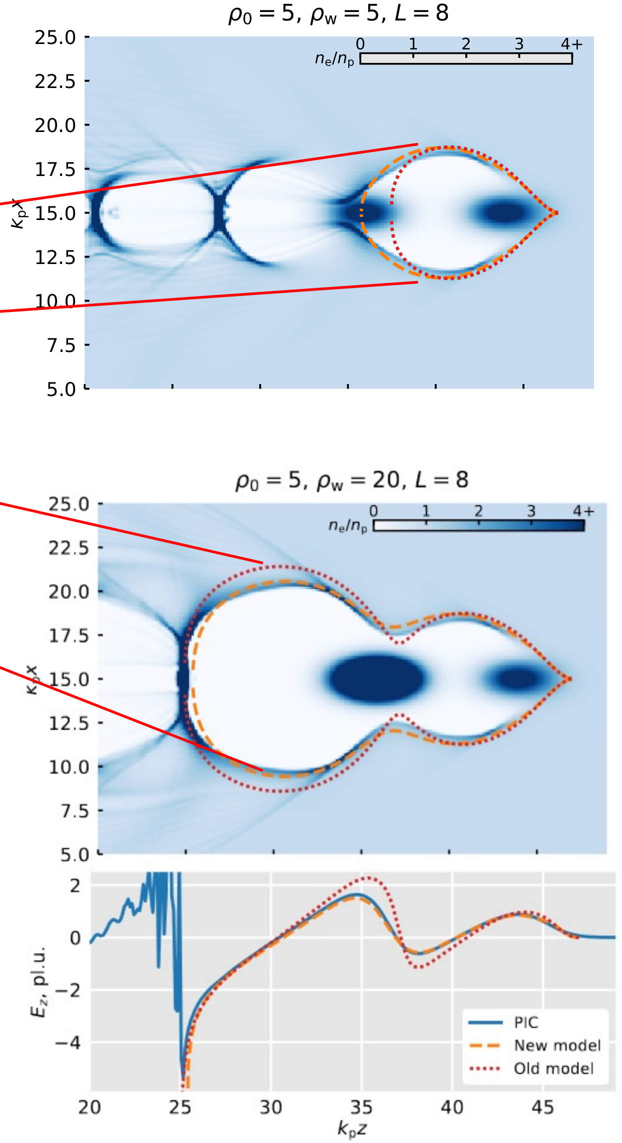


Direct influence of witness' space charge field

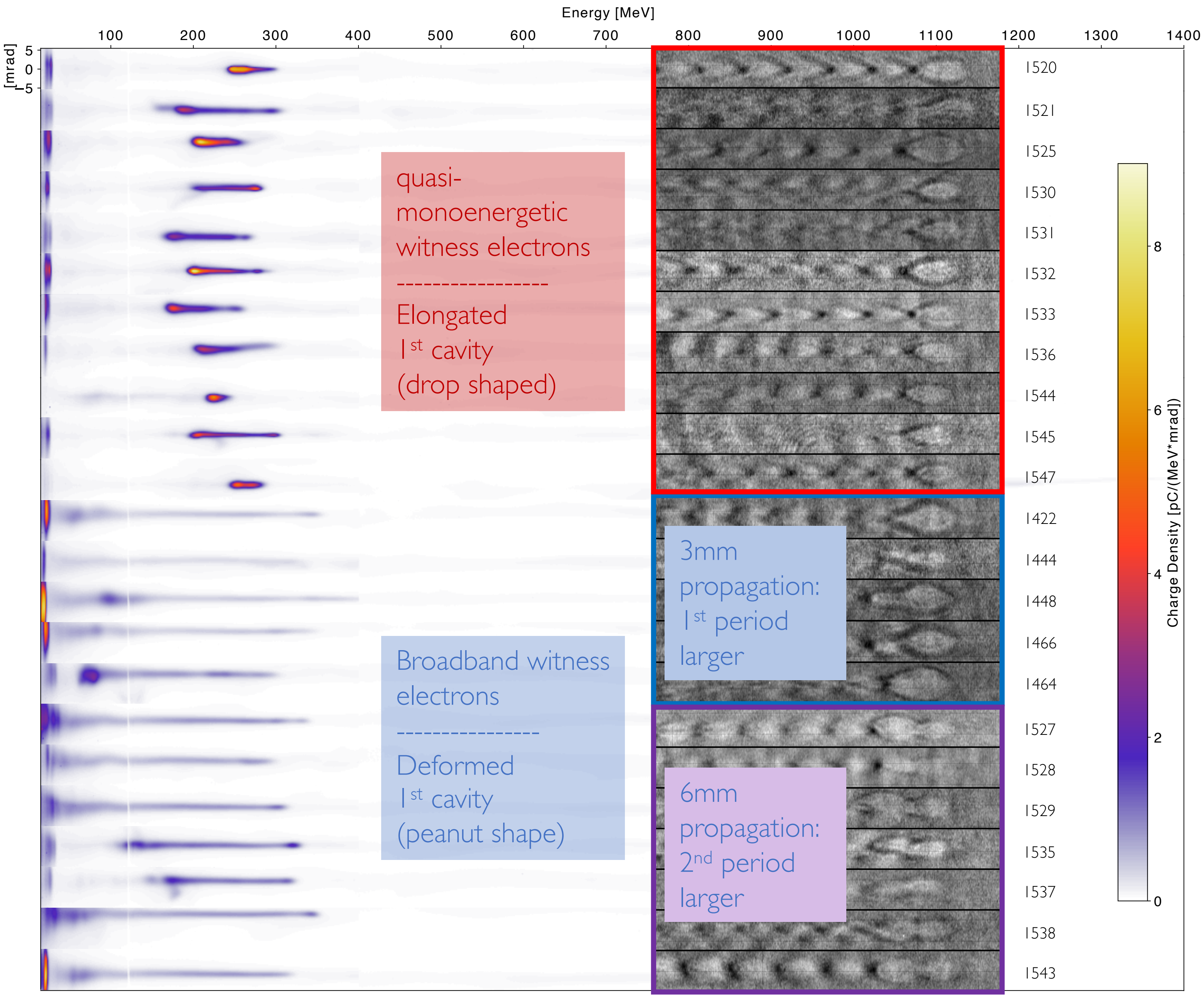
→ can we learn more about witness current?

Some first bubbles are broken: correlated to broadband witness

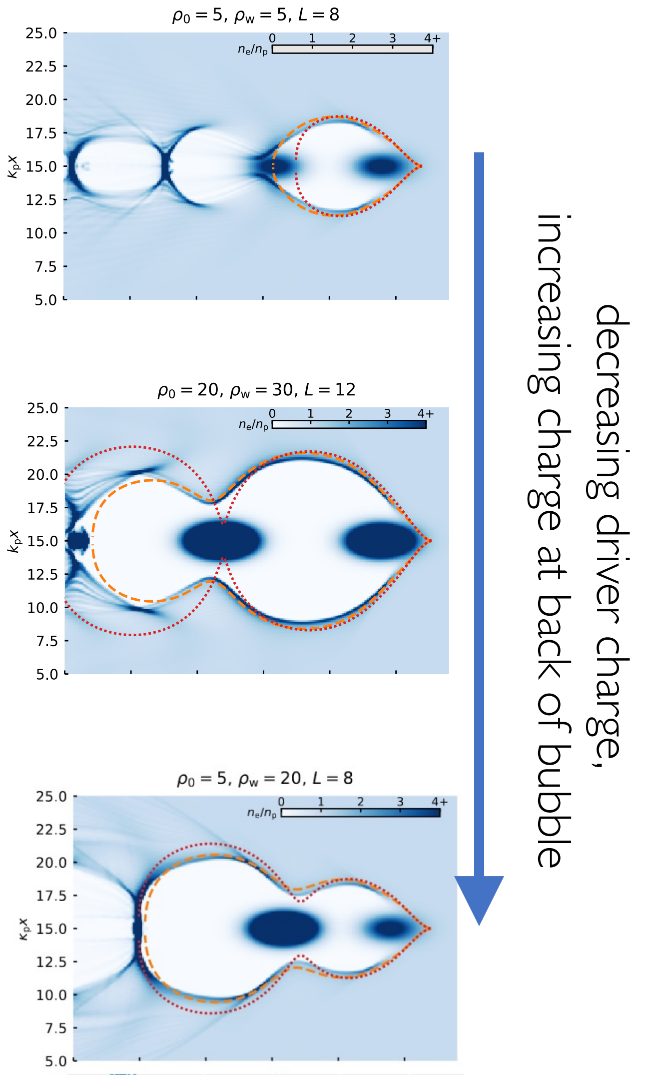




- can the morphology be related to injected charge/monochromatic vs. broadband acceleration?
- did we observe resonant wake enhancement in the beam-driven case?



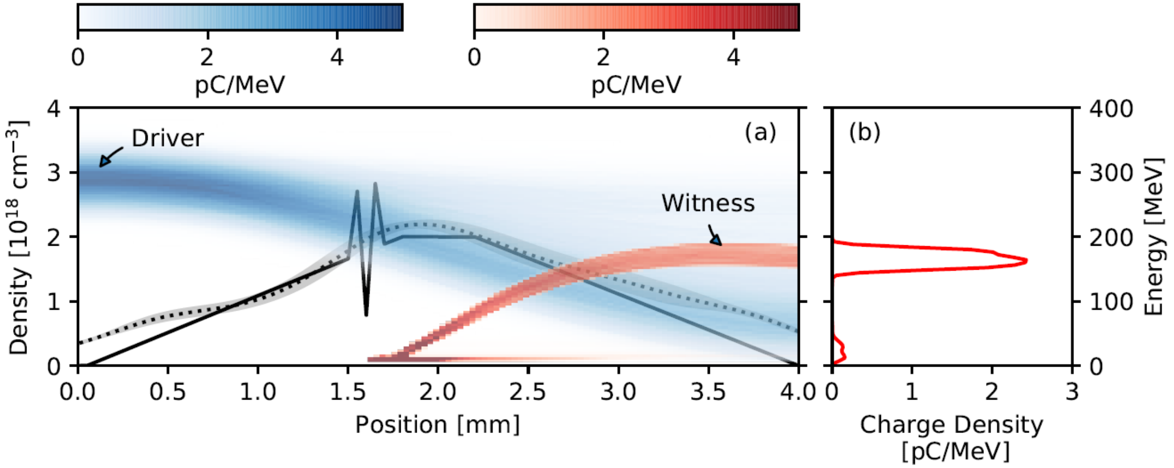
[2023_GOLOVANOV et al._Energy-Conserving Theory of the Blowout Regime of Plasma Wakefield doi:10.1103/PhysRevLett.130.105001]

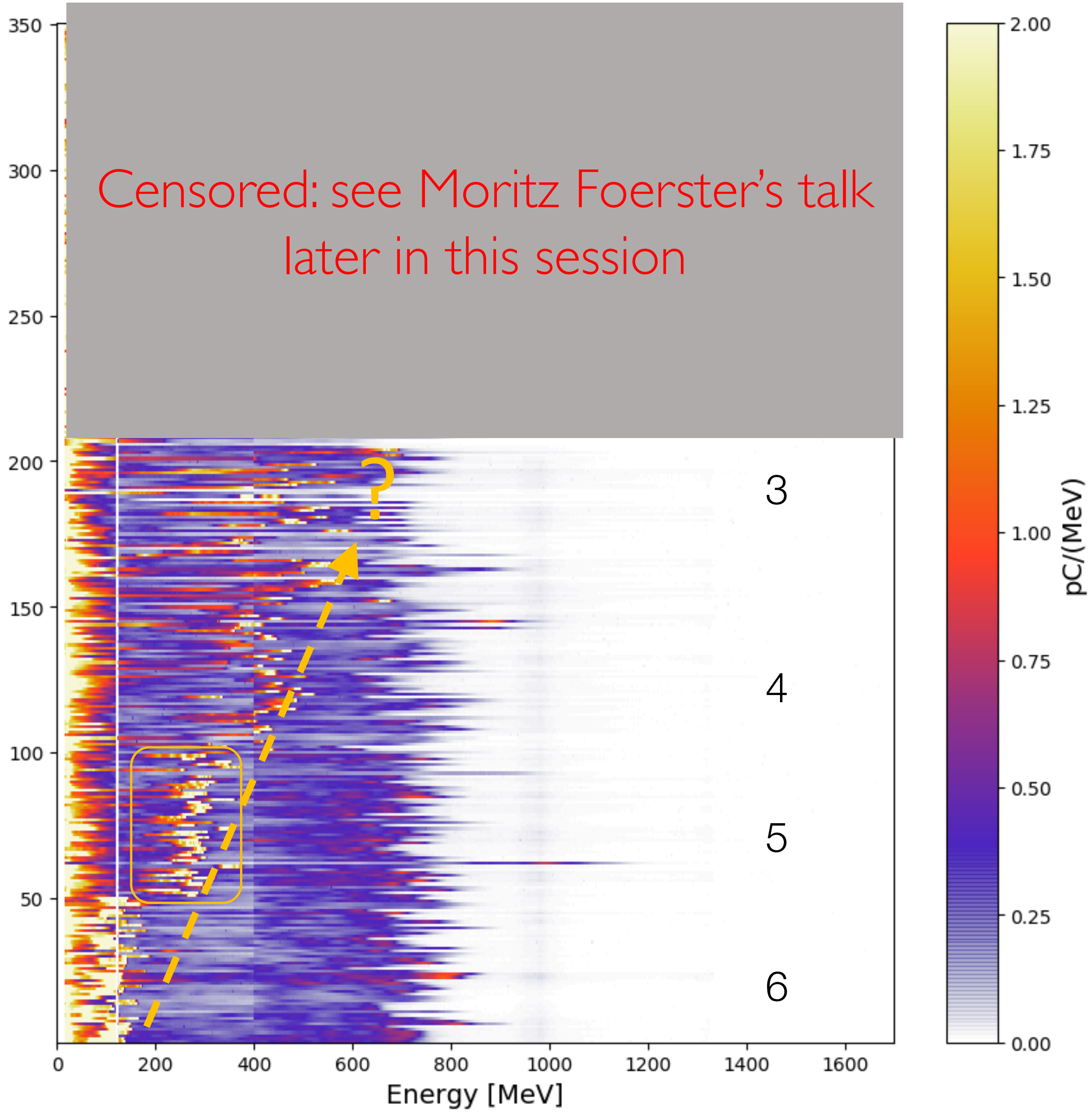


Next steps: Transformer Ratio Challenge

100 GeV/m gradients, but witness beams start at zero energy ⟹ typical final energy ~ 50% of driver energy

Potential cause low-energy driver, short PWFA target with long gradients



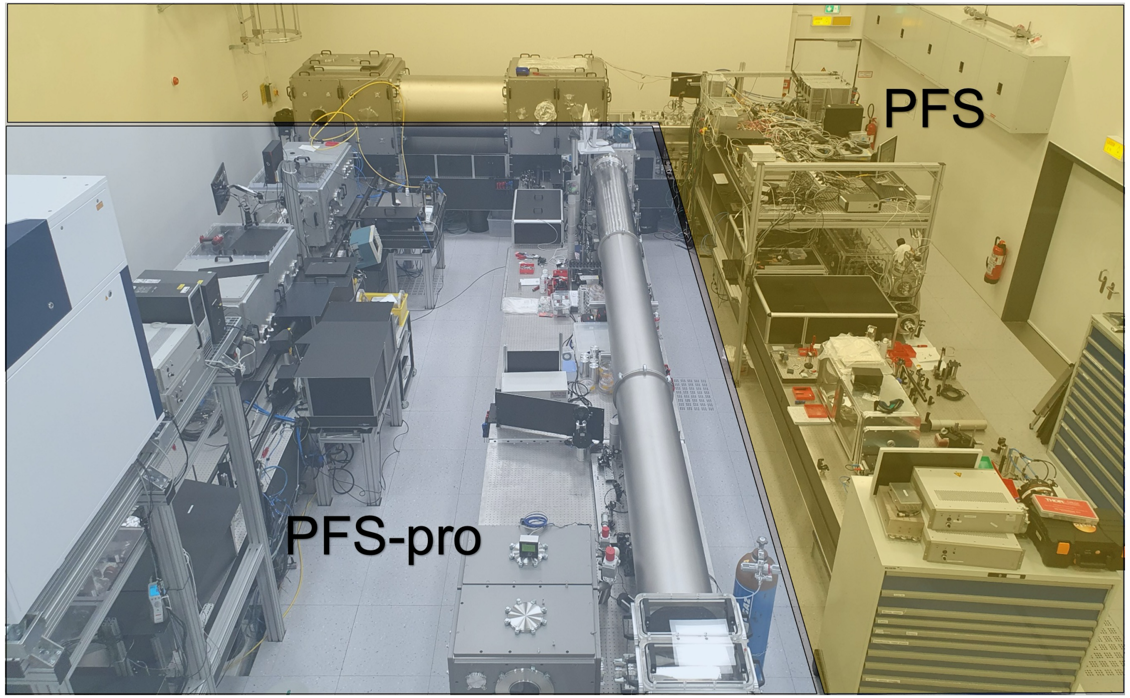


Laser development for P-MoPA @ CALA

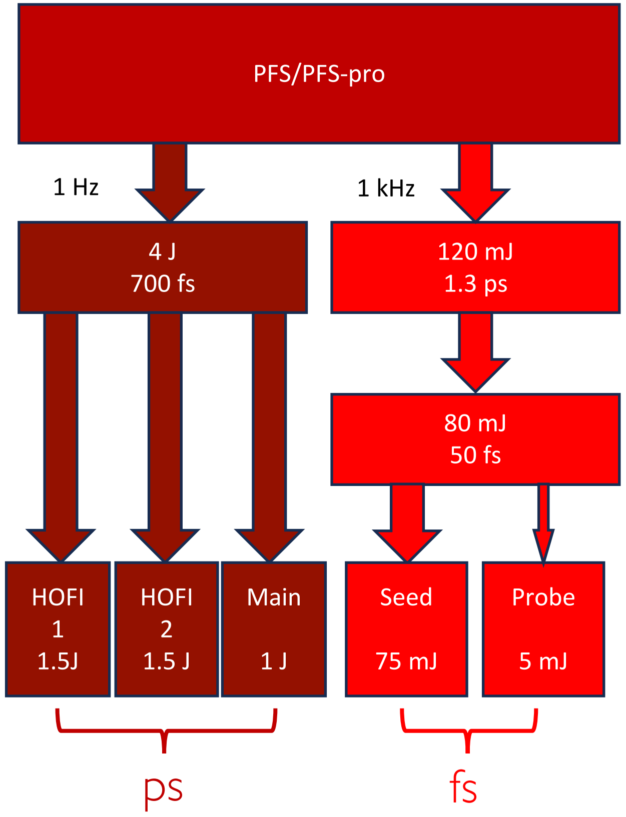
Two synchronized laser systems:

- PFS (7 J, 700 fs, 1-10 Hz): Diode-pumped CPA thick disk homebuilt prototype OPCPA pump, excellent near & far field
- PFS-pro: (120-200 mJ, 1.3 ps, 1 kHz + 80 mJ, 50 fs, 1 kHz): Prototype for Trumpf DIRA CPA disk laser + Herriott cell

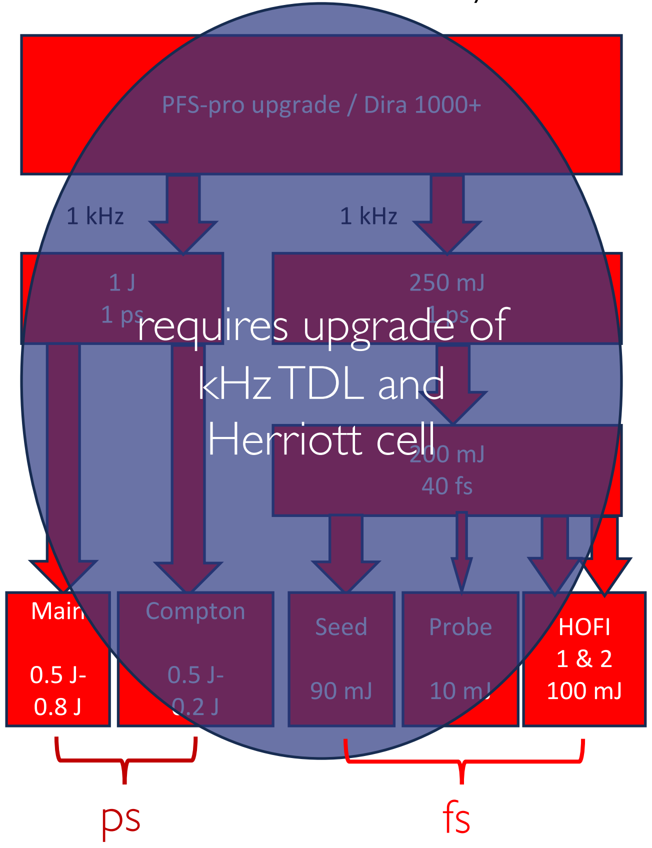
Both multi-% wall-plug efficiency



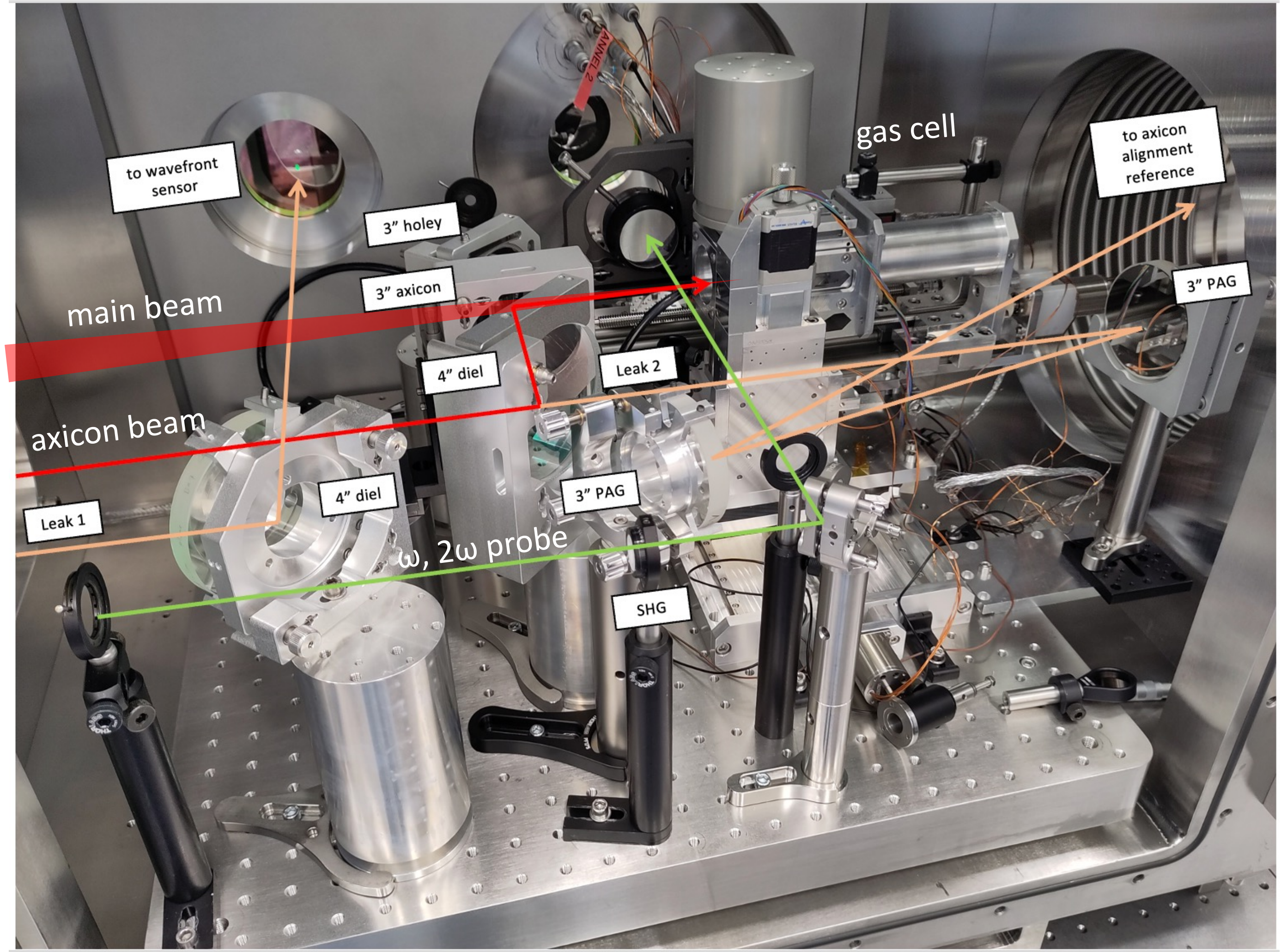
Current: 1 Hz test experiment

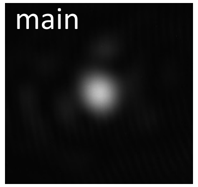


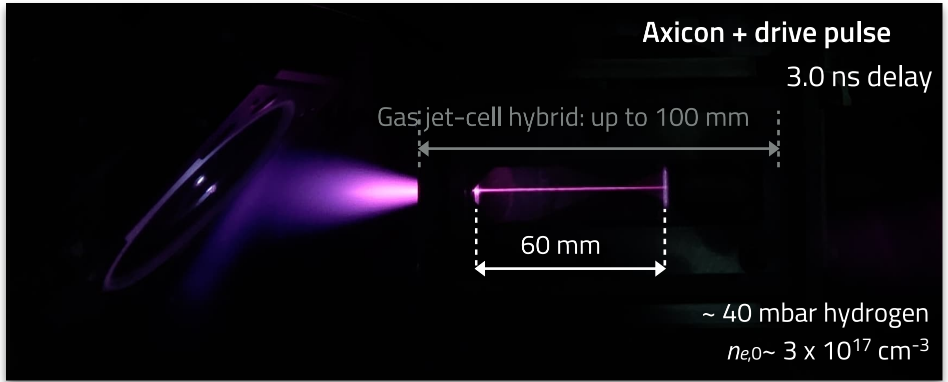
Future: 1 kHz facility



1st steps for P-MoPA @ CALA (w/ S. Hooker's group, UOxf.)







Guiding with ps-pulses works.

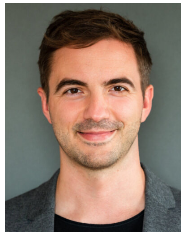
Next steps: Seed pulse and modulation

Acknowledgements to:

CALA



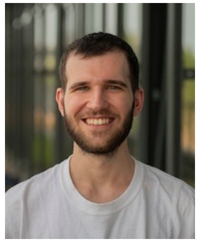




CALA

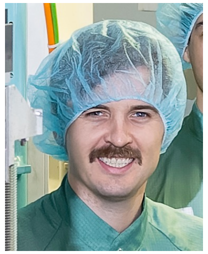



HZDR





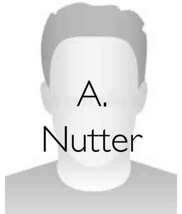
Weizmann


LOA



Strathclyde/HHUD





A. Nutter

Bay. StMWK

Horizon 2020 Programme

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