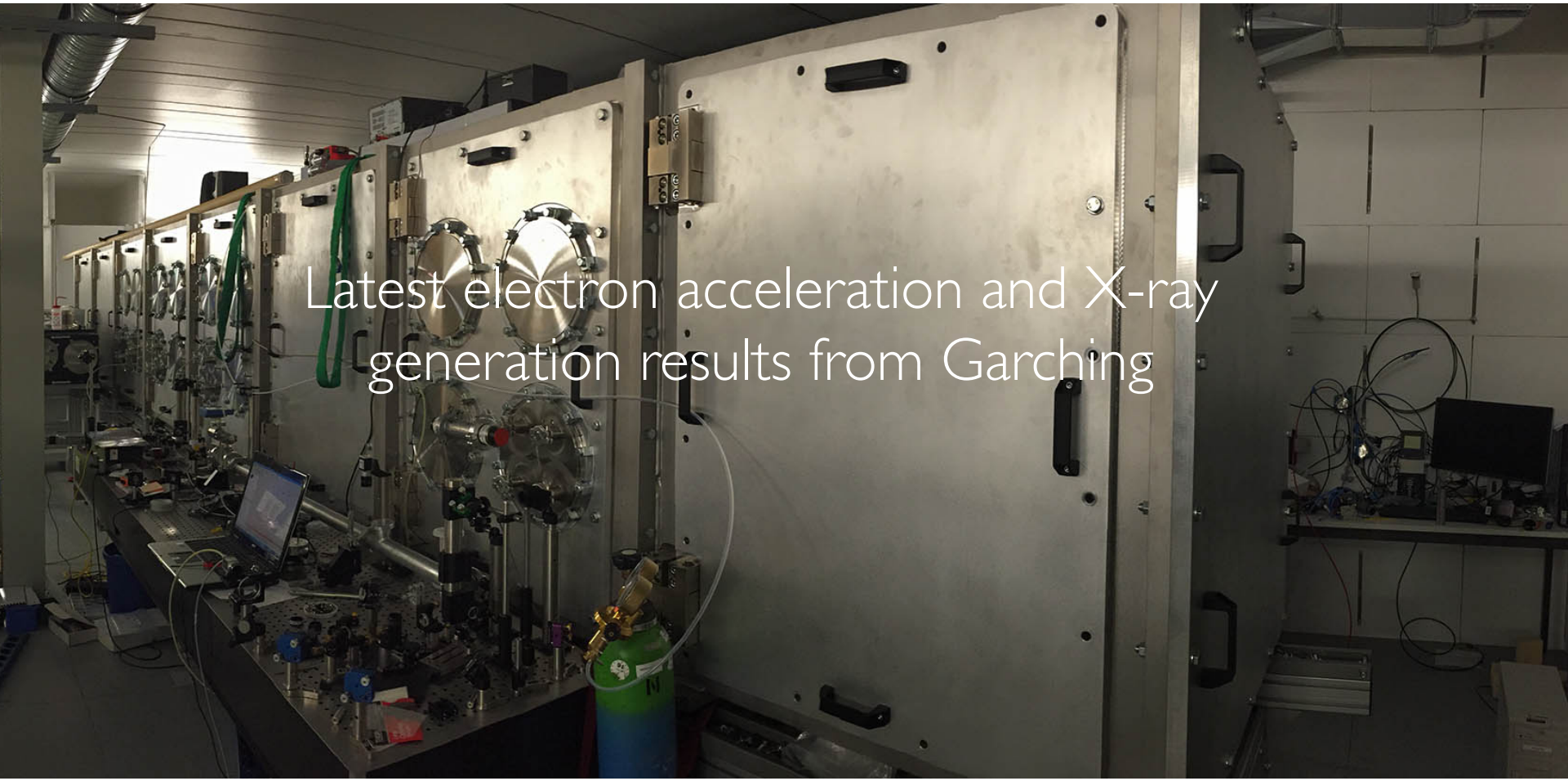


Latest electron acceleration and X-ray generation results from Garching

Stefan Karsch
Ludwig-Maximilians-Universität München/
MPI für Quantenoptik
Garching, Germany

Why have we been so unproductive at Garching?

This talk

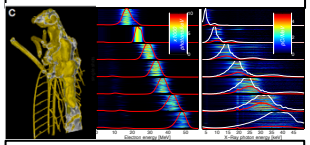
2012	2013	2014	2015	2016	2017	2018

Mainly…

Experiments with 60TW ATLAS laser

Construction of new LEX lab at LMU

Termination of MPQ activities



"old stuff"

Debugging and fixing building media supply and infrastructure

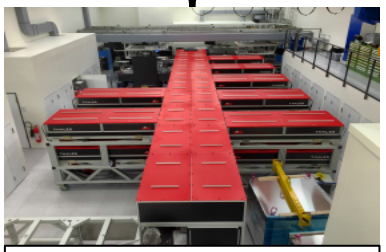
Homemade 200 TW laser upgrade

Construction of beam delivery and experimental chambers

Planning and procurement for new CALA lab @ LMU

Experiments in LEX photonics

CALA procurement



Laser upgrade to 2.5PW (not entirely homemade)

Installation of beam delivery and experiments

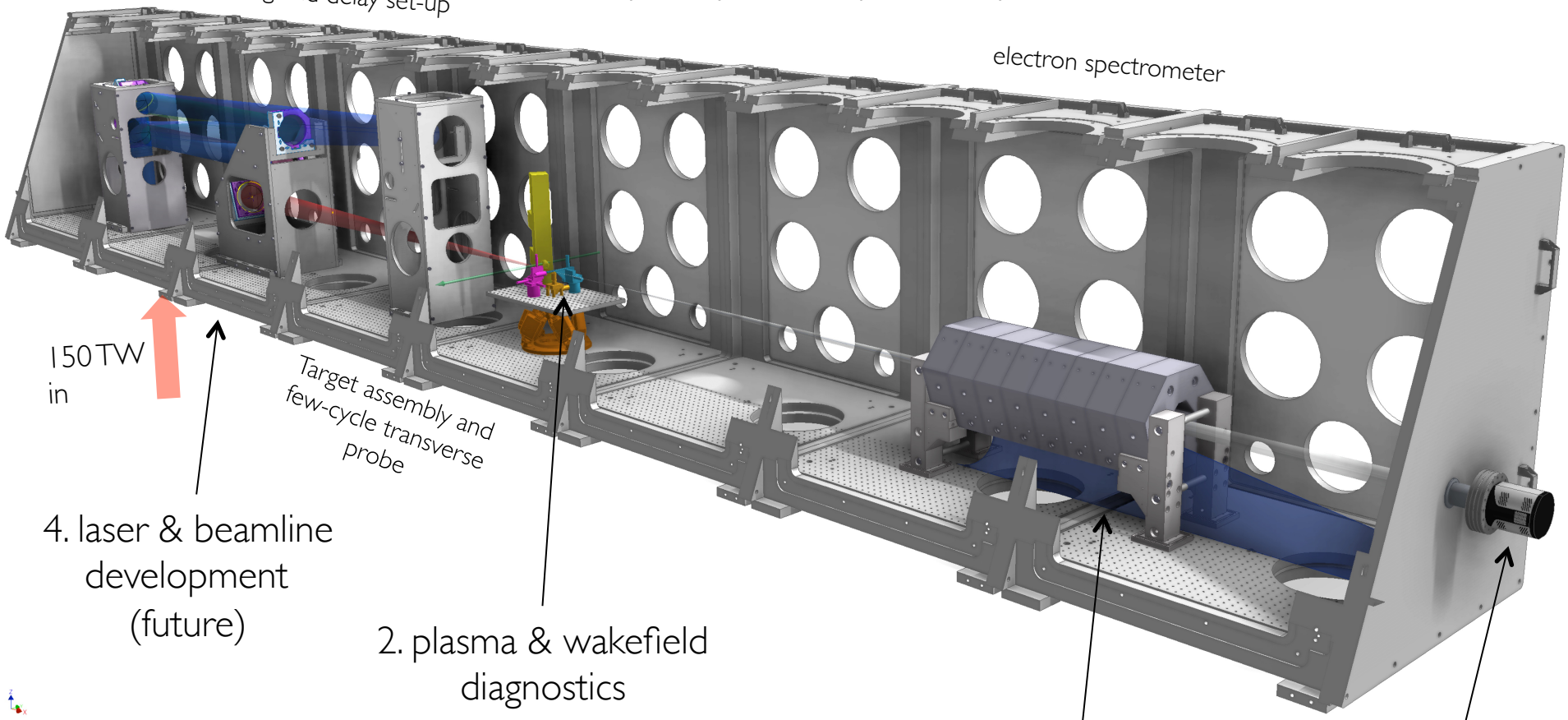
Troubleshooting…

Experiments at CALA?

Move to LEX Photonics @ LMU

Move to CALA

Layout (talk & experiment)

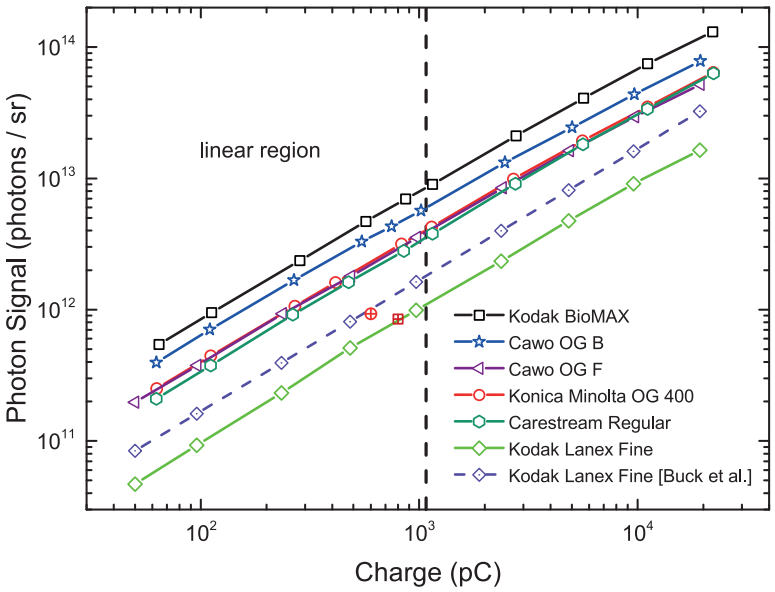


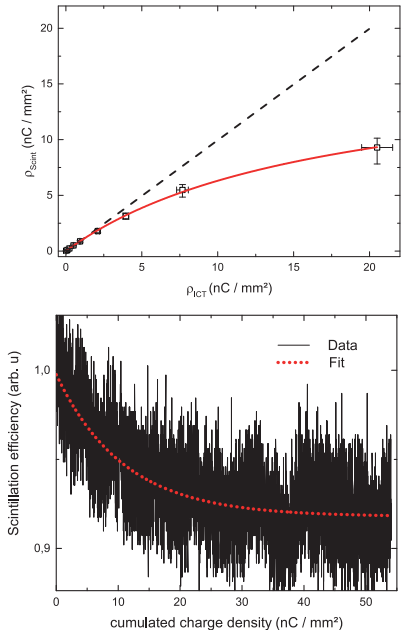
Electron diagnostic: new scintillation screen charge calibration at ELBE linac (HZDR)

Gaseous tritium light source (GTLS) was used for absolute calibration of screen brightness. Poor knowledge of GTLS's decay curve leads to large sytematic errors.

⟹ Replaced master GTLS with stabilized LED source and calibrated camera for off-line calibration of daughter GTLSs or LEDs.

⟹ Extended screen brightness vs. charge density calibration towards high fluence, saturation and damage effects.



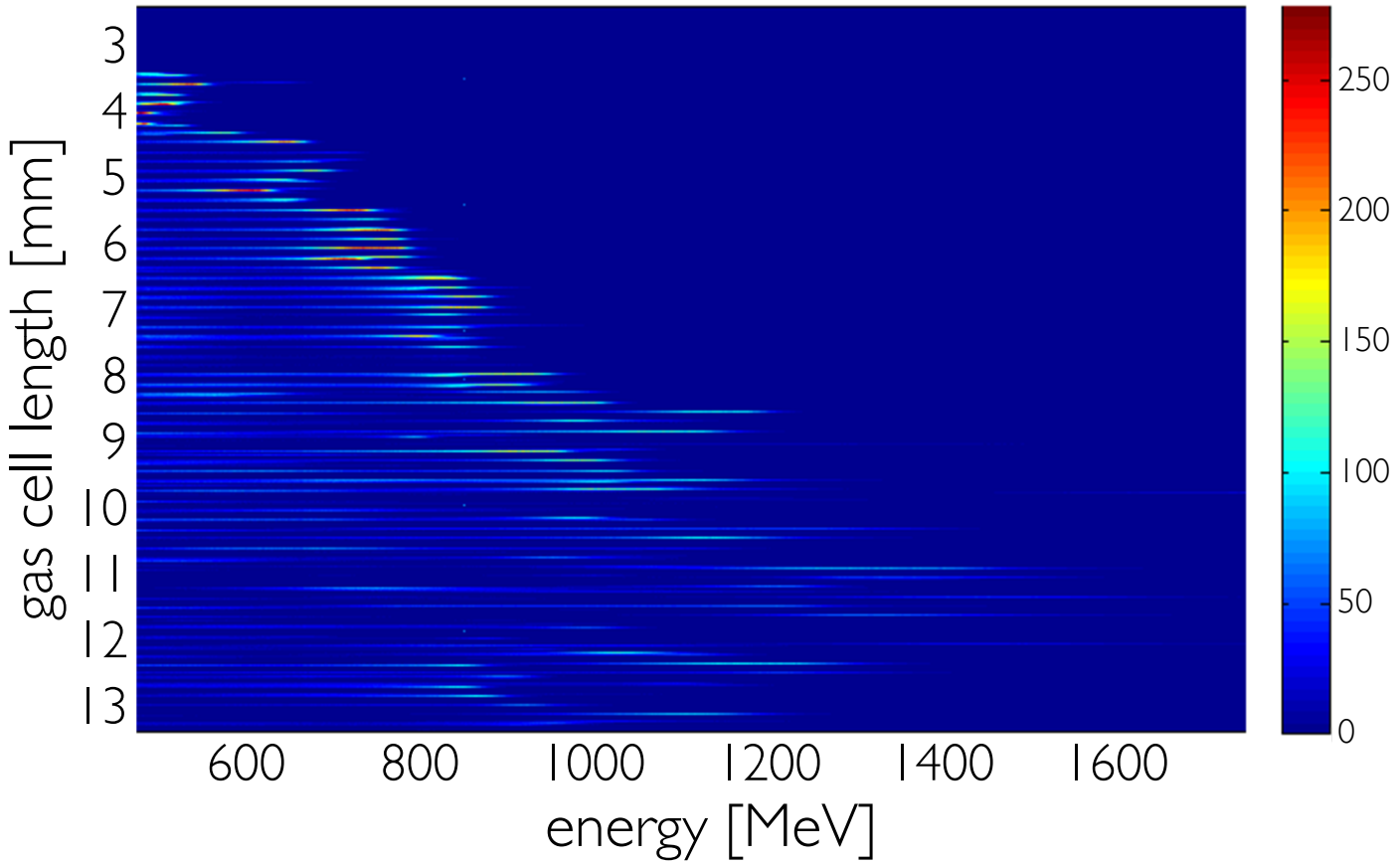


In collaboration with:
U. Schramm, T. Kurz et al. (HZDR)
J.Osterhoff, R. d'Arcy et al. (DESY)

Electron acceleration: Wavebreaking injection:

Length-variable gas cell: up to >1 GeV beams with multi-100 pC charge

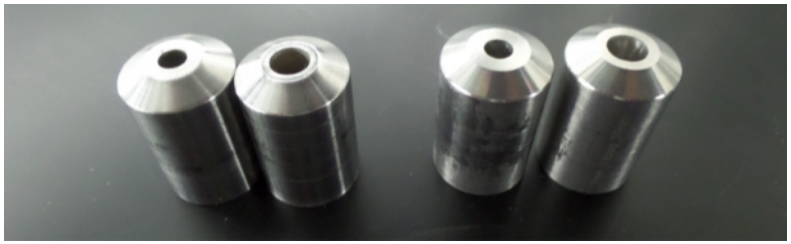
- Peaked spectra up to 800 MeV
- Unstable, fluctuating spectra beyond 1 GeV – possible LWFA/PWFA transition

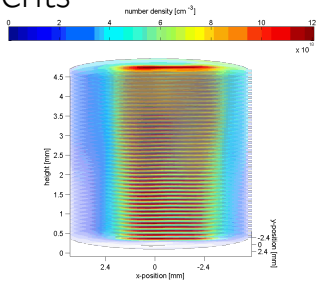


Electron acceleration: Shock-front injection

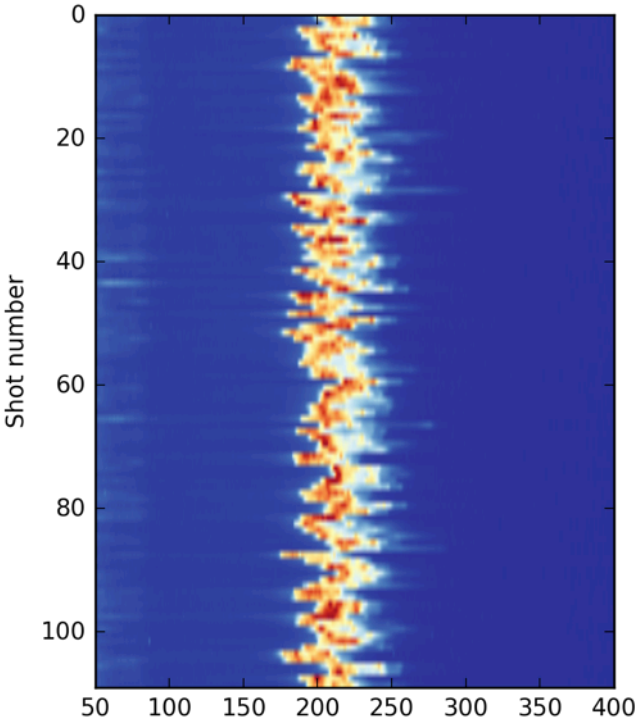
- Upgraded laser (now 2-3 J on target)

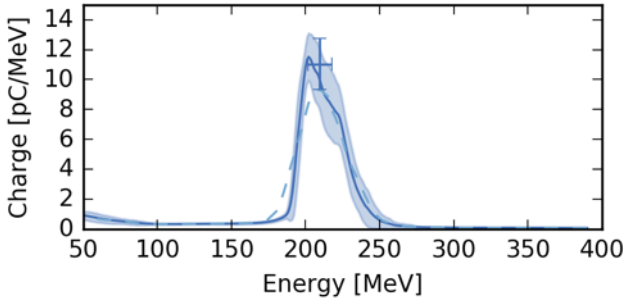
- Made new nozzles (Mach 6+) for sharper gradients





- **Stable, monoenergetic, high charge electron beams**
  - Charge: **256 ± 36 pC (14 %)**
  - Peak energy: **210 ± 8 MeV (4 %)**
  - Energy spread (rms): **13.4 ± 1.6 MeV (6.5 %)**
- What is the scaling of this?

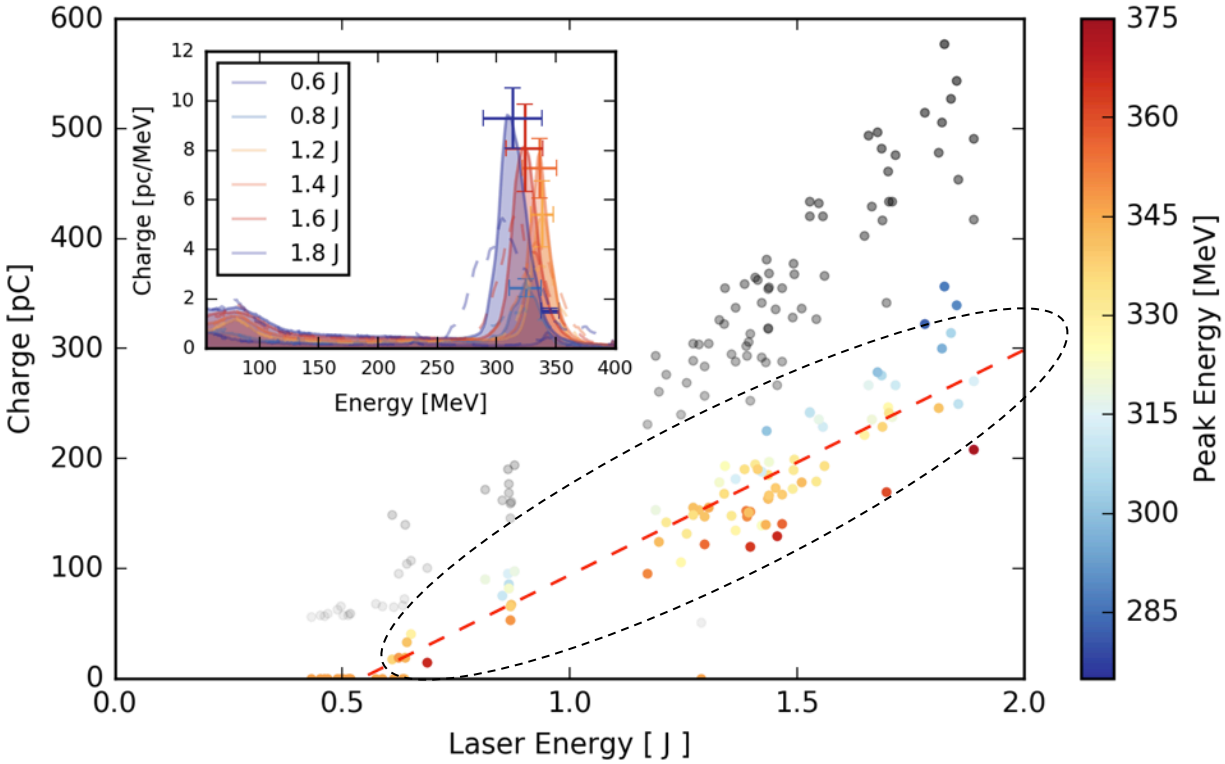




Energy Scan & Scaling

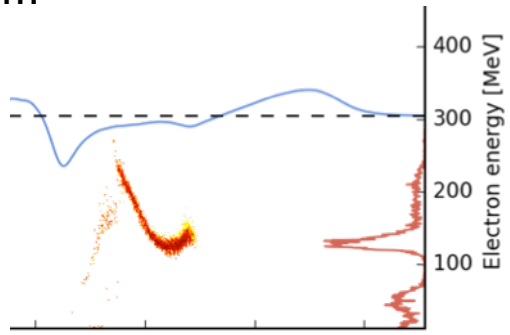
Laser Energy Scan from 0.3 – 2.0 J

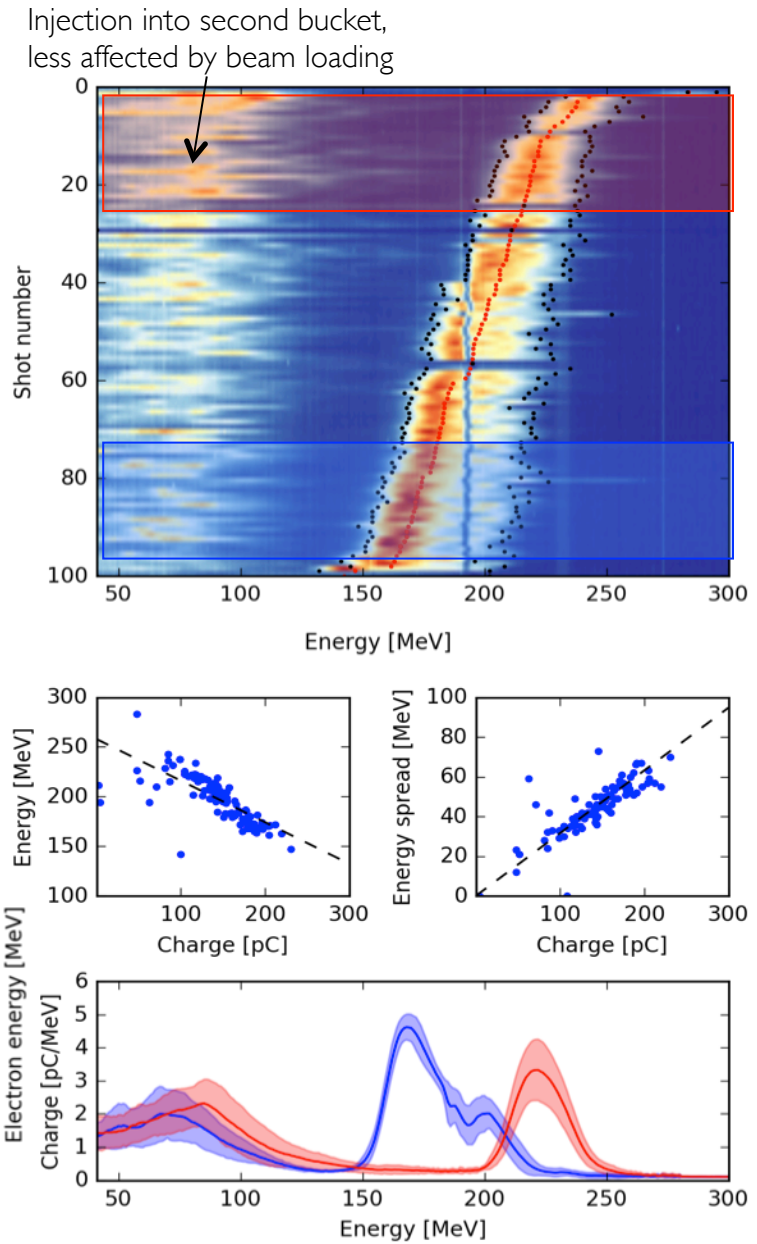
- Injection threshold at 500 mJ
- Charge scales linearly with energy
- Data seem to show beam-loading effects
- But peak energy is also affected by laser energy



More beam loading effects

- Data from a less stable run (compared to other run)
  - Charge: **142 pC ± 43 (30 %)** (14 %)
  - Peak energy: **198 ± 26 MeV (13 %)** (4%)
  - Energy spread (rms): **16 ± 19 MeV** (13 ± 1.6 MeV)
- **When sorted by peak energy a clear pattern emerges**
- Both **beam energy and energy spread scale with beam charge**
- **Peak skewed towards low energy side is a signature of beam-loading in the spectrum**
- Two bunches in two buckets
  ⟹ driver-witness?





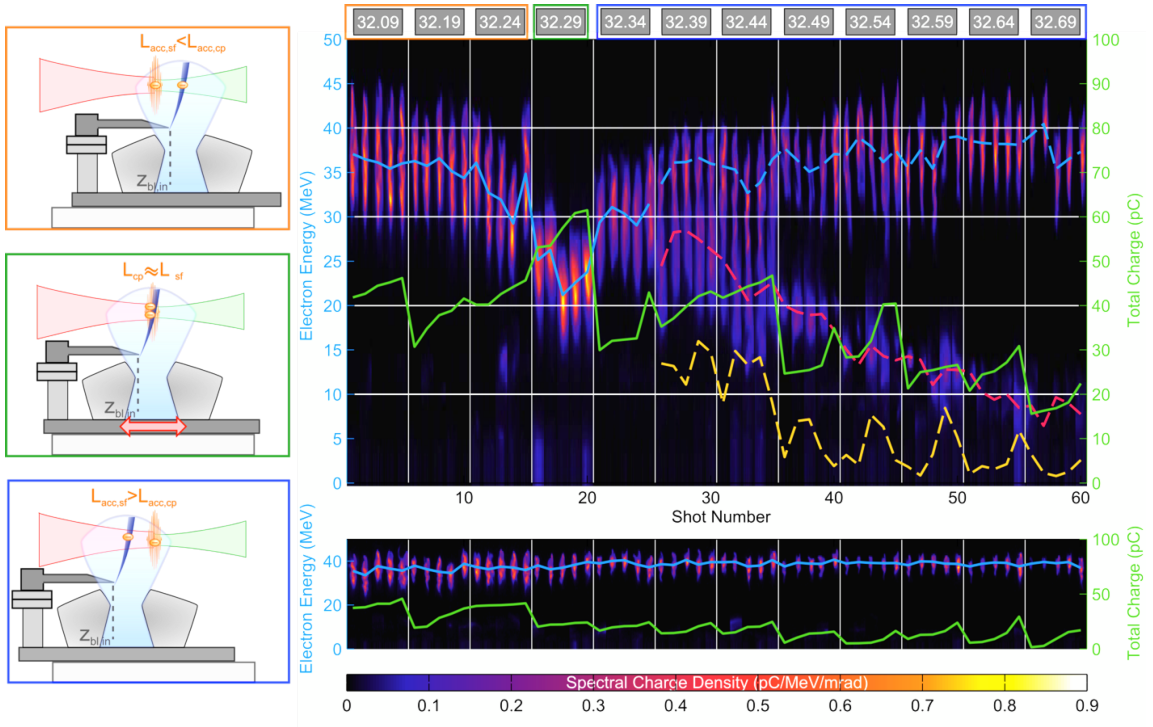
Dual shock front/colliding pulse injection:

data from 60 TW:

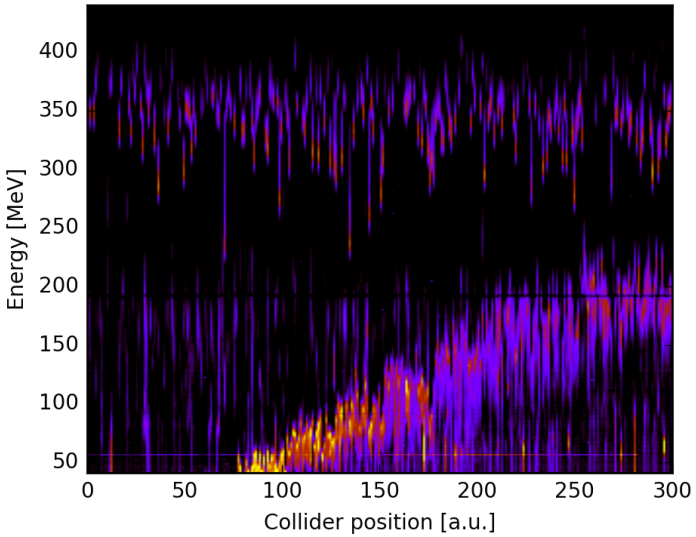
Collision position:

before.....at.....behind.....

shock position



data from 150 TW:

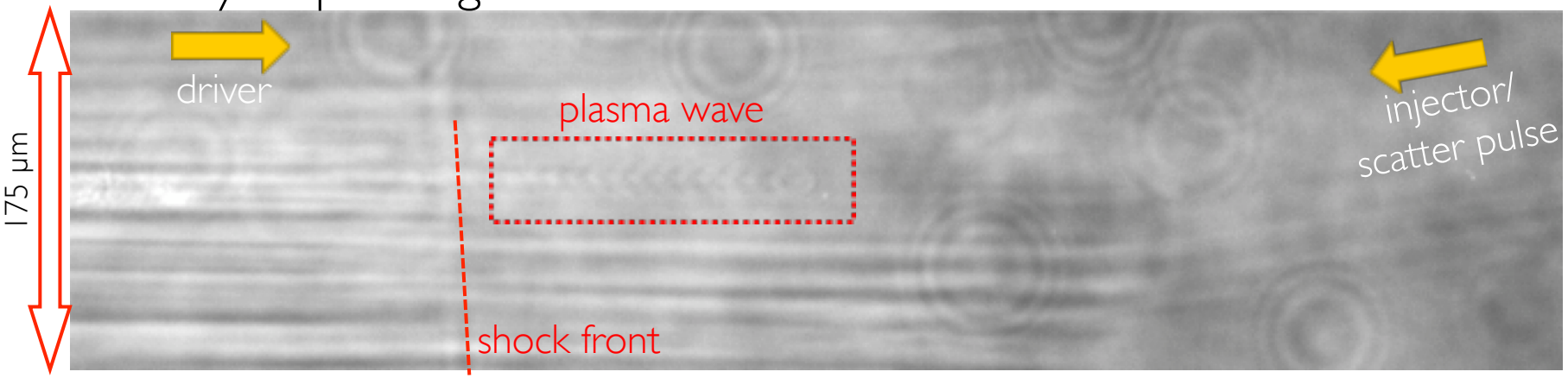


Two independently tuneable electron bunches from one bucket, interacting via beam-loading.

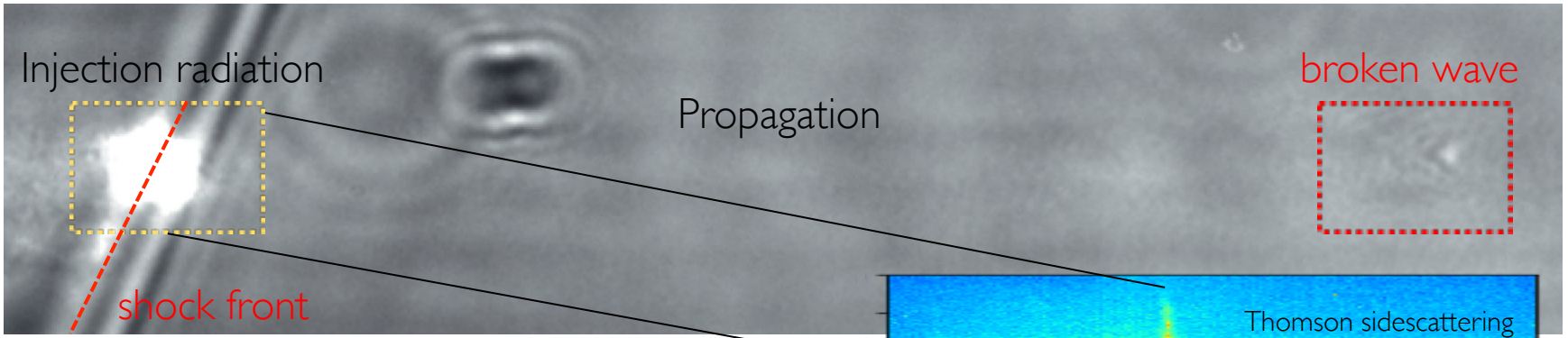
⟹ more flexible driver-witness experiments

Extend to arbitrary bucket by transverse optical injection

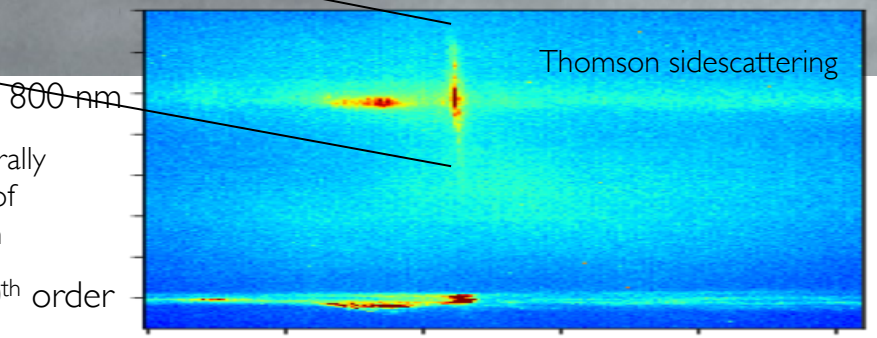
Few-cycle probing



plasma wave with more than 10 oscillation periods

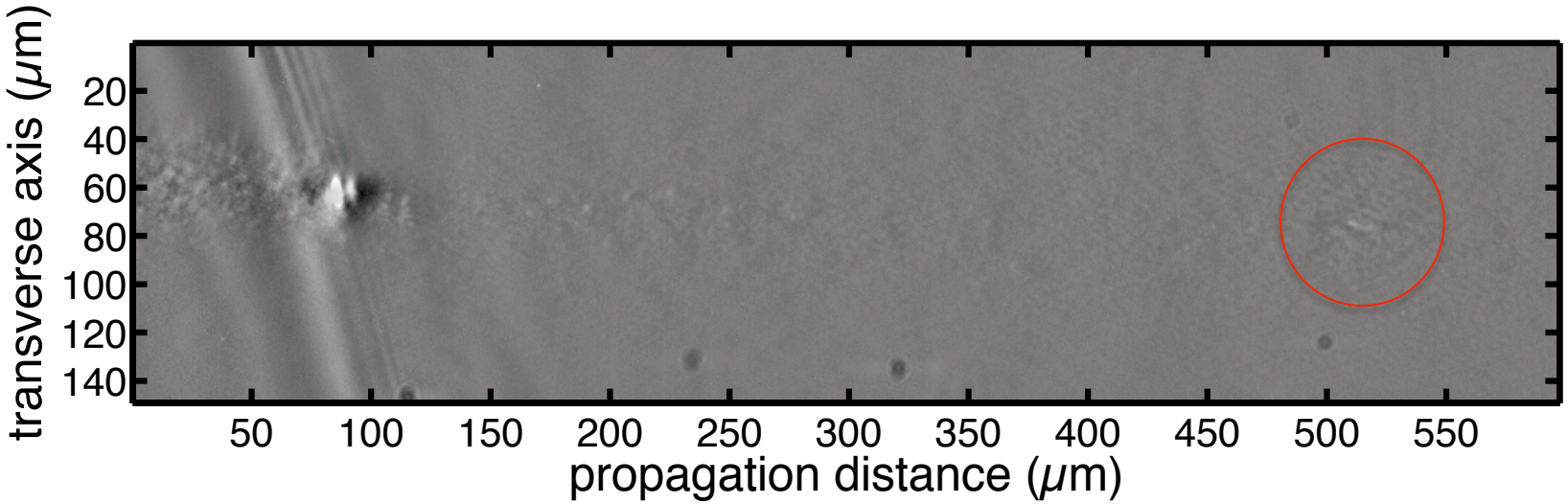


fully broken bubble



Faraday rotation signal

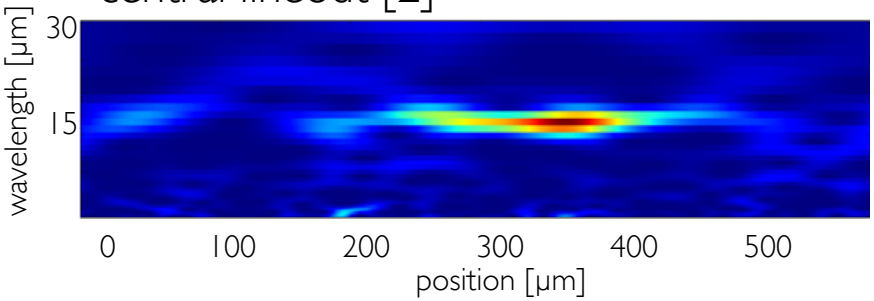
- maps bunch magnetic field
- indicates only one bucket filled with high-charge beam



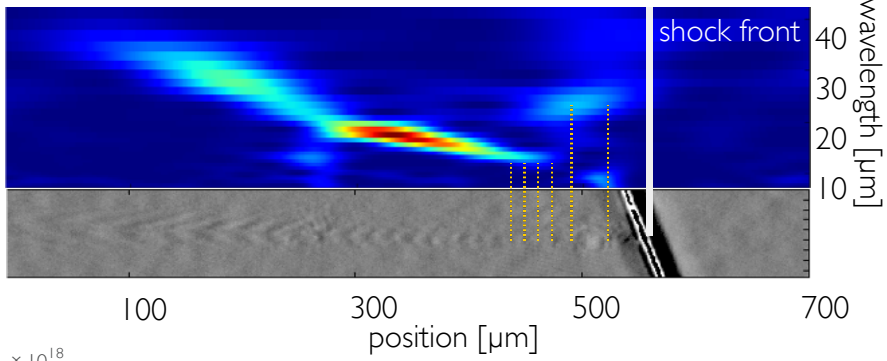
Wakefield analysis

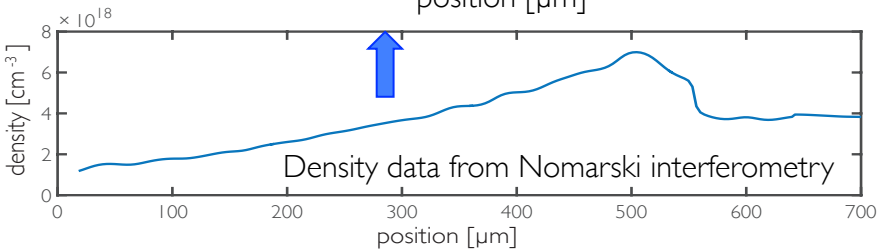
subtract the spline fit for every horizontal line from the raw image [1]

continuous wavelet transform of the central lineout [2]

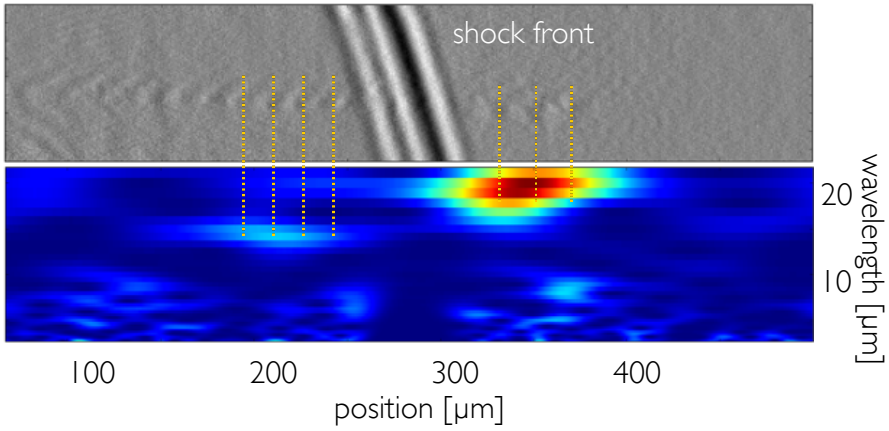


Wakefield elongation due to strong gradient before shock:





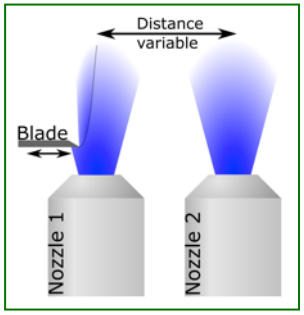
Wake elongation across shock:

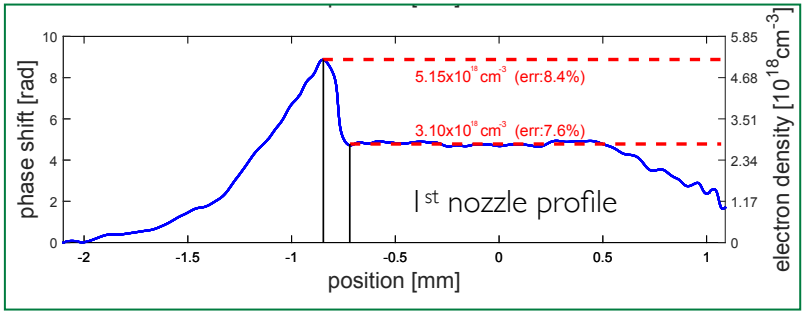


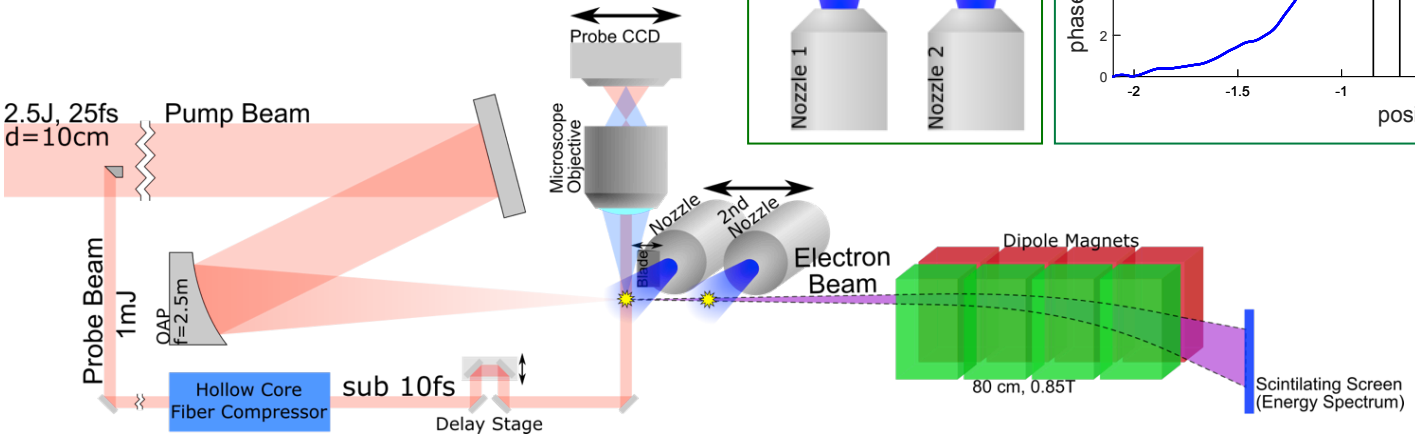
[1] A. Sävert, et al., PRL 115, 055002 (2015)
[2] P. Tomassini, et al., Appl. Opt. 40, 6561-6568 (2001)

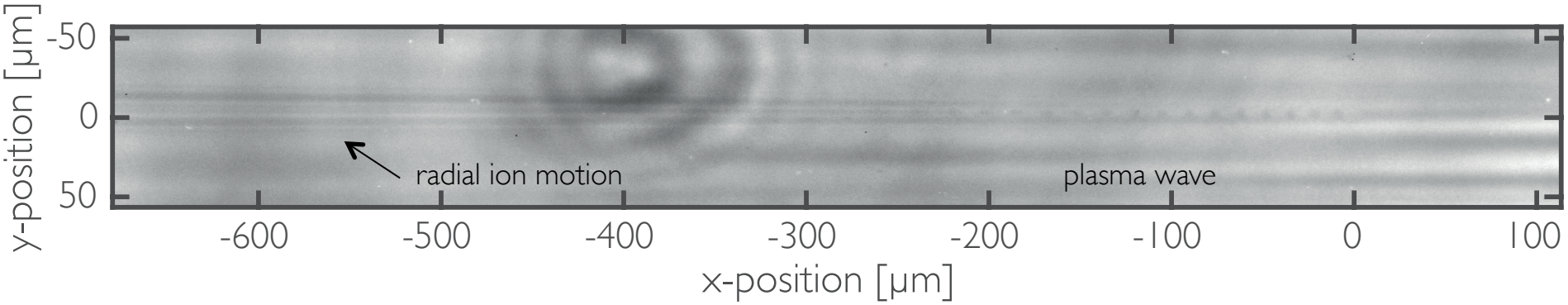
Beam-driven wakes: Experimental setup

1st nozzle: 4 mm, 4×10^{18} e^-/cm^3
2nd nozzle: 1 mm, 1×10^{18} e^-/cm^3



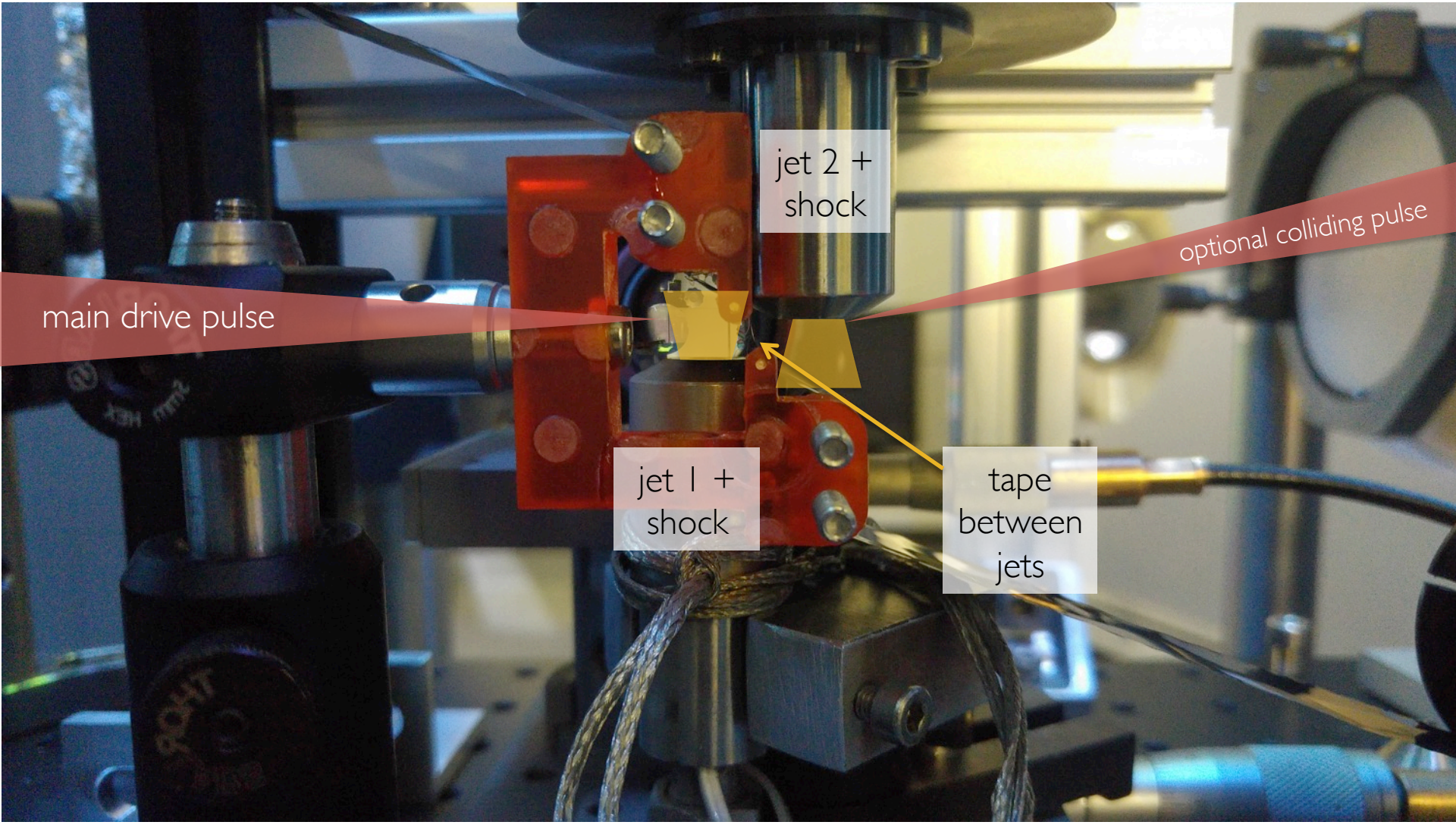






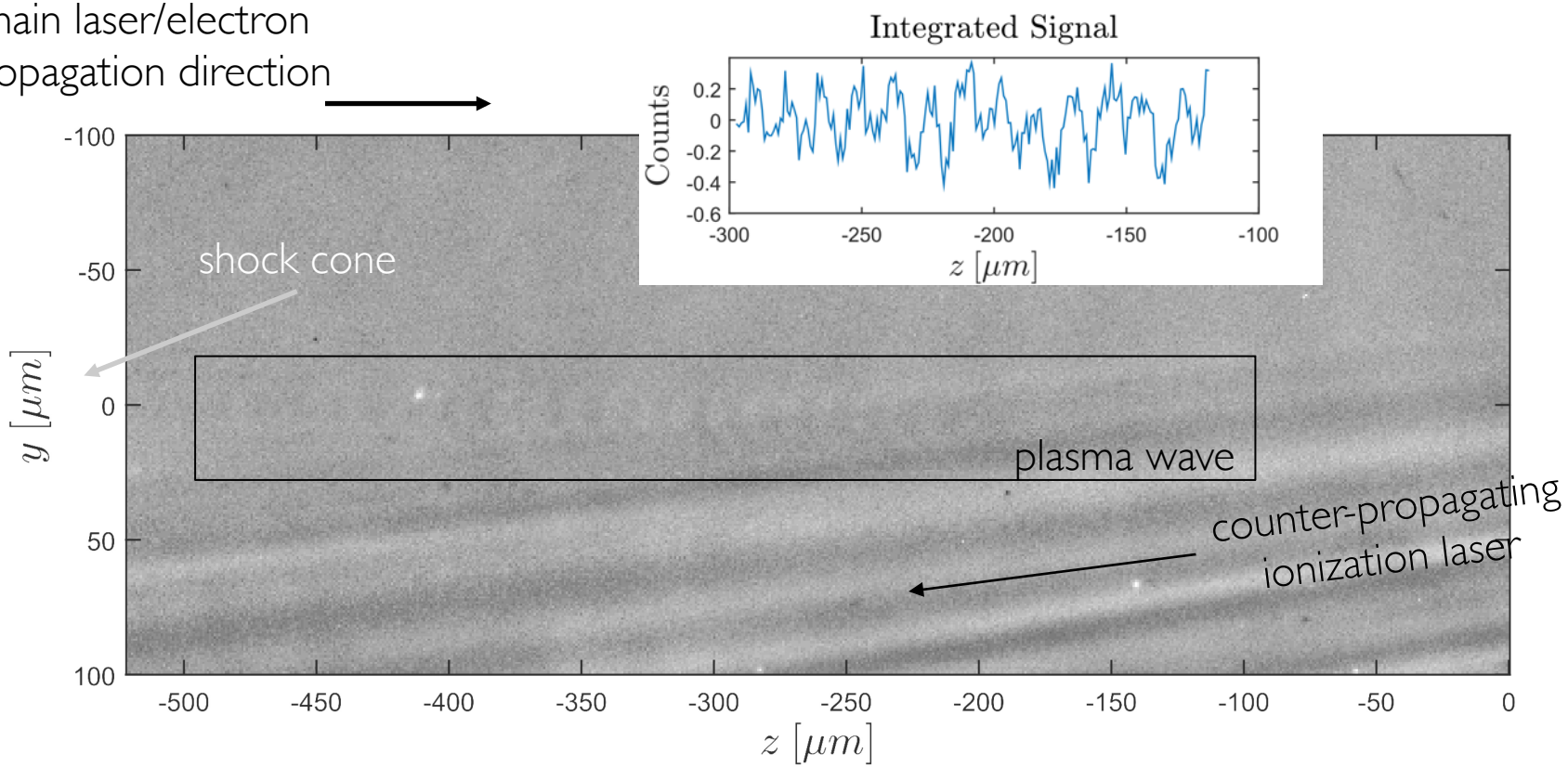
Observation of ion channel is correlated with occurrence of electron beam:
→ electron beam self-focussing radius is much smaller than laser radius

Refined set-up: block the laser



wakefield in jet 2: main laser blocked by tape

main laser/electron propagation direction →

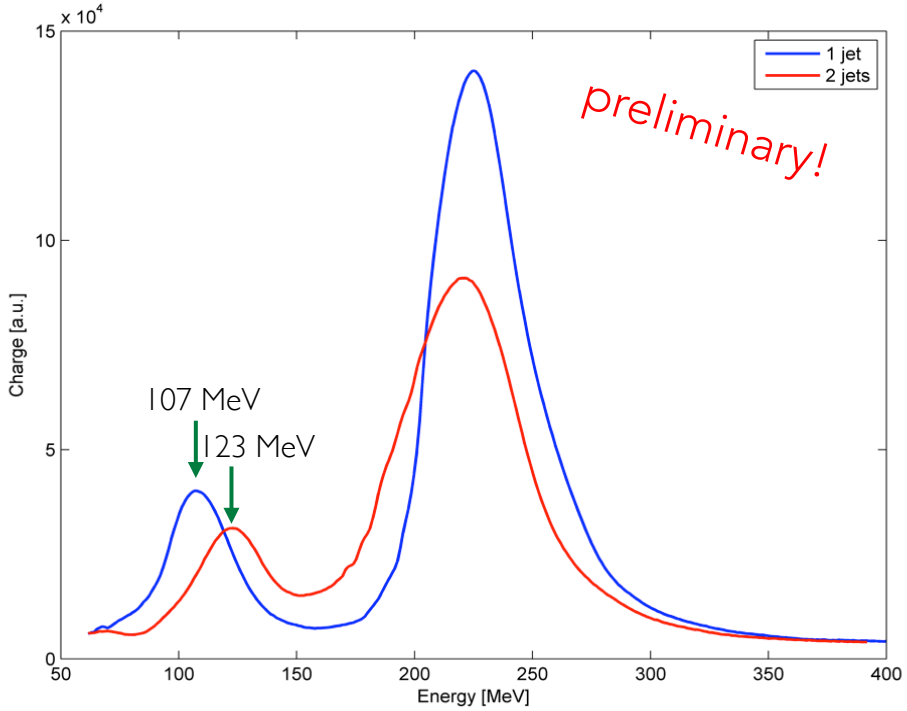


Problem: tape debris coats probe optics → limited shot number to find and record signal

1st direct observation of LWFA-beam driven wakefield
→ Can it accelerate particles?

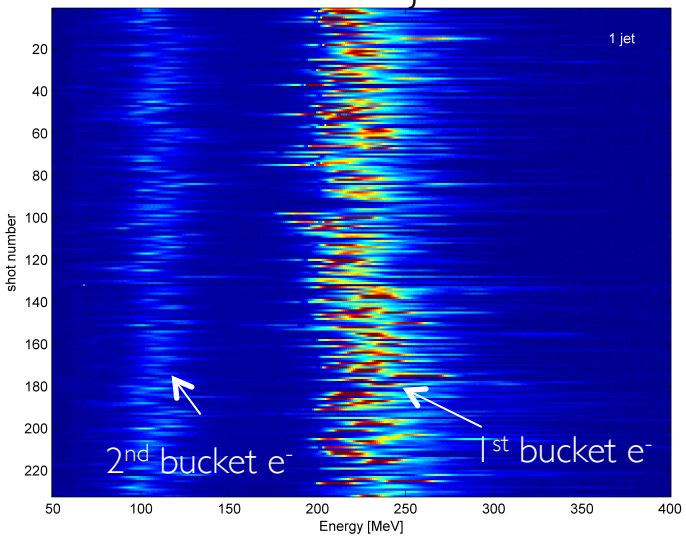
Beam-driven boost?

Shock-front injection produces two bunches from first two buckets → "driver" and "witness"

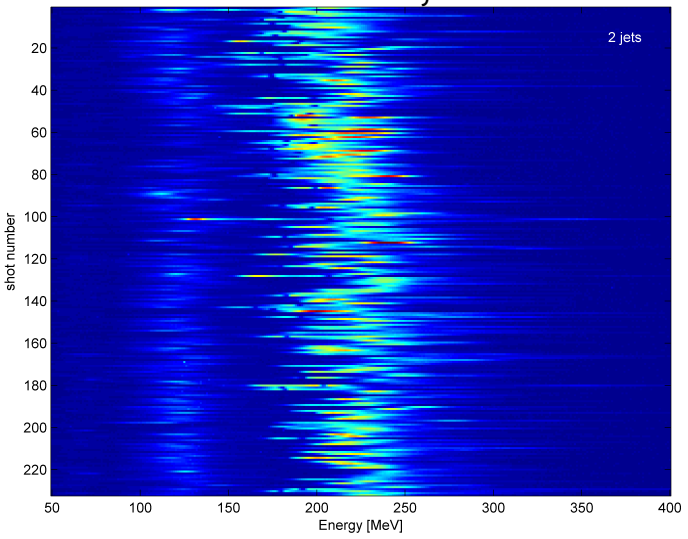


We detect energy loss in „driver" and 16 GeV/m energy gain in „witness" peak

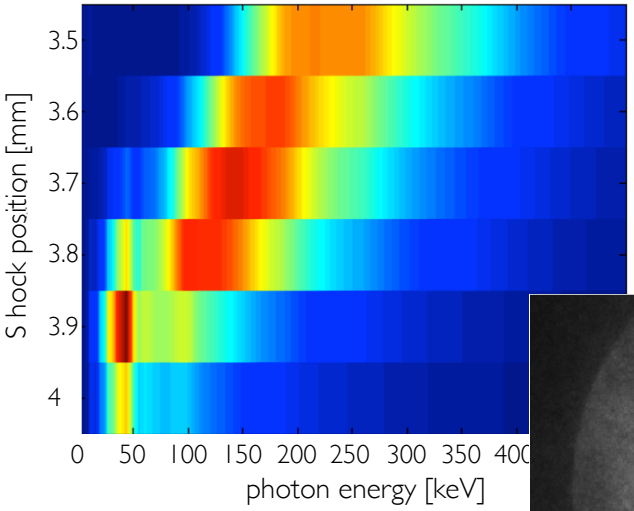
acceleration in 1st jet



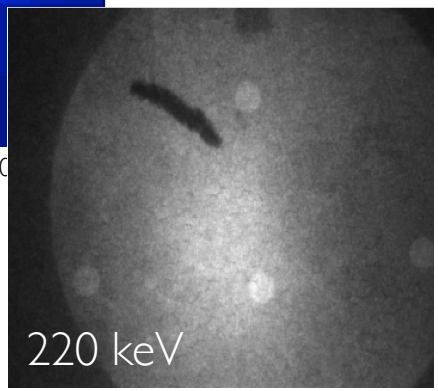
acceleration in 2nd jet

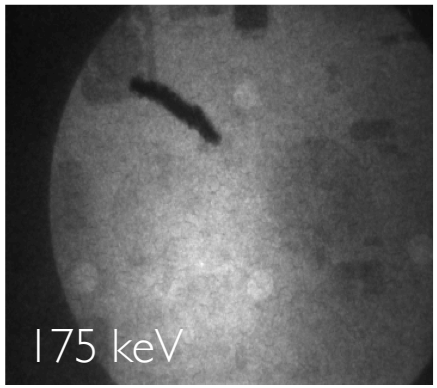


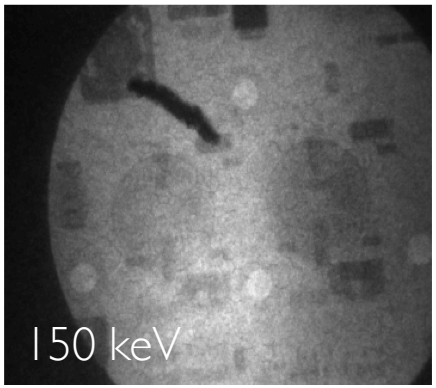
Latest imaging results with ATLAS-300

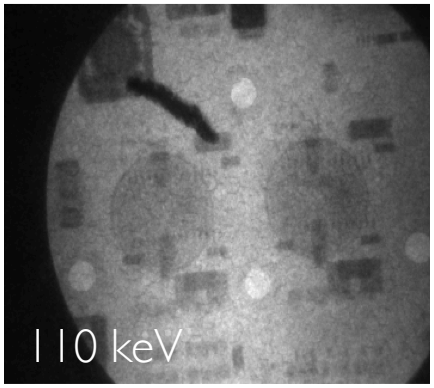


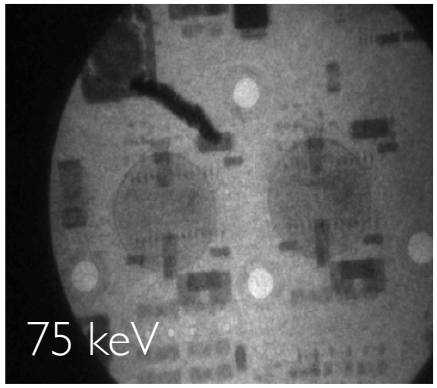
Thomson scattering off shock-front injected beams:

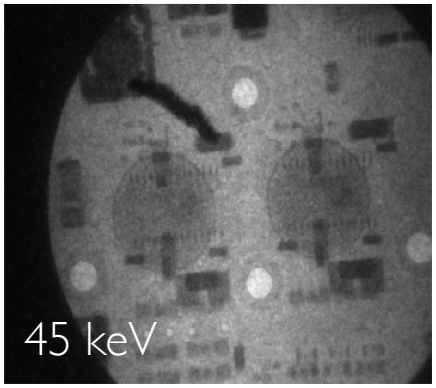






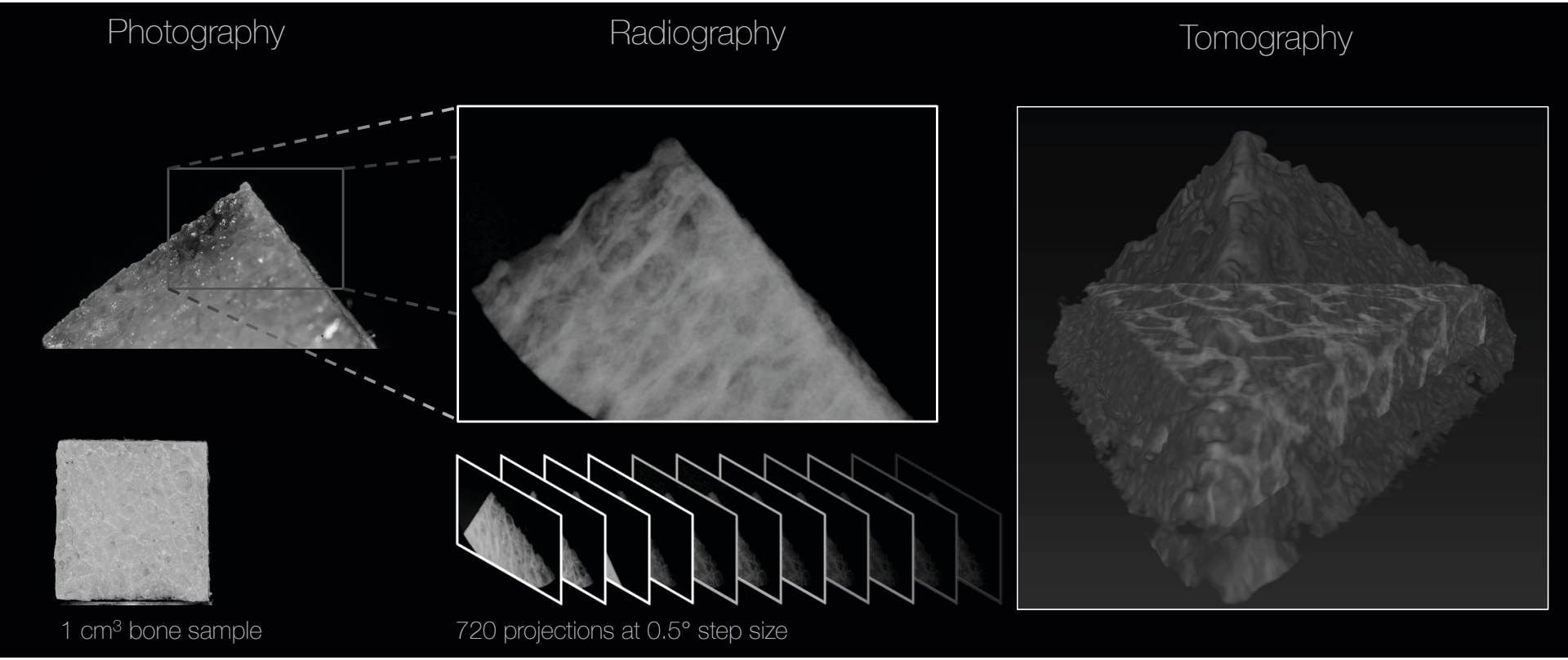






Latest imaging results with ATLAS-300

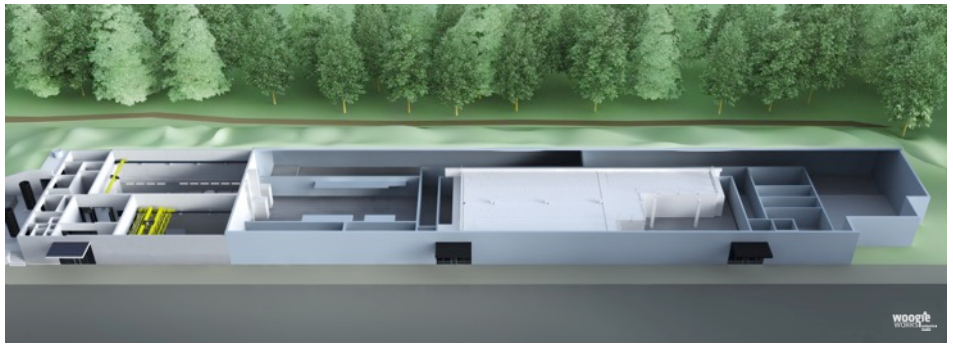
Human bone tomography with 1 Hz repetition rate, few min. scan time



Submitted to Phys. Rev. Applied

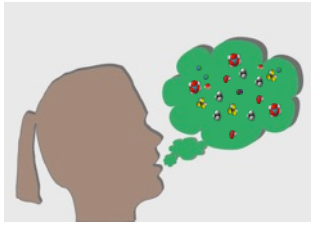
II. Munich's new Center for Advanced Laser Applications

CALA



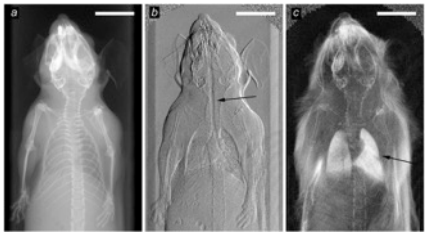
Develop technology for:

Early detection of cancer:
Molecular fingerprinting of exhaled air, blood, urine



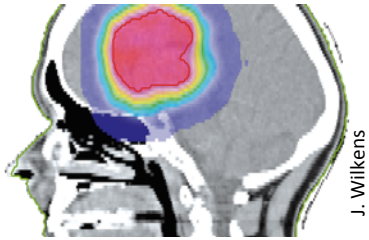
I.Pupeza

Localization of cancer:
X-ray phase-contrast imaging



F.Pfeiffer

Treatment of cancer:
Particle therapy with Laser-accelerated protons/ions



J. Wilkens

+

- Laser-sources development
- Secondary X-ray/particle sources development
- HHG molecular electron dynamics
- Acceleration extreme regimes physics

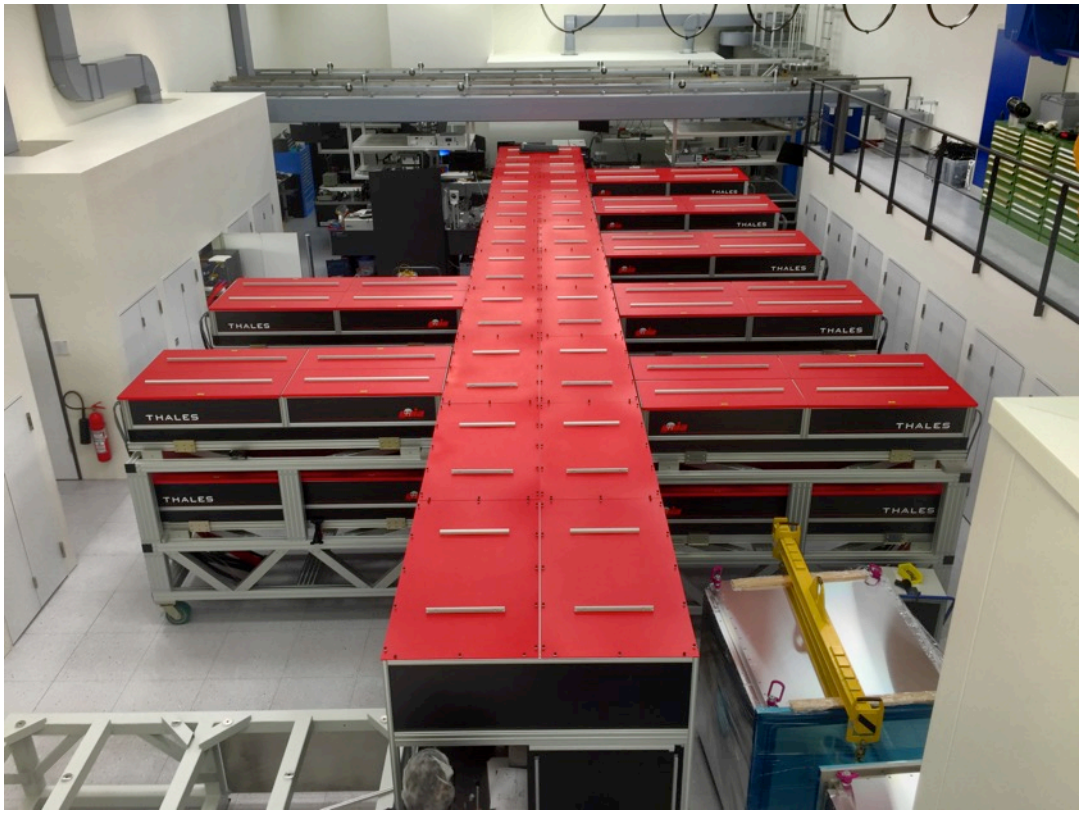
LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

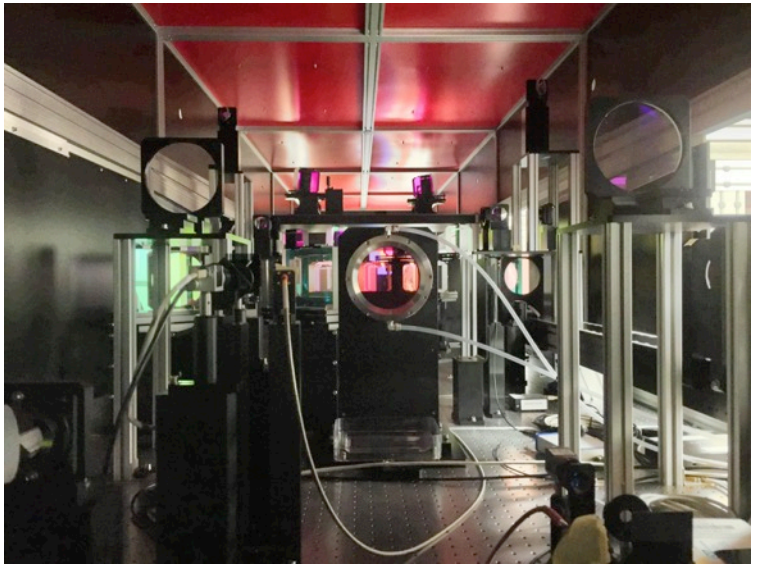
TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

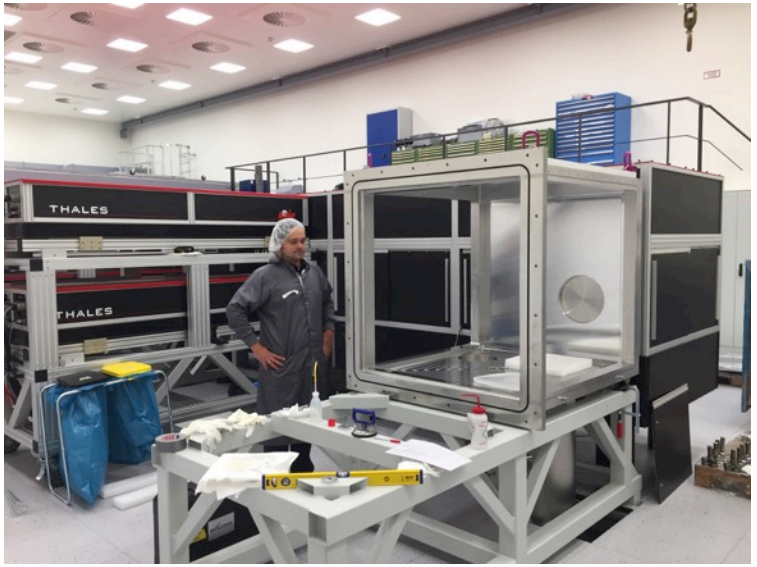
MPG

Munich-Centre for Advanced Photonics

Atlas - 3000







Experiment beamlines

ETTF - 14m long electron acceleration chamber

LUX – focusing and electron target chamber

Credits:

WG Karsch:
Postdoc:
- A. Döpp

PHD candidates:
- J. Wenz
- M. Heigoldt
- K. Khrennikov
- M. Gilljohann
- H. Ding
- S. Schindler
- J. Götzfried

Master students:
- M. Hüther
- B. Günther
- T. Kurz
- T. Heider
- F. Daiber
- L Wildgruber

Engineers:
- G. Schilling
- A. Münzer

WG Veisz:
PHD candidates:
- A. Buck
- S.W. Chou
- J. Xu

S. Hooker, U Oxford:
- S. Bajlekov
- N. Bourgeois
- G. Cheung

L.O. Silva, Lisbon:
- J. Viera
- R. Fonseca

F. Pfeiffer, TU München
- S. Schleede
- M. Bech
- P. Thibault