Summary – LA3NET workshop

3rd Topical workshop on Novel Acceleration Techniques

28-30 April, 2014

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DESY, Zeuthen
03 July, 2014

HELMHOLTZ | ASSOCIATION

3rd Topical workshop on Novel Acceleration Techniques

- 27-30 April, 2014 HZDR
- 3rd Topical workshop on Novel Acceleration Techniques
- Topics:
  - ✓ Plasma wake field acceleration
  - ✓ Dielectric accelerators
  - ✓ Advanced diagnostics
  - ✓ Scientific, medical and industrial applications
- 62 participants
- Day1 - 28th, 12 talks
- Day2 - 29th, 12 talks
- Day3 - 30th, 6 talks
- PITZ Contributions: Talk from Matthias
  - ❑ Workshop talks at:
  - ❑ http://indico.cern.ch/event/285723/speakers

Status and Prospects of Normal Conducting and Superconducting RF Acceleration, P. Mcintosh, ASteC

- Introduction to different accelerators around the world e.g. LHC, ILC@CERN, LCLS@SLAC, XFEL@DESY, DLS@RAL etc.
- Application of accelerators - Security, Medical, Sterilisation etc.
- AC power Comparison between NC and SC $\frac{P_{NC}}{P_{SC}} = 4.5$

Normal Conducting:

- Less infrastructure required
- Simpler technology (pulsed)

- Higher RF power needed
- Expensive amplifiers
- Thermal problems (high DF)
- Lower gradients (high DF)

Superconducting:

- Stable operation
- Less RF power
- Smaller amplifiers
- Well suited to CW operation

- Cryogenic system required
- Complicated cavity fabrication
- Sensitive cavities

Ion acceleration with short-pulse laser – Paul Gibbon, Germany

Direct acceleration in laser field inefficient, since

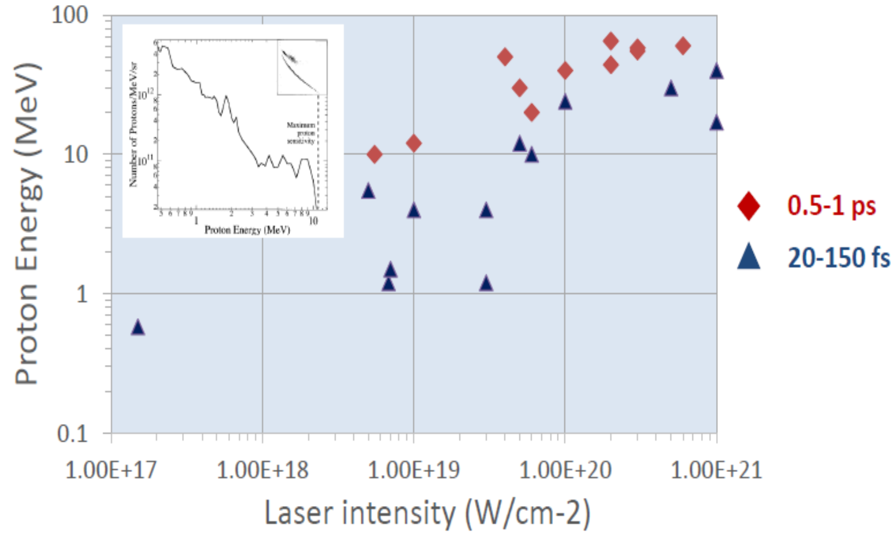
$$\frac{v_i}{c} \simeq \frac{eE_L}{m_i \omega c} = \frac{m_i}{m_e} a_0 \leq \frac{a_0}{1836}$$

Get relativistic ion energies for

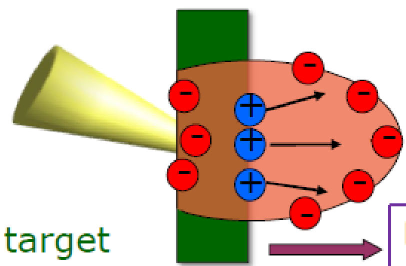
$$a_0 \sim 2000$$
$$\text{or } I\lambda_L^2 \geq 5 \times 10^{24}\ \text{Wcm}^{-2}\mu\text{m}^2$$

Therefore need means of transmitting laser energy to ions over many optical cycles → exploit electrostatic field in plasma.

Experimental proton energies 2000-2014



PW Laser:
30 J/30 fs



Hot electron cloud $T_h \sim$ MeV
Debye length $L_D \sim \mu$m

Solid target
(Al, CH, Au foil)

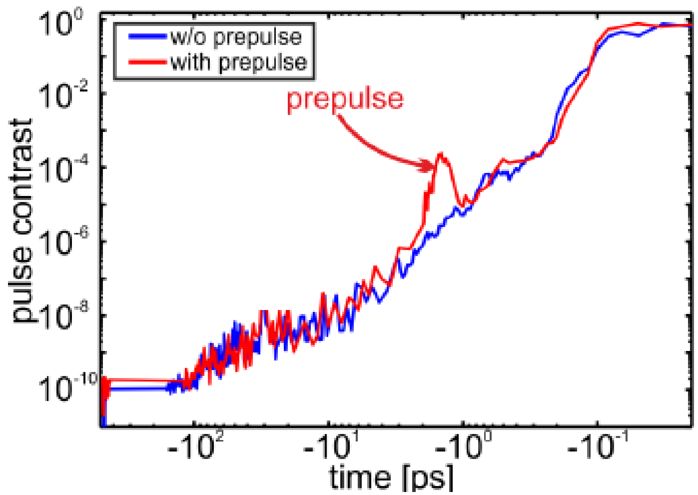
Electric field
$E_0 = \frac{T_h}{eL_D} \sim \sqrt{T_h n_h} \sim 10^{12}$ Vm^{-1}

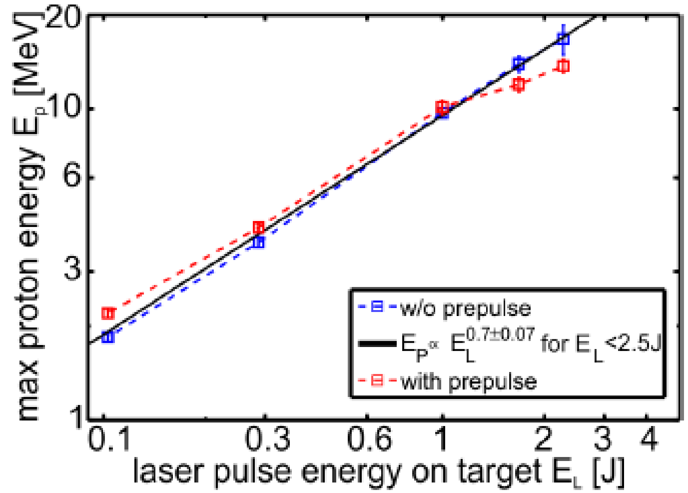
Electron heating: T_{hot} scaling depends on absorption physics

- Electrons heated to T_h ~ MeV via **j x B** and other mechanisms on target front
- Lighter ions (protons) preferentially accelerated off target rear

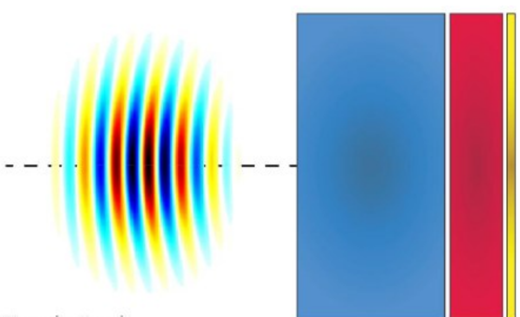
Laser Ion Acceleration

Laser ion acceleration at HZDR – k.Zeil, HZDR





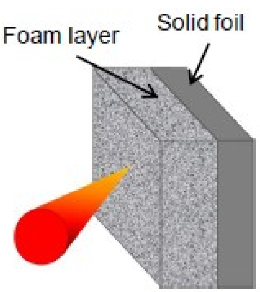
Research on super intense laser-driven ion acceleration at politecnico di milano – M.Passoni, Italy

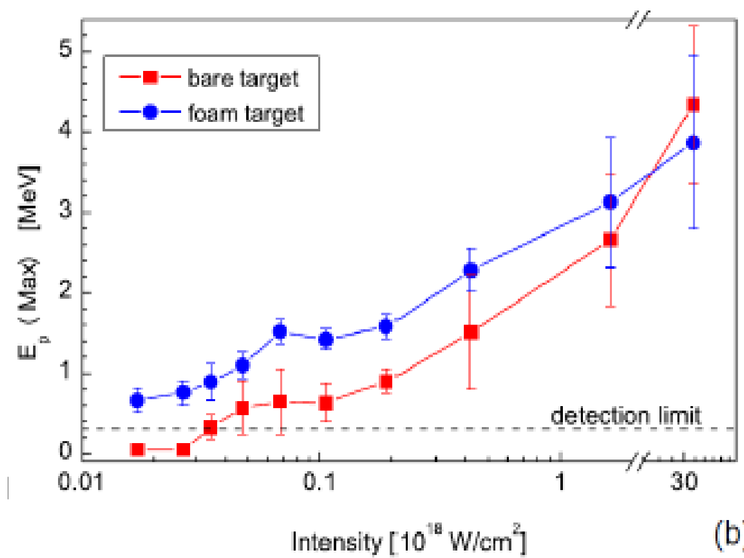


Laser *(P-polarized)*
τ=25 fs
w = 3μm
λ=0.8 μm
P=3-120 TW a=3-20
θ_{inc}=0°-30°-45°-60°

Foam	Metal	Impurities
C^{6+}	Al^{9+}	H^{+}
1-12 μm	0,5 μm	50 nm
1-8n_c	80 n_c	9 n_c

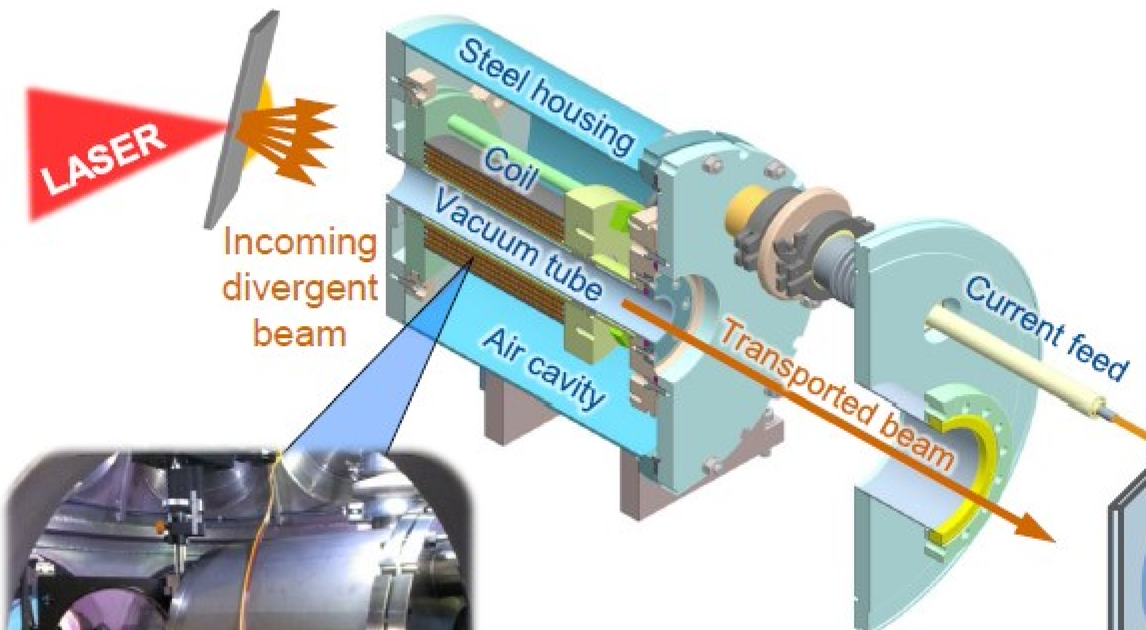
Production of low-density C foams by Pulsed Laser Deposition (PLD)

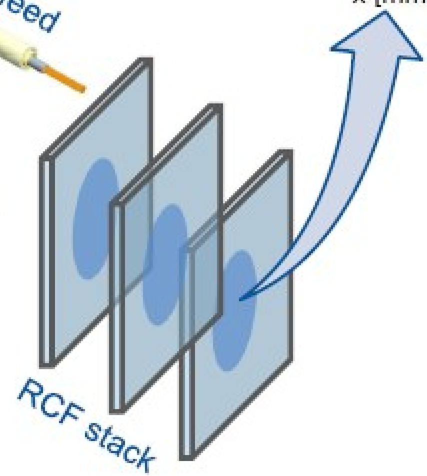




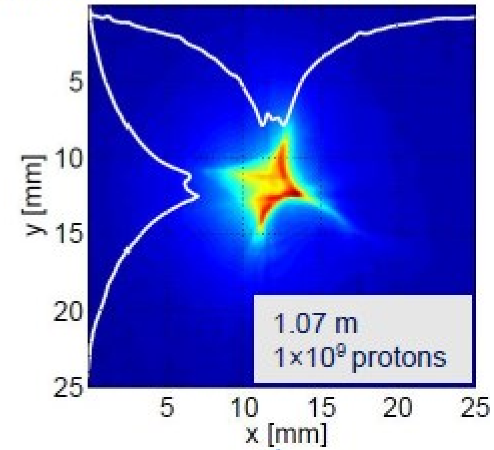
Pulsed high fields magnets: Unique opportunities for handling laser accelerated ions – F. Kroll, HZDR

Capturing solenoid



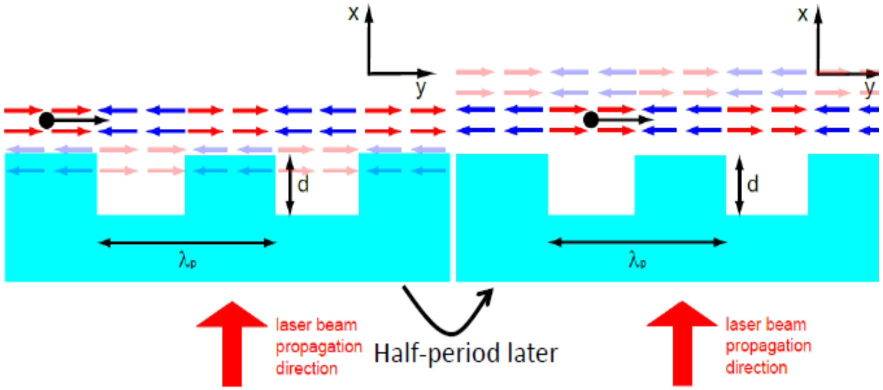


S. Busold, et al., Phys. Rev. ST Accel. Beams 16, 101302 (2013)



- ~ 20 T @ 24 kA (24 kV)
- 270 µH
- 120 windings in 4 layers
- 40 mm free aperture

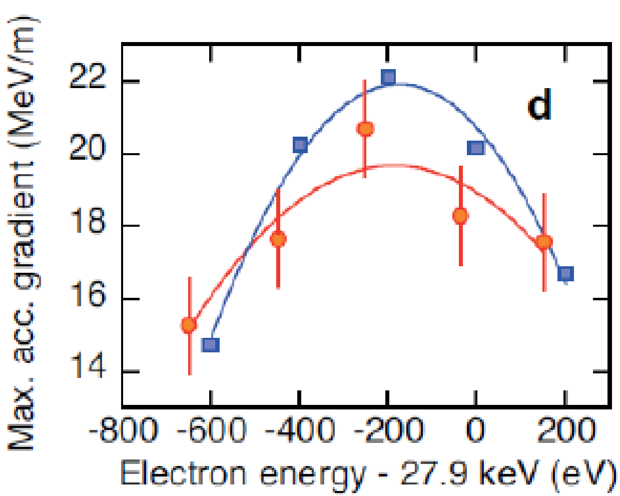
Recent experimental results and future directions of dielectric laser accelerators – J.McNeur, Germany



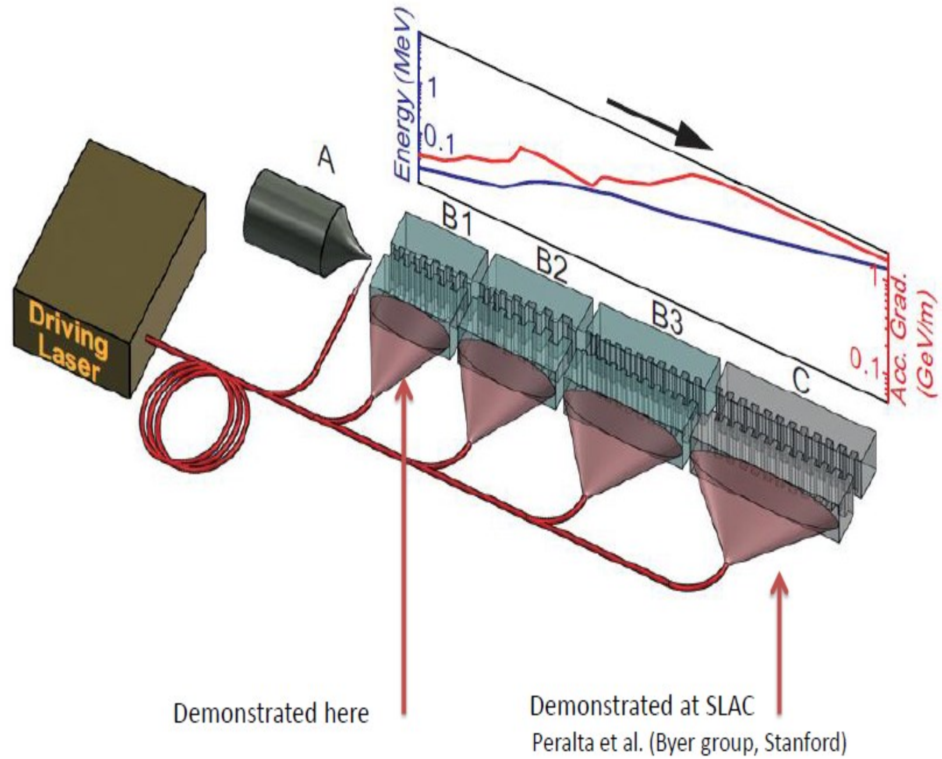
Synchronicity condition:

$$\lambda_p = m\beta\lambda \quad (m = 1, 2, 3, \ldots)$$

(m: # of laser cycles per electron passing one period, $\beta = v/c$, λ : laser wavelength)

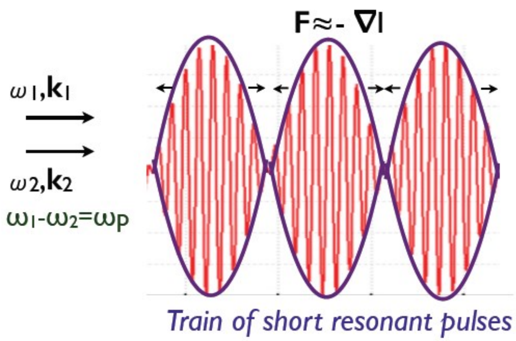


FUTURE DIRECTIONS

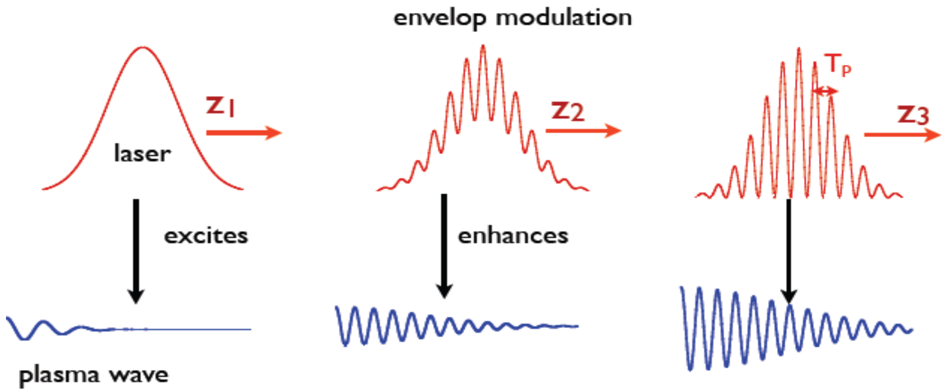


Overview of laser-driven electron acceleration – V. Malka, France

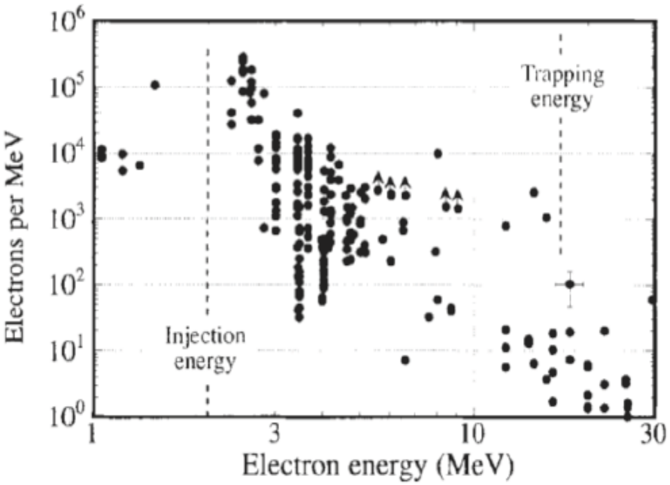
Different laser plasma acceleration schemes – LWFA, LBWA, SM-LWFA



LBWA

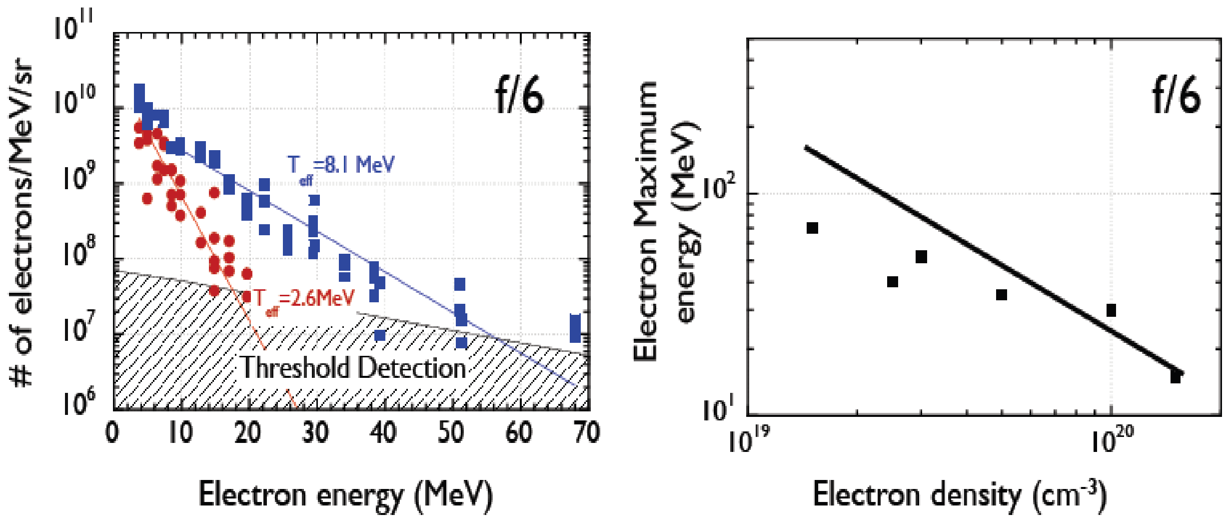


SM-LWFA



M. Everett *et al.*, Nature 1994

LBWA



SM-LWFA

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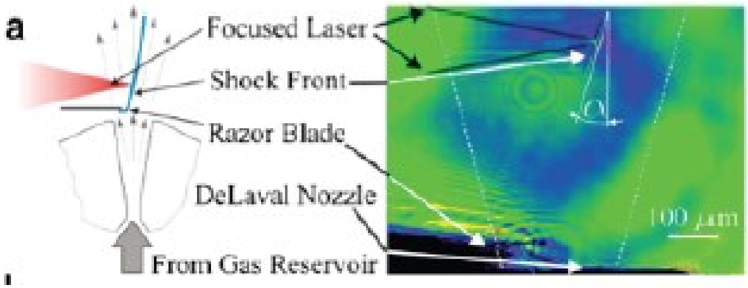

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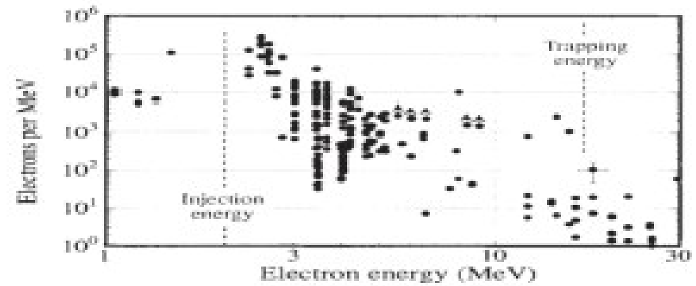
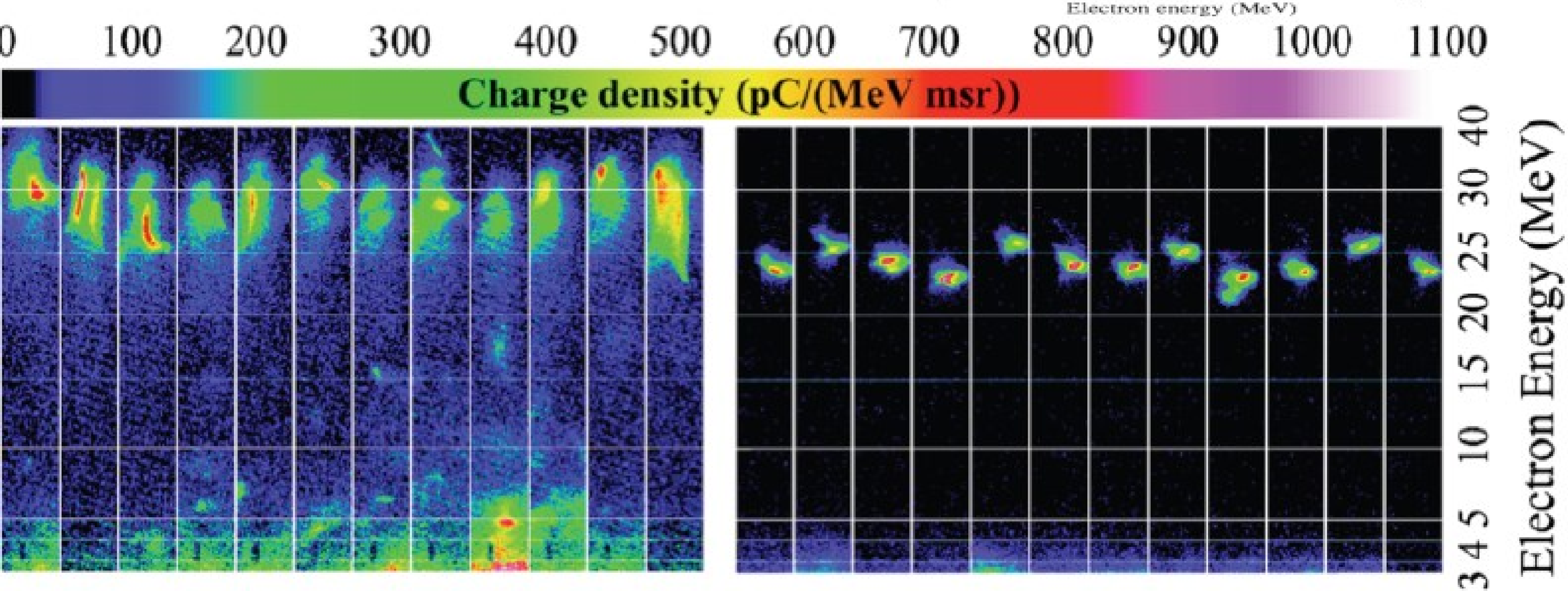




(a) Self injection

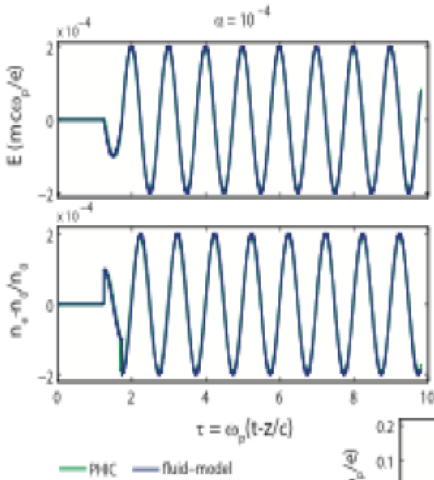
(b) Injection at density transition

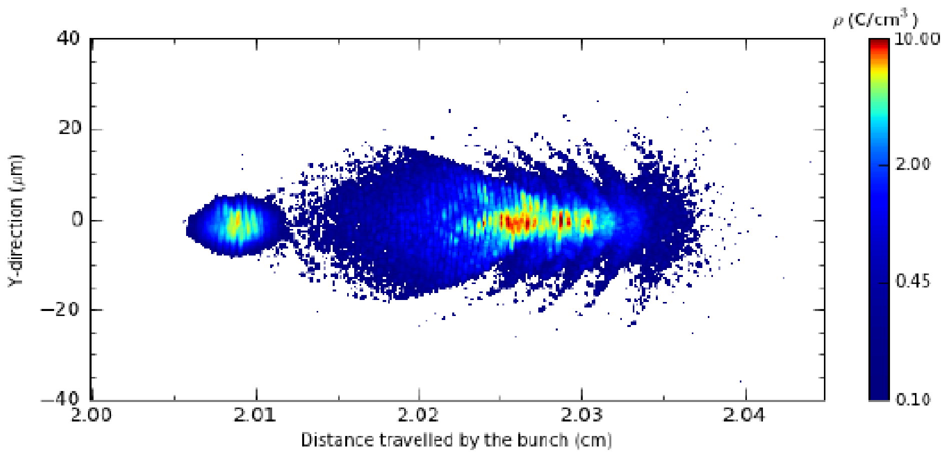
K. Schmid et al., PRSTAB 13, 091301 (2010)

From 1D fluid model to 3D PIC simulations for resonant PWFA experiments at SPARC_LAB – A. Marocchino, Italy

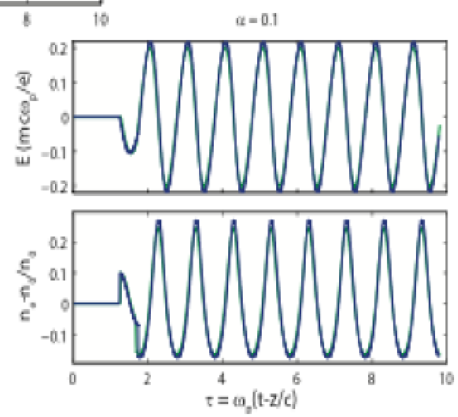
1D HD VS PIC

α=10^{-4} – linear case
perfect agreement





α=10^{-1} – linear case
begin discrepancies

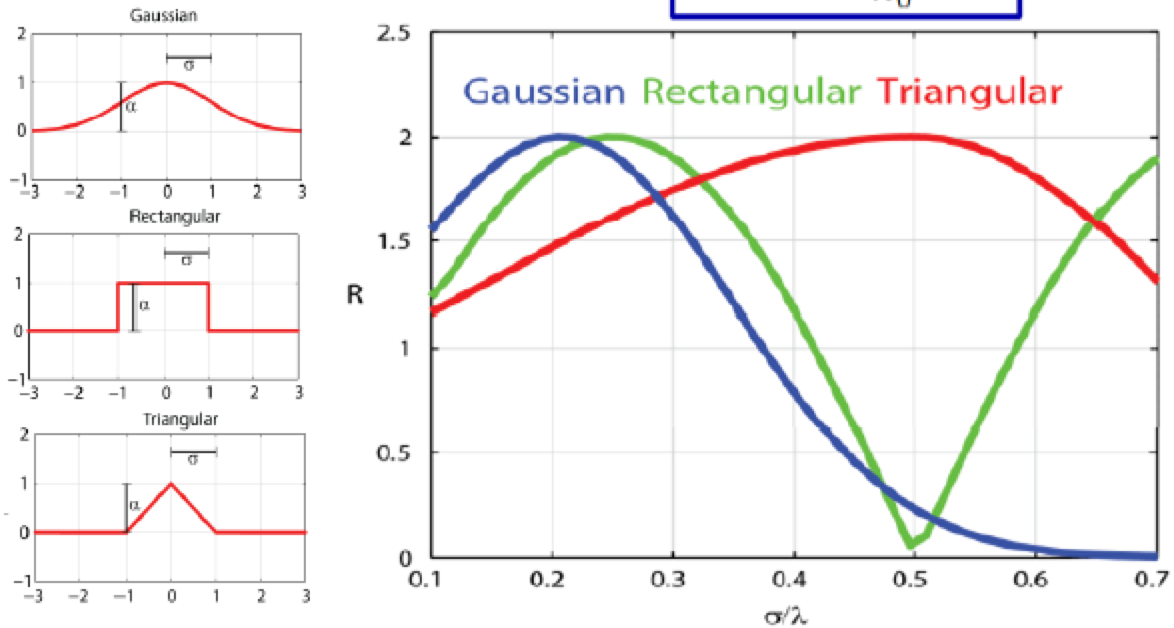


- 1D model good accordance with 1D-PIC.
- Inclusion of a damping effect to extend the model validity to quasi-non-linear regimes.

Plasma based acceleration experiments at SPARC-LAB, E. Chiadroni, Italy

Transformer ratio critically depends on the bunch shape and on the density ratio.

Linear regime: $\alpha = \frac{n_{driver,peak}}{n_0} = 10^{-4}$



- Electron optical sampling structure for bunch measurement.
- Simulations for both external injection based experiments at SPARC_LAB are ongoing.

Advanced Proton Driven Plasma Wake Field Acceleration Experiment (AWAKE) at CERN – M. Martyanov, CERN

Plasma	Rb plasma density	$10^{14} \div 10^{15}$ cm^{-3} $7\cdot(10^{-3} \div 10^{-2})$ mBar at 500°K
	Uniformity	<0.1%
	Length	10 meters
Proton bunch	Energy	400 GeV → 64 nJ/p^+ → 19.2 kJ/bunch
	Charge	$3\cdot10^{11}$ particles → 48 nC
	Length, σ_z	12 cm → 400 ps
	Radius, σ_r	200 μm
Electron bunch	Energy	20 MeV → 3.2 pJ/e^- → 4 mJ/bunch
	Charge	$1.25\cdot10^9$ particles → 200 pC
	Length, σ_z	0.25 cm → 8 ps
	Radius, σ_r	200 μm
Laser	Energy	up to 450 mJ
	Pulse duration	120 fs
	Beam size at Rb vapor (focused from 40m)	a few mm
	Focused intensity	> 50 TW/cm2

Advanced Proton Driven Plasma Wake Field Acceleration Experiment (AWAKE) at CERN – M. Martyanov, CERN

- **Ti:Sa laser system comprises:**
  - laser with 2 beams (for plasma creation and for the e-gun)
  - delay line is possible in either one of these beams
  - focusing telescope (lenses, in air), long 40m focusing
  - optical compressor (in vacuum)
  - optical in-air compressor and 3rd harmonics generator for e-gun

- **Ti:Sa laser parameters for plasma creation:**
  - max energy 450 mJ
  - pulse duration 120 fs after compression
  - max beam diameter 40 mm

} Only reflective optics on the compressed pulse way

Rule of thumb (B<1): $I[GW/cm^2] \cdot L[cm] < 36$

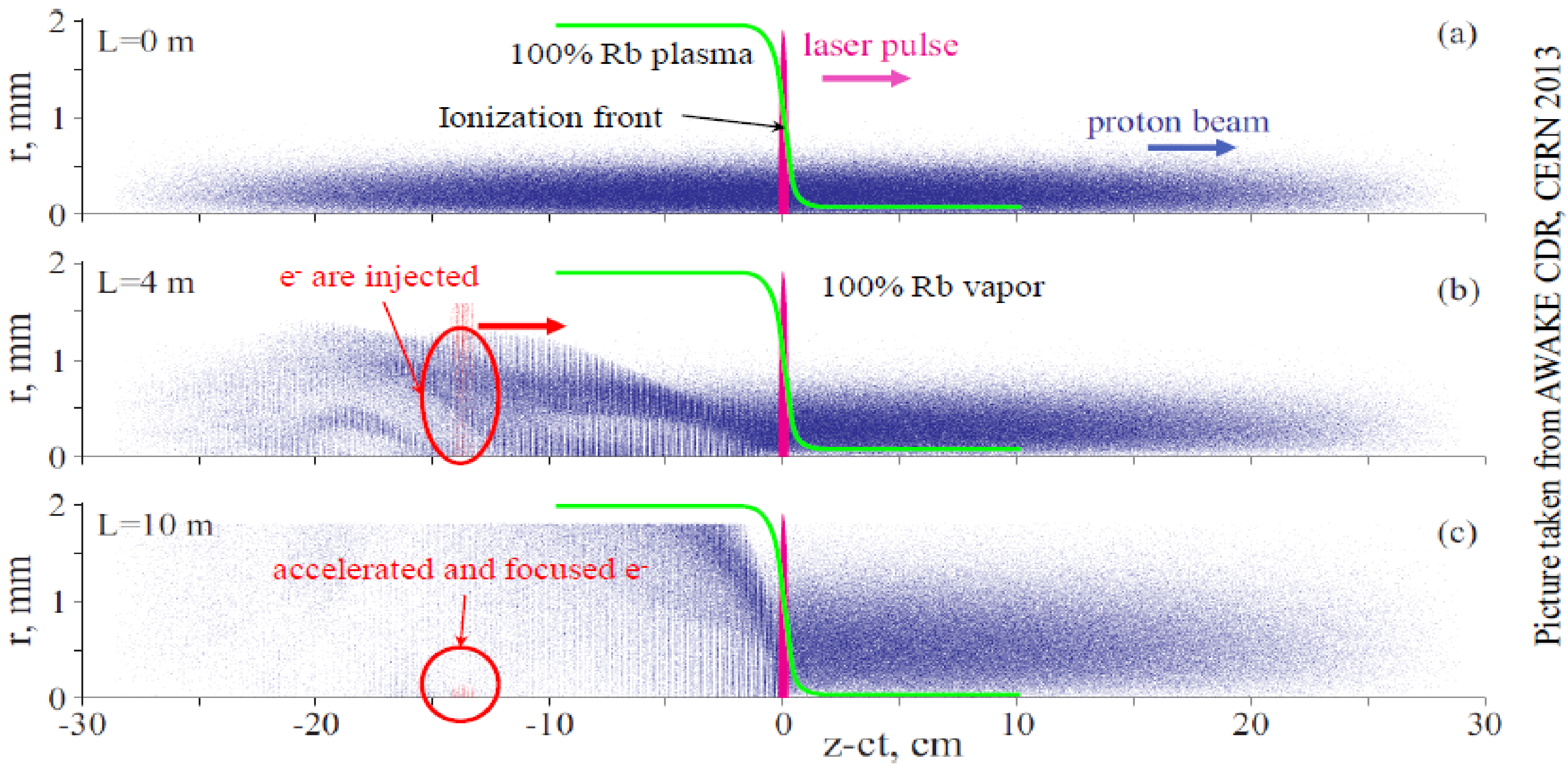
Advanced Proton Driven Plasma Wake Field Acceleration Experiment (AWAKE) at CERN – M. Martyanov, CERN

Propagation of long bunches in plasma – instability competition

- Self-modulation instability: generation of large amplitude wakefields
- Hosing instability or beam break up instability prevents generation of large amplitude wakefields

Ionization front is co-propagating with a short laser pulse and seeds Self Modulation Instability (SMI)

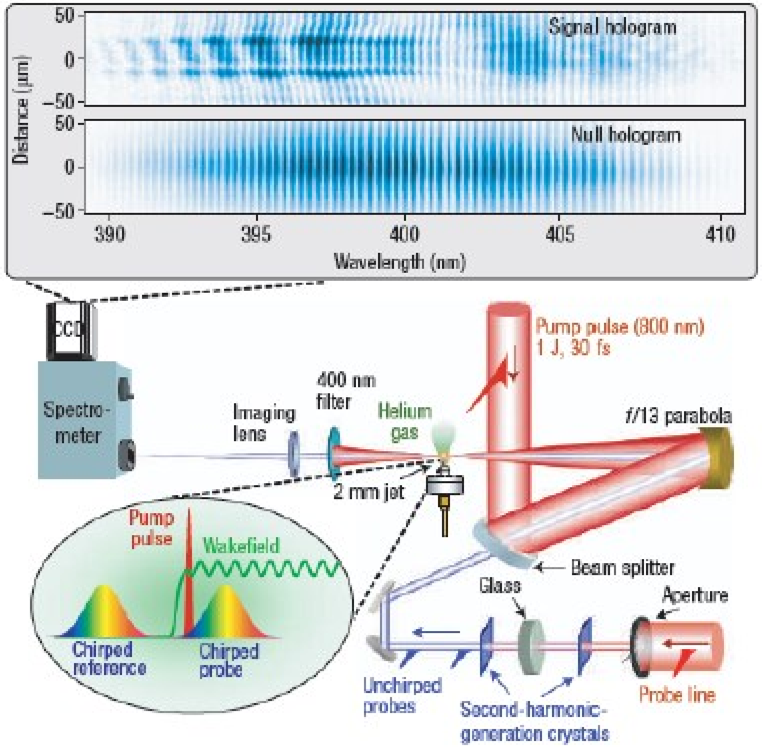
$\tau_{laser} \sim 100$ fs $<<$ $\tau_{wake} \sim 3$ ps

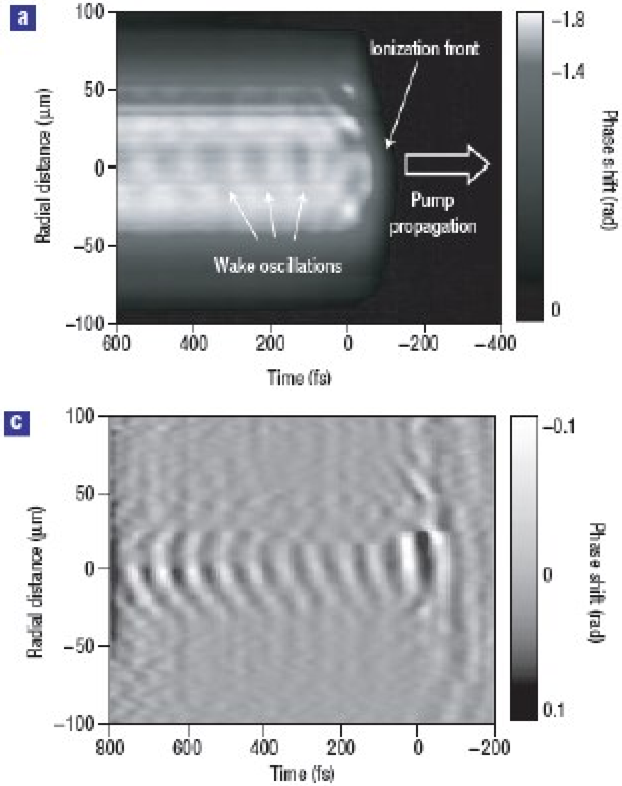


Optical diagnostics for laser driven plasma accelerators – M.C. Kaluza, Jena

Visualization of (time integrated) shape of plasma wave

Split off part of the compressed main pulse, chirp it and let it co-propagate





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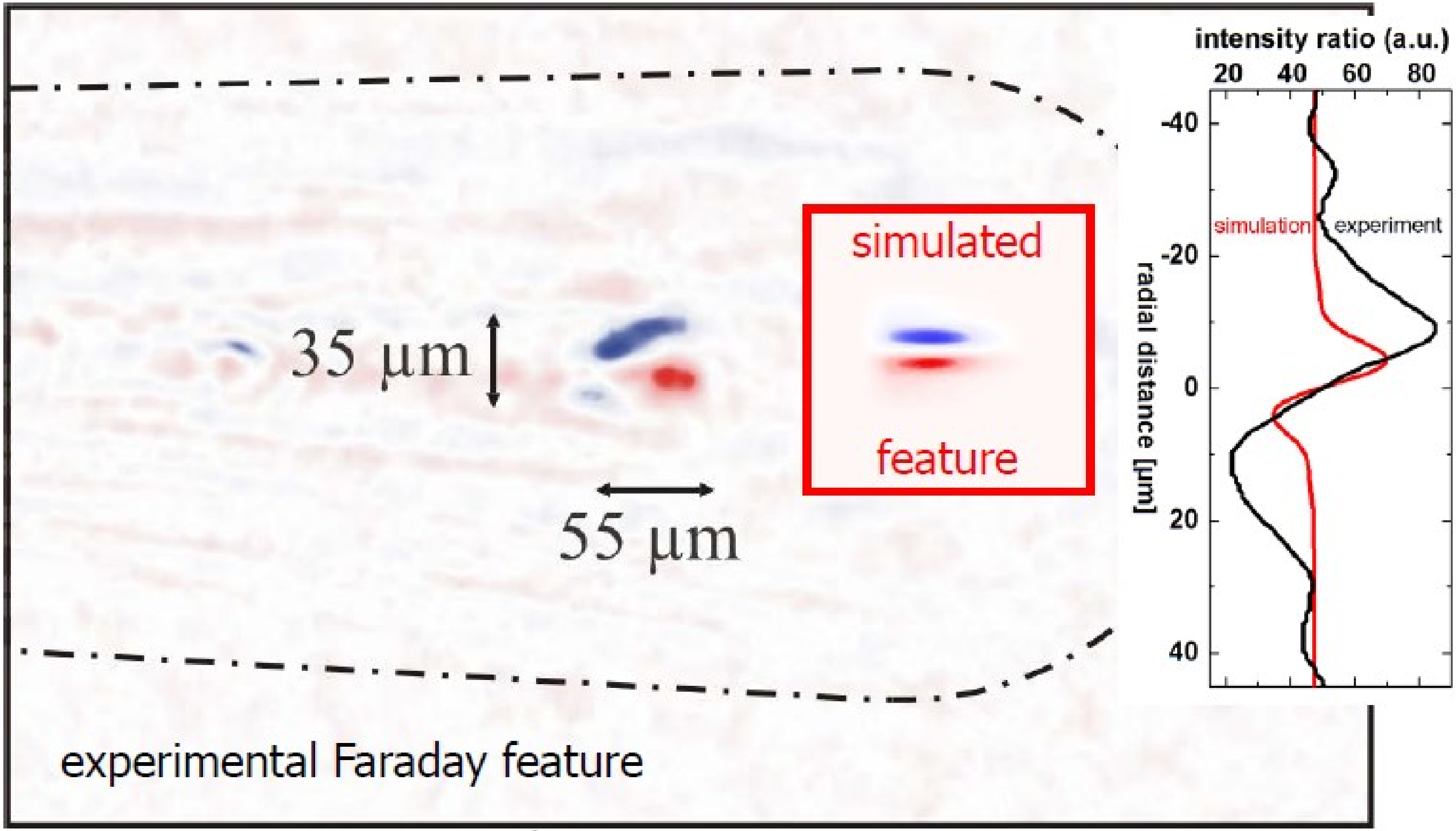

Faraday rotation with 100fs