Characterisation of gas-jet targets for laser-plasma electron acceleration

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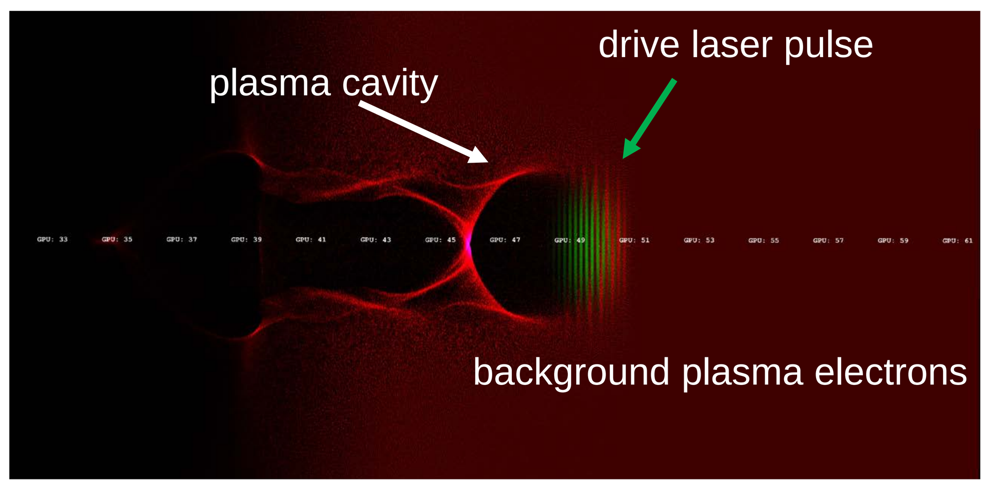
Motivation: Laser Wakefield Acceleration

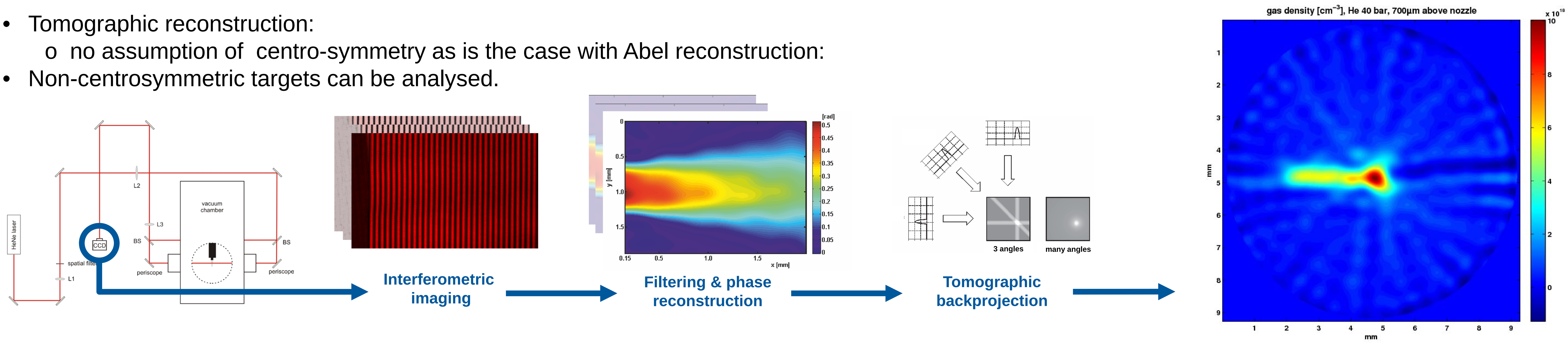
- In laser-plasma electron acceleration a high intensity ultrashort laser pulse drives plasma waves, inducing a high field gradient (~GV/m) which can accelerate electrons to high energies within a very short distance.
- For applications, e.g., ultra-fast pump-probe X-ray spectroscopy as a preparation stage for XFEL 2015, important issues are tunability, stability and scalability.
- To address these issues we carefully analyse the acceleration targets, enabling:
  - o PIC-on-GPU simulations using real-life experimental parameters.
  - o Precise control and adjustment of experimental parameters.

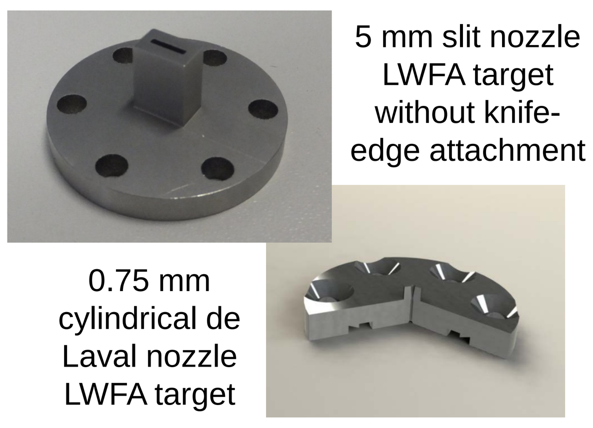


PIC-on-GPU simulation (64 NVIDIA Fermi GPUs) of wakefield formation in the bubble regime. One 3D simulation requires only 45 minutes of simulation time.
H Burau, et al, IEEE Trans. on Plasma Sc. 38(10), 2831-2839

LWFA target characterisation: Mach-Zehnder interferometric tomography

- Tomographic reconstruction:
  - o no assumption of centro-symmetry as is the case with Abel reconstruction:
- Non-centrosymmetric targets can be analysed.



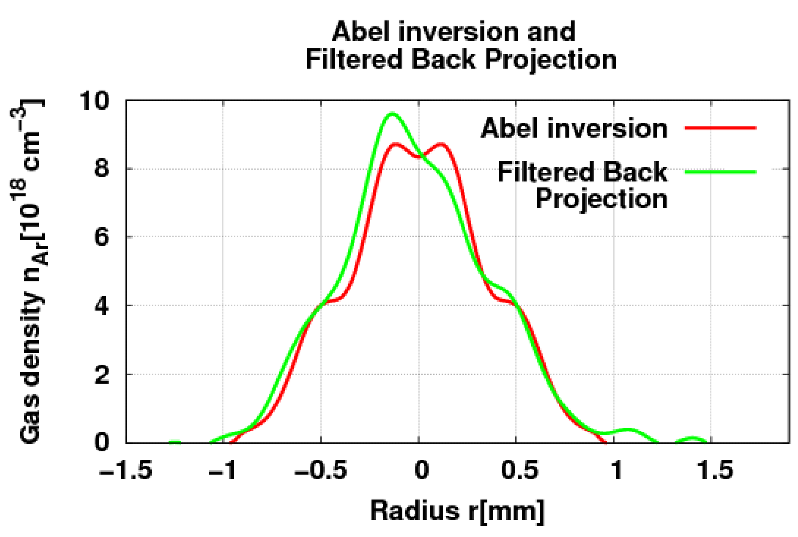


5 mm slit nozzle LWFA target without knife-edge attachment

0.75 mm cylindrical de Laval nozzle LWFA target

750 µm cylindrical de Laval nozzle with imperfection due to laser ablation in LWFA experiment

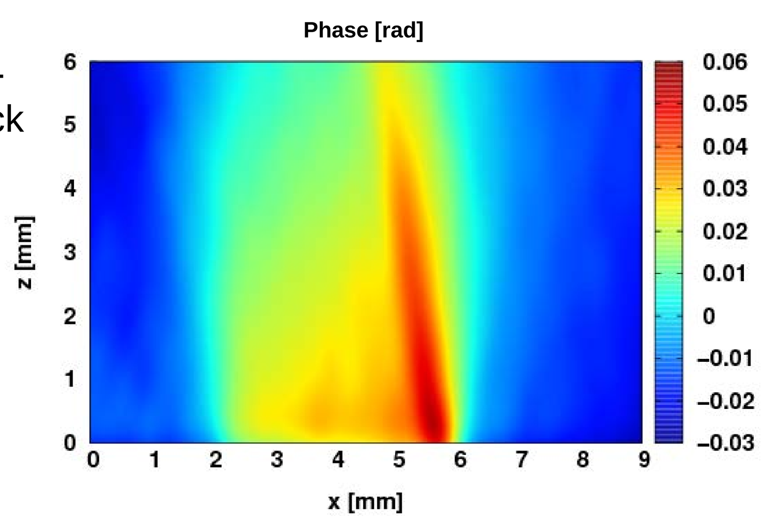
- **Tomography vs. Abel inversion**
  - o Imperfections in cylindrical nozzles can be revealed.

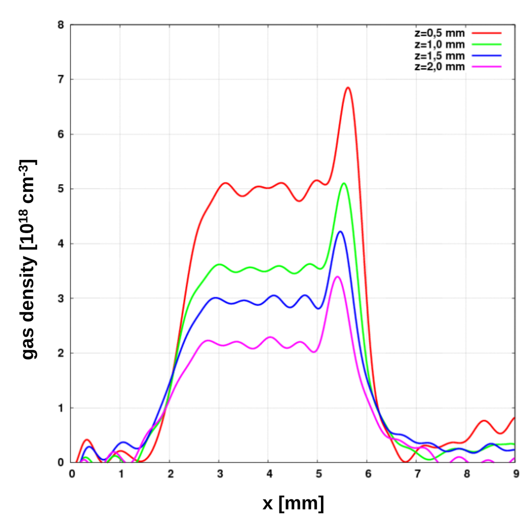


- **Two-stage acceleration target:**
  - o A knife edge induced shock forms a density down-ramp gradient up to 8 x 10^{19} cm^{-4} as down-ramp injection stage
  - o Followed by a 2.5 mm acceleration plateau stage

Tomographic reconstruction of a 5 mm slit nozzle helium jet with knife-edge induced shockfront. 40 bar back pressure

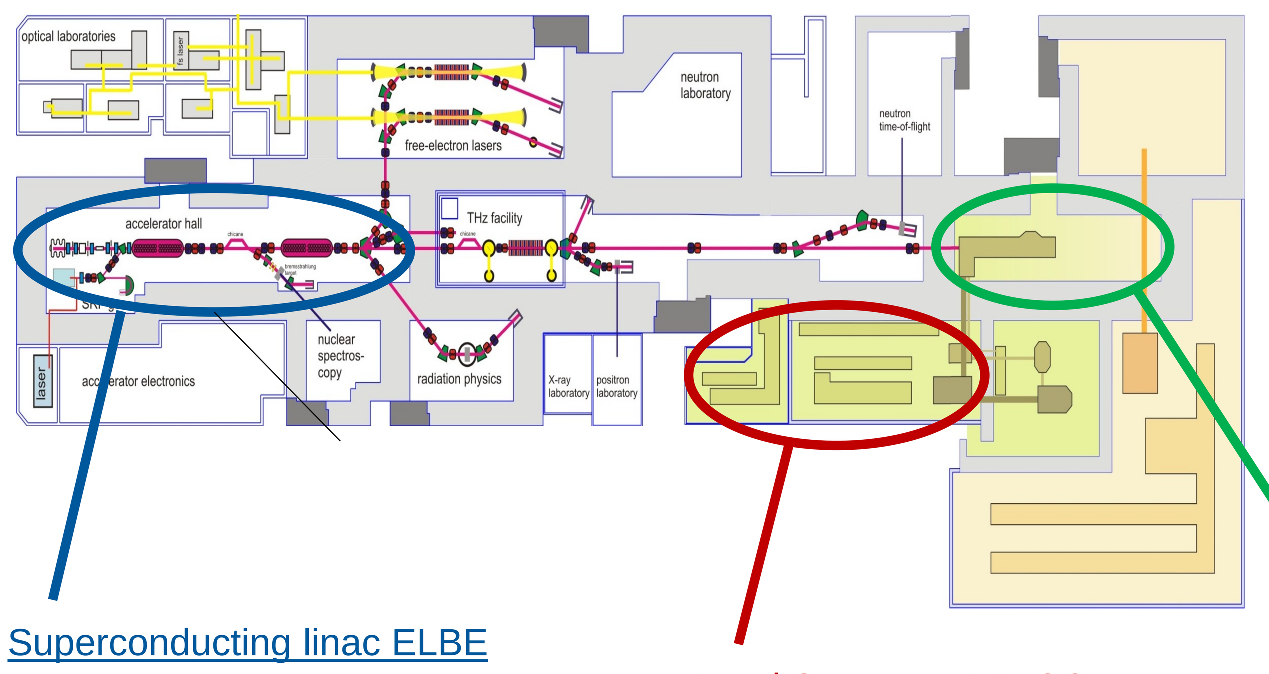
- o 2-D map at 700 µm above the nozzle exit (top right)
- o 2-D phase shift along the nozzle axis (bottom centre)
- o Density profile along the nozzle axis at multiple distances above the nozzle (bottom right)





Facility

- Combined facility with access to both high intensity laser & conventional electron accelerator:
  - o Thomson backscattering experiments as stepping stone towards fully laser driven Thomson backscattering x-ray source.

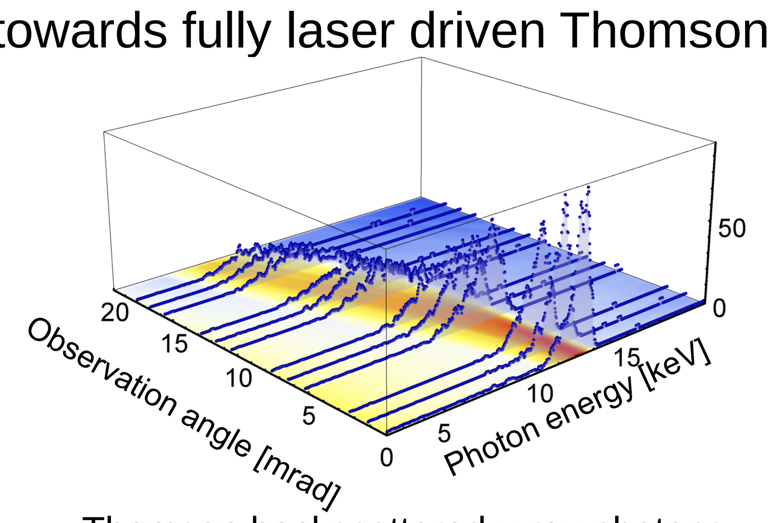


Superconducting linac ELBE

	Thermionic	SRF
pulse frequency	10 Hz	1 Hz
beam energy	24 - 30MeV	
bunch length	4 ps (FWHM)	
bunch charge	1...77 pC	1...77 pC
trans. emittance	15 π mm mrad	5 π mm mrad

1 PW Ti:Sa Laser DRACO

- λ_0 = 800 nm
- 10 Hz repetition rate
- 2 beam output
- Up to 25J + 4J on target
- 30…500 fs pulse width (FWHM)



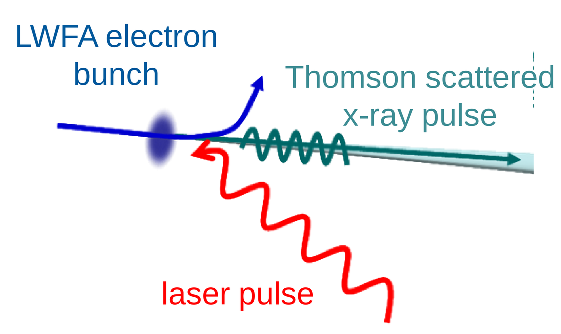
Thomson backscattered x-ray photons
Traces (data) & Base layer (simulation)

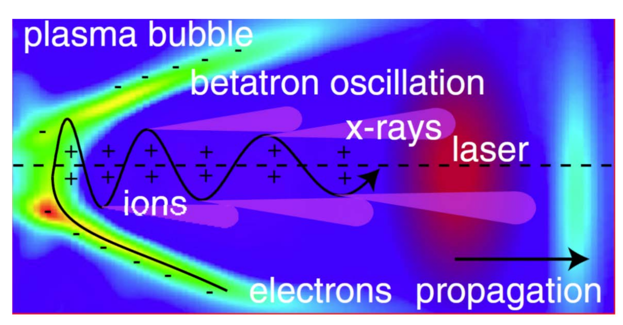
DRACO laser parameters on target:
90 mJ, 500 fs, 35 µm (FWHM), a_0=0.05
ELBE parameters on target:
77 pC, 9 π mm/mrad, 170 µm (FWHM)
Jochmann et al., PRL in press

Outlook

A stable compact laser-driven electron accelerator can be used as a driver for unique x-ray sources via:

- electron/laser Thomson scattering
- betatron radiation





S. Kneip et al., Phys. Rev. ST Accl. Beams 15.021302 (2012)

X-ray characteristics:
- finite bandwidth
- tuneable
- ultra-fast (~fs)

Such a source enables new experiments such as ultra-fast pump-probe X-ray spectroscopy.

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