EUROPEAN NETWORK FOR NOVEL ACCELERATORS

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Proton beam divergence measurements from radiation pressure driven shock acceleration with a CO_2 laser

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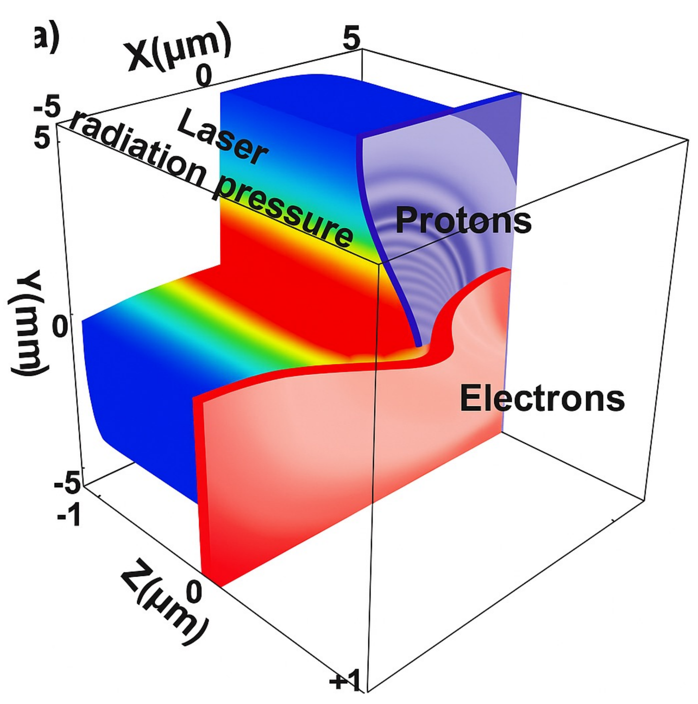
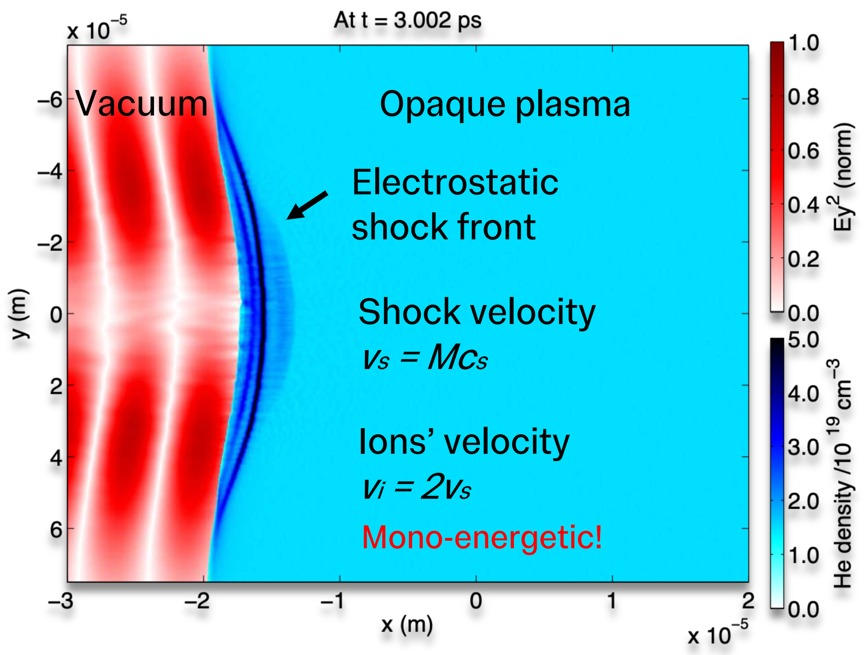
Acceleration mechanism:

Radiation Pressure Acceleration



In this regime a collisionless shock can arise [1,2]



Why a CO_2 laser?

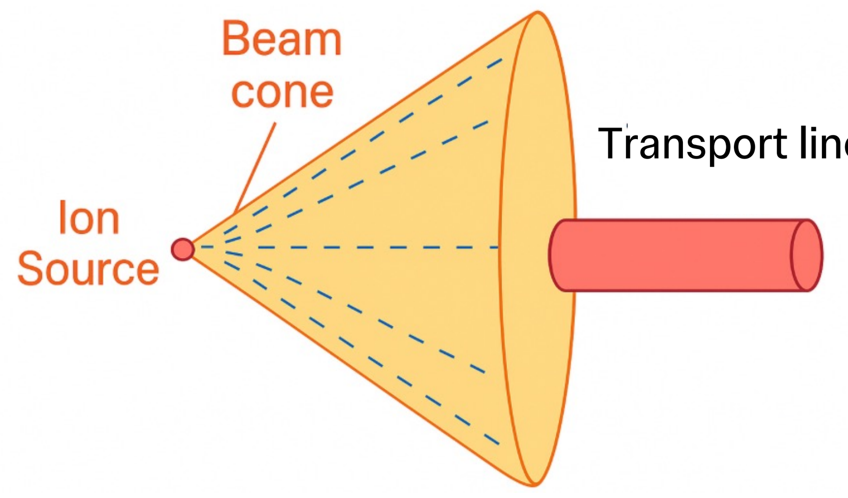
Very long wavelength ~ 9.2 μm

- the a_0 of the laser scales favorably as: $a_0 = \frac{E_0 e \lambda}{m_e c}$,
- the critical density is 100 times lower than for Ti-sapph lasers: $n_c = \frac{m_e \varepsilon_0}{e^2 \lambda^2}$ [3].

Hence gas targets can be used in n_c regime.

- they produce pure beams needed in medical applications
- they don't generate debris,
- And they can operate at high rep rates

The importance of measuring divergence



Ion beam divergence: $> 20^\circ$

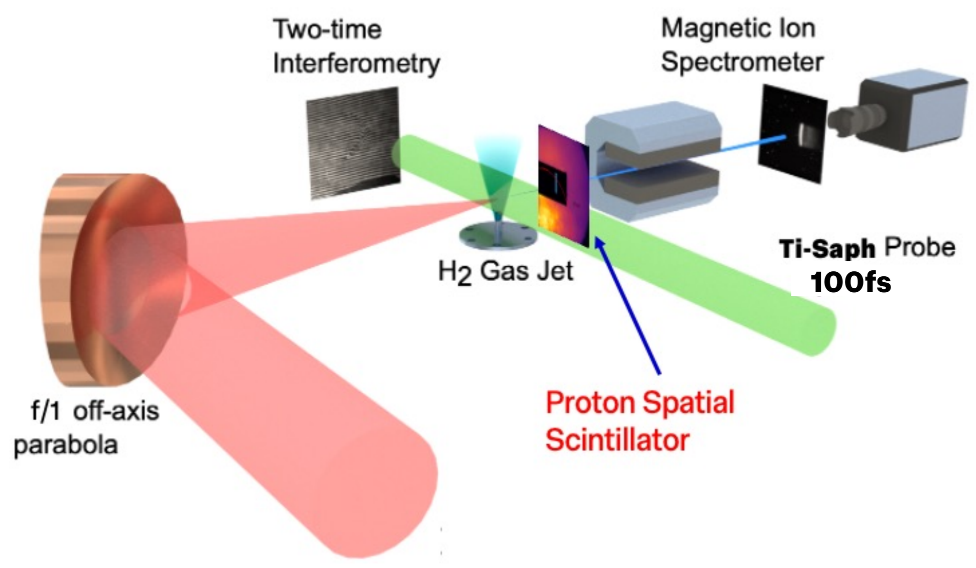
Transport line acceptance angle: $< 1^\circ$

The first step to improve the divergence is measuring it in a reliable way.

Experimental set-up:

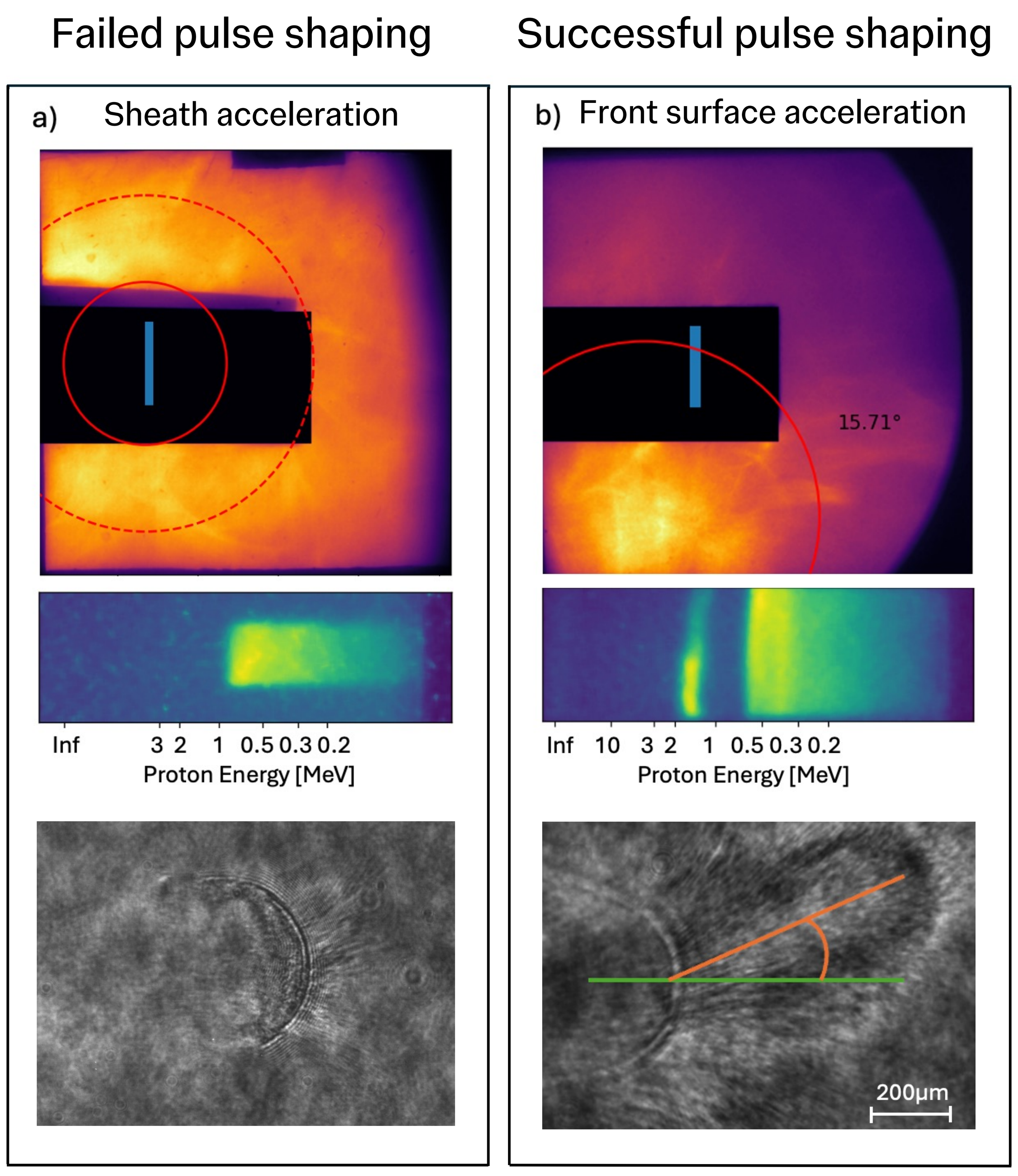
Laser parameters:

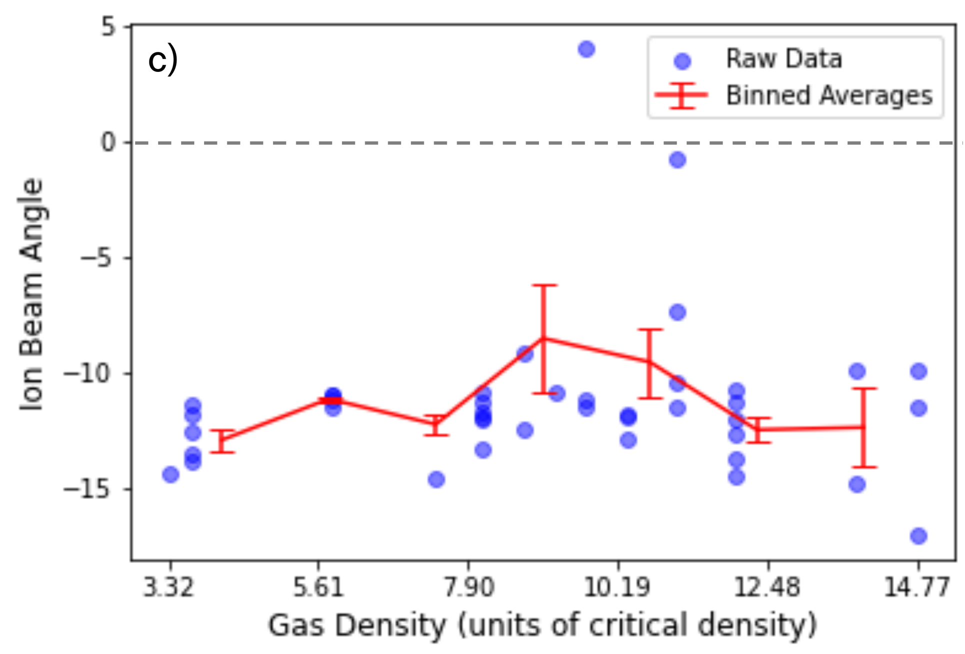
- wavelength: 9.2 μm,
- pulse length: 3 ps,
- energy on target: 5J,
- focal spot: 25 μm,
- intensity: 10^{22}W/cm^2
- a_0: 5.4

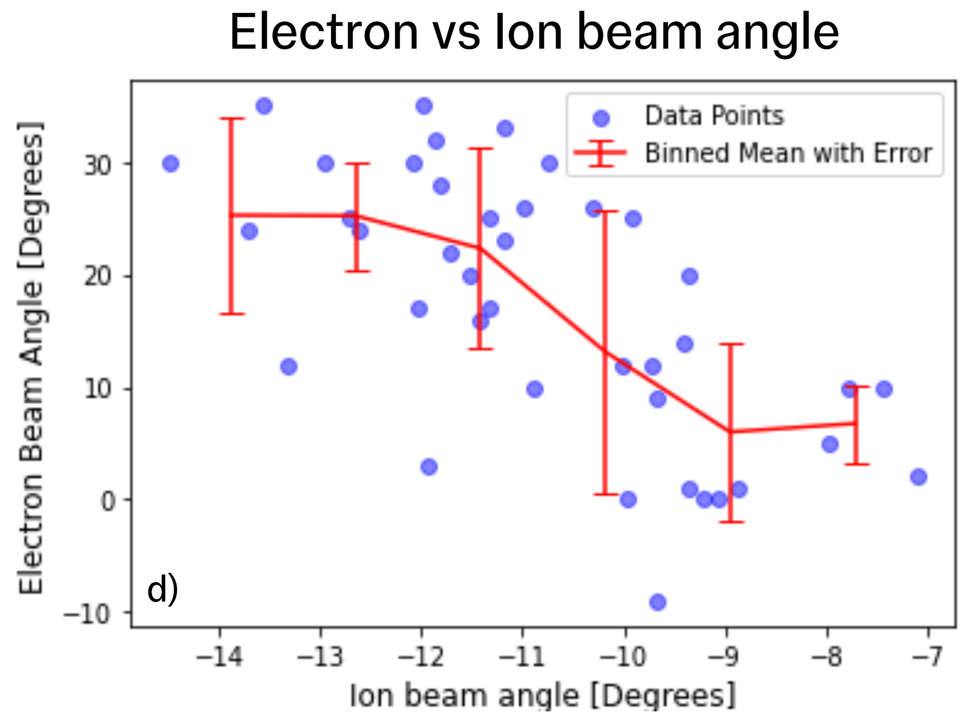


Schematic of our experimental set-up. The red shaded cone represents the CO_2 laser, which is focused by an off-axis parabola onto the hydrogen gas target. The laser-plasma interaction is probed by a 100 fs Ti-sapph laser. The ions generated in the interaction travel to the proton spatial diagnostic screen, where a slit allows them to continue towards the spectrometer.

Raw Data and analysis results:







a),b) Representative proton spatial (top), Thompson spectrometer (middle) and shadowgraphy data (bottom) for two different acceleration modes: sheath acceleration in a) and front surface acceleration in b) The blue region on both scintillator images shows where the Thompson parabola's slit is located spatially. The red circles in a) show the 10 and 20 beam divergence boundaries, in b) the red circle shows the FWHM of the ion beam obtained by fitting Gaussians.

c) The vertical offset angle of the ion beam centroids for varying gas densities. The dashed line marks the laser's mean propagation direction.

d) The electrons' deflection angles plotted versus the corresponding ions' deflection angles. The red line which is a trend of the data after binning shows a general negative correlation.

Explanation:

- Electrons follow in the laser's wake
- Protons travel perpendicular to the shock

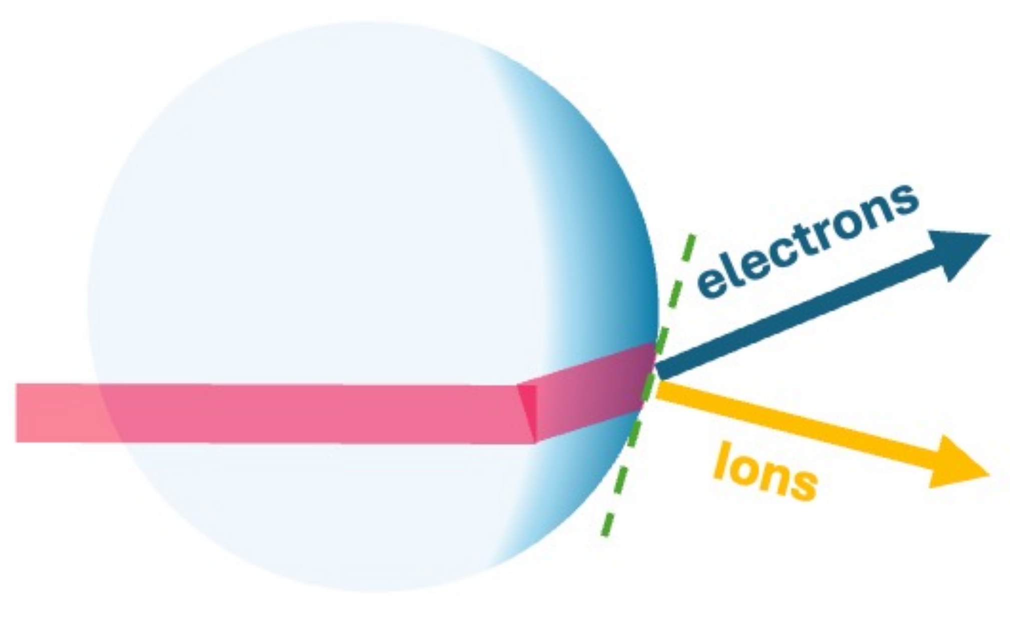
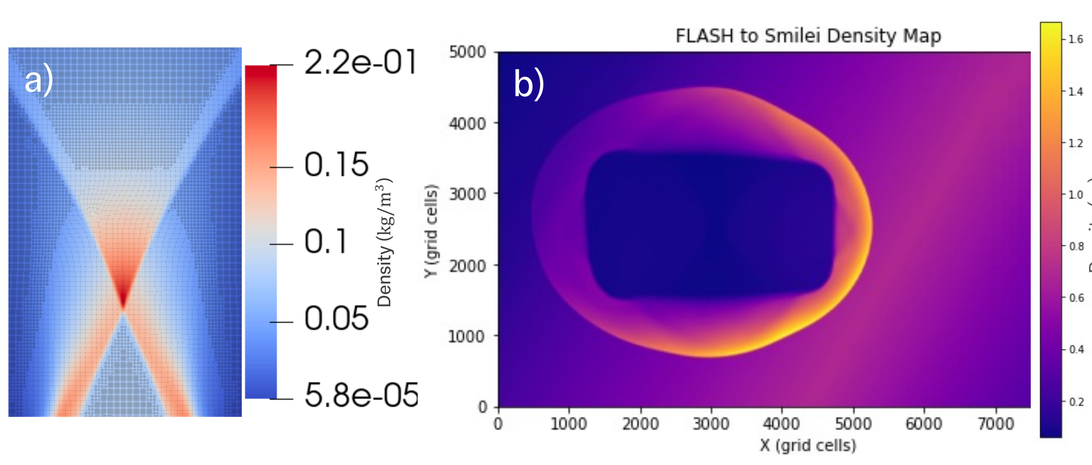


Diagram showing the laser beam interacting with the blast wave below its center. The laser is the diffracted upwards. The electrons follow the laser's direction whereas the protons are accelerated orthogonally to the shock front's plane.

Simulations:

- OPENfoam was used to simulate the gas flow,
- FLASH to generate a realistic BW and
- SMILEI will be used to simulate the laser interacting with the BW.



a) Converging nozzle gas jet profile simulated using OPENfoam. Backing pressure 6 bar.
b) FLASH simulation of a blast wave initialised and evolved in density profile taken from OPENfoam [5].

Conclusions:

- We measured divergence angles of ion beams produced through CSA.
- Blast-wave pulse shaping improves beam divergence.
- Both ions and electrons are deflected wrt the laser axis. The two deflection angles are negatively correlated.
- We are working on decoupling blast wave generation and shock acceleration beam

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