Spectral study of the lateral trace-space of laser-driven proton beams

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Introduction

Accurate analysis of the phase space of laser-driven proton and ion beams is essential for effective beam manipulation and focusing. The relationship between spatial and angular coordinates and their dependence on ion energy is characterized through transverse emittance measurements.

For a beam with a preferential direction z and transverse coordinate, the root-mean-square trace-space emittance [1] is:

$$\varepsilon_{rms} = \sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle x x' \rangle^2}$$

Using a Pepper Pot measurement [2], emittance will be calculated as:

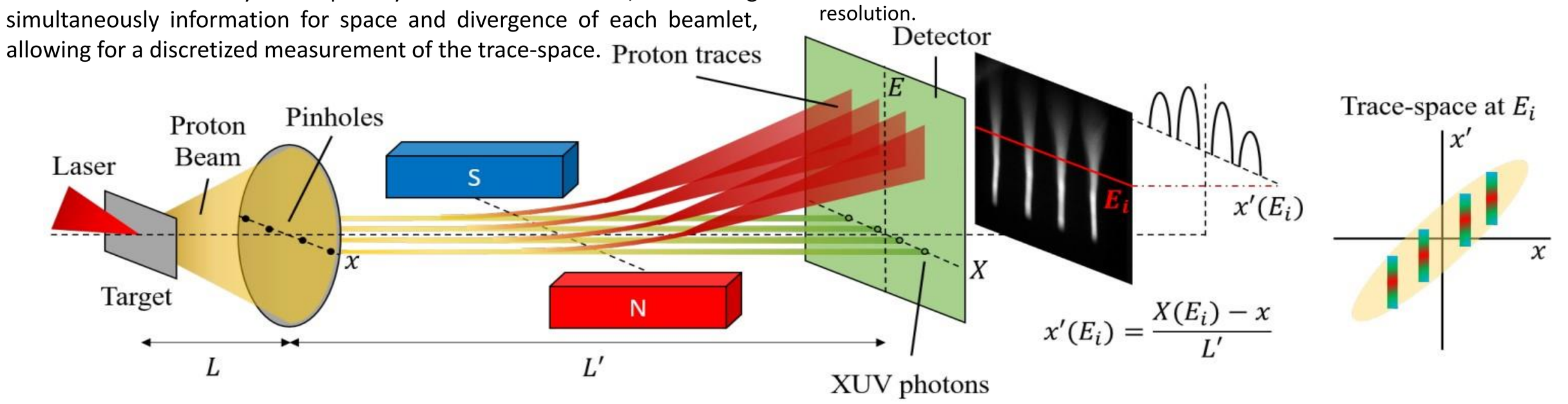
$$\varepsilon_{rms} \approx \frac{1}{N} \sqrt{\left\{\sum_i^p n_i (x_i - \langle x \rangle)^2\right\}\left\{\sum_i^p \left[n_i \sigma_i'^2 + n_i \left(\langle x_i' \rangle - \langle x' \rangle\right)^2\right]\right\} - \left\{\sum_i^p \left(n_i x_i \langle x_i' \rangle\right) - N \langle x \rangle \langle x' \rangle\right\}^2}$$

Method

We have used a magnetically streaked pepper-pot technique, enabling energy-resolved, single-shot diagnostics [3]. Pepper-pot consists of the individual detection of pieces of the beam, which is physically split by a pinhole mask. After some free flight distance L', the different beamlets are characterized by a spatially resolved detector, obtaining simultaneously information for space and divergence of each beamlet, allowing for a discretized measurement of the trace-space.

1D pinhole mask discretizes the beam in one of its transverse axes; which travel towards the detector and are deflected by a large magnetic field. A modified version of a Thomson Parabola spectrometer with angular resolution [4] was employed.

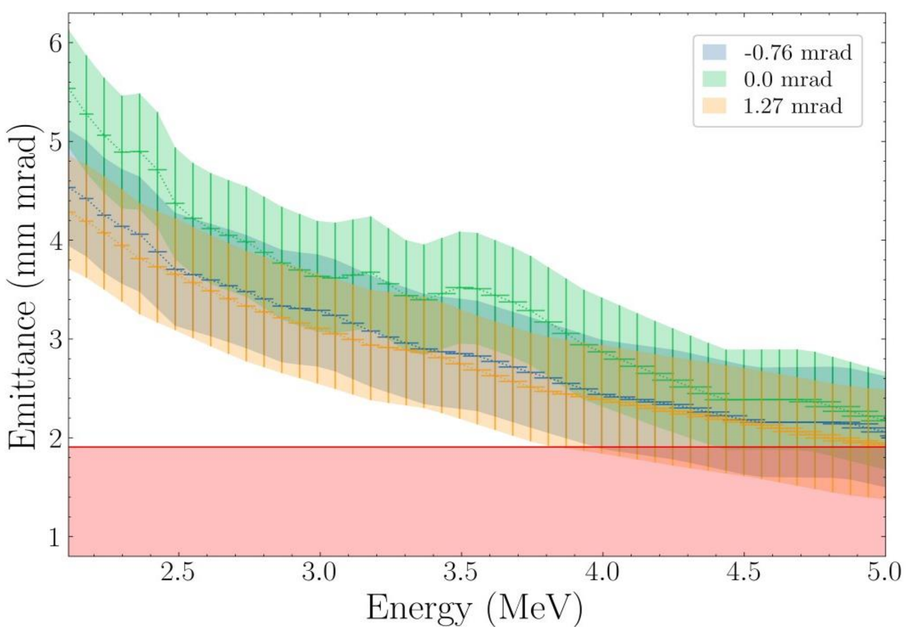
A plastic scintillator was used as proton trace detector, improving the angular acceptance of the device but still keeping the HRR operation and enough spatial resolution.



Results

The emittances calculated after joining 8 traces from 8 evenly distributed horizontal positions measured in 4 different shots, spanning an total beam horizontal angle of 13.4◦. This process was repeated at 3 different vertical angles.

- The shot-to-shot laser pointing instability can led to an artificial enhancement of the emittance.
- The rms trace divergence was calculated after the deconvolution of the raw trace width with a point spread function (PSF).



Conclusions

- This method could be implemented in HRR beamlines and in laser-driven ion acceleration experiments.
- This diagnostic technique can be extended to laser-driven electron accelerators.

For next experiments:

- Increased angular acceptance towards a complete beam retrieval
- Improvement of the spectral and spatial resolution
- Charge absolute calibration

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