# Transport and focusing of laser-accelerated protons at Z6*

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## LIGHT

Irradiation of $\mu$m-thin foils with high-intensity laser pulses ($> 10^{19}$ W/cm$^2$) became a reliable tool during the last decade for producing high-intensity proton bunches, providing up to $10^{14}$ protons in about a pico-second from a sub-millimeter source. However, the proton energy distribution is of an exponential shape with a currently achievable cut-off energy $< 100$ MeV (TNSA mechanism) and the beam is highly divergent with an energy-dependent envelope-divergence of up to 60 degrees. Thus, for most possible applications it is necessary to be able to capture and control these protons as well as select a specific energy. Therefore, the LIGHT collaboration (**L**aser **I**on **G**eneration, **H**andling and **T**ransport) was formed, dedicated to investigate the possibilities of compact laser-driven ion sources for ions in the multi-MeV range. In this context, a lot of preperative work had been done at GSI in the last years and the most promising results could be obtained with small quadrupol magnets [1] and pulsed high-field solenoids [2, 3]. And since the commissioning of the PHELIX 100 TW beamline [4] some experiments could already move to the Z6 area, where now short-pulse laser technology and conventional accelerator infrastructure can be merged in a unique way.

## pulsed high-field solenoid

The first experiment in 2012 for transport and focusing of laser-accelerated protons was done at the Z6 area, where PHELIX can deliver about 15 J of laser energy on target, exceeding $10^{19}$ W/cm$^2$. While the laser hits the front of the target, a 5–10 $\mu$m thin metal foil, the protons are accelerated targetnormal from the back side. The pulsed solenoid, placed 80 mm behind the target, is 150 mm long, has an open aperture of 40.5 mm diameter and can reach a maximum field of 10 T.

The magnetic field was adjusted to focus 4.5 MeV protons at 695 mm behind the solenoid (925 mm behind the target). The Detection of the proton beam in front of the solenoid and directly behind (still inside the targetchamber) showed the expected energy-dependet focusing and beam rotation. A proton focus could be reached inside the attached Z6 ion beamline at 695 mm behind the solenoid, containing $5 \times 10^8$ particles and with a spot size of 3 mm (FWHM).

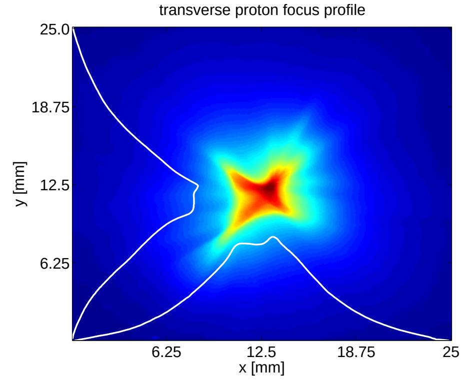


Figure 1: Transverse focus profile of 4.5 MeV protons at nearly 1 m from source, produced with the pulsed high-field solenoid.

The results are in good agreement with accompanying simulation studies, which are performed with CST particle studio and TraceWin.

## permanent-magnetic quadrupole triplet

In a second experimental campaign in 2012, the transport and focusing of laser-accelerated protons could be tested in the PHELIX laserbay with a permanent-magnetic quadrupole triplet. Here, intensities of $5 \times 10^{19}$ W/cm$^2$ were used with about 60 J laser energy on target; i.e. more particles are produced initially.

A sub-aperture of the full beam (40 mrad divergence) was transported through the triplet and at 630 mm distance to the source, 10 MeV protons were focused in a 3x6 mm (FWHM) spot size, containing up to $10^9$ particles.

## References

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