A laser-driven proton beamline at GSI*

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The LIGHT beamline. Laser-based ion acceleration became an extensively investigated field of research during the last 15 years. Within several micrometers particles are accelerated to MeV energies. The main drawback for many applications is their continuous exponential energy spectrum and large divergence angle from source. The exploration of proper beam shaping and transport is the major goal of the LIGHT collaboration [1], for which an experimental test beamline has been built at GSI. This *LIGHT beamline* at GSI is located at the Z6 area within the experimental hall. The PHELIX 100 TW laser beamline is currently capable of delivering up to 15 J of laser energy in a 650 fs short pulse on target, focused to intensities exceeding 10^{19} W/cm^2 within the Z6 target chamber. Protons could be accelerated via the TNSA mechanism to maximum energies of 28.4 MeV and propagated through a pulsed high-field solenoid with a field strength up to 9 T, which is used to select a specific energy interval from the continuous initial spectrum via chromatic focusing. A large capture efficiency of 34% of the initial protons within a selected energy interval (ΔE=(10$\pm$0.5) MeV) was measured [2].
The protons are weakly focused to a $15\times15\,\mathrm{mm}^2$ spot at 3 m distance to the source, containing particle numbers $>10^9$ in a single 8 ns short bunch. The energy spread of the bunch is (18$\pm$3)% and the central part of the bunch can be described by a Gaussian-like distribution:

$$\frac{dN}{dE} = \frac{N_0}{E} exp\left(-\frac{(E-E_0)^2}{2\sigma^2}\right) \quad (1)$$

Figure 1 (upper graph) shows the experimental results (E_0=9.6 MeV, σ=(0.7$\pm$0.06) MeV) compared to simulations.
First experiments on phase rotation. The cavity is a three gap spiral resonator, inserted to the beamline between 2 and 2.55 m distance to the laser target and connected to the UNILAC rf system. Injection at -90 deg synchronous phase and 100 kW input power leads to energy compression of the bunch. The energy spread at FWHM ($\Delta E/E_0$=2.35σ/E_0) could be reduced to (2.7$\pm$1.7)% at a central proton energy of E_0=9.7 MeV (see lower graph in figure 1) and particle numbers of 1.2×10^9 ($\pm$15%) within the FWHM were measured. A detailed description has been published in [3].
Furthermore, the experimental setup allows for phase focusing. Simulations predict shortest possible bunch durations down to the sub nanosecond regime. Highest single bunch intensities of 10^{10} protons/ns are accessible. An experimental campaign is planned for 2014.
Thanks to the compact laser-driven source the whole beamline is only 3 m long in total and represents a currently unique combination of novel laser and conventional accelerator technology to generate highest single bunch intensities in the multi-MeV region.

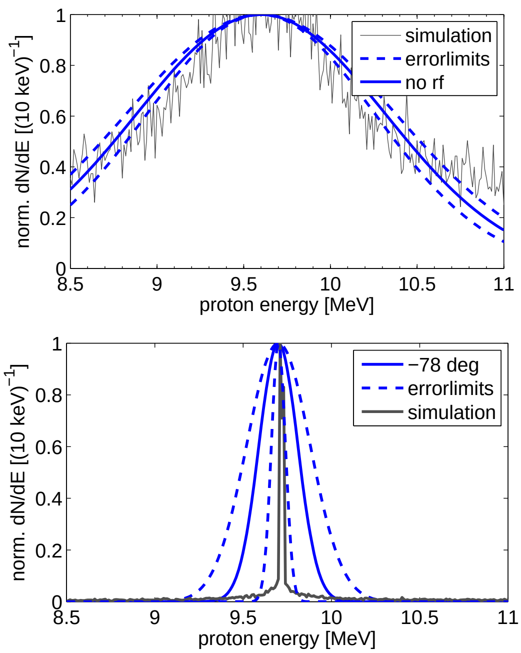

Figure 1: Simulated and measured proton spectra at a distance of 3 m to the source for solenoid focusing only (upper) and additional energy compression (lower figure) for a central bunch energy of E_0=(9.6$\pm$0.1) MeV.

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References

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