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EXPERIMENTAL RESULTS OF A COMPACT LASERWIRE SYSTEM FOR NON-INVASIVE H^- BEAM PROFILE MEASUREMENTS AT CERN's LINAC4

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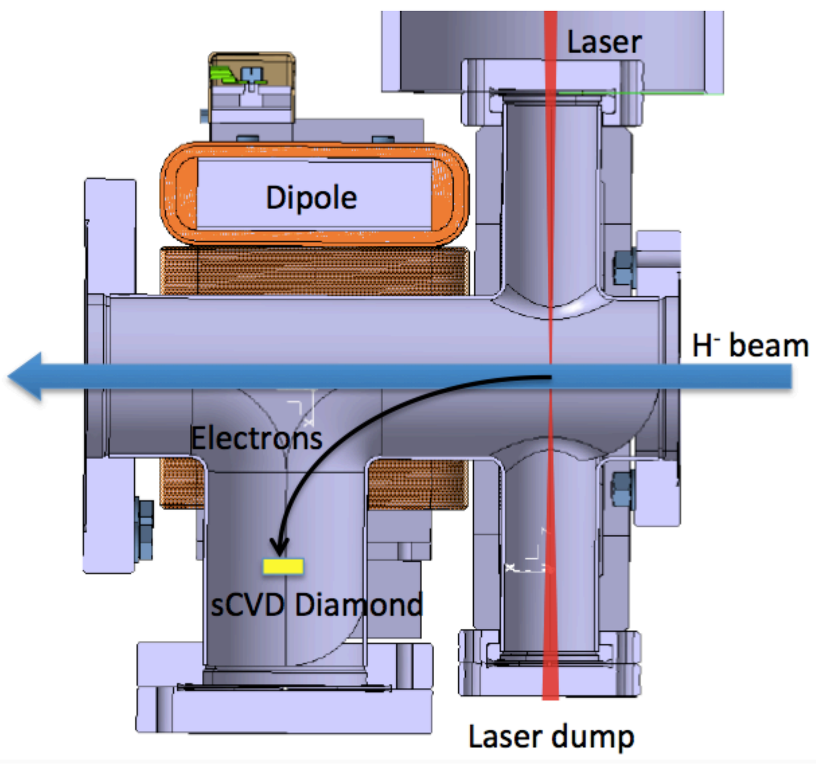
Motivation

Conventional beam diagnostics such as SEM-grids or wire scanners inherently obstruct a significant fraction of the particle beam during measurements. Therefore, a non-invasive laserwire system is being developed for quasi-continuous monitoring of the transverse profile and emittance of the final 160 MeV beam at CERN's LINAC4.

As part of these developments, a compact laser-based profile monitor was recently tested during LINAC4 commissioning at beam energies of 50 MeV, 80 MeV and 107 MeV.

The beam profile monitor detects electrons liberated from the H^- beam as it traverses the laserwire.

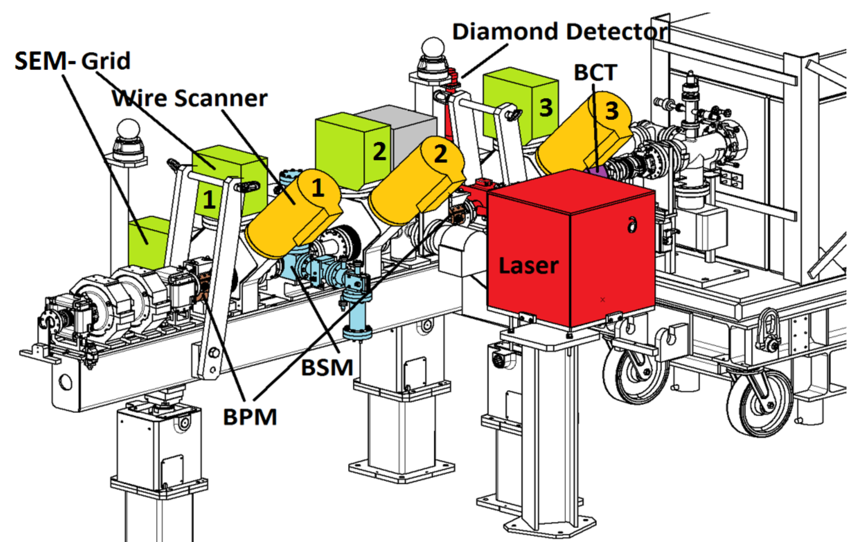


Beam Profile Monitor Concept

A transverse slice of the H^- beam is neutralised as it passes through the laserwire focus, liberating low energy (27 keV for 50 MeV H^-) *electrons* that are readily deflected through 90º by a 0.9 mTm integrated field of a weak dipole magnet. The main H^- beam remains almost undeflected by the weak dipole.

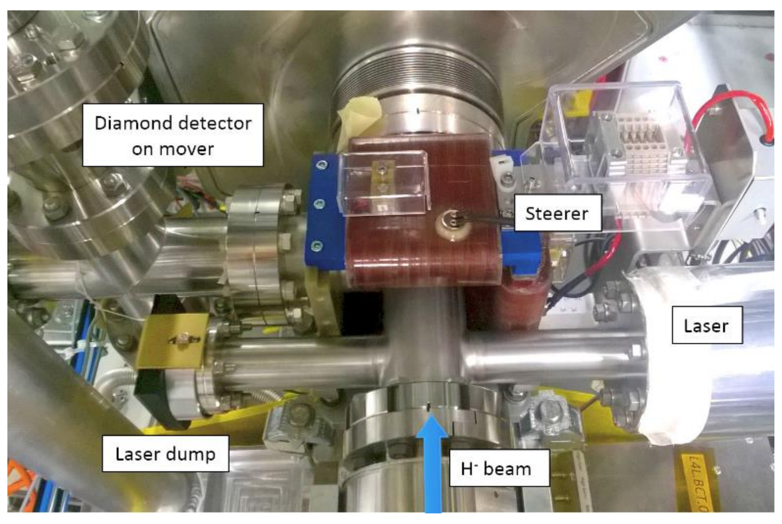
Electrons are collected by a fast 4x4 mm^2, sCVD diamond detector, that can be moved vertically in synchronisation with the laserwire position, allowing the beam profile to be reconstructed.

Experimental setup



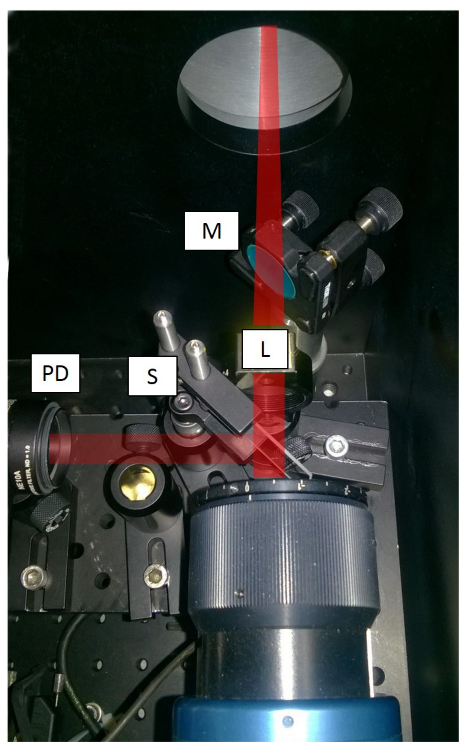
Diagnostics test bench

Laserwire interaction chamber



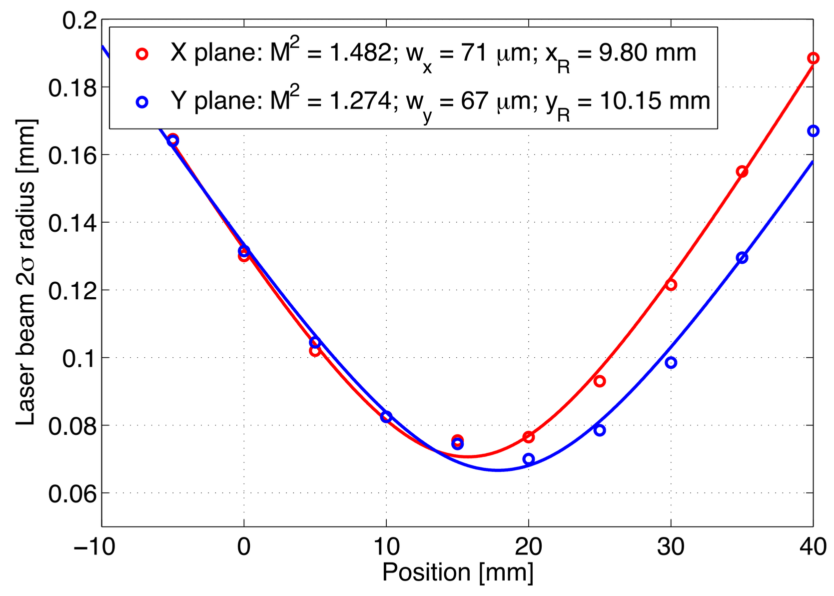
The laserwire formed part of a temporary diagnostics test bench, that characterised the LINAC4 H^- beam at the end of the DTL cavities and later after the first PIMS cavity. The laser beam delivery box shown in red, shines collimated light into the interaction chamber, pictured on the upper right. The fine position of the focusing optics is remote-controlled to scan the laserwire vertically. An AR-coated beam sampler (S) diverts a 4% reflection to the photodiode (PD) to mitigate small pulse-to-pulse laser power fluctuations.

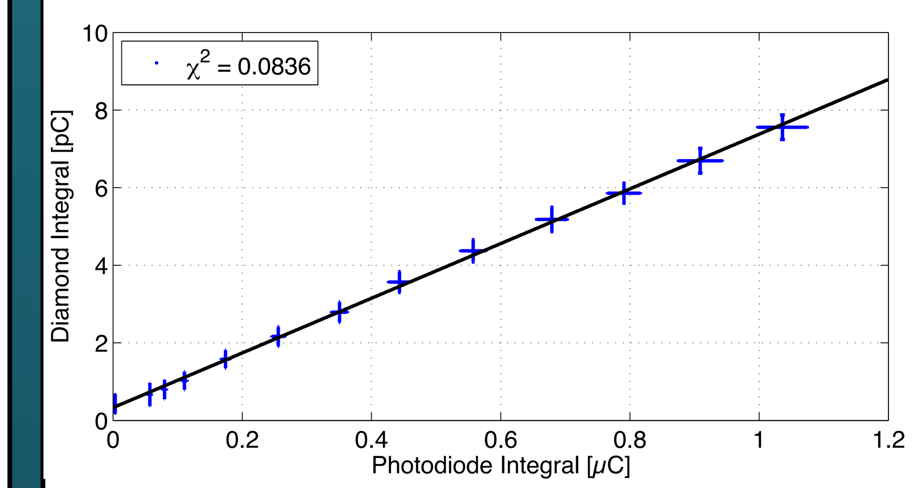
Focusing optics in the laser beam delivery box



System Characterisation

The beam delivery optics include a camera that can be translated along a focus equivalent to the interaction point to characterise the laserwire in-situ. An improved spatial profile of the laserwire was achieved for the 50 MeV tests compared to previous 3 /12 MeV measurement campaigns.

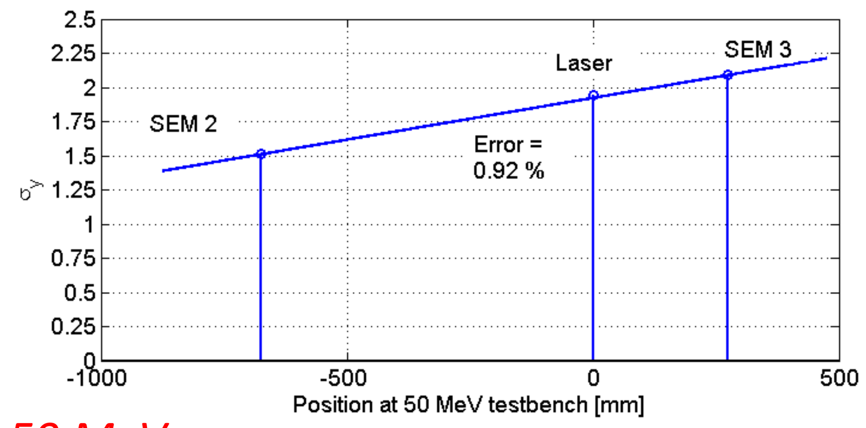


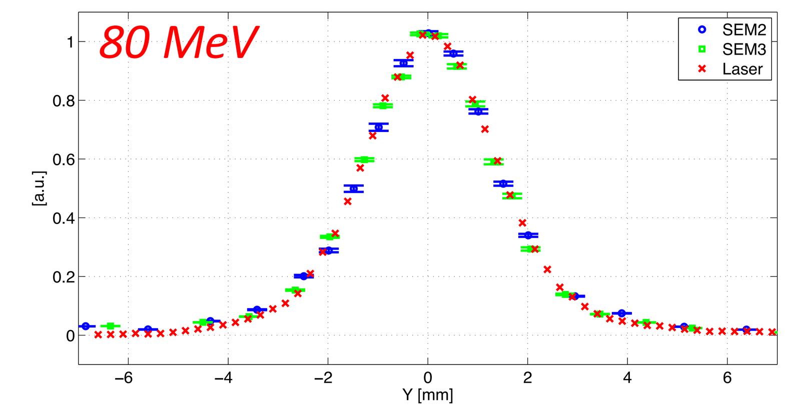


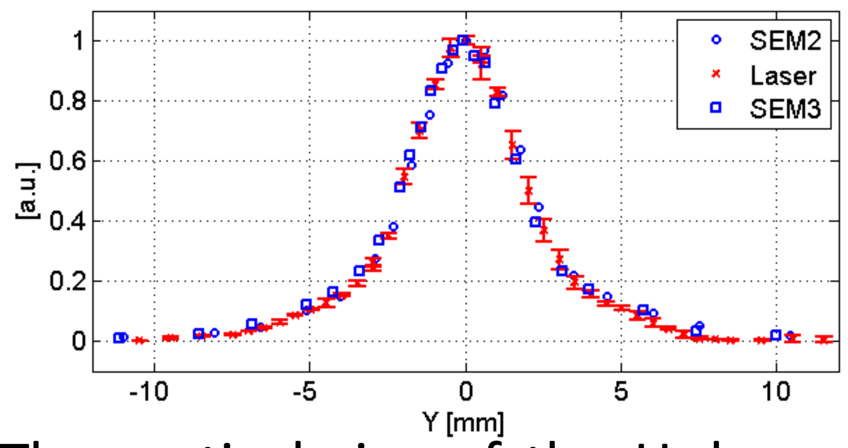
The diamond detector response is found to linearly follow the photodiode for a range of pulse energies.

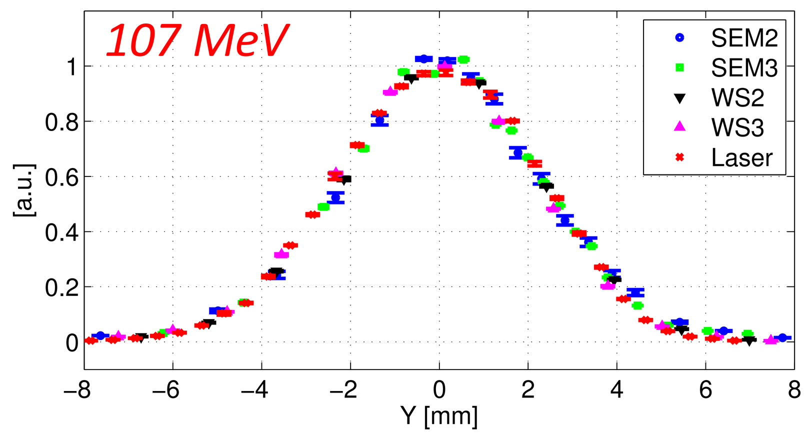
A small offset is observed due to a background of stray protons, H^0 or H^- directly impacting the diamond sensor in the 50 MeV setup.

H^- Beam Profile Measurements







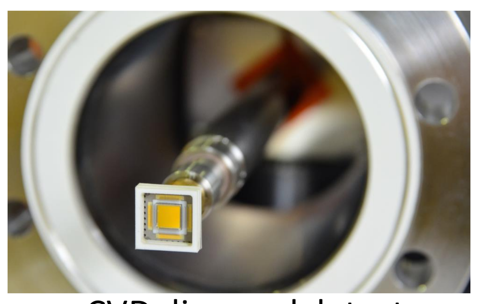


The vertical size of the H^- beam, σ_Y, was measured by laserwire scans at three beam energies and compared with measurements from nearby SEM-grids and wire scanners. Accounting for H^- beam drift, the laserwire result is extremely close to the interpolated value between SEM-grids. The SEM-grid and wire scanner profiles are scaled to the position of the laserwire: ***good agreement was found that is consistently below ±2% error on the H^- beam size***.

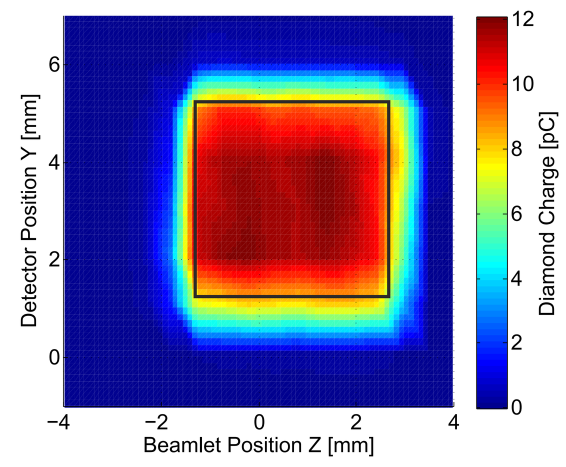
Electron Beamlet Deflection and Detection

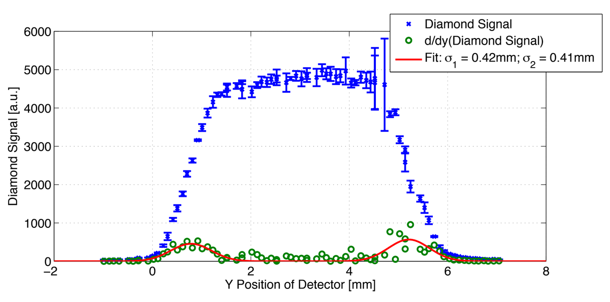
Each transverse slice of H^- beam neutralised by the laserwire liberates a thin beamlet of electrons, that is magnetically steered towards the diamond detector. The field was adjusted at each beam energy to compensate for the different electron momenta and optimised to target the 4 x 4 mm^2 diamond sensor placed at the focus.

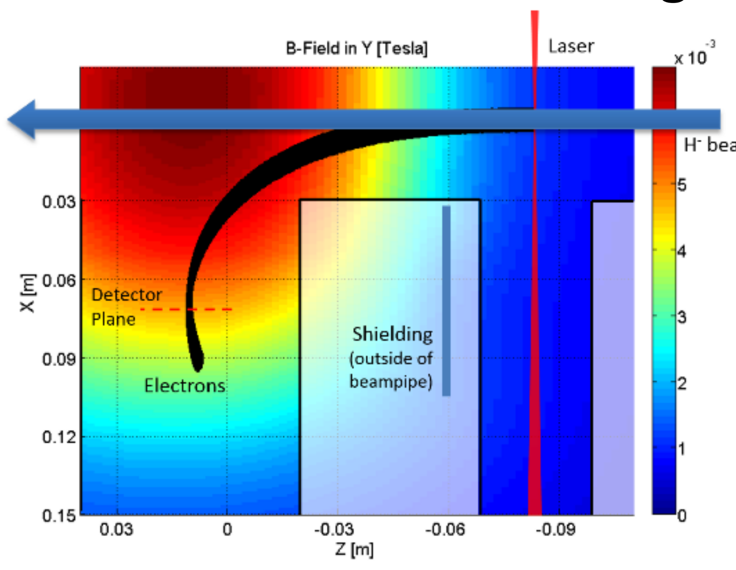
The beamlet size is measured by 2D scans of the vertical diamond detector position and the horizontal beamlet position by adjusting the field. The beamlet dimensions are extracted from the signal derivate.

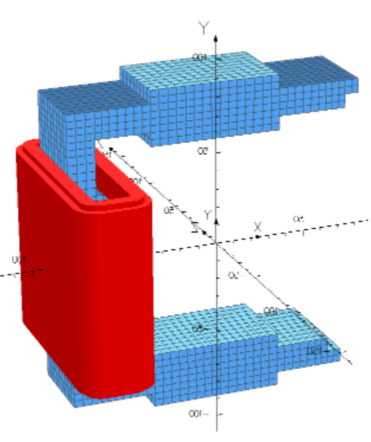


sCVD diamond detector









Steerer as a dipole

Crucially, the measured beamlet size of 0.4 x 0.45 mm^2 can be entirely collected by the 4 x 4 mm^2 diamond sensor.

Outlook: Based on these and our earlier results, a permanent laserwire at 160 MeV will be installed at LINAC4 to measure the transverse emittance in both planes, and will include beam profile monitors that measure the photo-detached electrons using electron multipliers to further reduce the background of scattered protons.

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