A FIBRE COUPLED, LOW POWER LASERWIRE EMITTANCE SCANNER AT CERN LINAC4

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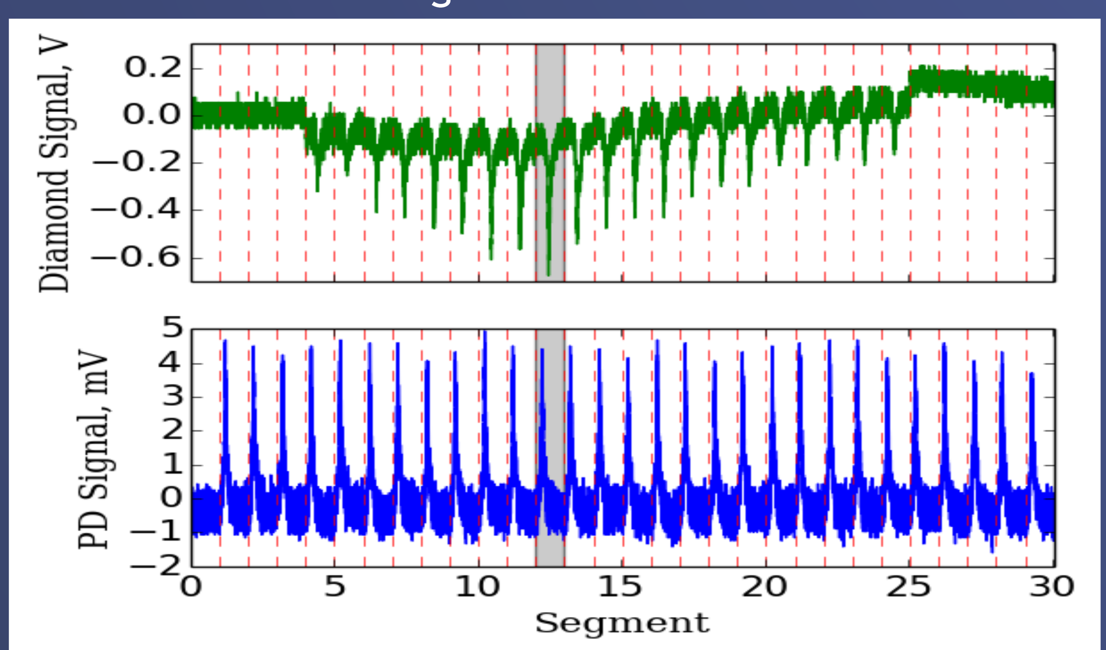
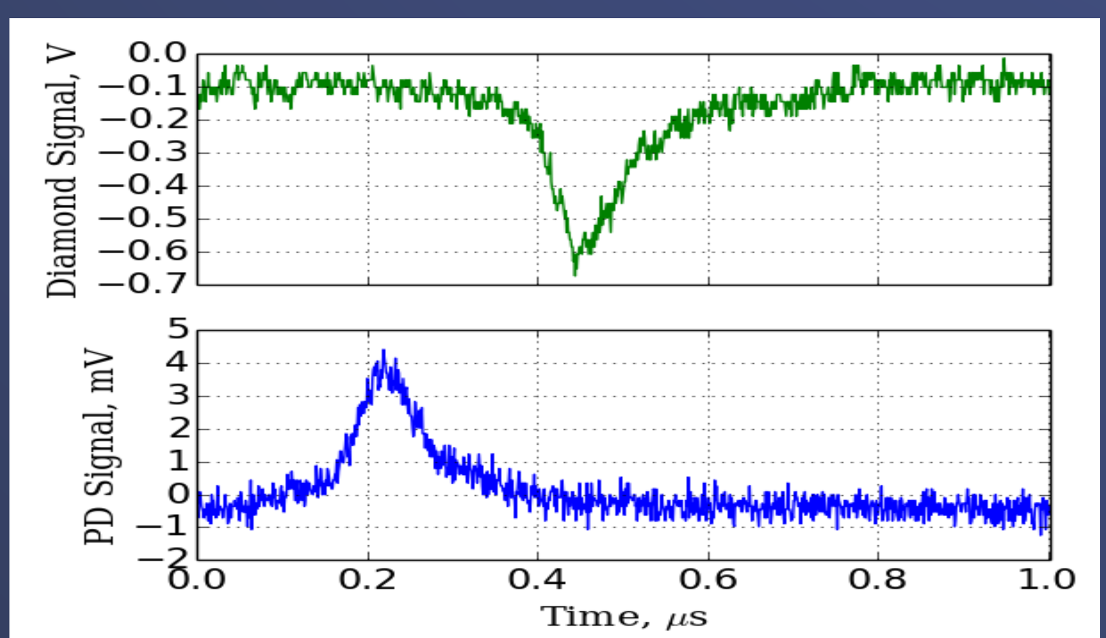
ABSTRACT

The new LINAC4 will accelerate H⁻ ions to 160 MeV and ultimately replace the existing 50 MeV LINAC2 in the injector chain for the LHC upgrade. During commissioning in 2013, a laserwire scanner and diamond strip detector were installed for non-invasive emittance measurements of the 3 MeV H⁻ beam. Synergy with the 3 MeV H– Front End Test Stand at RAL, has stimulated collaborative development of a novel laserwire system. A low peak power (8 kW) pulsed laser is fibre-coupled for remote installation and alignment free operation. Motorized focusing optics enable remote control of the thickness and position of the laserwire delivered to the vacuum chamber, in which the laser light neutralises a small fraction of H⁻ ions. Undeflected by a dipole magnet, these H atoms drift downstream, where their spatial profile is recorded by a highly sensitive diamond strip detector with ns-time resolution. We present first tests of the laserwire emittance scanner, including measurements of the photo detachment signal with respect to the background from residual gas interactions. The first laserwire transverse beam profile and emittance measurements are compared with conventional slit-grid diagnostics.

PHOTO DETACHMENT SIGNAL AND RESIDUAL GAS BACKGROUND

During 3 MeV beam commissioning the LINAC4 352.2 MHz bunches arrive in a macro-pulse of 400 μs every 1.2 s. The laserwire intercepts the macro-pulse with a train of laser pulses at 60 kHz, with < 1kW pulse peak power at the interaction region. Each 110 ns laser pulse can interact with 38 bunches. The plot shows the train of 60 kHz laser pulses, recorded by the photodiode before the fibre coupling. Corresponding peaks are observed in the diamond signal, due to the photo-detached H^0. The peak height is modulated by the beam current, which varies during the macro-pulse. The change in pedestal level between laser peaks is due to neutrals from upstream residual gas background interactions and is present in the diamond detector signal, independent of whether the laser is powered. The time resolution of the diamond detector enables good discrimination between signal and background. A zoomed region for one segment around the diamond signal is shown.

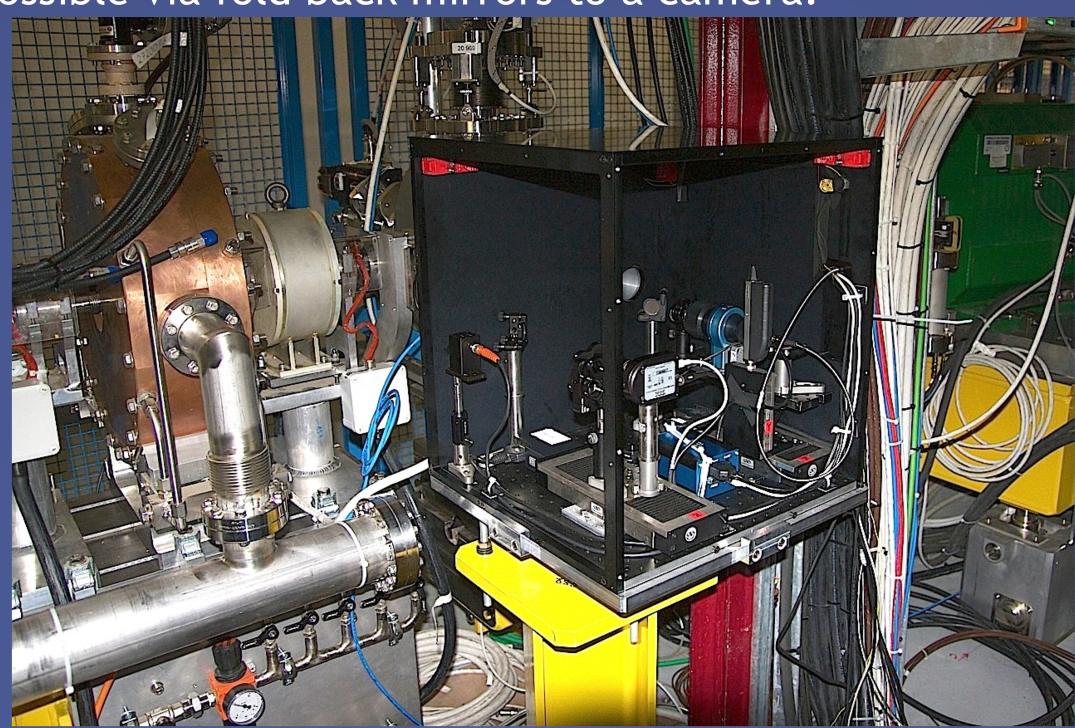


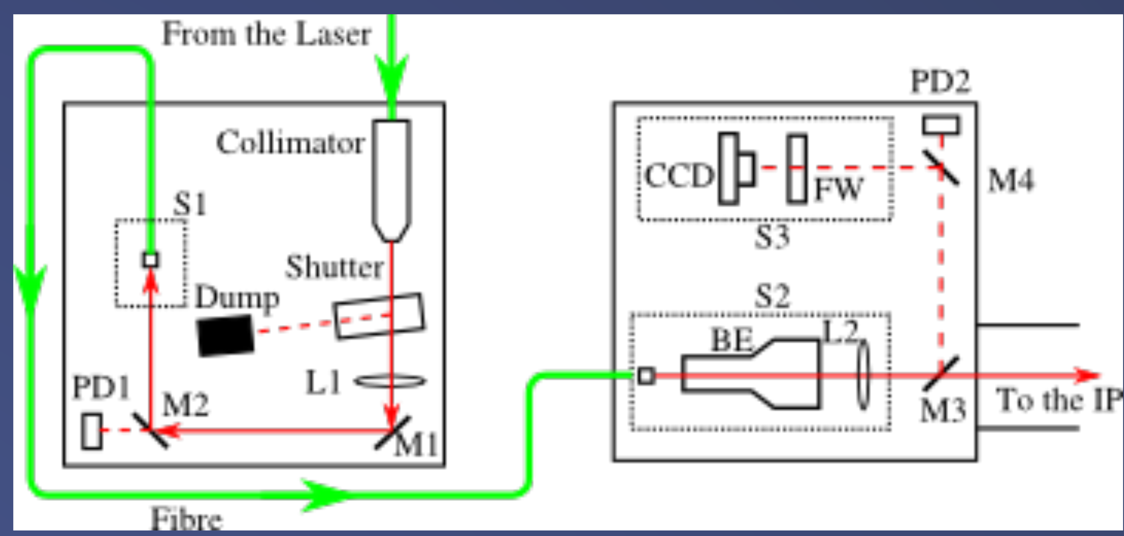


OVERVIEW AND EXPERIMENTAL SETUP

The laserwire emittance scanner consists of a remotely housed, pulsed laser connected via an optical fibre to a motorized focusing optics, which control the thickness and position of the laserwire delivered to the accelerator. A diamond detector downstream of a dipole magnet records the photo detachment signal from the neutralised H⁻ beam.

The laser is a Q-switched, diode pumped, all-fibre MOPA, that generates 110 ns pulses at a repetition rate selectable between 30 and 100 kHz, at λ = 1080nm. A reduced pulse peak power of < 1 kW at the interaction region was sufficient to generate a good signal. The laserwire collimation optics were mounted on translation stages that control the position with micron resolution. In situ monitoring of the laser focal region is possible via fold back mirrors to a camera.





Diamond detector

Diamond was selected for its sensitivity (10^4 electrons/H^0), bandwidth (3 ns time constant), and radiation hardness (>10^{15} MeV neq cm^{-2}). The detector is mounted on a translation stage to permit vertical movement into the beamline, so that the spatial profile of the neutralised beamlet can be determined (and retracted from the main beamline when the spectrometer magnet is off). A detector with finer granularity is envisaged for the final system, to eliminate the need to move the detector and reduce the measurement time. The detector was biased at 600 V and the readout channels were individually instrumented with linear amplifiers, which were found to give the most reliable signal in the analysis below.

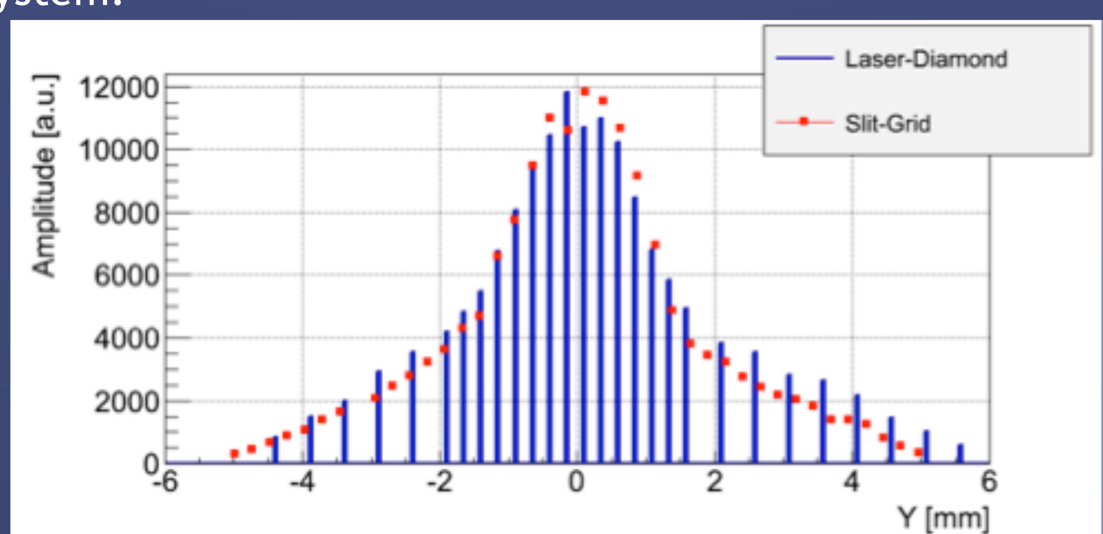
Detector consisting of 500μm thick polycrystaline diamond with five 3.5 x18 mm aluminium electrodes

BEAM PROFILE AND EMIITANCE MEASUREMENT RESULTS AT 3 MeV

Automated vertical scans of the horizontal laserwire were performed for different diamond detector positions. At each step, diamond detector data were acquired in 30, 1μs segments, for one accelerator macro-pulse. The laserwire position was then moved ready to acquire a subsequent accelerator pulse.

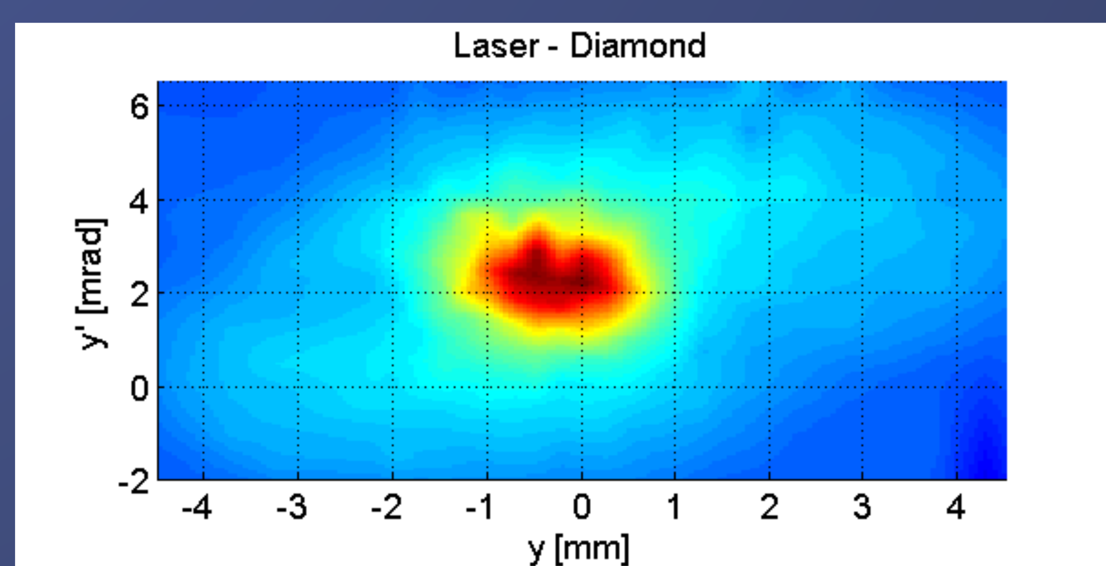
The data were analysed by first applying a smoothing filter (width = 10 samples) to the diamond signal to reduce noise. A linear fit to the residual gas background pedestal was then performed for each segment, and subtracted from the photo detachment signal region, before integration over the window containing the peak. The background subtracted signals were averaged over five of the laser pulses (in segments 10 to 14) from the same LINAC4 macro-pulse.

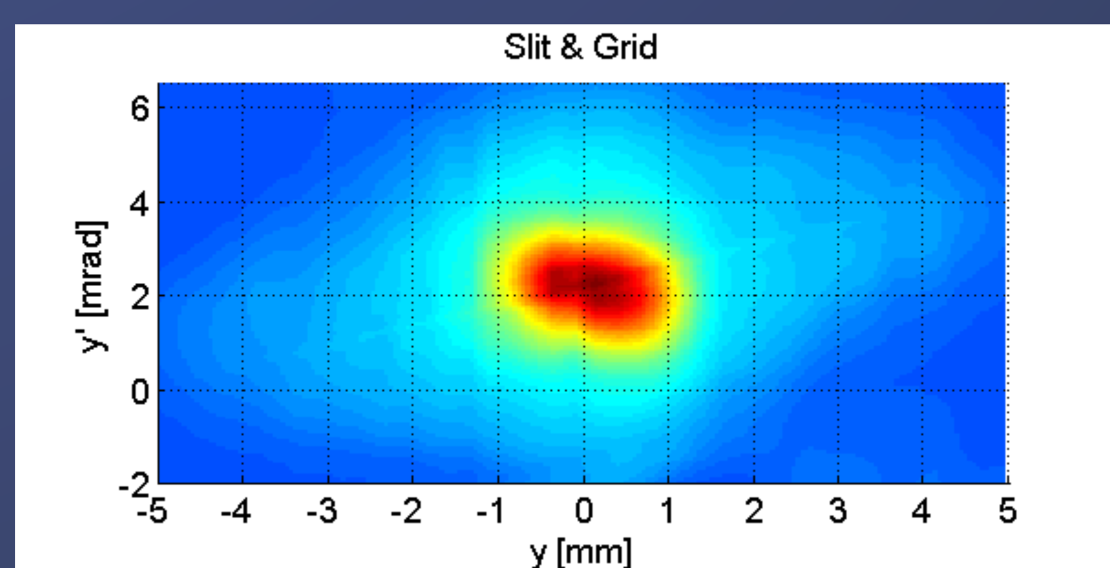
The integrated and averaged signal is plotted below versus the laserwire vertical position to give the transverse profile of the LINAC4 beam. The laser results were verified with independent measurements from conventional slit scanner at the same location as the laser wire and measured by a downstream SEM-grid. Very good agreement is found for the beam-core. The beam halo values are slightly bigger when measured with the laser system.



Comparison of Emittance Measurements from Laserwire and Slit-Grid Diagnostics

Laserwire beam profile measurements were recorded for a range of diamond detector positions and the results used to reconstruct the transverse emittance of the LINAC4 beam. A comparison with the emittance measured by the slit-grid method is shown. Despite the lower spatial resolution of the laser data in these first tests, the ellipse size and orientation is in good agreement. The measured emittance values are the ***same to within 10 %.***





CONCLUSION & FUTURE

The first low-power, fibre coupled laserwire for H⁻ beams has been collaboratively developed and tested at the LINAC4 during 3 MeV commissioning. First beam profile and emittance measurement results from the laserwire scanner demonstrate very good agreement with conventional slit-grid diagnostics. While further tests are planned for 12 MeV commissioning, these results already encourage prospects for a final laser emittance station at 160 MeV.

ACKNOWLEDGEMENTS

We acknowledge support from the Marie Curie Networks LA³NET and oPAC under Grant Agreements GA-ITN-2011-289191 and PITN- GA-2011-289485.
We are grateful to the LINAC4 operation team and our CERN colleagues, R. Jones, U.Raich, E. Bravin and F. Zocca for helpful discussions.