IBIC 2013 17.9.13 Oxford TUPF15

Science & Technology Facilities Council

S. M. Gibson*, G. Boorman, A. Bosco – Royal Holloway, Egham, UK
P. Savage, J. Pozimski –Imperial College, London, UK
C. Gabor, A. Letchford – STFC/RAL, Didcot, UK
T. Hofmann – CERN, Switzerland
*Stephen.Gibson@rhul.ac.uk

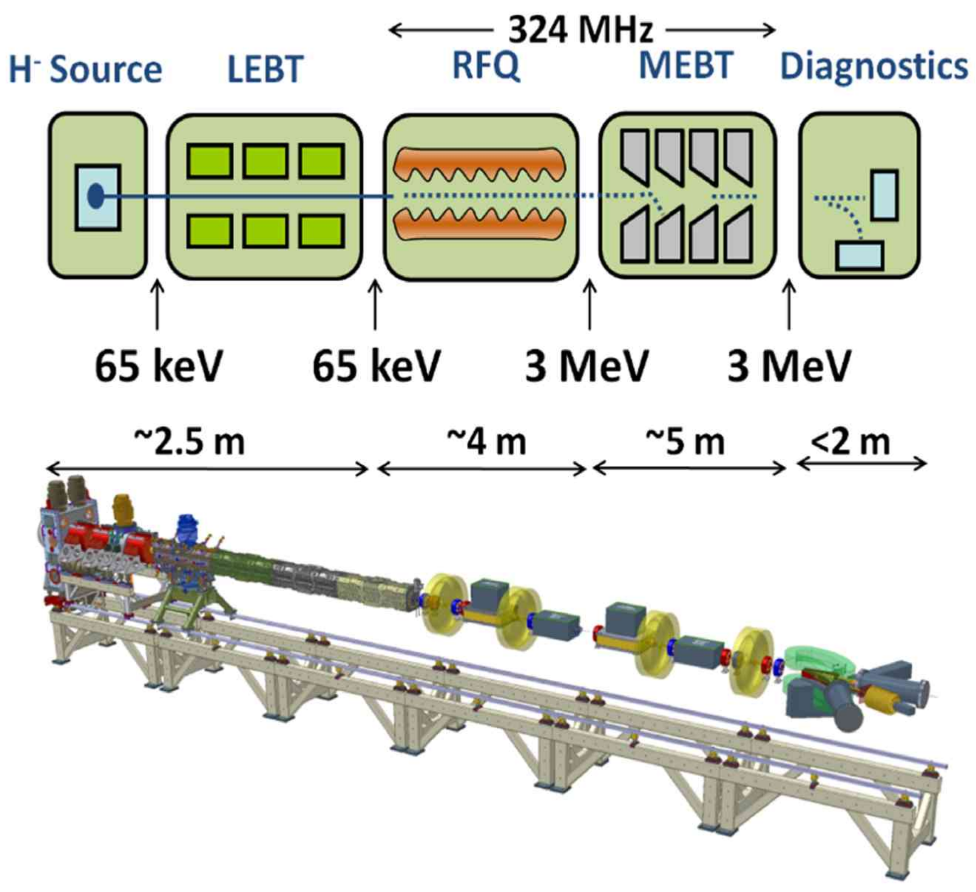
Overview of Laserwire Beam Profile and Emittance Measurements for High Power Proton Accelerators

Introduction

High power proton (H$^-$ ion) linacs are of interest for: Spallation Neutron Sources, a Neutrino Factoy, a Muon Collider and Accelerator Driven System for sub-critical reactors. Damage thresholds for beam powers in the megawatt regime limit the use of interceptive beam diagnostics, such as wire scanners. However, laser-based wire scanners (laserwires) offer a non-invasive method to probe high intensity beams. We present a generic laserwire emittance scanner suited to non-invasive beam profile and emittance measurements at high-power H$^-$ linacs, being developed collaboratively for FETS and LINAC-4.

Front End Test Stand at RAL

FETS consists of a H$^-$ ion source, a magnetic low energy beam transport (LEBT), 324 MHz Radio Frequency Quadrupole accelerator (RFQ), medium energy transport line (MEBT), high speed beam chopper and comprehensive diagnostics. A 60 mA beam current at 50 Hz is routinely achieved from the ion source and LEBT with up to 2ms pulse duration.



LINAC-4 at CERN

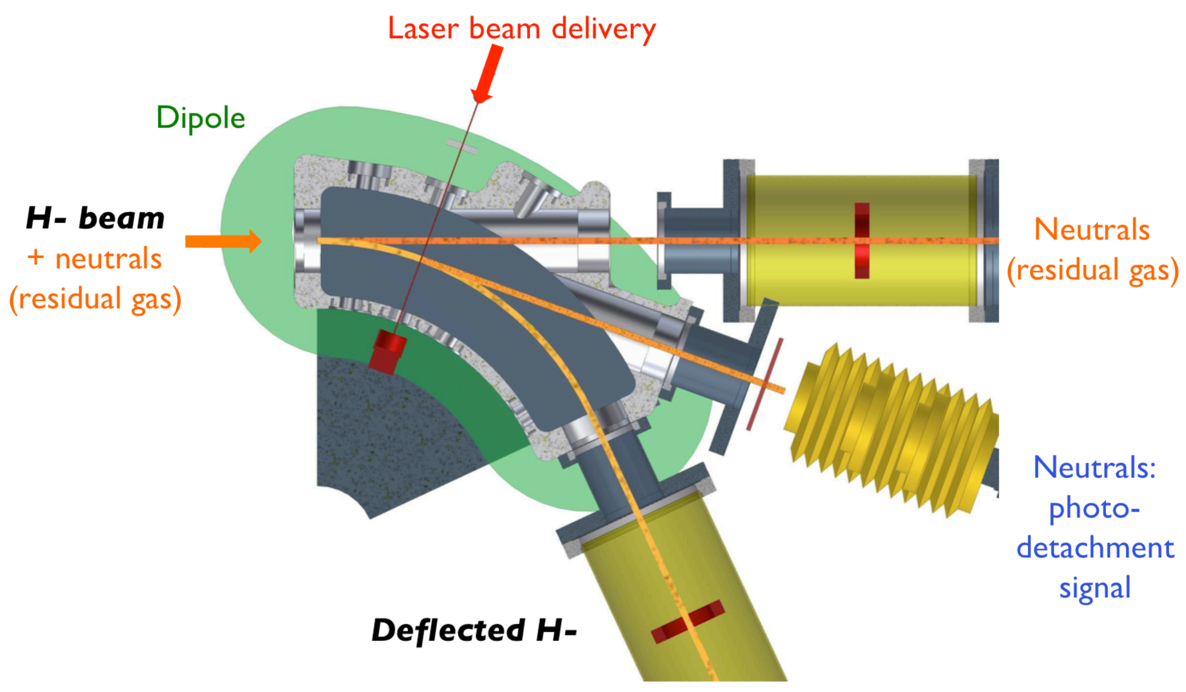
A 160 MeV replacement linac for the new LHC injector (SPL) is under construction at CERN. The ion source, 3 MeV RFQ and MEBT which includes a chopper have been commissioned on the surface and is currently being moved to the tunnel in readiness for initial tests at 3 MeV, then later with the full Linac-4 chain at 160 MeV.

Collaborative effort

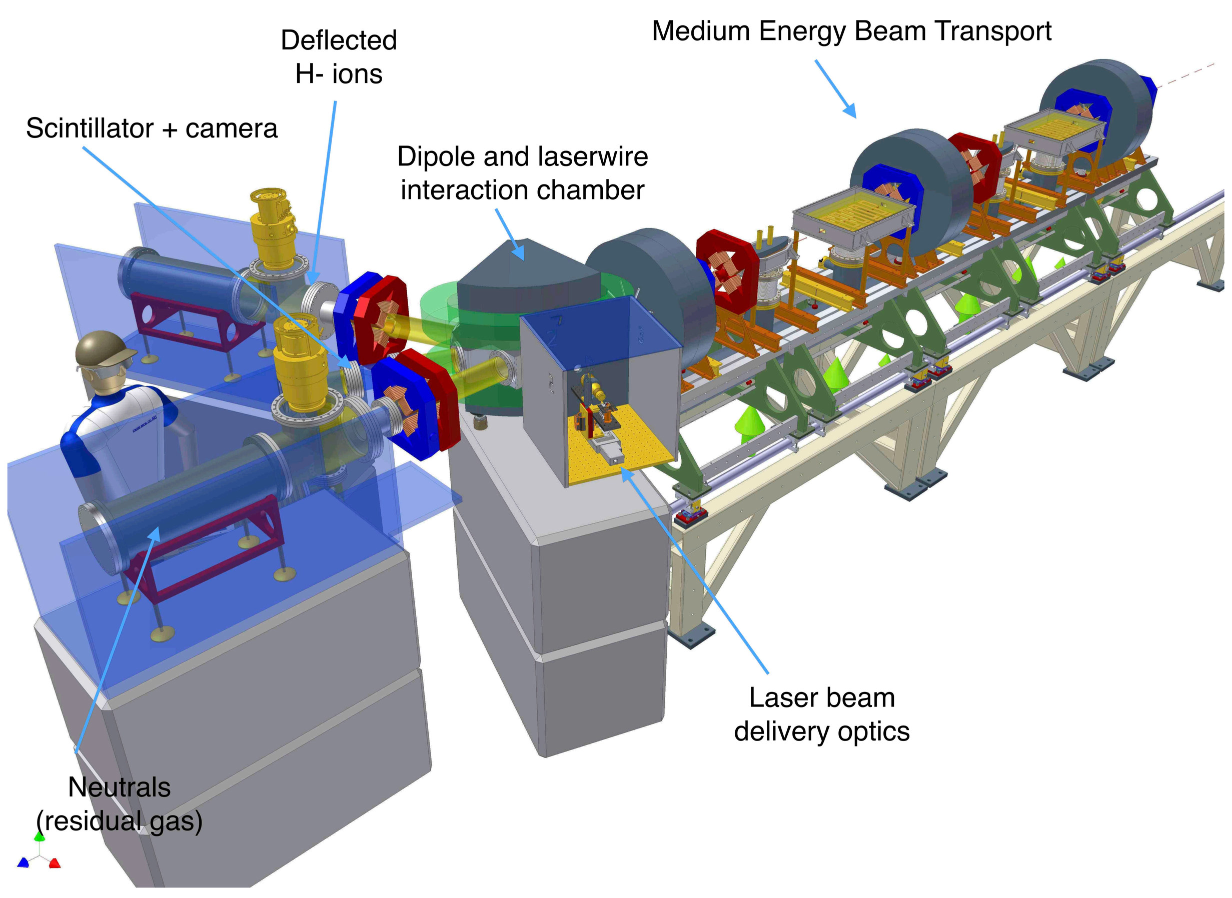
A non-invasive laserwire emittance scanner is being developed for Linac-4 as part of a fruitful collaborative study, which uses the laser and beam delivery optics from FETS. As a first step, the laserwire system will be deployed for tests at the Linac-4 3 MeV front end in late 2013.

Measurement Principle

The laserwire photon energy of 1.16 eV is sufficient to liberate a weakly bound (0.75 eV) electron from the H$^-$ ion. The laserwire emittance scanner operates by slicing out a beamlet of neutralized particles, which propagate to a downstream to a position sensitive detector. The transverse emittance is reconstructed from the spatial profile as the laserwire position is scanned. A dipole deflects the main H$^-$ beam.



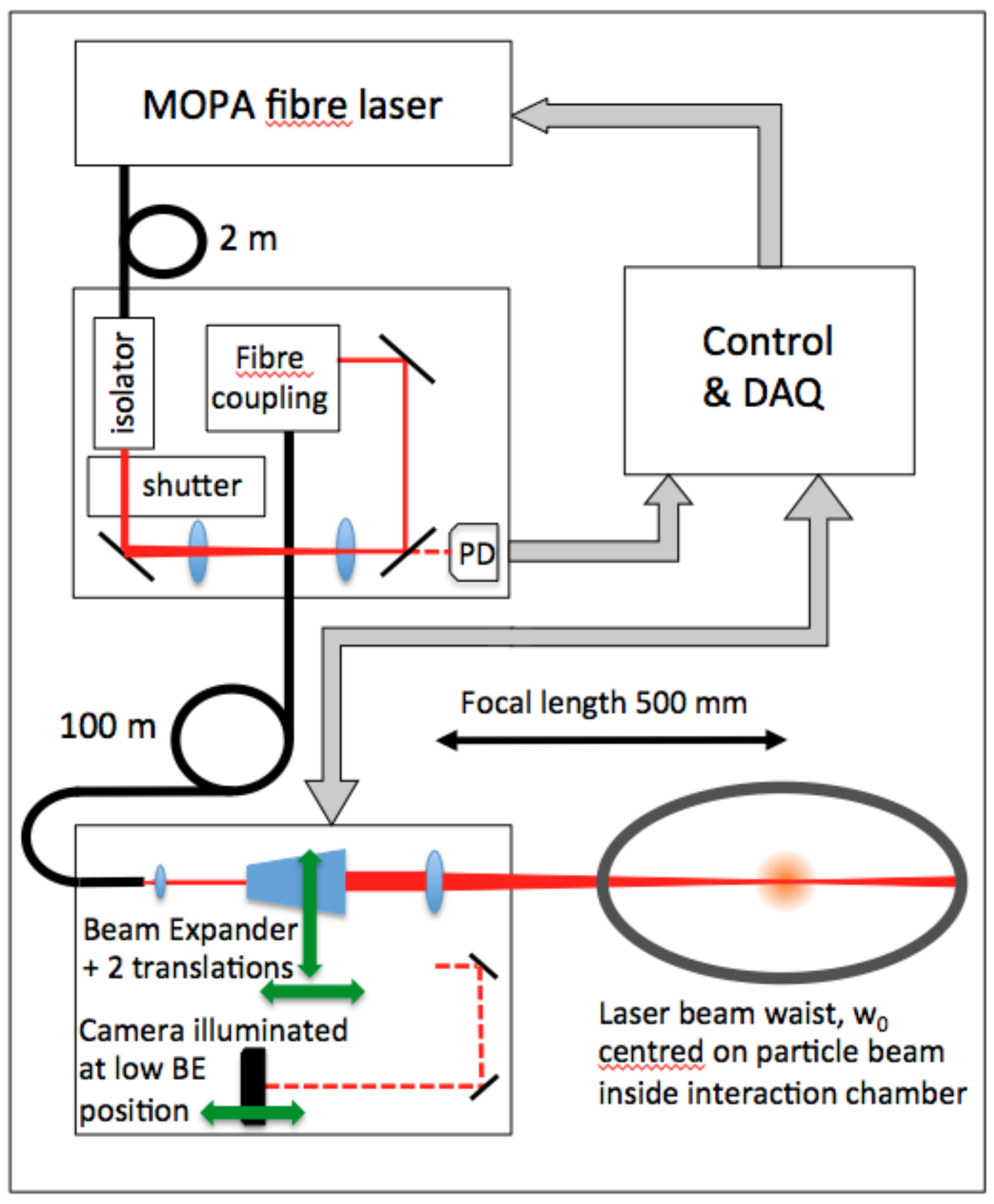
Upstream residual gas interactions can generate a background of neutral particles on top of the signal from the photodetachment process. At FETS the background is avoided by arranging the laser interaction point one third into the dipole field, such that the neutral background particles are first separated from the H- ion beam, before the laserwire photodetachment.



Laser Transport and Delivery

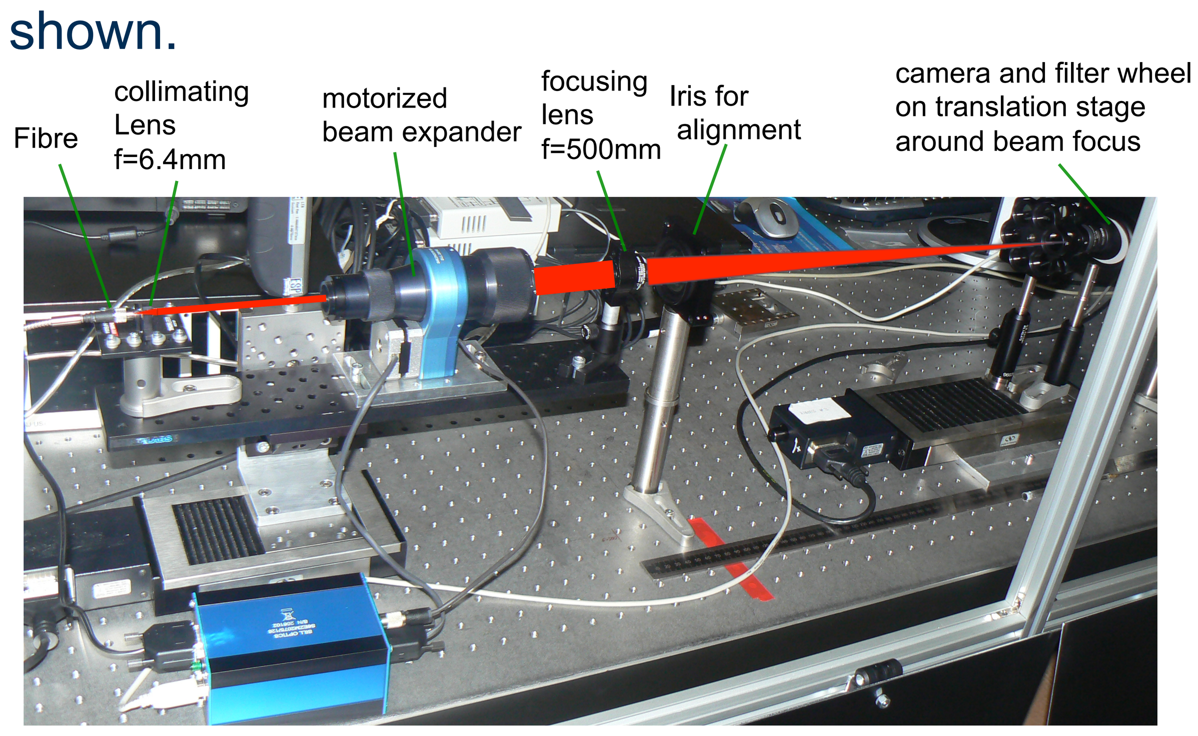
A pulsed 30 kHz, 8 kW peak power laser is fibre-coupled to motorized collimating optics, which controls the position and thickness of the laserwire delivered to the H- interaction chamber. A pair of translation stages control the vertical and longitudinal position of the laser beam, with micron-level resolution. A motorized beam expander enables various laser spot sizes to be obtained in eight magnification steps. Further adjustment can be made by careful selection of the collimating lens at the output of the fibre and the focusing lens after the beam expander. The setup offers flexibility to generate a range of different laser beam sizes.

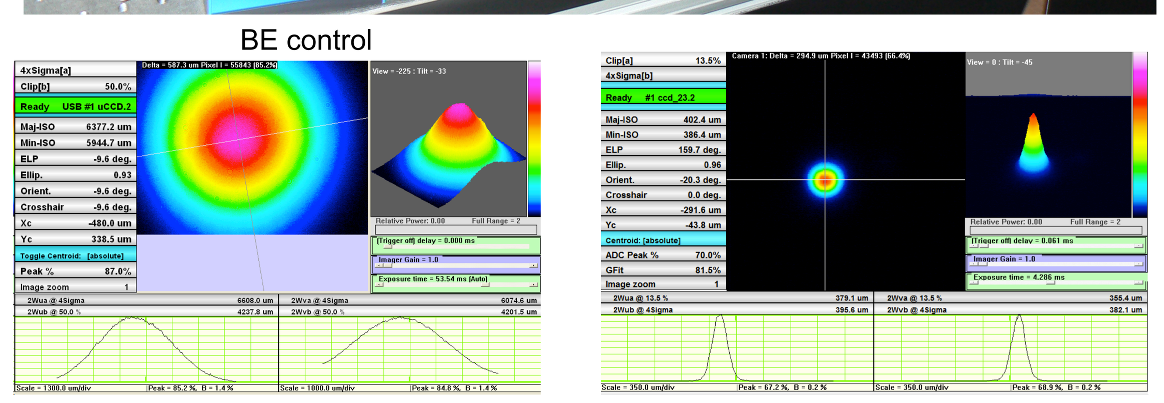
Laser Delivery System



Laser Beam Quality Measurements

The profile of the laser beam emerging from the collimation optics was measured by a camera mounted on a translation stage, giving a beam quality of M^2<1.76. This is marginally better than the raw quality from the laser output, most likely due to mode cleaning qualities of the long fibre. The Gaussian beam profiles directly out of the fibre (left) and after (right) the collimating and focusing optics are shown.





Conclusions and outlook

A laserwire emittance scanner enables non-invasive beam diagnostics at high power proton accelerators. The beam delivery system developed for FETS has been optically tested and found to meet the specified beam quality after the transport fibre. The system is planned to be tested in the Linac-4 beamline at CERN in late 2013 as part of a collaborative effort to develop an laserwire emittance scanner for the next generation LHC injector.

The Front End Test Stand Collaboration

Science & Technology Facilities Council ISIS
Science & Technology Facilities Council ASTeC
Imperial College London
Royal Holloway University of London
JAI John Adams Institute for Accelerator Science
THE UNIVERSITY OF WARWICK
ESS bilbao
UCL