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DITANET - INVESTIGATIONS INTO ACCELERATOR BEAM DIAGNOSTICS

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Abstract

DITANET is a Marie Curie initial training network in beam diagnostics. The network members, universities, research centers and industry partners, are developing diagnostics methods for a wide range of existing or future particle accelerators, both for electron and for ion beams. This is achieved through a cohesive approach that allows for the exploitation of synergies, whilst promoting knowledge exchange between partners. In addition to its broad research program, the network organizes schools and topical workshops for the beam instrumentation and particle accelerator communities. This contribution gives an overview of the Network's research outcomes to date and summarizes past and future training activities.

INTRODUCTION

Beam diagnostics is a rich field in which a great variety of physical effects are made use of and consequently provides a wide and solid base for the training of young researchers. Moreover, the principles that are used in any beam monitor or detector enter readily into industrial applications or the medical sector which guarantees that training of young researchers in this field is of relevance far beyond the pure field of particle accelerators. Partners within the DITANET project develop beam diagnostics techniques and technologies for present and future particle accelerators. The project started on 1.6.2008 and will continue until then end of May 2012. It consists of ten beneficiary partners and presently 17 associated and adjunct partners [1].

The participation of industry is an integral part of the training within DITANET and all partners from industry are included as members of the supervisory board to ensure that industry-relevant aspects are covered in the different projects carried out within the network and to enhance knowledge transfer. In addition, they offer internships to the early stage and experienced researchers from the network to complement the scientific training and thus actively contribute to building the bridge between the academic and the industrial sector.

SELECTED RESEARCH RESULTS

The research projects within DITANET cover all different kinds of accelerator instrumentation for both low and high energy accelerators and light sources. This section gives a brief overview of some recent research results.

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Beam Profile and Emittance Measurements for LINAC4

As a part of the upgrade of the LHC injector chain, the LINAC4 will replace the LINAC2 in the next few years. This linear accelerator will accelerate H^- from 45 KeV to 160 MeV. A number of wire grids and wire scanners will be used to characterize the beam transverse profiles. In addition, a slit and grid system has been developed in the frame of the ESR project of B. Cheymol at CERN for measuring the transverse emittance during the commissioning of the low energy part, i.e. up to 12 MeV.

The slit can be considered as a beam dump, as most of the beam is stopped inside it. Considering the nominal beam parameters for the commissioning phase (100 µs pulse length and an intensity of 65 mA), the thermal load would damage on the slit. Analytical calculations and numerical simulations have shown that the best material for the slit is graphite. The slit geometry has been chosen to dilute the energy deposition over the maximum available graphite volume and a final design of the slit has been worked out.

In order to measure beam profiles along the linac, several SEM grid and wire beam scanner (WS) monitors will be installed between the RF cavities from 50 MeV to 160 MeV. Two wire scanners will also be installed at the chopper located in the 3 MeV MEBT line. The SEM grids are retractable devices that will be inserted into the beam in a single step, while WS are driven by stepping motors that will allow slow scans of the particle distribution over multiple beam pulses. For H^- beams, the signal on the wire is generated by Secondary Emission (SE) induced by the particles entering or exiting the wire and the charge deposition of proton or stripped electrons. For the LINAC4 SEM grid and WS monitors, two types of wire are presently considered: 40 µm diameter Tungsten wires and 33 µm diameter Carbon wires.

The thermal load induced on the wires by the beam can produce thermo-ionic emission of electrons that would perturb the measurement. If the wire temperature increases further, the wires can break due to melting or sublimation. The thermal load induced by the nominal LINAC4 beam (I=40mA, 400 µs pulse length) is too high for Tungsten wires. The increase in temperature is lower with Carbon wires, but the signal is also lower. In order to keep the signal at a sufficient level for good profile measurements, the final design of the Wire Beam Scanner and SEM grid will use Tungsten wires. Nevertheless, the pulse length has to be reduced to 100 µs, to prevent any damage on the wire.

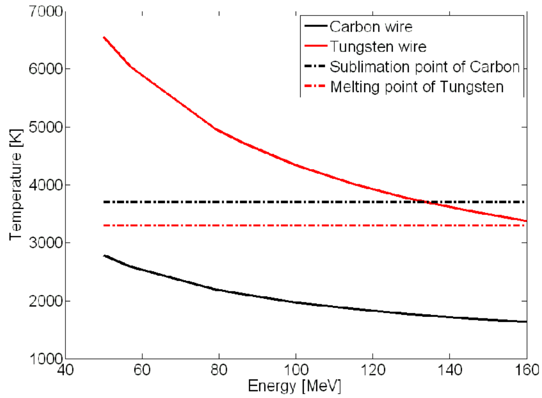

Figure 1: Temperature evolution for 100 μm diameter Carbon and Tungsten wire as function of beam energy, for a LINAC4 40 mA, 400 μs pulse and typical beam sizes at the monitors locations.

Results from simulation of the wire temperature dependence on beam energy are shown in Fig. 1 [2].

Curtain Gas Jet-based Beam Profile Monitor

A neutral supersonic gas jet target, shaped into a thin curtain, and bi-dimensional imaging of the gas ions created by impact with the beam to be monitored is a promising candidate for minimum perturbing beam profile monitoring and is the subject of M. Putignano's ESR project at U Liverpool, UK. Keeping the curtain at a 45° angle from the impinging direction of the main beam, and extracting the ions perpendicularly to the jet-projectile beam interaction plane on a position sensitive detector, an image of the projectile beam transverse section is formed on the detector, much like a mirror reflection. A prototype installation has been assembled and commissioned at the Cockcroft Institute, UK and has recently started full operation, collecting first data for the neutral beam scanner transverse profile monitor.

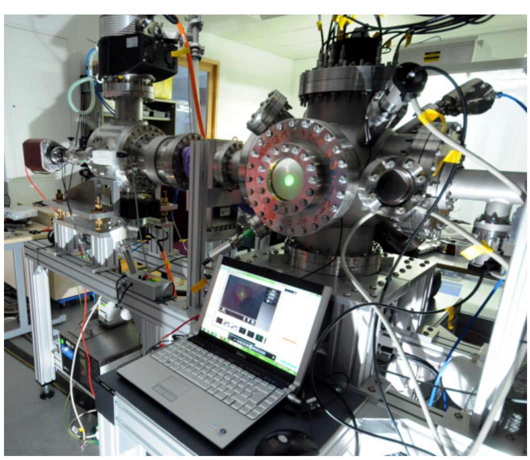

Figure 2: Photograph of the curtain gas jet setup at the Cockcroft Institute, UK [3].

The installation consists of the main detector chamber, equipped with an MCP detector, coupled to a phosphor screen and a dedicated imaging camera. It includes an ion extraction system, a precision valve for finely varying the background pressure and a 5 keV electron gun. The detector chamber is now connected to the gas-jet generation chamber, which houses variable nozzles and skimmer apertures for the collimation of the jet, and an electronically controlled pulsed valve for pulsed jet operation.

The setup can also be used as a residual gas monitor, imaging the transverse profile of the beam of interest via interaction with the background gas. Measurements have been taken recently to demonstrate this mode of operation [3]. The operation of the full monitor is anticipated for later in 2011. Possible applications range from ultra-low energy antiproton beams to high intensity, high energy hadron and electron beams.

Ionization Beam Profile Monitor

In the frame of the International Fusion Material Irradiation Facility (IFMIF), a prototype for a non-interceptive transverse beam profile monitor based on residual gas ionization (IPM) has been built and characterized in detail in the frame of J. Egberts' ESR project at CEA, France. Test measurements have been performed at GSI, Darmstadt with pulsed Ca^{10+}, Xe^{21+}, and U^{28+} beams of up to 1.6 mA at 5 MeV/u and at CEA Saclay with 80 keV protons in a cw beam of up to 10 mA. It was found that the electric extraction field of the monitor is highly uniform. By varying the extraction voltage, it was shown that at given beam conditions the electric field is strong enough to dominate the extraction process and that distortions from space charge and the like are minimal. The effects of N_2 and different rare gases in the pressure range from $4 \cdot 10^{-7}$ mbar - $5 \cdot 10^{-4}$ mbar have also been investigated. The signal was read out by different electronic cards, based on linear and logarithmic amplifiers as well as on charge integration. Furthermore the extraction voltage of the IPM field-box was varied between 0.5 and 5 kV. Beam profiles were investigated with respect to signal intensity and profile shape and were compared to a secondary electron emission grid and a beam induced fluorescence monitor. Profiles of all monitors match nicely for the residual gases with differences in beam width well below 5% and the spatial resolution of the IPM was conclusively determined to be below 100μm [4].

TRAINING AND OUTREACH

In addition to the local training provided by the respective host institutions, DITANET organizes a number of network-wide events, such as Schools, Topical Workshops, and conferences that have to be attended by the network trainees, but are also open to the wider diagnostics community.

International Schools

The network has organized two international schools on beam diagnostics to date. The first took place March March 30th-April 3rd 2009 at Royal Holloway, University of London, UK with Grahame Blair as local organizer. This school started with an introduction to accelerator physics and the definition of particle beams, before basic beam instrumentation such as for example beam energy, beam current or transverse beam profile measurement were covered. Later the week more advanced topics, such as the monitoring of the machine tune or electron cloud diagnostics were presented. An excursion to Rutherford Appleton Laboratory including visits to ISIS and DIAMOND, as well as two tutorials and one poster session complemented the broad program, see [5].

An advanced DITANET School took place in Stockholm, Sweden March 7th–11th 2011. The event was hosted by Manne Siegbahn Laboratory with Anders Källberg as local organizer. This school joined around 100 researchers and started with a recap of some of the key concepts introduced during the first school back in 2009. Helmut Wiedemann, Professor emeritus from Stanford University, gave an introduction to accelerator physics, before beam profile and beam position measurements were covered in one hour lectures by leading experts in the respective field.

During the week, beam instrumentation for specific applications, such as low energy accelerators, light sources, colliders or high intensity accelerators were presented in detail. The intense lecture program was complemented by dedicated Question & Answer sessions, as well as focused tutorials. In addition, participants were given the opportunity to present their own work in this interdisciplinary field in a poster session that triggered many interesting discussions [6].

Topical Workshops

In addition to its international schools on beam diagnostics, the network has been organizing a series of Topical Workshops since 2009. To date, workshops on *"Low Energy, Low Intensity Beam Diagnostics"* in Hirschberg, Germany (November 2009) [7], *"Longitudinal Beam Profile Measurements"* at the Cockcroft Institute, UK (July 2010) [8] and *"Ultra Bright Electron Sources"* at the Cockcroft Institute, UK (July 2011) [9] have been realized.

Additional workshops on *"High Intensity Proton Beam Diagnostics"* (Paris, France, September 2011), *"Technology transfer"* (Solkan, Slovenia, September 2011), *"Particle Detection Techniques"* (Seville, Spain, November 2011), *"Beam Position Monitoring"* (CERN, 2012) and *"Beam Loss Monitoring"* (DESY, 2012) will complement this series.

Conference on Beam Diagnostics

The DITANET Consortium will organize a three day international conference on diagnostic techniques for particle accelerators and beam instrumentation in Seville, Spain between 9.-11. November 2011. This conference will bring together all partners, but is also open to participants from the world-wide diagnostics community, in particular to researchers at the early career stage. The latest developments and trends in the field of accelerator instrumentation will be presented in both, oral and poster sessions. It is expected that this event will provide ample opportunities for critical discussions of research outcomes, exchange of knowledge and for meeting friends from the diagnostics community. The conference will be held at Centro Nacional de Aceleradores (CNA) with J. Gomez as local organizer [10].

DITANET Prize

The consortium awards a cash prize of 1,000 € for an outstanding contribution to the field of beam instrumentation for particle accelerators to a researcher in the first five years of their professional career.

The 2010 prize was awarded to Frank Becker (GSI) for his research which was focused on beam induced fluorescence (BIF). Applications for the 2011 prize can be submitted until 31.10.2011. Full application details can be found on the DITANET web site [1].

CONCLUSION

The research projects within DITANET have made remarkable progress with experimental results now being available across the network. A small selection of recent research outcomes was presented in this paper together with an overview of the network's very broad training and outreach program. Several Topical Workshops are planned in 2011 and 2012 and an international conference in November 2011 will complement the activities of the consortium.

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