RESEARCH RESULTS FROM THE DITANET PROJECT

C.P. Welsch#
Cockcroft Institute and the University of Liverpool, UK
on behalf of the DITANET Consortium

Abstract

Beam diagnostics systems are essential constituents of any particle accelerator; they reveal the properties of a beam and how it behaves in a machine. Without an appropriate set of diagnostic elements, it would simply be impossible to operate any accelerator complex let alone optimize its performance. Future accelerator projects will require innovative approaches in particle detection and imaging techniques to provide a full set of information about the beam characteristics. The DITANET project covers the development of advanced beam diagnostic methods for a wide range of existing or future accelerators, both for electrons and ion beams. During the past four years, a consortium of 31 institutions has developed beyond state-of-the-art techniques for beam profile, current and position measurement. The network also organized a large number of training events, such as international schools and workshops that were open to the whole community. This contribution presents some of the latest research results and summarizes recent events.

INTRODUCTION

The DITANET consortium develops beam diagnostics techniques and technologies for present and future particle accelerators. The project started on 1st June 2008 and will come to an end in May 2012. It presently consists of ten beneficiary partners and 21 associated and adjunct partners [1]. Around one third of the partners are from the academic sector, another third are research centres and the remaining partners are from industry.

More than 20 early stage and experienced researchers have been trained within the project. Their training was mostly through the realization of cutting edge research projects in the area of beam diagnostics and instrumentation, but was complemented by a network-wide secondment scheme and a broad and interdisciplinary training program. This consisted of several international schools that brought together all trainees, a number of topical workshops that were also open to participants from outside the network and a final conference where all research results were presented. With the aim to maximize the employability of all fellows, and to provide them with an extremely broad skills set that shall serve them as a solid basis for their future careers, DITANET set out to define improved training standards in the area of beam diagnostics. This new approach has already proven to be very successful, resulting in a formal recommendation by the UKRO to the European Commission to consider DITANET as one of the Marie Curie success stories.

*Work supported by the EU under contract PITN-GA-2008-215080.
#c.p.welsch@liverpool.ac.uk

SELECTED RESEARCH RESULTS

The research projects within DITANET cover many different types of accelerator instrumentation both for low and high energy accelerators and light sources. This section gives an overview of some recent research results.

Beam Instrumentation for Medical Accelerators

A non-invasive beam current monitor based on the multi-strip LHCb VELO silicon detector has been developed at the Cockcroft Institute/University of Liverpool and first tests will soon be carried out at the treatment beam line at the Clatterbridge Centre for Oncology (CCO), UK. Originally, this detector was designed to track vertices in the LHCb experiment at CERN, but first feasibility tests performed at the CCO treatment beam line in 2010 demonstrated the possibility of non–intrusive beam monitoring. The initial measurements consisted of data taken at several points along the beam line and gave high count rate, high resolution results. It is now planned to relate the proton 'halo' region hit rate, as measured by the VELO detector, with absolute beam current value, determined by a purpose-built Faraday cup. An illustration of the setup is shown in Fig. 1. Full details about the design of the monitor are included in [2]

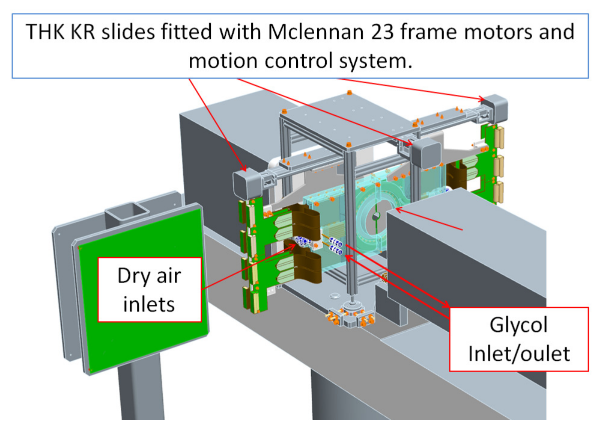

Figure 1. LHCb VELO integration stand at the Clatterbridge Centre for Oncology.

Betatron Tune Measurements with High Intensities at GSI SIS-18

There are two tune measurement systems under parallel operation at GSI SIS-18. The first is called tune and position measurement system (TOPOS), which is primarily digital position evaluation system. Baseband tune is determined by Fourier transformation of the individual bunch position data. The second system is

ISBN 978-3-95450-121-2

called base band tune measurement system (BBQ) and it works on the principle of diode based bunch envelope detection. Several tune measurement campaigns were performed with U^{73+} and Ar^{18+} ion beam at highest achievable intensities of $2 \cdot 10^9$ and $2.5 \cdot 10^{10}$ respectively using these systems during the course of this work. The primary goal of these investigations was to determine the optimum excitation type and its power required for continuous tune monitoring while causing minimal disturbance to the beam during the acceleration cycle during normal operation. Substantial modification of the tune spectra were observed at high intensities and are attributed to the induced bunch head tail oscillations after further investigations. An example measurement is shown in Fig. 2. Full details on the modified tune spectra, corresponding space charge effects and further experimental details can be found in [3].

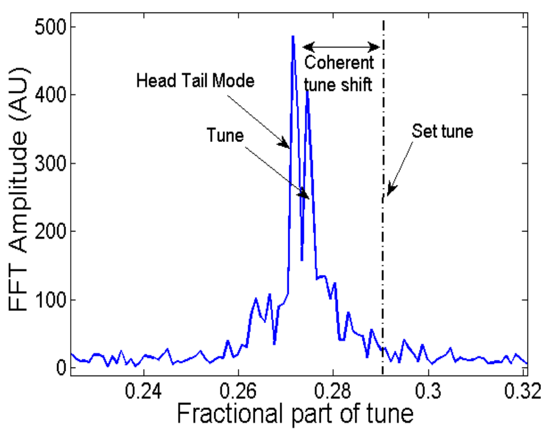

Figure 2: Vertical tune spectrum using 1024 position points of an individual bunch.

Beam Tomography

Beam-induced fluorescence profile measurement was incorporated with tomography to reconstruct the spatial distribution of the SILHI beam. Six cameras were installed around the beam at directions of 0°, 30°, 60°, 90°, 120°, and 150° with respect to the beam axis. Images of the beam fluorescence due to the beam–residual gas interaction were captured in each direction. From the images, transverse profiles were obtained which correspond to six angular projections for the tomographic reconstruction. Full details about the experimental setup are given in [4]. Careful alignment of the cameras is necessary prior to profile measurements because a 16-pixel or about 1-millimeter misalignment in the profiles results to distortions in the reconstructed profile.

The reconstructed beam profile of the SILHI beam with a beam current of 19mA is shown in Fig. 3. At the moment, because of limitations in the software for image and profile acquisition, profile measurements from each camera cannot be done simultaneously. This results to a total of about ten seconds to obtain the profiles and to reconstruct the 2D spatial beam distribution.

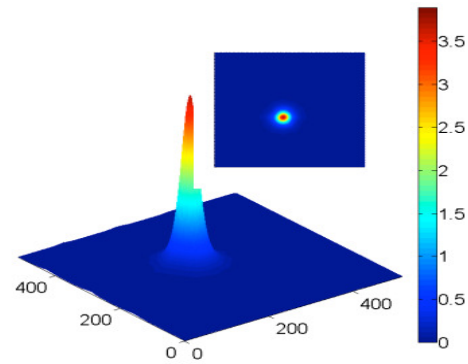

Figure 3: 2D and 3D reconstructed transverse profile of the SILHI beam at 19 mA.

Design and Test of the LIPAc IPM

When the beam passes through the beam pipe, it will partly ionize the residual gas which is present in any kind of accelerator. Inside the Ionization beam Profile Monitor (IPM), an electric field is applied which is directed perpendicularly to the beam. The ionization products are accelerated by the electric field and drift towards strips where they deposit their charge. By reading the strip current one can reconstruct the actual beam profile. The latest prototype of the IPM was designed based on Finite Element Method (FEM) simulations to achieve a good electric field homogeneity in the field box, Fig. 4. It was tested in two campaigns at GSI in May and November 2010 and at CEA Saclay in December 2010. Various tests have been performed, including linearity checks and resolution of the profile center.

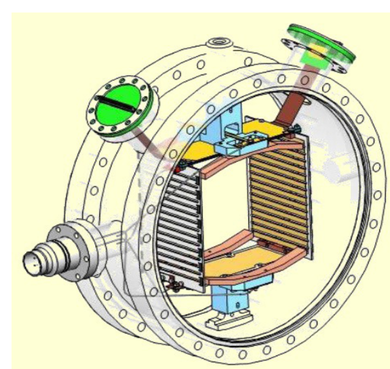

Figure 4: Illustration of the LIPAc IPM.

The IPM was found to have a good resolution of the profile center, as illustrated below, however, there are mechanisms that lead to profile distortions without effecting the beam position, e.g. beam space charge or intrinsic particle velocities. To account for such effects, the IPM has been compared with a Beam Induced Fluorescence (BIF) Monitor from GSI. Profiles have been taken for different residual gases at various pressures and extraction voltages, see [5] for full details.

ISBN 978-3-95450-121-2

EOSD Bunch Profile Monitor

A bunch profile monitor based on electro-optic spectral decoding (EOSD) is being designed for the probe beam of CLIC Test Facility 3 at CERN. The profile information of an electron bunch can be encoded into a chirped laser pulse and decoded by a spectrometer. It is mandatory for our EOSD bunch profile monitor to synchronize the laser pulse and an electron bunch. For the system, the oscillator of the laser can be locked to the RF signal which is driving the photo-injector of CALIFES. A pulse generator is used between the laser oscillator and amplifier to slow down the laser repetition frequency before the amplifier. The OTR photons generated by electric beam and laser beam will be steered to a streak camera for timing observation. A phase shifter and a delay stage will be used to adjust the timing. A trigger signal from CALIFES will be provided to the ICCD camera to choose the correct laser pulse which is carrying the beam information among an amount of pulses without the information. The transfer lines for both laser and OTR photons are designed. The monitor is expected to be installed and tested in the summer of 2012 [6].

TRAINING AND OUTREACH

In addition to the local training provided by the host institutions, DITANET has organized a number of network-wide events, such as Schools, Topical Workshops and a conference that were also open to the wider diagnostics community. Full details can be found in the CERN indico system (search for DITANET).

Topical Workshops

The network has recently held two Topical Workshops: the first being at DESY, Germany on 5th – 7th December 2011. This workshop was devoted to the field of beam loss monitoring. The main scope of the event was to review novel detector developments in the applications of beam loss monitoring. Aspects of detector simulation and calibration in addition to practical operation were covered. The event brought together 22 participants, including both world recognized experts and young scientists and students.

CERN hosted the DITANET Topical Workshop on Beam Position Monitors 16th - 18th January 2012. The event took place over two and a half days and included 28 talks. It covered all aspects of beam position monitoring systems: new trends in pick-up design, review of radio-frequency simulation tools, update on high resolution BPM technology and an exhaustive review of acquisition electronics for both linear and circular accelerators. In all 53 experts in BPM technology came from all over the world to present their work and their most recent achievements. With the presence of researchers from experimental, theoretical and simulations fields, the workshop provided an opportunity to discuss common issues and an excellent training for those DITANET trainees who took part.

Conference on Beam Diagnostics

The DITANET Consortium held a three day international conference on diagnostic techniques for particle accelerators and beam instrumentation in Seville, Spain between 9th and 11th November 2011. The conference was hosted by DITANET partner Centro Nacional de Aceleradores (CNA)/ University of Seville and brought together all beneficiary, associate and adjunct partners from the consortium. It was also open to participants from the world-wide diagnostics community, in particular to researchers in their early career stage. The latest developments and trends in this research area were presented in both, oral and poster sessions. Invited talks given by research leaders from around the world formed the core of this interdisciplinary event. They were complemented by talks that were selected from all contributors to the conference. The scientific program of this conference reflected the extremely broad research program that is being carried out by the DITANET partners and covered all essential aspects of state-of-the-art beam diagnostics R&D.

In addition, three prizes were awarded at the conference: Best poster (C. Schömers, HIT/Germany), best conference talk (J. Egberts, CEA/France) and the DITANET 2011 Award (M. Putignano, Cockcroft Institute/University of Liverpool, UK).

CONCLUSION

The research projects within DITANET have made excellent progress and many results are presented at this workshop. Here, some selected examples were given and an overview of recently organized workshops and conference was given. Based on the DITANET training concept and vision, two new initiatives, oPAC and LA³NET were selected for funding by the EC recently and both started at the end of 2011. They will guarantee that the DITANET concepts will continue to benefit the international accelerator community.

REFERENCES

[1] http://www.liv.ac.uk/ditanet

[2] T. Cybulski et al., "Non-invasive Beam Diagnostics for a 60 MeV Proton Beam", Proc. BIW, Newport News, USA (2012).

[3] R. Singh et al., "High Intensity Effects on Betatron Tune at GSI SIS-18", Proc. BIW, Newport News, USA (2012).

[4] C.M. Mateo et al., "Non-Intercepting Tomographic Reconstruction of the Transverse Spatial Distribution of SILHI Ion Source Beam", Proc. BIW, Newport News, USA (2012).

[5] J. Egberts et al., "Design and Test of the LIPAc IPM", Proc. BIW, Newport News, USA (2012)

[6] R. Pan et al., "Timing Design of a Bunch Profile Monitor Based on Electro-Optic Spectral Decoding", Proc. BIW, Newport News, USA (2012).

ISBN 978-3-95450-121-2