DITANET - AN INTERNATIONAL NETWORK IN BEAM DIAGNOSTICS

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Abstract

DITANET is the largest-ever EU funded research and training network in beam diagnostics. It brings together universities, research centers and industry partners to jointly develop diagnostics methods for a wide range of existing or future particle accelerators. 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 a large number of international schools and topical workshops for the beam instrumentation and particle accelerator communities. This contribution presents some of the network's recent research outcomes and training activities.

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 22 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.

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. In total more than 20 research projects have been completed during the four years project duration and led to many publications. This section lists three examples from recent research results.

Cryogenic Current Comparator for FAIR

One of the unique features of the upcoming FAIR accelerator facility [2] will be the availability of beams of a large variety of ion species at unprecedented high intensities. However, in certain locations of the High Energy Beam Transport (HEBT) sections, such as in the slow extraction lines from the synchrotrons and at the experiments using slowly extracted beams with spill length of several seconds, the beam currents will be very low, down to few nano Ampere. These currents are well below the detection threshold of conventional non-intercepting beam current transformers. Therefore, an online measurement device is required and cryogenic current comparators (CCCs) are foreseen in six different locations of the HEBT section for absolute beam intensity measurement. A former prototype study [3] had shown, that the CCC offers an absolute measurement of beam current, independent of energy and trajectory of the beam, with a current resolution of < 65 pA/√Hz.

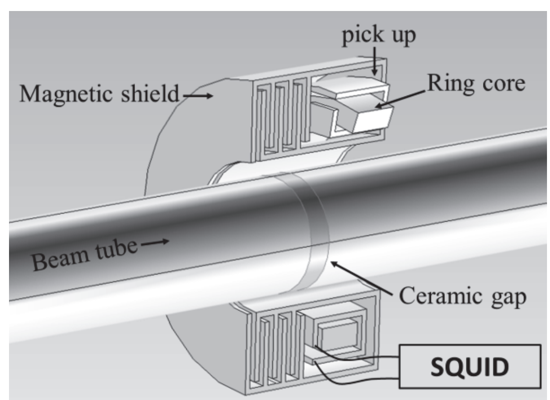

Figure 1: Schematic cross-section of the sensor setup.

Recently, the magnetic field attenuation through a meander-shaped shield geometry as shown in Fig. 1 was studied for various field components [4]. It was found through simulations that the nonazimuthal magnetic field components can be attenuated strongly by an appropriate shield geometry. In order to compare the attenuation factor with experimentally observed values, the coupling of the nonazimuthal magnetic field components with the magnetic alloy ring core will need to be taken into account. Also, more realistic results can be achieved by investigating the direction of the dominant noise field components present at the installation locations of the CCC.

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LHC Longitudinal Density Monitor

The longitudinal density monitor (LDM) is primarily intended for the measurement of the particle population in nominally empty rf buckets. These so-called satellite or ghost bunches can cause problems for machine protection as well as influencing the luminosity calibration of the LHC. The high dynamic range of the system allows measurement of ghost bunches with as little as 0.01% of the main bunch population at the same time as characterization of the main bunches. The LDM is a single-photon counting system using visible synchrotron light. The photon detector is a silicon avalanche photodiode operated in Geiger mode, which allows the longitudinal distribution of the LHC beams to be measured with a resolution of 90 ps. The monitor allows for a precision measurement of the longitudinal density profile in the LHC, see Fig. 2.

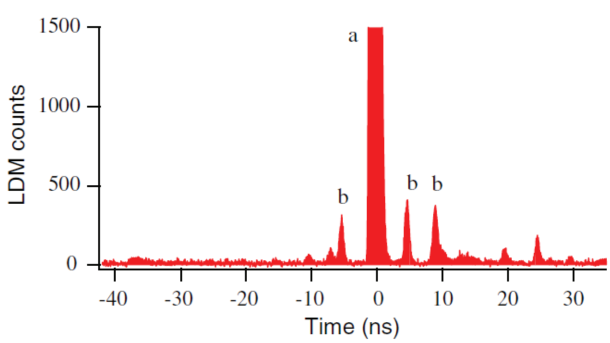

Figure 2: Typical pattern of satellites in an LHC fill with protons showing (a) main bunch with peak at $1.3 \cdot 10^5$ counts, (b) satellites, and (c) ghost bunches [5].

The active area of the APD has a diameter of only 50 μm. The beam spot produced by the synchrotron light telescope is roughly Gaussian with a sigma between 100 and 500 μm depending on the emittance of the beam. This reduces the coupling efficiency since only a fraction of the beam spot can be sampled. In addition, it creates a dependence of the coupling efficiency (and therefore the measured beam population) on the transverse size of the bunch, and therefore on the bunch emittance. If the detector is centered in the beam spot, then bunches with larger emittance will appear to have lower population. Conversely, if the detector position is away from the beam center, bunches with larger emittance will appear to have a larger population. If the transverse emittance of the satellite / ghost bunches is systematically different from that of the main bunches, this will result in an incorrect estimation of their population.

The optical line for the beam 2 LDM has been modified during the winter stop 2011/12 in order to reduce to a minimum the dependence on transverse beam size. A diffuser with a Gaussian point spread function (PSF) scatters the incident light. The effect of the transverse emittance on the measured bunch population was investigated during dedicated machine development sessions before and after the changes to the optical line. Some bunches had their emittance blown up by insertion of a screen in the SPS to LHC transfer line or by use of the transverse dampers, giving a much larger than usual spread in emittance. It was shown that the use of the diffuser almost completely eliminates the dependence on emittance [6].

The LDM has already become a highly valued tool for LHC operation and optimization. Full details about recent results from the LDM are presented in [5, 6], including a proposed method for constructing a 3-dimensional beam density map by scanning the LDM sensor in the transverse plane. There, a scheme to improve the sensitivity of the system by using an optical switching technique is also presented.

Silicon Strip Detectors for Medical Beam Imaging

For a given photon beam at a given source to surface distance (SSD), the dose rate at a certain depth *d* in a phantom depends on the field size. The output factor (OF) is defined as the ratio of the dose for any field size to the dose for a reference field at the same source to surface distance, and at the same depth *d* in a slab phantom. Usually the reference field is a square field of 10x10 cm^2 at an SSD of 100 cm; the larger the field size, the higher the dose. The OF is an intrinsic characteristic of the accelerator and is measured periodically to make sure that the accelerator is operating properly in order to treat patients. As mentioned above, in radiation therapy, the output factor is measured in slab phantoms. However, for the purpose of verifying a new detection system and its calibration, the dose given by various square fields in an in-house designed cylindrical phantom, normalized to the reference field, was measured as well and is here referred to as output factor, too. See Fig. 3.

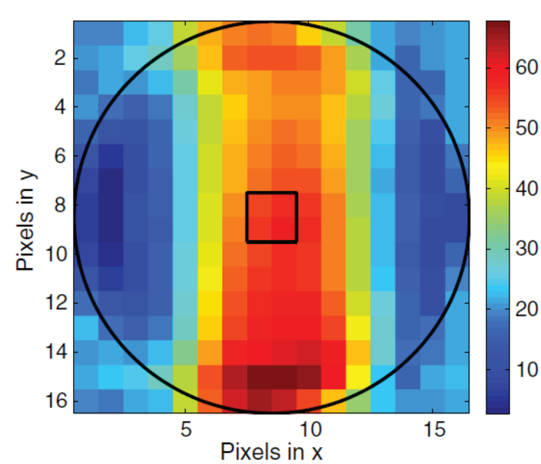

Figure 3: Reconstructed dose map for the 2x2 cm^2 in the cylindrical phantom. The legend on the right represents the dose value in cGy.

Measurements were carried out at the Virgin Macarena University Hospital in Seville, Spain [7]. Output factor measurements of a Siemens ONCORTM linac [2] were realized with a silicon strip detector, model W1(SS)-500 from Micron Semiconductor Ltd. coupled to phantoms,

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electronics, and a slow control system all built at CNA/U Seville, Spain. Those measurements, performed for various field sizes and shapes, were compared to the ones carried out using the ionization chamber (either simulated with the TPS or experimentally measured), in order to validate the previously performed calibration of the system in standard conditions. Remarkable agreement within the error bars was found.

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 awards were presented at the conference: Best poster (C. Schömers, HIT/Germany), best conference talk (J. Egberts, CEA/France) and the DITANET Prize for an outstanding contribution to the field of beam instrumentation for particle accelerators (M. Putignano, Cockcroft Institute/University of Liverpool, UK).

CONCLUSION

The research projects within DITANET have made excellent progress and in this contribution progress on the CCC project (GSI, Gemarny), the LDM for the LHC (CERN, Switzerland) and the use of Silicon strip detectors for imaging medical beams (CNA/US, Spain) were used to highlight a few of the many recent examples. In addition an overview of recently organized workshops and the network's final conference was given.

Based on the DITANET research and training concept and vision, two new initiatives, the oPAC and LA³NET projects, were recently selected for funding by the EC under very strong competition. Both projects started at the end of 2011 and have a duration of 4 years. They will guarantee that the DITANET concepts will continue to benefit the international accelerator community.

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