DITANET – INVESTIGATIONS INTO ACCELERATOR BEAM DIAGNOSTICS

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Abstract

The Marie Curie Initial Training Network DITANET covers the development of advanced beam diagnostic methods for a wide range of existing or future accelerators, both for electrons and ions. The network brings together research centers, such as CERN and DESY, universities, and private companies. DITANET currently has 27 partner institutions and is committed to training young researchers in this field through cutting edge research in beam instrumentation, and by the exploitation of synergies within this community.

This contribution presents some examples of the research outcomes within the first two years of DITANET and summarizes the network's training activities.

INTRODUCTION

The DITANET project started on 1.6.2008 and consists of ten network beneficiary partners and presently 17 associated and adjunct partners. While the research projects were already defined in the initial proposal, the network is not to be seen as a fixed frame. Institutions that share the network's research and training ideas and visions are strongly encouraged to consider an active participation to the various research projects and training events.

The participation of industry is an integral part of the training within DITANET. It is expected that the smooth integration of industry not only in the research projects, but also in the overall training of the network's fellows will help improving their career perspectives.

EXAMPLES FROM THE RESEARCH PROGRAM

DITANET covers the development of diagnostic methods for a wide range of existing and future accelerators, both for electrons and ions, low and high energies. This section presents some of the research outcomes to date.

High Energy Accelerators

The Compact Linear Collider (CLIC) is a potential future multi–TeV electron–positron collider for particle physics, based on an innovative two-beam acceleration scheme, where a high intensity drive beam powers a main beam of a high-frequency (30 GHz) linac with a gradient of 150 MV/m. The CLIC Test Facility 3 (CTF3, CERN) aims to demonstrate the feasibility of this concept [1].

Preservation of beam quality is one of the most important issues at the CTF3. In particular energy losses and energy spread are of a great concern. A very short bunch length is required after recombination for efficient 30 GHz power production. Therefore, the longitudinal electron profile is one of the parameters which need to be monitored closely. The longitudinal electron distribution in a bunch is crucial for maximisation of the luminosity.

A setup for the investigation of Coherent Diffraction Radiation (CDR) from a conducting screen as a tool for non-invasive longitudinal electron beam profile diagnostics has been designed and installed in the CRM line of the CTF3 in February 2009 and is part of the research at DITANET partner Royal Holloway, UK. Initial studies on CDR spatial distribution have been undertaken and a working system has been established.

Beam based backgrounds were observed in the CRM line of the CTF3, which were caused by OTR screens installed behind the CDR setup. In order to eliminate these backgrounds, an off-centre adapter flange was designed and installed and a quartz fused-silica UHV window, through which radiation was detected, was replaced by a diamond window in September 2009 to increase the performance of the setup.

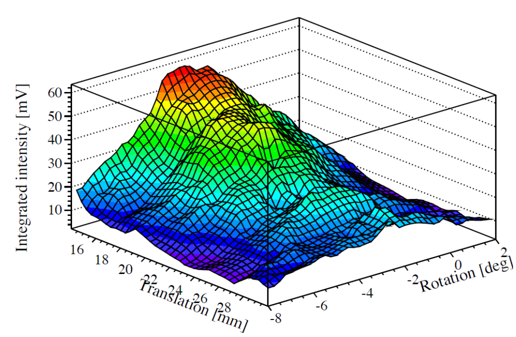

Figure 1: Vertical polarization component of CDR spatial distribution for one target configuration.

First interferometric and spatial distribution measurements on CDR were performed [2]. Further upgrade of the setup was carried out in February 2010, which included the installation of a second target, a pyroelectric detector and an automation of various components that made system nearly complete [3]. High performance simulations on CDR from one target and also studies on radiation spatial distribution for two targets are part of the ongoing studies, see Fig. 1.

Laser-wire systems use a finely focused beam of laser-light to scan across a particle beam to measure the

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transverse beam profiles. Laser-wires can be employed at electron machines using the Compton Effect, where the laser photons are scattered by the electrons and can be detected downstream as gamma rays in a calorimeter. A laser-wire can also be used at H^- machines, where the fundamental process is photo-ionization of the H^- ion to form neutral H-atoms; the neutralised H-atom and/or the released electron can then be detected downstream. Both techniques are under study as part of an Early Stage Researcher (ESR) project within DITANET. The aim of these studies is the development of a laser-wire monitor for Linac4 at CERN, a 160 MeV H^- linear accelerator, replacing Linac2 as injector to the PS Booster (PSB).

The electron machine under study is the newly-completed PETRA-III accelerator at DESY, Hamburg. PETRA-III is the world's most brilliant source of synchrotron light for the wavelengths it offers. Understanding the emittance of PETRA-III is very important in achieving its ultimate performance; the electron beam size is typically in the order of ten microns. Using a vertical optical table, laser light can be directed so as to scan in either the vertical or horizontal directions, illustrated in Fig. 2. The system was tested at RHUL before it was shipped to DESY. Currently, the emphasis is on commissioning and on integrating the laser-wire data acquisition into the PETRA-III system.

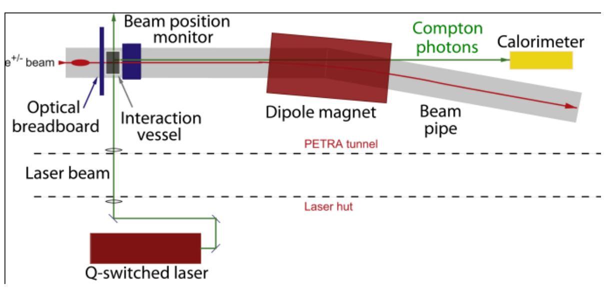

Figure 2: Overview of the laser-wire setup.

Low Energy Accelerators

Low-energy physics and storage rings are recently attracting growing interest in the scientific community, as characteristics of quantum systems are most conveniently studied at low projectiles energies in the keV range [4]. At very low energies, most conventional beam diagnostic techniques no longer work. In particular the need for long beam life times triggers the development for least interceptive techniques.

In the frame of the Ultra-low energy Storage Ring (USR) project at the Facility for Low energy Antiproton and Ion Research (FLAIR), a neutral supersonic gas jet target, shaped into a thin curtain, used for bi-dimensional imaging of the gas ions created by impact with the projectiles, is being developed by the QUASAR Group [5].

Optimization of the monitor requires investigations into different characteristic jet parameters. For that purpose extensive simulation work with the Gas Dynamics Tool (GDT) was carried out. The results of these studies allowed identifying behavioral trends of the jet curtain, isolating the contribution to the jet performance of each separate geometric and thermodynamic variable. An example of such trends is shown in Fig.3. The plot describes the variation of the Mach Number of the jet, which is a measure of the expansion efficiency, when the nozzle-skimmer distance is varied, and highlights how a maximum in expansion efficiency can be obtained for a nozzle-skimmer distance of 7.5mm, in optimized geometrical conditions [6].

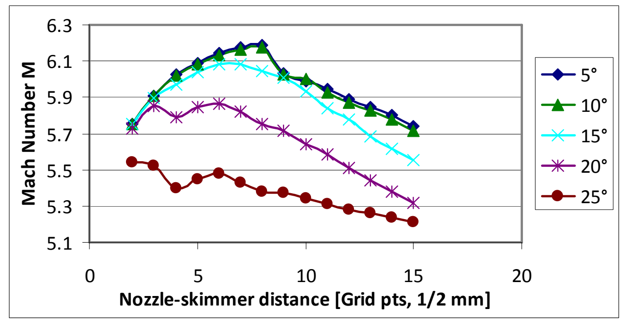

Figure 3: Mach number plotted as a function of nozzle-skimmer distance, with the aperture angle α as parameter.

It can be seen how increasing α brings about a decrease in Mach Number, and hence decreases the expansion efficiency, worsening the directionality of the jet. The simulations also lead to the design of an optimized geometry for the nozzle-skimmer system, which considerably increases the accuracy and resolution of the resulting jet, allowing for a split-curtain operation mode, useful to monitor only the halo of the beam, cutting out the central core of the beam.

Another example of a low energy accelerator for which instrumentation is being developed in the frame of DITANET is the Double ElectroStatic Ion Ring ExpEriment (DESIREE) at Manne Siegbahn Laboratory (MSL), Sweden. This experimental facility consists of two electrostatic rings of the same circumference, 9.2 m, and a common straight section of length 1 m for merged-beam experiments with ions of opposite charges. It can be operated at both room and cryogenic temperatures (~20 K) under ultra high vacuum (~10^{-11} mbar). In addition to merged beam experiments, DESIREE will also be used for single ring experiments. In terms of beam instrumentation, the main objective is to develop reliable and accurate diagnostic tools for determination the absolute currents stored in the machine, and the position, width and shape of the two beams in the merger section. The main ingredients necessary for this are electrostatic pick-up electrodes, position-sensitive detectors for neutral particles from residual-gas collisions and a system of beam scrapers. The fact that all diagnostics inside DESIREE have to be compatible with the cryogenic environment, as well as the ultra-high vacuum requirements, is a challenge to the design.

A beam diagnostic system of the REX-Viewer type, which can operate over a wide range of beam currents and energies for the DESIREE, was already tested [7]. A spatial resolution down to 2 mm was achieved and a sensitivity that is high enough to detect even single particles was demonstrated [8].

Particle Detection

Detecting and reconstructing the particle trajectory of a beam or a fragment requires a good time and position (angular) resolution, as well as a high energy resolution. The dedicated electronics, coupled to the detection system should be able to keep up with its characteristics in terms of a good resolution, high counting rate capability, etc. Moreover, powerful and well adapted data acquisition systems are required.

DITANET partner CNA, Spain's national accelerator centre, has decided to use Silicon Micro-Strip technology to explore its limits for Beam Tracking, i.e. time-of-flight, position and energy measurements, fragment identification in form of energy and angular resolution measurements, as well as for dose reconstruction.

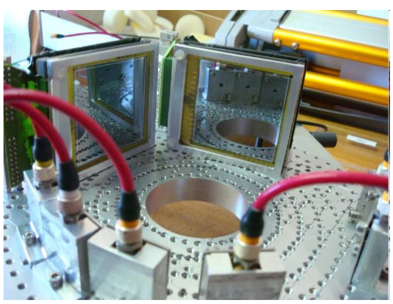

Figure 4: Setup of experiment for fragment identification.

Regarding Beam Tracking, silicon detectors were used for experiments at GSI [9]. Two transmission MCP detectors, followed by two 16x16 silicon strip detectors, were mounted in the beam. One side of the silicon detectors was mounted on a low voltage fast pre-amplifier, developed and built at GSI, to perform fast timing measurements, while the other side was used to measure the deposited energy of the particles. Very good energy (around 5%) and time resolution (FWHM ~100 ps) were obtained. Concerning fragment identification, the CNA group measured elastic and inelastic proton scattering on heavy ions around the Coulomb barrier in October 2009 with the setup as indicated in Fig. 4.

TRAINING

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. To date a 'School on Beam Diagnostics' was held at Royal Holloway in March/April 2009, a first Topical Workshop on 'Low Energy, Low Intensity Beam Diagnostics' was organized in Hirschberg, Germany in November 2009, and a School on Complementary Skills took place in Liverpool in March 2010. Future events include a second topical workshop on 'Longitudinal Beam Profile Measurements in Accelerators and Light Sources' that will be organized at the Cockcroft Institute, UK on July 12th/13th 2010 and an advanced School on Beam Diagnostics' that will be held at MSL, Stockholm from March 7th-11th 2011. Scholarships for the latter event will be available to external participants. Information on all past and future events is accessible via the network's homepage [10].

CONCLUSION

DITANET strives for defining improved research and training standards through close collaboration between all network partners. In order to provide the network's trainees with the best possible career perspectives, the industry partners have a very prominent role in all research projects. The network also offers a wide training program to its trainees as well as to the wider diagnostics community and past events were briefly described.

The newly introduced adjunct partnership status allows additional institutions that share the network's ideas and visions to join the DITANET frame and participate in its research and training program.

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