# DITANET – A EUROPEAN TRAINING NETWORK ON NOVEL DIAGNOSTIC TECHNIQUES FOR FUTURE PARTICLE ACCELERATORS

C.P. Welsch
*University of Heidelberg, GSI, Darmstadt and MPI-K, Heidelberg, Germany*
on behalf of the DITANET consortium

*Abstract*

Marie Curie Initial Training Networks (ITN) are aimed at improving the career perspectives of researchers who are in the first five years of their career by offering structured training in well defined scientific and/or technological areas as well as providing complementary skills and exposing the researchers to other sectors including private companies.

The European Training Network DITANET - "**DI**agnostic **T**echniques for particle **A**ccelerators – a Marie Curie initial training **NET**work" - covers the development of advanced beam diagnostic methods for a wide range of existing or future accelerators, both for electrons and ions. The developments in profile, current, and position measurement techniques stretch beyond present technology and will mark the future state of the art. This contribution presents the scientific challenges that will be addressed within the next four years, together with the networks' structure.

## 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. 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.

DITANET covers the development of advanced beam diagnostic methods for a wide range of existing or future accelerators, both for electrons and ions. DITANET consists of the following network participants:

University of Heidelberg (coordinator, Germany), CEA (France), CERN (Switzerland), DESY (Germany), GSI (Germany), HIT GmbH (Germany), IFIN-HH (Romania), Stockholm University (Sweden), Royal Holloway University of London (UK), and the University of Seville/Centro Nacional de Aceleradores (Spain).

It is complemented by twelve associated partners from all over the world:

ESRF (France), idQuantique (Switzerland), INFN-LNF (Italy), Instrumentation Technologies (Slovenia), MPI for Nuclear Physics (MPI-K), PSI (Switzerland), THALES (France), Thermo Fisher Scientific (USA), TMD Technologies Limited (UK), TU Prague (Czech Republic), ViALUX (Germany), and WZW Optics (Switzerland).

## TRAINING

Young researchers participating in the network program will not only get the possibility to perform state-of-the-art research, they will also get a much wider training in the domain of beam diagnostics by interaction with other network participants and close collaboration with associated partners from the industrial sector. This includes regular exchanges of trainees between the partners that will thus get the possibility to participate in ongoing R&D work at linked institutes and universities.

This way, DITANET will provide a cohesive, flexible framework for the training and professional development of researchers in beam diagnostic techniques for particle accelerators, with a strong focus on possible applications of these principles in industry.

DITANET will organize one week courses on beam diagnostic techniques in spring 2009 and fall 2010 that will be open to all network participants as well as to external participants. Details on these courses will be published on the DITANET web site [1].

## RESEARCH

The accelerator projects that will be covered within DITANET range from the next generation of linear colliders (ILC, CLIC) and the most advanced high energy accelerators (LHC, FAIR), to innovative light sources (X-FEL) and novel low-energy storage ring projects (DESIREE, USR). Only a few examples of the research projects within DITANET are outlined in the following sections. Many more projects can be found on the DITANET web page [1].

### *The Heidelberg Ion Therapy Center*

HIT is a 100% daughter company of the university clinics in Heidelberg, responsible for the operation of the HIT accelerator facility and the irradiation systems [2]. The treatment of cancer with beams from an accelerator has proven to be extremely successful and a state-of-the-art and reliable diagnostic system is an essential part of such a facility.

Within the DITANET frame, an ESR will work at HIT on the enhancement of the beam measurement system that measures the transverse 2D-beam profile as well as the beam emittance in an accelerator-based cancer therapy centre. The work will mainly focus on low-energy monitors, installed directly behind the ECR ion source, optionally detectors that can be used at the high energy beam transport may be examined in addition.

This includes, among others, a pepper-pot emittance meter that fits within the already existing beam line installations. The aim is to create a measurement system which can be used to optimize the output emittance of the ion source.

The high energy beam transfer lines of the HIT accelerator facility presently use very expensive and maintenance-intense multi-wire proportional chambers to cover beams from protons to oxygen ions at different energies and intensity variations of three orders of magnitude. The trainee may optionally put an additional focus on new camera techniques and enhanced target materials to improve on the existing luminescent screen systems.

### *Beam Diagnostics for CLIC*

One of the major decisions in particle physics over the next 3 years will be to decide on the next major accelerator to access the multi-TeV energy scale. The CLIC two-beam acceleration scheme [3] is one of the candidates for the next accelerator for the high-energy frontier, and the CLIC Test Facility (CTF3) at CERN [4] is the unique facility to test the CLIC acceleration principle and to prove the feasibility of associated RF systems.

In addition to the RF accelerating systems themselves, a host of beam diagnostics will need to be developed to cope with the challenging environment of CLIC. There exists space at the CLEX area of the CTF3 facility to build a new Instrumentation Test Beam (ITB). One of the first tasks of the trainee will be to design the machine optics for the ITB in collaboration with the CERN experts and to work with the CLIC diagnostics team to optimize the layout and functionality for future key diagnostics projects.

In addition to the ITB design, the Early Stage Researcher (ESR) with work with TMD technologies to assess the opportunities for RF system development and to identify a fruitful new line of R&D where the expertise of TMD can be combined with the expertise at RHUL and CERN to develop a new product of use to the CTF3/CLIC project.

The system design work will be complemented by frequent data taking and machine operation at CTF3. This combination of practical experience, beam-line design, and industrial collaboration, will provide a unique training opportunity.

### *The Ultra-Low Energy Storage Ring (USR)*

To enable the efficient investigation of some very essential questions regarding the physics with low-energy antiprotons and possibly exotic highly charged ions, a novel electrostatic cooler synchrotron, the ultra-low energy storage ring (USR) [5], and a state-of-the-art in-ring spectrometer [6] will be developed in the QUASAR group at the Kirchhoff Institute for Physics/Max-Planck Institute for Nuclear Physics in close collaboration with the GSI Atomic Physics Division, and other groups from the University of Heidelberg.

The aim of the USR will be to slow down antiprotons as well as possibly highly charged ions (up to bare uranium) to very low energies between 300 and 20 keV/q. This will provide world-wide unique conditions for both in-ring studies with an intensity of up to $10^{12}$ cooled and stored antiprotons or highly charged ions per second, as well as for experiments requiring extracted slow beams. In the frame of an Early Stage Researcher (ESR) project, the beam diagnostic elements as they are required for a successful operation of such a machine will be developed. The boundary conditions of the USR project put very high demands on the machine's instrumentation: In order to ensure reasonable life times in the ring, ultimate vacuum pressures have to be realized extending to below $10^{-14}$ mbar if highly charged ions shall be stored and slowed down. Hence, an approach considered in the present study is to cryogenically cool the vacuum chambers of the USR to a temperature of only a few Kelvin. The extremely low vacuum pressure of the (cooled) USR together with a beam energy of only 20 keV and low currents of singly charged antiprotons between 1 nA and 1 uA require the development of new diagnostic methods as most of the standard techniques will no longer work.

### *Development of a "Zero-time" Detector*

For applied accelerator systems such as accelerators for cancer therapy, a detailed knowledge of the beam geometry is required. This should be done in real time and in direct ion beam using a so called "zero time detector" type. It can be used to study the composition and the heavy ions position inside a beam. Also the position and the focalization of the global beam can be done. This detector can be realized, for example, having a parallel-epipedic shape. The backscattered electrons released by an aluminum foil are deflected away from the main beam, by the aid of a magnetic field perpendicular on the applied electric field. The heavy ions beam pass through the grid of the anode, toward the cathode. Following the interaction with the aluminized mylar window, back scattered electrons with zero velocity are released in the chamber. Because of the applied electric field they will be accelerated and the magnetic field will bend their trajectories on an ellipsoidal path, out of the main beam.

An Early Stage Researcher (ESR) will be responsible for the detector design, perform detailed numerical studies for its optimization and finally conduct tests with beam.

### *Development of a CCC-based Current Monitor*

The FAIR storage rings have to be capable of the operation with very low ion currents, i.e. much below 1 μA. In particular, in the case of radioactive ion beams and antiprotons the amount of stored particles in the FAIR storage rings is too low for standard beam diagnostic devices. For the slow extraction from the SIS100 synchrotron the high-energy beam transfer-lines require diagnostic devices for the non-destructive measurement of ion currents down to the nA region. For this purpose, the installation of Cryogenic Current Comparators (CCC) is foreseen, offering a non-intercepting and absolute current measurement. The basic principle is the determination of the beam's magnetic field using a sensitive SQUID-based magnetic flux detector. A CCC prototype was realized at GSI already in 1996 [7] and an improved design is now planned to be used at DITANET participant DESY [8] for dark-current detection at the X-FEL acceleration cavities. The optimization, standardization and commissioning of a new CCC is the goal of the DITANET PhD work with the time frame of DITANET.

## INVOLVEMENT OF INDUSTRY

The participation of industry is an integral part of DITANET. As shown in the beginning of this article, a number of private companies are included as associated partners to the network. They are 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, one third of the DITANET Steering Committee members come from industry.

From the beginning, the DITANET management encouraged the involvement of these partners in the training program at the highest possible level. This led to the participation of HIT GmbH as a full network member with a PhD project that will be hosted by this company. In addition, the associated partner THALES, who is considered as a world-wide leader in the development of klystron technology, will host the trainee from CEA during up to 25% of the PhD project, thus taking over a considerable part of the training.

WZW Optics , Vialux, Thermo Fisher and idQuantique are among the leading companies in the field of optics, scientific cameras and detector systems. Instrumentation Technologies from Slovenia and TMD technologies from the UK have long-standing links to accelerator laboratories and have pushed the development of beam diagnostic techniques on various occasions in the past.

All companies as well as the other associated partners from academia (TU Prague, MPI for Nuclear Physics) and research (PSI, INFN, ESRF) have agreed to host the DITANET trainees during some weeks up to several months. This ensures that every trainee will get the possibility to realize an extended research stay at a leading partner institute from industry and to take part in its R&D efforts.

Thereby it is guaranteed that all trainees will be provided with a true multi-disciplinary and inter-sectorial training, where they will not only work on their main project, but learn about neighboring fields and get a view of possible applications and of the impact of their work in the industrial sector.

These measures will complement the scientific training and actively bridge between the academic and the industrial sectors within DITANET.

## CONCLUSION

The largest ever coordinated EU education action for young researchers in the field of beam diagnostic techniques for particle accelerators has been awarded to a consortium of ten partners from all over Europe within the EU-Marie Curie program for initial training networks. The joint effort in setting up DITANET and the corresponding administrative and training-related boundary conditions will guarantee a continuous training of young researchers in this field. Close collaboration between the network participants and the associated partners with a very prominent role of industry, ensures that the basis for DITANET is laid in a true international approach with a clear long term perspective.

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