INTRODUCTION

The ARDENT (Advanced Radiation Dosimetry European Network Training) is a Marie Curie Initial Training Network (ITN) funded by the European Commission under the 7th Framework Programme involving 14 partner institutes worldwide. The group that was involved in activities at the CN accelerator consists of researchers from the European Organization for Nuclear Research (CERN, Switzerland) and the Polytechnic of Milan (POLIMI, Italy).

In collaboration with worldwide institutes, over the last 10 years CERN has developed two detector technologies in the field of dosimetry, beam and plasma monitoring: the gas electron multiplier (GEM) and the silicon detector Medipix. The GEM technology has seen a number of applications including high-flux particle detection near accelerator beam pipes (including the LHC, Large Hadron Collider) and detection of thermal and fast neutrons (n_TOF facility). CERN has also designed and tested several versions of the Medipix detector (e.g., Timepix), mainly for detection and imaging of neutrons and X-rays with high spatial resolution.

During the last decade, the POLIMI research group was involved in the design, construction and characterization (experimentally and via Monte Carlo simulations) of a silicon microdosimeter based on a monolithic silicon telescope detector and of its electronics (low-noise preamplifiers, data acquisition systems, etc.). Microdosimetric spectra were measured with the silicon detector across the Bragg peak in phantoms irradiated with 62 MeV/u protons and carbon ions. Another research activity was in the field of microdosimetry and spectrometry of pulsed neutron fields. A prototype of a moderation based neutron detector with modified front end electronics was developed, capable to withstand neutron burst with intensity up to a few µSv. Further research activities were in the field of neutron detection (with silicon detectors, Bonner Sphere spectrometers, activation techniques, CR39 track detectors, etc.) and radiation field characterization.

ARDENT focuses on three main technologies:

- gas detectors: gas electron multipliers (GEM) and tissue equivalent proportional counters (TEPC);
- solid state detectors: Medipix, silicon microdosimeters;

The program addresses the potential uses of a class of instruments based on the above technologies with the three main objectives:

- disentangle the various components of the radiation field and determine the dosimetric quantities due to each component;
- measure the radiation quality of the radiation field (micro-dosimetry);
- obtain information on the energy distribution of the various components of the radiation field (photon and neutron spectrometry).

More detailed information can be found on the ARDENT web site: [www.cern.ch/ardent](http://www.cern.ch/ardent).

The ARDENT collaboration submitted an application for beam time in June 2013 and was assigned two shifts of two days each in December 2013 and January 2014, as well as additional shifts in 2014. The next section describes the general experiment on microdosimetry with silicon and GEMPIX detectors, which started in 2013 and is being carried out throughout 2014. The last section of this paper provides details on the specific experiments that took place during the first two shifts of December and January.

MICRODOSIMETRY WITH SILICON AND GEMPIX DETECTORS

GEMPIX is a new-concept detector which is made of three layers of gas electron multipliers (GEM). In such a detector, the ionizing charge is collected and read by a chip of 250,000 channels (Medipix). The total active area is 10 cm². The goal of the set of experiments planned at the CN accelerator is to test the GEMPIX detector as microdosimeter and as interaction analyser.

In the case of microdosimetry, the detector will be supplied with a tissue-equivalent gas in order to measure the energy deposition in a material equivalent to 20-30 human cells. Thanks to the detector spatial resolution of 50 µm, a very accurate reproduction of the dose deposited inside a cell is expected.

For the study of GEMPIX as interaction analyser, a sample of real tissue will be inserted in the gas gap. The charged particles produced by the interaction of neutrons with the sample will be reconstructed in 3D with a 50 µm resolution. The active volume of the detector is 40 cm³.

The Medipix chip will be configured in such a way that both the spatial distribution of charged particles and their time of arrival are traced and analysed.

The results of this experiment will be compared with the ones from irradiation of silicon detectors for microdosimetry, which were performed in the frame of the SID/MICRO-Si experiment in March and May 2013.
MEASUREMENT OF NEUTRON FIELDS WITH TIMEPIX DETECTOR

Timepix chips covered with polyethylene and boron converter layers were irradiated in order to measure fast and thermal neutrons respectively; three Timepix chips with and without converter layers are shown in figure 1. Slow hadronic particles produce characteristic blobs like clusters in the Timepix due to the charge sharing effect. We successfully measured protons produced by the polyethylene by measuring their distinctive clusters. After producing a thermalized neutron field using a large block of polyethylene, thermal neutrons were measured with a boron converter layer using the reaction $^{10}\text{B} + \text{n} \rightarrow ^{4}\text{He} + ^{7}\text{Li}$. Discrimination between the two alpha energies produced by the boron converter and residual protons emitted by the polyethylene block is possible, based on a cut in TOT (a surrogate for the deposited energy) and the number of pixels in one cluster.

INITIAL MEASUREMENTS WITH THE GEMPIX DETECTOR

The neutron field generated in the CN accelerator was also measured with the GEMPix. The detector is built with a stack of three GEM foils placed in front of 4 naked chips of Medipix with a total active area of 3x3 cm². The spatial resolution is of the order of 50 μm. The GEMPix is able to identify long curly tracks from high energy electrons, small blobs that correspond to photons and long characteristic tracks which appeared to originate from recoil protons produced by the neutron field as shown in figure 2. A series of voltage scans were carried out, varying the voltages on the GEM foils and transport fields in order to further understand the performance of the detector when used with a tissue equivalent gas. On insertion of a thin $^{10}\text{B}$ target inside the detector it was possible to see the secondary particles emerging from the target. An integral over many different tracks with this detector is shown in figure 3, clearly showing the particles emitted from the target, including what seems to be an alpha or lithium nuclei from $^{10}\text{B}$ neutron capture. Future experimentation will repeat this procedure with a tissue equivalent target.

CONCLUSIONS

An initial set of measurements was carried out, with a view to characterize Timepix and GEMPix for dosimetric applications. Future work will focus on fully characterizing the LET of the produced secondary neutrons in the GEMPix in order to perform a quantitative comparison with other microdosimeters.