Proposed experiments for the facilities of CNAO and HIT

In-beam measurements

Beam monitoring

One goal of this part of the program is to verify the feasibility of evaluating the beam profile by placing a thin metal foil in the beam and by measuring the secondaries that reach a Medipix silicon detector, placed close to the beam.

Contrary to Medipix (which would not survive the typical beam intensities of CNAO, ~10^{10} ptc/s for protons and ~4 10^{8} for carbon ions, even if the beam intensity is reduced by a factor of 100), the GEM detector can be placed directly in the beam. In particular, the triple GEM detector system has an extended dynamic range (up to 10^{8} particles cm^{-2} s^{-1}) and is radiation hard (2 C/cm^{2}). In order to fully characterize the beam two GEM detectors will be used. The first detector will be specifically designed and constructed with a 128-pad readout for a total active area of 24x24 mm^{2}. This detector will be directly placed in the beam with the aim to measure its profile. The second detector, namely a TPC ionization chamber, was already tested in CNAO in June 2011and will be used to measure the beam intensity and time profile.

Another objective of this project is to test a detector where the Medipix chip is coupled to the GEM detector (GEM-PIX). The Medipix chip is much more radiation resistant than the associated silicon sensor. In the GEM-PIX configuration, the silicon sensor of Medipix is either replaced by one or more GEM foils in gas, or it is coupled to a microchannel plate under vacuum. The feasibility of a 28x28 mm^{2} GEM-PIX beam monitor will be assessed.

The GEM-PIX monitor would allow the detection of beam displacement and profile during a single spill (~1 s) well within the requested spatial resolution (0.5 mm) and over the detector sensitive area (28x28 mm^{2}). The monitoring repetition rate is estimated to be 10 Hz, to be confirmed by measurements.

Homogeneity scan

In addition to the measurement of the beam profile, the GEM can accomplish scanned beam-monitoring for homogeneity checks, which require a sensitive area of 20x20 cm^{2} and for which the 3 mm resolution of the GEM is sufficient. It is suggested that the detector used for pencil beam scanning is moved mechanically to a few reference points within the scanned area. At the same time, the mechanical movement must be fast enough to allow the scanning in the required reference time. Alternatively, the detectors can be permanently installed in the desired reference points. This experiment will allow verifying the feasibility of such beam monitoring system.

Calibration of the Timepix detectors

Spectroscopic detection of energetic heavy charged particles with semiconductor detectors is a rather complicated problem. High local charge deposition influences the homogeneity of the electric field in the sensor and distorts the signal. Other effects are given by the limited operation range of the readout electronics. The aim of the measurement campaign is to collect data from monoenergetic charged particles under different irradiation angles to understand the Timepix detector response for proper mixed field data interpretation and comparison with simulations models.

In-phantom measurements

Secondary dose to patient

The secondary radiation received by a patient during therapy can be estimated by in-phantom measurements with various detectors: CR-39, Medipix and GEM in addition to ion chambers. Such measurements offer an excellent opportunity to compare CR-39 with active detectors and distinguish amongst the different components on the radiation field also in terms of LET. The shape profile of tracks inside the phantom will be measured with Medipix, and the independence of the measurements on the detector parameters will be checked.

Microdosimetry

The quality of hadron-therapy beams can be assessed through microdosimetry. The microdosimetric spectra give the absorbed dose distribution against lineal energy (a quantity which can be related to LET). These spectra will be measured in-phantom across the Bragg peak in order to assess the variation of the absorbed dose against LET. The spectra acquired with the silicon telescope microdosimeter will be compared with the ones measured with other microdosimeters, i.e. the SOI microdosimeter developed by UOW (see below) and possibly some of the detectors used for the measurements under point C. The absorbed dose values integrated over the microdosimetric spectra will be compared with the data measured with the other dosimeters employed in the framework of the present experiment. Measurements will be performed in-phantom, both in-beam and off-beam, the latter to assess the contribution of secondary particles to the dose in healthy tissues.

SOI microdosimeters will be used for measurements of dose equivalent out of field laterally and downstream of the SOBP. New microdosimeters with 3D sensitive volumes will be used in parallel with previous generation of planar SVs. RBE will be obtained in-beam and out of the field for different locations of the microdosimeters.

Passive measurements

Stacks of CR39 will be placed in beam to measure the position of the Bragg peak. The track analysis system permits to evaluate the LET distribution and to obtain the adsorbed dose. Track detectors with wide area (tens of square cm) will be arranged to cover both the in-beam and the off-beam region. This permits to obtain a map of the dose delivered to healthy tissues. The results will be compared with the data obtained by other detectors in the frame of this experiment.

Out-of-phantom measurements

Passive dosimeters

Passive dosimeters (CR-39) are currently used at CNAO for the measurement of stray radiation. During the measurement campaign, Medipix will act as an active nuclear-track detector and will be compared with the CR-39 dosimeters. Anti-coincident measurements with stacked Medipix detectors and neutron converters will allow the active discrimination of charged particles from recoil protons.

Vertex

A stack of Medipix devices will work coincidently to reconstruct the tracks of secondary charged particles produced during particle therapy. The goal of this measurement is to reconstruct the Bragg peak by comparing these tracks with the beam path through the patient. Also, the vertexes of fragmentation events can be reconstructed by detecting multiple emitted charged particles, a method which is intrinsically more accurate than the single-track based method.

Calibration of Space Flight Medipix Hardware

Detectors configured like the space flight hardware will be placed in the beam in order to acquire data to be compared with that acquired on the ISS. This will entail taking data at known fixed angles with respect to the incident beam and at a variety of beam energies. The detectors internal settings will also be varied during the data taking. The result of these measurements will be used to further improve the algorithms used on the actual space flight data.

Active measurements

These measurements aim at assessing the stray radiation (mainly neutrons) inside the treatment room. Radiation fields are characterized by a pulsed structure. For this reason a prototype of radiation monitor, called LUPIN, will be used, which is optimized to work in pulsed neutron fields.