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Construction and tests of an in-beam PET demonstrator (LAPD) for hadrontherapy beam ballistic control

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We present the first results obtained with a detector, called Large Area Pixelized Detector (LAPD), dedicated to the study of the ballistic control of the beam delivered to the patient by in-beam and real time detection of secondary particles, emitted during its irradiation in the context of hadrontherapy. These particles are 511 keV gammas from the annihilation of a positron issued from the beta+ emitters induced in the patient tissues along the beam path.

The LAPD basic concepts are similar to a conventional PET camera. The 511 keV gammas are detected and the reconstructed lines of response allow to measure the beta+ activity distribution. Nevertheless, when trying to use gamma from positron annihilation for the ballistic control in hadrontherapy, the large prompt gamma background should be taken into account and properly rejected. This demonstrator should prove the possibility of in line selection of the two gammas annihilation events and highly reject beam induced background noise events.

The presentation is organized in two parts.

The first part starts with a description of the detector geometry and the technical choices made for its construction. The detector electronics will then be described. Some emphasis will be put on the main component of this electronic system which is the ASM board. This board is used for both the generation of trigger signals and the sampling/digitization of physics signals used downstream in the analysis.

The current version of the data acquisition system is then described. One originality of the DAQ software is that it is partly written using the Go language. Reasons for this choice will be shortly described.

The current DAQ system is characterized by a large dead-time due to the use of VME-based technologies. Work is under progress to upgrade this DAQ system and move from VME-based to xTCA-based technologies. This should reduce the dead time by a factor of at least 40. These developments are also briefly described in the presentation.

Then, the monitoring system is described. This system is of crucial importance for this application as results should eventually be served online to clinical staff. It is therefore mandatory to have an online software able to perform the entire analysis (event selection and event reconstruction) in real time and to present the reconstruction results in real time too. The online software is briefly discussed as well as the way results are presented by the monitoring system. This discussion will end the first part of the presentation.

The second part is dedicated to the presentation of the tests that were carried recently and the performances that were derived from them.

First, measurements obtained with a phantom filled with a high intensity FDG source at the cancer research center of Clermont-Ferrand are shown. Basic performances obtained from these measurements are presented as well as reconstruction results showing the ability of the LAPD detector to measure the beta+ annihilation signal and reconstruct beta+ activity maps.

Then, measurements performed on low energy proton beam (65 MeV) at the Centre Antoine Lacassagne (CAL) in Nice are reported. After a short presentation of the experimental setup and experimental conditions, first results of online measurements of the beta+ activity profile along the beam axis using PMMA targets are presented.

Finally, some conclusions will be drawn and some perspectives regarding the futur evolution of the system will be given.