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Precise on-line position measurement for particle therapy

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Introduction

Field of particle therapy proved to be very effective for cancer treatment all over the world. At the Paul Scherrer Institute (PSI) Gantry 2 is a therapy delivery system which operates using proton beams of energies ranging from 70 MeV to 230 MeV [1]. Gantry 2 employs an active spot scanning technique which allow following the tumour shape by means of the fast energy change scanning in depth and two sweeper magnets which deflect the proton beam to a required position in a plane perpendicular the beam direction (lateral plane). Gantry 2 offers beams with dose per spot changing over three orders of magnitude. Beam size can vary from 2 mm to over 1 cm. The precision of the dose delivery in depth depends on the energy selection accuracy and description of the propagation medium. The homogeneity of the delivered dose distribution directly depends on the lateral position accuracy, thus the signal of any provided parameters must be reconstructed with sub-millimeter precision. In order to verify a reliable high quality patient treatment the on-line dose and position monitoring of the proton beam during the treatment as well as regular stability checks are of highest importance for the Quality Assurance (QA).

Method

There are many different methods available which can be used for lateral position verification with highest position resolution at single particle count level. However, in a case of particle therapy for on-line position verification the detector has to be placed right in the beam and, as a consequence, has to have possibly low material budget in order to reduce the multiple scattering during the beam delivery. Using the experience of the Gantry 1 therapy system [2] Gantry 2 chooses an ionization strip chamber for the on-line lateral position verification which is installed in the gantry nozzle[1]. This chamber covers the full scanning area with two perpendicular planes of 88 and 128 strips and a strip size of 2 mm. The strip chamber is equipped with advanced readout electronics which transfer the data to the therapy verification system. Spot position is propagated to the iso-center taking into account the Gantry 2 beam optics and cross-checked with an expected value within one millisecond time.

Apart from on-line position monitor an ionization strip chamber of the same type is used for regular position cross-checks. In addition to that, two smaller strip chambers with active area of 7 by 7 cm and strip size of 2.2 mm are used for the daily verification of the beam size, position and direction.

Results

A position deviation of more than one millimeter can lead to a dose fluctuation of several percents; therefore the required position precision has to reach the sub-millimeter level. The Gantry 2 strip monitor allows an on-line position and shape control of the full range of beams available at our machine with sub-millimeter precision. Signals varying from a high-weighted spots till lowest dose used by our therapy planning system (order of tenth of a milligray) can be reconstructed with the required precision level due to the low detector noise. The detector granularity of 2 mm allows the same reconstruction precision for all spot sizes produced by Gantry 2 beams. The daily QA routine which is performed prior the patient treatment verifies the precision and stability of the delivered beam for the whole scanning area.

Conclusions & Outlook

The strip ionization chambers have proven to be an appropriate verification and QA tool for the scanning proton beam therapy system. Its suitable design allowed operating in a simple, efficient and extremely stable way over several years. The system demonstrates a sub-millimeter precision of the position reconstruction which is needed for dose homogeneity of better than 1% to guarantee a patient treatment quality at the highest achievable level. However, the sector of beam delivery technologies is developing and the design of the position detector could require further improvements using a lower material budget, different detector strip size or improved read-out electronics.

References

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