Radiation Measurements 46 (2011) 244–249

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Short communication

Performance characteristics and long-term calibration stability of a beam monitor for a proton scanning gantry

D.F. Nichiporov [a,*], A.V. Klyachko [a], K.A. Solberg [a], Q. Zhao [b]

[a] Indiana University Cyclotron Facility, 2401 Milo B. Sampson Ln., Bloomington, IN 47408, USA
[b] Midwest Proton Radiotherapy Institute, 2425 Milo B. Sampson Ln., Bloomington, IN 47408, USA

ARTICLE INFO

Article history:
Received 9 November 2009
Received in revised form
29 July 2010
Accepted 17 November 2010

Keywords:
Proton beam
Monitor
Gantry
Uniform scanning

ABSTRACT

A monitor for a uniformly scanned beam was designed and constructed by the Indiana University Cyclotron Facility for use in a clinical proton gantry at the Midwest Proton Radiotherapy Institute. The beam monitor is a thin-walled, wide-aperture ionization chamber, which provides information about dose, beam size, symmetry, flatness, and position. Several characteristics of the monitor's performance were studied, including linearity in dose rate, reproducibility, recombination correction, and dependence on both radiation field size and gantry angle. Additionally, stability of the detector output was analyzed using daily monitor calibrations performed over a period of 21 months.

The beam monitor was found to meet design requirements for linearity (±1%), calibration stability (±2%), and stability of response as a function of gantry angle (±1%). Beam monitor calibration statistics also revealed a sine-like yearly trend with a ±2% maximum deviation from the average. These and other beam monitor test results are presented and discussed in the context of the detector design. Design changes aimed at further improving the detector's performance characteristics are proposed.

1. Introduction

The first treatment room with a uniform scanning gantry at the Midwest Proton Radiotherapy Institute (MPRI) was commissioned for patient treatments in March 2007 (Farr et al., 2008), and has been in operation since then. Most of the components of the MPRI treatment system, including dose monitors, were designed and built by the Indiana University Cyclotron Facility (IUCF). This work reviews the design of the Patient Dose Monitor (PDM) used in the uniform scanning gantry, discusses only performance characteristics which are directly related to the measurement of dose, and proposes a number of improvements. The purpose of this work is to discuss some of the PDM design features that should not be overlooked when designing a dose monitor for a scanning beam gantry.

Currently there are no published standards for beam monitors used in heavy charged particle clinical beams. We therefore refer, where possible, to recommendations available for medical electron accelerators (IEC, 2008).

* Corresponding author. Tel.: +1 812 856 0072; fax: +1 812 855 6645.
E-mail address: nichipor@indiana.edu (D.F. Nichiporov).

1350-4487/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.radmeas.2010.11.017

2. Materials and methods

2.1. Method of beam delivery

The quasi-continuous, 205 MeV proton beam is provided by the IUCF cyclotron and transported to a gantry treatment room. The beam energy (penetration in water) is adjusted, as prescribed by the patient treatment plan, by a degrader located in the beam line upstream of the gantry. After exiting from the gantry, the beam passes through the nozzle components, as shown in Fig. 1, in the following order: i) the wide-aperture parallel plane ionization chamber used as a beam intensity monitor, ii) the X–Y scanning magnet (Anferov, 2005), whose scanning amplitudes define the size of a square field at the PDM location, based on the prescribed patient-specific field size, iii) the movable X- and Y-collimators (jaws) used as part of the shielding, and iv) the PDM located immediately downstream of the jaws. The final shaping of the field in the transverse direction is done by a patient-specific brass aperture. A number of redundant quality control and safety mechanisms are implemented in the beam control system in order to maintain the high spatial stability of the beam in the nozzle and to ensure the correct implementation of a homogeneous scanning pattern. All commissioned fields have been verified to

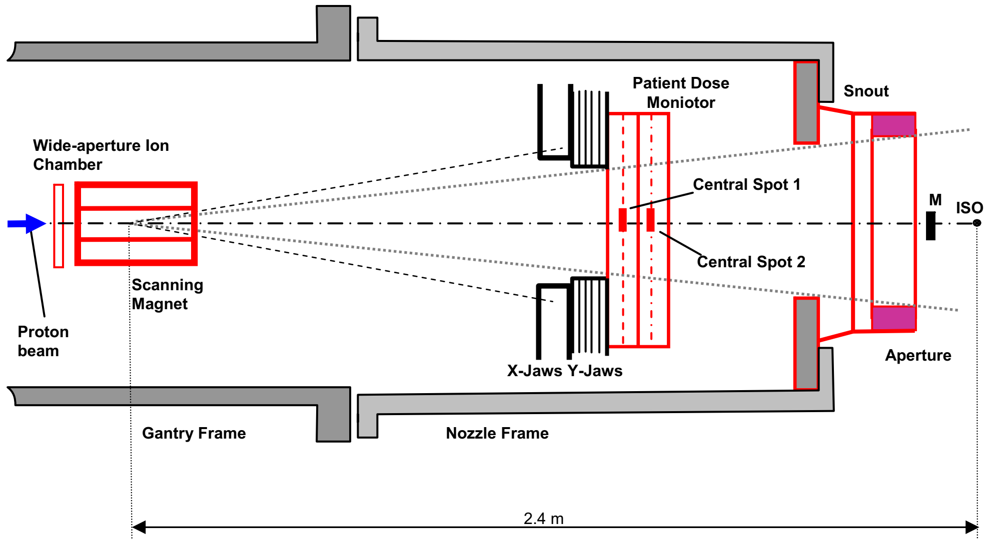

Fig. 1. Schematic diagram of the uniform scanning nozzle (not to scale). ISO – gantry isocenter; M – Markus ion chamber position during the PDM linearity measurements.

meet the ±2.5% transversal uniformity requirement. A more detailed description of the uniform scanning beam delivery technique and related hardware is given by Farr et al. (2008).

2.2. Detector requirements and design

The primary task of the PDM in the uniform scanning nozzle is the measurement of dose during proton therapy. The PDM was designed to meet a number of requirements, in particular: i) redundancy of dose measurements, ii) linearity of response to beam currents between 0.2 nA and 10 nA, and iii) stability of signal output vs. gantry angle within ±1%.

The PDM, shown schematically in Fig. 2, is comprised of a series of signal and high voltage electrodes, and is essentially a group of parallel plate ionization chambers with signal electrodes of various configurations, separated by ground planes. All electrodes, serving different purposes, are located in a common housing. The requirement of redundancy of dose measurements is addressed by using two ionization chambers with small signal pads (Central Spots 1 and 2), placed in the centers of two separate electrodes. All critical components associated with dose measurements, such as electrode planes, bias power supplies, and signal readouts are redundant and independent from one another, ensuring that the failure of a component in one ion chamber will not compromise the performance of the other.

All electrodes are made of conductive graphite paint on a 25 μm Mylar film, and their total thickness is less than 0.04 g/cm^2. Each film is stretched and glued to a square frame. In the PDM, Central

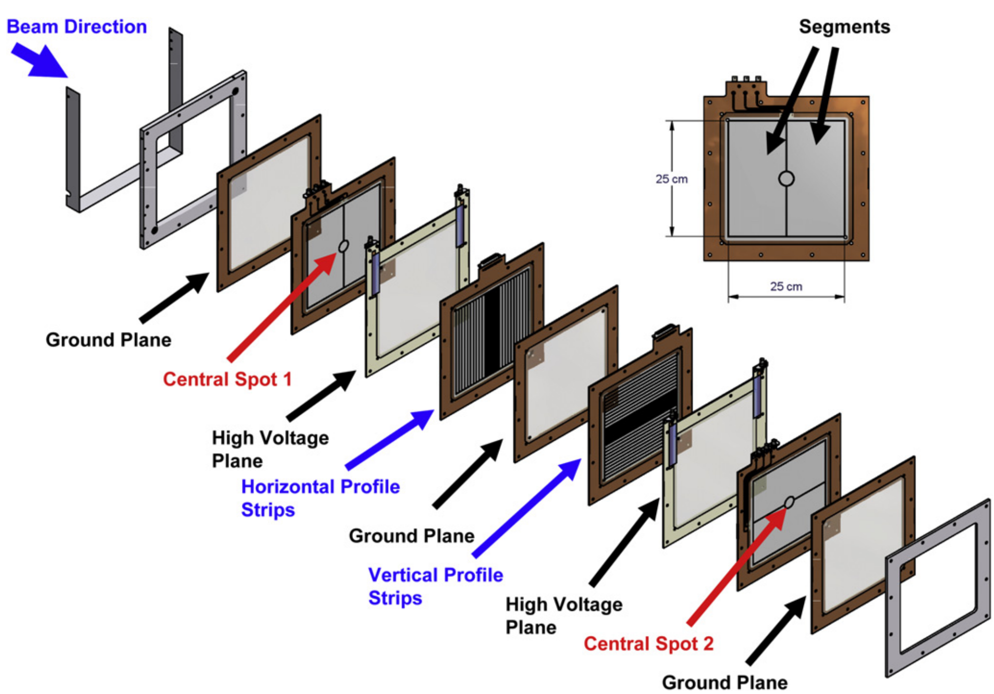

Fig. 2. Exploded view of Patient Dose Monitor showing two redundant central spot electrodes for measuring the radiation dose, two pairs of rectangular segments and two sets of strips. Signal leads for central spots are on reverse sides of the electrodes and are not shown. The inset shows a central spot electrode plane layout and its dimensions.