PARTICLE THERAPY QA TOOLS
A complete range of tools for absolute dosimetry, machine QA and patient plan verification
Introduction

In recent years more and more particle therapy centers, especially proton centers, are being established to optimize radiation treatment for cancer patients. In contrast to photons and electrons, heavy particles exhibit improved accuracy for absorbed dose deposition due to the physical features of these particles, such as limited scattering and a sharply defined maximum range. The depth of the target volume can easily be matched by means of the spread-out Bragg peak method, varying the energy of the particle beam.

Although most dosimetry tools used in classical radiotherapy centers can also be used in particle centers, there are some specific requirements that are to be addressed. Beam scanning systems for particle therapy centers sometimes may have to be used in any spatial orientation, and as the beam energy is a very crucial quantity, the requested scanning precision may be higher than in classical systems. The dosimetry equipment should feature convenient computer interfaces such as network interfaces (TCP/IP) to allow centralized control. Frequently, dosimeters and test tools are controlled by software provided by the supplier of the accelerator, so simple software interfaces must be available.

To date, there are few standards dealing with QA procedures in heavy particle beams [ICRU, IAEA]. PTW’s ionization chambers are mentioned in IAEA 398, allowing the clinical physicist to apply the required correction factors for absolute dose determination. Some of the QA procedures and tools mentioned in this document are described in [Jäkel, Karger_a and Karger_b, Ciocca_a and Ciocca_b].

Beam Scanning Systems

PEAKFINDER

PTW offers a wide range of beam scanning systems including the PEAKFINDER, a tool for the very precise measurement of the depth of the Bragg peak. The PEAKFINDER consists of two water-filled bellows, one of which serves as absorber for the incident radiation, the other one serves as water reservoir at the distal end. The thickness of the absorber column can be varied from approximately 1.5 to 35.5 cm in increments of 10 µm (exact water-equivalent thickness to be determined by the user). The device is sealed and can be used in any spatial orientation. It contains two thin-window Bragg peak chambers as measuring and reference detectors. The PeakScan software package scans and evaluates Bragg curves. A gate input facilitates synchronization with accelerator spills. The public interface commands allow easy integration of the PEAKFINDER in the hospital’s or particle therapy center’s QA software system.

MP3-P

The MP3-P is a 3D scanning system which offers increments of 100 µm. It can be mounted onto a table top, next to its optional water reservoir and the electronics, e.g. the specially developed TANDEM XDR electrometer. As an alternative configuration it is also available with a SCANLIFT carriage and reservoir. A thin exchangeable entrance window of 250 mm x 250 mm x 5 mm PMMA makes the system suitable not only for vertical but also for horizontal beams. The scanning range is 380 mm vertically and 350 mm horizontally. Dual chamber holders allow the fixation of Bragg peak chambers to the MP3-P. One chamber is mounted to the entrance window outside of the water tank and serves as reference chamber, the second chamber is mounted to the moving mechanism for relative dose measurements. The comprehensive MEPHYSTO mc² software package facilitates data acquisition and evaluation.
MP3-PL
Larger variant of the MP3-P. The scanning range is 405 mm vertically and 500 mm horizontally.

MP3-P45
In addition to the functionality of the MP3-P/PL this 3D-scanning system offers a unique possibility to measure a beam at a 45° incident angle. The system is available with a SCANLIFT carriage and reservoir.

Detectors for the MP3 system

Bragg peak chamber 34070
This plane-parallel chamber features a large electrode diameter of 81.6 mm and a measuring volume of 10.5 cm³. Therefore all scattered particles are collected, allowing the precise measurement of the position of the Bragg peak. The PMMA entrance and exit windows are thick enough (3.47 mm and 7.48 mm respectively) to withstand varying water pressures, allowing the chamber to be used at varying water depths. These features make the type 34070 the standard Bragg peak chamber for the application in water.

Thin-window Bragg peak chamber 34080
This chamber differs from model 34070 by the thin PMMA windows with thicknesses of 0.62 mm and 1.16 mm respectively. The chamber is not intended for use in water. Thin-window Bragg peak chambers are used for in-air measurements, e.g. in the PEAKFINDER, or in solid state phantoms.

Bragg peak chamber 34073
The design of this plane-parallel chamber is derived from the design of the well-known Roos electron chamber type 34001. The chamber has relatively small dimensions, thin windows and a sensitive volume of 2.5 cm³. The electrode diameter is approximately 40 mm, the thickness of the PMMA entrance and exit windows is 1.13 and 1.46 mm respectively. During the measurements the water depth should not vary to prevent changes of the chamber's sensitivity.

microDiamond 60019
The microDiamond detector is a synthetic single crystal diamond detector with near tissue-equivalence. It has an active volume of 3.8 mm² x 1µm. It provides excellent spatial resolution for measuring beam profiles, even in the penumbra region of small fields. This waterproof detector can be used in air, solid state phantoms and in water.

Dosimetry Diode PR 60020
This diode made of p-type silicon provides excellent spatial resolution for measuring beam profiles in particle beams, even in the penumbra region of small fields. The active volume of the diode is 1 mm² x 20 µm. This waterproof detector can be used in air, solid state phantoms and in water.

PinPoint Chamber 31015
This thimble ionization chamber is suitable for the measurement of small fields. The vented sensitive volume is 0.03 cm³ with a diameter of 2.9 mm and a length of 5 mm. The aluminium electrode minimizes energy dependence. The chamber can be used in water.
Dosimetry Systems

**OCTAVIUS Detector 729 XDR**

The OCTAVIUS Detector 729 XDR is a panel detector based on 729 vented plane-parallel ionization chambers arranged in a 27 x 27 cm matrix. It differs from the standard PTW product OCTAVIUS Detector 729 by its measuring range which is adapted to the high dose rates encountered in particle beams (0.8 ... 300 Gy/min). The device is operated at a chamber voltage of approx. 1000 V to minimize saturation losses in the ionization chambers. The OCTAVIUS Detector 729 XDR allows fast measurements of beam flatness and symmetry as well as dose distribution measurements for patient treatment plan verification. The device is supported by the software packages MultiCheck and VeriSoft. This device is compatible with the OCTAVIUS I and II patient verification systems.

**OCTAVIUS Detector 1500 XDR**

The OCTAVIUS Detector 1500 XDR is a panel detector based on 1405 vented plane-parallel ionization chambers arranged in a 27 x 27 cm matrix. It differs from the standard PTW product OCTAVIUS Detector 1500 by its measuring range which is adapted to the high dose rates encountered in particle beams (0.25 ... 800 Gy/min). The device is operated at a chamber voltage of approx. 1000 V to minimize saturation losses in the ionization chambers. The OCTAVIUS Detector 1500 XDR allows fast measurements of beam flatness and symmetry as well as dose distribution measurements for patient treatment plan verification. The device is supported by the software packages MultiCheck and VeriSoft. This device is compatible with the OCTAVIUS I and II patient verification systems.

**3D Detector Block**

The 3D detector is an alternative to the array based patient verification systems. It is a PMMA block that can be mounted to the moving mechanism of an MP3-P system. It fixes up to 24 PinPoint ionization chambers in different planes, allowing the verification of a patient plan at up to 24 points simultaneously. The chamber spacing is 10 and 12 mm. The use of 24 PinPoint chambers requires two MULTIDOS electrometers and adaption boxes. No specific software is available from PTW to support the 3D Detector Block.

**Absolute Dosimetry**

**UNIDOSwebline**

The UNIDOSwebline is the ideal dosemeter for particle therapy centers as it features a TCP/IP interface along with simple software instructions for remote control. All ionization chambers relevant for particle dosimetry can be connected. The determination of absorbed dose for monitor calibration is usually performed in a PMMA slab phantom (T2967). A radioactive check source can be used to check the dosimetry system independently.

**Farmer chamber 30013**

The standard ionization chamber recommended for absolute dose measurements in particle therapy is the Farmer chamber type 30013. Data for other suitable PTW ionization chambers, including the Roos and Markus chambers, as well as relevant procedures and correction factors for absolute dose determination can be found in [IAEA].

**Film-based daily QA**

**All-in-one Phantom**

The All-in-one Phantom is a PMMA phantom to check pencil beam positioning, pencil beam shape and the field geometry of a particle therapy beam delivery system. For this purpose the phantom is mounted on the film holding device.
Positioning QA Tools

Robot Calibration Plate
This 30 x 30 cm PMMA plate checks the congruence between laser positions and the coordinate system of the patient couch or a positioning robot. Engravings with an accuracy of 0.1 mm allow checks of linear and angular scales.

Sphere with Micrometer Drives
A radio-opaque sphere with 2 mm diameter, supported by a radio-transparent stem, checks the isocentric rotation of e.g. the treatment couch by producing an image on a radiographic film EPID positioned behind the sphere. In addition, the isocentric beam position at different energies can be checked. The sphere is adjustable in 1 µm increments. As an option, an additional 5 mm sphere with adjustment cube is available.

Accessories

Inhomogeneous Phantom
This phantom checks the system’s ability to correctly irradiate inhomogeneous targets. It consists of a PMMA hemisphere of 200 mm diameter with 11 inhomogeneities of 24 mm diameter and 10 mm length. The densities vary from 0.001 g/cm³ (air) to 1.82 g/cm³. The Cylindric PinPoint chamber adapter T21005 allows the fixation of up to 24 PinPoint chambers next to the inhomogeneities for dose measurements. Alternatively, the phantom can be positioned next to the side wall of an MP3-P system (also to the 45° window in case of the MP3-P45), allowing dose measurements behind the phantom using either a single ion chamber or the 3D Detector Block. The PMMA hemisphere can also be mounted without inhomogeneities using the holding device T41029.1.230. More details can be found in [Karger_a].

PMMA Wedge
This wedge with a base of 200 mm x 200 mm and a height of 120 mm can be mounted to the side wall of an MP3-P/P45 system. It can be used to e.g. correlate film measurements to measurements done in the MP3-P phantom.

3D Detector Block
Compare “Dosimetry Systems”, page 4

Linear Detector Holder
This detector holder allows the use of 24 PinPoint chambers as a linear array in a water scanning system. This gives the functionality of PTW’s well established LA48 linear array at high dose rates common to particle therapy systems.

PEAKFINDER Holder
This holder allows the PEAKFINDER water column to be positioned at angles from 0° to 180° with respect to the treatment table in 15° steps, allowing easy measurements at different gantry angles.

OCTAVIUS Detector and slab phantom holder
This device can be used to position an OCTAVIUS Detector array and a PMMA slab phantom horizontally as well as vertically.

Angle device for OCTAVIUS Detector and slab phantom holder
With this accessory the device can be used at angles from 0° to 180° in 15° steps with respect to the treatment table, allowing easy array measurements at different gantry angles.
References


[Jäkel] Quality assurance for a treatment planning system in scanned ion beam therapy, O. Jäkel et al., Med. Phys. 27(7), July 2000, 1588-1600

[Karger_a] Quality management of medical physics issues at the German heavy ion therapy project, Christian P. Karger et al., Med. Phys. 27(4), April 2000, 725-736


Ordering Information

The following items are standard PTW components without software (if not mentioned otherwise). Different connecting systems may be available upon request. Ask PTW for a full quotation including all of the necessary components.

Beam Scanning Systems

L981257 PEAKFINDER water column, closed water column, scan range 1.5 – 35.5 cm, 10 µm increments. 3 mm Quartz glass windows. Inc. TANDEM xd® electrometer, 2 Bragg peak chambers type TM34080/TM34082 (connecting system M), TCP/IP interface. Length calibration in particle beam to be made by user

S080052 PeakScan software, program for control of the PEAKFINDER L981257. Measures Bragg curves and analyzes the position and width of the Bragg peak

L981233 MP3-P water phantom, exchangeable thin entrance window, with reservoir next to tank, mounted on table top. Overall height approx. 50 cm, scanning volume 35 x 25 x 38 cm, TANDEM xd®, Mephysto mc2 software w/o options, no detectors included, TCP/IP converters included

L981393 MP3-P45 measuring system for particle therapy for 0°, 45° and 90° beam, SCANLIFT, positioning device, chamber cable holding device, 2 x MULTIDOS, 2 x detector connection box, 24 x PinPoint chamber, TBA control unit, RS232-TCP/IP interface, all holders and cables. Software not provided

L981299 MP-3P measuring system for particle therapy incl. SCANLIFT, positioning device, chamber cable holding device, 2 x MULTIDOS, 2 x detector connection box, 24 x PinPoint chamber, TBA control unit, RS232-TCP/IP interface, all holders and cables. Software not provided

L981403 MP3-P water phantom. Measuring system for particle therapy incl. SCANLIFT, MP3-S positioning device, Bragg peak chambers T34070 and T34080, TANDEM xd®, TBA Control Unit, RS232-TCP/IP interface, all cables and holders

L981404 MP3-P45 water phantom. Measuring system for particle therapy for 0°, 45° and 90° beam, SCANLIFT, positioning device, Bragg peak chambers T34070 and T34080, TANDEM xd®, TBA Control Unit, RS232-TCP/IP interface, all cables and holders

L981422 Dual chamber holder, for fixation of two Bragg peak chambers 34073 to the MP3-P tank. One chamber is fixed as reference chamber outside the tank, the other chamber measures depth distributions in horizontal beams

L981423 Dual chamber holder, for fixation of two Bragg peak chambers to the MP3-P tank. A chamber type 34070 or 34080 is fixed as reference chamber outside the tank, a chamber type 34070 measures depth distributions in horizontal beams

T4316/U551 TRUFIX holder for Bragg peak chamber 34070, mounts a Bragg peak chamber 34070. Requires TRUFIX basis equipment L981150. For vertical scans only

T4316/U561 Bragg peak reference chamber holder, for attaching a Bragg peak chamber 34070 or 34080 to the water tank as reference chamber. Suitable for vertical beams. Requires TBA reference chamber holding device T4316/U171

Detectors for the MP3 system

TM34070-2,5 Bragg peak chamber 10.5 cm³, PMMA plane-parallel chamber for relative depth dose measurements in heavy particle beams. For determination of the position of the Bragg peak. Waterproof, vented design. Thickness of entrance window 3.47 mm PMMA, cable length 2.5 mm, connecting system M

TM34080-2,5 Thin-window Bragg peak chamber 10.5 cm³, PMMA plane-parallel chamber for relative depth dose measurements in heavy particle beams. For determination of the Bragg peak position. Not waterproof, vented design. Thickness of entrance window 0.62 mm PMMA. Connecting system M

TM34073 Bragg peak chamber 2.5 cm³, PMMA plane-parallel chamber for relative depth dose measurements in heavy particle beams. For determination of the Bragg peak position. Waterproof, vented design. Thickness of entrance window 1.13 mm PMMA. Water depth must not vary. Connecting system M

TM60019 microDiamond. Synthetic single crystal diamond detector (SCDD) for the measurement of photons and high-energy electrons and protons. Sensitive volume 1.1 mm radius, 1 µm thickness. No detector bias needed

TM60020 Dosimetry Diode PR pre-irradiated p-Si diode for the measurement of high energy proton radiation distributions in a water phantom. For field size (1 x 1 ... 40 x 40) cm². Radiation sensitive volume is a cylinder of 1 mm² x 20 µm

TM31015 PinPoint chamber 0.03 cm³, fully guarded therapy ion chamber with acrylic wall. For dose measurements in high energy photon beams. Waterproof, open chamber volume, 2.9 mm in diam. Cable length 1.3 m, connecting system M. Inc. acrylic build-up cap and 36 mm rigid stem for mounting
Dosimetry systems

L981386 OCTAVIUS Detector 729 xDR system (27 x 27 chambers), ion chamber array, vented, mounted in a 22 mm acrylic slab, for dosimetry of proton and heavy ion beams. Includes electronics, array/RS232 interface, cables, data acquisition software and carrying case. Dimensions 300 x 420 x 22 mm. PC not included

L981464 OCTAVIUS Detector 1500 xDR with 1405 ion chambers in a 27 x 27 cm² measuring field, for dosimetry of proton and heavy ion beams. Includes electronics, data acquisition software and detector carrying case

S070009 VeriSoft software, dose verification software that allows to compare calculated and measured radiation distributions, especially in IMRT applications. Supports film scanner (RadiLink, VIDAR, Kodak/Lumasys) and 2D-ARRAY. Please specify type of treatment planning system

S070011 MultiCheck software, for constancy checks on LINACs with the 2D-ARRAYSTARCHECK. Checks homogeneity, symmetry, central dose, leaf positions, wedge angle, coincidence of light field and radiation field

T21003 3D Detector Block, for fixation of up to 24 PinPoint chambers at 3 different depths, to be mounted to the C arm of an MP3-P, MP3-P45, MP5-M or MP3

T10004 MULTIDOS, therapy dosimeter with 12 input channels, built-in high-voltage 400 V, RS232 interface, system M. For 115/230 V, 50-60 Hz. Incl. power cord and MultiCal calibration software. For use with more than 2 detectors a detector connection box is required

T16007 Detector connection box 12 x M, connects up to 12 ionization chambers with connecting system M. Requires connection cable T26011 to the MULTIDOS electrometer

Absolute Dosimetry

T10021 UNIDOS secondary standard reference class dosimeter for radiotherapy, diagnostic radiology, mammography and health physics. Complies with IPEM. Incl. Ethernet and RS232 interface, trip output, rechargeable batteries. For 115/230 V, 50-60 Hz. Connecting system M

T2967 Acrylic slab phantom 30 x 30 cm, consists of 33 plates machined to 30 x 30 cm of various thicknesses with a maximum tolerance of 0.1 mm (29 plates 10 mm thick, 1 plate 5 mm thick, 2 plates 2 mm thick, 1 plate 1 mm thick). Weight approx. 35 kg. Requires special plate for ion chamber

T2967/29 Acrylic plate for PTW Farmer chambers, single 300 x 300 x 20 mm plate for Farmer chambers PTW 30xx or NE 2571

T40041 PMMA slab phantom, 25 x 25 cm slabs of different thickness. Total thickness is 27 cm. One slab accommodates a Farmer chamber type 30010 and a temperature sensor. The slabs can be screwed together

T40041.1.100 45° holding device for PMMA slab phantom, for setting up slab phantom T40041 at an angle of 45°

TM30013 Farmer type chamber 0.6 cm³, waterproof, acrylic/aluminum; fully guarded therapy chamber with acrylic wall and aluminum electrode. Cable length 1.3 m, connecting system M. Includes acrylic build-up cap

T2954/K2-10 Extension cable ‘M10m’, 10 m detector to dose-meter extension cable, connecting system M. Raw cable see part no. L172012

T48012 Check device 90-Sr for thimble chambers, contains well-type radioactive source of approx. 33 MBq 90-Sr. Includes thermometer to check the device temperature. Purchaser must declare to have the permission for use and the import license (if required) for the radioactive source before shipment

Film based daily QA

T43027 Robot calibration plate, 30 x 30 cm PMMA plate with engraved lines for calibration of robot positions. Accuracy of engravings 0.1 mm

T43028 Sphere with micrometer drives, 2 mm sphere, adjustable in 1 µm increments, horizontal range +/- 10 mm, vertical range +/- 5 mm

T43028.1.004 Needle with 5 mm sphere, exchange sphere 5 mm for T43028, including adjustment cube

Positioning QA Tools

T43031 Inhomogeneous phantom, semi-spherical PMMA phantom. Features different cylindrical inserts of known density as defined by supplier. To be mounted to the side wall in front of the entrance window of a water tank or to the cylindrical PinPoint chamber adapter

T41029.1.230 Holding device for hemisphere, holding plate for fixation of the PMMA hemisphere of the Inhomogeneous Phantom T43031 at the side wall in front of the entrance window of an MP3-P or MP3-P45 water tank

T21005 Cylindric PinPoint chamber adapter, for fixation of up to 24 PinPoint chambers 31015 for head-on irradiation (axial irradiation). To be used in conjunction with the Inhomogeneous phantom

T41029.1.220 PMMA wedge for MP3-P, PMMA wedge with 120 mm height, base area 200 x 200 mm². To be mounted to the side wall in front of the entrance window of an MP3-P or MP3-P45 water tank

T43029 Positioning phantom, cylindrical PMMA phantom with internal markers for checks of the coordinate systems of lasers and imaging devices

T40040 Film holding device, for fixation of 265 x 325 mm radiographic film, mountable to table top. Incl. film markers, positioning accuracy 0.1 mm

T40040.3.005 45° foot for film holding device, for use with film holding device T40040

T21004 Linear detector holder for fixation of up to 24 PinPoint chambers along a 25 cm line, to be mounted to the C arm of a MP3-P

T41041/T41049 PEAKFINDER holder, allows the PEAKFINDER water column to be positioned at angles from 0° to 180° with respect to the treatment table in 15° steps

T40065 OCTAVIUS Detector and slab phantom holder

T40066 Angle device for OCTAVIUS Detector and slab phantom holder
Dosimetry Pioneers since 1922.

It all started with a brilliant invention – the revolutionary Hammer dosemeter in 1922. Ingenuity coupled with German engineering know-how shaped the company’s history, leading to innovative dosimetry products that later became an industry standard. Over the years, PTW has maintained its pioneering spirit, growing into a global market leader of dosimetry applications well known for its product excellence and innovative strength. Today, PTW dosimetry is one of the first choices for healthcare professionals in radiation therapy, diagnostic radiology, nuclear medicine and health physics.

For more information on Particle Therapy QA Systems and other PTW products, visit www.ptw.de or contact your local PTW representative: