ST 7 Strahlentherapie mit schnellen Ionen II

Zeit: Dienstag 11:30–13:10 Raum: D

ST 7.1 Di 11:30 D

Untersuchungen zur Vielfelderoptimierung in der Ionentherapie — •Alexander Schmidt — GSI-Biophysik, Darmstadt, Germany

Ein wesentlicher Bestandteil der Bestrahlungsplanung in der Tumortherapie an der GSI ist die Optimierung, bei der die Teilchenfluenzen von typischerweise mehreren tausend Einzelstrahlen pro Strahlrichtung (Feld) so festgelegt werden, dass eine tumorkonforme Dosisverteilung erzielt wird. Seit kurzem ist es möglich die Fluenzen der Einzelstrahlen aller Felder unter voller Berücksichtigung der biologisch effektiven Dosis gleichzeitig zu bestimmen. Hierzu wird eine Bewertungsfunktion mit verschiedenen, wählbaren Gradientenverfahren minimiert. In Simulation und Experiment zeigt diese neue Methode (Vielfelderoptimierung) eine verbesserte Tumorkonformität und vor allem auch eine deutliche Dosisreduktion in kritischen Organen.

ST 7.2 Di 11:40 D

4D-Bestrahlungsplanung für rastergescannte Kohlenstofftherapie — •Christoph Bert[1], Eike Rietzel[1], Sven O. Grözinger[1], Thomas Haberer[2] und Gerhard Kraft[1] — [1]Biophysik, Gesellschaft für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt — [2]Heidelberg Ionenstrahl-Therapie Centrum, Uniklinik, INF 400, 69120 Heidelberg

Die bei der Gesellschaft für Schwerionenforschung (GSI) durchgeführte Kohlenstofftherapie ist bisher auf stereotaktisch fixierbare Tumorvolumina beschränkt. Bei der Strahlapplikation mit dem Rasterscanner-System werden die Strahlpositionen je Tumorschicht meanderförmig abgefahren. Bewegungen während der Bestrahlung führen aufgrund von Interferenzen mit der dynamischen Strahlapplikation zu Dosisdegradation. Bei durch die Atmung bewegten Tumoren kann die Strahlposition lateral und in der Tiefe der Bewegung nachgeführt werden, um trotz Tumorbewegung eine homogene Dosisverteilung zu erzielen.

Eine solche bewegungskompensierte Bestrahlung erfordert außer der technischen Umsetzung der Strahlnachführung die Erfassung der Tumorbewegung parallel zur Bestrahlung und eine erweiterte Bestrahlungsplanung. Für die Bestrahlungsplanung wurden neue Module in die GSI-Planungssoftware TRiP integriert. Sie berücksichtigen auf Basis von 4D-Computertomographie den zeitlichen Ablauf einer Bestrahlung. Somit können für gängige Techniken zur Minimierung von Bewegungseinfluss Dosisverteilungen unter Bewegung berechnet werden. Außerdem ist die Optimierung von bewegungskompensierten Bestrahlungen möglich. Vorgestellt werden die Details der Bestrahlungsplanung unter Bewegungseinfluss und die Ergebnisse der experimentellen Validierung.

ST 7.3 Di 11:50 D

CT calibration for Heavy-ion treatment planning at the DKFZ — •Sima Qamhiye[1], Malte Ellerbrock [1], Dieter Schardt[2], and Oliver Jäkel[1] — [1]German Cancer Research Center (DKFZ) - Heidelberg — [2]Gesellschaft für Schwerionenforschung (GSI) - Darmstadt

The uncertainty of ion-range in Carbon-therapy is mainly related to the electron density of the irradiated tissues. CT-numbers (HU) are the only indication to electron density with reasonable spatial resolution. Therefore, a calibration between ion range and HU is required to accurately calculate Carbon-range in tissue. The empirical calibration currently used for treatment planning at the GSI facility allows spatial accuracy up to 2-3 mm of Carbon range in head or neck tumors. In this work, the CT-calibration techniques currently used in the DKFZ to obtain a HU- ion range empirical calibration is presented. Gammex electron density substitutes and fresh tissue were cleaned and stacked in Plexiglas containers for both water equivalent path length (WEPL) and CT measurements. substitute measurements were used to obtain the empirical calibration curve of the CT in question while tissue measurements were used to estimate the quality of the calibration curve and the dependent range calculation. Substitutes used for CT-calibration should be carefully chosen but tissue measurements should be used to check the accuracy of empirical calibration. Tissue measurements show a good agreement with the calibration curves developed for different CT machines, maximum deviation 5%.

ST 7.4 Di 12:00 D

Calculation of Stopping Power Ratios for heavy ion dosimetry — •Oksana Geithner[1], Oliver Jäkel[1], Nikolai Sobolevsky[2], Pedro Andreo[3], and Günther Hartmann[1] — [1]Department of Medical Physics, German Cancer Research Center (DKFZ), 69120 Heidelberg, Germany — [2]Department of Neutron Research, Institute for Nuclear Research of the Russian Academy of Sciences, 117312 Moscow, Russia — [3]Division of Human Health, International Atomic Energy Agency, A-1400 Vienna, Austria

Water-to-air stopping power ratio calculations for clinical carbon ion beams of initial energies from 50 to 450 Mev/n have been performed using the Monte Carlo technique. To simulate the transport of a particle in water the computer code SHIELD-HIT v2 was used. In this most recent version of the code a number of modifications were implemented. The predecessor code SHIELD-HIT v1 was completely rewritten replacing formerly used single precision variables with double precision variables. The lower limit of the particles transport energy was reduced from 1 MeV/n down to 10 keV/n. For this purpose, the Bethe-Bloch formula was modified for lower energies. MSTAR and ICRU73 data for the stopping power values were included. The fragmentation model was verified and its parameters were adjusted. The presented version SHIELD-HIT v2 shows excellent agreement with experimental data. Calculations with the most recent version of SHIELD-HIT yielded input data for the calculation of stopping power ratios. The uncertainty of the stopping power ratio has been decreased to 0.5% compared to the uncertainty of 2% given in TRS-398.

ST 7.5 Di 12:10 D

Optimization of biological effects in intensity modulated radiotherapy with charged particle beams — •Jan Wilkens and Uwe Oelfke — German Cancer Research Center (DKFZ), Department of Medical Physics in Radiation Oncology, Im Neuenheimer Feld 280, D-69120 Heidelberg

In tumour therapy with charged particle beams, the biological effect is not determined by the physical dose alone. The relative biological effectiveness (RBE) varies three-dimensionally in space due to different local particle spectra. For protons, these RBE variations are often disregarded in treatment planning, while they become essential for heavier ions. We investigate the potential impact of a variable RBE for scanning techniques in intensity modulated radiotherapy with particle beams and present strategies to include RBE variations into the inverse planning process.

The first approach is to employ the dose-averaged linear energy transfer (LET) to characterize the radiation field. In the optimization, LET constraints can be added to the conventional dose-based objective function to aim for homogeneous dose and LET in the planning target volume, while avoiding high values of dose or LET in organs at risk. A second, more general method is the direct optimization of the biological effect (i.e. RBE times dose) by using time-efficient models for the RBE to allow for simultaneous multifield optimization of the biological effect in a reasonable time. We demonstrate the successful application of these strategies for protons, and report on the ongoing extension to heavier ions like carbon.

ST 7.6 Di 12:20 D

Aufbau eines 2D-Systems zur biologischen Dosimetrie — •Cläre von Neubeck — GSI Biophysik, Planckstaße 1, 64291 Darmstadt

Die Tumortherapie mit Kohlenstoffionen an der GSI setzt Modellrechnungen für die Bestrahlungsplanung ein, die eine Vorhersage über die Dosisverteilung und das Zellüberleben im Zielvolumen erstellen. Die Abhängigkeit der relativen biologischen Wirksamkeit (RBE) von der Energie und dem linearen Energie Transfer (LET) des Ions sowie das Reparaturvermögen der Zelle muss für jeden Punkt in die Planung integriert werden. Für die biologische Verifikation der Bestrahlungsplanung wurde ein Kopfphantom mit zweidimensionaler Auflösung in x,z-Richtung und einer Ortsauflösung von 3 mm entwickelt. Die CHO-K1-Zellen (Chinese hamster ovary) wuchsen als Monolayer auf Halterungen, die in mehreren Schritten konditioniert wurden. Für die Bestrahlung mit Kohlenstoffionen wurde ein zylindrisches Gefäß, ähnlich dem aus früheren Publikationen [1] verwendet. Das Zellüberleben wurde mittels colony forming assay ermittelt und mit den Berechnungen der Bestrahlungsplanung verglichen. Röntgenstrahlen mit 250 kV Beschleunigungsspannung dienten als Vergleich.

Referenz: [1] A. Mitaroff et al, Radiat Environ Biophys (1998) 37:47-51

ST 7.7 Di 12:30 D

Synthetic diamonds for heavy-ion therapy dosimetry — •Monika Rebisz, Eleni Berdermann, Andreas Heinz, Michał Pomorski, and Bernd Voss — Gesellschaft für Schwerionenforschung mbH, Planckstraße 1, D-64291 Darmstadt, Germany

In this paper we report on results obtained using Chemical-Vapor-Deposition (CVD) diamond detectors irradiated with heavily ionizing particles. At the heavy-ion therapy facility of GSI Darmstadt, the carbon pencil beam with spot sizes between 4 to 10 mm (FWHM), and fluencies of 10E6-10E8 ions/second were used. For initial energies from 80 up to 430 MeV/u the detectors were operated in transmission mode. Experiments at the UNILAC facility of GSI were carried out with ions from 12C up to 238U, fluencies between 10E4 and 10E5 ions/second/mm2 and a maximum size of the beam of 45 mm in diameter. With initial energies of 11.4 MeV/u the particles were stopped in the active detector volume. Two types of electronics were used to process the signals obtained from the diamonds. Fast amplifiers with a bandwidth of 2.2 GHz and 50 Ω impedance together with a 300 MHz Phillips discriminator served to count the number of impinging particles. Alternatively, an electronic based on a specially designed ASIC integrated the current signals from the detectors.

The Thermoluminescence (TL) response of synthetic-diamond dosimeters to heavily ionizing particles has also been studied. A discussion of the results from the passive radiation-detection and dose verification is given.

ST 7.8 Di 12:40 D

Experimental and theoretical study of the neutron dose produced by carbon therapy beams — •Hiroshi Iwase, Emma Haettner, Dieter Schardt, Michael Kraemer, and Gerhard Kraft — Biophysik, GSI, Planckstr. 1, 64291 Darmstadt

High-energy ^{12}C ions offer favorable conditions for the treatment of deep-seated local tumor. Several facilities for the heavy ion therapy are planned or under construction, for example the new clinical ion-therapy unit HIT at the Radiological University Clinics in Heidelberg.

For the purpose to provide further reliable models for the treatment planning, it is essential to evaluate the secondary fragment production and to include these contributions to the therapy dose with higher accuracy than those of the existing treatment planning systems.

Secondary neutrons are most abundantly produced in the reactions between ^{12}C beams and tissues. The dose contribution to tissues by a neutron is fairly small compared to ones of the projectile and the other charged fragments due to no ionization and small reaction cross-sections, however it distributes in a considerably wider region beyond the bragg-peak because of the strong penetrability.

Systematic data on energy spectra and doses of secondary neutrons produced by ^{12}C beams using water targets of different thicknesses for various detection angles have therefore been measured in this study at GSI Darmstadt. The measured data are compared with theoretical predictions by the heavy ion Monte-Carlo code PHITS. The use of the measured and calculated data is discussed for improving databases of secondary fragments for treatment planning.

ST 7.9 Di 12:50 D

Experimental fragmentation studies with ^{12}C therapy beams — •Emma Haettner, Hiroshi Iwase, and Dieter Schardt — Biophysik, GSI, Planckstr. 1, 64291 Darmstadt

For heavy ion therapy the effect of nuclear fragmentation is of particular importance as it affects the depth-dose profile and results in a complex radiation field. The primary particle beam is attenuated exponentially with increasing depth and the build-up of lighter fragments gives rise to a dose tail behind the Bragg peak.

Using 200 MeV/u and 400 MeV/u ^{12}C beams delivered by the heavy ion synchrotron SIS-18 we investigated the fragmentation characteristics of these beams in a water absorber of variable thickness. The data include depth-dose profiles, attenuation of the primary ions and build-up of charged fragments as a function of depth. For the ^{12}C beam attenuation measurements a telescope detector positioned close to the target exit provided energy loss and total energy information. It was found that approximately 70% of the 200 MeV/u and 30% of the 400 MeV/u primary ^{12}C ions reached the Bragg peak. In addition, angular distributions for charged fragments were measured with the 400 MeV/u beam at various water depths. Particles were identified by coincident recording of time-of-flight and energy loss signals. The measurements were performed at angles from -1° to 10° in steps of 0.5° to 2°. The amount of fragments spread forward in a cone with an opening angle of 20° was obtained by integration of the angular distributions.

ST 7.10 Di 13:00 D

Production of secondary from patients during therapy with C-ions; their dose contributions and potential risks — •Anwar Chaudhri — Inst. of Medical Physics, Klinikum-Nuernberg & PCSIR, Lahore, Pakistan

During therapy with C-ions a large number of neutrons are produced in patients* tissues which have the potential to induce new cancers. There is no information in the literature on the fluence, energy distributions and doses due to these neutrons. By using neutron out-put data from different elements we have shown that for every C-ion 4,3,1.4 and 0.3 neutrons are produced from patients at incident energies of 400, 300, 200 and 100 MeV / u, respectively. For a physical treatment C-ion dose of 20 Gy in the Bragg Peak, the total number of secondary neutrons produced in patients are 1.6 x 10 9 / cm 2, 7.3 x 10 8 / cm 2, 2.5 x 10 8 / cm 2 and 4,1 x 10 7 / cm 2 respectively at carbon-ions energies of 400,. 300, 200 and 100 MeV/u. These approximately correspond to effective whole body doses of around 950, 120 and 19 mSv cm 2 respectively at C-ions energies of 400, 200 and 100 MeV/u, and doses to various organs which could be as much as over 200 mGy cm 2 at 400 MeV/u energies of C-ions. In our opinion the large number of secondary neutrons produced from patients during therapy with C-ions, and their corresponding doses, indicate they could have real potential to cause new primary cancers and cause other harmful side-effects in patients. It is therefore strongly recommended that serious and careful considerations should be given before deciding to treat patients with C-ions, especially children, younger people and those who still have many years to live.