ST 1: Radiation Therapy I Fast Ions: Production, Physical Dosimetry, Biological Effets, Medical Effects

Time: Monday 14:00–16:45 Location: POT 112

ST 1.1 Mon 14:00 POT 112

Intense high-quality medical proton beams via laser fields — •Benjamin J. Galow, Zoltán Harman, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69029 Heidelberg, Germany

Simulations based on the coupled relativistic equations of motion show that protons stemming from laser-plasma processes can be efficiently post-accelerated employing pulsed laser beams in different configurations focused to spot radii on the order of the laser wavelength. We demonstrate in [1] that the laser fields produce quasi-monoenergetic accelerated protons with kinetic energies exceeding 200 MeV, small energy spreads of about 1% and high densities as required for hadron cancer therapy. To our knowledge, this is the first scheme allowing for this important application based on an all-optical set-up.

[1] B. J. Galow, Z. Harman, and C. H. Keitel, Opt. Express **18**, 25950–25957 (2010)

ST 1.2 Mon 14:15 POT 112

EBIS-Ionenquellen als Hadronenquellen für die medizinische Strahlentherapie — •Günter Zschornack[1], Frank Grossmann[2], Vladimir P. Ovsyannikov[2], Falk Ullmann[2], Andreas Schwan[2] und Erik Ritter[1] — [1]Technische Universität Dresden, Fachbereich Physik, Dresden — [2]Dreebit GmbH, Dresden

Gegenwärtig werden etwa 45 Prozent aller Krebserkrankungen durch chirurgische Eingriffe, Chemotherapie und/oder Strahlentherapie erfolgreich behandelt. Als besonders effektiv erweist sich bei der Strahlentherapie die Bestrahlung von Tumoren mit energetischer Hadronenstrahlung, vornehmlich mit Protonen und Kohlenstoffionen. Der Beitrag beschreibt neueste Entwicklungen bei der Bereitstellung qualitativ hochwertiger Hadronenstrahlen aus EBIS (engl.: Electron Beam Ion Source)-Ionenquellen. Die speziell für die Teilchentherapie entwickelten Ionenquellen können Einsatz in synchrotronbasierten Teilchentherapieanlagen, in CYCLINACs, in DDAs (engl.: Direct Drive Accelerator), DWAs (engl.: Dielectric Wall Accelerator) und RCMS (engl.: Rapid Cycling Medical Synchrotron) finden. Es wird das Wirkprinzip einer neu entwickelten EBIS als Ionenquelle für die Strahlentherapie mit den aufgeführten Beschleunigern erläutert und deren anwendungsrelevante Parameter wie Impulsformen, Teilchenzahlen pro Puls, Emittanz, Langzeitstabilität und Strahlreinheit werden im Vergleich zu ECR-Ionenquellen diskutiert.

ST 1.3 Mon 14:30 POT 112

Dosimetrie und biologische Wirksamkeit Laser beschleunigter Protonenstrahlen — •Leonhard Karsch[1], Baumann Michael[1], Beyreuther Elke[2], Burris-Mog Trevor[2], Cowan Tom[2], Dammene Yassine[1], Enghardt Wolfgang[1], Laschinsky Lydia[1], Lessmann Elisabeth[2], Kraft Stefan[2], Metzkes Josefine[2], Naumburger Doreen[1], Richter Christian[2], Sauerbrey Roland[2], Schramm Ulrich[2], Schürer Michael[1], Sobiella Manfred[2], Woithe Julia[1] und Pawelke Jörg[1] — [1]OncoRay - Nationales Zentrum für Strahlenforschung in der Onkologie — [2]Forschungszentrum Dresden-Rossendorf (FZD)

Einleitung: Bevor die neue Technologie der Laser Beschleunigung in der Strahlentherapie eingesetzt werden kann, müssen Beschleuniger einen stabilen, steuerbaren Strahl mit genügender Strahlstärke liefern. Ausserdem müssen die entstehenden ultra kurzen, sehr intensiven Strahlpulse auf ihre biologische Wirksamkeit und dosimetrische Erfassung hin untersucht werden.

Methoden: Es wurde ein integriertes Dosimetrie- und Zellbestrahlungssystem (IDOCIS) entwickelt, getestet und umfangreich kalibriert. Die Kombination verschiedener Dosimeter erlaubt eine präzise Absolutdosimetrie und Strahlüberwachung in Echtzeit. Nach zusätzlicher Modifizierung und Optimierung des 150 TW Lasersystems DRACO (FZD) wurden Zellbestrahlungen mit Laser beschleunigten Protonen durchgeführt.

Ergebnisse: Der Laserbeschleuniger lieferte über Wochen einen stabilen und reproduzierbaren Protonenstrahl. Zusammen mit der präzisen dosimetrischen Erfassung mit Hilfe des IDOCIS wurden Dosiseffektkurven bestimmt.

Schlussfolgerung: Vor einem Einsatz Laser beschleunigter Protonen in der Strahlentherapie sind verschiedene Verbesserungen der Lasertechnik und die Durchführung von tierexperimentellen Studien notwendig.

ST 1.4 Mon 14:45 POT 112

Uncertainty analysis of film dosimetry for ion beam therapy — •Francis Twumasi Boateng[1,2], Peter Steidl[1], Dirk Müssig[1], Daniel Richter[1], Alexander Gemmel[1,3], Claus Grupen[2], Marco Durante[1], and Christoph Bert[1] — [1]GSI, Darmstadt, Deutschland — [2]Universität Siegen, Deutschland — [3]Siemens AG, Healthcare, Erlangen, Deutschland

Radiographic films are well-established 2D dosimeters with excellent spatial resolution. Numerous publications discuss the different aspects of film dosimetry and its response to different radiation fields.

In this study, we performed several experiments to assess the uncertainties related to dosimetry with `Kodak X-Omat V` films in scanned ion beam therapy. The measured film response is potentially influenced by the condition of the developing machine, the time delay between irradiation and development, storage temperature, and the 2D densitometer. Since quantitative assessments in ion beam therapy are done against the modeled film response that is based on the photon response of the film, the study also included ^{60}Co and linac based photon beam irradiation. We present and discuss intermediate results of this study.

ST 1.5 Mon 15:00 POT 112

New measurements of W-values in argon, nitrogen and air for protons, helium and carbon ions — •Jeannine Beck[1], Ulrich Giesen[1], Dieter Schardt[2], Markus Bender[2], and Daniel Severin[2] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]Helmholtzzentrum für Schwerionenforschung GmbH (GSI), Planckstraße 1, 64291 Darmstadt

In particle therapy for cancer the dosimetry of the charged-particle radiation is mostly performed by measuring the ionization produced in gas-filled ionization chambers. The conversion of the reading of an ionization chamber into absorbed dose requires W-values, which are defined as the average energy needed to produce an ion pair.

Because of the increasing importance of ion therapy and the lack of experimental W-values for heavy charged particles in air new measurements of W-values are being carried out at PTB and GSI. Existing measurements for protons in air indicate an uncertainty of 4 % and the main goal of the present studies is to achieve an accuracy of about 1 %. Preliminary results of measurements for protons, helium and carbon ions in argon, nitrogen and air in the energy region of 1 MeV/u up to 6 MeV/u will be discussed.

ST 1.6 Mon 15:15 POT 112

Radiation therapy with laser-driven accelerated particle beams: physical dosimetry and spatial dose distribution — •Sabine Reinhardt[1], Walter Assmann[1], Peter Kneschaurek[2], and Jan Wilkens[2] — [1]Ludwig-Maximilians Universität München — [2]MRI, Technische Universität München

One of the main goals of the Munich Centre for Advanced Photonics (MAP) is the application of laser driven accelerated (LDA) particle beams for radiation therapy. Due to the unique acceleration process ultrashort particle pulses of high intensity ($> 10^7$ particles /cm^2/ns) are generated, which makes online detection an ambitious task.

So far, state of the art detection of laser accelerated ion pulses are non-electronic detectors like radiochromic films (RCF), imaging plates (IP) or nuclear track detectors (e.g. CR39). All these kind of detectors are offline detectors requiring several hours of processing time. For this reason they are not qualified for an application in radiation therapy where quantitative real time detection of the beam is an essential prerequisite. Therefore we are investigating pixel detectors for real time monitoring of LDA particle pulses. First tests of commercially available systems with 8-20 MeV protons are presented.

For radiobiological experiments second generation Gafchromic films (EBT2) have been calibrated with protons of 12 and 20 MeV for a dose range of 0.3-10 Gy. Dose verification in proton irradiation of subcutaneous tumours in mice was successfully accomplished using these films.

Cofffee Break

ST 1.7 Mon 16:00 POT 112

Effects of X-ray and heavy ion radiation on organotypic slice cultures of liver and pancreas — •Mareike Müller[1,2,3], Marco Durante[2,3,4], Gisela Taucher-Scholz[2], Francesco Natale[3], Horst Stöcker[2,3], and Horst-Werner Korf[1] — [1]Dr. Senckenbergisches Chronomedizinisches Institut, Fachbereich Medizin, Goethe-Universität Frankfurt/Main — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Frankfurt Institute for Advanced Studies, Frankfurt/Main — [4]Institut für Festkörperphysik, Technische Universität Darmstadt, Darmstadt

Cancers developing from liver and pancreas still have a poor prognosis and the efficacy of current therapeutic strategies is very limited. Properly timed X-ray and heavy ion irradiation may strongly improve the treatment of these cancers, but little is known how normal and neoplastic tissues from liver and pancreas respond to these treatments at various daytimes. Our interdisciplinary project aims at answering these questions by investigating the effects of X-ray and heavy ion irradiation on organotypic slice cultures (OSC) of liver and pancreas. Investigations of OSC present a novel approach in radiation research, they provide more relevant results than analyses of pure cell lines because OSC maintain the three-dimensional parenchymal architecture and the stromal compartment with functional extracellular matrix, the latter being an essential determinant of the tissue response to irradiation.

We present first results from X-ray irradiated OSC, analyzed for DNA damage and the number of proliferating and apoptotic cells.

ST 1.8 Mon 16:15 POT 112

The full simulation of dose response curves using the Local Effect Model — •Uwe Scholz, Thomas Friedrich, Marco Durante, and Michael Scholz — Department of Biophysics, GSI Helmholtz Centre for Heavy Ion Research Darmstadt, Germany

The purpose of the Local Effect Model (LEM) is to calculate the dose dependent relative biological effectiveness (RBE) of charged particle radiation with respect to conventional photon radiation. The linear-quadratic parameters α and β (the initial slope and the curvature of ion dose response curves) are modelled based on their values for the photon dose response. Usually this is done within a low fluence approximation where the biological damage of a radiation field at arbitrarily high irradiation dose is deduced from the damage pattern deposited by one single charged particle.

To investigate the reliability of the approximation, the LEM has been extended to simulate the actual damage pattern of an arbitrarily high number of ion traversals and their stochastic distribution by means of a full Monte Carlo simulation.

The analysis of the resulting survival curves revealed that the β-term in the full simulation increases compared to the original formalism. Furthermore, investigation of the dose dependence of the RBE showed that the RBE approaches values > 1 even at very high doses. This is in line with experimental results and can be understood mechanistically within the LEM formalism.

ST 1.9 Mon 16:30 POT 112

Fractionated treatment of moving tumors with scanned heavy ion beams — •Jens Wölfelschneider[1,2], Michael Scholz[1], Marco Durante[1,3], and Christoph Bert[1] — [1]GSI, Darmstadt — [2]Fachhochschule Giessen-Friedberg — [3]Technische Universität Darmstadt

Scanned beam irradiation of moving targets typically results in inhomogeneous dose distributions if only margins are used. To overcome this so called interplay effect, currently technically elaborative methods, such as beam tracking, gating or rescanning, are proposed.

With respect to absorbed dose, the dose homogenization that can be achieved with volumetric rescanning is comparable to a conventional fractionated treatment. In the scope of this work we investigated if fractionated dose delivery also results in homogeneous target coverage if the biological effect is incorporated.

By using the treatment planning system `TRiP 4D` together with α and β values of the Linear-Quadratic-Model, we calculated the equivalent uniform dose (EUD) for tumor and organs at risk in a fractionated treatment of lung tumors. The motion parameters were changed in each fraction, resulting in different interplay patterns. The summed dose distributions after varying the number of fractions were determined.

Homogenization of the resulting dose distribution with increasing number of fractions was observed for the absorbed dose. The degree of homogenization for the biologically effective dose is currently analyzed. Results and the comparison to other treatment methods will be presented.