ST 4: Accelerators for Medical Applications (joint session ST/AKBP)

Time: Wednesday 13:45–15:45 Location: ZHG009

Invited Talk ST 4.1 Wed 13:45 ZHG009

Mixed ion beams for treatment monitoring: recent developments and future prospects — •Elisabeth Renner[1], Hermann Fuchs[2], Matthias Kausel[3,1], and Claus Schmitzer[3] — [1]Atominstitut, TU Wien, Vienna, Austria — [2]MedUni Wien, Vienna, Austria — [3]MedAustron, Wiener Neustadt, Austria

In recent years, the use of mixed ion beams has been proposed as a method for treatment monitoring in ion beam therapy. A promising candidate in this context is a $^{12}C^{6+}$ beam with a small $^{4}He^{2+}$ contribution. The similar charge-to-mass ratios of these two ion species enable their simultaneous acceleration in medical synchrotrons. Being extracted at almost the same energy per mass, $^{4}He^{2+}$ features a range in matter approximately three times that of $^{12}C^{6+}$. This opens the possibility for tumor treatment with $^{12}C^{6+}$ while simultaneously performing $^{4}He^{2+}$ imaging downstream of the patient.

In 2024, the first successful delivery of a mixed $^{12}C^{6+}/^{4}He^{2+}$ beam in a clinical facility was achieved at MedAustron. Instead of being generated in a single ion source, as realized at GSI in late 2023, the two ion species were mixed during the injection into the synchrotron, before being simultaneously accelerated and extracted into the research irradiation room. There the ion mix was characterized using radiochromic films, low-gain avalanche diode detectors, and a configuration of two ionization chambers separated by multiple PTW RW3 slabs.

This talk provides a general overview of recent breakthroughs in mixed ion beam delivery, discusses technical challenges, and explores the future potential for treatment monitoring in ion beam therapy.

ST 4.2 Wed 14:15 ZHG009

Beam Dynamics and Energy Variation in H-Type Drift Tube Linac for Proton Eye Therapy — •Ali Almomani — Physics Department, Yarmouk University, 21163 Irbid, Jordan

In this study, we investigate the beam dynamics of a proposed H-type drift tube linac (DTL) designed for proton therapy in eye cancer treatment, utilizing the KONUS (Kombinierte Null Grad Struktur) beam dynamics approach and LORASR code. The linac design accelerates protons from 3 MeV to 70 MeV across six cavities with 140 accelerating gaps along a 20-meter structure, operating at a frequency of 325.244 MHz. To ensure transverse beam focusing and beam matching, 11 triplet quadrupole lenses are distributed along the linac. The beam dynamics analysis yielded optimized values for drift tube lengths and gap distances, and simulations showed 100% beam transmission efficiency. The design demonstrated low emittance growth, with less than 20% transversely and 90% longitudinally, ensuring a highly focused beam. The output beam emittances are smaller than what cyclotron can offer, facilitating the generation of a pencil beam capable of scanning the tumor volume from one point to another. Additionally, energy variation options allow flexible beam energy adjustment between 58 and 70 MeV, enabling customizable treatment depths. The energy variation may be realized by varying the gap of voltage levels. The simulation results indicate a stable structure even in the presence of machine errors, supporting further development for RF simulations and mechanical modeling. The overall outcomes are promising, confirming the feasibility of the design for proton therapy applications.

ST 4.3 Wed 14:30 ZHG009

Beam spot diagnostics of highly focused electron beams in therapeutic X-Ray generators via Optical Transition Radiation — •Thomas Beiser[1] and Kurt Aulenbacher[2] — [1]Helmholtz-Institute Mainz, (Germany), GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany) — [2]Helmholtz-Institute Mainz, (Germany), GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany), Johannes Gutenberg-University, Mainz (Germany)

Optical Transition Radiation (OTR), which is commonly used for beam diagnostics in accelerators at high energies (e.g. MeV to GeV electrons), allows for beam spot diagnostics of intense and highly focused electron beams in therapeutic X-Ray generators with energies as low as 100 keV, using off-the-shelf camera equipment.

ST 4.4 Wed 14:45 ZHG009

Development of a Fast Extraction Method to Extract High Intensity Short Pluses at ELSA — •Leonardo Thome, Klaus Desch, Dennis Proft, and Michael Switka — Physikalisches Institut der Universität Bonn

The electron accelerator facility ELSA delivers electron beams up to 3.2 GeV energy, extracted via slow resonance extraction from the stretcher ring in an extraction cycle of typically 10 s. Currently ongoing studies for radiation therapy, investigating the FLASH effect, require short beam pulses reaching from ns to ms. In a preliminary operation mode the booster synchrotron is already used to deliver electrons beam pulses of 1.2 GeV energy with fixed length of 250 ns to irradiate cell samples. To cover higher energies up to 3.2 GeV and different pulse lengths ranging from ns up to several ms, a fast extraction method from the stretcher ring is developed. The concept and realization by different techniques such as a repurposing of the existing injection kickers for extraction or utilizing a dispersive orbit to extract the beam is evaluated.

ST 4.5 Wed 15:00 ZHG009

First Results from Cell Irradiation Experiments with Ultrahigh-Energy Electrons (UHEE) at ELSA — •Susanne Spaeth[1], Manuela Denz[2], Klaus Desch[1], Stephan Garbe[2], Frank Giordano[3], Barbara Link[3], Carsten Herskind[3], Barbara Link[3], Dennis Proft[1], and Leonardo Thome[1] — [1]Physikalisches Insitut der Universität Bonn — [2]Klinik für Strahlentherapie und Radioonkologie, Universitätsklinikum Bonn — [3]Klinik für Strahlentherapie und Radioonkologie, Universitätsklinikum Mannheim

A new approach to improve radiotherapy is the use of the so-called FLASH effect, a phenomenon characterised by significantly reduced toxicity in healthy tissue at high dose rates (>40 Gy/s). This effect potentially broadens the therapeutic window, improving tumour control while minimising side effects. At the electron accelerator facility ELSA, the FLASH@ELSA project utilises ultra-high energy electrons (UHEE) to study their effect on tumour cells. Electrons with energies of 1.2 GeV are delivered in sub-microsecond pulses via the booster synchrotron, enabling dose rates up to 10 MGy/s due to the short pulse lengths of 250 ns. Cell samples are irradiated within a water phantom, with dosimetry performed using radiochromic films and luminous screens. Further the FLASH irradiation at ELSA is compared to conventional radiotherapy using a medical linear accelerator (Varian TrueBeam STx) at the University Hospital Bonn. This comparison provides the first survival curves contrasting FLASH and conventional irradiation.

ST 4.6 Wed 15:15 ZHG009

Dosimetry of broadband electrons from laser-plasma accelerators — •Antonio Tarzikhan[1], Arpad Lenart[2], Chuan Zheng[1], Thomas Heinemann[1], Constantin Aniculaesei[1], Mirela Cerchez[1], and Bernhard Hidding[1] — [1]Institute of Laser- and Plasmaphysics, Heinrich Heine University, Düsseldorf, Germany — [2]University of Strathclyde, Glasgow, Scottland

Laser-plasma accelerators (LPA) offers compact sources of highly relativistic electron beams for various applications. This study focuses on the dosimetry of broadband electron beams, which are accelerated using the Arcturus laser system at the University of Düsseldorf with laser pulse energies of several millijoules sufficient to accelerate electrons to kinetic energies in the mega-electronvolt range, resulting in an energy distribution characterized by a shallow penetration and high dose deposition at the surface. These electron beams are therefore ideally suited for the treatment of skin cancer. We present the design and calibration of various diagnostics components and report on first experimental results obtained in a recent measurement campaign, incorporated with simulations to optimize the parameters used for the characterization of the electron beam energy- and angular-distribution and the charge calibration to determine the dose. Additionally, accelerated electron beams from intrinsic ultra-short bunch durations, are excellent candidates for FLASH radiotherapy and thus, minimizing damage to surrounding healthy tissues. This highlights the potential of LPA as a new technology in medical physics.

ST 4.7 Wed 15:30 ZHG009

Acoustic tracing of dose deposition of laser accelerated ion-bunches by modulation of the depth-dose curve — •Jeannette Cadeggianini, Alexander Prasselsperger, Anna-Katharina

Schmidt, and Jörg Schreiber — Ludwig-Maximilian-Universität, München, Germany

A high-repetition-rate online dose reconstruction method is crucial for accelerated particle applications. Ionoacoustic measurements determine monoenergetic ion energies by recording acoustic signals generated by localized thermal expansion in the Bragg region. These waveforms encode the ion beam's energy and spatial distribution.

However, this method depends on pronounced spatial energy density gradients, which are absent in laser-accelerated ion beams, which exhibit broad, exponential energy spectra. To address this, we introduce TIMBRE (Tracing Ionoacoustic Modulations of Broad Energy Distributions), which uses modulator foils to create steeper energy deposition gradients. These foils serve two functions: due to the materials the stopping power in the foils is higher than in the interspaces, generating an acoustic wave at each interface because of the steep pressure gradient. Simultaneously, each foil reduces the amplitude of the signals from shallower foils, compressing the dynamic range.

By unfolding the measured acoustic traces with the corresponding analytic model, TIMBRE reconstructs depth dose distributions of laser-accelerated ion bunches. It offers a real-time diagnostic, supporting modern accelerators operating at Hz-level repetition rates and beyond.