ST 1: Medical Imaging

Time: Tuesday 11:00–12:15 Location: KH 01.013

ST 1.1 Tue 11:00 KH 01.013

Investigation of a Simulation Framework for the Two-Plane Imaging System — Patricia Borrego Jiménez, Kevin Kröninger, Hendrik Speiser, Annsofie Tappe, •Helen Thews, Jens Weingarten, and Sophia Wortmann — TU Dortmund, department of physics, Dortmund, Germany

In radiotherapy for cancer treatment, proton therapy is an important treatment due to the steep dose gradient, which leads to a high conformal dose distribution while sparing healthy tissue. However, anatomical changes of the patient have a high impact on the range of the protons; this uncertainty leads to larger safety margins. One opportunity to minimize this uncertainty is to use proton imaging in adaptive proton therapy.

A Two-Plane Proton Imaging System (TPIS) consisting of two ATLAS IBL pixel detector planes offers the opportunity to take water-equivalent-thickness (WET) images of the patient. These WET images can be used to identify anatomical changes in the patient's body. To take a look at the reachable WET resolution and the full-body dose, a simulation framework is being developed, which is validated using RayStation. The simulation framework mainly consists of TOPAS to simulate the dose in the patient's body and the deposited energy in the sensor. The detector readout is afterward simulated in Allpix Squared.

This talk will introduce the TPIS and its current status. Then the simulation framework is discussed. Finally, the first results of simulation studies using this simulation framework are shown.

ST 1.2 Tue 11:15 KH 01.013

Clinical studies on the proton radiography system — •Sophia Wortmann, Patricia Borrego Jiménez, Kevin Kröninger, Hendrik Speiser, Helen Thews, and Jens Weingarten — TU Dortmund Department of Physics, Dortmund, Germany

In proton radiography the water-equivalent thickness (WET) is determined to characterize material and density distributions with high precision. In adaptive proton therapy this information can be used to detect range changes that arise from anatomical variations between treatment fractions. A two-plane imaging system (TPIS) was developed for this purpose and a corresponding simulation framework was created. The goal of this project is to validate the framework by comparing its results with calculations from the RayStation treatment-planning system and to prepare it for use in preclinical studies.

In this work the experimental measurements with the TPIS are reproduced in TOPAS and WET reconstructions that allow quantitative comparison are generated. The validation starts with simple PLA plate phantoms and is later extended to a more complex skull phantom. For all phantoms the achievable spatial resolution, the WET accuracy and the deposited dose are evaluated. These results provide an initial evaluation of the imaging performance of the system and are intended to support its use in future preclinical proton radiography studies.

ST 1.3 Tue 11:30 KH 01.013

From Compton Kinematics to Physics-Informed Neural Network Reconstruction for High-Energy Gamma Imaging — •Yazeed Balasmeh, Atharva Bahekar, Ivor Fleck, Mara Fries, Lars Maczey, and Devanshi Mehta — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

Compton cameras enable collimator-free imaging of high-energy gamma rays and are attractive for medical imaging, online range verification in cancer therapy, and targeted alpha therapy. This work presents a physics-informed neural network for Compton-camera image reconstruction that converts measured interaction positions and energies into a 2D source probability map. The objective is a general-purpose model that is computationally efficient, accurate, and stable across operating conditions, including incident energies from about 500 keV to 2 MeV and sources with varying sizes, shapes, and spatial distributions. Physical consistency is encouraged through physics-inspired inputs (e.g., reconstructed scatter angle, interaction-ordering cues, and detector-geometry features) and loss terms that penalize violations of Compton kinematics and constrain predictions to physically feasible Compton cones. A major focus is performance in low-statistics regimes relevant to Ac-225 targeted alpha therapy, where only a small number of detectable 1.57 MeV photons is available. We train and evaluate on Geant4-based simulations spanning count levels, energy spectra, and source configurations, and report energy- and statistics-dependent SSIM and peak-distance error.

ST 1.4 Tue 11:45 KH 01.013

Dark-field imaging of cancerous breast tissue — •Markus Kraft, Markus Schneider, Gisela Anton, Martin Rongen, Veronika Ludwig, Constantin Rauch, and Stefan Funk — ECAP FAU, Erlangen, Deutschland

Talbot-Lau X-ray phase-contrast imaging provides, next to the attenuation of X-rays, additional information about the phase shift in the object.This yields two additional image modalities, the differential phase image and the dark-field image, which results from small-angle scattering.

For breast-cancer detection, the dark-field signal is particularly valuable, as it yields a higher sensitivity to fine structures like microcalcifications. Those can be an indicator for ductal carcinoma in situ (DCIS), which accounts for 20-30% of breast cancer cases.

Currently, in at about 30% of DCIS operations, the cancer is not completely removed and a second operation is necessary. The goal of our project is to investigate the edges of the freshly removed cancer tissue for microcalcifications, via a dark-field CT. Ideally, this will enable us to provide immediate feedback to the surgeon if an increase of the surgical margin is necessary and, thereby preventing a second surgery.

Currently, we are optimizing the dark-field CT setup and are investigating sealed cancer-tissue samples provided by the "Pathologie Uniklinikum Erlangen" to verify the feasibility of the localization of microcalcifications.

ST 1.5 Tue 12:00 KH 01.013

Reconfigurable Metamaterials in MRI — •Dennis Philipp[1,2], Johannes Mueller[1,2], and Matthias Guenther[1,2] — [1]Fraunhofer MEVIS, Bremen, Germany — [2]University of Bremen, Bremen, Germany

Reconfigurable metamaterials (MTMs), operated in Tx and/or Rx during an MRI scan are an exciting new technology to leverage the full potential of MRI towards new imaging paradigms and potentially overcome existing limitations in terms of, e.g., SNR and imaging speed. They allow for on-demand RF field shaping during and/or between acquisitions and, thus, introduce new degrees of freedom into MRI. The potential advantages are, e.g., tailored local and spatio-temporal SNR enhancement for manifold applications.

Reconfigurable MTM prototypes are studied in simulations to infer a suitable geometry and parameter range of lumped elements for use in a 3T scanner. Prototypes are manufactured on rigid/flexible substrates and validated.