ST 2: Medical Imaging Concepts

Time: Tuesday 17:00–18:30 Location: ZEU/0146

ST 2.1 Tue 17:00 ZEU/0146

Investigation of the prospects of BaF2 as a fast scintillator for TOF-PET — •Katrin Herweg, Vanessa Nadig, Volkmar Schulz, and Stefan Gundacker — Department of Physics of Molecular Imaging Systems, RWTH Aachen University, Aachen, Germany

Future time-of-flight positron emission tomography (TOF-PET) will be in need of ultra-fast scintillation, with potential seen in cross-luminescencent materials like BaF2, which shows a sub-100ps decay time with 300 photons produced per MeV. However, it poses challenges such as medium radiation length, low photofraction, moderate light yield and VUV emission around 200nm. A slow emission at 310nm presents an additional challenge, which has been addressed before by doping BaF2 with yttrium. Recent developments in UV-sensitive SiPMs (here manufactured by Hamamatsu) have the potential to establish cross-luminescence for ultrafast TOF in PET. In this work, we aim to study BaF2, read out by these new VUV SiPMs, as a viable alternative to LYSO:Ce:Ca. Comparing the coincidence time resolution (CTR) of air-coupled 2 x 2 x 20mm3 undoped and yttrium-doped BaF2 crystals to LYSO:Ce:Ca crystals of the same size, with high-frequency readout electronics, we reached 233ps with undoped BaF2 and 213ps with BaF2:Y. The performance of LYSO:Ce:Ca was 181ps with Hamamatsu SiPMs optimized for LYSO. Conducting measurements at different depth of interaction positions shows a pronounced impact on the CTR. Furthermore, we investigated the performance for systems of BaF2 with TOFPET2c ASIC measurements and Geant4 simulations for effective sensitivity comparisons to LYSO:Ce:Ca.

ST 2.2 Tue 17:15 ZEU/0146

Advancements in Energy Resolution for Positron Emission Tomography with light sharing Scintillation Crystals — •Matthias Bovelett[1], Florian Müller[1], Yannik Kuhl[1], Stephan Naunheim[1], David Schug[1,2], and Volkmar Schulz[1,2] — [1]Department of Physics of Molecular Imaging Systems, RWTH Aachen University — [2]Hyperion Hybrid Imaging Systems GmbH

Positron Emission Tomography (PET) is widely used in clinical and pre-clinical applications. Commercially available PET-detectors use arrays of segmented scintillators coupled to a SiPM matrix. Of current scientific interest are detectors using light sharing scintillators. In these, the scintillator covers multiple SiPM channels and, therefore, one gamma interaction shares the light among the optically coupled SiPM channels. Key parameters of the gamma interaction, i.e., interaction position, timing, and energy information, need to be reconstructed from the measured light distribution. To acquire a good energy resolution in PET it is necessary to filter out specimen scattered events, thereby reducing background, and improving the signal to noise ratio. This work presents a framework, in which a light sharing scintillator is divided in virtual voxels. For each voxel a dedicated energy calibration is performed. Different summation pattern of involved SiPM channels and their impact on the energy resolution are discussed, including events for which not all SiPM channels were read-out. For these "incomplete" light distributions ($\sim$ 15% of all) imputation strategies are presented. Overall, the presented strategies result in an improvement from 14% to below 12% for energy resolution of all events.

ST 2.3 Tue 17:30 ZEU/0146

Metamaterials for Magnetic Resonance Imaging — •Dennis Philipp — Fraunhofer Institute for Digital Medicine MEVIS, 28359 Bremen, Germany

Electromagnetic metamaterials (MTMs) offer manifold degrees of freedom in MRI applications. Most prominently, field homogeneity improvement and signal-to-noise ratio (SNR) enhancement are typical use cases. However, passive MTMs also have some drawbacks such as transmit field (Tx) deformations. Here, we pave the way towards dynamic and active MTMs, which overcome some of the open problems. Bluetooth-controlled, reconfigurable MTMs for signal-to-noise ratio (SNR) enhancement in MRI are presented. These metasurfaces allow to be wirelessly interfaced and tuned during an MRI scan by means of a digital capacitor (DCAP), which is connected to a low-power microcontroller with BLE capabilities. Two prototypes are manufactured, one of which is a metasurface with adjustable resonance frequency, and the second one is dynamically tunable at the meta-atom (unit cell) scale. It includes multiple DCAPS and, thus, is the first wirelessly reconfigurable MTM for MRI that offers field shaping capabilities, adjustable FoV, focal regions, sequence sync., and active Tx detuning. A MTM arrangement that encloses a volume "metaBox" is shown to yield a significant and volume-homogeneous SNR enhancement in 3T MRI. Due to the integration of non-linear components, the structure self-detunes in Tx whilst being resonant in Rx. Fine-tuning capabilities are included in two different prototypes via (i) a manually trimmable capacitor and (ii) a BLE controlled DCAP.

ST 2.4 Tue 17:45 ZEU/0146

Proton Radiography: An Overview and Outlook — Jana Hohmann, Kevin Kröninger, Isabelle Schilling, •Hendrik Speiser, and Jens Weingarten — TU Dortmund, department of physics

For years, proton therapy has been increasingly used to treat cancer because of its well-known advantages, such as the high dose precision of protons. However, exploiting this precision requires improved imaging techniques to ensure accurate patient positioning and dose delivery. This allows to reduce the safety margin around the target volume and protecting the surrounding healthy tissue.

One such enhanced imaging technique is proton radiography. It allows to take images whose properties are directly dependent on the proton interactions with the structures in the patient. Therefore, by measuring the residual energy of protons after passing through the patient, conclusions on the stopping power distribution in the patient can be drawn. Extending a proton radiogram to a CT allows to reduce the proton range uncertainty from the conversion of Hounsfield units into stopping power. However, even a single proton radiogram taken on the treatment day can be used to verify the predefined therapy plan and the correct patient positioning.

This talk will include an introduction into the topic of proton radiography followed by an overview of several proton radiography approaches. Subsequently, two new methods developed and investigated at the TU Dortmund University are presented and discussed.

ST 2.5 Tue 18:00 ZEU/0146

A Two-plane Spectral Proton Radiography System using Silicon Pixel Detectors — •Jana Hohmann, Kevin Kröninger, Isabelle Schilling, Hendrik Speiser, Jens Weingarten, and Jolina Zillner — TU Dortmund University, Germany

To take advantage of the locally high dose in proton therapy the irradiation must be planned precisely. X-Ray CT images are used for this purpose. However, when Hounsfield units are converted to the stopping power of the material, this entails a range uncertainty in the treatment plan, which can lead to unintentional radiation damage in healthy tissue or to missing dose in the tumor.

To avoid this, the stopping power of the protons can be determined via imaging techniques with protons themselves. This could be used to verify and adjust the existing irradiation plan.

One attempt is a two-plane system that is designed to measure the water equivalent thickness (WET) directly, from which the stopping power can be calculated. Two pixelated silicon detectors with an absorber in between track the deposited energies of individual protons. With a reference measurement and the initial proton energy, the WET of a phantom can thus be determined.

The detector design is simulated and optimized in GEANT4. This is then used to determine the 2D WET distribution of a known phantom. The talk summarizes the simulation results and provides a comparison to the single plane method.

ST 2.6 Tue 18:15 ZEU/0146

Experimental characterization and comparison of two Si-based compact setups for proton radiography and tomography of small animals for image-guided proton irradiation — •Angelica Noto[1], Guyue Hu[1], Katrin Schnürle[1], Matthias Würl[1], Franz Englbrecht[1], Johannes Gebhard[1], Julie Lascaud[1], Marco Pinto[1], Ze Huang[1], Jonathan Bortfeldt[1], Mateusz Sitarz[2], Per Poulsen[2], and Katia Parodi[1] — [1]Medical Physics Department, LMU, Munich, Germany — [2]Danish Center for Particle Therapy, Aarhus University Hospital, Aarhus, Denmark

In the project SIRMIO we develop advanced imaging for positioning and treatment planning to aid precise proton irradiation of small animals.In contrast to the widely adopted X-ray cone beam CT, the project integrates 3 solutions of proton imaging. Here, we compare 2 approaches that provide spatially resolved detection of individual or integral proton energy deposition relying on the commercial Timepix3 or Lassena Si-based pixelated detectors. Proton radiographs were acquired at the Danish Center for Particle Therapy for a calibration phantom housing inserts of well characterized relative stopping power values. We will compare the achievable spatial resolution and accuracy of water equivalent thickness retrieval in radiographic mode for different systems and imaging doses. Moreover, ongoing acquisitions of tomography with the Timepix3 will be presented for the calibration phantom and a dedicated mouse-like phantom. The work is supported by EU through the grant agreements 725539, 730983 and 101008548. The authors would like to thank Nordson and Advacam.