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#09-164 Multi-Feature Treatment Verification in Particle Therapy

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Particle therapy constitutes a promising and rapidly developing method in modern cancer treatment. In order to exploit its full potential, however, it requires detailed dose verification.
Although the applicability of in-beam positron emission tomography and prompt gamma rays has already been demonstrated in patients, range verification is not yet part of the clinical routine in particle therapy. This is due to not only the methodological limitations of previous systems, but also to commercial, clinical and physical boundary conditions.
In pencil beam scanning, the state-of-the-art treatment method in particle therapy, the number of secondary particles (essentially positrons, prompt gamma rays and fast neutrons) available per spot ($\Delta t = 10$ ms to 100 ms) is limited. This leads to statistical accuracy limits for verification systems exploiting these secondary particles as range probes. The development of a clinically useable treatment verification system requires gathering as much information about the local dose, as possible.
The instantaneous fluence rate of prompt gamma rays reaching 5×10^6 cm^{-2}s^{-1} to 10^8 cm^{-2}s^{-1} challenges modern data acquisitions connected to monolithic inorganic scintillators with typical sizes used in present verification systems. In order to reduce the detector load, and also with regard to the ever higher intensities of next generation medical accelerators, future systems have to be more granular.
Multi-Feature Treatment Verification combines and extends established methods (prompt gamma-ray imaging, spectroscopy, timing, etc.) in order to achieve higher reliability and performance. This idea was taken up by the NOVO project and expanded by a multi-particle approach. The NOVO (i.e. *N*eutron and gamma-ray imaging with quasi-monolithic *o*rganic detector arrays –a novel, holistic approach to real-time range assessment-based treatment *v*erificati*o*n in particle therapy) consortium is a large collaboration of medical, nuclear and detector physicists, nuclear engineers, and mathematicians, which aim to develop a holistic real-time treatment verification system in particle therapy.
Elements of a potential multi-feature/multi-particle treatment verification multi-channel system were characterized in a double time-of-flight experiment at the pulsed photo-neutron source *n*ELBE (neutrons @ *E*lectron *L*inac for beams with high *B*rilliance and low *E*mittance). The essential properties (time resolution, light yield, detection efficiency and pulse shape discrimination) of an EJ-276 plastic scintillator were determined.
The very first experimental results show that the time resolution ($\Delta T < 400$ ns) of a $20 \times 20 \times 200$ mm^3 EJ-276 plastic scintillator with double-sided readout will reach the high demands of such a proposed range verification system. However, the determined quality of the pulse-shape discrimination, the energy resolution and the quite high neutron detection threshold of above 200 keV show that the light yield of this type of scintillator is not high enough to be used in a multi-feature-based treatment verification system. Particle transport calculations with MCNP6 and GEANT4 were performed to confirm the experimental results of a single detector element. Furthermore, they also show a promising measurement accuracy of a multi-channel overall system.

Primary author: KÖGLER, Toni (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany)

Co-authors: Dr ALAGOZ, Enver (Department of Computer Science, Electrical Engineering and Mathematical Sciences, Western Norway University of Applied Sciences, Bergen, Norway); Dr BEYER, Roland (Helmholtz-Zen-

trum Dresden –Rossendorf, Institute of Radiation Physics, Dresden, Germany); Mr HAMMER, Sebastian (Department of Computer Science, Electrical Engineering and Mathematical Sciences, Western Norway University of Applied Sciences, Bergen, Norway); Dr HYSING, Liv Bolstad (Department of Oncology and Medical Physics, Haukeland University Hospital, Bergen, Norway); Dr LUTZ, Benjamin (Helmholtz-Zentrum Dresden –Rossendorf, Institute of Radiation Physics, Dresden, Germany); Dr MERIC, Ilker (Department of Computer Science, Electrical Engineering and Mathematical Sciences, Western Norway University of Applied Sciences, Bergen, Norway); Mrs PERMATASARI, Felicia Fibiani (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany); Dr PETTERSEN, Helge Egil Seime (Department of Oncology and Medical Physics, Haukeland University Hospital, Bergen, Norway); Mrs ROEMER, Katja Ellen (Helmholtz-Zentrum Dresden –Rossendorf, Institute of Radiation Physics, Dresden, Germany); Dr SCHELLHAMMER, Sonja (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany); Dr SKJERDAL, Kyrre (Department of Computer Science, Electrical Engineering and Mathematical Sciences, Western Norway University of Applied Sciences, Bergen, Norway); Mr TURKO, Joseph (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany); Dr WAGNER, Andreas (Helmholtz-Zentrum Dresden –Rossendorf, Institute of Radiation Physics, Dresden, Germany); Dr WEINBERGER, David (Helmholtz-Zentrum Dresden –Rossendorf, Institute of Radiation Physics, Dresden, Germany); Mrs WERNER, Rahel-Debora (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany); Dr YTRE-HAUGE, Kristian (University of Bergen, Bergen, Norway); Dr PAUSCH, Guntram (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany)

Presenter: KÖGLER, Toni (OncoRay –National Center for Radiation Research in Oncology, Faculty of Medicine and University Hospital Carl Gustav Carus, Technische Universität Dresden, Helmholtz-Zentrum Dresden - Rossendorf, Dresden, Germany)

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