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Editorial: Prompt-gamma imaging in particle therapy

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Editorial on the Research Topic
Prompt-gamma imaging in particle therapy

Prompt gamma imaging (PGI) is a promising technique to tackle range uncertainties in particle therapy with protons, helium and carbon ions. Several concepts have been investigated since PGI was first proposed in 2003 [1]. Real-time tracking of the particle beams within the human body via PGI may represent a new leap into a more accurate method of dose delivery to tumors.

A young investigator's workshop was organized by the editors of this Research Topic to attract young investigators to this field and give them the opportunity to present their work and hear the insights from the pioneers and top experts. This workshop was held in July 2023 and attracted over 80 attendees from 18 countries (4 continents).

Following the workshop, we received 8 submissions and accepted 5 manuscripts for publication within the Frontiers in Physics Prompt-gamma Imaging in Particle Therapy Research Topic. Cheon and Min published a mini-review detailing several PGI systems currently under development, such as the knife-edge slit camera [2], the Compton camera [3, 4], the multi-array collimator camera [5], PGI with coded aperture [6], and the gamma electron vertex imaging [7]. The authors outlined several advantages and pitfalls of each system in verifying the beam range and suggested further improvements in detection efficiency, spatial resolution, and background reduction for integration in clinical practice.

He et al. developed a Monte Carlo study for prompt gamma timing (PGT) to explore a non-linear correlation between the PGT spectral width and range. The authors demonstrated a functional relationship between both for homogeneous materials as well as for simulated range shifts through the insertion of air cavities. Such results should offer new prospects for monitoring proton therapy range through PGT. Further studies will validate the contribution of the actual temporal structure of the proton beam and the temporal resolution of the detectors to the broadening of the time spectrum's width [8].

Nutter et al. suggested a modified Compton camera to infer the dose delivered to the patient via boron neutron capture therapy (BNCT). The authors proposed a $LaBr_3$ array and presented results simulated with Geant4. In such an array, all detectors may act as absorbers or scatterers, thus increasing the number of channels available for image reconstruction. The effect of shielding, also commonly used in SPECT cameras [9], was evaluated indicating a significantly lower background noise with ^{6}Li neutron shielding and significant 511 keV background associated to heavy element shielding. A source of the 478 keV photons was successfully identified in a simple water phantom containing a tumor region of 400 ppm ^{10}B for a neutron fluence of 1.0×10^{11} cm^{-2}. Such a feasibility study may open new avenues into PGI research for BNCT dosimetry.

Schellhammer et al. proposed a hybrid treatment verification using two radiation types: prompt gammas and neutrons. Employing machine-learning-based feature selection and multivariate modelling in the analysis of GATE-simulated data of a lung cancer case, they showed that such an approach leads to an improved precision of beam range verification by 30%–50%. The study constitutes an interesting alternative to other multi-modal approaches, e.g., PET-PGI [10].

Everaere et al. presented a novel prompt gamma detection technique, referred to as prompt gamma energy integration (PGEI), which is derived from prompt gamma peak integration [11]. PGEI involves the measurement of the energy deposited by all secondary particles emitted from proton or ion beam interactions. GATE simulations in a PMMA phantom surrounded by $LaBr_3$ crystals illustrated correlation between energy deposition and target position, while experimental measurements have allowed for the characterization of a $PbWO_4$ scintillator which can withstand clinical beam intensities without readout system saturation. This study demonstrates the feasibility of this novel method and lays the groundwork for further advancement of PGEI for online range verification.

These manuscripts illustrate the depth and breadth of technology currently under development to advance PGI and improve our abilities to accurately deliver proton and ion beam therapies. However, these authors also demonstrate the difficulties and challenges that still exist with PGI. It is crucial for young investigators and experts within the field to continue to collaborate to push the boundaries of PGI and continue to advance these techniques to further improve treatment accuracy and patient outcomes in particle therapy. PGI has advanced significantly since it was first proposed and, with further development, may soon re-define how particle therapy treatments are delivered.

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Publisher's note

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