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#9-192 Real-Time Proton Therapy Monte Carlo Simulations in Highly Parallelised Systems

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Proton therapy represents an advancement in modern brain cancer treatment, offering high precision in targeting tumours while sparing healthy brain tissue. A significant challenge still faced in proton therapy is uncertainty in the depth of proton penetration, which critically impacts successful treatment. The current leading candidate to tackle this problem is prompt gamma-ray monitoring, showing great promise in minimising collateral damage to healthy tissue. These techniques rely heavily on Monte Carlo simulations, which can take up to several hours to produce reliable results. However, treatment lasts approximately 2 minutes, and as such the simulations provide valuable insights only after treatment has been completed.

For a pencil-beam treatment plan of a typical tumour size, a simulation of ~1000 proton beams is required. If computation time of single proton beam could be reduced to an order of one tenth of a second, the entire simulation would be complete in under two minutes, matching the irradiation time of a patient in each treatment session. This reduction would allow real-time synchronisation of the simulations with beam delivery, enabling an alarm signal to be issued if a large deviation was observed between the experimental measurement and the simulation, before proceeding with the next beam treatment.

To achieve these simulation times, standard Monte Carlo simulation engines, even if parallelised in several CPU threads, have shown to be insufficient. Therefore, parallelisation of these algorithms in architectures with a higher degree of parallelism is the theoretical solution to the problem. A promising candidate for this purpose is SYCL (SYstem-wide Compute Language), a cross-platform and hardware-agnostic language that supports parallelisation on both GPUs and FPGAs. We are implementing pencil-beam dose calculation algorithms in this framework with promising results: computational speed has been increased by one order of magnitude. The future aim of this project is to gradually increase the complexity of these models to include nuclear reactions for prompt gamma-ray production, gamma-ray transport in the patient, and detection in an external scintillation detector used for monitoring, using established Monte Carlo simulation engines as a reference. The finalised algorithms will then be benchmarked against other hardware-specific methods such as cuda and OpenMP.

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