
Experiences with PRAVDA and future options

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Abstract

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PRAVDA is a fully solid-state proton imaging system developed as a flexible research bench to explore the capabilities and practicality of proton imaging, including pCT, for Proton Beam Therapy (PBT). In its current implementation, it employs custom silicon strip detectors (SSD) for both proton trackers and the range telescope (RT). The system is the result of four years work by the PRAVDA Consortium (funded by the Wellcome Trust).

An accepted estimate of range uncertainty in PBT is $\pm 2.4\% + 1.2$ mm. For a tumour situated at 20 cm inside a patient's body, the uncertainty on the delivered range would be in the order of ± 6 mm. This uncertainty can have a significant impact on the way dose is delivered, for example by increasing the need for larger treatment margins. Range uncertainties appear to be a major reason that prevents proton therapy reaching its maximum potential in sparing healthy tissue.

Several groups worldwide are working on the development of pCT imaging systems with the aim of reducing range uncertainty in treatment planning to $\leq 1\%$, to achieve a percent dose difference (D) to 'distance to agreement' (DTA) of $D/DTA=1\%/1$ mm as specified for treatment QA.

Due to the nature of proton scattering, quality pCT can only be realised by identifying individual proton trajectories through the patient by means of tracking detectors, to which a residual energy or range can be associated. In common with other pCT setups, PRAVDA considers a pair of proximal trackers to provide an incident vector, a pair of distal trackers for the exit vector and a residual energy (range) detector for recording the residual energy. Each tracker consists of three equi-rotated SSDs to allow higher fluences to be recorded. The SSDs are made of 150 μm -thick n-in-p silicon with an active area of $93 \times 96 \text{mm}^2$ and a strip pitch of $90.8 \mu\text{m}$. Detectors comprise 2048 strips (channels), readout by 16 ASICs. The ASICs are read out at a frequency of 26 MHz and up to 8 channels can be read out per readout cycle (39 ns). This translates into 2×10^8 protons/s being detectable over the full detector area.

The PRAVDA RT comprises 21 layers of SSD interleaved with variable thickness interlayer PMMA absorbers, so a 2 mm absorber provides a Water Equivalent Thickness (WET) of 2.8 mm per layer and an overall WET of 58.8 mm. The thickness of a single layer has been optimised to allow detection of lower energy protons, while first and last layers can be used as veto layers.

The PRAVDA custom data acquisition system (DAQ) is a highly modular design, which

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provides flexibility to seamlessly adjust the instrument to different experimental conditions (proton energy, phantom, thickness etc.) by simply adding or removing readout modules. Each module represents a group of three SSDs and their associated FPGAs, local memory and internal multiplexer, whose data output is handled by an external multiplexer. Data streams from each readout module is managed by a third level of multiplexers. The total data rate for the system is 28 Gb/s for the trackers and 42 Gb/s for the RT.

An exemplar pCT result for a 75 mm diameter PMMA spherical phantom with tissue substitute inserts (85 mm diameter 125 MeV proton beam) yielded accuracies in Relative Stopping Power (RSP) for the tissue substitute inserts of $\leq 1.6\%$

This presentation will discuss some of the practical issues in developing such instruments such as the need for accurate timing delays through the system as the protons decelerate, challenges of calibration, and the successful management of high data rates.

We have recently been awarded a further grant to develop a new system for pencil-beam delivery systems (to be installed in the Research Room of the The Christie PBT Centre, Manchester). Scanned delivery presents a new set of challenges and hence solutions; these will be introduced. PRaVDA2.0 will be very different to the original.

Though we will reliably obtain RSPs $< 1\%$, we need to work closely with clinicians and radiotherapists to understand what they need and how to fit into their workflows. Finally, we need to work towards solution that can be translated into the commercial world and so eventually benefit our "end customers" – cancer patients.