Faster QA through improved proton calorimetry. Another spin-off from particle physics

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Quality assurance (QA)

Energy quality assurance procedures take significant time and adjustment at different energies. An accurate calorimeter is needed to provide QA measurements in order to ensure the treatment is carried out safely and fast.

The aim of this project is to adapt the SuperNEMO calorimeter to the needs of clinical protons. In addition, the detector will also be used as the basis for a fast energy QA system. This will allow several energies to be measured across the full energy range available at the nozzle in only a few minutes, significantly reducing the time taken to carry out the daily QA.

Proton calorimetry development inspired by SupeNEMO scintillator detector R&D

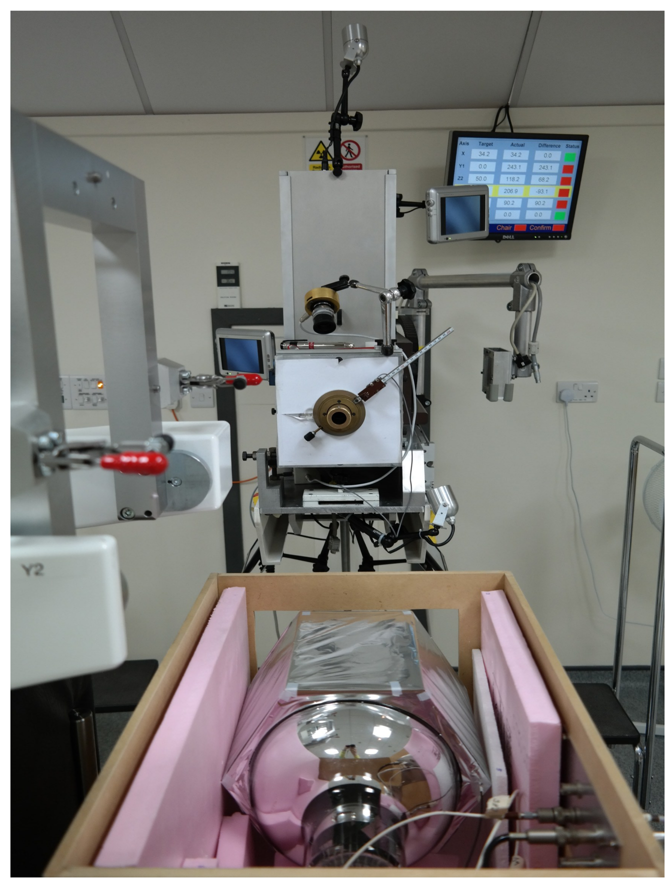
SuperNEMO is a neutrinoless double-beta decay experiment and it uses a Geiger mode tracker in conjunction with a plastic scintillator calorimeter (Fig. 1). The calorimeter has been optimised to measure electrons with energies of $E_e \sim 0.5$ - 4 MeV which is the energy range of interest for neutrinoless double-beta decay. Some preliminary calculations showed that the SuperNEMO detector can achieve an energy resolution in the region of 1% for clinical proton energies. This is remarkable for a plastic scintillator and required careful design.

The Clatterbridge Cancer Centre

The Clatterbridge Cancer Centre is the first proton therapy facility within UK (Fig. 2) treating different types of ocular tumours using a 60 MeV cyclotron. The 60 MeV beam is suitable for proton therapy, having a maximum clinical range of 31 mm in water. The staff from the Centre were very kind to give us access to the cyclotron, in order to take the measurements.

Figure 1: A PVT scintillator block. The block is 19.3 cm deep and the minimum thickness of scintillator between the front face and the PMT mounted at the rear is 10 cm. This device was found to have the best resolution for MeV energy electrons.

A)



B)

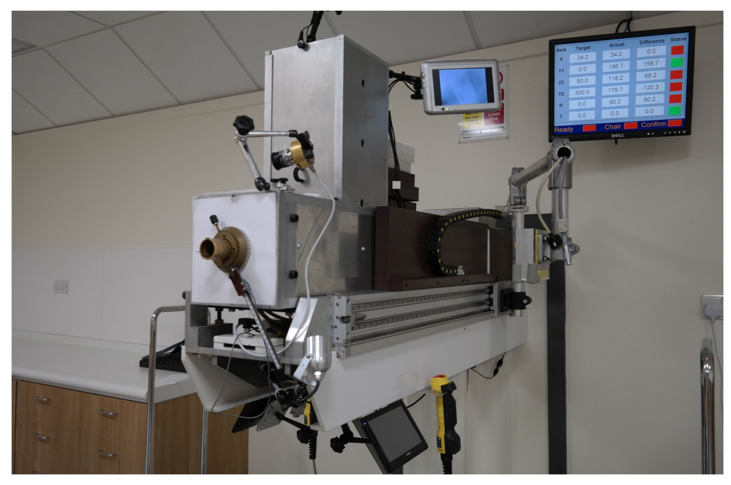


Figure 2. A) and B) Clatterbridge beam line.

Pulses

Data taken at the Clatterbridge Cancer Centre.

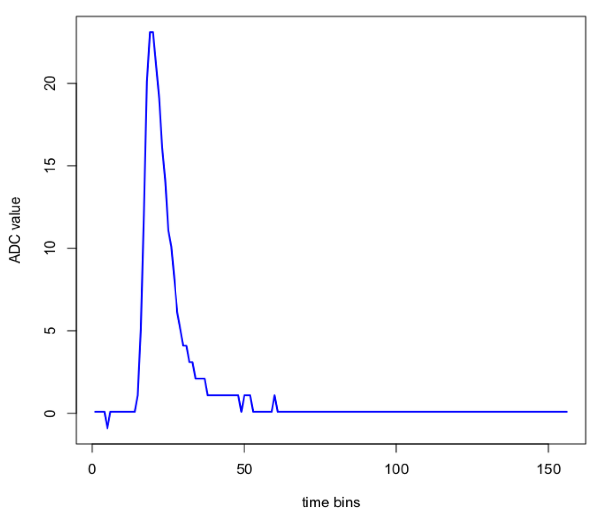


Figure 3: First pulse.

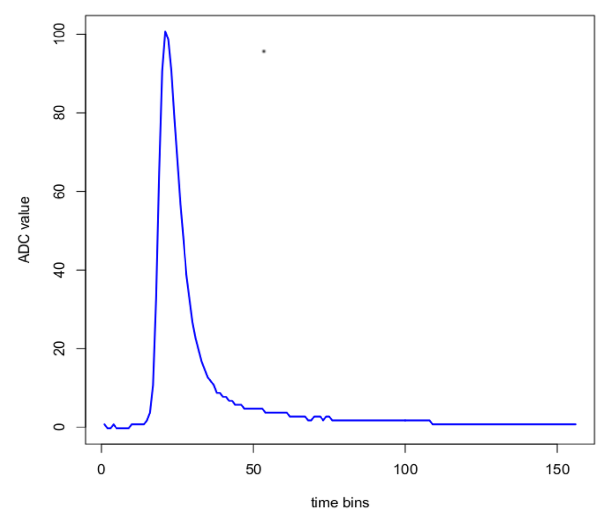


Figure 4: Second pulse.

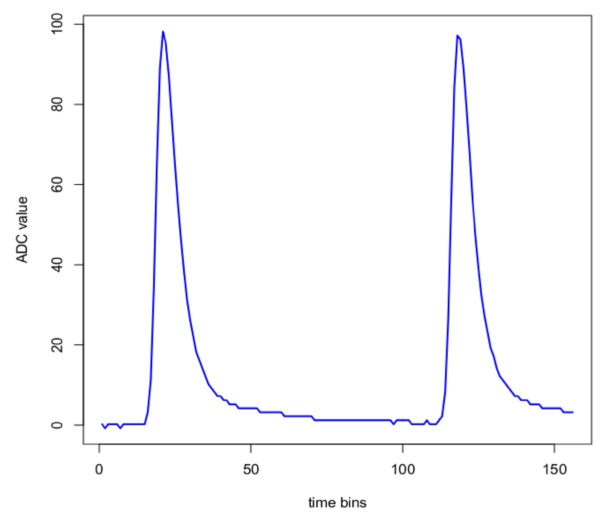


Figure 5: Double pulse.

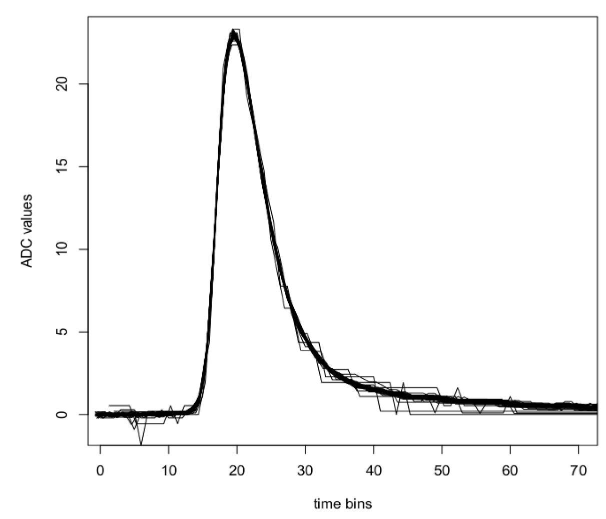


Figure 6: First 50 pulses scaled and superimposed. Gives a universal shape.

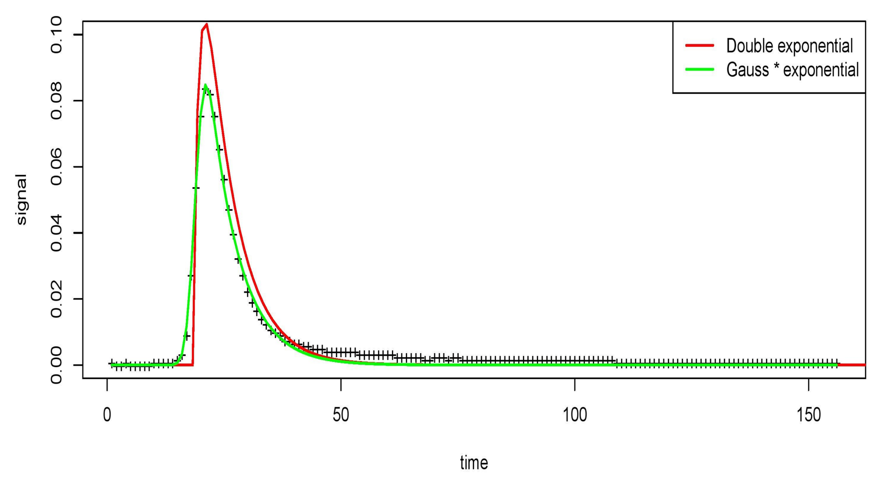


Figure 7: Double exponential is a poor fit. Gaussian exponential better fit.

Energy resolutions

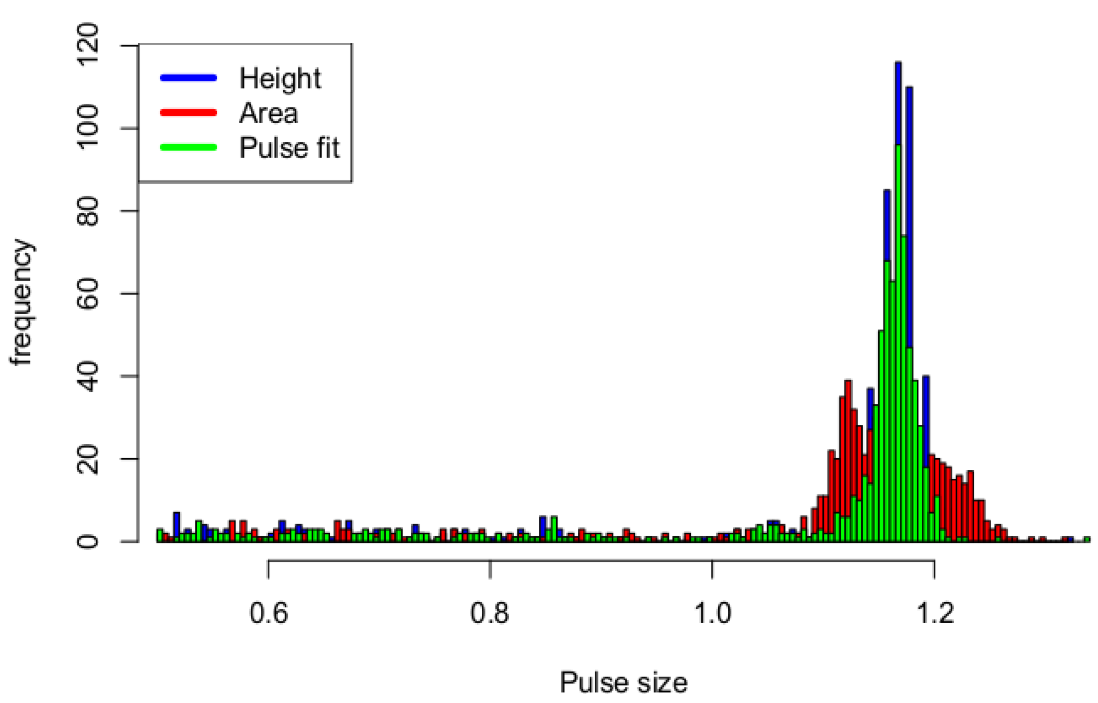


Figure 8: Pulse fit gives a better resolution than the height and the area. Resolution bellow 1%.

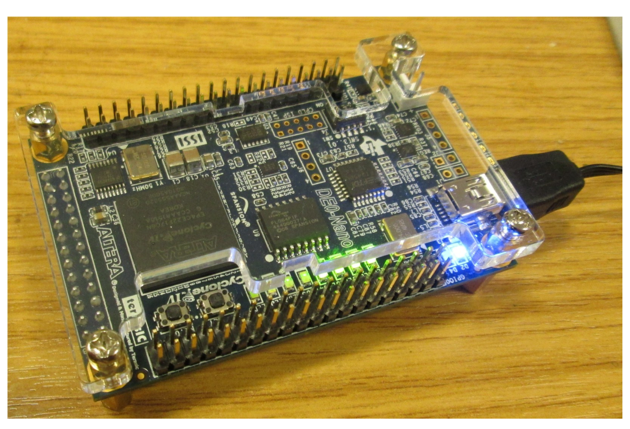


Figure 10: FPGA

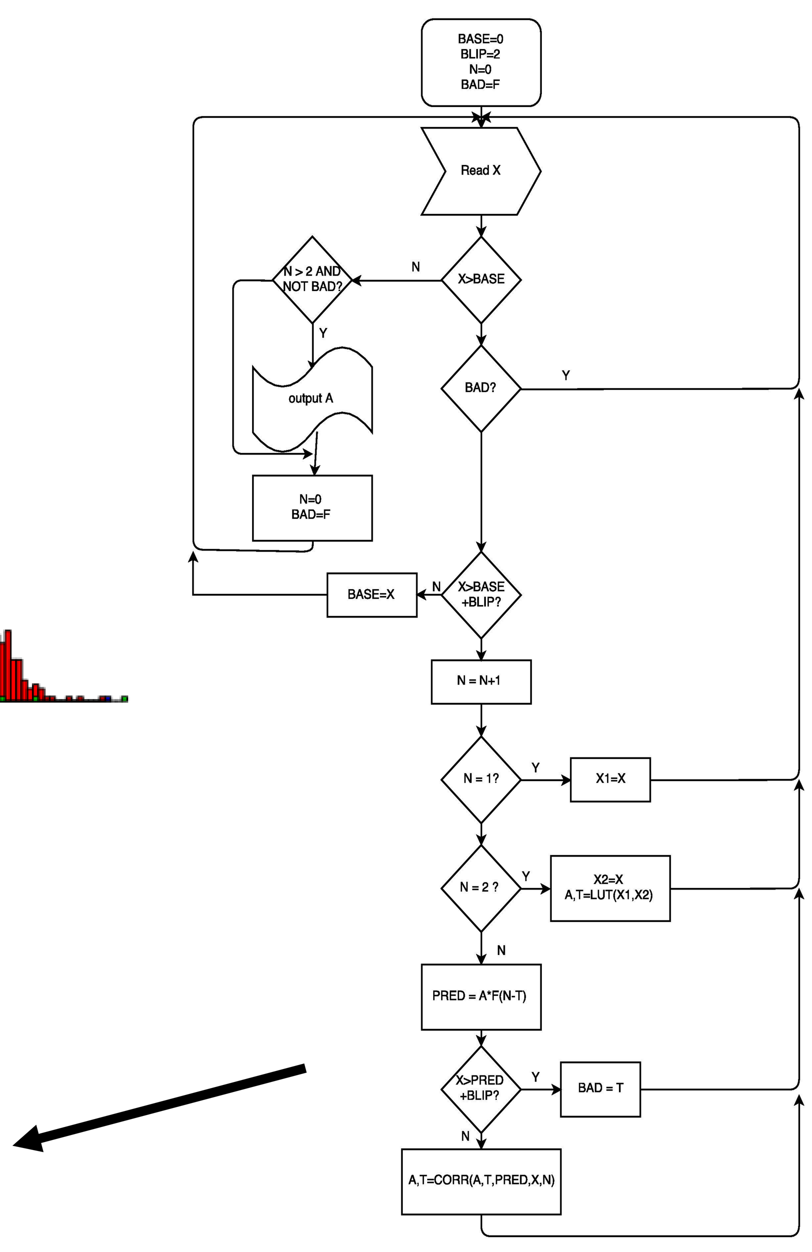


Figure 9: Flow chart for pipe-lined pulse analysis in FPGA.

Proton CT

The aim of this study seeks to adapt existing calorimetry technology for the precise measurement of proton energy in clinical setting. The primary goal is to provide a high-speed, accurate calorimeter for a proton QA, but hopefully it may also be used for a full proton CT detector (Fig. 11).

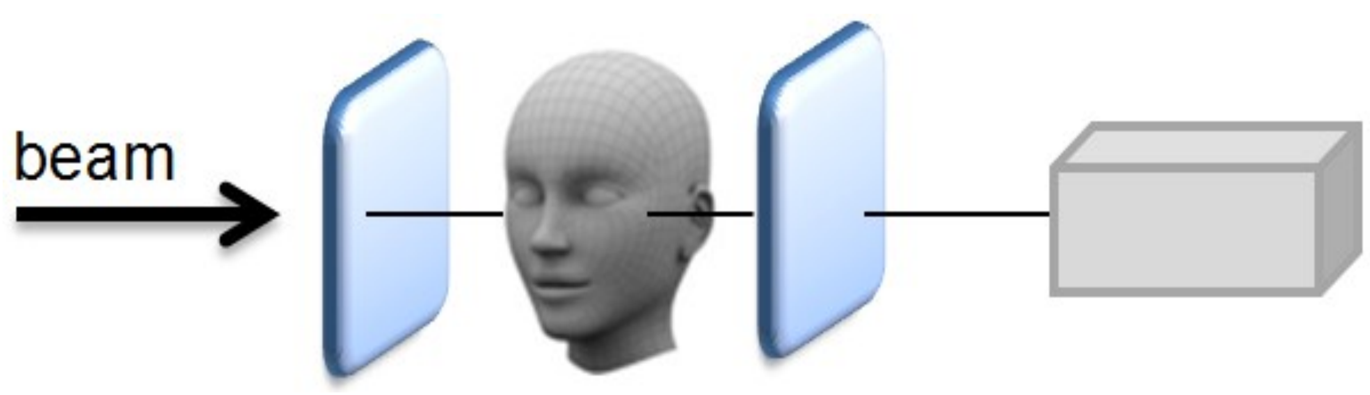


Figure 11: Schematic approach to pCT: tracking chambers and plastic scintillator.