Proof of Principle Detector for Fast Patient Quality Assurance

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Overview

Treatment plan verification (TPV), or patient-specific quality assurance (patient QA), requires detailed information about the volumetric dose deposition within an instrumented volume, to ensure the accurate delivery of dose for a given treatment plan. Current methods of patient QA are time-consuming, necessitating the repeated scanning of water phantoms. A collaboration between the High Energy Physics group at University College London and the Physics Dept. at the University of Birmingham is developing a prototype system for fast patient QA.

Combines a single-module plastic scintillator-based calorimeters developed at UCL for the SuperNEMO high energy physics experiment to measure single proton energy with the silicon trackers developed at Birmingham for the PRaVDA proton CT project to reconstruct 2D proton position.

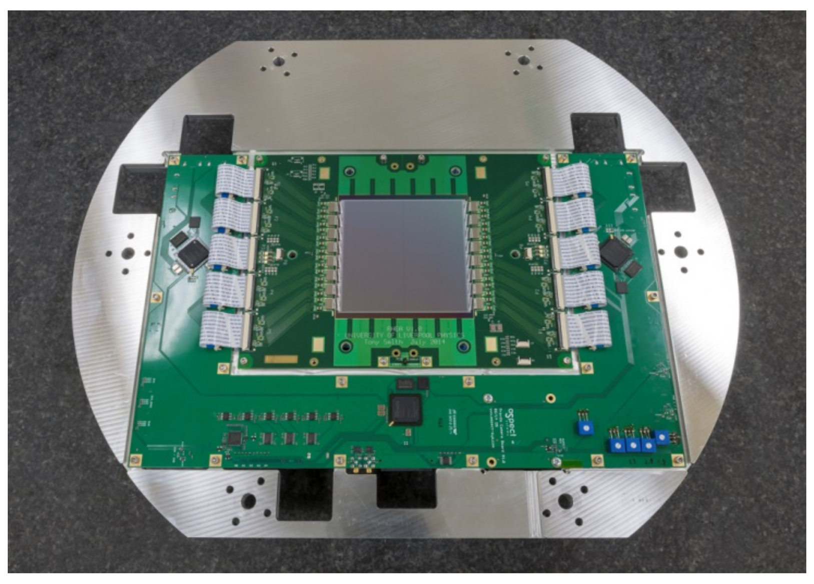
Also the potential for reconstructing the 3D dose deposition for individual protons and therefore build up the complete volumetric dose distribution for a given treatment plan.

Silicon Strip Trackers

The tracking system uses silicon strip detectors developed by the PRaVDA project to measure the position of the protons. The tracking detector consists of 3 sensors that are rotated at 60˚relative to each other to allow the reconstruction of proton tracks in an x-u-v co-ordinate system. This configuration had been show to reduce ambiguities at higher beam currents.

Strip Sensor Parameters:

- Active area of 93x96 mm^2
- 150 um thick n-in-p silicon
- Strip pitch of 90.8 um
- Read out at 26 MHz
- Radiation hard



The firmware was modified from the PRaVDA project such that a trigger signal is generated less than 100 ns after a hit over threshold is registered on two or three layers

UCL Proton Calorimeter

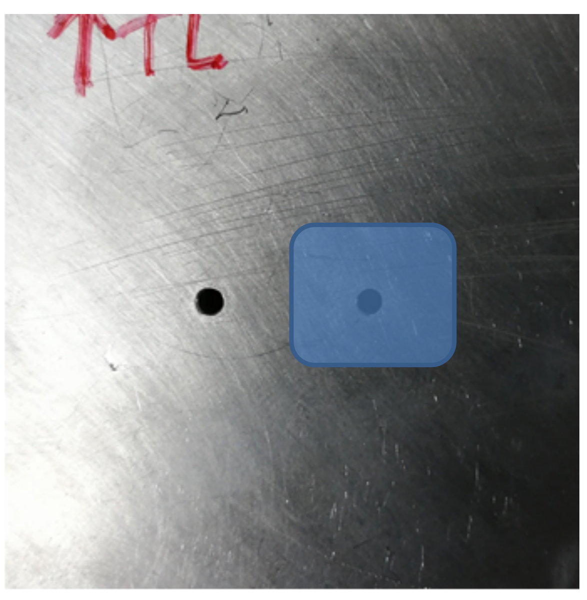
Based on the calorimeters developed for the SuperNEMO neutrino-less double beta decay experiment where excellent energy resolution is paramount. 3x3x5cm polystyrene scintillator block wrapped in Mylar foil and read out with a Hamamatsu R13089 PMT

- Polystyrene is almost water equivalent
- High light output yields excellent energy resolution
- Response time in the order of ns
- Previous measurements at Clatterbridge Cancer Centre have demonstrated an energy resolution of 0.5% σ @ 60 MeV

Experiments

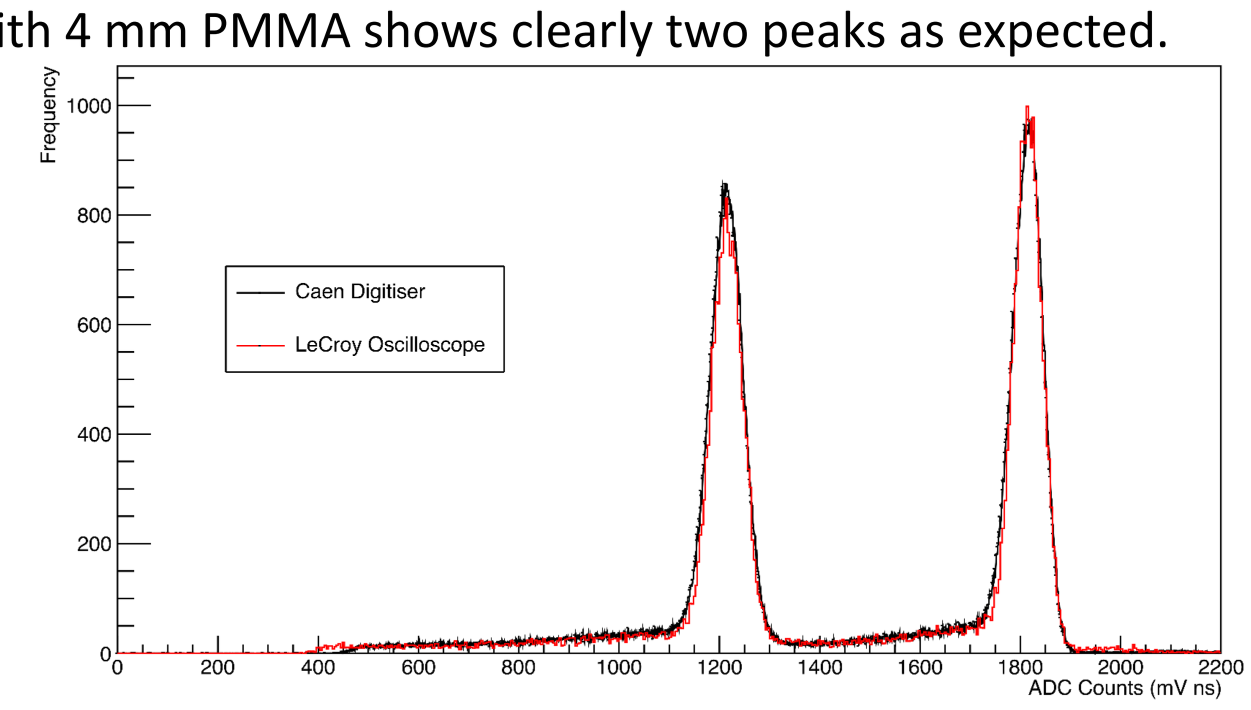
Experiments conducted on the University of Birmingham MC40 cyclotron combining the readout of the silicon tracker and UCL proton calorimeter. Calorimeter read out by both a CAEN digitizer and LeCroy 'scope triggered by the PRaVDA silicon tracker.

- Spot size = 5 mm
- Proton current ~= 10 pA
- Beam Energy = 36 MeV
- Energy calibrated by degrading beam with sheets of 1-6 mm PMMA
- Snake bite collimator with one hole covered with PMMA to mix energies into the calorimeter volume

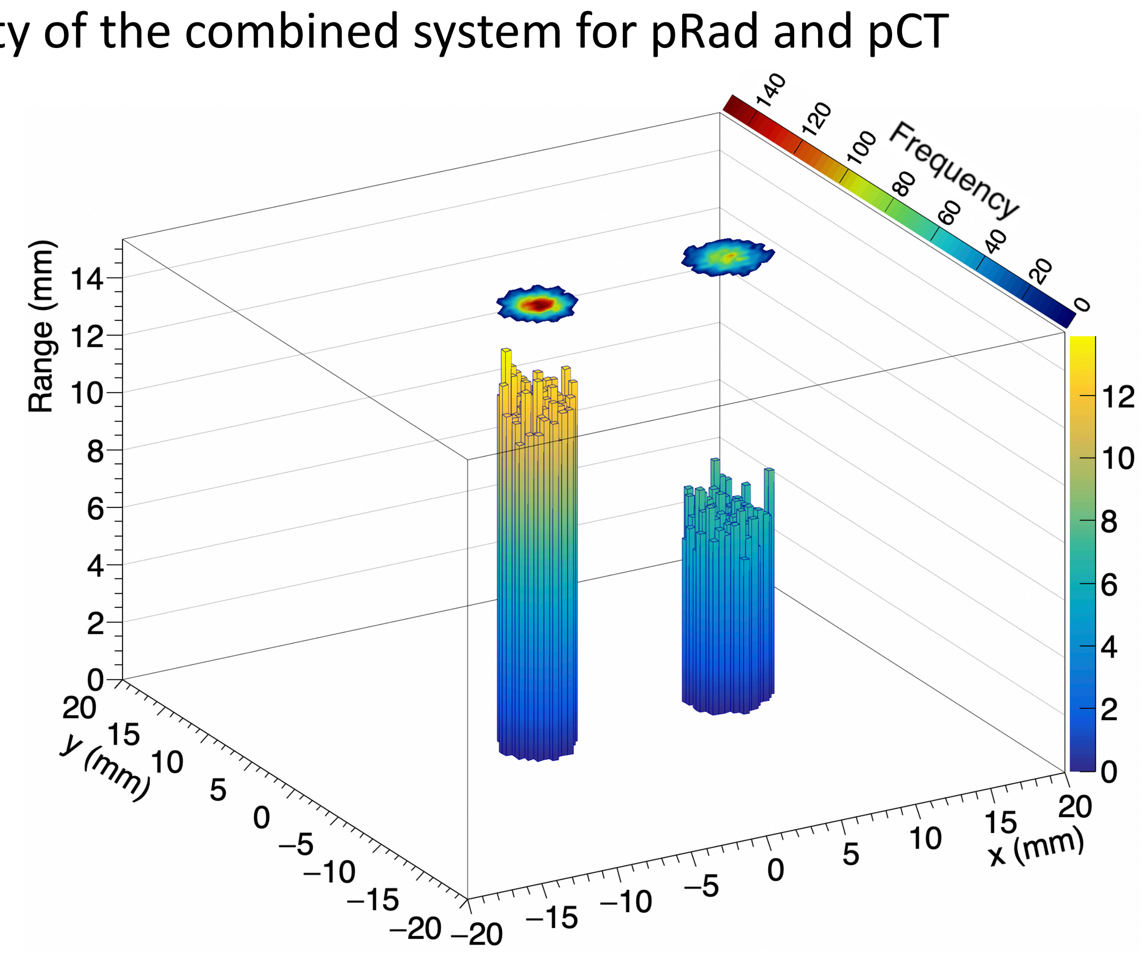


Results

Triggering the UCL Proton Calorimeter readout using the PRaVDA tracking unit allowed the two systems to be tied together in space and time. The energy response of the calorimeter for the 36 MeV beam and 36 MeV beam with 4 mm PMMA shows clearly two peaks as expected.



The reconstructed proton ranges are then combined with position information from the PRaVDA tracker to create a 3D range plot. The 2D plot superimposed at the top shows the reconstructed position from the trackers and shows excellent synchronisation between the two systems. Future work will add the full PRaVDA tracking system and investigate the rate capacity of the combined system for pRad and pCT



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