Detection and Simulation of Bragg Peaks in Proton Therapy Using Plastic Scintillators and Multiple Cameras

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INTRODUCTION

Knowledge of the precise location of the Bragg Peak (BP) in proton therapy for cancer treatment is crucial for optimizing its therapeutic effects and to minimize damage to healthy tissues [1]. In this work, we present experimental results and simulations of the light emitted by organic scintillators exposed to different proton energies and visualised by multiple cameras, in order to reconstruct the BP. Additionally, a CAEN WPET system was used to detect prompt gammas generated by the proton interactions with the scintillator, which would be used to confirm the Bragg Peak position. The TOPAS Monte Carlo simulation tool [2], based on Geant4, was used to accurately model the energy deposition of the proton beams and their light generation processes within the scintillators.

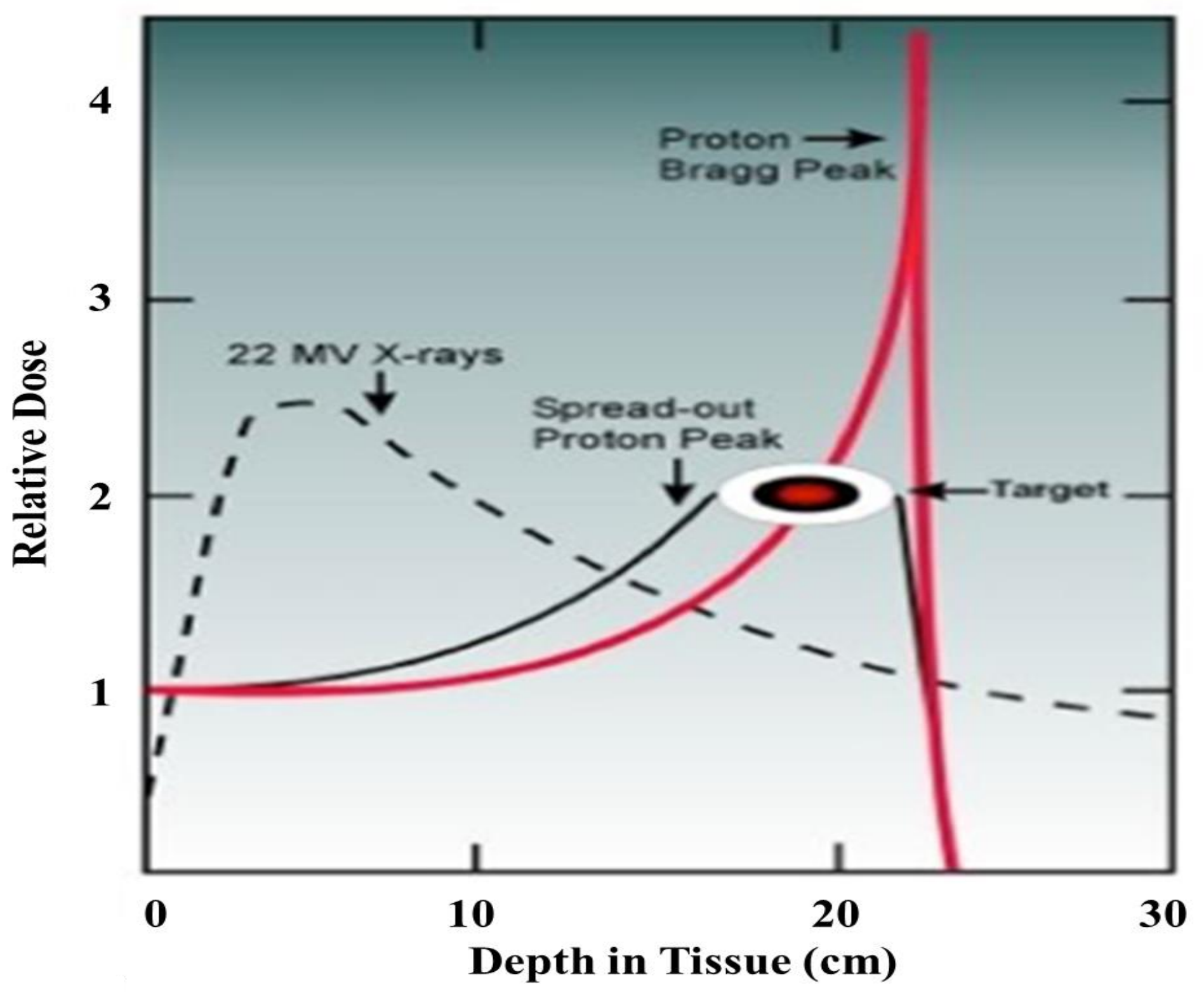

Fig.1 Relative dose against depth in tissue for X-rays and Protons

EXPERIMENTAL SETUP

To personalize the treatment for each patient, we use plastic scintillators and precise cameras to detect the BP before it is delivered to the tumor. Here, we have used 4 Raspberry Pi camera modules with different sensor types and with auto and fixed focuses to image the BP. Beam tests were performed at the Christie Proton Therapy Centre, Manchester, United Kingdom using a cuboidal polystyrene plastic scintillator with beam energies between 70 and 235 MeV. Image data were recorded using 16& 12.3 Megapixel Raspberry Pi cameras with Sony IMX519 & Sony IMX477 sensors positioned around the scintillator [3]. Further tests have been done using a CAEN WPET (LYSO+SiPMT) system [4] to detect prompt gammas produced within the scintillator. This has two detectors, each containing 64 LYSO + SiPMT arrays, read out by 16x8 ASIC channels.

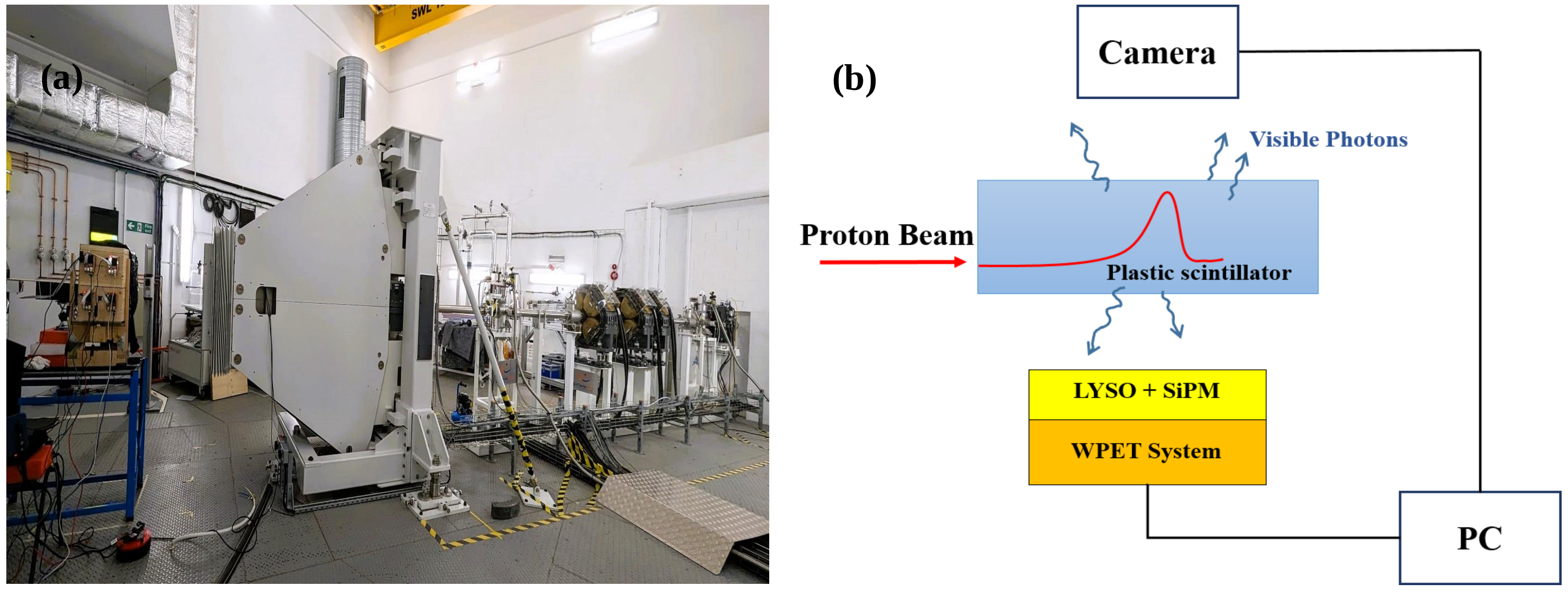

Fig.2(a) Experiments were carried out at the Christie Proton Beam Research Centre,UK, and (b) Schematic diagram of the experimental setup with Raspberry Pi cameras (to detect scintillation photons) & CAEN WPET system (to detect prompt gamma).

EXPERIMENTAL RESULTS

A proton beam interacting with a plastic scintillator produces visible photons (captured by Raspberry Pi cameras), and prompt gammas (recorded by the CAEN detector system (LYSO + SiPMT). Image data from the Raspberry Pi cameras are post-processed to determine the beam edges, beam spread, BP location and beam depth in the scintillator. The CAEN WPET system data have been processed to measure the energy spectrum of the prompt gammas & cumulative charges recorded by the two detectors. The WPET system gives good coverage of the gamma spectrum up to 4 MeV. This shows the general energy distribution of the prompt gammas, allowing for comparison with TOPAS simulations.

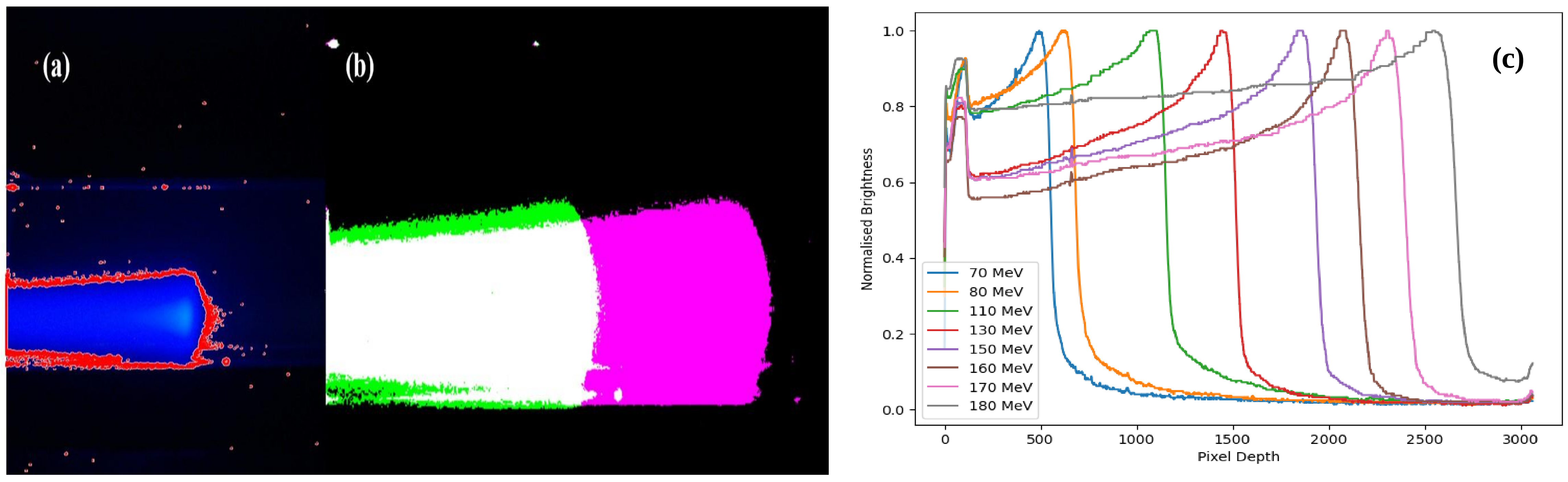

Fig. 3 (a) 160 MeV of Proton beam in plastic scintillator, image showing the brightest edges. Sober Kernel has been used to set up thresholds and edge cleaning has been performed by calculating the horizontal and vertical gradients, (b) Detection of beam spread while varying beam energy (convolution). Images are post-processed using MATLAB Machine Learning and image processing tools [5],and (c) Measured BP profiles at energies between 70 and 180 MeV, with normalized brightnesses.

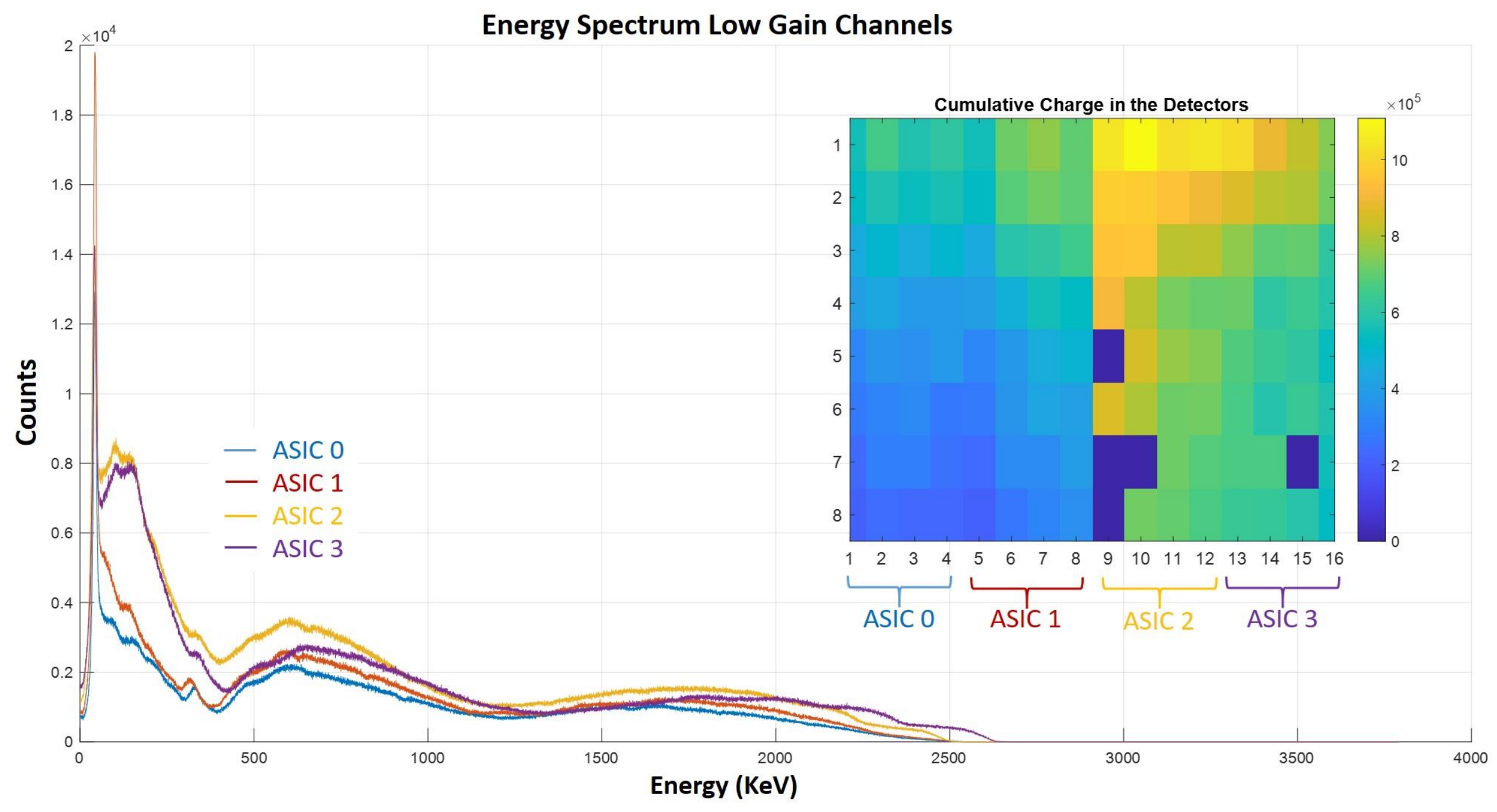

Fig.4 Gamma Spectrum at 160 MeV Proton Beam Energy recorded by the CAEN WPET system. Data from detector 1 is read out by ASIC 0 & ASIC 1, and detector 2 by ASIC 2 & ASIC 3. Inset shows the cumulative charge accumulated in the detectors, with detector 2 showing more charge as it is positioned closer to the BP.

COMPARISON OF DATA WITH SIMULATION

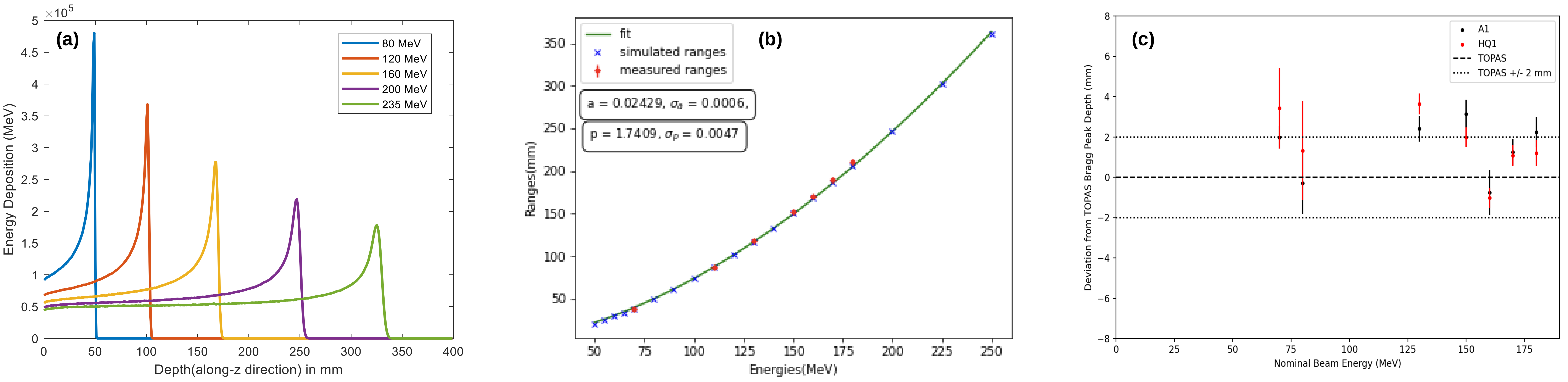

Fig.5 (a) Simulation of the Bragg Peak at various proton beam energies in plastic scintillators, (b) Simulated and measured mean ranges from TOPAS with a non-linear least square fit applied to optimise for parameters of the Bragg-Kleeman rule for polystyrene of density ρ = 1.03 ± 0.03 g cm−3. (c) The deviation of Bragg Peak depths (uncorrected and corrected), observed by the side cameras, from TOPAS simulations.

CONCLUSIONS: Experimental tests and Monte Carlo simulations were performed to determine the precise position of the Bragg Peak using a plastic scintillator coupled with precise cameras. The prompt gamma spectrum was also recorded using a CAEN WPET system. The experimental results match the theoretical predictions well and validate the methodology used. Further work will attempt the reconstruction of the Bragg Peak in 3-dimensions using the multiple-camera projections, as well as a more thorough analysis of the prompt gamma spectrum.

REFERENCES:

[1] W. D. Newhauser and R. Zhang, "The physics of proton therapy", *Physics in Medicine & Biology*, vol. 60, pp. 155-209, March 2015.
[2] "TOPAS tools for particle simulation", https://www.topasmc.org/home
[3] “Raspberry-pi 16MP Autofocus Camera from Arducam”, *<u>https://www.arducam.com/downloads/</u>arducam-16mp-autofocus-camera-product-brief.pdf*
[4] “CAEN WPET System”, https://www.caen.it/products/dt5550w
[5] “MATLAB image processing and computer vision toolbox”, *https://uk.mathworks.com/help/overview/image-processing-and-computer-vision.html?s_tid=hc_product_group_bc*

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