Time-of-Flight PET for Proton Therapy (TPPT)

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Introduction

Proton Therapy is an extremely powerful cancer treatment option that allow for precise treatment of cancers in vital organs due to the Bragg peak governing the depth of energy deposition. Using Time-of-Flight (ToF) PET imaging, the project seeks to provide real-time information of beam location and intensity. Specifically, the team is using Monte-Carlo Simulation and experimental data in conjunction to optimize the PET scanner for Proton Therapy by understanding detector response to isotopes produced by tissue activation.

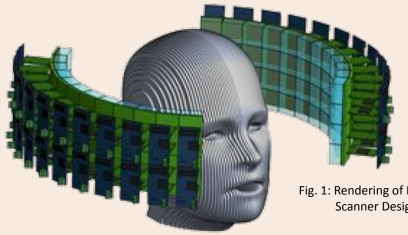


Fig. 1: Rendering of Final PET Scanner Design

Technical Details

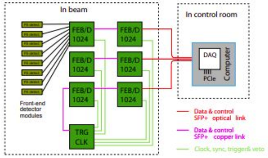


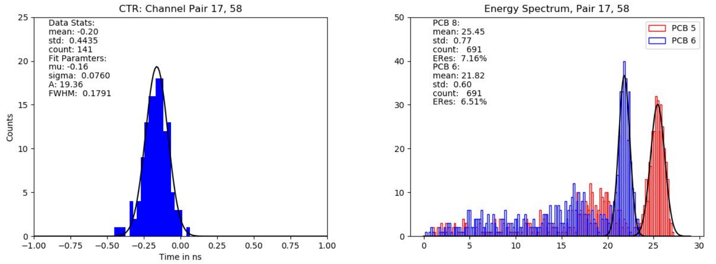
Fig. 2: Electronics Topology for the full scanner

Readout electronics were provided by PETSys Electronics and the topology for said readout is displayed on the left. The individual channel readout electronics use the TOFPET2 ASIC [1] in conjunction with the FEB/S SiPM readout board and the FEB/I ASIC interface board. The SiPM Model used is the Hamamatsu S14161-3050HS-08MPPC (multi-pixel photon counter) and was glued to the FEB/S with the EPO-TEC 301 epoxy which was chosen for its transparency and to match the crystal refractive index.

1: Francesco, A. et. al (2016). TOFPET 2: A high-performance circuit for PET time-of-flight. *Nucl. Instrum. Methods Phys. Res.*824. 194-195.

Figures and Results

Fig. 3 (top) shows the Coincidence Time Resolution (CTR) and Energy deposition spectra (charge scale not linearized) for a specific channel pair taken from experimental runs of crystal arrays already assembled in our labs. The CTR of 179 ps shows our full scanner will be on the cutting edge of performance, far exceeding scanners in popular use today.



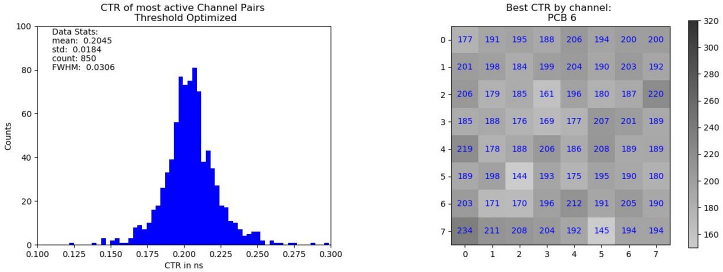
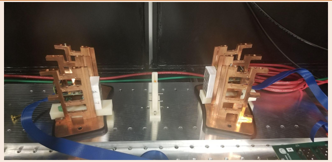


Fig. 4 (bottom) shows a histogram (left) of CTRs from all channel pairs once an optimization of electronic parameters has been completed, which is equivalent to a full scanner CTR. A mean CTR of 201 ps again demonstrates the superior performance this scanner will have, and greatly increases the precision of TOF reconstruction methods. Fig 4 also shows a heatmap (right) of the best CTR values per pixel for one of our arrays. The relatively even distribution shows we are receiving high quality data from many lines of response (LORs) at different orientations.

Experimental Setup



The experimental setup, pictured left, shows 4 LYSO crystal arrays coupled to the electronics with a Na-22 button source placed midway vertically between the pairs of arrays. Data runs were taken in a dark box for 30 minutes to ensure a robust data set and temperature control was maintained by an air cooling system pictured behind the arrays.

Conclusion

The combined power of PET Imaging and Proton Therapy treatment would allow for unparalleled precision in real time beam imaging that would make proton therapy a preferred option for cancer treatment. The preliminary experimental results, specifically the threshold adjusted CTR of 201 ps, show that the scanner has the potential to provide the extremely accurate beam position information needed to reduce or eliminate the amount of healthy tissue that is irradiated. This would vastly improve patient wellness post treatment compared to traditional radiation therapy and allow for the treatment of inoperable cancers in vital organs ike the brain, liver, and lungs.

Acknowledgments

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