Detector Performance Effects on Compton Camera Data Quality

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P. Maggi[1], S Peterson[2], D Mackin[3], R Panthi[3], S Beddar[3], J Polf[1]
[1] University of Maryland School of Medicine, Baltimore, MD
[2] University of Cape Town, Rondebosch, ZA
[3]University of Texas M. D. Anderson Cancer Center, Houston, TX

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INTRODUCTION

Compton imaging of prompt gamma emissions from proton therapy is a potential method for range verification. However, current Compton camera (CC) systems have multiple limitations at clinically relevant dose rates; they primarily suffer from high dead-time and false coincidence rates. This study presents the effects of different detector performance parameters on the data quality from the CC.

AIM

Determine how modifying the detector performance affects Compton camera data quality.

METHOD

Using a Monte Carlo plus Detector Effects (MCDE) model of our CZT based CC, we modified several detector performance parameters: 1) event coincidence acceptance window temporal length; 2) dead time scaling; 3) individual vs grouped crystal readout; 4) reduced crystal thickness. For each change we assessed the false coincidence percentage and event classification for intra-module events; detection efficiency for inter-module events; and total amount of data suitable for image reconstruction. Eight detector modifications were tested at three dose rates for a 150 MeV proton pencil beam incident on HDPE: 0 kMU/min (reference), 20 kMU/min (minimum cyclotron output), and 180 kMU/min (maximum cyclotron output). Data is reported primarily for doubles (two interactions, intramodule event) and triples (three interactions, intramodule event). Table 1 presents the specifics of each modification.

CONCLUSION

Reducing activation window time significantly reduces false-coincidence without affecting inter-module events. Reducing dead-time increase total data (including inter-module events), but does not improve data quality. Individual readout detectors are superior to grouped readout. Reducing crystal thickness did not offer a significant benefit.

RESULTS

The figures present the detected event distributions for the different detector modifications. Table 2 shows the total number of good events (i.e. events that could be usable for reconstruction) per unit proton.

***Table 1*: Labels and information regarding each detector modification.**

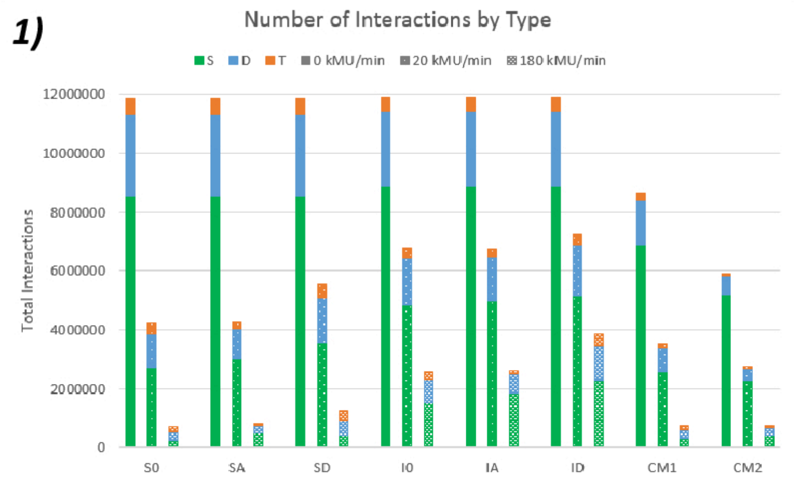
Designator	Acceptance Window	Dead Time Scaling	Readout Type	Crystal Thickness
S0	1.5 µs	1	4-Crystal group	10 mm/15 mm
SA	0.5 µs	1	4-Crystal group	10 mm/15 mm
SD	1.5 µs	0.5	4-Crystal group	10 mm/15 mm
I0	1.5 µs	1	Individual Crystal	10 mm/15 mm
ID	1.5 µs	0.5	Individual Crystal	10 mm/15 mm
IA	0.5 µs	1	Individual Crystal	10 mm/15 mm
CM1	1.5 µs	1	4-Crystal group	5 mm/10 mm
CM2	1.5 µs	1	4-Crystal group	2.5 mm/5 mm

***Table 2*: Expected number of good events per unit proton**

Dose-rate (kMU/min)	S0	SA	SD	I0	IA	ID	CM1	CM2
20	15.3×10^{-6}	14.0×10^{-6}	20.7×10^{-6}	24.0×10^{-6}	23.0×10^{-6}	27.1×10^{-6}	8.8×10^{-6}	3.9×10^{-6}
180	7.6×10^{-6}	6.6×10^{-6}	10.3×10^{-6}	10.9×10^{-6}	10.2×10^{-6}	12.3×10^{-6}	4.1×10^{-6}	1.6×10^{-6}

Figures (clockwise from top right):

1) Breakdown of total number of interactions at three different dose rates. S = Singles. D = Doubles. T = Triples. 0 kMU/min is an effective value to show the underlying distributions.
2) True and false intramodule double information.
3) True, false, and double-to-triple (2->3) intramodule triple information.
4) Number of possible intermodule events

1)


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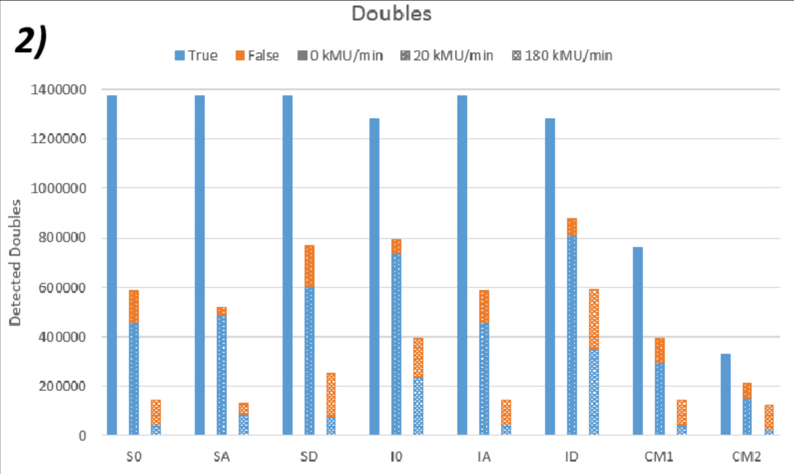

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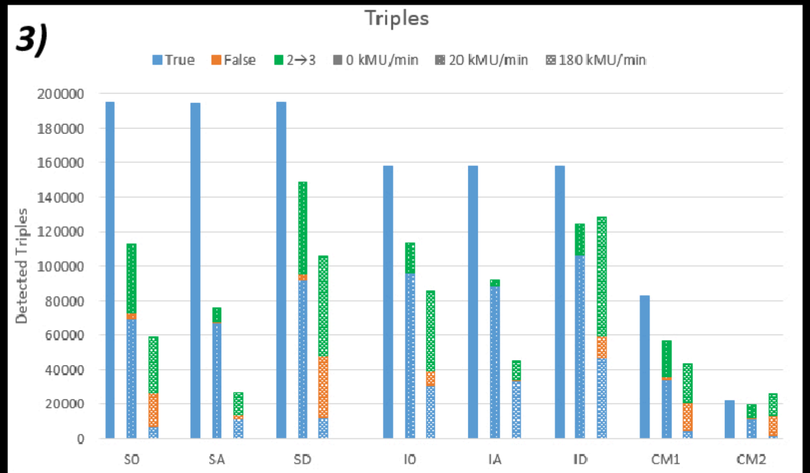

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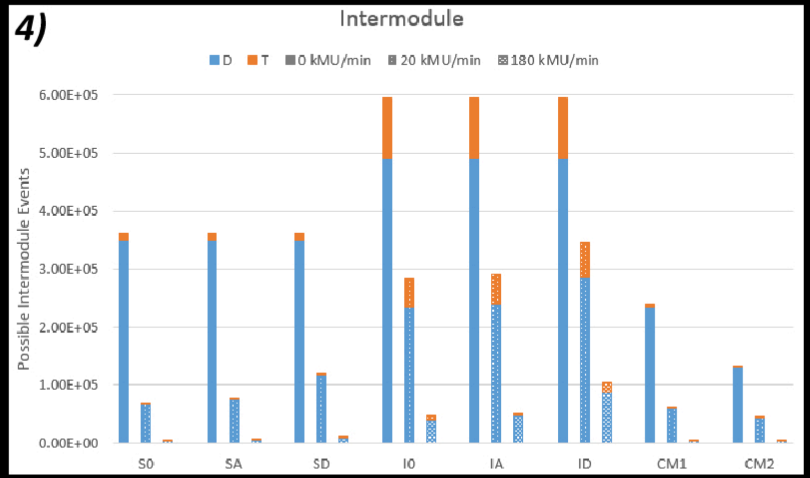

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CONTACT INFORMATION

Paul Maggi: paul.maggi@umm.edu