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# Report on Radiation Damage in Fourteen Mu2e CsI Crystals

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**Report for the Mu2e Calorimeter Group**

# A Brief Summary

- Two additional CsI samples (SIC-C1130 and SG-C1174) were irradiated in two steps to 10 and 100 krad. Both failed some spec after 100 krad.
- The average LO is 136 and 109 p.e./MeV after 10 and 100 krad for ten SIC crystals and 106 and 92 p.e./MeV for four S-G crystals, with losses of 19% and 35% for SIC and 30% and 39% for S-G.
- In average, slightly degraded ER, F/T ratio and LRU are observed. Two samples from each vendor show LO of <100 p.e./MeV after 100 krad.
- SIC-C1130 failed the LRU spec after 100 krad. SG-C1174 failed the LO, ER and LRU spec after 100 krad. Need to check samples from the same batch.

# Summary: Ten SIC Csl Crystals

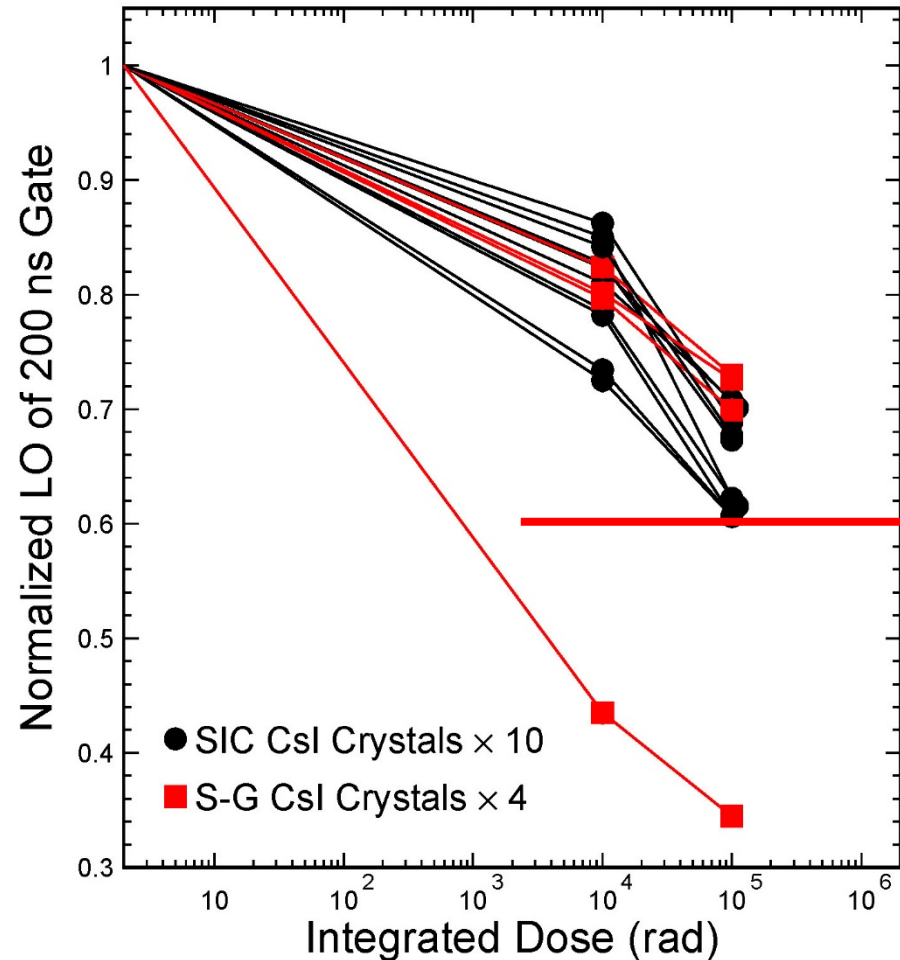
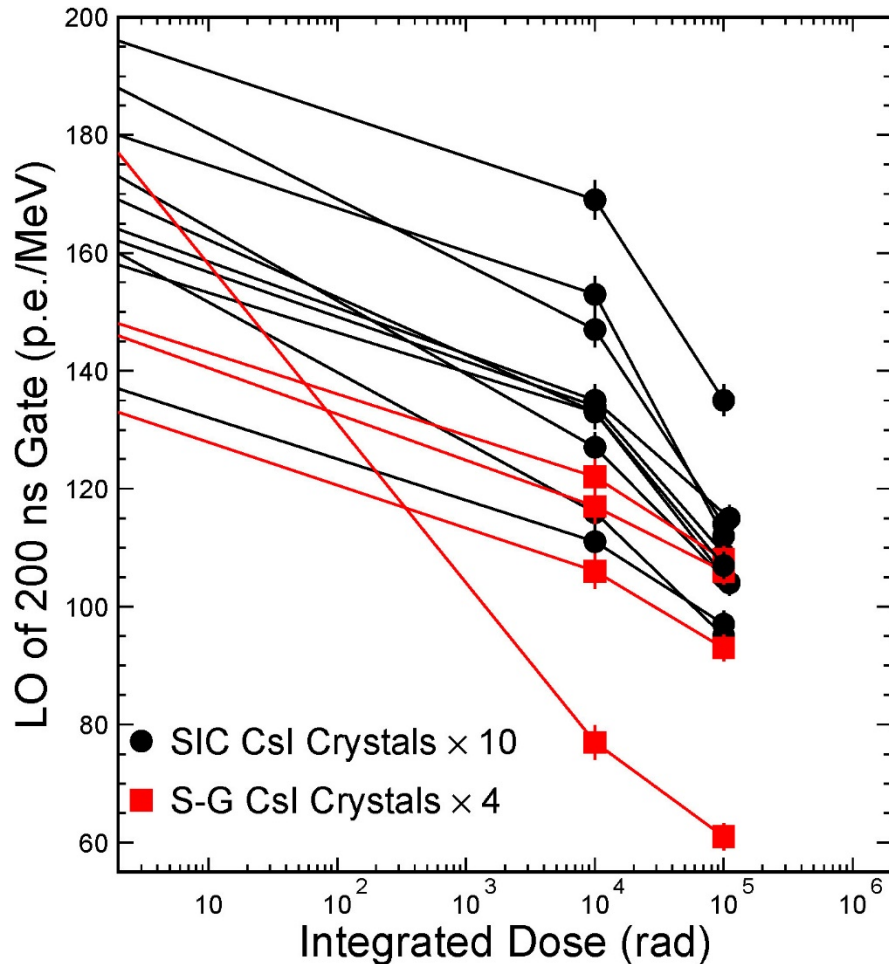
Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
SIC-C0002	Before IR	164	34	91	2.2
	10 krad	<b>135 (82%)</b>	35	90	0.83
	110 krad	115 (70%)	36	92	1.9
SIC-C0012	Before IR	169	33	89	2.7
	10 krad	<b>133 (79%)</b>	35	89	1.2
	110 krad	104 (62%)	37	90	1.5
<b>SIC-C0202</b>	Before IR	180	32	82	2.9
	10 krad	153 (85%)	33	86	1.0
	100 krad	112 (62%)	36	90	2.8
SIC-C0276	Before IR	196	32	86	2.9
	10 krad	169 (87%)	33	86	1.1
	100 krad	135 (69%)	35	85	1.5
SIC-C0326	Before IR	188	32	85	1.4
	10 krad	<b>147 (78%)</b>	34	85	1.7
	100 krad	114 (61%)	36	86	2.6
SIC-C0351	Before IR	173	33	90	2.2
	10 krad	<b>127 (73%)</b>	35	88	2.1
	100 krad	105 (61%)	37	91	3.5
SIC-C0438	Before IR	160	34	95	1.5
	10 krad	<b>116 (73%)</b>	36	92	2.6
	100 krad	95 (60%)	37	93	4.6
SIC-C0667	Before IR	137	35	80	1.4
	10 krad	<b>111 (81%)</b>	36	80	3.6
	100 krad	97 (71%)	37	79	4.9
<b>SIC-C0906</b>	Before IR	162	34	90	2.7
	10 krad	<b>134 (83%)</b>	35	90	5.0
	100 krad	109 (67%)	36	89	4.9
<b>SIC-C1130</b>	Before IR	158	34	95	4.6
	10 krad	<b>133 (84%)</b>	35	93	<b>5.8</b>
	100 krad	107 (68%)	39	96	<b>7.9</b>
Average (RMS)	Before IR	<b>168 (11%)</b>	<b>33 (1.1)</b>	<b>88 (6.0%)</b>	<b>2.5 (1.02)</b>
	10 krad	<b>136 (13%)</b>	<b>35 (1.1)</b>	<b>88 (4.6%)</b>	<b>2.5 (1.87)</b>
	100 krad	<b>109 (11%)</b>	<b>37 (1.1)</b>	<b>89 (5.7%)</b>	<b>3.6 (2.13)</b>

# Summary: Four S-G Csl Crystals

Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
<b>SG-C0770</b>	Before IR	133	35	91	0.8
	10 krad	<b>106 (80%)</b>	36	92	1.3
	100 krad	93 (70%)	37	90	2.8
<b>SG-C0950</b>	Before IR	148	31	96	2.0
	10 krad	<b>122 (82%)</b>	34	97	3.0
	100 krad	108 (73%)	36	96	2.7
SG-C1063	Before IR	146	31	98	1.1
	10 krad	<b>117 (80%)</b>	34	96	2.4
	100 krad	106 (73%)	36	97	3.0
<b>SG-C1174</b>	Before IR	177	29	95	1.6
	10 krad	<b>77 (44%)</b>	42	98	<b>5.1</b>
	100 krad	<b>61 (34%)</b>	<b>48</b>	96	<b>6.0</b>
Average (RMS)	Before IR	<b>151 (16%)</b>	<b>32 (1.6)</b>	<b>95 (2.3%)</b>	<b>1.4 (0.64)</b>
	10 krad	<b>106 (33%)</b>	<b>37 (6.5)</b>	<b>96 (1.5%)</b>	<b>3.0 (2.0)</b>
	100 krad	<b>92 (41%)</b>	<b>39 (9.8)</b>	<b>95 (0.9%)</b>	<b>3.6 (2.6)</b>

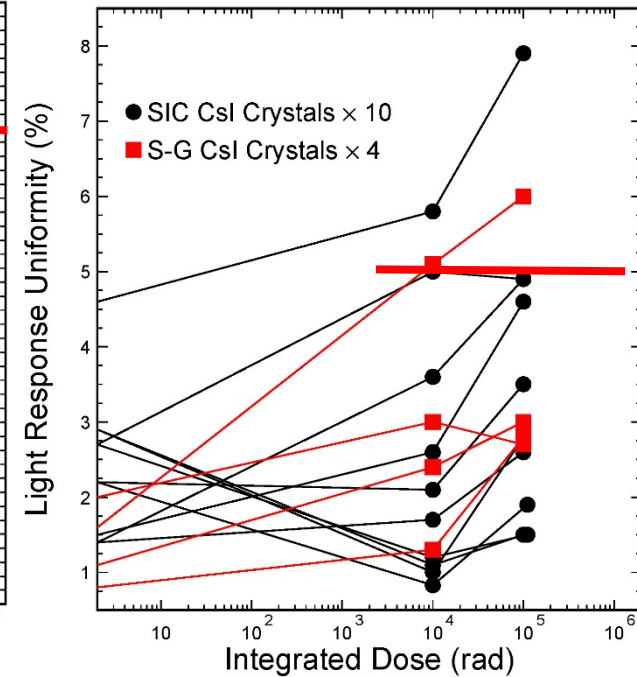
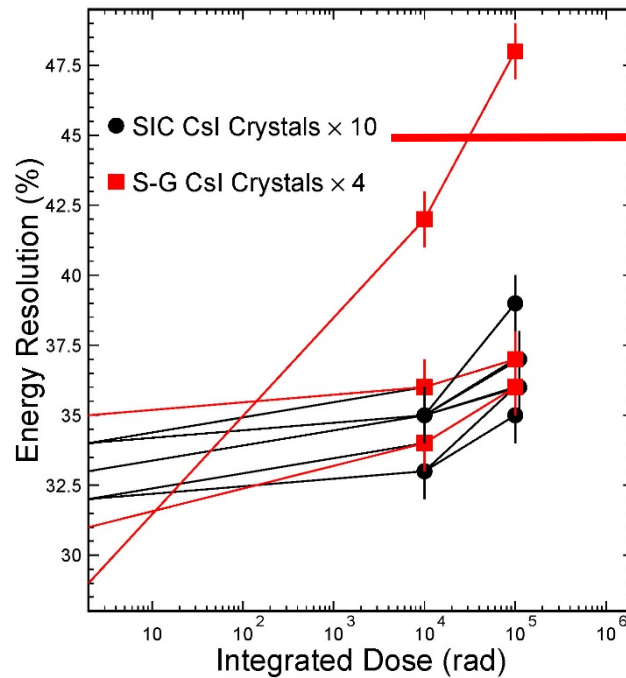
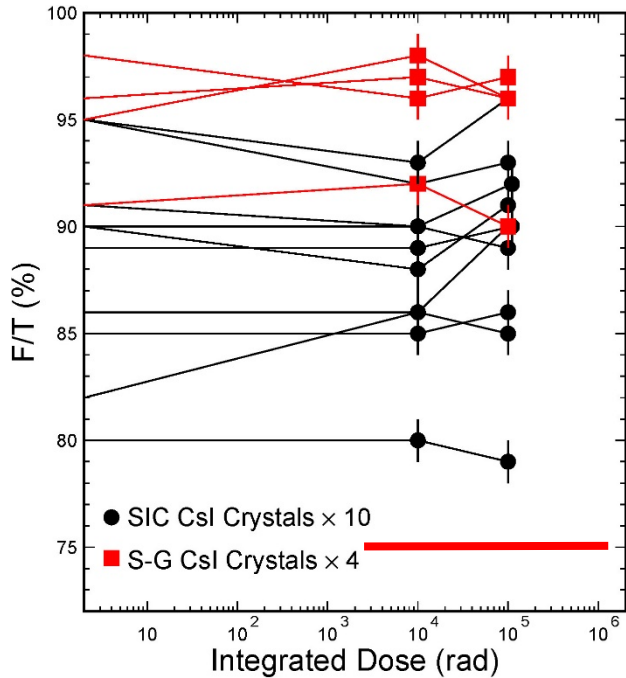
# Light Output vs Integrated Dose

All, except four, show  $> 100$  p.e./MeV after 100 krad  
All, except one SG, meet Mu2e RH spec:  $> 60\%$  after 100 krad



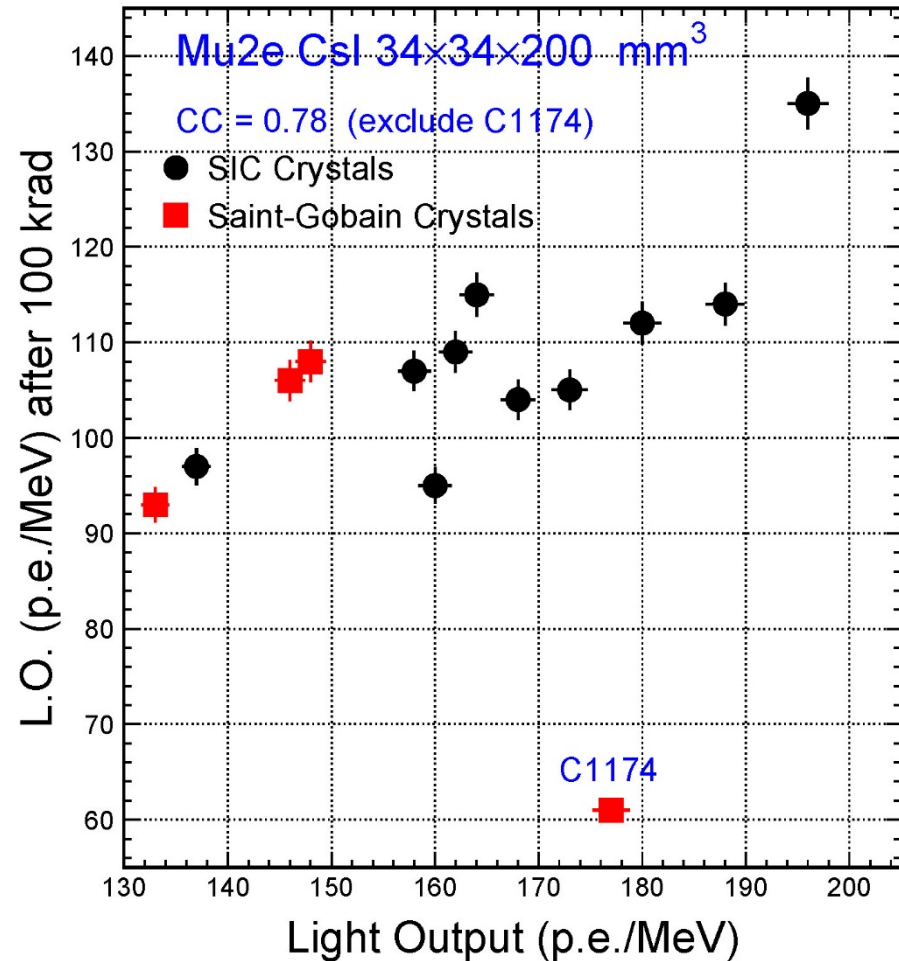
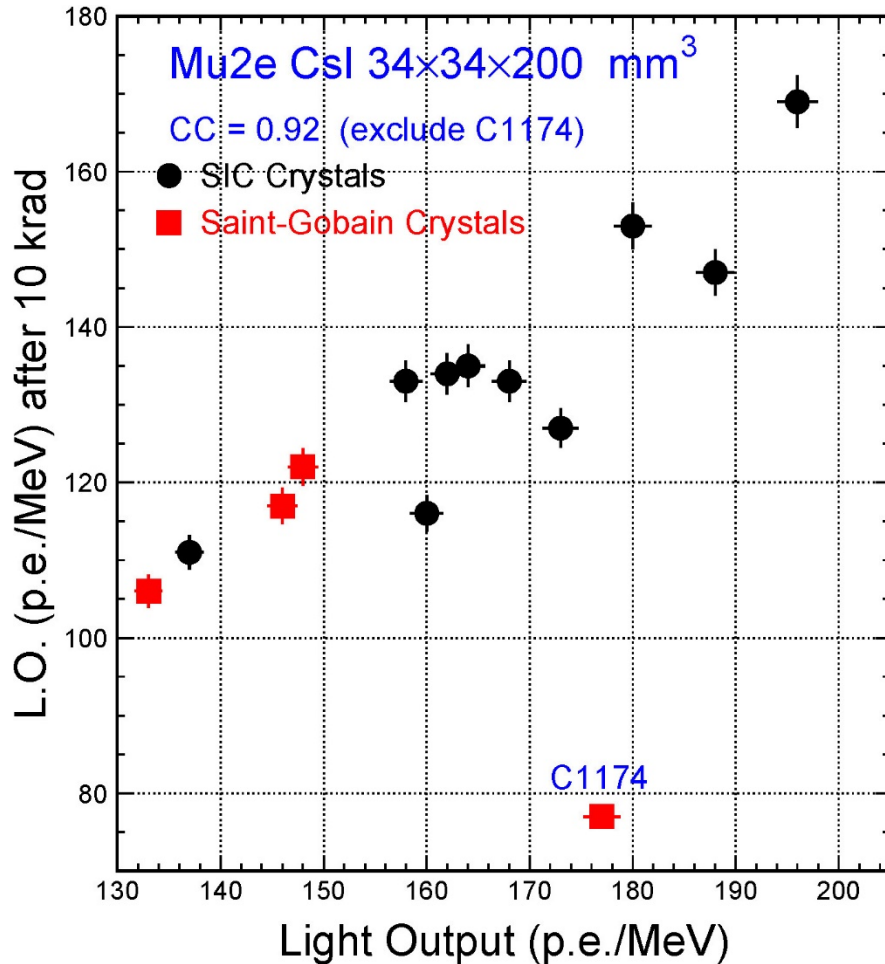
# F/T, Resolution and LRU vs Integrated Dose

All, except 0, 1 and 2, meet Mu2e spec in F/T, resolution and uniformity

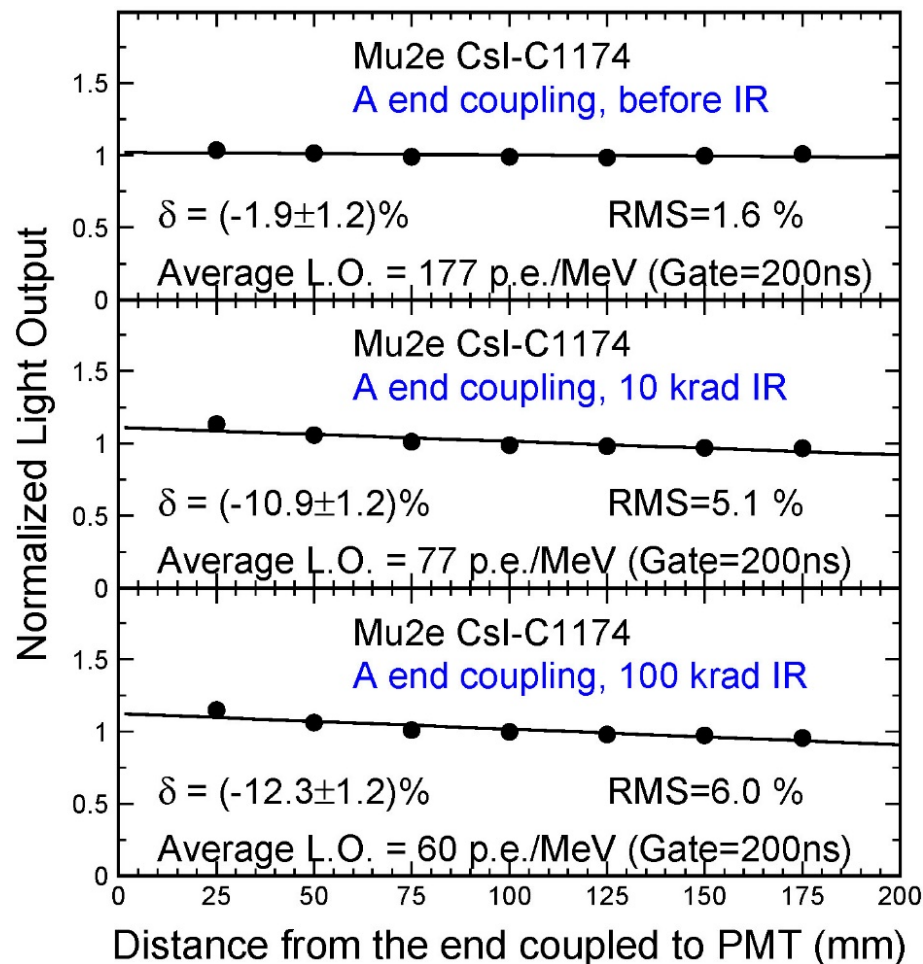
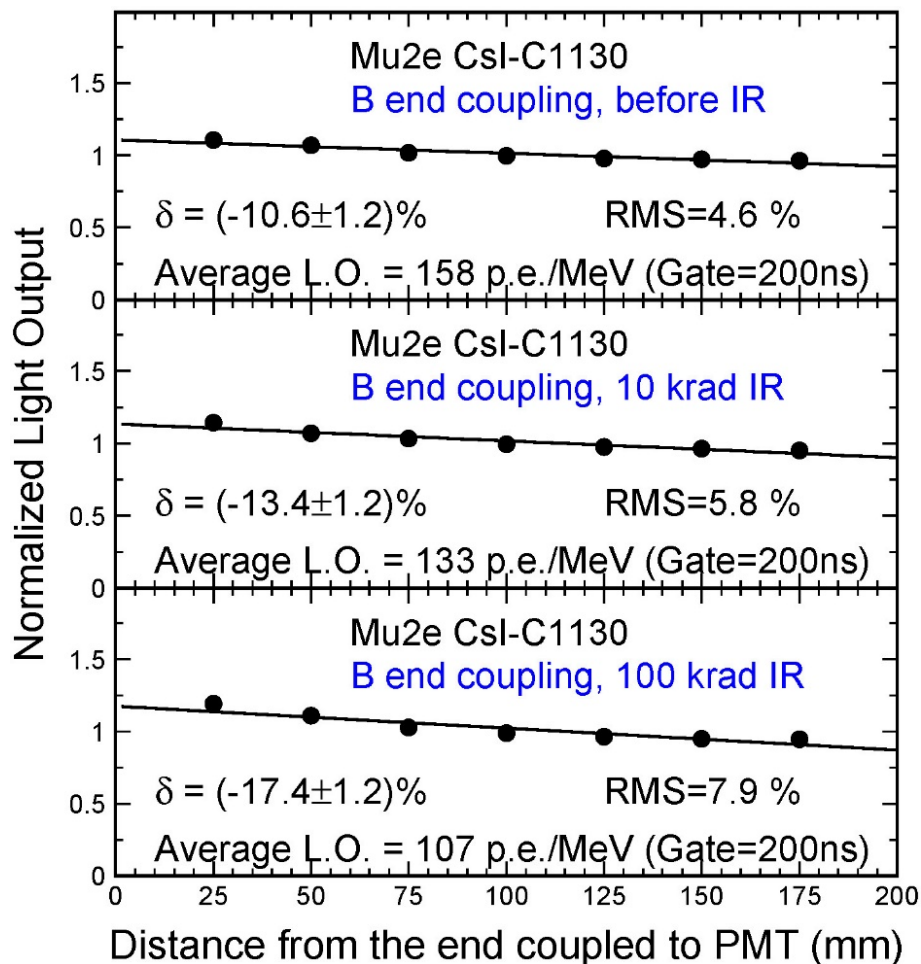


# Correlations: $LO_{\text{before}}$ vs $LO_{\text{after}}$

Excluding SG-C1174, good correlations observed

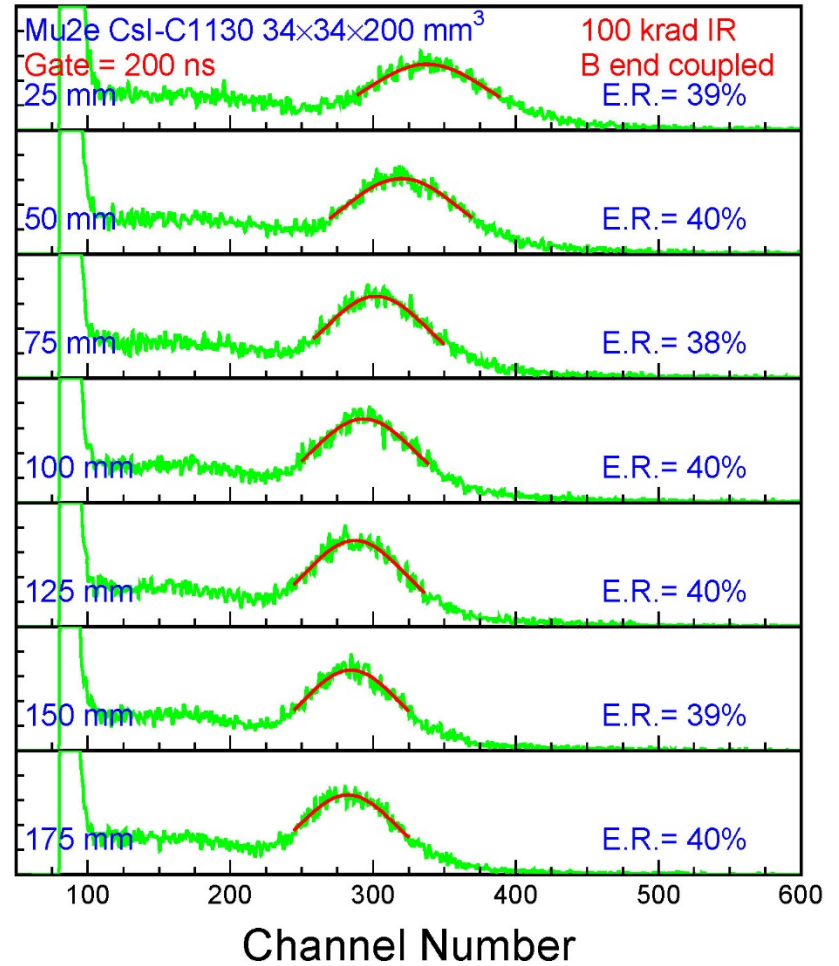
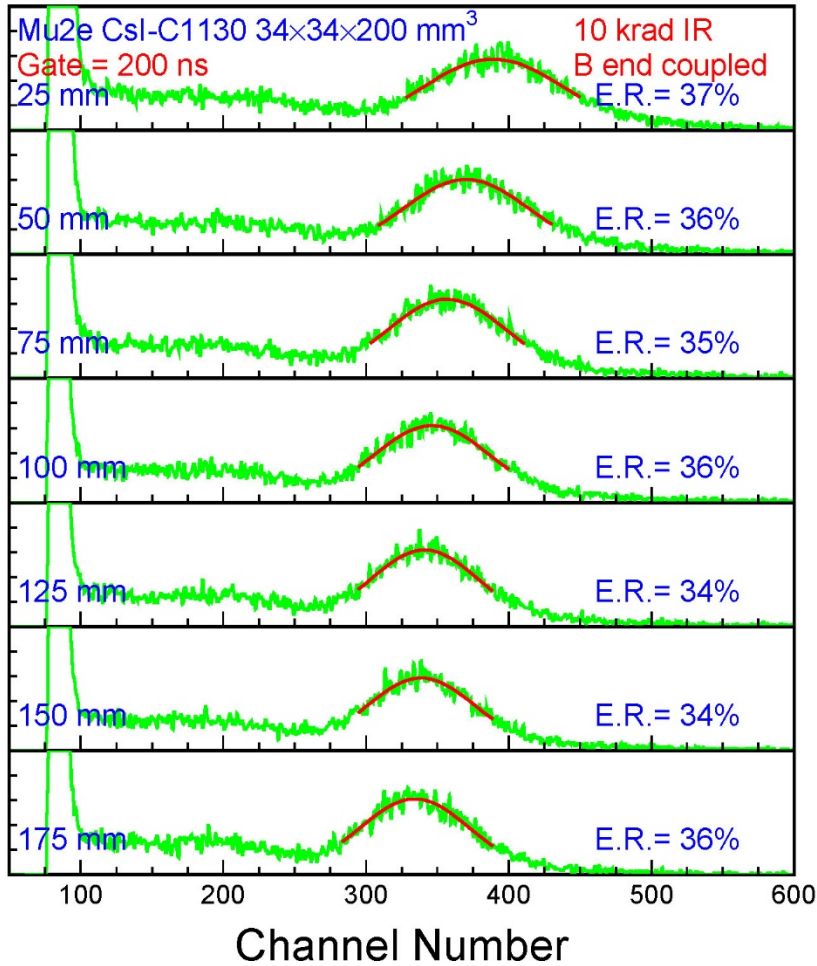


# LO & LRU after $\gamma$ -ray IR of 10 and 100 krad

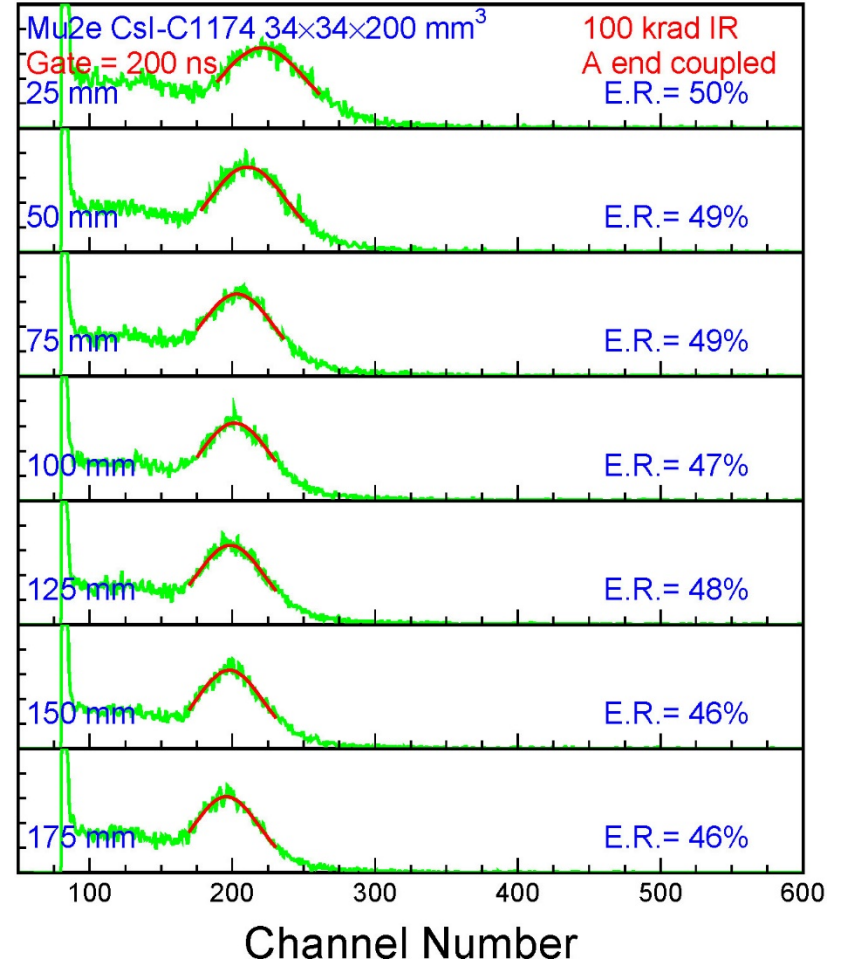
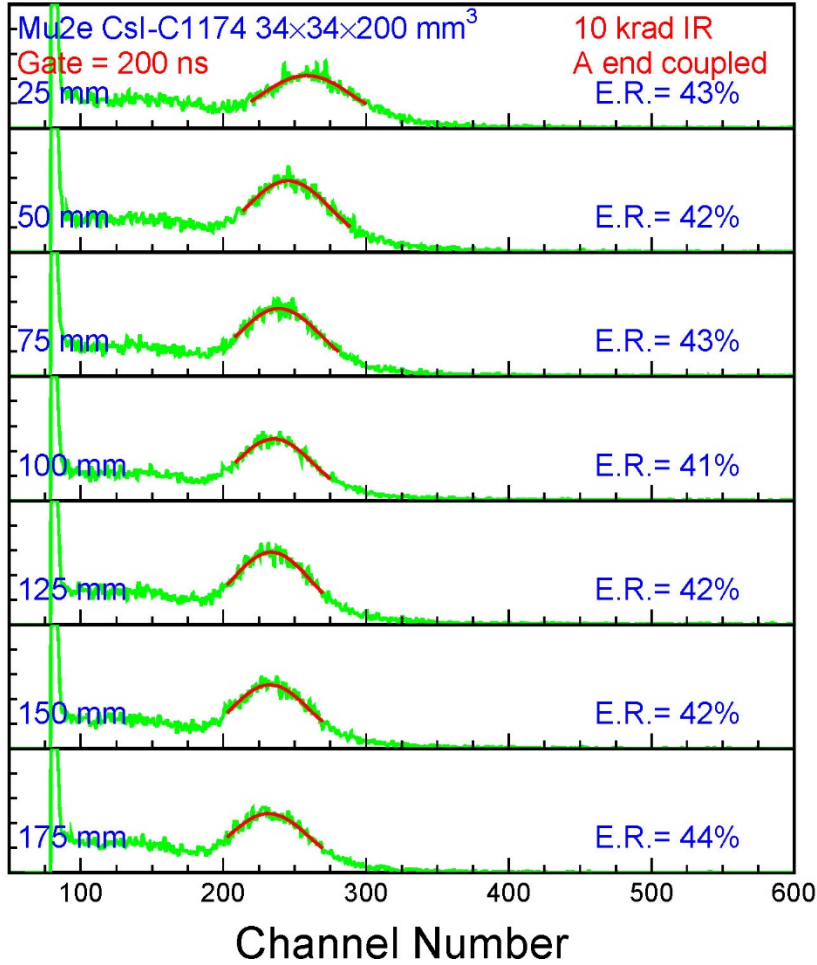




# Mu2e Pure CsI Crystal C1130 (after IR)



# Mu2e Pure CsI Crystal C1174 (after IR)



# Summary of Two Samples after Irradiation

Consistent results observed 14 days after 100 krad irradiation

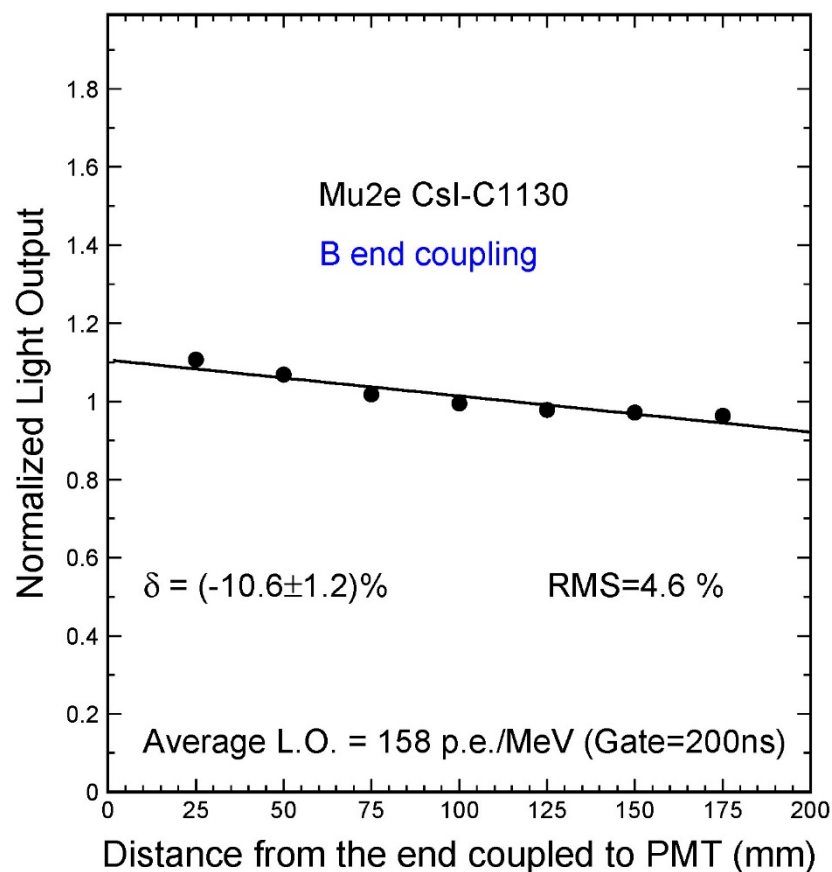
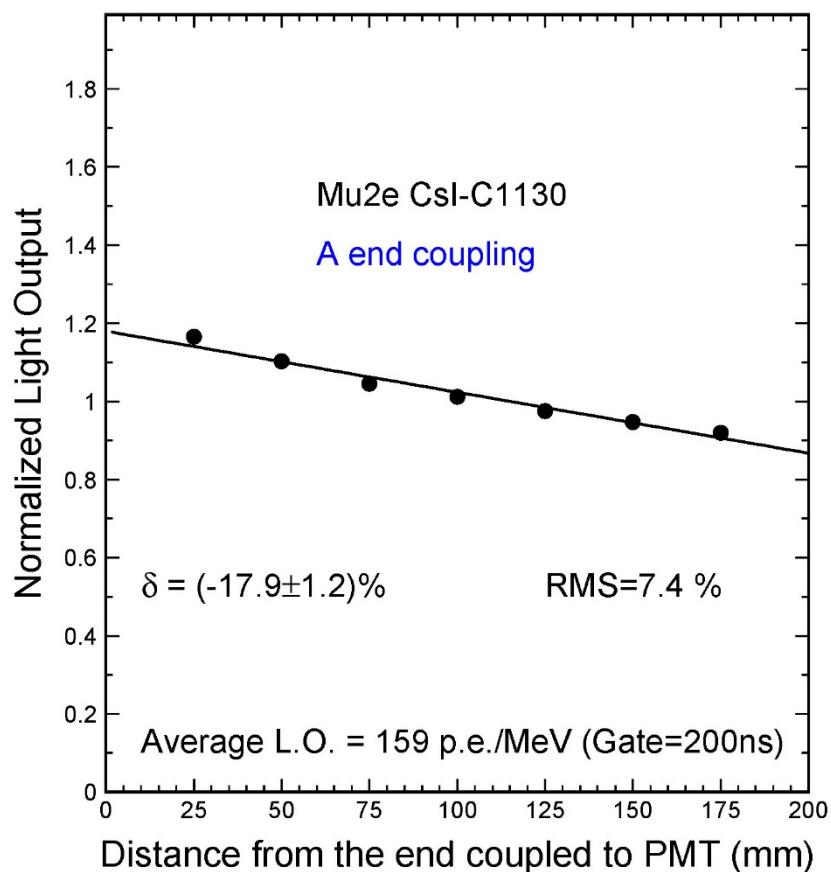
Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
SIC-C1130	Before IR	158	34	95	4.6
	10 krad	<b>133 (84%)</b>	35	93	<b>5.8</b>
	100 krad	107 (68%)	39	96	<b>7.9</b>
	13 days recovery	108 (68%)	39	97	<b>9.1</b>
SG-C1174	Before IR	177	29	95	1.6
	10 krad	<b>77 (44%)</b>	42	98	<b>5.1</b>
	100 krad	<b>61 (34%)</b>	<b>48</b>	96	<b>6.0</b>
	14 days recovery	<b>68 (38%)</b>	<b>47</b>	97	<b>5.6</b>

Samples from the same batch need to be checked

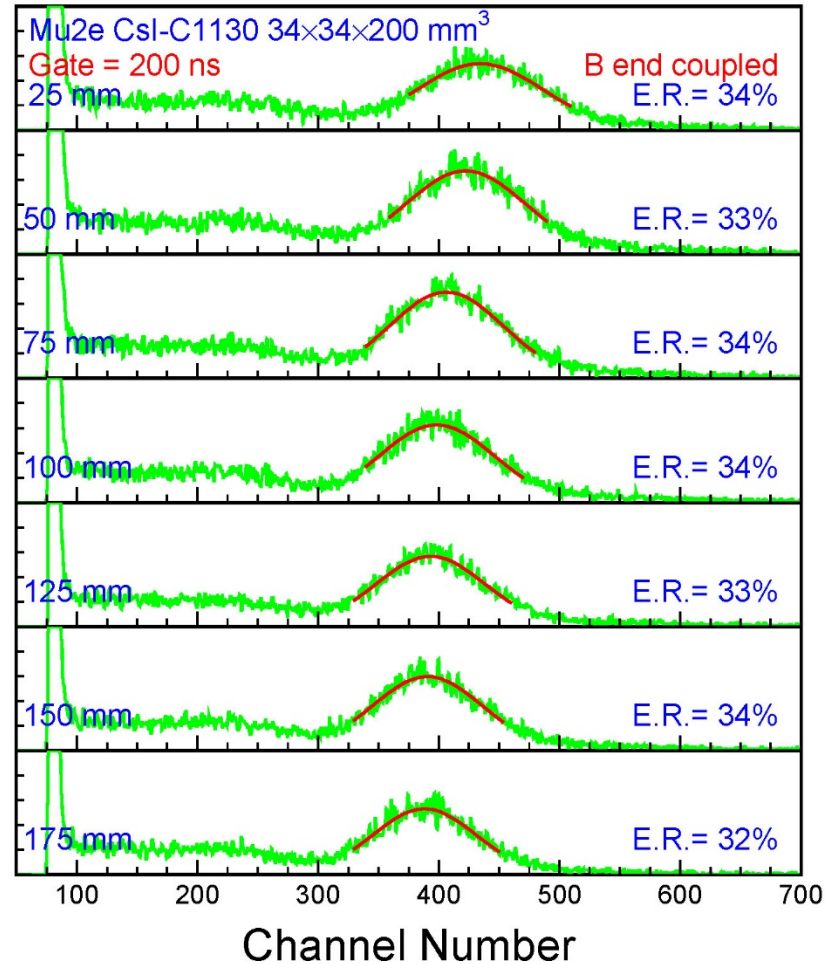
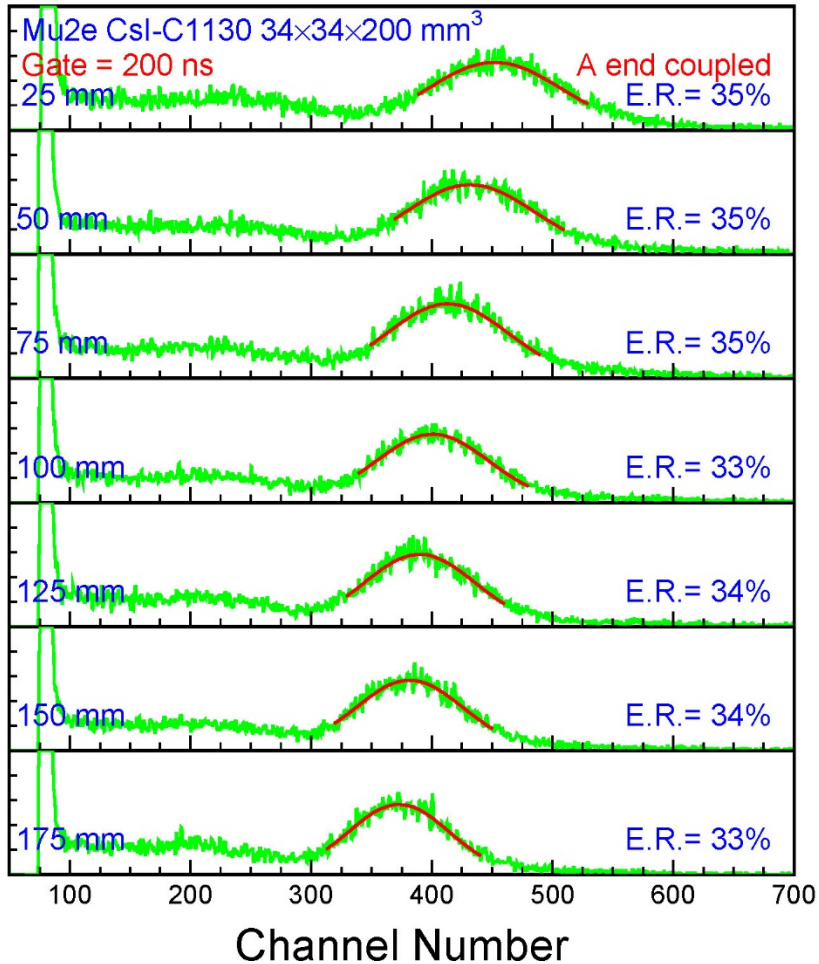
# Mu2e Pure CsI Crystal C1130 (Before IR)

Crystal ID	Coupling end	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
C1130	A	159	34	96	7.4
	<b>B</b>	<b>158</b>	<b>34</b>	<b>95</b>	<b>4.6</b>

B end chosen



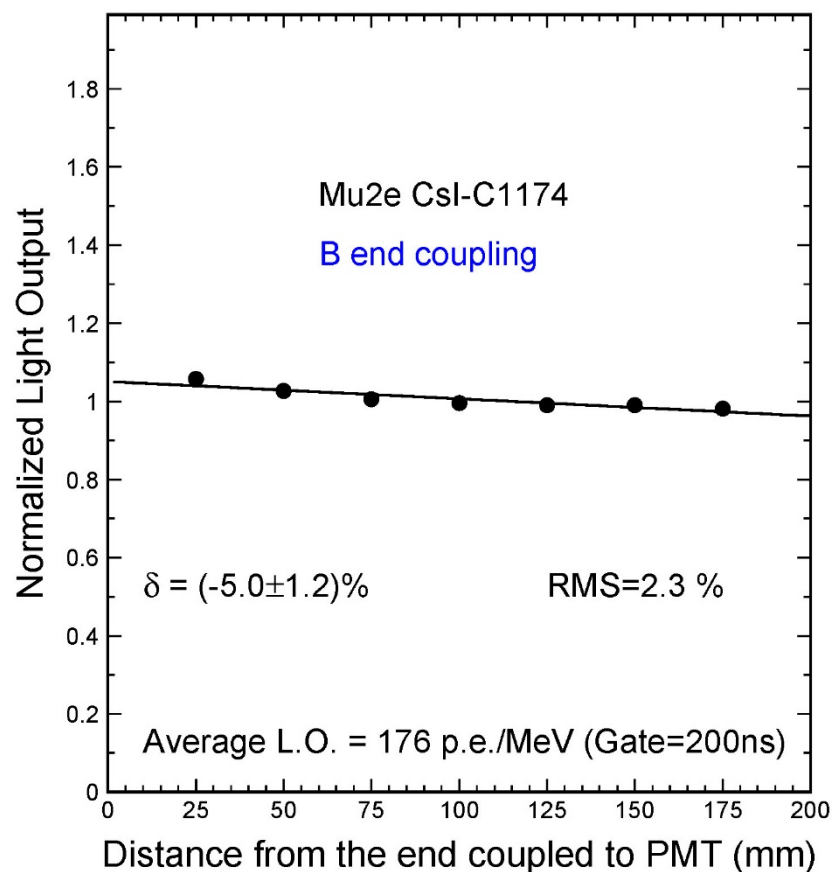
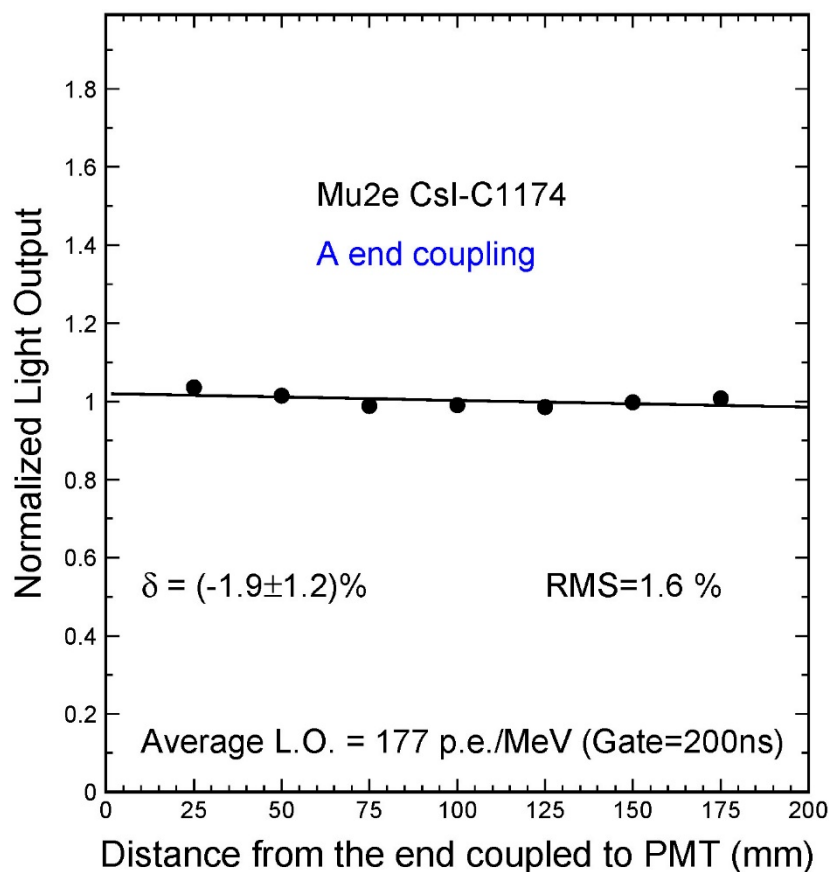
# Mu2e Pure CsI Crystal C1130 (Before IR)



# Mu2e Pure CsI Crystal C1174 (Before IR)

Crystal ID	Coupling end	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
C1174	A	177	29	95	1.6
	B	176	29	96	2.3

A end chosen



# Mu2e Pure CsI Crystal C1174 (Before IR)

