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# Report on Radiation Damage Two 2020 SIC CsI Crystals Summary: 12 SIC & 6 SG Crystals

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# A Brief Summary

- Two 2020 SIC production CsI samples (C1328 and C1643) were irradiated in two steps to 10 and 100 krad.
- Both show LO of  $> 100$  p.e./MeV after 100 krad. The average LO is 124 and 116 p.e./MeV respectively after 10 and 100 krad with losses of 23% and 28%.
- Slightly degraded ER, F/T and LRU are observed. Sample C1328 shows LRU  $> 5\%$  after 10 and 100 krad, partly due to damaged coupling surface during operation.
- A total of twelve SIC samples and six SG samples are tested so far. All, except a few, meet Mu2e specification: LO  $> 100$  p.e./MeV, FWHM ER  $< 45\%$ , F/T  $> 75\%$  and LRU  $< 5\%$  after 100 krad, indicating that the radiation hardness of Mu2e CsI crystals is well under control.
- Good correlations, excluding SG C1174, between LO<sub>before</sub> and LO<sub>after</sub> observed, are observed.
- No recovery observed up to 1,313 & 929 days in two CsI crystals each from SG and SIC respectively, indicating a stable calorimeter.

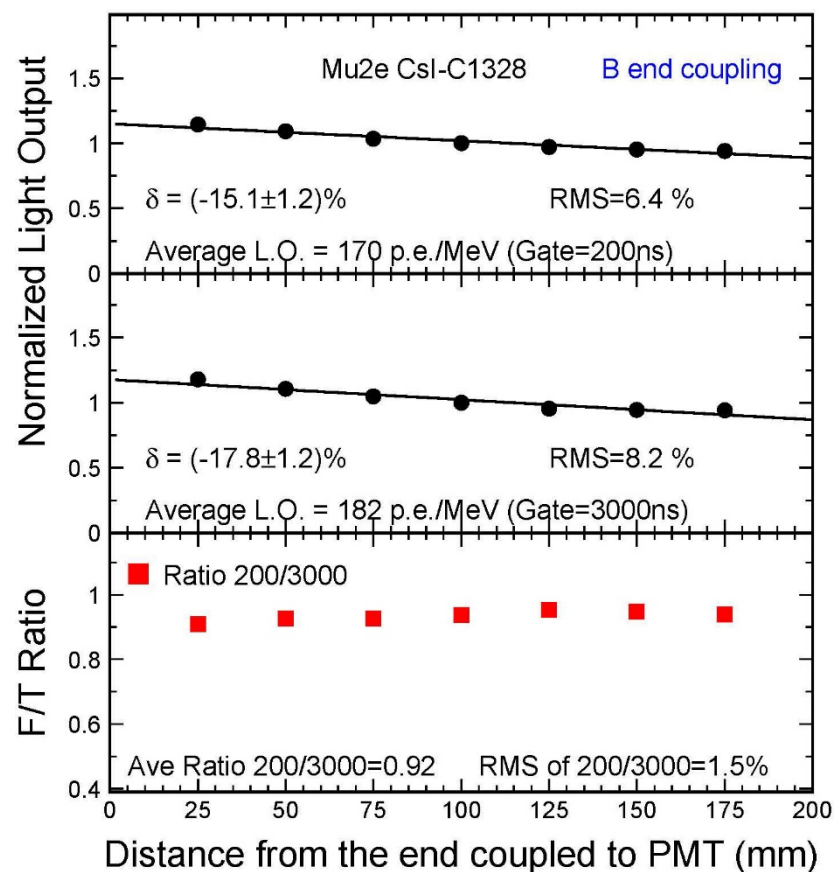
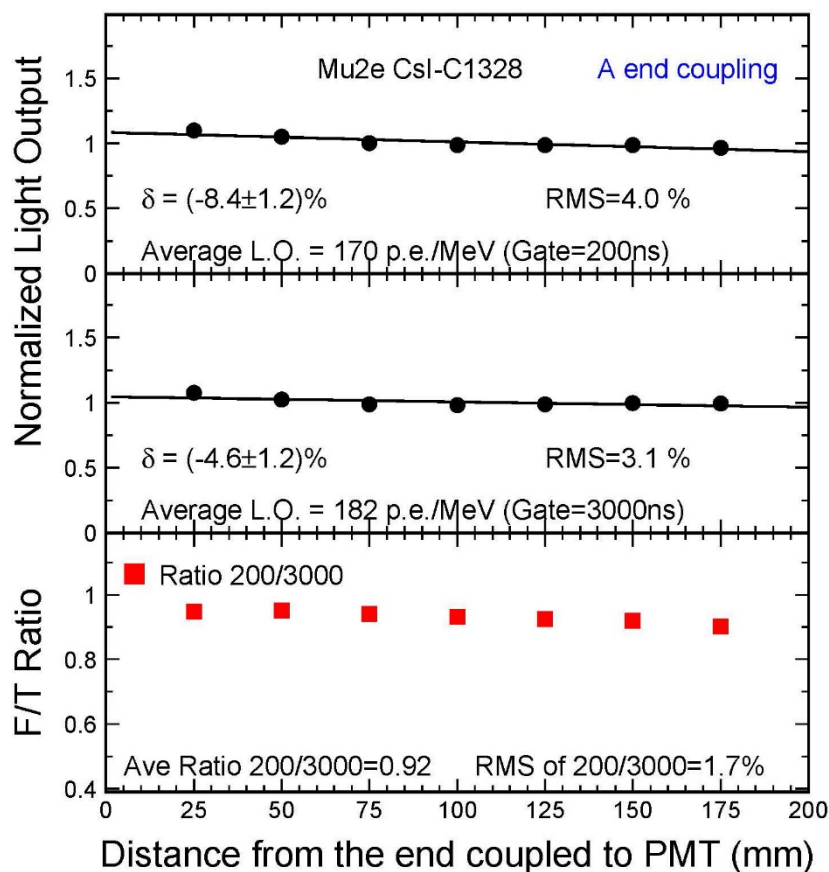
Acknowledgements: DOE OHEP Award: DE-SC0011925

# Two 2020 SIC CsI Crystals

Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
SIC-C1328	-	170	33	92	4.0
	10 krad	123 (72%)	34	93	<b>5.9</b>
	100 krad	113 (66%)	35	93	<b>7.1</b>
SIC-C1643	-	154	35	83	2.2
	10 krad	124 (81%)	36	83	2.8
	100 krad	118 (77%)	36	84	4.2

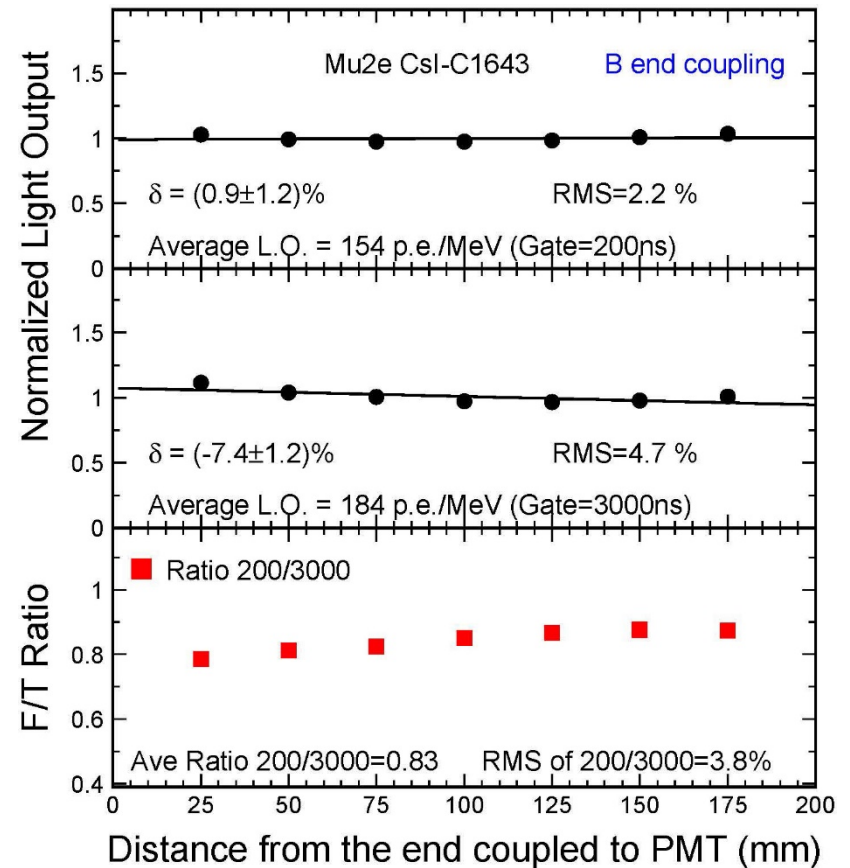
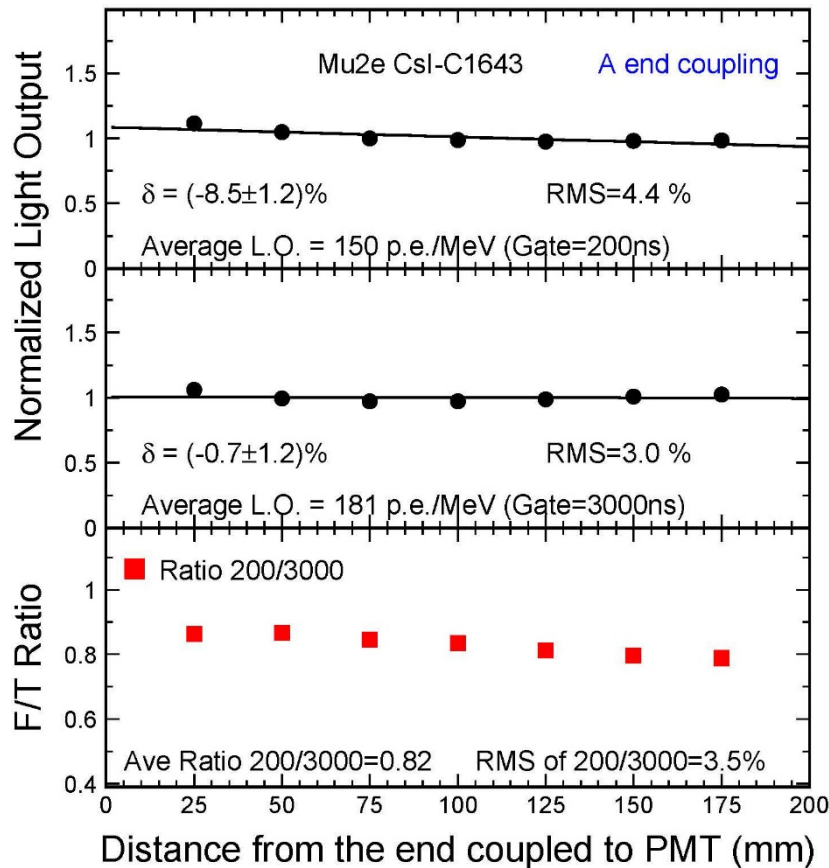
# LO, LRU and F/T: 1328 (A end Chosen)

Crystal ID	Coupling end	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
C1328	A	170	33	92	4.0
	B	170	33	92	6.4

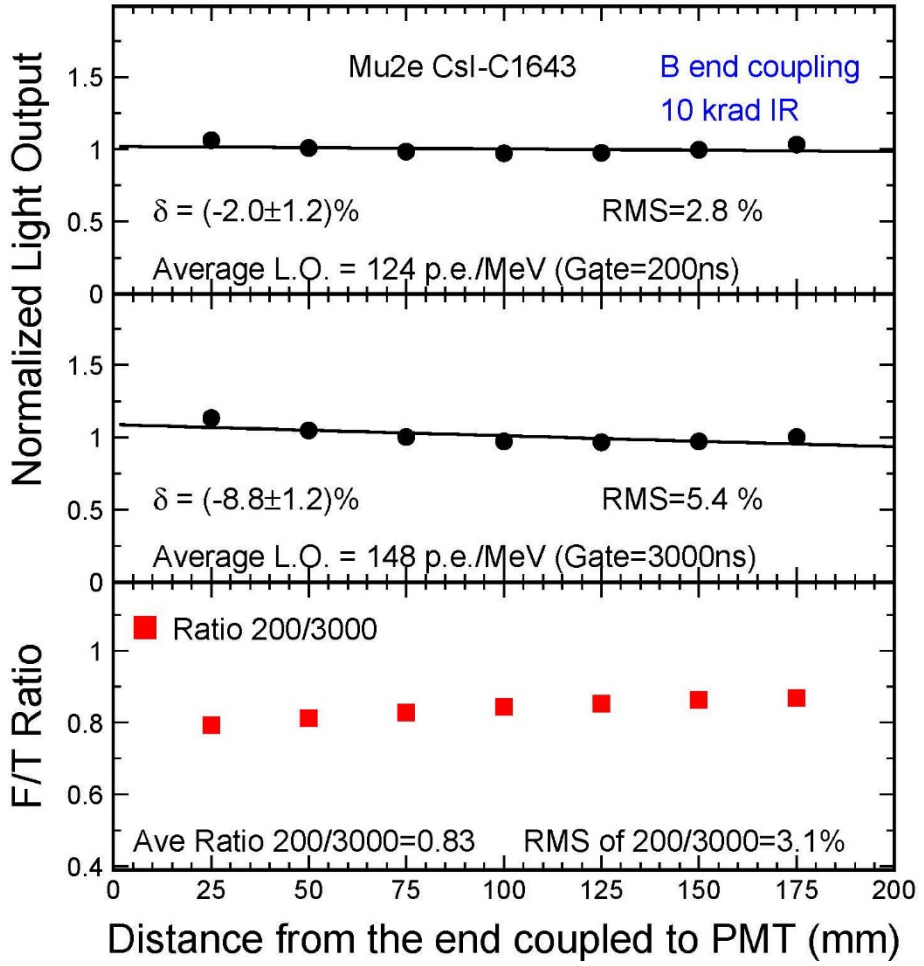
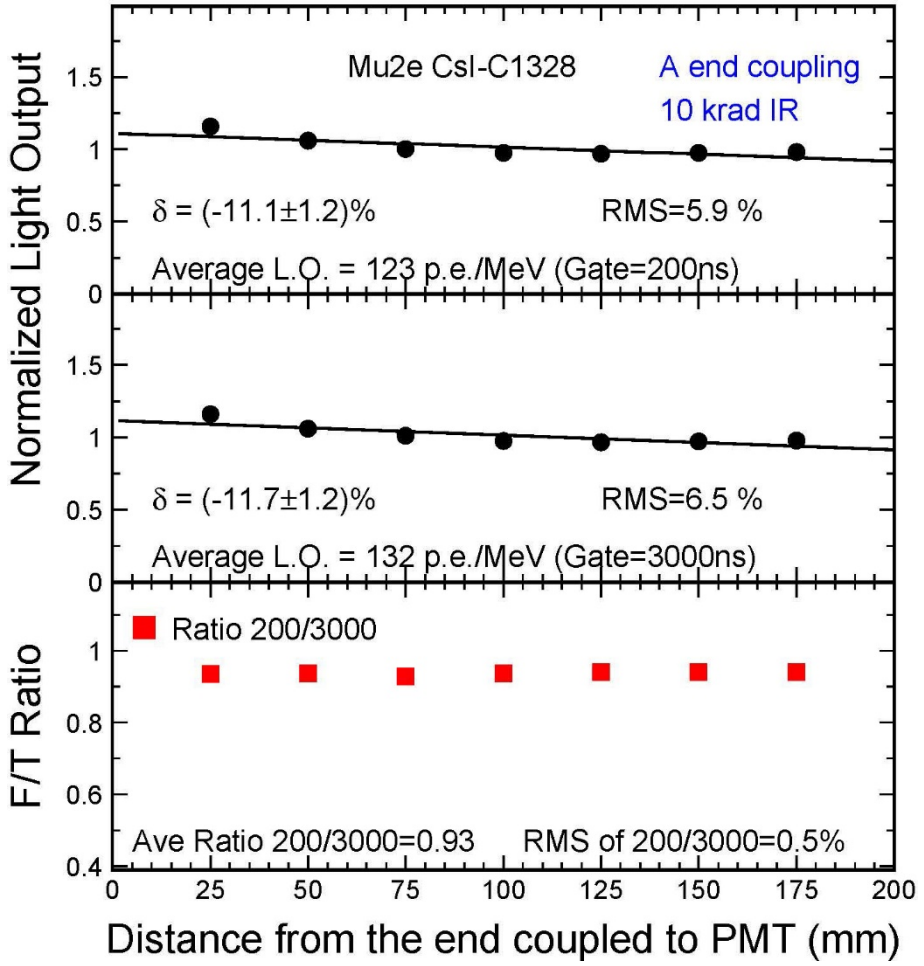


# LO, LRU and F/T: 1643 (B end Chosen)

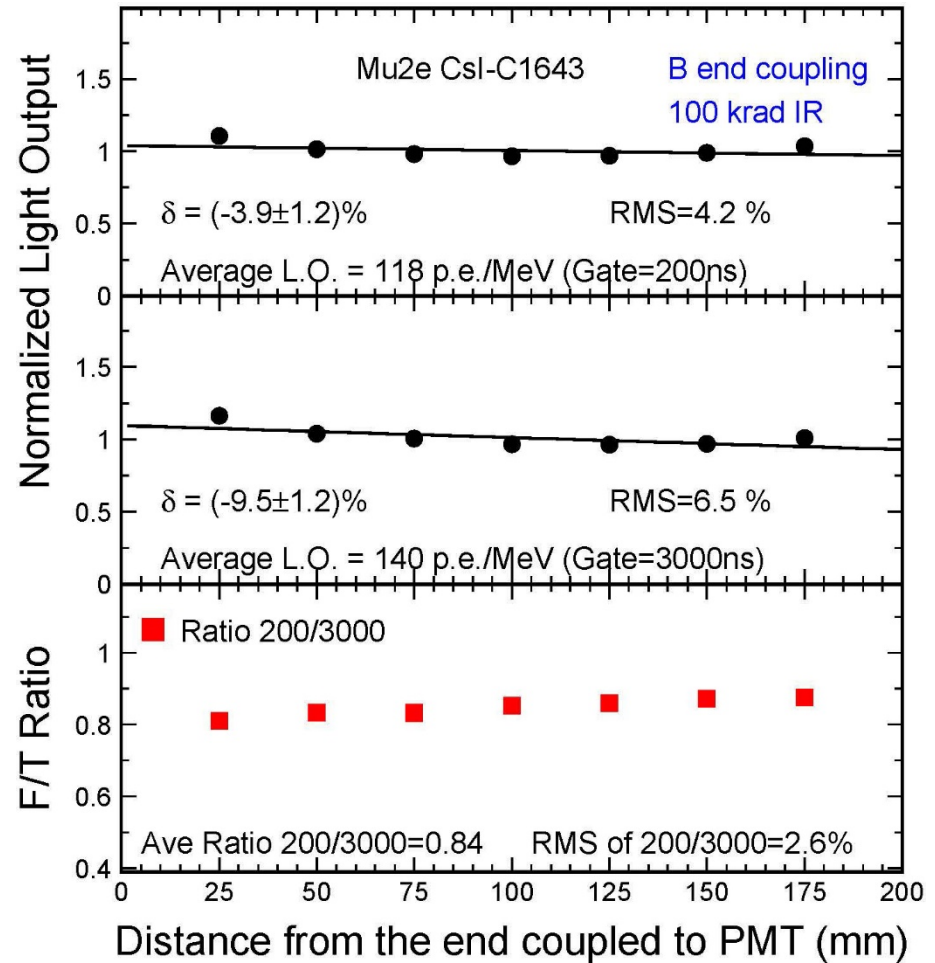
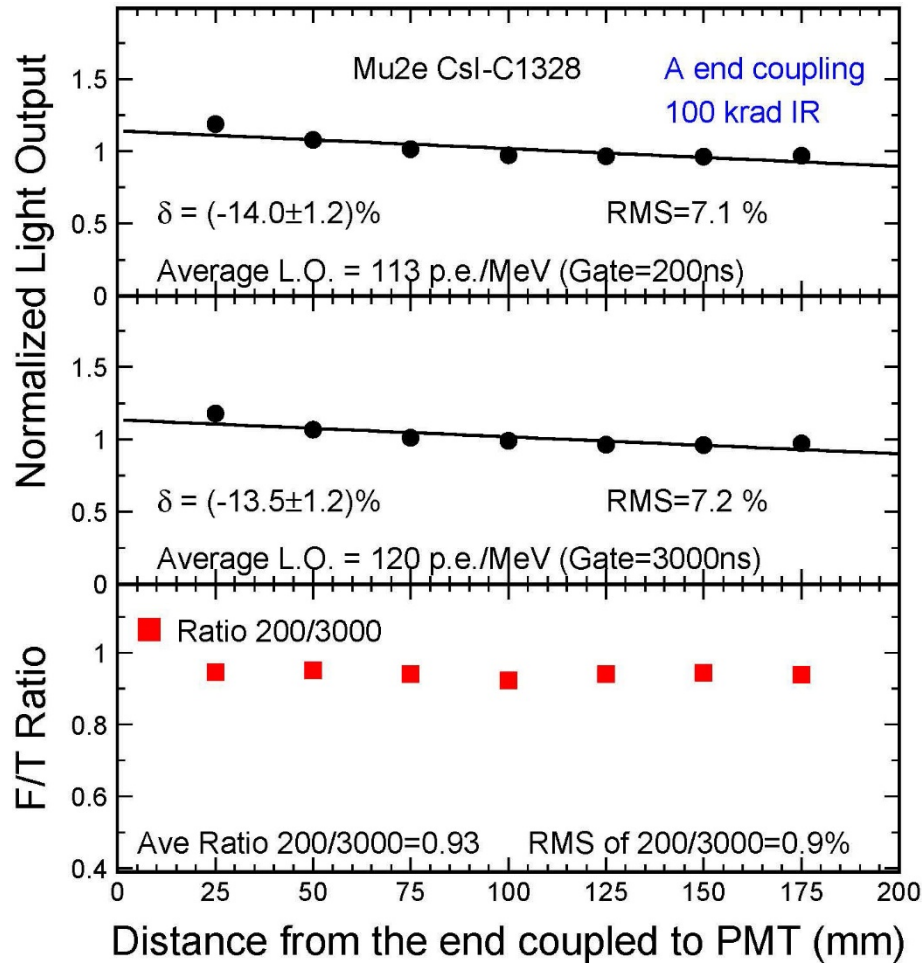
Crystal ID	Coupling end	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
C1643	A	150	35	82	4.4
	B	154	35	83	2.2



# LO, LRU and F/T after 10 krad: 1328 & 1643

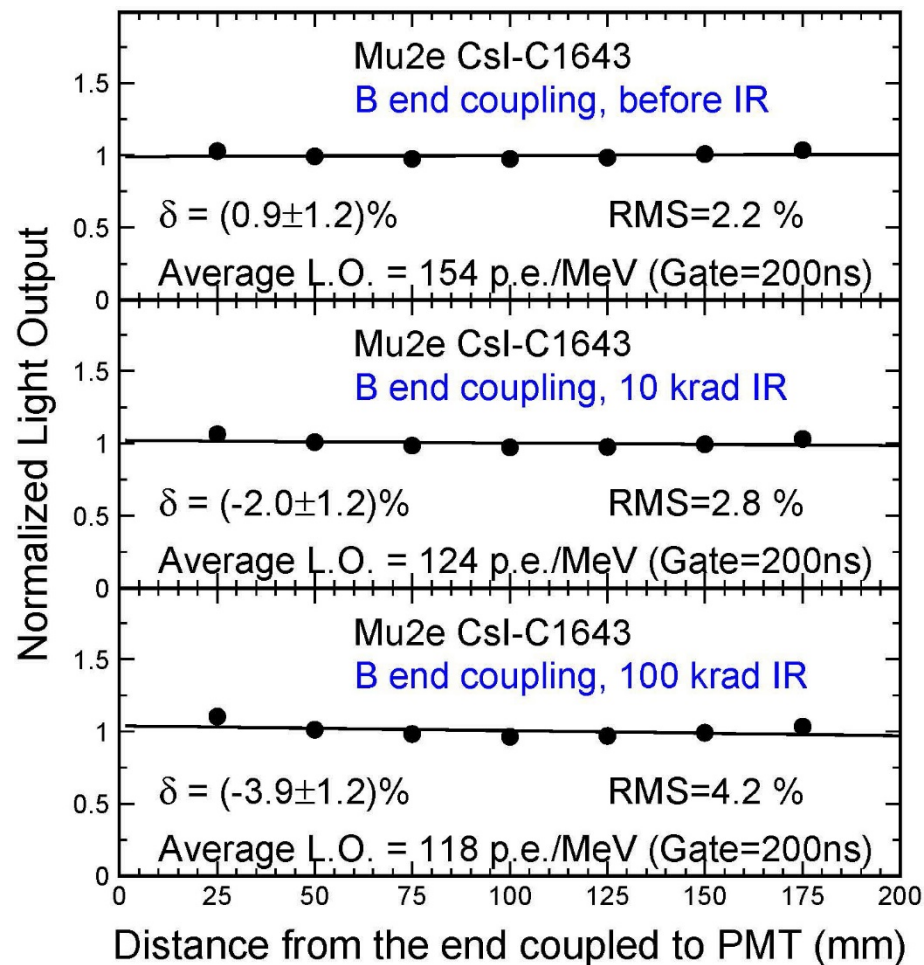
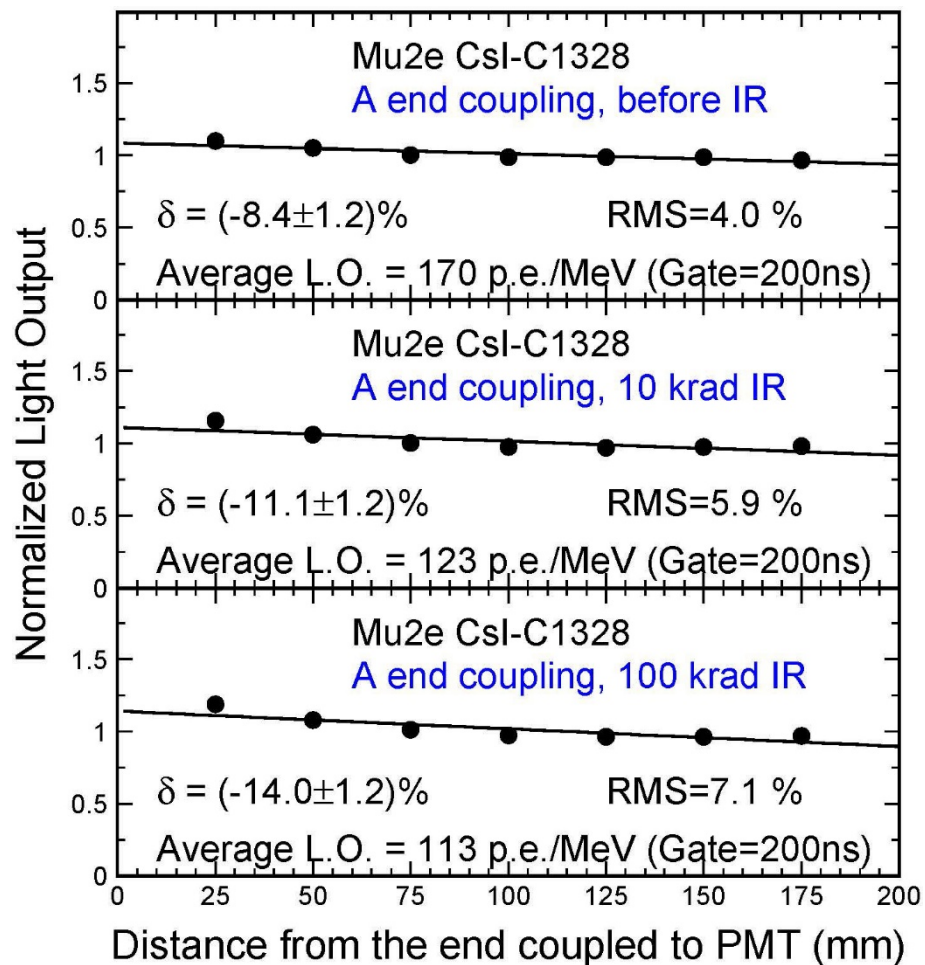


# LO, LRU and F/T after 100 krad: 1328 & 1643





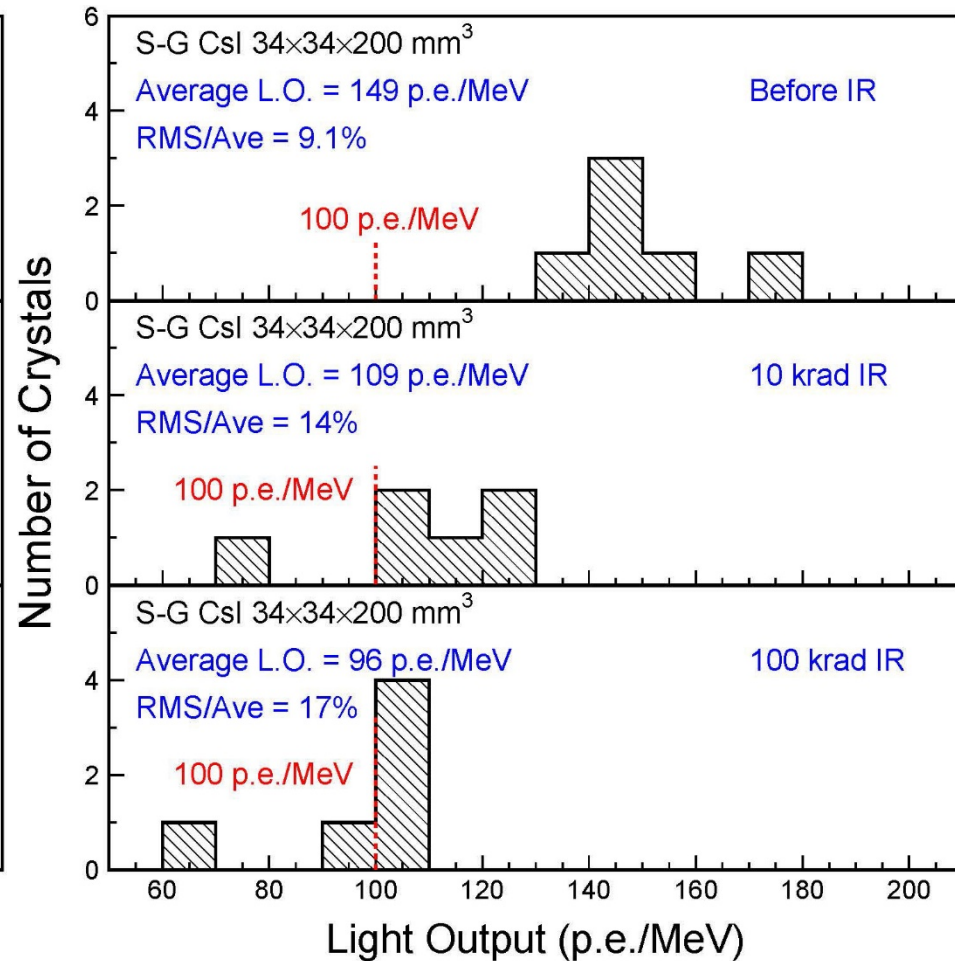
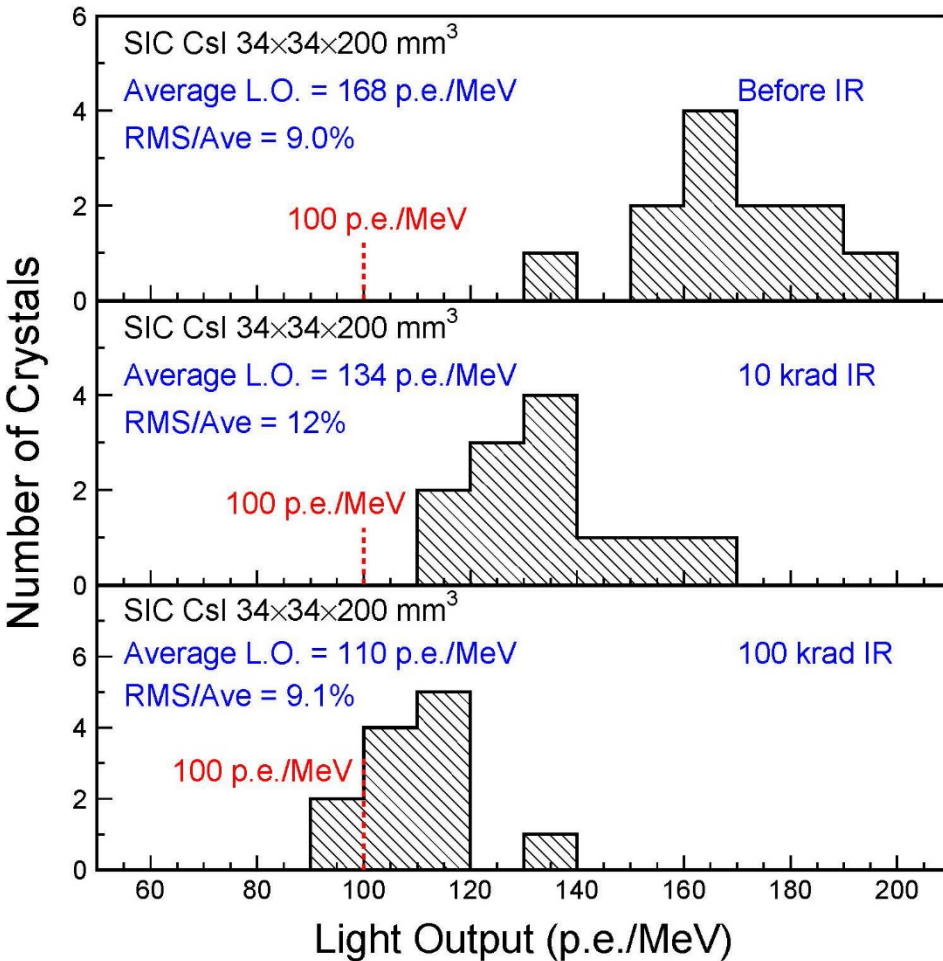
# Summary: LO & LRU after 10 & 100 krad





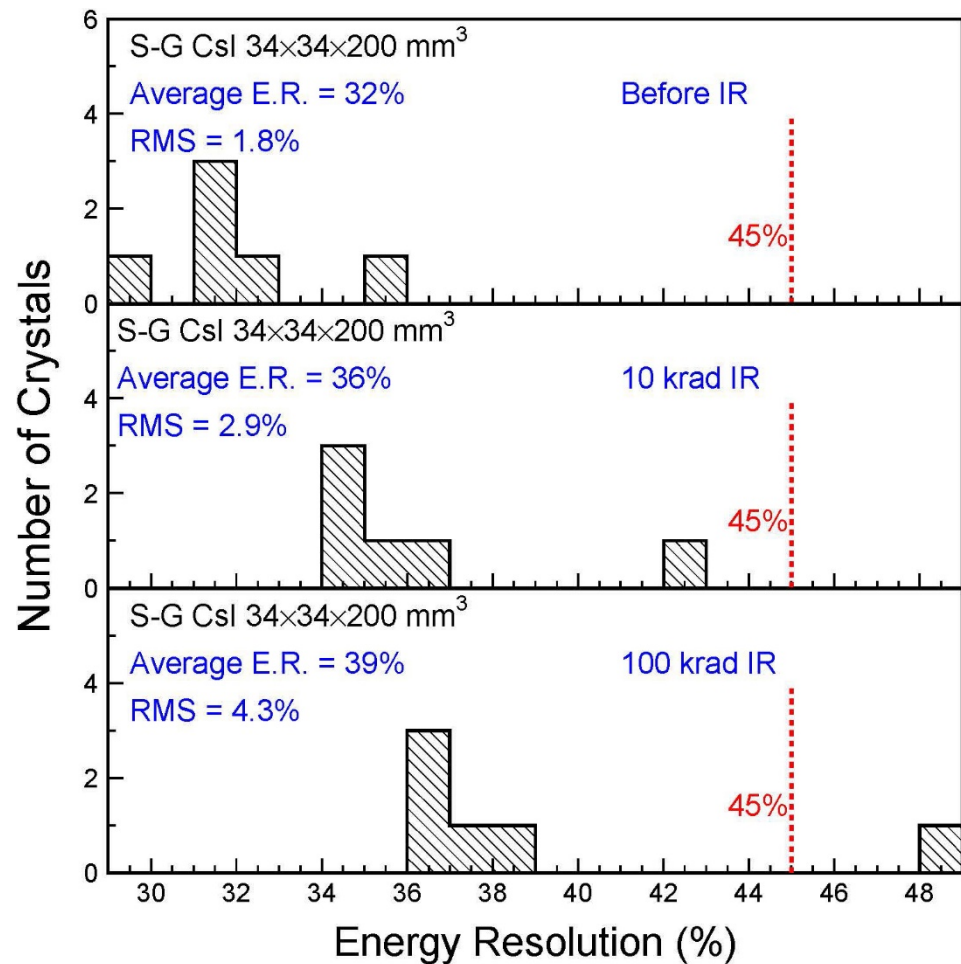
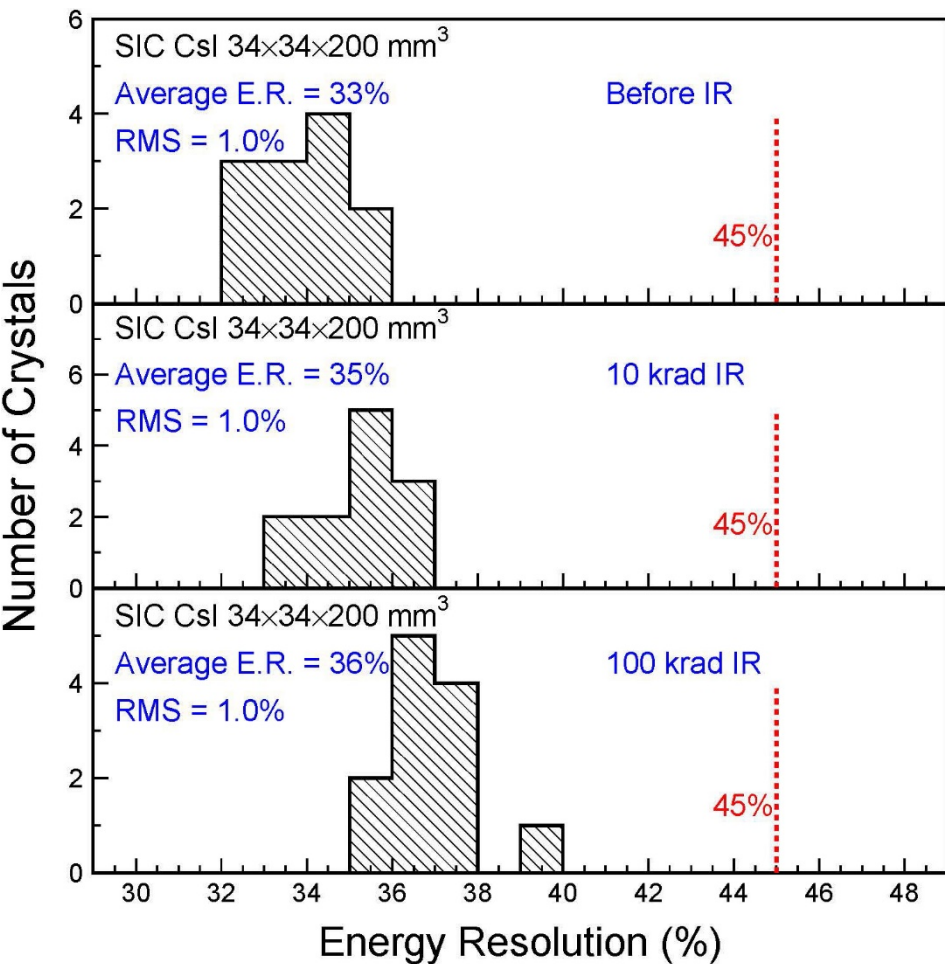
# LO Summary: Twelve SIC & Six SG Csl

All, except a few, show LO >100 p.e./MeV after 100 krad



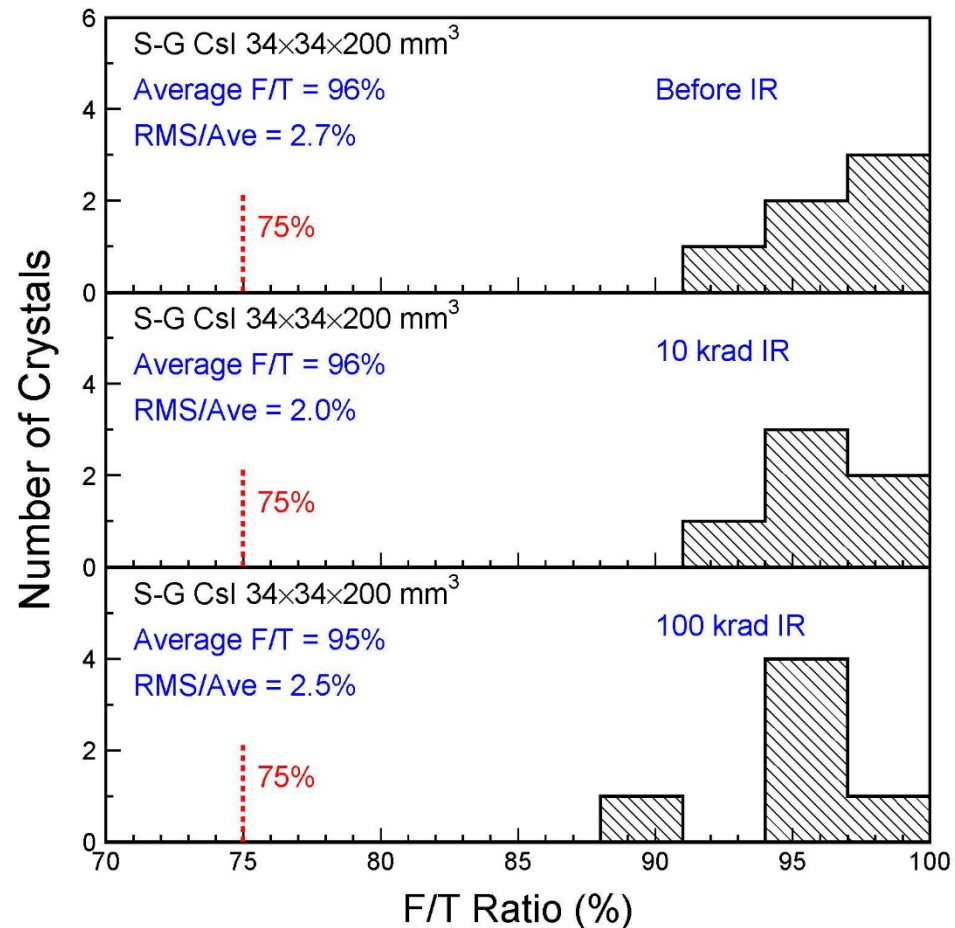
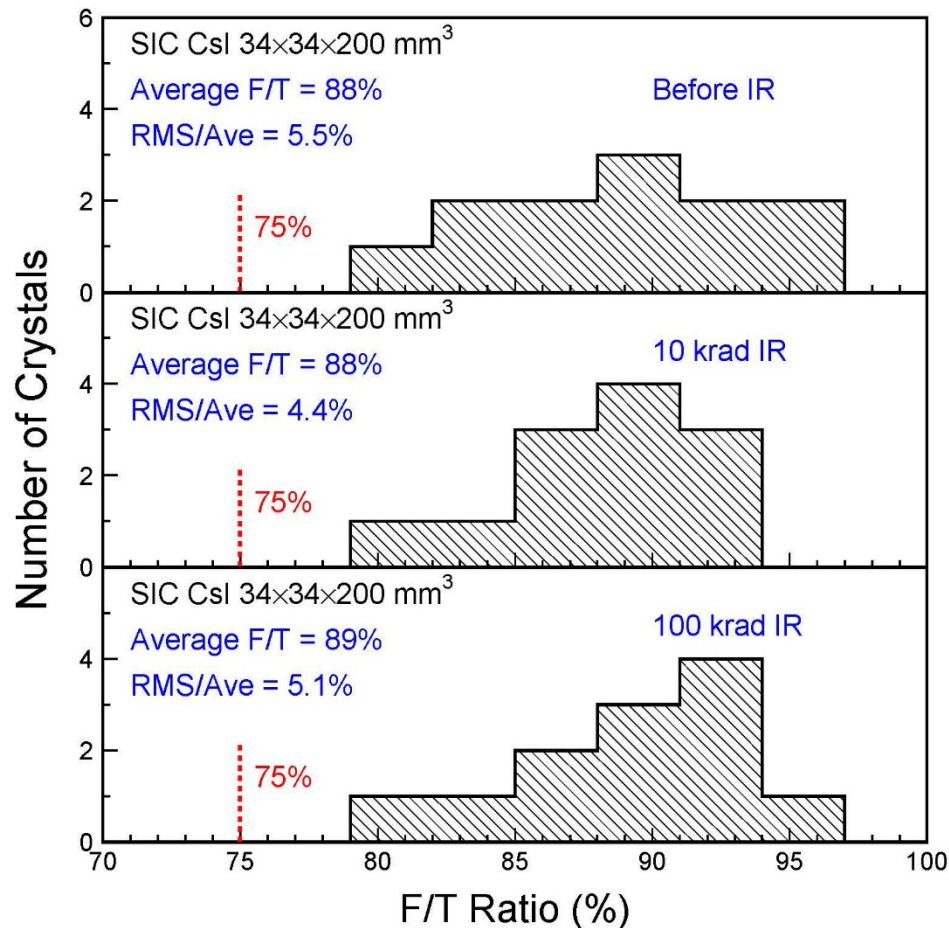
# ER Summary: Twelve SIC & Six SG Csl

All, except one, meet FWHM ER < 45% after 100 krad



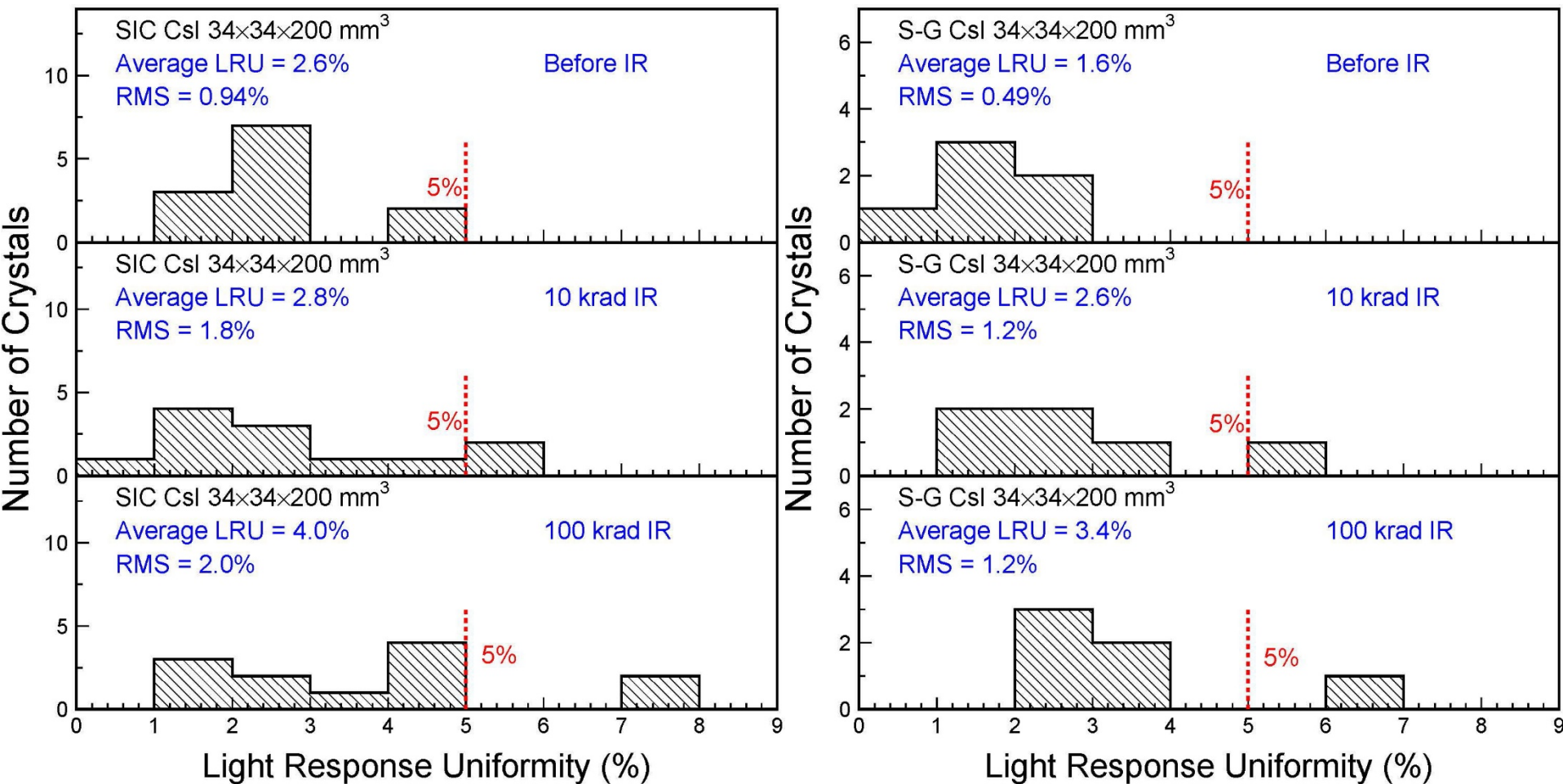
# F/T Summary: Twelve SIC & Six SG Csl

All satisfy  $F/T > 75\%$  after 100 krad



# LRU Summary: Twelve SIC & Six SG Csl

All, except a few, meet LRU < 5% after 100 krad



# Summary: Twelve 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	135 (82%)	35	90	0.83
	110 krad	115 (70%)	36	92	1.9
SIC-C0012	Before IR	169	33	89	2.7
	10 krad	133 (79%)	35	89	1.2
	110 krad	104 (62%)	37	90	1.5
SIC-C0202	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	147 (78%)	34	85	1.7
	100 krad	114 (61%)	36	86	2.6
SIC-C0351	Before IR	173	33	90	2.2
	10 krad	127 (73%)	35	88	2.1
	100 krad	105 (61%)	37	91	3.5
SIC-C0438	Before IR	160	34	95	1.5
	10 krad	116 (73%)	36	92	2.6
	100 krad	<b>95</b> (60%)	37	93	4.6
SIC-C0667	Before IR	137	35	80	1.4
	10 krad	111 (81%)	36	80	3.6
	100 krad	<b>97</b> (71%)	37	79	4.9
SIC-C0906	Before IR	162	34	90	2.7
	10 krad	134 (83%)	35	90	5.0
	100 krad	109 (67%)	36	89	4.9
SIC-C1130	Before IR	158	34	95	4.6
	10 krad	133 (84%)	35	93	<b>5.8</b>
	100 krad	107 (68%)	39	96	<b>7.9</b>
SIC-C1328	Before IR	170	33	92	4.0
	10 krad	123 (72%)	34	93	<b>5.9</b>
	100 krad	113 (66%)	35	93	<b>7.1</b>
SIC-C1643	Before IR	154	35	83	2.2
	10 krad	124 (81%)	36	83	2.8
	100 krad	118 (76%)	36	84	4.2
Average (RMS)	Before IR	<b>168 (9.0%)</b>	<b>33 (1.0)</b>	<b>88 (5.5%)</b>	<b>2.6 (0.94)</b>
	10 krad	<b>134 (12%)</b>	<b>35 (1.0)</b>	<b>88 (4.4%)</b>	<b>2.8 (1.8)</b>
	100 krad	<b>110 (9.1%)</b>	<b>36 (1.0)</b>	<b>89 (5.1%)</b>	<b>4.0 (2.0)</b>

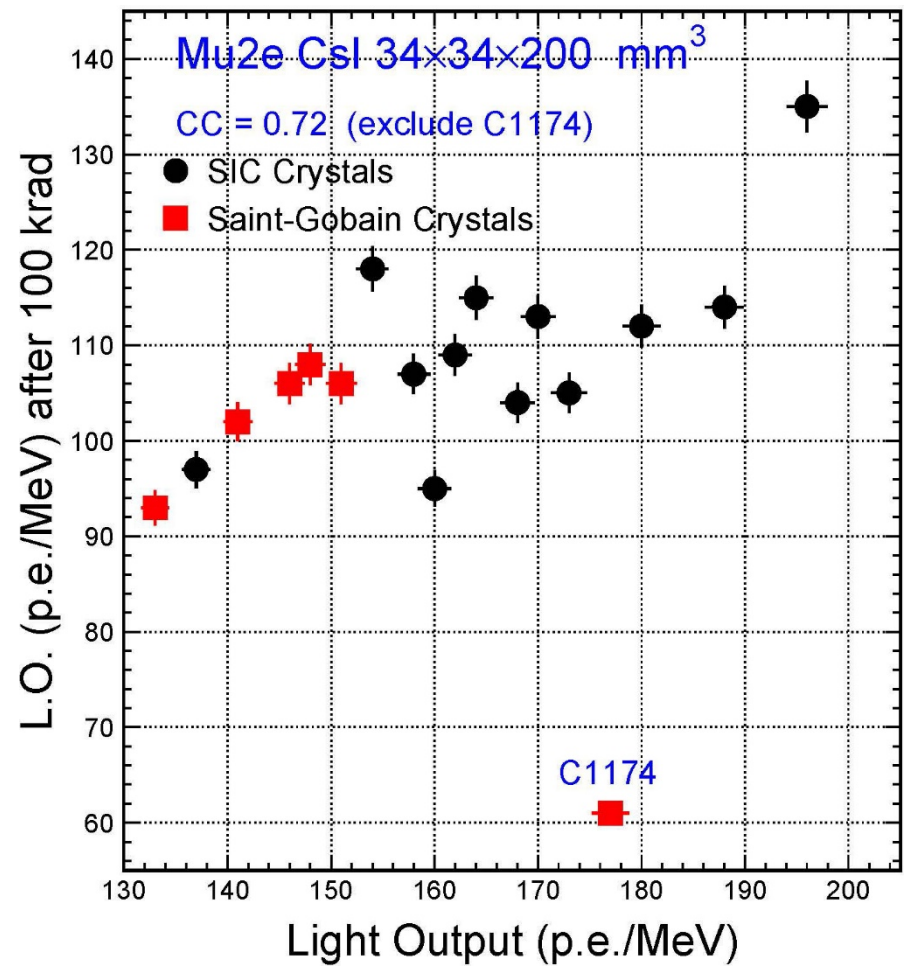
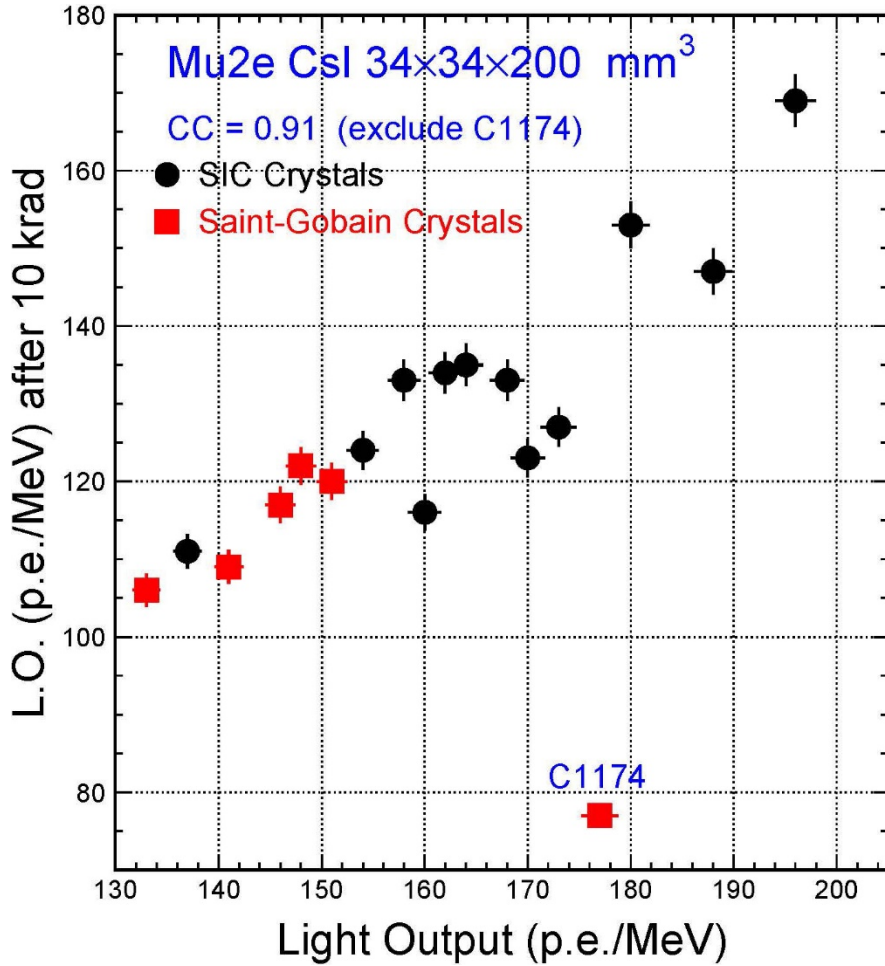


# Summary: Six SG Csl Crystals

Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
SG-C0770	Before IR	133	35	91	0.8
	10 krad	106 (80%)	36	92	1.3
	100 krad	<b>93</b> (70%)	37	90	2.8
SG-C0950	Before IR	148	31	96	2.0
	10 krad	122 (82%)	34	97	3.0
	100 krad	108 (73%)	36	96	2.7
SG-C1063	Before IR	146	31	98	1.1
	10 krad	117 (80%)	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</b> (44%)	42	98	<b>5.1</b>
	100 krad	<b>61</b> (34%)	<b>48</b>	96	<b>6.0</b>
SG-C1181	Before IR	151	31	99	2.2
	10 krad	120 (79%)	34	96	2.1
	100 krad	106 (70%)	36	94	2.6
SG-C1268	Before IR	141	32	97	1.8
	10 krad	109 (77%)	35	95	1.9
	100 krad	102 (72%)	38	96	3.0
Average (RMS)	Before IR	<b>149 (9.1%)</b>	<b>32 (1.8)</b>	<b>96 (2.7%)</b>	<b>1.6 (0.49)</b>
	10 krad	<b>109 (14.0%)</b>	<b>36 (2.9)</b>	<b>96 (2.0%)</b>	<b>2.6 (1.2)</b>
	100 krad	<b>96 (17%)</b>	<b>39 (4.3)</b>	<b>95 (2.5%)</b>	<b>3.4 (1.2)</b>

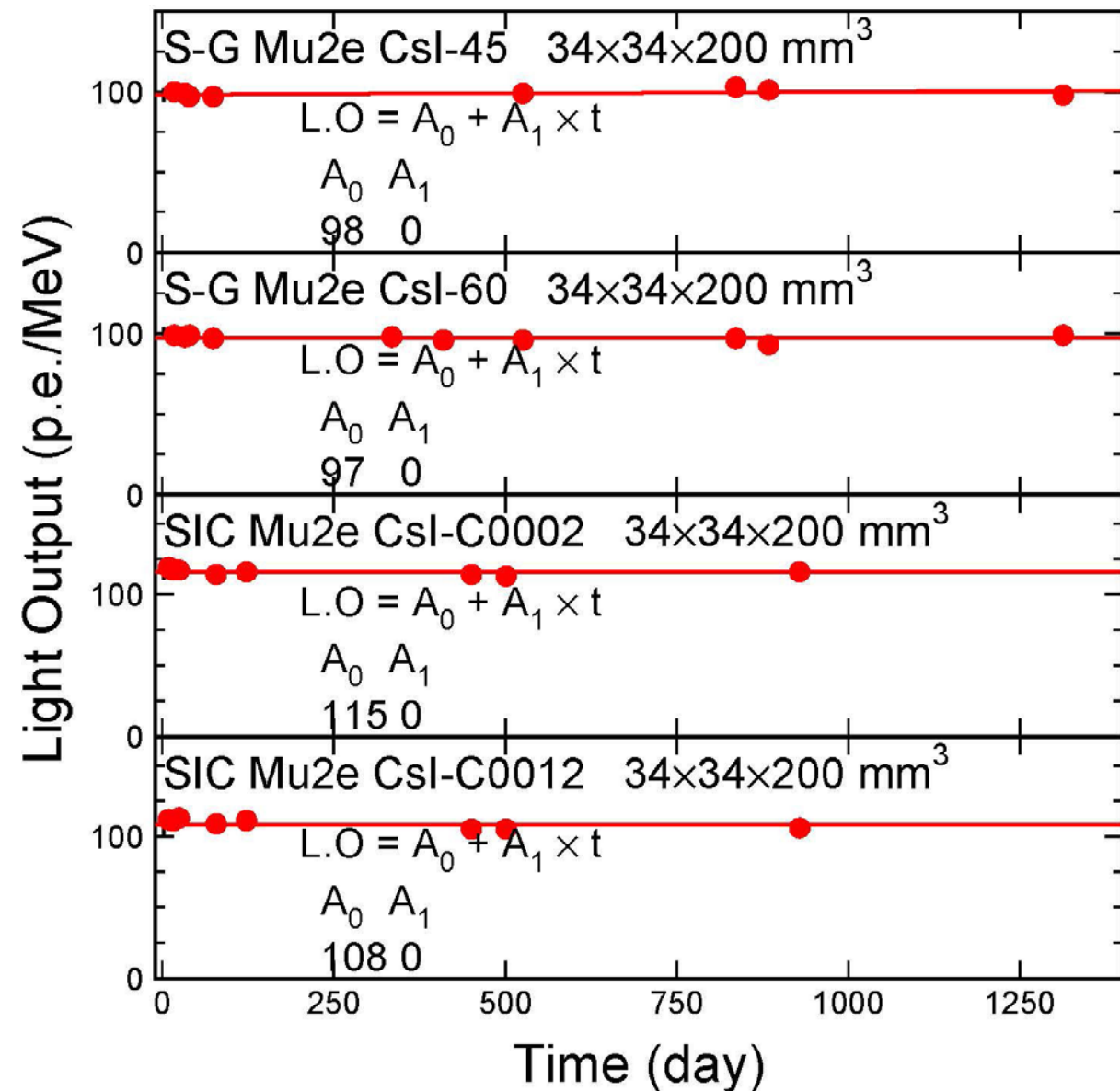
# Correlations: $LO_{\text{before}}$ vs $LO_{\text{after}}$

Good correlation, excluding SG C1174, observed





# Long Term LO Recovery after Radiation



No recovery was observed up to 1,313 & 929 days for two CsI crystals each from SG and SIC respectively, indicating a stable calorimeter