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# Report on Radiation Damage in Four SIC CsI Crystals and One S-G Cube Sample

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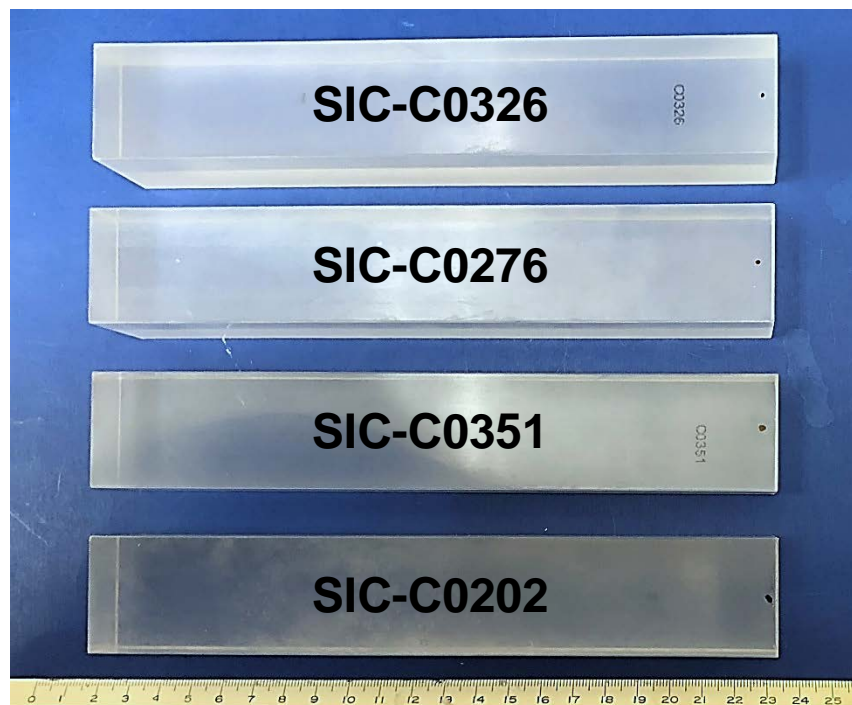
September 27, 2018

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Report given in the Mu2e Calorimeter Group Meeting



# Four SIC CsI Samples



ID	Dimension (mm <sup>3</sup> )	Polishing
SIC-C0326, 0276, 0351, 0202	34x34x200	All faces

## Experiments

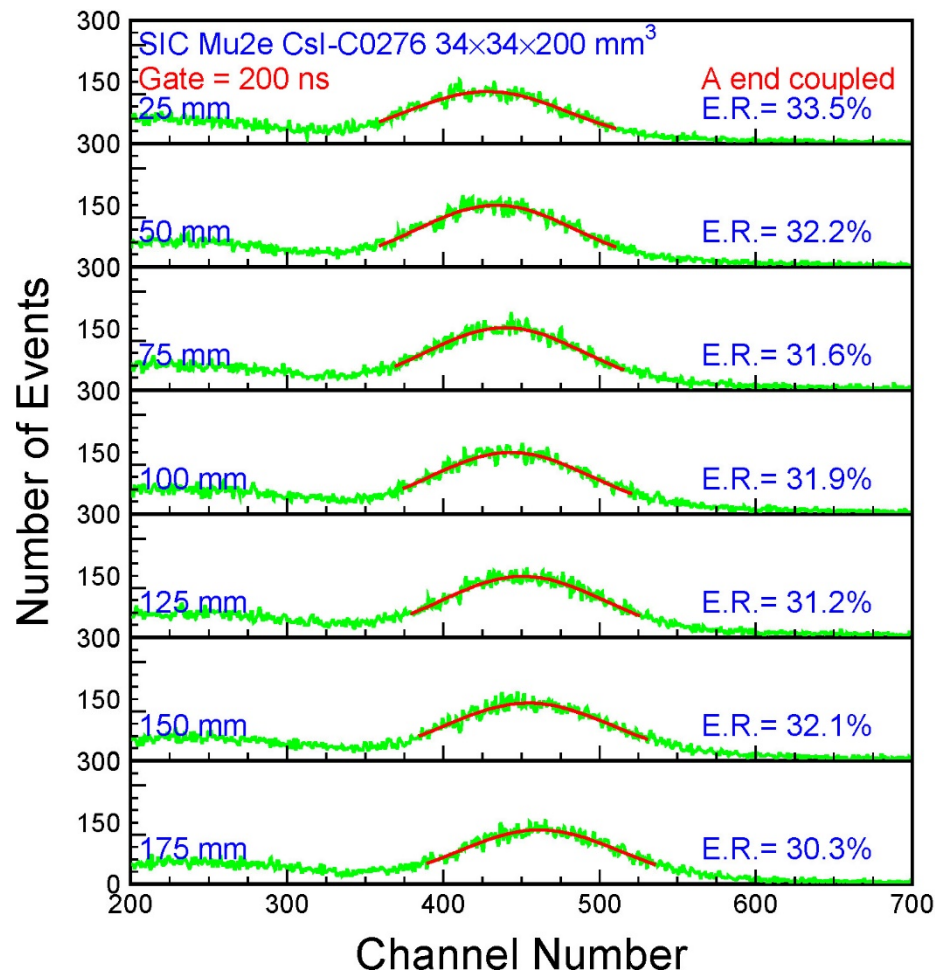
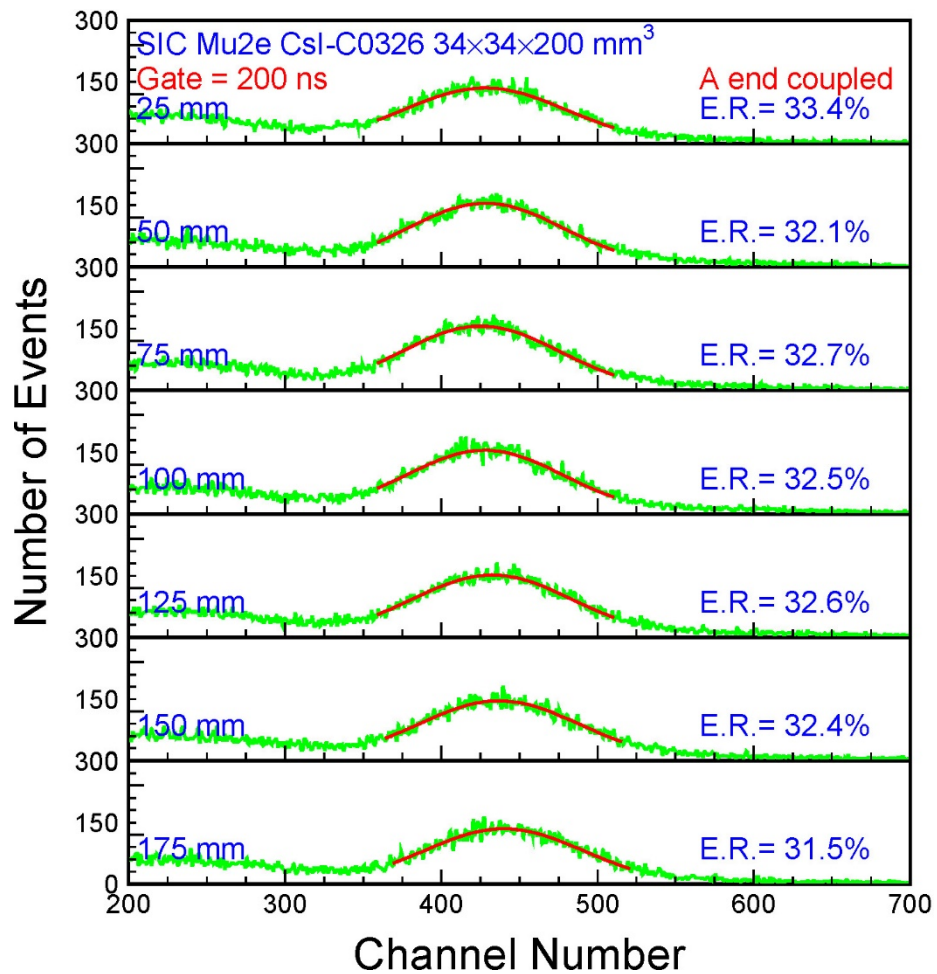
- Properties measured at room temperature : LO, ER, F/T, and LRU



# Pulse Height Spectra



Good light output and energy resolution

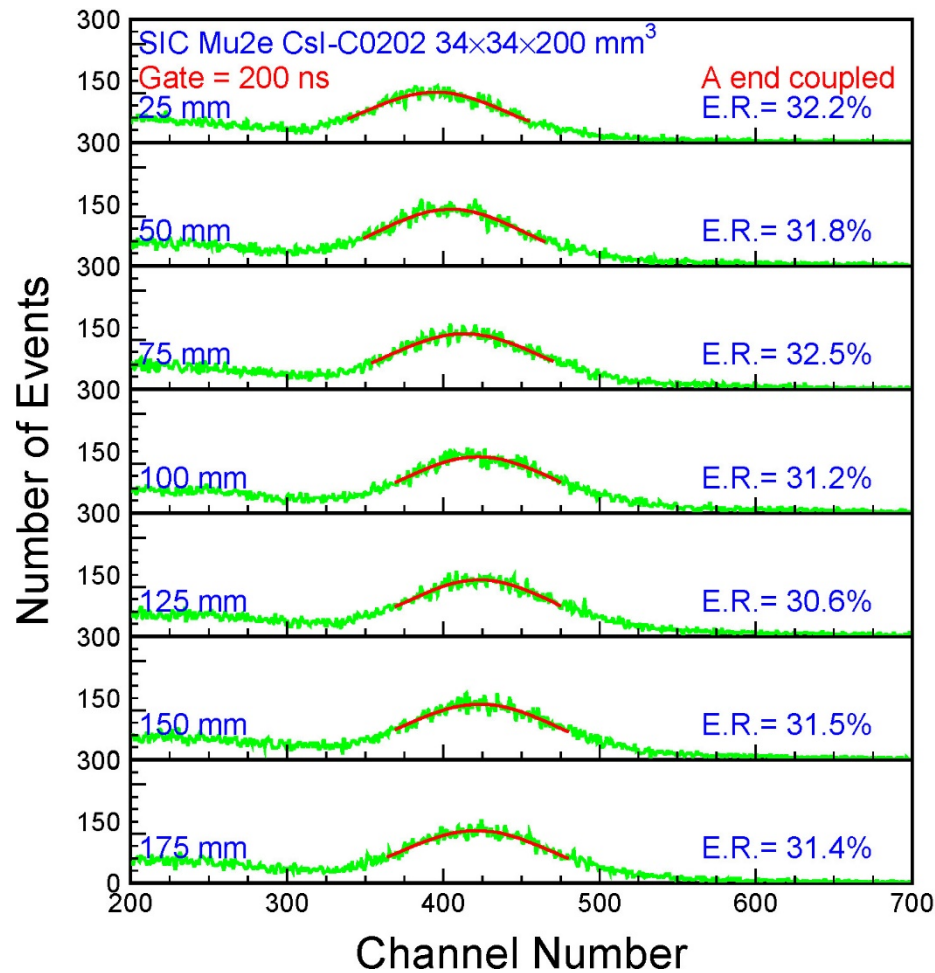
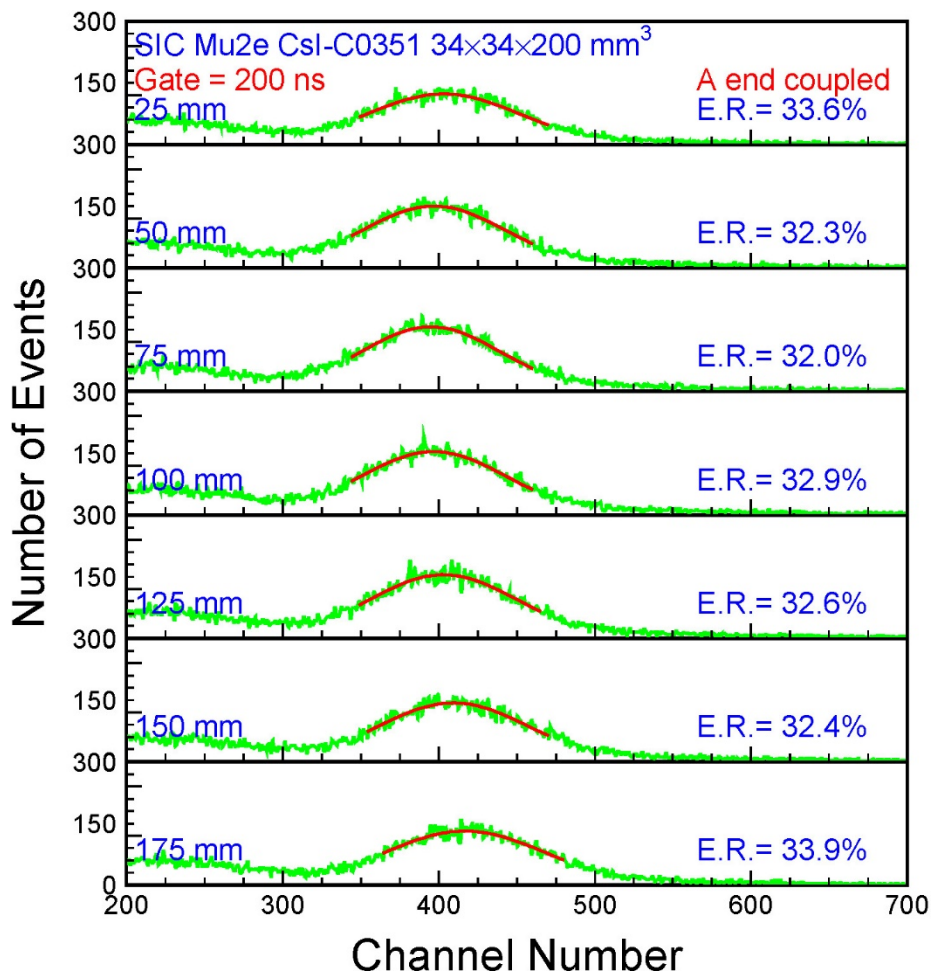




# Pulse Height Spectra



Good light output and energy resolution

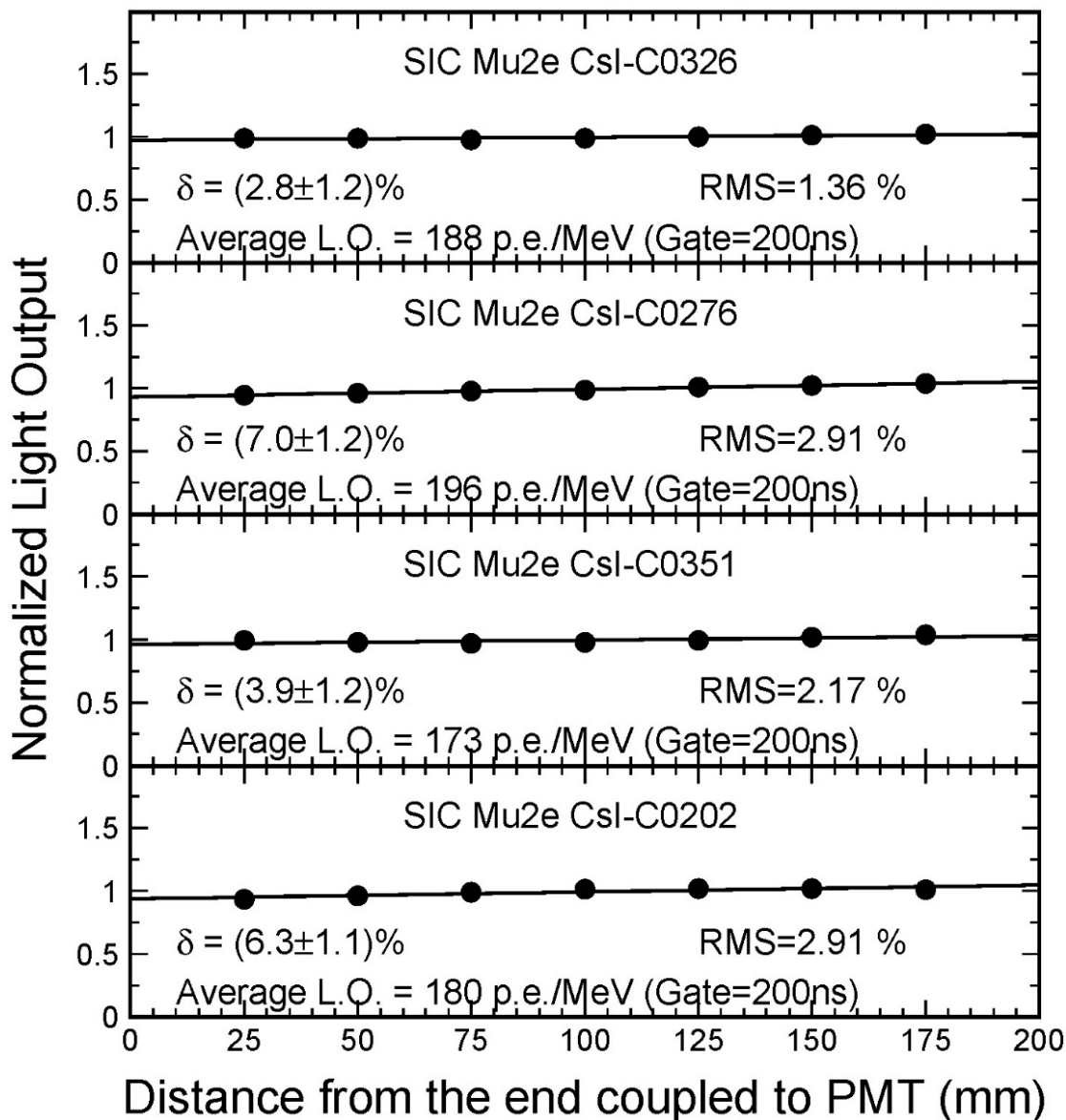




# Light Response Uniformity



Good LRU  
observed  
in all  
samples







# Summary of Four SIC Samples



Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)
SIC-C0202	Before IR	180	32	82.3	2.91
	10 krad	153 (85.2%)	33	86.3	0.96
	100 krad	112 (62.4%)	36	89.5	2.81
SIC-C0276	Before IR	196	32	85.8	2.91
	10 krad	169 (86.6%)	33	85.9	1.14
	100 krad	135 (69.0%)	35	84.8	1.50
SIC-C0326	Before IR	188	32	85.2	1.36
	<b>10 krad</b>	<b>147 (78.3%)</b>	34	85.0	1.71
	100 krad	114 (60.7%)	36	85.6	2.62
SIC-C0351	Before IR	173	33	90.1	2.17
	<b>10 krad</b>	<b>127 (73.4%)</b>	35	88.4	2.14
	100 krad	105 (60.9%)	37	90.5	3.49
Average (RMS)	Before IR	<b>184</b> (4.7%)	<b>32</b> (0.48)	<b>85.9</b> (3.2%)	<b>2.34</b> (0.64)
	10 krad	<b>149</b> (10.1%)	<b>34</b> (0.83)	<b>86.4</b> (1.4%)	<b>1.49</b> (0.47)
	100 krad	<b>117</b> (9.6%)	<b>36</b> (0.71)	<b>87.6</b> (2.8%)	<b>2.61</b> (0.72)



# Two SIC Samples (Mar 1, 2018)



Damages, including Tyvek, meet Mu2e spec after 110 krad, but not after 10 krad

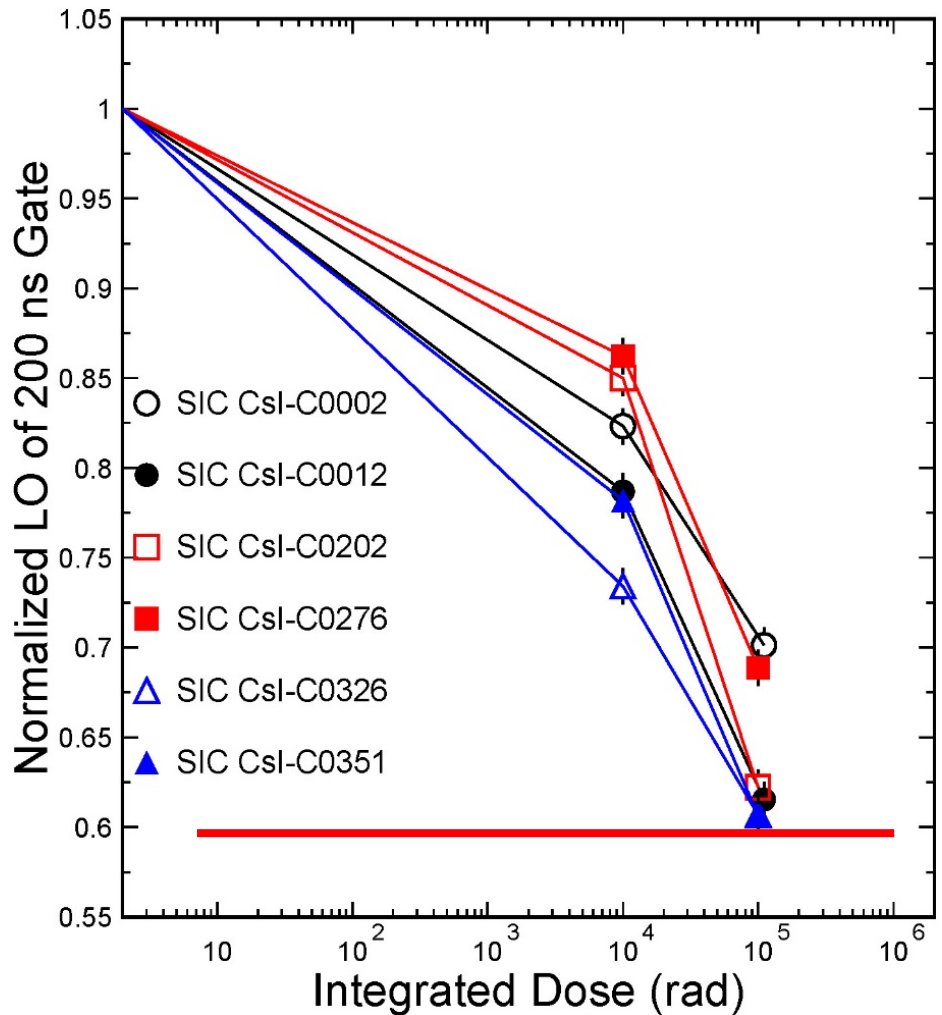
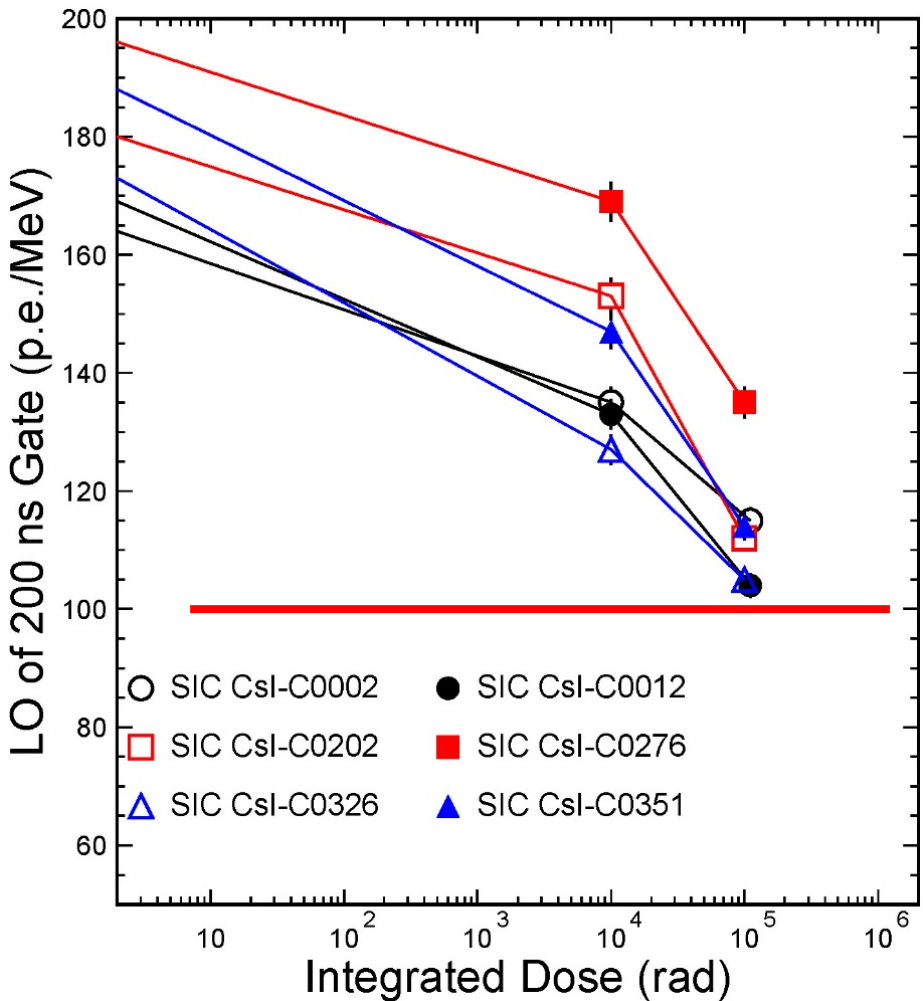
Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)	LRU (%)	$\delta$ (%)
SIC-C0002	-	164	34	90.5	2.20	4.7
	10 krad	135 (82.3%)	35	89.8	0.83	1.0
	110 krad	115 (70.1%)	36	91.7	1.88	-3.4
SIC-C0012	-	169	33	88.6	2.71	6.0
	10 krad	<b>133 (78.7%)</b>	35	88.5	1.21	1.5
	110 krad	104 (61.5%)	37	89.6	1.49	-2.5



# Light Output vs Integrated Dose



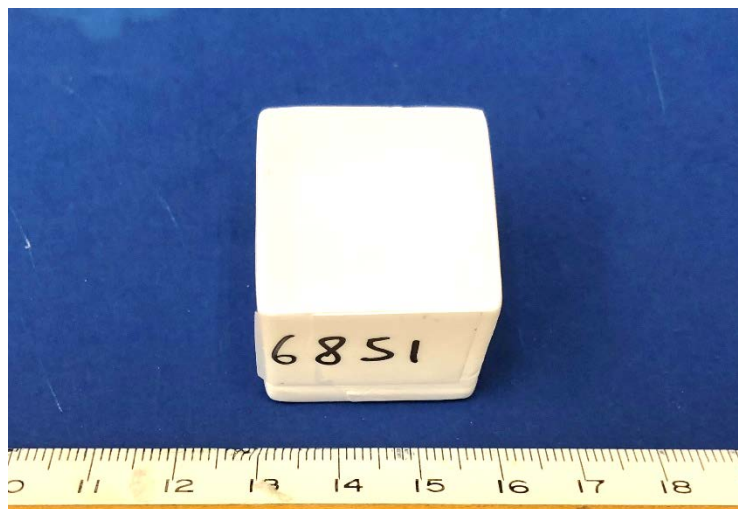
All have more than 100 p.e./MeV after 100 krad and meet Mu2e RD spec  
Three samples lose more than 20% light after 10 krad







# The 7<sup>th</sup> 2018 S-G Undoped CsI Cube



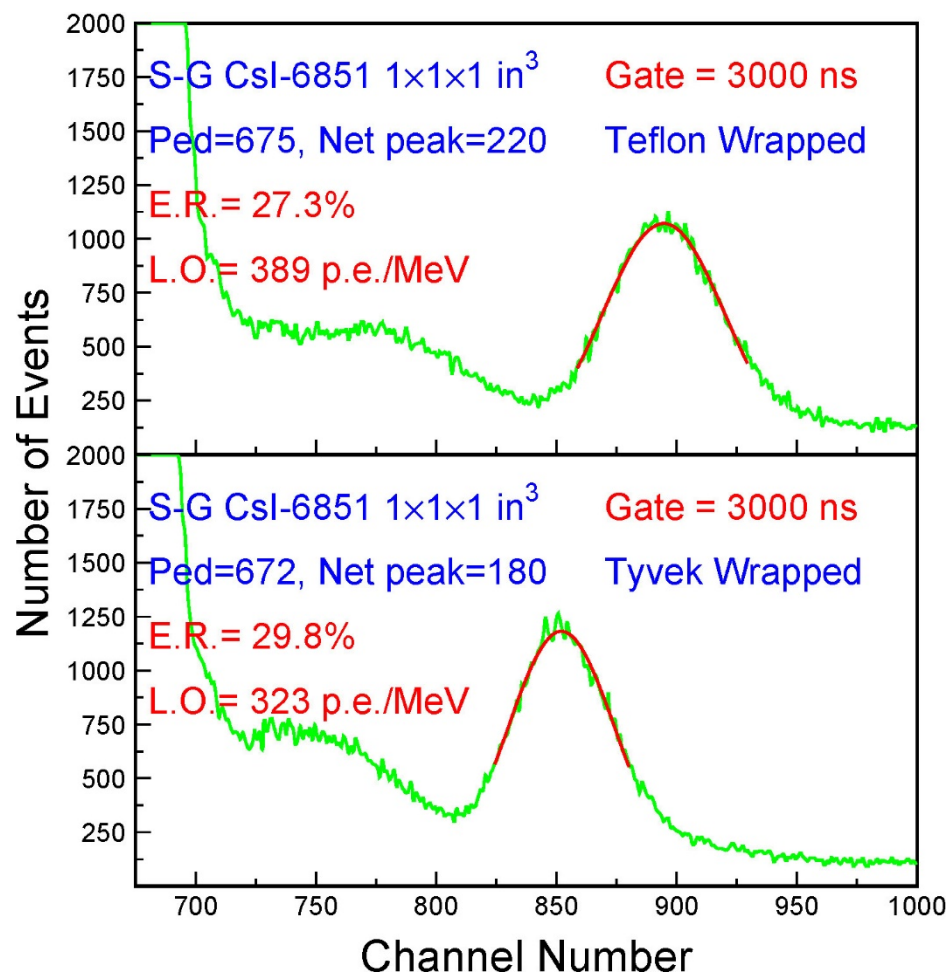
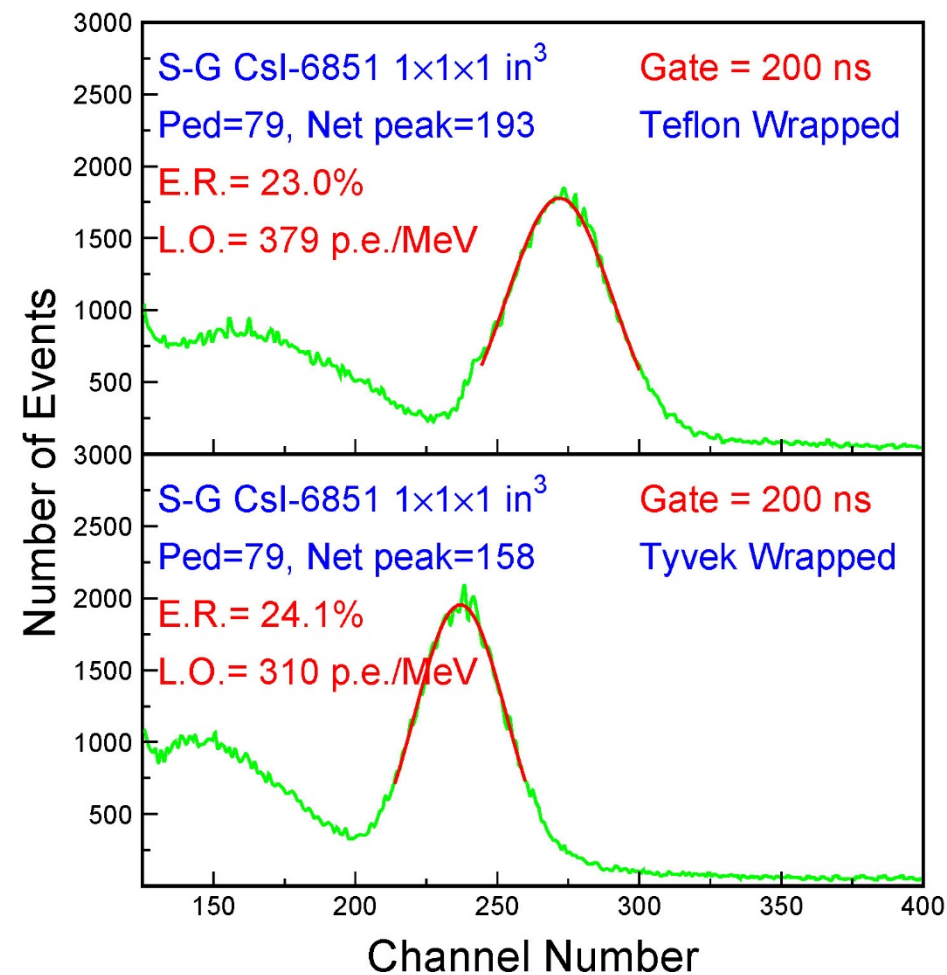
ID	Dimension (mm <sup>3</sup> )	Polishing
S-G 6851	1x1x1	One face

## Experiments

- Properties measured at room temperature : LO, ER, and F/T

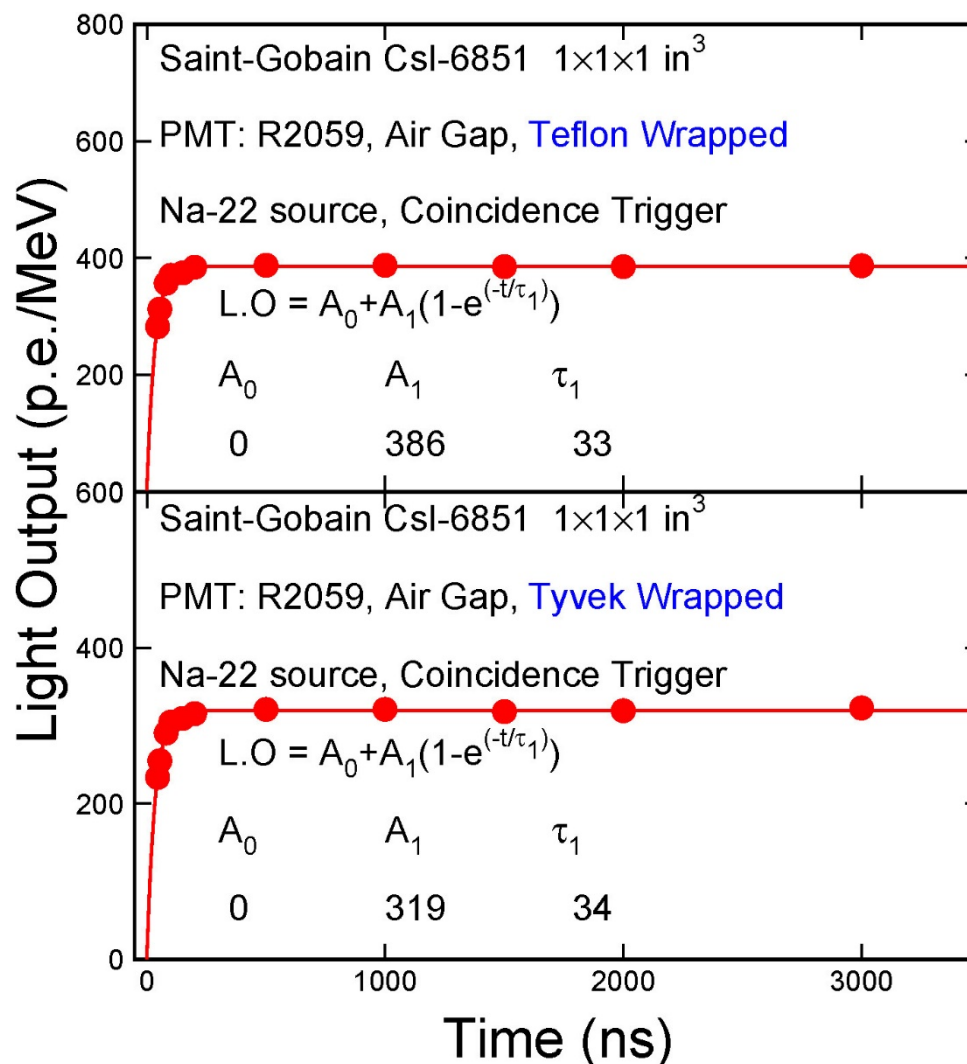


# PHS of S-G Cube: Tyvek & Teflon





# LO & Decay Kinetics: Tyvek & Teflon





# Summary of All S-G Cubes



ID	200 ns ER (%)	200 ns LO (p.e./MeV)	3000 ns LO (p.e./MeV)	100 ns LO (p.e./MeV)	1000 ns LO (p.e./MeV)	LO(200) /LO(3000)	LO(100) /LO(1000) (Caltech)	Conversion Factor* (Caltech)	LO(100) /LO(1000) (SGCD)	Conversion Factor (Caltech & SGCD)
S-G 6827	26.9	266	273	261	270	97.4	96.5	<b>99.0</b>	87.6	<b>89.9</b>
S-G 6828	25.3	279	283	276	280	98.8	98.4	<b>99.6</b>	87.9	<b>89.0</b>
S-G 6834	25.8	315	326	308	322	96.6	95.6	<b>98.9</b>	86.4	<b>89.4</b>
S-G 6835	22.7	379	389	363	386	97.5	93.6	<b>96.1</b>	88.3	<b>90.6</b>
S-G 6838	24.5	316	324	309	324	97.5	95.3	<b>97.8</b>	87.5	<b>89.7</b>
S-G 6840	24.4	298	301	293	301	98.5	97.3	<b>98.8</b>	88.5	<b>89.8</b>
<b>S-G 6851</b>	<b>24.1</b>	<b>310</b>	<b>323</b>	<b>299</b>	<b>319</b>	<b>95.8</b>	<b>93.7</b>	<b>97.9</b>	<b>85.5</b>	<b>89.3</b>
<b>Ave</b>	<b>24.8</b>	<b>309</b>	<b>317</b>	<b>301</b>	<b>315</b>	<b>97.4</b>	<b>95.8</b>	<b>98.3</b>	<b>87.4</b>	<b>89.7</b>
<b>RMS /Ave</b>	<b>5.0%</b>	<b>10.8%</b>	<b>11.1%</b>	<b>9.9%</b>	<b>11.2%</b>	<b>1.0%</b>	<b>1.7%</b>	<b>1.1%</b>	<b>1.1%</b>	<b>0.5%</b>



# Summary of Damage in S-G Cubes

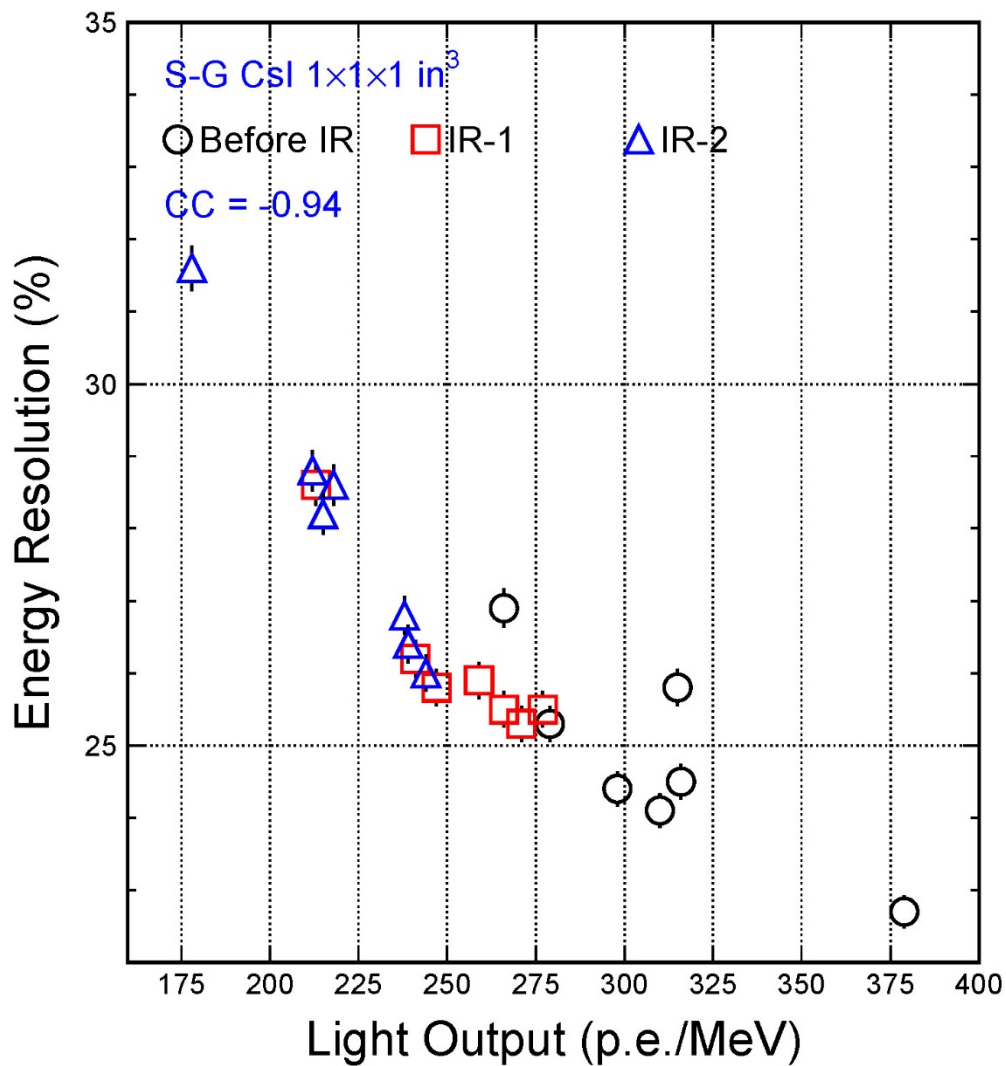


Crystal ID	Dose	L.O. (p.e./MeV)	E.R. (%)	F/T (%)
SG-6827	-	266	26.9	97.4
	10 krad	<b>213 (80.1%)</b>	28.6	95.5
	110 krad	178 (66.9%)	31.6	96.2
SG-6828	-	279	25.3	98.8
	10 krad	241 (86.4%)	26.2	99.6
	110 krad	218 (78.1%)	28.6	98.8
SG-6834	-	315	25.8	96.6
	10 krad	<b>266 (84.4%)</b>	25.5	98.3
	110 krad	239 (75.9%)	26.4	99.5
SG-6835	-	379	22.7	97.5
	10 krad	<b>271 (71.7%)</b>	25.3	98.7
	110 krad	244 (64.3%)	26.0	97.7
SG-6838	-	316	24.5	97.5
	10 krad	<b>259 (82.0%)</b>	25.9	99.2
	110 krad	238 (75.3%)	26.8	99.9
SG-6840	-	298	24.4	98.5
	10 krad	<b>247 (83.2%)</b>	25.8	100
	110 krad	215 (72.1%)	28.2	99.7
SG-6851	-	<b>310</b>	<b>24.1</b>	<b>95.8</b>
	<b>10 krad</b>	<b>277 (89.4%)</b>	<b>25.5</b>	<b>95.2</b>
	<b>110 krad</b>	<b>212 (68.4%)</b>	<b>28.8</b>	<b>95.0</b>





# LO vs ER for 7 CsI Cubes





# Summary

- Four SIC production CsI crystals were irradiated to 10/100 krad. All meet the Mu2e spec after 100 krad. Two lose more than 20% light after 10 krad.
- Including two SIC production CsI crystals reported on Mar 1, all six have more than 100 p.e./MeV after 100 krad with a light output loss of less than 40%.
- The 7<sup>th</sup> 1" S-G CsI cube was characterized, and with radiation damage measured for 10/100 krad. The results were provided to S-G. Additional 1" cubes were requested for neutron test at ORNL.