

# The Radiation Hardness of Specific Multi-mode and Single-mode Optical Fibres at $-25^{\circ}\text{C}$ to Full SLHC Doses

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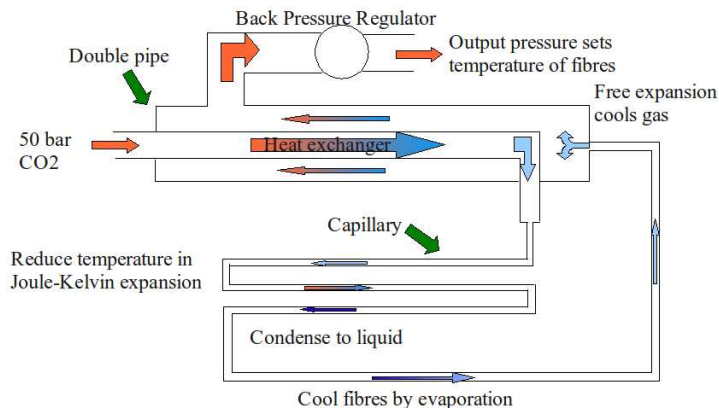
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- SLHC is planned with integrated luminosity increased by a factor of 10 compared to LHC
- General purpose detectors will need upgraded inner detectors to handle increase in data rates and radiation damage
- Optical fibres to transfer data to and from the tracker that are radiation hard in the cold ( $-25^{\circ}\text{C}$ ) environment of the tracker must be identified
- Fibres are damaged more in cold environment due to decreased annealing
- Fibres are damaged more by higher dose rates

# Previous Measurements

- A selection of Single Mode (SM) and Multi-Mode (MM) fibres have been tested to beyond a full 'worst case scenario' SLHC dose (375kGy(Si)) in a warm environment
- Some fibres have been tested at a range of temperatures
- Evidence seen for RIA having temperature dependence, as expected from literature
- For cold ( $-25^{\circ}\text{C}$ ) tests dose was limited by use of Peltier coolers
- Cold testing up to full SLHC dose is required
- Required radiation hard cooling system

# CO<sub>2</sub> Cooling System

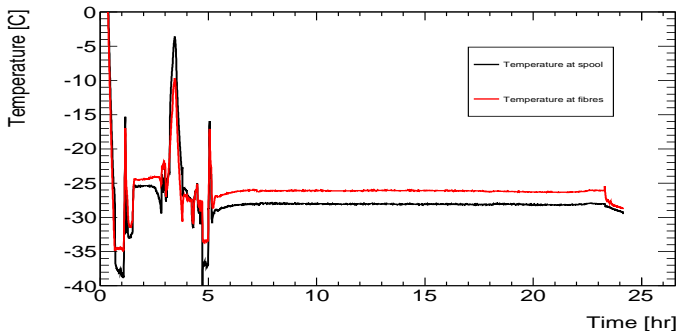


# Experimental Setup

- A selection of Single Mode (SM) and Multi-Mode (MM) fibres tested
- SM fibres illuminated by 1310nm EELs, MM fibres illuminated by 850nm VCSELs
- Fibres cooled by CO<sub>2</sub> cooling system
- Cooling system lowered into array of <sup>60</sup>Co in canal filled with water for shielding at SCK-CEN in Mol, Belgium
- <sup>60</sup>Co array provides  $\gamma$  at 27 kGy(Si) / hr
- Light power transmitted through fibres in the radiation zone compared with reference fibres out of radiation zone
- Radiation Induced Absorption (RIA) found as dB loss relative to reference fibre, per metre

# Experimental Run

- Cooling system ran well for over 1 hour before becoming unstable
- System removed from radiation zone due to cooling failure
- System re-cooled and forward pressure increased
- System returned to radiation zone and maintained stable temperature for 18 hours



# Fibres Tested

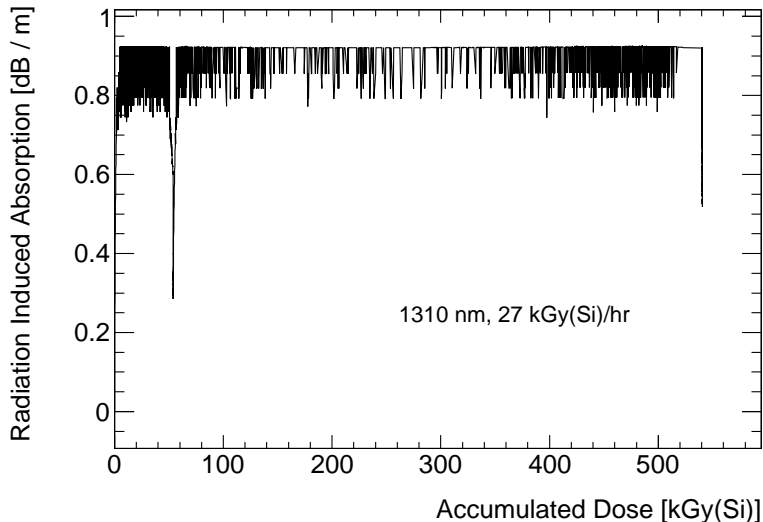
Manufacturer	Fibre	Mode	Wavelength
Corning	SMF-28e+	SM	1310 nm
Corning	Infinicor SX+	MM	850 nm
Draka	DrakaElite™ Super RadHard Single-Mode Fiber (SRH-SMF)	SM	1310 nm
Manufacturer X	Fibre X	SM	1310 nm

- Draka SRH-SMF and Fibre X fibres performed excellently
- Corning fibres' light levels dropped below the dynamic range of the DAQ system very rapidly, so a lower limit on RIA is set

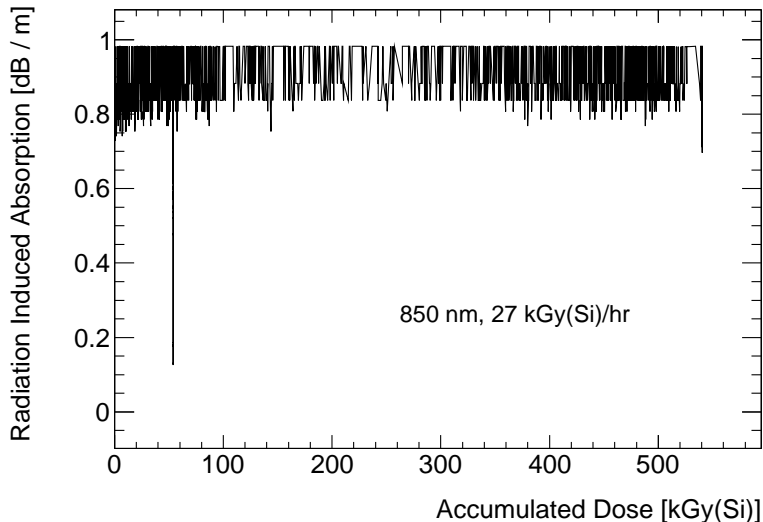
Fibre	RIA(375 kGy) [dB/m]
Corning SMF-28	> 0.9
Corning Infinicor SX+	> 0.9
Draka SRH-SMF	0.067
Fibre X	0.022



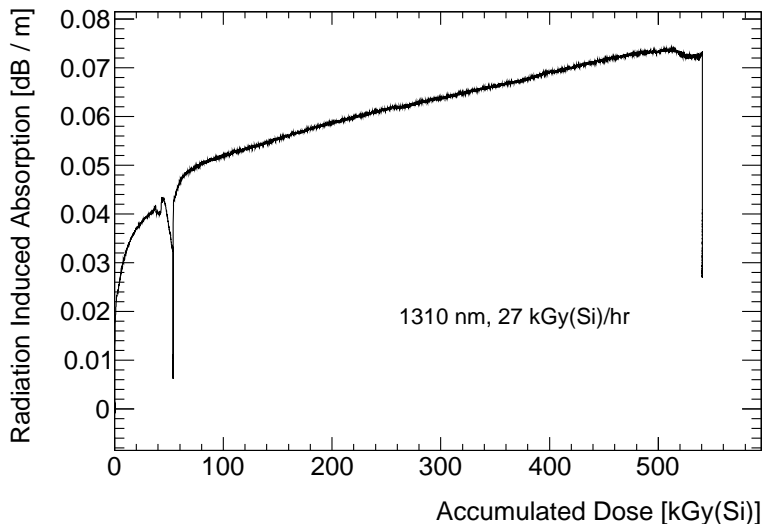
# Results - Corning SMF-28



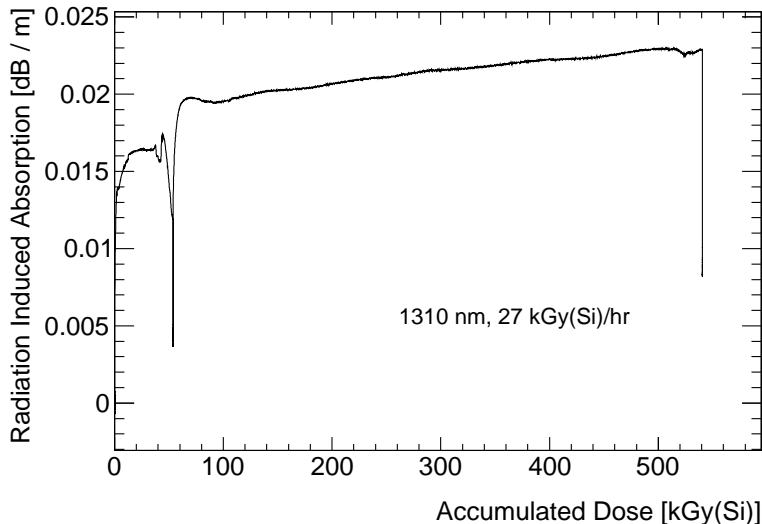
# Results - Corning Infinicor SX+



# Results - DrakaElite™ Super RadHard Single-Mode Fiber



# Results - Fibre X



# Modelling Realistic Fibre Path

- Draka and Producer X RIA(dose) function fitted
- LHC dose map scaled to SLHC doses
- Total RIA for a realistic path through a general purpose inner detector was calculated
- Total budget for RIA in whole length of fibre set as 1dB
- Very high dose rate means damage is overestimated
- Draka SRH-SMF total RIA calculated to be 0.142 dB
- Fibre X total RIA calculated to be 0.064 dB

# Conclusion and Further Work

- A number of fibres have been measured above full SLHC dose at  $-25^{\circ}\text{C}$  for the first time
- Full SLHC dose given in a day, leading to largely overestimated RIA
- DrakaElite<sup>TM</sup> Super RadHard Single-Mode Fiber and Fibre X fibres performed very well even with such high dose rates
- Very confident that these fibres could withstand SLHC dose even in cold environment
- Corning fibres cannot be excluded since they have performed well at lower dose rates
- Investigating the possibility of retesting fibres at lower dose rate

# Acknowledgements

- We would like to thank the Oxford Physics Workshop for designing and constructing the CO<sub>2</sub> cooling system.
- We would also like to acknowledge the work done by SCK-CEN in preparing our system, evaluating the safety of our planned experiment and for help setting up and running our experiment.
- Also like to thank Draka for providing fibres