UNIVERSITY OF LIVERPOOL

Development of the Optical Calibration System for the Outer Detector of LUX-ZEPLIN

Harvey Birch (MPhil Student)
Supervised by: Dr. Sergey Burdin and Dr. William Turner

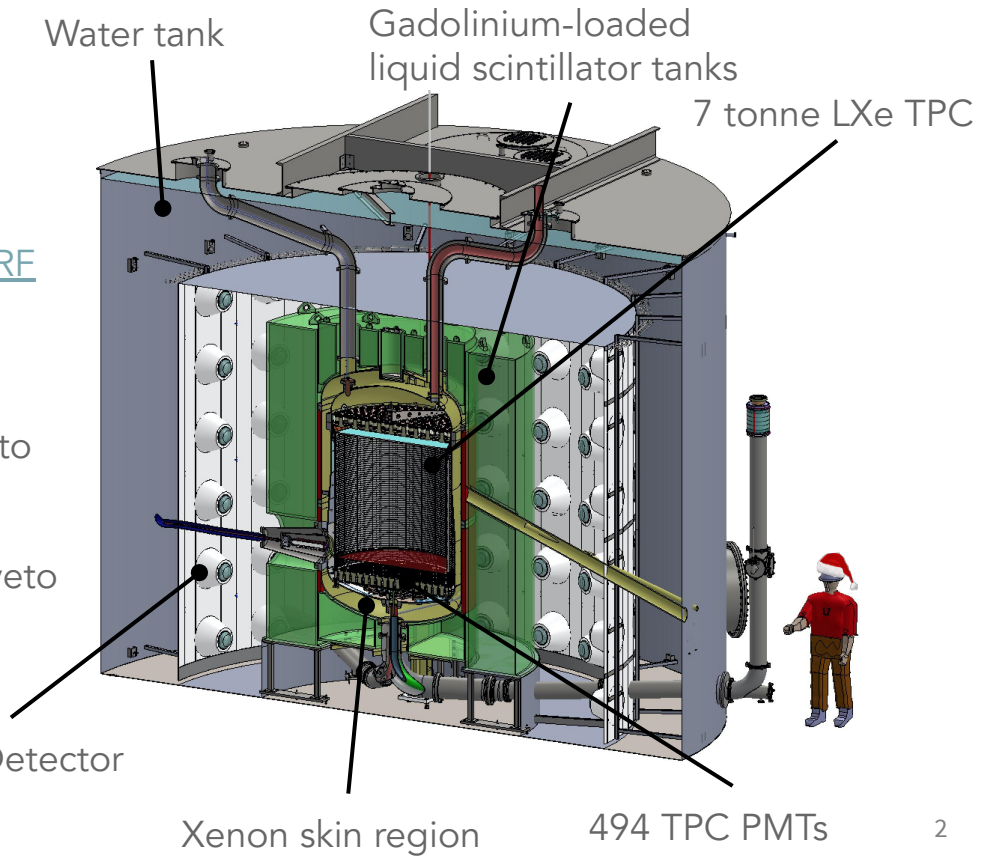
LUX-ZEPLIN dark matter direct detection experiment

- LZ is a Generation 2 dark matter direct detection experiment.

- The detector is currently being commissioned at SURF in South Dakota, USA. Planning to start taking data in Summer 2020.

- Dual-Phase Liquid Xenon Time Projection Chamber to detect WIMPs.

- The TPC will be surrounded by a three component veto system, which will be used to reject and characterise background radiation from the environment.



LUX-ZEPLIN (LZ) Technical Design Report arXiv:1703.09144

Outer Detector Optical Calibration System

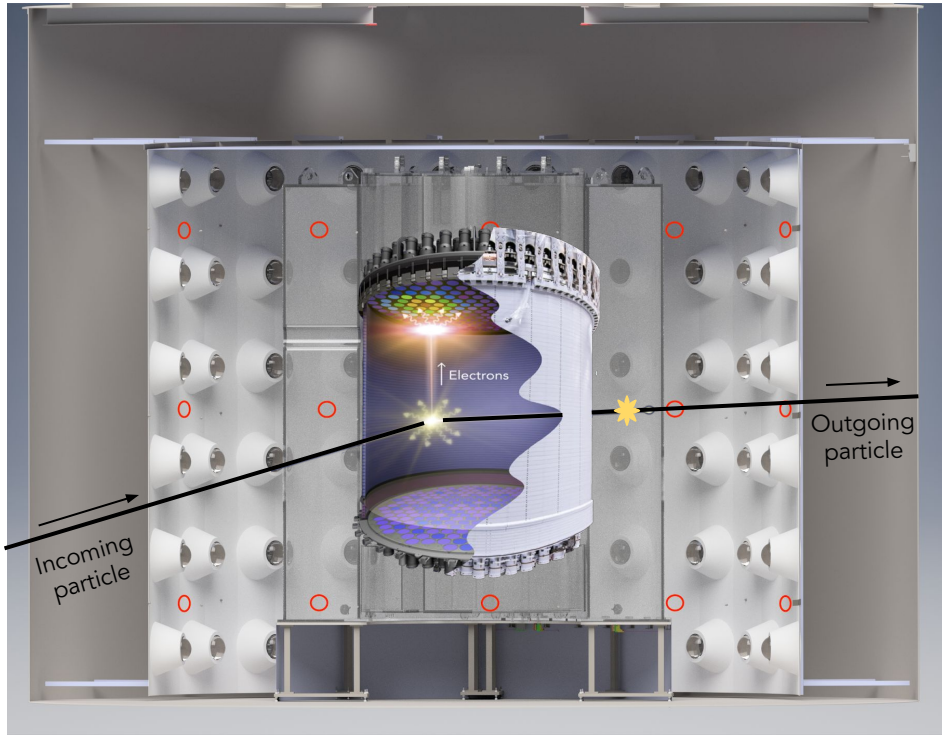
- A xenon skin layer will be used to veto background gamma radiation and shield TPC.

- The Outer Detector (Scintillator tanks & water tank) will be used to veto neutron and muon background signals.

- LZ will use an Optical Calibration System to monitor and calibrate the OD PMTs.

- 30 injection points situated within the array of OD PMTs.

- 5 injection points situated beneath the scintillator tanks directed upwards will monitor the LS and acrylic.



Outer Detector render. Courtesy of Dr. W. Turner

OCS installation and testing

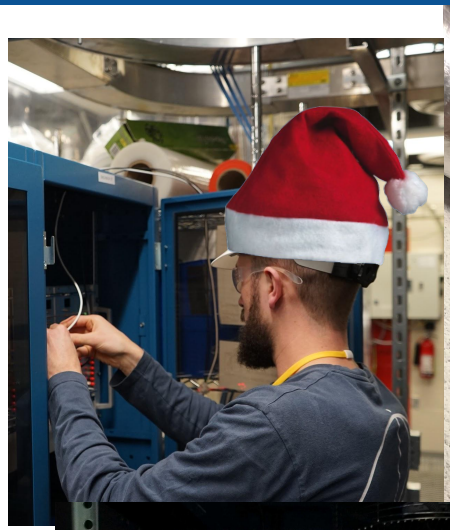
- Over the last year the OCS system has been developed in Liverpool.

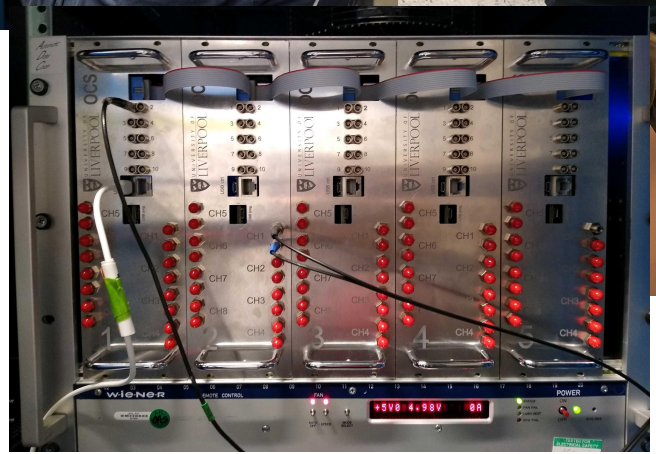
- In October, the OCS system was shipped to SURF.

- In November, myself, Will Turner and Alice Baxter travelled over to SURF to install the electronics system and perform re-calibration tests.

- The system arrived safely at SURF and passed an initial arrival visual inspection.

- All 40 channels were tested and calibrated in-situ successfully.



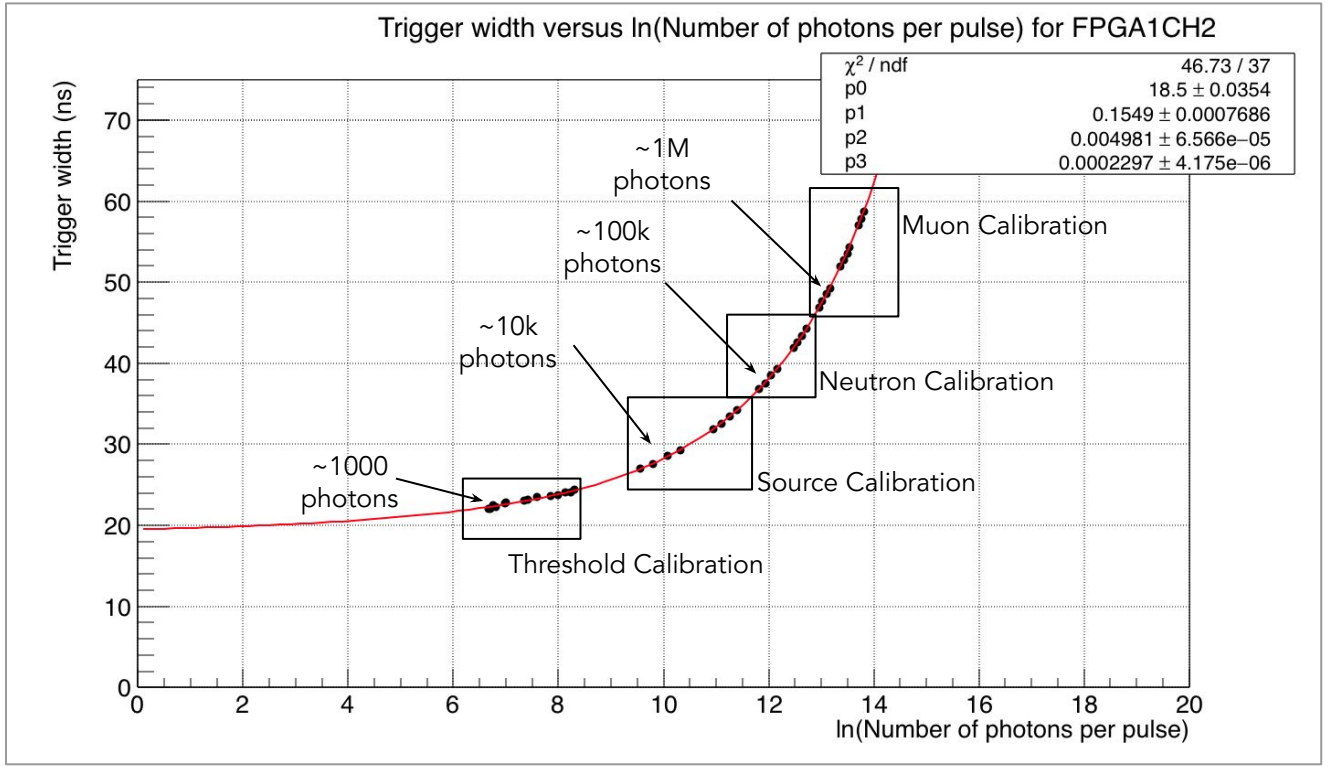


OCS Calibration

- Light intensity is controlled by the electrical pulse (Trigger width) received by the pulser board.

- Data is fitted with a function, the function will be used in the OCS to determine the trigger width needed on each channel in order to inject the specified number of photons.

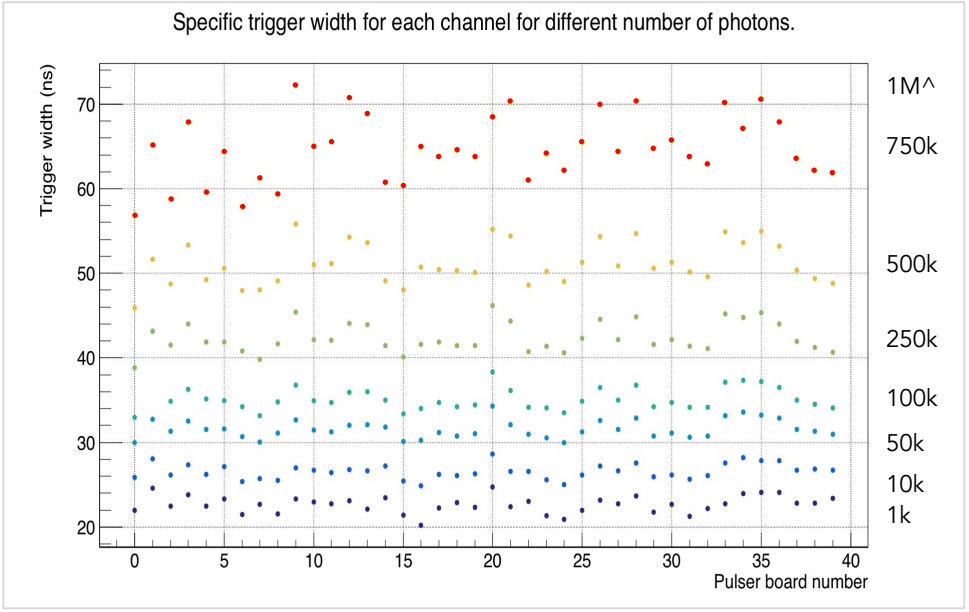
- Specific channel characterisation is essential for the OCS.

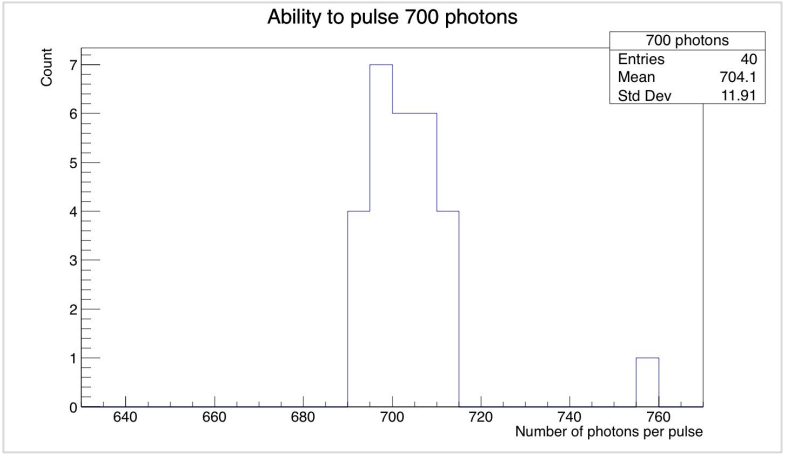


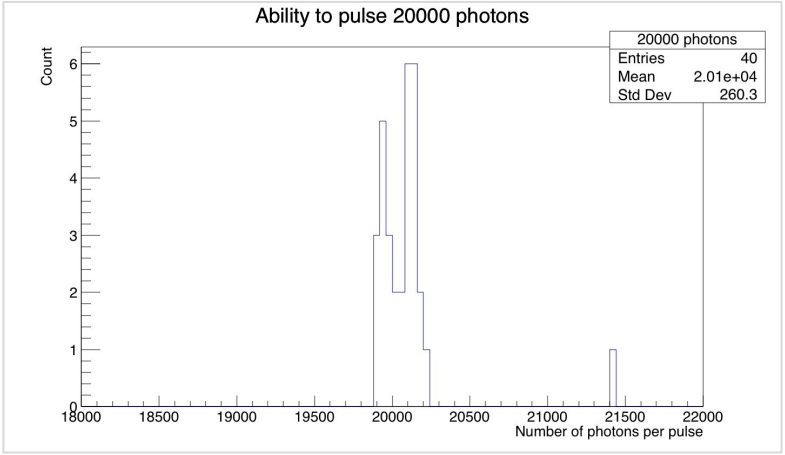
OCS Calibration

- We have the ability to precisely inject a specific number of photons on each channel.

- The system meets the requirement to pulse from 700 upto 50k with a pulse to pulse variation <10%.







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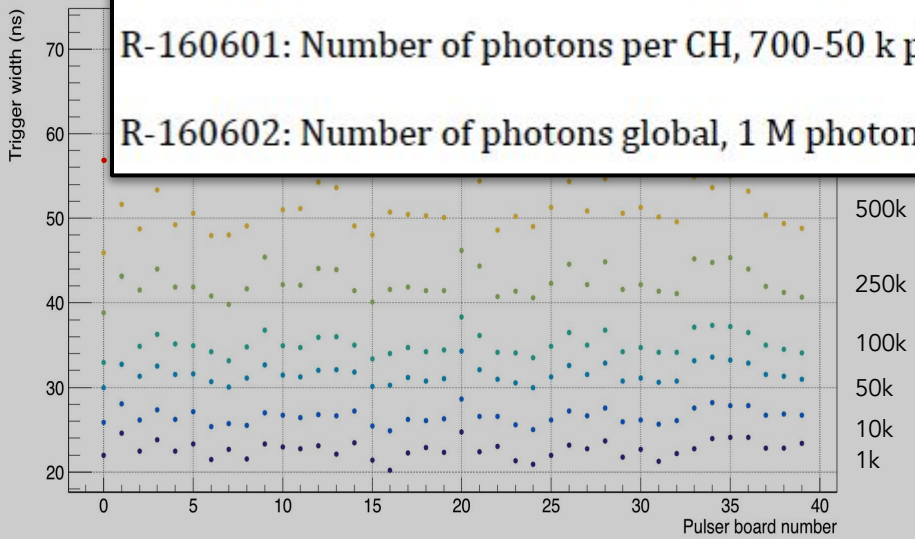
In-situ measurements

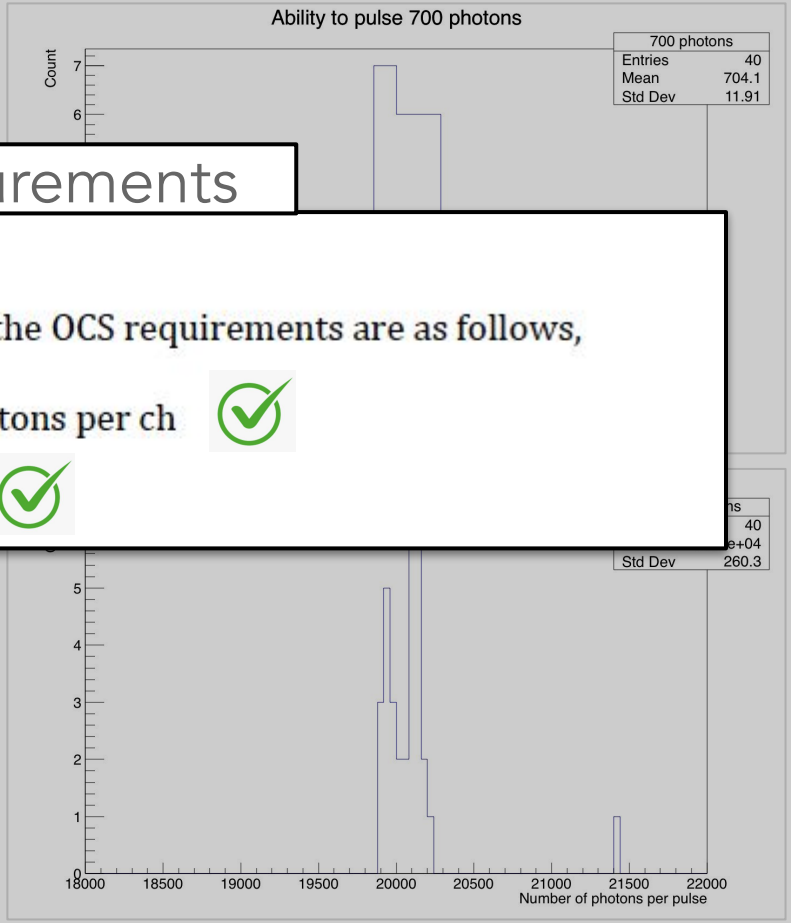
Key Requirements

As outlined in the main LZ Requirements document the OCS requirements are as follows,

R-160601: Number of photons per CH, 700-50 k photons per ch

R-160602: Number of photons global, 1 M photons





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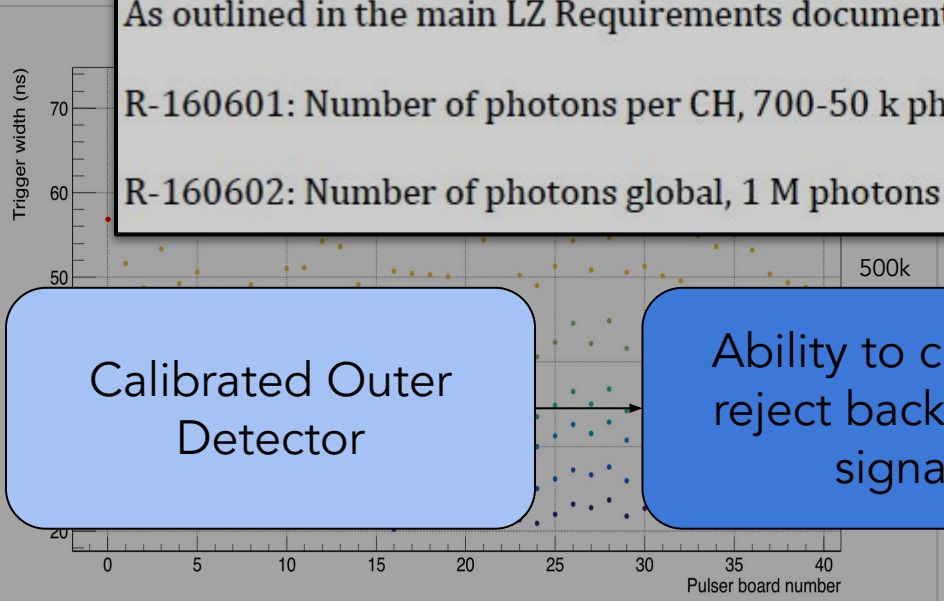
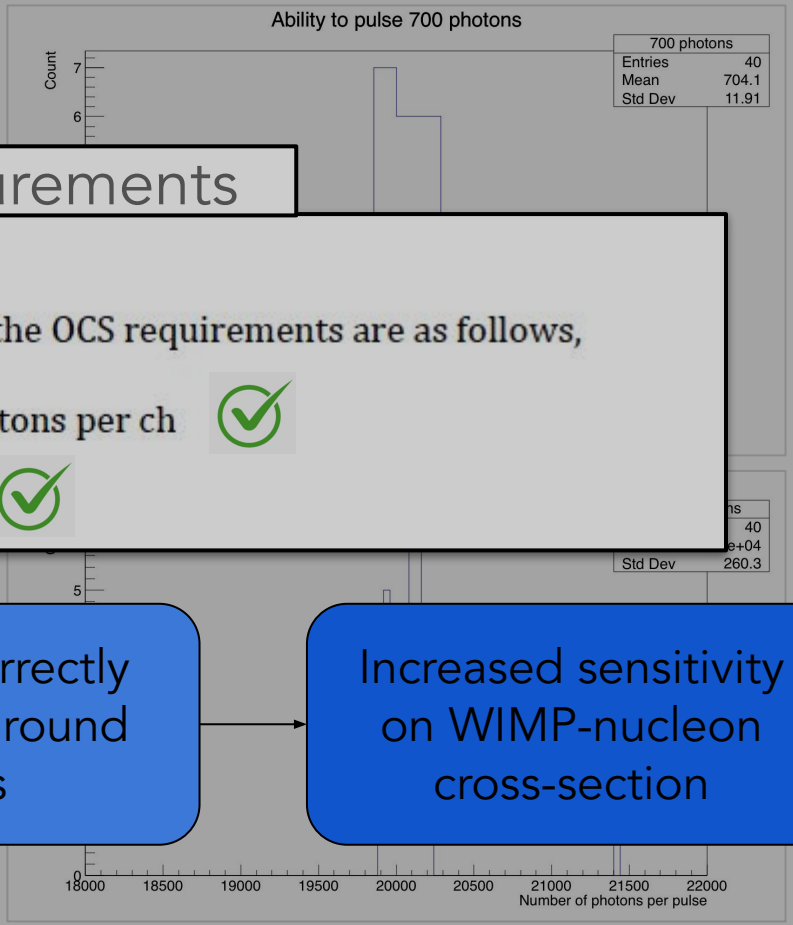




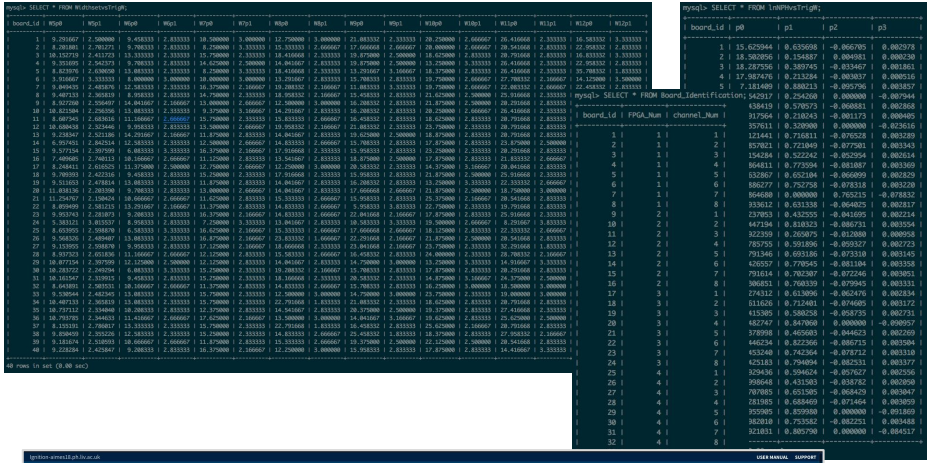
Calibrated Outer Detector → Ability to correctly reject background signals → Increased sensitivity on WIMP-nucleon cross-section

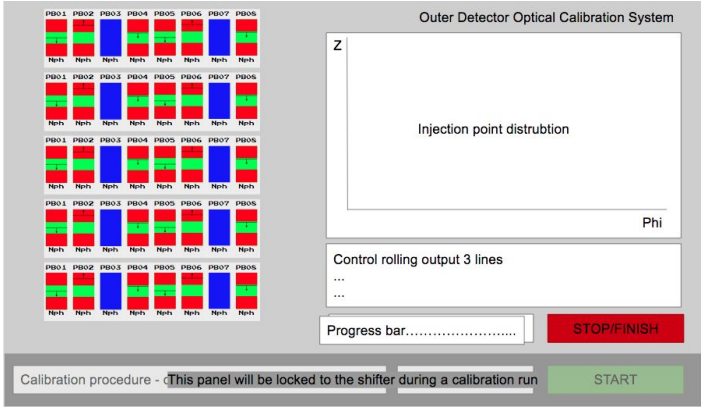
Optical Calibration System Database and GUI

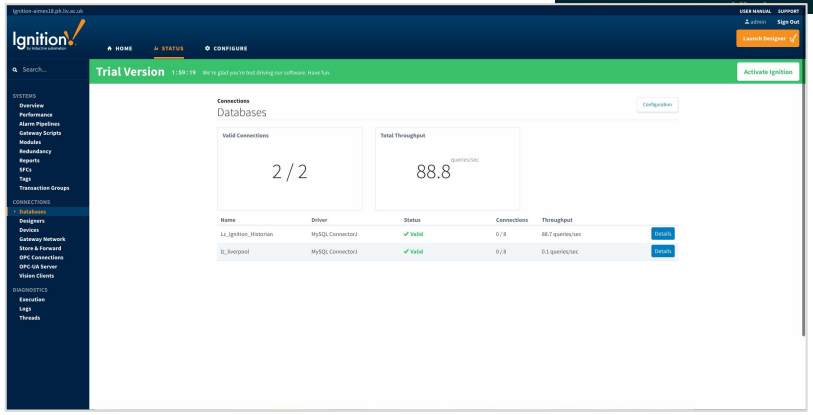
- Created a local SQL database system with tables to store calibration parameters and constants.

- Linked the local database to the LZ Slow Control server on Ignition.

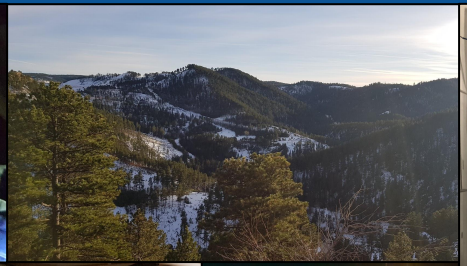
- Developed the design for the Optical Calibration GUI using Ignition Designer.



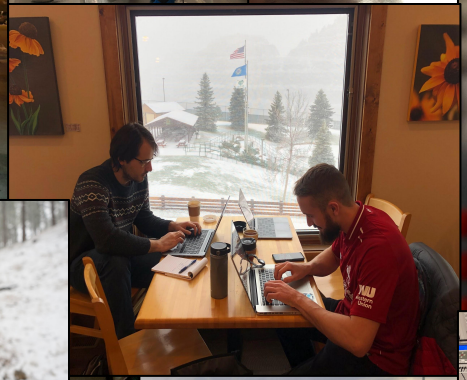


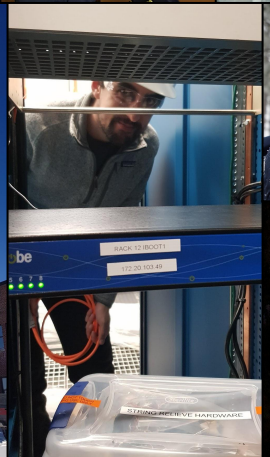


Any questions? Merry Christmas and a Happy New Year!

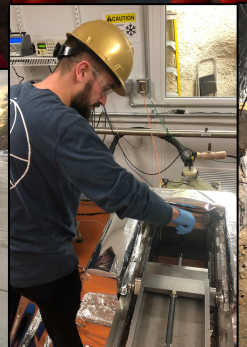







BACK UP

OCS test stand

- A script loops over many test points for each channel, constants and configuration settings are sent to the FPGA.

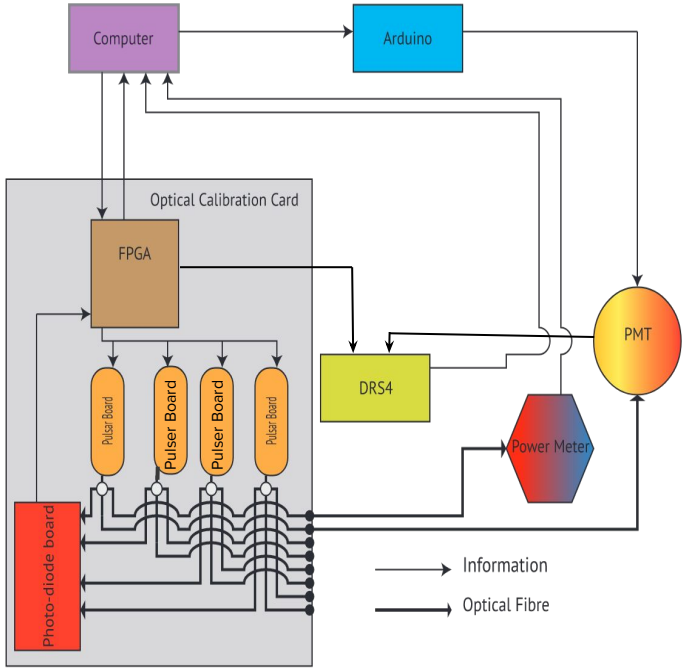
- LED is pulsed on pulser board. Light from the PB is split down three optical fibres using an optical coupler, 1st to the PMT, 2nd to power meter and 3rd to photodiode board.

- Data from the power meter and photodiode are all read back within the script.

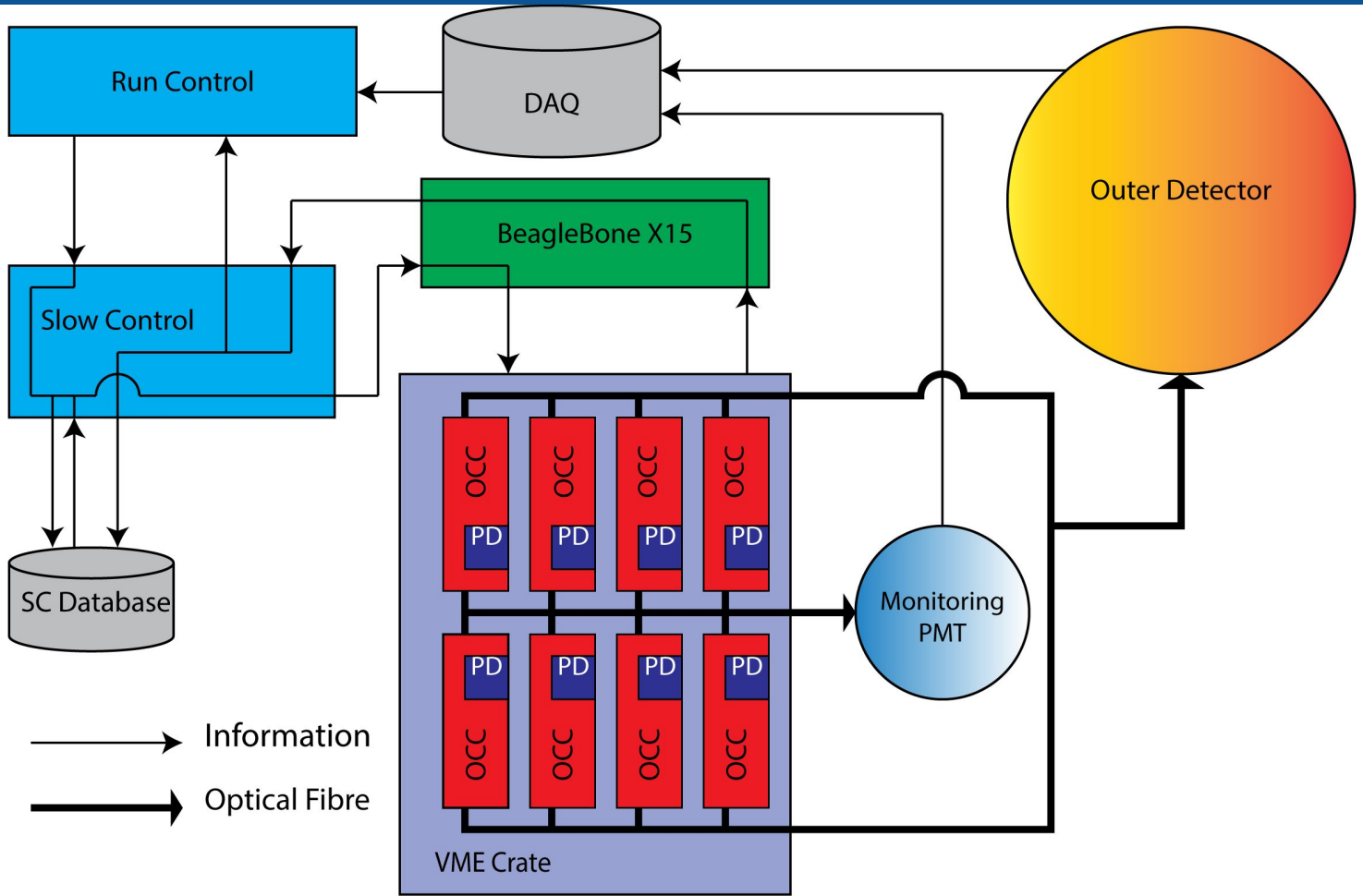
- Waveforms of the electrical trigger and PMT pulses are digitised by a DRS4 and saved into output file.

- An arduino is used to control the gain of the PMT based on the read back PMT pulse width.

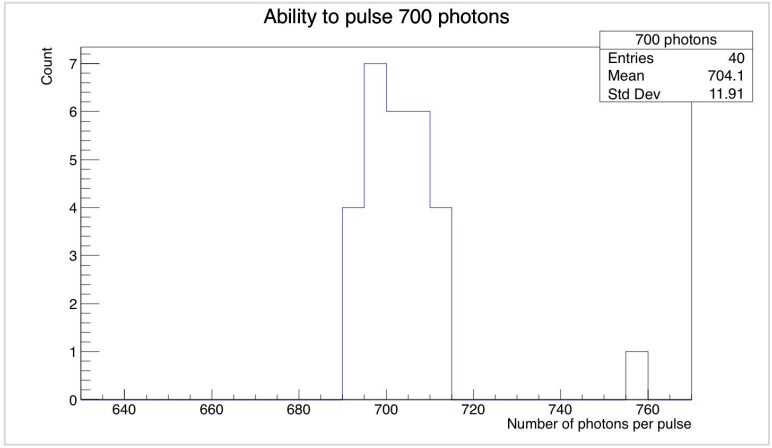
- Test stand highlighted in red beneath a blackout curtain.

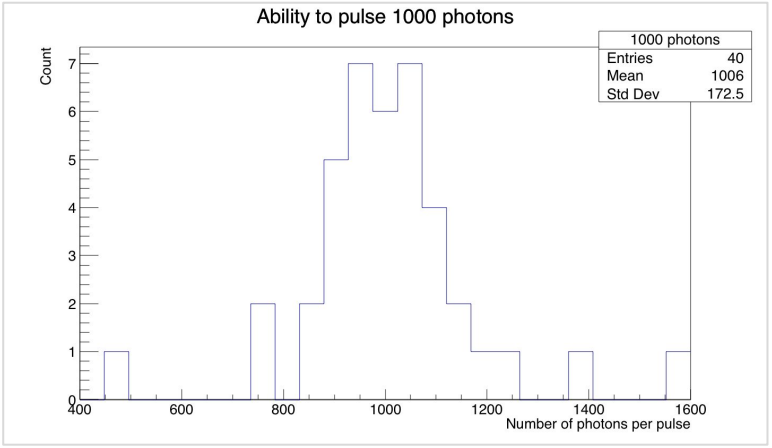


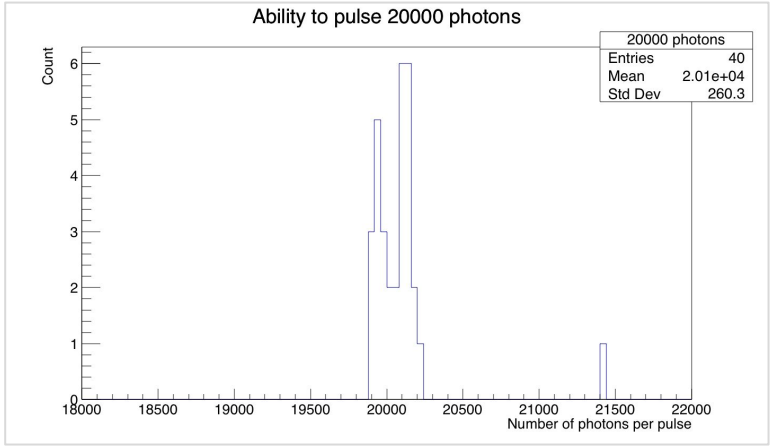
Outer Detector Optical Calibration System schematic

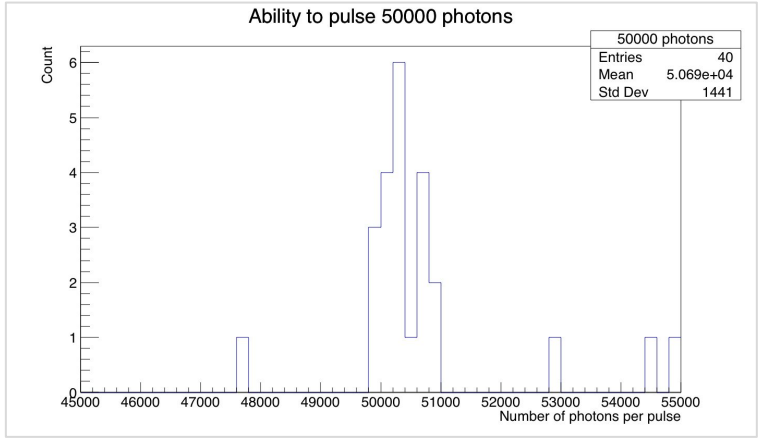


OCS Calibration: Pulse injection









OD Prominent Backgrounds

Outer Detector Components	Mass / kg	U_e^{238}	U_l^{238}	Th_e^{232}	Th_l^{232}	Co^{60}	K^{40}
		Activity (mBq/kg)					
Outer Detector Tanks	3200	0.16	0.39	0.02	0.06	0.04	5.36
Liquid Scintillator	17600	0.01	0.01	0.01	0.01	0.00	0.00
Outer Detector PMTs	205	570	470	395	388	0.00	534
OD PMT Supports	770	1.20	0.27	0.33	0.49	1.60	0.40
Fibre Support Structures	**10.5**	**31**	**3.0**	**6.0**	**3.0**	**0.5**	**330**
Optical Fibres (including couplers)	**5.53**	**91.5**	**8**	**10.5**	**4.5**	**1.75**	**302.5**

- Gammas from surrounding cavern rock and decay chains of detector components.

- Neutrons from detector components and surrounding environment.

- Alphas from detector components.

- OD background detector rate ~100 Hz.