Light Injection Calibration Systems for the T2K ND280 ECal Modules

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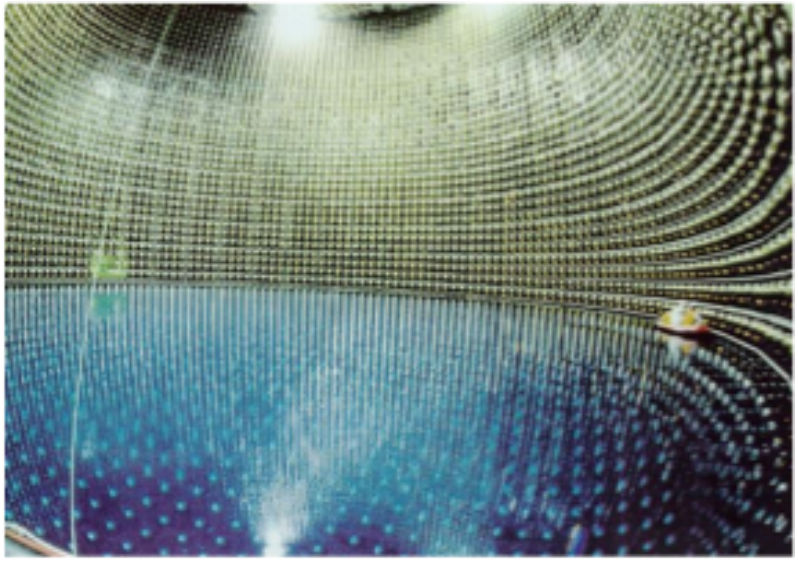
T2K Experimental Overview

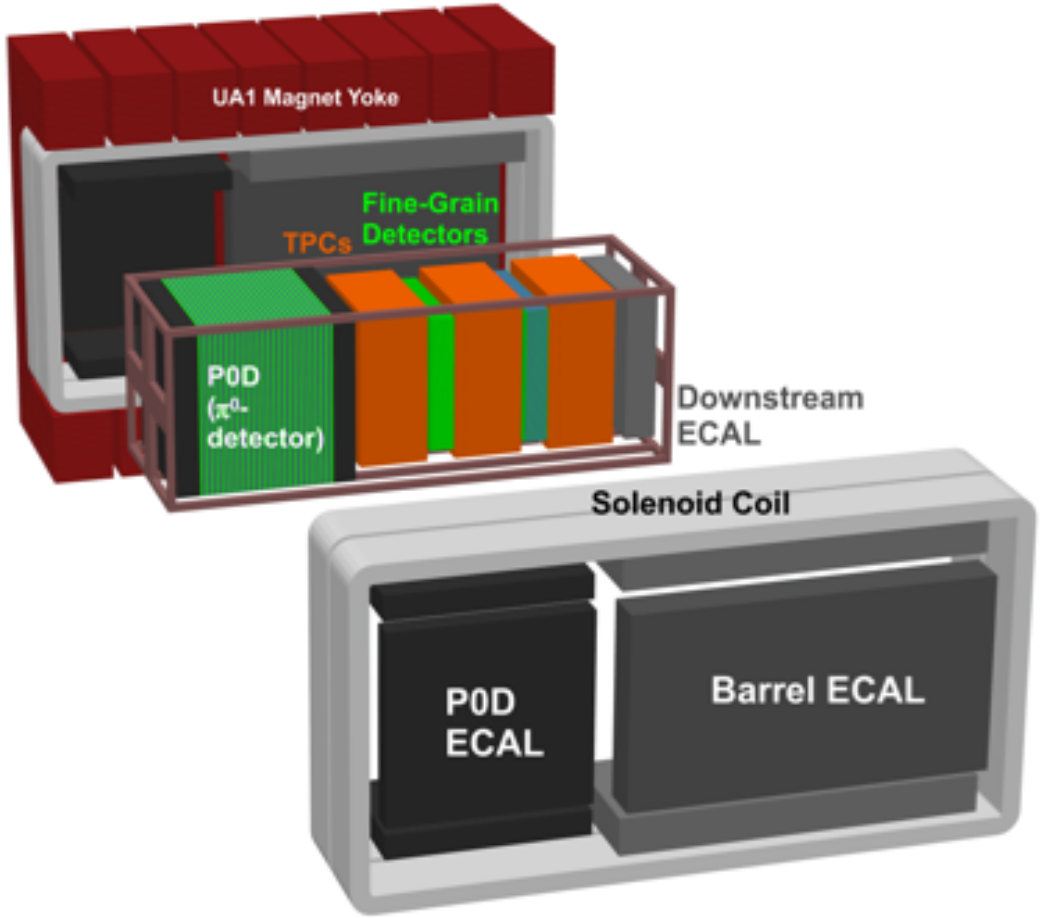
- Long Baseline Neutrino Oscillation experiment.
- 295km Baseline between J-PARC Accelerator in Tokai and Super Kamiokande Detector

Main physics objectives:

- Reduce the values of Δm^2_{23} and $\delta\theta_{23}$ to $10^{-4}eV^2$ and 0.01 by monitoring the ν_μ disappearance rate.
- Establish a non-zero value for θ_{13} through the observation of an ν_e appearance signal



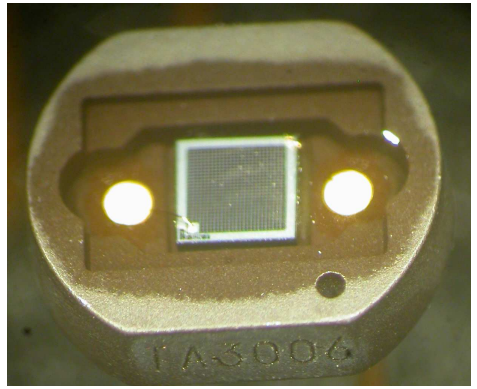
The ND280 Detector



- Responsible for initial characterisation of neutrino beam and parameterisation of background noise sources.
- Consists of a π^0 detector (P0D), Time Projection Chambers (TPCs), Fine Grain Detectors (FGDs) and Electromagnetic Calorimeters (ECal) housed within a 0.2T magnetic yoke.
- Gaps between magnet coils hold Side Muon Ranging Detector (SMRD).

T2K Electromagnetic Calorimeters and Multi-Pixel Photon Counters (MPPCs)

- The ECal units used in the ND280 detector have alternating layers of PPO and POPOP doped polystyrene scintillator bars and lead sheeting (which act to increase the number of target nuclei for incident particles).
- The scintillator bars alternate between x and y orientation; readout is accomplished using Kuraray Y-11 wavelength shifting fibres connected to MPPC photosensors.
- MPPCs, which are also known as Geiger Mode Avalanche PhotoDiodes (GM-APD) or Silicon Photomultiplier Tubes (SiPMT), are based on Geiger mode reverse biased P-N junctions which emit a pulse of electrons upon the impact of a photon.
- As a recent development their long term behaviour is not yet well understood.
- An MPPC monitoring/calibration system is therefore required.



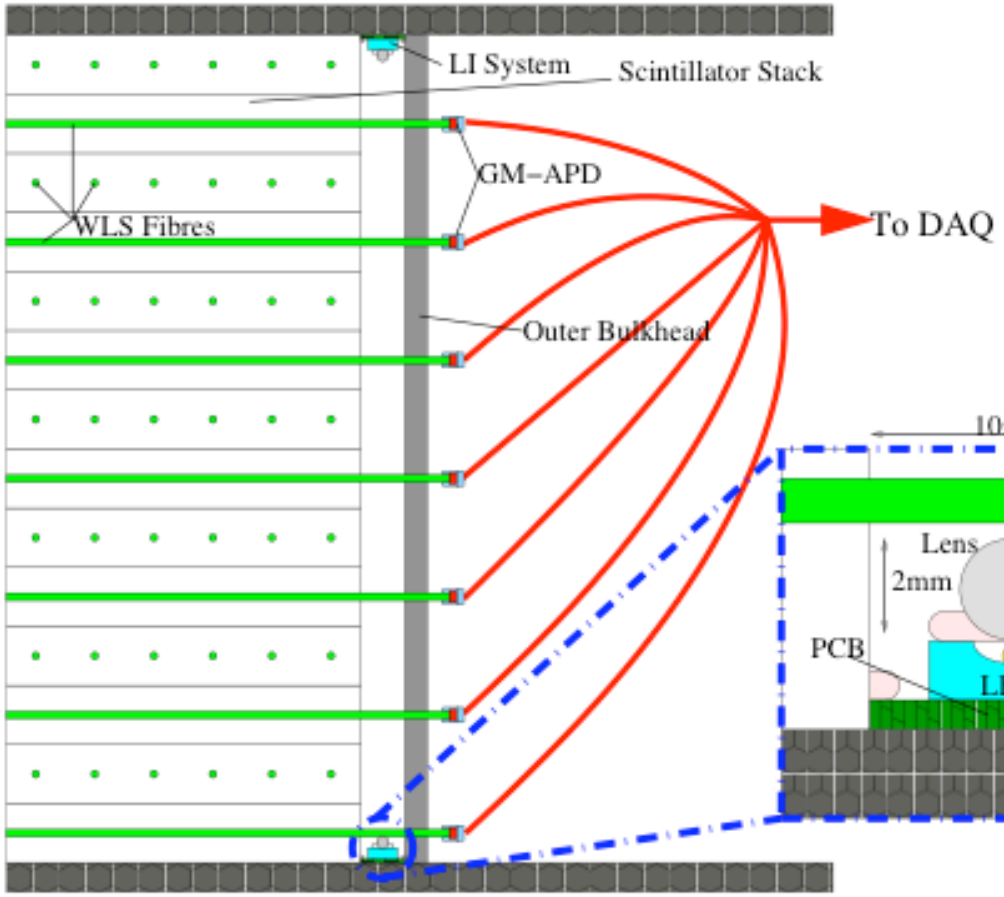
Light Injection Calibration: System Requirements

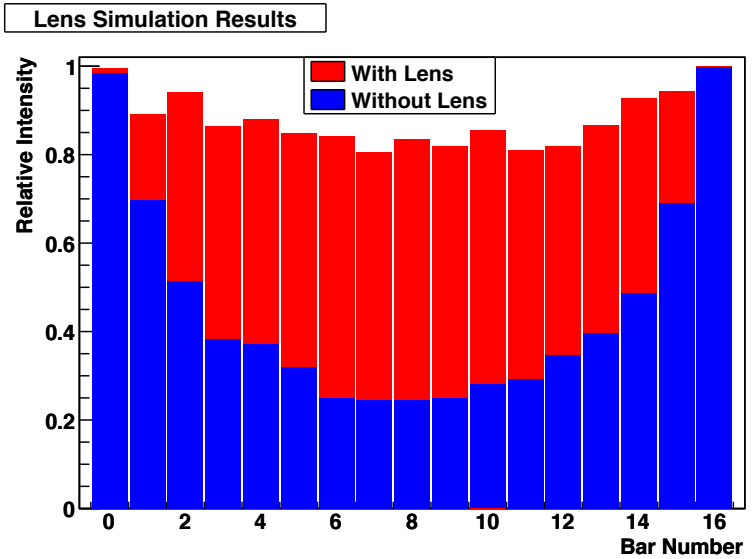
- Channel Integrity tests- Essential.
  - The original purpose of the LI system was to provide a simple binary test of functionality for each MPPC channel.
- MPPC Gain Monitoring- Very Desirable.
  - The system remit was subsequently expanded to include the ability to gain scan the photosensors, which necessitates a variable intensity light output.
- Timing Calibration- Very Desirable.
  - If the sensors can be triggered to provide a bright, synchronised light pulse across the entire bulkhead, this can be used as a timing calibration baseline.
- MPPC Linearity and Saturation Response- Would Be Nice.
  - Although linearity and saturation response testing would have been a useful capability, it would have necessitated careful monitoring of the light intensity output; a prohibitively expensive modification.

Light Injection Calibration: System Constraints

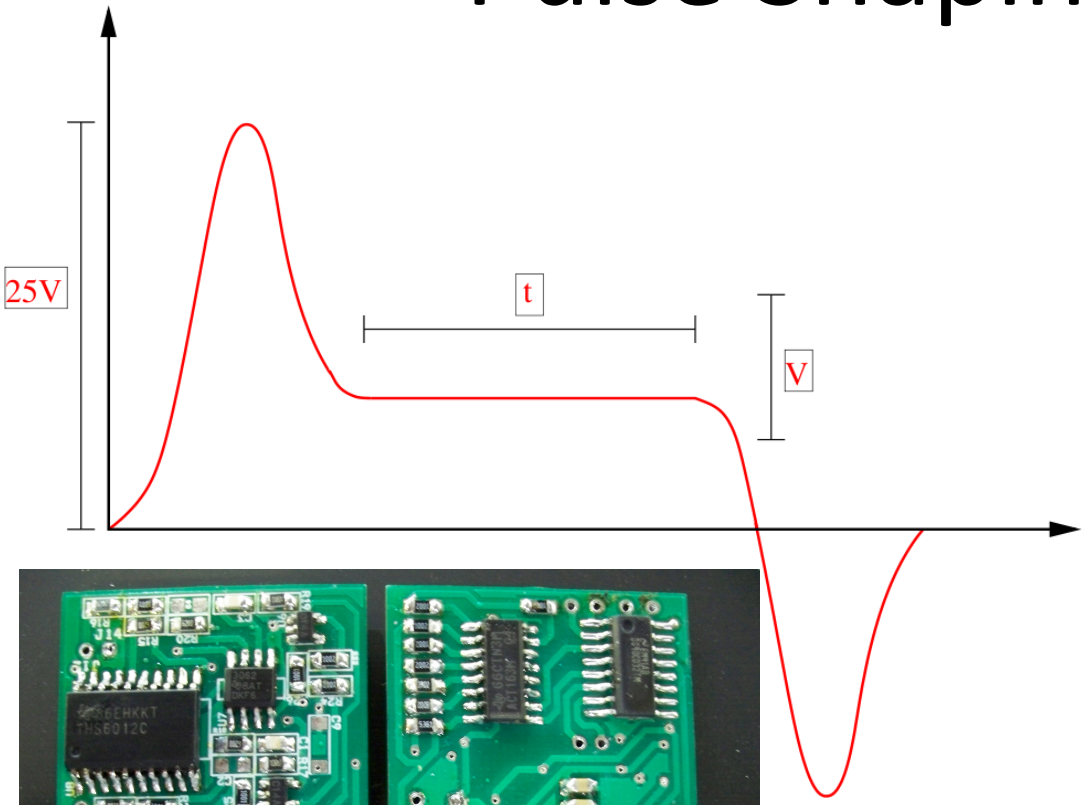
- System must generate short (microsecond scale) duration pulses.
- System must have instant turn on (to full illumination) and turn off.
- System cannot generate any output when inactive.
- System must not generate electromagnetic noise, or other interference, when active.
- System must fit within narrow bulkhead cavity.
- System light output must be predictable and as uniform as possible.

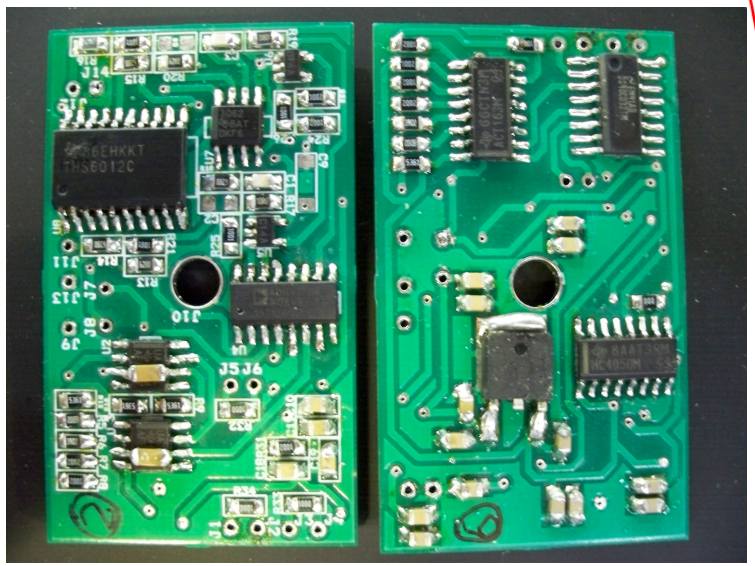
Emissive Element: PCB LED Strips





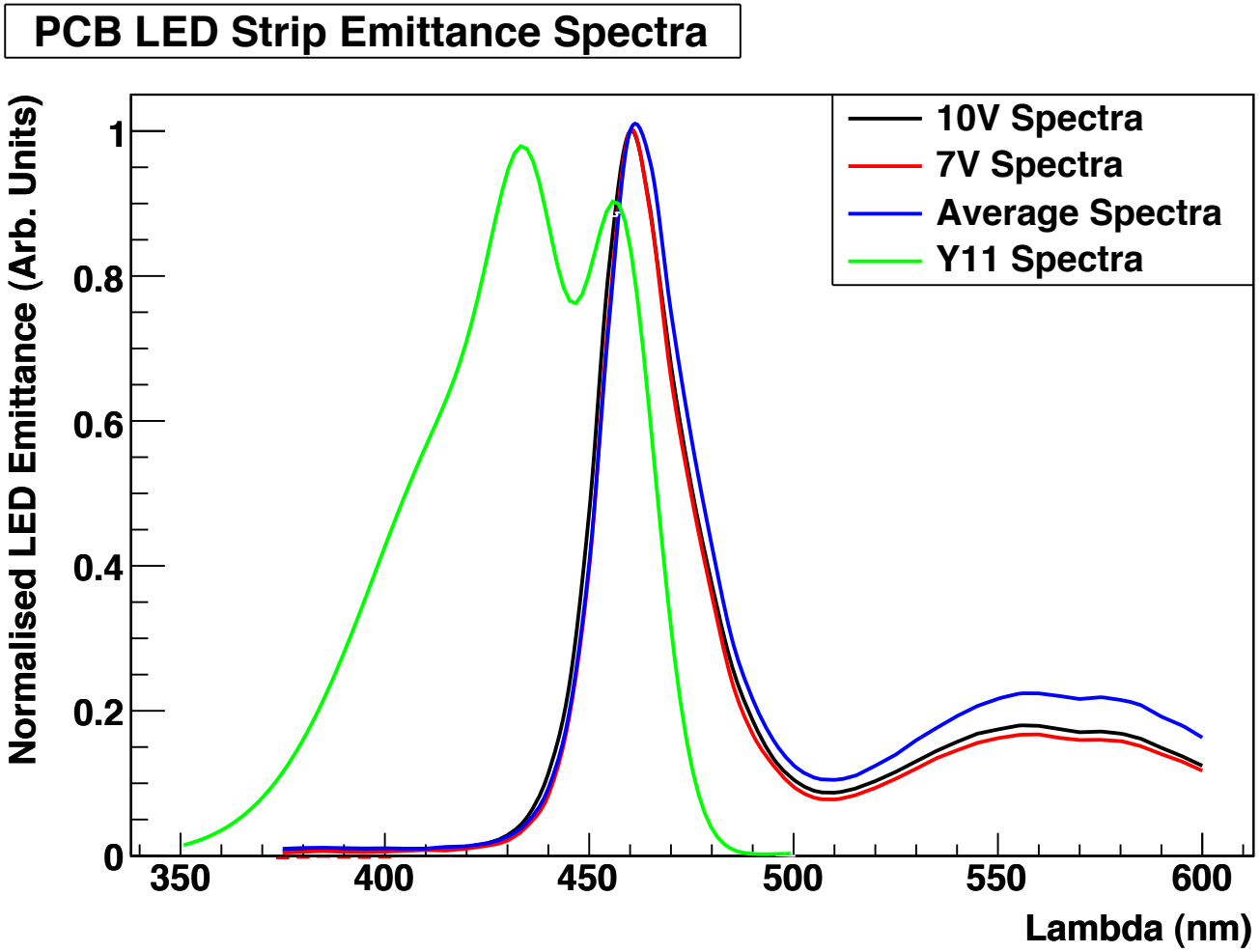
Pulse Shaping Board



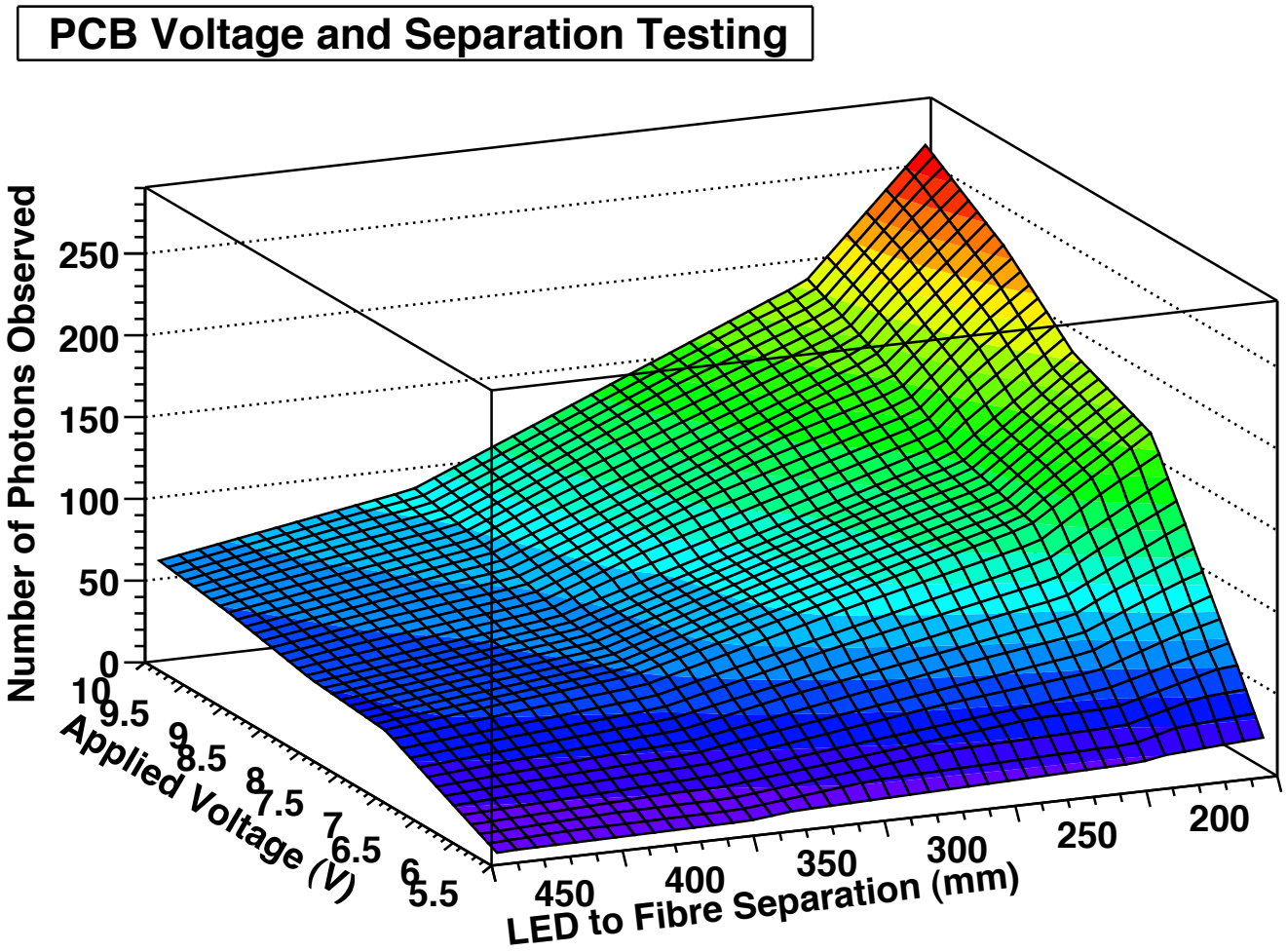


- Each circuit board controls 2 PCB LED strips.
- Triggering pulse for strips has an irregular profile.
- Large leading and trailing voltage spikes force rapid LED activation and shut down
- Peak voltage is above recommended LED operational levels, so short duration spike is necessary.
- Plateau voltage level is variable (5V-10V) to allow a range of light output intensities to be used.

Spectral Matching



Luminosity Variation

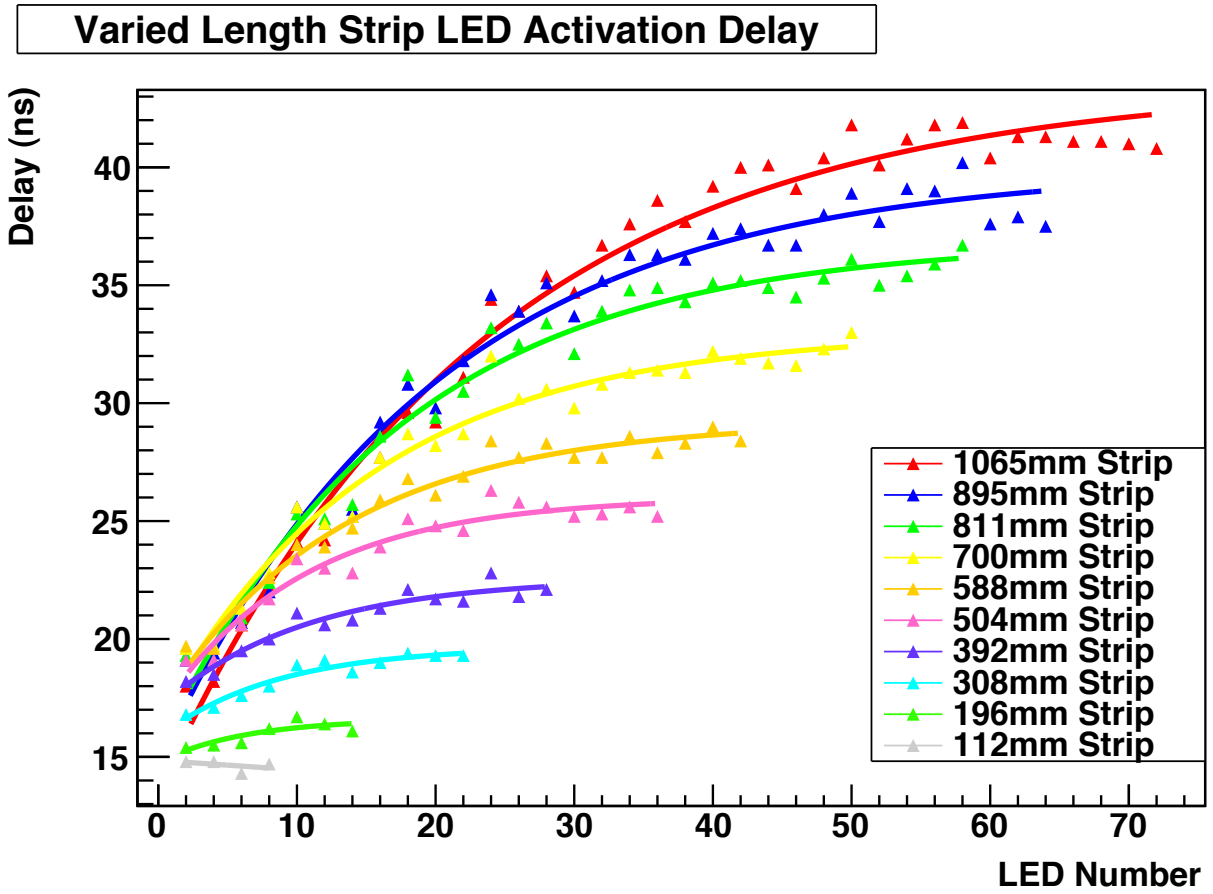


Activation Delay Behaviour

B is proportional to the strip capacitance.

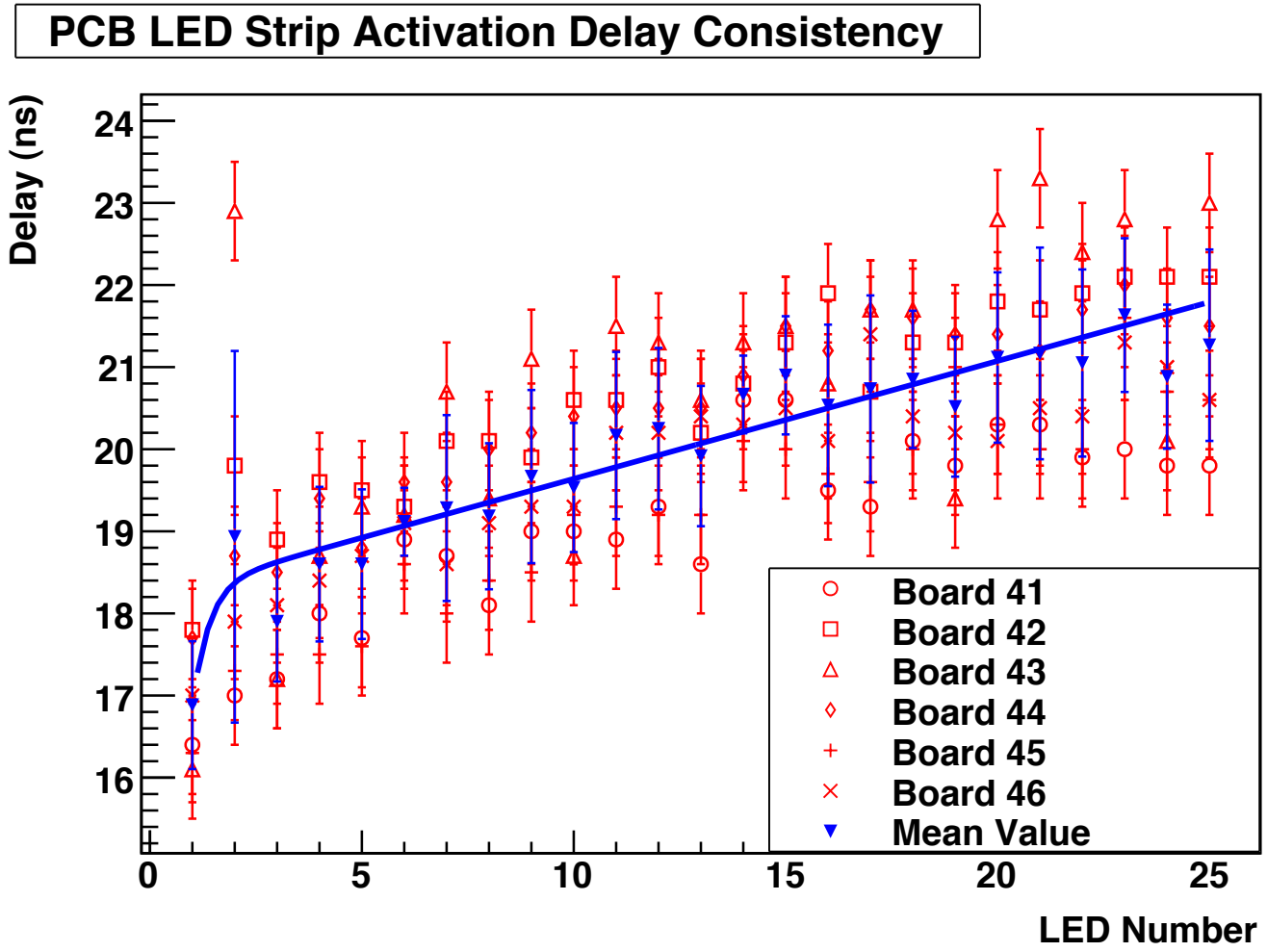
C is proportional to the strip length.

The scatter of the points is due to the individual LED capacitances, which vary randomly along the strip.



$$T_D = A(1 - e^{-Bx}) + Cx$$

Activation Delay Consistency



Data Analysis Plan

- 4 of the modules are fully constructed.
- 3 further modules are currently under construction around the UK, with LI system installation ongoing.
- Synchronisation issues between clock module, LI trigger system and DAQ system are currently being resolved.
- Full system performance data will be collected toward the end of April.