Pisa Meeting on Advanced Detectors

LANTERN

Sapienza Università di Roma

INFN

A novel characterization technology for cryogenic detectors

Giorgio Del Castello

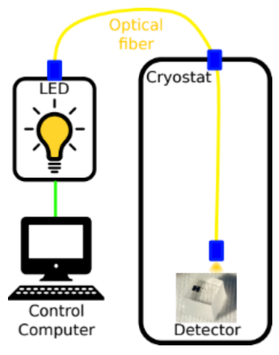
Recent advancements in low-energy rare-event searches rely on cryogenic calorimeters, these detectors face challenges in accurately characterizing responses within the region of interest (ROI). Traditional calibrations with radioactive sources produce signals above the ROI.

LANTERN, an optical calibration system, can instead be used to accurately probe the ROI of the cryogenic detectors. It utilizes LED pulses to generate photo-statistics in order to perform detector calibration. LANTERN's LED matrix allows for fast characterization of up to 64 calorimeters independently, spanning energies from a few eV to hundreds of keV. Its minimal electronics and optics make LANTERN a cost-effective and customizable solution. Being electronically activated, LANTERN can validate detector performance periodically without adding any background. LANTERN thus allows to enhance the capabilities of segmented calorimeters in low-background setups, and it's currently being employed by the BULLKID and NUCLEUS experiments.

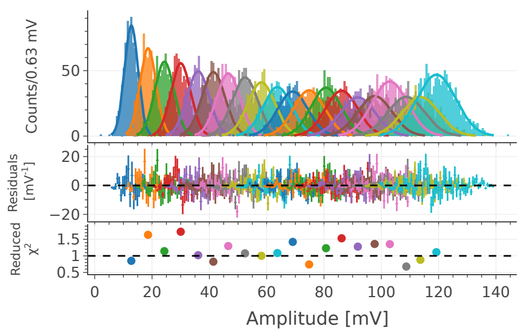
CALIBRATION CONCEPT

1. Shine on detector with monochromatic LED changing the mean number of photons deposited
2. Fit energy distributions
3. Fit photon-statistics (Poissonian) hypothesis to measure calibration constant
4. Study and correct non-linearities of detector using LED pulses as reference population

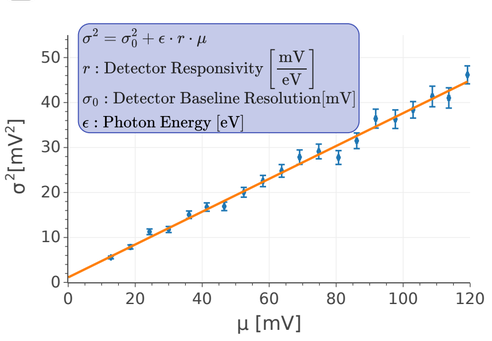
Setup Concept



①② Calibration Gaussian Fit



③ Absolute Calibration Fit



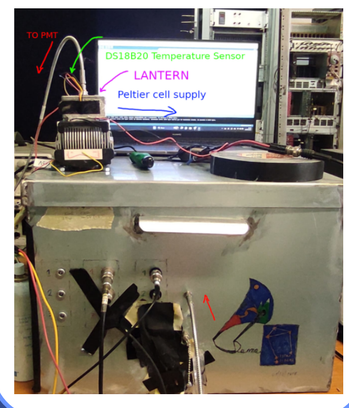
[1] *Al/Ti/Al phonon-mediated KIDs for UV–vis light detection over large areas*, L. Cardani et al., Supercond. Sci. Technol. 31 (2018) 075002

PROTOTYPE VALIDATION

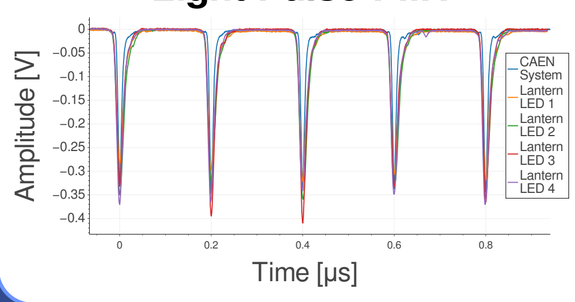
LANTERN test on PMT Hamamatsu R11065-20:

- Speed comparable with commercial single LED system
- LED power much greater than commercial system
- No increase in dark count rate (no background production)
- Homogeneous response between different LEDs

PMT Validation



Light Pulse PMT

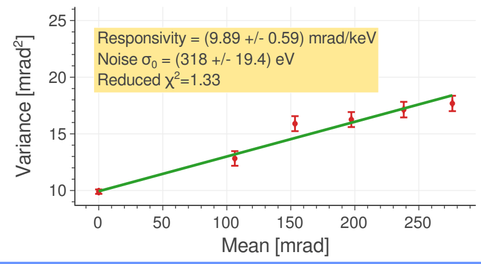


CYOGENICS TESTS AND SETUP

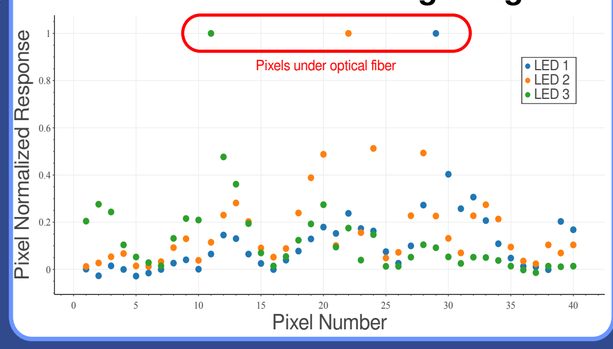
LANTERN test on BULLKID:

- Reproduced results of commercial system
- No pulse shape differences on LED induced signal
- 3D pixel mapping of a stacked detector array geometry using infrared (IR) LEDs (semitransparent to the detector material)

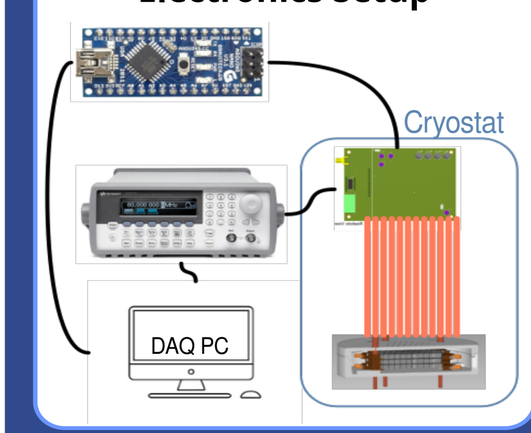
BULLKID LED Calibration



Pixel identification using IR light



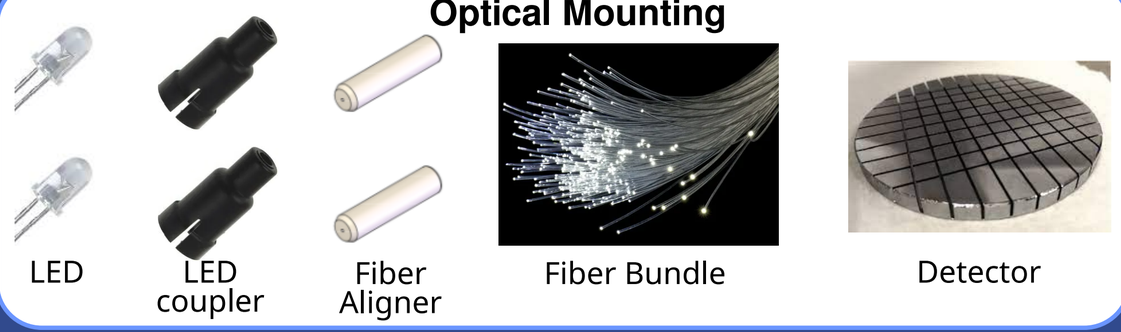
Electronics Setup



Setup Concept:

- System mounted inside dry cryostat to avoid multiple vacuum fiber feed-throughs
- Automatic calibration of a whole detector array
- Full detector-array response characterization (data analysis tuning on LED induced pulses)

Optical Mounting

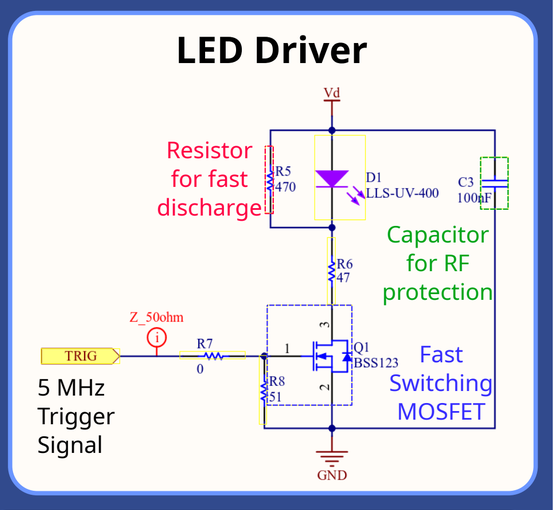


See D.Delicato's Poster: BULLKID: Array of particle absorbers sensed by Kinetic Inductance Detectors

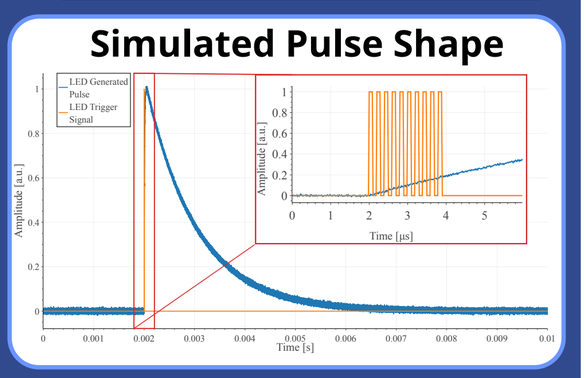
ELECTRONICS & FEATURES

1. 64x Multiplexed LEDs (customizable)
2. Customizable LED wavelength (prototype built with 400nm)
3. Up to 5MHz LED switching
4. Controllable through serial communication using an Arduino interface
5. Software LED power regulation with 64 step digital resistor
6. Light deposition regulation via external trigger generator (serial interface)
7. Vacuum compatible electronics in order to operate inside dry cryostats
8. Customizable geometry for space requirements
9. Integrable in most data acquisitions (DAQs)

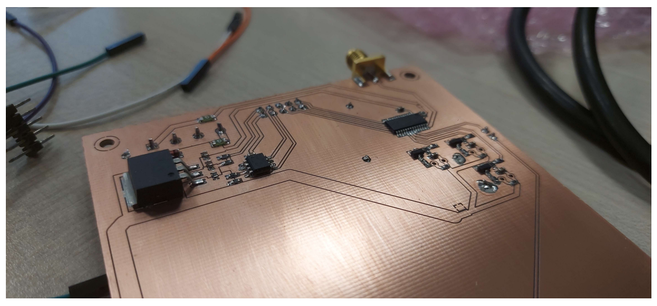
LED Driver



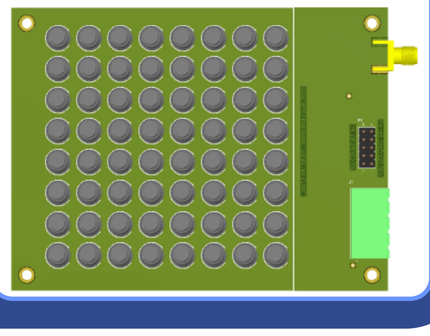
Simulated Pulse Shape



LANTERN Prototype PCB



64 LED PCB Design



Giorgio Del Castello - PhD Candidate - Università di Roma "Sapienza" - Contact: giorgio.delcastello@roma1.infn.it