Optical Calibration Systems for DEAP-3600

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DEAP-3600 is a single phase liquid argon dark matter experiment currently in advanced stages of construction at SNOLAB. An 85cm diameter acrylic vessel contains 3600 kg of liquid argon and is instrumented with 255 photomultiplier tubes (PMTs) to detect the scintillation light from particle interactions. Pulse shape discrimination is used to distinguish nuclear recoil events, as expected for dark matter interactions, from potential background electronic interactions. Two systems are used to optically calibrate and monitor the properties of the PMTs and to characterize the overall detector response. The first consists of a deployed LED sphere and diffuse laser ball lowered into in the interior of the acrylic vessel prior to filling with liquid argon. The second calibration system, installed permanently in the detector and operational throughout the lifetime of the experiment, injects light to 20 PMTs using fibre optic cables.

LED Sphere & Laser Ball

Two optical calibration sources, a 405nm laser ball and a 244nm LED sphere, can lowered into the detector prior to filling with argon. This system was designed and built by collaborators at University of Sussex. Access into the acrylic vessel is controlled through a deployment system at the top of the neck. The sources are deployed from a main power and signal cable bundle, and prevented from rotating via two secondary bobbins. Although the radial position is limited to the axis of the neck, the z-position of the sources can be varied. Prior to deposition of the wavelength shifter tetraphenyl butadiene (TPB) over the interior of the acrylic vessel, the laser ball is deployed (Fig. 6); after TPB deposition, the 244nm LED ball (Fig. 7) is deployed and can be used to monitor TPB thickness and uniformity. Source non-uniformity can be deconvolved by varying the z-position and initial attachment orientation of the source. Simulations on the PE per PMT for a uniform TPB coating against no TPB coating can be seen in Figure 8. The effect of non-uniform TPB coating geometries have been also been simulated.

Figure 6 : 11 244nm LEDs are mounted in a dodecahedronal pattern on a stainless source. The 12th vertex is saved for the attachment point. The two eyelets on the sphere are attached to secondary bobbins to prevent the source from rotating. The LED driver is based on the Kapustinsky pulser and can produce 10ns wide pulses (FWHM).

Figure 7 : Laser Ball. The 405nm diode laser is attached to an acrylic rod inside the steel shaft in the center of the quartz sphere. The sphere is filled with diffuse gel, which sufficiently scatters the light from the laser diode to provide a uniform distribution of light.

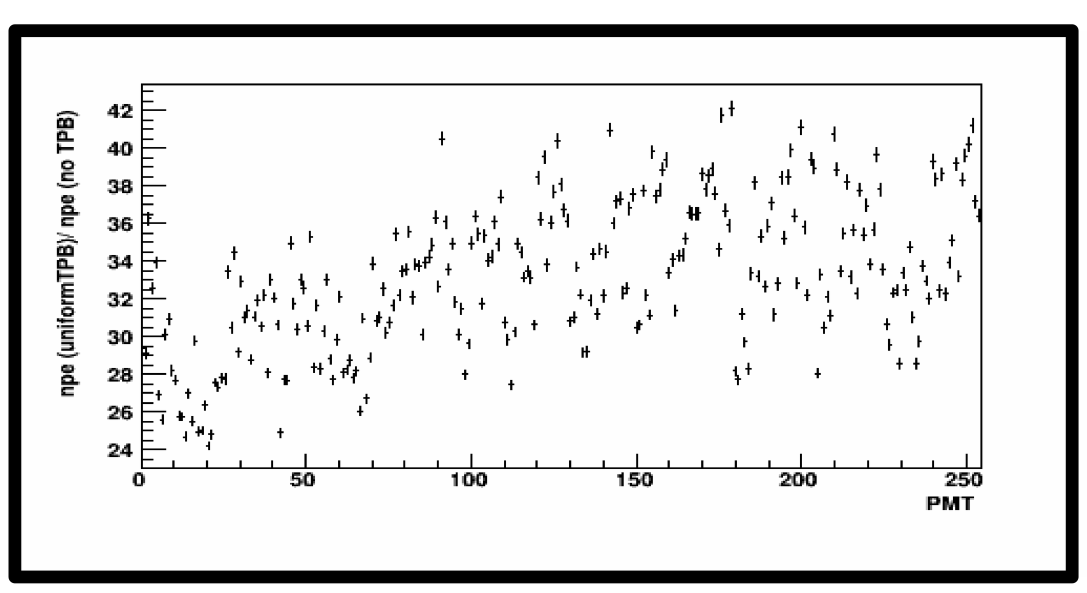

Figure 8 : Ratio of the expected number of PE for each PMT for a uniform 0.9 micron coating versus no coating. No LED is located on the top of the souce (the attachment point) which leads to decreased PE in the PMTs near the neck (low numbered PMTs).

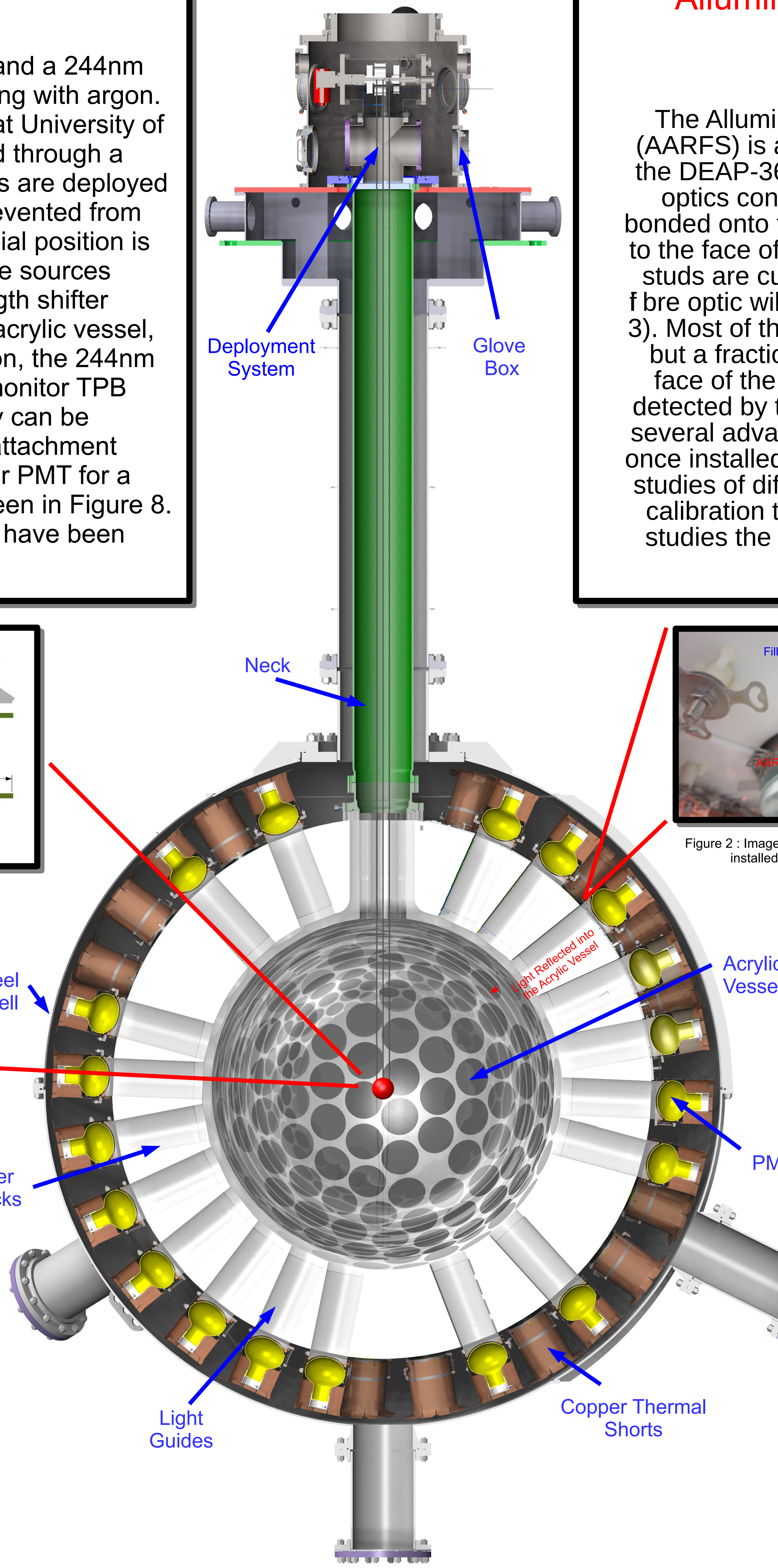

Figure 1 : Section image of the DEAP-3600 detector. Main detector components are labelled.

Alluminium & Acrylic Reflector and Fibre Optic System (AARFS)

The Alluminium and acrylic reflector and fibre optic system (AARFS) is a non-invasive optical calibration method used for the DEAP-3600 detector. This system is composed of 20 fibre optics connected to an acrylic stud, coated in Alluminium, bonded onto the light guides at a 10 degrees angle with respect to the face of the light guide (see Fig. 2). At one end the acrylic studs are cut at an angle such that the light injected from the fibre optic will reflect straight to the centre of the PMT (see Fig. 3). Most of the light will be detected by the corresponding PMT, but a fraction of the injected light (~20%) will bounce off the face of the PMT back into the inside of the experiment and detected by the rest of the PMTs. This calibration method offer several advantages : all hardware is outside the acrylic vessel, once installed it can be run at any point and it allows for several studies of different detector properties. The main focus for this calibration tool will be to investigate the PMTs response and studies the uniformity of the detector throughout its life-time.

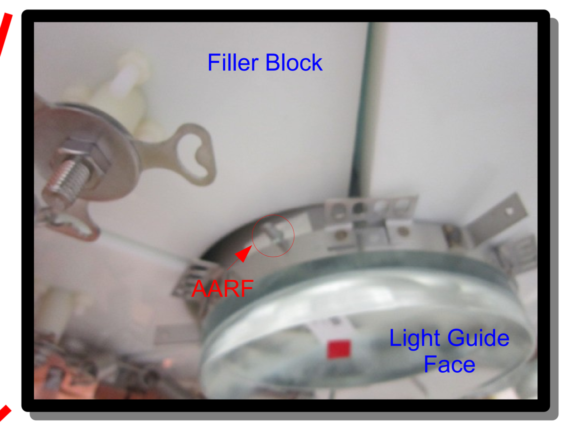

Figure 2 : Image of an AARF acrylic stud installed on a light guide.

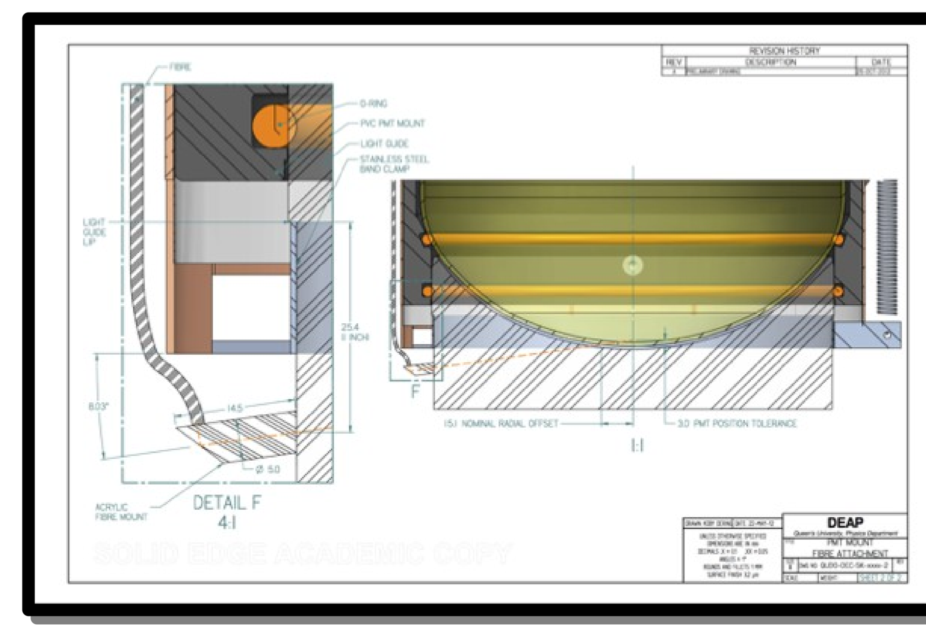

Figure 3 : Engineering drawing for the AARFS. This image shows how the light from the optical fibre will be reflected onto the PMT face.

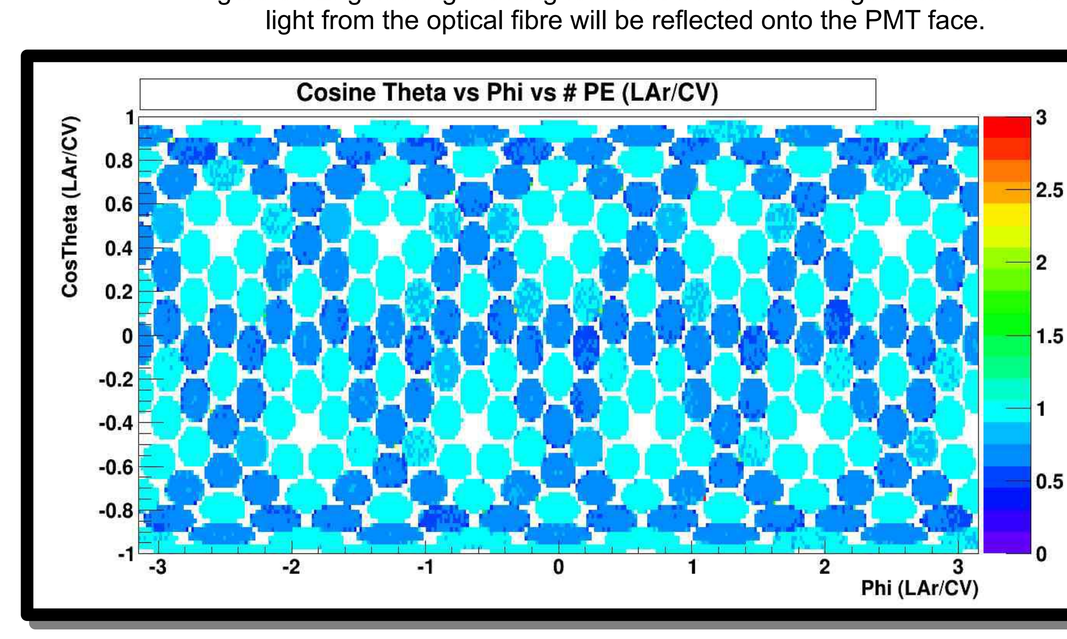

Figure 4 : Ratio between angular distributions of detected PE, for the cases where the detector if filled with LAr and when is at cryogenic vacuum state (100k mc events) .

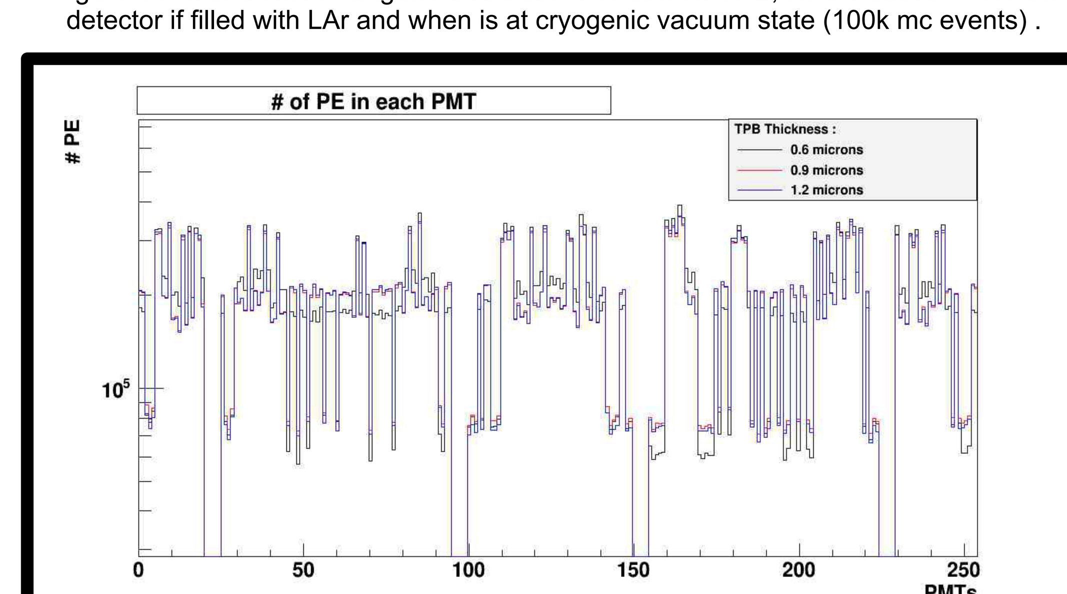

Figure 5 : TPB Uniformity studies showing distributions for detected PE vs PMT ID, for simulations where the deposited TPB layer thickness is set at : 0.6, 0.9 and 1.2 microns.

The optical calibration system for DEAP-3600 will be used to characterize and monitor PMT response, timing, and efficiency before and during the lifetime of the experiment. Additionally, mapping of light attenuation and TPB uniformity can thus be investigated. Currently in advanced stages of construction, early optical calibration data aims to be taken by the end of summer.