VULCAN experiment: Measurement Plan

Concise measurement plan to measure the optical properties at VUV wavelengths of materials used in DUNE

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Contents

1 Objective **2**

2 Measurement **2**

3 Optional measurements **2**

4 Equipment **3**

5 Preliminary procedures for the measurements **4**

6 Analysis **5**

1 Objective

This measurement plan contains the outline of the experiment to measure the reflectivity and wavelength shifting efficiencies at VUV wavelengths of detector components in the VULCAN setup. The end goal is to measure reflection and transmission properties of materials that are used in the DUNE neutrino detector, also focusing on wavelength-shifting materials. In order to achieve this, calibration procedures need to be done for the SiPMs along with proper alignments and slit size optimization.

2 Measurement

Below is a description of the main measurement that will be performed during this project.

1. Reflection measurement
    - Measure the specular reflection of the sample by placing the SiPM at the reflection angle
    - Measure the diffuse reflection of the sample by placing the SiPM at various angles
    - Mitigate intensity loss due to reflection by adjusting slit sizes
    - Repeat for different wavelengths in VUV range

3 Optional measurements

Below is a brief and rough description of three different measurements that also can be performed during this project with the same VULCAN setup.

1. Transmission measurement
    - Place the SiPM behind the sample.
    - This measurement is partly to verify the results of the reflection measurement (reflection and transmission should add up to 1)
2. Wavelength shifting measurements
    - Measure the wavelength shifting efficiency by sending UV light onto the sample and measuring the reflectivity with a visible light sensitive SiPM.
    - Comparing the light intensity of the visible reflection light with the UV light, taking into account the reflectivity of the sample for that wavelength
3. Fluorescence measurement
    - Still have to look into how to measure fluorescence properties of the samples.

4 Equipment

Below is a list of the primary components of the VULCAN setup that are necessary for this experiment, along with notes required for commissioning the setup.

1. Vacuum Chamber (Ideal Vacuum Cube) with Pfeiffer vacuum pump.
    - Chamber needs to be cleaned and rearranged
    - Vacuum needs to be tested over the weekend
2. SiPM with VUV sensitivity (Hamamatsu S13370-3050CN)
    - Currently installed SiPM might be broken, others should be tested.
    - Soldering should be redone with the soldering machine from the electronics department.
    - UPDATE: The problem was with the readout box (see item 1.7). The SiPM probably still works but soldering should still be redone.
    - Install Hamamatsu S13370-6050CN SiPM with bigger surface area which is vor UV light? (Ask Marjolein)
    - Install a 3 by 3 SiPM array. 3D print a SiPM holder.
3. Deuterium Lamp producing VUV light in the range of 115 nm to 240 nm.
4. Monochromator (McPherson 302) with an aberration-corrected diffraction grating.
5. Temperature sensors
    - Not currently installed.
    - This might be necessary to account for temperature dependancy of the dark count (see item 4.1).
6. CAEN digitizer 14-bit
    - The other digitizer has arrived. This one can be installed but should be checked if this is necessary.
    - Ask Auke-Pieter to install the same thing he did for the XAMS experiment to fix the "busy" problem without the external trigger.
7. Custom readout box and amplifier
    - It is possible that the last channel is now also dysfunctional. This channel is currently being tested by the electronics department.
    - A new and improved single-channel readout box was in the makings. It should be checked if this is nearly completed.
    - UPDATE: The channel is indeed broken and Julio is fixing one channel with priority now

5 Preliminary procedures for the measurements

This section provides the required procedures in order to successfully do the measurements.

1. SiPM's Dark count measurements
    - The dark count rates of the SiPM will be measured before every measurement because the applied bias can vary due to uncertainties.
    - The temperature may fluctuate during the measurement. To investigate the temperature dependence of the dark count, it can be measured as a function temperature beforehand to check if this has an effect on the outcome.
    - UPDATE: The few degrees difference in temperature will probably not make a big difference in dark count looking at previous measurements.
2. Spectrum calibration for the lamp spectrum
    - Spectrum calibration by measuring the wavelength spectrum of the lamp and comparing it to the spectrum in the manual.
    - To do the spectrum calibration, the deuterium lamp and monochromator should be setup correctly and a vacuum should be achieved.
    - Monochromator grating can also influence the light intensity according to the manual, but the monochromator corrects for this?. Jasmijn ignored this effect in her research. It should be found out if this effect is negligible.
    - The SiPMs also have a wavelength sensitivity. This should be corrected for (there is already code for this).
    - Earlier measurements showed SiPM saturation for certain wavelengths. The calibration should be performed with different intensities and slit sizes to avoid this.
3. Reflection standard measurement
    - Measure the reflectivity of the reflection standard in the setup to verify if the experiment is properly set up and aligned.
    - Calibrate the system by comparing measurements against the standard.
    - This should be done several times during the experiment to verify the accuracy. How many times can be calculated by checking the timeframe for which the result is constant.
4. Set up the sample and sample holder
    - Obtain and prepare the different DUNE samples and the reference sample.
    - The samples might be oxidized. Should they be cleaned? They should be in the same state as in the DUNE detector where they are likely also oxidized.
    - By the looks of it, the sample holder closes on the back. This means that there is no need for distance corrections due to different thickness between sample and reference sample.

5. Align the setup

    - Use visible laser light for initial alignment and determining the starting point.
    - The code from Yannick/Tomas can be used for alignment.

6 Analysis

Most of this code is already written during and for Mano's project so it can directly applied to this experiment.

1. Data collecting

    - Find out if data should be taken in current setup in 2 ns phases with the external trigger, or continiously with update from Auke Pieter.
    - If data will be collected in current setup, should the trigger be aligned with the light pulses? Probably not since the trigger is unbiased.
    - Determine for how long data should be collected in each measurement.

2. SPE calibration

    - Determine the charge of one single photon to convert the pulses to photon count.
    - This should be done every time a dark count measurement is performed for previously mentioned reasons.

3. DC rate calculation

    - Identify the charge pulses in the DC measurment.
    - Calculate the dark count rate with the SPE calibration or with the peak finder. (Discuss if the latter can be applied to our data)

4. Data analysis

    - Apply baseline correction to each sample
    - Subtract the DC from the collected data
    - Integrate over the peaks to calculate the peak area and determine intensity with SPE calibration.

5. (MAYBE: SiPM saturation correction)

    - This will be necessary if the optimization of intensity and slit sizes in order to avoid SiPM saturation is not successful. I do not yet know how to approach this.