Characterization Of FASER PMTs

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Overview

My summer project has been to follow up on the previous work done by my supervisors on the PMT+Light guide+Scintillator setup

Things accomplished:
- Created analysis code for fitting PMT data and extracting gains
- Built setup for PMT characterization in Scintillator Lab
- Measured gain curves for the three available scintillator PMTs (Hamamatsu R329-02)
- Measured gain curve for calorimeter PMT (Hamamatsu R7899-20)
- Measured gain linearity of calorimeter PMT
- Check the efficiency of new bent light guide
- Measured the quantum efficiency as a function of wavelength for all available PMTs

Things still to do:
- Measure gain linearity for scintillator PMTs
- Build cosmic ray test setup with new scintillators and calorimeter
- Incorporate digitizer into setup rather than oscilloscope
New small experiment to be installed in LHC in ~1 year
- Designed to search for light, weakly interacting particles produced in pi0 decays, such as dark photons
- Detector consists of a decay volume followed by a spectrometer and then calorimeter
- Dark photons will enter the decay volume and decay to electron positron pair before detection
- Need to use scintillators to veto charged particles entering decay volume

Intro to FASER (ForwArd Search ExpeRiment)
Gain measurement

Gain = \frac{Q_{out}}{Q_{in}}

\( Q_{in} \) is the charge of an electron
\( Q_{out} \) is what we want to measure

\[ Q_{out} = \frac{V_{ave} \times t}{R} = I_{ave} \times t \]

- Fit the histogram with two gaussians and find the distance between the two means.
- Divide this value by the resistance (50 \( \Omega \)) and the electron charge to get the gain for that voltage.
Scintillator PMT Gain Curves

- Measured gains from 1400V-2500V in steps of 100 V

- Log-log scale vs log-linear scale
Only one calorimeter PMT (LB8732)

Measured from 1550-1750 in steps of 50 V, then extrapolated down to 600 because signal to noise ratio was too low.
- Move LED back and forth to produce large and small signals in PMT output.
- Ratio of pulses changes as signal grows
- When signal is too big, current saturation affects the output pulse and ratio goes down
- Depends on PMT voltage

Gain Linearity Measurements

Deviation from Linearity vs Peak Current for Different PMT Voltages

Peak Anode Current (mA)

Deviation from Linearity (%)


We got a new bent light guide with an approximate bending radius of 6.5 cm

<table>
<thead>
<tr>
<th>Light Guide</th>
<th>N Photoelectrons</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>104(1)</td>
<td>100%</td>
</tr>
<tr>
<td>Straight</td>
<td>96(1)</td>
<td>92%</td>
</tr>
<tr>
<td>Bent</td>
<td>68(1)</td>
<td>66%</td>
</tr>
</tbody>
</table>

Didn’t use optical grease for sealing interfaces

30% loss is slightly worse than the previous bent light guide (12 cm) with 20%
Quantum Efficiency Measurements

- Measured QE using $\epsilon_Q(\lambda)^{DUT} = \frac{I_{DUT}}{I_{REF}} * \epsilon_Q(\lambda)^{REF}$, where DUT = Detector Under Test and REF = Reference Detector
- Couldn’t measure scintillator PMTs because of voltage divider
- Measured all calorimeter PMTs except soldered one
- Found position dependence on photocathode and issues with precision due to reference PD
Summary

- We made good progress in characterizing available PMTs
- Measured gain curves for the scintillator and calorimeter PMTs correspond to specifications
- Gain linearity of calorimeter PMT seems reasonable for our experiment

- New bent light guide has comparable loss to previous one
  - Measurement could be improved with the use of optical grease

- QE measurements made for calorimeter PMTs

- Still to do:
  - Measure gain linearity of scintillator PMTs
  - Build cosmic ray test setup with scintillators and calorimeter
  - Integrate digitizer into system
Cultural Experiences!
Thank you to the National Science Foundation and the University of Michigan for supporting this research and the cultural experiences I had as a CERN summer student!
Back-ups
Power supply
Oscilloscope and Pulse Generator

Jesse Kruse  |  FASER  |  15/08/2019
QE Measurement Setup

![Diagram of QE Measurement Setup](image)

- PMT under test
- Calib. PD
- Monochromator
- Xe lamp
- Mirror