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# Photomultiplier tests - Some recent results

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## 1 Abstract

This report presents some recent data on tests on photomultiplier tubes (PMT's) carried out at the University of Oxford. The standardized testing procedures have been extensively documented in another report [1] which describe the 'Mortar' apparatus and the conditions used.

These measurements principally concern :

1. The single photon counting efficiency,
2. The Transit Time Spread (TTS) of single photon signals,
3. The Single Photoelectron Resolution (SPR),
4. The noise or dark count rate, and
5. Afterpulse rates.

Whilst the first and second parameters are of greatest concern to SNO, the others are also recorded.

## 2 Mortar Results to date

Presented here are some data on several photomultipliers which might be of interest to the SNO collaboration.

### 2.1 Efficiency measurements

At present time the Mortar has not been calibrated in the sense that Monte Carlo calculations have not yet been performed in order to estimate the absolute (Anode) efficiency. Thus we present these data in a relative format. Note that the discriminator level is given in units of 1 Single PhotoElectron (SPE) peak height. The right hand column gives the count rate per unit PhotoCathode Area (PCA). The errors quoted are *random* and exclude systematics.

| PMT Type | Serial Number | Anode Number | Discriminator level (SPE) | Count rate | Counts per unit PCA |
|---|---|---|---|---|---|
| EMI 9350(F) | 7102 | 326840 | 0.10 | 3646 | 128,000 |
| EMI 9350 | 6460 | 326079 | 0.10 | 3307 | 116,000 |
| Burle C83061E | H00063 | 14894 | 0.10 | 3569 | 78,100 |
| | | | 0.25 | 3311 | 72,500 |
| Errors (1 $\sigma$) | | | 0.02 | 0.3 % | 3 % |

Table 1. PMT relative anode efficiencies

## 2.2 Transit time spread results

These data give absolute values to the transit time spread (or jitter) of the photomultiplier under test.

### 2.2.1 Systematic corrections due to the FTT

There is a correction made for the TTS of the FTT. This is estimated by the manufacturers to be $t_{TTS} \simeq 0.55$ ns, however we have not yet verified this.

It is proposed that this value be assumed, but including an uncertainty of 0.1 ns at the one standard deviation level. The effects of any other transit time spreads add *in quadrature* to the main effect so that resulting errors are small.

### 2.2.2 Systematic errors due to the CF discriminator

The PMT tests were carried out with the discriminator level set at 1/10 of a single photoelectron (SPE). In general, the lower the discriminator level, the worse (i.e. larger) the TTS. This could be due to effects within the discriminator: if it not set up correctly it may contribute to the TTS. This measurement then gives a upper limit to the TTS as the PMT will probably never be counted at the 1/10 of a SPE level in the SNO detector. It should be noted that these effects appear at the 50 ps level and are not thus not very significant.

### 2.2.3 TTS representation : FWHM vs standard deviation

Since most PMT's do not have a gaussian distribution of TTS's, we are in favour of quoting results in terms of the standard deviation of the TTS distribution. The advantage of quoting results in terms of the FWHM is that this value is easily determined from experimental output, however it is felt that the standard deviation should be calculated as :

1. The actual vertex reconstruction resolution is related to the standard deviation.

2. The standard deviation systematically indicates the effect of outliners (or 'satellite') peaks in the TTS distribution.

| PMT Type | Serial Nō | Anode Nō | Volts K - D1 | TTS FWHM |
|---|---|---|---|---|
| EMI 9350(F) | 7102 | 326840 | 750 | 2.8 ns |
| | | | 870 | 2.60 ns |
| EMI 9350 | 6460 | 326079 | 403 | 8.6 ns |
| | | | 547 | 8.4 ns |
| | | | 748 | 8.0 ns |
| Burle C83061E | H00063 | 14894 | 1046 | 2.46 ns |
| Errors (1 $\sigma$) | | | 0.5 % | 1 % |

Table 2. PMT Transit time spreads

## 2.3 Other measurements

Here we list measurements of

(a) The Single Photoelectron Resolution (SPR)

(b) The Dark count rate (Noise rate).

(c) Afterpulse rates

### 2.3.1 Single Photoelectron Resolution

This quantity is measured in coincidence to avoid confusion with the noise spectrum. The resolution is quoted as the ratio of the peak height to the 'valley' of the distribution, the larger the better.

### 2.3.2 Noise rates

These are quoted with a discriminator level of 1/10 of a single photoelectron. This is lower than the SNO standard of 1/4 but allows for the fact that lower discriminator levels may be set in software for an established event. The noise at 1/4 of a SPE is about 80 % the value at 1/10 SPE discriminator level.

The noise of a PMT is very complicated and varies on may parameters such as temperature, applied voltage and exposure history. For this reason the PMT's noise rate is measured after one day in darkness after a being exposed to room level illumination. This is *not* a quantitative test, but merely gives an indication of noise levels.

### 2.3.3 Afterpulse Rates

The rate is estimated between 0.4 $\mu$s and 100 $\mu$s after a single photon event. This time is related to the muon lifetime of 2.2 $\mu$s. The discriminator level is 1/10 of a SPE. The rate is expressed as a percentage probability of a primary pulse producing an afterpulse in this time interval.

| PMT Type | Serial Nō | Anode Nō | SPR P/V | Noise | Afterpulsing |
|---|---|---|---|---|---|
| EMI 9350(F) | 7102 | 326840 | 2.7 | 2000 | N/A |
| EMI 9350 | 6460 | 326079 | 3.8 | 700 | 0.8 % |
| Burle CS30061E | H00063 | 14894 | 3.0 | 5000 | N/A |
| Errors (1 $\sigma$) | | | 5 % | 10 % | 0.1 % |

Table 3. Other PMT parameters.

# References

[1] R.J.Boardman. *Photomultiplier tests - Requirements for SNO and standardized testing procedures* Oxford University internal report.