Investigating the Effects of Magnetic Fields on the PM Tubes for the BSC Sub-system

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Tube Description: Thorn (Electron Tubes) Model 9902KA 10 dynode PMT.

Introduction

These tests were conducted to determine the strength of an external magnetic field at which the Photomultiplier tubes to be used in the Beam Scintillation Counter will fail. The PMTs will need some modifying in order to achieve a satisfactory grounding scheme and minimize noise production. These modifications would only be meaningful when the equipment is installed in an environment with two separate grounds, such as the UXC and S1 counting room. For these tests, the PMTs were not modified. The High Voltage Grounds and Signal Grounds of each tube were electrically connected.

The PMTs will be mounted in their μ-shield within a Faraday cage in the upper, forward facing corners of the HF structure. The stray magnetic field in this region is expected to be between 200 – 300 Gauss.

Experimental Setup:

![Figure 1 Experimental Setup to test PMT operating threshold in a perpendicular magnetic field.](image)

The set up consisted of two scintillation tiles with the embedded LEDs pulsed simultaneously by the Pulse Generator. The LED light was captured by the internal wavelength shifting fibres and sent to two unmodified PMTs, one of
which was placed in a variable strength magnet with its central axis laid horizontal and perpendicular to the field and surrounded by a µ-shield. The second PMT was situated about 2 m from the magnetic field. The Gauss meter measured no field at the position of this PMT at any of the field strengths used. The electrical signals from the PMTs were sent to a Lecroy digital oscilloscope with a GPIB interface card to communicate with the PC.

By adjustment of the HV and the pulse generator signal amplitude to the LEDs, the amplitude of the signals seen on the oscilloscope were equalized in the absence of any magnetic field.

Measurements of the peak-peak amplitudes were made for various values of magnetic field ranging from zero (magnet off) to 1000 Gauss (0.1T). The flow chart shows a summary of how the measurements were made.

![Flow chart](image)

**Fig 2. Data gathering flow chart**

**Results**

The graphs below show the average amplitudes (for 50 samples) recorded over a time of approximately 5 minutes. 50 averages were calculated during this time and shows the stability of the amplitude measurements. The red line represents PMT1 in the magnetic field. The blue line represents PMT2, positioned 2 m from the magnet and outside the influence of the magnetic field.
The PMT operation began to fail at around 900G ±10G and the signal was completely lost by 1000G (see Fig 3).
For all values of magnetic field, the HV current monitor remained constant at 214 µA @ -850V for PMT1 and 205 µA @ -815V for PMT2. RMS measurements of the noise also remained constant (~ 0.5mV for the particular tube chosen) up until 900G when the signal and noise began to be suppressed by the magnetic field.

![Fig 3 The effect of increasing the magnetic field on the average signal amplitude.](image)

The mean signal amplitude from the PMT in the magnetic field is shown in red. The mean signal amplitude from the reference PMT positioned ~2m away is shown in blue. The magnetic field starts to effect the PMT signal at >900 G. The signal is 50% of its original amplitude at a magnetic field of ~960 G.

The datasheet for the 9902KB PMT (9902KA is the same tube except that the photo-cathode’s sensitivity if highly uniform) only states the magnetic sensitivity for this tube in its most sensitive orientation (parallel to the field) and with no µ-shield. The figure quoted is of $1.3 \times 10^{-4}$ T (1.3 Gauss) for the signal output to fall by 50%. This figure couldn’t be verified as the minimum field for the magnet used was ~ 100G. However, placing the tube in a 100G field with no µ-shield quickly eradicated the signal in any orientation other than the horizontal showing the obvious importance of using the µ-shields.
Conclusion

With the correct orientation and $\mu$-shields fitted to each PMT, there should be no degradation of the output signals for magnetic field strengths < 800G. The tests did call attention to the need to check each of the selected PMTs individually for excess noise and seek ways of reducing this when designing an HV/signal isolation scheme. Further tests of the effect of orientation of the tubes (fitted with $\mu$-shields) relative to the magnetic field will be carried out. It is important to know the consequence of incorrect alignment of the PMTs with the stray magnetic fields. Ideally, the PMTs should be positioned with their central axis at $90^\circ$ to the stray magnetic field lines. The orientation at the front, upper corners of HF will need to be known to ensure optimum installation of the PMT boxes on the HF structure.