

Magnetic Shielding for ACD Photomultipliers

Requirement

ACD has agreed to tolerate a magnetic field (any orientation) of 2 Gauss (0.1 milliTesla).

According to the accompanying Hamamatsu figure R647.magfld.data.pdf, a type R647 PMT (the commercial equivalent of the R4443 ACD flight PMT) exhibits a gain decrease of 10% at ~2 Gauss. This would be almost tolerable without magnetic shielding. However, since the Hamamatsu figure is for a single non-flight PMT, we need to reduce the 2 Gauss external magnetic field by at least a factor of 10 at the location of the ACD PMT's.

Shielding Calculations

The shielding factor of an infinite cylinder of diameter D , wall thickness $t \ll D$, and magnetic permeability $\mu \gg 1$ is

$$S_i \approx \frac{t\mu}{D}.$$

For the best (low field) magnetic shielding materials (80% Ni - 20% Fe : Mu-Metal, Co-Netic, Shieldmu 30, AdMu-78), $\mu \sim 4 \times 10^4$ for low fields.

For soft iron, $\mu \sim 2000$.

For a semi-infinite cylinder, the shielding factor is

$$S = \frac{S_i S_o}{S_i + S_o},$$

where S_i is the shielding factor for the infinite cylinder and S_o is an effective shielding factor for the opening (from A. J. Mager):

$$S_o = 3e^{7x/D},$$

where x is the distance from the end of the semi-infinite cylinder to the point of measurement (positive inside the shield).

For $x = 0$ (no extension of the shield past the PMT face), $S_0 = 3$, and

$$S = \frac{3S_i}{3 + S_i},$$

which gives a maximum shielding factor of 3 regardless of S_i (i.e., the thickness and permeability of the magnetic shield). This is not adequate for the ACD PMT's.

For $x = D/2$, (the canonical relationship for PMT shielding), $S_0 = 3e^{3.5} \approx 100$, so

$$S = \frac{100S_i}{100 + S_i}.$$

For a 15 mm diameter PMT recessed 8.5 mm into a high permeability 17 mm shield of thickness 0.2 mm,

$$S_i = \frac{4 \times 10^4 \times 0.2}{17} \approx 470,$$

$$S = \frac{100 \times 470}{570} \approx 82.$$

If soft iron ($\mu \sim 2000$) is used for the same task (15 mm diameter PMT recessed 8.5 mm into a 17 mm shield of thickness 0.2 mm),

$$S_i = \frac{2000 \times 0.2}{17} \approx 23.5, \text{ and}$$

$$S = \frac{100 \times 23.5}{123.5} \approx 19,$$

which is adequate for ACD.

Conclusions

It is essential that the magnetic shielding extend past the face of the PMT. The nominal extension is one radius of the shield.

The PMT magnetic shielding requirement for ACD is very minimal. It does not require high permeability shielding material; 0.2 mm of any material with permeability (at 2 Gauss) ≥ 1000 would suffice.