5 Photomultiplier Tubes and Practical Considerations

5.1 High Voltage

Photomultiplier Tubes may be run with either positive or negative high voltage power supplies. In either case, of course, the anode must be more positive than the cathode (electrons are negative). The bases with resistive dividers inside are built for one polarity or the other so one must know which it is. Most of the bases are labeled. If you don't know which it is; ask. Typical maximum voltages go up to about 2000 volts. Check the manufacturer's specifications for a particular tube. The current drawn depends on the resistive divider chain whose design depends on the rate of pulses expected. Typical divider chains draw from 1 to 3 mA.

Warning: *Most high voltage power supplies can deliver large currents: perhaps 10-20 mA or more and are therefore potentially* **lethal**. *Check personally that the power supply is off before handling tube. Obviously you should never remove or attach a base or a high voltage cable with power on.*

5.1.1 Negative Voltage

When a negative supply is used the cathode is at the high negative potential while the anode where the signal is developed is near ground. Usually a resistor (1 k perhaps) is placed between the anode and ground and the anode is connected directly to the output connector. In this configuration the electrostatic shield that surrounds the glass envelope on most tubes is at high voltage. Often this shield is connected to the high voltage through a big, (1 M or more) resistor for safety: but don't count on it. In this configuration since the tube envelope is at high voltage it is a poor idea to place metal in proximity to the tube, in particular the cathode region. Doing so could be dangerous but in any case may result in large noise pulses and breakdown due to leakage currents. Tubes should never be handled when the high voltage is on.

5.1.2 Positive Voltage

When a positive supply is used the cathode and tube shield are at ground potential so leakage and breakdown are not a problem but the anode is at high potential so the output signal is extracted through a high voltage capacitor. The output side of the capacitor should be connected to ground through a resistor inside the base to keep it at a definite potential (ground). If the output side were not grounded the capacitor could float up to high voltage. This could have the effect of destroying any circuit that the output cable is plugged into. Therefore with positive high voltage one should be careful about connecting cables when power is on.

5.2 Light

Tubes should never be exposed to light when the voltage is on. When you assemble a counter and use black electrical tape or black paper to seal it from light there may still be some small light leaks. These are not disastrous but you must find them and eliminate them before using the tube. The best way is to turn on the tube to a low high voltage, perhaps 1500 or 1600 volts and illuminate various suspicious connections, joints, etc with a flashlight. Light leaks will show up as an increase of noise pulses on scope. The leaks can be repaired with black tape. Once you can find no more light leaks the counter is ready to use. It is a good idea not to expose the tube to strong light even when the voltage is off unless you are working on it. This may increase the noise level but it will recover.

5.3 Magnetic Fields

Tubes need to be shielded from magnetic fields. They will operate in fields of 0.1 gauss but the earth's field (0.5 gauss) is enough to reduce electron collection efficiency. In the earth's field it is sufficient to wrap one or two layers of a high permeability alloy around the tube. This shield should extend for at least one tube diameter in front of the cathode. We have available some sheets of alloys which can be wrapped around tubes. If you are working near a magnet an outer layer of soft iron is usually needed in addition as the high permeability alloys may saturate.

5.4 Base design

The current owing in a resistive divider chain should be larger than the time-averaged pulse current. In a typical divider chain one might arrange for 1 mA of current (2 kV/2 Megaohms). After amplification by the dynodes the current owing during a pulse will normally exceed that (1 mA = 0.050 volts/50 ohms). The charge delivered by the pulse (integral of i dt) must be made available from capacitors placed across the last few stages of the divider chain. During the pulse charge is drawn from these capacitors that then recharge between pulses. Since less charge is needed as one goes up the divider chain the capacitors can get smaller. The capacitor size is chosen so that there is not a significant voltage drop during the pulse ?? V ? $\frac{?\,Q}{C}$?.For an example calculation see Knoll page 283ff. At accelerators particles often arrive in periodic bursts. In that case the capacitors must be large enough to sustain the voltage during a burst and recharge between bursts. One must design for some pulse rate per burst. Sometimes zener diodes or even individual power supplies are used to maintain stable dynode voltages in high rate situations.

5.5 Output signals

Tube bases are normally built with an output from the anode. The signals from the anode are negative (electrons are negative). You should always terminate the cable with its characteristic impedance when looking at the signal on scope. Many circuits (discriminators and fast amplifiers, for example) to which you will send the signal are already terminated in 50 ohms; if not, you need to use an external terminator. A few tube bases have a 50-ohm terminator at the base but this is unusual. You can check whether a particular circuit has a 50-ohm input impedance by connecting a signal source "through" the scope to the circuit with a long cable and looking for reflections. Many tube bases also provide an output from the last dynode through a coupling capacitor. This signal is smaller than the anode signal and is positive (why?). In some cases it is convenient to have this additional signal to send to a pulse height analyzer or to logic circuits. Since most of the electronic circuits designed for high-energy physics accept only negative signals the dynode signal must be inverted with a pulse transformer.

Most discriminators used for photomultiplier signals have minimum thresholds of 30 mV. Older circuits may have higher minimum settings (100 mV) and newer ones often go down to 10 mV. You will need pulses in the appropriate range; the pulse size can be controlled with high voltage up to a point or else with an amplifier.

6 Scintillation counters: Practical Considerations

Scintillation plastics are usually wrapped in aluminum foil for reflection but the half-inch closest to the tube should be wrapped in white paper (an insulator) especially if it is to be used with a negative High Voltage tube base. The wrapping should not make good optical contact with the plastic since one would like to take advantage of total internal reflections. The outside must be made light tight: black electrical tape or black paper are both good. Wrapping should be kept thin if you are trying to detect low energy particles, especially electrons. For alpha particles you cannot possibly make it thin enough. Counters work best if a good optical contact is made with the front window of the tube; one often uses silicones with the proper index of refraction. Some times a bond can be made with "5-minute epoxy" which gives mechanical strength but is not difficult to remove. For temporary set-ups one can simply place the scintillator in contact with the tube with no coupling material.

Light pipes made of Lucite (Plexiglas, Perspex) are commonly used between the scintillator and the tube. This permits the tube to be located at some distance from the active region of scintillator, outside the particle beam, magnet, etc. Even if that is not a consideration the light pipe serves to couple the cross-sectional area of the scintillator to the round face of the tube. Normally the areas should be equal and the light pipe should taper gradually. An additional reason for using a light pipe even with a small scintillator is that it provides a more uniform response over the volume of the detector since the fractional range of distances to tube face is smaller.