Testing and Development of the P10 Scintillator for the Focal Plane Detector:

Delving into the Depths of Plastic

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Abstract

The P10 scintillator is a component of the Focal Plane Detector being developed at Michigan State University. The scintillator will stop and determine the energy of incoming isotopes. The project focused on testing and calibration of the thick scintillator. Photomultiplier tubes were tested then coupled to the scintillator. The PMTs were then gain matched. Tests were run to determine the position sensitivity of the scintillator and test the response of the PMTs. The scintillator was found to be position sensitive.

Introduction

The Focal Plane Detector (Figure 1) being developed at the National Superconducting Cyclotron Laboratory (NSCL) is composed of five parts: two Cathode Readout Drift Chambers (CRDCs), to determine position and angle of incoming charged particles, an ion chamber to ascertain the isotopes change in energy, and a thin and thick scintillator to stop and determine the energy of detected particles. The thin scintillator acts as a gate for the thick scintillator, which is what stops and finds the energy of the isotopes.

The project focused on the thick scintillator. A method for testing the scitillator was designed and implemented. Photomultiplier tubes (PMTs) were tested for uniformity then four were coupled to the scintillator. On the scintillator the PMTs were gain matched using Cobalt-60, the primary source used to test the scintillator. Using Cobalt-60 the position sensitivity of the detector was evaluated for each PMT. Further tests were done to check the validity of the results and the effectiveness of each PMT.

Theory

The Focal Plane Detector (FPD) will be used to detect rare isotopes. These isotopes are created at the NSCL. An ion beam is accelerated through the two cyclotrons, first the K-500 then the K1200. Shortly after the ions leave the second accelerator they collide with a target source. The charged particles created from this collision travel though the beam line to the FPD.

Using the mass-to-charge ratio of the created particles it is possible to limit the type of particles that reach the FPD. Along the beam line there is a series of dipole magnets that bend the beam around corners. By adjusting the magnetic field from these magnets the radius of curvature for a specific mass-to-charge ratio changes. Setting the dipole magnets at a specific field limits the charged particles that make it around the bends.

The primary purpose of the FPD is the study of rare isotopes. It is very hard to detect and study these rare isotopes because they are extremely unstable and decay almost immediately after they are produced. Using the FPD rare isotopes that lie outside the neutron drip line, such as Be-16, might finally be detected. The neutron drip line is the boundary where isotopes contain so many neutrons they cannot exist in nature, because they spontaneously expel excess neutrons. Many isotopes beyond the neutron drip line have been theoretically predicted but remain to be found experimentally. The FPD will be used to search for some of these isotopes. It may be possible to study the spectrums, half lives, and beta-delayed neutron emission probabilities of some rare isotopes. This will provide a fuller understanding of the underlying structures and reactions, as well as test modern nuclear theory.

The isotopes detected by the FPD are stopped, and their energy is ascertained with the scintillator. When the isotope enters the scintillator, it interacts with the material causing electrons to be excited to higher energy levels. When the electrons decay back down they emit a photon. The photons created in the scintillator are collected by photomultiplier tubes (Figure 2). Inside the PMT the photons hit a photocathode where they are converted into electrons. The electrons then travel to the electron multipliers, a series of dynodes that release many electrons (in proportion to the incoming electron) for each electron that hits them. In this way a few electrons are turned into a large shower of electrons. The electrons are collected in the anode, where they are read out as a current. This signal is then feed through a series of electronics and becomes meaningful data.

Experimental Set-Up

The scintillator is a Bicron BC-404 Pilot B. This organic scintillator was chosen for its high absorptions of electrons and fast neutrons, fast decay times of approximately 1.8 nanoseconds and scintillation pulse height of 68. The scintillator was coupled, using Baysilon 300000, an optical coupling oil, to four Hamamatsu R329 PMTs. The scintillator, with PMTs attached was wrapped in several layers of black paper and black plastic to prevent optical light from entering and causing overflow in the PMTs. A picture of this set up is shown in figure 3.

The PMTs were powered by a high voltage power supply held at roughly –2000 volts. The dynode outputs of the PMTs were terminated and the anode outputs were run through preamplifiers to the inputs of amplifiers. From the uni-polar outputs of the amplifiers the signals are sent to the ADC where they are read by the computer. The fast timing outputs of the amplifiers are connected to a Quad CFD, where the gate is generated. The outputs of the CFD are feed into a Coincidence box. The Coincidence box has two outputs each to a Gate

Generator. The first Gate Generator sends a signal back into the Coincidence box when it is not busy, so that the Coincidence box only sends out signals to the Gate Generators when they are not in use. The first Gate Generator sends the signal it receives from the Coincidence box to the computer. The second Gate Generator sends the signal it receives to the strobe input of the ADC. A diagram of the electronics is shown in figure 4.

Testing the Scintillator

To test the scintillator a 10 micro-curie source of Cobalt-60 was placed directly on top and center of the covered scintillator. The PMTs were then gain matched using the amplifiers. Each PMT was individually triggered off of the Coincidence and the peak of the spectrum from each PMT was centered at roughly channel 100 on the computer.

After gain matching the PMTs, a series of spectrums was taken. For each PMT the source was placed directly in front of it, in the center of the scintillator, and at the far corner from the PMT. While taking these spectrums the PMT being tested, was also the PMT that triggered the gate.

Results

After taking the spectrums the data was saved and transferred to Excel, where it went through preliminary analysis. The graphs from this analysis show a definite correlation between the position of the source on the scintillator and the spectrum (Figure 5). When the source is nearest the PMT the peak on the spectrum is largest. The peak is usually highest when the source is closest to the PMT and in all cases integrating under this spectrum peak gives the greatest value. The spectrum peak from when the source is centered on the PMT is also very large, though slightly smaller than when the source is near the PMT. Finally, when the source is placed in the far corner, the spectrum peak is significantly smaller than in the other two cases.

This shows distinct position sensitivity in the scintillator. As the radiation enters the scintillator further from a specific PMT, the spectrum from that PMT changes, and the energy peak from the radiation is smaller.

Conclusions

The P10 scintillator is position sensitive. The degree of this position sensitivity is not yet determined. Further tests must be done to determine the patterns of sensitivity. It may be possible to find where radiation entered the scintillator from spectrum differences in the four PMTs. Whether this can be done depends on whether there is a clear position dependant pattern.

The channel numbers on the computer generated spectrums need to be calibrated to energy values. To do this a source with two known energy peaks is needed. Then the energy value of the channel number where each peak falls is known, and a proportionality constant between the channel numbers and energy values can be calculated.

Finally, when the scintillator is placed in the FPD, experiments will be done with known ions to test its response and check that all the components are working correctly.

Bibliography

[1] Sweeper Magnet Proposal. 31 March 1999. Thoennessen, Michael. 11 July 2001. <http://www.nscl.msu.edu/~thoennes/personal/papers/sweeper.pdf>.

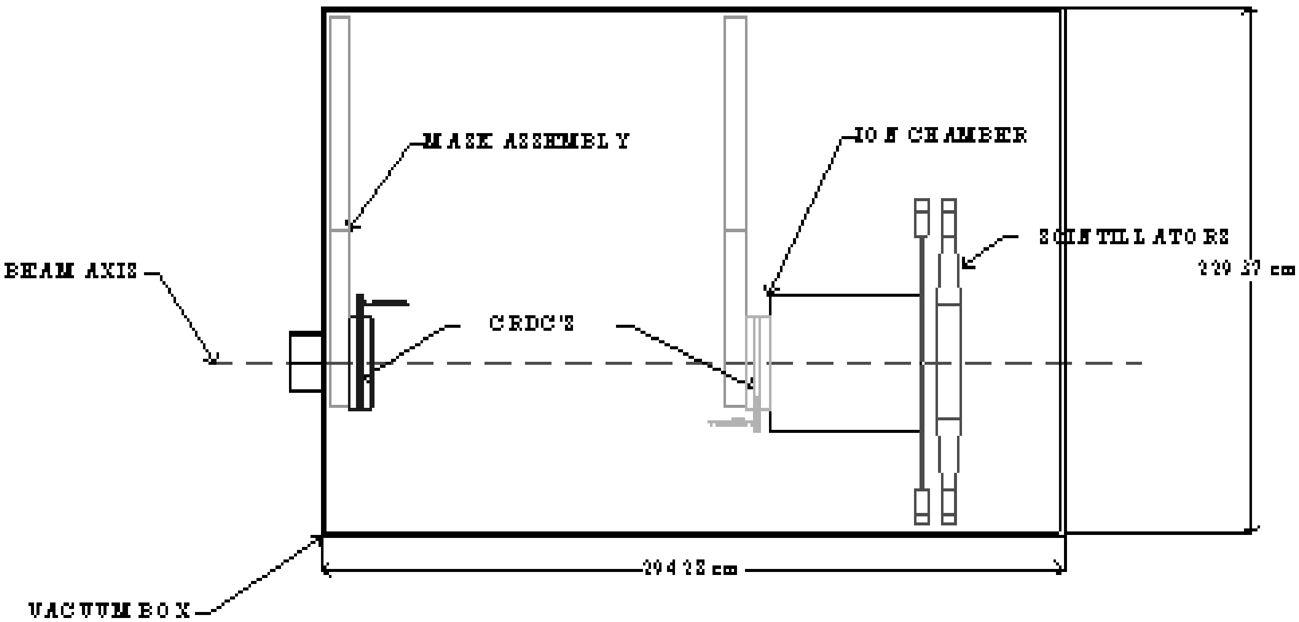
[2] Knoll, Glenn F. Radiation Detection and Measurement. New York: John Wiley and Sons, Inc., 2000.

[3] Photomultiplier Tube Construction. Hamamatatsu Corporation. July 16, 2001. <http://usa.hamamatsu.com/electron-tube/pmt/pmt-construction.htm>.

Figure Captions

1. Diagram of the Focal Plane Detector.
2. Diagram of How a Photomultiplier Tube Works.
3. Diagram of the Scintillator.
4. Diagram of Electronics Set-Up.
5. Peak position of ^{60}Co as a function of source position on the scintillator.

Figure 1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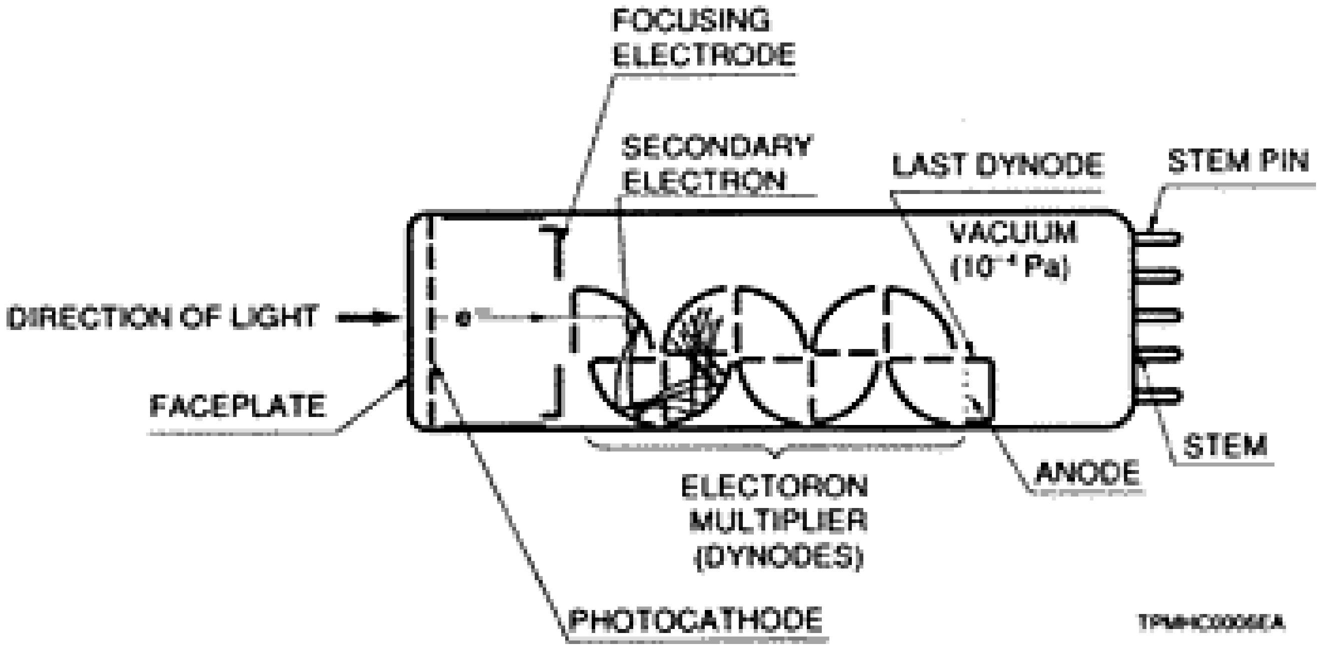
SCINTILLATORS
BEAM AXIS
229.37 cm
CRDC'S
294.28 cm
VACUUM BOX

Figure 2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SECONDARY ELECTRON
LAST DYNODE
STEM PIN
VACUUM
(10^{-4} Pa)
DIRECTION OF LIGHT
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STEM
ANODE
ELECTORON MULTIPLIER (DYNODES)
PHOTOCATHODE
TPMHC0006EA

Figure 3

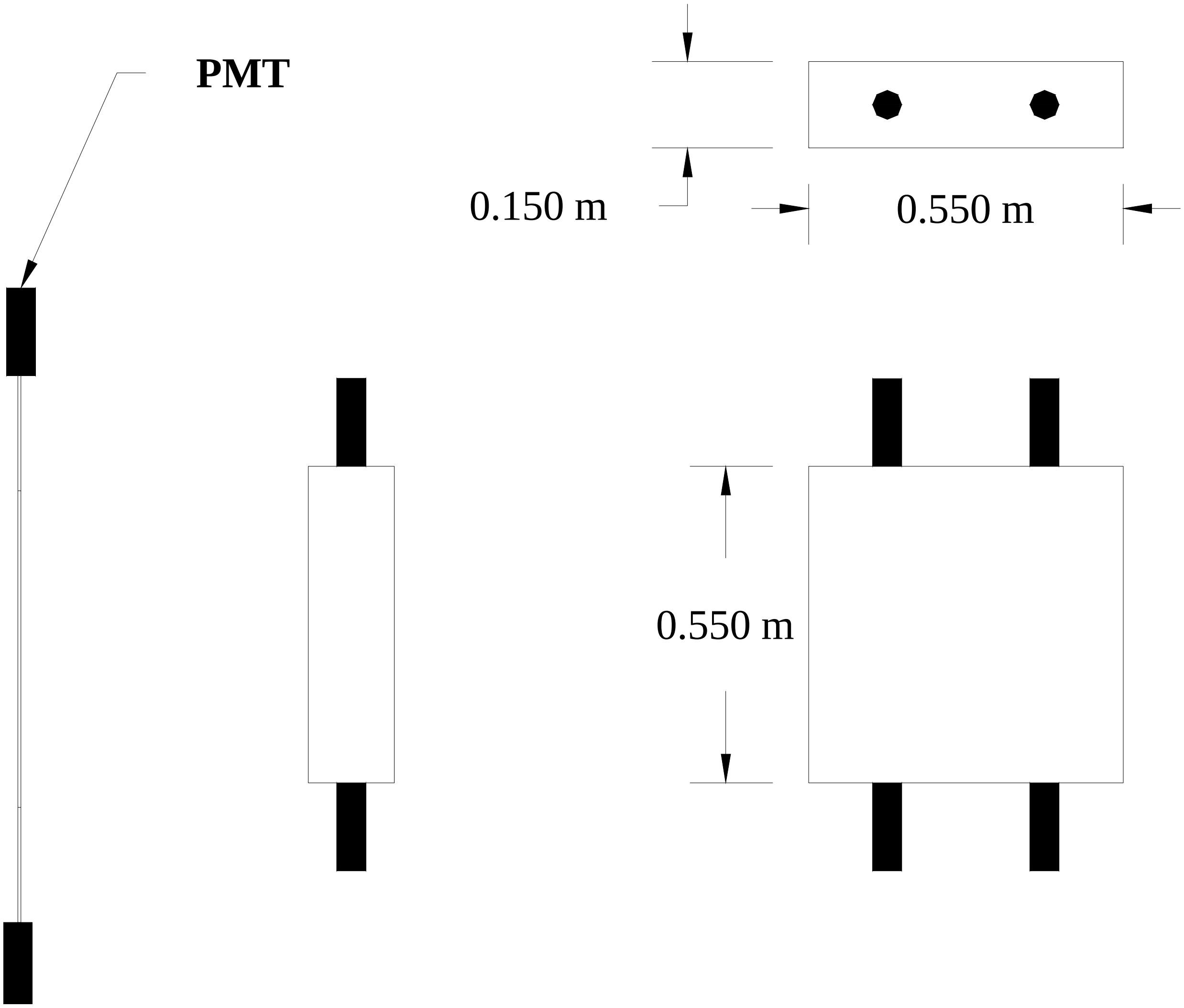


Figure 4

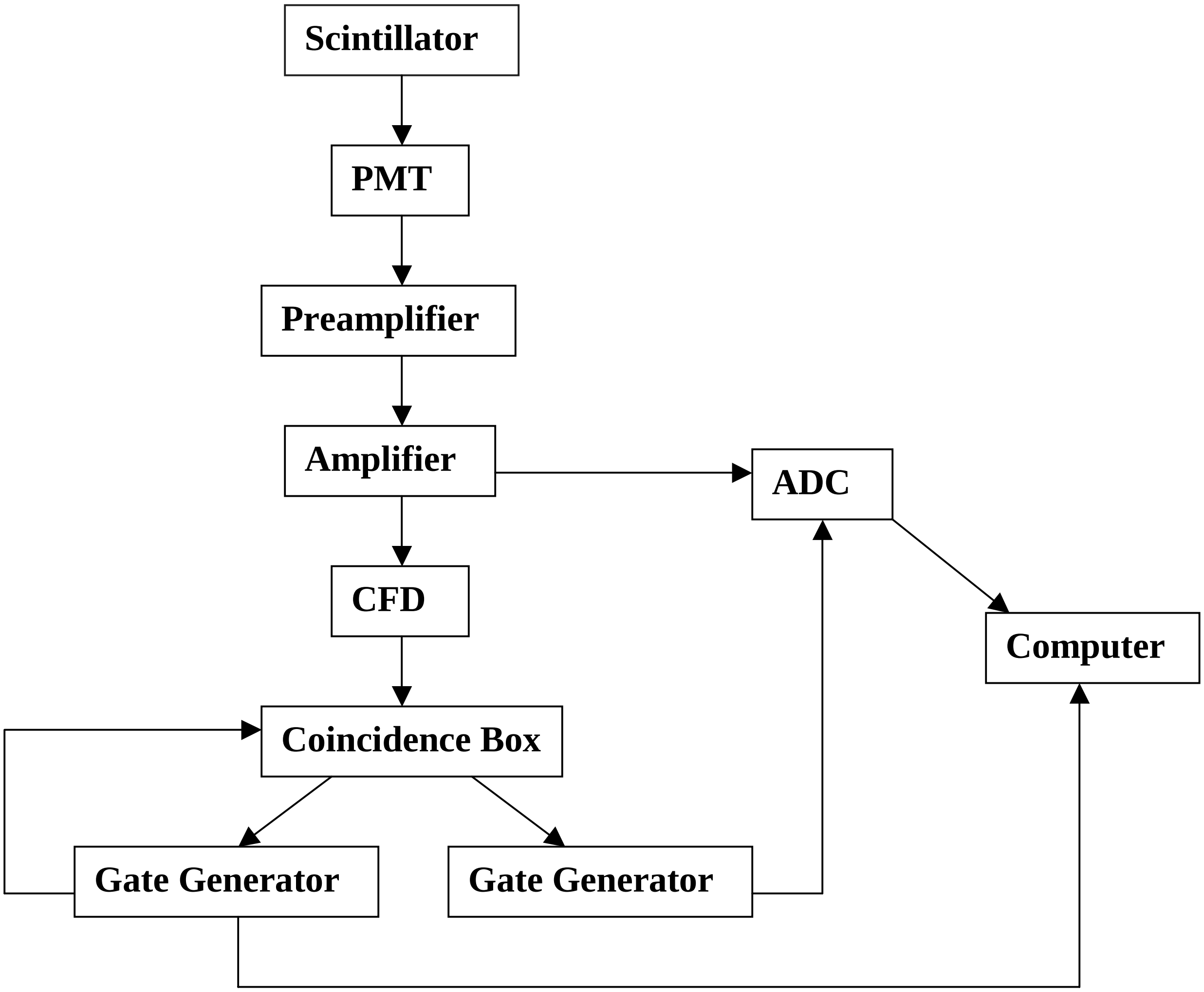
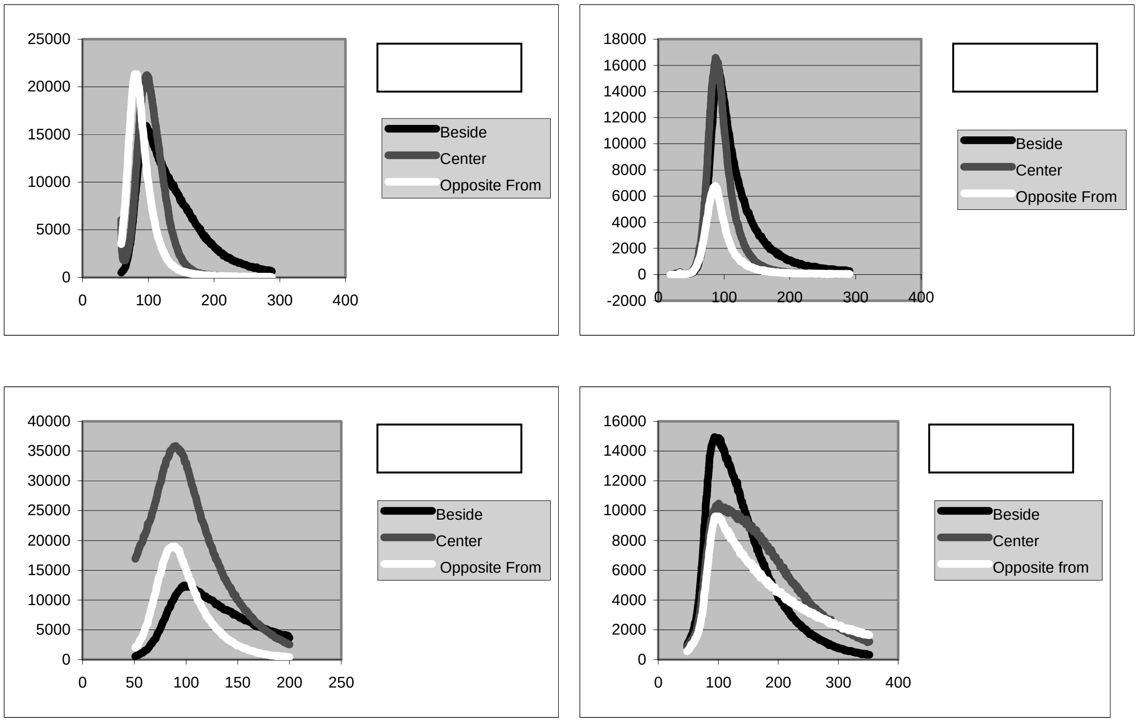

Scintillator
PMT
Preamplifier
Amplifier
ADC
CFD
Computer
Coincidence Box
Gate Generator
Gate Generator

Figure 5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