ICFA 95 INSTRUMENTATION SCHOOL
Ljubljana, Slovenia

Measurement of Attenuation Length of Photons and Determination of Photon Yields in Plastic Scintillators

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Introduction

This experiment is to measure photon yields and attenuation lengths for photons in a polystyrene based fiber doped with Butyl PBD and POPOP scintillating compounds. The scintillator emits photons efficiently at a characteristic wavelength of 418 nm, blue light. An RCA 31000 photomultiplier tube with a bi-alkali photocathode with peak quantum efficiency around 420 nm is used to detect the scintillation photons. The photomultiplier has a first focusing dynode arranged to make it uniquely capable of detecting single photons. For this reason, it is called a "Quantacon," (Quantum Counter). Several lectures will be given on the subject and some of the latest papers will be available for perusal.

Materials

- o Butyl PBD + POPOP scintillating fiber ribbons
  - 8 layers of staggered fiber ribbons composed of 2 mm singly clad fibers
    Cladding material is poly-methyl-metacrylate (PMMA).
    Trade name Lucite.
  - Fibers are about 150 cm long
  - Fiber is painted with white reflective paint to prevent cross talk
  - Both ends of the fiber bundle are polished using a special diamond cutting tool (at Fermilab)
- o RCA 31000 photomultiplier tube (PMT) with base
- o High voltage power supply for the PMT
- o Electronics
  - 2 NIM amplifiers: LeCroy 333, LeCroy 612
  - LeCroy 621 pulse height discriminator (used as a gate generator)
  - LeCroy 2249 CAMAC 12 channel ADC
  - NIM and CAMAC bins with power supplies and Jorway 73A contoller
  - Macintosh laptop computer with SCSI interface to CAMAC and software
  - In-line pulse inverter, attenuators, and cables
- o Bismuth-207 beta source (provides ~ 1 MeV electrons) with lead collimator

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[1] Assisted by Ervin Krizanic and Timothy Meyer
[2] Manual prepared by Timothy Meyer

The experimental arrangement:

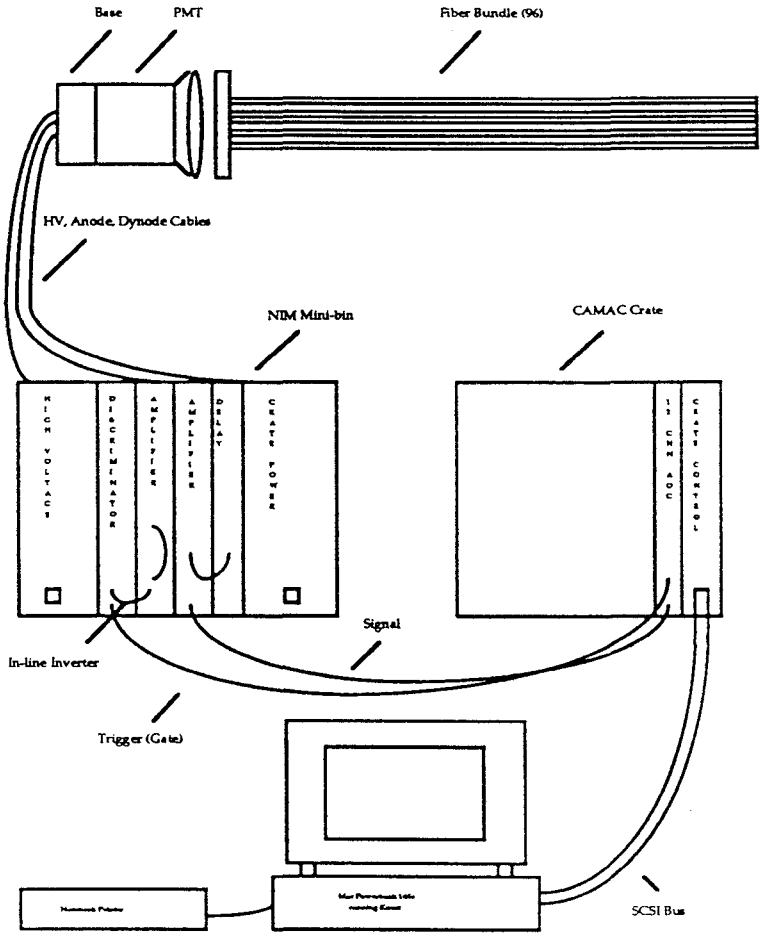

Fig. 1 Diagram of Setup

Procedure:

o Become familiar with the experimental setup. Examine the two inputs to the ADC, the gate trigger, and the PMT signal on an oscilloscope. Review the Kmax appendix to learn about the data acquisition program.

o Using the Kmax program on the Macintosh, determine the pedestal and the first photoelectron peak of the PMT, without using the beta source. What is causing the single electron peak? Is it possible to distinguish the second photoelectron peak? What can you tell from the peak sum?

o Take pulse height spectra with the beta source at various distances from the PMT: 5, 10, 15, 20, 30, 50, 70, 100, 125, and 132 cm. Record the weighted average of each spectrum. (See Figure 2 for examples.) Be sure to set the cursors properly

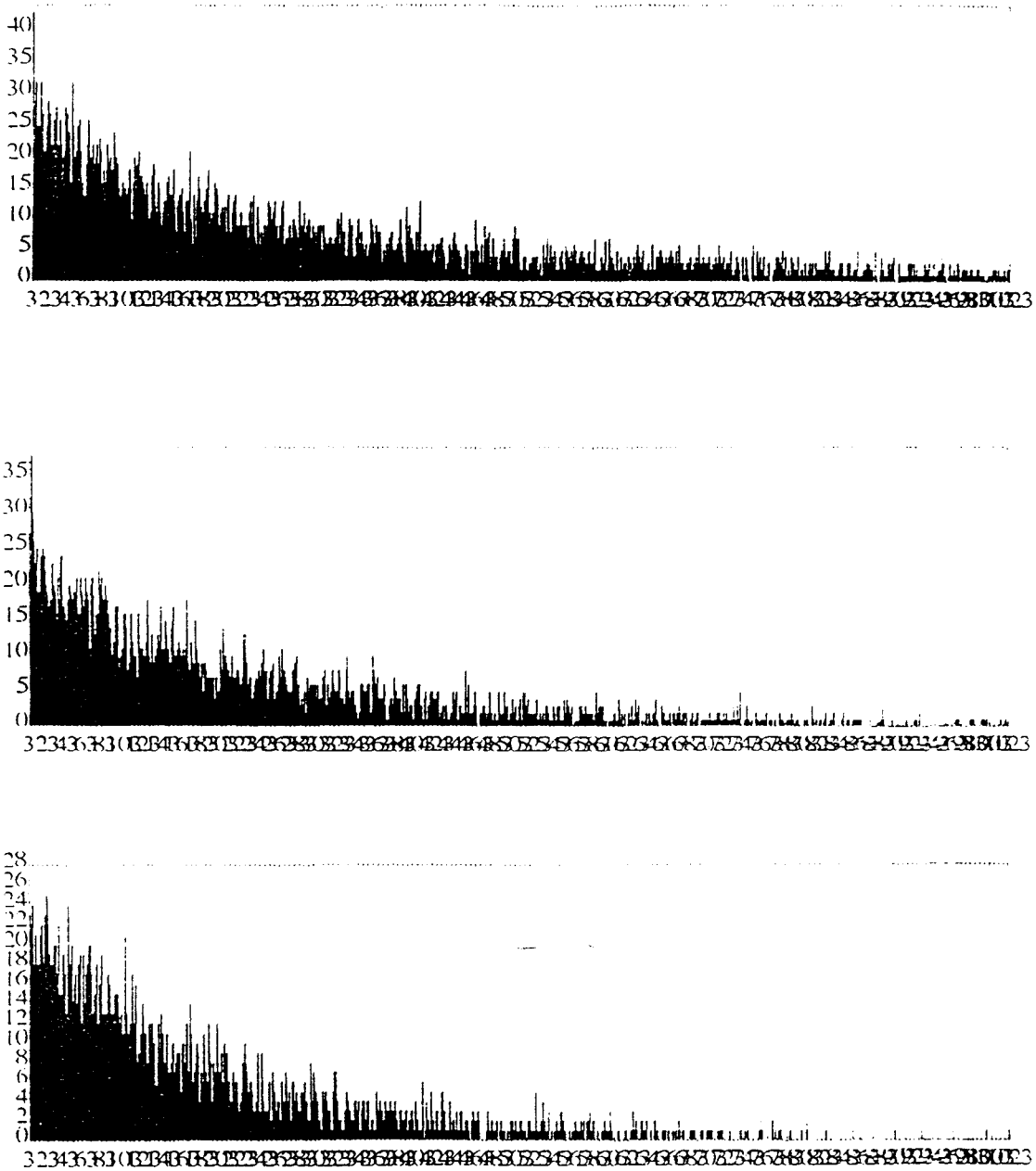

Fig.2 Typical pulse height spectra gathered by Kmax from Bi-207 positioned at 20, 70, and 125 cm respectively.

to trim off the pedestal, or try using an attenuator on the PMT signal before the ADC. What do you use and why?

o Display and plot each of the results in semi-log form. Knowing that there are two causes for the attenuation, what do you expect to see? (See Figure 3.)

o Determine the attenuation lengths for the fiber bundle between 5 and 30 cm, and from the 30 to 132 cm positions. Why do we ask this?

o With the knowledge of the pedestal and first photoelectron peak values, determine the photoelectron yield in the fiber at the 5 cm and 30 cm points. Assume a 1 MeV electron travels 5 mm in the fibers.

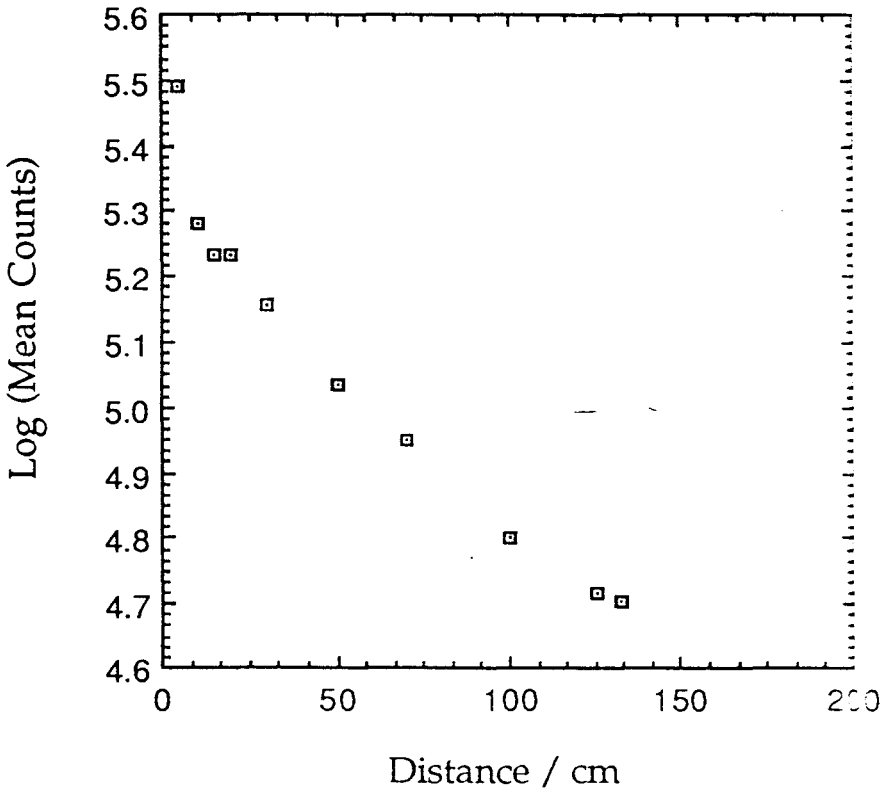

Fig. 3 Semi-log plot of ADC counts vs. distance (of the source). Note the appearance of two trends governing the attenuation.

The intensity of scintillation photons is expected to behave as a function of distance from the source in a form like below. (See Figure 4 for a curve of this form fit to the data.)

$$I = I_0 [B \exp(- x / l_1) + (1 - B) \exp(-x / l_2)]$$

B represents the relative fraction of the attenuation from the two types of attenuation : absorption by the core material or self-absorption by the fluor, or imperfections in the cladding-core interface.

l_1, l_2 are the two attenuation lengths

I_0 is the unattenuated photon intensity, equivalent, then, to 0 cm.

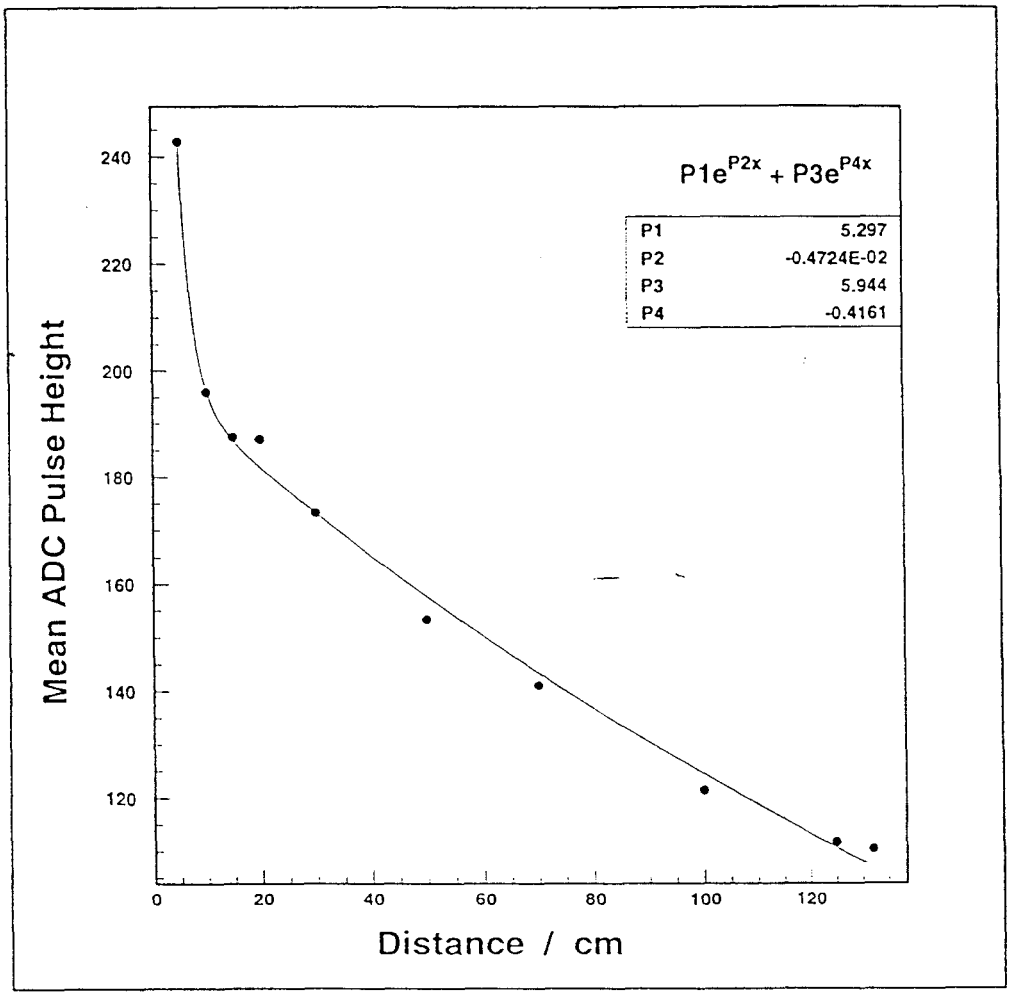

Fig. 4 A four paraneter curve fit for a sum of two exponentials. The attenuation lengths for each effect are read off directly. Note the reigion of each one's dominance.

Appendix: Kmax Basics

Setup:

Connect SCSI Cable from laptop to crate controller with in-line terminator. Make sure cable is inserted properly into laptop. Turn on the CAMAC crate and then pen the laptop and press the start button on the rear left. If the laptop does not boot properly, try the procedure again.

Running Kmax:

After the desktop has been loaded, insert the floppy desk with the Kmax software. Double click on the instrument program called "AD2249_SRQ." This launches the Kmax program and the proper instrument file. Once running, there will be three windows present: a Control Panel labeled "AD2249_SRQ", a DATA window, and a Report window. The instrument is turned on by clicking the mouse on the left most button on the control panel. (The attached sheet explains some of the functions of other buttons on the bar.) As the instrument starts, it will ask for the channel number of the ADC from which the data is to be read.

Controls:

The following controls are available in the control panel. The pair of buttons labeled Run and Stop start and stop the data acquisition sequence. The Run Timer button is used to set the length of time for which data is to be acquired. At the end of the time, Kmax will stop gathering data. To force it to be free running, enter a time of 0 minutes. The run timer takes priority over the event counter control. The event counter control allows a user entered number of events to be accumulated, after which Kmax stops. The event counter will count only data between the cursors in the data window. Any data acquisition sequence can be stopped with the Stop button.

Other Information:

To save a plot to disk, select the DATA window (the title bar will be highlighted), and choose Save As from the File menu. These can be opened by double-clicking on the icon, or choosing the Open -> Histogram option in the File menu list.

The printer uses single sheets of paper fed in the back. Insert a sheet and press the yellow button to feed in the paper. Then with the DATA window in front, choose Print from the File menu list. After the printing is completed, stick in a second sheet of paper, and answer okay to the computer's prompt.

Statistics on the histogram can be obtained by holding down the SHIFT key and clicking on the blank area of the menu bar on the instrument's Control Panel. Another SHIFT-click will bring more information. The vertical scale can be adjusted by choosing Vertical Scale from the Format menu. The vertical scale can also be automatically scaled by choosing Turn Auto Scale On from the format menu. The cursors denote the active region of the histogram, from which statistics are calculated. They can be set from the Set Cursors option from the Format menu, or by using the mouse on the active DATA window. Using the Expand command from the Format menu will fit the selected portion of the histogram to the DATA window.

The instrument must be stopped before Kmax can be exited. This can be done by stopping the data acquisition by stopping the data gathering, and then clicking the Kmax halt button on the leftmost side of the control panel menu bar. When exiting the program, do NOT save changes to the instrument. Saving histograms must be done before exiting the program.

Figure 3-1

The Kmax Control Panel

The **Control Panel** area between the button bar and the footer message bar can be used to show messages, data, controls, and other custom information that the user may want to display. The window can be formatted as an array of cells by using the **Panel** item in the **Format** menu. The cells or the footer message bar are accessed by using the **CSL DISPLAY** command. The foreground and background colors of the **Control Panel** are changed by selecting a color option from the color submenus in the **Windows** menu.

When the instrument is running, (i.e., Kmax event processing is enabled) the Go/Halt button,  , is inset,  . If the instrument running is paused, the Pause/Continue button,  , is inset, 

Clicking the buttons in the **Control Panel** button bar is equivalent to selecting items from the **Control** and **Instrument** menus. The equivalence is shown in Table 3-1.

Table 3-1

	**Control** Menu:**Go** item/**Halt...** item
	**Control** Menu:**Pause** item/**Continue...** item
	**Instrument** Menu:**Module Setup...** item
	**Instrument** Menu:**Sequence Setup...** item
	**Instrument** Menu:**Sort Setup...** item
	**Instrument** Menu:**Conditions Setup...** item
	**Instrument** Menu:**Turn Data Sort On/Off** item
	**Instrument** Menu:**Turn Data Save On/Off** item
	**Instrument** Menu:**Turn AutoStart On/Off** item
	**Instrument** Menu:**Lock/UnLock** item

Instrument **Control Panels** are easily customized by using a drawing program to design a picture to be used as the background of the **Control Panel**. This picture must be stored in Kmax or the instrument file as a PICT resource. When a Kmax instrument document is opened, all open resource files (this includes the document being opened) are searched for a PICT resource named "PANEL" (case sensitive). If found, it is used as the background of the **Control Panel**. The **Control Panel** can be further customized from **Command Sequence Language** by using the **DRAW** and **ERASE** commands to draw and erase PICT resources on the **Control Panel**. A picture drawn in the **Control Panel** is shown in Figure 3-2.