Experiment 7
CAMAC Data Acquisition and Plastic Scintillator

Contents

Chapter 1

Comments

This script is based on the old script. Unfortunately, I do not know who did write it. Anyway, **Thanks old script very much**. It had a couple of very useful information which gave me understanding of this experiment.

1.1 Two Reports

- Your group number, full names, lab course date, and your email address must be written in your reports.
- **One report per One group**. It does not matter how many students join one group.
- Send your reports to me by email.

1.2 Grading and Cheating Policy

- Your final grade is based on several things:
  - 2 major reports.
  - The first report can be several answers and solutions about preparatory things which you can find later. The score of each problem or question is 10. Total score is 90 (roughly 67% of your total score in first test).
  - The second report can be final experiment report (roughly 67% of your total score in second test).
  - 2 major experimental activities (roughly 33% of your total score in both test).
- Cheating in any form, including copying answers and results on both reports, is banned. Any person did cheating will earn 0 score in this course.

1.3 Handling and Care of

1.3.1 Radioactive Source

All radioactive sources are potentially dangerous and have to be treated with caution.

- NEVER eat, drink, or smoke something in the laboratory area.
- Wash your hands at the end of the experiment.
- ^{207}Bi source contains low activity and can be safely handled with your fingers. It is good practice to always handle the source by the edge of the disk.

1.3.2 CAMAC

- Never unplug the CAMAC-modules from the frame while power supply is being on. Plug and unplug the modules while power is being off.
- Keep paying attention to the ventilator which is running throughout measurement.

1.3.3 Power Supply

- To turn off the power supply requires a deal of patience. Firstly, slow down the voltage with a knob. Secondly, **please wait a couple of minutes until a needle points to zero roughly**. Then turn it off.

Chapter 2

Preparatory Things

Nothing in the world can take the place of persistence. Talent will not; nothing is more common than unsuccessful men with talent. Genius will not; unrewarded genius is almost a proverb. Education will not; the world is full of educated failures. Persistence and determination alone are omnipotent.

Calvin Coolidge

2.1 Questions and Problems

Questions

Firstly, read all following questions, and try to answer the questions. Do not exceed one page of A4 paper to answer four questions.

- What is an isomeric transition (IT)?
- There is a nucleus with Z (atomic number) and A (atomic weight). During the isomeric transition, how can Z and A be changed?
- What is an internal conversion (conversion electron) and what is a γ Decay ?
- Explain the difference between β^- decay and internal conversion.

Problem 1

^{207}Bi was first reported by Neumann and Perlman[2]. Consult the references about the more information about ^{207}Bi[3, 4, 5, 6, 7]. Explain the following decay scheme individually and what is the difference between the two decay schemes[8] (Fig.2.1,2.2)?

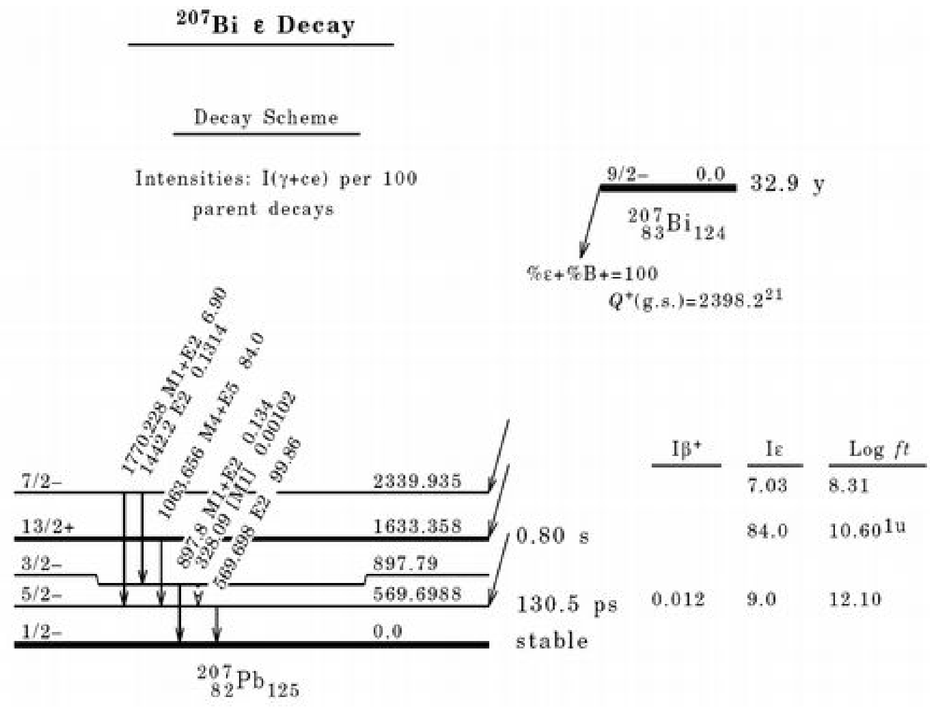


Figure 2.1. Electron Capture Decay Scheme

Problem 2

Atomic-electron binding energies of ^{82}Pb is the following[9]. From the decay scheme (Fig.2.2)

Shell Binding Energy	K	L_1
Unit [keV]	88.0045	15.8608

of IT, find the energies of the internal conversion electrons roughly, and compare these with the values which you have already known as following Table[16]:

Nuclide	Half-life (year)	Type of decay	Electron Energy (MeV)	Emission prob. (%)	Photon Energy (MeV)	Emission prob. (%)
$^{207}_{83}$Bi	31.8	Electron Capture (EC)	0.481	2	0.569	98
			0.975	7	1.063	75
			1.047	2	1.770	7

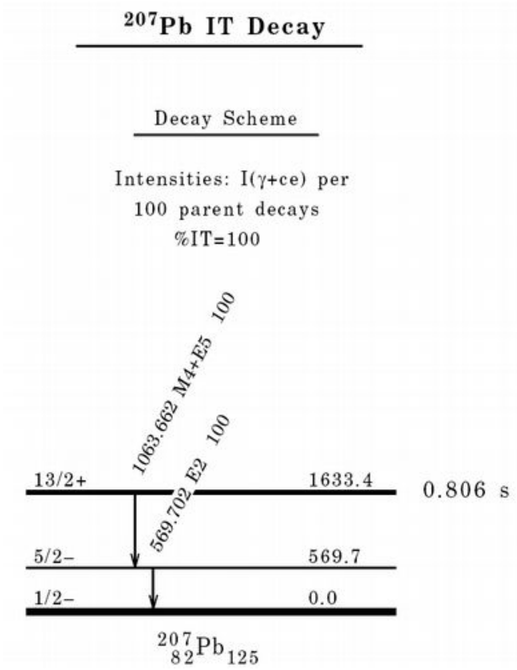


Figure 2.2. Isomeric Transition Decay Scheme

Problem 3

What is the three major types of interaction mechanisms for γ rays in matter? And explain the three processes in more detail.

Problem 4

3 MeV photons are counted by a NaI(Tl) detector. Sketch the expected spectrum and explain what you sketch and the physics process beneath it.

Problem 5

From the incoming of an charged particle or γ in a plastic scintillator to the output signal of the photomultiplier tube (PMT), explain how a plastic scintillation counter works.

Problem 6

How many counts are needed to make the standard deviation equal to 1%? And if one obtains 8,423,456 counts in 300 seconds, what is the standard deviation of the count rate?

Problem 7 [10]

Random processes play an important part in subatomic physics. We shall consider about the production of electrons at the photocathode of a multiplier. Each incident photon produces n photoelectrons as output. We can repeat the measurement of the number of output electrons N times, where N is very large. In each of these N identical measurements, we shall find a number n_i, $i - 1, ..., N$. The average number of output electrons is then given by

$$\bar{n} = \frac{1}{N} \sum_{i-1}^{N} n_i. \tag{2.1}$$

The question of interest can be stated: How are the various values n_i distributed around $\bar{n}$? Another way of phrasing the same question is: What is the probability $P(n)$ of finding a particular value n in a given measurement if the average number is $\bar{n}$? The probability $P(n)$ of observing n events is given by the *Poisson distribution*,

$$P(n) = \frac{(\bar{n})^n}{n!} e^{-\bar{n}}, \tag{2.2}$$

where $\bar{n}$ is the average defined by the above equation.

With $\bar{n} = 3.5$, calculate the probability of observing 2 events and a standard deviation, and then plot(sketch) the distribution.

Problem 8

A counter is set to count gamma rays from a radioactive source. The total number of counts, including background, recorded in each 1 min interval is listed in the accompanying table. An independent measurement of the background in a 5 minutes interval gave 58 counts. From these data find:

(a) The mean background in one minute interval and its uncertainty.

(b) The corrected counting rate from the source alone and its uncertainty.

Trial	1	2	3	4	5	6	7	8	9	10
Total Counts	125	130	105	126	128	119	137	131	115	116

2.2 Textbooks

For convenience, the textbooks, which one has to read before the laboratory exercise, are collected in other script.

Chapter 3

Detail Instructions

What would a physicist do if he were asked to study ghosts and telepathy? We can guess. He would probably (1) perform a literature search and (2) try to design detectors to observe ghosts and to receive telepathy signals. The first step is of doubtful value because if could easily lead him away from the truth. The second step, however, would be essential. Without a detector that allows the physicist to *quantify* his observations, his announcement of the discovery of ghosts would be rejected by *Physical Review Letters* [1].

3.1 The First Week

CAMAC(**C**omputer **A**utomated **M**easurement **A**nd **C**ontrol) is a modular system. Equipment assemblies are formed by mounting appropriate *plug-in units* in a standard chassis or *crate*. Each plug-in unit occupies one or more mounting *stations* in the crate. At each station there is an 86-way connector socket giving access to the CAMAC Dataway, a data highway which forms part of the crate. The Dataway consists mainly of bus-lines for data, control, and power [15].

CAMAC modules, which we will use in this experiment, have already been plugged into a CAMAC crate which has 25 stations, numbered $1 - 25$. Station 24 and 25, the rightmost two stations, usually are reserved for a Crate Controller(CC), whereas stations 1 - 23 are normal stations used for CAMAC modules. The purpose of CC is to issue CAMAC commands to CAMAC modules and transfer information between PC and CAMAC modules.

3.1.1 A Word Generator : WG2401

WG2401 is a 24 bit word generator, which is a single-width CAMAC module. A 24 bit word can be issued by some combinations of switches. One can read the results, which are generated by WG2401, by CAMAC commands.

What will we understand?

The main purpose of the first task is to understand basic CAMAC commands by a word generator.

What do we have to do?

1. The station number N in the range 1 to 23 (24−25 for CC) is for the position of a module(see the number on the front panel of CAMAC crate). The function number F (0−31) defines the type of operation and the sub-address A(0−15) defines special registers or inputs / channels. In WG2401 case, we only use F(0) and A(0). *What do F(0) and A(0) mean?*

2. You may find a strange behavior of the word generator. *If do, is it really a problem of the word generator or a problem of CAMAC crate? How can one decide it? Explain the method.*

3.1.2 On your mark with a small detector

What will we understand?

The main purpose of this task is to understand the plastic scintillator and the energy measurement. The superficial and simple results of this task are easily understood. However, a more sophisticated approach is needed to understand important process beneath them. **Students should understand how light is generated in a scintillator, how light is transmitted to a Photomultiplier tube(PMT), and how a PMT generates an electric signal. This means that students are supposed to discuss scintillator performance in terms of the following: the energy deposition, the scintillation material, the material geometry, the path length, the light collection, the light transfer efficiency, the quantum efficiency of the PMT, and the gain of the PMT.** Remember that this simple and basic task is more crucial. If one can use some kind of detector system, one has to do the same thing.

What do we have to do?

In the Figure 3.1, the shadow area denotes the plastic scintillator which is a small cylinder shape and has already been combined with PMT. Its diameter is 20 mm and the height is 9.7 mm. The CAEN Model N 401 QUAD LINEAR FAN-IN FAN-OUT is a single width NIM module equipped with four independent sections, whose input signals can be negative, positive, or bipolar. For each section, a single input signal generates four identical output signals with a $\pm 1\times$ gain [17]. The discriminator is a device which responds only to input signals with a pulse height greater than a certain threshold value. If this criterion is satisfied, the discriminator responds by issuing a standard logic signal; if not, no response is made. The value of the threshold can usually be adjusted by a screw on the front panel [11]. The QD410 Charge Digitizer is a CAMAC standard single width module that contains

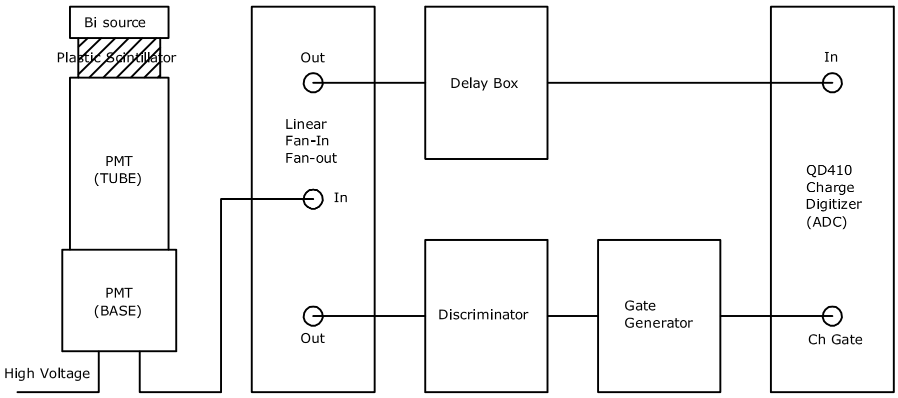


Figure 3.1. The setup of the energy measurement

four separate 10-binary-bit charge sensitive analog-to-digital converters (ADCs) and buffer registers. The unit is designed to operate on negative-going input signals in the range of 0 to 250 pC. Each ADC is preceded by a linear gate that switches the input current to the integrator and also rejects unwanted input signals. For more information about QD410, see the technical data of it.

1. Before setting to work on Fig. 3.1, one has to check out the following by an oscilloscope:

   - Decide a proper high voltage (HV) value of PMT (roughly 1300 V). Connect HV cable and a signal cable. And the other side of the signal cable will be connected to an oscilloscope. When a high voltage is increased, one might get more and larger signals from PMT. However, QD410, which is used in the lab course, has a maximal 2^{10}(1024) channels and the range of 0 to 250 pC. In order to use a whole channel, provided by QD410, the high voltage of PMT is crucial to determine properly. How can one do this? *Explain one possibility by the following equation.*

$$Q = \int \frac{U(t)}{R} \mathrm{d}t \simeq \frac{1}{2} \frac{(\text{height of a signal} \times \text{width of a signal})}{50(\Omega)} \tag{3.1}$$

   Is there an additional possibility to determine HV?

- The signal cable will be connected to **In** of FAN-IN FAN-OUT. Check out two **Outputs**. *Is there some discrepancies between an In and two Outputs?* The unused input and output connectors must be terminated in 50Ω.
- Determine a threshold value of a discriminator, and determine a width of its output signal according the property of QD410. If the threshold value is given too much, many signals might be lost. *What is good threshold value and width of your setup?*
- Determine delay values of a delay box. Make sure that a signal, which comes from the delay box and is connected to **In** of QD410, must be inside other signal, which comes from a gate generator and is connected to **Ch Gate**. *Why do we need to do it? Explain the reason.*

2. Now, it is playing time with NAF commands.

   - Please fill the following table and discuss the difference between A, B, and C?

#	N	A	F	Q	X	comment	interpretation
A	3	0	0				
B	3	0	0				
	3	0	9				
	3	0	0				
C	3	0	2				
D	3	12	1				
	3	12	8				

   - Some data can be read by using NAF commands. *Determine a minimum number and a maximum number of the data. What do these data mean?* If HV is good for PMT, one should get data which will be in the whole range of QD410. If not, please adjust the high voltages of PMT. *Is it good agreement with the former calculation Eq.(3.1)? If not, why?*

3. Take the spectrum with the bismuth source, and the background spectrum without the source for 300 seconds.

4. *According to the level scheme and the table of isotopes about* ^{207}Bi*, what do we expect to see?, and how about the measured spectrum?* The resolution [11] is usually given in terms of the full width at half maximum of the peak(FWHM). Energies which are closer than this interval are usually considered unresolvable. If we denote this width as ΔE , then the relative resolution at the energy E is Energy Resolution $= \frac{\Delta E}{E}$. Equation (4) is usually expressed in percent.

   Discuss forms of the measured spectrum and calculate energy resolutions.

3.1.3 Time Calibration

The TD811 Time Digitizer contains eight precision time-to-digital converters (TDCs) that are coupled to a common start input for measuring time intervals over a range of 0 to 200 ns with 100 ps resolution. The 11 bits of each register are reserved for valid data (providing 2047 channels).

What will we understand?

The main purpose of the third task is to understand how TDC works and to do calibration of TDC.

What do we have to do?

1. The setup for time calibration is shown as below Fig. 3.2 :

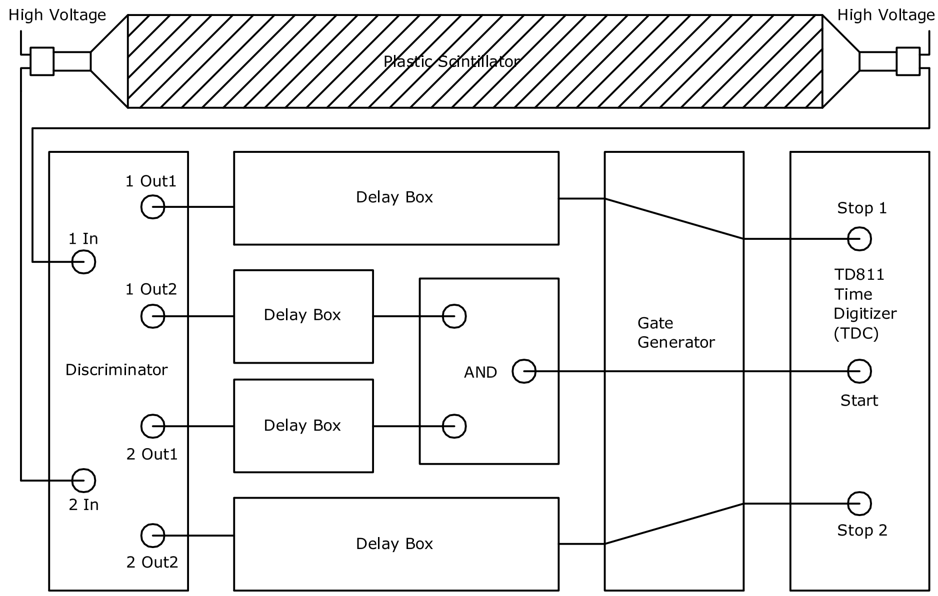


Figure 3.2. The setup of the time calibration. The HV range of PMTs is roughly 2050 $\sim$ 2150 V.

2. It will be crucial to make an AND signal from two discriminator signals since two spectra of TDC, which you can measure by PC, will depend on it. There are two ways to make an AND signal. The width of AND signal can be adjusted by a screw driver. *Which one do you want to use?*

3. After you select the one way and finish to make an AND signal, connect three signals, which will be connected to Start, Stop 1, and Stop 2, to an oscilloscope. Determine two values of two delay boxes since Start signal must be faster than two Stop signals and care about the shapes of three signals on a screen of the oscilloscope. These will give handy hints on understanding TDC spectra.

4. Take TDC spectra without the bismuth source by the Multi program. *How about your TDC spectra? Could you see what you expect?*

5. Insert an extra delay box between Stop 1 or Stop 2 and the delay box. Take TDC spectra without the bismuth source by increasing the delay time with 10 ns up to 60 ns. The distances between the peaks, which could be produced by the different delay times, then give a relation between a time and a channel of TDC. One peak might be Dirac δ-function shape, dependent on your method to make the AND signal. If you see a δ-function of TDC spectra, this spectrum could be defined as a trigger signal of your setup. *If you do not see a δ-function, how can you make it?*

6. Plot the delay times of the extra delay box versus the channels of peak position of the spectrum of TDC. Determine an conversion factor (constant), which enables conversion from any of these units to any other. One can use the following equation to get the conversion factor

$$\text{delay}[ns] = A[ns] + B[ns/ch] \cdot \text{peak}[ch],$$

where B is the conversion factor or the slope. *Does your conversion factor agree with a resolution of TDC?* See the technical data of TD811.

3.2 The Second Week

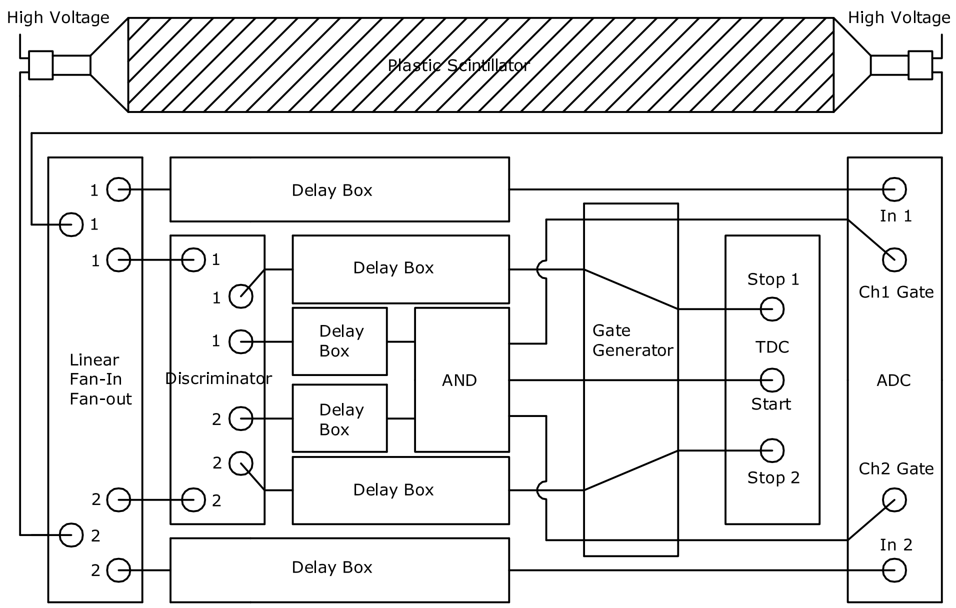
You did the energy measurement with ADC and the time calibration with TDC last week. With these experiences the tasks of the second week will be easy of you to do and understand.

3.2.1 Effective Propagation Speed and Intensity of Light in the Scintillator

What will we understand?

The main purpose of this task is to understand some properties of a plastic scintillator and some processes beneath an detector system by measuring an effective speed and an intensity of light (photon) in the scintillation material.

What do we have to do?



1. One of the signals from PMTs should be used for triggering the system. AND signal should be used for a gate signal of ADC and for a start signal of TDC. Care about the width of it according to the property of ADC and TDC.

2. Take the spectra of ADC and TDC without the bismuth source and discuss the results.

3. Put the bismuth source on the scintillator with the different positions, and take the spectra for 300 seconds.

position on a scintillator	peak position of a spectrum
30	
60	
...	...
150	

- The distances between the peaks of TDC, produced by the different positions, give a a relation between a position and a channel of TDC.

4. Plot the different positions on the scintillation versus the channels of peak position of the spectrum of TDC. Determine an conversion factor with using the following equation.

$$\text{peak}[ch] = C[ch] + D[ch/cm] \cdot \text{position}[cm],$$

where D is the conversion factor.

5. Calculate an effective propagation speed of light in the scintillator by using the two conversion factors, B and D (see Time Calibration). Compare this result with an ideal case with the refractive index of the plastic scintillator. (n $\simeq$1.58)

- Hint :

$$\frac{m}{s} = \frac{m}{cm} \cdot \frac{ns}{s} \cdot \frac{cm}{ns} = 10^2 \cdot 10^{-9} \cdot \frac{cm}{ns}$$

The dimension of B times D $= BD = \left[\frac{ns}{ch}\right]\left[\frac{ch}{cm}\right] = \left[\frac{ns}{cm}\right]$

The speed of light in the vacuum [12]

$= 2.99752458 \times 10^8 [m/s] = \mathbf{29.9752458 [cm/ns]}$

By comparison with the above results, a large discrepancy is easy to see. *Why?*

6. Charged particles pass through a plastic scintillator and lose their energy, deposited in the material. The deposited energy is converted into scintillation lights, called optical photons. Part of that lights stays due to the total reflection in the material, and travels to the one of the end of the scintillator, where the PMT and the scintillator are coupled together. Since these photons are emitted isotropically in the scintillator, a small fraction of those photons can be propagated along scintillator's length and be captured by PMT. The light collection and transfer efficiency (CT) may be estimated by the following expression [18]:

$$CT = (\delta\Omega/4\pi)\,[A(x) + R \cdot A_R(x)] \cdot T. \tag{3.2}$$

Here, $\delta\Omega/4\pi$ is the tapping efficiency, $A(x)$ is the attenuation of the direct scintillation light, R is a non-zero factor only if one consider a reflection of the end of the scintillator, $A_R(x)$ is the attenuation of the reflected scintillation light, T is the transmission coefficient through the optical connector between the scintillator and PMT, and x denotes the location of the ionization position from one readout end of the scintillator. Here $A(x)$ is denoted by

$$A(x) = A_0 e^{-\frac{x}{a}}, \tag{3.3}$$

where a is the attenuation length and A_0 is the initial light intensity. For the sake of simplicity, just ignore the tapping efficiency, the reflection R, and the transmission T, and then determine the attenuation length of the plastic scintillator with using the above ADC data.

3.2.2 Time-of-Flight(TOF) measurement

What is the Time-of-Flight measurement? Before finding an answer of it, let us introduce more physical question. What is the mass? This question is hard to answer. We need to make one definition that mass is one of units, used to describe Nature. And mass is also used to identify the particle. If one can measure a momentum and a velocity of an unknown particle, this particle can be classified as a known particle e.g. electron, pion, etc. Sometimes this process is called the Particle Identification(PID).

Now let us return the first question. TOF measurement is usually used to determine a velocity. Two scintillation detectors provide a start signal and a stop signal. The distance between two detectors is fixed. Therefore the velocity of an particle, passes through two detectors, can be determined by a simple relation $v = d/\Delta t$.

What will we understand?

The main purpose of this task is to understand a simple principle of TOF measurement.

What do we have to do?

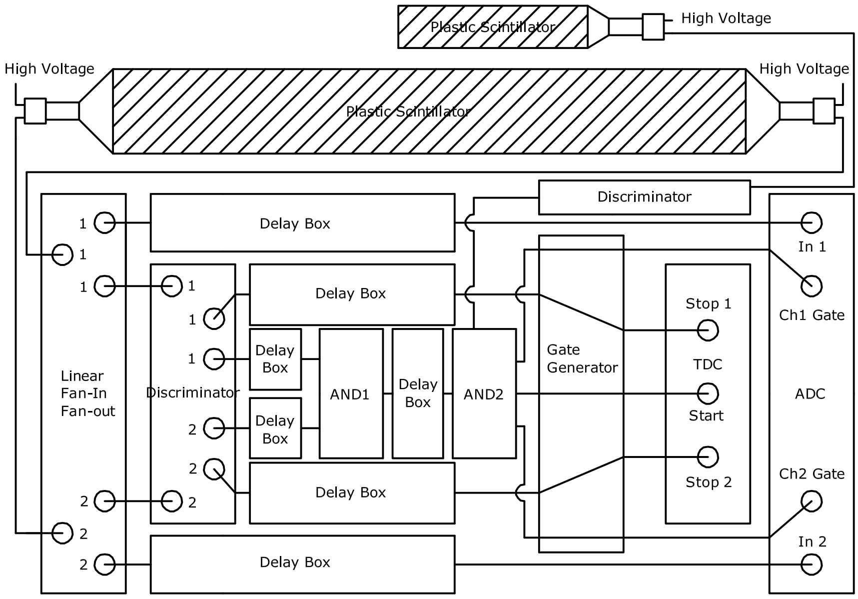
Actually, the effective speed inside the scintillation material can be determined by this setup.

1. The Time-of-Flight(t_{TOF}) and the location(x) along the scintillator where the particle penetrated the counter are given by

$$t_{TOF} = \frac{TDC_L + TDC_R}{2}, \tag{3.4}$$

$$x = \frac{TDC_L - TDC_R}{2} \cdot v_{\text{eff}} = t_x \cdot v_{\text{eff}}, \tag{3.5}$$

where v_{eff} is the effective speed of light. *Derive the above equations.*



2. Put the trigger scintillator on the large scintillator with three different positions, take the spectra without the bismuth source for 600 seconds. Compare the effective speed of light with the former calculation.

position	TOF	t_x
middle - 20 cm middle middle + 20 cm	$\cdots$	$\cdots$

3. In the menu *Secondary parameter* of Multi program, additional new parameters can be defined. Allowed are simple equations containing the operations $+, -, *, /$ and the use of brackets (8 bracket levels allowed). In defining equations measured parameters (P1, P2, P3, P4,.....) as well as constants (integer values) can be connected as shown in the following example,

$$P7 = (P3 + P4)/2, \qquad P8 = (P3 - P4)/2, \qquad P9 = (P4 - P3)/2.$$

And define new spectrum with P3, P4, P7, P8, and P9.

4. If one has time and wants to find out more about the TOF measurements, consult the reference [14].

Chapter 4

Technical data

EG&G/ORTEC QD410 CAMAC CHARGE DIGITIZER

1. CHARACTERISTICS

The EG&G/ORTEC QD410 Charge Digitizer is a CAMAC-standard (per USAEC report TID-25875) single-width module that contains four separate 10-binary-bit charge-sensitive analog-to-digital converters (ADCs) and buffer registers. The unit is designed to operate on negative-going input signals in the range of 0 to 250 pC, and its wideband input circuit will accommodate signals from fast photomultipliers while maintaining a high degree of protection against overloads.

Each ADC is preceded by a linear gate that switches the input current to the integrator and also rejects unwanted input signals. Each gate has extremely fast switching characteristics that make the QD410 especially suited to high-speed, single-event, transient recording. Convenient front panel connectors allow monitoring of the actual switching time of the gate and the dc current applied to the integrator (pedestal current plus input signal current).

The pedestals of all four sections are adjustable by separate internal potentiometers, and, in order to minimize the drift of this zero offset, the temperature coefficients of both the pedestal current and the input offset voltage have been carefully controlled. The QD410 features exceptionally good overall stability and linearity.

A 4-bit look-at-me (LAM) status register allows the four channels of the QD410 to run asynchronously. The completion of a valid conversion cycle in any channel causes the corresponding bit in the LAM status register to be set to a logical 1. The four outputs of this register are connected in logical OR to generate a CAMAC Dataway L-line signal. The L-line, or LAM, signal can be controlled at the module level by a LAM enable/disable latch.

On receipt of the proper CAMAC command the selected ADC presents its 10-bit data word to the CAMAC Dataway R1 through R10 lines, with overrange, or overflow, detection being effected by the automatic setting of the outputs from the data register involved to all logical 1s.

The N(M)·F(25)·A(Y) CAMAC Dataway command (where M is the number of the crate station at which the QD410 is installed and Y is any number from 0 through 15) allows a rough check of the operational accuracy of the module. The pedestal adjustment potentiometers should be adjusted until all four pedestal currents are equal at approximately 0.5 mA. The N(M)·F(25)·A(Y) command results in a signal being sent to each of the four charge-to-time converters that is virtually the same as a gating input signal fed to any front panel Ch Gate (0–3) input connector for a period of 40 to 50 ns. With the pedestals adjusted and no signal applied to any of the Ch In input connectors, there should be a reading of approximately 20% of full scale from each scaler.

Additional testing and calibration can be performed by applying a negative dc voltage to the correct pins in a special rear panel connector that is in addition to the CAMAC Dataway connector. Pins 1 through 4 on this connector are associated with channels 0, 1, 2, and 3 respectively, pin 5 is grounded, and the other pins are not connected to anything. The application of a negative voltage between any of the five pins causes current to be drawn from the input circuit of the associated channel through a 2-kΩ resistor. A negative voltage thus applied simulates an input signal of the correct polarity.

These test input connections are useful for feeding a signal into the charge input independent of charge input connections. When the pedestals in all four channels are set for zero current at the input to yield zero readings from their corresponding scalers, for example, the QD410 could not initiate a conversion process with zero input as a result of the N·F(25) command. The functional readiness and relative (channel-to-channel) calibration can be checked by drawing the same fixed current from the test point in each channel when the N·F(25) command is sent. When the test input signals are removed, the system returns to its original status. These test input connections can also be used as external pedestal adjustments.

2. SPECIFICATIONS

2.1. INPUTS

In 0–3 Data inputs, one per section, accept negative signals.
Impedance 50Ω nominally, direct-coupled.
Bandwidth dc to >200 MHz.
Range 0 to −1.25 V (0−25 mA).
Relections <2% for 2-ns rise time, 20-ns pulse width, 1-V amplitude; <±4% for 2-ns rise time, 50-V input.
Protection ±5 V dc. Tested to −150 V with pulse of 60-ns width at 100 pulses/s.
Overload Recovery <20 ns for −10-V input, 1-ns rise time.
Offset ±2.5 mV; ±20 μV/°C.

Gate 0–3 Single input in each section controls linear gate; accepts NIM fast logic signals.
Impedance 50Ω, dc-coupled.
Protection ±2.5 V dc.
T_r, T_f ~0.8 ns.
Width Determined by width of gate signal; <5 ns to 60 ns approximately.
Propagation Delay ~2 ns.

Test Rear panel connector allows injection of current into the input through a 2-kΩ resistor.

2.2. OUTPUTS

Mon 0–3 ac-coupled monitor output is the sum of the input signal and pedestal (should be terminated in 50Ω for best results), used for aligning input and gate signals.
Calibration Monitor amplitude is 17 mV for every mA of input current when terminated in 50Ω.

Data 10 bits per channel onto CAMAC Dataway read lines R1 through R10 with appropriate CAMAC commands.

2.3. CONTROLS

Pedestal Each channel has an internal 5-turn potentiometer to control pedestal current; range, 2 mA. Pedestal charge is a product of pedestal current and gate width.

2.4. PERFORMANCE

Pedestal
Range 0 to −2 mA (referred to linear input).
Stability Average, ±0.5 μA/°C (0 to 60°C), typically, ±0.3 μA/°C (15 to 45°C); maximum, ±2.5 μA/°C (0 to 60°C).

Range
Normal 0 to 256 pC.
Overflow Will cause the corresponding scaler to set to the 1 state.

Calibration 0.25 pC/count.

Resolution 1 part in 1024.

Temperature Instability ±0.01%/°C (average) measured at 10-ns gate width; ±0.015% (maximum), 0 to 60°C.

Nonlinearity
Integral ±0.5%, 5 to 100% full scale, at 10-ns gate width.
Differential ±2.0%, 5 to 100% full scale, at 10-ns gate width.

Conversion Time 20.5 μs maximum (full-scale linear range).

Gate Feedthrough Zero for −100-V pulse, 60-ns width, 2-ns rise time applied to linear input with gate input terminated in 50Ω.

Cross Talk <1 part per 1000 in any adjacent channel.

Operating Range 0 to 50°C.

2.5. CAMAC COMMANDS

INPUTS TO THE MODULE

The correct CAMAC Dataway N-line signal is assumed for each of the following CAMAC codes involving a function code:

F(0)·A(0–3) Read selected scaler.

F(1)·A(12) Read LAM status register:

Ch0 on R1; Ch1 on R2; Ch2 on R3; Ch3 on R4.

F(2)·A(0–3) Read and clear selected scaler.

F(8)·A(12) Test LAM, Q = L.

F(9)·A(0–3) Clear selected scaler.

F(10)·A(0–3) Clear LAM.

F(24)·A(12) Disable LAM.

F(25)·A(0–3) Test all channels.

F(26)·A(12) Enable LAM.

I Simultaneously inhibits the acceptance of data input signals by all four channels.

Z Clears all registers, disables LAM.

C Clears all registers.

OUTPUTS FROM THE MODULE

Q and X Are returned for all above function codes and subaddresses, except F(8)·A(12) when Q = L.

L Sent by the module at the completion of a conversion cycle in each channel, provided the LAM enable/disable latch is set to its enable state.

2.6. ELECTRICAL AND MECHANICAL

Dimensions Single-width CAMAC module per TID-25875. Fully shielded.

Connectors
Front Panel LEMO 00C50.
Rear Panel Amphenol 41300 9-pin mounted; mates with Amphenol 41309 (supplied with module).

Power Required +6 V, 670 mA; +24 V, 185 mA;
−6 V, 370 mA; −24 V, 120 mA.

3. OPERATION

3.1. INSPECTION AND INSTALLATION

After carefully unpacking the unit, thoroughly inspect it for evidence of damage in shipment. If it has been damaged, refer to the Warranty section for further instructions.

CAUTION

> Always ensure that CAMAC crate power is turned off before installing or removing a CAMAC module.
>
> Always ensure that all pins on the CAMAC Dataway connector on the rear of the unit are clean before installing a CAMAC module in its crate.
>
> Never use excessive force in installing or removing a CAMAC module.

After observing the above precautions, install the unit in its assigned crate at its assigned numbered crate station.

3.2. SIGNAL CONNECTION AND APPLICATION OF POWER

Installing the module in the crate completes its interconnection with the CAMAC Dataway. Interconnection with other equipment requires the use of RG-174/U or some other 50Ω type of coaxial cable. When adapters must be used, LB050 (LEMO-to-BNC) and BL050 (BNC-to-LEMO) adapters can be obtained from ORTEC.

The Ch0 In through Ch3 In input connectors accept the charge pulses from photomultiplier tubes. The four Gate input connectors accept negative fast logic pulses. The four Mon output connectors yield output signals that enable the timing of the gating signals relative to the charge pulses to be visually monitored on an oscilloscope in order to facilitate manual correction by the operator of gating signal timing. These output signals also permit external monitoring of the dc current applied to the integrator in each channel.

After the QD410 has been interconnected with the other equipment, turn on CAMAC crate power. The module is now ready for operation.

3.3. OPERATING INSTRUCTIONS

The QD410 is operated entirely with CAMAC Dataway commands, which are listed in Section 2.5. The operation of the entire CAMAC-computer system is dependent on the CAMAC signals generated by the QD410, also listed in Section 2.5. At the end of each valid conversion cycle in each channel, if the LAM enable/disable latch is in the enable state, the QD410 will generate a LAM signal on the CAMAC Dataway L line from the numbered crate station at which the QD410 is installed.

EG&G/ORTEC

Technical Data

CAMAC

TD811 Time Digitizer

March 1975

- 8 precision TDCs per module
- 100-ps resolution over 200-ns range
- Excellent linearity and stability
- 11-bit data storage plus overflow
- Fixed conversion time
- Full LAM logic
- Fast clear input — 1-µs reset
- Start veto and common stop inputs

The TD811 octal Time Digitizer contains **eight precision time-to-digital converters** that are coupled to a common start input for measuring time intervals over a range of **0 to 200 ns** with **100-ps resolution**.

The flat-topped channel profile of the TD811 yields **excellent linearity**, and a unique converter design offers **high thermal stability** over wide temperature ranges. The unit also features a **full 12-bit readout** for each converter. The first 11 bits of each register are reserved for valid data (providing 2047 channels), and the latching 12th bit is used to detect an overrun in that section. The data are stored in eight individual registers for subsequent readout through the CAMAC dataway.

On receipt of a timely start signal the stop inputs are rapidly enabled and an internal busy latch is set (which may be tested by CAMAC command). Stop signals may be accepted within a 200-ns time period and will trigger a normal conversion. If no stops occur within this range, an internal timer will simulate a stop and signal overrange. This limits the converter circuit and reduces recovery time.

The Time Digitizer is designed with a 90-µs **fixed conversion time**, which is independent of the start-stop period, and features **full LAM logic.** At the completion of the conversion cycle the unit generates a service request by setting a LAM status bit. The LAM may be controlled at the module level by an enable/disable latch and may be tested by CAMAC command in accordance with recommended practice.

If it is desired to abort the conversion cycle, a front panel **fast clear input** may be used at any time during the first 70 µs of the conversion, and total **reset** will be accomplished **within 1 µs** from the leading edge of the clear signal. The Time Digitizer will then be ready to accept another start signal. After the 70-µs time period has elapsed, the clear input is blocked and the normal conversion cycle will be completed.

A **veto input** is included to achieve fast gating of the start signal. If this input signal is used, however, it must overlap the valid start signal for correct operation.

The module can be tested externally by use of the **common stop input**. If computer testing is desired, the module will respond to the CAMAC command F(25), which simulates an overrange in all eight converters and generates a request for service.

The TD811 may be blocked by either the internal busy latch or a dataway inhibit signal. In this condition start inputs are rejected. A "B" indicator on the front panel shows when the unit is in the blocked condition, and an "N" indicator shows when the unit is being addressed.

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For more information on EG&G/ORTEC products or their applications, contact your local ORTEC representative or:
Europe: ORTEC GmbH, P. O. Box 860646, Herkomerplatz 2, 8000 Munich 86, W. Germany; Telephone (089) 98-71-73; Telex (841) 528257
United Kingdom: ORTEC Limited, Dallow Road, Luton, Bedfordshire, England; Telephone LUton (0582) 27557/8/9; Telex 82477
Other: ORTEC Incorporated, 100 Midland Rd., Oak Ridge, TN 37830; Telephone (615) 482-4411; Telex 055-7450

SPECIFICATIONS

INPUTS

START One front panel input connector, common to all channels, accepts NIM fast logic signals 5 ns or greater (recommended operation, 5 to 10 ns).

Impedance 50Ω, dc-coupled.
Protection ±5 V dc.

VETO One front panel input connector, common to all channels, accepts NIM fast logic signals to block start input. Veto signal must overlap start signal for correct timing; 3 ns-leading edge and 15-ns trailing edge.

Impedance 50Ω, dc-coupled.
Protection ±5 V.

STOP 0–7 8 front panel input connectors, one per channel, accept NIM fast logic signals 5 ns or greater.

Impedance 50Ω, dc-coupled.
Protection ±5 V dc.

COMMON STOP One front panel input connector, common to all channels, accepts NIM fast logic signals 5 ns or greater.

Impedance 50Ω, dc-coupled.
Protection ±5 V, dc.
Timing Typically +5 ns relative to single stop input.

CLEAR One front panel input connector, common to all channels, accepts NIM fast logic signals 5 ns or greater within 70-μs time period from valid start.

Impedance 50Ω, dc-coupled.
Protection ±5 V, dc.

OUTPUTS

DATA 11 bits per channel onto CAMAC read lines R1–R11 per TID-25875.

OVERFLOW Indicated by 12th bit.

CONTROLS AND INDICATORS

CALIBRATE 8 internal potentiometers set channel calibration.

B Indicator lights when unit is in blocked condition.

N Indicator lights when unit is being addressed.

PERFORMANCE

RANGE 4 to 200 ns (11 binary bits).

RESOLUTION 100 ps.

CALIBRATION 100 ps/bit.

INTEGRAL NONLINEARITY ±0.1% (10% to 100% FSD).

DIFFERENTIAL NONLINEARITY ±2% (10% to 100% FSD).

CONVERSION TIME <90 μs all channels in parallel.

TEMPERATURE COEFFICIENT ±0.02%/°C (0 to 50°C).

CAMAC CODES

F(0)·A(0–7) Read selected register.

F(2)·A(0–6) Read register (0–6).

F(2)·A(7) Read register 7; clear all registers, busy, and LAM.

F(8)·A(12) Test LAM; Q = LAM.

F(10)·A(12) Clear LAM.

F(11)·A(12) Clear all registers, LAM, and busy.

F(24)·A(12) Disable LAM.

F(25) Test all registers (internal start-stop signal).

F(26)·A(12) Enable LAM.

F(27)·A(12) Test busy; Q = busy.

Q AND X Are returned for all above function codes and subaddresses except F(8)·A(12) and F(27)·A(12), where the Q response is conditional.

C Clears all data registers, busy, and LAM status.

Z Clears all data registers, busy, and LAM status and disables LAM.

I Inhibits operation of all sections.

ELECTRICAL AND MECHANICAL

PACKAGING Single-width CAMAC-standard module per TID-25875 fully shielded.

CONNECTORS LEMO 00C50.

POWER REQUIRED

+ 6 V, 500 mA; − 6 V, 700 mA;
+24 V, 95 mA; −24 V, 55 mA.

WEIGHT

Net 2 lb (0.9 kg).

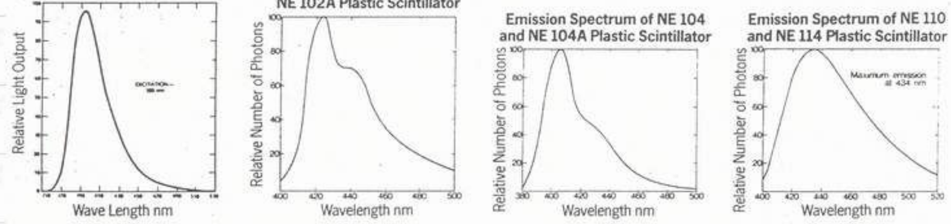
Shipping 5 lb (2.3 kg).

TECHNICAL DATA

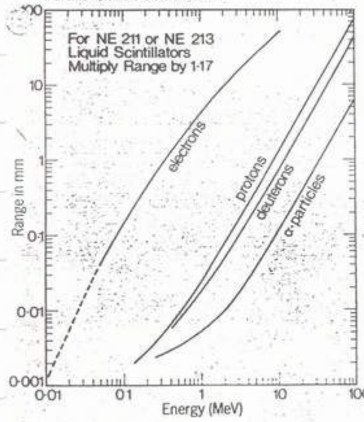
Type	Light Output % Anth.	Pulse Width FWHM ns	Decay Time ns	Rise Time ns	Light Atten. Length cm	Wavelength Max. Emission ns	Ratio H:C Atoms	No. of C atoms per cm³ x 10⁻²³	No. of C atoms per cm³ x 10⁻²²	No. of H atoms per cm³ x 10⁻²²	Principle Applications
NE 102A	65	2.7	2.4	0.9	250	423	1.104	3.39	4.78	5.28	fast n, protons, electrons etc.
NE 104	68	2.2	1.8	0.6	120	406	1.100	3.37	4.74	5.21	fast counting
NE 104B	59	3	3	1	120	406	1.107	3.37	4.73	5.24	with BBQ light guides
NE 110	60	4.2	3.2	1.0	400	434	1.104	3.39	4.78	5.28	fast n, protons, electrons etc. large area applications
NE 114	50	5.3	4.0		400	434	1.109	3.37	4.73	5.25	as for NE 110
Pilot U	67	1.2	1.4	0.5	100	391	1.100	3.37	4.97	5.21	ultra fast time

EMISSION DATA

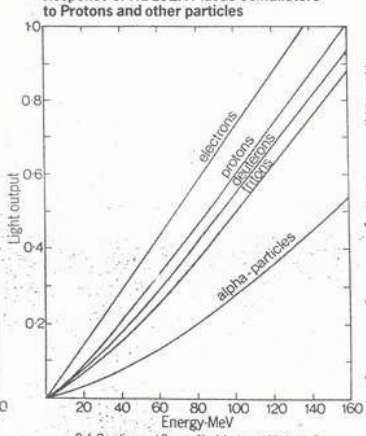
Emission Spectrum of Pilot U Plastic Scintillator — Emission Spectrum of NE 102A Plastic Scintillator — Emission Spectrum of NE 104 and NE 104A Plastic Scintillator — Emission Spectrum of NE 110 and NE 114 Plastic Scintillator



Range of Electrons, Protons, Denterons and Alpha Particles in NE 102A, NE 104, NE 110, NE 111, and NE 113 Plastic Scintillator



Response of NE 102A Plastic Scintillators to Protons and other particles



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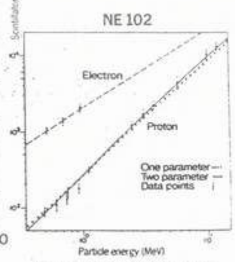
NE 102



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