Internal Report No. 34
Part I

# β-SPECTROMETER ELECTRONICS

by

Solomon Vidor

The β-spectrometer uses an electron source and magnet to provide an electron beam with an adjustable energy (to greater than 3 Mev with the $Ru^{106}$ source). An instruction manual can be found with the β-spectrometer [1]. The purpose of this report is to describe the electronics that handle the output from the detectors that are tested in the β-spectrometer. The detectors used in the lab are surface barrier and lithium drifted detectors. The β-spectrometer can be used to find the response of the detectors to electrons.

Table 1 has a list of the pieces of apparatus described. All except the WEA pulser have instruction manuals. A picture of the instrumentation is shown in figure 1. An electrical schematic is shown in figure 2a. A schematic of the cable connections between the various pieces of apparatus is shown in figure 2b. The two diagrams are different in several minor respects. For instance the 901 RM power supply takes the TC100B output and passes it from a connector in back to one in front. The 901 RM doesn't affect the output from the TC100B, but it makes the cable connections less cumbersome.

Note:

1) When cables are changed a note should be made since a different cable may affect the signal.

2) When adjusting the gain on amplifiers, make sure the signal isn't near the saturation region of the amplifier or of a following piece of equipment. If a further gain increase increases the output of the last piece of equipment, saturation hasn't been reached.

TABLE 1

| Manufacturer | Model # | Description |
|---|---|---|
| Tennelec: | TC 100B | preamp (2) |
| | TC 200 | amplifier |
| | TC 202 | linear amplifier |
| | TC 212 | dual summer and inverter |
| | TC 250 | biased amplifier and stretcher |
| | 901 RM | dual power supply |
| | TC 907 | power supply* |
| Ortec | 406A | single channel analyzer |
| | 409 | linear gate and slow coincidence |
| | 421 | integral discriminator |
| | 427 | delay amplifier |
| | 210 | detector control unit |
| General Radio | 1191-B | scaler |
| Berkeley Nucleonics | PB-2 | pulse generator |
| Kepco | KS 120-5M | regulated DC supply |
| Northern | NS 601 | 256 channel analyzer |
| Teletype | 33 | |
| Power Designs | 2005A | precision power source |
| | 4005R | transistorized power supply |
| | 5005R | transistorized power supply |
| WEA pulser | | |

* Not presently used.

| | Model # | Function |
|---|---|---|
| A) | TC 100B | preamp |
| B) | 2005A | precision power source |
| C) | NS 601 | analyzer |
| D) | 901 RM | power supply |
| E) | TC 907 | power supply |
| F) | TC 200 | amplifier |
| G) | TC 250 | amplifier |
| H) | WEA | pulser |
| I) | 406A | single channel analyzer |
| J) | TC 202 | amp |
| K) | 409 | coincidence |
| L) | 421 | discriminator |
| M) | TC 212 | inverter |
| N) | 427 | delay |
| O) | 33 | teletype |
| P) | 210 | detector power |
| Q) | 1191-B | scaler |
| R) | PB-2 | pulse generator |
| S) | KS 120-5M | magnet power |

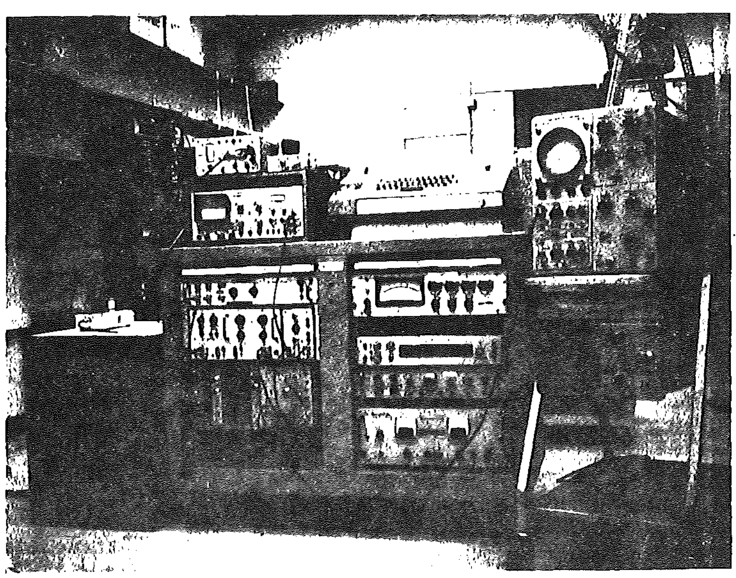


fig. 1

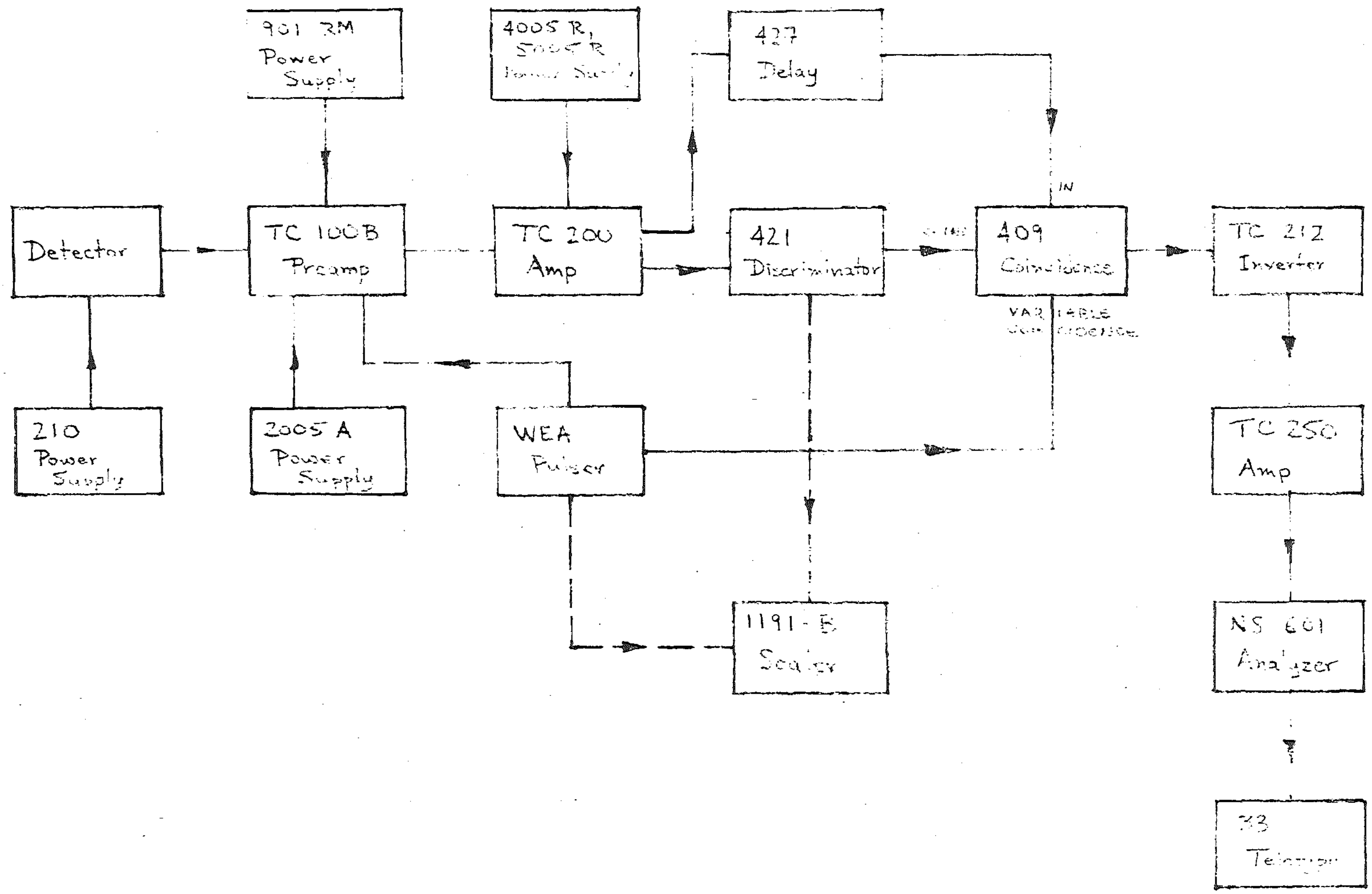



fig. 2a Schematic for looking at detector output.

Spaced line indicates addition for measurement of noise.

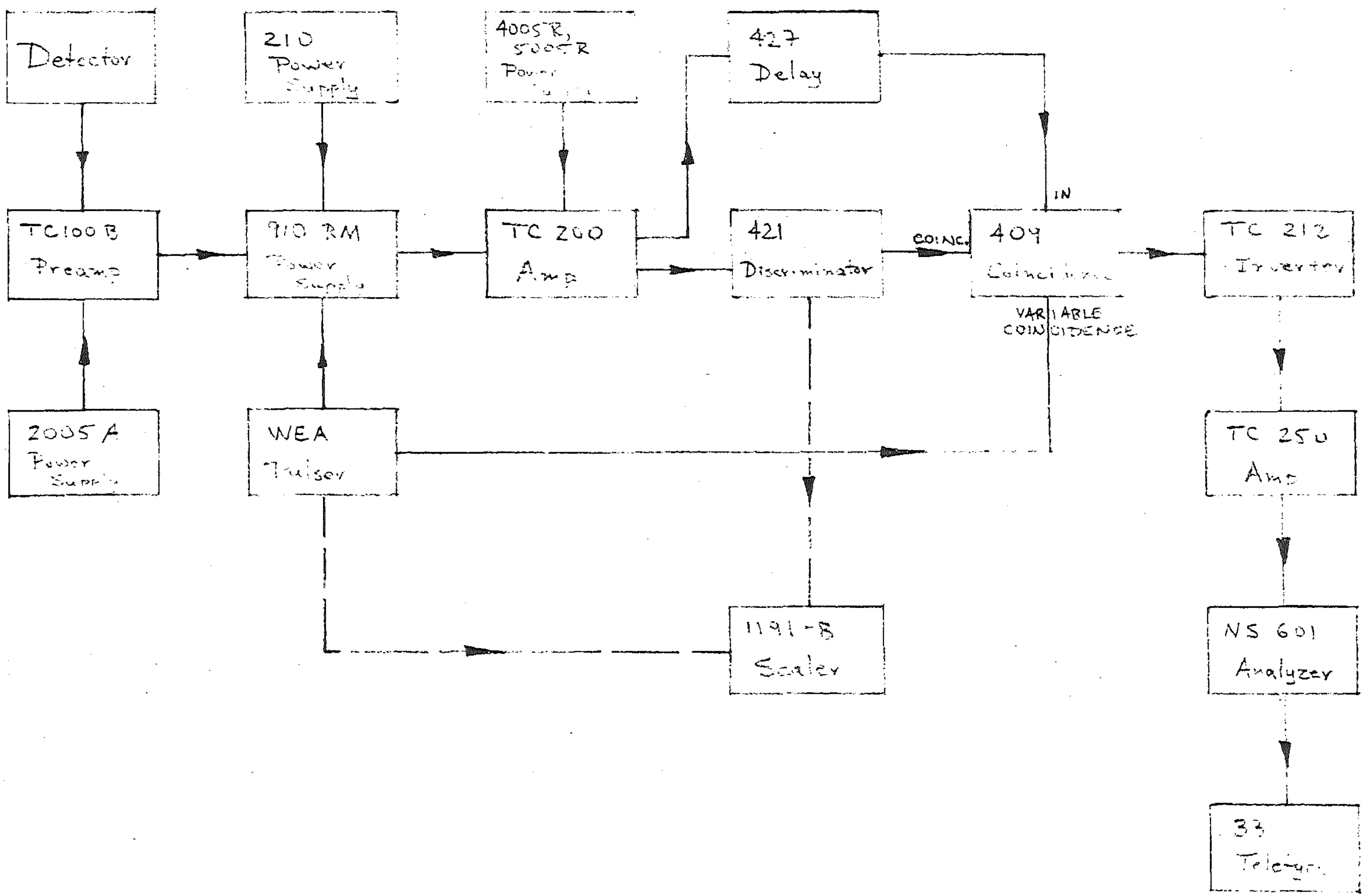



fig. 2b Schematic for cable connections.

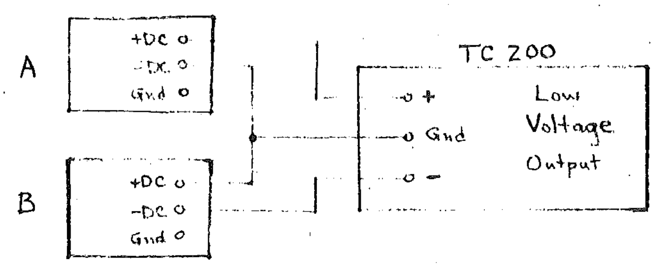
Spaced line indicates addition for noise measurements.

## DESCRIPTION OF APPARATUS

The individual pieces of apparatus will now be described.

I) Power Designs 4005R, 5005R transistorized power supplies.

These power supplies are used to supply ±14 v to the TC 200 amplifier.




Both supplies should be used as voltage sources in the voltage limit mode with the voltage set at 14 v. A supplies 380 ma, while B supplies 320 ma.

II) Ortec 210 detector control unit.

This unit is used to provide high voltage to the detectors and to monitor the detector leakage current.

CAUTION: Apply and remove bias slowly. Do not turn control unit off when high voltage is on detector.

The control unit has 4 outputs in back and a switch for controlling which output is biased with high voltage. In our setup the output is connected to the BNC connector marked external bias on the Tennelec 901 RM power supply (see fig. 2b). Output 1 is for preamp 1 (A); output 2 is for preamp 2 (B).

Note:

1) The polarity is positive in most cases.

2) The bias network in the preamp has a 10 M resistor in series with the detector. Therefore, the bias on the detector is

$$V_{bias} = V_{applied} - I_{leakage} R$$

$$\text{where } R = 10 \times 10^{6}\ \Omega$$

III) Power Designs 2005A precision power source.

This controls the voltage of the test pulse to the preamp. The output is connected to the terminal marked "DC in" on the TC 100B (preamp B, since only B has this terminal). Calibrations show the voltage to be accurate to 0.1 mv or 0.02%, whichever is higher. Claimed accuracy is 0.1 mv or 0.1%. At 20 v, 0.02% corresponds to a 4 mv error. Drifts of 0.002% per hour have been observed. The conversion factor between voltage of the test pulse and energy loss in a silicon detector has been adjusted so that 1 v $\overset{\sim}{\leftrightarrow}$ 1 Mev. The conversion can be changed by adjusting the capacitance at the pulser input of the TC 100B. A separate internal report describes the calibration of the pulser.[2]

IV) WEA pulser.

The output is connected to the test pulse input of the Tennelec 901 RM power supply (see fig. 2b). The coincidence output usually goes to the coincidence input of the Ortec 409.

When the WEA pulser is used as a time base for the scaler (i.e. when it is connected to input B of the scaler), the trigger output should be used instead of the coincidence output. The coincidence output has a glitch that can double the rate at which the scaler is triggered.

V) Tennelec preamp TC 100B.

The d.c. power supply for the pulser voltage goes into "D.C. in". The detector is connected by means of the BNC connector in front of the preamp. The bias is positive if Ortec 210 control unit polarity switch is positive. The cable connecting the preamp and detector should be short and of low capacitance to maximize signal to noise ratio. The multi-pin connector in back of the preamp is connected to the "preamplifier" connection in back of the 901 RM power supply.

Switch settings normally used (see TC 100B):

Sensitivity: 8
++,+- : +-

VI) Tennelec 901 RM dual power supply.

This supplies power to the preamps. Detector bias is connected to the BNC marked "external bias" in back of the 901 RM, the preamp is connected through the multipin connector in back marked "preamp", and the pulser is connected to "test pulse input" in front (see fig. 2b). The preamp signal is taken from the BNC in front of the 901 RM marked "preamplifier output."

Switch position normally used: int

VII) Tennelec TC 200 amplifier.

Power for this amplifier is supplied by the transistorized power supplies #4005R, 5005R. The preamp output goes to the first stage input of the TC 200.

NOTE: If during use the output of the TC 200 is also connected to the scope, adjust the scope's vertical scale so that the scope isn't overloaded. Overloading the scope can affect the pulse reaching the pulse height analyzer on the order of 100 kev out of 8 Mev (this effect is nonlinear).

Switch positions normally used:

term: out

int, ext: ext

polarity: direct

2nd differentiator: 1 msec

1st differentiator, integrator: .8 μsec, but may be varied to obtain optimum performance

For best signal to noise, the time constants of the 1st differentiator and integrator should be equal and the 2nd differentiator should be out (1 msec.) At high count rates the 2nd differentiator can be used to reduce the duration of the pulse undershoot.

VIII) Ortec 421 integral discriminator.

The threshold trigger can be adjusted from .1 v to 10 v.

IX) Ortec 427 delay amplifier.

With the cables and setup presently used (see fig. 2 for setup), a delay of .5 μsec barely allows the entire pulse to pass through the linear gate of the coincidence circuit. This delay may have to be changed with a different setup.

X) Ortec 409 linear gate and slow coincidence.

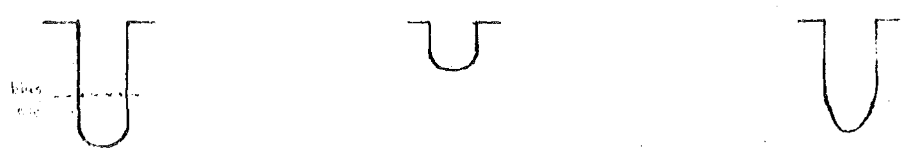
The linear gate is an amplifier with a gain of unity. If any of the coincidence switches are set to the "in" position, a simultaneous pulse to these coincidence inputs is required to open the linear gate (i.e. allow pulse to pass through). Only positive pulses can pass through the linear gate. The linear gate input is usually taken from the 427 delay amplifier. One coincidence input usually comes from the 421 discriminator. Another one usually comes from the "coinc. out" of the WEA pulser. This switch is used with the "in" and "out" position, depending on the measurement being made.

XI) Tennelec TC 212 dual summer and inverter.

The addition and subtraction of signals that the TC 212 feature can be looked up in the manual. In the present setup the TC 212 is used to invert signals since the TC 250 biased amplifier accepts only negative pulses. The input is taken from the 409 linear gate and slow coincidence, and the output goes to the TC 250.

XII) Tennelec TC 250 biased amplifier and stretcher.

The TC 250 can subtract a fixed amount from each signal and amplify the remaining portion (fig. 3).



input    biased signal    amplified biased signal

fig. 3

This amplifier allows a portion of the spectrum to be examined with high resolution. For example, if a 5.443 and 5.486 Mev pulse are to be resolved, the bias can be set at 5.4 Mev, and the gain turned up, expanding 200 kev over the entire range of the pulse height analyzer.

The TC 250 accepts negative input pulses. Switch positions normally used:

gate: open
strobe: long
rise: fast
polarity: +

XIII Northern NS-601 256 channel analyzer.

The high level input is used. The analyzer accepts positive pulses. To manually go from the measure to the readout mode or vice versa, the stop button must be pushed first. When the erase button is pushed in the start readout mode, the analyzer sets the elapsed time to 0.

Switch positions normally used:

add, subtract: add
p.h.a.,m.c.s.: p.h.a.
coinc.,off/anticoinc: off/anticoinc.
amp: on
threshold: minimum
u.l.d.: maximum
zero level: 0
amplifier gain: 10

XIV) Teletype model #33.

The teletype reads out the data stored in the pulse height analyzer. Turning the knob from "off" to "local" sets the teletype in operation.

Switch position normally used:

teletype reader, analyzer readout: analyzer readout

CAUTION: There is a small, open metallic box in back of the teletype that has high voltage. A high voltage label is on the box.

XV) Kepco KS 120-5M power supply.

This supplies power to the magnet coils. The current limit mode should be used since the magnetic field is determined by the current flow. The voltage knob should be turned high enough to allow the current limiter to operate, and the "current" light should be on. A calibration curve converting magnetic field to electron energy can be found in the β-spectrometer room.

XVI) General Radio 1191B (scaler).

In the usual mode of operation (noise measurements), input A is taken from the discriminator output, and input B is taken from the WEA pulser trigger output.

Settings normally used:

a.c., d.c.: a.c.
separate, common: separate
polarity and attenuator: +1
threshold: centered

XVII) Berkeley Nucleonics PB-2 pulse generator

This pulse generator provides variable amplitude and variable frequency pulses, and it is sometimes used as a time base for the scaler (by connecting it to input B of the scaler).

Switch positions normally used:

mode: int.
polarity: +
rise: .05 μsec.
width: minimum
attenuator: x1

XVIII) Ortec 406A single channel analyzer, and Tennelec TC 202 linear amplifier.

These last two pieces of equipment are not normally used, but are available for special applications. The instruction manuals explain their operation.

## COMMON MEASUREMENTS

I) Voltage vs. leakage current of detectors.

The leakage current is read directly from the Ortec 210 detector control unit. The bias voltage equals the applied voltage minus the drop across the bias resistor $R_B I_{leakage}$ where $R_B$ = 10 M in the TC 100B preamp.

II) Alpha depletion measurements.

At nearly the depletion voltage, a scan with α-particles on the back (Al) side of a surface barrier detector is taken along two axes of a detector to find the soft spot (spot which is least depleted or at which α's seem to lose least energy). At this spot the α energy loss is found as a function of detector voltage. The voltage at which the α energy loss levels off to a maximum is the depletion voltage.

III) Noise measurements.

See figures 2a, 2b for a schematic of the setup. The two coincidence switches are set to the "in" position. The trigger output of the WEA pulser is connected to input B of the scaler and thereby serves as a time base. The discriminator output goes to input A of the scaler.

If the detector and electronics were noiseless, the pulses from the TC 200 would have a constant amplitude. The superimposed noise varies this amplitude (see fig. 4).

noiseless noise superimposed

fig. 4
Pulses as seen on oscilloscope

The discriminator level is set to the neighborhood of the pulse height. The fraction of pulses that trigger the discriminator is read from the scaler. Theoretically, by varying the discriminator threshold, the width of the noise distribution can be determined. (84.1% - 15.9% pulses passing through the discriminator determines the $2\sigma$ width for a Gaussian distribution.) However, this is impractical since a noise value in kev is more useful than one in volts. An equivalent and more practical method of measuring the noise is to keep the discriminator threshold constant and to vary the voltage of the pulse by adjusting the 2005A power supply (1v $\overset{\sim}{\leftrightarrow}$ 1 Mev).

Example: With 2005A set at 0.935 v, 84.1% of the pulses trigger the discriminator. At 0.877 v 15.1% of the pulses trigger the discriminator.

The noise can be calculated as follows:

$$2\sigma = 935 \text{ kev} - 877 \text{ kev} = 58 \text{ kev}$$
$$\sigma = 29 \text{ kev}$$
$$\text{FWHM} = 2.36\ \sigma = 68 \text{ kev}$$

IV) Electron beam measurements.

The detector is mounted on the paddle above the electron beam. The beam energy is controlled by the power supply for the magnet. A calibration curve relates magnetic field to electron energy. The beam size is controlled by the slits used. Several different size slits exist. A lead slit is often used above an aluminum slit to absorb the $\gamma$-rays. (if the lead slit were used first, too much bremsstrahlung would be produced.) The slits should be oriented properly (see figure 5). Lead shielding should also be placed around the slit on the table of the $\beta$-spectrometer to reduce background.

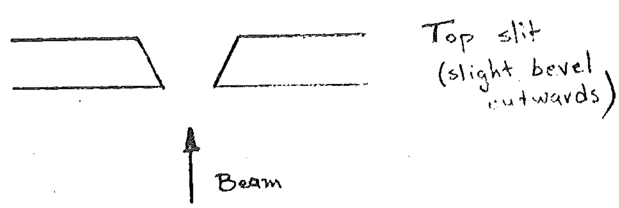



fig. 5

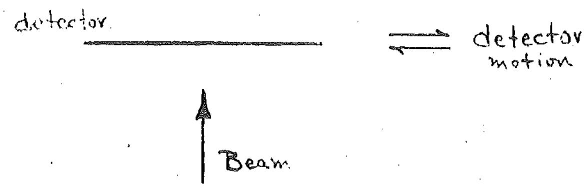
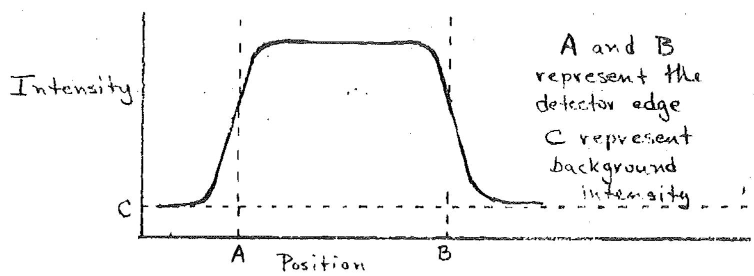



fig. 6

V) Size scans.

The detector is moved across the electron or α beam (fig. 6), and the intensity as a function of position is observed. The beam used should be narrower than the desired resolution of the detector size.




The Spread of the beam can be determined by mounting a mask in front of the detector and making a scan (fig. 7).

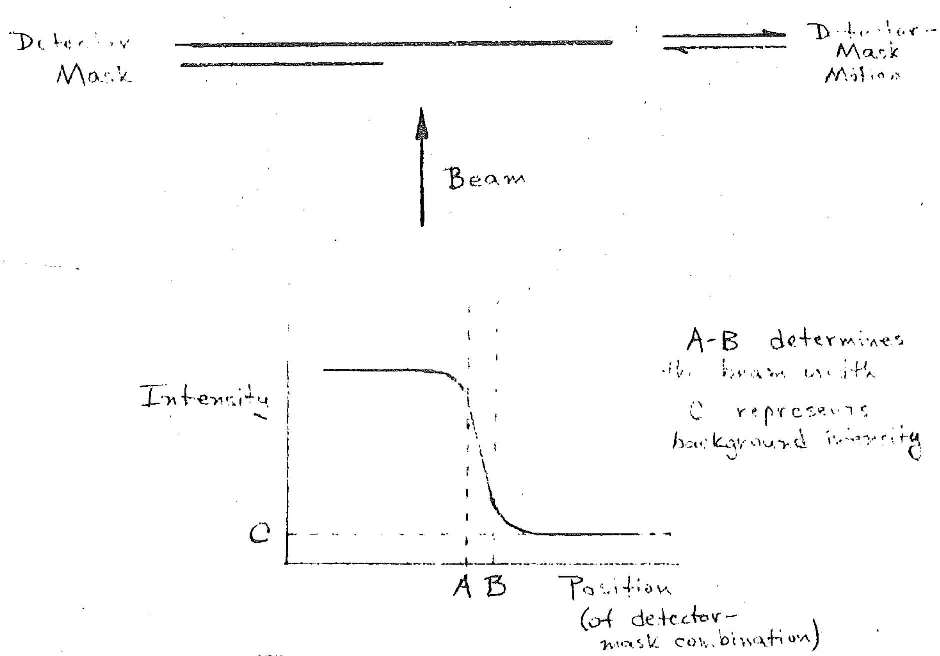


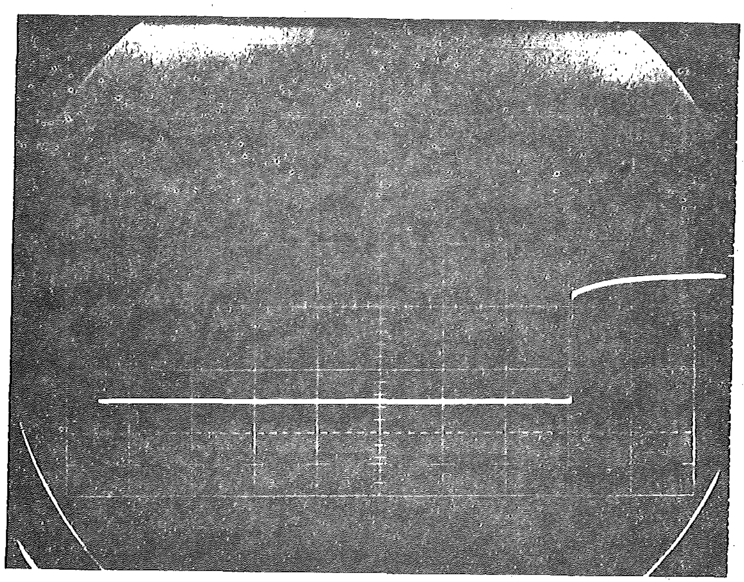

fig. 7

A jig for centering the detector on the beam (so that the scan is along a diameter) is in room 228. For a diagram and description of use see Robert Offermann's notebook β-spectrometer 1971.

A collimator for the α-source is in room 228. When the collimator is on the β-spectrometer table the α-beam is at the same height as the center of the detector and the scan is therefore along a diameter of the detector. For a diagram see Solomon Vidor's notebook IMP Detectors TVS " β-spectrometer" section.

# OUTPUT PULSES OF ELECTRONICS

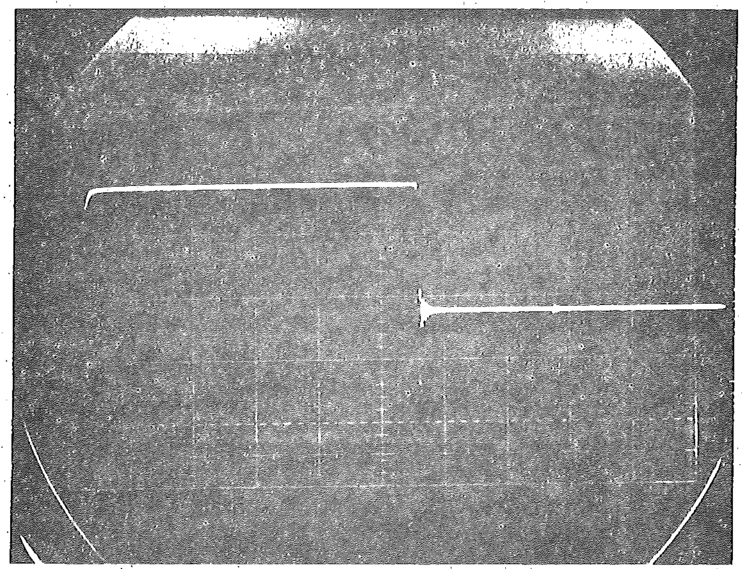
The outputs of the various pieces of equipment are shown in the following pictures. The set up is as in figure 2, and the settings used are described in this report. The WEA pulser (with a voltage of 400 volts) was used to supply the pulses. If the pulses came from particles losing energy in a detector, the pulse from the preamp would decay much more slowly. Therefore, at the TC 200 output only the positive pulse would be observed.



WEA pulser output

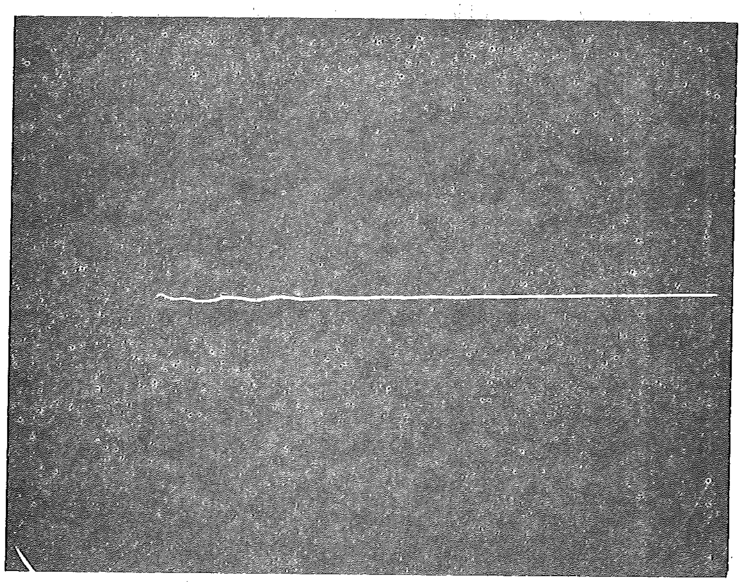
Scale: 2.5 v/cm

1 μsec/cm



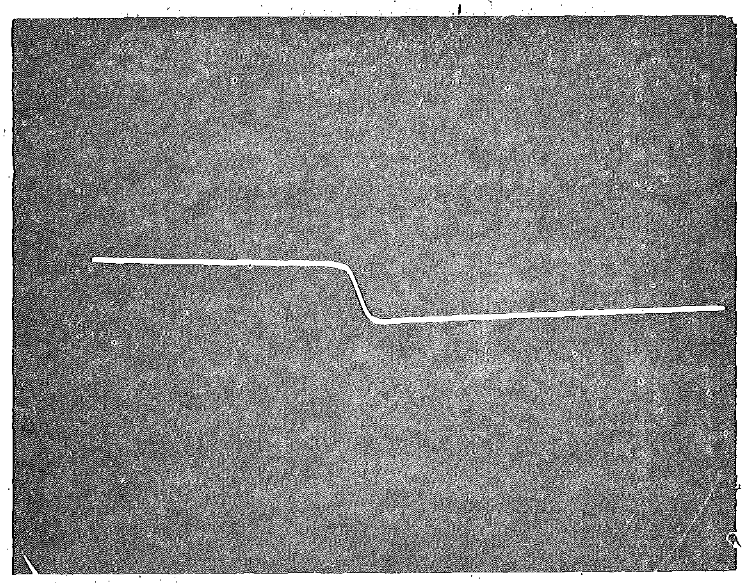
WEA pulser coincidence output (not terminated)

Scale: 2 v/cm
1 μsec/cm



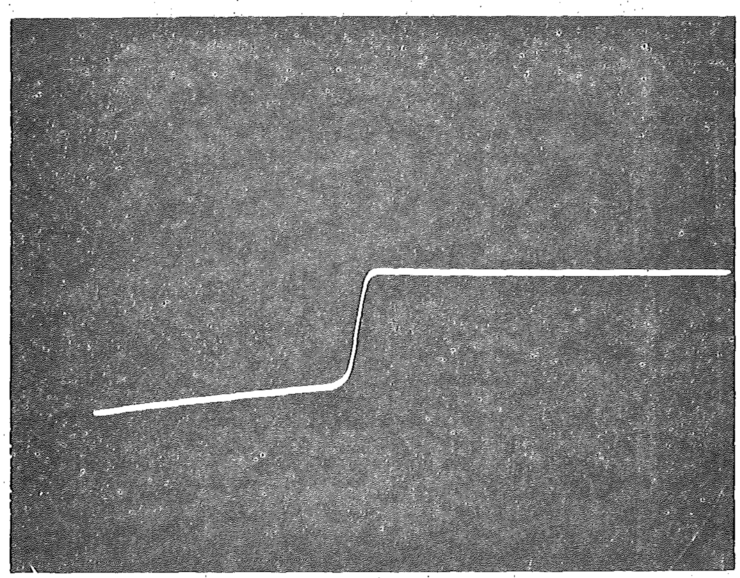
WEA pulser trigger output

Scale: 0.5 v/cm
0.1 μsec/cm



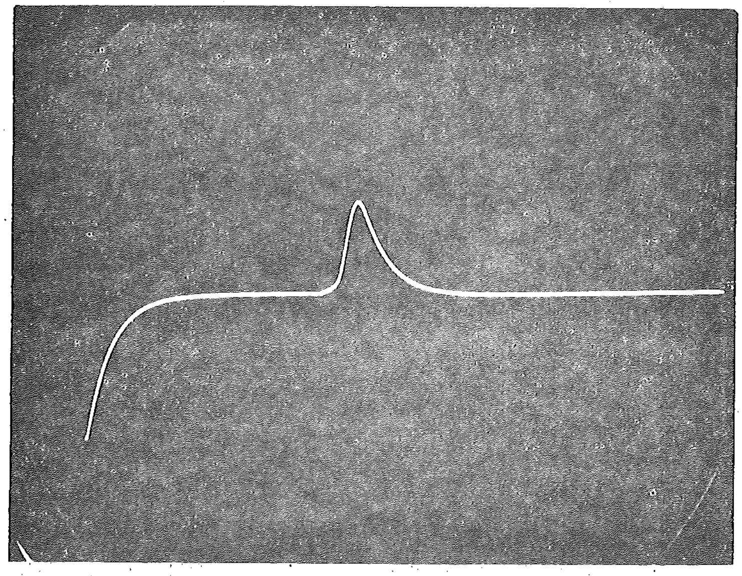
Preamp output

Scale: 0.2 v/cm
2 μsec/cm



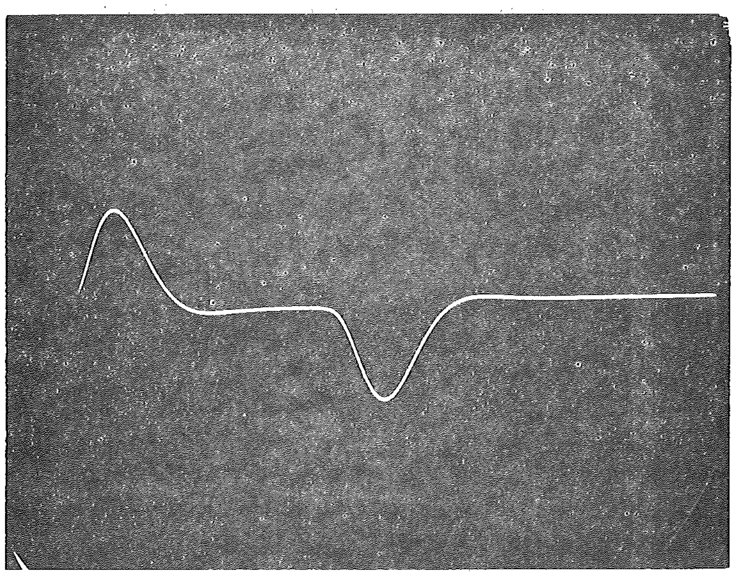
TC 200 1st stage output

Scale: 0.2 v/cm
2 μsec/cm



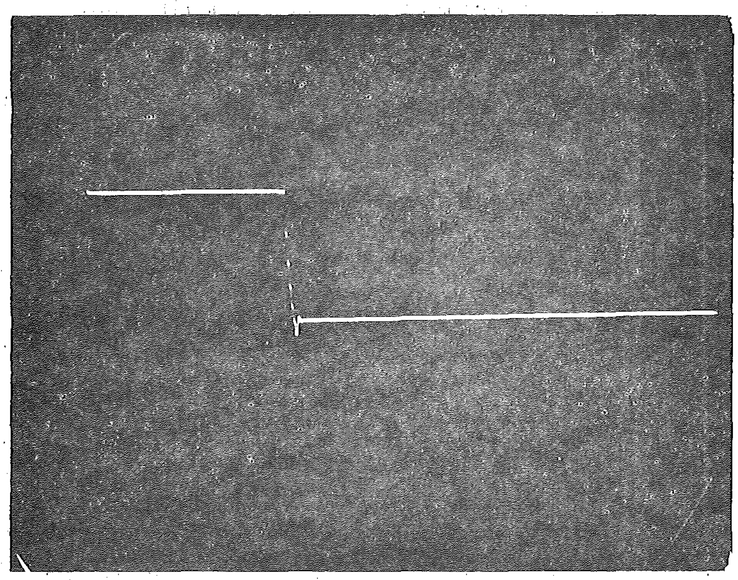
TC 200 2nd stage output

Scale: 0.2 v/cm
2 μsec/cm



TC 200 3rd stage output

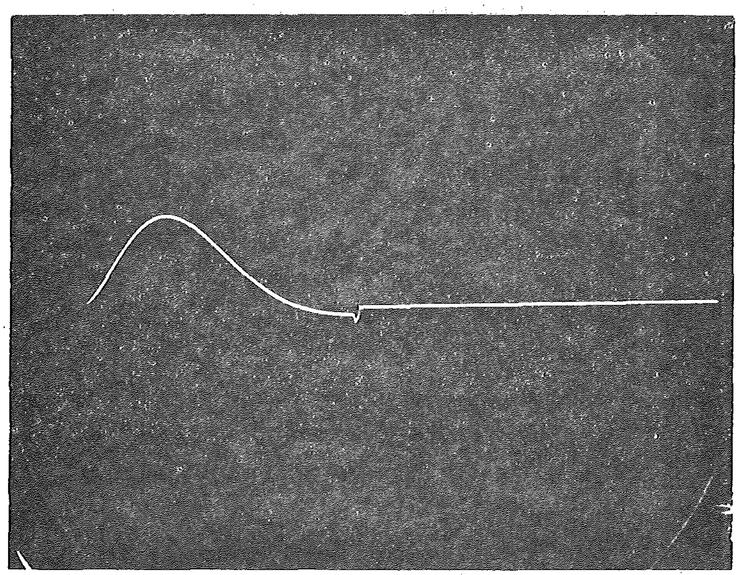
Scale: 1 v/cm
2 μsec/cm



Ortec 421 discriminator output

Scale: 2.5 v/cm

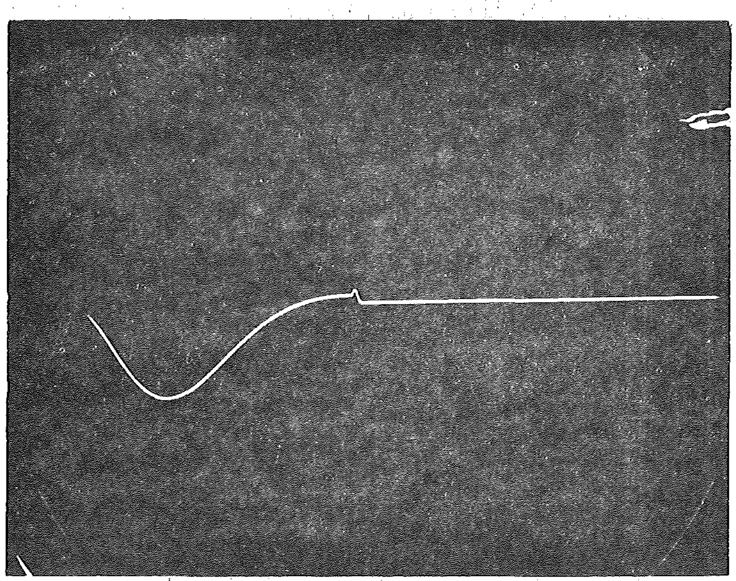
1 μsec/cm



Ortec 409 linear gate and slow coincidence output

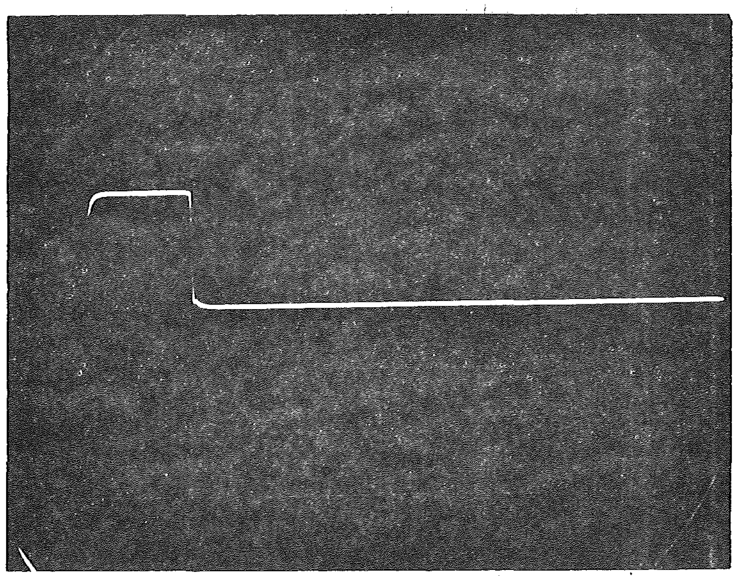
Scale: 1 v/cm

1 μsec/cm



TC 212

Scale: 1 v/cm
1 μsec/cm



TC 250 output

Scale: 1 v/cm

1 μsec/cm

# REFERENCES


1) β-spectrometer manual. Should be near the β-spectrometer in room 228.

2) Internal Report #31 by S. Vidor on pulser calibration of preamp.