A HIGH ENERGY NEUTRON DETECTOR USING PROPORTIONAL WIRE CHAMBERS

M. Atac
National Accelerator Laboratory

R. Majka and S. Dhawan
Sloane Physics Laboratory, Yale University

July, 1972

Abstract

A neutron detector using alternating layers of multiwire proportional chambers, steel plates and plastic scintillators and a proportional chamber readout system were built. The results indicate that a spatial resolution of σ = 7 mm with a 61% total detection efficiency in determining the neutron positions can be achieved. This type of detector may also be used in identifying high energy muons.

1. Introduction

An experiment to study the properties of negative hyperons produced by the Brookhaven National Laboratory Alternating Gradient Synchrotron[1] required a neutron detector to identify the fast (15 - 20 GeV/c) neutrons resulting from hyperon decays of interest, e.g., $\Sigma^- \rightarrow n e^- \bar{\nu}$. Figure 1 shows a schematic of the apparatus. The extracted proton beam (about 5×10^{11} protons per pulse at 28 GeV/c) is allowed to strike a small target at the entrance of the magnetic channel. Negative hyperons, Σ^-, Ξ^-, and Ω^-, produced in the forward direction traverse the channel and have their position recorded by a special high resolution spark chamber[2] at the channel exit. Most of the hyperons that decay downstream of this chamber have their charged decay particles momentum analyzed by the two spectrometer magnets and four clusters of magnetostrictive spark chambers. The fast forward neutrons produced in some decays are then detected by the device described here. A measurement of the neutron position and hence angle; along with a rough measurement of its energy, is desired.

As shown in Figure 2 the detector consists of two parts, the neutron position detector and the neutron calorimeter. The first section contains alternating layers of 3.2 cm thick steel plate, 0.6 cm thick plastic scintillator, and a pair of orthogonal proportional wire chambers. There are five such layers each having a cross section of about 60 cm x 60 cm. The calorimeter[3] was built by the University of Michigan group and consists of alternating layers of steel plates (3.8 cm thick) and plastic scintillators (0.6 cm thick). It contained over four interaction lengths of material.

Neutrons of momentum 13 to 21 GeV/c interact in the steel plates to give charged hadronic and electromagnetic cascades. The position of these cascades is given by the proportional wire chambers. The scintillators in both the position detector and the calorimeter are summed to give pulse height information, hence a measurement of the energy deposited. This pulse height is used in the trigger and also recorded by the data collection system.

A similar type of detector with a single converter plate was reported.[4] G. Coignet et al., obtained ±2.2 mm accuracy in determining the interaction vertex of neutrons in a carbon converter with an efficiency of 6.5%.

2. Description of Detector

As shown in Figure 2 the detector consists of 10 proportional wire chambers, five steel plates and 6 scintillation counters. The active area of the proportional chambers is 48 cm x 48 cm. Each chamber (see Figure 3) contains 48 signal wires (25 micron diameter gold-plated tungsten) which are 1 cm apart. The spacing between the wire plane and the outer electrodes is 8 mm. The outer electrodes are made of 50 micron copper foils on 1.5 mm thick epoxy glass sheets. The same material is also used around the chamber as an electromagnetic shield. The grounding of these outer copper foils reduces the noise level on the wires by about a factor of 10.

Each steel plate is 3.2 cm thick and covers the active area of the chamber. A pair of proportional chambers (one in the vertical and one in the horizontal direction) and a 6 mm thick plastic scintillator are sandwiched between the steel plates. Thus the detector consists of five modules of these sandwiches. A 20% CO_2 and 80% Argon gas mixture has been used in the chambers for over three months with no sign of signal deterioration. Efficiencies of the chambers are measured to be above 99.5% with a full gate width of 120 nsec. The time resolution of the chambers is determined to be ±35 nsec at the half width at half maximum. An appropriate trigger turned on the coincidence gates for the pulses from the proportional chambers.

Every wire in the chamber is coupled to an amplifier circuit which is kept in an aluminum shielded box directly coupled to the chamber. Good AC and DC ground connections and good shielding enabled us to operate our electronics with threshold levels of 0.2 to 0.3 mV without noise pickup in a rather noisy environment.

3. Electronics

The electronics is designed with an input voltage threshold of 0.3 mV, a cable delay, and time gated flip-flop latches. The amplifiers are packaged 8 per card. The latches are packaged into groups of 32 and read out on a 32-bit data bus by a ring counter type scheme. The read in to the PDP-15 computer is on a 1 binary bit per chamber wire basis. The 18-bit computer word is made up by 16 latch bits, a non-zero latch bit and an odd parity bit. The electronics for the amplifier and the latch cards was developed by W. Sippach and H. Cunitz of Nevis and J. Dieperink of CERN.[5]

The signals from each chamber wire are amplified by a MECL 1035 integrated circuit and discriminated with a threshold of 0.3

mV or higher. The discriminator output is connected to line drivers which are capable of driving the flat ribbon cable. A wired "OR" signal is also available whenever any one of the eight discriminators is triggered.

A 32-channel flat ribbon cable is used for time delay. The length of this cable is 200 feet. Each channel has a set of 3 conductors, 1 each for signal, signal return and ground.

All the cables are brought to a latch bin, which is located in the electronics trailer. A 32-channel latch card receives signals differentially and reshapes the signal waveform. This is necessary because of the waveform degradation due to the cable. The shaper output is differentiated, time gated and stored in latches. The time gate is distributed by MECL III gates in parallel to all the latch cards.

A latch bin accommodates up to 24 latch cards and 1 bin controller. The bin controller has the necessary electronics to read sequentially 32 bits from each latch card; divide this into two 16 bits. An internal odd parity and a non-zero data bit is added to the 16 latch bits to make the 18 bits for the computer. Since our chambers have 48 wires each, we use 2 latch cards per chamber and read out 3 computer words per chamber.

The data is transferred to a CAMAC module by a multiconductor twisted pair cable. All the signals on this cable are driven and received differentially, so that it will be unaffected by spark chamber noise.

Figure 4 is a simple block diagram of the CAMAC module. This module can be used to provide all the necessary timing when it is used independently. When used with spark chambers, the longer dead times are provided by the spark chamber CAMAC module. The Enable/Disable FF is enabled by command F26 and disabled by F24. This enable level is used to enable the trigger logic so that a trigger (event) can be accepted. When a trigger is accepted, it disables the E/D FF and sets LAM FF. The LAM is recognized by the CAMAC branch driver and the computer. Then the data can be transferred by Command F(4)A(0). This reads the first 18-bit word from the latch bin, clears LAM FF and advances the scanner to fetch the next word.

The F(4)A(0) is executed repeatedly, until all the data is read in. After this the Software clears the latches, initializes the scanner and re-enables the E/D FF to accept the next trigger. Some of the control signals are provided on front panel LEMO connectors for monitoring purposes.

4. Results

A typical picture of a hadronic and electromagnetic cascade resulting in the detector from the interaction of a 15 GeV/c π and a n respectively is shown in Figure 5a and 5b. In this picture each row of a vertical projection or a horizontal projection corresponds to a proportional chamber plane and each (1) represents a wire pulse. This data along with all other relevant data concerning the event was recorded on magnetic tape by our DEC PDP-15 computer. Even a cursory perusal of these projection plots indicated that showers were indeed being detected and a measurement of the neutron interaction was possible. A spatial resolution of $\sigma = 7$ mm with a 61% total detection efficiency in determining the neutron positions was achieved. The exact determination of this position is a pattern recognition problem which is discussed in the following paper.[6]

Figure 5c shows a picture of a μ track obtained from the detector. Muons are used for determining the relative alignment of the proportional chambers. An obvious identification of the muons is that they leave straight tracks or single tracks with a δ-ray branch formation in the detector.

The authors would like to express their appreciation to Drs. J. Lach, J. Marx, A. Roberts, J. Sandweiss and W. J. Willis for very useful discussions and to J. Bloomquist, B. Lombardi, E. Steigmeyer and I. J. Winters for their help in constructing the detector and the readout system.

References

[1] AGS proposal #430; study of production and decay of high energy Σ^-, Ξ^- and Ω^-.

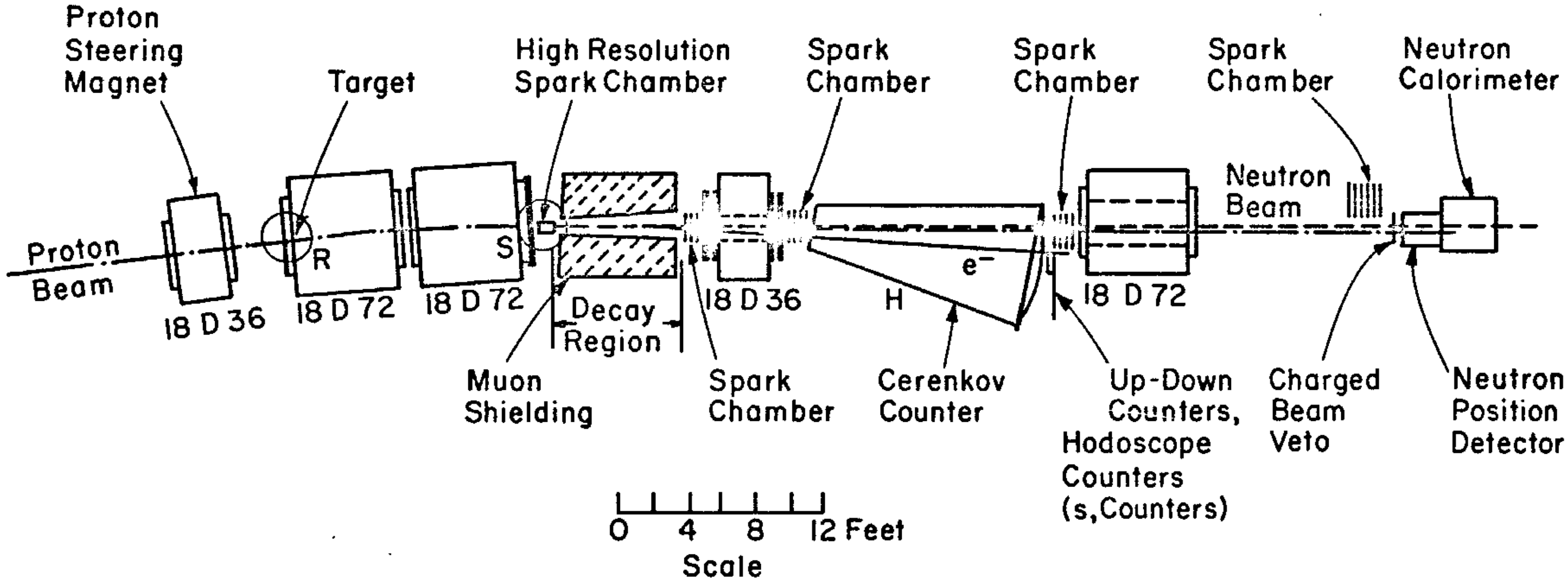
[2] W. J. Willis, V. Hungerbuehler, W. Tanenbaum, and I. J. Winters, Nucl. Instr. and Meth. 91, 33-36(1971).

[3] L. W. Jones, M. J. Longo et al; Phys. Letters, Vol. 36B, No. 5 (1971) 509-512.

[4] G. Coignet et al., Nucl. Instr. and Meth. 99, 19-24(1972).

[5] W. Sippach, H. Cunitz and J. Dieperink, Nucl. Instr. and Meth. 91, 211-220(1971).

[6] William Tanenbaum, Nucl. Inst. and Meth. (following paper).



Proton Steering Magnet
Target
High Resolution Spark Chamber
Spark Chamber
Spark Chamber
Spark Chamber
Neutron Calorimeter
Neutron Beam
Proton Beam
R
S
e⁻
H
18 D 36
18 D 72
18 D 72
18 D 36
18 D 72
Decay Region
Muon Shielding
Spark Chamber
Cerenkov Counter
Up-Down Counters, Hodoscope Counters (s,Counters)
Charged Beam Veto
Neutron Position Detector
0 4 8 12 Feet
Scale

Fig. 1

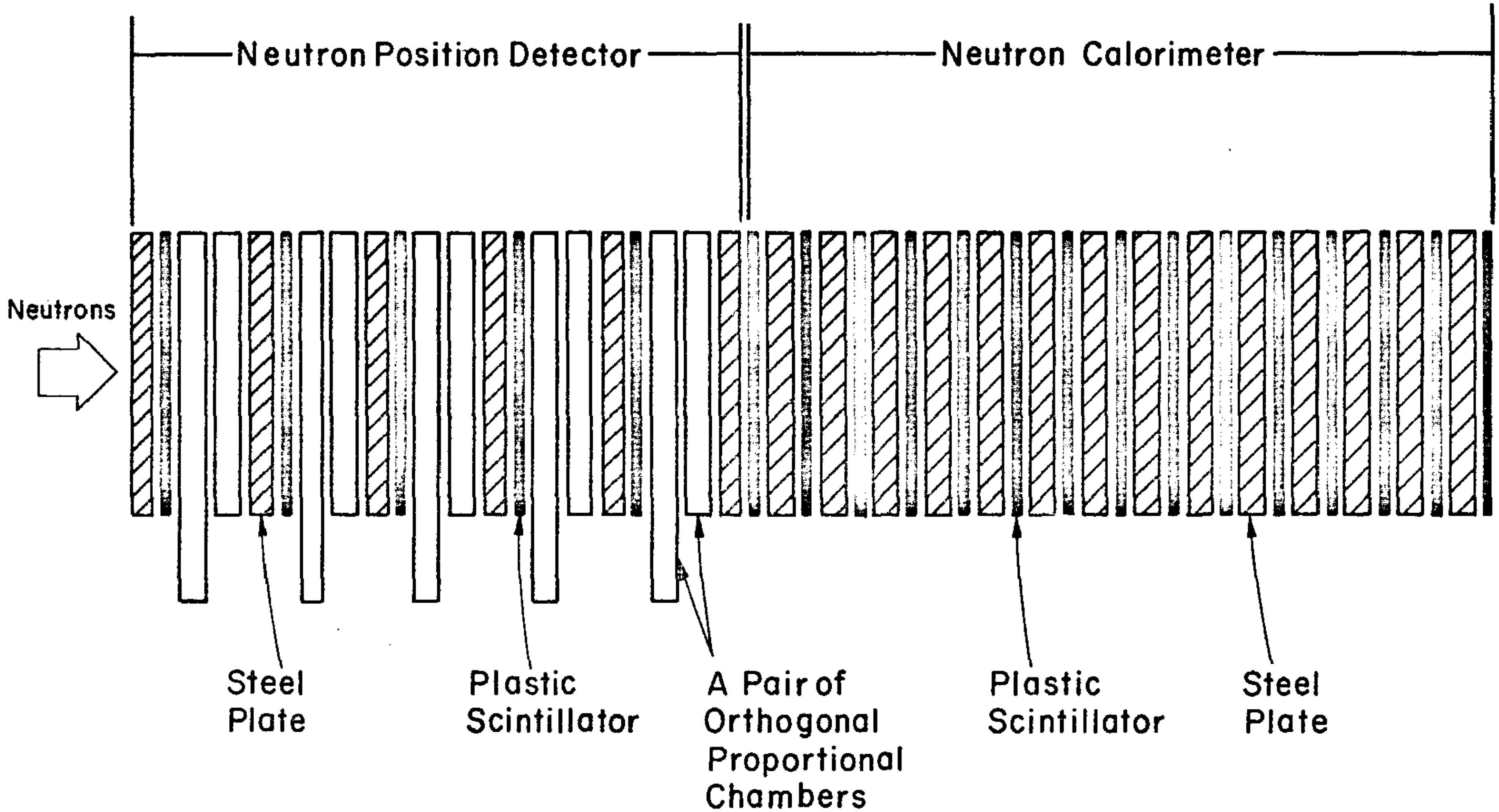

Neutron Position Detector
Neutron Calorimeter
Neutrons
Steel Plate
Plastic Scintillator
A Pair of Orthogonal Proportional Chambers
Plastic Scintillator
Steel Plate

Fig. 2

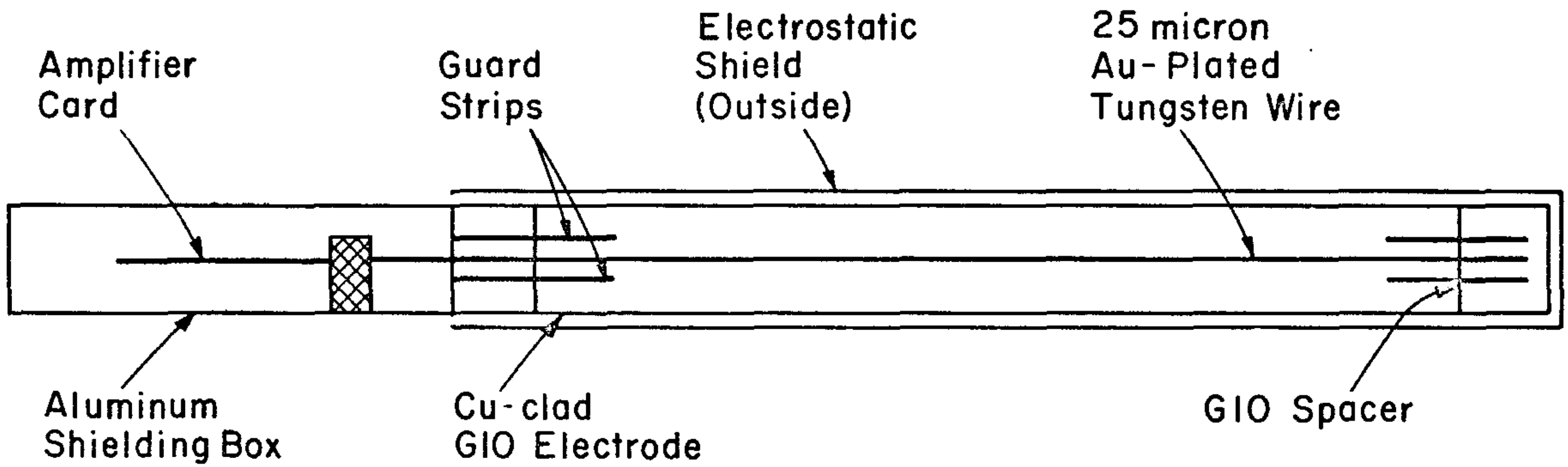

Amplifier
Card
Guard
Strips
Electrostatic
Shield
(Outside)
25 micron
Au-Plated
Tungsten Wire
Aluminum
Shielding Box
Cu-clad
GIO Electrode
GIO Spacer

Fig. 3

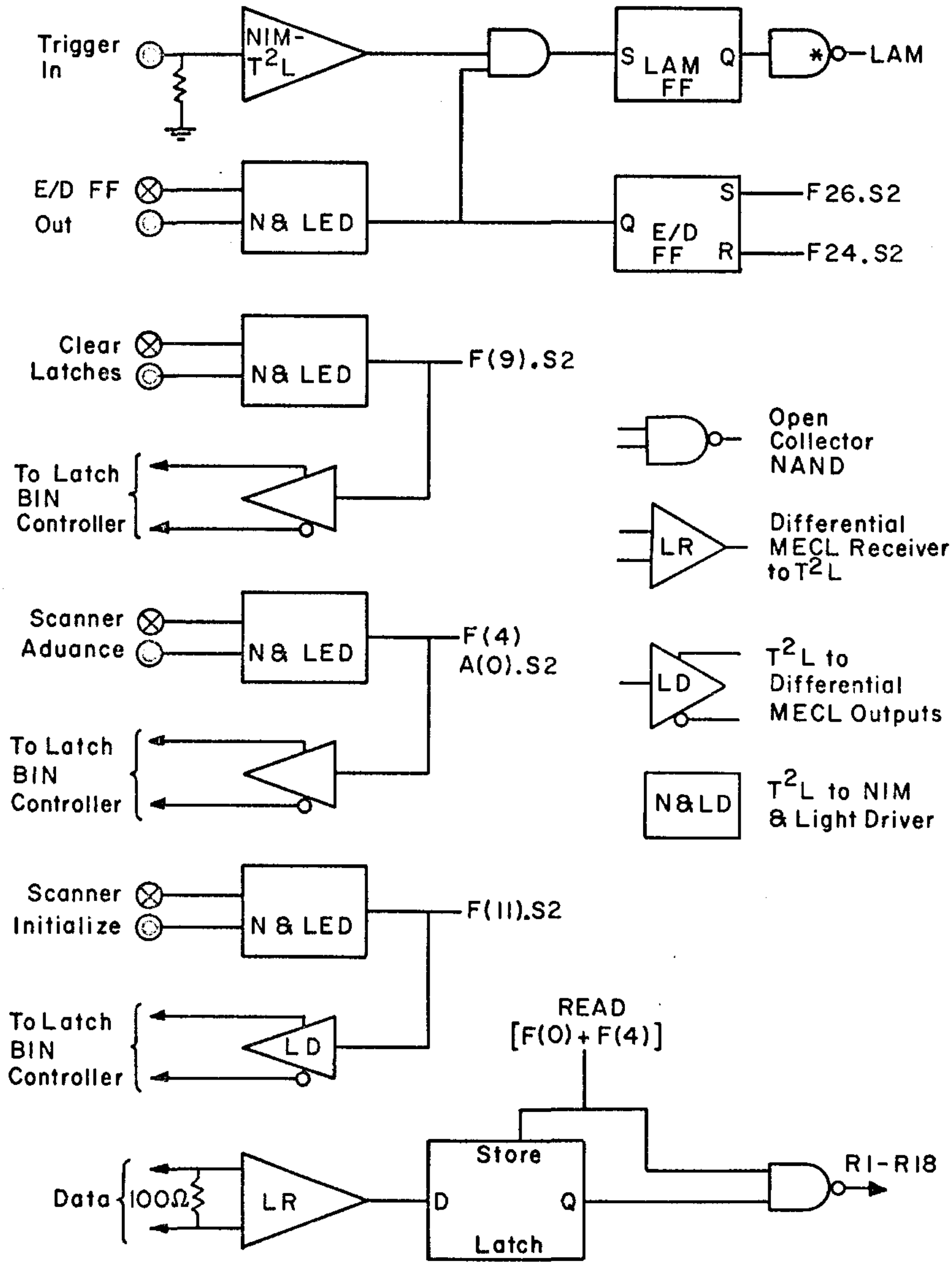

Trigger In
NIM-T^2L
S LAM FF Q
LAM
E/D FF Out
N & LED
Q E/D FF S R
F26.S2
F24.S2
Clear Latches
N & LED
F(9).S2
To Latch BIN Controller
Open Collector NAND
LR
Differential MECL Receiver to T^2L
Scanner Aduance
N & LED
F(4) A(0).S2
LD
T^2L to Differential MECL Outputs
To Latch BIN Controller
N&LD
T^2L to NIM & Light Driver
Scanner Initialize
N & LED
F(11).S2
To Latch BIN Controller
LD
READ [F(0) + F(4)]
Data
100Ω
LR
D Store Latch Q
R1-R18

Fig. 4

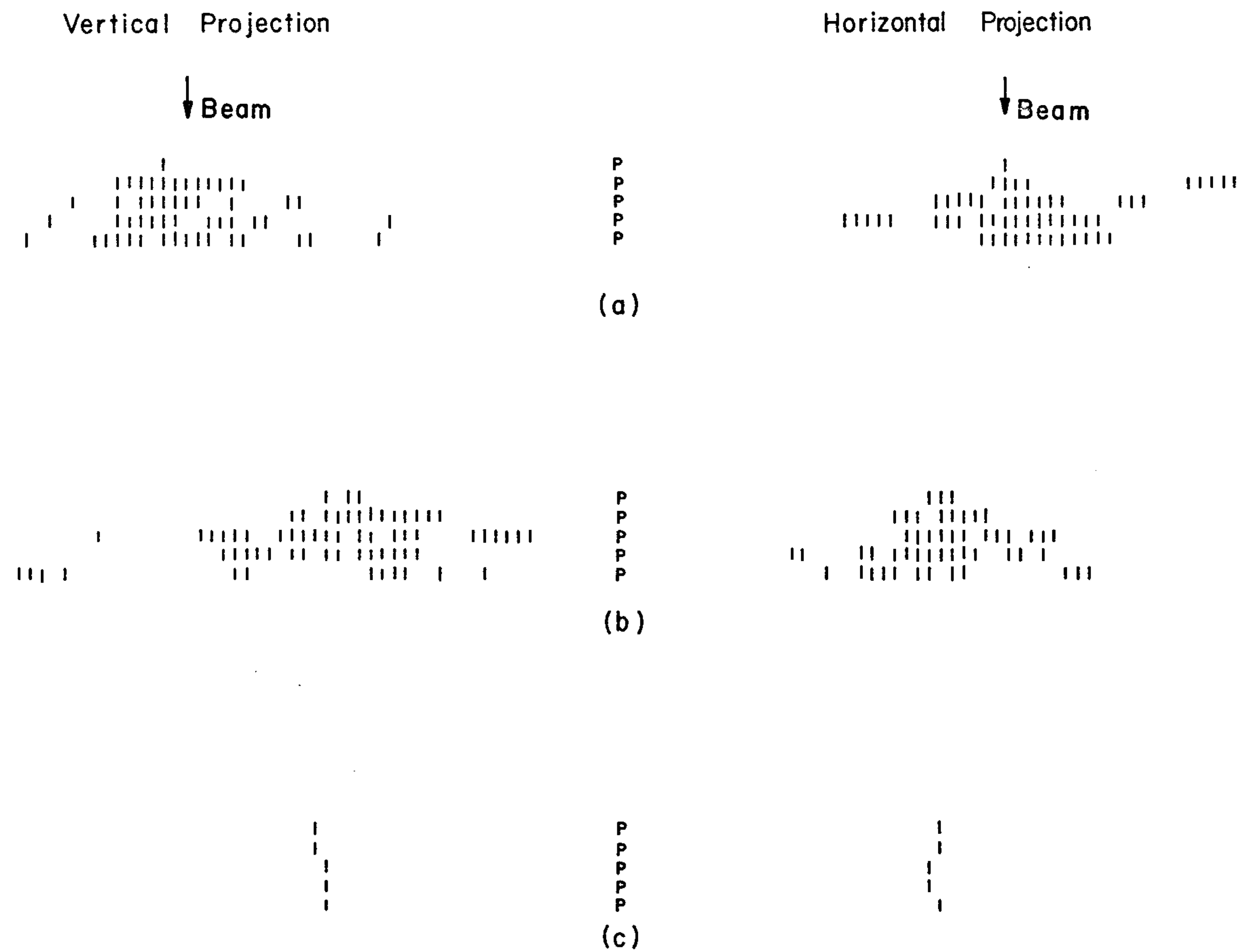

Vertical Projection
Horizontal Projection
Beam
Beam
P
(a)
(b)
(c)

FIG. 5