TECHNICAL DEVELOPMENT

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A SIMPLE LEADING EDGE DISCRIMINATOR FOR THE ASSOCIATED-GAMMA RAY TIME-OF-FLIGHT EXPERIMENT

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Abstract

A simple tunnel diode leading edge discriminator has been constructed for use as a time pickoff device with a NaI(Tl) scintillator in an associated-gamma ray time-of-flight measurement. When using a 2"x2" NaI(Tl) and a 2"x 2" fast plastic scintillators NE102 as detectors of the fast coincidence system, it is found that the timing resolution of the system is 6.1 nsec(FWHM) for a 10:1 dynamic range using ^{60}Co radioactive source. The system was checked by measuring the spectrum of neutrons emitted in coincidence with gamma rays from Am-Be source. Details of circuit descriptions and experimental measurements are described in this paper.

Introduction

In the neutron spectrum measurement employing associated-gamma ray time-of-flight (TOF) technique, two detectors designated strart and stop detectors are used. The start detector produces a signal from the interaction between a gamma ray and the scintillator. This pulse serves as a time reference signal and is used to start the Time to Amplitude Converter (TAC). The stop signal for the TAC is developed in the other detector from the interaction between the neutron and the scintillator. These scintillators ought to be fast-response type when highly precise timing information is required. Generally, they are organic scintillators. The convenient time pickoff method for these scintillators can be fast crossover timing using the clipping stub technique for scintillators with small decay time constant[1].

This technique, however, is not usable with NaI(Tl) scintillator. The reason of this exception is that the relative statistical amplitude fluctuations are very large for the region far from the tail of the current pulse[2]. These fluctuations will increase the timing resolution of the time spectrometry system which causes distortion in the resulting neutron spectrum. It can be said that zero crossover timing is not suitable with scintillators having a long decay time. The alternative time pickoff method for NaI(Tl) scintillation is leading edge timing. We report in this paper the construction of a Leading Edge Discriminator (LED) to be used in our experiment utilizing the associated-gamma ray TOF technique.

Circuit Description

Fig. 1 shows block diagram of the Leading Edge Discriminator. This discriminator has two channels. Channel 1 is an amplitude discriminator used to prevent noise generating false outputs. When an input pulse size is larger than the trigger level of channel 1, an output pulse from channel 1 will enable channel 2.

Channel 2 is the actual Leading Edge Discriminator. The input signal to channel 2 is delayed so that it arrives after the enable pulse from channel 1. The trigger level of channel 2 is set to about 20% of the input signal amplitude. This is the optimum percentage in order to keep walk effect to a minimum. When the input signal reaches this value a fast output is generated from channel 2. The output circuit provides standard fast negative and slow positive output pulses.

The advantage of the above arrangement is that channel 2 is normally insensitive to noise, and is made sensitive just a short time before receiving the input signal whose timing information is to be extracted.

Fig. 2 shows the detailed circuit diagram modified trom that proposed by Soucek and Chase[3]. Channels 1 and 2 are tunnel diode discriminators D_1 and D_2 respectively, which are fed by commonbase stages T_1 and T_2. The circuit is intended for use with negative anode input signals. The input impedance of both these common base stages is designed to be 100 ohms so that the combined input impedance is a standard 50 ohm. Potentiometers P_1 and P_2 set the trigger levels of the tunnel diode monostables and inductors L_1 and L_2 set the periods. In our circuit L_1 has value 55 μH and L_2 43 μH. The value of the delay at channel 2 input is made just longer than the total channel 1 delay from T_1 input to T_3 output.

The negative output pulse from tunnel diode D_2 is amplified by transistors T_5 and T_6 to have an amplitude of 6V and pulse width of 300 nsec. The collector of transistor T_6 is connected to a 40 cm RG-174 cable which serves as a shorted stub for clipping the signal amplitude down to 2V and pulse width down to 8 nsec. The negative portion of this signal is fed out through T_7, to be a standard negative fast output signal of 1V amplitude and 8 nsec width. An inversion of this same signal appears at the collector of T_7, and triggers the monostable, T_8 and T_9. The signal from the collector of T_9 is buffered by emitter-follower T_{10} as a positive 5V signal of 0.5 μsec width and furnished as a standard slow output[4]. The pulse shapes observed at various positions in the discriminator circuit are presented in Fig. 3.

Experimental Measurements

The Leading Edge Discriminator was used in the time spectrometry system as a time pickoff device with a 2 in. diam. by 2 in. high NaI (Tl) scintillator. This scintillator was used as a start detector whereas the stop detector was a 2 in. diam by 2 in. high NE102 plastic scintillator (manufactured by Nuclear Enterprise Inc., USA). The time pickoff method for the stop detector utilizes the fast crossover timing with the clipping stub technique, consisting of a shorted stub 45 cm long and the single channel analyzer triggering at the zero crossing of a bipolar pulse. Fig. 4 shows the experimental block diagram of electronics circuit used in the experiment. The timing resolution of the system as shown in Fig. 5 is 6.1 nsec (FWHM) for 10:1 dynamic range using two gammas from the ^{60}Co radioactive source.

The time spectrometry system was tested by measuring the spectrum of neutrons above 1 MeV emitted from the Am-Be source. Fig. 6 displays a typical time-of-flight spectrum of neutrons emitted in coincidence with gamma radiations from Am-Be source. The flight time t of a neutron with a given rest mass M was converted into kinetic energy T using the relativistic relation[5].

$$T = M\left[\frac{1}{\sqrt{1-\frac{x^2}{(ct)^2}}} - 1\right] \qquad (1)$$

Where x is the flight path of the neutron (120 cm) and c is the velocity of light.

The energy resolution of the system (FWHM) was calculated by the equatton[5]:

$$\frac{\Delta T}{T} = \frac{(T+M)\,(T+2M)}{M^2}\left[\left(\frac{\Delta x}{x}\right)^2 = \left(\frac{\Delta t}{t}\right)^2\right]^{\frac{1}{2}} \qquad (2)$$

where T is the kinetic energy of the neutron, M is the rest mass of a neutron, Δx is the uncertainty in neutron flight path, x is the neutron flight path (120 cm), Δt is the intrinsic time dispersion of the system, and t is the flight time of the neutron. At 6 meV the energy resolution is $\pm$18 percent.

Because the efficiency of a plastic scintillator depends on the incident neutron energy, the neutron yield has been corrected for energy dependent detecting efficiency calculated from the Monte Carlo computer code developed by Cecil *et al*[6]. Fig. 7 shows the neutron detecting efficiencies at various incident neutron energies.

The resulting energy spectrum is shown in Fig. 8. Also shown in Fig. 8 are the experimental results obtained by Guarrini *et al*[7] and Thompson *et al*[8]. In the region between 2 and 6 MeV our spectrum agrees with other measurements. It should

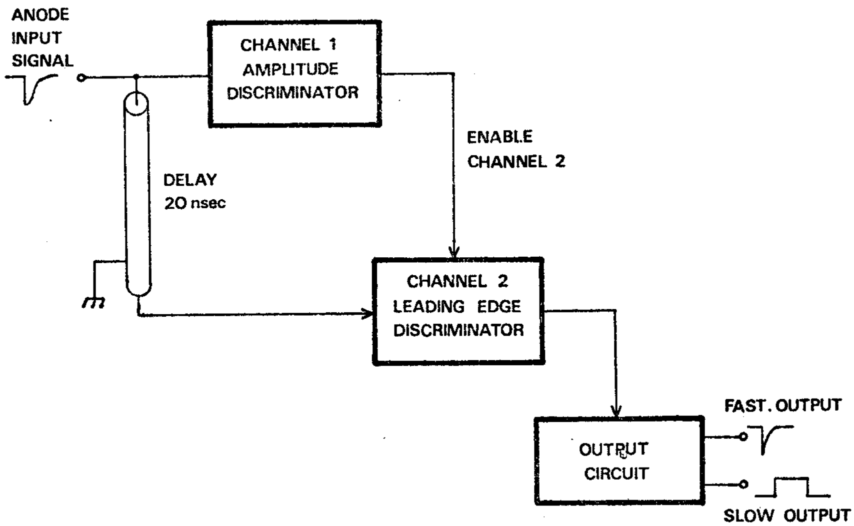


Fig. 1. Block diagram of the discriminator.

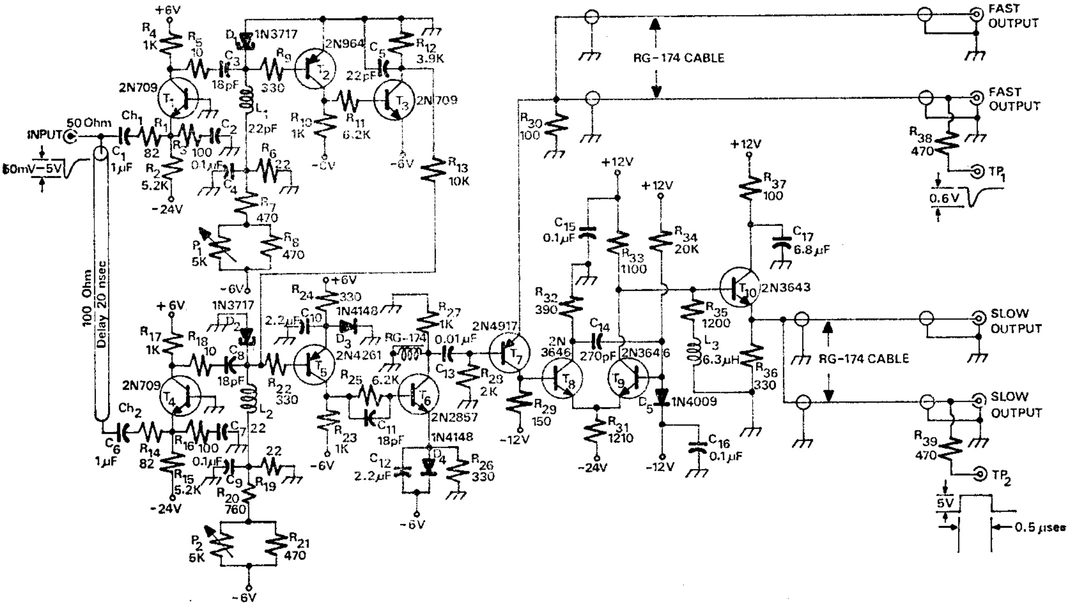
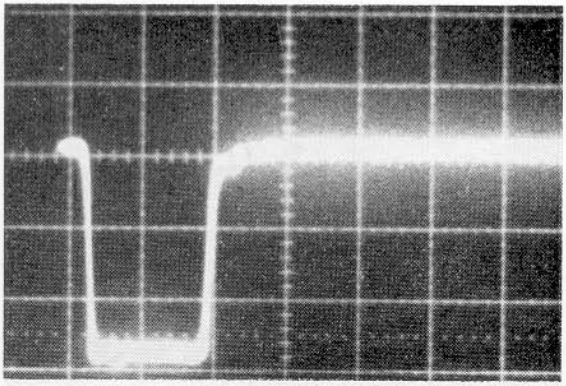
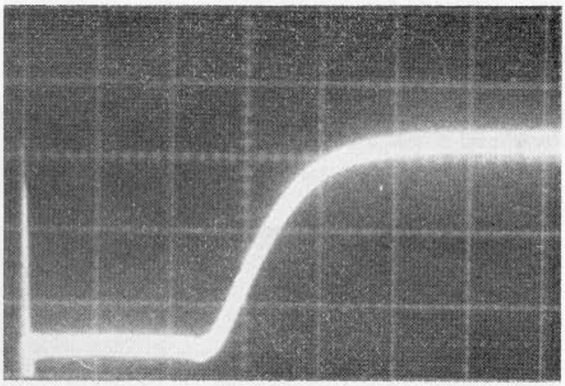


Fig. 2. Circuit diagram of the discriminator. All resistors in ohm.

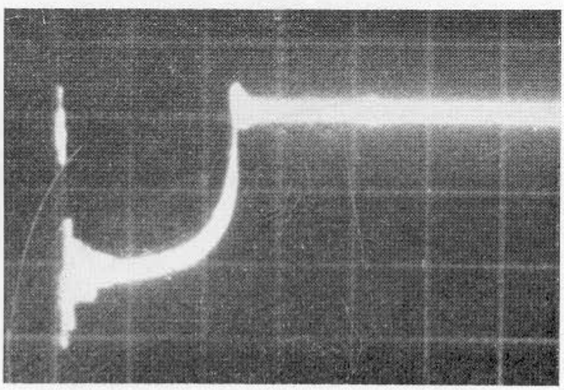
Fig. 3. Pulse shapes observed at various positions of the discriminator when triggered by a pulse generator



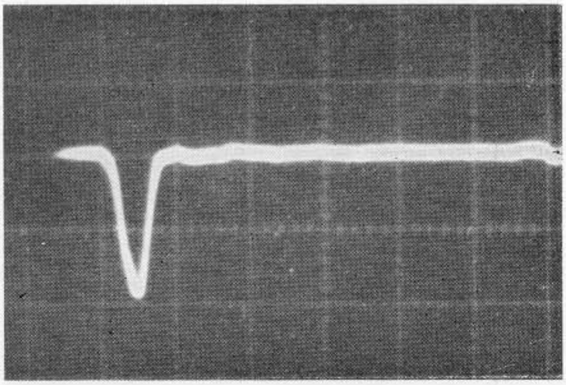
(a) Input signal; Vertical scale : 50 mV/div., Horizontal scale : 100 nsec/div.



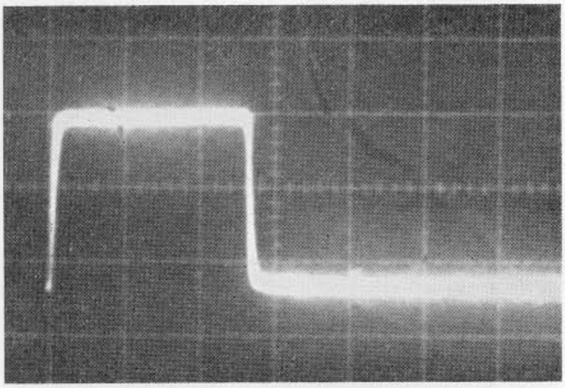
(b) Output from channel 1; Vertical scale : 0.2 V/div., Horizontal scale : 100 nsec/div.



(c) Output from channel 2; Vertical scale 0.2 V/div., Horizontal scale : 100 nsec/div.



(d) Standard fast output signal; Vertical scale : 0.5 V/div., Horizontal scale : 20 nsec/div.



(e) Standard slow output signal; Vertical scale : 2 V/div., Horizontal scale : 200 nsec/div.

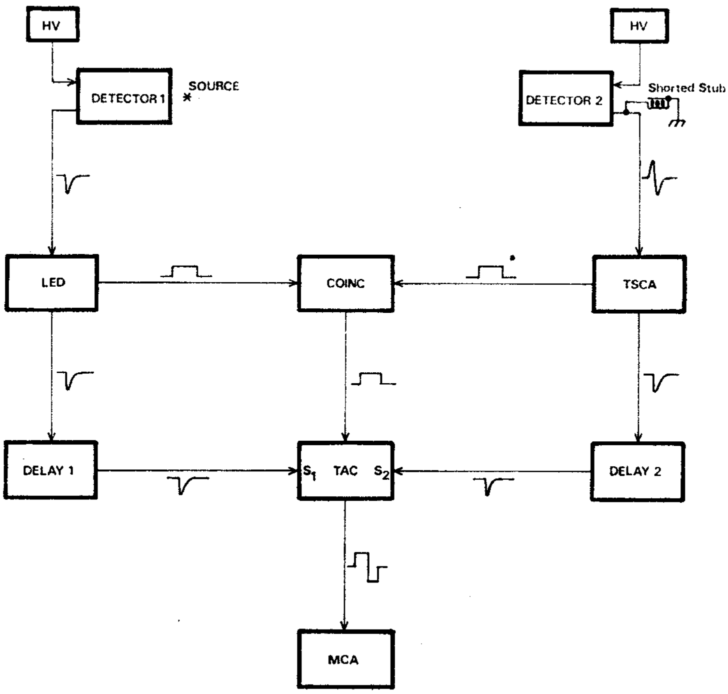


Fig. 4. Block diagram of the time spectrometry system using associated-gamma ray time-of-flight technique. (S_1 – start, S_2 – stop, TSCA – Timing single channel analyser).

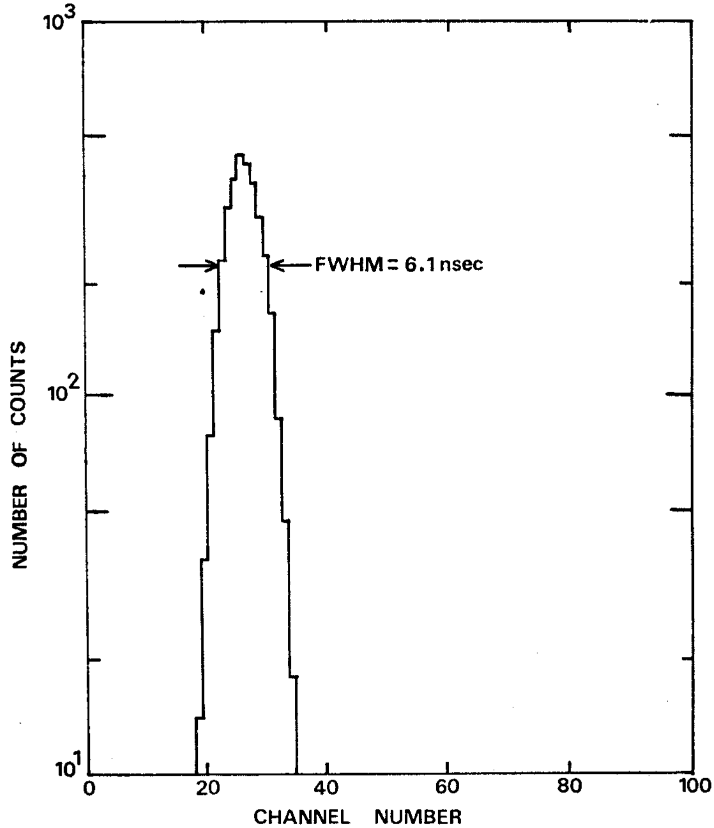


Fig. 5. Typical Time Resolution using NaI(Tl) and NE102 Plastic Scintillator.

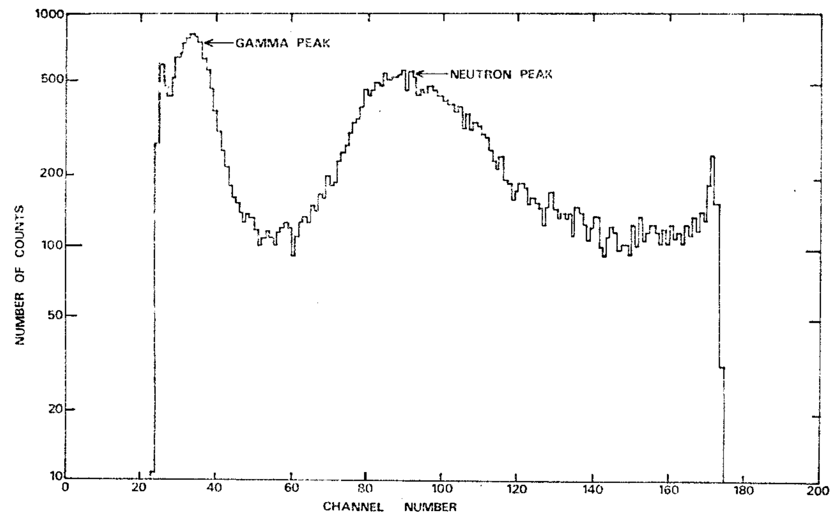


Fig. 6. Typical time-of-flight spectrum of neutrons emitted in coincidence with gamma rays from the Am-Be source.

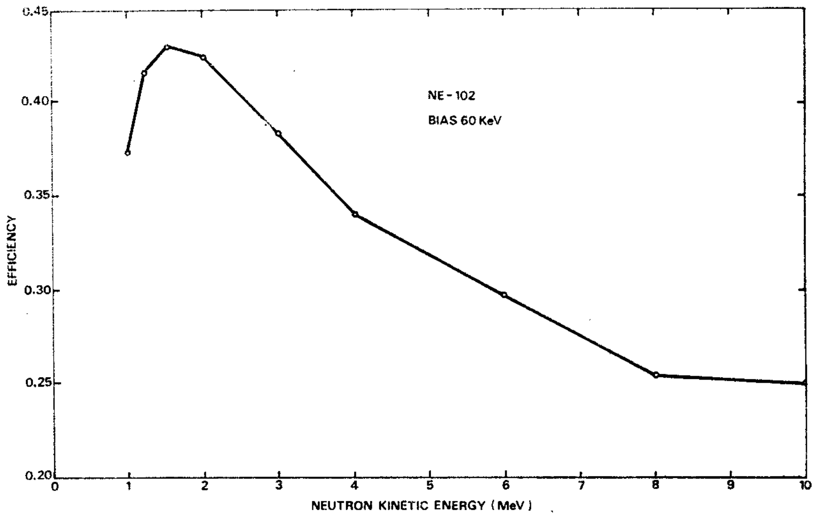


Fig. 7. The neutron detecting efficiency of a 2 in. diam. by 2 in. high scintillator.

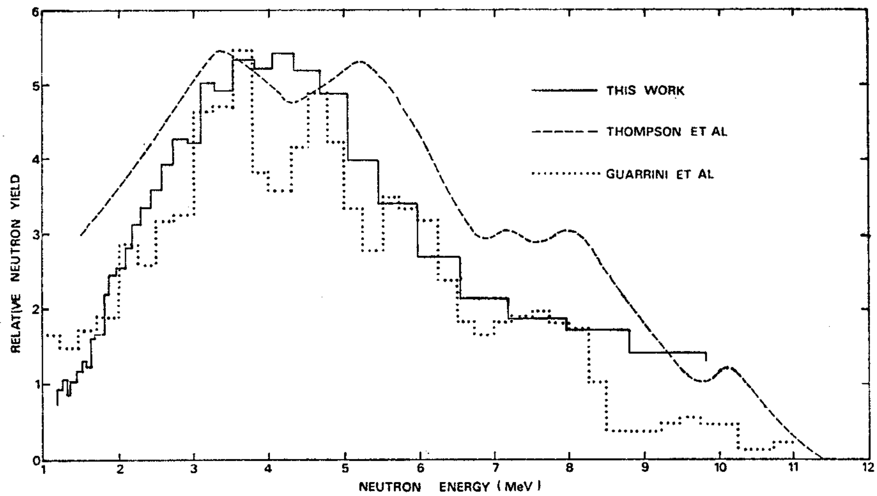


Fig. 8. Comparison of various Am-Be spectra. The solid line is our measured spectrum using associated-gamma rays TOF technique, the dashed line is the measured spectrum using proton recoil spectrometer reported in Ref. 8) and the dotted line is the measured spectrum using nuclear emulsion method reported in Ref. 7).

be noted that our measurement is not sensitive to neutrons above 6 MeV which has no correlated gamma rays.

Conclusion

Although our time spectrometry system cannot give details of the spectrum, nevertheless, the measured spectrum agrees reasonably well with other measurements[7,8]. The experiment indicates that the leading edge discriminator can be considered useful for NaI (Tl) scintillator in the case where high detection efficiencies is of primary concerned. Our result supports Bell's[9] calculation that leading edge timing is always superior to crossover timing for slow delector responses.

Acknowledgement

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References

1. Crouthamel, C.E., Adams, F. and Dams, R. (1970), *Applied Gamma-Ray Spectrometry*, 2nd Ed., Pergamon Press, Hungary, pp. 164.
2. Gedcke, D.A. and McDonald, W.J., (1968), *Nucl. Instr. Meth.* **58**, 255.
3. Soucek, B. and Chase,R.L., (1967), *Nucl. Instr. Meth.* **50**, 71.
4. *ORTEC Operating and Service Manual of Timing Single Channel Analyser Madel 420A*, pp. 6
5. Madey, R. and Waterman, F.M., (1973), *Nucl. Instr. Meth.* **106**, 89.
6. Cecil, B.A., Anderson, B.D. and Madey, R., (1979), *Nucl. Instr. Meth.* **161**, 440.
7. De Guarrini, F. and Malaroda, R., (1971), *Nucl. Instr. Meth.* **92**, 279.
8. Thompson, M.N. and Taylor, J.M., (1965), *Nucl. Instr. Meth.* **37**, 306.
9. Bell, R.E., (1966), *Nucl. Instr. Meth.* **42**, 211.

บทคัดย่อ

Tunnel diode leading edge discriminator ได้ถูกสร้างขึ้นเพื่อใช้เป็นหน่วย time pickoff ของหัววัดรังสี NaI(Tl) ในระบบวัดเวลาการเคลื่อนที่โดยใช้เทคนิค associated-gamma ray time-of-flight เมื่อใช้หัววัดรังสีชนิด NaI(Tl) และพลาสติกที่มีการตอบสนองเร็ว NE102 ขนาด 2"×2" พบว่า timing resolution ของระบบมีค่า 6.1 nsec (FWHM) สำหรับค่า dynamic range ที่มีอัตราส่วน 10 : 1 เมื่อใช้ ^{60}Co เป็นสารกัมมันตรังสี ระบบนี้ได้รับการทดสอบยืนยันจากการวัดสเปคตรัมของนิวตรอนที่ถูกปล่อยออกมาโคอินซิเดนซ์ กับรังสีแกมมาจากแหล่งกำเนิด Am-Be รายละเอียดของวงจร leading edge discriminator ที่สร้างขึ้น และผลการทดลองจะได้กล่าวถึงในรายงานนี้