A^+ RICH COUNTER

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In this note I consider a design for a RICH (Ring Imaging CHerenkov Counter) to identify the K^- from $A^+ \to \Lambda^0 K^- \pi^+ \pi^+$ at the trigger level. I discuss here single particle response of the counter and a possible scheme for a K^- trigger within 10 μsec of the event. I have not yet studied multi-particle response in detail, nor have detailed mechanical, optical or electronic designs been made.

Counter Design

Recall from my previous note(1) that all accepted K^- from the A^+ decay fall in the angular range after the first spectrometer:

$$-25 \le \theta_x^{K^-} (mR) \le -5$$
$$-6 \le \theta_y^{K^-} (mR) \le 6$$

$$40 \le P^{K^-} (GeV/c) \le 200$$

The positions of the K^- at the Z of the RICH mirror are:

$$-50 \le X^{K^-} (cm) \le -10$$
$$15 \le Y^{K^-} (cm) \le 15$$

The usual Cerenkov equations are:

$$\delta = \delta_0 P \quad ; \quad \delta = n - 1 \qquad \delta_0 = 293 \times 10^{-6} / atm \text{ for } N_2 \tag{1}$$

$$\theta_c = \sqrt{2\delta - 1/\gamma^2} \qquad \gamma = E^{K^-}/M^{K^-} \tag{2}$$

$$N_{pe} = A L \theta_c^2 \tag{3}$$

A = 100 photo-electrons / cm
L = counter radiator length

(1) "DESIGN STUDY FOR A STRANGE CHARMED BARYON BEAM EXPERIMENT", P. S. Cooper, June 15, 1984.

I choose for parameters:

A = 100 pe/cm (we got A = 140 pe/cm with the E-715 counter)
L = 10m = 1000 cm
P = 0.17 ATM of N_2

This gives:

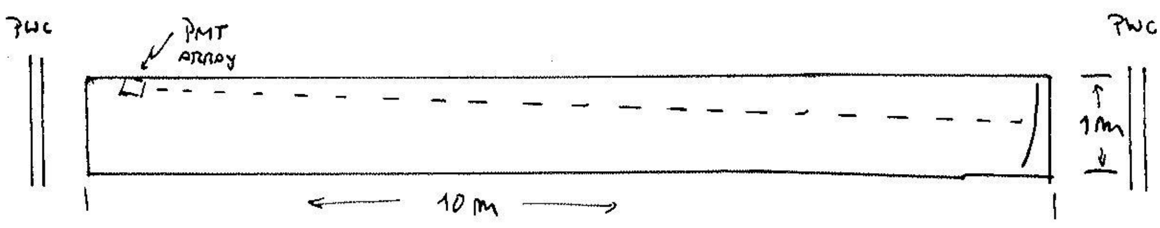
$\gamma_{Threshold}$ = 100 ($E_K \cong P_K \cong$ 50 GeV/c)
N_{pe}^{max} = 10 } for a fast particle ($\gamma \gg \gamma_{Thres}$)
θ_c^{max} = 10 mR

The photon detector I have in mind is a ~500 phototube array of 1/2 inch HAMAMATSU R-760 Tubes arranged Hexagonally close packed. These Tubes have The following properties

Spectral Response	160 ~ 650 nm	
dynodes	10 in line	1250 volts Max 1000V Typical
Quantum eff	25% Typical	
Price	$ 136	In lots of 100 <u>with</u> base
diameter	13.5±.5mm	
Photocathode diameter	10.0 mm	

This is essentially identical To The C31000M RCA Tubes we used in E715 & E-497. The gain is somewhat lower. Typical output pulses want a 10mV Threshold Discriminator.

Physically The counter is 10m + long ~ 1m in diameter with a single 36" spherical Mirror. Essentially just like The E-715 counter only a little bigger



SINGLE PARTICLE RESPONSE

I have Monte-Carloed the response of the counter using the K^- tracks from Ref (1). Each track is run twice, once as a Kaon and once as a Pion. Photo-electrons are generated Possion distributed in number with mean given by equation (3) for each track. Recall that in the focal plane of a spherical mirror:

$$R = f\theta \qquad (4)$$

where θ is the incident polar angle a ray makes with respect to the optic axis and R is the distance from the axis in the focal plane (f is the focal length). For convenience I work with unit focal length so that R is measured in mRad:

$$R = \sqrt{(\theta_x - \theta_x^0)^2 + (\theta_y - \theta_y^0)^2} \qquad (5)$$

where θ_x^0, θ_y^0 is the optic axis in the experimental coordinate system. With a focal length f = 13.5 m each phototube covers 1 mRad.

I don't try to match the photon flux to the 10 mm Φ photocathodes, photon which miss the center of a phototube by more than 5 mm are lost. This is an obvious improvement - the lost photo electrons are about 1/2 of the total flux.

For each detected photo-electron I calculate R_i the angular distance from the track (like in equation (5) above). The track angles are those measured by the surrounding PWC's and the photo-electron angles are given by the coordinates of the center of the hit phototube. The average over all detected photo-electrons ($\bar{R}$) is then calculated.

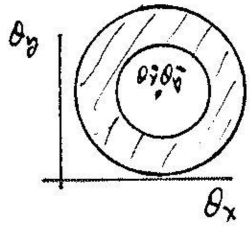
In Figure 1 I plot $\bar{R}$ versus the momentum of the track. The upper band is for the tracks as π's the lower as K's. Seperation is clean up to 160 GeV by eye (There are 1288 tracks for each particle type). Cutting at 80 GeV to remove the region of the π^- band where $\bar{R} < 1$ and projecting to make and $\bar{R}$ distribution gives Figure 2. A cut at $\bar{R} < 0.97$ keeps almost all of the K^- and rejects 95% of the π's.

In Figure 3a is shown the whole K^- momentum spectrum (solid) and those K^- with $\bar{R} < 0.97$ (dashed). The ratio of these two distributions, shown in Figure 3b, is the K^- detection efficiency vs momentum. Notice that it is typically 90% and reasonably flat over all momenta.

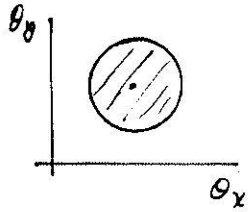
TRIGGER

Figure 4 shows a schematic of a Readout and Trigger processor for the Photo Tube array. I assume a Track finding processor driven by 8 wire fast OR's from the surrounding PWC's to provide 10 bit $\theta_x \theta_y$ words (± 32mR x, ± 8mR y, 6 bits, 4 bits) for each negative track. Assume a Do Loop Module as in Tom Nash's E-516 processor so that the angles of the first track are available while the second is being processed.

Each PMT has a discriminator and two latches the first for readout and the second for the processor. Each channel has a 2K memory the output of which is ANDed with the latched PMT output. The address of all memorys is provided by the 10 bit $\theta_x^* \theta_y^*$ word plus 1 bit call Ring. The pattern stored in the memorys are shown below



RING = 0



RING = 1

For RING=0 a memory has a 1 for a given $\theta_x^* \theta_y^*$ if that PMT is in the angular range $.95 < R/R_{max} < 1.05$. For Ring=1; $R/R_{max} < .95$.

The search for Kaon candidates proceeds in two passes. First, with RING=0 the number of hits in the Pion Ring for a given track is summed, system wide. The time for this using the TTL chips I've shown is about 500 nsec. If the number of hits found is above a cut a clear signal is generated removing all the hits associated with the Pion. If not a Pion the address is saved in another do loop module as a Kaon candidate. After all tracks are checked as Pions any Kaon candidate are checked with Ring=1 to eliminate bad tracks from the track finder.

The whole process can be done in ~10 μsec or about 10% deadtime assuming every interaction (10KHz) is processed.

CONCLUSIONS

I believe the above is a very promising candidate for a K^- trigger in the 50 - 200 GeV/c momentum range. The total cost of the device is estimated below

Mechanical + Gas system	20 K
Optics	10 K
PMTS + HV (512 Tubes)	75 K
Electronics ($100 / channel)	50 K
	155 K

More design is clearly called for. Particularly a study of multi particle response and better engineering are called for.

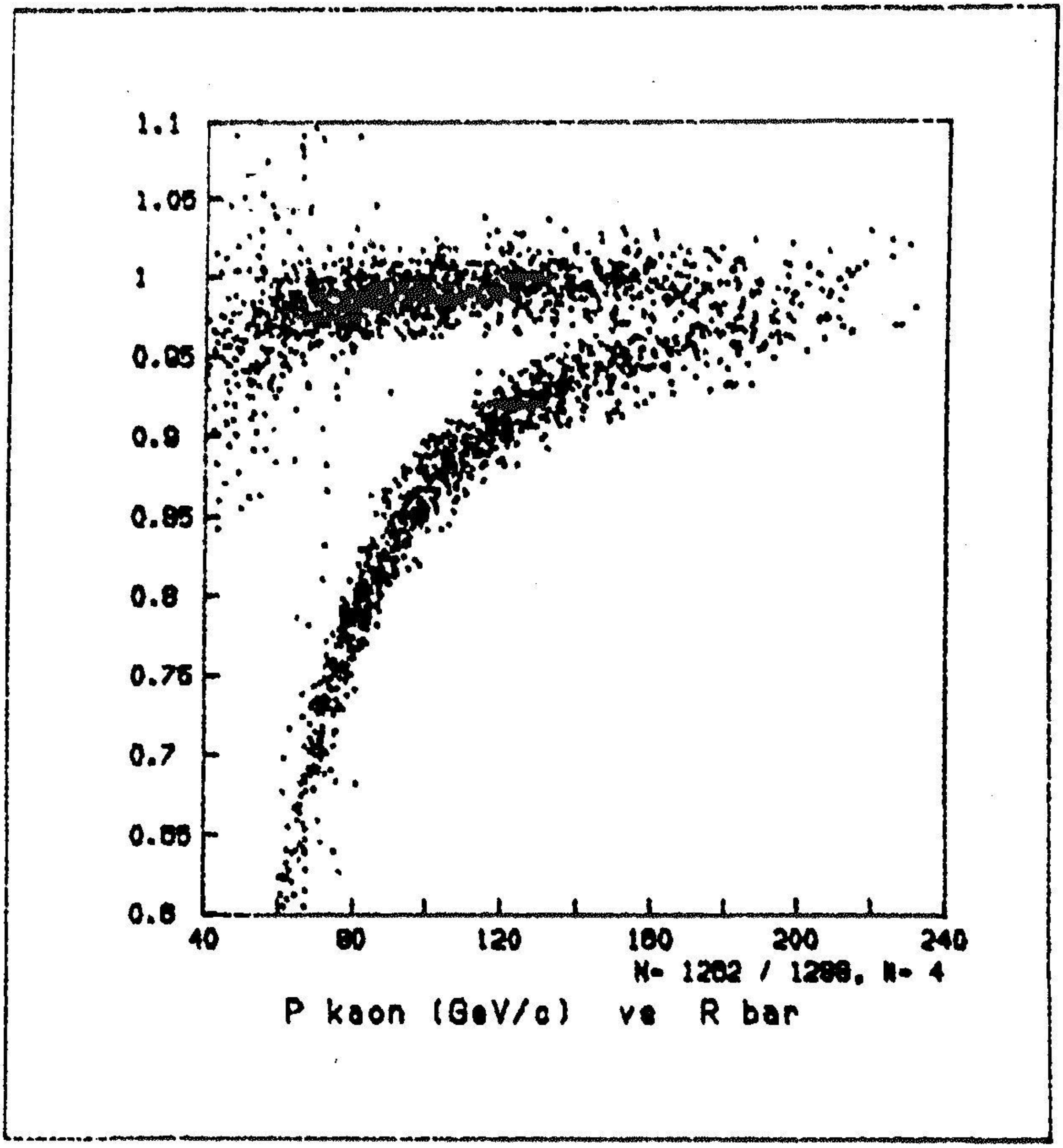


Figure 1: $\bar{R} / \bar{R}_{MAX}$ for tracks vs momentum. Upper band is π^-, lower K^-. <u>Note</u> suppressed zero.

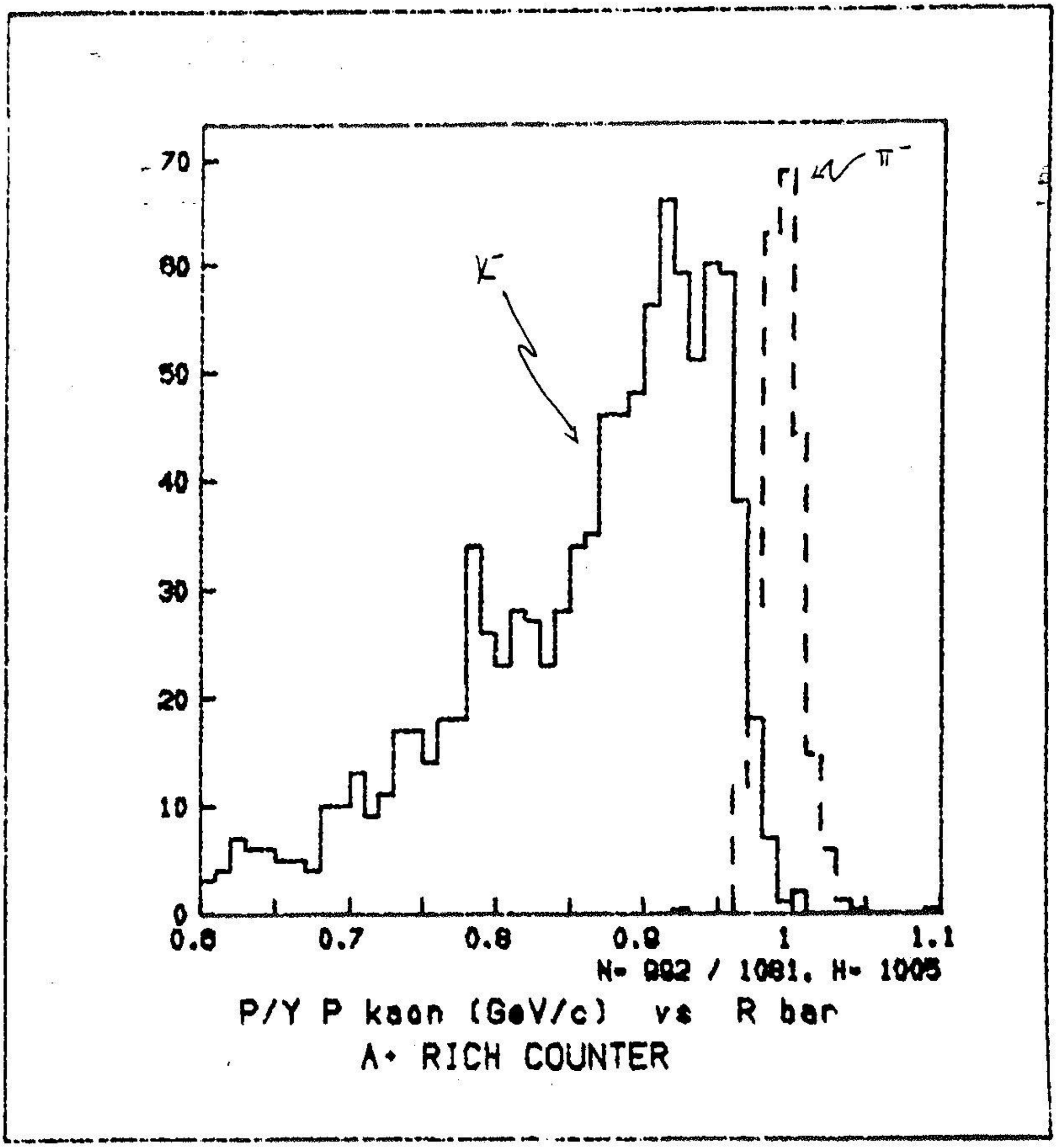


Figure 2: dN/dx vs. x $\quad x = \bar{R}/\bar{R}_{max}$ For π^-/K^- with $P > 80$ GeV/c

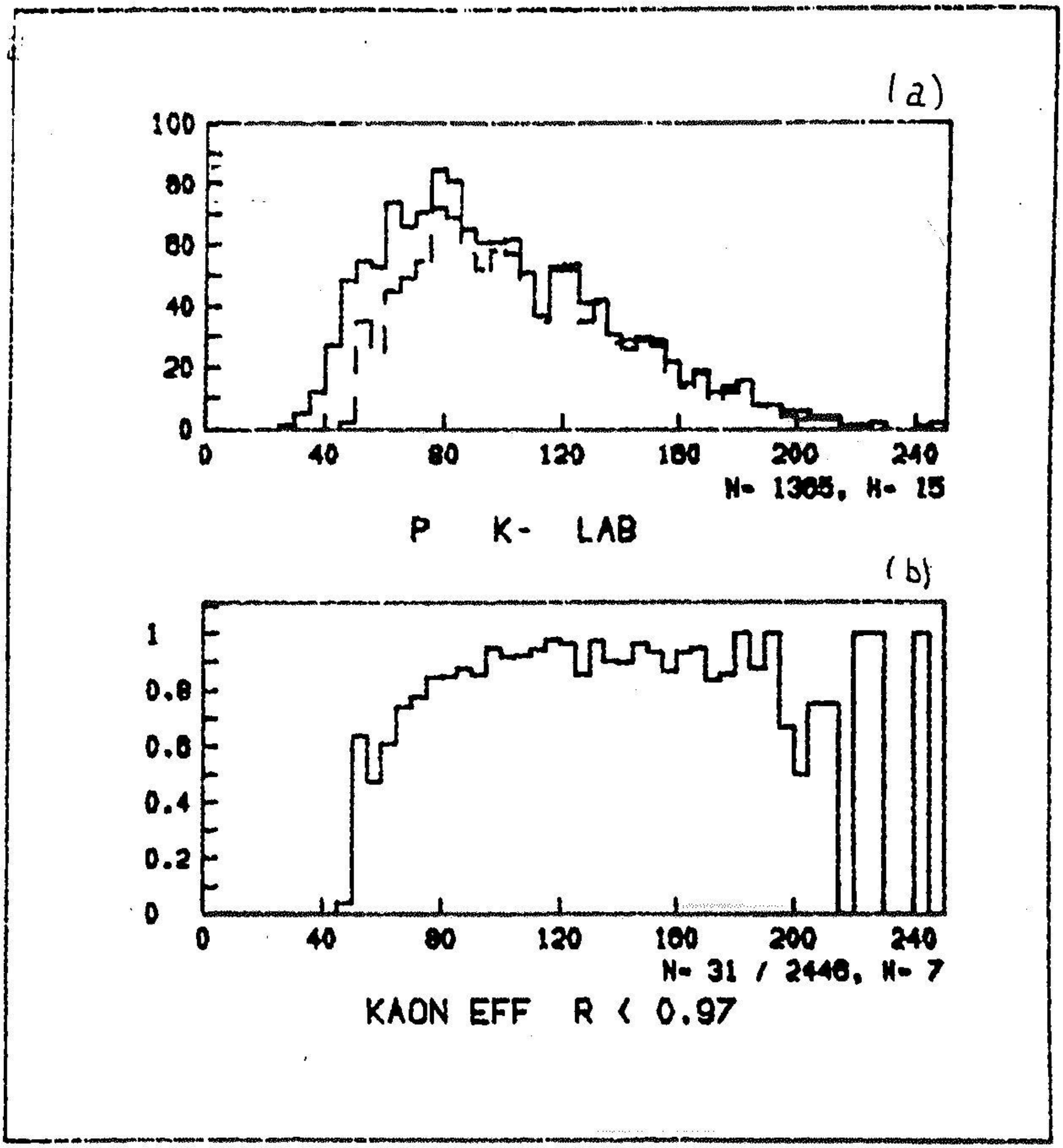


FIGURE 3: (a) K^- momentum for all accepted K^- and detected K^- (dashed) vs P_{K^-}
(b) Ratio of above - efficiency to detect K^- vs P_{K^-}

A+ RICH Trigger Processor

PSC 8-Nov-84

16 Channels / Module 32 Modules / System

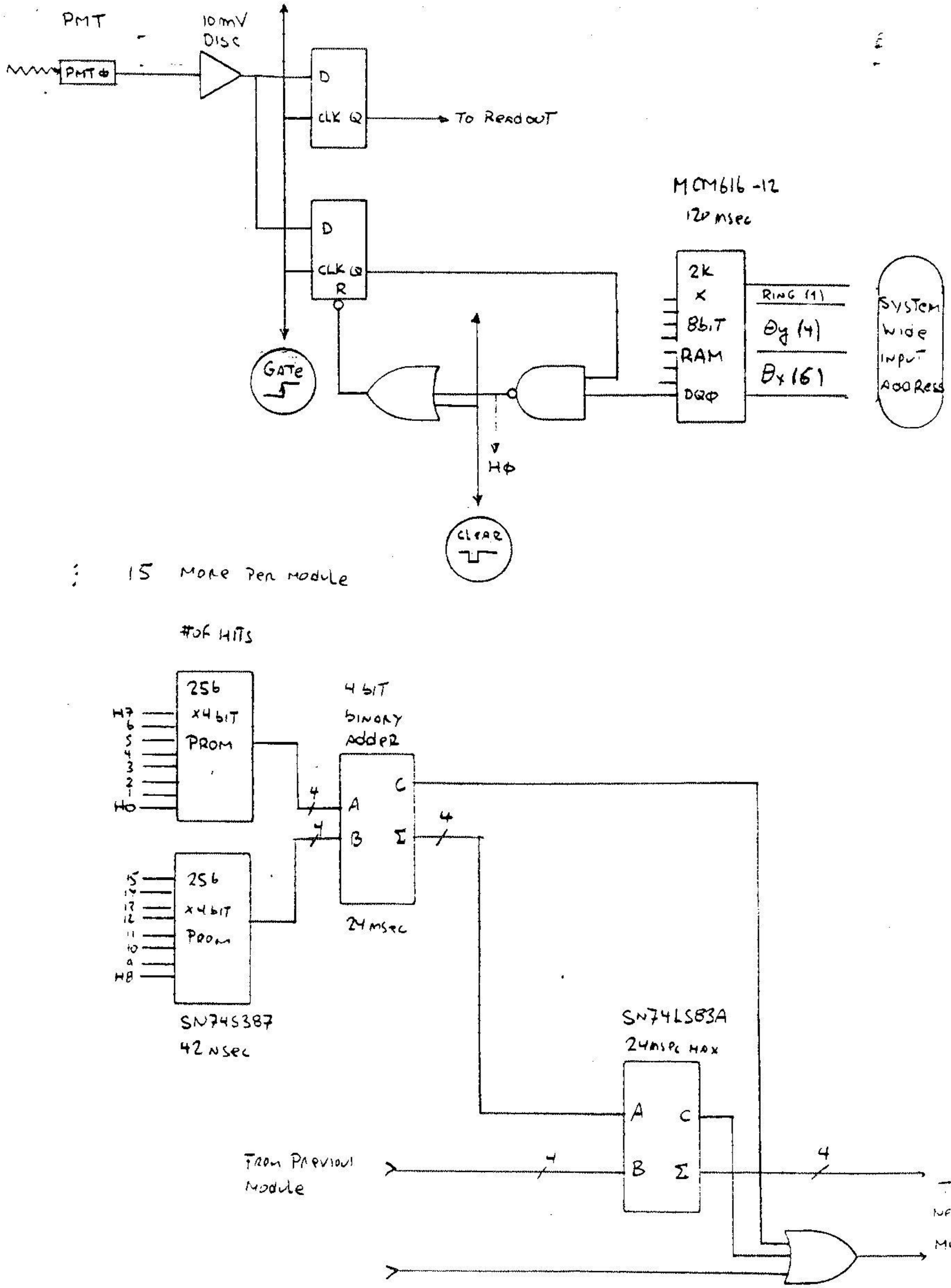


FIGURE 4