A FAST ANALOG PHOTON TRIGGER FOR FERMILAB EXPERIMENT 705

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ABSTRACT

An analog cluster finder / transverse energy trigger for the electromagnetic detector of Experiment 705 is described. The trigger selects interactions having one or more energy clusters over preset transverse energy thresholds in less than 100 nanoseconds plus integration time for the analog signal. The capability of making trigger decisions on this time scale makes this scheme particularly suited to the high rate environment of the SSC type collider.

Fermilab Experiment 705 [1] is a study of charmonium and direct photon production by 300 GeV $p, \bar{p}$, π^+ and π^- beams incident on nuclear targets, including H_2 and D_2. The inclusive production of χ states are studied via the decay $\chi \to \psi + \gamma$; $\psi \to \mu^+ \mu^-$. The key elements of the apparatus include a large aperture, open geometry spectrometer and a high resolution electromagnetic detector. A di-muon trigger processor is used to select high mass di-muons as a trigger for ψ's. A photon cluster finder, which is the subject of this report, selects interactions containing one or more clusters over preset p_t thresholds.

A view of the spectrometer is shown in Figure 1. The electromagnetic detector, located 10 meters from the target, has an angular acceptance of $\pm$ 180 mr in x and $\pm$ 90 mr in y. It is composed of a 176 element 3.5 radiation length active converter, a gas tube position hodoscope with 0.8 cm wire spacing and a 21.5 radiation length main array composed of 392 elements. The active converter elements are 3.5 cm x 3.5cm x 89 cm SCG1-C scintillation glass blocks made by Ohara Optical Co. The main array is composed of three regions of glass blocks. Ninety two elements in the central region are SCG1-C blocks and have the same dimensions as the active converter. Surrounding this central core are 76, 15 cm x 15 cm x 89 cm SCG1-C blocks. The remainder of the elements are 15 cm x 15 cm x 45 cm SF5 lead glass. This arrangement allows maximum energy resolution in the region of the detector most populated by ψ photons.

Test results indicate that $\sigma/\sqrt{E} = 2\%/\sqrt{E} + 1\%$ is achievable in the SCG1-C. $\sigma/\sqrt{E} = 5\%/\sqrt{E} + 1\%$ should be achievable with SF5.[2]

The phototube bases and electronics associated with the glass blocks have been selected to give linearity and precision over a dynamic range of 300 MeV to 100 GeV. The electronics consists of three parts: 1) a front-end charge integrating amplifier, 2) a precision ADC system and 3) a cluster finder / p_t trigger. A block diagram of the concept is shown in Figure 2. All three sections were designed by the Fermilab Research Division Electrical Group. Production was done outside the laboratory.

The front end amplifiers, a multiplexer and a single ADC for 16 channels are contained in a single module. The modules are read out via CAMAC, though the vertical dimension of the boards is 2.5 times larger than standard CAMAC modules. Up to 14 modules can be included in a single modified CAMAC crate. Two five-foot, 50 Ω ribbon co-ax cables transfer the analog signals from a single front end card to two cluster finder modules. Fifty-four cluster finder modules, containing up to eight channels per module are arranged in four custom crates. Each crate has a wire wrapped back plane which transfers the analog signal from each channel to the channels of each of its nearest neighbors. (A nearest neighbor is defined as sharing an edge or a corner.)

The cluster finder is designed to trigger on clusters of $p_t > 1$ GeV/c, corresponding to energies > 5 GeV. An adjustable minimum energy threshold (MET) of 1.5 GeV is required for any channel to be considered a cluster center. Typically this threshold corresponds to a 25 millivolt threshold on the analog input signal. Electronic noise and d.c. offsets in the system are maintained at < 5 millivolts.

The three major components of the trigger scheme are illustrated in Figure 3. These are 1) cluster finding, 2) p_t formation and 3) trigger formation. Each is done on all channels in parallel. The criteria for finding a cluster is that the analog signal in a given channel is greater than each of its neighbors. If these two conditions are satisfied a logical true level is set for that channel. This channel is said to be "peak and over threshold" or POT = .TRUE. Simultaneous with the neighbor comparisons, an analog sum of each channel and its neighbors is formed. Each sum is then attenuated by a set of proportioning resistors which convert the energy sum to transverse energy or p_t. The proportionality factor for each channel is determined by the angle defined by the z-axis and the projection from the center of the target to the center of the block. The p_t sums for each channel are then compared to four different analog d.c. levels which are transported onto each board via a ribbon cable from a computer programmed digital-to-analog converter or DAC. (This same cable also distributes the minimum energy threshold.) The ouputs of the four threshold comparitors are then .AND.'ed with the POT condition for that channel. When the cluster finder board is strobed by the interaction trigger, the four outputs become a 4-bit latch which correspond to four trigger levels for each channel.

The 4-bit latch is .OR.'ed for all channels in a quadrant of the array, yielding a 16-bit condition from which the trigger is derived. The time to produce a trigger to this level is 90 nanoseconds pluse 90 to 120 nanoseconds integration time. Note the integration time is a function of the shape of the analog pulse. These times are measured from the time the analog signal enters the cluster finder.

Each p_t level from the four quadrants is .OR.'ed together. Typical values for the thresholds (in GeV) are $1 \leq p_{t1} < 2$, $2 \leq p_{t2} < 3$, $3 \leq p_{t3} < 4$, $p_{t4} \geq 4$. p_t levels 1 to 3 were prescaled before being written to tape by 2^{11}, 2^8 and 2^5 respectively. All level 4 triggers were written on magnetic tape.

Experimental running conditions of 10^6 interactions/second in a 1 meter H_2 target yield approximately 10 $p_t > 4$ GeV triggers per second.

ACKNOWLEDGEMENTS

Members of the E705 collaboration are the University of Arizona, University of Athens, Duke University, Fermilab, Florida A & M University, Mc Gill University, Northwestern University and Shandong University.

Aaron Lynch and Carl Wegner of the Fermilab Electrical Group designed electronics for the system.

REFERENCES

[1] Fermilab Proposal E-705 (1981).

[2] D. E. Wagoner, et. al., Nucl. Instr. and Meth. 238 (1985) 315.
J. A. Apple, et. al., Nucl. Instr. and Meth. 127 (1975) 495.

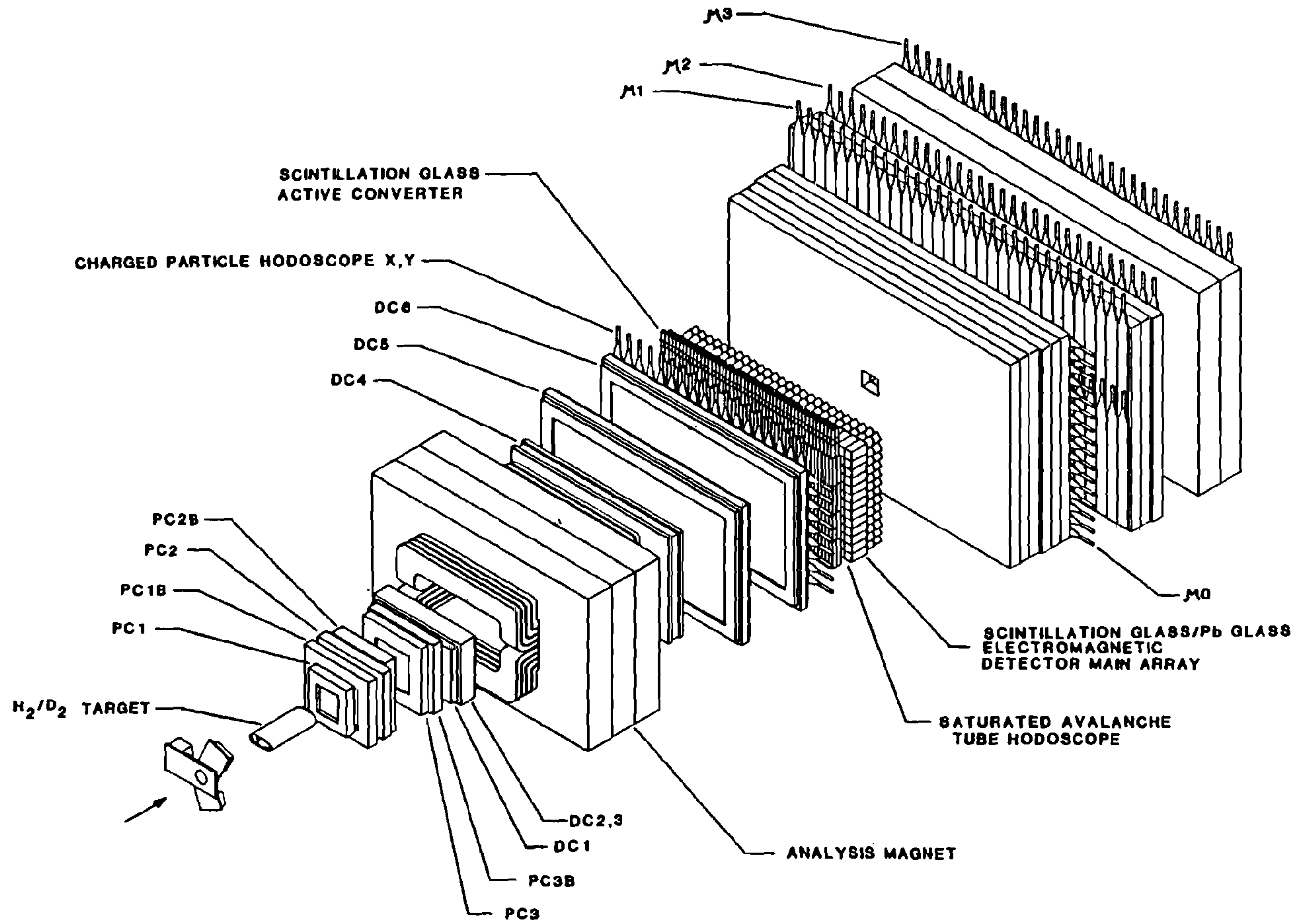

Figure 1 Experimental layout for E705. Note that the electromagnetic detector is located 10 meters from the target.

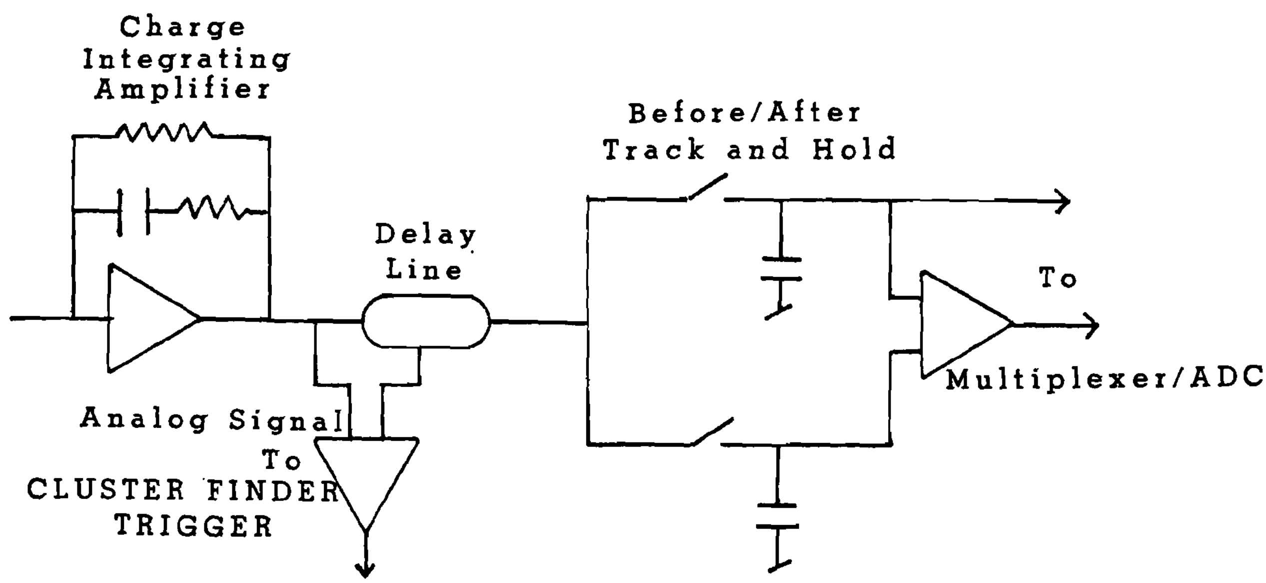

Figure 2 Block diagram of the "front-end" electronics for the e-m detector.

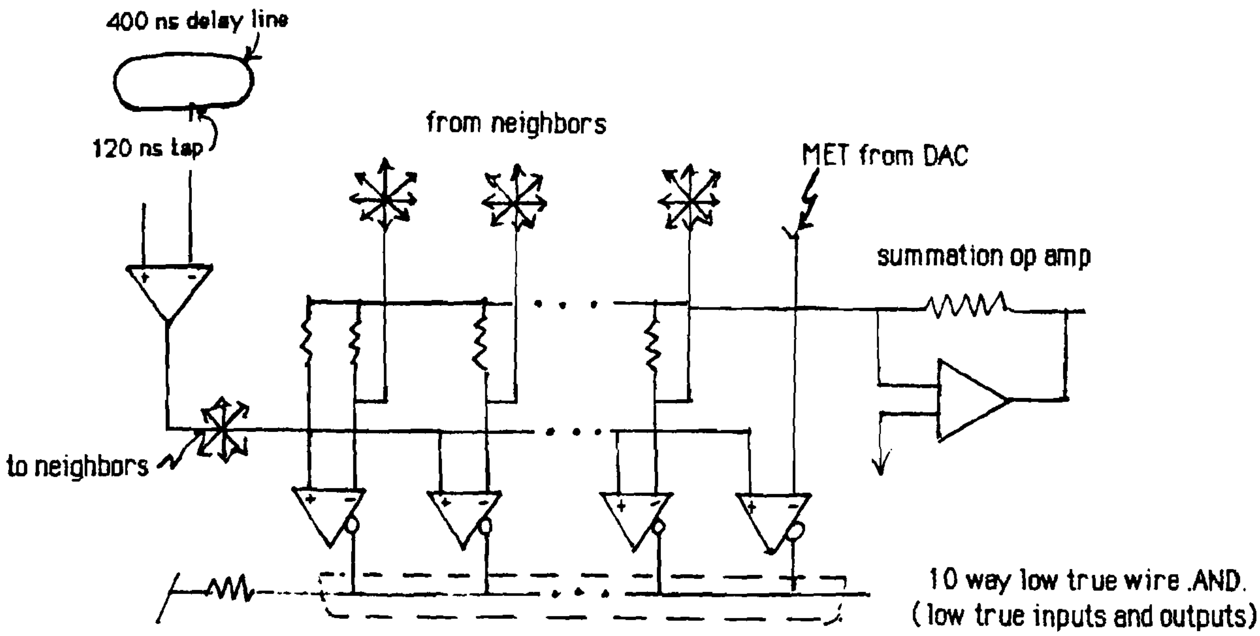

Figure 3a Nearest neighbor and Minimum Energy Threshold comparisons and neighbor summing section.

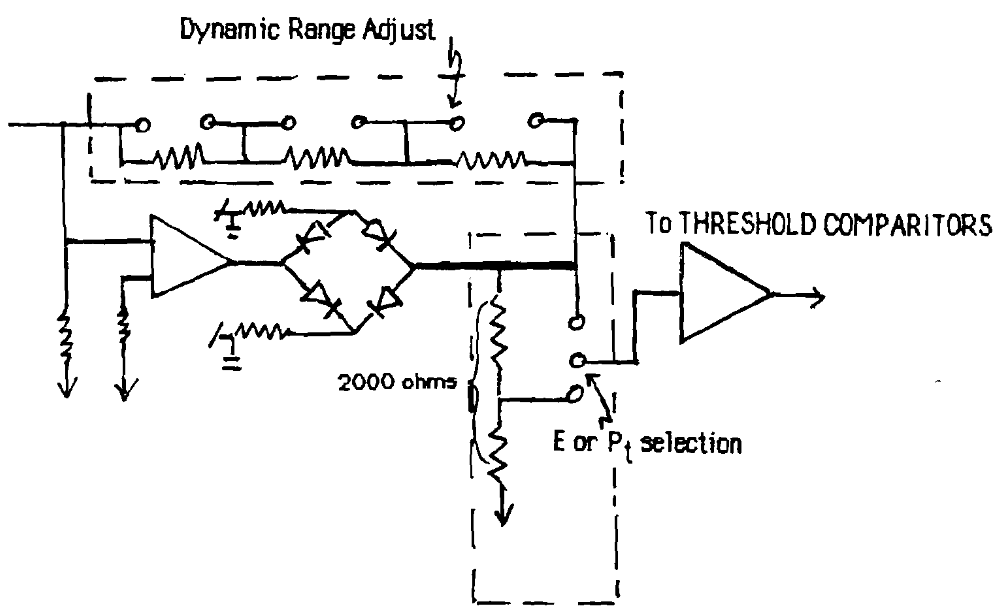

Figure 3b Transverse energy attenuation. Note the system can be operated in an energy mode by use of a jumper wire.

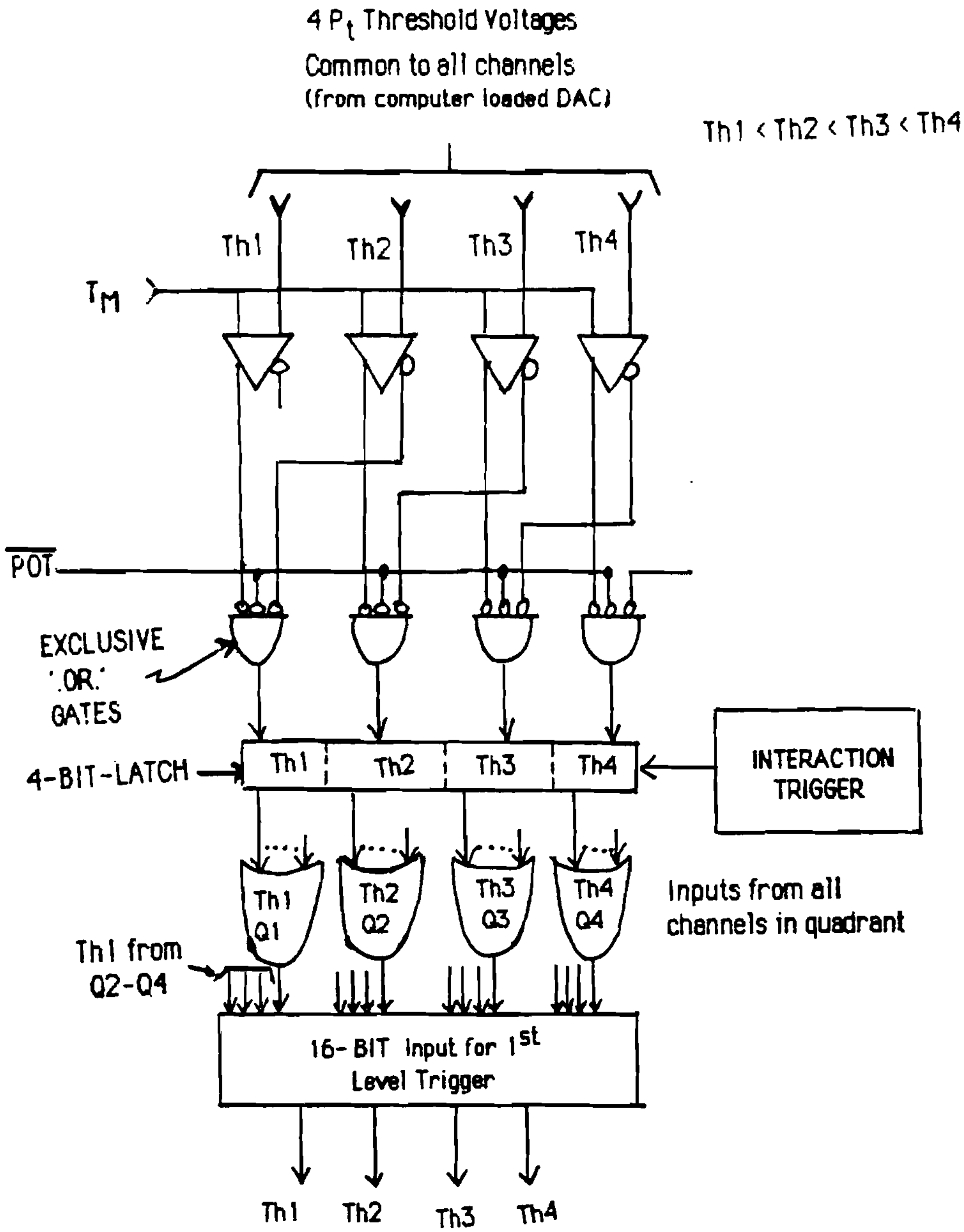

Figure 3c Threshold comparitor and trigger formation section.