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CERN-PRE-78-042

PROGRAMMABLE TRACK SELECTOR FOR NUCLEAR PHYSICS EXPERIMENTS

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CERN, Geneva, Switzerland

(Presented at the Wire Chamber Conference,
Vienna, 14-16 February 1978)

Geneva - 28 February 1978

1. SUMMARY

A rapid Programmable Track Selector (PTS 1) permits track validity decisions to be made on data in pairs of multiwire proportional chambers (MWPCs) in less than 1 μ sec (according to the number of wires hit). All possible acceptable tracks are pre-calculated and stored in the form of a correlation pattern in the PTS 1 memory which then acts as a rapid look-up table.

Acceptable pairs of coordinates falling in chosen areas are made available in buffers for presentation to further, cascaded units.

PTS 2 is similar to PTS 1 but rejects, rather than accepts, tracks in the chosen area and is used in experiment SC 73¹⁾.

Modified PTS units (called FPC = Fast Programmable Calculator) can be used for rapid calculations by loading the memories as look-up tables of the pre-calculated values, thus allowing linear or non-linear single-valued transformations.

A fourth unit called Arithmetic Control Unit (ACU) can indicate a chosen opening angle between two tracks detected by one or several post-target chambers.

2. INTRODUCTION

High-interaction-rate nuclear experiments demand sophisticated inspection of data to eliminate uninteresting events and thus reduce recording rates to manageable proportions.

A separate paper²⁾ explains in detail the physics arguments and the way in which the PTS 1 and FPC units will be used in a particular experiment (WA 6 at CERN)¹⁾. In a second application the PTS 2 is used to reject uninteresting tracks and the ACU to detect electron pairs with a given opening angle (experiment SC 73)¹⁾.

An alternative way of solving this problem would be to have an AND gate for every possible combination of wire hits in the two MWPCs. Thus for chambers with 1024 wires there would be 2^{20} gates. A recent paper³⁾ proposed a solution where 2^{20} integrated latches would be required for two chambers of 1024 wires each [they propose to use 2^{21} latches (= 2,097,152) for three chambers of 128 wires each].

The PTS does not provide a gate for every possible track. By storing pre-calculated data, only 20,480 bits ($< 2^{15}$) are required for two chambers of 1024 wires each.

3. THE READ-OUT SYSTEM

Use is made of the new system called RMH⁴⁾, which is a hybrid version of a fast MWPC read-out system constructed in ECL logic. Each wire chamber plane will

be associated with its own read-out system (crate) so that a binary number representing each hit wire is available to the Programmable Track Selector with the minimum of delay.

The RMH system finds the first word in a crate in 160 nsec, further words each take, on average, 120 nsec (80 nsec if in the same 16-wire group). The read-out systems for each chamber operate concurrently, the data words being stored in 15-word buffers in the Programmable Track Selectors.

4. THE PROGRAMMABLE TRACK SELECTOR

4.1 General

The PTS (Fig. 1) contains a Random Access Memory of 1024 words of 20 bits. This memory is pre-loaded via CAMAC with the relevant pre-calculated values indicating which data in chamber B correspond to data in chamber A.

For each hit wire in the upstream chamber one or more corresponding hits in a downstream chamber may represent an interesting track. This information is stored in memory in the following way.

Each of the possible 1024 wires in the A chamber corresponds to an address in memory. The memory words are split in two parts: the first 10 bits define the first valid X_B wire number corresponding to the X_A wire; the second 10 bits give the last valid X_B wire. All wires between these two values of X_B are valid. After each event the logic of the PTS addresses the memory corresponding to each X_A value and compares the stored information sequentially with each X_B value, the comparator hardware selecting X_B values which fit within the indicated range.

4.2 Signals

The PTS will produce an ACCEPT signal if a good pair of words (a desired track) has been found, or a REJECT indicating no valid tracks. In the case of ACCEPT the valid pairs of words are available in 15-word X_A and X_B buffers, thus allowing valid tracks found in one pair of chambers to be used in further decisions with data in chambers further downstream.

4.3 Operation

An event trigger (from a beam hodoscope, etc.) strobes MWPC signals into the RMH latches. The read-out systems start sending coded data words into the PTSs under control of the PTSs. When both chambers have transferred their data the READ END signals initiate the decision process.

The first X_A word addresses the memory, and then the corresponding stored words for X_B are compared in sequence with each chamber X_B value. If more than

one X_A value is present, each X_A is utilized in sequence and goes through the same comparison with X_B . All good pair combinations are stored in the output memories for subsequent use by further PTS units and an ACCEPT signal is made available if a valid track is found.

4.4 Timing

The time to find the wire numbers has been mentioned above. On reception of both READ END signals from the RMH systems, the PTS begins its decision making. The time to make all comparisons depends on the number of words presented. For one word A and one word B, 40 nsec are required to produce an ACCEPT, or 100 nsec to produce a REJECT, and 100 nsec to store a pair of good words in the output buffer. Three words in A and three in B take 480 nsec for decision and a further 600 nsec for storing. Intermediate combinations take intermediate times.

Thus a single track can be rejected in a total time of 100 nsec or accepted and stored in 180 nsec. Three tracks can be rejected in 340 nsec or accepted and stored in 1080 nsec (measured from the READ END signal).

4.5 Construction

The PTS units require large surface cards to minimize decision delays and are housed in special crates. The loading of the memory is via a special CAMAC module (No. 212). Reading of the memory for checking purposes is done via CAMAC module No. 134. Ten units fit into one crate, allowing comparison of 10 pairs of 1024 wire chambers or of various cascaded decision requirements.

5. THE FAST PROGRAMMABLE CALCULATOR (Fig. 2)

5.1 General

As in the PTS, there are two memory blocks, each of 1024 words of 10 bits. The memories are loaded via CAMAC with values corresponding to any linear or non-linear transformation desired to be performed on the hit wire numbers coming from two chambers A and B (see Fig. 1). The transformed values are then added or subtracted (as desired) and the results made available at an output buffer for further applications in the decision procedure. Each value of A is calculated with each value of B so the number of results is the product of the numbers from A and B.

5.2 Signals

Apart from the word inputs and outputs there is an overflow signal if the calculator tries to furnish more than 15 results (this can occur if too many good track combinations have been found).

5.3 Application

The FPC is a very flexible unit since the actual function transformation may be freely chosen (within the range of the memory, i.e. 0 to 1023).

5.4 Timing

As shown on Fig. 2 the input word transfer time is approximately 100 nsec/word. The calculation + storage takes 120 nsec, and the time for output transfer to a PTS is 100 nsec.

5.5 Construction

The remarks made for the PTS are also applicable to the FPC.

6. THE ARITHMETIC CONTROL UNIT

The ACU receives good post-target chamber words from PTS 2 and stores (for one chamber) the words in input buffers. It then makes subtractions of all possible combinations and compares the result with a value (loaded via CAMAC). For example if we have X_I , X_{II} , X_{III} the ACU will first calculate $X_I - X_I$, then $X_I - X_{II}$, then $X_I - X_{III}$, then $X_{II} - X_I$, $X_{II} - X_{II}$, $X_{II} - X_{III}$, and $X_{III} - X_I$, $X_{III} - X_{II}$, $X_{III} - X_{III}$.

Each subtraction result, as it is found, is compared with the appropriate stored number (pre-loaded via CAMAC: α for X, β for Y, γ for U, δ for V) relevant to that chamber. If the subtraction result is greater than the stored number (i.e. the opening angle for two tracks is greater than the chosen value), one is added to the output counter.

At this point the choices are:

- i) the opening angle has been found to be greater than the chosen value, so the whole event is accepted;
- ii) it is not greater, so we go on to read the next pair of chambers;
- iii) it is greater, we add one to the output counter and then go on to read the next pair of chambers.
- iv) In the case of (iii) when all chambers have been read the system reacts to the number stored in the output counter.

7. PHYSICS REMARKS

The PTS will be used for angular and coplanarity correlation between forward and backward elastic scattering particles, and in other cases in which a correlation exists as a consequence of focusing effects. The fact that new correlation

patterns can be loaded quickly and easily gives great flexibility to experiments. The FPC allows simple non-linear arithmetic to be performed on data. The ACU checks opening angles of pairs of tracks. The units can be combined for more powerful decision making.

8. OTHER APPLICATIONS

In Fig. 3 are illustrated three basic applications from which one can build up complex decisions.

9. CONTRIBUTIONS

This work was initiated after discussions with G. Fidecaro and collaborators; in particular, we acknowledge the valuable contributions of A. Penzo and A. Vascotto.

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- 2) CERN SPSC Proposal 74-17/P 8 (1974).
- 3) E.D. Platner et al., Brookhaven preprint BNL-21831, submitted to Nuclear Instruments and Methods (1978).
- 4) J.B. Lindsay, C. Millerin, J.C. Tarlé, H. Verweij and H. Wendler, A fast and flexible data acquisition system for multiwire proportional chambers and other detectors, presented at this Conference.

Figure captions

Fig. 1 : Programmable Track Selector

Fig. 2 : Fast Programmable Calculator

Fig. 3 : Illustrative applications

- a) Accept particles of given momentum.
- b) Eliminate non-interacting beam particles.
- c) Accept interaction giving greater than a chosen opening angle.

PROGRAMMABLE
TRACK
SELECTOR 1
FIGURE 1

* MAXIMUM 15 WORDS

ASSEMBLY 7245

FAST PROGRAMMABLE CALCULATOR

7241-4A2

FIGURE 2

EP

DE 771212

A/ ACCEPT PARTICLES OF GIVEN MOMENTUM

B/ ELIMINATE NON INTERACTING BEAM PARTICLES

C/ ACCEPT INTERACTION GIVING GREATER THAN CHOSEN OPENING ANGLE

FIG. 3