

# Microcomputer Assisted Multiple Coulomb Scattering Measurements in Nuclear Emulsion Pellicles

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## Introduction

Attempts have been made in the past to automate various aspects of microscope measurement of elementary particle tracks in nuclear emulsion targets exposed to high energy primary particle beams from particle accelerators. These attempts, based largely on obtaining magnified, external 2-d projections, have proved to be uncompetitive since they do not incorporate the built-in 3-d "stereo" view advantage inherent to the microscope method of measuring collision star tracks. However, there is great labor in performing measurements partaking of this "human" factor. Recently, however, the use of on-line, inexpensive microcomputers can simplify and improve the taking of data during various measurement algorithms as well as provide immediate feedback of measurement results toward on-line re-measurement decision making.

In this work, we will discuss the adaptation of a KIM-1 (6502) based microcomputer to the automation of the technique of "multiple scattering" that determines particle track momentum from measurements of the "waviness" of the track of grains.

## Method

A schematic of the automation architecture hardware used is seen in (FIGURE 1). In a typical "multiple scattering" measurement involving the y-coordinate, the Koristka measuring microscope's micrometer eyepiece scale moves up and down relative to a stationary notch as the external knob shaft is rotated clockwise or counterclockwise respectively, thus indicating a change in the crosshair's y-coordinate.

A Dynamics Corporation Model 77 optical encoder, mounted concentric to the knob shaft, transduces a y-coordinate "first difference", amounting to two shaft rotations, into a total of 2,880 successive square pulses (5 volts each). At 550X magnification, this amounts to 4.66 microns in the emulsion. Actually, two parallel pulse trains A & B are sent out, A leading B by 90° for a clockwise rotation and B leading A for a counterclockwise rotation.

On the processing board is a logic circuit shown in (FIGURE 2) that gates through the first train of pulses (A or B) that arrive there and suppresses the trailing train.

The board also contains a NOR gate (see Figure 3) whose inputs are tied to the A & B input lines which enter the computer port, so that its output goes low every time a pulse of the surviving pulse train (A' or B') arrives at the port bits. Since the gate's output is tied to the maskable interrupt (IRQ), an A or B pulse signals the computer to proceed to either the add or subtract service machine subroutines (see KDPASM below). The output of the NOR gate is also tied to still a third port bit, so

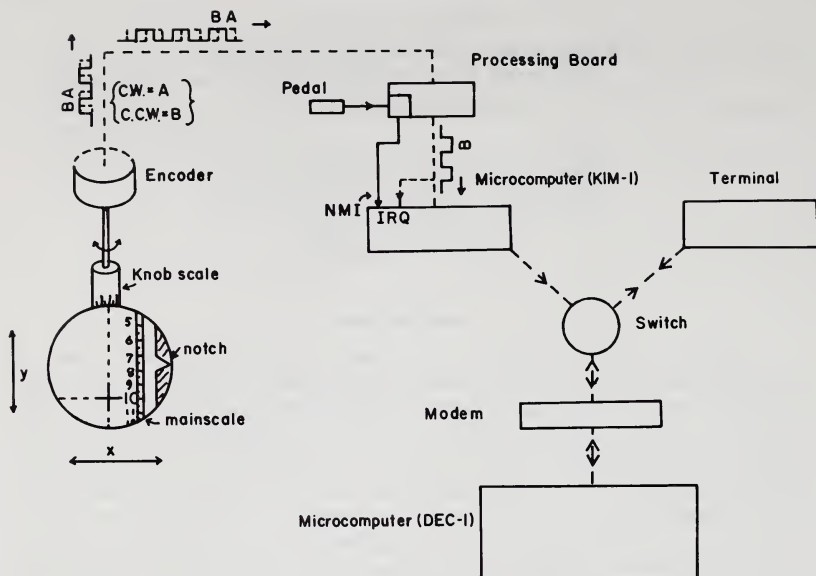


FIGURE 1. *Eyepiece Scale Automation Architecture*

the software can determine when each pulse is finished in order to set up for the next pulse arrival.

A machine language program, previously read in, is used by the KIM-1 to process the various pulse totals for microscope knob twists. This three page (3/4 K, RAM) measurement program (KDPASM) is discussed below. A pedal is tied through a NAND gate debouncing circuit on the board to the non-maskable (NMI) interrupt and is used to jump to various interrupt subroutines of the program during measurement.

By switching the KIM-1 into the role of a terminal for the macrocomputer (DEC-10), the data that was collected and collated by the KIM-1 program can then be dumped through a modem and phone line to the large computer (DEC-10) for computation of particle momentum using the FORTRAN momentum program (SCAT). The function of the terminal (DEC WRITER) is to open and close the hex data input file, and request execution of the SCAT momentum program and finally display the momentum results leading to possible re-measurement.

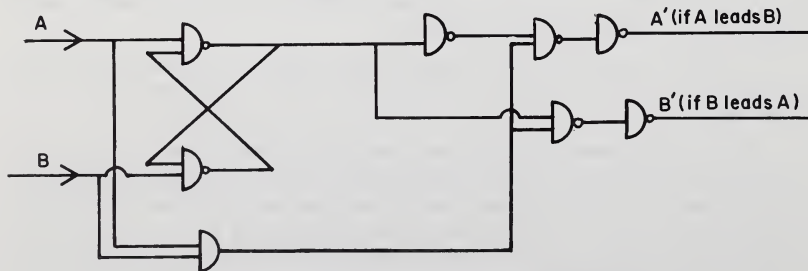


FIGURE 2. *Angular Direction Logic Circuit*

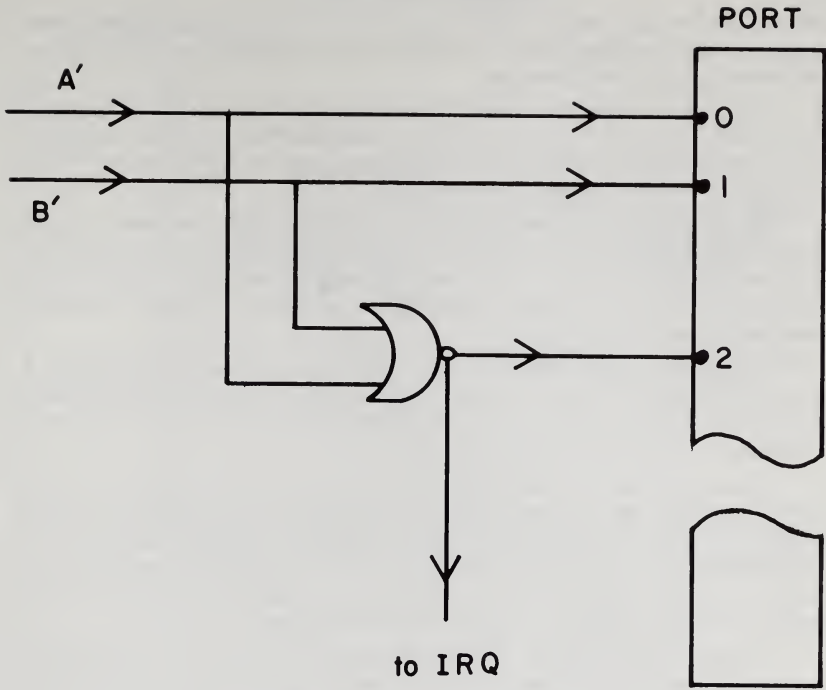


FIGURE 3. *Data Acquisition at Port*

The switch (see FIGURE 1 and FIGURE 4) permits 1) half-duplex between the KIM-1 and the DEC-10 for dumping data to the DEC-1 data file and 2) full-duplex

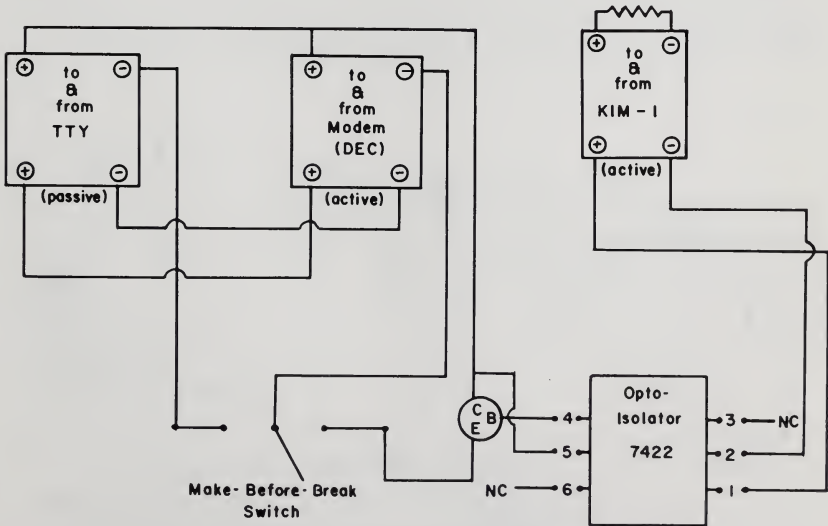


FIGURE 4. *Associated Switch Circuitry*

between the terminal and the DEC-1 for setting up data files and calling fortran programs in the user disk file-in one direction, and receiving calculation results on the terminal-in the other direction.

An associated 7422 opto-isolater chip and a make-before-break feature insures that the DEC-10 does not break off its line of communication with either the KIM-1 or the terminal during switch over between them as inputs devices to the DEC-10, and circumvents electrical ground ambiguity.

The software machine program (KDPASM) was written to receive groups of pulses such as are generated during a typical "multiple scattering" (1) measurement as depicted in (FIGURE 5). Now, once demographic parameter data is keypad entered, several sets of pulses are generated, one for each cell length of x-motion in the general direction of the track.

The overall program description and flow diagram is seen in (FIGURE 6). A pedal interrupt (NMI) signals the end of each segment (of one cell length) and 2 pedal interrupts signal either the end of a track or the end of the "star" of tracks as indicated by pressing the D (dump) key as shown.

Note that within the NEXTSEG subroutine, the segment's *net up* (+ y) or *net down* (- y) (clockwise or counterclockwise knob rotation respectively) number of pulses is always referred to a value of  $8000_H$  (reset for each segment of track). For example, an outputed value of  $7F8F_H$  means  $8000_H - 7F8F_H = 113_{10}$  *net* counterclockwise pulses have been recorded for a segment and  $82F0_H$  means  $82F0_H - 8000_H = 02F0_H = 752_{10}$  *net* clockwise pulses.

A sample DEC-10 data file printout, seen exactly as stored and outputed from the KIM-1 in hex form, is shown in (TABLE 1) and in decimal form suitable for data input to SCAT in (TABLE 2). The pulses per segment are converted to main scale divisions ( $\Delta y$ ) per segment by dividing by 2880 (2880 pulses = 1 eyepiece division) and then microns by multiplying by 4.66 microns per division. This is done in the SCAT fortran program.

The multiple scattering of a charged elementary particle due to collision with emulsion nuclei coulomb fields gives rise to (1) an observed average second difference  $\langle D \rangle$  of y-readings that is related to the momentum p as follows (1):

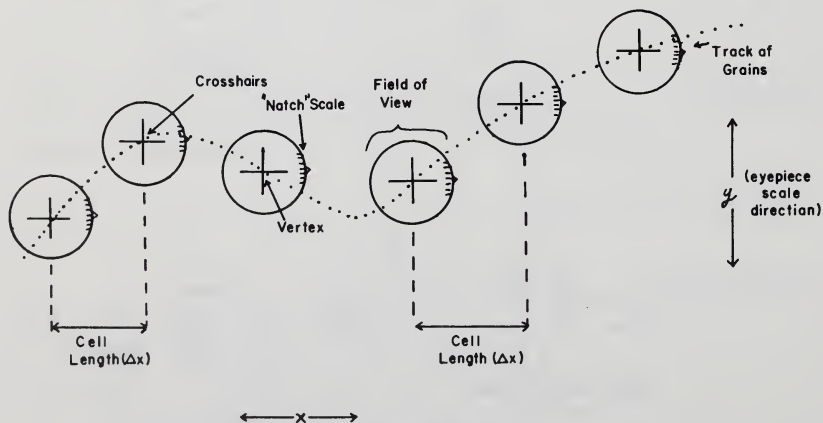


FIGURE 5. Multiple Scattering Measurement Procedure

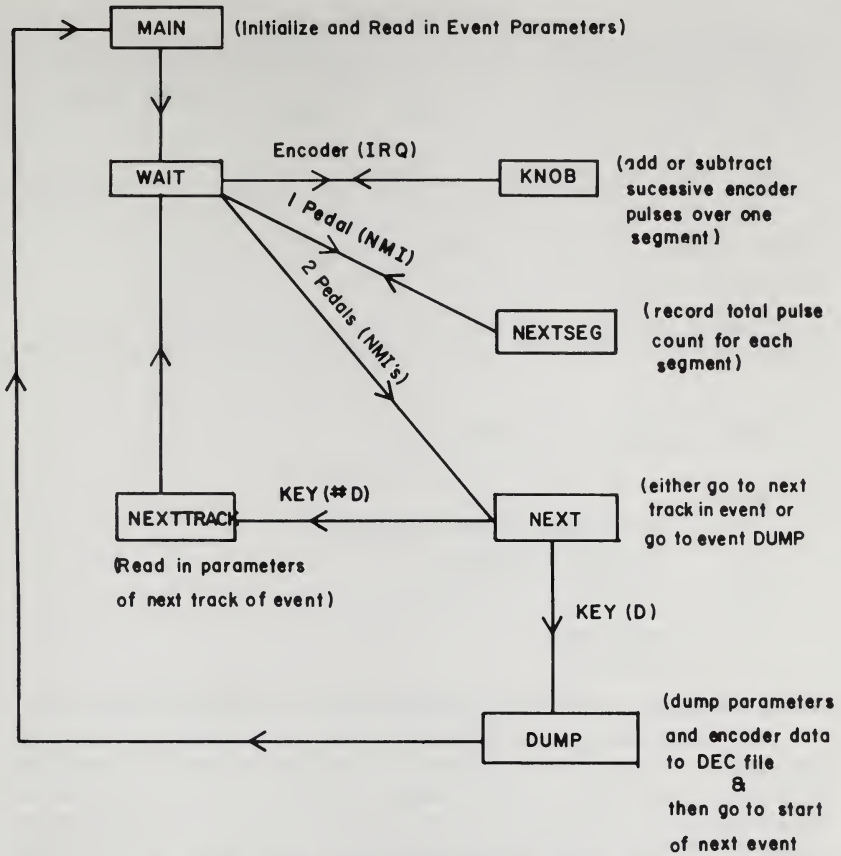


FIGURE 6. KDPASM Machine Program Flow Diagram

TABLE 1. Hex Data File

Name	Plate	Plate	Type	Event	Microns/eyepiece scale division
AA	101279	22	0003	0071	0466

- 01 - One track in event
- 01 - Track number one
- 0250 - Cell length
- 06 - Twice number of segments

3 Segments	{	7F8F - 113 Pulses Counterclockwise (below 8000)	
		814C - 332 Pulses clockwise	(above 8000)
		82FO - 752 Pulses clockwise	(above 8000)

TABLE 2. *Decimal Data File*

Name AA	Event 71	Type 00 + 03P	Date 101279	Name AA
250 cell length		500 2X cell length	.00466 scale	04 readings
				1 track number
10,000	09887	10219	10971	
- 113 pulses	+ 332 pulses	752 pulses		

$$p\beta c = \frac{K C \frac{3}{2}}{573 < D >} - (p \text{ in Mev/c})$$

Where

- K = approximate constant from theory ( $\cong 47$ )
- C = cell length in microns
- < D > = average second difference
- $\beta$  = v/c
- v = particle speed
- c = light speed

This is computed by the FORTRAN program (SCAT) and returned to the terminal.

The overall sequence of software relevant to the multiple scattering algorithm for finding particle momentum then consists of using the machine file KDPASM to receive, treat and store encoder pulse data and then dumping the hex data to the DEC-10 macrocomputer, once a data file has been opened from the terminal. After receipt of data in this file, the file is closed and a fortran program (HEXCVT) located in the DEC-10 converts the hex format to a decimal format. This decimal data file is then used by the SCAT fortran program to compute and return the sought after momentum to the terminal.

### Results and Conclusions

The KIM-1 microcomputer based automation proved to be adequate to provide relatively immediate feedback of particle momenta following measurement of eyepiece scale y-coordinate displacements. In particular, of crucial importance was the relatively short KIM-1 (6502) word-time coupled with short enough add & subtract software routines. This allowed the microprocessor to not miss any pulses arriving at the port during real time "counter" activity. Use of the DEC-10 to make computations is somewhat inconvenient in the sense of manual switching required, DEC-10 down times, etc., but computation time is short with the DEC-10, and only modest KIM-1 RAM memory is required for both machine programming of data manipulation ( $\frac{3}{4}$  K) and for data storage (few K). With the current influx of not too expensive 16 bit, higher speed microcomputers, it would be possible to time-share real-time service of encoders attached to all three microscope dimensions. This would be a giant step toward cheap automation of coordinate measurement both in scanning and plotting of collision events and in multidimensional measurement processes in the emulsion detection approach to High Energy Physics.

**Literature Cited**

1. POWELL, C. F., P. H. FOWLER and D. H. PERKINS. 1959. The Study of Elementary Particles by the Photographic Method. Pergamon Press. London. 114-129. 669 pp.