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ON LINE DATA ANALYSIS OF HIGH ENERGY P-P SCATTERING EXPERIMENT*

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In order to carry out a series of p-p inelastic scattering experiments at high energy, we have developed a system which is capable of analyzing the data from 12 digitized spark planes⁽¹⁾ on line to a PDP-6 computer. During recent test runs at the A.G.S., we have analyzed 10^6 events under various conditions at an average rate of 15 msec per event. This paper describes our operational experience with this system.

Digitized Planes Arrangement:

A general description of the experimental setup is given elsewhere.⁽²⁾ The 12 digitized planes are divided into 3 segments, called X1, Y1, and X2, each of which consists of 4 planes equally separated by a distance of 10'. Each plane of segment X1 has 196 wires running vertically with a spacing of 1/20" in an area 9" wide and 4" high. Each plane of segment Y1 has 96 wires running horizontally with the same spacing and the same effective area as that of X1. Both segments are placed on a line which intersects the incident beam at the center of the target at a given angle. These segments are used to establish the scattering angle of each event. The segment X2, which consists of larger planes with 352 wires running vertically in an area 18" wide and 8" high, is placed after the bending magnets to determine the momentum.

Data Handling System:

A block diagram of the on line data handling system is shown in Fig. 1. The digitized spark planes are pulsed by a suitable coincidence among

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the trigger detectors which include several scintillation counters and, in some cases, a threshold gas Cerenkov counter to reject pions. The trigger logic simultaneously initiates the read out system,⁽³⁾ which reads the cores in groups of 32 and assembles, through a shift register, a spark address in an 18 bit format. Bits 13-17 give the wire number within a group, while the group number is counted in bits 4-12. Bit 0 is used to indicate a beginning of the event. Bits 1 and 2 designate a "double" or "triple" for the cases in which a spark sets simultaneously two or three neighboring cores. Two spark addresses are packed into one 36 bit word and stored successively into a magnetic core buffer memory of 4096 word capacity. At present, it takes about 350 μ sec to read and store the spark addresses from 12 digitized planes, which are spread over a distance of $\sim$ 100 feet.

With each block of events, which corresponds to one A.G.S. pulse, we feed into the buffer memory the run identification, the experimental conditions, the magnetic field reading, and some option flags for program control. They are manually set up by six Digiswitches⁽⁴⁾ and consist of six 36 bit words. In addition, contents of eight scalers are also read into the buffer for each A.G.S. pulse, to provide the beam monitor and other relevant coincidence counts for analysis.

In general, the data stored in the buffer memory are transferred into the computer and simultaneously transcribed on a magnetic tape after each A.G.S. pulse. The transfer speed is limited by that of magnetic tape writing, which is 16 μ sec per 6 bit character at present. However, the program sets up a busy bit to prevent the buffer from transferring any more data until it processes the last event of the previous pulse. The buffer, in turn, inhibits the electronics from triggering during the next pulse when it is still filled with the data from the previous pulse. Thus, for instance, if the event rates exceeds the processing rate by 10%, the system will miss one pulse per every 10 pulses on the average. Alternatively, the program has an option for analyzing only a sample of events on line, while a whole data are stored in the magnetic tape.

On Line Analysis Program:

At the beginning, the program is loaded with input parameters relevant to the experimental conditions. It is normally in a loop waiting for

a start signal from the buffer memory, which precedes the data transfer by 3 msec. As soon as a whole block of data is transferred into an input buffer area assigned by the program, it goes into an initialization process, which sets up a busy bit, interprets and stores the information from the Digiswitches in a proper form, adds the scaler counts, and clears the event counters and histogram area. Then it proceeds to process event by event in the following steps:

- 1) Pick up those spark addresses which belong to one particular event and decode them in terms of a coordinate in each plane.
- 2) Sort out the events in which at least 3 out of 4 planes in a segment have a good cluster of sparks (single, neighboring double or triple). Count the rejected events which have either double misses, one miss and one multiple, or multiples in more than one plane in any segment.
- 3) Fit a straight line through 3 or 4 spark points in each segment. If any one of the 3 points deviates from the fitted line by more than a given number of wire spacings the event is rejected from further analysis. This deviation criterion can be changed as an input parameter to the program.
- 4) Establish the particle trajectory before and after the bending magnets in the laboratory system. Calculate the polar and azimuthal angle of scattering (θ and φ).
- 5) Calculate the momentum p and make a small correction due to inhomogeneity of the field, if necessary.
- 6) Count the accepted events in several histograms, correlating p and $\cos\theta$, φ and $\cos\theta$, or p and φ in preselected ranges of these parameters.
- 7) Store p , $\cos\theta$, φ and other pertinent information per event on magnetic tape at 800 B.P.I. This is to reserve the information per event for more sophisticated analysis to be done off line.

When the last event of the block is processed, the program clears the busy bit and returns to the loop waiting for a transfer of the next block of data from the buffer memory. The run can be terminated by setting a particular bit in one of the Digiswitches before any A.G.S. pulse. Then the program immediately prints out the results on a line printer. Figure 2 shows a typical example of the summary of the run for the set up at 60 mr. It includes the run identification, experimental conditions, accumulated scaler events, a list of input parameters, and the number of events accepted and rejected by the sorting and the line fitting processes.

Figure 3 tabulates the counts of single, double, triple, miss and multiple in each plane. We found that this information is very valuable in monitoring the performance of the spark planes during the run.

Figure 4 is the histogram correlating p and $\cos\theta$ in the ranges indicated by the heading. Any column gives the momentum distribution at a particular angle bin, while any row gives the angular distribution within a particular momentum bin. The range and step of each parameter can be fed to the program through the teletype at the beginning of the run.

Figure 5 shows a similar histogram correlating φ and $\cos\theta$.

Figure 6 gives both horizontal and vertical distributions of the beam obtained by extrapolating each event line to the center of the target. Any number of these histogram counts can be plotted on a line printer or can be displayed on a scope. Figures 7 and 8 show examples of such a plot.

The program has an option to process events from the magnetic tape input, as well as on line. This will enable us to continue taking data on tape and analyze them later in case the computer has a temporary failure during the run.

The total size of our program is about 11,000 words, half of which are instructions and the rest are used for input-output buffer and histogram storage. In addition, a control routine called "DDT"⁽⁵⁾ is loaded with the main program. With the extensive use of this routine, a great amount of flexibility is built into our program for changing any memory content, con-

sequently changing program flow or input parameters to satisfy the different experimental requirements.

The program can be used, with minor modifications, for a similar scattering experiment involving more than 12 planes. With the addition of a plane in which wires run diagonally, it is also possible to extend our system to analyzing two-track events.

We wish to express our gratitude to J. Fischer for developing planes according to our need and to H. R. Pate and W. A. Higinbotham for designing and improving the readout system.

References:

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G. B. Collins, J. Fischer, W. A. Higinbotham, CERN 64-30, 117, June 1964.
2. E. Bleser et al., a paper submitted to this conference.
3. W. A. Higinbotham, J. F. Jacobs, H. R. Pate, BNL Report #8519.
4. An alphanumeric switch coded for 6 bit ASCII, manufactured by the DIGITRAN Co., Pasadena, California.
5. "Dynamic Debugging Technique", supplied by Digital Equipment Corporation, Maynard, Massachusetts.

Figure Captions:

- Fig. 1. Block diagram of on line data handling system for digitized spark planes.
- Fig. 2. An example of the summary of the run. The systems are set up at a nominal 60 mr scattering angle for 10 BeV/c incident beam.
- Fig. 3. A table for the performance of the planes. The last two columns (WRPOS and PLPOS) are input parameters for each plane.
- Fig. 4. A histogram correlating p and $\cos\theta$. The momentum is divided into 40 bins between 6.5 BeV/c (top of the column) and 10.5 BeV/c (bottom of the column) with a step of 0.1 BeV/c. The cosine of scattering angle ranges from 0.9975 (extreme left) to 0.9990 (extreme right) with a step of 0.0001. Any column, thus, corresponds to the momentum distribution in an angular bin of 1.67 mr.
- Fig. 5. A histogram correlating ϕ and $\cos\theta$.
- Fig. 6. The horizontal (TGTX) and vertical (TGTY) distribution of the beam at the center of the target. The unit for MIN, MAX, and STEP is 0.025".
- Fig. 7. A plot of the momentum distribution of scattered protons at $\cos\theta = .9986-.9987$. The elastic peak corresponds to 9.85 BeV/c. The bin size is 0.1 BeV/c.
- Fig. 8. A plot of the vertical distribution of the beam at the target, (corresponds to the 2nd histogram of Fig. 6). The bin size is 0.2".

FIG. 1

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RUNNO = 137, DATE = MAR 29, EXPCON = 1.F060, PINC = 10 BEV, HLPB = 035.00, OPSW = 1H280, SINFLG = 0
SCALER(0) - SCALER(7) = 373337 370136 13771813 632412 13501310 1084492867 0 0
SEGMENT POSITION
SEG SA CA XZERO YZERO ZZERO
1 0.26200000 -0.99819999 563.33999 96.000000 6192.5599
2 0.26200000 -0.99819999 563.33999 96.000000 6192.5599
NO OF MAGNET = 1, MG FIELD IN KG = 7.9800000, CONFAC = 0.00228000, PCONST = 0.00076149, SEPMAG = 0.00000000
MAGNET POSITION
NO XM ZM MPX MPZ
1 37.619999 620.09999 0.07739999 0.99699999
2 42.199999 691.90000 0.07739999 0.99699999
TOTAL INPUT EVENTS = 23305, INPUT RECORDS = 1071, OUTPUT RECORDS = 0
SORT SUMMARY
REJECTED BY XSEG1 = 160, BY YSEG1 = 141, BY XSEG2 = 224
REJECTED BY XDBL1 = 1021, BY YDBL1 = 329, BY XDBL2 = 378
TOTAL SORT EVENTS = 21052
FIT SUMMARY
CONDITION FOR FIT, MAXDEV = 4
REJECTED BY XSEG1 = 836, BY YSEG1 = 727, BY XSEG2 = 139
TOTAL FIT EVENTS = 19350
SELECTION ON INTERSECTION, ZMIN = -180.00000, ZMAX = 180.00000
REJECTED BY INT1 = 0, BY INT2 = 0
SELECTION ON MAGNET, MAXDDX = 0.60000000
REJECTED BY MAGNET = 174
12
11 TOTAL GOOD EVENTS = 19176
10 IGE/TIE = 0.92282771
9 IGE/SCALER(0) = 0.05136378
8 IGE/SCALER(1) = 0.05180798
7
6
5
4
3
2
1

```

FIG. 2

PLANE SUMMARY							
PLANE	SINGLES	DOUBLES	TRIPLES	MISSES	MULTIPLES	MRPOS	PLPOS
1	9592	16964	219	528	3418	000021000001	000000000000
2	6380	17555	160	885	1151	000041000301	011300000000
3	9815	14090	63	595	726	000061000601	022600000000
4	5944	17471	167	917	676	001301001101	034100000000
5	16972	7789	27	767	1738	400021001401	000120000000
6	14280	9296	13	801	598	400041001541	011420000000
7	15070	8392	18	806	477	400061001701	022720000000
8	14379	9175	15	714	471	405301002041	034220000000
9	5343	17216	254	1535	566	000022002201	000000000000
10	1460	21018	1444	688	779	000042002741	011300000000
11	1724	19939	1862	825	603	000062003501	022600000000
12	837	19523	2830	75	627	005702004241	034100000000

FIG. 3

HISTOGRAMS

PCOR. PMIN = 5.500000, PMAX = 10.500000, DP = 0.09999999
 THETA, TMIN = 0.99749999, TMAX = 0.99899999, DT = 0.00009999
 PHI, MIN = -20.000000, MAX = 20.000000, DTP = 1.0000000
 INSIDE = 18954, OUTSIDE = 212

0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	8
0	0	0	0	0	0	0	0	0	0	0	0	0	18	11	5
0	0	0	0	0	0	0	0	0	0	0	0	1	21	10	4
0	0	0	0	0	0	0	0	0	0	0	0	13	37	17	9
0	0	0	0	0	0	0	0	0	0	0	0	33	35	6	2
0	0	0	0	0	0	0	0	0	0	0	2	48	45	12	5
0	0	0	0	0	0	0	0	0	0	0	3	72	35	6	7
0	0	0	0	0	0	0	0	0	0	1	16	76	38	11	3
0	0	0	0	0	0	0	0	0	0	1	28	61	44	17	10
0	0	0	0	0	0	0	0	0	0	1	54	58	44	6	8
0	0	0	0	0	0	0	0	0	0	10	55	78	30	8	7
0	0	0	0	0	0	0	0	0	1	17	90	72	43	10	3
0	0	0	0	0	0	0	0	0	0	20	82	70	42	12	5
0	0	0	0	0	0	0	0	0	0	37	84	73	39	21	3
0	0	0	0	0	0	0	0	0	3	54	69	59	39	8	7
0	0	0	0	0	0	0	0	1	14	66	81	67	47	10	2
0	0	0	0	0	0	0	0	0	19	71	70	83	40	11	13
0	0	0	0	0	0	0	0	2	30	84	74	72	39	14	3
0	0	0	0	0	0	0	0	1	43	64	83	99	44	14	8
0	0	0	0	0	0	0	0	6	60	95	96	86	51	17	7
0	0	0	0	0	0	0	0	6	73	80	111	87	51	14	6
0	0	0	0	0	0	0	0	12	79	68	89	92	40	15	4
0	0	0	0	0	0	1	21	80	66	84	87	56	15	3	3
12	0	0	0	0	0	0	25	47	64	75	74	28	15	6	6
0	0	0	0	0	0	6	21	48	50	52	69	38	11	10	10
11	0	0	0	0	0	1	2	18	38	44	50	56	25	9	11
0	0	0	0	0	0	5	13	30	24	57	59	25	16	4	4
10	0	0	0	0	0	0	10	59	63	50	73	60	34	12	10
0	0	0	0	0	1	58	220	221	245	262	169	103	30	18	18
9	0	0	0	0	1	3	165	593	621	748	850	762	353	72	21
0	0	0	0	0	5	140	404	531	746	957	1009	514	90	30	30
8	0	0	0	0	6	65	145	185	251	377	463	266	67	23	23
0	0	0	0	0	1	18	26	47	74	98	128	75	27	6	6
7	0	0	0	0	0	4	6	5	10	13	27	17	7	0	0
0	0	0	0	0	0	1	0	4	3	7	7	6	2	0	0
6	0	0	0	0	1	0	0	0	2	1	3	1	0	0	0
0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
5	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0

FIG. 4

PHI, MIN = -20.000000, MAX = 20.000000, DIP = 1.000000
 THETA, TMIN = 0.99749999, TMAX = 0.99899999, DT = 0.00009999
 PCOR, PMIN = 6.500000, PMAX = 10.500000, DP = 0.09999999
 INSIDE = 18954, OUTSIDE = 212

0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	0	0	1	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	1	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0	1	1	0	0	0	0
0	2	0	0	0	0	0	0	1	0	0	1	0	1	0
0	2	0	0	0	0	0	0	0	1	0	0	1	1	1
0	2	0	0	0	0	0	0	0	0	3	9	3	2	1
0	2	0	0	0	0	1	16	25	38	78	97	55	14	8
0	2	0	0	0	1	55	228	321	382	520	530	280	81	41
0	2	0	0	0	5	97	306	463	530	666	688	342	103	47
0	2	0	0	0	4	108	320	416	559	668	670	369	92	34
2	2	0	0	0	2	96	301	367	556	691	697	388	83	48
0	2	0	0	1	2	77	246	351	520	730	705	404	105	41
2	2	0	0	1	2	39	146	236	359	512	648	337	108	41
0	2	0	0	0	0	0	15	61	99	169	216	178	40	14
2	2	0	0	0	0	1	0	0	3	5	6	8	6	1
0	2	0	0	0	0	0	0	0	0	2	2	2	0	1
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	1	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	0	0	0	0	0	0	1	0	0	0	1	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	1	0	0	0
10	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
6														
5														
4														
3														
2														
1														

FIG. 5

TGTX MIN = -160.00000, MAX = 160.00000, STEP = 8.0000000
 INSIDE = 18911, OUTSIDE = 265

0	0	1	1	0	0	1	1	2	9
15	18	61	103	205	373	617	937	1156	1493
1708	1894	2002	1799	1560	1307	975	754	460	373
277	162	93	74	88	99	87	69	66	71

TGTY MIN = -160.00000, MAX = 160.00000, STEP = 8.0000000
 INSIDE = 19175, OUTSIDE = 1

0	2	0	1	0	0	2	2	2	3
3	2	5	6	9	24	55	388	1457	2757
3711	4062	3771	2401	400	44	20	9	6	5
2	3	2	5	2	3	1	0	0	2

FIG. 6

RUNN0 = 137

IDISPL = 00214 SUMHIS = 4273 MAXIM = 1000

FIG. 7

RUNN0 = 137

IDISPI = 03000 SUMHIS = 19175 MAXIM = 4862

FIG. 8