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REAL-TIME ON-LINE PROGRAMS FOR THE π-e SCATTERING EXPERIMENT USING AN HP 2116B COMPUTER. II

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Адылов Г.Т., Алиев Ф.К., Гаевски В. и др. **E1 - 6908**

Математическое обеспечение $\pi - e$ эксперимента в реальном масштабе времени на базе вычислительной машины *HP 2116B*. Часть 2

Дано описание программы геометрического и кинематического восстановления упругих двухлучевых событий в реальном масштабе времени эксперимента по $\pi - e$ рассеянию, выполненного на ЭВМ *HP 2116B*.

Сообщение Объединенного института ядерных исследований
Дубна, 1973

Adylov G.T., Aliev F.K., Gajewski W. et al. **E1 - 6908**

Real-Time On-Line Programs for the $\pi - e$ Scattering Experiment Using an HP 2116B Computer. II

The trackfinding programs are described which recover "pair" events by geometrical and kinematic criteria at the real-time of the $\pi - e$ experiment using an HP 2116B computer.

Communications of the Joint Institute for Nuclear Research.
Dubna, 1973

This paper presents a detailed description of the program TRFIT. The software of the $pi - e$ elastic scattering experiment for the HP 2116B computer uses this program. The basic software is described in ref. /1/ the experimental setup is presented in ref. /2/.

The program TRFIT is written in assembler language and is disk-resident. TRFIT is scheduled by the control program ASR (see ref. /1/).

The program includes the main program TRFIT and subroutines: BOX $_{1-3}$, TRFIN, PAIR, FITER, DPMLY and RESID. The subroutines BOX $_{1-3}$ decode information by appropriate blocks of spark and proportional chambers. The arrays of spark coordinates ("XY")and of the number of sparks in the chambers ("NSXY")are used by the subroutine TRFIN for track finding in one view (XOZ or YOZ) in each block. The parameters of tracks found have been calculated by the least-square method using FITER. We use DPMLY for fitting track parameters in double precision words because the maximum available number of modules, M, is 32768. RESID calculates the residuals for each track in the given chamber. The main program initiates the work of the decoding and track-finding subroutines in all blocks of the chambers. PAIR is called for two- and three-track events in the second block and looks for an intersection (pair vertex) of two tracks in the target, calculates the momenta of secondary particles and analyzes the coplanarity of the event.

a) Subroutine for decoding information from the spark and proportional chambers.

The coordinate of the i-th spark in the j-th chamber in the orthogonal coordinate system of the given block of the chambers in XOZ view is expressed by the formula:

$$X_{i,j} = X'_{i,j} \cdot D_{i,x} + C_{i,x}$$

and correspondingly in YOZ view:

$$Y_{i,j} = Y'_{i,j} \cdot D_{i,Y} + C_{i,Y}$$

where X' (or Y') is the spark coordinate in the coordinate system of the chamber along OX (or OY) axis; $D_X(D_Y)$ is the normalized signal velocity in the magnetostrictive ribbon. This value is determined by the program FUDUK /1/. C_X (or C_Y) is the correction constant (compensate for chamber misalignment) of the chamber; l is the index of the chamber number; i is the index of the spark number in the l -th chamber; X (or Y) is a new spark coordinate in the orthogonal coordinate system of the given block.

The spark coordinates were used as integer numbers and corresponded to counts of the 20 megacycle oscillator of the readout electronics (''clock'' counts).

The spark coordinates of the rotated chambers in the coordinate system of the given block are obtained by transforming:

$$X_i = X'_i \cdot D_{l,X} \cdot \cos a + Y'_{ii} \cdot D_{l,Y} \cdot \sin a + C_{l,X} ,$$

$$Y_{ii} = Y'_{ii} \cdot D_{l,X} \cdot \cos a - X'_i \cdot D_{l,X} \cdot \sin a + C_{l,Y} ,$$

where a is the rotation angle of the l -th chamber.

For the proportional chambers the numbers of the wires fired are also calculated in the coordinate system of the first block, namely:

$$X = N \cdot K + C_X ; \quad Y = N \cdot K + C_Y ,$$

where N is the number of a wire fired; K is the coefficient of transformation of the coordinate into the ''clock'' counts (this value is equal to 11.196 mm); C_X (C_Y) is the diddle constant.

When two adjacent wires fired in the proportional chamber we used an average coordinate value of both wires; in the case of three wires we used the coordinate of the average wire. The cases with four or more wires were not considered.

b) Track finding algorithm

The track finding algorithm in (XOZ or YOZ) views in one block of the chambers is as follows. Two chambers, called ''magic chambers'' were chosen. A straight line was drawn through two sparks of the two chambers. This straight line was considered as a new one if it had parameters (e.g., slope) different from previously found tracks (slope - 1 mrad, intercept - 5 mm). Sparks in the other planes are found on condition that:

$$|X_l - X'| < \epsilon ,$$

where X_l is the coordinate of the l -th spark in the chamber; X' is the coordinate of the straight line projection onto the plane of the chamber; ϵ is the five standard deviations of coordinate accuracy (± 3 mm).

In each track we required four sparks as the minimum number to define a track. The coordinates of a new track were compared with the coordinates of all previous tracks. If the new track was different from the previous ones by at least one spark in the first K sparks (K is a constant for each block), the track was considered to be a new one. It could happen that the coordinate of one and the same spark or even the coordinates of $K-1$ sparks are used for two different tracks. Such a procedure is necessary for finding pair events with a small opening angle (≈ 2 mrad). Then the parameters of each new track were calculated by the least-square method. For the slope parameter a we have:

$$a = \frac{n \sum_l^n X_l Z_l - \sum_l^n X_l \sum_l^n Z_l}{n \sum_l^n Z_l^2 - (\sum_l Z_l)^2},$$

where n is the number of sparks in the track; X_l is the spark coordinate in the l -th chamber; Z_l is the position of the l -th chamber along the beam. The slope parameter was expressed in units: ''clock'' counts/8 meters ($\approx$ 0.03 mrad).

The intercept b is as follows:

$$b = \frac{\sum X_l \cdot \sum Z_l^2 - \sum X_l Z_l \sum Z_l}{n \sum Z_l^2 - (\sum Z_l)^2} .$$

The quality of the track parameters found was estimated by the χ^2 criterion:

$$\chi^2 = \sum \left(\frac{X_l - a \cdot Z_l - b}{\sigma} \right)^2 < \eta ,$$

where η is a limit on the limiting value of χ^2 and σ is the coordinate error of the chambers. The value χ^2 normalized to the number of sparks, was introduced into the histogram of the χ^2 distribution. Figure 1 presents this distribution for tracks in the first block.

In order to continue track finding, a new straight line was drawn through other spark combinations in the chambers. If all sparks of one of the chambers were considered the program uses the next two ''magic'' chambers. For each block we used three pairs of the ''magic'' chambers. For a more efficient performance of the program and fast rejection of background events, special conditions - characteristic for each block - were required for track finding. The track finding conditions for the first block are as follows:

- it is necessary that the proportional chambers ("X" or "Y") should fire only for one track;
- the track found should project through the liquid hydrogen target;
- only one-track events were considered.

The track finding conditions for the second block are:

- each track in the target must be matched to the track of the first block;
- $K-1$ sparks ($K=4$ for the second block) of one track can be used by another track;
- track finding was stopped after three matching tracks were found.

The track finding conditions for the third block of the chambers are:

- only those straight lines that are matched to tracks of the second block are drawn through the sparks of the chambers: the coordinate difference of the track projections from the second and third blocks into the center of the magnet in XOZ and YOZ views must be less than 10 mm, and in the YOZ view, more than 3 mrad in slope;
- only one spark can be used by two different tracks;
- only the first three matched tracks were used.

c) Selection of "pair" events

The momentum P is calculated for each track of the second block that matched a track in the third one. The magnetic field is assumed to be homogeneous.

$$P = \frac{H}{X'_3 - X'_2 + a},$$

where H is the constant for the analyzing magnet SP-12 at a field of 17 kilogauss; X'_3 and X'_2 are the slope parameters of the track in the third and second blocks respectively; a is the rotation angle of the third block (65 mrad).

Tracks found in block two were tested two at a time to look for a pair vertex. Each combination was tested as a pair and then for kinematic cuts. The events were tested as a pair as follows. The opening angle of secondary particles is determined

in each view. The Z-vertex of the pair is determined in the view (XOZ or YOZ) that has the largest opening angle. The difference between the projections A_1 from the second block A_2 from the first block is defined as the Z-coordinate. The given event satisfies a pair test if the difference between A_1 and A_2 satisfies the inequality:

$$|A_{1X} - A_{2X}| < \epsilon \qquad \text{and} \qquad |A_{1Y} - A_{2Y}| < \epsilon$$

ϵ is the number that depends on the angular accuracy of the chamber blocks.

The distributions of the corresponding coordinates A_X, A_Y and Z are presented in Figs. 2,3 and 4. Figure 5 gives the total momentum distribution of events from the selected pairs.

Finally, the combination was tested for coplanarity. The event withstood a coplanarity test if $\cos^2\theta$ between the primary particle and the perpendicular to two secondary tracks satisfied the cut:

$$\cos^2\theta = \frac{1}{X'^2_3 + Y'^2_3 + 1}\left\{\frac{(X'_1Y'_2 - Y'_1X'_2) + (X'_2Y'_3 - Y'_2X'_3) + (X'_3Y'_1 - X'_1Y'_3)}{\sqrt{(Y'_1-Y'_2)^2 + (X'_2-X'_1)^2 + (X'_1Y'_2 - Y'_1X'_2)^2}}\right\}^2 < \eta,$$

where η is a small value equal to 25×10^{-10} rad.; and Y'_i and X'_i are the slope parameters of the i tracks in YOZ and XOZ views, respectively.

Figure 6 gives the histogram of the $\cos^2\theta$ distribution.

The transverse momentum was calculated by the formula:

$$P_X = x'_0 \cdot P_0 - x'_1 \cdot P_1 - x'_2 \cdot P_2 ,$$

where X'_0 is the slope of the track in the first block; X'_1 and X'_2 are the slopes of the tracks in the second block; P_0 is the beam momentum (50 GeV); and P_1 and P_2 are the momenta of secondary particles.

Thus, the following independent conditions were used to select pair events:

- the total momentum of secondary particles must correspond to that of the incident beam;
- the position of X, Y and Z vertices must be in the target;
- the event must be coplanar;
- the sum of transverse momenta of primary and secondary particles must be close to zero.

The number of the events satisfying all these conditions was also determined.

References

1. G.T.Adylov et al. JINR Preprint, E1-6907, Dubna, 1973.
2. G.T.Adylov et al. JINR Preprint, E13-6658. Dubna, 1972.

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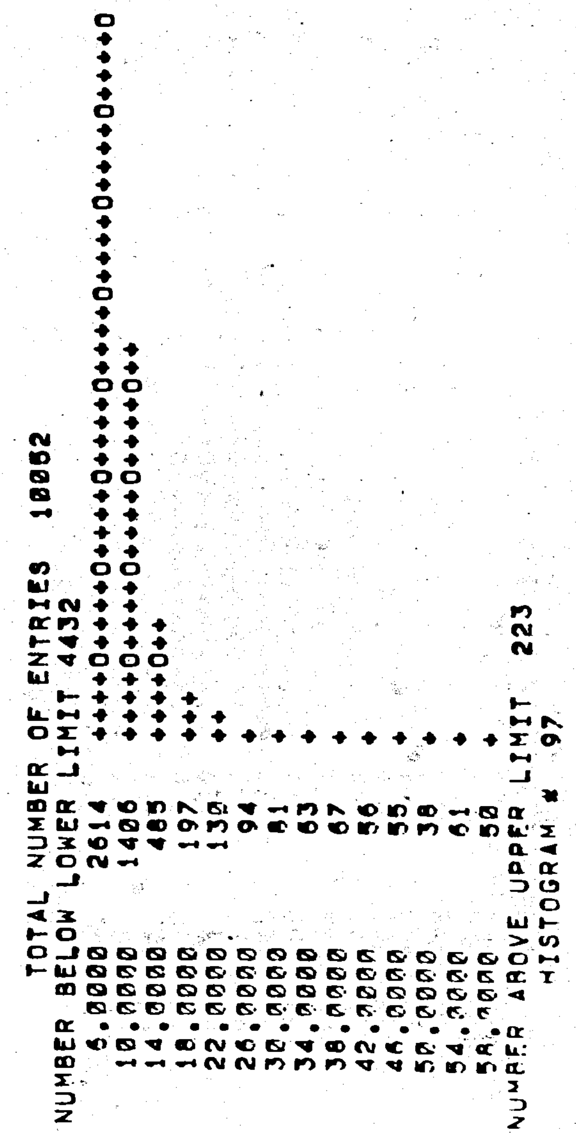

Fig. 1. χ^2 distribution.

```
          TOTAL NUMBER OF ENTRIES     576
    NUMBER BELOW LOWER LIMIT     0
      362.5000        0
      387.5000        0
      412.5000        1
      437.5000        0
      462.5000        1
      487.5000        7    ++
      512.5000       51    ++++0++++0++
      537.5000      133    ++++0++++0++++0++++0++++0++++0+
      562.5000      170    ++++0++++0++++0++++0++++0++++0++++0++++0
      587.5000      130    ++++0++++0++++0++++0++++0++++0+
      612.5000       68    ++++0++++0++++0+
      637.5000       13    +++
      662.5000        2
      687.5000        0
    NUMBER ABOVE UPPER LIMIT     0
            HISTOGRAM # 112
```

Fig. 2. Pair event X vertex distribution.

```
          TOTAL NUMBER OF ENTRIES     576
    NUMBER BELOW LOWER LIMIT     0
      362.5000        0
      387.5000        0
      412.5000        0
      437.5000       28    ++++0+++
      462.5000      111    ++++0++++0++++0++++0++++0++++0
      487.5000      138    ++++0++++0++++0++++0++++0++++0++++0++
      512.5000      148    ++++0++++0++++0++++0++++0++++0++++0++++0
      537.5000       94    ++++0++++0++++0++++0++++0+
      562.5000       60    ++++0++++0++++
      587.5000        9    ++
      612.5000        2    +
      637.5000        0
      662.5000        0
      687.5000        0
    NUMBER ABOVE UPPER LIMIT     0
            HISTOGRAM # 113
```

Fig. 3. Pair event Y vertex distribution.

```
         TOTAL NUMBER OF ENTRIES     576
NUMBER BELOW LOWER LIMIT    64
  -65.0000         0
  -55.0000         1
  -45.0000         0
  -35.0000         4    ++
  -25.0000        18    ++++0+++
  -15.0000        37    ++++0++++0++++0+
   -5.0000        56    ++++0++++0++++0++++0++++0
    5.0000        75    ++++0++++0++++0++++0++++0++++0+++
   15.0000        87    ++++0++++0++++0++++0++++0++++0++++0+++
   25.0000        91    ++++0++++0++++0++++0++++0++++0++++0++++0
   35.0000        61    ++++0++++0++++0++++0++++0++
   45.0000        20    ++++0++++
   55.0000        11    ++++0
   65.0000         4    ++
NUMBER ABOVE UPPER LIMIT    47
         HISTOGRAM # 114
```

Fig. 4. Pair event z vertex distribution.

```
         TOTAL NUMBER OF ENTRIES     670
NUMBER BELOW LOWER LIMIT     9
   600.0000        0
  1000.0000        0
  1400.0000        5    +
  1800.0000        9    +
  2200.0000       10    ++
  2600.0000       14    ++
  3000.0000        5    +
  3400.0000       23    ++++
  3800.0000       29    ++++0
  4200.0000       81    ++++0++++0+++
  4600.0000      232    ++++0++++0++++0++++0++++0++++0++++0++
  5000.0000      250    ++++0++++0++++0++++0++++0++++0++++0++++0
  5400.0000        3
  5800.0000        0
NUMBER ABOVE UPPER LIMIT     0
         HISTOGRAM # 104
```

Fig. 5. Total momentum distribution of scattered particles.

```
          TOTAL NUMBER OF ENTRIES     576
NUMBER BELOW LOWER LIMIT  178
     7.5000       47    ++++O++++O++++O++++O++++O++++O++++O++++O
    12.5000       37    ++++O++++O++++O++++O++++O++++O+
    17.5000       26    ++++O++++O++++O++++O++
    22.5000       27    ++++O++++O++++O++++O+++
    27.5000       13    ++++O++++O+
    32.5000       18    ++++O++++O++++O
    37.5000        8    ++++O++
    42.5000        1    +
    47.5000       10    ++++O++++
    52.5000        2    ++
    57.5000        9    ++++O+++
    62.5000        6    ++++O
    67.5000        8    ++++O++
    72.5000        5    ++++
NUMBER ABOVE UPPER LIMIT  181
          HISTOGRAM # 115
```

Fig. 6. Coplanarity.