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E13 - 6658

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AN ON-LINE MAGNETOSTRICTIVE SPARK CHAMBER SYSTEM USED IN A PION-ELECTRON SCATTERING EXPERIMENT AT 50 GEV/C

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A pion-electron scattering experiment to probe the electromagnetic structure of the pi-meson /1/ was carried out at the Serpukhov accelerator in 1970-71. The experimental set-up is presented in fig.1. A magnetic spectrometer with magnetostrictive spark chambers on-line to a Hewlett-Packard 2116B computer was used to record the trajectories of the incident pion and of the scattered pion and electron before and after a magnet. The number of spark chambers used, their sizes, positions on the trajectories and maximum spark capacity were chosen on the basis of data obtained by simulating the experiment with a Monte-Carlo computer program. Eighteen spark chambers (36 planes) were required, each capable of registering six sparks, and distributed in three blocks, Block I,II and III being before the target, between the target and the magnet, and after the magnet, respectively.

Spark Chambers

Two sizes of spark chambers were chosen 250 mm by 250 mm and 420 mm by 600mm, each with an 8 mm gap; the larger chambers being used in Block III. The chambers were constructed at the Laboratory of High Energies, JINR, Dubna. "Small" and "large" chambers were of similar construction /2/; the frames were made of epoxy and the electrodes were wound using 0.1 mm diameter Be-Cu wire with a 1 mm spacing. The distance between electrodes was slightly larger near the edge than in the rest of the chamber in order to avoid edge break-down. Each chamber had two 60 μ thick mylar windows glued to the epoxy frame.

Magnetostrictive ribbons (Vacoflux 50) 0.1 mm by 0.5 mm were fixed in special supports (wands) to provide a convenient method of attachment to the chamber. The supports provided the structure for the necessary tension (by means of a spring) and reflection damping of the ribbons (by means of Silastic contained in a plexi tube a few cm long at each end of the ribbon). A shielding box with pick-up coils, small bar magnet, and preamplifier was attached at the end of the support.

Spark Chamber Alignment

Figures 2 and 3 show the method of installation of the 12 small chambers of Blocks I and II and the six large chambers of Block III. The chambers of each block were placed on a heavy metal frame 5 to 7 m long placed on the top of a long row of concrete shielding blocks. Each chamber had an individual support "carriage" permitting it to be moved along the frame (Z axis) and clamped into position. The frame attached to the carriage permitted adjustment of the chambers in the plane perpendicular to the Z axis so that the X and Y axes of all chambers in a block were parallel. One chamber in Block I and two each in Blocks II and III were rotated by 45° to remove reconstruction ambiguities.

Precise fiducial marks, enscribed on each chamber at known distances from the wires of the X and Y planes during chamber reconstruction, were used for precision optical alignment of the chambers, the distances between fiducials being 280 $\pm$ 0.1 mm for the small chambers and 480 $\pm$0.1 mm and 630 $\pm$ 0.1 mm for the large chambers. Survey measurements were made several times during the experiment, either to determine a new geometry in case of changes, or to find accidental shifts. Accuracies of $\pm$ 1 mm in the Z position and better than $\pm$ 0.5 mm in the X and Y position were obtained.

During the pi-e experiment, the chambers of Block III were rotated with respect to those of Blocks I and II by an angle of 72.7 mradians in order to optimize the geometrical acceptance for these events. A common coordinate system for all chambers was found using particle trajectories. Since the beam did not pass through all Block III chambers with the magnet degaussed, a special trigger was set up for scattered particles that passes through Blocks II and III. Accuracies of $\pm$ 0.3 mm in the X and Y positions were obtained by this method.

Gas System

Pure neon with alcohol and freon as quenching additions was used for the spark chambers during the experiment [3]. The gas system had separate channels for neon, the mixture of neon with alcohol, and the mixture of neon with freon so that precise adjustment of the needed concentration was possible. Each chamber had its own fill line which included a precision needle valve and a flowmeter. Flow through each chamber was monitored by oil-filled bubblers on the output line.

All gas control and monitor equipment was collected on one board. No automatic temperature compensation was used and only in rare cases of rapid and large temperature changes was the alcohol concentration corrected. Under normal circumstances, the mixture flowed through a "small" chamber at the rate of 20 cm^3/min and through a "large" chamber at 40 cm^3 /min. At these flow rates, a mixture change in the chambers took about six hours.

HV Pulsers

The high voltage was pulsed on the chambers using a vacuum tube circuit[4] that gave currents up to 120A. A spark chamber, depending on its size, was charged during 25 to 40 ns. Pulse shape was defined mainly by an RC network (R is the resistor in parallel with the chamber, C is the capacitor feeding the chamber). This time constant was chosen to be about 100 nsec as was seen to be best from the point if view of edge breakdown. By changing R or C, we could match the individual characteristics of each chamber. The pulse current passing through R also passed through fiducial wires glued on each chamber thus exciting fiducial signals in the magnetostrictive lines.

The HV pulsers were placed underneath the chambers and connected to them by 2 m cables. High voltage to the pulsers was fed from two UPU-1 power supplies (one for the Block I and II chambers, the second for the Block III chambers) with an additional 75μF booster capacity. Even in the maximum case of 120 triggers per spill, the voltage sagged by less than 2-3%. These pulsers were triggered by a fast + 5V signal; the delay in the HV module was about 30 to 50 nsec.

A pulse clearing field with an amplitude as high as 1.2 kV lasting for 4.5 msec was fed to the chambers 0.5 msec after they had been fired. This pulse field greatly shortened spark chamber recovery time. Clearing field modules were positioned near the chambers; each module supplied a few chambers.

Readout Electronics

Spark positions were digitized using readout electronics based on the parallel-series principle using a magnetostrictive delay line as an intermediate memory for information from the chambers. This electronics is discussed in a separate report[5].

Pickup coils on the chambers had 80 turns of Cu wire 0.05 mm in diameter wound around a teflon tube 0.8 mm in diameter. DC coupled preamplifiers with an impedance matching transformer at the input (7 : 50 turns) gave an amplification of about 70. These transformers also decoupled the pickup coils from ground for the case when information was being read from a high voltage plane. Preamplifiers were placed directly on each chamber.

The amplifier-discriminators, placed in the control area of the experiment, were sensitive either to the leading edge (Block II) or the maximum of a pulse (Blocks I and III), the former being used where data were being registered from both ends of the magnetio-strictive line in order to distinguish two sparks separated only by very short distances. The resolving time of the readout electronics for one pickup coil was about 1 μ sec. (5 mm in space), this limitation coming from the characteristics of the magnetostrictive line. Pulses as close as 1.5 mm could be resolved using the double readout.

The readout electronics measured the coordinates of up to six sparks, from each of 50 pickup coils, relative to the first fiducial of each chamber. The sensitivity of the system, using a preamplifier and amplifier gain of about 10^4, corresponded to a signal generated by a fiducial current of 3-5 A. The accuracy of position of the second fiducial was found to be $\pm$ 0.6 counts ($\pm$0.15 mm). Changes in the fiducials during the experiment were not larger than $\pm$1 count for the "small" chambers and $\pm$2 counts for the "large" ones. No systematic shifts were observed; we conclude that the parameters of the magnetostrictive ribbon (intermediate memory as well as chamber lines) did not change after many triggers with an accuracy of 10^{-3}. The stability of the generator was better than 10^{-4}.

Data from the readout electronics were transferred to the HP 2116 B computer. Measurement and transfer time for the data from 50 pickup coils was equal to 2.4 msec.

Spark Chamber Trigger

The trigger for the spark chambers was produced by a fast electronic logic system that processed pulses from scintillation and Čerenkov counters. The electronic logic was located directly beside the beam channel between Blocks II and III, near the calculated optimum position (1/6 L where L is the length of the setup) that minimized delay between passage of a particle and application of the high voltage pulse. This minimization was necessary since the intensities of 2-3 x 10^5 particles per second in the chambers required using the shortest feasible spark chamber memory time. The delay ultimately obtained was about 400 nsec for the first block of chambers and about 250 nsec for the third block.

On-Line Spark Chamber Programs

Use of the HP 2116 B computer allowed checks of spark chamber efficiency, dependence of the efficiency on the number of sparks, spark position accuracy, and a calculation of the average spark number for each plane in the experiment. This required more than 100 histograms, each of which could be presented either on the screen of the Tektronix 611 storage oscilloscope or printed by a line printer. An operator could call any one of these histograms and print it or erase it, by means of a control panel of switches.

A simplified method that did not use too much computer time was used to compute spark chamber efficiencies. If any track was reconstructed, the spark chambers with no spark on the tracks (X and Y tracks) were found, within three standard deviations of the observed spark accuracy. This inefficiency was further subdivided into groups that depended on the number of additional sparks in the chambers. The fiducial pulses were very useful in providing checks of the spark chambers and readout system. Each 30 minutes a small program calculated the average of fiducials of the last 50 triggers, computed the standard deviations from these values, and computed the shifts with respect to the initial values. Inaccuracies of shifts were usually related to spark chamber malfunctions.

Spark chamber accuracies, as well as the constants needed for the overall coordinate system of each block, were found using the track-finding program. Distributions of differences between the track position and spark position gave the accuracies; the centers of these distributions gave shifts relative to the coordinate system. Spark frequency histograms were produced by a program which sorted events according to the number of sparks in each view.

A visual test of the spark chambers could be made by means of a display which presented an individual block of spark chambers in either X or Y view on the storage oscilloscope display and marked sparks registered in one event.

Operating Characteristics

The on-line spark chamber system worked successfully in the 1000 hours of the experiment. Up to 120 events per spill were occasionally taken (for example, during "beam" runs); the average number of events per one burst was about 30. About 30×10^6 total triggers were taken.

Operating Parameters

The operating parameters of the spark chamber system were chosen mainly during background runs when an extensive parametric study of the system was performed. Figure 4 presents high voltage plateau curves for the Block I (small) and Block III (large) chambers. Figure 5 shows the relevant memory curves. These curves apply for a typical gas mixture at the chosen high voltage. Adding 0.2% of alcohol or 0.005% of freon shifted the beginning of the plateau about + 100 V. During normal runs, we observed shifts of the plateau of about $\pm$50 to 100 V even for the same gas mixture; we ascribe this to temperature changes of the gas components, alcohol level, humidity, etc.

The effects of the pulse clearing field and of the time interval between triggers (dead time) was also investigated during background runs. A change of clearing field from 1.2 to 0.6 kV or a pulse width from 4.5 to 2.5 msec. increased the number of events with two sparks by 5 to 10% whereas the time interval between triggers did not influence extra sparks when varied in the range 7 to 13 msec.

Operating conditions were chosen to be the following:

--gas mixture: neon +1.5% alcohol +0.008% freon

-- high voltage: 4.6 kV "small" chambers, 4.4 kV "large" chambers.

-- DC clearing field: 100V for "small" chambers
140V for "large" chambers
-- pulsed clearing field: 1.0 kV for 4.5 msec.
-- dead time: 10-13 msec.

A typical histogram showing the beam distribution in X and Y projection is shown in fig. 6. Figure 7 shows the spark distributions (number of sparks per event) for one spark-chamber in each of Blocks I, II and III, respectively.

Spark Chamber Efficiency

A typical histogram of spark chamber efficiency as calculated by the on-line program is shown in fig.8. The low efficiency of the last chamber (75.5%) is spurious because many tracks found by the on-line program did not pass through the chamber. Figures 9 and 10 present the efficiency as a function of the number of sparks for "small" and "large" chambers, respectively.

For the "small" chambers, edge breakdown was sometimes a problem. Typically, breakdown would begin partway through an accelerator spill and rob the chamber until it recovered between spills. This effect was not so serious for "large" chambers because larger wire spacing (larger inductance) decoupled the active area from the edges. On the whole, edge breakdown was unimportant to the experiment; if it occurred in a particular chamber, it could be solved by cutting a few external wires or by connecting them to the HV through resistors.

Spatial Accuracy of Spark Chambers

The spatial accuracy of these chambers was very good. Typical data for the "small" and "large" chambers is shown in fig.11. The average accuracy for the small chambers was $\pm$0.4 in the X plane (HV plane) and $\pm$0.3 mm for the Y plane. The "large" chambers gave $\pm$0.35 mm and $\pm$0.24 mm, respectively. The better accuracy in the Y plane is thought to result from the fact that the spark started from the X plane (negative) and spread during propagation to the Y plane striking several wires. Since the measurement of a coordinate corresponded to the peak of the magnetostrictive signal, the accuracy ultimately obtained is better than the 1.0 mm wire spacing.

In conclusion we would like to express our gratitude to a large team of people from JINR-Dubna who participated in preparation and exploitation of the spark chamber system, particularly: A.F.Eliseev, Yu.V.Kulikov, V.P.Pugachevich, B.M.Starchenko, V.A.Sutulin, D.V.Uralsky and A.J.Shirokov.

References

1. Yu.D.Bardin et al. Investigation of the Electromagnetic Structure of π-Meson Using the IHEP (Institute of High Energy Physics) Accelerator.JINR, E1-4786 Dubna (1969).
2. V.P.Pugachevich. Patent No.231019 (1966).
3. T.S.Grigalashvili et al. Characteristics of Magnetostrictive Spark Chambers for Large Background Experiments. JINR, 13-5273, Dubna (1971).
4. P.I.Filippov. Pulse Supply of Filmless Spark Chambers. JINR, 13-3958, Dubna (1968).
5. Z.Guzik et al. Readout Electronics for the π-e Experiment at 50 GeV/c. JINR, E1-5818, Dubna (1971).

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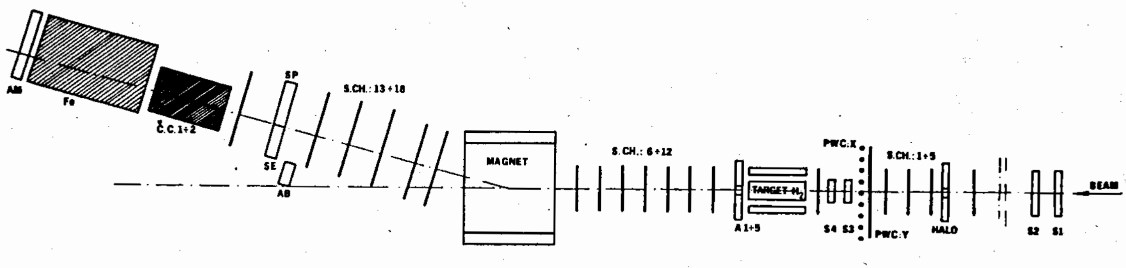

Fig.1. Experimental setup in the π-e experiment.

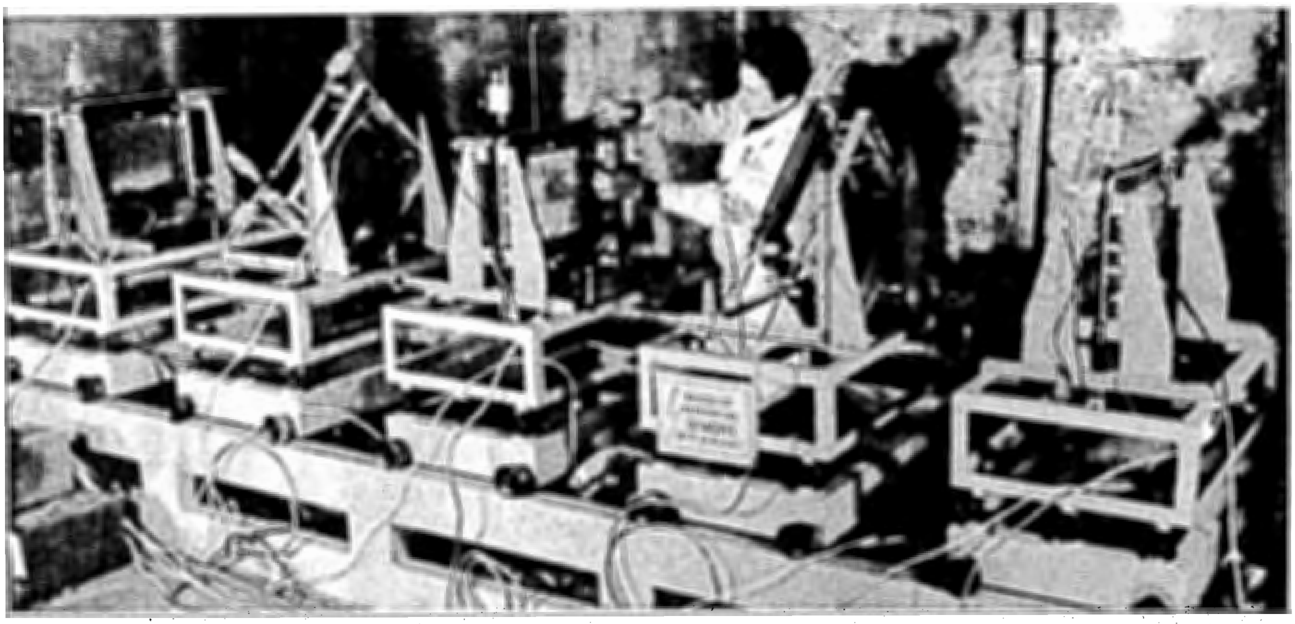

Fig.2. Block II of the spark chambers in the channel.

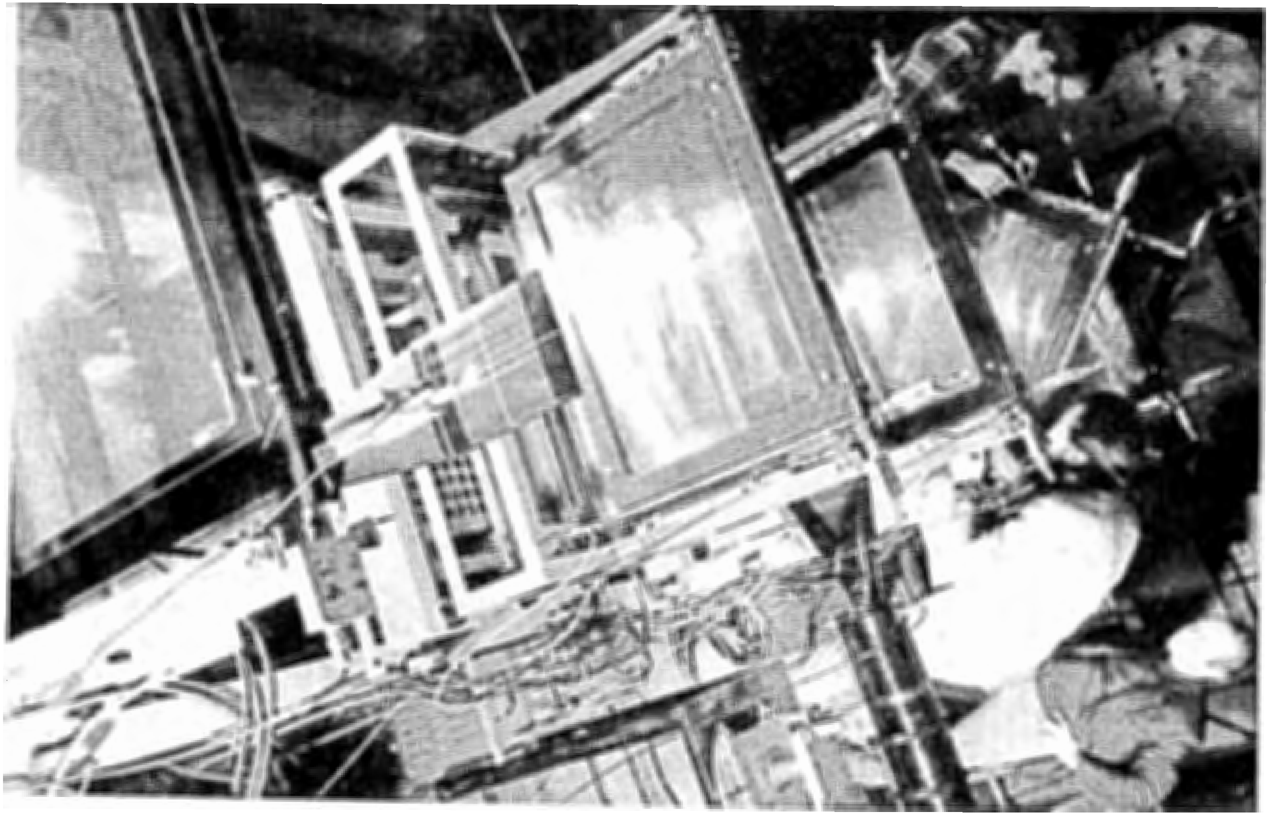

Fig.3. Block III of the spark chambers in the channel.

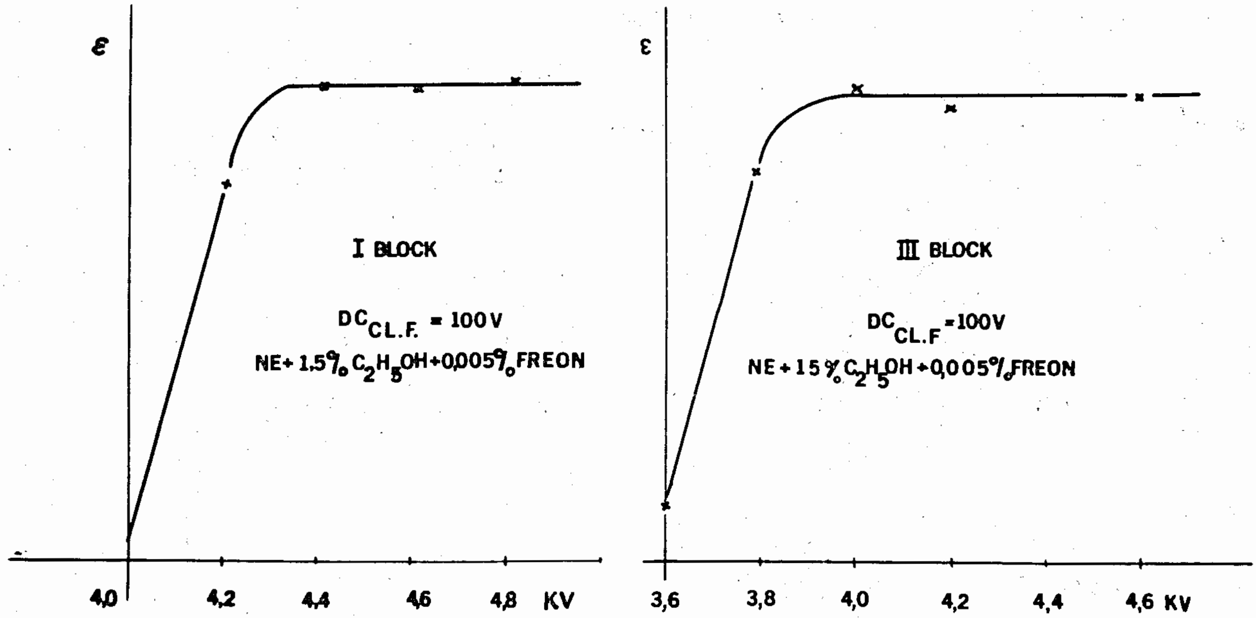

Fig.4. High voltage plateau for the Block I and Block III chambers.

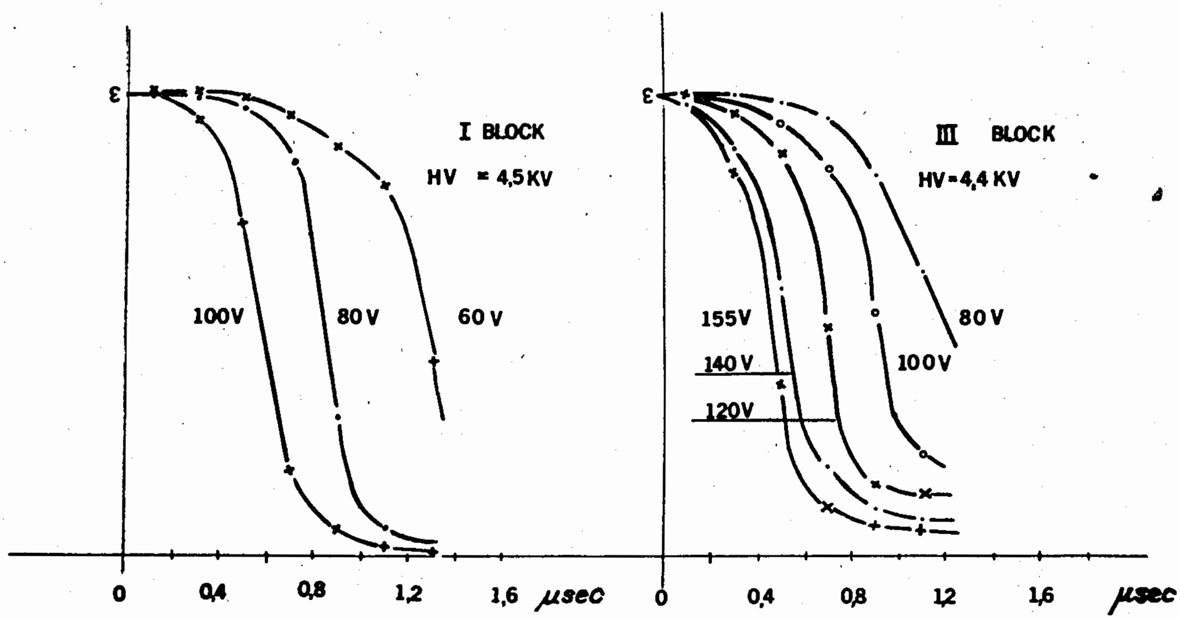

Fig.5. Memory curves for the Block I and Block III chambers (time additional to intrinsic delay is put on the horizontal axis).

```
           TOTAL NUMBER OF ENTRIES      774
   NUMBER BELOW LOWER LIMIT      0
     49.5000         0
     82.5000         0
    115.5000         0
    148.5000         0
    181.5000         0
    214.5000         3    +
    247.5000         2    +
    280.5000         1
    313.5000         3    +
    346.5000         2    +
    379.5000         2    +
    412.5000         0
    445.5000         5    ++
    478.5000         6    ++
    511.5000        43    ++++0++++0++++0
    544.5000       108    ++++0++++0++++0++++0++++0++++0++++0++
    577.5000       117    ++++0++++0++++0++++0++++0++++0++++0++++0
    610.5000       101    ++++0++++0++++0++++0++++0++++0++++0
    643.5000        16    ++++0
    676.5000         6    ++
    709.5000         1
    742.5000         2    +
    775.5000         3    +
    808.5000         2    +
    841.5000         1
    874.5000         0
    907.5000         2    +
    940.5000         1
    973.5000         0
   1006.5000         0
   NUMBER ABOVE UPPER LIMIT   347
           HISTOGRAM #  14

           TOTAL NUMBER OF ENTRIES      764
   NUMBER BELOW LOWER LIMIT      0
     49.5000         0
     82.5000         0
    115.5000         1
    148.5000         2
    181.5000         1
    214.5000         0
    247.5000         1
    280.5000         2
    313.5000        10    ++
    346.5000         2
    379.5000         2
    412.5000         5    +
    445.5000        20    ++++0
    478.5000       117    ++++0++++0++++0++++0++++0+++
    511.5000       165    ++++0++++0++++0++++0++++0++++0++++0++++0
    544.5000        36    ++++0++++
    577.5000        14    +++
    610.5000         7    ++
    643.5000         9    ++
    676.5000         3    +
    709.5000         2
    742.5000         3    +
    775.5000         2
    808.5000         2
    841.5000         3    +
    874.5000         2
    907.5000         2
    940.5000         2
    973.5000         2
   1006.5000         0
   NUMBER ABOVE UPPER LIMIT   347
           HISTOGRAM #  15
```

Fig.6. Beam distribution in X and Y projection in one spark-chamber of Block I.

```
          TOTAL NUMBER OF ENTRIES   14409
     NUMBER BELOW LOWER LIMIT    30
         1.5000     8165    ++++0++++0++++0++++0++++0++++0++++0++++0
         2.5000     5059    ++++0++++0++++0++++0++++0
         3.5000     1064    ++++0
         4.5000       89
         5.5000        1
         6.5000        1
     NUMBER ABOVE UPPER LIMIT     0
           HISTOGRAM # 125

          TOTAL NUMBER OF ENTRIES   14409
     NUMBER BELOW LOWER LIMIT   362
         1.5000     5665    ++++0++++0++++0++++0++++0++++0++++0++++0
         2.5000     5476    ++++0++++0++++0++++0++++0++++0++++0++++
         3.5000     2252    ++++0++++0++++0+
         4.5000      529    ++++
         5.5000      103    +
         6.5000       22
     NUMBER ABOVE UPPER LIMIT     0
           HISTOGRAM # 155

          TOTAL NUMBER OF ENTRIES   14409
     NUMBER BELOW LOWER LIMIT   113
         1.5000     1808    ++++0++++0++++0++
         2.5000     4310    ++++0++++0++++0++++0++++0++++0++++0++++0
         3.5000     4202    ++++0++++0++++0++++0++++0++++0++++0++++
         4.5000     2460    ++++0++++0++++0++++0+++
         5.5000     1036    ++++0++++0
         6.5000      480    ++++
     NUMBER ABOVE UPPER LIMIT     0
           HISTOGRAM # 165
```

Fig.7. Distribution of the number of sparks per event for one spark-chamber in each of Blocks I,II and III.

```
          TOTAL NUMBER OF ENTRIES =16427
NUMBER BELOW LOWER LIMIT10000
     1.5000      9617    ++++0++++0++++0++++0++++0++++0++++0++++
     2.5000      9586    ++++0++++0++++0++++0++++0++++0++++0++++
     3.5000      9780    ++++0++++0++++0++++0++++0++++0++++0++++
     4.5000      9545    ++++0++++0++++0++++0++++0++++0++++0+++
     5.5000         0
     6.5000      9368    ++++0++++0++++0++++0++++0++++0++++0+++
     7.5000      9128    ++++0++++0++++0++++0++++0++++0++++0++
     8.5000      9338    ++++0++++0++++0++++0++++0++++0++++0+++
     9.5000      9774    ++++0++++0++++0++++0++++0++++0++++0++++
    10.5000      9757    ++++0++++0++++0++++0++++0++++0++++0++++
    11.5000      9539    ++++0++++0++++0++++0++++0++++0++++0+++
    12.5000      9549    ++++0++++0++++0++++0++++0++++0++++0+++
    13.5000      9162    ++++0++++0++++0++++0++++0++++0++++0++
    14.5000      9629    ++++0++++0++++0++++0++++0++++0++++0++++
    15.5000      9939    ++++0++++0++++0++++0++++0++++0++++0++++0
    16.5000      9813    ++++0++++0++++0++++0++++0++++0++++0++++
    17.5000      9752    ++++0++++0++++0++++0++++0++++0++++0++++
    18.5000      9353    ++++0++++0++++0++++0++++0++++0++++0+++
    19.5000      7554    ++++0++++0++++0++++0++++0++++0
    20.5000         0
    21.5000         0
    22.5000         0
    23.5000         0
    24.5000         0
    25.5000         0
    26.5000         0
    27.5000         0
    28.5000         0
    29.5000         0
    30.5000         0
NUMBER ABOVE UPPER LIMIT     0
          HISTOGRAM # 171
```

Fig.8. Spark chamber efficiency by the on-line program.

```
        TOTAL NUMBER OF ENTRIES =17535
NUMBER BELOW LOWER LIMIT10000
     1.5000     9687    ++++0++++0++++0++++0++++0++++0++++0++++0
     2.5000     9491    ++++0++++0++++0++++0++++0++++0++++0++++
     3.5000     9447    ++++0++++0++++0++++0++++0++++0++++0++++
     4.5000     9376    ++++0++++0++++0++++0++++0++++0++++0++++
     5.5000        0
     6.5000        0
NUMBER ABOVE UPPER LIMIT      0
        HISTOGRAM # 172

        TOTAL NUMBER OF ENTRIES =12314
NUMBER BELOW LOWER LIMIT10000
     1.5000     9769    ++++0++++0++++0++++0++++0++++0++++0++++0
     2.5000     9575    ++++0++++0++++0++++0++++0++++0++++0++++
     3.5000     9465    ++++0++++0++++0++++0++++0++++0++++0++++
     4.5000     9412    ++++0++++0++++0++++0++++0++++0++++0++++
     5.5000     5091    ++++0++++0++++0++++0
     6.5000        0
NUMBER ABOVE UPPER LIMIT      0
        HISTOGRAM # 173

        [illegible]ER OF ENTRIES =16487          [illegible]
NUMBER BELOW LOWER LIMIT10000
     1.5000     9840    ++++0++++0++++0++++0++++0++++0++++0++++0
     2.5000     9837    ++++0++++0++++0++++0++++0++++0++++0++++0
     3.5000     9610    ++++0++++0++++0++++0++++0++++0++++0++++
     4.5000     9762    ++++0++++0++++0++++0++++0++++0++++0++++0
     5.5000        0
     6.5000        0
NUMBER ABOVE UPPER LIMIT      0
        HISTOGRAM # 174
```

Fig.9. Efficiency of the "small" spark chamber as a function of the number of sparks.

```
         TOTAL NUMBER OF ENTRIES    2946
NUMBER BELOW LOWER LIMIT10000
     1.5000     9882    ++++0++++0++++0++++0++++0++++0++++0++++0
     2.5000     9774    ++++0++++0++++0++++0++++0++++0++++0++++0
     3.5000     9750    ++++0++++0++++0++++0++++0++++0++++0++++
     4.5000     9788    ++++0++++0++++0++++0++++0++++0++++0++++0
     5.5000     9529    ++++0++++0++++0++++0++++0++++0++++0++++
     6.5000     9759    ++++0++++0++++0++++0++++0++++0++++0++++0
NUMBER ABOVE UPPER LIMIT     0
         HISTOGRAM # 166

         TOTAL NUMBER OF ENTRIES    1228
NUMBER BELOW LOWER LIMIT10000
     1.5000     9837    ++++0++++0++++0++++0++++0++++0++++0++++0
     2.5000     9811    ++++0++++0++++0++++0++++0++++0++++0++++0
     3.5000     9775    ++++0++++0++++0++++0++++0++++0++++0++++0
     4.5000     9617    ++++0++++0++++0++++0++++0++++0++++0++++
     5.5000     9509    ++++0++++0++++0++++0++++0++++0++++0++++
     6.5000     8215    ++++0++++0++++0++++0++++0++++0+++
NUMBER ABOVE UPPER LIMIT     0
         HISTOGRAM # 167

         TOTAL NUMBER OF ENTRIES    -614
NUMBER BELOW LOWER LIMIT10000
     1.5000     8757    ++++0++++0++++0++++0++++0++++0++++0++
     2.5000     9444    ++++0++++0++++0++++0++++0++++0++++0++++0
     3.5000     9327    ++++0++++0++++0++++0++++0++++0++++0++++0
     4.5000     9389    ++++0++++0++++0++++0++++0++++0++++0++++0
     5.5000     8926    ++++0++++0++++0++++0++++0++++0++++0+++
     6.5000     9079    ++++0++++0++++0++++0++++0++++0++++0+++
NUMBER ABOVE UPPER LIMIT     0
         HISTOGRAM # 168
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Fig.10. Efficiency of the "large" spark chamber as a function of the number of sparks.

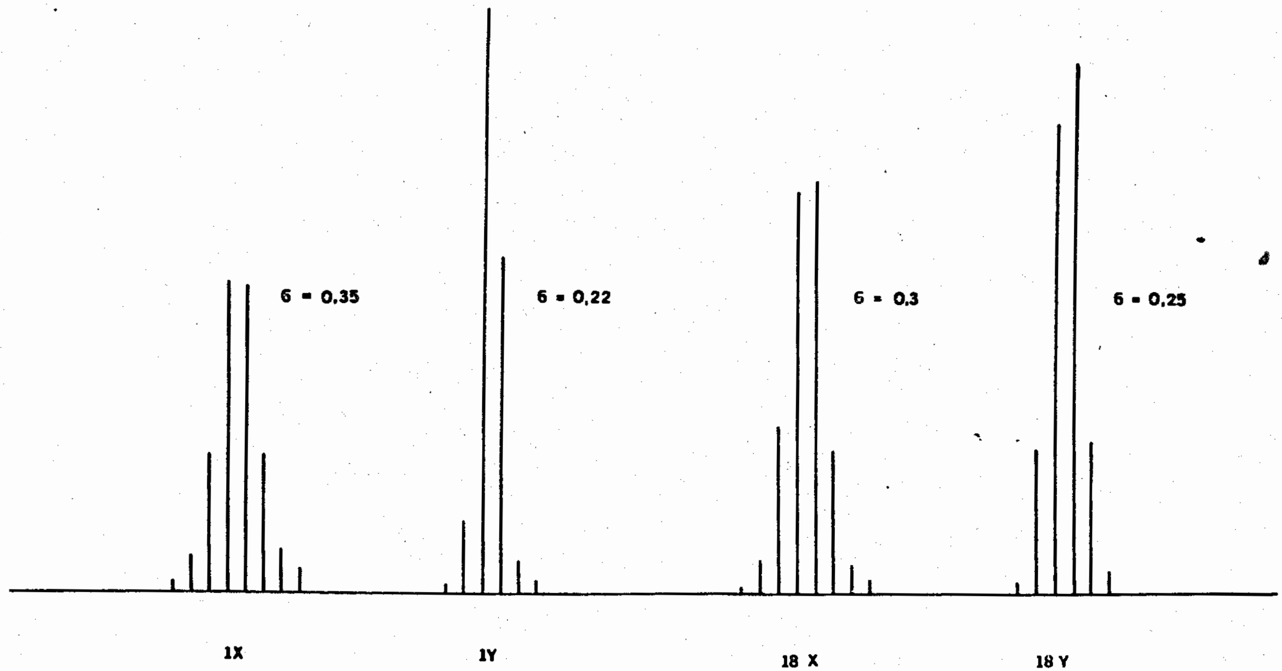

Fig.11. Spatial accuracy of the ''small'' (lX,lY) and ''large'' (18X,18Y) chambers.

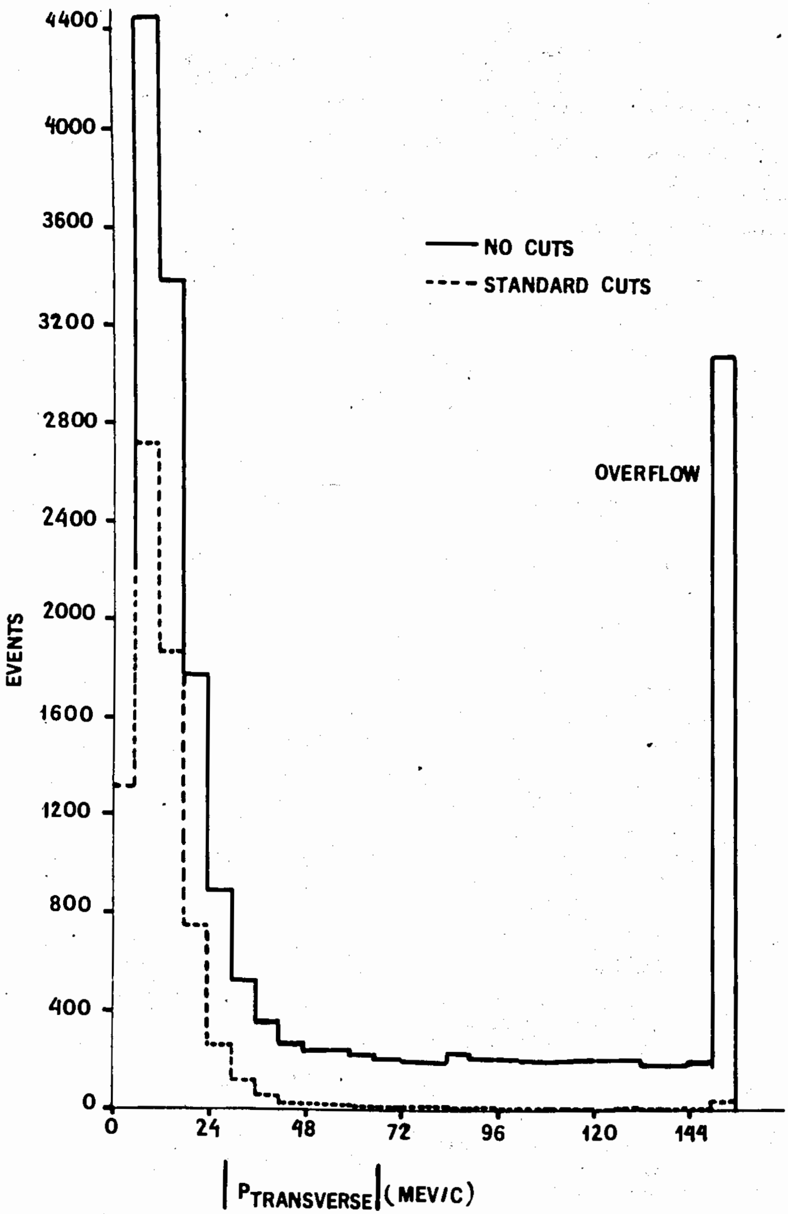

Fig.12.Resolution of the system in terms of P_T , the total transverse momentum of the scattered pion and electron.