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A MEASUREMENT OF THE ACCURACY OF LOCATION OF SPARKS IN A WIRE SPARK CHAMBER WITH MAGNETOSTRICTIVE READOUT, AND AN APPLICATION TO THE MEASUREMENT OF MULTIPLE SCATTERING(*)

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Summary.

The accuracy of location of sparks in wire chambers with magnetostrictive read-out has been determined by comparing, by means of an analog system and a multichannel pulse height analyser the coordinates of the sparks induced in three chambers traversed by straight charged particles. It has been found that for the particular chambers investigated, the accuracy was ± 0.4 mm on each spark.

The same set up has been used for the determination of the projected angular distribution for multiple Coulomb scattering of 1.5 GeV/c pions in materials of different thickness. The extrapolation to zero thickness gives a result in agreement with the apparent angular spread originated from the spread of the sparks.

Riassunto.

Si è misurata la precisione nella localizzazione delle scintille in camere a filo a lettura magnetostrittiva confrontando, per mezzo di un sistema analogico ed un analizzatore multicanale, le coordinate delle scintille indotte in tre camere a scintilla a filo attraversate da particelle cariche indeviate. Si è trovato, per il particolare tipo di camera studiato, che la precisione era di ± 0.4 mm per scintilla.

Lo stesso dispositivo è stato usato per la determinazione della distribuzione angolare proiettata di mesoni π da 1.5 GeV/c diffusi per urto coulombiano multiplo in materiali di vario spessore. La estrapolazione a spessore zero fornisce un risultato in accordo con lo sparpagliamento angolare originato dallo sparpagliamento delle scintille.

1. - Introduction.

Magnetostriction wire spark chambers have been extensively described by various authors ([1,2]) during the last two years. In view of the future experiment to be performed by our group, several wire spark chambers have been built in our laboratory, and we devised a system to find out the accuracy of location of the sparks. Such a system turned out be to quite feasible to perform multiple scattering measurements: since accurate data on multiple scattering of high energy particles are still missing, we belive that a fast, high precision, automatic system such as the one to be described, could be of some interest.

Each spark chamber, 50×50 cm^2, has four wire arrays which form two 8 mm gaps; the wires (Ø 0.1 mm) are made of a copper-berillium alloy, and are threaded 1 mm apart.

The inner electrodes are pulsed with the H.T., while the other two are connected to ground. The wires in each plane of a gap are mutually orthogonal, and four nickel wires provide magnetostrictive radout.

The three chambers are pulsed by individual spark gaps, mounted on the chamber themselves, and triggered by a main spark gap. The existing triggering system is the limiting factor of the rate of the whole system: it can't be pulsed more than about 50 times a second, but we mean to improve it in order to attain higher counting rates, since it is known that the recovery time of wire spark chambers is less than 1 msec ([3]).

In these preliminary tests we used the information coming from only one array per gap: the magnetostrictive signals induced in every nickel wire by the sparks in the chambers are picked up by a coil, and enter a Fairchild micrologic amplifier, operating in the trigger mode by means of a suitable positive feedback. The output signal of this trigger is a positive pulse, 300 nsec wide at the base, and 2 Volts high. To find out the position of a spark, we measure the time interval between the pulse corresponding to the spark and a fixed reference pulse. To generate reference signals, we pulse, every time the chamber is triggered, two reference wires per electrode, 40 cm apart.

2. - Alignement of the sparks and errors.

In order to determine the precision with which our system is able to give the coordinates of the trajectory of a particle, we used the technique illustrated in Fig. 1.

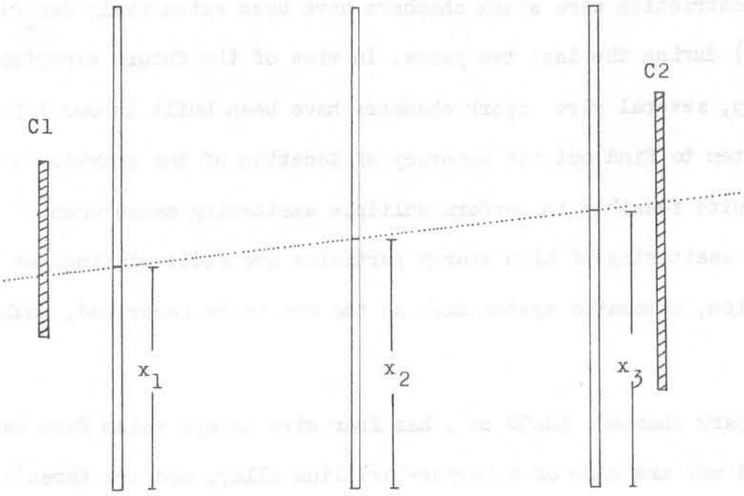

Fig. 1

Experimental set-up. C1 and C2 are plastic scintillation counters.

We handled only the magnetostrictive signals coming from the first ground electrode of each chamber: for every chamber there is a time-to-pulse-height converter, which gives an output proportional to the coordinate of the spark in the horizontal plane. We will give to these three pulses the same names we use for the corresponding coordinates, that is x_1, x_2, and x_3. These three pulses are handled in a mixer, whose output is

$$z = (x_1 + x_3 - 2x_2)\ g + R$$

where g is a gain factor, and R is a reference voltage whose presence will be justified later. Since x_1, x_2 and x_3 are independently measured and have the same standard deviation σ_x, we expect the distribution of z to be centered around R, and have a standard deviation

$$\sigma_z = \sqrt{6g^2\ \sigma_x^2 + \sigma_R^2}$$

A knowledge of σ_z, and σ_R, allows us to evaluate σ_x, the r.m.s. error in the measurement of one coordinate. In order to find out σ_z, every time a particle triggers the system we send the output pulse z into a Multi-channel Pulse Analizer CN 110, built by Thechnical Measurement Corporation. The reference voltage R is needed since the pulses to be stored must have always the same polarity. Much effort has been devoted to obtain a reference pulse both stable in time and defined with an accurancy of one part out of a thousand.

The chambers were placed in the M4 pion beam at the CERN Proton-Synchrotron. The 1.5 GeV/c momentum pions reached our chambers after crossing a liquid hydrogen target, used for another experiment. Fig. 2 is a block diagram of the electronics involved; a coincidence between counters C1 and C2 (Fig. 1) triggers the system. The triggering rate is adjustable externally by means of a paralyzing gate; if more than one spark takes place in a chamber, a suitable gate rejects the event.

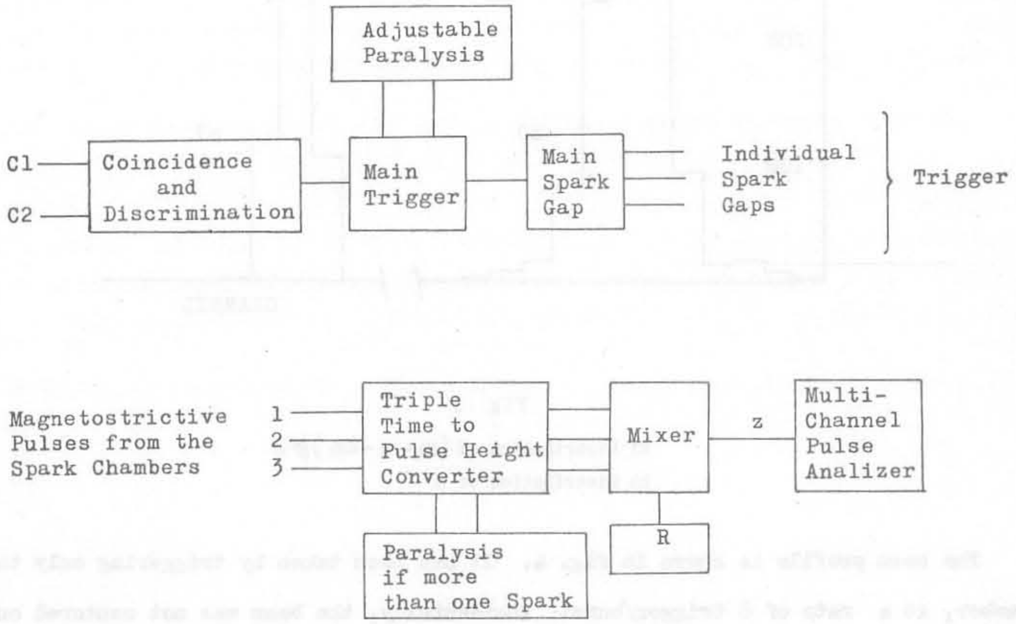

Fig. 2

Block diagram of the electronics.

Fig. 3a shows the distribution of z after 1300 triggers: the number of events in the plot is 1170, that is about 10% of the events had two or more sparks in at least one chamber. This ratio was expected, due to the intensity of the beam, which was about $1.2 \cdot 10^5$ particles per burst (200 msec long).

Fig. 3b shows the spread of the reference voltage. From the values of σ_z ($\simeq 0.6$ mm) and of σ_R ($\simeq 0.4$ mm), we get

$$\sigma_x \simeq 0.4 \text{ mm}$$

To our knowledge, this value had not yet been measured by operating magnetostrictive wire sparks chambers in real experimental conditions.

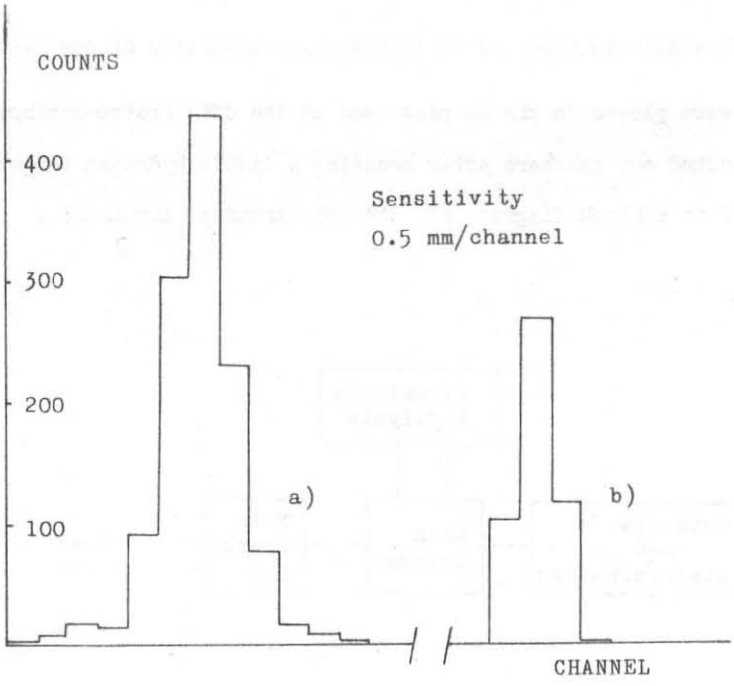

Fig. 3

a) Distribution of $(x_1+x_2-2x_3)g+R$

b) Distribution of R

The beam profile is shown in fig. 4. It has been taken by triggering only the first chamber, at a rate of 8 trigger/burst: incidentally, the beam was not centered on counter C1 in this first run.

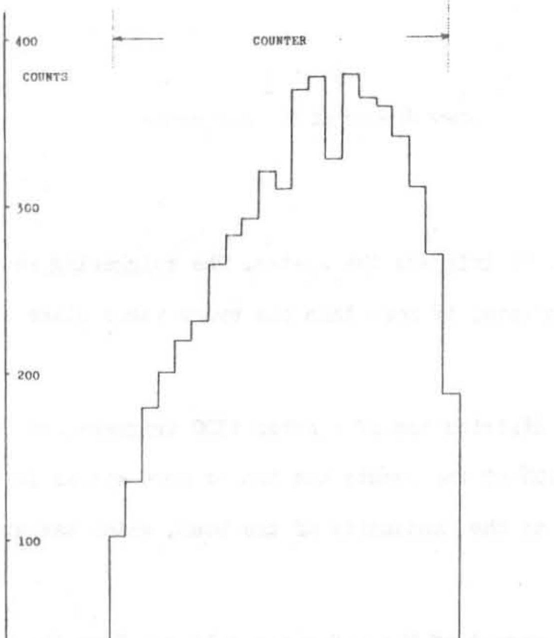

Fig. 4

Example of beam profile determined with a magnetostrictive spark chamber.

3. - Multiple Scattering.

With the same apparatus used to find out the accuracy of location of the sparks, we measured multiple scattering in a sample of different materials. Fig. 5 illustrates the new geometry: the scattering material is placed immediately after the second chamber. If the angular spread of the incoming beam is small, then

$$x_1 + x_3 - 2x_2 = s \tan\alpha$$

were α is the projection of the scattering angle, and s the distance of the target from the electrode of the last chamber.

Since the chambers were 50 cm apart, the angular resolution was of the order of 0.06 degrees: obviously it can be improved just by increasing the distance between the spark chambers.

A small divergence in the beam does not introduce an appreciable error in α: as a limiting case, if δ=1 deg. and α=10°, the error in the measure of the scattering angle is less than 0.03°, which is one half of the angular resolution of our chambers (in our case the divergence of the beam was less than 0.5°).

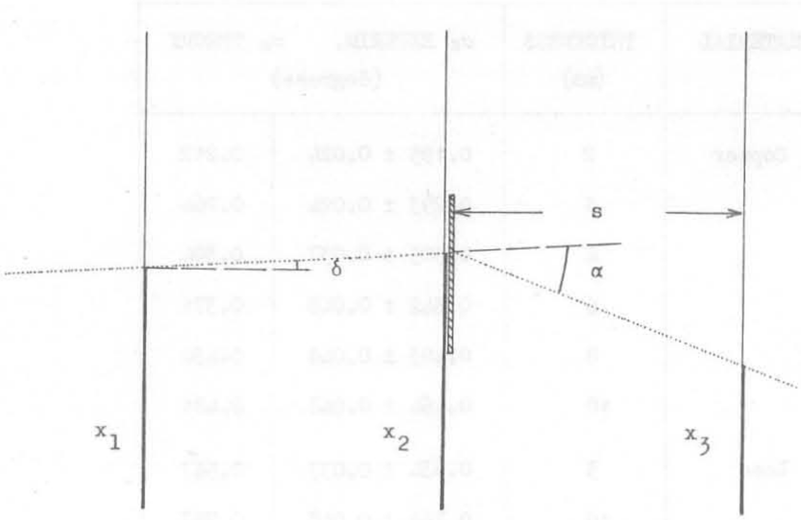

Fig. 5

Schematic of the set-up used for the determination of the multiple scattering angular distribution.

The technique illustrated in the previous paragraph allows one to get on the scope of a Multi-channel Pulse Analizer directly the distribution of tanα: apart from a factor $1/\cos^2\alpha$ (which is practically one, if α is small), this is just the distribution of the projected scattering angle.

Fig. 6 shows some of the angular distributions we obtained performing multiple scattering on copper, lead and aluminum plates at various energies. A first approximation of the theory of multiple scattering gives for the projected angle of scattering a normal distribution, with the mean square deflection

$$\sigma_\alpha^2 = \frac{1}{2}\left(\frac{21.2}{P\beta}\right)^2 t$$

where P is the momentum of the incident particles, in MeV/c, and t the thickness of the scattering plate, measured in radiation length units.

The results of our multiple scattering measurements, non corrected for the angular spread originated by the resolving power of the chambers (see section 2), have been collected in figure 7. Our angular resolution can be obtained from the extrapolation to zero thickness of the data; the extrapolated value is in agreement with the angular resolution deduced from the measurements of section 2, as shown in the figure.

The mean square deflections, corrected for this known angular resolution, are compared in table 1 with the values expected according to (4). As can be seen, the agreement with the theory is good.

MATERIAL	THICKNESS (mm)	σ_α EXPERIM. (degress)	σ_α THEORY
Copper	2	0.195 ± 0.024	0.212
	3	0.293 ± 0.024	0.264
	4	0.305 ± 0.037	0.304
	6	0.342 ± 0.048	0.371
	8	0.403 ± 0.048	0.430
	10	0.464 ± 0.048	0.481
Lead	5	0.634 ± 0.037	0.567
	10	0.769 ± 0.048	0.797
Aluminum	10	0.171 ± 0.024	0.194
		P = 1505 MeV/c	

Table 1

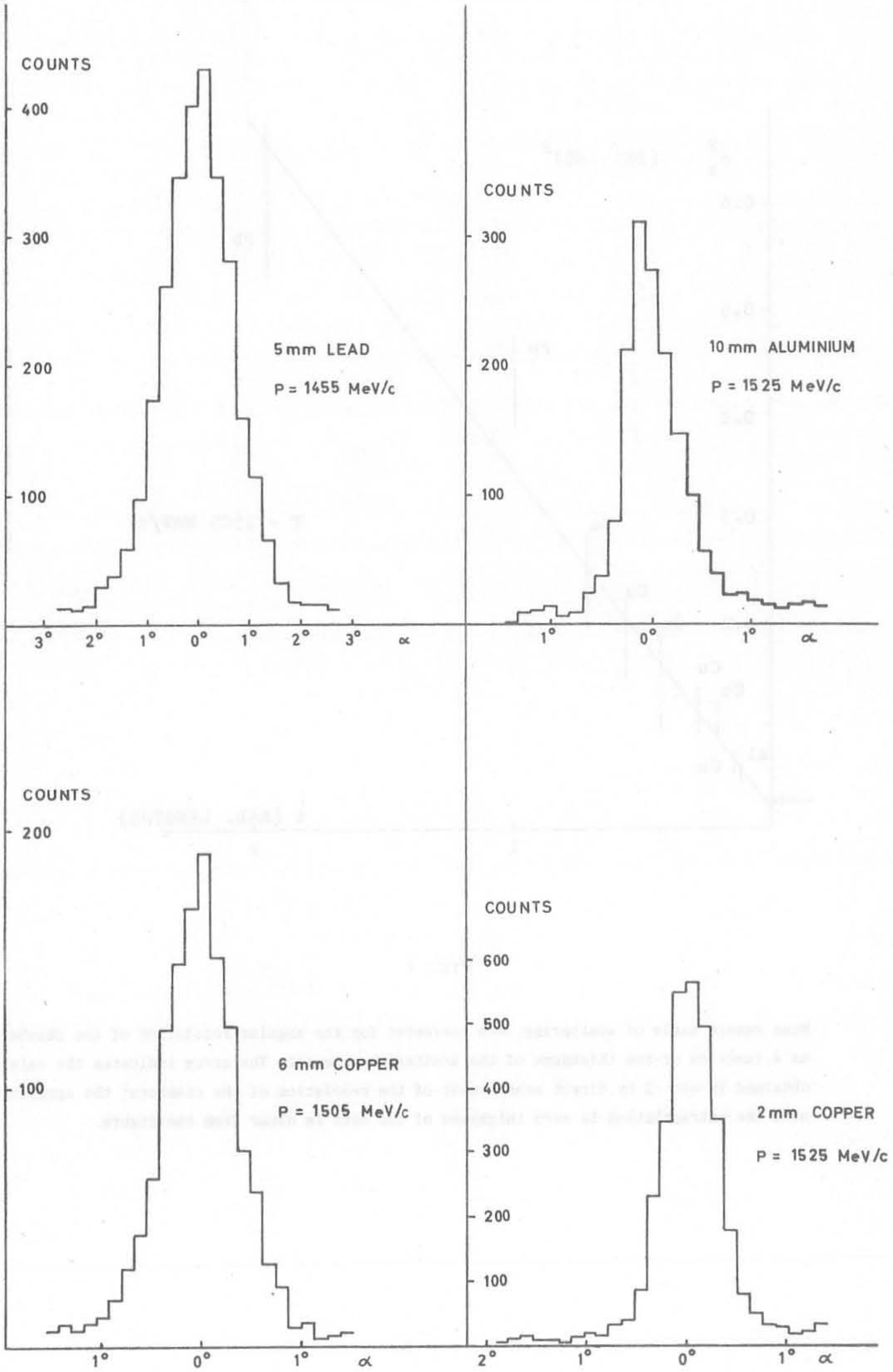

Fig. 6

Angular distribution of the multiple scattering, non corrected for the angular resolving power of the chambers.

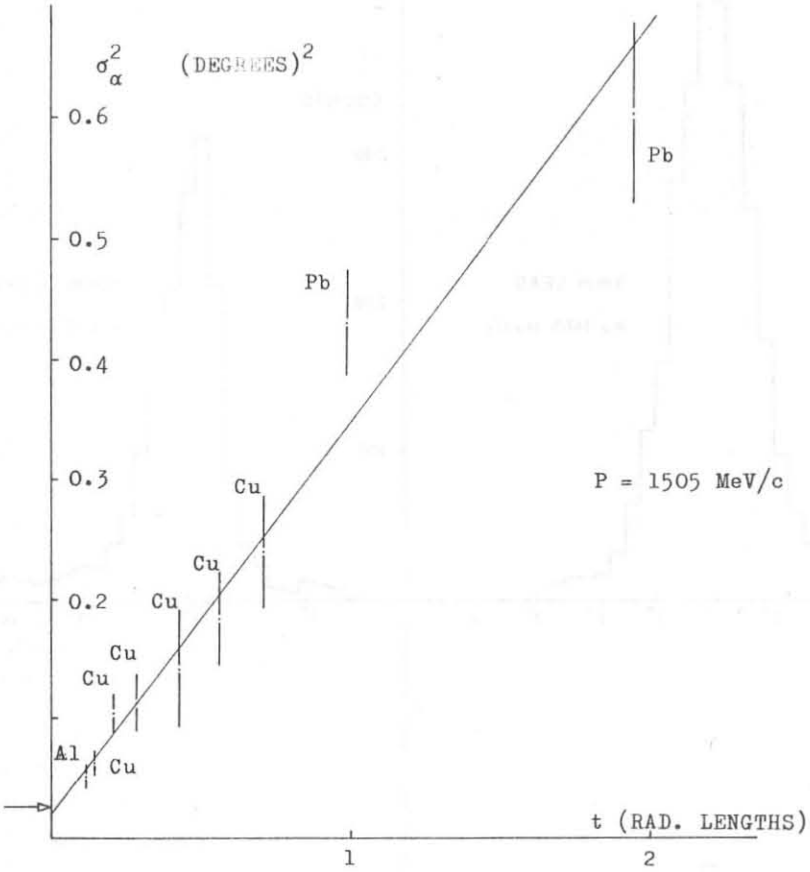

Fig. 7

Mean square angle of scattering, non corrected for the angular resolution of the chamber, as a function of the thickness of the scattering material. The arrow indicates the value obtained in sec. 2 by direct measurement of the resolution of the chambers: the agreement with the extrapolation to zero thickness of the data is clear from the figure.

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The wire spark chambers have been built by the technicians of our group, M.P. Dechelette and M. Renevey.

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