ACOUSTICAL SPARK CHAMBER SYSTEM FOR THE STUDY OF SMALL ANGLE PROTON-PROTON SCATTERING

G. COCCONI, A.N. DIDDENS, E. LILLETHUN, J. PAHL,
A.C. SHERWOOD, J.P. SCANLON, C.A. STAHLBRANDT,
C.C. TING, J. WALTERS and A.N. WETHERELL

CERN, Geneva

(presented by E. Lillethun)

1. INTRODUCTION

The work described here is a confirmation of that described by A.E. Taylor earlier this afternoon. I have tried to leave out points that have already been discussed in his report. The present set-up is shown schematically below:

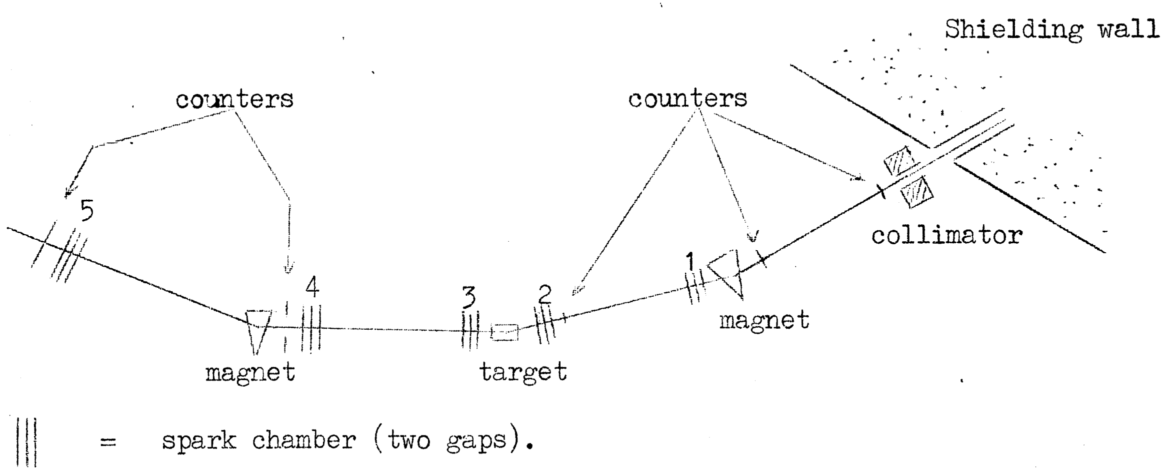

Fig. 1

2. CONSTRUCTION OF SPARK CHAMBERS

Figure 2 shows a view of a partly assembled spark chamber. The chamber is made from perspex in order to reduce the possibilities for high voltage breakdown. It is sealed with O-rings to prevent leaks and contamination of the gas and encased in aluminium to reduce the electromagnetic radiation from the spark. This radiation could in some cases lead to a disturbing pickup in the electronics system.

The construction of the probe carrying the microphone (a lead zirconate transducer) is shown in Fig. 3. Since the transducer positions act as the fiducial marks in an acoustical spark chamber it is necessary to be able to locate them very accurately. For this purpose crosses are engraved on the probe sockets which are screwed on to the spark chamber. When the precision-made probes are tightly seated in the sockets, the distances from the crosses to the transducers are known within 0.1 mm. This allows a change of probe without a remeasurement of the transducer position.

3. MULTIPLE SPARKS

The present system is not able to handle more than one spark per gap per event. A perfect event is one in which all gaps (two in each chamber) give a single spark. This puts a severe limitation on the admissible instantaneous rate of particles through a chamber. The delay between particle passage and high voltage application is about 0.5 μsec due to the electronics and the long distance (35 m) between the first and last chamber. Therefore, the sensitive time of the chambers must be kept to about 1 μsec. In this case an instantaneous rate of 10^5 particles per sec (e.g. 10^4 particles in a 100 msec burst, will produce double sparks in 10% of the events in a gap.

The effect of increased particle flux on the efficiency of the whole set-up can be seen from Fig. 4. At the time when these data were taken the system was not in its best mood. The beam burst length was about 100 msec. If one attributes the rapidly falling efficiency to double or multiple sparks the conclusion is that general background must be kept very low (1 particle per cm^2 gives 1500 particles in our largest chamber which is 30 cm x 50 cm), a difficult task since most of this background in a high-energy experiment consists of muons of high energy.

It should be noted that Fig. 3 shows the most pessimistic result since one has required a good spark in each gap. One may allow an event to be "rescued" if only one gap is missing on either side of the target, by making use of the fact that the trajectory of a particle is a straight line in the vertical projection before and after the scattering. If a gap has no spark or if the coordinates obtained in the two gaps of one chamber are different, the straight line fit through the remaining gaps shows which spark is the wanted one. The rescue process has been tried successfully as can be seen from Fig. 8 where the dotted line represents clean events and the full line the total of clean and rescued events. The two distributions are very similar.

4. RECORDING OF EVENTS

The electronics used in the system have been described elsewhere[1]. In general a coincidence in the triggering system sends a high voltage pulse (10 kV) to the spark chambers and, after a pre-set delay, opens the gates of a bank of scalers fed by a 10 Mc/s oscillator. The signals from the transducers, after amplification and shaping, shut the gates of their respective scalers. If no transducer signal has arrived within 3 msec the scaler gate is shut by a signal which also starts the data recording. The data from 60 scalers are stored on magnetic tape in the form of BCD characters, 200 ch/inch, in about 180 msec. This limits the rate of data acquisition to one event per burst.

We are now developing an on-line system with a small, fast computer which will reduce the scaler readout time to about 2 msec. The computer will also be used for continuous checking of the data and for simplified reconstructions of sample events. With the increased data transfer speed we will be able to record 10 to 20 events per burst, allowing us to study regions where background events are dominating (e.g. lower the minimum scattering to 2 mrad, an angle which still sees the wings of the main beam).

5. COMPUTATION

The computer programme for the experiment falls naturally into three parts :

1. FINDXY, a programme which computes the spark coordinates from the recorded times. The mathematics behind this programme was discussed by P. Zanella in the preceding paper.

2. ALIGN, which treats events triggered by the non-scattered beam. The alignment of the chambers is done by this programme by finding the mean positions of the beam in the chambers.

3. PPSCAT, which handles the scattered events, using the coordinates found by FINDXY to compute momenta and scattering angles. It stores each event in the proper momentum-angle interval and at the end of a run transforms this to cross-sections and forms histograms of these. (See Fig. 7.)

In order to illustrate the use, and misuse, of FINDXY, the programme discussed by Zanella, Fig. 4 shows the difference between the x coordinate in the two gaps of a 30 cm x 50 cm chamber. In the central position the distribution is very tight, a Gaussian with a standard deviation of 0.14 mm, 20 cm from the centre the equivalent distribution has been smeared out over ± 2 mm. This behaviour is actually expected, as can be seen from Fig. 11 in the preceding paper by Zanella. I would like to stress that the wide distribution is entirely caused by the computation. The times recorded in the two positions both show equally tight distributions.

6. TEST RESULTS

During tests at the CERN proton-synchrotron recently we obtained the distributions of the momentum of the incoming proton beam (Fig. 6), the momentum difference between incoming and outgoing non-scattered beam of 18.1 GeV/c (Fig. 7) and the scattering angle of the same beam (Fig. 8). The scattering material present was 3 mm of plastic scintillator and 2 m of air.

The standard deviations of these distributions give the resolution of our system and are 0.05 GeV/c ($\frac{\Delta p}{p}$ = 0.28%) and 0.11 mrad for the momentum difference and scattering angle respectively. These encouraging results show that the experiment can indeed be done with the acoustical spark chambers, and with an on-line computer we should be able to study p-p elastic scattering at angles down to 2 mrad.

ACKNOWLEDGMENT

We would like to thank R. Donnet for his assistance with the experimental equipment.

Reference

1. C.A. Stahlbrandt, Proceedings of the International Symposium on Nuclear Electronics, Paris, 365, (1963).

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Figure captions

Fig. 1	Schematic diagram of present experimental set-up (see page 183)
Fig. 2	Partly assembled acoustical spark chamber
Fig. 3	Construction of the probe holding the lead zirconate transducer
Fig. 4	Efficiency of 10 gap set-up as function of single particles through the last chamber
Fig. 5	Difference between x-coordinate in two gaps of a chamber. This demonstrates that there are certain regions in the chamber where the programme does not work well (see text for details)
Fig. 6	Momentum distribution of incoming proton beam of 18.1 GeV/c
Fig. 7	Distribution of the difference between incoming and outgoing non-scattered beam of 18.1 GeV/c protons (computer output)
Fig. 8	Distribution of the scattering angle measured in a non-scattered beam of 18.1 GeV/c protons

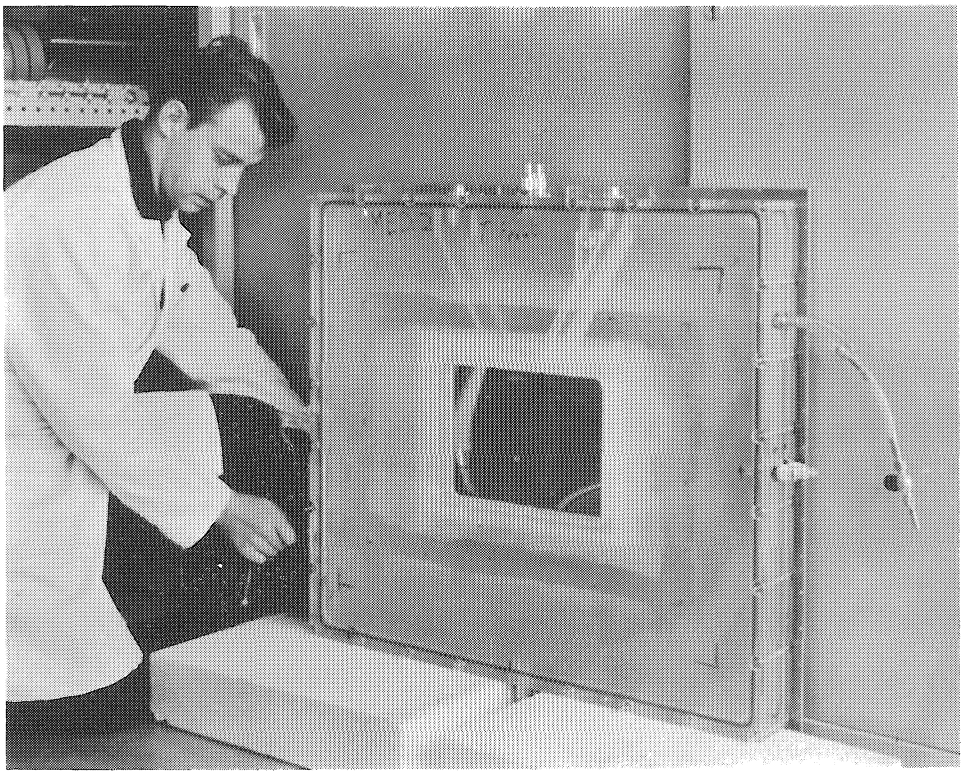

Fig. 2

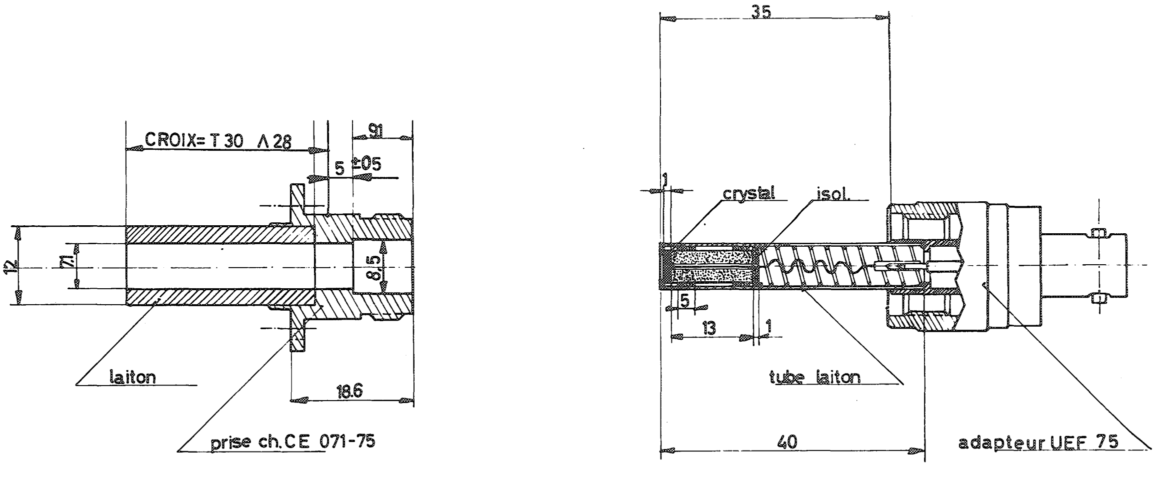

Fig. 3

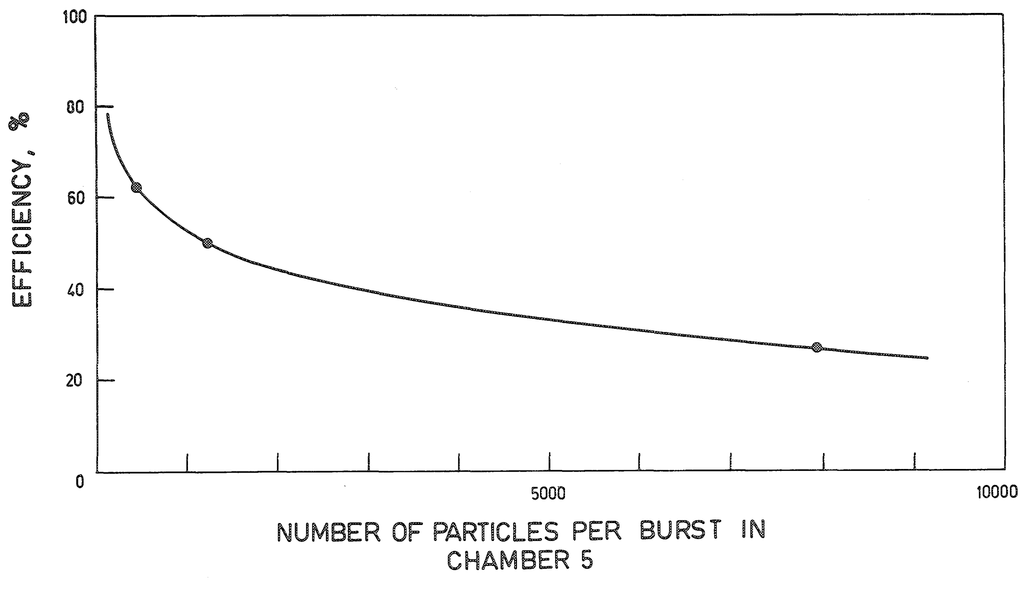

Fig. 4

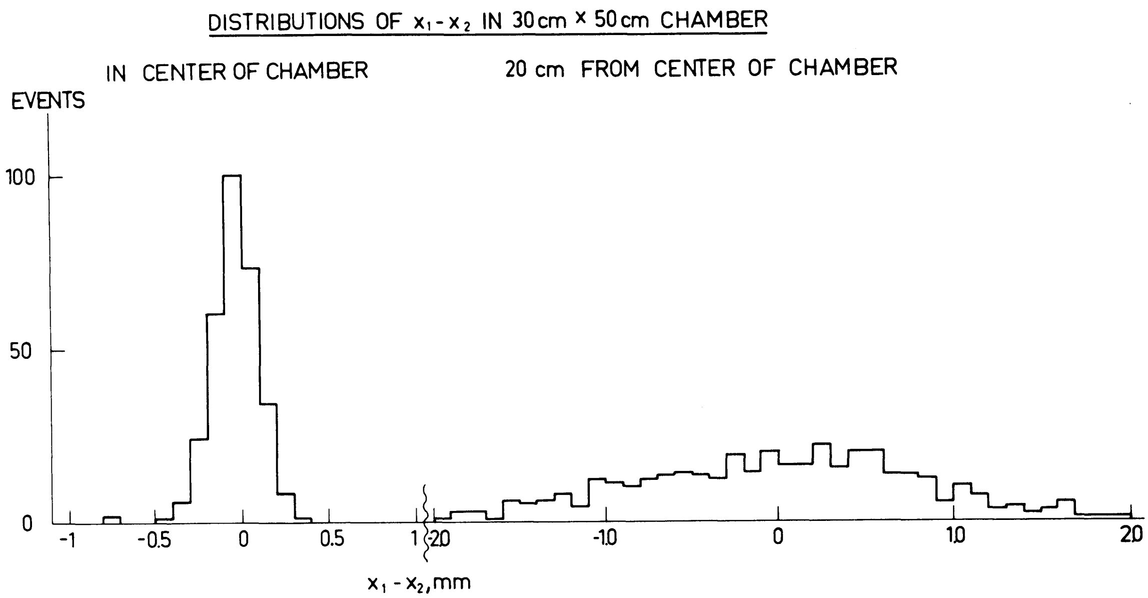
DISTRIBUTIONS OF x₁ - x₂ IN 30 cm × 50 cm CHAMBER
IN CENTER OF CHAMBER
20 cm FROM CENTER OF CHAMBER
EVENTS
100
50
0
-1
-0.5
0
0.5
1
-2.0
-1.0
0
1.0
2.0
x₁ - x₂, mm

Fig. 5

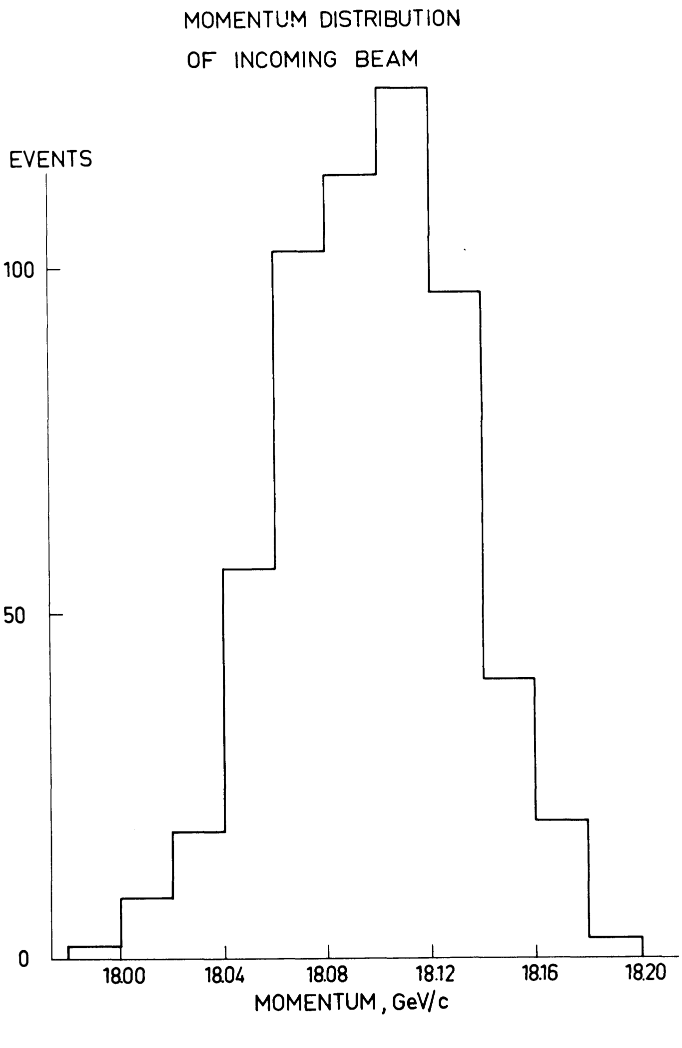
MOMENTUM DISTRIBUTION
OF INCOMING BEAM
EVENTS
100
50
0
18.00
18.04
18.08
18.12
18.16
18.20
MOMENTUM, GeV/c

Fig. 6

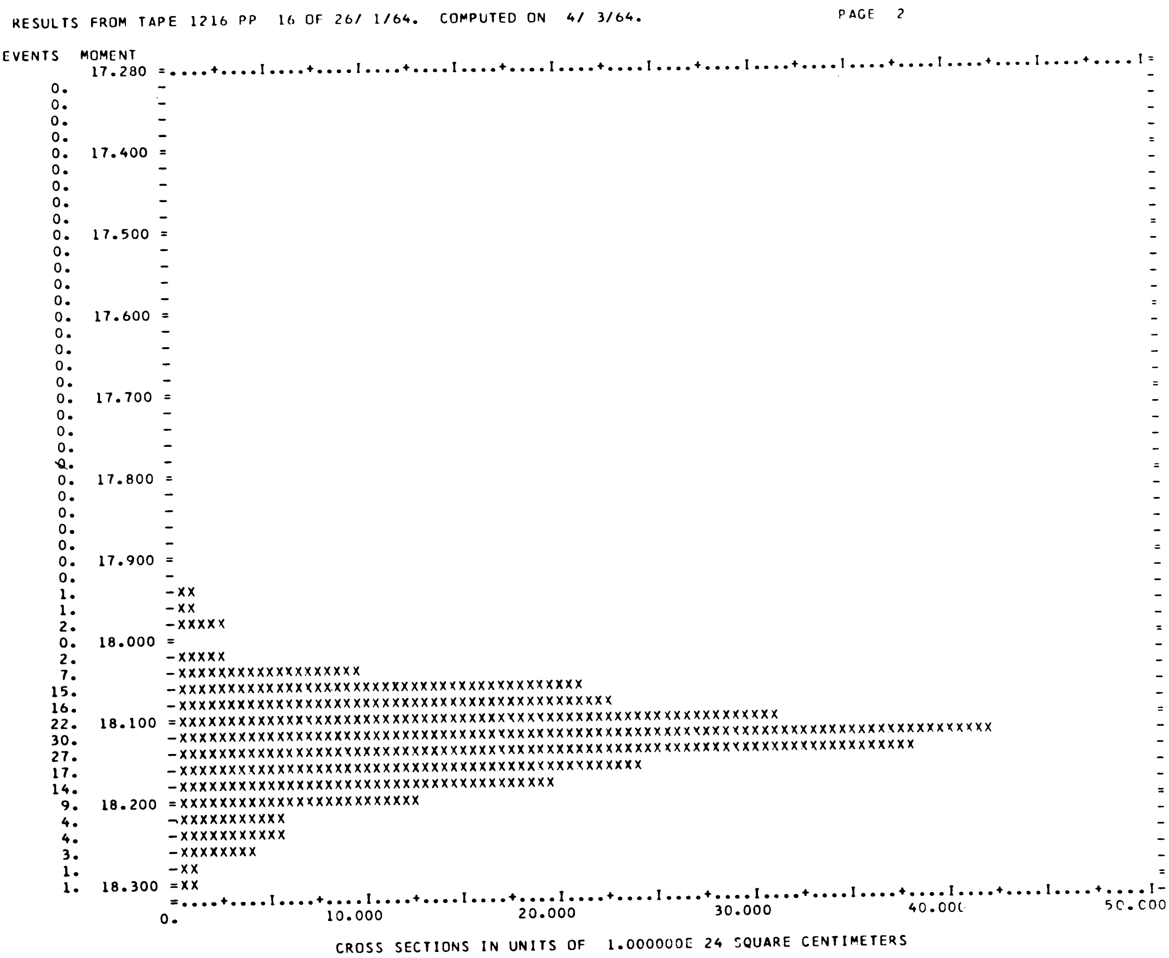
RESULTS FROM TAPE 1216 PP 16 OF 26/ 1/64. COMPUTED ON 4/ 3/64.
PAGE 2
EVENTS
MOMENT
17.280
17.400
17.500
17.600
17.700
17.800
17.900
18.000
18.100
18.200
18.300
0.
10.000
20.000
30.000
40.000
50.000
CROSS SECTIONS IN UNITS OF 1.0000000E 24 SQUARE CENTIMETERS

Fig. 7

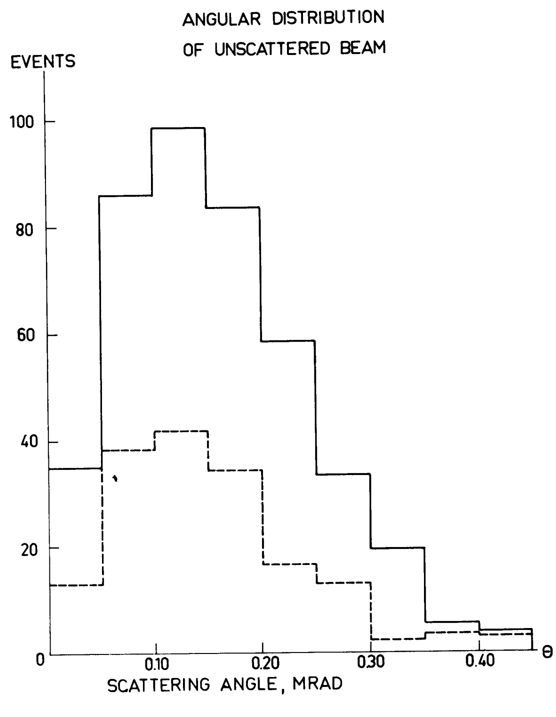
ANGULAR DISTRIBUTION
OF UNSCATTERED BEAM
EVENTS
100
80
60
40
20
0
0.10
0.20
0.30
0.40
θ
SCATTERING ANGLE, MRAD

Fig. 8

DISCUSSION

MAGLIC: The chamber for which you showed that in the centre the resolution has essentially a full width of 0.5 mm and for 20 cm off the centre has 4 mm - isn't this just the chamber for which Zanella's programme of propagation of errors showed exactly that this poor behaviour would be expected due to the relative geometry of the probes and the active area ?

LILLETHUN: This is quite right.

MAGLIC: Can you observe a phenomenon like this with a chamber for which Zanella's programme shows that it should be good everywhere ?

LILLETHUN: We have not really studied it yet.

ANDERSON: Could you say something about the attenuation in the spark as you increase the distance, the size of the chamber. What can you say about the upper limit of size of sonic spark chambers ?

LILLETHUN: I wouldn't like to say much about the upper limit. In our case we use lead zirconate transducers and our signals are not very large, but on the other hand if you use electrostatic microphones then you can always raise the bias voltage and get larger pulses. In our largest chamber which has 30 by 50 cm active area we have observed a drop in pulse height from one end to the other of about a factor 4. We found that it was going more rapidly than 1/R.

MANNING: Would members of the audience like to comment on the size of chambers they have made. We ourselves have made chambers with an active area of 110 cm length. Has anyone made chambers of larger size ?

ANDREWS: We have made chambers up to 130 cm and this is nowhere near the limit. I shall show curves of pulse height against distance which may be extrapolated. It is then a matter of how much amplification you are prepared to use.

LIPMAN: With regardto the size of chambers, I wanted to make the point that it doesn't matter if the signal drops off providing that the noise level is low. With our chamber we found there was an important mechanical pickup from the discharge condensers onto the spark chamber. We found enough pickup signal coming through that we were getting fairly close to the limit on our large chambers, but by shock mounting the actual discharge condensers that supply the energy we were able to get over this difficulty.

WINZELER: Does your set-up integrate over the azimuthal angle too ?

LILLETHUN: Yes. If we consider the fourth chamber, the one which actually defines the scattering angle, we cut out the direct beam with a hole in the triggering system and we include the whole solid angle up to something like 7 mrad, from thereon we use only one side.

WINZELER: Why then use these three counters behind the chamber ?

LILLETHUN: It is in order to have three separate triggering systems to make things more selective. It gives us a momentum selection so as not to trigger on all the inelastic particles.