A CURVED ACOUSTIC SPARK CHAMBER

U. AMALDI, Jr.
Laboratori di Fisica, Istituto Superiore di Sanità, Rome

The acoustic spark chamber we shall describe is meant to be a hodoscope to be added to a counter system to improve their spatial resolution and for this reason could better be called an acoustic spark "counter".

Quite often it is necessary to measure the angle of charged particles produced or scattered in a small target. The best detector geometry would be, of course, a spherical spark chamber. This geometry offers the advantage of a big solid angle together with the property that the particle tracks are always perpendicular to the chamber plates. We think that such detectors could be very useful, for instance, in colliding beam experiments.

The difficulties one expects to encounter in the use of a curved spark chamber are due to the many reflections the sound undergoes along its path. It is thus necessary to study the behaviour of sound shock waves in a curved gap. This is one of the aims of the present work.

There are technical difficulties in constructing a spherical spark chamber of large radius (by "large" we mean a radius of the order of 50 cm so that a 2 or 3 cm target could be considered pointlike ). Thus as a first step towards large solid angle curved spark chambers we have chosen a cylindrical geometry.

Our spark chamber has only two gaps; in this way the electronics is very simple and, on the other hand, there is still the possibility of distinguishing a "spurious spark" (a single spark in one of the gaps) from an "event" (two aligned sparks).

*) More details about the same subject are contained in the report ISS 63/26.

**) This work has been partially supported by the Istituto Nazionale di Fisica Nucleare.
The spark chamber is shown in Fig. 1. In two plexiglass plates 10 mm thick slits are machined 0.6 mm thick and 1 mm deep; aluminium foils 0.4 mm thick and 10 cm high are held by these slits and constitute the chamber plates. The aluminium near the probes has been replaced by bakelite laminas 15 cm long having the same thickness as the aluminium foils. Mylar foils glued all around insure the chamber's vacuum tightness. The useful angle of the chamber is 130°.

To detect the sound wave we use solid dielectric probes.

The probe we have constructed is drawn in Fig. 2; it is mounted on a UHF connector. The mylar foil is 5 μ thick and the O-rings insure both electrical insulation and vacuum tightness. The mylar foil is aluminium coated on the external surface. The DC voltage applied to the central electrode is 180 V and is supplied by four small batteries in series enclosed in a metal box to avoid any electrical pickup from the sparks. The probe dimensions are quite big because our gap is large and we want to collect as much energy as possible.

The probe response to a shock wave from a spark outside of the chamber is shown in Fig. 3a. The spark is obtained by discharging 2000 pF charged to 10 kV; the distance between the spark and the probe is 20 cm. It is seen that the probe output is clean; some of the late oscillations are probably due to sound reflections on the spark and probe holders. The rise time of the pulse is about 3 μsec.

The electronics does not require any special discussion. Four gate circuits are opened by the "event" pulse and 1 MHz frequency feeds through. The probe outputs are amplified by means of transistor amplifiers (amplification variable between 250 and 1000, input impedance 200 kΩ) and shaped by pulse shapers whose thresholds are at 1.5 V. These pulses close the four gates. The 1 MHz pulses fed through are counted by fast scalers.

In the following we shall measure the angular position of the artificial spark in a gap starting from the probe head and we shall call it θ. Moreover by N₁ and N₂ we shall indicate the numbers read on the scalers stopped by the two probes in the same gap. Having only two probes per gap it is not possible to take into account the fact that the velocity of the shock wave varies with the distance from the production point. We are thus forced to neglect the "spark size" parameter ΔR discussed in detail in Ref. 1. The obtainable accuracy in the determination of the position of the sparks will thus be much poorer than the one obtained with four probes in a flat chamber.1)
If we call \( y \) the distance of the spark from the mean plane of the chamber in the vertical direction, the equations which determine \( \alpha \) and \( y \) are:

\[
\alpha^2 r^2 + y^2 = (kN_1)^2 \tag{1}
\]

\[
(\alpha_M - \alpha)^2 r^2 + y^2 = (kN_2)^2
\]

where \( r \) is the gap radius and \( \alpha_M \) is the angular distance between the two probes.

From (1) we get:

\[
\alpha = \frac{k^2}{2(\alpha_M^2 - N_2^2) + \frac{\alpha_M}{2}} \tag{2}
\]

\[
y = \pm (kN_1^2 - \alpha^2 r^2)^{\frac{1}{2}}. \tag{3}
\]

To check experimentally the validity of eqs. (2) and (3) it is necessary to produce sparks in very well known positions. Because we did not have at our disposal a narrow beam of particles we have put in each gap a small movable plexiglass carriage holding a needle in an easily variable position. The application of a 13 kV pulse to the chamber plate touching the conductor connected to the needle results in a spark between the needle itself and the grounded plate facing it. We shall call these sparks "artificial sparks". During these tests air is contained in the chamber; the positions of the carriage are varied by means of nylon strings coming out of the gaps near the acoustic probes.

The top trace in Fig. 3b is the output of one of the probes for \( \alpha = 135^\circ \), the second for \( \alpha = 75^\circ \) and the third for \( \alpha = 150^\circ \). Prior to the main oscillations due to sound transmission in air, some sound is received by the probe for \( \alpha = 75^\circ \) and \( \alpha = 135^\circ \). The more natural interpretation is that they are due to sound partly transmitted through the aluminium plates and then reemitted in air. For this reason we have cut the gap plates into segments 7 cm long. As is shown in Fig. 3c (to be compared with Fig. 3b) this is enough to prevent such a transmission. The oscillations which are left after the first peak are due to true sound waves arriving at the probe and they last about 2 msec.

In Fig. 4 we have plotted \((N_1^2 - N_2^2)\) as a function of \( \alpha \). The needle was sparking at the centre of the gap towards the inner plate. The dimensions
of the points are of the order of the errors obtained repeating the measurements in the same position. In spite of the many reflections suffered by the sound in the gap the relation between \( \alpha \) and \((N_1^2 - N_2^2)\) is exactly linear, as predicted by eq. (2). It must be noted that for \( y = 0 \), \( \alpha \) is linear not only in \((N_1^2 - N_2^2)\) but also in \((N_1 - N_2)\). In fact \((N_1^2 - N_2^2) = (N_1 - N_2)(N_1 + N_2)\) and for \( y = 0 \), \((N_1 + N_2)\) does not depend upon \( \alpha \) and is proportional to sound velocity. Moreover, for \( y = 0 \) the angle \( \alpha \) obtained applying eqs. (1) and (2), where the "sparking size" \( \Delta R \) has been neglected, equals the solution of the correct equations

\[
a \alpha = kN_1 + \Delta R
\]

\[
(a_M - \alpha) \ r = kN_2 + \Delta R.
\]

Other measurements have been done under the following conditions: needle at the centre of the gap sparking towards the outer plate and needle on one side of the gap sparking towards the inner and the outer plates. The differences \((N_1^2 - N_2^2)\) measured in these conditions coincide, for the same \( \alpha \), with the values plotted in Fig. 4 within less than 0.16 units of the vertical scale. Because 2.9 units correspond to \( 10^9 \) we conclude that the error in the determination of \( \alpha \) for all \( y \)'s is less than 0.6 degrees. A big contribution to this error comes from the fact that we have neglected \( \Delta R \) in eqs. (1) and (2). With more probes in a curved gap it should thus be possible to achieve an accuracy closer to the one obtained in flat chambers. We recall that in our chamber 0.6° correspond in space to about 6 mm. Because this error is of systematic origin, it must be interpreted as a total maximum error.

From Fig. 4 and eq. (2) we get \( (r = 55 \text{ cm}) \):

\[ k^2 = 0.9462 \times 10^{-3} \text{ cm}^2 \]

\[ \alpha_M = 149.1^0 \]  

(4)

Eq. (3) in principle determines also the \( y \) position of the spark. Using the experimental value (4) for \( k^2 \), we find that it is possible to get a good value for \( y \) if the spark is not too far from one of the probes (less than about 40°).

The chamber has also been tested with cosmic rays. In this case the applied voltage is 14 kV and the coupling capacitor is 6000 pF. While the results of the calibration obtained with artificial sparks have been confirmed, it is observed that almost no sound is transmitted through the plates before the main pulse. The most reasonable interpretation of this fact is that in the case of artificial sparks the carriage in the gap transmits oscillations to the plates.
In Fig. 5 the response of a probe to cosmic ray sparks is shown for α = 15° and α = 135°. The rise time of the first peak of these pulses does not depend upon α and it is about identical with the value obtained in free air. The pulses due to artificial sparks on the contrary showed a pronounced dependence of the rise time upon α. To explain this result we first note that the energy of the cosmic ray spark is bigger by more than a factor of 4 than the energy of the artificial sparks. Moreover, a comparison of Figs. 3 and 5 shows that the cosmic ray pulses are much bigger and cleaner than the artificial ones. These two facts tend to indicate that the shock wave was not developing properly in the tests with artificial sparks and suggest the conclusion that in a curved gap an energetic shock wave can propagate, guided by the plates, preserving its rise time.

ACKNOWLEDGEMENTS

We are indebted to Dr. B. Maglić for useful discussions and to Professor N. Ageno for his continuous interest.

Reference


8446/nn
Figure captions

Fig. 1  Spark chamber mechanical construction.

Fig. 2  The solid dielectric probe.

Fig. 3  

a) Response of a solid dielectric probe to a spark in free air; left: (.2 msec/cm) x (30 mV/cm); right: (15 μsec/cm) x (30 mV/cm).

b) Probe response to artificial sparks in the curved chamber after the amplifier (amplification ≈ 200). From the top:

\[ \alpha = 135^\circ \times (0.2 \text{ msec/cm}) \times (2 \text{ V/cm}) \]

\[ \alpha = 75^\circ \times (0.2 \text{ msec/cm}) \times (2 \text{ V/cm}) \]

\[ \alpha = 15^\circ \times (0.2 \text{ msec/cm}) \times (5 \text{ V/cm}) \]

c) Same as b) after segmenting the chamber plates (amplification ≈ 500).

Fig. 4  \((N_1^2 - N_2^2)\) as a function of the angular distance of the artificial spark from the probe (see text).

Fig. 5  Probe response to cosmic ray sparks before the amplifier. From the top:

\[ \alpha = 15^\circ \times (10 \text{ μsec/cm}) \times (50 \text{ mV/cm}) \]

\[ \alpha = 15^\circ \times (0.2 \text{ msec/cm}) \times (50 \text{ mV/cm}) \]

\[ \alpha = 135^\circ \times (10 \text{ μsec/cm}) \times (20 \text{ mV/cm}) \]

\[ \alpha = 135^\circ \times (0.2 \text{ msec/cm}) \times (20 \text{ mV/cm}) \]
DISCUSSION

LIPMAN: I haven't quite understood whether the sound follows a straight line or whether it follows the curvature of the aluminium foil or whether it follows the curvature of the lucite? Could you explain this?

AMALDI: The only way the sound reaches the probe is by following the curvature. Probably due to the fact that the sound path is well guided by this small chamber there is no loss in the rise time of the pulse.

ANDERSON: But what about the attenuation in the pulse height. Does the amplitude of the pulse vary depending on where the spark is?

AMALDI: It varies, but not very much. The amplitude, when the spark is near the probe, was of the order of 70 millivolts, and of the order of 30 millivolts when the spark was near the far end of the chamber. I would like to remark that the rise time of my probe is quite slow in comparison with others. The reason is probably that the area is quite big.

MACLEOD: Have you thought about how many microphones you will in fact need when you extend this to a spherical system? Your conditions about guiding the sound will presumably no longer hold under these conditions.

AMALDI: I think that for a hemispherical chamber I would use of the order of 5 microphones - 1 on the vertex and 4 on the sides, but I have not considered the ambiguity problems.

CHARPAK: Is the velocity you expect in a curved path exactly the same velocity as in a straight line?

AMALDI: I don't know enough about sound propagation to answer your question.