DETERMINATION OF THE POSITION OF SPARKS BY MEANS OF MEASUREMENT OF CURRENTS

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(presented by G. Charpak)

When a discharge occurs in a spark chamber it is associated with several physical effects containing the information about the spatial position of the spark. We have investigated some of the electromagnetic aspects of the spark.

The use of the finite velocity time for the electric charge to propogate at two opposite ends of the ground plate has been proved to be feasible[1]. It requires, however, special structure for the ground electrode in order to increase the path of the currents. The recent progress in the making of printed circuit electrodes could justify new attempts along this line.

The use of the intensity of the pick-up signal in a loop placed on the side of the chamber has also been tried. The loop was part of a ringing circuit of low frequency, excited by the spark. The height of the signal was strongly depending on the position of the spark, with a high power of the distance.

The method that proves, however, to be the most simple and easy to operate is to measure the relative distribution of currents when several channels are offered to the current for leaving the electrode after the discharge[2]. Fig. 1 illustrates the method, with two outputs to ground.

The charge Q carried by the storage capacitor is split in two parts, Q_1 and Q_2, according to the relative impedance of the two paths to ground. If the impedance of the connections of the plates to ground is low when compared to the impedance of the electrodes, then the current splitting depends only on the relative path length on the electrode, i.e. the position of the spark. Measuring the difference between Q_1 and Q_2 can be done in several ways.

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The most simple is to use a transformer where the primary is the ground connection passing through the centre of a ferromagnetic core. Ten turns around the core give signals of sufficient amplitude.

With a tuning capacity C (Fig. 2) of 30000 pF, the ringing frequency of the external circuit is rather low (0.5 MHz). With a diode circuit only the first half oscillation is selected and a clean pulse of several volts is obtained, of a height depending on the position of the spark. The following observations have been made.

The spark itself gives rise to very high frequency currents and the impedances are governed by the high frequency properties. Because of the skin effect, only the properties of the surfaces are important. The impedance of a path depends strongly on its coupling to neighbouring ground leads. For this reason, rigid ground connections are preferable.

The dependence of $Q_1 - Q_2$ over the position is linear in the central part of the chamber. End effects appear when the spark occurs at the ends. This can be made of little importance by extending the ground electrode outside the chamber.

The dependence of the currents on the coordinates is not cartesian when the connection to ground is made through limited area. Considerable improvement is obtained when the connection to ground is done through two lateral slabs of a material with a conductivity much higher than the conductivity of the electrode. This gives the method a very great flexibility.

It is possible, by properly choosing the shape of the ground electrodes to obtain directly the information in various coordinate systems, for instance, cylindrical coordinates (Fig. 3).

The limit to the accuracy is given by the fluctuations in the total charge $Q_1 + Q_2$. By using one additional core through which the total current has to pass before reaching the ground, or by using two additional windings on the two cores of Fig. 1, with the addition of the pulse heights, one obtains a monitor signal eliminating this effect. Analogue circuits may give directly the ratio $Q_1 - Q_2/Q_1 + Q_2$.

The signal can be obtained within times shorter than the memory time of spark chambers and this can be used, as an additional logical element, to trigger other spark chambers.

The analogue display can allow fast combination of the signals from several spark chambers. For instance, in a pair spectrometer, the sum of the diameters of the two electrons can readily be obtained, thus giving directly the energy of the γ-ray.

It does not prevent the use in parallel of any other method if it is judged preferable for any reason, since normal spark chambers are used.

The simplicity of the data extraction can allow the extraction of the data from complex arrangements. For instance, in a range chamber with a great number of gaps, it is very easy to obtain the number of gaps traversed by the particle, together with information about eventual missing gaps, or spurious sparks.

The weak point of the method now is its inability to identify multi-spark events. In this respect it is different from the sonic method where the addition of probes gives redundant data. There, the addition of a new lead to ground, on one electrode, brings more information but also changes the current passing through all other leads. We see a way out of this difficulty by the use of electrodes with printed circuit wires on fibre glass and epoxy*). These electrodes present considerable advantages.

1. The conductors are linear and only connected at the end. All end effects then disappear**). The response is linear on the whole length. The response is independent of the lateral position, thus giving a perfect cartesian system,

2. It is easy to split the electrodes in independent elements, for instance cm by cm. The currents of an element of 1 cm are passing through a flipping core, before going all together through the central hole of the core giving the coordinate information. The flipping cores are then interrogated first to know whether more than one spark has occurred.

References

1. G. Charpak, Nucl. Instrum. Meth., 15, 318 (1962).

2. G. Charpak, J. Favier and L. Massonnet, Nucl. Instrum. Meth, 24, 501 (1963).

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*) Thin electrodes of this type have been provided by Philips, Zürich.

**) This has been observed by Mr. Jeanjean, at the Faculté des Sciences d'Orsay (private communication).

Figure captions

Fig. 1 Diagram of the extraction of information from the chamber. The pulse-height is proportional to $Q_1 - Q_2$ or $Q_1 + Q_2$, depending on the relative winding direction of the two cores, C is a capacity controlling the frequency of the external circuit (~ 30000 pF). R is a resistor used to shift the zero out of the middle of the chamber. L is a choke to absorb the fast transients.

Fig. 2 Ground electrode structure giving cartesian coordinates. The current on each side is extracted through contacts of silvered brass.

Fig. 3 Spark chamber giving directly the scattering angle. A hole through the chamber eliminates the direct beam. Two concentric ground connections of high conductivity give directly the distance of the spark to the centre of the chamber.

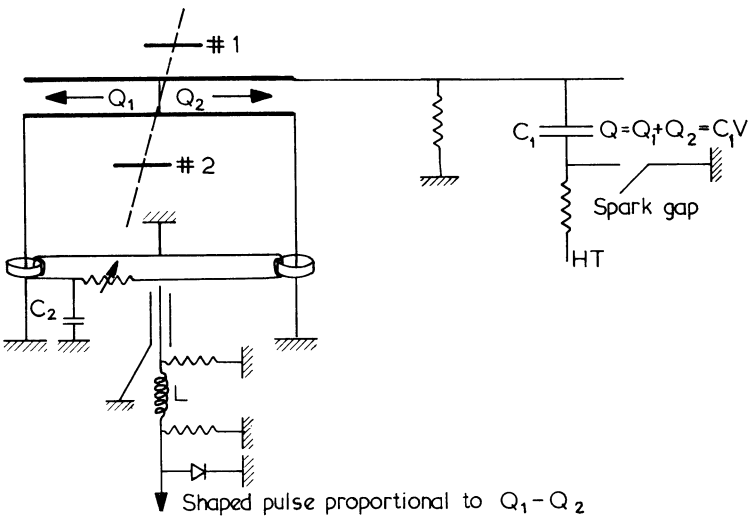


Fig. 1

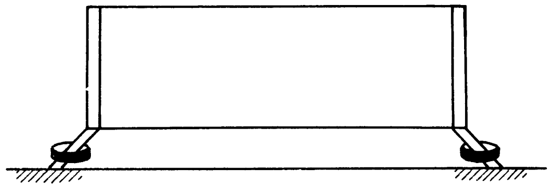
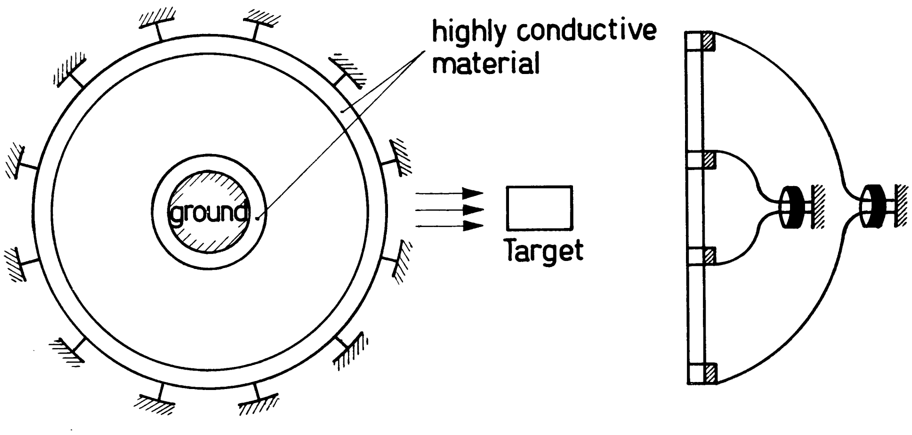


Fig. 2



Fig, 3

DISCUSSION

CHAIRMAN: Are there any questions on this very interesting development ?

R.H. MILLER: Your discussion seems to be based on the current division being controlled by resistance of the lines and I have the impression that it would largely be controlled by the inductances of this system, and particularly with this annular system you described, it is not quite clear to me that you are going to get the information independent of y because of the inductance structure of this system if you have single grounding points.

CHARPAK: You wouldn't use single grounding points. You would take the precaution of taking out the current along the circumference. I agree with you that the division is controlled by the inductances of the different lines. For instance, if the return to ground happens to come closer to one side the circuit becomes asymetrical. It is good to have rigid connections and be aware that uncontrolled metallic masses moving around the chamber may change the properties.

LIPMAN: For the question I would like to ask I wish to use the blackboard if I may ? It is not quite clear to me that you would get complete uniformity of response in your system because you have the current coming out from a single point so what you are trying to measure is R1 to R2 and you are hoping that R1 to R2 will be as X1 is to X2, but depending on the position of the spark of course you will get various current patterns through the space, and it is not absolutely clear why you get uniformity which is as good as it is. As you come out towards the side one would also expect these non-uniformity effects. But if I may go on - one other solution to this problem which I see is that you could have copper printed lines, on aluminium electrodes, in the direction perpendicular to the measured coordinate. In this case when the spark occurs the current is distributed up and down the copper strips and then you will get complete uniformity of the spark. Now you said that perhaps you would put a series of cores on the end of a printed wire electrode in order to get information on which wire went off. Of course it may not be necessary to go over to a digital system. You could, for example, have a delay line, as Mervyn Hine suggested in the discussion of Giannelli's paper, and let these be transformers and simply find the delay at which the wire goes off.

ROBERTS: I would like to also add a brief comment of my own here. I mentioned yesterday that we had considered these cores. There is only one objection I can see for putting cores for identifying the wires and that is that if they are the usual type of computer cores they introduce a non-linear impedance which may make the accuracy of location much worse.

MAEDER: It was mentioned previously that the approach using magneto restrictive wires would be the first chamber which would consist of only one plane and gives everything, but it seems you can have the same thing if you do go over to a complete wire chamber and put ferrites around each wire. Now you use it on one hand, for distinguishing the individual wires and on the other hand, on both sides for determining the position of the spark along each wire and you thus get all the coordinates even for multiple tracks as long as they are not multiple tracks on the same wire, for which the probability would be small.

CHARPAK: The only thing, it seems to me, if you have to go to the complexity of a wire chamber, which is after all quite a good system, why not use completely a wire chamber with its storage cores. Then our system does not give you much more except the fast response that you may want to use or not want to use.

MAEDER: But it solves the problem of multiple tracks ?

CHARPAK: Yes, but the wire chambers resolve it already.

MAEDER: But then you have to use at least three planes. One horizontal, one vertical and one at 45° and here you could do with just one single set.

AMALDI: I think that this system is very good. In fact we made a chamber of this type and we have tested it in Frascati in an experiment we are doing but it seems that a remark has to be made. We have used a mesh as suggested by Charpak for the plate because it has a higher resistibility and we have a single gap and measure one dimension. This is useful in our case because we have to tune a beam which has a horizontal focus irrespective of the vertical focus so we send the pulse directly on a kick sorter, and there we see the image in the horizontal plane without any information about the vertical plane, which is what we want. It is clear that if the system is very simple this is a wonderful system. It can be done in a day, but if the system comes out a bit complicated you need for each gap a kick sorter in a certain sense. What do you do when you like to digitize in amplitude ? You transform it in a digitized form with a height to time converter. With the sound you get immediately the time transformation. So my impression is that it is very useful for simple systems but less useful for a complicated system.

ROBERTS: We could summarize this by saying that since the information here is analog information it is considerably more expensive to record it than digital information, and consequently more suitable for smaller systems. Are there any more questions ?

COLLINS: If I am not mistaken there is some advantage in retaining the wires not necessarily the cores because I think if you have large planes the capacity of this system means that the energy that goes into the discharge is large and therefore you produce a lot of ions and the recovery time is increased, whereas if you just discharge one wire the energy is less and so you can operate at a higher repetition rate.

CHARPAK: This is the case when the wires are on the high voltage side.

COLLINS: Yes.

CHARPAK: You want to say that the reason why at Brookhaven you reached these high rates of 10^4/sec is because of the low capacity of the wires.

COLLINS: I think so.

CHARPAK: But with iodine discharge chamber working at low voltage we had found that we can operate at a very high rate also, although it was between two planes. The dead time was about 100 μsecs. The pulse will be much smaller, and further development work is necessary to know whether we can use this method under such conditions.

VERNON: Is it possible that you may have developed a simple analog divider to normalise the difference of the charge to be able to use only one pulse height analyser ?

CHARPAK: It is certainly possible, and I know that in Frascati a circuit is being built that is extremely simple and it gives directly the ratio of the two pulses. In the experiment we are planning now we are going to have information printed from a set of scalers. But that is a rich man's method because we have these CERN scalers which are very convenient.

MELMED: Have you made any measurements on the current distribution on the wire system as opposed to the measurements you showed on the slide which I assume was for a plate system ?

CHARPAK: This has been done at Orsay and with a wire chamber they said to me they had absolute linearity from one end to the other.

QUERCIGH: What happens if the other electrode is a spiral ?

CHARPAK: It seems to me that if you use a spiral there is a problem of triggering. You want to have a good rise time, so if you apply a pulse on a spiral maybe your rise time will suffer a little bit. But you can probably overcome this by having the spiral and then a concentric metallic electrode separated by a dielectric and you pulse these electrodes so by capacitive coupling probably you bring the whole spiral to a given potential, and it seems to me that then it will work; it will take some time for the currents to go out and that will tell you if you make a time difference, where the spark has occurred. And also if you measure the difference in current at the two ends.

R.H. MILLER: Is there any limitation as to the fractional accuracy you can get out of this ? In principle the spiral you are beginning to talk about is a very long wire one that maybe some 10 metres long or something like this, and then if you start talking about one millimetre resolution you are beginning to talk about one part in 10^4 and there would be some question as to whether you can retain fractional accuracies like that.

CHARPAK: The accuracy could in principle be better than the level of the spark accuracy itself.

R.H. MILLER: I would be surprised if you could locate it to within a millimetre in a kilometre.

CHARPAK: If you have an analog display there is a problem in your time conversion but if you have plenty of time I have the impression that you can go very far; it means that you have to open a gate and have a stable oscillator.

ROBERTS: This question as to the ultimate accuracy is an interesting one because when you get into all sorts of problems like lead inductance from the ends of the chamber and at the 1/10th per cent level this is not trivial any more, so like in any analog measurement there is some limit.

CHARPAK: The only problems in lead inductance I see is that the lead has to be fixed. You can compensate for anything as long as it is constant.

ROBERTS: Yes and you also have the two transformers which you are using in an approximately linear mode but they aren't really linear because they contain ferromagnetic elements and they are not good to better than a fraction of a per cent.

CHARPAK: We have tried with a two metre chamber and had the system working easily.

GIANNELLI: The idea could be to make a system which is a composition of the delay line system and the system you describe.

CHARPAK: When we made the method with the delay line we were a little bit blind because we were getting on each side signals that were delayed, but at that same time we observed that they were of different pulse height, and we just did not react to this. It took us a long time to find out that this was in fact an information independent of the structure and for this reason more interesting because you can take a standard spark chamber and have the information.