Nuclear Instruments and Methods in Physics Research A251 (1986) 196–198
North-Holland, Amsterdam

Letter to the Editor

HIGH RESOLUTION DIGITAL AUTORADIOGRAPHY OF SHORT AND LONG RANGE β^- EMITTERS USING A SINGLE STEP PARALLEL PLATE CHAMBER

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Received 25 March 1986

The use of single step parallel plate counter for the two-dimensional imaging of β^- emitters is discussed. The parallel plate chamber has a resistive germanium anode and a cathode made up of a nickel mesh having 600 line pairs/in. A ≈ 500 μm (fwhm) resolution for ^{3}H and a ≈ 1 mm (fwhm) resolution for ^{14}C have been measured.

One or two-dimensional imaging of β^- emitters is a very useful technique in many fields of applied research (radiochromatography, tissue autoradiography etc...). The use of passive techniques like film blackening [1] results in a very high spatial resolution but, as opposite, in a very low time resolution (several days of exposure are common). On the other hand, active techniques like gas proportional counters [2] are characterized by a very good time resolution (a few minutes of exposure are usually sufficient to collect statistically significant data) but by a low spatial resolution. This is due, mainly, to the parallax error which is particularly severe when using long range β^- emitters. Recently Petersen et al. [3], Abdushukurov et al. [4], Bateman et al. [5] have proposed the use of a Multistep Wire Chamber to obtain a high resolution two-dimensional imaging of long range β^- emitters.

In this paper we present a simplified approach to this problem showing how a high resolution two-dimensional reconstruction of β^- distributions can be obtained using a single step parallel plate avalanche chamber working at atmospheric pressure.

A parallel plate chamber (PPC) consists of two continuous electrodes mounted parallel to each other (see fig. 1). When a potential difference is applied between close electrodes, a uniform, intense, electric field is established inside the detector volume. Ionization electrons delivered by a traversing particle start to multiply until they are collected by the anode. In the case of extended ionization the number of secondary electrons is given by:

$$n = \int_0^d n_0/d\ e^{\alpha x}\, dx,$$

with

n_0 = number of primary electrons

d = drift length

x = first Townsend coefficient.

Ionization collisions close to the cathode give a greater contribution to the total signal than those close to the anode. A gas gain up to 10^4–10^5 can be easily obtained. If the electrode plates are both made of conducting material a voltage pulse due to the collection of the drifting charges can be observed in a external circuit connected to one of the electrodes. However, because the whole electrode plane moves to the new potential no positional information can be obtained

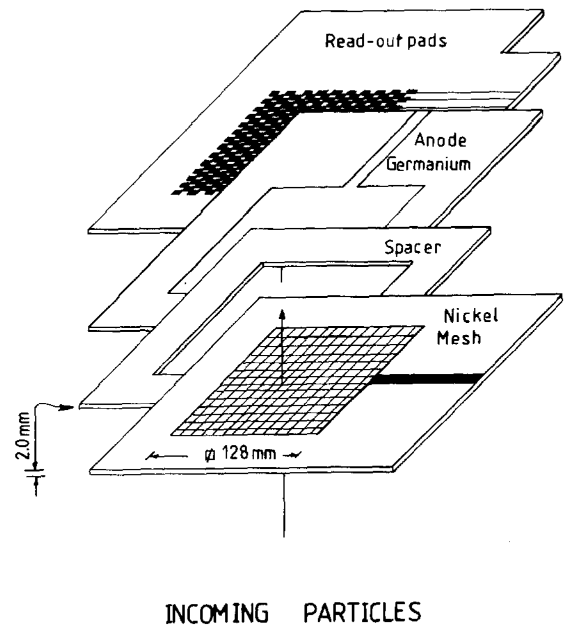

Fig. 1. Schematic view of the detector assembly.

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from this signal. The situation is completely different if one or both of the electrodes are made of a semiconductor material with a sufficiently high sheet resistivity. In this case we can consider the electrode as a two dimensional array of resistances. If an array (one or two dimensional) of capacitances is placed behind the resistive plane a "short circuit" to ground is established for impulsive current. We can say that the resistive plane acts as a conductor for dc currents, so that it can be charged to a suitable potential, while it acts as a dielectric for very short currents so that it is transparent to the corresponding impulses. The positional information can be obtained from the distribution of the charge collected on the external capacitances.

The material we choose for the construction of the resistive anode is germanium which has a resistivity of 60 Ω cm. As a support of the germanium deposit we used a machined epoxy plane or polished glass. The cathode is made of nickel mesh having 600 line pairs/in. (50% optical transparency). This transparent material was chosen to have an entrance window for short range particles such as low energy X or β^- rays. Behind the anode plane a double-sided chess board of 2 mm × 2 mm "pads" collects the fast electron impulse and is used to obtain the event position. Half of the pads are zig-zag connected to form rows on one side of the chess-board. Metallized holes of 0.5 mm diameter connect the remaining half of the pads to form columns on the back side of the chess-board. In this way a two dimensional read out is obtained looking at the detector from one side only, leaving the front side free as window for the incoming particles. The detector active area is 13 cm × 13 cm and the gas filling was argon (90%) and methane (10%). A typically operating voltage when working at normal pressure was 3.2 kV corresponding to a uniform electric field of 16.0 kV/cm for a 2 mm gap.

The advantages of this set up are:
1) two dimensional positional information is obtained from a perfectly homogenous, self triggering detector;
2) the detector and the read-out system are physically and logically separated so that they can be optimized independently;
3) the data rate is subdivided over the whole detector volume;
4) the detector is mechanically very simple and sturdy (no fragile wires in the same detector).

From the point of view of digital imaging of long range β^- emitters the most important point is that ionization electrons created close to the entrance window (the cathode) have the largest gain so that an "electronic collimation" of inclined tracks is obtained. All acts as the "active" thickness of the detector is reduced to a few 100 μm thus reducing the parallax error.

The event position is obtained from the measurement of the centroid of the charge distribution on the read-out pads. For a detailed discussion of the detector construction and of the read-out system we refer to a preceeding paper [6].

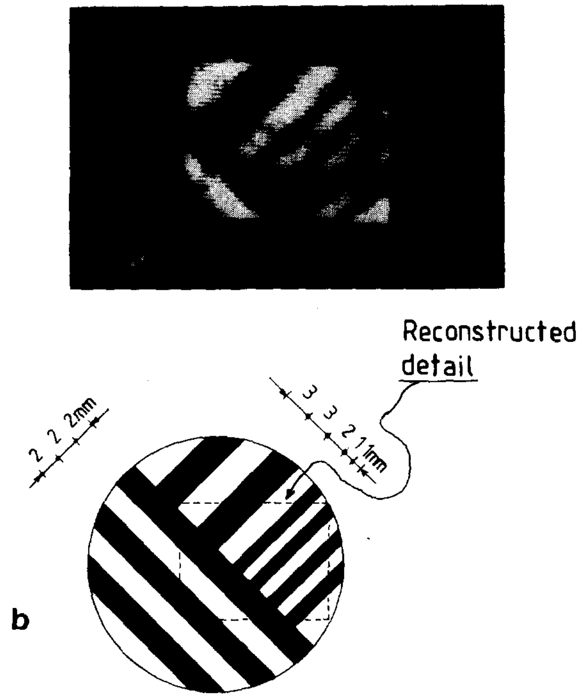

Fig. 2. The reconstructed image of the detail inside the dashed box (a) and ^3H resolution phantom (b).

To test the two dimensional reconstruction capability of the device we have used two resolution phantoms which were placed directly inside the gas vessel, just outside the active volume at a distance of ≈ 500 μm from the nickel mesh. The first resolution pattern was

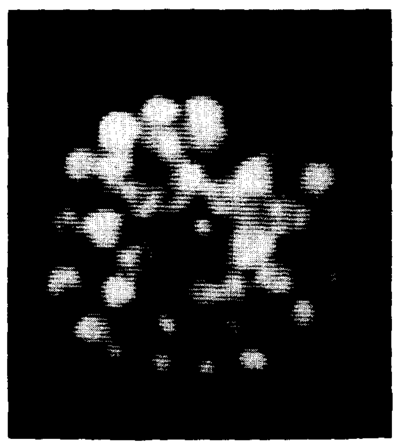

Fig. 3. Reconstructed image of a ^{14}C disk source made up of several "point sources".

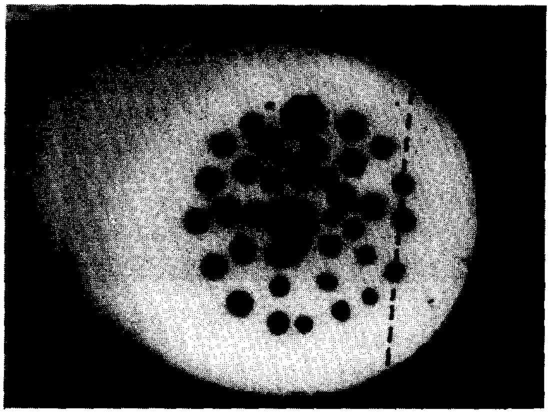

Fig. 4. Film autoradiography of the same ^{14}C disk source of fig. 3.

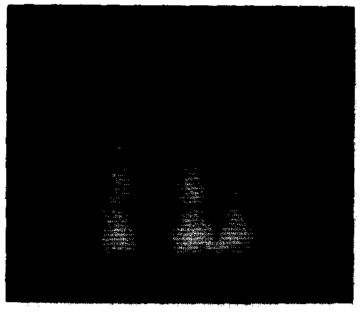

Fig. 5. A profile along the dashed line shown in fig. 4. The separation between the three sources is 4 mm and 2 mm.

obtained superimposing a mask made of parallel lines to a ^3H disk source. The mean free path of ^3H β^- rays is ≈ 1 mm in gas at STP, so that the ^3H resolution phantom was used to check the two-dimensional imaging of short range β^- emitters. Fig. 2 shows the resolution phantom together with a detail of the reconstructed image. All the 1 mm lines are perfectly resolved indicating that a resolution of ≈ 500 μm (fwhm) is achievable for tritium. To check the two dimensional imaging of long range β^- emitters we used ^{14}C which has a range of several centimeters in gas at STP. Fig. 3 shows the reconstructed image of a ^{14}C disk source made up of several individual sources having radii between 0.5 and 1.5 mm and separation between 1 and 5 mm. Fig. 4 shows for comparison the film autoradiography of the same source. Fig. 5 shows a profile along the dashed line shown in fig. 4. The separation between these three particular sources is 4 and 2 mm. A resolution of ≈ 1 mm can be estimated for both the coordinates.

As a conclusion we can say that a high resolution digital imaging in two dimensions of β^- emitters of short and long range has been demonstrated by using a single step parallel plate avalanche chambers.

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