Fermi National Accelerator Laboratory

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BUBBLE CHAMBER SUBTRACTION PHOTOGRAPHY

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ABSTRACT

A method is described that enables one to photograph the event of interest from among a background of unwanted tracks in a single bubble chamber expansion. This then permits one to search for rare interactions which may be identified by downstream counter systems. The signal from the downstream system can be used to trigger the cameras modified as described below to obtain the picture of the event of interest, ignoring the unwanted background events. Up to 10,000 particles/second may be sampled thus. Given the greater path lengths available in bubble chambers as compared to targets used in counter experiments, (which have to be point like by necessity), the method, if implemented, promises to make the bubble chamber competitive with counters and even superior to them for searching for rare interactions.

Description- Consider a charged particle beam, in which particles are delivered in bursts separated in time by a millisecond. Let each burst contain ten particles. The duration of each burst is of the order of 0.1 μs. There is a downstream counter system capable of deciding whether an event is wanted or not in a few microseconds. When an event of interest occurs, at least a millisecond has to elapse before the bubbles produced by the tracks become visible. Before they become visible, a photographic record of the state of the chamber is made. After they become visible, another photographic image is made, which is subtracted from the previous image. The image that is left would consist of the event of interest along with other particles that entered the chamber in the same burst. Since there are roughly ten particles per burst, this would present a manageable picture. We thus sample 10 particles/ms which is equivalent to 10^4 particles/second.

The Subtraction Mechanism - We utilize the Pockels effect in a $KD_2\ PO_4$ crystal cooled to its Curie temperature (-50°c). The device described here has been developed by Donjon et. al.,[1] and has been called Phototitus by them. The device consists of a crystal of KD_2 PO4 coated with a transparent platinum film acting as an electrode. On the other side is sandwiched a dielectic mirror and over the mirror a layer of amorphous selenium coated again with platinum (Fig. 1). Light from the tracks in the bubble chamber causes pairs of electrons and holes to be formed in the selenium. By applying a suitable voltage ($\simeq$ 100 V) between the platinum.

electrodes, one can cause either electrons or holes to be deposited on the crystal of KD_2 PO_4 where they produce local birefringence according to the Pockels Effect. The image becomes visible when viewed in polarized light.

Typical recording time is of the order of 10 μs. Further details may be found in ref. 1. When an event of interest occurs in the chamber, the counter logic responds within a few microseconds but the bubbles of interest are not visible. A recording of the chamber state is made on Phototitus by strobing a flash of 10 μs duration. A millisecond later when the bubbles from the event of interest have grown, the polarity of the voltage between the platinum electrodes is reversed and another recording of the chamber state is made. This will now cause the subtraction of the second image from the first since holes will now be deposited on KD2 PO_4 where electrons were previously. Such subtraction procedure for ordinary images is described in Donjon et. al.[1]

Only particles present in the final burst will be visible. The image on the phototitus is now photographed in polarized light. (See Fig. 1).

Fiducials of the chamber will be absent from this photograph as they will have been subtracted. One way out of this is to have specially illuminated fiducials which flash only on one of the two pictures. The other is to add the fiducials by a third strobe with a clean chamber on to the phototitus, after an event has been accepted.

Type of Bubble Chamber Required

A continuously sensitive bubble chamber volume is required with periods of sensitivity of up to 0.5 sec. I am told that such chambers are possible provided one uses perspex sides.[2] Maximum bubble sizes of up to 2 mm can be tolerated in the chamber since these will be subtracted out by Phototitus. At a point where they become too large, to be determined by experiment, the chamber is recompressed and the Pockels cell image is erased.

Bubble movement in the chamber is not a problem since the two flashes are taken a millisecond apart in time. Ultrasonic chambers are another possibility.[3]

Resolution - Donjon et. al., claim a resolving power of 40 lp/mm for the device. This should be adequate for bubble chamber photography. The maximum contrast ratio exceeds 70:1.

The author realizes that image subtraction can be achieved by digital techniques employing TV cameras, but these suffer from lack of adequate resolution. Good resolution is important when looking for short lived particles that decay close to the interaction vertex - charmed particles, if they exist, may fall into this category.

Erasure - The image on the Phototitus may be erased by short circuiting the electrodes and flooding the selenium with light. The tracks in the chamber, when they become too many are got rid of conventionally by recompression. This should only occur once every tenth of a second or so.

Advantages over Streamer Chambers -

Triggerable streamer chambers can be run at rates greater than the ones described here but the vertex cannot be detected. For searching for particles of short life time, the detection of the vertex is essential.

Also if one wanted to study the secondary interaction of a shortlived particle such as $\Omega^{-}p$ scattering, this will not be possible in streamer chambers due to the low density of the chamber gas.

Quality Control of the Subtraction Mechanism

In order to remove the background tracks completely, it is necessary to have the two flashes to be of exactly equal intensity. This can be tested in real time by electronically sensing the contrast on an area of the crystal not in the field of view of the chamber on which a dark spot is imaged. If the subtraction is satisfactory, the dark spot should be completely removed. If it is unsatisfactory, a third correcting flash could be made at this time with a voltage difference between the platinum electrodes adjusted to give the required amount of corrective effect. This could be done in real time and one can thus ensure that only the tracks of interest are photographed.

Modification of the Phototitus for use as a Vertex Detector

One may speculate on using the Pockels effect to view particle tracks directly without the bubble chamber. Instead of the selenium, some other suitable material can be used of sufficient thickness in which particles produce electron hole pairs upon their passage. It might be possible to produce a cascade from these and deposit the cascade end products on the $KD_2\,PO_4$ crystal producing visual images of particle tracks. Any particle interaction in the material could then be made visible in a matter of micro seconds and can be erased in similar time if not required. The resolution of such images should be much higher than one can hope to achieve with bubbles. If charmed particles exist, and are shortlived, here surely would be a method of detecting them. The resolution of the particles tracks observed will be a function of the thickness of the material used, the greater the length of the cascade, the broader being the images.

Limitations of the Subtraction Technique

One of the fundamental assumptions made is that the images of tracks separated in time by a millisecond are identical enough for exact cancellation. Bubbles do grow in a millisecond but they grow as the square root of time, the larger the bubble the slower the rate of growth. So one should expect more or less exact cancellation for "old" tracks where as the "recent" tracks might cause some trouble. Bubble growth in a millisecond for bubbles that already exist is a second order process and one might conceivably devise operating conditions where these effects are below the optical resolution of the system.

Other Uses of the System

The system implemented in the 30" chamber can be used to remove unwanted background and make scanning easier.

The 15' chamber could benefit a great deal since piston boiling and scotchlite boundaries would be removed.

More on Resolution - If the resolution of 40 lp/mm is not sufficient, then subtraction by transmission is another possibility. The first image is formed on the Phototitus as described and the second image is made on film with the Phototitus desensitized. The first image acts as a mask and removes all unwanted tracks. The limiting resolution is now that of the film. (The dielectic mirror in Fig. 1 would be absent for this application in order to transmit light during the second flash).

REFERENCES

[1]A. Pockels - Effect Light Valve: Phototitus. Applications to Optical Image Processing.
Jacques Donjon, Francois Dumont, Michel Grenot, Jean-Pierre Hazan, Gerard Marie, Jean Pergrale. IEEE Transactions on Electron Devices. Vol. ED-20, N011, November, 1973. Pages 1037-1042.

[2]C. Fisher, Piivate Communication.

[3]Ultrasonic Bubble Chamber Development at CERN. R. C. A. Brown, G. Harigel, H. J. Hilke, P. D. Jarman CERN Geneva, Switzerland.

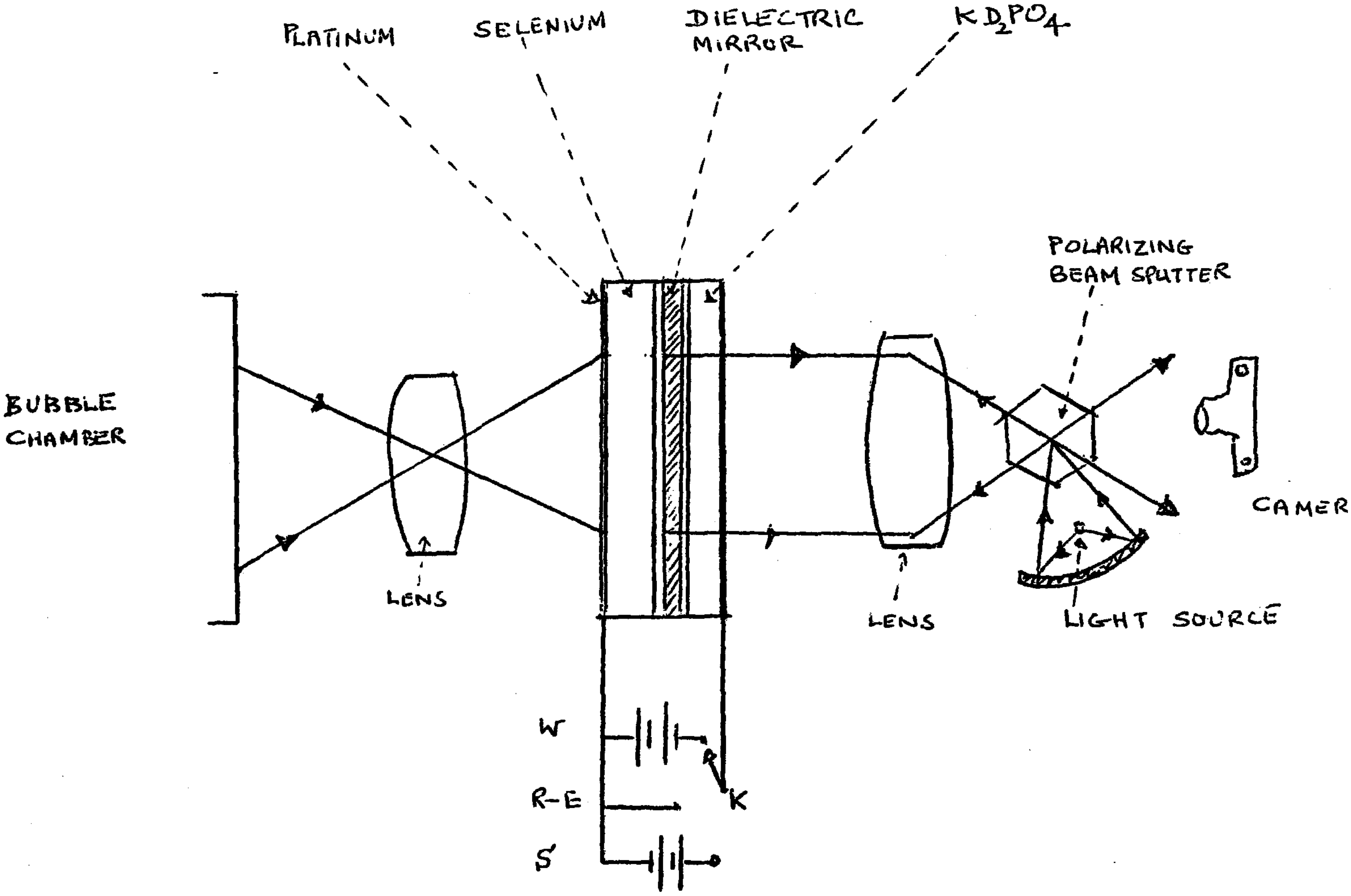

FIG-1

SWITCH K IN POSITION W FOR WRITING ON TO PHOTO TITU.
R-E FOR READING (PHOTOGRAPHING) OR ERASING
S FOR SUBTRACTING