III.F. THE SCINTILLATION CAMERA AND THE MICRO-CHANNEL PLATE

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Introduction

Two devices have been investigated for possible use as triggerable track chamber-targets in experiments designed to search for short-lived particles and measure their lifetimes. Test results indicate that both devices should be valuable for such applications. Furthermore, both are "live" so that information from them can be used on the trigger.

The first device is the scintillation camera which is an improved version of the luminescent chamber of twenty years ago. The operating principle is through the use of an image intensifier to store, gate, amplify, and record on photographic film the image of a high energy interaction occurring in a scintillating target medium.

The second device is a micro-channel plate (MCP). It has been found that a minimum ionizing particle passing through an MCP on a trajectory normal to the axes of the channels can excite a few per cent of the channels it traverses. An image can be formed and transferred to film in a manner similar to that used in the scintillation camera.

Scintillation Camera

The heart of the scintillation camera is a four stage magnetically focused image intensifier (EMI-type 9912). As used in the scintillation camera, the first, third, and fourth stages are quiescently on; the second stage is quiescently off. Scintillation light from an NaI(Tl) crystal target is focused by a lens system onto the input photocathode of the image intensifier and stored on the first stage phosphor for a length of time characteristic of the decay of the phosphor. When an interesting high-energy interaction occurs in the target crystal, the second stage of the image intensifer can be gated on (and the first off) to amplify the stored image further and transfer it to photographic film via another lens system. Some scintillation light not focused onto the image intensifier is collected by a PMT, which is used in the formation of the event trigger (see Fig. 1).

The images recorded on film are similar to those obtained with a bubble chamber or nuclear emulsion (see Figs. 2 and 3). Measured performance of a prototype scintillation camera and that expected of a practical device are summarized in Table I. Measured results were obtained with a 7 GeV/c proton beam. Spatial resolution is limited in the prototype by the quality of the lens viewing the NaI(Tl) crystal and by reflections off the crystal backing; the ultimate limitations are

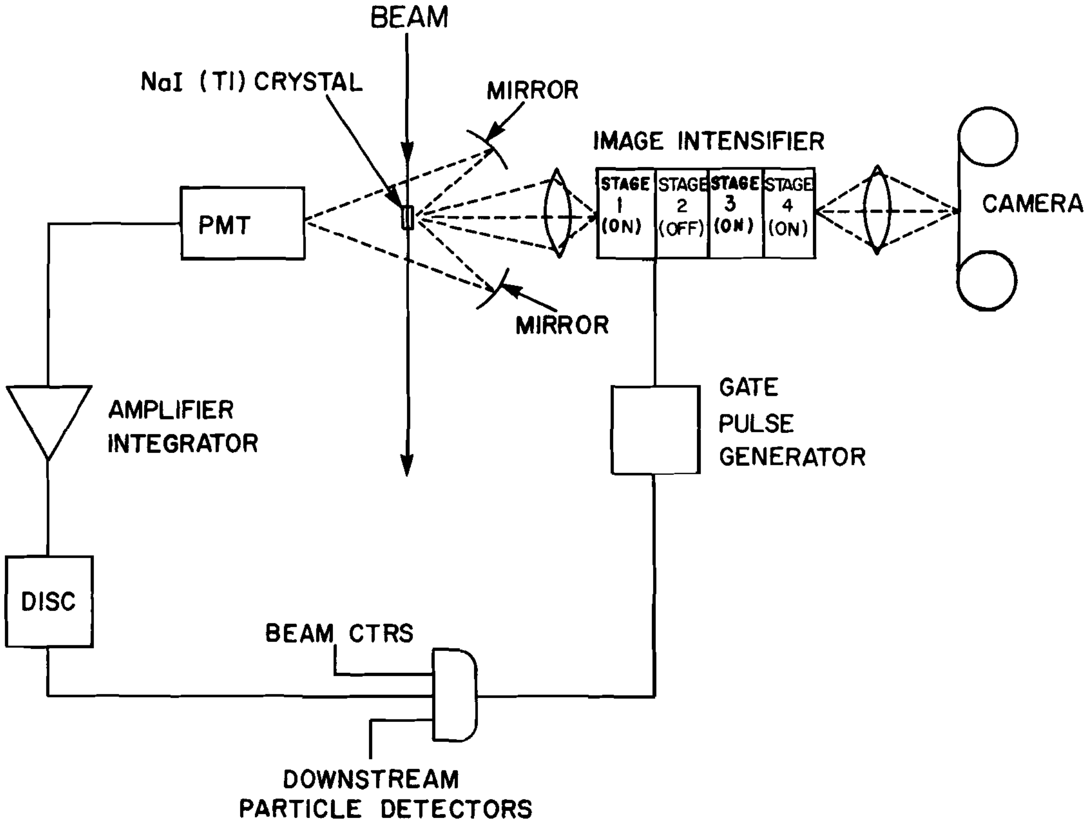

Fig. 1. Schematic of Scintillation Camera.

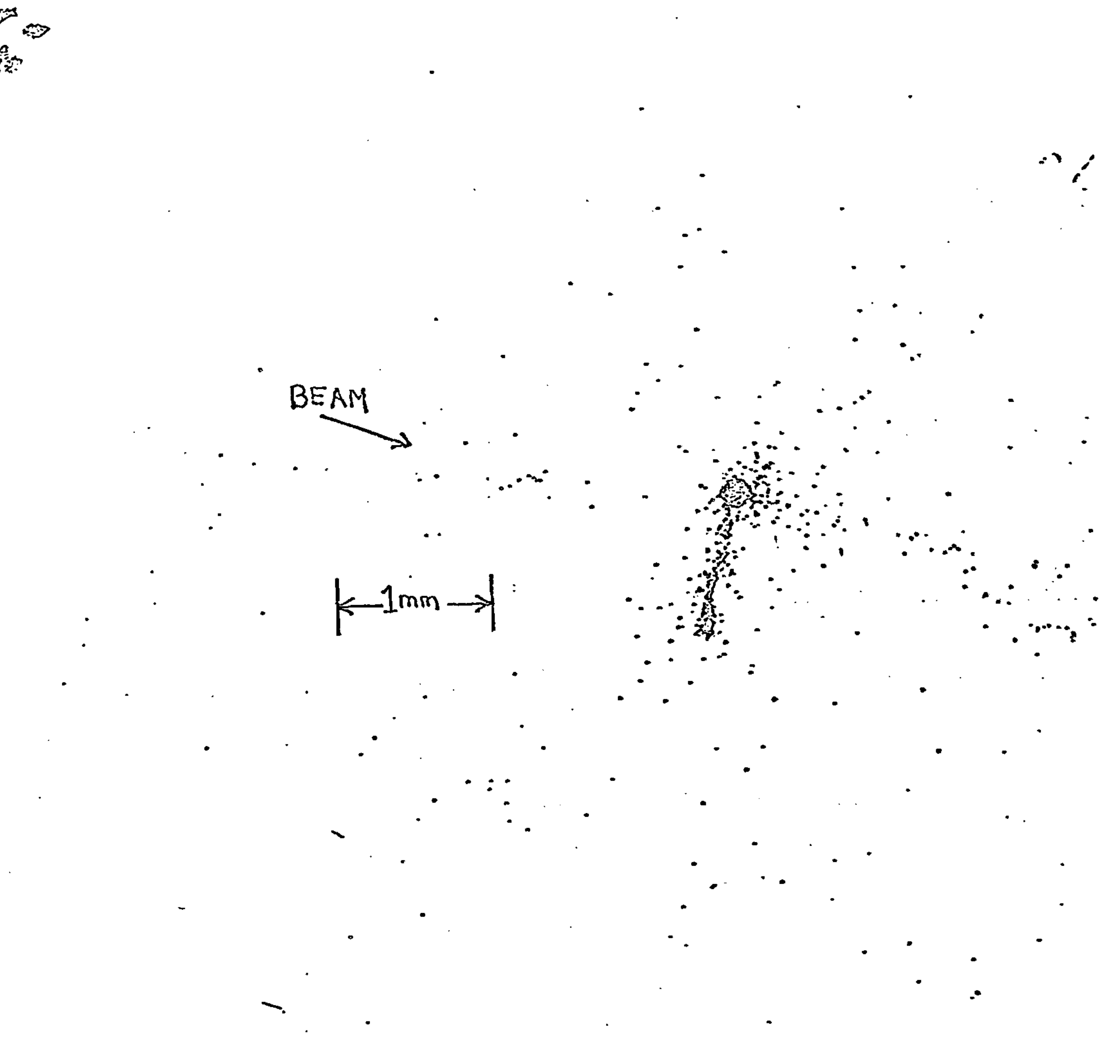

Fig. 2. A (typical) interaction in which nuclear breakup occurs recorded by the scintillation camera. (The reproduction in this and the following four figures do not do justice to the original images).

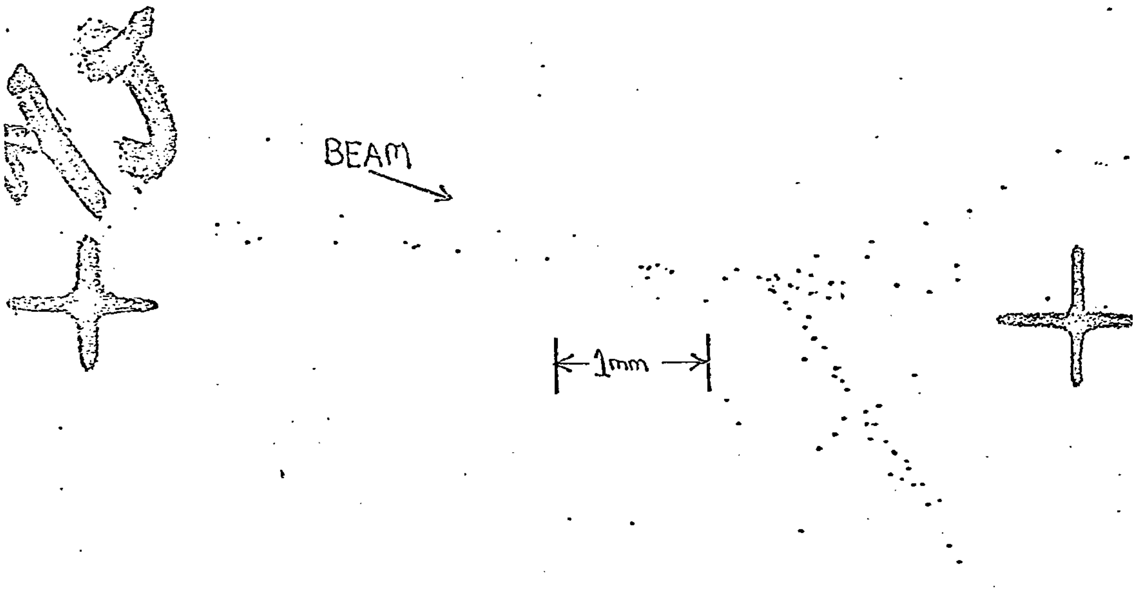

Fig. 3. An (atypical) interaction in which no nuclear breakup occurs recorded by the scintillation camera.

Table I. Performances of Scintillation Camera and MCP Device.

	Dots/mm of Min. Ionizing Track	Dot Diameter (at Target)	Dot Resolution rms (at Target)	Time Resolution	Target[a] Size
Measured performance of prototype scintillation camera	8	20 μm	30 μm	10-15 μs	0.015 in. × 0.375 in. × 0.375 in.
Expected performance of practical scintillation camera	8	20 μm	11 μm	<10 μs	0.020 in. × 0.8 in. diam
Measured performance of MCP test device	2	100-200 μm	<10 μm	Not Measured	0.020 in. × 0.7 in. diam
Expected performance of practical MCP device	2	<60 μm	<10 μm	<10 μs	0.1 in. × 2 in. diam

[a] The first dimension listed is that along the optical axis (transverse to beam).

diffraction in the viewing lens and depth of field required for a crystal of finite dimensions along the optical axis (i.e., parallel to the beam). Time resolution is governed primarily by the decay characteristics of the first stage phosphor but is also affected by the characteristic curve of the film and the gate pulse length. The number of dots per mm of track in the target is fixed by the lens aperture, efficiency of the scintillator, and absorption of the optical train. Dot size is determined primarily by the spatial resolution of the image intensifier.

Micro-Channel Plate

A micro-channel plate (MCP) is a wafer of lead glass perforated by a matrix of tiny holes, or channels. Each channel acts as an independent electron multiplier which can be excited by charged particles and UV, X- and γ-radiation. The probability of a channel to be excited by a charged particle depends on the secondary emission coefficient, and, therefore, on (among other things) the local specific ionization; consequently, the probability is small for a minimum ionizing particle.

To examine the feasibility of using an MCP as a triggerable track chamber-target, a proximity focused MCP image intensifier tube was substituted for the NaI(Tl) crystal of the scintillation camera. The dimensions of the MCP were 18 mm diameter and 0.020 in. thick; the channels were 11 μm diameter and on 12.5 μm centers. A high-energy beam was passed through the MCP parallel to the thin dimension (i.e., normal to the axes of the channels). Figures 4-6 and Table I display the results obtained with a 7 GeV/c proton beam. Note that the images displayed in the figures are of nearly the same scale and look similar to those of the scintillation camera. Table I also indicates the characteristics expected of a MCP device which could be built on a short time scale. Such a device would probably employ a thick MCP both to increase the volume of the target and to produce by saturation dots of uniform intensity, and use proximity focusing throughout (i.e., gating would be accomplished by a proximity focused diode image intensifier and fiber optic plates would be used for all optical coupling, including that to the film).

The MCP has three distinctly attractive inherent features, which, if could be exploited in a practical device might outweigh the obvious disadvantage of low point density along the tracks. First, the intrinsic resolving time at the MCP itself is less than a nanosecond; thus, an extremely high interaction rate should be achievable. Second, the ultimate limit to the spatial resolution should be the channel diameter, which if 10 μm implies a 10μm rms point error. Third, the MCP is "live" so that information from it--perhaps even fairly detailed information about event topology--could be used in the trigger. Finally, it is relevant to note that, if secondary vertices and flight rates cannot be observed directly, but must be reconstructed using the trajectories at daughter particles, the point density along the track is not important.

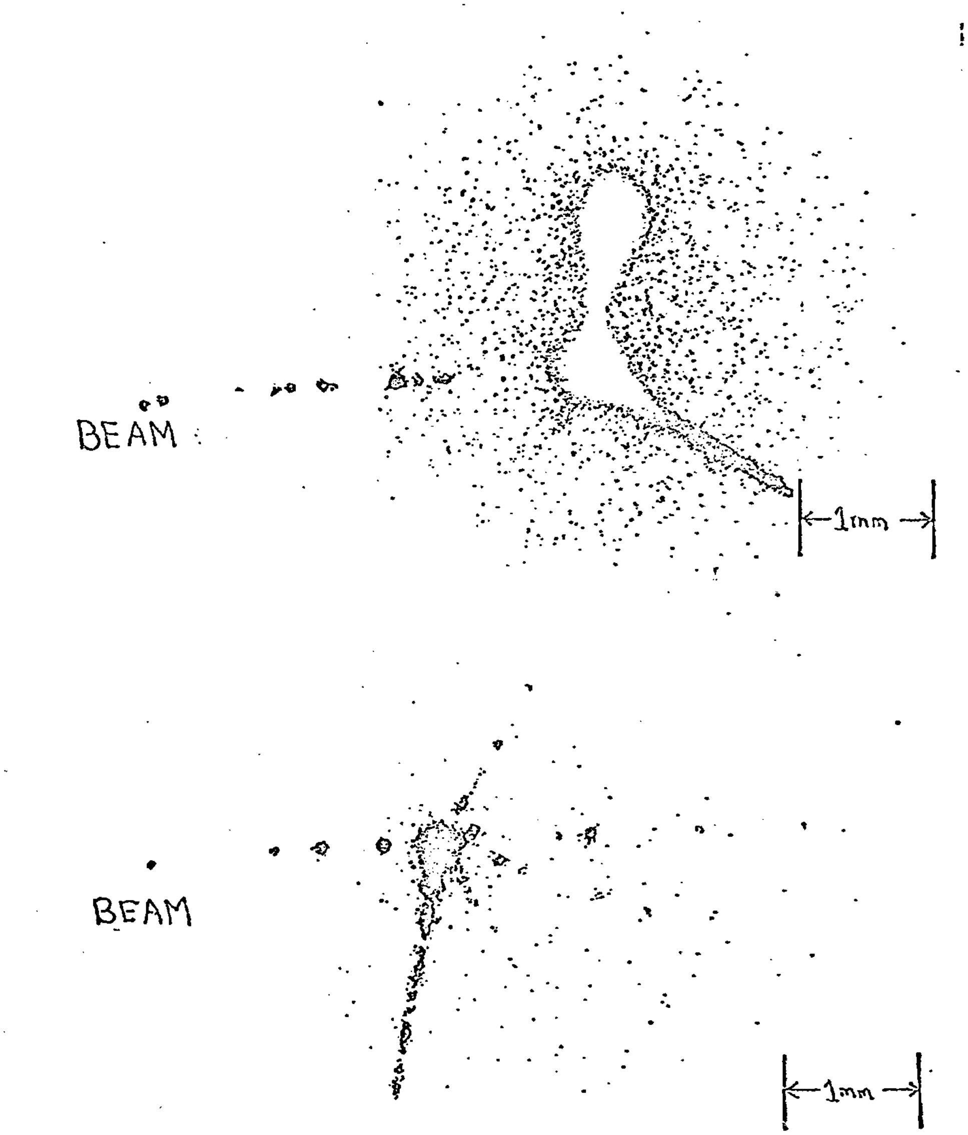

Fig. 4. Two interactions recorded by the MCP device.

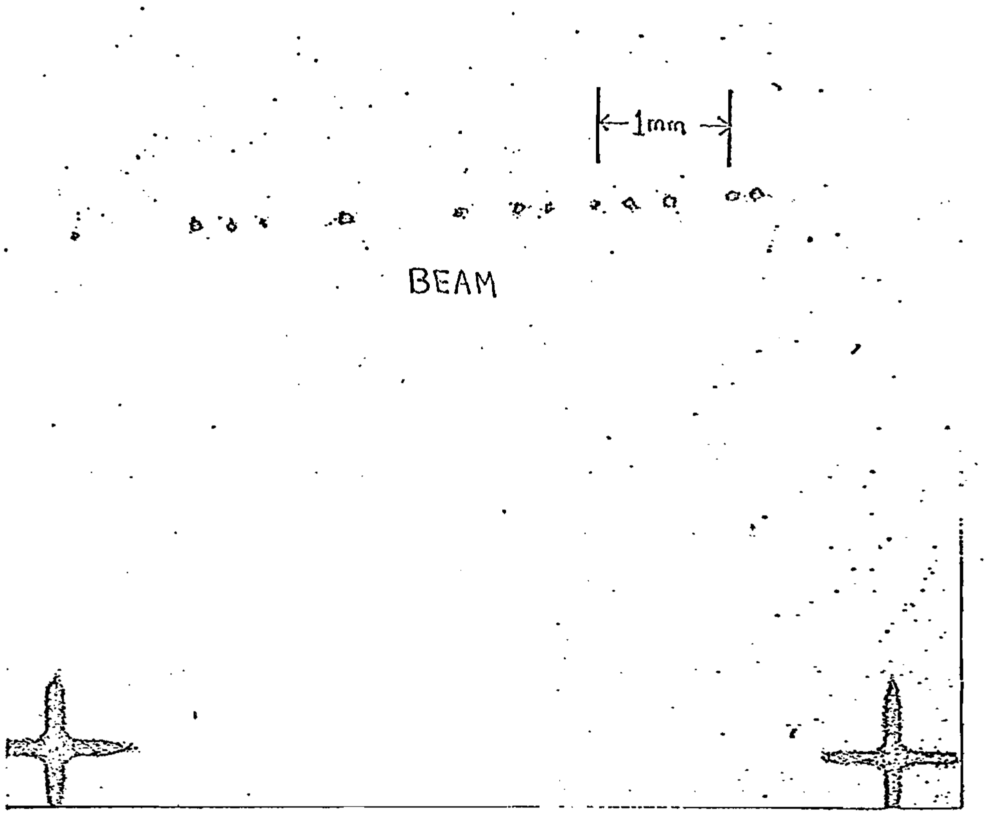

Fig. 5. Beam track recorded by the MCP device.

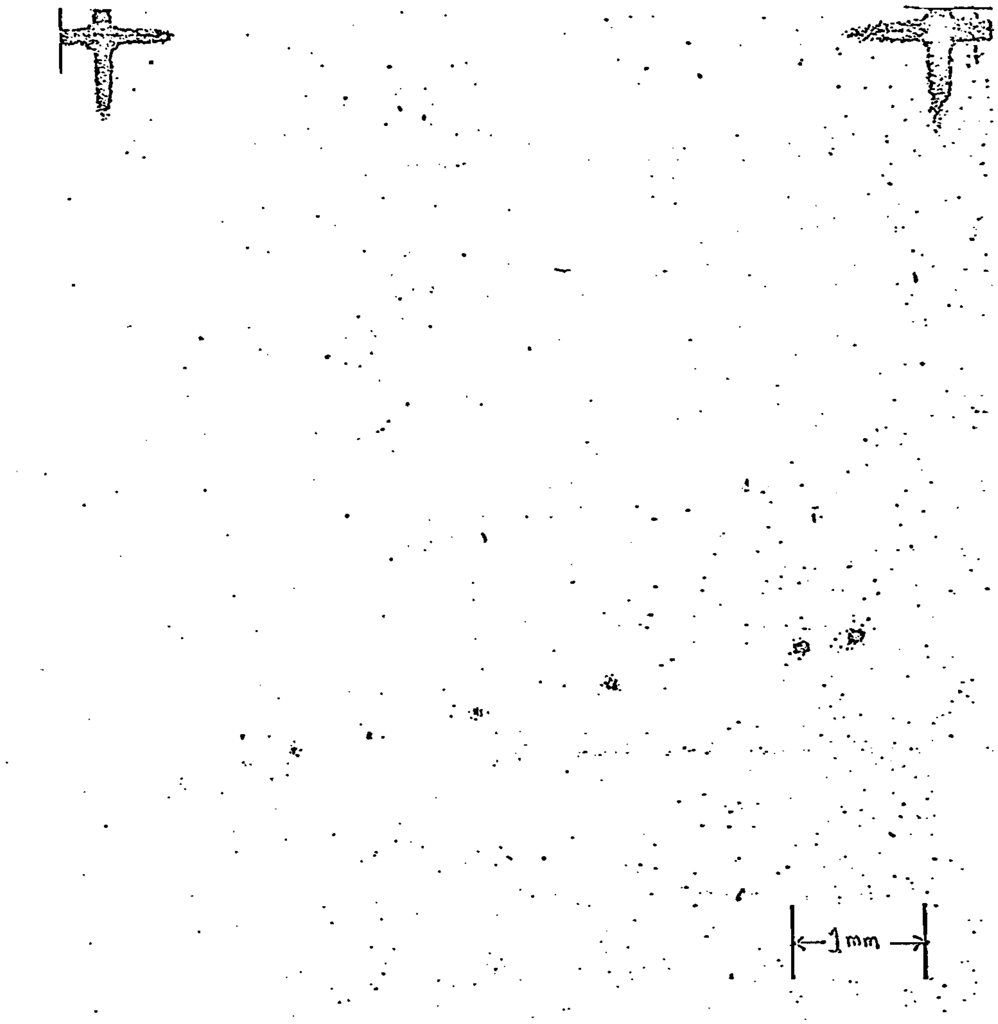

Fig. 6. Track recorded by the MCP device. The photographic density of the individual dots is an indication of the local depth of the track in the MCP.