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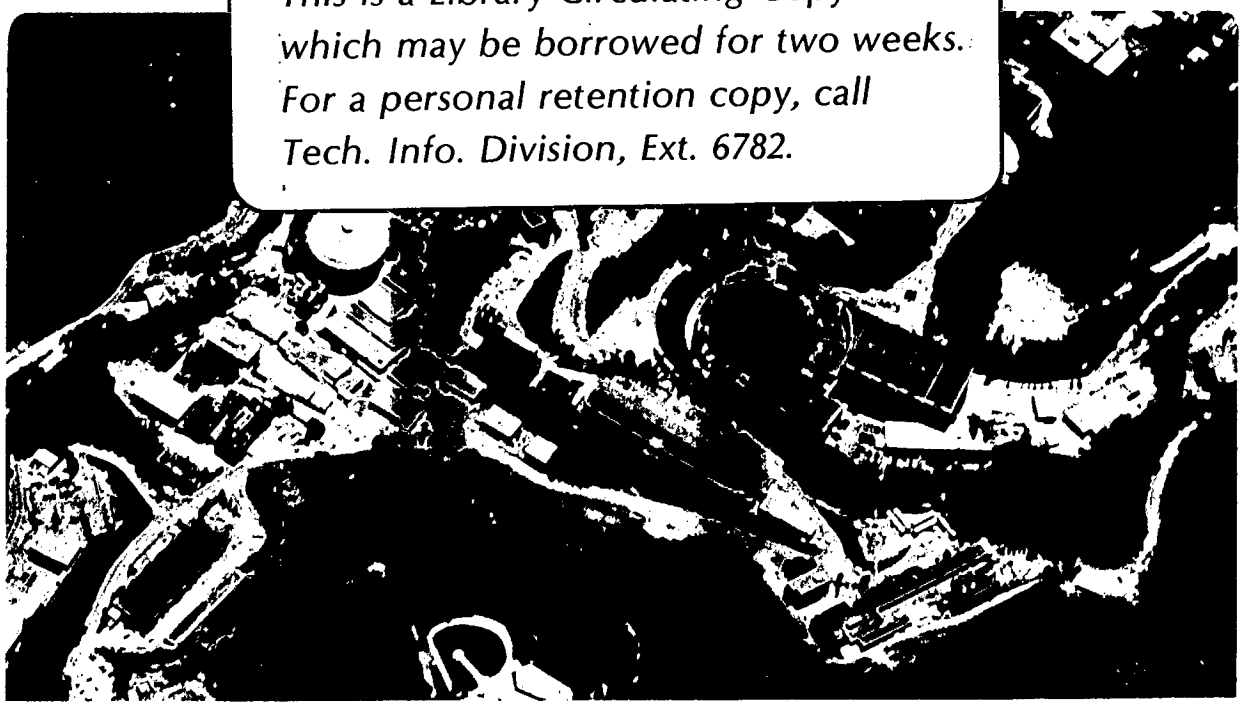

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MWPC's for Positron Imaging: an Update*

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Abstract

Based on the experience achieved at LBL in the last five years, we present up to date results of dense drift space MultiWire Proportional Chambers; we also propose a six module MWPC Positron Camera, as a high spatial resolution camera for medical imaging with positron emitters.

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A schematic drawing of the camera is shown in Fig. 1. Six modules are arranged to form the lateral surface of a hexagonal prism; each module (50×50 cm^2) consists of a single MWPC (active area 45×45 cm^2) sandwiched by two 2 cm thick lead glass tube converters.

We have built a 50×50 cm^2 MWPC module, but for convenience we have made extensive measurements(1,2) with a smaller module, consisting of a MWPC (15×15 cm^2 active area) and 1 cm thick converter. The anode plane is made of 20 m stainless steel wires, 3 mm apart; the two cathode planes, consisting of 100 μm stainless steel wires 2 mm apart, are arranged at 90° relative to each other in order to allow both x and y localization. The converter is made of high density lead glass capillaries (80% PbO by weight, glass density of 6.2 g/cm^3), fused to form a honeycomb matrix(3). The glass matrix is leached in a H_2 atmosphere to produce a resistive layer, allowing for drifting the electrons in the resultant uniform voltage gradient. A voltage is applied between the ends of the tubes, and the conversion electrons from the 511 KeV γ-rays are drifted along the electric field lines to the wire planes of the chamber. The overall efficiency of the detection process depends both on the wall thickness of the tube and on the total gas density traversed by the conversion electron. Various converters of different diameters(4) have been used. Our highest efficiency has been obtained so far with 0.9 mm diameter tube matrices with 0.096 mm wall thickness. Detection efficiencies for this type of converter (1 cm thick) and an Argon-Methane (70-30) gas mixture are presented in Figure 2, as a function of the anode discriminator threshold (the anode signal was previously amplified 220 times). Measurements were taken at various pressures with an effective

voltage setting ($V_{eff}=V_{anode}-V_{cathode}$) which produces a negligible background count rate. Very stable operations conditions and full reproducibility of the results over a period of several months have been obtained. At 2 atm an efficiency of 4.5% has been measured with a plateau longer than 30 dB. At this pressure very big amplitude and partially saturated pulses were detected with the chamber working close to the self-quenching streamer regime(5). Fast delay lines, standard integrated amplifier and comparator electronics were adopted for the position readout. With an Ar (70%) - CH_4 (30%) gas filling, at 2 atm we have measured a spatial resolution of 1.3 mm (FWHM). The time to process one event is less than 500 ns for a 45 cm delay line, thus allowing for high event rate capability. A well established figure of merit for a positron camera is the ratio $\varepsilon^2 \Delta\tau$, where ε is the efficiency of a single module and $\Delta\tau$ is the resolving time (in our case the drift time through the converter). Several gases have been used(3). For a fast gas mixture (69% Ar+20% CH_4+ 20% CF_4+1% C_2H_2), a $\Delta\tau$ of 100 ns for 1 cm thick converter has been measured.

The specifications and the expected performance of the proposed Positron Camera are listed in Table 1. For a True/Accidental coincidence ratio ≥ 1, the source strength must be $\lesssim 400$ μCi. If an activity of 400 μCi is uniformly distributed within a typical head phantom (10 cm radius, 10 cm long cylinder), taking into account the scattering inside the phantom, we may estimate a true coincidence count rate of ~40000 c/s for the system, of ~4000 c/s per slice (1 cm apart), and of ~10 c/min per voxel ($0.5 \times 0.5 \times 0.5$ cm^3).

In conclusion, the progress in electronics technology and the increased knowledge of gas avalanche properties has now rendered the MWPC solution competitive with the multi-ring scintillator cameras. In addition to the low cost and simplicity of construction, its fully three-dimensional capability has made this type of detector very attractive for medical research with positron emitters.

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Table 1

Specifications and expected Performance

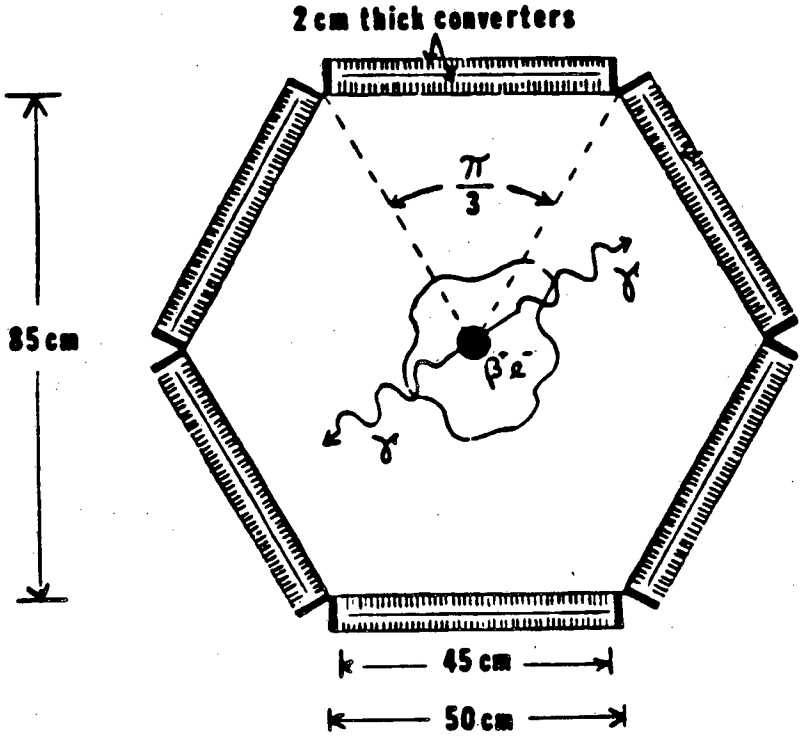
of the proposed Positron Camera

NUMBER OF MODULES	6
ACTIVE AREA OF EACH MODULE	45×45 cm^2
SOLID ANGLE COVERAGE	$\sim 2\pi$
EFFICIENCY OF EACH MODULE	15%
COINCIDENCE RESOLVING TIME	200 ns
POINT RESPONSE FUNCTION (in air)	2.0 mm
OVERALL IMAGE RESOLUTION (FWHM)	5.0 mm
TOTAL COUNTING RATE (True=Accidental)	3.4×10^5 counts/sec
RECONSTRUCTION ALGORITHMS	Limited Angle(6)

Figure Captions

1. Proposed Positron Camera made of six modules arranged to form a hexagonal prism. Each module has a 45 × 45 cm^2 active area and two 2 cm thick lead glass tubes converters: plan view of the camera (TOP), cross view of a single module (BOTTOM).

2. Efficiency of the 15 × 15 cm^2 module as a function of the anode discriminator threshold at various pressures. Gas filling: Argon (70%) - Methane (30%).


2 cm thick converters
85 cm
π/3
γ
β⁻
γ
45 cm
50 cm

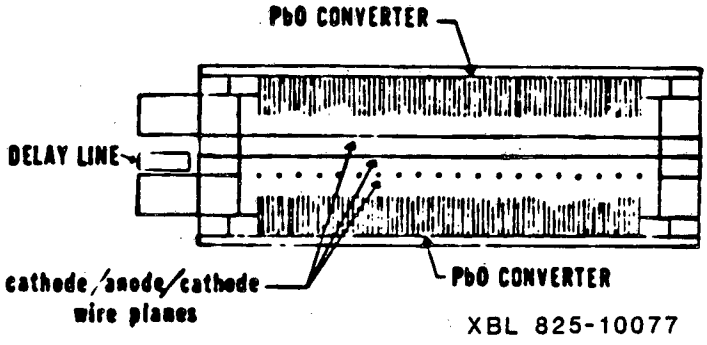

PbO CONVERTER
DELAY LINE
cathode/anode/cathode
wire planes
PbO CONVERTER
XBL 825-10077

Fig. 1

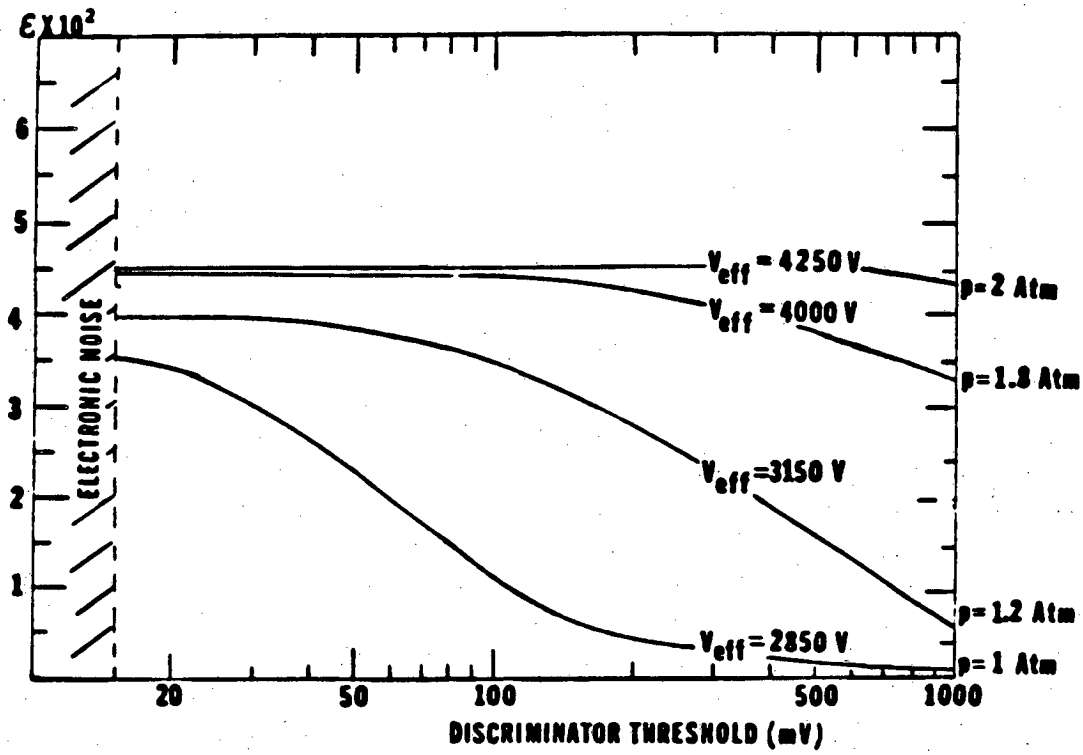


Fig. 2

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