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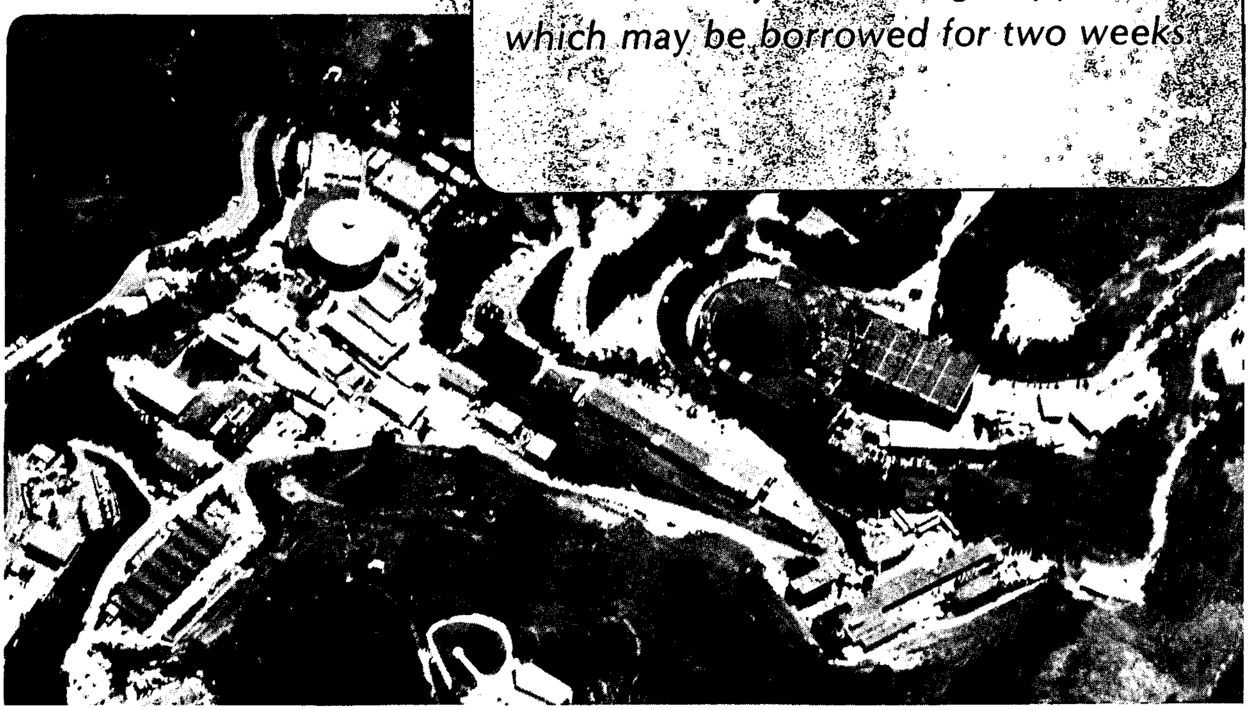

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DISCLAIMER

A HIGH SPATIAL RESOLUTION POSITRON EMISSION TOMOGRAPH WITH A 2π SOLID ANGLE COVERAGE *

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We describe the HISPET project: a HIgh Spatial resolution Positron Emission Tomograph based on MultiWire Proportional Chambers with lead-glass dense drift space converters.

1. THE MWPC - CONVERTER SYSTEM

The detection of 511 keV γ-rays with a MWPC requires the use of a high density, high Z converter with a large surface to volume ratio. We have developed a converter made of glass capillaries with a high lead content (70 - - 80% PbO by weight, glass density of 5.2 - 6.2 g/cm^3), fused to form honeycomb matrices (1). The lead glass matrices are treated in a H_2 reduction process to form a uniform resistive layer on the inner walls of each tube. The Compton or Photoelectron produced by the photon interacting within the converter has a finite range which depends on its energy. If it reaches the gas region within the tube, a number of primary ionization electrons are produced. A voltage difference applied between the ends of the tubes drifts these primary electrons along the electric field lines within the tube towards the chamber avalanche region. A schematic diagram of the detector is shown in figure 1.

Various size capillaries of different tube diameter and wall thickness have been tried. Our best results have been obtained with a matrix of lead-glass tubing with 0.48 mm inner diameter, 0.06 mm wall thickness, which gives a measured efficiency of 6.5% for a 1 cm thick converter (2). The experimental efficiency measurements for the various converter types agree very well with the Monte Carlo predictions (3).

A well known figure-of-merit parameter for a "large area" positron camera is $\varepsilon^2/2\tau$, where ε is the detection efficiency (for 511 keV γ-rays) of one element and τ is the FWHM of the time resolution (in our case the transit time of the primary ionization electrons within the glass-tube matrix). Thus, for a given efficiency, the gas mixture with the highest electron drift velocity should be used to improve the time resolution. With a gas filling of Argon-Methane (70-30) at 3 atm a time resolution of $\sim$ 100 ns (FWHM) has been measured for a 1 cm thick converter (2).

In hopes of improving the time resolution in PET, a program of studies of electron transmission and multiplication in arrays of lead glass tubing has being carried out (4). Using a mixture of 96% (Ne-He) + 4% C_2H_6 at atmospheric pressure a modest avalanche multiplication has been observed (a factor of two at a reasonably low field of 4.6 (kV/cm). On the other hand, electron transit time failed to improve, thus suggesting that multiplication occurred via Penning effect instead of the more favorable process of photon mediated avalanche. Different gas mixtures and higher electric field are still under investigation.

To measure the x - and y - coordinate of the interacting photon we have been using delay line readout (figure 1). Fast delay lines (specific delay 8 ns/cm) are capacitively coupled to the cathode wires. For each coordinate the signal from one end of the delay line is used as the START and the signal from the other end as the STOP of a Time to Digital Converter. The time difference is directly related to the coordinate position. Using simple integrated amplifiers and comparator electronics a spatial resolution of 1.3 mm (FWHM) has been measured with a test chamber along the coordinate parallel to the anode wire (5). The spatial resolution along the other direction is determined by the spacing of the anode wires (typically 2 mm).

2. THE MWPC-PET PROTOTYPE

We have now assembled a first prototype positron camera which consists of two 50x50 cm^2 MWPC, each equipped with a 2 cm thick lead-glass converter plane (80% PbO by weight, glass density of 6.2 g/cm^3, inner and outer diameters of a tube 1.33 and 1.59 mm, respectively). An efficiency of 3.6% for 511 keV γ-rays per module, a time resolution of 200 ns (FWHM) and a spatial resolution of 2.5 mm (FWHM) has been measured (6).

A fast date taking system is under development, based on the recent improvement on FASTBUS. The first imaging results will be presented.

3. THE HISPET DESIGN

We have designed a large positron camera: HISPET. It will consist of six modules arranged so as to form the lateral surface of a hexagonal prism. Each module of HISPET will have two MWPC and two 1 cm thick converter planes (0.48 and 0.60 mm ID and OD, respectively), see figure 2.

HISPET will be capable of imaging three-dimensional distributions of a positron emitting radioisotope within a typical volume of 3 liters. It will have a volume sensitivity of $\sim$ 100000 c/s per 0.1 μCi/ml, a signal to noise (true to accidental coincidences) ratio of 3:1 and an intrinsic spatial resolution of less than 4.5 mm(FWHM).

To illustrate the imaging capabilities of HISPET a computer simulation has been made of simple phantoms with uniform activity (Figg. 3 and 4). A crude 3D Back Projection algorithm has been used for the reconstruction. The improvement in image quality from 8 mm FWHM (as in PET with scintillators) to 4 mm FWHM spatial resolution (as in HISPET) is clearly visible from the comparison between figg. 3c and 3d, and figg. 4c and 4d. The improvement should further increase when more appropriate reconstruction algorithms (7) will be used.

The HISPET project has now started and is expected to be completed during 1987.

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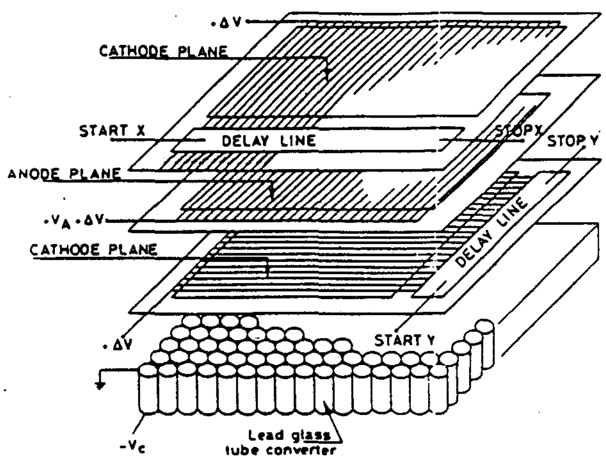

Fig.1 - Schematic drawing of a MWPC equipped with delay line readout and a single layer of lead-glass tube converter.

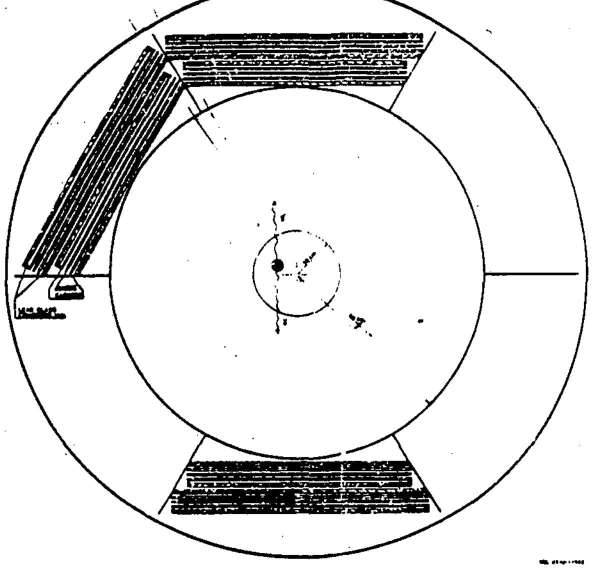

Fig. 2 - Schematic drawing of HISPET: only three modules are shown.

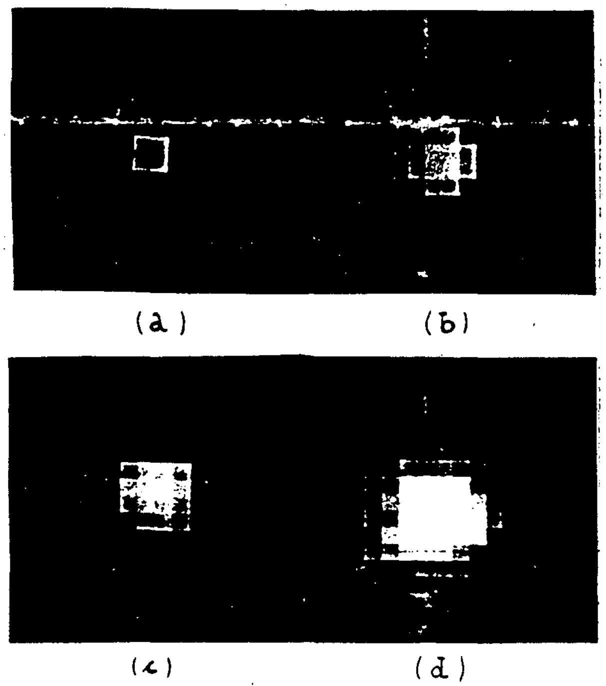

Fig. 3 - Simulation of the HISPET imaging of a sphere with a radius of 2 mm and a uniform activity. The central slice (2 mm thick) is shown; (a): the original distribution (four 2x2x2 mm^3 voxels, statistical error ~ 4% per voxel); (b),(c) and (d): the reconstructed distributions for a gaussian spatial resolution with FWHM = 0.0 mm(b), 4.0 mm(c), 8.0 mm (d).

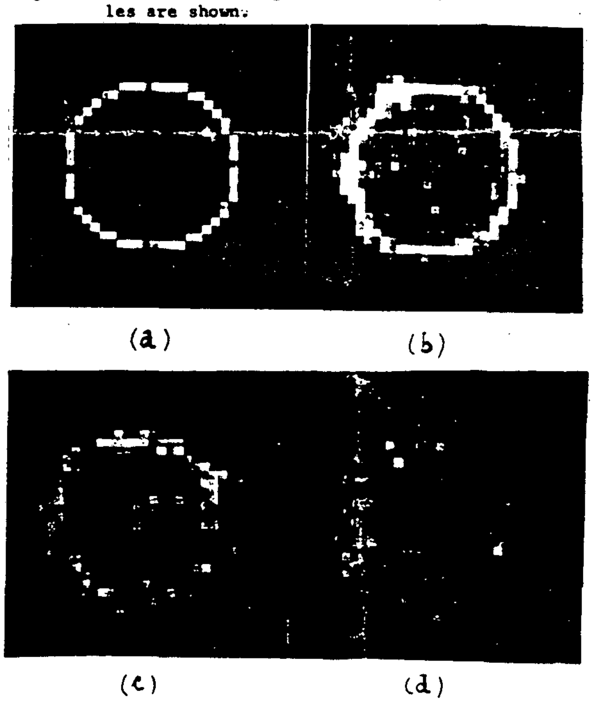

Fig. 4 - Simulation of the HISPET imaging of a spherical shell with a radius of 2 cm and a uniform activity. The central 5 slices (2 mm thick) are added up to produce a standard PET 1 cm slice; (a): the original distribution (statistical error ~ 15% per 2x2 mm^2 pixel); (b),(c), (d): the reconstructed distributions for a gaussian spatial resolution with FWHM = 0.0 mm (b), 4.0 mm (c), 8.0 mm (d).

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