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FURTHER IMPROVEMENTS IN THE DESIGN OF A POSITRON CAMERA WITH DENSE DRIFT SPACE MWPCs

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We describe the improvements achieved in the last three years towards the construction of a large solid angle positron camera with dense drift space MWPCs. A multiplane three-dimensional tomograph is proposed, made of six MWPC modules (active area 45 × 45 cm^2 each), arranged to form the lateral surface of a hexagonal prism. Its expected performance is presented and is shown to be very competitive with the multiring scintillator positron camera.

In a previous paper [1] we presented the preliminary imaging performance of a two plane MWPC positron camera consisting of two MWPC modules equipped with converters made of lead corrugated banded strips.

Since then we have developed [2] a more efficient type of converter, which consists of high density lead glass capillaries (80% PbO by weight, glass density of 6.2 g/cm^3) fused to form a honeycomb matrix. The glass matrix is leached in a H_2 atmosphere to produce a resistive layer, allowing for drifting of 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 electrons. Various converters [2,3] of different diameters have been used. The measured efficiencies are in excellent agreement with Monte Carlo predictions [4]. Our highest efficiency has been recently obtained with 0.48 mm diameter tube matrices, with 0.06 mm wall thickness. The measured efficiency is 3.5% for a 5 mm thick converter.

Fast gas mixtures [3] have also been tested ($Ar–CH_4–CF_4$/70–20–10) to reduce the transit time of the electron within the converter tubes to 100 ns/cm.

Test chambers have been successfully operated in the 'self-quenching streamer' regime [5] with two main advantages: (1) bigger amplitude pulses (i.e. simplified electronics and better signal-to-noise ratio), (2) effective half-gap discrimination at MHz rate (i.e. reduced parallax error in positron imaging [4]).

Printed circuit delay lines, standard integrated amplifier and comparator electronics have been adopted for the position read-out. A spatial resolution of 1.3 mm fwhm has been measured along the coordinate parallel to the anode wires [6]. The use of fast delay lines (8 ns/cm) allows a high event rate capability.

A multiplane three-dimensional positron camera has been proposed [6], made of six dense drift space MWPC modules (50 × 50 cm^2 each), arranged to form the lateral

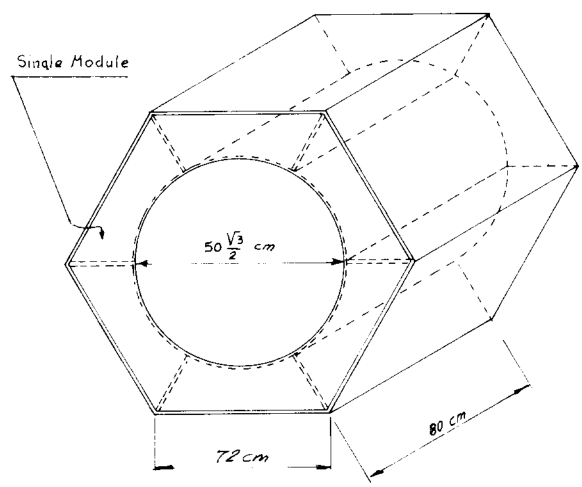

Fig. 1(a). Artistic drawing of the proposed hexagonal tomograph: perspective view.

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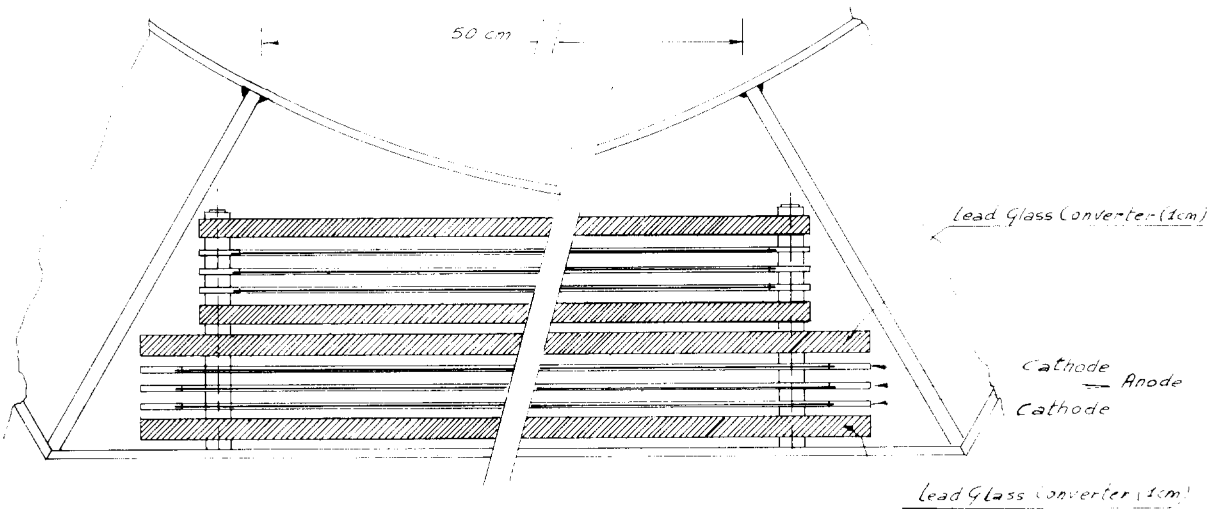

Fig. 1(b). Artistic drawing of the proposed hexagonal tomograph: cross view of a single module.

surface of a hexagonal prism. Due to recent successful measurements on the 0.48 mm diameter tube matrices, we decided to have two MWPCs for each module, and two 1 cm thick converter (0.48 mm diameter tubes) for each MWPC (fig. 1). A complete Monte Carlo simulation has been made [7], which predicts a spatial resolution of less than 4.5 mm (fwhm) for a ^{18}F point-like source in a water phantom. The characteristics and the expected performance of the proposed tomograph are presented in table 1.

In conclusion, the hexagonal tomograph will have a sensitivity of ~ 100000 c/s/0.1 μCi/ml (for a signal-to-noise of 3 : 1), and a spatial resolution of ~ 4.5 mm (fwhm). This performance is very competitive with that of the multiring scintillator positron cameras of the next generation [8], and it can be obtained at a much lower cost.

Table 1
Characteristics and performance of the proposed tomograph

Number of modules	6	True coincidence rate for the tomograph	252 kHz
Characteristics of each module:		Total coincidence rate for the tomograph	336 kHz
Active area	45×45 cm^2	Count rate for a uniform activity in a cylindrical water phantom (10 cm long × 10 cm radius):	
Converter tubes diameter	0.48 mm	Source strength	~ 300 μCi
Total converter thickness	4×1 cm	True coincidence rate for the tomograph	84 kHz
Gas pressure	2 atm	Number of simultaneous (1 cm thick) slices	10
Efficiency for 511 keV γ-rays	22.5%	Number of pixel (6×6 mm^2) per slice	~ 870
Covered solid angle	2π	Statistical uncertainty of the signal per pixel in one minute (accidental coincidences subtracted)	7%
Performance of the tomograph in air:		Compton distributed noise	1/3
Coincidence efficiency for β^+ decay	2.2%		
Coincidence resolving time	100 ns		
Spatial resolution (point-like ^{18}F source)	≤ 4.5 mm (fwhm)		
True coincidence (T) to accidental coincidence (A) ratio = T/A	3		
Single rate per module	375 kHz		
True coincidence rate per module pair	84 kHz		

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