

# Development of a Simultaneous PET/MRI Scanner

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**Abstract--** A combined Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) scanner would be a great benefit to nuclear medicine. The anatomical detail given by MRI and spectroscopy available with Magnetic Resonance Spectroscopy (MRS) complement the quantitative physiological imaging obtained with PET. Such a device has not become a reality because of the incompatibilities of photomultiplier tubes (PMTs) and their associated electronics with MRI's high magnetic fields, as well as significant constraints on PET camera size due to the limited patient port of MR scanners. Recent advances in solid-state electronics have opened the possibility of replacing photomultiplier tubes with avalanche photodiodes (APDs) that are compact and do not share the vulnerabilities of PMTs to magnetic fields. Currently, we are planning to build a miniature PET tomograph using only solid-state electronics to give a combination MRI/PET scanner for small animals. This technology, once developed, can be extended to human scanner designs.

## I. INTRODUCTION

The detector system design for the RatCAP small animal scanner[1], which consists of a segmented array of  $2 \times 2 \times 5 \text{ mm}^3$  Lutetium Oxyorthosilicate (LSO) crystals read out with a matching avalanche photodiode (APD) array and a custom Application Specific Integrated Circuit (ASIC), should be completely compatible for use in high magnetic fields. This configuration will open up an entirely new approach for simultaneous dual modality imaging with MRI. The accurate co-registration of PET and MRI images provides information on the relationship between structure and function, permits precise anatomically based definition of the region-of-interest, and may facilitate partial volume correction of the PET data. It could also give a priori information to be used in statistical image reconstruction methods. Using MRI to obtain anatomical details combined with the physiological information available only with PET would be a great advance in imaging technology, and offer enormous advantages to researchers and clinicians in interpreting the significance of their data. Standard photomultiplier tubes (PMT) cannot be used in a magnetic field because the electron cascade providing the amplification will be diverted and lost. Even a small magnetic field is sufficient to alter the gain of a PMT. The major challenge in integrating PET and MRI is to develop a PET detector module that operates well in strong magnetic

fields, does not seriously distort or cause artifacts in MR images, and can withstand the intense radiofrequency (RF) fields utilized to excite the nuclear magnetic moments. Ferromagnetic materials in the detector will adversely affect the homogeneity of the main magnetic field. It is also essential to protect the PET detector's circuits from the intense RF fields associated with the MRI pulse sequence.

There is another added advantage in carrying out PET experiments in a high magnetic field; namely, the reduction in the positron's range caused by the magnetic field. The positrons travel in a helical path along the axis of the magnetic field. This effect was investigated and the improvement in resolution documented [1], [2]. The largest gains are likely to be realized with high energy positron emitters, such as oxygen-15.

Some attempts have been made to combine MRI with PET, or at least with radiotracer detection[4]. One combination scanner (McPET) was built and has produced images[2], [3], [4], [5]. That design used optical fibers to transport the light emitted by the scintillation crystals to the PMTs residing well outside the magnetic field. This arrangement allows the simultaneous collection of MRI and the PET data. Its disadvantage is the loss in light collection efficiency due to using optical fibers, and the difficulty of reading out large numbers of crystals, each of which requires its own fiber. The images produced with the McPET were free from artifacts and have good resolution[2].

## II. EXPERIMENTAL

There are two potential configurations for the combination PET/MRI scanner we will build. The first places the PET ring outside the RF coil used to excite the magnetic moment of the nuclei in the object to be imaged, and the second places it inside the coil. Figure 1 shows the two configurations. Each of these configurations has some advantages and disadvantages although we believe that configuration 2 will be superior with our scanner.

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Manuscript received November 2, 2004. This work is part of a joint collaboration between Brookhaven National Lab, and Stony Brook University and is supported under a grant from the DOE Office of Biological and Environmental Research and DOE Contract DE-AC02-98CH10886. D. Schlyer, C. Woody, W. Rooney, P. Vaska, A. Kriplani and S. Stoll are with Brookhaven National Laboratory..

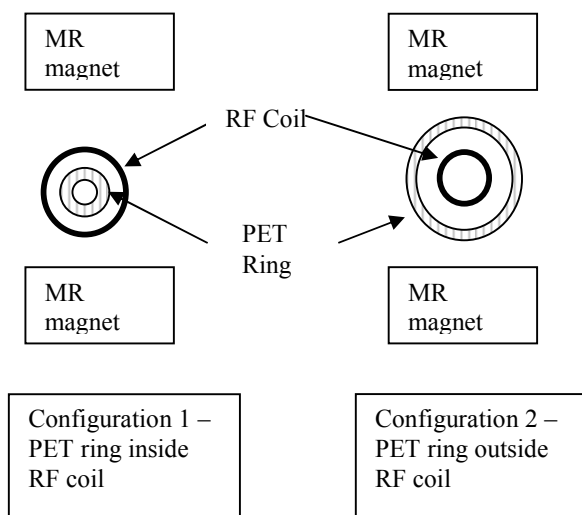


Figure 1. Configurations for the PET MRI scanners.

In our initial experiments, we placed a 4x8 array of LSO as is being used in the RatCAP. This array was coupled to the Hamamatsu S8550 APD. The output of APD was connected to our ASIC. The assembly was placed in the sensitive volume of a 27 cm 170 MHz RF coil and advanced into the center of BNL's 4 T magnet.  $^{137}\text{Cs}$  spectra were then acquired to determine if components of the MRI environment (i.e. static magnetic field, RF field, magnetic field gradients) had a negative impact on data acquired with the solid-state PET electronics.

The power to the RF coil and magnetic field gradients were systematically increased to simulate a typical MRI acquisition. Figure 2 shows the apparatus being inserted into the 4T magnet human scanner at BNL.

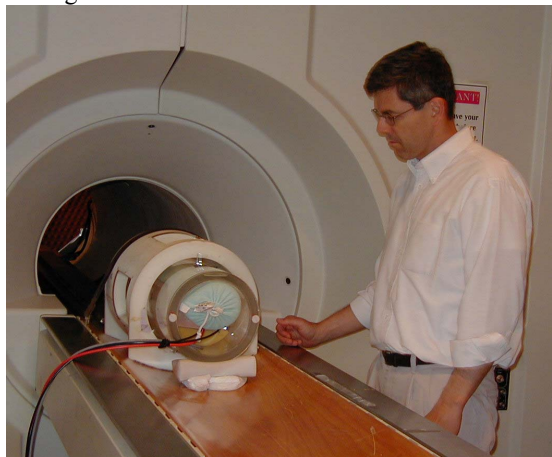


Figure 2. Experimental apparatus being placed into the 4T magnet

The resulting spectrum is shown in Figure 3.

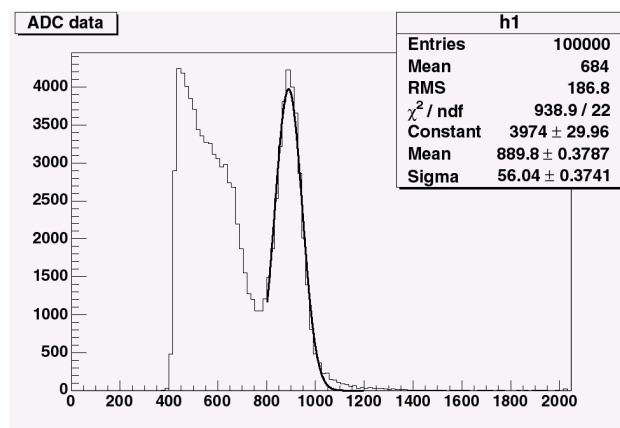


Figure 3. Spectrum of Cs-137 taken in the lab with no magnetic or RF field.

The apparatus placed in the MRI is shown in Figure 4.

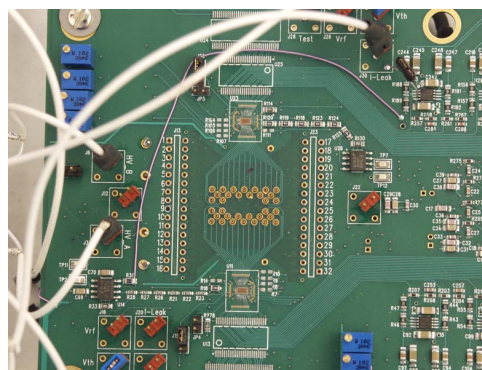


Figure 4. Printed circuit board placed in the magnetic field. Note the APD with connections to the two ASICs shown on either side of the APD socket.

The assembly was then moved to the field of the 4T magnet at the BNL MRI facility. The spectrum was again taken and showed no apparent differences from the spectrum taken in the lab. The spectrum displayed in Figure 5 was acquired with RF and magnetic field gradient levels typical for a human head MRI study. It is clear that the data acquisition was not affected by the static magnetic field, pulsed magnetic field gradients, or high pulsed RF power.

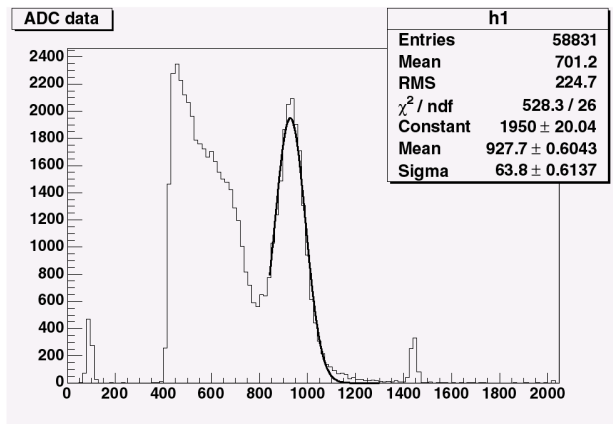


Figure 5. Spectrum of Cs-137 taken in the 4T MRI field with RF power on. The small peaks on the sides are inserted for calibration.

In the near future we plan to set up two planar arrays in the 4T magnetic field and acquire planar images at the same time we acquire an MRI image of a phantom using the new front end electronics developed for the RatCAP small animal scanner [10], [11].

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