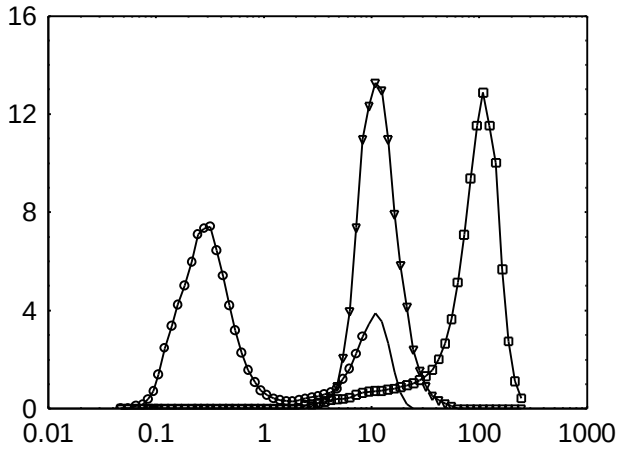
16
12
8
4
0
0.01
0.1
1
10
100
1000

by 75-mm screens were fabricated using the three different ^{6}LiF powder samples mixed with the ZnS powder in an epoxy binder. The ^{6}LiF/ZnS weight ratio is 1:3 and the area density of the ^{6}LiF was set at 40 mg/cm^2. These values were determined to be optimum from previous measurements[1]. Samples prepared with a higher mass density of ^{6}LiF and ZnS powders exhibited lower neutron detection efficiency, which is believed to be due to higher self-absorption of the scintillation light. The powders are mixed with a sufficient quantity of clear epoxy to form screens 2-mm thick.

The test fixture has been used to determine the neutron detection efficiency of the three scintillator sample screen. The screens were mounted in mechanical contact with 30 1-mm square wavelength shifting fibers and placed into a light tight aluminum housing. Each alternate fiber was attached to one of two Hamamatsu R1924 photomultiplier tubes, which were operated in coincidence mode to eliminate tube noise counts and direct interaction with background gamma rays. The output pulses from the photomultiplier tubes are amplified by a charge sensitive pre-amp with a charge gain of 1 volt/pC and filtered by an amplifier with a shaping time constant of 300-nanosec. The shaped pulses are fed into two ORTEC Model 550 NIM single-channel analyzers followed an ORTEC Model 418AA NIM coincidence unit. The coincident pulses were counted by an ORTEC Model 996 NIM counter. The detector was exposed to a 0.056 eV neutron from the High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory. A 4-atm 50-mm diameter ^{3}He neutron detector (assumed to be 90% efficient) was a reference counter for the measurements. The results of the neutron efficiency measurements are shown in Figure 3. For a mass density of 40 mg/cm^2, the efficiency peaks for the L3 sample with a size of 12-microns. The lowest efficiency occurs for the largest particle size of 100-microns. The detector was then reconfigured with the two highest efficiency screens placed on either side of the fibers resulting in a detector with a total mass density of 80 mg/cm^2. For this case the measured efficiency is approximately 75%. The solid curve on the graph is the calculated efficiency based on the neutron absorption cross-section for neutrons with an energy of 0.056 eV.

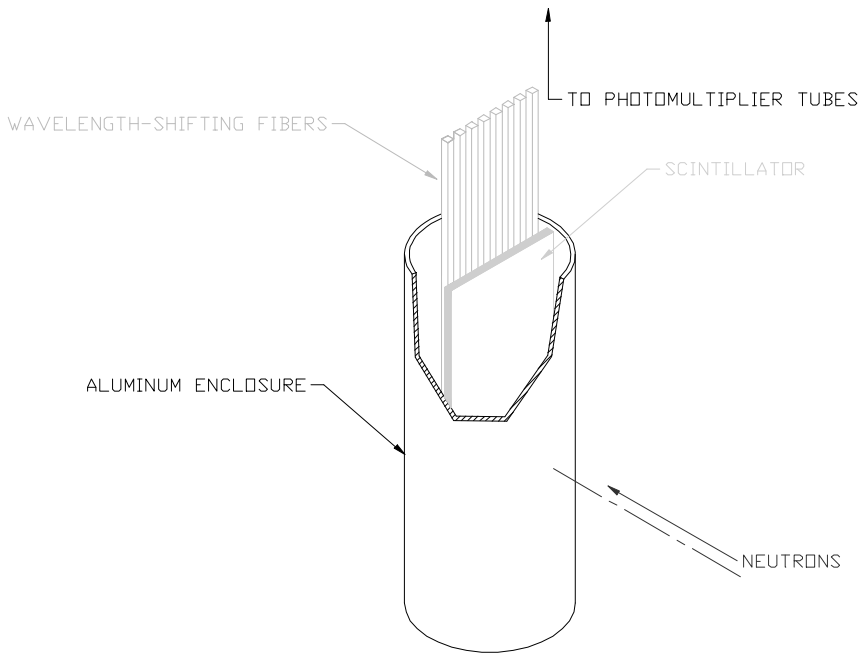

Figure 3 Single Layer Scintillator Test Fixture

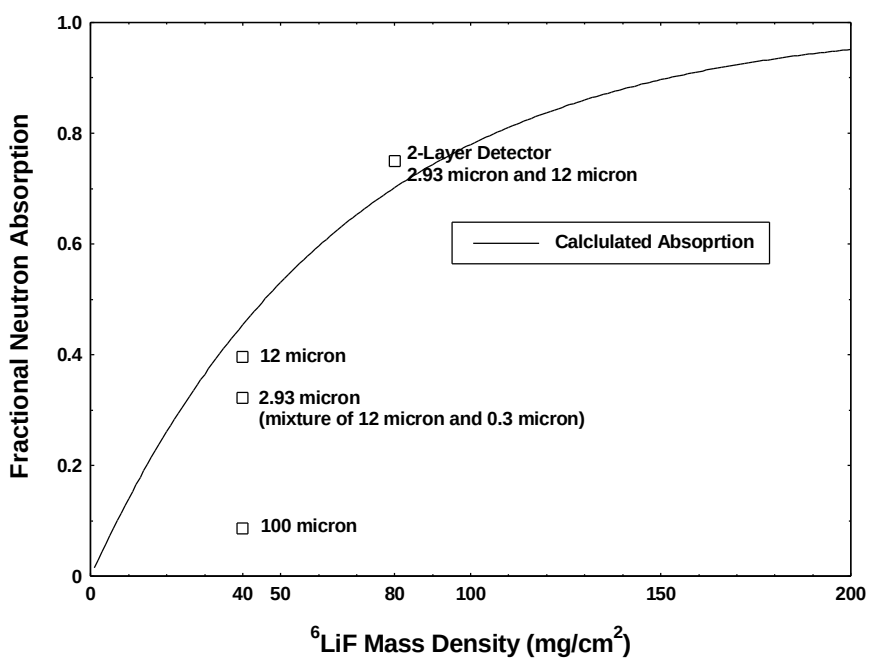

Figure 2 Detector Efficiency versus Particle Size

The higher efficiency observed for the smaller particle-sized powders is explained by the range of the alpha and triton particles generated by neutron absorption in ^{6}Li. The alpha and triton range in ^{6}LiF is calculated to be on the order of 20-microns. The larger 100-micron ^{6}LiF powder does not allow escape of the charged particles to excite emission in the ZnS scintillator powder. Based on these results the screen for the 25 x 25-cm position sensitive detector has been fabricated using the 12-micron diameter ^{6}LiF powder.

2. POSITION SENSITIVE DETECTOR

Using the scintillator screen described above, a 25 x 25-cm position sensitive detector has been designed and constructed. A photograph of the detector and fiber optics readout array is shown in Figure 4. The neutron scintillator screen, fiber optics readout and photomultiplier tubes are mounted in an aluminum light-tight enclosure. Neutrons enter the detector through a 0.125-inch thick cover plate. An array of wavelength-shifting fibers is clamped on the screen opposite the cover plate in a 2-dimensional array with 48 fibers in each direction. One end of every fiber is mapped onto an individual cathode of a Philips XP1704 multi-anode photomultiplier tube. This tube contains 96 individual anodes in a single vacuum envelope. The other end of the fibers are attached to a single anode Hamamatsu R1924 tube which provides a coincidence pulse for each detection event. In Figure 4, the coincidence tube is located on the left of the photograph and the black delrin mount for the multi-anode tube is on the right. The optical fibers are held in place by delrin clamps located on the periphery of the scintillator screen.

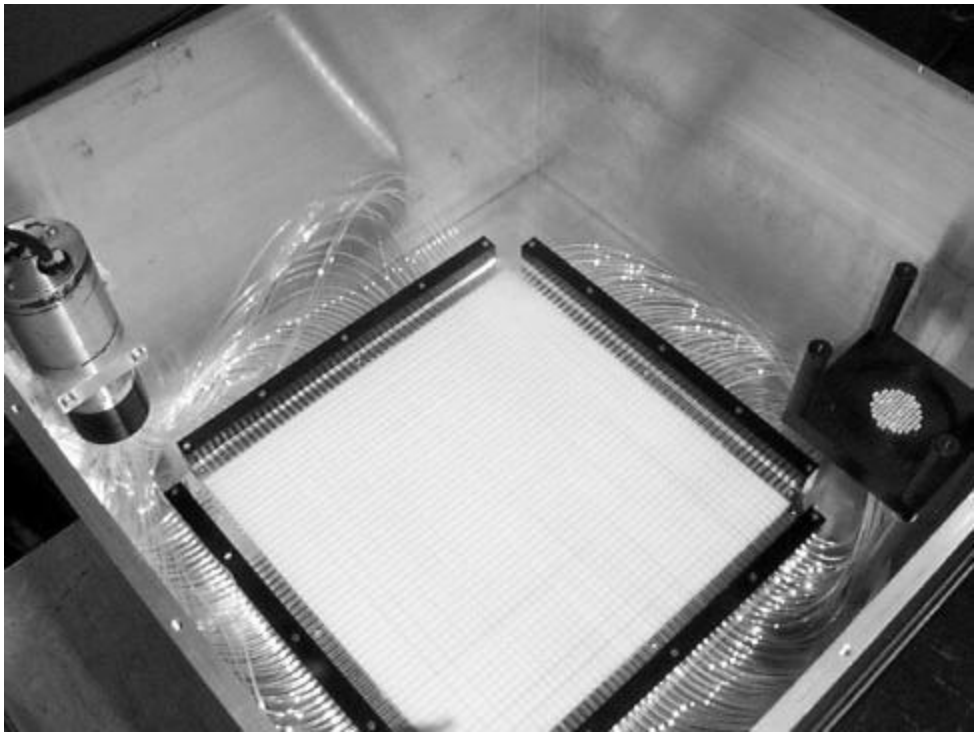

Figure 4 Scintillator Screen and Fiber Readout Array

The 96 anodes of the multi-anode photomultiplier tube are connected to two resistive divider networks, one for each axis of the detector. A diagram of the electronics for one axis of the detector is shown in Figure 5. The resistive dividers allow the pulse current from each detection event to be divided between the charge-sensitive pre-amplifiers attached to the ends of the divider strings. The pulses then pass though shaping amplifiers (τ = 300-nanosec) to A/D converters. This combination of amplifiers produce gaussian-shaped pulses whose height is proportional to the current coming from each end of the resistive divider strings. Zero-crossing detectors following a pair of differentiators in the processing electronics module triggers the A/D converters on the peak of the pulses. Only pulses that also generate a coincident pulse in the R1924 photomultiplier tube will trigger the A/D converters. The digitized data is recorded by a computer that calculates and stores the x and y coordinates of each event. After the computer records an event, the triggering circuit is re-armed for another event. Because the computer is in the timing loop, the count rate limit for the detector is currently limited to approximately 50 kHz. Future improvements to the electronics will include a hardware position determining circuit so that the count rate will be limited only by the 1-microsec timing of the pulse shaping amplifiers. Initial testing of the detector involved the measurement of neutrons scattered from a piece of single crystal germanium placed in a 0.056 eV neutron beam from the HFIR reactor. A plot of the scattered neutron image from a germanium crystal is shown in Figure 6. The neutron beam generated by the crystal is approximately 20-mm in diameter and is accurately matched by the spot size in the image.

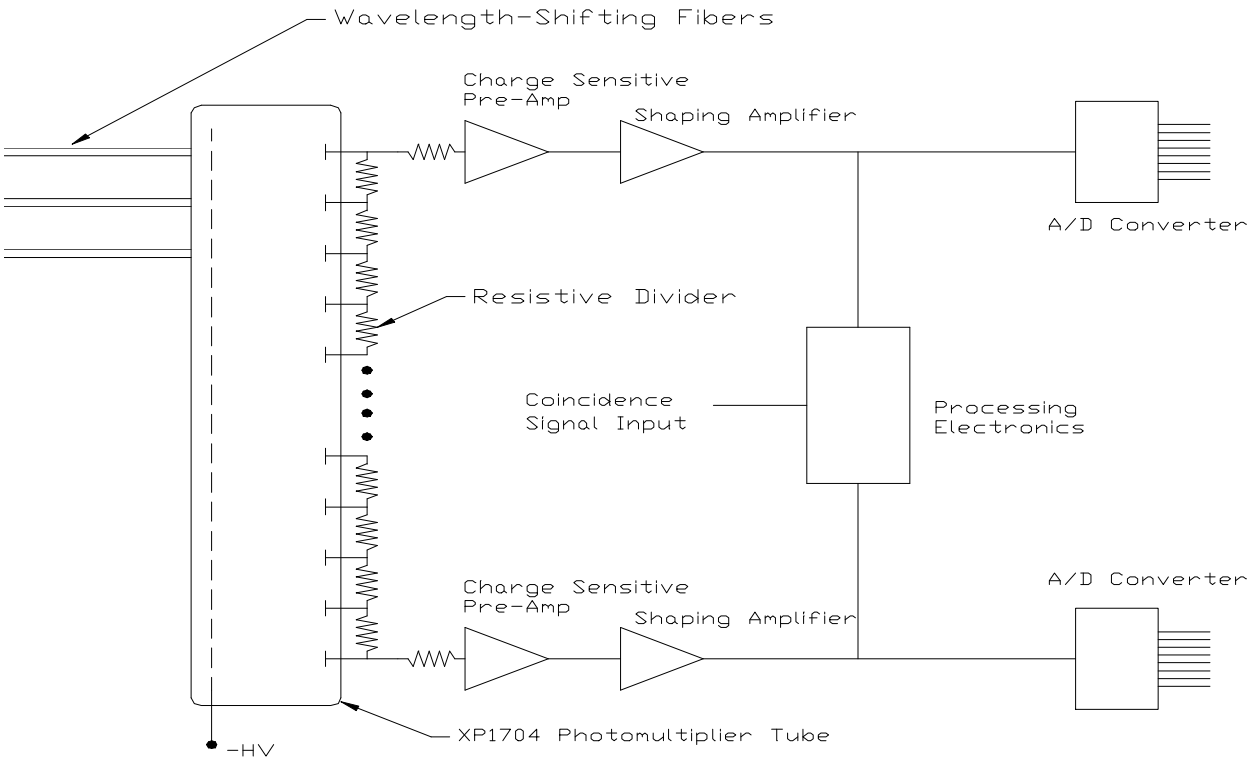

Figure 5

3. SUMMARY

Several screen mixtures of ^{6}LiF and ZnS have been evaluated to optimize thermal neutron detection efficiency. Using this information a 25 x 25-cm position sensitive thermal neutron detector has been constructed and tested demonstrating the imaging capability of this technique. Although the detector is still undergoing tests to determine the spatial resolution and count rate limit, these initial results are very promising. Currently, new and improved processing electronics are under development, which will optimize detector speed, sensitivity and spatial resolution.

[1] S. A. McElhaney, private communication.