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Neutron Sensitivity of LSDT Chambers

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Abstract:

We have tested the sensitivity of the Limited Streamer Drift Tubes (LSDT) to neutrons using a Cf^{252} spontaneous fission source. We obtain an "efficiency" for neutron detection of ~0.4% in either the direct beam from the source or from the moderated flux outside a 30 cm radius Boron loaded (5%) polyethylene can surrounding the source.

I. Introduction

The hadronic showers in the calorimeters of the SSC detectors develop through successive collisions with the nuclei of the stopping material. Such collisions result in the production of spallation neutrons. The phenomenon is well known and gives rise, as an example, to the so-called π/e energy ratio in calorimeters where the neutron component which is associated with a hadron shower is not efficiently detected[1]. This is a considerable effect ($\sim$ 5-10%). The spectrum of neutrons so produced has a distribution in energy characteristic of nuclear momenta and peaks in the 1 Mev region. One should expect that the number of neutrons so produced will be proportional to the energy dumped into the calorimeter by the hadronic showers and thus be dependent on the angle with respect to the beam; there will also be neutrons from small angle jets going into the up and downstream hardware adjacent to the detectors. By the same mechanism one might expect neutron sources from proton losses in the accelerator; for the time being we will not consider these.

The heavy nuclei in the calorimeter are not efficient in moderating the neutrons; however there are sufficient light nuclei and hydrogen in the other materials of the calorimeter e.g. G-10, scintillator, etc., that the neutrons are considerably moderated by the time they exit the calorimeter (see Fig. 1).

It is important that we measure the sensitivity of the various detecting elements of the GEM detector to such neutron fluxes so that we may ascertain;

1.) the random counting rate and its contribution to chance coincidences for triggering purposes and its contribution to random "noise" in an event,

2.) the deterioration of the detector through excessive radiation and/or number of pulses,

3) what to do about it.

II. Experimental Setup

Lacking a super collider at hand, we obtained a source, the spontaneous fissioner Cf^{252}, suitably stored in a Borated, polyethylene can. We also obtained from its author[3], the calculated spectrum of neutrons and photons expected to emanate from the enclosing can. This spectrum was calculated for a 40 cm radius sphere of B-Poly with a Cf source; we have renormalized it to our 30 cm diameter can. This spectrum is plotted in Figure 1 along with a spectrum generated by L. Waters[2] which represents the neutron flux expected from just outside the GEM barrel calorimeter from one SSC event (actually, an average over 50 events) moderated by 10 cm of borated polyethylene placed outside the calorimeter. It is not surprising that the shape of the two spectra are similar; the sources are both "spallation" neutrons and the moderators are both Borated polyethylene plus the hydrogenic material present in the GEM calorimeter. Note also from the integral spectra (Fig. 1b) that the majority of neutrons are still "high" energy, > 20 kev. Measurements made outside the Cf^{252} can should be a good representation of the expectations from the GEM environment. The normalizations are, of course, quite different, one being per SSC event, the other per Cf neutron.

The experimental setup for our measurements is shown in Figure 2. We could open the "cork" in the can and expose the LSDT tubes to the direct beam from the Cf source. We could also expose the tubes to the moderated beam by placing them at the side of the can.

In order to measure the "efficiency" for the tubes we require a measure of the neutron flux impinging on the tubes. We have two ways of doing this:

1.) We know the absolute neutron flux of the Cf source and can use the calculations of ref. 3 to get the flux outside the can,

2.) We have a neutron flux monitor, Nuclear Research Corporation Model NP-2,which, though it reads in Rem, it is provided with an energy response curve.

We had a NaI crystal operating into a LeCroy QVT to measure gamma ray spectra.

III. Measurements

A. Gamma Rays

Though the Boron-Poly case does indeed attenuate the neutrons it is ineffective with respect to gamma rays. Thus the calculations of reference 3 indicate that one gets 1.05 gammas outside the case for every Cf neutron; this gamma corresponds predominantly to the Boron capture gamma (0.42 Mev). Figure 3 shows the gamma spectrum observed outside the case with a comparison spectrum from Na^{22} (the 0.51 Mev annhilation gamma); the spectrum is consistent with the Compton spectrum from the Boron capture. In most of our measurements we protected the tubes from the gamma radiation with 5 cm of Pb.

B. Measurements in the direct Cf beam.

In all our measurements we used a 22 cm long, 2.2x2.2 cm cross section LSDT. Figure 4 shows an attenuation curve as a function of the thickness of interposed Pb with the tube over the open hole above the source. It shows an initial drop off characteristic of the Boron capture gamma followed by a drop off consistent with the scattering out cross section of neutrons on Pb.

We also varied the gas composition in the tube i.e. the relative amounts of Argon and Isobutane. If we assume that our pulses come from knock-ons on all the gas atoms with probability given by the tabulated cross sections then the Argon contributes little compared to the Isobutane (1 atom compared to 14 per molecule). The counting rate(CR) vs. gas composition is shown in Figure 5; the CR vs. % Isobutane shows a satisfactory linear dependence but the extrapolation to zero gives a finite contribution! This contribution is comparable with that from the gas. For the present we believe this may be due to some hydrogenic film or deposition due to lack of cleanliness in the original tube or from higher hydrocarbons in the flowing gas. Unfortunately, this effect was discovered after the Cf source was returned to its owner; the hypothesis has yet to be checked. Using the neutron monitor to measure the neutron flux we obtain an "efficiency" of 4.3×10^{-3}. If we consider the "efficiency" for the gas alone (see Fig. 5) we get 3.1×10^{-3}.

C. Measurements on the side

The tube was also placed on the side of the can where we have a moderated flux, again, behind 5 cm of Pb to partially eliminate the Boron capture gammas. In this case we obtain a gas efficiency of $4.0\text{x}10^{-3}$. We have corrected the monitor flux measurement to eliminate the contribution from the thermalized component and the counting rate to eliminate the residual Boron capture gamma component. We also operated the tubes in the proportional region. Since the streamer mode will trigger on very small ionization such as might arise from the recoil of a heavy struck nucleus we wished to see if we were getting appreciable number of pulses from such sources. The "efficiency" in the proportional mode was only 20% less indicating this was not the main source of pulses.

D. Capture gammas

We have calculated the probability of counts from Al capture gammas in our tubes; this is small compared to the direct neutron counts, depending, as it does, on the product of two reaction probabilities. However, for a real array of chambers, where more mass is involved, the effect should be considered.

IV. Conclusions

The experimental measurement of our sensitivity to neutrons is in relatively good agreement with expectations, namely, that we detect these neutrons from knock-ons in the gas.

In summary:

1.) The detection efficiency of our 1" cross section Aluminum tube is of the order of 0.4% per incident neutron.

2.) There remains a source of counts which is probably due to tube uncleanliness or deposition from the flowing gas. This remains to be checked.

3.) The calculated counting rates from the neutron fluxes expected outside the GEM calorimeter and in the barrel region coupled with these chamber efficiencies is acceptable from either background counting or tube aging with the use of some moderator placed in or just out of the calorimeter.

4.) The use of polyethylene as a moderator should be followed by Pb to eliminate the capture gammas.

5.) The effects of capture gammas in the detectors themselves is not addressed by the above test since it depends more than linearly on the detector disposition.

References

1.) R. Wigmans, NIM A259, 389 (1987); NIM A265, 273 (1988).

2.) D. M. Lee, R. E. Prael, L. Waters, GEM Note TN-92-91; L. Waters, private communication.

3.) E. Greenspan, private communication, Dept. of Nuclear Engineering, Univ. of California at Berkeley, Berekley, Calif.

Figures

Fig. 1 Calculated neutron spectra for outside the GEM barrel calorimeter (ref.2) and for outside the can containing a Cf^{252} source plotted; a) differentially, b) integrally.

Fig. 2 A schematic layout for the measurements made on LSDT tubes with the Cf source.

Fig. 3 The gamma ray spectrum observed outside the can(b) and a Na^{22} refernce spectrum(a).

Fig. 4 The counting rate in the tube as a function of Pb thickness.

Fig. 5 Counting rate in the neutron beam as a function of gas composition-relative % of Argon and Isobutane.

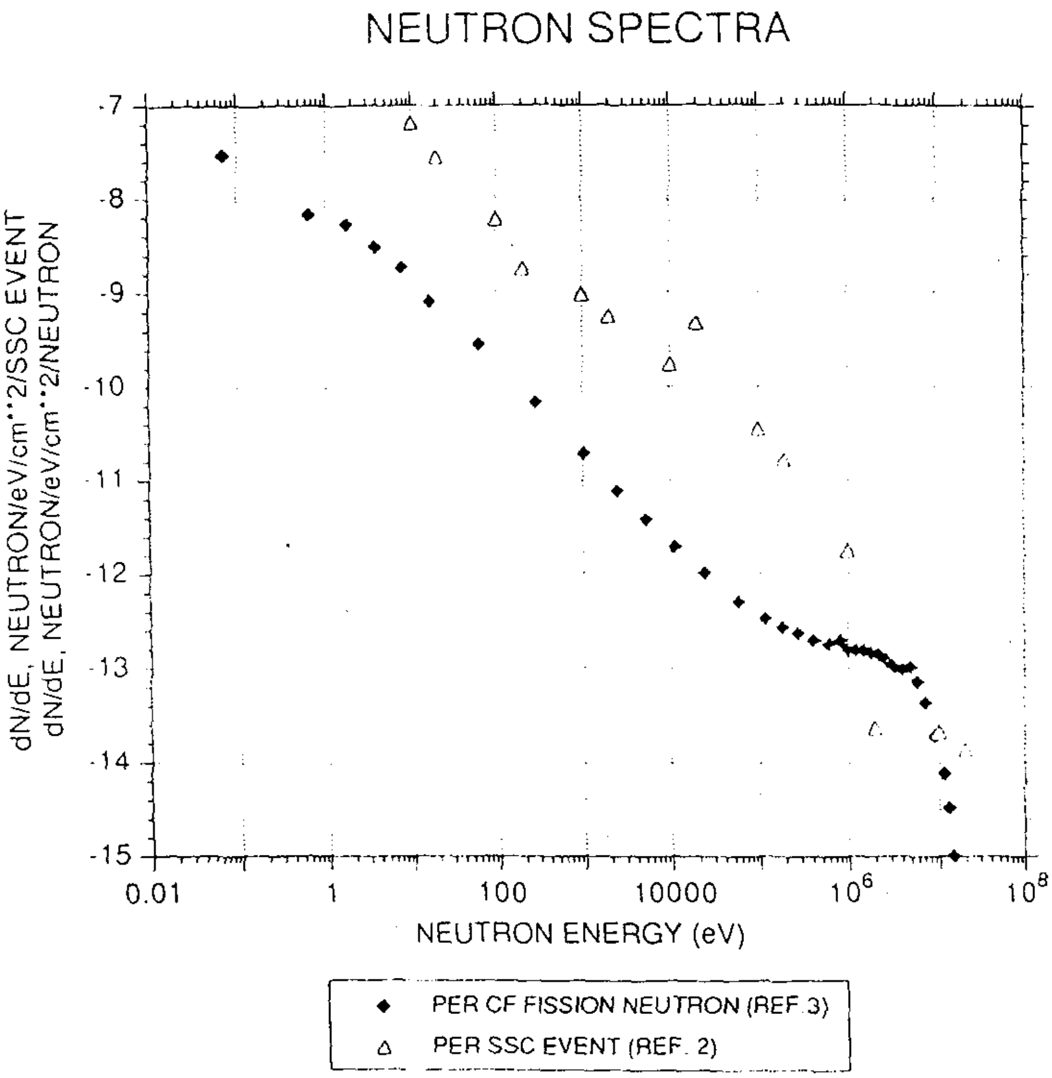

Fig. 1a Calculated neutron spectra for outside the GEM barrel calorimeter (ref.2) and for outside the can containing a Cf^{252} source (ref 3).

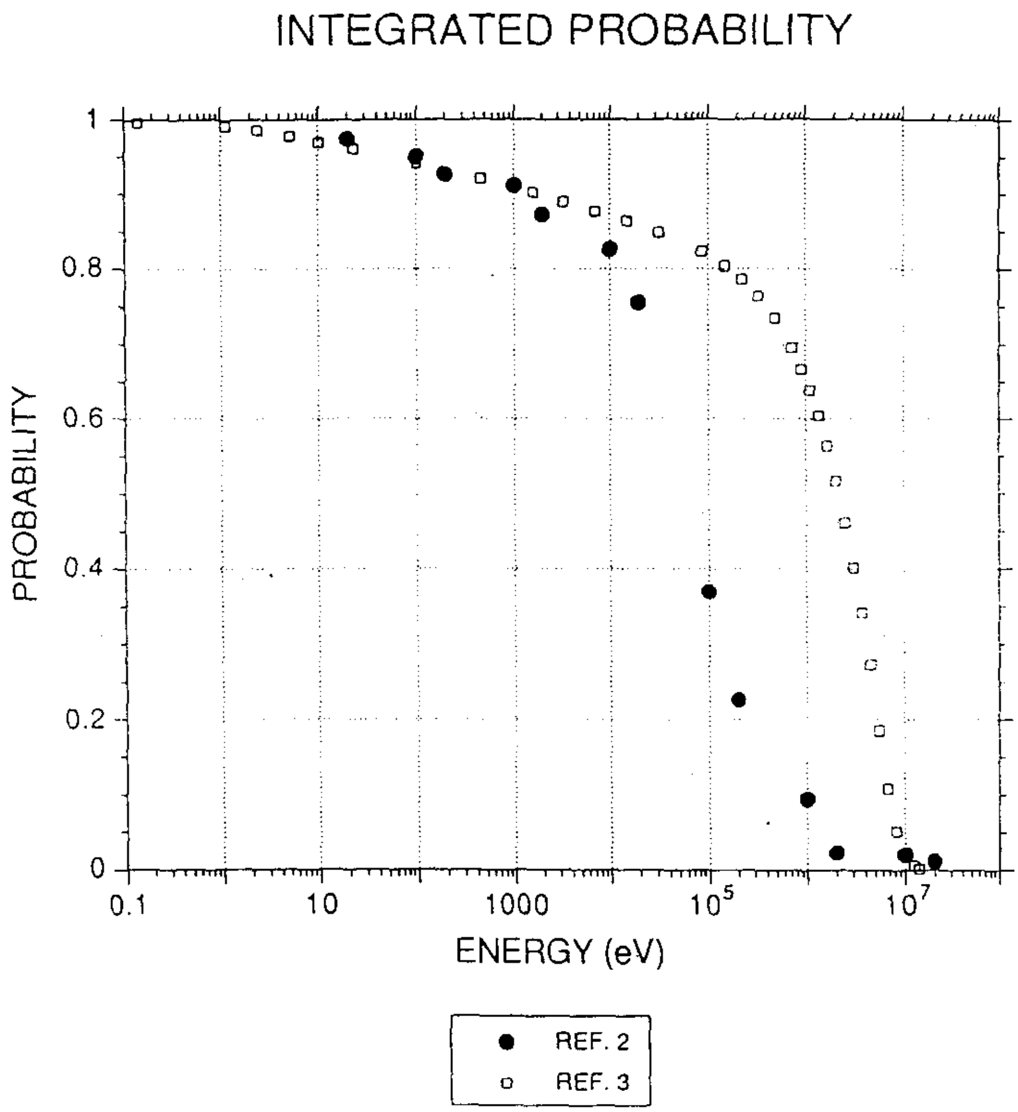

Fig. 1b The integral neutron spectra[2,3]. Note that these "moderated" fluxes are still primarily high energy neutrons.

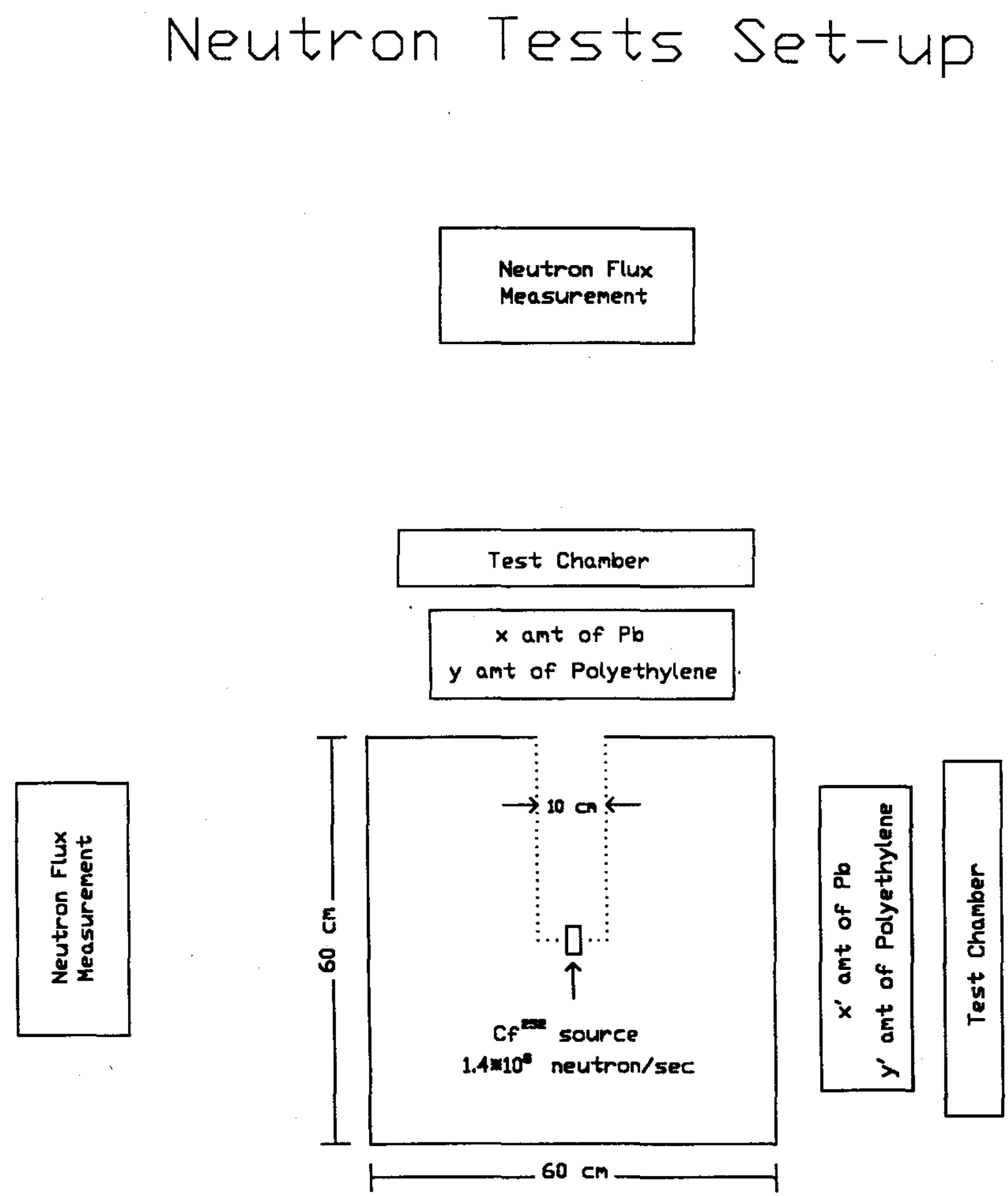

Fig. 2 A schematic layout for the measurements made on LSDT tubes with the Cf source.

a)

b)

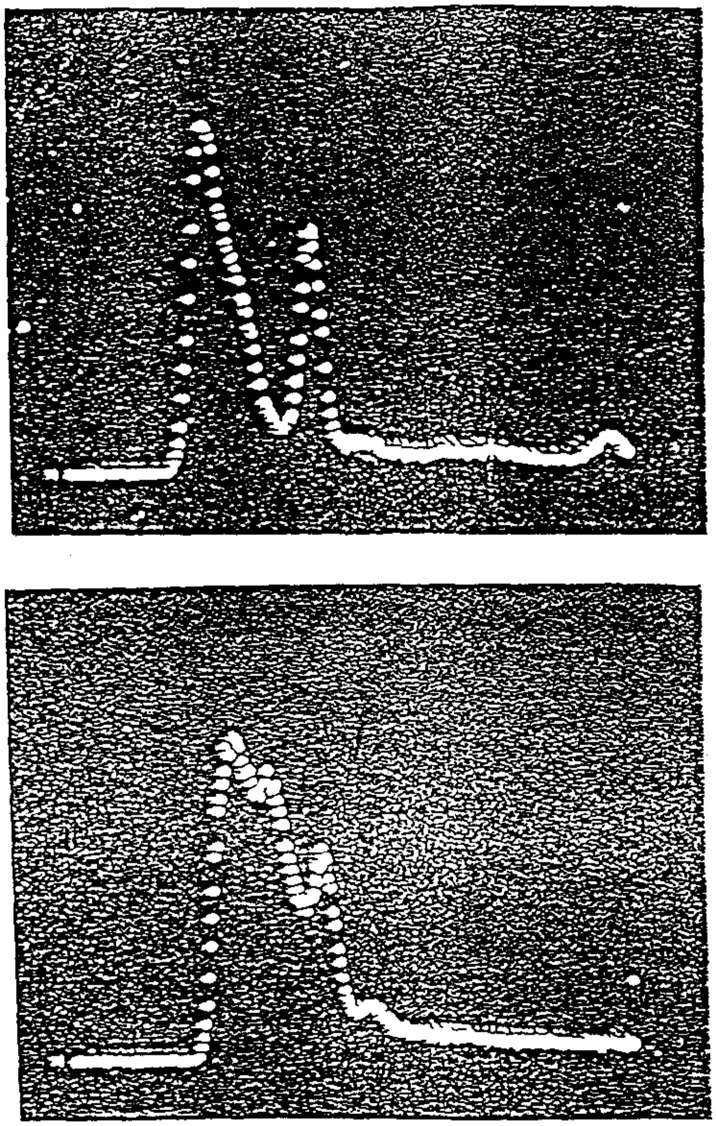

Fig. 3 The gamma ray spectrum observed outside the can(b) and a Na^{22} refernce spectrum(a).

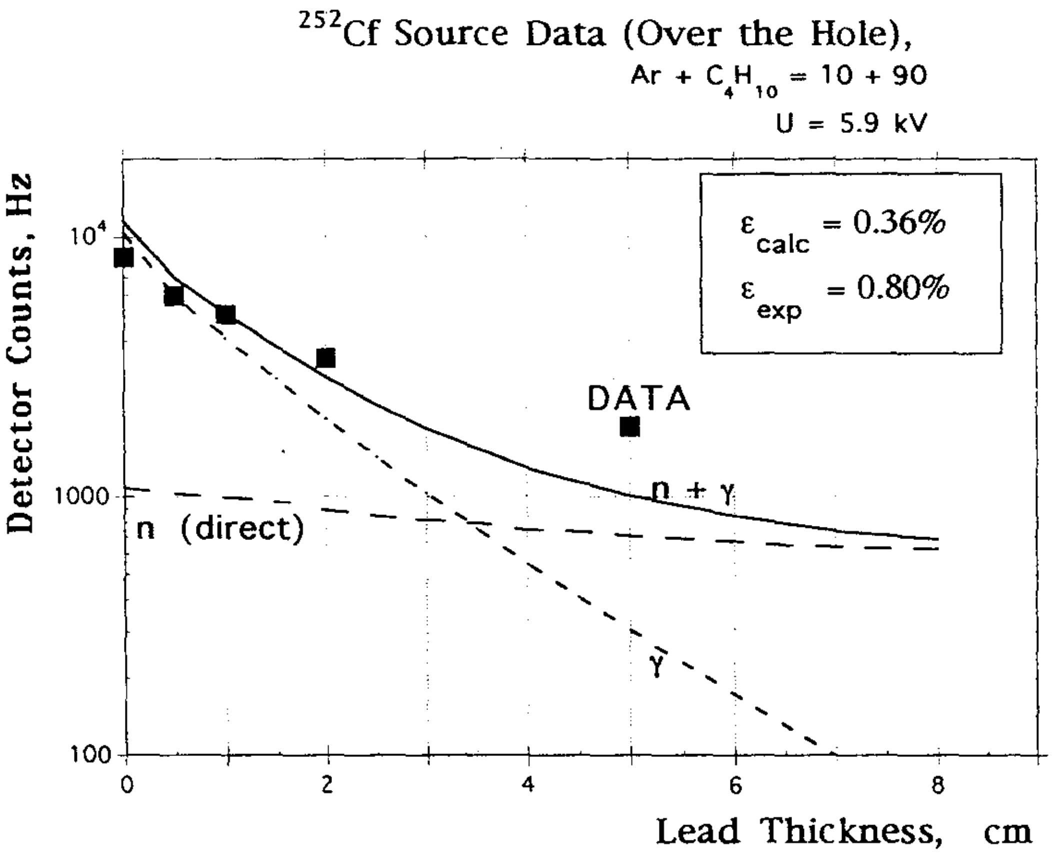

Fig. 4 The counting rate in the tube as a function of Pb thickness.

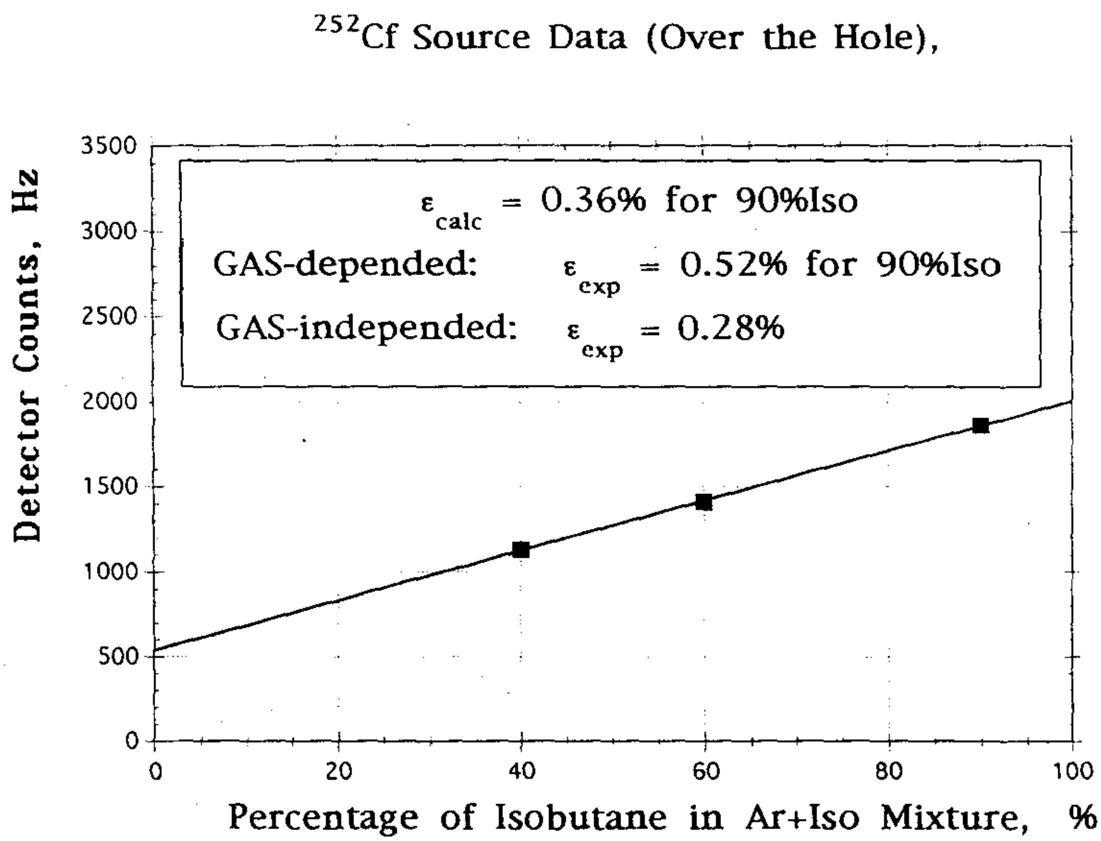

Fig. 5 Counting rate in the neutron beam as a function of gas composition-relative % of Argon and Isobutane.