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Estimating the High Energy Neutron Flux in the SUF

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1 Introduction

We have arrived at a new and unexpected situation in CDMS I, where we believe that the major source of background is high energy neutrons penetrating the shield. Earlier neutron measurements and Monte Carlo studies have focused on the relatively large flux of neutrons below 50 MeV. The "low energy" neutrons are produced from natural radioactivity and muon interaction in the rock. Reference [1] describes the spectra and flux of these neutrons in some detail, and gives a sketchy treatment of the higher energy neutrons produced from hadronic cascades. At the time of [1], there was concern over the veto efficiency, and so the work concentrates primarily on the neutrons produced in the shield by muons escaping the muon veto.

As the veto efficiency proves trustworthy, our focus shifts away from leakage of muons into the shield and towards neutrons penetrating the shield which the veto has little chance of detecting.

Despite the sharp decrease in neutron flux in the tunnel at high energies, the high energy neutrons are far more likely to penetrate the 20 cm of polyethylene shielding and excite a detector.

2 Spectrum

The spectrum of neutrons from hadron cascades was obtained using a typical neutron spectrum from hadrons [3] and propagating neutrons with these energies through 5 m of rock. It agrees with fluxes estimated in [4]. Analytically it is of the form:
$dN/dE = A_1/\sqrt{E}$ for $10 \le$ E ≤ 90 MeV,
$dN/dE = A_2/E^2$ for $90 \le$ E ≤ 1.2 GeV,

Figure 1 shows the spectrum estimated in this way.

(*Steve Y uses an analytic form:*
$dN/dE = A_1/\sqrt{E} + A_2 e^{-E/10.3}$ *for* $11.5 \le E \le 50$ *MeV,*
$dN/dE = A_3/E$ *for* $50 \le E \le 100$ *MeV,*

with $A_1 = .901 * 10^{-7}, A_2 = 1.24 * 10^{-7}$, *and* $A_3 = 6.86 * 10^{-7}$.

Steve Y's form includes the neutrons from μ *production.*
It would be nice to plot it.)

3 Normalization

To estimate an event rate in the detectors due to neutrons from hadron cascades, one needs to know the flux of these neutrons in the tunnel. Measurements made with the BF_3 counter [1] cannot be used to estimate this flux because the measured rates are dominated by low energy neutrons from natural radioactivity and muon interactions in the rock while the range of sensitivity of these measurements does not extend to energies high enough to include a significant contribution from "cascade neutrons". The measurement made by Chen *et al.* [2] is more useful in this regard because the energy window used for the flux measurement (11.5 to 50 MeV) includes a sizable chunk of the "cascade neutron" spectrum (31 % of it is in this range) and excludes the low energy contribution from natural radioactivity (mostly below 2 MeV). However, neutrons

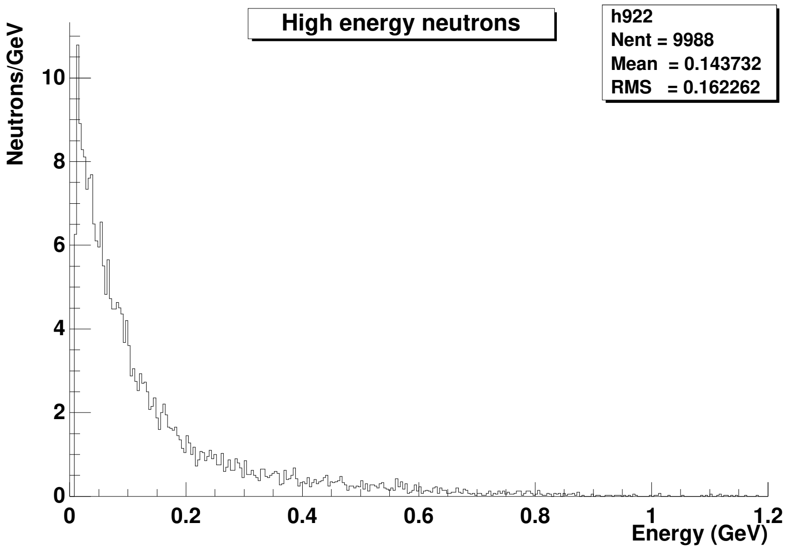

Figure 1: *The spectrum of neutron flux in the SUF cavern normalized to 1 neutron between 0 and 1 GeV.*

from muon interaction in the rock do contribute significantly to the rate within this window making it difficult to determine the flux due to cascade neutrons alone. According to [2] the flux of neutrons with energies between 11.5 and 50 MeV is $(1.07^{+.41}_{-.30}) \times 10^{-6}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The authors of [2] estimate that 62 % of these neutrons are from hadron cascades while the rest are from muon interactions in the rock. All the rates quoted here follow from this estimate and the measured rate.

Reference [2] does not estimate an uncertainty on the fraction of their sample which are "cascade neutrons". All techniques for estimating this breakdown of the flux ([1, 3]) give the "cascade" to "muon" ratio between 50% and 70%.

This leads to

$$\phi = (6^{+4}_{-3}) \times 10^{-7}\mathrm{n/cm^2/s} \tag{1}$$

between 11.5 and 50 MeV.

Finally, we estimate that including the lower energy neutrons from natural radioactivity and muon interactions in the rock will not increase the rate in detectors by more than 15 %.

References

[1] A. Dasilva. *Development of a Low Background Environment for the Cryogenic Dark Matter Search.* Ph.D. Thesis, University of British Columbia. April, 1996.

[2] M. Chen *et al. Measurements of the fast neutron flux at 20 mwe underground* NIM A 336(1993) 232-235.

[3] F. F. Khalchukov *et al. High-Energy Hadron Background in Proton Decay Experiments* Il Nuovo Cimento 6C, N 3, May-June 1983.

[4] F. F. Khalchukov *et al. Hadrons and Other Secondaries Generated by Cosmic-Ray Muons Underground.* Il Nuovo Cimento 18C, N 5, Sept-Oct 1995.

[5] M. Aglietta *et al. Neutron Flux Generated by Cosmic-Ray Muons at* $5200 hg/cm^2 s.r.$ *Underground. Depth-Neutron intensity Curve.* Il Nuovo Cimento 12C, N 4, July-August 1995.

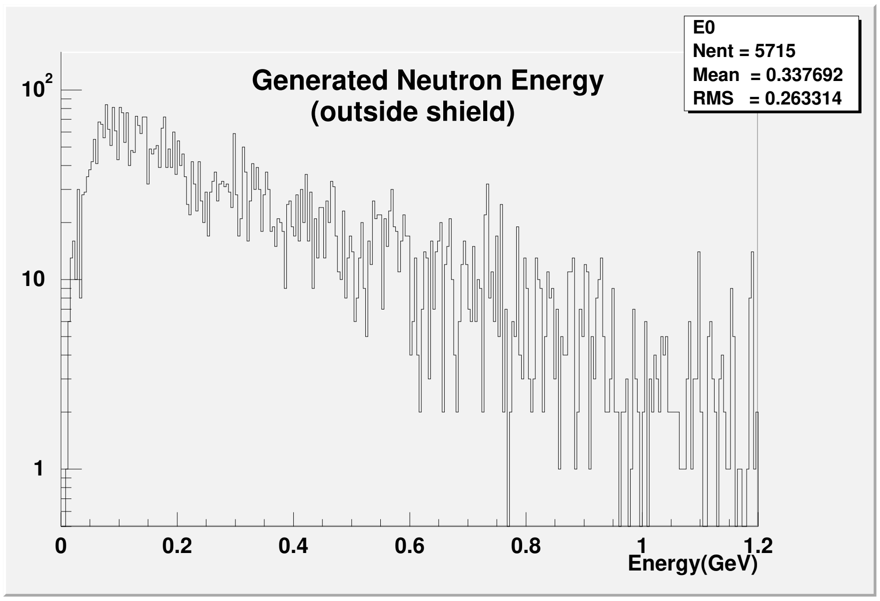

Figure 2: *The spectrum of neutron energies outside the shield which reach the detector.*

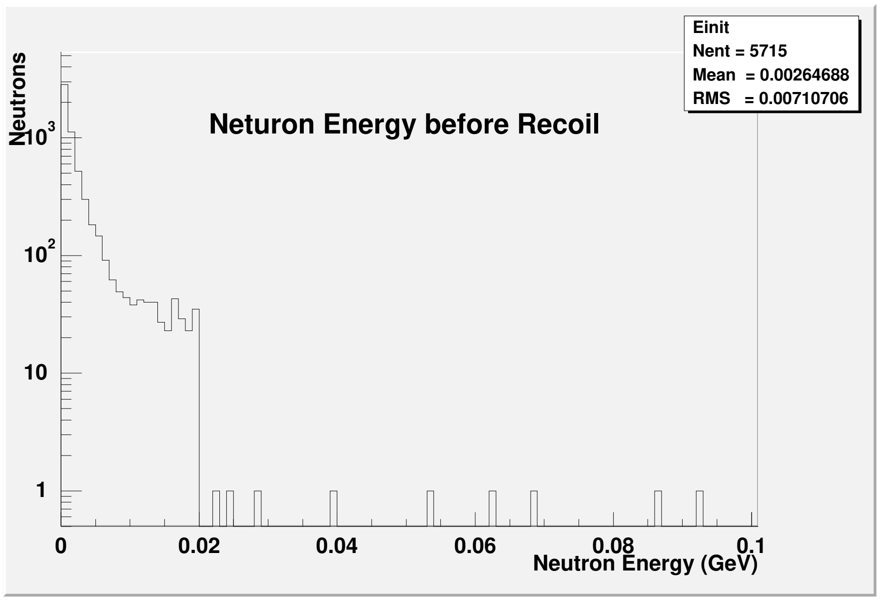

Figure 3: *The spectrum of neutron energies inside the shield, just before recoiling on the detector. The sharp cutoff at 20 MeV is due to the MICAP edge.*