OG 9.3-5

AN APPROACH OF REDUCING THE BACKGROUND INDUCED BY NEUTRONS

Shen Changquan Ma Yuqian
Gu Yidong Dai Changjiang
Sun Yangfang Fan Zhenzi

Institute of High Energy Physics,Academia Sinica
P.O.Box 918 Beijing,China

1.Introduction

The background induced by interactions of neutrons with detector material (and shield material) is difficult to be rejected.It is one of the most important factors to affect the sensitivity of a balloon-borne gamma-ray astronomical telescope.

The main component of neutron flux at the major detector of the telescope is incident neutrons,that consists of atmospheric neutrons and neutrons locally produced in the balloon platform. Therefore,shielding the detector from incident neutrons is a possible way to reduce the background. NaI (Tl) crystal is very widely used in gamma-ray astronomical telescope. Our balloon-borne experiment have shown that ^{6}LiF shield is effective to reduce the background in NaI crystal.

2.Methods

The energy range of neutrons which can produce important background effects in gamma-ray telescope goes from thermal energies to several hundred MeV (1,2). For our perpose,the ideal neutron shield is an effective absorber or moderator with little gamma-ray production. The isotope ^{6}Li has large (n,α) cross section,which is 942 barns for thermal neutrons and inversely proportional to the square root of neutron energy. Also both ^{6}Li and F nuclei have very little gamma-ray production in neutron flux. Therefore we use ^{6}LiF as the neutron shield.

We built a balloon payload with two identical 75 mm dia. by 75 mm thick NaI (Tl) crystals. It was launched two times, in June of 1983 and in June of 1984. The block diagram of the experiment is shown in Fig 1. The apparatus consists of two identical parts: A and B. The only difference between them is that crystal A is surrounded by a passive neutron shield but crystal B is naked. For the first flight,the shield was 0.4 $g.cm^{-2}$ thick ^6LiF covered by 6.5 cm thick polythene. For the second flight it was o.6 $g.cm^{-2}$ thick ^6LiF only. The powdery ^6LiF was sticked between two layer of 2 mm thick polythene with silica gel,then this sandwich was shaped as a 12 cm dia.by 16 cm deep cylinder and crystal A was placed in it.

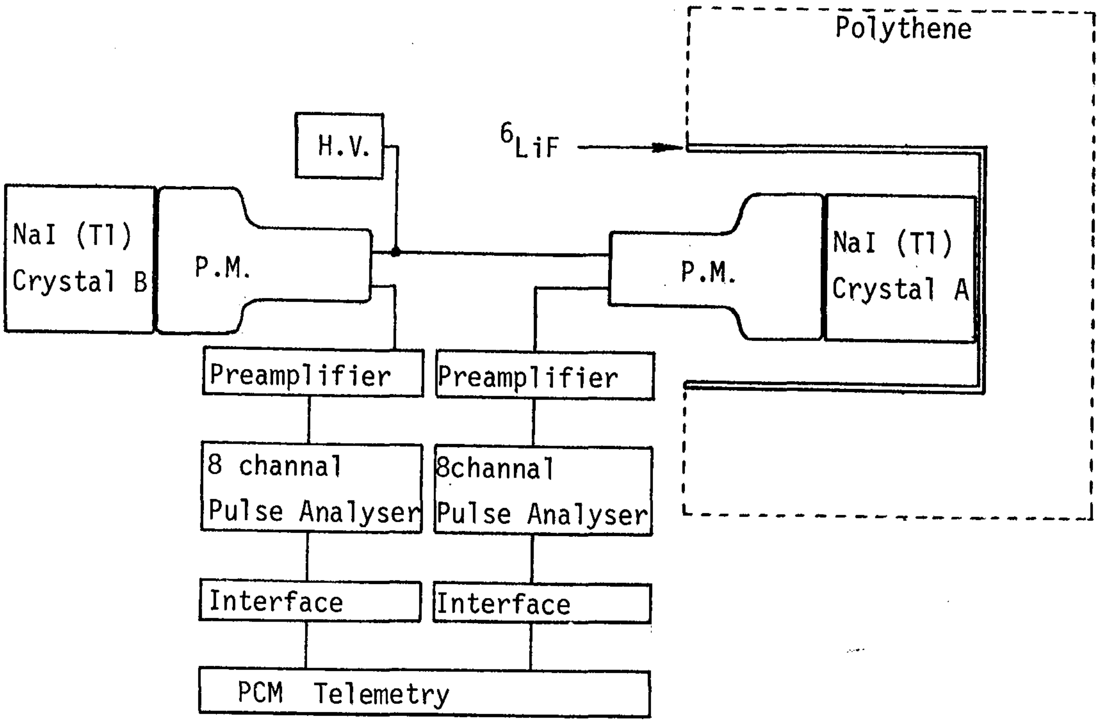

Fig 1. The block diagram of the on board experiment.

3. Result

During the first flight, the background spectra measured by the two detectors with/without neutron shield respectively are different, but they have similar integral background rate in 0.06-2 MeV range.

For the second flight, the integral background rate of the shielded detector in 0.06-2 MeV is about 12% lower than that of the naked one at the altitute 17±1 km where the background rate has its maximum. This value is in excess of 21 times of its standard deviation. The integrated spectra measured there for both detector A and B is shown in Fig 2. In the spectra all counts with energy higher than 2 MeV have been taken off since most of them are contributed by cosmic rays. At other altutute, similar results were recorded.

4.Discussion

Neutrons arriving at a NaI detector may interact by several mechanisms that lead to background counts which have the appearance of the desired gamma-rays events.Firstly,they may undergo radiation capture at either the ^{127}I or ^{23}Na nuclei of the NaI crystal. The ^{127}I has a much larger cross section for neutron absorption than ^{23}Na.

Radiative absorption of ^{127}I leads to a variety of possible prompt gamma-rays via the reaction $^{127}I\ (n,r)^{128}I$. Over an energy range from 60 keV up to about 6.7 MeV,184 different energies were recorded by Archer et al (3).There is also a delayed effect from each neutron absorption on ^{127}I by the beta decay of the product ^{128}I with a half-life of 25 minutes. It makes a continuous spectrum in the energy range less than 2.2 MeV and some gamma-rays e.g. 443 keV gamma-ray.

^{127}I has a resonance region over 15 eV to 1.0 keV in which approximately 75% of absorption events originate,and the strongest resonance region is over 20 eV to 50 eV. Whereas ^{6}LiF can effectively absorbs neutrons in these energy range,for example 0.6 g.cm^{-2} thick LiF layer can absorbs 44% of 15 eV neutrons, 25% of 50 eV neutrons and 7% 1 keV neutrons.This is the reason why ^{6}LiF shield reduces the background.

The second important neutron interaction mecanisms is the inelastic acattering of neutrons at an ^{127}I nucleus. Some energy levels of ^{127}I to be excited by this effect can contribute to the background by emission of gamma-rays at certain energies among which the 58 and 203 keV is the strongest two. Some calculations (2) show that the overall effect of inelastic scattering of the same order as that from prompt effects of neutron absorption and the energy loss spectrum for this mechanisms is roughly a power low of order -1.5 in the energy range 0.2-12 MeV. The background contributed by this mechanisms has not been reduced since we have not found any effective absorber or moderator with little gamma-ray production for fast neutrons.

In our first flight, 6.5 cm thick polythene was used as a moderator. It could slow down some neutrons and make them easier to be absorbed by ^{6}LiF,so that it seems to reduce the background further. But the result is negative, it is similar to Leventhals experiment (4). It indicates that there is some effects in this moderator which increase the background and off set advantage of ^{6}LiF. It seems that it should be careful to add lots of material surround the major detector, since all material could be a background source in the space environment.

In our experiment, since there is no active shield surrounding the NaI (Tl) detectors, the atmospheric gamma-rays are dominant component in background. In this case the value 12% is a significant part of the neutron induced background. Therefore the results are interesting if you also consider 0.6 mm thick ^{6}LiF is neither heavy nor expensive.

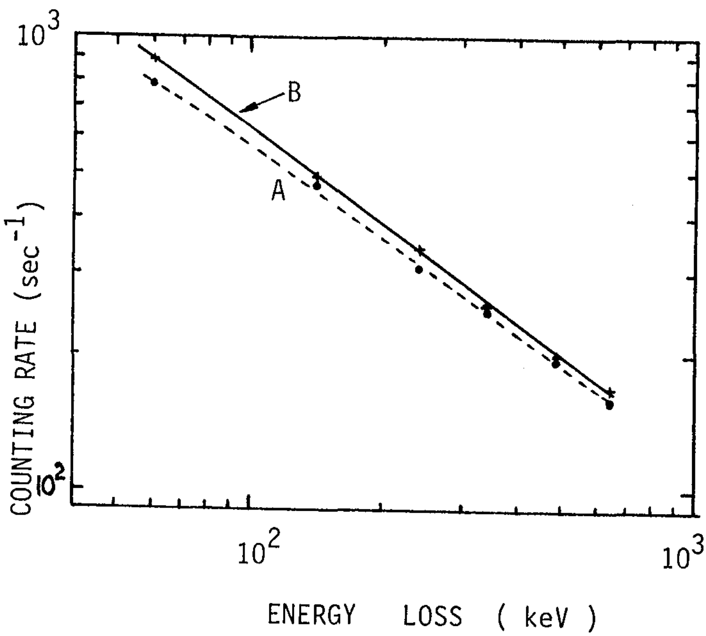

Fig.2. The energy loss spectrum integrated up to 2 MeV at the altitude 17 km for naked detector B (line) and detector A (dot line) shielded by 6LiF.

References

(1) Chupp E.L., "Gamma-ray Astronomy", Published by D.Reidel Publishing Company (1976), p218

(2) Charalambous P.M. et al., Nucl.Instr.and Meths (1985), (in Press)

(3) Archer N.P. et al., Nucl. Phys. 83, 241 (1966).

(4) Leventhal M. et al., Ap.J. 240, 338 (1980)