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TEST OF LEAD GLASS SHOWER COUNTERS*

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Abstract

Lead glass counters made of wedge shaped blocks of SF6 were tested with positrons at SLAC. The beam energy ranged from 2-17.5 GeV. Energy dependence and beam position dependence of pulse height and energy resolution were studied with lead glass blocks of various lengths. The effect of a BK-7 light guide on pulse height was clearly observed. Degradation of the energy resolution due to aluminum absorbers of various lengths was investigated. A mesh type photomultiplier was also tested.

1. Introduction

An array of a new type of lead glass SF6, radiation length $X_0 = 1.7$ cm, has been tested in a positron beam at SLAC. The glass is intended to be used in barrel calorimeters for TRISTAN experiments at KEK. Some 10,000 pieces of lead glass ultimately will be required. The block segments are to be wedge shaped to better fill the annular volume of the barrels.

2. Experimental Procedure

A 3 $\times$ 3 array of the glass was exposed in a secondary positron beam, with beam energy of 2 to 17.5 GeV. The beam had a spot size of about 2 mm diameter and a beam energy spread, $\Delta E/E$, of less than 0.5%. The experimental layout is shown in Fig. 1. The lead glass block array was positioned and moved transverse to the beam with a precision of less than 1 mm. A coincidence signal of defining counters, S1 (3 mm in diameter and 2 cm long) and S2 (2 cm $\times$ 5 cm), was used as a trigger. The beam intensity was set to be an average of 0.1-0.3 particles per pulse with beam repetition rate of 10 Hz. Pulse length was about 150 nsec. Data from pulses with more than 1 positron were rejected by imposing a tolerance on the pulse height from S2.

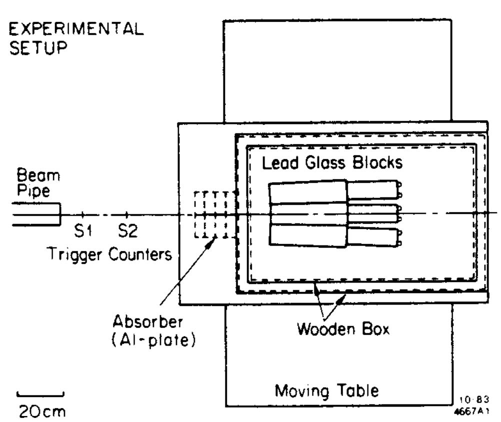

Fig. 1. Experimental layout.

The lead glass block to be measured was placed at the center of the 3 $\times$ 3 array and pulse height data for all 9 blocks were digitized, collected and written onto magnetic tape for every event. The surrounding 8 counters were each of $20X_0$ with a cross section of 9.0 cm $\times$ 10.3 cm at the beam entrance and 10.3 cm $\times$ 10.3 cm at the rear surface (the horizontal side faces were tapered by 1^o). Whenever the beam position dependence was studied, the top middle block was also replaced by one of the same type as the center block and the beam was scanned vertically from the center block through the top block.

Lead glass blocks of $15X_0$, $18X_0$ and $20X_0$, and a wedge-shaped block of $18X_0$, were tested. The effects of a 4 cm long light guide (3 inches in diameter) of BK-7 glass were also measured. To each block was attached a 3-inch diameter photomultiplier, Hamamatsu R594-02, using an ultra high vacuum grease of excellent transparency to attach the tube. Each lead glass block was wrapped with aluminized mylar and black tape to ensure light tightness.

The signals from the lead glass blocks were digitized by an 11-bit ADC, Lecroy 2249W, using a gate width of 200 nsec. The linearity of the ADC's was checked in advance and was found to be linear to within 2 counts throughout the entire dynamic range. By means of an LSI-11 mini-computer, data was collected, analyzed and written onto magnetic tape to permit further off-line analysis. To adjust the gain constant for each channel (including the ADC's), the nine counters of the array were successively exposed to 10 GeV positrons. The high voltage for each counter was then adjusted to give roughly the same mean amplitude in pulse height. After adjusting the high voltages, the mean amplitudes for 10 GeV positron signals were used to generate normalization constants for the off-line analysis.

Figure 2 shows the typical pulse height spectrum for a $20X_0$ lead glass block array exposed to a 17.5 GeV positron beam. The pulse heights for the nine blocks has been summed. The energy resolution was obtained by fitting the Gaussian shape to the spectrum as shown with the solid line in the figure. For those circumstances in which the spectra was asymmetric, independent Gaussian distributions were fitted separately to the upper and lower halves and the average sigma was used to determine the energy resolution.

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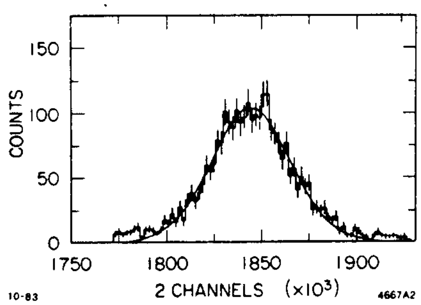

Fig. 2. Pulse height spectrum of positrons with energy of 17.5 GeV for a $20X_0$ lead glass counter. The solid curve is a Gaussian fit to the data.

3. Results

In Fig. 3, the energy resolutions for lead glass blocks of lengths $15X_0$, $18X_0$ and $20X_0$ are shown as a function of $1/\sqrt{E}$(GeV) (hereafter the unit of energy will be GeV). The resolutions are expressed as $(0.78 + 3.26/\sqrt{E})$%, $(0.34 + 4.15/\sqrt{E})$% and $4.92/\sqrt{E}$% for blocks of $15X_0$, $18X_0$ and $20X_0$, respectively. Lead glass blocks with shorter lengths are seen to have larger constant terms, an effect thought to be due to the greater shower leakage out of the back. No deterioration in the linearity of the pulse height is observed with energy up to 17.5 GeV despite shower leakage, perhaps explained by compensation between the reduction of the pulse height due to the shower leakage and the enhancement of the pulse height caused by the reduction of the attenuation length.

Figures 4 and 5 show the energy resolution with an aluminum absorber located in the beam ahead of the lead glass counter array; the resolution is expressed as $\sigma/E = 6.5/\sqrt{E}$ (%) for a $1X_0$ absorber. The deterioration in resolution is negligibly small when the thickness of absorber is less than $0.5X_0$ for an energy of 2 GeV or when less than $1.2X_0$ for 16 GeV. The mean pulse height is reduced by the absorber as shown in Fig. 6.

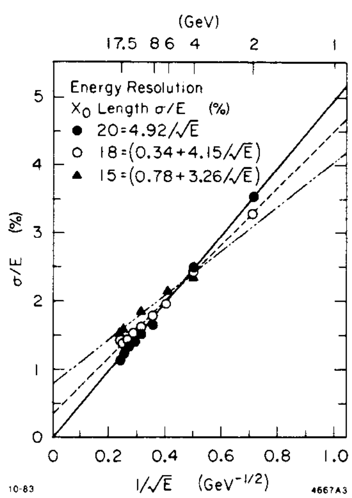

Fig. 3. Energy resolution for $15X_0$, $18X_0$, and $20X_0$ blocks.

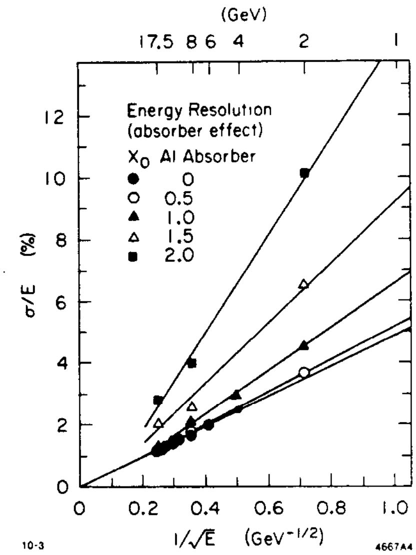

Fig. 4. Energy resolution for a $20X_0$ block with an aluminum absorber in front of the block.

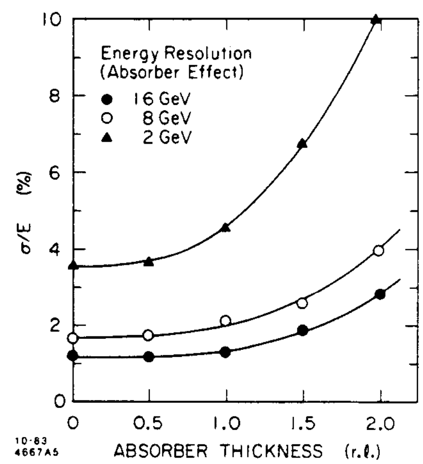

Fig. 5. Energy resolution versus absorber thickness for energies of 2 GeV, 8 GeV and 16 GeV.

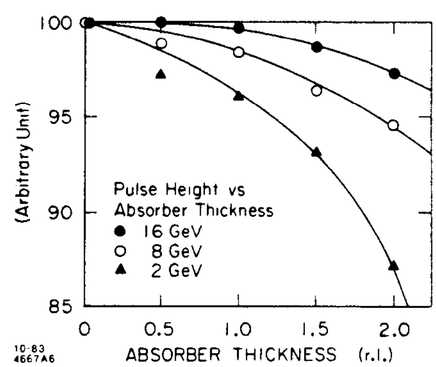

Fig. 6. Relative pulse height versus absorber thickness for energies of 2 GeV, 8 GeV and 16 GeV.

In Figs. 7 and 8 are shown the light guide effects. Lead glass blocks of various radiation lengths ($15X_0$, $18X_0$ and $20X_0$) were exposed to the beam with energy of 10 and 17.5 GeV. The beam was scanned vertically from the center of the array to the center of the adjacent blocks, with a fixed horizontal position of the blocks. In this way the beam position dependence of the pulse height and the energy resolution was studied, both with and without the light guide of BK-7 optical glass. Figure 7 shows the beam position with a beam energy of 10 GeV and no light guide. The pulse height sum of the adjacent two blocks is seen to be quite flat except at the boundary of the blocks. With the light guide attached, an energy resolution of $\sigma/E = (0.2 + 4.9/\sqrt{E})\%$ is a little worse than without the light guide. This deterioration in the energy resolution is explained by attenuation of light in the light guide together with the smaller geometrical acceptance. Figure 8 shows the same beam position dependence for a $20X_0$ block with the light guide attached.

The energy resolution for a wedge-shaped lead glass block is shown in Fig. 9. The block has a cross section of 10.3 cm × 8 cm at the front surface and 10.3 cm × 10.3 cm at the rear surface; the length is $18X_0$. The high voltage was set so that the sum of the pulse height of the nine blocks, including the wedge-shaped block, gave the same value as that of nine normal blocks. The resolution was measured to be $\sigma/E = (0.3 + 4.7/\sqrt{E})\%$. The deterioration in resolution is about 0.3% at 2 GeV. No deviation from linearity is seen.

Tests were performed with a new mesh type phototube, Hamamatsu R1652X, attached to a $20X_0$ lead glass block. The tube is designed for operation in a high magnetic field. The energy resolution was found to be $\sigma/E = (0.06 + 5.94/\sqrt{E})\%$, compared to $4.92/\sqrt{E}\%$ with the conventional type photomultiplier, Hamamatsu R594-02.

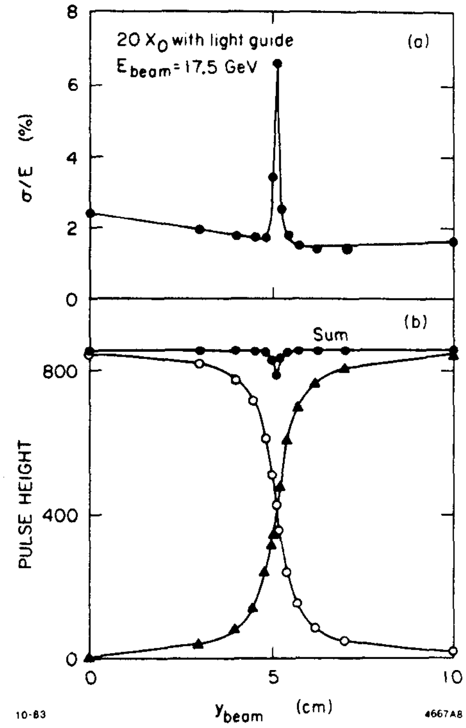

Fig. 8. Beam position dependence of the pulse height for a $20X_0$ lead glass block with light guide for a beam energy of 17.5 GeV.

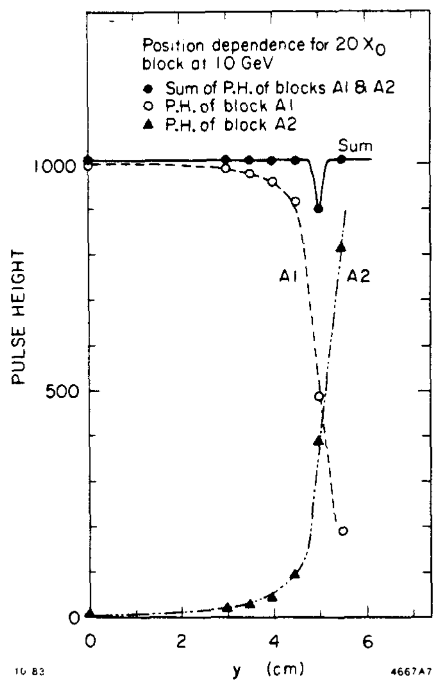

Fig. 7. Beam position dependence of the pulse height for a $20X_0$ lead glass block.

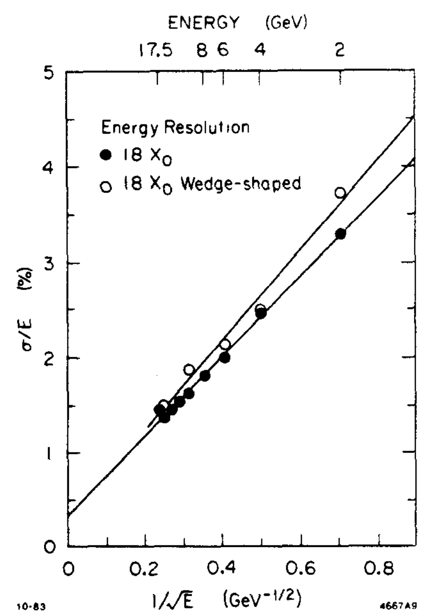

Fig. 9. Energy resolution for a wedge-shaped lead glass block of $18X_0$ (open circles). Energy resolution for the normal block of $18X_0$ is shown for comparison (closed circles).

4. Conclusions

A SF6 lead glass counter array has been tested. The results are summarized as follows:

1. SF6 lead glass counters have preferable energy resolution for TRISTAN experiments for an energy range of 2 GeV to 17.5 GeV. The resolution is about $5/\sqrt{E}$ (%).
2. A length of $18X_0$ to $20X_0$ is recommended for the blocks. Lead glass of $18X_0$ has been measured to have a relatively small constant term of 0.34% in the energy resolution. The unit radiation length is 1.7 cm.
3. A light guide is to be used to reduce the effects of the magnetic field at the position of the photomultiplier. With a light guide, no position dependence of the pulse height was seen for $20X_0$ counters. There is a slight degradation in energy resolution.
4. The effect of an absorber can be rather large. Material in front of the lead glass counter should be less than $1X_0$.
5. Wedge-shaped lead glass counters have shown reasonable energy resolution.
6. The energy resolution measured when using the new mesh type photomultiplier, Hamamatsu R1652X, is slightly worse. More improvement in the photomultiplier is necessary.

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