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TEST RESULTS OF A BaF₂ CALORIMETER TOWER

WITH A WIRE CHAMBER READOUT

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ABSTRACT

The results from a calorimeter tower consisting of BaF₂ crystals coupled to photosensitive, low-pressure wire chambers are presented. The longitudinal and lateral shower development is shown. The results for 108 MeV and 200 MeV electrons yield an energy resolution of $\sigma/E = 2.5\% E^{-1/2}$ (GeV).

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1. INTRODUCTION

There has been a continuing effort in the development of the scintillator BaF_2 coupled to a photosensitive wire chamber [1-4]. This new instrument, consisting of a solid scintillator plus a proportional counter, has been given the abbreviation SSPC. The photosensitive material used to detect the BaF_2 scintillation has been TMAE^{*}, used in the form of gas [1], liquid photocathode [2], and as an adhered surface [3-4].

As the only scintillator demonstrated to work in an SSPC, BaF_2 has many fortunate characteristics. It is non-hygroscopic, has a density of 4.9 g/cm^3 and a radiation length of only 2.1 cm. The short-wavelength component to which TMAE is sensitive has a decay constant of only 0.6 ns. This is about 500 times faster than NaI(Tl) or BGO.

In order to enhance the photoelectron collection efficiency [3] and reduce the sensitivity of the wire chamber to passing particles, low-pressure wire chambers have been used. (See Breskin [5,6] on the subject.) Low-pressure chambers have the added advantage of high positive ion mobility. Thus an SSPC using such a wire chamber yields an instrument with good timing and high rate capability.

In an earlier work a resolution of 28.5% FWHM was measured for protons losing about 18 MeV in an SSPC. But there has never been a measurement made with a stopping high-energy particle. In this work we report results of a test done with an SSPC calorimeter tower stopping high-energy electrons, μ^- and π^- .

2. TOWER DESIGN

Figure 1 shows a schematic of the SSPC tower. It consists of 14 BaF_2 crystals, 12.6 cm in diameter, varying in thickness from 1 cm to 5 cm. The

* Tetrakis(dimethylamine)ethylene.

total thickness of BaF_2 is 40.5 cm, making 19.3 radiation lengths, X_0 . Each crystal is preceded by its own wire chamber to maximize the position resolution at each step [4]. Table 1 gives the crystal thickness. In general, the crystals become thicker with depth, with the exception of No. 6 which was made thinner to examine the shower after $4.5 X_0$. Unfortunately, owing to an oversight, the cathode grouping of this module was not made proportionately narrow. The entire tower was placed in a thin aluminium chamber so that all wire chambers share a common gas volume.

Figure 2 shows a schematic of an SSPC module. Each crystal is coated on one surface with aluminium to provide an electrode for the next chamber and to maintain optical isolation. For the first chamber a thin aluminium plate was used as the first electrode. The other surface of the BaF_2 is coated with about 15 Å of NiCr to provide a conductive, UV transparent surface. Between the crystal surfaces and the anode are two orthogonal, cathode planes to give the x-y event location. The anode is made of 15 μm wires with a 1 mm pitch, while the cathodes are made of 100 μm wires with the same 1 mm pitch. The cathode wires are connected in groups of various widths (see Table 1) and operated at ground potential. The spacing between each electrode plane is 3 mm. See Ref. 4 for more details on the operation principles of an SSPC.

Before filling, the aluminium chamber was first evacuated for several days and checked for leaks. It was then exposed to liquid TMAE and allowed to come to equilibrium. The chamber was filled to 3 Torr of isobutane and the valve closed. No degradation in performance was seen during the two weeks of tests.

Because of the cool environment of the test area, the TMAE temperature was only 17 °C. This corresponds to a TMAE partial pressure of 0.28 Torr. An increase in TMAE pressure results in an increase of photon efficiency.

Thus it would have been desirable to have been able to heat the chamber and TMAE. This will be done in future work.

3. TEST RESULTS - SHOWER DEVELOPMENT

Before putting the tower in the test beam, it was first calibrated with cosmic rays. The gains were adjusted so that the average dE/dx in each crystal was the same. The tower was put in a test beam at the CERN Synchro-cyclotron, where π^- , μ^- , and electrons were available with momenta of 108 MeV/c and 200 MeV/c.

Figures 3a and 3b show the energy deposit per module for 108 MeV and 200 MeV electrons. There are 2000 events in each sample. The energy deposit in module 6 seems low because it is only 1 cm thick. The longitudinal shower development can be easily seen, with the shower maximum moving deeper for increased energy. Figure 3c shows the energy deposit per module for 108 MeV/c π^- and μ^- . The ratio of π^-/μ^- is about 2:1. Here the short range of these particles is obvious.

To see the lateral shower development, we used the induced pulses on the cathodes. Figure 4 shows the x and y pulse-height distribution in the first 5 modules for 108 MeV electrons. Unfortunately, owing to electronics problems during the test, we were unable to calibrate the gain of the cathode amplifiers, but the lateral development of this shower is clearly visible.

4. TEST RESULTS - ENERGY RESOLUTION

The pulse-height spectra for 108 MeV and 200 MeV electrons are shown in Fig. 5. By simply dividing the widths at half maximum by the peak values, the resolutions are 30% and 20%, respectively. But this is not the

true energy resolution. Because of leakage from the sides of the tower, the peak channel is not at the full energy.

In order to estimate the energy resolution of an SSPC that is large enough to totally confine the particle energy, we used the Monte Carlo simulation, EGS [7]. Table 2 gives the experimental results and the simulation results. The simulation EGS(A) is for a tower with perfect resolution. Thus the spread is due only to energy leakage. EGS(B) is the same simulation but for an inherent detector resolution of $\sigma/E = 2\% E^{-1/2}$ (GeV). Channel resolution is as defined above. Energy resolution is the energy width at half maximum divided by the full particle energy.

The simulation EGS(B) is in good agreement with the experimental results if the resolution is degraded by about 25%. A substantial fraction of the line broadening is due to lateral energy leakage. From these results it seems a resolution of $\sigma/E = 2.5\% E^{-1/2}$ (GeV) is a good estimate of the performance of an SSPC calorimeter.

5. CONCLUSION

It has been shown that a BaF_2 SSPC has good energy resolution for an electromagnetic calorimeter. A resolution of $\sigma/E = 2.5\% E^{-1/2}$ (GeV) has been determined with a TMAE pressure of only 0.28 Torr. If the entire chamber was heated to 40 °C, the TMAE pressure would be increased by a factor of 5. This would increase the UV photon detection efficiency and improve the energy resolution.

An SSPC calorimeter also allows the longitudinal and lateral shower development to be monitored. This, combined with its good position resolution [4] and timing resolution [3], should make the SSPC a very powerful instrument for medium- and high-energy physics.

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Table 1BaF₂ crystal thickness and cathode group width

Crystal No.	Crystal thickness (cm)	Cathode grouping (cm)
1-2	1.0	0.5
3-4	2.5	1.0
5	2.5	1.5
6	1.0	1.5
7	2.5	1.5
8-10	2.5	2.0
11-12	5.0	2.0
13-14	5.0	10.0

Table 2

Tabulated resolution of the experiment; and that for the EGS simulations with energy leakage, but with perfect detector resolution, (A); and a detector resolution of $\sigma/E = 2\% E^{-1/2}$ (GeV), (B). See text.

	180 MeV		200 MeV	
	Channel (% FWHM)	Energy (% FWHM)	Channel (% FWHM)	Energy (% FWHM)
Experiment	30	--	20	--
EGS(A)	14	13	11	10
EGS(B)	24.5	22	16	15

Figure captions:

Fig. 1 : Schematic diagram of the SSPC tower design.

Fig. 2 : Schematic diagram of the SSPC module design.

Fig. 3 : Energy deposit per module for a) 108 MeV e^- , b) 200 MeV e^- ,
and c) 108 MeV/c π^-/μ^- .

The energy deposit in module 6 seems low because it is 1 cm thick.

Fig. 4 : x and y cathode signals for modules 1-5.

Fig. 5 : Pulse-height distribution for 108 MeV e^- and 200 MeV e^- .

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5