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**STUDY OF A PLANAR VERSION OF THE BAYAN
EM-CALORIMETER AT HIGH ENERGIES**

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Abstract

Dolgoplov A.V. et al. Study of a planar version of the BAYAN EM-calorimeter at high energies: ПИЕР Preprint 94.67. Protvino, 1994. — p. 6, figs. 6, refs.: 6.

A planar version of the BAYAN electromagnetic calorimeter has been tested with 10, 25, 50 and 100 GeV electrons. The BAYAN energy resolution shows a very low constant term: $\sigma_E/E = 7.7\%/\sqrt{E} \oplus 0.2\%$. In the range $E \geq 100$ GeV it drops well below 1%.

Аннотация

Долгоплов А.В. и др. Исследование характеристик планарного варианта электромагнитного калориметра БАЯН при высоких энергиях: Препринт ИФВЭ 94.67. — Протвино, 1994. — 6 с., 6 рис., библиогр.: 6.

Прототип планарного электромагнитного калориметра БАЯН изучен на пучке электронов с энергией 10, 25, 50 и 100 ГэВ. Энергетическое разрешение калориметра БАЯН характеризуется очень маленьким постоянным членом: $\sigma_E/E = 7.7\%/\sqrt{E} \oplus 0.2\%$. При энергиях $E \geq 100$ ГэВ оно значительно лучше 1%.

Introduction

The results of beam studies of a novel sandwich-type electromagnetic calorimeter BAYAN have been already described [1,2]. In this calorimeter thin converter and scintillator layers are placed along the beam direction and have a wave-like shape. Such a photon (electron) detector has a number of advantages as compared to other sandwich-type calorimeters existing so far:

- good energy resolution,
- high uniformity in depth,
- good lateral uniformity of detector response,
- the lack of any dead zone and bordering effects,
- simplicity in manufacturing and assembling as well as of the projective geometry design (essential for large scale collider experiments).

The design and manufacturing of the detector become much easier if a planar BAYAN version is used [3]. In this case alternative converter and scintillator layers are not bent to a wave-like shape but the whole detector is assembled using the planar scintillator and lead strips and is turned to a small angle towards the beam direction.

This paper describes the test results of the planar BAYAN calorimeter in electron beams with energies from 10 GeV to 100 GeV using the H8 beam of the SPS CERN accelerator. This study is a part of R&D project of the BARC EM-calorimeter (ALICE, LHC) [4]. Preliminary results have been reported [5].

1. Prototype design

The studied BAYAN calorimeter prototype consists of 9 towers assembled in a 3×3 matrix. The lateral tower dimensions are $70 \times 70 \text{ mm}^2$, the length is 600 mm ($23X_0$). The tilt angle of the tower axis towards the beam direction is $\theta = 120 \text{ mrad}$. Each tower consists of 37 lead layers and 37 scintillating elements (fig. 1). Prototype is assembled of $210 \times 600 \text{ mm}^2$ lead plates $0.37 \pm 0.02 \text{ mm}$ thick and $70 \times 600 \text{ mm}^2$ scintillating elements. A scintillating element consists of $1.4 \pm 0.1 \text{ mm}$ thick scintillator strip and 1.1 mm diameter wavelength shifting (WLS) fiber placed along the edge of a scintillator strip. The front end of a fiber is polished, thin aluminum layer is evaporated on it as a mirror providing 80% reflection. Each scintillating element has been wrapped into aluminized mylar. A polystyrene scintillator doped with 1.5% PTP (paraterphenil) + 0.001% POPOP (1,4-bis-[2-(5phenyloxazolyl)]-benzene), extruded according to the technology developed at IHEP [6], is used in the scintillating elements.

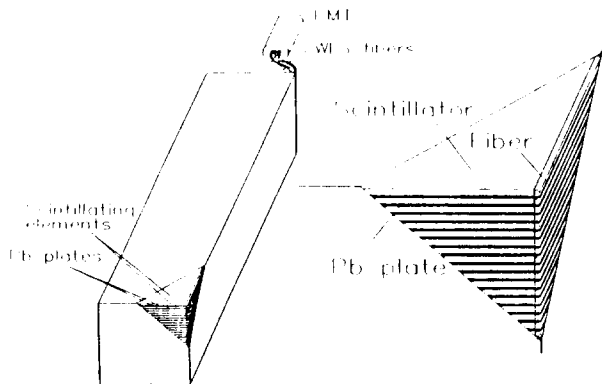


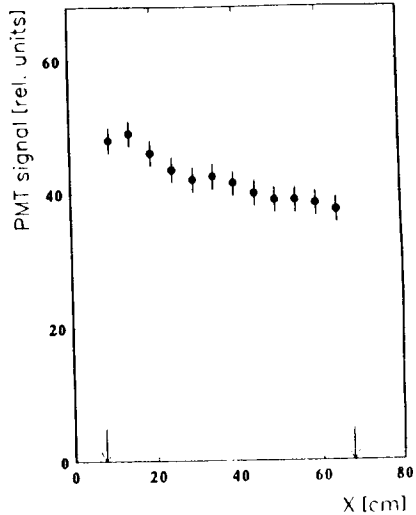
Fig.1.Schematic view of a planar BAYAN module.

The WLS fibers (the polystyrene core with K-27 dopant, cladding made which a fluorinated PMMA) were fabricated at INR (Moscow). The fibers are epoxy glued into bundles with $\pm 0.1 \text{ mm}$ position accuracy and coupled to a photomultiplier (PMT) by an air light guide. The fibers are read out with FEU-84 PMTs. Light-emitting diodes are used for monitoring. A typical light attenuation curve of the scintillating element is shown in fig. 2. The variation of response along the element is 25% (1.1% per radiation length). Hence, the

contribution of the longitudinal calorimeter nonuniformity to the constant term in the energy resolution should be smaller than 0.6%.

The light yield is measured according to the technique described in [2]. It is found to be 1.3 photoelectrons per 1 mm of m.i.p. track length in the scintillator. Though not very high, the light yield is enough for photoelectron fluctuations to contribute negligibly to the calorimeter energy resolution.

Fig.2.A typical light attenuation in the scintillating element. Arrows show the front and rear edges of the element.



2. Beam test results

The BAYAN prototype has been tested in the electron beams with energies 10, 25, 50 and 100 GeV using the NA12/2 GAMS setup. The electron coordinates are measured with the scintillator hodoscopes of 1 mm precision. The prototype calibration is performed in both electron and muon beams.

A mean electron-to-muon ratio of the detector response is about 120 at 50 GeV (fig. 3). So, the muon signal corresponds to 400 MeV of the electron energy deposited in the calorimeter. The number of photoelectrons corresponding to this energy deposit is determined with the monitoring light-emitting diode. It equals to 350. Hence the measured light yield is 0.9 ph.e./MeV.

The calorimeter spectrum measured at 100 GeV is shown on fig. 4. A tail to the left side of the distribution at 50 GeV and 100 GeV is due to the presence of

some passive material in the beam upstream our setup ($0.2 X_0$) and the leakage of EM-showers, especially at 100 GeV.

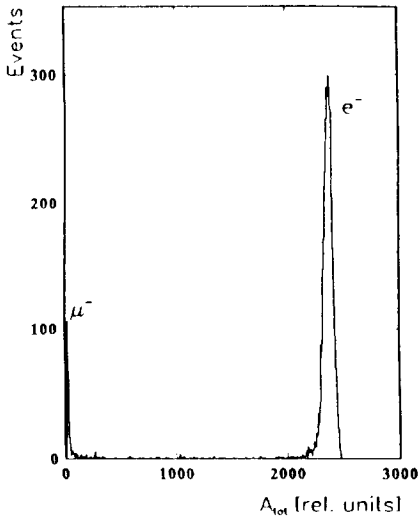


Fig.3. Amplitude spectrum of the summed signal of the planar BAYAN calorimeter measured in the 50 GeV electron beam.

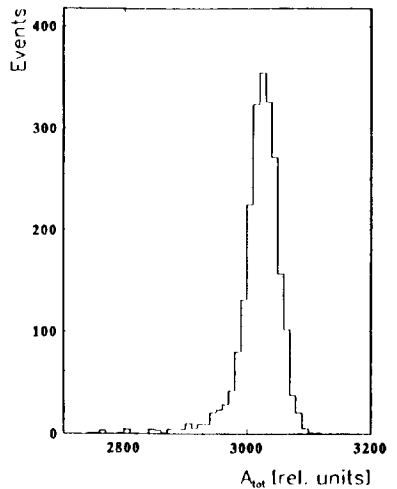


Fig.4. Same as in fig.3, but for the 100 GeV electron energy.

The measured BAYAN energy resolution is plotted in fig. 5. It is well described by

$$\sigma_E/E = 7.7\%/\sqrt{E} \oplus 0.2\%. \quad (1)$$

The stochastic term in formula (1), σ_{stoch}/\sqrt{E} , may be represented as $\sigma_{stoch} = \sigma_{samp} \oplus \sigma_{ph.e.}$. The contribution of the photoelectron statistics to the energy resolution is $\sigma_{ph.e.} = 3.4\%$, thus $\sigma_{samp} = 6.9\%$.

This experimental data is in a good agreement with the GEANT simulations, according to which $\sigma_{samp} = 6.7\%$, when $\theta = 120$ mrad (fig. 6). The θ -dependence of the energy resolution is well fitted by

$$\sigma_E/E = 0.055/(\sqrt{\sin\theta} + 0.55) + 0.006. \quad (2)$$

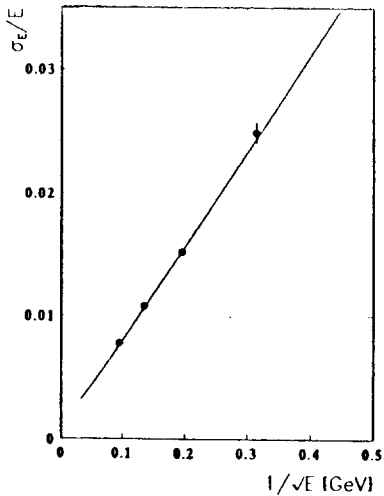


Fig.5. Planar BAYAN energy resolution vs the electron energy. Points are the measurement results, curve is formula (1).

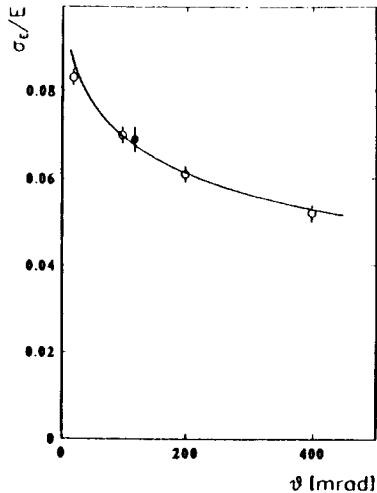


Fig.6. Monte Carlo simulation results for σ_{simpl} vs the inclination angle of scintillator and converter plates towards the beam direction. Black point shows the experimental data, open circles are the simulation results. Curve is dependence (2).

Conclusion

The planar version of the BAYAN calorimeter described in this paper satisfies the requirements for the BARC detector of the ALICE experiment [4]. It shows good energy resolution and large light yield. The design of the detector is simple, the detector is cheap in fabrication and assembling. High uniformity may be achieved in a large-volume calorimeter of this type.

We would like to thank all GAMS collaboration members for their help in the beam tests of the BAYAN prototype.

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