HERMES calorimeter cell equalization

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Abstract

We present the results of equalization measurements of the 840 F101 lead-glass blocks of the HERMES calorimeter. The counters were equalized at 3 GeV within $\pm$ 3%.

1 Introduction

HERMES is a new experiment [1, 2] designed to measure the spin structure of the nucleon by deep inelastic scattering from the proton and neutron using the longitudinally polarized electron beam [3] at HERA and internal polarized gas targets [4].

One of the components of the HERMES detector is a Pb-glass calorimeter, which consists of 840 radiation resistant F101 lead-glass blocks [5] made by Lytcarino factory [6] arranged in two large-area walls, placed 7.20 m downstream of the target above and below the beam axis. This calorimeter is designed to identify electrons, and determine their energy and coarse position. Then, in combination with a preshower wall and a hodoscope wall it allows for an efficient trigger of the data acquisition.

To fulfill this task it is important that all Pb-glass blocks have a good uniformity of the response relative to impact point and angle of incidence.

Here we report on the Pb-glass blocks equalization procedure and present the experimental results.

2 Description of the apparatus

All Hermes calorimeter blocks were equalized using 3 GeV electrons from Desy test beam 21. Experimental setup is shown in the fig. 1.

A tome of 42 calorimeter blocks at a time were placed side by side in a supporting table, which could be translated in horizontal and vertical directions, permitting to vary the impact point of the beam on the counters.

The equalization trigger was identified by a coincidence of two 10 mm thick cross scintillators F1, F2 and the anti-coincidence with the hole counter HC (with hole diameter of 4 mm). A 1.5 radiation length thick Pb plate was installed before the calorimeter blocks assembling, for providing experimental conditions close to real ones. Typical electron beam conditions were: trigger rate 170 s^{-1} and beam momentum spread $\sigma_p/p \approx 4\%$ at 3 GeV. The collimators on the beam line were used to keep pile-up effects at a negligible level.

In order to equalize the calorimeter blocks and adjust the PMT gains, each module was mounted on a motorized table (in 6x7 assembling), which could be moved by remote control so that the axis of each calorimeter cell could be aligned to the beam. A program based on RS232 master-slave protocol was developed to move the calorimeter cell assembling. The same electronics (ADC Lecroy 1881M, splitters, delay) was used as for the real experiment.

The equalization procedure for the electro-magnetic calorimeter cells consisted in varying the PMT high voltages by means of a computer controlled high voltage power supply, until the most probable charge measured by the ADC was

$$Q_0\ (\mathrm{pC}) = 22.22\ \mathrm{E}\ (\mathrm{GeV})$$

where E is the most probable energy deposition in the cell.

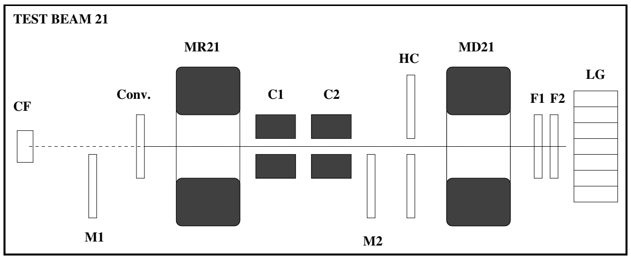

Figure 1: Experimental setup: CF is a Carbon Fiber, $Conv.$ is an Al converter, $MR21$ is a magnet that define the energy of the extracted beam, $MD21$ is a deflecting magnet, while $C1$ and $C2$ are two collimators; the other symbols are described in the text.

A binary search model was applied to choose the current HV value. In practice the voltage adjustment procedure was stopped when the most probable charge differed from Q_0 by $\approx 1\%$. At this point the information from a sample of 10000 flash triggers was recorded on magnetic tape for a further more refined off-line determination of the calorimeter cell equalization.

HV control and motorized table moving programs allowed a fully automatic equalization procedure.

3 Photo-multipliers

The photo-multipliers were chosen to provide high stability and linearity. The Philips XP3461 photo-multipliers (green extended) were selected having satisfactory performance at an acceptable cost. Their characteristics are listed in the Table 1.

Table 1. Characteristics of the Philips XP3461 photo-multipliers

Cathode diameter	70 mm
Cathode type	semi-transparent head on
Refraction index of PM glass	1.54
Multiplier	8 stage linear focusing
Maximum operating voltage	1800 V
Maximum average current	200 μA dc
Typical operating voltage	1200-1800 V for gain $\approx 10^6$
Dark current	< 50 nA
Linearity deviations	$< 2\%$
Stability (maximum variation of gain in 10 h)	1%
Rate stability (on variation of I)	1.0%
Anode pulse rise time	3 ns

The photocathode of Philips XP3461 is made of bialkali and the spectral response is given in fig.2. XP3461 has a linear focused dynode structure which provides a good linearity for a wide dynamic range without loss of energy resolution.

Phototubes were tested before being mounted on lead glass counters to measure their gain variation. The results of these tests for the 840 PMTs of the HERMES calorimeter are plotted in the fig.3 : as it is seen the distribution of the gain constants is well described by a Gaussian curve with $\sigma/\mathrm{mean} \approx 3\%$.

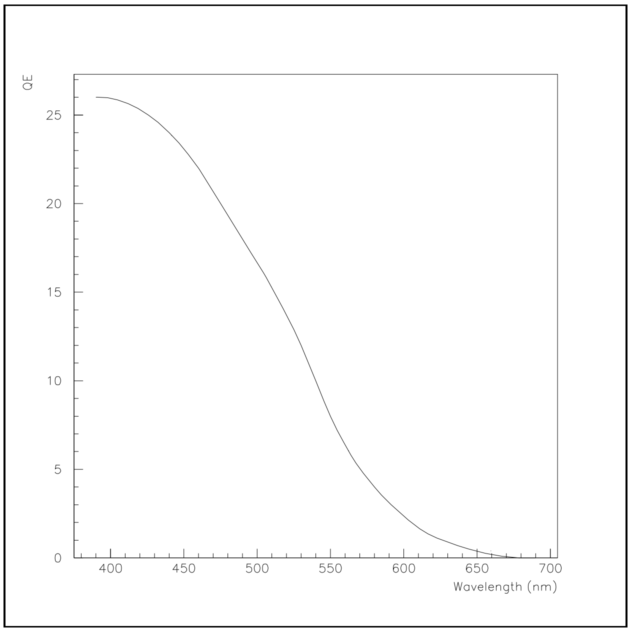

Figure 2: Quantum efficiency for the Philips XP3461 PMT

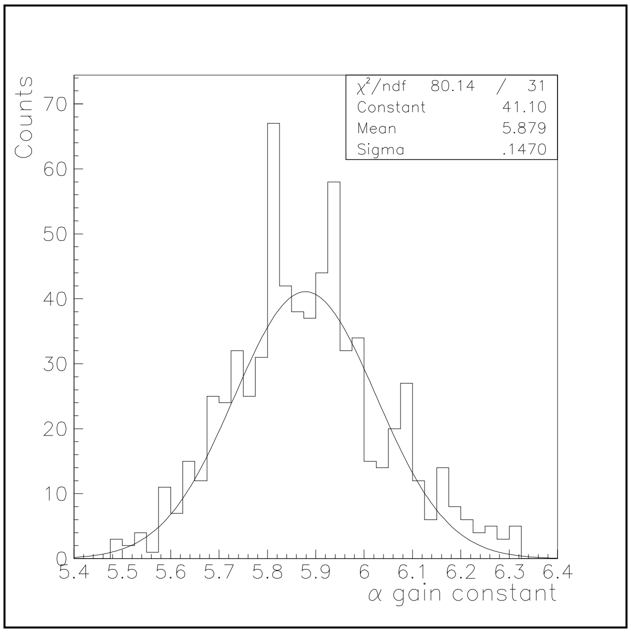

Figure 3: Distribution of the gain constant of the Philips XP3461 PMTs

4 Data analysis

The equalization data (about 120 tapes) were extracted into ADAMO GAF tables. This made it possible to apply different analysing models, without reading the tapes again and again. The HV equalization values from off-line analysis were compared with the values extracted on-line. The gain curves for all counters were extracted from ADAMO GAF tables and stored as a separate database. A typical gain curve is shown in fig. 4. As it is seen for a given counter the required value for the equalization HV was obtained by the binary search after 5 steps.

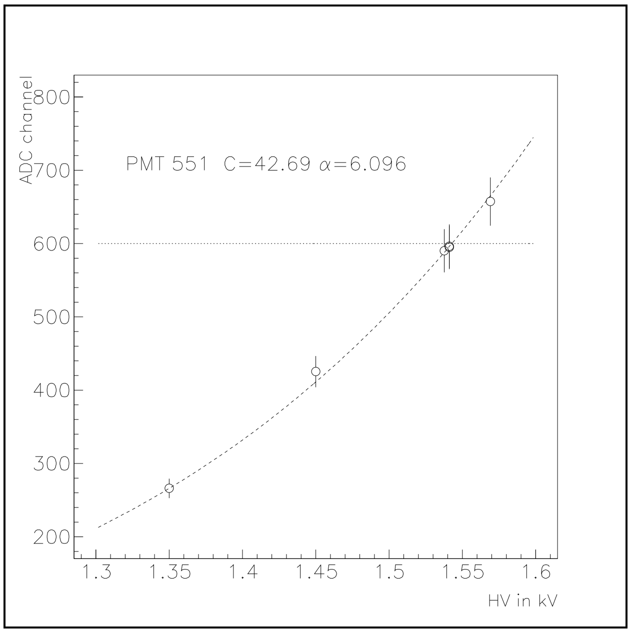

Figure 4: Gain curve for one Philips XP3461 PMT

The information accumulated in the ADAMO databases for equalization is the following:

- ADC response for a set of different HV values which were sampled during the binary search;
- ADC pedestal value during the equalization;
- ADC responses in the adjacent blocks and corresponding pedestal values during the equalization of the central block;
- Monitoring signals from pulses of the gain monitoring system.

A detailed analysis of equalization data revealed a few cases of misdefined HV values, due to wrong initial pedestal values, uncontrolled shifts of beam from the center of the block exposed to beam and other reasons. The obtained gain curves were used for off-line correction of the high voltage values.

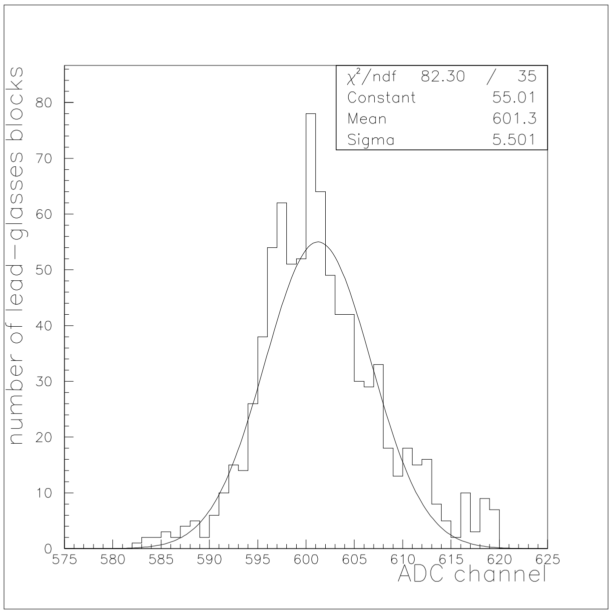

Figure 5: Distribution of the mean ADC values of the Pb-glass response to 3 GeV electrons

In figs. 5 and 6 are shown the distribution of the mean ADC value and of the relevant σ in the responses of the 840 blocks to a 3 GeV electron beam hitting the center of the block. As it is seen the main ADC channels for all F101 counters are spread between 580 and 620, that is within $\pm 3\%$, with a distribution well described by a Gaussian curve centered at the value 601.3 with σ=5.5. The standard deviations, σ, of the responses of the 840 lead-glass blocks are also distributed according to a Gaussian curve with a central value 61.7 $\pm$ 3.1%.

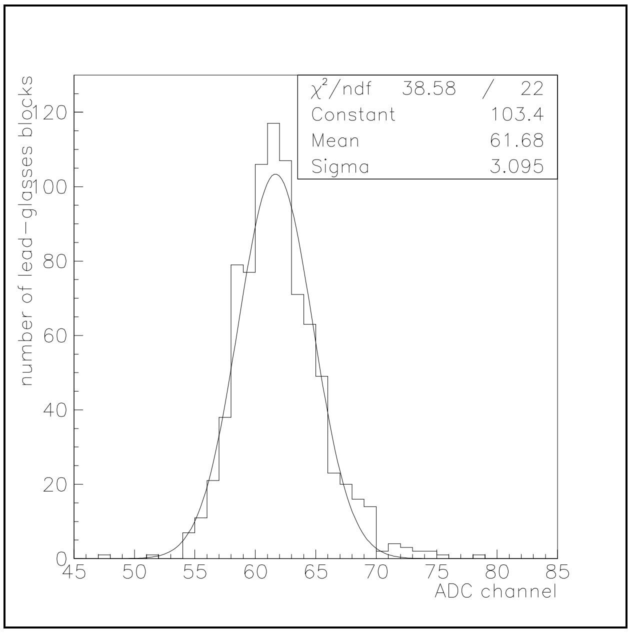

Figure 6: Distribution of the σ of the pulse height spectra of the 840 Pb-glass to 3 GeV electrons

5 Summary

The results of the over two month experimental runs for the equalization of the HERMES calorimeter cells was reported. The responses of F101 counters to 3 GeV electrons were equalized within $\pm 3\%$.

Acnowledgments

We thank the NMSU-HERMES group for providing the splitters and delay modules of the electronics, W. Brueckner for providing the data acquisition system and the Frascati (M. Albicocco, A. Orlandi, W. Pesci, A. Viticchié) and NIKHEF HERMES technical staff for the continual and effective assistance during the work.

This work was supported in part by "Stichtting voor Fundamenteel Onderzoek de Materie" (FOM), which is financially supported by the "Nederlandse Organisatie voor Wetenschappelijk Onderzoek" (NMO).

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