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L. Demortier, N.D. Giokaris, K. Goulianos, D.M. Khazins
The Rockefeller University

D.F. Anderson, S. Cihangir, A. Para, J. Zimmerman
Fermi National Accelerator Laboratory

J. Budagov, G.A. Ivanov, A.I. Kalinin, N.O. Poroshin, S. Tokar, A.D. Volkov
Joint Institute for Nuclear Research (Dubna)

G. Fanourakis
University of Rochester

D. Carlsmith
University of Wisconsin

H.R. Gustafson
University of Michigan

M. Morgan
Ability Engineering Technology, Inc.

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L. Demortier, N.D. Giokaris, K. Goulianos, D. M. Khazins**
Experimental Physics Department
The Rockefeller University
New York, NY 10021

D. F. Anderson, S. Cihangir, A. Para, J. Zimmerman
Fermi National Accelerator Laboratory
Batavia, IL 60510

J. Budagov***, G. A. Ivanov, A. I. Kalinin, N. O. Poroshin, S. Tokar, A.D. Volkov
Joint Institute for Nuclear Research (Dubna)
P.O. Box 79, 101 000 Moscow

G. Fanourakis
Department of Physics and Astronomy
University of Rochester
Rochester, NY 14627

D. Carlsmith
Physics Department
University of Wisconsin
Madison, WI 53706

H. R. Gustafson
University of Michigan
Ann Arbor, MI 48109-1120

M. Morgan
Ability Engineering Technology, Inc.
South Holland, IL 6047

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**Also JINR, Dubna

*** Also INFN, Pisa, I-56010 Pisa

Abstract

A prototype parallel plate electromagnetic (EM) calorimeter, filled with several gas mixtures, has been tested in a test beam at Fermilab. Data were taken in the pressure range 20 to 100 atm and in the energy range 20 to 125 GeV. Results on the calorimeter response as a function of electric field, gas pressure and energy are presented for a gas mixture of 95% Ar + 5% CH_4. The measured energy resolution of the calorimeter is compared with that predicted by the EGS4 Monte Carlo.

1. Introduction

The motivation for considering high pressure gas calorimetry arises after one reviews other types of unity gain calorimetry (i.e. liquid argon and warm liquids such as TMS and TMP), as well as calorimetry with gas at one atmosphere. Liquid argon requires cryogenics, which cause well known safety, access and dead space problems. On the other hand, the electron drift velocity in liquid argon (~ 250 ns/mm [1]) is rather slow in terms of the number of SSC bunch crossings. As for warm liquids, TMS is no longer seriously considered for any large experiment because of safety problems. TMP is still receiving consideration. Its main disadvantage (as well as that of other warm liquids) is that it is very sensitive to impurities at the ppb level. This requires that the detector be made of many sealed boxes, which makes it very expensive and produces a substantial fraction of dead area. It also requires very high operating voltages. For an electric field of 2 kV/mm, the electron drift velocity is about the same in TMP as in liquid argon [1]. Furthermore, under intense irradiation, (i.e. ~10^7 rads, which corresponds to about one year of SSC running at a luminosity of 10^{33} $cm^{-2}sec^{-1}$, at a polar angle of 1.5 degrees and at a distance of about 12 meters from the interaction point [2]), radiolysis of part of TMS or TMP releases gaseous hydrocarbons that can build up to a moderate pressure (~ 6 Atm) and may eventually reduce the size of the collected signals [3].

Calorimeters using gas at 1 atm as sampling medium have their own problems. They have an extremely low energy sampling fraction (about 0.01%), so that if hydrogen is present in the gas or in the chamber walls, protons scattered by slow moving neutrons in the hadronic showers or in the beam halo cause significant fluctuations in energy measurement. This phenomenon, known as "Texas Towers", has been observed in the CDF as well as other gas calorimeters [4]. In addition, their gain is very sensitive to many factors, among which we can mention the barometric pressure (1% change in barometric pressure results in a 7% change in gain for the CDF gas calorimeters). Therefore it is very difficult to control or even just correct for such

changes. Because the gain is so high (10^4 to 10^5 for the CDF gas calorimeters), wires in regions with high particle flux start drawing high current (this problem is frequently referred to as "glow mode"), which requires the chamber's voltage to be turned off for several minutes if not hours. For the same reason, measures have to be taken to prevent the wires from being corroded.

However, there is one possibility that could avoid all of the above problems, while maintaining the main advantages of calorimeters with liquid argon, TMS, TMP or 1 atm gas as sampling medium. This possibility is to use a gas such as argon or xenon, but at high pressure, as sampling medium. The pressure should be high enough that the density of the gas is only a few times less than the density of its liquid phase (for example 100 atm argon gas has a density of ~1/8 of liquid argon). Measurements done on the physics of argon gas and argon + CH_4 gas mixture at high pressures [5] and the building and testing of actual prototype calorimeters at 20 atm [6,7] have proven the feasibility of this calorimetric technique.

The calorimeter described in the following section was designed to operate at up to 100 atm pressure. The reasons for going to a higher pressure are to improve the signal to noise ratio and to suppress further the rate of "Texas" towers. The main objects of our test were to prove that a calorimeter can be built and safely operated at 100 atm, to measure the effect of CH_4 on signal size and speed, to compare the response of the calorimeter for different gas mixtures and to select the best mixture and, finally, to measure the energy resolution and compare it with expectations. In section 2 we describe the experimental setup. In section 4 the data analysis is described and results are presented. In section 5 the conclusions are listed and future plans are described.

2. Experimental setup

A schematic diagram of the prototype EM calorimeter is shown in Fig. 1. It consists of ten high pressure vessels. Each vessel consists of two steel plates bolted together. The thickness of each plate is 1.25 inches and its diameter is 12 inches. A 10 inch diameter, 5mm deep groove is milled in one of the two plates. A 1mm thick copper clad G-10 readout board is placed in the groove and supported with ceramic spacers. A 7 inch diameter electron pad and a 1.25 inch diameter muon pad are etched on each side of the board and are electrically connected via small holes drilled through the board. The gas is supplied through a valve mounted in an especially drilled port on the side of one plate. Each vessel is equipped with a 101 atm safety relief valve.

High pressure gas occupies a 2mm gap on both sides of the G-10 board. The signal produced by ionization in the gas is transported from the collection pads to the preamplifiers through high voltage, high pressure feedthroughs. To minimize the source capacitance and therefore the noise, the boxes with the preamplifiers are mounted as close to the feedthroughs as possible. Three of the ten vessels have an ^{241}Am alpha source mounted in front of the muon pad. The signals from the alpha sources allow continuous monitoring of the gas. The outputs of the preamplifiers go to a LeCroy 2280 CAMAC ADC system. The ADC is read out by a MAC II computer with the LABVIEW2 software system. The calorimeter is 30 radiation lengths long and its energy sampling fraction, for a 100 atm argon fill, is 0.185%.

The calorimeter was tested at the NT electron test beam at Fermilab towards the end of the 1991 fixed target run.

3. Data aquisition - Data Analysis- Results

The bulk of our data was taken with a gas mixture of 95% Ar + 5% CH_4 in the pressure range 20 to 100 atm and in the energy range 20 to 125 GeV. Two fast and low noise types of preamplifiers were used: the preamplifier developed by the Shuvalov group [8] (output signal rise time ~5 nsec, effective noise charge ~3000 e's for a source capacitance equal to zero, input impedance ~125 Ohm) and the Volkov preamplifier with approximately the same time and noise characteristics but with the considerably lower input resistance of 50 Ohm. Data were also taken with 2% and 10% CH_4 to study the effect of methane concentration on signal size and energy resolution. We also took data with 95% Ar + 5% CF_4, 95% Ar + 5% C_2H_6 and 95% Xe + 5% CH_4 to study the dependence of signal size and energy resolution on the gas composition. In this note we report preliminary results from the data taken with the 95% Ar + 5% CH_4 gas mixture. Results from the rest of the data will be reported in a forthcoming SDC note.

Our trigger was BEAM*T1*TRD*T2, where BEAM is a beam defining, upstream set of counters, T1 is a 1 inch x 1 inch scintillation counter right in front of the calorimeter, TRD is an upstream transition radiation detector used to identify electrons, and T2 is a 4 inch x 4 inch scintillation counter behind the calorimeter and used to reject hadrons that triggered the TRD. This trigger resulted in very clean electron samples at 20 and 50 GeV. A small fraction of pions however, contaminated our samples at the two highest energies (see Fig. 2).

Pedestal events were collected during data taking between successive beam spills. The trigger was provided by a pulser.

A calibration run was taken at the end of each set of runs done under the same conditions. A pulse of known charge, and with a width similar to that produced by beam particles, was injected at the input of each preamplifier. These data provide the absolute charge calibration and the relative channel to channel calibration.

The data analysis is very simple. The average pedestal for each channel is calculated and subtracted from the pulseheight of that channel for each event. The relative gain correction is then applied on each channel using the calibration run. The sum of the ten electron channels is formed and the mean and width of the corresponding distribution are extracted by fitting the data as shown in Fig. 2. The signal vs. high voltage across the two mm gas gap, for 100 atm and 50 GeV is shown in Fig. 3. We notice that the signal saturates at the comfortable electric field of about 700 V/mm. We therefore set the high voltage at 1.5 kV during normal data taking. The calorimeter response vs. pressure, at 50 GeV, is shown in Fig. 4. The signal is linear with pressure up to the highest point of 100 atm. The signal vs. energy, at 100 atm, is shown in Fig. 5 and it is again very linear.The energy resolution vs. energy is shown in Fig. 6 and compared with the EGS4 Monte Carlo prediction for the energy resolution which is (46+-1)%/sqrtE. The beam momentum bite (our best present estimate [9] is: (2.5+-0.5)%) and the electronic noise term have not been subtracted. Finally, the dependence of the resolution on the pressure is shown in Fig. 7 for 50 GeV electrons. We see that the resolution of our calorimeter "saturates" at about 80 atm even before the electronic noise contribution to the energy resolution is subtracted out.

Pictures of the signal from an alpha source with the Shuvalov preamplifier and from electrons with the Volkov preamplifier are shown in Figs. 8a and 8b respectively. The rise time of these signals is less than 15 nsec and their base widths, 50 and 60 nsec respectively, are close to the 40 nsec expected just from the electron drift velocity in 95% Ar + 5% CH_4 gas mixture. The charge measured was 3.9+-0.4 fC/GeV which is in good agreement with the calculated value of 4.5 fC/GeV (the calculation assumed an e/μ ratio of 0.92 [10]).

4. Conclusions

We have successfully constructed and tested, without any problems, a prototype EM calorimeter with 95% Ar + 5% CH_4 at 100 atm. This is a new record for high pressure calorimetry. Our preliminary results show that: a) the signal saturates at the comfortable electric

field of about 700 V/mm, b) the calorimeter response is very linear in the pressure range 20 to 100 atm and in the energy range 20 to 125 GeV, c) the energy resolution agrees well with the EGS4 Monte Carlo prediction and d) signals with rise time less than 15 nsec and base width of about 60 nsec were achieved.

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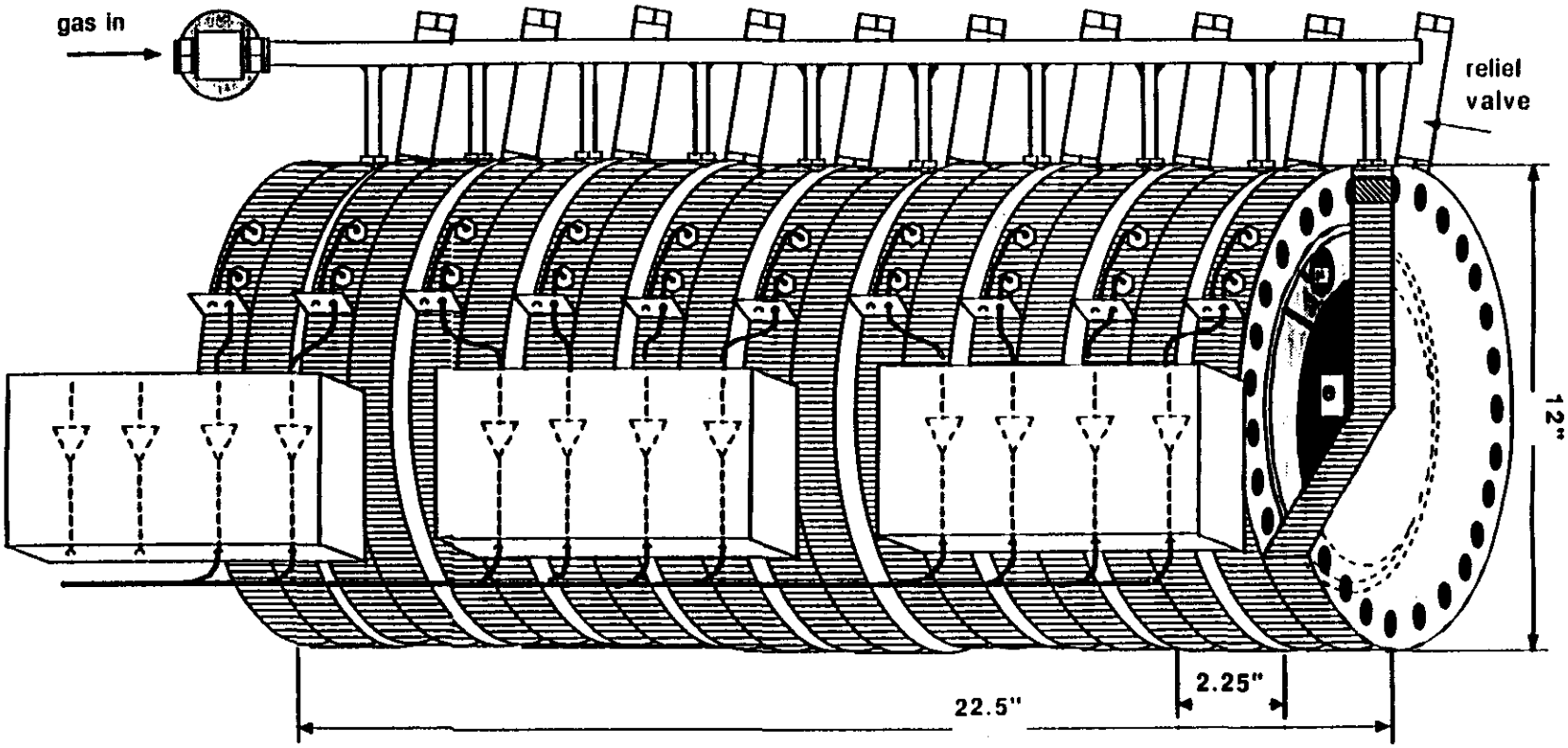


Fig. 1. Schematic diagram of the prototype parallel plate electromagnetic calorimeter.

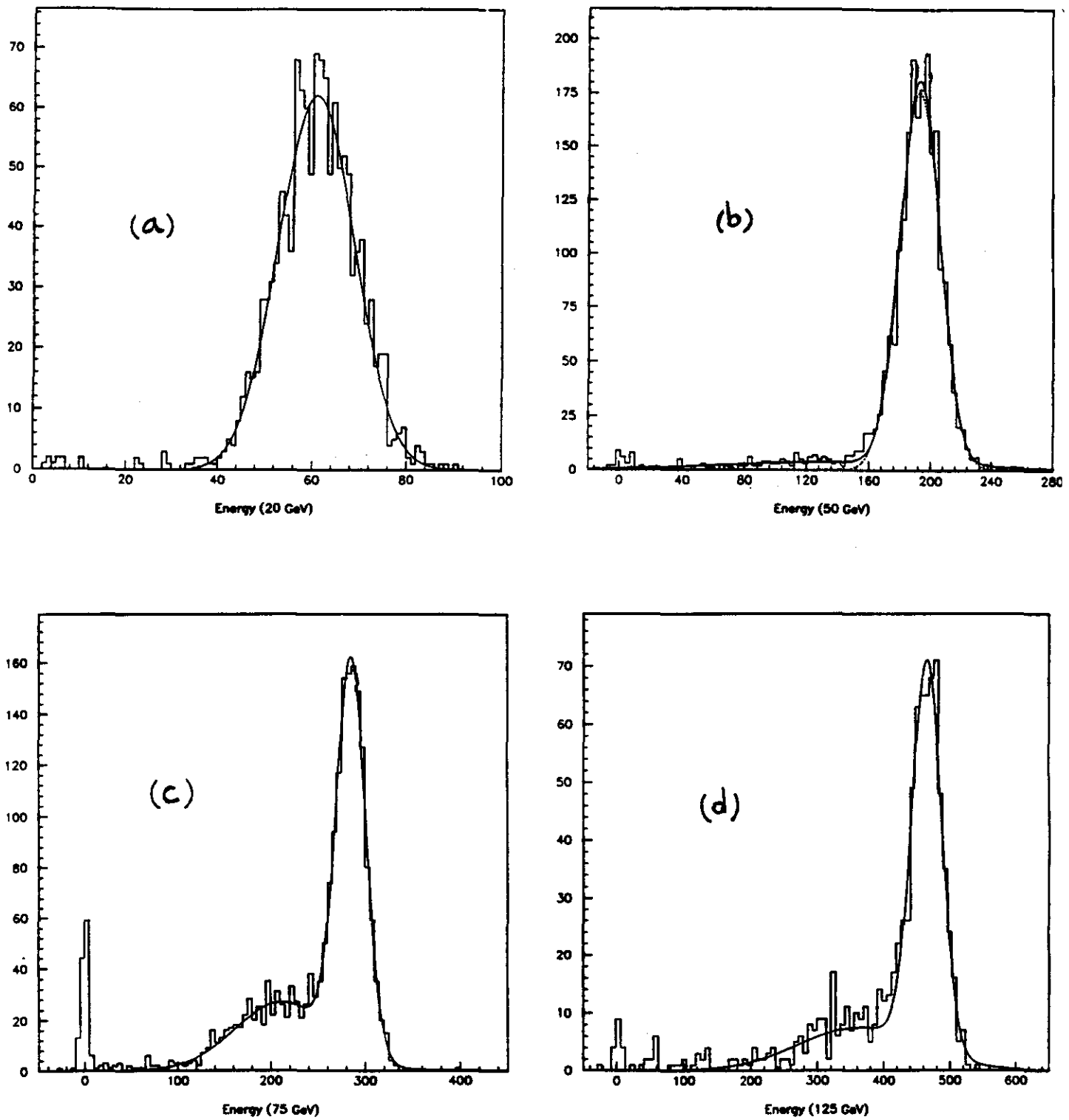


Fig. 2. Pulse height spectra for the four beam energies.

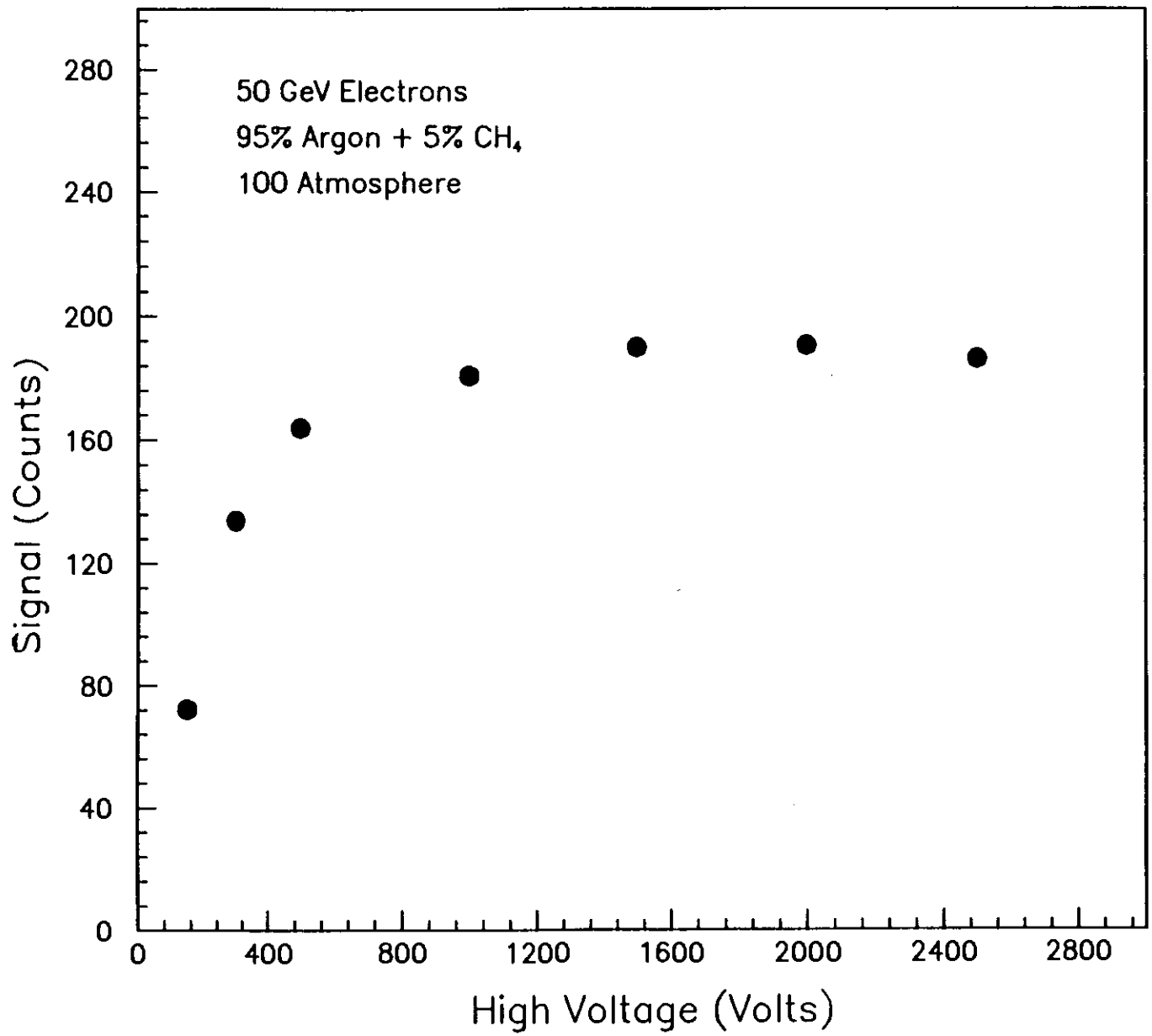


Fig.3. Signal vs. high voltage.

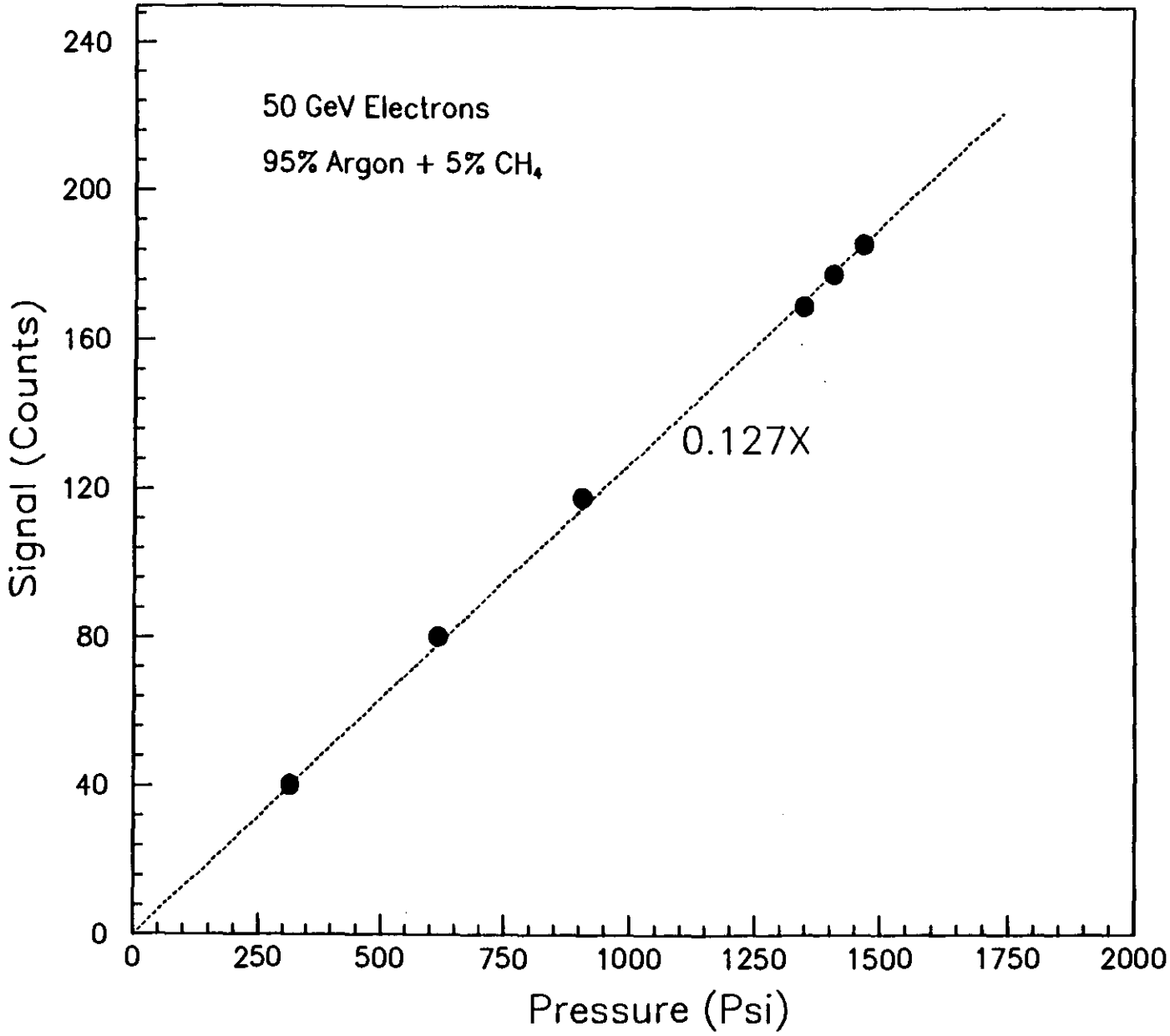


Fig. 4. Signal vs. pressure.

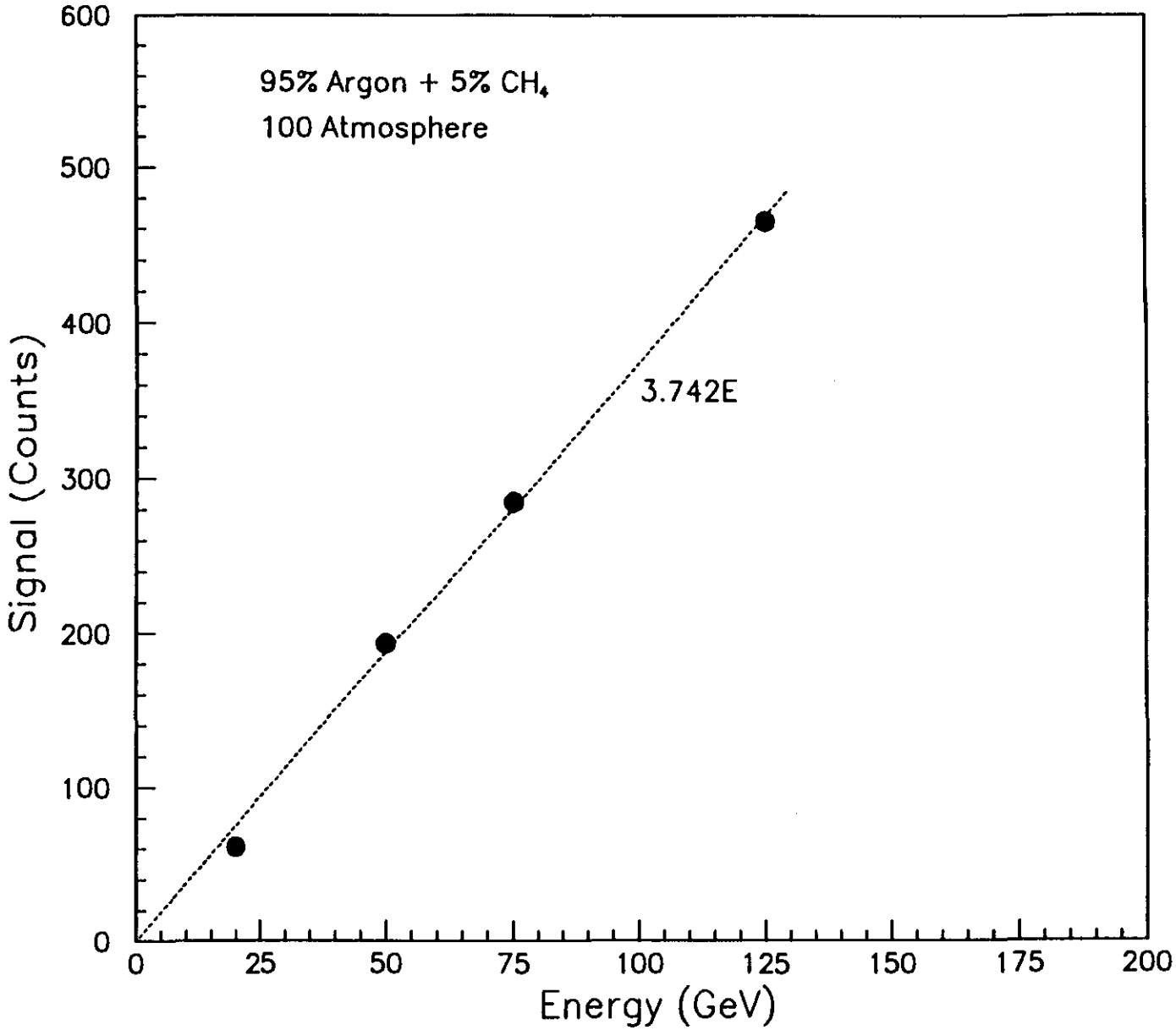


Fig. 5. Signal vs. beam energy.

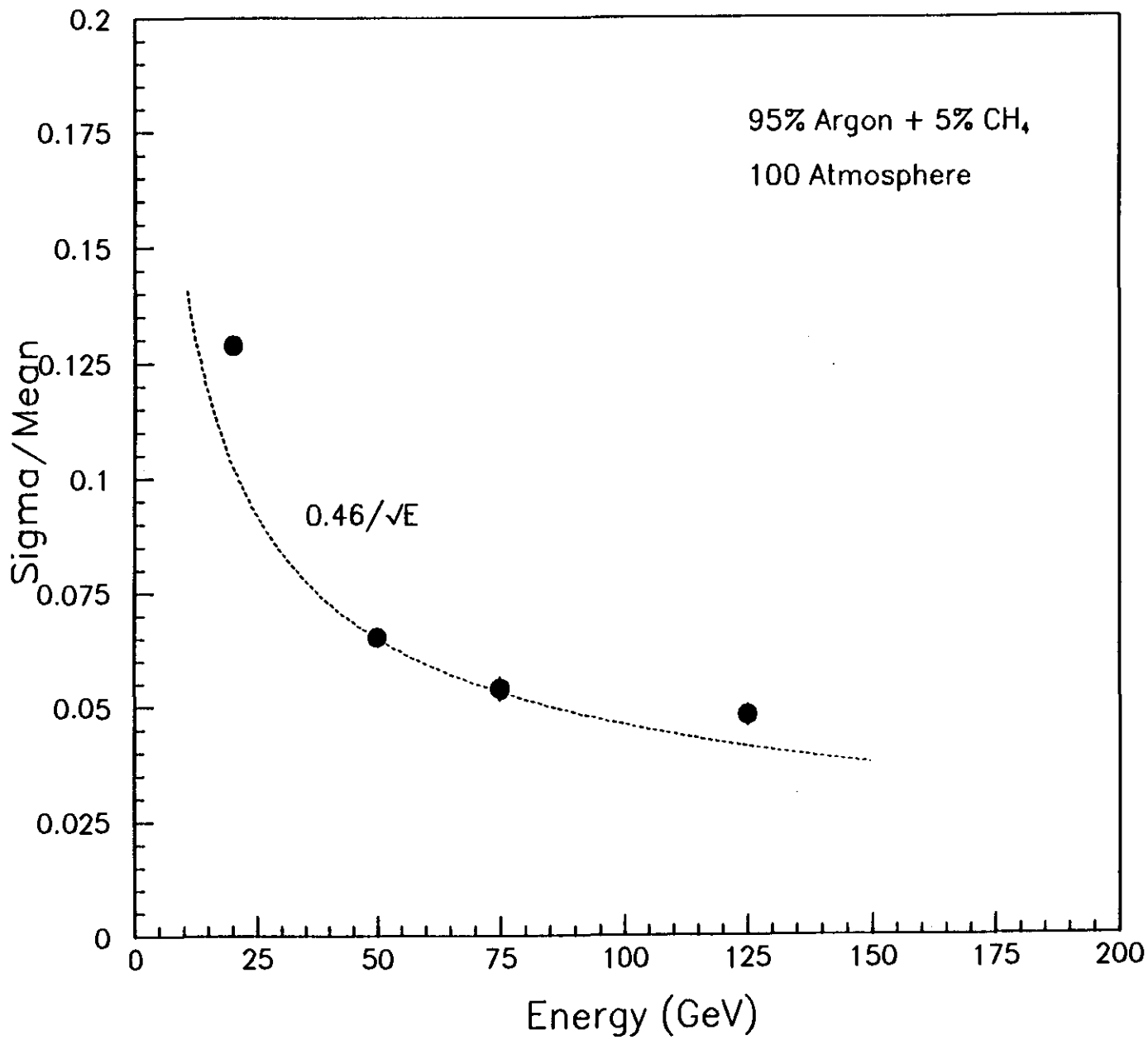


Fig. 6. Energy resolution vs. beam energy. The Monte Carlo prediction is also shown for comparison.

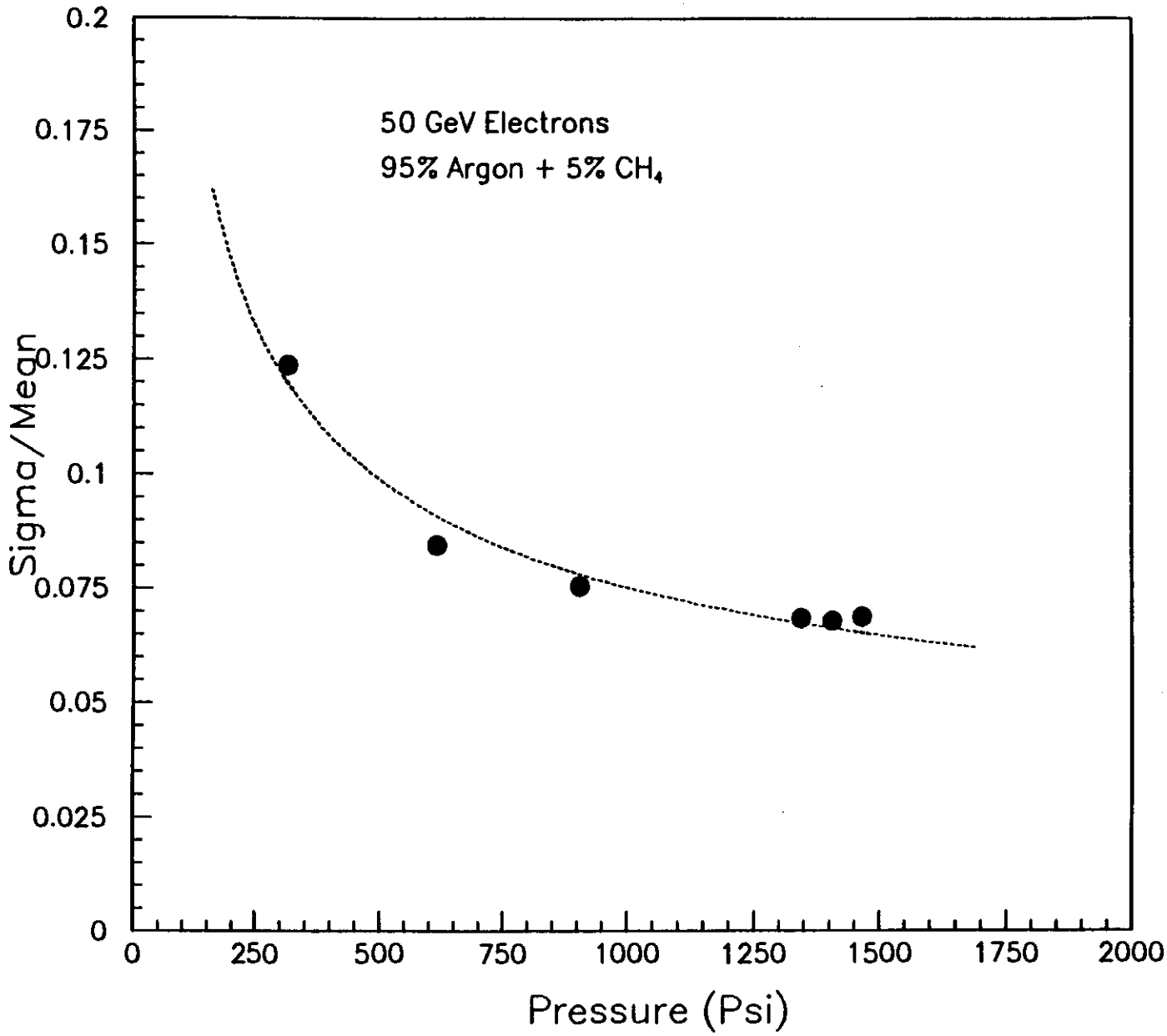
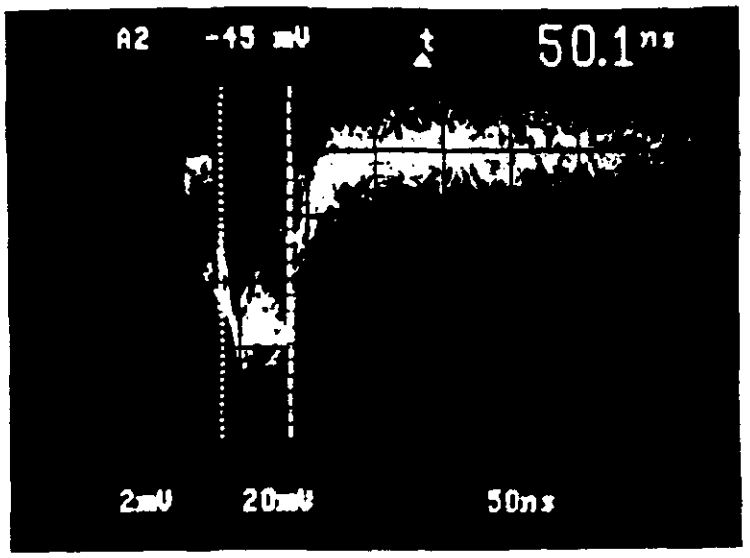


Fig. 7. Energy resolution vs. pressure.



95% Ar + 5% CH4 at 100 Atm

E = 1.25 kV/mm

Am241 alpha source

Shuvalov preamplifier

(a)

95% Ar + 5% CH4 at 100 Atm

E = 0.75 kV/mm

50 GeV electrons

Volkov preamplifier

(b)

Fig. 8. Pictures of the signals from the alpha source (8a) and from beam electrons (8b).