MEMORANDUM NFSt. Note 6

To: CPLEAR Collaboration February 7, 1994

From: Guido Polivka

Subject: **Energy Calibration of the Calorimeter**

Abstract

This note describes the energy calibration of the electromagnetic calorimeter of the CPLEAR detector for gamma rays. Its energies were identified from events $p\overline{p} \rightarrow K^+K^-\pi^0 \rightarrow K^+K^-\gamma\gamma$, using the kinematical information from the charged particles and the impact points of the γs. The data used came from the 1992 runs (P17-P22).

A good agreement was found between the selected and the prototype data. The energy resolution is in the expected range of $\sigma(E)/(E) \approx 15\%/\sqrt{E(GeV)}$.

1 Introduction

At the end of 1991 the CPLEAR calorimeter was fully equipped with the readout electronics. With the first data the alignment and some improvements in the decoding and the shower pattern recognition were done. In the second half of 1992 everything was ready for a final energy calibration. There are mainly two differences to the prototype, which made a special calibration necessary:

- The CPLEAR calorimeter has "holes" (dead tubes).
- In the prototype data the number of wire hits for a given shower was simply counted, whereas today the showers first have to be searched for, before counting their number of hits.

This leads to the tendency that the prototype and the CPLEAR calorimeter see a different mean number of hits for a photon of a given energy.

2 Data selection

The data used were taken during the run periods P17 - P22. Events with two primary tracks and two neutral showers were selected. The primary tracks were verified as kaons using the information from the PIDs. First a 1C fit, requiring a π^0 at the primary vertex, then a 3C fit, requiring energy and momentum conservation and a missing π^0 mass, were performed. The primary information about the γs used in the fit were only the impact points of the γs in the calorimeter. The γ energy was a result of the fit. The γ energy resolution of the fit was determined by comparing it with Monte Carlo data and was better than 4% (fig. 1).

3 Calibration

With this sample the response of the calorimeter to photons of a certain energy converted in a given layer was determined. These hit distributions are not symmetric and they have a bias, because the shower pattern recognition program accepts a cluster in the calorimeter only, when there are at least three hits (fig. 2). Neither a Gauss nor a Poisson function are suited to fit the observed distributions. We have found, that a good choice for a function to reproduce the distributions is [1]

$$\mathrm{H(w,E)} = \mathrm{N(E)e^{-(w-w_0(E))^2 a(w,E)}} \tag{1}$$

where at $\mathrm{w_0(E)}$ the maximum value of H(w,E) is reached for a given E. a(w,E) represents a kind of squared inverse width and N(E) is the normalization factor. A good parameterization for a(w,E) is

$$\frac{1}{\mathrm{a(w,E)}} = 2(\sigma_0^2(\mathrm{E}) + \frac{\Omega(\mathrm{E})((\mathrm{w}-\mathrm{w_0}) + \mid \mathrm{w}-\mathrm{w_0} \mid)}{4}), \tag{2}$$

which takes this asymmetry into account. Above a photon energy $\mathrm{E_0}$ of approximately 250 MeV the Ω is compatible with zero. The hit distributions are then gaussian and the Ω may therefore be set to zero. This is shown in figure 3.

The parameters $\mathrm{w_0}$, σ_0 and Ω of the hit distributions can again be parameterized as a function of the energy. In addition the mean value $< \mathrm{H(w,E)} >$ of the hit distributions is calculated (fig. 4). We use

$$\begin{aligned}
\mathrm{w_0(E)} &= \mathrm{a_w + b_w E + c_w E^2} && (3)\\
< \mathrm{H(w,E)} > &= \int \mathrm{wH(w,E)dw} &&\\
&= \mathrm{a + bE + cE^2} && (4)\\
\Omega(\mathrm{E}) &= \mathrm{p_\Omega(E - E_0)} \ \text{ for } \ 0 < \mathrm{E} < \mathrm{E_0} &&\\
&= 0 \ \text{ for } \ \mathrm{E} > \mathrm{E_0} && (5)\\
\sigma_0 &= \frac{\mathrm{p_{\sigma1}E}}{\mathrm{p_{\sigma2}E + p_{\sigma3}}} && (6)
\end{aligned}$$

As will be seen later, the parameters a, b and c are most suitable for further calculations. They represent a set of parameters which contains the whole information of the hit distributions for photons converted in a particular layer. These parameters for one layer can now be plotted as a function of the conversion layer. This is useful to get a reasonable calibration for the higher conversion layers, where the statistics is low. This is shown for the example of the maximum number of hits $\mathrm{w_0}$ in figure 5.

The shower may swap out of the calorimeter for higher energies and photons converting in higher layers. This effect is shown in figure 6. In addition there is a separate calibration for photons with a hit in S1, the Čerenkov or S2 (fig. 7).

4 Resolution and Comparison with Prototype Data

A good approximation for the r.m.s. width of the hit distributions of Eqs. 1 and 2 is [1]

$$\sigma_\mathrm{w}^2 = \sigma_0^2(\mathrm{E}) + 2\Omega^2(\mathrm{E}). \tag{7}$$

We define a reduced resolution as

$$\mathrm{R} = \frac{\sigma_{\mathrm{w}}\sqrt{\mathrm{E(GeV)}}}{< \mathrm{H(w,E)} >}. \tag{8}$$

In fig. 8 the reduced resolution for different conversion layers is shown. The reduced resolution in the prototype raised from 0.11 for a 50 MeV photon to 0.14 for a 350 MeV photon (converted in the first four layers) and to 0.2 using all photons. The figure 9 shows a comparison between CPLEAR and prototype data [2]. One can see that the CPLEAR data have somewhat less hits for higher energies.

5 Comparison with Monte Carlo Data

The present Monte Carlo simulation is not yet tuned to reproduce the correct number of hits for a given energy. A Monte Carlo shower contains about 11% less hits than a real shower. For the time being this is corrected in the calibration routine by multiplying the number of hits by a factor of 1.11 (fig. 10). The width σ_{w} of the hit distributions is in good agreement with the real data.

6 Software

There are two subroutines available:

'Cashenew' calculates for a given cluster a "mean energy" assuming the number of hits is the mean value of the hit distribution. In addition a "max energy" which is the energy corresponding to the maximum of the hit distribution is calculated. Further it returns the parameters of the hit distribution.

'Cashhi' returns for a given energy and conversion layer the parameters of the hit distribution and the effective width σ_{w}

A general description, the kernels of these subroutines and a table of the used parameters is given in appendix A.

7 π^0 Mass Calculation

The photons used for the calibration originated from a decaying π^0. Therefore it must be possible to obtain a correct value for the π^0 mass using these photons and the calibration. The usual way calculating this is

$$\mathrm{m}_{\pi^0} = \sqrt{2\mathrm{E}_{\gamma 1}\mathrm{E}_{\gamma 2}(1 - \cos\Theta)} \tag{9}$$

where Θ is the opening angle of the two photons. But we measure hits and not energies. We know very well the response of the calorimeter for a photon of a given energy. But there is no information about the energy distribution for a given number of hits. So we cannot expect that it is correct just to multiply the energies as given by the routine 'Cashenew'. The data show indeed that it is not (fig. 11)!

To solve this problem, we have to take a closer look at

$$\mathrm{p} = \mathrm{E}_{\gamma 1}\mathrm{E}_{\gamma 2}. \tag{10}$$

For a given Θ this product is a fixed, precise number. The aim of the following considerations is the experimental determination of p:

The mean value of the hit distribution was parametrized in the following way:

$$\begin{aligned}
<\mathrm{w}> &= \int \mathrm{F(E)dE} \int_0^{+\infty} \mathrm{wH(w,E)dw} \\
&= \int \mathrm{F(E)dE} < \mathrm{w,E} > \\
&= \int \mathrm{F(E)dE(a + bE + cE^2)} \\
&= \mathrm{a + b < E > + c < E^2 >} \qquad (11)
\end{aligned}$$

where F(E)dE is the energy spectrum. Now what is the mean value of the product of two hit distributions?

$$\begin{aligned}
<\mathrm{w_1 w_2}> &= \int \mathrm{F(E_1)dE_1} \int_0^{+\infty} \mathrm{w_1 H(w_1,E_1)dw_1} \int_0^{+\infty} \mathrm{w_2 H(w_2,E_2)dw_2} \\
&= \int \mathrm{F(E_1)dE_1} < \mathrm{w_1,E_1} >< \mathrm{w_2,E_2} > \\
&= \int \mathrm{F(E_1)dE_1(a + bE_1 + cE_1^2)(a + bE_2 + cE_2^2)} \qquad (12)
\end{aligned}$$

As mentioned above we assume $\mathrm{p=E_1E_2}$ is fixed. The integration leads to

$$<\mathrm{w_1 w_2}> = \mathrm{a}(<\mathrm{w_1}> + <\mathrm{w_2}>) - \mathrm{a}^2 + \mathrm{bcp}(<\mathrm{E_1}> + <\mathrm{E_2}>) + \mathrm{b^2p} + (\mathrm{cp})^2 \qquad (13)$$

So we have to measure the quantities $<\mathrm{w_1w_2}>$, $<\mathrm{w_1}>$ and $<\mathrm{w_2}>$ for a certain angle bin. The a,b and c are known from the calibration and the spectra of $\mathrm{E_1}$ and $\mathrm{E_2}$ have to be determined elsewhere. Then we can calculate p and, using the opening angle, we get the π^0 mass.

The above calculation assumes that both photons converted in the same layer. The generalization, that the photons may convert in different layers, is easy and leads to

$$\begin{aligned}
<\mathrm{w_1 w_2}> &= \mathrm{a_2} < \mathrm{w_1} > + \mathrm{a_1} < \mathrm{w_2} > - \mathrm{a_1 a_2} + \mathrm{b_2 c_1 p} < \mathrm{E_1} > + \\
&\quad \mathrm{b_1 c_2 p} < \mathrm{E_2} > + \mathrm{b_1 b_2 p} + \mathrm{c_1 c_2 p^2} \qquad (14)
\end{aligned}$$

The plot 1 in figure 13 shows the π^0 mass as a function of the opening angle for photons converted in layer 1 or 2. This yields to a mean value of (135.4 ± 2.124) MeV/c^2 for this specific layer configuration. In the next plots (fig. 13) one can see this mean value for various layer configurations.

It is possible to get the mean energy $<\mathrm{E_1}>$ and $<\mathrm{E_1}>$ of the photons in Eq.14 in a first approximation out of the data. To do this the spectrum is determined using Eq. 11 with c=0. The result is shown in figure 12.

8 Conclusion

The calorimeter has been calibrated using P17-P22 data. Included is a calibration for photons converting already in the PIDs. The resolution is $\sigma(\mathrm{E})/(\mathrm{E}) \approx 15\%/\sqrt{\mathrm{E(GeV)}}$ for the big bunch of our detected photons.

The Monte Carlo data cannot yet completely reproduce the real data. This leads to a correcting coefficient in the calibration routine.

Calculating the π^0 mass in a statistical way shows that the calibration is consistent.

References

[1] *Eichung des Kalorimeters*
H.-J. Gerber
Notiz, 12. Oct. 1992

[2] *Design and test of a prototype gas-sampling electromagnetic calorimeter of high granularity for the CPLEAR experiment*
R. Adler et al.
Nucl. Instr. and Meth. A321 (1992) 458

A Used Routines and Parameters

A.1 Calculations done in the routine CASHENEW

This routine calculates for a given shower number INUM the mean energy (ENER) and its error (DENE), the parameters of the hit distribution w_0 (maximum of distribution, RHIG), Ω and σ_0 (parameterization of the width OMEG and SI0G) (Eqs. 1, 2, 3, 4, 5 and 6) and the r.m.s. width σ_w (SIGM) (Eqs. 7 and 8).
Warning: All variables returned from the routine are of type real! All protections and debug statement in the following code have been removed.
The shower number INUM is according to the numbering in ANAPB. First it is checked, whether there is a a hit in the PIDs for this shower. If yes, the conversion layer IRL is set to 1 (S1), 2 (Če) or 3 (S2). Otherwise the conversion layer found by the calorimeter shower pattern recognition is used and raised by 3.
The number of hits of the shower is called MWI and taken from the ANAPB commons. If Monte Carlo data is used, the number of hits are multiplied by 1.11.
For the calculation of the shower energy, the first 3 fields of RERECAEN (see A.3) are used. The routine checks, whether RERECAEN(3,IRL) is set to zero. If yes, the energy ENER is obtained by (linear function):

```
      ENER=(REAL(MWI)-RERECAEN(1,IRL))/RERECAEN(2,IRL)
```

Otherwise the maximum of the quadratic function (see fig. 6) is calculated and dependant on this the shower energy ENER:

```
      RMAXENE=-RERECAEN(2,IRL)/(2.*RERECAEN(3,IRL))
      RMAXHIT=RERECAEN(1,IRL)+RERECAEN(2,IRL)*RMAXENE+
     >   RERECAEN(3,IRL)*RMAXENE**2
C
      IF(REAL(MWI).GT.RMAXHIT) THEN
         ENER=RMAXENE
      ELSE
         DISC=RERECAEN(2,IRL)*RERECAEN(2,IRL)-4
     >      *(RERECAEN(1,IRL)-REAL(MWI))*RERECAEN(3,IRL)
         DISC=SQRT(DISC)
         ENER=(DISC-RERECAEN(2,IRL))/(2.0*RERECAEN(3,IRL))
      ENDIF
```

The error on the energy DENE is calculated in the following way:

```
      DENE=RERECAEN(4,IRL)+ENER*RERECAEN(5,IRL)
      DENE=1000.*DENE*SQRT(ENER/1000.)
```

The parameters of the hit distribution are calculated dependant whether the distribution is gaussian (energy bigger than 250 MeV) or not. EMAG is the energy corresponding to maximum of the hit distribution, RHIG the maximum of the distribution, OMEG the deviation from a gaussian and SIG0 the width of the gaussian.

```
      IF (ENER.LT.250) THEN
         RFAC=RERECAEN(6,IRL)+ENER*RERECAEN(7,IRL)
```

```
            EMAG=ENER/RFAC
            RHIG=MWI/RFAC
            OMEG=RERECAEN(11,IRL)+ENER*RERECAEN(12,IRL)
         ELSE
            EMAG=ENER
            RHIG=MWI
            OMEG=0.
         ENDIF
C
         SIOG=(RERECAEN(8,IRL)*ENER)/
     >      (RERECAEN(9,IRL)*ENER+RERECAEN(10,IRL))
```

The last parameter is the effective width SIGM of the hit distribution, obtained by the reduced hit resolution R (Eq. 8).

```
         SIGM=RERECAEN(13,IRL)+ENER*RERECAEN(14,IRL)
         SIGM=SIGM*MWI/SQRT(ENER/1000.)
```

A.2 Calculations done in the routine CASHHI

This routine calculates the following parameters, assuming that the given energy (ENER) and conversion layer (ILAY) correspond to the mean number of hits of the particular distribution: w_0 (maximum of distribution RHIG), Ω and σ_0 (parameterization of the width (OMEG and SI0G), the mean number of hits $< H(w, E) >$ (RHIT) and the r.m.s. width σ_w (SIGM). (Eqs. 1, 2, 3, 4, 5, 6, 7 and 8).
If there is a hit in the PID in front of the shower, one has to set ILAY to to -2 (S1), -1 (Če) or 0 (S2).
Warning: All variables returned from the routine are of type real! All protections and debug statement in the following code have been removed.
First the given layer number is raised by 3 and called IRL. Then the maximal energy for this conversion layer is calculated. Depending on the comparison of the given energy and the calculated maximum energy, the mean value RHIT of the distribution is calculated.

```
      IF (RERECAEN(3,IRL).EQ.0.) THEN
         RMAXENE=-RERECAEN(2,IRL)/(2.*RERECAEN(3,IRL))
      ELSE
         RMAXENE=1000.
      ENDIF
C
      IF(ENER.GT.RMAXENE) THEN
         RHIT=RERECAEN(1,IRL)+RERECAEN(2,IRL)*RMAXENE+
     >          RERECAEN(3,IRL)*RMAXENE**2
         IFLA=1
      ELSE
         RHIT=RERECAEN(1,IRL)+RERECAEN(2,IRL)*ENER+
     >          RERECAEN(3,IRL)*ENER*ENER
      ENDIF
```

If Monte Carlo data is used, the obtained number is multiplied by 1.11.
In the next steps, all the parameters of the hit distribution are calculated. This happens in the same way as in the routine CASHENEW.

```
      IF (ENER.LT.250) THEN
         RFAC=RERECAEN(6,IRL)+ENER*RERECAEN(7,IRL)
         RHIG=RHIT/RFAC
         OMEG=RERECAEN(11,IRL)+ENER*RERECAEN(12,IRL)
      ELSE
         RHIG=RHIT
         OMEG=0.
      ENDIF
C
      SIOG=(RERECAEN(8,IRL)*ENER)/
     >       (RERECAEN(9,IRL)*ENER+RERECAEN(10,IRL))
C
      SIGM=RERECAEN(13,IRL)+ENER*RERECAEN(14,IRL)
      SIGM=SIGM*RHIT/SQRT(ENER/1000.)
```

A.3 Table of the Calibration Parameters

The array 'RERECAEN' contains 20 records with 14 fields. The first three records contain the constants for showers with a hit in S1, Če or S2, followed by 17 records for each conversion layer in the calorimeter. The fields have the following meaning:

Conversion layer	a	b	c	ΔE_1	ΔE_2
	R_1	R_1	σ_1	σ_2	σ_3
	Ω_1	Ω_2	rms_1	rms_2	

The parameters a,b and c are used in Eq. 4, σ_1, σ_2 and σ_3 in Eq. 6. If the energy is less than 250 MeV then Ω_1 and Ω_1 are used in Eq. 5. Otherwise Ω is set to zero. To calculate the rms-width of the distributions the plots in fig. 8 have been fitted with a straight line (offset rms_1 and slope rms_2). The same is done to calculate the error on the energy (using ΔE_1 and ΔE_2). Again for energies less than 250 MeV the variable w_0 is obtained by multiplying $< H(w, R) >$ and an energy dependant factor RFAC $= R_1 + < H(w, E) > *R_2$.

S1	1.0240000	0.5507900E-01	0.0000000E+00	0.1740732	0.6030157E-04
	1.501493	-.2122820E-02	0.1349100	0.1558000E-01	2.052700
	3.085578	-.1196727E-01	0.1834900	0.4924600E-04	
Ce	0.3312100	0.6519200E-01	0.0000000E+00	0.1265418	0.1145148E-03
	1.364805	-.1678330E-02	0.1340601	0.1097916E-01	3.642740
	2.733195	-.1095679E-01	0.1555824	0.1998886E-04	
S2	1.152500	0.7201026E-01	-.1418393E-04	0.9866320E-01	0.2280947E-03
	1.199839	-.9890635E-03	0.1322662	0.1168779E-01	3.667678
	2.448772	-.8997619E-02	0.1214130	0.1026551E-03	
L1	1.551498	0.7745064E-01	-.2125197E-04	0.1105841	0.1551521E-03
	1.220204	-.1046531E-02	0.1308882	0.1111856E-01	3.850366
	2.703692	-.1025611E-01	0.1186888	0.5429029E-04	
L2	1.868321	0.7701300E-01	-.2608306E-04	0.1128203	0.1652075E-03
	1.163973	-.7615418E-03	0.1319414	0.1190706E-01	3.655037
	2.190400	-.8000882E-02	0.1000572	0.1368168E-03	
L3	1.999990	0.7638609E-01	-.2730626E-04	0.1137130	0.1571027E-03
	1.196919	-.8739060E-03	0.1276257	0.1051189E-01	4.151475
	2.536830	-.8034516E-02	0.1059867	0.1214003E-03	
L4	1.999990	0.7555673E-01	-.3515103E-04	0.1109590	0.2223129E-03
	1.166028	-.7791098E-03	0.1305011	0.1214418E-01	3.713008
	2.193882	-.8007786E-02	0.9646642E-01	0.1706615E-03	

L5	2.000000 1.169304 2.574198	0.7303913E-01 -.7978555E-03 -.9185220E-02	-.3221842E-04 0.1306179 0.1048962	0.1192947 0.1290083E-01 0.1698938E-03	0.1788024E-03 3.596233
L6	2.000000 1.153561 2.449782	0.7156978E-01 -.7258980E-03 -.9133349E-02	-.3367861E-04 0.1299498 0.1044602	0.1231263 0.1271816E-01 0.1745999E-03	0.1955821E-03 3.675980
L7	2.000000 1.160077 2.613415	0.6732576E-01 -.7784832E-03 -.9581670E-02	-.3345221E-04 0.1300890 0.9860379E-01	0.1296731 0.1108807E-01 0.2907844E-03	0.2094398E-03 3.869305
L8	1.999999 1.220272 2.780168	0.6693028E-01 -.1113339E-02 -.9020244E-02	-.3682273E-04 0.1282860 0.1079010	0.1065426 0.1387807E-01 0.2533335E-03	0.3265580E-03 3.629851
L9	2.000000 1.181283 2.463600	0.6183766E-01 -.9063833E-03 -.8814100E-02	-.3400842E-04 0.1281336 0.1119799	0.1454041 0.1412405E-01 0.3499002E-03	0.1631868E-03 3.612414
L10	2.000000 1.148080 2.463600	0.5753169E-01 -.5616732E-03 -.8814100E-02	-.3523881E-04 0.1229113 0.9134842E-01	0.1351525 0.1266633E-01 0.4323454E-03	0.2402285E-03 4.196391
L11	2.000000 1.176500 2.463600	0.5492358E-01 -.8339100E-03 -.8814100E-02	-.3922801E-04 0.1272420 0.9748280E-01	0.1587630 0.1177700E-01 0.3812300E-03	0.1506392E-03 3.761400
L12	2.000000 1.176500 2.463600	0.4954800E-01 -.8339100E-03 -.8814100E-02	-.4030200E-04 0.1268420 0.9641300E-01	0.1352240 0.1177700E-01 0.4122740E-03	0.2670800E-03 3.761400
L13	2.000000 1.176500 2.463600	0.4449900E-01 -.8339100E-03 -.8814100E-02	-.4160120E-04 0.1264410 0.9534320E-01	0.1375850 0.1177700E-01 0.4433180E-03	0.2772720E-03 3.761400
L14	2.000000 1.176500 2.463600	0.3903660E-01 -.8339100E-03 -.8814100E-02	-.4290040E-04 0.1260410 0.9427340E-01	0.1399470 0.1177700E-01 0.4743620E-03	0.2874640E-03 3.761400
L15	2.000000 1.176500 2.463600	0.3316100E-01 -.8339100E-03 -.8814100E-02	-.4419960E-04 0.1256400 0.9320360E-01	0.1423080 0.1177700E-01 0.5054060E-03	0.2976560E-03 3.761400
L16	2.000000 1.176500 2.463600	0.2687220E-01 -.8339100E-03 -.8814100E-02	-.4549880E-04 0.1252400 0.9213380E-01	0.1446700 0.1177700E-01 0.5364500E-03	0.3078480E-03 3.761400
L17	2.000000 1.176500 2.463600	0.2017000E-01 -.8339100E-03 -.8814100E-02	-.4679800E-04 0.1248390 0.9106400E-01	0.1470310 0.1177700E-01 0.5674940E-03	0.3180400E-03 3.761400

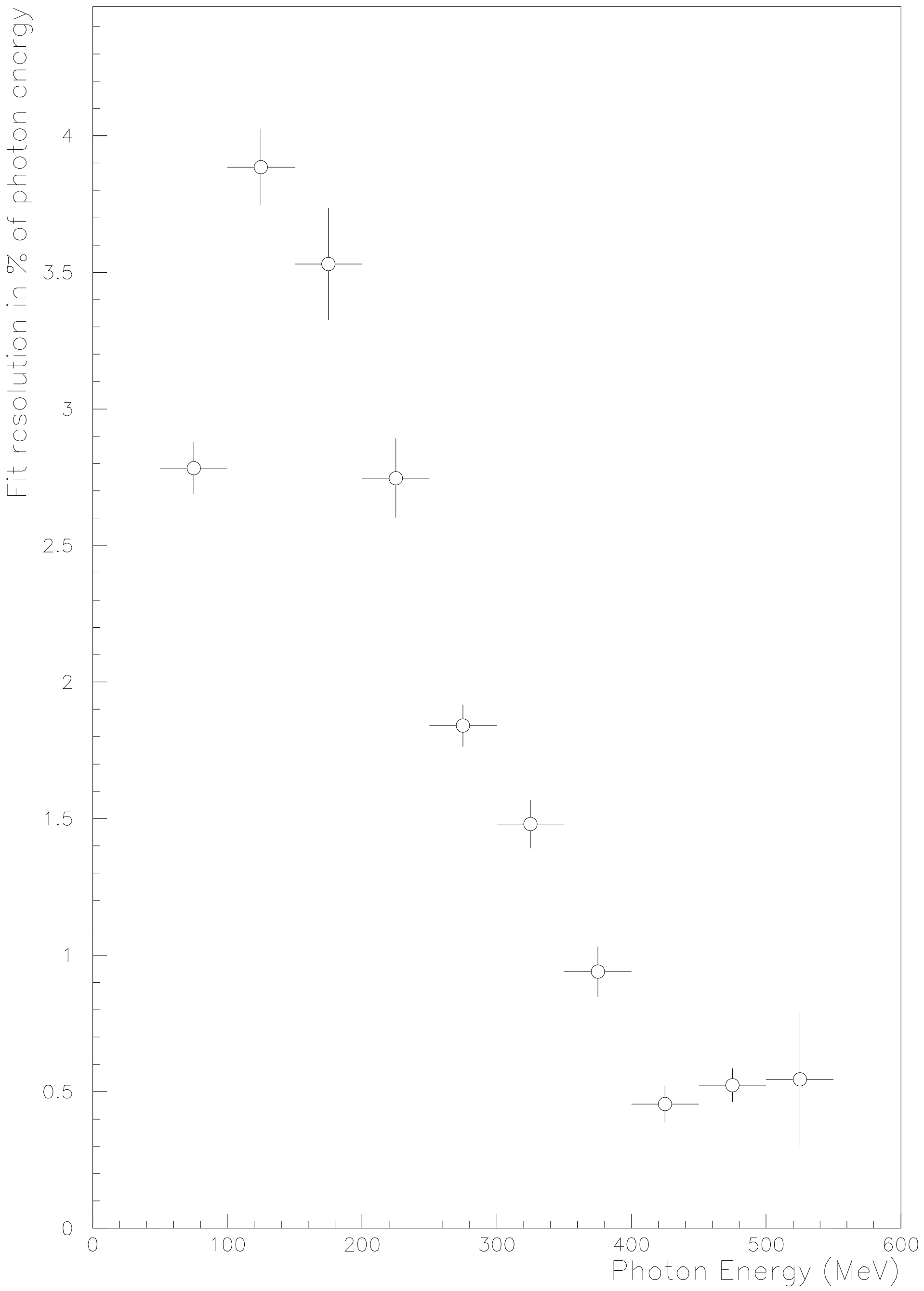

Figure 1: Intrinsic energy resolution of the 3C fit, obtained by comparing the fitted energy with the true one (using Monte Carlo data).

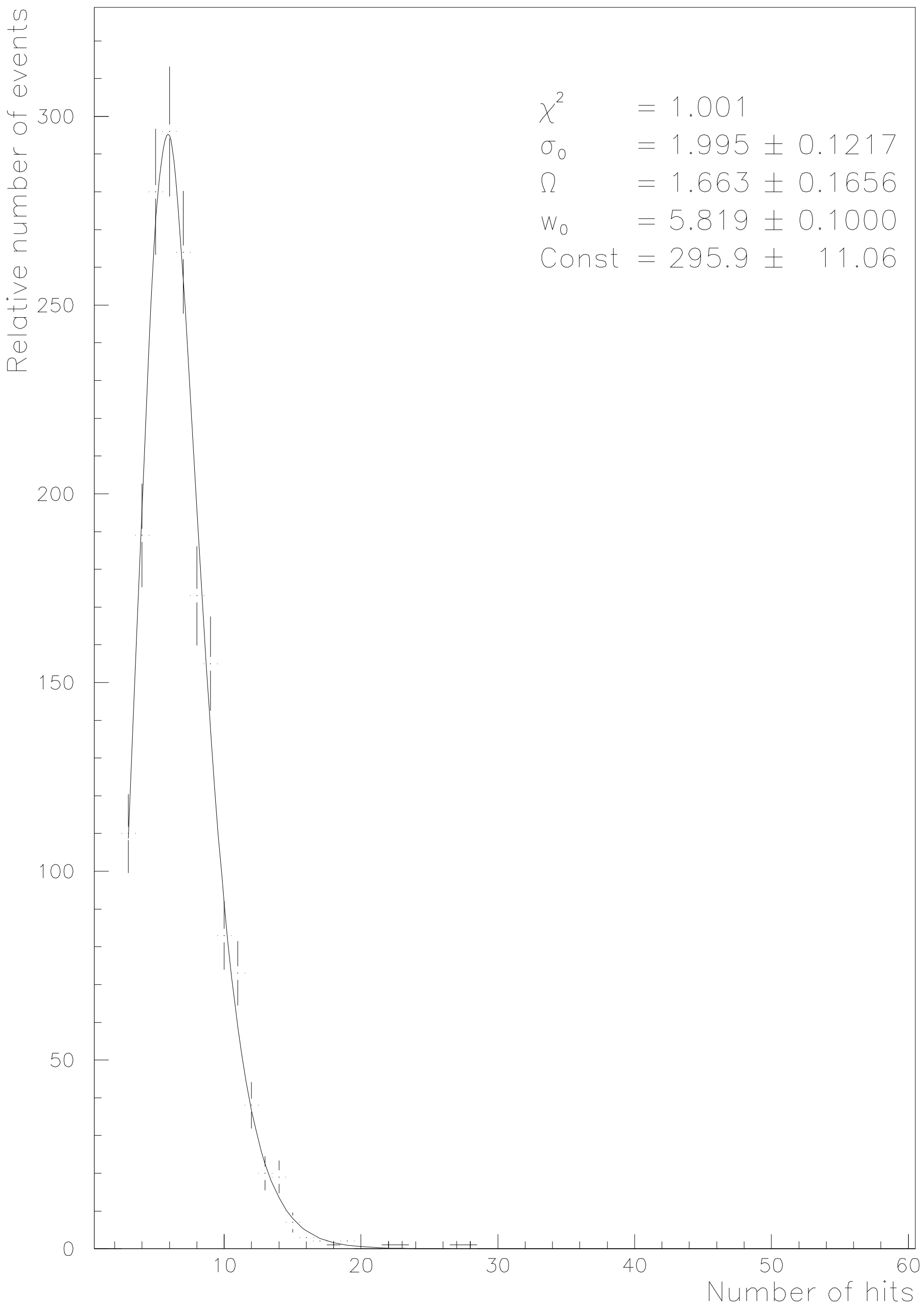

Figure 2: Distribution of the number of hits in the calorimeter due to photons with an energy between 60 Mev and 80 MeV, converted in layer 1.

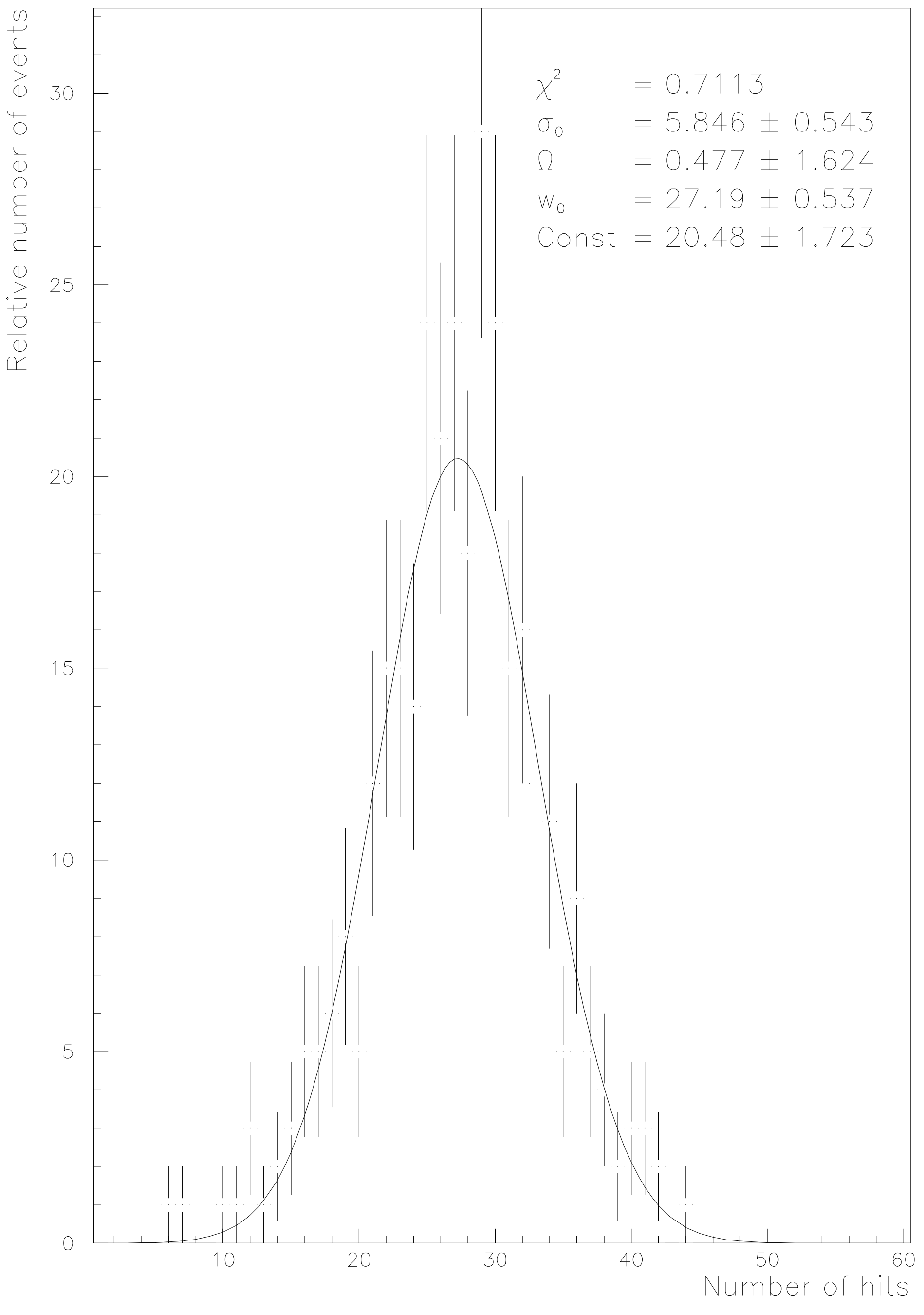

Figure 3: Hit distribution for photons with an energy between 360 Mev and 380 MeV. At gamma ray energies above $\sim$ 250 MeV the distribution is gaussian (Ω = 0). (The data used here has the photon conversion in layer one.)

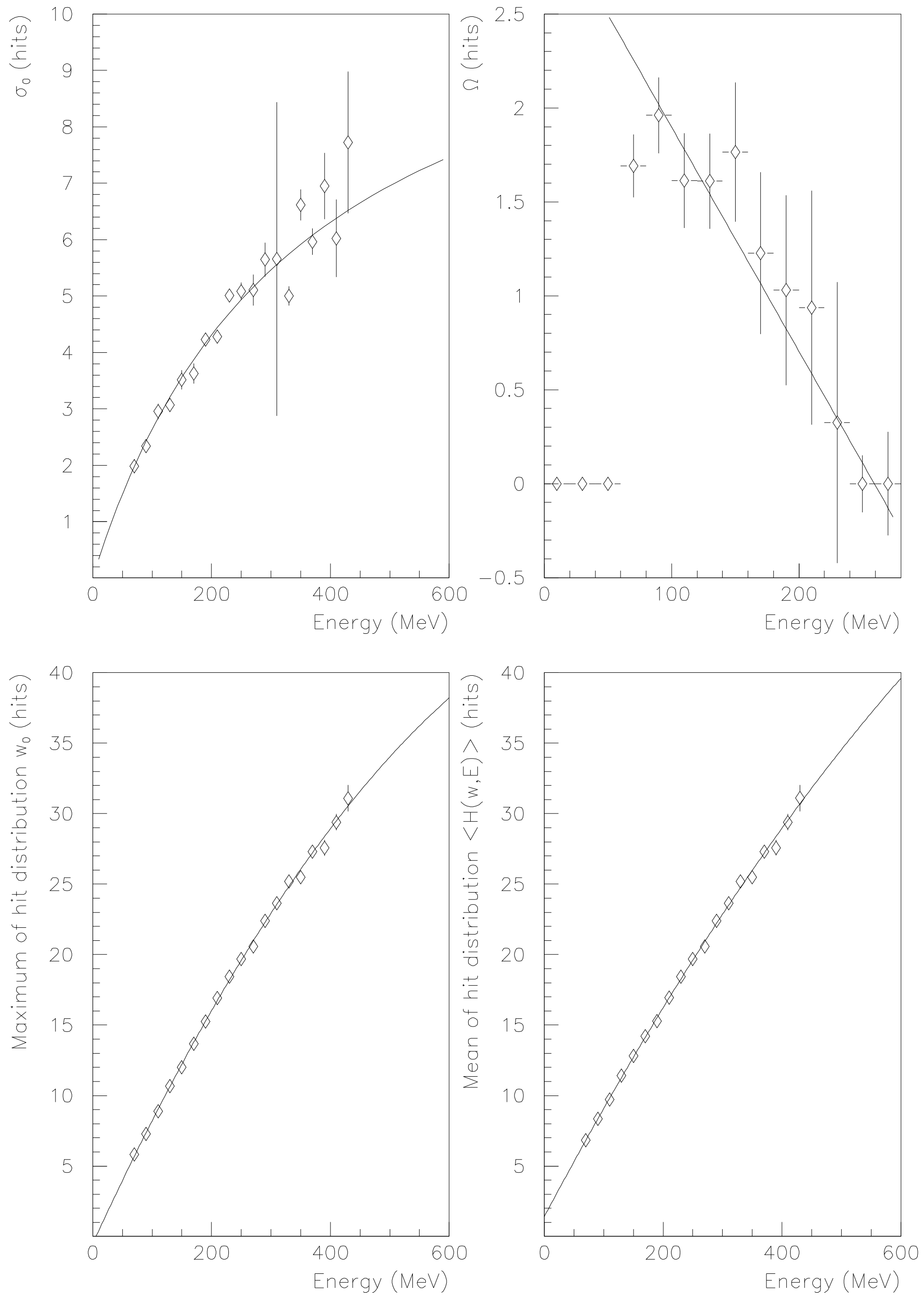

Figure 4: The points represent the parameters of the hit distributions (Eqs. 1 and 2) as a function of the photon energy for photons converted in layer one. The curves show a fit to determine the parameters of Eqs. 3, 4, 5 and 6.

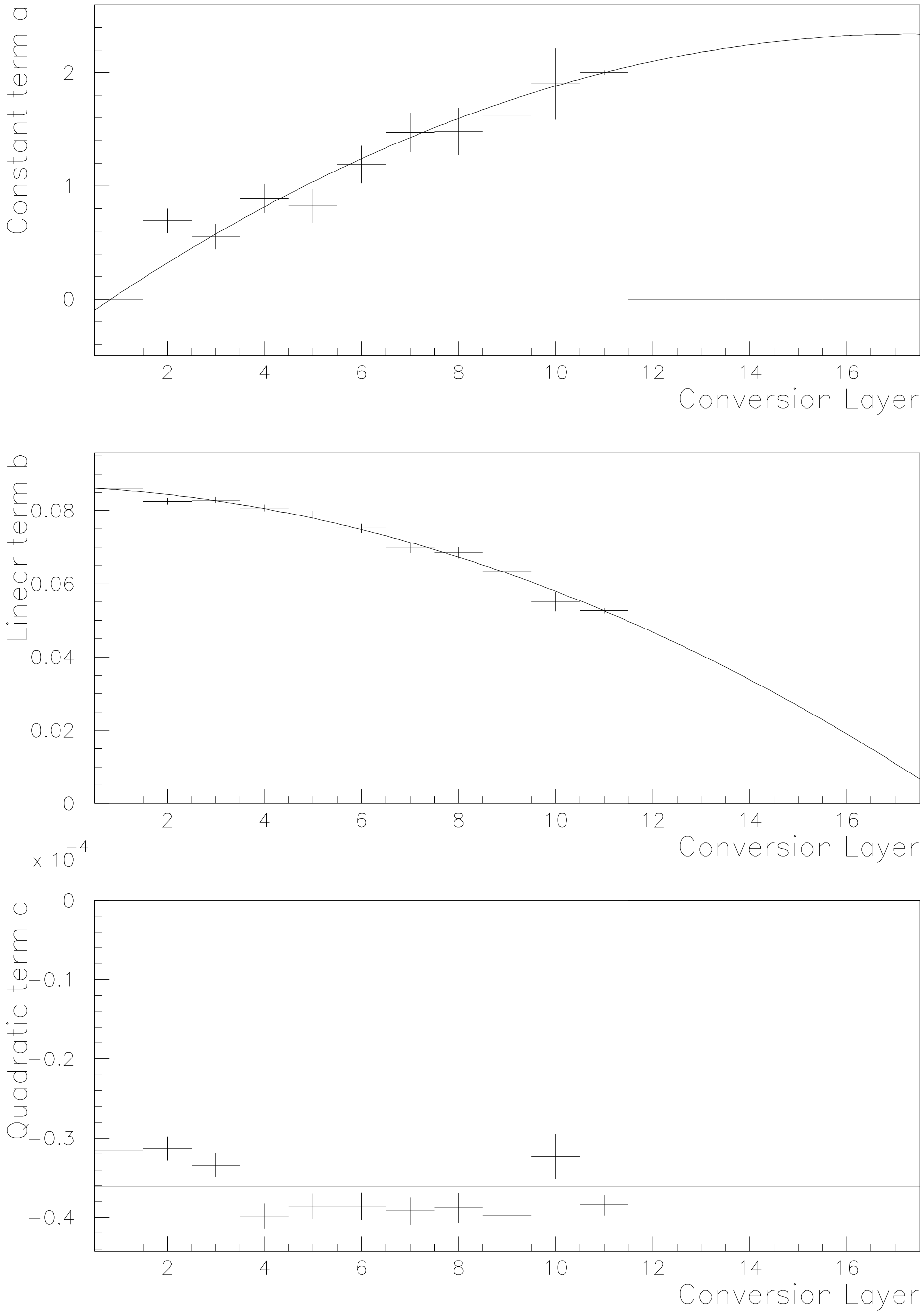

Figure 5: An example for the dependency of the calibration parameters on the layer where the photon converts: $w_0 = a_w + b_w E + c_w E^2$ (Eq. 3). These curves reflect the finite depth of the calorimeter.

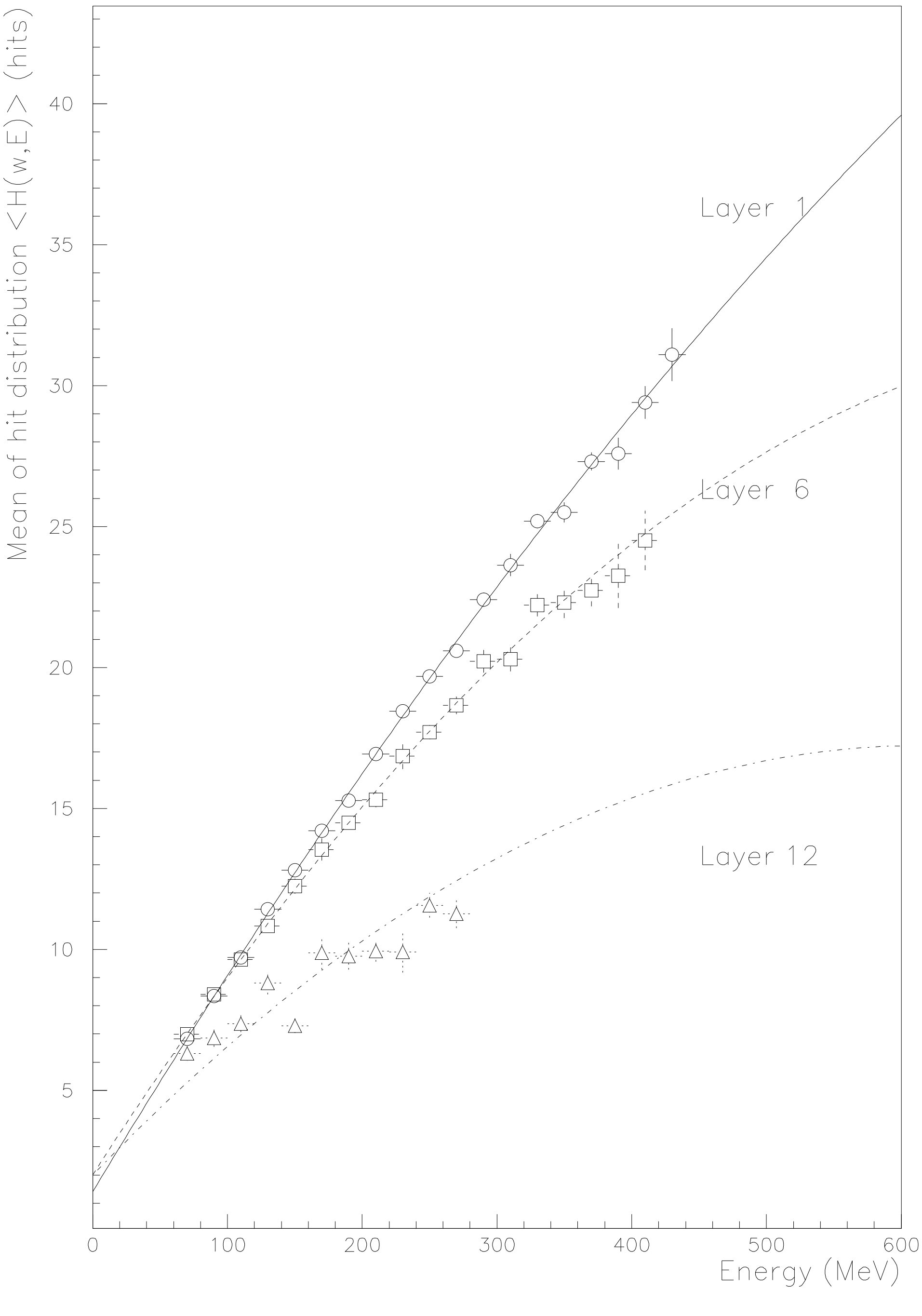

Figure 6: Points: Response of the calorimeter for various conversion layers. Due to the finite depth of the calorimeter showers starting in late layers tend to partially leak out. The curves represent the fits to determine the parameters of Eq. 4. For a summary of the results see fig. 5 and appendix A.

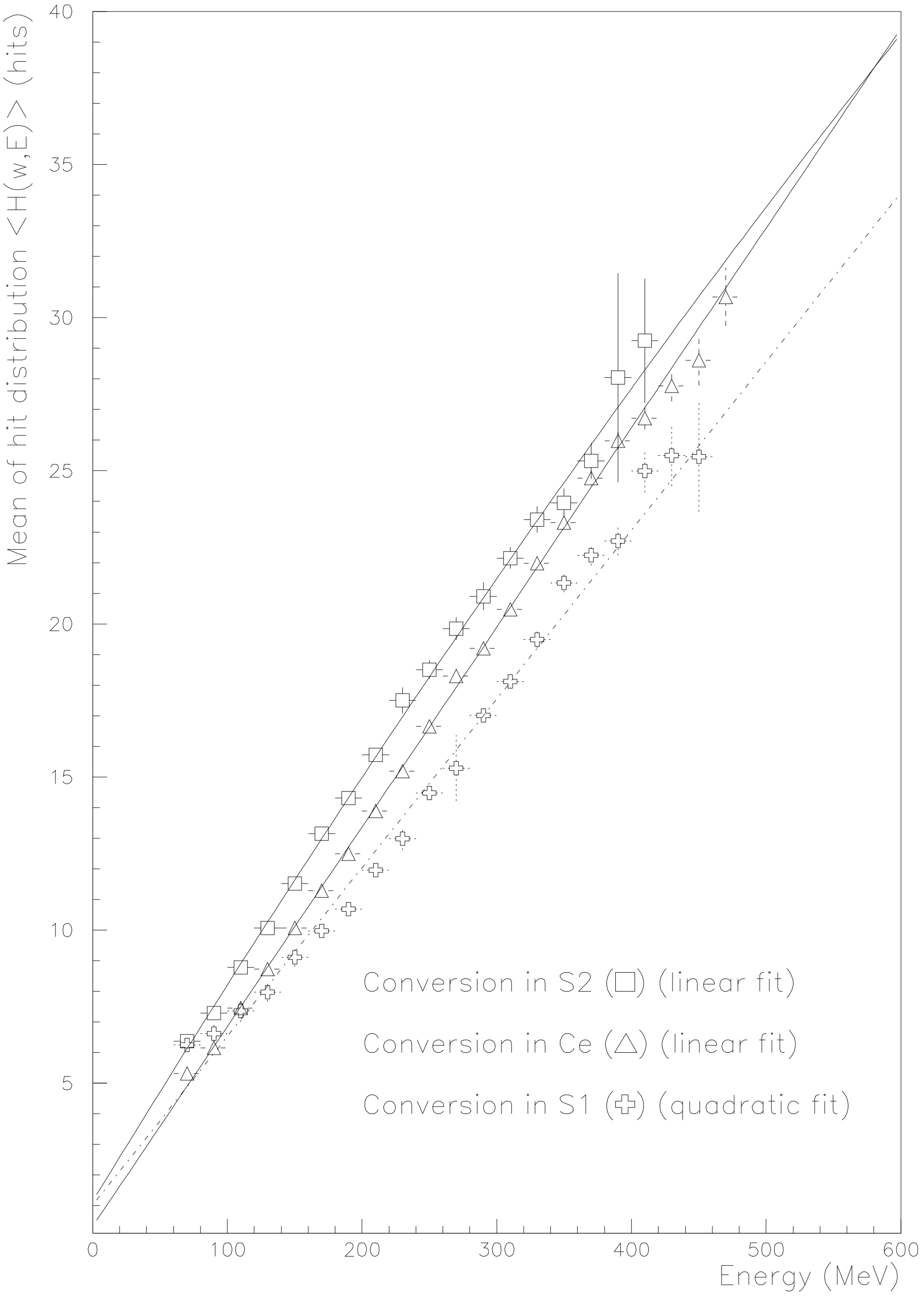

Figure 7: Energy calibration for photons with a hit in the PIDs. Curves: Eq. 4.

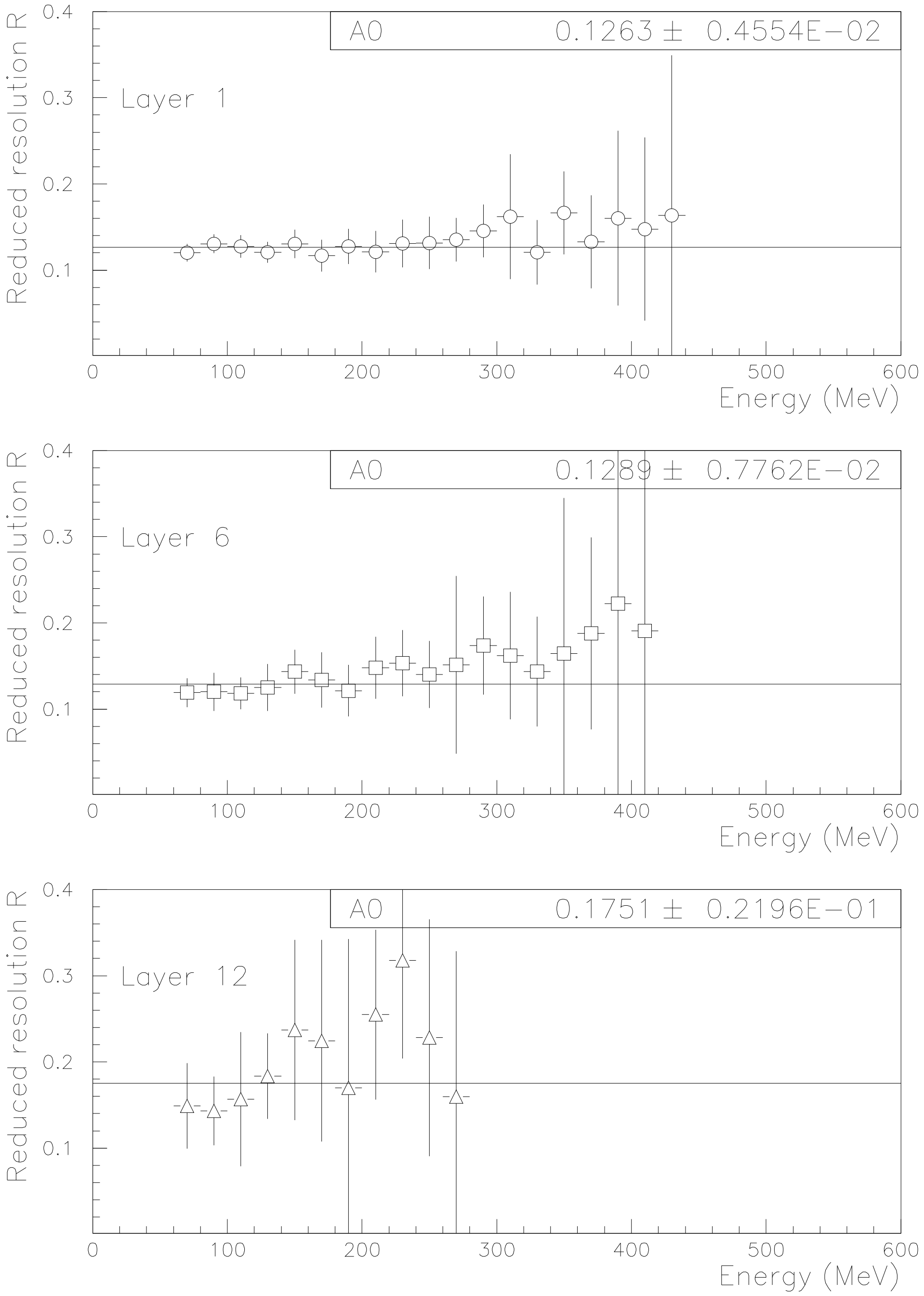

Figure 8: Reduced hit resolution R as function of the energy. Fits represent constant values.

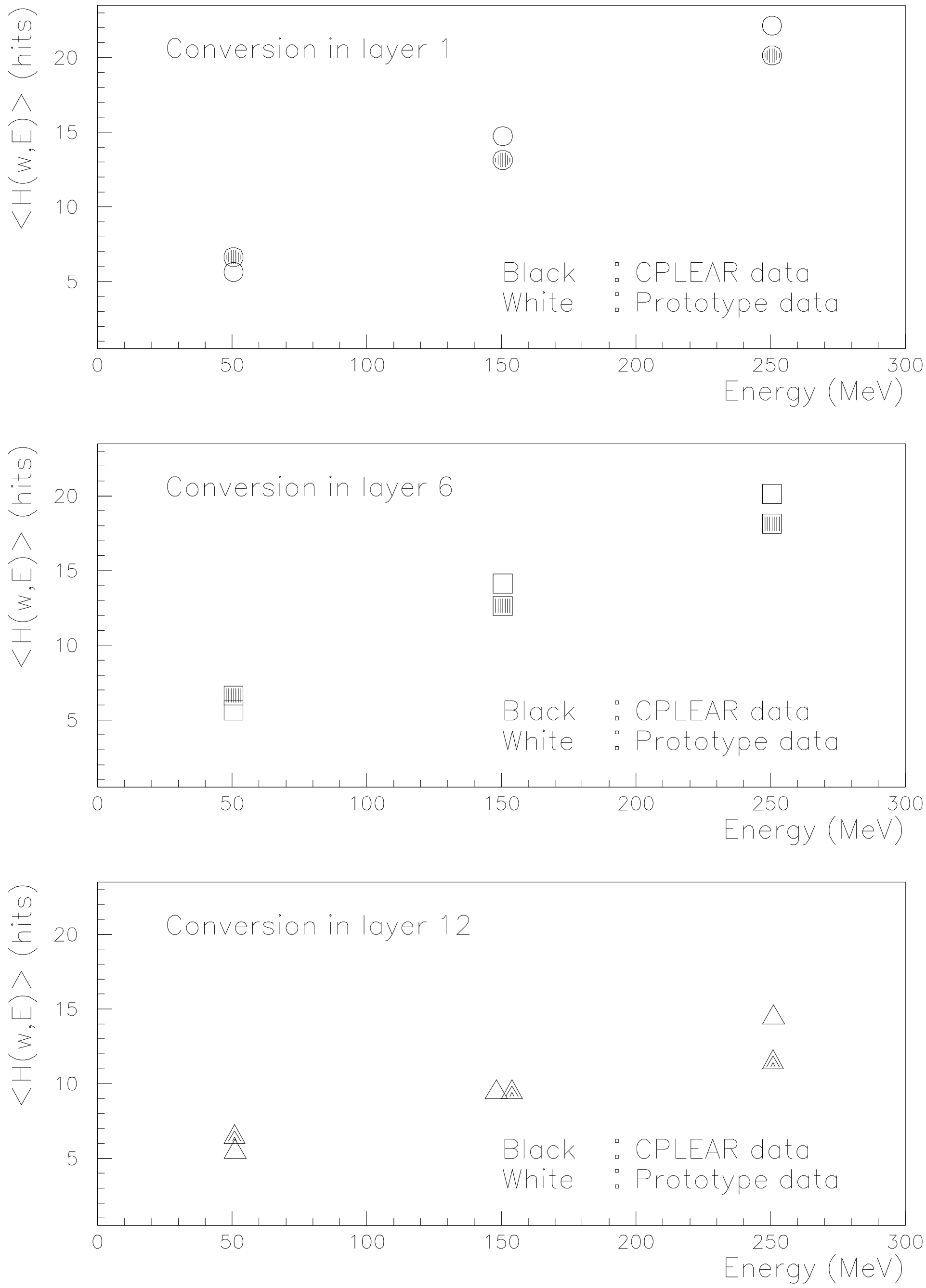

Figure 9: Comparison of the mean number of hits between prototype and CPLEAR calorimeter.

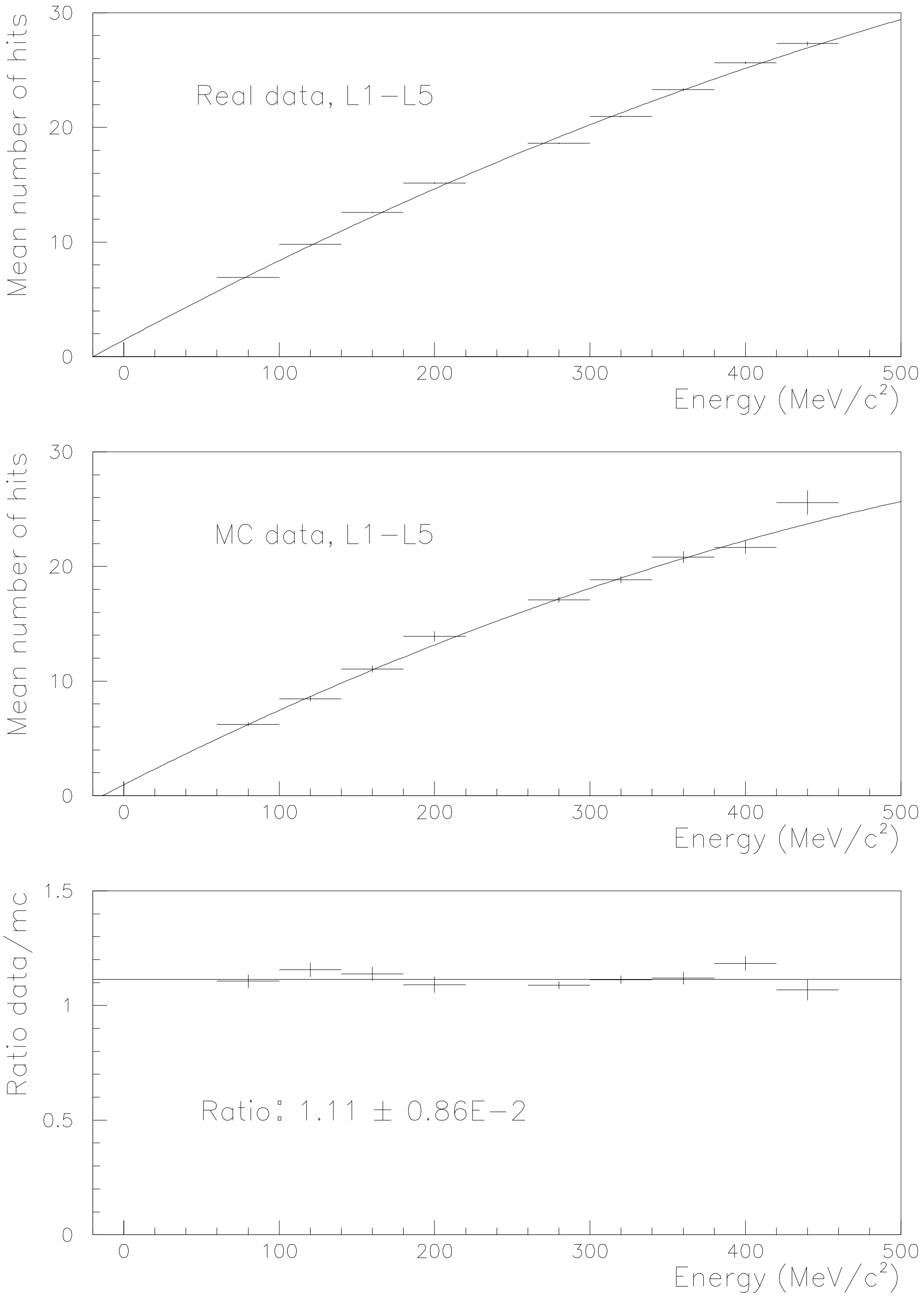

Figure 10: Comparison of the mean number of hits between real and Monte Carlo data. The Monte Carlo program reproduces correctly the energy dependency of the mean number of Hits <H(w,E)>, but its absolute values are low by a factor of 1.11.

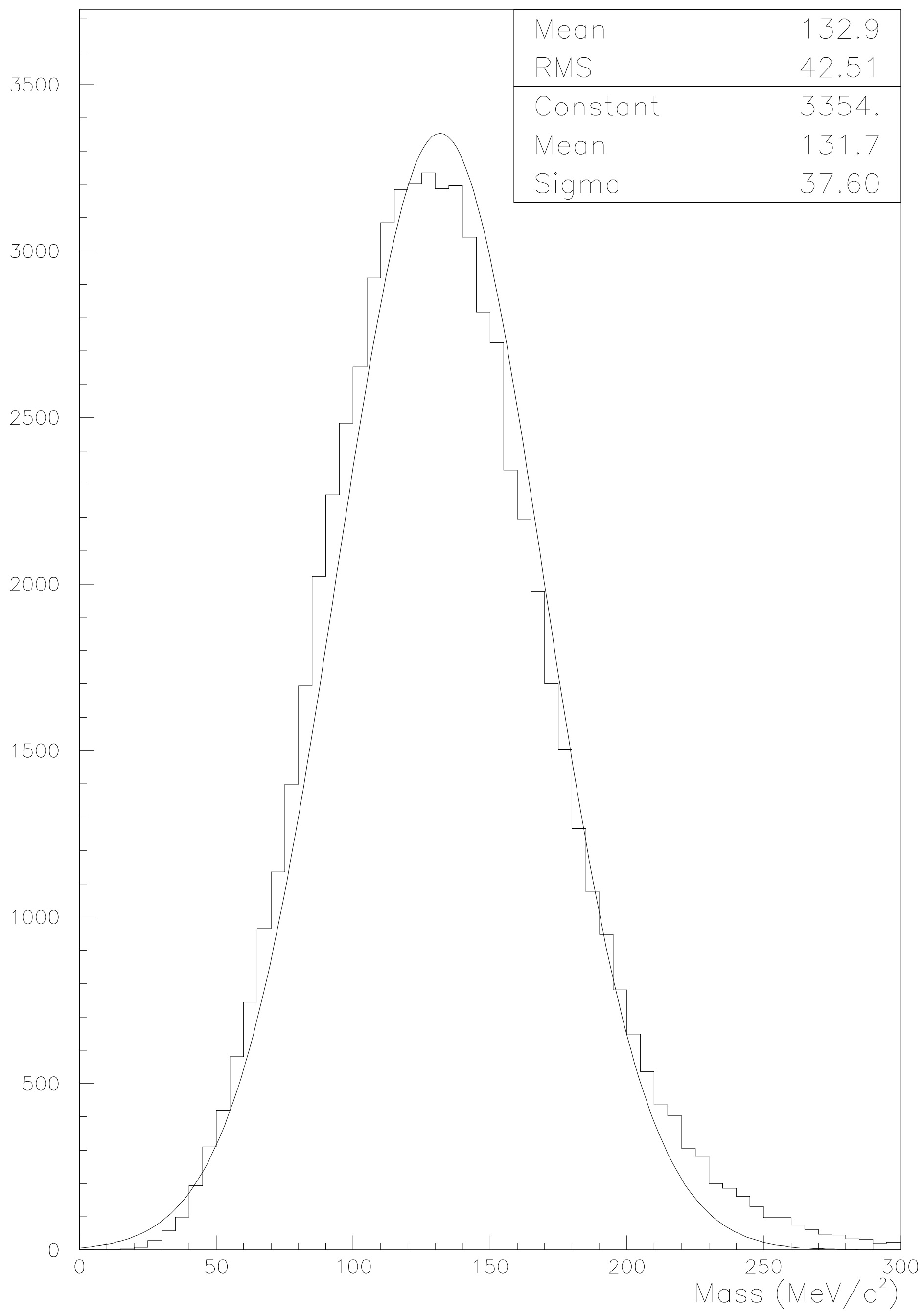

Figure 11: Distribution of calculated π^0 masses using Eq. 9 and the energy values supplied by the routine "Cashenew". A less approximate method is given by Eq. 14, whose results are displayed in figs. 12 and 13.

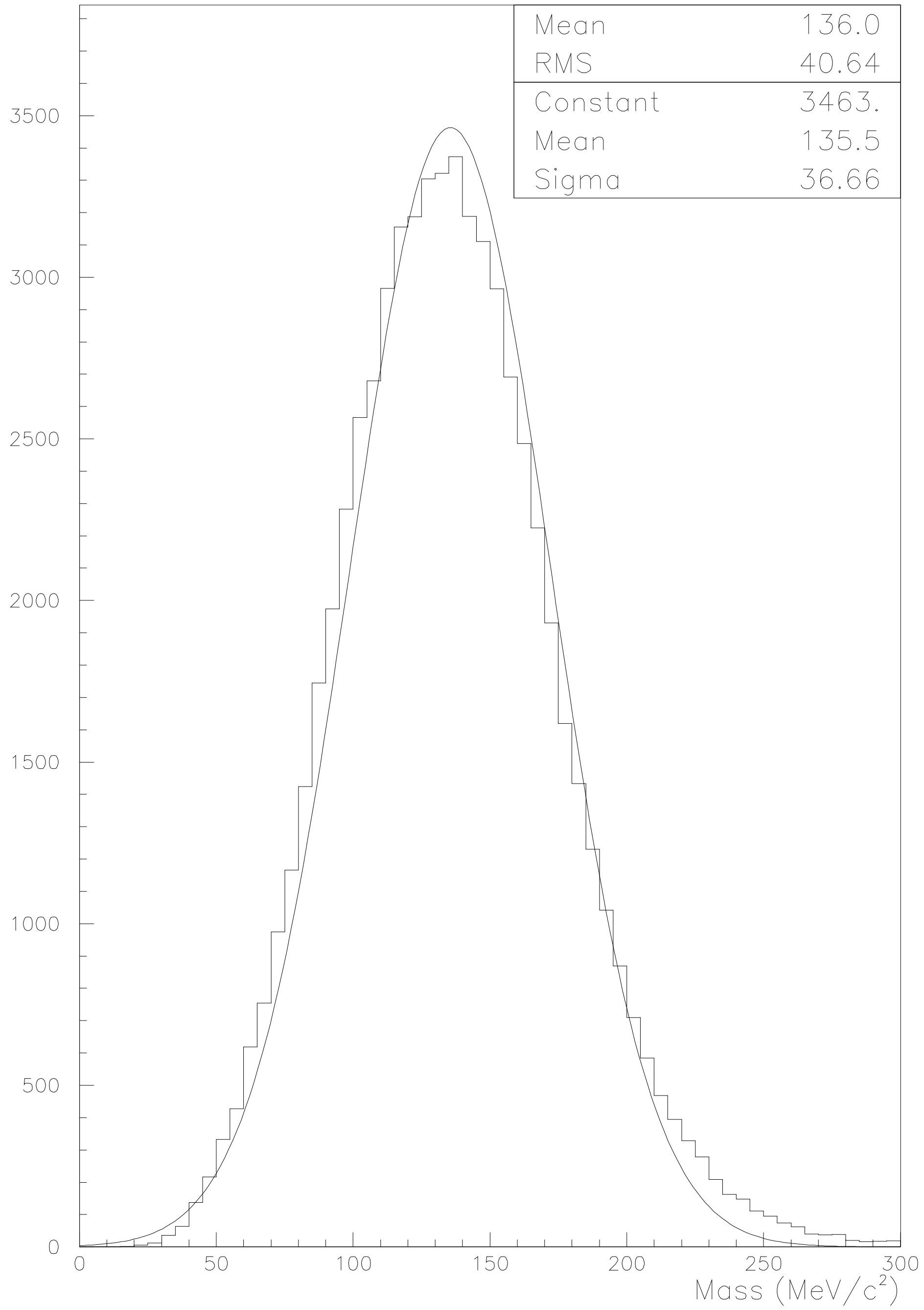

Figure 12: Distribution of calculated π^0 masses using Eqs. 9 and 14 with p=E_1E_2 deduced from Eq. 14. The mean energies of the photon samples $< E_1 >$ and $< E_2 >$ in Eq. 14 are taken from Eq. 11 with c=0.

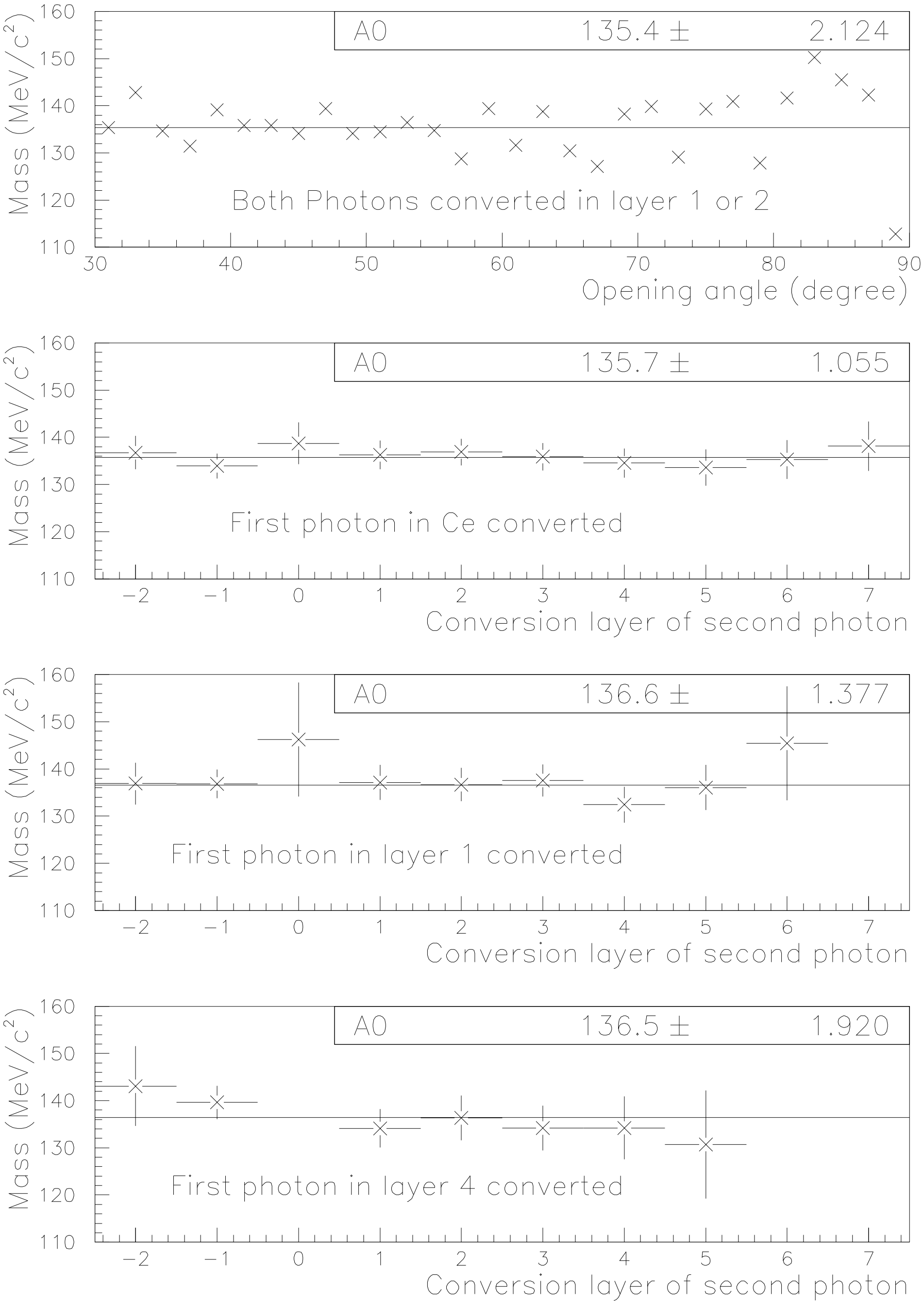

Figure 13: Top plot: m_{π^0} as function of the $\gamma\gamma$ opening angle for photons converted in layer one or two, based on Eqs. 9 and 12. Plot 2 -4: m_{π^0} according to the method of Eqs. 9 and 14 for various layer configurations, where layer -2, -1 and 0 correspond to conversion in S1, Če and S2 respectively.