MEMORANDUM NFSt. Note II

To: CPLEAR Collaboration September 3, 1993

From: Ronny Adler

Subject: **Alignment of the Calorimeter**

Abstract

This note describes the alignment of the electromagnetic calorimeter of the CPLEAR experiment, which has been finished by the end of September 1992. The method how the alignment was effected differs slightly compared with the method the prototype calorimeter was aligned. The data to make the alignment were taken in the run period P12 (1991) with a minimal bias trigger and some quality cuts on the used tracks.

The difference of the shower foot and the extrapolated tracks was found to be of the order of 3.6 mm in $r\varphi$ and 7.3 mm in z for the first layer. The internal resolutions were of the order of 2.2 $mrad$ in φ and 6.5 mm in z.

1 Introduction

At the end of 1991 the 18-layer gas-sampling electromagnetic calorimeter (6.2 radiation lengths) of the CPLEAR experiment was for the first time fully equipped with the readout electronics needed for the offline reconstruction of the showers in $r\varphi$ and z respectively. Because the positions of the some 17'000 wires and 43'000 pick-up strips until then were only known by some geometrical measurements, an accurate alignment of the calorimeter using the whole detector was needed. Especially for the ongoing analysis of the K^0-decay into neutral pions, i.e. for a good vertex resolution of this K^0-decay, the impact points of the photons play an important role. The desired precision for the measured CP-violating parameters requires a high spatial resolution of the photon showers of the order of $\sigma \approx 5$ mm.

While the prototype calorimeter [1] could be aligned with an internal fit of a straight line through the calorimeter hits, the final calorimeter was found to behave too complexly to use the same method. The result of such an internal alignment was very much depending on the start values and on the chosen calorimeter chambers which would have been kept fixed. The results differed so much that we decided to align the calorimeter only externally by means of the track chambers. Despite this method the final resolutions were in the expected order.

2 Data used

The charged track sample used for the alignment of the calorimeter was obtained from minimum bias tapes taken in the run period P12 end of 1991. Due to the main annihilation channels, the sample contained mostly pionic tracks.

Some quality cuts on the tracks (enough $r\varphi$ and z information / only tracks from the center) provided a good sample to allow the extrapolation from the track chambers to the various layers of the calorimeter. This extrapolation was kept most simple switching our magnet off during data taking and extrapolating the tracks offline as straight lines. We therefore lost the information of the track momentum.

A shower in the calorimeter was defined to be a charged shower if the shower was found to lie not more than 25 cm away from the extrapolated charged track (both in $r\varphi$ and z). This charged shower was required to have at least five hits. In addition, it was required that in the wire projection there is only one wire hit per layer and in the strip projection there are not more than three strip hits per layer. At least three hits should lie in subsequent layers to exclude clusters originating from noise in the calorimeter.

The charged showers, obtained in this way, were then used for the alignment in φ and (if the information was present) also in z for the two pick-up strip planes surrounding the wires. The mean hit multiplicity of the used charged showers in the calorimeter was around 13 hits, as shown in fig. 1, top.

With a sample of trigger T1 tracks recorded with the magnetic field switched on, the same analysis was made. Fig. 1, bottom, shows the resulting momentum distribution with the cuts explained above.

3 Method to align the wires

For the wires, the alignment was done comparing the φ-coordinate of the extrapolated charged tracks with the wire φ-information. In order to minimize the multiple scattering in the PID's, only tracks in the central region of the calorimeter were used ($-20\ cm < z < 20\ cm$).

In a first step the so-called sets (consisting out of 8-14 wire chambers) were aligned separately. With a Gaussian fit of the $\Delta\varphi$-distributions the mean positions were determined. For the higher layers the Gaussians became rather broad but could still be approximated in a sufficiently precise way. The coordinates of the sets were then corrected by the displacement of the Gaussian compared to zero. This step was repeated iteratively until a given cut value was reached. This cut value was smaller than 0.3 $mrad$ for layer 1, increasing to 0.9 $mrad$ for layer 18. Out of the more than 150 histograms a sample, after passing the described processing, is shown in fig. 2.

In a second step each wire chamber (consisting out of 8 wires) of each set was aligned separately. Here again, the $\Delta\varphi$-distributions were fitted with a Gaussian and the mean value was iteratively taken as a correction factor. Histograms with less than 50 hits (i.e. with dead wires) were not fitted and the correction factor for the corresponding chamber was extrapolated from the other chamber corrections in the set. Because the chamber histograms had far less entries than the set histograms of the first step, the cut values were somewhat bigger: $< 1\ mrad$ in layer 1 and $< 4\ mrad$ in layer 18. Out of the more than 1500 histograms a sample of final $\Delta\varphi$-distributions is shown in fig. 3.

In a third step each set was aligned along z (there were not enough tracks to do it for each chamber separately). This was done leaving the central positions of the sets fixed and looking for an angle of the wires along z, as shown in a sample of histograms in fig. 4.

In the final step, a comparison of the now obtained corrections with the positions of the wires one would expect, was made, provided they were calculated using the known wire spacing. A clear evidence of a global displacement of the calorimeter frame with respect to the CPLEAR frame (defined by the tracking chambers) was found. Such a displacement should theoretically lead to a $\Delta\varphi$-dependance of the corrections which follows a sine (see fig. 5, histograms on the top). The measured $\Delta\varphi$-dependance was fitted to a sine function and the result showed a constant displacement for all the layers in the order of -1.9 mm in x and -5.7 mm in y, as can be seen in fig. 5, histograms in the middle. For higher layers an additional ellipse correction was introduced, which should theoretically lead to a $\Delta\varphi$-dependance of a sine with twice the frequency as for the observed displacement. This new correction term gave (for layers higher than layer 7) a significantly better approximation of the $\Delta\varphi$-dependance (compare fig. 5, histograms of layer 14 on bottom and top). The ellipse parameters in function of the different layers were fitted with a polynomial of degree 3, as shown in fig. 5, histogram on the bottom, right.

4 Method to align the pick-up strips

All the corrections for the wires were used in the strip alignment, i.e. in the calculation of the z-coordinate. The displacement of the calorimeter was taken into account, calculating first the φ of the wires in the calorimeter frame. Only with that φ the calculation of z was made.

For both pick-up strip planes (U-strips with an angle of $+30$ degrees and V-strips with an angle of -30 degrees with respect to the wires) the alignment was done comparing the z-coordinate of the extrapolated charged tracks with the z-information obtained combining the wire and strip information. Again, this step was made in the central region of the calorimeter (-20 $cm < z < 20$ cm). With a Gaussian fit of the Δz-distributions the mean positions were determined and the same iterative process as for the wires was applied. For higher layers, here again, the Gaussian became rather broad but could still be approximated sufficiently. The cut values here lay between 0.3 mm for layer 1 and 0.6 mm for layer 18. Out of the more than 100 histograms a sample is shown in fig. 6.

There was no significant evidence that the position in z could be obtained in a better way if one included an angle of the strips along z.

5 Data of 1992

For 1992 data the displacement of the calorimeter with respect to the CPLEAR frame changed slightly. This was due to the new position of the tracking chambers (which define the CPLEAR frame) after the dismounting of the detector in winter 1992. The displacement differs in the order of about 1.5 mm in y and about 1.4 mm in z to the old values and introduced a global rotation of 0.9 $mrad$ of the whole calorimeter with respect to the DC's (see fig. 7). Nevertheless this is an example how sensitively the calorimeter detects some tiny effects.

The same results were observed by the PID group [2]. They obtained the following values: 1.4 mm movement in y and 1.1 $mrad$ as global rotation.

6 Conclusion

The calorimeter has been finely tuned with P12 data of 1991, using separate chamber corrections for the wires and a global displacement of the calorimeter (in respect to the CPLEAR frame, defined by the tracking chambers) in the order of -1.9 mm in x and -5.7 mm in y.

With the selected data the final resolutions for charged tracks in the whole calorimeter (only considering the first layer) were of the order of 3.6 mm in $r\varphi$ and 7.3 mm in z as shown in fig. 8. These values originate from a double Gaussian fit of the $\Delta\varphi$- and Δz-distributions, where the width of the smaller Gaussians was defined to be the resolution. But they still include an error contribution from multiple scattering and from the track extrapolation to the calorimeter.

Internal resolutions were obtained comparing the φ of the wires with the φ using both pick-up strip informations. The resolutions of these $\Delta\varphi$-distributions were of the order of 2.2 $mrad$, as shown in fig. 9, histograms on the left, and almost reached the intrinsic hit resolution (with a given wire spacing of 5 mm) of:

$$\sigma_\varphi^{theo.} = \frac{5\ mm}{\sqrt{12} \cdot Radius} \approx 1.8\ mrad$$

Another approach for an estimate of internal resolutions was made by the comparison of the z-information obtained using on one hand the wires and the U-strips and on the other the wires and the V-strips. The resolutions of such Δz-distributions were of the order of 6.5 mm and can be seen in fig. 9, histograms on the right.

These two values of internal resolutions depend on each other. If one looks how z is calculated:

$$z = const. + \frac{Radius \cdot \varphi}{\tan 30^\circ} = const. + \sqrt{3} \cdot Radius \cdot \varphi$$

one finds with the $\Delta\varphi$-resolution of 2.2 $mrad$:

$$\sigma_z = \sqrt{3} \cdot Radius \cdot \sigma_\varphi \approx 3.1\ mm$$

For the z-information, both U-strip and V-strip values are combined. Because

$$\Delta z = z_{w,u} - z_{w,v} \quad \Longrightarrow \quad \sigma_{\Delta z} = \sqrt{\sigma^2_{z_{w,u}} + \sigma^2_{z_{w,v}}} \approx 6.5\ mm$$

where the Δz-resolution of 6.5 mm was used, one finds:

$$z = 0.5 \cdot (z_{w,u} + z_{w,v}) \quad \Longrightarrow \quad \sigma'_z = 0.5 \cdot \sqrt{\sigma^2_{z_{w,u}} + \sigma^2_{z_{w,v}}} = 0.5 \cdot \sigma_{\Delta z} \approx 3.3\ mm$$

which is almost identical with the previous calculated σ_z!

References

[1] *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

[2] *Scintillator Positions in P19 as Compared to in P7*
Kare Jansson, Kerstin Jon-And
CP/SW/042

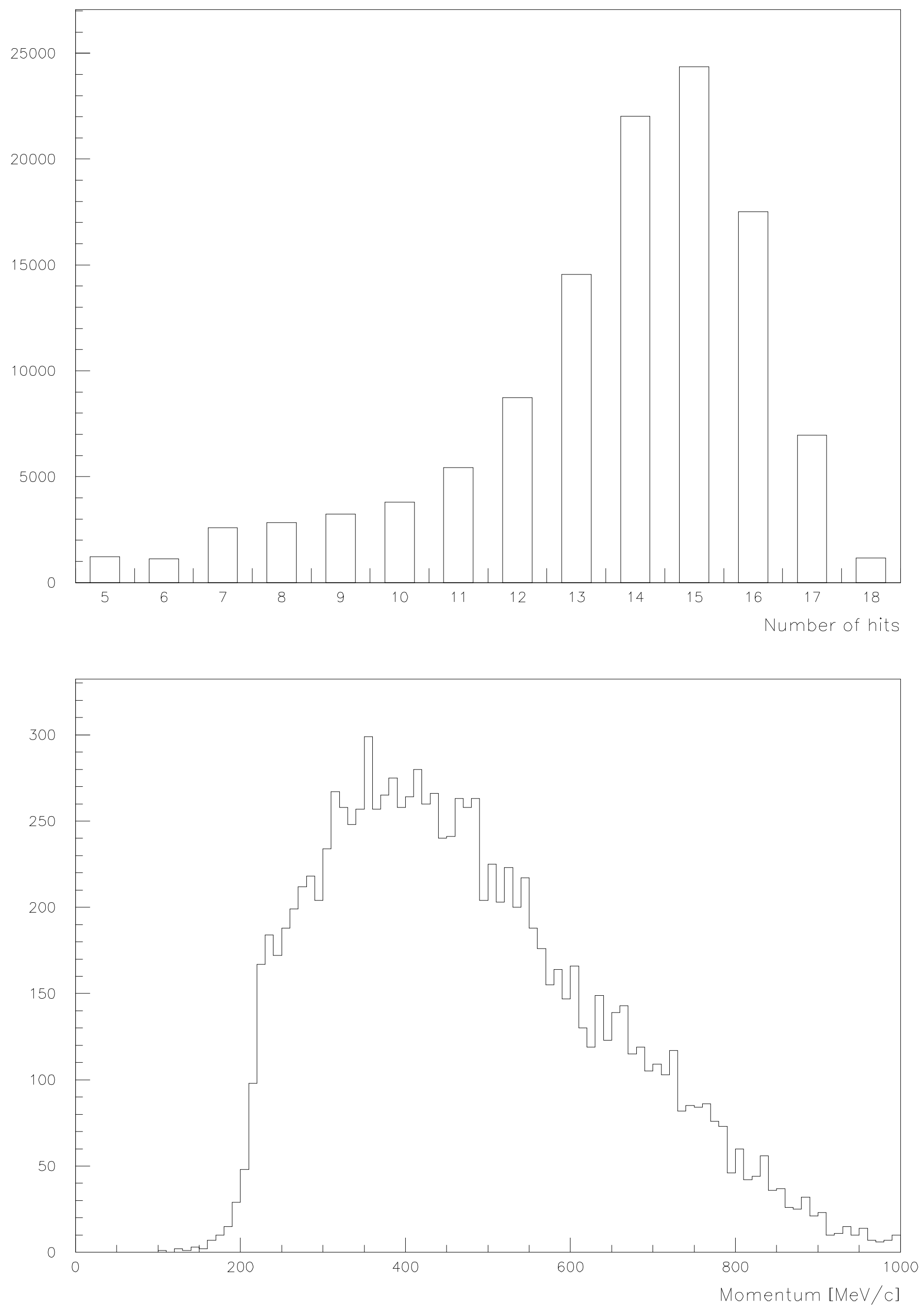

Figure 1: Hit distribution of the used charged showers (top) and momentum distribution of a corresponding track sample (bottom).

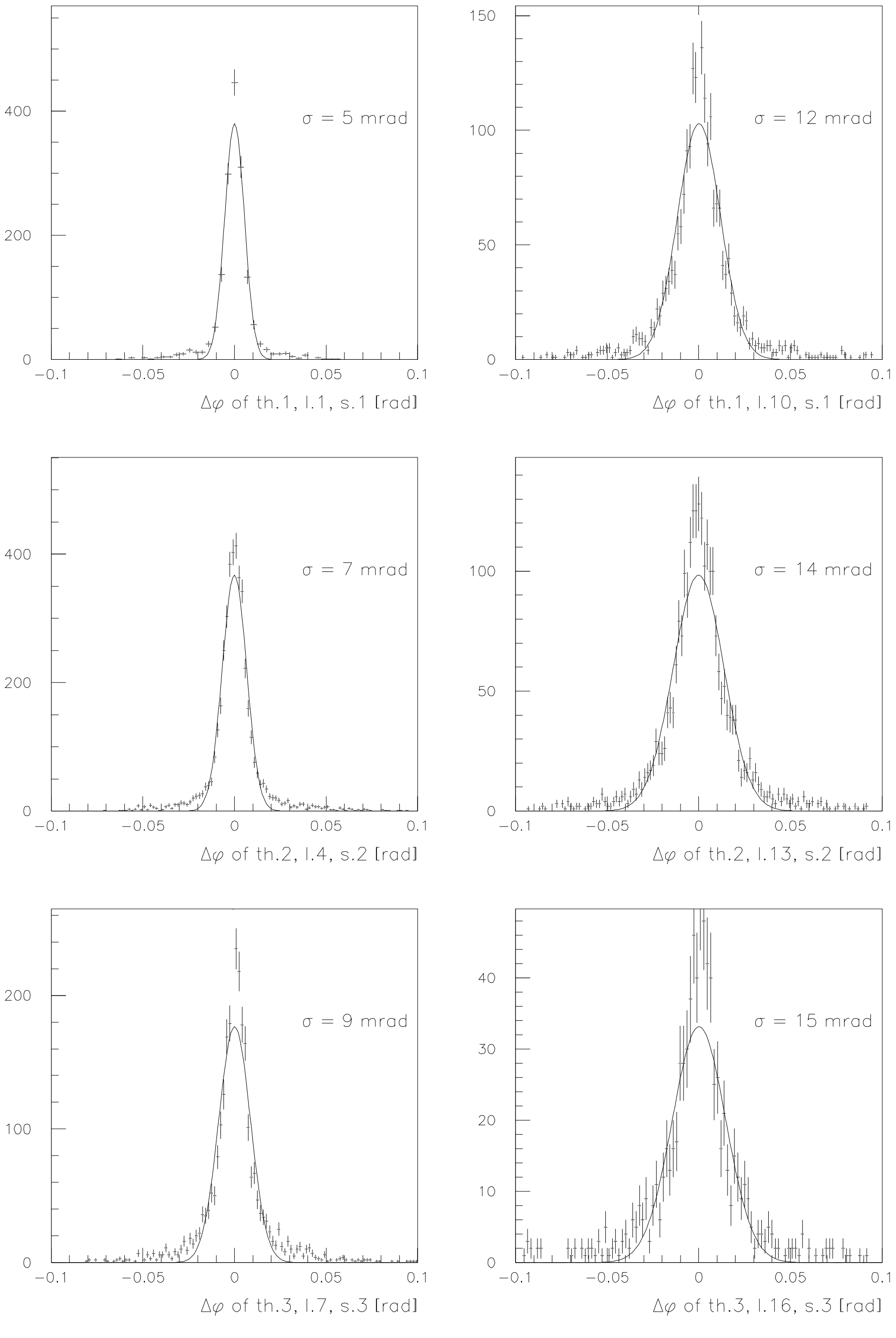

Figure 2: $\Delta\varphi$**-distributions for different sectors, layers and sets.**

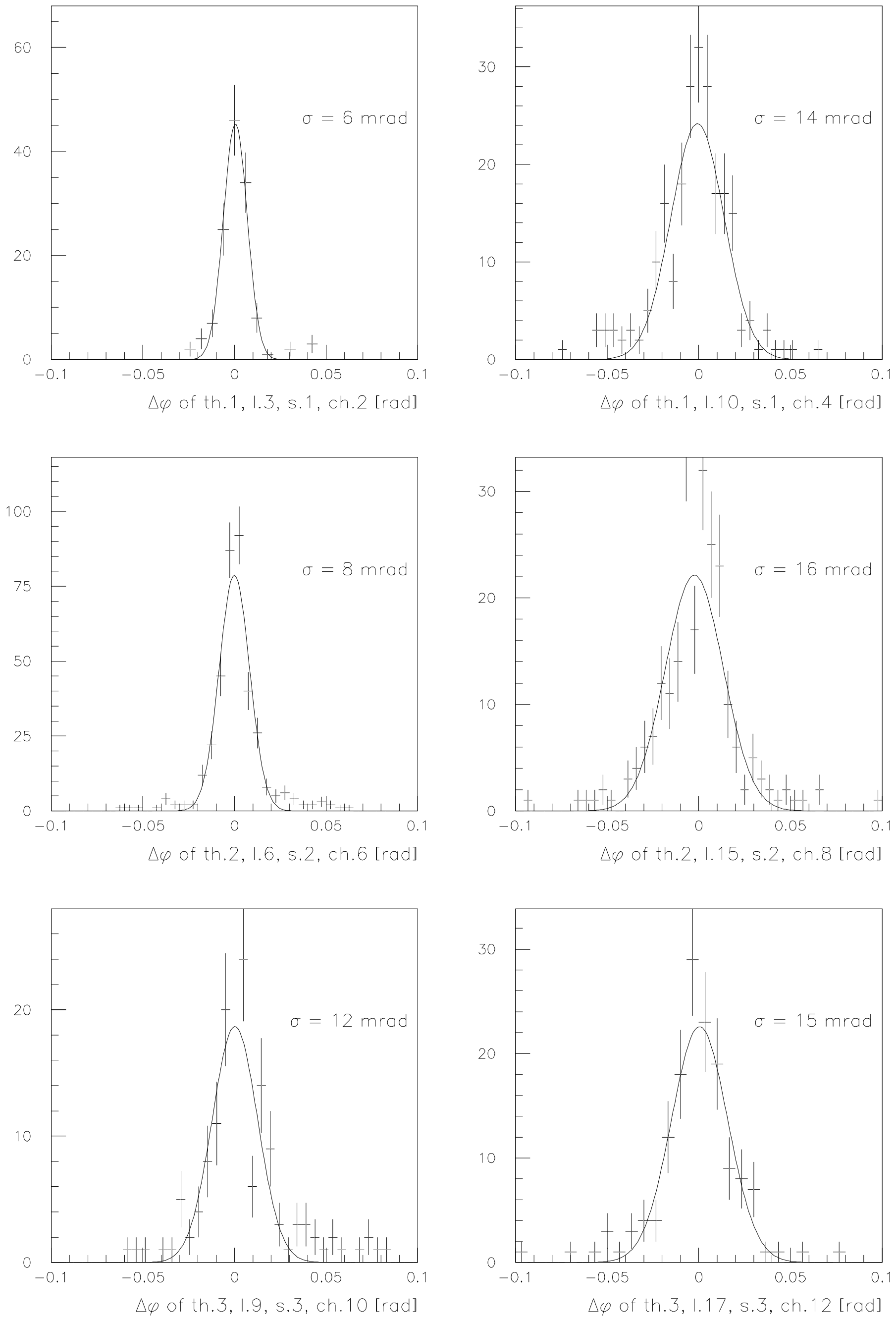

Figure 3: $\Delta\varphi$-distributions for different sectors, layers, sets and chambers.

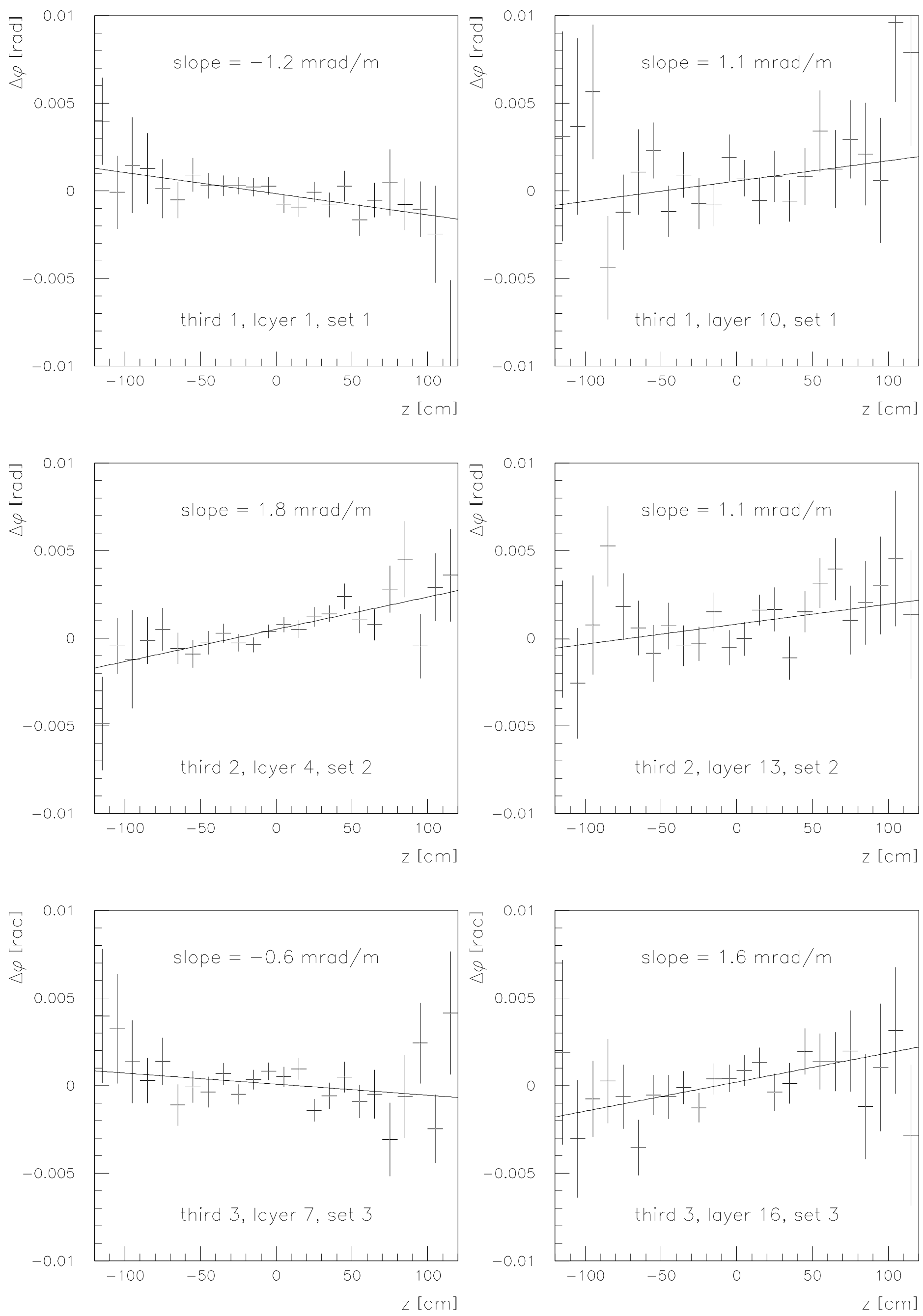

Figure 4: $\Delta\varphi$ **as function of** z **for different sectors, layers and sets.**

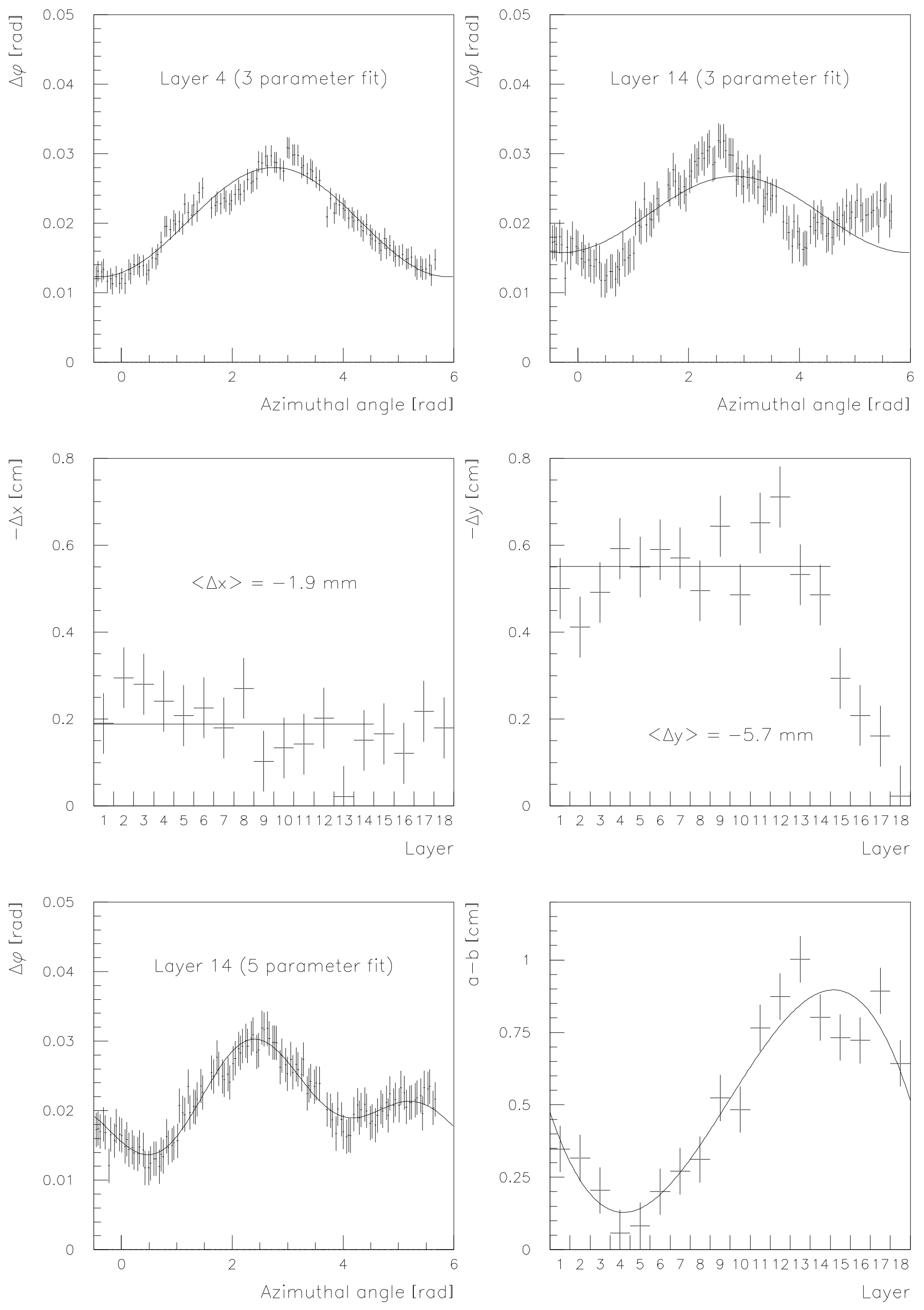

Figure 5: Effects of the displacement of the calorimeter with respect to the CPLEAR frame.

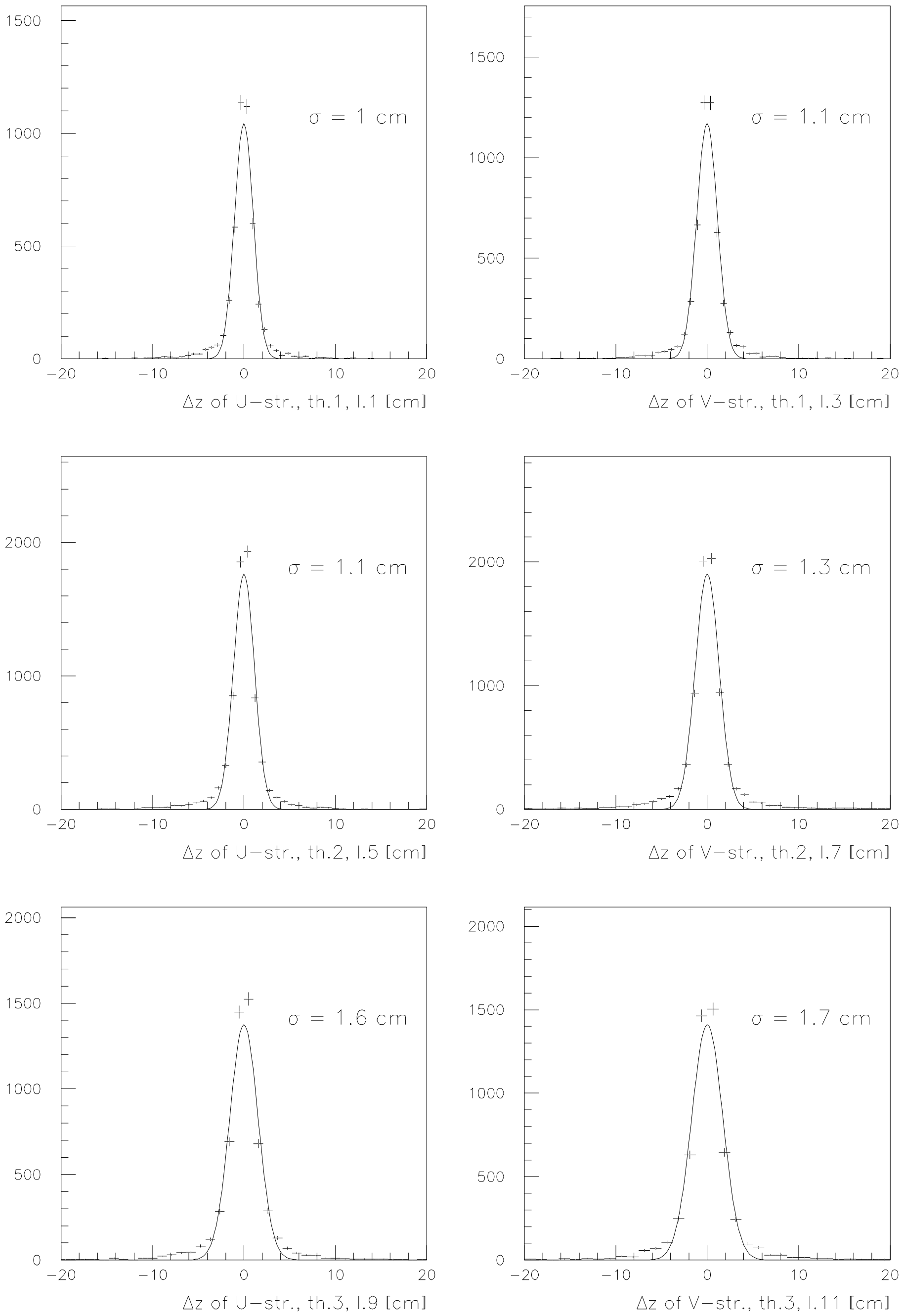

Figure 6: Δz-distributions for both strip planes and different sectors and layers.

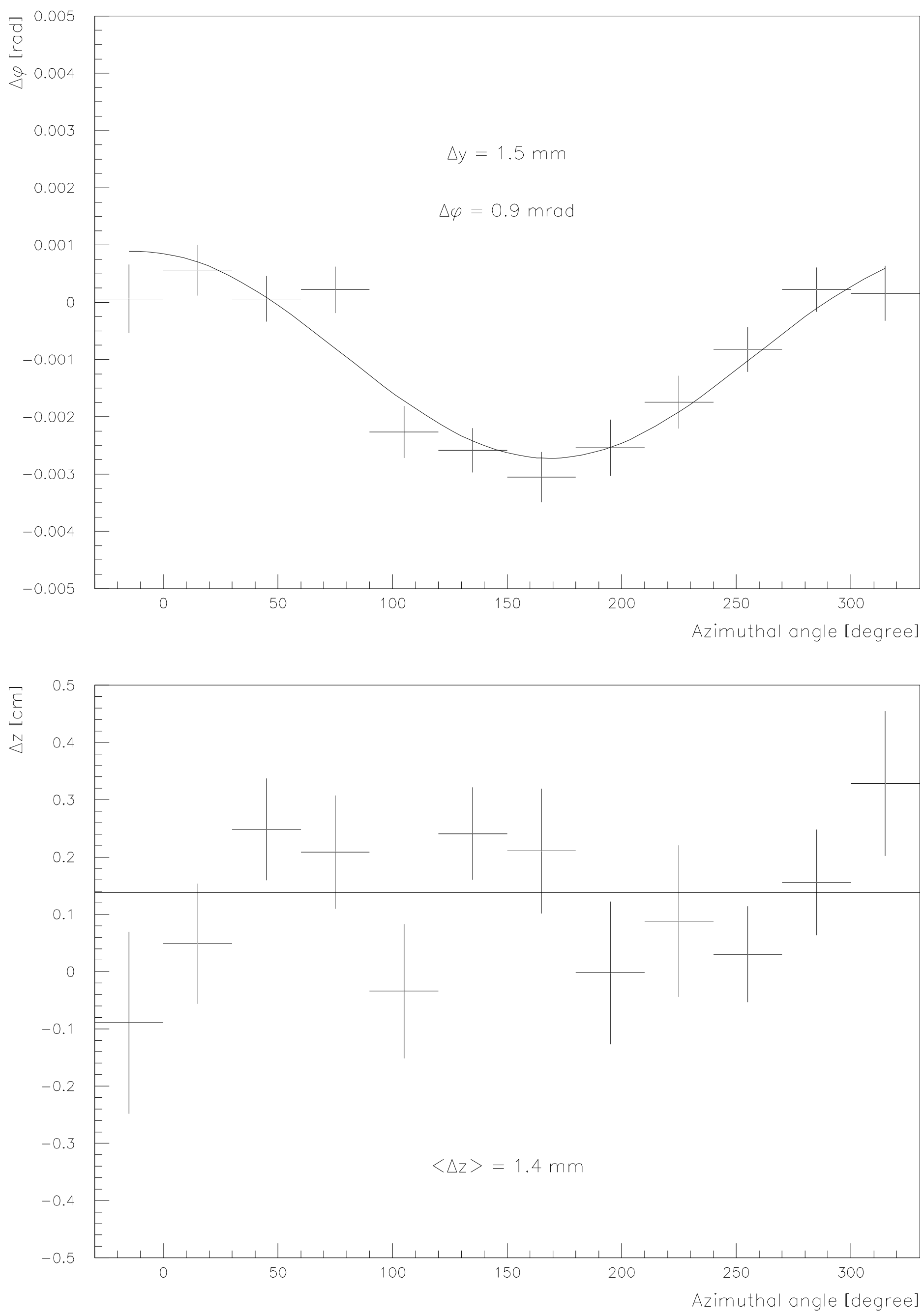

Figure 7: Effects of the new displacement for 1992 runs.

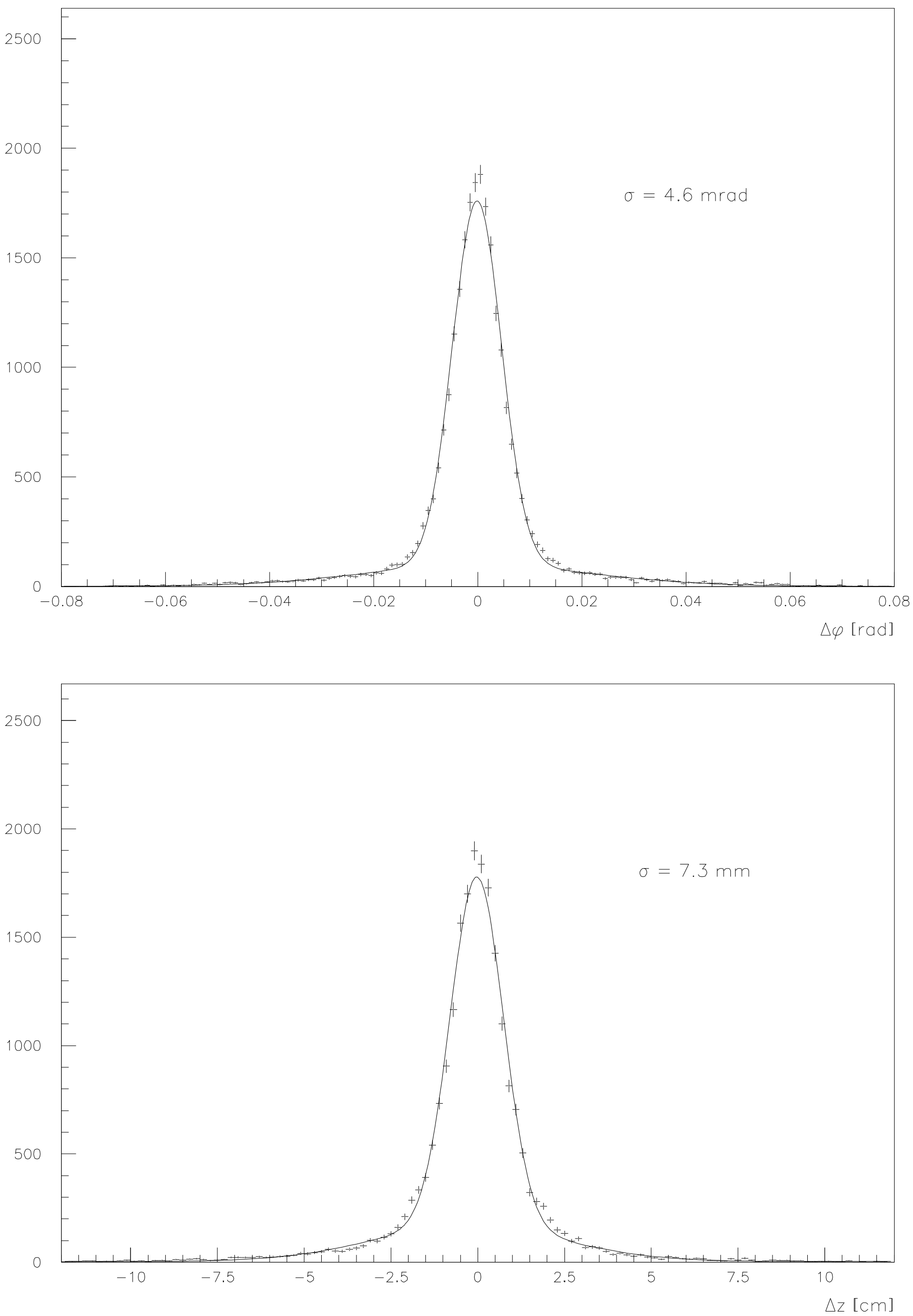

Figure 8: Final impact point resolutions in layer 1 for the selected charged showers.

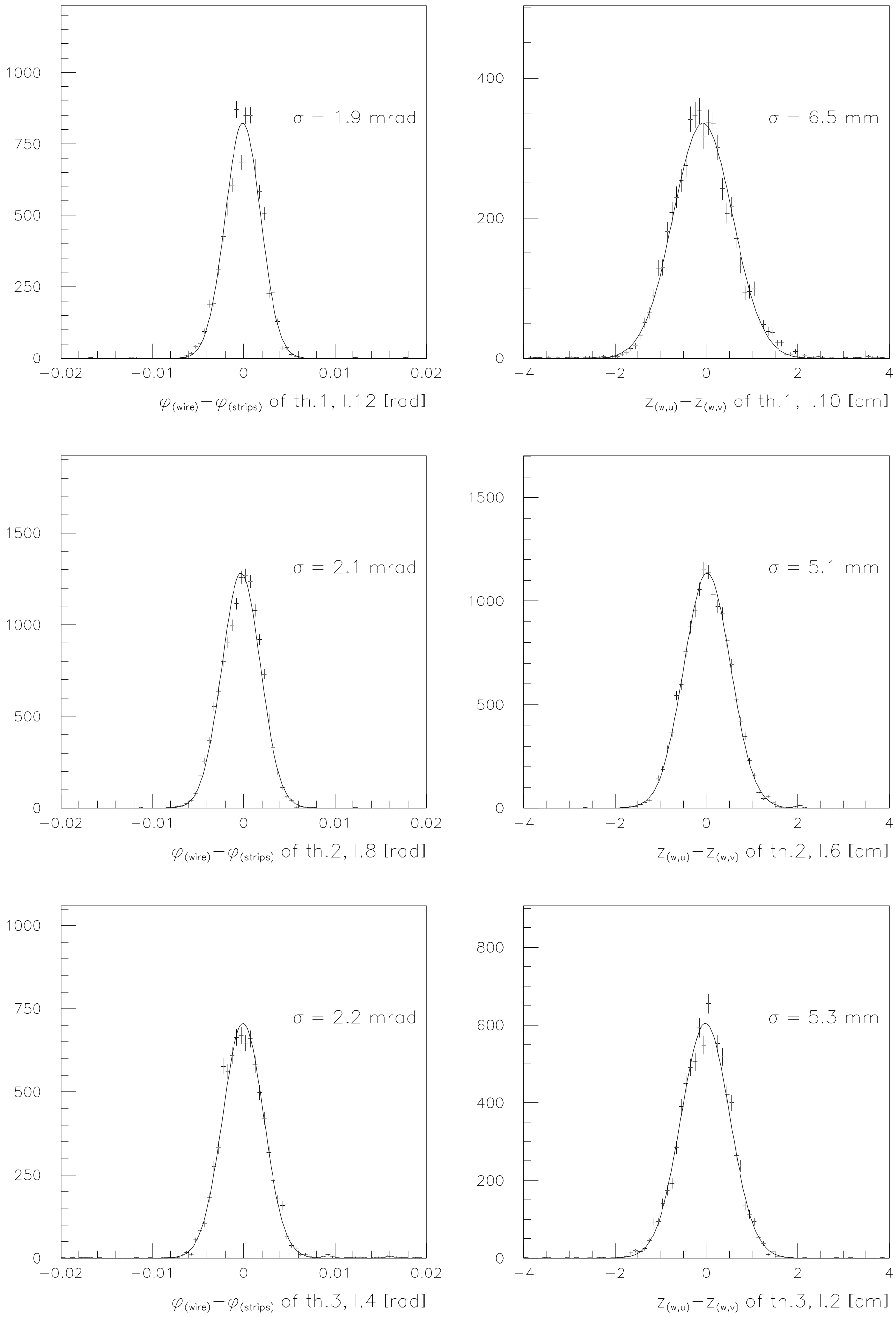

Figure 9: Internal φ- and z-resolutions for different sectors and layers.