HERA-B Note
HERA-B RICH
HERA-B ECAL
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Alignment of RICH and ECAL with reconstructed Čerenkov rings and converted photons

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Abstract

We report on results of an analysis of the RICH-ECAL relative alignment where converted high energy photons were used as sorces of Čerenkov photons. Converted photon candidates as given by the target and calorimeter cluster position were compared to the direction of the conversion products as deduced from the rings, which were found by the stand-alone ring search algorithm on the photon detector of the RICH counter. A good agreement was found with other studies.

1 Introduction

The simplest method for the alignment of the RICH and ECAL is, in case no precise tracking is available[1], the use of straight tracks. These are either charged tracks in the absence of magnetic field, or we can use, with the field switched on, high energetic photons which have converted between the magnet and the RICH. The former approach was used in the study by M. Starič [1]. In the analysis calorimeter clusters defined track candidates, together with the assumption that the track originates in the target. The relative alignment is then found by looking for systematic displacements of the ring on the photon detector relative to the position as expected from the track data. Only single unambiguous Čerenkov photons are used in the analysis thus simplifying the separation of contributions of individual mirror segments to a possible misalignment. The study yielded data on the RICH–ECAL relative alignment over the solid angle simultaneously covered by the two detectors, and was also able to separate the contributions of planar and spherical mirrors.

In the present study of the RICH-ECAL relative alignment, an independent analysis was performed by using the second method. A large set of converted photon candidates (about 1M) was extracted from the magnet on data, recorded in April '99. In this report we shall discuss the data and the method used, present the results, and compare them to the results of two other studies, the one mentioned above, and a study very similar to ours by D. Dujmić [3].

[1]Note that the alignment of the RICH in a spectrometer with good tracking capabilities was covered in Ref. [2]

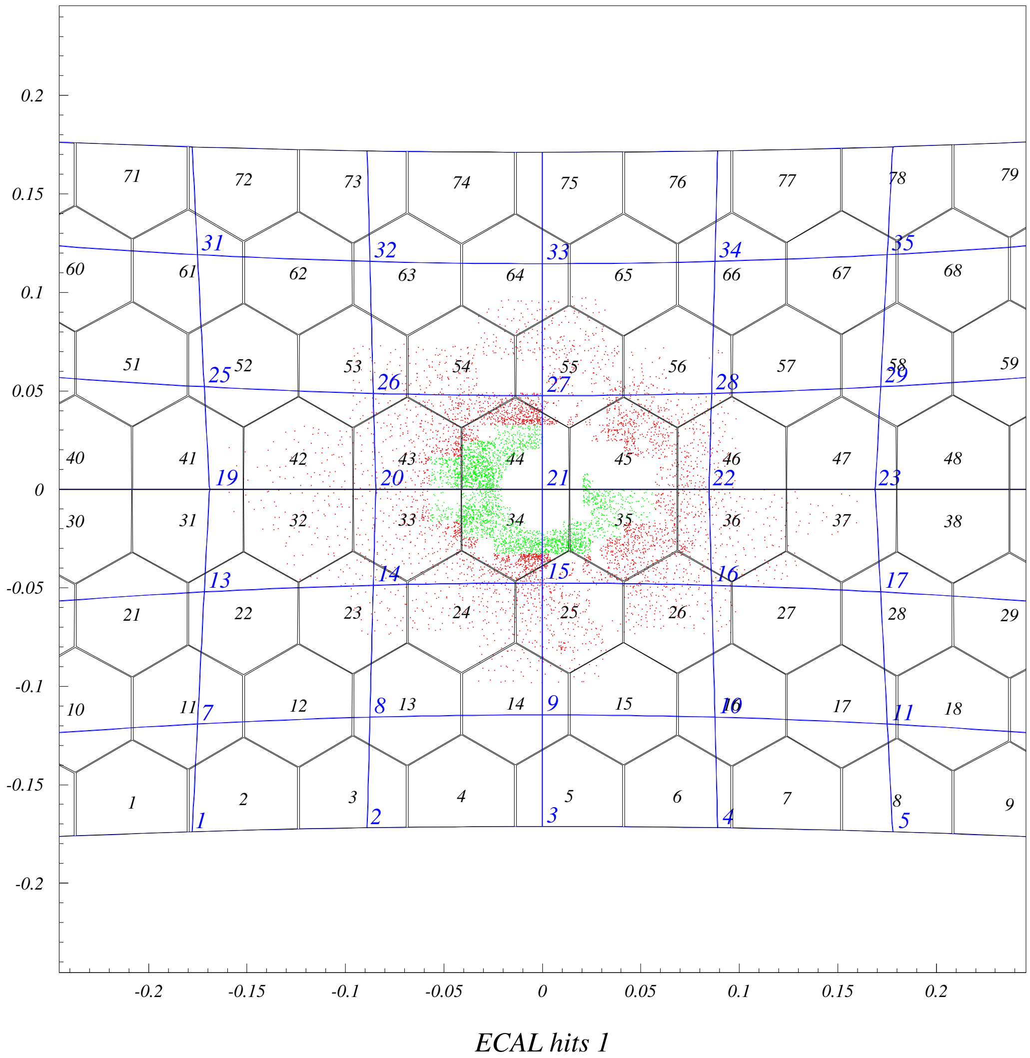

Figure 1: The system of mirrors in the HERA-B RICH: indices of spherical mirrors are given in the middle of the segment, of the planar ones in the lower left corner (the same notation is used as in [1]). The spherical mirror segment 23 coresponds to the mirror (2,3) in the usual, two dimensional notation, and 56 is (5,6). Also shown is the distribution of clusters on the calorimeter.

2 Data selection

Data used are from the runs between 4686 and 5538. They were grouped according to the conditions under which they were recorded (target wire type, trigger type), as can be seen from the table below.

Run numbers	target wire	trigger, rate
4686, 4787, 4804, 4808, 4837,	Inner II	minimum bias, 5 MHz
5113, 5116, 5125 5150, 5153	Inner II	pretrigger, FLTE, 3 MHz
5183, 5184, 5188, 5196	Above I, Below I	pretrigger, 10 MHz
5207, 5219, 5277, 5278, 5284, 5287, 5291, 5299, 5305, 5306	Above I, Below I	pretrigger, FLTE, 10 MHz
5516, 5522, 5536, 5537, 5538	Below I, Inner I	pretrigger, FLTE, 5 MHz

The nominal wire position of a given set of data was used as the coordinate of the origin of tracks[2]. The position of the ECAL cluster was calculated from the data by using the proper ECAL module size as determined by a survey in the May-June shut-down.

The straight track candidates, corresponding to cases where a photon has converted after the magnet, producing an electron–positron pair which did not get bent in the magnetic field, were selected by the following criteria:

- ring was found in the RICH by the standard stand-alone ring search routine RISE [4], by requiring $S/\sqrt{(B)} > 5$
- a cluster found in the ECAL by the CARE algorithm [5] could be associated with the track candidate direction as given by the RICH such that the target-to-cluster direction differed by less than 5 mrad in both projections

The two track segments given by the RICH and by the ECAL were associated by using the MARPLE matching package [6, 7]. Note that a common shift of RICH rings by -0.54 mrad in t_y was applied in order to minimize the overall relative angular displacement of the two systems. This shift is applied in the reconstruction phase and is not noticed by the user [8].

Note also that in the analysis it turned out to be essential to use the proper transformation of the ring center angles to the track parameters, which is not the same as for tracks that were bent in the magnetic field [9].

[2] In cases two wires were used, the average position of the two was used.

3 The method

To investigate the relative alignment of the RICH and ECAL in a given region in the solid angle, typically 20 mrad x 20 mrad or 10 mrad x 10 mrad in t_x and t_y, we plotted the differences Δt_x and Δt_y between the track direction given by the Čerenkov ring and the target-to-cluster direction. To each of the resulting two histograms, we fit a sum of a Gaussian function to describe the signal and a linear function to account for the background (Fig. 2).

In most cases with enough statistics, the distributions look as expected, with the σ of the Gaussian function around 1 mrad, and the error on the mean below 0.2 mrad (Figs. 3, 4, 5). Such data are then used to generate the plots showing the variation of the RICH-ECAL relative orientation over the solid angle covered by a sufficient number of converted photon candidates. In Figs. 6 and 7 only relative orientation is plotted for the cases where the error on the Gaussian mean, given by the fit, was below 0.3 mrad.

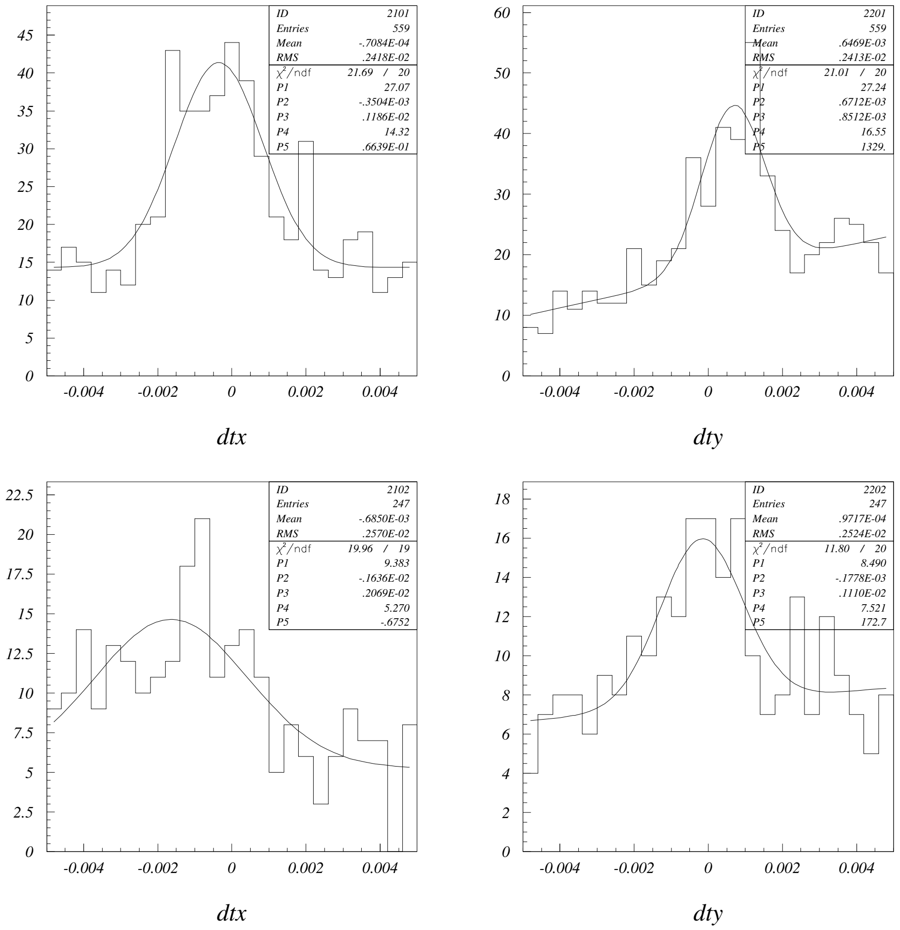

Figure 2: Examples of distributions of the difference of the track direction given by the Čerenkov ring and the target-to-cluster direction. The lower one clearly gives a bad fit, and is not included in the corresponding summary plot, Fig. 7.

For some of the regions, however, at least one of the two distributions becomes less well

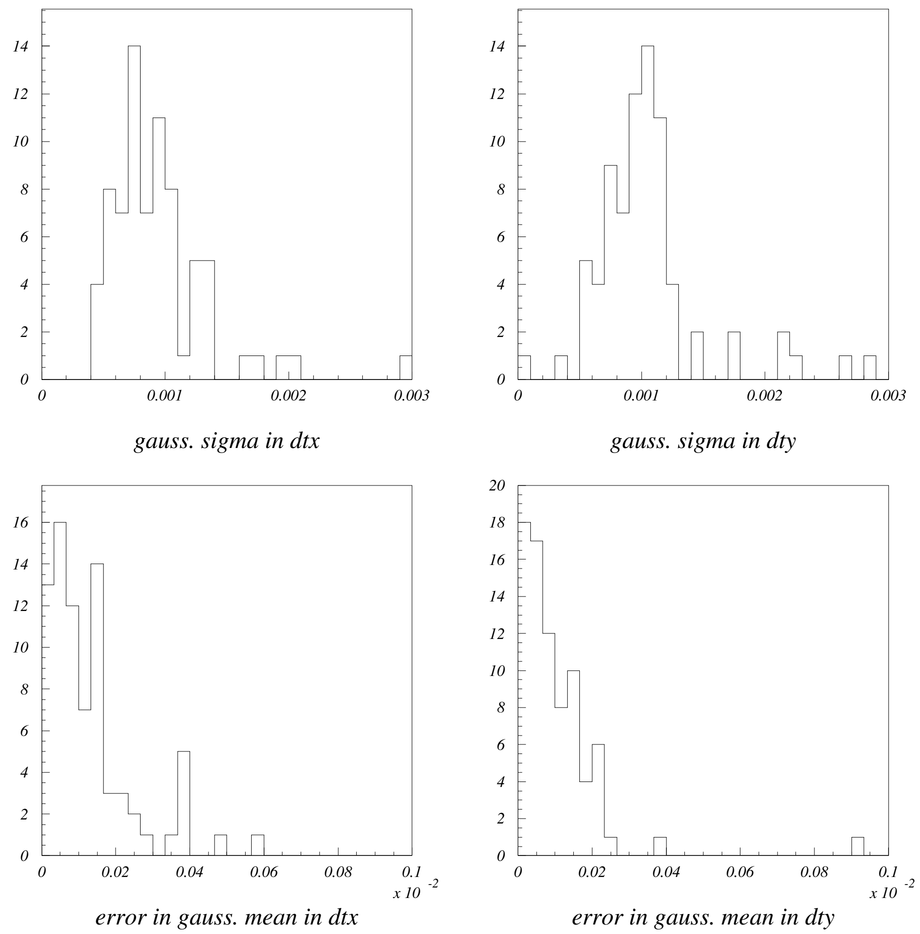

Figure 3: Results of fitting: distribution over the fitted value of sigma, and the error in the fitted value of the Gaussian mean, for both projections.

pronounced, as can be seen in the bottom part of Fig. 2. In such cases the fit errors are large and are therefore not included in the alignment summary pictures, Figs. 6 and 7. Note that the region covered by the spherical mirror 45 coincides with the part of the Inner ECAL which was not fully equipped in the run period in question, and therefore lacks reliable data.

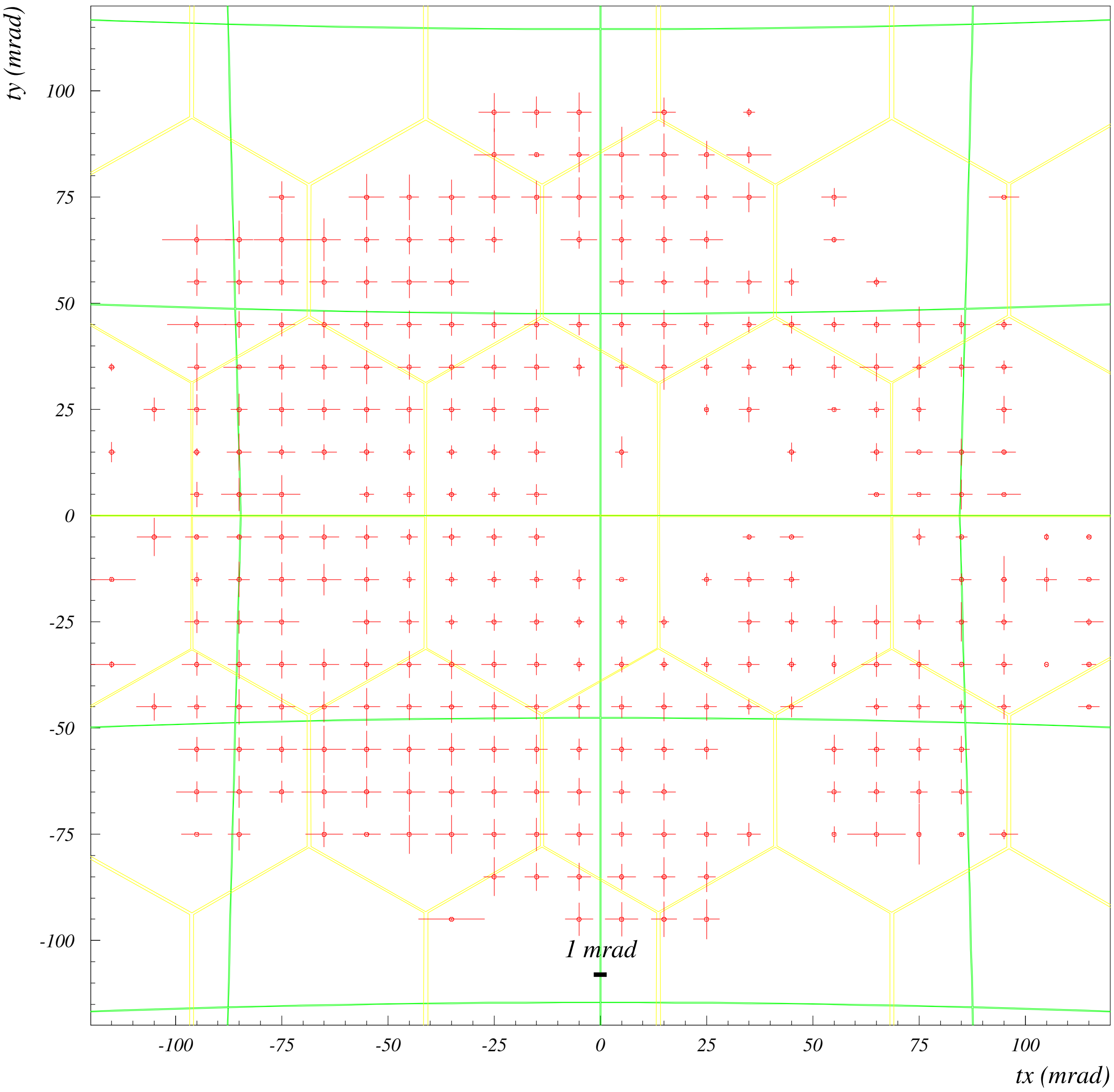

Figure 4: Results of fitting: fitted values of sigma in both projections, shown as crosses for each of the analysed regions. The area with smaller errors roughly coincides with the inner calorimeter region with finer granulation.

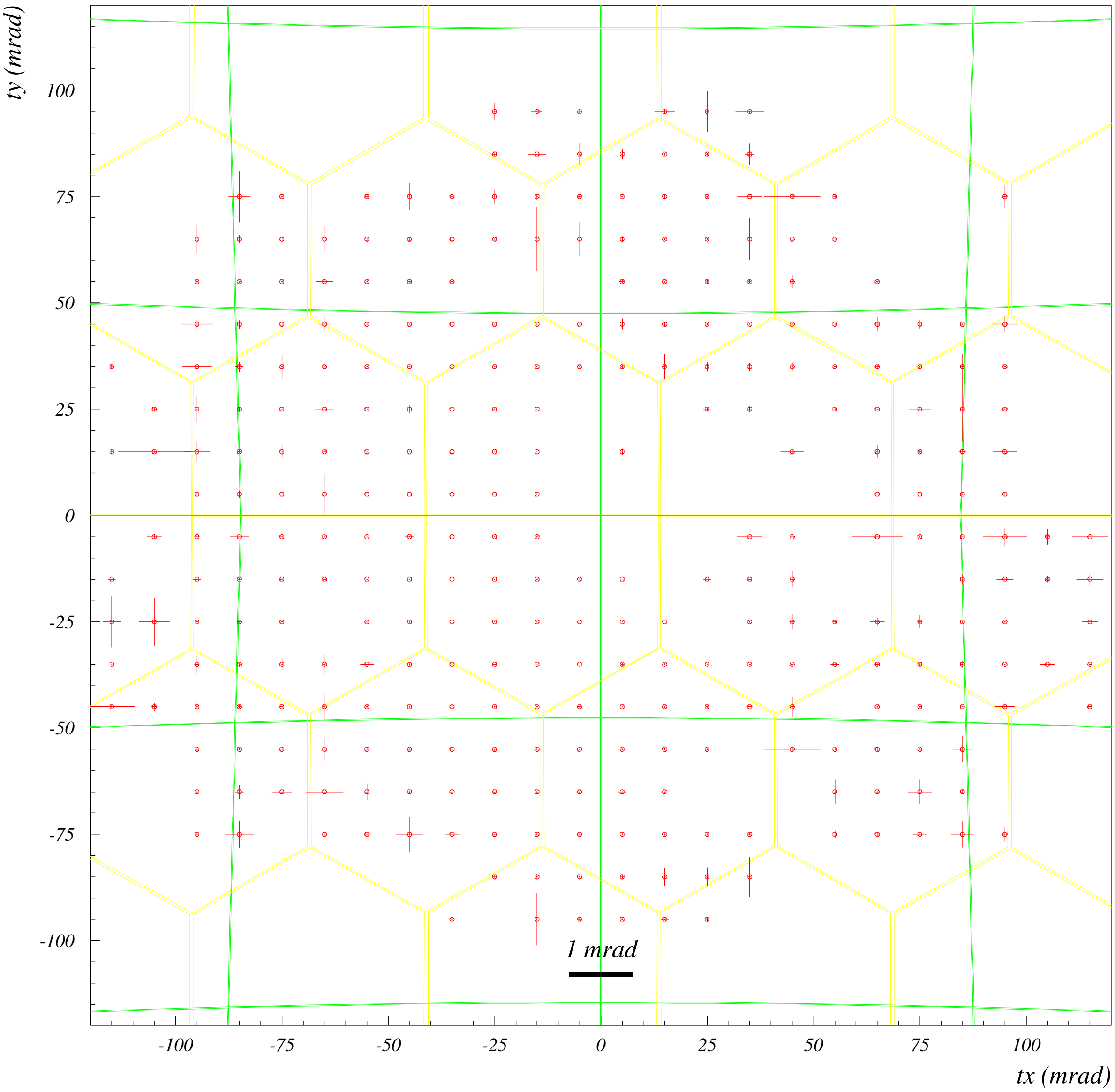

Figure 5: Results of fitting: errors in the fitted values of the Gaussian means in both projections, shown as crosses for each of the analysed regions.

4 Results

4.1 Relative alignment as determined by converted pairs

The method was tried on several sets of data. Figs. 6 and 7 show the results for two different granularities, on triggered data with two wire targets.

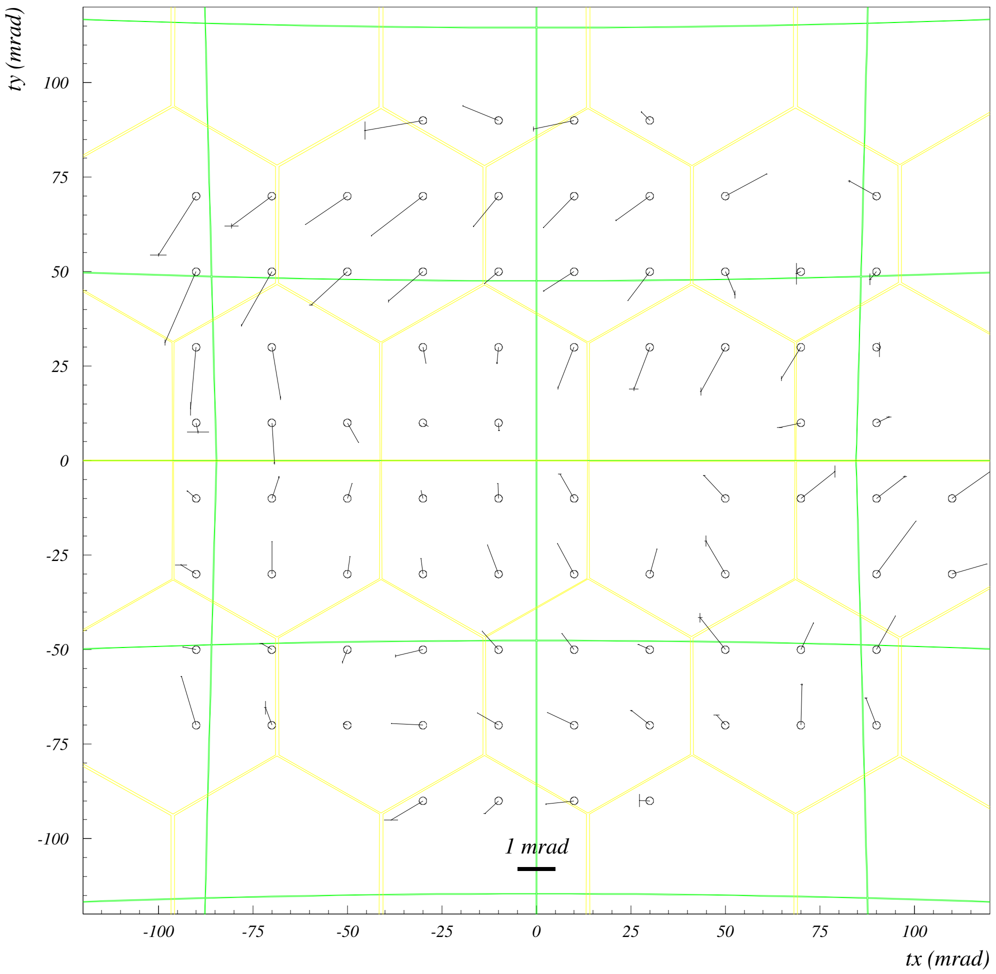

Figure 6: Alignment of the RICH relative to the calorimeter as determined by converted pairs. Only results with fit errors below 0.3 mrad are included, the errors are indicated as crosses on top of the arrows. The scale of the errors differs from the scale of the plot, and is indicated in the lower part of the plot by a line corresponding to 1 mrad. The errors are indicated as crosses on top of the arrows. Data are triggered, taken with the Above I and Below I wire targets at 10 MHz interaction rate.

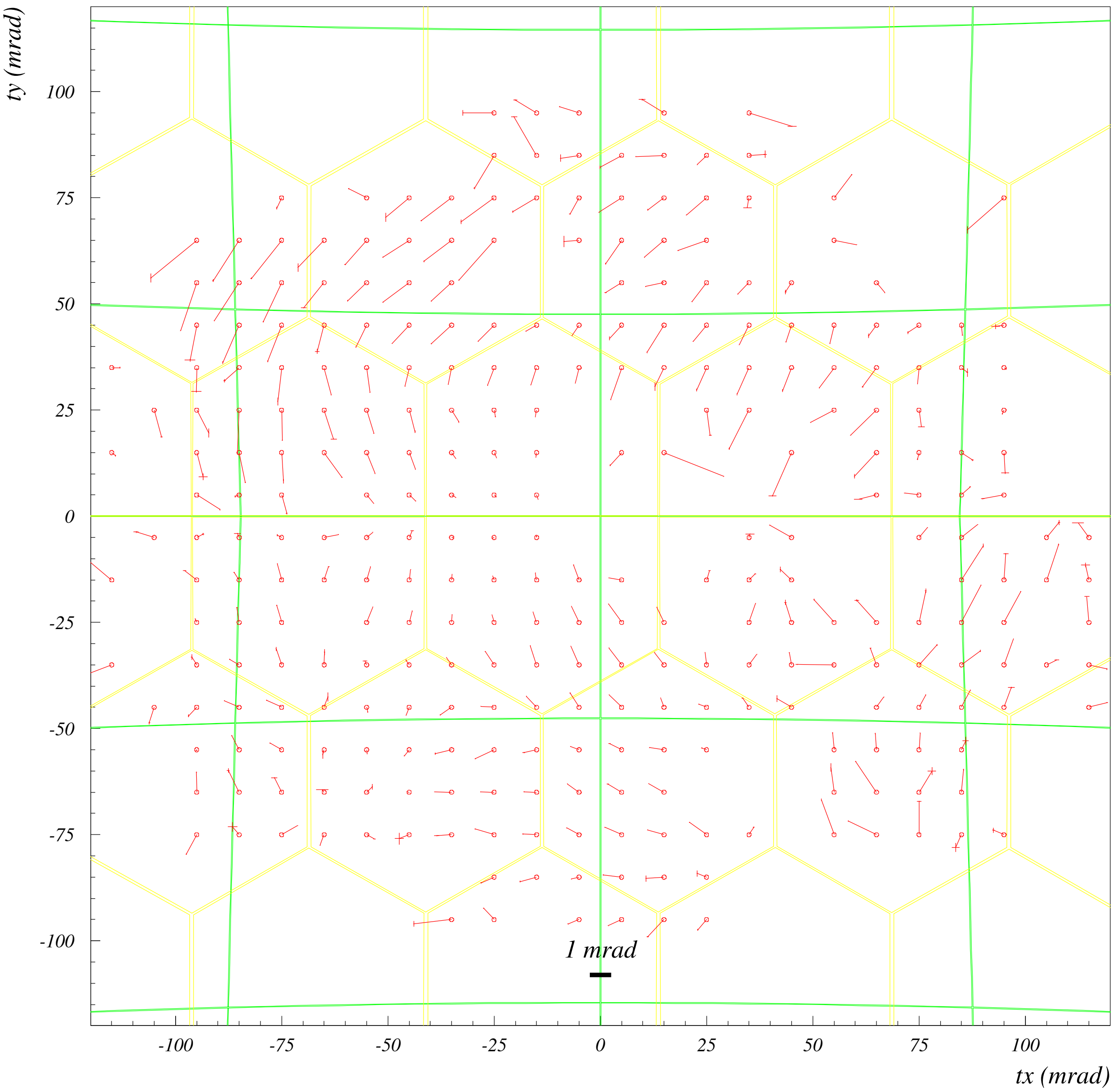

Figure 7: Alignment of the RICH relative to the calorimeter as determined by converted pairs with a finer granularity. Data: same as in Fig. 6. Note that to prevent the figure to become to busy, we have reduced the scale of the arrows as compared to other plots in this report. Again, the absence of the arrow in a region indicates that the distributions could not be fitted well enough.

4.2 Checking the method on data

Since there could be systematic effects related to the running conditions, we have compared the results of analyses of data samples taken without any trigger, with the pretrigger, with the FLTE, as well as data collected with various wire targets. Results for two sets of data are shown in Figs. 8 and 9. All analyses give consistent results, showing no systematic differences.

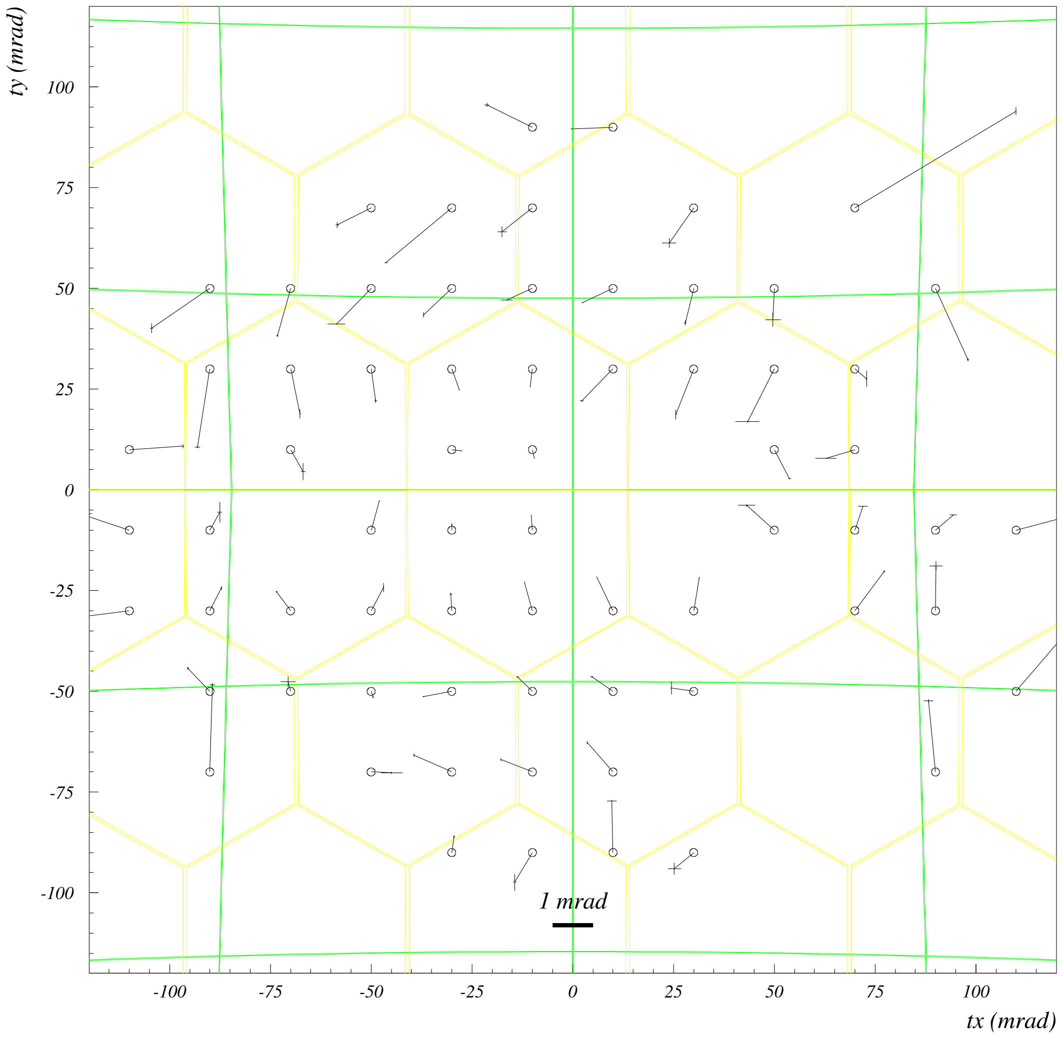

Figure 8: Alignment as determined by different sets of data: minimum bias, recorded with the Inner II wire target.

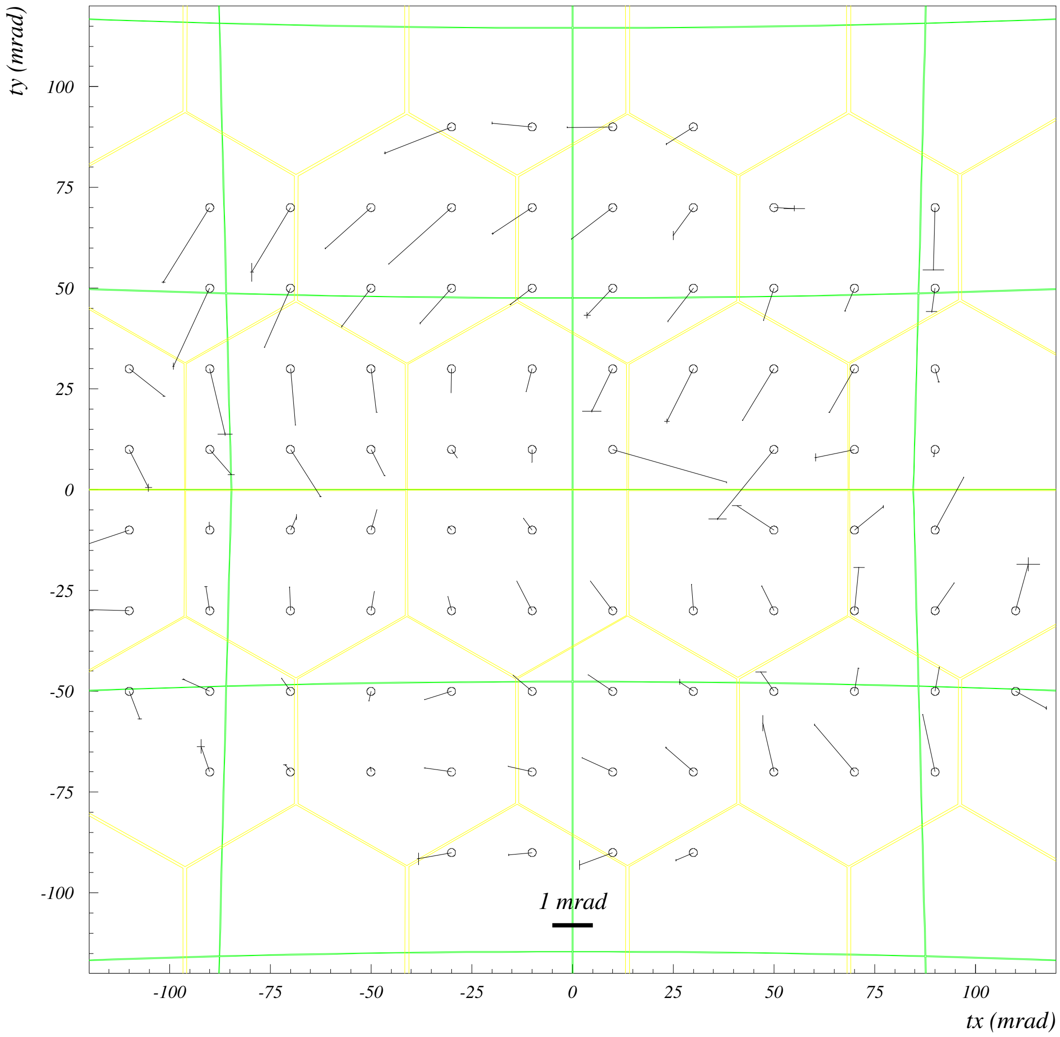

Figure 9: Alignment as determined by different sets of data: FLTE triggered data, with Inner II wire target.

4.3 Impact of dead calorimeter channels

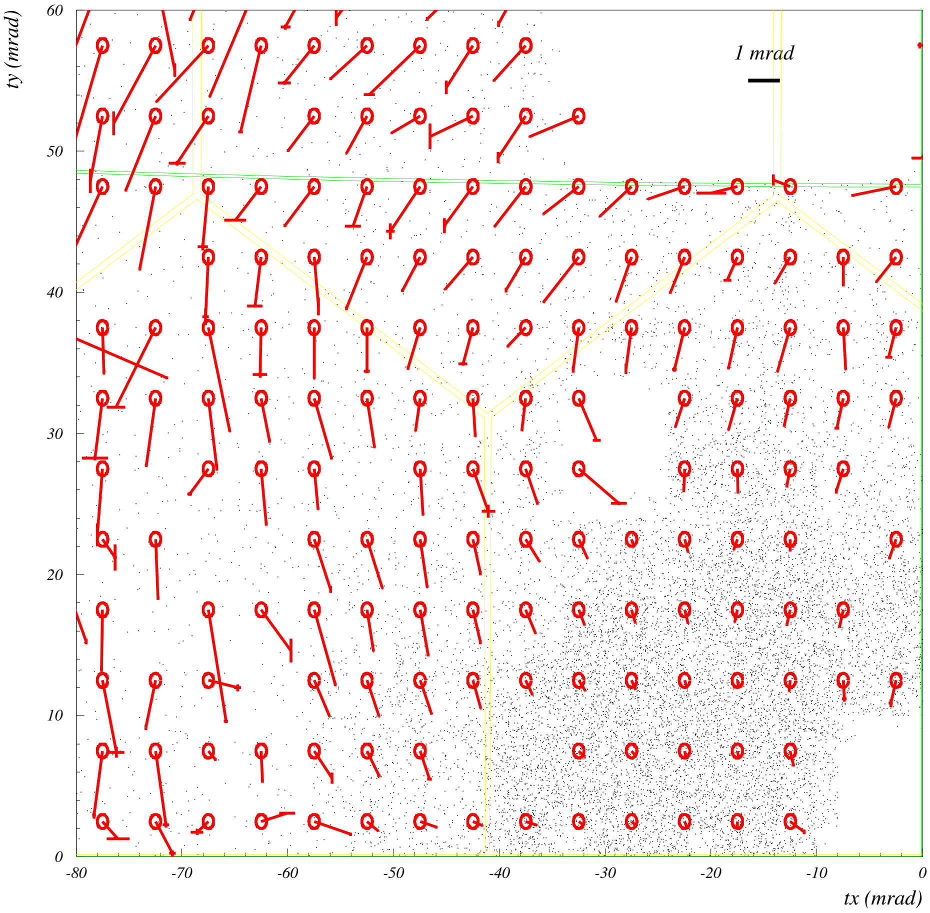

Figure 10: Influence of holes in calorimeter acceptance: expanded view of one of the regions with calorimeter hits superimposed.

In the determination of the calorimeter cluster coordinate no corrections are made for the possible influence of dead modules in the center-of-gravity calculation. Since we plot the difference between the RICH given direction and the direction as deduced from the ECAL, it is easy to see that as a result the relative alignment vector should locally be attracted by the hole in acceptance. In order to check the range of this effect, and a possible influence of missing modules on the alignment parameters, we have chosen an even finer granularity (5 mrad x 5 mrad). To increase the statistics, we have for this particular analysis merged all available data sets. Note that as already discussed above no deviations of alignemnt parameters between various data sets could be observed (Figs. 6 and 8), so that such a merging of data makes sense.

As can be seen from Fig. 10, the missing or dead modules do indeed deform the directional vectors, but this is an effect that remains very local (up to 5mrad), and seems to be averaged out if a larger area is considered. Note that the "bulk" alignment (more than 5 mrad away from the boundary) is consistent with the coarser granularity results.

4.4 Checking the method on simulated data

Possible systematic effects were also checked by using MC generated data. 50k minimum bias events were generated, and subsequently analysed by using the same program as in the case of real data. In the simulation all mirror segments were assumed to be perfectly aligned with the calorimeter.

From the resulting summary plot, given in Fig. 11, we conclude that there are some systematic effects, which are rather small (order 0.1 mrad) in the central region, and increase for outer segments, but clearly more statistics is needed to clear the issue. Note the the relative alignment parameters as observed in real data (e.g. Fig. 6) have different values (typically larger) and directions.

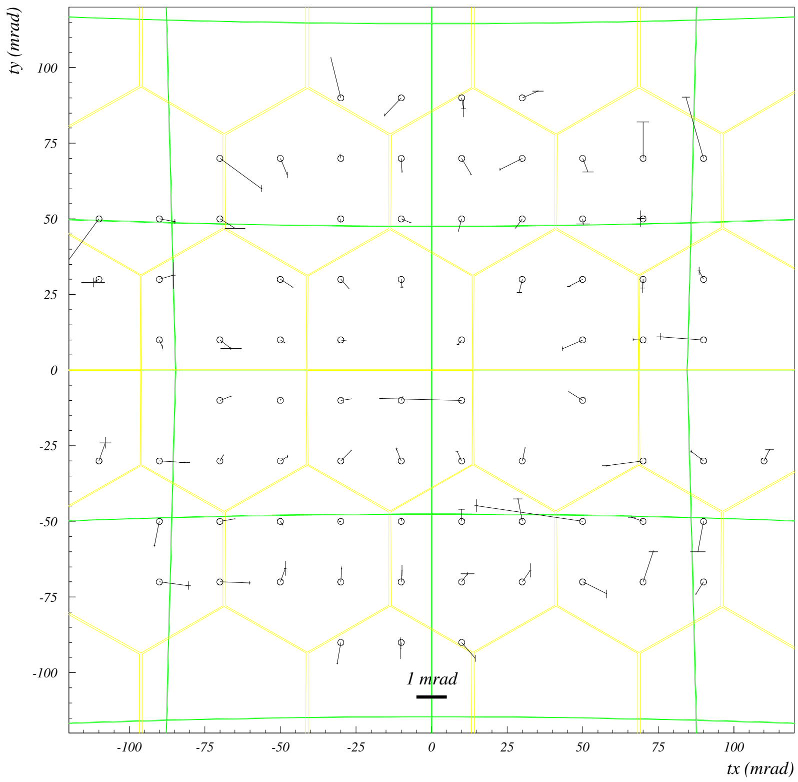

Figure 11: Simulated data: alignment of the RICH relative to the calorimeter as determined by converted pairs. In the simulation all mirror segments were assumed to be perfectly aligned with the calorimeter.

4.5 Comparison with other studies

We first compare in Fig. 12 our results with a similar analysis carried by D. Dujmić [3]. In his case, only rings with ring centers close to the center of individual spherical mirrors were considered. We observe that the results of the two studies agree reasonably well.

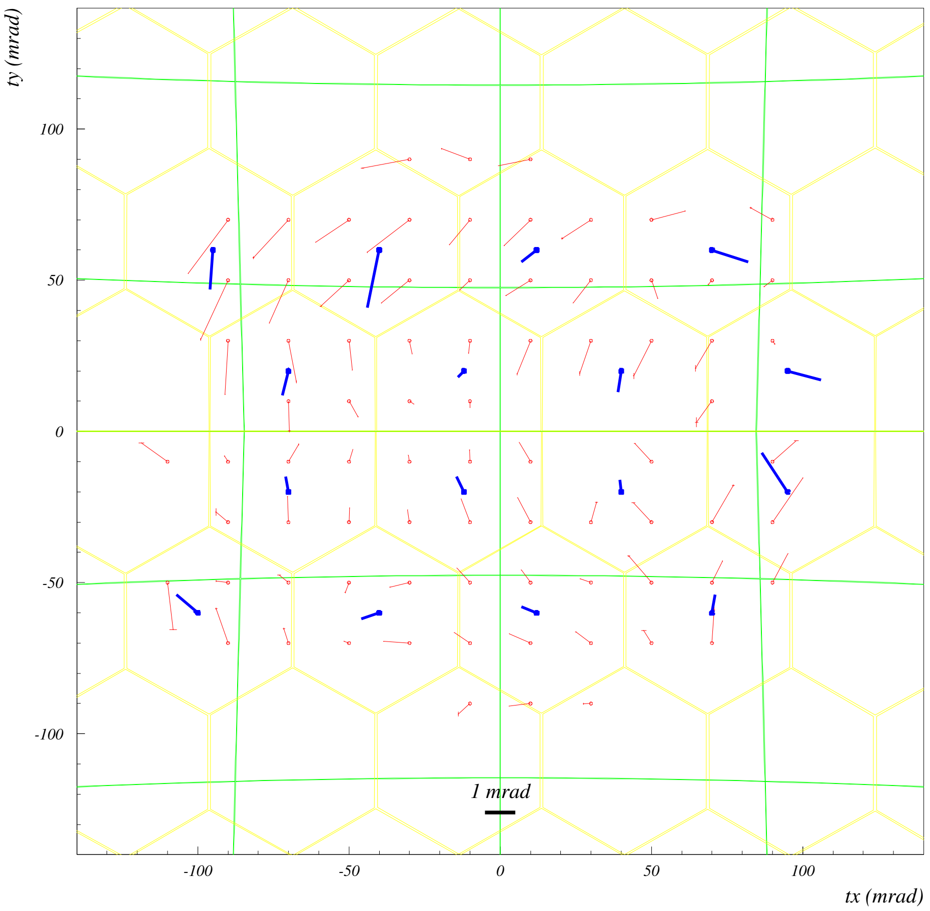

Figure 12: Alignment of the RICH relative to the calorimeter as determined in the present study (thin arrows), compared to the results in Ref. [3] (thick arrows).

To allow for a comparison of the present analysis with the study by M. Starič [1], the results of the latter were corrected by the the common shift of -0.54 mrad in t_y in the same way as the data used in this study (see Section 2).

We observe that in many regions the results of the studies agree reasonably well. Note that the two methods are essentially independent, they only share raw data. To understand where differences between the two might come from, we have to take into account that the method used in the study by M. Starič, which we shall call *alignment with individual unambiguous Čerenkov photons*, distinguishes photons according to their optical path, and thus enables the separation of contributions of individual mirror segments to a possible misalignment. The present study, which we shall call *alignment with full Čerenkov rings*, employs full rings, and should give the same result only in regions where there are no major local variations in the alignment parameters such that the photons belonging to a ring all have similar optical paths. Close to the boundaries of segments with different alignment the differences between the two approaches should be more pronounced, since part of the ring gets shifted in one direction, and the rest in another. Finally, let us note that we intend to try a combination of the two approaches by preselecting clusters where a ring candidate could be associated with a cluster.

5 Summary

To summarize we note that

- The method of comparing the converted pair track direction given by ring position with the direction given by the cluster position looks very promising for alignment checks.
- There are systematic effects in the simulated data which are not yet understood, but seem to be od different nature that the effects observed in the real data.
- The resulting relative alignment does not depend on the way the data were recorded (trigger conditions, rate, target wire type).
- A comparison with two independent analyses shows a good agreement.

References

[1] M. Starič, HERA-B Collaboration meeting, RICH parallel session, July 20, 1999, HERA-B Note 99-135; M. Starič and P. Križan, *RICH-ECAL alignment with data*, IJS-DP-8113.

[2] A. Gorišek, P. Križan, IJS Report, IJS-DP-7688, April 1997, HERA-B Note 97-181; A. Gorišek, Diploma thesis, University of Ljubljana, June 1997; A. Gorišek et al., Nucl. Inst. and Meth. A433, 408-412.

[3] D. Dujmić,

`http://www.desy.de/~ddujmic/ftp/align/exp01/nominal/spherical_mirror_offsets.ps.gz`

[4] R. Eckmann et al., The RISE package

[5] M. Villa, *Progress Report on the ECAL Reconstruction Software.*, HERA-*B* note ECAL-97-135

[6] O. Igonkina, The MARPLE package, HERA-B Note 98-128.

[7] O. Igonkina, *Particle observation with RICH, ECAL, VDS*, HERA-B Collaboration meeting, Software plenary session, HERA-B Note 99-148.

[8] T. Oest, Alignment parameters for the reconstruction.

[9] D. Dujmić, Alignment meeting, Sept. 9, 1999.

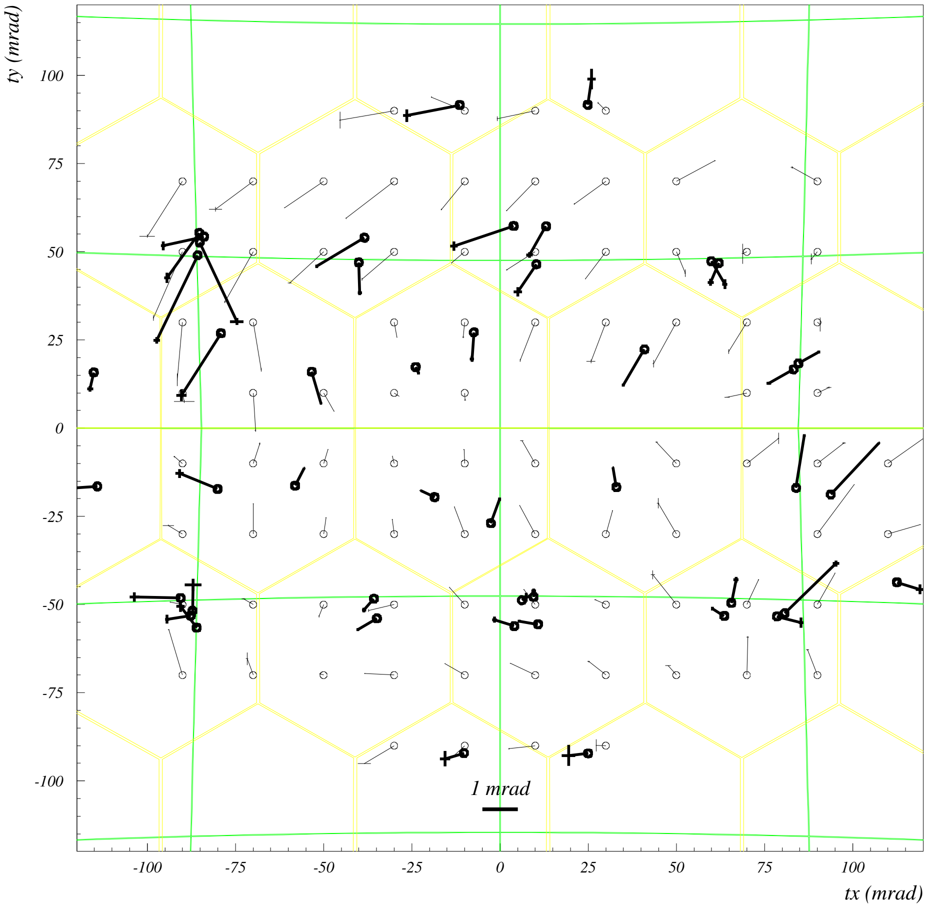

Figure 13: Alignment of the RICH relative to the calorimeter as determined with converted pairs in the present study, Fig. 6, (thin arrows), compared to the results in Ref. [1] (thick arrows). Note that the thick arrows with different directions can have close origins: this just means that part of the ring is reflected by one and the rest by another spherical–planar mirror combination. In this plot results with fit errors below 0.3 mrad are shown.