COMPASS RICH 1
Hints for Mirror Alignment

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P. Schiavon

Abstract

The problem of checking the positioning of more than 100 mirror elements using the data from the experiment is all but trivial.
What is discussed here is an idea to perform this job, based on the pattern recognition and *ring* reconstruction procedure at present under study by the Trieste team.
No conclusions can be drawn at this stage and further development is needed to understand whether it could be eventually used.

1 Introduction :

The mentioned pattern recognition method for the identification of *rings* in the COMPASS RICH 1, is based on a recipe for the Cerenkov emission angle reconstruction originally found in the literature (see e.g. : T. Ypsilantis and J. Seguinot, Nucl. Instr. and Methods, A343 (1994) 30) and already described, in the form adapted to the COMPASS software, in some COMPASS Internal Notes by P. Schiavon, available on the COMPASS Web page ('Studies of the Cerenkov emission angle reconstruction Part 1.' (10/6/97) and 'Part 2.' (27/10/97), 'Pattern recognition for COMPASS RICH 1' Progress Report (February '99)), to which we refer.

We recall here the essential steps :
a) The method assumes that the particle trajectory is known.
b) It assumes that each measured cluster on the detector surface is a photon impact and that all the Cerenkov photons emitted by a particle are originated in the middle of its trajectory inside the radiator;
then the emission polar angles θ and ϕ around the trajectory are computed; this is equivalent to a tranformation from the detector x-y plane to the particle θ-ϕ frame.

In fig.1 a simple event (with only one *ring*) is shown on the detector plane (a) and in the corresponding θ-ϕ plane (b). The Cerenkov photons align along a straight line at constant θ.

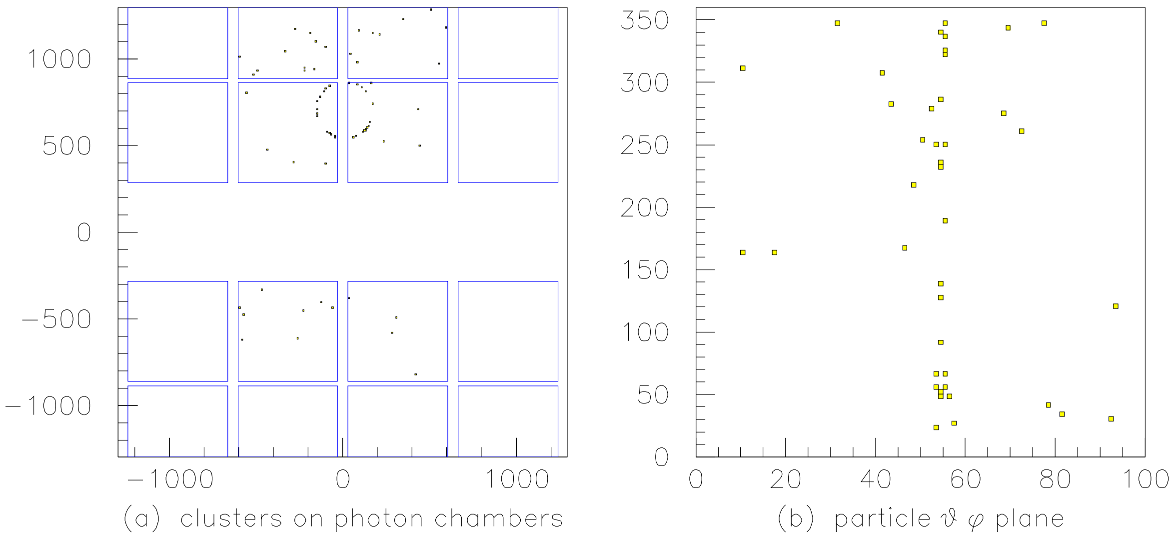

Figure 1: (a) Display of a simple event with only one ring, on the photon chamber planes and (b) the corresponding θ, ϕ angles around the particle trajectory, as reconstructed; the Cerenkov photons cluster at fixed θ. (mrad)

2 The idea :

A sample of MC (COMGeant) events (LEPTO generated) is used in the simulation studies.
The photon distribution on the mirrors is shown in fig.2 (a), where the whole mirror (up and down) surface has been divided into 144 square elements, roughly corresponding to the real hexagonal mirror elements. It is evident that the peripheric elements are very poorly illumanated.
The corresponding distribution of the photons on the photon chambers is shown in fig.2 (b).

In fig.3(b) we present the same distribution as in fig.1(b), but for a large sample of particles, hitting all the possible positions on the mirrors, as shown in (a); in (c) we plot versus ϕ the average value of the difference θ_{photon}-θ_{ring}, where θ_{ring} is the reconstructed θ emission angle for each particle. The fit is done to a $cos(\phi)$ shape in which the amplitude (p_1), the phase (p_2) and a (unessential) vertical shift from 0. (p_3) are determined.
In this case the mirrors are perfect mirrors and the resulting fit is essentially a straight line.

On the other hand, a selected sample of particles can be used to illuminate only one mirror element at a time; In fig.4(a) we show the particle distribution on the mirror element; in (c) the same fit as in fig.3(c), with the same comments; it has been checked that this feature doesn't depend on the mirror element position or on the particle parameters.
In fig.4(b) are plotted the cumulative distributions of the experimental distribution of (c) and, superimposed, that of a flat distribution; this is to appreciate the difference by eye; the probability printed is the probability of the Kolmogorov test for the two distributions being the same (uniform).

The position of each mirror element is defined (as far as this exercise is concerned)

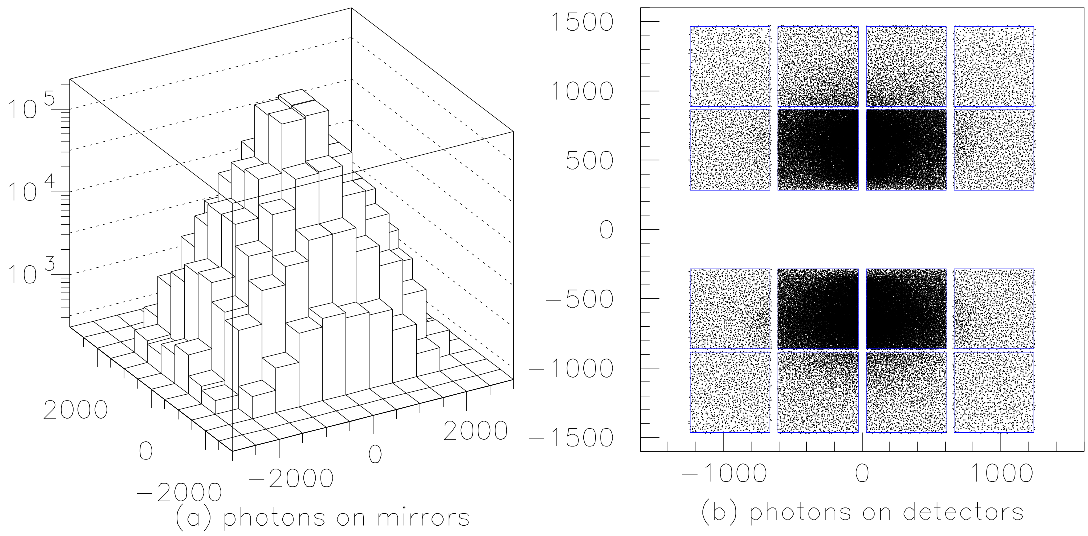

Figure 2: (a) The photon distribution on the mirrors for MC events; the mirror (up and down) surface has been divided into 144 square elements, roughly corresponding to the real hexagonal mirror elements. In (b) the photon distribution on the detectors.

by 6 parameters : the position of the centre of the reflecting surface (x_{me}, y_{me}, z_{me}), the direction of the normal to the centre (α_{me} in the xz plane and β_{me} in the yz plane) and the radius of curvature (R_{me}).
We assume that a mirror element is misaligned when one of these parameters is not correctly set.
To study the problem, we move one of the parameters at a time, noting that, when R_{me} is varied, x_{me}, y_{me}, z_{me} are kept fixed and the centre of curvature is then moved.
Moreover, we assume that the mirror wall can be displaced as a whole with respect to the trackers (Main Reference) or/and the photon chambers as a whole with respect to the trackers.

In fig.5 are shown the distributions of fig.3(c) for nine different mirror element positions when the x coordinate of the photon chamber system is varied by Δx_{det}=+2. mm. The fits show a constant phase, a shift compatible with 0. (as expected) and an amplitude wich is a function of the mirror element position. The positions have been selected to have a reasonable statistics in all of them and correspond to x_{me}, y_{me} = (0.,100.), (600.,100.), (1200.,100.), (0.,500.), (600.,500.), (1200.,500.), (0.,1000.), (600.,1000.), (1200.,1000.).
In fig.6 are shown the corresponding cumulative distributions and the Kolmogorov probabilities, which quantify the amount of misalignment.

In fig.7 are shown the same distributions when the angle α_{me} is moved by $\Delta\alpha$=+0.0002 rad; the general behaviour is much the same, but the common phase is different from the previous case.
In fig.8 the angle β_{me} is moved by $\Delta\beta$=+0.0002 rad, with similar comments.
In fig.9 the effect of varying R_{me} by 1% of its nominal value (ΔR=+66. mm); it is, as already known, relatively less important.
Note that, in all cases, when the sign of the variation is opposite, the phase of the fit changes by 180. deg.

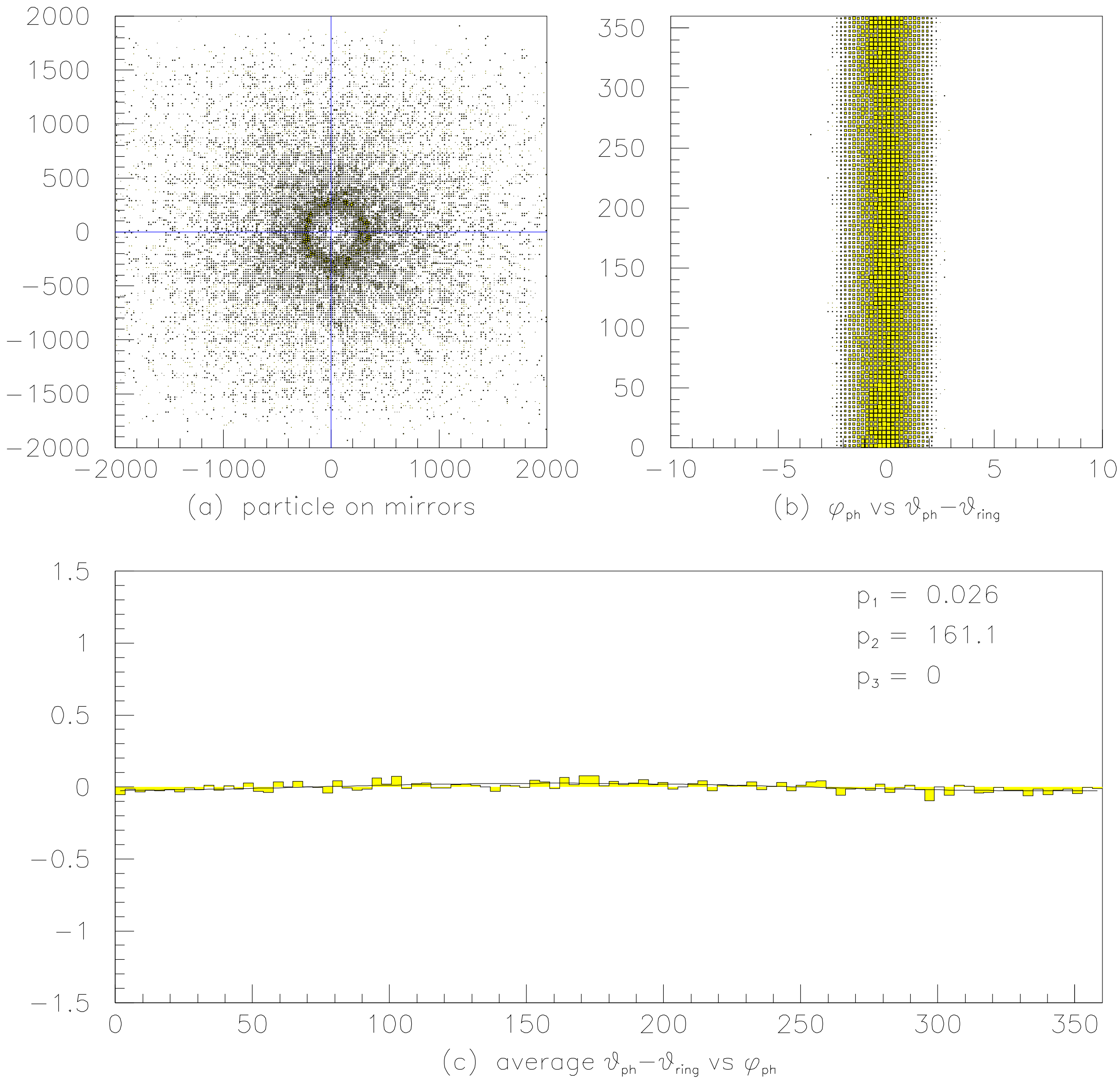

Figure 3: (a) Particle distribution on mirrors for a full MC sample; in (b) the photon distribution in the θ, ϕ plane relative to each particle; in (c) the average value of the difference $\Delta\theta$=θ_{photon}-θ_{ring}; the fit is to a $cos(\phi)$ shape.

In fig.10 (a)(b)(c)(d)(e)(g)(h) we show, for the fixed mirror position (0.,100.), the separate effects of ΔR, $\Delta\alpha$, $\Delta\beta$, Δx_{det}, Δy_{det}, Δx_{mir} and Δy_{mir}; in (f) the combined effect of ΔR, $\Delta\alpha$, $\Delta\beta$ and in (i) the combined effect of all five variations.

The sample used consists of $\sim$ 50 000 particles; note that what is used is any reconstructed particle with no further constraint.
To have a significant statistics also on the peripheric mirror elements, we need to run at least a factor of 100 more events (assuming the same particle multiplicity in the real life), which means of the order of 5 millions events; this is a non negligeable job, but still affordable.

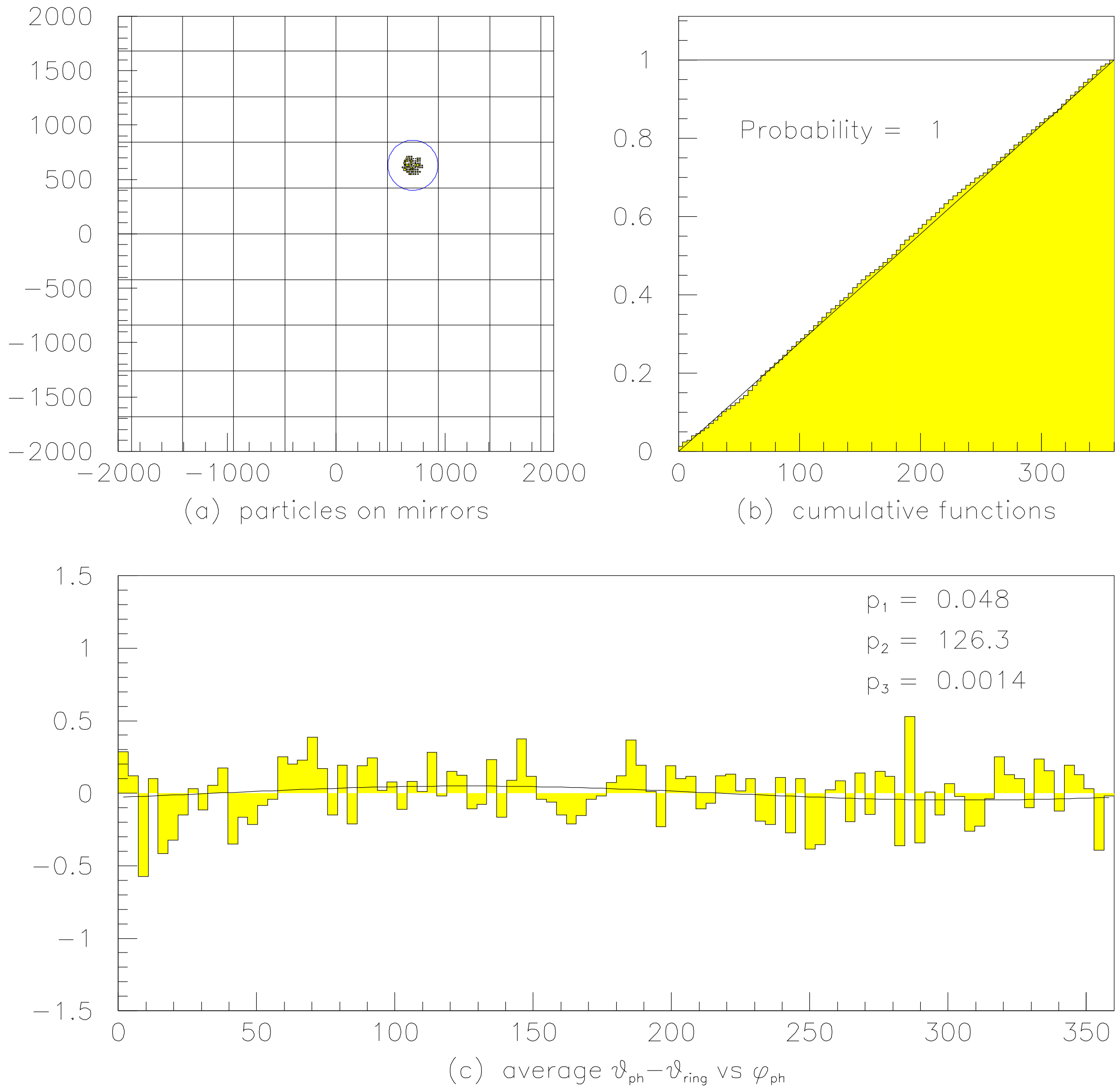

Figure 4: (a) and (c) as in fig.3; in (b) the probability of the Kolmogorov test for the distribution in (c) being a uniform one.

3 Conclusions :

The method seems to be promising and further studies will follow; but it is clear from now that the various contributions to the misalignment will be hardly separable. Moreover what is crucial to understand is at what extent the interference among the different causes of misalignment will cancel the effect and then the significance of the procedure.

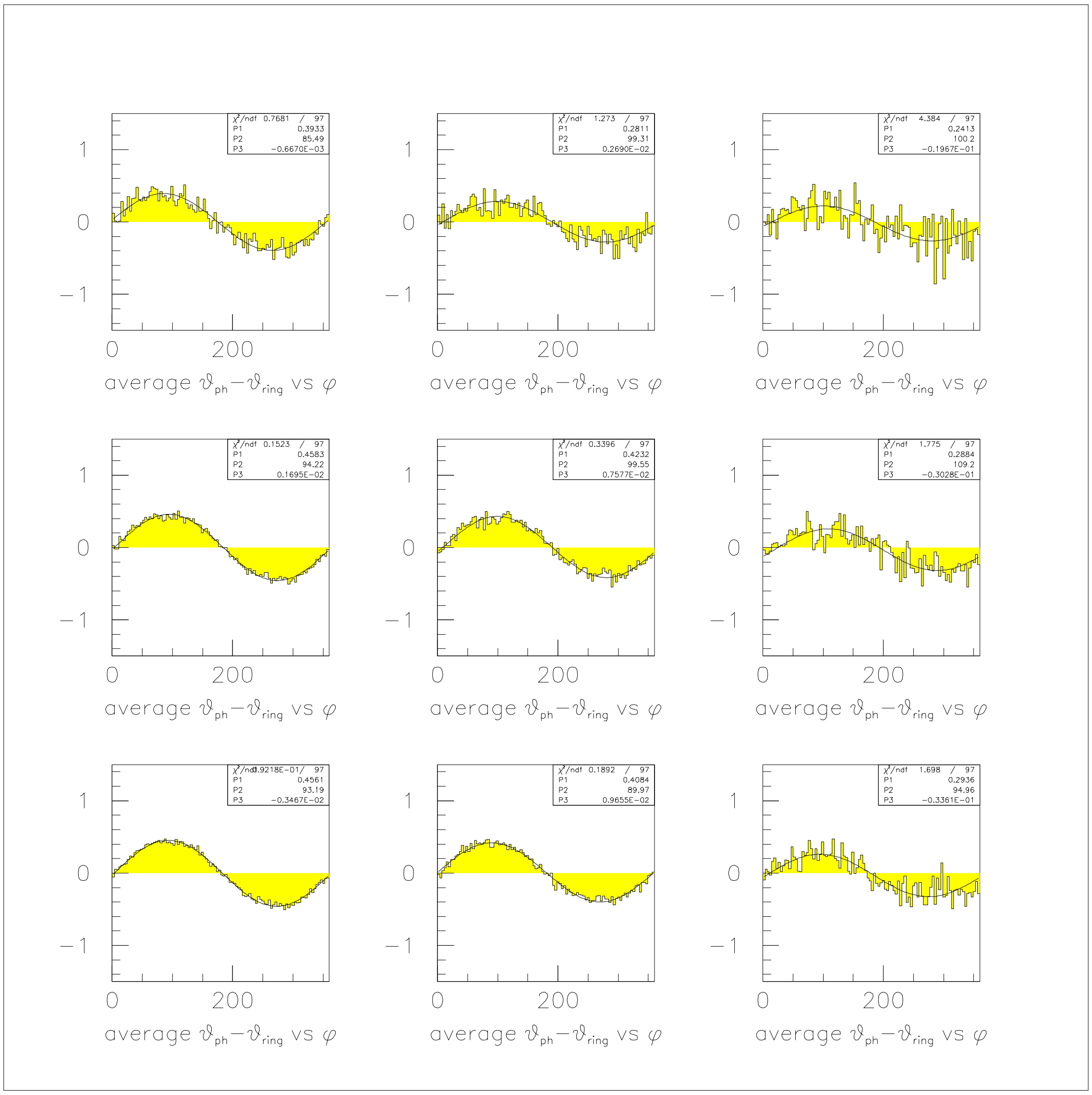

Figure 5: $\Delta\theta$ vs ϕ for nine different mirror element positions when the x coordinate of the photon chamber system is varied.

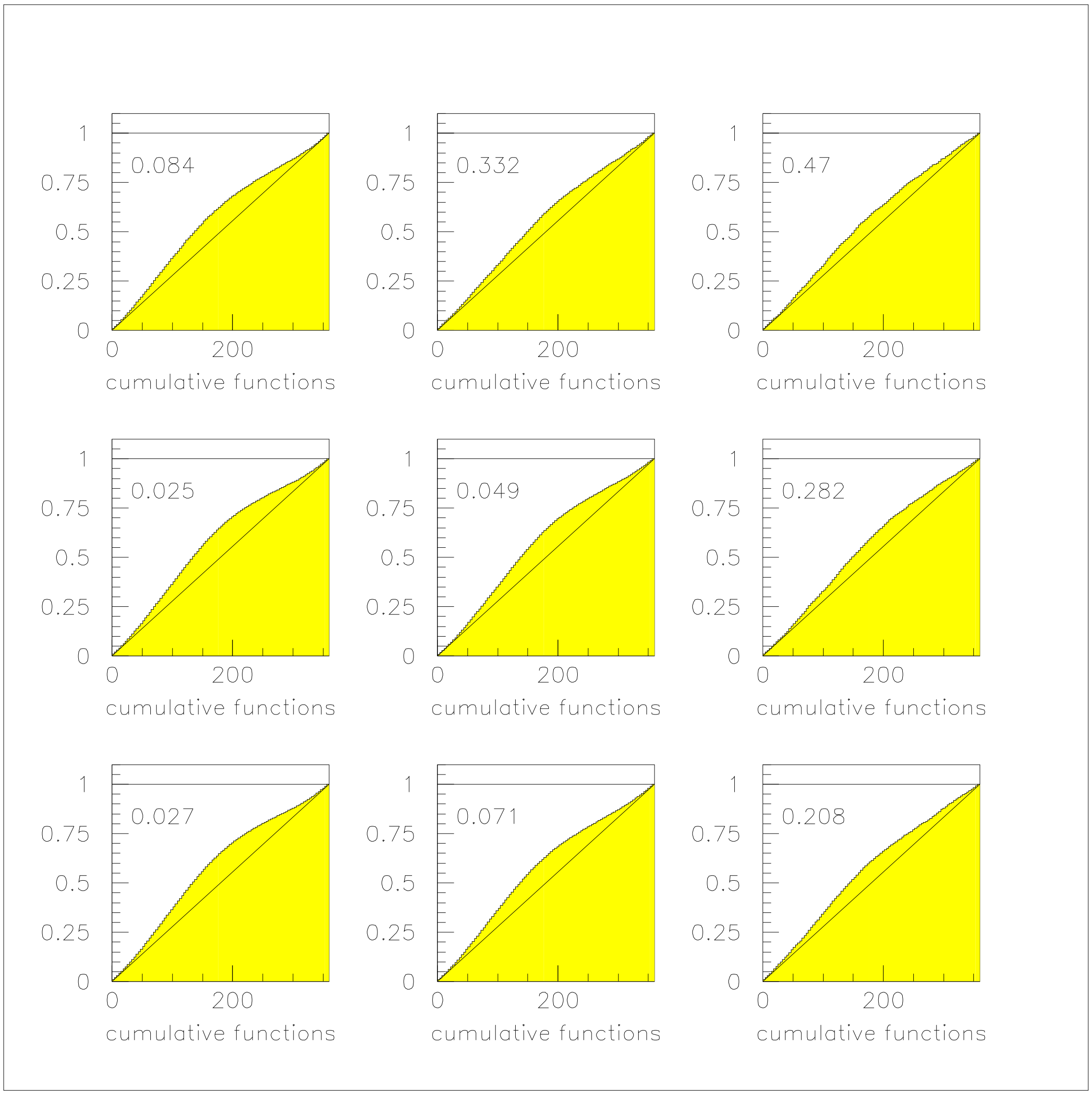

Figure 6: The cumulative distributions and the Kolmogorov probabilities for the distributions of fig.5.

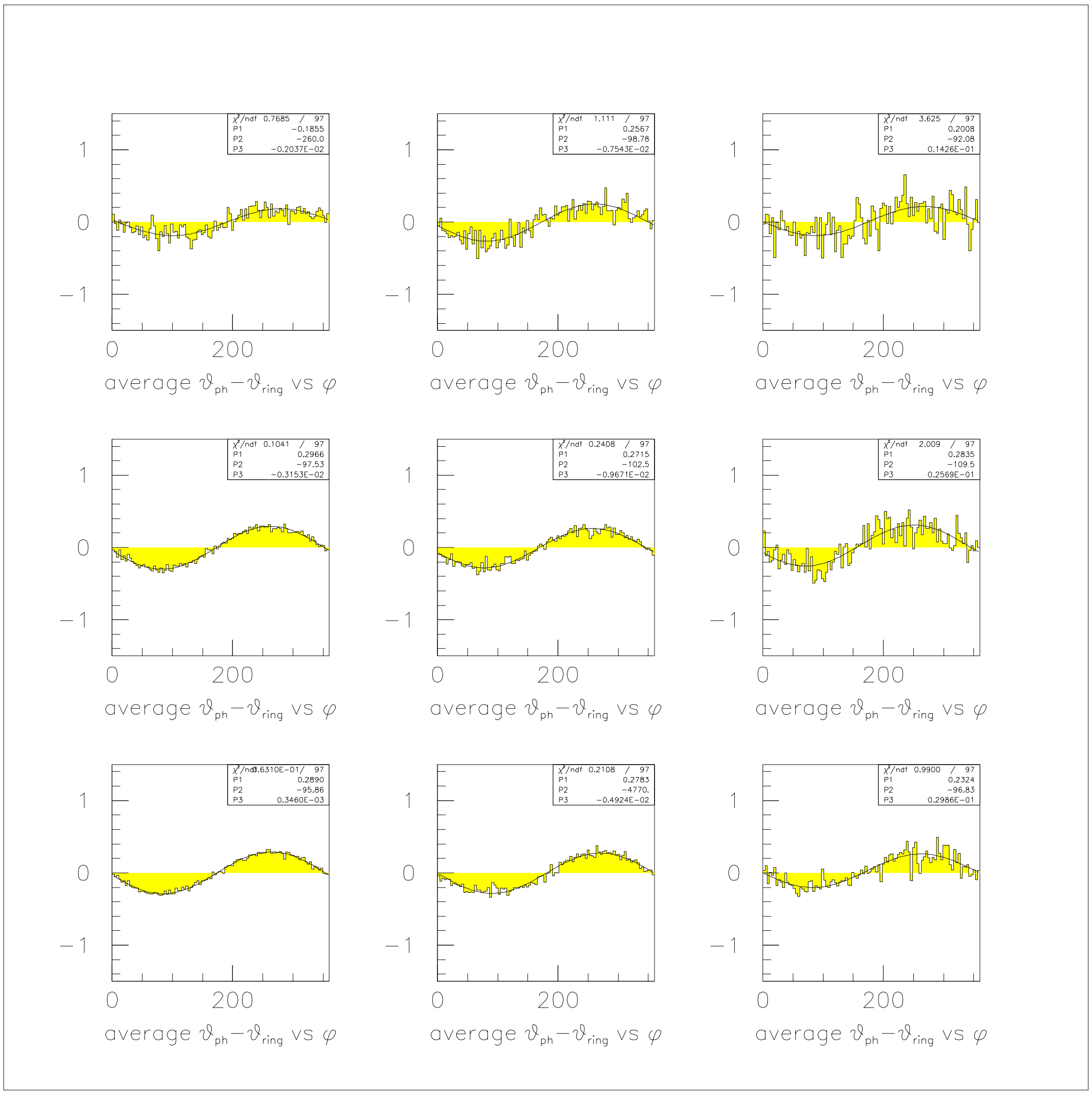

Figure 7: $\Delta\theta$ vs ϕ for the same nine mirror element positions when the angle α_{me} of the mirror element is varied.

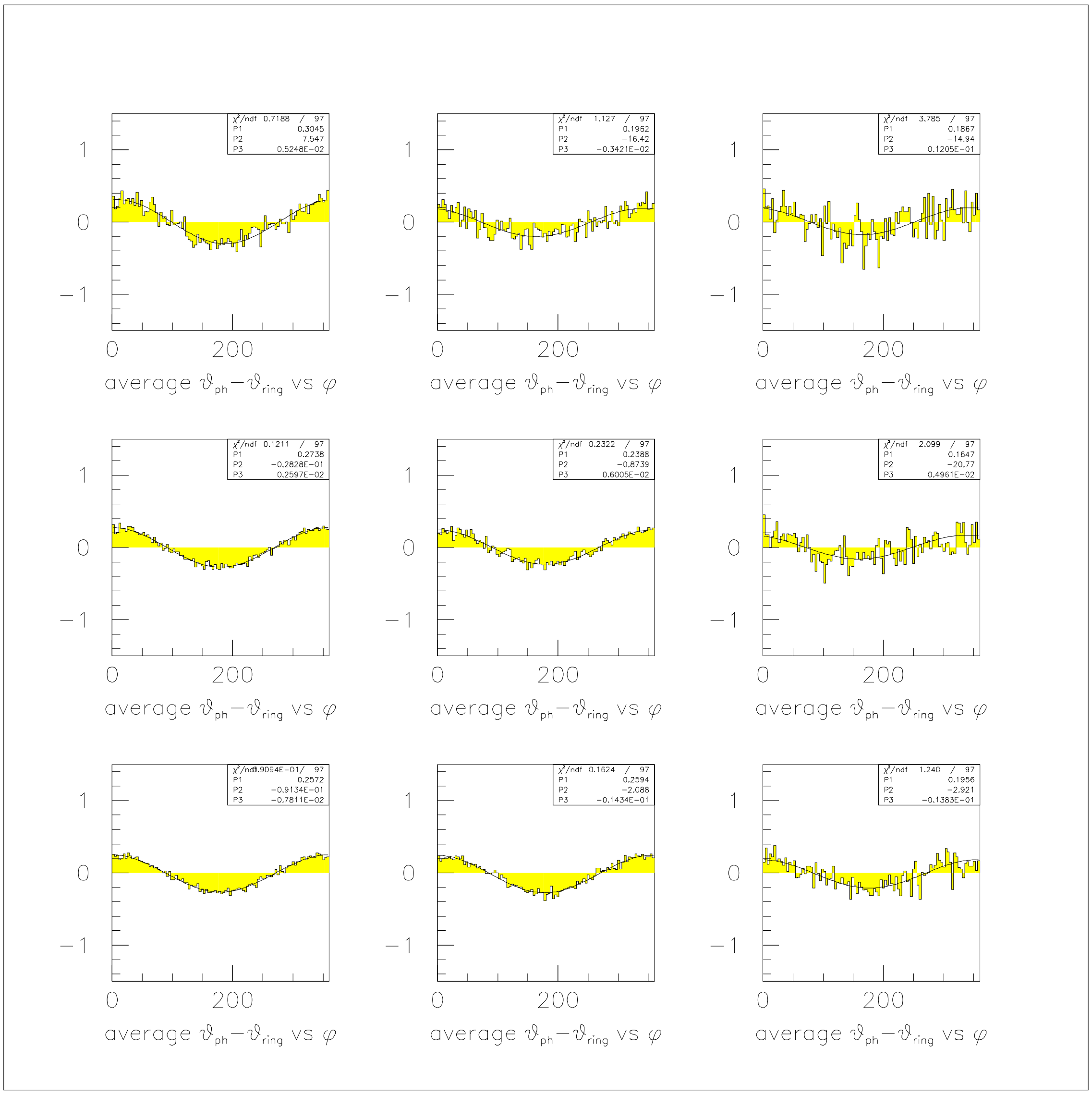

Figure 8: $\Delta\theta$ vs ϕ for the same nine mirror element positions when the angle β_{me} of the mirror element is varied.

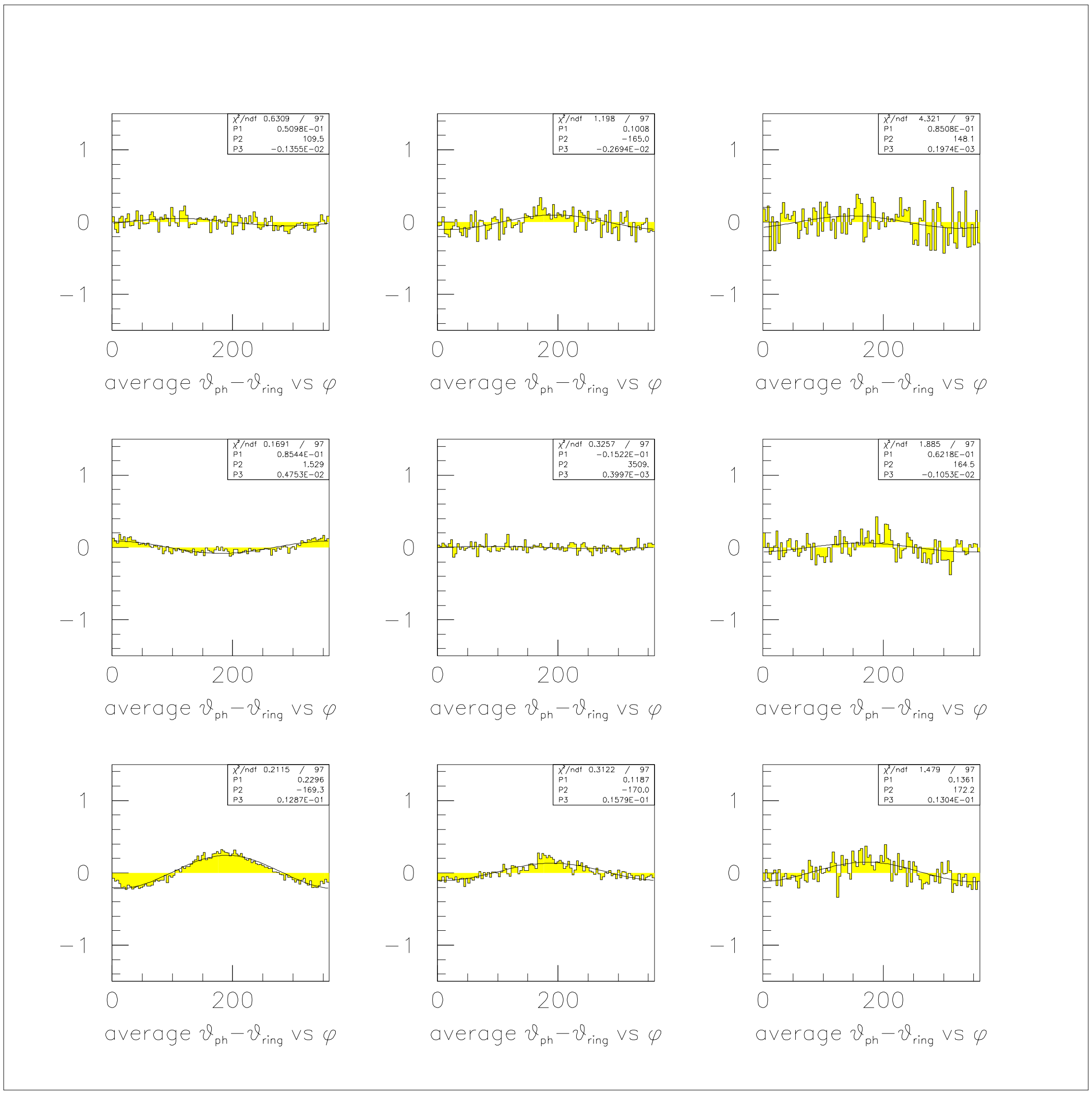

Figure 9: $\Delta\theta$ vs ϕ for the same nine mirror element positions when the radius of curvature of the mirror element is varied.

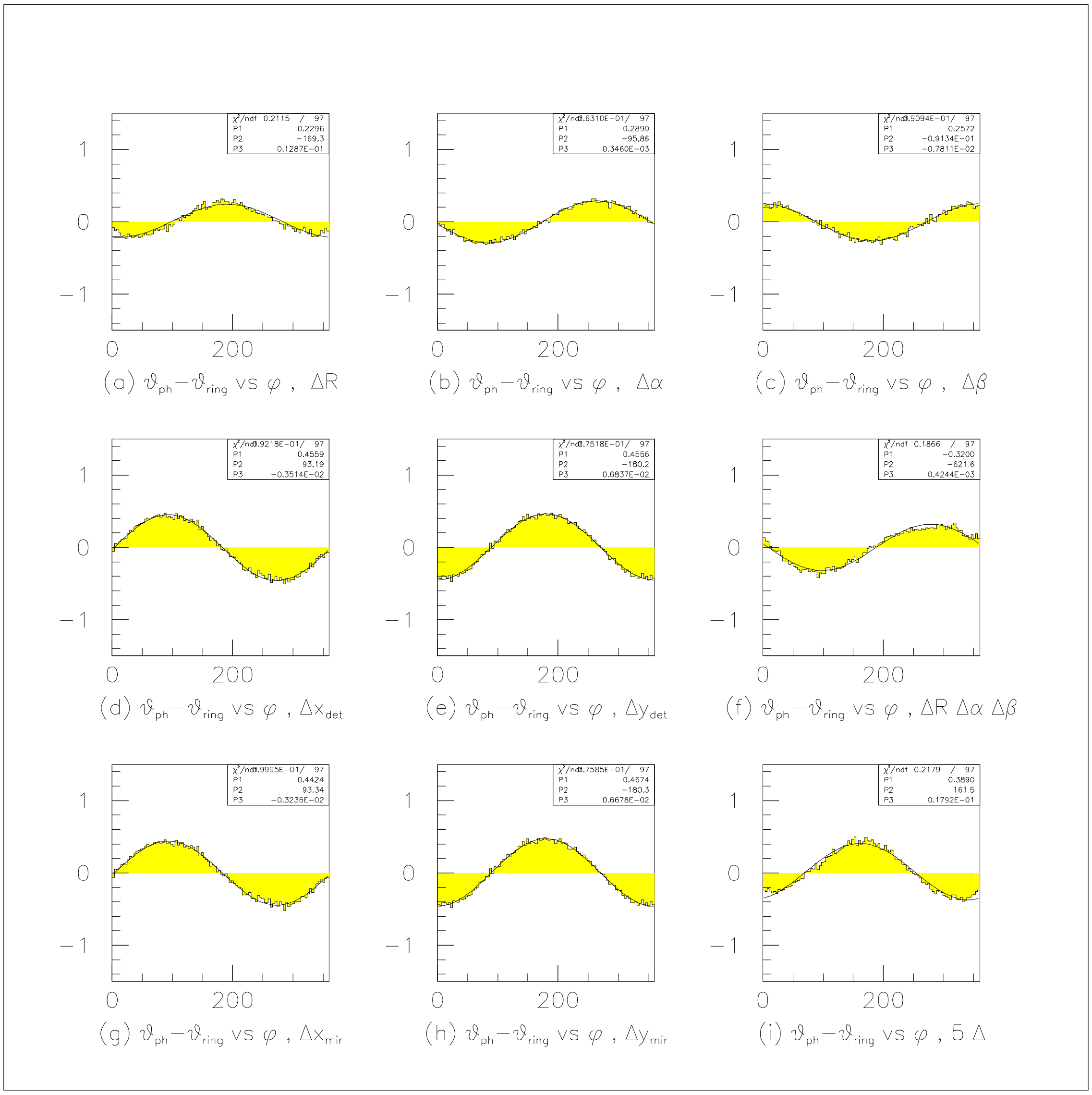

Figure 10: For a fixed mirror element position, the comparison of the previous effects; in (f) the combination of cases (a)(b)(c), as indicated; in (i) the combination of all five.