Studies for the optimization of the RICH 1 detector position by MonteCarlo simulation.

P. Schiavon

COMPASS / RICH / PS / Report 5.a

5/97 - rev. 5/ 1/98.

1 Geometry :

The geometry of the RICH 1 is defined as follows :

a) The origin of the reference system is in the centre of the (μ beam) production target;
the z-axis is in the beam direction, the y-axis pointing upwards and the x-axis in the horizontal plane, to the left (looking downstream).

b) The centre of curvature of the (upper) RICH mirror spherical surface is at $z_C =$ 1900. mm and $y_C = 1600.$ mm and $x_C = 0.$ mm; its radius is $R = 6600.$ mm.

c) The radiator entrance is at $z = 5500.$ mm and its end at the mirror surface (maximum length $= 3000.$ mm at height y_C).

d) Joining the mirror centre to the intersection between the mirror surface and the z-axis ('beam line'), we get the mirror 'tilting angle': $\alpha = 14.$ deg ($\sin(\alpha) = y_C/R$).

e) The theoretical focal surface is the $R/2$ spherical surface.

f) The detector is assumed to be a planar surface; its position is defined by means of the angle (θ_D) it makes with the vertical plane ($z = 0.$) and the value of its intercept (z_D) with the line parallel to the z-axis at the height y_C and $x = 0$.

g) Only the upper mirror ($y > 0.$) is taken into account.

2 Assumptions :

a) In the simulation, particles are generated reading a GEANT pre-processed file (using the LEPTO generator), for a more realistic 'illumination' of the mirror (see COMPASS / RICH / PS / Report 1 for more information); only one particle per event is used and the condition $\beta = 1.$ is forced;

b) Cerenkov photons are emitted along the particle trajectory (straight line) inside the radiator, at a constant emission angle (θ_C), with a uniform distribution in distance (s) along the particle path length and in angle (ϕ) around the particle trajectory.

c) As a special case, for each generated photon azimuthal angle (ϕ), many (n_s, typically 20) photons are generated at different s (then on the same plane); after reflection, their trajectories do not belong anymore to the same plane (in general), but a *centroid* can be calculated as the centre of mass of the middle points on the minimum distance segments between any two trajectories; this *centroid* can be assumed as the best approximation to the $focus$ of each (parallel) photon beam at fixed ϕ; as ϕ is varied, the *centroid* position changes in space along a distorted *ring* (not planar); the *ring* of the detected photons (on the detector) is the projection of such a *space ring* on the detector surface.

Several procedures have been tested; the following ones resulted the most reliable and in rather good agreement to each other.

3 Procedure 1 :

a) For each particle, the average expected number of photons (typically 30) is generated as specified in point (b) of section 2 above.

b) After reflection on the mirror, the impact point of each photon on the detector surface is computed.

c) For all the photons of a particle, the emission angle is reconstructed using the recontruction procedure described in COMPASS / RICH / PS / Report 2; the average of these values gives the particle (*ring*) Cerenkov emission angle (θ_Y); the difference between θ_Y and the MC-generated angle θ_C is then computed (Δ_θ);

d) For each generated event (with one particle only in this study), the detector position is systematically varied on a grid of values of angle (θ_D) and z-position (z_D), typically $11 \times 9 = 99$ configurations; for each detector position the value of Δ_θ and Δ_θ^2 are averaged over all the events generated; the variance σ_θ^2 is then computed for each detector position and recorded in a channel of a 2-dimensional (11×9) histogram (h.554); note that, for a more direct comparison, the same particle and the same related photons are used for all the detector configurations;

e) From the analysis of the histogram contents, a minimum in θ_D, z_D can then be found ($\theta_{D,min}$, $z_{D,min}$) using a fitting procedure (see Fig.1).

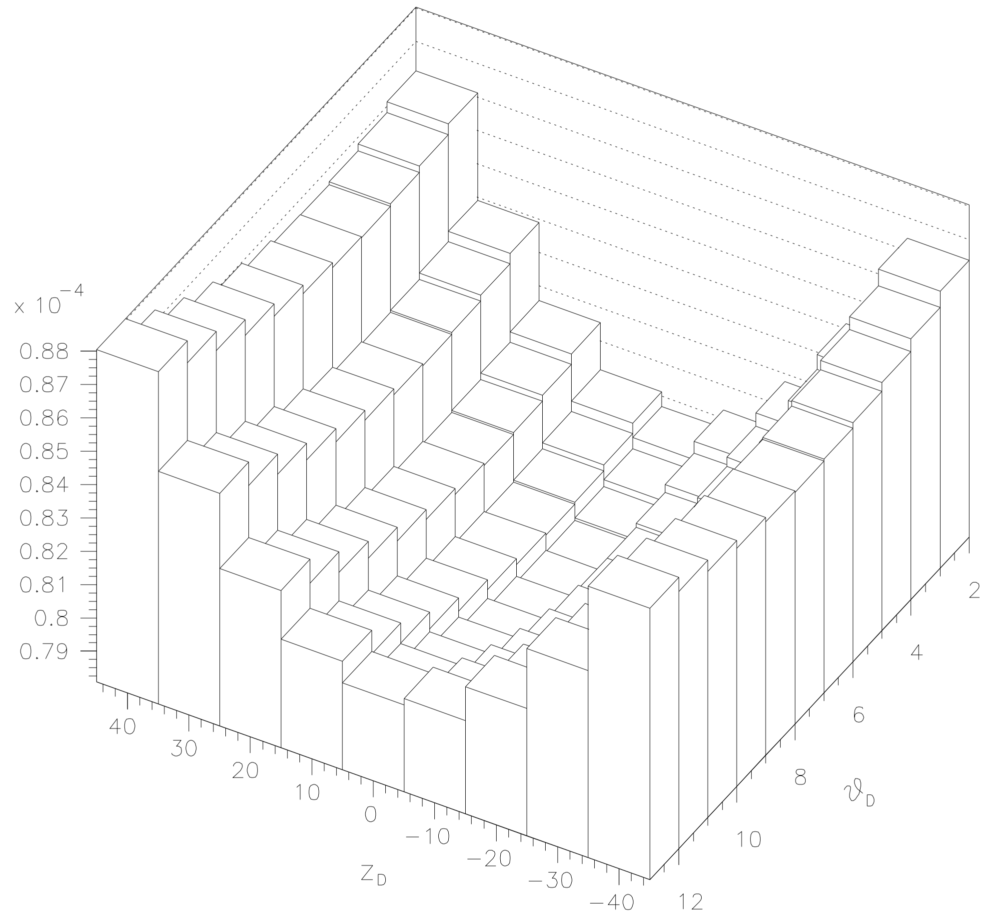

Figure 1: Example of the distribution of the figure of merit as a function of the detector configuration θ_D, z_D; this histogram is the result of procedure 1: the channel content is the square root of the variance of the reconstructed Cerenkov emission angle (σ_θ^2) averaged over many events of the 'physical' sample of particles. The position of the minima for the various cases are reported in Table 1 (see text for more details).

4 Procedure 2 :

a) For each particle, a large number of photons (typically 600) is generated as specified in point (b) of Section 2 above.

b) After reflection on the mirror, the impact point of each photon on the detector surface is computed; these impact points distribute along a *ring*, with some scatter with respect to a perfect ellipse, due to the spherical aberrations of the mirror.

c) A first approximation *centre* of the *ring* is calculated as the impact point on the detector of the particle virtually 'reflected' from the mirror;
the *ring* is divided in 40 sectors (9. *deg* wide each); for all the photons in each sector, the distance from the *centre* (*radius*) is calculated and then the mean quadratic difference, divided by the *radius* squared (σ_S^2); the average value of σ_S^2 (σ_r^2) is then computed over all the (not empty) sectors of the *ring*; this procedure eliminates the dependence on the approximate *centre* position; the average of σ_r^2 ($<\sigma_r^2>$)is then taken over all the particles of each event (= 1 in our approach).

d) For each event, the detector position is systematically varied under the same conditions specified at point (d) of Procedure 1 (Section 3) above;
for each position the value of $< \sigma_r^2 >$ is recorded in a channel of a 2-dimensional (11×9) histogram and the content of each channel is then averaged over all the events generated $(< \sigma_r^2 >_{ev})$.

e) Find the minimum in θ_D, z_D.

5 Procedure 3 :

It should be statistically equivalent to Procedure 2, at least for large number of photons.

a) For each particle, a number of photons (typically 30) is generated as specified in point (b) of Assumptions (Section 2) above and with the condition of the point (c) of Section 2.

b) After reflection on the mirror, the impact point is computed for each photon on the detector surface; for fixed ϕ, the impact points distribute along a (curved) segment.

c) The variance of the distributions of both x- and y-coordinates of the impact points are computed (σ_x^2 and σ_y^2), added and averaged over all the particles of each event (=1 in our approach) $(< \sigma_f^2 >)$.

d) For each event, the detector position is systematically varied under the same conditions specified at point (d) of Procedure 1 (Section 3) above;
for each position the value of $< \sigma_f^2 >$ is recorded in a channel of a 2-dimensional (11×9) histogram and the content of each channel is then averaged over all the events generated $(< \sigma_f^2 >_{ev})$.

e) Find the minimum in θ_D, z_D.

6 Results :

The results are presented in Table 1 :

In row 1 the position of the detector used in the proposal studies.
In row 2 the position $(\theta_{D,min},\ z_{D,min})$ of the minimum ('optimum' position), using the procedure 1 (see Fig.1); typically 180000 (6000×30) particles $\times$ photons have been used for each detector position; the grid of the detector positions has steps of 1. deg and 10. mm ('fine' size); a bi-dimensional quadratic form has been used in the fit to evaluate the minimum.
In rows 3 to 5 the 'optimum' position is shown varying some of the conditions or the procedure type, to estimate the resolution of the method :
row 3, as in row 2, but 600 photons per particle are generated instead of 30;

row	condition	θ_D deg	z_D mm
1	proposal	8.6	5408.
2	proc. 1, 30 photons	6.4	5344.
3	proc. 1, 600 photons	6.6	5336.
4	proc. 2, 600 photons	7.9	5336.
5	proc. 3, 30×20 photons	8.0	5335.
6	proc. 1, all β	4.9	5348.
7	proc. 1, uniform sample, β=1	2.2	5335.

Table 1: Optimized detector position ($\theta_{D,min}$, $z_{D,min}$) for different optimization procedures and for different choices of the relevant parameters (see text for details); in row 1 the detector position as in the COMPASS proposal studies, for reference.

row 4, the procedure 2 is used (600 photons per particle);
row 5, the procedure 3 is used ($\sim$600 particles $\times$ 30 $\times$ 20 photons);
In rows 6 and 7 the particle sample is different:
row 6, as in row 2, but the condition β=1 has been released;
row 7, as in row 2; a sample of particles coming straight from the origin (point (a) of section 1) with an uniform angular distribution and β=1 has been used instead of the 'physical' sample;

7 Conclusions :

a) The minimum in θ_D, z_D is well defined and an 'optimum' position of the detector can be defined for all the procedures.

b) The procedure 1 gives results slightly lower than the procedures 2 or 3; the differences are of the order of $\sim$1.5 deg in angle and $\sim$10. mm in position;
such a difference is in principle expected because the minimization requirements of the two approaches are different.

c) Procedures 2 and 3 (geometrical approach) are in quite good agreement between them for both θ_D and z_D, at least when a large number of photons is taken into account, as they require.

d) On the other hand, procedure 1 is preferred because it corresponds to the current definition of the resolution in the reconstructed Cerenkov emission angle, as used in the other RICH properties studies ('physical' approach).

e) The dependence on the particle sample type is appreciable and certainly will play a role if we want to push the detector positioning optimisation.