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Evaluation of tracking errors in the extrapolation of charged tracks to the HMPID in ALICE

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Abstract

A precise determination of impact points and incidence angles of charged particles that reach the HMPID modules in ALICE is mandatory for the succesful recognition of Cherenkov photoelectron patterns. In the present note we report an estimation of the expected errors by extrapolating the charged tracks measured in the ALICE tracking systems up to the HMPID array.

1 Introduction

The reconstruction of the charged tracks in the ALICE detector will be achieved by using the ITS (Inner Tracking System) and the TPC. The high momentum hadrons will be identified by an array of RICH detectors which modules (fig.1) will be placed at about 500 cm distance from the beam line, i.e. about 250 cm from the end of the TPC wall[1].

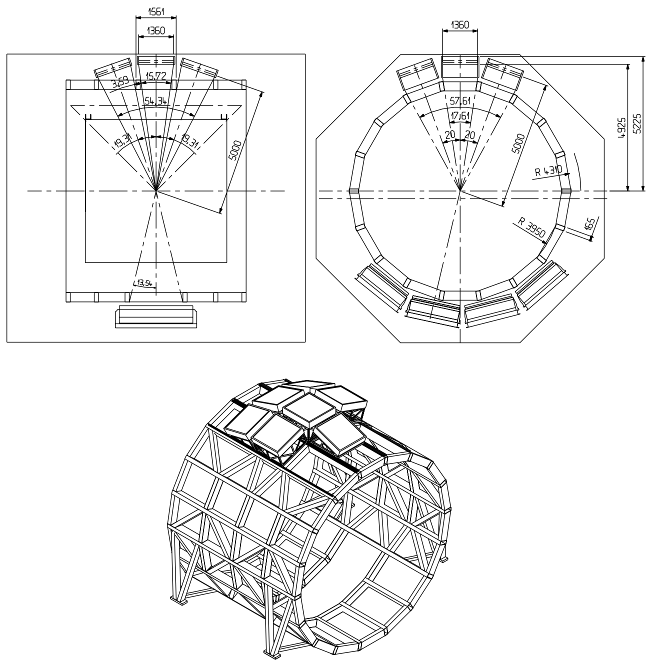

Figure 1: *Layout of RICH modules in ALICE.*

The pattern recognition of the Cherenkov photons relies heavily on the precise knowledge of the momentum of the particles, their angle of incidence and impact point. In particular, it is of primary importance to demonstrate that, at the expected particle density in the HMPID ($\approx 50\ \mathrm{m}^{-2}$ including noise hits), we are able to correctly match the reconstructed tracks with the impact points at the HMPID level.

The tracking through the ITS and TPC and the extrapolation to the HMPID have been performed by using simulated particles, with momenta ranging 0.5 to 5 GeV/c. The points generated in the ITS and TPC detectors have been fitted in order to extract the kinematic parameters to be used for the extrapolation of that track to the HMPID. After a calculation of the impact coordinates and direction cosines of the fitted track on the RICH module, the relevant quantities have been compared with those of the simulated track after its full evolution through the ALICE apparatus. These quantities have also been studied as a function of the track momentum.

Concurrently we have investigated the possible use of the HMPID as an additional tracking plane at very large momenta, by using an iterative procedure. The proposed method gives an improved momentum resolution at large momenta.

2 Track simulation

The GEANT-based package GALICE[2] has been used to simulate tracks in the ALICE apparatus. Tracks are generated with flat momentum distribution, ranging from 0.5 to 5 GeV/c and rapidity $|\eta| < 0.4$. The evolution of the track through the ALICE subsystems (6 silicon layers in the ITS, 75 planes in the TPC region and the final set of RICH modules) has been determined by GEANT routines.

Multiple scattering in the beam pipe, silicon layers, TPC gas mixture and also in mechanical support, cooling systems and in electronics has been taken into account (totally equivalent to ≈ 8 % X_o) according to the detector design reported in the ALICE Technical Proposal (TP)[1] (see table 1, where is reported the averaged material budget corresponding to the interesting momentum range for the HMPID as well as to ITS spatial acceptance).

	Radius (cm)	X/X_o (%)			Radius (cm)	X/X_o (%)
ITS				TPC		
Beam pipe	3.0	0.17		Inner vessel	52	0.27
Si pixel 1	3.9	0.64		CO_2	52-78	0.14
Si pixel 2	7.3	0.64		Inner cage	78	0.52
Si drift 1	14	0.64		Working gas	78-250	0.56
Si drift 2	24	0.64		Outer cylinder	250	1.33
Si strip 1	40	0.64				
Si strip 2	45	0.64				
Outer shell	50	1.00				
Air	3-52	0.16				

Table 1: *Averaged material budget in the tracking volume.*

About 5000 tracks (over all momenta) have been processed, in a uniform magnetic field of 0.2 Tesla. Fig.2 shows the impacts of simulated tracks onto each detector; the

HMPID detector consisting of 7 RICH modules is supposed to be placed about 500 cm far from the emission point, covering an acceptance of $\pm\ 30^o$ angle with respect to the X axis in XY projection (bending plane): the reference system assumed has the Z axis along the beam direction.

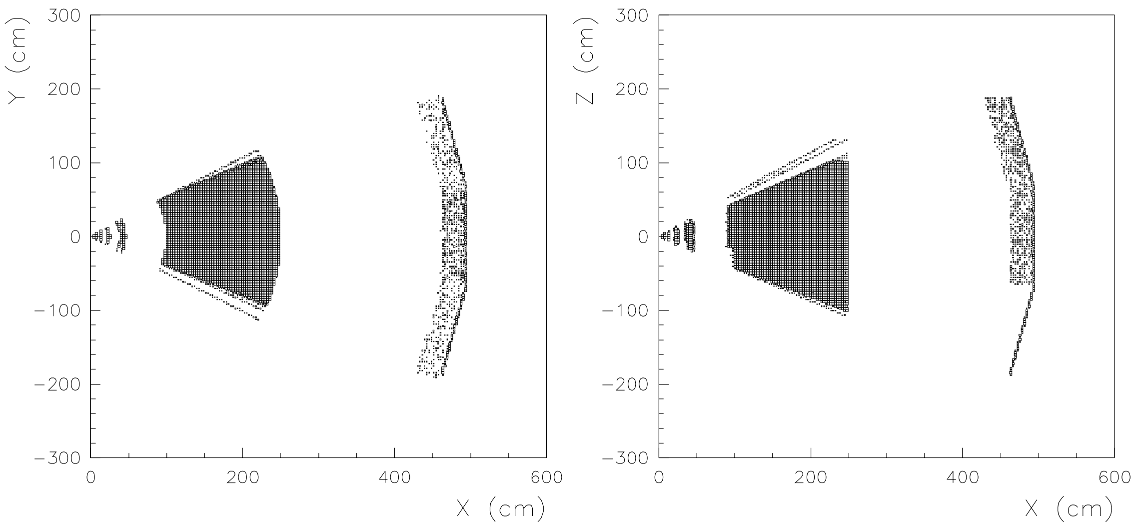

Figure 2: *Impact of simulated tracks onto ALICE detectors.*

3 Track reconstruction

The fitting routines take into account all the hits, both in the ITS and in the TPC detectors. Therefore in the GEANT simulation all the detectors are supposed to be 100% efficient and we have 81 (6 ITS + 75 TPC) points per each track to be used for the fit.

In the fitting model the tracks are supposed to be helices[3] with common vertex at (0,0,0), polar and azimuthal emission angles λ and ϕ_o respectively and radius of curvature R $= p \cos\lambda$ / K B (K = 0.003, B = 0.2 and track momentum p in GeV/c) in the XY-plane. All the hits (points in the fit) have been weighted, taking into account the detector spatial resolution and the multiple scattering error propagation through the different layers.

In fig.3 we report the distributions of the residuals between simulated and reconstructed track kinematic parameters. After reconstruction, angular resolutions of less than 1 mrad have been found, while average $\Delta p/p$ (over all momenta distribution) comes out to be around 2%. These values are compatible with the tracking resolution estimates reported in the TP. The $\Delta p/p$ versus p behaviour will be discussed later in this note.

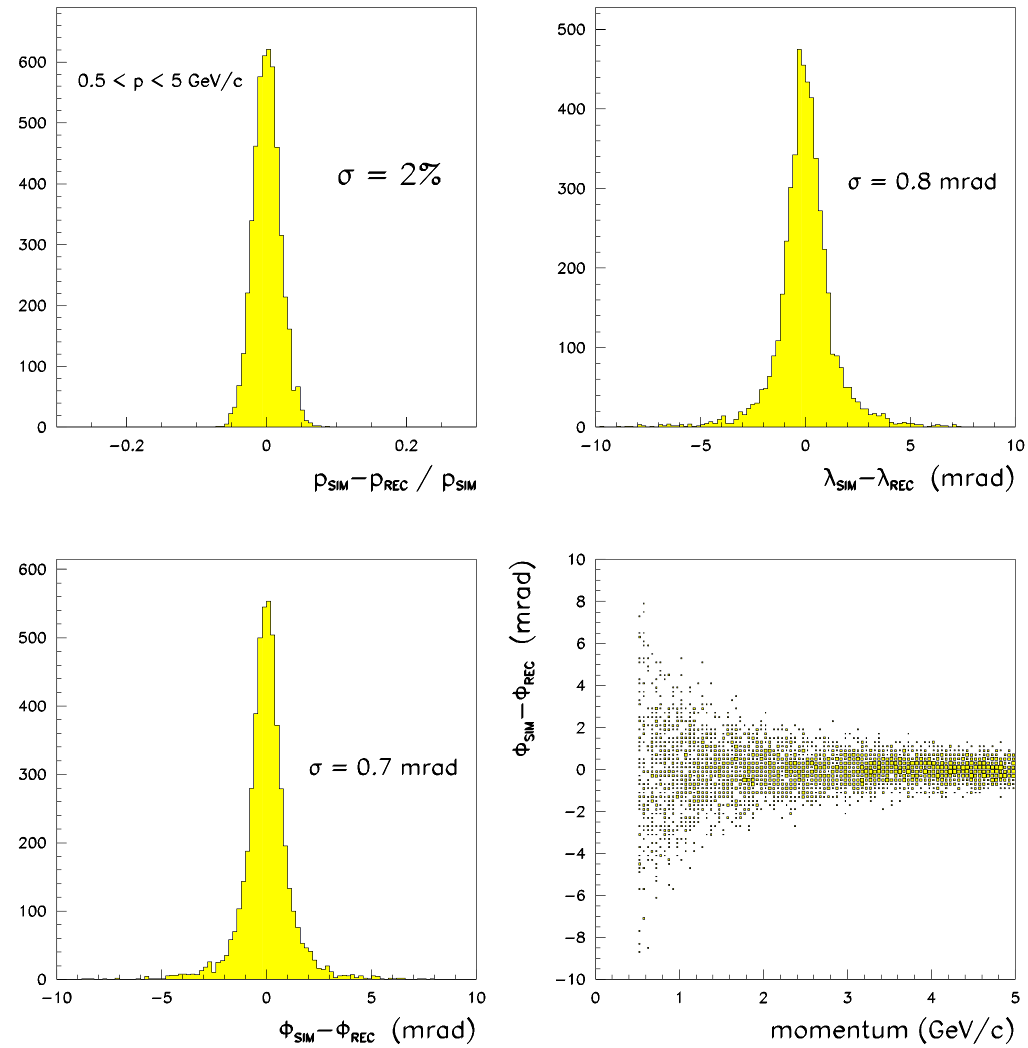

Figure 3: *Residuals of simulated and reconstructed kinematic parameters.*

Track fit residuals have been calculated for each detector layer; in particular, it is interesting to look at the residuals on the last pad row of the TPC, which is the end of the track measurement region. In the fig.4 the distribution of the difference in $r\phi$ and z coordinates between fitted crossing point and "data" point have been reported; they refers to the overall momenta sample, while the table 2 resumes the values of the sigmas of these distributions in function of the track momentum.

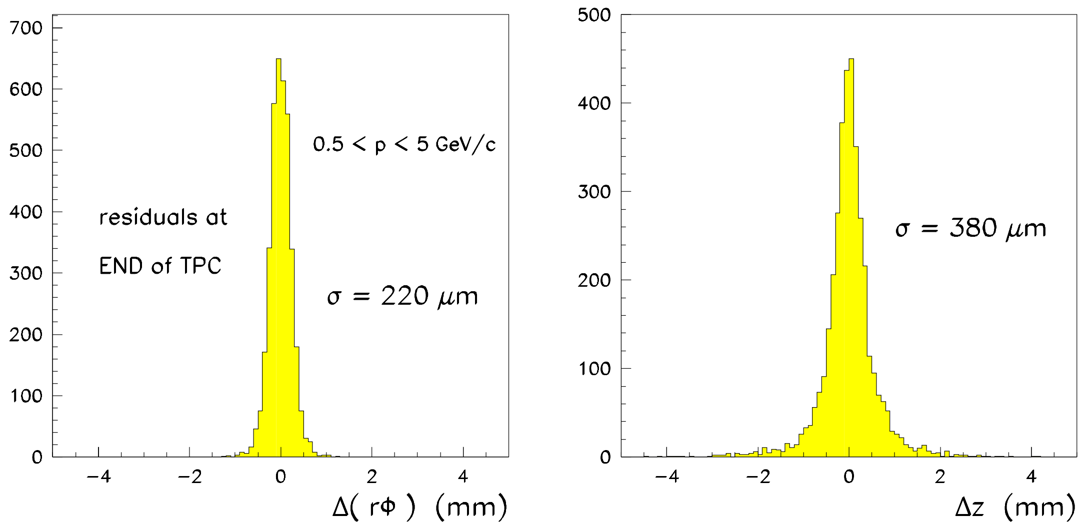

Figure 4: *Fit residual distributions at the end of TPC.*

Momentum range (GeV/c)	0.5 - 1.	1. - 1.5	1.5 - 2.	2. - 3.	3. - 4.	4. - 5
$r\phi$-residuals (μm)	410	300	220	210	180	170
z-residuals (μm)	1060	660	450	320	230	210

Table 2: *Sigmas of the residual distributions at the end of TPC.*

4 Extrapolation to the HMPID

4.1 Evaluation of the tracking errors at the HMPID

The reconstructed track can be extrapolated from the last measured point in the TPC up to the HMPID modules by using the fitted kinematic parameters. Track by track impact coordinates and momentum vector components at the HMPID have been extracted: these have to be compared with real points and momenta provided by GEANT on the same detector module.

In the actual experiment the extrapolated impacts and directions are the starting point for the matching of track hits in the HMPID with the tracks in the TPC. It's useful to remind that the uncertainites in this determination are expected to be greatly amplified with respect to the fit residuals found at the end of TPC: this not only because of the fit error propagation along the 250 cm path from the TPC to the HMPID, but also because of the multiple scattering in the outer vessel of the TPC volume ($\approx 1.3\%\ X_o$).

To get the estimation of the final expected resolution on the impact and angles onto the RICH, we have to look at the distributions of the differences between extrapolated crossings and the "data" point. The fig.5 shows the distribution of the difference $\Delta(r\phi) = (r\phi)_{real}$ - $(r\phi)_{extrap}$ and the same for Δz calculated at the RICH for all momenta (between 0.5 and 5 GeV/c).

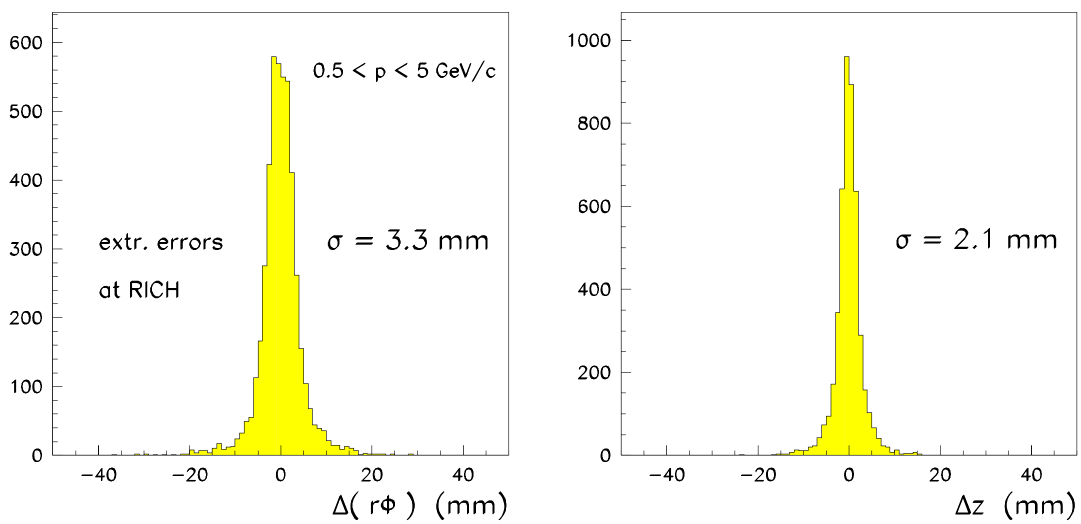

Figure 5: *Distributions of difference between extrapolated and real impacts at the RICH.*

The widths of these distributions provide the expected extrapolation error for $r\phi$ and z coordinates of the track impact onto the RICH modules. The same calculation has been performed for the polar and azimuthal angles λ and ϕ of the track. The following error estimates have been extracted:

$$\sigma_{r\phi} = 3.3\ mm \qquad \sigma_{\phi} = 1.9\ mrad$$
$$\sigma_{z} = 2.1\ mm \qquad \sigma_{\lambda} = 0.7\ mrad$$

The tracking error estimations have been studied in different momentum ranges within the interval [0.5, 5] GeV/c: we resume the obtained results in fig.6, where the standard deviations of relative distributions are plotted as a function of p.

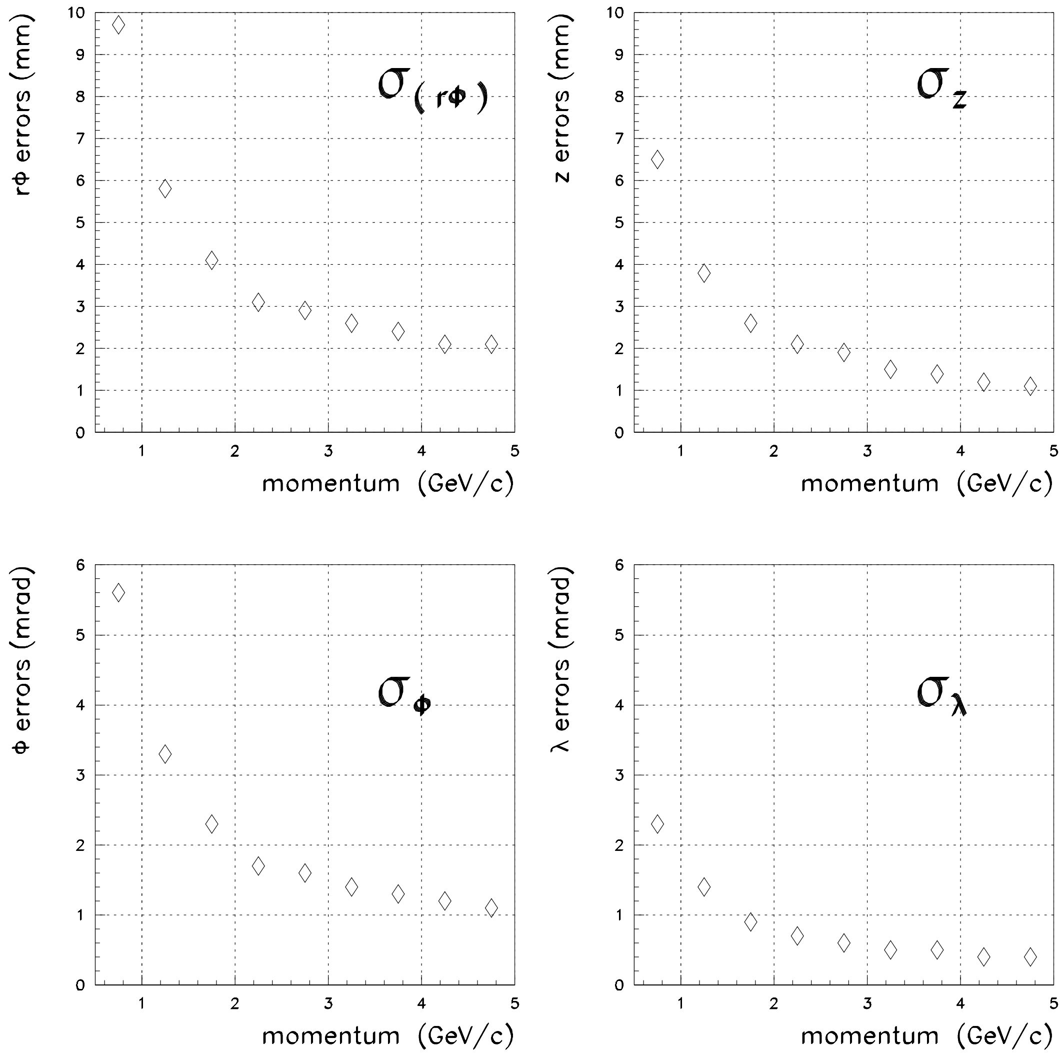

Figure 6: *Extrapolation errors at RICH as a function of the track momentum.*

4.2 Evaluation of the matching efficiency

An important aspect to investigate is how the high multiplicity environment spoils the track information at the level of the HMPID. We have therefore investigated the probability of a fake matching between the extrapolated track and the corresponding hit in the HMPID; this can occurr due to the high hit density expected in the RICH modules in lead-lead events at LHC.

50 hits per m^2 have been randomly implanted in the HMPID to simulate the expected environment. The non-shaded distributions reported in fig.7 correspond to the distance between the extrapolated and the real impact of the track, while the shaded ones correspond to the distance between the extrapolated impact and the nearest hit onto the HMPID.

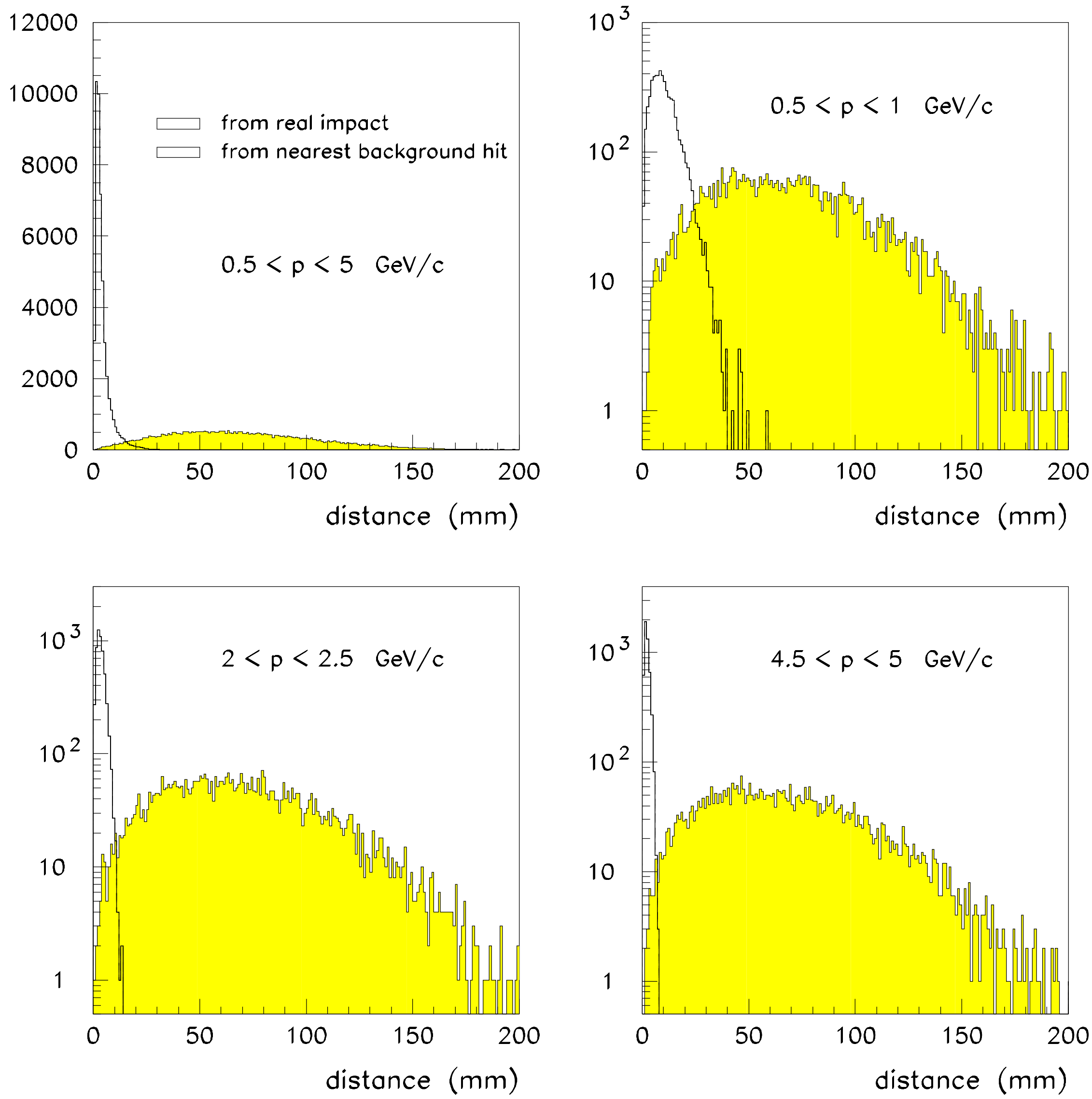

Figure 7: *Distance between tracking prediction and nearest hit, compared with distance from real track impact in the HMPID, at different momentum ranges.*

A fake matching occurs when the nearest hit falls closer to the tracking prediction than the real impact of the track. The fraction of these fake associations with respect to the total number of tracks comes out to be around 0.4%.

The amount of "mismatches" has also been computed as a function of track momentum as reported in table 5.

Momentum range (GeV/c)	0.5 - 1.	1. - 1.5	1.5 - 2.	2. - 3.	3. - 4.	4. - 5
Fake matchs prob.	2.1%	0.8%	0.3%	0.2%	0.1%	0.1%

Table 4: *Estimated probabilities for fake matchings between the track and the hit in the HMPID.*

The results show that the probability of mismatches between tracks and the corresponding hit in the HMPID is negligible at the estimated tracking impact resolutions.

4.3 Improved momentum resolution in the ALICE tracking

We have investigated the effect of a possible iterative procedure: in the first step the "impact" point of the extrapolated track should be used to determine the closest real impact of the track; then the identified impact should be introduced in the fitting procedure as an additional track point.

We have checked this, assuming the "data" hit onto the HMPID provided by GEANT as an additional point in our fit. The finite resolution of the photodetector has been taken into account, contributing as $\sigma_{r\phi} = 400\ \mu m$ and $\sigma_z = 1.15\ mm$ to the weight of the last point in the fit.

Due to the large contribution of multiple scattering errors, the hit in the HMPID doesn't influence a lot the tracking precision in our momentum range, giving only an improvement of less than 10% in the ϕ resolution. However at momenta above 10 GeV/c the inclusion of the RICH point improves significantly the momentum resolution as shown in fig.8.

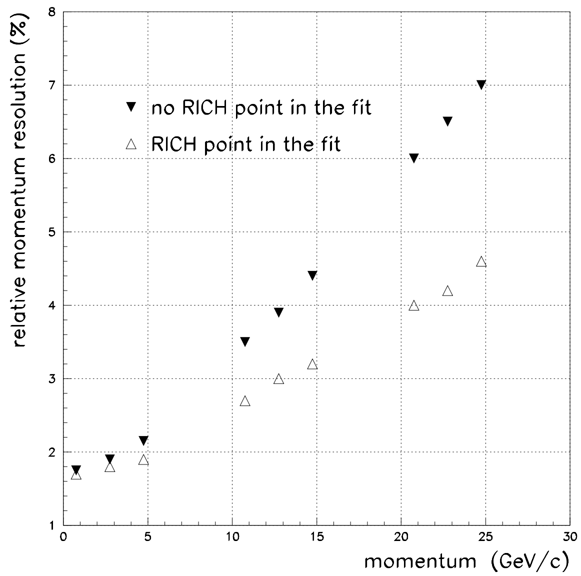

Figure 8: *Relative momentum resolution as a function of p.*

5 Conclusion

In the present note we have determined the impact errors caused by the tracking of particles to the HMPID, both in space and in incidence angles. The precision on the reconstructed angle of incidence, in the range of the HMPID (1 to 3 GeV/c), goes from 3 to 1.5 mrad, respectively. This estimate is acceptable if compared with the 9 mrad single photon resolution.

At 50 m^{-2} density, the probability of a mismatch between the track and the corresponding hit onto HMPID ranges from 0.8% to 0.2%, for the same momentum interval as above. This makes the particle position onto the photodetector easily recognizable.

Finally the inclusion of the HMPID point in the ALICE tracking improves considerably the momentum resolution at large momenta, *e.g.* at 25 GeV/c we reach a resolution of 4.5% with HMPID compared to only 7% with the conventional tracking.

References

[1] ALICE Collaboration, *Technical Proposal*, CERN/LHCC 95-71.

[2] N. van Eijndhoven, ALICE/95-44, Internal Note, 1995.

[3] N. Chernov and G. Ososkov, Computer Phys. Comm. 33 (1984), 329.