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Influence of the TOF and TRD detectors in matching tracks from TPC to HMPID

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Abstract

We report on the effect of the additional detectors on the performance of the HMPID. The effect on extrapolation of tracks, occupancy and track incident angle precision on the HMPID has been studied. The present results have been obtained according to the latest specifications of the ALICE subsystems in the respective Technical Design Reports.

The influence of the error on the reconstructed Cherenkov angle of the track, in terms of efficiency and contamination, will be also presented.

Finally the effect of the space-frame, recently designed for supporting the TRD and TOF, on the effective HMPID acceptance will be addressed.

1 Introduction

Track impact points and incident angles onto the HMPID array will be achieved by extrapolating the particle trajectories reconstructed in the ITS and TPC detectors. The precision of such an evaluation depends on the extrapolation distance, the accuracy with which tracks are reconstructed within the tracking volumes and the amount of material in between the last tracking plane and the HMPID detectors.
An evaluation of tracking errors in extrapolating the reconstructed tracks to the HMPID array has been already reported in a previous note [1]. Recent changes in the material budget of the ITS and TPC detectors and the addition of an array of transition radiation detectors (TRD), require an update on the tracking precision evaluation.
The mechanical frame designed for supporting the TRD and TOF modules will somehow reduce the effective HMPID acceptance, since the large amount of material (in terms of fraction of X_o) in the supporting elements will stop a certain number of particles that could reach the detector plane in absence of material: in the following such an acceptance reduction effect will also be discussed and quantified.

2 Material budget in the tracking system

About 100K tracks have been generated with a flat momentum distribution ranging from 0.5 to 5 GeV/c and a pseudo-rapidity $|\eta| < 0.4$. They have been followed through the ALICE subsystems (firstly in the ITS + TPC only, then in the ITS + TPC + TRD + TOF, up to reach the HMPID position), assuming an uniform 0.2 Tesla magnetic field. The procedure to evaluate the extrapolation errors is described in ref.[1].
The current amount of material budget in the tracking volume, as taken from [2,3], is reported in table 1. All the values correspond to the material traversed by particles with normal incidence except for those related to ITS detectors that are averaged over track pseudo-rapidity and azimuthal angles.
In the same table the total amounts of material for TRD and TOF detectors have been also reported as taken from [4,5].

	R (cm)	X/X_o (%)			R (cm)	X/X_o (%)
ITS				**TPC**		
Beam pipe	3.0	0.28		Inner vessel / cage	61	0.92
Si pixel 1	4.0	1.03		Insulating CO_2		0.10
Si pixel 2	7.0	1.03		Working gas	80-258	0.58
Shield / Support		0.36		Insulating CO_2		0.09
Si drift 1	14.9	0.94		Outer vessel / cage	278	1.36
Si drift 2	23.9	0.95				**3.05**
Shield / Support		0.42				
Si strip 1	39.1	0.91		**TRD**	294-368	**10.2**
Si strip 2	43.6	0.87				
		6.79		**TOF**	370-399	**18.4**

Table 1: *Averaged material budget in the tracking volume and for TRD/TOF detectors.*

3 Influence of the TRD and TOF material budget

3.1 Tracking errors

The track fitting procedure assumes an optimal detector efficiency (100%) both for ITS and TPC detectors, nominal spatial accuracies as taken from [2,3] and the absence of dead zones in the tracking volume.

Fig.1 shows the track reconstruction precision in the azimuthal (ϕ) and polar (λ) angles, in the relative momentum and in the impact parameter: the shadowed distribution corresponds to the impact parameter D in the transverse plane while the white distribution corresponds to the impact parameter Z_o along the beam axis.

An estimation of the tracking errors has also been performed using the associated hits on the TRD layers for the track fit: in this case 6 detector layers have been taken into account, each of them corresponding to a thickness of 1.70 % X_o (table 1) and providing a 200 μm and 1.3 cm spatial resolution, in $r\varphi$ and z coordinates, respectively[4].

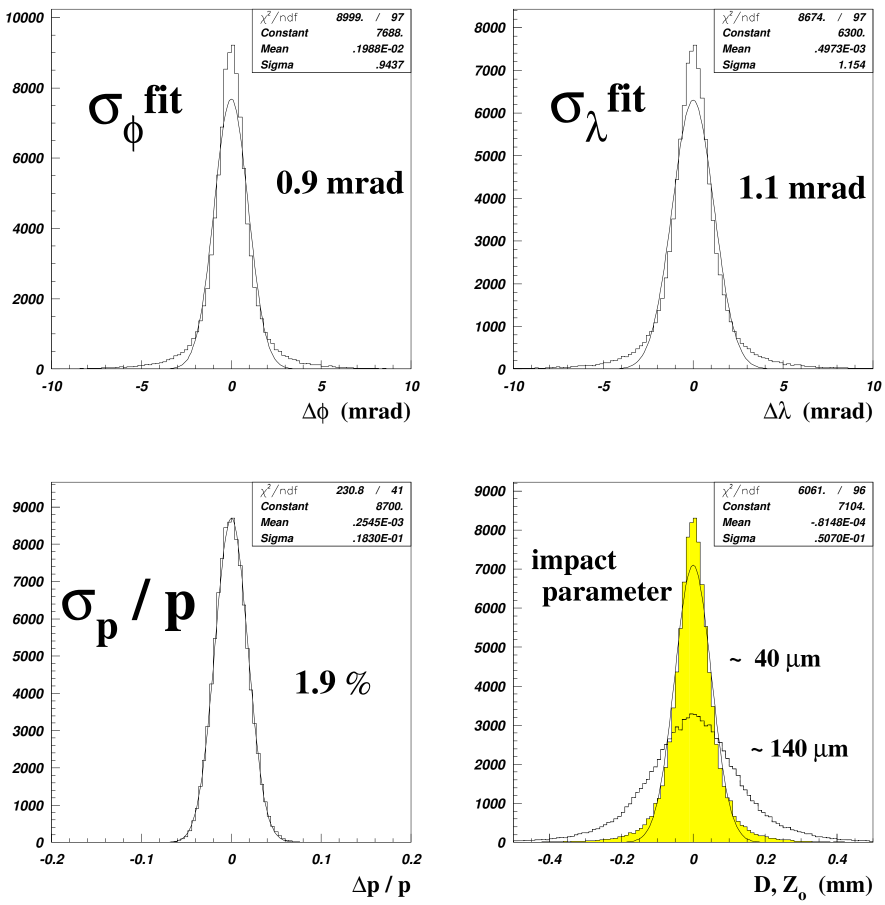

Figure 1: *Track fit precision using ITS and TPC points.*

Results have been obtained for five different cases:

- no TRD and TOF material in front of the HMPID (ITS + TPC only);
- only TRD material in front of the HMPID (+ TRD);
- only TRD material in front of the HMPID and TRD information used in the tracking procedure (+ TRD fit);
- both TRD and TOF material in front of the HMPID (+ TRD + TOF);
- both TRD and TOF material in front of the HMPID and TRD information used in the tracking procedure (+ TRD fit + TOF).

The obtained tracking errors have been summarized in table 2: they correspond to the standard deviations of the distributions of residuals (TRACKING PREDICTION - ACTUAL HIT), both for impacts and incidence angles of the track onto the HMPID modules.

	$\sigma_{r\varphi}$ (mm)	σ_z (mm)	σ_ϕ (mrad)	σ_λ (mrad)
ITS + TPC only	**3.3**	**2.0**	**1.9**	**0.7**
+ TRD	4.0	3.3	2.4	1.4
+ TRD(fit)	2.8	3.3	1.8	1.4
+ TRD + TOF	**4.6**	**4.0**	**3.3**	**2.2**
+ TRD(fit) + TOF	3.4	4.0	2.8	2.2

Table 2: *Evolution of extrapolation errors w/wo TRD/TOF.*

The track fitting precision improves by using the TRD hits in the bending plane (therefore also the tracking extrapolation to the HMPID).
The behaviour of the extrapolation errors at the HMPID has been also studied as a function of the track momentum: results are shown in fig.2 where their evolution between 1 and 5 GeV/c momenta are reported for both cases, with (black stars) and without (open simbols) TRD/TOF modules.

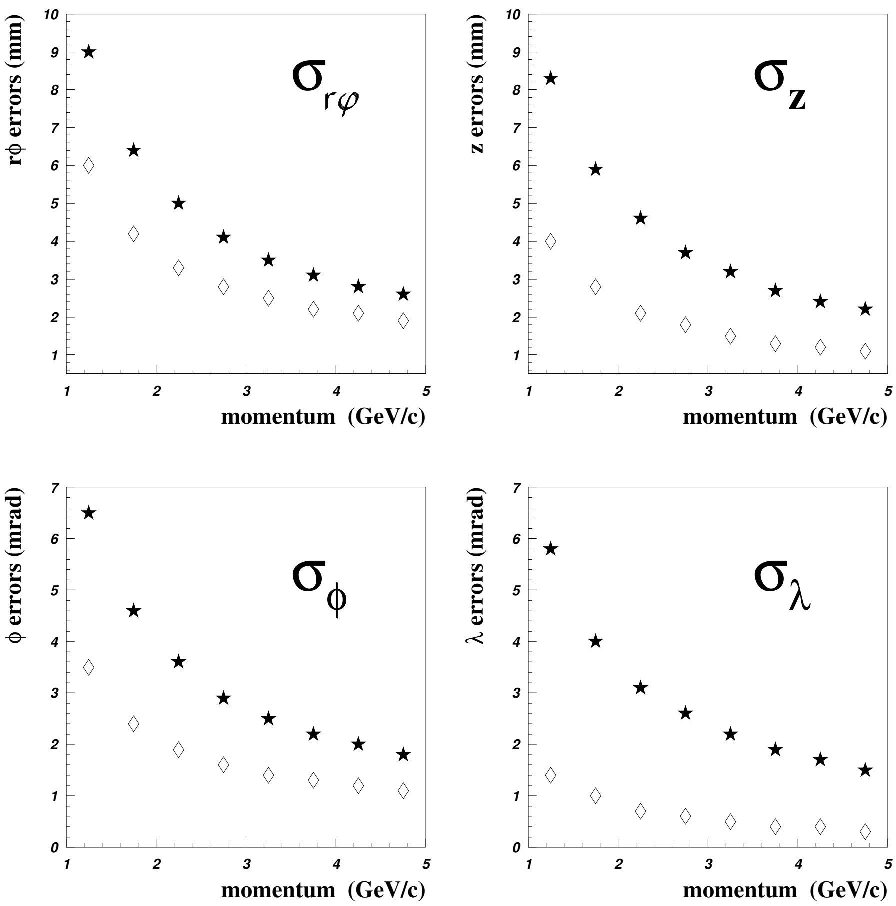

Figure 2: *Extrapolation errors vs. momentum with and without TRD/TOF materials.*

Let's note that the track fitting precision does not depend strongly on the material in the tracking volume. The most important source of error is the distance of extrapolation and the presence of material in that space between the end of TPC and the HMPID modules. The results are shown in the momentum range where the HMPID will be operative. In the estimates reported in the fig.2 TRD points have not been taken into account in the fit procedure.

Taking into account the outcoming resolution in the impact coordinates of the track onto the HMPID, an estimate of the probability of fake matchings between the tracking prediction and the real impact of the track has been carried out. A fake matching occurs, by definition, when a background hit falls closer to the tracking prediction than the real impact of the track. The computation of this probability has been made by assuming a background level corresponding to 100 particles per m^2 onto the HMPID modules[6]: the evolution of the result with particle momentum and material budget is illustrated in table 3, where the percentual fractions of fake matchings in different momentum slices are reported.

momentum (GeV/c)	1. - 1.5	1.5 - 2.	2. - 3.	3. - 4.
ITS + TPC only	**1.5**	**0.7**	**0.4**	**0.3**
+ **TRD**	2.9	1.6	0.7	0.5
+ **TRD(fit)**	2.4	1.1	0.5	0.3
+ **TRD** + **TOF**	**4.1**	**2.1**	**1.1**	**0.5**
+ **TRD(fit)** + **TOF**	3.3	1.5	1.3	0.5

Table 3: *Evolution in percent of fakes vs. momentum, w/wo TRD/TOF.*

Since the fake probability is quite low even at the lowest momenta, the real impact of the track onto the HMPID is reliably recognizible by the closest hit selection criterium. However the resolution in the incidence angles of the track influences the Cherenkov angle reconstruction and then the separation power itself.

3.2 Cherenkov angle reconstruction

The influence of extrapolation errors on the high momentum particle identification by the RICH has been estimated by considering their effects on the identification efficiency and

contamination for π, K, p impinging the detector plane at different momentum values. In order to study a set of ring patterns at fixed momentum and incidence angle in the ALICE multiplicity environment, one full central Pb-Pb event ($\sim$13% of pad occupancy) has been simulated in the ALICE setup with Geant3.21[7], for the highest expected charged particle multiplicity (dN$_{ch}$/dy=8000).
At first the total response (charged particles and photons) of a HMPID module has been generated and then a track with its Cherenkov photons at a given momentum and incidence angle has been generated and superimposed to the event(fig.3).

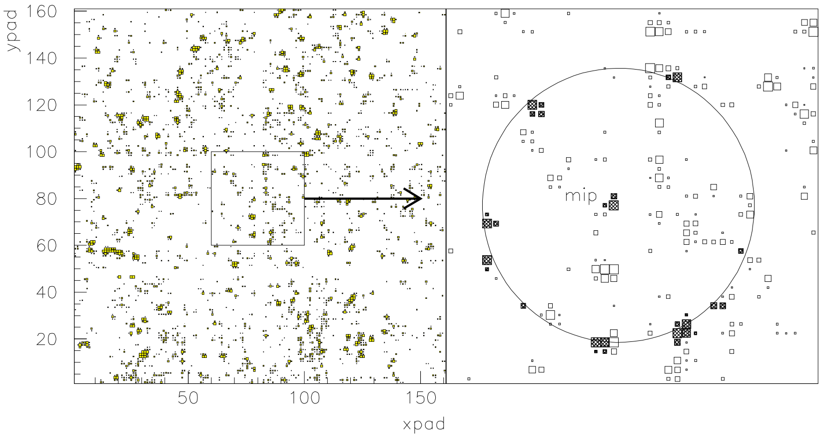

Figure 3: *Left: hit map of central HMPID module in ALICE generated with the GEANT for one Pb-Pb central event (dN$_{ch}$/dy=8000). Right: a detail of the previous hit map showing the region where the generated ring has been merged to the event (the ring pads are in black).*

The procedure has been repeated for pions, kaons and protons reaching the central HMPID module[6] at normal incidence, in the momentum range between 1.5 and 5 GeV/c, until a satisfactory statistics has been reached per each particle.
The track reconstruction precision in ϕ and λ has been taken into account. For this purpose different configurations for the inner detectors have been distinguished, i.e. including in the ALICE setup at the beginning only ITS and TPC, then with the addition of the TRD used as tracking device and finally the TOF.
The pattern recognition method has been applied to obtain the respective distributions of the reconstructed Cherenkov angle, so that efficiency and contamination for the three species of hadrons could be examined. For efficiency Eff$_i$ and contamination Cont$_i$ concerning the particle of type $i = \pi, K, p$ at a fixed momentum value, the following definition

has been employed:

$$\mathrm{Eff}_i = \frac{N_i^{found}}{N_i^{tot}} \quad ; \qquad\qquad \mathrm{Cont}_i = \frac{N_j^{found}+N_k^{found}}{N_i^{found}+N_j^{found}+N_k^{found}} \quad i{\neq}j{\neq}k \quad (i = \pi, K, p)$$

where N_i^{found} denote the number of the reconstructed rings with Cherenkov angle in a selected range, while N_i^{tot} is the number of the total simulated rings for particle of i type. The dependence of expected particle production ratios from the momentum, estimated with HIJING, have been taken into account to calculate Cont_i[8].

The cuts made in the analysis reflected the best compromise between efficiency and contamination. It is indicative since anyhow cuts will depend on the physics signal under study with the HMPID. Fig.4 reports the efficiencies and contaminations, in the three different conditions, computed for π in the momentum range 1.5÷4 GeV/c, for K in the momentum range 1.5÷3 GeV/c and for p in the momentum range 2÷5 GeV/c.

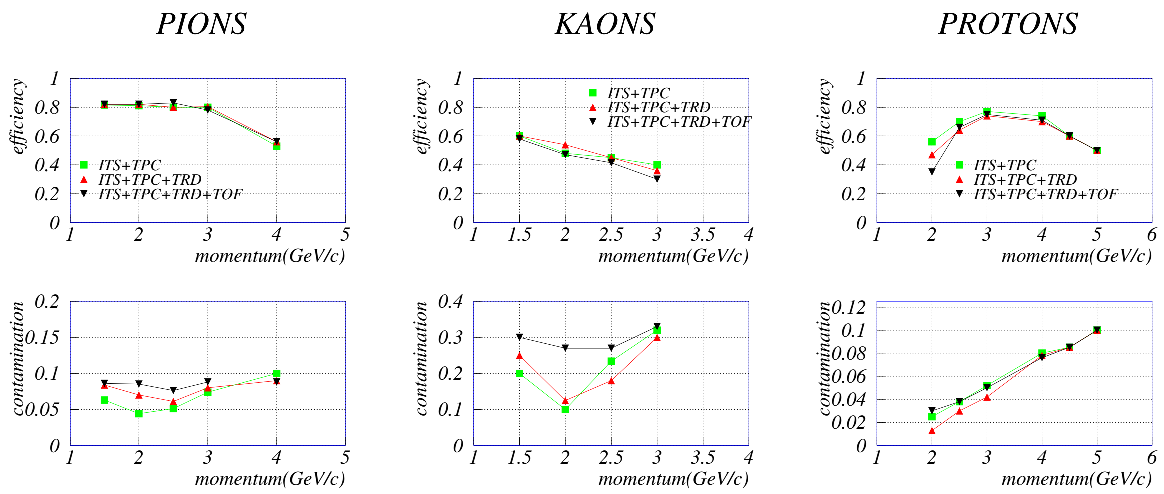

Figure 4: *Efficiency and contamination for pions, kaons and protons.*

3.3 Particle multiplicities in the HMPID

The HMPID simulation package (AliRICH) and geometry was integrated in the framework of AliRoot3.02[9], the official offline software package of ALICE. This allows to use other detector full simulation packages with the most updated configurations and geometries and to have a virtual ALICE detector generating all the signals and noise. The HMPID response in the environment of ALICE events has been simulated using response parameters determined in test beam events and is well reproduced by the AliRICH package.

The aim of the present simulation was to determine the effects of the presence of TOF and TRD modules in front of the HMPID in contrast to the solution presented in the HMPID TDR [6]. The primary particle flux has been simulated by sampling from pion and kaon pseudo-rapidity distributions obtained from the HIJINGparam event generator as described in [10]. The normalisation was adjusted to obtain 8000 particles per unit of rapidity in the central region and all physical processes are present [11]. Fig.5 shows the origins of the particles hitting the HMPID with the TOF and TRD materials in front.

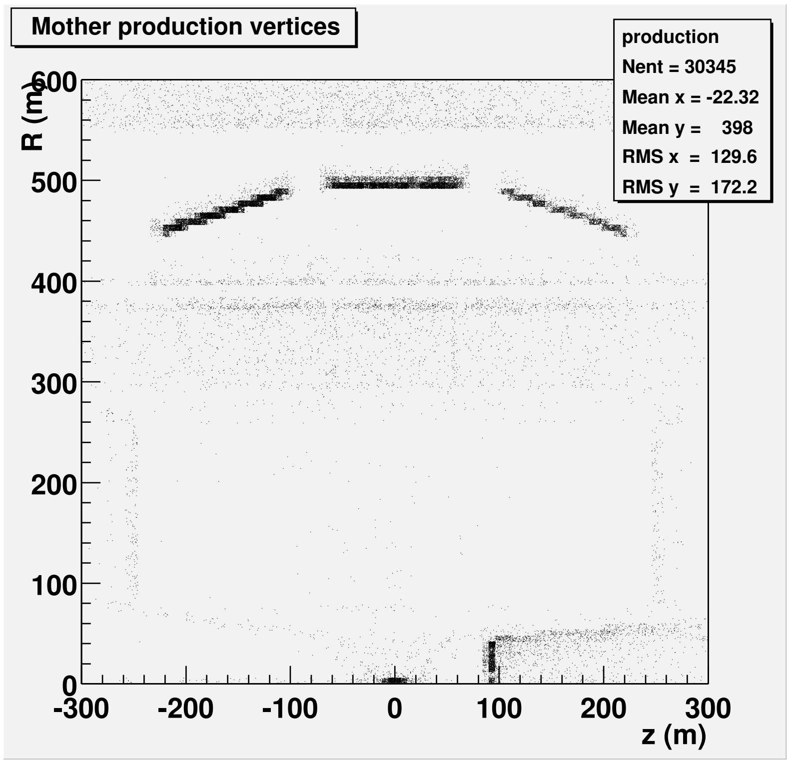

Figure 5: *Origins of particles hitting the HMPID with TRD and TOF modules in front. (Top to bottom - L3 magnet, RICH modules, TOF modules, TRD modules, TPC, ITS, absorber).*

It is clear that both TOF and TRD generate some additional noise affecting the overall occupancy. This is shown in the following fig.6.

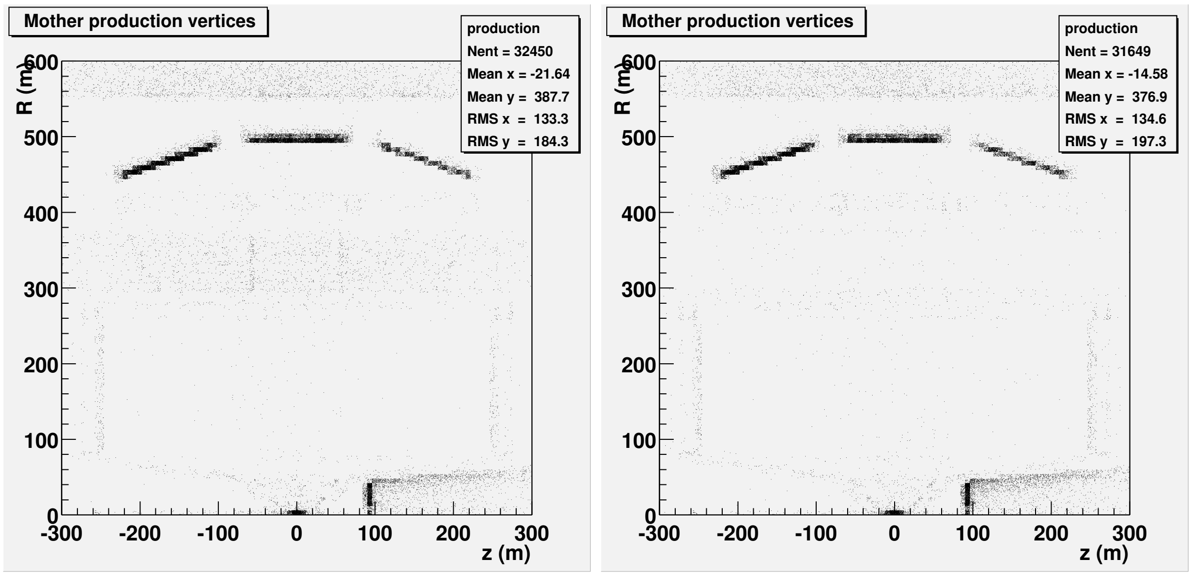

Figure 6: *Origins of particles hitting the HMPID with/without TRD, no TOF.*

The values in percentage of the individual chamber occupancies and the overall means are plotted in table 4 with the additional cases of different space frames (holes vs. no holes in the space frame itself).

Chamber	1	2	3	4	5	6	7	Overall
Full configuration, frame w. holes	13.9	12.0	11.4	11.4	13.8	13.5	11.5	**12.5**
Full conf., fr. wo. holes	13.0	9.8	11.0	10.2	11.6	11.6	12.6	**11.4**
Full conf., fr. wo. holes, TOF	12.4	11.0	11.4	9.1	13.8	12.0	12.1	**11.7**
Full conf., fr. wo. holes, TOF, TRD	10.8	10.8	11.6	9.8	13.0	11.2	10.9	**11.2**

Table 4: *Particle occupancies in the different configurations.*

Individual particle fluxes were also studied. In fig.7 are plotted several particle spectra hitting the HMPID in the three individual configurations. From left to right: full configuration[6], TRD, TRD+TOF.

For each species the total particle spectrum (gray) is plotted and the secondaries produced in the zone occupied by TOF an TRD are shown as the unshaded area.

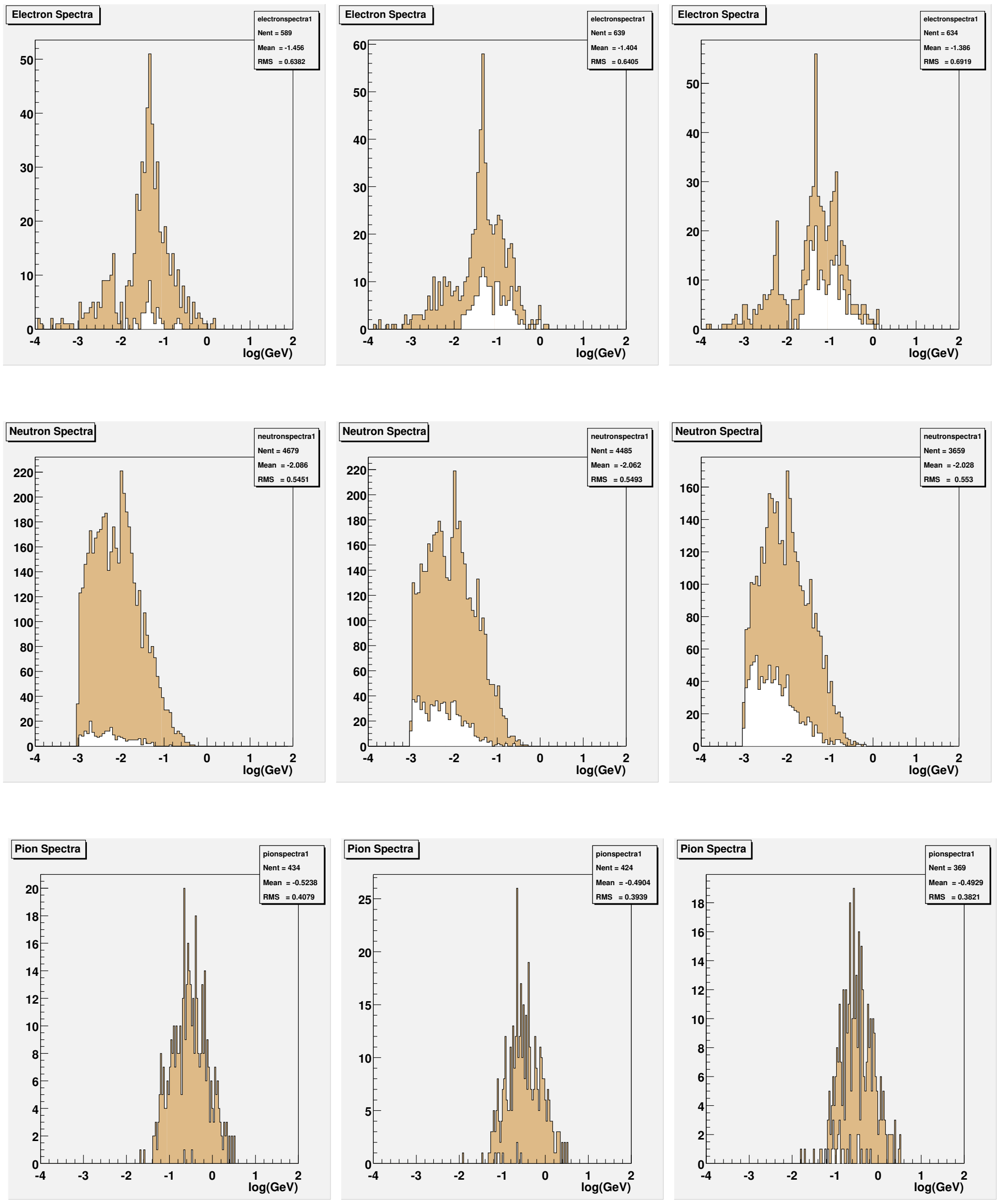

Figure 7: *From top to botton: electron, neutron and pion spectra, each in the three configurations (from left to right).*

From the figure we can see that there is additional noise in terms of electron-positron pairs and neutrons. The shielding pions and kaons spectra are influenced only in the low momenta region as shown for the pion case still in fig.7. The observed decrease of low momentum pions is due to acceptance effects discussed below.

4 Effect of the space-frame on the HMPID acceptance

The space frame designed to account for TRD/TOF detector support will introduce a large amount of material in the 18 regions, equally spaced in the $r\varphi$ plane ($\sim 20^o$), of $\sim 2^o$ width. The assumption is that the tracks missing these structures will really reach the HMPID, as schematically shown in the left part of fig.8.

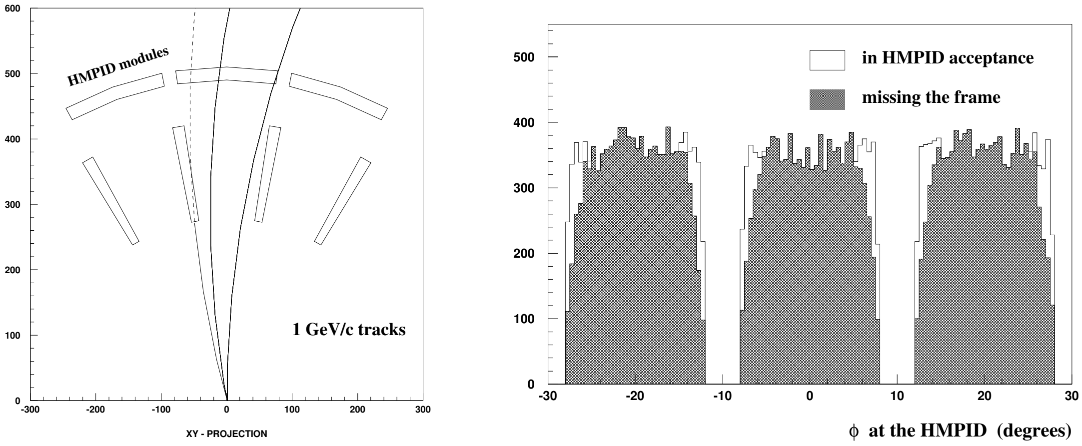

Figure 8: *From left to right: schematic drawing of the space frame effect and distributions of impacts at the HMPID.*

The evaluation of the reduction in the HMPID acceptance has been carried out by means of a geometrical simulation of the structure and by considering the track curvature in 0.2 Tesla field in the momentum range between 1 and 5 GeV/c. The right part of fig.8 reports the distribution (white) in the φ coordinates of the impacts of all the tracks within the HMPID acceptance assuming no space frame in front of it, i.e. a hole in the space frame, and the same distribution but only for those tracks missing the frame (shadowed one), in the momentum range between 1 and 2.5 GeV/c. The effective acceptance gets reduced to ~ 91 % due to the space frame effect, in the momentum range of interest for particle identification. The effect is quite negligible for tracks above 3 GeV/c.

5 Conclusion

The estimation of the errors on track coordinates and angles at the impact onto the HMPID in ALICE has been performed according to the last design specified in the de-

tectors TDR's and the new amount of material corresponding to the TRD and TOF detectors. The effect of the additional material, in particular, leads to a tracking error that is up to a factor two larger than without the additional detectors in front of the HMPID. More important is the effect on the determination of the incidence angle of the particle on the Cherenkov radiator, which comes out to be substantial.
The effect of additional material in front of the HMPID, on the efficiency and contamination in the pattern recognition using tracks with normal incidence, is noticeable especially for kaons; work on non-normal incidence is in progress.
In terms of occupancy, the inclusion of TOF and TRD modules will not degrade the signal and will even filter the noise generated by other structures.
The last item addressed is that related to the effect of the space frame, designed for the TRD and TOF detectors, on the effective HMPID acceptance: the reduction estimated is about 10% in the momentum range of interest for particle identification.

References

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