ALICE/98-37
Internal Note/DIM
August 1998

Proposal for the TC5/6 station of the ALICE dimuon arm

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Abstract

In this report, a TC5/6 chamber geometry is proposed in order to provide four (x,y) coordinates (instead of two) inside the magnetic volume of the dipole. A better background rejection could be achieved, due to these extra measurements which, furthermore, allow the possibility of local tracking for a part of the background charged particles.

1 Introduction

The trajectories of the muons in the ALICE dimuon arm have to be measured in an environment of large background coming from the front absorber and the beam shielding [1]. Each of the five tracking chamber (TC) stations is illuminated by a large number of impacts ranging from about 250 (220 charged particles) in the TC1/2 station to about 600 (420 charged particles) in the TC5/6 station. The maximum density of this background, recorded at small distance r from the beam shielding, is about 3 10^{-2} cm^{-2} and 1.5 10^{-2} cm^{-2}, decreasing by factors of 10 and 3 at large distance respectively.

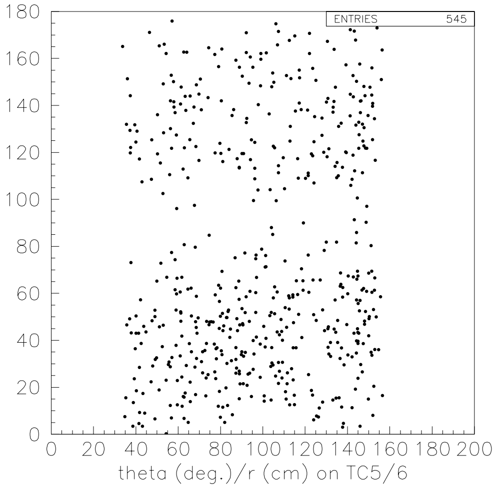

Figure 1: Correlation between the incident angle θ and the distance r from the beam for the charged particle background at the TC5/6 location (θ larger than 90° corresponds to back-scattering particles).

The cathode segmentation of the chambers [1] is supposed to be variable in such a way that the occupancy function along r on each segment is kept constant. This requirement is fulfilled by choosing for each chamber (anode wires along the x axis, perpendicular to the magnetic field and with a 2.54 mm pitch) the first cathode plane dedicated to the x coordinate measurement (horizontal width fixed to $w_x = 5.08$ mm, and vertical length variable from 7.62 mm) and the second cathode plane dedicated to the y coordinate measurement (vertical width fixed to $w_y = 7.62$ mm, and horizontal length variable from 5.08 mm). A (x,y) measurement is thus achieved from two cathode planes set on each side of the anode wire plane. In this configuration, each TC station which is composed of two chambers, provides two (x,y) independent information for each track.

The angular acceptance of the dimuon arm is about 2°-9° relative to the beam axis. The individual muon track incidence on the detection planes offered by the chambers is nearly within the same range. On the contrary, the background tracks have incidence angles which can be much larger that the above ones, due to the fact that a lot of these tracks originate from the small angle beam shielding. About 70% and 95% of tracks have an angle larger than 10° in the TC1/2 and TC5/6 location respectively. Fig. 1 shows, for the charged particles, the correlation between the incident angle θ and the distance r at the TC5/6 location, namely at the dipole median plane coordinate.

In order to increase the constraints on the muon tracking, we propose to study a special wire chamber configuration for the TC5/6 station which would give four (x,y) independent information instead of two. That should allow to get a better efficiency for the dimuon tracking and a larger dimuon acceptance at low transverse momentum. Evaluations of those effects are in progress and are not reported here. In this report, we only evaluate the efficiency of measuring charged particle background tracks which travel inside the dipole.

2 Geometry of the chambers

The chambers described in the Technical Proposal [1] are symmetric wire chambers where both cathode planes are equipped with read-out pads or strips (Fig. 2). The center of gravity of the induced charges on each cathode plane is determined by the charge partition on the anode wire plane. This geometry allows thus to get (x,y) information. We propose here an alternative chamber design by adding one anode wire plane and two cathode planes as shown in Fig. 2. The latter are not segmented. The active pads of the two segmented cathode planes provide two independent (x,y) coordinates, and therefore give, as opposed to the first geometry, a measurement of the track angle.

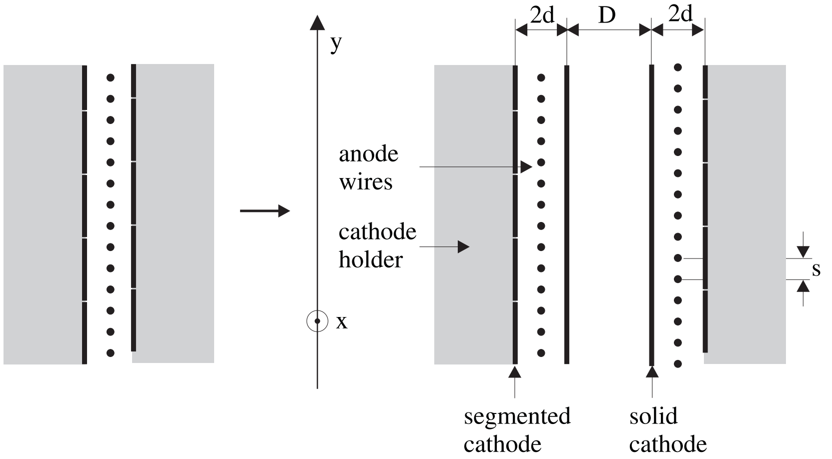

Figure 2: Schemes of the TC5/6 tracking chamber as proposed here and compared to the Technical Proposal.

The chamber has an anode cathode spacing d = 3.75 mm, equal to the wire pitch s. The wires of each plane are parallel and shifted by a half s interval in order to increase the resulting vertical resolution measurements. The pads have constant dimensions all along r with $w_x = 6.5$ mm and $w_y = 11.25$ mm for both cathode planes. These dimensions respect the 5% limit for the occupancy value at small r where the hit density is about 1.5 10^{-2} cm^{-2} and allow a simultaneous measurement of the x and y coordinates from each cathode plane. The distance between the anode planes is 2d + D, where D is the interval between the solid cathodes which is of the order of a few centimeters. Apart from the x (y) resolution performance of the chamber, the parameter D influences directly the precision on the angle measurement of the tracks. The prototype has an inter-anode distance fixed to 50 mm.

The geometry of the proposed TC5/6 tracking chambers leads to parameters which are gathered in Table 1 and compared with those given in the Technical Proposal [1].

	This TC5/6	The TP TC5/6
outer radius (cm)	173	=
inner radius (cm)	34	=
full station sensitive area (cm^2)	2 x 181000	=
pad size (cm^2)	0.65 x 1.125	$\geq$0.508 x 0.762
full station number of pads (x10^3)	2 x 248	2 x 121
anode cathode gap (mm)	3.75	2.54
anode wire spacing (mm)	3.75	2.54

Table 1: Main parameters of the tracking chambers TC5/6 as proposed here and compared to the Technical Proposal.

3 Simulation

3.1 Resolution of the chamber

The resolution of such a chamber along the anode wire direction (x direction) has been measured by the Orsay [2] and Gatchina [3] groups. RMS values close to 150 μm have been obtained before evaluation of the real track measurement uncertainty contribution. The dependence of the resolution with the incidence angle of the tracks on the chamber has been measured in the 0°-10° interval, which corresponds to the angular acceptance for primary particles originating from the collision. The resolution of the chamber has not been evaluated for tracks with much larger incidence angles, situation encountered for the background tracks in the ALICE dimuon arm (Fig. 1).

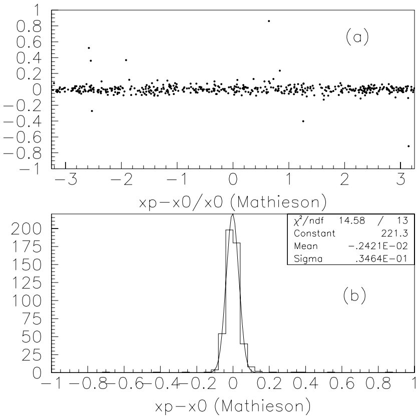

Figure 3: Chamber under perpendicular tracks distributed all across one pad. a) x-residual as a function of the true position, b) integrated x-residual.

We have simulated, with a program [4] adapted to our geometry, the resolution of the detector with respect to the incident angle (θ, ϕ) of the tracks. The track angle is defined by θ, the incident angle relative to the chamber, and ϕ, the azimuthal angle, where $\phi = 0°$ indicates tracks in a plane normal to the chamber and parallel to the anode wires (in this case $\theta_x = \theta$) and where $\phi = 90°$ indicates tracks in plane perpendicular to anode wires (in this case $\theta_y = \theta$). The charge collected by the pads has been calculated using the Mathieson function [5]. The center of gravity of the charges has been calculated by minimisation of this function on three adjacent pad charges with a noise of 0.5% (σ_{noise}) around a level of 1000 e^- per channel.

The resolution of the chamber is shown in Fig. 3 for tracks perpendicular to the chamber and uniformly distributed all across one pad. An integrated resolution along the wire of about 35 μm is found. The dependence of the resolution with the incident angle is given in Fig. 4 for three azimuthal angles, $\phi = 0°$, $45°$ and $90°$. The resolution which remains nearly constant with θ for tracks perpendicular to anode wires ($\phi = 90°$) decreases when θ increases for tracks with smaller azimuthal angles. This effect is due to larger ionisation fluctuations along the x direction when the track azimuth decreases. A similar observation could be drawn concerning the y resolution of such a chamber. One anode wire should collect charges for tracks with azimuth close to 0°. On the contrary, a few anode wires could contribute for tracks with larger value of ϕ, resulting in a possible degradation of the y resolution performance of the chamber.

The simulation is supposed to represent an idealistic detector. We propose to perform a specific experimental study of the chamber under large incidence angles θ as a function of azimuthal angles ϕ, in order to get a realistic quantitative evaluation of the signal development on the pads and, thus, to represent it by an adequate parametrization.

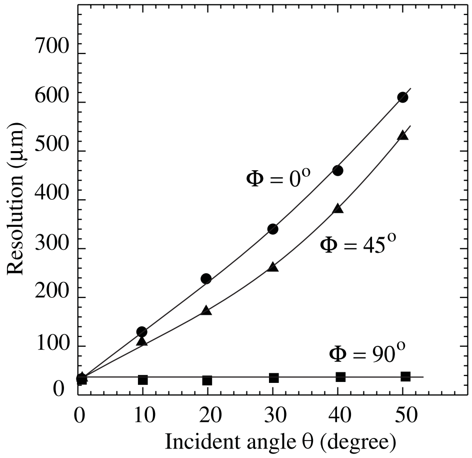

Figure 4: Chamber under inclined tracks distributed all across one pad. x resolution as a function of incident angle θ for three azimuthal angles ϕ.

3.2 Charged background recognition capability

The efficiency of the background track recognition inside the magnetic volume of the dipole has been evaluated using a central Pb-Pb collision simulated in the experimental environment of the ALICE dimuon arm [6]. The charged particle tracks are characterized by a straight line in the non bending plane (vertical y direction) and a circle in the bending plane (horizontal x direction). Consequently, the vertical incident angle (θ_y) and the horizontal radius of curvature (ρ) of the tracks are relevant information to be measured. The simulated correlations of those quantities are plotted in Fig. 5a for positive and negative charged particles. We observe that the background events are localized far outside the (θ_y, ρ) zones of the μ^+ μ^- tracks which feed areas defined by $\theta_y = 0°$-$10°$ and $|\rho| >2000$ cm.

The background track recognition performed by measuring the (θ_y, ρ) correlation requires the measurement of at least 3 coordinates. If we suppose that each chamber has a 100% efficiency and does not introduce any uncertainty on the measurement of the curvature radius and the vertical incident angle of the tracks, we can evaluate the efficiency for recognizing the background tracks by simply counting tracks which give 3 or 4 coordinates in the four chambers. The anode wire planes of the chambers are set at -25, -20 cm and +20, +25 cm relative to the median plane of the dipole which is at +975 cm away from the collision. The calculation is done for particles with a kinetic energy larger than 10 MeV. This threshold cuts mainly electrons (about 75% of the charged particles) which populate an area around $\rho = 0$ and which, by no means, could be tracked with this device. About 60% of tracks have been found with 3 or 4 detectable coordinates. The (θ_y, ρ) correlations are plotted in Fig. 5b for those events. A large percentage of tracks with large momentum (mainly with small θ_y and large ρ) can be measured. On the contrary, tracks with small momentum (any θ_y and small ρ), which correspond mainly to electrons emerging

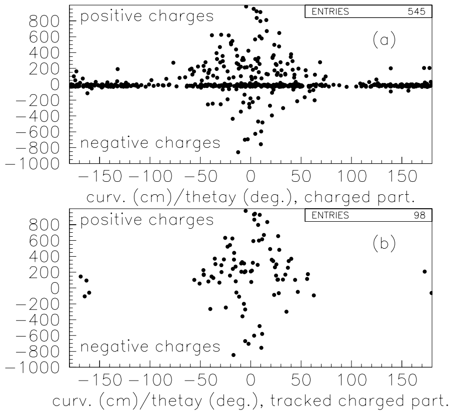

Figure 5: Correlation curvature/vertical incident angle of a) background tracks inside the dipole (all charged particles), b) and giving 3 or 4 coordinates (only charged particles with kinetic energy larger than 10 MeV).

from the beam shielding, are of much less concern. For a more realistic evaluation of the local tracking efficiency, it remains to take into account the resolution of the chambers and the effect of their material components on the various coordinate measurements.

It has to be noted that this efficiency of 60% reduces to about 20% if all the charged particles are considered. This number could be regarded as small. Nevertheless, even if we do not measure the trajectory of a lot of particles, the capability of measuring four (x,y) coordinates (instead of two), will provide more constraints on the muon tracking and will allow to reject more background contributions (including the contribution by neutral particles) inside the dipole. This improvement is not evaluated in this report. In conclusion, the use of special chambers to equip the TC5/6 station should allow a better two muon tracking efficiency of the dimuon arm.

4 Prototype description

4.1 Pad reading

The 16-channel GASSIPLEX chip developed at CERN will be used for the cathode readout. We will adopt the electronics scheme with three GASSIPLEX circuits grouped on one electronics card. An individual pad reading would be the ideal situation. Nevertheless, due to the excessive number of pads given by the present geometry (496 10^3 for full TC5/6 station compared to 242 10^3 in the Technical Proposal [1]), and after suggestion to read several pads in parallel [7], we propose to read at small r the individual pads (Fig. 7), and at larger r, 2 pads (Fig. 6a) or more (Fig. 6b) in parallel by a single GASSIPLEX channel. The connected pads always belong to distinct clusters which cover 9 pads around the impacts. The necessary reading of 48 channels for 3 GASSIPLEX circuits and a minimum number of individual pads for a correct cluster signature lead to a channel reduction factor smaller than 2 and 4, namely 1.5 and 2.25. The proposed set-up is given in Table 2 and shows a significant reduction of total electronics channels (283 10^3).

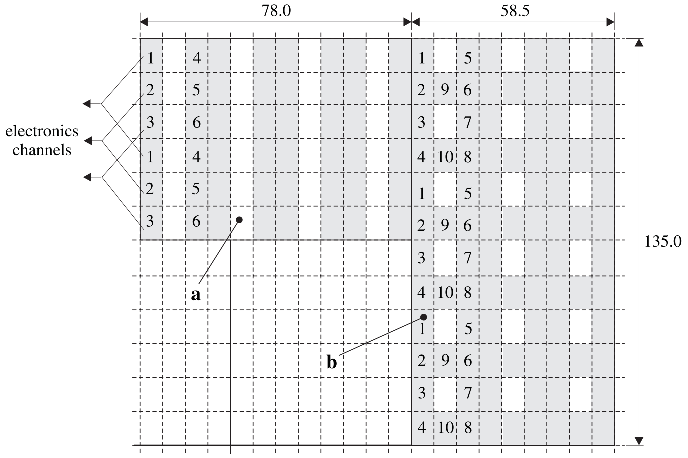

Figure 6: Scheme of the cluster (3x3 pads) information recorded through the parallel reading of a) 6x2 pads repeated four times and b) 10x3 pads repeated three times. The pads in white are read individually and each area inside solid lines includes 48 electronics channels.

A crude evaluation of the double hit rate has been done in the case of a central Pb-Pb collision [6]. Each impact produces a 9 pad cluster. 3 pads in the central vertical direction and 3 pads in the central horizontal direction are defined as "main" pads from which the vertical (y) and horizontal (x) coordinates are calculated. The 4 pads localized in the corners of the cluster are not used for the coordinate determination. Furthermore, pads which are connected in parallel with pads of the cluster are neutralized. They cannot be used for the measurement of an other impact. We count a double hit when the charge collected by (at least) one "main" pad of a cluster comes from two different clusters. On the contrary, we do not count as a double hit clusters belonging to the same electromagnetic shower. The area of the cathode has been divided in three concentric rings for which the pads are read individually and according to the schemes a and b as described in Fig. 6. The smaller the distance is to the beam, the larger is the granularity of the detection. The result of this evaluation is given in Table 2. It shows a reasonable double hit rate in the inner zone of the chamber and a weak increase with r, due to the effective detection granularity function which does not make constant the occupancy function given by the reading geometry. A better matching could be studied if necessary, at the cost of an increasing number of electronics channels. This result promises a good pattern recognition efficiency which is being presently studied.

Ring size (cm/cm)	Area (cm^2)	Pads per channel	Number of channels	Occupancy (%)	Double hits (%)
34/70	11762	1	16085	6	8
70/110	22619	1.5 (a)	20622	8	11
110/173	56011	2.25 (b)	34043	10	14
Total	90500		70750		12

Table 2: Double hit calculation in the case of a central Pb-Pb collision. The TC5/6 segmented cathode is divided in three concentric rings for which the pads are read individually (inner ring) and according to the schemes a and b (central and outer rings) as described in Fig. 6. The area, the average number of pads per electronics channel, the number of electronics channels, the occupancy and the double hit rate are given for each concentric detection ring.

4.2 Construction and materials

Strip/pad chamber prototypes have already been constructed for ALICE by the Orsay [2] and Gatchina [3] groups. We propose to construct a chamber prototype as described in Section 2. We choose to apply the technical solutions already used and tested and to reduce as much as possible the thicknesses of the various mechanical elements of the chamber, in such a way that the total radiation length X/X_0 would be minimized.

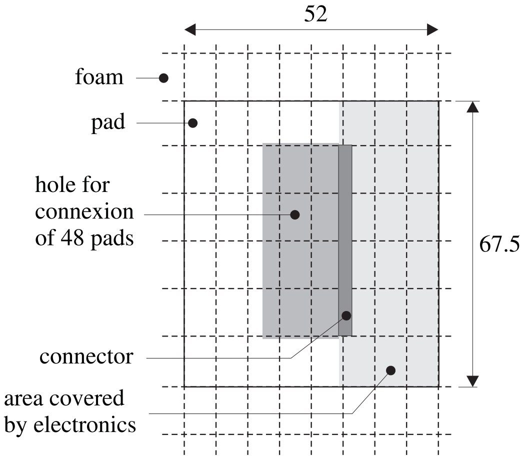

Figure 7: Scheme of the electronics set-up for an individual pad reading. The area inside full lines includes 48 channels.

The radiation length of the electronics set-up can be coarsely estimated using the configuration pattern shown in Fig. 7. This figure (corresponding to the individual pad reading) sketches one of the 1365 holes through the cathode support for the signal pick-up (covering the total area 13000 cm^2), together with the electronics support (18000 cm^2), and the electronics nylon connectors (2600 cm^2), numbers to be compared to the full area of one cathode plane (90500 cm^2). On the area devoted to the electronics, we have assumed an area for silicon circuits (1.5 cm^2) and for plastic capsules (9 cm^2). Table 3 gives the contribution of these materials in term of X/X_0. In fact, this set-up will have to be adjusted to the real electronics configuration which will be adopted.

Although the present proposition for the TC5/6 station makes the chambers geometrically thicker, the additional material (2 cathodes and 2 windows) represents negligible additional effect regarding the muons through the spectrometer. Table 3 summarizes the material thicknesses and their corresponding radiation lengths. A total value of ≈2.0% for X/X_0 can be expected.

Material	Thickness (mm)	X_0 (mm)	Number of layers	Covered area (%)	Average X/X_0 (%)
Foam	50	10000	2	70 (40)	0.7
PCB	0.2 (0.4)	194	4	100	0.41
Cu	0.009 (0.0175)	14.3	6	100	0.38
Gold	0.001 (0.005)	6.1	6	100	0.1
Glue	0.1 (0.0)	200	4	100	0.20
Mylar	0.05	287	2	100	0.03
Aluminium	0.0127	89	2	100	0.03
PCB (Kapton)	0.1	250	2	20	0.02
Nylon (electronics)	2.7	300	2	3	0.05
Si (electronics)	0.3	93.6	2	3	0.02
Chip (electronics)	1.5	400	2	14	0.11
Total					2.05

Table 3: Thickness and radiation length of materials of one of the TC5/6 chambers. When different, the values of the ALICE muon spectrometer Technical Proposal are given in parenthesis.

Tests in the T10 beam line will be carried out. The conversion and acquisition of the data will be done through CAEN VME modules and VME processor linked to a HP workstation available to the users [8].

5 Test measurements

The first test of the prototype chamber is planned in December 1998. The main measurements will be:

- study of the chamber under beam incidence inside the 0°-10° θ range: analysis of the signal, resolution, dependence of physical parameters like gas composition, high voltage, ... (priority for the first test).

- measurement of the resolution and the efficiency of the chamber for tracks through and between reading zones of the cathode (priority for the first test).

- study of the chamber under large angle beam incidences $\theta > 10°$. Dependence on the azimuthal angle of the tracks between $\phi = 0°$ (tracks in the plane of anode wires) and $\phi = 90°$ (tracks in a plane perpendicular to the anode wires).

- study of the chamber inside a magnetic field: measurement of the Lorentz angle, the position and angle resolutions, ...

6 Participation to this project

The IPN-Lyon collaborators explicitly associated to the construction of the chamber prototype are R. Bouvier, M. Chartoire, D. Delaunay, D. Essertaize, M. Goyot, G. Jacquet, M. Jacquin, M. Miguet, S. Vanzetto and the members of the workshop. The colleagues from the laboratory or from Orsay, Gatchina and CERN laboratories, who are often consulted, are warmly acknowledged.

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