ALICE/99-37
Internal Note/DIM
July 28, 1999

Pad segmentation for stations 4 and 5 of the ALICE Muon spectrometer CPC's

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Abstract

A pad segmentation based on 3 types of PCB's for each cathode plane for the stations 4/5 is presented. PCB's of 40 x 40 cm^2 are used with only one pad size on each. The 4 chambers are builded with the same mechanics and the electronics is only implemented inside the acceptance. This solution leads to an easier design and construction. The total number of channels for the stations 4 and 5 are found to be 487 680.

1 Introduction

Modular solutions for the CPC's (Cathode Pad Chamber) and CSC's (Cathode Strip Chamber) for the last 2 stations of the ALICE Muon spectrometer have been discussed during the last few months. Among the advantages of a modular solution over a more standard approach (see the Technical Proposal [1] for more details) for a large wire chamber we can find : reliability in case of wire breaking, easy construction and task sharing, low cost, small tickness in radiation length, ...

One of the important challenges in the LHC heavy ion collisions is to be able to cope with the high particle multiplicity with a reasonable number of channels. We review a pad segmentation consistent with a simple design where the occupancy stays around the 5% value required by the ALICE Muon spectrometer tracking.

2 Requirements

In order to achieve the physics goals, a resolution < 100 μm in the bending plane (Y) and ≈ 2 mm in the non-bending plane (X) are needed [1].

One of the main criteria that dictates the segmentation is the particle density. Several codes [1] have been used by the ALICE collaboration to get the density distributions which are expected in a Pb-Pb central collision. The *official* particle density distributions coming after the Evian meeting [2] are shown for the last 2 stations in fig. 1. A security factor of 2 is already included in these distributions. As we see, the particle density decreases with the radius exponentially. For our purpose here we take the following distribution for station 4 and 5 :

$$f(r) = e^{\alpha r + \beta}$$

with $f(r = 50 \text{ cm}) = 10^{-2}$ particles/cm^2 and $f(r = 260 \text{ cm}) = 1.5\ 10^{-3}$ particles/cm^2. We get $\alpha = -9.03\ 10^{-3}$ cm^{-1} and $\beta = -4.15$.

The number of particles between two radii R_1 and R_2 is then given by :

$$N = \int_{R_1}^{R_2} 2\pi r f(r) dr = \frac{2\pi e^{\beta}}{\alpha^2} \left\{ e^{\alpha R_2}(\alpha R_2 - 1) - e^{\alpha R_1}(\alpha R_1 - 1) \right\}$$

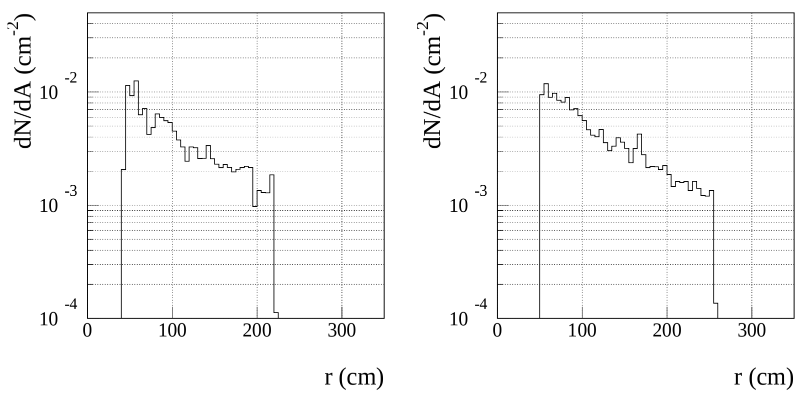

Figure 1: Particle density versus radius for stations 4 (left) and 5 (right)

PCB type	Δx (cm) $\times$ Δy (cm)	number of MCM's	number of channels
1	2.5 $\times$ 0.5	20	1280
2	5 $\times$ 0.5	10	640
3	10 $\times$ 0.5	5	320

Table 1: Pad segmentation for the PCB's in the bending plane (Y)

We obtain for instance $N = 730$ particles between 50 and 260 cm which is the standard coverage of station 5 [1].

Since the dimensions of the chambers are rather close for stations 4 and 5, we suggest to build only one type of chamber in order to simplify the design and the construction. This unique chamber can have an inner radius of 40 cm and an outer one of 260 cm for the active area. Since the beam pipe absorber has a radius of 30 cm, then we have 10 cm for the mechanics. We can decide not to fully implement the electronics in the outer part of some modules, this is of course the case for the chambers of station 4.

Several constraints come from the PCB's (Printed Circuit Board). It is difficult to find in industry PCB's larger than $\approx$ 50 cm at a reasonable price. There is also a limitation for the etching precision which leads for the standard quality of PCB's to a pitch greater than 400 μm between two lines in the circuit.

Another point concerns the electronics integration. For the tracking chambers, the 16-channel GASSIPLEX chip is implemented in a MCM (Multi Chip Module) board containing 4 chips. This leads to a simplification if each PCB board contains a number of pads divisible by 64.

3 PCB geometry and segmentation

One has to cover the maximum amount of the active area limited by the 2 radii (40 and 260 cm), which leads to a natural choice for the PCB active area of 40 cm x 40 cm. To simplify the PCB design and building we propose to use only one pad dimension in a given PCB. The pad sizes are taken to fit as close as possible to the density and to satisfy the requirements of section 2, which leads to 6 different PCB types (3 for X and 3 for Y measurement).

For the bending plane cathodes (perpendicular to the anodes wires), pads with a width of 0.5 cm are used to measure the Y coordinate. This solution has been extensively tested and satisfies the resolution requirements ($<$ 100 μm in the bending plane) [3] if we use a wire spacing and a half gap of 2.5 mm. The pads of each PCB are read on top and on bottom, giving for the smaller pads (worst case) a 625-μm pitch for the readout lines, well above the 400 μm limit quoted previously. Table 1 gives the pad size used for each PCB type in the bending plane. The pad width in the X coordinate goes from 2.5 cm to 5 cm, and then to 10 cm. The number of channels per PCB is always equal to a multiple of 64 to fit to an integer number of MCM's in the bending plane.

For the non-bending plane cathodes, a pad width of 1 cm covering 4 wires is a convenient choice for the X coordinate measurement (1 cm $/\sqrt{12} \approx 2.8$ mm). Most of the time 2 pads are fired, leading to a resolution better than 2 mm. In order to keep the occupancy at the same level for the 2 cathodes planes, we suggest the

PCB type	Δx (cm) $\times$ Δy (cm)	number of MCM's	number of channels
1	1×2.5	10	640
2	1×5	5	320
3	1×10	2.5	160

Table 2: Pad segmentation for the PCB's in the non-bending plane (X)

PCB type (X or Y)		number of PCB's (X + Y)	number of channels (X + Y)
1		28 + 28	35840 + 17920
2		44 + 44	28160 + 14080
3	Station 5	72 + 72	23040 + 11520
	Station 4	36 + 36	11520 + 5760
Total	Station 5	288	130560
	Station 4	216	113280

Table 4: PCB distribution for one chamber

pad sizes given in table 2 for the non-bending plane. We observe that the number of channels don't fit with an integer number of MCM only in one case.

The distribution of the 3 PCB types in each cathode is dictated by the maximum occupancy that can be tolerated for pattern recognition. Each PCB of a given type in the bending plane is in front of the same PCB type in the non-bending plane. Fig. 2 and table 4 shows one configuration for the PCB's geometry for the chambers of station 4 and 5. This solution leads to 487 680 channels for the 4 chambers of 2 stations.

4 Occupancy and ghosts

Fig. 3 gives the corresponding pad occupancy for the 3 PCB types in the bending plane cathode for one chamber of station 5, assuming that each particle hit is seen by 3 pads in the Y direction. We use a radius of 0.75 cm [4] for the charge influence region, leading to a 6 pads fired when the hit is near the pad boundary. For this simulation, 1 million events of 760 particles each was generated according to the density distribution of section 2.

As we can see the occupancy for all pads stays at reasonable level compared to 5%. As an example, fig. 4 shows the occupancy for the type-1 PCB closest to the beam pipe.

Since the X and Y coordinates are measured in 2 different cathodes planes, if we have more than 2 hits in the area formed by the rectangle XY, we have an ambiguity to match each Y position to the corresponding X position. In that case we have *ghosts* hits added to the real hits. We can calculate the probability to find one signal hit together with a background hit in the same XY rectangle. The fig. 5 shows this probability for each PCB type. The level for the pads of type 3 PCB's (outer region) are in the 15-20 % range, which could produce troubles in the tracking procedure. This point has to be checked with care using the simulation/tracking programs. Nevertheless we can use the charge correlation between the 2 cathodes to help the maching of X and Y coordinates. The PNPI Gatchina team test recently this possibility in a chamber prototype [5], and they found that the X and Y mismatching could be below 3% using 0.5 cm width strips. It is not proved that charge correlation is feasible with wider strips.

5 Conclusion

We show that it is possible for the large chambers to find out a reasonable PCB geometry configuration using only 3 pad sizes for each cathode with one single pad size per PCB. This configuration fulfills the requirements and ensures an easy design and construction. The total number of channels for the 4 chamber (487 680) is found to be $\approx$ 65% larger than in the Technical Proposal [1] whereas the density was increased by a factor 2.5 at small radius.

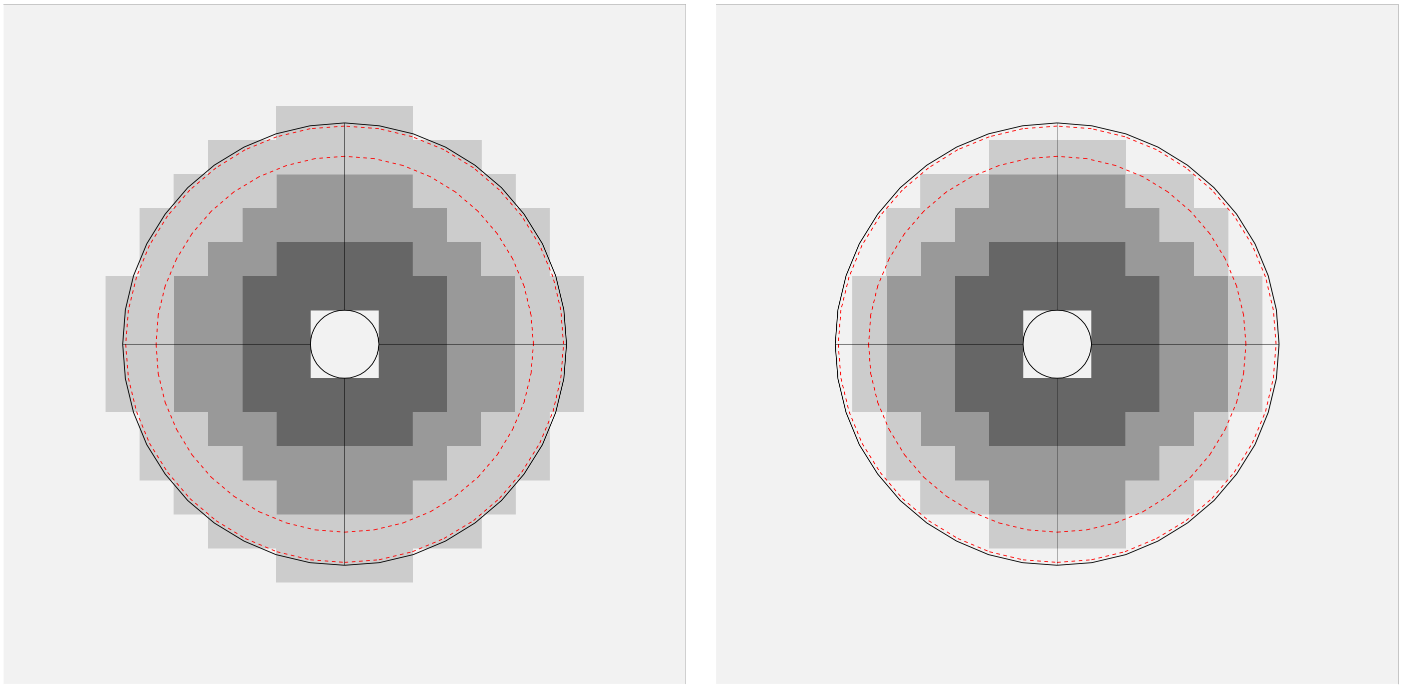

Figure 2: PCB geometry distribution in the chamber for station 5 (left) and station 4 (rigth). Type 1 (deep grey), type 2 (medium grey) and type 3 (light grey). The 2 limit circles 40 and 260 cm of radius are shown (solid lines). The 2 circles (dashed lines) of radius equal to 256.5 and 221 cm corresponding to the Technical Proposal limits.

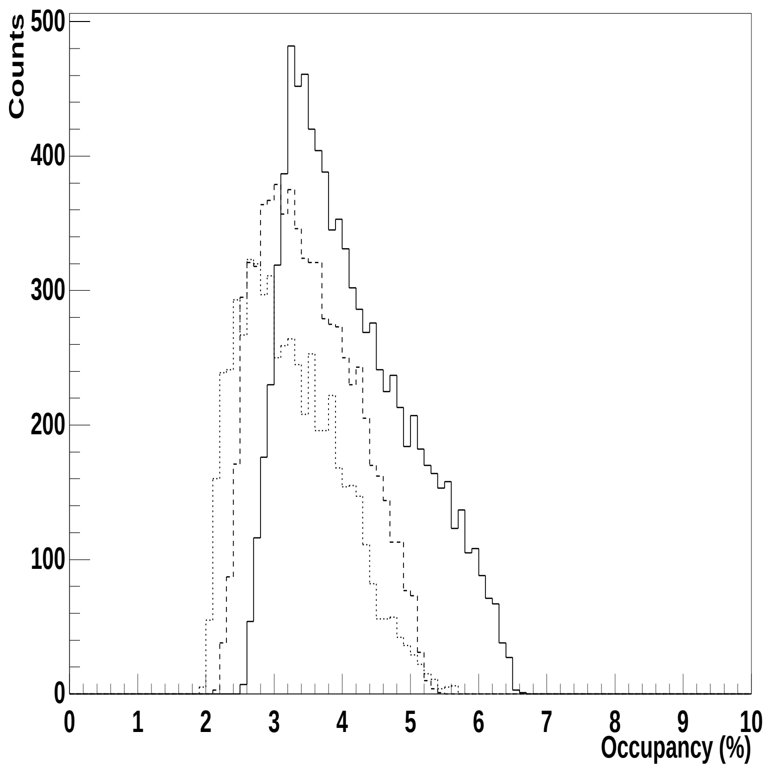

Figure 3: Occupancy distribution for one chamber of station 5 in the bending plane for pads in the 3 types of PCB : type 1 (solid line), 2 (dashed line) and 3 (dotted line)

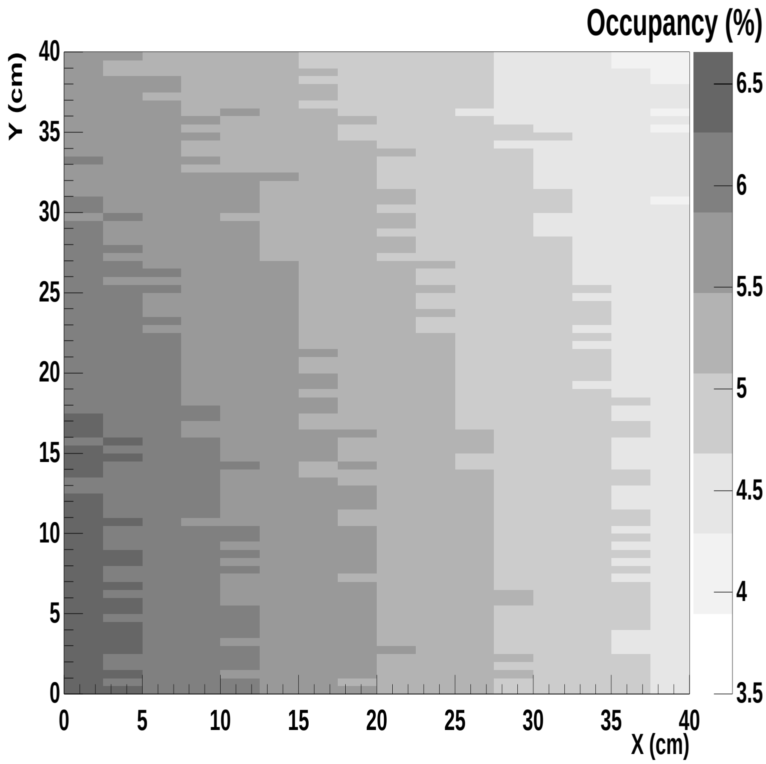

Figure 4: Pad occupancy for the type-1 PCB closest to the beam

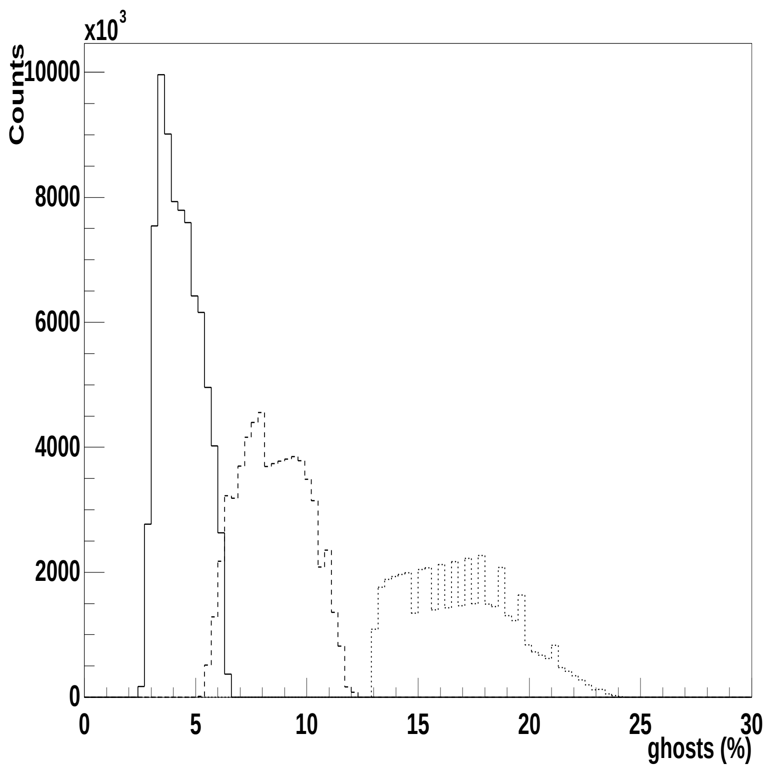

Figure 5: Probability to find a signal hit with a noise hit in the XY association for the 3 PCB types : 1 (solid line), 2 (dashed line) and 3 (dotted line)

Since only one type of chamber is used, one requires less tooling and less spares have to be built. A complete simulation using a more realistic geometry with module superposition and a cluster simulation could be the next step.

If the tracking procedure can not handle with the level of ghosts, the charge correlation could be an interesting solution. If the major part of ambiguities can be solved, we could use only one strip size (0.5 x 10 cm^2) in the non-bending plane. The number of channels of this solution is about the same that the solution presented here and would give only a few % of mismatching to the tracking. More tests and simulatons are needed to conclude.

References

[1] The forward muon spectrometer. Addendum to the ALICE Technical Proposal, CERN/LHCC 96-32, LHCC/P3-Addendum 1, 15 Oct. 1996.

[2] ALICE Muon spectrometer meeting, Feb. 1-5 1999, Evian, France.

[3] See for instance the chapter 2 of the Muon Spectrometer TDR.

[4] See also note ALICE/99-23

[5] PNPI test beam results and V. Nikulin private comunication.