Письма в ЭЧАЯ. 2010. Т. 7, №5(161). С. 581–586

МЕТОДИКА ФИЗИЧЕСКОГО ЭКСПЕРИМЕНТА

THE SPATIAL RESOLUTION OF THE CMS ME1/1 MUON STATION CATHODE STRIP CHAMBERS WITH CRAFT08 DATA

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The spatial resolution of the outer part of the ME1/1 muon station has been studied with CRAFT08 (Cosmic Rays At Four Tesla-2008) data at the CMS detector (CERN). The ME1/1 Cathode Strip Chamber (CSC) layer spatial resolution as a function of the CMS solenoid magnetic field is presented. The influence of the strip width and anode wire tilt on the spatial resolution has been studied. Finally, the spatial resolution for the ME1/1 6-layer CSC was calculated and the ME1/1 outer part spatial resolution was estimated.

Изучалось пространственное разрешение внешней части мюонной станции ME1/1 установки CMS (ЦЕРН) по данным CRAFT08 (Cosmic Rays At Four Tesla-2008). Представлена зависимость пространственного разрешения однослойной катодно-стриповой камеры (КСК) станции ME1/1 от величины магнитного поля соленоида CMS. Изучено влияние ширины стрипа и поворота анодных проволок на пространственное разрешение. Проведены расчеты пространственного разрешения для шестислойных КСК ME1/1, и дана оценка пространственного разрешения внешней части станции ME1/1.

PACS: 29.40.Cs; 29.40.Gx

INTRODUCTION

ME1/1 is the innermost muon station of the CMS endcap muon system [1]. It is composed of 36 six-layer Cathode Strip Chambers (CSC) [2] in each endcap (Fig. 1). In 2008 the CMS detector operated at a magnetic field of $B = 0{-}3.8$ T with cosmic muons. The chambers operated at the nominal anode–cathode voltage of 3.0 kV. This paper presents the results of a study of ME1/1 CSC spatial resolution in CRAFT08 runs.

1. ME1/1 CONSTRUCTION FEATURES

Details of the ME1/1 CSC construction and readout system are described in [3, 4]. To make the results presented here more understandable we would like to mention some special features of the ME1/1 construction. Figure 2 shows schematically how the cathode strips are grouped. The strips are read out by 5 cathode front-end boards (CFEB) [5]. A gap cut at

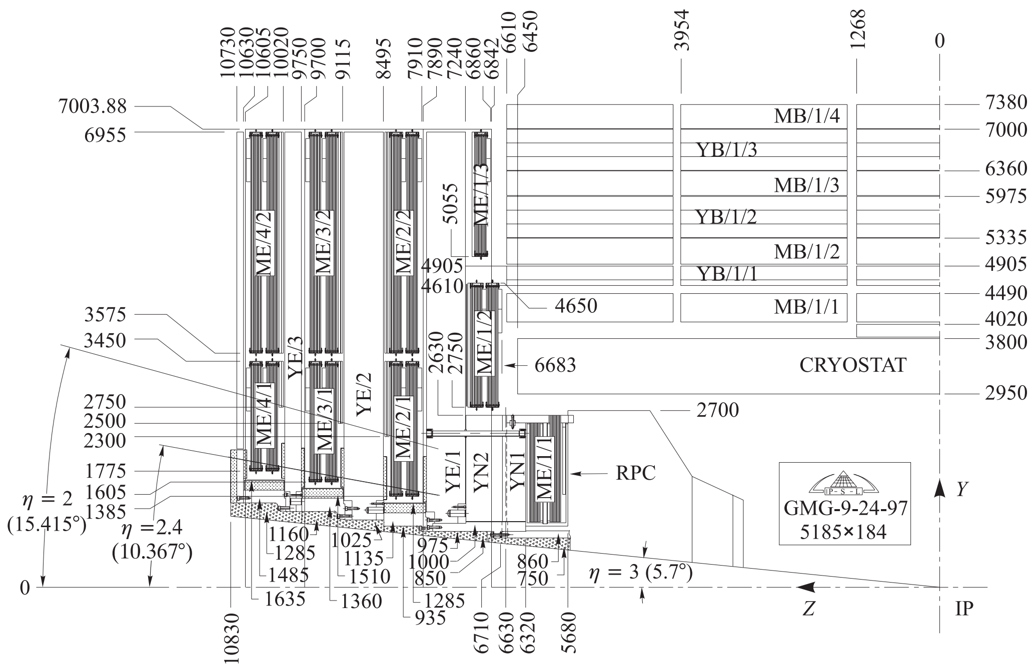

Fig. 1. CMS cross section, quarter-view

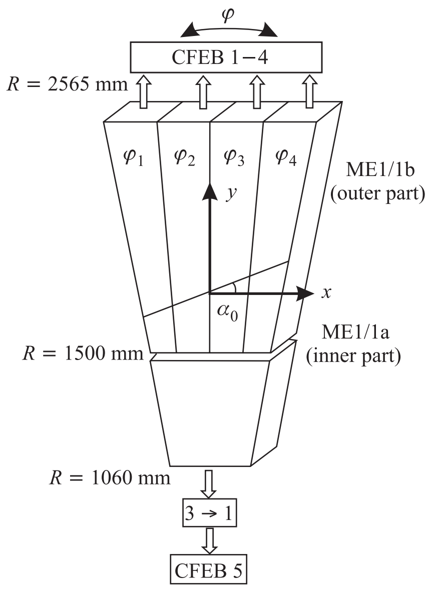

Fig. 2. ME1/1 cathode strip areas; x, y — local chamber coordinates

$R = 1500$ mm (where R is the radial distance from the beam line) divides the chamber into two parts: the outer part (ME1/1b) with 4 CFEBs and the inner part (ME1/1a) where 3 strips are connected to 1 readout channel via a «3-to-1 box» connected to 1 CFEB. The ratio of the sensitive areas of these two parts is 3.9:1. The strip structure covers the angle $\varphi \pm 5.42°$ so in the ME1/1 outer part each CFEB reads out 16×6 strips spanning $2.71°$. For CFEBs 1–4 the centres of these spans are at angles $\varphi_1 = -4.07°$, $\varphi_2 = -1.36°$, $\varphi_3 = +1.36°$, and $\varphi_4 = +4.07°$ (local φ-coordinates). The anode wires are tilted at an angle of $\alpha_0 = 29°$ with respect to the perpendicular to the chamber axis [3]. For CFEB 1–4 strip areas this angle varies and the mean values are $\alpha_1 = 24.9°$, $\alpha_2 = 27.6°$, $\alpha_3 = 30.4°$, and $\alpha_4 = 31.1°$. Taking this into account one can study the influence of the wire tilt on the layer spatial resolution in the magnetic field. The mean strip width in the outer part is 6 mm.

2. ME1/1 SPATIAL RESOLUTION

For the layer spatial resolution calculation we adopted the following event requirements:

• A track segment requires 6 hits (in the 6 CSC layers);

• Large angle muons are excluded by the following cut: $|dx/dz| < 0.15$ (chamber local coordinates);

• $\chi^2/\text{nDoF} < 200/8$ for spatial track segment fit;

• $\chi^2/\text{nDoF} < 50/4$ for plain track segment fit on strips;

• The main background outliers, tracks having residuals of more than 0.2 strip width, are excluded;

• The cut for the sum of charges for 3 strips in 3 time slices in a layer is: $250 < Q(3 \times 3) < 4000$ ADC counts (Fig. 3).

The Gatti function [6] is used to determine the precise (strip) coordinate for each layer. A track segment is composed of 6 strip coordinates and is fitted by a straight line. The residuals are the differences between the measured and fitted track-segment strip coordinates in each layer.

Coming to the layer spatial resolution one has to multiply the residuals for each layer by the correction factors calculated from the diagonal elements of the «Hat matrix» [7]. For ME1/1 CSC layers the correction factors are 1.45 for layers 1 and 6, 1.19 for layers 2 and 5, and 1.10 for layers 4 and 3. Figure 4 shows the residuals multiplied by the correction factors for ME1/1b layers at $B = 3.8$ T. To subtract the secondaries that originate mainly from δ electrons, a Gaussian + parabola fitting curve is used (see [1, Subsecs. 4.8.2 and 4.8.4]). Taking into account that the histogram x-axis is in units of strip width, the layer spatial resolution is calculated to be $\sigma = 0.0189 \times 6\ \text{mm} = 113\ \mu\text{m}$.

We also studied the influence of the solenoid magnetic field on the layer spatial resolution (Fig. 5). The points at $B = 1.95$ and 2.85 T correspond to data collected when the magnetic

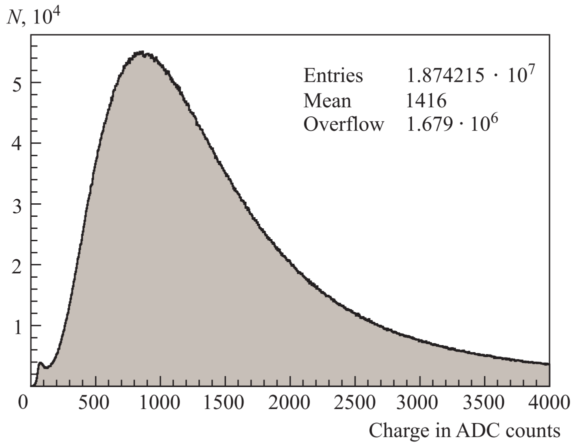

Fig. 3. The cluster charge in ME1/1 layer for all the reconstructed hits. The sum of charges in three neighboring strips in three 50 ns time slices is plotted. Small peak ($\sim$ 100 ADC counts, 1 ADC = 0.54 fC) on the left is a pedestal contamination

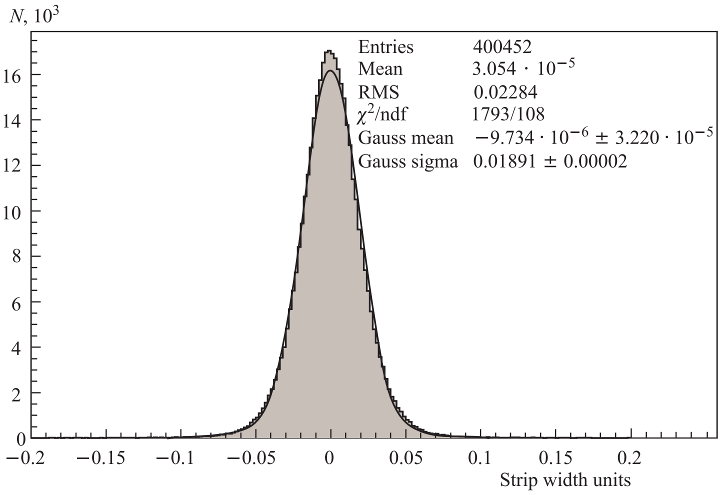

Fig. 4. Residuals with correction factors for ME1/1b layers. The fitting curve is the sum of a Gaussian and parabola

field was rising or lowering during a run. One can see that the spatial resolution clearly depends on the magnetic field.

The layer spatial resolution as a function of the radial coordinate R (distance from the beam line) is presented in Fig. 6. Radial cuts were made to separate ME1/1b into four 266-mm-wide regions, labelled $R1{-}R4$. The strip width increases with the global radius. With the present chamber geometry this leads to degradation in the resolution [8]. For a more comprehensive study of the layer spatial resolution, we made 4 cuts separating the CFEB 1–4 areas where anode wire tilt angles are different (see Sec. 1). The spatial resolution for these areas is plotted in Fig. 7. One can see that the best spatial resolution is in the CFEB 3 region where evidently the anode wire tilt reaches the optimal value for compensating of the ionization electrons shift in the magnetic field.

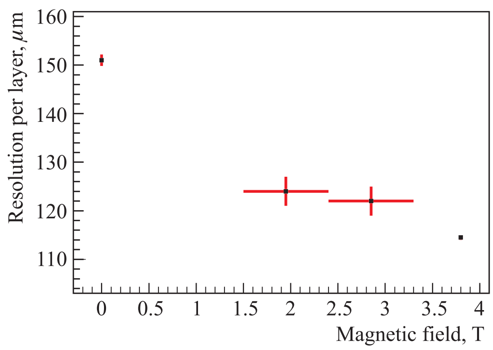

Fig. 5. Layer spatial resolution vs. CMS magnetic field

To calculate the spatial resolution for a CSC with N layers one has to divide the single layer spatial resolution value by $\sqrt{N}$, where $N = 6$ in our case. However, we have to consider that δ electrons can spoil the spatial resolution in a layer [2]. Assuming that there is on average one distorted cluster of 6 we calculated the spatial resolution for ME1/1 chambers as the layer resolution divided by $\sqrt{5}$ (Fig. 8). The mean value of the ME1/1 CSC spatial resolution for both endcaps is about $50\ \mu$m.

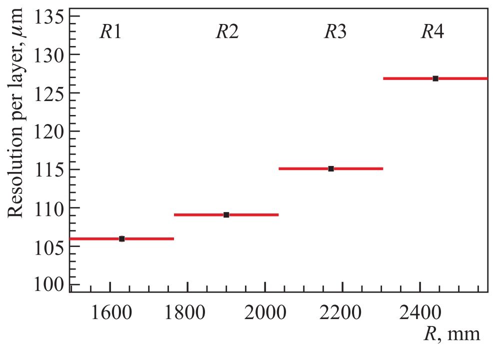

Fig. 6. Layer spatial resolution vs. radial coordinate R

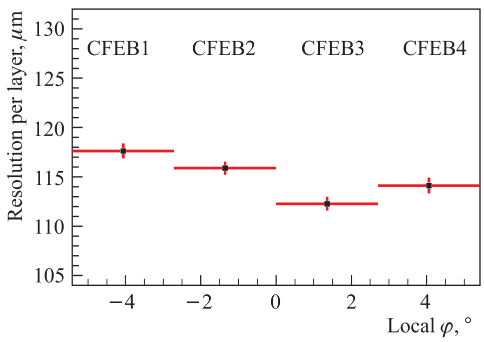

Fig. 7. CFEB 1–4 layer spatial resolutions

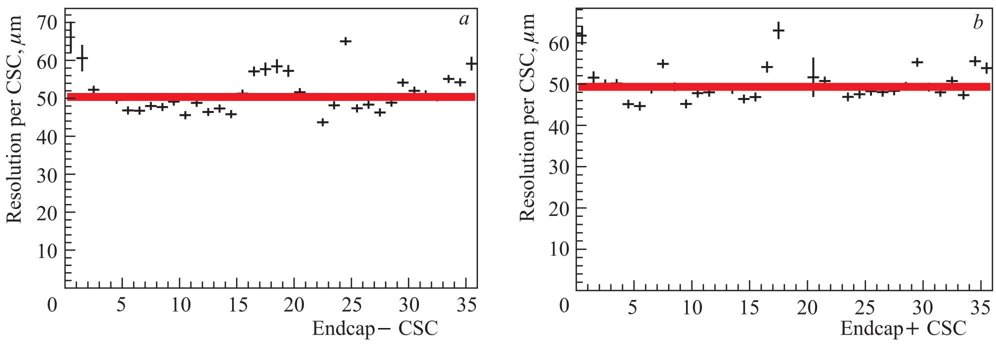

Fig. 8. ME1/1 outer part spatial resolution for both endcaps. The vertical bars show the statistical errors

CONCLUSION

The spatial resolution of the CMS ME1/1 muon station was studied with cosmic rays CRAFT08 data. The ME1/1 CSCs operated with the gas mixture $\mathrm{Ar} + \mathrm{CO_2} + \mathrm{CF_4}$ $(40 + 50 + 10\%)$ at the anode–cathode voltage of 3.0 kV. For data processing, only 6-hit tracks were used. At the solenoid field of $B = 3.8$ T, the layer spatial resolution was 113 μm. It was shown that without the field the spatial resolution degrades to 151 μm. In addition, a study of the layer spatial resolution across the CSC sensitive area was made. The 6-layer spatial resolution for the CSCs in both endcaps was calculated. From these data the ME1/1 outer part spatial resolution is estimated to be 50 μm. This is better than the Muon TDR requirement [1] for the ME1/1 spatial resolution (75 μm).

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Received on January 22, 2010.