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CATHODE STRIP CHAMBER FOR CMS ME1/1 ENDCAP MUON STATION

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Seventy-six serial ME1/1 cathode strip chambers have been produced in Dubna. These chambers are the coordinate detectors of the first muon station of the CMS detector at CERN. This paper describes the design of the chamber, its main mechanical parameters and the results of the cosmic ray test.

В Дубне было изготовлено 76 серийных катодно-стриповых камер ME1/1. Эти камеры являются координатными детекторами первой мюонной станции детектора CMS в ЦЕРН. В этой статье описывается конструкция камеры, ее основные механические параметры и результаты теста с космическими лучами.

INTRODUCTION

ME1/1 is a first muon station of the CMS Endcaps [1]. It is composed of 36 six-layer Cathode Strip Chambers (CSCs) [2] in each Endcap. A number of full-scale prototypes of ME1/1 CSC have been designed and constructed at JINR, Dubna [3, 4]. A comprehensive study of the prototypes with cosmic rays and CERN SPS muon beams has been made [5–8]. The design of the serial CSC has been modified in comparison with the last prototype's one [4]. This paper describes the design of the serial ME1/1 CSC optimised for mass production, its main mechanical parameters and results of test with cosmic rays.

1. LAYOUT AND MAIN PARAMETERS OF THE ME1/1 CSC

One CSC is a 10° ME1/1 ϕ-sector [1, 3]. It is a unit of six identical proportional chambers of trapezoidal shape, layers, with cathode strip readout. Each layer is formed by two cathode electrodes: strip and continuous having gap of 7 mm. The anode wires electrode is placed in the middle of the gap (see Fig. 1). The main construction element of the CSC is a honeycomb panel. There are seven panels in each chamber. The ME1/1 CSC layout is shown in Fig. 2 and the basic chamber parameters are presented in Table 1.

The radial strip structure covers the angle $\phi = \pm 5.42^\circ$ to provide the overlap with the neighboring CSCs in the CMS Endcaps.

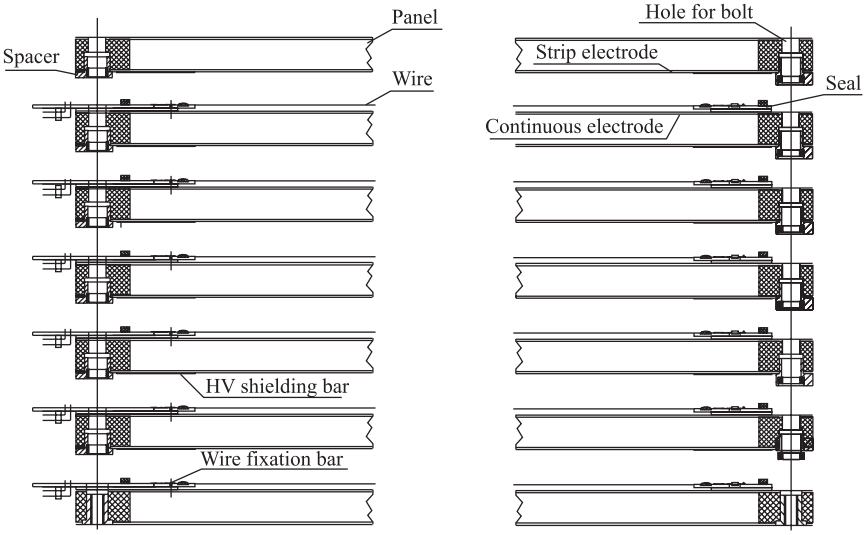

Fig. 1. ME1/1 CSC cross section

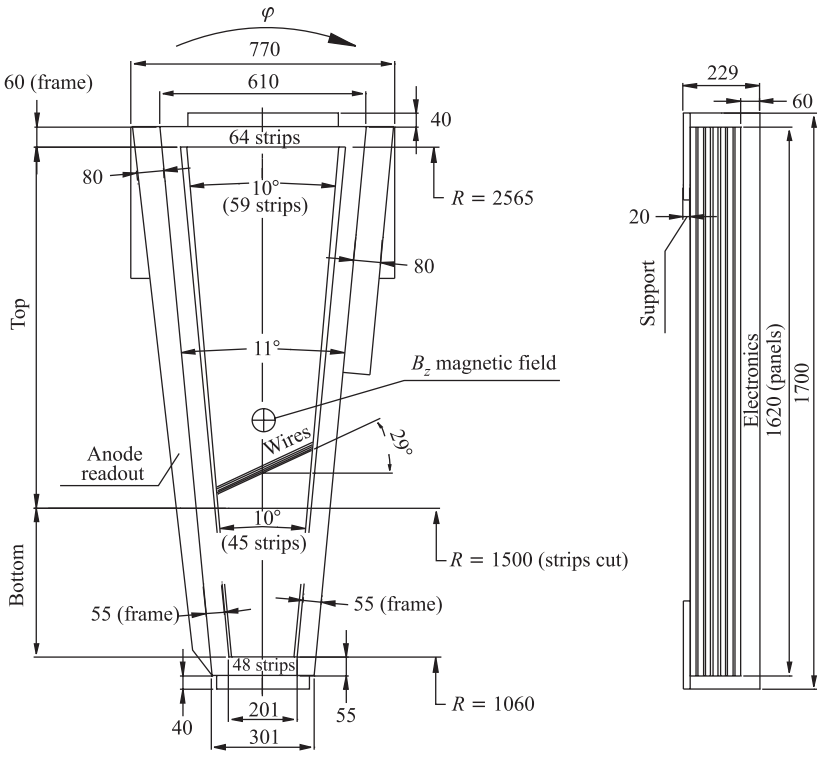

Fig. 2. Overall dimensions of ME1/1 CSC (in millimeters)

Table 1. **ME1/1 CSC parameters**

ME1/1 CSC	Layers / CSC	6
	Inner radius, m	0.965
	Outer radius, m	2.665
	Strip channels	672
	Anode channels	288
	Gas volume, l	25
	Weight with electronics, kg	135
CSC Layer	Anode-cathode gap, mm	3.5
	Panel:	
	Height, m	1620
	Bottom width, m	0.301
	Top width, m	0.610
	Thickness, mm	15
	Area, m^2	0.73
	Sensitive area, m^2	0.51
	Cathode strips:	
	Shape	Radial
	Number of channels:	
	top part	64
	bottom part	48
	Readout strip pitch width:	
	top, mrad	2.96
	bottom, mrad	3.88
	Strip length:	
	top, mm	1065
	bottom, mm	440
	Anode wires:	
	Diameter, μm	30
	Wire spacing, mm	2.5
	Number of wires	587
	Number of channels	48
	Wires/group	11
	Incline angle, degree	29

The effect of the CSC spatial resolution deterioration due to the presence of magnetic field should be compensated by wires inclination [7]. Taking into account that nominal value of the field in the CMS solenoid could be in the range of $B = 3.5{-}4.0$ T, the anode wires are positioned at an inclination angle of 29° in respect to the perpendicular to the chamber axis (see Fig. 2). The groups of 11 anode wires are connected to one readout channel providing

radial coordinate measurements, while the interpolation of charges induced on strips gives the precise measurement of φ coordinate [9–12].

The background rate at the bottom of the chamber is expected to be significantly higher than that at the top [13, 14]. To decrease the counting rate per strip readout electronics channel, the strip electrode is mechanically separated into two groups: with length of 1065 mm at the top and 440 mm at the bottom (see Fig. 2). Fast channel strip readout electronics of the top part provides muon Level-1 trigger.

ME1/1 CSC panel design and strip layout are similar to the P4 prototype ones [4].

The CSC assembling procedure is mainly the same as described in [4, 8].

2. MECHANICAL PARAMETERS CONTROL

The CSC mechanical parameters such as anode wire tension, panel thickness and strip–strip capacity have been tested. Each CSC has been tested for leak.

Figure 3 shows the wire tension measurements for one layer. The mean tension is 80.8 with RMS = 1.3 g. The elastic limit for 30-μm gold plated tungsten wire is about 125 g.

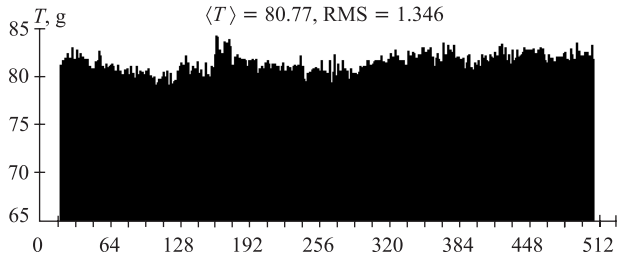

Fig. 3. Typical wires tension for one layer

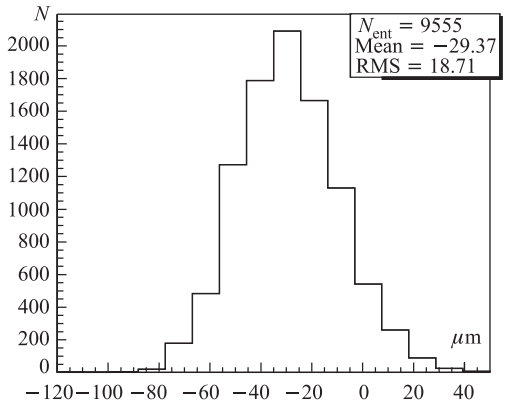

Fig. 4. Panels thickness deviation

Figure 4 shows the panels thickness deviation from nominal value of 15 mm for 273 panels (35 points measured on each panel).

The strip–strip capacity for the top and bottom parts of the layer is shown in Fig. 5. The capacity for the first and last strips grows up slightly due to the influence of the peripheral ground.

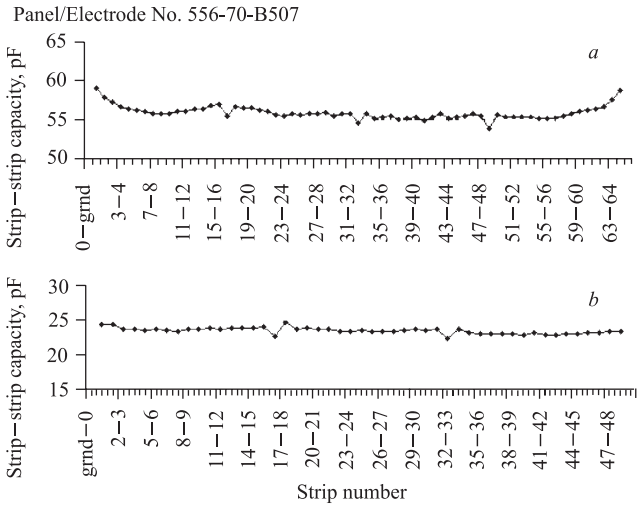

Fig. 5. Typical strip–strip capacity for one layer: *a*) top; *b*) bottom

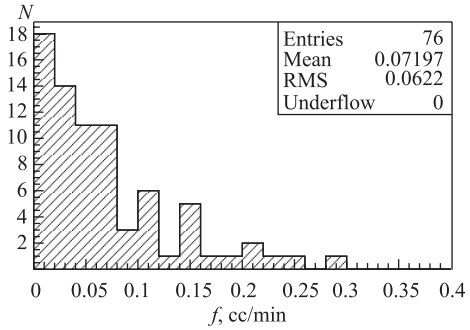

Fig. 6. CSC leak rates

Figure 6 represents the results of the tests of all the 76 CSCs for gas leak. The tests were made at an overpressure of 10 mbar. In CMS Gas project [15] the expected gas leak from all Endcap CSCs should not be higher than 0.44% of the total gas flux.

Each four CSCs of the ME1/1 muon station are connected consequently with a flux of 19 l/h. This gives a 0.35 cc/min as mean leak value for one CSC. One can see that all the chambers have gas leaks below this limit.

3. COSMIC TEST

For CSC (*2*) tests with cosmic muons a cosmic test setup has been made (Fig. 7). It includes the upper and lower scintillation hodoscopes (*1*), 0.5-m iron muon filter (*3*), high-voltage and low-voltage systems, trigger electronics, data acquisition system (DAQ), gas mixer and water-cooling system.

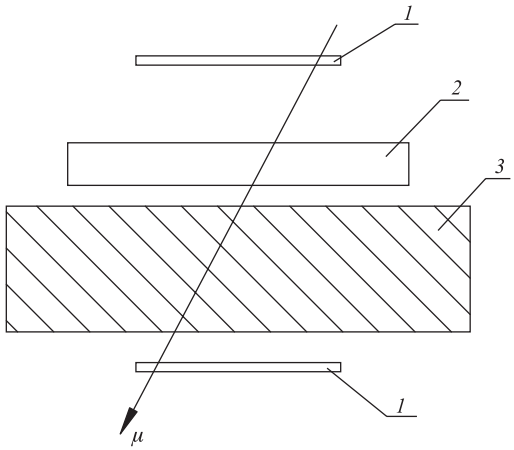

Fig. 7. Cosmic test setup

Signals from the cathode strips are amplified and shaped by five Cathode Front End Boards (CFEBs) [16, 17], each of them reads out 16 strips from six layers of the chamber.

Signals from the anode wires are amplified and discriminated in the Anode Front End Boards (AFEBs) [18]. The discriminator bits are transmitted to the Anode Local Charge Track (ALCT) board where signals are stored as hits. Each AFEB reads out 16 wire groups from two layers of the CSC. An ALCT board reads out all the 18 chamber AFEBs.

All data for a CSC are read out by a single DAQ Motherboard located in the VME crate. Data from the five CFEBs on the chamber are directly transmitted to the DAQ Motherboard. ALCT data reaches the DAQ Motherboard through the Trigger Motherboard, also located in the VME crate.

The gas mixer prepared the basic CSC gas mixture $Ar + CO_2 + CF_4$ (40/50/10) with a flow of 5–30 l/h. The water-cooling system provided a water flux of 2 l/min to cool the on-chamber electronics. During the tests the CSC high voltage was varied in the range of 2.6–3.3 kV.

4. RESULTS

All the produced CSCs have been tested at the cosmic test setup to study the registration efficiency as a function of anode–cathode voltage. Figure 8 shows the efficiency and noise of a single CSC layer. One can see that the operation region lies in the range of 2.9–3.2 kV.

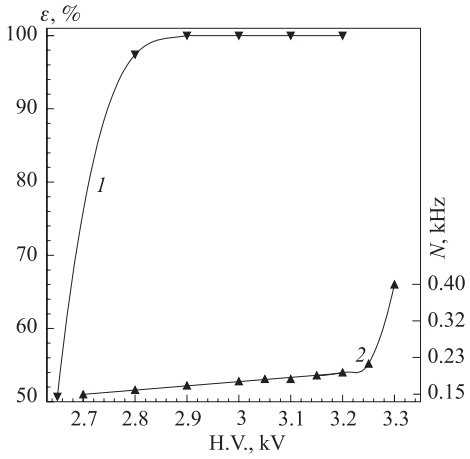

Fig. 8. Layer track registration efficiency ε (*1*) and noise N (*2*) vs. high voltage

CONCLUSION

Seventy-six serial ME1/1 Cathode Strip Chambers for the CMS experiment (CERN) have been produced at the Laboratory of Particle Physics, JINR. The results of the tests of the main CSC mechanical parameters, such as anode wire tension, panel thickness, strip–strip capacity and CSC leak rate, are presented. The tests of the chambers with cosmic rays show that they have a working range of 300 V for the gas mixture $Ar + CO_2 + CF_4$ (40/50/10).

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