УДК 539.1.05

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CBM EXPERIMENT. CHARACTERIZATION STUDIES OF THE DETECTOR MODULES FOR SILICON TRACKING SYSTEM

The double-sided silicon microstrip detector prototypes with 50 μm pitch developed together with CiS, Germany, have been characterized in a 2.4 GeV/c proton beam at COSY, Forschungszentrum Jülich, Germany. Data analyses including reconstruction of 1-strip and 2-strip clusters have been performed. We have done the study of charge sharing in the interstrip gap. In particular it was found that there is a charge loss of less than 10 % in the interstrip gap. The calculated signal-to-noise ratio is around 19 for the p-side of the sensor and it is sufficient for hit reconstruction. Also the charge sharing function which allows more precise determination of the hit position in silicon sensor, have been reconstructed.

Keywords: microstrip detector, silicon tracker, charge sharing function, minimum ionizing particle, cluster.

Introduction

The CBM (Compressed Baryonic Matter) [1] experiment at the future Facility for Antiproton and Ion Research (FAIR) will study properties of nuclear matter in heavy ion collisions covering the regions in the QGP phase diagram with moderate temperature and high net baryon density. CBM will study phase transition from cold nuclear matter to quark-gluon plasma and hadron properties in dense matter. The detector will face the challenge of measuring Au + Au interactions at 45 GeV/nucleon and 10 MHz rate producing up to 1000 charge particle tracks per event. Large data volumes produced in such an environment demand for a fast data acquisition system based on self-triggering electronics with online event selection. Development of the detector is in progress.

Silicon Tracking System

The CBM experiment is a forward spectrometer (Fig. 1). The detector will be able to measure hadronic and leptonic signatures. The core detector is the Silicon Tracking System (STS) designed for high performance tracking and momentum determination of charge particles from beam-target interactions.

The STS comprises 8 tracking stations placed between 30 cm and 100 cm downstream of the target in a dipole magnet. Each station is a modular structure of double-sided silicon microstrip detectors of different sizes to match the non-uniform channel occupancy distribution from the beam pipe to the periphery. The sensors will be held by low-mass carbon fiber support structures with read-out electronics outside of the detector aperture, thus minimizing multiple Coulomb scattering of particles. The silicon detector is designed minimizing the total amount of material. Silicon sensors 300 μm in thickness were chosen to give an acceptable balance of signal-to-noise ratio and material budget.

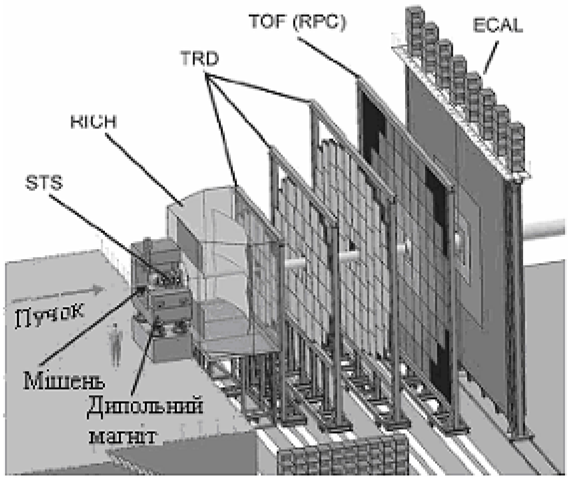

Fig. 1. Schematical view of the CBM experiment

Results

In January 2012, prototype modules of the CBM Silicon Tracking System were tested in a 2.4 GeV/c proton beam at COSY, Forschungszentrum Jülich, Germany. The double-sided sensor CBM02-B2 (256 orthogonal strips per side with 50 μm pitch) was assembled into a demonstrator board; the readout was performed by 4 nXYTER chips. The sensor was operated at a bias voltage of 100 V, the full depletion voltage being 80 V.

1-strip and 2-strip clusters were reconstructed. Most probable values of the deposited energy were determined with a Landau fit. Comparing the values of the charge collected by single strip and two adjacent strips it was found that in the case of proton penetration in the middle between two strips (both strips collected same fraction of the charge), the full charge of the cluster is approximately 10 % lower than in the case of proton penetration into one strip (corresponds to 1-strip clusters). Therefore there is a charge loss of less than 10 % in the interstrip gap, which is too small to significantly affect the performance of the sensor.

The correlation of the charge registered in two adjacent strips are shown in Fig. 2 for both the p-side and the n-side of the investigated sensor. The charge on the p-side peaks at about 130 ADC units, corresponding to the most probable signal from minimum ionizing particles (82 keV). The signal on the n-side is approximately 10 ADC units less than that on the p-side. The calculated signal-to-noise ratio is around 19 for the p-side and 18 for the n-side. This is sufficient for a reliable registration of useful events on top of the background for the not irradiated sensor of 285 μm thickness.

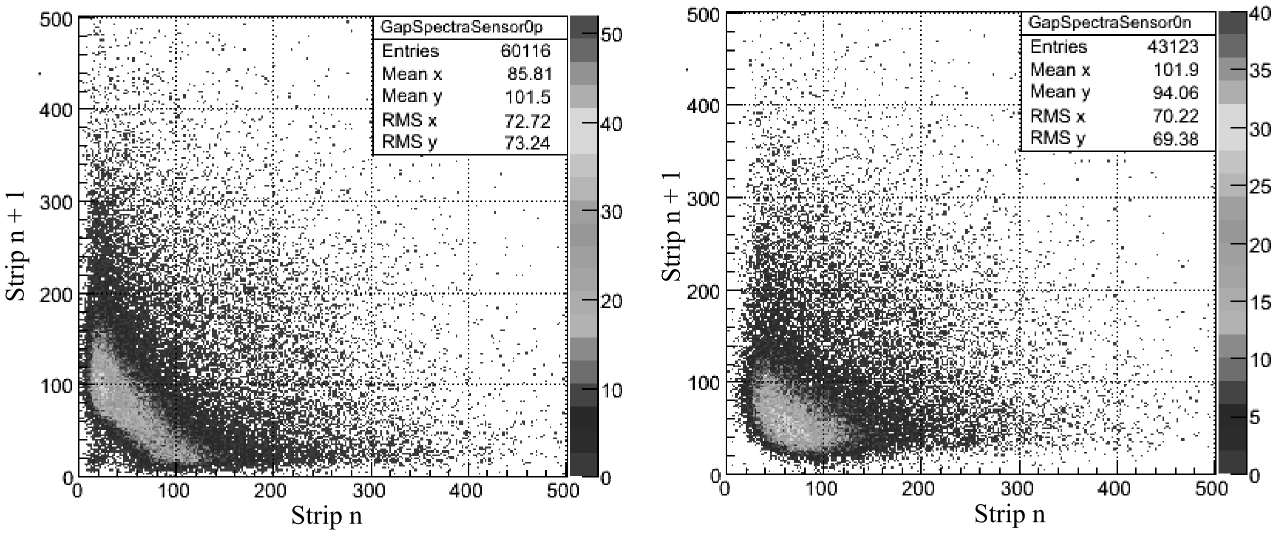

Fig. 2. Charge correlation for two adjacent strips. *Left*: p-side; *right*: n-side of the sensor.

For tracks generating enough charge on two adjacent strips to exceed the threshold value in both of them, the position can be determined more precisely if the charge sharing function (η-function) is known. η is defined as the ratio of charge collected by the right strip to the total charge of the cluster. Fig. 3 shows the distribution of η obtained from the experimental data. Only 2-strip clusters were taken into account for this analysis.

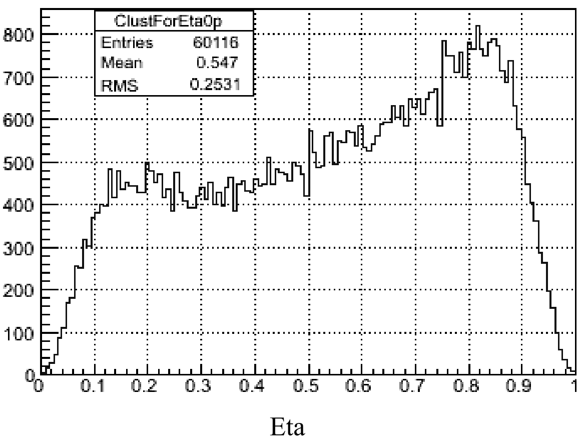

Fig. 3. Experimental distribution of η for the sensor CBM02-B2 with a pitch 50 μm.

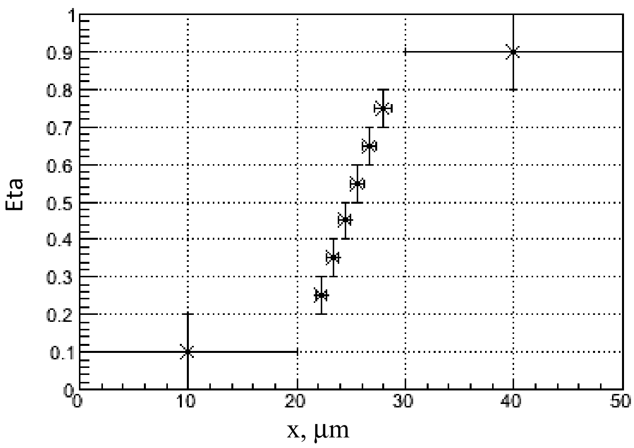

Fig. 4. Variable η versus hit position between two adjacent strip.

The presence of two peaks in the η distribution signals that the charge division between the two strips is far from being linear. The capacitive coupling between the strips moves the peaks towards the center of the distribution, because a certain fraction of the charge is always collected in the neighboring strips.

Sinse the beam is much broader than the strip pitch, the distribution dN/dx is constant. Then, the hit position between two adjacent strips, in units of the strip pitch, is given by:

$$X_0 = \frac{1}{N_t}\int_0^{\eta_0}\frac{dN}{d\eta}d\eta, \qquad (1)$$

where N_t is the total number of entries in the $dN/d\eta$ distribution and η_0 is the fraction of the signal collected by the right strip in the considered event. Thus, from Fig. 3 the dependence of η on the hit position between the two strips can be derived. The result is shown in Fig. 4.

Summary

The Silicon Tracking System of the CBM experiment is the central detector for track reconstruction and momentum resolution. The double-sided microstrip detector prototypes have been produced in cooperation of CiS Erfrut and GSI. They were characterized in a proton beam. Sensor CBM02-B2 demonstrated the expected behavior: Landau like signal, good separation between signal and noise. The signal to noise ratio has been obtained for both p- and n-side of the investigated sensor. This value is sufficient for reliable registration of useful events with such silicon strip detectors. It was demonstrated the functional suitability of the system for use in the Silicon Tracking System of the CBM experiment.

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ЕКСПЕРИМЕНТ CBM. ДОСЛІДЖЕННЯ ХАРАКТЕРИСТИК ПРОТОТИПІВ ЕЛЕМЕНТІВ ДЛЯ КРЕМНІЄВОГО ТРЕКЕРА

Представлено результати аналізу даних, отриманих при тестуванні кремнієвих мікростріпових детекторів на пучку протонів з енергією 2,4 ГеВ на синхротроні COSY (Юліх, Німеччина). Проведено дослідження прототипів двосторонніх сенсорів типу CBM02. Аналіз даних з пучка дав змогу реконструювати одно- та багатокластерні події, дослідити роботу міжстріпового проміжку. Зокрема, було встановлено, що має місце втрата майже 10 % заряду кластера в міжстріповому проміжку. Відношення сигналу до шуму було отримане на рівні 19 для p-сторони досліджуваного сенсора і є прийнятним для хорошого розділення сигналу від шуму. Була реконструйована функція ділення заряду, знання якої дає змогу більш точно визначати місце проходження зарядженої частинки в сенсорі.

Ключові слова: мікростріповий детектор, кремнієвий трекер, функція ділення заряду, мінімально іонізуюча частинка, кластер.

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ЕКСПЕРИМЕНТ CBM. ИССЛЕДОВАНИЕ ХАРАКТЕРИСТИК ПРОТОТИПОВ ЭЛЕМЕНТОВ ДЛЯ КРЕМНИЕВОГО ТРЕКЕРА

Представлены результаты анализа данных, полученных при тестировании кремниевых микростриповых детекторов на пучке протонов с энергией 2,4 ГэВ на синхротроне COSY (Юлих, Германия). Проведено исследование прототипов двухсторонних сенсоров типа CBM02. Анализ данных с пучка позволил реконструировать одно- и многокластерные события, исследовать работу междустрипового промежутка. В частности, было установлено, что имеет место потеря почти 10 % заряда кластера в междустриповом промежутке. Отношение сигнала к шуму было получено на уровне 19 для p-стороны исследуемого сенсора и является приемлемым для хорошего разделения сигнала от шума. Была реконструирована функция деления заряда, знание которой позволяет точно определить место прохождения заряженной частицы в сенсоре.

Ключевые слова: микростриповый детектор, кремниевый трекер, функция деления заряда, минимально ионизирующая частица, кластер.

Надійшла 09.07.2013
Received 09.07.2013