GEM TN-93-330

Results of Tests of the Dubna 1.5 m by 1.2 m CSC Prototype at the TTR

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Abstract:

The performance of the Dubna-built Cathode Strip Chamber (CSC) with 1.5 m long strips was studied at the TTR Laboratory. The resolution of about 70 μm was obtained with a limited number of electronics channels, going down to 60 μm in the restricted angle and charge ranges. The work was a part of the GEM Muon group R&D activity at the SSC Laboratory.

1. INTRODUCTION

The cathode strip chamber (CSC) technology chosen as a baseline GEM muon system is derived from suggestions made originally by Charpak and Sauli [1]. In CSC, a precise coordinate measurement is obtained by integration of pulses induced on an array of cathode strips that are perpendicular to anode wires of a conventional proportional chamber. The chief advantage of the technique is that the resolution depends mostly on the precision of strip position, but not on wire position. Optimum geometry for cathode strips have been studied [2], and several small CSC prototypes have been built. However, large CSCs have not been employed in experiments.

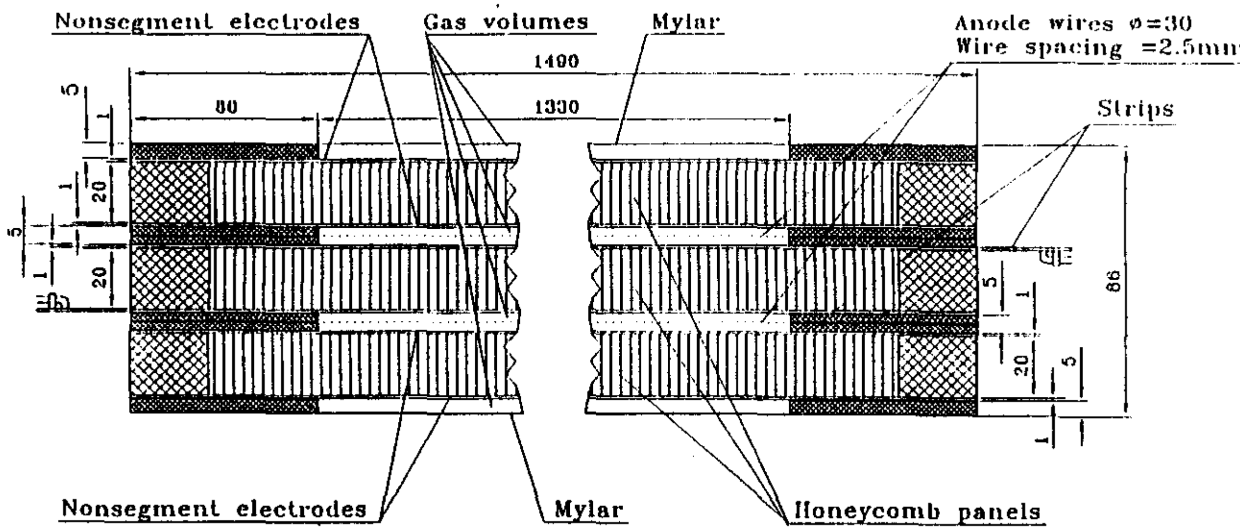
The goal of our study was to measure spatial resolution of a large two layer CSC prototype with 1.5-m long strips. The spatial resolution was measured using cosmic muons at the Texas Test Rig (TTR), which was built as a part of the GEM muon system R&D effort at the SSC Laboratory.

2. CSC DESIGN

The layout of the Dubna CSC prototype is shown in Fig. 1a and Fig. 1b. It consisted of two similar gas gaps which are formed by three sandwich honeycomb panels. These panels were made of 19-mm NOMEX core and two 0.5-mm thick fiberglass skins. On each side of the panel Cu-plated 0.8-mm thick (17 micron of Cu) G-10 layers were glued to form the cathodes. The chamber frames were made of a sets of thin G-10 layers glued together using a special technology which was designed to achieve precise thickness of the frames without machining. Anode planes were made of 30 micron diameter gold plated tungsten-rhenium wires tensioned with 160 g. Each group of eight wires was read-out separately and calibration feature using wire induced pulses on the cathode plane was built-in (Fig. 2). Wire spacing is 2.5 mm. Wires were soldered to the printed boards and then glued with epoxy.

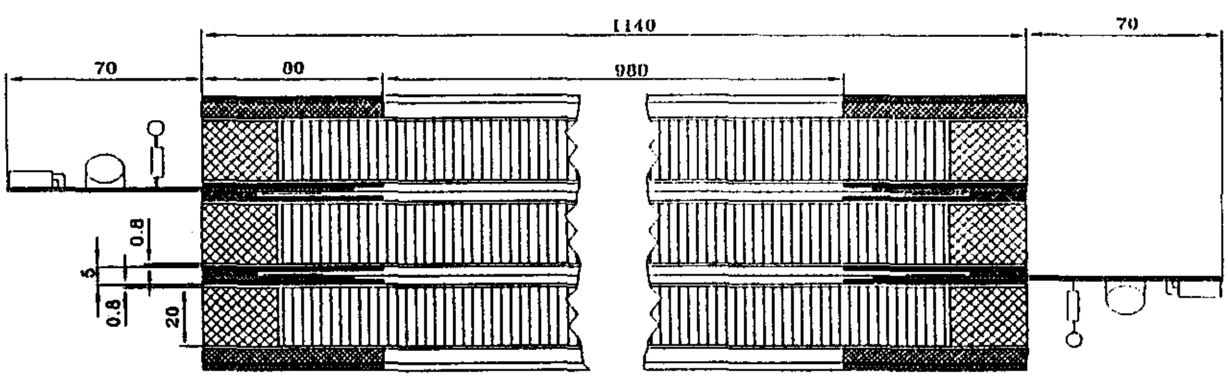
The gaps between anode and cathodes are equal to 2.5 mm. The sensitive area of the chamber is 130 cm by 100 cm. The strips are 150 cm long. The strips are oriented at 90°. with respect to anode wires. The strip layout with two floating strips was used (Fig. 3). Readout pitch is equal to 5.08 mm, active strip width is 1.6 mm and gaps between strips are 0.1 mm each.

DUBNA CSC PROTOTYPE



Cross-section of MWPC perpendicular to the wires
(All dimensions in mm)

DUBNA CSC PROTOTYPE



Cross-section of MWPC perpendicular to the strips
(All dimension in mm)

Fig. 1 Dubna CSC layout: a) cross-section across the wires; b) cross-section across strips.

WIRE PLANE

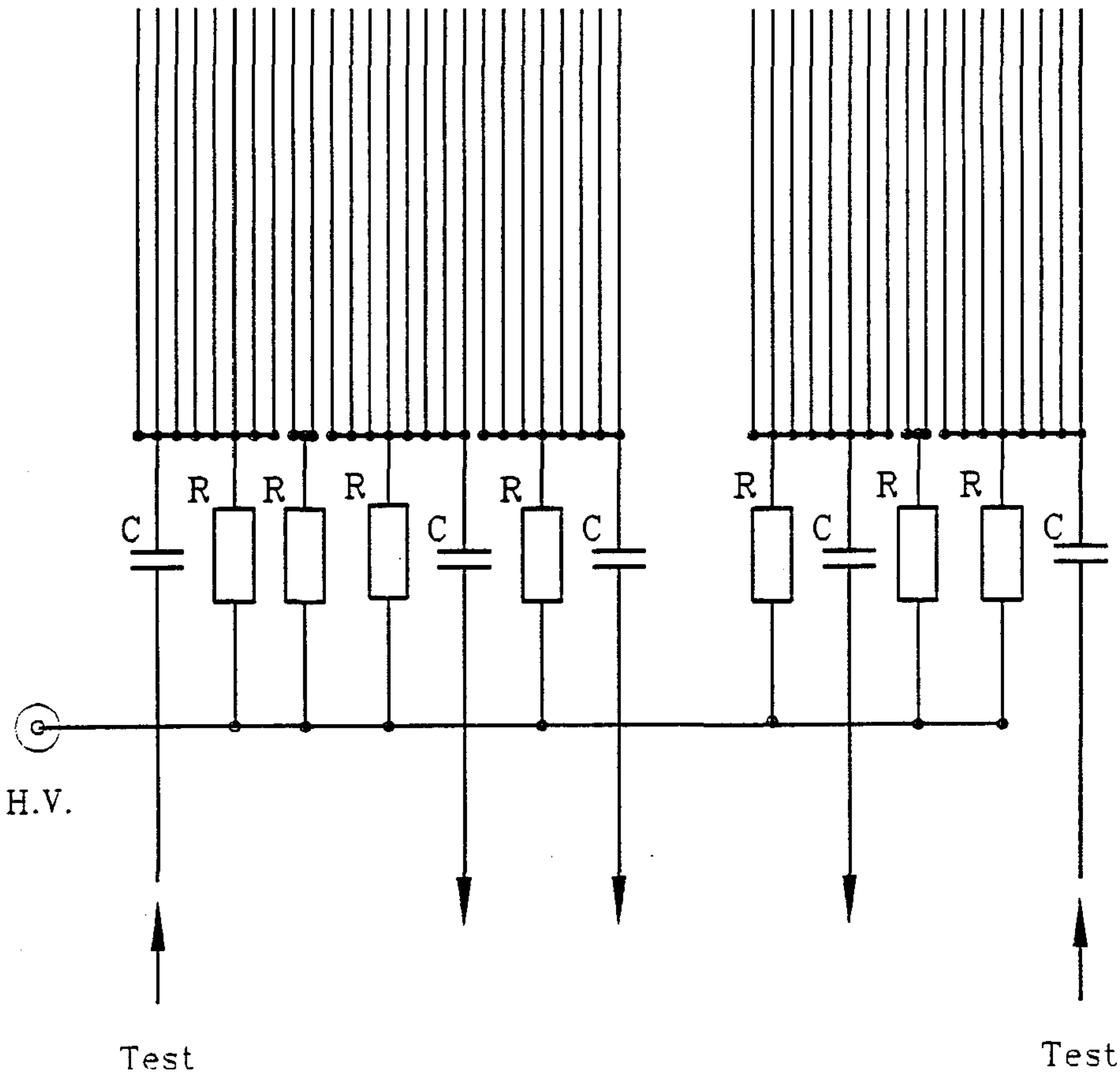


Fig. 2 High voltage and signal connections of the anode plane.

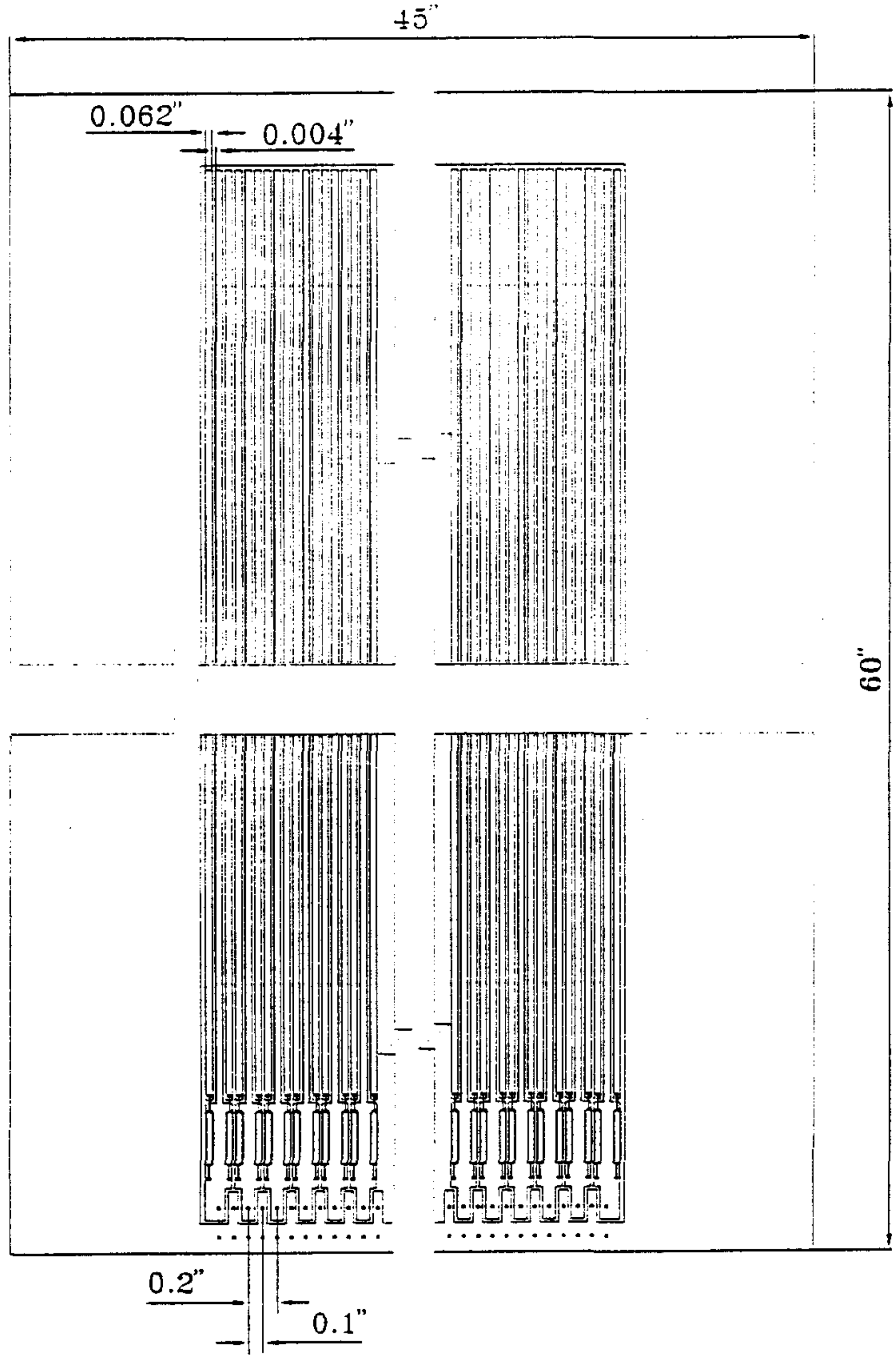


Fig. 3 Strip board layout; one out of each three strips is read-out, two floating ones are grounded through a large resistor.

3. DUBNA CSC AT THE TTR

3.1 Set-Up and Operation Conditions

The TTR consists of the two planes of scintillator hodoscopes with timing resolution of about 300 ps, four planes of 1-cm pitch two coordinate readout Iarocci chambers and 1-m thick stack of steel absorbing cosmic rays with less than about 1.3 GeV/c momentum. By removing the "soft" component of the spectrum with the steel, chamber resolution studies are less susceptible to the misleading effects of multiple scattering. The steel can be magnetized to 15 kG in order to raise the threshold, but this feature of was not used in these measurements.

The triggerable volume of the TTR has a surface area of 1.2 m by 5 m and a height of 3 m.

Dubna CSC was mounted right above Dubna RDT module (Fig. 4) to provide precise tracking for resolution calculation. The system was triggered by two adjacent scintillator paddles above the CSC active area, and two below to make more efficient event selection.

Since the CSC had only two layers, muon track hits measured in a Dubna-built Round Drift Tube (RDT) module [3] below the CSC were combined with CSC hits to define the track. The tube array was 4 m long and 0.5 m wide featuring 30 mm diameter stainless steel tubes, and it was precisely aligned off-line with respect to the CSC.

We used non-flammable gas mixture $Ar/CO_2/CF_4$ = 30/50/20, and with operation high voltage of 2.85 kV for upper plane and 3.10 kV for lower plane the gas gain was about 3.5×10^4, which corresponds to the proportional mode of gas amplification.

3.2 Electronics and Calibration.

For the strip readout we used electronics based on the LeCroy HQV-820 M hybrid chip. A block diagram of one channel of this electronics is shown in Fig. 5 and a schematic diagram of the readout is given in Fig. 6. The HQV-820M has a conversion gain 0.5 V/pC, optimized for an input capacitance up to 300 pF. The feedback capacitor is 2 pF and the feedback resistor is 100 Mohm. The charge-sensitive amplifiers are followed by a pole zero cancellation circuit with a shaping time of 2 microseconds, low-noise operational amplifiers, track/holds, multiplexers and one 10 bit ADC for all channels. The total conversion gain can be adjusted up to 44 V/pC. For the TTR measurements we used the conversion gain of 22 V/pC.

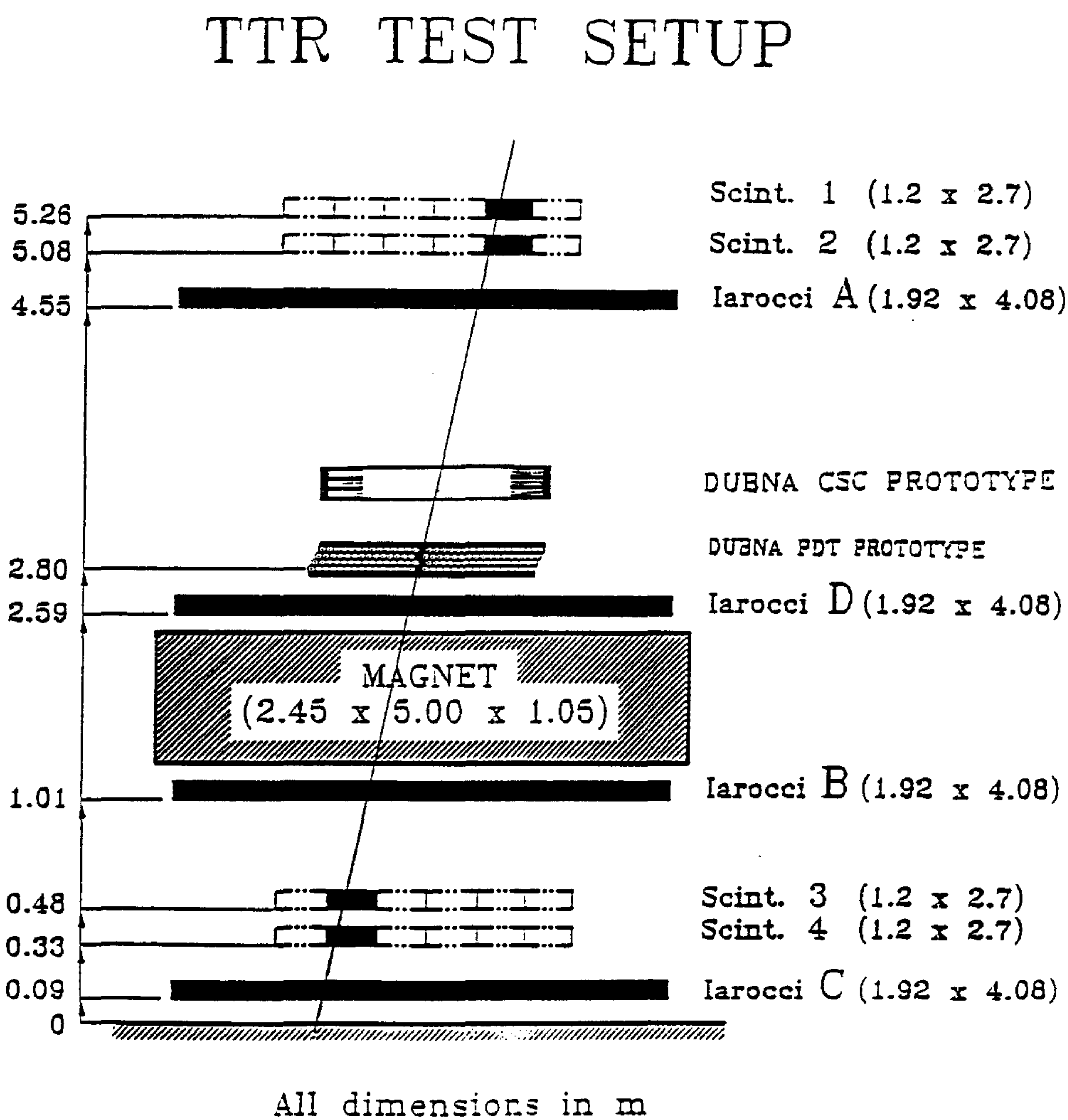
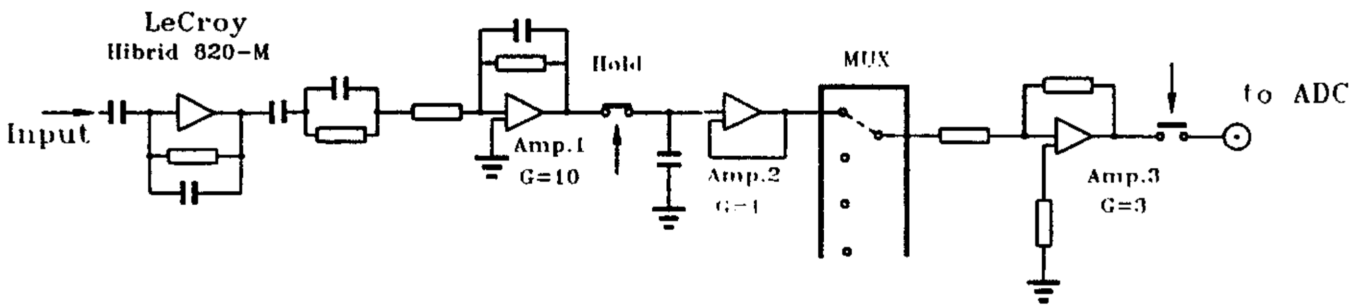


Fig. 4 CSC test setup in the TTR. The chamber is right above the RDT module used in these measurements for precision track reconstruction.

STRIP READOUT ELECTRONICS



Noise – ENC 2500± 500 r.m.s. electrons for 100 pF
Peaking time – 2 μs
Readout time ~ 1.5 μs/channel

Fig. 5 Dubna CSC electronics channel. Several stages of amplification and multiplexing are shown.

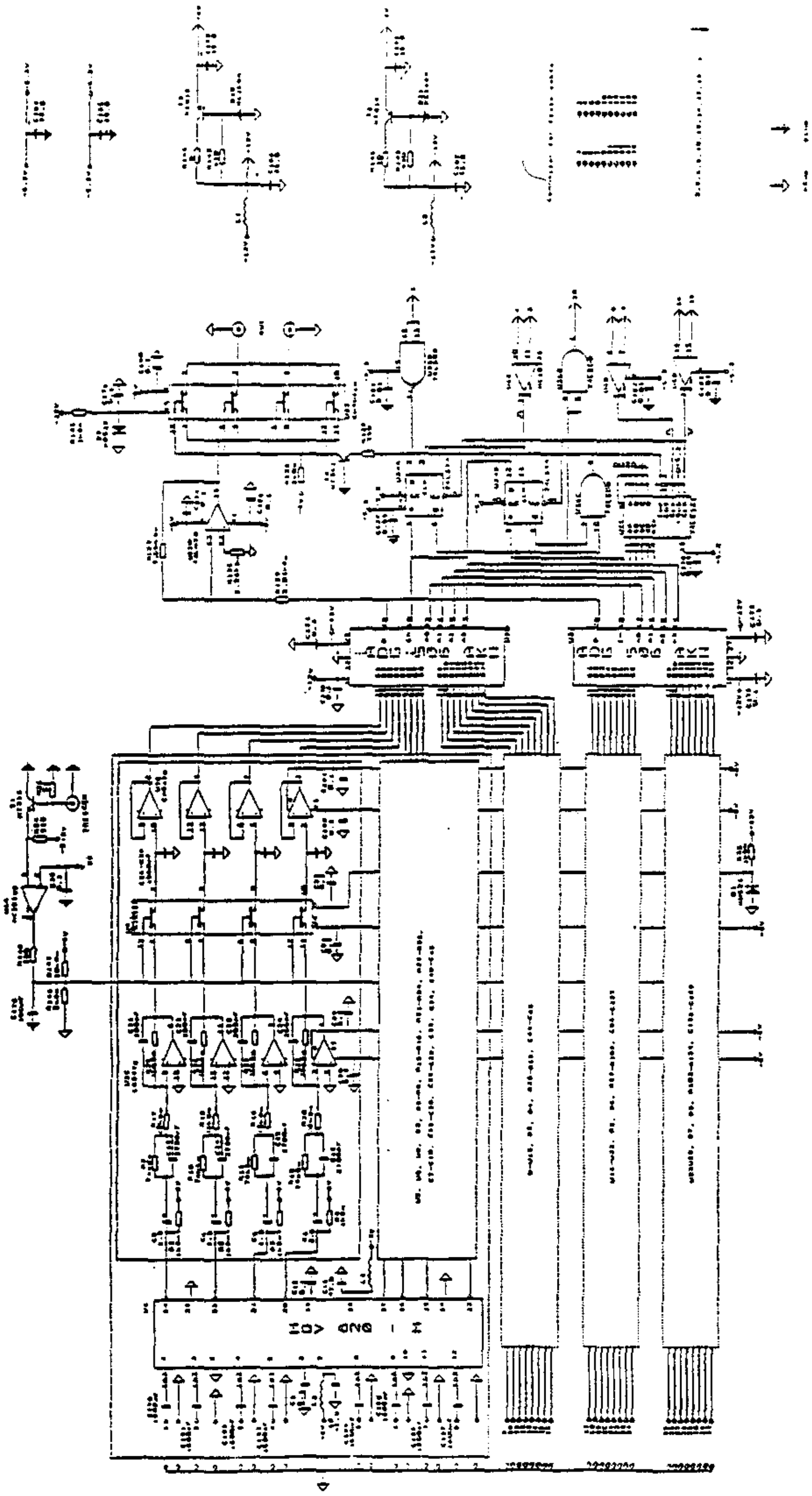


Fig. 6 CSC electronics block-diagram.

The 8 anode wires 100 μm in diameter as shown in Fig. 2 were used for relative calibration of electronic gains in neighboring channels. The amplitude of the precision pulser as well as a trigger were computer controlled. At regular intervals before and after cosmic ray run data taken calibration data were taken by stepping the pulser amplitude through 20 values spanning the whole dynamic range of the pulser. One thousand events were accumulated for every pulser amplitude and the mean values and RMS deviations calculated for all channels. A straight line was then fitted to these values. The fit coefficients were then stored and used to correct the amplitudes during analysis.

3.3. Data Analysis

To calculate the charge Q from the number of ADC counts for all CSC channels four calibration runs were used (one at the beginning, two during the data taking and one at the end). The Q (N_{adc}) characteristics were assumed to be linear. Slopes were found by averaging the results of 4 calibration runs. ADC pedestals were corrected for the correlated flowing of all CSC channels in each event. Pedestal widths determined after this correction correspond to the uncorrelated electronic noise of 1200e (rms).

Six CSC channels from each plane, corresponding to six internal channels of HQV-820M chip were selected for analysis (two channels on the edges of the chip did not operate properly). The cluster charge distribution is shown in Fig. 7. Cluster was defined as three adjacent strips for which the charge of the middle strip was higher than 60 channels of 9-bit ADC and was higher than the charge of both the left and the right strip. The events with ADC overflow were cut off. Total of 16.7% of events were rejected by the charge cut, i.e., when a charge in the first and/or second plane was small or in overflow.

The experimentally obtained shape of the integrated charge for one of the planes is represented in Fig. 8. This shape is characteristic for certain gas gap, so, it is possible, in principle, to reconstruct coordinate by fitting measured charges with this curve.

In this study the so-called "ratio" technique was used for coordinate reconstruction. Figs. 9a and 9b show the ratio Q_{left}/Q_{middle} plotted versus the ratio Q_{right}/Q_{middle} for two planes. Two such plots for two CSC layers are slightly different due to small differences in distances between anode wires and cathode planes. Following Ref. [4] we used the variable α to determine the Y coordinate perpendicular to the strips:

$$\alpha = \text{atan}\,[(1-Q_l/Q_m)/(1-Q_r/Q_m)]/\pi - 0.25 \qquad (4.1)$$

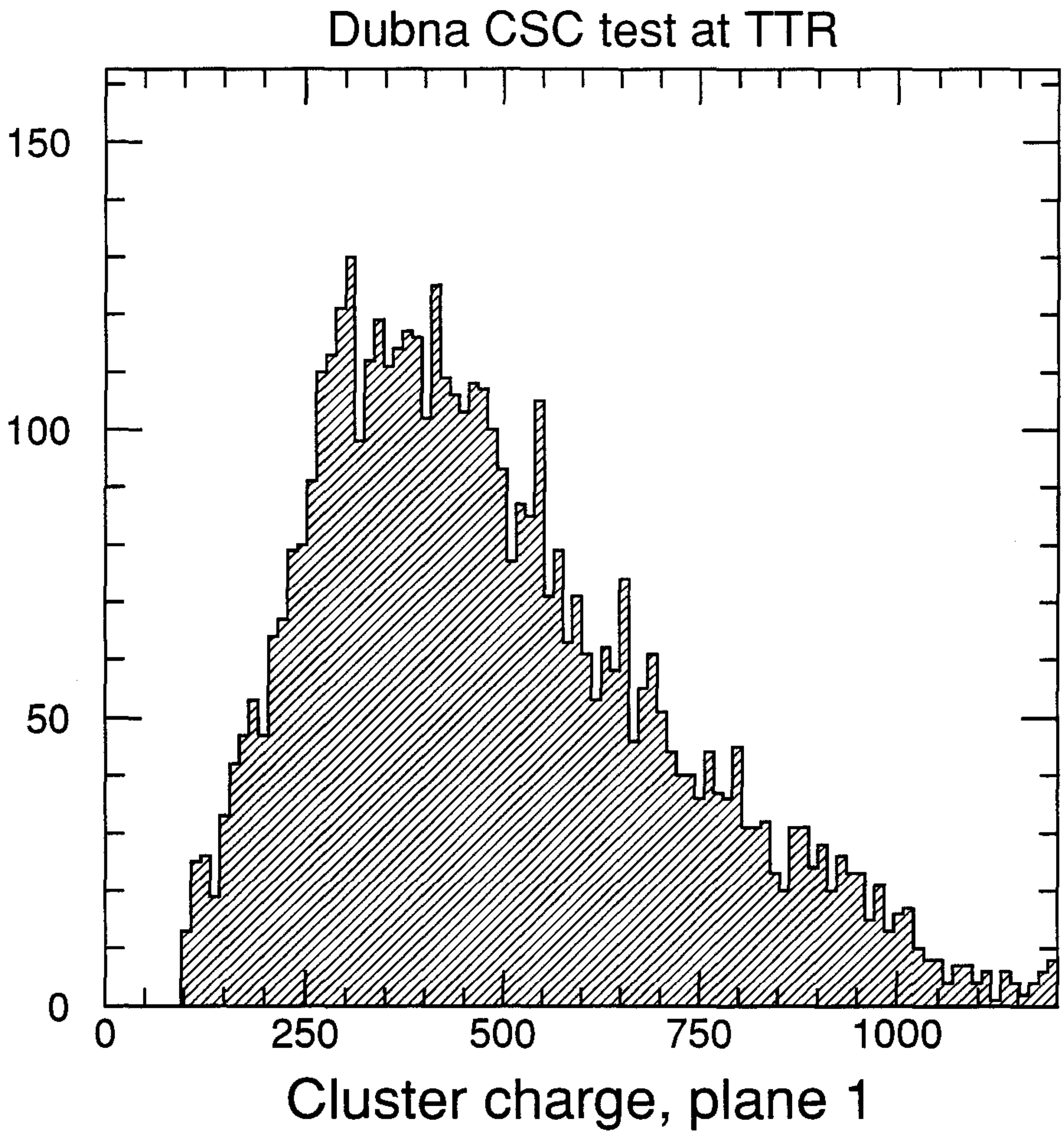


Fig. 7 Cluster charge distribution. Cuts are imposed on overflows and small amplitudes. Total of 16.7% were cut out.

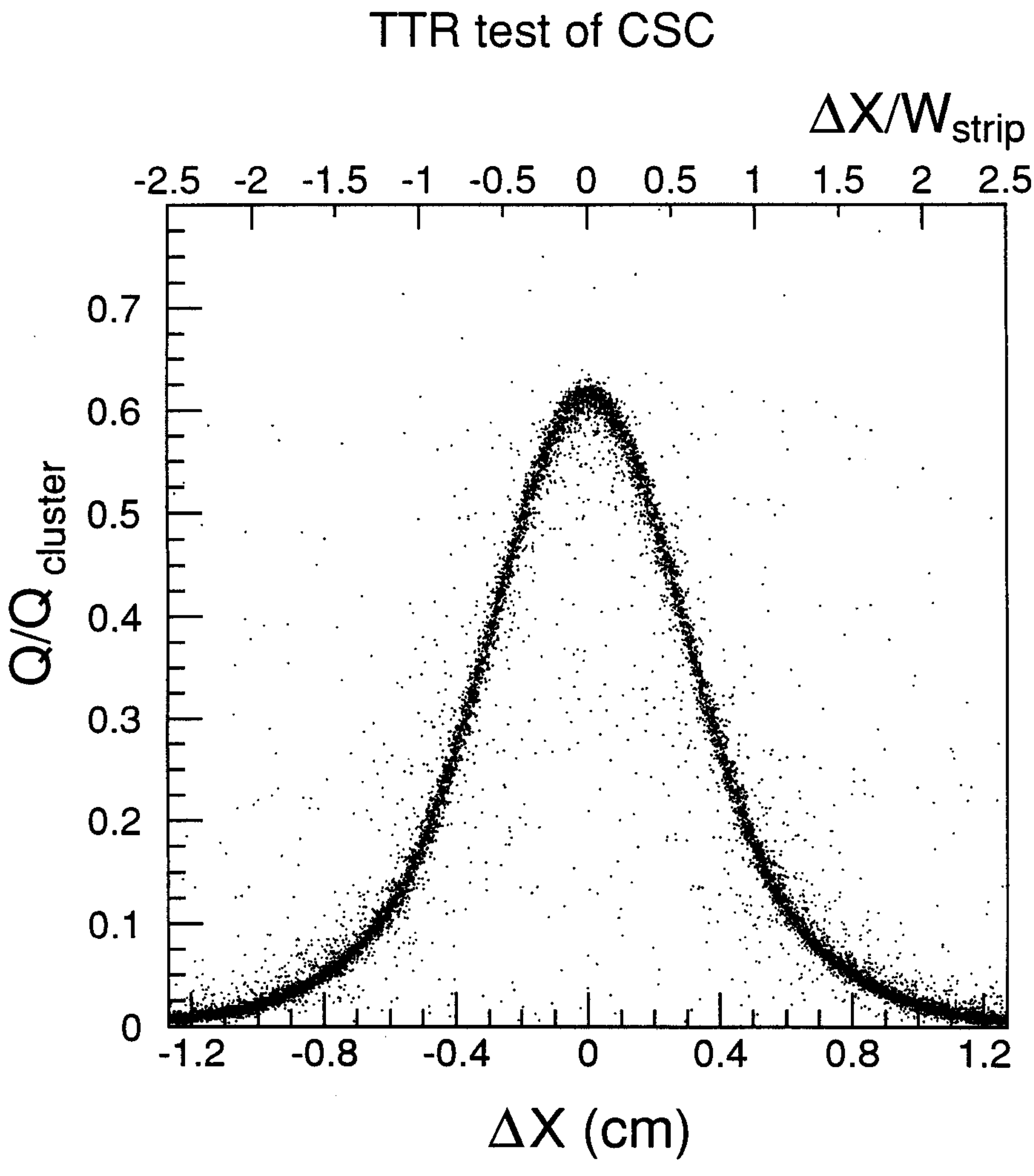


Fig. 8 Experimental integrated charge distribution.

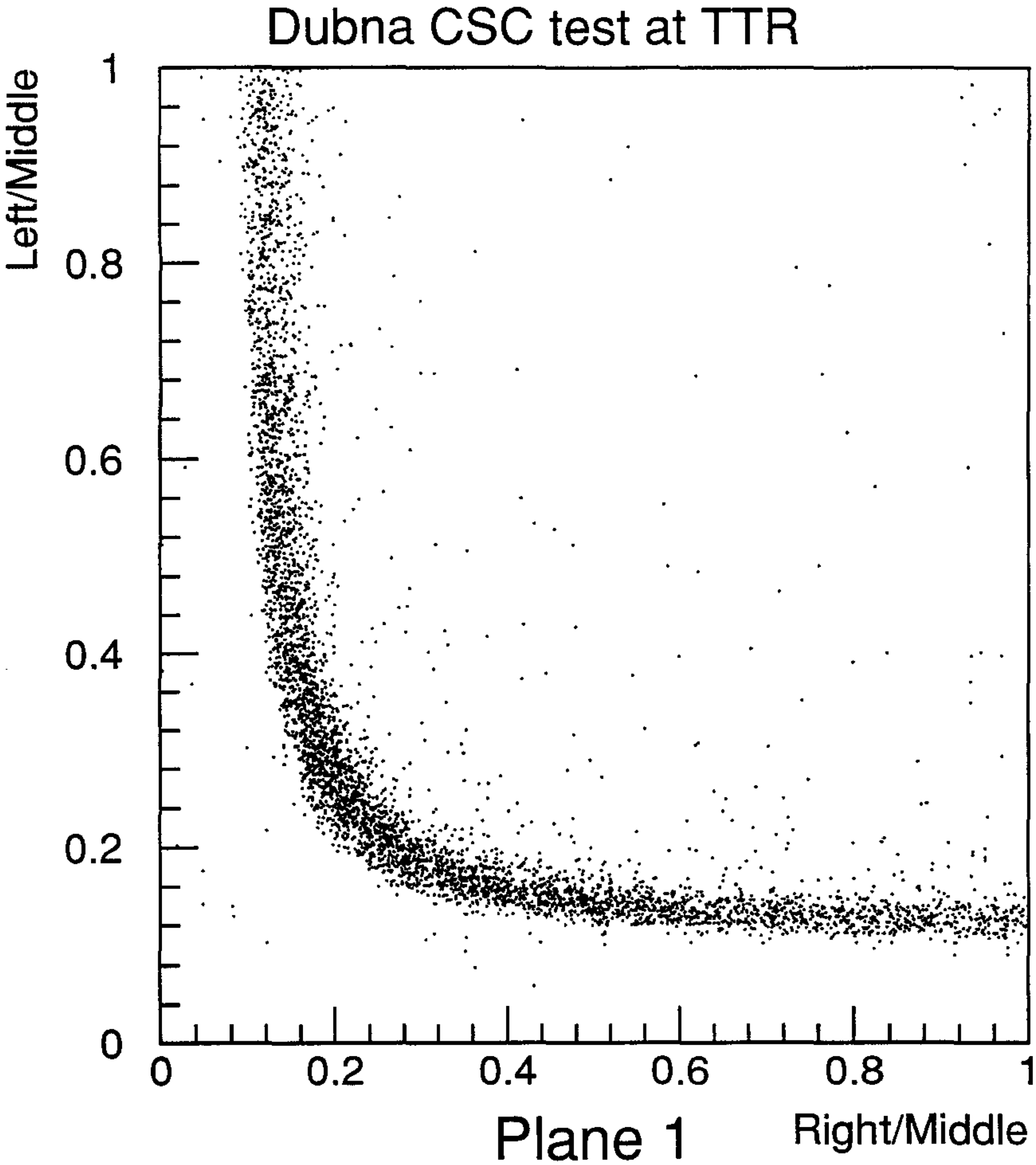


Fig. 9a Ratios Q_{left}/Q_{middle} versus Q_{right}/Q_{middle} are plotted for plane 1.

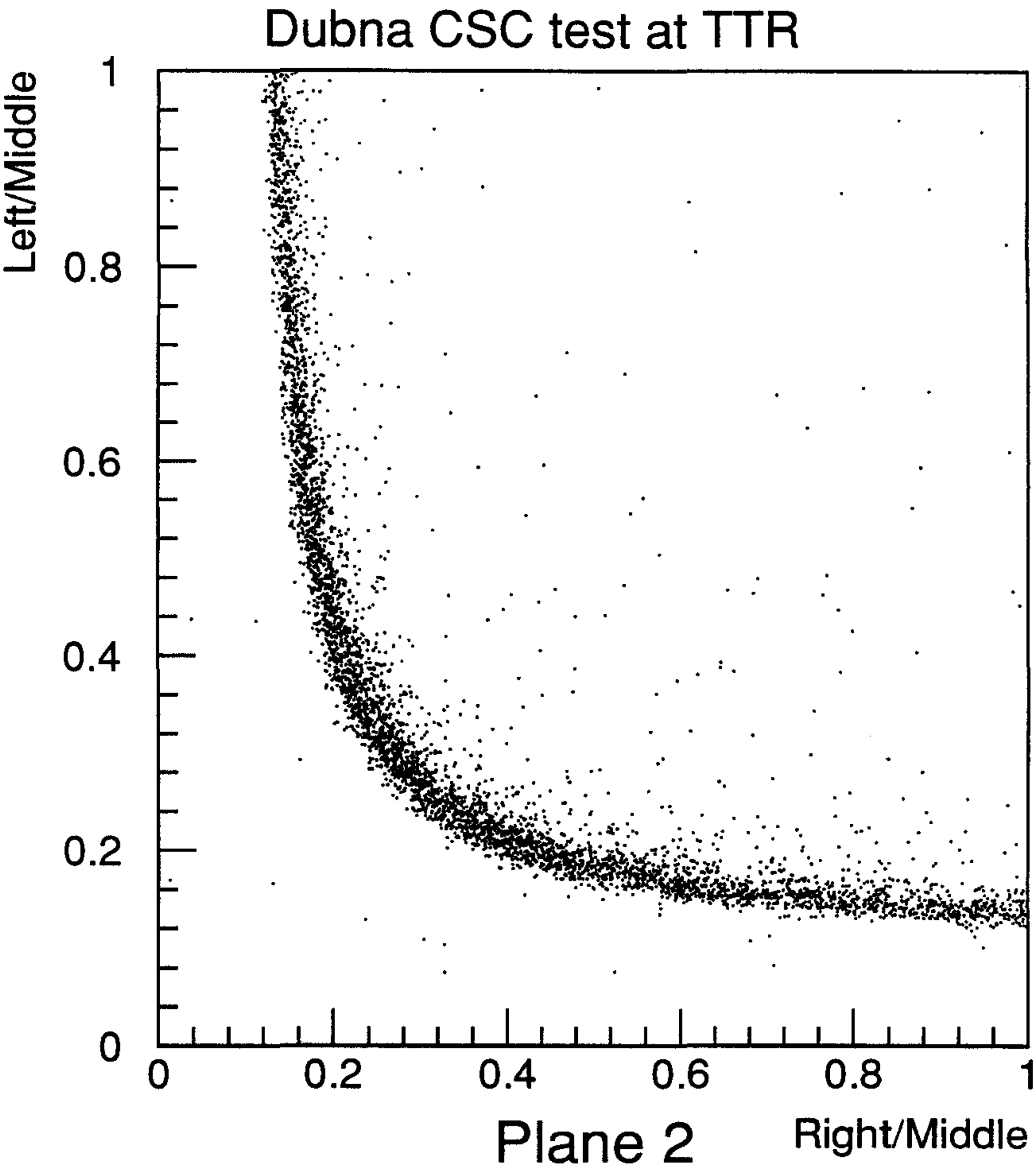


Fig. 9b Ratios Q_{left}/Q_{middle} versus Q_{right}/Q_{middle} are plotted for plane 2.

As a first approximation one can then assume that $Y - n_{strip} \times W$ is roughly proportional to α. Here n_{strip} is the number of the middle strip in the cluster, W is the strip pitch. To decrease the systematic uncertainties caused by this method of Y coordinate determination we used more general formulae:

$$Y = n_{strip} \times W + f(\alpha), \tag{4.2}$$

where f (α) was approximated by a polynomial function.

In order to determine the spatial resolution of CSC the difference in Y coordinates measured by two CSC planes was compared to the predicted value:

$$\Delta_Y = ((y_{csc1} - y_{csc2}) - h \times \tan(\phi))/\sqrt{2} \tag{4.3}$$

where h - is the distance between two anode planes, and tan(phi) was calculated using the average Y coordinates measured in CSC and two first layers of RDT, as well as the known distance H between CSC and RDT:

$$\tan(\phi) = [(y_{rdt1} + y_{rdt2}) - (y_{csc1} + y_{csc2})] / H \tag{4.4}$$

Only two RDT layers closer to the CSC were used, which allowed the effect of multiple scattering in the drift tubes to be reduced. The mutual orientation of RDT and CSC which should be known in this method very accurately was measured with the uncertainty of about 10-20 μm. The angles between RDT wires and CSC strips were determined with the accuracy of about 3×10^{-5}.

Fig. 10 shows the ϕ angle range selected by our set-up. In the following analysis only the region $|\phi| < 0.08$ was used which is slightly larger than GEM muon sector angular range $|\phi| < 0.065$ (for 48 sectors design).

The spectrum of Δ_Y is shown in Fig. 11a. The width of this distribution which is about 73 microns shows the spatial resolution of a single CSC plane (assuming both planes are identical). The contributions to Δ_Y arising from multiple scattering in RDT ($\sigma_{ms_{RDT}} < 7$ μm), from finite RDT spatial resolution ($\sigma_{RDT} = 8$ μm) and from the screening effect [4] ($\sigma_{screen} < 15$ μm for the largest angles [5]) are negligible. The contribution from the multiple scattering in CSC itself is expected to be 30 μm (for 1.4 GeV cosmic rays). For comparison the same spectrum but for the angular range $|\phi| < 0.04$ is shown in Fig.11b).

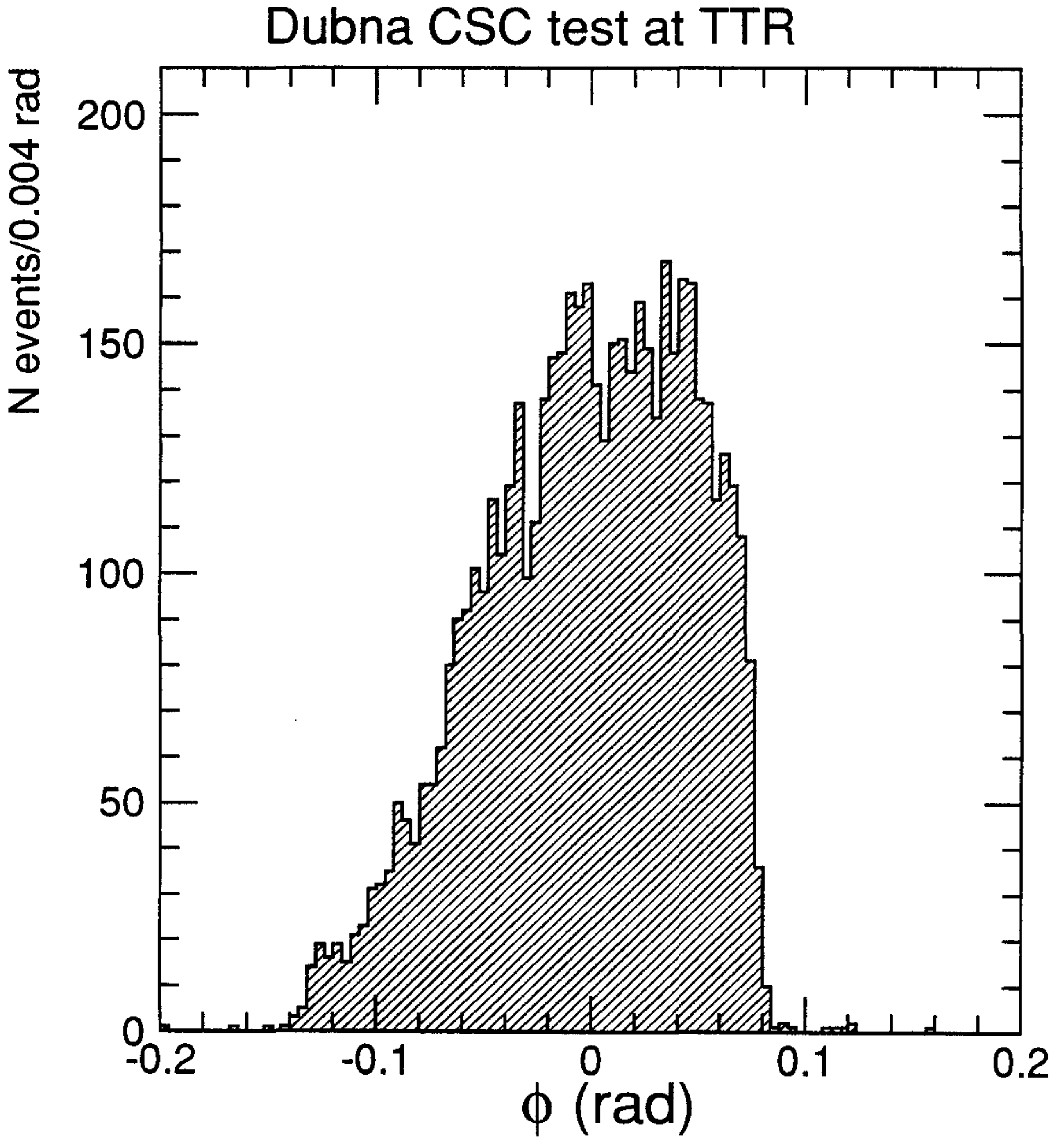


Fig. 10 Test setup ϕ angle acceptance. The accepted range is wider than in future GEM muon system chamber.

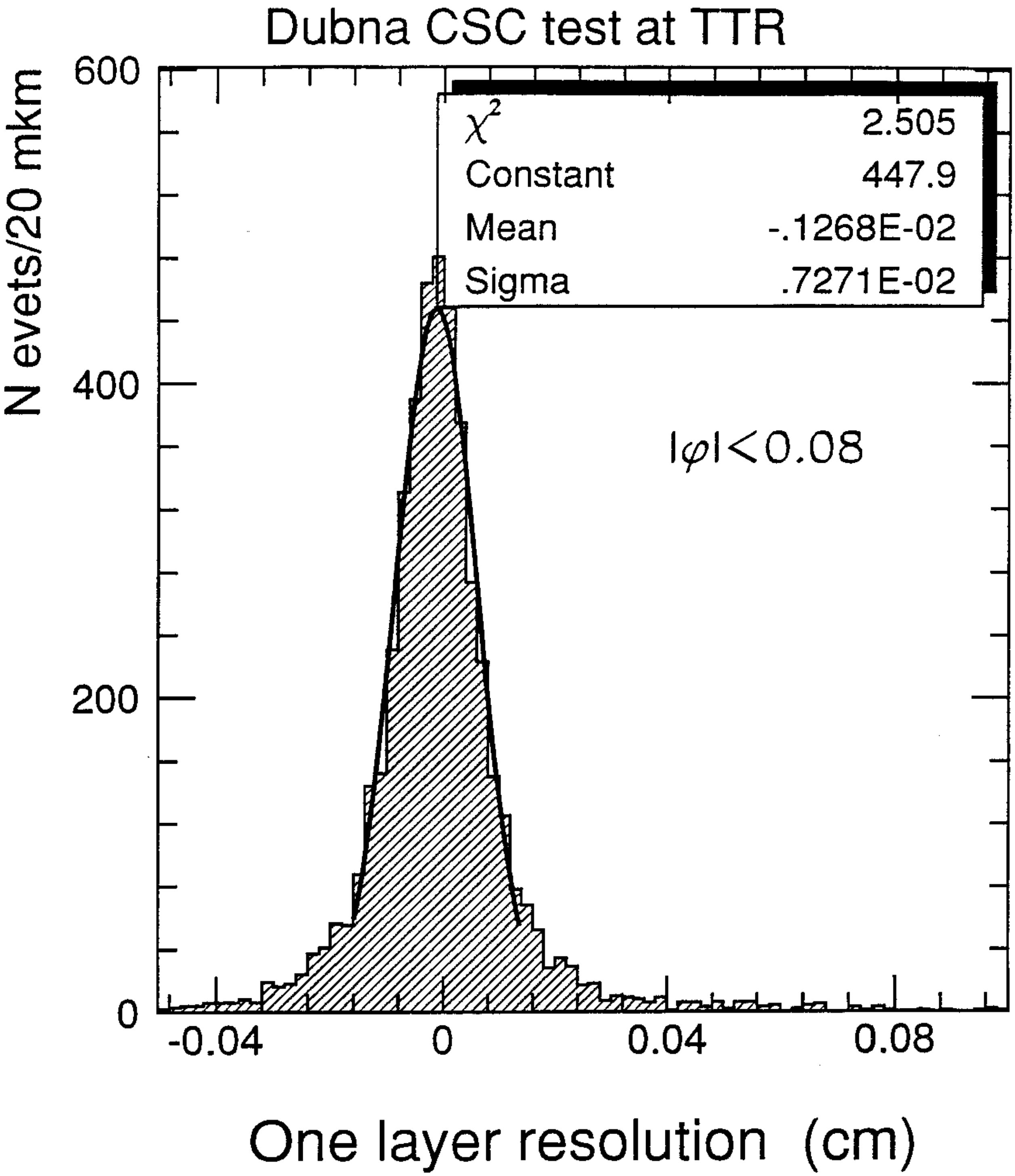


Fig. 11(a) Distribution of Δ_Y for $|\phi| < 0.08$, resolution is 73 microns;

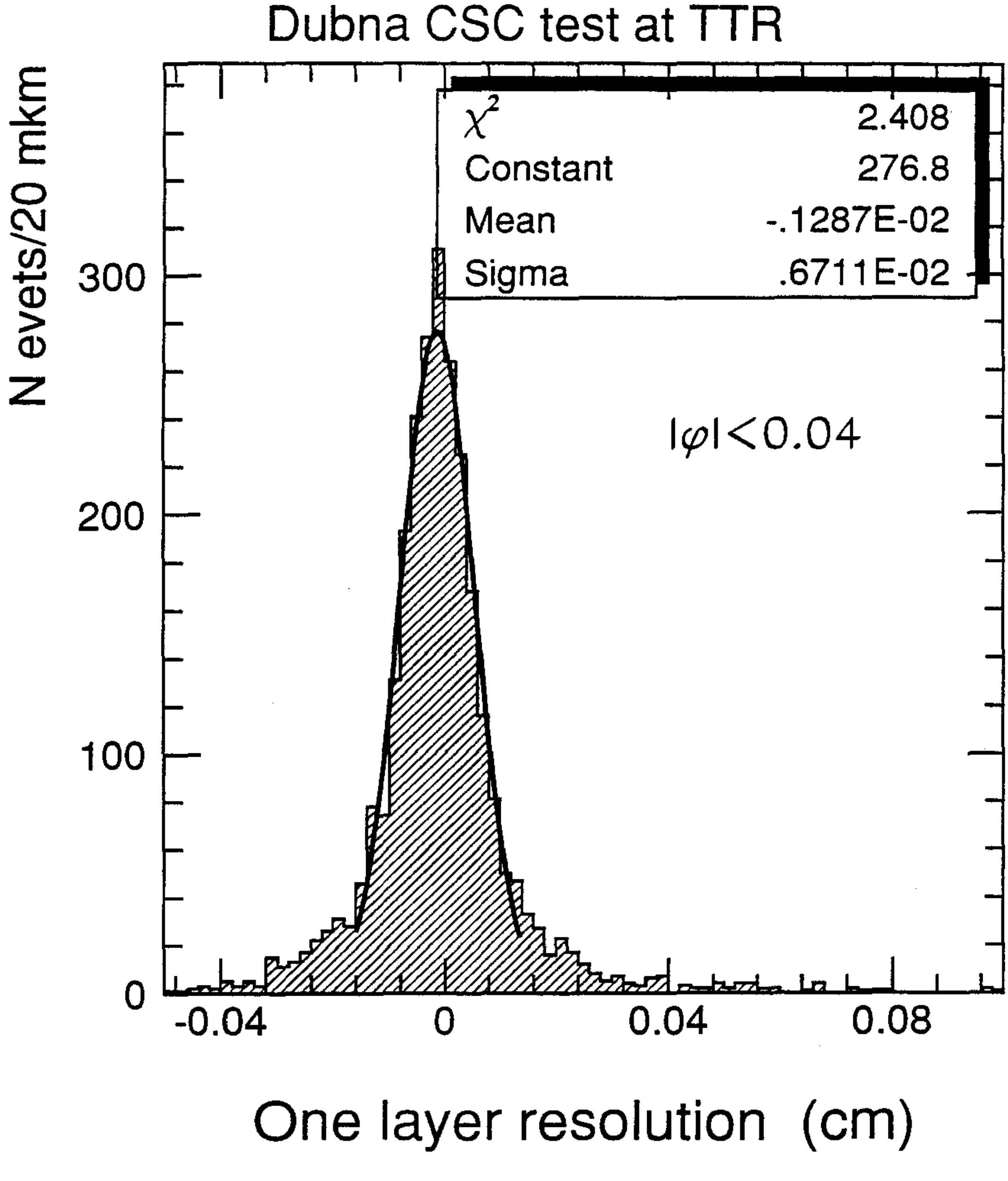


Fig. 11(b) Distribution of $|\phi| < 0.04$, resolution is 67 microns.

Since our calibration data cover only a half of ADC range we studied the events with small cluster charges separately. This analysis allows to estimate the resolution achivable by CSC with the calibration curves known in the full ADC region. The deterioration of spatial resolution due to electronics noise is expected to be even smaller in high cluster charge region, where the signal to noise ratio is larger. In Figs.12a and 12b the Δ_Y spectra for two angular ranges $|\phi| < 0.08$ and $|\phi| < 0.04$ are shown for events with cluster charge smaller than 500 ADC channels. The resolution of about 60 μm on the strips 1.5 m long is achived in the restricted angular range.

In order to study the phi angle dependence of spatial resolution the whole region $|\phi| < 0.08$ was divided into three parts: $-0.08 < \phi < -0.02$, $-0.02 < \phi < 0.02$ and $0.02 < \phi < 0.08$. The spatial resolutions in each of these parts are shown in Fig. 13. One can see that all 3 values are below 80 μm level.

5. CONCLUSIONS

The test of a large two-layer CSC shows that a CSC operated in the proportional mode will be able to provide required spatial resolution for GEM muon system and could be operated for 36 hours with stable calibration parameters. The resolution below 80 microns was obtained for tracks with incident angles less than 0.08, which covers the real GEM muon chamber ϕ angle acceptance.

The cosmic ray set-up such as TTR could provide a good possibility for testing the quality of large CSCs and their electronics. For the GEM muon CSC of sizes up to 1.3m by 3.5 m the advantages of cosmic ray set-up with respect to various test beams will be even greater.

6. AKNOWLEDGEMENTS.

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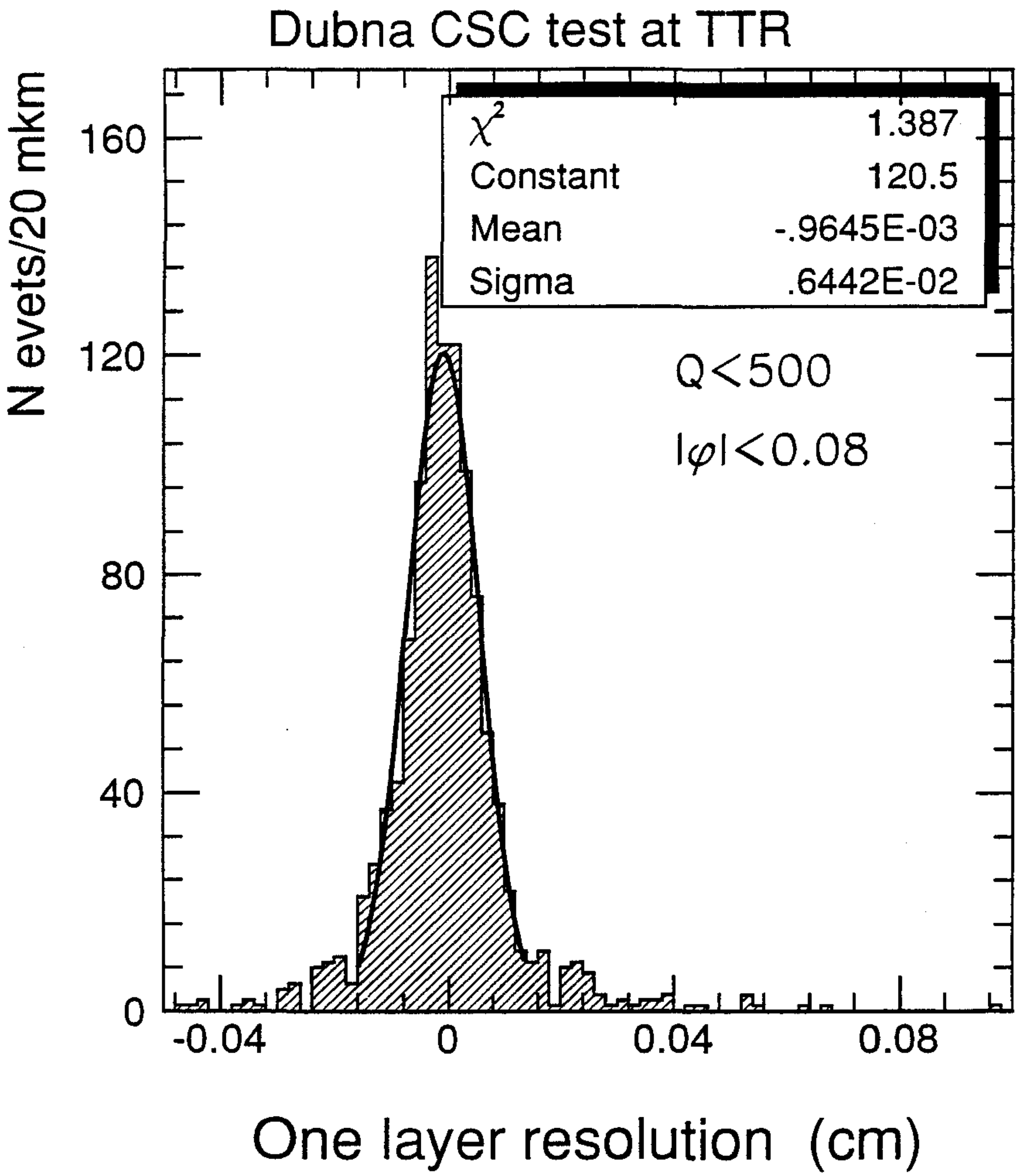

Fig. 12 (a) Distribution of ΔY for $|\phi| < 0.08$ and $Q_{cluster} < 500$, resolution is 64 microns

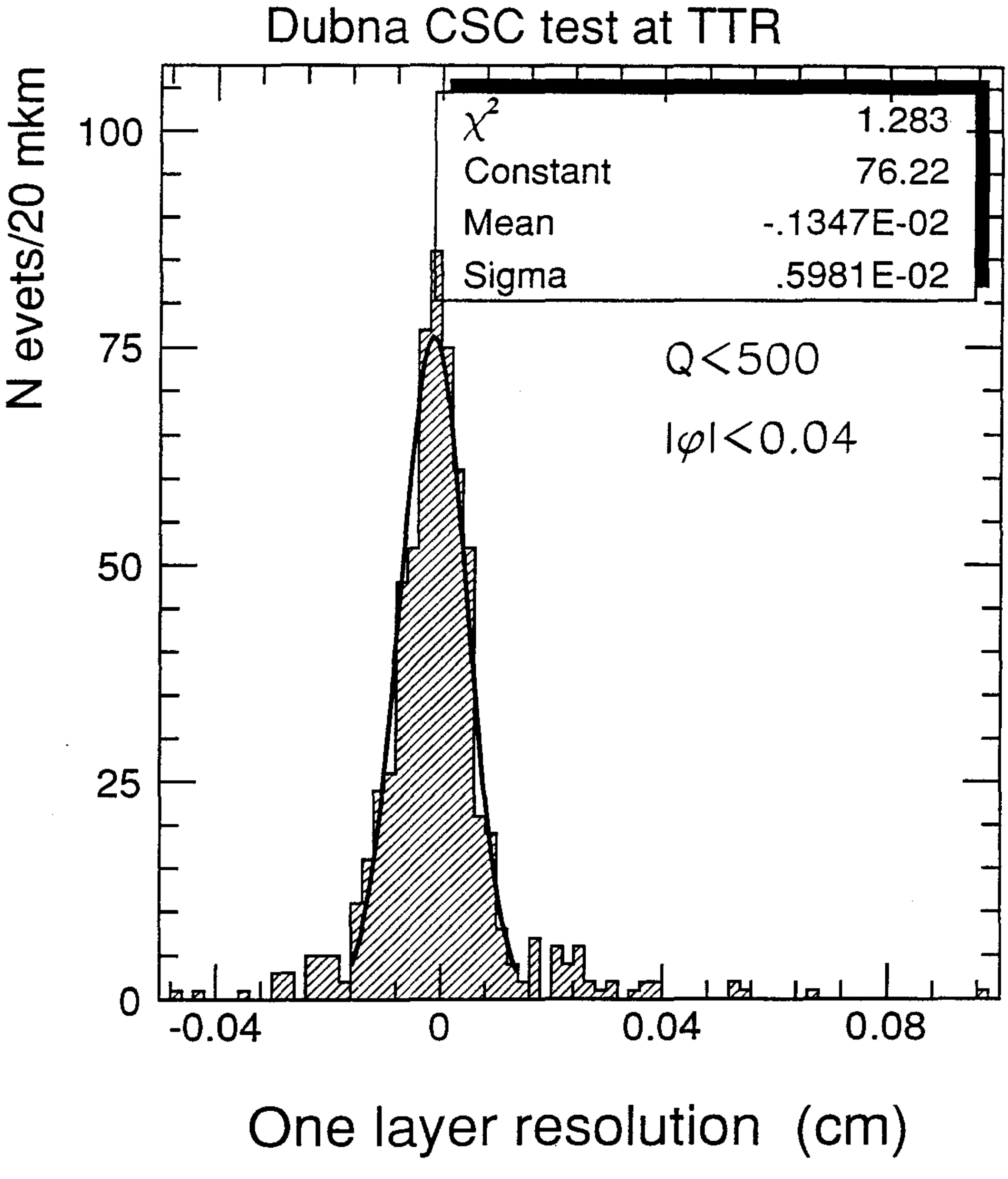

Fig. 12(b) Distribution of Δ_Y for $|\phi| < 0.04$ and $Q_{cluster} < 500$, resolution is 60 microns.

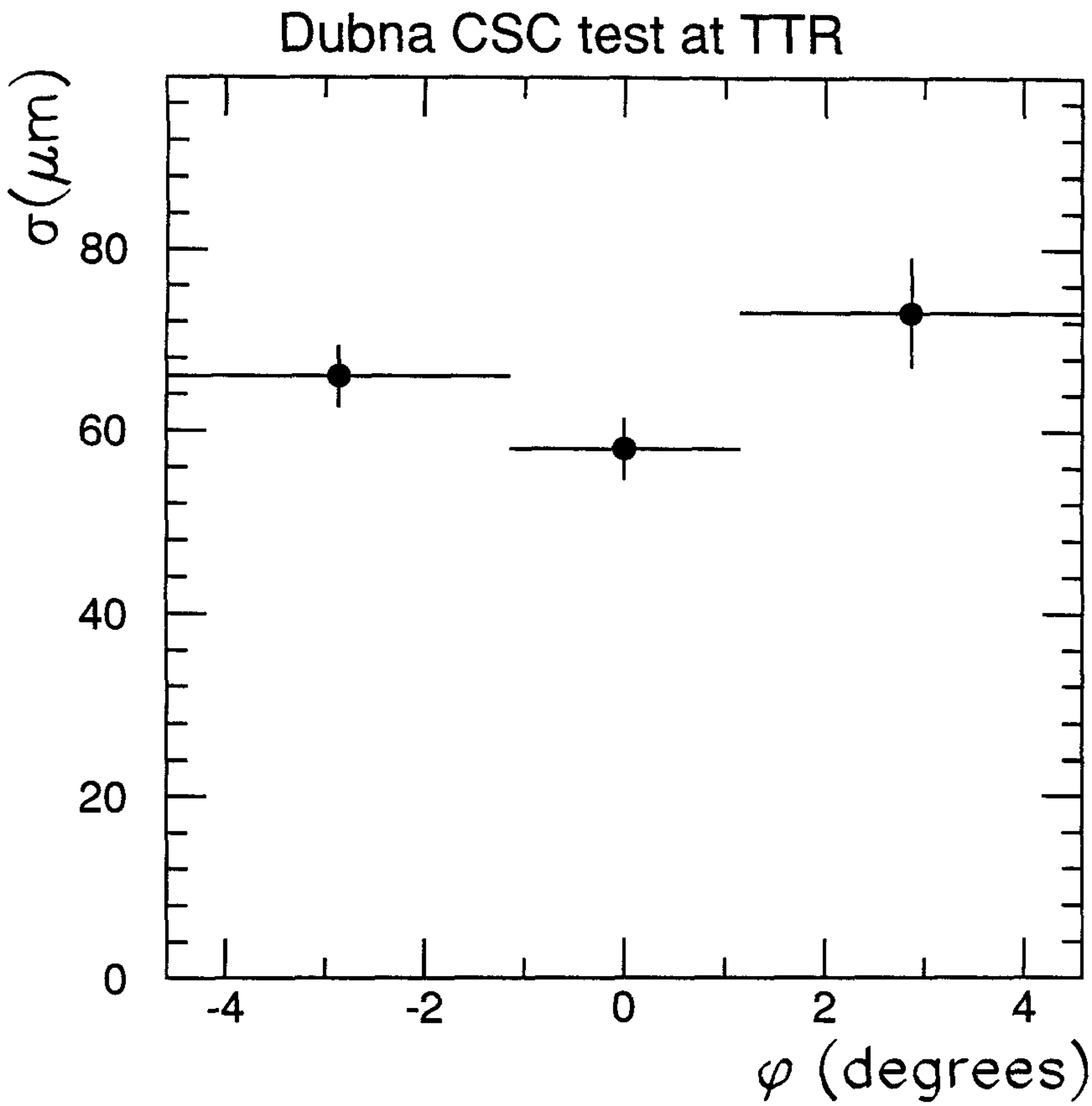

Fig.13 Single CSC layer spatial resolution as a function of ϕ.