GEM TN-93-402

Test Beam Results from the GEM Prototype Cathode Strip Chambers in RD5

J. Shank, E. Hazen, G. Varner, D. Warner, S. Whitaker
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A prototype of the proposed GEM endcap muon chambers was tested in a muon beam at CERN experiment RD5. Results on spatial resolution are presented. A single plane resolution of approximately 80 microns was obtained.

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A prototype of the proposed GEM endcap muon chambers was tested in a muon beam at CERN experiment RD5. Results on spatial resolution are presented. A single plane resolution of approximately 80 microns was obtained.

The Boston University Cathode Strip Chambers.

The cathode strip chambers(CSC) made at Boston University are shown schematically in figure 1. They are constructed as doublets with the two precision strip cathodes laminated back-to-back on a paper honeycomb structure (HMX20 Hexcell [1]). Figure 2 shows the pattern of the strips etched on each cathode. There are two patterns each with 5 mm readout pitch. One half has two floating strips between readout strips, the other has just one floating strip. The results presented here are just for the two floating strip section. Two doublets were bolted together to form the 4 layer chamber used in RD5.

Alignment marks in addition to the strips were etched on each cathode. These marks were visible from the outside after assembly. Precision steel washers were glued onto the alignment marks under a microscope so that the outer diameter of the washer overhung the edge of the chamber and the inner diameter was centered on the alignment mark. This allowed the different chamber layers to be aligned relative to each other by butting the washers up against a straight edge.

The wires were 30 micron diameter gold-plated tungsten spaced 2.5mm apart. The gap from strip cathode to top cathode was 5mm.

The gas used for this data was Argon (20%), CO_2 (60%), CF_4 (20%). The wires were at a voltage of 2600 Volts giving a gas gain of about 10^4.

The RD5 Experimental Setup.

The RD5 experiment is in the North Area of CERN in the H2 beam line[2]. The four layer CSC chamber was placed in the RD5 beam line behind 30λ of material (10λ calorimeter plus 20λ of magnet iron) as shown in figure 3. The cable run from the detector to the main CAMAC data acquisition crate was 35 meters. The data acquisition for the CSC was integrated into the RD5 MacUA1 system through a CAMAC crate.

Readout Electronics.

The cathode strips were readout using Amplex chips which were developed at CERN [3]. A custom board, made at Boston University, containing the Amplex chip and associated control logic was connected directly to the detector. Signals from 16 strips are fed into a single Amplex which does a sample/hold. The 16 held signals are then multiplexed up to the counting house through RG58 cable. In the counting house the signals are fed into a Lecroy FERA ADC system (Lecroy 4300B, 4301, 4302). There are 64 strips read out from each of 4 layers making a total of 256 channels in the FERA system. The timing signals needed to clock the Amplex outputs into the FERA system were generated by a custom CAMAC module made at Boston University.

The wire anodes were ganged in groups of 20 and connected to a preamp+shaper developed by BNL/PNPI. The preamp/shapers were mounted on a board developed at ORNL which also contained ECL discriminators. Each of these boards had 8 channels (160 wires) and a fast-OR output of all channels.

The ECL outputs were sent to the counting house and put into a Lecroy 2277 TDC. The fast-OR outputs, one for each layer, were put into a Lecroy 2228 TDC.

Run conditions.

The H2 test beam at CERN can supply muon and pion beams with energy from 10 GeV to 300 GeV. The data presented here is for 100-300 GeV muons. The data acquisition system limited the rate to 150 particles per 2.6 second spill.

The beam was at normal incidence to the cathode strip planes for the data presented here.

Event Selection.

In each layer, a cluster finding algorithm was applied. A cluster is defined as any number of contiguous strips which have a signal more than 10 ADC counts above pedestal. The distribution of the pedestal width is shown in figure 4 Figure 5 shows the distribution of the number of hit strips per cluster. A cluster is accepted if the following hold:

1. $2 \leq N_s \leq 5$
2. $50 < Q_t < 1200$ (ADC counts)

Where: N_s = The number of strips in the cluster.

$Q_t = \sum_{i=1}^{i=N_s} Q_i$ The total charge in the cluster.

Figure 6 shows the distribution of Q_t for all clusters for 100,200 and 300 GeV muons. For resolution studies, an event is accepted if there is one good cluster in each of the four layers and there is a single TDC hit for each layer. In addition the vertical position of the hit, determined from which group of wires is hit, is required to be the same in each layer.

Resolution.

There are a number of methods used to determine the best position resolution with cathode strip chambers [4]. The methods differ in the way they treat the problems of noise and differential non-linearity.

•Bias Method.

The bias method of position determination is a center-of-gravity method that uses a bias level subtraction to reduce the differential non linearity[5]. In particular, the position of a cluster is given by

$$x = \frac{\sum_{i=1}^{i=N_s}(Q_i - B)x_i}{\sum_{i=1}^{i=N}(Q_i - B)}$$

with $$B = \sum_{i=1}^{i=N_s} bQ_i$$

x_i is the center position of strip i.

b is chosen to be 0.05

•Ratio Method.

The ratio method used here determines the position of a cluster by fitting the ratio Q_{left}/Q_{big} to the sum of two exponentials. Where

Q_{big} is the largest charge on a strip in the cluster .

Q_{left} is the charge on the strip adjacent to the large one.

Q_{right} is the charge on the strip on the other side of the large one.

Figure 7 shows the distribution of Q_{left}/Q_{big} vs. the position within the strip with Q_{big} as determined by the bias method above. This plot is used to fit Q_{left}/Q_{big} to a sum of 2 exponentials which yields a function:

1.1 $$Q_{left}/Q_{big} = e^{(p_1+p_2x)} + e^{(p_3+p_4x)}$$

results of the fit: $p_1 = -4.073$

$p_2 = 0.730$

$p_3 = -1.525$

$p_4 = -0.626$

which can be solved numerically for the position given the charge ratio, Q_{left}/Q_{big}. The best position is obtained if the fit is used in the region where it is most sensitive to x, so Q_{left} or Q_{right} is used depending on the following algorithm:

If $Max(Q_{left}, Q_{right}) > 0.25$, then x is determined by solving 1.1 with $Max(Q_{left}, Q_{right})/Q_{big}$ as the charge ratio.

Otherwise the solution for Q_{left}/Q_{big} is averaged with the solution for Q_{left}/Q_{big}.

Using the position determined from the ratio method, a straight line was fit to the hits in 3 of the 4 layers and the deviation of the fourth hit from that line

used to measure the resolution. Figure 8 shows the slope of the line fit to all 4 layers showing the beam incident angle of 2.6 mr. It is evident from this figure that the beam is well collimated. Figure 9 shows the deviation of hits in layer 2 from the fitted track.

A Gaussian fit to this distribution yields a standard deviation ,$\hat{\sigma}$ = 101. microns. This width must be corrected to get the single plane resolution since this resolution also enters into the estimate of the fit parameters. It can be shown that the estimated standard deviation from fig 9, $\hat{\sigma}$, is related to the single plane standard deviation ,σ by:

$$\sigma = \hat{\sigma}\sqrt{1 + \frac{1}{N - \frac{(\sum(z_i - z_o))^2}{\sum(z_i - z_o)^2}}}$$

where N is the number of planes used in the fit, 3 for this case.

the sums are over the 3 z_i points used in the fit.

z_o is the position of the plane not used in the fit, plane 2 for fig 9.

The z positions of the 4 planes are (in mm):

$z_1 = 0.0$

$z_2 = 29.59$

$z_3 = 109.47$

$z_4 = 139.06$

The correction factor for fig 20 is $\sigma = \hat{\sigma}0.791$, giving a single plane resolution of

$$\sigma = 79.1 \text{microns}$$

Dependence of the Resolution on background rate.

In order to study the dependence of the position resolution on background rate, a ^{106}Ru source was placed at various distances from layer 4. The highest rate obtained from the source was 6 kHz/cm^2 At that rate, approximately 1% of the recorded events (using the RD5 muon trigger) had a hit from the source in layer 4 overlapping the beam region. There was no measurable degradation in the resolution obtained from this run.

Acknowledgment.

We would like to thank all our collaborators on RD5, in particular: Gyorgy Bencze for tirelessly providing us with all the hardware and support we

needed; Fritz Szoncso and Claudia E.-Wulz for setting up the data acquisition system; D. Peach for help setting up the gas system; C. Lyndon for on-line software support and data taking shifts; and M. Mohammadi, M. Rijssenbeek, A. Sanjari, for data taking shifts.

References.

[1] HMX20 Hexcell, Ciba Geigy, 5115 E. La Palma Ave, Anaheim, CA 92807

[2] Study of Muon Triggers and Momentum Reconstruction in a Strong Magnetic Field for a Muon Detector at LHC, M. Della Negra,*et al.* , CERN/DRDC/90-36, 1990. Status Report of the RD5 Experiment, A. Bohrer,*et al.*, CERN/DRDC/91-53, 1991.

[3] Amplex-A Low noise, Low power Analog CMOS Signal Processor for Multielement Silicon Particle Detectors., E. Beuville,*et al.* , CERN/EF89-9, Sept., 1989.

[4] H. van der Graaf, *et al.*, Nuclear Inst. and Methods, **A307**, 1991, p.220-230.

[5] G. Charpak and F. Sauli, in Experimental Techniques in High Energy Physics, T. Ferbel, ed.

CSC DOUBLET -- CONCEPTUAL DESIGN

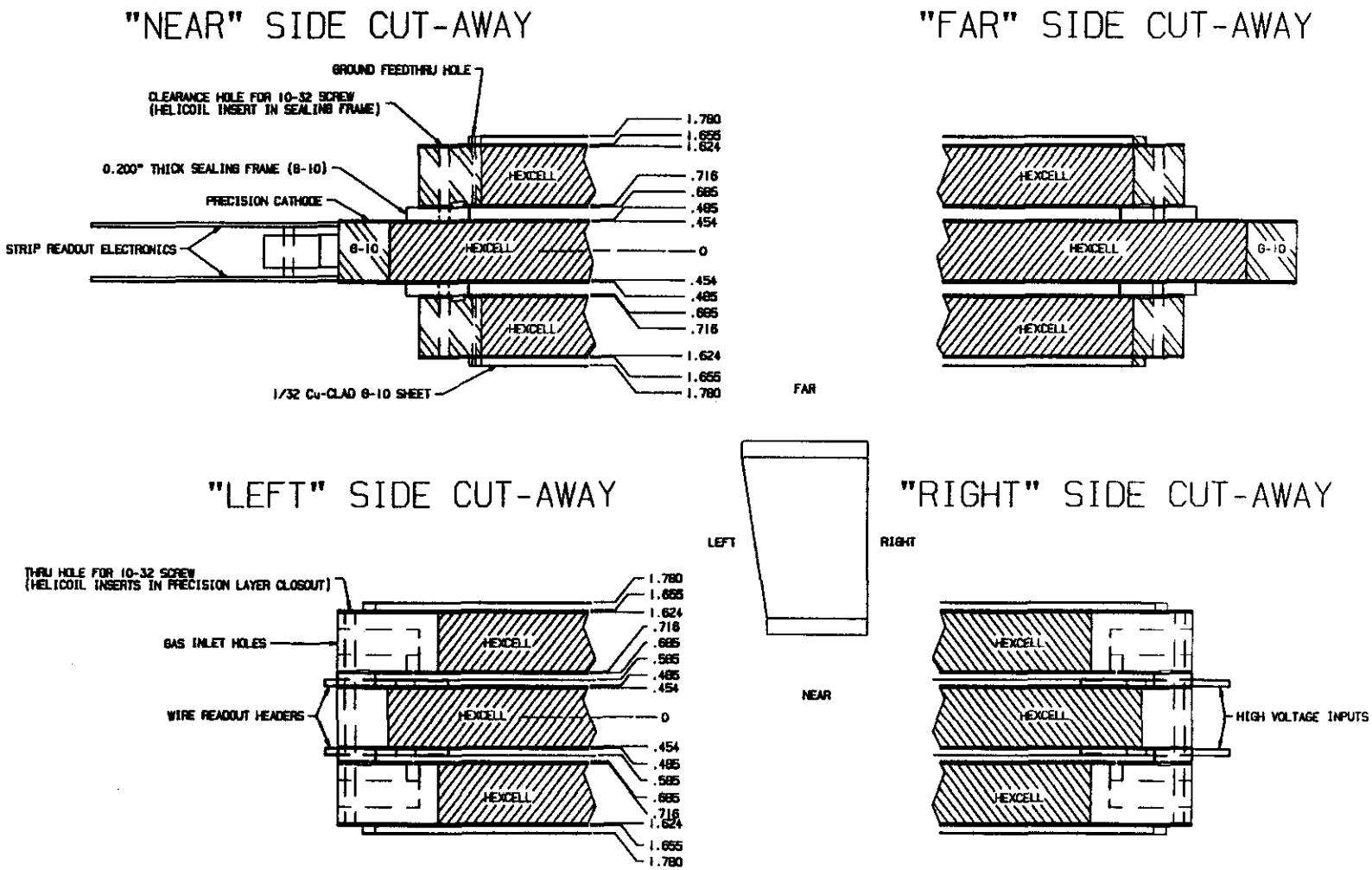


Figure 1.

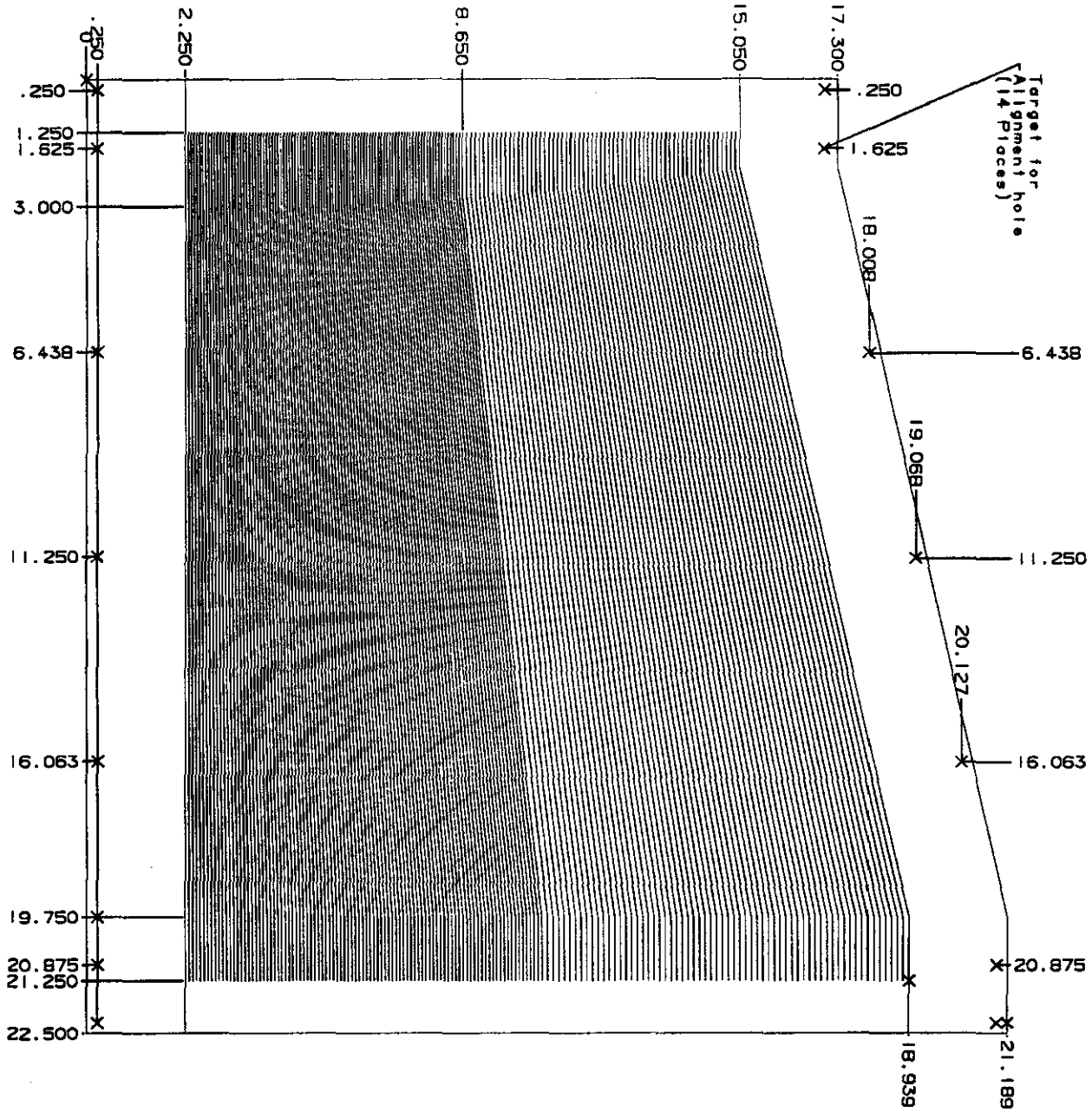
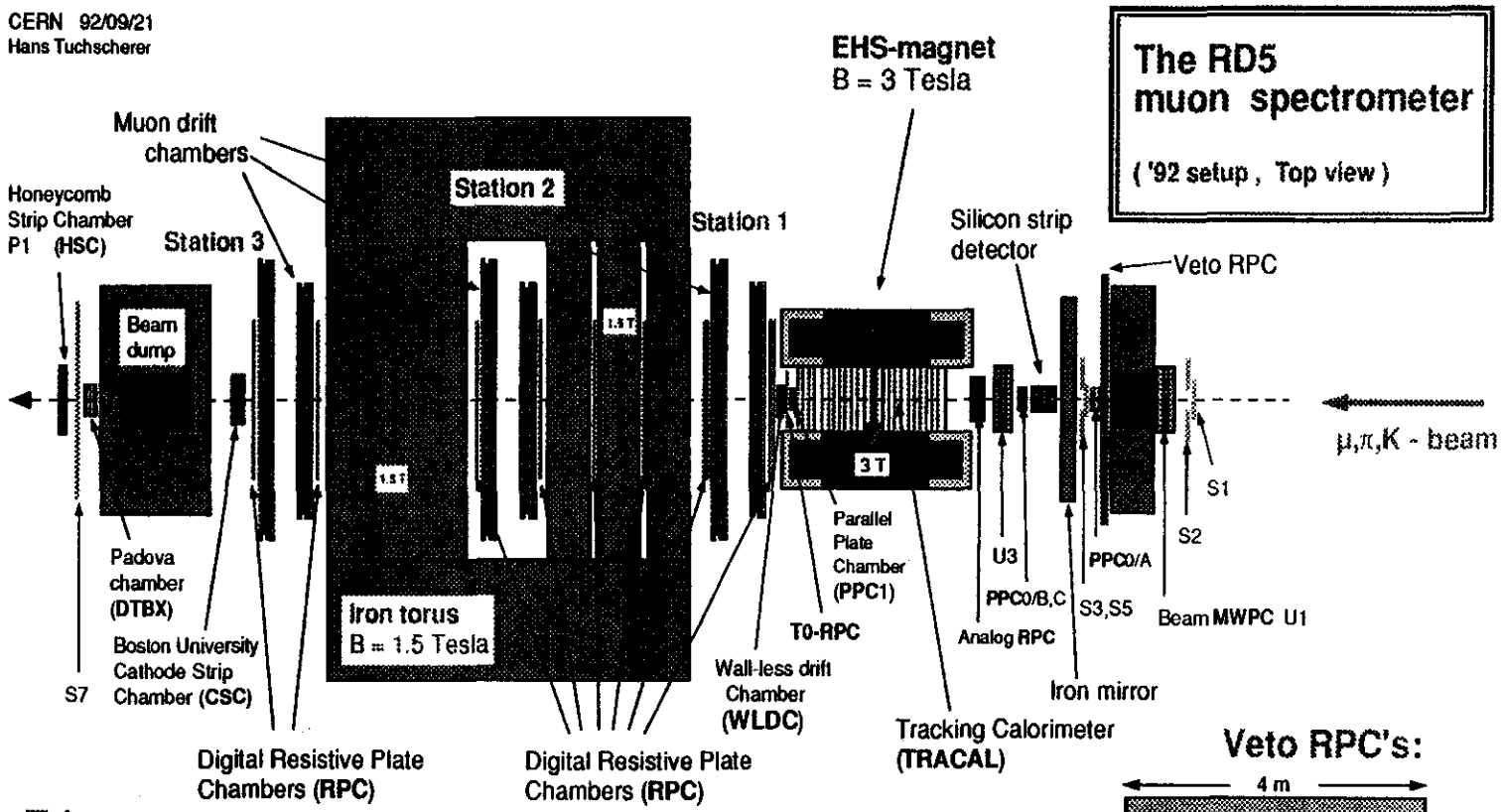


Figure 2. Cathode Strip Etch Pattern.



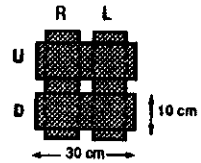
Trigger:

	μ	π		
		min.bias.	>10 λ	>20 λ
S1 x S5	●	●	●	●
VETO	●	●	●	●
PPC0	●	●	●	●
Station 1	●		●	●
Station 2	●			●
TRACAL		●	●	●

Scintillation counters:

S1: 10 cm x 15 cm
S5: 15 cm x 15 cm
S7: 100 cm x 250 cm

S2, S3 counters:



Veto RPC's:

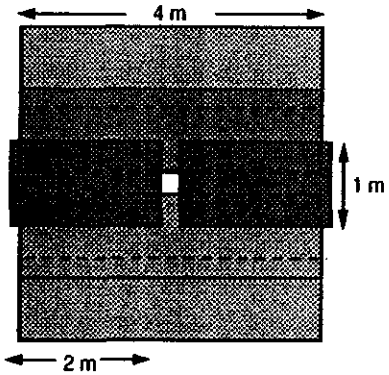


Figure 3. The RD5 Experimental Setup.

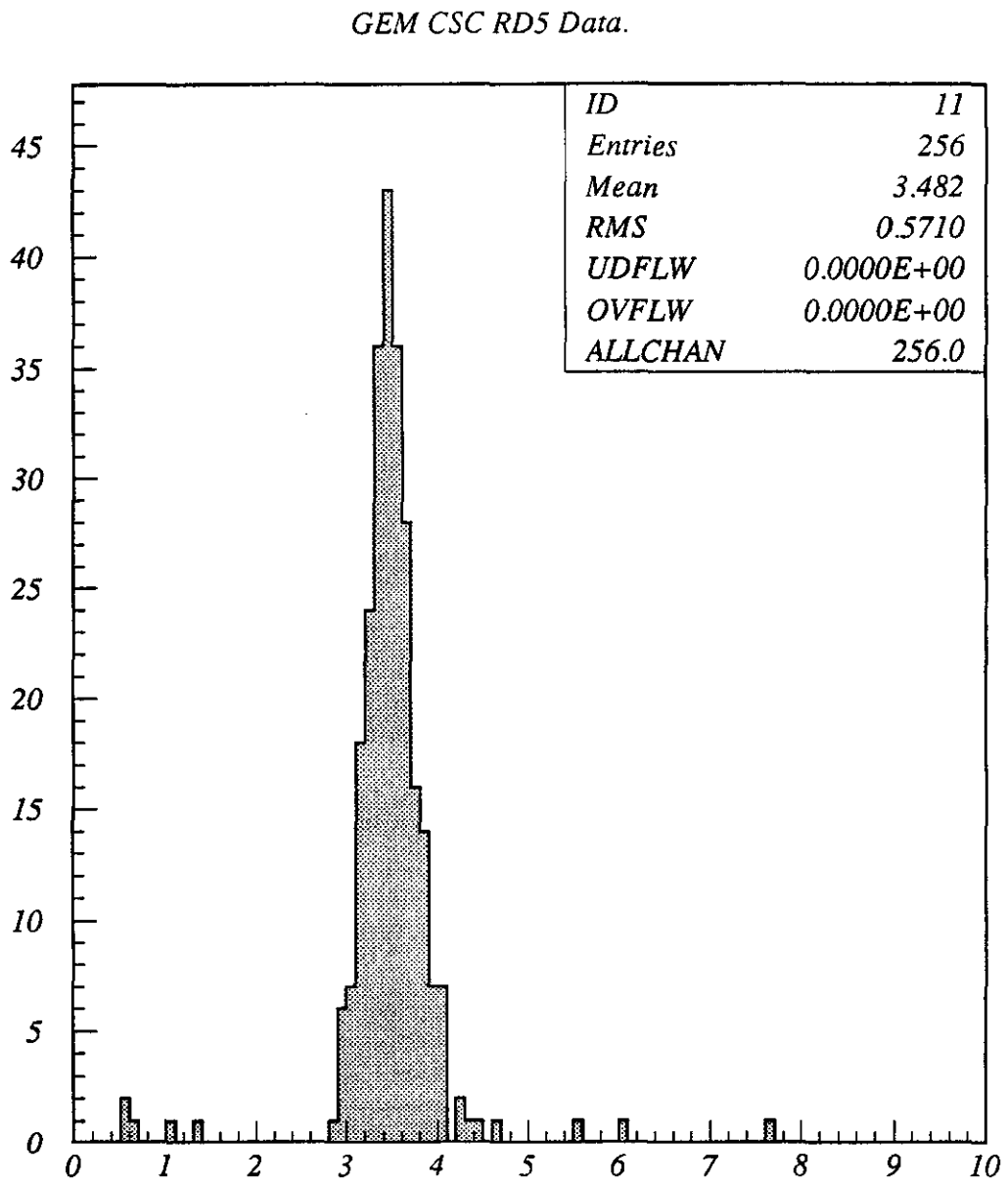


Figure 4. Pedestal rms distribution.

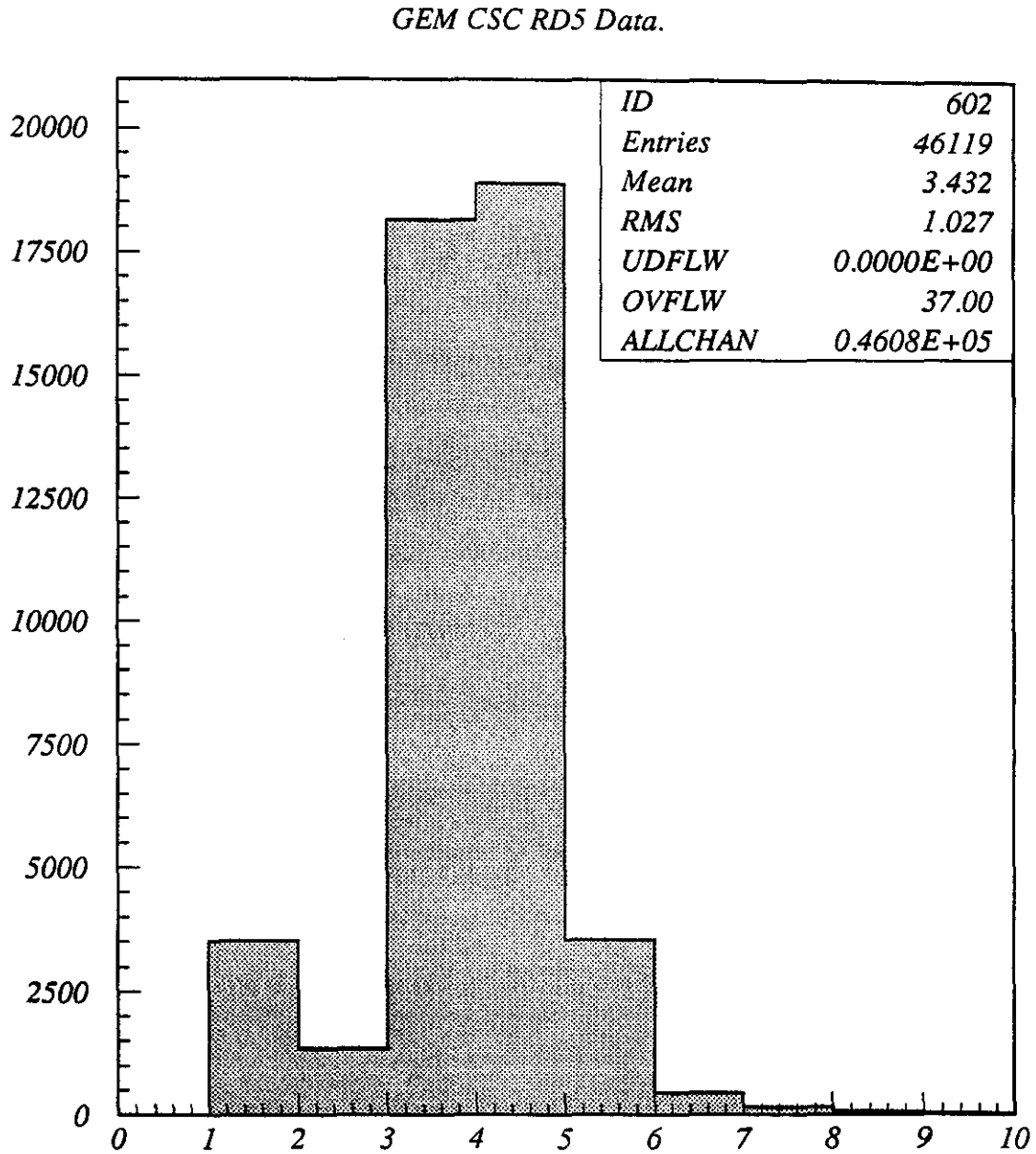


Figure 5. Number of hits/cluster

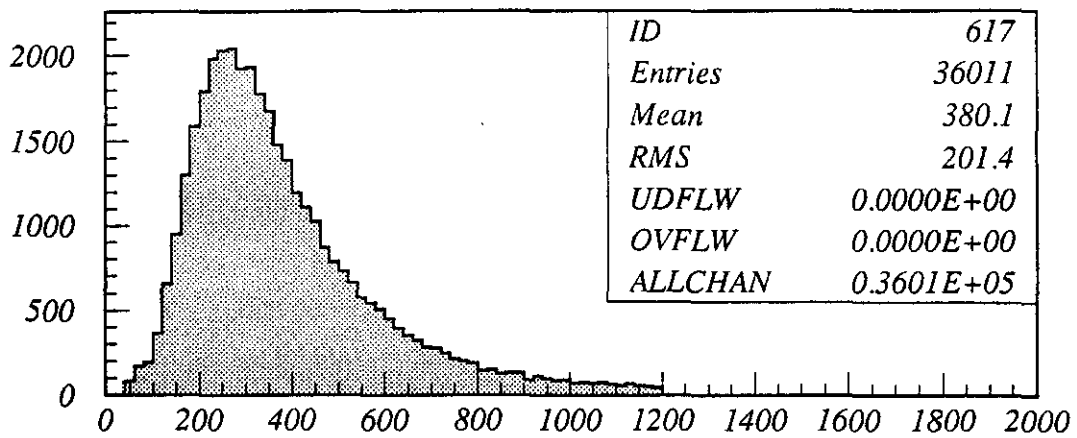


Figure 6(a). Pulse height of clusters for 300 GeV muons.

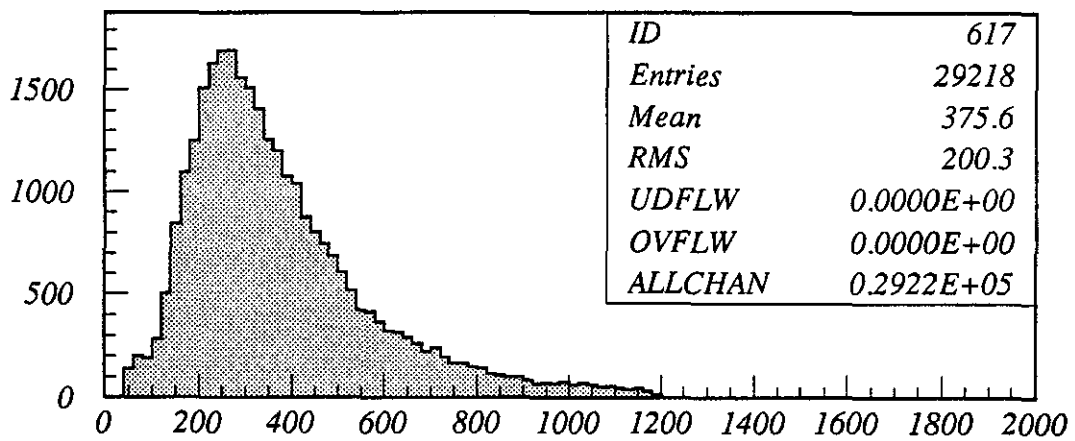


Figure 6(b). Pulse height of clusters for 200 GeV muons.

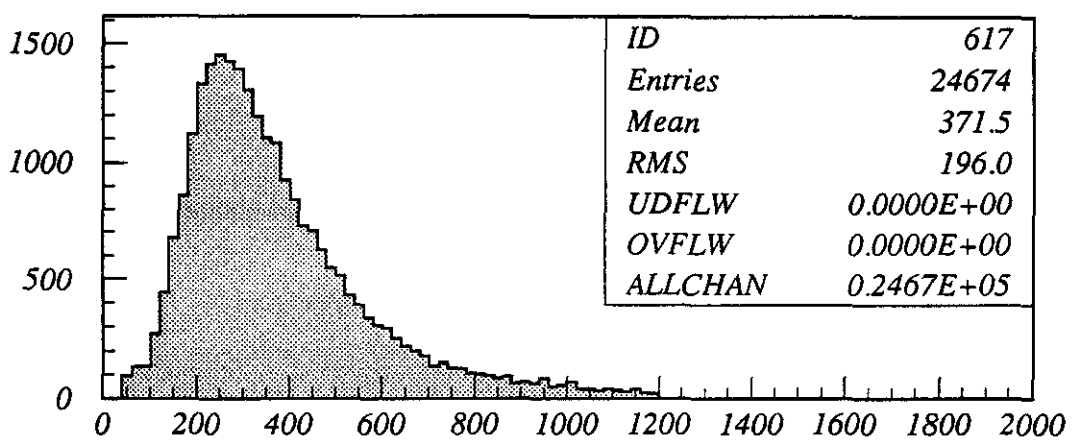


Figure 6(c). Pulse height of clusters for 100 GeV muons.

GEM CSC RD5 Data.

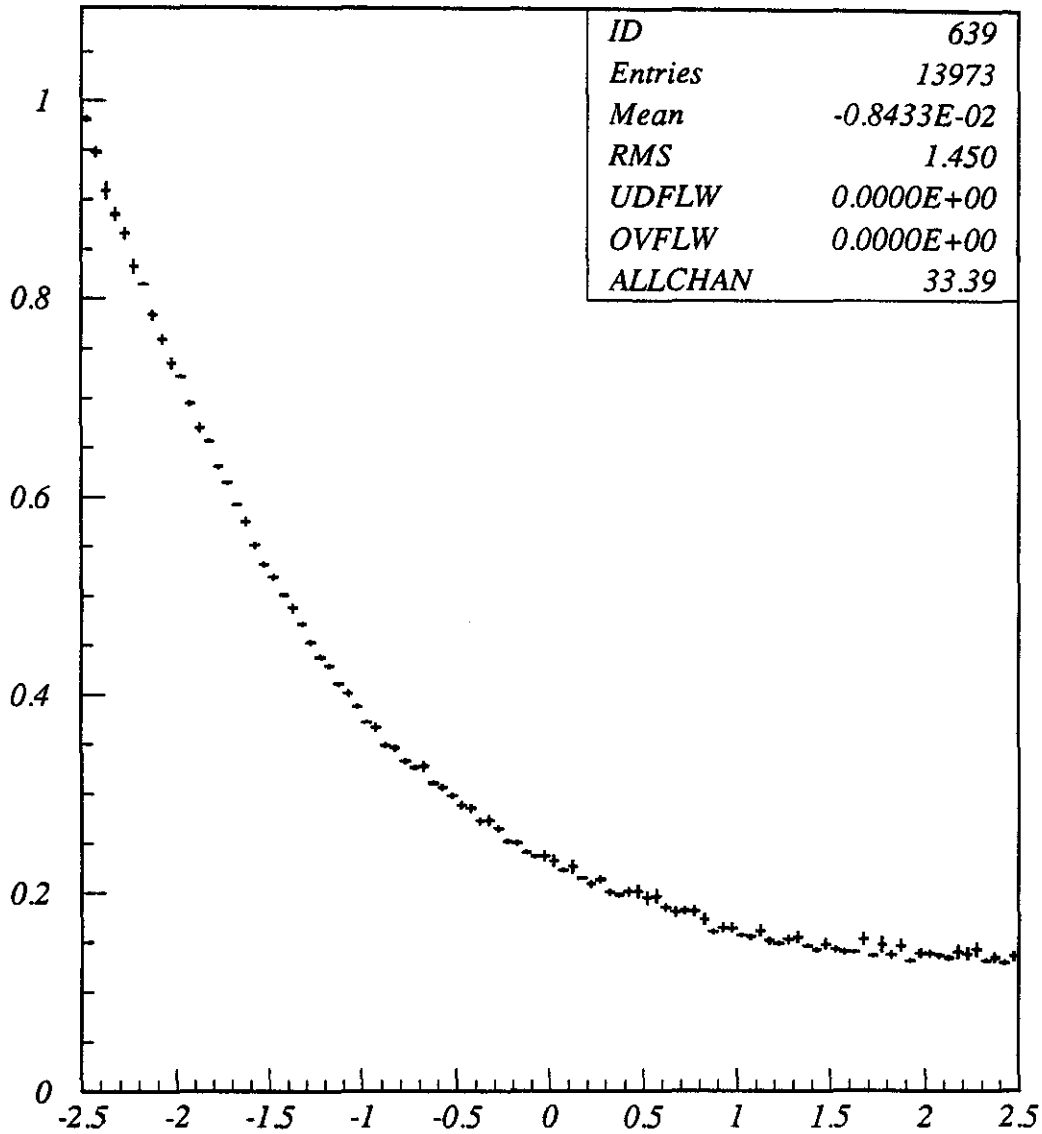


Figure 7. Right_ratio vs c.o.g. position

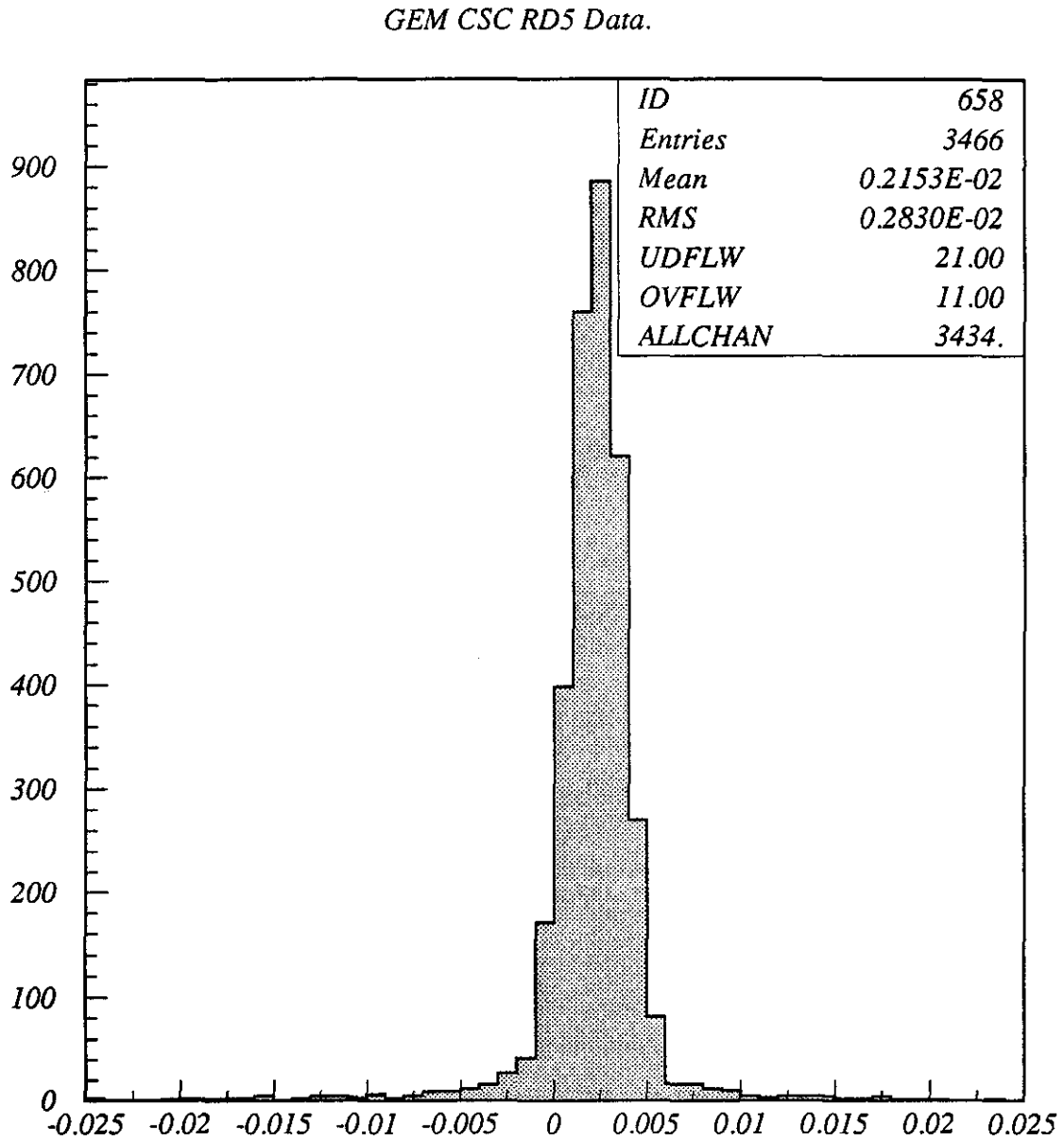


Figure 8. Slope from fit to all 4 layers.

GEM CSC RD5 Data.

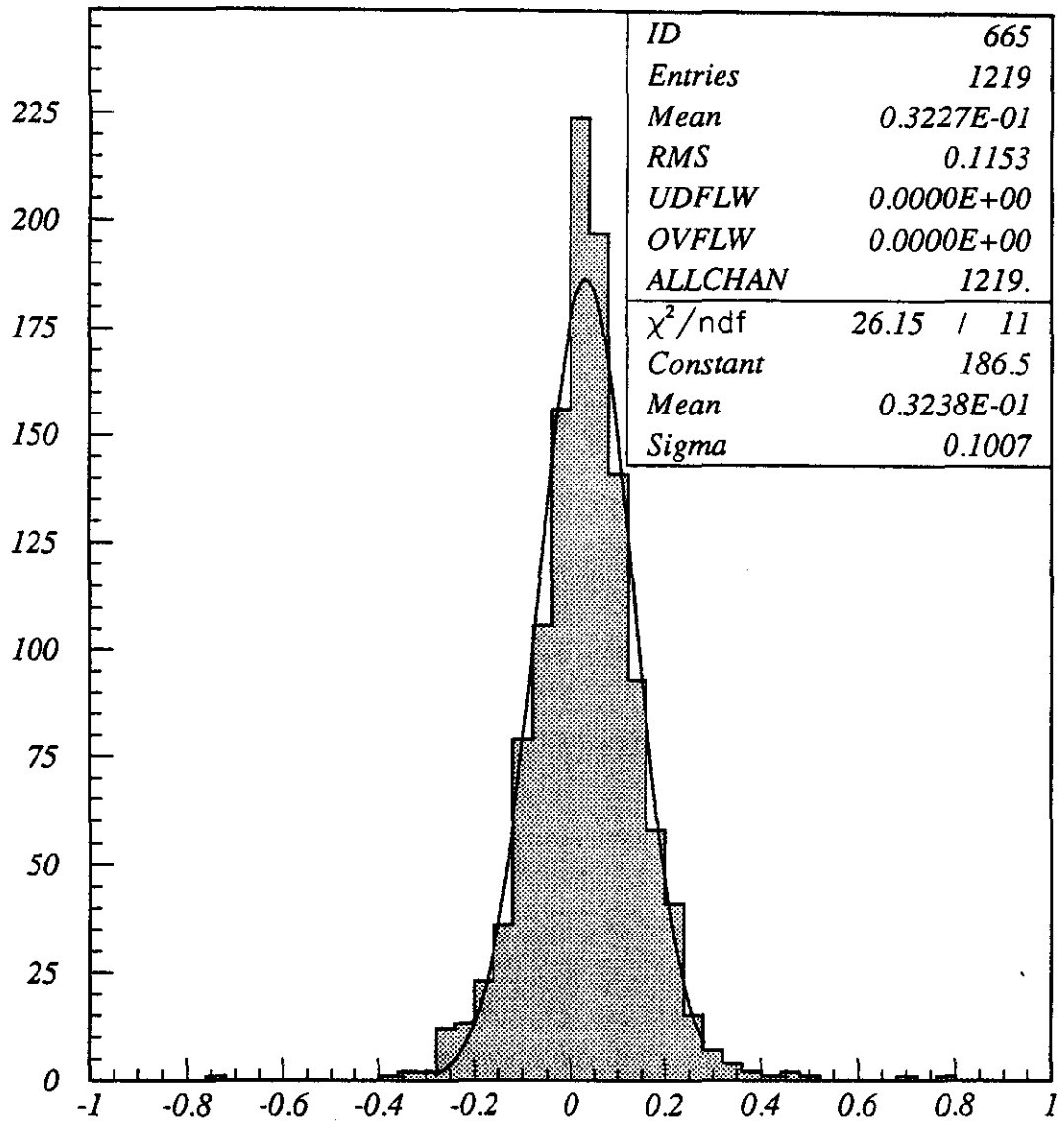


Figure 9. Deviation of hits in layer 2 from fitted line (mm).