STAR Note #52

Use of Time-of-Flight Detectors in the Trigger

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1 Introduction

The physics goals of STAR, particularly for complete particle identification, demand a comprehensive TOF system. The requirements for this system are to cover the pseudorapidity range $-1 < \eta < 1$ subtended by the barrel surface of the TPC, to identify pions with $0.3 < p_t < 1.5$ GeV/c; kaons with $0.3 < p_t < 1.5$ GeV/c and proton/antiprotons with $0.3 < p_t < 2.3$ GeV/c, and to provide a fast trigger sensitive to charged particle multiplicity in the central region.

The technical requirements posed by the above goals are challenging the timing resolution needed is $\sigma < 100$ ps. This requires a highly segmented cylindrical counter of 2.05 meter inner radius and about 4.5 meter long which is able to operate in a 5 kG magnetic field. The necessity of minimising secondary particles particularly photon conversions is the reason for putting the TOF system inside the solenoidal coil and the cryostat.

2 TOF System Design

The baseline design for the TOF system is the shingle design consisting of tiling the cylinder with 7776 single ended scintillators arranged in 216 trays (108 in $+Z$; 108 in $-Z$ direction). Figure 1 shows 108 trays arranged outside the TPC surface of radius 205 cm. Each tray which is 11.8 cm wide and 2.25 m long and houses 36 scintillators. The dimensions of each scintillator are 1.5 cm $\times$ 2.6 cm $\times$ 23.5 cm.

Due to budget constraints a descoped version will at first be used. This will consist of implementing $16 + 16 = 32$ trays which will cover approximately 53 degrees in phi. The rest of the cylinder will be implemented with 368 double ended TOF slats. These slats will be used as a trigger device for the mid-rapidity region and to provide lower resolution but still useful TOF data. The dimensions of each slat counter are 1.5 cm x 5.2 cm x 200 cm. Another alternative is to use 368 double ended TOF slats where the dimension of each slat will be 1.5 cm x 2.6 cm x 420 cm.

3 Monte Carlo Simulations

Intensive Monte Carlo simulations have been performed to study the performance of the descoped version of the TOF system, using 10 Fritiof 200 GeV/c Au + Au events as input to Geant 3.14. The program counts the primary tracks that make it to the TOF and thus provide a direct measure of the effective coverage. It turns out that although the geometrical coverage is only 84% (taking into consideration the longitudinal spacing between adjacent rows, as well as the dead region of 20.0 cm between the long scintillator slats), the effective loss in primaries is only 8% (averaged over the 10 events examined).

The characteristics of Bicron BC404 and BC408 were used in simulating the response of the shingles and scintillator slats, respectively. The response of a scintillator was parameterized in terms of the particle's beta and path length in the scintillator. The resultant light was transported to the phototube assuming a delay time of 75 ps/cm. The light attenution for a given scintillator was calculated from the bulk attenution length divided by the cosine of the critical angle. A 20% photocathode efficiency was used. A minimum of 100 photoelectrons was required for a light pulse to produce a signal in the PMT. The time spread of the hit was modelled by throwing a Gaussian distribution with a σ, in ps, given by $\sigma = a \times \sqrt{L}$ where L is the distance from the hit to the PMT, in cm, and a is an empirically determined constant equal to 20 for BC404 and 30 for BC408. These values and the value for the delay time were determined experimentally[1]. Typical time resolutions in both the shingles and the slats are shown in Figures 2a and 2b respectively. For shingles the average time resolution is found to be 64 ps whereas for slats it is 245 ps.

The distribution of the number of tracks and hits in both the shingle and slat regions averaged over 10 events, is shown in Table 1, for both primary and secondary tracks. Note that the number of hits is typically larger than the number of tracks, since a track can go through more than one scintillator. Figure 3 illustrates the hit multiplicity in the shingles for a typical event. Only the first hit to reach the phototube is recorded Figure 4 illustrates the hit multiplicity in the slats (a) and in the phototubes at both ends (b) and (c). If a multihit "pipeline", TDC is used, the possibility exists of getting multihit information from the long (200 cm) slats. In figures 4b and 4c, it has been assumed that light pulses reaching the phototubes with a time separation of greater than 10 ns will be recorded as separate hits. The pulse width of a phototube signal is about 6-7 ns. Our time cut of 10 ns was derived from the assumption that if two pulses are separated by more than 1.5 times the pulse width the signals can be recorded and the time information can be salvaged.

Figure 5a shows the typical p_t-distribution of all primary pions which hit the shingles, whereas in figure 5b, one can see the p_t-distribution of the primary pions which have been correctly identified. One should note that the lower limit is 0.2 GeV/c instead of 0.3 GeV/c. The cross hatched entries represent the primary pions which were not found. Figure 6 illustrates the same distribution for the slats. The pion reconstructed mass is shown in figure 7. The reconstruction efficiencies for primary pions, kaons and protons are shown in Table 2, averaged over the 10 events. The primary effect of the multihit capability is to improve the proton efficiency from 29% to 35%. The improvement for pion and kaon was not statistically significant.

The alternative design, consisting of using 420 cm long slats, has been examined as well, using the same 10 Fritiof events. The geometrical coverage in this case is 87% (by eliminating the 20 cm dead region at mid-rapidity), but the effective geometrical loss (averaged over 10 events) is only 3%. Table 3 illustrates the reconstruction efficiencies for primary pions, kaons and protons in the slat region, with and without pipeline TDCs. It is obvious from the above table that the use of the pipeline TDCs significantly improves the PID efficiency of the system and should thus be seriously considered. However the pulse shape for such a long slat has not yet been studied [1]. Further tests are necessary to verify if the 10 ns separation can be achieved. Figure 8 and 9 illustrate typical hit distributions and time resolutions in the long slat region respectively.

The total primary charged particle multiplicity versus the number of hits in the shingles or slats, or shingles and slats together is shown in figure 10. The effect of increasing the number of tracks per event was studied by overlapping two events, i.e. adding the tracks from two events assuming that the origins were coincident in space and time. Thus, one can easily see, there is a strong correlation between the number of hits (in any region) and the total number of charged particles through the TOF. Thus the TOF system, even in its descoped version, can provide useful multiplicity information even at twice the expected multiplicity.

References

[1] S. Ahmad *et al.*,Tests of Proximity Mesh Dynode Tubes and Evaluation of Shingle Counters, Star Note #50, 1992.

	Shingles	Slats
Total hits delivered	414	1950
Total tracks	326	1699
Secondary tracks	201	1007
Primary tracks	125	692
Primary pion tracks	110	618
Primary kaon tracks	8	39
Primary proton tracks	7	35

Table 1: Average hit and track multiplicities in the shingle and slat regions.

	Shingles	Slats
Pions	93%	65%
Kaons	88%	44%
Protons	90%	35%

Table 2: Average reconstruction effieciencies for primary pions, kaons, and protons.

	(a)	(b)
Pions	64%	56%
Kaons	55%	46%
Protons	48%	33%

Table 3: Average reconstruction effieciencies for primary pions, kaons, and protons in the slat region, using long slats, (a) with pipe-line TDC (time diff. = 10 ns) and (b) without (only first hit recorded).

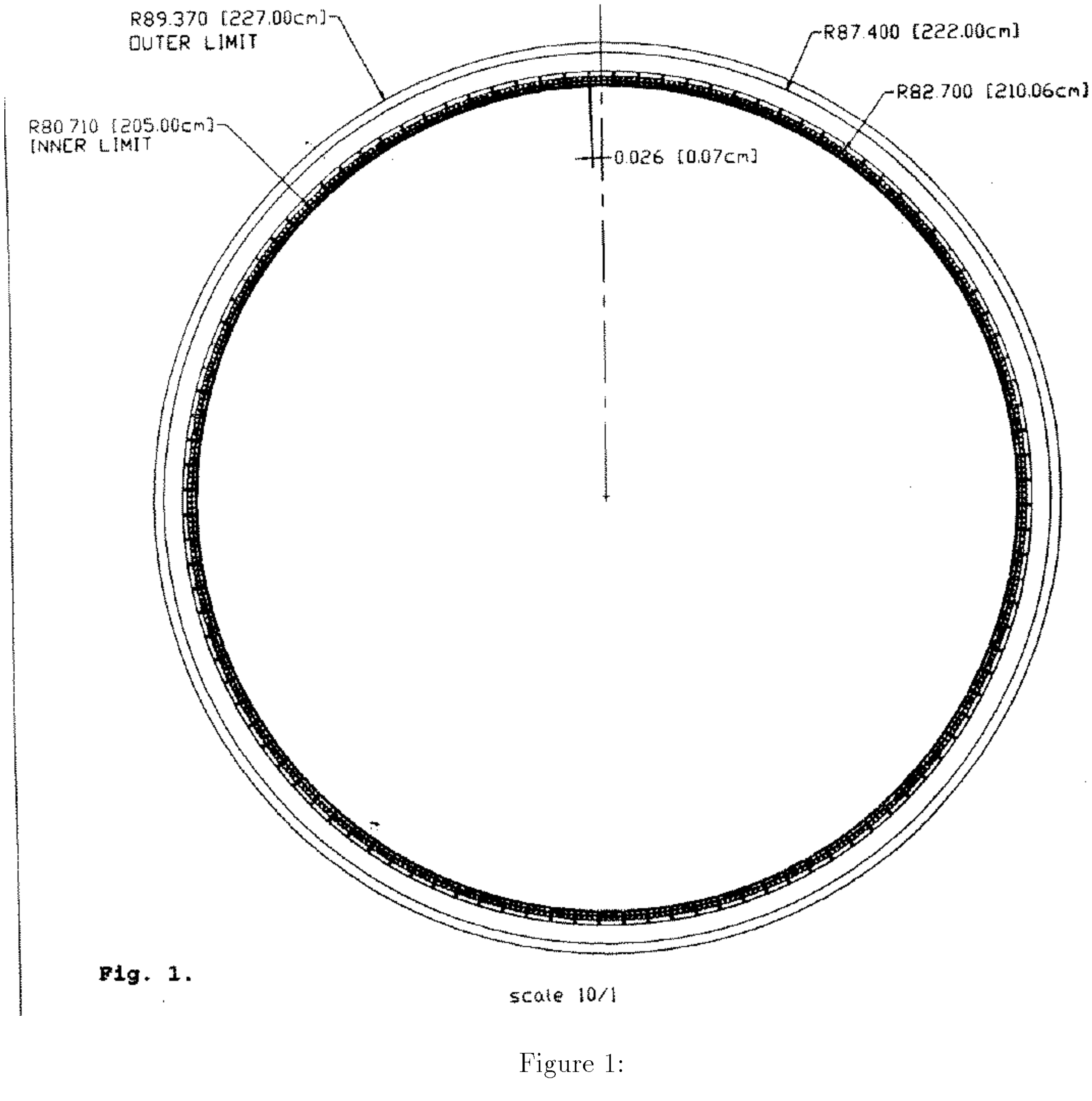

R89.370 [227.00cm]
OUTER LIMIT
R87.400 [222.00cm]
R82.700 [210.06cm]
R80.710 [205.00cm]
INNER LIMIT
0.026 [0.07cm]
Fig. 1.
scale 10/1

Figure 1:

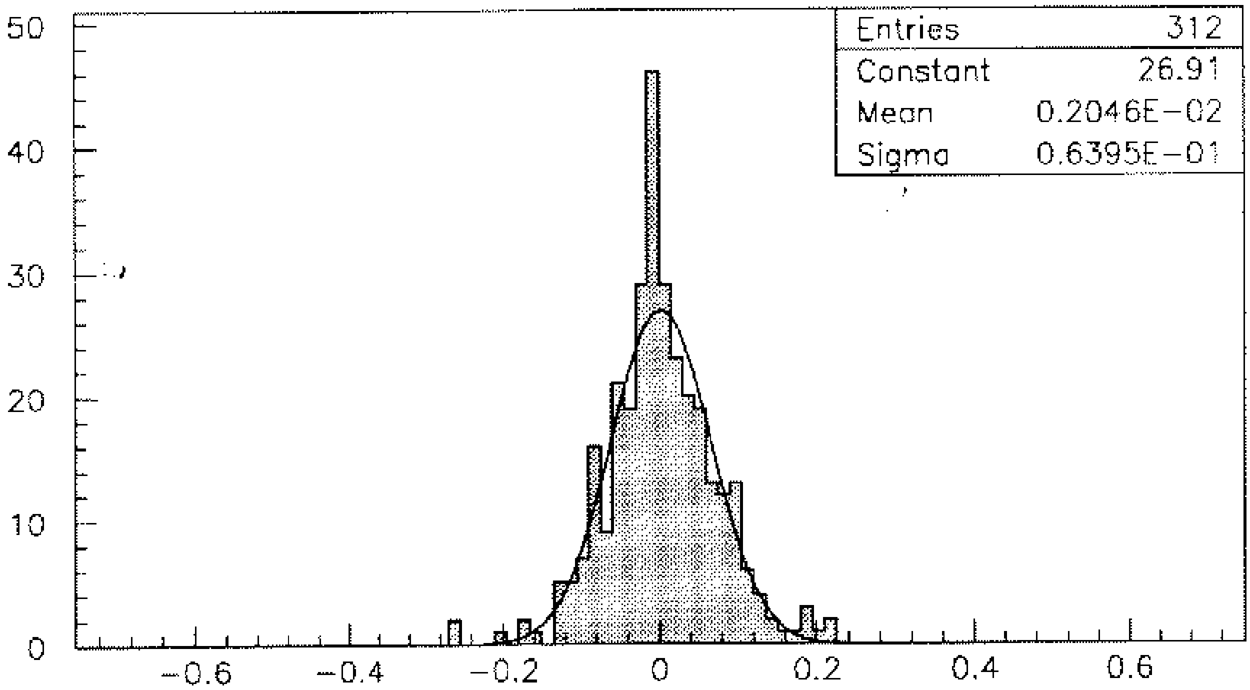


Fig. 2a. Avg. TOF resolution, shingle (ns)

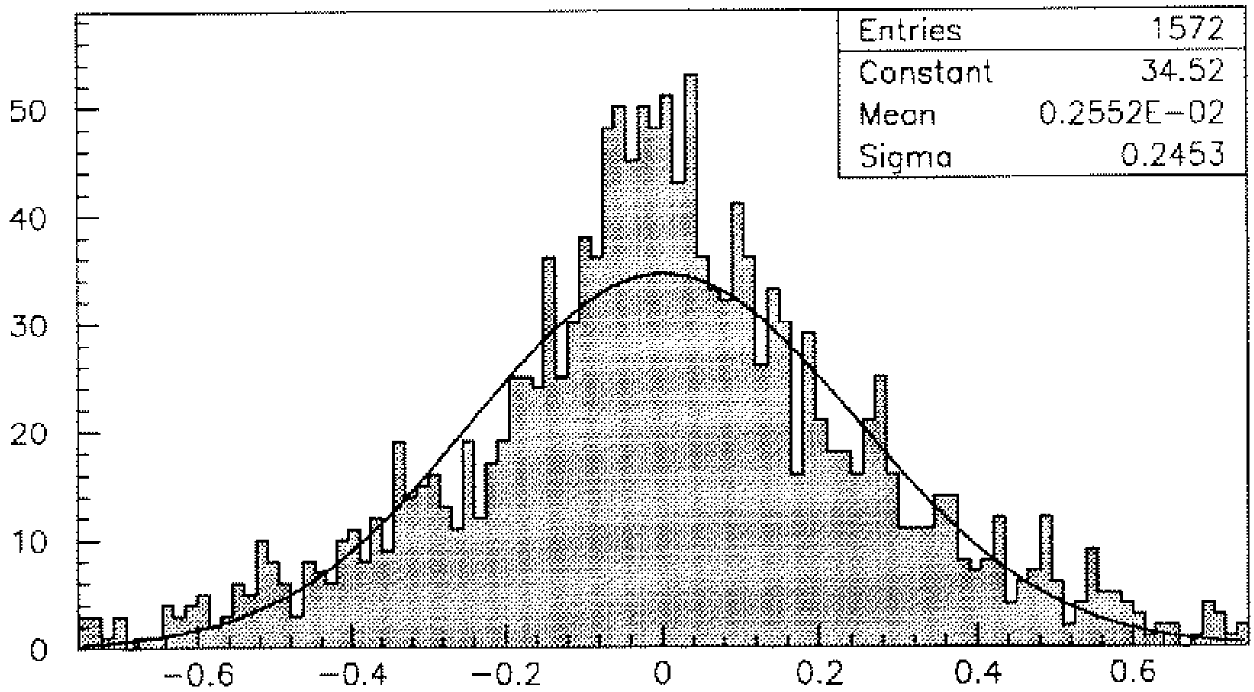


Figure 2:

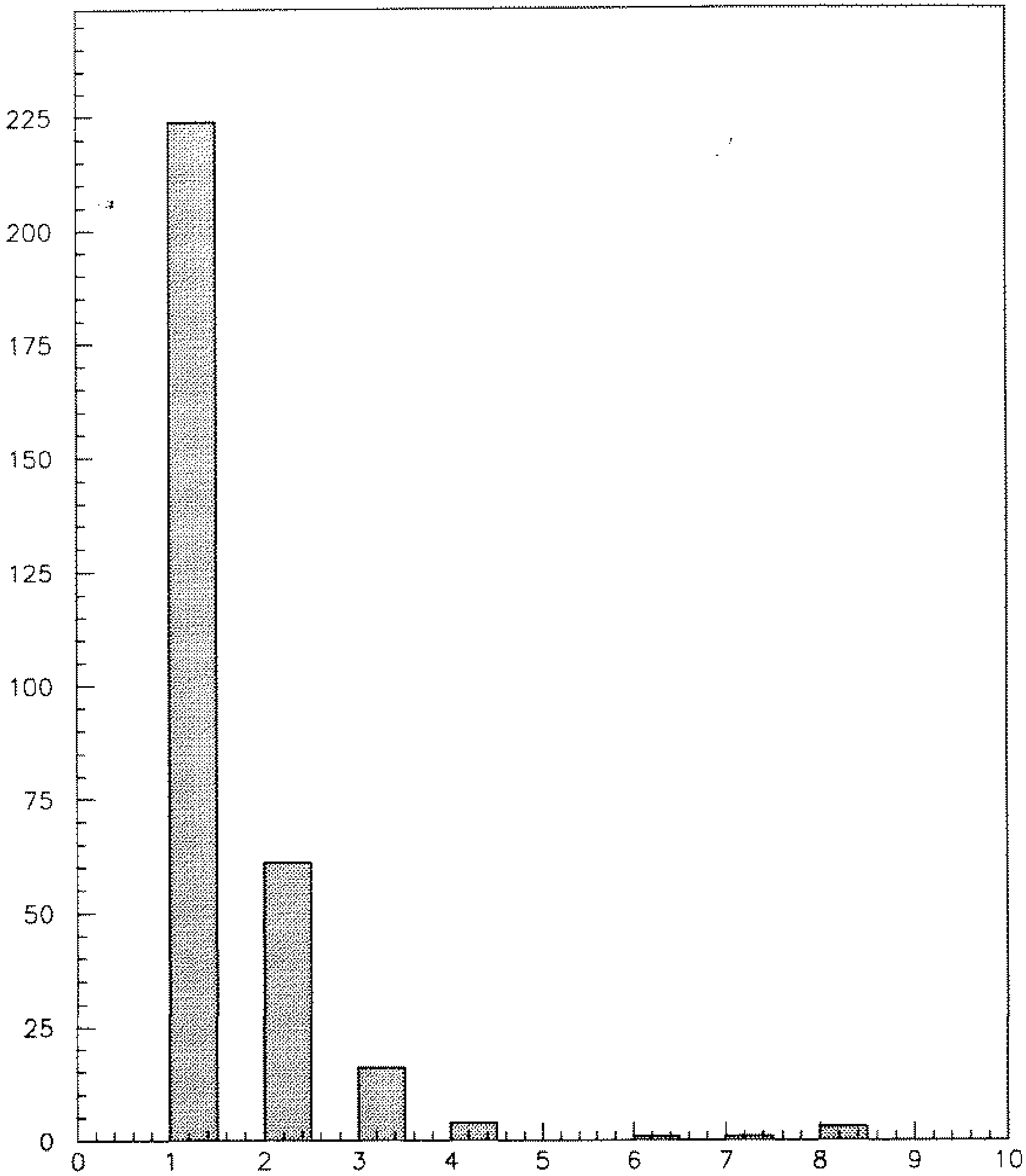


Figure 3:

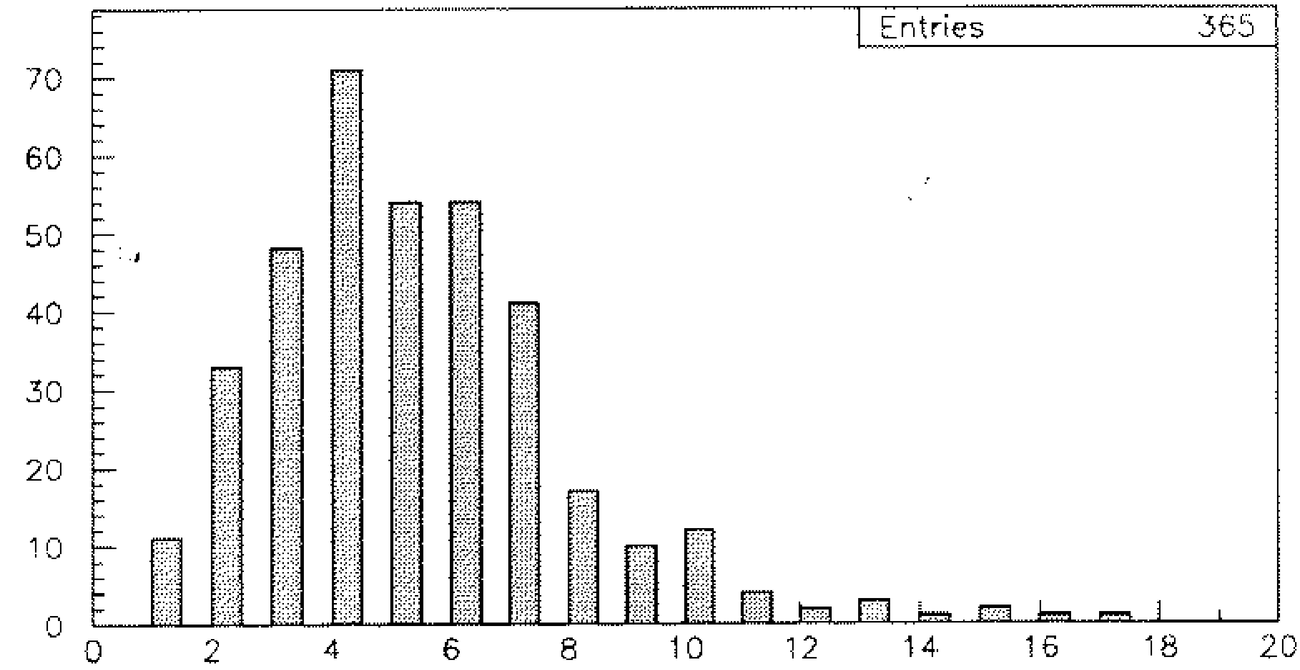


Fig. 4a. Hits per slot

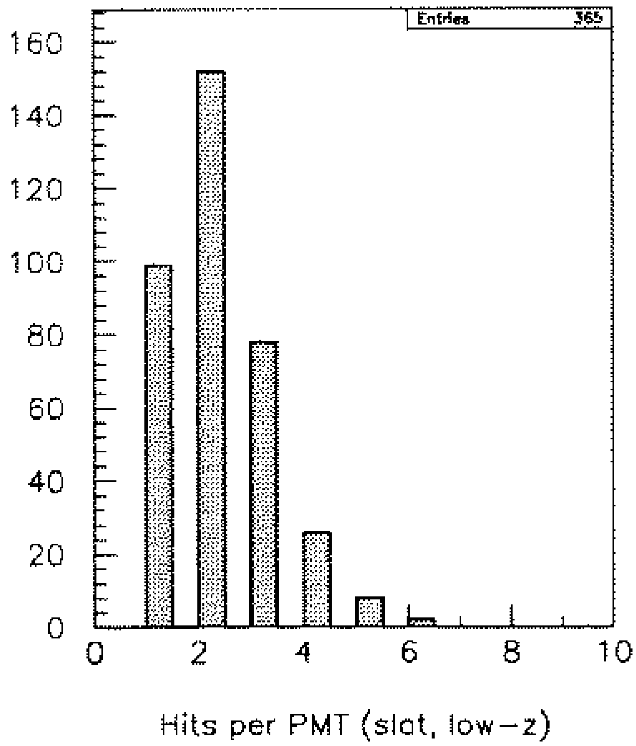


Fig. 4b.

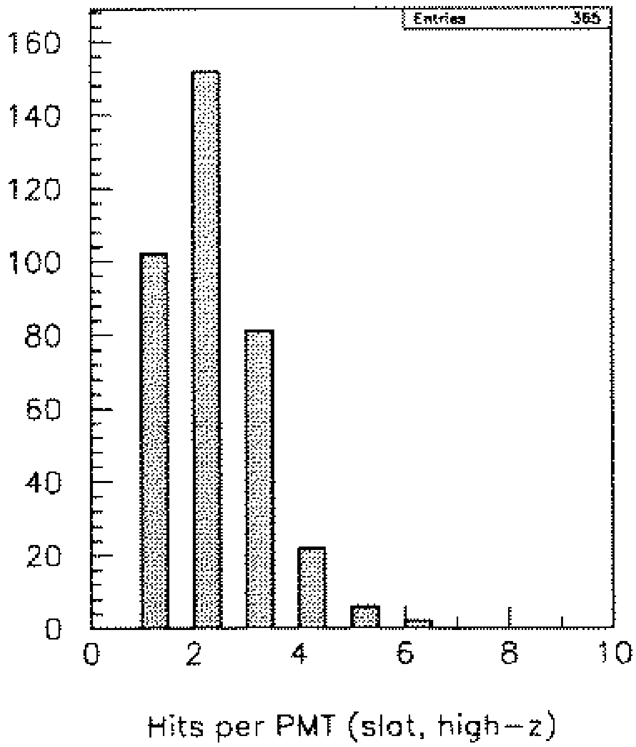


Fig. 4c

Figure 4:

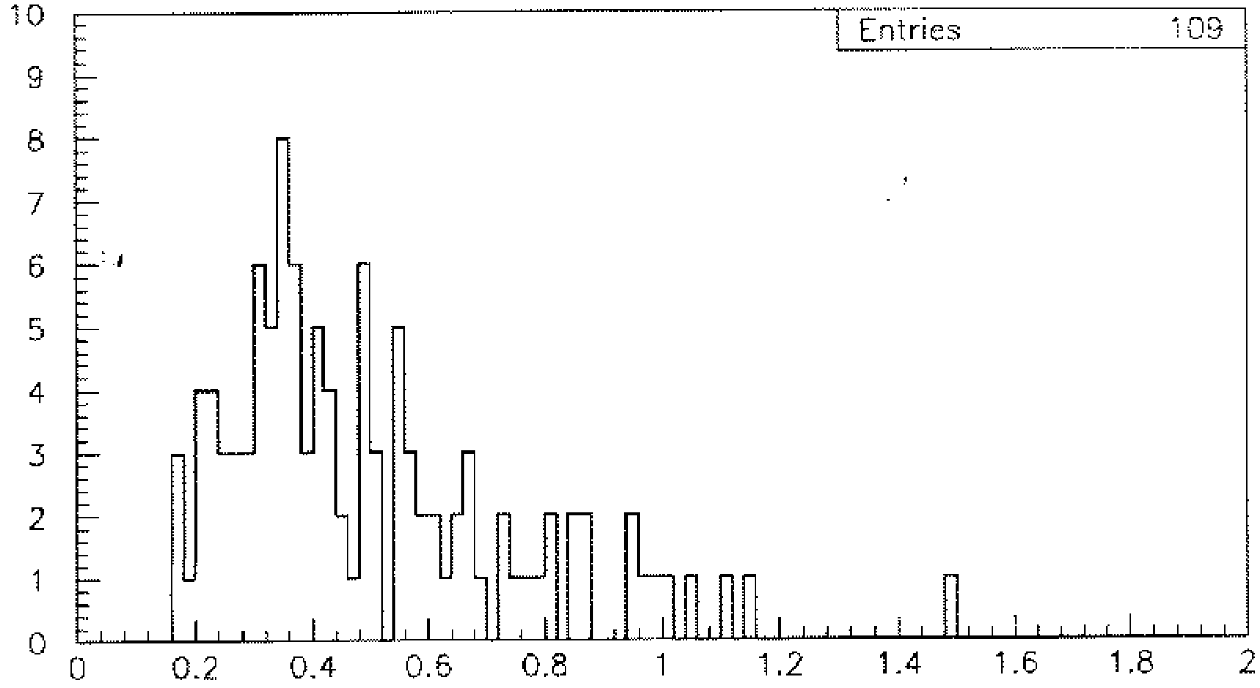


Fig. 5a Pt−distribution (primary pions, shingles, all)

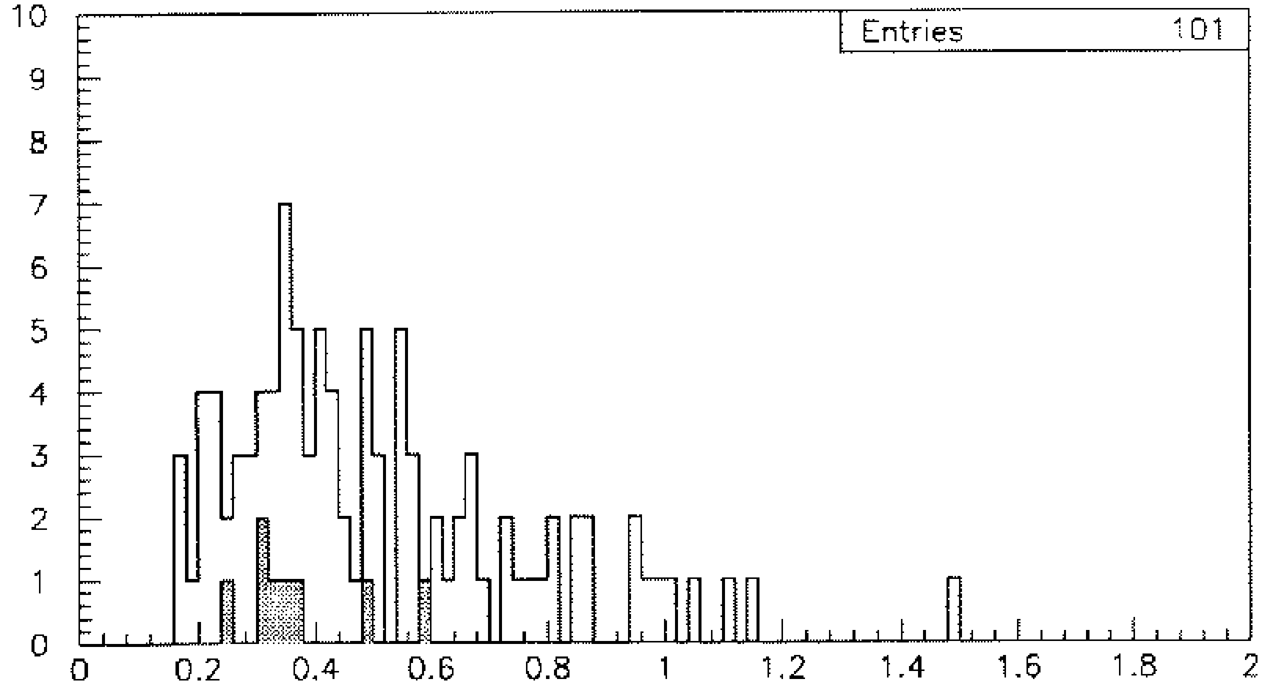


Fig. 5b Pt−distribution (primary pions, shingles, cid)

Figure 5: Scintillation Fibers Stacked

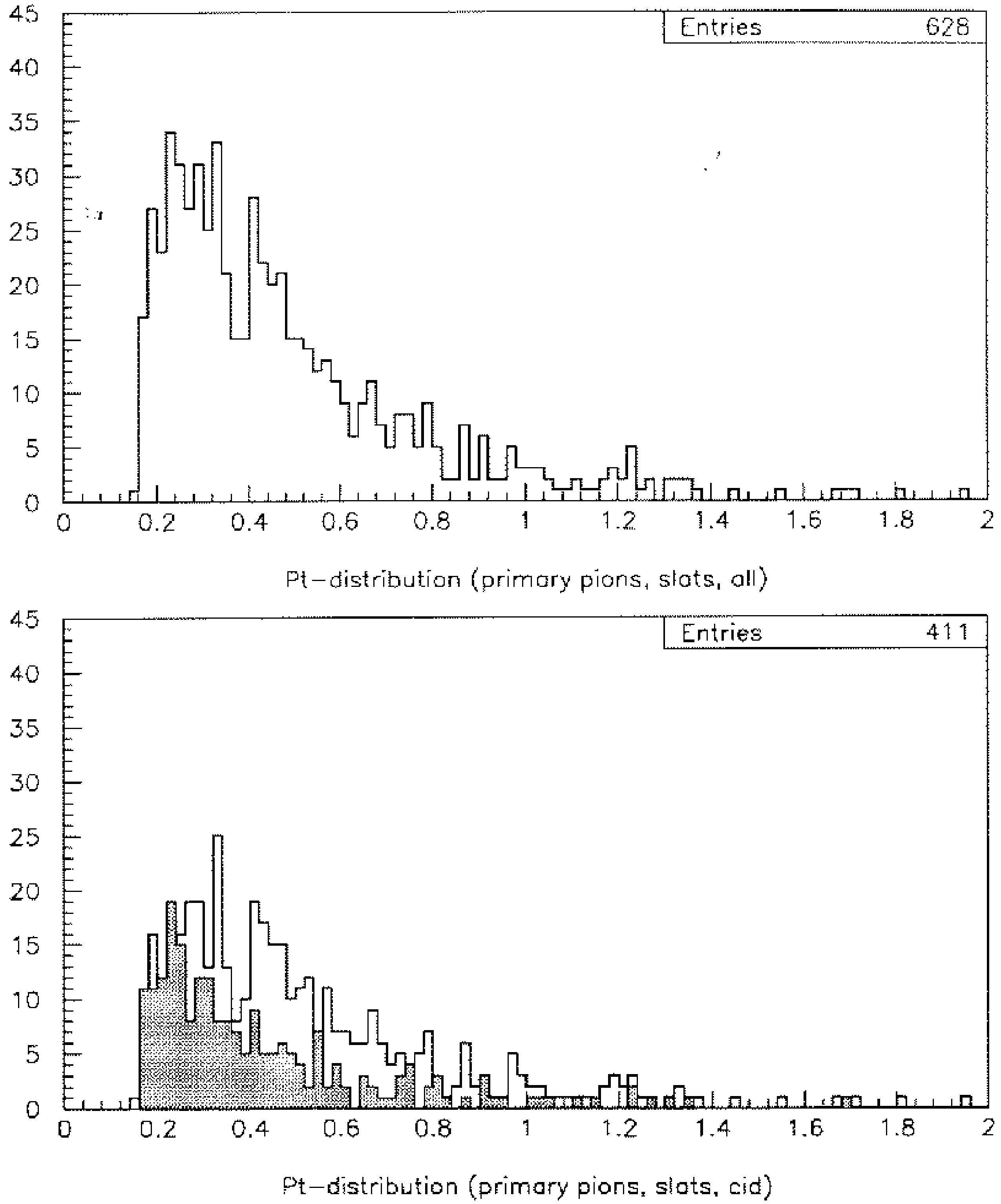
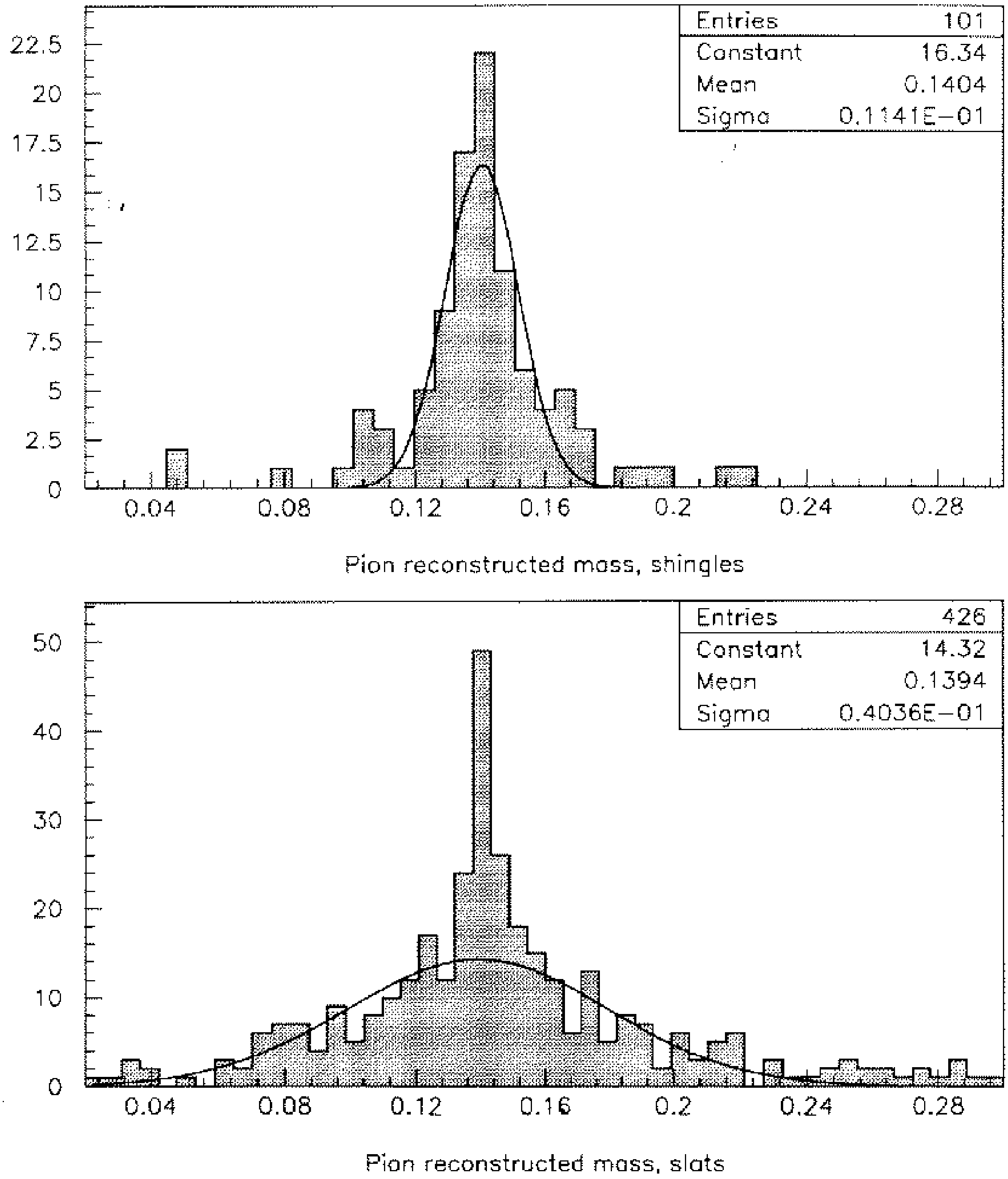

Entries 628
Pt−distribution (primary pions, slats, all)
Entries 411
Pt−distribution (primary pions, slats, cid)

Figure 6:



Entries 101
Constant 16.34
Mean 0.1404
Sigma 0.1141E−01
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
Pion reconstructed mass, shingles
Entries 426
Constant 14.32
Mean 0.1394
Sigma 0.4036E−01
50
40
30
20
10
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
Pion reconstructed mass, slats

Figure 7:

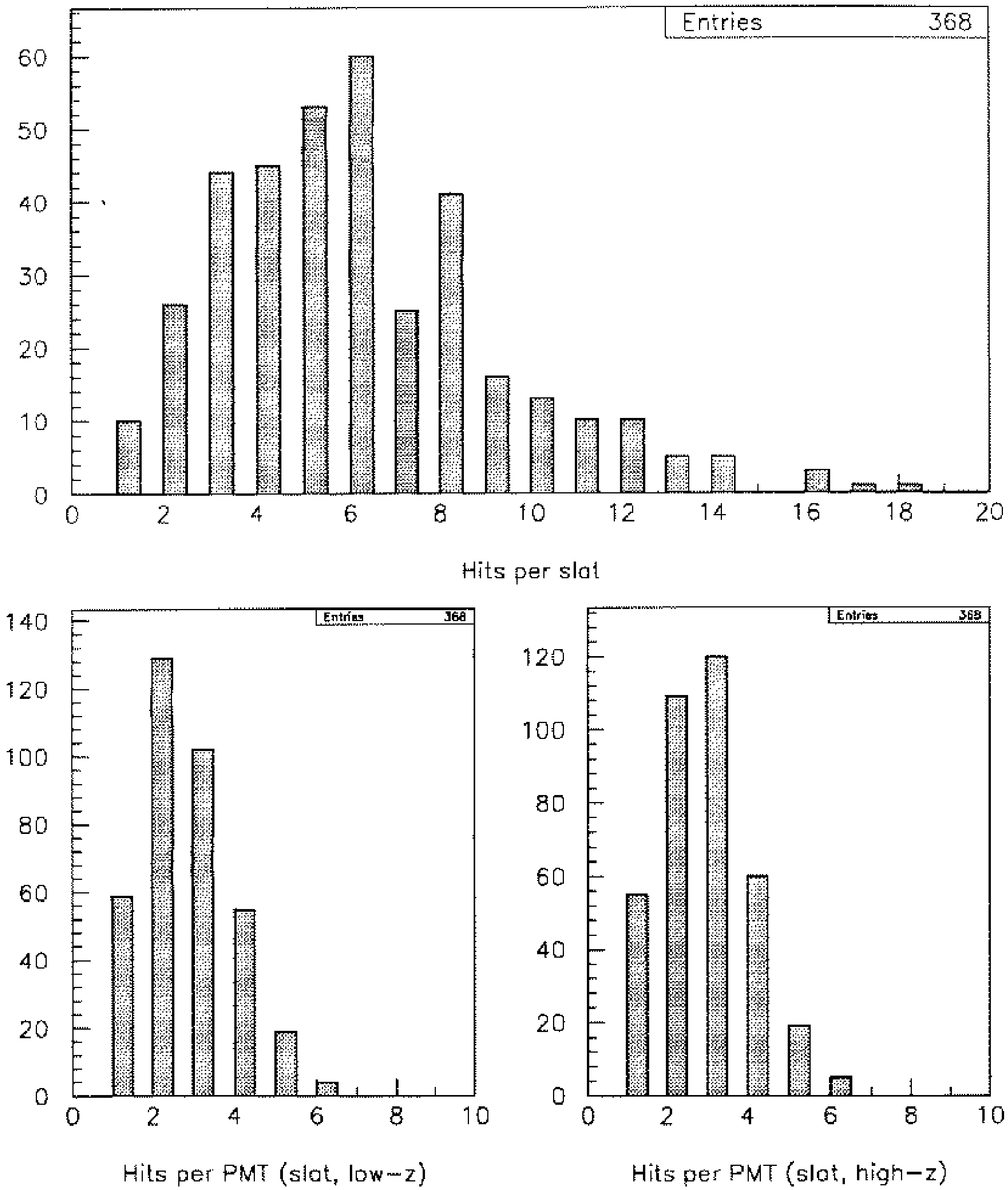

Entries 368
Hits per slot
Entries 368
Hits per PMT (slot, low−z)
Entries 368
Hits per PMT (slot, high−z)

Figure 8:

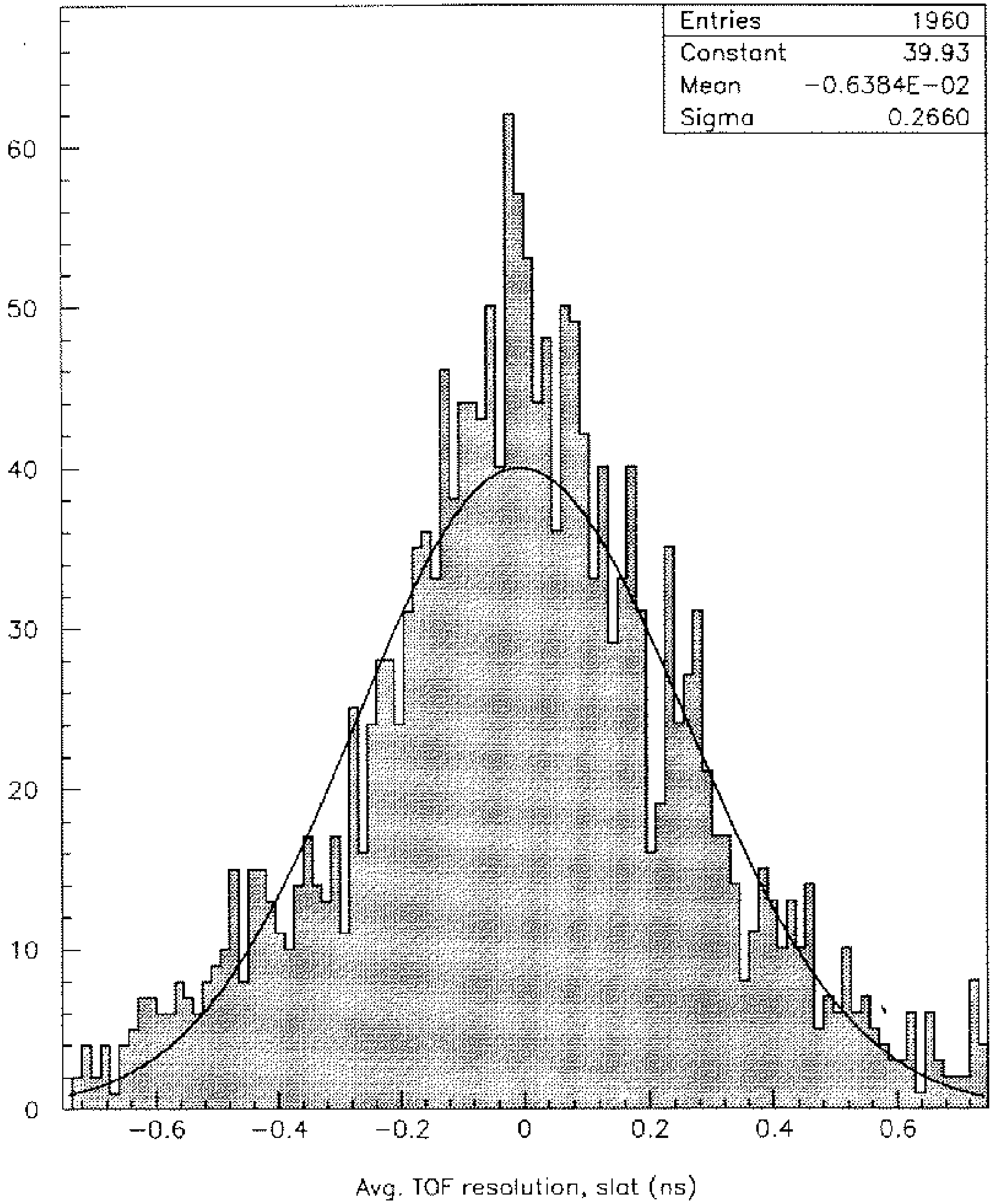
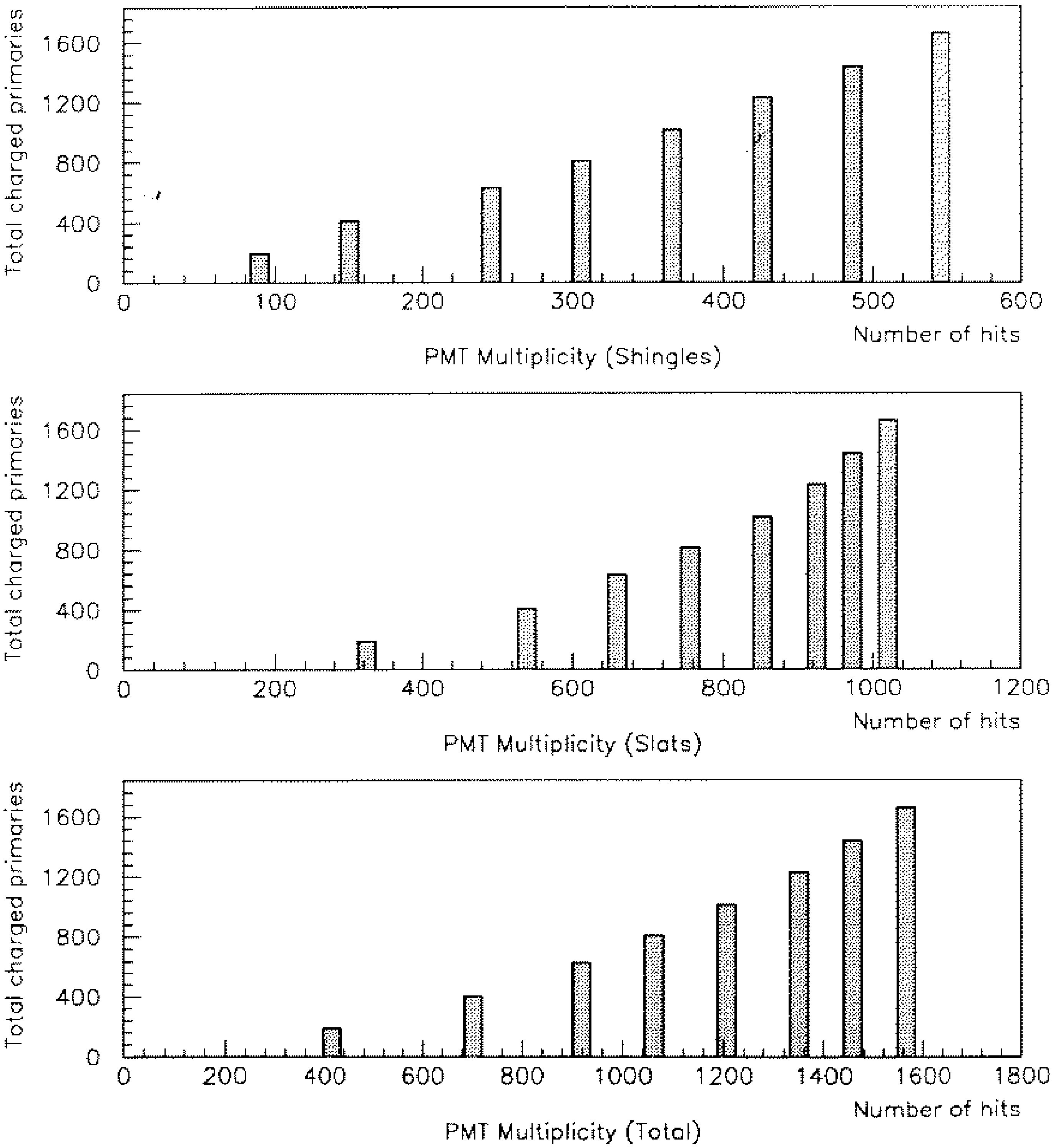

Entries 1960
Constant 39.93
Mean −0.6384E−02
Sigma 0.2660
60
50
40
30
20
10
0
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
Avg. TOF resolution, slat (ns)

Figure 9:



Total charged primaries
1600
1200
800
400
0
0
100
200
300
400
500
600
Number of hits
PMT Multiplicity (Shingles)
Total charged primaries
1600
1200
800
400
0
0
200
400
600
800
1000
1200
Number of hits
PMT Multiplicity (Slats)
Total charged primaries
1600
1200
800
400
0
0
200
400
600
800
1000
1200
1400
1600
1800
Number of hits
PMT Multiplicity (Total)

Figure 10: