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SEARCH FOR SPIN-DEPENDENT EFFECTS IN c-QUARK FRAGMENTATION

S. Abachi, C. Akerlof, P. Baringer, D. Blockus, B. Brabson, J-M. Brom, B. G. Bylsma, J. Chapman, B. Cork, R. DeBonte, M. Derrick, D. Errede, K. K. Gan,[a] C. Jung, P. Kesten,[b] D. Koltick, P. Kooijman, F. J. Loeffler J. S. Loos,[c] E. H. Low, R. L. McIlwain, D. I. Meyer, D. H. Miller,[d] B. Musgrave, C. R. Ng, D. Nitz, H. Ogren, L. E. Price, L. K. Rangan, J. Repond, D. R. Rust, A. Seidl,[d] E. I. Shibata, K. Sugano, R. Thun, J. M. Weiss,[e] M. Willutzky, and D. E. Wood[d]

Argonne National Laboratory, Argonne, Illinois 60439,
Indiana University, Bloomington, Indiana 47405,
Lawrence Berkeley Laboratory, Berkeley, California 94720,
University of Michigan, Ann Arbor, Michigan 48109,
Purdue University, West Lafayette, Indiana 47907

HRS COLLABORATION

Abstract

Events of the reaction $e^+e^- \to c\bar{c}$ at 29 GeV were isolated by observing D^* mesons through $D^{*+} \to D^0\pi^+$ decay. The D^0 decay modes used are $D^0 \to K\pi$, $K3\pi$, and $K\pi(\pi^0)$. The data, which correspond to an integrated luminosity of 300 pb^{-1}, were collected by the High Resolution Spectrometer at PEP. All angular distributions examined are consistent with being isotropic; there is no evidence for D^* alignment in the e^+e^- reaction.

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MASTER

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The fragmentation of heavy flavor quarks into hadrons has been studied, both theoretically[1] and experimentally; in particular considerable data are now available in e^+e^- interactions.[2] The experimental results verify the predictions of a hard fragmentation function for heavy flavor mesons, which is understood as being essentially a kinematical result of the high mass of the c and b quarks. In order to probe dynamical details such as the spin dependence of the fragmentation, it is necessary to compare vector/pseudoscalar ratios[3] with model predictions. Of particular interest is the possibility that the spin 1 D^* meson might be produced aligned, which would show up in the $D^* \to D^0\pi$ decay; such an effect could have a strong dependence on the energy sharing variable Z, where $Z = 2E_{D^*}/\sqrt{s}$. [4]

The High Resolution Spectrometer (HRS) at PEP has already been used to measure the electroweak production asymmetry of the c quark in $e^+e^- \to c\bar{c}$ at $\sqrt{s} = 29$ GeV by analyzing the D^{*+} charm mesons and their charge conjugates.[5] Here we use a data sample from an integrated luminosity of 300 pb^{-1} collected over a five-year running period of the HRS at PEP to study the $D^* \to D\pi$ decay angular distribution. The storage ring was operated at $\sqrt{s} = 29$ GeV.

The HRS is a general-purpose detector using a 1.62 T solenoidal magnetic field to give a momentum resolution for tracks at large angles of $\sigma_p/p \cong 2 \times 10^{-3}$ p (p in GeV/c).[6]

To select a clean sample of the annihilation multihadron events, the following requirements were imposed:

a. total visible energy for the event must exceed 13 GeV,

b. accepted tracks were required to have at least seven of the 17 possible drift chamber layers firing, and to have polar angle in the range 25° to 155°,

c. the magnitude of the charge imbalance for the event must be less than four.

Charged D^* production was studied for the decay mode

$$D^{*+} \rightarrow D^o\pi^+ \tag{1}$$

with the D^o decaying through $K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$ and $K^-\pi^+\pi^o$ modes, including also the charge conjugate states. In reconstructing the $D^{*+} \rightarrow D^o\pi^+$, no particle identification was used and each track satisfying the above cuts was tried as both a kaon and a pion. The excellent mass resolution of the HRS and the fact that the $D^{*+} \rightarrow D^o\pi^+$ reaction has a Q value of only 5.8 MeV means that clear signals with small backgrounds can be observed.

For the decay $D^o \rightarrow K^-\pi^+$, all $K^-\pi^+$ combinations were used and the quantity $\delta = (M_{K^-\pi^+\pi^+} - M_{K^-\pi^+})$ was constructed for those $K^-\pi^+$ combinations with $1.8 < M_{K^-\pi^+} < 1.93$ GeV, the mass range of the D^o meson. An additional requirement that the $K^-\pi^+$ pair satisfy the known D^o mass constraint with $\chi^2 < 4.0$ reduced the background under the D^{*+} but yet introduced a negligible loss of signal. The same technique was used also for the $K^-\pi^-\pi^+\pi^+$ decay of the D^o. For the $K^-\pi^+\pi^o$ decay mode, no attempt was made to reconstruct the π^o but the well-known kinematic enhancement around 1.6 GeV, the so-called S^o peak, formed by the $K^-\pi^+$ from the D^o was used. This region corresponds to the D^o decays where the D^o has a velocity close to that of the $K^-\pi^+$ system, so that the resolution in the energy sharing variable, Z, is still good. Background was further reduced by requiring $|\cos\theta_K^*| < 0.8$, where θ_K^* is the decay angle of the $K\pi$ system in its helicity frame.

At high Z the D^* meson is the leading particle in c quark fragmentation, and can be used to tag the primary c quark.[5] A lower Z, the D^* may also come from a c quark originating from b quark fragmentation. The Lund Monte Carlo simulation indicates that this feed-down becomes important for $Z < 0.4$.

A full detector simulation using Monte Carlo events indicates that the acceptance is essentially constant over the full $\cos\theta_D^*$ range (θ_D^* is the angle of the D^o in the D^* frame with respect to the D^* direction in the laboratory) for all the channels considered here, so that only small corrections are required to the helicity angle distribution in the $D^* \rightarrow D\pi$ decay.

The distribution in helicity angle for $D^{*+} \rightarrow D^{o}\pi^{+}$ using the $D^{o} \rightarrow K\pi$ decay mode is shown in Fig. 1, Fig. 2, and Fig. 3 for the Z ranges $0.2 < Z < 0.4$, $0.4 < Z < 0.6$, and $Z > 0.6$. The events selected are contained in the band $\delta = 145.5 \pm 2.5$ MeV of the mass difference distribution also shown in each figure. After verifying that the data were consistent with forward-backward symmetry, each angular distribution was folded about $\cos\theta_D^* = 0.0$. The curves shown were obtained by fitting to the function $1.0 + \alpha \cos^2\theta_D^*$. The values of α obtained are given in Table 1, together with the χ^2-per-degree of freedom for an isotropic distribution; there is no statistically significant departure from isotropy in any of these distributions.

For the $D^{o} \rightarrow K3\pi$ decay mode, it is only possible to use the high Z ranges: $0.4 < Z < 0.6$ and $Z > 0.6$. These data are shown in Fig. 4 and Fig. 5 and the α values are listed in Table 1. Again, the angular distributions are consistent with isotropy. This is also the case for the $D^{o} \rightarrow K\pi(\pi^{o})$ decay mode, where again it is only possible to use the Z ranges $0.4 < Z < 0.6$ and $Z > 0.6$. For this decay, the events selected are in the mass difference region 145.5 ± 5.0 MeV. The data are shown in Fig. 6 and Fig. 7, again the angular distributions are consistent with isotropy.

For the higher Z ranges, we have also combined the data. In Fig. 8(a,b) the $D^{o} \rightarrow K\pi$ and $D^{o} \rightarrow K3\pi$ samples are combined and in Fig. 9(a,b), all D^{o} decay modes are combined.

None of the angular distributions considered show evidence for alignment of the D^{*} meson. This result may be compared to the predictions of a simple model of heavy flavored quark fragmentation in which a light quark pair is created by a single gluon, leading to formation of a heavy flavored meson.[4] For the c-quark, this model predicts strong dependence of α on Z, with pronounced alignment in some Z regions. In contrast, statistical models of fragmentation would predict $\alpha = 0$.

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(a) Present address: Stanford Linear Accelerator Center, Stanford, CA 94305.

(b) Present address: Brandeis University, Waltham, MA 02254.

(c) Present address: Bell Laboratories, Naperville, IL 60566.

(d) Present address: Lockheed Missiles and Space Co., Sunnyvale, CA 94086.

(e) Present address: SRI International, Menlo Park, CA 94025.

REFERENCES

1. M. Suzuki, Phys. Lett. 71B, 139 (1977); J. D. Bjorken, Phys. Rev. D17, 171 (1978).

2. P. Avery et al., Phys. Rev. Lett. 51, 1139 (1983); M. Althoff et al., Phys. Lett. 126B, 493 (1983); S. Ahlen et al., Phys. Rev. Lett. 51, 1147 (1983); D. Bender et al., Phys. Rev. D30, 515 (1984); M. Derrick et al., Phys. Rev. 53, 1971 (1984) and Phys. Lett. 146B, 261 (1984); H. Yamamoto et al., Phys. Rev. Lett. 54, 522 (1985); S. L. Wu, Phys. Rep. 107, 59 (1984).

3. M. Derrick et al., Phys. Lett. 158B, 519 (1985).

4. "Spin Property of Heavy Hadron in Heavy Quark Fragmentation," M. Suzuki, LBL-19801 (June 1985).

5. M. Derrick et al., Phys. Lett. 146B, 261 (1984).

6. D. Bender et al., Phys. Rev. D30, 515 (1984).

Table 1

Channel	Z-Range	Value of α	χ^2/NDF for Istropic Distribution
$D^o \to K\pi$	$0.2 < Z < 0.4$	-0.14 ± 0.36	5.7/9
$D^o \to K\pi$	$0.4 < Z < 0.6$	0.16 ± 0.30	7.3/9
$D^o \to K\pi$	$0.6 < Z < 1.0$	0.89 ± 0.48	11.5/9
$D^o \to K3\pi$	$0.4 < Z < 0.6$	-0.30 ± 0.19	8.9/9
$D^o \to K3\pi$	$0.6 < Z < 1.0$	0.18 ± 0.29	12.5/9
$D^o \to K\pi(\pi^o)$	$0.4 < Z < 0.6$	-0.00 ± 0.24	8/9
$D^o \to K\pi(\pi^o)$	$0.6 < Z < 1.0$	0.15 ± 0.43	11.2/9
$D^o \to K\pi$, $K3\pi$	$0.4 < Z < 0.6$	-0.15 ± 0.16	6.5/9
$D^o \to K\pi$, $K3\pi$	$0.6 < Z < 1.0$	0.35 ± 0.24	13.2/9
$D^o \to$ All Modes	$0.4 < Z < 0.6$	0.12 ± 0.13	21.1/9
$D^o \to$ All Modes	$0.6 < Z < 1.0$	0.28 ± 0.21	4.2/9

FIGURE CAPTIONS

Fig. 1 The distribution in mass difference, $\delta = M(K^-\pi^+\pi^+) - M(K^-\pi^+)$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.0025 GeV, and $0.2 < Z < 0.4$.

Fig. 2 The distribution in mass difference, $\delta = M(K^-\pi^+\pi^+) - M(K^-\pi^+)$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.0025 GeV, and $0.4 < Z < 0.6$.

Fig. 3 The distribution in mass difference, $\delta = M(K^-\pi^+\pi^+) - M(K^-\pi^+)$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.0025 GeV, and $Z < 0.6$.

Fig. 4 The distribution in mass difference, $\delta = M(K^-\pi^+\pi^+\pi^-\pi^+) - M(K^-\pi^+\pi^+\pi^+\pi^-)$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.0025 GeV and for $0.4 < Z < 0.6$.

Fig. 5 The distribution in mass difference, $\delta = M(K^-\pi^+\pi^+\pi^-\pi^+) - M(K^-\pi^+\pi^+\pi^-)$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.0025 GeV and for $0.4 < Z > 0.6$.

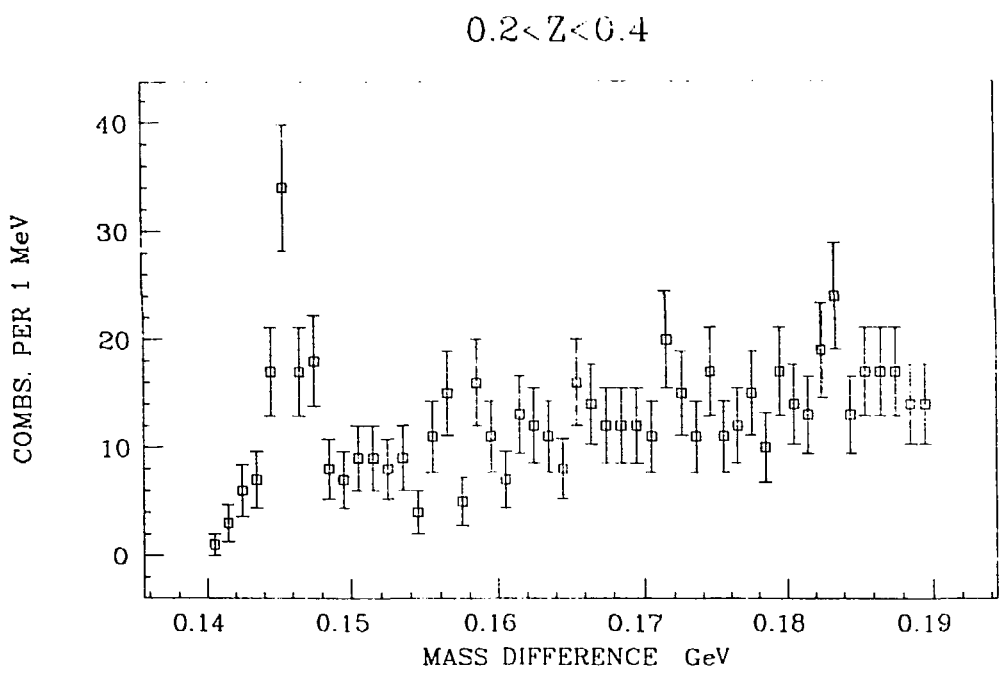
Fig. 6 The distribution in mass difference, $\delta = M(K^-\pi^+(\pi^o)\pi^+) - M(K^-\pi^+(\pi^o))$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.005 GeV and for $0.4 < Z < 0.6$.

Fig. 7 The distribution in mass difference, $\delta = M(K^-\pi^+(\pi^o)\pi^+) - M(K^-\pi^+(\pi^o))$, and the $D^{*+} \to D^o\pi^+$ decay angular distribution for the mass difference region 0.1455 ± 0.005 GeV, and $0.2 < Z > 0.6$.

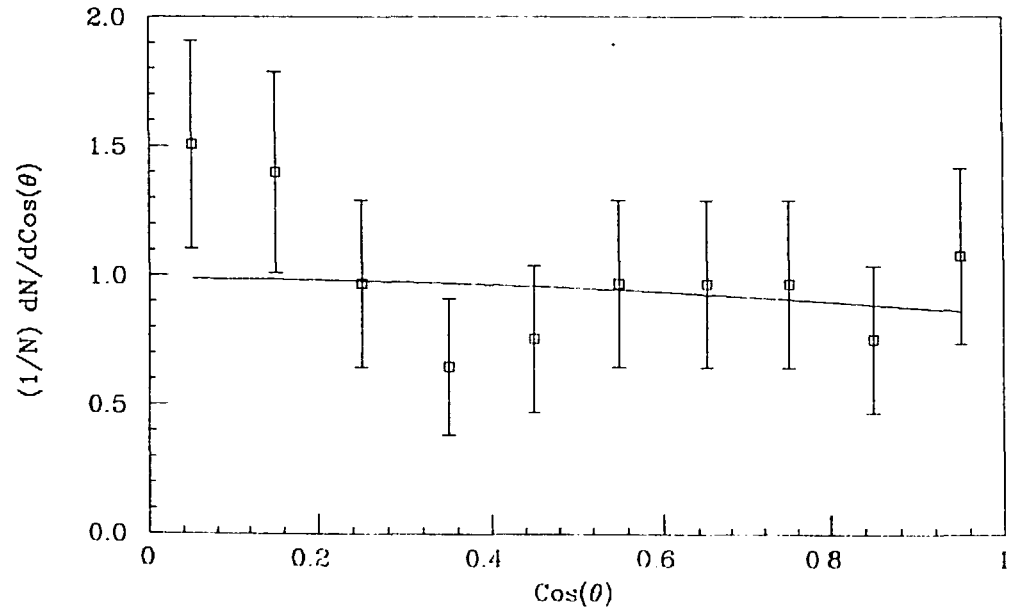
Fig. 8 The $D^{*+} \to D^o\pi^+$ decay angular distribution for the $D^o \to K\pi$, $K3\pi$ decay modes combined and (a) $0.4 < Z < 0.6$; (b) $Z > 0.6$.

Fig. 9 The $D^* \to D^o\pi^+$ decay angular distribution for all D^o decay modes, (a) for $0.4 < Z < 0.6$, and (b) for $Z > 0.6$.

Fig. 1

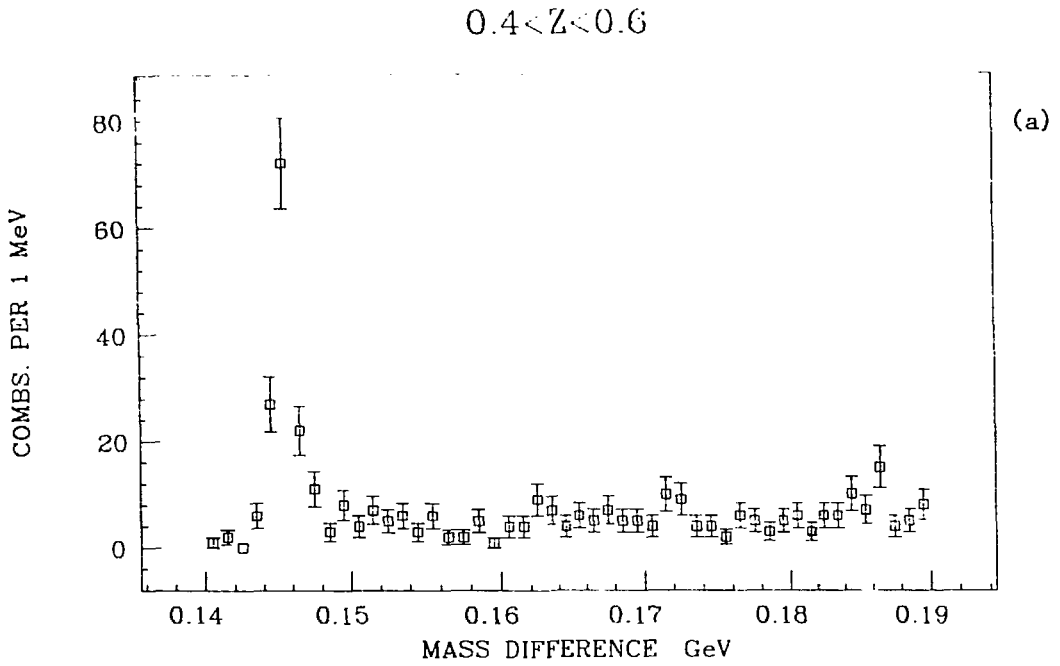

0.2<Z<0.4
COMBS. PER 1 MeV
40
30
20
10
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GeV

(a)


(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

(b)

Fig. 2


0.4<Z<0.6
(a)
COMBS. PER 1 MeV
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60
40
20
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GeV

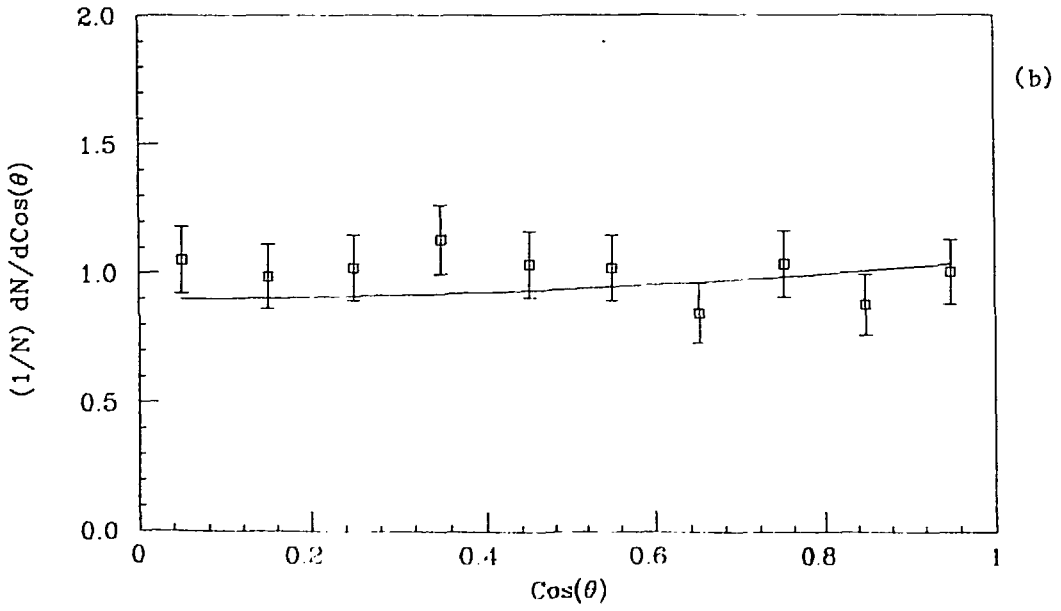
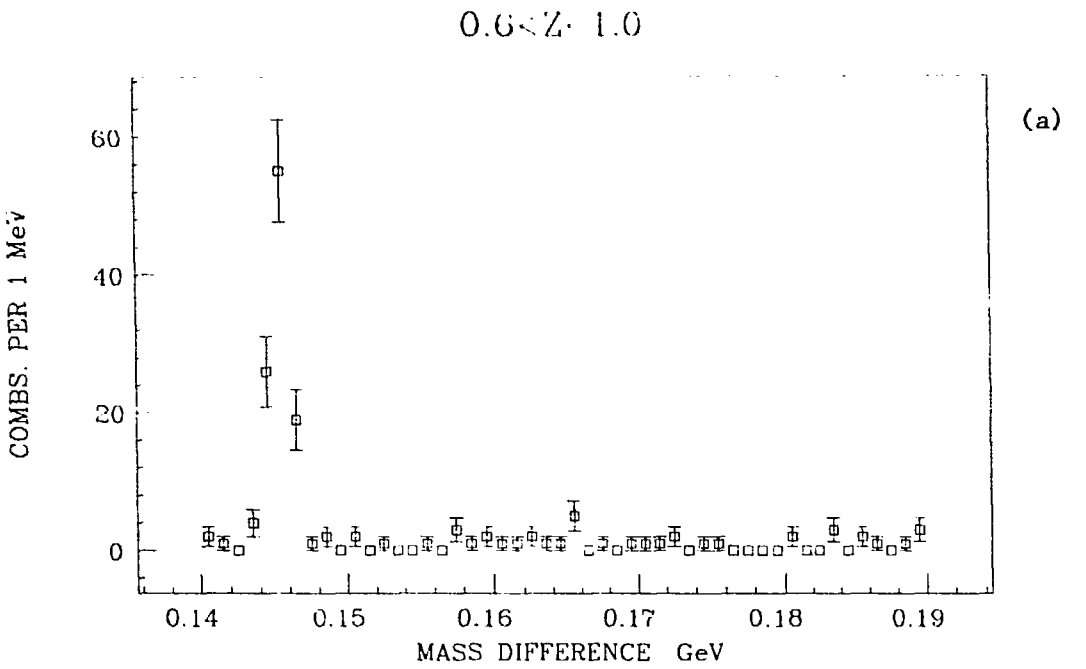
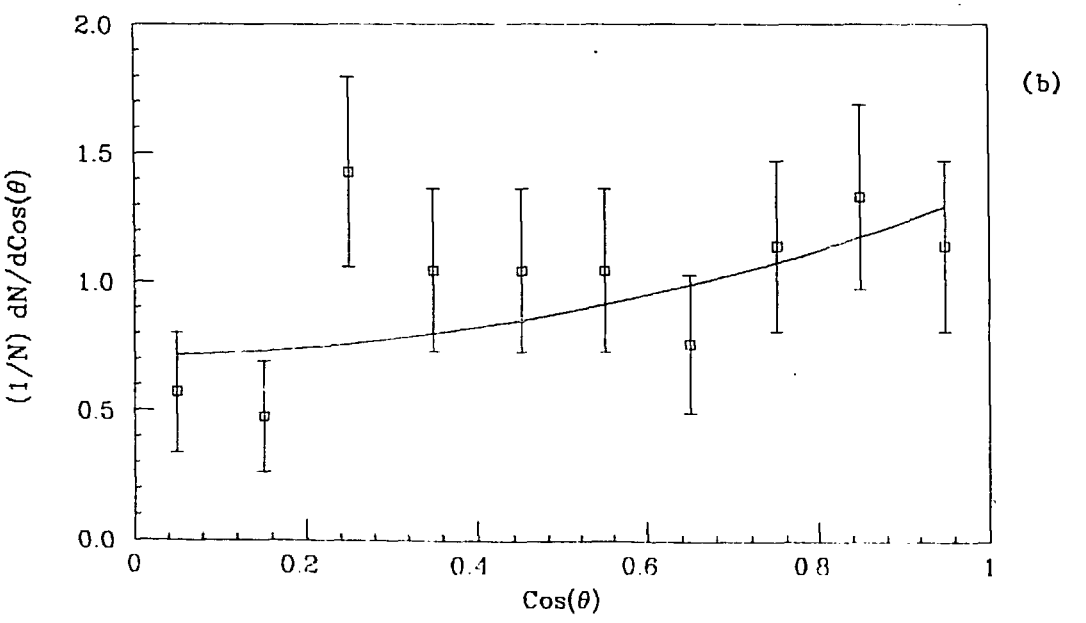

(b)
(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

Fig. 3


0.6<Z< 1.0
(a)
COMBS. PER 1 MeV
60
40
20
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GeV


(b)
(1/N) dN/dCos(θ)
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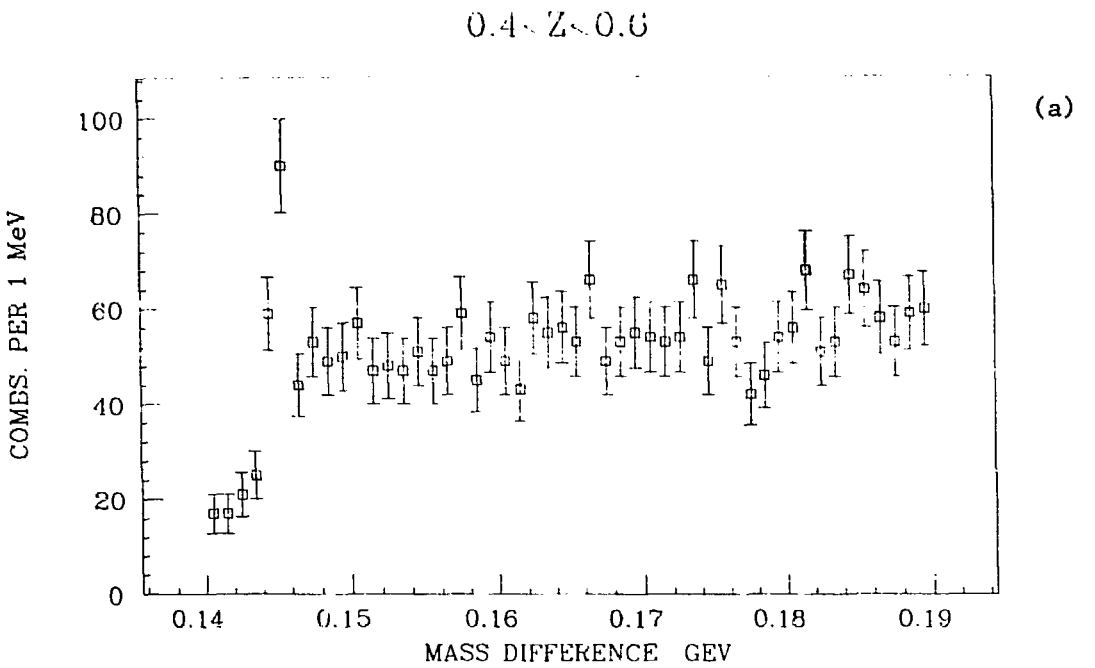
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

Fig. 4


0.4<Z<0.6
(a)
COMBS. PER 1 MeV
100
80
60
40
20
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GEV

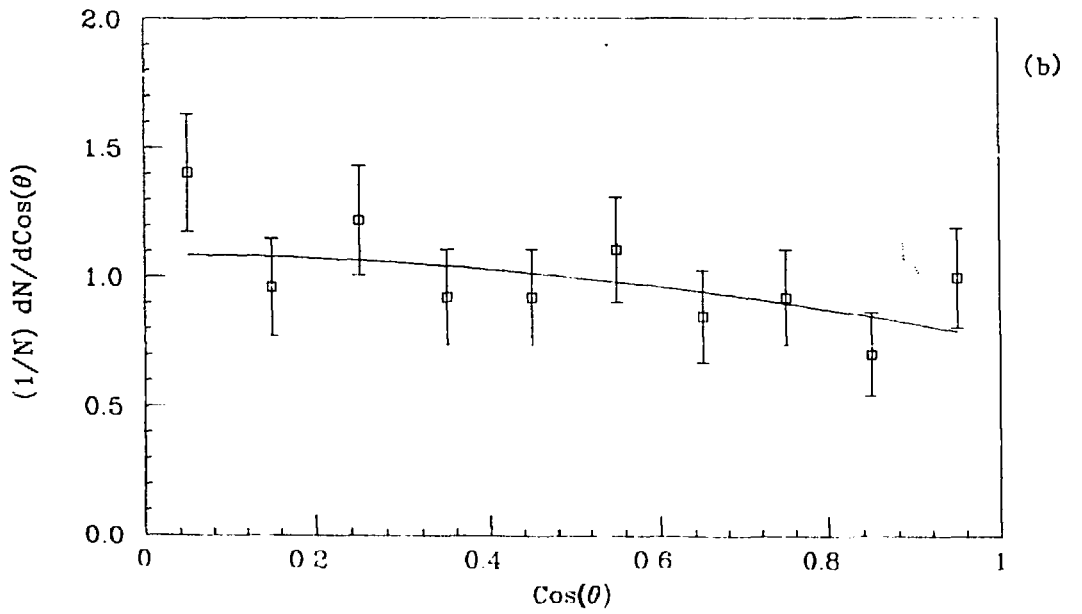
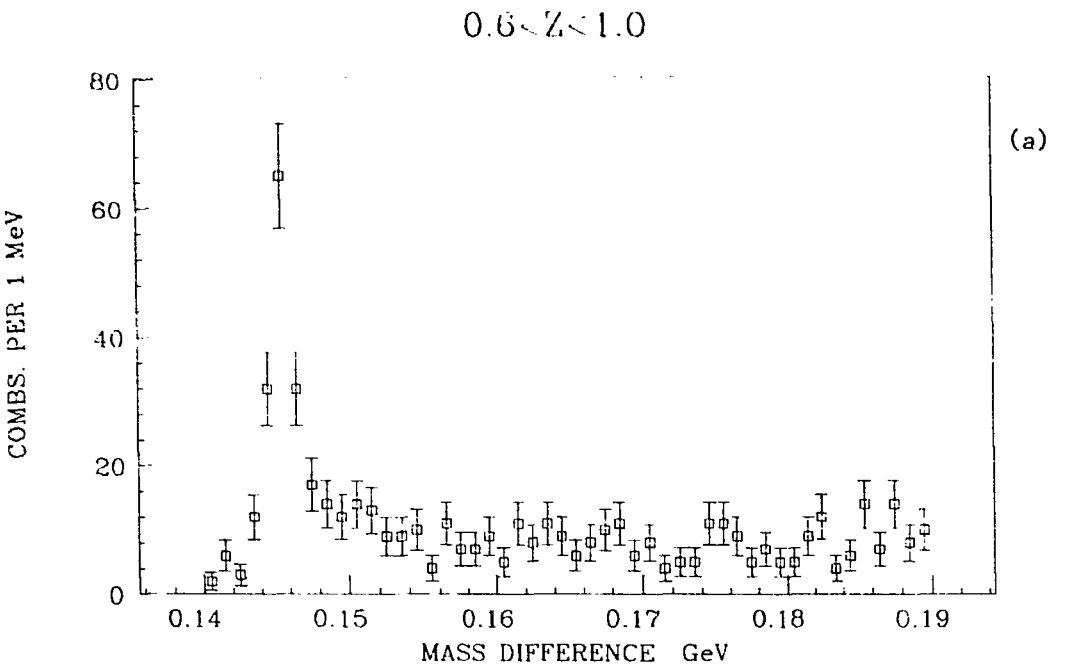
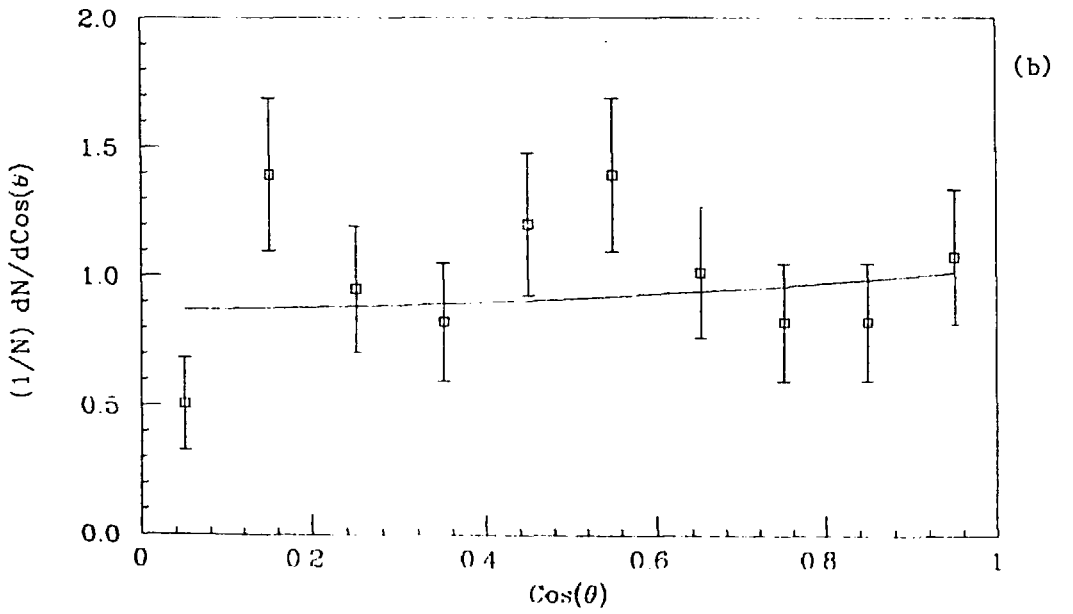

(b)
(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

Fig. 5


0.6<Z<1.0
(a)
COMBS. PER 1 MeV
80
60
40
20
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GeV


(b)
(1/N) dN/dCos(θ)
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1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

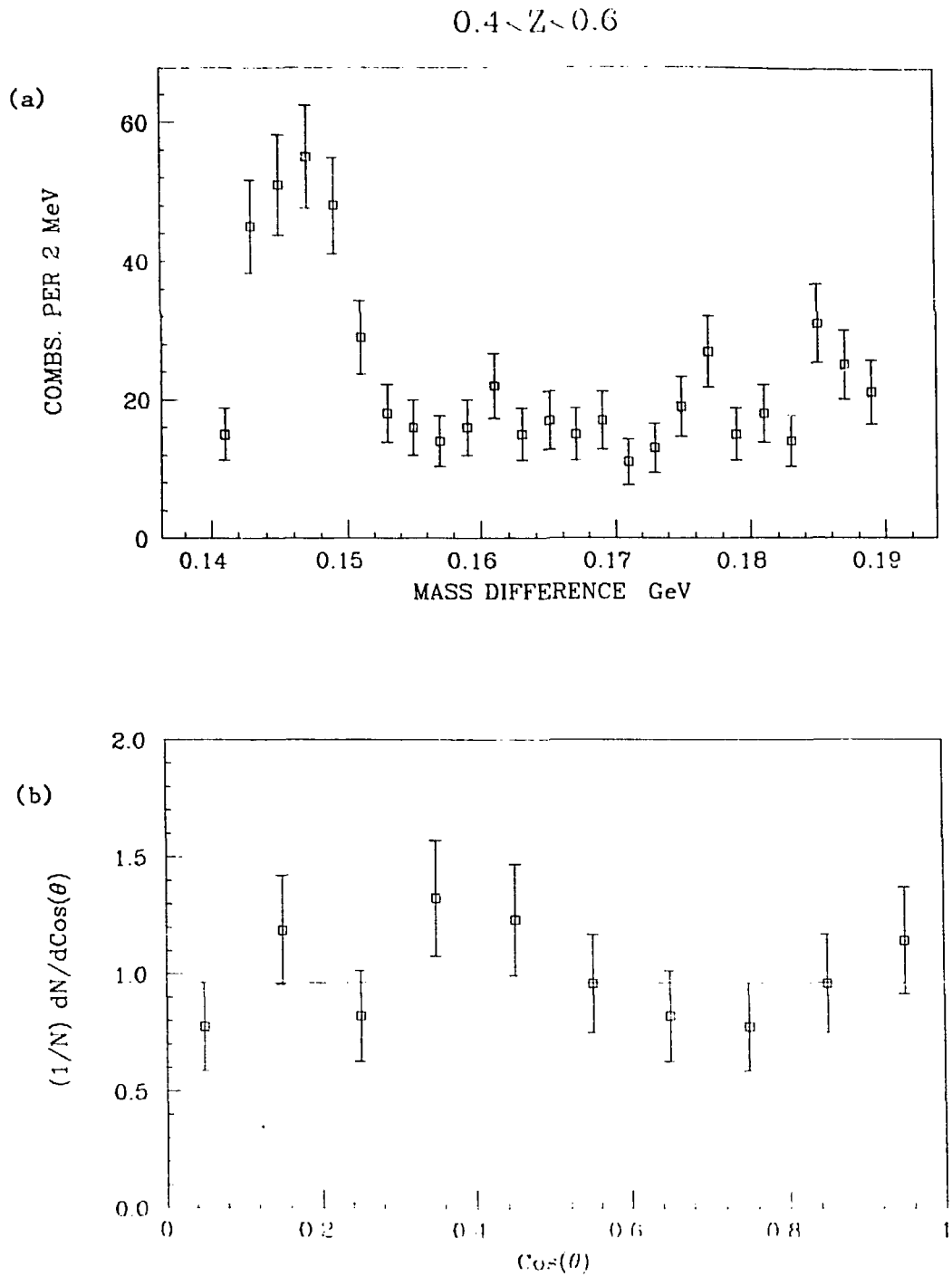
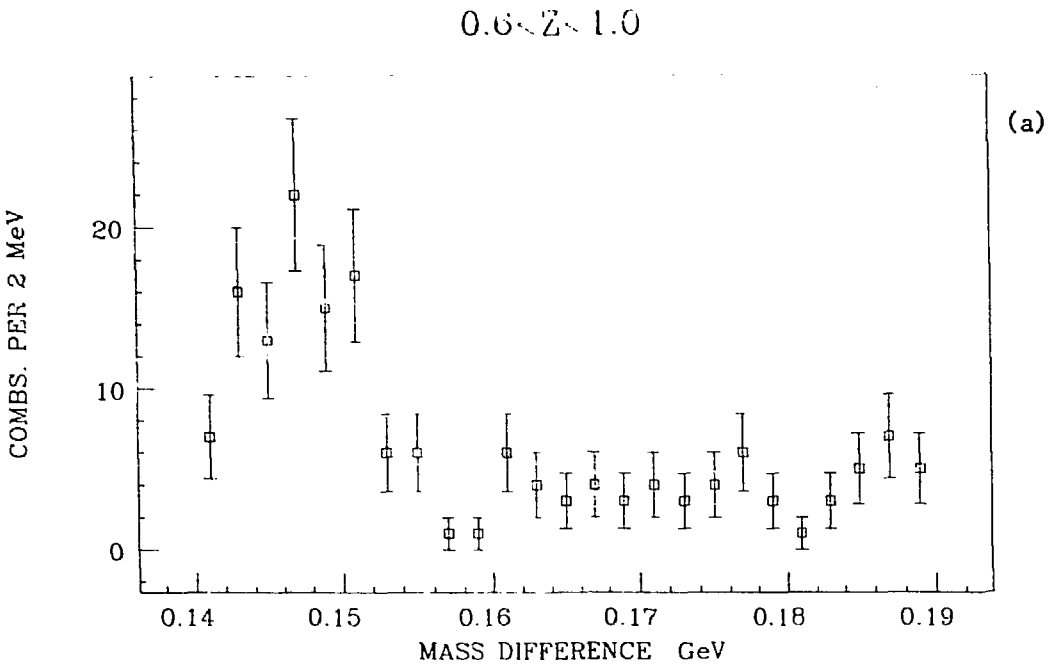
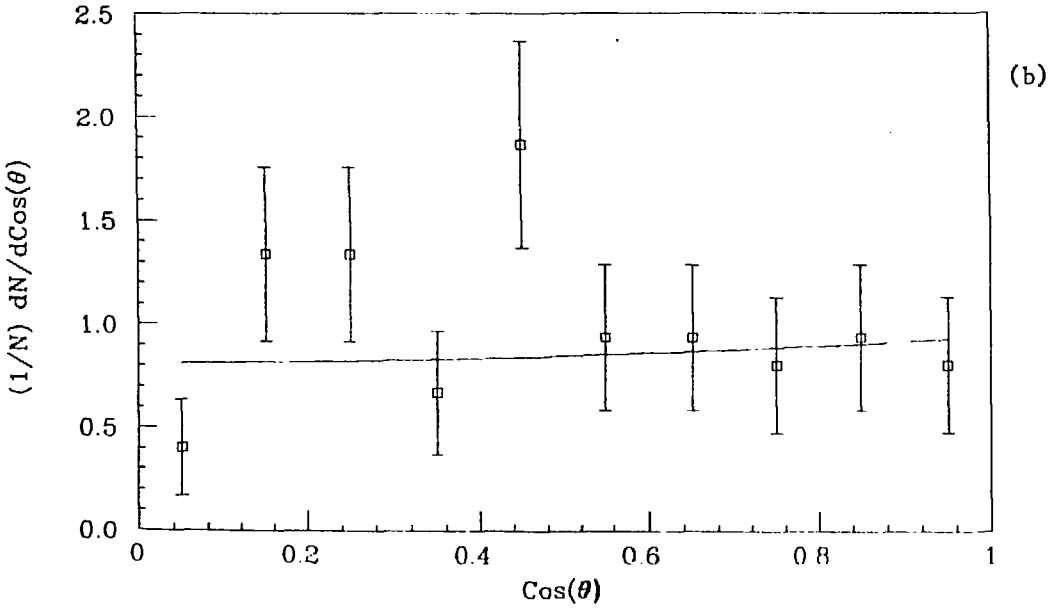

0.4<Z<0.6
(a)
COMBS. PER 2 MeV
60
40
20
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GeV
(b)
(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

Fig. 6

Fig. 7


0.6<Z<1.0
(a)
COMBS. PER 2 MeV
20
10
0
0.14
0.15
0.16
0.17
0.18
0.19
MASS DIFFERENCE GeV


(b)
(1/N) dN/dCos(θ)
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2.0
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1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

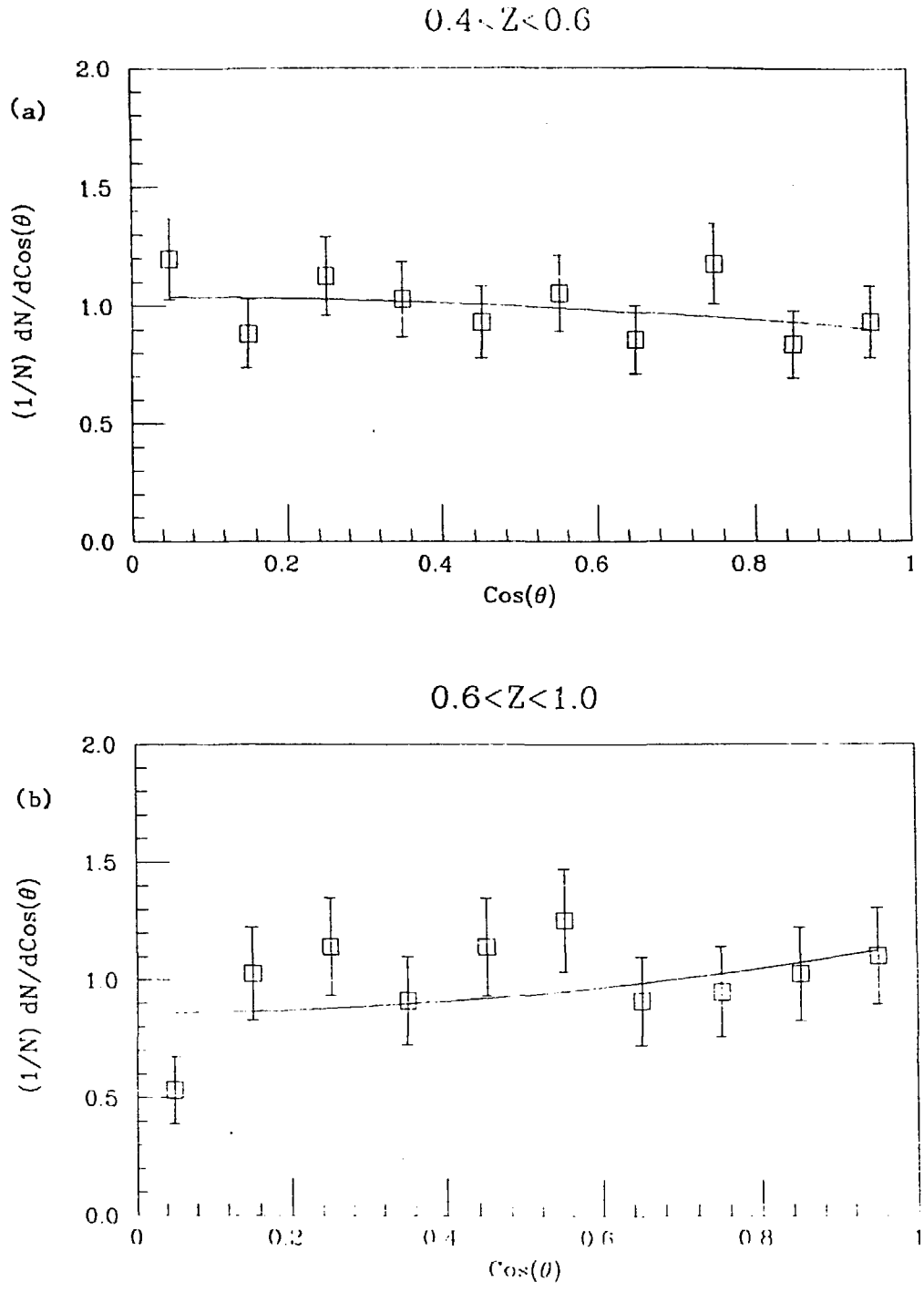
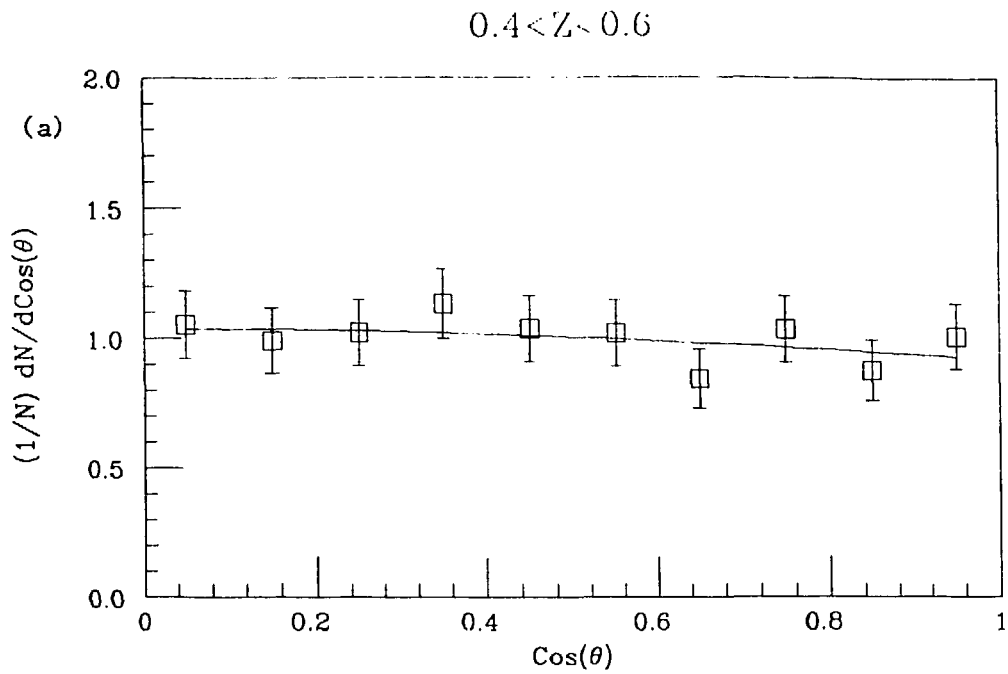

0.4<Z<0.6
(a)
(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)
0.6<Z<1.0
(b)
(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

Fig. 8


0.4<Z<0.6
(a)
(1/N) dN/dCos(θ)
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1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

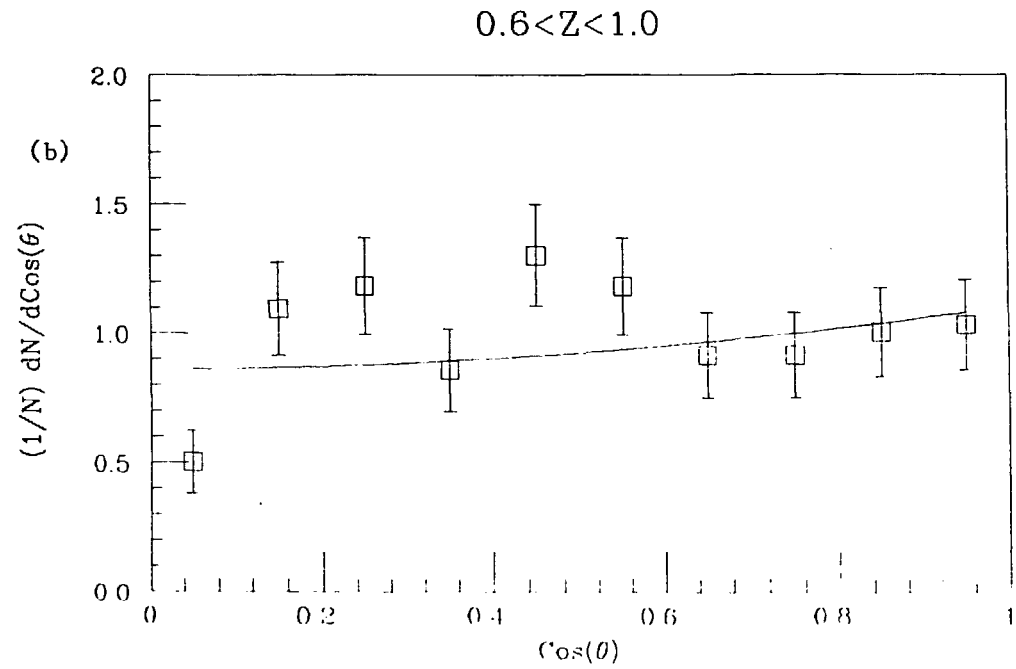
0.6<Z<1.0
(b)
(1/N) dN/dCos(θ)
2.0
1.5
1.0
0.5
0.0
0
0.2
0.4
0.6
0.8
1
Cos(θ)

Fig. 9