EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/79-57
15 June 1979

MEASUREMENT OF π^0 FRAGMENTS FROM JETS PRODUCED IN pp COLLISIONS AT THE CERN ISR

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ABSTRACT

The jet fragmentation function into π^0, f(z) has been measured using the away side high p_t π^0 or η mesons as a measure of the jet momentum. The fragmentation function is found to have an excess of events near $z \simeq 1$ compared with the exponential fall-off observed at lower z values. The data behaves like $1/z^3$ up to $z \simeq 1$, but deviates sharply from it for $z \geq 1$. Possible explanations of this effect are the single particle fragmentation mode of the quark or gluon jet, or quark fusion.

(Submitted to Physics Letters)

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6) Work supported by the US National Science Foundation.

The correlation between two high p_t particles can be analysed using different variables. In this letter we report on new measurements of the fragmentation variable $z = p_2/p_1 \cos\phi$, where p_1 is either a very high transverse momentum (p_t) π^0 or η meson and p_2 is a π^0. The hard scattering of the proton constituents produces high p_t jets [1-5], which usually fragment into several particles. The selection of single high p_t particles introduces a "trigger bias" [2] due to the rapidly falling p_t spectrum, which allows one to use the approximation that the direction and momentum of the high p_t meson are a measure of these quantities for the scattered constituents in the transverse plane. The variable z, while defined relative to the momentum of a single high p_t π^0 or η meson (p_1), is expected to provide a measure of the fragmentation into π^0's of the second scattered constituent.

The apparatus used (Fig. 1) in this experiment consisted of four identical liquid-argon calorimeters. Each calorimeter module covered a solid angle of approximately 1 sr, 50° to 130° in polar angle and 40° in azimuth. The energies and position of the electromagnetic showers were measured in the segmented lead - liquid-argon calorimeter. Discrimination between hadrons and electromagnetic showers was provided by measurement of shower development in the calorimeter. Energy resolution in the calorimeter was found to be $\sigma(E) = 10\%/\sqrt{E}$. A more detailed description of the apparatus is found elsewhere [6-12].

The trigger for this experiment was based on a large energy deposit in a single calorimeter module. The trigger efficiency rises from near zero at 4 GeV/c to a constant value of 95% for p_t above 6-7 GeV/c. The η production [10] was detected via $\eta \to 2\gamma$. The η acceptance increases as a function of p_t, because of both increasing trigger efficiency and geometrical acceptance. Note that in this experiment low-energy π^0's ($p_t \lesssim 3$ GeV) were resolved in the calorimeter and were detected as two separate electromagnetic showers. With increasing p_t the two showers overlap and the π^0 is reconstructed as a single shower. Thus one could not distinguish a single photon from π^0's in this analysis, and all showers were assumed to be π^0's.

The analysis is done in the plane transverse to the proton-proton interactions (Fig. 2). The data can be described by the variables p_1, p_2 and ϕ, the azimuthal difference between the two particles. The azimuthal acceptance of the apparatus being poor in the region where $\phi \leq 110°$, events in that region were not used. In this analysis the events were grouped in bins of fixed p_t of one of the particles (p_1). For the analysis of the η-π^0 correlation, p_1 pertains to an η meson. For π^0-π^0 studies the symmetry of the correlation between two identical particles is recognized by treating each pion both as p_1 and p_2 in turn. Thus events may appear twice in the plots.

In Fig. 3 we show the constituent fragmentation function f(z) into π^0. The constituent energy is estimated using the high p_t π^0 on the away side. A rapid fall-off in the distribution is observed for all p_1 bins. A more detailed investigation shows that for the region $0.8 \geq z \geq 0.2$ the fall-off is approximately exponential with a slope of $b \simeq 7$. An even steeper exponential fall-off is observed for events with lower z values ($z \leq 0.2$). This might be due to the fact that at lower momentum transfer, π^0's not directly related to the scattered constituent are included. A more interesting feature of the data is the excess of events with respect to the exponential fit observed near $z \simeq 1$. Note that the functional form $1/z^3$ (dotted line) describes the data well in the region up to $z \simeq 1$, but the data show a sharp deviation from this form beyond $z = 1$.

In Fig. 4 we show the constituent fragmentation function f(z) when the estimator of the constituent momentum is an η meson on the away side. The fragmentation function using the η-π^0 events shows the same features as were discussed in the π^0-π^0 events. While observation of a structure near $z \simeq 1$ for the η-π^0 case indicates that the effect is not due to γ-γ events, a γ-meson correlation is not ruled out.

The exponential fall-off of the fragmentation function has been observed earlier. It is worth while to note that the slope observed at FNAL [13] using lower p_t jets was 4.6 compared with our 7. This might be due to the fact that as the energy of the scattered constituent increases, the number of fragments also increases; thus $\langle z \rangle$ is decreased, resulting in a steeper slope. The deviation

from exponential fall-off or alternatively the charge in the $1/z^3$ behaviour at $z \geq 1$ could be the result of a number of effects, e.g. a large single particle fragmentation mode of the quark or gluon jets either in the meson-meson or γ-meson mode; a CIM [14] process favouring quark meson scattering or quark fusion. If we assume that the excess of events near $z \simeq 1$ is due to a single particle fragmentation mode its ratio to the total number of fragments is $R \simeq 2 \times 10^{-3}$. Assuming the average number of fragment in this $\hat{s}$ range ($\hat{s} \simeq 2p_1$) to be 5, the probability of a constituent to show up as a single particle is about 1%. A recent phenomenological analysis of high mass dihadron data from FNAL [15] concludes that R is smaller than our measured value and is consistent with being zero. That analysis is based primarily on the p_t dependence of the dihadron pairs rather than on direct measurements of the fragmentation function, and may be sensitive to other assumptions used in the analysis. An observation of this effect with pairs of mesons in different charge states may allow the identification of the mechanism involved. This effect can be an important tool for studying constituent scattering, as it implies that this region is dominated by two-body kinematics, and it would seem reasonable that the constituent characteristics such as quantum numbers would be more easily detected.

We would like to thank M. Jacob and R. Horgan for helpful discussion.

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Figure captions

Fig. 1 : The apparatus arrangement in the ISR.

Fig. 2 : The definitions of the variables p_1, p_2 and z.

Fig. 3 : The constituent fragmentation distribution into π^0 for π^0-π^0 events.

Fig. 4 : The constituent fragmentation distribution into π^0 for π^0-η events.

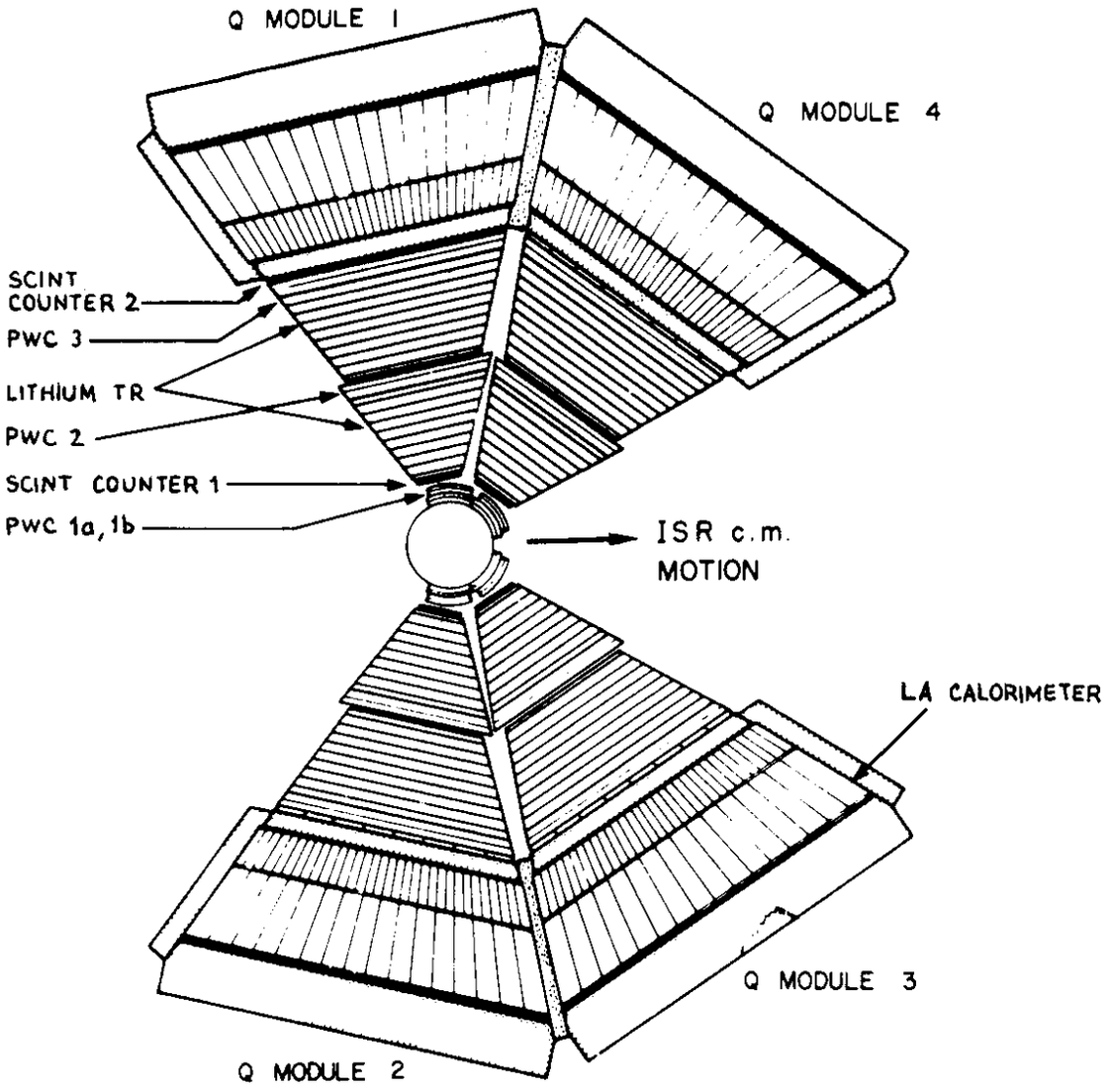
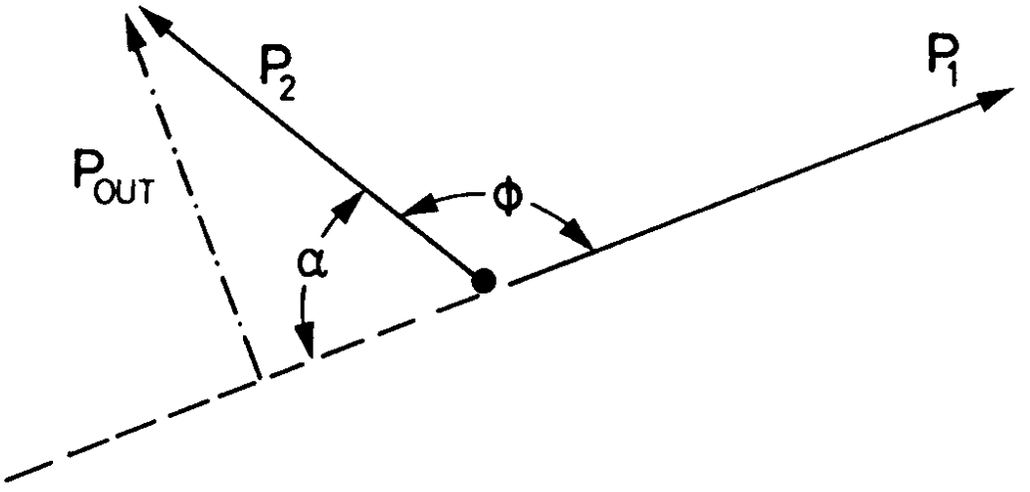

Q MODULE 1
Q MODULE 4
SCINT
COUNTER 2
PWC 3
LITHIUM TR
PWC 2
SCINT COUNTER 1
PWC 1a, 1b
ISR c.m.
MOTION
LA CALORIMETER
Q MODULE 3
Q MODULE 2

Fig. 1

PLANE PERPENDICULAR TO p-p COLLISION



$$z = P_2 \cos \alpha / P_1$$

Fig. 2

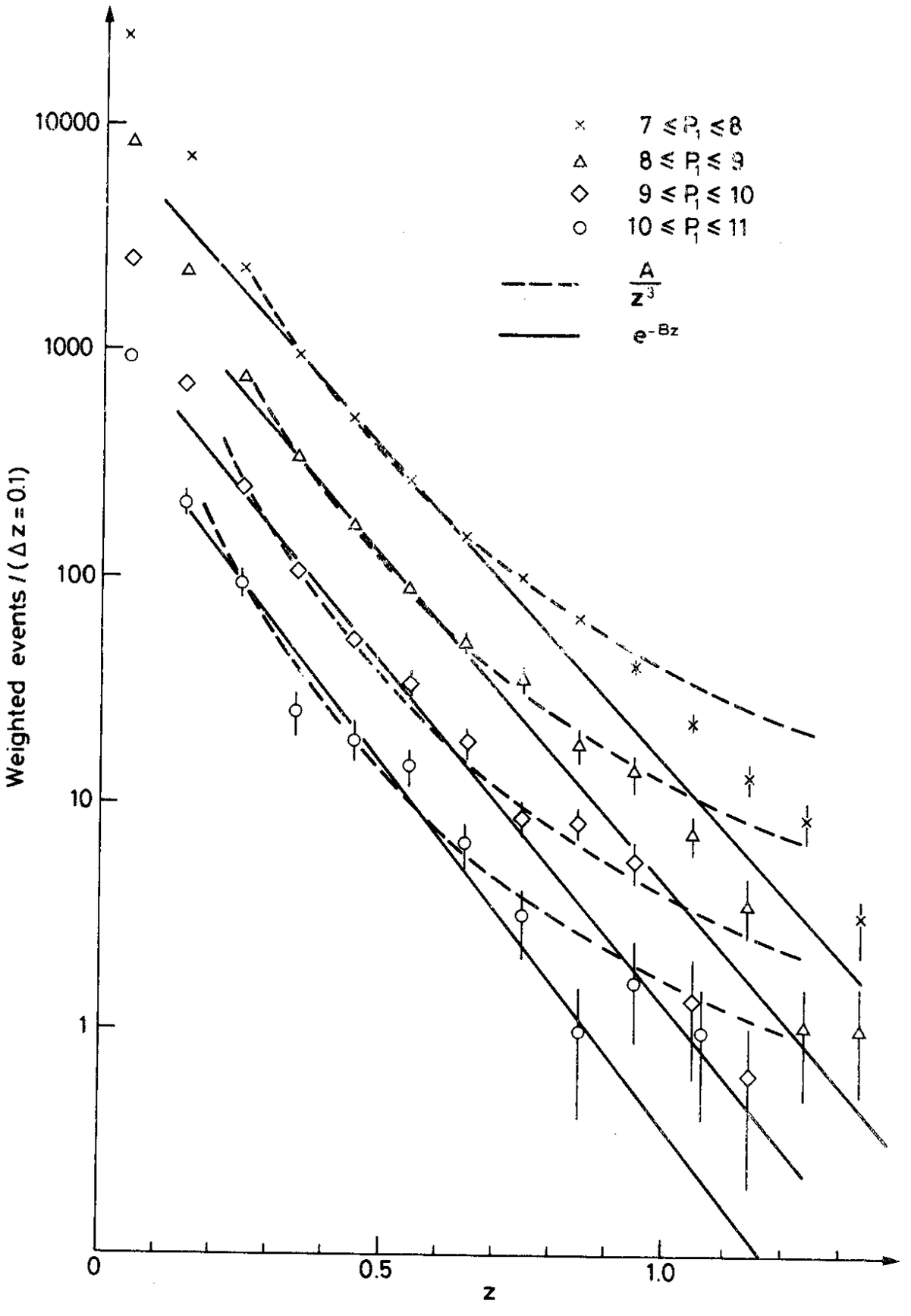

10000
1000
100
10
1
0
0.5
1.0
z
Weighted events / (Δ z = 0.1)
7 ≤ P1 ≤ 8
8 ≤ P1 ≤ 9
9 ≤ P1 ≤ 10
10 ≤ P1 ≤ 11
A/z3
e-Bz

Fig. 3

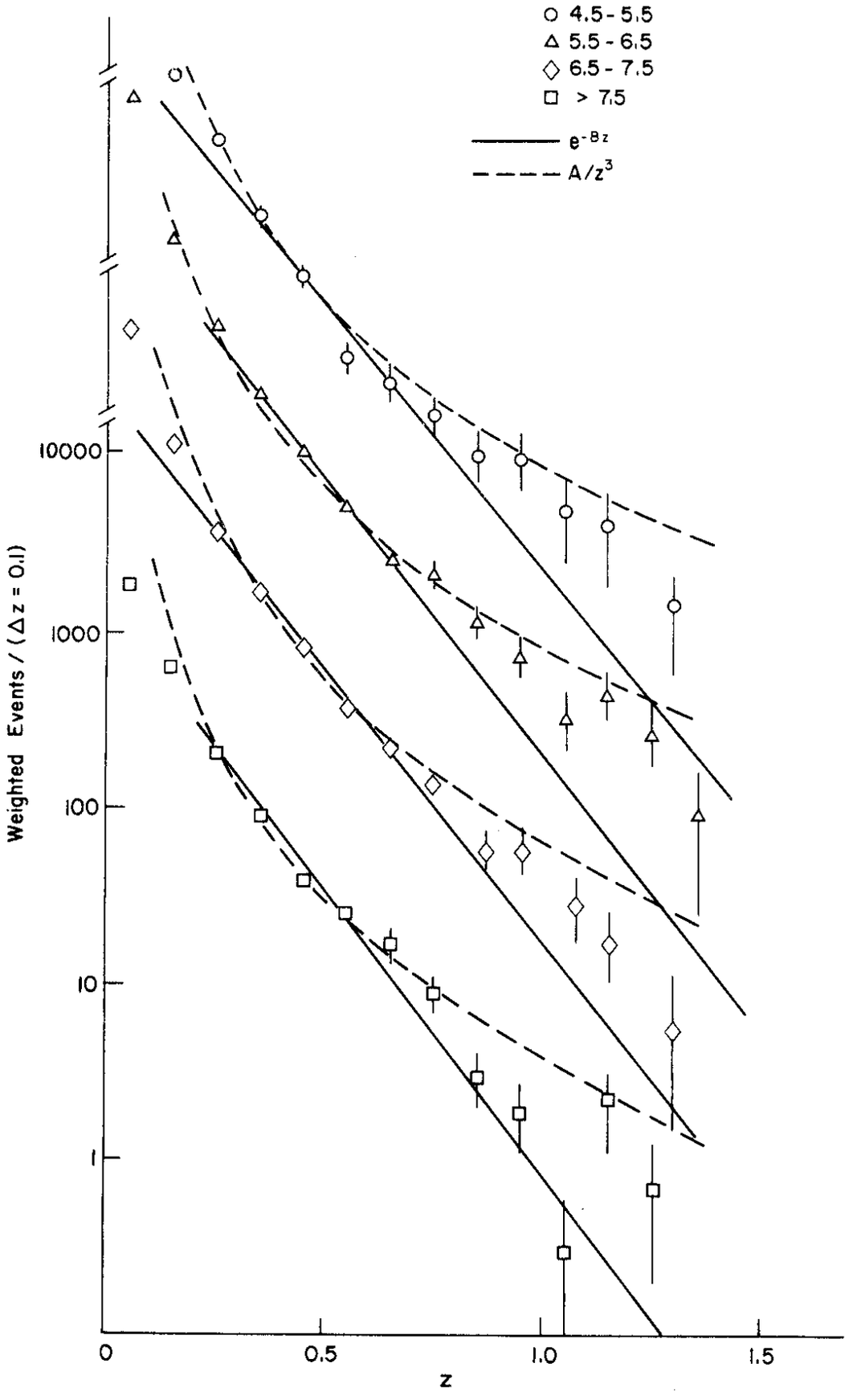

○ 4.5 - 5.5
△ 5.5 - 6.5
◇ 6.5 - 7.5
□ > 7.5
e^-8z
A/z^3
Weighted Events / (Δz = 0.1)
10000
1000
100
10
1
0
0.5
1.0
1.5
z

Fig. 4