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NEGATIVE RESULTS OF A SEARCH FOR ALIGNMENT IN HIGH ENERGY COLLISIONS

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ABSTRACT

Using proton-proton interactions at 205 and 300 GeV/c we have searched for an alignment of the produced particles due to high angular momentum in the primary collision. The negative results of this search are discussed.

It is interesting to consider the possibility that in a high energy collision the final state could show alignment effects. Such an effect would be predicted by several types of theory. For instance, when a 300 GeV/c proton collides with a proton at rest with an impact parameter of one fermi, the system has an intrinsic angular momentum of about 60 $\hbar$. If nuclear matter behaves in any respect like a viscous fluid this angular momentum would be seen in the final state as a preference for particles to be emitted in the plane perpendicular to the angular momentum.

Because the initial system is invariant under rotations about the initial direction of the beam, any alignment effect in a given event would have a random orientation. To find that direction in any given event one must use the event itself to define the direction. This leads to the obvious difficulty that one may be misled into seeing such an effect, even if it does not exist, by the intrinsic fluctuations in the individual events. This possibility is decreased as one considers final states with a larger number of particles.

We have looked for such an alignment using data on charged particle production (a) from the Fermilab-ANL 205 GeV/c bubble chamber run,[1] and (b) from two subsamples of events from the Fermilab-Cal Tech-Indiana-UCLA 300 GeV/c bubble chamber experiment.[2] Fig. 1 shows the distribution in the azimuthal angle, ϕ, about the beam for the 300 GeV/c data samples. For each event, the origin has been chosen to maximize the average value of $\cos^2 \phi$. The "low multiplicity" sample has an average of 7.5 charged particles/event; the "high multiplicity" sample has an average of 22 charged particles/event. We have also looked at the dependence of this apparent alignment on rapidity and on production angle. We find no obvious dependence on either of these variables.

The significance of the alignment observed in Fig. 1 has been tested by the following method. For any event the i^{th} particle may be characterized by (p_i, θ_i, ϕ_i) and we can define a test statistic for each event:

$$T = [(\sum_i w_i \cos 2\phi_i)^2 + (\sum_i w_i \sin 2\phi_i)^2]/(\sum_i w_i)^2 , \tag{1}$$

where $w_i = w_i(p_i, \theta_i)$ is any weight factor.

T is the difference of the eigenvalues of the second moment tensor of the distribution of ϕ. In the limit of an infinite number of particles, T would be zero if all values of ϕ were equally likely. However, for a finite multiplicity event T will have fluctuations and, since it is intrinsically positive, the average over many events will be different from zero. Assuming that all ϕ_i are uniformly and independently distributed, the mean and standard deviation of T are:

$$E(T) = (\Sigma w_i^2)/(\Sigma w_i)^2 \tag{2}$$

$$\sigma(T) = [(\Sigma w_i^2)^2 - \Sigma w_i^4]^{\frac{1}{2}}/(\Sigma w_i)^2 .$$

If all weights are chosen to be $w_i = 1$, then (2) reduces to:

$$E(T) = \frac{1}{N}$$

$$\sigma(T) = \frac{1}{N}\sqrt{\frac{N-1}{N}} , \tag{3}$$

when N is the average number of charged particles in the event sample.

Applying this statistical test to the 300 GeV/c data samples in Fig. 1, we get the results shown in Table 1. For this analysis we have chosen two different weight factors:

(a) $w_i = 1$, i.e., constant weight, and

(b) $w_i = p_i \sin \theta_i$, i.e., weighted by the transverse momentum.

For both cases, it is apparent that there is no effect beyond that expected on the basis of no alignment.

To further investigate this effect, we have also applied this test, using the same two weight factors, to data obtained from 205 GeV/c pp collisions. Figure 2 shows[3] the average value of T as a function of the charged particle multiplicity. To determine the significance, if any, of the alignment shown by these data, the solid lines show the expectations of Eq. (2). Again we observe no evidence for dynamical azimuthal alignment in the final state.

In summary, we have searched for alignment effects in charged particle production as a function of the final state charged multiplicity in data obtained from 205 and 300 GeV/c proton-proton interactions. The results of this analysis show no effects above those expected on the basis of a uniform and independent azimuthal angular distribution.

REFERENCES

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[1]For details see: Y. Cho et al., Phys. Rev. Letters 31, 413 (1973); R. Singer et al., Phys. Letters 49B, 481 (1974).

[2]The high multiplicity sample consists of 17 20-prong, 17 22-prong, 7 24-prong, and 6 26-prong events. The low multiplicity sample consists of 246 6-prong, 105 8-prong, and 47 14-prong events. More details on these events can be found in F. T. Dao, et al., NAL-Pub-74/37-EXP, to be published in Phys. Rev., and F. T. Dao, et al., Phys. Rev. Letters 33, 389 (1974).

[3]J. Whitmore, Phys. Reports 10C, 273 (1974).

Table 1. Asymmetry Values at 300 GeV/c

	Average Value of T	Expected Value[a]
Low Multiplicity		
No Weight ($w_i = 1$)	0.15 ± 0.15	0.14 ± 0.13
P_t Weight ($w_i = p_i \sin\theta_i$)	0.28 ± 0.22	0.25 ± 0.16
High Multiplicity		
No Weight ($w_i = 1$)	0.044 ± 0.035	0.046 ± 0.045
P_t Weight ($w_i = p_i \sin\theta_i$)	0.076 ± 0.097	0.080 ± 0.065

[a]Based on Eq. (2)

FIGURE CAPTIONS

Fig. 1. Distribution of the azimuthal angle, ϕ, about the beam for final state charged particles produced in 47 high multiplicity and 398 low multiplicity events from 300 GeV/c pp collisions. For each event the origin has been chosen to maximize $\cos^2\phi$.

Fig. 2. Average values of the test statistic, $\langle T \rangle$, for final state charged particles produced in 205 GeV/c pp interactions as a function of the charged multiplicity. The solid curves are the results of a calculation assuming a uniform and independent distribution (see text).

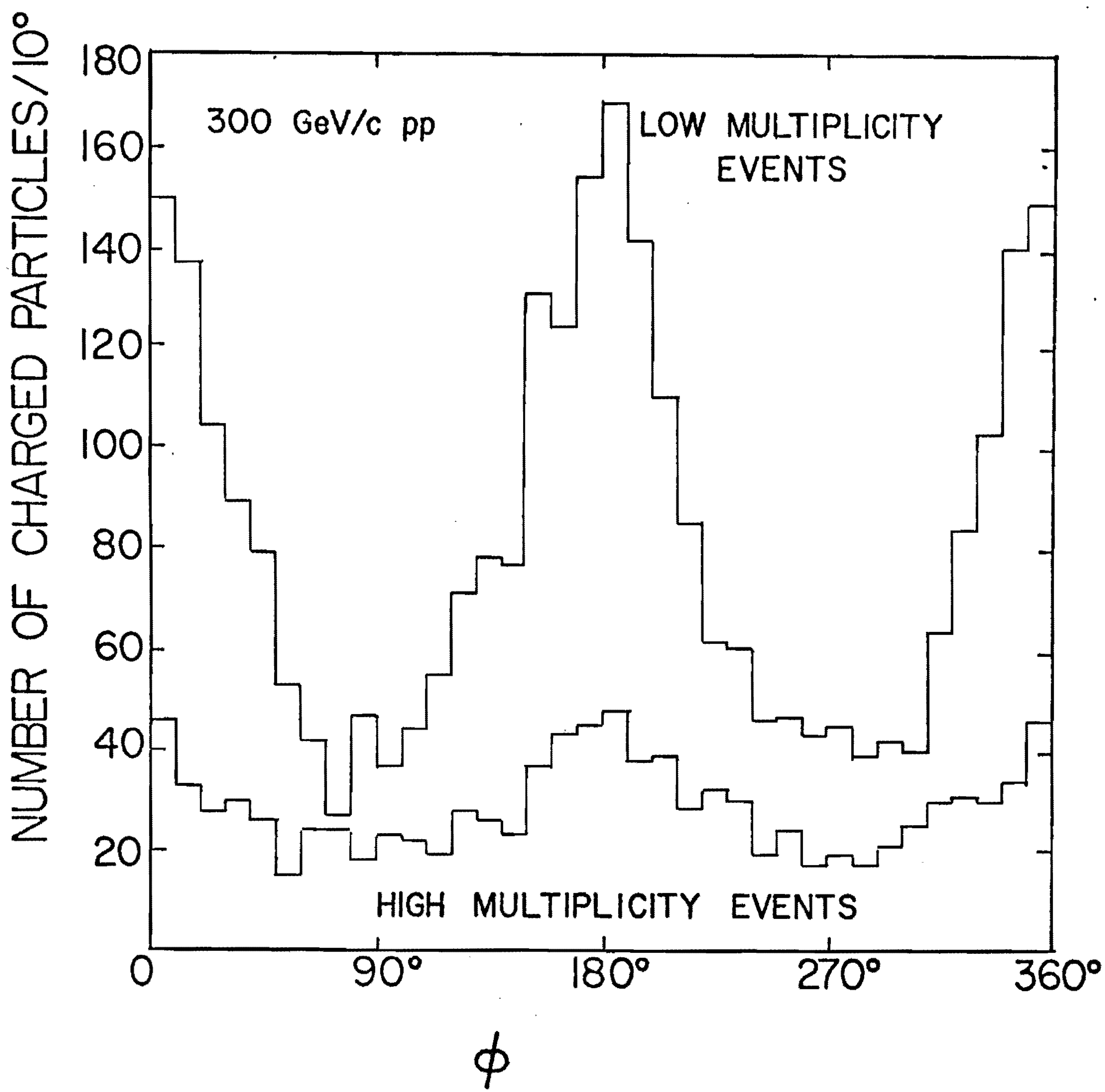
NUMBER OF CHARGED PARTICLES/10°
300 GeV/c pp
LOW MULTIPLICITY EVENTS
HIGH MULTIPLICITY EVENTS
180
160
140
120
100
80
60
40
20
0
90°
180°
270°
360°
φ

Figure 1

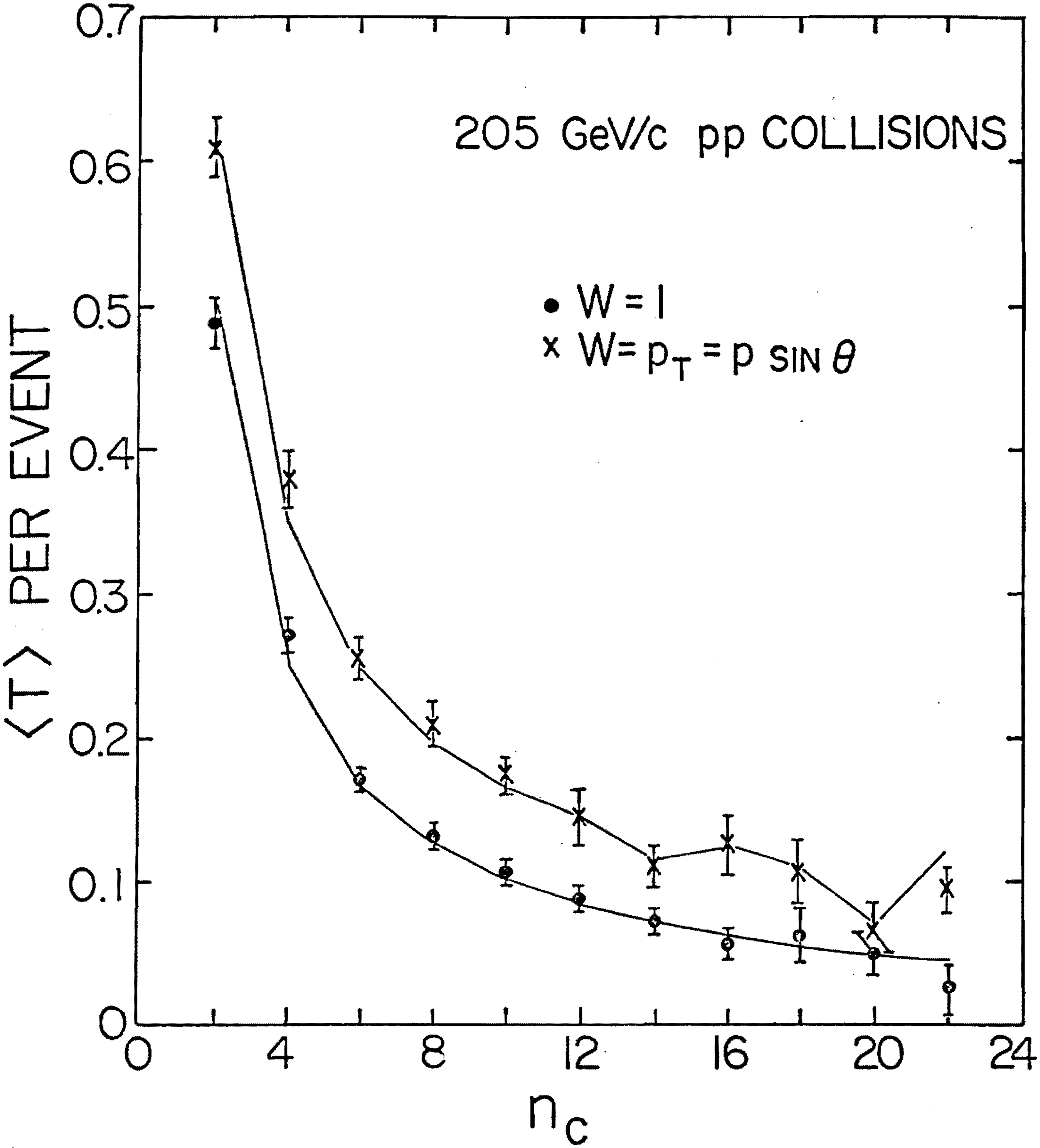
205 GeV/c pp COLLISIONS
● W = 1
x W= p_T = p sin θ
⟨T⟩ PER EVENT
n_c
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
4
8
12
16
20
24

Figure 2