CERN-EP/79-53
31 May 1979

AZIMUTHAL CORRELATION OF A HIGH p_T π^0 AND η
WITH A SECOND π^0 PRODUCED IN pp COLLISIONS AT THE ISR

C. Kourkouvelis and L.K. Resvanis
University of Athens, Athens, Greece

T.A. Filippas and E. Fokitis
National Technical University, Athens, Greece

A.M. Cnops, S. Iwata¹⁾, R.B. Palmer, D.C. Rahm, P. Rehak and I. Stumer
Brookhaven National Laboratory²⁾, Upton, NY, USA

C.W. Fabjan, T. Fields³⁾, D. Lissauer⁴⁾, I. Mannelli⁵⁾,
P. Mouzourakis, A. Nappi⁵⁾ and W.J. Willis
CERN, Geneva, Switzerland

M. Goldberg, N. Horwitz and G.C. Moneti
Syracuse University⁶⁾, Syracuse, NY, USA

ABSTRACT

The correlation between a high transverse momentum π^0 and η and a second π^0 have been measured using an apparatus with large azimuthal acceptance. The angular distribution of α , measuring the deviation from collinearity in azimuth, peaks near zero. The r.m.s. of the distribution is found to have a $1/\ln$ dependence rather than a $1/p$ fall-off.

(Submitted to Physics Letters)

-
- 1) Permanent address: Nagoya University, Nagoya, Japan.
 - 2) Research under the auspices of USDOE.
 - 3) Permanent address: Argonne National Laboratory, Argonne, Ill., USA.
 - 4) Permanent address: Tel-Aviv University, Israel.
 - 5) On leave of absence from the University of Pisa and INFN, Sezione di Pisa, Italy.
 - 6) Work supported by the US National Science Foundation.

In this letter we report on new measurements of the correlations found between a very large transverse momentum p_T π^0 and η and a second π^0 produced by proton-proton interactions at the CERN Intersecting Storage Rings (ISR). The correlation between two particles can be displayed using different variables. The present analysis uses the angle ϕ , the difference in the azimuthal angles of the two particles. High p_T particles are thought to be produced via the hard scattering of the proton constituents, which usually fragment into several particles [1-5]. Selecting a single high p_T particle introduces a "trigger bias" [2], due to the rapidly falling p_T spectrum, which allows one to make the approximation that the direction and momentum of the π^0 is a measure of the scattered constituent. The angle $\alpha = 180 - \phi$ measures the deviation from azimuthal collinearity, which can be due to the angular spread of the fragments relative to the "jet" axis, the transverse momenta of the constituent partons, and a component due to the bremsstrahlung of gluons just before or after basic scattering occurs [1].

The apparatus used in this experiment is shown in fig. 1. The proportional chambers, scintillator counters, and transition radiators in front of each calorimeter were for electron identification and were not used in this analysis. The energies and positions of the electromagnetic showers were measured in the segmented lead-liquid-argon calorimeter. Each calorimeter module covered a solid angle of approximately 1 sr, 50° - 130° in polar angle, and 40° in azimuth. Discrimination between hadrons and electromagnetic showers was provided by measurement of shower development in the calorimeter. The energy resolution in the calorimeter was found to be $\sigma(E) = 10\%/\sqrt{E}$. A more detailed description of the apparatus can be found elsewhere [6-9].

The trigger used in this experiment was based on a large energy deposit in a single calorimeter module. The trigger efficiency was found to rise from zero at 4 GeV/c to $\sim 95\%$ at 6-7 GeV/c, where it reaches a constant value. The η is measured by detecting two resolved electromagnetic showers from $\eta \rightarrow 2\gamma$, with both γ 's in the same calorimeter module. The mass spectrum and other experimental details were presented in a recent paper [10]. The p_T dependence of the η acceptance in the apparatus was calculated including the effects of geometrical acceptance and trigger efficiency.

Apart from the trigger particle, these events were required to contain a second particle, a π^0 with $p_T > 0.5$ GeV/c in one of the other three calorimeter modules. Below ~ 4 GeV, the two photons from the π^0 are usually resolved, while high-energy single showers are assumed to be π^0 's. Any directly produced single photons are thereby treated as π^0 's.

The events are analysed in the plane transverse to the proton-proton interactions (fig. 2a). The data can be described by the three variables p_1 , p_2 and ϕ . The azimuthal acceptance of the apparatus in the centre of mass is shown in fig. 2b. The lack of acceptance in the small angle $\phi < 20^\circ$ is due to the requirement that each particle be in a different module. The acceptance in the region of $110^\circ \geq \phi \geq 60^\circ$ was poor, and events in this region were not used in this analysis.

All $\pi^0\pi^0$ and $\eta\pi^0$ events were grouped in bins of fixed p_T . For events with η as the triggered particle, the events were grouped with respect to the η p_T . For the two π^0 events, the symmetry of the correlations between two identical particles is recognized by treating each pion as both p_1 and p_2 in turn. Thus in the π^0 correlation, events may appear twice in the plots.

The angular distribution in ϕ shows a peak in the back-to-back configuration. For large p_T events, this may be partly due to effects of momentum conservation, but we have presented evidence elsewhere [11] to show that this is not the full explanation in the p_T range used here. The distribution in $\alpha = 180 - \phi$ is found to be approximately Gaussian for $\alpha \leq 70^\circ$. In fig. 3 we show the $\langle \alpha \rangle_{\text{rms}}$ of the angular distributions with $\alpha \leq 70^\circ$ for the events with $\pi^0\pi^0$ in the final state. For all intervals in p_1 , $\langle \alpha \rangle_{\text{rms}}$ shows similar characteristics. There is a rapid decrease in $\langle \alpha \rangle_{\text{rms}}$ as p_2 increases from 0.5 to 4 GeV and then a nearly constant value $\langle \alpha \rangle_{\text{rms}} \approx 13^\circ$, rather than a decrease proportional to $1/p$ which would be expected if $\langle p_{\text{out}} \rangle$ reaches a limiting value. The fact that the limiting value is reached at relatively low p_2 suggests that this is not a kinematic constraint near the boundary ($p_1 \approx p_2$). The results from our earlier publication [12] for smaller p_1 are also shown. The data indicate a clear trend that for a fixed p_2 an increase in p_1 brings $\langle \alpha \rangle_{\text{rms}}$ closer to its limiting value.

In fig. 4 the $\langle \alpha \rangle_{\text{rms}}$ for $\eta\pi^0$ events are shown. The general features of the data are identical to those observed with the $\pi^0\pi^0$ sample. Here one also observes that with increasing p_T of the η and a fixed $\pi^0 p_T$, the $\langle \alpha \rangle_{\text{rms}}$ decreases toward its asymptotic value.

In the framework of constituent scattering, the spread of the π^0 fragments relative to the estimator of the second "jet" direction can be due to a number of factors. The intrinsic transverse momenta $\langle k_T \rangle$ of the proton constituents give rise to a relative angle with respect to each other in the over-all centre of mass. The emission of bremsstrahlung gluons just before the basic interactions and finally the meson fragment itself can all be emitted at an angle relative to the initial constituent direction. The observation that $\langle \alpha \rangle_{\text{rms}}$ tends to a limiting value at a relatively low value of p_2 and does not fall as $1/p$ indicates that $\langle p_{\text{out}} \rangle$ (defined in fig. 2a) continues to increase. This suggests that a fixed angular definition of a "jet" might be the appropriate one. The measurement showing that, for a fixed p_2 , increasing p_1 tends to bring $\langle \alpha \rangle_{\text{rms}}$ to a limiting value, suggests that it is valid to assume that the constituent direction can be estimated by a single high p_T particle. Note that the $\langle \alpha \rangle_{\text{rms}}$ fall-off observed is consistent with $1/\log(Q/\Lambda)$, ($Q = 2p_T$), as expected from QCD calculations [13,14].

We wish to thank M. Jacob and R. Horgan for discussing the data with us and offering many helpful suggestions.

REFERENCES

- [1] R.P. Feynman, R.D. Field and G.C. Fox, Phys. Rev. D 18 (1978) 3320.
- [2] M. Jacob and P.V. Landshoff, Nucl. Phys. B113 (1976) 395.
- [3] D. Sivers, S.J. Brodsky and R. Blankenbecler, Phys. Reports 23C (1978) 1.
- [4] S.D. Ellis and R. Stroynowski, Rev. Mod. Phys. 49 (1977) 753.
- [5] J.F. Owens, E. Reya and M. Glück, Phys. Rev. D 18 (1978) 1501.
- [6] C. Kourkouvelis, CERN 77-06 (1977).
- [7] A.J. Lankford, CERN EP Internal Report 78-3 (1978).
- [8] J.H. Cobb et al., Nucl. Instrum. & Methods 158 (1979) 93.
- [9] C. Kourkouvelis et al., Inclusive π^0 production at very large p_T at the ISR
(submitted to Physics Letters).
- [10] C. Kourkouvelis et al., Inclusive η production at high p_T at the ISR (sub-
mitted to Physics Letters).
- [11] J.H. Cobb et al., Phys. Rev. Lett. 40 (1978) 1420.
- [12] C. Kourkouvelis et al., Correlation of high transverse momentum π^0 pairs
produced at the CERN ISR (submitted to Nuclear Physics B).
- [13] G. Veneziano, Talk presented at the 19th Int. Conf. on High-Energy Physics,
Tokyo, 1978 (CERN preprint TH 2572, 1978).
- [14] A. De Rújula, Talk presented at the 19th Int. Conf. on High-Energy Physics,
Tokyo, 1978 (CERN preprint TH 2578, 1978).

Figure captions

- Fig. 1 : Arrangement of the apparatus in the ISR.
- Fig. 2 : a) The definitions of the variables used in this analysis.
b) Geometrical acceptance as a function of the variable ϕ .
- Fig. 3 : The angular deviation from collinearity of $\pi^0\pi^0$ events, $\langle\alpha\rangle_{\text{rms}}$ as a function of p_2 , for different p_T intervals of p_1 . The curves are: $1/p$ (dotted); $1/[\ln(Q/\Lambda)]$ (solid curve).
- Fig. 4 : The angular deviation from collinearity of $\eta\pi^0$ events, $\langle\alpha\rangle_{\text{rms}}$ as a function of p_2 , for different p_T intervals of η . The curves are: $1/p$ (dotted); $1/[\ln(Q/\Lambda)]$ (solid curve).

Fig. 1

PLANE PERPENDICULAR TO p-p COLLISION

Fig. 2

Fig. 3

Fig. 4