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CCOR Collaboration

CERN - Columbia - Oxford - Rockefeller

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TRIPLE-JET STRUCTURES IN PROTON-PROTON INTERACTIONS

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In this experiment, which uses a superconducting solenoid at the CERN ISR, a large sample of two-jet events produced in proton-proton collisions at 62 GeV centre-of-mass energy has been examined for evidence of three-jet structures. That is, for the presence of events in which three particle jets can be separately identified at large transverse momenta relative to the initial proton directions, there also being "spectator" jets following these directions, making five jets in all. Such three-jet events are expected to be produced by gluon bremsstrahlung, as has been observed in the e^+e^- case¹⁾, but several additional mechanisms are expected in the case of hadronic collisions²⁾.

The three-jet events are identified by cluster analysis, the particles of each event being sorted into the best three-cluster and two-cluster combinations. The function $W_n = \sum_{i=1}^n \langle j_T^2 \rangle_i$ is calculated for the two combinations, $n = 2$ and $n = 3$, where j_T is the individual particle transverse momentum with respect to the jet axis, which is taken as the vector sum of the momenta of the particles in the cluster. The event is then accepted as a three-jet candidate if $W_3/W_2 < 0.5$. This value of the cut identifies Monte Carlo generated events with full efficiency at large jet separation angles of at least 1.2 rad, but the efficiency falls away as the jet particles merge at smaller separations.

The method was applied to a sample of 42000 events with single π^0 trigger, average trigger-transverse momentum $\langle p_{Tt} \rangle = 6$ GeV/c, and with at least five particles within the acceptance. Calling jet 1 that containing the trigger π^0 , jet 2 the one with the highest momentum particle on the opposite side, then most remaining (jet 3)

centres lie close to jet 2, balancing the trigger momentum. The only significant background among the three-jet events comes from statistical fluctuations in the fragmentation of jet 2, an accidental clustering of particles in the "tail" of jet 2 being misidentified as a third jet. This background was measured by reprocessing the entire event sample, after "randomising" the tracks of jets 2 and 3 by rotating them through randomly-generated azimuth angles about their common momentum-sum vector.

From 42,000 events with at least 5 tracks, we obtain 1203 triple-jet events, together with 421 background events using the above procedure, giving a net signal of 782 events.

This signal is distributed uniformly over the acceptance of the apparatus, except that there is a correlation in the polar angle θ of jets 2 and 3. The two jets tend to lie at the opposite extremes of the polar angle range, that is, such that the difference $|\theta_2 - \theta_3|$ is maximal. Random events do not show this effect, being distributed uniformly up to the extremes of the acceptance. The correlation is attributed to the zero in the θ distribution of the triple-parton plane when it lies normal to the colliding partons. This zero occurs approximately at $\theta_2 - \theta_3 = 0$, after Lorentz transformation to the proton-proton colliding system. Observation of this correlation strongly supports the interpretation of the triple-jet events as arising in parton-parton collisions.

In Fig. 1, we show the opening angle distribution in ψ'_{23} , the observed angle between the summed momentum vectors of jets 2 and 3. The real data cut off sharply for angles $\psi'_{23} < 1.2$ rad, while the random continue in to small angles. Events with $\psi'_{23} > 1.5$ rad were used to assess the efficiency of the analysis for finding third jets. The efficiency was found to drop away from 100% at large ψ_{23} , and there was also a distortion of angles, jets being found at larger separations ψ'_{23} than their generated separation ψ_{23} . Both these effects were corrected in the data, giving finally a corrected ratio of triple-jets down to separation angles ψ_{23} of 0.7 rad, as in Table 1.

The yield of triple jets is large, e.g. for $\psi_{23} > 0.8$ rad we obtain 28% triple-jets. This can be compared with results from e^+e^- collisions³⁾, where as an example the Pluto collaboration obtained 9.3% separated three-jet events for angles > 0.8 rad. If we correct these two results for different cuts and different energies we obtain 5.3 ± 0.9 (statistical) ± 0.9 (systematic) as the ratio of hadronic to e^+e^- triple-jet production. This higher yield in hadronic processes is expected to occur due to the gluon contributions, and agrees with theoretical estimates²⁾.

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Table 1

F_3 = Fraction of the Event Sample with a third jet of > 3 tracks,
and separation $\psi_{23} > \psi_c$

ψ_c	0.7	1.0	1.5	2.0
$F_3(\psi_c)$	0.325	0.202	0.115	0.043
Statistical Error	0.043	0.013	0.010	0.007
Model Error	0.040	0.023	0.014	0.006

Figure 1

Angular distribution in ψ'_{23} , the observed angle between clusters 2 and 3 for real events, and for randomised events (shaded).