EXPERIMENTAL SEARCH FOR T DECAY INTO 3 GLUONS

PLUTO Collaboration

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ABSTRACT

The triplicity method was used to search for triple jets in the decay of T(9.46) into charged and neutral hadrons as an indication of the 3-gluon decay of the T. A comparison of the results with phase space, $q\bar{q}$ and 3-gluon predictions shows that the data is best described by a 3-gluon decay model.

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Quantum chromodynamics predicts the 3-gluon decay of heavy quarkonium such as the Υ(9.46) meson and the $(t\bar{t})$ expected at higher mass. It should give rise to a 3-jet structure of the hadrons emitted in such decays. The observation of such a structure would be considered an important confirmation of QCD. In a previous paper$^{1)}$ we have compared event topologies of charged hadrons from Υ decay with expectations from the 3-gluon process and other models. In the present study we also use information on neutral hadrons registered in the shower counters$^{2)}$ (covering a solid angle of 94 % of 4π) which were added to the original PLUTO detector. Moreover, we tried to identify the 3 jets directly. Details of the experiment, the event selection criteria and the bin by bin subtraction of background from the non-resonating continuum and the Υ decay via the vacuum polarisation were already described$^{1,2)}$.

To find the 3 jets the triplicity method$^{3)}$ was used: The final state hadrons with the momenta $\vec{p}_1, \vec{p}_2, \ldots \vec{p}_N$ are grouped into 3 non-empty classes C_1, C_2, C_3 with the total momenta

$$\vec{P}(C_\ell) = \sum_{i \in C_\ell} \vec{p}_i ; \qquad \ell = 1, 2, 3.$$

Triplicity is defined$^{+)}$ by

$$T_3 = (1/\sum_{i=1}^{N} |\vec{p}_i|) \max_{C_1,C_2,C_3} \{ |\vec{P}(C_1)| + |\vec{P}(C_2)| + |\vec{P}(C_3)| \} .$$

It ranges between $T_3 = 1$ for a perfect 3-jet and $T_3 = 3\sqrt{3}/8 = 0.65$ for a completely spherical event. Those classes C_ℓ^* of particles yielding the maximum T_3 are identified with the hadrons originating from the fragmentation of the gluon ℓ. Thus the jet momenta are the $\vec{P}(C_\ell^*)$, cf. fig. 1. We rename them $\vec{P}_1, \vec{P}_2, \vec{P}_3$ with the convention $P_1 \geq P_2 \geq P_3$. The jet directions are given by the unit vectors $\hat{n}_\ell = \vec{P}_\ell / P_\ell$ and the angles between the 3 jets by

$$\cos\theta_1^J = \hat{n}_2 \cdot \hat{n}_3, \qquad \cos\theta_2^J = \hat{n}_3 \cdot \hat{n}_1, \qquad \cos\theta_3^J = \hat{n}_1 \cdot \hat{n}_2 .$$

Then by identifying gluon and jet directions the gluon energies are (E_{cm} is the cm energy of the e^+e^- system)

$$E_\ell^J = E_{cm} \sin\theta_\ell^J / (\sin\theta_1^J + \sin\theta_2^J + \sin\theta_3^J)$$

or, in dimensionless variables, $x_\ell^J = 2\, E_\ell^J / E_{cm}$.

+) It should be noted that thrust$^{4)}$ is defined analogously by partition of momenta into 2 classes

$$T = (1/\sum_{i=1}^{N} |\vec{p}_i|) \max_{C_1,C_2} \{ |\vec{P}(C_1)| + |\vec{P}(C_2)| \} .$$

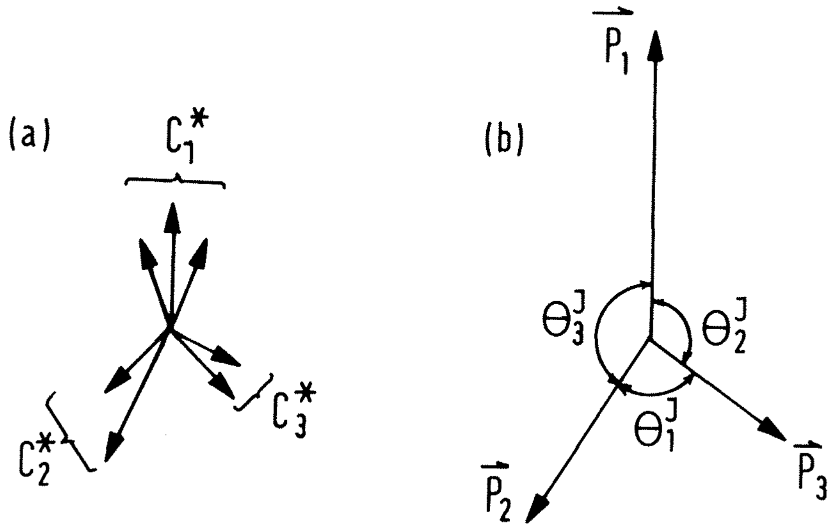

Fig. 1 Momentum configuration of hadrons (a) and jets (b) obtained by grouping hadrons into 3 classes.

The quantities E^J, x^J, θ^J as computed from the jets are expected to be identical to the gluon quantities E, x, θ only if the jets do not overlap in space. Since this is not always the case (expecially at the relatively low mass of the Υ) the measured quantities cannot be directly compared to theoretical predictions. We have therefore generated Monte-Carlo events using the 3-gluon decay matrix element[5)] and giving the gluon jets the same features (transverse momentum and multiplicity distributions) as those we observed for hadron jets of similar energy in the continuum. For comparison we also generated $q\bar{q}$ two-jet events according to the Field-Feynman model[6)] (using u, d and s quarks only) and events following a pure phase space with a mean multiplicity as observed on the Υ resonance. For the 3 sets of Monte-Carlo events the influence of the PLUTO detector and all experimental cuts were also simulated.

Our results are summarized in fig. 2 which shows the distributions of thrust T, triplicity T_3, the reconstructed gluon energies x_1^J, x_3^J and the angles between the gluon directions θ_1^J, θ_3^J. (It turns out that x_2^J and θ_2^J are not very discriminative. Therefore their distributions are not shown but the mean values are included in table 1 below.) In all distributions there is a clear difference between the data from the direct decay of the Υ (full data points) and the off-resonance events at E_{cm} = 9.4 GeV (open circles) which are subjected to the same analysis. The latter are rather well described by the Field-Feynman model. The Υ data are in very good agreement with the 3-gluon model. However, we observe a significant difference between the Υ data and phase space predictions. The observed mean values for the measured quantities and the corresponding predictions from the 3-gluon and phase space models are listed in table 1. The errors quoted are statistical only.

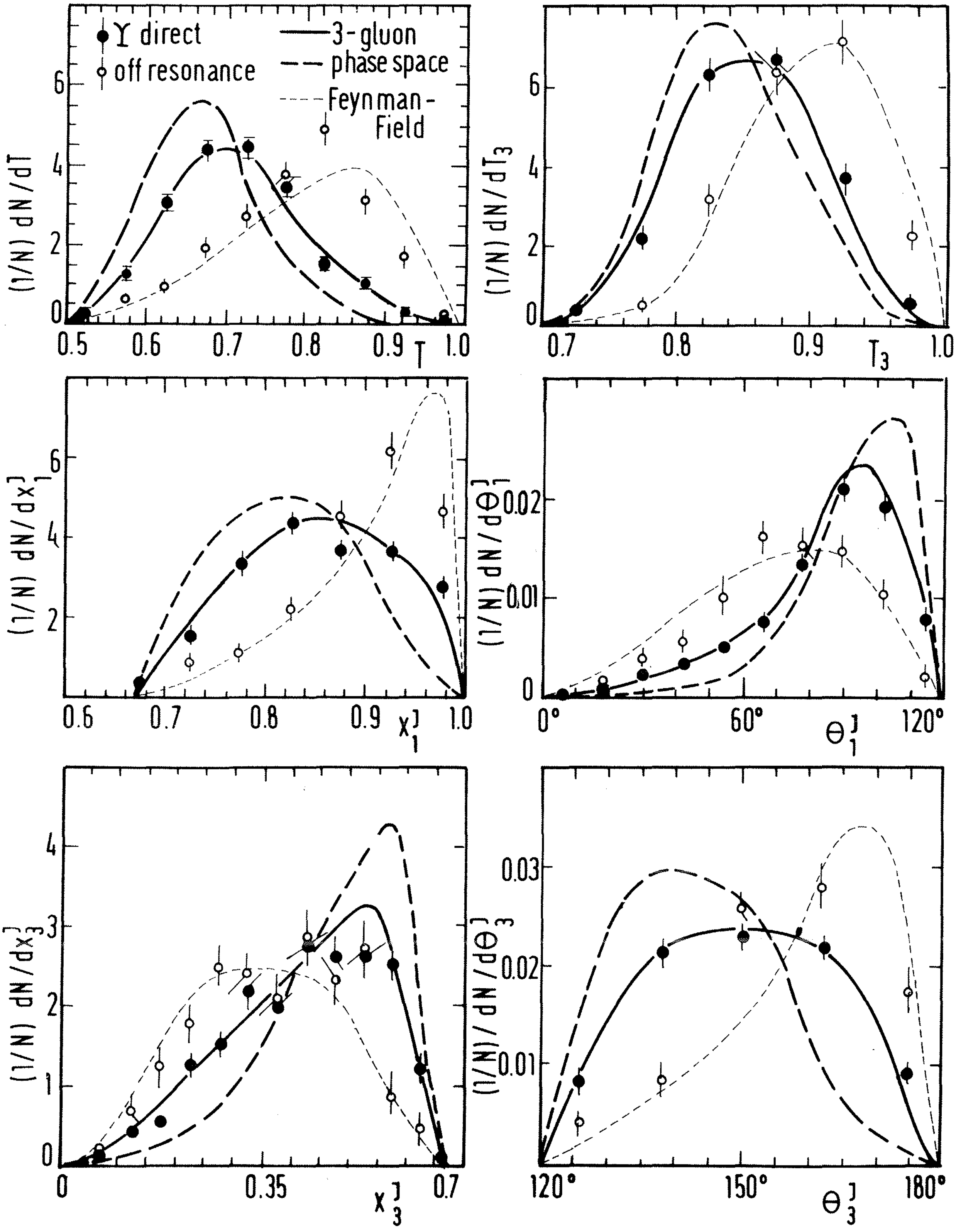

Fig. 2 Experimental distributions of thrust T, triplicity T_3 reconstructed gluon energies x_1^J, x_3^J and reconstructed angles θ_1^J, θ_3^J between gluons compared to Monte-Carlo calculations based on various models.

Table 1

Observed mean values and corresponding predictions of 3-gluon and phase space models.

	T direct data	3-gluon MC	phase space MC
$\langle T \rangle$	0.715 ±0.004	0.712 ±0.003	0.671 ±0.003
$\langle T_3 \rangle$	0.858 ±0.002	0.850 ±0.002	0.838 ±0.002
$\langle x_1^J \rangle$	0.855 ±0.004	0.853 ±0.003	0.819 ±0.002
$\langle x_2^J \rangle$	0.722 ±0.004	0.724 ±0.003	0.700 ±0.002
$\langle x_3^J \rangle$	0.423 ±0.006	0.422 ±0.005	0.481 ±0.004
$\langle \theta_1^J \rangle$	84.1° ±1.0°	85.5° ±0.8°	93.2° ±0.6°
$\langle \theta_2^J \rangle$	125.6° ±0.7°	124.3° ±0.5°	122.9° ±0.4°
$\langle \theta_3^J \rangle$	150.3° ±0.6°	150.2° ±0.5°	144.0° ±0.4°

In summary, we conclude that the decay structure of the T is clearly inconsistent with a simple $q\bar{q}$ or a pure phase space model. We cannot rule out more elaborate phase space models including resonances since these have many adjustable parameters. We should like to emphasize the fact that all experimental distributions are very well described if one assumes the 3-gluon decay of the T meson.

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REFERENCES

1) PLUTO Collab., Ch. Berger et al., Phys. Lett. 82B (1979) 449.

2) PLUTO Collab., Ch. Berger et al., Phys. Lett. 76B (1978) 243 and Phys. Lett. 78B (1978) 176.

3) S. Brandt and H.D. Dahmen, Z. Physik C, Particles and Fields 1 (1979) 61.

4) S. Brandt, Ch. Peyrou, R. Sosnowski and A. Wroblewski, Phys. Lett. 12 (1964) 57; E. Farhi, Phys. Rev. Lett. 39 (1977) 1587.

5) K. Koller and T.F. Walsh, Phys. Lett. 72B (1977) 227; 73B (1978) 504; Nucl. Phys. B140 (1978) 449; K. Koller, H. Krasemann and T.F. Walsh, Z. Physik C, Particles and Fields 1 (1979) 71.

6) R.D. Field and R.P. Feynman, Nucl. Phys. B136 (1978) 1.