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PLUTO RESULTS ON JETS AND QCD

PLUTO COLLABORATION

presented by V. Hepp

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PLUTO RESULTS ON JETS AND QCD

PLUTO COLLABORATION
(presented by V. Hepp)†

ABSTRACT

Results obtained with the PLUTO detector at PETRA are presented. Multihadron final states have been analysed with respect to clustering, energy-energy correlations and transverse momenta in jets. QCD predictions for hard gluon emission and soft gluon-quark cascades are discussed. Results on α_s and the gluon spin are given.

CLUSTER ANALYSIS

In contrast to existing methods of finding jet-axes, e.g. diagonalization of the momentum tensor[1], the geometrical pattern of the final state hadrons is used to extract their clustering properties. The idea is, of course, that a fast primordial parton is expected to materialize into a cluster of hadrons which are closely distributed around the original parton axis at high energies. In a first step, we use only the directions of charged and neutral particles to define preclusters by requiring any two of them to be within a 'collecting angle' α. Then preclusters are merged into clusters, if the momentum vectors of any two of them subtend an angle smaller than β. A cluster is called a jet, if the energy contained in it exceeds typically 2 GeV, as motivated by low energy results. For α and β values around 30^0 were used, corresponding to $\sim$ 7 % of 4 π. With this method the experimental number of jets in every event was determined. This number is not necessarily equal to the number of fast primordial partons. The efficiency of the collecting algorithm was determined with $q\bar{q}$, $q\bar{q}g$ and ggg Monte Carlo studies including complete simulation of the detector and radiation. The unbiased reconstruction of the parton quantities based on zero mass kinematics was verified.

The PLUTO data at cms energies between 27 and 32 GeV were passed through the cluster program. For each event the number of jets/event (n_j) was determined. In the sample of 860 selected hadronic events $\sim$ 250 were found with n_j = 3. Fig. 1 shows the observed n_j distribution (full circles) compared with the expected one for the $q\bar{q}$ and $q\bar{q}g$ Monte Carlo (triangles and rectangles, resp.). We find good agreement with the $q\bar{q}g$ prediction.

The n_j distribution for isotropic phase space has a maximum at n_j = 5 (not shown). $t\bar{t}$ production with Q = 1/3 would predict an excess of entries for n_j > 3 and is excluded by more than 7 s.d.. Since all events in the n_j = 4 class can be explained by the 1^{st} order QCD predictions, we do not see any sizeable production of 4 energetic jets in our data.

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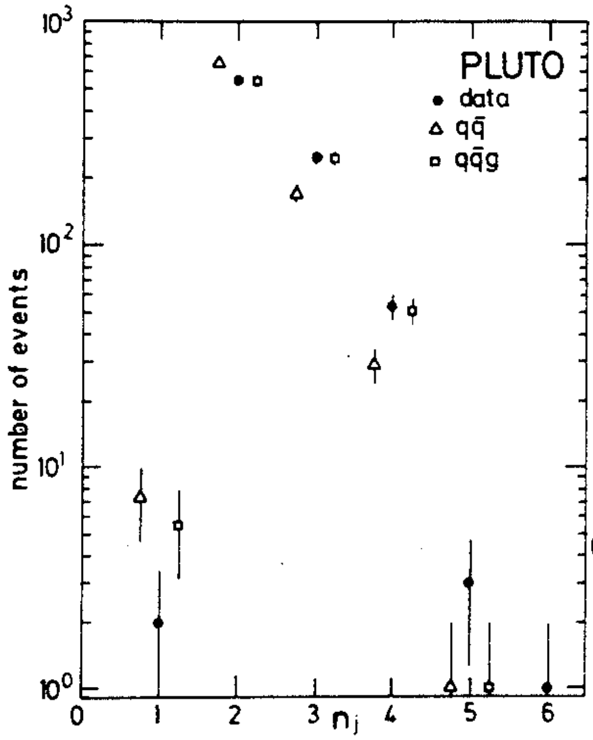

Fig. 1 n_j distributions (see text)

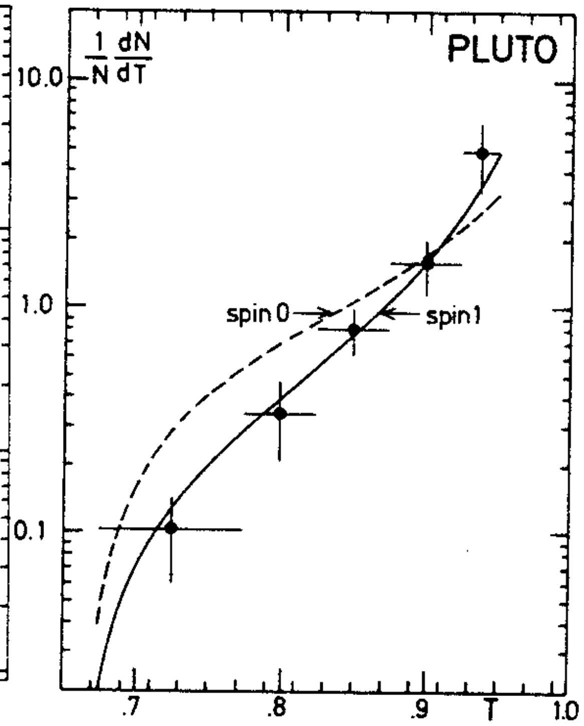

Fig. 2 Parton thrust distribution solid (dashed) curves: spin = 1 (0) predictions

From the $n_j = 2$ class we determined the transverse spread σ_q in the quark fragmentation to be $\sigma_q = (290 \pm 30)$ MeV. From the number of events with $n_j = 3$ we obtained (after applying more severe cuts, e.g. thrust < 0.925) for the strong coupling constant: $\alpha_s = 0.16 \pm 0.03$ (stat. error) $\pm$ 0.03 (syst. error). Background due to hard photons or 2γ events was found to be small. The systematic error in α_s reflects the uncertainties introduced by the cuts and the correlations with σ_q.

The parton thrust distribution after subtraction of the $q\bar{q}$ background is displayed in Fig. 2. The solid curve in the figure is the absolute prediction[2] from 1^{st} order QCD for gluon spin = 1. The dashed curve is the spin = 0 prediction[3] normalized to the number of events which is clearly disfavored (χ^2 is 28.7 for 4 degrees of freedom).

ENERGY-ENERGY CORRELATIONS

As a measure of parton cascading we studied energy-energy correlations of the form

$$\frac{1}{\sigma}\frac{d\sigma}{d\theta} = \sum_{a,\,b} \int \frac{1}{\sigma}\frac{d^3\sigma}{dz_a dz_b d\theta}\, z_a z_b dz_a dz_b$$

with $z_{a,\,b} = E_{a,\,b} / E_{cm}$, θ = angle between hadron a and hadron b.

The data are compared with theoretical QCD predictions which depend only on the scale parameter Λ. They are divided into 3 separate angular regions, namely:

i) small θ: QCD leading log approximation (LLA)[4]

ii) 90 degree region: 1^{st} order QCD[5]

iii) large θ: QCD-LLA[6]

However, additional correlations from the final hadron formation processes are neglected.

We have used only charged particles in the analysis and have corrected the data for particle losses, detector effects and radiation. Figs. 3 (a) and (b) show the energy-energy correlations for different energies.

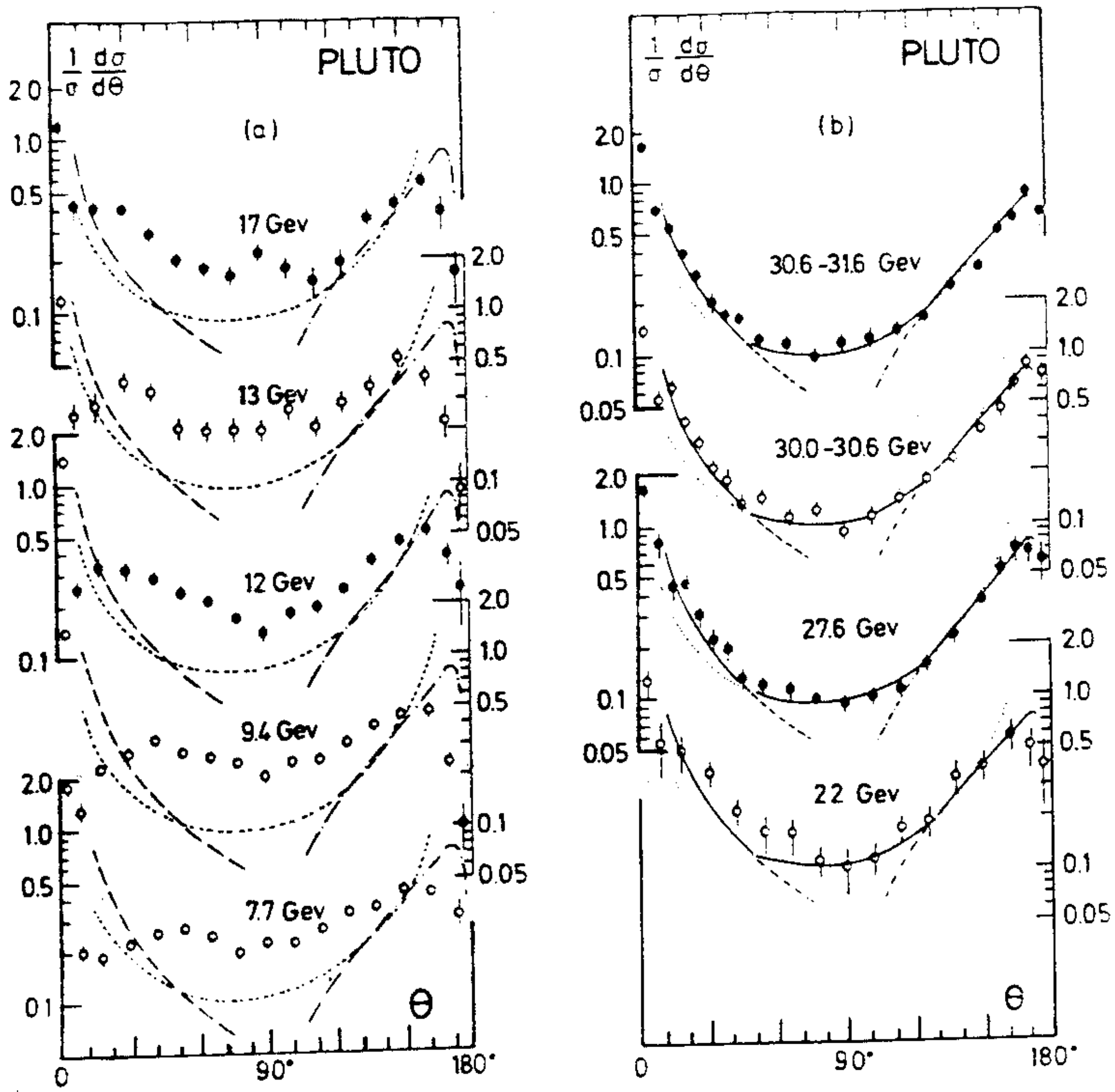

Fig. 3 Energy-energy correlations and theoretical predictions (see text). Dashed curves, ref. 4; dotted curves, ref. 5; dashed-dotted curves, ref. 6; full curves, fit to Λ.

In Fig. 3 (a) the theoretical expectations are given using Λ = 500 MeV. No attempt was made to fit the data, since large non-perturbative contributions are expected. The data above 20 GeV (Fig. 3 (b)) were fitted and an acceptable χ^2 was obtained for α_s = 0.26 ± 0.01 (stat. error) ± 0.06 (syst. error). This value is larger than α_s obtained from e.g. 3 jet studies[8] indicating a non-negligible contribution due to fragmentation even at our highest energy points.

TRANSVERSE MOMENTUM IN JETS

The summed transverse momentum $K_\perp$ in jets is expected to be less sensitive to hadronization effects that single particle transverse momenta $p_\perp$.

We define: $K_\perp = |\Sigma_i \vec{p}_{\perp i}|$ where $\vec{p}_{\perp i}$ is transverse to the trust axis T and summation includes only particles on one side of an arbitrary plane containing T. The trust axis T is defined in the usual way with neutral and charged particles. We use, however, for $K_\perp$ only charged particles and average $K_\perp$ over several random planes to reduce fluctuations. The data were fully corrected for detector- and radiation effects.

At low Q we find very good agreement with theoretical predictions[7] based on QCD-LLA, namely

i) the probability distribution $dP/dK_\perp$

ii) $x_\perp = K_\perp / \langle K_\perp \rangle$ scales ("scaling in the mean")

iii) $\langle K_\perp^2 \rangle$ is proportional to Q^2

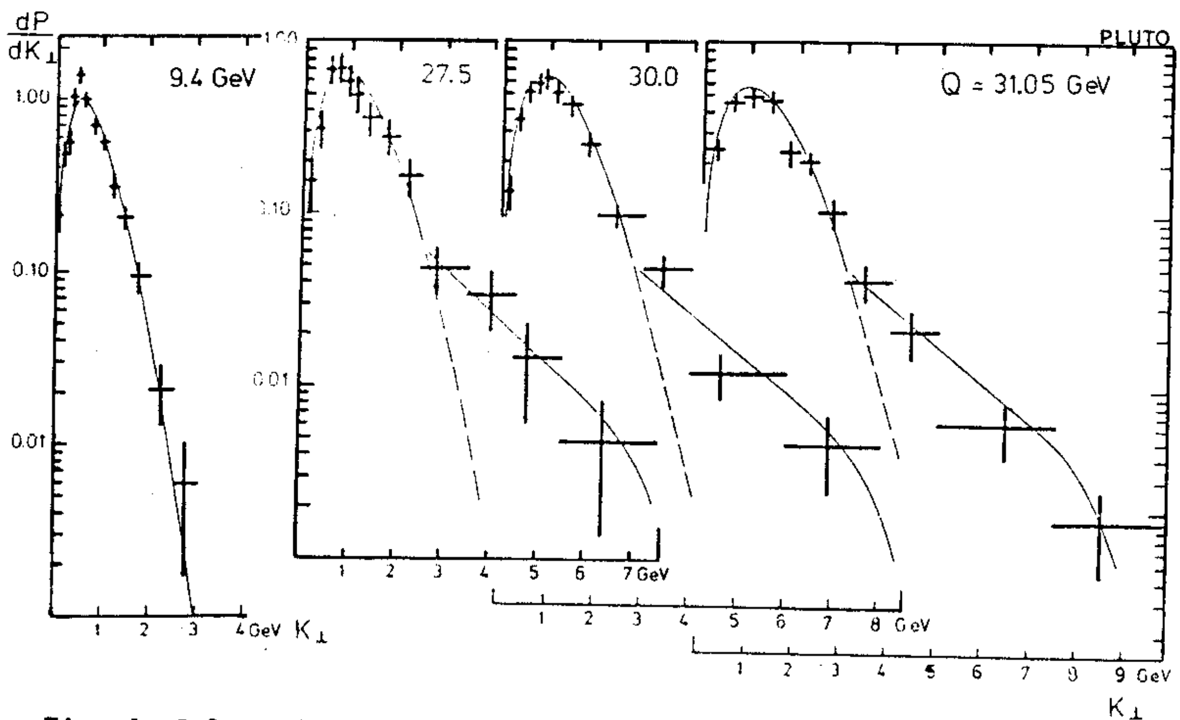

Fig. 4 Selected $K_\perp$ distributions (see text)

As an example we show in Fig. 4 some experimental $K_\perp$ distributions as function of Q. At low energies the QCD-LLA prediction i) describes the data very well. At high Q, however, we see clear deviations in the large $K_\perp$ tail of the distributions. We interpret the excess of data in the tails as due to the onset of hard gluon bremsstrahlung and fit that part of the distributions separately to 1st order QCD predictions. By comparing the two contributions we can determine α_s without recourse to Monte Carlo calculations involving fragmentation parameters or by explicitly counting jet numbers. Preliminarily we get: $\alpha_s = 0.19 \pm 0.02$ (stat. error) $\pm$ 0.04 (syst. error) at Q = 30 GeV. The systematic error is mainly due to the uncertainty in defining the high $K_\perp$ regime where $K_\perp$ is essentially given by the transverse momentum of the hard gluon.

SUMMARY

We have measured parton distributions in multi-jet events with a new cluster algorithm. We find excellent agreement with 1st order QCD predictions in the class of identified 3 jet events and determine: $\alpha_s = 0.16 \pm 0.03$ (stat. error) $\pm$ 0.03 (syst. error). From the 2 jet class we find: $\sigma_q = (290 \pm 30)$ MeV. The parton thrust distribution favors clearly gluon spin = 1.

We have measured the energy-energy correlations of any two particles in hadronic events. At high energies the data approach the predictions of perturbative QCD calculations.

We have measured the transverse momentum $K_\perp$ in jets as a function of energy. We find good agreement with various QCD predictions, based on LLA and the 1st order calculation of hard gluon emission, and in particular:

$K_\perp / < K_\perp >$ shows "scaling in the mean"

$< K^2_\perp >$ increases linearly in Q^2

α_s is directly given by the high $K_\perp$ tail at large energies.

I wish to thank all members of the PLUTO collaboration for their help in preparing this talk. I am very grateful to S. Ellis for many comments.

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