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Hadronic cross section. The precise measurement of the total hadronic cross section $\sigma(e^+e^- \rightarrow \text{hadrons})$ was extended up to the highest PETRA energies of E_{cm} = 46.78 GeV. A point to point systematic error of 1% and a 3% overall normalisation error was achieved. The data selection and the corrections applied are the same as described in ref. 1. Fig. 1 shows the measured values of $R = \sigma_{hadron}/\sigma_{point}$ with the statistical and point to point systematic error indicated. For the region 39.79 GeV < E_{cm} < 46.78 GeV, not covered in ref. 1, the mean R value is <R> = 4.13 ± 0.08 (stat.) ± 0.14 (syst.).

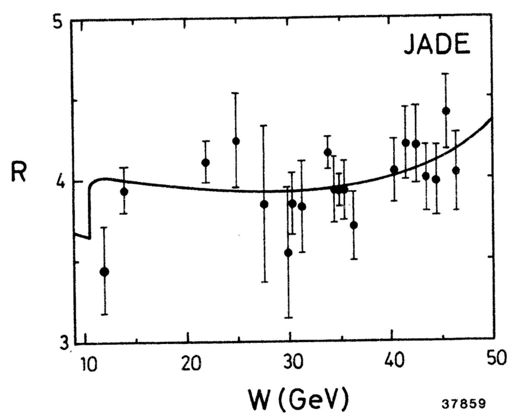

Fig. 1

A fit of the QCD predictions including the standard electro-weak interference effects with the running strong coupling strength α_s and the Weinberg angle $\sin^2\Theta_W$ as free parameters, yields: $\sin^2\Theta_W = 0.23 {+0.03 \atop -0.04}$ and $\alpha_s = 0.20 {+0.06 \atop -0.07}$ (at E_{cm} = 30 GeV). This measurement of α_s is independent of fragmentation.

Energy Energy Correlations. The energy energy correlation ($d\Sigma/d\Theta$) (Ref. 2) between particles produced by e^+e^- annihilation at high energies is expected to be symmetric around $\Theta = 90^0$ for 2-jet events, but in general not for 3-jet events. The asymmetry: $A(\Theta) = d\Sigma(\pi - \Theta)/d\Theta - d\Sigma(\Theta)/d\Theta$ is therefore expected to be especially sensitive to the effects of gluon emission. For the selection of hadronic events we refer to Ref. 3. Fig. 2 shows the corrected distributions of $d\Sigma/d\Theta$ and $A(\Theta)$, which are compared with the string model of the Lund group[4]. The calculations are based on a second order QCD calculation [5], and a y_{min} cut is used to distinguish different parton classes.

For $y = m_{i,j}^2 / s < y_{min}$, the four momenta of the partons i and j are combined. A low value for the y_{min} cut turned out to be essential for a good description of the data. Fig. 2 shows the dependence on the y_{min} cut. The value of α_s determined from $A(\Theta)$ in the region $\Theta > 36^0$ is α_s = 0.165 ± 0.01 (stat.) ± 0.01 (syst.).

We did not succeed in obtaining a similar reproduction of the experimental distributions by independent jet fragmentation models[6,7]. For these models, depending on the way of energy momentum conservation is enforced and the gluon is treated, α_s varies between 0.105 and 0.145. For further details see Ref. 3.

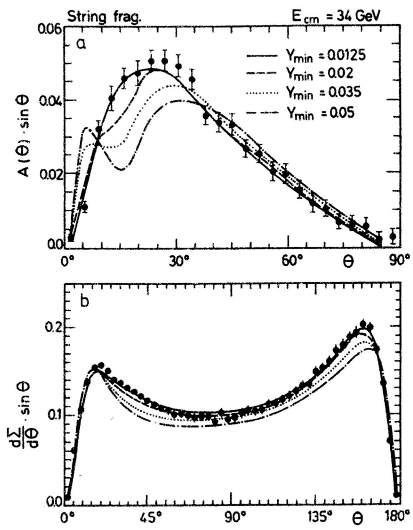

Fig. 2

QCD Shower Models. It has been shown[8], that 3-jet events produced in e^+e^--annihilation are better described by the string model of the Lund group[4] than by independent fragmentation models (Ref. 6,7). These models are based on perturbative QCD (up to order α_s^2) and connect partons and hadrons via phenomenological fragmentation schemes.

A different approach is made by the QCD parton shower models, which use leading log approximation for the QCD calculations. In the Gottschalk model[9], for instance, partons, produced far off mass shell in the hard process, evolve by successive branchings into jet-like cascade of partons closer to its mass shell. If Q^2 is the virtual mass of the first parton, then the second parton has to have a smaller one and so on, until it reaches the cut off limit Q_0^2, where the cascade stops. At the end each gluon splits into a $q\bar{q}$-pair. To get preconfinement, $q\bar{q}$-clusters are combined according to the evolution of the colour flux. These clusters decay into two particles in their rest system.

The leading log approximation was improved in recent theoretical studies on soft gluon interference[10], which leads to destructive interference effects. To interprete this in a semiclassical way, the ordering in 'off shellness' has to be replaced by an ordering of emission angles. This ordering of gluon emission angles instead of the ordering of virtual masses is incorporated into the Webber model[11], which otherwise has a parton shower evolution similar to the model of Gottschalk.

Comparing these QCD shower model calculations with our data one notices, that these models are unable to describe the observed number of 3-jet events and its distribution in detail, since they do not contain the full 3-parton matrix element.

Ignoring this deficiency the particle distributions in 3-jet events predicted by the QCD cluster models were studied. Fig. 3 shows the energy and the particle flow in the event plane of selected 3-jet events in comparison with the two models. (Please note that data and predictions are normalized to the number of 3-jet events observed.) For these distributions all the particles are projected onto the event plane. The events are ordered such that the flow starts from the axis of jet #1 and runs via jets #2 and #3 back to #1. The jet ordering is chosen according to the angles between the jet axis: jet #1 is opposite the smallest and jet #3 opposite the largest angle. Interpreting these 3 jets as caused by gluon bremsstrahlung $e^+e^- \rightarrow q\bar{q}g$ one finds that jet #3 is connected with the gluon in the majority of the cases.

The Webber model reproduces the data quite well including the region between the jets which has been shown to be sensitive to the so called string effect[8], whereas the Gottschalk model predicts too much energy and too many particles between the jets, especially between jets #1 and #2. It is also interesting to note, that the depletion between jets #1 and #2 increases with increasing transverse mass $\sqrt{m^2 + (p_\perp^{out})^2}$, is reproduced by the Webber model (and also by the Lund model) but not by the Gottschalk model. This is visible in Fig. 1c, where the particle flow is drawn only for particles with $p_\perp^{out} > 0.3$ GeV/c. The similarity between the string model and the Webber model has also been observed in several other distributions[12].

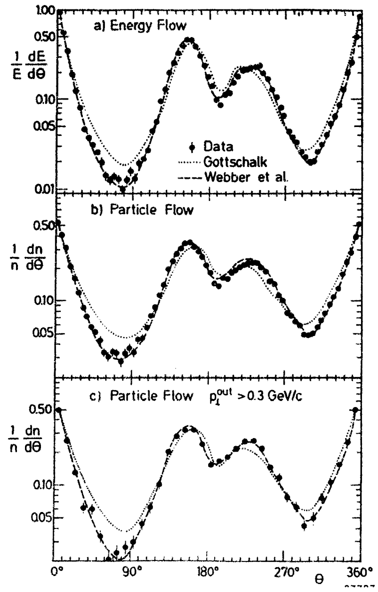

Fig. 3

In Fig. 4 the analogous distributions predicted by the models for partons instead of particles are plotted, exhibiting similar differences between Webber and Gottschalk model as predicted for the final hadrons. This shows that these differences are not caused by a possibly different treatment of the final decay of the preclusters into hadrons but by the difference in the QCD shower calculations.

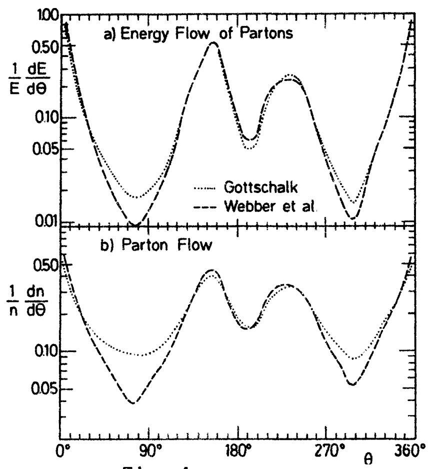

Fig. 4

Inclusive production of vector mesons. Vector mesons in multihadron final states from e^+e^- annihilation are both produced directly during the fragmentation as well as in the decays of higher mass particles. Using simple spin arguments the direct production of vector mesons relative to that of pseudoscalars should be in the ratio 3 :1. This ratio, however, is possibly modified due to the fact that the mesons do not have equal masses.

For the ρ^0 production the invariant mass $M(\pi^+\pi^-)$ is calculated for oppositely charged tracks using the pion hypothesis for both tracks. A smooth background and reflections from the decay $\omega^0 \to \pi^+\pi^-\pi^0$ as well as from $K^{*0} \to K^\pm\pi^\mp$ with the pion hypothesis taken for the $K^\pm$, are subtracted. The production rate per event extrapolated to the full x_E range is found to be 0.98 ± 0.09 ± 0.15 ρ^0/event.

$K^{*\pm}$ production is determined using the decay $K^{*\pm} \to K_S^0\pi^\pm$. The K_S^0 is identified through the decay $K_S^0 \to \pi^+\pi^-$. The details of the K_S^0 identification are described in ref. 13. From the spectrum of the invariant mass $M(K_S^0\pi^\pm)$ a smooth background was subtracted. After correcting for the branching ratio of $K^{*\pm} \to K_S^0\pi^\pm$ and for unseen decay modes of the K_S^0, the number of $K^{*\pm}$ mesons produced per multihadron event is determined to be $K^{*\pm}$/event = 0.87 ± 0.16 (stat.) ± 0.08 (syst.).

It has been suggested [14] that the ratio of pseudoscalars to vector mesons PS/V should be inversely proportional to their mass ratio. Fig. 5 shows the ratio PS/V as a function of M_V/M_{PS}. The production of pseudoscalars relative to that of vector mesons does indeed rise with increasing mass ratio. A fit to PS/V = $(1/3)\cdot(M_V/M_{PS})^\alpha$ yielding $\alpha = 0.5 \pm 0.1$, is shown in Fig. 5. For further details see Ref. 15.

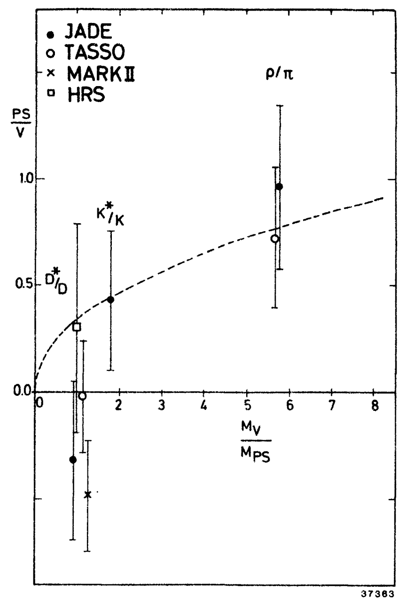

Fig. 5

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