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CHARGED-PARTICLE INCLUSIVE DISTRIBUTIONS FROM HADRONIC Z^0 DECAYS

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ABSTRACT

We have measured inclusive distributions for charged particles in hadronic decays of the Z boson. The variables chosen for study were the mean charged-particle multiplicity ($< n_{ch} >$), scaled momentum (x), and momenta transverse to the sphericity axes ($p_{\perp in}$ and $p_{\perp out}$). The distributions have been corrected for detector effects and are compared with data from e^+e^- annihilation at lower energies and with the predictions of several QCD-based models. The data are in reasonable agreement with expectations.

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We present measurements of charged-particle inclusive distributions in hadronic decays of the Z^0 boson. The data were taken with the Mark II detector at the SLAC e^+e^- Linear Collider (SLC) running on and near the Z boson resonance peak at 91.1 GeV.[1] These data correspond to a total integrated luminosity of 19.7 nb^{-1}. Comparisons with lower energy data are presented, in particular with measurements at 29 GeV taken with the same detector.

The Mark II detector has been described in detail elsewhere.[2] Charged particles are measured with a 72-layer cylindrical drift chamber in a 4.75 kG solenoidal magnetic field. The momentum (p) resolution was determined from Bhabha scattering events at 29 GeV to be $\sigma(p)/p = 0.0046p$ (p in GeV/c). When the charged tracks are constrained to originate at the e^+e^- interaction point (IP), the momentum resolution improves to $\sigma(p)/p = 0.0031p$. The trigger includes charged particle and neutral energy components and has an estimated efficiency of greater than 99% for hadronic Z decays.[1]

Events were selected based on the reconstructed charged tracks and electromagnetic showers. The charged tracks were required to pass through a cylinder around the measured IP of radius 0.01 m and half-length 0.03 m along the beam direction. The polar angles had to satisfy $|\cos\theta| < 0.82$, where θ is the polar angle relative to the beam direction. The momenta transverse to the beam direction were required to exceed 0.3 GeV/c.

Electromagnetic showers were measured in two systems. In the central calorimeter (lead–liquid argon) they were required to satisfy $|\cos\theta| < 0.68$ and be away from cracks between modules. The fiducial volume for the endcap calorimeter (lead–proportional tube) was defined to be $0.74 < |\cos\theta| < 0.95$. An energy greater than 0.5 GeV was required. Showers were not retained if associated with a charged track.

Events were required to have at least 5 charged tracks passing these cuts and an additional cut on the invariant hemisphere mass was used to eliminate τ decays with a 3–3 topology. The visible energy (calculated from showers and charged tracks assuming pion masses) was required to be greater than $0.4E_{cm}$. The number of events passing all selection criteria was 398. Backgrounds from beam-gas scattering, Z decays into lepton pairs and two-photon scattering were estimated to be less than 0.8 event.[3] Contamination from accelerator-related backgrounds was included by superimposing data from random beam crossings onto Monte Carlo (MC) events with detector simulation.

The data are compared with events simulated by three QCD-based MC event generators. The models used are the Lund parton shower model with string fragmentation (JETSET 6.3 shower),[4] the Webber-Marchesini parton shower model with cluster fragmentation (BIGWIG 4.1),[5] and the parton shower model of Gottschalk and Morris (Caltech-II 86) with a combined fragmentation method.[6] The parameters of these models were tuned to fit Mark II data at 29 GeV.[7] The Lund model based on second-order QCD matrix element calculations, again with string fragmentation, was not used because an extrapolation to 91 GeV is not possible without changing parameters which should be kept constant.[8]

The data were corrected for detector inefficiencies, resolutions and machine backgrounds using bin-by-bin correction factors derived from the JETSET 6.3 shower MC with full detector simulation. Charged particles from all K_S^0 and Λ decays were included in the corrected distributions. Typical correction factors were ~ 1.2, with a spread of $\sim 30\%$ for the different bins in each distribution. Systematic errors included differences between the QCD models. Corrections for QED radiative effects were included but were less than 2% for these data. All errors shown for these data have statistical and systematic uncertainties added in quadrature.

The charged-particle multiplicity distribution was not corrected using this bin-by-bin method because the correlations between bins are large. An unfold procedure[9] was used to measure the mean corrected charged-particle multiplicity to be $<n_{ch}> = 20.1 \pm 1.0 \pm 0.9$. This number is consistent with the extrapolation from the lower energy data. For comparison, the JETSET 6.3 shower model gives a multiplicity of 21.4, BIGWIG 4.1 predicts 20.1 and the Caltech-II model gives 22.5.

Figure 1(a) shows the corrected inclusive distribution $1/\sigma_{had}\ d\sigma_{trk}/dx$, where $x = 2p/E_{cm}$, compared with the predictions of the models. The quantities σ_{had} and σ_{trk} are the total hadronic and charged-particle inclusive cross sections, respectively. All of the models predict a spectrum consistent with the observed distribution. Figure 1(b) compares the results of this analysis with data from other e^+e^- experiments.[7,9,10] The solid line is the prediction of the JETSET 6.3 shower model. The higher x bins show small scaling violations, in agreement with this model and qualitatively expected from QCD. The increase in the lower x bins are due to the increase in available phase space for particle production.

The transverse momenta defined by the sphericity axes[11] in the event

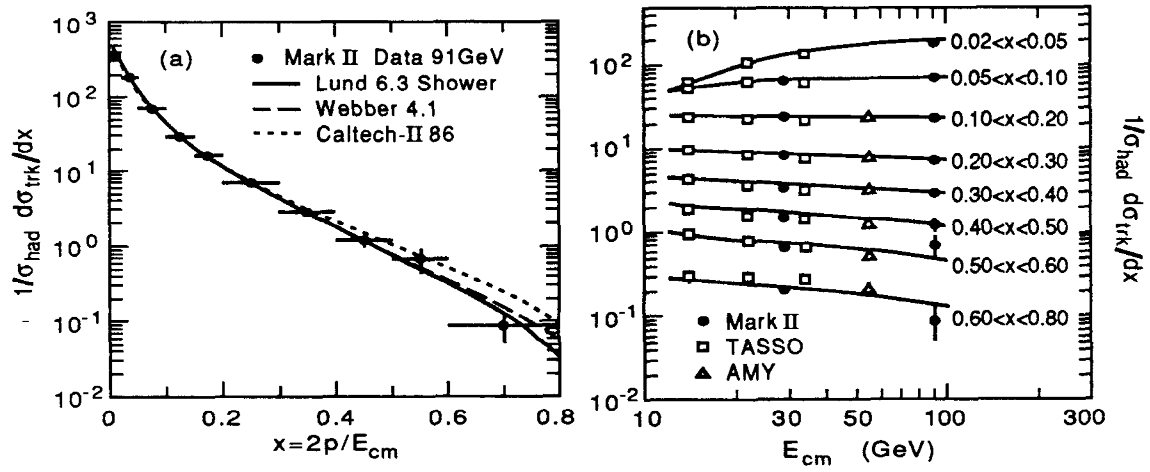

Fig. 1. (a) Corrected charged-particle inclusive distribution $1/\sigma_{had}\ d\sigma_{trk}/dx$, where $x = 2p/E_{cm}$, compared with several models. (b) Comparison between charged-particle inclusive distribution in x for hadronic Z^0 decays and e^+e^- experiments at lower E_{cm}.

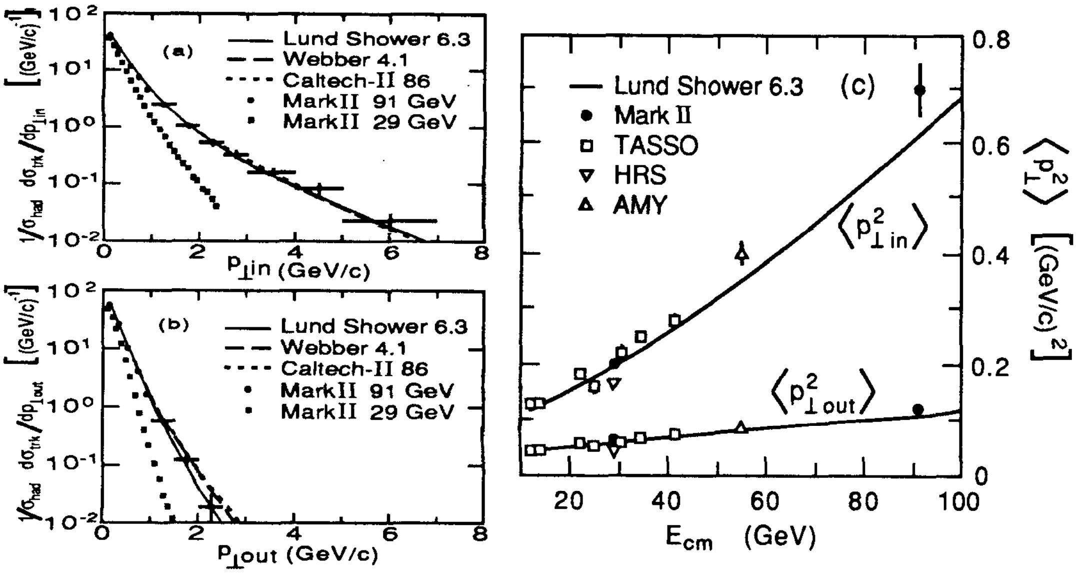

Fig. 2. Corrected charged-particle distributions (a) $1/\sigma_{had}\ d\sigma_{trk}/dp_{\perp in}$ and (b) $1/\sigma_{had}\ d\sigma_{trk}/dp_{\perp out}$ compared with the predictions of several models and with Mark II data at 29 GeV. (c) Comparison between means of $p^2_{\perp out}$ and $p^2_{\perp in}$ distributions for e^+e^- experiments at various E_{cm}.

plane ($p_{\perp in}$) and out ($p_{\perp out}$) are shown in figures 2(a) and 2(b). The $p_{\perp in}$ distribution is sensitive to 3–jet events whereas the $p_{\perp out}$ distribution sees effects from events with 4 or more jets. The distributions compare well with the model predictions. Mark II data taken at 29 GeV[7] is also shown for comparison. The corrected mean square values were measured to be $<p^2_{\perp in}> = 0.70 \pm 0.05$ (GeV/c)^2 and $<p^2_{\perp out}> = 0.121 \pm 0.005$ (GeV/c)^2, and these are compared with the results from other experiments in Figure 2(c).[7,9,10,12] The solid lines show the JETSET 6.3 shower model predictions, which are slightly below our measured values for both $<p^2_{\perp in}>$ and $<p^2_{\perp out}>$. The differences arise mainly from the tails of the data distributions which are broader than the MC predictions.

The charged-particle inclusive distributions presented here for hadronic decays of Z bosons are consistent with our extrapolations of the three models and lower energy data. These models also described the detected event shapes, such as sphericity, thrust, aplanarity and number of jets.[3] The small differences observed when compared with the data, e.g. in the momenta transverse to the sphericity axes, are not indicative of significant inadequacies in the models.

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