PRELIMINARY MEASUREMENT OF LEADING PARTICLE EFFECTS IN HADRONIC Z^0 DECAYS*

The SLD Collaboration**

Stanford Linear Accelerator Center

Stanford University, Stanford, CA 94309

ABSTRACT

We present preliminary evidence for leading particle production in hadronic decays of the Z^0 to light quark pairs using 150,000 events recorded in the SLD experiment at SLAC. The highly polarized electron beam produced by the SLC is used to tag quark and antiquark jets, and a signed impact parameter technique is employed to reject heavy-flavor events. Charged hadrons are identified in the SLD Cherenkov Ring Imaging Detector (CRID), and $\Lambda/\bar{\Lambda}$ are reconstructed using their charged decay modes. In a high-purity sample of quark jets, the baryon momentum spectrum is harder than that of the antibaryon, and conversely for a sample of antiquark jets, supporting the hypothesis that the faster particles in jets are more likely to carry the primary quark or antiquark from the Z^0 decay. Similarly, more high-momentum K^- than K^+ are observed in quark jets and conversely for antiquark jets, consistent with the hypothesis that leading $K^\pm$ are produced predominantly in $s\bar{s}$ events rather than $u\bar{u}$ events.

1 Introduction

A well-known feature of hadron-hadron and lepton-hadron interactions is that one particular particle in the final state often has a momentum close to the maximum permitted. This observation is commonly referred to as the "leading particle effect", and it has been related [1] to the quantum number flow from the initial state to the particle in the final state, on the basis that the particle which carries more constituents of the initial state will have a sizable fraction of the four-momentum of the initial state [1]. For example, in pp collisions there is an especially pronounced leading particle effect for protons in the final state, a smaller effect for Λ's, which contain two of the initial quarks, and no effect for antiprotons, which have no quarks in common with the incident proton. Several authors have discussed [2, 3] the leading particle effect by using quark jet models, assuming that valence quarks interact, and the spectator quark or diquark systems fragment into jets of particles with low transverse momentum. It has been noted that a leading particle effect of the type described above was not observed in early e^+e^- experiments [4], which is not surprising because of the absence of quarks in the initial state.

In this paper we consider a generalized definition of the leading particle effect. We define a particle to be leading if one of its constituent quarks is of the same type as a primary quark, for example the u or $\bar{u}$ in $e^+e^- \rightarrow Z^0 \rightarrow u\bar{u}$. Then the experimental question is whether the inclusive properties are different for particles that could be "leading" and those that could not.

Evidence from, e.g. lepton production at the Z^0 [5], suggests that in jets initiated by heavy *(b, c)* quarks, there is a single heavy hadron that carries a large fraction of the available energy, and the decays of such particles have been used to measure the forward-backward production asymmetries of heavy quarks in e^+e^- experiments [6]. Also, inclusive kaon production asymmetries in Z^0 decays have been interpreted in terms of s- quark production asymmetries [7] despite the background from decays of heavy hadrons in b and c jets. In this paper we consider light-quark jets and take a

more direct approach to the study of leading particles. We select a high-purity sample of tagged light quark (and antiquark) jets by utilizing the large electroweak production asymmetry in polar angle induced by the electron beam polarization at the SLAC Linear Collider (SLC). Having identified quark and antiquark jets, we consider the jets separately. We look for evidence of a leading particle effect by comparing the scaled momentum distribution of a given particle with that of its antiparticle in a pure sample of quark (or antiquark) jets.

Baryons provide an unambiguous signature, because a baryon can contain a primary quark but an antibaryon cannot. Since a meson is composed of a quark and an antiquark, a simple separation of quark and antiquark jets might not produce a signal. However, at the Z^0, there are different production rates of up- $(Z^0 \rightarrow u\bar{u})$ and down-type $(Z^0 \rightarrow d\bar{d}, s\bar{s})$ quarks, and so one might expect a small signal from mesons containing combinations like $u\bar{d}$ and $u\bar{s}$. In addition, if leading kaons are produced more often in $s\bar{s}$ than $u\bar{u}$ jets, then a signal might be observed. We present an analysis of scaled momentum spectra of $\Lambda, \bar{\Lambda}, p, \bar{p}, K^-, K^+, \pi^-$, and π^+, produced in light quark jets from hadronic Z^0 decays collected by the SLC Large Detector (SLD). The analysis is based upon the approximately 150,000 hadronic events from e^+e^- interactions at the Z^0 pole obtained in runs of the SLAC Linear Collider (SLC) between 1993 and 1995.

2 Apparatus and Hadronic Event Selection

This analysis uses charged tracks measured in the Central Drift Chamber (CDC) [8] and silicon Vertex Detector (VXD) [9]. Charged hadrons are identified in the Cherenkov Ring Imaging Detector (CRID) [10]. The trigger and initial selection of hadronic events is described in [11]. A set of cuts is applied in order to select events well-contained within the detector acceptance. Tracks are required to have (i) a closest approach to the beam axis within 5 cm, and within 10 cm along the beam axis of the measured

interaction point (IP), (ii) a polar angle θ with respect to the beam axis with $|\cos\theta| <$ 0.80, (iii) a minimum momentum transverse to this axis $(p_\perp)$ of 200 MeV/c, and (iv) a maximum momentum (p) of 50 GeV/c. Events are required to contain a minimum of seven such tracks, a thrust axis polar angle with respect to the beam axis θ_T within $|\cos\theta_T| < 0.71$, and a minimum charged visible energy $E_{vis} > 18$ GeV when all tracks are assigned the charged pion mass. A sample comprising 90,213 events passed these cuts. Of these, 76,445 events were recorded with a fully operational CRID.

Collisions at SLC are produced by highly polarized electron beams. For the 1993 and 1994/5 runs the average beam polarization magnitudes were 63% and 77%, respectively, and the beam helicity was selected randomly between collisions. The beam polarization induces a large asymmetry in the polar angle distribution of quark jets, which prefer to follow the electron (positron) beam direction for left- (right-)handed beam. Each event is divided into two hemispheres by the plane perpendicular to the thrust axis $\vec{t}$, and tracks with $\vec{p} \cdot \vec{t} > 0$ are defined to have come from a jet with polar angle $\theta_h = \cos^{-1}(t_z/|t|)$, where t_z is the component of the thrust axis along the electron beam direction. The remaining tracks are assigned $\theta_h = \cos^{-1}(-t_z/|t|)$. Hemispheres with $\cos\theta_h > 0.2$ produced with left-handed beam and those with $\cos\theta_h < -0.2$ produced with right-handed beam are tagged as quark jets. Hemispheres opposite quark-tagged jets are tagged as antiquark jets. The Standard Model at tree level predicts the purities of the quark- and antiquark-tagged samples to be about 73%.

To enrich the sample in primary light flavors, an additional cut is made, based on impact parameters of charged tracks measured in the VXD. All tracks passing a set of impact parameter quality cuts [12] were required to extrapolate to within three standard deviations of the IP in the plane transverse to the beam. The flavor composition of the light-flavor sample is estimated from our Monte Carlo simulation to be $uds : c : b = 85 : 12 : 3$.

3 Charged hadron and $\Lambda/\bar{\Lambda}$ analysis

The identification of charged hadrons uses the CRID and is described in detail in Refs. [13, 14]. Briefly, Cherenkov photons emitted by charged particles passing through liquid and gaseous radiators are detected in TPCs containing a photosensitive gas. A likelihood technique is employed, based upon the number of detected photoelectrons and their measured angles, the expected numbers and angles for each charged particle hypothesis $(\pi/K/p)$, and the estimated background. Particle separation is achieved by examining the difference in the logarithms of the likelihoods for the different particle hypotheses.

For each momentum bin, the number of observed particles identified as a given type is related to the true production fraction by an efficiency matrix. This matrix is determined using high-punt y samples of pions from K_s and τ decays, and protons from Λ decays. A detailed detector simulation is used to relate these measurements to efficiencies for global samples of tracks of each type in Z decays. Efficiencies for correctly identifying particles that pass a set of quality cuts are above 80% for most of the momentum range 0.5-35.0 GeV/c. There is a gap in K-p separation for momenta between 6 and 10 GeV/c. Misidentification rates are below 3% for all but a few narrow momentum regions which have peaks up to 8%. The efficiency matrix is inverted and applied to our observed rates of identified particles to obtain inclusive production rates of charged pions, kaons, and protons.

To measure the production of $\Lambda/\bar{\Lambda}$, all pairs of oppositely-charged tracks are considered as V^0 candidates if both tracks have (i) at least 40 hits in the CDC, (ii) a polar angle satisfying $|\cos\theta| < 0.80$, and (iii) $p_\perp > 0.15$ GeV/c. A vertex is fitted to each pair, and the probability of the resulting χ^2 is required to be greater than 2%. A minimum vector-sum momentum of 0.5 GeV/c is required. The vertex is required to be displaced from the IP by at least 5 standard deviations, which accepts V^0 candidates with flight lengths as low as 2 mm. A candidate is rejected if its vertex is located outside of the VXD but includes a track with more than one VXD hit. In the plane

perpendicular to the beam, the angle between the vector sum of the momenta of the two charged tracks and the line joining the IP to the secondary vertex is required to be less than the smaller of 60 mrad and $1.75 \cdot (2 + 20/p_\perp + 5/p_\perp^2)$ mrad, where $p_\perp$ is in units of GeV/c.

Cinematically-overlapped K_s are rejected from the Λ sample only for candidates whose vector-sum momentum is below 1.8 GeV/c, as above this momentum the "misidentified" K_s contribute a uniform background to the $p\pi$ invariant mass distribution. This rejection is done by removing all $\Lambda/\bar{\Lambda}$ candidates whose $\pi\pi$ invariant mass is within 3σ of the K_s mass, up to a maximum deviation of 30 MeV/c^2. This removes approximately 30% of the sample. Additionally, photon conversions are removed from the $\Lambda/\bar{\Lambda}$ sample by requiring that the helicity angle between the V^0 flight direction and the positive decay track in the V^0 rest frame satisfies $\cos\theta^* \geq$ –0.95. This removes approximately 2.5% of the $\Lambda/\bar{\Lambda}$ signal.

The remaining $\Lambda/\bar{\Lambda}$ candidates are divided into bins of scaled momentum $x_p = 2p/\sqrt{s}$. In each bin the number of observed $\Lambda/\bar{\Lambda}$ are derived from the $p\pi$ invariant mass distributions, where the faster track is assigned the proton mass. See Ref. [14] for additional details on the V^0 analysis.

4 Leading particle effects

Using the samples of q- and $\bar{q}$-tagged hemispheres described in Section 2, we derive differential production rates (per light quark jet per unit scaled momentum) of the eight hadrons $\Lambda, \bar{\Lambda}, p, \bar{p}, K^-, K^+, \pi^-,$ and π^+. We combine the positively charged tracks in the q- tagged jets and the negatively charged tracks in the $\bar{q}$-tagged jets, and perform the analysis described in Section 3 to obtain raw production rates of $p, K^+,$ and π^+ in q- tagged jets. The same procedure, using the negatively charged tracks in q- tagged jets and positively charged tracks in $\bar{q}$-tagged jets, yields raw rates of $\bar{p}, K^-,$ and π^- in q- tagged jets. An analogous procedure is employed for Λ and $\bar{\Lambda}$ rates. We

subtract the contributions to these samples from heavy quark events, estimated from the Monte Carlo simulation. For each hadron type *h,* the resulting rates are unfolded for the purity of the quark tagging to obtain differential production rates $R(q \rightarrow h)$ in light quark jets.

Figure 1 shows these corrected rates as a function of scaled momentum $x_p = 2p/\sqrt{s}$. The errors are dominated by statistics. Systematic uncertainties from the purity of the light-flavor and quark-jet tags and the subtraction of tracks from heavy quark events are negligible. Not shown are overall normalization uncertainties of 2% for π, K and *p,* and 3.4% for Λ. The production of baryons and antibaryons is approximately equal up to about x_p = 0.1, but differs thereafter. At very high scaled momenta, the data are consistent with no production of antibaryons in quark jets. The production of K^- and K^+ is also equal up to x_p = 0.1, but at higher scaled momenta there is significantly more K^- than K^+ production. In contrast to baryons and kaons, there is no significant difference between π^+ and π^- over our entire measured x_p range.

One way to quantify the leading particle effect is to define the difference between particle and antiparticle production rates normalized by their sum, e.g.

$$D_{\pi^-} = \frac{R(q \rightarrow \pi^-) - R(q \rightarrow \pi^+)}{R(q \rightarrow \pi^-) + R(q \rightarrow \pi^+)}$$

and similarly for D_{K^-}, D_p, and D_Λ. The systematic uncertainties largely cancel in this variable. Figure 2 shows these normalized differences as a function of x_p. For each, the differences are consistent with zero at low x_p. For the π's the difference is also consistent with zero at high x_p, whereas for the others a significant positive difference is observed for x_p above $\sim$ 0.15.

Since the baryons contain no constituent antiquarks, we interpret the positive normalized differences as clear evidence for leading baryon production in quark jets. The steep rise in D_p and D_Λ with increasing x_p suggests that baryon production is dominated by leading baryon production as $x_p \rightarrow 1$. If production of $\pi^\pm (K^\pm)$ mesons were dominated by leading meson production, *and* $\pi^- (K^-)$ were produced equally in jets containing primary $\bar{u}$ and *d(s)* quarks, then we would expect to observe normalized

8

differences of 0.13 for the mesons, due to the $22:17$ production ratio for $Z^0 \to d\bar{d}(s\bar{s})$:
$Z^0 \to u\bar{u}$. Our data are more consistent with $D_\pi = 0$ than $D_\pi = 0.13$ over the entire measured x_p range, suggesting some dilution of leading pions for $x_p \lesssim 0.7$. The effects of resonance decays such as the ρ^0 might be one source of dilution. Our measured D_K values above $x_p \simeq 0.2$ are consistently above 0.13, indicating both that *i)* there is leading kaon production at high momentum, and *ii)* leading kaons are produced more often in $s\bar{s}$ events than in $u\bar{u}$ events.

5 Summary

We have studied leading particle effects in hadronic Z^0 decays produced by e^+e^- interactions at the SLAC Linear Collider. The large electron beam polarization permits high-purity tagging of quark and antiquark jets via the electroweak production asymmetry. Impact parameters measured in the Vertex Detector are used to select light-flavor quark jets, and the identification of charged hadrons in the jets is achieved with the Cherenkov Ring Imaging Detector. $\Lambda/\bar{\Lambda}$ are identified by the charge of the high-momentum track in the V^0 reconstruction.

In the light quark jets, we observe an excess of Λ over $\bar{\Lambda}$, and an excess of p over $\bar{p}$. These differences increase with momentum, and provide direct evidence for the "leading particle" hypothesis that faster baryons are more likely to contain the primary quark. No such difference is observed between π^- and π^+ production. For kaons, we observe a significant excess of high momentum K^- over K^+, indicating that a fast kaon is likely to contain a primary quark (or antiquark) from the Z^0 decay, and that leading $K^\pm$ are produced predominantly in $s\bar{s}$ events rather than $u\bar{u}$ events.

Acknowledgments

thank G. Farrar for useful discussions.

References

[1] M. Basile *et al.,* Il Nuovo Cimento A **66** (1981) 129.

[2] M. Bardadin-Otwinowska *et al.,* Z. Phys. C **13** (1982) 83.

[3] N. Hashimoto, J. Phys. Soc. Japan **60** (1991) 2588.

[4] M. Basile *et al.,* Il Nuovo Cimento A **79** (1984) 1 and references therein.

[5] ALEPH Collaboration: D. Buskulic *et* al., Z. Phys. C **62** (1994) 179.
DELPHI Collaboration: P. Abreu *et al.,* CERN-PPE/95-08 (1995).
L3 Collaboration: B. Adeva *et al.,* Phys. Lett. B **261** (1991) 177.
OPAL Collaboration: R. Akers *et al.,* Z. Phys. C **60** (1993) 199.

[6] SLD Collaboration: K. Abe *et al.,* Phys. Rev. Lett. **74** (1995) 2895.
ALEPH Collaboration: D. Buskulic *et al., Z.* Phys. C **62** (1994) 179.
DELPHI Collaboration: P. Abreu *et al.,* Phys. Lett. B **276** (1992) 536.
OPAL Collaboration: P. Acton *et al.,* Z. Phys. C **60** (1993) 19.
L3 Collaboration: O. Adriani *et al.,* Phys. Lett. B **292** (1992) 454.

[7] P. Abreu *et al.,* Z. Phys. C **67** (1995) 1.

[8] M.D. Hildreth *et al.,* IEEE Trans. Nucl. Sci. **42** (1994) 451.

[9] C. J. S. Damerell *et al.,* Nucl. Inst. Meth. **A288** (1990) 288.

[10] K. Abe, *et al.,* Nucl. Inst. Meth. **A343** (1994) 74.

[11] SLD Collaboration, K. Abe *et al.,* Phys. Rev. Lett. **73** (1994) 25.

[12] K. Abe *et al.,* Phys. Rev. D **53** (1996) 1023.

[13] K. Abe *et al.,* "Preliminary Measurement of Production of π, K, p, K^0 and Λ in Hadronic Z^0 Decays", SLAC-PUB-7199, contributed to this conference.

[14] K.G. Baird, Ph.D. Thesis, Rutgers University, 1996, SLAC-R-483 (1996).

**List of Authors

K. Abe,[19] K. Abe,[29] I. Abt,[13] T. Akagi,[27] N.J. Allen,[4] W.W. Ash,[27]†

D. Aston,[27] K.G. Baird,[24] C. Baltay,[33] H.R. Band,[32] M.B. Barakat,[33]

G. Baranko,[9] O. Bardon,[15] T. Barklow,[27] A.O. Bazarko,[10] R. Ben-David,[33]

A.C. Benvenuti,[2] G.M. Bilei,[22] D. Bisello,[21] G. Blaylock,[6] J.R. Bogart,[27]

B. Bolen,[17] T. Bolton,[10] G.R. Bower,[27] J.E. Brau,[20] M. Breidenbach,[27]

W.M. Bugg,[28] D. Burke,[27] T.H. Burnett,[31] P.N. Burrows,[15] W. Busza,[15]

A. Calcaterra,[12] D.O. Caldwell,[5] D. Calloway,[27] B. Camanzi,[11] M. Carpinelli,[23]

R. Cassell,[27] R. Castaldi,[23](a) A. Castro,[21] M. Cavalli-Sforza,[6] A. Chou,[27]

E. Church,[31] H.O. Cohn,[28] J.A. Coller,[3] V. Cook,[31] R. Cotton,[4]

R.F. Cowan,[15] D.G. Coyne,[6] G. Crawford,[27] A. D'Oliveira,[7] C.J.S. Damerell,[25]

M. Daoudi,[27] R. De Sangro,[12] R. Dell'Orso,[23] P.J. Dervan,[4] M. Dima,[8]

D.N. Dong,[15] P.Y.C. Du,[28] R. Dubois,[27] B.I. Eisenstein,[13] R. Elia,[27]

E. Etzion,[4] D. Falciai,[22] C. Fan,[9] M.J. Fero,[15] R. Frey,[20] K. Furuno,[20]

T. Gillman,[25] G. Gladding,[13] S. Gonzalez,[15] G.D. Hallewell,[27] E.L. Hart,[28]

J.L. Harton,[8] A. Hasan,[4] Y. Hasegawa,[29] K. Hasuko,[29] S. J. Hedges,[3]

S.S. Hertzbach,[16] M.D. Hildreth,[27] J. Huber,[20] M.E. Huffer,[27] E.W. Hughes,[27]

H. Hwang,[20] Y. Iwasaki,[29] D.J. Jackson,[25] P. Jacques,[24] J. A. Jaros,[27]

A.S. Johnson,[3] J.R. Johnson,[32] R.A. Johnson,[7] T. Junk,[27] R. Kajikawa,[19]

M. Kalelkar,[24] H. J. Kang,[26] I. Karliner,[13] H. Kawahara,[27] H.W. Kendall,[15]

Y. D. Kim,[26] M.E. King,[27] R. King,[27] R.R. Kofler,[16] N.M. Krishna,[9]

R.S. Kroeger,[17] J.F. Labs,[27] M. Langston,[20] A. Lath,[15] J.A. Lauber,[9]

D.W.G.S. Leith,[27] V. Lia,[15] M.X. Liu,[33] X. Liu,[6] M. Loreti,[21] A. Lu,[5]

H.L. Lynch,[27] J. Ma,[31] G. Mancinelli,[22] S. Manly,[33] G. Mantovani,[22]

T.W. Markiewicz,[27] T. Maruyama,[27] H. Masuda,[27] E. Mazzucato,[11]

A.K. McKemey,[4] B.T. Meadows,[7] R. Messner,[27] P.M. Mockett,[31]

K.C. Moffeit,[27] T.B. Moore,[33] D. Muller,[27] T. Nagamine,[27] S. Narita,[29]

U. Nauenberg,[9] H. Neal,[27] M. Nussbaum,[7] Y. Ohnishi,[19] L.S. Osborne,[15]

R.S. Panvini,[30] H. Park,[20] T.J. Pavel,[27] I. Peruzzi,[12][b] M. Piccolo,[12]

L. Piemontese,[11] E. Pieroni,[23] K.T. Pitts,[20] R.J. Plano,[24] R. Prepost,[32]

C.Y. Prescott,[27] G.D. Punkar,[27] J. Quigley,[15] B.N. Ratcliff,[27] T.W. Reeves,[30]

J. Reidy,[17] P.E. Rensing,[27] L.S. Rochester,[27] P.C. Rowson,[10] J.J. Russell,[27]

O.H. Saxton,[27] T. Schalk,[6] R.H. Schindler,[27] B.A. Schumm,[14] S. Sen,[33]

V.V. Serbo,[32] M.H. Shaevitz,[10] J.T. Shank,[3] G. Shapiro,[14] D.J. Sherden,[27]

K.D. Shmakov,[28] C. Simopoulos,[27] N.B. Sinev,[20] S.R. Smith,[27] M.B. Smy,[8]

J.A. Snyder,[33] P. Stamer,[24] H. Steiner,[14] R. Steiner,[1] M.G. Strauss,[16] D. Su,[27]

F. Suekane,[29] A. Sugiyama,[19] S. Suzuki,[19] M. Swartz,[27] A. Szumilo,[31]

T. Takahashi,[27] F.E. Taylor,[15] E. Torrence,[15] A.I. Trandafir,[16] J.D. Turk,[33]

T. Usher,[27] J. Va'vra,[27] C. Vannini,[23] E. Vella,[27] J.P. Venuti,[30] R. Verdier,[15]

P.G. Verdini,[23] S.R. Wagner,[27] A.P. Waite,[27] S.J. Watts,[4] A.W. Weidemann,[28]

E.R. Weiss,[31] J.S. Whitaker,[3] S.L. White,[28] F.J. Wickens,[25] D.A. Williams,[6]

D.C. Williams,[15] S.H. Williams,[27] S. Willocq,[33] R.J. Wilson,[8]

W.J. Wisniewski,[27] M. Woods,[27] G.B. Word,[24] J. Wyss,[21] R.K. Yamamoto,[15]

J.M. Yamartino,[15] X. Yang,[20] S.J. Yellin,[5] C.C. Young,[27] H. Yuta,[29]

G. Zapalac,[32] R.W. Zdarko,[27] C. Zeitlin,[20] and J. Zhou,[20]

[1]*Adelphi University, Garden City, New York 11530*

[2]*INFN Sezione di Bologna, I-40126 Bologna, Italy*

[3]*Boston University, Boston, Massachusetts 02215*

[4]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*

[5]*University of California at Santa Barbara, Santa Barbara, California 93106*

[6]*University of California at Santa Cruz, Santa Cruz, California 95064*

[7]*University of Cincinnati, Cincinnati, Ohio 45221*

[8]*Colorado State University, Fort Collins, Colorado 80523*

[9]*University of Colorado, Boulder, Colorado 80309*

[10]*Columbia University, New York, New York 10027*

[11] *INFN Sezione di Ferrara and Università di Ferrara, I-44100 Ferrara, Italy*

[12] *INFN Lab. Nazionali di Frascati, I-00044 Frascati, Italy*

[13] *University of Illinois, Urbana, Illinois 61801*

[14] *Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720*

[15] *Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*

[16] *University of Massachusetts, Amherst, Massachusetts 01003*

[17] *University of Mississippi, University, Mississippi 38677*

[19] *Nagoya University, Chikusa-ku, Nagoya 464 Japan*

[20] *University of Oregon, Eugene, Oregon 97403*

[21] *INFN Sezione di Padova and Università di Padova, I-35100 Padova, Italy*

[22] *INFN Sezione di Perugia and Università di Perugia, I-06100 Perugia, Italy*

[23] *INFN Sezione di Pisa and Università di Pisa, I-56100 Pisa, Italy*

[24] *Rutgers University, Piscataway, New Jersey 08855*

[25] *Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX United Kingdom*

[26] *Sogang University, Seoul, Korea*

[27] *Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309*

[28] *University of Tennessee, Knoxville, Tennessee 37996*

[29] *Tohoku University, Sendai 980 Japan*

[30] *Vanderbilt University, Nashville, Tennessee 37235*

[31] *University of Washington, Seattle, Washington 98195*

[32] *University of Wisconsin, Madison, Wisconsin 53706*

[33] *Yale University, New Haven, Connecticut 06511*

†*Deceased*

[a] *Also at the Università di Genova*

[b] *Also at the Università di Perugia*

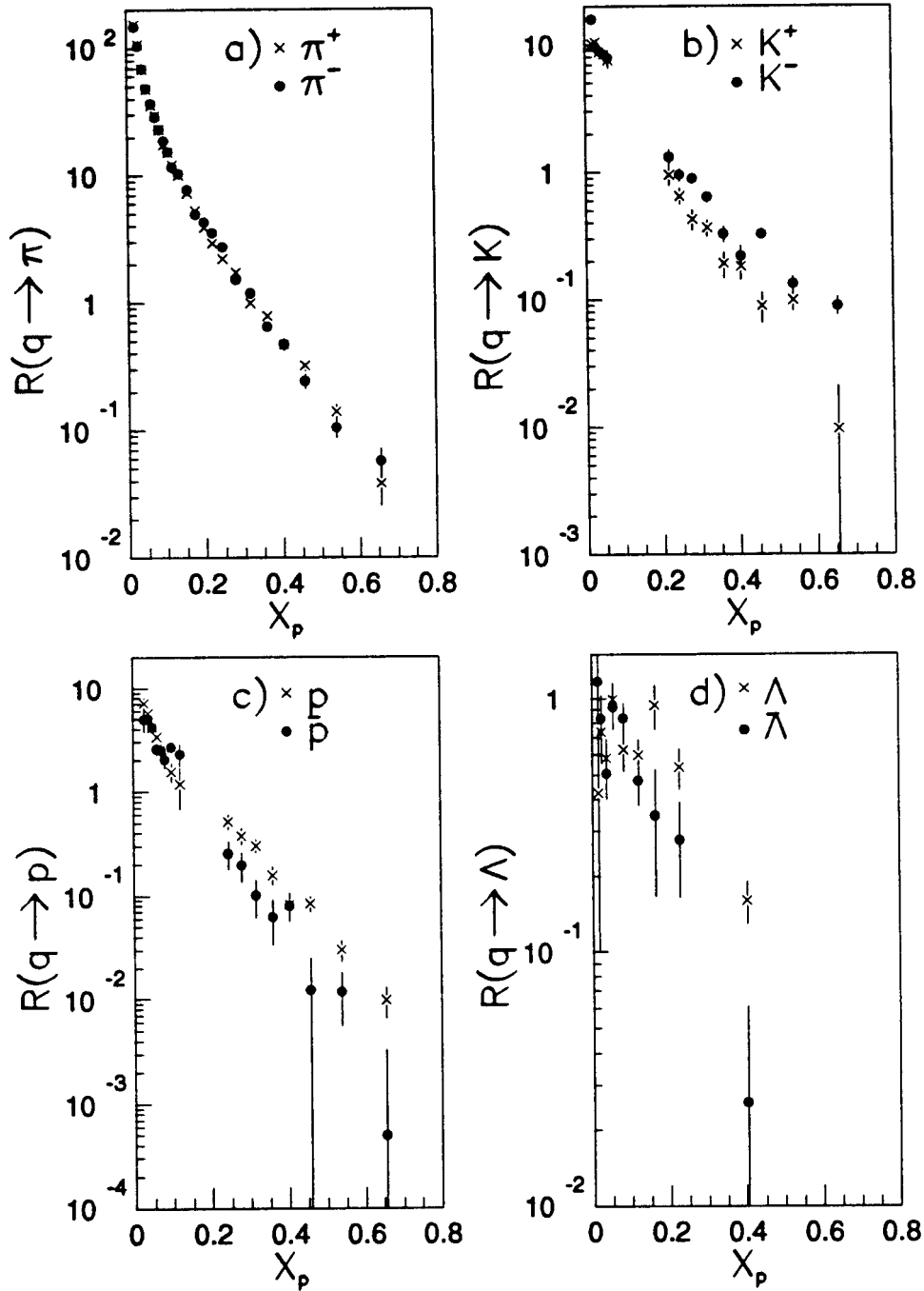Figure 1: Differential production rates as a function of scaled momentum for (a) π^- and π^+, (b) K^- and K^+, (c) p and $\bar{p}$, and (d) Λ and $\bar{\Lambda}$. The ordinates represent average multiplicities per light quark jet per unit interval in scaled momentum.

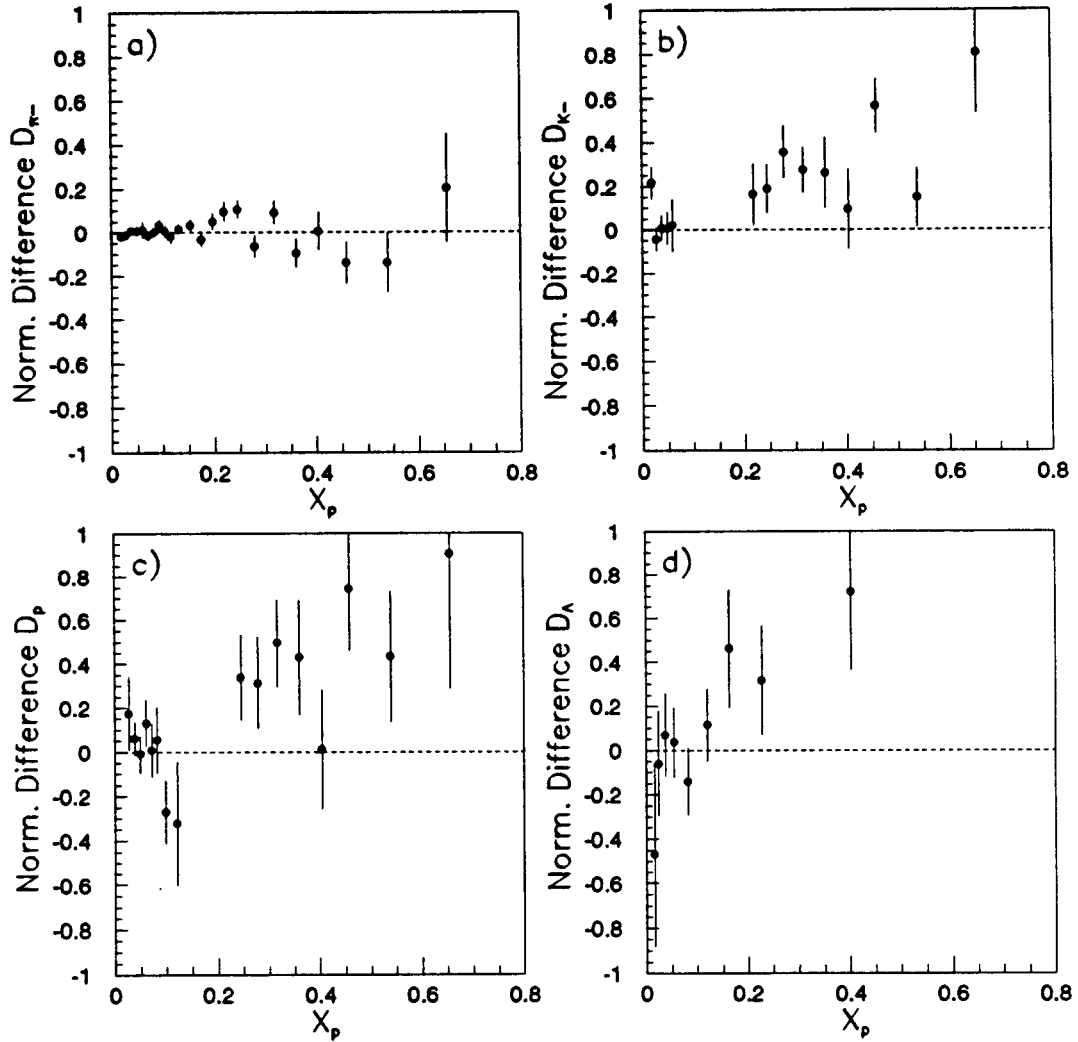Figure 2: Normalized production differences as a function of scaled momentum for (a) charged pions, (b) charged kaons, (c) protons and (d) Λ's.