Title

K*| AND Ks| MESON PRODUCTION IN e+e- ANNIHILATIONS AT 29 GeV

Permalink

https://escholarship.org/uc/item/14r1n5x1

Author

Aihara, H.

Publication Date

1984-09-01

LBL-18325
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

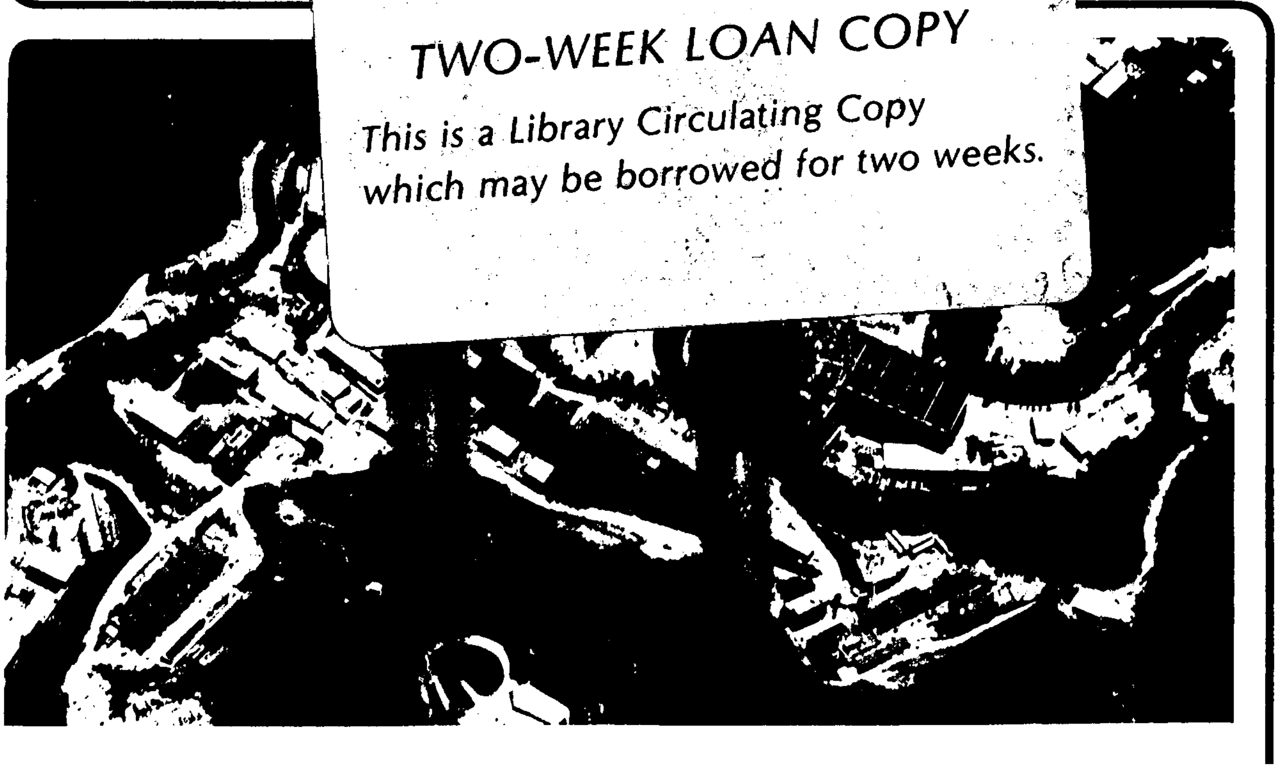
Physics Division

To be submitted for publication

K^{*0} AND K^0_S MESON PRODUCTION IN e^+e^- ANNIHILATIONS AT 29 GeV

PEP-4 TPC Collaboration

September 1984



Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

DISCLAIMER

K^{*0} and K_S^0 Meson Production in e^+e^- Annihilations at 29 GeV

H. Aihara, M. Alston-Garnjost, J.A. Bakken, A. Barbaro-Galtieri, A.V. Barnes, B.A. Barnett, B.J. Blumenfeld, A.D. Bross, C.D. Buchanan, O. Chamberlain, C-Y. Chien, A.R. Clark, A. Cordier, O.I. Dahl, C.T. Day, K.A. Derby, P.H. Eberhard, D.L. Fancher, H. Fujii, T. Fujii, B. Gabioud, J.W. Gary, W. Gorn, N.J. Hadley, J.M. Hauptman, W. Hofmann, J.E. Huth, J. Hylen, T. Kamae, H.S. Kaye, R.W. Kenney, L.T. Kerth, R.I. Koda, R.R. Kofler, K.K. Kwong, J.G. Layter, C.S. Lindsey, S.C. Loken, X-Q. Lu, G.R. Lynch, L. Madansky, R.J. Madaras, K. Maruyama, J.N. Marx, J.A.J. Matthews, S.O. Melnikoff, W. Moses, P. Nemethy, D.R. Nygren, P.J. Oddone, D.A. Park, A. Pevsner, M. Pripstein, P.R. Robrish, M.T. Ronan, R.R. Ross, F.R. Rouse, R.R. Sauerwein, G. Shapiro, M.D. Shapiro, B.C. Shen, W.E. Slater, M.L. Stevenson, D.H. Stork, H.K. Ticho, N. Toge, R.F. van Daalen Wetters, G.J. VanDalen, R. van Tyen, E.M. Wang, M.R. Wayne, W.A. Wenzel, H. Yamamoto, M. Yamauchi, W-M. Zhang

Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720,
University of California, Los Angeles, CA 90024,
University of California, Riverside, CA 92521,
Johns Hopkins University, Baltimore, MD 21218,
University of Massachusetts, Amherst, MA 01003, and
University of Tokyo, Tokyo 113, JAPAN

September 1984

Abstract

The inclusive production cross sections and transverse momentum distributions of K^{*0} and K_S^0 mesons in e^+e^- annihilation at a center of mass energy of $29\,GeV$ have been measured, using the Time Projection Chamber detector in the PEP-4 experiment. The mean multiplicities are found to be 0.49 ± 0.04(stat)± 0.07(syst) $(K^{*0} + \overline{K^*}^0)$, and 1.22 ± 0.03(stat)± 0.15(syst) $(K^0 + \overline{K}^0)$ per event.

PACS numbers: 13.65.+i, 14.40.Aq, 14.40.Ev

The study of resonance production in high-energy e^+e^- annihilations has a twofold significance. First, since resonance production is expected to be less dominated by decays of heavy particles as compared to stable hadrons, its dynamics is more directly related to the original momentum and quantum number flows in an event. Second, this type of data serves further to constrain various quark fragmentation models with a number of phenomenological parameters, among which is the production ratio of resonances and stable particles. In this letter we report measurements of K^{*0} and K^0_S production, based on data taken by the PEP-4 Time Projection Chamber (TPC) facility at the PEP storage ring at SLAC. The TPC has a typical momentum resolution of $(\delta p/p)^2 = (0.06)^2 + (0.035p)^2$ (p in GeV/c), and identifies charged particles by dE/dx measurement with a typical resolution of 3.7 %.[1] The event selection criteria have been described elsewhere.[2] The data sample consists of 29100 events, corresponding to an integrated luminosity of $77\,pb^{-1}$ at a center of mass energy of $29\,GeV$.

The K^{*0} and $\overline{K^*}^0$ (hereafter, we write only the particle state to indicate both particle and antiparticle states) are reconstructed in the decay mode $K^{*0} \to K^+\pi^-$, where both K^+ and π^- are identified by the TPC. The charged track selection and particle identification follow the procedure described in Ref.3. In this analysis a charged track is counted as a K^+ or π^- if its particle weight $W(K)$ or $W(\pi)$ exceeds 0.5. This results in K (π) sample purities of 55–90% (85–95%) and efficiencies of 50–70% (50–70%), depending on the momentum. Figure 1a) and b) show the $K\pi$ invariant mass spectra in the range $0.0618 < x < 0.800$ ($x = 2E/\sqrt{s}$) for opposite-sign and like-sign combinations, respectively. A prominent peak is seen for the opposite-sign combinations in the K^* region ($M_{K\pi} \simeq 0.89\,GeV$), but is absent for the like-sign combinations. The spectrum is well fitted with a smooth background plus a P-wave Breit-Wigner resonance shape as shown by solid curves in Figure 1a). We find 2750 ± 104 entries, $M = 900.5 \pm 3.6\,MeV$,[4] and $\Gamma = 88.1 \pm 9.5\ MeV\,(FWHM)$ for the peak, consistent with the K^{*0} intrinsic width ($50.2\ MeV$) folded in with the detector resolution. Effects of $\rho^0 \to \pi^+\pi^-$, $\omega \to \pi^+\pi^-\pi^0$, $K^0_S \to \pi^+\pi^-$, $D \to K^-\pi^+X$ (with the $K\pi$ pair not coming from K^{*0}), and photon conversion pairs, whose products were taken to be a $K\pi$ pair, are estimated with a Monte-Carlo calculation.[5] They form only a small structure in the K^* region as shown by the dashed curve in Figure 1a), and are comparable with statistical fluctuations of the overall background level. This justifies the use of a single smooth background in our analysis.

Neutral K-meson production is studied by reconstructing the decay $K^0_S \to \pi^+\pi^-$, whose decay vertex is separated from the event-vertex. Combinations are formed for opposite-sign pairs of tracks each of which satisfies : 1) momentum p exceeds $0.15 GeV/c$, 2) estimated error in the momentum measurement fulfills $\delta p/p < 0.4$ or $\delta p/p^2 < 0.3$, 3) χ^2 $(DOF = 1)$ for a $\pi^\pm$ hypothesis calculated from the momentum and dE/dx is smaller than 7, and 4) distance of closest approach to the event-vertex is larger than $\sqrt{0.04 + 0.02/p^2}\ cm$. A track pair is accepted as a K^0_S candidate if, 1) the minimum 3-dimensional distance between the tracks is smaller than $0.5\ cm$, 2) the momentum vector of the pair points within $14°$ to the event vertex, and 3) the flight path from the event vertex is longer than $1.5\ cm$. Pairs whose tracks are consistent with photon conversions are rejected. Figure 2 shows the $\pi^+\pi^-$ effective mass spectra in the range $0.05 < x < 0.60$. Fitting the spectrum with a smooth background plus a Gaussian line shape (indicated by the solid smooth curve in Figure 2), results in 2076 ± 52 entries, $M = 499.7 \pm 0.6\ MeV$,[4] and $\sigma(rms) = 23.3 \pm 0.5\ MeV$ for the peak, consistent with our detector resolution.

The production rates of K^{*0} and K^0 are obtained as functions of x and p_T^2 (p_T is the transverse momentum relative to the thrust axis) by using the fitted $K\pi$ and $\pi\pi$

mass spectra in various energy and p_T^2 intervals, assuming half of K^0 would turn out to be K_S^0. Background shapes are inferred from a Monte-Carlo calculation.[5] Due to the large Q value ($0.288\, GeV/c$) of its decay, the acceptance for K^{*0} is nearly constant ($15-20\%$) over a wide momentum range. The K_S^0 acceptance varies between 6 and 20%, with a momentum dependence dominated by the cut on flight path.

The K^{*0} and K^0 rates, corrected for acceptance and effects of initial state radiation,[6] are stable against changes in track selection and particle identification cuts. However, our Monte-Carlo study shows that the shape and the magnitude of the $K\pi$ background in the K^{*0} analysis are sensitive to uncertainties in the multiplicities and momentum distributions of $\pi^{\pm}$ and $K^{\pm}$ to be assumed for the annihilation events. Therefore, we assign systematic errors of typically 15% for K^{*0} rates, dominated by uncertainties in the background subtraction. The results are summarized in Figure 3, Figure 4 and Table 1. We observe an average of $0.49 \pm 0.04 \pm 0.07$ $(K^{*0} + \overline{K^*}^0)$ per event in the range $0.0618 < x < 0.8$, and $1.07 \pm 0.03 \pm 0.13$ $(K^0 + \overline{K}^0)$ in $0.05 < x < 0.6$. The first error quoted is statistical and the second systematic. The Lund Monte-Carlo program[5] predicts that 99.7% of K^{*0} and 87.6% of K^0 are contained within these energy ranges, inferring the total multiplicities of K^{*0} (K^0)[7,8] to be $0.49 \pm 0.04 \pm 0.07$ $(1.22 \pm 0.03 \pm 0.15)$. Our K^0 multiplicity is consistent with the results from experiments at PETRA[9] and with the $K^{\pm}$ rate reported by the TPC.[2]

The measured average p_T^2 relative to the thrust axis is $0.57 \pm 0.07 \pm 0.03 (GeV/c)^2$ for K^{*0} in $0.0618 < x < 0.8$, and $0.51 \pm 0.10 \pm 0.18 (GeV/c)^2$ for K^0 in $0.05 < x < 0.6$. Predictions of the Lund model in the same ranges are $0.59 (GeV/c)^2$ for K^{*0} and $0.49 (GeV/c)^2$ for K^0, both consistent with our measurement. For comparison, the average p_T^2 for $\pi^{\pm}$ measured by this experiment is $0.30 \pm 0.01 \pm 0.02 (GeV/c)^2$ in $x > 0.01$. The p_T^2 distributions, including $\pi^{\pm}$ data, are shown in Figure 4.

These results, together with our previously measured production rates of $K^\pm$ (Ref. 2) permit us to estimate the ratio $V/(V+P)$, fraction of vector meson production for strange mesons.[10] Using the measured D^*/D production ratio,[11] the assumption that 13% of primary charm would turn into F or F^* mesons, and the measured charm/bottom decay branching ratios,[12] we estimate the multiplicity of $K^\pm$ (K^0) from charm/bottom decays to be 0.41 ± 0.06 (0.34 ± 0.07). After subtracting these contributions and effects of ϕ decays, the number of $K^\pm$ (K^0) which are of non-charm/bottom and non-ϕ origin is 0.86 ± 0.15 (0.82 ± 0.16). Similarly,[12] the K^{*0} multiplicity from non-charm and non-bottom origin is estimated to be 0.39 ± 0.11. Assuming that K^{*0} and $K^{*\pm}$ are produced at an equal rate, we obtain $V/(V+P) = 0.47 \pm 0.11 \pm 0.09$, where the first error is experimental, and the second error comes from ambiguities in charm/bottom decay branching ratios. This is in fair agreement with the values reported by TASSO[13] and JADE.[8]

Using the ratio of our measured production rates for ϕ (Ref.3) and K^{*0}, we can estimate the suppression factor of $s\bar{s}$-quark pair production from the vacuum – the s/u ratio. From $2N(\phi)/N(K^{*0})$, with corrections for charm/bottom decays and primary strange quarks, we obtain $s/u = 0.37 \pm 0.15 \pm 0.08$. Also, by comparing K^{*0} and TASSO's ρ^0 rates,[13] we get $s/u = 0.32 \pm 0.09 \pm 0.05$ from $N(K^{*0})/2N(\rho^0)$. We observe that both the ϕ/K^{*0} and K^{*0}/ρ^0 production ratios appear to be governed by a single parameter s/u, as assumed in many quark fragmentation models.

We acknowledge the efforts of the PEP staff, and the engineers, programmers and technicians of the collaborating institutions who made this work possible. This work was supported by the Department of Energy under contracts numbers DE-AC03-76SF00098, DE-AM03-76SF00034, and DE-AC02-76ER03330, the National Science Foundation, and the Joint Japan-U.S. Collaboration in High Energy Physics.

Table 1. The inclusive K^{*0} and K^0 production rates normalized to the total annihilation cross section into hadrons. Here $x = 2E/\sqrt{s}$ and β is the particle velocity. The first error quoted is statistical, the second is systematic.

$e^+e^- \to K^{*0},\bar{K}^{*0} + X$			$e^+e^- \to K^0,\bar{K}^0 + X$		
x	$\langle x \rangle$	$(1/\sigma_h\beta)(d\sigma/dx)$	x	$\langle x \rangle$	$(1/\sigma_h\beta)(d\sigma/dx)$
0.0618-0.10	0.079	5.80±0.66±0.63	0.05-0.075	0.062	9.27±0.91±2.19
0.10-0.20	0.14	2.01±0.28±0.35	0.075-0.10	0.086	6.61±0.55±0.80
0.20-0.30	0.25	0.92±0.16±0.14	0.10-0.15	0.12	4.91±0.29±0.42
0.30-0.40	0.35	0.53±0.10±0.06	0.15-0.20	0.17	3.15±0.17±0.24
0.40-0.60	0.48	0.18±0.04±0.02	0.20-0.25	0.22	2.40±0.14±0.19
0.60-0.80	0.67	0.038±0.016±0.007	0.25-0.30	0.27	1.57±0.21±0.15
			0.30-0.40	0.34	0.87±0.10±0.10
			0.40-0.60	0.68	0.27±0.04±0.03

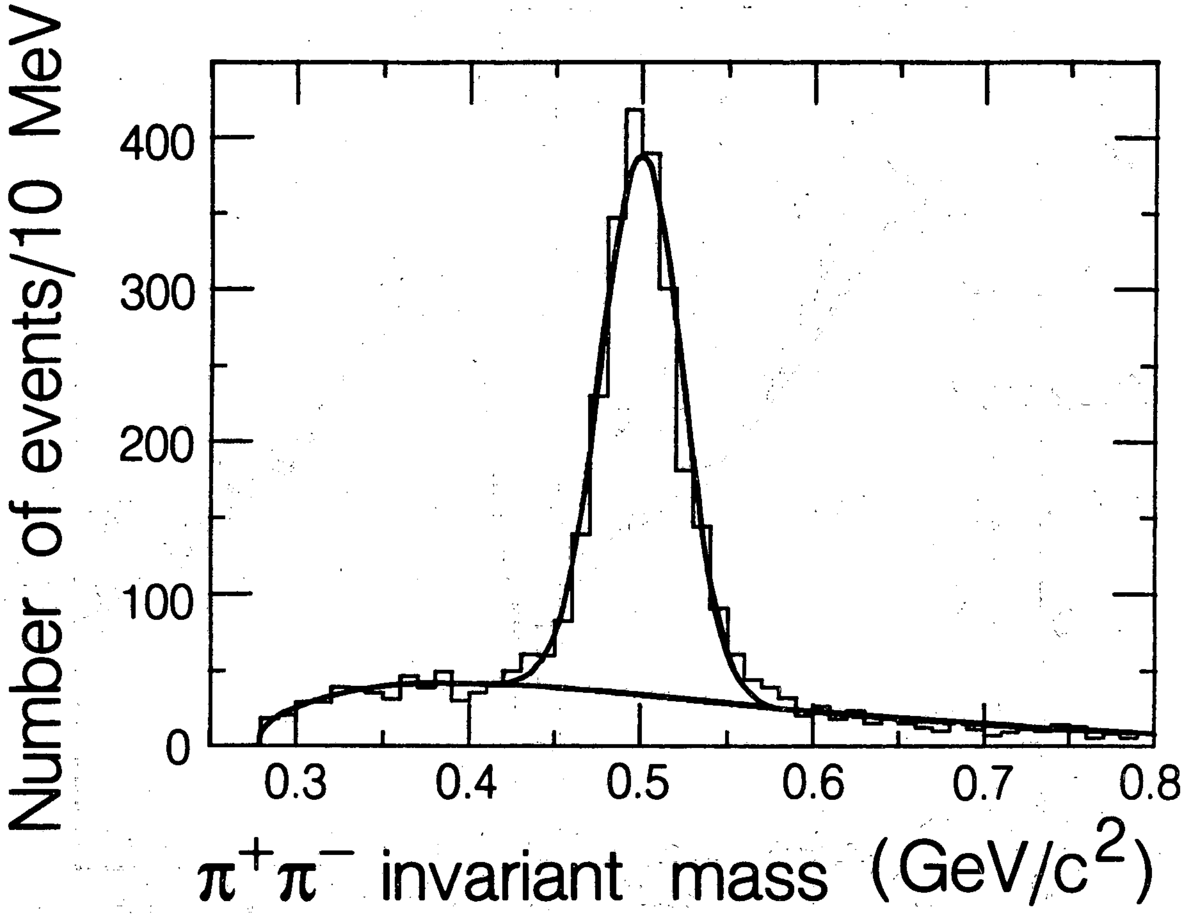
References

1. H. Aihara et al. (TPC), IEEE Trans. Nucl. Sci. NS-30, 63, 67, 76, 117, 153 (1983).
2. H. Aihara et al. (TPC), Phys. Rev. Lett. 52, 577 (1984).
3. H. Aihara et al. (TPC), Phys. Rev. Lett. 52, 2201 (1984).
4. The error is statistical only. The systematic error in the mass due to uncertainty in the magnetic field is estimated to be 0.5 %.
5. We use the Lund model, B. Andersson et al., Z. Phys. C 20, 317 (1983), in conjunction with our detector simulation program. See Ref.3.
6. F.A. Berends and R. Kleiss, Nucl. Phys. B 178, 141 (1981).
7. Consistent results have been recently reported for the MARK II collaboration. J. Kadyk, to be published in the Proceedings of the Int. Conf. on High Energy Physics, Leipzig (1984).
8. W. Bartel et al. (JADE) DESY-84-058 (to be published) reports $0.87 \pm 0.16(\text{stat}) \pm 0.08(\text{syst})$ $K^{*\pm}$/event, larger than our measured K^{*0} multiplicity by 2 standard deviations. Within the Lund model, they obtain $V/(V+P) = 0.70 \pm 0.15 \pm 0.11$. It also reports $0.98 \pm 0.09 \pm 0.15$ ρ^0/event.
9. R. Brandelik et al. (TASSO), Phys. Lett. 94B, 91 (1981) ; Ch. Berger et al. (PLUTO), Phys. Lett. 104B, 79 (1981) ; W. Bartel et al. (JADE), Z. Phys. C 20, 187 (1983).
10. In arguments in this and the next paragraphs we implicitly assume that the productions of higher spin mesons ($J^P = 1^+, 2^+, \ldots$) and baryon resonances can be neglected.

11. J.M. Yelton et al. (MARK II), Phys. Rev. Lett. 49, 430 (1982) ; S. Ahlen et al. (HRS), Phys. Rev. Lett. 51, 1147 (1983). The ambiguity in the $D/D^*/F/F^*$ ratio affects our values of V/(V+P) and s/u by less than $3\,\%$.

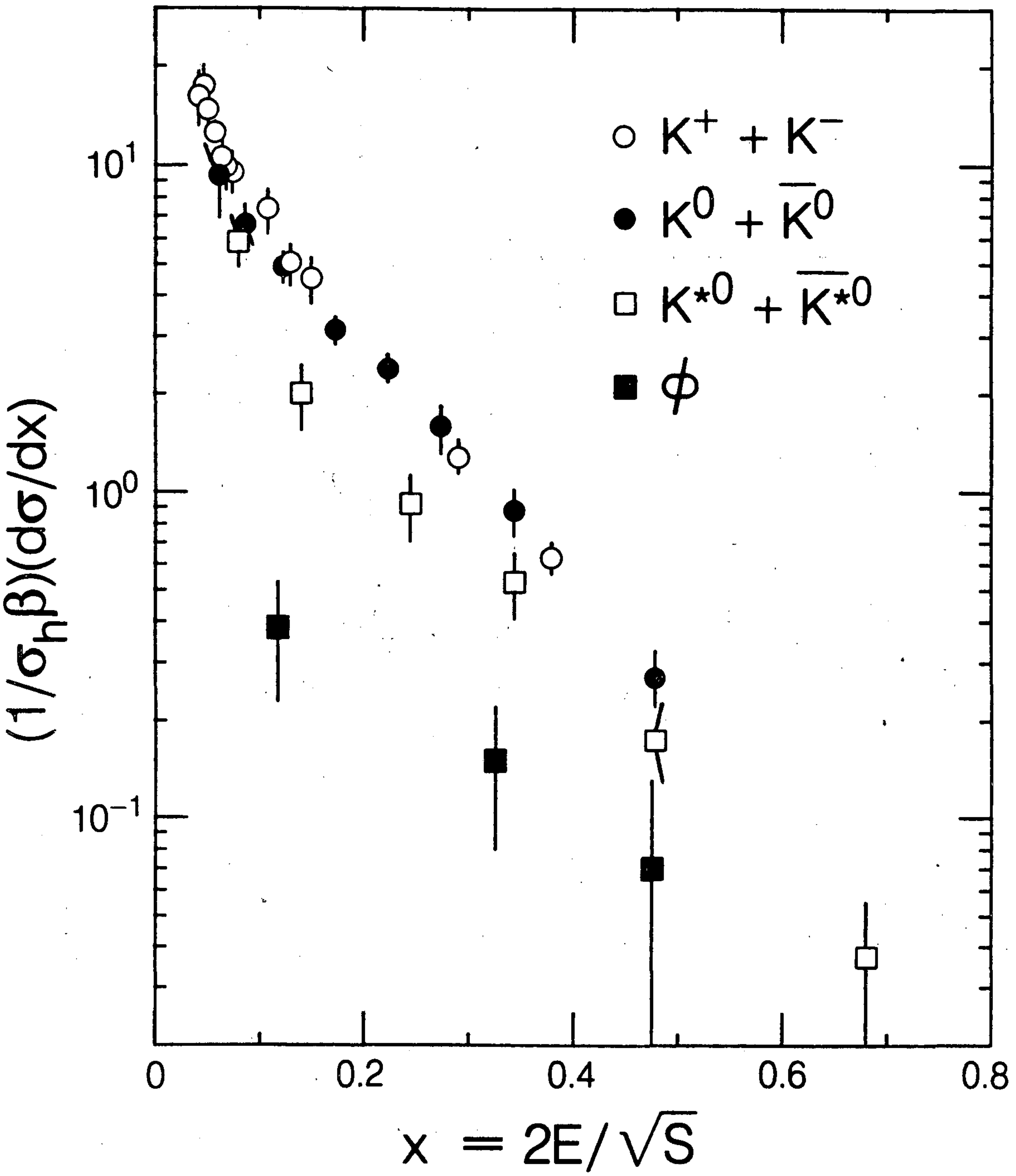
12. R.H. Schindler et al. (MARK II), Phys. Rev. D 24, 78 (1981) ; J. Green et al. (CLEO), Phys. Rev. Lett. 51, 347 (1983). We also assume D and F decay branching ratios as follows : $BR(D \to K^*X) = BR(D \to \rho^0 X) = BR(F \to K^*X) = 10 \pm 10\,\%$, $BR(F \to K^0 \; or \; \overline{K}^0 X) = BR(F \to K^{\pm} X) = 50 \pm 25\,\%$. Note that a K-$\overline{K}$ pair is often expected as decay products of F.

13. R. Brandelik et al. (TASSO), Phys. Lett. 117B, 135 (1982) reports 0.22 ± 0.02(stat)± 0.05(syst) ρ^0/event in $0.2 < x < 0.7$. Within a Field-Feynman fragmentation model, they obtain $V/(V+P) = 0.58 \pm 0.08 \pm 0.15$. Using a prediction of the Lund model, we estimate the total ρ^0 multiplicity to be $0.72 \pm 0.07 \pm 0.16$/event.



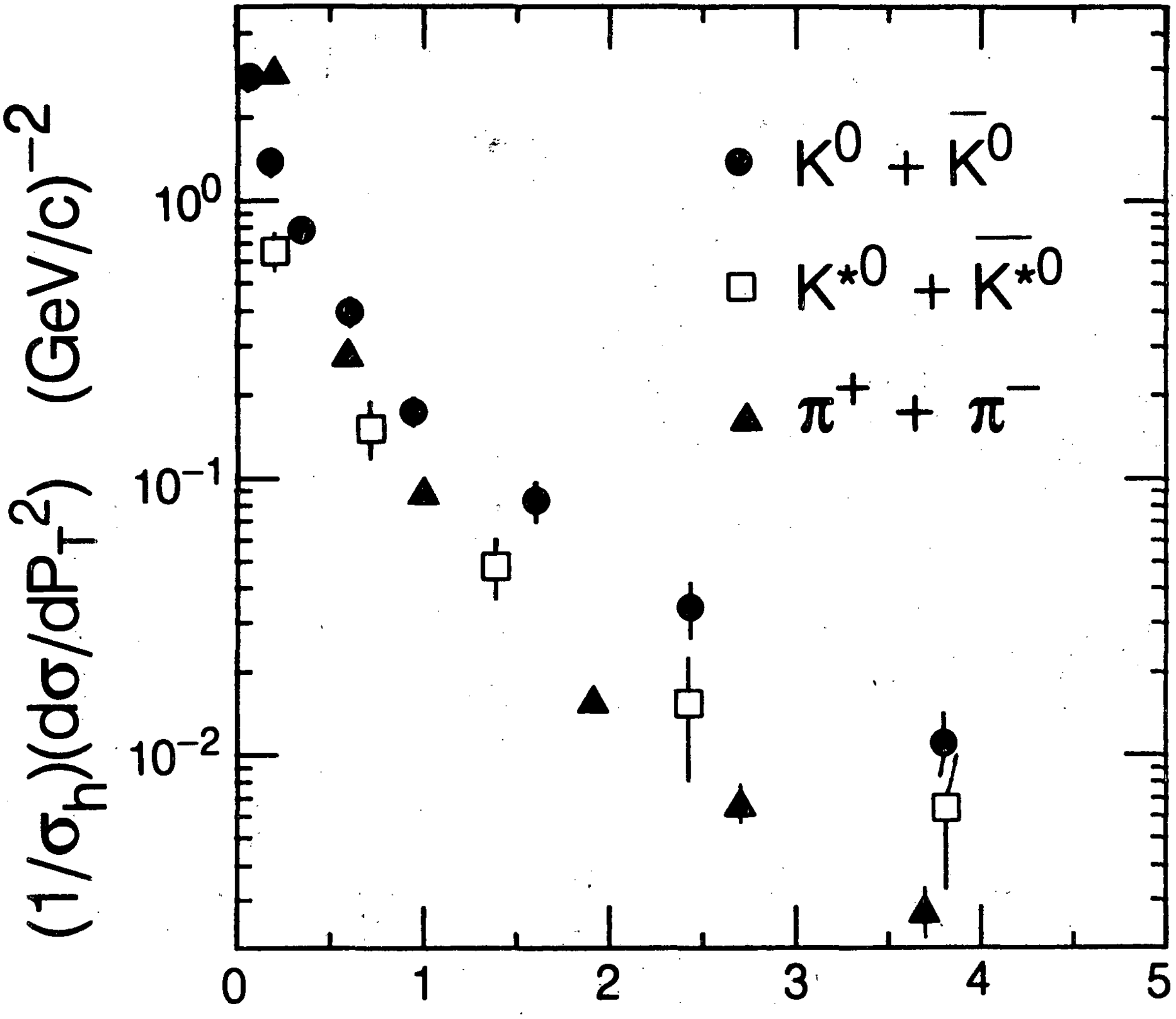
XBL 847 8518

Figure 2



XBL 847 8519

Figure 3



XBL 847 8520

Figure 4

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720