LBL--30734

DE92 000853

MESON AND BARYON CORRELATION STUDIES USING THE PEP-TPC/2γ FACILITY[1]

Michael T. Ronan
Physics Division, Lawrence Berkeley Laboratory
1 Cyclotron Rd, Berkeley, CA 94720

March, 1991

[1]This work was supported by the Director, Office of Energy Research Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

MESON AND BARYON CORRELATION STUDIES
USING THE PEP-TPC/2γ FACILITY

Michael T. Ronan
Lawrence Berkeley Laboratory
University of California, Berkeley
California 94720, USA

Representing the TPC/Two-Gamma Collaboration

ABSTRACT

Results on vector meson, and strange and charmed-baryon production are presented for data taken during the period 1982-1986 using the TPC/2γ detector at PEP. Vector mesons (ρ^0, K^* and ϕ) with 0, 1 and 2 strange quarks are used to obtain redundant measures of strange-quark suppression and of the vector to pseudoscalar ratio in hadronization. Measurements of the production rates of Λ, Ξ^-, Ω and Ξ^{*0} hyperons and for the Λ_C and of rapidity correlations between $\Lambda\overline{\Lambda}$ pairs provide sensitive tests of baryon production in fragmentation models. In addition, two- and three-particle correlations between like sign pions provide further evidence for the Bose-Einstein effect in e^+e^- interactions including the relativistic motion of particle sources.

Presented at the XXVIth Rencontre de Moriond, Les Arcs, France, March 17 - 23, 1991.

1. Introduction

Measurements of vector meson production provide an important probe of the hadronization process, for these particles are not as diluted as are the pseudoscalars by the decays of higher-mass states. I will report on unpublished measurements[1-2] of total multiplicities for ρ^0, K^{*0}, $K^{*\pm}$ and ϕ vector meson production. Combining these measurements with values for π and K production, we obtain redundant measures of strange-quark suppression and of the vector to pseudoscalar production ratio in hadronization.

Next, I will present a study[3] of Bose-Einstein interference effects, enhancements observed for pairs of particles produced in the hadronization process at small four-momentum difference, $q = (q_0, \mathbf{q}) = p_1 - p_2$. Measurements by several groups[4-6] indicate that Bose-Einstein correlations are well described by a function that depends only on $Q \equiv \sqrt{-q^2}$. To test if the enhancement disappears for pairs that are highly boosted, we measure the correlation function as a function of both Q and the energy difference in the laboratory frame, $q_0 = E_1 - E_2$.

Due to the high mass of strange and charmed baryons, their inclusive production rates give direct tests of various hadronization models, while their flavor correlations probe the detailed color confinement mechanism in the baryon formation process. Lastly, I will report on new preliminary results for Λ, Ξ^-, and Ω production and first observation of Ξ^{*0} and Λ_C production at $\sqrt{s} = 29$ GeV, and then compare our measurement of $\Lambda\overline{\Lambda}$ correlations with predictions of the Lund[7] and UCLA[8] models.

2. Inclusive Vector Meson Production

Data were recorded during 1982-1983 and 1984-1986 at PEP using the TPC/2γ Detector Facility with low-field (4 kG) and with high-field (13.2 kG) magnets. The detector and trigger systems as well as the hadronic event selection criteria are described in detail elsewhere[9]. Utilizing the unique particle identification capabilities of the TPC, pions and kaons are selected to form the mass spectra shown in Fig. 1 for $\pi^\pm$ pairs, charged pions plus charged and neutral kaons, and K$^\pm$ pairs. The observed signal to background varies from the ρ^0, at a level which is comparable to other experiments, to the ϕ, which is seen with superb separation. Extrapolating our measured differential cross sections to threshold, we determine the following multiplicites per event: for the ρ^0, N(ρ^0) = $0.77 \pm 0.08 \pm 0.15$; for charged and neutral K^*, N($K^{*\pm}$) = $0.54 \pm 0.08 \pm 0.06$ and N(K^{*0}) = $0.58 \pm 0.05 \pm 0.11$; and for the ϕ, N(ϕ) = $0.079 \pm 0.008 \pm 0.010$.

Subtracting the expected contribution to vector meson production from decays of charmed and bottom mesons, we perform a global Lund model fit to the number of primary ρ^0,K^*,ϕ and to world-average values for the total number of $\pi^\pm$ and K$^\pm$, varying the Lund Symmetric Fragmentation Function parameter a, the strange quark suppression factor, $\frac{s}{u}$, and the fraction of vector mesons, $\frac{V}{(V+PS)}$, while setting the $\frac{V}{(V+PS)}$ ratio for strange mesons equal to that for the light non-strange mesons. We obtain a good fit, with χ^2= 0.7 for two degrees of freedom, with $a = 1.10 \pm 0.29$, $\frac{s}{u}$= 0.30 ± 0.03 and $\frac{V}{(V+PS)}$= 0.45 ± 0.11. Each value is consistent with previous measurements, and the determination of strange quark suppression is obtained with errors comparable to the previous world average errors[8].

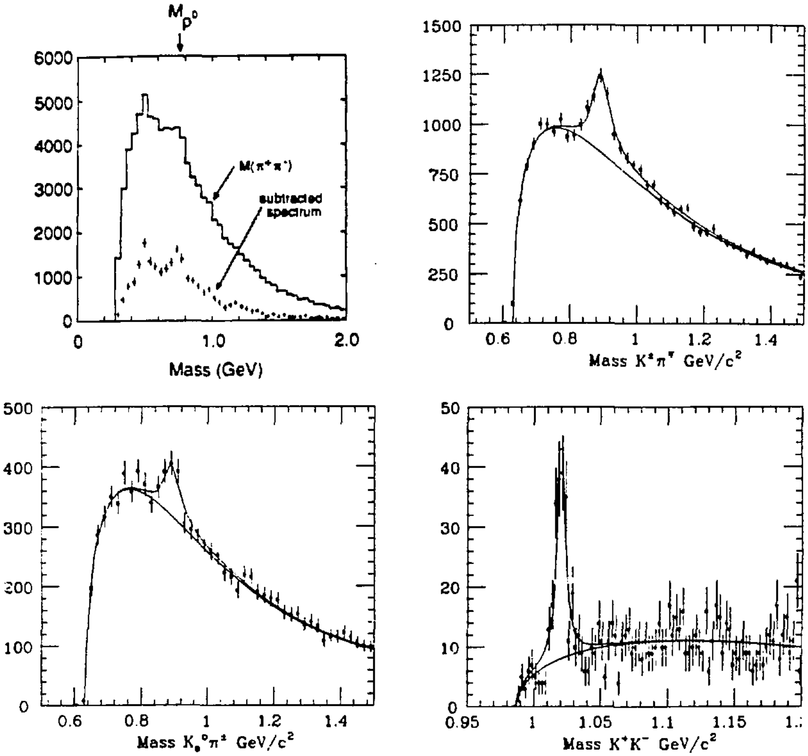

Figure 1: Mass spectra for $\rho^0\to\pi^+\pi^-$, $K^{*0}\to K^\pm\pi^\mp$, $K^{*\pm}\to K^0_s\pi^\pm$, and $\phi\to K^+K^-$.

3. Bose-Einstein Correlations

We measure two-pion Bose-Einstein correlations using a correlation function defined as:

$$R(Q) = P(Q)/P_0(Q), \tag{1}$$

where $P(Q)$ is the probability distribution of like-sign pion pairs and $P_0(Q)$ is a similar reference distribution in which the correlations are absent. We choose two methods to determine appropriate reference distributions: One method uses unlike-signed pairs, which have the same correlations due to jet structure and energy conservation as like-sign pairs; the other uses event mixing by which tracks from two different events are combined to form a pair with the kinematic variables being determined from the momenta of the particles relative to the event axis in each event. Corrections for expected correlations, such as due to resonance production, and for detector acceptance effects are described in Ref.[3)].

Here, we present the correlation function, $R(Q)$, using the unlike-sign and mixed-event reference distributions normalized with the correlation function obtained from Monte Carlo simulations. To determine how well Bose-Einstein correlations can be described as depending only on Q, we form $R(Q)$ in bands of q_0 for each method as shown in Fig. 2. The correlation function is fit to the following function with 4 parameters,

$$R(Q) = A(1 + BQ)(1 + \alpha \exp[-(rQ)^2]), \tag{2}$$

where α is interpreted as the amount of enhancement at $Q = 0$, r as the effective size of the source of pions, and A,B describe a linear background term and an overall normalization. Fixing the background parameters, A and B, at values obtained in a separate fit to the data averaged over q_0, we plot our results for the remaining parameters as a function of q_0 in Fig. 3. We observe that a significant Bose-Einstein enhancement is obtained when Q is small even when the energy difference, q_0, is substantial. Thus providing evidence that the Bose-Einstein correlations are best described by models that account for the relativistic motion of the particle sources.

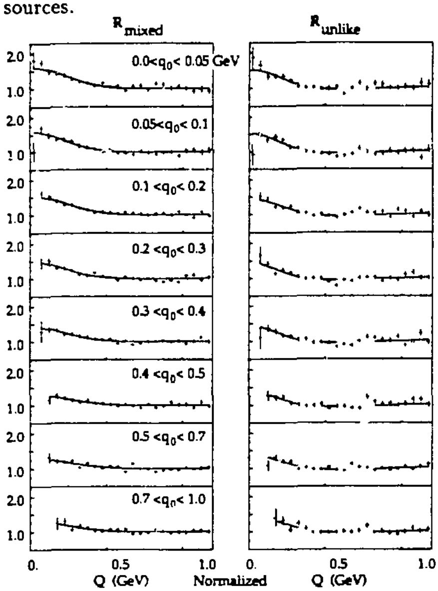

Figure 2: Correlation function vs Q with fit in bands of q_0.

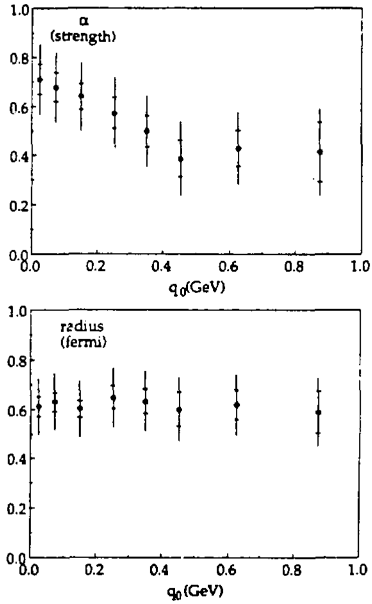

Figure 3: Weighted average of parameters from fits vs q_0 for different methods.

Three-pion correlations are observed using a simple generalization of the method used for two pions. The correlation function for triplets of identical particles is given by:

$$\begin{aligned} R_3(p_1, p_2, p_3) &= 1 + |\tilde{\rho}(q_{12})|^2 + |\tilde{\rho}(q_{23})|^2 + |\tilde{\rho}(q_{31})|^2 \\ &\quad + 2Re[\tilde{\rho}(q_{12})\tilde{\rho}(q_{23})\tilde{\rho}(q_{31})], \end{aligned} \tag{3}$$

where $\tilde{\rho}$ is the fourier transform of the source density and $q_{ij} = p_i - p_j$. The first three enhancement terms are just the correlations that must occur between pairs of pions in the triplet. The last term is unique to triplets, and becomes small if any one particle in the triplet has a large momentum difference from the others.

In the three-pion analysis, only the event mixing technique is used to construct a reference sample, with the distribution obtained by mixing a pair of tracks from one event with a track from another event being used to measure the correlation between pairs of pions within a triplet. Subtracting the correlations due to the three pairs within the like-signed triplet distribution from one event, we form a triplet distribution that should only exhibit the "pure" triplet enhancement plus an uncorrelated background, and define the "pure" three-pion correlation function as,

$$R_3^{pure}(Q_3^2) = \frac{P^{pure}(Q_3^2)}{P^{+++}(Q_3^2)}. \qquad (4)$$

where $P^{pure}(Q_3^2)$, $P^{+++}(Q_3^2)$ are the probability distribution of like-sign triplets and the triplet reference distribution, respectively, and $Q_3^2 = q_{12}^2 + q_{23}^2 + q_{31}^2$, as used by other groups[6], is a generalization of the two-particle variable Q^2.

The pure-triplet correlation function obtained in this way is shown in Fig. 4 for different normalizations: a) unnormalized, b) using a Monte Carlo correlation function, and c) normalized at large Q_3^2. Fitting the data in Fig. 4c to the form of Eq. 2, we obtain the following results: $\alpha_3 = 0.55 \pm 0.10 \pm 0.10$ and $r_3 = 0.77 \pm .09 \pm 0.10$ fermi, where the primary systematic uncertainty is in the correction for the effect that two-particle correlations have on the pure-three-pion correlations. The values for α_3 and r_3 are in agreement with the corresponding two-pion correlation parameters ($\alpha_2 = 0.62 \pm 0.03 \pm 0.13$, and $r_2 = 0.66 \pm 0.03 \pm 0.11$ fermi). Thus providing additional confidence that these correlations are really the result of Bose-Einstein interference.

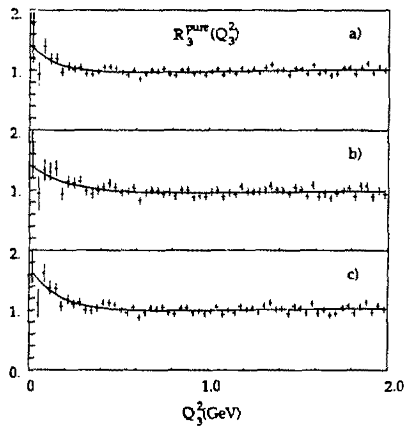

Figure 4: Pure 3 pion correlation function for different normalizations.

4. Inclusive Strange and Charmed Baryon Production

Our study of baryon production is based on approximately 26,000 hadronic events from our 1984-86 high-field sample. Our measurements of hyperon (Λ,Ξ^-,Ω,Ξ^{*0}) production, displayed in Figure 5, provide the first observation of the Ξ^{*0} in the higher energy fragmentation regime. We determine the following multiplicites per event: $N(\Lambda) = 0.211 \pm 0.009 \pm 0.014$, $N(\Xi^-) = 0.020 \pm 0.004 \pm 0.003$, $N(\Omega) = 0.0037 \pm 0.0018 \pm 0.0014$, and $N(\Xi^{*0}) = 0.0097 \pm 0.0039 \pm 0.0043$. Compared to the strange baryons, the Λ_C is a fairly difficult particle to search for. Applying dE/dx cuts which minimize the misidentification of pions as kaons or protons and restricting our search for Λ_C to $x_P > 0.5$, we obtain the signal for Λ_C production shown in Fig. 6. Using

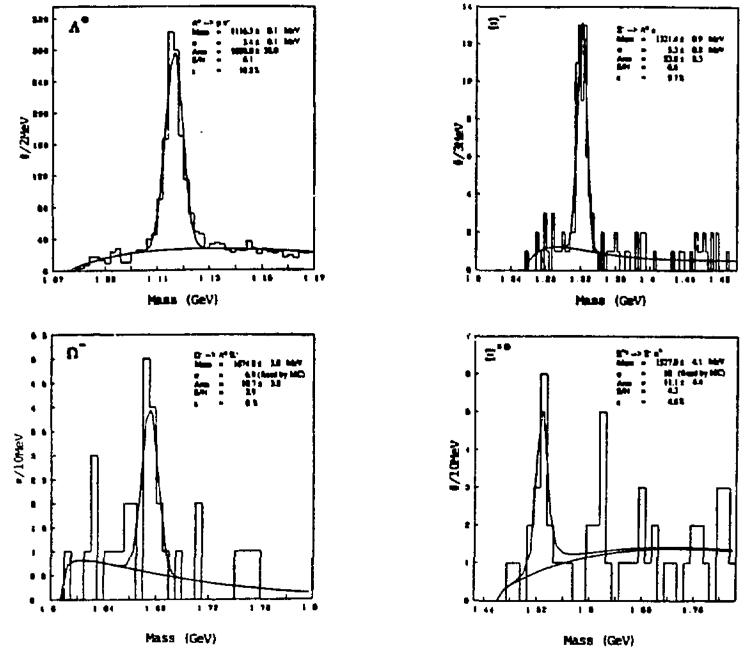

Figure 5: Mass spectra for $\Lambda^0 \rightarrow \pi^- p$, $\Xi^- \rightarrow \pi^- \Lambda^0$, $\Omega^- \rightarrow K^- \Lambda^0$, and $\Xi^{0*} \rightarrow \pi^+ \Xi^-$.

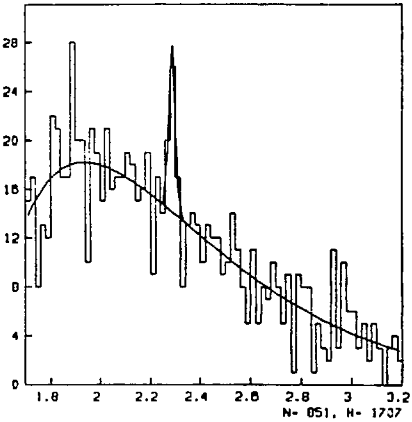

Figure 6: Reconstructed mass for $\Lambda_C \rightarrow p K^- \pi^+$.

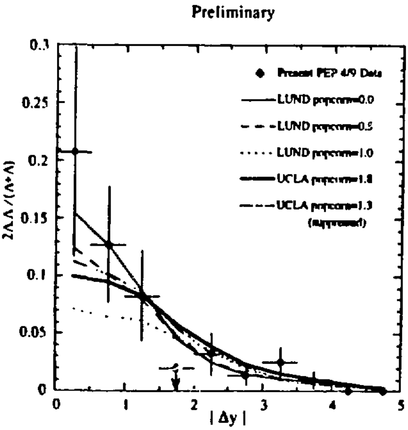

Figure 7: Rapidity separation between Λ and $\overline{\Lambda}$ compared with various predictions of the Lund[7] and UCLA[8] models.

the PDG value for the $pK\pi$ braching ratio, B.R. = 2.6±0.9%, we obtain the multiplicity for Λ_C production to be N(Λ_C) = 0.22±0.11, somewhat larger than predicted by hadronization models.

Measuring baryon correlations, we find (with a signal-to-noise ratio of 16:1) 55.4 ± 8.0 $\Lambda\overline{\Lambda}$ pairs, corresponding to 0.053 ± 0.007(stat.) ± 0.011(sys.) $\Lambda\overline{\Lambda}$ pairs per hadronic event after acceptance corrections. Models of baryon formation in the fragmentation process, such as "diquark" and "popcorn" models, predict different baryon-antibaryon correlations. In Figure 7 we obtain a measure of the $\Lambda\overline{\Lambda}$ correlation length by plotting the distribution of $\Lambda\overline{\Lambda}$ as a function of the absolute value of the rapidity difference ($|\Delta y|$) between the Λ and $\overline{\Lambda}$. Predictions of the Lund model with popcorn fractions of 0, 0.5 and 1 (in solid, dashed and dotted lines, respectively), and the UCLA model with and without popcorn suppression (in dot-dashed and dark solid lines) are also shown. At this point, our preliminary data appears to disfavor the Lund model with 100% "popcorn" baryon production.

5. Conclusions

In terms of the final stage of hadronization, our measurements of vector meson production yield new results for: $\frac{s}{u}$ = 0.30 ± 0.03 and $\frac{V}{(V+PS)}$ = (45 ± 11)%. Our new precise measurements of strange and charmed baryon production are presently being compared to detailed Lund and UCLA model predictions.

As part of our systematic studies of correlations in the fragmentation process: We probe the space-time structure using Bose-Einstein interference effects and obtain consistent measurements of source size ~0.7f and strength ~0.6, in two- and three-pion correlations. The observation that these enhancements persist in two-pion correlations at large q_0 (~ 1 GeV) suggests a boosted source. Our measurements of strange baryon correlations provide sensitivity to physics in the fragmentation process at relatively high virtuality, Q ~ 3 GeV, and establish a test bed for models of baryon production in e^+e^- annihilation.

I would like to acknowledge my collegues on the TPC/2γ collaboration. I appreciated the warm, friendly atmosphere of "Moriond", especially during the time of world conflict, and thank the organizers for an enjoyable conference.

References

[1] T. K. Edberg, PhD thesis, University of California, Berkeley, 1988. LBL-25652.

[2] D. A. Crane, PhD thesis, Johns Hopkins University, 1988. JHU-HEP-88-1002.

[3] R. E. Avery, PhD thesis, University of California, Berkeley, 1989. LBL-26593.

[4] P. Avery et al. (CLEO Collaboration), Phys. Rev., **D32**, 2294 (1985).

[5] H. Aihara et al. (TPC/2γ Collaboration), Phys. Rev., **D31**, 996 (1985).

[6] M. Altoff et al. (TASSO Collaboration), Z. Phys., **C30**, 355 (1986).

[7] B. Andersson et al., Phys. Rep., **97**, 33 (1983).

[8] C.D. Buchanan and S.-B. Chun, UCLA-HEP-90-003 and references therein.

[9] H. Aihara et al., LBL-23737, Lawrence Berkeley Laboratory, 1988.