CONF-870797--7

ANL-HEP-CP-87-60
IUHEE-87-8
UM-HE-87-15
PU-87-599
June 15, 1987

ANL-HEP-CP--87-60

DE88 002919

PRODUCTION OF η MESONS IN e^+e^- ANNIHILATIONS AT $\sqrt{s}$ = 29 GeV

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HRS COLLABORATION

Submitted to the 1987
International Symposium on Lepton and Photon Interactions at High Energies
July 26 - 31, 1987, Hamburg, W. Germany
by P. Kooijman, Argonne National Laboratory

Abstract

Data from e^+e^- annihilations at 29 GeV have been used to measure the production and fragmentation of η mesons. The signal is observed in the $\eta \to \gamma\gamma$ decay channel. The fragmentation function for p_η > 1.5 GeV/c agrees well with the shapes predicted by both the Lund and Webber models. However, the mean multiplicity is measured to be $\langle n_\eta \rangle = 0.37 \pm 0.08$ η mesons per hadronic annihilation event, which is significantly lower than the values predicted by either model.

DISCLAIMER

The annihilation of e^+e^- into hadrons is well understood in the context of the quark-parton model and QCD. In this picture, the e^+e^- annihilates to form a virtual photon or Z^0, that subsequently emits a quark-antiquark pair, which are sometimes accompanied by one or more gluons. These partons then fragment to form the observed hadrons. The latter process is less well understood theoretically, but has been reasonably parameterized by Monte Carlo models. The two most successful models in recent years have been the Lund string fragmentation model(1) and the Webber-Marchesini cluster model(2). These models contain arbitrary parameters that must be extracted from the measurements of hadron production. At present both models give a good description of the fragmentation process and account for most of the known data.(3) In this paper, we present new measurements of η-meson production in e^+e^- annihilation, which further test these models.

The data sample on which this paper is based, was collected over a period of five years by the High Resolution Spectrometer (HRS) at the PEP e^+e^- storage ring at a center of mass energy, $\sqrt{s}$ = 29 GeV, and corresponds to an integrated luminosity of 300 pb^{-1}.

The HRS detector(4) consisted of a solenoidal magnet of 4.5 m-diameter with a central field of 1.6 T, and which contained 17 layers of drift chambers. The magnetic field volume also contained 40 barrel shower counter modules with alternate layers of lead and scintillator, each subtending an angle of 9^o in azimuth. The modules were segmented in depth into a $3X_o$ and an $8X_o$ section with a single layer of 14 proportional wires separating the two regions.(5) The energy resolution of the shower counters was $\sigma_E/E = 16\%/\sqrt{E}$ (E in GeV). The z position, along the beam axis, was determined by current division in the PWC layer to an accuracy of $\sigma(z)$ = 2.5 cm. The forward and backward regions were covered by endcap shower counters.

The η meson decays predominantly into neutral particles, and for the present analysis, we use the decay mode $\eta \rightarrow \gamma\gamma$. To detect the photons from the η decay, only the barrel shower counter system was used because of its superior position and energy resolution. The algorithm for extracting photons from the shower counter information is as follows:

- All PWC wires with a pulse height above threshold were scanned to create clusters of contiguous wires in azimuth. In this clustering, gaps of up to 3 wires were allowed, however, no cluster was allowed to have two or more gaps.

- Inside these clusters, a scan was made to ensure consistent z positions on all wires. If this was not the case, the cluster was split into two or more subclusters in each of which the z information was consistent.

- From previous measurements of radiative Bhabha scattering, it was determined that photon/electron clusters typically have fewer than 7 PWC wires, so any cluster with 10 or more wires was split into two, at the wire with the lowest pulse height, regardless of the z information.

- All charged tracks in the event were extrapolated to the PWC plane of the shower counter, and clusters with consistent azimuthal angles and z positions were associated with the charged tracks.

- If only one cluster inhabited a module, the energy of that module was associated with that cluster. If more clusters appeared in one module, the energy was shared equally between all clusters, with the exception of clusters associated with tracks, which were given the mean energy deposition for a minimum-ionizing particle of 200 MeV. The remaining energy of the module was then distributed equally among the non-track clusters.

- All clusters not associated with tracks were then considered as photon candidates.

For the final analysis, only those photons which did not share a shower counter module with any other photons and which had at least 250 MeV of energy were used.

In Fig. 1 we show representative $\gamma\gamma$ mass spectra where it is required that the opening angle of the photon pair be less than 90^{o}. Figure 1(a) shows the spectrum for $P(\gamma\gamma) > 3$ GeV, and Figs. 1(b), 1(c) and 1(d) show the equivalent spectra for $P > 4$ GeV, $P > 5$ GeV, and $P > 6$ GeV. Clear enhancements are seen at $M(\gamma\gamma) \cong 550$ MeV corresponding to the η meson. In Fig. 1(d) an additional enhancement is seen at ~ 370 MeV. This enhancement is due to the $K^o_s \to \pi^o\pi^o$ decay where each π^o is detected as a single photon cluster, due to the small opening angle in the $\pi^o \to \gamma\gamma$ decay.

To measure the η signal, the $\gamma\gamma$ mass spectra were fit to a smooth background, with gaussian contributions at the η, π^o, and $K^o(\gamma\gamma)$ masses. The widths of the resonance contributions were left as free parameters in the fit. The lines in Fig. 1 show the results of the fits. This procedure was repeated for many momentum bins, and Table I gives the number of signal events as a function of $z(= E_\eta/E_{beam})$. The errors include both a statistical and a systematic contribution. The systematic errors, which dominate for values of $z < 0.5$ were determined by varying the parameters in the fits to the $\gamma\gamma$ mass spectra.

The acceptance was determined using a Monte Carlo simulation. Events were generated with the Lund Monte Carlo generator and passed through a simulation of the detector. The resulting events were then analyzed in the same way as the data, to extract the number of detected η mesons. Table I shows the resulting acceptances, including a $BR(\eta \to \gamma\gamma)$ of 39%. The systematic error on the acceptance, estimated by examination of the various contributing factors, is 15%, independent of Z. This error is not included in the cross section given in Table 1.

Figure 2 shows the scaling cross section, $\frac{s}{\beta}\frac{d\sigma}{dz}$, for η mesons, as a function of z. Here we use a radiatively corrected value of $\sqrt{s} = 28.3$ GeV. Also shown in Fig. 2 are the data from the JADE experiment[6] at PETRA. Where the data overlap, there is good agreement.

In Fig. 2(a) the fragmentation function is compared to the shape predicted by the Lund Monte Carlo. The curve, when fitted to the data of this experiment gives a mean multiplicity $\langle n_\eta \rangle = 0.39 \pm 0.04$, which is to be compared to the predicted value of 0.68 from the Lund model. In Fig. 2(b), the data is compared to the shape predicted by the Webber model. This shape also agrees well with the data and results in $< n_\eta > = 0.36 \pm 0.04$, which is in good agreement with value extracted from the fit to the Lund shape. However, the multiplicity is much lower than the value of $< n_\eta > = 0.95$ predicted by the Webber model. The weighted mean of the two extrapolations gives $< n_\eta > = 0.37 \pm 0.05$ η mesons per hadronic annihilation event. Folding in the systematic uncertainty in the acceptance then yields $< n_\eta > 0.37 \pm 0.08$.

In conclusion, we have presented data on η production in e^+e^- annihilation over a wide range in Z. The shape of the fragmentation function agrees well with the shapes predicted by both the Lund and Webber Monte Carlo programs. The mean multiplicity in hadronic events, $< n_\eta > = 0.37 \pm 0.08$, however, is significantly lower than the values predicted by these models.

This work was supported by the U.S. Department of Energy under contracts W-31-109-ENG-38, DE-AC02-76ER01112, DE-AC03-76SF0098, DE-AC02-76ER01428, and DE-AC02-84ER40125.

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Table I

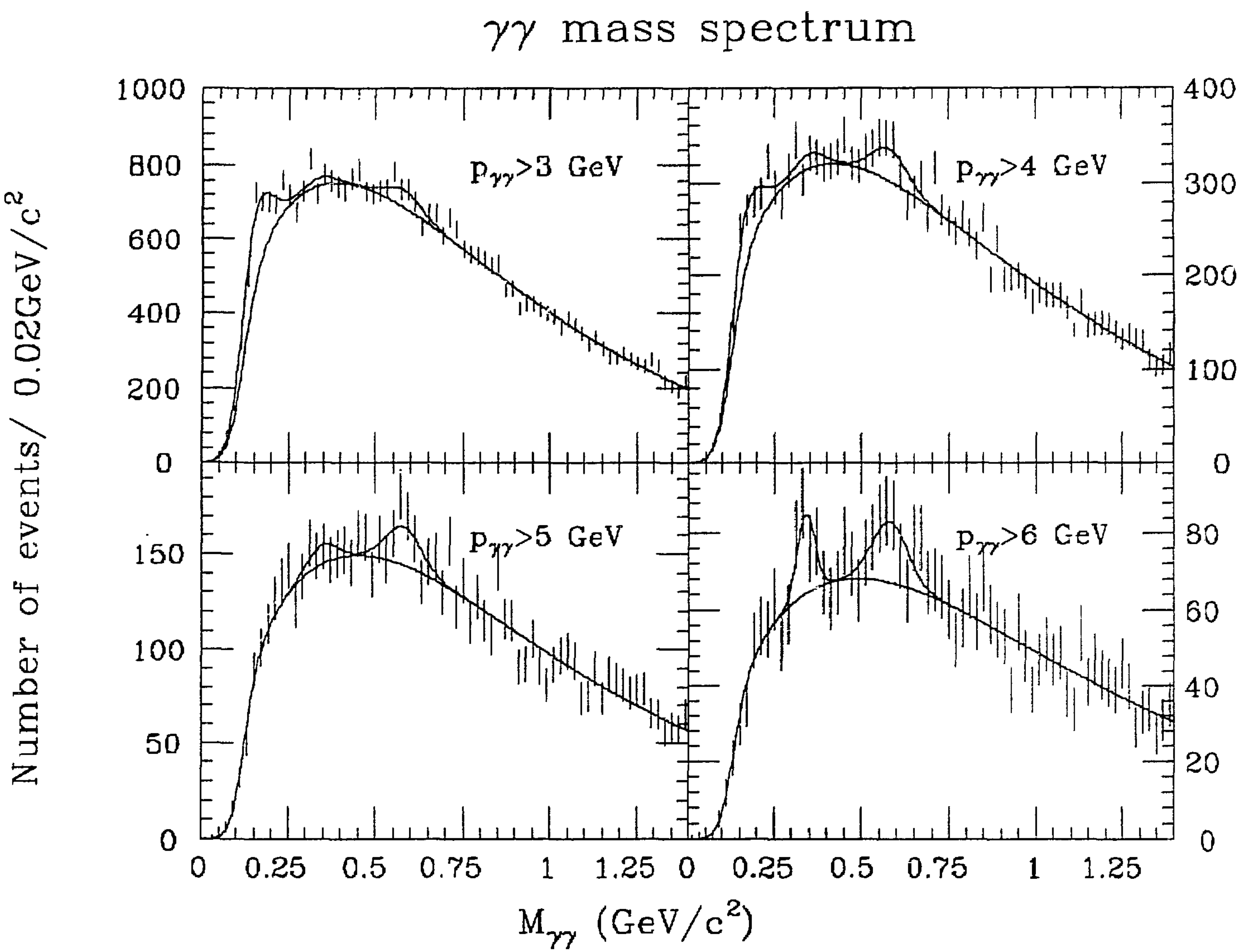
Number of events, detection efficiency, and scaling cross section for η-meson production.

z	**Number of Events**	**Acceptance** $\epsilon \cdot BR(\eta \rightarrow \gamma\gamma)$ **(%)**	$\frac{s}{\beta}\frac{d\sigma}{dz}$ (μb GeV^2)
0.160	97 ± 30	0.95	0.85 ± 0.26
0.193	45 ± 15	1.15	0.31 ± 0.11
0.227	30 ± 15	1.35	0.18 ± 0.09
0.261	49 ± 16	1.65	0.24 ± 0.08
0.296	42 ± 11	1.95	0.172 ± 0.045
0.330	44 ± 15	2.40	0.146 ± 0.050
0.364	26 ± 9	2.75	0.075 ± 0.029
0.398	10 ± 6	3.30	0.025 ± 0.014
0.433	26 ± 9	3.70	0.056 ± 0.019
0.467	25 ± 11	4.30	0.046 ± 0.020
0.518	16 ± 9	5.05	0.012 ± 0.007
0.587	20 ± 12	6.15	0.013 ± 0.008
0.656	4 ± 4	7.20	0.002 ± 0.002

Figure Captions

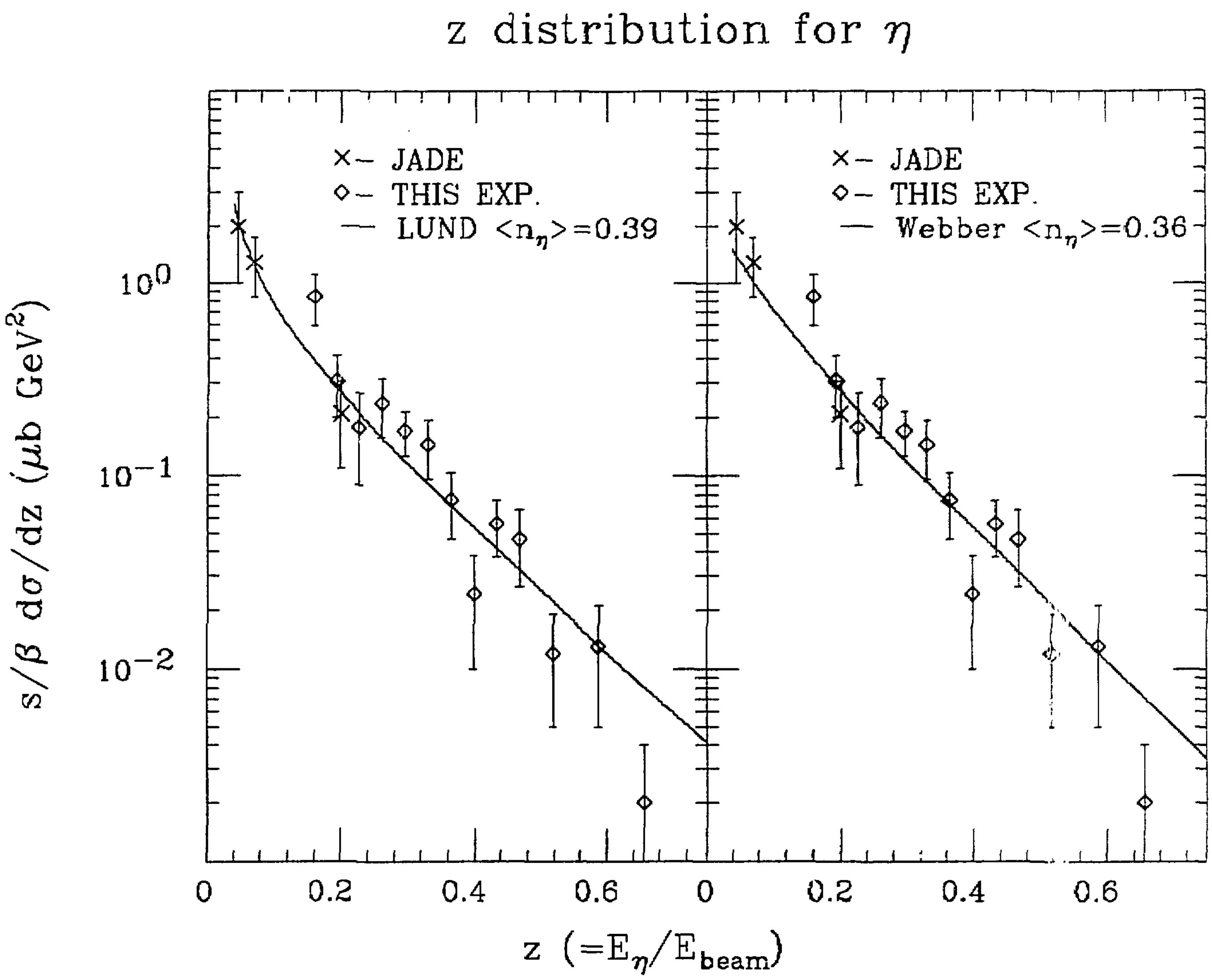
1. Photon-photon mass spectra for (a) $p_{\gamma\gamma} > 3$ GeV, (b) $p_{\gamma\gamma} > 4$ GeV, and (c) $p_{\gamma\gamma} > 5$ GeV, (d) $p_{\gamma\gamma} > 6$ GeV. Lines are results of the fits discussed in the text.

2. Scaling cross section for η-meson production as a function of the scaled energy z. (●) this experiment. (x) JADE data. The lines are results of fits to the shape of the Lund fragmentation function: (a) Webber and (b) fragmentation function.



$\gamma\gamma$ mass spectrum
$p_{\gamma\gamma}>3$ GeV
$p_{\gamma\gamma}>4$ GeV
$p_{\gamma\gamma}>5$ GeV
$p_{\gamma\gamma}>6$ GeV
Number of events/ 0.02GeV/c^2
$M_{\gamma\gamma}$ (GeV/c^2)
1000
800
600
400
200
0
400
300
200
100
150
50
80
60
40
20
0.25
0.5
0.75
1
1.25

Fig. 1



z distribution for η
×– JADE
◇– THIS EXP.
— LUND $<n_\eta>=0.39$
×– JADE
◇– THIS EXP.
— Webber $<n_\eta>=0.36$
$s/\beta\ d\sigma/dz\ (\mu b\ GeV^2)$
10^0
10^{-1}
10^{-2}
0
0.2
0.4
0.6
0
0.2
0.4
0.6
$z\ (=E_\eta/E_{beam})$

Fig. 2