Lawrence Berkeley National Laboratory
Recent Work

Title
TWO PHOTON PHYSICS WITH THE MARK II AT PEP

Permalink
https://escholarship.org/uc/item/9f33v45q

Author
Gidal, G.

Publication Date
1985-06-01

eScholarship.org Powered by the California Digital Library
University of California

LBL-19992 c.2

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Physics Division

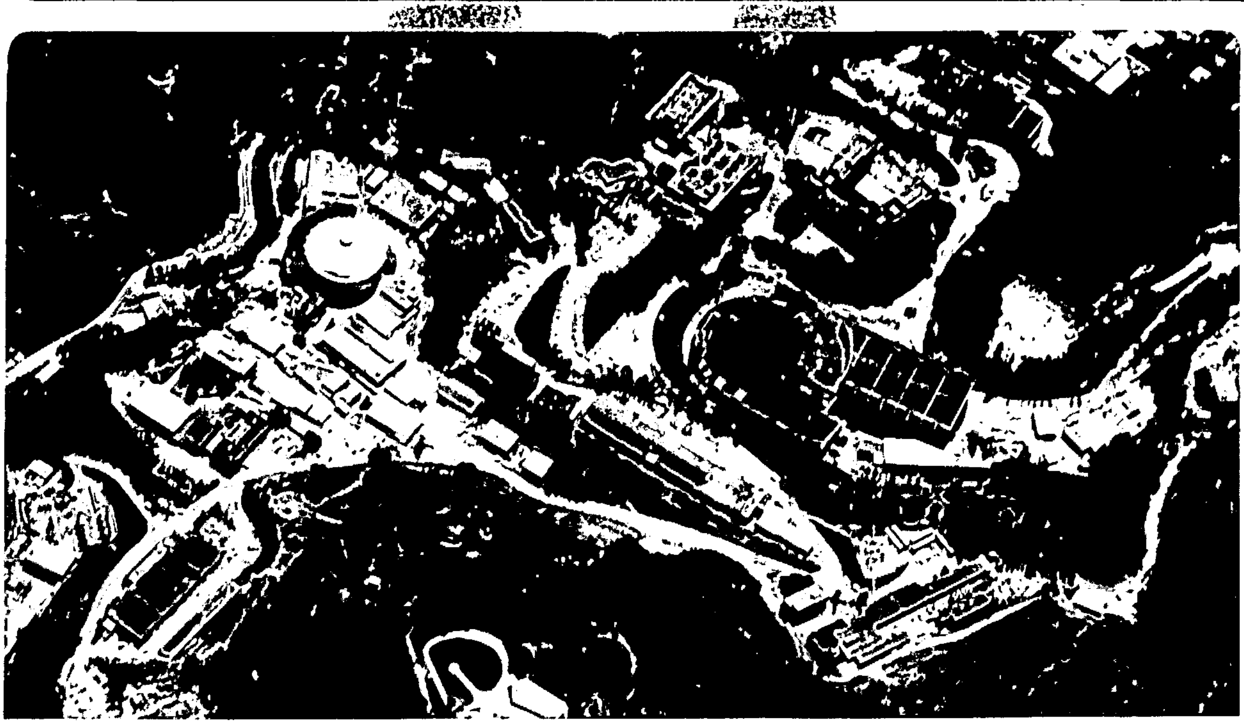
Presented at the XVI Symposium on Multiparticle Dynamics, Kiryat-Anavim, Israel, June 9-14, 1985

TWO PHOTON PHYSICS WITH THE MARK II AT PEP

G. Gidal

June 1985

RECEIVED
LAWRENCE
BERKELEY LABORATORY
OCT 9 1985
LIBRARY AND
DOCUMENTS SECTION



LBL-19992 c.2

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

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL-19992

Paper presented at the XVI Symposium on Multiparticle Dynamics,
9-14 June 1985, Kiryat-Anavim, Israel

TWO PHOTON PHYSICS WITH THE MARK II AT PEP*

G. Gidal

MARK II Collaboration

Lawrence Berkeley Laboratory and Department of Physics
University of California, Berkeley, California 94720

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Department of Physics
Harvard University, Cambridge, Massachusetts 02138

ABSTRACT

Measurements of the mass spectrum and angular distribution of high mass meson pairs produced in $\gamma\gamma$ interactions are compared with QCD predictions. The radiative width $\Gamma(\eta' \rightarrow \gamma\gamma)$ is measured using three different η' decay modes. Upper limits for the iota radiative width are given.

*This work was supported in part by the U.S. Department of Energy under contracts DE-AC03-76SF00098 and DE-AC03-76SF00515.

Several features of the Mark II detector at PEP allow us to make unique contributions to $\gamma\gamma$ physics at this time: (1) The low magnetic field (2.3 kg) allows us to trigger on relatively low p_T charged particles; (2) The vertex chamber permits us to measure these low p_T particles accurately, compensating for the decreased magnetic field; (3) We have accumulated a rather high integrated luminosity (230 pb^{-1}). We take advantage of these features to measure the high mass meson pairs and the $\gamma\gamma$ width of the η' , and to give an upper limit for the $\gamma\gamma$ width of the $\iota(1450)$.

I. $\gamma\gamma \to$ high mass $\pi^+\pi^-$ pairs

Brodsky and Lepage[1)] have made the absolute QCD predictions shown in Figure 1. For charged pion pairs these predictions are rather insensitive to assumptions concerning the contributing amplitudes. We indicate the region of cos θ^* accessible to the Mark II detector. Untagged two prong events with $m_{\pi\pi} > 1.6$ GeV, with visible energy $< 0.4\, E_{CM}$, and with net $p_T < 300$ MeV/c are first selected. A brute force application of the liquid argon and muon detectors is then used to reduce the contribution of the dominant ee and $\mu\mu$ final states to an acceptable level.

Since we do not distinguish kaons from pions, Monte Carlo detection efficiencies are determined for each type of particle. The ansatz of reference (1) that $\frac{d\sigma}{dt}(\gamma\gamma \to K^+K^-) = 2\,\frac{d\sigma}{dt}(\gamma\gamma \to \pi^+\pi^-)$ is then used with these efficiencies to determine the cross section, $\sigma(\gamma\gamma \to \pi^+\pi^- + K^+K^-)$. Figure 2 shows these results compared to the hard scattering predictions of reference (1). While there is good agreement above 2 GeV, there is a discrepancy at the lower masses, where we are presumably still in the resonance region. In Figure 3 we replot this same data as a function of $|\cos\theta^*|$. The limited statistics and angular range prevent us from checking the predicted rise with $|\cos\theta^*|$ in the mass region above 2 GeV. The lower mass region again presumably shows the effect of resonances.

As a further check of this point we have looked at the Q^2 dependence of single tagged events. The SAT allows us to detect electrons and positrons scattered between 21 and 83 mrad. Almost all these tagged events have $m_{\pi\pi}$ below 2 GeV. The Q^2 distribution is shown in Figure 4 together with the corresponding result for muon pairs. The latter is typical of point scattering with acceptance folded in and is represented by the smooth curve. The pion pairs clearly fall off more steeply with Q^2, probably confirming that they are still in the resonance region.

II. Measurements of $\Gamma(\eta' \rightarrow \gamma\gamma)$

The radiative width of the η' has always been measured using the $\rho\gamma$ decay and has been the subject of some controversy. The early measurements gave an average width of 5.5 ± 0.7 KeV but did not use the complete decay matrix element to determine their efficiencies. This is important since for most detectors the photon detection efficiency varies rapidly in the low energy region. The PLUTO[2] group were the first to use the proper magnetic dipole matrix element and measured a width of 3.8 ± 0.6 KeV. The TASSO[3] group then reported 5.1 ± 0.4 KeV with the proper matrix element.

Our low magnetic field and good resolution allows us to measure this width using three distinct η' decay modes.

$$\begin{aligned} \eta' &\rightarrow \rho^0\gamma \\ &\qquad \rightarrow \pi^+\pi^- \end{aligned} \tag{1}$$

$$\begin{aligned} \eta' &\rightarrow \eta\pi^+\pi^- \\ &\qquad \rightarrow \gamma\gamma \end{aligned} \tag{2}$$

$$\begin{aligned} \eta' &\rightarrow \eta\pi^+\pi^- \\ &\qquad \rightarrow \pi^+\pi^-\pi^0, \pi^+\pi^-\gamma \end{aligned} \tag{3}$$

A) For reaction (1) we select events with two charged tracks and a photon with energy greater than 150 MeV and make the usual $\gamma\gamma$ physics cuts; $E_{VIS} < 0.4\ E_{CM}$ and $P_T^2 < 0.007\ \mathrm{GeV}/c^2$. In order to reduce the radiative QED background, we calculate θ_H, the helicity angle of the π^+ with respect to the γ in the $\rho^0 CM$, and require $|\cos\theta_H| < 0.8$. In addition, we improve our resolution by constraining the transverse gamma energy to balance the P_T of the pions. The resultant distribution in $\pi^+\pi^-$ mass is shown in Figure 5. A clear, narrow η' signal dominates the distribution. There is also a broad contribution from $\gamma\gamma \rightarrow A_2 \rightarrow \rho\pi$ where only one γ from the π^0 decay is used. A fit to a polynomial background, A Gaussian η' and a Gaussian fit to a Monte Carlo simulated A_2 give the η' parameters as $M = 955 \pm 1$ MeV and $\sigma = 23 \pm$ MeV.

The efficiency is obtained using a magnetic dipole matrix element $|M^2| \sim p^2 K^2 M^2_{\pi^+\pi^-} \sin\theta_H \cdot B_\omega$ in the Monte Carlo. In Figure 6 we show the measured distributions in $\cos\theta_H$, E_γ, P_T^2 and $M_{\pi^+\pi^-}$ compared with the Monte Carlo simulation. The good agreement illustrates the importance of using the correct η' decay matrix element. Consistent results were obtained from data samples with full magnetic field (4.5 kg) and half field, and no dependence on gamma energy cutoff was observed. At this stage of the analysis we quote a result from the $\rho\gamma$ decay mode

$$\Gamma(\eta' \to \gamma\gamma) = 3.8 \pm 0.5 \text{ KeV}$$

where the error is a combination of statistical and systematic errors.

B) For reaction (2) we again select two prong events with gammas having at least 150 MeV energy, and the gammas are constrained to the η^0 mass. The P_T of the $\eta\pi^+\pi^-$ system is required to be less than 100 MeV/c. To minimize the combinatorial background from events with multiple π^0's we consider the unconstrained gamma-gamma mass distribution. As the minimum gamma energy is raised the combinatorial peak is reduced and shifted to higher masses. We choose a cutoff of 200 MeV and limit the unconstrained mass to lie between 450 and 750 MeV. The resultant $\eta^0\pi^+\pi^-$ mass distribution is shown in Figure 7. Again we see a clear η' peak, and its width is well reproduced by the Monte Carlo. The 160 events above background translate into a preliminary radiative width, $\Gamma(\eta' \to \gamma\gamma) = 4.3 \pm 0.8$ KeV. Figure 8 shows the P_T^2 distribution of the events in the η' peak region and confirms the 2γ nature of the events.

C) Lastly we consider the decay mode (3). If we select all four prong events with net transverse momentum less than 200 MeV and $E_{VIS} < 0.4\, E_{CM}$ we obtain the 4π mass spectrum shown in Figure 9. We recognize the well known $\rho^0\rho^0$ peak, but previous experiments have cut off near 1 GeV. Our low magnetic field allows us to see the new peak near 800 MeV. Preliminary Monte Carlo simulations of reaction (3) are shown as the solid histogram and clearly identify the origin of this peak. There is little or no background. Figure 10 shows the P_T distribution of the events in the peak. Although we are missing a γ or π^0 and hence see a turnover at small P_T, we are still able to pick out the untagged $\gamma\gamma$ events. Preliminary estimates of the efficiency give

$$\Gamma(\eta' \to \gamma\gamma) = 3.6 \pm 1.0 \text{ KeV}.$$

The JADE[4)] group has presented results to this conference on $e^+e^- \to e^+e^-\gamma\gamma$. The resulting $\gamma\gamma$ mass spectrum is shown in Figure 11. Their fit to η, η', and A_2 contributions results in $\Gamma(\eta \to \gamma\gamma) = 0.53 \pm 0.04 \pm 0.04$ KeV and $\Gamma(\eta' \to \gamma\gamma) = 4.0 \pm 0.9$ KeV. All these measurements of $\Gamma(\eta' \to \gamma\gamma)$ together with the TPC result presented in the next talk are summarized in Figure 12.

III. Search for $\iota(1450) \to \gamma\gamma$

The Mark III[5] group has presented evidence for $\iota(1450) \to \rho\gamma$ in ψ decays and have measured

$$\frac{BR\,(\psi \to \gamma\iota) BR\,(\iota \to KK\,\pi)}{BR\,(\psi \to \gamma\iota) BR\,(\iota \to \rho\gamma)} \cong 50\,.$$

By adding an additional Gaussian $M(\iota) = 1450$ MeV, $\sigma(\iota) = 50$ MeV to the fit in Figure 5 we obtain an upper limit

$$\Gamma(\iota \to \gamma\gamma) BR\,(\iota \to \rho\gamma) < 0.2 \text{ KeV}$$

using the above Mark III result and using $BR\,(\iota \to KK\,\pi) \simeq 1$, we translate this limit to $\Gamma(\iota \to \gamma\gamma) < 10$ KeV. A more direct way to measure the ι width is to look at $e^+e^- \to e^+e^-K^0K^\pm\pi^\mp$. We select events with 4 charged tracks of net charge 0 with net $P_T < 70$ MeV/c and require that at least one K^0 decay vertex be found. Figure 13 shows the resulting $K^0K^\pm\pi^\mp$ mass distribution (each event plotted twice) together with a Monte Carlo distribution for $\gamma\gamma \to \iota(1450) \to K^0K^\pm\pi^\mp$. We find $\Gamma(\iota \to \gamma\gamma) BR\,(\iota \to KK\,\pi) < 2$ KeV at the 90% C.L. These limits are in the range of typical $\gamma\gamma$ widths of ordinary mesons and already rule out some models of the $\iota(1450)$.

References

1) S.J. Brodsky and G.P. Lepage, Phys. Rev. **D24,** 1808 (1981).

2) Ch. Berger et al., Phys. Lett. **142,** 125 (1984).

3) M. Althoff et al., Phys. Lett. **147B,** 487 (1984).

4) W. Bartel et al. (JADE Collaboration), submitted to this conference.

5) J. Perrier (Mark III Collaboration), SLAC-PUB-3436 (September 1984).

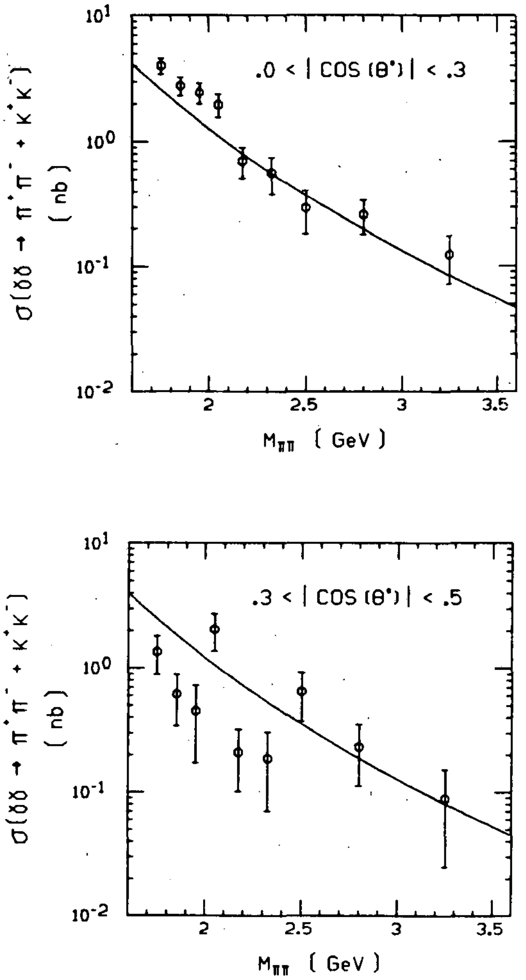


Fig. 2

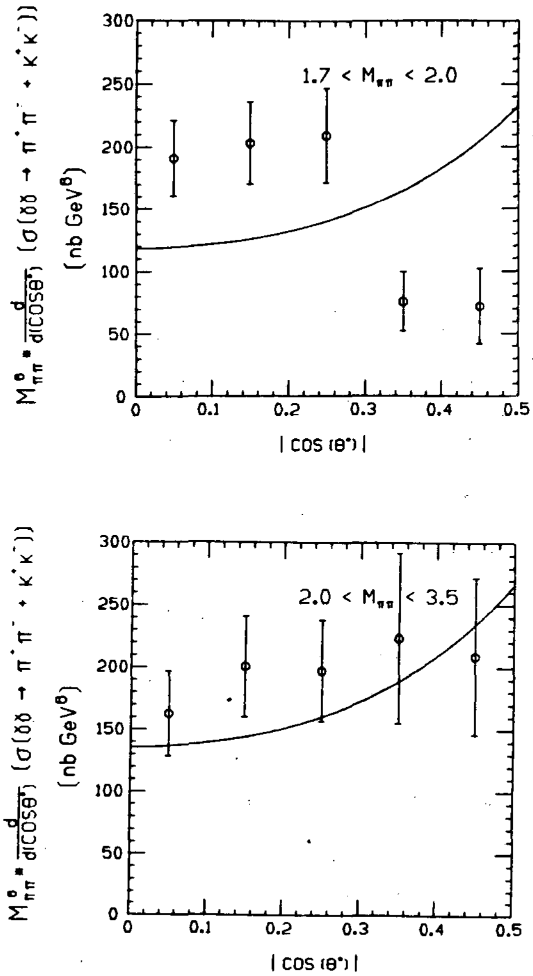


Fig. 3

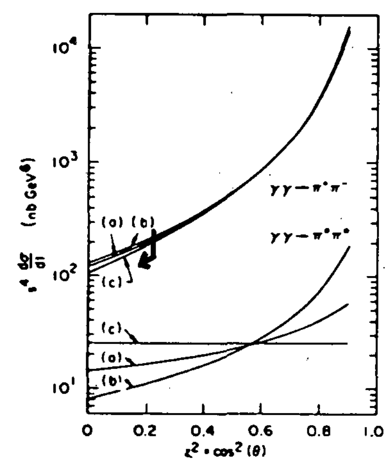


FIG. 1. QCD predictions for $\gamma\gamma\to\pi\pi$ to leading order in QCD. The results assume the pion-form-factor parametrization $F_\pi(s)\sim 0.4\ \mathrm{GeV}^2/s$. Curves (a), (b), and (c) correspond to the distribution amplitudes $\phi_M = x(1-x)$, $[x(1-x)]^{1/4}$, and $\delta(x-\frac{1}{2})$, respectively. Predictions for other helicity-zero mesons are obtained by multiplying with the scale constants given in Table I.

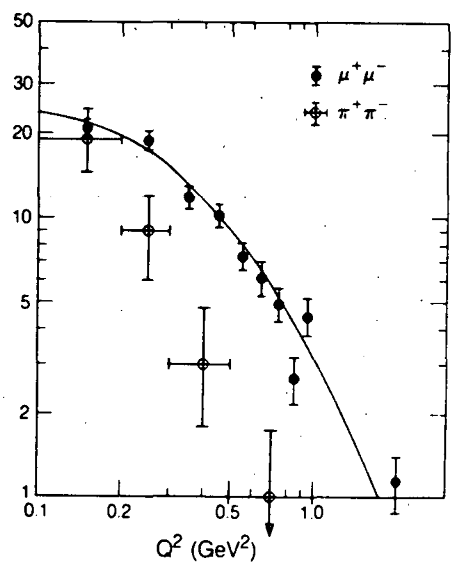
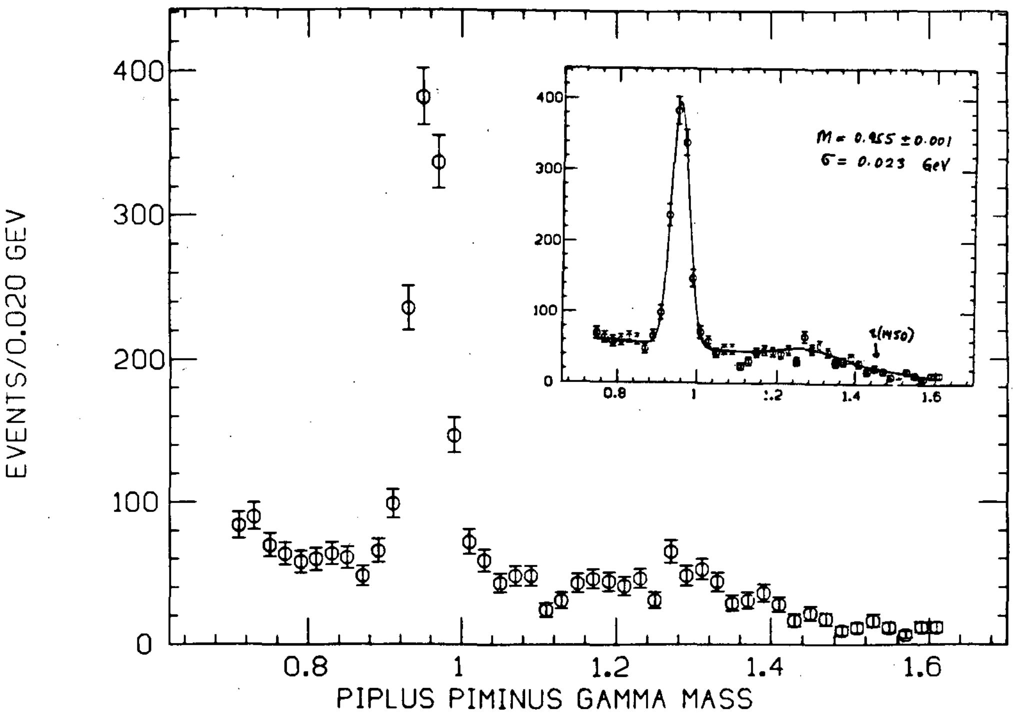


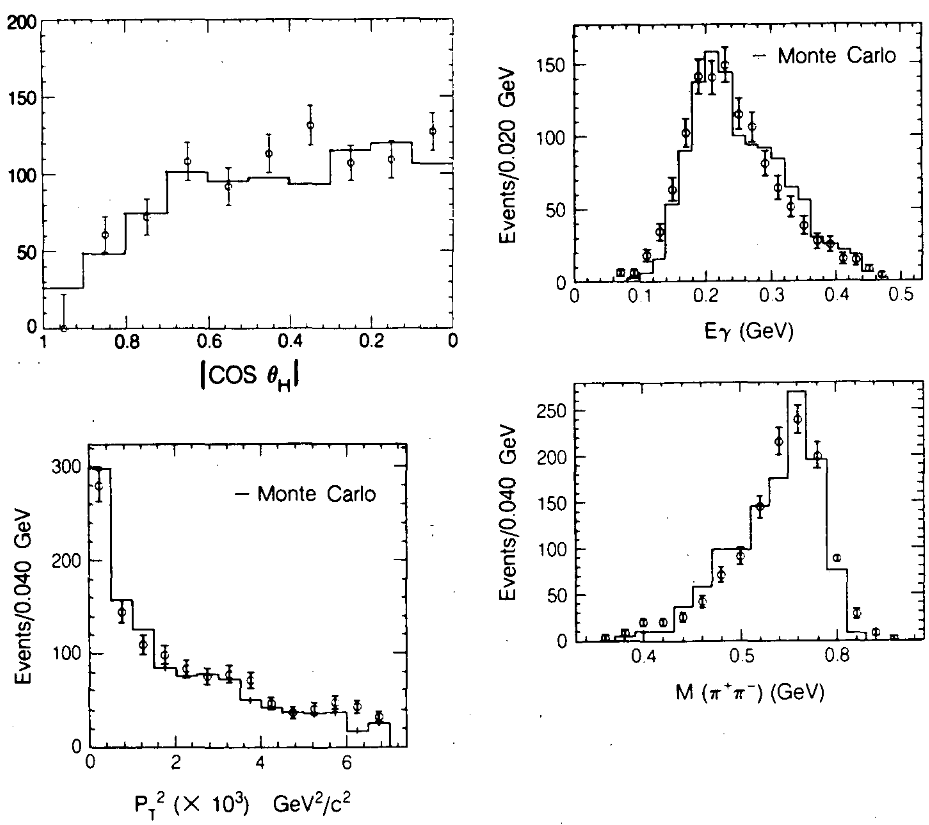
Fig. 4

XBL 858-3600



EVENTS/0.020 GEV
PIPLUS PIMINUS GAMMA MASS
0
100
200
300
400
0.8
1
1.2
1.4
1.6
M = 0.955 ± 0.001
σ = 0.023 GeV

Fig. 5



|COS θH|
— Monte Carlo
Events/0.020 GeV
Eγ (GeV)
Events/0.040 GeV
P_T^2 (× 10^3) GeV^2/c^2
Events/0.040 GeV
M (π⁺π⁻) (GeV)

Fig. 6

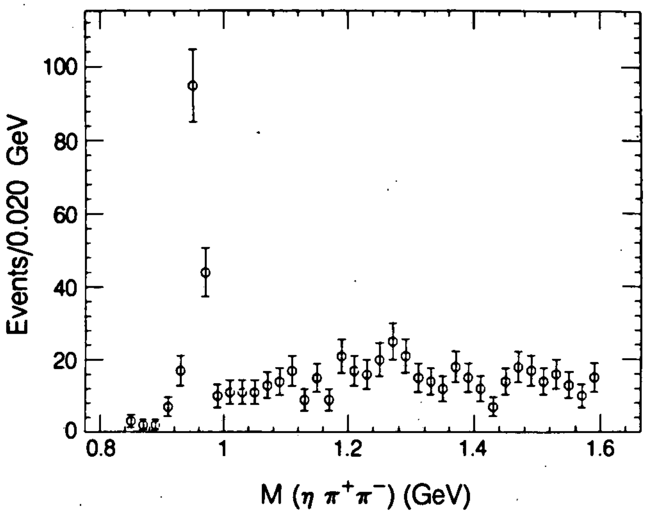


Fig. 7

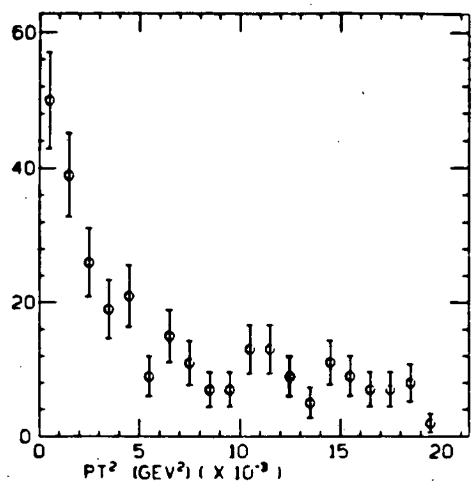


Fig. 8

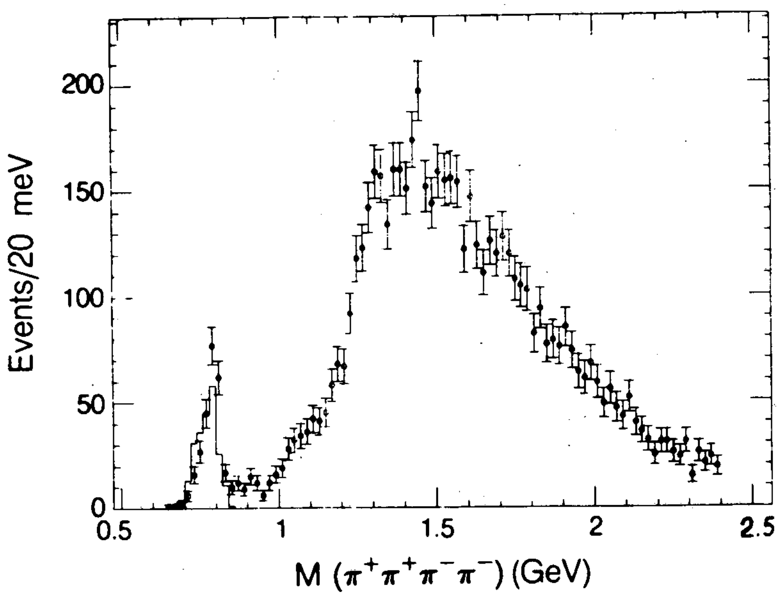


Fig. 9

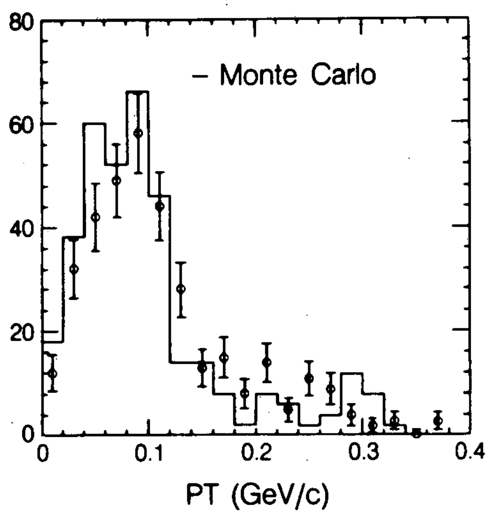


Fig. 10

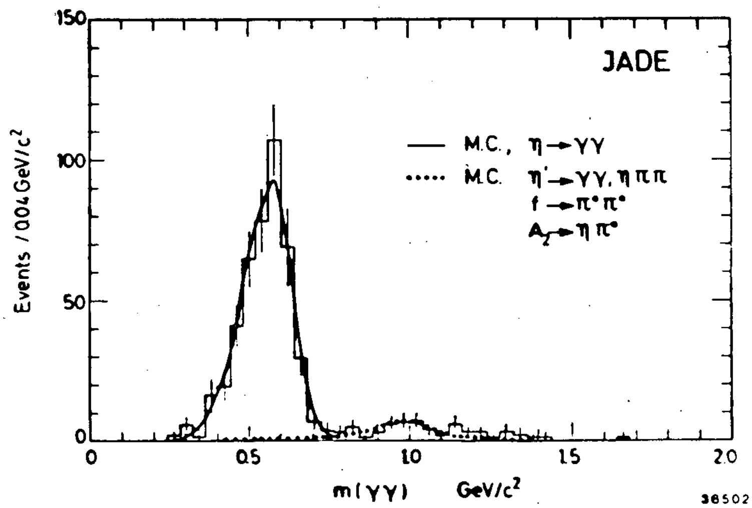


Fig. 11

XBL 858-3602

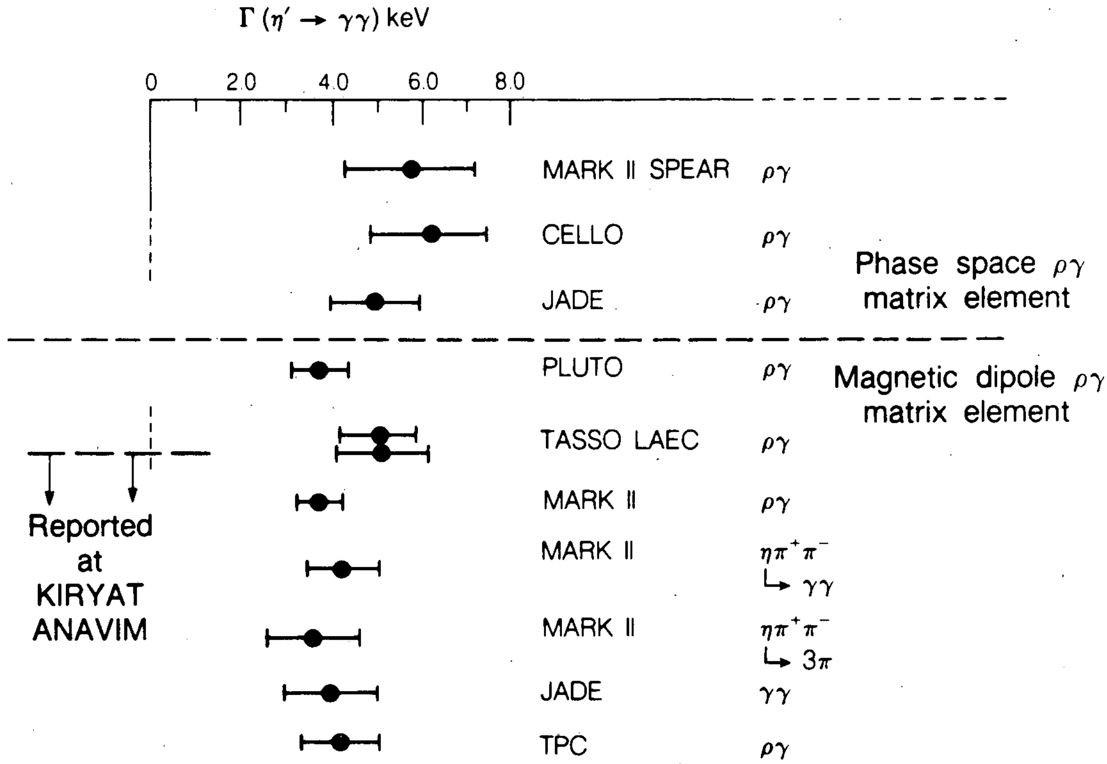


Fig. 12

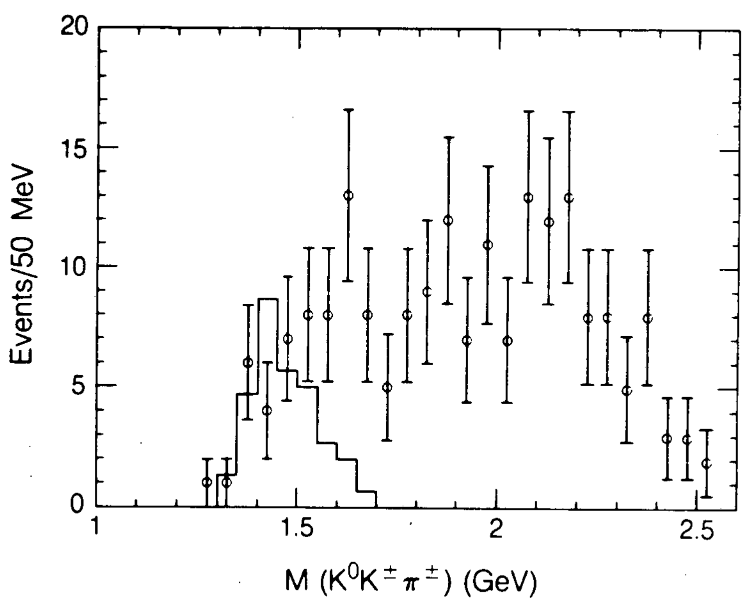


Fig. 13

XBL 858-3601

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

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