

Lawrence Berkeley National Laboratory

Recent Work

Title

SIGN OF THE $K1| - K2|$ MASS DIFFERENCE

Permalink

<https://escholarship.org/uc/item/0fg5v44t>

Authors

Meisner, Gerald W.
Golden, Robert L.
Crawford, Bevalyn B.
et al.

Publication Date

1963-09-16

University of California
Ernest O. Lawrence
Radiation Laboratory

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 5545*

SIGN OF THE $K_1^0 - K_2^0$ MASS DIFFERENCE

Berkeley, California

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.

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

SIGN OF THE $K_1^0 - K_2^0$ MASS DIFFERENCE

Gerald W. Meisner, Robert L. Golden, Bevalyn B. Crawford
and Frank S. Crawford, Jr.

September 16, 1963

SIGN OF THE $K_1^0 - K_2^0$ MASS DIFFERENCE

Gerald W. Meisner, Robert L. Golden, Bevalyn B. Crawford,
and Frank S. Crawford, Jr.

Lawrence Radiation Laboratory
University of California
Berkeley, California

September 16, 1963

About six months ago, Camerini, Fry, and Gaidos invented a beautiful method for determining the sign of $m(K_1^0) - m(K_2^0)$.¹ This method differs from all previous suggestions in one very important respect; it leads to a performable experiment.

In our experiment the method works as follows. At time $t = 0$ a K^0 is created in the 72-inch hydrogen bubble chamber, via the reaction



At time t the neutral kaon has become a superposition of K^0 and \bar{K}^0 , with amplitudes whose magnitudes depend on the K_1 and K_2 lifetimes, and whose relative phase depends on $(m_1 - m_2)t$.¹ (The formula is well known, and we need not write it down here.) Thus the relative phase of the K^0 and \bar{K}^0 components is known provided $m_1 - m_2$ is known. At time t this superposition scatters elastically from a $\frac{1}{2}$ proton. The K^0 part of the wave has its phase shifted by the elastic scattering phase shift in the process



The \bar{K}^0 part has its phase shifted by the process



If we know the scattering phase shifts for processes (2) and (3) and know $m_1 - m_2$, then, after the scattering, we still know the relative phase of the K^0 and \bar{K}^0 parts of the wave. We now find the K_1^0 projection of the superposition, by detecting the decay



The overall rate (as a function of t) contains terms in both $\sin(m_1 - m_2)t$ and $\cos(m_1 - m_2)t$.¹

1. U. Camerini, W. F. Fry, and J. Gaidos, *Nuovo Cimento* 28, 1096(1963).

In our experiment we have found 27 events of the type just described. The K^0 momenta lie between 200 and 900 MeV/c, as is shown in Fig. 1. We accept only the 18 events with K^0 momenta between 300 and 600 MeV/c, because only in this momentum interval are we sure that the phase shifts for reactions (2) and (3) are known well. For reaction (2) we use the phase shifts of Chinowsky, Goldhaber, Goldhaber, Lee, O'Halloran, Stubbs, Slater, Stork, and Ticho, as summarized in the thesis of Wonyong Lee.² These were obtained from experiments in the 15-inch hydrogen bubble chamber, involving $K^+ + p \rightarrow K^+ + p$, and $K^+ + n \rightarrow K^0 + p$ in deuterium between 350 and 800 MeV/c. We have extrapolated their results to 300 MeV/c.

The phase shifts for reaction (3) were obtained from a complete analysis of K^-p interactions between 250 and 513 MeV/c, by Watson, Ferro-Luzzi, and Tripp, using data from the 15-inch chamber.³ Their results can be extrapolated with confidence to 600 MeV/c, but not farther than that. (Above 600 MeV/c one is approaching the 1660-MeV resonance, which has the quantum numbers of reaction (3). This is shown in Fig. 1, where we have included a Breit-Wigner curve corresponding to the 1660-MeV resonance.)

For the 18 events between 300 and 600 MeV/c we proceed as follows. For each event we use the information on the K momentum and on the scattering angle in reaction (2) + (3). This yields the phase shifts. For a given value of $m_1 - m_2$ (including the sign) we can then construct a normalized curve of betting odds versus the time t when the scattering occurred, between $t = 0$ and T , where T is the potential time (maximum possible value of t) and is different for each event. We then add the 18 curves together to obtain an expected time distribution for the 18 events. The distribution depends on $m_1 - m_2$. [In adding the individual curves together we lose information as to which event goes with which curve, and thus we lose the (possible) opportunity to obtain very large betting odds based on one or two very favorable scatterings. On the other hand, we are less at the mercy of fluctuations; each of the 18 events has equal weight.]

We already believe that the magnitude $|m_1 - m_2|$ is in the neighborhood of 1.6 natural units. (Our preliminary value of $|m_1 - m_2|$, based on entirely different data, is included in the summary talk of W. F. Fry.) We therefore first compare our data with the expected time distributions for $m_1 - m_2 = -1.6$ and for $m_1 - m_2 = +1.6$. This comparison is shown in Fig. 2 for one set of K^0-p phase shifts, and in Fig. 3 for another set.² It is clear that -1.6 is highly favored, i. e., $m_2 > m_1$.

2. Wonyong Lee, Lawrence Radiation Laboratory Report UCRL-9694, May 19, 1961.

3. Mason B. Watson, Massimiliano Ferro-Luzzi, and Robert D. Tripp, Lawrence Radiation Laboratory Report UCRL-10542, Jan. 15, 1963, and private communication from Tripp.

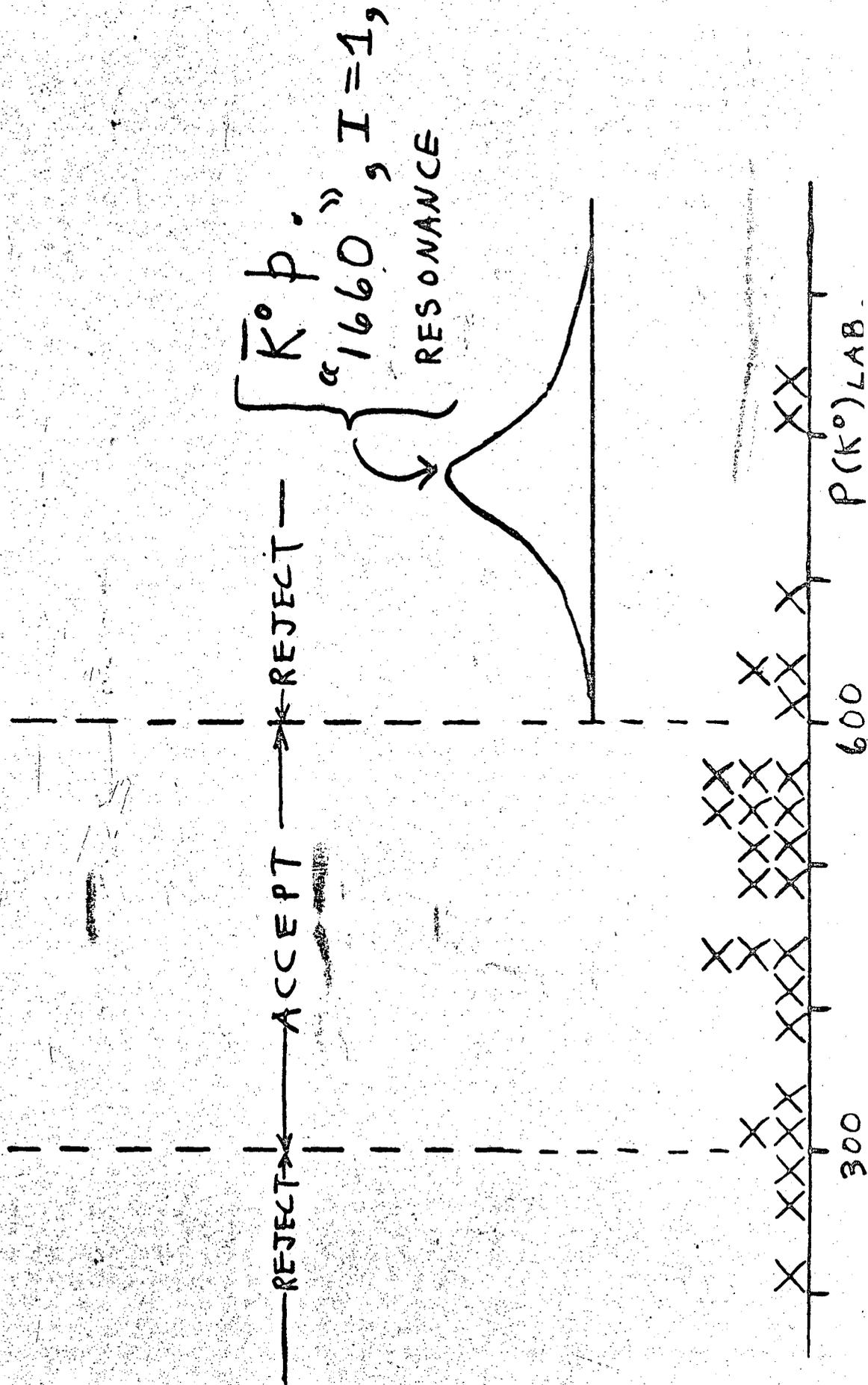
We next allow m_1, m_2 to vary continuously from -2.5 to + 2.5 and plot the relative-likelihood function. This is shown in Fig. 4, for the "Fermi" set of phase shifts corresponding to Fig. 2. We see that this likelihood function peaks at -1.4. (It also starts to rise towards a "first harmonic" at -2.8. We believe that the harmonics will be suppressed when we have included all the information!)

In order to go from a likelihood ratio to betting odds, we have performed Monte Carlo experiments in which we distribute 18 events according to one of the probability distributions of Figs. 2 and 3, and then calculate likelihood ratios in the same way as in the actual experiment. In this way we find betting odds of about 5000/1 against $m_1 > m_2$, using the Fermi set of K^0 -p phase shifts (Fig. 2), and about 1000/1 using the Yang set (Fig. 3).

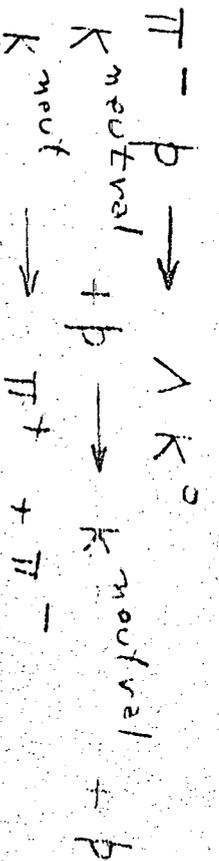
Our result, $m_2 > m_1$, is still preliminary, for the following reasons. First, we have not yet tried varying the phase-shift solutions within their expected errors. Second, there are other phase-shift solutions that include D wave for both K^0 p and \bar{K}^0 p scattering.^{2,3} We have not yet tried these solutions.

Once we are certain of the sign of $m_1 - m_2$, we hope to be able to turn the problem around and determine which set of phase-shifts fits best.

Fig. 1



18 EVENTS :



"FERMI" PHASE SHIFTS

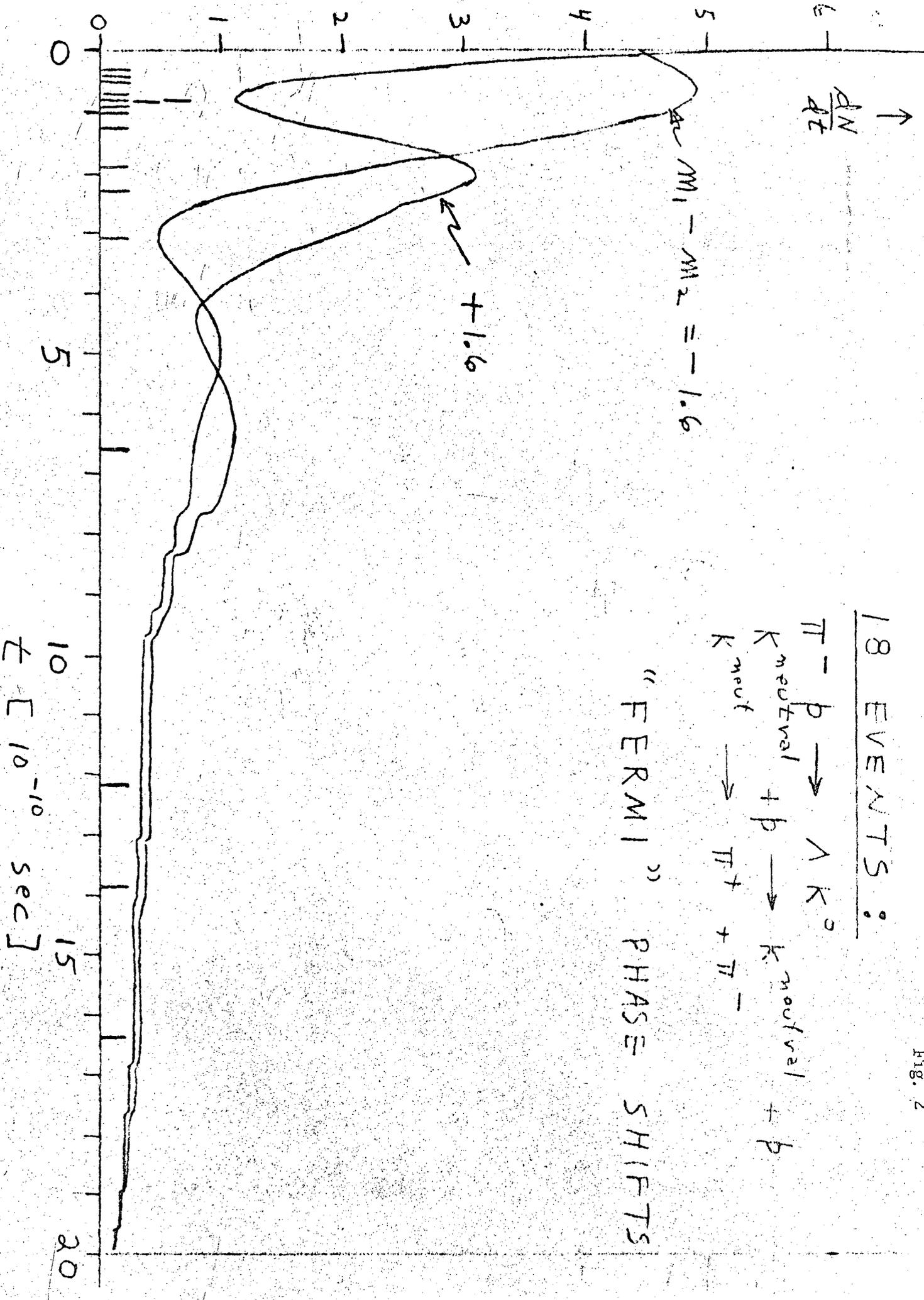
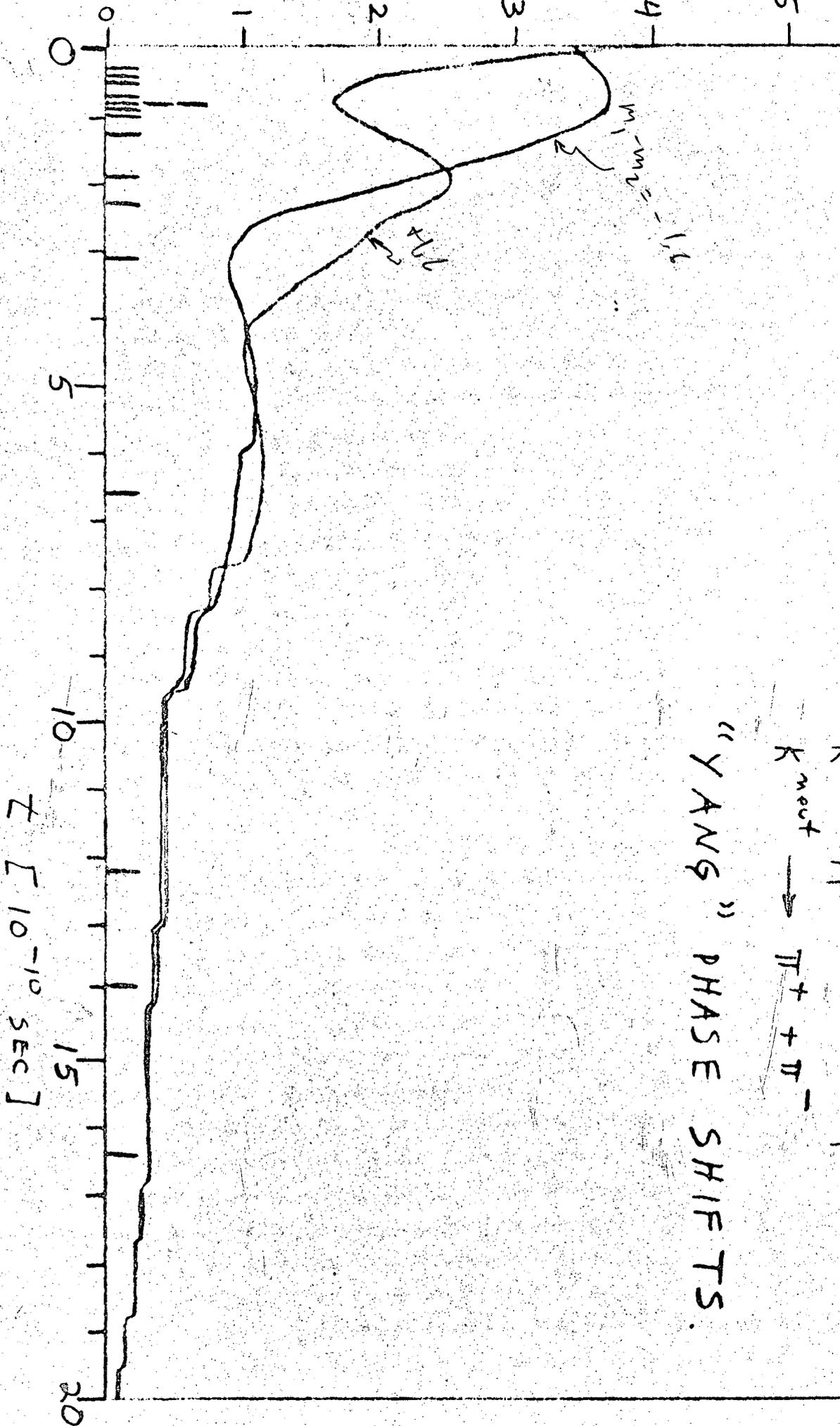


Fig. 3

\uparrow
 $\frac{dN}{dt}$



18 EVENTS:



“YANGS” PHASE SHIFTS.

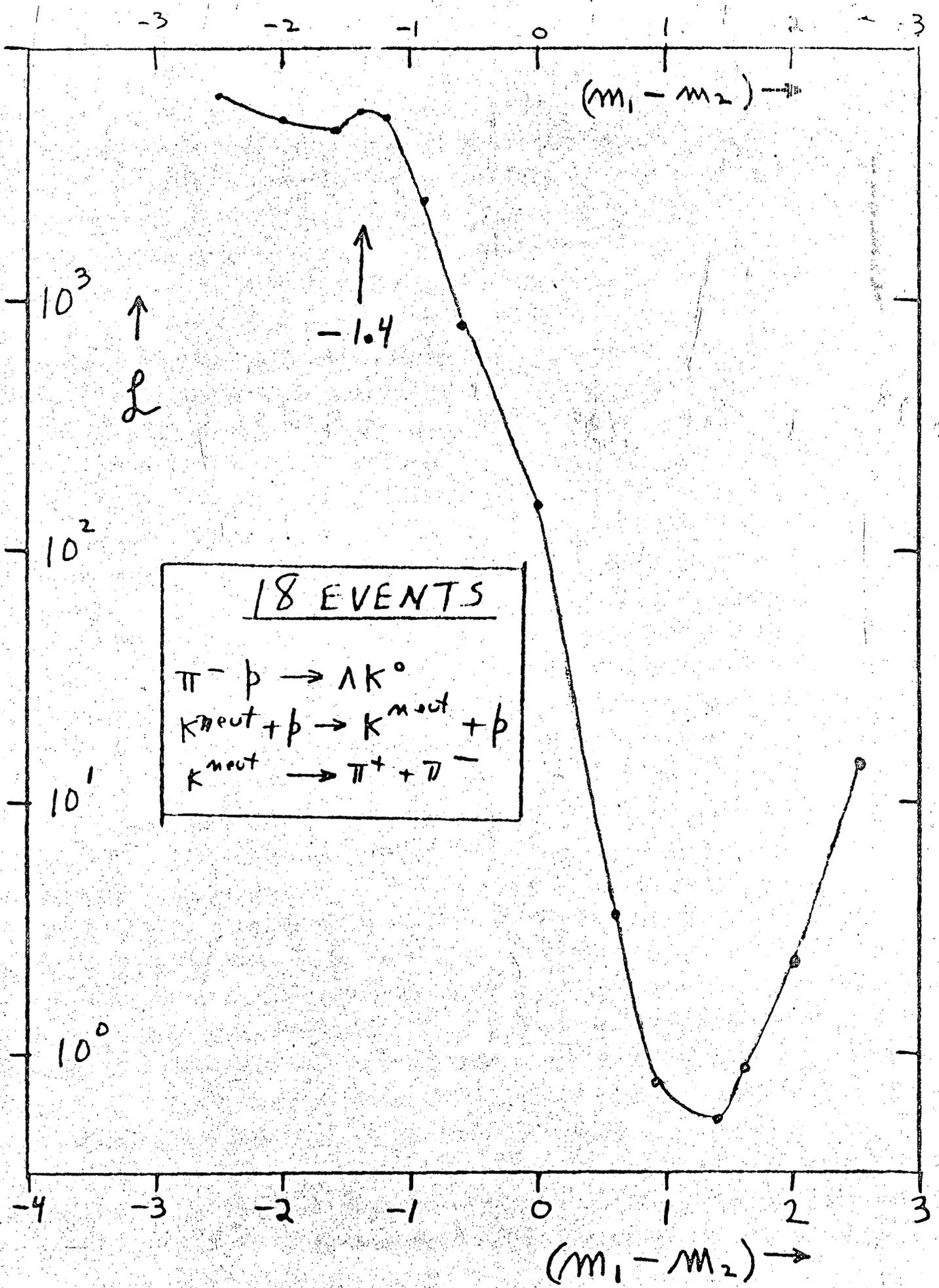


Fig. 4

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

