nov, Teor. Mat. Fiz. 10, 153 (1972) [Theor. Math. Phys. 10, 99 (1972)].

[13]G. 't Hooft, Nucl. Phys. B33, 173 (1971), Sect. IV.

[14]P. Cvitanović and T. Kinoshita, Phys. Rev. D 10, 3978 (1974).

[15]That the color magnetic moment is singular has also been noted by Y.-P. Yao [Phys. Rev. Lett. 36, 653 (1976)] and by E. de Rafael (private communication).

[16]J. Schwinger, Phys. Rev. 73, 416 (1948).

[17]C. P. Korthals Altes and E. de Rafael, Phys. Lett. 62B, 320 (1976).

[18]P. Cvitanović, to be published.

Evidence for Parity Nonconservation in the Decays of the Narrow States near 1.87 GeV/c^2*

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We have studied the Dalitz plot for the recently observed charged state decaying into $K^{\mp}\pi^{\pm}\pi^{\pm}$ at 1876 MeV/c^2 and we find that the final state is incompatible with a natural spin and parity assignment. This information, coupled with the earlier observation of the $K^{\pm}\pi^{\mp}$ decay mode (a final state of natural spin and parity) of the neutral state at 1865 MeV/c^2, suggest parity nonconservation in the decays of these objects if they are members of the same isomultiplet as their proximity in mass suggests.

We have recently reported our observation in e^+e^- annihilation of a narrow, charged state of mass 1876 MeV/c^2 decaying into the exotic decay mode $K^{\mp}\pi^{\pm}\pi^{\pm}$.[1] The proximity in mass of this state to the neutral state decaying into $K\pi$ and $K3\pi$ at 1865 MeV/c^2 suggests that they are members of the same isomultiplet. As such they are expected to have the same parity. Since the $K\pi$ final state is one of natural spin and parity, a demonstration that the $K\pi\pi$ final state of the charged member of the isomultiplet is inconsistent with natural spin and parity implies parity nonconservation in the decay. In this Letter we present evidence, based on a study of the $K^{\mp}\pi^{\pm}\pi^{\pm}$ Dalitz plot, for such parity nonconservation, suggesting that the decay proceeds via the weak interaction as expected for the (D^+, D^0) isodoublet of charm.[2]

The present analysis is based on $K\pi\pi$ events observed among a sample of ~44 000 hadronic events taken from 3.9- to 4.25-GeV center-of-mass energy. These data were taken with the Stanford Linear Accelerator Center–Lawrence Berkeley Laboratory magnetic detector at SPEAR.

The $K\pi\pi$ combinations are selected with the aid of the time-of-flight system described in Goldhaber *et al.*[3] In the present analysis we have used a modified form of the time-of-flight (TOF) weighting technique described earlier.[1,3] A given track in a multiprong hadronic event is assigned a definite particle identity on the basis of the agreement between its observed TOF over a 1.5–2.0-m flight path and that predicted for either a π or a K with a momentum as measured. Specifically we compute a χ^2 value for both the π and K hypotheses (χ_π^2 and χ_K^2) based on the observed and expected TOF and the 0.4-ns rms resolution of the TOF system. Tracks satisfying the requirements $\chi_k^2<\chi_\pi^2$, $\chi_K^2<3$, are called kaons. Protons and anitprotons are separated from kaons in a similar fashion. The remaining tracks are called pions.[4] The above technique allows the direct study of scatter plots and in particular the Dalitz plot for the $K\pi\pi$ system.

In order to obtain a relatively clean sample of $K\pi\pi(1876)$ events we make use of the result that for the $E_{\text{c.m.}}$ region $3.9<E_{\text{c.m.}}<4.25$ GeV, the recoil mass (M_{rec}) spectrum shows a sharp spike near 2 GeV.[1] We thus used a data sample with the $E_{\text{c.m.}}$ region chosen as above coupled with a cut $1.96<M_{\text{rec}}<2.04$ GeV/c^2. Figures 1(a) and 1(b) show the resulting exotic and nonexotic $K\pi\pi$ invariant-mass distributions. A fit to the spectrum of Fig. 1(b) was appropriately scaled to serve as a background for Fig. 1(a). Figure 1(a) shows a fit to a Gaussian peak over this back-

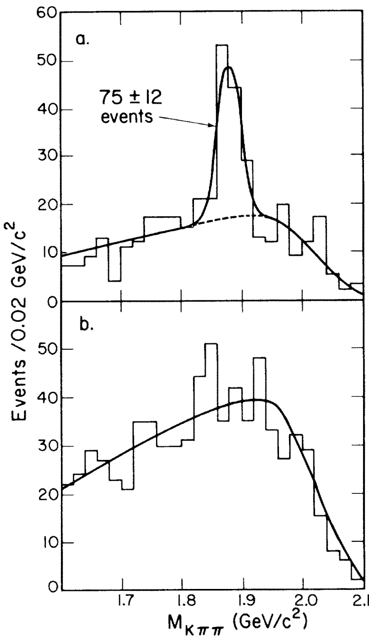

FIG. 1. The $K\pi\pi$ mass distribution with the cuts designed to enhance the signal-to-background ratio: $E_{c.m.} = 3.90-4.25$ GeV and $M_{rec} = 1.96-2.04$ GeV/c^2. (a) Exotic combination $K^{\mp}\pi^{\pm}\pi^{\pm}$; (b) nonexotic combination $K^{\pm}\pi^{+}\pi^{-}$.

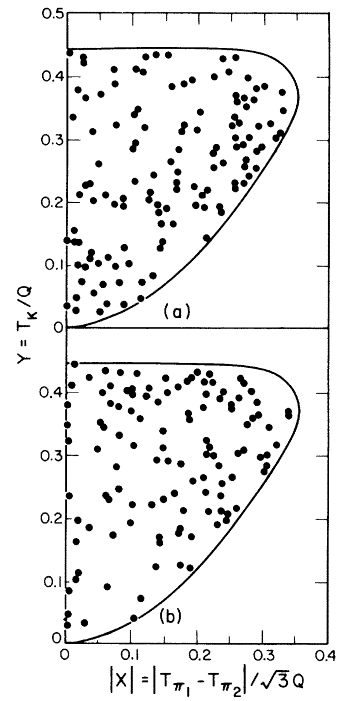

FIG. 2. Dalitz plots, folded around y axis, for the $K\pi\pi$ system with the mass cuts $M = 1.86-1.92$ GeV/c^2 and the cuts given for Fig. 1. (a) Exotic combination $K^{\mp}\pi^{\pm}\pi^{\pm}$; (b) nonexotic combination $K^{\pm}\pi^{+}\pi^{-}$. Here $Q = T_K + T_{\pi_1} + T_{\pi_2}$.

ground. Figure 2(a) shows the (folded) Dalitz plot for $K^{\mp}\pi^{\pm}\pi^{\pm}$ events with the additional invariant mass (M) requirement $1.86 < M < 1.92$ GeV/c^2. We find a sample of 126 events in the Dalitz plot of Fig. 2(a) of which we estimate that 58 are background. In Fig. 2(b) we show a background Dalitz plot consisting of 112 nonexotic combinations $K^{\mp}\pi^{+}\pi^{-}$ satisfying the same mass and missing-mass cuts as the exotic combinations of Fig. 2(a).

Both signal and background Dalitz plots are consistent with uniform population density. A uniformly populated Dalitz plot is incompatible with a $K\pi\pi$ final state of pure, natural spin and parity.[5] For the case of a natural spin and parity state decarying into three pseudoscalars one expects a depopulation (or zero) along the Dalitz plot boundary. This follows from the necessity of constructing the matrix element from the vector product of the two independent center-of-mass momenta—a vector which vanishes on the Dalitz-plot boundary where momenta are collinear. If, as in the case of $K^{\mp}\pi^{\pm}\pi^{\pm}$, two of the pseudoscalars are identical, one expects additional zeros. Since three pseudoscalars cannot be in a 0^+ spin and parity state, 1^- and 2^+ exhaust natural spin and parity combinations for spin less than 3. For the case of 1^- one expects an additional zero along the y axis (symmetry axis), while in the case of 2^+ one expects a higher order zero at the top of the Dalitz plot.

In order to rule out quantitatively the $K\pi\pi$ final states of 1^- and 2^+ we have utilized the phenomenological matrix elements of Zemach.[5] These are the simplest matrix elements and are subject to multiplication by arbitrary form factors. Barring the presence of rapidly varying form factors, they can be expected to give a good approximation to the extent of the regions of depopulation, allowing a quantitative comparison with the experimental distribution.

For $J^P = 1^-$ the matrix element is constructed from an axial vector symmetric under the exchange of the two pions. The essential form of such a quantity is $(T_{\pi_1} - T_{\pi_2})\vec{\pi}_1 \times \vec{\pi}_2$, where $\vec{\pi}$ represents a pion momentum in the rest frame of the $K\pi\pi(1876)$, and T_π represents its kinetic energy. For the case of unpolarized production one then expects an intensity I_{1^-} given by

$$I_{1^-} \propto |T_{\pi_1} - T_{\pi_2}|^2 |\vec{\pi}_1 \times \vec{\pi}_2|^2.$$

To compare the distribution of I_{1^-} with the data, we have divided the Dalitz plot into two discrimination regions divided by a contour of constant I_{1^-}. The particular contour was chosen so that an equal number of events would be found in each region for a phase-space decay of the state $K\pi\pi(1876)$,[5] as determined by a Monte Carlo calculation. Because of the approximately uniform $K\pi\pi$ detection efficiency over the Dalitz plot these regions have nearly equal areas. Figures 3(a) and 3(b) show the $K^\mp\pi^\pm\pi^\pm$ invariant-mass spectra for events with Dalitz variables lying inside the two 1^- discrimination regions as indicated by the shaded area in the respective insets.

A fit to a Gaussian signal over the scaled background of Fig. 1(b) reveals 34 ± 9 signal events in the peripheral region compared to 38 ± 9 signal events in the central region. Such a division is consistent with equal population with a χ^2 of 0.1 for one degree of freedom (DF) or a confidence level CL = 75%. On the other hand, a Monte Carlo simulation of $K\pi\pi$ decays using the intensity distribution I_{1^-} gives an expected population division of 1:8.2 for peripheral to central region. This is effectively ruled out with a χ^2 of 18.1 (CL $= 2\times 10^{-5}$).

For 2^+ we construct a symmetric, traceless, second-rank tensor which is also symmetric under the exchange of the two pions. We use $A^{ij} = \Delta\pi^i q^j + \Delta\pi^j q^i$, where $\Delta\pi$ is the difference of the pion momenta and q is their cross product. For unpolarized production one expects an intensity given by:

$$I_{2^+} \propto \sum_i \sum_j A^{ij} A_{ji} = |\vec{\pi}_1 - \vec{\pi}_2|^2 |\vec{\pi}_1 \times \vec{\pi}_2|^2.$$

Here we again divide the Dalitz plot into two regions, using a contour of constant I_{2^+} chosen to give equal population for phase space decay. I_{2^+} depopulates the peripheral region relative to the central region by 1:5.6. Figures 3(b) and 3(c) show the $K^\mp\pi^\pm\pi^\pm$ invariant-mass spectra for events with Dalitz variables in the shaded 2^+ discrimination regions. Our fits give 31 ± 9 events in the peripheral regions and 35 ± 10 events in the central region. This result is again consistent with equal population with a χ^2 of 0.1 for one DF (CL = 75%), and inconsistent with I_{2^+} with a χ^2 of 9.4 for one DF (CL = 0.002). The observed sample population of the 2^+ peripheral discrimination region indicates the absence of a general boundary zero. The absence of such a zero argues against natural spin and parity final states of spin 3 and greater as well.

In summary, the distribution in the Dalitz plot is incompatible with the zeros expected for spin and parity 1^- or 2^+ for the $K\pi\pi(1876)$. Parity nonconservation then follows from the observation that the presumed isomultiplet state at 1865 MeV/c^2 decays into $K\pi$, a natural spin and parity state.

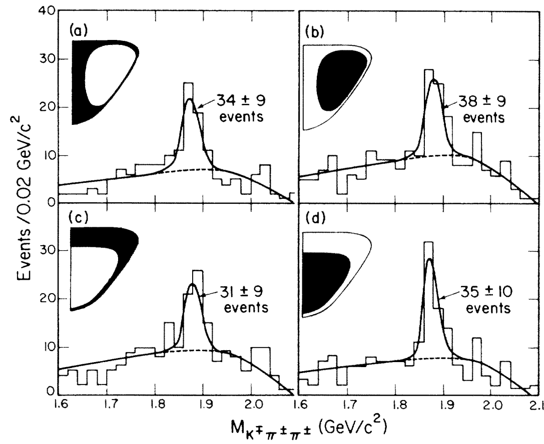

FIG. 3. $M(K^\mp\pi^\pm\pi^\pm)$ distribution for the same data sample as in Fig. 2. (a) "Peripheral" and (b) "central" regions (on the folded plot) for a contour of 1^- matrix element as indicated by the shaded regions of the insets; (c) "peripheral" and (d) "central" regions for a contour of a 2^+ matrix element. The solid curves are fits to a Gaussian signal over the scaled backgrounds of Fig. 1(b).

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[1] I. Peruzzi *et al.*, Phys. Rev. Lett. 37, 569 (1976).

[2] B. J. Bjørken and S. L. Glashow, Phys. Lett. 11, 255 (1964); S. L. Glashow, J. Ilipoulos, and L. Maiani, Phys. Rev. D 2, 1285 (1970); M. K. Gaillard, B. W. Lee, and J. L. Rosner, Rev. Mod. Phys. 47, 277 (1975); A. De Rújula, H. Georgi, and S. L. Glashow, Phys. Rev. Lett. 37, 398 (1976); K. Lane and E. Eichten, Phys. Rev. Lett. 37, 477 (1976).

[3] G. Goldhaber *et al.*, Phys. Rev. Lett. 37, 255 (1976).

[4] Tracks which lack reliable TOF information are in-

cluded in the "pion" category.

[5]C. Zemach, Phys. Rev. B 133, 1201 (1964); see also B. W. Lee, C. Quigg, and J. L. Rosner, Fermilab PUB 76/73 Thy, 1976 (unpublished).

[6]A phase-space decay is possible for the $K\pi\pi$ spin and parity assignment of 0^-.

Search for Superheavy Elements in Monazite Ore from Madagascar

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Superheavy elements have been searched for by neutron-induced fission of mass-separated samples in the monazite ore. Fissioning masses have been collected in the 294–361 mass region. No evidence for superheavy elements has been found at a level of 10^{-12} g/g in this ore.

Intriguing findings concerning the existence of superheavy elements (SHE) in nature have recently been published by Gentry *et al.*[1] They found evidences for the existence of element 126, and possibly elements 124 and 127, in inclusions of monazite observed in the center of giant pleochroic halos. The evaluated amount of superheavy elements in these inclusions (of about 1 μg) is of the order of several hundred picograms; this would correspond to a fantastic concentration of 10^{-4} g/g in the inclusion. According to Gentry,[2] the occurrence of such giant halos is 10^{-6}, a reasonable expectation can then be a concentration of 10^{-10} g/g of superheavy elements in the monazite crystals from the same ore. These results have prompted many experimentalists to search for superheavy elements in monazite minerals.[3]

The present work reports on the search for superheavy elements in a monazite sample originating from the same place where the giant halos were found (i.e., "col de Monangothry" near Fort Dauphin Madagascar). This sample contains sheets of mica biotite in which normal halos —about 100—were found. No giant halos were detected which does not contradict the statistical occurrence quoted above. It contains also big crystals of monazite. We have verified by an electron microprobe analysis and by x-ray fluorescence analysis that the composition of these was very similar to the one of the monazite inclusions in mica as can be deduced from the spectra given by Gentry *et al.*[1] Our search has been done on these crystals since they should be rich in superheavy elements according to the reasons given above.

For the elements 124, 126, and 127 theoretical calculations predict that the most stable isotopes should have 228 neutrons,[4-6] so the masses expected should be 352, 354, and 355.

The very sensitive method used has already been described.[7] About 1 g of the sample is mass-separated in an isotope separator (Sidonie from Laboratoire René Bernas). The ions in the region of $A = 294-361$ where SHE's are expected are collected on a quartz plate which acts as a detector of fission tracks after a subsequent neutron irradiation.

Two runs on the isotope separator were needed —one with 0.85 g, the collection between $A = 296-325$ and another with 0.83 g for the collection between $A = 326-361$. The sample was completely exhausted after each separation.

The quartz plates were irradiated during 1 week in the swimming pool reactor TRITON from Commissariat à l'Energie Atomique (Fontenay aux Roses). They were wrapped in a cadmium foil to eliminate slow neutrons and placed behind a lead wall to reduce the γ irradiation of the plates. Assuming a 10-MeV fission barrier as found by Quentin[8] in his calculations (he quotes that this high value of the fission barrier is in-