The foregoing discussion is sufficient to prove our assertions to all orders in perturbation theory excluding closed loops where the Lorentz indices are contracted along the loop (an example of such a loop is the internal photon loop in scalar electrodynamics). In such a case the cancellation of the extra field degrees of freedom is a consequence of the statistics of the field variables: Whereas the 5 and 6 components in (7) [(15)] are commuting [anticommuting] the θ and $\bar{\theta}$ components are anticommuting [commuting]. Thus there is a relative minus sign for these fields and hence their contributions cancel each other. This completes our proof of the equivalence to four-dimensional quantum theory.

We have shown that conventional quantum theories can be viewed as restrictions of superspace supersymmetric theories to the (physical) four-space. This new approach to ordinary quantum theories can be interpreted as stochastic quantization, an interpretation on which we shall focus elsewhere.[6]

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[7] The symbol [} stands for a graded commutator: $[A,B\} = AB - (-1)^{n_A n_B} BA$ where $n_A = 1$ for A anticommuting and $n_A = 0$ otherwise.

[8] Superspace Feynman rules for several theories are given in Ref. 6.

[9] We normalize so that $\int d\bar{\alpha}\, d\alpha\, \alpha\bar{\alpha} = 1$.

Search for Resonance Structure in the *np* Total Cross Section below 800 MeV

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The *np* total cross section has been measured from 40 to 770 MeV with good statistical precision and better than 1% energy resolution. No evidence is seen for narrow resonances with areas greater than 5 mb MeV or for the $I = 0$, ${}^1F_3$ state reported by other authors. From 200 to 700 MeV the present results are as much as 6% lower than previous data.

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During the last few years both experimental claims and theoretical predictions of the existence of many dibaryon resonances have been made.[1,2] A number of new experiments have been performed to test these claims; nevertheless, it is generally agreed that present data on the existence of dibaryon resonances are inconclusive.[3]

One of the most straightforward methods of searching for resonance structure is a total-cross-section measurement.[4] Not only can data be obtained with small statistical uncertainty, but neutron time-of-flight (TOF) measurements utilizing a "white" source of incident neutrons have the additional advantage that high-resolution data can be recorded simultaneously over a broad range of energy.

In the present work, we have measured the *np* total cross section from 40 to 770 MeV (1900 to 2230 MeV $E_{\mathrm{c.m.}}$) using neutron TOF techniques. Such measurements are sensitive to dibaryon resonances resulting from states with isospin either $I=0$ or $I=1$. States which have been predicted to give significant structure in our energy range are listed in Table I.[1,2,5-8] Because those states which have not yet been observed may have narrow widths,[2,9] the present data were taken

TABLE I. Proposed $I = 0$ and $I = 1$ dibaryon resonances for $E_{\mathrm{c.m.}} < 2240$ MeV.

State (I)	$E_{\mathrm{c.m.}}$ (MeV)	Γ (MeV)	x_e	Experimental evidence
${}^1S_0(1)^{\mathrm{a}}$	2020	?	?	None
${}^3P_1(1)^{\mathrm{a}}$	2060	?	?	None
${}^1D_2(1)^{\mathrm{b,c}}$	2170	$\simeq 75$	$\simeq 0.1$	$\Delta\sigma_L(pp)$, $\Delta\sigma_T(pp)$, $C_{LL}(pp)$
${}^3F_3(1)^{\mathrm{b-d}}$	2200	$\simeq 125$	$\simeq 0.2$	$\Delta\sigma_L(pp)$, $P(pp)$, $C_{LL}(pp)$, $\sigma_t(np)$
${}^1P_1(0)^{\mathrm{e}}$	2110	?	?	None
${}^1F_3(0)^{\mathrm{f}}$	2190	50	0.12	$\sigma_t(np)$, $\sigma_r(I = 0)$, $\Delta\sigma_L(I = 0)$, $P(pn)$

[a] Ref. 5.
[b] Ref. 1.
[c] Ref. 6.
[d] Ref. 7.
[e] Ref. 2.
[f] Ref. 8.

with high resolution, e.g., $\Delta E_{\mathrm{c.m.}} = 1.4$ MeV at 2110 MeV $E_{\mathrm{c.m.}}$. The present work is the first high-resolution study of the NN system over this energy range.

The experiment was performed in good geometry at the Weapons Neutron Research (WNR) Facility of Los Alamos National Laboratory. Neutrons with a broad energy range were produced by bombarding a 3-cm-thick ^{238}U target with an 800-MeV pulsed proton beam from the Clinton P. Anderson Meson Physics Facility (LAMPF) and were defined at 0° by two 1-m-long iron collimators located 3.3 and 15.8 m from the production target. After passing through the uranium, the proton beam was deflected by a bending magnet to a shielded beam dump. Transmission samples were located 25 m from the production target in a computer-controlled changer.

The samples were sets of 7.6-cm-diam matched cylinders of high-purity polyethelene and graphite. The main set had 1-m-long polyethelene. We also fabricated half-thickness samples to use as a check on background conditions. Each sample was quantitatively analyzed for impurities and x rayed to look for voids. Areal densities determined after the experiment with the graphite machined to the measured beam diameter indicated that the carbon in the samples was matched to better than 0.01%.

The main neutron detector consisted of a $15 \times 20 \times 7\text{-cm}^3$ NE110 plastic scintillator with two edge-mounted photomultiplier tubes. A thin veto counter was placed in front of the main detector to reject charged particles. Neutron TOF spectra were obtained using an Ortec TDC-100 time digitizer. Time channel widths were 125 ps per channel and 8192 channels of data were stored. The neutron flight path was determined to be 67.27 ± 0.02 m by use of carbon resonances at 4.937, 5.368, 6.297, and 7.747 MeV for calibration.[10] A neutron-flux monitor consisting of a veto counter and a proton-recoil detector was placed in the neutron beam at about 0.5 m in front of the samples for relative normalization of the data. Fast scalers were used to record flux-monitor sums and other diagnostic information.

To insure that our main detector system could resolve narrow structure we measured the response for 800-MeV neutrons using a 3-cm-thick ^{7}Li production target. In that test, the width of the ${}^7\mathrm{Li}(p,n)$ charge-exchange peak was measured to be 8 MeV full width at half maximum, which was consistent with that calculated from the beam-pulse width (~200 ps), target thickness, detector, and electronics contributions taken in quadrature.

Proton-beam and room-scattered neutron backgrounds were measured, respectively, by removing the neutron production target and by replacing the transmission sample with a 7.6-cm-diam, 75-cm-long cylinder of ^{238}U. In both cases the integrated backgrounds were negligible.

The cross-section data were taken by cycling either the polyethelene or the graphite sample into the beam at two-minute intervals. After 20 min of accumulation, data were recorded on magnetic tape. This technique eliminated many sources of systematic error and permitted off-line corrections for slight timing shifts which occurred during the interval between tape dumps.

The final data set consisted of approximately 600 runs of 20 min each. Each run was corrected for a time shift of one or two channels if necessary and for dead-time losses. The 600 runs were broken into four groups for comparison purposes and from the sum of each group a small time-independent background (typically 0.01%) was subtracted. Cross sections calculated from each group using broad time bins to provide improved statistics showed consistency to about 0.5%. A second set of data taken with the half-length samples agreed with the thick-sample results to better than 1%, thus indicating that background and dead-time corrections had been properly made.

The present results are compared with previous data[11-14] and with phase-shift predictions[15] in Fig. 1. For clarity the data were combined into energy bins ($\Delta E = 10$ MeV) much larger than the experimental energy resolution. Here our error bars represent statistical uncertainties only. The total systematic uncertainty of the present results is estimated to be $<1\%$. This estimate, based on variations in neutron-flux normalization and on our sample-thickness determinations, is consistent with that obtained from comparisons with precise low-energy data in the regions of overlap. In comparison with both existing data[11-14] and phase-shift predictions[15] our data are in excellent agreement below 200 MeV, but are substantially lower from 200 to 700 MeV. Near 750 MeV, the phase-shift solution agrees with our results within about 1%.

It is seen in Fig. 1 that the most prominent feature of the *np* total cross section over this energy range is the broad anomaly near 700 MeV observed previously by Devlin *et al.*[13] The present work confirms this structure up to 770 MeV. We have pointed out elsewhere that this anomaly can be interpreted in terms of the proposed $I=1$, $^3F_3$ dibaryon resonance.[7]

No evidence is observed in the present data for the proposed $^1D_2$ state.[3,6] This fact is not surprising, because no evidence is seen in values of $\sigma_t(pp)$ calculated from phase shifts which are consistent with a $^1D_2$ resonance interpretation (see, e.g., Fig. 3).[15] Presumably no structure is observable because this proposed state is highly inelastic, interferes strongly with the $^1D_2$ background phase shift, and is very close to the $N\Delta$ threshold.[6,15]

Part of the present data was binned into 0.25-ns intervals and fitted with a smooth curve to show the effects of predicted resonances (see Table I) and to facilitate a search for narrow structure. A good fit (reduced $\chi^2 = 0.9$) was obtained from 250 to 700 MeV (2000 to 2200 MeV $E_{\mathrm{c.m.}}$) with a cubic polynomial.

The present data minus the polynomial fit are given in Fig. 2. Also shown are Breit-Wigner (BW) curves for the proposed $I=1$, $^3P_1$, and $I=0$, $^1P_1$ resonances.[2,5] No curve is given for the predicted $I=1$, $^1S_0$ state,[5] because here threshold effects may be significant. The BW curves shown were calculated assuming the elasticity $x_e = 1$ be-

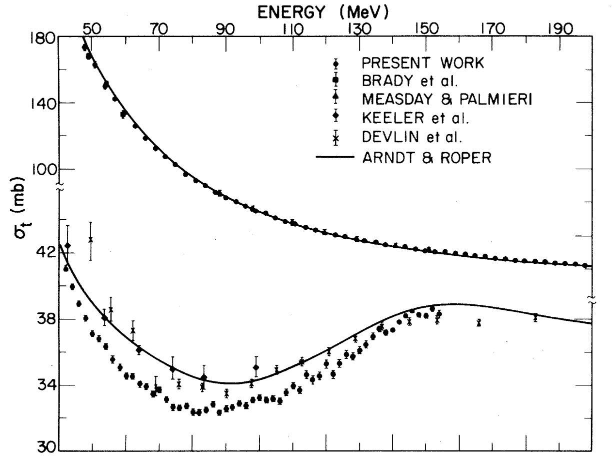

FIG. 1. Comparison of present results with selected high-accuracy *np* total-cross-section data and with phase-shift predictions. The upper (lower) data correspond to the upper (lower) energy scale. Note that the cross-section scale for the upper data is a factor of 10 smaller than for the lower data.

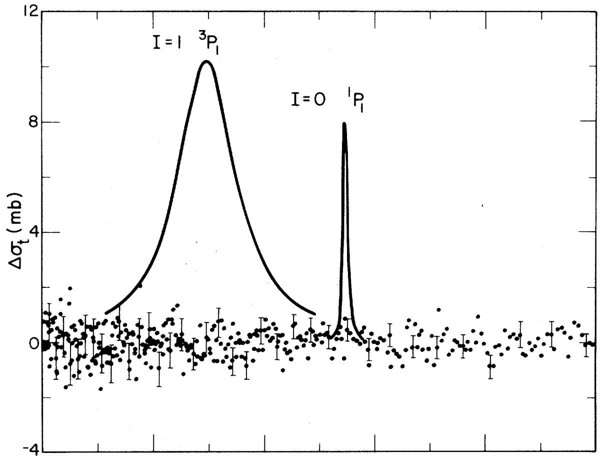

FIG. 2. The deviation of our *np* total-cross-section data (dots) from a cubic polynomial fit. The results correspond to 250-ps time bins. The solid curves were calculated using Breit-Wigner resonance parameters described in the text.

cause for both these p waves the associated inelastic cross sections are negligible at the energies of interest.[15,16] MacGregor has claimed that the $I=1$ states listed in Table I are members of a rotational band.[5] Thus, we have assumed for his predicted $^3P_1$ resonance that the width of this state is equal to the *elastic* width of the $^3F_3$ state, 25 MeV (see Table I). Because the $I=0$, $^1P_1$ resonance at 2110 MeV predicted by Mulders, Aerts, and de Swart[2] may be narrow, that BW curve was computed using a width equal to our experimental resolution at that energy, 1.4 MeV.

It is clear from Fig. 2 that neither of these theoretically predicted p-wave resonances[2,5] is present in the data. The absence of the $I=1$, $^3P_1$ resonance implies that the $I=1$, $^1S_0$ state does not exist either, since this latter state is the bandhead of the proposed rotational band.[5] In any event there is no evidence for the $^1S_0$ state ($E_{\mathrm{c.m.}} = 2020$ MeV) in the data of Fig. 2.

The $I=0$ total cross section for the NN system was computed from the expression $\sigma_t(I=0) = 2\sigma_t(np) - \sigma_t(pp)$. The results for $\sigma_t(pp)$ obtained from the phase-shift solution of Arndt and Roper,[15] $\sigma_t(np)$, and $\sigma_t(I=0)$ are shown in Fig. 3. The $\sigma_t(pp)$ values were assigned an uncertainty of 1% in the calculation of $\sigma_t(I=0)$. The dashed curve was computed from the BW resonance parameters given by Hashimoto and Hoshizaki[8] for the $I=0$, $^1F_3$ state (see Table I) using the dot-dashed curve from a cubic polynomial fit to the $\sigma_t(I=0)$ data as background. This resonance was proposed to explain structure in their phase-shift solution near $E_{\mathrm{c.m.}} = 2190$ MeV. Even though the proposed $^1F_3$ state has a small elasticity,[17] the effect would be easily observable in our $I=0$ cross section. Our data show no evidence for this resonance.

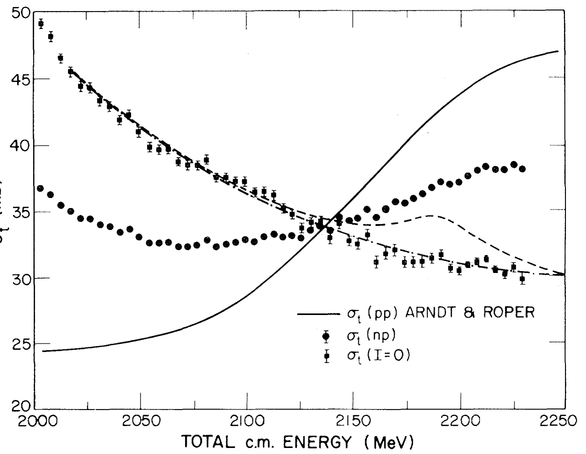

FIG. 3. Nucleon-nucleon total cross sections. The $\sigma_t(np)$ amd $\sigma_t(I=0)$ data were binned in 10-MeV intervals. The solid curve represents $\sigma_t(pp)$ as calculated from the phase shifts of Arndt and Roper (Ref. 15). See text for details.

Finally, other dibaryon states have been predicted in the energy range under investigation for which both the width and elasticity may be small.[2] We therefore made a careful search for weak, narrow structure using the data shown in Fig. 2. Each candidate for a resonance was judged on the basis of three characteristics: width, area (A), and shape. The width was required to be consistent with the experimental resolution; the area, to be statistically significant $[(A/\Delta A) > 3]$; and the shape, to be compatible with the single-level BW equation including an interference term. The first two of our criteria ruled out the existence of narrow resonances with areas greater than 5 mb MeV. No candidates were found which had a statistically significant BW amplitude when a least-squares analysis was performed.

In summary, we have obtained high-resolution, statistically precise np total-cross-section data over the laboratory energy range from 40 to 770 MeV and find no evidence for narrow structure. The broad anomaly previously observed in the np system and attributed to the $I=1$, $^3F_3$ resonance is confirmed by these results. The $I=0$, $^1F_3$ state proposed by Hashimoto and Hoshizaki[8] is not observed. Finally, from 200 to 700 MeV our measured cross sections are significantly lower than both existing data and recent phase-shift predictions.

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Identification of a Pseudoscalar State at 1440 MeV in J/ψ Radiative Decays

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From a partial-wave analysis of the $K\bar{K}\pi$ system in the decay $J/\psi \to \gamma K^+K^-\pi^0$, it is determined that the quantum numbers of the $K\bar{K}\pi$ resonance at 1440 MeV, previously identified as the $E(1420)$, are $J^{PC} = 0^{-+}$. This new particle has been named the ι.

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We have identified a pseudoscalar state with mass $M = 1440^{+20}_{-15}$ MeV in J/ψ radiative decays. This state was previously reported by the Mark II,[1] but was tentatively identified as the $E(1420)$ (a state[2] with spin and parity 1^+) as the spin of the state was not known. We, in collaboration with the Mark II group, have named this pseudoscalar the $\iota(1440)$.[3] Although the theoretical interpretation of this state is uncertain,[4] possible interpretations are a two-gluon bound state or a member of a radially excited $q\bar{q}$ nonet.

In this Letter, we report on a partial-wave analysis of the $K^+K^-\pi^0$ system in the process

$$J/\psi \to \gamma K^+K^-\pi^0. \tag{1}$$

The analysis is based on a sample of 2.2×10^6 produced J/ψ events. The data were collected with the Crystal Ball Detector at the Stanford Linear Accelerator Center e^+e^- storage ring facility SPEAR at the peak of the $J/\psi(3095)$ resonance. The detector consists primarily of a segmented array of NaI(Tl) crystals for high-reso-