ANL-HEP-CP-80-66
CONF-800994--12

MASTER

SUMMARY OF PHYSICS FROM MEASUREMENTS WITH LONGITUDINALLY POLARIZED BEAMS AND TARGETS AT ZGS ENERGIES

by

Akihiko Yokosawa

Prepared for

International Symposium

on

High Energy Physics with Polarized Beams and Targets

Lausanne, Switzerland

September 1980

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Operated under Contract W-31-109-Eng-38 for the

U. S. DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

The facilities of Argonne National Laboratory are owned by the United States Government. Under the terms of a contract (W-31-109-Eng-38) among the U. S. Department of Energy, Argonne Universities Association and The University of Chicago, the University employs the staff and operates the Laboratory in accordance with policies and programs formulated, approved and reviewed by the Association.

MEMBERS OF ARGONNE UNIVERSITIES ASSOCIATION

The University of Arizona
Carnegie-Mellon University
Case Western Reserve University
The University of Chicago
University of Cincinnati
Illinois Institute of Technology
University of Illinois
Indiana University
The University of Iowa
Iowa State University
The University of Kansas
Kansas State University
Loyola University of Chicago
Marquette University
The University of Michigan
Michigan State University
University of Minnesota
University of Missouri
Northwestern University
University of Notre Dame
The Ohio State University
Ohio University
The Pennsylvania State University
Purdue University
Saint Louis University
Southern Illinois University
The University of Texas at Austin
Washington University
Wayne State University
The University of Wisconsin-Madison

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use or the results of such use of any information, apparatus, product or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights. Mention of commercial products, their manufacturers, or their suppliers in this publication does not imply or connote approval or disapproval of the product by Argonne National Laboratory or the United States Government.

DISCLAIMER
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or 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 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. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Akihiko Yokosawa

SUMMARY OF PHYSICS FROM MEASUREMENTS WITH LONGITUDINALLY POLARIZED BEAMS AND TARGETS AT ZGS ENERGIES*

Akihiko Yokosawa
Argonne National Laboratory, Argonne, Illinois 60439

ABSTRACT

An extensive amount of data were obtained from measurements of proton-proton elastic scattering from 1 to 12 GeV/c using longitudinally polarized beams and targets. We summarize physics learned from these data as well as other related experimental results. The topics will include structures observed in nucleon-nucleon scattering at lower energies and dinucleon resonances, pp scattering-amplitude measurements at 6 GeV/c, and large $p_\perp$ results in pp elastic scattering.

I. STRUCTURE IN NUCLEON-NUCLEON SYSTEM AND DINUCLEON RESONANCES

i) I = 1 System

A striking energy dependence has been observed in the difference between the nucleon-nucleon total cross-sections for pure spin states:

$$\Delta\sigma_L = (4\pi/k)\ \mathrm{Im}\{\phi_1(0) - \phi_3(0)\} = \sigma^{\mathrm{Tot}}(\uparrow\downarrow) - \sigma^{\mathrm{Tot}}(\uparrow\uparrow)\ ,$$

and

$$\Delta\sigma_T = -(4\pi/k)\ \mathrm{Im}\ \phi_2(0) = \sigma^{\mathrm{Tot}}(\uparrow\downarrow) - \sigma^{\mathrm{Tot}}(\uparrow\uparrow)\ .$$

Since then many authors have attempted to interprete the results using not only these results but other channels such as pp elastic scattering, πD elastic scattering, $pp \to \pi D$, γD reactions etc. Summary of the investigation is for instance given in Ref. 1. Figure 1 shows $\Delta\sigma_L$ data. At present, more energy points in $\Delta\sigma_L$ including the existing points have been measured at LAMPF in Los Alamos and simultaneously $\Delta\sigma_T$ by a Rice group.

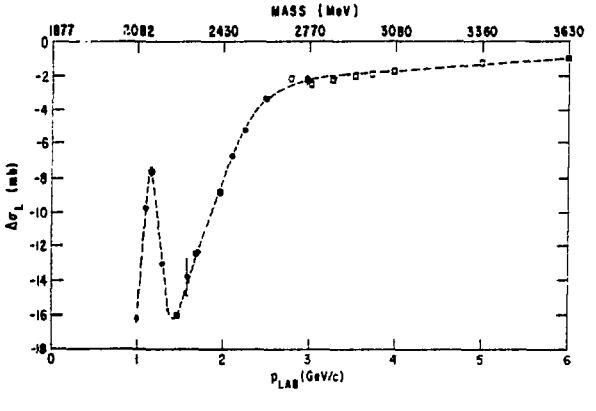
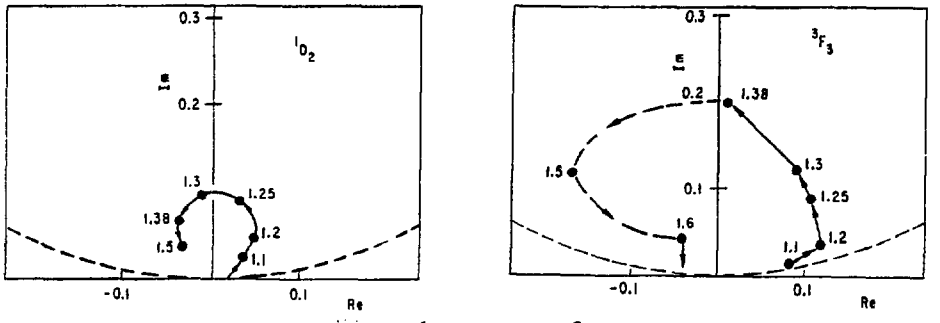


Fig. 1 Total cross-section difference $\Delta\sigma_L = \sigma^{\mathrm{Tot}}(\uparrow\downarrow) - \sigma^{\mathrm{Tot}}(\uparrow\uparrow)$. The white squares are preliminary data.

The large energy dependence are seen not only in $\Delta\sigma_L$ and $\Delta\sigma_T$, but in polarization, $C_{NN} = (N,N;0,0)$, $C_{LL} = (L,L;0,0)$. The typical analysis carried out so far are the Argand plot by dispersion and relation,[2] elastic total cross section,[3] Legendre coefficient analysis,[4] and C_{NN} data analysis,[1] and phase-shift analyses. All of these analyses are consistent with the existence of diproton resonances. Particularly, strong indication of resonance in the $^1D_2$ and $^3F_3$ states are established by phase shift analyses[5,6] as shown in Figs. 2 and 3.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED



Figs. 2 Argand diagrams of the $^1D_2$ (a) and $^3F_3$ (b) partial waves (points are in GeV/c); the background contributions have been subtracted.

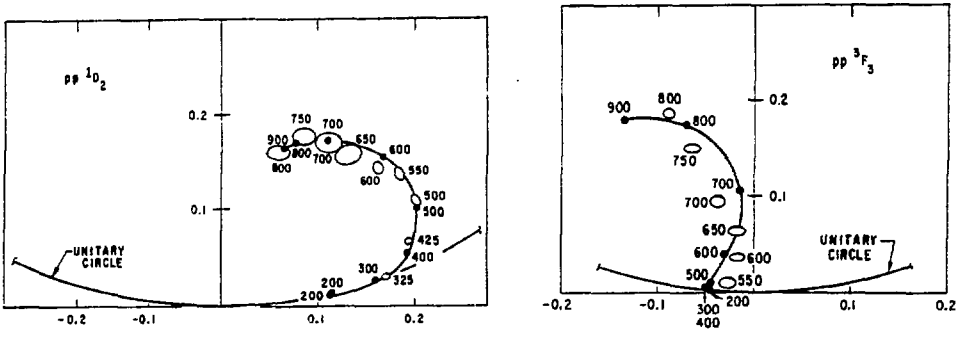
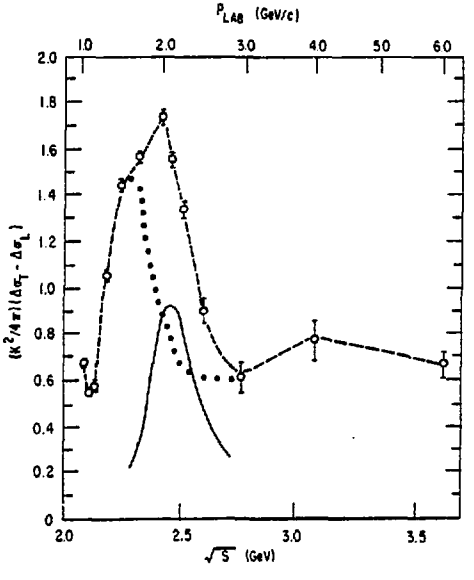


Fig. 3 Argand diagram of the $^1D_2$ (a) and $^3F_3$ (b) partial waves based on Arndt's phase shifts (points are in kinetic energy, MeV). The ellipses represent the errors in the real and imaginary parts of the amplitudes for energy-independent solutions. The continuous curves represent the energy-dependent solutions.



Other possible resonances in pp system include a singlet resonance in $\Delta\sigma_T$ at 2 GeV/c, a triplet resonance appearing in $(k^2/4\pi)(\Delta\sigma_T - \Delta\sigma_L)$ as shown in Fig. 4. We also note that there is no $^1D_2$ and $^3F_3$ contribution to the polarization data at

Fig. 4 New triplet structure at 2.0 GeV/c; the dotted curve is deduced from $\Delta\sigma_L$ data.

$\theta_{c.m.} = 63°$. We see an interesting structure in a plot of $k^2 P(d\sigma/d\Omega)/\sin 2\theta_{c.m.}$ vs. p_{lab} as shown in Fig. 5. The quantity is proportional to

$$(2\ \mathrm{Im}^3P_0) + 3\ \mathrm{Im}^3P_1)(\mathrm{Re}^3P_2) - (2\ \mathrm{Re}^3P_0 + 3\ \mathrm{Re}^3P_1)(\mathrm{Im}^3P_2)$$

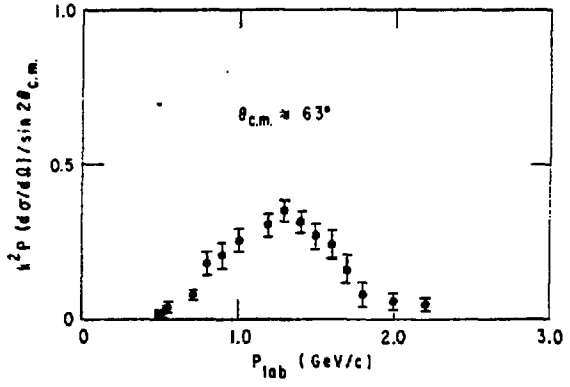


Fig. 5 Energy dependence of $P(d\sigma/d\Omega)$ at $\theta_{c.m.} \approx 63°$.

Recently Borisov et al.[7] investigated the energy dependence of $(C_{NN} - C_{LL})$ at $\theta_{c.m.} = 90°$ in where neither $^1D_2$ nor $^3F_3$ contribution exist. As shown in Fig. 6, there is a sharp structure around 1.3 GeV/c. One may conclude $^3P_0$ partial wave is responsible for the structure.

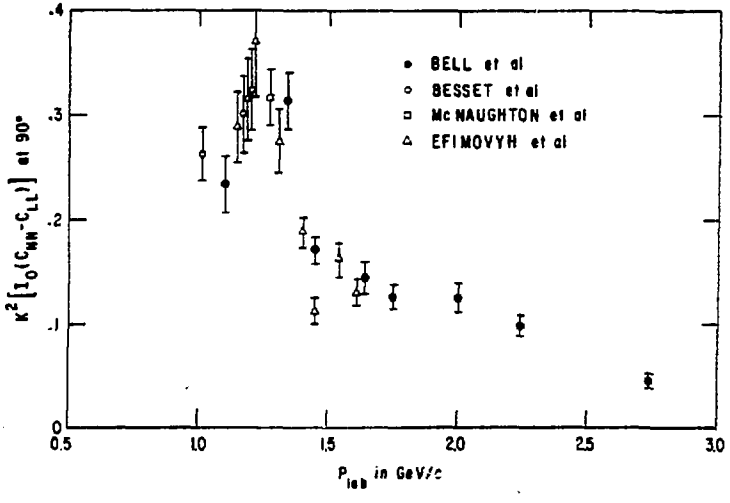


Fig. 6 A plot of $k^2[I_0(C_{NN} - C_{LL})]$ at 90° versus P_{lab} in GeV/c.

ii) $\Delta\sigma_L$ (I = 0) Measurements

The Argonne PPT group has recently measured the difference between isoscalar nucleon-nucleon total cross sections for pure longitudinal

initial spin states, $\Delta\sigma_L$(pd), using a polarized proton beam and a polarized deuteron target.[8] In the simplest approximation, $\Delta\sigma_L$(pd) $\approx$ $\Delta\sigma_L$(pp) + $\Delta\sigma_L$(pn). One can extract $\Delta\sigma_L$(I=0) data using both $\Delta\sigma_L$(pd) and $\Delta\sigma_L$(pp) as shown in Fig. 7; a significant structure is observed around 1.5 GeV/c. This seems to suggest the existence of a new isoscalar spin-singlet dinucleon resonance. We note here that there exists a clear shoulder in the np total cross-section data[9] in the vicinity of 1.5 GeV/c.

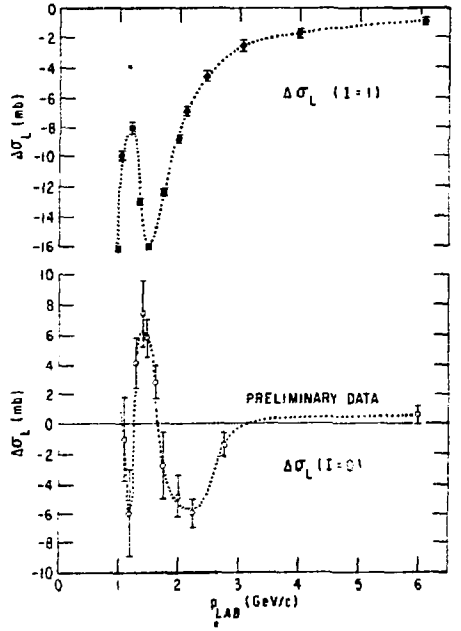


Fig. 7 $\Delta\sigma_L$(I = 0) together with $\Delta\sigma_L$(I = 1).

A recent phase-shift analysis using these preliminary data by Hoshizaki et al.[10] suggests that there exists a partial wave whose behavior is consistent with the Breit-Wigner Resonance formula, namely, the spin singlet $^1F_3$ wave. From the dispersion analysis of a forward I = 0 scattering amplitude using the data on $\Delta\sigma_L$(I = 0), Grein and Kroll[11] showed that the Argand plot of the amplitude has a resonancelike behavior around 1.5 GeV/c, and that suggests the existence of a spin-singlet dibaryon resonance.

iii) Conclusion on I = 0 and I = 1 Resonances

Candidates for dibaryon resonances that can couple to nucleon-nucleon systems are summarized in the table below.

Candidates for Dinucleon Resonances

i) I = 1 Isospin State

	B_1^2 (2.14)	B_1^2 (2.18)	B_1^2 (2.22)	B_1^2 (2.43)	B_1^2 (2.43)
Mass, GeV	2.14 - 2.17	2.18 - 2.20	2.20 - 2.25	2.43 - 2.50	2.43 - 2.50
Width, MeV	50 - 100	100 - 200	100 - 200	~150	~150
Quantum State	$^1D_2$	Triplet P ?	$^3F_3$	probably $^1G_4$	Triplet R_{JJ} ?

ii) I = 0 Isospin State

	B_0^2 (2.14)	B_0^2(2.22)	B_0^2 (2.43)
Mass, GeV	2.14 - 2.17	2.20 - 2.26	2.40 - 2.50
Width, MeV	50 - 100	100 - 200	
Quantum State	Triplet ?	$^1F_3$	Triplet ?

II. SCATTERING-AMPLITUDE MEASUREMENTS

The present state of measured observables toward pp scattering-amplitude was summerized in a report.[12] Here we will not document the details.

III. pp SPIN CORRELATIONS AT HIGH $p_\perp$

Elastic scattering at high $p_\perp$ has been theoretically studied by Chen[13], Farrar et al.,[14] Brodsky et al.,[15] and Wolters.[16]

It is our major aim to observe if the quark would carry the spin of the proton. The prediction of QIM assumes helicity conservation among quarks, that is, quark mass is nearly zero. In order to test the prediction at 12 GeV/c (highest momenta at ZGS), we need to measure only two spin-spin correlation parameters so that we test if the s-channel helicity amplitude $\phi_2 = \langle --|++\rangle = 0$ or not; experimentally we need to check if $C_{SS} = -C_{NN}$ where a value of C_{SS} can be obtained by measuring C_{LL}, because at $\theta_{c.m.} = 90°$ the following relationship holds:

$$C_{SS} = C_{NN} - C_{LL} - 1$$

The parameter C_{NN} is already measured by the Michigan Group.[17] We have measured C_{LL} at $\theta_{c.m.} = 90°$, and preliminary data (about 1/3 of the existing data) are shown in Fig. 8. Together with these data the quark helicity conservation is verified within our statistical error.

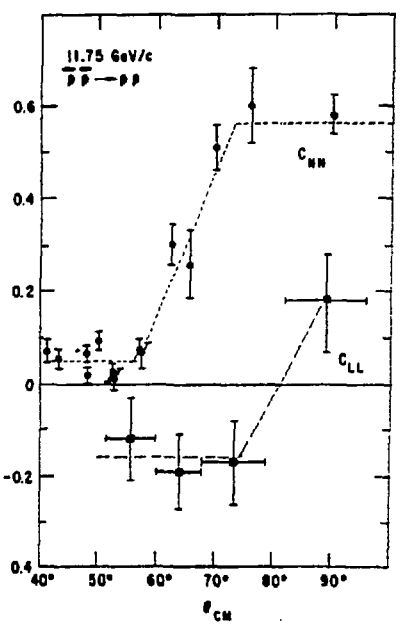


Fig. 8 Spin correlation parameters C_{LL} and C_{NN} for pp elastic scattering at 11.75 GeV/c near $\theta_{c.m.} = 90°$. The curves shown are to guide the eye.

References

1. A. Yokosawa, to be published in Phys. Reports, Volume 64, No. 2, (1980); A. Yokosawa, Proceedings of the 1979 INS Symposium on Particle Physics in GeV Region, p. 442, Tokyo, Japan (November, 1979); and references therein.

2. W. Grein and P. Kroll, Nucl Phys. B137, 173 (1978); P. Kroll, University of Wuppertal preprint WUB 78-13 (1978).

3. To obtain the total elastic cross section from 1.2 to 1.7 GeV/c, we have integrated the differential cross-section data of B. A. Ryan et al. Phys. Rev. 3, 1 (1971). These data were used because of internal consistency.

4. K. Hidaka et al., Phys. Lett. 70B, 479 (1977); and references therin.

5. N. Hoshizaki, Prog. Theor. Phys. 60 1796 (1978); 61 129 (1979).

6. R. A Arndt, talk given during LAMPF Nucleon-Nucleon Workshop, July 1978; also private communication 1980.

7. N. S. Borisov et al., Academy of Sciences of the USSR, Leningard Nuclear Physics Institute, Report 581, Leningard, (1980).

8. D. Underwood et al., Bull. of Am. Phys. Soc. 24, 636 (1979), to be published.

9. T. J. Devlin et al., Phys. Rev. D8, 136 (1973).

10. N. Hoshizaki et al., Proceedings of the 1979 INS Symposium, on Particle Physics in GeV Region, p. 475, Tokyo, Japan (November 1979).

11. Private communication.

12. A. Yokosawa, Proceedings of the Meeting on Nucleon-Nucleon Interactions and Dibaryon Resonances, HUPD-8001, p. 1, Hiroshima, Japan January 1980.

13. C. K. Chen, Phys. Rev. Lett., 41, 1440 (1978).

14. G. R. Farrar et al., Phys. Rev. D20, 202 (1979).

15. S. J. Brodsky et al., Phys. Rev. D20, 2278 (1979).

16. G. F. Wolters, Nationaal Instituut voor Kernfysica en Hoge - Energiefysica, Amsterdam, The Netherlands preprint (1980).

17. K. Abe et al., Phys. Lett. 63B, 239 (2976); H. E. Miettinen et al., Phys. Rev. D16, 549 (1977); J. R. O'Fallon et al., Phys. Rev. Lett. 39, 733 (1977); E. A. Crosbie et al., University of Michigan preprint UM HE 80-2 (1980).

* Work supported by the U.S. Department of Energy.