Final Report

Virginia Tech Scattering Analyses

(May 1, 1988 to May 1, 1997)

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Evolution of the SAID Partial-Wave Analyses

In 1988, our group was maintaining and updating analyses of the elastic πN , NN , and KN databases. To these we have added databases and analyses of pion photoproduction, elastic πd scattering, and the reaction $\pi d \rightarrow pp$. In addition to this, a database for pion electroproduction has been assembled for future analysis.

Our results were initially made available through Telnet connections to a VAX computer at Virginia Tech and through the distribution of tapes to sites around the world. Since 1988, we have moved our analyses to UNIX workstations and have started a website, in order to make our results available to a wider range of users.

Ph.D. Students

A number of Ph.D. students either began or completed their studies between 1988 and 1997. In chronological order, we worked with:

John M. Ford

'Analysis of Pion-Nucleon Scattering' (Ph.D. April 1988)

John S. Hyslop

'Analysis of K^+ -Nucleon Scattering' (Ph.D. August 1990)

Zhujun Li

'An Analysis of Pion-Photoproduction' (Ph.D. April 1992)

C.H. Oh

'A Unified Analysis of the $B=2$ System' (Ph.D now completed)

Submissions and Publications

Approximately 75 articles were written over the period of this grant. Some of these (the Review of Particle Properties) file entire issues of Phys. Rev. D. As a cost saving measure, we do not regularly purchase reprints of our articles. Given the above situation, we have provided a representative sample of our publications, supplemented by the following full bibliography.

Δ^+ mass reexamined,

R.L. Workman,

Phys. Rev. C **56**, 1645 (1997).

E2/M1 ratio from the Mainz $p(\vec{\gamma}, p)\pi^0$ data,

R.L. Workman,

Phys. Rev. Lett. **79**, 4511 (1997).

Nucleon-nucleon elastic scattering analysis to 2.5 GeV,

R.A. Arndt, C.H. Oh, I.I. Strakovsky, R.L. Workman, and F. Dohrmann,

Phys. Rev. C **56**, 3005 (1997).

Combined analysis of the reactions $pp \rightarrow pp$, $\pi d \rightarrow pp$, and $\pi d \rightarrow \pi d$,

C.H. Oh, R.A. Arndt, I.I. Strakovsky, and R.L. Workman,

Phys. Rev. C **56**, 635 (1997).

Comment on 'Measurement of the $\pi^+\vec{p}$ analyzing power at 68.3 MeV',

R.A. Arndt, I.I. Strakovsky, and R.L. Workman,

Phys. Rev. C **56**, 579 (1997).

Pion photoproduction in the delta resonance region,

R.A. Arndt, I.I. Strakovsky, and R.L. Workman,

Phys. Rev. C **56**, 577 (1997).

Influence of spin-rotation measurements on partial-wave analyses of elastic pion-nucleon scattering,

I.G. Alekseev, V.P. Kanavets, B.V. Morozov, D.N. Svirida, S.P. Kruglov, A.A. Kulbardis,

V.V. Sumachev, R.A. Arndt, I.I. Strakovsky, and R.L. Workman,

Phys. Rev. C **55**, 2049 (1997).

Ambiguities in the partial-wave analysis of pseudoscalar-meson photoproduction,

G. Keaton and R.L. Workman,
Phys. Rev. C **54**, 1437 (1996).

Review of Particle Properties,

R.M. Barnett, C.D. Carone, D.E. Groom, T.G. Trippe, C.G. Wohl, F. James, M. Mangano, K. Mönig, L. Montanet, J.L. Feng, H. Murayama, J.J. Hernandez, A. Manohar, M. Aguilar-Benitez, C. Caso, R.L. Crawford, M. Roos, N.A. Törnqvist, K.G. Hayes, K. Hagiwara, K. Nakamura, M. Tanabashi, K. Olive, K. Honscheid, P.R. Burchat, R.E. Shrock, S. Eidelman, R.H. Schindler, A. Gurtu, K. Hikasa, G. Conforto, R.L. Workman, C. Grab, and C. Amsler,
Phys. Rev. D **54**, 1 (1996).

Particle Physics Summary,

R.M. Barnett et al.,
Rev. Mod. Phys. **68**, 611 (1996).

Amplitude ambiguities in pseudoscalar meson photoproduction,

G. Keaton and R.L. Workman,
Phys. Rev. C **53**, 1434 (1996).

Do we have three S_{11} resonances in the second resonance region?,

Z. Li and R.L. Workman,
Phys. Rev. C **53**, R549 (1996).

Updated resonance photo-decay amplitudes to 2 GeV,

R.A. Arndt, I.I. Strakovsky, and R.L. Workman,
Phys. Rev. C **53**, 430 (1996).

Extraction of the πNN coupling constant from np charge exchange data,

R.A. Arndt, I.I. Strakovsky, and R.L. Workman,
Phys. Rev. C **52**, 2246 (1995).

An updated analysis of πN scattering data to 2.1 GeV: The Baryon Spectrum,
R.A. Arndt, I.I. Strakovsky, R.L. Workman, and M.M. Pavan,
Phys. Rev. C **52**, 2120 (1995).

Reply to Comment on 'Pion-nucleon partial-wave analysis to 2 GeV',
R.A. Arndt, I.I. Strakovsky, and R.L. Workman,
Phys. Rev. D **52**, 5381 (1995).

The SAID Program: A Guide for Users,
R.A. Arndt and R.L. Workman,
submitted to the πN Newsletter.

Updated analysis of NN elastic scattering to 1.6 GeV,
R.A. Arndt, I.I. Strakovsky, and R.L. Workman,
Phys. Rev. C **50**, 2731-2741 (1994).

Analysis of πd elastic scattering to 500 MeV,
R.A. Arndt, I.I. Strakovsky, and R.L. Workman,
Phys. Rev. C **50**, 1796-1806 (1994).

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L. Montanet, K. Gieselmann, R.M. Barnett, D.E. Groom, T.G. Trippe, C.G. Wohl, H. Murrayama, J. Stone, J.J. Hernandez, F.C. Porter, R.J. Morrison, A. Manohar, M. Aguilar-Benitez, C. Caso, P. Lantero, R.L. Crawford, M. Roos, N.A. Törnqvist, K.G. Hayes, G. Höhler, S. Kawabata, D.M. Manley, K. Olive, R.E. Shrock, S. Eidelman, R.H. Schindler, A. Gurtu, K. Hikasa, G. Conforto, R.L. Workman, and C. Grab,
Phys. Rev. D **50**, 1173-1826 (1994).

The Gerasimov-Drell-Hearn sum rule and current algebras,
L.N. Chang, Y. Liang and R.L. Workman,
Phys. Lett. B **329**, 514-518 (1994).

Width distribution for random-walk interfaces,

G. Foltin, K. Oerding, Z. Racz, R.L. Workman, and R.K.P. Zia,
Phys. Rev. **E 50**, R639-R642 (1994).

Pion-nucleon partial-wave analysis with fixed-t dispersion relation constraints,

R.A. Arndt, R.L. Workman and M. Pavan,
Phys. Rev. **C 49**, 2729-2734 (1994).

Status of the Virginia Tech Partial-Wave Analyses,

R.A. Arndt and R.L. Workman,
Few-Body Systems Suppl. **7**, 64-67 (1994).

Analysis of the reaction $\pi d \rightarrow pp$ to 500 MeV,

R.A. Arndt, I.I. Strakovsky, R.L. Workman and D.V. Bugg,
Phys. Rev. **C 48**, 1926-1938 (1993); **C 49**, 1229 (1994) (Erratum).

Comment on 'The role of g_2 in relating the Schwinger and Gerasimov-Drell-Hearn sum rules',

R.L. Workman and Zhenping Li,
Phys. Rev. Lett. **71**, 3608 (1993).

The VPI pion-nucleon partial-wave analyses: The pion-nucleon coupling constant,

R.A. Arndt, I.I. Strakovsky, R.L. Workman, and M.M. Pavan,
 πN Newsletter No.8, 37-41 (1993).

Resonance photodecay amplitudes to 1.8 GeV,

Zhujun Li, R.A. Arndt, L.D. Roper and R.L. Workman,
Phys. Rev. **C 47**, 2759-2763 (1993).

Does the πNN coupling 'constant' vary with energy?,

R.A. Arndt, I.I. Strakovsky and R.L. Workman,
Phys. Rev. **C 48**, 474-475 (1993).

How well do we know the E2/M1 ratio for the $\Delta(1232)$?,

R.L. Workman, R.A. Arndt and Zhujun Li,

Phys. Rev. C **46**, 1546-1547 (1992).

Partial-wave analysis of K^+ -nucleon scattering,

J.S. Hyslop, R.A. Arndt, L.D. Roper and R.L. Workman,

Phys. Rev. D **46**, 961-969 (1992).

Uncertainties in np cross sections from 25-225 MeV,

R.A. Arndt and R.L. Workman,

Phys. Rev. D **46**, 1192-1194 (1992).

H(n,n)H cross section standard below 350 MeV,

R.A. Arndt and R.L. Workman,

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Nucleon-nucleon partial-wave analysis to 1.6 GeV,

R.A. Arndt, L.D. Roper, R.L. Workman and M.W. McNaughton,

Phys. Rev. D **45**, 3995-4001 (1992).

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R.L. Workman, H.W.L. Naus and S.J. Pollock,

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Phys. Rev. D **45**, 1789-1791 (1992).

On the Goldberger-Miyazawa-Oehme sum rule,

R.L. Workman, R.A. Arndt and M. Pavan,

Phys. Rev. Lett. **68**, 1653-1655 (1992); **68**, 2712 (1992) (Erratum).

Reply to Comment on 'Determination of the πNN coupling constant from elastic pion-nucleon scattering data',

R.A. Arndt, Zhujun Li, L.D. Roper and R.L. Workman,
Phys. Rev. Lett. **68**, 549 (1992).

On threshold pion photoproduction and low-energy theorems,

R.L. Workman, R.A. Arndt and Zhujun Li,
Mod. Phys. Lett. A **6**, 1757 (1991).

Comment on 'Kaon photoproduction: Data consistency, coupling constants and polarization observables',

R.L. Workman,
Phys. Rev. C **44**, 552 (1991).

The pion-nucleon coupling constant,

R.A. Arndt, Zhujun Li, L.D. Roper and R.L. Workman,
Phys. Rev. D **44**, 289 (1991).

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R.A. Arndt and R.L. Workman,
Phys. Rev. C **43**, 2436 (1991).

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R.A. Arndt, Zhujun Li, L.D. Roper, R.L. Workman and J.M. Ford,
Phys. Rev. D **43**, 2131 (1991).

Pion photoproduction resonance couplings in second resonance region,

R.A. Arndt, R.L. Workman, Zhujun Li and L.D. Roper,
Phys. Rev. C **42**, 1864 (1990).

Partial-wave analysis of pion photoproduction,

R.A. Arndt, R.L. Workman, Zhujun Li and L.D. Roper,
Phys. Rev. C **42**, 1853 (1990).

Absorptive model of kaon photoproduction,

R.L. Workman,

Phys. Rev. C **42**, 781 (1990).

Determination of the πNN coupling constant from elastic pion-nucleon scattering data,

R.A. Arndt, Zhujun Li, L.D. Roper and R.L. Workman,

Phys. Rev. Lett. **65**, 157 (1990).

Proton-proton bremsstrahlung at 280 MeV,

K. Michaelian, P. Kitching, D.A. Hutcheon, R. Abegg, G.H. Coombes, W.K. Dawson, H.W.

Fearing, H. Fielding, G. Gaillard, P. Green, L.G. Greeniaus, M. Hugi, C.A. Miller, G.C.

Neilson, W.C. Olsen, J. Soukup, N.R. Stevenson, J. Wesick and R.L. Workman,

Phys. Rev. D **41**, 2689 (1990).

Radiative capture of kaons by the deuteron and the $\Lambda - n$ scattering lengths,

R.L. Workman and H.W. Fearing,

Phys. Rev. C **41**, 1688 (1990).

Generalized Skyrme model with pion masses,

S. Nam and R.L. Workman,

Phys. Rev. D **41**, 2323 (1990).

Comment on 'Role of rescattering in pion photoproduction at threshold',

R.L. Workman,

Phys. Rev. Lett. **64**, 702 (1990).

Observables in kaon photoproduction,

R.L. Workman,

Phys. Rev. C **40**, 2922 (1989).

Coupling constants in kaon photoproduction,

R.L. Workman,

Phys. Rev. C **39**, 2456 (1989).

Comment on 'Electromagnetic production of kaons',

R.L. Workman,

Phys. Rev. C **39**, 2076 (1989).

Analyzing powers in $\pi^\pm p$ (polarized) elastic scattering from $T_\pi = 98$ MeV to 263 MeV,

M.E. Sevior *et al.*, Phys. Rev. C **40**, 2780 (1989).

Radiative capture of stopped kaons: $K^-p \rightarrow \Lambda\gamma$ and $K^-p \rightarrow \Sigma^0\gamma$,

R.L. Workman and H.W. Fearing,

Phys. Rev. D **37**, 3117 (1988).

Uncertainties in the np interaction at medium energies,

R.A. Arndt,

Phys. Rev. D **37**, 2665 (1988).

Single channel dominance of pp inelasticities near 1 GeV: Parametrizing spin coupled waves,

R.A. Arndt,

Phys. Rev. Lett. **61**, 529 (1988).

Few body kaon reactions,

H.W. Fearing and R.L. Workman in *3rd Conference on Intersections between Particle and Nuclear Physics*, Rockport, 1988, ed. G.M. Bunce,

AIP Conference Proceedings no. 176, p.677.

Other Conference Contributions

Amplitudes and Ambiguities in the Scattering and Photoproduction of Pseudoscalar mesons,

G. Keaton and R. Workman, contribution to PANIC 96, Williamsburg, May 1996.

Status of the Virginia Tech Analyses,

R.A. Arndt, C. Oh, I.I. Strakovsky, and R.L. Workman, contribution to PANIC 96.

Resonance structure of the VPI πN analysis,

R.A. Arndt, I.I. Strakovsky, and R.L. Workman, contribution to the 6th Int. Symposium on Meson-Nucleon Physics and the Structure of the Nucleon, Blaubeuren/Tübingen, Germany, July 1995.

The Gerasimov-Drell-Hearn sum rule,

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VPI Analyses of Two-Nucleon Systems,

R.A. Arndt, I.I. Strakovsky and R.L. Workman, contribution to the 14th International IUPAP Conference of Few Body Problems in Physics, Williamsburg, May 1994.

Can CEBAF Improve Photo-decay Couplings Determined from Pion Photoproduction Data?,

R. Arndt, J. Ficenec, D. Jenkins, I. Strakovsky, R.L. Workman and W. Briscoe, contribution to the Few Body Conference, Williamsburg, May 1994.

Study of two-nucleon systems at VPI,

R.A. Arndt, I.I. Strakovsky, and R.L. Workman,
poster presented at 11th Int. Symp. on High Energy Spin Physics and 8th Int. Symp. on Polarization Phenomena in Nucl. Phys. , Bloomington, Indiana, Sept., 1994, ed. E.J. Stephenson.

Pion Photoproduction: Current Data and the Potential for Improvement of Physics Insights with CLAS at CEBAF

J. Ficenec, R.A. Arndt, D. Jenkins, I.I. Strakovsky, R.L. Workman, and W. Briscoe, presented at the APS Division of Nuclear Physics Meeting, Washington, October, 1994.

E2 Excitations of the Delta and the Limitations of Multipole Analyses,

R.L. Workman, R.A. Arndt and Zhujun Li, invited talk, *Workshop on Hadron Structure from Photo-reactions at Intermediate Energies*, Brookhaven National Lab, May 1992.

Photo-decay couplings of the N^* resonances,

Zhujun Li, R.A. Arndt and R.L. Workman, contribution to *Baryon 92*, Yale, June 1992.

A modified Gerasimov-Drell-Hearn sum rule from extended current algebras,

L.N. Chang, Y. Liang and R.L. Workman, contribution to *Baryon 92*.

Resonance photon-decay amplitudes,

Zhujun Li, R.A. Arndt, L.D. Roper and R.L. Workman, in *Hadron 91: 4th International Conference on Hadron Spectroscopy*, University of Maryland, August 1991.

Pion-nucleon scattering analyses to 2 GeV,

R.A. Arndt, Zhujun Li, L.D. Roper and R.L. Workman, contribution to *Paris 90, 7th International Conference on Polarization Phenomena in Nuclear Physics*, Paris, July 1990.

What can pion photoproduction say about the ωNN coupling constant?,

Zhujun Li, R.A. Arndt and R.L. Workman, contribution to *PANIC XII International Conference on Particles and Nuclei*, M.I.T., June 1990.

Charge densities in variants of the Skyrme model,

S. Nam and R.L. Workman, contribution to *PANIC XII*.

Are we closer to an understanding of kaon photoproduction?,

R.L. Workman, contribution to *PANIC XII*.

Model dependence in kaon photoproduction,

R.L. Workman, in *Proceedings of the 12th International Conference on Few Body Problems in Physics*, Vancouver, 1989, ed. B.K. Jennings, p.19.

Multipole analysis of pion photoproduction to 1 GeV,

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NN elastic scattering analyses at VPI and SU,

R.A. Arndt and L.D. Roper,

proceeding of conference of Physics with Polarized Beams and Polarized Targets, Spencer, 1989.