

# The 60<sup>th</sup> Anniversary (1964-2024) of the Reporting of the “Roper Resonance” Discovery

The Etymology of a Democratic Scientific Term

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## Etymology of the term “Roper resonance” in particle physics

In Physical Review Letters 12.34 (1964) the paper “Evidence for a  $P_{11}$  Pion-Nucleon Resonance at 556 MEV” by L. David Roper, the discovery of the long-expected  $P_{11}$  resonance was first reported in a peer-reviewed journal.

The first time the author knows about the calling of the discovered  $P_{11}$  pion-nucleon resonance the “Roper resonance” was in the paper Physical Review 147.1028 (1965), where the term was used several times. Another later paper, Physical Review Letters 17.764 (1966) used the same term several times. Another 1966 paper, Physical Review 152.1254 (1966) also used the term several times. A paper, Il Nuovo Cimento LIV A, N.4 (21 Aprile 1968) referred to the “so-called Roper resonance”.

The first paper the author knows about that used the Roper term in the title of the paper is “Roper excitation in  $\alpha$ -proton scattering” in Physical Review C.53.277 (1996). The term is used in three ways several times: Roper excitation, Roper resonance and Roper signal. Many papers since then have used the “Roper resonance” in the title.

The Wikipedia web page for the Roper resonance is [https://en.wikipedia.org/wiki/Roper\\_resonance](https://en.wikipedia.org/wiki/Roper_resonance).

Google Scholar lists 3,600 results for papers that have the “Roper resonance” in the title, abstract or body:

[https://scholar.google.com/scholar?start=10&q=%22Roper+resonance%22&hl=en&as\\_sdt=0.47](https://scholar.google.com/scholar?start=10&q=%22Roper+resonance%22&hl=en&as_sdt=0.47)

Here are two papers published in 2024 that use the term “Roper resonance” in the title:

- Configurational entropy and the  $N+(1440)$  Roper resonance in QCD. Annals of Physics 2024 Elsevier
- The  $N(1440)$  Roper resonance in the nuclear model with explicit mesons, arXiv 2401.11947.2024

I think the latest paper about the structure of the Roper Resonance is Colloquium: Roper resonance: Toward a solution to the fifty year puzzle, Volker D. Burkert and Craig D. Roberts Rev. Mod. Phys. 91, 011003. 14 March 2019.

The term has consistently been used in particle-physics papers for the entire 60 years.

There are two non-physics factors that may have been at work in “Roper resonance” being used in particle-physics papers instead of the technical “ $P_{11}$  resonance” term:

- Alliteration: “the commencement of two or more words of a word group with the same letter, as in *apt alliteration's artful aid*. (<https://www.dictionary.com/browse/alliteration>). Apparently, human sensibilities like alliterations, such as “Roper resonance”.
- The inefficiencies of typing the 11 subscripts in  $P_{11}$  compared to typing Roper in Microsoft Word or other word processor. Apparently, human sensibilities like efficiencies.

**There is no official designation of the  $P_{11}$  Pion-Nucleon Resonance being labeled as the “Roper resonance.” That labeling is a democratic labeling; naturally occurring through extensive use by particle-physics researchers.**

## History of the Discovery of the Roper Resonance

L. David Roper (LDR) was a theoretical-physics graduate student at Massachusetts Institute of Technology (MIT) starting in August 1958. In 1961 his PhD professor became Dr. Bernard T. Feld (BTF), a particle-phenomenology specialist. Prof. Feld and LDR selected pion-nucleon scattering analysis as the PhD thesis subject for LDR.

William M. Layson had previously done a PhD thesis on pion-nucleon scattering analysis with Prof. Feld. However, much new data from high-energy particle accelerators around the world, such as by the [Burton Moyer](#) group at the [Bevatron](#), were due to be published soon; so, a continuation of the analysis was in order.

LDR spent the summers of 1962 and 1963 as a research assistant in the Particle Physics Group (PPG) at Lawrence Radiation Laboratory (LRL; the name was later changed to Lawrence Livermore Laboratory) with the PPG director being Michael J. Moravcsik (MJM). The PPG had developed expertise in analyzing nucleon-nucleon scattering, including a complex Fortran computer code. When MJM learned of the PhD thesis selection of pion-nucleon scattering for LDR, he realized that the nucleon-nucleon code, developed by a UC-Berkeley student and LRL employee, Richard A. Arndt (RAA), could be easily converted to pion-nucleon scattering. In 1962 he sent LDR back to MIT with a proposal that LRL would provide the very powerful computers at LRL and a computer programmer to convert the code for LDR's thesis. Prof. Feld agreed. So, LDR began the arduous task of gathering old, new and not-yet published pion-nucleon scattering data and the theoretical-physics equations to use in the calculations at LRL, which he forwarded to the programmer, Robert M. Wright (RMW), regularly. While LDR was at MIT he exchanged letters with RMW at LRL about the progress of the project, including the data and equations. MJM was in Pakistan for the 1963 school year; LDR exchanged weekly letters with MJM there about the progress of the project.

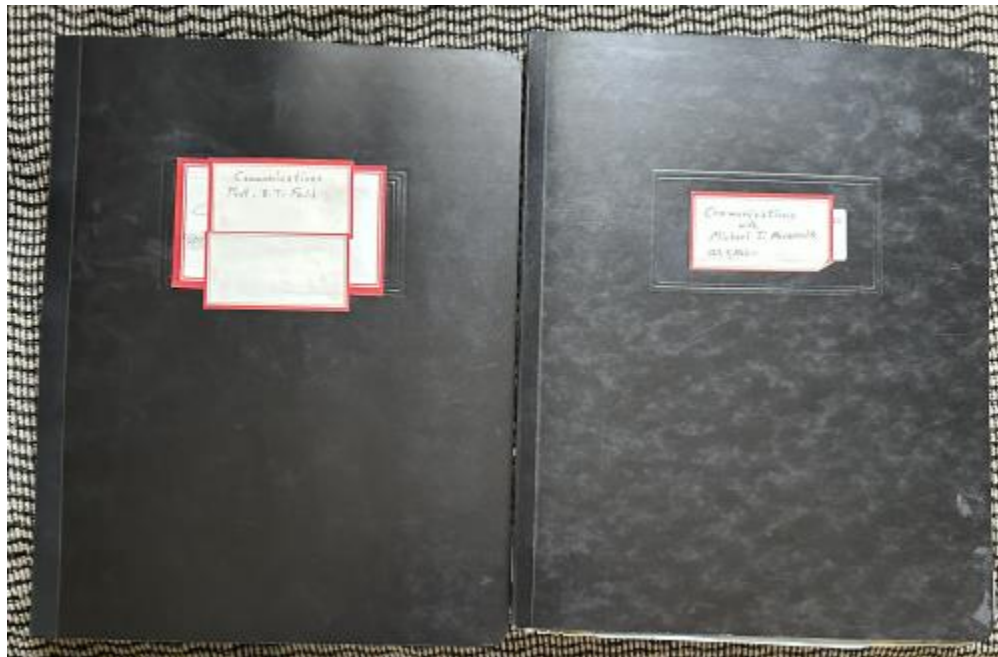
The results of this pion-nucleon analysis predicted the large set of scattering data, within their error bars, that had just been measured by the Burton Moyer group at the Bevatron. After that, the analysis results were used to help decide which future experiments would best determine the pion-nucleon scattering amplitudes.

LDR was accepted as a postdoctoral appointee at LRL to begin after the PhD was awarded by MIT. The thesis work was not completed by the end of the 1963 school year; so, LDR went to LRL as a research assistant for the 1963 summer to complete the analysis. While at LRL, LDR exchanged letters with BTF about the progress of the project. When the thesis work was done, LRL flew LDR back to MIT to defend the thesis, which was accepted by LDR's thesis committee. The many letters exchanged between BTF and LDR and between MJM and LDR have been saved. (See the picture below.)

At MJM's request, BTF at MIT agreed that only LDR's name should be listed as only author of the Physical Review Letters paper announcing the existence of the  $P_{11}$  resonance, the first excited state of the proton. Later, two more detailed papers had BTF's and RMW's names as co-authors. MJM did not want his name on any of the papers, although he was as much LDR's thesis advisor as was BTF and had provided a large amount of supercomputer time and much time of a programmer.

The first published paper about the thesis work was "Evidence for a  $P_{11}$  Pion-Nucleon Resonance at 556 MeV" Physical Review Letters 12.34 (1964). The two following, more detailed, papers, were "Energy Dependent Pion-Nucleon Phase-Shift Analysis" Physical Review 138.1B.190 (1965) and "Pion-Nucleon Phase-Shift Analysis: 0-350 MeV" Physical Review 138.4B.921 (1965). Two decades later at Virginia Tech was the paper "Pion-Nucleon Partial-Wave Analysis to 1100 MeV", Physical Review D32, 1085 (1985).

These are binders of many letters between BTF & LDR and between MJM & LDR:



(The Internet was not yet available!)

The availability of high computing power at LRL ( IBM-7094 mostly, later CDC-3600 and CDC-6600) was crucial to doing the pion-nucleon analysis. I owe large gratitude to Michael J. Moravcsik and Sidney Fernbach for making that possible. I do not know what computing facilities would have been available to me at MIT, since I never did any computing there.

There was considerable **serendipity** of my being at the right places at the right times with the right people and the right amount of new data, coupled with many hours collecting data, studying scattering theory and lugging two boxes of punched cards to computers, to do pion-nucleon scattering analysis for my MIT theoretical-physics thesis and discover the Roper resonance 60 years ago.

Similar analyses were done for alpha-nucleon scattering and K<sup>+</sup>-proton scattering. See <http://roperld.com/personal/vita.htm> for references.

The RAA-LDR pion-nucleon, nucleon-nucleon and other particle-scattering computer codes were moved from LRL to Virginia Polytechnic and State University (VPI&SU), also known as Virginia Tech (VT), in 1967. (Richard A. Arndt and L. David Roper were hired there as a team.) An Internet online access to the VT scattering analyses was developed: **Scattering Analyses Interactive Dial-in (SAID)**. The energy dependence was changed from power-series expansions for phase shifts

and absorption parameters to the K-matrix representation of the scattering matrix: 
$$S = \frac{1 + iK}{1 - iK}$$

(<https://www.sciencedirect.com/science/article/abs/pii/S0003491620301676>); K is expanded in a power series in momentum.

When Richard A. Arndt retired at VT in 1996, he moved the VT analyses and SAID data and programs to the Institute for Nuclear Studies at George Washington University in DC (<https://gwdac.phys.gwu.edu/>). SAID is the major online source for particle scattering data and analyses results.

Reference: <http://roperld.com/science/roperres.htm>