

LAWRENCE R. SULAK  
Abbreviated Curriculum Vitae

EDUCATION

1970 Ph.D., 1968 A.M., Physics, Princeton University, Advisor: Professor Val L. Fitch, Nobel Laureate (1980)  
Thesis: "A Precise Measurement of the  $K_1^0 - K_2^0$  Mass Difference" (first at the 1% level)  
1966 B.S., Physics, Carnegie Mellon University, citation "highest academic record in the class of 1966"

POSITIONS AFTER HIGHEST DEGREE

2003-2005 Guggenheim Fellow  
2003-2005 Visiting Professor, University of the Mediterranean, Luminy campus  
2003-2005 Senior Research Scientist, Center for Particle Physics of Marseille (CPPM), Marseille, France  
2001-present Fellow, University Professors Program, Boston University  
1993.1994 Distinguished Visiting Scientist, Centre D'Etude, Saclay, Gif-sur-Yvette, France  
1990-present David M. Myers Distinguished Professor (Boston University endowed chair)  
1986-2005 Chairman and Professor of Physics, Boston University, Boston, MA  
1984.1985 Visiting Professor of Physics, Harvard University, Cambridge, MA  
1979.1984 Associate Professor of Physics (with tenure), University of Michigan, Ann Arbor, MI  
1979.1981 Visiting Scholar, Harvard University, Cambridge, MA  
1975.1979 Associate Professor of Physics, Harvard University, Cambridge, MA  
1974-present Guest Associate Physicist, Brookhaven National Laboratory, Upton, NY  
1971.1976 Visiting Physicist, Fermi National Accelerator Laboratory, Batavia, IL  
1971.1975 Assistant Professor of Physics, Harvard University, Cambridge, MA  
1970-present Visiting Physicist, European Center for Nuclear Research (CERN), Geneva, Switzerland  
1970-1971 Chargé de Recherche, Département de Physique Nucléaire et Corpusculaire, Université de Genève, Switzerland

AWARDS AND HONORS

2005 Research Prize, City of Marseille, for contributions to Antares Neutrino Observatory  
2001-present Fellow, University Professors Program, Boston University  
2000 One of the "Top 1000 Scientists of the Millennium"  
1998 One of 10 "Greatest Science Achievements of 1998." Discovery of neutrino mass, awarded by *Popular Science*  
1998 ASAHI Prize, "Discovery of the Finite Mass of Neutrinos," shared with Super-K collaborators  
1993 "Faces & Names to Watch..." *Boston Magazine* (see Vol. 48, No. 12, 1992)  
1992-present Who's Who in Science and Engineering  
1990-present David M. Myers Distinguished Professor, Boston University  
1989 Bruno Rossi Prize of the American Astronomical Society, Discovery of Neutrinos from Supernova 1987a  
1984 Outstanding Young Scientist Award, "America's 100 Brightest Scientists," *Science Digest* (December 1984)  
1984-1986 Faculty Research Honorary Society, University of Michigan Research Club  
1984-present Fellow, American Physical Society  
1966-1970 National Science Foundation Fellow, Princeton University  
1962 Outstanding Freshman Physicist Award, Carnegie Mellon University

PUBLICATION over 420 papers in refereed journals cited over 18,000 times in Spire database

RESEARCH CONTRACTS

1986-present Initiator of, and Principal or Co-principal Investigator on Proton Decay, Neutrino Astrophysics, g-2 and CMS tasks of U.S. Department of Energy Contract at Boston University  
FY 2005 awards: \$0.7 M to tasks for which LRS is P.I. or Co-P.I., \$7.1 M for total DOE grant

RECENT SCIENTIFIC PRESENTATIONS

2006 Colloquium, University of Florida, Gainesville, April  
Colloquium, The Perimeter Institute, May  
2005 "The Future of Cherenkov Ring-Image Calorimetry," Invited talk, International Conference on the High Energy Frontier, HIF '05, Elba, France, May 28-June 1, 2005  
"Status of Electronic Development for Antares," Biannual Antares Collaboration Meeting, CERN, January 2005  
"The Value of the ITER Project to Science," Invited presentation, Region of Aix-en-Provence. Co-presenters: Mayor of Aix; President of Region of Aix; Director, Cadarache Nuclear Research Lab (French Los Alamos)  
Invited talk: "Searches for Proton Decay and Neutrino Oscillations: Physics from Cherenkov Ring-Image Calorimetry," 40th Rencontre de Moriond, French Physical Society International Conference, March 2005  
"Progress of the Antares Experiment," Rencontre d'Aosta, Italian Physical Society International Conference  
National Presbyterian School, Washington DC, November 21-26, 2005, 4 lecture/demonstrations on "How much fun it is to be a scientist"  
2004 Invited presentation, 25th International Neutrino Conference, Paris, France

- "Megaton and Cubic Kilometer Detectors: the non-accelerator future for particle physics," Invited speaker, CPPM Conference on the Future of Particle Physics in Europe  
 Featured speaker, Inauguration of Antares Neutrino Observatory, with many Euro science ministers  
 Rene Turlay Memorial Conference, invited presentation, Ecole Polytechnique, Paris  
 Int'l School for Particle Astrophysics, Erice, Italy. Invited talks on Super-K, K2K, and Antares.  
 2003 "Recent results from Super-K," invited talk at CERN CMS Annual Meeting, December  
 Invited speaker, All France Particle Physics Retreat, "Physics with Future Water Cherenkov Detectors," Hyeres

#### RECENT PAPERS PUBLISHED (2004 and 2005)

Massive Cherenkov neutrino facilities. their evolution, their future: twenty-five years at these international neutrino conferences, L. R. Sulak, Nucl. Phys. Proc. Suppl. 143:317-326, 2005. Also in Paris 2004, Neutrino physics and astrophysics 317-326, 21st International Conference on Neutrino Physics and Astrophysics (Neutrino 2004), Paris, France, 14-19 Jun 2004.

The future of Cherenkov ring-image calorimetry, High Energy Frontier HIF '05, Elba, France, May 2005, submitted for publication.

A measurement of atmospheric neutrino oscillation parameters by Super-Kamiokande I. Y. Ashie et al. Jan 2005. Published in Phys. Rev. D71:112005,2005. (A top cited paper for 2005, with > 50 citations)

Search for coherent charged pion production in neutrino-carbon interactions, M. Hasegawa et al., DAPNIA-05-106, Jun 2005. Published in Phys. Rev. Lett. 95:252301, 2005.

Search for nucleon decay via modes favored by supersymmetric grand unification models in Super-Kamiokande-I, K. Kobayashi et al. Feb 2005. Published in Phys. Rev. D72:052007,2005.

Solar neutrino measurements in Super-Kamiokande-I. J. Hosaka et al., Aug 2005. Submitted to Phys.Rev.D.

Evidence for muon neutrino oscillation in an accelerator-based experiment. K2K Collaboration ([E. Aliu et al.](#)). Nov 2004. Published in Phys. Rev. Lett. 94:081802,2005. (a top cited paper for 2005, with > 50 citations)

Measurement of single pi0 production in neutral current neutrino interactions with water by a 1.3-GeV wide band muon neutrino beam, K2K Collaboration ([S. Nakayama et al.](#)). Aug 2004. Published in Phys. Lett. B619:255-262, 2005

Search for dark matter wimps using upward through-going muons in Super-Kamiokande, [S. Desai et al.](#). Apr 2004. Published in Phys. Rev. D70:083523, 2004, Desai was LRS's PhD student; this is his thesis work.

Final search for lightly ionizing particles with the MACRO detector, MACRO Collaboration ([M. Ambrosio et al.](#)). Feb 2004.

Limits on the neutrino magnetic moment using 1496 days of Super-Kamiokande-I solar neutrino data, Super-Kamiokande Collaboration ([D.W. Liu et al.](#)). Feb 2004. Published in Phys. Rev. Lett. 93:021802, 2004. e-Print Archive: hep-ex/0402015

Search for electron neutrino appearance in a 250 km long baseline experiment. [M.H. Ahn et al.](#) Phys. Rev. Lett.93:051801,2004.

The cosmic ray proton, helium and CNO fluxes in the 100-TeV energy region from TeV muons and EAS atmospheric Cherenkov light observations of MACRO and EAS-TOP, [M. Aglietta et al.](#) Published in Astropart. Phys.21:223-240, 2004

Measurements of atmospheric muon neutrino oscillations, global analysis of the data collected with MACRO detector, MACRO Collaboration ([M. Ambrosio et al.](#)). 2004. Eur. Phys. J.C36:323-339, 2004

Search for stellar gravitational collapses with the MACRO detector, [M. Ambrosio et al.](#) Published in Eur. Phys. J.C37:265-272,2004

#### SELECTED SCIENTIFIC PUBLICATIONS from some 425 papers cited over 18,000 times in Spires database

##### **Discovery of Oscillation of Neutrinos and of Neutrino Mass**

1. *First proposal for a massive underground ring-imaging water Cherenkov detector, focusing on both the detection of proton decay and the identification of the critical signals for muon- and electron neutrino induced events.*

"Studies of a Detector to Test for Baryon Stability to a Lifetime of  $10^{33}$  Years," L. R. Sulak, Proceedings of the Seminar on Proton Stability, Madison (D. Cline, ed.) 8 December 1978, p. A1; also appeared as Harvard University Particle Physics Preprint HUPP 252.

"A Nucleon Decay Search: Design of a New Experiment Sensitive to a Lifetime of  $10^{33}$  Years," B. Cortez et al., Int'l Conf. on Neutrino Physics 1979 (A. Haadtuft and C. Jarlskog, ed.), Trykk: Astvedt Industrier A/S, Vol. 3 (1979), p. 121.

*Introduction of up/down asymmetry technique, which led to the discovery of neutrino mass and oscillations*

"A Long Baseline Neutrino Oscillation Experiment Sensitive to Mass Differences of Hundredths of an Electron Volt", B. Cortez and

L.R. Sulak, *Unification of the Fundamental Particle Interactions* (S. Ferrara, J. Ellis, and P. Van Nieuwenhuizen, eds.) Erice, March 17-24, 1980, Plenum Press, (1980), pp. 661-671.

“The Irvine-Michigan-Brookhaven Nucleon Decay Facility: Status Report on a Proton Decay Experiment Sensitive to a Lifetime of  $10^{33}$  Years,” and a Long Baseline Neutrino Oscillation Experiment Sensitive to Mass Differences of Hundredths of an Electron Volt, L. Sulak, *First Workshop on Grand Unification* (Paul H. Frampton, Sheldon L. Glashow, Asim Yildiz, eds.), April 10-12, Math Sci. Press, University of New Hampshire, (1980), p. 163.

2. *IMB: The first suggestion of a muon deficit in the cosmic ray atmospheric neutrino after one live year of data taking.*  
“A Search for Nucleon Decay Into Lepton and  $K^0$ ,” B. Cortez, Harvard University Ph.D. Thesis, September 1983 (advisor: LRS)

*First refereed publication of a deficit of atmospheric muon neutrinos (relative to the number of electron neutrinos), the precursor to the discovery of neutrino oscillations:*

“Calculation of Atmospheric Neutrino Induced Backgrounds in a Nucleon Decay Search,” T.J. Haines et al., *Phys. Rev. Lett.* 57, (1986) (107 cites)

“Measurement of Atmospheric Neutrino Composition with IMB-3, D. Casper *et al.*, *Phys. Rev. Lett.* 66, p 2561, 1991. This is Casper's thesis with LRS as advisor. (499 cites)

3. *Super-K high statistics proof of the oscillation of muon neutrinos and the unexpected non-zero mass of the neutrino, the first observation of physics beyond the standard model. The series of papers has been cited over 4600 times, the most highly cited experimental particle physics work ever.*

“Evidence for Oscillation of Atmospheric Neutrinos,” Y. Fukuda et al., *Phys. Rev. Lett.* 81 (1998) p. 1562-1567. (2475 entries in Citation Index)

4. *Super-K demonstration that oscillations of muon neutrinos most likely into tau neutrinos.*

“Tau Neutrinos Favored Over Sterile Neutrinos in Atmospheric Muon Neutrino Oscillation,” S. Fukuda et al., Super-Kamiokande Collaboration, *Phys. Rev. Lett.* (2000). (> 500 cites)

#### **Precision Measurement of the Muon Magnetic Moment**

5. *Invention of high-rate detectors segmented in time and in space for a new generation g-2 experiment at BNL. LRS led conceptual design, prototyping and test beam effort and drafted proposal. Most highly cited experimental particle physics paper in 2001, with 1073 citations for the series of 5 papers.*

“Design and Performance of a New Electron Calorimeter for the Muon g-2 Experiment”, C. W. Heisey et al., *Nucl. Instr. and Meth.* (1988).

“Scintillating Fiber Calorimeters with Cast Absorbers,” D. Brown et al., *IEEE Trans. Nucl. Sci.* (1991).

“Cast Lead Eutectic Solid and Liquid Scintillating Fiber Shower Calorimeters,” T. Coan, W. Worstell, J. Miller, B. L. Roberts, L. R. Sulak, D. R. Winn, P. Cushman, S. Dhawan, and V. W. Hughes, *Nucl. Instr. Meth.* (1991).

“Improved Measurement of the Positive Muon Anomalous Magnetic Moment”, R. Carey et al., *Phys. Rev. D.* (2000)

“Precise Measurement of the Positive Muon Anomalous Magnetic Moment,” H. N. Brown et al., Muon g-2 Collaboration, *Phys. Rev. Lett.* 86, (2001) (719 entries in Citation Index) First of a series of 5 papers.

#### **Discovery of Neutrinos from a Supernova collapse**

6. *First observation of extra-galactic neutrinos from the gravitational collapse of a supernova, simultaneously observed by the Kamiokande detector.*

“Observation of a Neutrino Burst in Coincidence with Supernova 1987A in the Large Magellanic Cloud,” R.M. Bionta, *et al.*, *Phys. Rev. Lett.*, Vol. 58, No. 14, (6 April 1987), p. 1494. (588 entries in Citation Index)

#### **Searches for the Ultimate Decay of the Proton and for Grand Unification**

7. *First limit on proton lifetime at the Grand Unification scale, 5 orders of magnitude better than previous measurements. Elimination of the simplest and most elegant theory, SU5. LRS PI, originator of technology, and the initial advocate of the building of the IMB detector.*

“A Search for Proton Decay into  $e^+ \pi^0$ ,” R.M. Bionta *et al.*, *Phys. Rev. Lett.*, Vol. 51, No. 1, 27 (4 July 1983) (140 citations)

“Search for Nucleon Decay into  $\mu^+ K^0$  and  $\nu K^0$ ,” B.G. Cortez et al., *Phys. Rev. Lett.*, Vol., 52 (26 March 1984).

8. *Limits on 44 decay modes of the nucleon, most remain world records to date.*

“A Search for Nucleon Decay Using the IMB-3 Detector,” C. McGrew *et al.*, *Phys. Rev. D* 59 (1999) p. 5204.

### The Discovery and Elucidation of Weak Neutral Currents

9. *First observation (with C. Rubbia at experiment E1A, Fermilab) of neutral-current neutrino events, contemporaneously with measurements at Gargamelle, CERN. Unification of electromagnetism and weak interactions. LRS responsible for designing and building the first totally absorptive liquid scintillator calorimeter 100 T, the first to use his technique of total-internal reflection from Teflon, large liquid scintillator trigger counters, and data acquisition electronics. He performed the analysis of the first events and drafted this paper.*

"Observation of Muonless Neutrino-Induced Inelastic Interactions," A. Benvenuti *et al.*, Phys. Rev. Lett., Vol. 32, No. 14, p. 800 (8 April 1974, received 3 August 1973). (224 entries in Citation Index)

10. *The first observation of both elastic neutrino- and antineutrino-proton elastic scattering, the weak analog of beta decay (E613 at Brookhaven) LRS spokesman, responsible for designing and building the world's largest drift chambers (4x4 m), a 60 ton segmented liquid scintillator detector, and the data acquisition system.*

"Observation of Elastic Neutrino-Proton Scattering," D. Cline *et al.*, Phys. Rev. Lett. Vol. 37, No. 5, p. 252 (2 August 1976). (121 entries in Citation Index)

"Observation of Elastic Antineutrino-Proton Scattering," D. Cline, *et al.*, Phys. Rev. Lett., Vol. 37, no. 11, p. 648 (13 September 1976). (105 entries in Citation Index)

11. *The first determination of the space-time structure of the weak neutral current, showing that it fits the electro-weak theory:*

"Model Independent Determination of Hadronic Neutral Current Couplings", M. Claudson, E. A. Paschos, J. Strait, and L.R. Sulak, Phys. Rev. D, Vol. 19, No. 5, p. 1973, (1 March 1979).

### Precision Measurement of K Meson Mass Difference

12. *First measurement of the neutral kaon mass difference at the 1% level and the phase of  $\eta_{+-}$  to  $5^\circ$ , at Brookhaven with V. Fitch (Princeton) Nobel Laureate (1980).*

" $K_1^0 - K_2^0$  Mass Difference," R. K. Carnegie, V. L. Fitch, M. Strovink, and L. R. Sulak, Phys. Rev. D. Vol. 4 (1 July 1971), p.1

### SCIENTIFIC ADVISORY PANELS, EXPERIMENT SPOKESMANSHIPS, AND CONFERENCE ORGANIZATION

|              |  |
|--------------|--|
| 2002         | Canadian Foundation for Innovation, Experts Panel for Particle Physics in Next 10 Years, funded SNO expansion 1998 |
|              | International Conference on High Energy Physics, convenor of Astrophysics Sessions,                                |
| 1997         | Int'l Workshop in Supernova Early Detection Network, advisory committee  |
| 1995-1996    | Int'l Workshops on Proton Decay and Neutron-Antineutron Oscillations, Int'l Advisory Committee                     |
| 1994-1996    | Technical Board of CMS   |
| 1994-present | Collaboration Council of CMS   |
| 1994-1996    | Spokesman, Quartz Fiber Calorimetry CMS Group  |
| 1994-1996    | Co-Spokesman of the Forward Calorimeter, CMS Detector for the Large Hadron Collider (LHC) at CERN                  |
| 1993-1994    | Review Committee, French National Plan for Science and Education Policy for the Next Ten Years                     |
| 1993-1994    | Program Advisory Committee, Department of Physics, Astrophysics and Instrumentation, Centre d'Etude, Saclay        |
| 1993-1995    | Co-chairman, Commission on Astroparticle Physics, United Nations OECD Forum on Megascience                         |
| 1990-1992    | Theoretical and Phenomenological Aspects of Underground Physics, Int'l Advisory Committee                          |
| 1988-1992    | Co-Spokesman, TEXAS Detector for the Superconducting Super Collider  |
| 1987-1991    | U.S. Department of Energy High Energy Physics Advisory Panel (HEPAP)   |
| 1984-1988    | National Institute of Nuclear Physics, Italy, Scientific Program Committee, Gran Sasso National Laboratory         |
| 1984-1985    | Interministerial Commission for Scientific Research, Spanish National Government, Science Policy Committee         |
| 1984-1986    | Executive Committee, American Physical Society, Division of Particles and Fields                                   |
| 1983         | Natural Sciences / Engineering Research Council, Committee on New Canadian Projects in Particle Physics            |
| 1981         | U.S. Department of Energy High Energy Physics Advisory Panel (HEPAP), subpanel on Long Range Planning              |
| 1980.1982    | Executive Committee, American Physical Society, Division of Particles and Fields 2/21/06                           |