John David Jackson: Physicist, Teacher, Citizen

David Quigg photograph

Chris Quigg · Fermilab

CAP Annual Congress · Queen's University · 1 June 2017


JACKSON
CLASSICAL ELECTRODYNAMICS
THIRD EDITION
WILEY
JACKSON
Classical Electrodynamics
Second Edition
WILEY
CLASSICAL ELECTRODYNAMICS
JACKSON
WILEY

994 Waterloo Street, London ON

UWO Honours Physics & Maths ’46

“Some Snapshots from a Physicist’s Life”


Eric Vogan JDJ Don Hay
UWO 4th-year Radio Physics, 1946

MIT, Ph.D. 1949

Field Theory of Traveling-Wave Tubes*

L. J. CHU†, ASSOCIATE, I.R.E., AND J. D. JACKSON†, STUDENT, I.R.E.

Summary—The problem of a helix-type traveling-wave amplifier tube, under certain simplifying assumptions, is solved as a boundary-value problem. The results indicate that the presence of the beam in the helix causes the normal mode to break up into three modes with different propagation characteristics. Over a finite range of electron velocities one of the three waves has a negative attenuation, and is thus amplified as it travels along the helix. If the electron velocity is too high or too low for net energy interaction, all three waves have purely imaginary propagation constants; no amplification occurs. Consideration of the beam admittance functions shows that, during amplification, the electron beam behaves like a generator with negative conductance, supplying power to the fields through a net loss of kinetic energy by the electrons. Curves are shown for a typical tube, and the effects of beam current and beam radius are indicated. The initial conditions are investigated, as are the conditions of signal level and limiting efficiency. In the Appendix a simple procedure for computing the attenuation constant is given.

I. Introduction

THE ANALYSIS of traveling-wave tubes as amplifiers has been carried out by Pierce[1,2] of Bell Telephone Laboratories and Kompfner[3] of the Clarendon Laboratory. In Pierce's paper,[2] the action of the field on the electron beam and the reaction of the beam back on the field were formulated. A cubic equation was obtained which yielded three distinct propagation constants corresponding to the three dominant modes of propagation. Kompfner followed a different line of attack and arrived at essentially the same results.

The present analysis follows the procedure which Hahn[4,5] and Ramo[6,7] used in dealing with velocity-modulated tubes. The problem of the traveling-wave tube is idealized, and such approximations are introduced that the field theory can be used throughout to correlate the important factors in the problem. Numerical examples are given for a specific tube to illustrate the effects of various parameters upon the characteristics of the tube.

In this paper, only the helix-type of traveling-wave tube will be considered. It consists of a cylindrical helical coil which, in the absence of an electron beam, is capable of supporting a wave along the axis of the helix with a phase velocity substantially less than the light velocity. When an electron beam is shot through the helix, the electrons are accelerated or decelerated by the field of the wave, especially the longitudinal electric field. As a result, the electrons will be bunched. The bunched beam travels substantially with the initial velocity of electrons, which is usually different from the phase velocity of the wave. Because of the bunching action, there will be, in time, more electrons decelerated than those accelerated over any cross section of the helix or vice versa. As a result, there will be a net transfer of energy from the electron beam to the wave or from the wave to the beam. The bunching of the electrons produces an alternating space-charge force or field which modifies the field structure of the wave, and consequently its phase velocity. The average energy of the electron beam must change as it moves along, on account of the energy transfer. The process is continous, and a rigorous solution to the problem is probably impossible. The procedure of analysis is, therefore, to find the modes of propagation which can have exponential variation along the tube in the presence of the electron beam. We are interested in those modes which will either disappear or degenerate into the dominant mode when the beam is removed. By studying the properties of these modes and combining them properly, we hope to present a picture of some of the physical aspects of the helix-type traveling-wave tube.

II. Solution of the Problem

A. Formulation

In order to obtain some theoretical understanding about the behavior of the traveling-wave tube, we have to simplify the problem by making numerous assumptions. Instead of a physical helix, we shall use a lossless helical sheath of radius a and of infinitesimal thickness. The current flow along the sheath is constrained to a direction which makes a constant angle $(90°-\theta)$ with the axis of the helix. The tangential component of the electric field is zero along the direction of current flow, and finite and continuous through the sheath along the direction perpendicular to the current flow. The force acting on the electrons is restricted to that associated with the longitudinal electric field only; and the electrons are assumed to have no initial transverse motion. We shall further assume that the electrons are confined within a cylinder of radius b concentric with the helical sheath. The time-average beam-current density is assumed constant over the cross section, the

* Decimal classification: R339.2. Original manuscript received by the Institute, July 30, 1947; revised manuscript received, December 29, 1947. Presented, I.R.E. Electron Tube Conference, Syracuse, N. Y., June, 1947. This work has been supported in part by the U. S. Army Signal Corps, the Air Matériel Command, and the Office of Naval Research, and appeared originally as Technical Report No. 38, April 28, 1947, of the Research Laboratory of Electronics, M.I.T.

† Massachusetts Institute of Technology, Cambridge 39, Mass.

[1] J. R. Pierce and Lester M. Field, "Traveling-wave tubes," Proc. I.R.E., vol. 35, pp. 108–111; February, 1947.

[2] J. R. Pierce, "Theory of the beam-type traveling-wave tube," Proc. I.R.E., 35, pp. 111–123; February, 1947.

[3] Rudolf Kompfner, "The traveling-wave tube as amplifier at microwaves," Proc. I.R.E., vol. 35, pp. 124–128; February, 1947.

[4] W. C. Hahn, "Small signal theory of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 258–270; June, 1939.

[5] W. C. Hahn, "Wave energy and transconductance of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 497–520; November, 1939.

[6] Simon Ramo, "Space charge and field waves in an electron beam," *Phys. Rev.*, vol. 56, pp. 276–283; August, 1939.

[7] Simon Ramo, "The electron-wave theory of velocity-modulated tubes," Proc. I.R.E., vol. 27, pp. 757–763; December, 1939.

Blatt · French · Feshbach ·VFW

Charge-independence of nuclear forces?

PHYSICAL REVIEW VOLUME 26, NUMBER 1 JULY 1, 1949

On the Interpretation of Neutron-Proton Scattering Data by the Schwinger Variational Method*

JOHN M. BLATT AND J. DAVID JACKSON
Department of Physics and Laboratory of Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

(Received March 2, 1949)

$$k \cot \delta = -\frac{1}{a} + \tfrac{1}{2} r_0 k^2 + P r_0^3 k^4 + \ldots$$

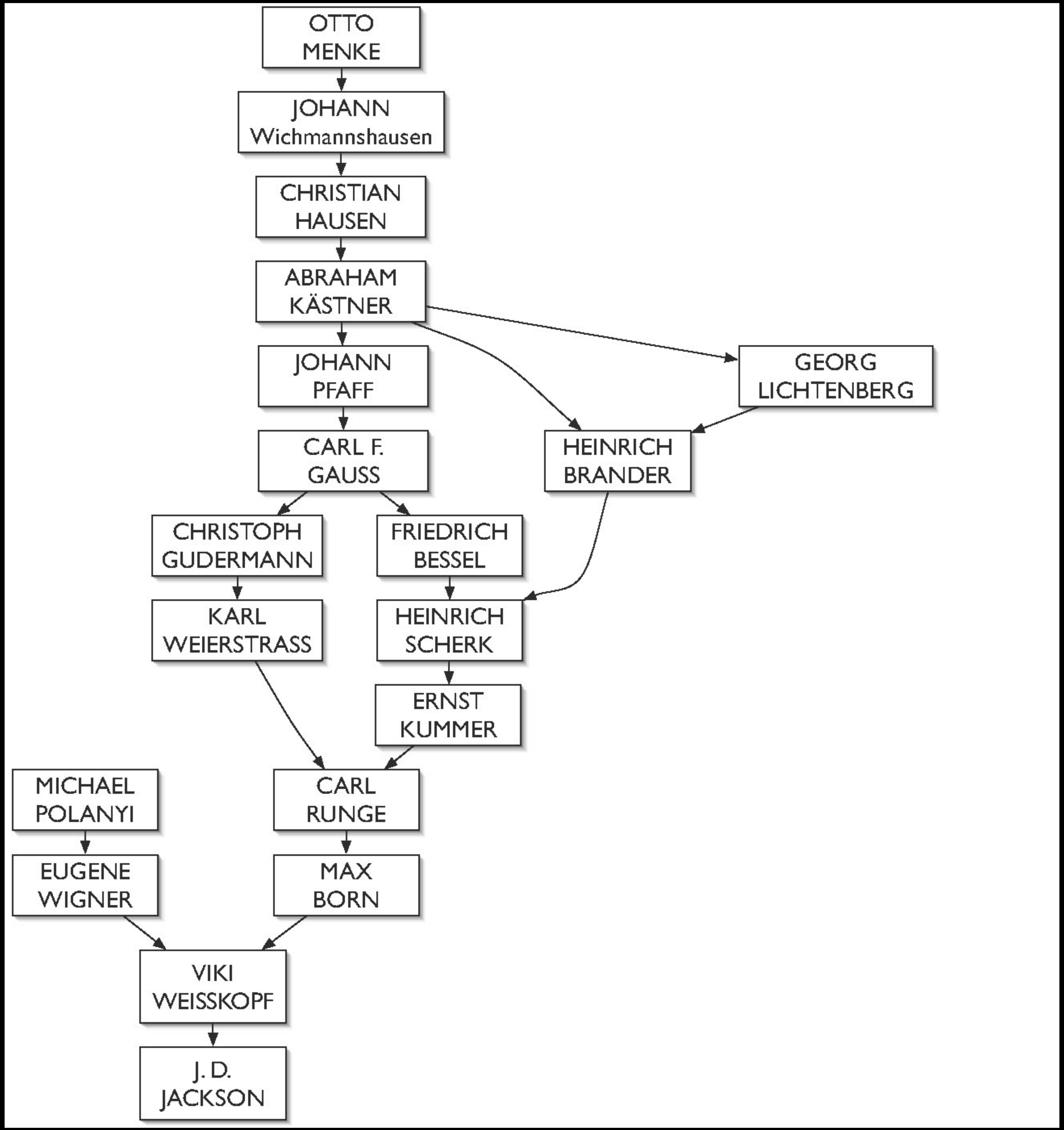
REVIEWS OF MODERN PHYSICS VOLUME 22, NUMBER 1 JANUARY, 1950

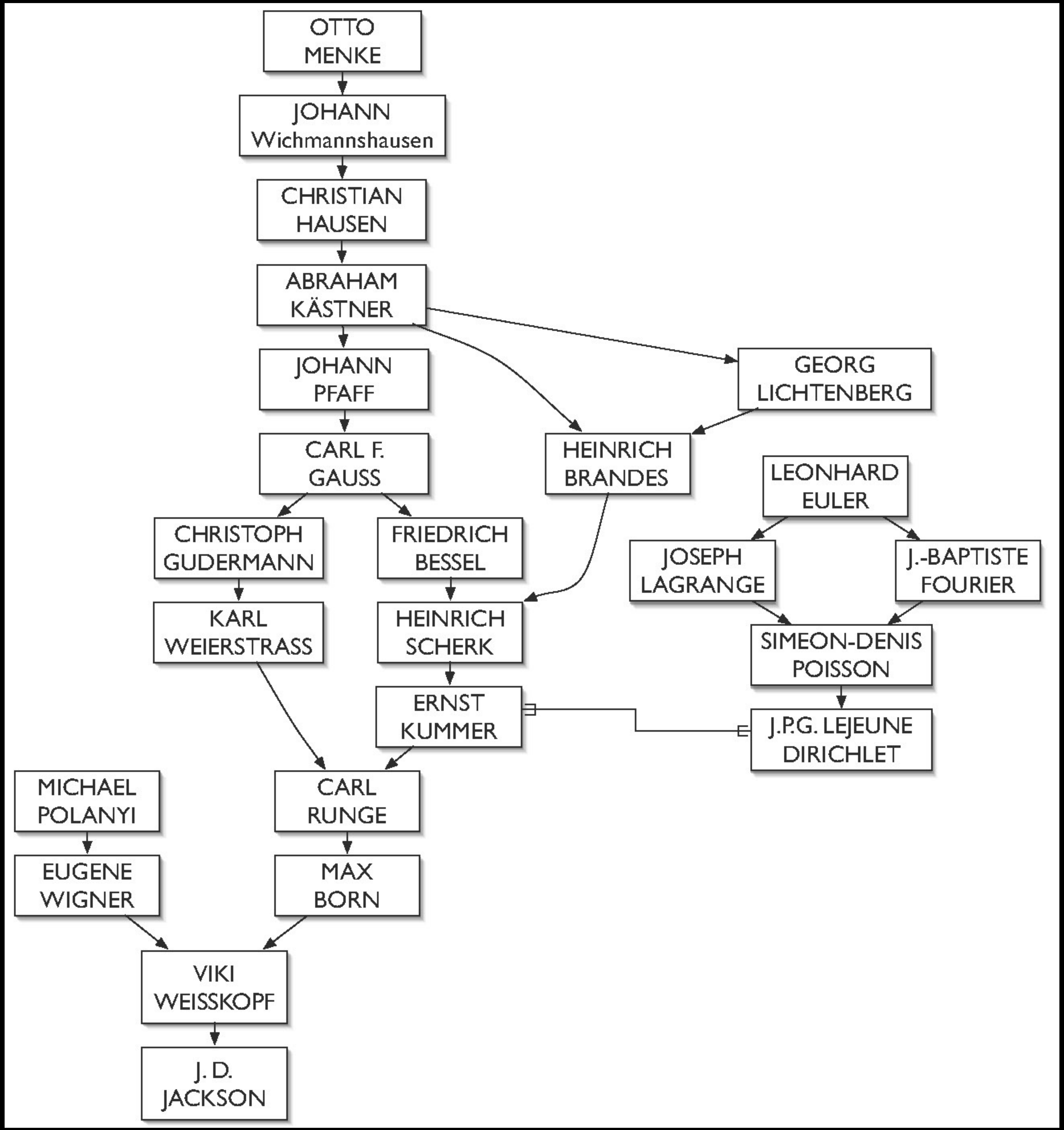
The Interpretation of Low Energy Proton-Proton Scattering*†

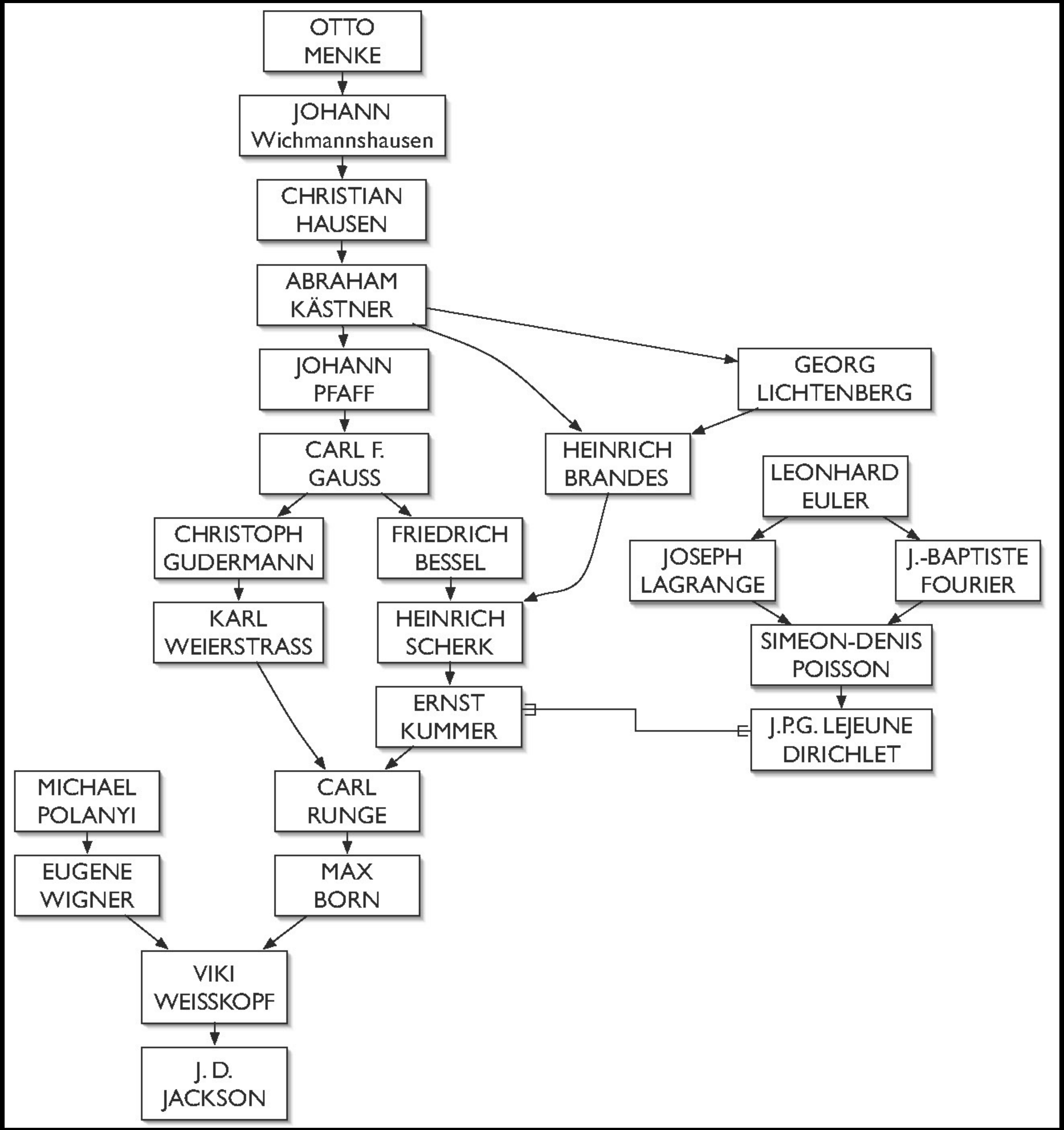
J. DAVID JACKSON‡ AND JOHN M. BLATT¶
Department of Physics and Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

"a painfully thorough analysis"

Small deviation found, resolved as magnetic dipole interaction


OTTO MENKE
JOHANN Wichmannshausen
CHRISTIAN HAUSEN
ABRAHAM KÄSTNER
JOHANN PFAFF
GEORG LICHTENBERG
CARL F. GAUSS
HEINRICH BRANDER
CHRISTOPH GUDERMANN
FRIEDRICH BESSEL
KARL WEIERSTRASS
HEINRICH SCHERK
ERNST KUMMER
MICHAEL POLANYI
CARL RUNGE
EUGENE WIGNER
MAX BORN
VIKI WEISSKOPF
J. D. JACKSON


OTTO MENKE
JOHANN Wichmannshausen
CHRISTIAN HAUSEN
ABRAHAM KÄSTNER
JOHANN PFAFF
GEORG LICHTENBERG
CARL F. GAUSS
HEINRICH BRANDES
LEONHARD EULER
CHRISTOPH GUDERMANN
FRIEDRICH BESSEL
JOSEPH LAGRANGE
J.-BAPTISTE FOURIER
KARL WEIERSTRASS
HEINRICH SCHERK
SIMEON-DENIS POISSON
ERNST KUMMER
J.P.G. LEJEUNE DIRICHLET
MICHAEL POLANYI
CARL RUNGE
EUGENE WIGNER
MAX BORN
VIKI WEISSKOPF
J. D. JACKSON


OTTO MENKE
JOHANN Wichmannshausen
CHRISTIAN HAUSEN
ABRAHAM KÄSTNER
JOHANN PFAFF
GEORG LICHTENBERG
CARL F. GAUSS
HEINRICH BRANDES
LEONHARD EULER
CHRISTOPH GUDERMANN
FRIEDRICH BESSEL
JOSEPH LAGRANGE
J.-BAPTISTE FOURIER
KARL WEIERSTRASS
HEINRICH SCHERK
SIMEON-DENIS POISSON
ERNST KUMMER
J.P.G. LEJEUNE DIRICHLET
MICHAEL POLANYI
CARL RUNGE
EUGENE WIGNER
MAX BORN
VIKI WEISSKOPF
J. D. JACKSON

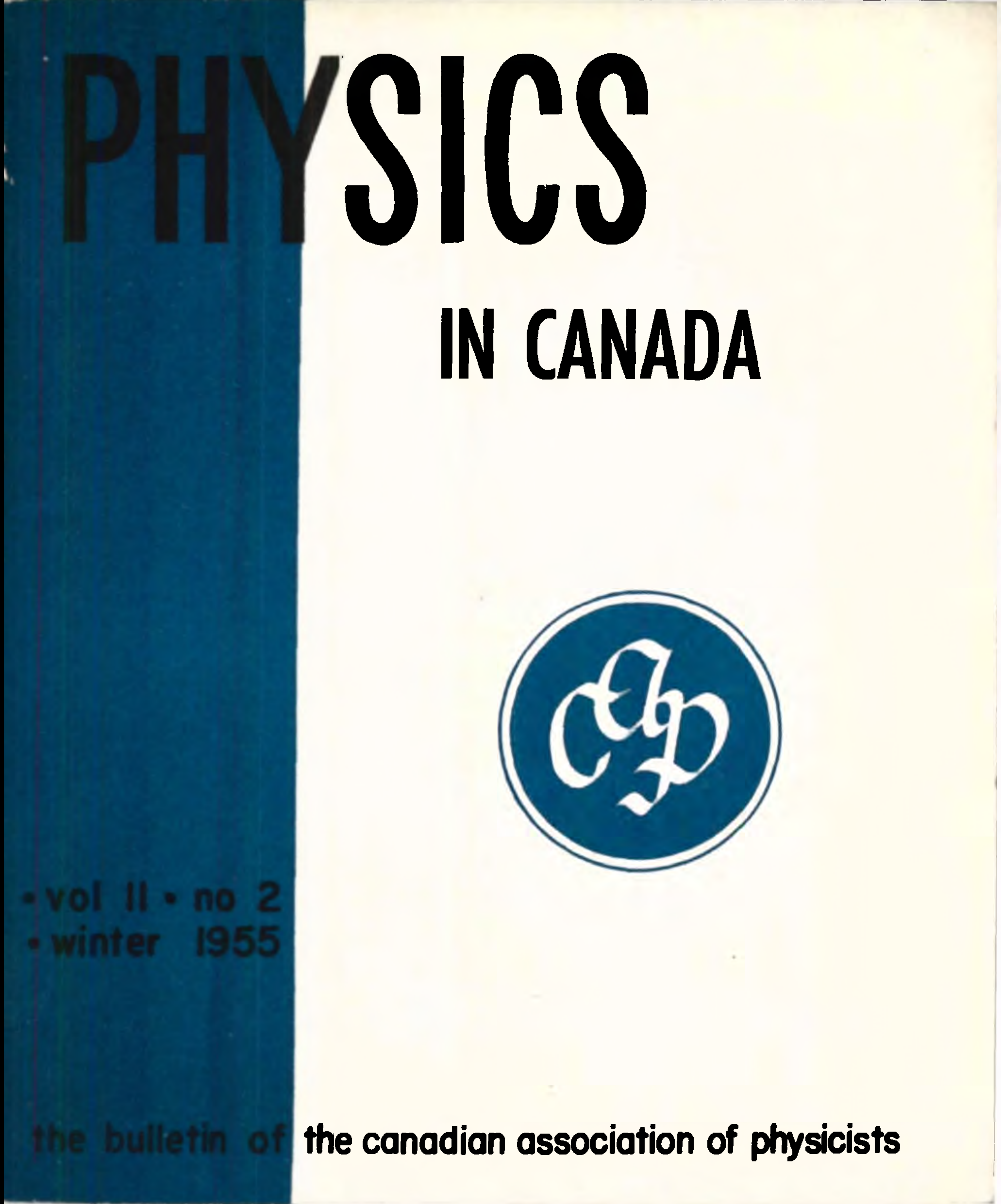

80
FRIEDRICH WILHELM BESSEL
1784 Astronom und Mathematiker 1846
DEUTSCHE BUNDESPOST
1984

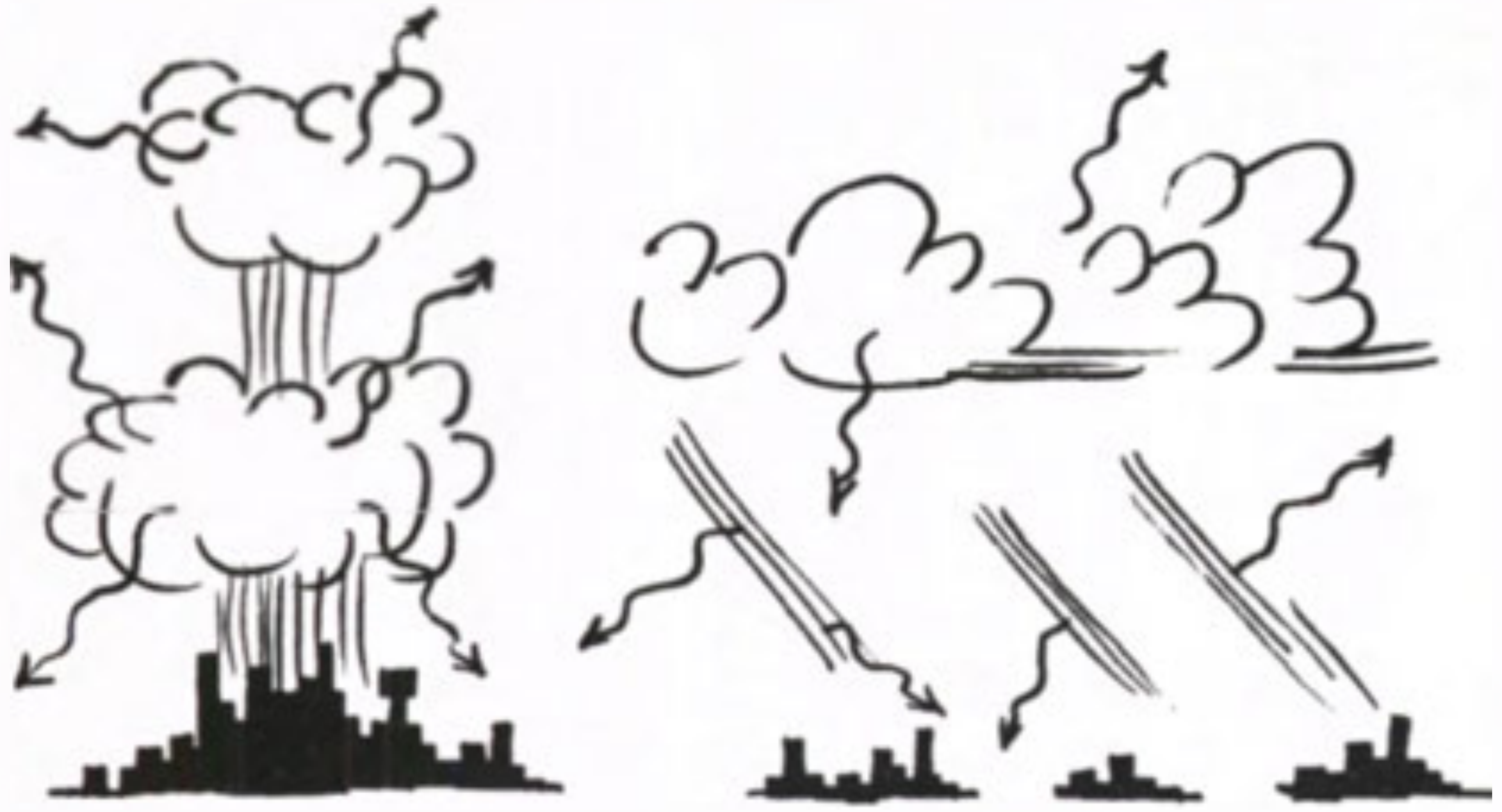
“From the Rutherford Era to Modern High-Energy Physics” (Kurt Gottfried)

1950: Assistant Professor of *Mathematics* at McGill

S. Wagner, J.D. Jackson, G.T. Ewan, S. Marshall. W.M. Telford, W. Hitschfeld, K.L.S. Gunn
M. DeAngelis, E.R. Pounder, Anna McPherson, J.S. Foster, G.A. Woonton, H.G.I. Watson, F.R. Terroux, J.R. Whitehead

McGill Physics + JDJ, 1955





FALL-OUT
FACT AND FANTASY

J. D. Jackson

The world at large first became aware of radioactive fall-out as a significant aftermath of nuclear explosions nearly two years ago. Since that time much has been written on the subject in publications for the bourgeois intellectuals, if not in the mass media journals. To this physicist at least, the sequence of statements to inform the public on the nature and importance of radioactive fall-out and its implications for defensive measures in time of war presents a wonderfully conflicting and sometimes fantastic parade. Honest, factual, but unofficial, accounts have been given; conjectures have been made; official pronouncements have appeared, only to be countered by equally official pronouncements expressing divergent views. Out of it all, the

Teaching!

McGill

Sp 1950	Mathematics 672, Theoretical Nuclear Physics II (second semester) [Math. physics, e&m, diff. eqns ?]
Fa 1950	Mathematics 62 = Physics 62, Quantum Mechanics I Mathematics 1260, Differential Equations for Engineers
Sp 1951	Mathematics 62 = Physics 62, Quantum Mechanics II Mathematics 48b, Advanced Dynamics Mathematics 1260, Differential Equations for Engineers
Fa 1951	Mathematics 62 = Physics 62, Quantum Mechanics I Mathematics 68, Electromagnetic Theory I Mathematics 69, Seminar in Applied Mathematics (with Morris and Wallace)
Sp 1952	Mathematics 62 = Physics 62, Quantum Mechanics II Mathematics 68, Electromagnetic Theory II Mathematics 48b, Advanced Dynamics Mathematics 69, Seminar in Applied Mathematics (with Morris and Wallace)
Fa 1952	Mathematics 668, Electromagnetic Theory I Mathematics 672, Theoretical Nuclear Physics I Mathematics 69, Seminar in Applied Mathematics (with Morris & Wallace)
Sp 1953	Mathematics 668, Electromagnetic Theory II Mathematics 672, Theoretical Nuclear Physics II Mathematics 48b, Advanced Dynamics Mathematics 69, Seminar in Applied Mathematics (with Morris & Wallace)
Fa 1953	Mathematics 661, Methods of Mathematical Physics I Mathematics 672, Theoretical Nuclear Physics I
Sp 1954	Mathematics 661, Methods of Mathematical Physics II Mathematics 672, Theoretical Nuclear Physics II Mathematics 331b = Physics 31b, Statics & Dynamics
Fa 1954	Mathematics 661, Methods of Mathematical Physics I Mathematics 672, Theoretical Nuclear Physics I Mathematics 669, Seminar in Applied Mathematics (with Morris & Wallace)

Princeton, 1956–57

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

Condensation of U. S. Weather Bureau forecast: Partly cloudy and colder today and tomorrow.

Temperature range today: 42—30. Temperature range yesterday: 45.7—35.7. Full U. S. Weather Bureau Report, Page 28.

VOL. CVI...No. 36,134. Entered as Second-Class Matter, Post Office, New York, N. Y. NEW YORK, SATURDAY, DECEMBER 29, 1956. Times Square, New York 36, N. Y. Telephone LAckawanna 4-1000 FIVE CENTS

BOMB HOAX WAVE COMPELS POLICE TO LIMIT CHECKS

Experts and Equipment Now Kept in Quarters Unless a Device Is Found

TESTERS EXPLODE PIPES

2 Found Capable of Going Off by Own Mechanisms, but Third Has No Powder

By ALEXANDER FEINBERG

Bomb scares and hoaxes reached epidemic proportions yesterday. Threats and warnings kept a large part of the Police Department rushing from one "threatened" building to another.

The situation became so bad that in the late afternoon Chief of Detectives James B. Leggett directed the bomb squad and its special equipment not to respond to alarms unless a device was actually discovered.

False alarms were reported in many sections. Whipped up by the recent depredations of, and

Atomic Energy Produced By New, Simpler Method

Coast Scientists Achieve Reaction Without Uranium or Intense Heat—Practical Use Hinges on Further Tests

Special to The New York Times.

MONTEREY, Calif., Dec. 28—A third and revolutionary way to produce a nuclear reaction was described here today. It does not involve uranium, as in the fission reaction, or million-degree heat, as in the fusion reaction.

The new process is called "catalyzed nuclear reaction." It was discovered accidentally a few weeks ago during routine work with the huge atom-smashing bevatron at the University of California radiation laboratory.

A team of twelve scientists from the university explained the process to the American Physical Society here. The team was headed by Dr. Luis W. Alvarez, assistant director of the laboratory.

Curiously enough, it was made not at the laboratory at Livermore, where scientists are attempting to control thermonuclear reaction for practical uses, but at the Berkeley laboratory, which is devoted to fundamental research.

Thus far, the new reaction is little more than a laboratory curiosity, the scientists said. The energy it produced came from the fusion of a few hydrogen atoms, they explained, and was scarcely enough to register on highly sensitive measuring instruments.

The process has no commercial value now, though it suggests possible industrial uses of immeasurable importance. It may, scientists said, point a way toward taming the intense heat of the hydrogen bomb to make it useful for peacetime purposes.

Others in the University of California group were Dr. Hugh Bradner, Dr. Frank S. Crawford Jr., Dr. John A. Crawford, Dr. Paul Falk-Vairant, Dr. Myron L. Good, Dr. J. Don Gow,

Continued on Page 6, Column 2

Javits and Harriman Differ

DULLES WILL SEE U.N. HEAD MONDAY ON MIDEAST CRISIS

Senators Express Doubts About Granting President Right to Use Troops

By WILLIAM S. WHITE

Special to The New York Times.

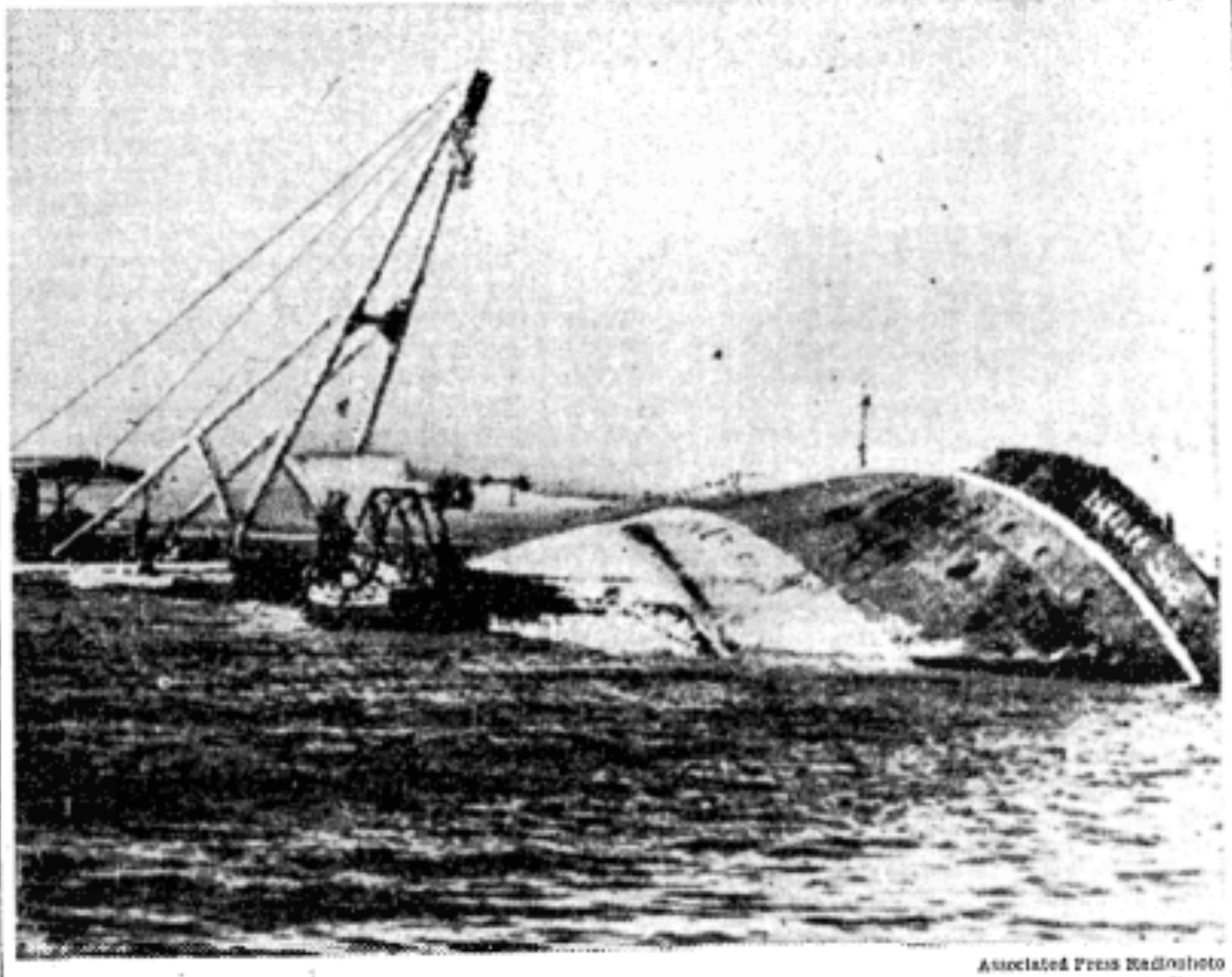
WASHINGTON, Dec. 28—Secretary of State Dulles has arranged a New Year's Eve conference on the Middle Eastern situation with Dag Hammarskjold, Secretary General of the United Nations.

This was announced today coincident with indications that Congress would be skeptical, if not ultimately hostile, toward any appeal from President Eisenhower for authority to use United States forces as he might see fit to oppose Communist aggression in the Middle East. The President is understood to be considering such a request.

The State Department, in disclosing that Mr. Dulles would go to New York Monday to see Mr. Hammarskjold, observed that the United States Government viewed the "Middle Eastern situation quite seriously."

White Qualifies Comment

Divers Start Work at Southern End of Suez Canal



Associated Press Radiophoto

Salvage work under way on the capsized Egyptian ship Zamalek in the harbor at Suez

By OSGOOD CARUTHERS

Special to The New York Times.

CAIRO, Dec. 28—Egyptian divers have begun hacking away at a sunken vessel blocking the channel from the Red Sea to Suez as a first step in clearing the southern end of the Suez Canal. Reports from Suez said the captains of two United Nations salvage vessels still were working on plans for clearing three hulks from the mouth of the canal. Actual work probably will start tomorrow morning, officials said.

Both Egyptian and United Nations authorities said everything was ready for commencement of one of the biggest salvage jobs ever undertaken, the removal of about fifty sunken craft and the

Continued on Page 4, Column 3

PEIPING'S REGIME SCORES TITOISM; HAILS SOVIET TIES

Official Broadcast Excuses Stalin's Errors and Says the West Perils Peace

BACKS STEPS IN HUNGARY

Yugoslavia's Policy Is Called 'Non-Objective' in Seeming Reversal by China Reds

By GREG MacGREGOR

Special to The New York Times.

HONG KONG, Dec. 28—Communist China made clear today its allegiance to the Soviet Union and paid unexpected tribute to the memory of Stalin.

In an official broadcast from Peiping, the Chinese Communists reaffirmed their approval of Soviet military activities in Hungary, denounced "Titoism," excused the mistakes of Stalin and accused the Western democracies of being the major threat to world peace.

The broadcast was a report of an extraordinary session of the

Atomic Energy Produced By New, Simpler Method

Coast Scientists Achieve Reaction Without Uranium or Intense Heat—Practical Use Hinges on Further Tests

Special to The New York Times.

MONTEREY, Calif., Dec. 28—A third and revolutionary way to produce a nuclear reaction was described here today. It does not involve uranium, as in the fission reaction, or million-degree heat, as in the fusion reaction.

The new process is called "catalyzed nuclear reaction." It was discovered accidentally a few weeks ago during routine work with the huge atom-smashing bevatron at the University of California radiation laboratory.

A team of twelve scientists from the university explained the process to the American Physical Society here. The team was headed by Dr. Luis W. Alvarez, assistant director of the laboratory.

Curiously enough, it was made not at the laboratory at Livermore, where scientists are attempting to control thermonuclear reaction for practical uses, but at the Berkeley laboratory, which is devoted to fundamental research.

Thus far, the new reaction is little more than a laboratory curiosity, the scientists said. The energy it produced came from the fusion of a few hydrogen atoms, they explained, and was scarcely enough to register on highly sensitive measuring instruments.

The process has no commercial value now, though it suggests possible industrial uses of immeasurable importance. It may, scientists said, point a way toward taming the intense heat of the hydrogen bomb to make it useful for peacetime purposes.

Others in the University of California group were Dr. Hugh Bradner, Dr. Frank S. Crawford Jr., Dr. John A. Crawford, Dr. Paul Falk-Vairant, Dr. Myron L. Good, Dr. J. Don Gow,

Continued on Page 6, Column 2

Atomic Energy Produced By New, Simpler Method

Coast Scientists Achieve Reaction Without Uranium or Intense Heat—Practical Use Hinges on Further Tests

Special to The New York Times.

MONTEREY, Calif., Dec. 28— A third and revolutionary way to produce a nuclear reaction was described here today. It does not involve uranium, as in the fission reaction, or million-degree heat, as in the fusion reaction.

The new process is called "catalyzed nuclear reaction." It was discovered accidentally a few weeks ago during routine work with the huge atom-smashing bevatron at the University of California radiation laboratory.

A team of twelve scientists from the university explained the process to the American Physical Society here. The team was headed by Dr. Luis W. Alvarez, assistant director of the laboratory.

Curiously enough, it was made not at the laboratory at Livermore, where scientists are attempting to control thermonuclear reaction for practical uses, but at the Berkeley laboratory, which is devoted to fundamental research.

Thus far, the new reaction is little more than a laboratory curiosity, the scientists said. The energy it produced came from the fusion of a few hydrogen atoms, they explained, and was scarcely enough to register on highly sensitive measuring instruments.

The process has no commercial value now, though it suggests possible industrial uses of immeasurable importance. It may, scientists said, point a way toward taming the intense heat of the hydrogen bomb to make it useful for peacetime purposes.

Others in the University of California group were Dr. Hugh Bradner, Dr. Frank S. Crawford Jr., Dr. John A. Crawford, Dr. Paul Falk-Vairant, Dr. Myron L. Good, Dr. J. Don Gow,

Continued on Page 6, Column 2

Cold Fusion of Hydrogen Atoms

Discovery of a revolutionary way to fuse nuclei of hydrogen atoms without the multi-million-degree temperature required in the thermonuclear hydrogen fusion process was announced Friday at the winter meeting of the American Physical Society at Monterey, Calif., by a team of twelve scientists at the University of California headed by Prof. Luis W. Alvarez.

The discovery, it was pointed out, is at present of pure scientific interest only, as the process can now be used only on a very small scale. However, the observation is of great scientific importance and may eventually lead to a practical and economical method for producing enormous amounts of atomic energy by the process of "cold fusion" of hydrogen nuclei.

A Fourth Method

The new phenomenon is described as a "catalyzed nuclear reaction." This adds a new and fourth way to make a nuclear reaction (a reaction to produce atomic energy) take place.

One of the older ways is to induce a thermonuclear reaction, in which two nuclei of light elements, particularly hydrogen, are fused into a heavier element when the temperature is raised to about 100,000,000 degrees Centigrade. (This is the fusion reaction that takes place in the hydrogen bomb.) The second method is that of fission, the splitting of a heavy element such as uranium, by neutrons, into two lighter elements (the method used in the atomic bomb and in atomic power plants). The third method is to bombard an element with nuclear particles fired from accelerators like the cyclotron.

Pulling Together

Basically, the new discovery is that a nuclear particle known as the negative mu meson, which has an atomic mass 210 times that of an electron, can pull together the nuclei of a light hydrogen atom and a heavy hydrogen atom and make them fuse into an atom of helium. This fusion can take place at any temperature. And such "cold fusion," like the thremonuclear fusion in the hydrogen bomb and in the sun and hot stars, releases enormous amounts of energy, twice as much as that released in the fission of uranium.

The difficulty that at present stands in the way of utilizing this "cold fusion" reaction on a practical scale is the extremely short life, as well as the scarcity, of the mu mesons.

W. L. L.

PHYSICAL REVIEW VOLUME 106, NUMBER 2 APRIL 15, 1957

Catalysis of Nuclear Reactions between Hydrogen Isotopes by μ^- Mesons

J. D. JACKSON*
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

(Received January 10, 1957; revised manuscript received February 4, 1957)

The mechanism by which negative μ mesons catalyze nuclear reactions between hydrogen isotopes is studied in detail. The reaction rate for the process ($p+d+\mu^-\rightarrow He^3+\mu^-+5.5$ Mev), observed recently by Alvarez *et al.*, is calculated and found to be in accord with the available data. The μ^- meson binds two hydrogen nuclei together in the μ-mesonic analog of the ordinary H_2^+ molecular ion. In their vibrational motion the nuclei have a finite, although small, probability of penetrating the Coulomb barrier to zero separation where they may undergo a nuclear reaction. The intrinsic reaction rates for other, more probable, reactions are also estimated. The results are $\sim 0.3\times 10^6$ sec^{-1} for the observed $p-d$ reaction, $\sim 0.7\times 10^{11}$ sec^{-1} for the $d-d$ reaction, and $\sim 0.4\times 10^{13}$ sec^{-1} for the $d-t$ reaction. For the reaction observed by Alvarez rough estimates are made of the partial widths for nonradiative and radiative decay of the excited He^3 nucleus. The ejection of the μ^- meson by "internal conversion" seems somewhat less likely. Speculations are made on the release of useful amounts of nuclear energy by these catalyzed reactions. The governing factors are not the intrinsic reaction rate once the molecule is formed, but rather the time spent ($\sim 10^{-8}$ sec) by the μ^- meson between the breakup of one molecule and the formation of another and the loss of μ^- mesons in "dead-end" processes. These factors are such that practical power production is unlikely. In liquid deuterium, each μ^- meson will catalyze only ~ 10 reactions in its lifetime, while for the $d-t$ process it will induce ~ 100 disintegrations. A longer lived particle will not be able to catalyze appreciably more reactions.

See also "A Personal Adventure in Muon-Catalyzed Fusion"

PHYSICAL REVIEW VOLUME 106, NUMBER 2 APRIL 15, 1957

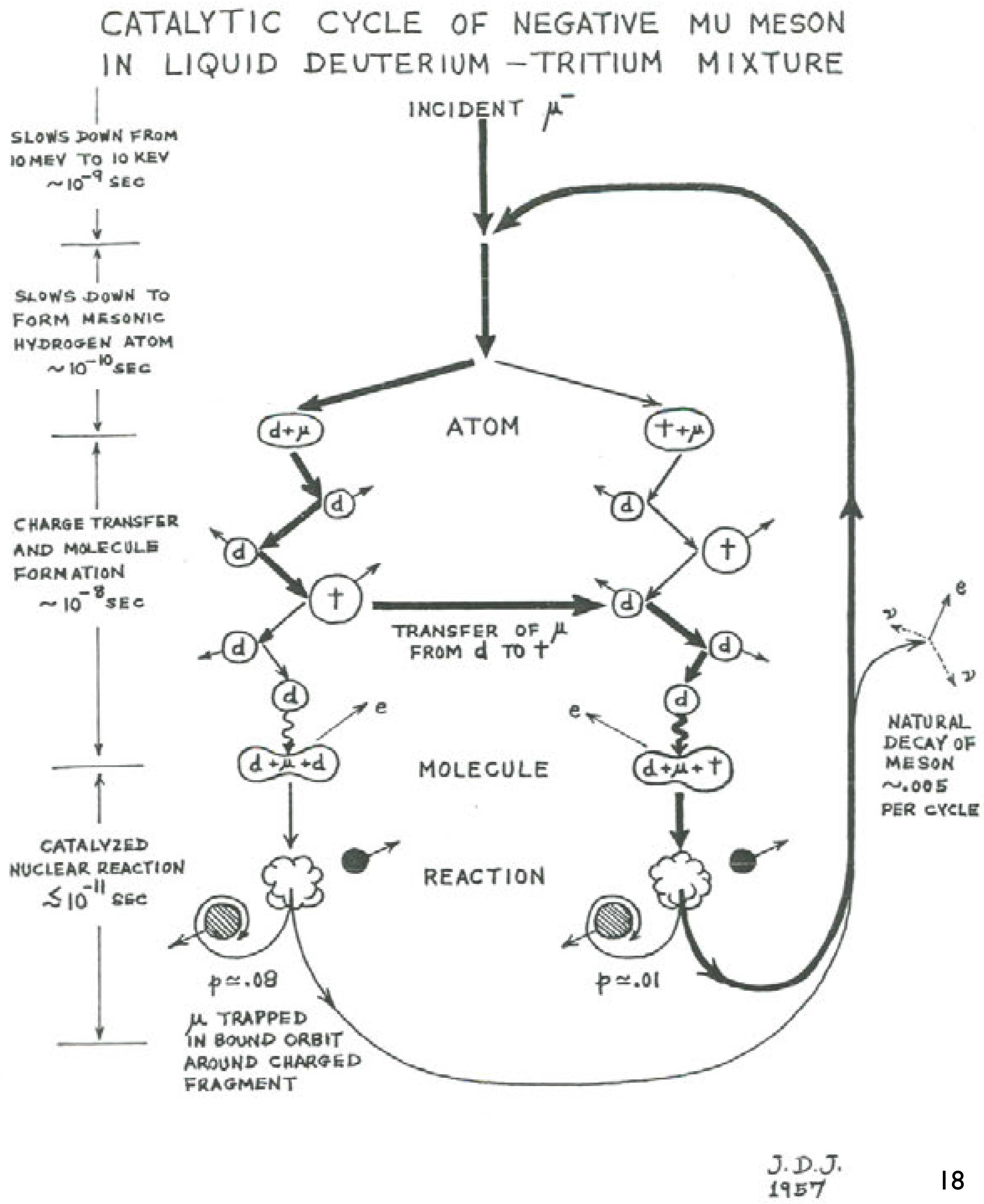
Catalysis of Nuclear Reactions between Hydrogen Isotopes by μ^- Mesons

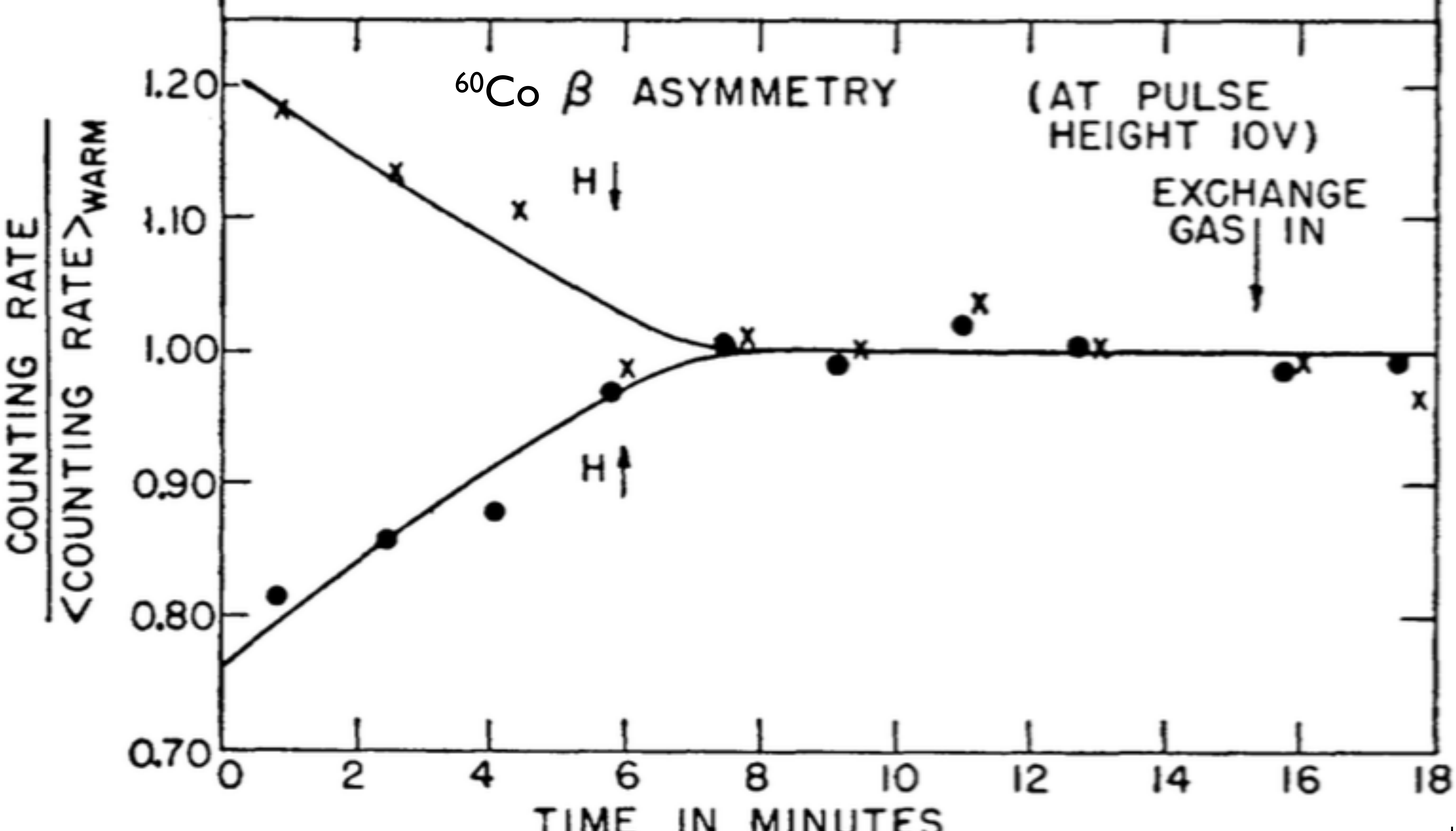
J. D. JACKSON*
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

(Received January 10, 1957; revised manuscript received February 4, 1957)

The mechanism by which negative μ mesons catalyze nuclear reactions between hydrogen isotopes is studied in detail. The reaction rate for the process ($p+d+\mu^- \rightarrow He^3+\mu^-+5.5$ Mev), observed recently by Alvarez *et al.*, is calculated and found to be in accord with the available data. The μ^- meson binds two hydrogen nuclei together in the μ-mesonic analog of the ordinary H_2^+ molecular ion. In their vibrational motion the nuclei have a finite, although small, probability of penetrating the Coulomb barrier to zero separation where they may undergo a nuclear reaction. The intrinsic reaction rates for other, more probable, reactions are also estimated. The results are $\sim 0.3\times 10^6$ sec^{-1} for the observed $p-d$ reaction, $\sim 0.7\times 10^{11}$ sec^{-1} for the $d-d$ reaction, and $\sim 0.4\times 10^{13}$ sec^{-1} for the $d-t$ reaction. For the reaction observed by Alvarez rough estimates are made of the partial widths for nonradiative and radiative decay of the excited He^3 nucleus. The ejection of the μ^- meson by "internal conversion" seems somewhat less likely. Speculations are made on the release of useful amounts of nuclear energy by these catalyzed reactions. The governing factors are not the intrinsic reaction rate once the molecule is formed, but rather the time spent ($\sim 10^{-8}$ sec) by the μ^- meson between the breakup of one molecule and the formation of another and the loss of μ^- mesons in "dead-end" processes. These factors are such that practical power production is unlikely. In liquid deuterium, each μ^- meson will catalyze only ~ 10 reactions in its lifetime, while for the $d-t$ process it will induce ~ 100 disintegrations. A longer lived particle will not be able to catalyze appreciably more reactions.

See also "A Personal Adventure in Muon-Catalyzed Fusion"





^{60}Co β ASYMMETRY
(AT PULSE HEIGHT 10V)
EXCHANGE GAS IN
H↓
H↑
$\frac{\text{COUNTING RATE}}{\langle\text{COUNTING RATE}\rangle_{WARM}}$
1.20
1.10
1.00
0.90
0.80
0.70
0
2
4
6
8
10
12
14
16
18
TIME IN MINUTES

Treiman

PHYSICAL REVIEW VOLUME 106, NUMBER 3 MAY 1, 1957

Possible Tests of Time Reversal Invariance in Beta Decay

J. D. JACKSON,* S. B. TREIMAN, AND H. W. WYLD, JR.
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

(Received January 28, 1957)

Noninvariance under space reflection and charge conjugation has now been established for beta decay processes. Invariance under time reversal remains an open question, however. We discuss here several possible tests for the validity of this symmetry operation. General expressions are given for the distribution function in three experimental situations, which have the possibility of detecting terms in allowed beta decay that are not invariant under time reversal: (a) experiments in which the nuclei are oriented and electron and neutrino momenta are measured; (b) experiments in which the nuclei are not oriented, but the recoil momentum and electron momentum and polarization are observed; (c) experiments in which the nuclei are oriented and the electron momentum and polarization are measured. The distribution functions obtained omit Coulomb distortion effects and relativistic corrections for the nucleons, but are otherwise complete. Such experiments should permit, in addition to the detection of terms which are not invariant under time reversal, the beginnings of a determination of the ten complex coupling constants which now characterize beta decay. An additional, somewhat surprising, result is found. If the two-component neutrino theory of Lee and Yang is correct, and if certain perhaps reasonable assumptions concerning the relative magnitudes of the various coupling constants are valid, then the longitudinal polarization of electrons in allowed beta decay even from unoriented nuclei should be almost complete (specifically, equal to v/c).

Wyld

PHYSICAL REVIEW C **86**, 035505 (2012)

Search for a *T*-odd, *P*-even triple correlation in neutron decay

T. E. Chupp,[1] R. L. Cooper,[1] K. P. Coulter,[1] S. J. Freedman,[2] B. K. Fujikawa,[2] A. García,[3,4] G. L. Jones,[5] H. P. Mumm,[6] J. S. Nico,[6] A. K. Thompson,[6] C. A. Trull,[7] F. E. Wietfeldt,[7] and J. F. Wilkerson[3,8,9]

1957–1967: University of Illinois

Summer schools: Edinburgh (1960) dispersion relations;
Brandeis (1962) weak interactions;
Les Houches (1965) decay angular distributions

The Physics of Elementary Particles (1958)
Mathematics for Quantum Mechanics (1962)
Classical Electrodynamics (1962)

1963–1964: CERN

Peripheral model with absorption, t-channel frame, density matrix, phenomenological analysis of resonances. Mountains!

1967–1993: University of California, Berkeley
emeritus from 1993

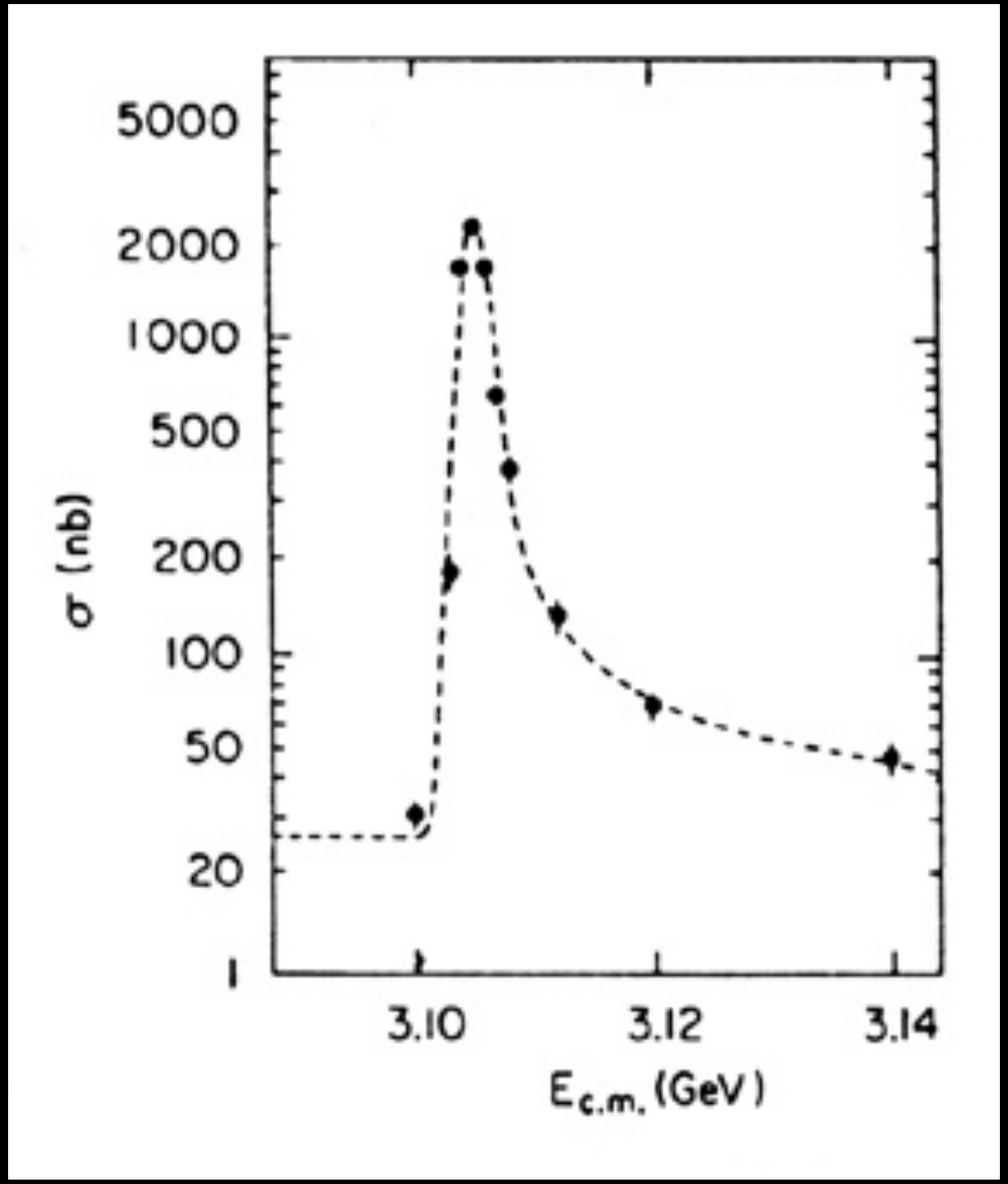
Dynamics of strong interactions, Regge theory

“Born a century too late!”

1967–1993: University of California, Berkeley
emeritus from 1993

Dynamics of strong interactions, Regge theory

"Born a century too late!"



J D JACKSON

Nov 10/74

Spear results (Kadyk call, ~4 pm)

Peak in e^+e^- cross section at

$$W = 2(1.552)\ \text{GeV} = 3.104\ \text{GeV}$$

$R \gtrsim 150 \qquad \sigma \sim 1500$ nb

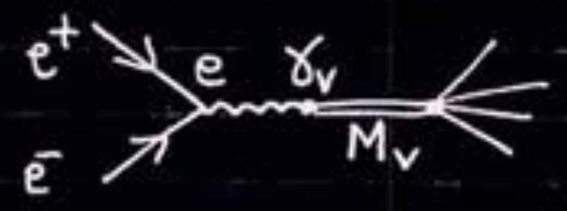
$(\text{FWHM})_{\text{observed}} = 2$ MeV

[Note that R_{max} for ρ is $\sim 6.5-7.0$]

$\frac{\Delta E}{E} \sim 3\times10^{-5}$

Presently mapping out the peak.
Yield of hadrons at peak is qualitatively similar to yield at nearby energies.

See OVER



For $e^+e^- \to$ state n, the resonant cross section is

$$\sigma_n = \frac{(2J+1)\pi ƛ^2}{(2s_1+1)(2s_2+1)} \frac{\Gamma_{e^+e^-}\Gamma_n}{(M-W)^2+\left(\frac{\Gamma}{2}\right)^2}$$

where $\Gamma = \sum_n \Gamma_n$ is the total width.

We have $2J+1 = 3$, $(2s_1+1)(2s_2+1) = 4$, $ƛ^2 = k^{-2} = \frac{4}{s} = \frac{4}{W^2}$

The total cross section is therefore

$$\sigma = \frac{3\pi\times4}{W^2\times4} \frac{\Gamma_{e^+e^-}\Gamma}{(M-W)^2+\frac{\Gamma^2}{4}}$$

$$\sigma_{max} = \frac{12\pi}{W^2}\cdot\left(\frac{\Gamma_{e^+e^-}}{\Gamma}\right)$$

With $\sigma_{\mu\mu} = \frac{4\pi\alpha^2}{3W^2}$ we have $R = 9(137)^2\left(\frac{\Gamma_{e^+e^-}}{\Gamma}\right)$

Nov 11/74 8

$\bar{R}_{max} = 255 \qquad \therefore \frac{\alpha \bar{R}_{max}}{3} = 0.620$

$$\frac{d\sigma/d\Omega}{(\ \ )_{QED}} = \left|-1 + \frac{0.620}{x-i}\right|^2 + 0.385\left(\frac{\Delta W}{\Gamma}\right)\left[\frac{1}{1+x^2}\right]$$

where $x = (M-W)\cdot\frac{2}{(\Gamma+\Delta W)}$.

$$= 1 - 1.24\frac{x}{1+x^2} + 0.385\left(1+\frac{\Delta W}{\Gamma}\right)\frac{1}{1+x^2}$$

Observed peak value is $\sim 80-100$ nb whereas QED value is 9. This means

$$\left(\frac{\Gamma+\Delta W}{\Gamma}\right) \simeq \frac{(8-10)}{.385} \sim 20-25.$$

With $\Delta W = 1.3$ MeV, $\Gamma \simeq 52-63.$ KeV

If $\sigma_{\mu\mu} \sim 123$ nb, $\frac{\Gamma+\Delta W}{\Gamma} \simeq \frac{13.6}{.385} = 35.4$

With $\Delta W = 1.3$ MeV, $\Gamma = 37$ KeV.

This means $R_{max} = 8.9\times10^3$

Now $R_{max} = 9(137)^2\frac{\Gamma_{ee}}{\Gamma} \quad \therefore \frac{\Gamma_{ee}}{\Gamma} = \frac{8.9\times10^3}{9(137)^2} = .053$

$$\left[\frac{e^+e^-\to e^+e^-}{(\ \ )_{QED}}(90°)\right] \simeq \frac{1}{9}\left(8+(8-12)\right) \simeq 1.8-2.2.$$

Beautiful! $\Gamma \simeq 40-60$ KeV

$\frac{\Gamma_{ee}}{\Gamma} \simeq 0.053 \simeq \frac{\Gamma_{\mu\mu}}{\Gamma}$

Note $\Gamma_{ee} = \frac{\bar{R}}{9(137)^2}\Delta W = 2.0\times10^{-3}$ MeV for $\bar{R} = 255$, $\Delta W = 1.3$ MeV
independent of value of Γ.

PHYSICAL REVIEW LETTERS

VOLUME 37 | 25 OCTOBER 1976 | NUMBER 17

Use of Dipole Sum Rules to Estimate Upper and Lower Bounds for Radiative and Total Widths of $\chi(3414)$, $\chi(3508)$, and $\chi(3552)$*

J. D. Jackson
Department of Physics and Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720
(Received 18 August 1976)

Upper and lower bounds on the widths for $\chi_J \to \gamma\psi(3095)$ can be estimated by assuming $E1$ transitions and approximate Russell-Saunders coupling for the $c\bar{c}$ system. Experimental widths for $\psi(3684) \to \gamma\chi_J$ make the lower bound more restrictive, giving radiative widths of 160→240, 230→400, and 280→480 keV for 3414-, 3508-, and 3552-MeV states, respectively. Cascade branching ratio data permit estimation of the total widths as >1.6, 0.3–1.5, and 0.6–4 MeV, respectively.

In the spectroscopy of new particle states uncovered in e^+e^- annihilation it is now rather clearly established that the three states[1-3] generically labeled as χ have $J^{PC} = 0^{++}, 1^{++}, 2^{++}$ for the 3414-, 3508-, and 3552-MeV states, respectively.[4] The spin and parity values and ordering of these states are just what is expected of the triplet p states in any $q\bar{q}$ bound-state model that parallels positronium.[5,6] The χ states are formed by the radiative decay $\psi(3684) \to \gamma\chi$. They are observed to decay into hadrons and also, for the $J = 1$ and $J = 2$ (and marginally for the $J = 0$) via the two-photon cascade, $\psi(3684) \to \gamma_1\chi \to \gamma_2\psi(3095)$. Recently, branching ratios have been reported for the $\psi(3684) \to \gamma\chi_J$ transitions[7,8] and also products of branching ratios for the cascade transitions.[8-10] These are summarized in Fig. 1.

The view that these states are describable to a good approximation by a nonrelativistic potential model, with v^2/c^2 corrections, receives increasing support from the data.[6] I adopt this picture here. In the Russell-Saunders limit (J^2, J_z, L^2, and S^2 diagonal) the states have the designations shown in Fig. 1. The details of the binding potential need not concern us, but I make the assumption from the outset that tensor forces, relativistic effects, coupled channel effects, etc. are unimportant enough that they do not vitiate my use

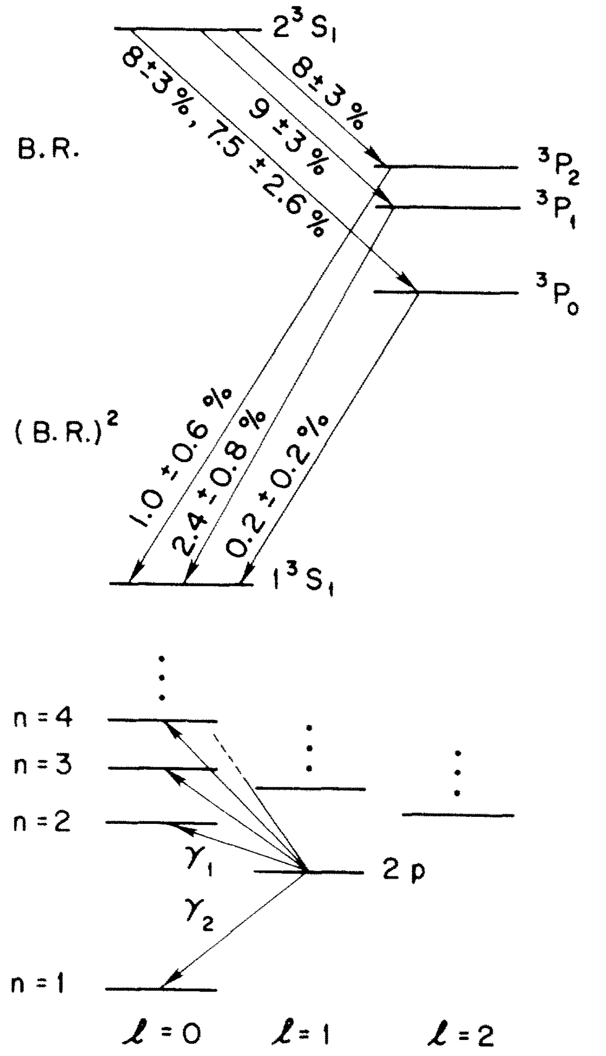


FIG. 1. (Top) Observed radiative transitions through the χ states. For the first transitions the numbers are branching ratios (Ref. 7; for the $J = 0$ final state the second number is from Ref. 8). For the second step the numbers are the *products* of the branching ratios (Refs. 8 and 10). (Bottom) Schematic diagram showing the transitions involved in the second sum rule, used to set *lower limits* on the radiative widths.

Thomas–Reiche–Kuhn: $2\mu\sum_j \omega_{ji}|\langle j|\vec{r}|i\rangle|^2 = 3$

Kirkwood–Wigner: $2\mu\sum_n \omega_{n\mathrm{S},2\mathrm{P}}|\langle n\mathrm{S}|r|2\mathrm{P}\rangle|^2 = -1$

The Women Graduate Students of the Department of Physics
of the

University of California

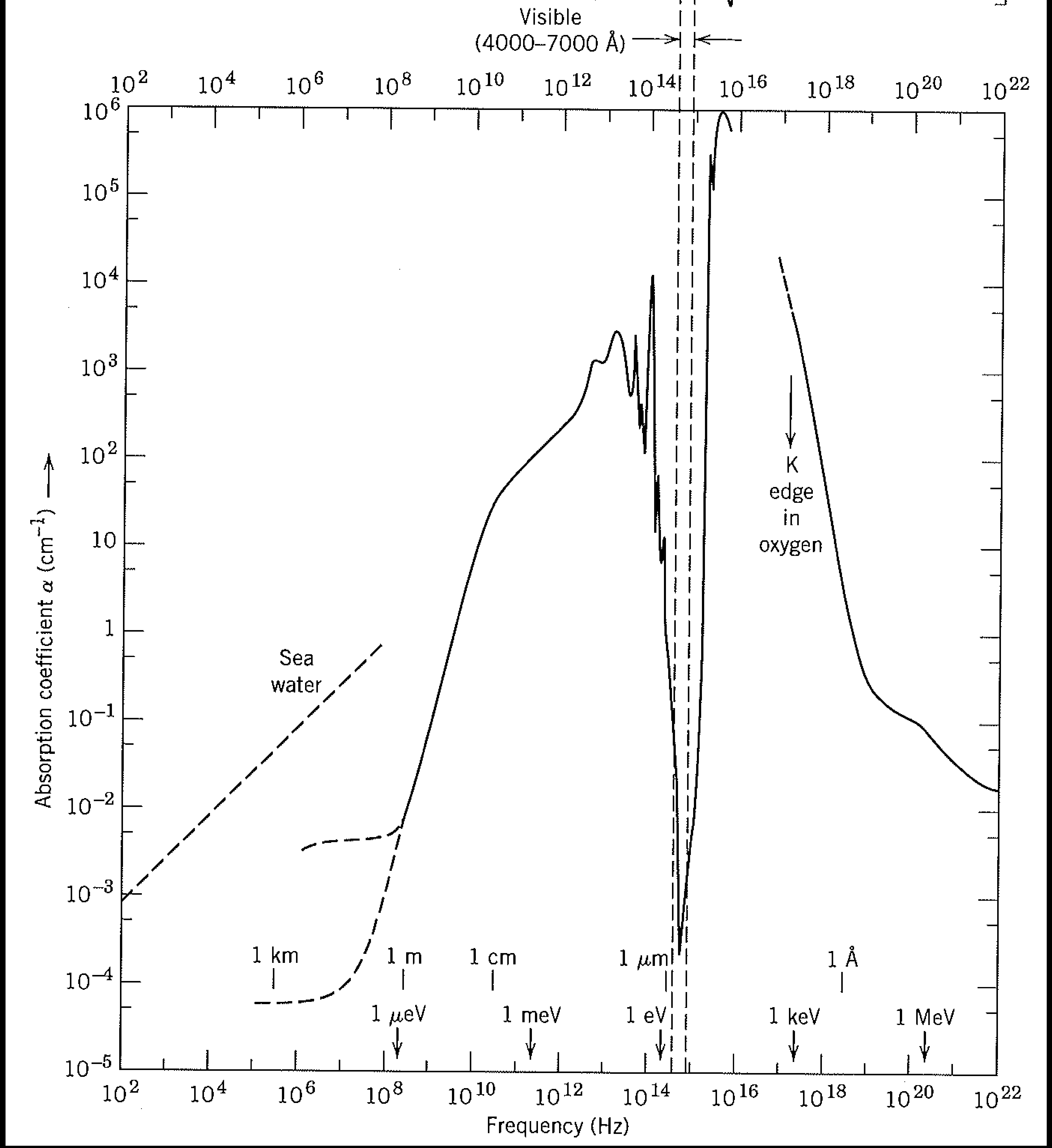
confer upon

John David Jackson

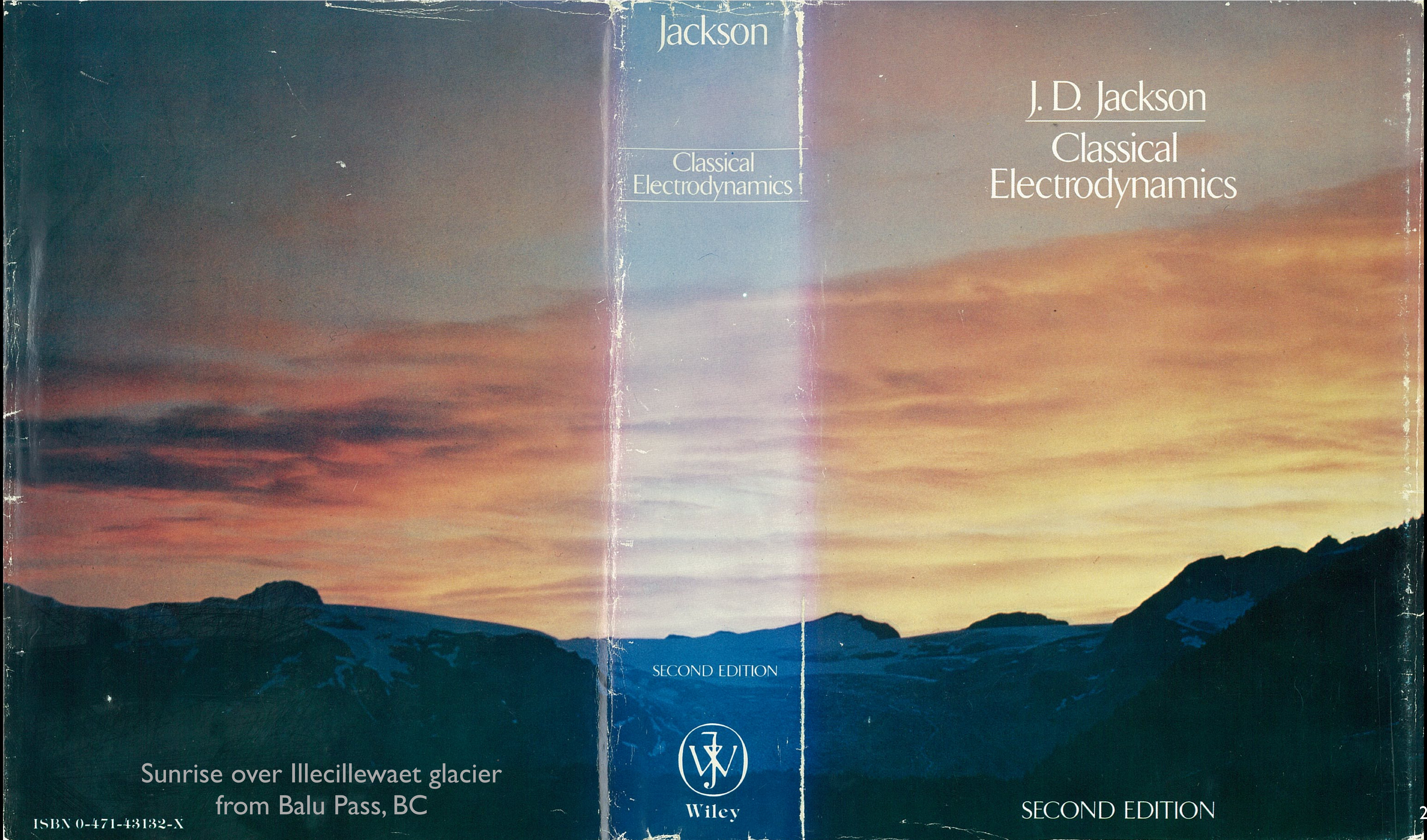
the title of HONORARY WOMAN, with all rights and privileges thereto pertaining, in recognition of outstanding achievements as chairman of the Department of Physics 1978 - 1981.

Given at Cragmont Park

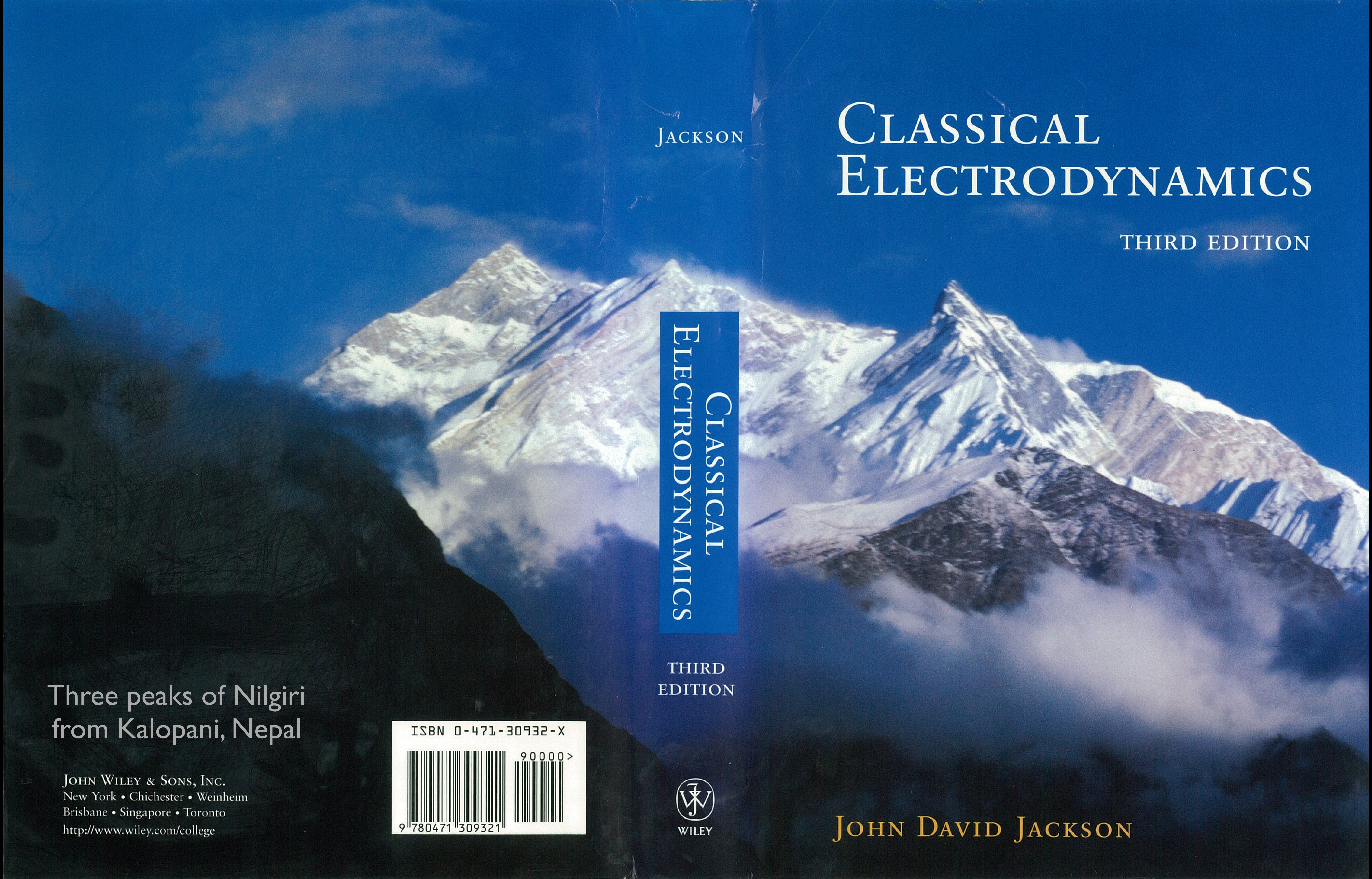
May 31, 1981



CED Fig. 7.9— "The reader may meditate on the fundamental question of biological evolution on this water-soaked planet, of why animal eyes see the spectrum from red to violet and of why the grass is green."



Sunrise over Illecillewaet glacier
from Balu Pass, BC


Three peaks of Nilgiri
from Kalopani, Nepal
JOHN WILEY & SONS, INC.
New York • Chichester • Weinheim
Brisbane • Singapore • Toronto
http://www.wiley.com/college
ISBN 0-471-30932-X
90000>
9 780471 309321
JACKSON
CLASSICAL ELECTRODYNAMICS
THIRD EDITION
WILEY
CLASSICAL
ELECTRODYNAMICS
THIRD EDITION
JOHN DAVID JACKSON


Jet d’eau, Genève

ELSEVIER

Physics Reports 320 (1999) 27–36

PHYSICS REPORTS

www.elsevier.com/locate/physrep

From Alexander of Aphrodisias to Young and Airy

J.D. Jackson

University of California, Berkeley, CA, USA and Lawrence Berkeley National Laboratory, University of Berkeley, Berkeley, CA, 94720, USA

Abstract

A didactic discussion of the physics of rainbows is presented, with some emphasis on the history, especially the contributions of Thomas Young nearly 200 years ago. We begin with the simple geometrical optics of Descartes and Newton, including the reasons for Alexander's dark band between the main and secondary bows. We then show how dispersion produces the familiar colorful spectacle. Interference between waves emerging at the same angle, but traveling different optical paths within the water drops, accounts for the existence of distinct supernumerary rainbows under the right conditions (small drops, uniform in size). Young's and Airy's contributions are given their due.

PACS: 01.30.Rr; 42.15.Dp; 42.25.Fx; 42.68.Ge

'This pedagogical piece on rainbows is dedicated to Lev B. Okun, colleague and friend, on his 70th birthday. On an extended visit to Berkeley in 1990, Lev saw on my office wall a picture of a double rainbow with at least three supernumerary bows visible inside the main bow. As part of my "lecture" on the photograph, I showed Lev a copy of these 1987 handwritten notes prepared for a class. He said, "Are these published somewhere?" My answer was no, but now they are, in augmented form. Lev is an amazing man, a physicist-mensch – a brilliant researcher, mentor, and warm human being. I have a vivid memory of a wonderful trip to Yosemite National Park with an allegedly ailing Lev. In the early morning hours, we found Lev outside our tent in Curry Village perched on a sloping rock doing vigorous calisthenics! Lev, may you have Many Happy Returns!'

The rainbow has fascinated since ancient times. Aristotle offered an explanation (not correct), as did clerics and scholars through the ages. Newton and Descartes established the elementary theory, according to what e now know as geometrical optics. But long before Newton and Descartes, as early as the 13th century, the puzzling occasional phenomenon of supernumerary rainbows was noted. These "aberrations" were inexplicable in terms of geometrical optics. It was not until the beginning of the 19th century that Thomas Young, promoting the wave theory of light against acolytes of Newton, offered the correct explanation of the supernumeraries as results of interference. Airy put the theory on a firm mathematical footing in 1836. A scholarly treatment of the

0370-1573/99/$ - see front matter
PII: S0370-1573(99)00088-5

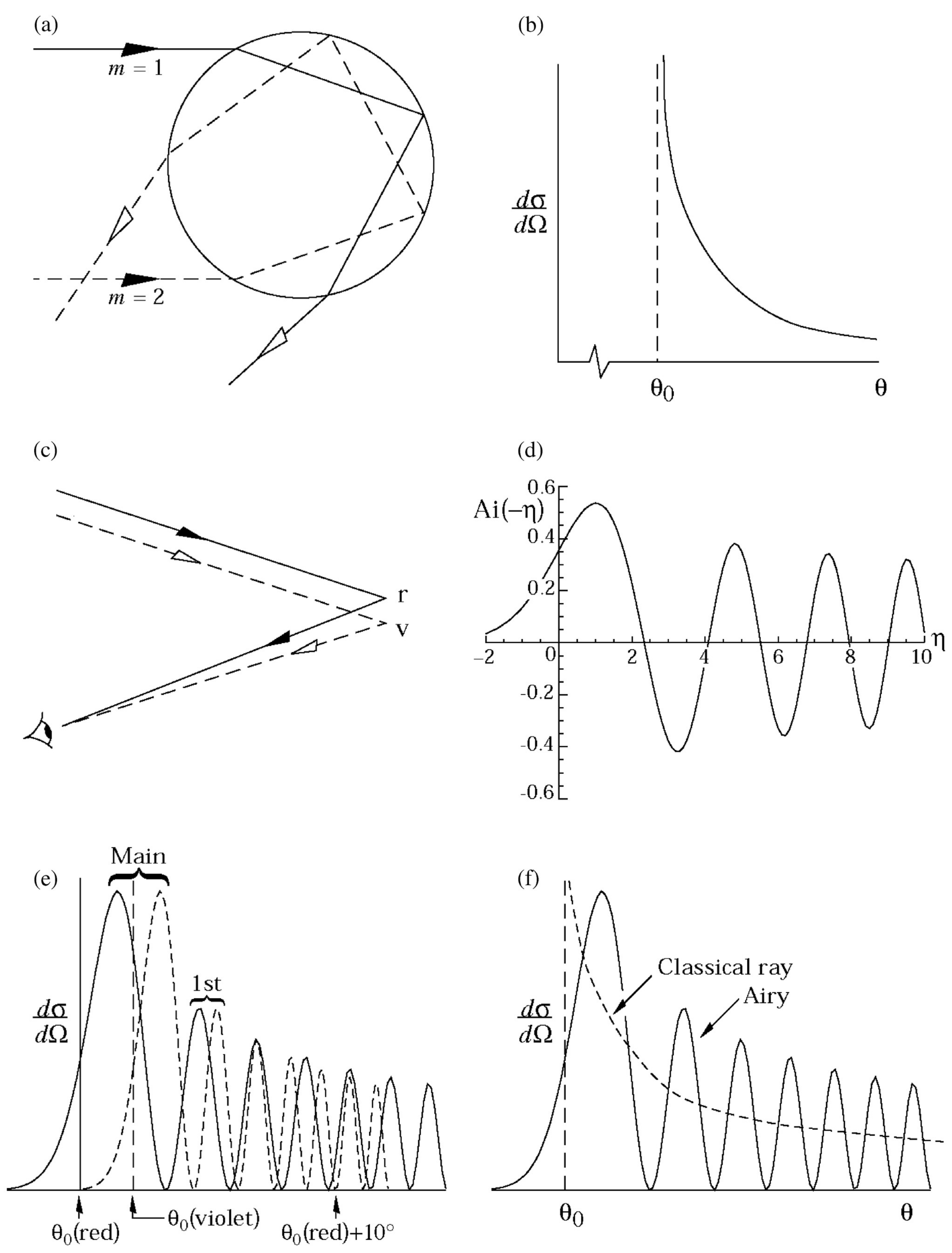
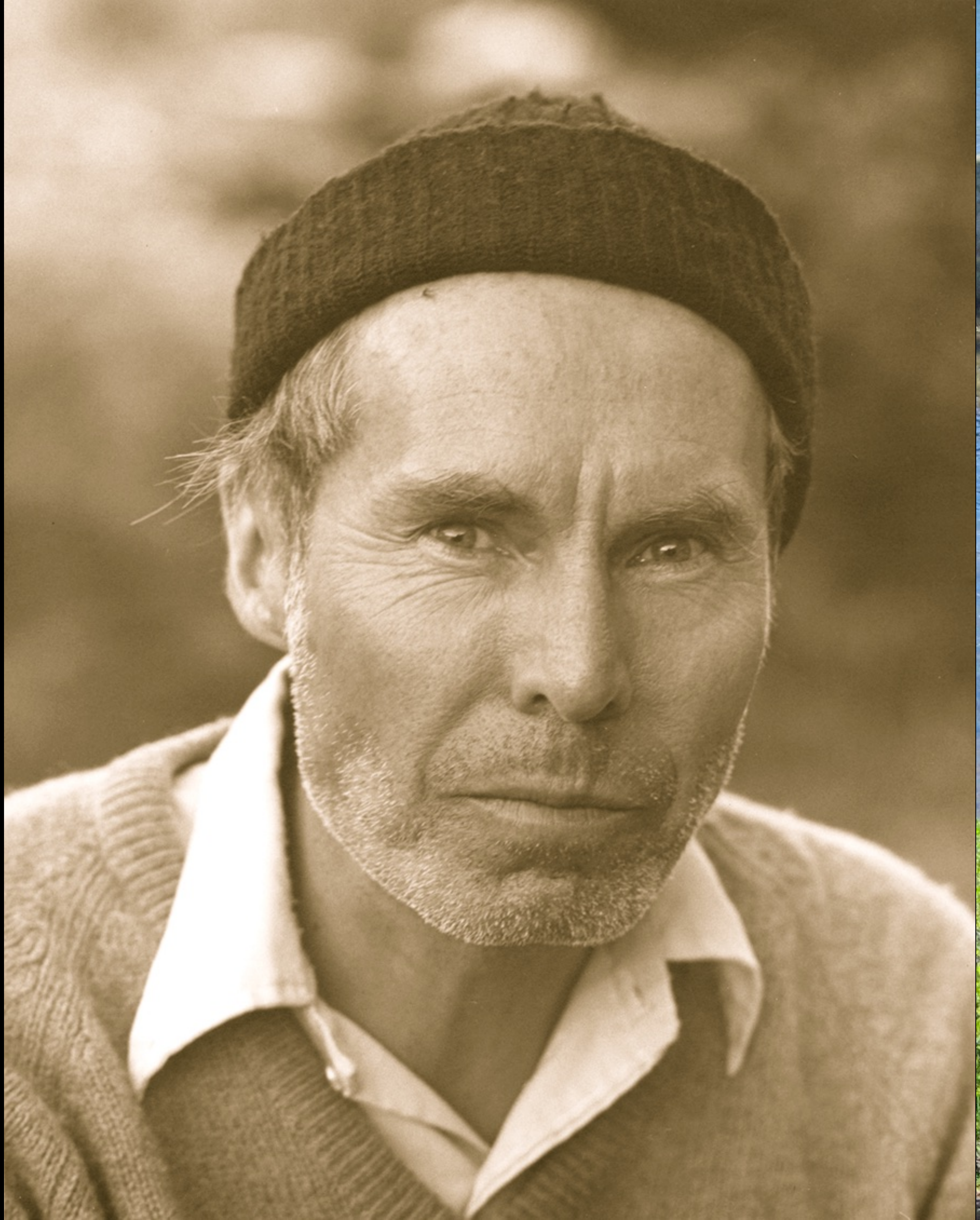


Fig. 4. Sketches to accompany the text.

At the rainbow angle,

$$\left(\frac{\mathrm{d}\theta}{\mathrm{d}n}\right)_{x_0} = \frac{2}{n}\sqrt{\frac{4-n^2}{n^2-1}} \tag{9}$$

For $n = 4/3$, $\mathrm{d}\theta/\mathrm{d}n|_{x_0} = 2.536$. With $\Delta n = 1.3\times10^{-2}$, we find $\Delta\theta_0 = 3.3\times10^{-2}$ radians $= 1.89°$. The colors of the rainbow are spread over about 2° out of the 42° away from the anti-solar point (180° − 138°). Since $\mathrm{d}n/\mathrm{d}\lambda < 0$, the red light emerges at a smaller angle than the violet.



Lake Ediza, 1978 Kurt Gottfried photo

Near Lake Tahoe, August 2011 Nan Jackson photo

JDJ’s home page

Commemoration at Lawrence Berkeley Laboratory

CQ, Obituary in Physics Today

Gottfried & Tigner, Obituary in the CERN Courier

Wikipedia article

JDJ's Articles in American Journal of Physics

R. N. Cahn, Biographical Memoir (NAS, to appear)

Thanks to Maureen & Nan Jackson, Bob Cahn, Kurt Gottfried

UATC Cadets

Del Rumbold, David Jackson, Gar Woonton, Don Hay, Harold Tull, Eric Vogan
4th-year Radio Physics students and staff at UWO, 1946

John Harvey · JDJ · Douglas Van Patter · Harry Gove
Canadian physics students at MIT, 1948

My Ph.D. and M.Sc. students

In my seven and one half years at McGill, one on leave, I supervised two Ph.D. students and three M.Sc. students. Their names and thesis topics and photographs are given in chronological order:

Schiff, Harry, Ph.D., 1953
Theoretical calculations of electron capture cross sections.

Vosko, Seymour H., M.Sc., 1953
Theoretical interpretation of radiation emitted in neutron capture reactions.

Betts, Donald Drysdale, Ph.D., 1955
A theoretical investigation of resonance electron capture cross sections.

Reeves, Hubert, M.Sc., 1956
The formation of positronium in hydrogen and helium gases.

Chapdelaine, J. L. Marc, M.Sc., 1956
Scattering of positrons by hydrogen atoms and formation of Positronium.

No photograph available