Tribute to Samoil Mihelevich Bilenky

(1928 - 2020)

S. T. Petcov

SISSA/INFN, Trieste, Italy,
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Neutrino Telescopes
Venice, Italy/Virtual Workshop
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Samoil Mihelevich Bilenky, an eminent Russian theoretical physicist, passed on November 5, 2020. A teacher of a generation of particle physicists not only in Russia, but also in the former Eastern countries and later in Western Europe, Samoil Bilenky, as many friends and collaborators called him, was a founder of modern neutrino physics and played a leading role in its evolution to the present advanced state.

At a seminar in 2018. (From the photo archive of JINR.)

Background

Bilenky was born on May 23, 1928, in Zmerinka, a town in Ukraine, in a family of an engineer.

He graduated in 1952 "cum laude" from the renowned Moscow Engineering and Physics Institute. His master thesis adviser was the famous Soviet theoretical Physicist I. Ya. Pomeranchuk.

The same year Bilenky got a permanent position at the Laboratory for Nuclear Problems (LNP) in Dubna, near Moscow, which became in 1956 the Joint Institute for Nuclear Research (JINR), and ever since was a staff member of JINR.

The Laboratory of Nuclear Problems was created in connection with the building of the first Soviet accelerator centre in the small town of Ivan'kovo (which was later "absorbed" by the newly built science town Dubna), about 120 km north of Moscow, on the banks of river Volga. This was a proton synchro-cyclotron with energy of the proton beam of 460 MeV. The accelerator was built in the record time of two years and became operational in 1948. Later (in the 1950s) a 10 GeV proton synchrotron was also built. The accelerator complex and LPN were classified until 1954; they were called "Hydro-Technical Laboratory" (not far there existed (and still exist) a dam with a hydro-electric power plant) and "Ploshchatka" ("The Plot"). At LNP a Theoretical Physics Section was formed under the leadership of Pomeranchuk, who was instrumental for the hiring of Bilenky.

In 1956 within JINR, the Laboratory of Theoretical Physics (LTP) was created. N. N. Bogoliubov was appointed Director of LTP and Bilenky became a staff member of this new theoretical physics unit. He remained a staff member of LTP ever since.

In 2006 Bilenky moved with his wife Sofa Isaevna to Vancouver, Canada, to be close to his son who after an unfortunate accident could move only on wheel-chair.

Research

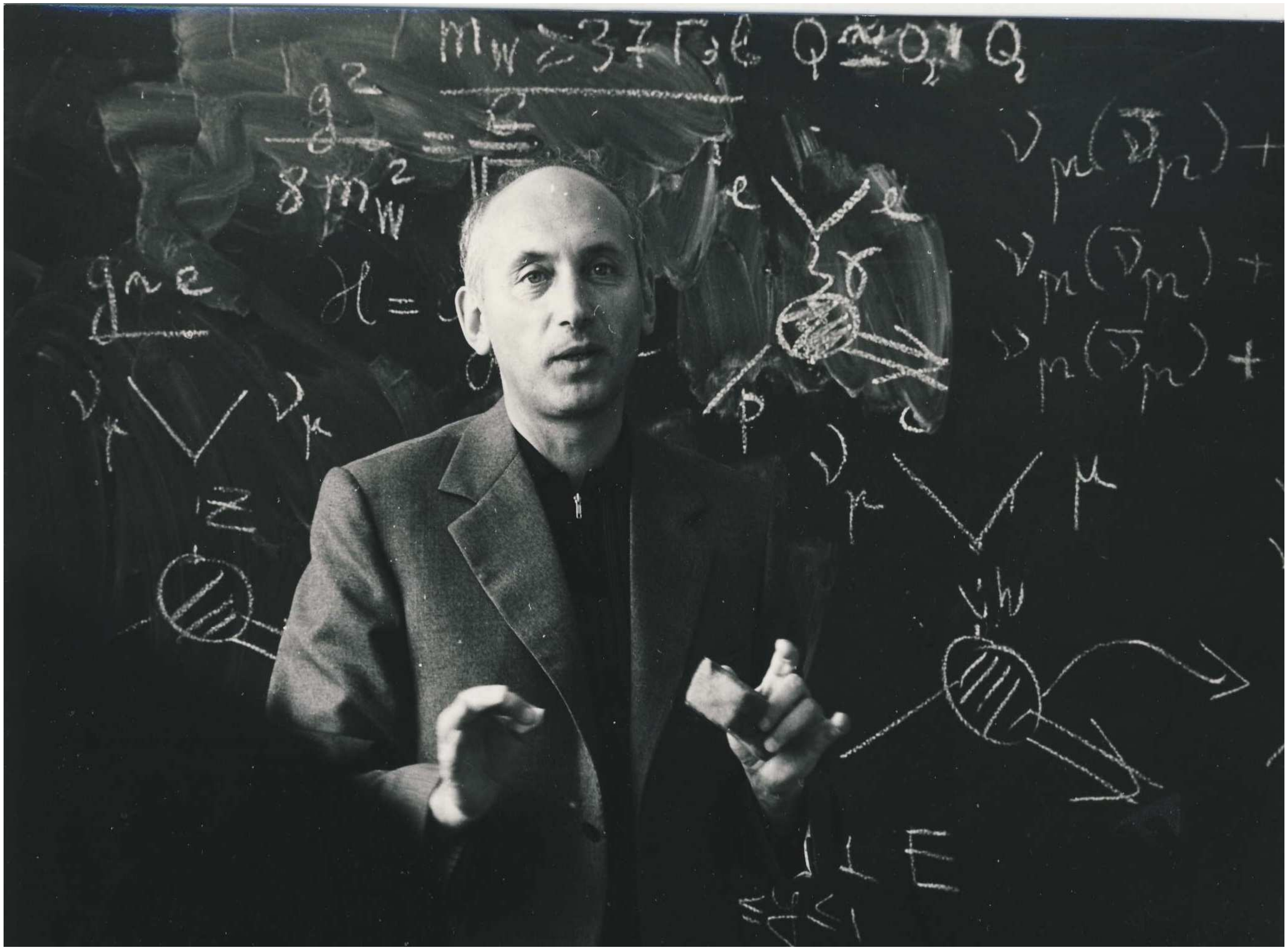
S.M. Bilenky is author and co-author of more than 250 scientific articles and 5 books.

Bilenky's scientific style is characterized by the striving to use model-independent approach to physical problems. In his works he built bridges between theory and experiment. He taught his students and junior collaborators to always see the physics behind the mathematical formulas.

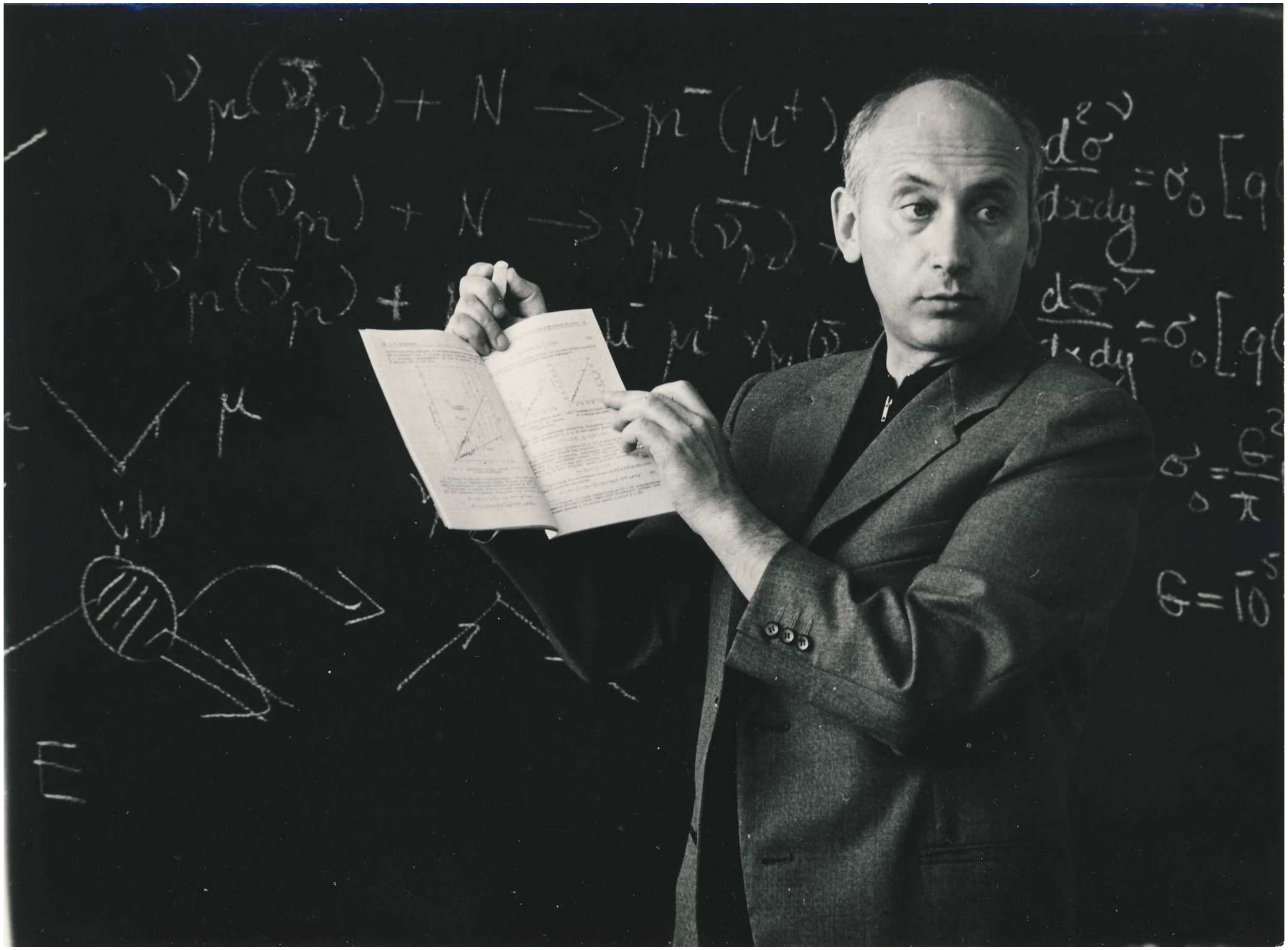
S.M. Bilenky obtained his Ph.D. degree in 1957 at LTP, JINR, for applications of the dispersion relation theory to weak interaction processes.

In a subsequent series of articles Bilenky discovered a general connection between polarisation effects and internal parities of particles in scattering processes and proposed a method of determination of parities of strange particles later used in experiments at LBL Berkeley and CERN. These articles also initiated the development of the polarised proton target technique in scattering experiments.

"Parity test for Omega$^-$ using polarized hydrogen target" S.M. Bilenky, R.M. Ryndin (Dubna, JINR). Sep 1965. 2 pp. Published in Phys.Lett. 18 (1965) 346-347



Giving a talk at JINR, Dubna (early 1970s). (From the photo archive of JINR.)

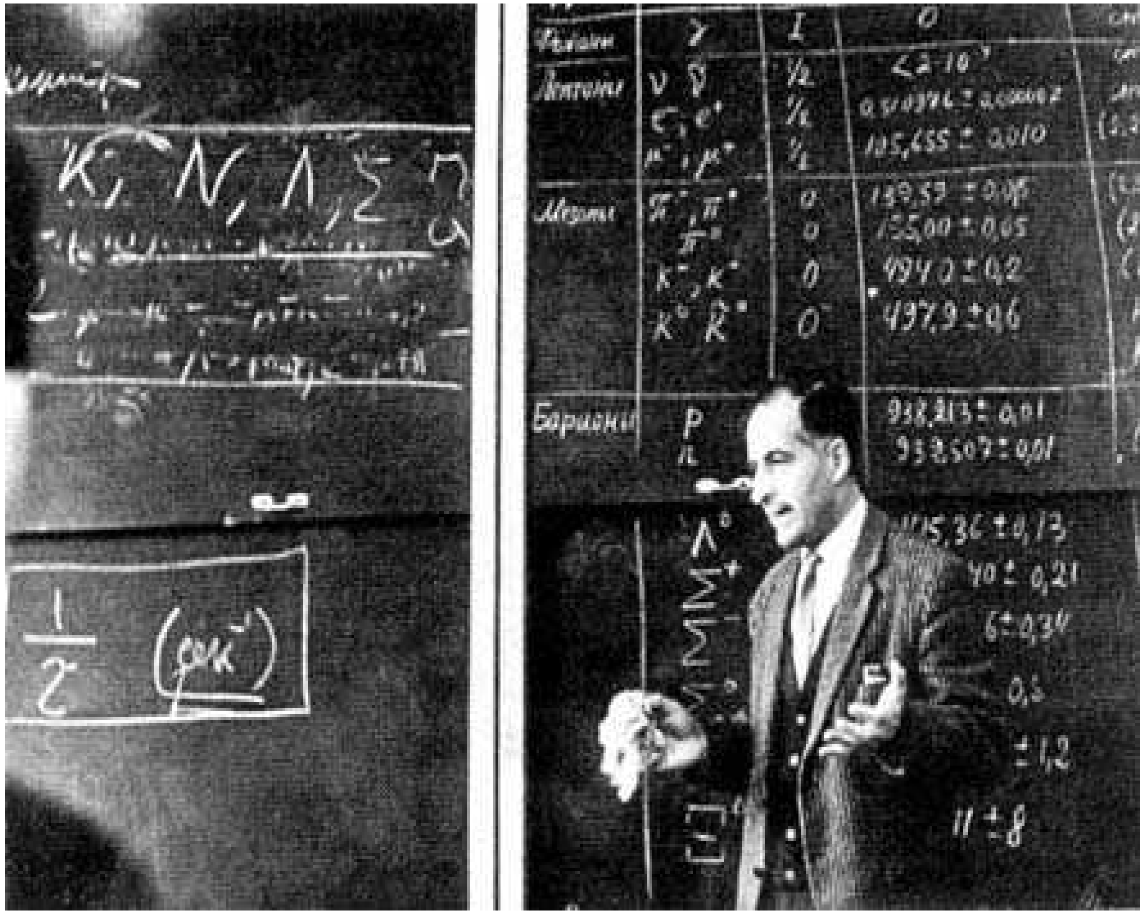


Giving a talk at JINR, Dubna (early 1970s). (From the photo archive of JINR.)

Contributions to Neutrino Physics

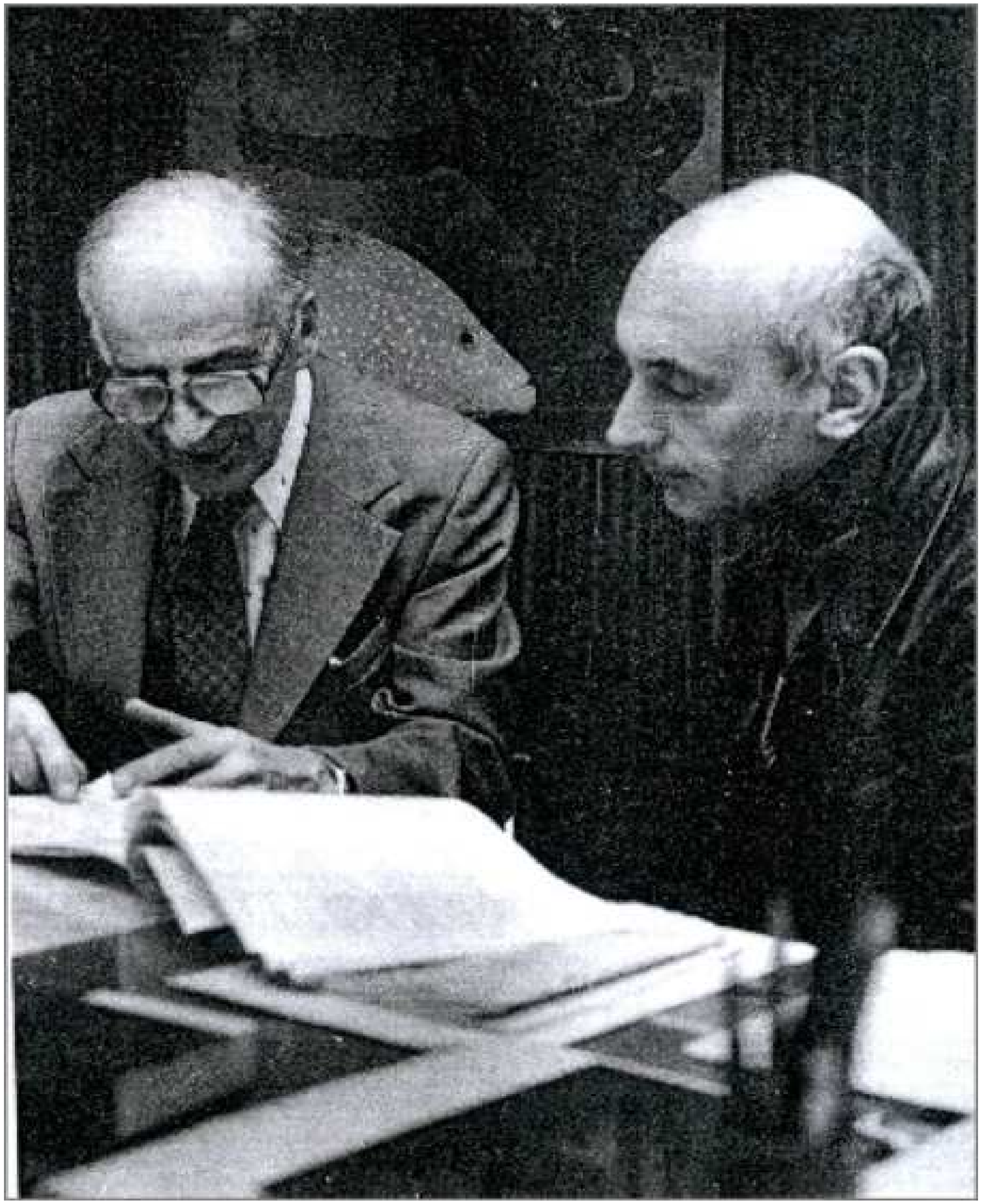
Collaboration with B. Pontecorvo

Bilenky's most prominent and well known contributions today are in the field of neutrino physics. In a fruitful collaboration and co-authorship with Bruno Pontecorvo, which started in the early 1970s, they developed the theory of neutrino oscillations in vacuum and laid the foundations of the phenomenological theory of neutrino mixing, on which every theoretical model of neutrino mass generation (including GUTs) is based. B. Pontecorvo moved to Soviet Union in 1950 and in 1952 joined the Laboratory for Nuclear Problems in Dubna, the same year in which Bilenky became a staff member of the Laboratory.



B. Pontecorvo giving a talk at JINR, Dubna. (From the photo archive of JINR.)

B. Pontecorvo at a seminar at JINR, Dubna. (From the photo archive of JINR.)



With B. Pontecorvo at JINR in 1980s. (From the photo archive of JINR.)

S.M. Bilenky and B. Pontecorvo have written together 28 articles.

– "Quark-Lepton Analogy and Neutrino Oscillations", Samoil M. Bilenky, B. Pontecorvo (Dubna, JINR). Dec 1975. 3 pp., Phys. Lett. 61B (1976) 248.
– "The Quark-Lepton Analogy and the Muonic Charge (In Russian)", S. M. Bilenky, B. Pontecorvo (Dubna, JINR), 1976, 6 pp., Yad.Fiz. 24 (1976) 603 (ov.J.Nucl.Phys. 24 (1976) 316).
– "Again on Neutrino Oscillations", Samoil M. Bilenky, B. Pontecorvo (Dubna, JINR). May 1976. 11 pp., Lett. Nuovo Cim. 17 (1976) 569.
– "Lepton Mixing, $\mu \to e + \gamma$ Decay and Neutrino Oscillations", Samoil M. Bilenky, S.T. Petcov, B. Pontecorvo (Dubna, JINR). Jan 1977. 4 pp., Phys. Lett. 67B (1977) 309.
– "Lepton Mixing and Neutrino Oscillations" (review), Samoil M. Bilenky, B. Pontecorvo (Dubna, JINR). 1978. 37 pp., Phys. Rept. 41 (1978) 225.
– "Majorana and Dirac Masses, Neutrino Oscillations and the Number of Charged Leptons", Samoil M. Bilenky, B. Pontecorvo (Dubna, JINR). Jun 1980. 4 pp., Phys. Lett. 95B (1980) 233.
– "Neutrino Oscillations in New Mixing Schemes With Either Dirac or Majorana Masses", S.M. Bilenky, B. Pontecorvo (Dubna, JINR), Dec 1980. 3 pp., Phys. Lett. 102B (1981) 32.
– "Neutrino Oscillations With Large Oscillation Length in Spite of Large (Majorana) Neutrino Masses?", S.M. Bilenky, B. Pontecorvo (Dubna, JINR). Mar 1983. 7 pp., Yad.Fiz. 38 (1983) 415-419, Lett. Nuovo Cim. 37 (1983) 467.
– "Reactor Experiments And Solar Neutrino Problem". Samoil M. Bilenky, B. Pontecorvo (Dubna, JINR). Mar 1984. 6 pp., Lett. Nuovo Cim. 40 (1984) 161.

The style of the articles is extremely concise.

Bilenky and Pontecorvo, in particular, laid the foundations of the phenomenological theory of neutrino mixing, on which every theoretical model of neutrino mass generation is based. They were the first to understand in 1975-1976 that the properties of massive neutrinos (Dirac, Majorana) and of neutrino mixing in gauge theories of particle interactions are determined by the properties of the neutrino mass term, and more specifically, by the symmetries the neutrino mass term and the Lagrangian of the theory have. Later this idea found its natural realization in gauge theories of electroweak interactions and in GUTs.

They were the first to consider, e.g., the possibility of neutrinos having the so-called "Dirac + Majorana" mass term, which is at the basis of the seesaw mechanism of neutrino mass generation. This was done in 1976 on purely phenonemological grounds. Later it was used and is still being used in GUTs unifying the electroweak and strong interactions and in other non-GUT theories employing the seesaw mechanism. The seesaw mechanism not only provides a natural explanation of the smallness of neutrino masses, but via the leptogenesis theory relates the generation and smallness of neutrino masses to the generation of the matter-antimatter asymmetry of the Universe.

Again on Neutrino Oscillations.

S. M. BILENKY and B. PONTECORVO

Joint Institute for Nuclear Research,
Laboratory of Theoretical Physics - Dubna, U.S.S.R.
Laboratory of Nuclear Problems - Dubna, U.S.S.R.

(ricevuto il 19 Settembre 1976)

The question of oscillations in neutrino beams has been discussed for some time (1-7). To start with we list below the various schemes which have been recently treated:

i) In ref (6) neutrino oscillations were considered on the basis of a theory (6,8) of the weak interaction of four leptons, which is fully analogous to the theory of the weak interaction of four quarks (9). In this scheme the two neutrino fields ν and ν', describing particles with definite masses m and m' different from zero, enter the interaction through the two orthogonal combinations

$$\nu_e = \nu\cos\theta + \nu'\sin\theta\,,$$

$$\nu_\mu = -\nu\sin\theta + \nu'\cos\theta\,,$$

where θ is a mixing angle, which *a priori* has nothing to do with the hadron Cabibbo angle. In this scheme ν_e and ν_μ are not stationary states and the oscillations $\nu_e \rightleftarrows \nu_\mu$, $\bar\nu_e \rightleftarrows \bar\nu_\mu$ arise, the origin of which can be traced to the mass difference $|m - m'|$. Let us emphasize here that, first, in this scheme the overall number of neutral-lepton states is 8 (2 four-component neutrinos,) and that, second, in the case of maximum mixing ($\theta = \pi/4$), the properly averaged intensity of ν_e at large distances from a source of ν_e (let us say the Sun) is equal to $\frac{1}{2}$ of the intensity expected when oscillations are absent.

ii) In ref. (5,7) a scheme was considered which is a generalization of the preceding case to that of N four-component neutrinos with masses different from zero ($4N$-states). Here too oscillations will take place, as the particles entering the weak interaction will not be described by stationary states and will be orthogonal mixtures of the mass eigen-

(1) B. PONTECORVO: *Žurn. Èksp. Teor. Fiz.*, **33**, 549 (1957); **34**, 247 (1958); **53**, 1717 (1967).
(2) V. GRIBOV and B. PONTECORVO: *Phys. Lett.*, **28** B, 493 (1969).
(3) J. BAHCALL and S. FRAUTSCHI: *Phys. Lett.*, **29** B, 623 (1969).
(4) B. PONTECORVO: *Usp. Fiz. Nauk*, **104**, 3 (1971).
(5) B. PONTECORVO: *Žurn. Èksp. Teor. Fiz. Pis. Red.*, **13**, 281 (1971).
(6) S. M. BILENKY and B. PONTECORVO: *Phys. Lett.*, **61** B, 248 (1976).
(7) H. FRITZSCH and P. MINKOWSKY: preprint CALT-68-525.
(8) S. ELIEZER and D. A. ROSS: *Phys. Rev. D*, **10**, 3088 (1974).
(9) S. L. GLASHOW, J. I. ILIOPOULOS and L. MAIANI: *Phys. Rev. D*, **2**, 1285 (1970).

S.M. Bilenky, B. Pontecorvo, Lett. Nuovo Cim. 17 (1976) 569.

Dirac+Majorana mass term with $\nu_{\ell L}(x)$ and $\nu_{\ell R}(x)$; massive neutrinos: ν_j, j=1,2,...,6, m$_j \neq 0$ - Majorana particles.

$$\mathcal{L}^{\nu}_{D+M}(x)$$
$$= -\overline{\nu_{l'R}}(\mathbf{x})\mathbf{M}_{Dl'l}\,\nu_{lL}(\mathbf{x}) + \frac{1}{2}\nu^{\mathsf{T}}_{l'L}(x)\mathbf{C}^{-1}\mathbf{M}^{LL}_{l'l}\,\nu_{lL}(\mathbf{x}) + \frac{1}{2}\nu^{\mathsf{T}}_{l'R}(\mathbf{x})\mathbf{C}^{-1}(\mathbf{M}^{RR})^{\dagger}_{l'l}\,\nu_{lR}(\mathbf{x}) + \text{h.c.},$$

$(\mathbf{M}^{LL})^T = \mathbf{M}^{LL}$, $(\mathbf{M}^{RR})^T = \mathbf{M}^{RR}$

$$M = \begin{pmatrix} M^{LL} & M_D \\ M_D^T & M^{RR} \end{pmatrix} = M^T$$

If $\mathbf{M}_{Dl'l} \neq 0$ and $\mathbf{M}^{LL}_{l'l} \neq 0$ and/or $\mathbf{M}^{RR}_{l'l} \neq 0$:

$\mathbf{L}_l \neq$ *const.*, $\mathbf{L} \neq$ *const.*; n = 6 (>3)

M = M$^{\mathsf{T}}$, complex; M^{diag}=W$^{\mathsf{T}}$MW, W-unitary, 6×6; $W^T \equiv$ (U^T V^T); U$\equiv$ U$_{\text{PMNS}}$: 3×6.

$\nu_{lL}(x)=\sum_{j=1}^{6} U_{lj}\chi_j(x)$, $\chi_j(\mathbf{x})$ - Majorana νs, m$_j \neq 0$, l=e,μ,τ;

$\nu^C_{lL}(\mathbf{x}) \equiv \mathbf{C}(\overline{\nu_{lR}}(\mathbf{x}))^{\mathsf{T}} = \sum_{j=1}^{6}\mathbf{V}_{lj}\,\chi_j(\mathbf{x})$, $\nu^C_{lL}(\mathbf{x})$: sterile antineutrino

$\mathcal{L}^{\nu}_{D+M}(x)$ possible in the ST + ν_{lR}: M^{LL} = 0; seesaw: $|M_D| << |M^{RR}|$.

Review article with B. Pontecorvo:
– "Lepton Mixing and Neutrino Oscillations", Samoil M. Bilenky, B. Pontecorvo (Dubna, JINR). 1978. 37 pp, Published in Phys. Rept. 41 (1978) 225-261 (cited in 930 papers).

Was used universally for a long period as a reference article on the subject of neutrino mixing and neutrino oscillations.

PHYSICS REPORTS (Section C of Physics Letters) 41, No. 4 (1978) 225–261. NORTH-HOLLAND PUBLISHING COMPANY

LEPTON MIXING AND NEUTRINO OSCILLATIONS

S.M. BILENKY and B. PONTECORVO

Joint Institute for Nuclear Research, Dubna, USSR

Received 27 June 1977

Contents:

Single orders for this issue

PHYSICS REPORT (Section C of PHYSICS LETTERS) 41, No. 4 (1978) 225–261.

Copies of this issue may be obtained at the price given below. All orders should be sent directly to the Publisher. Orders must be accompanied by check.

Single issue price Dfl. 18.00, postage included.

B. Pontecorvo was on friendly terms with the whole Bilenky's family. Misha, Bilenky's son, made humorous sketches on the occasion of Pontecorvo's 75th birthday, which are now kept in Ponteorvo's office in LNP, JINR, Dubna.

B. Pontercorvo's office in LNP, JINR, Dubna.

B. Pontercorvo's office in LNP, JINR, Dubna.

B. Pontecorvo liked practical jokes. His most famous one was played in 1954 together with Migdal on Landau.

In the early spring of 1976 Pontecorvo played one on Bilenky.
"The discovery of the $W^{\pm}-$ bosons at CERN..."

Even during the period of collaboration with B. Pontecorvo, S.M. Bilenky made independent original and insightful contributions to the development of neutrino physics and continued to do so after the passing of B. Pontecorvo in 1993.

He was involved in studies devoted to all aspects of contemporary neutrino physics:
phenomenology of neutrino mixing and of neutrino oscillations,
neutrinoless double beta decay,
the problem of determination of neutrino mass ordering,
CP violation in neutrino oscillations,
tests of existence of sterile neutrinos at the eV scale,
the problem of determination of the absolute neutrino mass scale, etc.
Bilenky wrote also many review articles and lecture notes.

1980, Majorana Phases

S.M. Bilenky, J. Hosek, S.T.P., May 1980;

$\chi_k(x)$**-4 component (spin 1/2), Majorana, m**$_k \neq 0$**:**

C$(\bar{\chi}_k(x))^{\mathsf{T}}$ **=** $\xi_k \chi_k(x)$**,** $|\xi_k|^2$ **= 1.**

U(1): χ_k**(x)** $\rightarrow e^{i\beta}\chi_k$**(x)- impossible!**
$\chi_k(x)$ **cannot absorb phases.**

j$_\alpha^{(lep)}$ **=** $2\,\bar{l}(x)\,\gamma_\alpha\,U_{lk}\,\chi_{kL}(x)$**, U = VP; n families,**

V: (n-1)(n-2)/2 Dirac CPV phases;

P = diag$(1, e^{i\frac{\alpha_{21}}{2}}, e^{i\frac{\alpha_{31}}{2}}, ..., e^{i\frac{\alpha_{n1}}{2}})$ **- (n-1) Majorana CPV phases;**
n=3, V: 1 Dirac CPV phase; P: 2 Majorana CPV phases.
n=2, V: CP conserving; P: 1 Majorana CPV phase.

In the same article:

$\mathbf{j}_\alpha^{(lep)} = 2\,\bar{l}(x)\,\gamma_\alpha\,U_{lk}\,\chi_{kL}(x)$, $\mathbf{U} = \mathbf{VP}$

$\nu_l \leftrightarrow \nu_{l'}$, $\bar{\nu}_l \leftrightarrow \bar{\nu}_{l'}$, $l, l' = e, \mu, \tau$, not sensitive to the Majorana CPV phases and thus to the nature of ν_j.

$A(\nu_l \leftrightarrow \nu_{l'}) = \sum_j U_{l'j} e^{-i(E_j t - p_j x)} U^\dagger_{jl}$,

$\mathbf{U} = \mathbf{VP}$: $\mathbf{P}_j e^{-i(E_j t - p_j x)} \mathbf{P}^*_j = e^{-i(E_j t - p_j x)}$

P - diagonal matrix of Majorana phases.

The result is valid also in the case of oscillations in matter (P. Langacker *et al.*, Nucl. Phys. B282 (1987) 589).

$\nu_l \leftrightarrow \nu_{l'}$ oscillations are not sensitive to the nature of ν_j.

S.M. Bilenky had collaborators in many countries mostly, but not only, in Europe. An incomplete list includes:
W. Alberico, C. Giunti, A. Bottino, V. Wataghin, S. Pascoli, F. Capozzi, A. Masiero, M. Fabbrichesi (Italy);
J. Bernabeu, A. Santamaria, J. Grifols, E. Masso, F. Botella, J. Segura (Spain);
M. Lindner, W. Winter, W. Potzel, F. von Feilitzsch, A. Faessler, G. Motz (Germany);
W. Grimus, Th. Schwetz (Austria);
T. Ohlsson (Sweden);
M. Mateev, E. Christova (Khristova), N. Nedelcheva (Bulgaria);
F. Simkovic (Slovakia);
C.W. Kim (S. Korea), B. Kayser (USA);
K.M. Graczyk (Poland).

For his devotion to the studies of neutrinos, which he called "exceptional particle, the most interesting among the elementary particles", and – in view of the fact that neutrino properties suggest the existence of New Physics Beyond the Standard Model – "a Gift of Nature", his long term friend and renowned particle physicist Jose Bernabeu proposed once jokingly that Bilenky should be called "Mister Neutrino".

Teacher and Mentor

Bilenky was an excellent teacher, mentor and inspiration for many young researchers in the field of elementary particle and neutrino physics. His lectures on different topics of theoretical particle physics at Moscow University, where he taught for 30 years, and on neutrino physics at various International Schools were always characterized by remarkable clarity. This made him a sought after speaker and he was invited and gave lectures at Universities all across Europe (Turin, Milan, Vienna, Prague, Valencia, Barcelona, Sofia, SISSA and ICTP in Trieste, Helsinki, among others) and in Israel (Technion).

Visiting SISSA in 2013 (with D. Amati, R. Iengo, SISSA students and postdocs).

Attending the Neutrino Telescopes Workshop in the 1990s. S.M. Bilenky attended several of the Workshops organised by Milla and enjoyed them immensely.

During one of the visits to SISSA and Trieste.

Bilenky is the author of 5 monographs in Russian and English, which have undergone several editions, appreciated by both theorists and experimenters.
"Introduction to the Feynman Diagram Technique",
"Introduction to the Physics of Electroweak Interaction",
"Introduction to the Scattering Theory"
have long become table books for generations of physicists. His many years of experience and achievements in neutrino physics are presented in
"Lectures on the Physics of Neutrino and Lepton-Nucleon Processes" and
"Introduction to the Physics of Massive and Mixed Neutrinos".

These books also helped and continue to help many young scientists enter professionally into the fascinating fields of modern particle and neutrino physics.


С.М. Биленький
Введение в диаграммную технику Фейнмана
INTRODUCTION TO FEYNMAN DIAGRAMS
by
S. M. BILENKY
PERGAMON PRESS
С.М. БИЛЕНЬКИЙ
ЛЕКЦИИ ПО ФИЗИКЕ НЕЙТРИННЫХ И ЛЕПТОН-НУКЛОННЫХ ПРОЦЕССОВ
INTRODUCTION TO THE PHYSICS OF
ELECTROWEAK
INTERACTIONS
S M BILENKY
Joint Institute for Nuclear Physics, Dubna
Translated by G B PONTECORVO, Dubna
PERGAMON PRESS
С. М. Биленький
ВВЕДЕНИЕ В ТЕОРИЮ РАССЕЯНИЯ
С. М. Биленький
ВВЕДЕНИЕ В ДИАГРАММЫ ФЕЙНМАНА И ФИЗИКУ ЭЛЕКТРОСЛАБОГО ВЗАИМОДЕЙСТВИЯ
Samoil Bilenky
LECTURE NOTES IN PHYSICS 817
Introduction to the Physics of Massive and Mixed Neutrinos
Springer
ozon.ru

Bilenky started in 1998 and was a tireless organiser of the well known Pontecorvo Neutrino Physics School. The School had eight editions so far (the last was in 2019) and was one of the reference international schools on neutrino physics in Europe.


VI International Pontecorvo Neutrino Physics School
August 27 – September 4, 2015
Horný Smokovec, Slovakia
(http://theor.jinr.ru/~neutrino15/)
Organizing Committee:
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Lectures at School:
Neutrinos in SM and beyond: Samoil Bilenky (JINR Dubna)
Phenomenology of ν-mixing and oscillations: Serguey Petcov (SISSA)
Long baseline ν-oscillation experiments: David Wark (Oxford U.)
Reactor ν experiments: Rupert Leitner (Charles U.)
Atmospheric neutrinos: Yoichiro Suzuki (U. of Tokyo)
Solar- and geo-neutrinos: Oleg Smirnov (JINR Dubna)
Sterile neutrinos: Carlo Giunti (INFN Torino)
Vyacheslav Egorov (JINR Dubna)
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Baryogenesis from Leptogenesis: Sasha Davidson (IPNL Lyon)
Direct ν-mass search: Christian Weinheimer (U. of Muenster)
Theory of 0νbb-decay: Martin Hirsch (U. of Valencia)
Double Beta Decay Matrix Elements: Francesco Iachello (Yale U.)
0νββ-decay: EXO and KamLAND-Zen: Andreas Piepke (U. of Alabama)
0νββ-decay: GERDA: Stefan Schoenert (TU Muenchen)
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Baikal experiment: Zhan-Arys Dzhilkibaev (INR Moscow)
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Progressive detection techniques: Ettore Fiorini (U. di Milano-Bicocca)
Progressive detection techniques II: Ivan Štekl (CTU Prague)
Statistics for Nuclear and Particle Physics: Louis Lyons (U. of Oxford)

VIII International Pontecorvo
Neutrino Physics School
September 1 – September 10, 2019
Sinaia, Romania
http://theor.jinr.ru/~neutrino19/
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ν -oscillation phenomenology Boris Kayser (Fermilab)
ν -oscillations experiments:
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Atmospheric ν –experiments Juan Pablo Yanez (Univ. of Alberta)
Accelerator ν –experiments Maury Goodman (Argonne National Lab)
Reactor ν-experiments- Dmitry Naumov (JINR Dubna)
Spectra of ν's from reactor Anna Hayes (Los Alamos National Lab)
Light sterile neutrinos
theory - Carlo Giunti (INFN)
experiments - Yuri Shitov (JINR Dubna)
Heavy sterile neutrinos Dmitry Gorbunov (INR RAS Moscow)
Measurement of ν-mass Kathrin Valerius (KIT in Karlsruhe)
0νββ–decay experiments Andrea Giuliani (CSNSM in Paris)
0νββ–decay NMEs Javier Menendez (Univ. of Tokyo)
Coherent scattering of ν's Henry Wong (Academia Sinica, Taipei)
ν – nucleus interactions Jan Sobczyk (Univ. of Wroclaw)
Leptogenesis Pascuale DiBari (Univ. of Southampton
ν-telescopes Nathan Whitehorn (Univ. of California)
ν-properties from cosmology Richard Battye (Univ. of Manchester)
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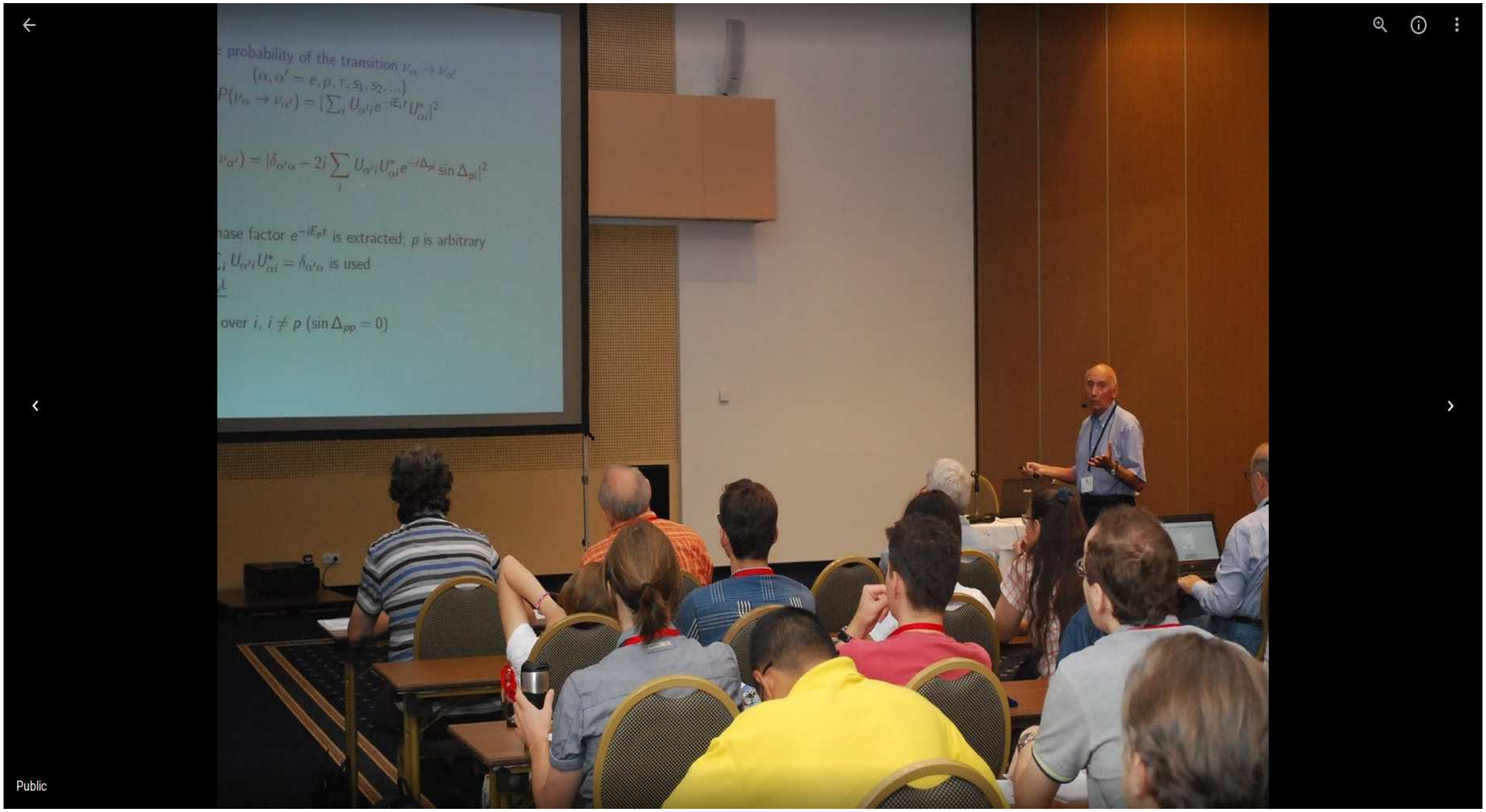
Physics of gravitational waves Imre Bartos (Univ. of Florida)
Everything about Higgs boson Guenakh Mitselmakher* (Univ. of Florida)
Statistics for ν-experiments Thomas Schwetz (KIT in Karlsruhe)



Lecturing at the Pontecorvo Neutrino Physics School in 2015 held in Slovakia.

For his research and teaching activities Bilenky received many recognitions: the Russian state medal "For distinguished service to the State", the International Bruno Pontecorvo Prize, the Humboldt Prize, the Medal of First Degree of the Faculty of Physics and Mathematics of Charles University in Prague, and other prizes.

Вручение премии им. Б. Понтекорво 2002 года
проф. С.М. Биленькому
Директор ЛЯП проф. Н.А. Русакович и
Директор ОИЯИ акад. В.Г. Кадышевский,
2003 г.

Receiving of B. Pontecorvo's Diploma for 2002
by Prof. S.M. Bilenky
LNP Director Prof. N.A. Russakovich and
JINR Director Acad. V.G. Kadyshevsky
2003, JINR

I was lucky to be a student of Samoil Mihelevich at the Joint Institute of Nuclear Research (JINR) in Dubna in the 1970'ies when JINR was one of the leading world centers for studies in the field of elementary particle physics, and later to continue to collaborate with him. This collaborations was highly fruitful and valuable for me. We have co-authored altogether 22 articles. Our last joint article (with F. Capozzi) was published in 2017 and updated in June of 2020.

"Massive Neutrinos and Neutrino Oscillations", Samoil M. Bilenky, S.T. Petcov. Jul 1987. 84 pp. Published in Rev. Mod. Phys. 59 (1987) 671.

"On Oscillations of Neutrinos with Dirac and Majorana Masses", S.M. Bilenky, J. Hosek, S.T. Petcov (Dubna, JINR). May 1980. Phys. Lett. 94B (1980) 495.

"Lepton Mixing, $\mu \to e + \gamma$ Decay and Neutrino Oscillations", Samoil M. Bilenky, S.T. Petcov, B. Pontecorvo (Dubna, JINR), Jan. 1977, Phys. Lett. 67B (1977) 309.

"Majorana neutrinos, neutrino mass spectrum, CP violation and neutrinoless double beta decay. 1. "The Three neutrino mixing case", Samoil M. Bilenky (Dubna, JINR and SISSA, Trieste), S. Pascoli, S.T. Petcov (SISSA/INFN, Trieste). Feb 2001. 51 pp. Phys. Rev. D64 (2001) 053010.

"An alternative method of determining the neutrino mass ordering in reactor neutrino experiments", S.M. Bilenky (Dubna, JINR and TRIUMF), F. Capozzi (INFN, Padua), S.T. Petcov (SISSA/INFN, Trieste Tokyo U., IPMU), Phys.Lett. B772 (2017) 179, Erratum: Phys.Lett. B809 (2020) 135765.

Bilenky attracted people with his kind and obliging character and had collaborators, students and friends in many countries. His human warmth and benevolent personality embodied the best humanistic and cultural traditions of the Russian Intelligentsia to which Samoil Mihelevich Bilenky belonged.

Bilenky loved his "job"– his research and teaching activities. His great interest in physics, the search for new ideas in science, did not diminish throughout his prolific life. He was constantly thinking and working on problems in neutrino physics, and more generally, in particle physics.

Bilenky's words are - for a theoretician there is no retirement. Of his more than 250 articles, about 40 have been published in recent years. And only a three weeks before he passed, he published a review on "Basics of the General Theory of Relativity for Beginners" – an area completely new to him.

Basics of General Theory of Relativity for Beginners

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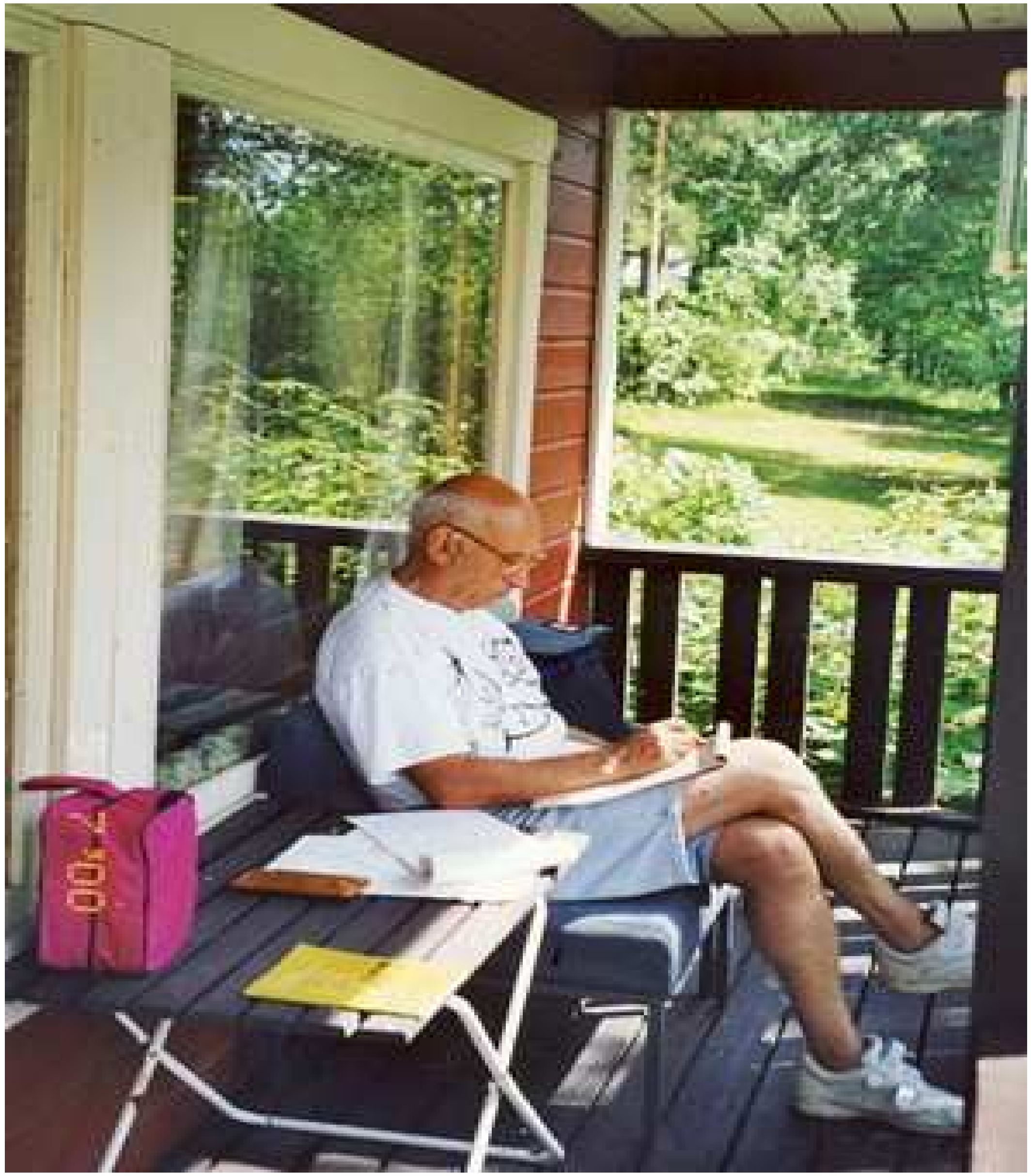
Abstract

We present a basics of the Einstein General Theory of Relativity. In the first part of this review we derive relations of Riemann geometry which are used in the General Relativity. In the second part we discuss Einstein Equations and some of its consequences (The Schwarzschild solution, gravitational waves, Friedman Equations etc). In the Appendix we briefly discuss a history of the discovery of the Einstein Equations.

1 Introduction

General Theory of Relativity is a great theory, confirmed by all existing data (see, for example, "Experimental Tests of Gravitational Theory" by T. Damour in PDG [1]) It is based on the requirement of invariance under the general transformations of coordinates in a curved Riemann space. The General Theory of Relativity, apparently, support a suggestion[1] that in a correct theory the simplest possibilities are realized. Recent discovery of the predicted by GTO gravitational waves opened a new and very powerful way of the investigation of the Universe. In the book "Classical Theory of Fields" L.D. Landau and E.M. Lifshitz wrote : "The General Theory of Relativity which was created by Einstein (and finally formulated by him in 1916) is, apparently, the most beautiful of all existing physical theories. It is remarkable that it was built by Einstein in a purely deductive way and only later was confirmed by astronomical observations" In this review I tried to present the basics of the General Theory of Relativity and some of its consequences in such a way that all derivations can be easily followed by a reader.

[1]"Simplicity is a guide to the theory choice" A. Einstein.



At a summer house near Helsinki, Finland, 2000.