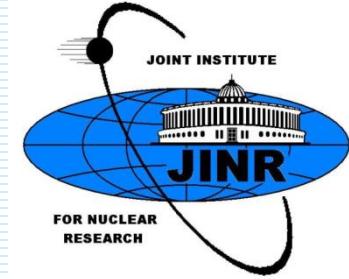




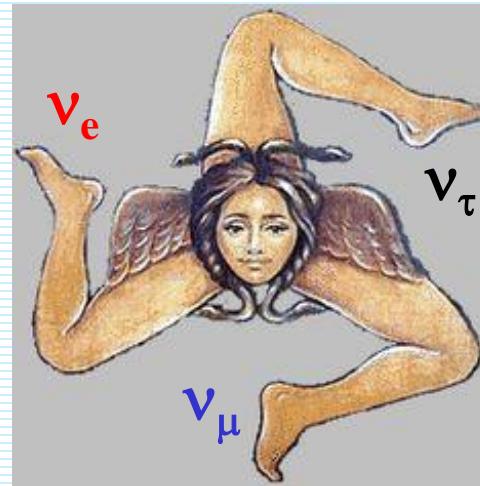
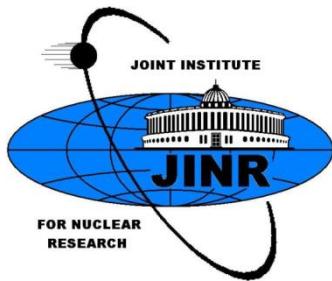
Institute of Physics
Slovak Academy of Sciences
Bratislava, 18.05. 2018



RECFA meeting for Slovakia

„*Neutrino physics in Slovakia: Advances and Challenges*“

Fedor Šimkovic
Comenius University and JINR Dubna





Content

1. Neutrino physics nowadays
2. Slovak neutrino physics groups
3. Theoretical neutrino physics research in Slovakia
4. Slovak participation in NEMO-SuperNEMO experiments
5. Slovak participation in Baikal GVD experiment
6. Slovak participation in JUNO experiment
7. Organization of Pontecorvo summer schools
8. Funding of neutrino physics in Slovakia
9. Conclusions and Outlook

1. Neutrino physics nowadays



Importance of Neutrino physics nowadays

INSPIRE: find title x and date y

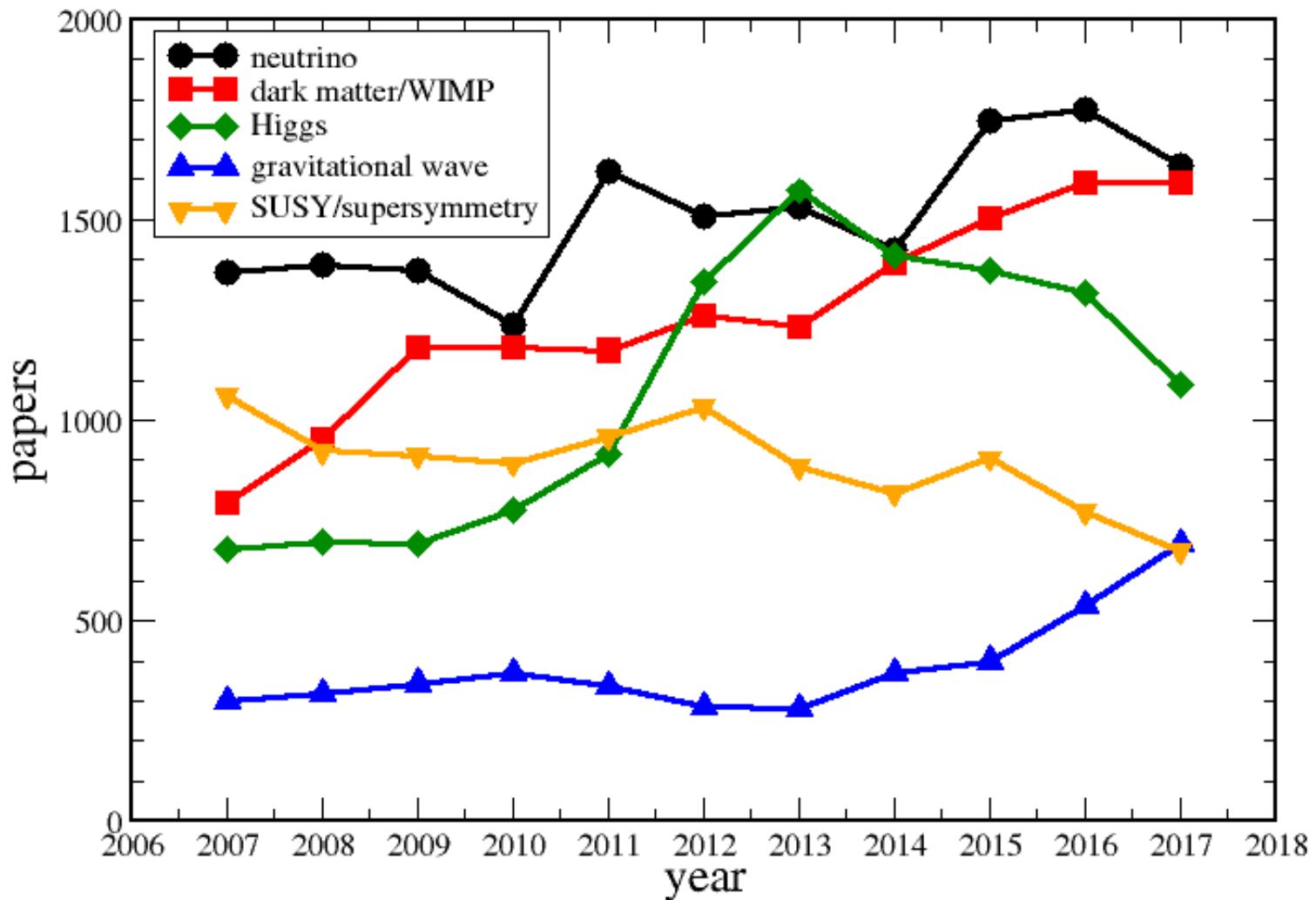
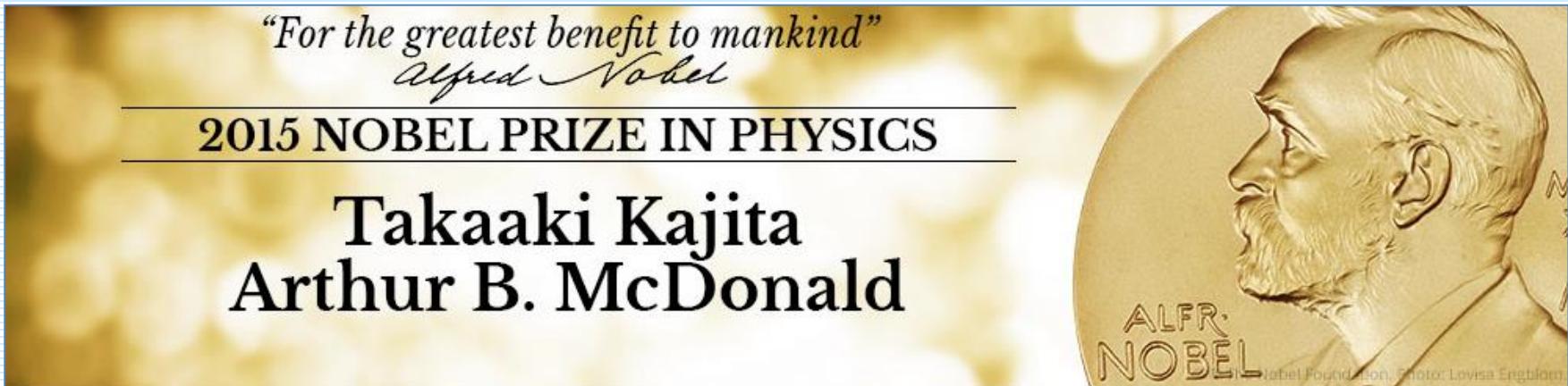


Figure of Werner Rodejohan presented at Trento workshop in March, 2018

Stockholm, October 6, 2015



2015 Physics Laureates: Takaaki Kajita, photo © Takaaki Kajita and Arthur B. McDonald, photo K. MacFarlane. Queen's Univ/SNOLAB

2015 Nobel Prize in Physics

The Nobel Prize in Physics 2015 was awarded jointly to [Takaaki Kajita](#) and [Arthur B. McDonald](#) "for the discovery of neutrino oscillations, which shows that neutrinos have mass".



Illustration: © Johan Jernestad/The Royal Swedish Academy of Sciences

They Solved the Neutrino Puzzle

Takaaki Kajita and Arthur B. McDonald solved the neutrino puzzle and opened a new realm in particle physics. They were key scientists of two large research groups, Super-Kamiokande and Sudbury Neutrino Observatory, which discovered the neutrinos mid-flight metamorphosis.

A screenshot of a video player interface. At the top, there is a play button, the text "The Nobel Prize", and a subtitle "I gave my wife ...". Below the video frame is a waveform and the duration "4:20". At the bottom, there is a "Cookie policy" link and a counter showing "1,578".

"I Gave My Wife a Hug!"

"It's ironic, in order to observe the sun you have to go kilometers under ground. That's not what you would expect." An interview with Arthur B. McDonald, awarded the 2015 Nobel Prize in Physics.

[→ Transcript of the interview](#)

The Nobel Prize in Physics 1988

Leon M. Lederman, Melvin Schwartz and Jack Steinberger

"for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino"

ν_μ



v v v v v v

The Nobel Prize in Physics 1995
"for pioneering experimental contributions to lepton physics"
Martin L. Perl
"for the discovery of the tau lepton"
Frederick Reines
"for the detection of the neutrino"

v_e

1

Raymond Davis Jr. and Masatoshi Koshiba
**"for pioneering contributions to astrophysics, in particular for the detection
of cosmic neutrinos"**

$$\nu_e, \nu_\mu$$

The Nobel Prize in Physics 2015

Takaaki Kajita and Arthur B. McDonald

$$\theta_{12}, \theta_{23}$$

"for the discovery of neutrino oscillations, which shows that neutrinos have mass"

After 59 years
we know

- 3 families of light (V-A) neutrinos:
 ν_e, ν_μ, ν_τ
- ν are massive:
we know mass squared differences
- relation between flavor states and mass states (neutrino mixing)

Atomic nucleus is a laboratory to study Fundamental properties of neutrinos

No answer yet



Currently main issue

Nature, Mass hierarchy, CP-properties, sterile ν

The observation of neutrino oscillations has opened a new excited era in neutrino physics and represents a big step forward in our knowledge of neutrino properties

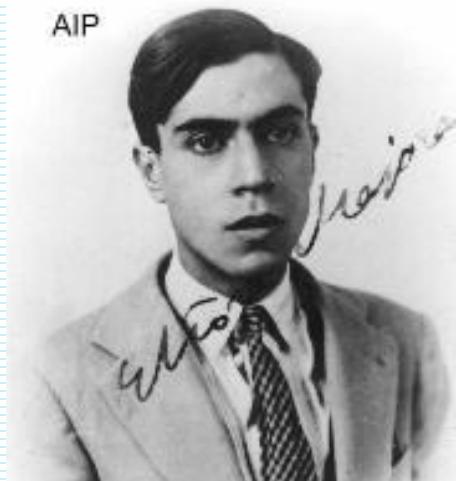
- Are ν Dirac or Majorana?
- Is there a CP violation in ν sector?
- Are neutrinos stable?
- What is the magnetic moment of ν?
- Sterile neutrinos?
- Statistical properties of ν? Fermionic or partly bosonic?

The answer to the question whether neutrinos are their own antiparticles is of central importance, not only to our understanding of neutrinos, but also to our understanding of the origin of mass.

What is the nature of neutrinos?



$$\nu \Rightarrow \text{GUT's}$$



Symmetric Theory of Electron and Positron
Nuovo Cim. 14 (1937) 171

Only the $0\nu\beta\beta$ -decay can answer this fundamental question

Analogy with
kaons: K_0 and \bar{K}_0

Fedor Simkovic

Analogy with
 π_0

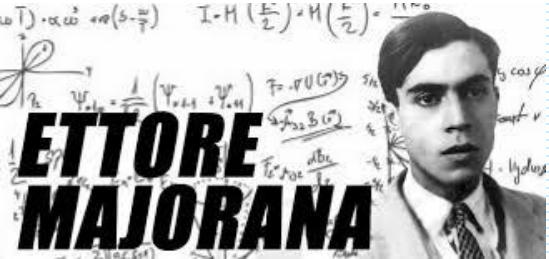
Majorana fermion



https://en.wikipedia.org/wiki/File:Ettore_Majorana.jpg

Celebrating 80 *years*

1937 - 2017



Fedor Si

TEORIA SIMMETRICA DELL'ELETTRONE E DEL POSITRONE

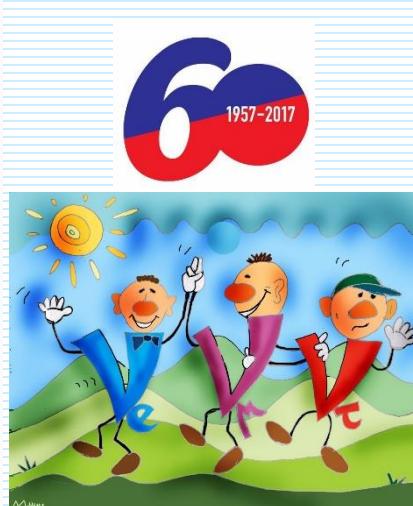
Nota di ETTORE MAJORANA

Symmetric Theory of Electron and Positron Nuovo Cim. 14 (1937) 171

Sunto. - Si dimostra la possibilità di pervenire a una piena simmetrizzazione formale della teoria quantistica dell'elettrone e del positrone facendo uso di un nuovo processo di quantizzazione. Il significato delle equazioni di DIRAC ne risulta alquanto modificato e non vi è più luogo a parlare di stati di energia negativa; né a presumere per ogni altro tipo di particelle, particolarmente neutre, l'esistenza di « antiparticelle » corrispondenti ai « vuoti » di energia negativa.

Per quanto riguarda gli elettroni e i positroni, da essa si può veramente attendere soltanto un progresso formale; ma ci sembra importante, per le possibili estensioni analogiche, che venga a cadere la nozione stessa di stato di energia negativa. Vedremo infatti che è perfettamente possibile costruire, nella maniera più naturale, una teoria delle particelle neutre elementari senza stati negativi.

(¹) P. A. M. DIRAC, « Proc. Camb. Phil. Soc. », **30**, 150, 1924. V. anche W. HEISENBERG, « ZS. f. Phys. », **90**, 209, 1934.



MESONIUM AND ANTIMESONIUM

B. PONTECORVO

Joint Institute for Nuclear Research

Submitted to JETP editor May 23, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) 33, 549-551 (August, 1957)

INVERSE BETA PROCESSES AND NONCONSERVATION OF LEPTON CHARGE

B. PONTECORVO

Joint Institute for Nuclear Research

Submitted to JETP editor October 19, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) 34, 247-249
(January, 1958)



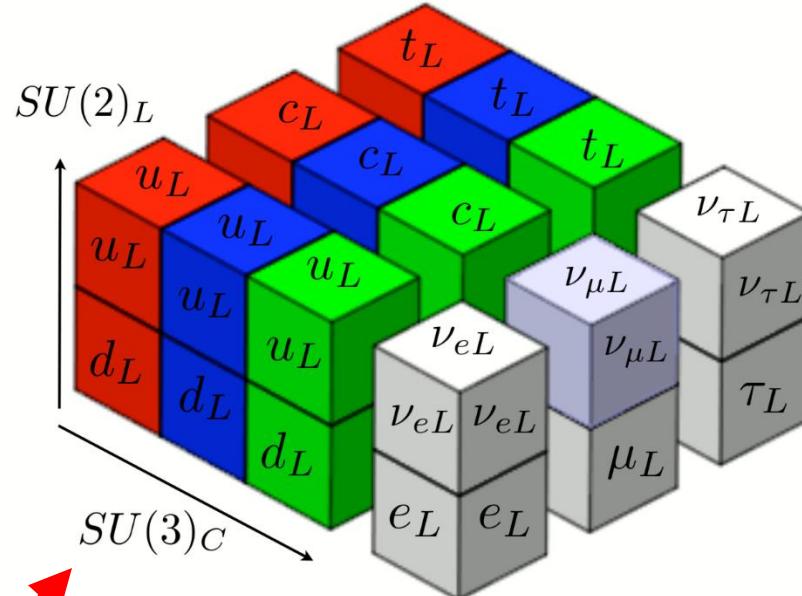
I ragazzi di via Panisperna



It follows from the above assumptions that in vacuum a neutrino can be transformed into an antineutrino and vice versa. This means that the neutrino and antineutrino are “mixed” particles, i.e., a symmetric and antisymmetric combination of two truly neutral Majorana particles ν_1 and ν_2 of different combined parity.⁵

**1968 Gribov, Pontecorvo [PLB 28(1969) 493]
oscillations of neutrinos - a solution
of deficit of solar neutrinos in Homestake exp.**

Beyond the Standard model physics (EFT scenario)



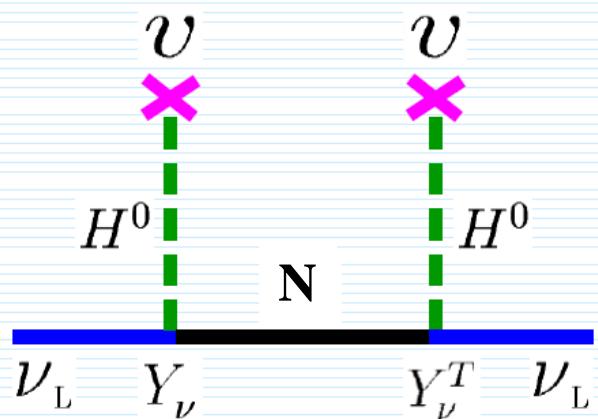
$$\mathcal{L} = \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda} \sum_i c_i^{(5)} \mathcal{O}_i^{(5)} + \frac{1}{\Lambda^2} \sum_i c_i^{(6)} \mathcal{O}_i^{(6)} + O(\frac{1}{\Lambda^3})$$

The absence of the right-handed neutrino fields in the Standard Model is the simplest, most economical possibility. In such a scenario Majorana mass term is the only possibility for neutrinos to be massive and mixed. This mass term is generated by the lepton number violating Weinberg effective Lagrangian.

$$\mathcal{L}_5^{eff} = -\frac{1}{\Lambda} \sum_{l_1 l_2} \left(\bar{\Psi}_{l_1 L}^{lep} \tilde{\Phi} \right) \dot{Y}_{l_1 l_2} \left(\tilde{\Phi}^T (\Psi_{l_2 L}^{lep})^c \right)$$

$$m_i = \frac{v}{\Lambda} (y_i v), \quad i = 1, 2, 3 \quad \Lambda \geq 10^{15} \text{ GeV}$$

Heavy Majorana leptons N_i ($N_i = N_i^c$)
singlet of $SU(2)_L \times U(1)_Y$ group
Yukawa lepton number violating int.



The three Majorana neutrino masses are suppressed by the ratio of the electroweak scale and a scale of a lepton-number violating physics.

The discovery of the $\beta\beta$ -decay and absence of transitions of flavor neutrinos into sterile states would be evidence in favor of this minimal scenario.

2. Slovak neutrino physics groups



Slovak neutrino physics groups and physicists



F. Šimkovic
R. Dvornický
D. Štefánik
P. Maták
L. Fajt
M. Macko

Theory

JUNO

NEMO

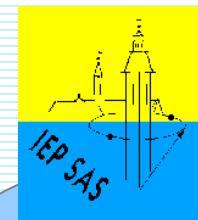
Baikal
GVD

T. Blažek
P. Maták
V. Černý ...

NA62

P. Povinec
R. Breier

NEMO



B. Pastirčák

Baikal
GVD



Striebornú medailu Univerzity Komenského v Bratislave

Špičkovému vedeckému tímu Fakulty matematiky, fyziky a informatiky

„Fyzika hmotných neutrín, podzemných laboratórií
a štruktúra jadra“

Autec

Bratislava, 22. september 2013

**Team from the Comenius U.
„Physics of Massive Neutrinos,
Underground Labs. and
Nuclear Structure“**

**have received a recognition
„Excellent scientific team“
(the only team from the field of
particle and nuclear physics
at Slovak universities)**

**Evaluated for the years
2008-2013**

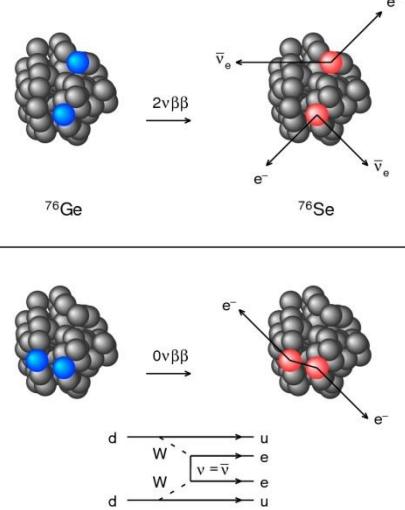


3. Theoretical neutrino physics research in Slovakia

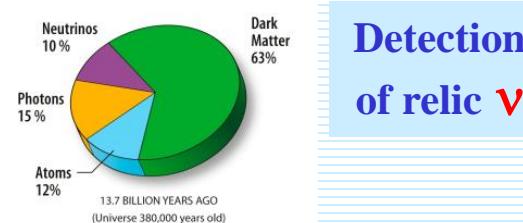
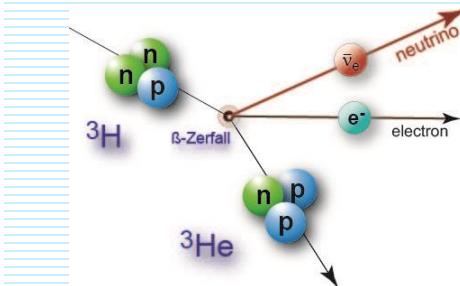


Fundamental properties of ν

Atomic nucleus – a laboratory to study fundamental Symmetries, interactions and properties of ν (theory)



Measuring mass of neutrinos



Nature of ν

Scattering of low energy ν

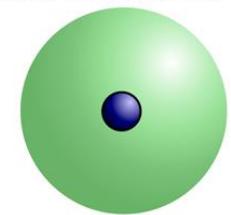


Cooling of white dwarfs

two-particle system

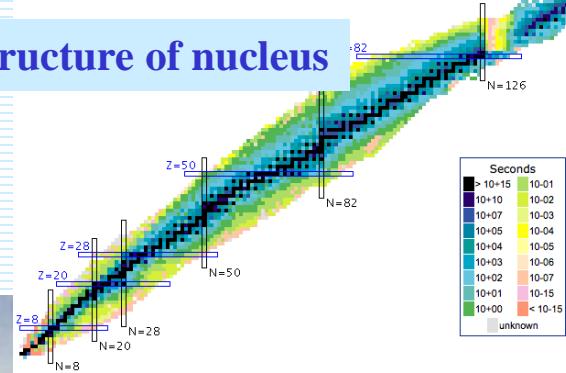
few-particle system

many-particle system



Development of new Many-body methods

Structure of nucleus



Structure of Neutron stars

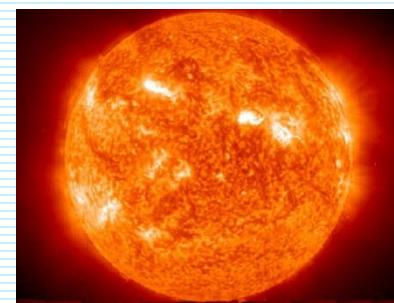
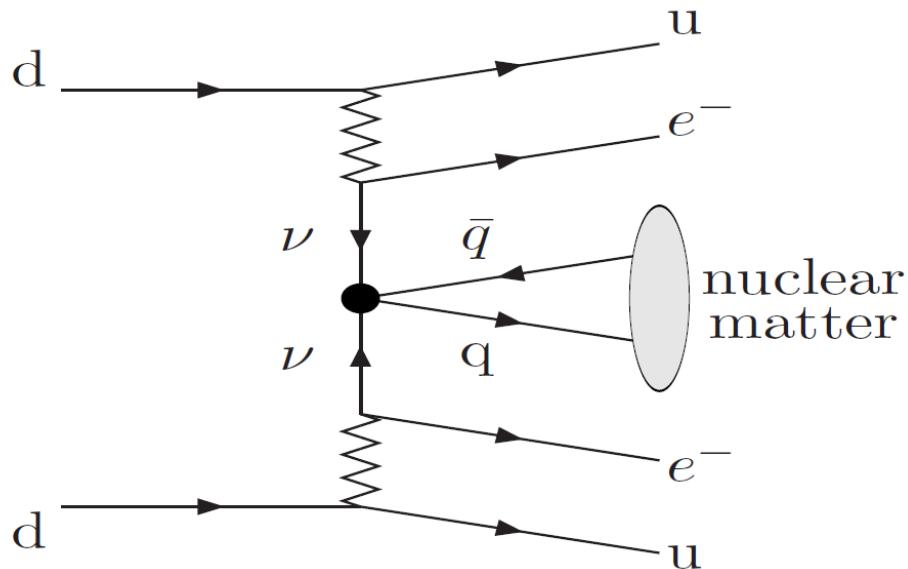


Nuclear medium effect on the light neutrino mass exchange mechanism of the $0\nu\beta\beta$ -decay

S.G. Kovalenko, M.I. Krivoruchenko, F. Š., Phys. Rev. Lett. 112 (2014) 142503

A novel effect in $0\nu\beta\beta$ decay related with the fact, that its underlying mechanisms take place in the nuclear matter environment:

- + Low energy 4-fermion $\Delta L \neq 0$ Lagrangian
- + In-medium Majorana mass of neutrino
- + $0\nu\beta\beta$ constraints on the universal scalar couplings

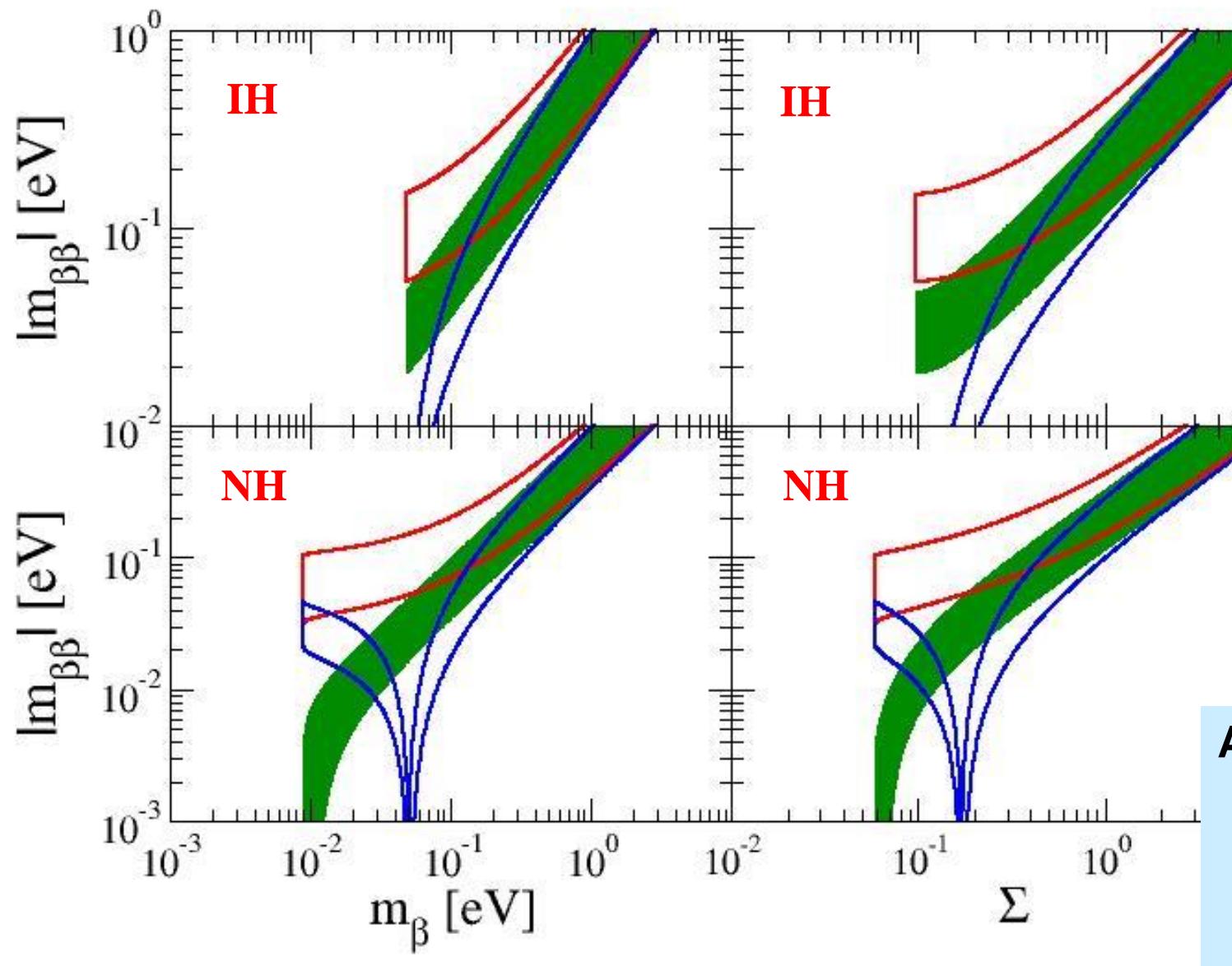


Non-standard
 ν -int. discussed
e.g., in the context
of ν -osc. at Sun

$\rho_{\text{Sun}} = 1.4 \text{ g/cm}^3$
 $\rho_{\text{Earth}} = 5.5 \text{ g/cm}^3$
 $\rho_{\text{nucleus}} = 2.3 \cdot 10^{14} \text{ g/cm}^3$

Complementarity between β -decay, $0\nu\beta\beta$ -decay and cosmological measurements might be spoiled

$$m_{\beta\beta} = \sum_{i=1}^n U_{ei}^2 \xi_i \frac{\sqrt{(m_i + \langle \chi \rangle g_1)^2 + (\langle \chi \rangle g_2)^2}}{(1 - \langle \chi \rangle g_4)^2}.$$



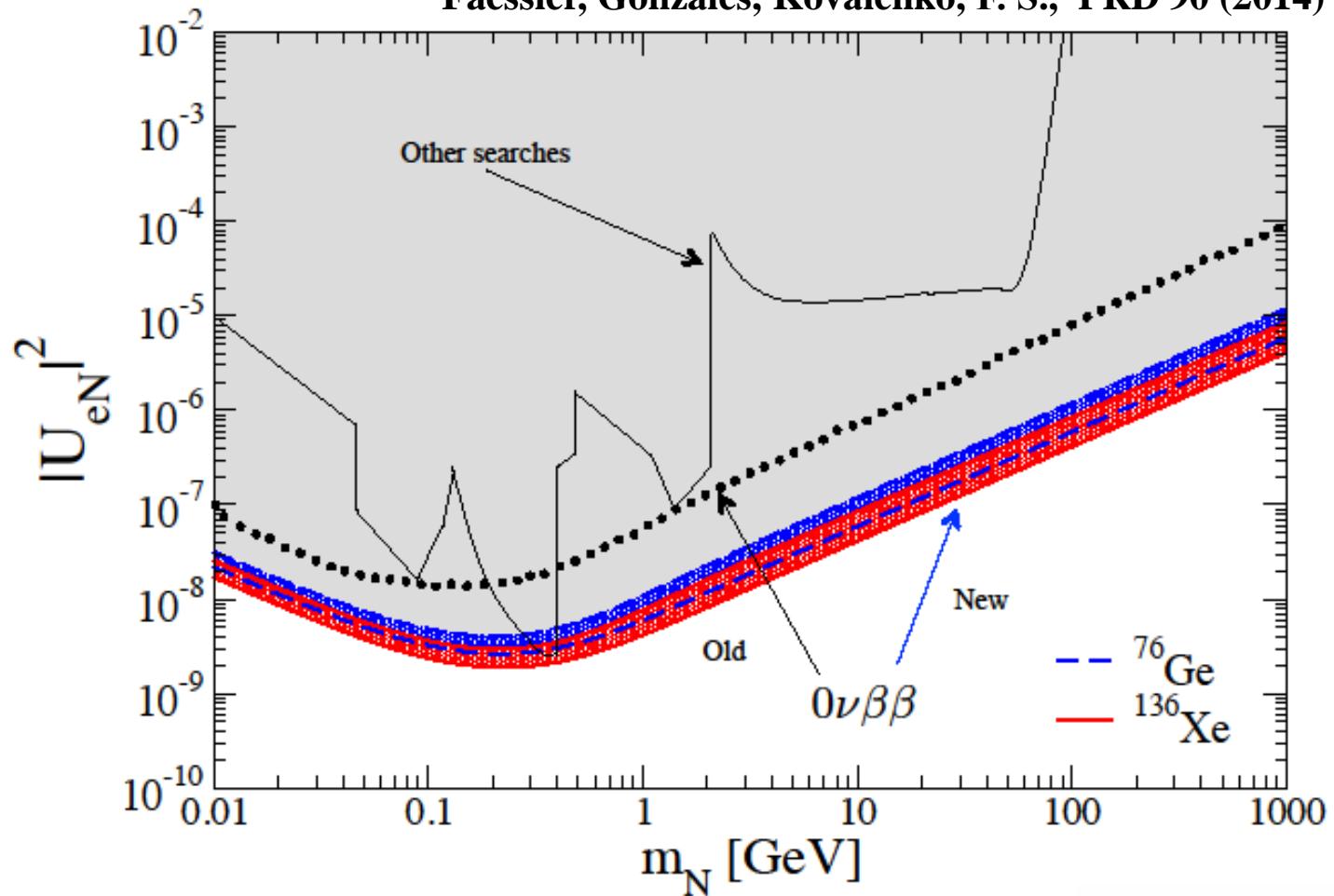
$$\cdot \frac{g_\chi g_{ij}^a}{m_\chi^2} = \frac{G_F}{\sqrt{2}} \varepsilon_{ij}^a$$

Exclusion plot in $|U_{eN}|^2 - m_N$ plane

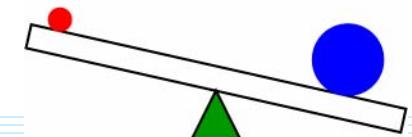
$$T^{0\nu}_{1/2}(^{76}\text{Ge}) \geq 3.0 \cdot 10^{25} \text{ yr}$$

$$T^{0\nu}_{1/2}(^{136}\text{Xe}) \geq 3.4 \cdot 10^{25} \text{ yr}$$

Faessler, Gonzales, Kovalenko, F. Š., PRD 90 (2014) 096010]



$$N = \sum_{\alpha=s,e,\mu,\tau} U_{N\alpha} \nu_\alpha$$

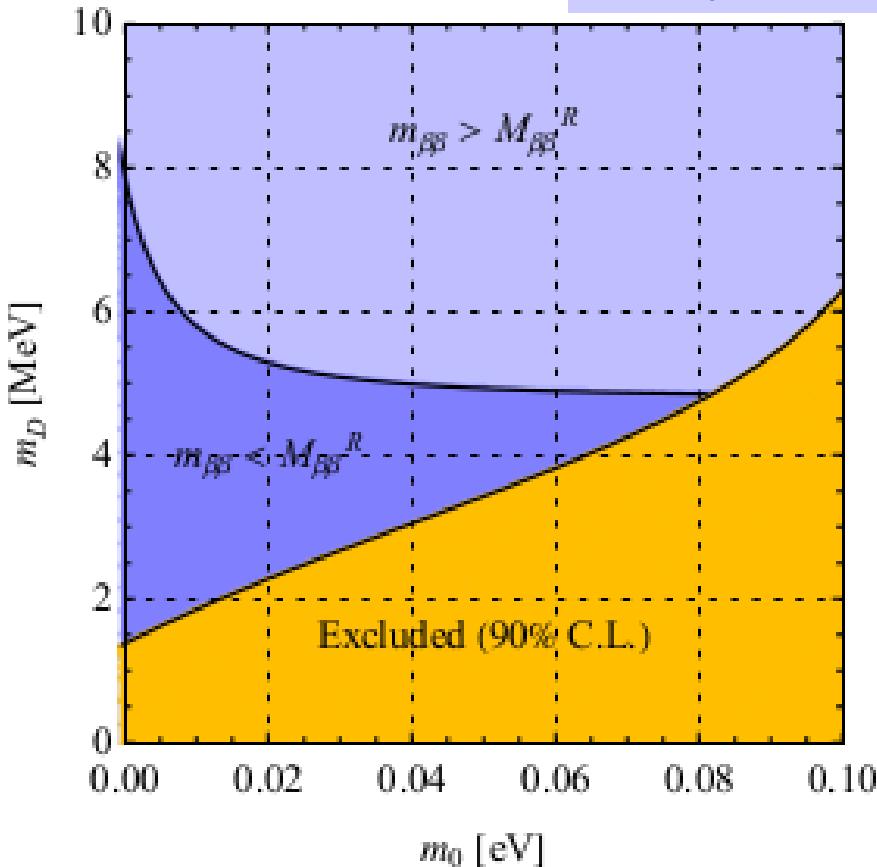


Left-right symmetric model - see-saw scenario

$$\eta_{\nu N}^2 = \frac{1}{m_e^2} \left(m_{\beta\beta}^2 + (M_{\beta\beta}^R)^2 \right)$$

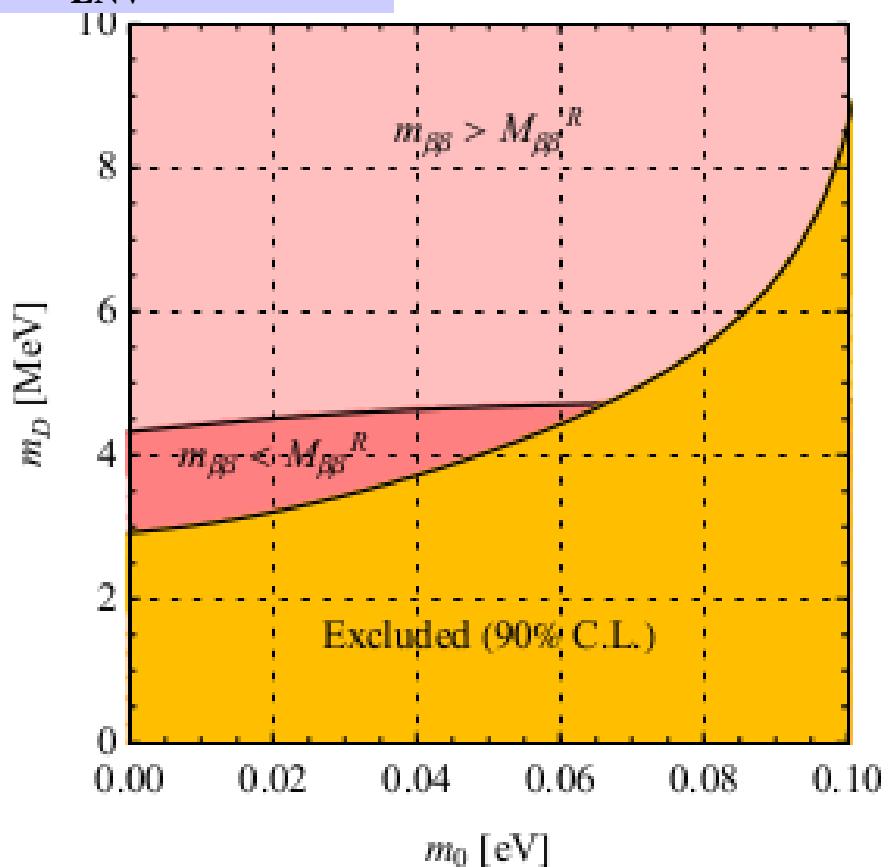
- Interpolating formula
- 6x6 PMNS ν -mixing matrix

Normal spectrum



Light ν mass $\approx (m_D/m_{\text{LNV}}) m_D$
 Heavy ν mass $\approx m_{\text{LNV}}$

Inverted spectrum



Theory of neutrinoless double-beta decay

J D Vergados^{1,2}, H Ejiri^{3,4} and F Šimkovic^{5,6}

¹ Theoretical Physics Division, University of Ioannina, GR-451 10, Ioannina, Greece

² CERN, Theory Division, Geneva, Switzerland

³ RCNP, Osaka University, Osaka, 567-0047, Japan

⁴ Nuclear Science, Czech Technical University, Brehova, Prague, Czech Republic

⁵ Laboratory of Theoretical Physics, JINR, 141980 Dubna, Moscow region, Russia

⁶ Department of Nuclear Physics and Biophysics, Comenius University, Mlynská dolina F1, SK-842 15 Bratislava, Slovakia

E-mail: vergados@uoi.gr, ejiri@rcnp.osaka-u.ac.jp and Fedor.Simkovic@fmph.uniba.sk

**Theory of neutrinoless double-beta decay
(Review article)**

J.D. Vergados, H. Ejiri, F. Šimkovic,

Rep. Prog. Phys. 75 (2012) 106310 (52pp)

291 SCI citations (WoS)

282 citations (HEP-spires)

**Neutrinoless double beta decay and neutrino mass
(Review article)**

J.D. Vergados, H. Ejiri, F. Šimkovic,

Int. J. Mod. Phys. E25 (2016) no.11, 1630007.

162 SCI citations (WoS)

44 citations (HEP-spires)

Fedor

**Review articles on
Double Beta Decay**

Review

International Journal of Modern Physics E
Vol. 25, No. 11 (2016) 1630007 (59 pages)
© World Scientific Publishing Company
DOI: 10.1142/S0218301316300071



Neutrinoless double beta decay and neutrino mass

J. D. Vergados*

*ARC Centre of Excellence in Particle Physics (CoEPP),
Department of Physics, University of Adelaide,
Adelaide SA 5005, Australia*

*Center for Axion and Precision Physics (CAPP),
IBS, KAIST University, Daejeon 305-701, South Korea*

*Board of Trustees, Technical Educational Institute,
Kozani, Greece*

*vergados@uoi.gr

H. Ejiri

*RCNP, Osaka University, Osaka 567-0047, Japan
Nuclear Science, Czech Technical University,
Brehova, Prague, Czech Republic*

F. Šimkovic

*Laboratory of Theoretical Physics, JINR,
Dubna 141980, Moscow region, Russia*

Measuring ν -mass with electron-capture of ^{163}Ho - ECHO exp.

$$\frac{d\Gamma}{dE_c} \propto (Q - E_c) \sqrt{(Q - E_c)^2 - m_\nu^2}$$

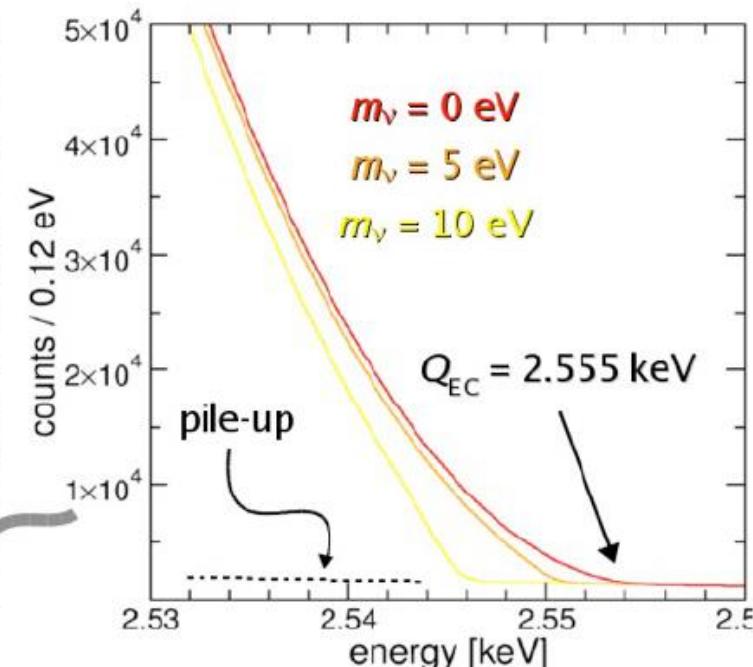
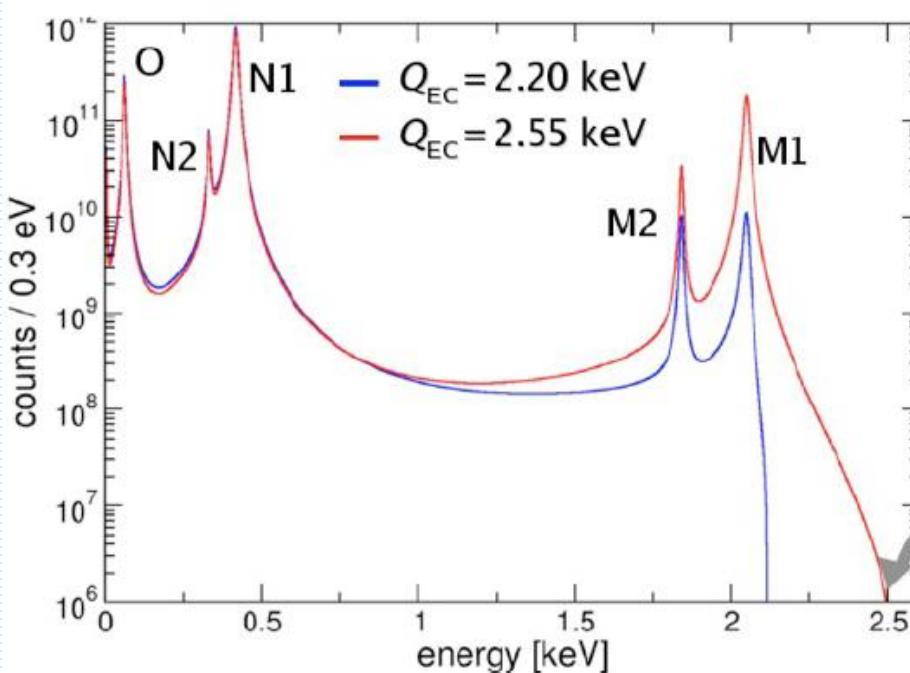
$$* \sum_H \varphi_H^2(0) B_H \frac{\Gamma_H}{2\pi} \frac{1}{(E_c - E_H)^2 + \Gamma_H^2/4}$$

$$\implies \mathcal{K} (Q - E_c) \sqrt{(Q - E_c)^2 - m_\nu^2},$$

From ν phase space

Not much progress in theory for a long period

$$E_c = Q - m_\nu$$

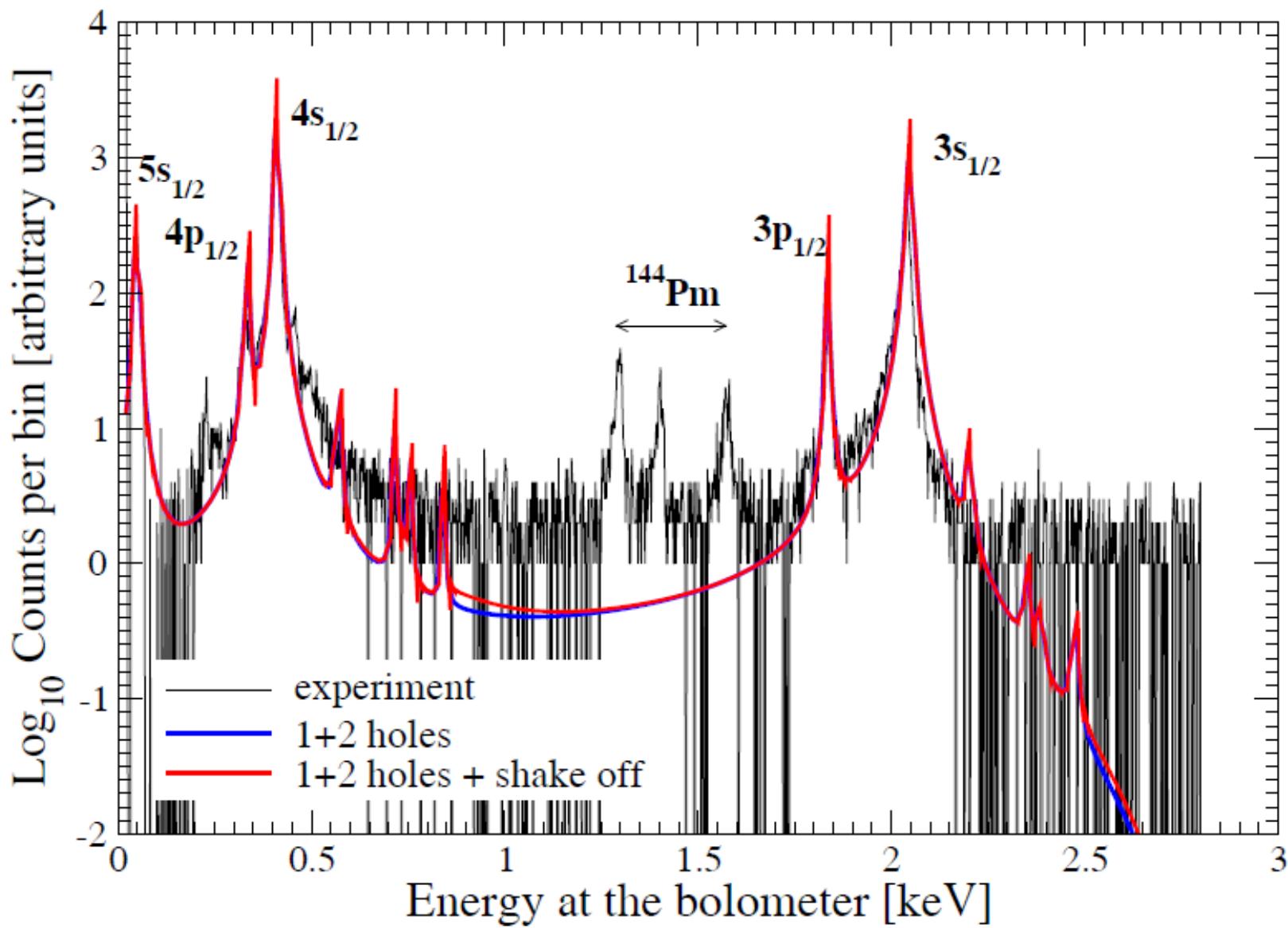


$$2 \text{ keV}/\Gamma_M = 2 \text{ keV}/13 \text{ eV} \approx 100$$

1+2 holes and shake-off effect

A. Faessler, Ch. Enss, L. Gastaldo, F.Š., PRC 91, 064302 (2015) (two and 3 holes)

A. Faessler, L. Gastaldo, F.Š., PRC 95, 045502 (2017) (shake off)



Ocenenie Najlepšia publikácia by publisher „Nauka“ for the year 2012

Российская академия наук



Pleadies Publishing, Inc

ДИПЛОМ

№ 140

лауреата Премии за 2012 год
«Международной академической издательской компании
«Наука/Интерпериодика» за лучшую публикацию
в издаваемых ею журналах

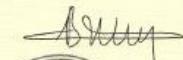
Премии учреждены «Международной академической
издательской компанией «Наука/Интерпериодика»
14 марта 1995 года

Решением Комиссии по присуждению Премий
от 19 ноября 2013 года, Протокол заседания № 2

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«Наука/Интерпериодика»
за лучшую публикацию в издаваемых ею журналах

Президент
Российской академии наук
Академик



Фортов В.Е.

Президент компании
«Плеадес Паблишинг, Инк.»
Доктор, права магистр экономики управления



г. Москва

Scientific awards

The first prize for theoretical physics for the year 2012

ON FEBRUARY 17, 2012, THE SCIENTIFIC COUNCIL
OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH
AWARDED

THE FIRST PRIZE
OF THE JOINT INSTITUTE
FOR NUCLEAR RESEARCH

to

Fedor ŠIMKOVIC

FOR THE WORK
«NEUTRINOLESS DOUBLE-BETA
DECAY AND DOUBLE-ELECTRON CAPTURE»

Chairman of the Scientific Council
of the Joint Institute
for Nuclear Research,
Director

Vice-Director

Vice-Director

Dubna
February 17, 2012
No. 3691



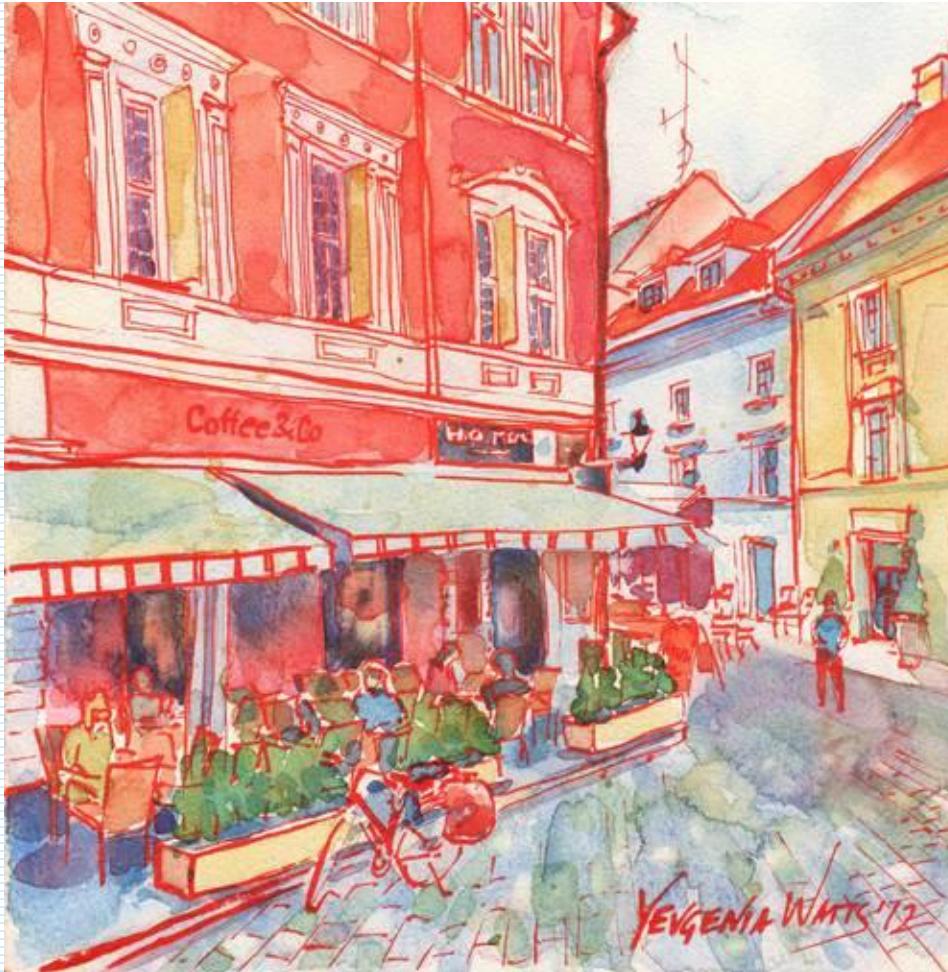
V. A. Matveev

M. G. Itkis

R. Lednický

Fedor Šimkovič

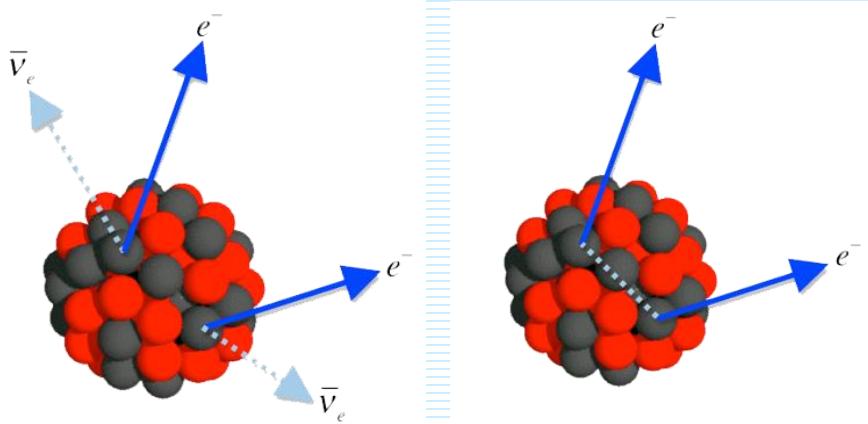
4. Slovak participation in NEMO3/SuperNEMO experiments



$2\nu\beta\beta$
observed

$0\nu\beta\beta$
ohranič.

NEMO3 a SuperNEMO experiments



F. Šimkovic,
M. Macko,
R. Dvornický
D. Štefánik

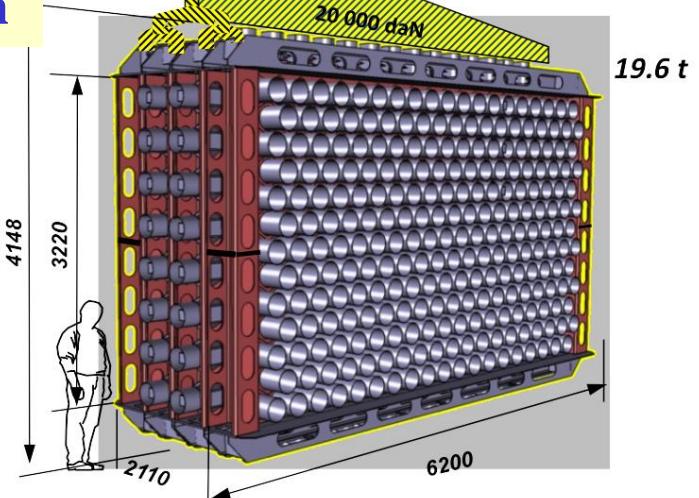
P. Povinec,
R. Breier

Physical program software, construction



ν

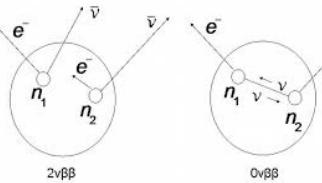
Fedor Šimkovic



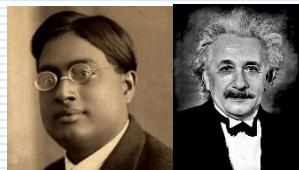
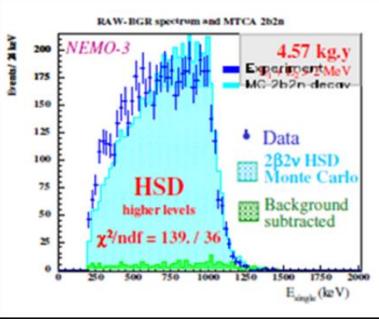
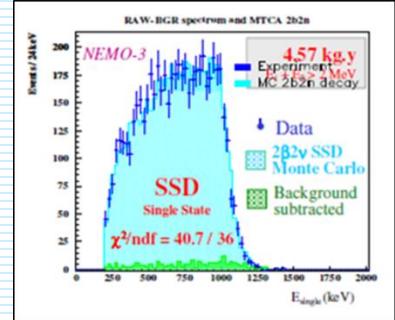


$2\nu\beta\beta$
observed

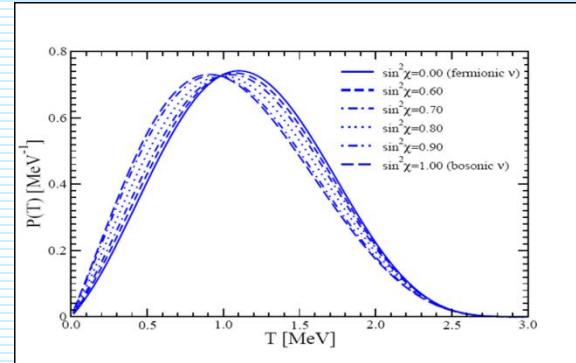
$0\nu\beta\beta$
ohranič.



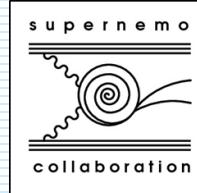
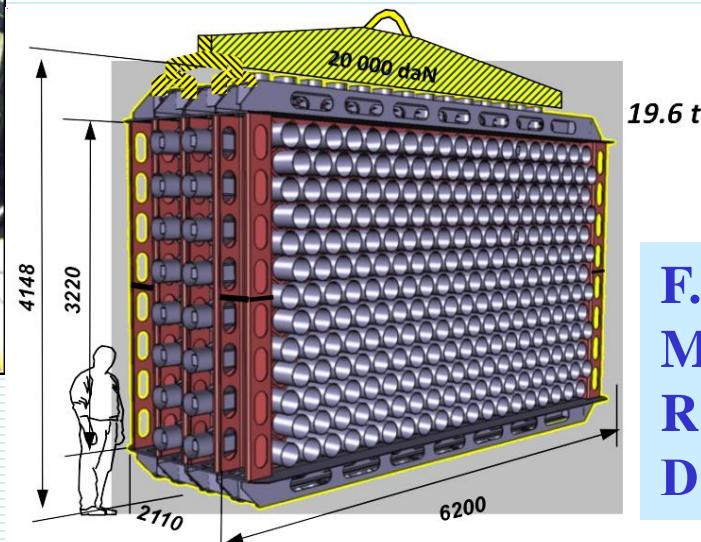
^{48}Ca , ^{82}Se , ^{96}Zr , ^{100}Mo , ^{116}Cd , ^{130}Te , ^{150}Nd



Statistical Properties of ν



NEMO3 a SuperNEMO experiments



F. Šimkovic,
M. Macko,
R. Dvornický
D. Štefánik

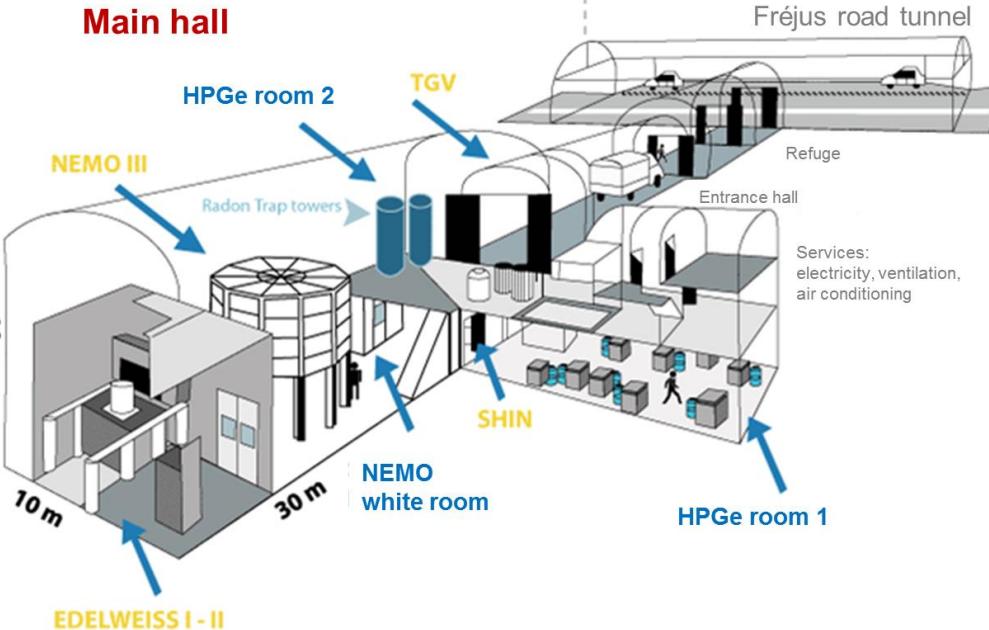
Physical program, software, construction



M. Macko

ITALY FRANCE

Main hall



Laboratoire Souterrain de Modane

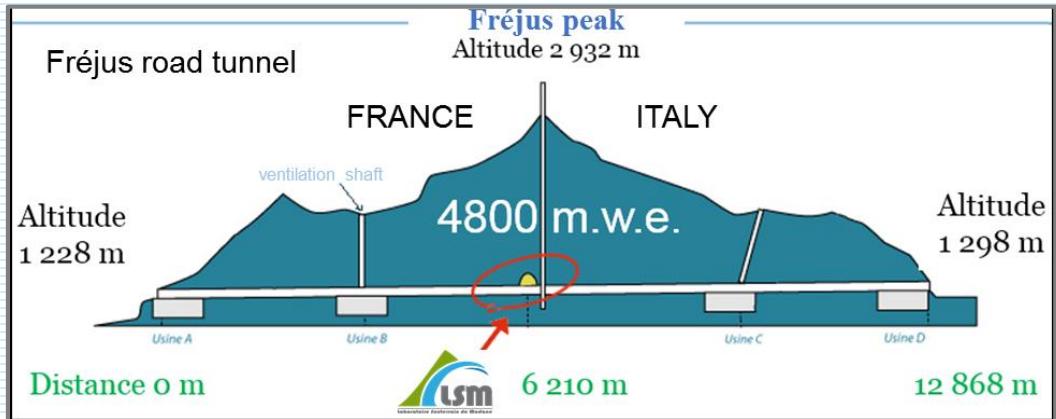


Nov. 9-10
2018
Super
NEMO
day

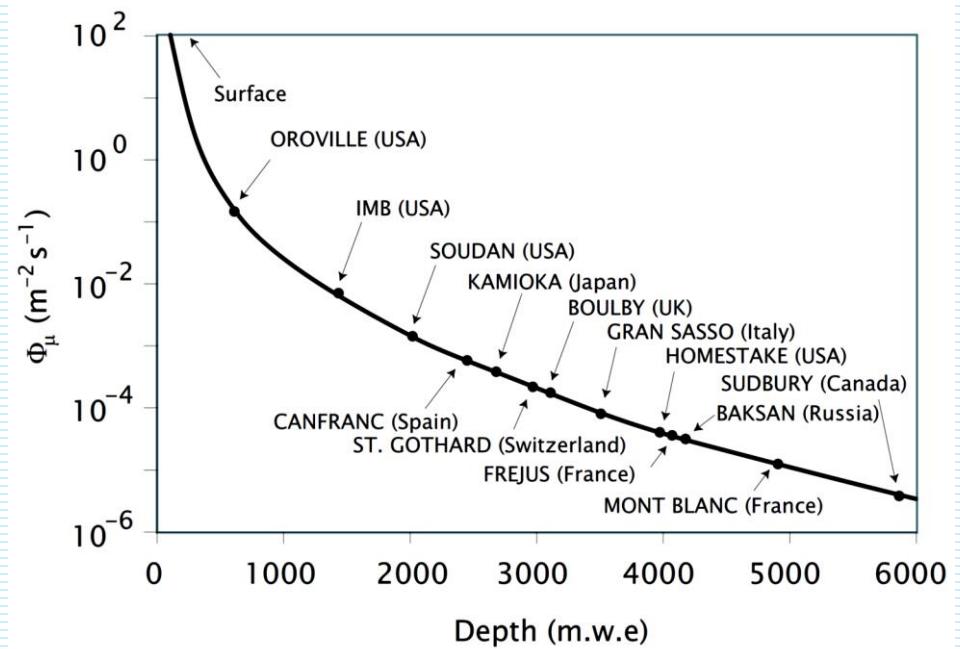
Presenten.
of
Demon-
strator



Joule agreement (CNRS-CTU-CU) access to Modane Underground Lab.



Main hall



HPGe room

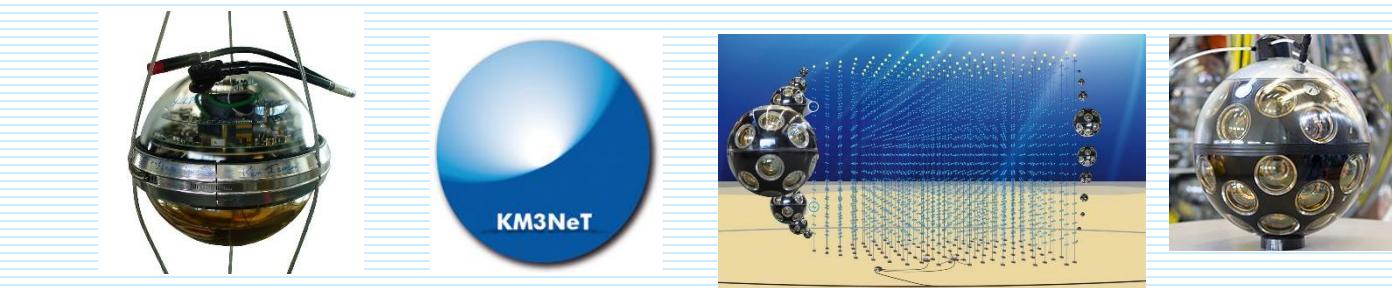
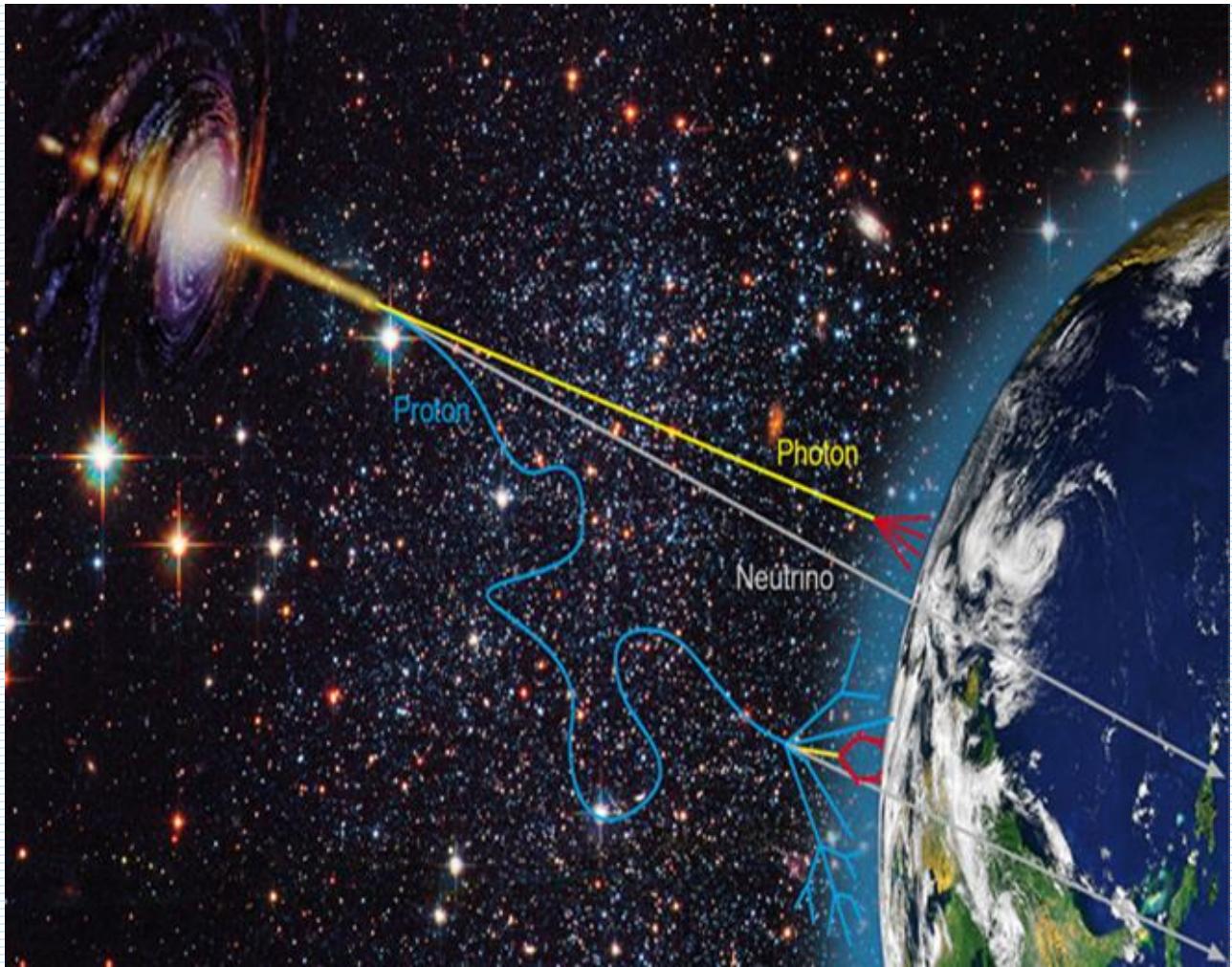
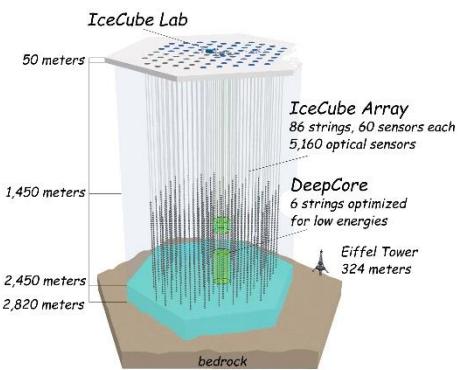
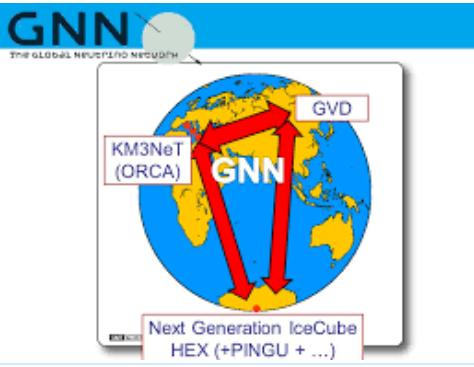
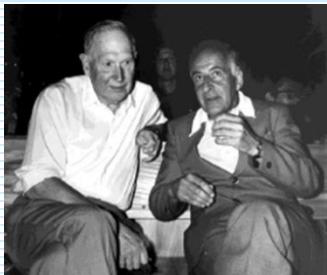


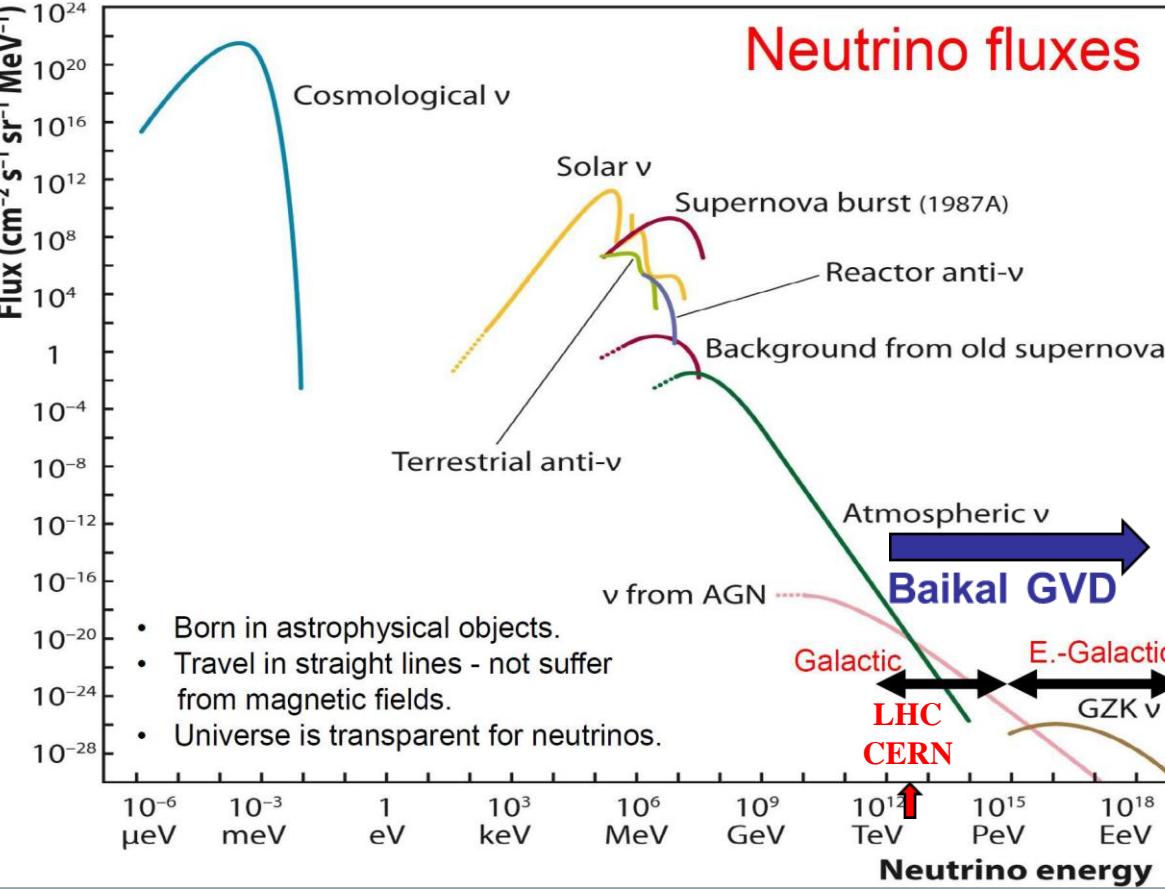
5. Slovak participation in Baikal GVD experiments



welcometobratislava.eu

Neutrino telescopes: Ice Cube, KM3Net, Baikal GVD





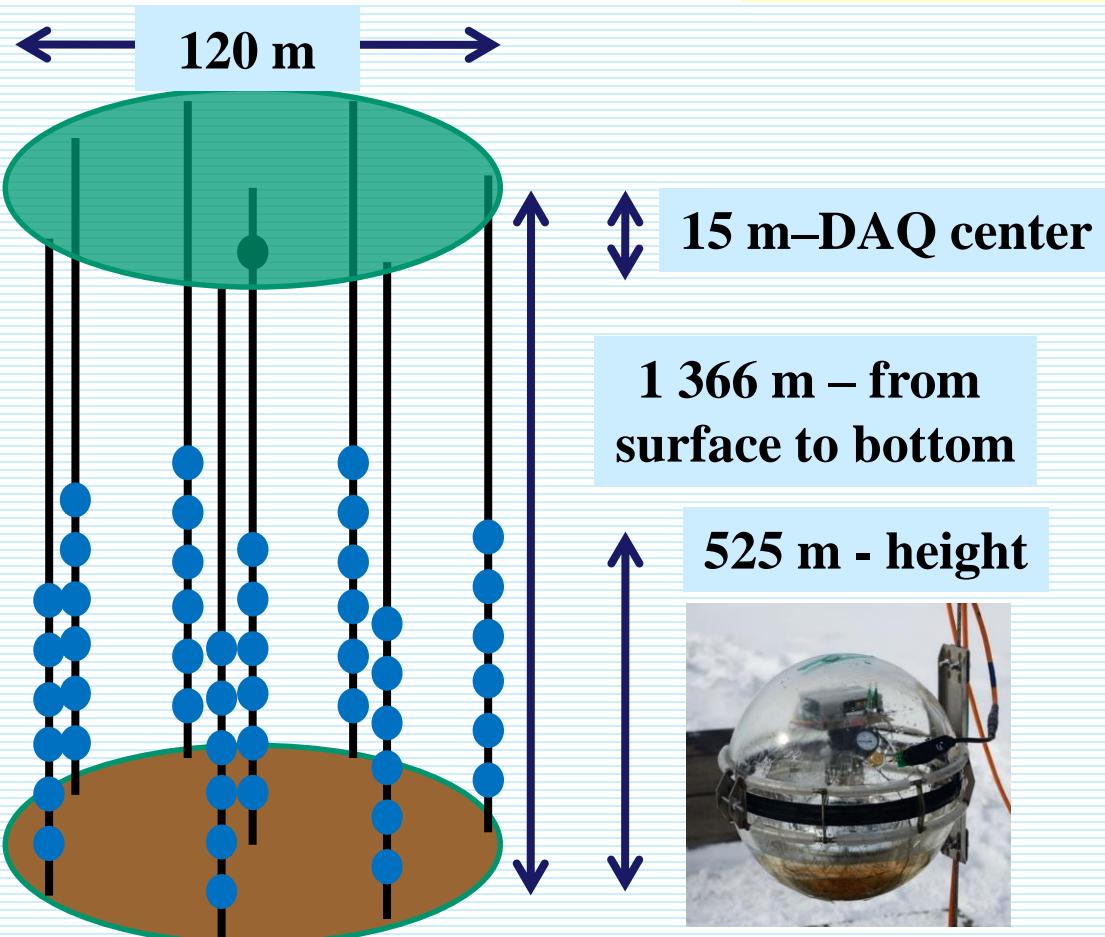
2016 we have become a part of the Baikal GVD coll.

F. Šimkovic (committee)
 R. Dvornický, soft. develop.
 construction of detector
 L. Fajt (PhD study),
 time calibration, construction
 of detector
 P. Kerenyi (Magister Study)
 Z. Bardáčová, E. Eckerová
 (Bachelor
 study)

Collaboration: 9 institutions

1. Institute for Nuclear Research, Moscow, Russia.
2. Joint Institute for Nuclear Research, Dubna, Russia.
3. Irkutsk State University, Irkutsk, Russia.
4. Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia.
5. Nizhny Novgorod State Technical University, Russia.
6. St.Petersburg State Marine University, Russia.
7. Czech Technical University, Prague, Czech Republic.
8. Comenius University, Bratislava, Slovakia.
9. EvoLogics GmbH., Berlin, Germany.

Consist of 288 Optical Modul.
(OMs) at 8 strings. 3 LED
calibration matrices. Acoustic
positioning system. 1 seabed
electro-optical cable. 1 DAQ
centre. Distance between
clusters 300m



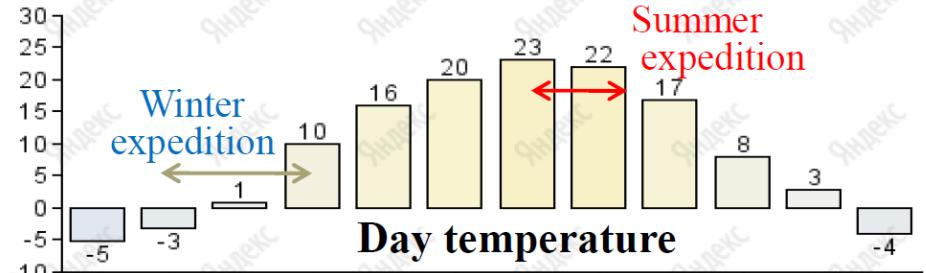
Cluster

Baikal GVD

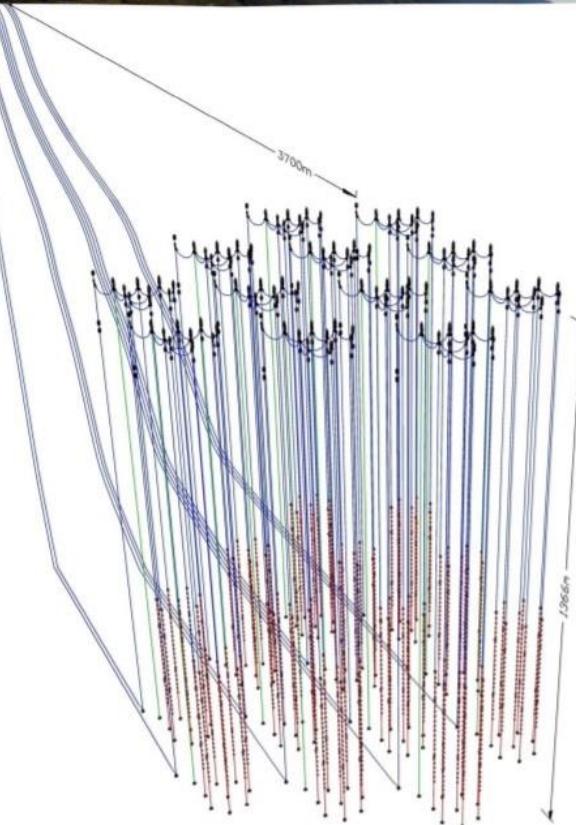
Consists of 8 clusters (in 2020). In total 2304 OMs.
Depths 750-1275 m. The first cluster "Dubna" has
worked since April 2015. The 2nd cluster in 2017
and 3rd in 2018. Two new clusters installed every
consecutive year.

Depth – 1360 m; flat the lake bed
at >3 km from the shore

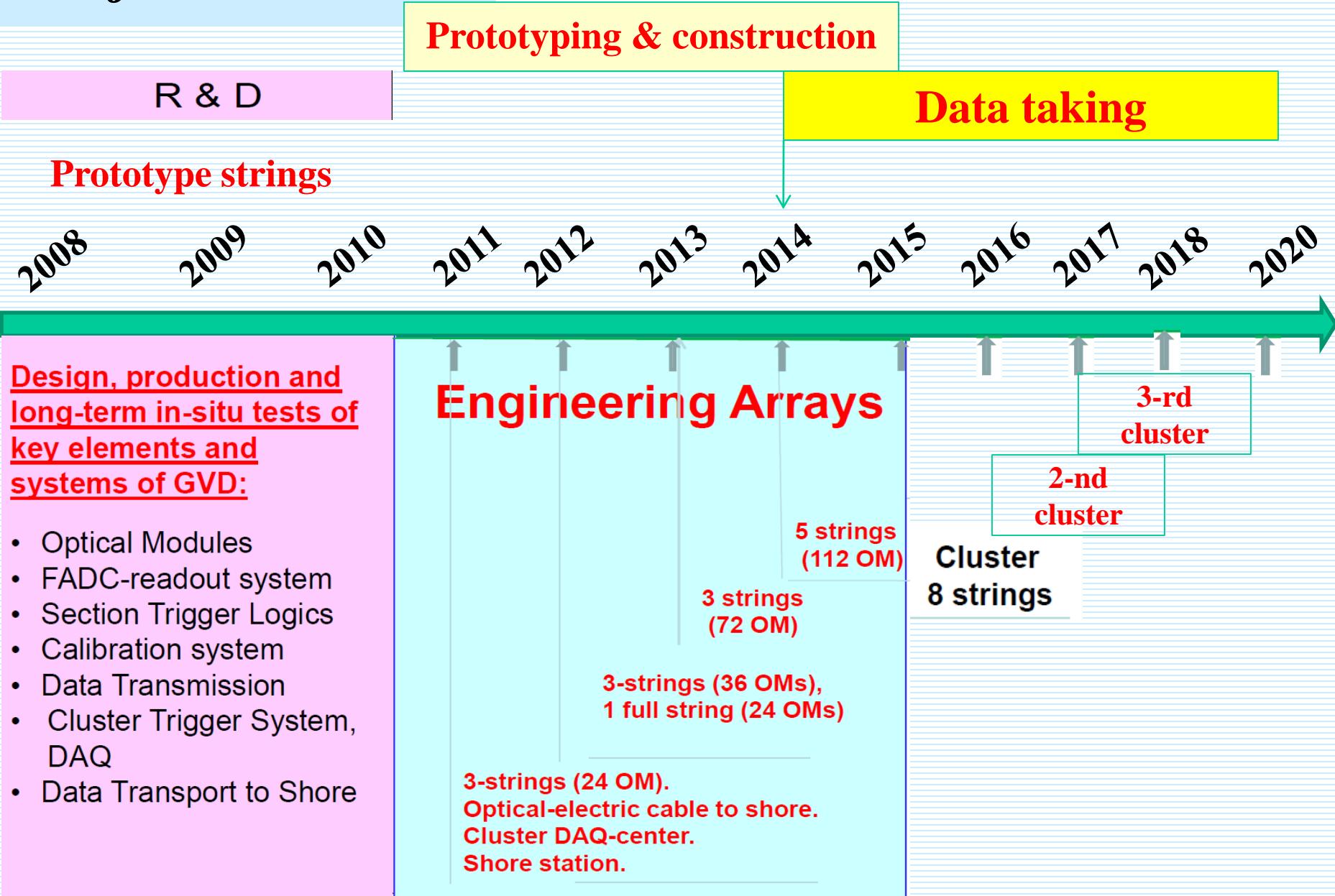




Baikal GVD winter expedition



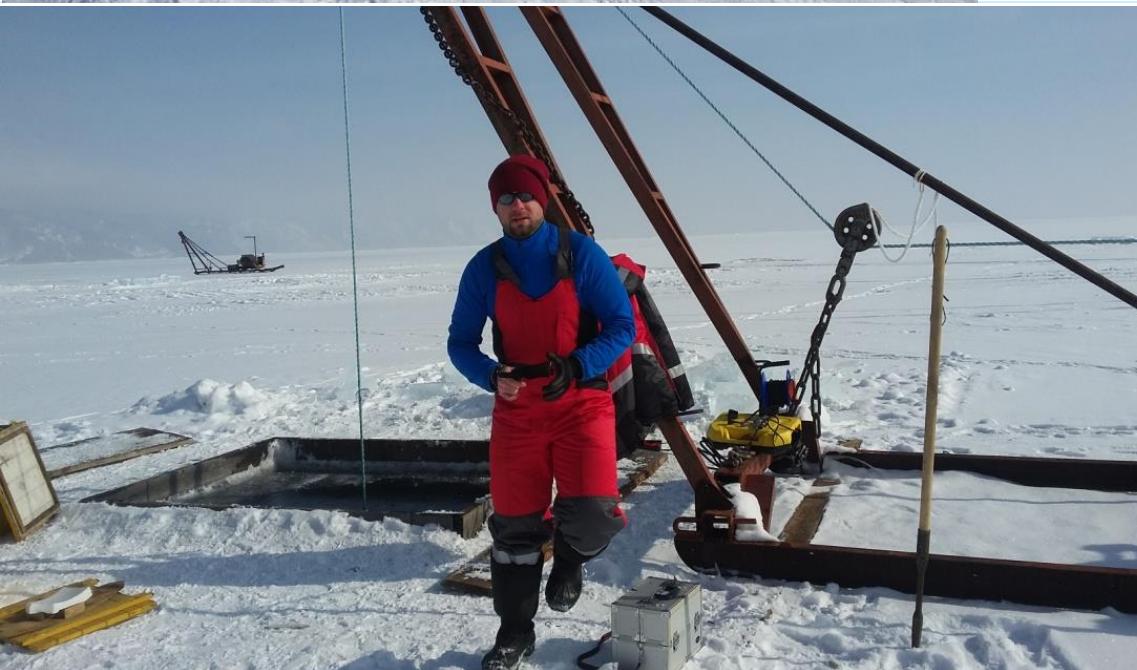
Project time-line





**R. Dvornický
P. Kerenyi (diploma)**

- charge and amplitude calibration
- installation and deployment of the detector
- MC simulations



**L. Fajt
Z. Bardáčová (bachelor)
E. Eckerová (bachelor)**

- time calibration and “time walk effect”
- double pulses analysis
- installation and deployment of the detector

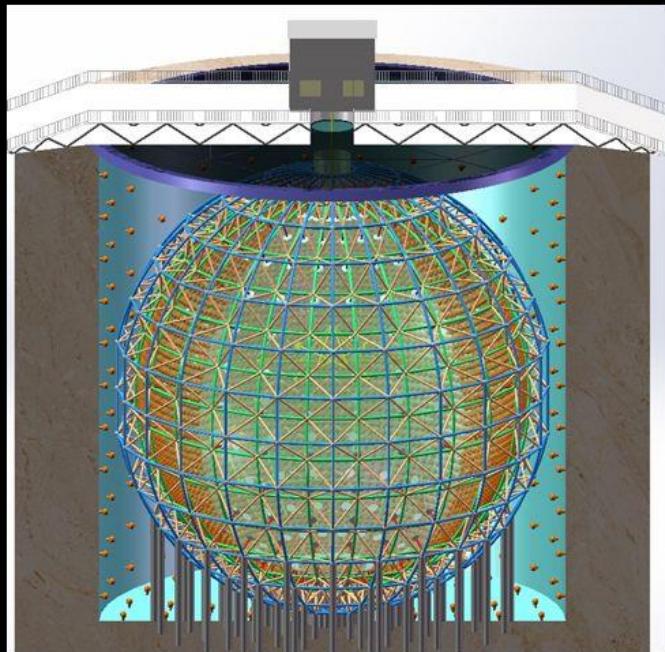
6. Slovak participation in JUNO experiments





The JUNO Experiment

- ◆ **Jiangmen Underground Neutrino Observatory (JUNO)**, a multiple-purpose neutrino experiment, approved in Feb. 2013, ~ 300 M\$.



- **20 kton LS detector**
- **3% energy resolution**
- **700 m underground**
- **Rich Physics Possibilities**
 - Reactor Neutrinos for neutrino mass hierarchy & precision measurement of oscillation parameters
 - Supernova Neutrino Burst
 - Diffuse Supernova Neutrino Background
 - Geoneutrinos
 - Solar Neutrinos
 - Atmospheric Neutrinos
 - Proton Decays
 - Exotic Searches



Proposed participation on



Theory:

We hope that the JUNO collaboration will appreciate our expertise concerning **(anti)neutrino fluxes from the reactor, the subject which is closely related with the problem of forbidden beta decays**. The goal is to predict reliable energy distribution of (anti)neutrinos from the reactor following the content of radioactive isotope there. For that purpose, we plan to collaborate with other groups of the JUNO collaboration interested in the thermal model description of nuclear reactors. Further, we would like to address the problem of the **global fit of neutrino oscillation parameters**.

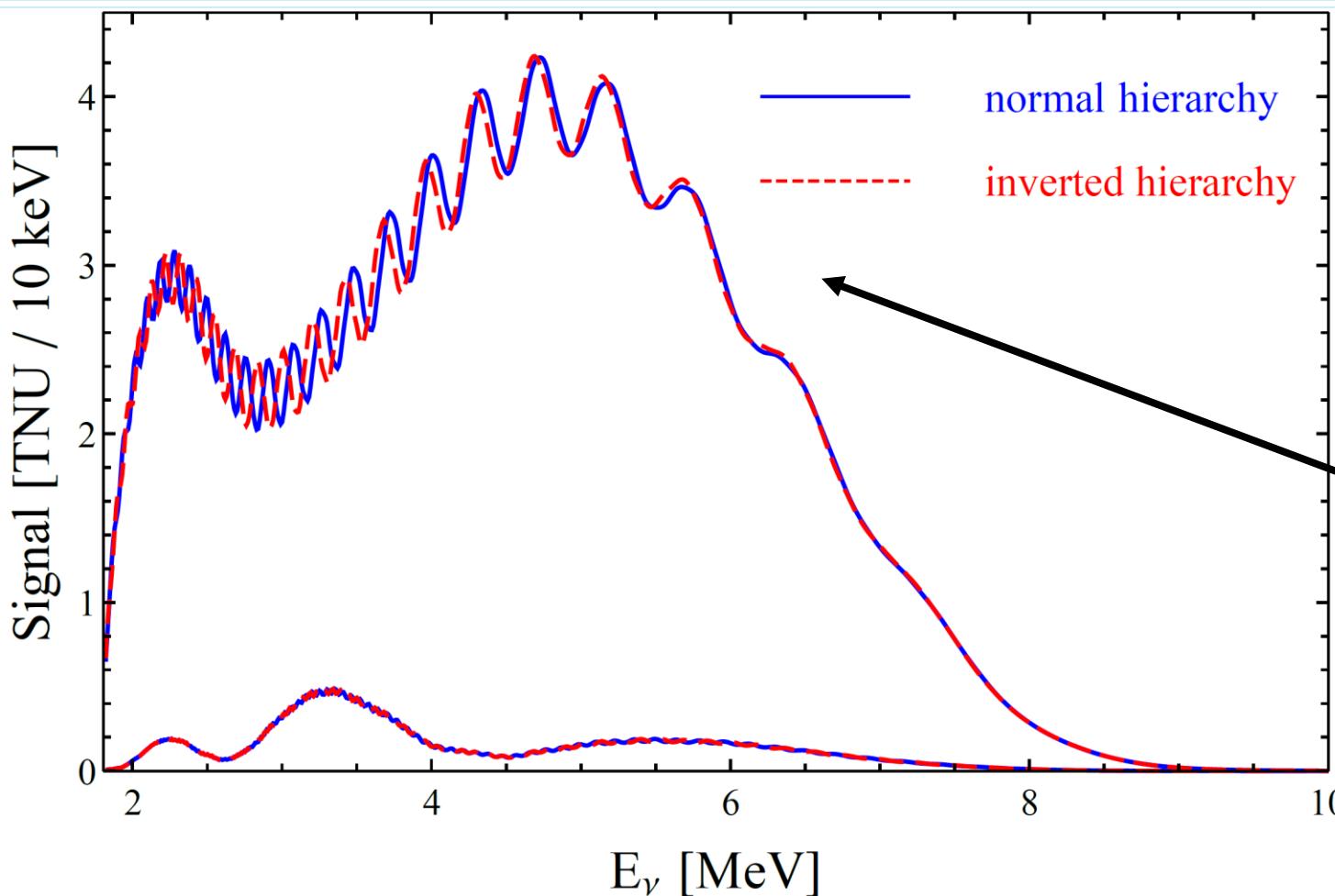
Software:

Currently, we do no plan to develop software for JUNO experiment. Contrary, we plan just to exploit JUNO software for solving of physical tasks.

Analysis:

We plan to participate in **data analysis and formation of the physical program** of the JUNO experiment.

Expected reactor antineutrino spectra in the JUNO experiment



Including the
Yangjiang and
Taishan reactors

$$N_{tot} = \varepsilon N_p \tau \sum_{i=1}^{N_{reactor}} \frac{P_{th}^i}{4\pi L_i^2} \langle LF_i \rangle \int dE_{\bar{\nu}} \sum_{k=1}^4 \frac{p_k}{Q_k} \lambda_k(E_{\bar{\nu}}) P_{ee}(E_{\bar{\nu}}, L_i) \sigma_{IBD}(E_{\bar{\nu}})$$

The reactor antineutrino spectrum associated with k-actinide emerges as the most critical component in the signal calculation.

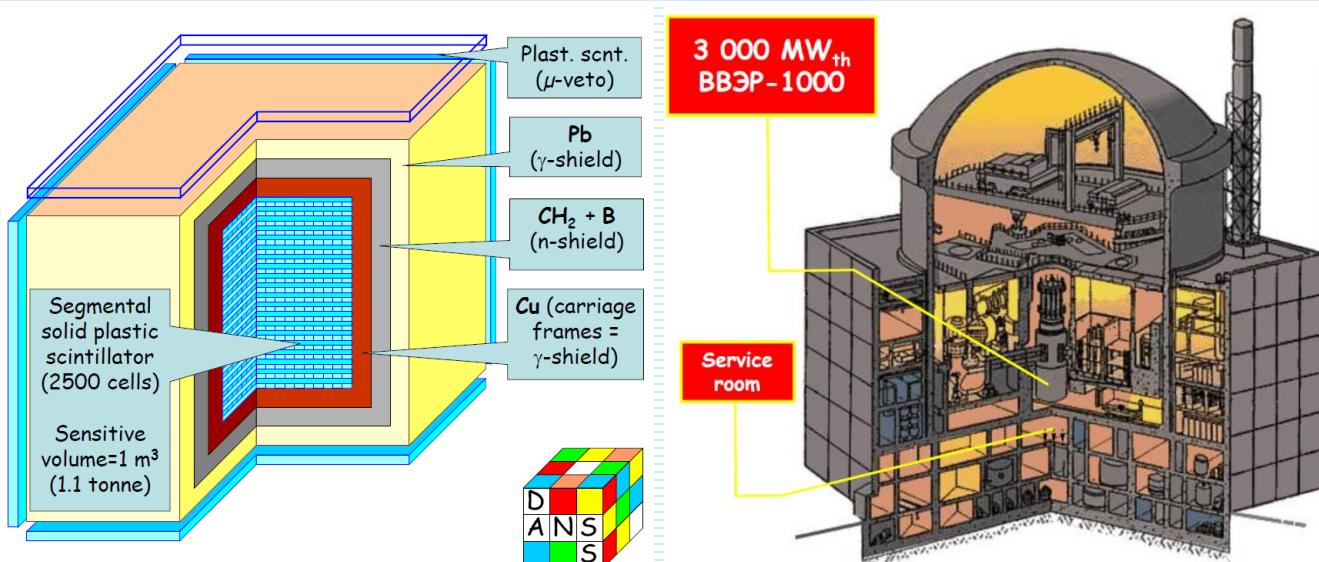
Detection of reactor neutrinos (theory, forbidden beta-decays, simulations)



STERILE NEUTRINOS

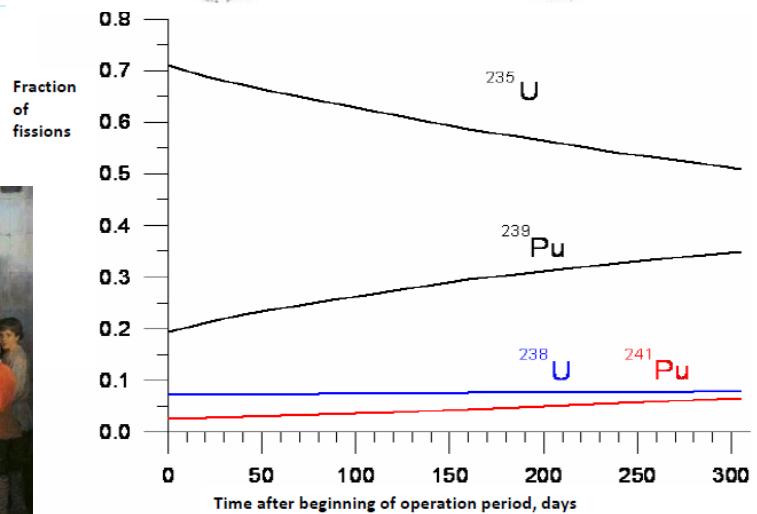
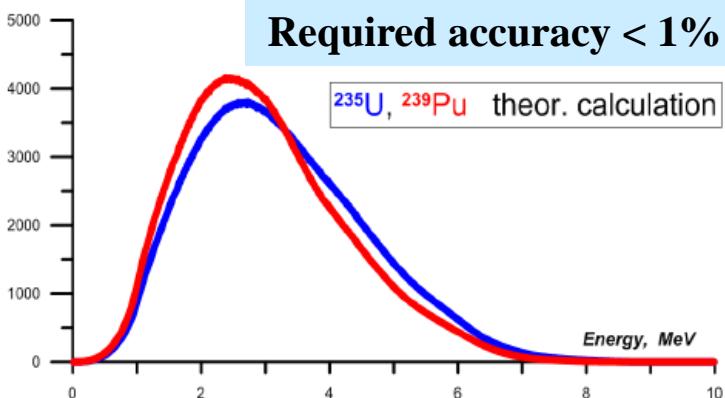


Does sterile ν
exist?



Online monitoring of reactor through
neutrinos

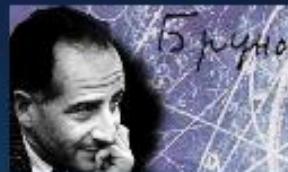
Required accuracy < 1%



7. Organization of Pontecorvo summer schools



VI International Pontecorvo Neutrino Physics School



August 27 – September 4, 2015
Horný Smokovec, Slovakia

(<http://theor.jinr.ru/~neutrino15/>)

Organizing Committee:

V. A. Matveev	- chairman	R. Leitner
S. M. Bilenky	- scientific program	V. B. Brudanin
F. Šimkovic	- vice-chairman	E. A. Kolganova
A. G. Olshevskiy	- vice-chairman	O. Matyukhina
I. Štekl	- vice-chairman	D. Štefánik
V. A. Bednyakov		A.E. Bolshakova
		R. Dvornicky



Lectures at School:

<i>Neutrinos in SM and beyond:</i>	Samoil Bilenky (JINR Dubna)	<i>0νββ-decay: EXO and KamLAND-Zen:</i>	Andreas Piepke (U. of Alabama)
<i>Phenomenology of ν-mixing and oscillations:</i>	Serguey Petcov (SISSA)	<i>0νββ-decay : GERDA:</i>	Stefan Schoenert (TU Muenchen)
<i>Long baseline ν-oscillation experiments:</i>	David Wark (Oxford U.)	<i>Neutrinos in cosmology and astronomy:</i>	Steen Hannestadt (Aarhus U.)
<i>Reactor ν experiments:</i>	Rupert Leitner (Charles U.)	<i>Physics at IceCube:</i>	Elisa Resconi (TU Muenchen)
<i>Atmospheric neutrinos:</i>	Yoichiro Suzuki (U. of Tokyo)	<i>Baikal experiment:</i>	Zhan-Arys Dzhilkibaev (INR Moscow)
<i>Solar- and geo-neutrinos:</i>	Oleg Smirnov (JINR Dubna)	<i>Supernova and relic neutrinos:</i>	Petr Vogel (CATLTECH)
<i>Theory of ν-masses:</i>	Werner Rodejohann (MPI Heidelberg)	<i>Dark Matter:</i>	Walter Potzel (TU Muenchen)
<i>Baryogenesis from Leptogenesis:</i>	Sasha Davidson (IPNL Lyon)	<i>News from CERN:</i>	Sergio Bertolucci (CERN)
<i>Direct ν-mass search:</i>	Christian Weinheimer (U. of Muenster)	<i>Progressive detection techniques:</i>	Ettore Fiorini (U. di Milano-Bicocca)
<i>Theory of 0νbb-decay :</i>	Martin Hirsch (U. of Valencia)	<i>Progressive detection techniques II:</i>	Ivan Štekl (CTU Prague)
<i>Double Beta Decay Matrix Elements:</i>	Fedor Šimkovic (Comenius U.)	<i>Statistics for Nuclear and Particle Physics:</i>	Louis Lyons (U. of Oxford)

Letná škola Bruna Pontecorva fyziky neutrín, Horný Smokovec, 27.8.-4.9. 2015





VII International Pontecorvo Neutrino Physics School 2017

<http://theor.jinr.ru/~neutrino17>



August 20 – September 1, 2017

Prague, Czech Republic

Introduction to ν -physics
Theory of ν -masses and mixing
 ν -oscillation phenomenology
Solar ν -experiments and theory
Accelerator ν -experiments
Reactor ν -experiments
Measurement of ν -mass

Ov $\beta\beta$ -decay experiments
Ov $\beta\beta$ -decay nuclear matrix elements
 ν -nucleus interactions
Sterile neutrinos

Leptogenesis
 ν -astronomy
 ν -telescopes
 ν -cosmology
Dark matter experiments
Observation of gravitational waves
Neutrino physics at CERN
Future colliders
Statistics for Nucl. and Particle Phys.

Bilenky S. (JINR Dubna)
King S.F. (Southampton Univ.)
Kayser B. (Fermilab)
Smirnov A. (MPI Heidelberg)
Feldman G.J. (Harvard Univ.)
Wang Y. (IHEP)
Tkachev I. (INR RAS, Moscow)
Gastaldo L. (Heidelberg Univ.)
Barabash A. (ITEP Moscow)
Vogel P. (Caltech)
Sobczyk J. (Wroclaw Univ.)
Link J. (Virginia Tech.)
Giunti C. (INFN Torino)
Davidson S. (IPNL Lyon)
Tamborra I. (Copenhagen Univ.)
Spiering C. (DESY)
Mangano G. (INFN Naples)
Fornengo N. (INFN Torino)
Barish B. (CALTECH)
Elsen E. (CERN)
Blondel A. (CERN)
Dyk D.V. (IC, London)

Organized by

Joint Institute for Nuclear Research (Dubna, Russia)
Czech Technical University (Prague, Czech Republic)
Charles University (Prague, Czech Republic)
Comenius University (Bratislava, Slovakia)
Institute of Nuclear Physics (Krakow, Poland)

M e m b e r s

Bednyakov V.A. (JINR) Leitner R. (ChU)
Zalewska A. (INP) Brudanin V.B. (JINR)
Rondio E. (NCBJ, Swierk) Kolganova E.A. (JINR)

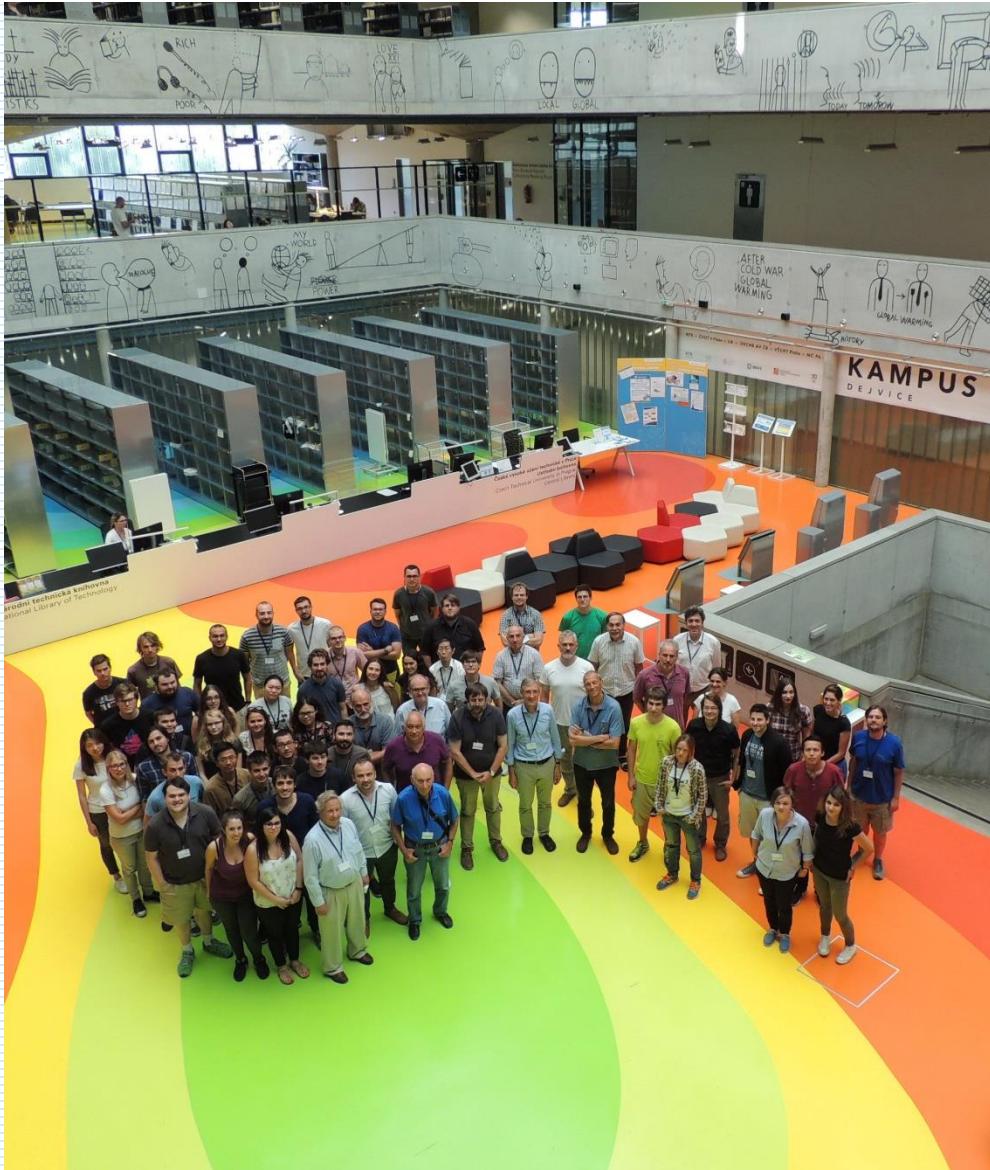
Organizing Committee

Matveev V.A. (JINR) - chairman
Bilenky S.M. (JINR) - scientific program
Šteklik I. (CTU) - vice-chairman
Olshevskiy A.G. (JINR) - vice-chairman
Šimkovic F. (CU/JINR) - vice-chairman
Jezabek M. (INP) - vice-chairman

S e c r e t a r i e s

Hodák R. (CTU) Rusakovich E. (JINR)
Rukhadze E. (CTU) Vanišová M. (CTU)





**70
students** '20

**JINR and Russia:
JINR member states instit.
(CZ-12, SK-6, RO-4, PL-2):**

**19 (4)
24**

**Europe (D, FR, ES, PT, GB, DK):
World (US, CN, TR, CL, PK):**

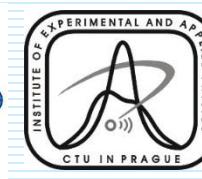
**20
7**

VII Pontecorvo Neutrino Physics School

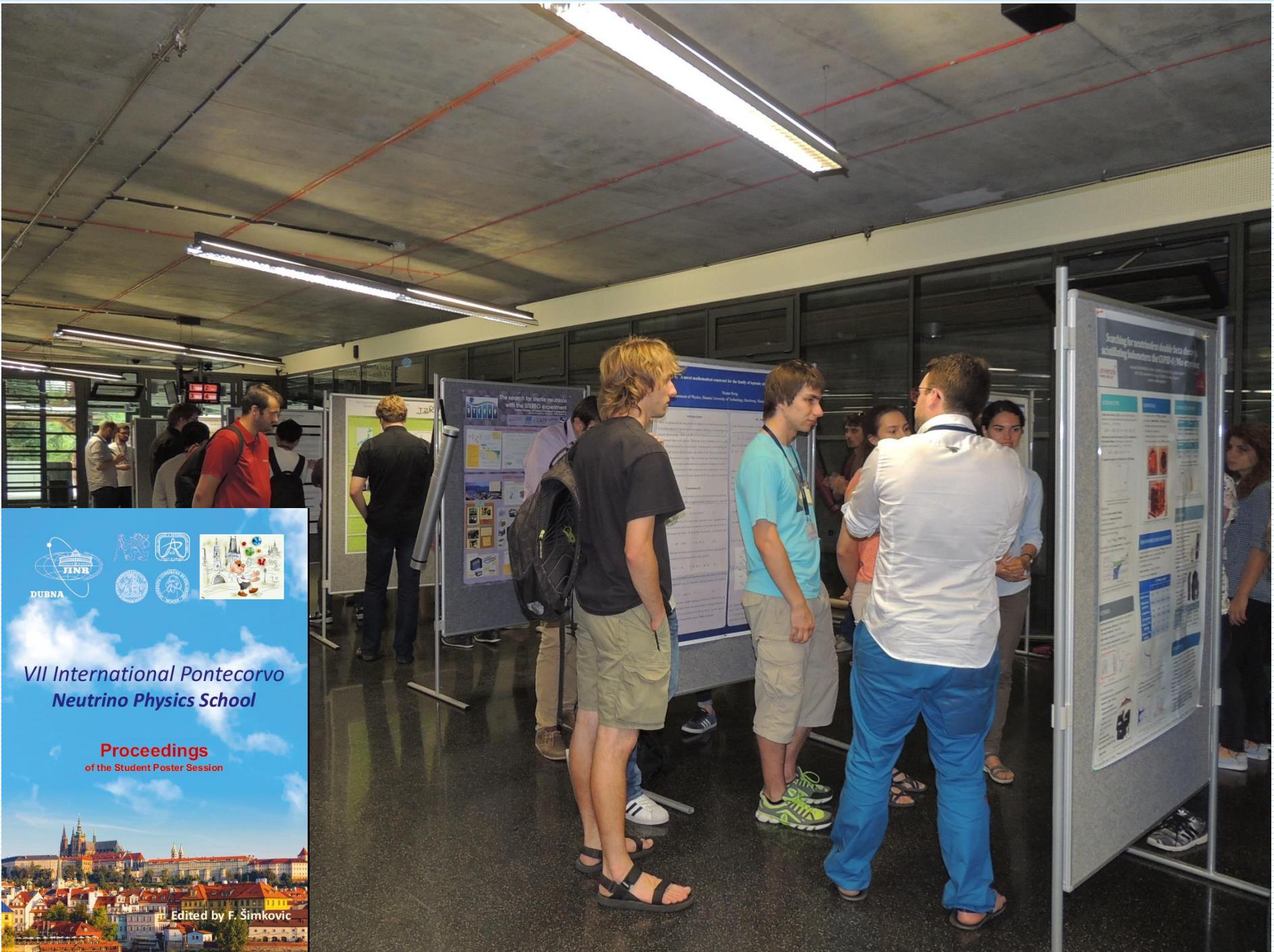
Prague, August 20 –
September 1, 2017

Joint success of the JINR and
institutions from JINR member states
on the field of
NEUTRINO PHYSICS

JINR+Slovakia+Czech Republic



- +Financed by Grants of Plenipotentiary of Czech Republic and Romania
- + Project Slovakia-JINR
- + Directorate of the JINR
- + IAEP CTU Prague



8. Funding of neutrino physics research in Slovakia





JINR Dubna - March 26, 1956

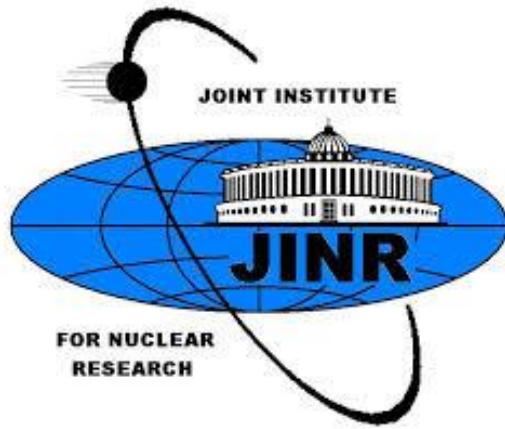
800 universities and institutions
collaborate with JINR Dubna
1500 scientific articles and contributions
to proceedings per year
40 International conferences and
workshops per year



Laboratory of theoretical physics = 1959



**Laboratory of nuclear problems
Physics of neutrinos**



- Project: Grand Unification, Fundamental Rare Decays and Nuclear Structure, F. Šimkovic
- Grants of plenipotentiary: R. Dvornický, F. Šimkovic, P. Povinec



AGENTÚRA
NA PODPORU
VÝSKUMU A VÝVOJA

- Rare nuclear processes and development of methods for their investigations, P. Povinec
- Structure, reactions and rare processes of nuclei, S. Antalic



- Nucleus as laboratory to study fundamental properties of neutrinos, F. Šimkovic

- Visegrad Fund

- Cosmic-Ray Extremely Distributed Observatory (CREDO), F. Šimkovic

Is neutrino physics in Slovakia at European level?



Statistics of publications 2011-2018

NuMassNS team	HEP	WK
Total number of publications:	108	99
Total number of citations:	1 684	1 376
Excluding self-citations:	1 324	1 166
Average citations per article:	15.6	13.9
h-index:	21	20



2015

JINR	CERN	NuMassNS team	
		WK	HEP
Publications: 1 033	Publications: 1161	Publications: 14	24
Citations: 1 285	Citations: 2140	Citations: 8	35
Excl. self-citat.: 1 113	Excl. self-citation: 1753	Excl. self-citat.: 4	28
Citácie/článok: 1.24	Citat./publ.: 1.84	Citat./publ.: 0.6	1.5
h-index: 14	h-index: 18	h-index: 1	3

9. Conclusions and Outlook



Instead of Conclusions

Neutrino
physics

$$\frac{1}{\Lambda} \sum_i c_i^{(5)} \mathcal{O}_i^{(5)}$$



LHC
physics

$$\frac{1}{\Lambda^2} \sum_i c_i^{(6)} \mathcal{O}_i^{(6)} + O\left(\frac{1}{\Lambda^3}\right)$$

We are at the beginning of the Beyond Standard Model Road...



The future of neutrino physics is bright



GRACIAS DANKSCHEEN
ARIGATO SPASSIBO
SHUKURIA NUHUN SNACHALHYA
JUSPAXAR TAVTAPUCH MEDAWARSE
GOZAIMASHITA
EFCHARISTO
FAKAAUE
TASHAKKUR ATU CHALTU YAQHANYELAY
MERASTAMHY SANCO
MAAKE ATTO DHANYABAD WABEEJA MAITEKA
KOMAPSUMNIDA LAH SUKSAMA EKHMET
MEHRBANI PALLDIES HUI
GRAZIE SPASIBO UNVALCHIHYA
MEHRBANI DENKAJJA NEMERSI
BOLZİN EKOJU SIKOMO
MERCI MINMONCHAR
TINGKI BİYAN SHUKRIA

