Report from the Neutrino Panel

Heidi Schellman for the Panel based on prior reports by Mandred Lindner



The IUPAP Neutrino Panel

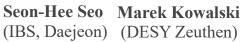
IUPAP has established the Neutrino Panel with the mandate:

- "to promote international cooperation in the development of experimental programs to study the properties of neutrinos" and
- "to promote international collaboration in the development of future neutrino experiments to establish the properties of neutrinos"

Start: co-chair's meeting during NEUTRINO 2018 in Heidelberg

→ basic principle: science only, balanced and broad







Nigel Smith (SNOLAB)



Manfred Lindner Takaaki Kajita (MPIK)

(ICRR, Tokyo)



Kate Scholberg Walter Winter



(Duke University) (DESY-Zeuthen)



Jun Cao (IHEP)



Kenneth Long (Imperial College)



Heidi Schellman (Oregon State U.)













Kunio Inoue (Osaka U.)



Renata Zukanovich Funchal (Sao Paulo)



Steven Barwick (UC Irvine)



M. Sajjad Athar (Aligarh Muslim U.)



(MPIK)



Werner Rodejohann Nathalie Palanque-Delabrouille **CEA-Saclay**

3 co-chairs from 3 regions 19 members / 11 countries

- → topical, political, age and fair gender balance
- → broad / balanced expertise Additional "contributing authors" as required
 - neutrinos ←→ sources
 - with / without neutrinos
 - → topics/members matrix

Panel Web Page and Wiki

https://www.iupapneutrinopanel.org

IUPAP NEUTRINO PANEL

To stimulate and facilitate international cooperation in physics and the worldwide development of science.

In addition a wiki: https://www.mpi-hd.mpg.de/IUPA

members → mandate →

Home

Meet the Panel

Terms of Reference

CONTACT US

iupap-nu-panel@mpi-hd.mpg.de

Community Feedback to the IUPAP Neutrino Panel draft report

2021-07-08 / MANFRED LINDNER / 0 COMMENTS

The IUPAP neutrino panel has the mandate to promote international cooperation in the development of an experimental program to study the properties of neutrinos and to promote international collaboration in the development of future neutrino experiments to establish the properties of neutrinos.

A main objective of the panel is to carry out a review of the present status of neutrino physics and the requirements and R&D that are necessary for the research field to fulfill its near- to long-term potential. The draft report in the form of a science-driven white paper is now ready for comments from the world-wide neutrino community.

Link to the draft report

Link to the online feedback form for comments, corrections, ...

We are grateful for any input which helps to further improve the document. The deadline for feedback is Aug. 29, 2021.

The IUPAP neutrino panel

Panel Meetings (Zoom)

				•			
WEDNESDAY, 30. MAY 2018		TUESDAY, 30. APRIL 2019		FRIDAY, 22. MAY 2020		WEDNESDAY, 16. DECEMBER 2	020
IUPAP chair telecon	13:00 14:00	IUPAP Neutrino Panel	15:00 17:00	IUPAP Neutrino Panel	14:00 16:00	IUPAP Neutrino panel	14:00 15:30
FRIDAY, 6. JULY 2018		WEDNESDAY, 15. JANUARY 202	20	TUESDAY, 26. MAY 2020		THURSDAY, 11. MARCH 2021	
Zoom Telecon: IUPAP	14:00 15:00	IUPAP Neutrino Panel	14:00 16:00	IUPAP Neutrino Panel Zoom	14:00 15:00	IUPAP neutrino panel	14:00 15:00
FRIDAY, 21. DECEMBER 2018		THURSDAY, 23. JANUARY 2020	<u> </u>	THURSDAY, 18. JUNE 2020		THURSDAY, 8. JULY 2021	
IUPAP nu-panel chair	19:00 20:00	IUPAP Neutrino Panel Zoom	14:00 16:00	IUPAP Neutrino Panel	14:00 15:30	IUPAP neutrino panel	15:00 16:00
··		FRIDAY, 21. FEBRUARY 2020		TUESDAY, 28. JULY 2020		TODAY	
TUESDAY, 15. JANUARY 2019		IUPAP Neutrino Panel	14:00	• • • • • • • • • • • • • • • • • • •			
15:00 IUPAP nu pane	15:00	Zoom	16:00	IUPAP Neutrino Panel	14:00 15:30	MONDAY, 13. SEPTEMBER 2021	ľ
To do to to the to the particular	16:30		WEDNESDAY, 18. MARCH 2020		WEDNESDAY, 19. AUGUST 2020		15:00 16:30
TUESDAY, 19. FEBRUARY 2019		IUPAP NuPanel Co-C	13:00 14:00	IUPAP Neutrino Panel	14:00		
15:00 IUPAP nu pane	15:00 16:30	MONDAY, 23. MARCH 2020	14.00	THURSDAY, 17. SEPTEMBER 20	15:30 20		
TUESDAY, 26. MARCH 2019		IUPAP Neutrino Panel Zoom	13:00 15:00	IUPAP Neutrino Panel	13:00 14:30		
IUPAP-pre-call	14:30 15:00	THURSDAY, 30. APRIL 2020		MONDAY, 26. OCTOBER 2020	14.50		
15:00 IUPAP nu pane	15:00 16:30	IUPAP Neutrino Panel Zoom Meeting	14:00 16:00	IUPAP Neutrino Panel	14:00 15:30		
FRIDAY, 5. APRIL 2019		MONDAY, 11. MAY 2020		TUESDAY, 24. NOVEMBER 2020)		
IUPAP NP Co-Chairs	15:00 16:30	IUPAP Neutrino Panel Zoom	14:00 15:00	IUPAP neutrino panel	13:30 15:00		

WG2:

3 v Abs. Mass

 $0\nu\beta\beta$, ν masses in cosmology, Kinematic ν mass meas.

WG3:

Interactions,
New v states,
v as Probes of
Fundamental physics

Sterile v,
Coherent scattering,
Cross sections,
NSI, MSW, GeV,
Weinberg angle, ...

WG1:

3 v Osc. Studies

 Δm^2 , θ_{ij} , δ_{CP} ,...

<u>WG4:</u>

Physics of v Sources

Solar, Atmospheric, Geo, Reactors, Astronomical (SN, AGN,...), Cosmological (BB, GZK,...)

IUPAP v Panel

WG5:

New Technologies & Frameworks for v Physics

Experimental & Theoretical underpinning, Future technologies & beams,...

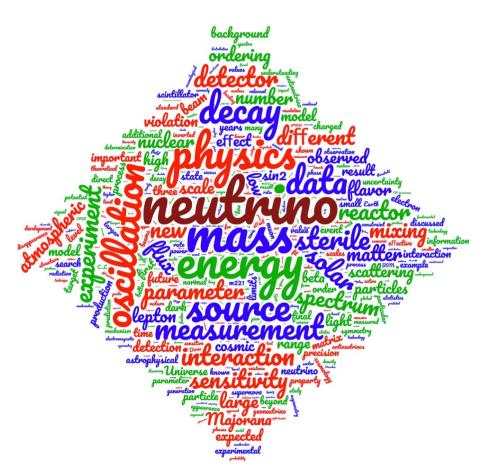
Neutrino Panel

In consultation with the broad neutrino-physics community:

- a) Cover the present status of the global neutrino physics program and the developments that can be expected on a 5 to 10-year time scale through a science driven white paper
- b) Collect R&D and measures (including software development) that are required for the near-term (<10-year) and medium- to long-term (10-25-year) program to fulfil their potential
- c) Collect feedback on a draft report from the community
- identify opportunities within neutrino physics, mutual benefits of global connections within neutrino physics and other fields, as well as the synergies of an international program

The Draft

IUPAP Neutrino Panel White Paper



The IUPAP Neutrino Panel:

M. Sajjad Athar¹, Steven W. Barwick², Thomas Brunner^{3,4}, Jun Cao⁵, Mikhail Danilov⁶, Takaaki Kajita*⁷, Marek Kowalski^{8,9}, Manfred Lindner^{*10}, Kenneth R. Long¹¹, Nathalie Palanque-Delabrouille¹², Werner Rodejohann¹⁰, Heidi Schellman¹³, Kate Scholberg¹⁵, Seon-Hee Seo¹⁶, Nigel J.T. Smith*^{4,17,18}, Walter Winter⁹, Geralyn P. Zeller¹⁹, Renata Zukanovich Funchal²⁰

*Co-Chairs

Additional contributing authors:

Stephen T. Dye³⁰Giorgio Gratta²¹, Soud Al Kharusi³, Livia Ludhova^{22,23}, Mary Hall Reno²⁴, Irene Tamborra²⁵, Christopher G. Tully²⁶, Kathrin Valerius²⁷, Roger A. Wendell^{28,29}

¹Department of Physics, Aligarh Muslim University, Aligarh-202002, India
²Dept. of Physics and Astronomy, University of California, Irvine, CA 92697, USA
³Physics Department, McGill University, Montreal, Quebec H3A 2T8, Canada
⁴TRIUMF, Vancouver, British Columbia V6T 2A3, Canada
⁵Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China
⁶Lebedev Physical Institute of the Russian Academy of Sciences, 53 Leninskiy Prospekt, Moscow, 119991,
Russia

⁷Research Center for Cosmic Neutrinos, Institute for Cosmic Ray Research (ICRR), The University of Tokyo, 5-1-5, Kashiwanoha, Kashiwa, Chiba, 277-8582, Japan

⁸Institut für Physik, Humboldt Universität zu Berlin, D.12/80 Berlin, Germany

⁸Institut für Physik, Humboldt-Universität zu Berlin, D-12489 Berlin, Germany ⁹DESY, D-15738 Zeuthen, Germany

Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
 Imperial College London, Department of Physics, London, United Kingdom
 IRFU, CEA, Universite Paris-Saclay, F-91191 Gif-sur-Yvette
 Department of Physics, Oregon State University, Corvallis OR, 97331, USA
 Scientific Computing Division, Fermilab, Batavia, IL, 60555, USA
 Duke University, Durham, NC 27708, USA

¹⁶Center for Underground Physics, Institute for Basic Science (IBS), 55, Expo-ro, Yuseong-gu, Daejeon, 34126, Korea

¹⁷Department of Physics and Astronomy, Laurentian University, Sudbury, Ontario, P3E 2C6, Canada
¹⁸SNOLAB, Lively, Ontario, P3Y 1M3, Canada

¹⁹ Fermi National Accelerator Laboratory, Batavia, IL 60510, USA
 ²⁰ Instituto de Fisica, Universidade de Sao Paulo, C.P. 66.318, 05315-970 Sao Paulo, Brazil
 ²¹ Department of Physics, Stanford University, Stanford, California 94305, USA
 ²² Institut für Kernphysik 2, Forschungszentrum Jülich, 52425 Jülich, Germany
 ²³ Physikalisches Institut III B, RWTH Aachen University, 52062, Aachen, Germany

²⁶Department of Physics, Princeton University, Princeton, NJ 08540, USA
²⁷Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
Institute for the Physics and Mathematics of the Universe (Kayli IPMI) WPI) Todai

³⁰Department of Physics and Astronomy, University of Hawaii, Honolulu, HI 96822, USA

57 Contents

				98	4.4	Reactor Neutrino Experiments
58	1	Executive Summary	9	99		4.4.1 Measurement of θ_{12} and $ \Delta m_{21}^2 $
				100		4.4.2 Measurement of θ_{13} and Δm_{ee}^{2}
59	2	Introduction	10	101		4.4.3 Projected Oscillation Measurements
				102	4.5	
60	3	Physics of Neutrino Sources	15	103		4.5.1 Measurement of θ_{23} and Δm_{32}^2
61		3.1 Introduction	15	104		4.5.2 Measurement of Mass Ordering and $\delta_{\rm CP}$ 61
62		3.2 Reactor Neutrinos	15	105		4.5.3 Projected Oscillation Measurements with Accelerators
63		3.2.1 Introduction	15			4.5.4 Possibilities with Accelerators
64		3.2.2 Current Status and open Questions		106	16	Global Fits
65		3.2.2.1 Absolute Reactor Flux Anomaly		107		
66		3.2.2.2 Shape Anomaly	19	108	4.7	Neutrino Oscinations: Summary
67		3.2.3 Future Outlook	20	109 5	Δh	solute Masses 71
60		3.3 Accelerator Neutrinos	20	110	5.1	
80		3.3.1 Conventional Beams				Kinematic Measurements of Neutrino Mass
69		3.3.2 Novel Neutrino Beams	21	111	0.4	5.2.1 Direct Mass Measurements with ν_e
70				112		
71		3.4 Solar Neutrinos		113		5.2.1.1 Tritium Beta-Decay 73 5.2.1.2 Electron Capture in ¹⁶³ Ho
72		3.5 Supernova Neutrinos		114		5.2.1.3 Outlook
73		3.6 Atmospheric Neutrinos		115		5.2.1.5 Outlook
74		3.7 High-Energy Astrophysical Neutrinos		116		5.2.2 Direct Mass Measurements with ν_{μ} and ν_{τ}
75		3.7.1 Introduction		117	F 9	5.2.3 Neutrino Mass from Supernova Neutrino Detection
76		3.7.2 Current Status	29	118	0.3	Neutrinoless Double Beta Decay
77		3.7.3 Future outlook	31	119		5.3.1 General Aspects
78		3.8 Geoneutrinos	32	120	- 1	5.3.2 Experimental Aspects
79		3.8.1 Introduction	32	121	5.4	Cosmology
80		3.8.2 Current Status	33	122		5.4.1 Main Experimental Approaches to Constrain $\sum m_{\nu}$
81		3.8.3 Future Prospects	34	123		5.4.2 Parameter Degeneracies
82		3.9 Cosmological Neutrinos	36	124		5.4.3 Upcoming and Proposed Experiments
83		3.9.1 Introduction		125	5.5	T T T
84		3.9.2 Direct Detection Experiments		126	5.6	Neutrino Mass: Summary
85		3.10 Neutrino Sources: Summary		C	NI	utrino Interactions 89
		•		127 6		Introduction
86	4	Neutrino Oscillations	46	128	0.1	
87		4.1 Introduction	46	129	0.0	6.1.1 Electron, Muon and Tau Neutrinos
88		4.2 Atmospheric Neutrino Experiments	49	130	6.2	
89		4.2.1 Introduction		131	6.3	
90		4.2.2 Measurement of θ_{23} and Δm_{32}^2		132		6.3.1 Quasi-Elastic Scattering
91		4.2.3 Measurement of the Mass Ordering	50	133		6.3.2 Cross Sections and Polarization Observables in Quasi-Elastic Processes 94
92		4.2.4 Projected Oscillation Measurements with Atmospheric Neutrinos	51	134		6.3.3 Inelastic Scattering
93		4.2.5 Possibilities with Atmospheric Neutrinos	52	135	0.4	6.3.4 Deep Inelastic Scattering
93		4.3 Solar Neutrino Experiments		136	6.4	Neutrino Interactions with Nuclei
95		4.3.1 Measurement of θ_{12} and Δm_{21}^2		137		6.4.1 Neutrino Energy Determination
95		4.3.2 Matter Effects in Solar Neutrino Oscillations	54	138		6.4.2 Neutrino Interaction Rate Determination
96				139		6.4.3 Nuclear Models
97		4.3.3 Projected Oscillation Measurements with Solar Neutrinos	54	140		6.4.4 Multi-Nucleon Correlation Effects

141			6.4.5 Final State Interactions
142			6.4.6 Random Phase Approximation and Spectral Functions 100
143			6.4.7 Neutrino Interactions in the few Tens of MeV Range 101
144			6.4.8 Coherent Elastic Neutrino-Nucleus Scattering
145			6.4.9 Ultra High Energy Neutrino Cross Sections
146			6.4.10 Present and Future Experiments
147		6.5	Neutrino Interactions: Summary
	7	The	Number of Neutrinos 108
148	-	7.1	Introduction
149		7.2	Sterile Neutrinos and Accelerators
150		1.4	7.2.1 Current Status
151			7.2.2 Future Prospects
152		7.3	Sterile Neutrinos and Reactors
153		1.3	7.3.1 Current Status
154			
155		71	
156		7.4	Sterile Neutrinos and other Experiments
157			7.4.1 Radioactive Sources
158			7.4.2 Neutrino Mass Experiments
159		7 F	7.4.3 Solar and Atmospheric Neutrinos
160		7.5	eV-Scale Sterile Neutrinos and Cosmology
161		7.6	Global Fits
162		7.7	The Number of Neutrinos: Summary
102			,
	8	Nev	
163 164	8		v Technologies, Cross-over to other Science, and Frameworks for Neu- o Physics
163	8		v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics
163 164	8	trin	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121
163 164 165	8	trin 8.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121
163 164 165 166	8	trin 8.1 8.2	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 122
163 164 165 166 167	8	8.1 8.2 8.3	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 128
163 164 165 166 167 168 169		8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132
163 164 165 166 167 168 169	9	8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 rsics Implications and Vision 134
163 164 165 166 167 168 169		8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 vsics Implications and Vision 134 Learning about Sources 134
163 164 165 166 167 168 169		8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 vsics Implications and Vision 134 Learning about Sources 134 9.1.1 Better understanding the interior of the Earth 135
163 164 165 166 167 168 169		8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 vsics Implications and Vision 134 Learning about Sources 134 9.1.1 Better understanding the interior of the Earth 135 9.1.2 Learning about the Sun 136
163 164 165 166 167 168 169 170 171		8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 Visics Implications and Vision 134 Learning about Sources 134 9.1.1 Better understanding the interior of the Earth 135 9.1.2 Learning about the Sun 136 9.1.3 Learning about the Death of Massive Stars 136
163 164 165 166 167 168 169 170 171 172 173 174		trin 8.1 8.2 8.3 8.4 8.5 Phy 9.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 121 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 rsics Implications and Vision 134 Learning about Sources 134 9.1.1 Better understanding the interior of the Earth 135 9.1.2 Learning about the Sun 136 9.1.3 Learning about the Death of Massive Stars 136 9.1.4 Learning about the Cosmos 137
163 164 165 166 167 168 169 170 171 172 173		8.1 8.2 8.3 8.4 8.5	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics 121 Introduction and Community 121 Technologies and Capabilities 122 Infrastructure 129 Theory 131 Impact and Societal Benefits 132 Visics Implications and Vision 134 Learning about Sources 134 9.1.1 Better understanding the interior of the Earth 135 9.1.2 Learning about the Sun 136 9.1.3 Learning about the Death of Massive Stars 136 9.1.4 Learning about the Cosmos 137 High-Energy Neutrino Astrophysics 138
163 164 165 166 167 168 169 170 171 172 173 174		trin 8.1 8.2 8.3 8.4 8.5 Phy 9.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics Introduction and Community Introduction and Capabilities Infrastructure Infrastructure Infrastructure Inpact and Societal Benefits Inpact and Societal Benefits Instructure Instru
163 164 165 166 167 168 169 170 171 172 173 174 175		trin 8.1 8.2 8.3 8.4 8.5 Phy 9.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics Introduction and Community Introduction and Community Infrastructure Infrast
163 164 165 166 167 168 169 170 171 172 173 174 175 176		trin 8.1 8.2 8.3 8.4 8.5 Phy 9.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics Introduction and Community Introduction and Community Infrastructure Infrast
163 164 165 166 167 168 169 170 171 172 173 174 175 176 177		trin 8.1 8.2 8.3 8.4 8.5 Phy 9.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics Introduction and Community Introduction and Community Infrastructure Infrast
163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178		trin 8.1 8.2 8.3 8.4 8.5 Phy 9.1	v Technologies, Cross-over to other Science, and Frameworks for Neu- to Physics Introduction and Community Introduction and Community Infrastructure Infrast

9.3	Theoretical Implications of Neutrino Mass and Lepton Mixing 14
	9.3.1 Dirac or Majorana Neutrinos?
	9.3.2 Origin of Neutrino Mass
	9.3.3 Flavor Symmetries
9.4	Connections of Neutrinos to beyond the Standard Model Physics 14
	9.4.1 Flavor Physics
	9.4.2 Dark Matter
	9.4.3 The Baryon Asymmetry of the Universe
	9.4.4 Unification
9.5	Sterile Neutrinos
9.6	New Physics in Neutrino Experiments
	9.6.1 Non-Standard Interactions
	9.6.2 Unitarity Violation
	9.6.3 Magnetic Moments and other electromagnetic Features
	9.6.4 Other Possibilities
9.7	Physics Implications: A final Word

Altogether 220 pages

163 pages text

• 841 references

- very positive community feedback
- Proposal to publish as review

Status & Plans

- Absorbing final comments and completing the executive summary
- Final steps and plans:
 - Finalize executive summary first week of October
 - submit to IUPAP C11 and General Council
 - put final report on panel web page
 - ask for permission to publish the science part as review