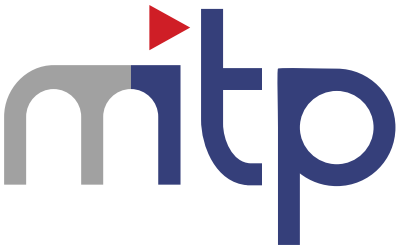


Mainz Institute for Theoretical Physics

Scientific Report 2022

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Contents

1 Bouncing back from the pandemic

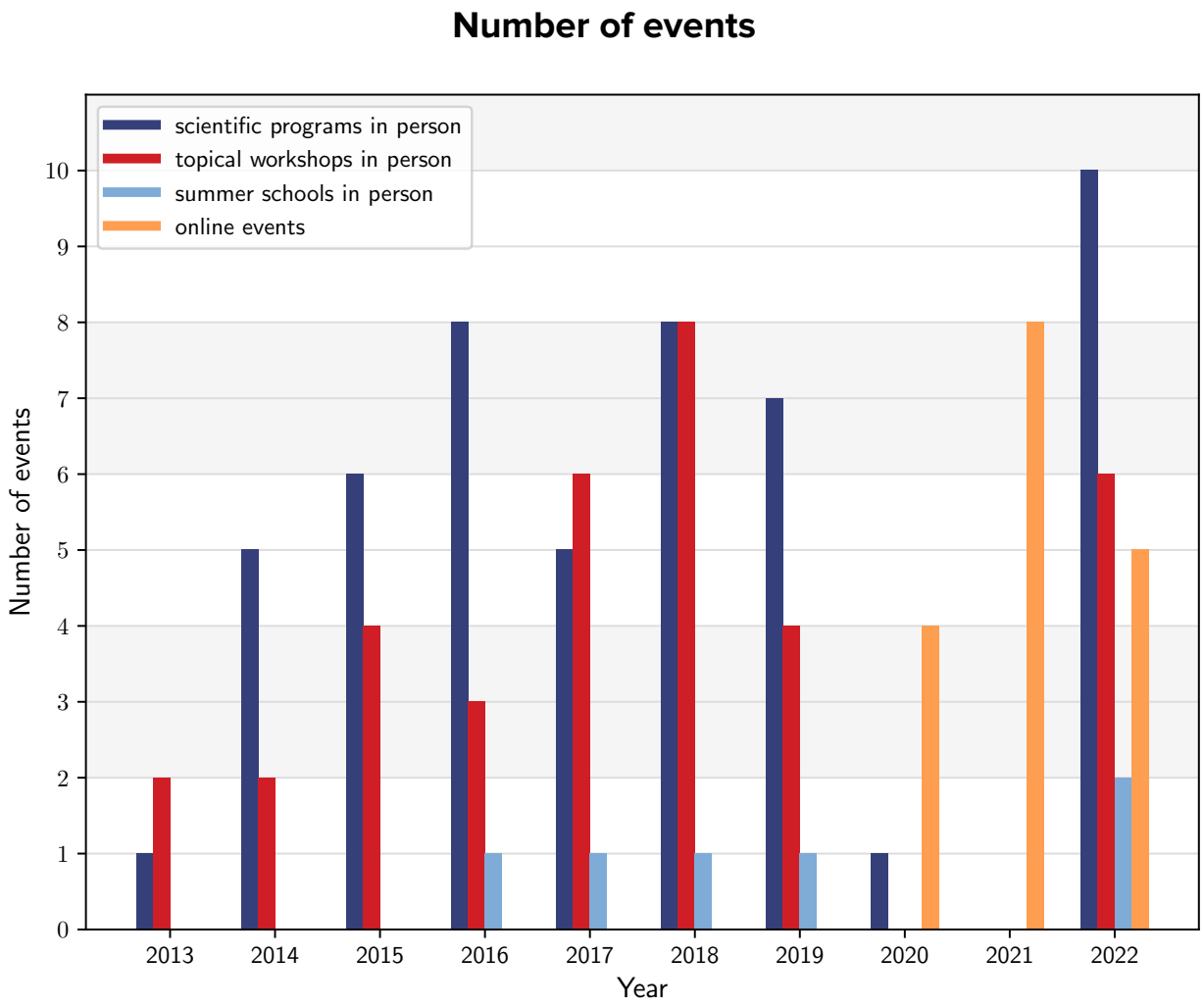
The **coronavirus pandemic**, reaching central Europe in the spring of 2020, had a disruptive effect on the MITP, driving activities to a halt. During 2020 only one scientific program could be celebrated in person, and the remaining seven programs, two topical workshops and one summer school had to be postponed. Adapting to the new situation, and given the continuing need of scientific exchange of the research community, MITP went ahead and organized four **virtual workshops** in the second half of 2020.

In 2021, the pandemic situation continued, and once more virtual events allowed MITP to stay relevant and serve the community. Out of the eight scientific workshops that were initially planned, four could be converted into virtual events. Similarly, one out of five topical workshops and one out of two summer schools took place online.

Responding again to the needs of the field, and particularly of young people starting their research career without an established network of collaborators, MITP organized a **new series of online events, the YOUNGST@RS program**, whose first workshop kicked off at the end of 2021. The 2021 virtual program was a success, attracting 1482 participants.

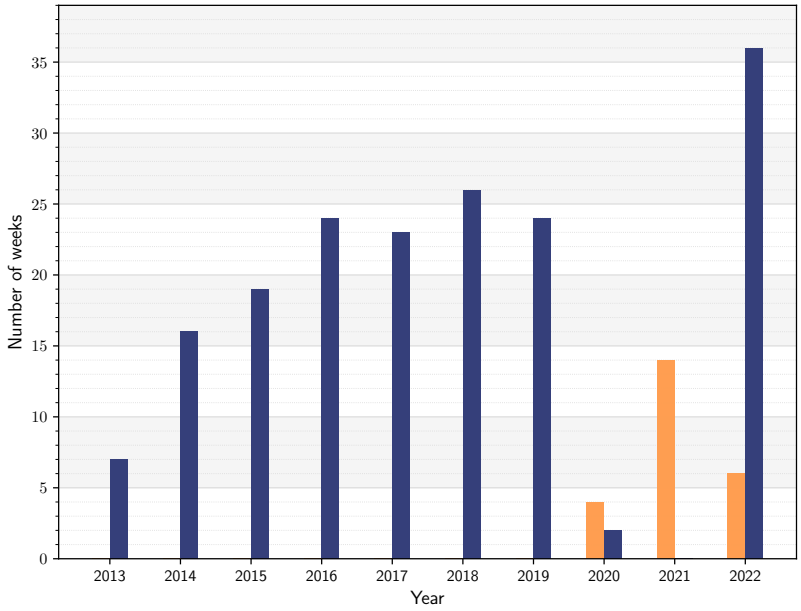
The virtual events continued in 2022, with four additional YOUNGST@RS events and a further workshop, distributed over six weeks of online events. Finally, after the first challenging years of the covid pandemic, the **in-person events** returned with full-force. 2022 saw a record-breaking of ten scientific programs, six topical workshops and two summer schools, distributed over 36 active weeks of in-person events. The **summer schools** merit special mention, as 2022 saw the **first TALENT summer school** and the **first joint school with ICTP/SAIFR** in São Paulo.

A record-breaking year



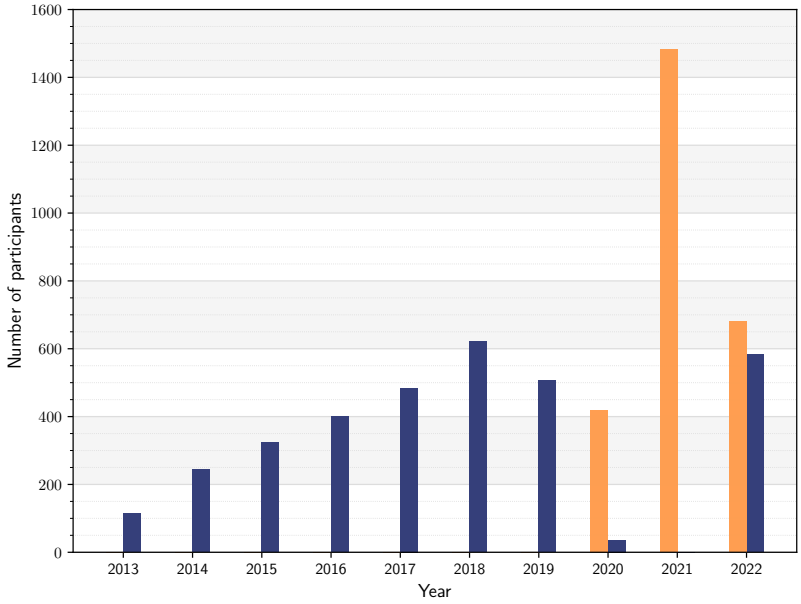
10 scientific programs
6 topical workshops
2 summer schools
5 online events

Number of weeks with virtual/in-person events



6 weeks of online events
36 weeks of in-person events

Number of virtual/in-person participants



680 virtual participants
583 in-person participants

2 Overview of scientific activities

2022 poster with in-person events:

mitp Mainz Institute for Theoretical Physics

ACTIVITIES 2022

www.mitp.uni-mainz.de

SCIENTIFIC PROGRAMS

Power Expansions on the Lightcone: From Theory to Phenomenology
Robert Szafron (Brookhaven Nat. Lab.), Ian Moult (Stanford Univ.) and Kai Yan (MPI Munich)
February 14 – 25, 2022

Hadron Spectroscopy: The Next Big Steps
Biplab Dey (Eötvös Loránd Univ.), Patricia Camargo Magalhaes (Univ. Bristol), Elisabetta Prencipe (Justus Liebig Univ. Giessen), Jonas Rademacker (Univ. Bristol)
March 14 – 25, 2022

Mega Dark Matter: Theory and Detection
Yang Bai (Univ. Wisconsin-Madison), Joseph Bramante (Queen's Univ.), Dorota Grabowska (CERN), Andrew Long (Rice Univ.), Jessica Turner (Durham Univ.)
May 2 – 20, 2022

Flavor at the Crossroads
Javier Fuentes-Martín (JGU), Peter Stangl (Bern Univ.), Matthias König (TUM, Munich), Carla Marín Benito (LHCb, CERN), Giulio Dujany (Belle II, Strasbourg Univ.)
April 19-29, 2022

Amplitudes Meet BSM
Yu-tin Huang (National Taiwan Univ.), Ian Low (Northwestern Univ.), Alex Pomarol (IFAE Barcelona Univ.), Yael Shadmi (Technion)
May 30 – June 10, 2022

Neutrinos, Flavour and Beyond
Giulia Ricciardi (Univ. Napoli Federico II), Silvia Pascoli (IPPP Durham), Serguey Petcov (SISSA Trieste), Matthias Neubert (JGU)
June 6 – 17, 2022 Anacapri, Italy

A Deep-Learning Era of Particle Theory
Jim Halverson (Northeastern Univ.), Sven Krippendorf (Munich Univ.), Michela Paganini (DeepMind), Tilman Plehn (Heidelberg Univ.), Veronica Sanz (Univ. of Valencia / Univ. Sussex)
June 13 – July 8, 2022

Towards the Next Fundamental Scale of Nature: New Approaches in Particle Physics and Cosmology
Nathaniel Craig (UCSB), Nayara Fonseca (ICTP), Camila Machado (DESY), Gilad Perez (Weizmann), Pedro Schwaller (JGU), Ben Stefanek (Univ. Zurich)
July 11 – 22, 2022

Probing New Physics with Gravitational Waves
Yanou Cui (Univ. California, Riverside), Francesco D'Eramo (Univ. Padua / INFN Padua), Enrico Morgante (JGU), Lisa Randall (Harvard Univ.), Pedro Schwaller (JGU), Raman Sundrum (Univ. Maryland)
July 25 – August 12, 2022

What's the Matter? A Cross-Frontier Pursuit of the Origin of Matter
Djuna Croon (Durham Univ.), Kaori Fuyuto (UNM Los Alamos), Julia Harz (TUM), Joachim Kopp (CERN / JGU), Brian Shuve (Harvey Mudd College / UC Riverside)
August 22 – September 9, 2022

Flavour of BSM in the LHC Era
Diptimoy Ghosh (IISER Pune), Jernej Fesel Kamenik (Univ. Ljubljana), Seung J. Lee (Korea Univ.), Paride Paradisi (Univ. Padua / INFN Padua)
October 10 – 21, 2022

TOPICAL WORKSHOPS

The Evaluation of the Leading Hadronic Contribution to the Muon g-2: Toward the MUonE Experiment
Carlo M. Carloni Calame (INFN Pavia), Massimo Passera (INFN Padua), Luca Trentadue (Univ. Parma / INFN Milano Bicocca), Graziano Venanzoni (LNF Franscati)
April 4 – 8, 2022

Precision Tests with Neutral-Current Coherent Interactions with Nuclei
Jens Erler (JGU), Charles Horowitz (Indiana Univ.), Mikhail Gorshteyn (JGU), Hubert Spiesberger (JGU)
May 23 – 27, 2022

Searches for Wave-Like Dark Matter with Quantum Networks
Hendrik Bekker (HIM), Dmitry Budker (HIM), Derek F. Jackson Kimball (California State Univ. - East Bay), Tanja E. Mehlstäubler (PTB / Leibniz Univ. Hannover), Arne Wickenbrock (HIM)
August 15 – 19, 2022

Elliptic Integrals in Fundamental Physics
Johannes Blümlein (DESY Zeuthen), Ekta Chaubey (Durham Univ.), Claude Duhr (CERN)
September 12 – 16, 2022

Electroweak Precision Physics from Beta Decays to the Z Pole
Monika Blanke (KIT), Andreas Crivellin (Univ. Zurich / PSI), Martin Hoferichter (Univ. Bern), Chien-Yeah Seng (Bonn Univ. / HISKP), Mikhail Gorshteyn (JGU)
October 24 – 28, 2022

Quantum Methods for Lattice Gauge Theories
Mari-Carmen Bañuls (MPI Quantum Optics), Alessio Celi (Physics Dept. UAB), Karl Jansen (NIC, DESY Zeuthen), Simone Montangero (Univ. Padua)
November 7 – 11, 2022

MITP SUMMER SCHOOLS

TALENT School @ MITP
Effective Field Theories in Light Nuclei: From Structure to Reactions
Sonia Bacca (JGU), Nir Barnea (Hebrew Univ. of Jerusalem), Pierre Capel (JGU), Hans-Werner Hammer (TU Darmstadt), Kai Hebeler (TU Darmstadt), Daniel Phillips (Ohio University, Athens)
July 25 – August 12, 2022

BRAZIL
Joint ICTP-SAIFR / MITP Summer School on Particle Physics
Gustavo Burdman (IF-USP), Matthias Neubert (MITP), Rogerio Rosenfeld (IFT-UNESP / ICTP-SAIFR), Felix Yu (MITP)
September 12 – 23, 2022

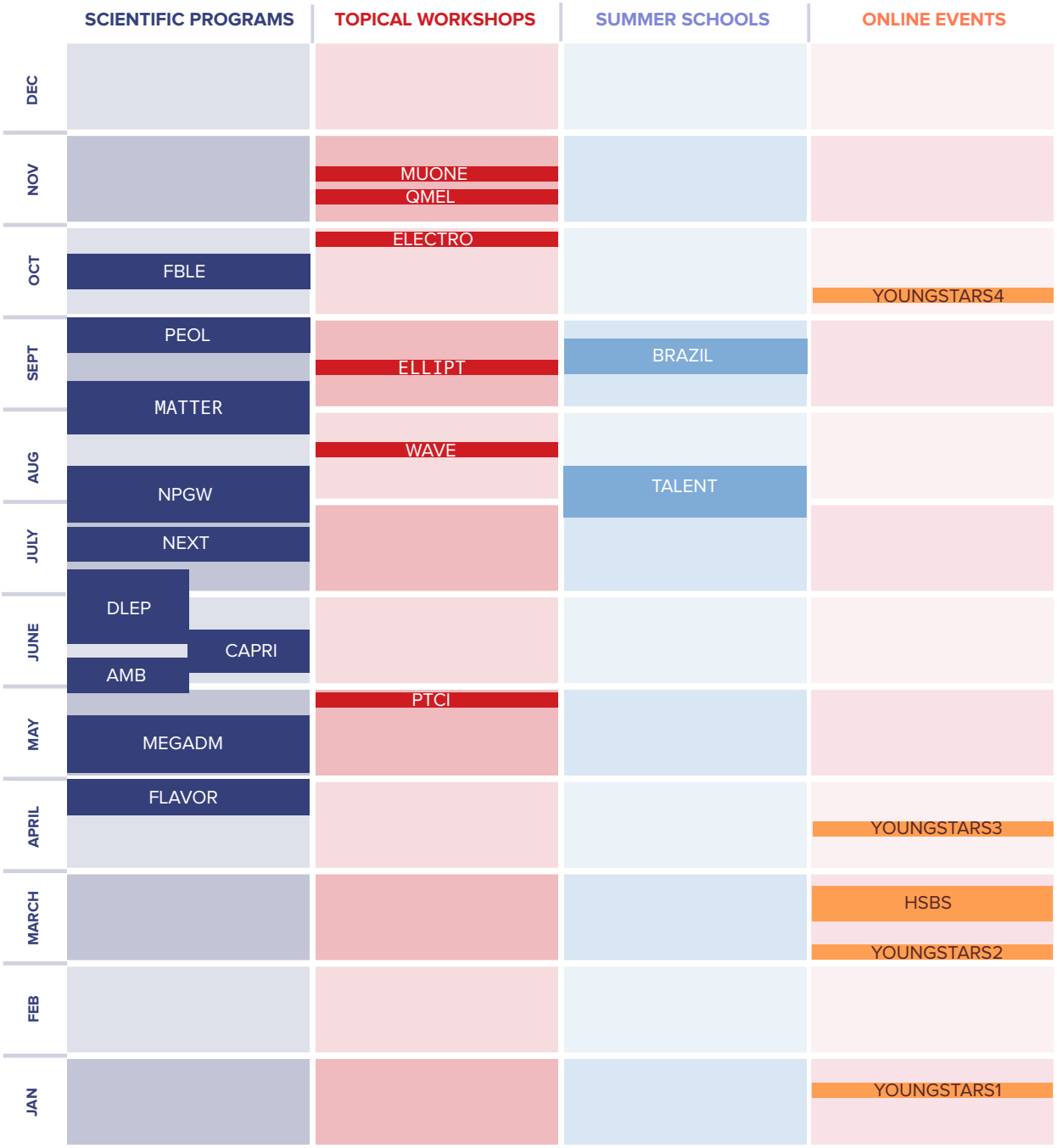
JGU

Cluster of Excellence PRISMA+ Precision Physics, Fundamental Interactions and Structure of Matter

Mainz Institute for Theoretical Physics
PRISMA+ Cluster of Excellence
Johannes Gutenberg-Universität Mainz, Germany

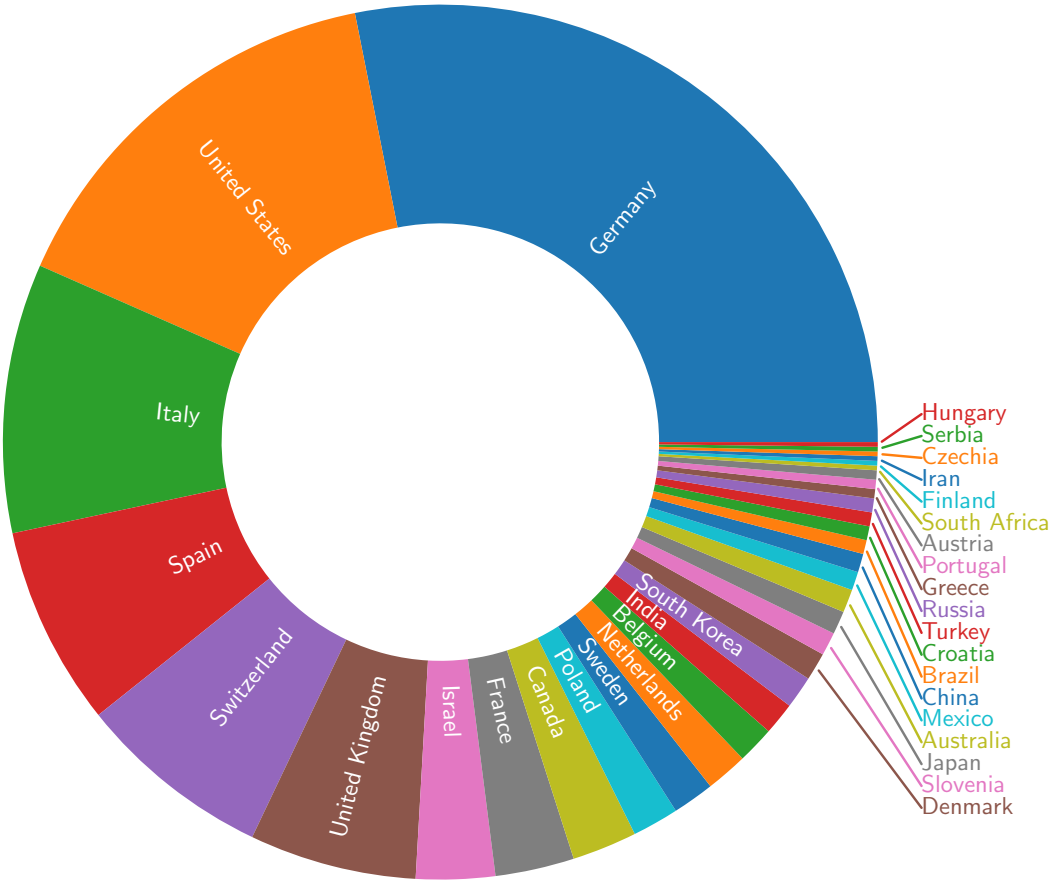
Calendar view of all events:

Abbreviations are used; see section 5 for the full names of the events.



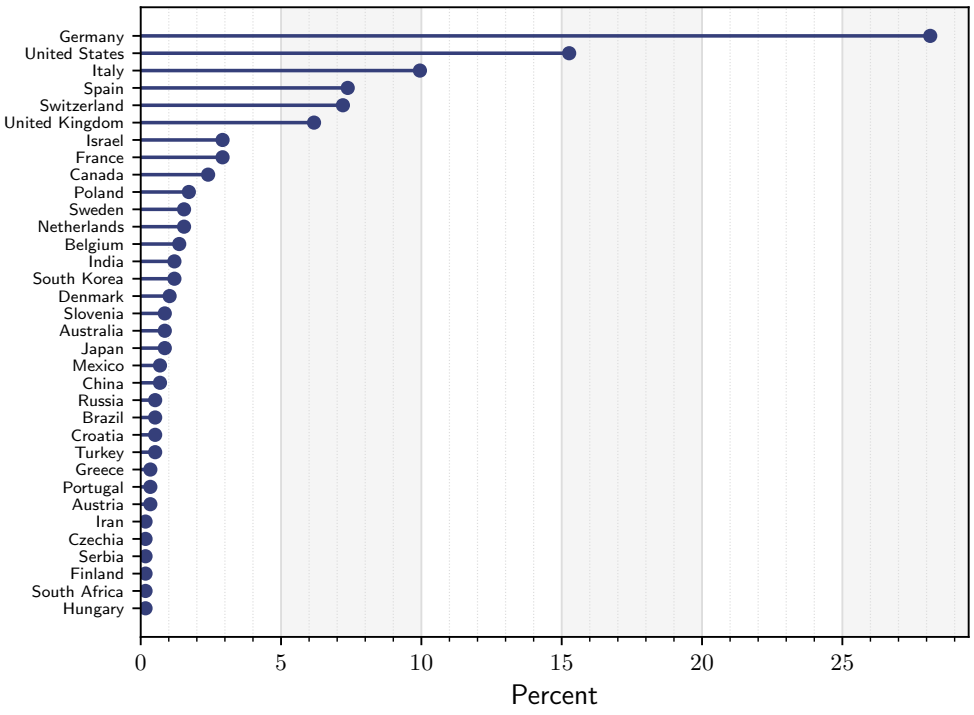
3 Statistics of participants and organizers

Country of home institute for in-person participants in 2022

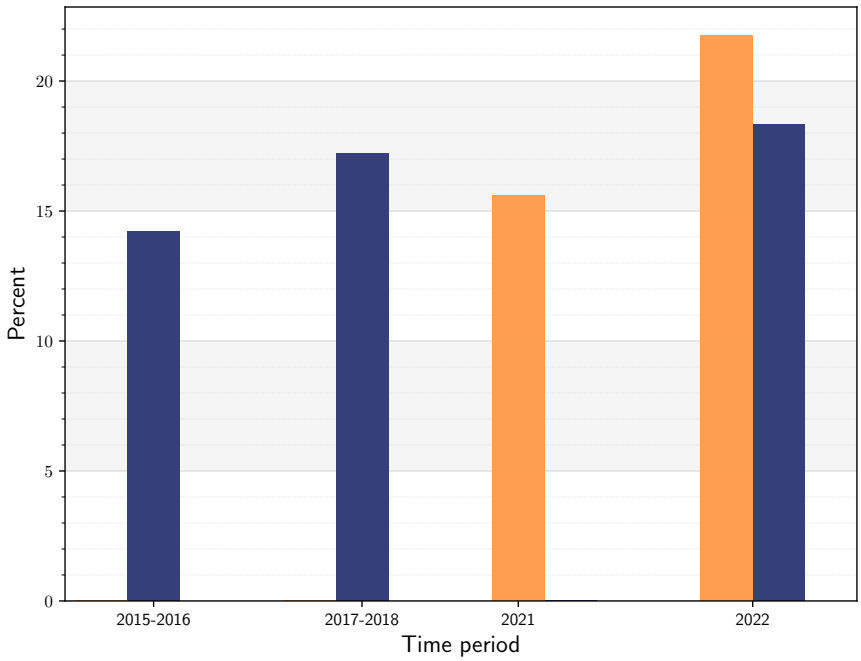


583 in-person participants
34 countries
72% international

Country of home institute for in-person participants in 2022

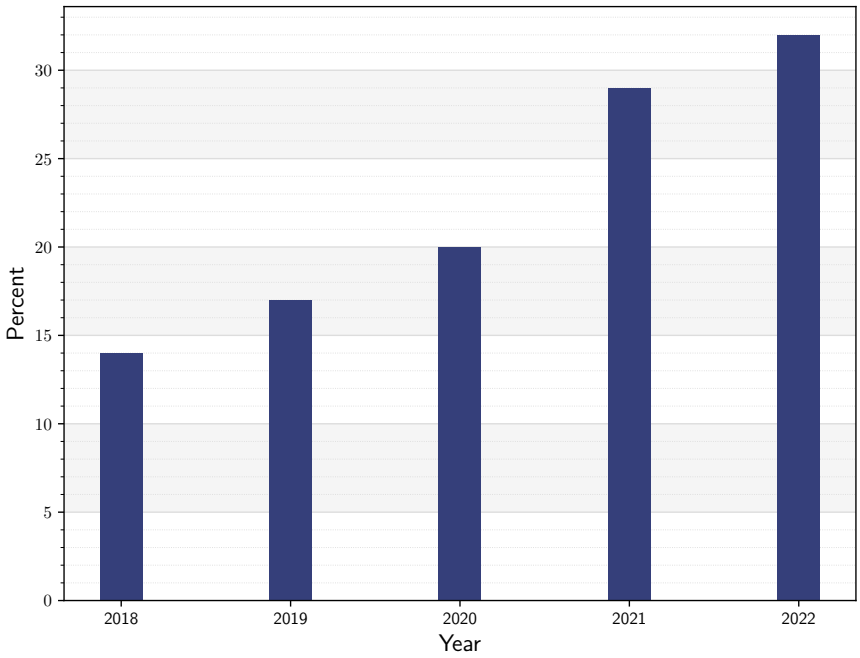


Percentage of female participants in virtual/in-person events



2022: highest participation of women in online and in-person events at MITP

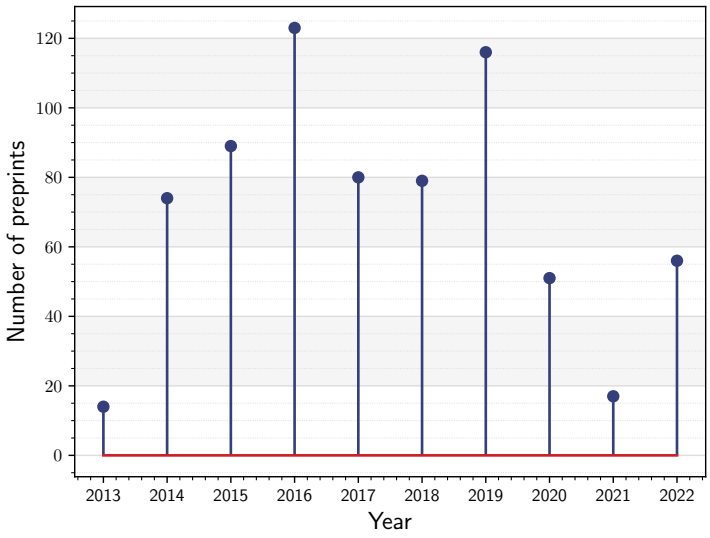
Percentage of female organizers in MITP events



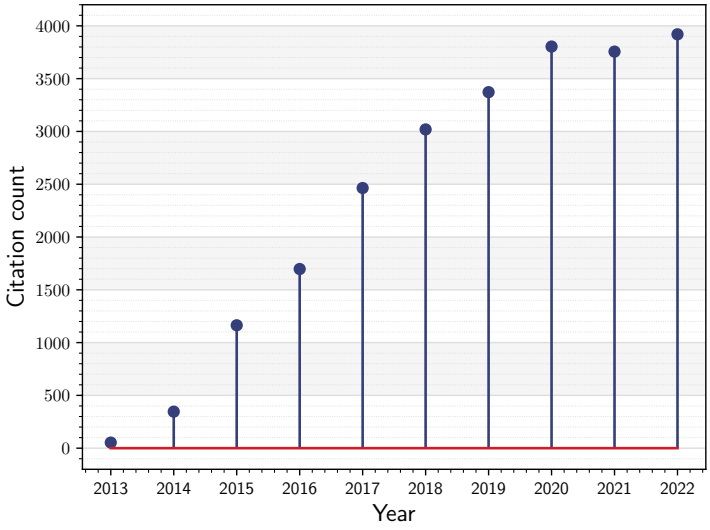
2022: highest proportion of female organizers

4 Scientific impact of MITP activities

Number of external preprints acknowledging MITP



Citations of external preprints acknowledging MITP



As illustrated in the figures above, the **impact of the pandemic** is reflected in the drop of external publications acknowledging MITP in 2020 and 2021. This was particularly notable in 2021 despite the larger number of virtual events, which shows that scientists are less prone to acknowledge the support of MITP during online workshops. Along the same lines, the yearly citation count generated by all preprints acknowledging MITP sank for the first time in 2021, where the citations were mainly driven by papers from the previous years. The return to in-person meetings reverted the trend and the total **citation count in 2022** experimented the **maximum** of the series.

5 Goals and achievements of the 2022 events

In the following, we provide summaries of the main aims and results of the MITP events of 2022. The content has been distilled from the executive summaries written by the workshop organizers, which can be downloaded from each event's webpage. After the full name of each event we provide the abbreviation used in the calendar of section 2.

5.1 Scientific Programs

5.1.1 Flavor at the crossroads [FLAVOR]

April 19 – 29, MITP Mainz

Giulio Dujany (IPHC CNRS), Javier Fuentes-Martín (Granada U.), Matthias König (TU Munich), Carla Marín Benito (CERN), Peter Stangl (Bern U.)

The program aimed to bring together theorist and experimentalists in order to discuss recent measurements and their theoretical interpretation, as well as novel directions for future runs at Belle II and LHC.

There was an almost even mix of theorist and experimentalists, and the discussions had their main focus on rare and semileptonic B-meson decays and related transitions. Model building ideas and the complementarity with direct searches at the LHC were also debated.

> This program helped strengthening collaborations between theorist and LHCb Run II and Belle II experimentalists, and led to multiple discussions that will ultimately impact decision-making process on future search priorities at those experiments.

5.1.2 Mega Dark Matter: Theory and Detection [MEGADM]

May 2- 20 2022, MITP Mainz

Yang Bai (Univ. Wisconsin-Madison), Joseph Bramante (Queen's Univ.), Dorota Grabowska (CERN), Andrew Long (RICE Univ.), Jessica Turner, (Durham Univ.)

The goal of the program was to accelerate the search for mega dark matter —i.e. with large mass or involving large sizes— by engaging experts on the theory and detection of dark matter. Examples of mega-dark matter candidates that were considered are dark nuclei, quark nuggets, Q-balls, primordial black holes, and objects such as axion stars.

The organizers highlight that the discussions during the program led to a thorough analysis of non-topological soliton formation, either from solitosynthesis or from phase transitions. The challenge of classifying dark nuclear states according to the energy deposition and the physical size was discussed. The input of the program has contributed to feasibility studies for novel searches of megadark matter.

> [...] a feasibility study of searching for mega dark matter at the largest neutrino detector, IceCube, has been performed with input from this program. A related study for dark matter induced nucleon decay signals in mesogenesis was also initialized during this program. A study on astrophysical x-ray signatures of boson stars benefited from workshop input.

5.1.3 Amplitudes Meet BSM [AMB]

May 30 – June 10 2022, MITP Mainz

Yu-tin Huang (National Taiwan Univ.), Ian Low (Argonne and Northwestern Univ.), Alex Pomarol (IFAE and Barcelona Autonoma Univ.), Yael Shadmi (Technion)

The purpose of the workshop was to bring together experts on amplitude methods and beyond-the-Standard-Model physics to discuss the newest lines of research and generate new ideas.

The discussions covered the following topics: constraints to EFT Wilson coefficients imposed by causality and unitarity; boundary structure; “positive” geometry and quantum effects; on-shell methods for theories without Lagrangian descriptions, and selection rules for quantum corrections.

> We received very good feedback from the participants about the workshop, which we consider to be a great success as it triggered many discussions and brought new insights into the field.

5.1.4 Neutrinos, Flavour and Beyond [CAPRI]

June 6 – 17, 2022 Anacapri, Italy

Matthias Neubert (JGU Mainz), Silvia Pascoli (Univ. Bologna), Serguey Petcov (INFN/SISSA), Giulia Ricciardi (Univ. Napoli Federico II)

The program was meant to address physics beyond the Standard Model from the combined perspectives of flavour, electroweak and neutrino physics, with the goal of interpreting the results from a wide range of experiments, and formulating a coherent framework to account for them.

The discussions covered flavour anomalies, the flavour problem for quarks and leptons and its connection to discrete or continuous symmetries, as well as connections between the Higgs sector and neutrinos.

> The 2022 edition has been a lively and successful one; all participants seemed glad to have the opportunity to meet in presence again after the pandemic.

5.1.5 A Deep-Learning Era of Particle Theory [DLEP]

June 13 – July 8, MITP Mainz

Jim Halverson (Northeastern Univ./IAIFI), Sven Krippendorf (LMU Munich), Tilman Plehn (Heidelberg Univ.), Veronica Sanz (Univ. of Valencia / Univ. of Sussex)

The workshop attracted experts in the growing field of machine learning in particle physics. The first main goal was the discussion of theoretical applications of machine learning to the following topics: string theory and mathematics, the simulation of quantum fields, cosmology, and accelerator phenomenology. A second goal was to kickstart a new stage in the relation between machine learning and particle physics, in which the physicists join forces and transition from applying established data science concepts to developing novel physics-specific ideas and tools, which in turn might impact the broader field of data science.

The organizers were impressed by the consistent quality of the talks and discussions, and note that the research directions driving the workshop have become the leading topics of many subsequent events, in which the participants of the MITP workshop could make an impact thanks to the preparation acquired in the Mainz event.

> [...] the goal of developing physics-specific ML-approaches and connecting them closer to the physics community, like LHC Monte Carlo simulations, has been reached.

5.1.6 Towards the Next Fundamental Scale of Nature: New Approaches in Particle Physics and Cosmology [NEXT]

July 11 – 22, MITP Mainz

Nathaniel Craig (UCSB), Nayara Fonseca (IBM Research Europe UK), Camila Machado (DESY), Gilad Perez (Weizmann), Pedro Schwaller (JGU Mainz), Ben Stefanek (Univ. Zurich)

Leading experts in particle physics and cosmology from around the world gathered to discuss innovative approaches to uncover the next fundamental scale of nature.

Recent experimental and model-building developments were discussed, with the organizers highlighting the presentations on axion searches.

> The event was a highly productive and exciting opportunity for the scientific community to learn about the latest developments in particle physics and cosmology, network with their peers, and work together towards uncovering the next fundamental scale of nature.

5.1.7 Probing New Physics with Gravitational Waves [NPGW]

July 25 – August 12, MITP Mainz

Yanou Cui (Univ. of California, Riverside), Francesco D'Eramo (Univ. of Padua/INFN Padua), Enrico Morgante (JGU), Lisa Randall (Harvard Univ.), Pedro Schwaller (JGU), Raman Sundrum (Univ. of Maryland)

This scientific program had the objective of discussing new opportunities offered by gravitational waves as probes of new physics in the early and late universe.

The participants discussed mechanisms to produce gravitational waves in the early universe, e.g. inflation, preheating, phase transitions and topological defects. The detectability of the corresponding signals was also debated, and the most promising testable scenarios for physics beyond the Standard Model were identified.

> [...] this event encouraged interdisciplinary interactions among different areas of particle physics and cosmology and facilitated the participation of young people.

5.1.8 What's the Matter? A Cross-Frontier Pursuit of the Origin of Matter [MATTER]

August 22 – September 2, MITP Mainz

Djuna Croon (Durham Univ.), Kaori Fuyuto (Los Alamos National Laboratory), Julia Harz (TUM), Joachim Kopp (CERN / JGU) and Brian Shuve (Harvey Mudd College / UC Riverside)

The program's motivation was to explore common and complementary opportunities for discovering the origin of the baryon asymmetry.

The discussions touched upon many topics in high-energy theory, including the development of new calculation tools, experimental tests at high and low energy, phase transitions and gravitational waves, neutrino physics and dark matter. The workshop hosted a discussion on the current status of diversity and equity and physics, where the participant shared their experiences and brainstormed about possible actions that can be taken to improve the present situation.

> One of the goals of the workshop was to [...] host an event where we could focus on the challenges of improving diversity and equity in physics. The consensus overall was that many participants found the discussion useful in a way that they had not found other similar conversations to be.

5.1.9 Power Expansions on the Lightcone: From Theory to Phenomenology [PEOL]

September 19 – 30, MITP Mainz

Ian Moult (Yale University), Robert Szafron (Brookhaven Nat. Lab.), Kai Yan (Shanghai Jiao Tong University)

The workshop brought together world-class experts in different methods for computing power corrections, such as approaches based on effective field theory, as well as diagrammatic and nonperturbative techniques. The goal was to unify recent progress by different groups in the understanding of subleading power corrections to lightcone expansions, and to solve outstanding technical issues.

The organizers speak of a remarkable success, with fruitful informal discussions that helped identify promising future directions for the field and forged or reinforced collaborations. New ways were identified in which different approaches could be combined to further advance the field, and novel phenomenological avenues were discovered.

> The gathering of experts working in various aspects of power expansion, such as gauge theories and gravity, over a two-week period with ample time for informal discussion provided opportunities to identify promising future directions for the field.

5.1.10 Flavour of BSM in the LHC Era [FBLE]

October 10 – 21, MITP Mainz

Diptimoy Ghosh (IISER Pune), Jernej Fesel Kamenik (Univ. Ljubljana), Seung J. Lee (Korea Univ.), Paride Paradisi (Univ. Padua / INFN Padua)

The scientific program had the goal of discussing how flavour physics fits into the big picture —both within well-motivated theories beyond the Standard Model or using model-independent approaches— and explore the interplay between direct searches at the LHC and indirect probes at LHCb, Belle II and other low-energy precision experiments.

The organizers highlighted the experimental review seminars on recent results from LHCb and Belle II, as well as the ensuing discussions on the implications for future collider experiments and possible BSM scenarios.

> The presentations sparked several interesting discussions on the intersection of flavor physics and naturalness both within and beyond the Standard model, which continued well into the evenings.

5.2 Topical workshops

5.2.1 Precision Tests with Neutral-Current Coherent Interactions with Nuclei [PTCI]

May 23-27, MITP Mainz

Jens Erler (JGU), Mikhail Gorshteyn (JGU), Charles Horowitz (Indiana Univ.), Hubert Spiesberger (JGU)

The main aim was to review the physics opportunities of ultra-high precision polarization experiments at the MESA facility in Mainz, setting them within a broader context connecting parity-violating coherent electron-nucleus scattering with other phenomena involving neutral-currents.

The discussions touched on the challenges arising in theoretical calculations, experimental techniques, and sensitivity to possible effects beyond the Standard Model.

> The MITP workshop [...] realized the long-awaited opportunity to once again bring together world experts in the fields of parity violation in atoms and nuclei and neutrino scattering.

5.2.2 Searches for Wave-Like Dark Matter with Quantum Networks [WAVE]

August 15 - 19, MIT Mainz

Hendrik Bekker (HIM), Dmitry Budker (HIM), Derek F. Jackson Kimball (California State Univ. - East Bay), Tanja E. Mehlstäubler (PTB / Leibniz Univ. Hannover), Arne Wickenbrock (HIM)

The workshop focused on searches for ultra-light dark matter using networked sensors.

The discussions touched upon the Global Network of Optical Magnetometers, as well as generalized networks of quantum sensors. The types and topologies of dark matter amenable to detection with quantum networks (e.g. axion-like particles, dark photons and axion stars) were debated.

> For many participants, this was the first time meeting in person in several years. Therefore, besides opening the door to new collaborations, existing ones were invigorated. Even local bonds were strengthened thanks to the enthusiastic participation of Dr. Felix Yu.

5.2.3 Elliptic Integrals in Fundamental Physics [ELLIPT]

September 12-16, MITP Mainz

Johannes Brödel (ETH Zurich), Ekta Chaubey (Univ. Turin), Claude Duhr (Univ. Bonn), Stefan Weinzierl (JGU Mainz)

The workshop had the goal of bringing together particle physicists, string theorists and mathematicians in order to advance our understanding of elliptic functions —which are relevant for both particle physics and string theory— and thus enable more precise predictions for future physics experiments.

The organizers highlighted dynamic and productive discussions. Young participants reported on state-of-the-art results, while a final discussion considered future directions of the field, as well as interfaces to experimental physics and more phenomenologically oriented physicists.

> While the institute itself already provides a vivid and flexible environment, it is also the vibrant city center of Mainz with many cozy accommodations, restaurants and pubs, which substantially supported the successful workshop.

5.2.4 Electroweak Precision Physics from Beta Decays to the Z-Pole [ELECTRO]

October 24-28, MITP Mainz

Monika Blanke (KIT), Andreas Crivellin (Univ. Zurich / PSI), Mikhail Gorshteyn (JGU Mainz), Martin Hoferichter (Univ. Bern), Chien-Yeah Seng (Bonn Univ. / HISKP)

The workshop explored the interplay between the global electroweak fit and the determination of CKM matrix elements, in light of recent evidence for a deficit in the first-row unitarity of the CKM matrix.

The discussions covered prospects for improved Standard-Model predictions, novel experimental opportunities, and implications for scenarios of new physics.

> Triggered by the discussions at the workshop, we envision a short write-up that summarizes the status of the universal radiative corrections, including a recommended value for future Vud extractions.

5.2.5 Quantum Methods for Lattice Gauge Theories [QMEL]

November 7-11, MITP Mainz

Mari-Carmen Bañuls (MPI Quantum Optics), Alessio Celi (Physics Dept. UAB), Karl Jansen (NIC, DESY Zeuthen), Simone Montangero (Univ. Padua)

The workshop gathered experts on high-energy physics, condensed matter, quantum information and applied mathematics to discuss the development and application of quantum techniques to lattice gauge theories.

Topics covered included applications of quantum methods to the Standard Model, condensed matter and string theory, and the latest developments in tensor network algorithms. There were also presentations about models that are potentially realizable in quantum engineered systems.

> All in all, the workshop was successful. The participants enjoyed the activity, especially the opportunity to discuss among themselves, and the hospitality of the MITP. A significant number of actively participating young researchers testifies to the liveliness and future perspectives of the topic.

5.2.6 The Evaluation of the Leading Hadronic Contribution to the Muon $g-2$: Towards the MUonE Experiment [MUONE]

November 14-18, MITP MAINZ

Carlo M. Carloni Calame (INFN Pavia), Massimo Passera (INFN Padua), Luca Trentadue (Univ. Parma / INFN Milano Bicocca), Graziano Venanzoni (INFN Pisa)

This topical workshop had the goal of assessing the status of the theoretical determination of the muon anomalous magnetic moment in view of the E989 experiment at Fermilab, as well as the E34 experiment being developed at J-PARC.

The workshop focused on the leading-order hadronic contribution to the muon's magnetic moment, with particular attention devoted to the possibility of extracting it from space-like scattering data such as the muon-electron scattering process (MUonE experiment at CERN). The status of the experiment and of the corresponding theoretical predictions were discussed.

> [...] the workshop was extremely successful and we received positive feedback from all the participants. The community [...] had the opportunity to overview the results reached so far, to set the bases for future work and to consolidate the collaboration.

5.3 Summer schools

5.3.1 TALENT School @ MITP - Effective Field Theories in Light Nuclei: From Structure to Reactions

July 25-August 12, MITP Mainz

Sonia Bacca (JGU Mainz), Pierre Capel (JGU Mainz)

This school was part of the TALENT initiative (Training in Advanced Low Energy Nuclear Theory), and its goal was to provide the participants with a high-level training on effective field theories for nuclear physics and on numerical methods relevant for solving the few-body problem for light nuclei.

The school featured the following lectures:

- “Introduction to Effective Field Theory” by Hans-Wener Hammer (TU Darmstadt)
- “Chiral Effective Field Theory and Nuclear Forces” by Kai Hebeler (TU Darmstadt)
- “Few-Nucleon Structure” by Nir Barnea (Hebrew Univ. of Jerusalem)
- “Few-Nucleon Reactions” by Sonia Bacca (JGU Mainz)
- “Halo Effective Field Theory” by Daniel Phillips (Ohio University)
- “Reactions with Halo Nuclei” by Pierre Capel (JGU Mainz)

Lectures were given in the morning, while afternoons were devoted to active learning with exercises and hands-on sessions that included the use of existing computer programs and the development of code by the students.

5.3.2 BRAZIL - Joint ICTP-SAIFR / MITP Summer School on Particle Physics

September 12-23, ICTP-SAIFR, São Paulo

Gustavo Burdman (IF-USP), Matthias Neubert (JGU Mainz), Rogerio Rosenfeld (IFT-UNESP/ICTP-SAIFR), Felix Yu (JGU Mainz)

This event was the first joint school of the ICTP South American Institute for Fundamental Research (ICTP-SAIFR) and the MITP, and its goal was to provide in-depth lectures for advanced graduate students covering recent progress in cutting-edge topics in theoretical particle physics.

The school featured the following lectures:

- “Naturalness-motivated BSM” by Csaba Csaki (Cornell University, USA)
- “Cosmology” by Jay M. Hubisz (Syracuse U.):
- “Tools at the Frontiers of BSM: amplitudes” by Yael Shadmi (Israel Institute of Technology – Technion)
- “Tools at the Frontiers of BSM: future colliders and machine learning” by Tilman Plehn (University of Heidelberg)
- “The light and feeble frontier: light DM, Feebly Interacting Particles, Axion-like Particles and other beasts”, by Raffaele Tito d’Agnolo (IPhT-Saclay)
- “Frontiers in non-natural BSM” by Gilad Perez (Weizmann Institute)

5.4 Virtual events

5.4.1 YOUNGST@RS: The Quantumness of Hard Probes [YOUNGSTARS1]

Jan 17-21

João Barata (Univ. de Santiago de Compostela, Miguel Ángel Escobedo Espinosa (Univ. de Santiago de Compostela), Meijian Li (Univ. of Jyväskylä), Xiaojun Yao (Massachusetts Institute of Technology)

The workshop had the aim of discussing challenges in hard probes related to the quantum nature of these systems, and how quantum computing could potentially provide tools to address them.

The topics covered included quantum computers and the simulations of open quantum systems, real-time non-perturbative phenomena, quarkonium, jet-quenching and light-front quantization.

> We believed that there are a lot of synergies between these two fields and that there are many things to be learnt from the exchange of ideas. The development of the workshop has confirmed this.

5.4.2 YOUNGST@RS: Feebly Interacting Sectors Impact on Cosmology & Astrophysics [YOUNGSTARS2]

March 1-4

Andrea Caputo (Tel Aviv University & Weizmann Institute), Edoardo Vitagliano (University of California, Los Angeles)

The workshop brought together particle physicists, astrophysicists and astronomers to discuss how to probe fundamental physics, in particular feebly interacting sectors, through the study of astrophysical environments.

The discussions covered horizontal branch stars, the sun, supernovae, neutron stars and black holes. Constraints from energy loss, x-ray observations and the possibility of direct detection of feebly interacting particles were discussed.

> The [...] virtual workshop [...] brought together the particle physics, astrophysics and astronomy communities, forging new collaborations that will help refine existing ideas, identify the most promising candidate theories and come up with new possible signatures from astrophysical objects.

5.4.3 Hadron spectroscopy: the next big steps [HSBS]

March 14-25

Patricia Camargo Magalhaes (Univ. Bristol, Aeronautics Institute of Technology), Biplab Dey (Eötvös Loránd Univ.), Elisabetta Prencipe (Justus Liebig Univ. Giessen), Jonas Rademacker (Univ. Bristol)

The workshop had the goal of addressing recent challenges in hadron spectroscopy, given the recent observations of a plethora of states that do not fit the conventional potential models for baryons and mesons.

The main topics that were discussed included conventional spectroscopy, exotic states, potential models, lineshape studies, lattice calculations, amplitude analyses, muon magnetic moment, baryon-antibaryon interactions, and future collider perspectives.

> A plethora of new important results was presented at this workshop, focusing on a precise under- standing of the spectrum below open-charm and bottom thresholds.

5.4.4 YOUNGST@RS: Rebuilding the Tower of Babel: Bringing Together the Various Languages of Color–Kinematics Duality [YOUNGSTARS3]

April 11-13

Laura Johnson-Engelbrecht (ETH Zurich), Hyungrok Kim (Heriot-Watt Univ.), Tommaso Macrelli (ETH Zurich)

The workshop gathered researchers active in the field of color-kinematics duality (CKD) and double copy (DC) with the aim to provide a platform for discussing the latest results and to find a common ground to set future goals for the community.

The discussions covered different approaches to CKD/DC such as amplitude methods, methods using auxiliary spaces (e.g. pure spinors, twistor spaces, and double/exceptional field theory), approaches based on homotopy algebras and on classical solutions. Extensions to CKD/DC beyond Yang-Mills theory were also debated.

> [...] the task of formulating appropriate language(s) for CKD/DC remains an open and urgent question. While the various talks in the workshop presented fascinating and intriguing bridges between the various formalisms, still the big picture remains dimly lit.

5.4.5 YOUNGST@RS: Shoot for the Stars, Aim for the Axions [YOUNGSTARS4]

October 4-7

Pierluca Carenza (Stockholm Univ., OKC), Oindrila Ghosh (DESY) and Giuseppe Lucente (INFN Bari)

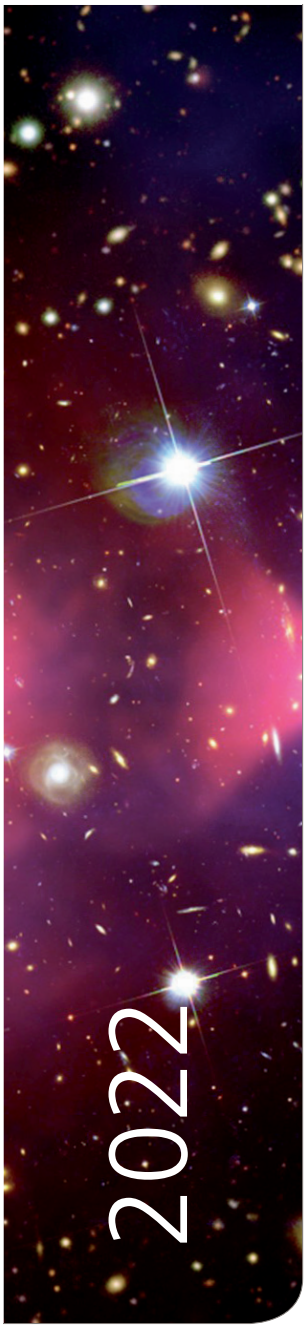
The goal of this virtual workshop was to link researchers in astrophysics, cosmology and high-energy physics in order to advance in our understanding of the properties of axion-like particles.

Topics covered included the theoretical landscape of axion-like particles, axions from stars, laboratory searches, and axion signatures in cosmic photon fluxes.

> The workshop played a crucial role in fostering collaborations across different fields and disciplines, and creating connections among young researchers and leading scientists.

6 Physik Im Theater

There were four “Physik Im Theater” (Physics in the theatre) events during 2022. The posters and abstracts are given below.



Mainzer Institut für Theoretische Physik

Physik im Theater

Öffentliche Vortragsreihe im
Staatstheater Mainz

02. Juni 2022, 19:00 Uhr, Kleines Haus
SCHNAPPSCHÜSSE AUS DEM FRÜHEN UNIVERSUM
Dr. Valerie Domcke | CERN

03. Juli 2022, 19:00 Uhr, Großes Haus
10 JAHRE HIGGS BOSON
Vom Higgs-Teilchen zur Suche nach Neuer Physik
Prof. Dr. Karl Jakobs | Universität Freiburg

10. Oktober 2022, 18:30 Uhr, Kleines Haus Sonderausgabe
Den Rätseln des Universums auf der Spur: Forschungs-Highlights aus 10 Jahren Excellenzcluster PRISMA
Prof. Dr. Matthias Neubert & Prof. Dr. Hartmut Wittig |
Johannes Gutenberg-Universität Mainz

24. November 2022, 19:00 Uhr, Großes Haus
Quantencomputer mit gefangenen Ionen
Prof. Dr. Ferdinand Schmidt-Kaler | Johannes Gutenberg-Universität Mainz

JGU

Cluster of Excellence PRISMA+
Precision Physics, Fundamental Interactions and Structure of Matter

Mainzer Institut für Theoretische Physik
Exzellenzcluster PRISMA+, JGU
www.mitp.uni-mainz.de

6.1 Snapshots from the early universe

02.06.2020, 19:00 Uhr, Kleines Haus

Dr. Valerie Domcke, Theoretical Physics Department at CERN

The ”Big Bang” model describes the evolution of our universe from a hot primordial plasma to the stars and galaxies that we see today. But what do we know about this early phase? Where are the laboratory logbooks of this high-energy experiment from which our universe emerged? The witnesses to this early phase of our universe are weakly interacting particles (photons, neutrinos, and gravitational waves) that can still carry imprints of the early history of our cosmos. In this lecture, Dr. Valerie Domcke will explain some of the resulting surprising insights into the properties of our universe.

6.2 10 years of the Higgs Boson. From the Higgs particle to the search for new physics

03.07.2022, 19:00 Uhr, Großes Haus

Prof. Dr. Karl Jakobs, University of Freiburg

The announcement of the discovery of the Higgs particle on July 4, 2012 by the ATLAS and CMS experiments at the European research center CERN in Geneva marked an important milestone in the study of the fundamental building blocks of matter and the forces acting between them. Where does particle physics stand today, 10 years after this discovery? At CERN, proton-proton collisions have been recorded very successfully during the past 10 years at the highest energies achievable so far. In the lecture, insights into this fascinating research will be given; thus, the present state, the open questions as well as perspectives will be discussed.

6.3 Tracing the Riddles of the Universe - Research Highlights from 10 Years of the Excellence Cluster PRISMA

10.10.2022, 18:30 Uhr, Kleines Haus

Moderation: Prof. Dr. Matthias Neubert und Prof. Dr. Hartmut Wittig, Johannes Gutenberg-Universität Mainz

Why did matter and antimatter not completely annihilate each other after the Big Bang? What is the invisible dark matter that makes up more than 80% of the mass of the cosmos? What is the role of the mysterious neutrinos in the early universe? For ten years now, scientists at the Cluster of Excellence PRISMA+ have been getting to the bottom of the greatest mysteries of modern physics. We would like to use this anniversary to take you on an exciting journey through time and around the world. It begins in 2012 in Switzerland with the discovery of the Higgs boson at the world's largest particle accelerator and then leads to Antarctica, where the IceCube experiment, buried deep in glacial ice, was able to detect a cosmic neutrino for the first time in 2018 —it came from a galaxy three billion light years away! At the end of the journey, we return to Mainz for a very special highlight: the electron accelerator MESA, which is currently being built on the campus of the Johannes Gutenberg University of Mainz, could provide important insights into the mysterious dark matter. We wish you a good trip!

6.4 Quantum computers with trapped ions

24.11.2022, 19:00 Uhr, Großes Haus

Prof. Dr. Ferdinand Schmidt-Kaler, Johannes Gutenberg-Universität Mainz

Quantum computers promise unprecedented computing power. What is the operating principle of these completely new machines? It is a consequence of the unexpected and unfamiliar properties of quantum mechanics. But what about the realization of the quantum computer? What are the first possible applications? Prof. Dr. Ferdinand Schmidt-Kaler will describe the way to build a quantum computer with ions, which will be connected to the high performance computer MOGON in Mainz. This combination will be particularly suitable for simulations of complex molecules and for energy optimization of chemical reactions.

7 New faces in the MITP team

All of the MITP management and guest relations staff changed in the pandemic years, which ensured no shortage of challenges. Added to that, there were new appointments for legal advice, IT support and scientific support. Here we give an overview of the new faces that have contributed to MITP in 2022.

Olga Zeeh-Sourli. New MITP manager

Barbara Behrend. Guest relations

Dominika Barrington. Guest relations

Constantin van de Loo. Legal advice

Andreas Welsch. IT support, coordination with PRISMA+

Carlos Tamarit. Scientific support

... and the challenges were met!

> We would like to extend our sincere gratitude to the MITP organization team for their efforts in organizing and hosting this scientific program. Their dedication and commitment to providing a top-quality program was truly commendable.

> We also thank the MITP secretaries, who made the organization of the workshop a real pleasure.

> We thank the MITP and especially its administrative staff for a professional and smooth running of the workshop. Especially the handling of last-minute cancellations and additions to the participant list was much appreciated during this time where the effects of Covid-19 could still be felt.

8 Snapshots from MITP activities

Group picture from MUONE participants

Group picture from FLAVOR participants

Participants of FLAVOR discussing in the lounge

Edition: Carlos Tamarit