The 8th Shanghai Symposium on Particle Physics and Cosmology: Cosmic Neutrinos, Multi-messengers and Innovative Detectors

Monday, 11 November 2024 - Friday, 15 November 2024

Tsung-Dao Lee Institute

Book of Abstracts

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Origin of Neutrino Masses and Lepton Flavor Mixing

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In this talk, we present a theoretical overview on our current understanding of neutrino masses and lepton flavor mixing. The typical ideas of Neutrino mass generation are summarized, and the basic properties of massive neutrinos are discussed in connection with future experimental observations.

Neutrino astronomy (MeV –EeV) / 3

Performance studies for the NEON project

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Over the last two decades, several breakthroughs have been made in multi-messenger astronomy, such as the successful observations of astrophysical neutrinos and very-high-energy gamma rays. However, the origin of cosmic rays is still mystery. No neutrino source has been significantly identified due to the lack of statistics and uncovered field of view. The next generation of high-energy neutrino telescope is in high demand. The proposed NEutrino Observatory in the Nanhai (NEON), located in the South China Sea, would be complementary for the global neutrino detectors. In this talk, I will introduce the design and layout of the array with a volume of 10 km^3, and present the performance studies. With our analysis the project will achieve an angular resolution of 0.1° at 100 TeV. With 10 years of operation, its 5σ sensitivity is estimated as $E^2\Phi \sim 2 \times 10^{-10}$ GeV cm^{-2} s^{-1} for a source spectrum index of -2.

Neutrino astronomy (MeV –EeV) / 4

Atmospheric neutrino flux calculation in low energies

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Atmospheric neutrinos are significant signals for studying neutrino oscillation physics and also serve as important backgrounds in the searches for diffuse supernova neutrino background, proton decay,

dark matter and other rare processes. To address the unknown questions in neutrino oscillation physics and to discover rare events, accurate predictions of atmospheric neutrino flux in the GeV and even lower energy ranges are required. In this talk, I will present the latest results on calculation of atmospheric neutrino fluxes at JUNO, Super-Kamiokande, Jinping and TRIDENT sites. The calculation scheme is based on the methods in [Honda et al. Phys. Rev. D 92, 023004 (2015)], with some improvements for greater precision in the low energy ranges.

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Neutrino Oscillation Analysis with New Event Samples at T2K

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Neutral current π^0 (NCπ^0) events are a major background for ν_e signal events in T2K neutrino oscillation measurements. These events, characterised by two photons from π^0 decay, can mimic the detector response of electrons in Super-Kamiokande (Super-K). Previously, there were no dedicated samples to effectively constrain this NCπ^0 background. To address this, events reconstructed with two Cherenkov rings (the 2-ring π^0 sample) have been selected, improving the modeling of NCπ^0 interaction cross-sections. In addition, events reconstructed as single-ring, which were previously rejected from the 1-ring e-like selection, are now included (referred to as the 1-ring π^0 sample). This adjustment recovers a portion of the ν_e signal events that were previously misidentified and rejected during selection.

The inclusion of these NCπ^0 samples offers a model-independent constraint on NCπ^0 backgrounds directly from Super-K data and increases the total ν_e ($\bar{\nu}_e$) signal events by 7% (11%) at T2K. Since NC interactions are flavor-independent, these samples provide a large event sample to serve as a cross-check of the total neutrino flux at Super-K, in comparison with the unoscillated flux measured near the neutrino beam production point. Furthermore, NCπ^0 samples offer unique advantages for sterile neutrino searches. A deficit in charged-current (CC) events without a corresponding deficit in NC events would be a strong signature of sterile neutrino oscillations.

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Testing neutrino mass origins with supernova neutrino time delay

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The origin of neutrino masses remains unknown. Both the vacuum mass and the dark mass generated by the neutrino interaction with dark matter (DM) particles or fields can fit the current oscillation data. The dark mass squared is proportional to the DM number density and therefore varies on the galactic scale with much larger values around the Galactic Center. This affects the group velocity and the arrival time delay of core-collapse supernovae SN neutrinos. This time delay, especially for the ν_e neutronization peak with a sharp time structure, can be used to distinguish the vacuum and dark neutrino masses. For illustration, we explore the potential of DUNE which is sensitive to ν_e. Our simulations show that DUNE can distinguish the two neutrino mass origins at more than 5σ C.L., depending on the observed local value of neutrino mass, the neutrino mass ordering, the DM density profile, and the SN location.

Data analysis techniques & tools / 7

Relic Neutrinos with Cosmic Gravitational Focusing

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The cosmic gravitational focusing (CGF) of relic neutrinos can provide an independent measurement of the absolute neutrino masses with a dependence on the fourth power of mass. In addition, CGF can help determine neutrino mass ordering. I will show that our projected CGF at DESI has a comparable sensitivity to the existing clustering method. Combining the projected CGF and clustering method can greatly constrain the neutrino mass and improve neutrino mass ordering from cosmology. Also, this result from cosmology can affect the prospects of neutrinoless double beta decay and single beta decay measurements.

Neutrino astronomy (MeV –EeV) / 8

Ultralight Black Holes as Astrophysical Particle Accelerators

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The *memory burden* effect, which stabilizes systems by storing information, plays a key role in black holes, where evaporation halts after roughly half the initial mass is lost. This suggests that light primordial black holes (PBHs) with mass below 10ˆ15 g, expected to have fully evaporated, may still be viable dark matter (DM) candidates. We show that their mergers could form "young" black holes, resuming evaporation and emitting ultrahigh-energy cosmic rays detectable by current experiments. Tensions arise between current neutrino flux measurements and light PBHs as DM, and we discuss refining these constraints through cosmic-ray, gamma-ray, and gravitational wave observations. Based on 2410.07037

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Probing and Knocking with Muons for Dark Matter and others

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We propose here a set of new methods to directly detect light mass dark matter through its scattering with abundant atmospheric muons or accelerator beams. Firstly, we plan to use the free cosmic-ray muons interacting with dark matter in a volume surrounded by tracking detectors, to trace possible interaction between dark matter and muons. Secondly, we will interface our device with domestic or international muon beams. Due to much larger muon intensity and focused beam, we anticipate the detector can be made further compact and the resulting sensitivity on dark matter searches will be improved. Furthermore, we will measure precisely directional distributions of cosmic-ray muons, either at mountain or sea level, and the differences may reveal possible information of dark matter distributed near the earth. Specifically, our methods can have advantages over 'exotic' dark matters

which are either muon-philic or slowed down due to some mechanism, and sensitivity on dark matter and muon scattering cross section can reach as low as microbarn level.

Reference: Phys. Rev. D 110, 016017

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Phenomenology with Massive Neutrinos in 2024

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Neutrino oscillation experiments have provided us with our only direct proof of physics beyond the standard model (BSM) in the form of lepton flavour violation in neutrino propagation due to neutrino masses and flavour mixing in the leptonic sector. In this talk I will first review the present status of neutrino masses and mixing in the minimal framework with three massive neutrinos. I will then discuss other new physics effects that can also probed with neutrino oscillations such as non standard neutrino interactions, models with new ultralight mediators or additional sterile neutrino states.

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A Brief Review of Ultrahigh-energy Gamma-ray Astronomy

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Ultra-High Energy (UHE, >0.1PeV) gamma-ray Astronomy is rapidly developing into an important branch of the gamma-ray astronomy with a lot of surprising discoveries. In this presentation, I will briefly review the main results of LHAASO, HAWC and ASgamma in recent years and discuss their physical implications.

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Understanding the multi-messenger and multi-wavelength data of the BOAT GRB 221009A

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The TeV afterglow of the BOAT GRB 221009A was interpreted as arising from a narrow jet, while the radio-to-X-ray afterglows were interpreted as arising from a wide structured jet. However, there is no model explaining the TeV and lower-energy multiwavelength afterglows simultaneously. We here investigate a two-component jet model, including a narrow uniform core with a wide structured wing, to explain both the multiwavelength afterglows that last up to 100 days.

Neutrino astronomy (MeV –EeV) / 13

Identifying cosmic ray transient sources with multimessenger observations initiated by high-energy neutrino signals

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Multmessenger follow-up observations triggered by high-energy neutrino signals offer a robust method for identifying cosmic ray (CR) sources, particularly when the sources are transient. In this talk, we propose a viable strategy for multimessenger observations to understand the origin of CRs. Optical transients, such as core-collapse supernovae, are among the major candidates for CR and neutrino sources, especially in the 10-100 TeV range. We show that demanding multiplet neutrino detection by a large neutrino telescope limits the distances of detectable neutrino sources, which allows us to identify emissions from abundant classes of objects by eliminating the possibility of the chance coincident transient detections. In the neutrino energy range above 100 TeV, the most likely source candidates are X-ray transients, particularly if the cosmic neutrino background radiation above 100 TeV originates from the same class of objects that emit ultrahigh-energy CRs (UHECRs). We demonstrate that this hypothesis is supported by model-indepent arguments. We illustrate how searches for X-ray counterparts conducted by wide-field X-ray satellites, such as Einstein Probe, provide insights into the unification models for UHECRs and neutrinos. The resulting bounds on the source parameter space place stringent constraints on the properties of UHECR origins.

Neutrino astronomy (MeV –EeV) / 14

A Unified Model for Multiepoch Neutrino Events and Broadband Spectral Energy Distribution of TXS 0506+056

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The blazar TXS 0506+056 has been proposed as a high-energy neutrino emitter. However, it has been shown that the standard one-zone model cannot produce sufficiently high neutrino flux due to constraints from the X-ray data, implying more complex properties of the radiation zones in the blazar than that described by the standard one-zone model. In this work, we investigate multiepoch high-energy muon-neutrino events associated with the blazar TXS 0506+056 that occurred in 2014–2015, 2017–2018, 2021–2022, and 2022–2023, respectively. We applied the so-called "stochastic dissipation model" to account for the neutrino-blazar associations detected in the four epochs simultaneously. This model describes a scenario in which the emission of the blazar arises from the superimposition of two components: a persistent component related to the quasi-stable state of the blazar and a transient component responsible for the sudden enhancement of the blazar's flux, either in electromagnetic radiation or in neutrino emission. The latter component could form at a random distance along the jet by a strong energy dissipation event. Under such an assumption, the multiepoch broadband spectral energy distribution can be well explained, and the expected number of high-energy neutrino events is statistically realistic. The expected number of neutrino events in half year is around 8.2, 0.07, 0.73, and 0.41, corresponding to the epoch in 2014–2015, 2017–2018, 2021–2022, and 2022–2023, respectively. Hence, our model self-consistently explains the episodic neutrino emission from TXS 0506+056.

Neutrino astronomy (MeV –EeV) / 15

The Camera System for Real-Time Optical Calibration in TRIDENT

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Following the groundbreaking discovery of astrophysical neutrinos by IceCube, TRIDENT has been proposed as a next-generation neutrino telescope, planned for construction at a depth of around 3,500 meters in the Western Pacific Ocean. TRIDENT aims to enhance the search for astrophysical neutrino sources and optimize all-flavor neutrino detection.

As a water-based neutrino telescope, TRIDENT faces unique challenges in optical calibration due to the dynamic and non-uniform optical properties of the deep-sea environment. In this talk, I will present a custom-designed CMOS camera system and its adaptive image processing algorithms for real-time optical calibration, successfully demonstrated in TRIDENT's Pathfinder experiment in 2021.

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Status of the Taishan Antineutrino Observatory

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The Taishan Antineutrino Observatory (TAO) is a satellite experiment of the Jiangmen Underground Neutrino Observatory (JUNO), designed to achieve a precise measurement of the reactor antineutrino spectrum with an unprecedented energy resolution of 2% at 1 MeV. Located 44 meters from one core of the Taishan nuclear power plant, TAO utilizes a ton-scale liquid scintillator detector nearly fully instrumented with cutting-edge silicon photomultipliers (SiPMs) featuring a photon detection efficiency (PDE) of approximately 50%, achieving a high photoelectron yield of around 4500 p.e./MeV. By operating the detector at -50℃, the SiPM dark current is reduced by three orders of magnitude. TAO may be the first experiment to reveal the fine structure of the reactor antineutrino spectrum and can help to validate reactor monitoring techniques using neutrinos. This talk will provide a comprehensive introduction to the TAO experiment and its current status.

Neutrino astronomy (MeV –EeV) / 17

Status and Prospects for the HUNT project

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The High-energy Underwater Neutrino Telescope (HUNT) is proposed to detect the neutrinos from LHAASO sources with significant gamma-ray emission above 100 TeV and identify the PeV cosmic-ray accelerators in our Galaxy. HUNT project has made substantial advancements in the simulations and pathfinder experiments over the past year. This report will briefly introduce the simulation framework upgrade, the array configuration design, the discovery potential estimate, the prototype string in Lake Baikal, and the future plans.

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Calibration of the JUNO Detector

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The JUNO experiment is a neutrino experiment based on a 20-kiloton liquid scintillator detector, which is expected to observe various types of neutrinos, including reactor, atmosphere, solar, geo, and supernova neutrinos. The detector consists of a 35.4-meter-diameter acrylic vessel filled with liquid scintillator, supported by a stainless steel structure, and equipped with over 40,000 photomultiplier tubes. The primary goal of the experiment is to determine the neutrino mass ordering by precisely measuring the reactor neutrino energy spectrum. This talk will report on the calibration of the non-linear and non-uniform energy responses of the detector, including the analysis plan as well as the introduction of the detector calibration systems that are essential for this objective. Additionally, the latest development of the detector calibration sources will be discussed.

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Measurement of Solar ^{8}B neutrino flux using PandaX-4T data

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PandaX-4T is a multi-tonne-scale dark matter direct searching experiment, utilizing 3.7 tonne liquid xenon as target material in sensitive volume. The experiment is located at China Jinping Underground Laboratory, with overburden of 2400 meter water equivalent. In this talk, a search of the coherent elastic neutrino-nucleus scatterings induced by the solar ^{8}B neutrinos using PandaX-4T data will be reported. Combining two data channels covering an energy region of about 0.4˜1.2keV, a signal significance of 2.6σ is obtained. The best-fit solar ^{8}B neutrino flux is (8.4+-3.1)$\times 10^{6}$ cm^{-2}s^{-1}, consistent with the standard solar model

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Neutrino mass bounds from cosmology

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In this talk I will review how current cosmological probes can help us to constrain the properties of neutrinos, in particular their absolute mass scale. I will discuss the results from the Planck observations of the Cosmic Microwave Background, present recent updates that take into account Baryon Acoustic Oscillation bounds from DESI and show how degeneracies with other cosmological parameters can impact the cosmological neutrino mass bound.

Neutrino properties / 21

Neutrino Oscillation Results from The Latest T2K Analysis and from A Joint Analysis between T2K Beam and Super-Kamiokande Atmospheric

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Tokai-to-Kamioka (T2K) is a long baseline neutrino oscillation experiment in Japan. A (anti-)muon neutrino beam with energy peak ˜0.6GeV is produced at Japan Proton Accelerator Research Complex (J-PARC) in Tokai, propagates through 295km and is observed in the far detector Super-Kamiokande (SK). T2K can perform precise measurements in the muon neutrino disappearance channel, i.e. �!" and |Δ�"! ! |, as well as search for CP violation in the electron neutrino appearance channel. This talk will introduce the latest oscillation analysis from T2K with 3.77 × 10!# protons on target. As a water Cherenkov detector, SK has a strong discriminating power between electrons and muons produced from neutrino-nucleon interactions and can observe diSerent sources of neutrinos with energy from a few MeV to a few hundred GeV. The atmospheric neutrino events observed at SK with various baseline lengths and the Earth matter eSect give SK additional sensitivity to the neutrino mass ordering. A joint oscillation analysis between the T2K beam and SK atmospheric neutrinos has the potential to break the degeneracy of �$% and mass ordering. In addition to the latest T2K results, this talk will also present the first oscillation results from the joint analysis.

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Physics goal-driven design of the TRIDENT detector

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The TRopIcal DEep-sea Neutrino Telescope (TRIDENT) aims to deploy optical detection modules within ˜8 km3 of seawater, approximately 3.5 km deep in the South China Sea. Following the discovery of diffuse astrophysical neutrinos by the IceCube Neutrino Observatory, next-generation telescopes with increased size and improved performance expect to be on the verge of multiple discoveries. TRIDENT's primary goals are to rapidly resolve multiple astrophysical neutrino sources and boost sensitivity to all neutrino flavours. Important inputs to achieving these goals are TRIDENT's size, layout, location near the equator and use of advanced photon detection technologies. In this talk, the telescope's design and expected performance will be discussed, along with an introduction to the simulation framework used to evaluate its optimal construction for its early phases and final form.

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Solving the Mystery of Neutrinos and the Origin of Atomic Nuclei

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We would like to propose a new astrophysical method to constrain still unknown neutrino mass hierarchy in terms of the flavor conversions at high-density in supernovae 1. There is a growing consensus in recent multi-messenger astronomy that the explosions of single massive stars, i.e. magneto-hydrodynamic jet supernova and collapsar, dominate the heavy-element enrichment over the entire history of cosmic evolution, while kilonova, i.e. neutron-star merger, could partly contribute only to the recent epoch of cosmic history because of cosmologically long time-delay until merger due to too slow GW radiation [2,3]. We will, first, discuss when and how these astrophysical sites have contributed to the enrichment of the heavy elements in our cosmic/Galactic chemical evolution model. We have recently found that the i- and s-processes also could occur in the collapsar nucleosynthesis [4]. These explosive phenomena emit extremely large flux of energetic neutrinos that provide unique nucleosynthetic signals of the neutrino-nucleus interactions at high-density. We will, secondly, discuss the neutrino-flavor conversion including collective oscillations and MSW matter effect which could drastically affect the yields of neutrino-nuclei such as 138La, 180Ta, 92Nb, 98Tc, 11B, 7Li and abundant p-nuclei like 92,94Mo and 96,98Ru [5] whose origin have not yet been identified uniquely since B2FH1957. We also discuss the roles of de-excitation of the Hoyle state of 12C for the neutrino-proton process in hypernova [6].

1 X. Yao, T. Kajino, Y. Luo, et al., to be published (2024).
[2] C. Kobayashi, A. Karakas, M. Lugaro, Ap. J. 900 (2020), 179.
[3] Y. Yamazaki, Z. He, T. Kajino, et al., Ap. J. 933 (2022), 112.
[4] Z. He, T. Kajino, M. Kusakabe, et al., Ap. J. Lett. 966 (2024), L37.
[5] H. Ko, D. Jang, M. Cheoun, et al. with T. Kajino, Astrophys. J. 937 (2022), 116;
H. Sasaki, Y. Yamazaki, T. Kajino, et al., Ap. J. 924 (2022), 29.
[6] H. Sasaki, Y. Yamazaki, T. Kajino, et al., Phys. Lett. B851 (2024), 138581.

Neutrino properties / 24

A Measurement of the Solar Boron-8 Neutrinos with the XENONnT Dark Matter Detector

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Solar neutrinos interacting with nuclei in dark matter detectors through coherent elastic neutrino-nucleus scattering (CEvNS), often referred to as the 'neutrino fog,' presents a significant challenge to direct DM detection efforts. The XENONnT detector, known for its large exposure and low background, offers an exceptional opportunity to investigate this interaction. Utilizing data from XENONnT's first and second science runs, we searched for CEvNS signals of solar B-8 neutrinos, resulting in 37 observed events above 0.5 keV, with the 26.4 background events expected, led to the rejection of the background-only hypothesis with a statistical significance of 2.73-sigma. This marks the first direct detection of nuclear recoils from solar neutrinos using a dark matter detector. In this talk, I will present a detailed view of the search for solar B-8 CEvNS signals with XENONnT.

Neutrino properties / 25

The potential accelerator neutrino flux with HIAF facility

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HIAF (High Intensity heavy ion Accelerator Facility) is a new facility currently being constructed in Huizhou, China. The facility will be ready at the end of 2025, with a maximum magnetic rigidity of 34 Tm, providing the proton beam with a maximum energy of 9.3 GeV and a maximum flux intensity of 10ˆ14 proton/s. Although HIAF is designed for heavy-ion-related research, its high-intensity and high-energy proton flux also provide the chance to generate a GeV-level neutrino flux, which can serve as an ideal neutrino source for neutrino physics studies including CP violation and mass ordering problems.

Data analysis techniques & tools / 26

The CORSIKA 8 code for the simulation of particle showers in air and dense media

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CORSIKA has been the most-used Monte Carlo code for simulating extensive air showers for more than 20 years. Due to its monolithic, Fortran-based software design and hand-optimized code, however, it has become difficult to maintain and extend for more complex simulation needs. These limitations led to the CORSIKA 8 project, which constitutes a complete rewrite of the CORSIKA core functionality in a modern, modular C++ framework. CORSIKA 8 currently supports the treatment of hadronic interactions with Sibyll 2.3d, QGSJet-II.04, EPOS-LHC and Pythia 8.3, and the treatment of the electromagnetic cascade with PROPOSAL 7.6.2. Particular highlights are the support for multiple interaction media, including air, ice, and water and even cross-media situations, as well as an advanced calculation of the radio emission from these particle showers. In this contribution, we discuss the design principles of CORSIKA 8, give an overview of the functionality implemented to date, the validation of its simulation results, and the plans for its further development.

Atmosphere & Earth modeling / 27

Jinping solar and geoneutrino spectrometer development with lithium salt fluorescent water

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We have studied saturated LiCl water solution for the neutrino detection for Jinping Neutrino Experiment. The solution takes advantage of the high electron-neutrino charge-current interaction cross-section with Li-7, high natural abundance of Li-7, and the high solubility of LiCl. We have achieved a 50-m long attenuation length at 430 nm. The solution is good in studying energy-dependent solar neutrino physics, including the solar neutrino upturn effect and light sterile neutrino. The sensitivity of a hundred-ton-scale Jinping detector is comparable with other multi-thousand-ton detectors. The contained Cl-35 and Li-6 also make a delayed-coincidence detection for electron-antineutrino possible. The Jinping Neutrino Experiment can measure the crust geo neutrinos of Tibet. In addition to being a pure Cherenkov detector medium, a wavelength shifter, carbostyril 124, is added to the LiCl aqueous solution enabling the development of lithium salt fluorescent water.

Neutrino astronomy (MeV –EeV) / 28

Where do high-energy astrophysical neutrinos come from?

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The discovery of TeV-PeV astrophysical neutrinos in 2013 by IceCube precipitated the decade of spectacular progress in which we thrive today. So far, we have found the first extragalactic transient and steady-state sources of high-energy astrophysical neutrinos, plus neutrinos from comparatively nearby, the Galactic Plane. I will review these discoveries, what we have learned about the first neutrino sources, and the larger insight we have garnered from them—and from the non-detection of neutrinos from other candidate sources—about the population of unresolved sources responsible for the bulk of the detected neutrinos. Finally, I will show fascinating prospects for the next decade or two: an enhanced, all-sky potential to discover much dimmer sources of high-energy neutrinos, thanks to a global distributed network of neutrino telescopes, and the discovery of long-sought ultra-high-energy neutrinos, above 100 PeV, which may finally reveal the origin of ultra-high-energy cosmic rays.

Neutrino astronomy (MeV –EeV) / 29

Radio Detection of UHE Cosmic Rays and Neutrinos off the Moon

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Particle cascades induced by ultra-high-energy (UHE) cosmic rays and neutrinos impacting on the lunar regolith usually radiate Cherenkov radio emissions due to the presence of excess negative charge, which is known as Askaryan effect. Many experiments have been proposed and carried out to detect such radio emissions in the lunar regolith. In this work, we studied the detection of the Cherenkov radio emissions with the lunar orbital radio telescope and the terrestrial radio telescope. We have carried out instrument modelling and analytic calculations for the analysis of aperture, flux and event rate, and the analyses show the detectability of the Cherenkov radiation. Based on the properties of the Cherenkov radiation, we have demonstrated that the cosmic ray and neutrino events could be reconstructed with the three ULW vector antennas onboard the lunar satellites via measurements of the Askaryan radio pulse intensity, polarizations, etc.

Neutrino properties / 30

Reactor neutrino liquid xenon coherent elastic scattering experiment (RELICS)

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The Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) was predicted in 1974. Still, it wasn't experimentally confirmed until 2017 due to its shallow energy deposit, making detection challenging

due to energy threshold and background levels. Liquid Xenon Time Projection Chambers (LXeTPCs) have shown excellence in dark matter searches and may be an ideal technology for detecting CEvNS. The RELICS experiment aims to utilize LXeTPC to detect reactor neutrinos via CEvNS. This report will cover the latest advancements in CEvNS detection.

Detector R&D, instrumentation & deployment（Deep-water telescope technologies）/ 31

Challenges of Deploying a Deep Sea Neutrino Telescope

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Based on deep-sea technologies such as manned and unmanned submersibles, we conduct various types of underwater operations, including deep-sea scientific exploration, deep-sea search and recovery, and deep-sea archaeology. Different seabed operations have distinct requirements for the ship-submersible platform and payload tools, as well as varying demands for seabed site selection, positioning and navigation, and underwater operation accuracy. This report will first introduce the practical applications of manned and unmanned submersibles in the areas of cold seep survey, rescue operations for a sunken submarine in Indonesia, and deep-sea archaeology. Subsequently, it will provide a comparative analysis of the specific requirements for deck and seabed operations in the context of neutrino telescope deployment, along with potential challenges faced during these operations.

Neutrino properties / 32

Neutrino mass measurements with the KATRIN experiment

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Neutrino mass measurements are crucial for understanding fundamental physics, as neutrinos are among the most abundant in the universe. Traditionally, neutrinos were thought to be massless, but experiments have shown they do possess a small mass. Determining this mass is challenging due to their weak interactions with matter.

The Karlsruhe Tritium Neutrino (KATRIN) experiment is a leading effort in this field. Located at the Karlsruhe Institute of Technology (KIT) in Germany, KATRIN aims to measure the effective mass of electron neutrinos with unprecedented precision. It uses the beta decay of tritium to detect the energy of emitted electrons. By analyzing the endpoint of the beta decay spectrum, KATRIN can infer the neutrino mass. The experiment has already set an upper limit of 0.8 eV/c^2 with 5% of the total expected data.

This talk will give a brief overview of neutrino mass investigations with an emphasis on the operation of the KATRIN experiment and the analysis of a larger data set with 25% of the KATRIN data showing improvements in signal-to-background ratio and systematics, leading to a new upper limit of the neutrino mass.

Neutrino properties / 33

Recent results on neutrinoless double beta decay searches in experiment

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Neutrinoless double decay is the most sensitive experimental probe to answer the question whether neutrinos have Majorana or Dirac nature. The confirmation of the neutrino's nature has significant ramifications for the investigation and development of the formulation of physics beyond the Standard Model and the grand unified theories. The observation of this rare decay would establish the Majorana nature of neutrinos, lepton number violations and provide the effective mass and investigate the neutrino mass hierarchy. Many collaborations search for this rare process using different detector technologies. In this report, I report the recent experimental results and future plans for neutrinoless double beta decay searches.

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GECAM observations of the extremely bright gamma-ray bursts

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Gamma-Ray Burst (GRB) is the most energetic explosive event in the universe. Some GRBs are likley associated with gravitational wave (GW) or high energy neutrino (HEN) event, thus they are the promising target in the multi-messenger era. Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM) is an x-ray and gamma-ray telescope constellation composed of four instruments on different spacecrafts, dedicated to obserse the GRBs, especially those associated with GW and HEN. Thanks to its novel designs, GECAM has accurately detected two extremely bright GRBs, GRB 221009A and GRB 230307A, while many other telescopes suffered instrumental effects owing to the exceptional brightness. In this talk I will present the discoveries of these historical events, with implications on the GRB physics. I will also briefly summarize the recent progress of the high energy space missions in China, which have been or will be playing an important role in the high energy transient observation in the multi-messenger era.

Neutrino astronomy (MeV –EeV) / 35

Status of the KM3NeT neutrino Telescope

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KM3NeT is a deep-sea neutrino observatory currently under construction in the Mediterranean Sea. Its main goals are the search for sources of high energy cosmic neutrinos and the study of neutrino oscillation phenomena with atmospheric neutrinos.

KM3NeT comprises 3D arrays of multi-PMT optical modules optimised to detect the Cherenkov light emitted by charged particles resulting from neutrino interactions in the vicinity of the detectors. With its two sites: ARCA a 'sparse' km3-scale detector offshore from Sicily and ORCA a 'dense'

7 MTon detector offshore from the south of France, KM3NeT is sensitive to neutrino energies ranging from Mev to PeV.

In this talk the status of the KM3NeT detector is presented and the latest results obtained with partial detector configurations are reported. Results will include searches for diffuse, steady and transient cosmic sources, measurement of the atmospheric neutrino oscillation parameters, tau appearance, neutrino mass ordering, BSM effects.

Neutrino astronomy (MeV –EeV) / 36

Progress of Giant Radio Array for Neutrino Detection (GRAND)

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Ultra-high-energy cosmic rays (UHECRs) remain one of astrophysics' greatest mysteries. Observing ultra-high-energy (UHE) neutrinos offers a unique means of tracing these high-energy particles to their distant sources, as neutrinos can travel across the universe largely unimpeded, even beyond the Greisen-Zatsepin-Kuzmin (GZK) horizon.

The Giant Radio Array for Neutrino Detection (GRAND) is a proposed large-scale observatory aimed at detecting UHE neutrinos and cosmic rays through a dual approach: collecting unprecedented UHECR data while simultaneously searching for UHE gamma rays and neutrinos. GRAND is envisioned to deploy 200,000 radio antennas across 200,000 km^2 in roughly 20 sub-arrays of 10,000 km^2 each, targeting a neutrino sensitivity of approximately 10ˆ −10 [GeV cmˆ −2 sˆ −1 srˆ −1] for energies above 5 * 10ˆ17 [eV], with sub-degree angular resolution.

GRANDProto300, a 300-antenna prototype array, is currently under construction in Xiao Dushan, Gansu province, China, with data collection anticipated in 2024. Its objectives include autonomous radio detection of inclined air showers and probing the cosmic ray energy spectrum around the Galactic-extragalactic transition. In the first stage, an 80-antenna array will be operational. We will present the preliminary designs, simulated performance projections for GRAND, and early results from GRANDProto300.

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300kg CsI Detector for Coherent Elastic Neutrino-Nucleus Scattering (CICENNS)

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Coherent elastic neutrino-nucleus scattering (CEvNS) is the primary and enhanced interaction process for low-energy neutrinos with matter. To precisely study neutrino physics via this process, we are constructing an array of scintillation crystal detectors with a total mass of 300 kg of CsI(Na), named CICENNS. This detector will be installed at the China Spallation Neutron Source (CSNS) and make a precise measurement of the CEvNS signal as well as efficient searches for new physics using ˜30 MeV neutrinos from pion and muon decays at rest. In this talk, I will present the progress and expected results of the CICENNS experiment.

Multi-messenger probes / 38

Toward Simulating Flavor Instability in Neutron Star Mergers

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While neutrino flavor transformation in low-density environments is the target of many experimental and observational campaigns, the rich phenomenology of neutrino flavor transformation in neutrino-dense environments like core-collapse supernovae and neutron star mergers is presently the object of intense theoretical efforts. These phenomena have the potential to alter the course of explosion, mass ejection, and nucleosynthesis, but the small length and time scales seem to make direct simulation impossible. I will present our work to reliably account for flavor transformation effects on multiple fronts, including particle-in-cell methods, moment methods, and machine-learning subgrid models, and discuss the potential implications for future multi-messenger observations.

Neutrino astronomy (MeV –EeV) / 39

TRIDENT: Advancing Future Deep-sea Neutrino Observatory

Author: Xin Xiang[None]

TRIDENT: Advancing Future Deep-sea Neutrino Observatory

Atmosphere & Earth modeling / 40

Status and Astrophysical Neutrinos with the JUNO experiment

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose observatory under construction in China. The JUNO detector consists of a 20 kton liquid scintillator target monitored by about 18k 20-inch Photomultiplier Tubes (PMTs) and about 26k 3-inch PMTs. This detector is strategically located 53 km from the Taishan and Yangjiang Nuclear Power Plants in order to primarily determine the neutrino mass ordering and to precisely measure several oscillation parameters. In this talk,
In this talk, after a short introduction on the detector design and the construction status, I will discuss the experiment’s physics potential with a focus on astrophysical neutrinos and multi-messenger observations.

Neutrino astronomy (MeV –EeV) / 41

Could the steady-state neutrino emission of TXS 0506+056 come from the core of the active galactic nuclei?

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The blazar TXS 0506+056 is a candidate of high-energy neutrino sources. We propose that its neutrino emission could originate from the core region rather than the jet. We suggests that high-energy protons, accelerated by magnetic reconnection within a magnetically arrested disk (MAD) near the central black hole, interact with photons from the accretion disk and corona to produce neutrinos.

Multi-messenger probes / 42

Magnetic reconnection driven by intense lasers and electron acceleration

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Here we demonstrate turbulent magnetic reconnection in laser-generated plasmas created when irradiating solid targets. Turbulence is generated by strongly driven magnetic reconnection, which fragments the current sheet, and we also observe the formation of multiple magnetic islands and flux-tubes. Our findings reproduce key features of solar fare observations. Supported by kinetic simulations, we reveal the mechanism underlying the electron acceleration in turbulent magnetic reconnection, which is dominated by the parallel electric field, whereas the betatron mechanism plays a cooling role and Fermi acceleration is negligible. Then, we adopted the same analytical method to analyze the relativistic laser-induced and current-induced magnetic reconnection, and found the electron acceleration mechanism had some difference.

Neutrino properties / 43

Phenomenology with Massive Neutrinos in 2024

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Neutrino oscillation experiments have provided us with our only
direct proof of physics beyond the standard model (BSM) in the form of
lepton flavour violation in neutrino propagation due to neutrino
masses and flavour mixing in the leptonic sector. In this talk I will
first review the present status of neutrino masses and mixing
in the minimal framework with three massive neutrinos.
I will then discuss other new physics effects that can also probed with neutrino
oscillations such as non standard neutrino interactions,
models with new ultralight mediators or additional sterile neutrino states.

Neutrino properties / 44

Probing new physics with cosmic neutrinos

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The cosmic neutrinos detected by the IceCube Collaboration present a compelling opportunity to explore potential new physics beyond the Standard Model and conventional relativity. In this presentation, I will discuss how the association of IceCube neutrinos with gamma-ray bursts can serve as a valuable framework for investigating Lorentz Invariance Violation (LIV) in neutrinos. Furthermore, I will examine the implications of these associations for probing possible violations of Charge-Parity-Time (CPT) symmetry between neutrinos and their antiparticles. By analyzing the temporal and spatial correlations between neutrino events and gamma-ray bursts, we can gain insights into the fundamental properties of neutrinos and their interactions, potentially uncovering new phenomena that challenge our current understanding of particle physics and the nature of spacetime. This research not only aims to test the limits of established theories but also seeks to open new avenues for theoretical exploration in the realm of high-energy astrophysics.

Detector R&D, instrumentation & deployment（Deep-water telescope technologies）/ 45

Development of the Trident Phase One Project: An Ocean Engineering Perspective

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Development of the Trident Phase One Project: An Ocean Engineering Perspective

Detector R&D, instrumentation & deployment（Deep-water telescope technologies）/ 46

The potential influence of marine bioluminescence on deep-sea neutrino detection

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Marine bioluminescence, the natural emission of light by organisms like certain bacteria, jellyfish, and plankton, serves vital ecological functions in the dark depths of the ocean, aiding in communication, camouflage, and predation. This phenomenon introduces a unique challenge for deep-sea neutrino detection projects, These detectors aim to capture neutrino interactions in the assumed darkness of the deep sea. However, bioluminescent organisms create unexpected sources of light, adding background noise that can interfere with neutrino detection. Observations from ANTARES, P-ONE and similar projects reveal that bioluminescence complicates data by producing transient light signals, which may mimic neutrino events. This has prompted the development of improved algorithms and filtering techniques to distinguish bioluminescent activity from genuine neutrino interactions. Besides refining detection methods, these observations also offer valuable insights into deep-sea biology, revealing the behaviors and patterns of bioluminescent organisms. Thus, neutrino detection projects contribute to both high-energy physics and marine biology, enhancing our understanding of the deep-sea ecosystem and the potential impact of bioluminescence on scientific instrumentation in these dark environments.

Neutrino astronomy (MeV –EeV) / 47

Recent progress of IceCube and Progress with the Upgrade and IceCube-Gen2

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Recent results will be reviewed from IceCube, including refined measurements of the cosmic neutrino spectrum and the recent observations of neutrinos from the nearby galaxy M77 and the Milky Way. I will report on the design and construction progress of the IceCube Upgrade, which includes seven strings of dense instrumentation in the center of the IceCube. I will also discuss the design and progress of the IceCube-Gen2, a km3 scale extension of IceCube.

Data analysis techniques & tools / 48

Imprints of PeV cosmic-ray sources on the Galactic diffuse emission

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TRIDENT camera system redesign

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The self-contained PMT-DOM

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GPU-driven computing for neutrino detection

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The KM3NeT technology

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In this talk we will present the main technological solutions for construction of the KM3NeT ARCA and ORCA deep-sea neutrino telescopes.

Multi-messenger probes / 54

MeV Gamma-ray Astronomy in the Multi-messenger Era and the Future Mission

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MeV gamma rays are indispensable probes for high-energy astrophysics research, providing unique information to help address frontiers, such as the origin of cosmic rays, dark matter, the radiation mechanisms of compact objects, and etc. In particular, MeV range is the domain of nuclear gamma-ray lines that can provide a direct probe of the nuclear processes (such as supernovae, nucleosynthesis, and galactic chemical evolution) in our Universe to explore the fundamental problem of the origin of heavy elements in the Galaxy and beyond.
Despite recent improvements in many areas of multi-wavelength astronomy, the 0.1-100 MeV part of the electromagnetic spectrum is poorly covered by current detections. The current MeV observation sensitivity is about 1-2 orders of magnitude lower than the sensitivity in other energy bands. Studying the still largely unexplored MeV domain of astronomy would provide for a rich observatory science and enable discoveries of a wide range of extreme-process events. In this talk, I will briefly discuss the important science that will be addressed by the proposed MeV Gamma-Ray Observatory (MeVGRO) mission with high sensitivity and full MeV gamma-ray coverage.
I will also briefly summarize the recent progress of the high energy space missions in China, which have been or will be playing an important role in the high energy transient observation in the multi-messenger era.

Multi-messenger probes / 55

Superconducting Radio Frequency Cavity Searches for Dark Photon

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Dark photons have emerged as promising candidates for dark matter, and their search is a top priority in particle physics, astrophysics, and cosmology. We report the first use of a tunable niobium superconducting radio-frequency cavity for a scan search of dark photon dark matter with innovative data analysis techniques. We mechanically adjusted the resonant frequency of a cavity submerged in liquid helium at a temperature of 2 K, and scanned the dark photon mass over a frequency range of 1.37 MHz centered at 1.3 GHz. Our study leveraged the superconducting radio-frequency cavity's remarkably high quality factors of approximately 1010, resulting in the most stringent constraints to date on a substantial portion of the exclusion parameter space on the kinetic mixing coefficient ε between dark photons and electromagnetic photons, yielding a value of ε<2.2×10-16.

Multi-messenger probes / 56

Open-Source Tools for Neutrino Astronomy

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As we move towards the multi-telescope era of neutrino astronomy, it is i critical to develop collaborative approaches that ensure maximal scientific output. One facet of fulfilling this need is common tools for simulation and data analysis across detectors. In this talk, I will present Prometheus, an open-source framework for simulating neutrino interactions in neutrino telescopes. I will also present preliminary results from applying the open-source machine-learning package GraphNeT to Prometheus datasets from many current and planned neutrino telescopes.

Data analysis techniques & tools / 58

Optimizing the optical array geometry for TRIDENT

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The observation of astrophysical neutrino sources provides smoking-gun evidence for the origin of cosmic rays. IceCube has recently reported an excess of neutrino flux from NGC 1068 with a significance of 4.2�. TRIDENT is a proposed next-generation neutrino telescope located in the South China Sea. Owing to its large size, novel detector design, and location near the equator, TRIDENT will provide outstanding sensitivity to neutrino sources over the entire sky. In order to evaluate the detector ' s performance, we have conducted simulation studies using track-like events. Here, we present the effective area and angular resolution of TRIDENT, based on the optimization of the Penrose tilling layout where the spacing is optimized. Other array layout options such as Sunflower and Cluster, are also compared in terms of point source sensitivity using up-going track-like neutrino events.

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Progress on atmospheric muon simulation for TRIDENT

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Shower-type events reconstruction in TRIDENT

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Dissipation and Particle Acceleration in Relativistic Jets

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Opening Remarks / 62

SPCS 2024 Opening

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