The Future is Flavourful

Hosted by

Sponsored by

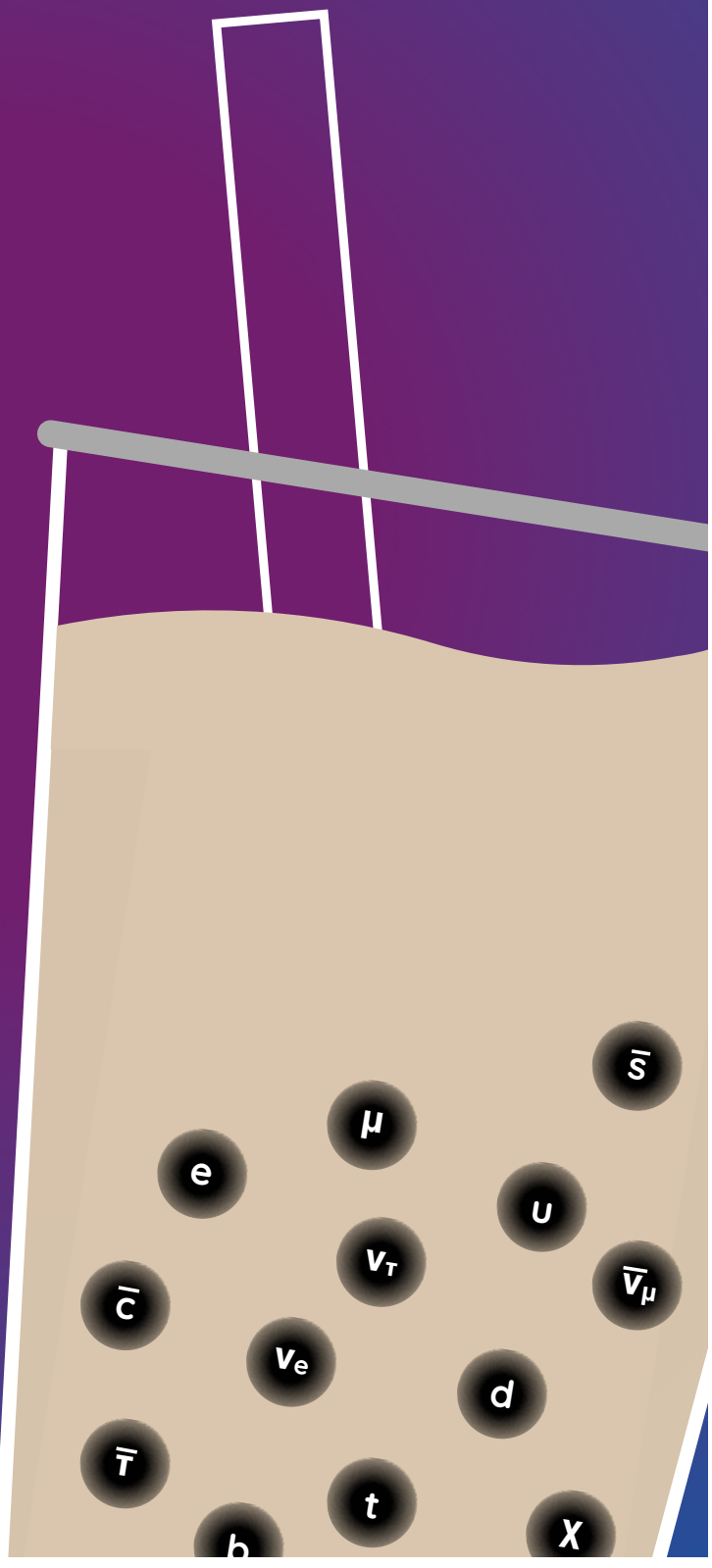
4th NCTS TG2.1 Future Workshop
June 4-6, 2024, Hsinchu, Taiwan

On the Menu

Lepton Flavours
Quark Flavours
Dark Flavours
Exotic Flavours

Keynote Speakers

Takehiko Asaka (Niigata U)
Wen-Chen Chang (AS)
Suchita Kulkarni (Graz U)
Hsiang-Nan Li (AS)
Stathes Paganis (NTU)
Henry Tsz-King Wong (AS)



The Future is Flavourful

4th NCTS TG2.1 Future Workshop

Tuesday, 4 June 2024 - Thursday, 6 June 2024

Hosted by NYCU & NTHU and sponsored by NCTS

Contents

Practical Information

In case of problems please contact the physics secretariat at NCTS, in particular: Jia-Yi Hsu, jyhsu@gapp.nthu.edu.tw or Renee Ho, renee.ho@gapp.nthu.edu.tw , Tel: +886-3-5731267

Workshop location: Room SC353 in Science Building III of NYCU. Address: No. 1001, University Road, Hsinchu, Taiwan 30010, R.O.C.

Internet access: Eduroam is broadly available on the NTHU and NYCU campuses. In case that does not work alternative access will be granted via guest accounts which will be provided onsite.

Food / store options nearby: There are a number of convenience stores, canteens and restaurants on the campuses and nearby. Please refer to the website for more information or the campus maps section at the end of this booklet.

Delivery: UberEats and Foodpanda are popular apps that provide delivery options for everything from groceries to dinner to shampoo to batteries straight to your door.

NTHU Guesthouse: Address: No. 101, Section 2, Kuang-Fu Road, Hsinchu, Taiwan 30013, R.O.C. (80 on the map), Tel: +886-3-5742100, Check in: 14:00 and check out: 12:00, website: https://affairs-guesths.vm.nthu.edu.tw/en/index.php

Welcome and Motivation

Hsinchu, May 2024

There is quite some debate of the status of particle physics which means that particle physics is, in fact, in a good state of healthy self reflection. This process will inevitably lead to new ideas and approaches which can only help us to gain a deeper understanding of the fundamental building blocks of nature.

In the next decade we can expect a plethora of new data from a very wide range of experiments, like colliders, neutrino experiments, B factories, dark matter searches, precision charged lepton experiments, gravitational wave experiments, and many more. It remains to be seen if existing experimental anomalies will survive and turn into new physics discoveries or if our understanding remains stuck with the Standard Model of particle physics with an ad-hoc addition of neutrino masses. In any case, the outcome of this experiments will determine how we will proceed experimentally and what theoretical challenges we have to face in the future.

In this workshop we therefore plan to bring together theorists and experimentalists from Taiwan and abroad to discuss the current status and new approaches to long-standing and upcoming problems.

This event is the fourth instalment of the workshop series "The Future is ..." initiated in 2021. After the first three installments, "The Future is Dark", "The Future is Illuminating" and "The Future is Non-Perturbative" this year we have decided on the guiding theme "The Future is Flavourful"with a main focus on leptonic, quark, dark and exotic flavours. Hopefully, we have found the right mix of ingredients to make this workshop a success and create new recipes for addressing difficult and interesting questions.

We warmly welcome you to our workshop and wish you a productive and inspiring time.

Martin Spinrath (on behalf of the organisers)

Timetables

On the following pages you can find the program as the time of compiling of this booklet. For updates please check our indico page here.

Tue 04/06

Go back | Print

09:00

Welcome & Farewell: Welcome — *Martin Spinrath*
Science Building III/SC353, NYCU 09:10 - 09:30

Experimental Neutrino Physics in Taiwan. — *Prof. Henry T. Wong*
Science Building III/SC353, NYCU 09:30 - 10:30

10:00

Coffee Break
Science Building III/SC353, NYCU 10:30 - 11:00

11:00

Sensitivity expectations for the next-gen neutrinoless double beta decay experiments — *Manoj Kumar Singh*
Science Building III/SC353, NYCU 11:00 - 11:30

Probing lepton-flavor-violating processes in e^+e^- colliders — *LAM THI TO UYEN*
Science Building III/SC353, NYCU 11:30 - 12:00

12:00

Lunch Break
Science Building III/SC353, NYCU 12:00 - 13:30

13:00

BSM Heavy Flavours, Non-Locality, and searches in Colliders — *Stathes Paganis*
Science Building III/SC353, NYCU 13:30 - 14:30

14:00

Implications of X17 boson to \(D\) meson, Charmonium, and \(\phi\) meson decays — *LAM THI THUC UYEN*
Science Building III/SC353, NYCU 14:30 - 15:00

15:00

Coffee Break
Science Building III/SC353, NYCU 15:00 - 15:30

SN1987A constraints to BSM models with extra neutral bosons near the trapping regime — *Chun Sing Jason Leung*
Science Building III/SC353, NYCU 15:30 - 16:00

16:00

Probing Axion-like Particles: Novel Detection Channels and Expanding Experimental Sensitivity for Dark Matter and Solar ALPs
Ms Greeshma Chandrabhanu

Massive neutrino self-interactions and the Hubble tension — *Shouvik Roy Choudhury*
Science Building III/SC353, NYCU 16:30 - 17:00

17:00

Mini Break
Science Building III/SC353, NYCU 17:00 - 17:15

Discussion Sessions: Particle Flavours & BSM — *Martin Spinrath*
Science Building III/SC353, NYCU 17:15 - 18:00

18:00

Wed 05/06

Go back | Print

09:00

How well do we understand the proton? *Wen-Chen Chang*
Science Building III/SC353, NYCU 09:30 - 10:30

10:00

Coffee Break
Science Building III/SC353, NYCU 10:30 - 11:00

11:00

Lattice extraction of the TMD soft function and CS kernel with the auxiliary field representation of the Wilson line
Dr Wayne Morris

Parton Distribution Functions in the Schwinger Model with Tensor Network States *Manuel Schneider*
Science Building III/SC353, NYCU 11:30 - 12:00

12:00

Lunch Break
Science Building III/SC353, NYCU 12:00 - 13:30

13:00

Origin of neutrino masses and its experimental tests *Takehiko Asaka*
Science Building III/SC353, NYCU 13:30 - 14:30

14:00

Dirac neutrino masses and meson decay anomalies with leptoquarks *Dr Leon M Garcia de la Vega*
Science Building III/SC353, NYCU 14:30 - 15:00

15:00

Coffee Break
Science Building III/SC353, NYCU 15:00 - 15:30

Positivity Bounds on Higgs-Portal Dark Matter *Kimiko Yamashita*
Science Building III/SC353, NYCU 15:30 - 16:00

16:00

Recent $B^+ \to K^+ \nu \nu$ Excess and Muon g−2 Illuminating Light Dark Sector with Higgs Portal *Shu-Yu HO*
Science Building III/SC353, NYCU 16:00 - 16:30

Leptoquark induced neutrino masses and the discrepancy of muon $g-2$ *Julio Julio*
Science Building III/SC353, NYCU 16:30 - 17:00

17:00

Mini Break
Science Building III/SC353, NYCU 17:00 - 17:15

Discussion Sessions: Astroparticle Physics & Cosmology *Po-Yen Tseng*
Science Building III/SC353, NYCU 17:15 - 18:00

18:00

Thu 06/06

Go back | Print

09:00

Dispersive constraints on the SM flavor structure *Hsiang-nan Li*
Science Building III/SC353, NYCU 09:30 - 10:30

10:00

Coffee Break
Science Building III/SC353, NYCU 10:30 - 11:00

11:00

Using the magnetic equation of state to determine the curvature of the chiral phase transition line of (2+1)-flavor QCD
Mugdha Sarkar

Lattice investigations of the chimera baryon spectrum in the $Sp(4)$ gauge theory *Ho Hsiao*
Science Building III/SC353, NYCU 11:30 - 12:00

12:00

Lunch Break
Science Building III/SC353, NYCU 12:00 - 13:30

13:00

Flavour of dark flavours *Suchita Kulkarni*
Science Building III/SC353, NYCU 13:30 - 14:30

14:00

Phenomenology of compact objects from a first order phase transition in the dark sector *Jan Tristram Acuña*
Science Building III/SC353, NYCU 14:30 - 15:00

15:00

Coffee Break
Science Building III/SC353, NYCU 15:00 - 15:30

Effects of Superradiance in Active Galactic Nuclei *Priyanka Sarmah*
Science Building III/SC353, NYCU 15:30 - 16:00

16:00

Quark flavor violation and axion-like particles from top-quark decays at the LHC *Fei-Tung Chung*
Science Building III/SC353, NYCU 16:00 - 16:30

A New Higgs Boson With Electron-Muon Flavor-Violating Couplings *Reinard Primulando*
Science Building III/SC353, NYCU 16:30 - 17:00

17:00

Mini Break
Science Building III/SC353, NYCU 17:00 - 17:10

Neutrino Emission upon Black Hole Formation in Core Collapse Supernovae *Jia-Shian Wang*
Science Building III/SC353, NYCU 17:10 - 17:40

Welcome & Farewell: Farewell *Po-Yen Tseng*
Science Building III/SC353, NYCU 17:40 - 18:00

18:00

List of Abstracts

Keynote Talks / 3

Experimental Neutrino Physics in Taiwan.

Author: Henry T. Wong[1]

[1] *Institute of Physics, Academia Sinica*

I will present an overview of the experimental neutrino physics programs in Taiwan: past, present and future. The development also reflects how the subject evolve.

Lepton Flavours / 24

Sensitivity expectations for the next-gen neutrinoless double beta decay experiments

Author: Manoj Kumar Singh[1]

Co-authors: Hau-Bin Li [1]; Henry T. Wong [1]

[1] *Institute of Physics, Academia Sinica*

Probing the inverted mass ordering region and venturing into the normal mass ordering region of neutrinos is a crucial goal for the next generation of neutrinoless double beta decay ($0\nu\beta\beta$) experiments. The absence of definitive signatures, the quest for heightened sensitivity, background minimization, statistical significance, and exploration of multiple isotopes collectively drive the move towards tonne-scale $0\nu\beta\beta$ experiments. Assessing the experimental requirements and their cost-efficiency is vital, considering the tonne-scale enriched isotopes and the years of effort these experiments necessitate. We undertake a comprehensive quantitative assessment of projected experimental sensitivities, placing specific emphasis on the discovery potentials anticipated prior to conducting the experiments. We investigate the sensitivity of the counting analysis using full Poisson statistics [1], its continuous approximation [2], and compare both with those based on maximum likelihood analysis, which integrates additional measurable signatures such as energy [3]. This study emphasizes the typical hurdle faced in making sensitivity projections for proposed projects and contends that counting-only analyses with Poisson or continuous approximations, currently employed by several experiments, are no longer sufficient. Incorporating energy information into sensitivity estimation is essential for optimizing cost-effectiveness assessments.

References
[1] M. K. Singh, H. T. Wong et al., "Exposure-background duality in the searches of neutrinoless double beta decay", Phys. Rev. D 101, 013006 (2020).
[2] M. Agostini, G. Benato et al., "Toward the discovery of matter creation with neutrinoless $\beta\beta$ decay", Rev. Mod. Phys. 95, 025002 (2023).
[3] M. K. Singh, H. T. Wong et al., "Projections of discovery potentials from expected background", Phys. Rev. D 109, 032001 (2024).

Lepton Flavours / **8**

Probing lepton-flavor-violating processes in e^+e^- colliders

Author: LAM THI TO UYEN[1]

Co-author: Guey-Lin Lin [1]

[1] *Institute of Physics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

Scenario with a lepton-flavor-violating (LFV) boson, either a scalar or a vector exchange, is an intriguing physics phenomenon beyond Standard Model. This LFV boson coupling in the presence of muons leads to a rich phenomenology including an extra contribution to muon anomalous magnetic moment desirable for alleviating the discrepancy between the SM prediction and the newest combined (Fermilab and BNL) experimental average using data collected until 2023. With the assumption of a positive real number $h_{e\mu} = g_{e\mu}$ in the low-energy effective coupling $\mathcal{L}_{\phi e\mu} = \phi\bar{e}(g_{e\mu} + h_{e\mu}\gamma^5)\mu$ + h.c., which turns electron into muon or vice versa through the scalar particle ϕ, we derive the ($h_{e\mu}$, M_ϕ) parameter space that could account for the discrepancy mentioned above. Furthermore, we calculate the cross section $e^+e^- \to e^\pm\mu^\mp\phi \to e^\pm e^\pm\mu^\mp\mu^\mp$ induced by $calL_{\phi e\mu}$ and SM vertices in the M_ϕ range of 1- 8 GeV. Based on two pairs of same-sign final-state electrons and muons we assume that the search for this LFV scalar at the electron-positron Belle II experiment is background free. For $\text{Br}(\phi \to e^+\mu^-) = \text{Br}(\phi \to e^-\mu^+) = 0.5$ and the selection criteria applied to the signal identification of processes $e^+e^- \to e^\pm e^\pm\mu^\mp\mu^\mp$, we found that for $1 \leq M_\phi/\text{GeV} \leq 8$, the upper limit for $h_{e\mu}$ with $\mathcal{L} = 1$ fb^{-1} at Belle II is already in the favorable parameter range to account for the measured $g_\mu - 2$. To probe LFV scalar mediator further, we note that this scenario can be constrained by lepton flavor-changing $\mu \to e$ conversion and muon decays of $\mu \to e\gamma$, $\mu \to 3e$ with the most stringent bounds $h_{e\mu} \lesssim 1.4 \times 10^{-4}$ for the mass range $M_\phi \lesssim 8$ GeV from $\mu \to e\gamma$ decay. Under such constraints, signatures of same-sign and same-flavor lepton pairs can still be searched for at full Belle II luminosity, which offers the possibility of discerning the current scenario from LFV interaction with a vector boson exchange due to significant differences in their event kinematic distributions. We propose an effective method to discriminate between these two scalar and vector scenarios.

Keynote Talks / **4**

BSM Heavy Flavours, Non-Locality, and searches in Colliders

Author: Stathes Paganis[None]

A number of gravitation-motivated theories, as well as theories with new coloured fermions predict heavy particle towers with spectral densities ρ(m^2) growing faster than e^m, a characteristic of nonlocalizable theories. In this talk we will discuss a general approach for extracting the new Physics from the data. Although the approach can be applied to dark sectors, fifth force search or Z'/W' phenomenology, our main focus is in nonlocal QFTs. A series of ongoing measurements are briefly discussed.
The double-Higgs production measurement at the LHC is proposed as a highly sensitive probe of nonlocality at the electroweak scale.

Exotic Flavours / **7**

Implications of X17 boson to D meson, Charmonium, and ϕ meson decays

Author: LAM THI THUC UYEN[1]

Co-authors: Guey-Lin Lin [1]; Fei-Fan Lee [2]

[1] *Institute of Physics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

[2] *Department of Physics, Jimei University, Fujian province, P.R. China*

The recent ATOMKI experiments provided evidence pointing towards the existence of an X17 boson in the anomalous nuclear transitions of Beryllium-8, Helium-4, and Carbon-12. The favored ranges for the couplings between the X17 boson and the first-generation quarks, denoted as ϵ_u and ϵ_d, are determined through fittings to the above nuclear transitions.
In this work, we consider X17 boson contributions to the previously measured D meson decays which include $D_s^{*+} \to D_s^+ e^+ e^-$, $D_s^{*+} \to D_s^+ \gamma$, $D^{*0} \to D^0 e^+ e^-$, and $D^{*0} \to D^0 \gamma$, as well as the measured decays of $\psi(2S) \to \eta_c e^+ e^-$, $\psi(2S) \to \eta_c \gamma$, $\phi \to \eta e^+ e^-$, and $\phi \to \eta\gamma$. In addition to the dependence on ϵ_u, these decays also depend on X17 boson couplings to the second-generation quarks, denoted as ϵ_c and ϵ_s. Using the data of the above meson decays, we perform an independent fitting to the coupling parameters ϵ_u, ϵ_c, and ϵ_s while keeping the X17 boson mass at the best-fit value obtained by ATOMKI experiments. In this fitting, we take the scenario that X17 is a vector boson and treat the couplings ϵ_u and ϵ_c as independent from each other rather than assuming the generation universality $\epsilon_u = \epsilon_c$. It is found that the above fitting renders a huge magnitude for ϵ_u, which is in serious tension with ϵ_u determined from the ATOMKI measurements of Beryllium-8, Helium-4, and Carbon-12 nuclear transitions. Implications of our findings are discussed.

Dark Flavours / 21

SN1987A constraints to BSM models with extra neutral bosons near the trapping regime

Authors: Chun Sing Jason Leung[1]; Guey-Lin Lin[2]; Kwang-Chang Lai[3]

[1] *National Tsing Hua University, Hsinchu, Taiwan*

[2] *Institute of Physics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

[3] *Chang Gung University*

New physics beyond the Standard Model (BSM) with an extra neutral boson can be constrained from the observation of SN1987A, since the production of this neutral boson in a supernova (SN) could accelerate the SN cooling and potentially lead to a period of the neutrino burst incompatible with the observation. The constraint to the model is formulated by the condition $L_{\rm NB} \leq 3 \times 10^{52}$ erg/s according to G. Raffelt with $L_{\rm NB}$ the luminosity of BSM neutral boson. Computing the above luminosity in the large coupling case, the so-called trapping regime, is non-trivial since the luminosity is a competition between the large production rate and the efficient absorption or decay rate of the neutral boson. We illustrate such a subtlety using $U(1)_{L_\mu - L_\tau}$ model as an example where the Z' luminosity, $L_{Z'}$, from the neutrinosphere is calculated.

We calculate Z' production, absorption, and decay rates through pair-coalescence, semi-Compton, loop-bremsstrahlung from proton-neutron scattering, and their inverse processes in a benchmark SN simulation with muons. We point out that, as the coupling constant $g_{Z'}$ increases, $L_{Z'}$ shall be approaching to a constant plateau value for a given $m_{Z'}$ instead of monotonically decreasing down to zero as obtained in the previous literature. We demonstrate that this plateau phenomenon can be understood by physical arguments and justified by numerical calculations. With a different result on $L_{Z'}$ from the previous one, we discuss impacts on the constraints to $U(1)_{L_\mu - L_\tau}$ parameter space by SN1987A. The implication of our result to the similar constraint on a generic BSM model with an extra neutral boson is also discussed.

Dark Flavours / 23

Probing Axion-like Particles: Novel Detection Channels and Expanding Experimental Sensitivity for Dark Matter and Solar ALPs

Author: Greeshma Chandrabhanu[1]

Co-authors: C.-P. Liu [2]; C.-P. Wu [3]; H.-C. Chi [4]; H.T. Wong [5]; J.-W. Chen [6]; L. Singh [7]; M.K. Pandey [8]

[1] *Institute of Physics, Academia Sinica, Taipei 11529, Taiwan & Department of Physics, Central University of South Bihar, Gaya 824236, India.*

[2] *Department of Physics, National Dong Hwa University and Physics Division, National Center for Theoretical Sciences, National Taiwan University, Taiwan*

[3] *Département de Physique, Université de Montréal, Montréal H3C 3J7, Canada*

[4] *Department of Physics, National Dong Hwa University, Shoufeng, Hualien 97401, Taiwan*

[5] *Institute of Physics, Academia Sinica, Taipei 11529, Taiwan.*

[6] *Physics Division, National Center for Theoretical Sciences, National Taiwan University and Department of Physics, CTP and LeCosPA, National Taiwan University*

[7] *Institute of Physics, Academia Sinica, Taipei 11529, Taiwan and Department of Physics, Central University of South Bihar, Gaya 824236, India.*

[8] *Department of Physics, CTP and LeCosPA, National Taiwan University, Taipei 10617, Taiwan*

Probing Axion-like Particles: Novel Detection Channels and Expanding Experimental Sensitivity for Dark Matter and Solar ALPs

Axions and axionlike particles (ALPs) represent a promising avenue in the quest for new physics, potentially shedding light on the profound mysteries enveloping our Universe, including the nature of dark matter and dark energy. ALPs are well-motivated dark matter (DM) candidates and can be produced in astrophysical environments and terrestrial laboratories. In recent years there has been remarkable progress in the physics of axions and ALPs in several directions. The primary contribution of this study is two-fold: firstly, it involves the identification of novel detection channels aimed at probing $g_{a\gamma\gamma}$ through terrestrial experiments. This new inelastic inverse Primakoff scatterings (inverse Primakoff Ionisation - IP_{ion}) between ALPs and matter as promising avenues, offering a method to investigate relic ALPs. The differential cross-section of this new channel is computed using sophisticated *ab – initio* atomic many-body theory. Secondly, expanding the parameter space in (m_a , $g_{a\gamma\gamma}$) for laboratory-based investigations for solar-ALPs and DM-ALPs. This was achieved by using TEXONO data taken with a point-contact germanium detector and high-purity germanium detector at the Kuo-Sheng Reactor Neutrino Laboratory by the TEXONO Collaboration. These detectors were specifically chosen for their dual attributes of low threshold and high energy reach, coupled with outstanding energy resolution for precise spectral peak detection [1], [2]. Furthermore, XENONnT data obtained from liquid xenon in the $1-140$ keV$_{ee}$ [3] range was also utilized due to its extensive exposure and advantageous characteristics of low threshold and background. For solar ALPs which are relativistic, inverse Primakoff elastic scattering (IP_{el}) with a one-photon final state is the dominant channel. The DM-ALPs are non-relativistic and interact predominantly via the two photon decay (TPD) and IP_{ion} channels. The exclusion regions at 90% CL from the TEXONO and XENONnT data for $g_{a\gamma\gamma}$ on solar-ALPs are derived. With the detection efficiencies taken into account, the standalone sensitivity regions for DM-ALPs analysis independent of other processes are derived. The upper reaches of the sensitivity regions are bounded by terrestrial attenuation by the Earth and its atmosphere before the DM-ALPs can reach the detectors. The TPD lifetime of ALPs has to be longer than the age of the Universe in order for the DM-ALP to reach and be observable in terrestrial experiments. This implies part of the (m_a, $g_{a\gamma\gamma}$) parameter space is not accessible by the direct experimental searches of DM-ALPs while future projects would be able to evade the stability bound and open new observable windows for DM-ALPs. As an extension of this work, presently we are working on establishing a robust axio-electric differential cross-section for ALPs utilizing advanced many-body techniques through a global approach considering the coupling between axions and photons, as well as axions and electrons.

References

[1] L. Singh et al. (TEXONO Collaboration), Phys. Rev. D 99, 032009 (2019).

[2] H. T. Wong et al. (TEXONO Collaboration), Phys. Rev. D 75, 012001 (2007).
[3] E. Aprile et al. (XENON Collaboration), Phys. Rev. Lett. 129, 161805 (2022).

Lepton Flavours / **10**

Massive neutrino self-interactions and the Hubble tension

Author: Shouvik Roy Choudhury[1]

Co-authors: Steen Hannestad [2]; Thomas Tram [2]

[1] *Academia Sinica Institute of Astronomy and Astrophysics*

[2] *Aarhus University, Denmark*

Based predominantly on arXiv:2012.07519 (JCAP 03 (2021) 084) and also on arXiv:2207.07142 (JCAP 10 (2022) 018).

We have updated the constraints on flavour universal (and also flavour specific) neutrino self-interactions mediated by a heavy scalar, in the effective 4-fermion interaction limit. We use the relaxation time approximation to modify the collisional neutrino Boltzmann equations, which is known to be very accurate for this particular scenario. Based on the latest CMB data from the Planck 2018 data release as well as auxiliary data we confirm the presence of a region in parameter space with relatively strong self-interactions which provides a better than naively expected fit. However, we also find that the most recent data, in particular high-ℓ polarisation data from the Planck 2018 release, disfavours this solution even though it cannot yet be excluded. Our analysis takes into account finite neutrino masses (parameterised in terms of $\sum m_\nu$) and allows for a varying neutrino energy density (parameterised in terms of $N_{\rm eff}$), and we find that in all cases the neutrino mass bound inferred from cosmological data is robust against the presence of neutrino self-interactions. Finally, we also find that the strong neutrino self-interactions do not lead to a high value of H_0 being preferred, i.e. this model is not a viable solution to the current H_0 discrepancy.

Keynote Talks / **14**

How well do we understand the proton?

Author: Wen-Chen Chang[None]

The proton is a spin-1/2 fundamental particle, discovered as a basic constituent of atomic nuclei by Rutherford in 1917. It and its isospin partner, neutron, carry the majority of visible mass in our universe. Starting from Gell-Mann's quark model, the substructures of protons have been explored mostly by the deep-inelastic scattering and Drell-Yan process for more than five decades. In this talk, I will focus on what we learn about the partonic structures of the proton, and how its mass and spin can be understood by their interesting dynamics resulting from the strong interaction. The physics results of ongoing experiments and Taiwan's participation in the future U.S. Electron-Ion Collider will be introduced.

Quark Flavours / **22**

Lattice extraction of the TMD soft function and CS kernel with the auxiliary field representation of the Wilson line

Authors: Anthony Francis[1]; C.-J. David Lin[2]; Issaku Kanamori[3]; Wayne Morris[1]; Yong Zhao[4]

[1] *National Yang Ming Chiao Tung University*

[2] *Institute of Physics, National Yang Ming Chiao Tung University*

[3] *RIKEN*

[4] *Argonne National Lab*

The TMD soft function may be obtained by formulating the Wilson line in terms of auxiliary 1-dimensional fermion fields on the lattice. We take inspiration from heavy quark effective theory (HQET) in order to define the auxiliary field. Our computation takes place in the region of the lattice that corresponds to the "spacelike"region in Minkowski space in order to obtain the Collins soft function. The matching of our result to the Collins soft function is achieved through the mapping of the auxiliary field directional vector to the Wilson line rapidity. I present exploratory numerical results of our lattice calculation, and discuss the methodology employed.

Quark Flavours / **20**

Parton Distribution Functions in the Schwinger Model with Tensor Network States

Authors: C.-J. David Lin[1]; Krzysztof Cichy[2]; Manuel Schneider[3]; Mari Carmen Bañuls[4]

[1] *Institute of Physics, National Yang Ming Chiao Tung University*

[2] *Adam Mickiewicz University of Poznan*

[3] *NYCU*

[4] *Max Planck institute of Quantum Optics*

Parton Distribution Functions (PDFs) describe universal properties of bound states and allow to calculate scattering amplitudes in processes with large momentum transfer. Calculating PDFs involves the evaluation of correlators involving a Wilson line in lightcone-direction. In contrast to Monte Carlo methods in euclidean spacetime, these correlation functions can be directly calculated in the Hamiltonian formalism. The necessary spatial- and time-evolution can be efficiently applied using established tensor network methods. In this talk I will give an introduction to PDFs and tensor network states, and discuss how we study PDFs in the Schwinger model using matrix product states.

Keynote Talks / **18**

Origin of neutrino masses and its experimental tests

Author: Takehiko Asaka[1]

[1] *Niigata University*

We discuss the origin of neutrino masses confirmed by various oscillation experiments. Especially, we consider the case when the Standard Model is extended by right-handed neutrinos and describe the so-called seesaw mechanism. We also discuss the possible tests of the seesaw mechanism where all neutrinos are Majorana fermions and the lepton number is violated. In particular, we show how properties of right-handed neutrinos, masses and mixings, are probed by the future experiments of neutrinoless double beta decays.

Lepton Flavours / **19**

Dirac neutrino masses and meson decay anomalies with leptoquarks

Author: Leon M Garcia de la Vega[1]

[1] *NCTS*

In this talk we will discuss the phenomenology of neutrino mass models where leptoquarks mediate the generation of Dirac mass terms. The presence of leptoquarks that couple to all generations of quarks and leptons can have interesting consequences for meson decays. In particular the RD, RD* anomalies can be addressed, as well as the recent observation by Belle-II of an excess in the $B \to K+$inv decay rate.

Dark Flavours / **13**

Positivity Bounds on Higgs-Portal Dark Matter

Authors: Seong-Sik Kim[1]; Hyun Min Lee[1]; Kimiko Yamashita[2]

[1] *Chung-Ang University*

[2] *Ibaraki University*

We consider the positivity bounds for scalar dark matter with effective Higgs-portal couplings up to dimension-8 operators. Taking the superposed states for Standard Model Higgs and scalar dark matter, we show that the part of the parameter space for the effective couplings, otherwise unconstrained by phenomenological bounds, is ruled out by the positivity bounds on the dimension-8 derivative operators. For a WIMP DM case, we find that dark matter relic density, direct and indirect detection, and LHC constraints are complementary to the positivity bounds in constraining the effective Higgs-portal couplings. In the effective theory obtained from massive graviton or radion, there appears a correlation between dimension-8 operators and other effective Higgs-portal couplings for which the strong constraint from direct detection can be evaded. Nailing down the parameter space mainly by relic density, direct detection, and positivity bounds, we find that there are observable cosmic ray signals coming from the dark matter annihilations into a pair of Higgs bosons, WW or ZZ. We also consider a FIMP DM case.

Dark Flavours / **12**

Recent $B^+ \to K^+\nu\nu$ Excess and Muon g–2 Illuminating Light Dark Sector with Higgs Portal

Author: Shu-Yu HO[1]

[1] *KIAS*

The Belle II collaboration recently announced that they observed the $B^+ \to K^+\nu\nu$ decay process for the first time. This dineutrino mode of $B^+ \to K^+\nu\nu$ has been theoretically identified as a very clean channel. However, their result encounters a 2.7σ deviation from the Standard Model (SM) calculation. On the other hand, last year, Fermilab released new data on muon g–2 away from the SM expectation with 5σ. In this letter, we study the simplest UV-complete U(1) L_μ-L_τ-charged complex scalar Dark Matter (DM) model. Thanks to the existence of light dark Higgs boson and light dark photon, we can explain the observed relic density of DM and resolve the results reported by both Belle II and Fermilab experiments simultaneously. As a byproduct, the Hubble tension is alleviated by taking $\Delta N_{\rm eff} \simeq 0.3$ induced by the light dark photon.

Lepton Flavours / **16**

Leptoquark induced neutrino masses and the discrepancy of muon g-2

Author: Julio Julio[1]

[1] *National Research and Innovation Agency*

Recent measurement of muon anomalous magnetic dipole moment (muon $g-2$), performed by the Muon $g-2$ Collaboration at Fermilab, differs from the Standard Model (SM) value calculated by the Muon $g-2$ Theory Initiative Group at the combined statistical significance of 5.1σ. Taking at face value, such discrepancy could be an indication of some sort of new physics. In this paper, we explain the discrepancy in the context of a model with leptoquarks, usually denoted as $S(3,1,-1/3)$ and $R(3,2,1/6)$. In this model, the muon $g-2$ can receive a top-mass chiral enhancement. The neutrino masses are induced at both one- and two-loop levels. We found a texture, where the latter could be competitive to the former. Given that the model can simultaneously explain neutrino masses and muon $g-2$ anomaly, it leads to several interesting predictions for lepton-flavor-violating rates, which could be probed by future experiments. The effects on $h \to \gamma\gamma$ and $h \to Z\gamma$ decays will also be discussed.

Keynote Talks / **6**

Dispersive constraints on the SM flavor structure

Author: Hsiang-nan Li[1]

[1] *Academia Sinica*

We perform dispersive analyses of representative physical observables (heavy quark decay widths, neutral meson mixing, etc.) and demonstrate that the parameters involved in scalar interactions of the Standard Model (SM) is not completely free. The mass hierarchy from the neutrino masses up to the electroweak scale, and the distinct quark and lepton mixing patterns may be accommodated by means of the internal consistency of the SM dynamics. This understanding also points to possible new physics scenarios beyond the SM at high energy scales.

Quark Flavours / **25**

Using the magnetic equation of state to determine the curvature of the chiral phase transition line of (2+1)-flavor QCD

Author: Mugdha Sarkar[1]

[1] *National Taiwan University*

We analyze the variation of the chiral phase transition temperature as a function of the baryon number and strangeness chemical potentials by calculating the leading order curvature coefficients in the light and strange quark flavor basis as well as in the conserved charge (B, S) basis. Making use of scaling properties of the magnetic equation of state (MEoS) and including diagonal as well as off-diagonal contributions in the expansion of the energy-like scaling variable that enters the parametrization of the MEoS, we explore the variation of the chiral phase transition temperature T_c along different lines in the (μ_B, μ_S) plane. We also show that close to the chiral limit the strange quark mass behaves like an energy-like variable in scaling relations for pseudo-critical temperatures and the chiral phase transition temperature decreases with decreasing strange quark mass.

Exotic Flavours / **26**

Lattice investigations of the chimera baryon spectrum in the $Sp(4)$ gauge theory

Authors: Biagio Lucini[1]; C.-J. David Lin[2]; Davide Vadacchino[3]; Deog Ki Hong[4]; Ed Bennett[1]; Ho Hsiao[5]; Jong-Wan Lee[6]; Maurizio Piai[1]

[1] *Swansea University*

[2] *Institute of Physics, National Yang Ming Chiao Tung University*

[3] *University of Plymouth*

[4] *PNU*

[5] *NYCU*

[6] *IBS, Korea*

We study the $Sp(4)$ gauge theory coupled to hyperquark matter fields. This theory potentially serves as an ultraviolet completion of the Standard model in the framework of composite Higgs models that utilize partial compositeness to generate the top-quark mass.
We focus on the spectroscopy of chimera baryons, which are composite states composed of two fundamental and one antisymmetric hyperquarks.
The chimera baryons having the same quantum number as the top quark are the top partners, which effectively lift the mass of the top quark by mixing with it.
Specifically, we investigate, in the quenched approximation, the three lowest-lying parity-even states: Λ_{CB}, Σ_{CB} (both with spin $1/2$), and Σ^*_{CB} (spin $3/2$). The spin-$1/2$ states are considered as top partner candidates.
We extrapolate our results to the continuum and massless limits by applying an effective treatment inspired by Wilson chiral perturbation theory.
This study sets the stage for our ongoing lattice simulations with the dynamical hyperquarks.

Keynote Talks / **17**

Flavour of dark flavours

Author: Suchita Kulkarni[1]

[1] *University of Graz*

I will take an overview of dark matter models and their potential connections with the world of flavours. This includes dark matter models where dark matters couples to specific Standard Model particles but also models where new dark flavours are proposed.

Exotic Flavours / **15**

Phenomenology of compact objects from a first order phase transition in the dark sector

Author: Jan Tristram Acuña[1]

[1] *Department of Physics, National Tsing Hua University*

The study of first order phase transitions (FOPT) in the early Universe provides a window into fundamental physics. One possible observational signature can come in the form of low frequency stochastic gravitational waves, which may explain the NANOGrav observation. FOPT dynamics may be realized in certain BSM scenarios, which can also accommodate particle species in the dark sector. In this talk,

we will discuss the formation of compact objects, formed from trapped dark matter particles in the false vacuum, that may subsequently collapse into primordial black holes (PBHs). We propose the use of pulsar timing to search for Doppler shifts in the pulsar timing signal, induced by these transiting PBHs. By also taking stochastic GWs as a complementary probe, we show that an SKA-like facility will be sensitive to transiting PBHs of masses 10^{-8} to 10 solar masses, and FOPT scenarios with critical temperatures lying in the 0.1-10 keV range. Furthermore, motivated by the result that black holes are characterized by their mass and spin, I will present some preliminary results on the spins of false vacuum bubbles, induced by cosmological perturbations during the FOPT. This may serve as a first step in determining the initial spins of PBHs produced from this mechanism.

Exotic Flavours / 11

Effects of Superradiance in Active Galactic Nuclei

Author: Priyanka Sarmah[1]

[1] *NTHU*

A supermassive black hole (SMBH) at the core of an active galactic nucleus (AGN) provides room for the elusive ultra-light scalar particles (ULSP) to be produced through a phenomenon called *superradiance*. This phenomenon produces a cloud of scalar particles around the black hole by draining its spin angular momentum. In this work, we present a study of the superradiant instability due to a scalar field in the vicinity of the central SMBH in an AGN. We begin by showing that the time-evolution of the gravitational coupling α in a realistic ambiance created by the accretion disk around the SMBH in AGN leads to interesting consequences such as the amplified growth of the scalar cloud, enhancement of the gravitational wave emission rate, and appearance of higher modes of superradiance within the age of the Universe. We then explore the consequence of superradiance on the characteristics of the AGN. Using the Novikov-Thorne model for an accretion disk, we divide the full spectrum into three wavelength bands- X-ray ($10^{-4} - 10^{-2}$ μm), UV (0.010-0.4 μm), and Vis-IR (0.4-100 μm) and observe sudden drops in the time-variations of the luminosities across these bands and Eddington ratio ($f_{\rm Edd}$) with a characteristic timescale of superradiance. Using a uniform distribution of spin and mass of the SMBHs in AGNs, we demonstrate the appearance of depleted regions and accumulations along the boundaries of these regions in the planes of different band-luminosities and $f_{\rm Edd}$. Finally, we discuss some possible signatures of superradiance that can be drawn from the observed time-variation of the AGN luminosities.

Quark Flavours / 28

Quark flavor violation and axion-like particles from top-quark decays at the LHC

Authors: Fei-Tung Chung[1]; Giovanna Cottin[None]; KINGMAN CHEUNG[2]; Zeren Simon Wang[None]

[1] *National Tsing Hua University*

[2] *NTHU*

We study axion-like particles (ALPs) with quark-flavor-violating couplings at the LHC. Specifically, we focus on the theoretical scenario with ALP-top-up and ALP-top-charm interactions, in addition to the more common quark-flavor-diagonal couplings. The ALPs can thus originate from decays of top quarks which are pair produced in large numbers at the LHC, and then decay to jets. If these couplings to the quarks are tiny and the ALPs have $\mathcal{O}(10)$ GeV masses, they are long-lived, leading to signatures of displaced vertex plus multiple jets, which have the advantage of suppression of background events at the LHC. We recast a recent ATLAS search for the same signature and reinterpret the results in terms of bounds on the long-lived ALP in our theoretical scenario. We find that the LHC with the full Run 2 dataset can place stringent limits, while at the future high-luminosity LHC with 3 ab^{-1} integrated luminosity stronger sensitivities are expected.

Lepton Flavours / 5

A New Higgs Boson With Electron-Muon Flavor-Violating Couplings

Author: Reinard Primulando[1]

[1] *Parahyangan Catholic University, Indonesia*

Motivated by a hint of possible excess of a new resonance decaying to eμ at 146 GeV, we try to interpret the excess in the context of the type-III two-Higgs-doublet-model. We find that the excess is only moderately constrained by low-energy lepton-flavor-violation processes, in particular the μ⟶eγ decay. We also compare the CMS bounds across the entire search region against constraints of μ⟶eγ and μ⟶e conversion in nuclei. Our finding indicates that the collider bounds can be superior to those of low-energy processes for the scalar mass between 110 GeV and 150 GeV, suggesting the importance of this mass range for future searches.

Lepton Flavours / 27

Neutrino Emission upon Black Hole Formation in Core Collapse Supernovae

Author: Jia-Shian Wang[1]

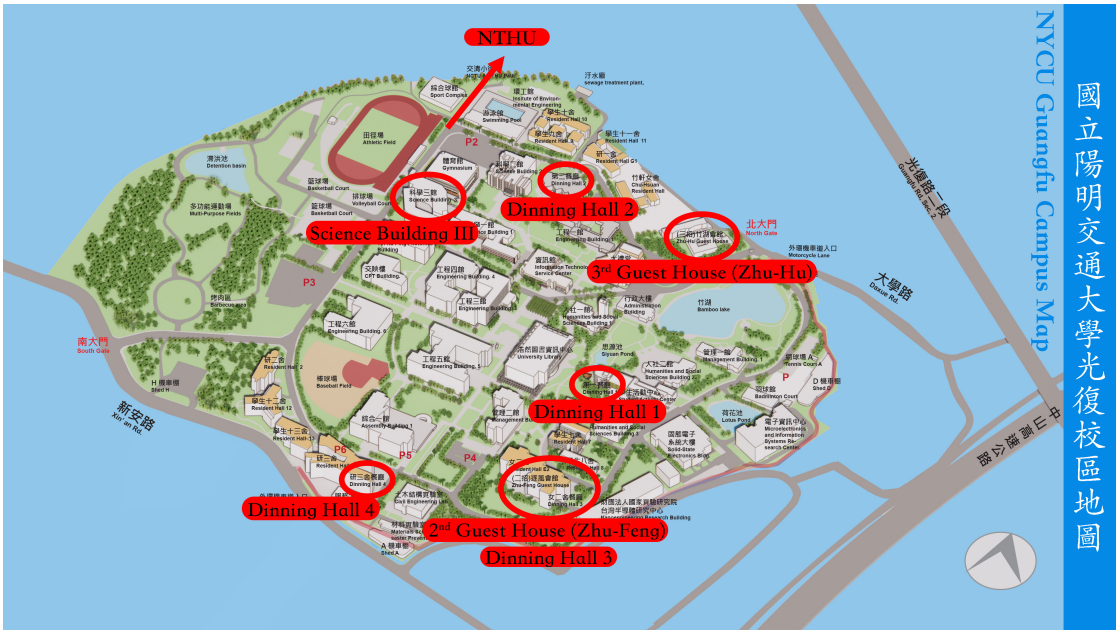
[1] *Academia Sinica*

When a core-collapse supernova fails to explode or barely exploded, i.e., unable to unbind most of the stellar envelope, the associated proto-neutron star is expected to eventually implode into a black hole. In this scenario, the neutrino luminosity spectrum will then see an abrupt end as a result of the engulfment of the luminous core and the increasing gravitational redshift. The dynamics of this violent cut-off is, however, not fully explored and, as a result, is usually treated by considering only specific trajectories. In this study, we perform a fully general relativistic ray-trace study that outlines the potential effects of the highly curved spacetime on neutrino emissions and the resulting signature of black hole formation. The effect of the rotation of the black-hole-forming progenitor is also investigated based on the Kerr metric. Following that, we explored, via more detailed hydrodynamical simulations and accounting for flavour oscillation, the delaying effects of neutrino interactions with the accreting matter flows, which can potentially convolve with the signatures of black hole formation.

Campus Maps

For your convenience we provide here an NYCU and an NTHU campus map.

NYCU campus map



NTHU campus map

	Restaurant	Remarks	Google maps links (click in pdf)
Breakfast	Shine Mood	waffles, drinks	at NYCU and at NTHU
	瑞斯飯團 (Rice balls)	rice balls, sandwiches, tea, soymilk	at NTHU
	早餐屋 (breakfast place)	Taiwanese breakfast snacks and drinks	nearby NTHU guest house
	7-11	convenience store	at NYCU and at NTHU
	Family Mart	convenience store	at NYCU and at NTHU
Dinner	Lala Kitchen	Western style dishes with vegan options	at NYCU
	Wavelight restaurant	Noodles, salads, rice meals	at NTHU
	十六區和風料理	Japanese style	in front of NTHU
	NYCU & NTHU student halls	various food options	check campus maps
Coffee shops	Cama Café		in front of NTHU
	Louisa		at NYCU and at NTHU
	RD Café		in front of NTHU
	HereCafé		at NYCU
	Panda Café		at NTHU
Vegan/Halal options	A+ Indian food		just outside NYCU campus gate
	Indian Darbar		just outside NTHU campus north gate

Table 1: Food options.