# 2018 NCTS Physics ANNUAL REPORT

National Center for Theoretical Sciences

# CONTENTS




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# ABOUT

The National Center for Theoretical Sciences was established on August 1997 by the National Science Council, NSC (NSC became Ministry of Science and Technology, MoST, since March 2014), with endorsement from some of the eminent scholars, including Professors Chen Ning Yang and Shing-Tung Yau. It was hosted on the campus of the National Tsing Hua University, Hsinchu, with National Tsing Hua University and the adjacent National Chiao Tung University acted as co-host in the last 18 years. The Center consists of two divisions: Mathematics and Theoretical Physics. In 2015, the Mathematics division moved to National Taiwan University and continue to serve the community.

The Physics Division, are committed to contribute to the advancement of frontier research in physics.

**Missions**

To act as an effective platform to stimulate and to enhance the interaction and collaboration among researchers.

To empower talented students and postdoctoral researchers to make significant contributions in the frontier of research subjects.

To serve as an efficacious channel to network the home researchers with other scholars and preeminent institutions abroad.

To explore new frontiers in physics research and innovation

To enhance the extent and breadth of interdisciplinary researches as well as the collaboration with scientists in the experimental fields.

# Forward

I am pleased to present you with the 2018 Annual report of the Physics Division of NCTS. This year has been another fruitful year.

NCTS scientists have made significant contribution in areas from such as the impact of ultralight axion Dark Matter on structure formation, novel interpretation of LHC anomalies in B mesons decay observed last year, Higgs coupling in the Georgi-Machacek model, new physics models with displaced vertices in broad sense, holography of conformal field theory with boundary, novel transport phenomena due to Weyl anomaly, hidden symmetry in gauge and gravitational theory in high energy physics to single-layer germanene with completely new 2D material with novel electronic properties, effect of a magnetic dopant impurity on the edge transport of a quantum spin Hall (QSH) insulator, quantum critical behaviors in heavy-fermion compound Ge-YRS system, in condensed matter physics, as well as quantum simulation with quantum gases, electromagnetically-induced-transparency(EIT) and related physical phenomena in system of cold atoms; and the exploration of the nature of these system-environment correlations in quantum information theory.

NCTS publishes 118 papers in 2018. This amounts to around 100 papers on average each year in the past four years. The publications are of high research quality with many high impacts results appearing in prestigious journals. About a third of them are published in high impact journals with the top 15 % of impact factor.

The DCS research program has been progressing well. Individual DCSs have successfully built up their research team with postdocs or assistant research scholars. On average, each DCS has about two postdoctoral researchers or assistant research scholars in his team. Together, the team as a whole interact with other scientists domestic or international collaborators, and students in the community, to engage in active research on frontier research topics. In terms of publication, the five DCS has written a total of 32 papers 2018. Out of which many important results has appeared in high impact journals such as Nano Letters, Nature communications, Physical Review Letters, 2d Materials, Journal of High Energy Physics etc. Collaboration is growing strong as can be seen from the many collaborative publications of the DCS research team.

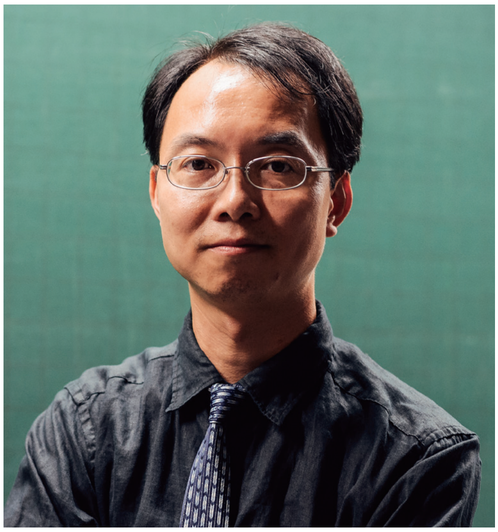
NCTS has played active role in promoting interaction and collaboration within the Taiwanese physics community and with researchers worldwide. We have hosted 221 visiting scientists from abroad in 2018. We organized around 11 international conferences and workshops in 2018. Among which 4 were joint meetings with other countries. Also over a few hundreds seminars on various subjects took place. I would like to compliment my colleagues for their commitment and all the hard works they have put in organizing and keeping a vibrant program of research at NCTS.

NCTS acts responsively to the emerging frontier of the research field through the organization of Rapid Response Workshop and special colloquium. For example in 2016 we have organized the "Rapid Response Workshop on 750 GeV Diphoton Resonance" where the phenomenology of the unexpected 750 GeV resonance was discussed. We have also organized a special colloquium on "Gravitational wave and the LIGO discovery" on Feb 25, two weeks after the announcement of the LIGO discovery on PRL. At the end of 2017, a rapid response meeting "NCTS Rapid Response Round Table Discussion Meeting on Excess of Electron-Positron Cosmic Ray from DAMPE" has been organized in respond to the anomaly observed in the DAMPE experiment.

The cultivation and nurturing of promising students and young researchers has been a very important part of NCTS efforts. The body of research fellows of NCTS has grown significantly. It has currently a body of 18 research staffs consisting of 4 assistant research scholars and 14 postdocs. All of them were hired anew since 2015. The society of postdoctoral researchers has been very active and has published 17 papers in 2015, 46 in 2016, 58 in 2017 and 63 in 2018 (up to Mar, 2019). The quality of our hires has been good and our postdocs were quite successful on the job market. Out of the first bunch of researchers we hired since 2015, Bo Xiong (AMO) has obtained a faculty position at the Wuhan university of technology, China in 2015/12, Yu-Kuo Hsiao has obtained a faculty position at the Shanxi Normal University in 2018/02, Hai-Shuang Lu has obtained a faculty position at the Soochow Univ 2018/03, Rong-xin Miao has obtained a faculty position at the Sun Yat-Sen University, 2018/04, Martin Spinrath has obtained a faculty position at NTHU 2018/08, Xing-Bo Yuan has started as a faculty at the Central China Normal Univ 2018/12.

NCTS has been actively facilitating the transfer of frontier research to the young generations, through organization of advanced schools and workshops specifically with them as target audiences. About 5-7 advanced schools are organized each year. Some of the schools are of interdisciplinary nature, combining theory and experiments, or traditionally different subjects such as chemistry and computation.

NCTS has continued in developing new bilateral agreements with other international institutions in order to foster scientific collaboration. We have built since 2015 new bilateral agreements with the Institute of Basic Science - Center for Theoretical Physics of the Universe, Korea; the Institute of High Energy Physics, the Chinese Academy of Sciences, Beijing; the Donostia International Physics Center, San Sebastian, Spain; Vilnius University, Lithuania, with plans to organize joint conferences and to work together on collaborative research projects. In 2016, NCTS has joined the research network, Fundamental Interaction SpaceTime (FIST), this year. FIST is a High Physics network formed by Research Institutions (primarily) in Asia in order to help building up and strengthening transnational research partnership and cooperation among researchers across Asia. NCTS has also joined the EU network Cooperation in Science and Technology (COST) on "Quantum structure of spacetime (QSPACE)". This year we have joined the Institute for Complex Adaptive Matter, ICAM. As a kick start, we have organized the annual



conference of ICAM here in NCTS in January $14^{th}$-$16^{th}$, 2019. The conference was followed by a frontier workshop on Strongly Corelated and Topological Physics from January $16^{th}$-$18^{th}$, 2019.

Scientists of NCTS have received various awards and recognition this year. Prof Kingman Cheung was awarded the 2018 Achievement in Asia Award by the International Organization of Chinese Physicists and Astronomers (OCPA). Prof Yu-tin Huang was awarded 2018 Ta-You Wu Memorial Award by the Ministry of Science and Technology of Taiwan, and the 2018 (the sixth) Nishina Asia Award by the Nishina Memorial Foundation. Prof Miguel Cazalilla was elected Fellow by the American Physical Society. Prof Guang-Yu Guo was awarded the Y. Z. Hsu Science and Technology Chair Professorship by the Far Eastern Y. Z. Hsu Science and Technology Memorial Foundation. I am grateful to my friend and colleague Professor Daw-Wei Wang for his commitment as the vice director of the center. I would also like to compliment the team of administrative staff for their hard work in making the operation of NCTS smooth and successful.

Chu Chong Sun

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2019

# Structure and Governance

## Operation and Management

The director is responsible for all the decisions of the Center. He/She leads the Academic Executive Committee, and is responsible for the decision making for the operation inside the division. The Executive Director is appointed by the Director to assist him/her in implementing policies and operations of the Center. As an academic, he/she also held a vital role in helping to push the center's academic programs and initatives. The center routine and daily operation is carried out by the center adminstrative team which consists of six adminstrative staff, an accountant and an IT staff. The center submits an annual report, with financial statements to the Minstry of Science and Technology (MoST), usually in October of the year. A grant midterm review is conducted in MoST in December to discuss the annual budget for the following year.

The Center Academic Executive Committee is set up by the Director to help the Director to make decision on the scientific personnel and academic matters. For exmaple, to give advices on the general policies and guidelines for the NCTS scientific activities and financial affairs, and to give recommendations to the director on the appointment of the NCTS scientific personnel. The committee meets four times a year. The Program Committee is comprised of the coordinators of the academic research groups (Thematic research groups, Experimental collaboratio group,interdisciplinary research groups) advanced by the center.

## International Advisory Committee

| | |
|---|---|
| Carlo Beenakker | Instituut-Lorentz for Theoretical Physics, Leiden University, Netherlands |
| Tohru Eguchi | Department of Physics and Institute of Theoretical Physics, Rikkyo University, Tokyo; Former director of the Yukawa Institute for Theoretical Physics, Japan |
| Antoine Georges | Director of the Simons Center for Computational Quantum Physics, USA |
| Tao Han | Director of the Pittsburgh Particle Physics, Astrophysics, and Cosmology Center, University of Pittsburgh, USA |
| Steven G. Louie | University of California at Berkeley, USA |
| Allan H. Macdonald | Sid W. Richardson Foundation Regents Chair; Professor of Physics, University of Texas, Austin, USA |
| Henry Tye | Former diector of the Institute for Advanced Study, Hong Kong University of Science and Technology, Hong Kong |

## Organization

National Tsing Hua University

Ministry of Science and Technology

International Advisory Committee

NCTS Physics Division Director

Vice Director

Administrative Office

Executive Committee

Program Committee

Center Scientists, Postdocs, Visitors

IAC meeting, Sep 28, 2018.
(From left) Profs. Carlo Beenakker, Steven G. Louie, Director Chong-Sun Chu, Profs. Henry Tye, Allan H. Macdonald.

# Major Academic Program

## Thematic Groups Research Program

In order to encourage and enhance the collaboration and innovation of the larger community, The primary aim of Thematic Group (TG) is to foster an efficient collaborative environment in the community.

act as an effective platform to bring together researchers with complementary scientific approaches and backgrounds so that a closer cooperation and collaboration of researchers could be fostered.

## Experimental Collaboration and InterDisciplinary Research Program

In order to enhance the collaboration between theorists and experimentalists, and to promote the exchange and cooperation between researchers in tradition different disciplines, the Center operates the Experimental Collaboration Program (ECP) and the InterDisciplinary Research Program (IDP). In these programs, the role of NCTS is to

## Seed Project

Seed Project (SP) is to support new research direction or research area where there is a relatively smaller representation in the local community.

The subject theme of the Thematic Research Program, Experimental Collaboration and InterDisciplinary Research Program and Seed Project as well as their coordinators are listed in the tables below.

## Thematic Groups

| TG | PROGRAM TITLE | COORDINATORS |
|---|---|---|
| TG1 | Particle Physics | Tzu-Chiang Yuan (AS) |
| TG2 | Dark Physics of the Universe | Chao-Qiang Geng (NTHU) |
| TG3 | Strings | Yu-Tin Huang (NTU) |
| TG4 | Topology & Entanglement in Quan. Many-Body Systems | Po-Chung Chen (NTHU) |
| TG5 | Complex Systems | Yeng-Long Chen (AS),<br>Kuo-An Wu (NTHU) |
| TG6 | Quantum Information Science and Quantum Control | Hsi-Sheng Goan (NTU),<br>Yueh-Nan Chen (NCKU) |
| TG7 | Quantum Gases | Ray-Kuang Lee (NTHU) |
| TG8 | Topology & Strong Correlations in Quan. Many-Body Systems | Chung-Hou Chung (NCTU) |
| TG9 | Quantum and Topological Materials | Feng-Chuan Chuang (NSYSU),<br>Horng-Tay Jeng (NTHU) |

## Experimental Collaboration Program

| ECP | PROGRAM TITLE | COORDINATORS |
|---|---|---|
| E1 | Quantum Optics and Quantum Manipulation of Ultracold Atoms | Ying-Cheng Chen (AS) |
| E2 | Light Dark Matter | Cheng-Pang Liu (NDHU), Henry Wong (AS) |
| E3 | LHC Experimental/Theoretical Exploration | Kingman Cheung (NTHU), Jennifer Hsu (NTHU) |

## Interdisciplinary Research Program

| IDP | PROGRAM TITLE | COORDINATORS |
|---|---|---|
| I1 | Multiscale studies for complex materials, catalysts, and biological systems – theoretical and computational approaches, and experimental stimulus | Jer-Lai Kuo (AS) |
| I2 | Geometry, Topology and String Theory | Nan-Kuo Ho (NTHU),<br>Siye Wu (NTHU) |
| I3 | Complex Systems and Mathematical Biology | Lee-Wei Yang (NTHU) |
| I4 | Explainable Artificial Intelligence | Jason Chang (NTHU),<br>Daw-Wei Wang (NTHU) |

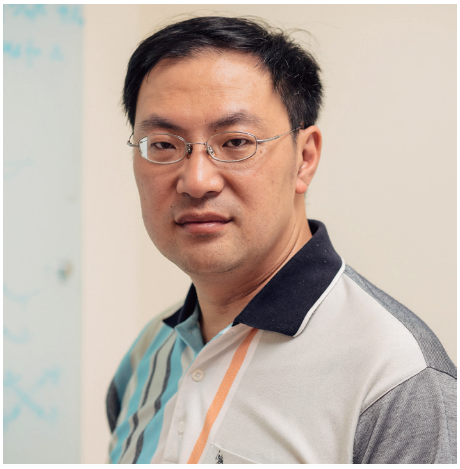
## Seed Project

| SP | PROGRAM TITLE | COORDINATORS |
|---|---|---|
| S1 | Quantum Transport | Chao-Cheng Kaun (AS) |
| S2 | Gravitional Wave and Numerical Gravity | Feng-Li Lin (NTNU) |
| S3 | Parton Distribution Functions from Lattice QCD | David Lin (NCTU) |
| S4 | Non-equilibrium Quantum Phenomena | Chung-Hsien Chou (NCKU) |

# PERSONNEL

## Director Office

Professor
### Chong-Sun Chu
**Director**
Distinguished Center Scientist
National Tsing Hua University
Particle Physics



Professor
### Daw-Wei Wang
**Vice Director**
National Tsing Hua University
Condensed Matter Physics

# (Distinguished) Center Scientists

Professor
## Miguel A. Cazalilla
**Distinguished Center Scientist**
National Tsing Hua University
Condensed Matter Physics

Professor
## Kingman Cheung
**Distinguished Center Scientist**
National Tsing Hua University
Particle Physics

Professor
## Guang-Yu Guo
**Distinguished Center Scientist**
National Taiwan University
Condensed Matter Physics

Professor
## Xiao-Gang He
**Distinguished Center Scientist**
National Taiwan University
Particle Physics

Professor
## Sung-Kit Yip
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Academia Sinica
Condensed Matter Physics

Professor
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**Center Scientist**
National Cheng Kung University
Atomic, Molecular & Optical Physics

Professor
## Cheng-Wei Chiang
**Center Scientist**
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Particle Physics

Professor
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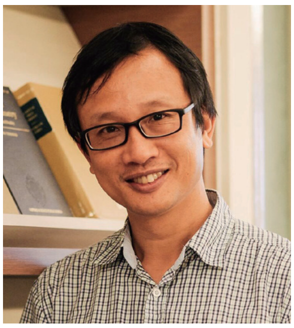

Professor
## Ying-Jer Kao
**Center Scientist**
National Taiwan University
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Professor
## Ray-Kuang Lee
**Center Scientist**
National Tsing Hua University
Atomic, Molecular & Optical Physics

Professor
## Yi Yang
**Center Scientist**
National Chiao Tung University
Particle Physics

# Thematic Group Coordinators

Professor
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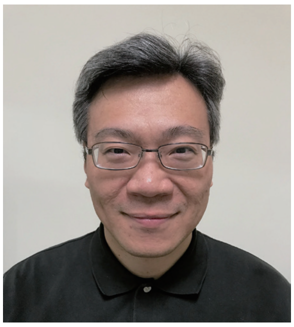
**Thematic Group 1: Particle Physics**
Academia Sinica

Professor
**Chao-Qiang Geng**
**Thematic Group 2: Dark Physics of the Universe**
National Tsing Hua University

Professor
**Yu-Tin Huang**
**Thematic Group 3: Strings**
National Taiwan University

Professor
**Po-Chung Chen**
**Thematic Group 4: Topology and Entanglement in Quantum Many-body Systems**
National Tsing Hua University

Professor
**Yeng-Long Chen**
**Thematic Group 5: Complex Systems**
Academia Sinica



Professor
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Professor
**Hsi-Sheng Goan**
**Thematic Group 6: Quantum Information Science and Quantum Control**
National Taiwan University

Professor
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Professor
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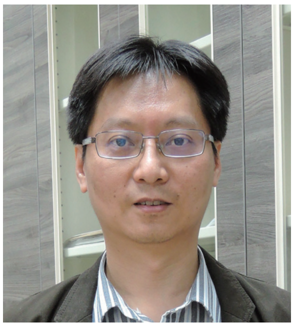
National Tsing Hua University



Professor
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National Chiao Tung University

Professor
**Feng-Chuan Chuang**
**Thematic Group 9: Quantum and Topological Materials**
National Sun Yat-Sen University

Professor
**Horng-Tay Jeng**
**Thematic Group 9: Quantum and Topological Materials**
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# Research Staffs

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**Postdoctoral Researcher**
Atomic, Molecular & Optical Physics

Dr.
## Nabarun Chakrabarty
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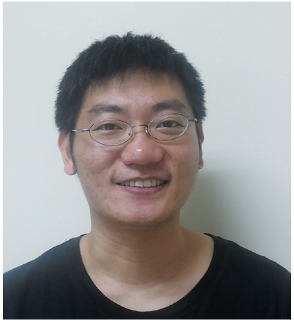
Particle Physics



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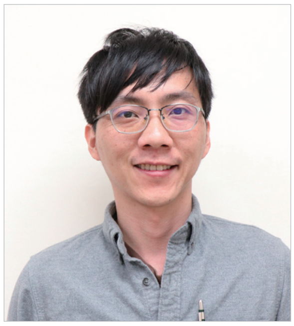

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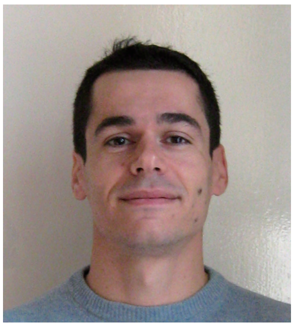

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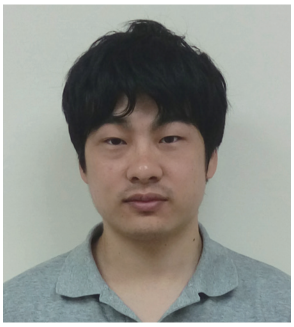

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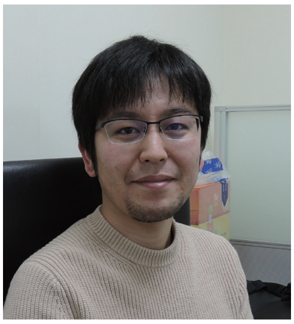

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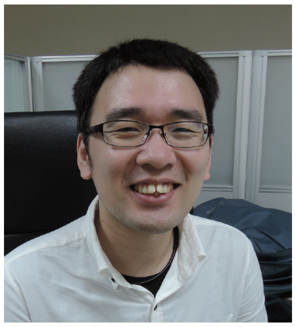

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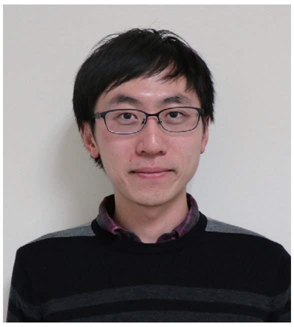

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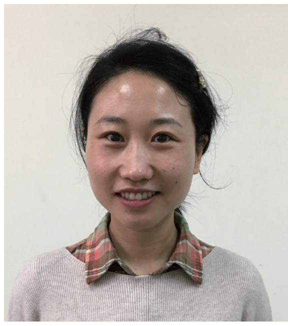

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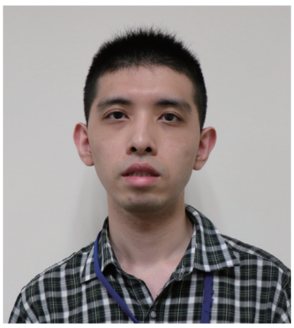

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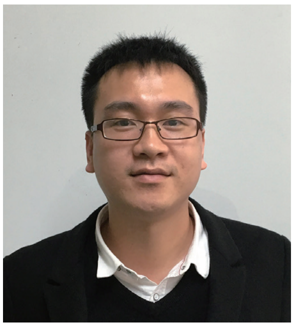

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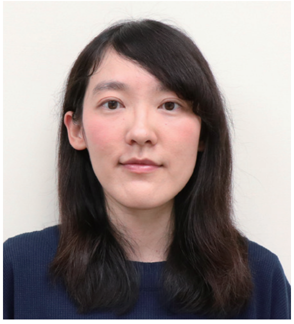

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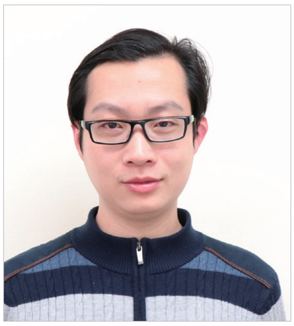


Dr.
**Chen Zhang**
**Postdoctoral Researcher**
Particle Physics

# RESEARCH

Research in NCTS is mainly conducted through the operation of the Center Scientists Program, Postdoctoral Research Program, Thematic Groups Research Program, Experimental Collaboration Program and the Interdisciplinary Research Program.

The principal function of thematic groups is to promote the growth and to strengthen the base of the larger community, through collaboration in research. Collaboration between theorists and experimentalists is essential and can be a very powerful way for advancing scientific discoveries and technological innovations. A successful and productive collaboration between theorists and experimentalists will also help to strengthen the overall research environment in the whole physics community. Besides, many major breakthroughs in science take place at the intersections of disciplines. This is particular so in the modern time due to the increasing complexity of problems. The Experimental Collaboration Program (ECP) is led by leading experimentalists. The interdisciplinary program (IDP) is led by PI in different research fields. These groups work closely with the Thematic research groups in their operation.

Apart from their own research, the center scientists (Distinguished center scientists DCS and center scientists CS) often work together with the Thematic groups (TG) to form collaborative research team. They also help to promote the research programs and activities of the center.

Below we give a description of some of the more representative research conducted by these respective entities.

# Reports from Center Scientists

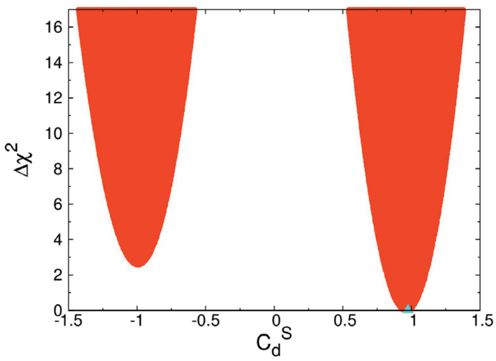
## Emerging Results in Higgs Precision Analysis

Professor
**Kingman Cheung**
**Distinguished Center Scientist**
National Tsing Hua University
Particle Physics

Ever since the discovery of a standard model (SM) like Higgs boson in 2012, the main focus of the LHC experiments has been put on fully establishing its identity. The Run II at the LHC finished at the end of 2018, followed by two years of long shutdown for upgrade. The data collected up to Summer 2018 have established most production channels and decay channels of the Higgs boson. On the production side, in addition to gluon fusion (ggF), vector-boson fusion (VBF), the associated production with a V = W/Z boson (VH), and the associated production with a top-quark pair (ttH) have been extensively investigated. On the decay side, $H \to b\bar{b}$ and $H \to \tau\tau$ were also very recently established. In Ref. [1], we performed global fits to all Higgs-boson signal strengths in various scenarios of new physics.

Although each signal strength seems consistent the SM prediction, collectively some interesting observations are found:

1. The combined average signal strength of the Higgs boson now stands at a 2-σ deviation from the SM value, namely μexp = 1.10 ± 0.05.
2. For the first time the bottom-Yukawa coupling shows statistical difference between the positive and negative signs. Thanks to the discriminating power of the Higgs-gluon vertex Sg the positive sign of the bottom-Yukawa is more preferred than the negative one. See Fig.1




3. The negative side of the top-Yukawa is now entirely ruled out, except in the scenarios with non-zero $\Delta S^{\gamma}$.
4. The nonstandard or invisible decay branching ratio of the Higgs boson is now reduced to less than 8.4% at the 95% CL, which improves substantially from the previous value of 19%. This is obtained by varying only $\Delta\Gamma_{tot}$.

If the overall signal strength continues to about 10% above the SM prediction while the uncertainties continues to reduce, it would pose a threat to the SM Higgs boson. One of the most economical fits to the Higgs-signal strength is to vary the total width of the Higgs boson. Naively, it is hard to imagine that one can add any new channels to reduce the total width. Nevertheless, one possibility is to reduce the partial width into $b\,\bar{b}$ with a reduced bottom- Yukawa coupling, provided that the current uncertainty of $H \to b\,\bar{b}$ coupling is of order 20%. In Ref. [2], we explore an extension by adding an SU(2) vector-like quark doublet with hypercharge Y/2 = - 5/6, of which the upper component $b'^{-1/3}$ mixes with the SM $b_R$. In such a way, the right-handed (RH) component of the bottom quark is reduced and thus the bottom-Yukawa coupling is reduced. Therefore, it can effectively explain why the average Higgs-signal strength is enhanced.

The structure of the new vector-like quark doublet is

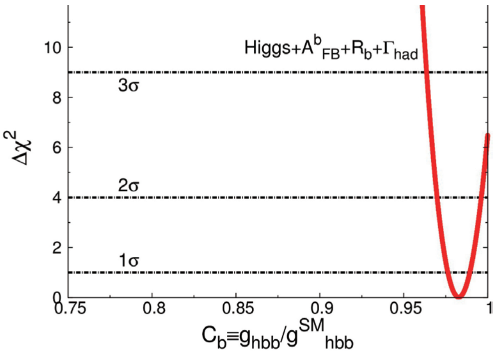
$$B_{L,R} = \begin{pmatrix} b'_{-\frac{1}{3}} \\ p'_{-\frac{4}{3}} \end{pmatrix}_{L,R} , \quad \left(\frac{Y}{2}\right)_B = -\frac{5}{6}$$

The upper component mixes with the SM b quark as The upper component mixes with the SM b quark as

$$\begin{pmatrix} b \\ b' \end{pmatrix}_{L,R} = \begin{pmatrix} \cos\theta_{L,R} & \sin\theta_{L,R} \\ -\sin\theta_{L,R} & \cos\theta_{L,R} \end{pmatrix} \begin{pmatrix} b \\ b' \end{pmatrix}^{m}_{L,R}$$

In this way, the bottom Yukawa coupling is reduced. Thus, it can explain the enhancement of Higgs signal strength.

On the other hand, the Zbb coupling is modified such that Z-boson observables, like total hadronic width, $R_b$, $A_{FB}b$ would be affected. We perform an analysis and find that a moderate improvement to the Higgs signal strength by adding the vector quark doublet (see Fig.2) but it is, however, severely constrained by the Z-boson observables.

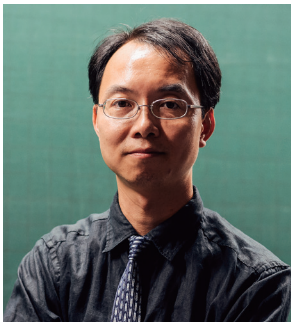



Such vector quark doublet of TeV can be searched at the LHC. Its decay b' -> bZ, bH potentially gives signatures of 1 or 2 charged lepton pairs at the Z mass plus multiple b jets.


[1] K. Cheung, J.S. Lee, P.Y Tseng, "New Emerging Results in Higgs Precision Analysis Updates 2018 after Establishment of Third-Generation Yukawa Couplings", arXiv: 1810.02521.

[2] K. Cheung, W.Y. Keung, J.S. Lee, P.Y Tseng, "Vector-like Quark Interpretation of Excess in Higgs Signal Strength", arXiv: 1901.05626.

# Boundary Phenomena of Vacuum



Professor
**Chong-Sun Chu**
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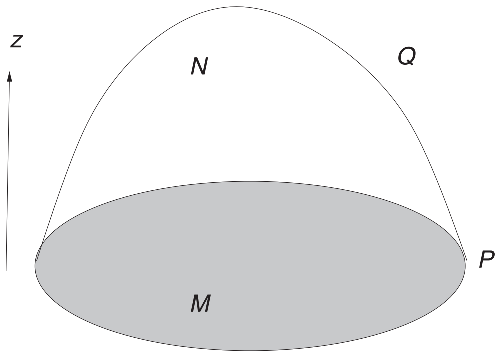
Particle Physics

## Casimir Effects and Exact Relations in BCFT [1]

The Casimir effect originates from the effect of boundary on the zero point energy-momentum of quantized fields in a system. As a fundamental property of the quantum vacuum, it has important consequences on the system of concern and has been applied to a wide range of physical problems, such as classic applications in the study of the Casimir force between conducting plates (and nano devices), dynamical compactification of extra dimensions in string theory, candidate of cosmological constant and dark energy, as well as dynamical Casimir effect and its applications.




In [1], Chong-Sun Chu and collaborators revealled elegant relations between a remarkable intergrability relation between the boundary behaviour of the stress tensor and the Weyl anomaly in BCFT.

$$(\delta \mathcal{A})_{\partial M} = \left( \frac{1}{2} \int_{x \geq \epsilon} \sqrt{g}\, T^{ij} \delta g_{ij} \right)_{\log(1/\epsilon)}$$

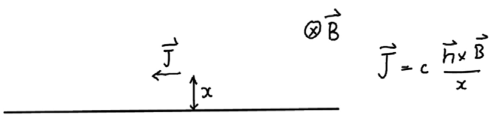
They showed that for any BCFT which has a description in terms of an effective action, the near boundary divergent behavior of the renormalized stress tensor is completely determined by the central charges of the theory. These relations are verified by free BCFTs. Chong-Sun etal. tested them with holographic models of BCFT and found exact agreement. They further proposed that these relations between Casimir coefficients and central charges hold for any BCFT. With the holographic models, they reproduced not only the precise form of the near boundary divergent behavior of the stress tensor, but also the surface counter term that is needed to make the total energy finite. As these are proportional to the central charges, the near boundary divergence of the stress tensor must be physical and cannot be dropped by further artificial renormalization. Their results have thus provided affirmative support on the physical nature of the divergent energy density near the boundary, whose reality has been a long-standing controversy in the literature.

RESEARCH

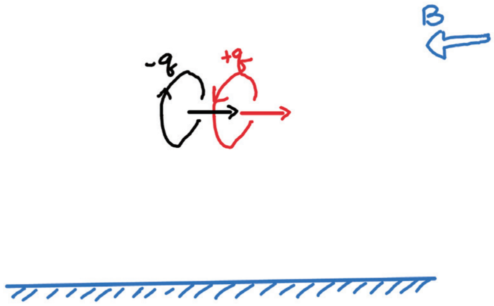
## Magnetic Casimir Effect in Boundary Quantum Field  Theories [2,3]

The quantum transportation of charges induced by anomaly is an interesting phenomena. For example, the chiral magnetic effect (CME) refers to the generation of currents parallel to an external magnetic field. And the chiral vortical effect (CVE) refers to the generation of a current due to rotational motion in the charged fluid.  One of the most well-known manifestation of the quantum nature of the vacuum is the Casimir effect.  This occurs since the energy of the vacuum is sensitive to the change in the boundary condition. After the above described discovery of the new relation between the Casimir effect and Weyl anomaly [1], Chong-Sun and collaborators further extended this idea to U(1) conserved current and find the existence of a novel anomalous current near the boundary of a vacuum when a background magnetic field is turned on [2].

$$\mathbf{J} = \frac{e^2 c}{\hbar} \frac{4 b_1 \mathbf{n} \times \mathbf{B}}{x}, \quad x \sim 0$$




The induced current is a magnetization current in origin: the movement of the virtual charges near the boundary give rise to a non-uniform magnetization of the vacuum and hence a magnetization current. This anomalous transport occurs in zero temperature vacuum without the need of material support.  And, in analogous to the Casimir effect, it is an intrinsic manifestation of the dependence of the quantum vacuum on boundary. Previously anomalous current transport were found only in material system. This discovered phenomena offers the first  occurence of an anomalous current in vacuum.




The holographic aspect of this phenomena was further investigated in [3].

## Boundary String Current and Weyl Anomaly in 6-dimensions [4]

It was discovered in [2] that for a boundary system  in the presence of a background magnetic field, the quantum fluctuation of the vacuum would create a non-uniform magnetization density for the vacuum and a magnetization current is induced in the vacuum. In [4], Chong-Sun etal. generalize this four dimensional  effect to six dimensions. We use the AdS/BCFT holography to show that  in the presence of a 3-form magnetic field strength H, a string current is induced in a six dimensional boundary conformal field  theory. This  allows us to determine the gauge field contribution to the Weyl anomaly in six dimensional  conformal field theory in a  H-flux background. For the (2,0) superconformal field theory of N M5-branes, the current has a magnitude proportional to N^3 for large N. This provide support to the conjecture of Klebanov and Tseytlin that the degree of freedoms scales as N^3 in the (2,0) superconformal theory of N multiple M5-branes. The prediction we have for the Weyl anomaly  is a new criteria that the (2,0) theory should satisfy.

[1] R. X. Miao and C. S. Chu, "Universality for Shape Dependence of Casimir Effects from Weyl Anomaly," JHEP 1803 (2018) 046.

[2] C. S. Chu and R. X. Miao, "Weyl Anomaly Induced Current in Boundary Quantum Field Theories," Phys. Rev. Lett. 121 (2018) no.25,  251602.

[3] C. S. Chu and R. X. Miao, "Anomalous Transport in Holographic Boundary Conformal Field Theories," JHEP 1807 (2018) 005.

[4] C. S. Chu and R. X. Miao, "Boundary String Current & Weyl Anomaly in Six-dimensional Conformal Field Theory," arXiv:1812.10273 [hep-th].

# Magnetic Order, Kondo Effect and Photonic Topological Phase in Two-dimensional Materials

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Atomically thin ferromagnetic (FM) films were recently prepared by mechanical exfoliation of bulk FM semiconductor $Cr_2Ge_2Te_6$. (see [1] and references). They provide a platform to explore novel two-dimensional (2D) magnetic phenomena, and offer exciting prospects for new technologies. By performing systematic *ab initio* density functional calculations, we recently study two relativity-induced properties of these 2D materials [monolayer (ML), bilayer (BL) and trilayer (TL) as well as bulk], namely, magnetic anisotropy energy (MAE) and magneto-optical (MO) effects [1]. Competing contributions of both magneto-crystalline anisotropy energy (C-MAE) and magnetic dipolar anisotropy energy (D-MAE) to the MAE, are computed. Calculated MAEs of these materials are large, being in the order of ~0.1 meV/Cr. Interestingly, we find that the out-of-plane magnetic anisotropy is preferred in all the systems except the ML where an in-plane magnetization is favored because here the D-MAE is larger than the C-MAE. Crucially, this explains why long-range FM order was observed in all the few-layer $Cr_2Ge_2Te_6$ except the ML because the out-of-plane magnetic anisotropy would open a spin-wave gap and thus suppress magnetic fluctuations so that long-range FM order could be stabilized at finite temperature. In the visible frequency range, large Kerr rotations up to ~1.0° in these materials are predicted and they are comparable to that observed in famous MO materials such as PtMnSb and $Y_3Fe_5O_{12}$. Moreover, they are ~100 times larger than that of 3d transition metal MLs deposited on Au surfaces. Faraday rotation angles in these 2D materials are also large, being up to ~120 deg/μm, and are thus comparable to the best-known MO semiconductor $Bi_3Fe_5O_{12}$. These findings thus suggest that with large MAE and MO effects, atomically thin $Cr_2Ge_2Te_6$ films would have potential applications in novel magnetic, MO and spintronic nanodevices.

In normal metals, the magnetic-moment of impurity-spins disappears below a characteristic "Kondo" temperature ($T_K$). This marks the formation an entangled state of polarized electrons that screen the spin of an impurity. This so-called Kondo effect is a prime example of an emergent many-body phenomenon in a quantum impurity system. In normal metals where the density of states (DOS) is finite and the coupling strength between impurity and electron bath ($\Gamma_0$) is non-zero, Kondo screening is ubiquitous. In insulators, in contrast, the impurity moments remain unscreened at all temperatures. In intermediate, pseudogap systems where the DOS vanishes at the Fermi energy ($E_F$), such as undoped graphene, theory predicts a quantum phase transition at a critical value of the coupling strength ($\Gamma c$) which separates a magnetic phase from a non-magnetic Kondo-screened phase (see Fig. 1 as well as [2-4] and references therein). Graphene, with its linear DOS and tunable chemical potential could provide a perfect playground for exploring the physics of this magnetic quantum phase-transition. However, attempts to experimentally confirm these predictions and their intriguing consequences such as the ability to electrostatically tune magnetic moments, have been elusive. Recently, we report the observation of the magnetic phase transition of a spin hosted by an isolated vacancy in graphene [2]. Using the spectroscopic signature of the Kondo effect obtained with

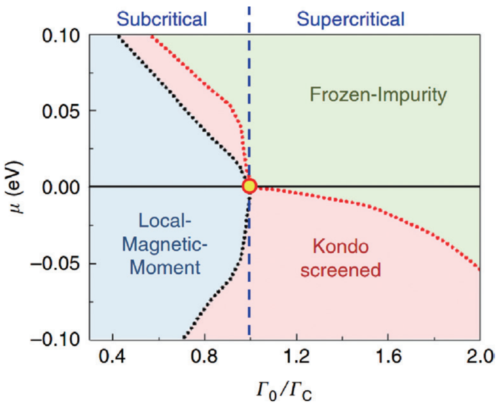


**Fig. 1** *Quantum phase transition and Kondo screening in graphene with carbon vacancies: $\mu-\Gamma_0$ phase diagram , where $\mu$ is chemical potential and $\Gamma_0$ ($\Gamma_C$) is the (critical) coupling strength [2].*

scanning tunneling spectroscopy (STS) together with renormalization-group calculations (NRG), we demonstrate that the vacancy magnetic moment and its switching between on and off states, can be controlled by tuning the gate voltage or the local curvature of the substrate. Our findings demonstrate the existence of the quantum critical point in graphene and provide a model system for exploring pseudogap Kondo physics.

Electronic and photonic topological insulators have attracted enormous attention in the past years because these systems exhibit fascinating wave transport properties. In particular, due to topologically nontrivial properties of their bulk band structures, the gapless edge states on the surface or at the interface between two topological insulators are unidirectional and robust against scattering from disorder. Thus, we recently study topological phases in a 2D photonic crystal with broken time (*T*) and parity (*P*) symmetries by performing calculations of band structures, Berry curvatures, Chern numbers, edge states and also numerical simulations of light propagation in the edge modes [5]. Specifically, we consider a hexagonal lattice consisting of triangular gyromagnetic rods. Interestingly, we find that the 2D crystal could host quantum anomalous Hall (QAH) phases with different gap Chern numbers ($C_g$) including $|C_g| > 1$ as well as quantum valley Hall (QVH) phases with contrasting valley Chern numbers ($C_v$), depending on the orientation of the triangular rods. Furthermore, phase transitions among these topological phases, such as from QAH to QVH and vice versa, can be engineered by a simple rotation of the rods. Our band theoretical analyses reveal that the Dirac nodes at the K and K' valleys in the momentum space are produced and protected by the mirror symmetry ($m_y$) instead of the *P* symmetry, and they become gapped when either *T* or $m_y$ symmetry is broken, resulting in a QAH or QVH phase, respectively. Moreover, a high Chern number ($C_g$ = -2) QAH phase is generated by gapping triply degenerate nodal points rather than pairs of Dirac points by breaking *T* symmetry. Our proposed photonic crystal thus provides a platform for investigating intriguing topological phenomena which may be challenging to realize in electronic systems, and also has promising potentials for device applications in photonics such as reflection-free one-way waveguides and topological photonic circuits.

[1] Y. Fang, S. Wu, Z.-Z. Zhu and G. Y. Guo, Large magneto-optical effects and magnetic anisotropy energy in two-dimensional Cr2Ge2Te6, Phys. Rev. B 98, 125416 (2018).

[2] Y. Jiang, P.-W. Lo, D. May, G. Li, G. Y. Guo, F. B. Anders, T. Taniguchi, K. J. Watanabe, J. Mao, and E. Y. Andrei, Inducing Kondo screening of vacancy magnetic moments in graphene with gating and local curvature, Nature Commun. 9, 2349 (2018).

[3] P. W. Lo, G. Y. Guo, F. B. Anders, Gate-tunable Kondo resistivity and dephasing rate in graphene studied by numerical renormalization group calculations. Phys Rev B 89, 195424 (2014).

[4] D. May, P.-W. Lo, K. Deltenre, A. Henke, J. Mao, Y. Jiang, G. Li, E. Y. Andrei, G. Y. Guo and F. B. Anders, Modeling of the gate-controlled Kondo effect at carbon point defects in graphene, Phys. Rev. B 97, 155419 (2018).

[5] H.-C. Chan and G. Y. Guo, Tuning topological phase transitions in hexagonal photonic lattices made of triangular rods, Phys. Rev. B 97, 045422 (2018).

# Flavor, Collider and Cosmology Studies Beyond Standard Model

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The aim of this NCTS research team on Flavor, Collider and Cosmology Studies Beyond Standard Model is to carry out forefront research in particle physics, particularly in the areas: 1) Beyond SM and Flavor Physics; 2) Beyond SM and Collider Physics; and 3) Beyond SM and Dark Matter and Dark Energy. Since the execution of this project in June 2015, we have vigorously carried out research in related fields and also organized activities accordingly.

In 2017 and 2018, we carried out research with emphasis on flavor physics and CP violation in B, Higgs physics, Dark Photon and Dark Matter physics. We published 20 papers in SCI journals. Among the published papers we have 4 papers listed by the Web of Science as "Highly Cited Papers" . We will briefly describe the results in these papers.

## Studies of Anomalies in B Meson Decays

In April 2017, the LHCb showed that there is an anomaly in B to $K^*\mu\mu$ decay, a deficit compared with SM prediction. Together with previous anomalies observed by Belle, Babar and LHCb, in B to $D^{(*)}$ $\tau\nu$, and in several b to s $\mu\mu$ induced processes, such as B to K $\mu\mu$, both provide hints for new physics beyond SM at about $4\sigma$ level. There are far reaching implications. Many efforts have been put theoretical model buildings to explain these anomalies. We have engaged in active research in related areas as early as 2013. Our research have received attentions fro peers. Two papers in the last two years were listed as "Highly cited Papers". In the paper published in Eur. Phys. J. C77, 134(2017), with my collaborator N. Deshpande of University of Oregon, we studied the possibility of solving the above two anomalies simultaneously in R-parity SUSY theory. This is inspired by the claim that leptoquark model can achieve this goal. We find that although there are similar leptoquarks in the theory, due to constrains from SUSY consideration certain terms are not allowed prohibiting the possibility to do the desired job compared with non-SUSY leptoquark models. The other study led to a publication in Phys. Lett. B779(2018)52 was a study of B to $D^{(*)}\tau\nu$ In this work with my collaborator G. Valencia of Monash University fund that a class of left-right symmetric models we proposed several years ago (Phys. Rev. D87(2013)014014) contains the right ingredient to help solve the problem from very different motivations. We proposed several measurements which can distinguish different models.

## Dark Matter Studies

Dark matter physics is one of our major activities. In Nov. 2017, the DAMPE collaborations announced their new results on possible indirect dark matter from cosmic electron-positron spectrum indicating the possibility of an electrophilic dark matter with a mass about 1.4 TeV. We quickly reacted with new data and proposed our new beyond SM explanations and predictions in two papers: Electrophilic dark matter with dark photon: from DAMPE to direct detection (Phys. Lett. B778, 292(2018). Collaborator Pei-Hong Gu) and Leptophilic dark matter in gauged $U(1)_{Le-Lm}$ model in light of DAMPE cosmic ray e+e- excess (Eur. Phys.J.C78(2018)323. Collaborators G-H Duan, L. Wu, J-M. Yang). Both papers were using leptophilic type of dark matter to explain data. But how to distinguish different models is a difficult task. We discussed various ways of achieving this goal. Leptophlic dark matter also makes the direct detection very difficult. We found that at loop level, the dark matter will interact with nuclei, but of course with much smaller interaction rate compared with dark matter interact directly with nuclei. This actually provide an interesting explanation why direct detection have not been able to find dark matter. But experiments are becoming more and more precise, the predicted detection rate may be achieved in next generation of dark matter search experiment. The models will be tested.

# Novel Electronic Structures of Topological Materials and Heterostructures

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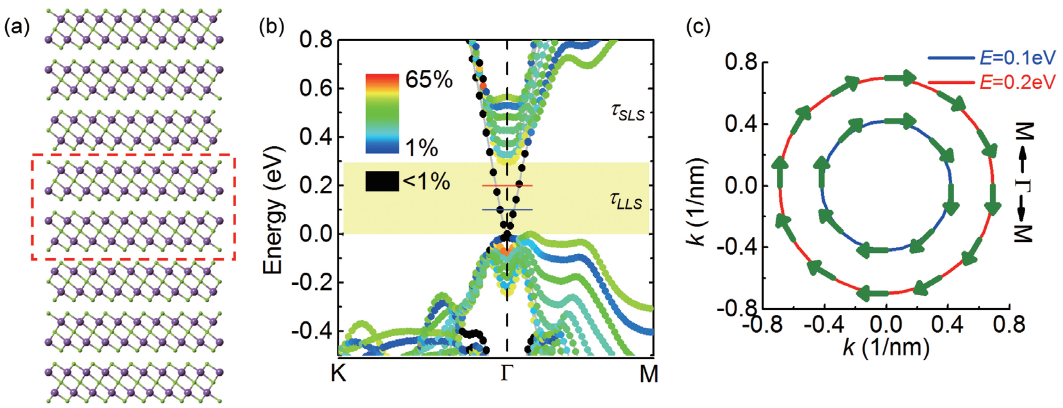
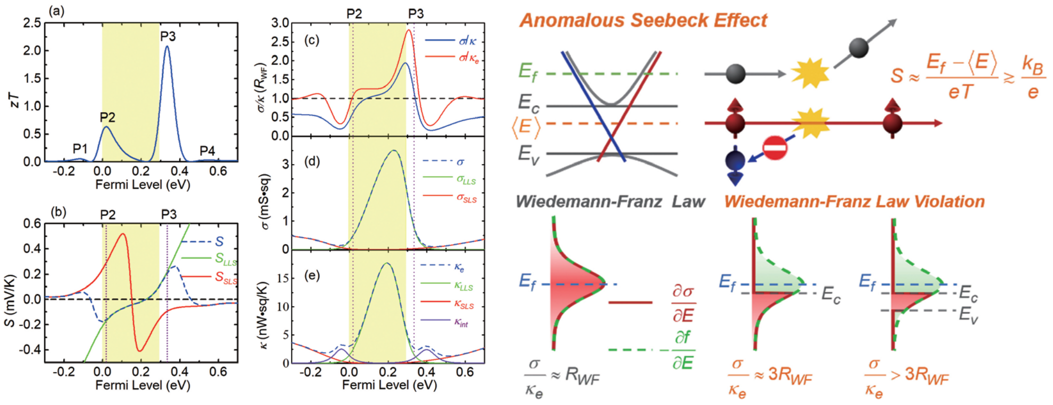
## Strongly Enhanced Thermoelectric Performance over a Wide Temperature Range in Topological Insulator Thin Films

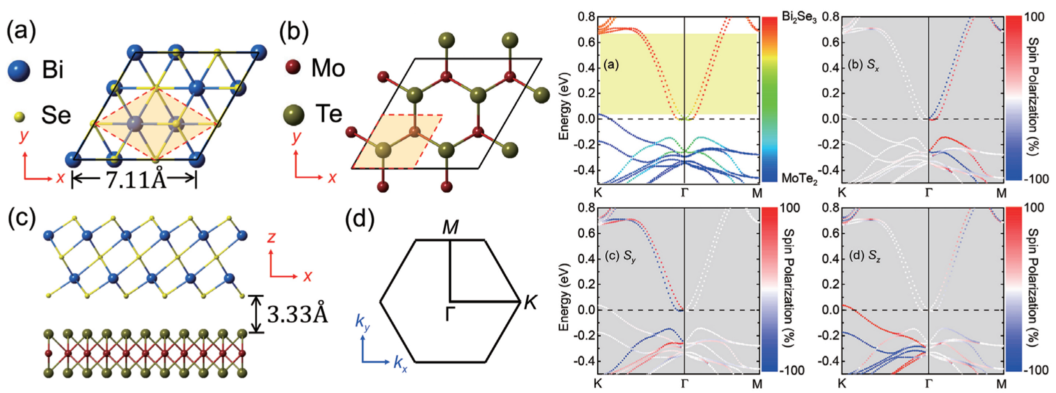
Thermoelectric (TE) devices have been attracting increasing attention because of their ability to convert heat directly to electricity. To date, improving the TE figure of merit remains the key challenge. The advent of the topological insulator and the emerging nanotechnology open a new way to design high-performance TE devices. By combining first-principles calculations with Boltzmann transport theory, we demonstrate for epitaxial Bi2Se3 thin films with thickness slightly larger than six quintuple layers, the relaxation time of the in-gap topological surface states can reach hundreds of femtoseconds, which is 2 orders of magnitude larger than that of the bulk states. Such a strong relaxation time enhancement achieves an approximately 3 times larger electrical- to thermal-conductance ratio than the value predicted by the Wiedemann-Franz law. This condition also enhances the Seebeck coefficient, and consequently leads to the excellent TE figure of merit zT~2.1 at room temperature with high TE efficiency over a wide temperature range. The TE performance can be further improved by introducing defects in the bulk-like middle layers of the thin film. The improvement is significant at room temperature and can be even better at a higher temperature. Similar strong enhancement of TE performance is expected in other topological insulator thin films. (ACS Appl. Energy Mater. 1, 5646 (2018))






# Wide-range Ideal 2D Rashba Electron Gas with Large Spin Splitting in Bi2Se3/MoTe2 Heterostructure

A pure two-dimensional (2D) Rashba electron gas (REG), i.e., nearly all the conduction electrons occupy the Rashba bands (RBs), is crucial for semiconductor spintronic applications. Wedemonstrate that a pure 2D REG with a large Rashba splitting can be realized in a topologicalinsulator (TI) Bi2Se3 ultra film grown on a transition metal dichalcogenides (TMD) MoTe2substrate through first-principle calculations. Our results show the RBs exclusively over a very large energy interval of about 0:6 eV around the Fermi level within the MoTe2semiconductinggap. Such a wide-range pure 2D REG with a large spin splitting, which is ideal for real devicesutilizing the Rashba effect, has never been found before. Due to the strong spin-orbit coupling, thestrength of the Rashba splitting is comparable with that of the heavy-metal surfaces such as Au andBi surfaces, giving rise to a spin precession length as small as ~10 nm. The maximum in-plane spinpolarization of the inner (outer) RB near the G point is about 70% (60%). The room-temperaturecoherence length is at least several times longer than the spin precession length, providing good coherency through the spin processing devices. The wide energy window for pure RBs, small spinprecession length, as well as long spin coherence length in this 2D TI/TMD heterostructure pavethe way for realizing an ultrathin nano-scale spintronic device such as the Datta-Das spin transistor at room-temperature. (Nature Computational Materials 3:5 ; doi:10.1038/ s41524-017-0011-5 (2017)).



# Holographic Correspondence and String Scattering Amplitudes

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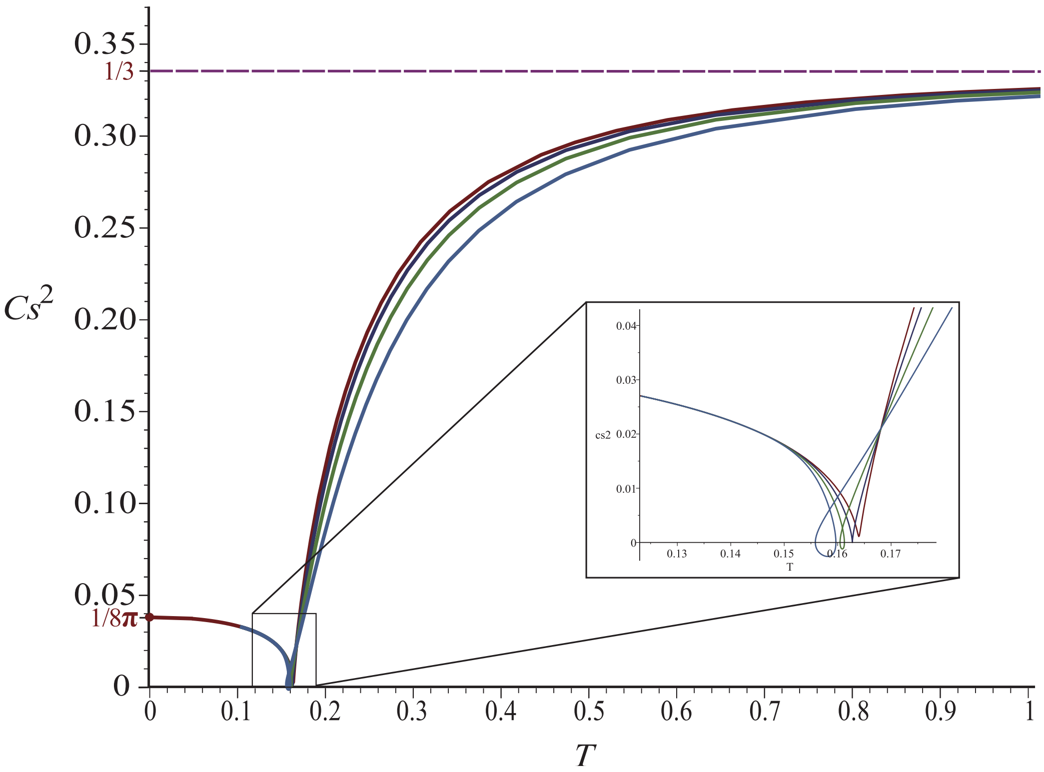
Particle Physics

## Y.Y. and Pei-Hung Yuan, "Universal Behaviors of Speed of Sound from Holography", Phys.Rev. D97, (2018) 126009.

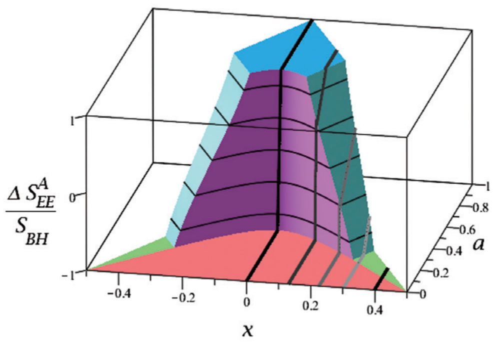
In this work, we studied the speed of sound in $(d+1)$-dimensional QCD. We show that there are several universal bounds for the speed of sound in QCD from holographic correspondence. In addition to the well-known upper bound $C_s^2 \to 1/d$ in the conformal limit, we reveal two more universal quantities: $C_s^2 \to (d-1)/16\pi$ in the low temperature limit and $C_s^2 \to (d-1)/16\pi d$ in the large chemical potential limit, as shown in Fig.1.



RESEARCH

## En-Jui Chang, Chia-Jui Chou and Y.Y., "Holographic Entanglement Entropy in Boundary Conformal Field Theory", Phys.Rev. D98, (2018) 106016.

In this work, we study the holographic entanglement entropy in a ($d$+1)-dimensional boundary quantum field theory at both the zero and finite temperature. The phase diagrams for the holographic entanglement entropy at various temperatures are obtained by solving the entangled surfaces in the different homology. We also verify the Araki-Lieb inequality and illustrate the entanglement plateau as shown in Fig.2.




## Sheng-Hong Lai, Jen-Chi Lee, Taejin Lee and Y.Y., "String Scattering Amplitudes and Deformed Cubic String Field Theory", Phys.Lett. B776 (2018) 150-157.

In this work, we study string scattering amplitudes by using the deformed cubic string field theory which is equivalent to the string field theory in the proper-time gauge. The four-string scattering amplitudes with three tachyons and an arbitrary string state are calculated. The string field theory yields the string scattering amplitudes evaluated on the world sheet of string scattering whereas the conventional method, based on the first quantized theory brings us the string scattering amplitudes defined on the upper half plane. For the highest spin states, generated by the primary operators, both calculations are in perfect agreement. In this case, the string scattering amplitudes are invariant under the conformal transformation, which maps the string world sheet onto the upper half plane. If the external string states are general massive states, generated by non-primary field operators, we need to take into account carefully the conformal transformation between the world sheet and the upper half plane. We show by an explicit calculation that the string scattering amplitudes calculated by using the deformed cubic string field theory transform into those of the first quantized theory on the upper half plane by the conformal transformation, generated by the Schwarz-Christofiel mapping.

## Sheng-Hong Lai, Jen-Chi Lee and Y.Y., "The *SL*(*K*+3,*C*) Symmetry of the Bosonic String Theory", arXiv:1806.05033, Nucl.Phys. B (2019).

In this work, we discover that the exact string scattering amplitudes of three tachyons and one arbitrary string state in the 26D open bosonic string theory can be expressed in terms of the basis functions in the in finite dimensional representation space of the $SL(K+3,C)$ group. In addition, we find that the $K$+2 recurrence relations among the LSSA discovered by the present authors previously can be used to reproduce the Cartan subalgebra and simple root system of the $SL(K+3,C)$ group with rank +2 . As a result, the $SL(K+3,C)$ group can be used to solve all the string scattering amplitudes and express them in terms of one amplitude. As an application in the hard scattering limit, the $SL(K+3,C)$ group can be used to directly prove Gross conjecture, which was previously corrected and proved by the method of decoupling of zero norm states.

# Research Highlights of Postdocs

Dimitrios Giataganas and his collaborators have constructed the first holographic model with broken rotational symmetry where the vacuum state confines color and exhibits a phase transition at finite temperature where the deconfined plasma state arises. This model provides significant information on the phase transition dependence on anisotropies and suggests that the breaking of isotropy acts as a catalyzer to such transitions. It has been publish in Phys. Rev. Lett. 121, 121601 (2018). Moreover, Dimitrios with his colleagues, has shown that there exist a unified study for the Brownian motion in strongly coupled theories, independent of the details of the theory under study. This clarifies the reason of the solvability of the Brownian motion in different theories that has been noticed in the past. Dimitrios' work provides a proof that all these theories belong to the same universality class and can be treated under a single simple framework. This work has been publishes in JHEP 1808 (2018) 110. Finally, Dimitrios in 2018 has given ten invited talks in seminars and conferences, and he was an Invited Lecturer at the "10th Joburg School on String Theory: Recent Trends in CFT and the Gauge/Gravity correspondence".

Wu-zhong Guo and his collaborators find more detail relation between local excitation in 2D CFT and two entangled anyons. Our results suggest it is possible to make constraints on the data of field theory by studying the entanglement entropy. [ JHEP 1805 (2018) 154] In other paper [Phys. Rev. Lett. 121, 251603 (2018) ] we develop a method to calculate Holevo information in conformal field theories, which may help us understand the problem of information loss in field theory side. In the paper [arXiv:1806.07595] we find constraints on the states in CFT that have geometric description. This would help us know more details of AdS/CFT.

Hiroyuki Ishida found an interesting dark matter scenario in the supersymmetric inverse seesaw framework [Journal of High Energy Physics Volume 1809, 071, Pages 1-29] which is based on his previous work [Journal of High Energy Physics Volume 1710, 039]. In this work, the distinguished feature is that the production of dark matter is strongly related to the lepton number symmetry breaking. Namely, he showed dark matter production is correlated with the origin of neutrino masses in the plausible electroweak supersymmetric inverse seesaw model. He also found a novel discrimination of new gauge bosons in gauged two Higgs doublet model. [The European Physical Journal C, Volume 78:613 Pages 1-19] He showed that even if there is electric charge neutral W boson apart from Z' boson, measurement of kinematical distribution has potential to distinguish from gauge bosons in other models which seem to have similar fundamental properties.

Hiroyuki Kitamoto found that if we take into account the Schwinger mechanism, the no-go theorem of anisotropic inflations may hold true regardless of whether a dilatonic coupling is present or not [Physical Review, D 98, 103512, 2018]. He also extened the infrared resummation formula in de Sitter space as it is applicable also in general scalar field theories with derivative interactions. The result of this study can be interpreted as a first step to the nonperturbative investigation of gravitational infrared effects [arXiv:1811.01830 [hep-th]].

Yoji Koyama constructed a non-spherical symmetric dynamical spacetime which admits a dynamical black hole with soft hair by supertranslation of Vaidya spacetime. Along with his collaborator, he addressed the quantum effects from the dynamical black hole with soft hair and found that the emission rate of Hawking radiation has the dependence on the soft hair configuration which turns out to be consistent with the factorization property of the black hole S-matrix [Journal of High Energy Physics, 11 April 2018, 056].

Martin Spinrath finished in 2018 two major papers. The first titled "Sneutrino Dark Matter via pseudoscalar X-funnel meets Inverse Seesaw" [published in JHEP 1809 (2018) 071, arXiv:1811.02895] was a follow-up based on a supersymmetric low-scale seesaw model developped at NCTS. In this follow-up they have studied how sneutrinos in this model can play the role of dark matter. This particular model with sneutrino dark matter is very predictive and can easily be ruled out, which makes it very appealing. The second paper "Confronting SUSY SO(10) with updated Lattice and Neutrino Data" [published in JHEP 1901 (2019) 005, arXiv:1806.04468] was actually finished shortly after he started his new job as assistant professor at National Tsing Hua University, but most of the work was done while we was still a NCTS member. In this work the authors update SO(10) fits to fermion masses and mixing data which improved tremendously in the last couple of years. They also included for the first time a certain class of sizeable corrections which was a major computational challenge.

Jusak Tandean has recently proposed different ways to probe new physics beyond the standard model with processes which can be pursued in the ongoing LHCb experiment. Specifically, several rare nonleptonic decays of the Bs meson, which are not yet observed, can supply complementary information about the possible new physics behind the recently reported anomalies in B-meson decays [arXiv:1810.11437 [hep-ph] and Journal of High Energy Physics, February 2018, page 74]. Also, the decay of Sigma-plus hyperon into a proton plus a muon-antimuon pair, observed last year at LHCb, can provide additional observables, namely muon asymmetries, which are potentially sensitive to new-physics signals [Journal of High Energy Physics, October 2018, page 40].

Chen Zhang studied the scalar potential of the Simplest Little Higgs model and was able to derive a relation between the top partner mass and the additional pseudo-Goldstone mass, which is a definite prediction of this scenario [Phys. Rev. D97, 115011, 4 June 2018]. He also showed the relevance of unitarity constraints and presented a characterization of the viable parameter space including a careful analysis of the degree of fine-tuning. In a following paper he then studied the phenomenology of the additional pseudo-Goldstone, including a careful derivation of the related Feynman rules and discussion of symmetric vector-scalar-scalar vertices [Phys. Rev. D98, 075023, 29 October 2018]. The impact of electroweak precision constraints and possible ways to detect the new scalar boson are discussed.

You-Lin Chuang proposed a scheme to simultaneously realize parity-time symmetric and anti-symmetric conditions in the field propagation direction along with the same direction as the applied external gradient magnetic field which maps the spectra information on spatial coordinate in the longitudinal direction. With the coherent interaction between light fields and double-Lambda type atomic system, the susceptibility of atomic medium can be controlled by the relative phase among interacting fields, which make all-optical switching between parity-time symmetry and anti-symmetry. This study based on quantum coherence control and zeeman effect induced by external magnetic field provides a new approach to investigate the field dynamics under parity-time symmetric condition.

Vijay Kumar Gudelli, performed a comprehensive theoretical study (arXiv:1902.03944 [cond-mat.mes-hall]) of the magnetic, electronic, optical and magneto-optical properties of multilayers [monolayer (ML), bilayer and trilayer] as well as bulk CrI3 , based on the density functional theory with the generalized gradient approximation plus on-site Coulomb repulsion scheme. Interestingly, all the structures are found to be single-spin ferromagnetic semiconductors. They all have a large out-of-plane magnetic anisotropy energy (MAE) of □0.5 meV/Cr, in contrast to the significantly thickness-dependent MAE in multilayers of Cr2 Ge2 Te6. They also exhibit strong magneto-optical (MO) effects with their Kerr and Faraday rotation angles being comparable to that of best-known bulk MO materials. Their findings of large out-of-plane MAEs and strong MO effects in these single-spin ferromagnetic semiconducting CrI 3 ultrathin films suggest that they will find valuable applications in semiconductor MO and spintronic nanodevices.

Ching-Yu Huang found the phase diagram spin-2 deformed-AKLT models on the square lattice by using tensor-network methods. She not only confirm the Néel phase but also find an XY phase with quasi-long-range order and a region adjacent to it, within the AKLT phase, with very large correlation length, and investigate the consequences of a perfectly factorizable point at the corner of that phase. [PHYSICAL REVIEW B 98, 014432 (2018) ]. She also investigated the topological properties of spin polarized fermionic polar molecules loaded in a multi-layer structure with the electric dipole moment polarized to the normal direction by an external electric field. [arXiv:1707.06419v2 [cond-mat.quant-gas] ].

Guan-Rong Huang developed a set of analytical approaches for the micro-structural analysis of soft matter flow and deformation using two-point anisotropic spatial correlation functions in real space as well as in reciprocal space. This methodology, as a foundation of data analysis in computer simulations and scattering experiments, allows people to investigate the local structural and dynamical correlation region of fluids at its non-equilibrium state, which was thought as a key to explore the rheological properties in response to an externally applied field [Physical Chemistry Chemical Physics Volume 28, Pages 38-45 (2019), Physical Chemistry Chemical Physics Volume 20(9), Pages 6050-6054 (2018), and Physical Review Letters Volume 108(19), 196001 (2014)]. This work was published in Physical Review E Volume 97(1), 012605 (2018).

Ioannis Kleftogiannis has investigated entanglement mechanisms in 1D many-body systems with imposed spatial constraints, using effective methods like the sector method for the density matrix and the entanglement entropy [arXiv:1902.06526 [cond-mat.str-el]]. Also, he has studied emergent topological phases, via simple self-organization mechanisms in 1D and 2D systems, using measures like the Euler characteristic and the spatial curvature [arXiv:1712.09239 [cond-mat.str-el]]. In addition he has investigated phase transitions in topological insulators at the presence of disorder and extracted universal features of the quantum transport, like universal conductance fluctuations(UCF)[J. Phys. Soc. Jpn. 87, 034701 (2018)].

Ramesh Babu found nontrivial band topology and superconductivity in niobium nitride (NbN) polytypes (arXiv:1808.05073v2). Specifically, he found δ-NbN and ε-NbN, δ′-NbN are, respectively, type-II and type-I Dirac metals, while WC-NbN is an emergent topological metal with exotic triply degenerate nodes. His calculations show that the electron-phonon coupling in δ-NbN ( $\lambda = 0.98$) is much stronger than in δ′-NbN($\lambda = 0.17$), ε-NbN ($\lambda = 0.16$) and WC-NbN ($\lambda = 0.11$). This results in a much higher superconducting transition temperature ($T_c$ = 18 K) than in δ′-NbN, ε-NbN and WC-NbN ($T_c \leq 1.0$ K). The findings thus suggest that the four NbN polytypes would provide valuable opportunities for studying exotic phenomena arising from the interplay between superconductivity and band topology.

Shiue-Yuan Shiau proposes an analytical procedure to fully solve a two-level system coupled linearly as well as quadratically to phonons [PRB 99, 014302 (2019)]. He uses composite boson (coboson) many-body formalism to tackle atom-dimer and dimer-dimer scattering lengths for cold fermionic atoms [Annals of Physics 400, 366 (2019)]. He studies the photo-absorption in n-doped two-dimensional (2D) and quasi-2D semiconductor quantum wells that takes into account the interaction of the photocreated exciton with Fermi-sea (FS) electrons. This work reveals the underlying physical mechanisms for the crossover from tion-hole complex to exciton-polaron as a function of doping [PRB 98, 235203 (2018)]. He predicts the existence of high-frequency modes in the interference pattern of two condensates made of fermionic-atom dimers. These modes, which result from fermion exchanges between condensates, constitute a striking signature of the dimer composite nature [New journal of Physics, in press]. He predicts that the collision of two fully dark exciton condensates produces an interference pattern that is optically detectable. This work allows us to finally observe the coherence of the elusive exciton condensate [arXiv:1903.01259].

Pei-Yun Yang investigated the transient buildup of Fano resonances in the time domain in a nanoscale Aharonov-Bohm interferometer consisting of laterally coupled double quantum dots (DQDs) coupled to the source and drain electrodes. [Phys. Rev. B 97, 054301 (2018)]. She also participated in the work of developing the exact master equation of Majorana zero modes under gate-induced charge fluctuations. [Phys. Rev. B 97, 054508 (2018)]. Within the exact master equation formalism, the non-Markovian decoherence dynamics of the Majorana zero modes under local perturbations is examined in detail.

RESEARCH

# Introduction of Research in Different Fields

## Phenomenological Particle Physics

Particle physicists in Taiwan work on the frontier of intensity, favor and cosmology. Frequent collaboration occurs among the theorists as well as among the theorists and experimentalists. Some of the results obtained this year are described below.

### Energy Frontier

High energy frontier explores the experiments that are carried at the very high energy level. Currently, it is the Large Hadron Collider (LHC) that is colliding protons at a center-of-mass energy 13 TeV. The major goal of the LHC is to thoroughly study the properties of the Higgs boson. Kingman has studied physics of the Higgs boson for many years. Among various works, the exploring of the self-coupling of the Higgs boson is extremely important for understanding the Higgs sector itself (JHEP 1508 (2015) 133). Higgs-pair production is a very useful probe of the Higgs self- coupling at the LHC. Kingman and collaborators thoroughly worked out all the backgrounds for the channel $H\,H \to (bb)\,(\Upsilon\Upsilon)$. They found that the HL-LHC cannot completely establish the self-coupling of the Higgs boson if it is SM-like. On the other hand, the 100 TeV collider is able to cover a much wider range of the self-coupling (1804.07130).

Furthermore, if any other Higgs bosons are discovered at the LHC, it is important to identify their CP properties. Kingman and collaborators finished a couple of works on measuring the CP properties of a hypothetical heavy Higgs boson through its decays into $ZZ \to 41$ (JHEP 1712 (2017) 053) and $H \to t\,t \to bW^{+}\,bW^{-}$ (JHEP 1805 (2018) 162). With careful measurements of the angular correlations, one actually can measure the CP-even and CP-odd couplings of the Higgs boson to about 10-20 % uncertainty.

Another work that Kingman did with a HEP experimentalist is a true collaboration between theorists and experimentalists. They used a new technique—2 step BDT to improve upon improving the purity of the VBF events from the ggF contamination. This is important to cleanly study the VBF, which is directly related to EWSB (Phys.Rev. D96 (2017) 096009).

Cheng-Wei has completed the full one-loop corrections to all the SM-like Higgs couplings with SM particles in the Georgi-Machacek (GM) model (Phys. Rev. D 98, 013008 (2018)). With Prof. He and Dr. Li, they investigated the possibility of experimentally determining the ratio of HWW and HZZ couplings for a general Higgs boson H and introduced a novel method for the ILC (1805.01689, to appear in JHEP). More recently, CW performed a thorough global analysis for the Higgs sector of the GM model, using the package of GMCalc and HEPfit (hep ph/1807.10660).

### Intensity Frontier

Xiao-Gang He, Chiang, Tandean, and Yuan published a work $\mathbf{RK()}$ and related $b \to sll^{-}$ anomalies in minimal flavor violation framework with $Z$ boson (Phys. Rev. D 96, 115022 (2017)), which has been cited more than 30 times in INSPIRES in a short period of time. New gauge bosons with flavor changing interactions may play an important role in explaining B anomalies. In this work, they take a model independent approach using minimal flavor violation as guidance to parameterize the flavor-changing interactions. They find that there is parameter space which can explain the B anomalies providing new direction for future experimental search and theoretical model building.

Subsequently, Xiao-Gang continues to pursue interpretations of B anomalies in various new physics models. His group reported their works in a number of international conferences.

Regarding heavy flavor physics, Cheng-Wei studied the $B0 \to D\bar{D}$ decays and found that existing data allowed one to make a prediction for the CP Asymmetry C00 in $B0 \to D0\bar{D}0$ decay (JHEP 1711, 087 (2017)). This work is useful for our experimental colleagues. CQ and Dr. Hsiao together with some other researchers or students wrote 14 papers related to B or hadronic physics. Their results have been useful to by B physics experimentalists in Belle and LHCb.

## Dark Matter and Cosmology

Xiao-Gang has published a couple of works related to the anomaly observed by the DAMPE experiment, which showed an unusual peak in the positron spectrum. One of the papers by Duan, He, Wu and Yang, Leptophilic dark matter in gauged $\mathrm{U}(1)\, L_e$ - $L_\mu$ model in light of DAMPE cosmic ray $e^+ + e$ excess (Eur. Phys. J. C 78, no. 4, 323 (2018)), becomes a Highly Cited paper by Web of Science. They were among the first groups to studied the implications. They find that features observed by DAMPE on positron excess can be accommodated by theoretical models and point out how to differential different model when more data become available.

Cheng-Wei and his collaborators studied another model to explain the DAMPE $e^+e$ excess, in which the model involves a vector dark matter candidate (Phys. Rev. D 97, 061302 (2018)). Cheng-Wei, Senaha and Lee revisited electroweak phase transition in the Standard Model (SM) extended with a real singlet scalar, in which they also studied the constraint from dark matter data (1808.01098). CQ together with C.C. Lee and Luo, they wrote 7 papers on gravity and related models.

Collaborating with peoples from Chinese University of Hong Kong, Kingman Cheng and his team proposed a new methodology to compute the N-body simulations, which tremendously saves a lot of computer resources and obtains a more or less the same accuracy as those with brute-force (Astrophys. J. 853 (2018) 51). With their technique the simulations can be carried out for a large cosmological simulations. They have obtained a new result of cosmological simulations and used the results to calculate the Lyman-alpha spectrum and compared to the observations (AstroPhys. J. 863 (2018) 73). One of Kingman's Master student, Jui-Lin Kuo, visited Professor Valle in Spain and they started a work on Majoron DM and studied the effects on structure formation. We finished a work on effects of warm dark matter on structure formation (1803.05650). It is under review. Recently, the EDGES reported a very interesting result on 21-cm absorption spectrum at redshift z=17, which showed a 2 sigma deviation from the conventional model. Kingman, Kuo, Ng, and Tsai used the face value of the data to constrain the DM interaction, and obtained a useful result. Their work showed that the 21-cm spectrum can be used to effectively constrain DM interactions when more data are available in future (1803.09398).

The group TG2 Dark Physics of the Universe has focused on dark matter and dark energy of the Universe. In October 2017, TG2 and ECP2 jointly organized the workshop 2017 NCTS workshop on Dark Matter, Particles and Cosmos in NDHU. The group involves visitors or collaborators from China, USA, Poland, UK, and Japan. This group has published 27 papers associated with the NCTS. An active member, Y.K. Hsiao has become a faculty member at Shanxi Normal University in China.

RESEARCH

# Condensed Matter Physics

Condensed matter physics research has a significant representation in Taiwan. Related research groups in NCTS (composed by two DCS, several TGs, and center research fellows) have developed several research directions to investigate related fascinating phenomena. Some of their researches conducted in this area are described below:

Condensed matter physics is the largest field of physics research in Taiwan. Research groups in NCTS have developed several research directions to investigate related fascinating phenomena. Major contribution is from DCS Guang-Yu Guo, CS Horng-Tay Jeng, CS Ying-Jer Kao, CS Miguel Cazalilla, and TG4 (Topology and Entanglement in Quantum Many-Body Systems), TG8 (Topology and Strong Correlations in Quantum Many-Body Systems) and TG9 (Quantum and Topological Materials). TG5 (Complex Systems) is the only group on soft-matter physics. Since the research topics in condensed matter physics are quiet broad, here we only highlight some of the major directions where more researchers are involved.

## Topological and Strongly Correlated Physics

A successful collaboration between theorists of TG8 (Chung-Yu Mou) and TG9 (Horng-Tay Jeng) and experimentalist (Shu-Jung Tang in NTHU) brings new physics ! They observe single-layer germanene with dual phases in germanene/Ag(111). This is the first one observation with a clear signature of single-layer germanene, and provides an completely new 2D material with novel electronic properties not investigated before. This important work has been published in Phys. Rev. Materials 2, 024003 (2018).

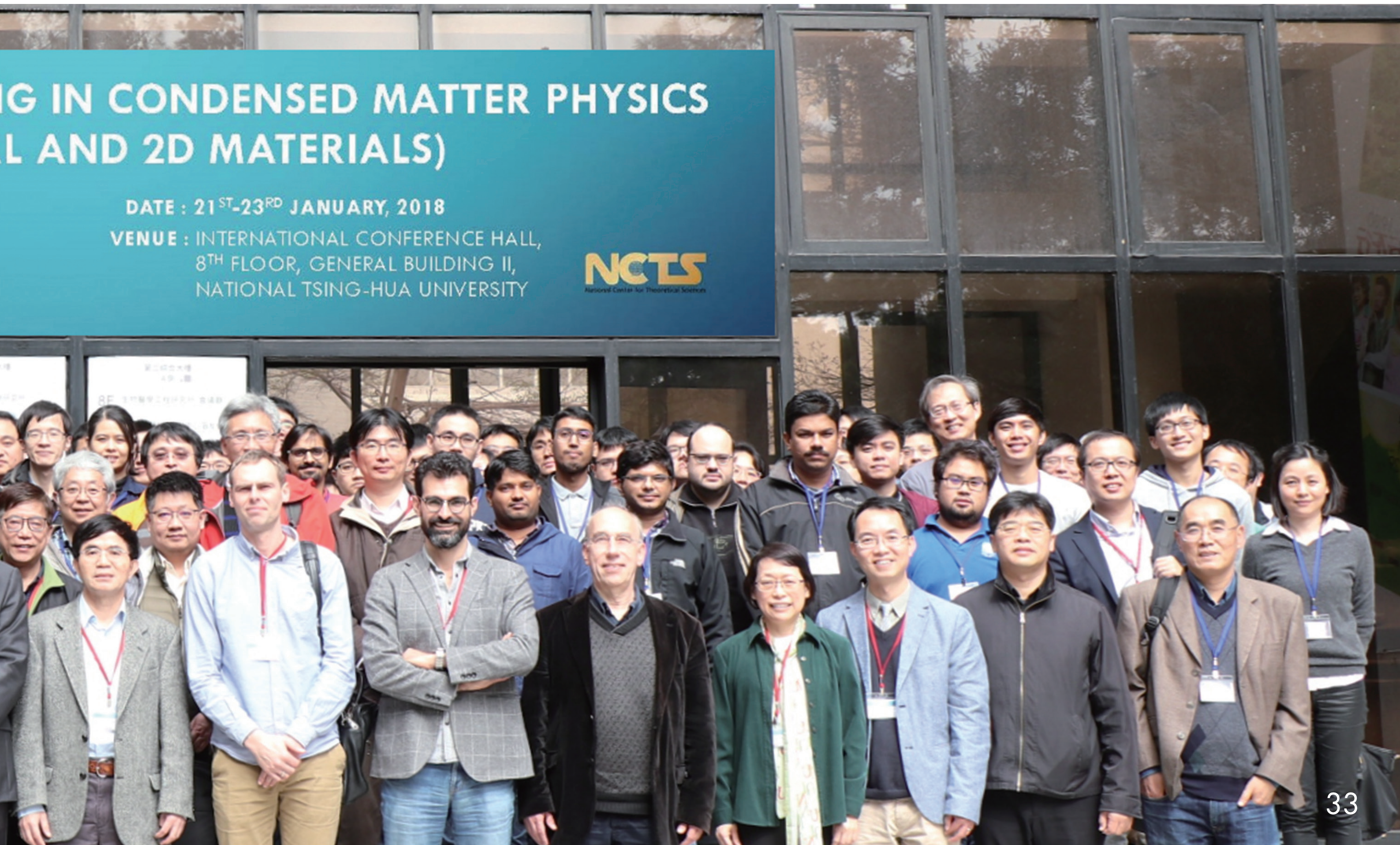
CS Cazalilla and his student nonperturbatively investigate the effect of a magnetic dopant impurity on the edge transport of a quantum

Group picture of 2018 NCTS Annual Meeting on Condensed Matter Physics, January 21-23, 2018.

spin Hall (QSH) insulator. They show that for a strongly coupled magnetic dopant located near the edge of a system, a pair of transmission anti-resonances appear. When the chemical potential is on resonance, interaction effects broaden the anti-resonance width with decreasing temperature, thus suppressing transport for both repulsive and moderately attractive interactions. Their work was published in (Phys. Rev. B 97, 235402 (2018)).

CS Kao and his collaborators use one-dimensional matrix product density operators to perform a fully quantum investigation of the dependence of the non-equilibrium steady states of this model on the signs of these parameters. Due to a symmetry in the Lindblad master equation, they find that simultaneously changing the sign of the interaction energies, hopping energies, and chemical potentials leaves the local boson number distribution and inter-site number correlations invariant, and the steady-state complex conjugated. This shows that all driven-dissipative phenomena of interacting bosons and has been published in Scientific Reports 8 , 3698 (2018).

Prof. Chung-Hou Chung (Coordinator of TG8) and his collaborators successfully addressed a long-standing open issue on quantum critical behaviors seen in heavy-fermion compound Ge-YRS system. Their theory goes beyond the standard Ginzburg-Landau theory of phase transitions, and starts new international collaboration with a well-known experimentalist Prof. Silke Paschen of TU Vienna. Their work has been published in Phys. Rev. B 97, 035156 (2018).



## New Quantum and Topological Materials

There is a long-term unresolved problem about the fate of magnetic-moments in intermediate, pseudo gap systems, such as graphene. DCS Guo and his experimental collaborators reported on the recent observation of Kondo screening and the quantum phase-transition between screened and un-screened phases of vacancy magnetic-moments in graphene. Using scanning-tunneling-microscopy (STM) and numerical-renormalization-group (NRG) calculations, they identified Kondo-screening by its spectroscopic signature and mapped the quantum phase-transition as a function of coupling strength and chemical potential. Their important results have been published in Nature Commun. 9, 2349 (2018).

CS Jeng and his experimental collaborators propose a new physical source: the spin chirality at the boundary of a topological insulator (TI). For the heterostructure: normal metal (NM)/TI, or equivalently NM/semiconductor with a chiral spin texture surface state, the SOC in TI plays the role as the orbital-dependent magnetic field in an insulator and allows NM QWS with the same spin and chirality as the TI SS to penetrate deeper than those with opposite spin and chirality. They demonstrate the momentum separation of the Rashba-like splitting in Ag/Bi2Se3junction is the largest one among the previously reported values for non-metallic-substrate systems. Many important and nontrivial electronic properties are also resulted from this new proposal, and their paper is published in Nature Asia Materials 8, 2016.173 (2016)).

CS Jeng and his collaborators demonstrate that a pure 2D REG with a large Rashba splitting can be realized in a topological insulator (TI) Bi2Se3 ultra film grown on a transition metal dichalcogenides (TMD) MoTe2 substrate through first-principle calculations. Their results show the RBs exclusively over a very large energy interval of about 0:6 eV around the Fermi level within the MoTe2 semiconducting gap. The room-temperature coherence length is at least several times longer than the spin precession length, providing good coherency through the spin processing devices. Their work have been published in Nature Computational Materials 3:5 (2017)).

Since the first principle calculation on new material is an active field in Taiwan, researchers in the community also hosted several workshops to enhance their collaboration. For example, in Jan. 2018, TG9, CS Jeng, and DCS Guo have organized NCTS Annual Meeting in Condensed Matter Physics, which emphasize on the Topological and 2D Materials. Their have been about 200 participants.

Group picture of AMO Physics Summer School

# AMO/QIS

In NCTS, both Atomic-Molecular-Optical (AMO) Physics and Quantum Information Sciences (QIS) have strong and rapidly growing teams in recent years. In the AMO field, the major research is conducted by DCS, Sungkit Yip (IoP, AS), CS Ray-Kuang Lee (NTHU) and TG7 (Quantum Gases). They also have a close collaboration with Experimental Collaborative Group on Quantum Optics and Quantum Manipulation of Ultracold Atoms (ECP1). QIS research is mostly conducted by CS Yueh-nan Chen (NCKU) and TG6 (Quantum Information Science and Quantum Control). Their research highlight is shown below:

## Light-Atom Interaction and Quantum Optics

DCS Sungkit Yip have been collaborating with the experimental group of Dr. Yu-ju Lin at Institute of Atomic and Molecular Sciences in Academia Sinica, and theorist Prof. Yuki Kawaguchi of Nagoya University in Japan, on studies of artificial gauge fields in cold atomic systems. They couple spin and orbital angular momentum of 87Rb spin-1 atoms, making use of Laguerre-Gaussian laser beams, and demonstrate this spin-angular momentum coupling and make use of it to generate coreless vortices. Their work has just been accepted by Physical Review Letters. (H. -R. Chen, et al. Phys. Rev. Lett. To appear).

For related research, ECP1 group and TG7 also co-organizing Joint International Workshop on Quantum Gases Quantum Measurements in NCTS.

## Many-body Physics in Ultracold atoms/molecules

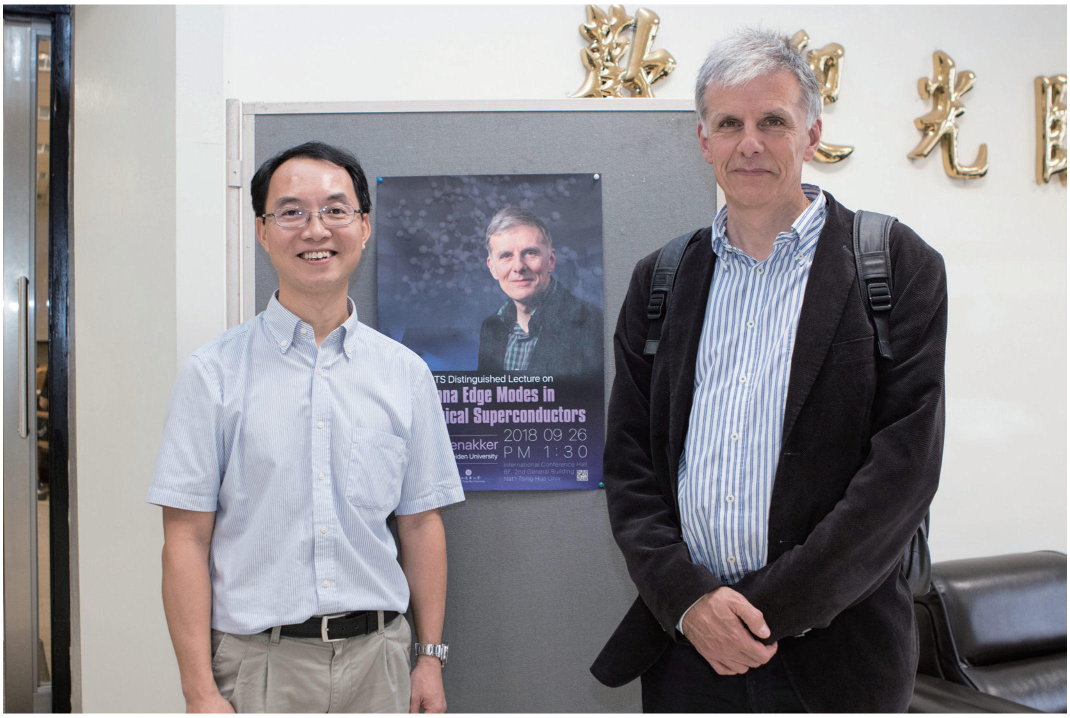
Another important research direction of TG7 is in the many-body physics of ultracold atoms and molecules. In the framework of the Gross-Pitaevskii equation, CS Ray-Kuang Lee and Dr. Yung-Lin Chuang (NCTS) collaborate to study the formation and stability of effectively two-dimensional solitons in dipolar Bose-Einstein condensates (BECs), with dipole moments polarized at an arbitrary angle relative to the direction normal to the system's plane. Using numerical methods and the variational approximation, they demonstrate that unstable Townes solitons, created by the contact attractive interaction, may becompletely stabilized (with an anisotropic shape) by the dipole-dipole interaction (DDI), in the interval $0 < \Theta \leq \pi/2$. [Phys. Rev. A 96, 043631 (2017)].

Vice Director Daw-Wei Wang had an international collaboration with Prof. G. V. Shlyapnikov to analytically and numerically study Fulde-Ferrell-Larkin-Ovchinnikov state in a bilayer dipolar system (Hao Lee, et al. Phys. Rev. A 96, 061602(R) (2017)). They for the first time to provide a full phase diagram of FFLO state with long-ranged interaction in 2D system. For the imbalance exceeding a critical value, the system undergoes a transition from the uniforminterlayer superfluid to the FFLO state with mostly a stripe structure, and at sufficiently large imbalance a transition from the FFLO to normal phase. Compared to the case of contact interactions, the FFLO regime is enhanced by the long-range character of the interlayer dipolar interaction, which can combine the s-wave and p-wave pairing in the order parameter.

## Application of Quantum Information Theory

CS Yueh-Nan Chen has a long term collaboration with the theory group of Prof. Nori (Riken, Japan). Recently they propose a novel way to assess the nature of these system-environment correlations by examining the system dynamics alone. Their approach is based on the possibility or impossibility to simulate open-system dynamics with Hamiltonian ensembles. Such (im)possibility to simulate is closely linked to the system-environment correlations. They thus define the nonclassicality of open-system dynamics in terms of the nonexistence of a Hamiltonian-ensemble simulation. This classifies any nonunital open-system dynamics as non-classical. They give examples for open-system dynamics that are unital and classical, as well as unital and non-classical. Their are published in Phys. Rev. Lett. 120, 030403 (2018).

Besides, they also worked on the topic of quantum steering, and show that there exists a hierarchy among the three temporal quantum correlations: temporal inseparability, temporal steering, and macrorealism. Given that the temporal inseparability can be used to define a measure of quantum causality, similarly the quantification of temporal steering can be viewed as a weaker measure of direct cause and can be used to distinguish between direct cause and common cause in a quantum network. The results are published in Phys. Rev. A 98, 022104 (2018). Many workshops and activities are also carried out by TG6 to support development in quantum information theory.



# Strings and Gravity

**One of the most important fundamental question of the physical universe is the quantum nature and origin of spacetime. This is vital for the understanding of various important questions concerning the universe, such as the nature of the big bang and black hole singularities and the initial condition for the inflationary universe etc.**

One approach to these fundamental questions is to employ string theory and the AdS/CFT correspondence. Recently Chong-Sun Chu and his team has initiated the study of the holography for boundary conformal field theory. They have resolved some of the difficult issues in the literature and obtained powerful results such as universal relations determining Casimir effects in terms of central charges of the theory. The study of amplitudes and the identification of hidden symmetry structures has also been an active and highly recognizable area of research.

In NCTS, research in string and gravity theory is mainly conducted by DCS Chong-Sun Chu, CS Yi Yang, CS Chao-Qiang Geng, Junior CS Yutin Huang and TG group member Feng-Li Lin. The string and gravity community in Taiwan is small compared to particle phenomenology and condensed matter physics community. Nevertheless the results obtained by the group is highly visible in the international community. Below we outline our achievements in these directions.

## Boundary Conformal Field Theory and Holography

BCFT has important applications in string theory and condensed matter physics. In a series of papers (New proposal for a holographic boundary conformal field theory, Phys.Rev. D96 (2017) no.4, 046005. arXiv:1701.0427; On New Proposal for Holographic BCFT, JHEP 1704 (2017) 089. arXiv:1701.07202), Chong-Sun and his team members investigated and obtained a complete formulation for the holographic duality for BCFT. The proposal has been applied successfully to many different settings, and new results like boundary Weyl anomaly, entanglement entropy of BCFT have been obtained. Moreover they found new universal understanding of Casimir effects for arbitrary shape of boundary in terms of boundary central charges of the theory (Universality for Shape Dependence of Casimir Effects from Weyl Anomaly, arXiv:1706.09652). Chong-Sun has also discovered a novel phenomena of current transport in the vicinity of boundary in the presence of a magnetic field Anomaly Induced Transport in Boundary Quantum Field Theories, arXiv:1803.03068; Anomalous Transport in Holographic Boundary Conformal Field Theories, JHEP 1807 (2018) 005, arXiv:1804.01648). This anomalous transport occurs in zero temperature vacuum without the need of material support. And, in analogous to the Casimir effect, it is an intrinsic manifestation of the dependence of the quantum vacuum on boundary. Previously anomalous current transport were found only in material system. Our discovery offers the first possibility of anomalous current in vacuum. As a result of the success of this program of study, Chong-Sun has given many talks internationally, such as the Sugawara Symposium on Fundamental Problems in Theoretical Physics, March 6-9, OIST, Japan; London Mathematical Society (LMS) symposium on Higher structures in M-theory, Aug 10-18, 018, Durham, UK; and a meeting to be held in Singapore in December.

## Scattering Amplitudes and Hidden Symmetry

The study of perturbative scattering amplitudes has led to a deeper understanding of quantum field theory and to powerful new tools for computing QCD processes. This is an area with important problems where both formal theorists and phenomenologist are interested in. Yutin Huang has worked extensively in this field. Collaboration with Nima Arkani-Hamed, Yutin has obtained compact results for scattering amplitudes for all masses and spins (arXiv:1709.04891). It is well known that soft behaviors of S-matrix for massless theories reflect the underlying symmetry principle that enforces its masslessness. Recently, Yutin and collaborators has studied the effect of soft symmetry breaking on the soft theorems (On the exactness of soft theorems, JHEP 1712 (2017) 052, arXiv:1705.10078). They found quite interestingly that the S-matrix of string theory verifies the translation symmetry breaking soft-theorems, and so in this sense string S-matrix"knows" about the presence of D-branes. Amplitude is an active area of research and the works of Huang has been highly visible and presented in various international meetings, including Strings 2018.

## Gravity

This is an area where Chiang-Mei Chen and Wen-Yu Wen have contributed significantly. Wen-Yu has worked on the weak gravity conjecture and its relation on the cosmic censorship (Phys. Lett 81 (2018) 713-718). Chiang-Mei has worked on the fundamental properties of gravitational energy and its definition in general (Gravitational Energy and the Gauge Theory Perspective, "C. M. Chen and J. M. Nester, arXiv: 1801.09503;Gravitational energy is well defined," C. M. Chen, J. L. Liu and J. M. Nester, arXiv:1805.07692). Their work has received international attention. For example, a submission of Chiang-Mei has received honorable mention for Essays on gravitational physics awarded by Gravity Research Foundation.

# Experimental Collaboration InterDisciplinary Research Program

In order to enhance the collaboration between theorists and experimentalists, and to promote the exchange and cooperation between researchers in tradition different disciplines, the Center has launched the Experimental Collaboration Program (ECP) and the Interdisciplinary research Program (IDP) two years ago. In these programs, NCTS act as a platform to bring together researchers with complementary scientific approaches and backgrounds so that a closer cooperation and collaboration of researchers could be fostered. Since its launching, it is evident that collaboration has been strengthened and new collaboration is forming. We highlight some of the developments in this regard.

## Quantum Optics and Quantum Manipulation of Ultracold Atoms

The group is leaded by Ying-Cheng Chen (IAMS) and works on three major directions:

(1) Rydberg atomic ensemble with emphasis on quantum optics,
(2) Electromagnetically-induced-transparency(EIT)-related physics,
(3) Quantum simulation with quantum gases.

In the first direction, Ite Yu's group has initiated an experimental study on quantum optics based on Rydberg-EIT. The goal of this proposal is to enhance the theoretical study on this topic. With the help of NCTS long-standing visitors, G. Juzeliunas and J. Ruseckas, they have established a close collaboration and generated some results (Nonlinear quantum optics for spinor slow light, arxiv 1805.00144). In the second direction, there are two major goals. The first is to establish a full quantum theoretical analysis of the atom-photon interaction related to EIT effect. Dr. You-Lin Chuang, Ray-Kuang Lee and Ite Yu have been working on this topic for a few years. They have published two papers (Resonance in modulation instability from non-instantaneous nonlinearities, Opt. Lett. 43, 3329(2018); "Quantum metrology beyond Heisenberg limit with entangled matter wave solitons, Opt. Express, 23, 330272(2018)) this year. The second goal is to establish a collaboration on the cooperative effect in cold atom experiments. Triggered by the observation of the spectral broadening in EIT and slow light experiments in Ying-Cheng Chen's group (Cooperative light scattering from helical-phase-imprinted atomic rings, Sci. Rep, 8, 9570(2018)), there have been extensive discussions between Hsiang-Hua Jen, Guin-Dar Lin, Ming-Chung Chang, Wen-Te Liao Ming-Shien Chang and Ying-Cheng Chen. Recently, Hsiang-Hua Jen has established a theoretical formalism to incorporate the resonant dipole-dipole interaction in the EIT theory, which can consistently explain the experimental observation. They are writing a manuscript (Spectrally entangled biphoton state of cascade emissions from a Doppler-broadened atomic ensemble, submitted. Arxiv 1807.06817) on this joint work. In the third direction, Yu-Ju Lin has obtained some experimental results related to spin-orbit coupling in quantum gases. She and Sungkit Yip (and another Japan scholar Yuki Kawaguchi) have established a close cooperation on this work. There have been fruitful results (Spin-orbital-angular momentum coupled Bose-Einstein condensates, accepted by Phys. Rev. Lett. arxiv 1803.07860; Rotating atomic quantum gases with light-induced azimuthal gauge potentials and the observation of Hess-Fairbank effect, submitted to Phys. Rev. Lett. arxiv 1808.00975) due to the enhanced activities of the experimental collaboration program of NCTS.

## Light Dark Matter

This group is leaded by Cheng-Pang Liu and Henry Wong. One of their regular activities is to have weekly teleconferencing group meetings. The group centers around studying and detection of light dark matter and neutrino using the state-of-art many body techniques to understand the responses in Germanium, Xenon, Argon detectors. The goals are not only to provide reliable constraints to dark matter and neutrino physics with experimental data, but also to explore potential new channels to shed light on these areas. One of the PI, Henry Wong, is a nuclear physicist focusing on neutrino and light dark matter experiments. They have successfully finished two paper (Neutron background measurements with a hybrid neutron detector at the Kuo-Sheng Reactor Neutrino Laboratory, Phys. Rev. C 98, 024602 (2018); Constraints on millicharged particles with low threshold germanium detectors at Kuo-Sheng Reactor Neutrino Laboratory, under review at Phys. Rev. D.). They have also given invited talk in major neutrino and dark matter conferences i. Neutrino-nucleus Coherent Scattering with Reactor and Solar Neutrinos, Neutrino 2018, Jun. 4-9, Heidelberg, Germany [plenary talk by H. T. Wong] ii. Atomic Aspects of Light Dark Matter Detection, Identification of Dark Matter 2018, Jul. 23-27, Providence, RI, USA [parallel talk by C.-P. Liu]. Their collaborations involve researchers from China, India, and Turkey.

## LHC Experimental / Theoretical Exploration

This group works to involve LHC experimentalists and theorists. Their approach is to organize regular workshops to bring the community together for interaction. They have focused on new physics models, in particular, those with displaced vertices in broad sense, at the LHC this year. One publication is realized in this group Vector Boson Fusion versus Gluon Fusion (Phys.Rev. D96 (2017) 096009). This is a true publication among theorists and experimentalists. A machine learning method – Boosted Decision Tree (BDT) is applied to study the VBF and ggF events in Higgs production, in which the purity of the VBF samples is improved with a new approach using a 2-step BDT method. The purity of VBF samples is important for isolating the electroweak symmetry breaking sector.

In June 2018, ECP3 and TG1 worked together to organize the first joint workshop at NCTS on New Physics with Displaced Vertices. They have invited both experimentalists and theorists from US, CERN, Korea, Hong Kong as well as local Taiwan community to discuss various new physics signals with displaced vertices. Besides providing the opportunity for international collaborations (among Taiwan-US, Hong Kong-Taiwan, etc.) and domestic collaborations, this workshop has also helped to boost the visibility of NCTS worldwide.

## Theoretical Chemistry

The program is coordinated by Jer-Lai Kuo (AS). The goals of the project is to stimulate and promote interactions among researchers in Chemistry and Physics to work on three main research projects:

(1) New materials for sustainable energy and technologies;
(2) Application and development of multi-scale molecular simulation methods;
(3) Development of Theoretical Tools to Understand Spectroscopic Data.

Following the spirit of interdisciplinary program (IDP), the group has coorganized four international conferences. These are: 2018/03/22-2018/03/23 The 1st Taiwan-Thailand-Vietnam Workshop on Theoretical and Computational Chemistry (K. Takahashi and J-L Kuo); 2018/05/29: Second Taiwan-Philippine Workshop; 2018/08/03: Second Meeting on CMR (Taiwan and NIMS, Tsukuba, Japan) 2018/10/09: Symposium on Multi-Scale and Multi-Physics Computational Materials Science. In addition, a number of domestic events has been organized for local researchers: 2018/01/12: "Workshop on Machine Learning and Big Data Applications to Drug Repurposing and Chemical Space" (Y-C Cheng and C-P Hsu); 2018/01/30-2018/01/31 "Annual Meeting of Theoretical and Computational Chemistry (Hsing-Yin Chen and J-L Kuo); 2018/09/04: Student Conference: (C-P Hsu).

Core-members have also served as committee members of many international organizations and communities. For example, Prof. C-H Yu and Dr. C-P Hsu for APACTCC (Asia-Pacific Conference of Theoretical and Computational Chemistry) and Dr. C-P Hsu. Prof. Jhih-Wei Chu and Dr. J-L Kuo are member of steering committee of ICMS (International Consortium of Molecular Simulations). Dr. J-L Kuo has been on the advisor board of Asian Consortium on Computational Materials Science (ACCMS).

## Geometry, Topology and String Theory

The program is coordinated by Nan-Kuo Ho (NTHU) and Siye Wu (NTHU). The aim of the program is to forge a link between mathematicians and physicists in Taiwan and the international community. We hope to stimulate the communications between members and visitors in doing research, as well as training and teaching postdocs and graduate students. Main activities are seminars, lecture series by distinguished visitors and workshop. In this calendar year, three lecture series have been organized. 2017 November: Matthew Young (CUHK) has delivered lectures on topological field theory. 2017 December: Hualiang Chang (HKU) and Meng-Chwan Tan (Singapore U) have delivered lecture series on Gromov-Witten theory. 2018 January: Masao Jinzenji (Hokkaido) delivered lectures on generalized mirror transformation. 2018 March: De Guo Chuan Thiang (Adelaide) and Kiyonori Gomi (Shinshu) delivered lectures on K theory, T-duality and topological insulators. A workshop on algebraic and geometric structure in QFT has been organized in November 2017.

In addition, the group also strive to help young researchers by educating them and putting them in contact with scholars from abroad. This year, the group has invited Professor Varghese Mathai from University of Adelaide in November 2016 to deliver a lecture series on K-theory and T-duality. During his visit, Dr. Fok, a postdoc of NCTS Math division, had a chance to meet and talk with Prof. Mathai, and then last year was able to obtain a postdoc position at the Institute in University of Adelaide. The platform provided by NCTS was much appreciated.

## Complex System and Mathematical Biology

Lee-Wei Yang (NTHU) led the group in 2017-18. The group aims for promoting activities in biophysical/ bioinformatics and behavioral neurology/computational neurology researches at both the molecular and higher levels as well as the cross-talk between these levels. The regular activity of his group is seminar series which provides opportunities for people from different background to come together to discuss and interact. In 2018, the group has organized four workshops and meetings. Thee are In very early 2018, the group sponsored a "behavior neurology" session in 2018 Congress of Animal Behavior and Ecology, where 1000 participants saw NCTS as one of the sponsors and promoted science relevant to them. In May, the group held the symposium "Advance in Structural Biology and Beyond", integrated as a satellite meeting, starting from this year, of the 2018 annual biophysics society meeting. 4 out of 7 funded plenary speakers were from China, Japan and USA. A special section was provided to showcase the instrumental progress in the Taiwanese biophysics society, including the first publication to report a structurally resolved protein using the new TPS beamline set up in NSRRC, the first peta-FLOP super computer in our country starting running in its full operation at the same month of the conference, and the 210,000,000 TWD worth new cryo-EM Titan Krios 300kV transmission electron microscopes newly installed in Academia Sinica. In Aug, the group orgainzed a Computational Biology Workshop (Aug 1-2). A special student presentation session was included so as to promote nurturing of the young generation. Lastly the group will co-organized the symposium "Symposium on Systems Neuroscience" in Nov with AS. Overall, the group has greatly enhanced the community (students, postdocs and faculties) members' exposure to techniques and science involving new spectroscopic tools, cell regeneration, self-powered devices, structural biology questions, 3D printing and bioinformatics used in translational medicine.

## Explainable Artificial Intelligence

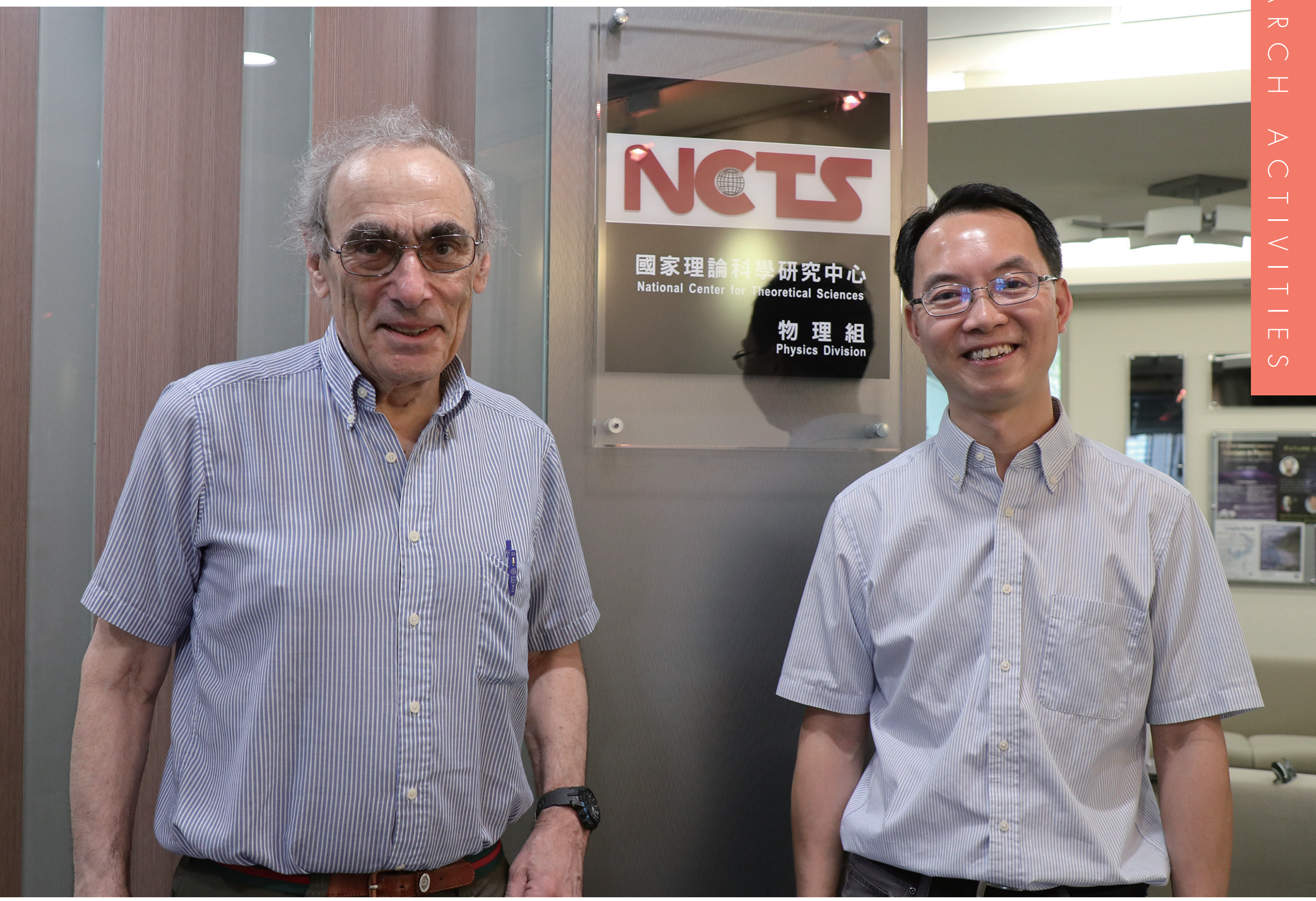
It is known that recent rapid progress of AI application are mainly promoted by the success of Deep Artificial Neuron Network (DANN) or Deep Learning (DL), which can be trained to find important hidden features inside the Big Data created (and sometimes annotated) by human. However, even though that, in many applications, shows great precision in prediction and classification, the results provided by ANN or DL are almost un-explainable due to the huge number of fitting parameter inside. In other words, the effectiveness of these AI application will be limited by the machine's current inability to explain their decisions to human users. In fact, DARPA of USA has called for proposals for XAI research in August 2016, showing the importance of this particular aspect in AI application. From physics point of view, such explanation can be understood as the process for extracting an effective model from a complex system, identifying the most important key factors after certain renormalization. Therefore, it can be a very proper and important interdisciplinary direction for researchers in theoretical physics, computer science, education, and other humanity disciplines. So far there is no such research proposal in Taiwan and the IDP program supported by NCTS will be a leading player for the whole community. The group was formed early 2018 and is led by Jason Chang (CS-NTHU) and Daw-Wei Wang (Phys-NTHU). The group has focused on the following areas: Features and Logic Identification as a new machine learning process; Natural Language as a model of explanation; and Expression and Education as an application interface.

The group has held regular interdisciplinary seminars on XAI to stimulate discussion of the subject and to encourage formation of collaboration across disciplines. The group will organize a small international workshop in March 2019. Preliminary signs of collaboration is evident. For example, DW Wang has worked with SP Lai (IOP-NTHU) to develop an AI machine to classify different types of astronomy objects such as stars, galaxy and young stellar objects (YSO) by providing a new Spectrum Classifier of Astronomical Objects (SCAO) by using the pattern recognition of an Deep Neural Network (DNN) based on their SEDs.

# HIGHLIGHTS of RESEARCH ACTIVITIES

# Tea Talk with Gordon Baym

Professor Gordon Baym visited the center in mid May. Apart from talks and meeting with students, we took this opportunity to conduct an interview with him. Professor Baym has received many awards, including the Hans A. Bethe Prize (2002), the Lars Onsager Prize (2008) and the Eugene Feenberg Memorial Medal (2011). He has been a Fellow of the US American Academy of Arts and Sciences since 1981, a member of the US National Academy of Sciences since 1982, and a member of the American Philosophical Society since 2000.



**Chu:**

Yesterday you mentioned that you were a student of Julian Schwinger. How was it to be a student of such a great scientist?

**Baym:**

Schwinger in public was very shy. However he was very different, open and warm, in private. Early on, he gave me the challenge of showing that $\varphi^3$ field theory does not have a ground state. Actually I proved it and came back with a written paper next day. He said "too fast!"(chuckles). That was my first publication. Then he got sick and he was out for several months. At this point I started learning about the many body problem from the little book by ter Haar. When Schwinger returned he and Paul Martin had also began work on the many body problem, so my thesis focused on applying many body techniques to metals. We were unaware of similar work being done in the Soviet Union, which basically involved the same techniques

**Chu:**

Communication was very difficult at that time.

**Baym:**

Yes. It was very difficult. In my thesis I started developing a theory, an approximation to the electron Green's functions. Martin pointed out, in my final examination, that my result wasn't quite right. I was off by a factor of 4/5 in the calculation of the electrical conductivity. As it turns out, factors of 5 were difficult to find diagramatically. My early carrier was then devoted to developing self-consistent nonlinear Green's function technology and applying it to transport problems.

**Chu:**

You started this during your Ph.D. That's impressive.

**Baym:**

(Chuckles) It was a good era to start that.

**Chu:**

Since you mentioned that Prof. Schwinger was sick, was he involved in your research during your Ph.D?

**Baym:**

Yes. He was involved. Basically I discussed with him what I had done and he made helpful suggestions, all the while supporting me. His support was very important in building my confidence. I learned the basic technology of Green's functions and quantum field theory from him. It was a very solid foundation for the future; I did not have to worry about the basic formalism. Schwinger did not think in terms of Feynman diagrams, and so I actually learned the approach from notes of Dick Arnowitt on pionnucleon physics.

**Chu:**

I believe he never forbade the use of Feynman diagrams but he did not encourage the use of them.

**Baym:**

In a funny incident Lowell Brown, who was a student along with me at that time, wrote down on Schwinger's board a Green's function with a subscript "F" [for Feynman]. Schwinger asked him, "Do you have to use that letter?" (Chuckles).

**Chu:**

You have a lots of stories to tell us about him. After that you became a faculty at University of Illinois in 1963. How was the research in condensed matter physics at that time compared to today?

**Baym:**

That was a fantastic time. When I was a postdoc in Copenhagen, Leo Kadanoff mentioned that there were three good places to do condensed matter physics in the world: the Landau institute in Moscow, Bell Telephones Laboratories in New Jersey, and the University of Illinois in Urbana. Leo Kadanoff actually left Copenhagen earlier to take a faculty position in Illinois and shortly after he arrived, I got a formal looking envelope from the University of Illinois. Before, nobody had sent me letters like that. I was very young (laughs). I said, before opening it, "Oh! My God! It is a job offer! And I am going to have to take it!". I did, never to my regret.

**Chu:**

You did not apply?

**Baym:**

No. I didn't apply at all. Students now cannot understand how it worked back then. After the Second World War physics was very valued, and was very well supported. Shortly after I came to Illinois, David Edwards discovered that Helium-3 could be dissolved in Helium-4, up to a lit-tle over 6% at very low temperatures. Helium-4 by itself is a superfluid at low temperature. while Helium-3 formed a Fermi liquid. I started working with John Bardeen as well as with David Pines on understanding these dilute solutions of Helium-3 in Helium-4. Bardeen was in-terested in whether Helium-3 could form a superfluid with BCS pairing, in the Helium-4. That system would have two interpenetrating superfluids, one bosonic and the other fermionic. But as we estimated, the transition temperature would be in the then unobtainable microkel-vin range.

**Chu:**

You said that you have an interest in nuclear physics. Yesterday you mentioned that you moved to nuclear physics from condensed matter physics. How did that happen?

**Baym:**

That's a very good question. Pulsars were discovered in late 1967 and we learned about them shortly after. My colleagues David Pines, Chris Pethick, Geoff Ravenhall, and I began studying neutron stars, realized to be the central engine of the pulsars. We, as condensed matter physicists, could only do very simple things like calculating electrical conductivity in very dense matter. The conductivity we found was so high that the large scale magnetic fields in neutron stars could not adiabatically change on a timescale of the age of the universe. We studied possible phases of neutron superfluidity and proton superconductivity. Even though the pro-tons in neutron stars become superconducting they must do so in the presence of the magnet-ic field; they don't have the time to expel magnetic fields.

In 1970 Chris Pethick and I were both at the Niels Bohr Institute in Copenhagen. The visitors' mail was put in boxes according to the first letter of the last name. After lunch one day early on I went to the B-box where I found a postcard addressed to Hans Bethe. So what do you do? I turned it over and read it. It was an acknowledgment from the journal, Astronomy and Astro-physics, of receipt of a paper he, together with Gerhard Börner and Katsuhiko Sato, wrote on neutron stars. There were two things I learned from the postcard. One was that he was working on neutron stars and the other was that he was coming to Copenhagen. Chris and I got hold of a preprint of the Bethe paper, which was developing a theory of how nuclei in the crust turn into nuclear matter fluid in the interior. We tried to improve his calculation with a better account of electron screening, and found that the more we improved the theory the more self-inconsistent their calculation became. The theory fell apart completely. Then Bethe arrived and he was very nice and said, "we must solve the problem." We then were trained in nuclear physics sitting at the feet of the great man – an amazing opportunity! And we wrote a quite lovely paper on the nuclear physics of neutron stars, published in 1971.

**Chu:**

Right time right question. Everything sounds right about that time. Exciting time.

**Baym:**

Yes. We did not have a sense of its importance at the time. By the way, Bethe was phenomenal at calculating with his slide rule. We used to joke that the only thing limiting his ability to cal-culate was the Lorentz contraction of the slider. Chris and I could only keep up to by learn to use computers. Copenhagen at the time had a first generation transistorized machine on which we did our neutron star calculations. One could actually hear the machine clicking as it stepped through the star. That was great fun. Bethe finally turned the calculating over to us.

**Chu:**

You have also developed an interest in the history of physics. Was it always an interest of yours? Or how did it start?

**Baym:**

That began because of my former wife who was a trained as a theoretical physicist and then went on towards history. She was writing about the development of the electron theory of solids, with me looking over her shoulder. That work expanded into a major study of the his-tory of solid state physics.

**Chu:**

Have you learned any good lessons from studying the history of physics?

**Baym:**

Yesterday at lunch I mentioned a story about Landau. At the Solvay meeting on neutron stars in 1973, I asked Rosenfield what he knew about the history of neutron stars. He recounted to me that Chadwick, on the day he discovered the neutron in 1932, sent a letter to Niels Bohr announcing the discovery. He went on to say that Bohr, Landau and he sat in Copenhagen on receiving the letter discussing what this new particle might be good for. Landau suggested, he said, that this new particle could form "strange stars." I told this story at the conference in 1982 to celebrate the 50th anniversary of the discovery of neutron, and even got permission from Mrs. Chadwick to publish a copy of the letter.

As It turned out that this history is quite inaccurate. In February 1932, Landau was definitely not, as I discovered, in Copenhagen, and as Chris found in the archives at the Bohr Institute, neither were Bohr nor Rosenfeld. They were travelling. The letter sat on Bohr's desk for a month. The story was too good to be true, but at the same time Rosenfeld's memory was too vivid for it not to have had some elements of the true history.

**Chu:**

The story has already propagated now one has to correct the history.

**Baym:**

Yes. Chris and I, together with Dima Yalkolev and Pavel Haensel, later wrote a paper with the actual history. Landau was in Copenhagen in February but it was a year earlier. A discussion did take place between Bohr, Landau and Rosenfeld but a year before the neutron was discovered. It turned out that Rosenfeld was thinking of Landau's paper written a year earlier where he had the idea of the possibility of matter in a star "forming a gigantic nucleus".

The moral of the story is that oral histories are good guides in figuring out what happened, but they shouldn't be trusted by themselves.

**Chu:**

You are not only a remarkable distinguished researcher but also a good educator. You have written textbooks. I know some people who I have had contact with, for example Bruno Zumi-no, whom I asked once, "Do you consider to write a textbook?". He was also a remarkable lecturer. He said that it would take a lot of time. I am sure that it might have taken a lot of your time too. I wonder what made you write textbooks.

**Baym:**

Yes. It does take a great time. About my Quantum mechanics textbook: when I came to Illinois I started teaching quantum mechanics, and decided the night before the first lecture to teach it my own way. The students said that they needed notes to read, so after class everyday I wrote 10-15 pages of notes, and in my mind could see the students staring back at me saying, "no, please explain it more carefully." At the end of a year and half I had a very thick pile of notes which I eventually published. The Quantum Statistical Mechanics book with Leo Kadanoff was a write-up of the lectures that both he and I were giving at various places in Europe on Green's function technology. We wrote that book in one month. The other book I mentioned yesterday, on the *Landau Theory of Fermi Liquids* with Chris Pethick, basically brought together re-view articles we wrote earlier.

**Chu:**

Do you have any advice for the young students who are looking forward to become researchers?

**Baym:**

Don't read history because history says transformations are hard. Instead go and read the current literature. and especially for theorists, learn experiments and talk to experimentalists, because experimentalists really know how the world works. That's really very important.

**Chu:**

During the 20th anniversary of NCTS, mathematician Prof. Shing-Tung Yau was sharing his experience as a researcher. He advised the students to learn from the original literature because there could be many ideas hidden.

**Baym:**

The same is true for physics. For example the Slater determinant for electrons in metals was first written down by Dirac. Papers of great men are truly gems.

**Chu:**

I am glad that you are here, I wish that the time was longer. Thank you very much.

**Baym:**

And thank you for your kind hospitality here.

# Cultivation Program

The presence of a community of excellent young postdoc fellows is vital to the establishment of a successful research environment at the Center. The cultivation and nurturing of students and young researchers is very important for a bright future for the science and economy of Taiwan.

## Recruitment of Postdoc

The recruitment of outstanding young people to come to work in the Center is very important to us. At the time of writing, the center has a body of 18 research staffs consisting of 4 assistant research scholars (2 in condensed matter/AMO/QIS/soft and 2 in particle physics/string/gravity) and 14 postdocs (6 in condensed matter/AMO/QIS/soft and 8 in physics/string/gravity). In terms of more refined research fields, 5 people works in condensed matter theory, 2 works in AMO, 1 works in soft-matter, 6 works in particle phenomenology, 2 works in string theory and 2 works in gravity and cosmology. In terms of nationality, 5 of them are from Taiwan and 13 of them are foreign ( China: 4, Japan: 3, India: 3, Europe: 2, Korea: 1, Indonesia: 1).

Out of the first bunch of researchers we hired since 2015, many has gotten faculty positions. For example, Bo Xiong (AMO) has obtained a faculty position at the Wuhan university of technology, China in 2015/12, Yu-Kuo Hsiao has obtained a faculty position at the Shanxi Normal University in 2018/02, Hai-Shuang Lu has obtained a faculty position at the Soochow Univ 2018/03, Rong-xin Miao has obtained a faculty position at the Sun Yat-Sen University, 2018/04, Martin Spinrath has obtained a faculty position at NTHU 2018/08, Xing-Bo Yuan will start as a faculty at the Central China Normal Univ 2018/12. The others are progressing well on their career path. For example, Chung-Chi Lee has won a Newton fellowship from the Royal society of UK in 2017 to work in Cambridge. This year, Yoshinori Honma has won a 5 years long term research position at the Meiji Gakuin University; Hiroshi Okada has won a 5 years position as a junior research group leader in APCTP; Pei-Yun Yang has just left for MIT for a postdoc position. Apart from the traditional career pathway, Chih-Piao Chuu has joined TSMC as a staff member scientist in a newly formed R& D division on future materials. A list of where our recent postdoc alumni continue on in their career can be found in the table.

| NAME | FIELD OF RESEARCH | DATE LEFT | | CURRENT |
|---|---|---|---|---|
| Bo Xiong | Condensed Matter | 2015/12 | F | Wuhan Univ. of Tech. |
| Carlos Cardona | String Theory | 2016/07 | R | Niels Bohr Institute |
| Jung Chang | Particle Physics | 2017/05 | R | Chonnam National Univ. |
| Ya-Fen Hsu | Condensed Matter | 2017/07 | R | DAMTP, Cambridge |
| Yen-Hung Ho | Condensed Matter | 2017/07 | R | Acad. Sinica |
| Chung-Chi Lee | Gravity & Cosmology | 2017/07 | - | Industry |
| Yue-Lin Sming Tsai | Particle Physics | 2017/10 | R | Acad. Sinica |
| Bor-Luen Huang | Condensed Matter | 2018/03 | R | Meiji Gakuin Univ. |
| Yoshinori Honma | String Theory | 2018/03 | R | NCKU |
| Hai-Shuang Lu | Condensed Matter | 2018/03 | F | Soochow Univ. |
| Rong-Xin Miao | String Theory | 2018/04 | F | Sun Yat-Sen Univ. |
| Chih-Piao Chuu | Condensed Matter | 2018/05 | S | R&D div., TSMC |
| Hiroshi Okada | Particle Physics | 2018/05 | R | APCTP |
| Xing-Bo Yuan | Particle Physics | 2018/07 | R | MIT |
| Md. Manirul Ali | Quantum Information | 2018/08 | R | NCKU |
| Martin Spinrath | Particle Physics | 2018/08 | F | NTHU |
| Pei-Yun Yang | Quantum Information | 2018/08 | F | Central China Normal Univ. |

Recent Alumni (hired since 2015). Key: R = research position, F = faculty, S = staff member

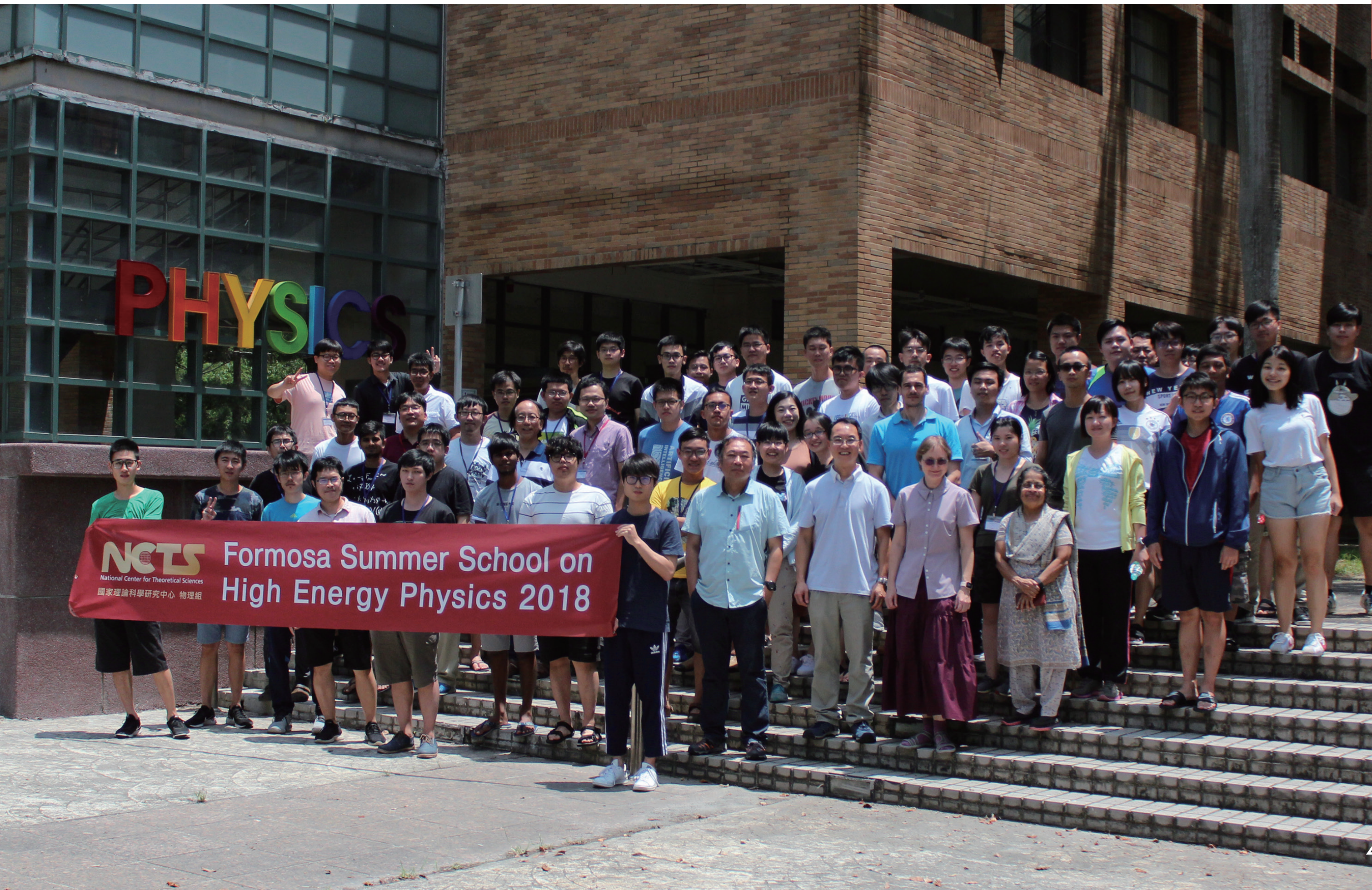
## Students and Postdocs Training

We pay much attention on efforts to facilitate the transfer of frontier research to the young generations, through organization of advanced schools and workshops specifically with them as target audiences. The center has regularly organized a number of schools this year. Some of the schools are of an interdisciplinary nature, combining theory and experiments, or traditionally different subjects such as chemistry and computation.

We also support promising students to attend international schools and conferences (about 50 per year), and exchange visit of our postdocs to institutes where we have an agreement on international exchanges.

| NCTS Schools | Date |
|---|---|
| 2018 Frontiers of Complex Systems Science: Soft Matter, Biophysics, and Statistical Physics | Jan 22-23 |
| 2018 Spring School on First Principles Computational Materials Research- Introductory Level | Apr 28-29 |
| 2018 Summer School on First Principles Computational Materials Research- Advance Level | Jul 16-20 |
| Formosa Summer School on High Energy Physics | Jul 16-27 |
| Computational Biology School | Jul 20-21 |
| NCTS 1-day Tutorial on Wannier Functions | Aug 09 |
| 2018 AMO Physics Summer School | Aug 28-31 |
| NCTS Summer School on Astrophysics 2018-Accretion and Emission of Ac- creting Black Holes | Sep 03-07 |

Group picture of Formosa Summer School on High Energy Physics, July 16-27, 2018.



# International Cooperation

NCTS has an active visitor program where we welcome scientists from all over the world to visit the center to exchange scientific knowledge through seminars, lectures and conference meetings, and to conduct collaborative projects with local scientists and staff. In 2018, we have hosted 221 international visitors.

NCTS has continued in developing new bilateral agreements with other international institutions in order to foster scientific collaboration. This year we have aided the development and signing of MOU between Bern University and our host university NTHU. Since 2016, NCTS has joined the research network, Fundamental Interaction SpaceTime (FIST), this year. FIST is a High Physics network formed by Research Institutions (primarily) in Asia in order to help building up and strengthening transnational research partnership and cooperation among researchers across Asia. The 3rd East Aisa Joint Workshop on Fields and Strings has helded in KIAS, Korea in Nov. In 2017 summer, NCTS has joined with IOP Academic Sinica to the Institute for Complex Adaptive Matter (ICAM). An ICAM-NCTS joint annual meeting has taken place in early January 2019, featuring research talk and public talk by Nobel Laureate Professor Duncan Haldane.

Former president of Hebrew University Prof. Hanoch Gutfreund visited NCTS on Jan 9, 2018.

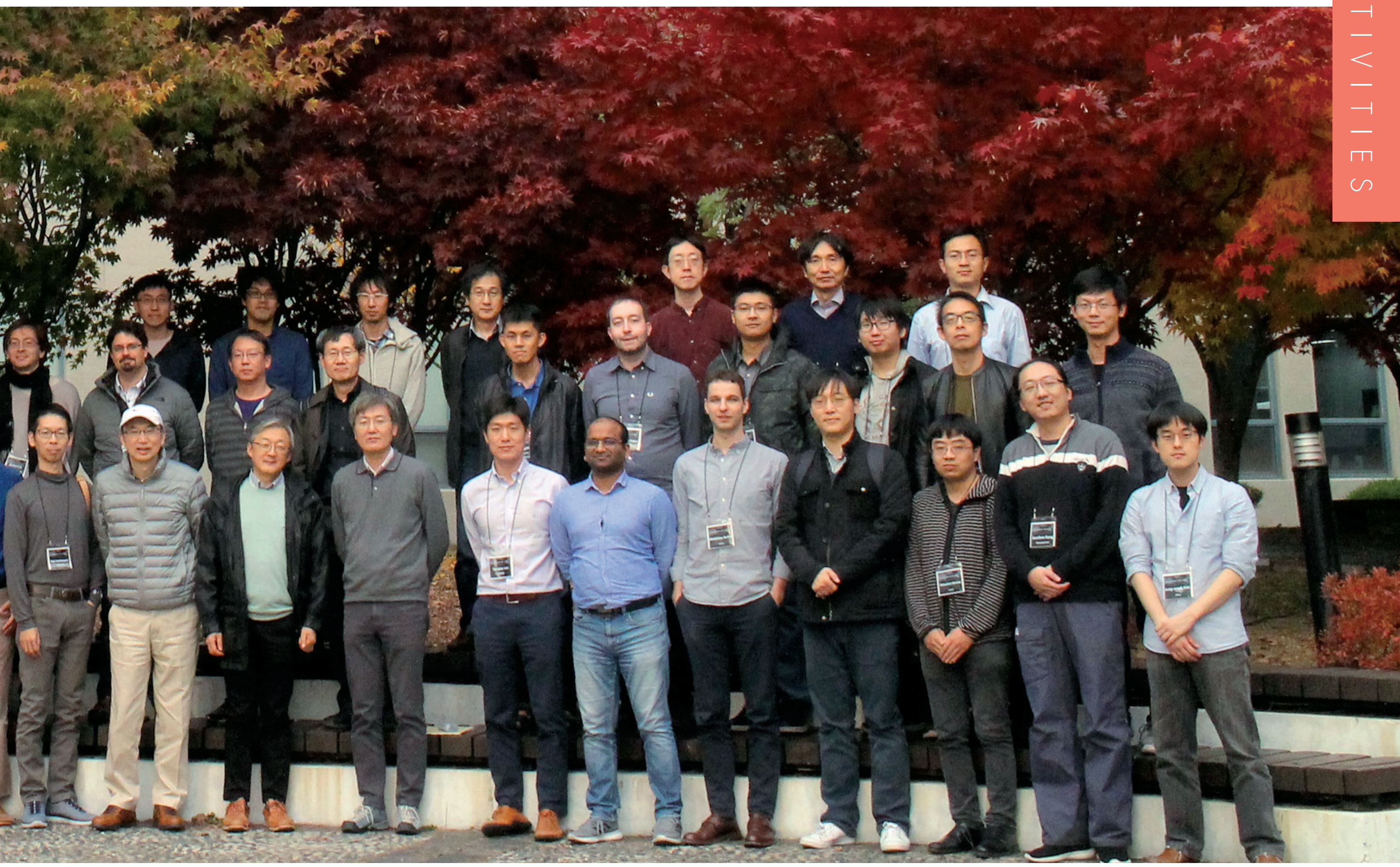
# Workshops

| WORKSHOPS/SYMPOSIA/CONFERENCES | DATE |
|---|---|
| **Atom-Molecules-Optics** | |
| NCTS Programs on AMO Physics(I): From Quantum Gases to Quantum Optics and Quantum Measurement | Mar 16-17 |
| NCTS Programs on AMO Physics(II): From Quantum Gases to Quantum Optics and Quantum Measurement | Mar 21-22 |
| Young Researchers Forum on Quantum Information Science | Jun 29-30 |
| Workshop on Quantum Science and Technology | Sep 03-05 |
| **Condensed Matter Theory** | |
| NCTS Annual Meeting in Condensed Matter Physics - Topological and 2D Materials | Jan 21-23 |
| Workshop on Quantum Materials | Mar 23-24 |
| The NCTS workshop on Correlated Quantum Many-body Systems: From Topology to Quantum Criticality | May 25-26 |
| The 16th Workshop on First-Principles Computational Materials Physics | Jun 25-26 |
| **Quantum Field Theory and High Energy Physics** | |
| NCTS Workshop on Non-Equilibrium Quantum Phenomena | May 24-25 |
| New Physics with Displaced Vertices | Jun 20-22 |
| 11th Taiwan String Workshop | Jun 21-24 |
| Cosmology Frontier in Particle Physics: Astroparticle Physics and Early Universe | Sep 27-29 |
| The 2nd Workshop on Parton Distribution Functions | Nov 26-28 |
| NCTS Annual Theory Meeting 2018: Particles, Cosmology and Strings | Dec 17-20 |
| **Soft Matter and Biophysics** | |
| Congress of Animal Behavior and Ecology | Jan 22-23 |
| Frontiers of Complex Systems Science: Soft Matter, Biophysics, and Statistical Physics | Jan 22-23 |
| Advance in Structural Biology and Beyond | May 22 |
| NCTS 2018 Workshop on Complex Fluids | Jun 19 |
| Statphys-Taiwan-2018 Workshop on Developments in Statistical, Nonlinear, and Biological Physics | Jun 25 |
| Computational Biology Workshop | Aug 01-02 |
| Symposium on Systems Neuroscience | Nov 20-21 |
| **Computational Chemistry** | |
| The 1st Taiwan-Thailand-Vietnam Workshop on Theoretical and Computational Chemistry | Mar 22-23 |

# Joint Meetings

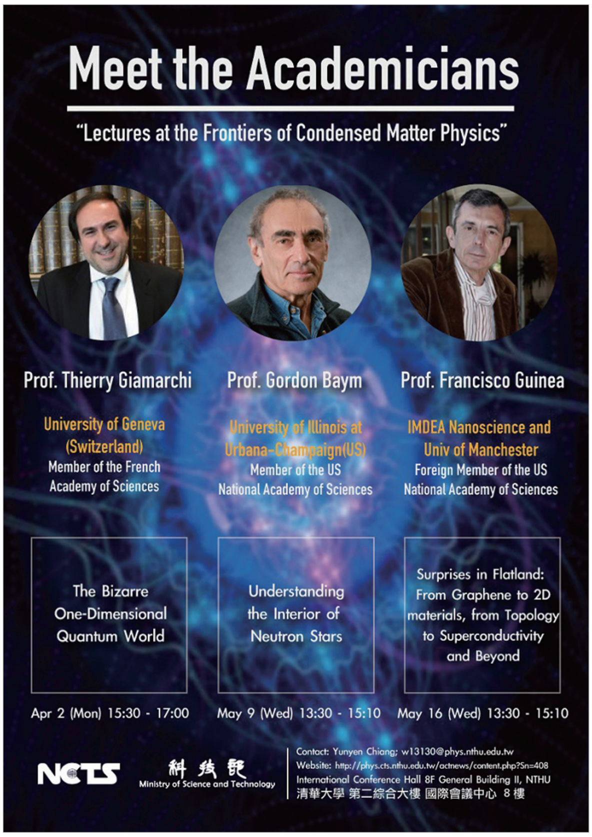
| JOINT MEETINGS | INVOLVED PARTIES | DATE |
|---|---|---|
| The 1st Taiwan-Thailand-Vietnam Workshop on Theoretical and Computational Chemistry | Taiwan/Thailand/Vietnam | Mar 22-23 |
| The 2nd Kyoto-NCTS Joint workshop on Field Theory and String Theory | Kyoto/NCTS | Oct 22-26 |
| The 3rd East Asia Joint Workshop on Fields and Strings | China/Japan/Korea/Taiwan | Nov 5-9 |
| 3rd KIAS-NCTS-KEK Joint Workshop | KIAS/NCTS/KEK | Dec 4-7 |

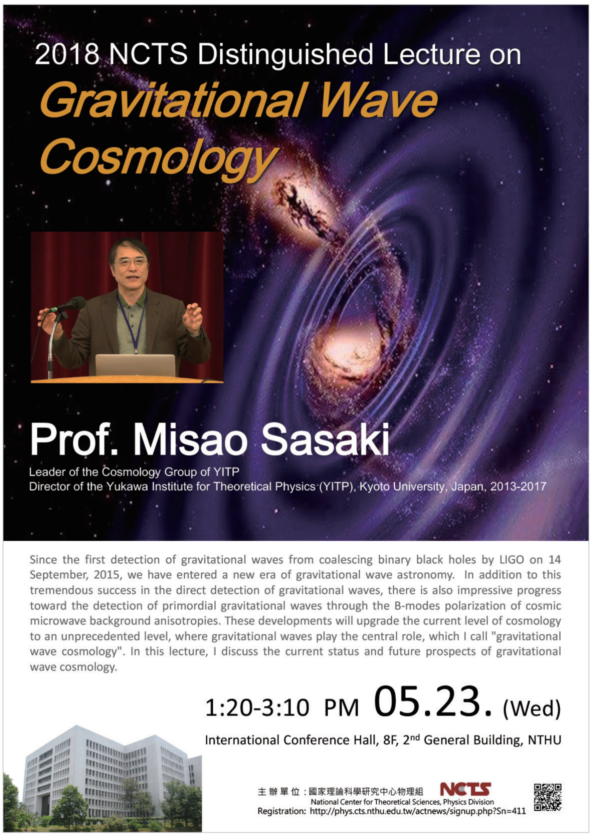
Right: group picture of the 3rd KIAS-NCTS-KEK Joint Workshop
Down: group picture of the 3rd East Asia Joint Workshop on Fields and Strings



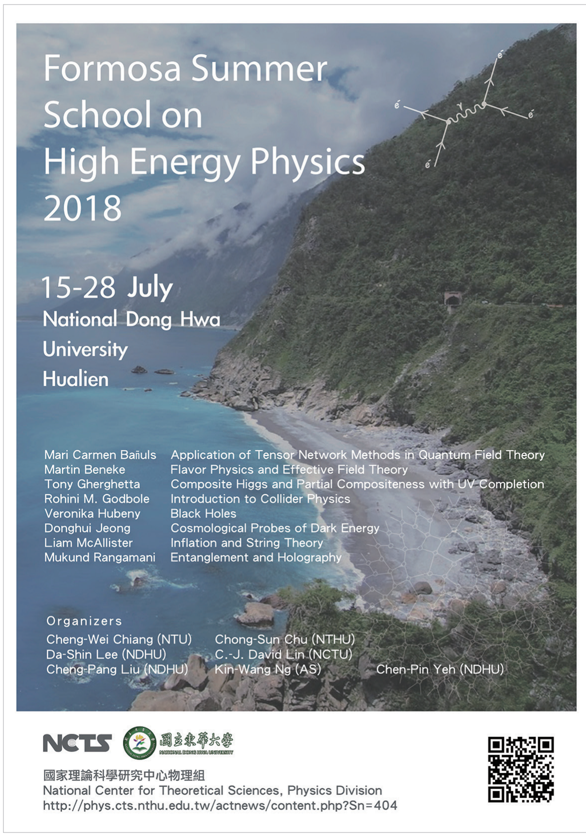
# Some of the Representative Meetings

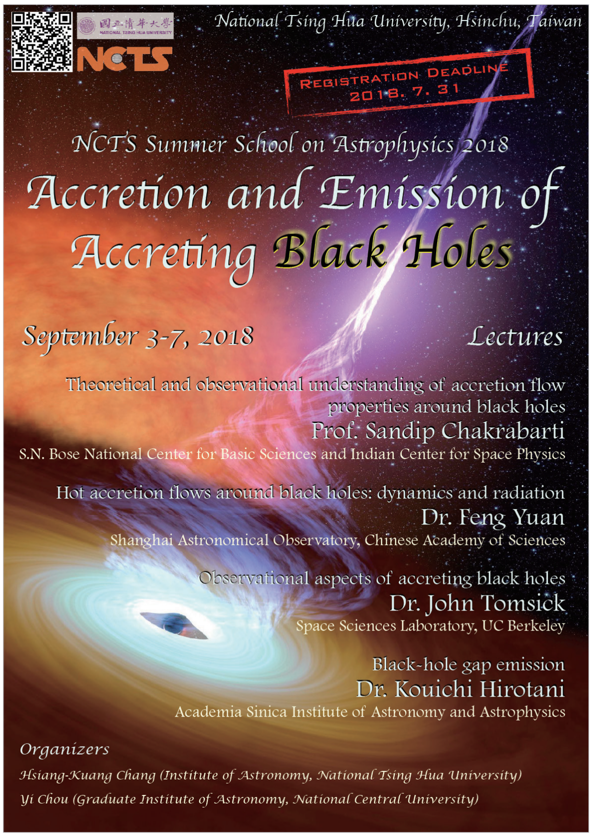


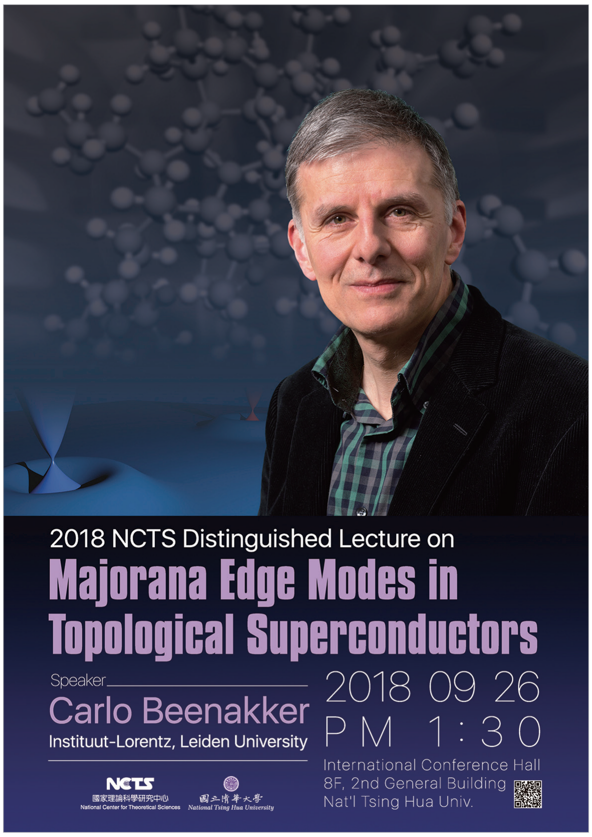



The 16th Workshop on First-Principles Computational Materials Physics
Date: June 25th – June 26th, 2018
Venue: International Conference Hall, 8th Floor, General Building II, National Tsing-Hua University
The 16th Workshop on First-Principles Computational Materials Physics, organized by the Focus Groups on Computational Materials Research (CMR) and Quantum Transport.
The aim of this workshop is to promote interactions and collaborations among local physicists who employ first-principles electronic structure calculations in their research. This year program will include plenary talks delivered by invited domestic or foreign scholars.
The Program Committee would also like to take this opportunity to identify the community members' interests and concerns in order to plan fruitful and successful activities in the future. Similar to previous years, all participants, particularly PhD students and young postdoctorals, are encouraged to share their latest research results. Fifty or thirty-minute reports by faculty members and fifteen-minute talks by postdoctors or PhD students will be scheduled in the program.
Speakers:
Prof. Gengchiau Liang (NUS)
Prof. Shin-Ming Huang (NSYSU)
Dr. Chia-Hsiu Hsu (SUSTech)
Dr. Xiaoting Zhou (NCKU)
Dr. Bahadur Singh (NUS)
Dr. Christian Crisostomo (NSYSU)
Dr. Ramesh Babu (NTU)
Mr. Angus Huang (NTHU)
Mr. Barun Ghosh (IIT, Kanpur, India)
Mr. Sougata Mardanya (IIT, Kanpur, India)
Prof. Aloysius Soon (Yonsei U.)
Dr. Chi-Cheng Lee (U. of Tokyo)
Mr. Rovi Angelo B. Villaos (NSYSU)
Mr. Yu-Shan Chen (NCKU)
Prof. Han Hsu (NCU)
Dr. Vijay Kumar Gudelli (NCTS)
Dr. Chi-Hsuan Lee (NCCU)
Mr. Jongmin Yun (Yonsei U.)
Mr. Bao-Huei Haun (NCU)
Organizing Committee:
Tay-Rong Chang - NCKU
Yu-Chang Chen - NCTU
Feng-Chuan Chuang (co-chair) - NSYSU
Guang-Yu Guo (co-chair) - NTU
Horng-Tay Jeng (co-chair) - NTHU
Chao-Cheng Kaun (co-chair) - RCAS,AS
Tsan-Chuen Leung - CCU
Shi-Hsin Lin - NSYSU
Chih-Kai Yang - NCCU
MOST 科技部
NCTS


Formosa Summer School on High Energy Physics 2018
15-28 July
National Dong Hwa University
Hualien
Mari Carmen Bañuls — Application of Tensor Network Methods in Quantum Field Theory
Martin Beneke — Flavor Physics and Effective Field Theory
Tony Gherghetta — Composite Higgs and Partial Compositeness with UV Completion
Rohini M. Godbole — Introduction to Collider Physics
Veronika Hubeny — Black Holes
Donghui Jeong — Cosmological Probes of Dark Energy
Liam McAllister — Inflation and String Theory
Mukund Rangamani — Entanglement and Holography
Organizers
Cheng-Wei Chiang (NTU)
Da-Shin Lee (NDHU)
Cheng-Pang Liu (NDHU)
Chong-Sun Chu (NTHU)
C.-J. David Lin (NCTU)
Kin-Wang Ng (AS)
Chen-Pin Yeh (NDHU)
NCTS
國家理論科學研究中心物理組
National Center for Theoretical Sciences, Physics Division
http://phys.cts.nthu.edu.tw/actnews/content.php?Sn=404


NCTS
National Tsing Hua University, Hsinchu, Taiwan
REGISTRATION DEADLINE
2018. 7. 31
NCTS Summer School on Astrophysics 2018
Accretion and Emission of Accreting Black Holes
September 3-7, 2018
Lectures
Theoretical and observational understanding of accretion flow properties around black holes
Prof. Sandip Chakrabarti
S.N. Bose National Center for Basic Sciences and Indian Center for Space Physics
Hot accretion flows around black holes: dynamics and radiation
Dr. Feng Yuan
Shanghai Astronomical Observatory, Chinese Academy of Sciences
Observational aspects of accreting black holes
Dr. John Tomsick
Space Sciences Laboratory, UC Berkeley
Black-hole gap emission
Dr. Kouichi Hirotani
Academia Sinica Institute of Astronomy and Astrophysics
Organizers
Hsiang-Kuang Chang (Institute of Astronomy, National Tsing Hua University)
Yi Chou (Graduate Institute of Astronomy, National Central University)


2018 NCTS Distinguished Lecture on
Majorana Edge Modes in Topological Superconductors
Speaker
Carlo Beenakker
Instituut-Lorentz, Leiden University
2018 09 26
PM 1:30
International Conference Hall
8F, 2nd General Building
Nat'l Tsing Hua Univ.
NCTS

Frontier of Condensed Matter Physics
Sept 27 (Thur.), 2018
Lecture Room A, 4F, NCTS
Carlo Beenakker
Leiden University
Spinoza Prize (1999)
Topologically protected Landau level in the vortex lattice of a Weyl superconductor
1:30 - 3:00 PM
Allan Macdonald
University of Texas at Austin
Oliver E. Buckley Condensed Matter Prize (2007)
Magic-Angle Twisted Bilayer Graphene
3:30 - 5:00 PM
主辦單位： 國家理論科學研究中心物理組
NCTS
National Center for Theoretical Sciences, Physics Division
General Building III, NTHU


NEW PHYSICS
WITH DISPLACED VERTICES
June 20th -22nd 2018
Lecture Room A of NCTS,
4F, 3rd General Building, NTHU
In this workshop, we will discuss strategies and algorithms to search for some of these long-lived particles and to unravel the very rich physics underlying these events. We attempt surveys on experimental side and theory side. On the theory side, a survey of various classes of BSM that produce signatures of displaced vertices. What kind of detectors can cover most of them.
On experimental side, there have been a number of discussions of special detectors on searches for various LLPs, such as milliQan, MoEDAL, and MATHUSLA. We try to bring attention to the TW community on such issues. What should be the recommendation for the design that can cover most of the BSM with LLPs? What are the best recommendations for new triggering strategies for LLPs in ATLAS, CMS, and LHCb?
Invited Speakers
Cristiano Alpigiani
ATLAS, University of Washington, Seattle
James Beacham
ATLAS, Ohio State University
Alberto Belloni
CMS, University of Maryland
Luis Roberto Flores Castillo
ATLAS, Chinese University of Hong Kong
Xin Chen
ATLAS, Tsinghua University
Ming Chung Chu
Chinese University of Hong Kong
Bob Hirosky
CMS, University of Virginia
Shieh-Chieh Hsu
ATLAS, University of Washington, Seattle
Pham Quang Hung
University of Virginia
Hyun Min Lee
Chung-Ang University
Hideyuki Oide
ATLAS, INFN e Universita Genova
Sebastian Trojanowski
National Centre for Nuclear Research
Yuhsin Tsai
University of Maryland
Yanjun Tu
ATLAS, University of Hong Kong
Organizing Committee
Kingman Cheung
Cheng-Wei Chiang
Giovanna Cottin
Jennifer Hsu
Tzu-Chiang Yuan
NCTS
Registration: http://phys.cts.nthu.edu.tw/actnews/signup.php?Sn=394
Please sign up before June 3rd, 2018.
Contact: yychiu@cts.nthu.edu.tw


NCTS Annual Theory Meeting 2018
Particles, Cosmology and Strings
Dec. 17th (Mon.) - 20th (Thu.)
International Conference Hall,
8F, 2nd General Building, NTHU
Invited Speakers
Giacomo Cacciapaglia, IPNL, Lyon
Spencer Chang, U. Oregon
Xuelei Chen, CAS
Hsin-Chia Cheng, UC Davis
Csaba Csaki, Cornell U.
Jonathan L. Feng, UC Irvine
Valentin V Khoze, IPPP Durham
Matthew Kleban, NYU
Hong Liu, MIT
Ian Low, Northwestern U.
Yutaka Matsuo, U. Tokyo
Michael Ramsey-Musolf, UMass Amherst
David Shih, Rutgers U.
Tadashi Takayanagi, Kyoto U.
Hai-Bo Yu, UC Riverside
+Others
Scientific Organizing Committee
Kingman Cheung (Co-chair), Cheng-Wei Chiang, Chong-Sun Chu (Co-chair), Chao-Qiang Geng, Xiao-Gang He, Kin-Wang Ng, Yi Yang, Tzu-Chiang Yuan
主 辦 單 位：國家理論科學研究中心物理組
NCTS
National Center for Theoretical Sciences, Physics Division
Registration: http://phys.cts.nthu.edu.tw/actnews/signup.php?Sn=434
Please sign up before Nov. 15th.
Contact Email: yychiu@cts.nthu.edu.tw


5th International Workshop on
Dark Matter, Dark Energy and Matter-Antimatter Asymmetry
暗物質、暗能量及物質-反物質不對稱
December 28, 2018 – National Center for Theoretical Sciences, Hsinchu, Taiwan
December 29–31, 2018 – Fo-Guang-Shan, Kaohsiung, Taiwan
With less than 5% of the energy content of the universe identified as the ordinary baryonic matter, the understandings of both dark matter and dark energy as well as the matter-antimatter asymmetry are among the paramount problems in fundamental science today including high energy and gravity physics. This workshop is devoted to questions pertaining to dark matter, dark energy and the matter-antimatter asymmetry in the universe. This meeting will bring together a wide range of international and local experts to discuss current ideas and models of the dark side and baryogenesis.
Website
• http://www.phys.nthu.edu.tw/~dark/2018/
Registration
• Registration deadline is November 15, 2018
Dark energy is pushing galaxies apart.
Dark Energy
Topics
• Baryogenesis and Leptogenesis
• Dark Energy
• Dark Matter
• Neutrino
• Gravitational Waves
• Inflation
• Flavor Physics
Matter
Antimatter
Organization Committee
• Chian-Shu Chen (Tamkang University)
• Jiunn-Wei Chen (NTU)
• Chao-Qiang Geng (NCTS/NTHU) (Chair)
• Xiao-Gang He (NCTS/NTU)
• Wolung Lee (NTNU)
• Cheng-Pang Liu (NDHU) (Co-Chair)
• Kin-Wang Ng (AS)
• Henry T. Wong (AS)
NCTS Secretary
• Ms. Tina Ke
Tel: +886-3-5742330
Fax: +886-3-5735086
E-mail: yzke@cts.nthu.edu.tw
Organization Scientific Secretary
• Mr. Shang-Yu Chien
Tel: +886-3-5715131 ext. 33275
Fax: +886-3-5735086
E-mail: s104022511@m104.nthu.edu.tw
Sponsors
• National Center for Theoretical Sciences (NCTS)
• National Tsing Hua University (NTHU)
NCTS
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# Visitors

Akhmedov, Emil T.
Moscow Institute of Physics and Technology
Mar 26-Apr 5, 2018

Akira, Furusawa
University of Tokyo
Mar 21-22, 2018

Alpigiani, Cristiano
University of Washington at Seattle
Jun 19-22, 2018

Argyres, Philip
University of Cincinnati
Jun 20-23, 2018

Bae, Joonwoo
Hanyang University,ERICA campus
Mar 03-09, 2018

Bahramy, Mohammad Saeed
RIKEN
Jan 19-24, 2018

Bai, Shandan
Kyocera Corporation
Oct 08-11, 2018

Bañuls, Mari Carmen
Max Planck Institute
Jul 11-20, 2018

Baulieu, Laurent
Laboratoire de Physique Théorique et Hautes Energies
Feb 24-Mar 24, 2018

Baym, Gordon
University of Illinois at Urbana-Champaign
May 08-13, 2018

Beacham, James
Ohio State University
Jun 20-22, 2018

Beenakker, Carlo
Leiden University
Sep 24-30, 2018

Belanger, Genevieve
Laboratoire d'Annecy-le-Vieux de Physique Théorique
Dec 27-31, 2018

Belloni, Alberto
University of Maryland
Jun 20-22, 2018

Beneke, Martin
Technische Universität München
Jul 15-23, 2018

Bergshoeff, Eric A.
University of Groningen
Jun 20-24, 2018

Bhabha, Gira
New York University
May 21-24, 2018

Bhattacharya, Mishkat
Rochester Institute of Technology
Aug 30-Sep 05, 2018

Bian, Guang
University of Missouri
Jan 20-24, 2018

Bihlmayer, Gustav
Forschungszentrum Jülich
Jan 20-24, 2018

Burko, Lior
Georgia Gwinnett College
Oct 07-10, 2018

Cacciapaglia, Giacomo
Institut de Physique Nucléaire de Lyon
Dec 16-23, 2018

Cannon, Kipp
University of Tokyo
Oct 07-10, 2018

Carlos Andres, Cardona G.
Niels Bohr Institute
Sep 14-29, 2018

Castro Neto, Antonio H.
National University of Singapore
Jan 12-22, 2018

Chakrabarti, Sandip
S.N. Bose National Center for Basic Sciences
Sep 02-09, 2018

Chan, Ho-Bun
Hong Kong University of Science and Technology
May 23-25, 2018

Chang, Chi-Ming
University of California at Davis
Jun 21-23, 2018

Chang, Ching-Has
Leibniz Institute
Jan 01-24, 2018

Chang, Der-Chen
Georgetown University
Jan 01-07, 2018
Jun 01-Jul 31, 2018

Chang, Jung
Chonnam National University
Jan 01-31, 2018
Jul 10-Aug 25, 2018

Chang, Tu-nan
University of Southern California
Mar 20-Apr 17, 2018
May 22-Jun 19, 2018
Oct 23-Nov 20, 2018

Chao, Wei
Beijing Normal University
Sept 26-29, 2018

Chen, Xue-Lei
Chinese Academy of Sciences
Dec 16-19, 2018

Cheng, Sin-Chia
University of California at Davis
Jan 24-26, 2018
Jun 17-Jul 07, 2018
Sep 01-22, 2018
Dec 16-20, 2018

Cheong, Chi-Kit
Chinese University of Hong Kong
Oct 17-18, 2018

Chien, Chih-Chun
University of California at Merced
Jun 11-14, 2018

Chu, Ming-Chung
Chinese University of Hong Kong
Jun 20-22, 2018

Corzo-Trejo, Neil V.
Laboratoire Kastler Brossel
Mar 15-17, 2018

Csaki, Csaba
Cornell University
Dec 16-19, 2018

Debbio, Luigi Del
University of Edinburgh
Nov 25-27, 2018

Derendinger, Jean-Pierre
Bern University
Nov 15-Dec 07, 2018

Dong, Hao
Nanjing University
May 21-24, 2018

Doyle, Patrick
Massachusetts Institute of Technology
Nov 14-16, 2018

Dubovsky, Sergi
New York University
Jun 21-23, 2018

Eberhard K. U. Gross
Max Planck Institute
Jan 20-24, 2018

Eichhorn, Timon
University of Freiburg
Jul 23-26, 2018

Ekiert, Damian
New York University
May 21-24, 2018

Fabre, Claude
Laboratoire Kastler Brossel
Nov 14-16, 2018

Feng, Yuan
Chinese Academy of Sciences
Sep 03-05, 2018

Feng, Jonathan L.
University of California at Irvine
Dec 17-22, 2018

Feng, Wei-Xiang
University of California at Riverside
Jul 15-20, 2018
Aug 20-30, 2018

Garraway, Barry
University of Sussex
Jun 04-08, 2018

Genzor, Jozef
Kobe University
May 24-Jun 01, 2018

Germani, Cristiano
University of Barcelona
Dec 27-31, 2018

Gerosa, Davide
California Institute of Technology
Oct 08-11, 2018

Gherghetta, Tony
University of Minnesota
Jul 15-21, 2018

Ghosh, Barun
Indian Institute of Technology Kanpur
Jun 24-26, 2018

Giamarchi, Tierry
University of Geneva
Mar 31-Apr 05, 2018

Gobble, Rohini M.
Indian Institute of Science
Jul 22-28, 2018

Gomi, Kiyonori
Kiyonori Gomi
Mar 18-30, 2018

Granick, Steve
Institute for Basic Science
Aug 12-15, 2018

Gross, Eberhard Kurt
Max Planck Institute
Jan 20-24, 2018

Guinea, Francisco
IMDEA Nanociencia Institute
May 15-17, 2018

Hamada, Yuta
University of Crete
Oct 31-Nov 03, 2018

Han, Wan-Biao
Chinese Academy of Sciences
May 10-16, 2018

Hansmann, Ulrich H. E.
University of Oklahoma
Jun 23-24, 2018

He, Hong-Jian
Shanghai Jiao Tong University
Sep 26-29, 2018

Heller, Michal P.
Max Planck Institute
Aug 17-20, 2018

Ho, Kai-Ming
Iowa State University
Jun 11-15, 2018

Homma, Yoshinori
Meiji Gakuin University
Oct 28-Nov 03, 2018

Hradil, Zdenek
Palacky University
Mar 20-25, 2018

Hsieh, Chang-Tse
Kavli Institute for the Physics and Mathematics of the Universe
May 24-Jun 01, 2018
Dec 09-19, 2018

Hsu, Chia-Hsiu
South University of Science and Technology
Jun 21-27, 2018

Hsu, Shih-Chieh
University of Washington at Seattle
Jun 19-22, 2018

Hu, Bei-Lok
University of Maryland
Jan 01-15, 2018
May 11-Jun 01, 2018

Huang, Chun-Li
Donostia International Physics Centre
Feb 21-May 17, 2018

Huang, Qing-Guo
Chinese Academy of Sciences
Oct 07-10, 2018

Huang, Li
Southern University of Science and Technology
Jan 18-26, 2018

Huang, Yi-Ping
Max Planck Institute
Jan 08-19, 2018

Hubby, Veronika
University of California at Davis
Jul 23-28, 2018

Ishizuka, Hiroaki
University of Tokyo
Feb 22-28, 2018

Ito, Nobuyasu
University of Tokyo
Jun 24-25, 2018

Ito, Sosuke
Hokkaido University
Jan 20-26, 2018

Jeong, Dong-Hui
Pennsylvania State University
Jul 21-28, 2018

Jeong, Hawoong
Korea Advanced Institute of Science and Technology
Jun 24-25, 2018

Jiménez-García, Karina
Laboratoire Kastler-Brossel
Mar 15-17, 2018

Jinzenji, Misao
Hokkaido University
Jan 08-11, 2018

Juzeliunas, Gediminas
Vilnius University
Apr 18-28, 2018
Oct 10-27, 2018

Kashyap, Hemant Kumar
Indian Institute of Technology Delhi
Oct 08-11, 2018

Keung, Wai-Yee
University of Illinois at Chicago
Jan 09-Feb 11, 2018
Nov 22-Dec 23, 2018

Khoze, Valentin
Durham University
Dec 16-19, 2018

Kim, Jae-Wan
Korea Institute for Advanced Study
Jun 17-21, 2018

Kirova, Teodora Velcheva
University of Latvia
Oct 12-16, 2018

Kitadono, Yoshio
Chinese Academy of Sciences
Jul 08-18, 2018

Kleban, Matthew
New York University
Dec 16-21, 2018

Korytár, Richard
Charles University
Dec 12-14, 2018

Kubo, Momoji
Tohoku University
Oct 08-11, 2018

Kuroda, Kumi O.
RIKEN
Nov 20-21, 2018

Lamporesi, Giacomo
Bose-Einstein Condensation Center
Mar 12-23, 2018

Lee, Hyun Min
Chung-Ang University
Jun 19-22, 2018

Lee, Jae-Sik
Chonnam National University
Jan 01-Feb 12, 2018
Jul 16, 2018

Lee, Chung-Chi
University of Cambridge
May 30-Jun 12, 2018
Dec 27-31, 2018

Lee, Jung-Hun
Gwangju Institute of Science and Technology
Jul 15-28, 2018

Li, Tjonnie
Chinese University of Hong Kong
Oct 07-10, 2018

Liang, Geng-Chiau
National University of Singapore
Jan 01-10, 2018
Jun 23-Jul 15, 2018

Lien, Amy
University of Maryland at Baltimore
Oct 07-10, 2018

Limpijumnong, Sukit
Suranaree University of Technology
Mar 21-24, 2018

Lin, Sin-Ted
Sichuan University
Jul 25-Aug 13, 2018

Liu, Hong
Massachusetts Institute of Technology
Dec 16-22, 2018

Liu, You-Xiao
Lanzhou University
Dec 27-31, 2018

Louie, Steven G.
University of California at Berkeley
Sep 27-28, 2018

Low, Ian
Northwestern University
Dec 20, 2018

Lu, Hai-Shuang
Changshu Institute of Technology
Sep 29-Oct 13, 2018

Lu, Zhun
Southeast University
Nov 25-28, 2018

Lubensky, Tom
University of Pennsylvania
Nov 06-10, 2018

Luo, Le
Sun Yat-sen University
Aug 27-Sep 02, 2018

Luu, Hoang-Nhan
Hong Kong University of Science and Technology
Jul 15-28, 2018

Ly, Mai-Xuan
Polish Academy of Sciences
Jun 23, 2018

Macdonald, Allan H.
University of Texas at Austin
Sep 25-28, 2018

Maldacena, Juan M.
Institute for Advanced Study
Jun 23-24, 2018

Marcis, Auzins
University of Latvia
Oct 12-16, 2018

Mardanya, Sougata
Indian Institute of Technology Kanpur
Jun 24-26, 2018

Matsui, Toshinori
Korea Institute for Advanced Study
Dec 27-31, 2018

Matsumoto, Takaki
Tsukuba University
Sep 27-29, 2018

Matsuo, Yutaka
University of Tokyo
Dec 19-21, 2018

McAllister, Liam
Cornell University
Jul 14-18, 2018

McCulloch, Iam
University of Queensland
Feb 01-13, 2018

Mckinley, Gareth
Massachusetts Institute of Technology
Jun 23-Jul 15, 2018

Mecca, Jerome
University of the Philippines Diliman
Oct 07-10, 2018

Mekys, Algirdas
Vilnius University
Oct 12-16, 2018

Morozumi, Takuya
Takuya Morozumi
Dec 27-31, 2018

Nguyen, Toan T.
Vietnam National University
Mar 21-24, 2018

Nishiwaki, Kenji
Korea Institute for Advanced Study
Dec 28, 2018-Jan 02, 2019

Noumi, Toshifumi
Kobe University
Nov 28-30, 2018

Oh, Choo-Hiap
National University of Singapore
Mar 20-24, 2018

Oide, Hideyuki
L' Istituto Nazionale di Fisica Nucleare
Jun 19-22, 2018

Okada, Hiroshi
Asia Pacific Center for Theoretical Physics
Dec 27-31, 2018

Okamoto, Hitoshi
RIKEN
Nov 21-23, 2018

Okumura, Hisashi
National Institutes of Natural Sciences
Jun 24, 2018

Orginos, Kostas
College of William and Mary
Nov 26-29, 2018

Papadimitriou, Ioannas
Korea Institute for Advanced Study
May 23-25, 2018

Papadopoulos, Theodoros
University of Chester
Mar 27-Apr 17, 2018

Parisi, Alessandro
Istituto Nazionale di Fisica Nucleare
Apr 11-Jul 08, 2018

Park, Chan-Yong
Gwangju Institute of Science and Technology
Jul 15-28, 2018

Park, Jeong-Hyuck
Sogang University
Oct 17-19, 2018

Park, Ju-Bin
Chonnam National University
Jan 01-31, 2018
Jul 12-Aug 24, 2018

Park, Seong-Chan
Yonsei University
Sep 26-30, 2018

Park, Wan-Il
Chonbuk National University
Sep 27-30, 2018

Paschen, Silke
Vienna University of Technology
May 25-28, 2018

Perlmutter, Eric J.
California Institute of Technology
Jun 22-24, 2018

Phillips W.
University of Illinois at Urbana-Champaign
May 23-57, 2018

Phonchantuek, Anajak
Naresuan University
Jul 15-29, 2018

Primulando, Reinard
Parahyangan Catholic University
Mar 17-25, 2018

Profumo, Stefano
University of California at Santa Cruz
Sep 24-29, 2018

Ramanathan , Ravishankar
Université Libre de Bruxelles
Nov 04-05, 2018

Ramsey-Musolf, Michael
University of Massachusetts at Amherst
Dec 15-20, 2018

Rangamani, Mukund
University of California at Davis
Nov 23-28, 2018

Rapcak, Miroslav
Perimeter Institute
Mar 07-13, 2018

Ruseckas, Julis
Vilnius University
Oct 12-16, 2018

Saito, Hayato
Hokkaido University
Jan 08-11, 2018

Sanchez-Soto, Luis L.
Max-Planck Institute
Mar 20-25, 2018

Sandvik, Anders
Boston University
May 24-Jun 03, 2018

Sasaki, Misao
Yukawa Institute for Theoretical Physics
Mar 06-13, 2018

Sato, Masatoshi
Yukawa Institute for Theoretical Physics
Feb 23-Mar 01, 2018

Sawada, Takahiro
Kindai University
Nov 25-29, 2018

Seelig, Johannes
Center of Advanced European Studies and Research
Nov 18-22, 2018

Shao, Shu-Heng
Institute for Advanced Study
Jun 14-15, 2018

Shiba, Shotaro
High Energy Accelerator Research Organization
Apr 24-May 02, 2018

Shih, Chih-Kang
University of Texas at Austin
Jan 21-23, 2018

Shih, David
Rutgers University
Dec 16-20, 2018

Shindou, Ryuichi
Peking University
May 23-25, 2018

Sin, San-Ji
Hanyang University
May 09-11, 2018

Singh, Bahadur
National University of Singapore
Jun 24-30, 2018

Son, Young-Woo
Korea Advanced Institute of Science and Technology
Jan 20-23, 2018

Soon, Aloysius
Yonsei University
Jun 24-28, 2018

Steinhoff, Jan
Max Planck Institute
Oct 07-10, 2018

Sugishita, Satora
Osaka University
Apr 19-21, 2018

Takayanagi, Tadashi
Yukawa Institute for Theoretical Physics
Dec 16-18, 2018

Takemura, Kazuhiro
Kazuhiro Takemura
May 21-23, 2018

Takeo, Inami
Sungkyunkwan University
Jun 05-11, 2018

Takeuchi, Hiromitsu
Osaka City University
Sep 26-29, 2018

Tey, Meng-Khoon
Meng-Khoon
Mar 15-17, 2018

Tezuka, Masaki
Masaki Tezuka
May 28-31, 2018

Thiang, Guo-Chuan
Hokkaido University
Mar 19-28, 2018

Thygesen, Kristian Sommer
Technical University of Denmark
Jan 21-23, 2018

Tomsick, John
University of California at Berkeley
Sep 01-07, 2018

Totsuka, Keisuke
Kyoto University
Nov 11-16, 2018

Trojanowski, Sebastian
National Centre for Nuclear Research
Jun 18-23, 2018

Tseng, Po-Yen
Kavli Institute for the Physics and Mathematics of the Universe
Jan 07-27, 2018
Jul 17-Aug 11, 2018
Dec 10-31, 2018

Tu, Wei-Yuan
University of Hong Kong
Jan 22-27, 2018

Tu, Yan-Jun
University of Hong Kong
Jul 19-22, 2018

Tye, Henry
Institute for Advanced Study, HKUST
Sep 27-29, 2018

Valenzuela, Irene
Utrecht University
Jun 20-24, 2018

Villanueva, John Adrian
Univierity of the Philippines
Diliman
Oct 07-10, 2018

Volkas, Raymond R.
University of Melbourne
Sep 22-30, 2018

Wang, Gang
Soochow University
Jan 01-Feb 02, 2018

Wang, Yu-Chiun
RIKEN
Jan 22-Jan 28, 2018

Wardell, Barry
University College Dublin
Oct 07-10, 2018

Watanabe, Masataka
Kavli Institute for the Physics and
Mathematics of the Universe
May 17-20, 2018

Wu, Pu-Xun
Hunan Normal University
Dec 27-31, 2018

Wu, Yi-Peng
Research Center for the Early
Universe
Dec 25-31, 2018

Wu, Yong-Shi
University of Utah
May 23-28, 2018

Xu, Fan-Rong
Jinan University
Jan 22-23, 2018

Xue, Xun
East China Normal University
Jul 15-28, 2018
Sep 26-30, 2018

Yamamoto, Kazuhiro
Hiroshima University
May 25, 2018

Yamashita, Kimiko
Ochanomizu University
Apr 16-May 25, 2018
Jun 04-Jul 13, 2018

Yang, Sheng-Yuan
Singapore University of
Technology and Design
Jan 20-27, 2018

Yao, Wang
University of Hong Kong
Jan 20-23, 2018

Yimnirun, Rattikorn
Vidyasirimedhi Institute of Science
and Technology
Mar 22-23, 2018

Yokozaki, Norimi
Tohoku U
Mar 21-22, 2018

Yoon, Yeo-Woong
Konkuk University
Aug 10, 2018

Yoshida, Kentaroh
Kentaroh Yoshida
Mar 11-16, 2018

Yu, Hai-Bo
University of California at
Riverside
Dec 16-27, 2018

Yu, Hong-Wei
Hunan Normal University
Dec 27-31, 2018

Yu, Yi-Kuo
National Institutes of Health
Jun 09-23, 2018

Yuan, Chien-Peng
Michigan State University
Sep 12-28, 2018

Yue, Rui-Hong
Yangzhou University
Sep 27-31, 2018

Zaanen, Jan
Universiteit Leiden
May 23-28, 2018

Zhang, Li-Jiang
Nanjing University
Mar 20-25, 2018

Zhang, Wen-Qing
Southern University of Science
and Technology
Jan 18-25, 2018

Zhang, Yang
Max Planck Institute
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Tsing Hua University
May 24-27, 2018

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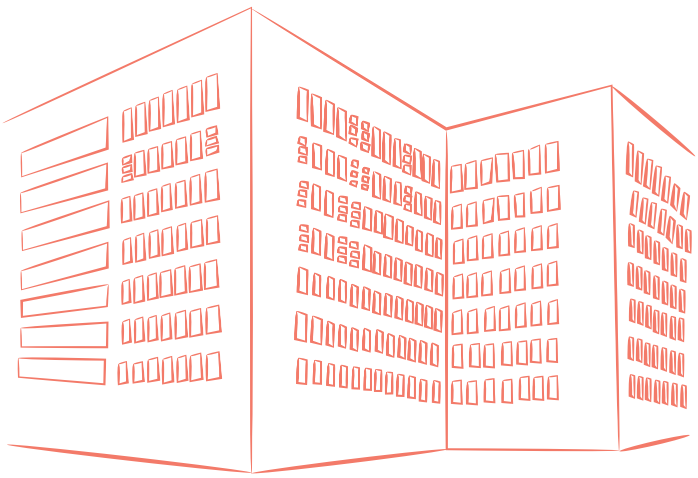

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