Institute of Physics, Academia Sinica
AAC Review 2023

MHEP – Experiment *[since ~1990]*: 9 Faculty Members
Wen-Chen Chang (章文箴) *[as convener]*

Recent Retirement:

Shih-Chang Lee
李世昌

Faculty Scientists:

Yuan-Hann Chang
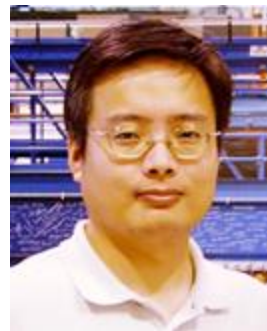張元翰

Henry Tsz-King Wong
王子敬

Suen Hou
侯書雲

Wen-Chen Chang
章文箴

Song Ming Wang
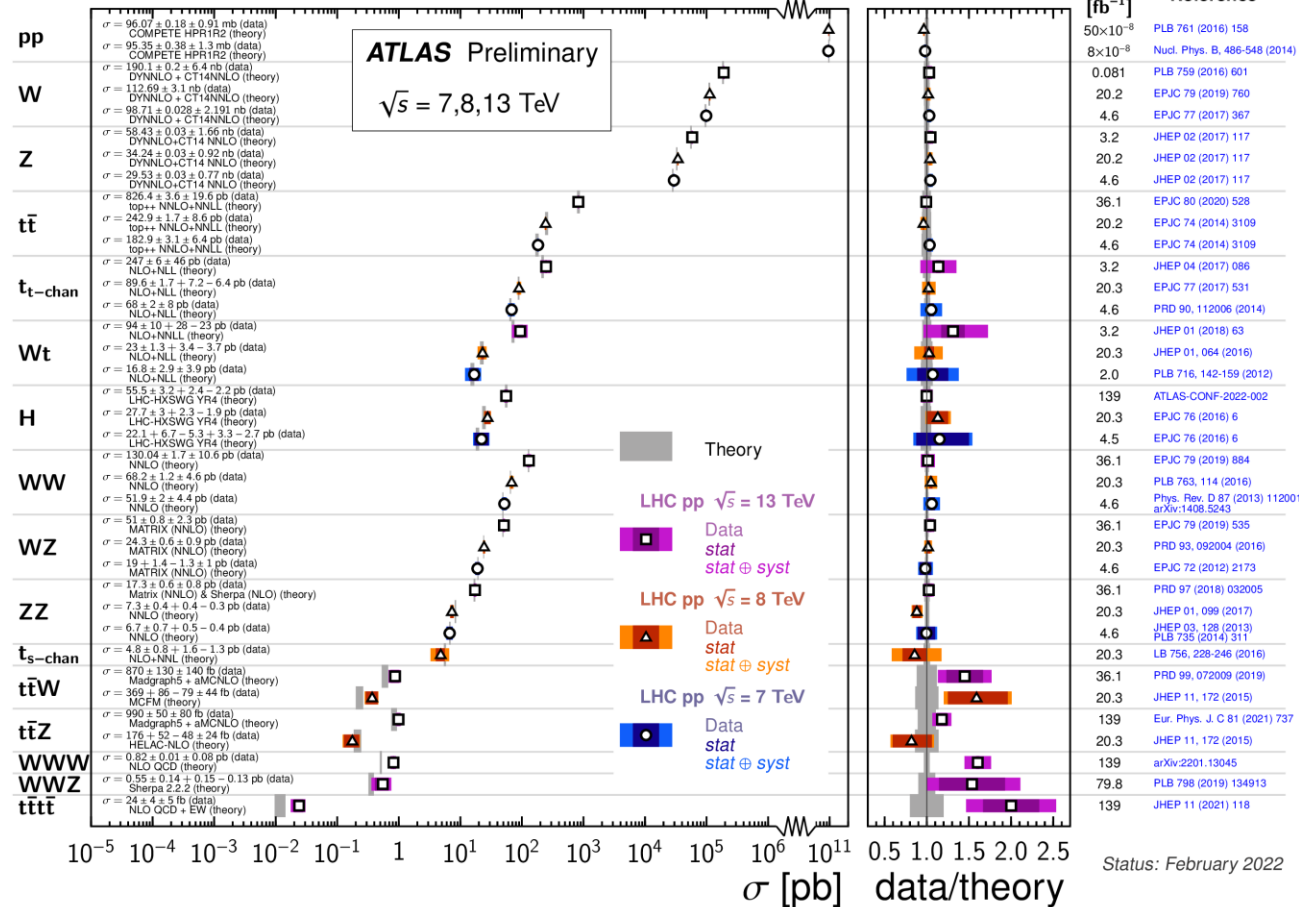王嵩銘

Sadakazu Haino
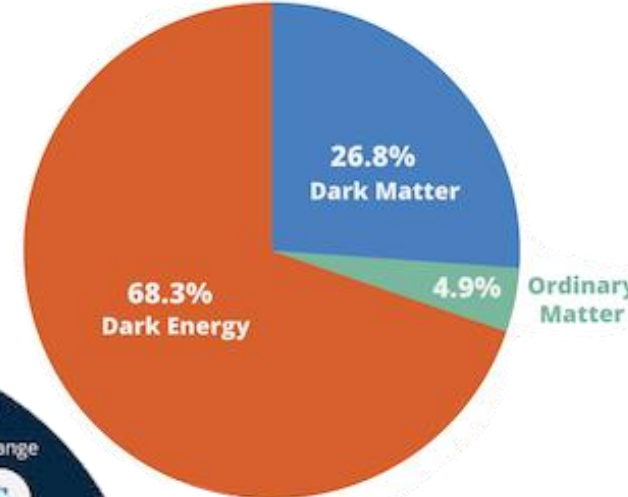灰野禎一

Ming-Lee Chu
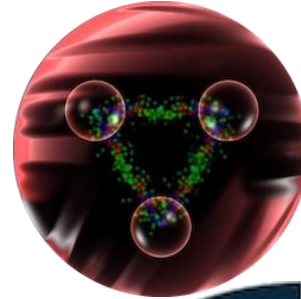朱明禮

Chih-Hsun Lin
林志勳

Eric Yen
嚴漢偉

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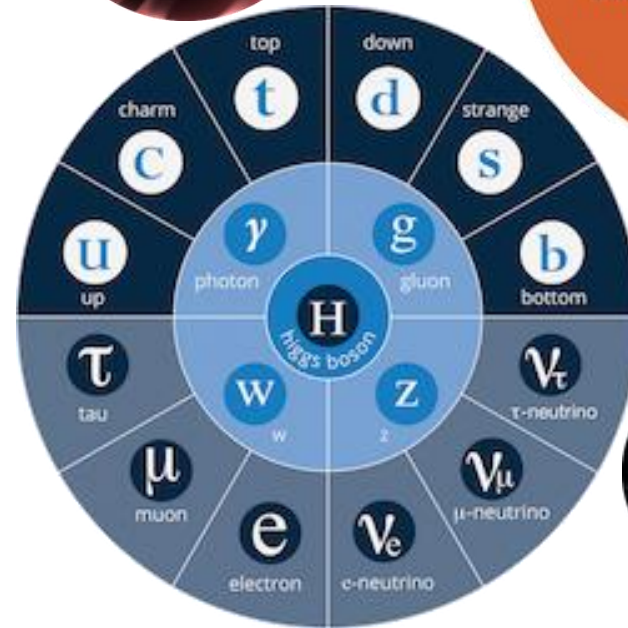# Success of Standard Model in HEP But Unknown Remains

Standard Model Total Production Cross Section Measurements

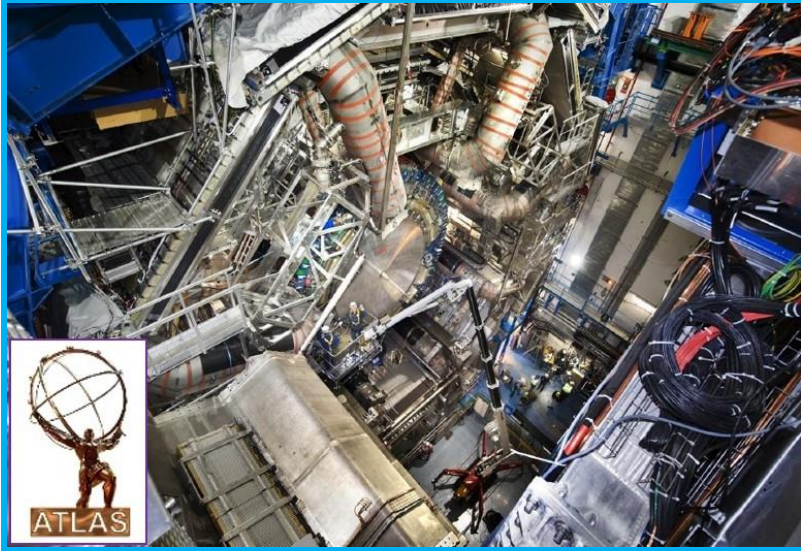Antimatter, Parity Violation

Dark Matter, Dark Energy

Early Universe, gravity

TEXONO

ATLAS

COMPASS

ECAL2
HCAL2
ECAL1
HCAL1
SM2
RICH
SM1
Polarized Target
Veto
π⁻
190 GeV/c
Muon-filter
Muon-filter

CAMERA recoil proton detector surrounding the 2.5m long LH2 target

Collider
ATLAS, EIC, CEPC
Fixed-target (Hadron)

TEXONO.ν@KSNL
Dark Matter
(AMS, TEXONO.DM@CDEX, TASEH)

Gravi. Wave
KAGRA
TEXONO.GR@LIGO

Instrumentation
ASGC
TIDC
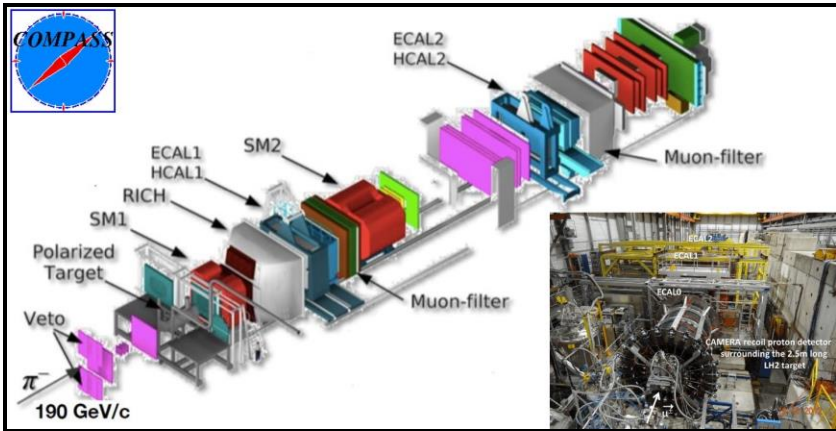
Academia Sinica drives e-science in Asia-Pacific

The Academia Sinica Grid Computing Centre (ASGC) in Taipei is currently the only LCG Tier-1 Centre in the Asia-Pacific area, with 400 KSI2K computing capacity, 50 TB disk space and a 35 TB tape library dedicated to the LCG. Since 2004, Academia Sinica has provided the services of a regional operation centre (ROC), site monitoring, virtual-organization
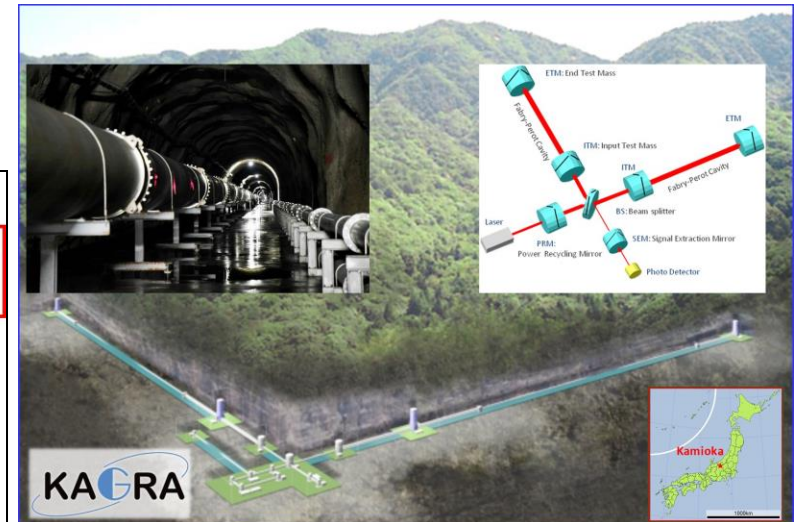
CERN COMPUTER NEWSLETTER
Volume XL, issue 4   September–October 2005

Tokyo University and other Tier-2 sites in this region for the ATLAS and CMS service challenges in the near future.
    ASGC is engaging in collaboration and sharing of information by taking advantage of e-science applications in the Asia-Pacific area. ASGC is also working with different partners to help form and support application-driven e-science communities in the Asia-Pacific region, to improve the next-generation research infrastructure and build up the e-science applications. Hosting the International Symposium on Grid Computing (ISGC) since

Sinica Grid Computing Centre.

CMS service challenge, ASGC received 20 TB of data from CERN at an average rate of 56 Mbit/s from 14 July to 14 August. The

CERN Computer Newsletter • September–October 2005

ASGC

KAGRA

ETM: End Test Mass
ITM: Input Test Mass
ETM
BS: Beam splitter
SEM: Signal Extraction Mirror
PRM: Power Recycling Mirror
Photo Detector
Laser
Fabry-Perot Cavity

Kamioka

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Institute of Physics, Academia Sinica
MHEP-EXP

Collider Physics
Search for new particles and new physics

> **ATLAS**
> **1999 ~**
> *S.M. Wang/ S. Hou*

> **CEPC – Higgs factory**
> *S. Hou*

Astroparticle Physics
Study cosmic-rays, search for anti-matter, dark matter

> **AMS**
> **1995 ~**
> *S. Haino/ Y.H. Chang*

Neutrino & Dark Matter Physics
With low energy detectors

> **TEXONO**
> **1996 ~**
> *H.T. Wong*

Axion Physics
Micro-wave Cavity Searches

> **TASEH**
> **2020 ~**
> *Y.H. Chang + QMP*

Experimental support;
Detectors Construction & Applications

> **Instrumentation TIDC**
> *M.L. Chu/C.H. Lin/ Y.H. Chang*
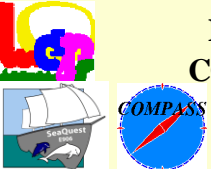
ASGC (Academia Sinica Grid Computing Center)
From HEP to e-Science

> **Computing**
> *Y.H. Chang/ E. Yen*

Hadron Physics
probing nucleons by GeV photons and hadrons

> **LEPS, SeaQuest, COMPASS, J-PARC**
> **1999 ~**
> *W.C. Chang*

Gravitational Wave
New tool to study our universe

> **World wide GW detector network (LVK)**
> **KAGRA**   **2016 ~** *S. Haino*
> **LIGO**   **2021 ~** *H.T. Wong*

> *Information & Details: Refer to Individuals' Reports ....*

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Collider Physics
Search for new particles and new physics

ATLAS
1999 ~
王嵩銘/侯書雲

CEPC – Higgs factory
侯書雲
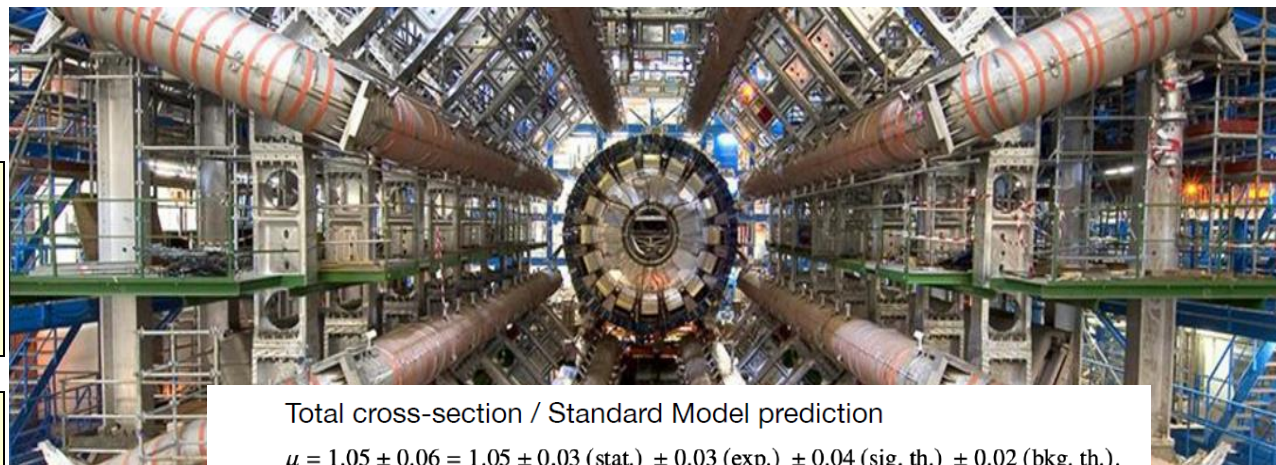
Total cross-section / Standard Model prediction

$\mu = 1.05 \pm 0.06 = 1.05 \pm 0.03 \text{ (stat.)} \pm 0.03 \text{ (exp.)} \pm 0.04 \text{ (sig. th.)} \pm 0.02 \text{ (bkg. th.)}.$

(benefits also from reduced theory uncertainty)

run 1   run 1   run 2   run 2
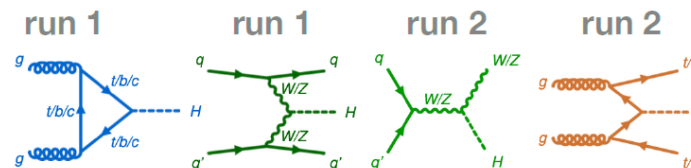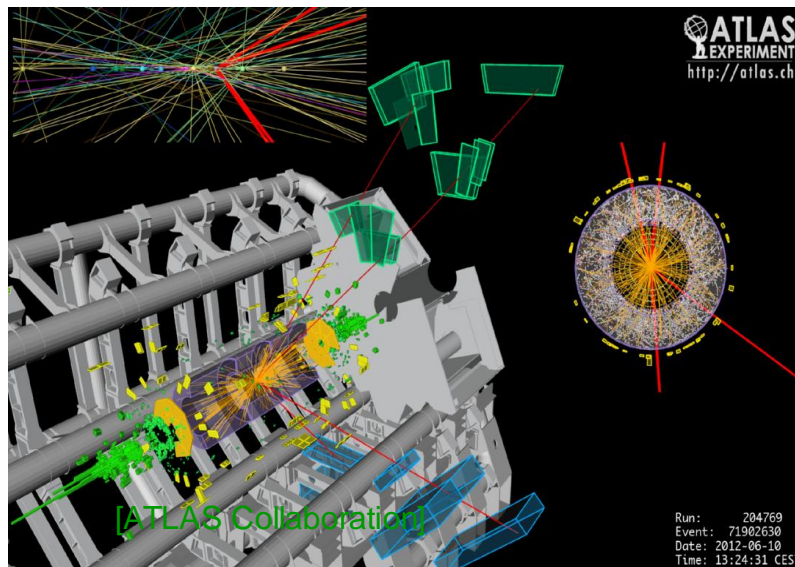
Measurements per production mode * decay channel:
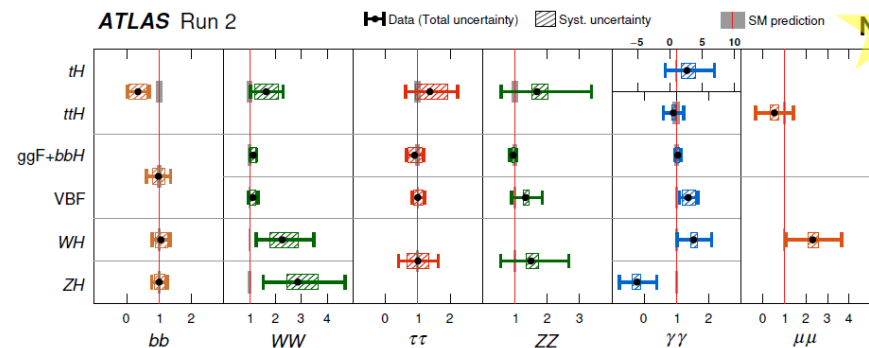
Nature 607 (2022) 52

$\sigma \times B$ normalized to SM prediction

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Astroparticle Physics

Study cosmic-rays, search for anti-matter, dark matter

AMS
1995 ~
灰野禎一/張元翰

- TRD
- TOF
- Tracker + Magnet
- TOF
- RICH
- ECAL

Positron Spectrum

- AMS-02
- Fit with Eq.(4) and 68% C.L. band

Source term

Diffuse term

PRL 122, 041102 (2019)

Energy [GeV]

Neutrino & Dark Matter Physics

With low energy detectors

TEXONO 1996 ~
王子敬

Kuo-Sheng Nuclear Power Station : Reactor Building

Neutrino Properties & Interactions at Reactor

quality ← **Detector requirements** → **mass**

Reactor Neutrino Spectrum

$\mu_\nu = 10^{-11} \mu_B$

$|\delta_Q| = 10^{-12}$

IV 同調散射 $\overline{\nu}_e N$ (SM)

III 微中子電荷 $\overline{\nu}_e$-A (δ_Q)

Observable Spectra with Reactor Neutrino "Beam"

II 標準模型 弱電作用 $\overline{\nu}_e e$ (SM)

I 微中子磁矩 $\overline{\nu}_e$-A (μ_ν)

Threshold ~ 100 eV

Rate (Count kg^{-1} keV^{-1} day^{-1}) vs T (keV$_{ee}$)
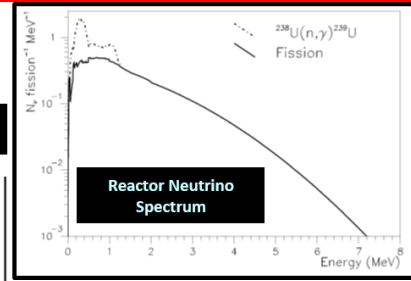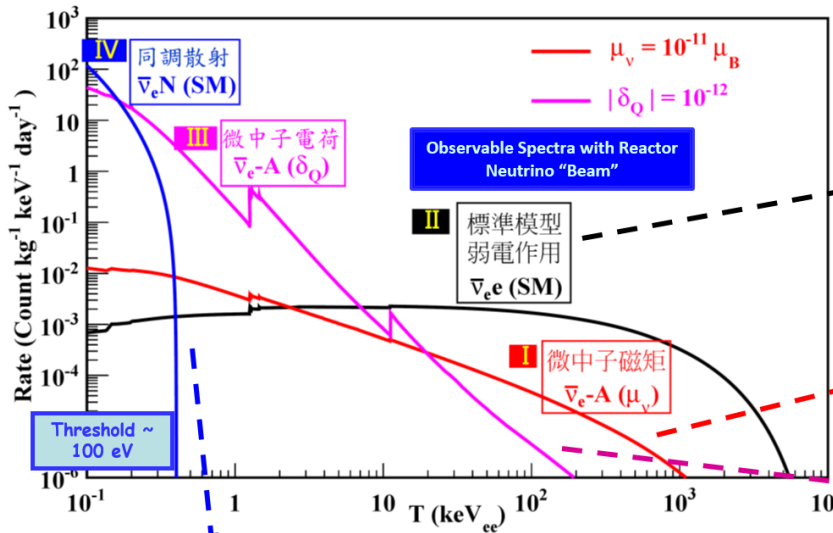
ν-e Scattering SM *[PRD10]* **& NSI/BSM** *[PRD10,PRD12,PRD15,2xPRD17]*
⇨ **200 kg CsI(Tl)**

Magnetic Moments *[PRL03,PRD05,PRD07]*
⇨ **1 kg HPGe**

Milli-charge ν/χ *[PRD14,PRD19]*
⇨ **sub-keV O(kg) PCGe**

sub-keV PCGe

νN Coherent Scattering *[Current Theme;PRD16]*
⇨ **sub-keV O(kg) ULEGe / PCGe**
⇨ **Dark Matter Searches @ KSNL** *[PRD09,PRL13,AP14,CJP19]*
⇨ **Theory Program w. NTU,NDHU ....** *[PLB14,PRD15,PRD16]*
⇨ **CDEX Program@CJPL** *[PRD13,2XPRD14,PRD16,PRD17,PC17,PRL18]*

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Axion Physics
Micro-wave Cavity Searches

TASEH
2020 ~
Y.H. Chang + QMP
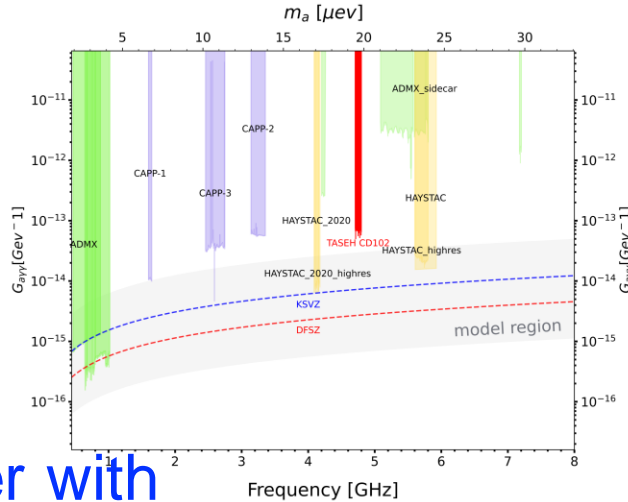
- Search for Axion Dark Matter with Haloscope type experiment:
  Measure Axion-converted photons (in microwave band) with a cavity in a 20mK environment with 9 Tesla field.

- Project started in 2020 with NSTC Vanguard project, first result obtained in 2021 and published 2022.

- **Developing quantum-limited-added-noise amplifier in Taiwan to improve the sensitivity by a factor of 10.**

Hadron Physics
probing nucleons by GeV photons and hadrons

LEPS, SeaQuest, COMPASS, J-PARC
1999 ~
章文箴

Wigner Distributions
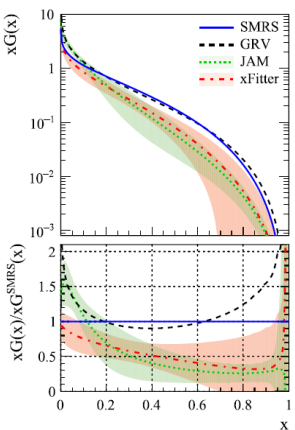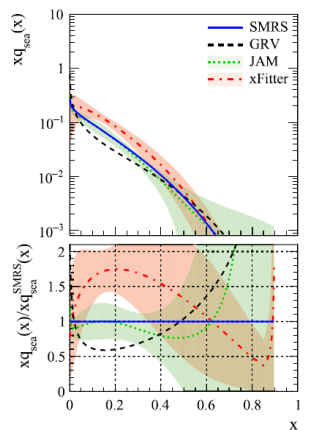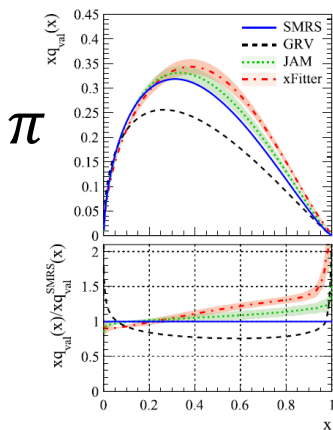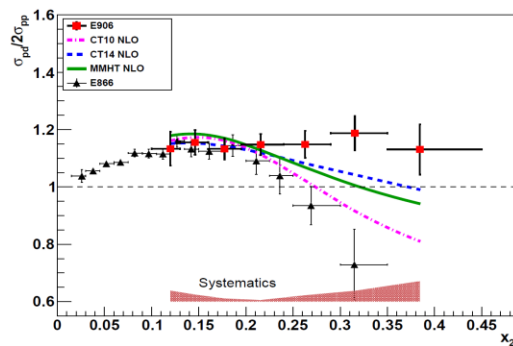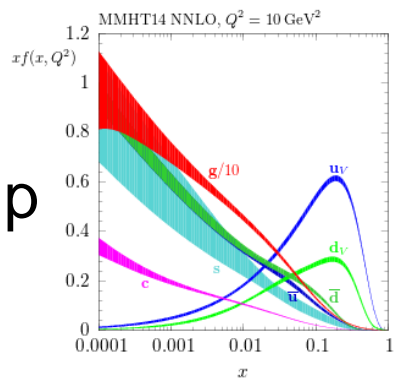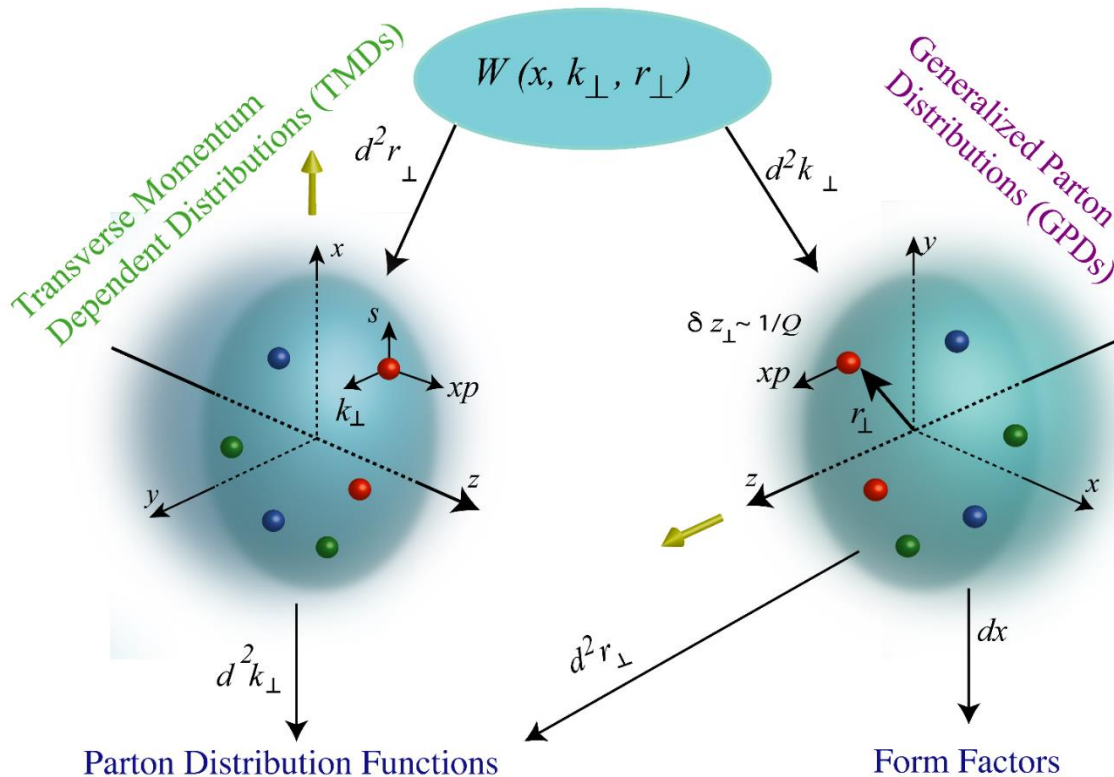
$W(x, k_\perp, r_\perp)$

Transverse Momentum Dependent Distributions (TMDs)

Generalized Parton Distributions (GPDs)

$d^2 r_\perp$

$d^2 k_\perp$

$\delta z_\perp \sim 1/Q$

$d^2 k_\perp$

$d^2 r_\perp$

dx

Parton Distribution Functions

Form Factors

Gravitational Wave
New tool to study our universe

World wide GW detector network (LVK)

KAGRA   2016 ~ *S. Haino*

LIGO   2021 ~ *H.T. Wong*

Gravitational Wave Observatories

LIGO – A GIGANTIC INTERFEROMETER

LIGO Hanford

LIGO Livingston

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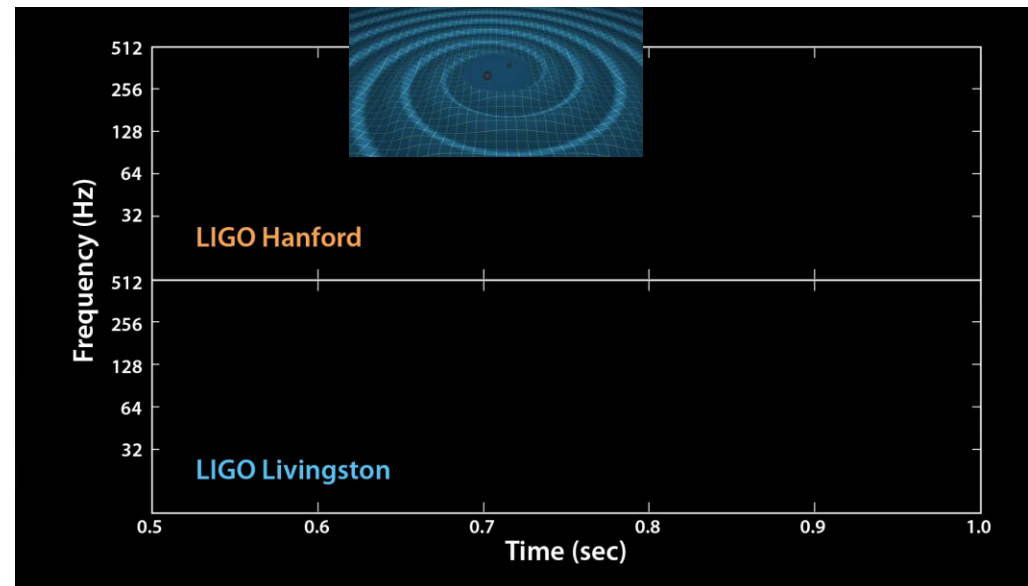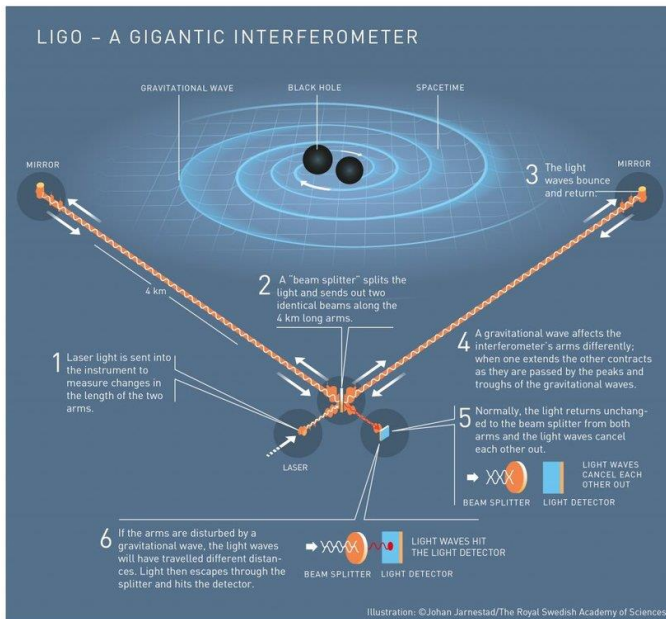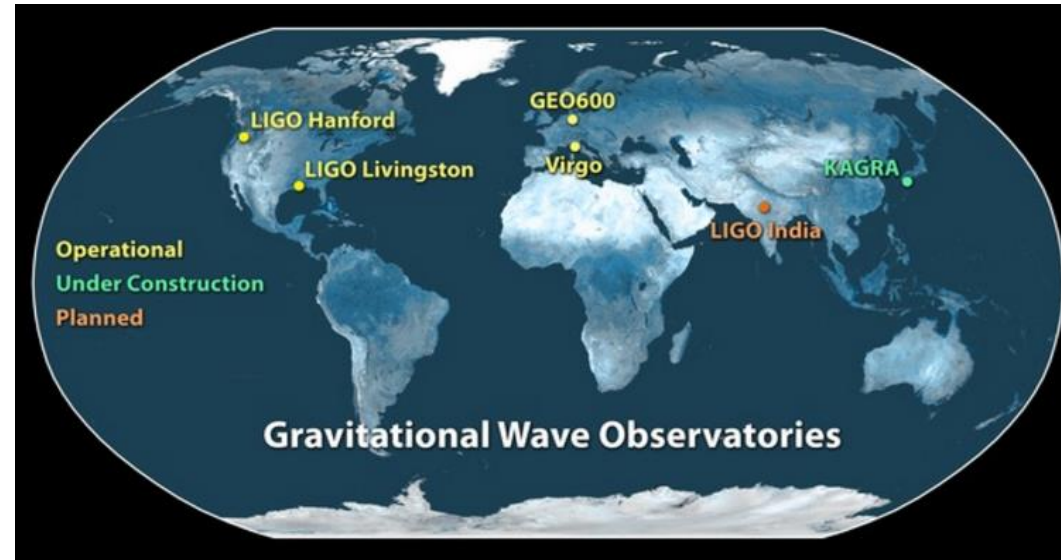
- **Proton Therapy Detector** 質子治療探測器

Experimental support; novel detectors & applications

Instrumentation
朱明禮/林志勳

Magnets

Treatment volume
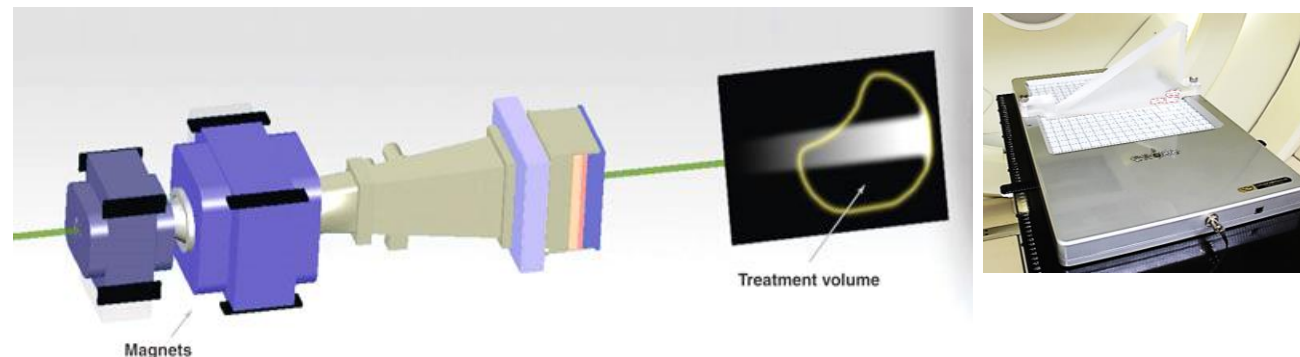
ASGC
From HEP to e-Science

Computing
張元翰/嚴漢偉

ASGC System Diagram

Internet

TWAREN / TANet

100Gbps

AS Campus Network

2x10Gbps

International R&E Network

WebUI for SaaS	SSH Terminal

100Gb/s Backbone

Batch for HPC (Slurm Workload Management)	Cloud Services (Kubernetes Framework, Containerization)
Scientific Software Repository, ML/AI Framework & Customized Image Pool	

Computing Resource: CPU (20,000 Cores), GPU (A100, V100, 3090)

Shared Storage Pools (30 PB)

Ceph Storage Pools	Tape Remote Backup	Cloud Storage

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ASGC

- **ASGC was established in 2006 to support the large computing requirement for ATLAS and CMS experiments**
  - One of the 11 initial Tier 1 center. The only Tier-1 in Asia, jointly funded by NSC and AS
  - Provided ~6% of computing resources to ATLAS at the start of LHC.
  - Actively participated in the development of the GRID technology with WLCG (World LHC Computing Grid). Very well respected by WLCG colleagues.
  - **NSC withdrawn its support in 2012. Subsequently ASGC terminated the Tier-1 operation for CMS.**

- **New challenges to ASGC**
  - **AS has decided to downgrade ASGC Tier-1 to Tier-2 center for WLCG in 2022.**
  - **2024 budget for ASGC is down to ~20% of 2022. Network down from 2x10Gbps to 2.5 Gbps.**
  - Establish an AS Core facility to support computing requirements within AS. However, with very limited budget support and request "User charge" policy.
  - **Major reduction in manpower and hardware is required based on this level of support.**

- **2022 NSTC called for proposal to establish a medium sized computing facility**
  - To have O(5000) core and O(10) petabytes storage, mainly for projects in the Physics division.
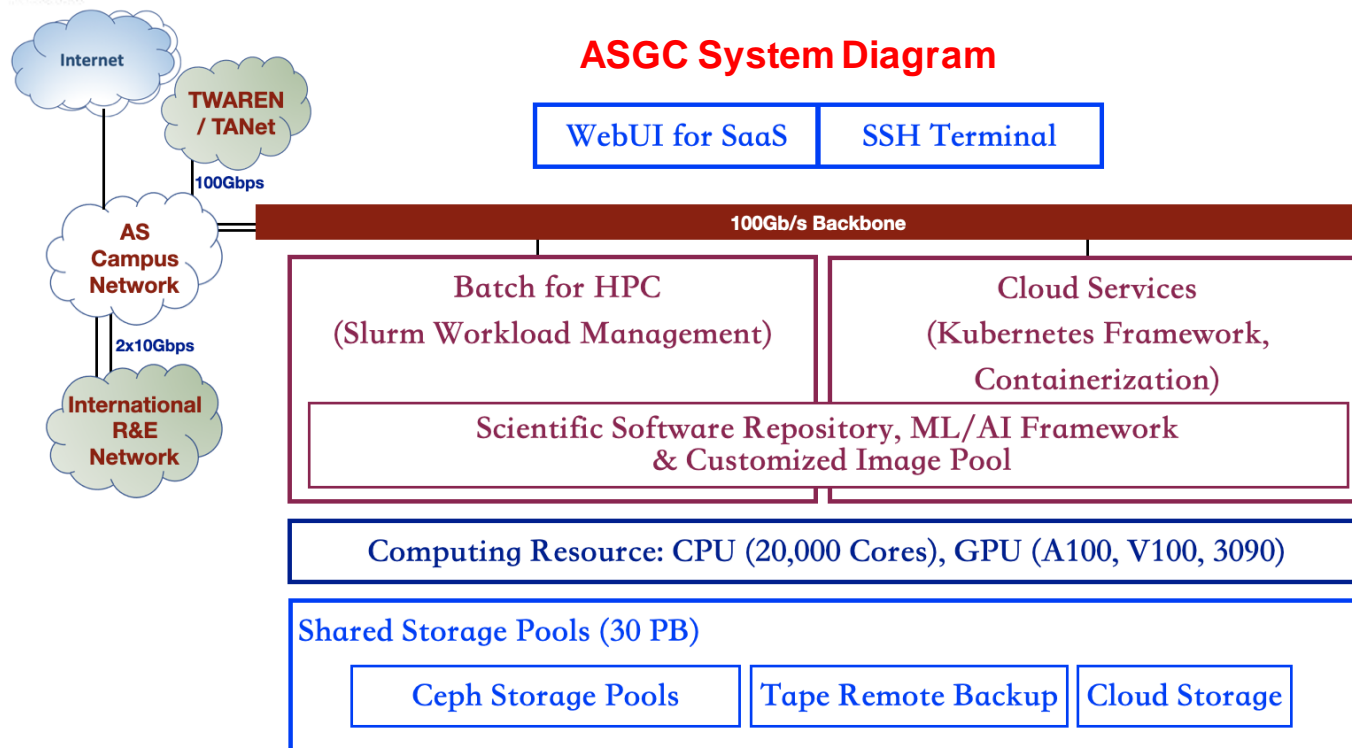 - **Among 10 competing proposals, ASGC won this project with a grant of 25M NT$/yr ➔ The expertise and experiences learned as WLCG Tier-1 is unmatched by any other computing center in Taiwan.**
  - ASGC is capable of supporting the NSTC core facility together with ATLAS Tier-2 and AS core-facility, but quite marginally.
  - Infrastructure is old (almost 20 years) and very challenging to maintain.

Achievements Highlights: *In Addition to -- Facilities & Teams & "Traditions" Building*

☑ **Participating in ATLAS@LHC@CERN**
  - Discovery of the Higgs Boson (2012), observation of H->bb (2018)
  - Search for New Physics at High Energy Frontiers

☑ **National Leadership in Participation in AMS@ISS**
  - Payload Operation Control Center in Asia ; Major Space Electronics Production
  - Precision Measurements of Primary Cosmic Rays
  - Observation of Anomalous Features consistent with Dark Matter
  - Studies of Cosmic Anti-matter

☑ **TEXONO program at Kuo-Sheng Reactor Neutrino Laboratory**
  - Studies of Neutrino Electromagnetic Effects at Kuo-Sheng Neutrino Laboratory
  - Still-Best Cross-section Measurement on {electron + electron-anti-neutrinos}
  - Pioneered searches of Light Dark Matter & sub-GeV Germanium Detectors
  - Catalyzed Realization of Jinping Underground Laboratory

☑ **Hadron Physics**
  - Several Generations of Experiments across the Globe; Diverse spectrum of topics
  - Characterize d-bar/u-bar in proton (Nature 2021) and pion/kaon partonic structure

☑ **ASGC Computing "GRID" Center**
  - WLCG (Worldwide LHC Computing Grid) Tier 2 Center
  - Core Facility of AS and Taiwan, for big data analysis and scientific computing

TIDC (Taiwan Instrument and Detector Center)

A consortium of HEP experimental groups for hardware development. The purpose is to share the instrument and technical expertise to maximize the benefit of hardware investment.

- **2020-2021: A first TIDC project supported by MoST, with 3M NT$ grant, operated by AS, as a pilot program, mainly for organization work.**
- **2022-2024: Expect a 8M NT$/year project, with actual funding for engineers and instruments. Now host by NTU group. (1.7M NT$ for 2022-2023)**
- **Development of Silicon detector related technology is the first goal → basically done with the establishment of NTU's silicon detector assembly lab and NCU's silicon detector test lab. Very strong support from AS machine shop.**
- **Prospects to expand the capacity of TIDC in this 3 year:**
  - **Establish strong connection with ASGC in ASIoP, to support computing.**
  - **Radiation hardness test facility**

TIDC (https://tidc.phys.ntu.edu.tw/WordPress/)

Schools/Workshops

- ISGC (International Symposium on Grids and Clouds) 2022 (21-25 March, 2022)

- TIDC summer school (June 27 - July 2, 2022)

- 10th anniversary of the Higgs boson discovery (July 4, 2022)

- The 1st TIDC EIC workshop (August 18 - 19, 2022)

- The 2nd TIDC EIC workshop (January 3, 2023)

- ISGC 2023 (19-24 March, 2023)

- HEPiX Spring 2023 (27-31 March 2023)

- PIRE GEMADARC Summer School , Collaboration Meeting and Undergraduate Research Experience (24 May - 2 Jun, 2023)

- 2023 TIDC Summer School Of Experimental High Energy (June 26-30, 2023)

- TIDC Autumn School On Electron-Ion Collider (EIC) (August 28-30, 2023)

- Asia EIC workshop (November, 2023)

Future Evolution and Directions:

✗ Continuation of On-Going Programs :

☑ ATLAS ; AMS ; TEXONO ; TASEH; Hadron ; GW(KAGRA/LIGO) ; TWGRID

✗ Future Collider Projects R&D *[TIDC, S. Hou …]*

☑ ASIC for Si-Detector for CEPC …

✗ Hadron Physics Program *[W.C. Chang]*

☑ E16,E50 experiments at J-PARC hadron physics

☑ Towards Electron-Ion Collider, as part of TW-team (>2030)

✗ Experimental Gravitational *[S. Haino, H.T. Wong, with Y. Inoue(NCU)]*

☑ In-House R&D on "deci-hertz" GW Detection (CHRONOS project)

☑ Cryogenic Techniques; Mirror Coating ; Calibration ; GW-inspired Physics

☑ Integrated domestic GW-related (HEP, Cosmo) Theorists

✗ Explore room in High-Energy Neutrino Astrophysics *[with Theory Gp. A. Fedynitch]*

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Concerns Raised in 2021 Reviews

- **Advanced analysis tool**: *"At the same time, the group seems to be lacking expertise in advanced physics analysis. In particular, despite strong expertise in scientific computing, there seems to be no machine learning expertise within the group. "*

- **Being focused**: *"As the MHEP experimental group is pursuing many ongoing programs as well as developing several future programs, it is clear that some hard decisions must be made to select the most promising areas of research. This represents a considerable challenge to the leaders of IOP and the MHEP group."*

- **Being focused**: *"the Review Committee feels that the group may be overstretched in terms of how many areas they are trying to cover, and recommends that new projects and initiatives are carefully weighed against the existing activities, and that forthcoming retirements are used to strengthen these new initiatives."*

Regarding the Analysis Tools

- Machine learning algorithms (e.g. Boosted Decision Tree, Neural Net) are already employed in the <u>ATLAS analyses</u> and we will apply more machine learning techniques in future analyses to gain more experience in it.

- Machine learning (use of AI packages to run on GPU for data analysis) has been our emphasis for years and routinely used in <u>AMS data analysis, TOF-PET image reconstruction, ASGC data center monitoring and control</u>.

TEXONO Program – Future Road Map *[H.T. Wong]*
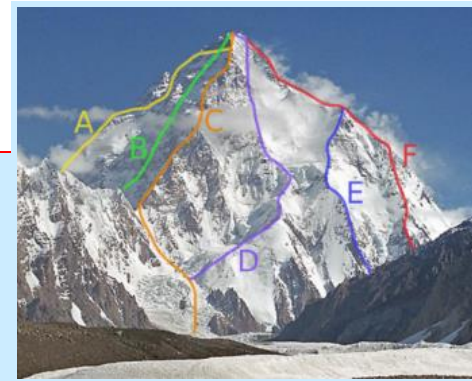
⚒ **TEXONO.ν @ neutrino physicis towards reactor νN observation**
  - ☑ **Reactor decommissioned 2023, operation till 2025, DM analysis**
  - ☑ **sub-keV EC-PCGe R&D, reduce threshold via new configuration**
  - ☑ **Options of moving [O(100eV) ECGe's] to international labs to continue (>2025)**

⚒ **TEXONO.DM @ CDEX-300 @CJPL**
  - ☑ **14-m diameter cryostat → operation & DAQ & Analysis**
  - ☑ **0νββ grade background control for DM searches**
  - ☑ **Light DM Searches with Diverse BDM scenario**
  - ☑ **Explore Ge1T "World Experiment" for 0νββ**

⚒ **TEXONO.Th**
  - ☑ **ν/χ-atom interactions; Time-of-Flight in DM & BSM; QM coherency in νN elastic**

⚒ **TEXONO.GR @LIGO,CHRONOS @ASGRAF**
  - ☑ **LIGO: Calibraion, Mirror Coating, Cryogenics, Physics**
  - ☑ **CHRONOS project**

Urgent Issusion: Recruiting

- In 2022, we interviewed three candidates with BGs on collider physics: one junior and two senior ones.

- The junior one did not match our expectations well. One senior colleague did not fit because he would like to stay at CERN due to family constrain. The other senior colleague was not considered due to age and his immediate/long-term research plan.

- **We keep looking for the candidates on collider physics and GW.**

Summary

- Future projects are classified under two themes of "**Collider**" and "**Gravitational Wave**", commonly supported by "**Instrumentation**".
- TIDC is a framework where the HEP expertise is shared among the whole Taiwan HEP community.
- We participates in World-wide GW Observatories, via contributions to two different sub-programs.
- **Faculty recruiting in the order of preference: Collider (LHC, EIC, CEPC(ILC/CLIC/FCC)); GW.**