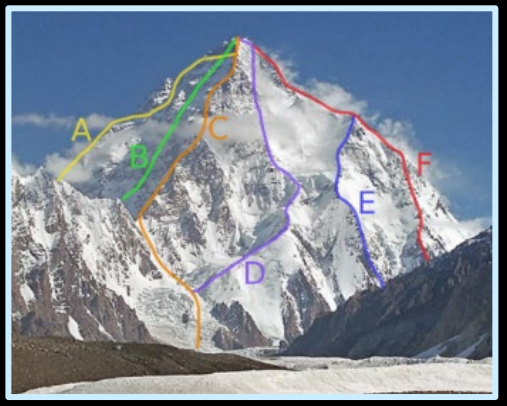
Overview of GW Projects/Plans @ ASIoP

- Grand Landscape
- Themes & Strategies
- Research Projects – Who, What, Why, How



Henry T. Wong / 王子敬
Academia Sinica / 中央研究院
January 2026

@ TIDC Annual Meeting
Jan 6-7, 2026

The Grand Landscape [大視野]

- Fundamental Conflict between the Universe comprehended via
  - Gravitation *[General Relativity – Macroscopic]* Vs
  - Particle Physics *[Standard Model – Microscopic]*

  微觀(粒子作用) 與 宏觀(重力現象) 在

  實驗數據 與 理論基礎 的 矛盾

  - ☑ Experimental Data (Observations)
  - ☑ Theoretical Formulation

  ⇒ Mainstream Interpretation:

  ~95% of the Energy Density of the Universe is not understood ??

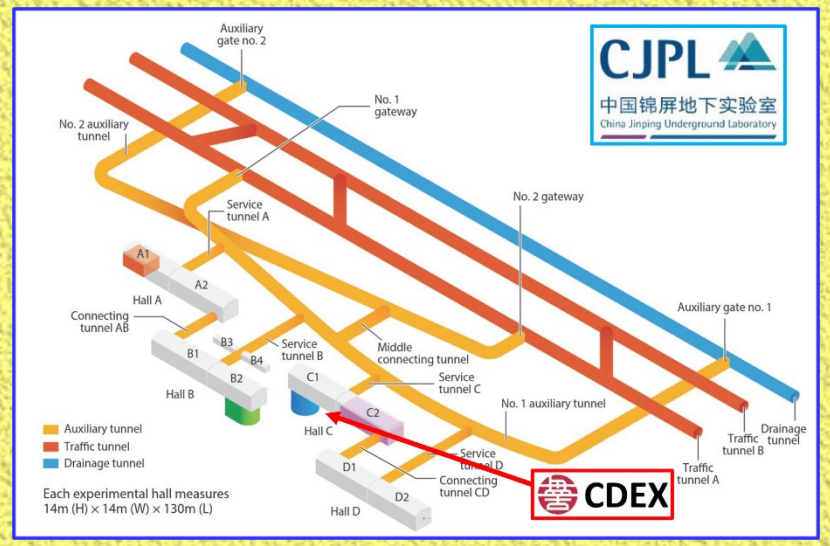
- Gravitation stands out in our lack of/incomplete understanding
  - ⇨ IOP to make a serious attempt into – *AND take lead in Taiwan on* --

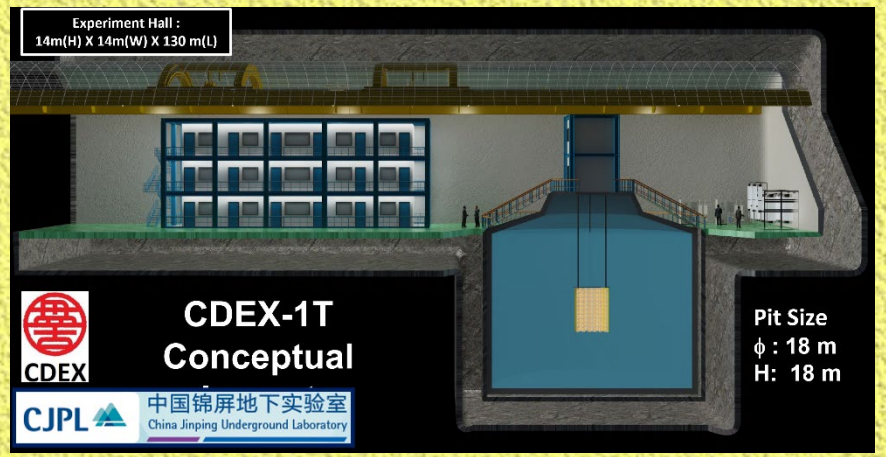
    "How to *Get Into/Confront* Gravitation Physics"
- Cosmology/Astro-/Astroparticle-/Multi-Messenger Physics is Thriving
  - ⇨ High-quality & excited (!) junior scientists +
  - ⇨ Motivated & excited (!) students populate the subjects

    ⇒ Gravitational Wave Science is a good (popular?) entry point

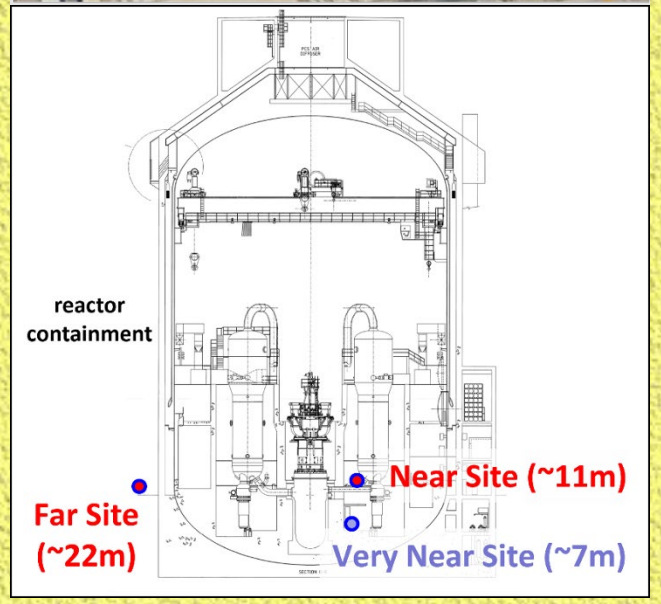
TEXONO.ν+DM

- ☑ Complete data analysis of KSNL ; detector & software R&D
- ☑ Consult and follow intense activities and explore future at CJPL, Sanmen & PATIC





CDEX(0νββ+DM) @ CJPL @ Sichuan

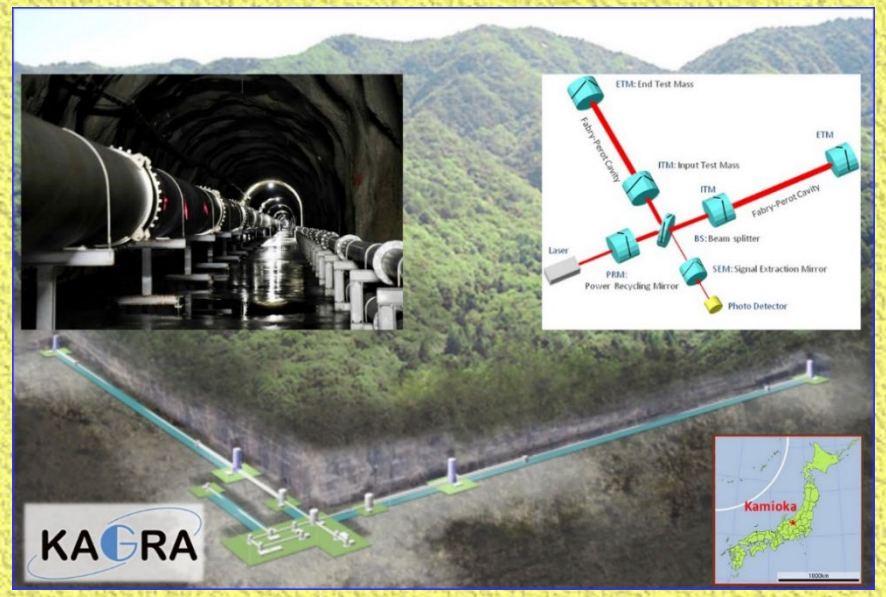


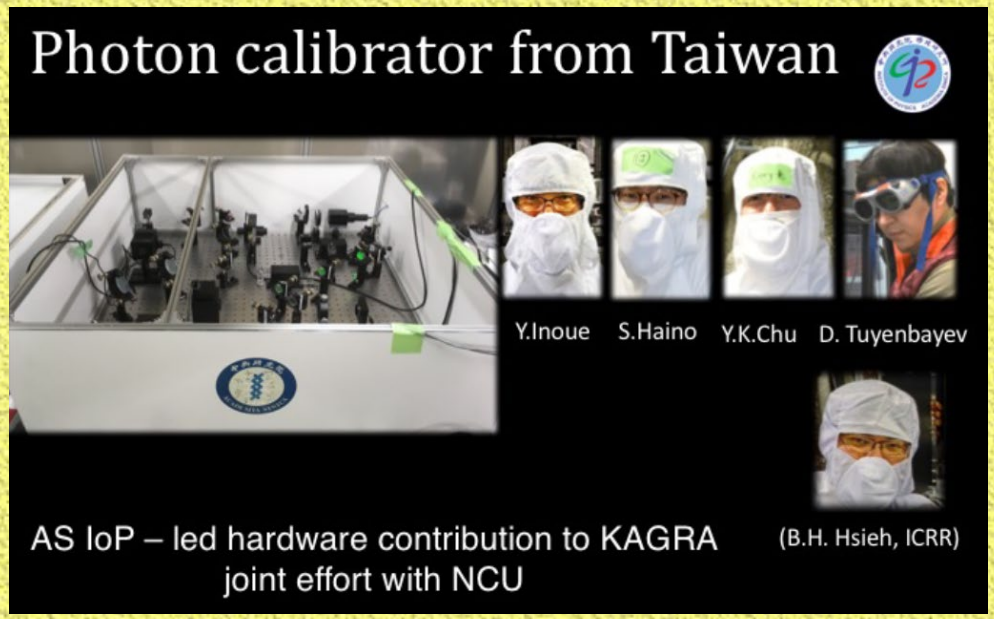
Sanmen Reactor Laboratory @Zhejiang

Ge-Technology & Industrial R&D @ PATIC @ Guangzhou

Experimental Gravitation in Taiwan

- Early table-top BSM-GR experiments at NTHU (Ni…)
- NTHU-EE **Shiuh Chao** @ LIGO since ~2010 *[i.e. on 2015 Discovery]*
- Sada Haino (AS) initiated KAGRA in TW (since ~2016)
- Expanding teams & communities: *NCU, NTHU, NTNU, TKU ….. + Theorists*
- AS @ KAGRA: *Calibration Leading Group (Laser, Gravity), High-Power Lasers, Computing Resources …….*
- Other TW@KAGRA: *Quantum Optics (NTHU), Analysis (Astro, Cosmo..)*

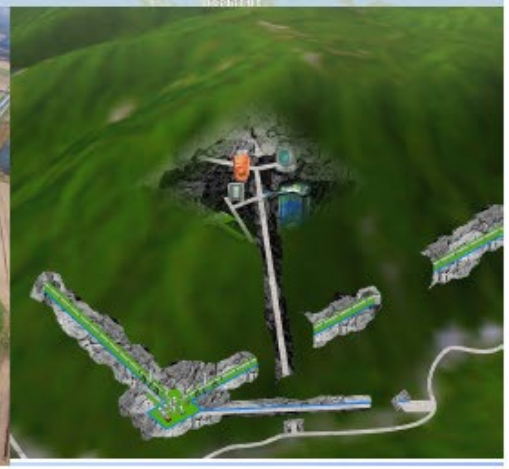




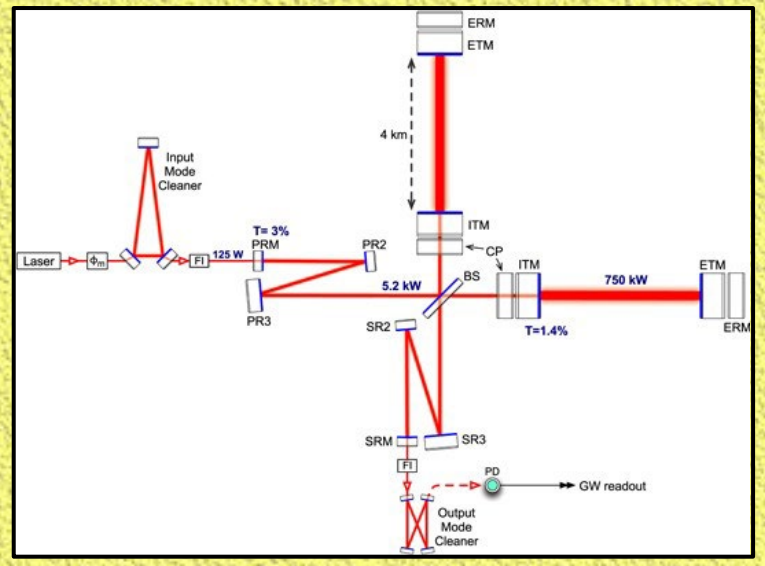
TEXONO @ Gravitational Physics

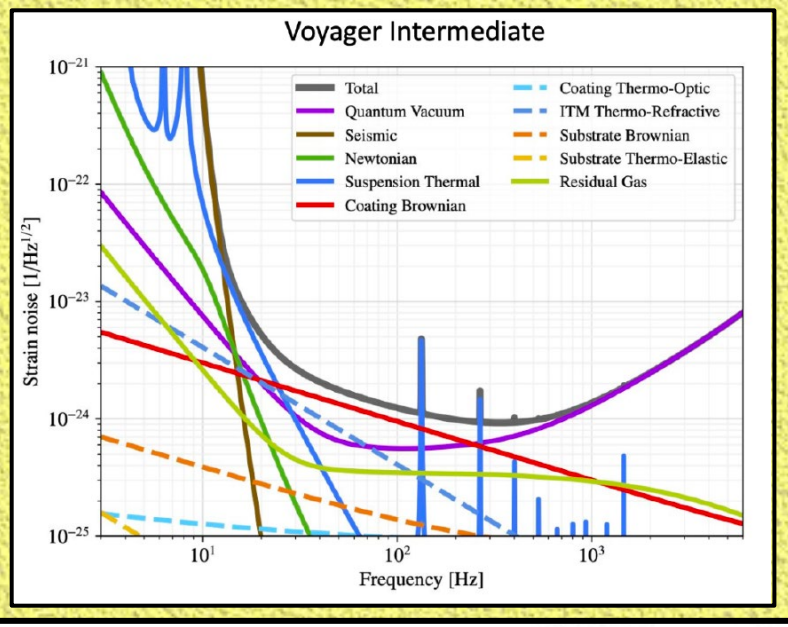
- **Spin Off/NG theme of TEXONO program**
  - ⇨ *(Low Energy Neutrinos and Dark Matter → pursued by alumni group)*
- **Joined LIGO 2021** ***(ASIoP with NTHU,NCU)***
  - ☑ *"Taiwan Instrumentation Group"*
  - ☑ *Calibration & Operation (NCU) ; Coating R&D (ASIoP + NTHU,NCU)*
- **IGWN Global Network by mid-2026**
  - ↳ **Current ASIoP LIGO & KAGRA activities will** ***MERGE***
  - ↳ *"ASIoP Group" @ IGWN*

International Gravitational-Wave Observatory Network (IGWN)

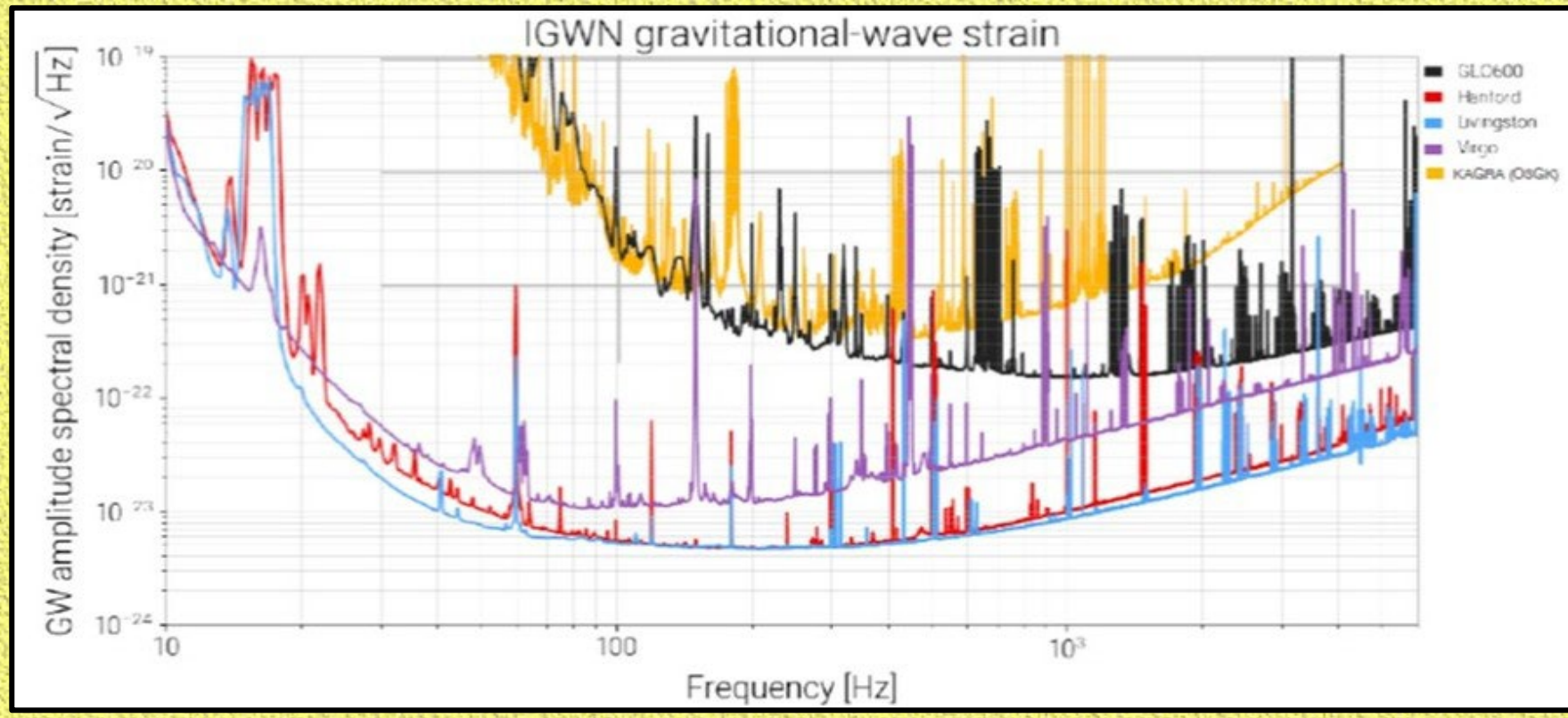


Dual recycling Fabry Perot Michelson Interferometer

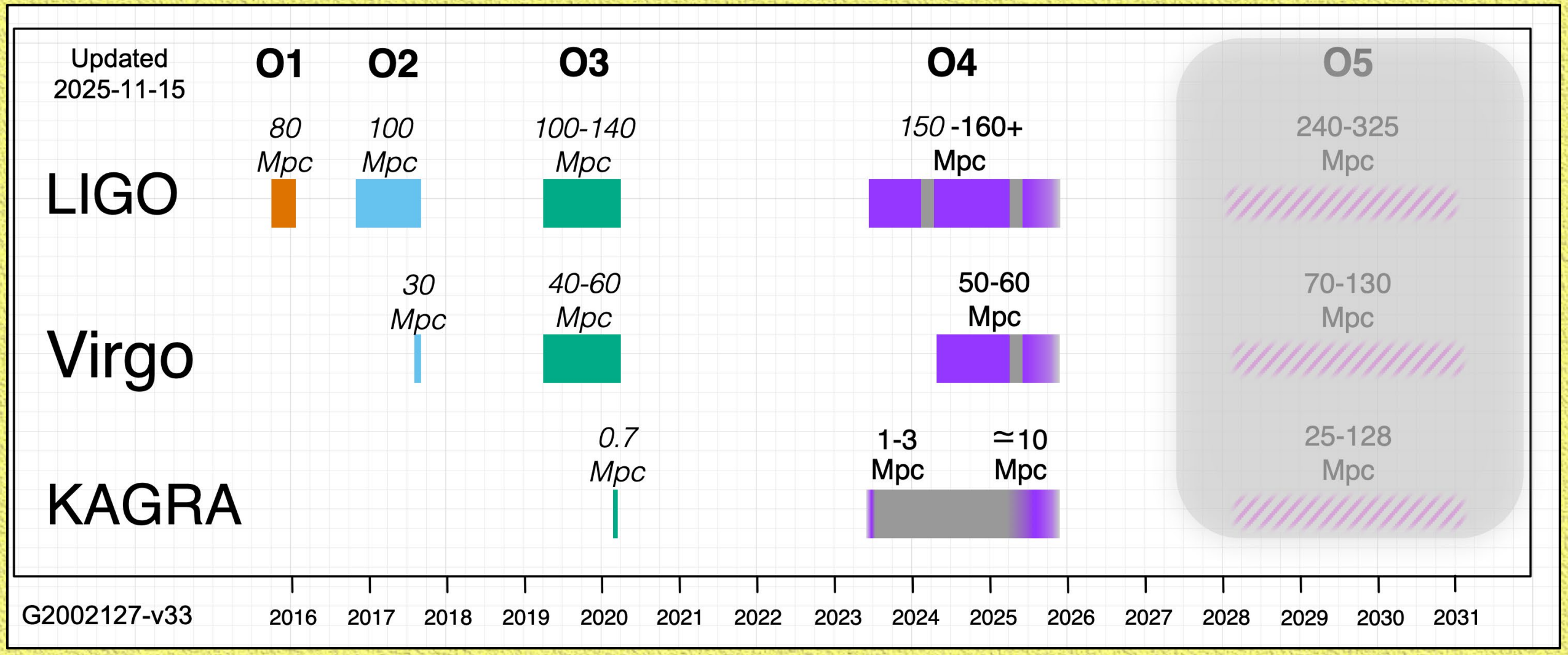




Each Noise Component is a Body of Learning and Research Subject

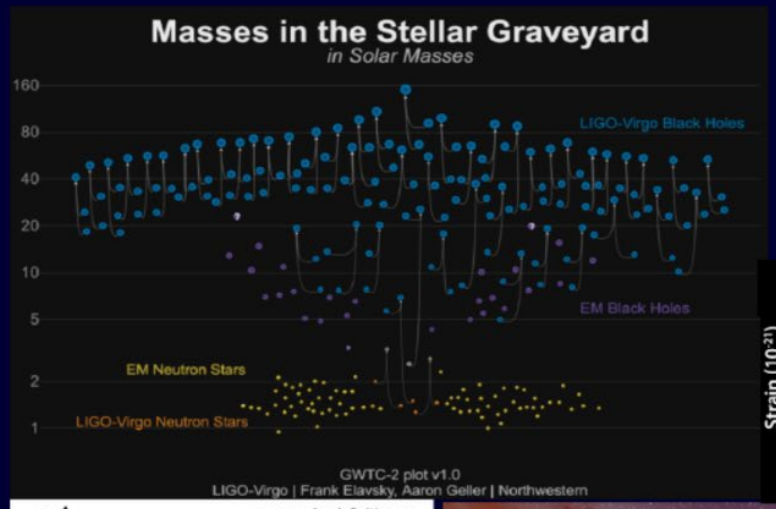


LVK Observing Runs

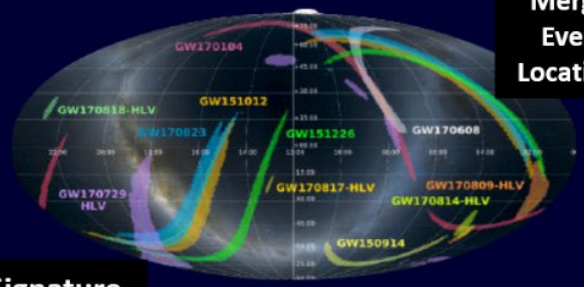


Sensitivity: Binary Neutron Star range for a single-detector SNR threshold of 8

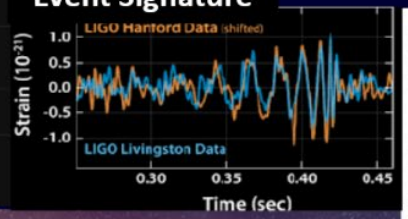
Science of LIGO

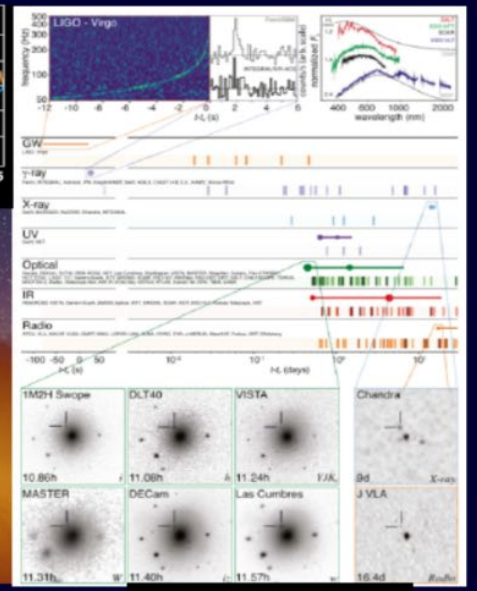


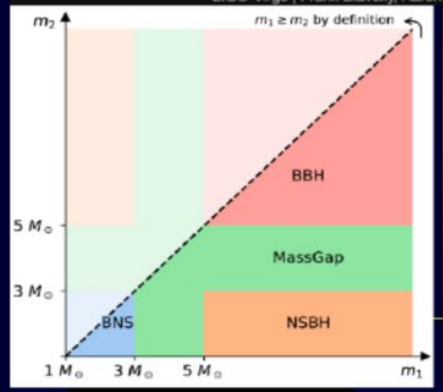
Merger Event Locations



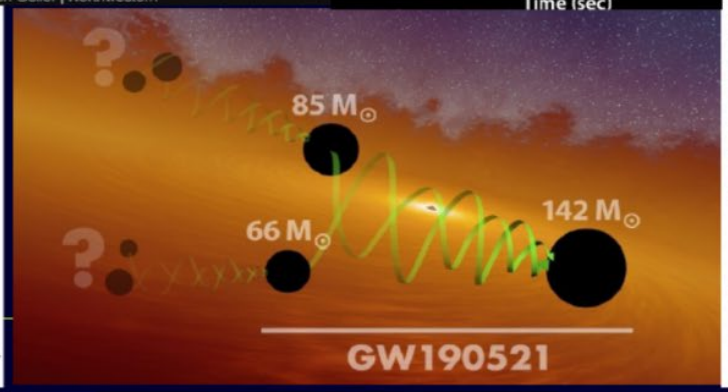
Event Signature





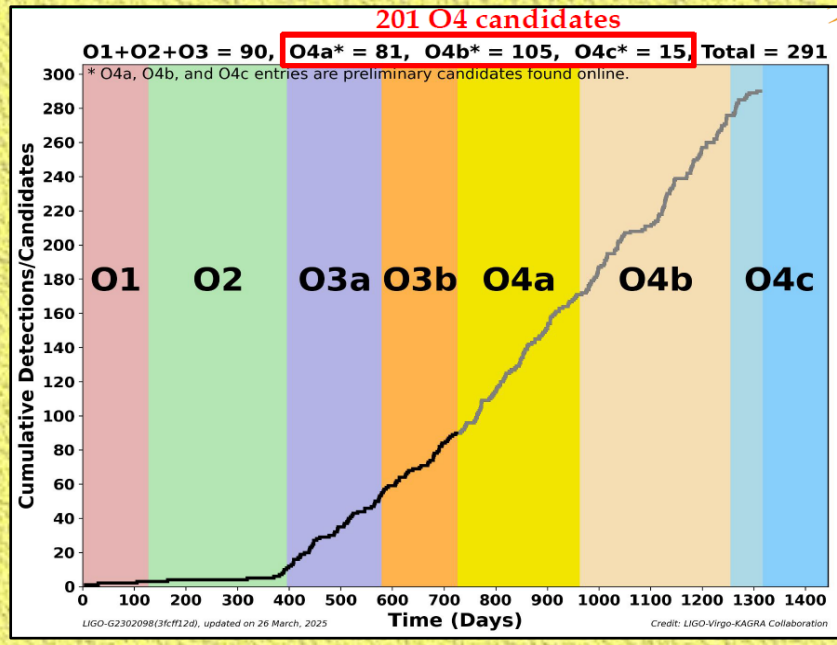


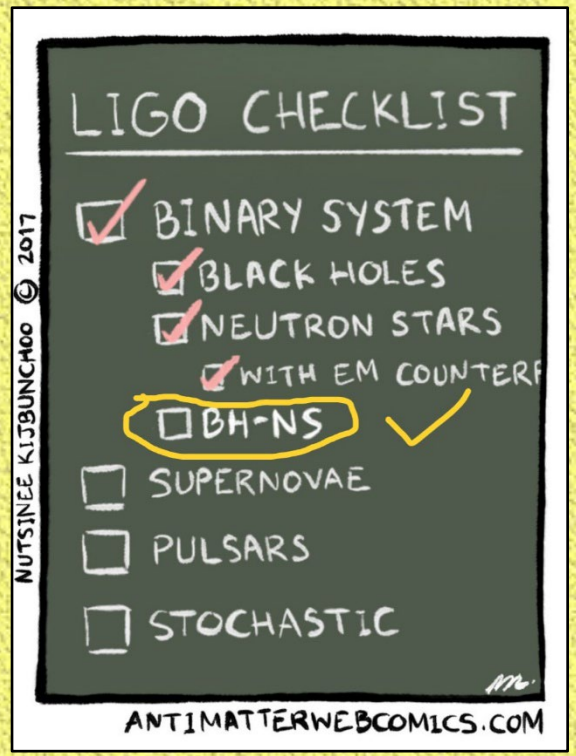
Merger Events Mass Distribution



Intermediate Mass Black Hole Merger Event

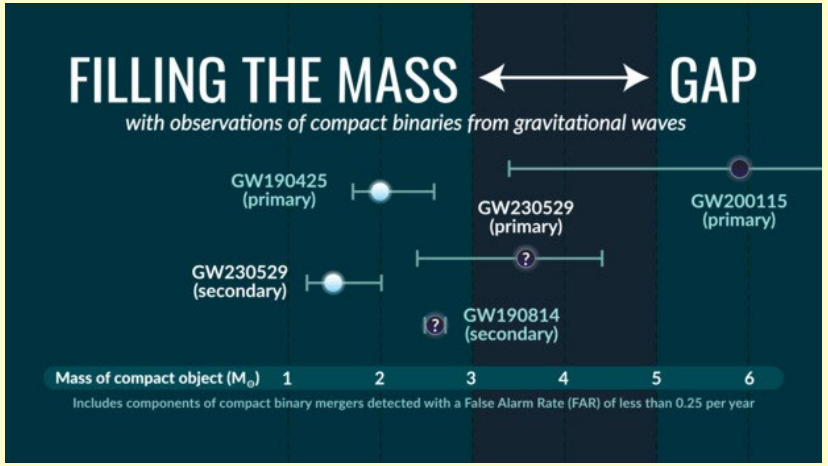
Multi-Messenger Event





Recent Science Highlights:

- Open Data Available for O3
- Successful Completion of O4 Observation
  ⇨ ~1 CBM/3 days ; total >300 ; Catalog published
- GW230529 – CBM
  (2.5—4.5 X 1.2—2.0 $M_\odot$) , likely BH+NS ⇨



- GW231123 -- BHM with total mass 190-265 $M_\odot$ (~137 X ~101) & high spin @ SNR~21, Most Massive BHM to-date.
- GW241011 (@SNR~36) & GW241110 – asymmetric mass, high-spin (one opposite) BHMs; tests of GR & BH-Theories
- GW250114 – Test Fine details (Hawking Area Theorem….) of BH theories (@SNR~80!) ; detect overtones

ASIoP @ IGWN – Goals : program & team building

WHAT / HOW ➔

A ***Physicists'*** Program – **multi & diverse & balanced projects**

⇨ **Instrumentation (Domestic) –**

- ☑ **Mirror Coating Fabrication *@ TSRI*,**
- ☑ **Characterization *@ IoP-B1-ASGRAF, TSRI, + ……***

⇨ **Operation –**

- ☑ **on-site posting & remote data quality monitoring *[LIGO,KAGRA]***
- ☑ **Laser support + R&D *[KAGRA]***
- ☑ **Computing *[KAGRA]***

⇨ **Physics/Science –**

- ☑ **BSM particle physics *[+M.Spinrath NTHU]***
- ☑ **Stochastic Background *[+LiuGC TKU, NgKW AS]***
- ☑ **neutron stars science *[+KuanHJ AS]***

ASIoP @ IGWN – Goals : program & team building

⇨ Connect multi-institute, cross-disciplinary teams -- beyond GW, beyond LIGO

- ☑ TW HEP resources & expertise – both experiment & theory
- ☑ Resources from TEXONO & CDEX teams *[Indian, Turkish groups ..]*
- ☑ Domestic astrophysics, theory, quantum materials and laser optics experts
- ☑ Connect TW semiconductors & lasers academic & industrial expertise

Mirror Coating & Characterization for NG-GW-R&D

WHAT?

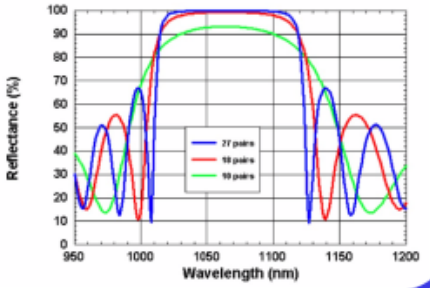
Chao Shiuh *(till 2021)*:

- ☑ Measurements of mechanical & optical loss at NTHU
- ☑ Thin Film Coating System at TSRI
- ☑ Both room & cryogenic temperature

🏆 🏆 🏆

Chao's team (NTHU-EE) are the *only* Taiwan authors in the 2015-GW discovery, and subsequent Nobel, Breakthrough ….. Prizes.. !!

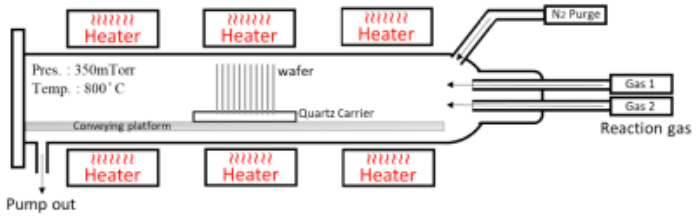
DEVELOPMENT OF LARGE COATING TECHNIQUE



TSRI

Uniformity check

MATERIAL DEVELOPMENT

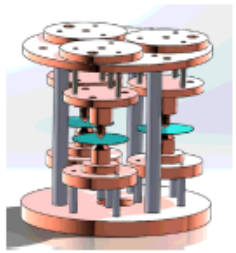


Improvement of fabrication process of high low coating

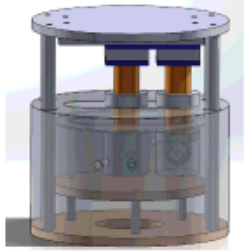
TSRI

DEVELOPMENT OF CRYOGENIC CHARACTERIZATION SYSTEM

Cryogenic Mechanical loss measurement system



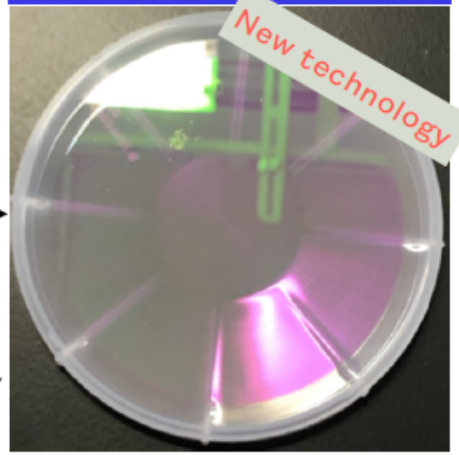
Cryogenic Optical loss measurement system



Measurement of loss at cryogenic temperature

NTHU→AS

6 INCH CRYOGENIC COATING TECHNOLOGY

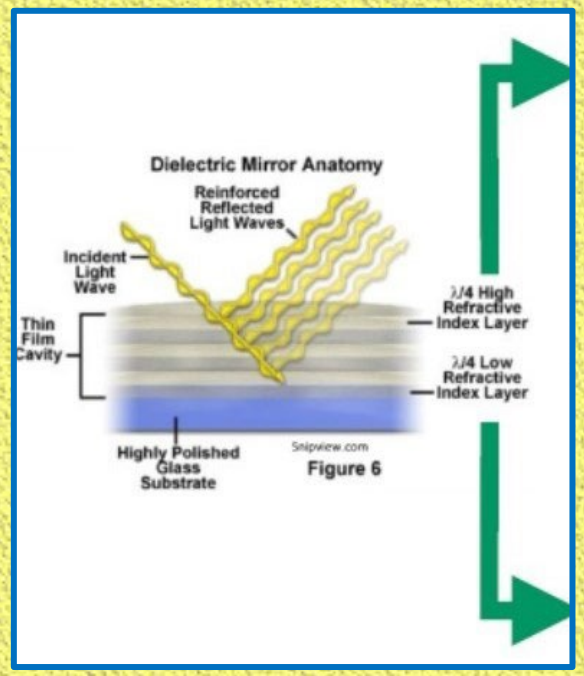


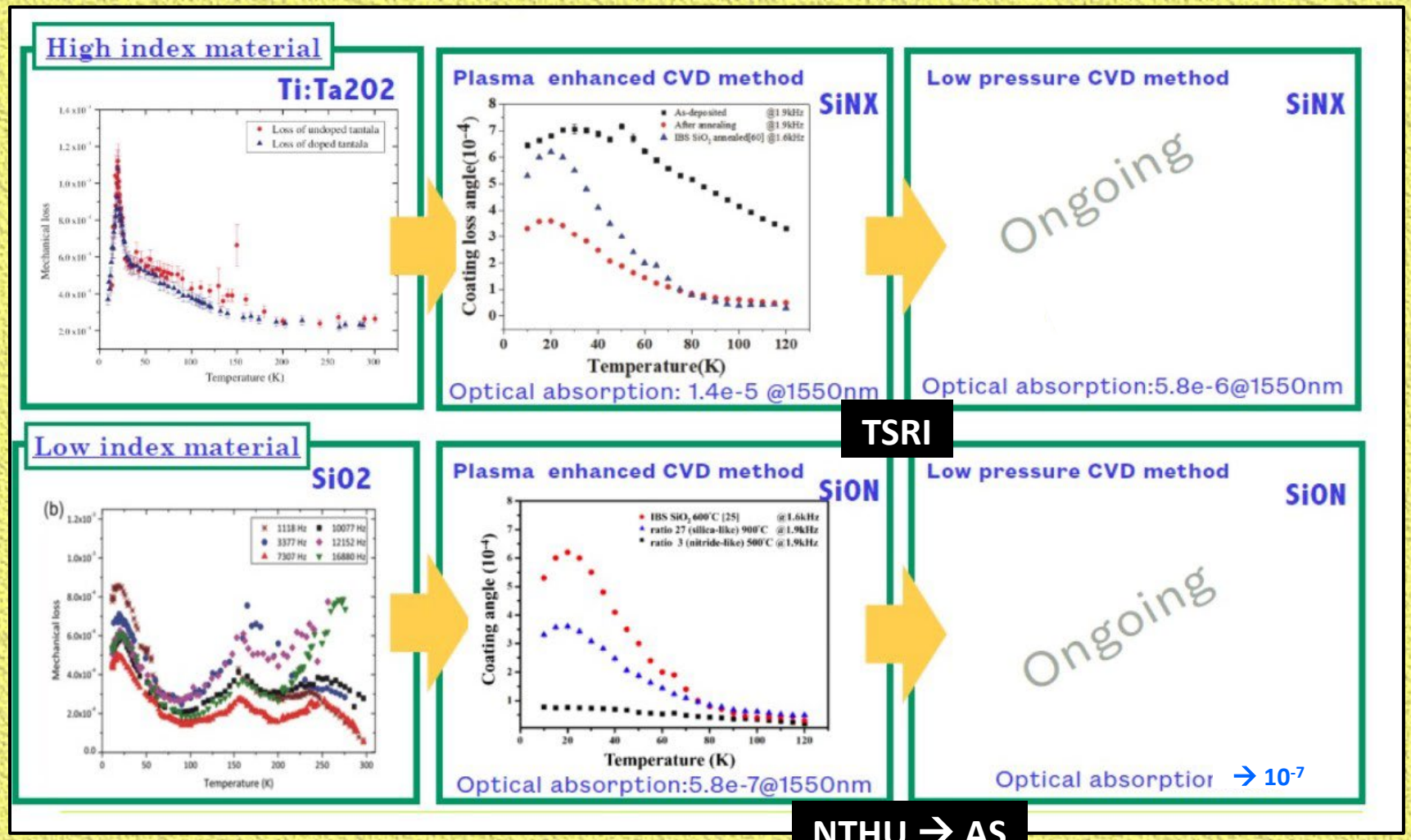
Requirement: κ~10^{-7} (@100K)

Selected Materials:
SiN, SiON, aSi ……

The Issues:

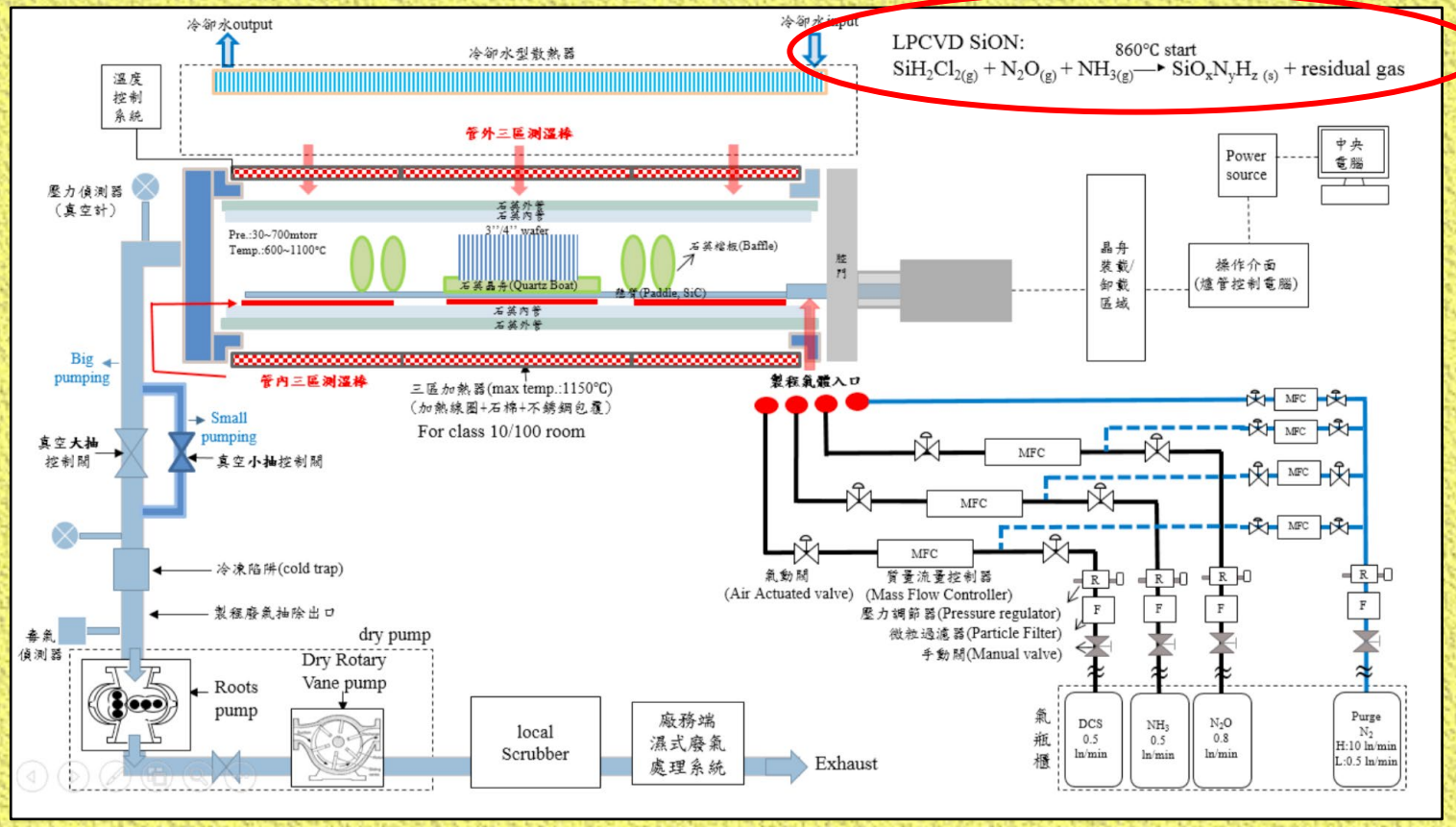
- Low Temperate → different mirror material, different optimal laser wavelenth
- Large Optical Loss at Low Temperature for current materials
- Mirror Noise : main contribution to sensitivity budget



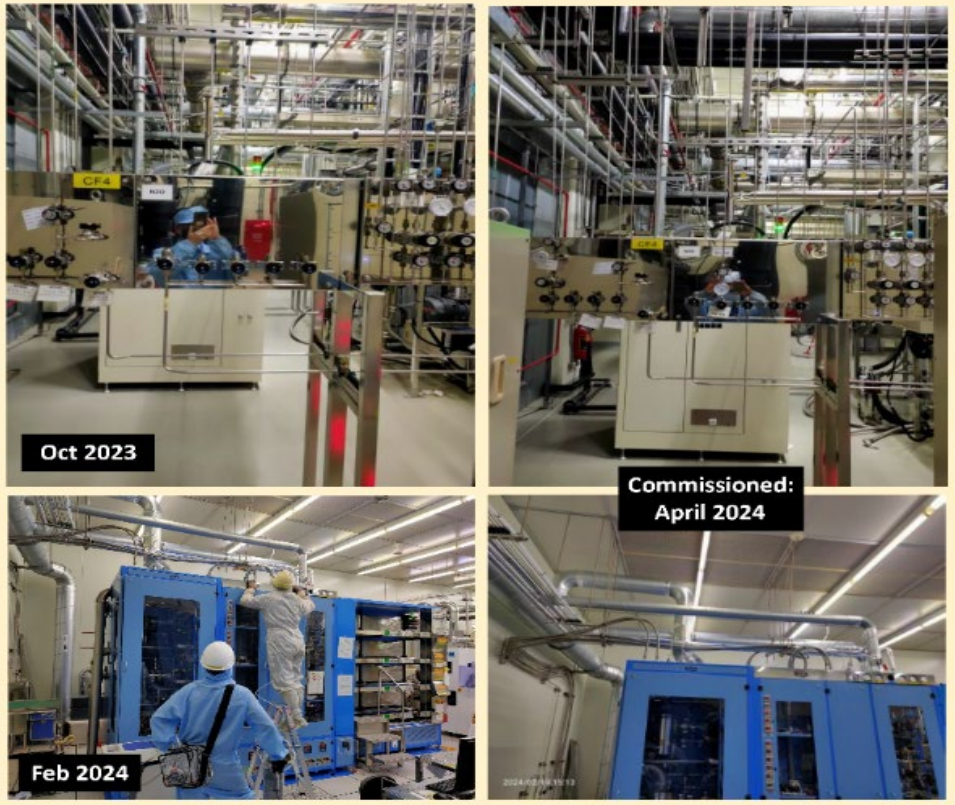


Low Pressure Chemical Vapor Deposition (LPCVD) Facility @

NARLabs 國家實驗研究院
台灣半導體研究中心
Taiwan Semiconductor Research Institute

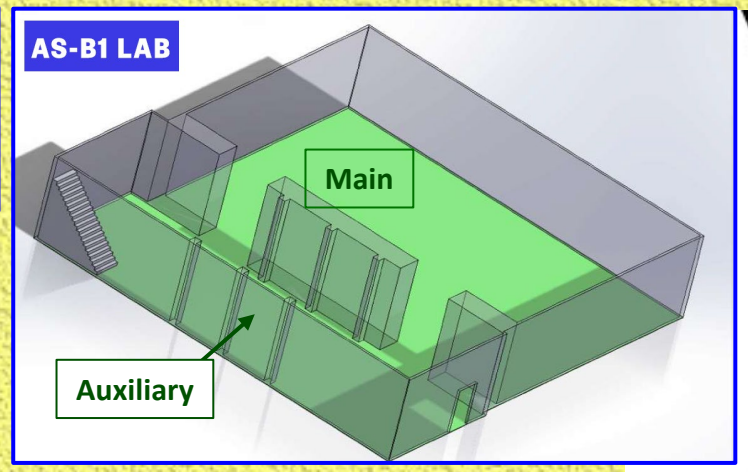


TSRI-LPCVD N2O Gas Line Construction



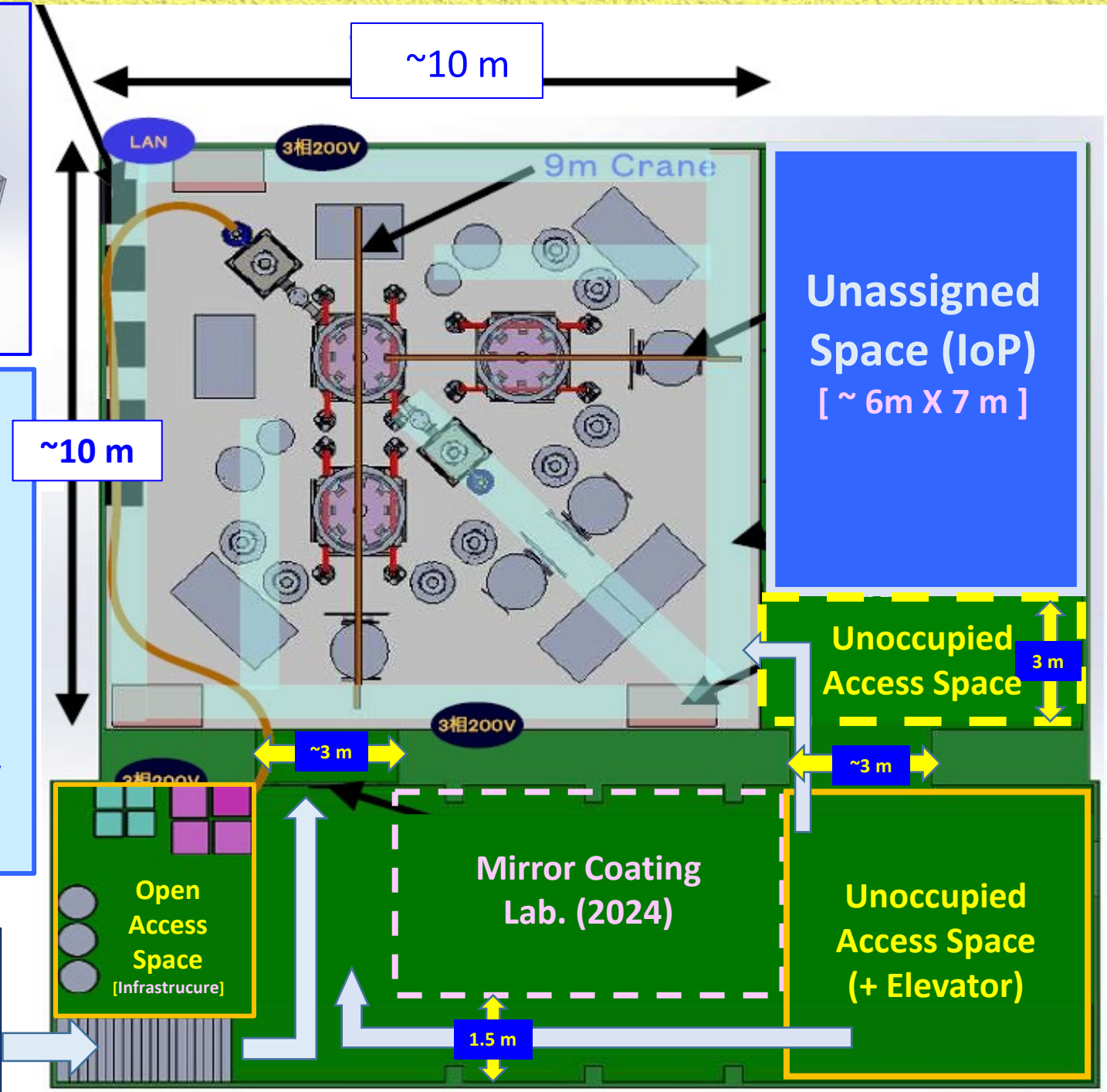
- ☑ NTHU team is a long time user; AS taking over
- ☑ AS built a new N_2O gas line, for SiON coating
- ☑ Need to learn how to effectively work there ….

ASGRAF
ACADEMIA SINICA
GRAVITATIONAL PHYSICS
RESEARCH FACILITY



ASGRAF (AS Gravitation Facility):

- IOP B1 10X10 m²
- Clean Room Spec @ C-10000
- Menu (Plans):
  - Mirror & Cryo & VIS Research
  - Move NTHU Lab (2024)
  - Future GW "System" Test Facility
  - Future CHRONOS prototype



Walk-In Possible with Hand-Held Equipment

Construction of ASGRAF (Moving of NTHU Mirror Lab)

Cross-Disciplinary is Desirable/Necessary

[after 3Y of homework on landscape & ecosystem]

- Thin film coating essentially a material science (condensed matter) subject
- Requiring Semiconductor, precision optics, cryogenic techniques & facilities & theories
- GW-OWG competing groups mostly from EE, Applied Physics Departments …..
- Particle Physics background lacks the broadness and fluency and control on the subjects
- Trainings & skills more aligned to interests & career credits for AP/EE/MS students.
- (Customized) positions available to assistants/students
- Invited faculties to join as PI/co-PI &/or connect to industry or applicaitons

DM/BSM@GW *[with Martin Spinrath, NTHU et al.]*

Discovery prospects for heavy dark matter in KAGRA

Chun-Hao Lee,[1,*] Reinard Primulando,[2,†] and Martin Spinrath[1,3,‡]
[1]*Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan*
[2]*Center for Theoretical Physics, Department of Physics, Parahyangan Catholic University, Jalan Ciumbuleuit 94, Bandung 40141, Indonesia*
[3]*Center for Theory and Computation, National Tsing Hua University, Hsinchu 30013, Taiwan*

PRD2023

- Walk through from "sensitivity projections of models" to "placing physics constraints with GW data"

  Demonstration/Promotion to HEP-Phenomenology Community !

- Learn how to use and analyse of *LVK public data*
- Explore on gravitational effects of BSM/DM on GW interferometers
- Future: explore DM/BSM/GW with quantum sensors concept.

Stochastic GW Background *[+ Liu Guo-Chin TKU & Ng Kin-Wang AS et al]*

- High on the list on “next GW discovery”
- Liu has been SGWB convener with KAGRA
- Learn how to analyse LVK internal data
  on “mainstream analysis”.
- Research: Anisotropy, Polarization, connection to other frequency like PTA @ nanoHertz ….
- ♥♥♥ Liu+Ng already mentored a TEXONO Turkish PhD student *(S. Karadag)* to a PRD draft on circular polarization ⇨ take up postdoc on SGWB

Neutron Star Science

- Recognized GW top priority science
- Driven by *Kuan Hao-Jui (NTHU, Tubingen, MPI-AEI, UIUC)* joining AS 2027
- Research: Accurate NG waveform models, “f-mode resonance”,
  multi-messenger astromony ….

Prospects & Outlook

- TEXONO.GW is a move to venture into new (desirable, necessary) area of gravitation physics
- Similarities to HEP ⇨ spirits of basic physics research (exciting science & excited students *above* skills within comfort zones)
- Differences / Challenges ⇨
  - NO existing pool of expertise
  - Cross-Disciplinary, Multi-teams + new structures & eco-systems desirable (necessary)

Recognize/Confirm Walls, *THEN* find SPACE !

期待：依然精彩