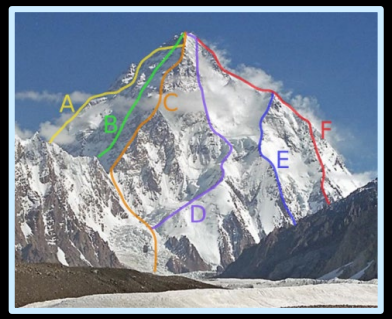
TEXONO Program : Overviews & Highlights

- Achievements *[Broadly Defined (Self-Promotion?)]*
- Status & Plans *[Road Maps]*



ELEVATOR PITCH

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

@ TIDC

TW HEP Meeting on 2021
Jan. 20 ~ Jan. 22, 2021

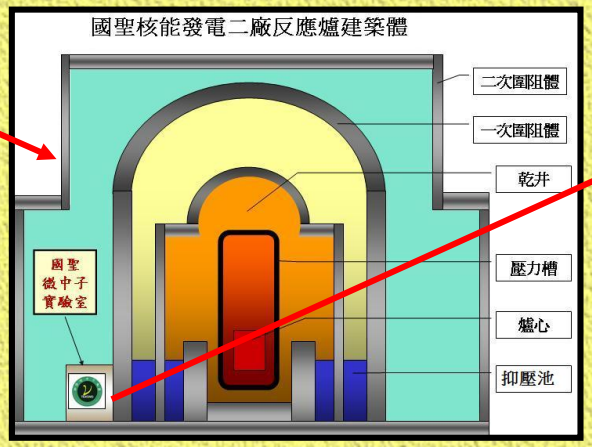
TEXONO Program *[since 1997]* *(PI: H.T. Wong)*

☑ **Themes:** *Low Energy Neutrino and Dark Matter Physics*

☑ **Teams:**

Taiwan (AS …), China (THU,SCU,CIAE,IHEP), India (BHU,GLAU,CUSB), Turkey (METU,DEU)

+ Theory (NTU,NDHU)



- Neutrino Physics at Kuo-Sheng Reactor Neutrino Laboratory (KSNL)
- Participate in International Programs World-wide
- Unifying Theme – Low Energy Low Background Germanium Detectors, for ν & DM

🏆 NSC-organized On-Site Visit & Meet-the-Press *2009/09/09* !!

Pioneering Spirits & Settings ……

TAIWAN Journal

Researchers make headway in neutrino study

By Myra Lu

After six years of painstaking work, researchers on the TEXONO project, or Taiwan Experiment on Neutrinos, have published the first results of what is admittedly a small experiment compared to what is being done at international laboratories. Nevertheless, the significance of the contribution for all the Chinese and Taiwanese scientists involved is no less evident.

Neutrinos are one of the more than 20 fundamental particles that make up the universe. Scientists around the world have conducted numerous experiments to learn more about this particle, which remains one of the least understood. Neutrinos are produced in the Earth's atmosphere, the sun, particle accelerators and nuclear power reactors.

Physicists believe that neutrino studies will help shed light on questions about the particle's mass and what roles they play in partic… significant amount of neutrinos. This … was quoted in the U.S.-based Science …

The Kuo-Sheng Nuclear Power Station, which produces electricity used by millions of households in northern Taiwan, also houses the research facilities of the TEXONO project.

Courtesy of TEXONO

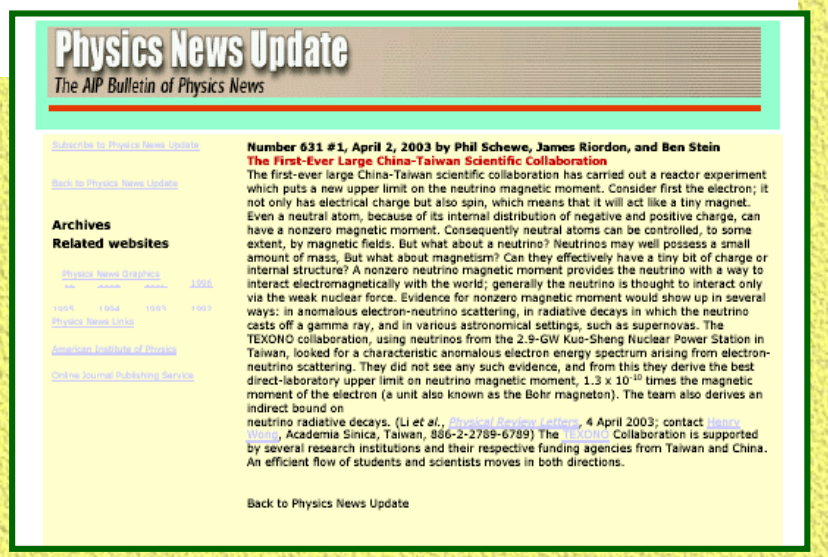
Wong said. The results of international collaborations such as the Super-Kamiokande in Japan and Sudbury Neutrino Observatory in Canada gave the Taiwan project what Wong described as a "positive impact."

This is because these earlier experiments have confirmed that the neutrino does have mass and that neutrino oscillation does take place. The latter refers to a phenomenon where neutrinos change from one type to another while traveling great distances. Such oscillation would not occur if neutrinos were entirely without mass, which scientists used to believe to be the case.

"These experiments use much larger instruments to explore different aspects of the neutrino properties from those pursued by the TEXONO experiment. However, given their findings, we know there is a grander picture behind and which direction to go," Wong noted.

- First Particle Physics Experiment and Facility *in* Taiwan

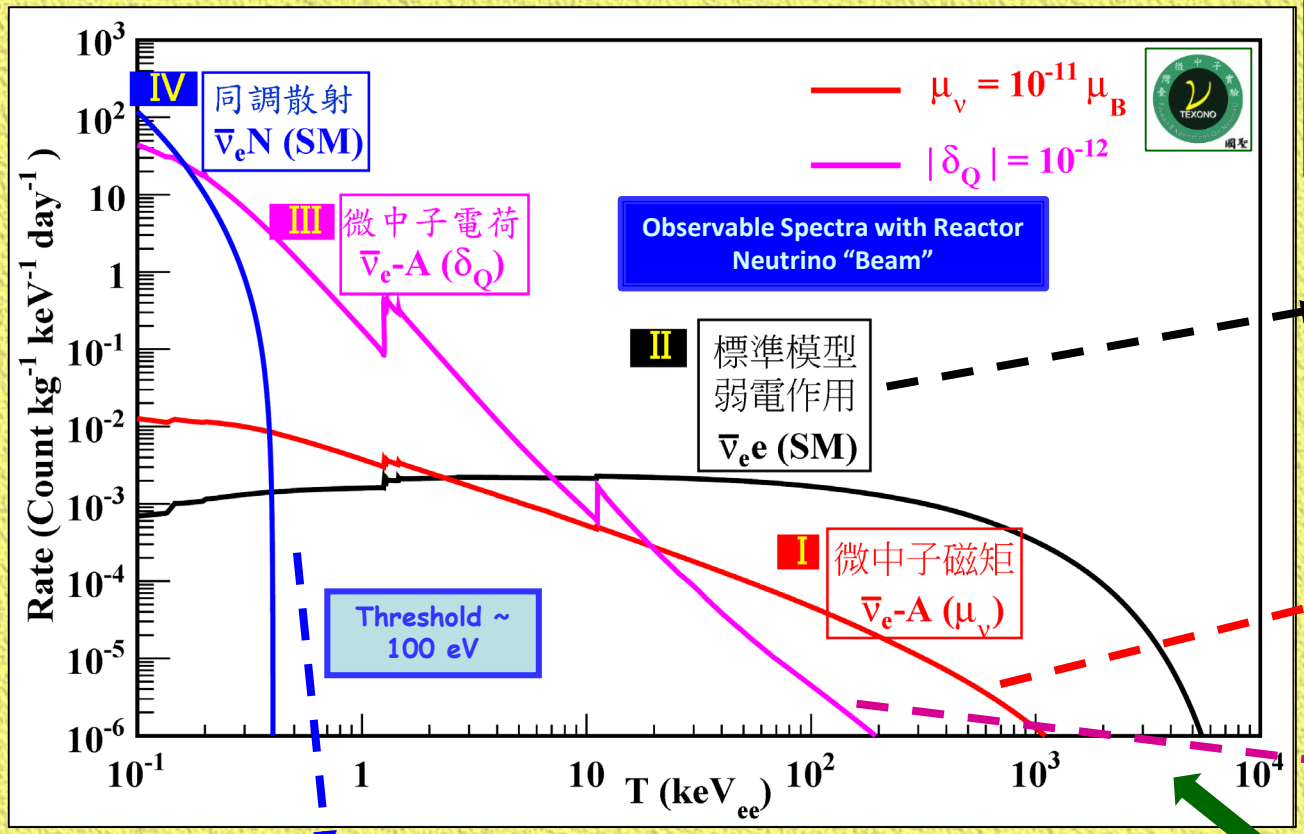
- First Institute-Scale Basic Research Collaboration between Taiwan and China

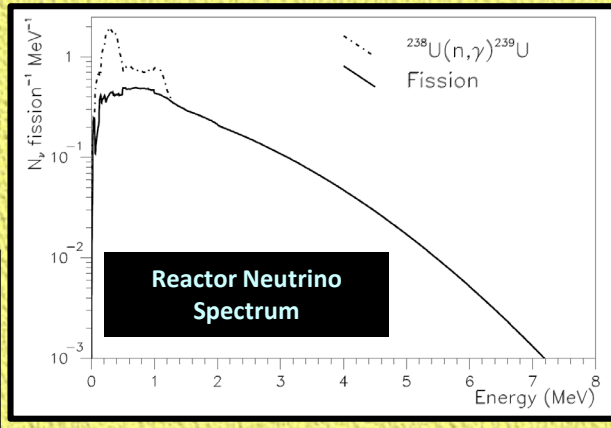


- Extended Posting of International *[China, India, Turkey]* Graduate Students *in* Taiwan to Pursue their Thesis Research

Neutrino Properties & Interactions at Reactor

quality ← Detector requirements → mass

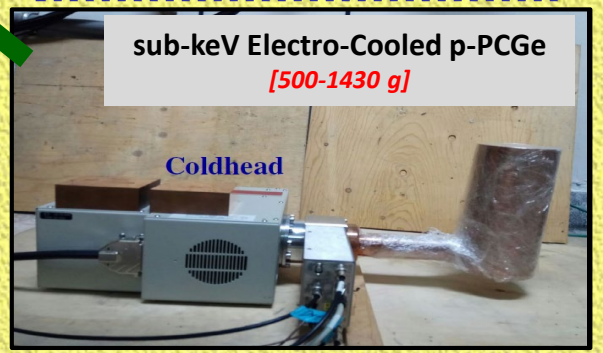




ν-e Scattering SM *[PRD10]*
& NSI/BSM
[PRD10,PRD12,PRD15,PRD17]
⇨ 200 kg CsI(Tl)

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

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



Current Theme: νN Scattering *[hep-ex05,MLPA08,PRD16]*

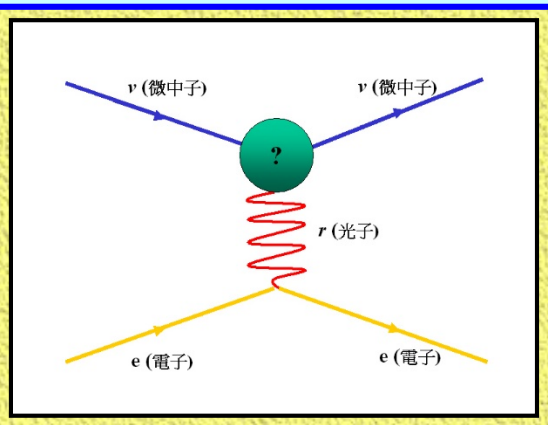
⇨ sub-keV O(kg) ULEGe / PCGe *[NIMA16]*

↳ Theory Program (Atomic effects in ν(χ)–N *[PLB14,PRD15… etc]*

↳ Light Dark Matter @ KSNL *[PRD09,PRL13,AP14]*

↳ CDEX Dark Matter @ CJPL *[PRD13,PRD14 ..etc]*

First Results on *(Then-Best)* Neutrino Magnetic Moments *(PRL03, PRD05,07)* Captured Attention of International Research Communities & Media



科學人雜誌

(Scientic American/Chinese)

2003年5月號

Dienstag, 15.4.2003

Süddeutsche Zeitung

Druckausgabe

Doppel-Null

Neutrino bleibt unmagnetisch

Auch Nicht-Ergebnisse liefern Physikern Einsichten – zum Beispiel der Versuch, an Neutrinos ein magnetisches Moment zu messen. Ein solches Moment kann theoretisch auch bei neutralen Teilchen wie Neutrinos entstehen, wenn eine Eigendrehung die negativen und positiven Ladungsanteile herumwirbelt. Deshalb suchten die Forscher nach subtilen Abweichungen von der – ohnehin extrem schwachen – Wechselwirkung von Neutrinos aus einem Kernreaktor mit Elektronen. Ihr Resultat: Null, wie bei früheren Experimenten. Allerdings haben sie die Null genauer vermessen; die Fehlergrenze liegt etwa beim zehnmilliardsten Teil des magnetischen Moments des Elektrons (Physical Review Letters, Bd.90, Nr.131802, 2003). Somit hält sich das Neutrino an die etablierte Theorie: Die elektromagnetische Wechselwirkung lässt es völlig kalt. Wärmer wurde hingegen das Verhältnis der beteiligten Forscher. Sie stammten aus der Volksrepublik China und aus Taiwan.

Czech Science News Digest : May 9, 2003

První velká vědecká spolupráce mezi Čínou a Tchaiwanem

První velká vědecká spolupráce mezi Čínou a Tchaiwanem proběhla při experimentech s jaderným reaktorem, jejichž cílem bylo určit novou horní mez magnetického momentu neutrina. Nabitá částice, jako je elektron, nese kromě elektrického náboje také spin, který odpovídá vnitřnímu magnetickému momentu částice. Elektricky neutrální atomy díky vnitřnímu rozložení elektrických kladných a záporných nábojů lze do jisté míry ovládat vnějšími magnetickými poli.
Neutrina mají malou klidovou hmotnost. Mohou však nést nějaký malý náboj nebo mít nějakou vnitřní strukturu? Nenulový magnetický moment neutrina by způsobil, že neutrino by reagovalo také na elektromagnetickou interakci a nikoliv pouze na slabou jadernou interakci, jak se dosud předpokládá. Důkaz nenulového magnetického momentu neutrina lze provést několika způsoby: pozorováním anomálních srážek elektronů a neutrin, studiem radioaktivního rozpadu, při němž neutrino doprovází gama záření nebo pozorováním astronomických jevů, jako jsou supernovy.
Společný tým TEXONO použil neutrina z jaderné elektrárny *Kuo-Sheng* o výkonu 2,9 GW na Tchaiwanu. Výzkumníci zde hledali charakteristické anomální spektrum energie elektronu, které by mělo provázet srážky elektronů a neutrin. Vědci však žádný takový důkaz nezískali a proto nejlepší laboratorně ověřený horní odhad magnetického momentu neutrina je 1,3.10-10 krát menší, než magnetický moment elektronu (tzv. Bohrův magneton). Tým také nepřímo stanovil mez radioaktivního rozpadu neutrina. (*Li et al., Physical Review Letters, 4. dubna 2003*; kontakt: **Henry Wong**, *Academia Sinica*, Taiwan, [M1])
Tým TEXONO má podporu několika vědeckých institucí (viz [X1]) a je financována příslušnými nadačními agenturami na Tchaiwanu a v Číně. Díky tomu poprvé došlo k výměně studentů a vědeckých pracovníků oběma směry. Tato spolupráce může mít také politický význam pro uvolnění napětí mezi oběma zeměmi. Připomeňme, že čínská komunistická vláda dosud považuje Tchaiwan za kolonii Čínské lidové republiky.

Subsequent Results are Recognized in Professional Circles

🏆 ***Still-Best*** **Cross-Section Measurement of Two of the Fundamental Leptons in Nature – electrons & electron anti-neutrinos** ***[PRD10]***

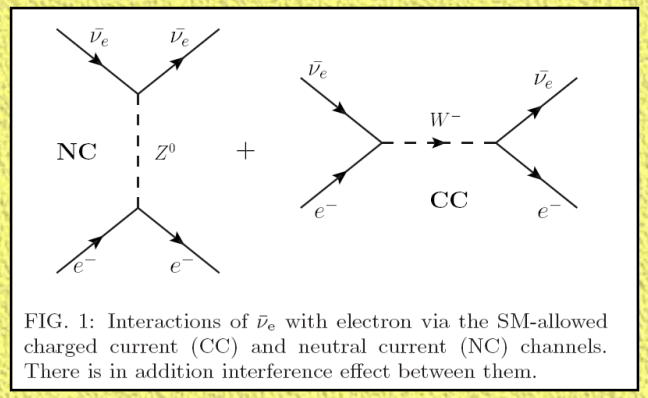
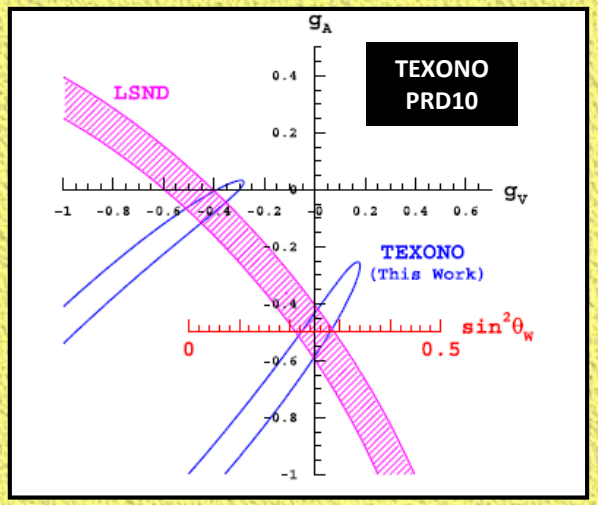
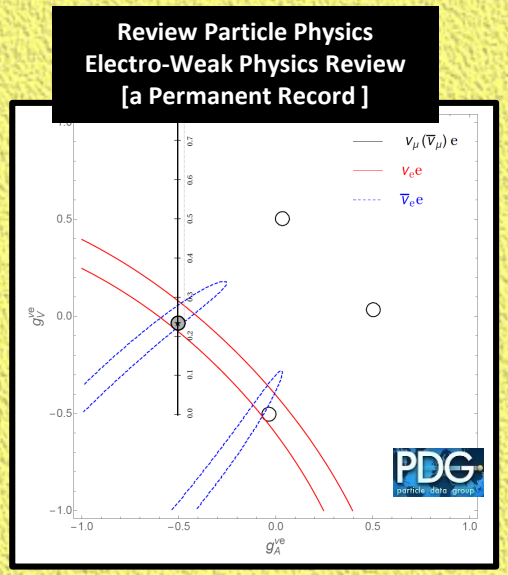


FIG. 1: Interactions of $\bar{\nu}_e$ with electron via the SM-allowed charged current (CC) and neutral current (NC) channels. There is in addition interference effect between them.





🏆 **Pioneered development on sub-keV Germanium Detectors** ***[NIMA16]***

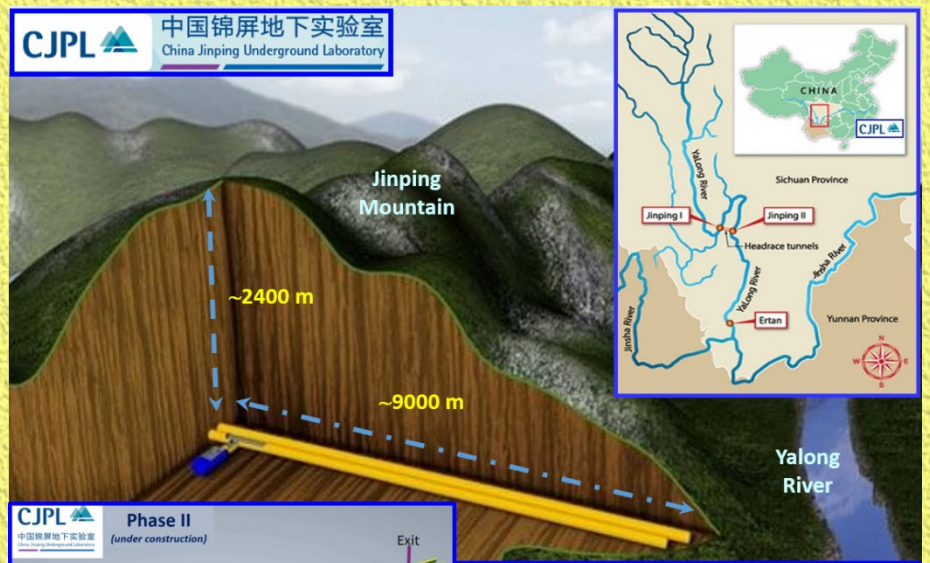
🏆 **Triggered Interest (& eventual observation) of coherent νN** ***[JPCS06]***

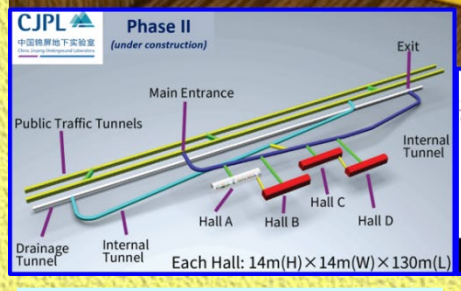
🏆 **Opened Window on "light-Dark Matter" searches** ***[PRD09]***

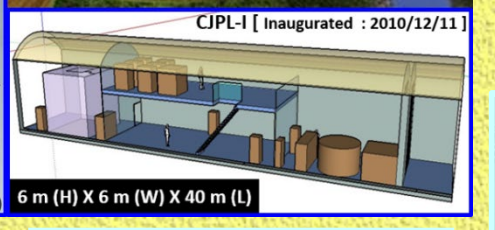
🏆 **Introduced Advanced Atomic Physics Calculations to σ(ν/χ N)** ***[PLB15+]***

🏆 **Introduced parameter to quantify QM coherency in elastic νN** ***[PRD16]***

TEXONO@KSNL directly catalyzed foundation of China Jinping Underground Laboratory (CJPL) and First-Generation CDEX Dark Matter Program.







PARTICLE PHYSICS:

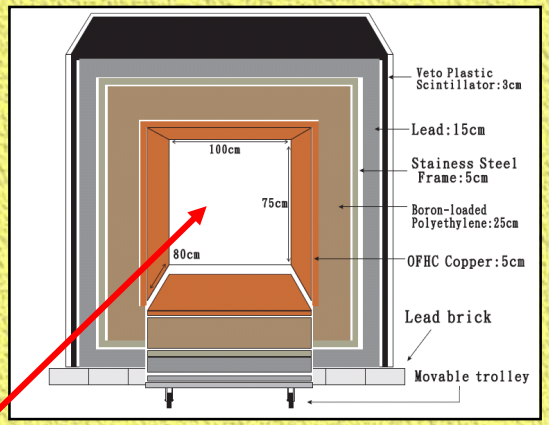
Chinese Scientists Hope to Make Deepest, Darkest Dreams Come True

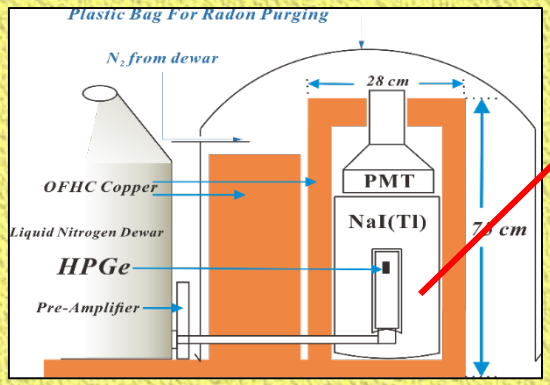
Dennis Normile

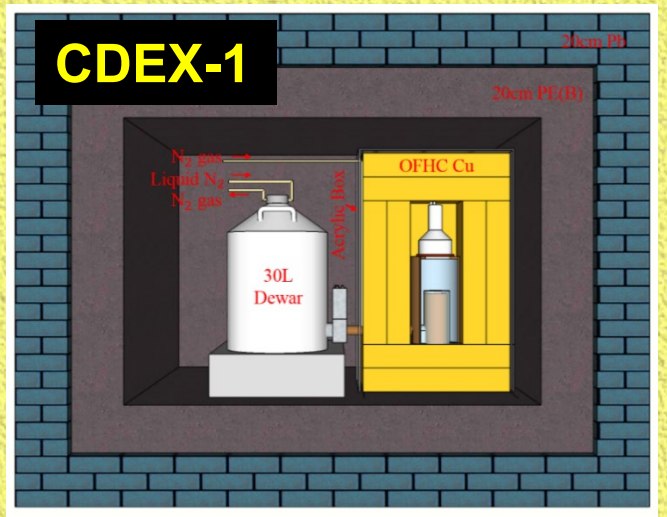
Science 5 June 2009:
Vol. 324. no. 5932, pp. 1246 - 1247
DOI: 10.1126/science.324_1246

- 2400+ m rock overburden, drive-in road tunnel access
- ~6 muons/m^2-month *(cf sea-level 100 Hz/m^2)*
- ***Deepest and Largest Underground Research Facility***

First-Generation CDEX-1 Dark Matter Searches at CJPL-I adopted *baseline design & software algorithms* of TEXONO@KSNL





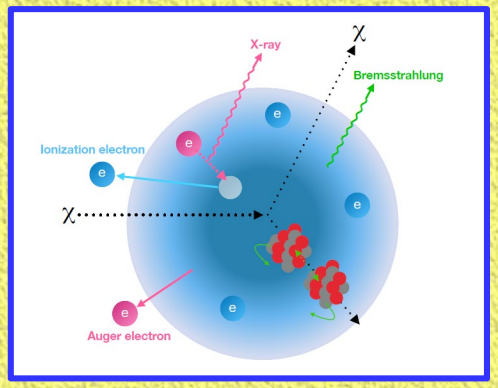


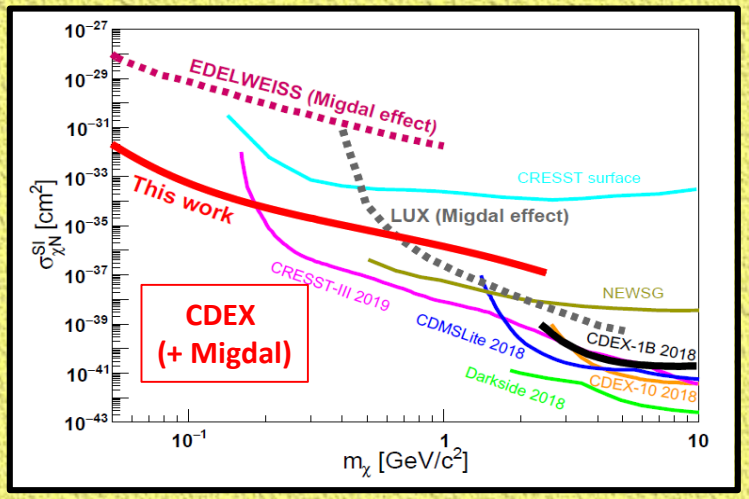
CDEX

Strength: Low Threshold *("Light" Dark Matter)* **; Resolving Spectral Structures** (axions…) **; Stability & Long Duration** *(Modulation Studies)*

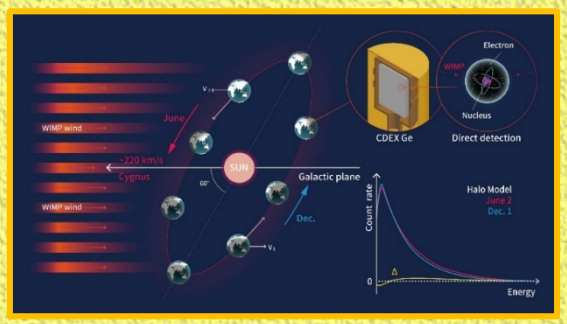
Recent Highlights ….

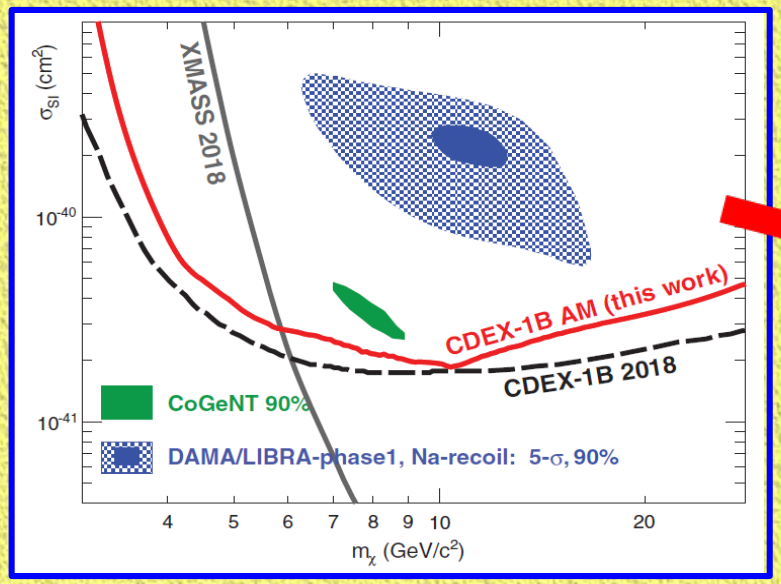
- **"Migdal Effects" Analysis (PRL19)** *[demonstrates we can "snatch" new ideas ..]*

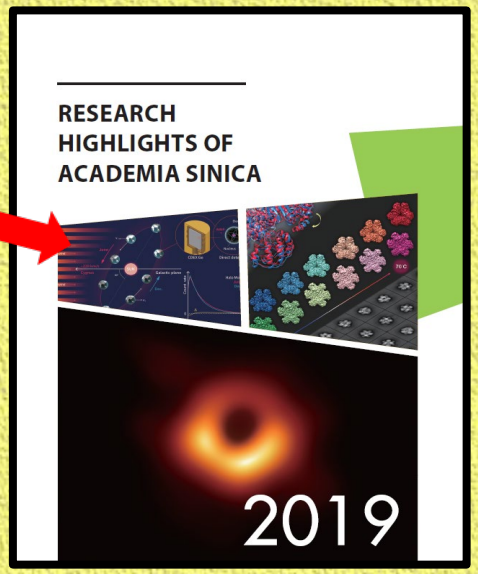




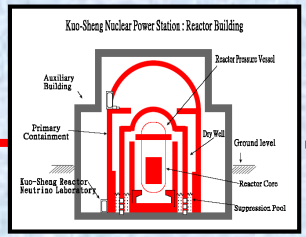
- **Annual Modulation Analysis (PRL19)** *[model-independent & apple-to-apple probe ; rejected other AM positive claims]*







TEXONO Program – Future Road Maps



νN

Decommission 2023
Access till 2025
(Good Shielding)

International Reactor Labs
(China, Korea, Russia, US…)

THEORY

+ TW Groups

EC-PCGe

GeIA—R&D

PIRE GEMADARC

~2023

Dark Matter

CDEX

CJPL 中国锦屏地下实验室 China Jinping Underground Laboratory

~2023

Future Program

L1T

SNOLAB

L200

LEGEND Large Enriched Germanium Experiment for Neutrinoless ββ Decay

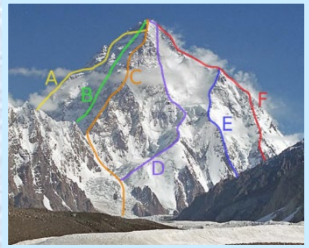
0νββ

INFN Laboratori Nazionali del Gran Sasso

~2027

Gravitational Physics

NEW Projects !



Ongoing Physics

Definite Plans

Possible Evolution

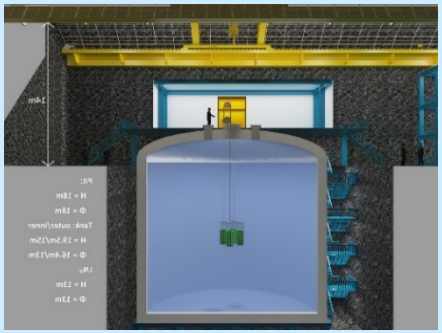
TEXONO Program for MOST-HEP-WP 2021+

Upgrade of Electro-cooled O(100 eV) Threshold Germanium Detectors

- νN scattering at Kuo-Sheng Reactor or elsewhere; Light WIMP searches at China Jinping Underground Laboratory

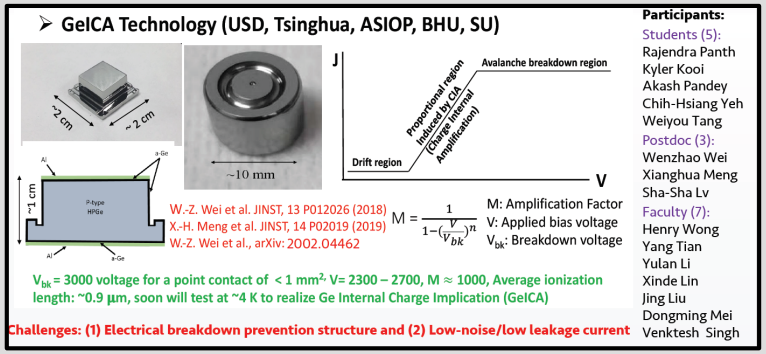
Neutrinoless Double Beta Decay with LEGEND:

- Execution of L200 ; R&D Towards (then preparation & execution) of Ton-scale L1000 at CJPL (or SNOLab)



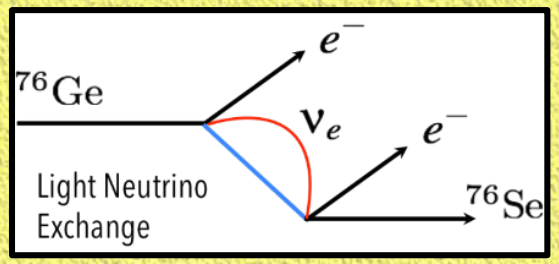
R&D Ge-Detector with Internal Amplification.

- Potential O(10 eV) threshold for future generations of νN scattering and Light WIMPs



- Continue Data Analysis on Novel DM Scenarios, QM Coherency in νN, 0νββ Sensitivities, Theory Project, *Explore New Ideas* ……

LEGEND Large Enriched Germanium Experiment for Neutrinoless ββ Decay



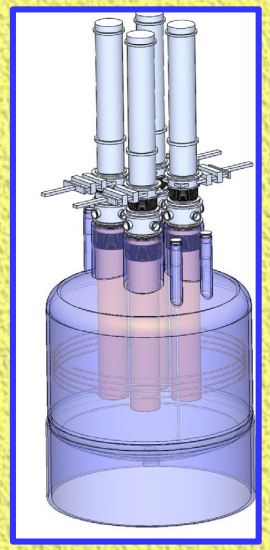
PHYSICS

Science V346, Nov 2014

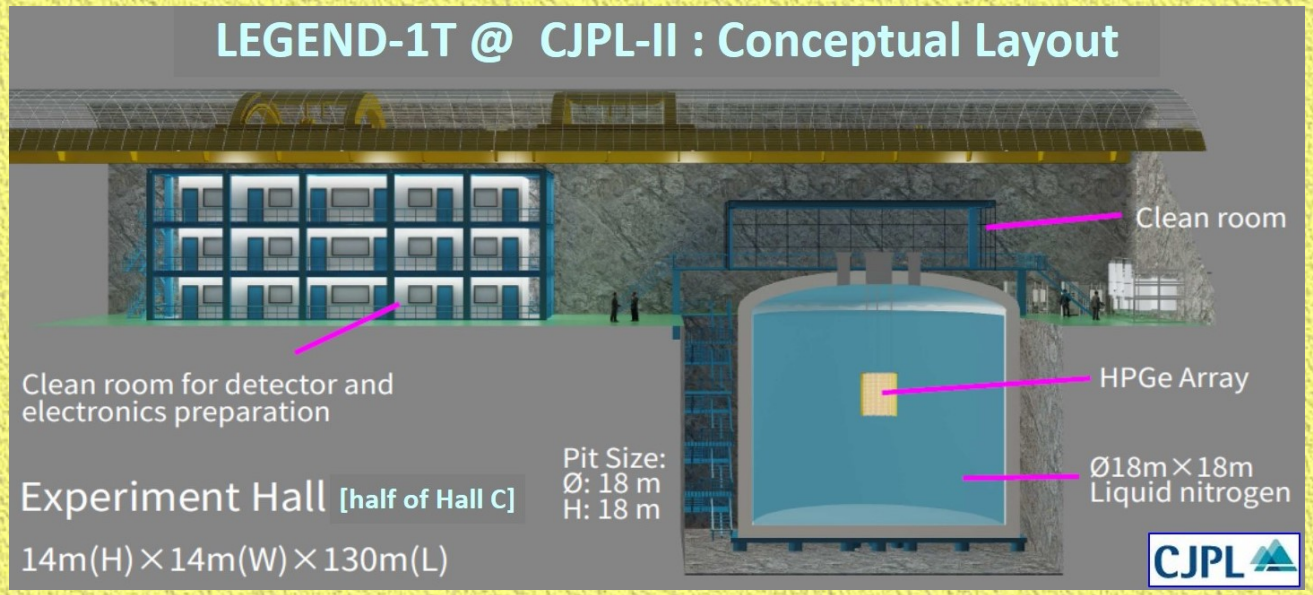
China supersizes its underground physics lab

Planned expansion could pave way for "ultimate dark matter experiment"

Towards Ton-scale enriched-Ge76 experiment for neutrinoless double beta decay experiment to cover the "Inverted Hierarchy"



L1T (?)



Summary & Prospects

TEXONO Program in Taiwan-HEP

☑ **Approach:** ***"Being Conductor in a Smaller Symphony Orchestra"*** **via Diversity & Versatility**

- ***"Choice" for Individual ; "Necessity" for Community*** ***[to Complement & Complete the*** ***Expt-HEP Experience]***

☑ **Delivered Good Science & International Presence, Built Facilities & Teams & "Brand Name"（品牌）, Acquiring Skills, Propagating DNAs** ***[qualified manpower, scientific content …]***

The first two decades….

Taiwan EXperiment On NeutrinO — History and Prospects

International Journal of Modern Physics A
Vol. 33, No. 16 (2018) 1830014 (30 pages)

DOI: 10.1142/S0217751X18300144

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The first decade ….

CDEX

CJPL

Annual Review of Nuclear and Particle Science

Annu. Rev. Nucl. Part. Sci. 2017. 67:231–51

The China Jinping Underground Laboratory and Its Early Science

Jian-Ping Cheng,[1] Ke-Jun Kang,[1] Jian-Min Li,[1] Jin Li,[1] Yuan-Jing Li,[1] Qian Yue,[1] Zhi Zeng,[1] Yun-Hua Chen,[2] Shi-Yong Wu,[2] Xiang-Dong Ji,[3] and Henry T. Wong[4]

Acknowledgments

The author is whole-heartedly grateful to the collaborators of both the TEXONO and CDEX groups, the technical and administrative staff of Academia Sinica and the collaborating institutes, as well as the supporting staff of the Kuo-Sheng Nuclear Power Station and the Yalong River Hydropower Development Company, for the various invaluable contributions which "made these happen." Funding support of the TEXONO program is provided by Academia Sinica and the National Science Foundation, Ministry of Science and Technology, and the National Center of Theoretical Science in Taiwan. The research programs of partner institutes are supported by the National Natural Science Foundation, the Ministry of Education and the National Basic Research Program in China, and the Scientific and Technological Research Council in Turkey.

期待：

更上層樓、依然精彩