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NSC Research Proposal (2001-2002) on Neutrino and Astroparticle Physics and Related Experimental Techniques

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on behalf of
The TEXONO[2] Collaboration

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Abstract

A Collaboration comprising scientists from Taiwan, Mainland China and the U.S.A has been built up since 1996 to initiate and pursue an experimental program in neutrino and astro-particle physics. A "flagship" experiment to be performed at the Nuclear Power Plant II in northern Taiwan is now taking first data on site, while various R&D projects towards future experiments are being pursued. This article presents an overview of our efforts and serves as part of the supporting materials submitted for the funding request from the National Science Council in the period August 2001 till July 2002. We request support in funding and positions to operate, maintain and perform data analysis for the reactor experiment, and for the procurement of equipment and materials to support the R&D program on (a) the feasibility studies towards a Dark Matter Search experiment, and (b) the development of methods with the Accelerator Mass Spectrometry techniques for the measurements of trace radio-purity.

1 Overview

Since 1996, under the initiation and leadership of the High Energy Physics group from the Institute of Physics of the Academia Sinica, a Collaboration comprising scientists from Taiwan, Mainland China and the U.S.A was built up to initiate and pursue an experimental program in neutrino and astro-particle physics [1]. By 1999, the TEXONO[3] Collaboration consists of more than 50 collaborators with diversified and inter-disciplinary background and expertise that cover a wide spectrum of experimental techniques. The collaborator list in 2001 is shown in Table 1. Strong connections have also been established with the industries and other major research institutes world-wide.

After an initial R&D effort on loaded liquid scintillator [4], the activities of the Collaboration since 1997 have been related to the general theme of adopting "Scintillating Crystal Detectors for Low-Energy Low-Background Experiments" [6]. The focus in 1997-1999 has been on the conception, formulation, prototype design studies and the construction of a "flagship" (previously called "pilot") experiment [2,8,TR1] to be performed near the reactor core of the Nuclear Power Plant II (NP2) [I] at northern Taiwan. It is based on a CsI(Tl) crystal scintillator to be placed 28 m from a reactor core to study various low energy interactions between neutrinos (electron-antineutrinos $\bar{\nu}_{\rm e}$ to be exact) and matter (electrons and nuclei). Extensive construction and on-site preparatory work were done in 1999-2000. By 2001, a broad-based program [7] starts taking shape. Various future directions are also discussed and explored [TR2].

From the beginning, the hardware specifications require that the detector, electronics and data acquisition systems as well the shieldings should be mostly independent of each other − to maximize the hardware flexibilities such that a variety of investigations can be carried out using reactor neutrinos as source, via the choice of various detectors.

Our first Ph.D. student (Dr. Liu Yan from IHEP, thesis on "Crystal Scintillator R&D") graduated in 2000, and is now doing research work at Caltech with the MINOS experiment. Currently there are three other Ph.D. students in the team: Li Hau-Bin (NTU, on the Reactor Experiment), Yue Qian (IHEP, on Dark Matter) and Xin Biao (CIAE, on Accelerator Mass Spectrometry).

Funding for the construction of the reactor experiment has been provided by the National Science Council (Taiwan), the National Science Foundation (Mainland China) and the National Science Foundation (U.S.A.) [I]. An independent proposal on Accelerator

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Mass Spectrometry is under preparation for the National Science Foundation (Mainland China).

It should be noted and stressed that our efforts represent one of the first large-scale collaborative research efforts in basic science among leading research institutes in Taiwan and Mainland China. During the course of our work since 1997, many difficulties were identified and solved. Many unexplored but necessary channels to run a big experiment, relating to the mutual flow of manpower, equipment and funding, were opened up. Extensive contacts have been established with the research communities and with the industries in Mainland China. An official Memorandum of Understanding [II] has been signed between Academia Sinica and the Institute of High Energy Physics. These experience and contacts will provide valuable reference to similar collaborative efforts in the future.

This Taiwan-Mainland China connection receives attention and recognition from the international community. The TEXONO project is particularly mentioned in a special feature report by Science Magazing on the Academia Sinica [Science, Vol. 288, No. 5469, Issue of 19 May 2000, pp. 1164 - 1166].

In the 2001-2002 time frame, the focus will be on the execution of the reactor experiment, as well as to carry on with the various R&D programs paving the way for future experiments which the Collaboration may evolve into. We request continuing support from NSC to consolidate and substantiate these efforts.

2 Research Projects

The details of the reactor experiment part are thoroughly discussed in the enclosed documents [III,IV,V], and the technical reports [TR1,TR2]. In this section, we present the status of the reactor experiment, and discuss the highlights of the R&D program.

2.1 Reactor Experiment

By December 2000, the 50-ton shieldings has successfully passed the safety reviews and construction was completed on site at the NP2 Reactor building [15]. A control room was built on site. The electronics, data acquisition and monitoring systems [10] were installed. Robust network communications were established between the NP2 site and the AS home-base. The cosmic veto system as well as radon purging system with pure nitrogen gas are commissioned.

That is, the **"Kuo-Sheng Nuclear Power Station Neutrino Laboratory"**, equipped with flexibly-designed shieldings, cosmic-ray 4-π active veto, powerful electronics which allow full digitization of multi-channel detectors for a 10 ms long duration, data acquisition and monitoring systems, as well as remote assess capabilities, was formulated, designed, constructed and commissioned from scratch within a time-span of three years.

The first 100 kg of CsI(Tl) were grown, out of which 20 kg were made operational as a detector system at the AS laboratories. The remaining pieces are under tests at IHEP-Beijing. The second 100 kg batch are under preparation – these will be 40 cm long single crystals, a new technical development made possible by our industrial partner, which are the longest CsI(Tl) single crystal production in the world. A 14-channel system has been in stable operation at the AS laboratory. Detector performance parameters are measured while the calibration procedures are worked out.

Since September 2000, data were taken on site with a high-purity germanium detector (HPGe). The initial background results (less than 1 Hz above 5 keV) inside the passive shieldings are encouraging (already better than the best commercial systems), such that we plan to take physics data in the first reactor cycle (Reactor OFF September 2001) with a "Ultra-Low Background" HPGe system equipped with a Low-Background NaI(Tl) anti-Compton detector. There are good chance of reaching the world-level sensitivities for neutrino magnetic moment searches with this system, when the cosmic-veto and radon-purge systems are fully operational.

The focus of 2001 will be to pursue this HPGe program on site while setting up and mastering the operation and calibration procedures of a 100-channel CsI(Tl) system at AS. There are adequate space within the shielding as well as high versatility for the electronics readout system (built-in flexibility from the beginning) such that a 100-channel CsI(Tl) system can run in parallel with the HPGe detector. in the first Reactor ON/OFF period. After completion of the HPGe program, the CsI(Tl) can be upgraded from the target mass of 100 kg to 200 kg.

Enclosed with the document [VIII] are the digital camera images of of (a) the Kuo-Sheng Neutrino Laboratory at NP2, (b) the control room with the electronics system, (c) the inside view shielding complex, where a high-purity germanium detector is placed, (d) the on-site view during installation in June 2000, (e) the AS prototype 14-channel system, and (f) the FADC module (20 MHz, 8 bit, 16 channels) developed by the Collaboration.

2.2 R&D Programs

The possible future directions of the Collaboration and our options and strategies to proceed are discussed in a technical report [TR2]. While the reactor experiment is entering the execution and analysis phase, several R&D projects are launched towards these ends. The topics and the respective leading institutes are listed below.

1. **Further Development on the Crystal Scintillator Technique:**
   Our industrial partner (Unique Crystal, Beijing) has successfully developed 40 cm long CsI(Tl) single crystal which will become their routine production - the longest in the world for production. In addition, we have completed (independent investigations by groups from Tokyo and Grenoble) feasibility studies for GSO crystal for low-energy solar neutrino detection, concluded by a publication [12].
   There are various fronts relating to the further development of this detector technique.

   - **Flat Panel PMT (AS):** Recently, Hamamatsu Photonics announced the availability of a new "Flat Panel PMT", which has potentials of revolutionizing PMTs' applications. We plan to study the adaptation of this device in low-background experimentation. The initial release date of "April 2000" is now re-scheduled to "2001".
   - **Development of Yb-based Scintillating Crystals (AS, RCNP/Osaka, SIC, Nanjing):**
     It is recognized recently that ^{176}Yb and ^{160}Gd are good candidate targets in the detection of solar neutrino by providing a flavor-specific time-delayed tag. Our work on the GSO crystal [12] indicated major background issues to be addressed with this crystal. Together with groups from RCNP/Osaka (PI: M. Fujiwara), we have been in touch with the famous Shanghai Institute of Ceramics (SIC) to explore the possibilities of developing Yb-based scintillating crystals like $YbAl_{l5}O_{12}$(YbAG) and/or $YbAlO_3$(YbAP).

   Though our goals are on low-energy low-background applications, these R&D efforts on the crystal techniques may well find applications in other areas.

2. **Radiopurity Measurements with Accelerator Mass Spectroscopy (CIAE, AS, NTHU, INER) [VI]:**
   Measuring the radiopurity of detector target materials as well as other laboratory

components are crucial to the success of low-background experiments. It is a "multi-million USD problem" worldwide.

The typical methods are direct photon counting with high-purity germanium detectors, α-counting with silicon detectors or the neutron activation techniques. We plan to explore the capabilities of radiopurity measurements further with the new Accelerator Mass Spectroscopy (AMS) techniques. This technique may be complementary to existing methods since it is in principle a superior and more versatile method as demonstrated in the ^{13}C system, and it is sensitive to radioactive isotopes that do not emit γ-rays (like single beta-decays from ^{87}Rb and ^{129}I) or where γ emissions are suppressed (for instance, measuring ^{39}K provides a gain of 10^5 in sensitivity relative to detecting γ's from ^{40}K).

A pilot measurement of the ^{129}I/^{127}I ratio in CsI was successfully made in 2000 ($< 10^{-12}$) demonstrating the capabilities of the Collaboration. Further beam time is scheduled at the CIAE Tandem accelerator in 2001 where we hope to extend the list of measure-able radio-isotopes as well as developing techniques on liquid scintillator as the base materials. The approval statement is enclosed [I].

The NTHU nuclear science group joined this part of the program with the goal of establishing further contacts with the expertise at CIAE and eventually building such a facility in Taiwan.

Complementary to the AMS program which is R&D oriented, the Collaboration has good access to the standard tools of HPGe photon counting at NTHU and CIAE, as well as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at INER.

3. **Feasibility Studies for Dark Matter Searches (NTU, AS, IHEP, Seoul):**
Experiments based on the mass range of 100 kg of NaI(Tl) are producing some of the most sensitive results in Dark Matter "WIMP" searches. Starting 2000, based on the NTU's CosPA framework, we are studying the feasibilities and technical details of adapting CsI(Tl) or other good candidate crystal like CaF_2(Eu) for these experiments [VII].
Experience and results from the reactor experiment shed much light on the feasibilities and sensitivities of this detector approach. For the nuclear recoil signatures due to WIMP-nuclei elastic scattering, the crucial issue is the detector performance and background at the 1-10 keV range Another signature based on WIMP-nuclei inelastic scattering are gamma-lines at the characteristic energies. A thorough physics and prototype studies have been carried out, while a neutron test beam measurement was successfully performed at CIAE Tandem. We have collected the world-lowest

threshold data for nuclear recoils in CsI, enabling us to derive the quenching factors as well as to study the pulse shape discrimination techniques at the realistically low light output regime. Optimization of crystal module dimensions as well as the readout device is under way.

A sizable group based at Seoul National University is interested in this CsI(Tl) approach to Dark Matter searches as well. They have a generous funding approval and an underground site already. A proto-collaboration is formed among groups from Taiwan, China and Korea where the first meeting was held at Seoul in December 2000. We agree to work closely together to study the case further with the goal of producing a working prototype meeting all requirements in 2001.

4. **Signal Processing with Neural Network (CKIT,AS,NTU):**
   The developed machinery based on Neural Network provides a powerful tool for the generic problem of optimization. It can find applications in many areas, including pulse shape processing from detector. A software engineering-oriented program is initiated to acquire the skill and experience in adopting the machinery to various applications.

5. **Applications of Electronics Scheme to Spring8-LEPS Experiment (AS, IHEP, RCNP/Osaka):**
   The AS nuclear physics group (PI: Chang Wen-Chen) has participated in the Spring8 LEPS experiment. We are studying the scenario of adapting the TEXONO reactor experiment FADCs and associated electronics for the TPC readout of LEPS upgrade.

6. **Discussions on a possible Long Baseline Experiment in Beijing (IHEP, AS):**
   Colleagues based at IHEP Beijing are considering a scenario of a "J2B" Long Baseline High Energy Neutrino Experiment at Beijing to receive a neutrino beam from the Japan Hadron Collider (JHF) due to be commissioned by 2006. The baseline of 2000 km is longer than current projects and the detector mass will have to be of the 50-100 kton range. While it is not to our interest (and ability) to push ahead this project in Beijing, we are nevertheless involved in some of the discussions towards its conception and formulation.

7. **Complementary Theory Program (AS, NCTS, CIAE):**
   TEXONO collaborators have been involved in the discussions and plannings to initiate a Core Program in Neutrino Physics Theory at NCTS. Several topics related to the TEXONO program are being studied, including " trident " (e^+e^-)

production with reactor neutrinos, matter effects of neutrinos and neutrino decays. Aother calculation-based project is the evaluation of the reactor neutrino and anti-neutrino spectra at low energies and their effects to the achieve-able sensitivities in the neutrino-electron scattering measurements.

Further details and a complete list of reference for some of the items discussed above can be found in the enclosed documents [6] and Technical Report [TR2].

3 Collaboration Organization and Tasks Sharing

The overall research efforts of the TEXONO Collaboration are co-ordinated by the AS group. Co-ordination of tasks as well as the funding request and management within the three regions are under the responsibilities of their respective principal investigators: Wong Tsz-king for Taiwan, Li Jin for Mainland China, and George Chang for the U.S.A. Collaboration meetings are held once every three to four months, while regular electronic mails, telephone meetings and video conferences provide the necessary communications in between.

Prototyping studies, design work and the construction of the different detector components for the reactor experiment are distributed among the collaborating institutes. The task sharing is summarized in Table 2. The assembly, installation and operation of the experiment, as well as the co-ordination of subsequent analysis, are under the responsibility of the AS group.

Collaborating institutes generate the various research projects mentioned in Section 2.2. The infra-structures and working relationships, as well as the efficient channels of communications and sharing of resources (equipment and expertise), already established in the past three years provide a solid base to carry out these projects. In particular, the NTU group (Project Leader: Wang Ming-Zu) and the CIAE group (Project Leader: Zhou Zu-Ying) spear-head the Dark Matter feasibility studies and AMS research efforts, respectively. The research program on signal processing is headed by the CKIT group (Project Leader: Lai Wen-Pin). The AS group (Project Leader: Chang Wen-Chen) is heading the efforts to adapt the TEXONO FADC readout scheme for Spring8-LEPS experiment.

The list of collaborating institutes and collaborators are expanding with time, as more contacts are established and as our efforts and idea are gaining further attention. The Collaboration expertise and connections are broad-based such that we can easily accomodate new initiatives from new group so long as new funding and manpower resources are allocated to the new programs.

4 Schedules and Goals : 2001-02

The goals for the 2001-02 time frame are:

1. **Reactor Experiment.**
   The 100-channel system will be made into robust operational at AS and then on-site at NP2. Procedures of calibration, monitoring and subsequent analysis will be established. Data taking on-site with both Ultra-High Purity Germanium detector (for its <10 keV threshold and excellent energy resolution for magnetic moment studies and background understanding) and the CsI(Tl) detector (100-200 channels) (for their large mass, spatial resolution for various other programs). The will be a Reactor OFF period in September and October of 2001. We strive to take valid physics data during that time and the ON period before and after that period.
   Future upgrades and directions of the reactor experiment, as well as the potentials of this approach in the world-scene, will depend on the operational experience, detector performance and the actual background achieved. Interested colleagues elsewhere are eager to know how far and how well we can proceed with this idea.

2. **R&D Projects.**
   The various R&D projects discussed in Section 2.2 will be pursued. In particular, conclusions and decisions will be drawn with the Korean groups regarding the possible Dark Matter experiment. Another neutron test beam period will be arranged to further improve the measurements. The AMS efforts will be further enhanced with beam-period allocated for trying out the new ideas on the unexplored radio-isotopes (the 2000 run was to demonstrate we can master the matured methods for ^{129}I). The low background flat-panel PMT will be purchased and studied whenever it is released to the market. The signal processing program with neural network will be initiated. The feasibilities of Yb-based crystal scintillator will be explored. The case for using the TEXONO FADC schemes for TPC readout for LEPS upgrade will be pushed forward. We will continue involved in the discussions of J2B with IHEP.

5 Publications

The published articles in SCI-journals as well as those with materials "in hand" scheduled to be submitted in 2001 are listed below.

1. "The Starting-Up of a Neutrino Project in Taiwan", C.Y. Chang, S.C. Lee and H.T. Wong, Nucl. Phys. **B** (Procs. Suppl.) **66**, 419 (1998).

2. "A Pilot Experiment with Reactor Neutrinos in Taiwan", H.T. Wong and J. Li, hep-ex/9805024, Nucl. Phys. **B** (Procs. Suppl.) **77**, 177 (1999).

3. "Charge Comparison Method to Discriminate Photons and Neutrons in Liquid Scintillators" (Chinese), Y. Chen et al., High Energy Physics and Nuclear Physics **23**, 616 (1999).

4. "A Feasibility Study of Boron-Loaded Liquid Scintillator for the Detection of Electron Anti-neutrinos", S.C. Wang et al., Nucl. Instrum. Methods **A 432**, 111 (1999).

5. "A CsI(Tl) Crystal Detector for Low Energy Neutrino Physics", H.T. Wong, J. Li and C.C. Chang, Nucl. Phys. (Procs. Suppl.) **B 87**, 517 (2000).

6. "Prospects of Scintillating Crystal Detector in Low-Energy Low-Background Experiments", H.T. Wong et al., hep-ex/9910002, Astropart. Phys. **14**, 141 (2000).

7. "Scintillation Crystal Detector for Low Energy Neutrino Physics", Henry T. Wong and Jin Li, Mod. Phys. Lett. **A 15**, 2011 (2000).

8. "A CsI(Tl) Crystal Scintillator for the Studies of Low Energy Neutrino-Electron Scatterings", H.B. Li et al., hep-ex/0001001, Nucl. Instrum. Methods, in press (2001).

9. "Applications of (α,γ) Discrimination in the Measurements of Intrinsic Radio-purity in CsI(Tl) Scintillating Crystal" (Chinese), Y. Liu et al., Nucl. Tech., in press (2001).

10. "The Electronics and Data Acquisition Systems of a CsI(Tl) Scintillating Crystal Detector for Low Energy Neutrino Experiment" W.P. Lai et al., hep-ex/0010021, Nucl. Instrum. Methods, in press (2001).

11. “Development of Charge-Sensitive Preamplifiers for the Readout of CsI(TI) crystals with Silicon Photo-diodes ” (Chinese), Z.Y. Zhang et al., Nuclear Electronics, in press (2001).

12. “Measurement of Intrinsic Radioactivity in a GSO Crystal” S.C. Wang, H.T. Wong, and M. Fujiwara, hep-ex/0009014, submitted to Nucl. Instrum. Methods **A** (2000).

13. “Studies of Prototype CsI(Tl) Crystals for Low-Energy Neutrino and Dark Matter Experiments”, C.P. Chen et al., in preparation for Nucl. Instrum. Methods (2001).

14. “Measurement of Nuclear Recoils in CsI(Tl) crystals with a Neutron Beam”, M.Z. Wang et al., in preparation for Phys. Rev. **C** (2001).

15. “Design, Construction and Background Measurements of a Shielding Structure at a Low-Depth Laboratory”, C.P. Chen et al., in preparation for Nucl. Instrum. Methods (2001).

In addition, the goals remain that with the data taken on-site with the first reactor ON/OFF period at NP2, we can arrive at some physics results and additional publications.

6 Request of This Proposal

In this Proposal to the NSC Research Grant (2001-2002), we focus on several specific items during this period.

1. **Operation of the Reactor Experiment**
   The Collaboration has secured funding adequate for the construction of 250 kg of CsI(Tl) crystals, 250 photo-multipliers and their base, 250 channels of Ver. 1.0. electronics plus data acquisition systems, and the entire 50-ton shielding complex. Most of those are already installed on-site. While taskes are distributed among the collaborating institutes during the prototying and construction phase, additional manpower support to be stationed in AS are necessary in the operation and analysis phase.

   In the 2001-02 time frame, we request funding for:

   - operating and maintaining the reactor reactor experiment, including mechanics construction, electronic components, connectors and cables, data storage disks, computing equipment, as well as travels between Taipei and NP2 and meeting trips to Beijing.

- 50% of an "Ultra-Low Background" Germanium detector to supplement and complement the CsI(Tl) crystal detector, together with its associated shieldings. The remaining 50% will be provided by the Academia Sinica operation fund. It will be placed on-site for the first Reactor-OFF period for magnetic moment studies at low threshold, and then be turned into a high-quality radiopurity testing facility for future projects.
- support of a visiting professorship position to an IHEP senior scientist is essential to maintain smooth operation of the Collaboration. Application materials will be submitted independently.
- support of three research assistants, who have been working with the Collaboration in previous year, and who have played important roles in realizing the status presented in this report.

2. **R&D Efforts**

Most of the resources necessary to launch the various R&D initiatives will be based on the operation funds from AS, IHEP, CIAE and UMD, and from the infrastructures the Collaboration built up in the past year. In *this* NSC proposal, we only request funding support for those parts which are more matured:

- sharing of the procurement of the new Hamamatsu Flat-Panel PMTs, with low-activity glass if available,
- beam sharing, accelerator upgrade sharing and materials cost for the Accelerator Mass Spectrometry efforts at CIAE as well as data taking trips there,
- beam sharing and materials cost for neutron test beam measurements, as well as data taking trips there.

The funding request to NSC-Engineering Division to support related software-oriented and signal-processing work is submitted independently by Dr. Wen-Pin Lai of the Chung Kuo Institute of Technology. The NSC-funding request for the electronics Spring8-LEPS upgrade is submitted independently by Dr. Wen-Chen Chang of the Academia Sinica under the Spring8 proposal.

7 Documents and Articles Included

Several documents prepared by the Collaboration are included to this Proposal. They provide many experimental details to substantiate the global framework described in the article. A comprehensive list of references are cited therein. Our public-domain articles as well as digital images can be refered to and down-loaded from our Web-page **http://hepmail.phys.sinica.edu.tw/EXONO/index.html/**.

I. Copies showing (a) the available funding from the National Science Foundation (Mainland China) and (b) the National Science Foundation (U.S.A.) for the construction of the pilot experiment, as well as (c) the official approval letters for working at Nuclear Power Plant II from Taiwan Power Company, and (d) for 2001 beam time at the Tandem acceleration at Mainland China's Institute of Atomic Energy for doing Accelerator Mass Spectroscopy and neutron test beam measurements.

II. The official Memorandum of Understanding signed between the PIs from the Academia Sinica and the Institute of High Energy Physics.

III. "Prospects of Scintillating Crystal Detector in Low-Energy Low-Background Experiments", "Prospects of Scintillating Crystal Detector in Low-Energy Low-Background Experiments", H.T. Wong et al., hep-ex/9910002, Astropart. Phys. **14**, 141 (2000).
(Art. 1 in WTK's Selected Publications and Ref. 6 in publication list)

IV. "A CsI(Tl) Scintillating Crystal Detector for the Studies of Low Energy Neutrino Interactions", H.B. Li et al., hep-ex/0001001, Nucl. Instrum. Methods **A**, in press (2001).
(Art. 2 in WTK's Selected Publications and Ref. 8 in publication list)

V. "The Electronics and Data Acquisition Systems of a CsI(Tl) Scintillating Crystal Detector for Low Energy Neutrino Experiment" W.P. Lai et al., hep-ex/0010021, Nucl. Instrum. Methods, in press (2001).
(Art. 3 in WTK's Selected Publications and Ref. 10 in publication list)

VI. Status Report and Plans for the "Measurement of Radio-purity with Accelerator Mass Spectrometry" Project.

VII. Status Report and Plans for the "Feasibility Studies of Dark Matter WIMP Search" Project.

VIII. Digital camera images of of (a) the Neutrino Laboratory at the Kuo-Sheng Nuclear Power Plant Station, (b) the control room, with the electronics and data acquisition systems (partly shown), (c) the inside view shielding complex, where a high-purity germanium detector is placed, (d) the on-site view during installation in June 2000, and (e) the AS prototype CsI(Tl) system. (f) the FADC module (20 MHz, 8 bit, 16 channels) developed by the Collaboration, which is being considered to be adopted to the TPC for Spring8 upgrade.

In addition, we note in particular two Technical Reports which are available on request or download-able from our Web-page. They have been submitted as supporting documents in our NSC-Proposal (1999-2000). We do not include them in this package for economy and simplicity reasons.

TR1. "A Pilot Experiment with Reactor Neutrinos in Taiwan : A Technical Status Report", C.P. Chen et al., TEXONO Collaboration, AS-TEXONO/98-07 (1998). *(120 pages, the "Blue Book" : description of experimental details of the pilot experiment)*

TR2. "Experimental Neutrino Research in Taiwan: Directions and Prospects", H.T. Wong, AS-TEXONO/98-08 (1998). *(40 pages, the "Brown Book" : discussions of directions and strategies and approaches)*

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Table 1: The institutes and collaborators list of the TEXONO Collaboration, for both the reactor experiment and various R&D projects.

Institutes	Tasks and Responsibilities (Revised: Jan 2001
AS	Overall coordination, physics, electronics design and construction, data acquistion and on-line control systems, simulations, offline software coordination, experiment installation and operation. **R&D: Overall coordination,** **Dark Matter,** **New Crystals for Solar Neutrinos†,** **Electronics for Spring8†**
CKIT	Offline software and simulations **R&D: Neural Network for Pattern Recognition†**
INER	Shielding design and construction, mechanics and workshop facilities, radiopurity (neutron activation, ICP-MS).
NTU	Student participation, data acquisition, physics and chemistry of scintillation. **R&D: Dark Matter†**
NTHU	Nuclear engineering, neutron transport calculation, radiopurity (germanium detectors), **R&D: AMS**
NP2	Site provision and logistic support, safety.
CIAE	Physics, neutron transport simulation, reactor neutrino spectrum calculation, radiopurity (germanium, AMS), neutron beam tests. **R&D projects : AMS†, Dark Matter**
IHEP	Physics, CsI(Tl) production and quality control, tests and measurements of prototypes, inner detector engineering design, electronics design and construction, simulations. **R&D: Dark Matter, Electronics for Spring8,** **Very Long Baseline Experiments†**
IRP	Electronics design and production.
THU	Physics, Detector R&D **R&D: Dark Matter**
NU	Analysis and simulations. **R&D: New Crystals for Solar Neutrinos**
UMD	Plastic scintillators and PMTs for veto, simulations. **R&D: New Crystals for Solar Neutrinos**

Table 2: Major items in the tasks and responsibilities sharing among the collaborating institutes. The R&D projects are denoted in **bold** with † after the respective Project Leaders .