Fermilab

Directorate

# MEMORANDUM OF UNDERSTANDING
# FOR THE 2011 – 2012 NEUTRINO PROGRAM

**T-1020**

**NaI Crystal Test for DM-Ice**

November 3, 2011

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## INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of the NaI Crystal Test for DM-Ice from the University of Wisconsin who have committed to participate in detector tests to be carried out during the 2011 – 2012 Fermilab Neutrino program.

The memorandum is intended primarily for the purpose of recording expectations for budget estimates and work allocations for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to modify this memorandum to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

*Description of Detector and Tests:*

The DM-Ice collaboration is designing a sodium-iodide (NaI) based detector for a direct dark matter search. The detectors should have low readout noise and background levels to carry out a sensitive search. A 17-kg version of the experiment is running at the South Pole, 2500 m deep in the Antarctic ice, and a larger scale experiment is currently being designed. One of the keys to the success of the experiment is to have a good understanding of the background levels intrinsic in the NaI detectors.

To measure the background level, the detectors have to be shielded against cosmic rays. The lead shielding used for DAMIC (see T-987) in the MINOS Underground Areas is a well-suited location for this test since it offers enough overburden to shield against cosmic rays, lead shielding, and experimental infrastructure.

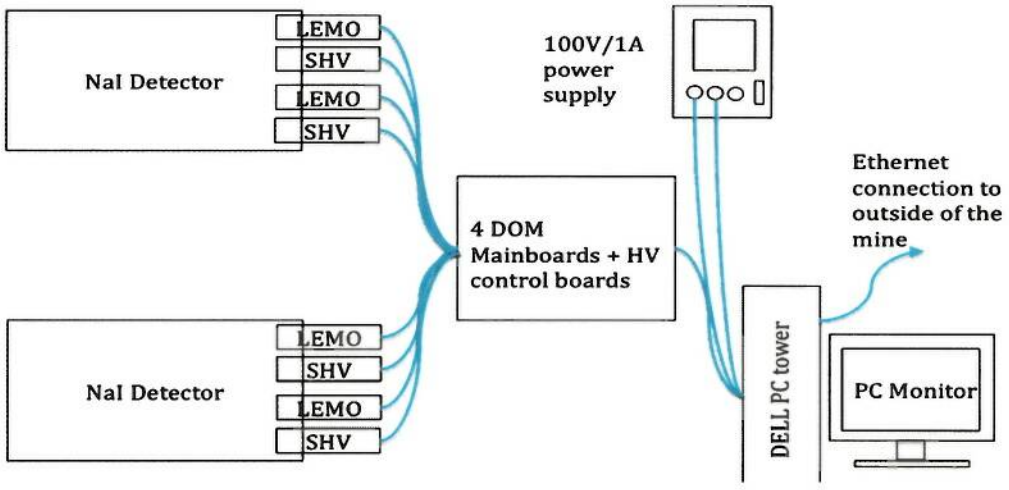



**Figure 1.: A schematic of the data acquisition for the DM-Ice NaI test**

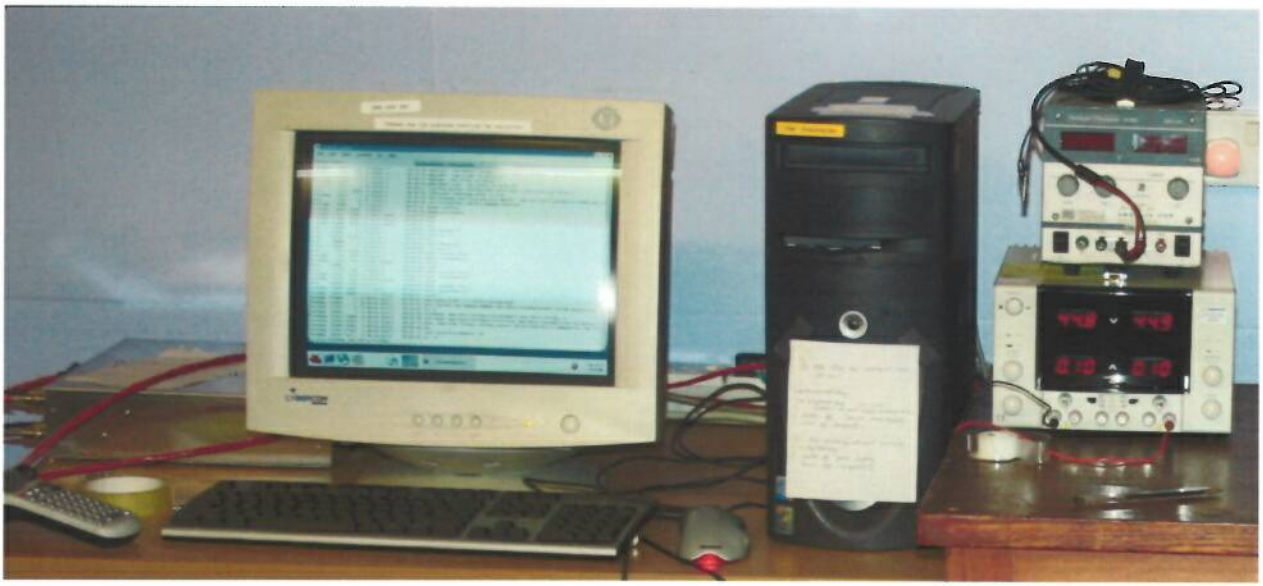


**Figure 2: From left: electronics chassis containing the HV generator and pulse shape digitization board, a PC monitor and tower, and two power supplies. Only the bottom power supply will be used in this experiment.**

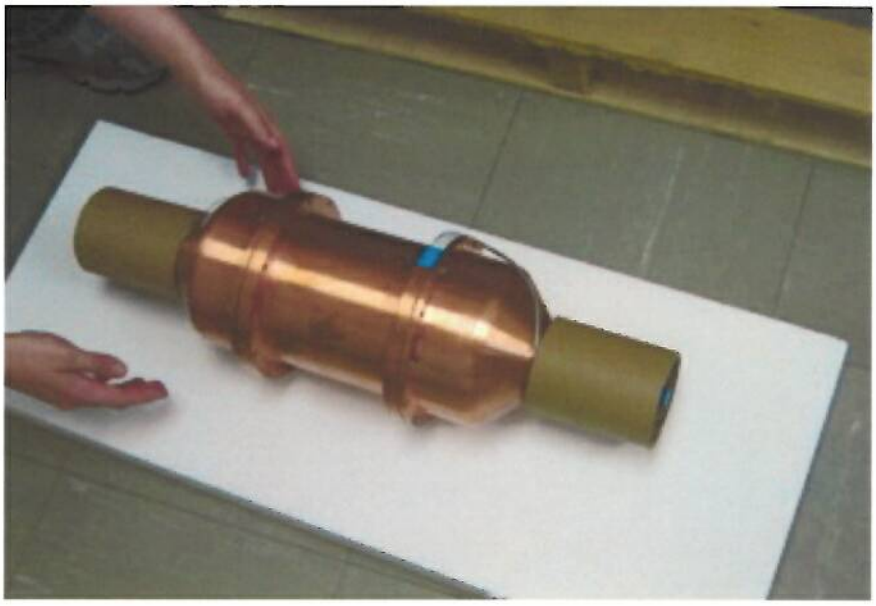


**Figure 3: NaI(Tl) detector to be tested consisting of two PMTs placed on either ends. This detector along with PMT bases will be placed inside the lead shielding.**

The goal of the test is to assess the background levels in the detector and to assess the characteristics of phosphorescence induced by muons and 100 keV - 3 MeV gamma rays.

## I. PERSONNEL AND INSTITUTIONS:

Spokesperson: Reina Maruyama

Physicist in charge of beam tests: Zachary Pierpoint

Fermilab liaison: Aria Soha

The group members at present are:

| | Institution | Collaborator | Country | Rank/Position | Other Commitments |
|---|---|---|---|---|---|
| 1.1 | University of Wisconsin, Madison | Reina Maruyama | USA | Assistant Professor | IceCube, CUORE |
| | | Karsten Heeger | USA | Associate Professor | Daya Bay, CUORE |
| | | Zachary Pierpoint | USA | Graduate Student | |
| | | Walter Pettus | USA | Graduate Student | |
| | | Benjamin Broerman | USA | Undergraduate | |
| | | Chris Hilgenberg | USA | Undergraduate | |
| | | David Webber | USA | Postdoc | Daya Bay |

## II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

### 2.1 LOCATION

2.1.1 The apparatus for the beam test(s) will be located in the MINOS Underground Area. The Detector Hall Access Tunnel has been recently used for the DAMIC experiment, and the experimenters request the use of their lead shielding for this test. Much of this area is well off the beam axis and would be ideal for the DM-Ice test. The experimental apparatus plus shielding will occupy a footprint roughly eight feet square. The apparatus requires standard 110 VAC lines for the electronics.

### 2.2 BEAM

#### 2.2.1 BEAM TYPES AND INTENSITIES

This test does not utilize any particle beams. The initial tests can be done when the beam is on. However the experiment should operate when the beam to the hall is off to minimize backgrounds.

### 2.3 EXPERIMENTAL CONDITIONS

#### 2.3.1 AREA INFRASTRUCTURE

Location of the experiment, underground, is depicted in Appendix I. Only the NaI(Tl) detector (see Fig. 3) and PMT voltage dividers will be placed inside the lead shielding. The electronics (Fig. 2) will be placed just outside. If possible, the PC tower shown should have Ethernet access to allow for remote operation and monitoring.

The NaI detector and data acquisition system are all light enough to be handled by a single person, though a cart to transport the equipment will be helpful.

Standard 110 VAC lines for the electronics are required, as well as one Ethernet connection. A second Ethernet connection is useful, though not absolutely necessary. The Ethernet connection to the data acquisition system will be used to remotely control and monitor the detector. It will also be used to transfer the data to servers at the University of Wisconsin.

The experiment acknowledges that due to the nature of the underground environment, ground water seeps from the ceiling and walls and pools on the floor, and will take measures to protect their equipment as they see fit, while abiding by fire hazard codes.

### 2.3.2 Electronics Needs

The experiment electronics are depicted in Figure 2, and consist of an electronics chassis containing the HV generator and pulse shape digitization board, a PC monitor and tower, and a small, commercial power supply. No rack, and therefore no rack protection equipment is necessary.

No PREP electronics are requested.

### 2.3.3 Description of Tests

After the initial setup and commissioning, the detector will be operated remotely via the Ethernet connection and data will be taken continuously, with an occasional interruption for detector calibration with gamma sources. The background levels at the detector and the system will be assessed, along with possible phosphorescence induced by muons and 100 keV - 3 MeV gamma rays. The detector and data acquisition setup are shown in Figs. 1 – 3.

## 2.4 Schedule

The DM-Ice NaI crystal test is ready for immediate setup and installation. We expect it will take 2-3 days to setup and start the test. The experimenters expect to be able to start the tests upon approval, in January 2012. After the installation is complete the experimenters will collect data continuously for ~1 month with occasional short calibrations. During data taking the experimenters will look at the results and decide on the next steps for this project.

The experimenters acknowledge that the apparatus will have to be removed by March 1, 2012 for the duration of the 2012–2013 Fermilab shutdown, and the underground space after the shutdown will need to be renegotiated.

## VI. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

### 3.1 UNIVERSITY OF WISCONSIN:

- The University of Wisconsin will be responsible for supplying the detector and data acquisition electronics as well as the personnel to run the detector. The equipment supplied are:
  - NaI(Tl) detector, each equipped with two photomultiplier tubes and bases. (qty: 2)
  - 2 electronics chassis containing 2 DOM mainboards and HV control boards. (2 BNC output, 2 SHV output, 1 input from PC) (qty 2)
  - 4 BNC – LEMO adaptors
  - 1 Tower PC equipped with one IceCube "dor" data acquisition card
  - PC monitor, keyboard, and mouse
  - 1 power supply (120V/1A)
  - 4 SHV cables
  - 4 LEMO or BNC cables
  - Connector/cable between power supply and dor card
  - Connector/cable between dor card and chassis to mainboards
  - 1 Ethernet cable

Total existing items: $15k

## IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

### 4.1 FERMILAB ACCELERATOR DIVISION:

No accelerator division support is required.

### 4.2 FERMILAB PARTICLE PHYSICS DIVISION:

4.2.1 The test-beam efforts in this MOU will make use of the MINOS Underground Areas as outlined in Section II. The Fermilab Particle Physics Division will be responsible for coordinating overall activities in the MINOS Underground Area. [2 person-weeks]

4.2.2 Technical support to assist in moving the experimental equipment into and out of the MINOS Underground Area and moving the lead shielding [0.4 person-weeks]

4.2.3 A person appropriately trained to handle sealed-sources for occasional detector calibration. [0.8 person-weeks]

4.2.4 Conduct a NEPA review of the experiment.

4.2.5 Provide day-to-day ES&H support/oversight/review of work and documents as necessary.

4.2.6 Provide safety training as necessary, with assistance from the ES&H Section.

4.2.7 Update/create ITNA's for users on the experiment.

4.2.8 Coordinate the ES&H Operational Readiness Clearence Review or other required safety reviews. [0.2 person-weeks]

### 4.3 FERMILAB COMPUTING SECTION

4.3.1 Internet access underground/on surface to allow for remote operation and monitoring.

### 4.4 FERMILAB ES&H SECTION

4.4.1 Assistance with safety reviews.

4.4.2 Loan of radioactive sources, Co-57, Co-60, and Cs-137 for 1 hour calibration runs scattered throughout the duration of the experiment.

4.4.3 Provide safety training, with assistance from PPD, as necessary for experimenters.

## V. SUMMARY OF COSTS

| Source of Funds [$K] | Materials & Services | Labor (person-weeks) |
|---|---|---|
| Particle Physics Division | 0.0 | 3.4 |
| Accelerator Division | 0 | 0 |
| Computing Section | 0 | 0 |
| ES&H Section | 0 | 0 |
| | | |
| Totals Fermilab | $0.0K | 3.4 |
| Totals Non-Fermilab | $15k | 4 |

## 6. General Considerations

6.1 The responsibilities of the Spokesperson and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Researchers": (http://www.fnal.gov/directorate/PFX/PFX.pdf). The Spokesperson agrees to those responsibilities and to ensure that the experimenters all follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the Division's Safety Officer.

6.3 The Spokesperson will ensure one person is on-call and available by phone at all times whenever the detector is being operated and that this person is knowledgeable about the experiment's hazards.

6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.5 All items in the Fermilab Policy on Computing will be followed by the experimenters. (http://computing.fnal.gov/cd/policy/cpolicy.pdf).

6.6 The Spokesperson will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Section management. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Section management.

6.7 The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment. Fermilab will be responsible for repair and maintenance of the Fermilab-supplied electronics. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

*At the completion of the experiment:*

6.8 The Spokesperson is responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.9 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such a rigging, crane operation, etc.

6.10 The experimenters will assist Fermilab with the disposition of any articles left in the offices they occupied.

6.11 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters' Meeting.

**SIGNATURES:**

11/ 09 / 2011

Reina Maruyama, Experiment Spokesperson

11 /10/ 2011

Michael Lindgren, Particle Physics Division, Fermilab

11 /21 / 2011

Peter Cooper, Computing Section, Fermilab

11 /10 / 2011

Nancy Grossman, ES&H Section, Fermilab

11/21 /2011

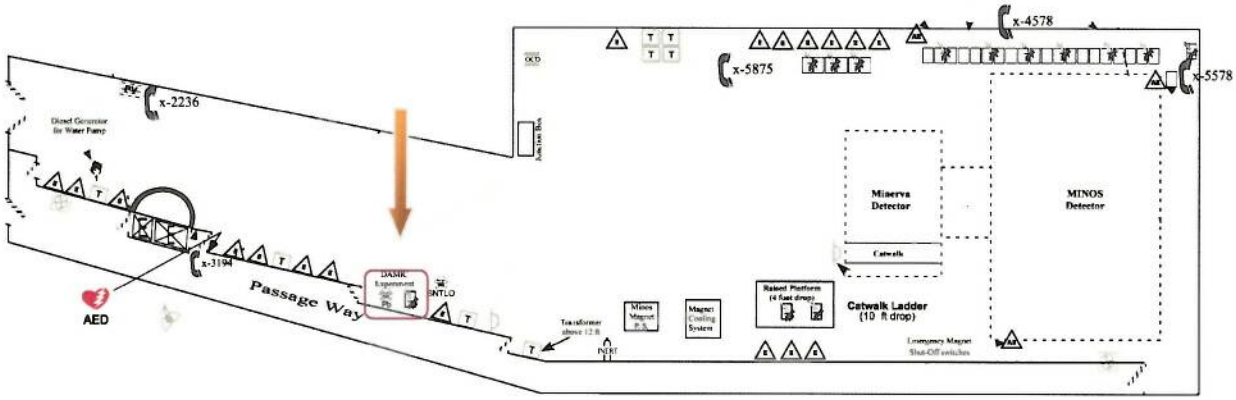
Greg Bock, Associate Director for Research, Fermilab

11 /28/2011

Stuart Henderson, Associate Director for Accelerators, Fermilab

## APPENDIX I: AREA LAYOUT

The test will utilize the lead shielding used for the DAMIC experiment. A table next to the shielding for the power supply, data acquisition electronics, and computer is requested.



## APPENDIX II: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked. See next page for detailed descriptions of categories.

| Flammable Gases or Liquids | | Other Gas Emissions | | Hazardous Chemicals | | Other Hazardous /Toxic Materials |
|---|---|---|---|---|---|---|
| Type: | | Type: | | | Cyanide plating materials | List hazardous/toxic materials planned for use in a beam line or an experimental enclosure: |
| Flow rate: | | Flow rate: | | | Hydrofluoric Acid | |
| Capacity: | | Capacity: | | | Methane | |
| **Radioactive Sources** | | **Target Materials** | | | photographic developers | |
| | Permanent Installation | | Beryllium (Be) | | PolyChlorinatedBiphenyls | |
| X | Temporary Use | | Lithium (Li) | | Scintillation Oil | |
| Type: | Co-57, Co-60, Cs-137 | | Mercury (Hg) | | TEA | |
| Strength: | 0.1 microCi | | Lead (Pb) | | TMAE | |
| **Lasers** | | | Tungsten (W) | | Other: Activated Water? | |
| | Permanent installation | | Uranium (U) | | | |
| | Temporary installation | | Other: | **Nuclear Materials** | | |
| | Calibration | **Electrical Equipment** | | Name: | | |
| | Alignment | | Cryo/Electrical devices | Weight: | | |
| Type: | | | Capacitor Banks | **Mechanical Structures** | | |
| Wattage: | | | High Voltage (50V) | | Lifting Devices | |
| MFR Class: | | | Exposed Equipment over 50 V | | Motion Controllers | |
| | | | Non-commercial/Non-PREP | | Scaffolding/ Elevated Platforms | |
| | | | Modified Commercial/PREP | | Other: | |
| **Vacuum Vessels** | | **Pressure Vessels** | | **Cryogenics** | | |
| Inside Diameter: | | Inside Diameter: | | | Beam line magnets | |
| Operating Pressure: | | Operating Pressure: | | | Analysis magnets | |
| Window Material: | | Window Material: | | | Target | |
| Window Thickness: | | Window Thickness: | | | Bubble chamber | |

## OTHER GAS EMISSION

**Greenhouse Gasses** (Need to be tracked and reported to DOE)

- ❑ Carbon Dioxide, including $CO_2$ mixes such as $Ar/CO_2$
- ❑ Methane
- ❑ Nitrous Oxide
- ❑ Sulfur Hexafluoride
- ❑ Hydro fluorocarbons
- ❑ Per fluorocarbons
- ❑ Nitrogen Trifluoride

## NUCLEAR MATERIALS

### Reportable Elements and Isotopes / Weight Units / Rounding

| Name of Material | MT Code | Reporting Weight Unit Report to Nearest Whole Unit | Element Weight | Isotope Weight | Isotope Weight % |
|---|---|---|---|---|---|
| Depleted Uranium | 10 | Whole Kg | Total U | U-235 | U-235 |
| Enriched Uranium | 20 | Whole Gm | Total U | U-235 | U-235 |
| Plutonium-242[1] | 40 | Whole Gm | Total Pu | Pu-242 | Pu-242 |
| Americium-241[2] | 44 | Whole Gm | Total Am | Am-241 | – |
| Americium-243[2] | 45 | Whole Gm | Total Am | Am-243 | – |
| Curium | 46 | Whole Gm | Total Cm | Cm-246 | – |
| Californium | 48 | Whole Microgram | – | Cf-252 | – |
| Plutonium | 50 | Whole Gm | Total Pu | Pu-239+Pu-241 | Pu-240 |
| Enriched Lithium | 60 | Whole Kg | Total Li | Li-6 | Li-6 |
| Uranium-233 | 70 | Whole Gm | Total U | U-233 | U-232 (ppm) |
| Normal Uranium | 81 | Whole Kg | Total U | – | – |
| Neptunium-237 | 82 | Whole Gm | Total Np | – | – |
| Plutonium-238[3] | 83 | Gm to tenth | Total Pu | Pu-238 | Pu-238 |
| Deuterium[4] | 86 | Kg to tenth | $D_2O$ | $D_2$ | |
| Tritium[5] | 87 | Gm to hundredth | Total H-3 | – | – |
| Thorium | 88 | Whole Kg | Total Th | – | – |
| Uranium in Cascades[6] | 89 | Whole Gm | Total U | U-235 | U-235 |

[1] Report as Pu-242 if the contained Pu-242 is 20 percent or greater of total plutonium by weight; otherwise, report as Pu 239-241.

[2] Americium and Neptunium-237 contained in plutonium as part of the natural in-growth process are not required to be accounted for or reported until separated from the plutonium.

[3] Report as Pu-238 if the contained Pu-238 is 10 percent or greater of total plutonium by weight; otherwise, report as plutonium Pu 239-241.

[4] For deuterium in the form of heavy water, both the element and isotope weight fields should be used; otherwise, report isotope weight only.

[5] Tritium contained in water (H2O or D2O) used as a moderator in a nuclear reactor is not an accountable material.

[6] Uranium in cascades is treated as enriched uranium and should be reported as material type 89.