FERMILAB-PROPOSAL-0993

(N. Nakashima)
cc: N. Mokhov
M. Lindgren
R. Dixon
P. Cooper
N. Grossman
Ramberg/Mazhoefer
orig to M. Tolian OQBP
2/2/10
jc

Directorate

Fermilab

MEMORANDUM OF UNDERSTANDING (MOU)

T-993

Shielding and Radiation Effect Experiments II

Japanese-American Study of Muon Interactions and Neutron detection (JASMIN-2, continuation of T972)

FNAL-Japan Radiation Physics Collaboration Team

December 7, 2009

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1. INTRODUCTION

This is a Memorandum of Understanding (MOU) between Fermilab and experimenters who have committed to participate in the "Shielding and Radiation Effect Experiments II (JASMIN-2) to be carried out over three years, starting November 2009. This is a continuation and extension of a successfully completed first stage, JASMIN (T972).

This memorandum is intended solely for the purpose of providing a work allocation for Fermilab and the participating institutions and universities. It reflects an arrangement that is currently satisfactory to the parties involved. It is recognized that changing circumstances of the evolving research program may necessitate further revisions. The parties agree to negotiate amendments to this memorandum to reflect such revisions.

In all the phases of the experimental work outlined in this MOU, the experimenters will abide by the Fermilab Environmental Safety and Health Manual (FESHM) as prescribed and guided by the laboratory's ES&H staff.

2. OUTLINE AND STATUS

The efforts covered by this MOU are meant to be the continuation and extension of the JASMIN project (T972) - a study of shielding and radiation effects at the Pbar target station and NuMI hadron absorber region at Fermilab. The project includes research for high-energy, high-intensity accelerators, space applications in the areas of particle production, showering and transmission in thick targets, collimators and radiation shielding as well as of radiation effects on instruments and materials.

The purpose of this project is to obtain the following data for high-energy particles using Fermilab accelerator facilities:

(1) Shielding data,

Measuring quantity	- Energy spectra of generated and transmitted particles
	- Prompt dose rates
	- Radioactive nuclide production rates in materials and air
Location	- Beam line, target & beam dump
	- Inside & outside shield
	- Penetration duct

(2) Radiation effect data

Measuring quantity	- Absorbed dose
	- Radionuclide production and residual dose
	- DPA (displacement per atom) of materials
	- Soft error of semi-conductors
Location	- use same locations for shielding-data measurement

Since experimental shielding data in the energy region above 1 GeV is very scarce, the data from this experiment will be very useful for the following:

(a) Benchmarking of simulation codes (MARS, PHITS):
    - Possible accuracy upgrade,
    - Modification of physical model and parameterizations.
(b) Material science, space science, high-energy accelerator science and engineering:
    - Provide irradiation field for radiation effect studies of materials or devices
    - Development of simulation code for radiation damage and radionuclide production.
(c) Radiation safety estimation:
    - Prompt dose distribution inside and outside shield and through penetration ducts
    - Residual activity in material and air

This MOU includes two experiments - one at the antiproton target station (termed "Pbar"), and one at the NUMI absorber termed "NuMI"). It is planned for the three years of the project (Nov. 2009 – Mar. 2012).

Two experiments at Pbar and NuMI were carried out in the former project JASMIN (T972) in Oct. 2007 – Mar. 2009:

(a) Pbar experiment

In order to estimate the radiation field characteristics on top of the Pbar target station, shielding experiments behind steel and concrete shields were carried out. Neutron reaction rates and flux distributions were measured by activation methods and various detectors. To understand the nuclear reactions occurring in the upper atmosphere from a geophysical aspect, residual nucleus distributions around air of the target was also measured using various filters. These data are undergoing analysis using the MARS and PHITS codes for benchmarking and establishing irradiation field.

(b) NuMI experiment

In order to study radioisotopes produced by cosmic fast muons and muon induced radioactivity in high intensity and energy accelerators as well as radiation characteristics downstream of the NuMI absorber, residual nucleus distributions and radiation reaction rate distributions were measured by the activation methods and various kinds of detectors. These data are also under analysis for benchmarking of MARS and inclusion of muon interaction in PHITS.

3. EXPERIMENTAL PLANS AND ITEMS

The experimental items planned for the next three years which are covered by this MOU are as follows:

(a) Pbar
- ➢ Secondary particle production from the Pbar target (continued from T972)
- ➢ Shielding experiment (continued and new)
    - ✧ In steel to the 90-degree direction (done in 2008) and a forward direction (using

another filler plate at the forward direction.)
    - ✧ In concrete (by plugging samples into the concrete cap block)
- ➢ Duct streaming experiments using the cable ducts (done a test experiment in 2008 and continued)
- ➢ Characterization of the neutron field in the air gap (required for analyses of duct streaming and in-concrete data)
- ➢ Gas and cooling water analysis
    - ✧ Gas analysis in the target tunnel (continued)
        - Measurement of filter-trapped products (continued)
        - Measurement of short-lived products with half-lives less than a few seconds (new)
    - ✧ Tritium analysis in the RAW systems (new experiment)
        - Condensed moisture in the target tunnel by a chiller
        - Cooling water of the Pbar-target devices (lens etc.) and the gamma-ray-resolved gas.
- ➢ Neutron spectrum measurement using active counters (continued and new)

As for shielding experiment in concrete, concrete shields set at upper side of the Pbar target are replaced by concrete shields with holes for setting samples as shown in fig. 3.1. The shields are made with the same concrete and the holes are plugged by concrete blocks. Thus, shielding effectiveness is unchanged. The detail is described in Appendix II.

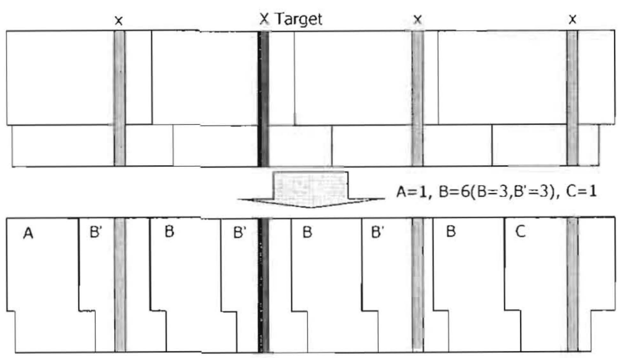

Fig. 3.1 Concrete shielding assembly above Pbar target

(b) NuMI
- ➢ Alcove 0 and 1
    - ✧ Confirmation of the muon beam position and direction (continued)
    - ✧ Characterization of the secondary particle field around the hadron absorber (continued, needed to establish the technical method for characterizing the mixed field of neutrons and muons)
    - ✧ From Alcove 2~4
    - ✧ Measurement of muon attenuation in rock (continued)
    - ✧ Measurement of nuclide production by muons (continued)
    - ✧ Measurement of muon and secondary particle spatial distribution (continued)

4. SCHEDULES (Apr. 2009 – Oct. 2009 and Nov. 2009 - Mar. 2012)

Experimental schedules between April 2009 and March 2012 are shown in Table 1, which includes Japanese visitor schedules and Pbar & NuMI access requests.

The first work in 2009 is to apply for machine time at the Meson Test Beam Facility. That work is outlined in a separate MOU – T994. The application process will start as soon as possible to obtain the machine time for at least one week in February, 2010. During the summer 2009 shutdown period, the Japanese collaborators visited Fermilab to set new samples in the NuMI alcove and to remove and analyze the old samples installed last year. They will visit again for 3~4 weeks in the winter, including the MTest machine time. During the stay, the experimenters will access the NuMI alcove to remove the samples and put dosimeters when a natural beam downtime occurs. In addition to the gas analysis which was carried out so far using the gas sampling system in Pbar, a test analysis of cooling water of the Pbar devices will be started. The access to the Pbar target station is not required because the experimenters do not plan the foil activation in Pbar in this year.

In 2010 or later, the experimenters plan the foil activation in the steel shield at a position downstream from the Pbar target and in the concrete shield. For the experiment, preparation of a new filler plate and the special concrete block into which activation foils can be installed will be started in 2009.

The visit schedules in 2010~2012 depends on the accelerator operation schedule and the machine time of MTest.

Table.1 Major experimental schedules, visit schedule and the access request for Pbar and NuMI between April 2009 and March 2011

Facility	Pbar		NuMI		Meson Test Beam Facility (MTest)		Visit Schedule	Access request for Pbar & NuMI
Experimental items	Neutron Field Characterization	Gas & Water Analysis in accelerator environment	Characterization of incident muon beam in the hadron absorber hall	Muon interactions in rock	Basic nuclear data	Development of elemental technique for field characterization		
2009		Sampling and analysis test of the condensed moisture in the beam tunnel Gas analysis	Measurement of the muon beam profile	Nuclide production by muon in Alcove 2~4 Distribution of muon and secondary using detectors	Proton-induced activation cross sections	Characterization of the secondary neutron field for the test target using counter and dosimeters	1week for sample setting at NuMI in August	Pbar: None NuMI: During the summer shut down for setting samples and on the natural downtime during our 2~3-week stay for removing them
2010	In the concrete shield Sample: Bi, Cu, Al, In Measurement of neutron dose rate using dosimeters	Analysis of the condensed moisture and cooling water Gas analysis	Muon and neutron field characterization in Alcove 0~1	Cont.	Activation by the secondary particle from a test target	Characterization of the secondary particle field for the test target using counter and dosimeters	1~2 months in total The visit timing will depends on the accelerator operation schedule and the MTBF machine time obtained [b].	Pbar: During a shutdown period for setting the samples in concrete shield. Need another access for removing them [a] NuMI: During a shutdown period for setting samples and on the natural downtime for removing them.
2011 & 2012 (~March)	In the steel shield at a downstream position Sample: Bi, Cu, Nb, Au Duct streaming	Cont.	Cont.	Cont.		Characterization of the secondary neutron and its attenuation for the test target Development of measurement technique for the characterization of high energy neutron field higher than 100 MeV	Same as above	Pbar: During a shutdown period for setting the samples in the steel. Need another access for removing them [a] NuMI: During a shutdown period for setting samples and on the natural downtime for removing them.

[a] The experimenters have to request operational stop of the accelerator unless they can use the natural downtime or the short downtime scheduled in advance.
[b] MTest machine time for 1~2 weeks will be requested every year.

5. PERSONNEL AND INSTITUTIONS

Co-spokespersons: Hiroshi Nakashima (JAEA), Nikolai Mokhov (APC)

The group members at present are:

JAEA (Japan Atomic Energy Agency)

Hiroshi Nakashima (Safety Division Deputy Leader, J-PARC center)
Yukio Sakamoto (Principal Scientist, Research Group Leader for Applied Radiation Physics)
Yoshimi Kasugai (Principal Scientist)
Yoshihiro Nakane (Principal Scientist)
Yosuke Iwamoto (Scientist)
Norihiro Matsuda (Scientist)
Fumihiro Masukawa (Scientist)
Tokushi Shibata (Scientific Consultant)

KEK (High Energy Accelerator Research Organization), Japan

Toshiya Sanami (Scientist)
Hiroshi Matsumura (Scientist)
Hiroshi Iwase (Scientist)
Masayuki Hagiwara (Scientist)
Hideo Hirayama (Professor)
Syuichi Ban (Professor)

Kyoto Univ., Japan

Hiroshi Yashima (Scientist)

Shimizu Corporation, Japan

Takashi Nakamura (Scientific Consultant, Professor emeritus of Tohoku Univ.)
Koji Oishi (Principal Scientist)

Kyushu Univ., Japan

Kenji Ishibashi (Professor)
Nobuhiro Shigyo (Assistant Professor)

Tsukuba Univ., Japan

Norikazu Kinoshita (Scientist)

RIST, Japan

Koji Niita (Head of Simulation code development group)

PAL (Pohang Accelerator Laboratory), Korea

Hee-Seock Lee (Head of Radiation safety group)

Fermilab

Nikolai Mokhov (Scientist III, Head of Energy Deposition Department, APC)
Igor Rakhno (Applications Physicist, APC)
Kamran Vaziri (Physicist, ES&H, Radiation Physics)
Tony Leveling (Physicist, AD, Pbar)
David Boehnlein (Physicist, PPD, Neutrino Department)
Aria Meyhoefer (Test beam liaison, PPD, EPP)
Eric McHugh (PPD Safety Officer)
Gary Lautenschlager (Radiation Physicist, AD, ES&H Radiation Safety)

6. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

- Funding for construction of new concrete shields will be borne by experimenters. (JAEA)
- Shipping Ge-detectors, scintillation counters, activation samples etc. from and back to Japan. Costs will be borne by experimenters. (JAEA)
- Setting up for Ge-detectors, active counters, their electronic circuit, and DAQ system. (JAEA, KEK and Kyoto)
- Setting and removing sample to be irradiated. (JAEA, KEK and Kyoto)
- Measurements of gamma rays from radionuclides from irradiated sample with Ge-detector. (JAEA, KEK and Kyoto)
- Active counter measurements. (JAEA, KEK and Kyushu)
- Chemical separation process. (KEK)
- Assist in designing concrete shields (JAEA, Shimizu Corp.)
- Data analysis. (All)

7. RESPONSIBILITIES BY INSTITUTION – FERMILAB

ACCELERATOR PHYSICS CENTER (APC)

- Assistance for the experimenters of this project.
- Full simulation support prior and after measurements.

ACCELERATOR DIVISION (AD)

- Provide budget code for design of new shielding blocks.
- Install concrete shields with detector slots above Pbar target station.
- Survey and assistance to equip or remove the detectors.
- Assistance for Fermilab safety training for the experimenters in AP0 building, NUMI hadron absorber region and NUMI muon alcoves.
- Coordinate access to the experimental area at AP0 building and to the NUMI muon alcoves.
- Number of protons at the Pbar target is provided as real-time electric signal pulse and/or as data of particle number history after beam time.
- Assistance of placing electronics with CAMAC crate and DAQ system at a counting area of AP0 building NuMI Hadron Absorber Room and Muon Alcoves for active counter measurement.
- Lend cables and connectors.
- Open, close and moving the concrete shield cap or steel shielding of air gap. (parasitic to other needs to open the cap or shielding)
- Use of existing crane for detector setting and removing during operation.
- Use of penetration ducts to pull detectors inside the air gap between steel and concrete shields using rope.
- Transport irradiated samples from the radiation area to a counting room at HIL.
- Accumulated toroid readings and POT history for the run.
- Organize Cryo Panel review and obtain PPD permission for use of LN in the counting room at HIL.

FACILITIES ENGINEERING SERVICE SECTION (FESS)

- Design concrete shields with detector slots for Pbar target station.

PARTICLE PHYSICS DIVISION (PPD)

- Assistance for Fermilab ES&H training for the experimenters in NuMI
- Receive irradiated samples at the HIL counting from AD and provide handling and storage instructions for irradiated samples at HIL.
- Ensure compatibility of JASMIN experimental apparatus with other existing experiments in the Hadron Absorber Room and Muon Alcoves.
- Assistance of placing electronics with CAMAC crate and DAQ system at bypass tunnel by muon alcoves.
- Lend 100 lead bricks until this project completes. All lead bricks will be covered and handled with gloves. (Eric McHugh)
- Lend 3 counting rooms in HIL (High Intensity Lab) for measurement of sample activities with several Ge-detectors, for data analysis, and for storage of all detectors, electronics, etc. until this project completes.

COMPUTING DIVISION

- Lend and maintain electronic modules & tools from PREP. (See Appendix III)
- Set up connection of an internet in a counting room at HIL to observe a real-time beam status (the connection may already exist).
- Lend and set up a printer for data analysis in the counting room.

ES&H SECTION

- Assistance with ES&H reviews.
- Lend a chemical laboratory in RAF for chemical separation of irradiated samples. (Only samples registering a contact dose rate of < 1 mrad/hr. can be processed at the Fermilab RAF chemistry lab and when this work does not interrupt services to the primary Fermilab program.)
- Lend RAF Ge-detectors when available.
- Lend a PC, to be used for the data acquisition only.
- Assistance for calibration sources.
- Assistance to transport irradiated samples to the counting room.
- Arrangement of a source storage box for calibration sources & irradiated samples in the counting room.
- Lend 100 virgin lead bricks until this project completes. A sufficient number of lead bricks are in the HIL building now. Half of them, lent by Vernon Cupps, are covered by plastic bags. The other half are newly bought, and painted. Gloves will be used for all lead handling.
- Assistance with shipping radio-active samples to Japan.
- Analyze radioactive water samples for tritium

8. BUDGET

	FY2009	FY2010	FY2011
FNAL			
(1) PPD Experimental support (Liquid nitrogen, etc.)	$1K	$1K	$1K
(2) AD Target station shielding block design	$5K		
Total Fermilab	$6K	$1K	$1K
Japan			
(2) Experimental devices and activation detector	$3.4K	$2.4K	$0K
(3) Transportation of experimental devices	$0.6K	$0.6K	$1K
(4) Travel expense	$48K	$40K	$48K
Total Japan	$52K	$43K	$49K

9. SPECIAL CONSIDERATIONS

9.1 The responsibilities and procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters": (http://www.fnal.gov/directorate/documents/index.html). The Spokespersons agree to those responsibilities and to follow the described procedures.

9.2 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 Spokespersons will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer and follow all procedures in the PPD Operating Manual.

9.3 The Spokespersons will ensure that at least one person who is knowledgeable about the experiment's hazards is present at the access of the Pbar target station, NuMI muon alcoves, or NuMI absorber.

9.4 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.

9.5 All items in the Fermilab Policy on Computing will be followed by the experimenters.

9.6 The spokespersons 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 Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.

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

9.8 At the completion of the experiment:

9.8.1 The Spokespersons are 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 of the group will be required to furnish, in writing, an explanation for any non-return.

9.8.2 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.

9.8.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied.

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

SIGNATURES:

1 / 12 / 2009
Hiroshi Nakashima,
Co-spokesperson, JAEA

1 / 12 / 2009
Yukio Sakamoto,
Research Group for Applied Radiation
Physics, JAEA

1 / 25 / 2009
Toru Ogawa,
Director General,
Nuclear Science and Engineering
Directorate, JAEA

12 / 28 / 2009
Nikolai Mokhov,
Co-spokesperson, APC, Fermilab

12 / 22 / 2009
Roger Dixon, Accelerator Division

12 / 15 / 2009
Mike Lindgren, Particle Physics Division

12 / 21 / 2009
Peter Cooper, Computing Division

12 / 14 / 2009
Nancy Grossman, ES&H Section

12 / 28 / 2009
Greg Bock,
Associate Director, Fermilab

12 / 28 / 2009
Stephen Holmes,
Associate Director, Fermilab

APPENDIX I - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked

Cryogenics		**Electrical Equipment**		**Hazardous/Toxic Materials**	
X	LN2 filled Ge detector		Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target	X	high voltage (power supply, 2kV, 4kV)	X	Radiation hazard: Irradiated foils or disks (Al, Bi, In, Au, Cu, Fe)
	Bubble chamber		exposed equipment over 50 V		
Pressure Vessels		**Flammable Gases or Liquids**			
	inside diameter	Type:			
	operating pressure	Flow rate:			
	window material	Capacity:			
	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation	**Target Materials**	
	inside diameter	X	temporary use (at AP0 building) (at NuMI bypass tunnel, need negotiation)		Beryllium (Be)
	operating pressure	Type:	**Co-60, Na-22, Cs-137**		Lithium (Li)
	window material	Strength:	**100 uCi**		Mercury (Hg)
	window thickness	**Hazardous Chemicals**			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
	Permanent installation		PCBs		Uranium (U)
	Temporary installation	X	NE213 organic liquid scintillator (1.6 liters, sealed in aluminum capsule with O-ring)	X	Other (foils, Al, Bi, In, Au, Cu, Fe) (Irradiated at AP0 building, measured at counting room)
	Calibration		Methane	**Mechanical Structures**	
	Alignment		TMAE		Lifting devices
type:			TEA		Motion controllers - manual
Wattage:			photographic developers		scaffolding/elevated platforms
class:		X	Other: Activated Water and air		Others

APPENDIX II – SAFETY ANALYSIS ON REPLACEMENT OF SHIELDING CONCRETE

The concrete shield of the Pbar target station will be replaced by special blocks designed for setting activation samples. A schematic drawing of the special shield blocks is shown in Fig.A2-1. Some of the special shield-blocks have through-holes with cylindrical shape. The holes will be filled with concrete plugs during proton beam operation, and the special blocks and plugs will be made with the same concrete as the original ones. Therefore, the shielding performance of the special blocks as bulk shield is almost unchanged in comparison with the original ones. However contribution of neutron-streaming effect of gaps between the shield blocks and plugs may not be negligible for radiation dose rates on the concrete shield. In order to estimate the contribution of streaming effect, the radiation doses at the reference positions shown in Fig.A2-1 were compared with non-gap case by using the Monte Carlo calculation code of PHITS. Ratios of neutron dose at the reference position with cases between on-gap and non-gap are tabulated in Table.A2-1. The result shows that the neutron dose on the concrete surface increases partially at the gap positions by a factor of 2 at a maximum after the replacement of the shield blocks.

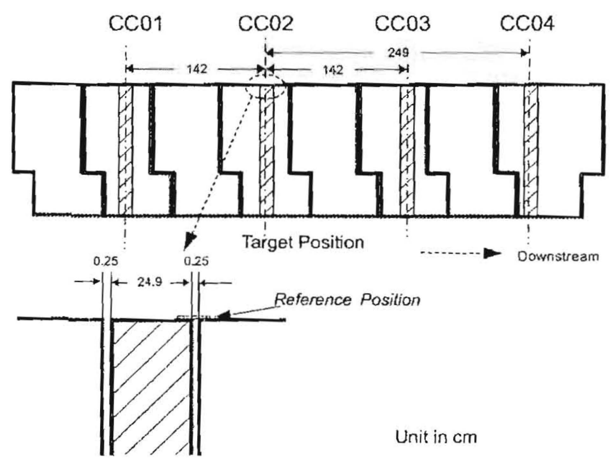

Fig. A2-1 Schematic drawing of the special concrete blocks. The positions of holes are named as CC01~CC04 from downstream to upstream for a proton beam direction, and the CC02 is located just on the target position. The plugs setting in the holes are shown by hatching. The gap between the plugs and the blocks are designed to be 0.25 cm.

Table A2-1 Ratios of neutron dose between on-gap and non-gap at the reference positions

Position	Ratio of Neutron Dose [On-gap/Non-gap]
CC01	2.0
CC02	1.4
CC03	1.3
CC04	1.0

APPENDIX III -- ELECTRONIC MODULES LOAN FROM PREP

The following electronic modules are needed to conduct the experiment. These modules are brought from Japan. Computing Division (PREP) may be asked to lend electronic modules for replacement of items in this list, if the need arises, and if those modules are available.

Number	Module name
<Scintillator>	
1	ADC (LeCroy 2249A)
1	TDC (LeCroy 2228A)
2	Constant Fraction Discriminator (ORTEC934)
2	Discriminator (LRS: 623B or 623A)
3	Gate & Delay Generator (EG&G)
2	Gate Generator (LRS 222)
2	Coincidence (LRS 622)
1	Level adopter (LRS 688AL)
2	Logic FAN-IN/FAN-OUT (LRS429A or 429)
2	High Voltage power supply (BERTAN210-05R, FLUKE 415B)
1	CAMAC Crate (DSP860C with power supply and fan)
3	NIM Crate (6V) (ORTEC 401[a] and 402H or equivalent PS)
1	Oscilloscope (faster than 200MHz) (TEK2465 or 2467)
2	NIM Crate (ORTEC 401A and 402H or equiv PS)

PPO

FERMILAB-PROPOSAL-0993-A1

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Directorate

ADDENDUM TO THE
MEMORANDUM OF UNDERSTANDING

T – 993 – A1

JASMIN in NuMI

Shielding and Radiation Effect Experiments by
Japanese-American Study of Muon Interactions and Neutron detection
(JASMIN Collaboration)
FNAL-Japan Radiation Physics Collaboration Team

January 17, 2013

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INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of JASMIN-3 who have committed to participate in beam tests to be carried out over three years, starting October 2012.

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.

This MOU fulfills Article 1 (facilities and scope of work) of the User Agreements signed (or still to be signed) by an authorized representative of each institution collaborating on this experiment.

In all the phases of the experimental work outlined in this MOU, the experimenters will abide by the Fermilab Environmental Safety and Health Manual (FESHM) as prescribed and guided by the laboratory's safety staff.

The efforts covered by this MOU are meant to be the continuation and extension of the JASMIN project (T-972 and T-993) - a study of shielding and radiation effects at the Pbar target station and NuMI hadron absorber region at Fermilab. The project includes research for high-energy, high-intensity accelerators, space applications in the areas of particle production, showering and transmission in thick targets, collimators and radiation shielding as well as of radiation effects on instruments and materials.

The purpose of this project is to obtain the following data for high-energy particles using Fermilab accelerator facilities:

(1) Shielding data,

Measuring quantity	- Energy spectra of generated and transmitted particles - Prompt dose rates - Radioactive nuclide production rates in materials and air
Location	- Beam line, target & beam dump - Inside & outside shield - Penetration duct

(2) Radiation effect data

Measuring quantity	- Absorbed dose - Radionuclide production and residual dose - DPA (displacement per atom) of materials - Soft error of semi-conductors
Location	- use same locations for shielding-data measurement 4

Since experimental shielding data in the energy region above 1 GeV is very scarce, the data from this experiment will be very useful for the following:

a) Benchmarking of simulation codes (MARS, PHITS and FLUKA):
   - Possible accuracy upgrade,
   - Modification of physical model and parameterizations.
b) Material science, space science, high-energy accelerator science and engineering:
   - Provide irradiation field for radiation effect studies of materials or devices
   - Development of simulation code for radiation damage and radionuclide production.
c) Radiation safety estimation:
   - Prompt dose distribution inside and outside shield and through penetration ducts
   - Residual activity in material and air

Two experiments at Pbar and NuMI were carried out in the former project JASMIN (T-972 and T-993) in Oct. 2007 – Mar. 2012:

a) Pbar experiment

   In order to estimate the radiation field characteristics on top of the Pbar target station, shielding experiments behind steel and concrete shields were carried out. Neutron reaction rates and flux distributions were measured by activation methods and various detectors. To understand the nuclear reactions occurring in the upper atmosphere from a geophysical aspect, residual nucleus distributions around air of the target was also measured using various filters. These data are undergoing analysis using the MARS and PHITS codes for benchmarking and establishing irradiation field.

b) NuMI experiment

   In order to study radioisotopes produced by cosmic fast muons and muon induced radioactivity in high intensity and energy accelerators as well as radiation characteristics downstream of the NuMI absorber, residual nucleus distributions and radiation reaction rate distributions were measured by the activation methods and some kinds of detectors. These data are also under analysis for benchmarking of MARS and inclusion of muon interaction in PHITS.

The Pbar experiment (a) has been successfully completed. In this MOU, the NuMI experiment (b) will be performed in the NuMI Muon Alcoves (termed "NuMI"). The project is planned to take three years (Oct. 2012 – Mar. 2015).

I. PERSONNEL AND INSTITUTIONS:

Spokespersons: Hiroshi Matsumura (KEK), Nikolai Mokhov (FNAL)

Fermilab Liaisons: Tony Leveling (AD), Aria Soha (PPD)

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	KEK (High Energy Accelerator Research Organization)	Japan	Hiroshi Matsumura	Scientist	
			Kotaro Bessho	Scientist	
			Toshiya Sanami	Scientist	
			Akihiro Toyoda	Technician	
			Shinichi Sasaki	Professor	
1.2	Kyoto University	Japan	Hiroshi Yashima	Scientist	
			Shun Sekimoto	Scientist	
1.3	Shimizu Corporation	Japan	Koji Oishi	Principal Scientist	
1.4	Fermilab	USA	Nikolai Mokhov	Scientist III	Energy Dep Dept, APC
			Igor Rakhno	Applications Physicist	APC
			Kamran Vaziri	Physicist	ES&H Rad Protection
			Tony Leveling	Engineering Physicist	AD, Muon
			David Boehnlein	Physicist	PPD, IF Dept
			Aria Soha	Engineering Physicist	PPD, IF&TB
			Gary Lautenschlager	Radiation Physicist	AD, ES&H Rad Safety

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

2.1 LOCATION

2.1.1 THE BEAM TEST(S) WILL TAKE PLACE IN:

NuMI Muon Alcoves 0 and 1:

- Confirmation of the muon beam position and direction (continued)
- Characterization of the secondary particle field around the hadron absorber (continued, needed to establish the technical method for characterizing the mixed field of neutrons and muons)

NuMI Muon Alcoves 2 – 5:

- Measurement of muon attenuation in rock (continued)
- Measurement of nuclide production by muons (continued)
- Measurement of muon and secondary particle spatial distribution (continued)

2.1.2 The experiment will also require the use of the North-east corner counting room in HIL (High Intensity Lab) for measurements of sample activities, with several Ge-detectors, for data analysis, and for storage of all detectors, electronics, etc. until the complete of the project.

Liquid nitrogen is required to be used in HIL for the Ge counting systems and special permission has been required in the past for this. Typically, there is a walkthrough by the village cryo review panel, most recently lead by Tom Page, to review the LN operating procedures JASMIN developed. Then, the PPD Head has to give approval for the temporary use of LN at HIL. AD has typically provided a few 160 liter Dewars of LN which covers the cryogenic needs for the typical 2 week counting room sessions. An AD or PPD liaison (see Section I) is required to be present when 30 liter Dewars are filled to observe the filling operation. The initial fill requires a couple of hours and then the Dewars are topped off weekly. A small Ge detector requires daily filling and does not required the presence of a liaison. The experiment can provide documentation on the operating procedures, walkthroughs, and previous approval process as required.

2.2 BEAM

2.2.1 BEAM TYPES AND INTENSITIES

The experiment expects to use the NuMI beam under whatever conditions are dictated by the NuMI experiments (MINOS+, MINERvA, NOvA).

2.2.2 Beam Sharing

The experiment expects to be parasitic and completely transparent to the NuMI experiments (MINOS+, MINERvA, NOvA). Although in an interlocked area, accesses are expected to be short and to take place during natural downtimes, few and far between.

2.3 Experimental Conditions

2.3.1 Electronics Needs

There are no custom electronics being used in the experiment. All electronics will be brought from Japan.

2.3.2 Description of Tests

Experimental schedules between October 2012 and March 2013 are shown in Table 1, which includes Japanese visitor schedules and NuMI access requests.

In March 2013, the Japanese collaborators will visit Fermilab to set new samples in the NuMI Muon alcoves. They will visit again for 2 weeks in the next year, during scheduled FTBF beam time. During the stay, the experimenters will access the NuMI Muon alcoves to remove the samples and install new samples when a natural beam downtime occurs. The visits, scheduled in April 2013 – March 2015, depend on the accelerator operation schedule and the available beam time of FTBF.

Table.1 Major experimental schedules, visit schedule and the access request for NuMI between October 2012 and March 2015

<table>
<tr><td>Facility</td><td>NuMI</td><td>FTBF (M01)</td><td rowspan="2">Visit Schedule</td><td rowspan="2">Access request for NuMI</td></tr>
<tr><td>Experimental Items:</td><td>Muon nuclear reaction and Muon behavior in rock</td><td>Basic experimental data</td></tr>
<tr><td>2013 (~March)</td><td rowspan="2">Nuclide production by muon in the hadron absorber hall, Alcove 1 and Alcove 2~4. Distribution of muon and secondary.</td><td></td><td>1week for sample setting at NuMI</td><td rowspan="2">During a regular shutdown period or natural downtime for setting samples and for removing them</td></tr>
<tr><td>2014</td><td>Proton-induced recoil property. Behavior of the Radioactive aerosol in air and colloid in water</td><td>1~2 weeks in total. The visit timing will depends on the accelerator operation schedule and FTBF beam time*</td></tr>
</table>

2015 (~March)			Same as above	

*FTBF beam time for 1~2 weeks will be requested every year.

2.4 SCHEDULE

The project is planned to take three years (Oct. 2012 – Mar. 2015).

III. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

3.1 KEK, KUR, ETC.:

- Shipping Ge-detectors, scintillation counters, activation samples etc. from and back to Japan.
- Setting up for Ge-detectors, active counters, and their electronic circuit.
- Setting and removing sample to be irradiated.
- Measurements of gamma rays from radionuclides from irradiated sample with Ge-detector.
- Active counter measurements.
- Chemical separation process.
- Data analysis.

	FY2009	FY2010	FY2011
(2) Experimental devices and activation detector	3.4k$	2.4k$	0k$
(3) Transportation of experimental devices	0.6k$	0.6k$	1k$
(4) Travel expense	48k$	40k$	48k$
Total	**52k$**	**43k$**	**49k$**

IV. Responsibilities by Institution – Fermilab

4.1 Fermilab Accelerator Division:

4.1.1 Radiation Survey and assistance to equip or remove the detectors
4.1.2 Assistance in transporting irradiated samples from the radiation area to a counting room at HIL
4.1.3 Accumulated toroid readings and POT history for the run
4.1.4 Coordinate access to the experimental area at AP0 building.
4.1.5 Organize Cryo Panel review and obtain PPD permission for use of LN in the HIL counting room, as specified in section 2.1.2.

4.2 Fermilab Accelerator Physics Center

4.2.1 Assistance for the experimenters of this project
4.2.2 Full simulation support prior and after measurements

4.3 Fermilab Particle Physics Division:

4.2.1 Receive irradiated samples at the HIL counting room from AD and provide handling and storage instructions for irradiated samples at HIL.
4.2.2 Assistance to transport irradiated samples from the radiation area to the counting room.
4.2.3 Ensure compatibility of JASMIN experimental apparatus with other existing experiments in the Hadron Absorber Room and Muon Alcoves.
4.2.4 Coordinate access to the muon alcoves during changing of detectors.
4.2.5 Accumulated toroid readings and POT history for the run.
4.2.6 100 lead bricks
4.2.7 Use of north-east corner counting room in HIL as described in Section 2.1.2
4.2.8 Conduct a NEPA review of the experiment.
4.2.9 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.
4.2.10 Provide safety training as necessary, with assistance from the ESH&Q Section.
4.2.11 Update/create ITNA's for users on the experiment.
4.2.12 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews.

4.4 Fermilab Scientific Computing Division

4.4.1 Internet access in the north-east counting room at HIL to observe a real-time beam status (the connection may already exist).

4.5 Fermilab ESH&Q Section

4.5.1 Assistance with safety reviews.

4.5.2 Use of a chemical laboratory in RAF for chemical separation of irradiated samples. (Only samples registering a contact dose rate of < 1 mrad/hr. can be processed at the Fermilab RAF chemistry lab and when this work does not interrupt services to the primary Fermilab program.)

4.5.3 Use of RAF Ge-detectors when available

4.5.4 Assistance for calibration of sources

4.5.5 Assistance in transporting irradiated samples to the counting room

4.5.6 Arrangement of a source storage box for calibration sources & irradiated samples in the counting room

4.5.7 Assistance with shipping radio-active samples to Japan

4.5.8 Provide safety training, with assistance from AD & PPD, as necessary for experimenters.

V. Summary of Costs

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Particle Physics Division	0.0	1.0
Accelerator Division	0	2.5
Scientific Computing Division	0	0
ESH&Q Section		
Totals Fermilab	$0.0K	1.5
Totals Non-Fermilab	$144K	14

VI. GENERAL CONSIDERATIONS

6.1 The responsibilities of the Spokespersons 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 Spokespersons agree 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 (ESH&Q) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokespersons 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 spokespersons will ensure that at least one person who is knowledgeable about the experiment's hazards is present at the access of the AP0 building, NuMI muon alcoves, or NuMI absorber.

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 ESH&Q 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 Spokespersons 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 Scientific Computing Division management. The Spokespersons also undertake to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector 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 Spokespersons are 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 Spokespersons 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 ESH&Q 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 effort at a Fermilab All Experimenters' Meeting.

MOU for JASMIN-3 in NuMI

SIGNATURES:

松村 宏 / 1/8/2013

Hiroshi Matsumura, Experiment Spokesperson, KEK

1 / 25 / 2013

Nikolai Mokhov, Experiment Spokesperson, APC, Fermilab

佐々木 慎一 1 / 12 / 2013

Shinchi Sasaki, Director of Radiation Science Center, KEK

Roger Dixon, Accelerator Division, Fermilab — 2 /15 /2013

Vladimir Shiltsev, Accelerator Physics Center, Fermilab — 1 /26 /2013

Michael Lindgren, Particle Physics Division, Fermilab — 1 /25 /2013

Robert Roser, Scientific Computing Division, Fermilab — 2 /6 /2013

Nancy Grossman, ESH&Q Section, Fermilab — 1 /31 /2013

Greg Bock, Associate Director for Research, Fermilab — 2 /15 /2013

Stuart Henderson, Associate Director for Accelerators, Fermilab — 2 /18 /2013

APPENDIX I: - 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	Irradiated foils or disks:
Radioactive Sources		**Target Materials**			photographic developers	Al, Bi, In, Au, Cu, Fe
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
X	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:	Co-60, Na-22, Cs-137		Mercury (Hg)		TEA	
Strength:	100uCi		Lead (Pb)		TMAE	
Lasers			Tungsten (W)	X	Other: Activated water and air	
	Permanent installation		Uranium (U)			
	Temporary installation	X	Other: Foils: Al, Bi, In, Au, Cu, Fe	**Nuclear Materials**		
	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:			Capacitor Banks	**Mechanical Structures**		
Wattage:		X	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:		X	LN2 filled Ge detector	
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.

Roger Dixon, Accelerator Division, Fermilab — 2/15/2013

Vladimir Shiltsev, Accelerator Physics Center, Fermilab — 1/25/2013

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