SpinQuest E1039 TSW

09.04.2020

SpinQuest Collaboration

Overview

This is a technical scope of work (TSW) document between the Fermi National Accelerator Laboratory (Fermilab) and its various divisions involved and the responsible parties noted in this document. The TSW is intended primarily for the purpose of recording expectations for budget estimates and work allocations for Fermilab. 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 scope of work to reflect such required adjustments. Actual contractual obligations may be set forth in separate documents such as the Collaboration Memorandum of Understanding (MOU) which outlines the agreements between SpinQuest and its members.

Motivation and Goals

It is well known that the proton is a spin-1/2 particle, but how the constituents (quarks and gluons) assemble to this quantized spin is still a mystery. There is a worldwide effort to map out the individual contributions to the proton spin. It is established that the quark spins contribute around 30%, while the gluon intrinsic angular momentum contribution is still under active investigation at the Relativistic Heavy Ion Collider. Fully resolving the proton spin puzzle requires information on the orbital angular momentum (OAM) of both quarks and gluons. Recent studies have shown that the so-called transverse momentum dependent parton distribution functions (TMDs) can inform us about the OAM of the partons.

One of the most important TMDs, and the main focus of E1039, is the so-called Sivers function. It was introduced in 1990 to help explain the large transverse single-spin asymmetries observed in hadronic pion production at Fermilab. The quark Sivers function represents the momentum distribution of unpolarized quarks inside a transversely polarized proton, through a correlation between the quark momentum transverse to the beam and the proton spin. On one hand, the Sivers function contains information on both the longitudinal and transverse motion of the partons and provides a unique way to perform 3-dimensional proton tomography in momentum space. On the other hand, it has been shown that there is a close connection between the Sivers function and quark OAM. Though the search for a rigorous, model-independent connection is still ongoing, it is clear that the existence of a non-zero Sivers function requires non-zero quark OAM. From a detailed analysis of the azimuthal distribution of the produced particles from a transversely polarized nucleon, one can deduce properties of the nucleon structure. Thus, a direct measurement of the Sivers function for the antiquarks has become crucial and can only be accessed cleanly via the Drell-Yan process. In the Drell-Yan process, a quark (antiquark) in the beam hadron annihilates with an antiquark (quark) in the target. E1039 will perform the first measurement of the sea quark Sivers function, using Drell-Yan production from an unpolarized 120 GeV proton beam scattering off a transversely polarized proton target.

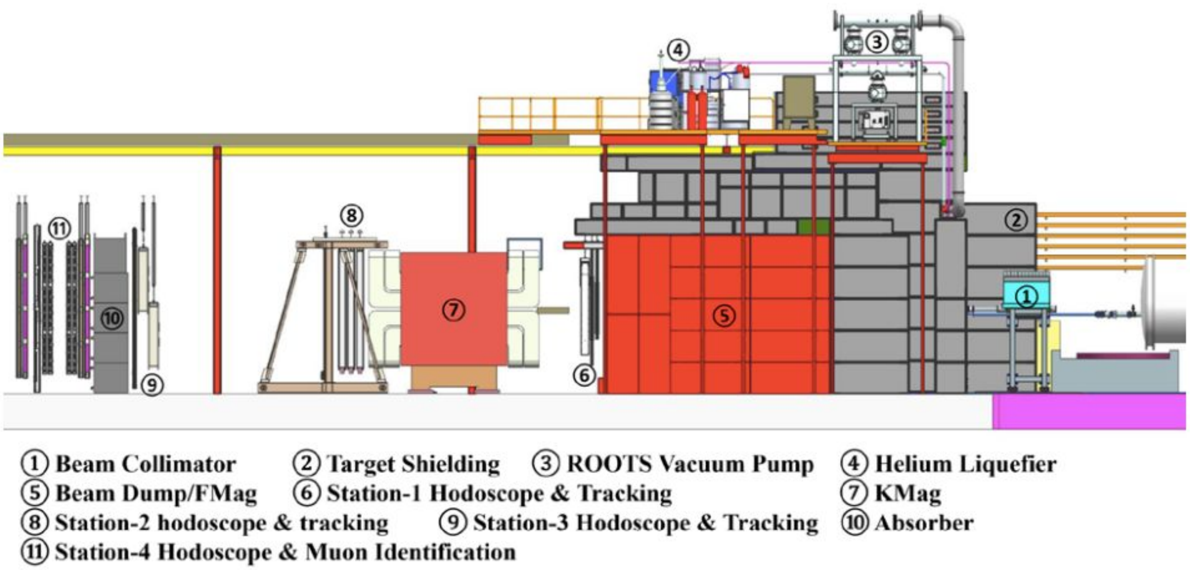

FIGURE 1 -- Beamline, target shielding cave, and muon spectrometer for SpinQuest

The experiment will use the E906/Seaquest spectrometer in the NM4 enclosure (see Fig. 1 above) with a modified beamline and will replace the current targets with a completely new transversely polarized system, jointly built by Los Alamos National Lab and the University of Virginia. This is a target with a transverse field configuration using the technique of dynamic nuclear polarization (DNP). In DNP, a microwave oscillator populates the desired polarization state through the hyperfine coupling between electrons and protons. It uses the fact that, while the electron spin relaxation time is short, the proton stays in the enhanced state due to a long spin relaxation time. Such a target requires a large pumping system to reduce the temperature of the liquid helium to 4K plus a closed loop helium liquefier system. The target material consists of frozen beads of NH3 and possibly ND3 immersed in a liquid helium bath.

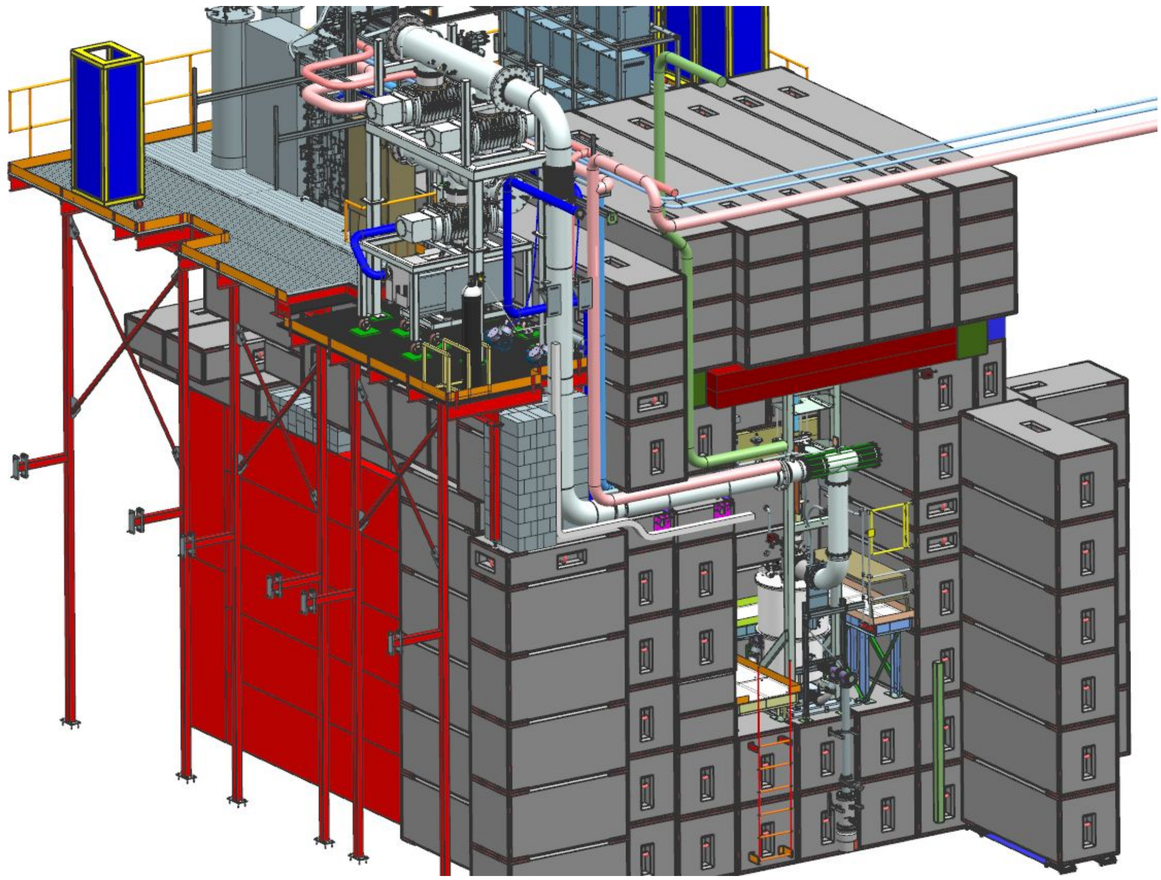

FIGURE 2 -- Detail view of target area and cryogenic support system

The transversely polarized target includes a superconducting 5T magnet upstream of the previous E906 target position and an associated refrigerator. This will require a rebuild of most of the target cave and the FMAG shielding. In addition, the target will require a large 15000 m^3/hr pump system to cool the system to 1K, shown in Figure 2 on the left side. To provide liquid Helium for the operation of the target, a closed loop system with a liquefier will be installed, shown on the platform behind the top shielding blocks. Also shown, in Figure 1, is a new collimator, which will be placed upstream of the target to protect the superconducting magnet from the beam.

Personnel

All SpinQuest Collaboration Full Members are listed below by institution at the time of this TSW document. The PI for each institution is presented in bold. These PIs from each institution serve or select a representative to serve on SpinQuest Institutional Board which is the main deliberative body of the collaboration. All SpinQuest collaboration members are asked to participate in a service commitment to the collaboration. These commitments along with the entirety of roles and responsibilities are presented in the ***Experimental Operations Plan*** (EOP) document. This document is amended with the SpinQuest

Memorandum of Understanding (MOU) with new members and new service commitments as needed.

Institution	**Country**	**Personnel**	**Position**
Abilene Christian University	USA	Michael Daugherity **Donald Isenhower** Shon Watson	Faculty Faculty Physicist
Argonne National Laboratory	USA	**Paul Reimer** Donald Geesaman	Physicist Physicist
Fermi National Accelerator Laboratory	USA	**Richard Tesarek** Carol Johnstone Charles Brown Cristina Suarez	Physicist Physicist Physicist (retired) Postdoc
University of Illinois, Urbana-Champaign	USA	**Jen-Chieh Peng** Ching Him Leung	Faculty Grad Student
Shandong University	China	**Qinghua Xu** Zhaohuizi Ji	Faculty Grad Student
KEK, Tsukuba, Ibaraki	Japan	**Shin'ya Sawada**	Faculty
Tokyo Institute of Technology	Japan	**Kenichi Nakano** Toshi-Aki Shibata	Faculty Faculty
Los Alamos National Laboratory	USA	**Kun Liu** Ming Liu Mikhail Yurov Astrid Morreale Kei Nagai	Scientist Scientist Postdoc Scientist Postdoc
University of Michigan, Ann Arbor	USA	**Wolfgang Lorenzon** Minjung Kim Ievgen Lavrukhin Noah Wuerfel	Faculty Postdoc Postdoc Grad Student
Mississippi State University	USA	**Lamiaa El Fassi** Dipangkar Dutta Catherine Ayuso Nuwan Chaminda	Faculty Postdoc Grad Student Grad Student
University of New Hampshire, Durham	USA	**Karl Slifer** David Ruth	Faculty Grad Student
RIKEN, Wako, Saitama	Japan	**Yuji Goto**	Faculty
University of Virginia	USA	**Dustin Keller** Zulkaida Akbar Ishara Fernando Anchit Arora Liliet Diaz	Faculty Postdoc Postdoc Grad Student Grad Student
Yamagata University	Japan	**Yoshiyuki Miyachi**	Faculty
New Mexico State University	USA	**Stephen Pate** Vassili Papavassiliou Abinash Pun	Faculty Faculty Postdoc

		Forhad Hossain Dinupa Nowarathne	Grad Student Grad Student
University of Colombo	Sri Lanka	**G.D.N. Perera** Vibodha Bandara Harsha Sirilal	Faculty Grad Student Grad Student
Alikhanian National Science Laboratory (Yerevan Physics Institute)	Armenia	**H. Marukyan**	Physicist

Experimental Area and Other Considerations:

I. Location

The experiment will take place in the NM4 hall at Fermilab.

Lab space near the experiment is required to set up the polarized target, to work on target material, and to fill the new target cells. Office space is needed for 10 physicists participating in the running and analysis of the experiment. Approximately 500 ft^2 is needed for target preparation which will include bringing in liquid nitrogen dewar.

II. Experimental Effort Conditions

Area Infrastructure

E1039 will continue to use the E906 spectrometer and require additional facility infrastructure. Fermilab will be responsible for decommissioning the E906 target and associated infrastructure around FMAG and the shielding currently in place around FMAG. Fermilab will also provide cooling water to pumps and cryogenic plants and will be responsible for the other conventional facilities in the NM4 hall. The collaboration has secured funding for the design and installation of E1039 from DOE, Office of Nuclear Physics. This will cover the costs of the design and installation of the E1039 target and the associated shielding and installation as well of a new protection collimator. This work will be performed by PPD and AD staff using the NP installation funds. For the installation of E1039, the target position has to be moved upstream from the current E906 position. This requires a new shielding design around FMAG, which has been performed by FNAL engineers and physicists. A new target stand for the polarized target will be designed, fabricated, and installed. Cryogenic transfer lines and pumping lines will be installed to provide the necessary connections between the target and the liquefier and the pump stand. In order to place this new equipment, a platform on top of FMAG must be designed and built. A new beam luminosity monitor will be installed in the rebuilt target cave. To protect the superconducting coils from any accidental beam movement, a copper collimator will be installed upstream of the target.The experiment will continue to use the existing beam monitoring equipment. Approximately 317kVA of 480VAC power is required to drive the pumps for the polarized target and the liquefier plant (Quantum Technology 160 liter/day system). Additionally, 65kVA of 120VAC and 208VAC electrical power will be needed for cryogenic controls, superconducting magnet power and target controls systems both on the cryo-platform and in the target cave. Approximately 200kW of water cooling for the liquefaction plant and vacuum pumps will be needed. The helium liquefier will require buffer gaseous helium tanks placed in the outside of NM4 as well as liquid nitrogen lines running from a large dewar outside the NM4 facility. A list of potential hazards that may require review can be found in Appendix II.

BEAM STRUCTURE AND REQUIREMENTS

The experiment will use a primary proton beam with a momentum of 120 GeV extracted from the Main Injector. The experiment requires a slow spill with a maximum rate of 5×10^{12} protons/spill with a macroscopic duty factor of 6% (one 4.2 second spill per minute) for a total of 2.8×10^{18} protons in a period of two years from the beginning of the experiment. The microscopic spill structure to the Fermilab beam is such that the protons are delivered in “buckets” that occur every 19 ns. The microscopic duty factor represents how evenly the protons are distributed over these buckets The microscopic duty factor is required to be 50% as measured by the experiment beam Cherenkov detector and the Accelerator Division. In the following table, we summarize the assumed efficiencies for the experiment that were used to determine the above POT and run-length requirements. The Target/Accelerator efficiency encompasses the down time by either the accelerator or the target. This is a conservative estimate assuming that these down times are independent. However, some of the target activities can be performed during planned accelerator downtimes, thus increasing the overall efficiency. The Spectrometer efficiency captures downtimes due to DAQ or hardware issues and trigger deadtime and is based on the E906 experience.

The contributing efficiencies to consider are included in the table below. The Target/Accelerator efficiency is an estimate of the contribution of acceptable protons delivered to the target. The spectrometer up-time, detection efficiency and overall acceptance are also listed. We also expect a trigger efficiency of approximately 50%. There is also a good percentage of events that are indistinguishable from background as well as some percentage that can not be reconstructed accurately. Together this contribution is approximately 60%.

Target/Accelerator Efficiency	Spectrometer Efficiency	Acceptance	Trigger Efficiency	Reconstruction Efficiency
50%	80%	2%	50%	60%

ELECTRONICS AND COMPUTING NEEDS

We will continue to utilize all the Fermilab electronic/computing facilities and resources that have been provided to the E906 collaboration, with additional support of a LabView-based target control computer. Below is a brief summary of the main computing needs; for detailed information on each item, please refer to the complete TSW between Fermilab Computing Sector and SeaQuest experiment (http://seaquest-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=1365).

Core computing services

- Authentication and directory services
- Backup and restore
- Central web hosting, for collaboration homepage and experiment monitoring tools
- LISTSERV, for mail list discussions
- Network service and infrastructure, including network setup and maintenance in both control room and experiment hall. Assistance in network security.
- Service desk support (24X7 network support to NM4)

Scientific services

- Distributed computing, including FermiGrid and Open Science Grid support and corresponding data storage
- Standard PREP support, including onsite replace/repair, and offsite loans. Please refer to Appendix I for more details
- Collaboration tools:
    - Redmine for software repository host and wiki
    - DocDB for documentation
    - ECL for experimental log and shift management

Operations Needs

Once the experiment is commissioned, the polarized target will require changing approximately once per week. During the target change, the experiment will require space for handling the old/new cryogenic target material in the NM4 building. The actual changeout will also require approximately 1/2 hour access time in the target cave with Fermilab Rad-Tech coverage.

- Target material changes: Every 7 to 10 days, will require entry in the target cave for 30 minutes 15 minutes in and out. (Rad tech coverage)
- Target material preparation and filling of cell; needs ES&H review of procedure
- Cooling water to FMAG, KMAG
- Chilled water to polarized target pumps and liquefier
- Electrical lines to pumps and liquefier plant (E1039 Installation costs)
- Rigging for installation of different components (E1039 installation costs)
- Maintenance and every day support of wire chambers (FNAL and collaboration)
- QIE and beamline instrumentation (FNAL)

- Occasional rigging and crane support (average once a week)
- Detector survey
- Beam line tuning and commissioning (collimator)
- Support wire chamber gas handling system
- Liquid nitrogen filling

EXPERIMENT MILESTONES

Start Installation: After completion of E906 decommissioning

- Install new target stand and polarized target
- Build new shielding in NM3
- Install platform on FMAG
- Install electrical circuits
- Install Target pumps and Helium liquefier
- Hook up cryolines of target and pumping lines
- Start commissioning target
- Start commissioning experiment
- Start data taking

III. Responsibilities by Institution

Responsibility	Primary Institution	Secondary Institutions
Spectrometer	LANL	FNAL
Target and Cryogenics	UVA	LANL
Slow Controls (Spec)	LANL	ANL
Slow Controls (Target)	University of Colombo	LANL, UVA, UNH
Hodoscope	NMSU	ACU, UVA
Chambers	MSU	LANL
Prop. Tubes	Shandong University	LANL, UVA
DAQ	LANL	UIUC, ANL
Trigger	UMich	ANL
Simulation	NMSU	UVA

Offline Reconstruction	NMSU	UVA
Online Reconstruction	MSU	NMSU, UMich
Data Analysis	UVA	MSU, NMSU
Onsite Computers	UIUC	ANL
Fiber Hodoscope	LANL	FNAL

IV. Responsibilities by Division -Fermilab

FERMILAB PARTICLE PHYSICS DIVISION

- Remove E906 target and disassemble target shielding.
- Provide personnel for installation of target, shielding, and target service equipment.
- Update/create ITNA's for users on the Experiment. Responsibility of the spokesperson or Fermilab Point of Contact.
- Initiate the Fermilab Operational Readiness Clearance, ODH, shielding, and environmental reviews and any other required safety reviews.
- Provide technical support for Fermilab-designed electronics. Technical support includes maintenance repair and engineering support, if needed, for the drift chamber Analog Shaper, Discriminator, Charge (ASDQ) boards, the drift chamber level translator boards and the Charge Integrator-Encoder (QIE) readout system for the beam intensity monitor.
- Provide repair and maintenance of the plumbing and instrumentation for wire chamber gas systems.
- Provide facilities for the collaboration to use for hodoscope (scintillator and light guide) repair and maintenance.
- Provide facilities for the collaboration to use for repair of the wire chambers
- Provide counting house and electronics areas with appropriate utilities installed.
- Provide necessary cooling to counting house
- Provide the same number of electronic equipment racks as used in E906 (25)
- Provide equipment staging areas as needed for work on polarized target
- Provide office space and furniture for approximately 10 persons for the duration of the experiment and analysis.
- Provide an alignment survey of the spectrometer once installed. The experimenters will supply alignment marks on the detector elements in consultation with Fermilab.

FERMILAB SCIENTIFIC COMPUTING DIVISION

Summary of PREP equipment pool needs.

• See Appendix I.

Computing:

- Provide appropriate networking at NM4 hall including WiFi in both the counting area and detector hall for commissioning, data transfers to mass storage, network access for users' laptops, etc. Provide firewalls/bridges which Fermilab deems necessary to isolate the experiment's network from the general Fermilab network.
- Provide "General Computing" accounts for collaborators. Primary analysis and Monte Carlo computing will be done on LINUX-based PC's provided by the collaboration.
- Provide storage for 50 TB of raw data. The collaboration also plans to keep a second copy of the raw data on a separate disk system.
- Support for 4 virtual machines.

Fermilab ESH&Q Section

- Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary. A list of potential hazards can be found in Appendix II.
- Review of the target shielding plan and the procedure for weekly target exchanges.
- Provide radiation safety interlocks and handle all aspects of radiation safety monitoring for the beam intensity delivered.
- Continued use of sources assigned to E906
- Provide ES&H training, with assistance from PPD, as necessary for researchers.
- Provide Rad Tech support during installation of the target shielding and collimator
- Provide Rad Tech support every 7 -10 days for 0.5 hours entry in target cave and storage of used target materials.
- Provide Rad Tech coverage as needed for repairs of target or spectrometer equipment.
- Provide necessary guidance and support to complete or update SAD, USID and ASE

Fermilab Accelerator Division

  - Provide quality beam meeting condition previously described
  - Install collimator
  - Provide, maintain, and operate the necessary equipment for the safe and efficient transport of primary beam to the experiment

Summary of Costs

The following describes the agreement for project funding as we understand it but the exact details remain to be worked out between the DOE NP and HEP.

FNAL funded by DOE-HEP will support the project construction and the expense associated with the preparation of the safety review. Once the green light is given by FNAL to run and commissioning of the beam and target are complete DOE-NP will fund the required run time to achieve the proposed statistical precision. This is expected to take two years of running. DOE-NP is expected to pay for all running costs including the operation and necessary maintenance expenses for the target and spectrometer outside of the FNAL-owned components. DOE-NP is also responsible for the expense of the beam operations during running.

E1039 will continue to use the E906 spectrometer and require additional facility infrastructure.

Fermilab will be responsible for decommissioning the E906 target and associated infrastructure around FMAG and the shielding currently in place around FMAG. Fermilab will also provide cooling water to pumps and cryogenic plants and will be responsible for the other conventional facilities in the NM4 hall.

The collaboration has previously secured partial funding for the design and installation of E1039 from DOE, Office of Nuclear Physics. This will partly cover the costs of the design and installation and cryogenic safety review preparations of the E1039 target and the associated shielding and installation as well of a new protection collimator. This work will be performed by PPD and AD staff using the NP installation funds. The remainder of the expense associated with construction and the preparation for the safety review should be covered by FNAL with support from HEP-DOE. All expenses associated with modification of instrumentation not in the FNAL scope should be covered by the SpinQuest collaboration with support from their corresponding funding agencies.

For the installation of E1039, the target position has to be moved upstream from the current E906 position. This requires a new shielding design around FMAG, which has been performed by FNAL engineers and physicists. A new target stand for the polarized target will be designed, fabricated, and installed. Cryogenic transfer lines and pumping lines will be installed to provide the necessary connections between the target and the liquefier and the pump stand. In order to place this new equipment, a platform on top of FMAG must be designed and built.

A new beam luminosity monitor will be installed in the rebuilt target cave. To protect the superconducting coils from any accidental beam movement, a copper collimator will be installed upstream of the target.

The experiment will continue to use the existing beam monitoring equipment, but will need a multiwire SWIC, available from FNAL.

Two 200A, 480V circuits are required to drive the pumps for the polarized target and the liquefier plant (Quantum Technology 160 liter/day system) as are electrical connections in the target cave area.

The Helium liquefier will require buffer tanks placed in the outside of NM4 as well as liquid nitrogen lines.

A list of potential hazards that may require review can be found in Appendix II.

General Considerations

- The responsibilities of the participants in the Experiment and the procedures to be followed by researchers are found in the Fermilab ES&H Manual: FESHM 1080 (http://esh- docdb.fnal.gov/cgi-bin/RetrieveFile?docid=347). The participants in the Experiment agree to those responsibilities and to ensure that the researchers all follow the described procedures.
- 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/Neutrino Division committee according to the requirements of FESHM 2005 (http://esh-docdb.fnal.gov/cgi- bin/RetrieveFile?docid=3311).
- 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.
- All items in the Fermilab Policy on Computing will be followed by the researchers.
(http://computing.fnal.gov/cd/policy/cpolicy.pdf).
- The participants in the Experiment 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 Spokespeople also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector management.

- The participants in the Experiment 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 listed in Appendix I. 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:
- The participants in the Experiment 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 participants in the Experiment will be required to furnish, in writing, an explanation for any non-return.
- The researchers agree to remove their equipment as requested by the Laboratory. 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 researchers unless removal requires facilities and personnel not able to be supplied by them, such as rigging, crane operation, etc.

V. SIGNATURES:

The Spokespeople are the official contacts and are responsible for forwarding all pertinent information to the rest of the group, arranging for their training and requesting ORC or any other necessary approval for the experiment. The spokespeople are responsible for marking equipment with emergency contact information and according to Fermilab Environmental Safety and Health Manual (FESHM) and Fermilab Radiation Control Manual (FRCM) rules.

Spokespeople of E1039: ______________________________________

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The following people have reviewed this TSW:

PPD Head: ______________________________________

AD Head: ______________________________________

SCD Head: ______________________________________

ESH&Q Head: ______________________________________

Appendix I: Equipment Needs

Equipment Pool and Host Division items needed to support effort (acquisition of PREP equipment is the responsibility of the researcher).

PREP Equipment Pool:

UNIT	Description	Number
ASTRO: 5103	FAN,CRATE,NIM,3 UNIT	1
ASTRO: 5103BB	FAN,CRATE,NIM,3 UNIT	1
ASTRO: 5106	FAN,CRATE,NIM/VME,6 UNIT	1
BLP: 1011	POWER SUPPLY,NIM,6@5A,12@2A,24@1A	4
BLP: 1011PG	POWER SUPPLY,NIM,6@5A,12@2A,24@1A	1
BLP: 1012	POWER SUPPLY,NIM,6@5A,12@2A,24@1A	1
BLP: 1012H	POWER SUPPLY,NIM,6@10A,12@2A,24@1A	2
BNC: 8020	GENERATOR,PULSE,125MHZ,NIM	1
CHRONETI: M21	DELAY,VARIABLE,NIM,2CH,.5-63.5NS,RACKMOUNT	1
DAWN: 11-1008617	SUBRACK,6U VME,20 SLOT,INTEGRATED PS AND FANS,INTERLOCKED,DART SPEC	5
DAWN: 11-1008741	SUBRACK,6U VME,9 SLOT,DESKTOP DEVEL,350W (5@50,+12@8,-12@4) INTEG. PS AND FANS	1
DAWN: 11-1010638-13A	SUBRACK,6U*160,VME-64,21 SLOT,ENET PORT,INTEGRATED 800W (TEV-BPM) DAWN ECO XXX	1
DSP: 860C	CRATE,CAMAC	3
DSP: 860C-Y1>+6	CRATE,CAMAC,Y1 TO +6V	2
DSP: 860F	FAN,CRATE,CAMAC	5
DSP: 860P	POWER SUPPLY,CAMAC,6@50;12@3;24@6	5
ELMA: 14VS-0716-RDVZ1J12-P750	SUBRACK,VME,21 SLOT,750W	1
FERMI: 029029	FAN,CRATE,NIM	2
FERMI: 11X2562	DIVIDER,HV,SHV-SHV	1
FERMI: 2107	FAN,CRATE,NIM	2
FERMI: ES-7092V	DIVIDER,HV,VERNIER,SHV-SHV	5
FERMI: ES-7109	POWER SUPPLY,HV,2CH,NEGATIVE,MWPC,NIM,(AKA DROEGE)	7
FERMI: ES-7139	FAN-IN/OUT,LINEAR,8CH,NIM	1
FERMI: RFD14	CONVERTER,32CH,NIM/ECL,RACKMOUNT	1
FERMI: RFD15	CONVERTER,32CH,NIM/ECL,RACKMOUNT	1
FERMI: RFDVS	SCALER,VISUAL,3CH,100MHZ,RACKMOUNT	1
FLUKE: 412B	POWER SUPPLY,HV,2KV@30MA	1
FLUKE: 415B	POWER SUPPLY,HV,3KV@30MA	4
FLUKE: 77	MULTIMETER,DIGITAL,HANDHELD	1
JOERGER: GG	GENERATOR,GATE,2CH,NON-UPDATING,NIM	5
JORWAY: 1880B	SCALER,2CH,VISUAL,NIM	2
LAMBDA: LM-E5	POWER SUPPLY,LV,5V@20A	5

UNIT	Description	Number
LAMBDA: LPD-421A-FM	POWER SUPPLY,LV,2CH,0-20V@1.7A	1
LRS: 127FL	FAN-IN,2CH,8-IN,LIN,BIPOLAR,NIM	1
LRS: 133B	AMPLIFIER,2CH,X1-X10,LIN,NIM	1
LRS: 1441	POWER SUPPLY,LV,1440 SYS	7
LRS: 1442	POWER SUPPLY,LV,1440 SYS	10
LRS: 1443NF/12	CARD,HV,16CH,NEG,1440 SYS	53
LRS: 1445	CONTROLLER,HV,1440 SYS	15
LRS: 1447	CONTROLLER,HANDHELD DIAGNOSTIC,1440 SYS	1
LRS: 1449M	MAINFRAME,HV,1440 SYS	6
LRS: 222	GENERATOR,GATE,2CH,NIM	18
LRS: 2249A	ADC,12CH,10B,Q,CAMAC	4
LRS: 3001	ANALYZER,QVT,MULTI-CHANNEL,NIM	2
LRS: 321B	DISCRIMINATOR,4CH,UPDATE,NIM	1
LRS: 335	AMPLIFIER,4CH,X6,LIN,NIM	1
LRS: 364	LOGIC,2CH,4-FOLD,MAJORITY,NIM	1
LRS: 365AL	LOGIC,2CH,4-FOLD,MAJORITY,NIM	8
LRS: 365ALP	LOGIC,2CH,4-FOLD,MAJORITY,NIM	2
LRS: 370	COINCIDENCE,STROBED,NIM	2
LRS: 4001	PROBE,LOGIC,ECL	1
LRS: 420I	DISCRIMINATOR,8CH,NIM	1
LRS: 429	FAN-IN/OUT,4CH,LOGIC,NIM	16
LRS: 429A	FAN-IN/OUT,4CH,LOGIC,NIM	25
LRS: 4413	DISCRIMINATOR,16CH,UPDATE,CAMAC	56
LRS: 4413F	DISCRIMINATOR,16CH,UPDATE,CAMAC	5
LRS: 4416	DISCRIMINATOR,16CH,CAMAC	1
LRS: 4616	CONVERTER,16CH,ECL/NIM/ECL,NIM	50
LRS: 465	LOGIC,3CH,4-FOLD,COINC,W/VETO,NIM	2
LRS: 612A	AMPLIFIER,12CH,X10,PHOTOMULT,NIM	7
LRS: 621BL	DISCRIMINATOR,4CH,110MHZ,BURST GUARD,NIM	2
LRS: 621BLP	DISCRIMINATOR,4CH,110MHZ,BURST GUARD,REMOTE PROGRAMMABLE,NIM	8
LRS: 621L	DISCRIMINATOR,4CH,NIM	2
LRS: 622	LOGIC,FAN-IN,4CH,2-FOLD,COINC,110MHZ,VETO,NIM	1
LRS: 623	DISCRIMINATOR,8CH,UPDATE,100MHZ,NIM	14
LRS: 624-16	MEANTIMER,8CH,NIM,16NS	10
LRS: 624-32	MEANTIMER,8CH,NIM,32NS	1
LRS: 624L	MEANTIMER,8CH,NIM	1
LRS: 688	ADAPTER,LVL,NIM/TTL-TTL/NIM,NIM	3
LRS: 821	DISCRIMINATOR,4CH,100MHZ,BURST GUARD,NIM	8
LRS: HV4032A/M	MAINFRAME,HV	1
LRS: HV4032A1N	POD,HV,4CH,NEG,3.3KV	8
MECHTRON: 151	BIN,NIM	3

UNIT	Description	Number
MECHTRON: 152	BIN,NIM	1
MECHTRON: 201	POWER SUPPLY,NIM,6V@10A,12V@3A,24V@1.5A	8
MECHTRON: 3034	BIN,NIM	14
MOTOROLA: MVME2304-0133	PROCESSOR,VME,SBC,333MHZ MPC 604,64MB DRAM,10/100 E-NET,4MB FLASH,IEEE 1101 HNDLS (43B)	1
MOTOROLA: MVME5500-0163	PROCESSOR,VME,SBC,1GHZ MPC7455,512MB SDRAM,10/100 E-NET,GIGE,IEEE HANDLES	25
NUC SPEC: PMF-875	BIN,NIM	1
ORTEC: 401A	BIN,NIM	14
ORTEC: GG202/N	GENERATOR,GATE,2CH,NIM	1
ORTEC: M127/N	FAN,CRATE,NIM	5
ORTEC: T140/N	DISCRIMINATOR,4CH,ZERO CROSS,NIM	1
PD: 1570-M4	POWER SUPPLY,HV,3KV@40MA	3
PD: AEC-320-5	POWER SUPPLY,NIMLP,12@2A,24@1A	1
PD: AEC-320-9	POWER SUPPLY,NIM,6@10A,12@3A,24@1.5A	18
PD: AEC-320-9-BPG	POWER SUPPLY,6@10A,12@3A,24@1.5A,NIM	1
PHILLIPS: 417	GENERATOR,PULSE,POCKET	3
PHILLIPS: 710	DISCRIMINATOR,8CH,UPDATE,150MHZ,NIM,THRESHOLD(-30MV/-1V),NIM	1
PHILLIPS: 7106	DISCRIMINATOR,16CH,LATCH,125MHZ,CAMAC	10
PHILLIPS: 710D	DISCRIMINATOR,8CH,UPDATE,150MHZ,NIM,THRESHOLD(-10MV/-1V)	2
PHILLIPS: 7126	TRANSLATOR,LVL,TTL/NIM/ECL,100MHZ,CAMAC	1
PHILLIPS: 726	TRANSLATOR,LVL,TTL/NIM/ECL,150MHZ,NIM	4
PHILLIPS: 740	FAN-IN/OUT,4CH,LINEAR,250MHZ,NIM	1
ROTRON: 029029	FAN,CRATE,NIM	2
SCHROFF: VMECRATE-21-PWR	SUBRACK,VME,21 SLOT,6U,POWERED	1
SEC: 850C	CRATE,CAMAC	5
SEC: 850F	FAN,CRATE,CAMAC	5
SEC: PCS850	POWER SUPPLY,6@50A,12@3A,24@6A,CAMAC	5
TEK: 2465A	OSCILLOSCOPE,4CH,350MHZ	1
TEK: 2465B	OSCILLOSCOPE,4CH,400MHZ	1
TEK: 2467B	OSCILLOSCOPE,4CH,400MHZ	2
TEK: TDS640A	OSCILLOSCOPE,DIGITAL REAL TIME STORAGE,4 CHAN,500MHZ,2GS/SEC	1
TEK: TDS640A-13-1F-2F	OSCILLOSCOPE,DIGITAL REAL TIME STORAGE,4 CHAN,500MHZ,2GS/SEC,HARD COPY,FILE SYSTEM,ADVANCED MATH	1
VK: 5900	POWER SUPPLY,HV,2CH,NEGATIVE,MWPC,NIM,(AKA DROEGE)	13
VK: 6900	POWER SUPPLY,HV,2CH,POSITIVE,MWPC,NIM,(AKA DROEGE)	11

Appendix II: - Hazard Identification

Flammables (gas, liquids):

Argon, Isobutane, Methylal (85.3%: 12.6%: 2.1% mix): Total Volume: 60.1 ft^3

Flow Rate: < 0.1 SCFH

Gasses:

Argon, CO_2 (80% :20% mix): SWICs (NM2, NM3) Total Volume: 1ft^3

Flow Rate: < 0.1 SCFH

Argon, Methane, CF_4 (88%: 8%: 4% mix): Total Volume: 610 ft^3

Flow Rate: ~1 SCFH

Hazardous Chemicals:

None

Other Hazardous/Toxic Materials:

NH_3(solid): 1000 g total (3 target cells, 14g each + spare material) ND_3(solid): 1000 g total (3 target cells, 14g each + spare material)

Radioactive Sources:

Radioactive sources on loan from Fermilab:

^{137}Cs (2.2μCi) ^{55}Fe (2.1μCi), ^{60}Co (2.6μCi)

^{90}Sr (3.1μCi)

Metals of Concern:

None

Lasers:

None

Electrical Equipment:

Custom analog shaper discriminators (ASDQ) (used by E906)

Custom logic level/ASDQ controllers Custom VME Time to Digital Converters Custom power distribution for SiPM Custom photomultiplier tube bases

Custom VME board for NMR measurement

(used by E906) (used by E906) (used by E906)

(used by E906, one base design modified for thermal management)

(LANL designed, electrical LANL safety passed)

As well as associated custom electronics to support target control and monitoring

Nuclear Materials:

None

Other Equipment:

5T split Helmhotz coil superconducting magnet

Max field at closest accessible point: Power requirements:

Liquid Helium reservoir volume: Liquid Nitrogen reservoir volume:

140 GHz microwave tube:

max power: 20W (enclosed volume)

Mechanical Structures:

Supports for hodoscopes and chambers (used by E906) Elevated platform: target stand

Vacuum Vessels:

Superconducting magnet vacuum 36K cubic centimeters and beam pipe ends. Titanium windows of 5 mils and windows on target nosepiece of 10 mils.

Pressure Vessels:

Superconducting magnet dewar (135 L), liquid nitrogen shield (45 L), refrigerator volume (12 L), separator volume (.4 L)

Two (2) gaseous helium buffer tanks, 790 ft^3 each (1580 ft^3 total) operating at 125 psig.

Cryogenics:

~70 l 0.13 mPa

4 cm TBD TBD

1. Helium liquefier system: a. storage capacity of 500 L in two QT commercial dewars.
   b. production capacity
2. Liquid Nitrogen 85 L in nitrogen shield, 45 L in QT purifier, main storage outside of the NM4 building

QT liquefier produced 200 L/day and transfers 135 L to target per day.

6000 liter outside tank. Oxygen deficiency hazard due to magnet quench which is mitigated by ODH vent system and quench line that goes out of the building.

Target cell of frozen NH3 and ND3 holding approximately 10 grams stored under liquid nitrogen at all times. In case of spillage ODH line connects cave and sensor system vents volume to outside keeping both NM4 and NM3 ODH class 0.