Fermilab

Office of the CRO

TECHNICAL SCOPE OF WORK

Experiment E1039

Effective Date: 1 May 2018

Expiration Date: 30 September 2021

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Note this is a public document, provisions to protect the document can be made with the host division.

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I. INTRODUCTION

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.

II. MOTIVATION AND GOALS OF E1039:

It is well known that the proton is a spin-½particle, 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 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.

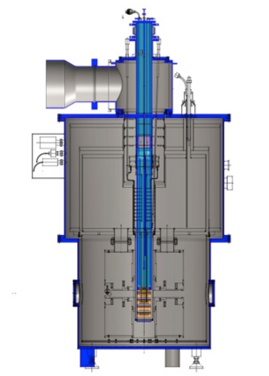

Figure 1: The polarized target

The experiment will use the E906/Seaquest spectrometer in NM4 (see Fig. 3) with the associated 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 elecotron 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 reduces the temperature of the liquid helium to 4K plus a closed loop helium liquefier system. The target material consists of frozen beads of NH_3 and possibly ND_3 immersed in a liquid helium bath.

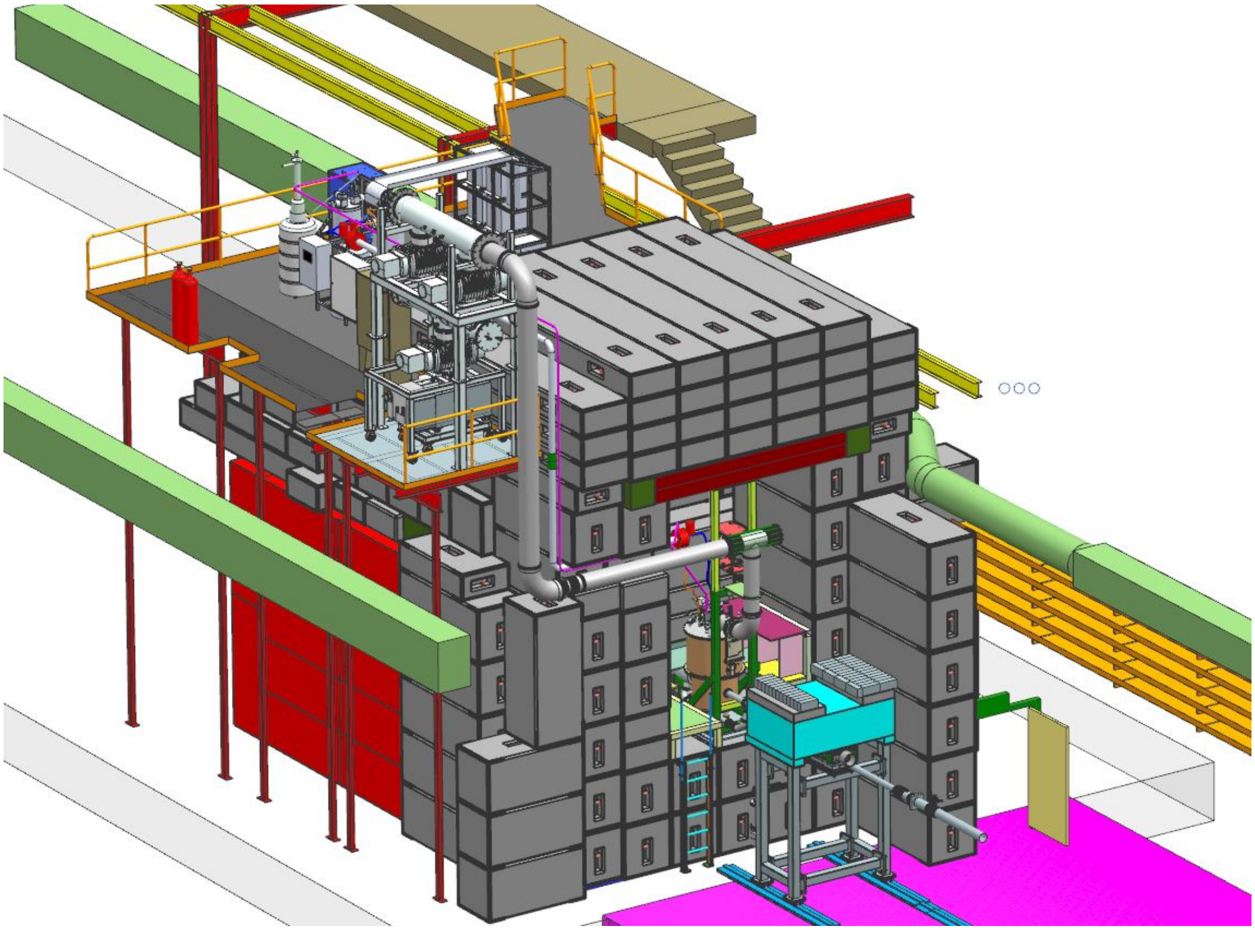

Figure 2: New shielding configuration with liquefier and pump

The transversely polarized target includes a superconducting 5T magnet upstream of the current 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 is a new collimator, which will be placed upstream of the target to protect the superconducting coils from beam movement.

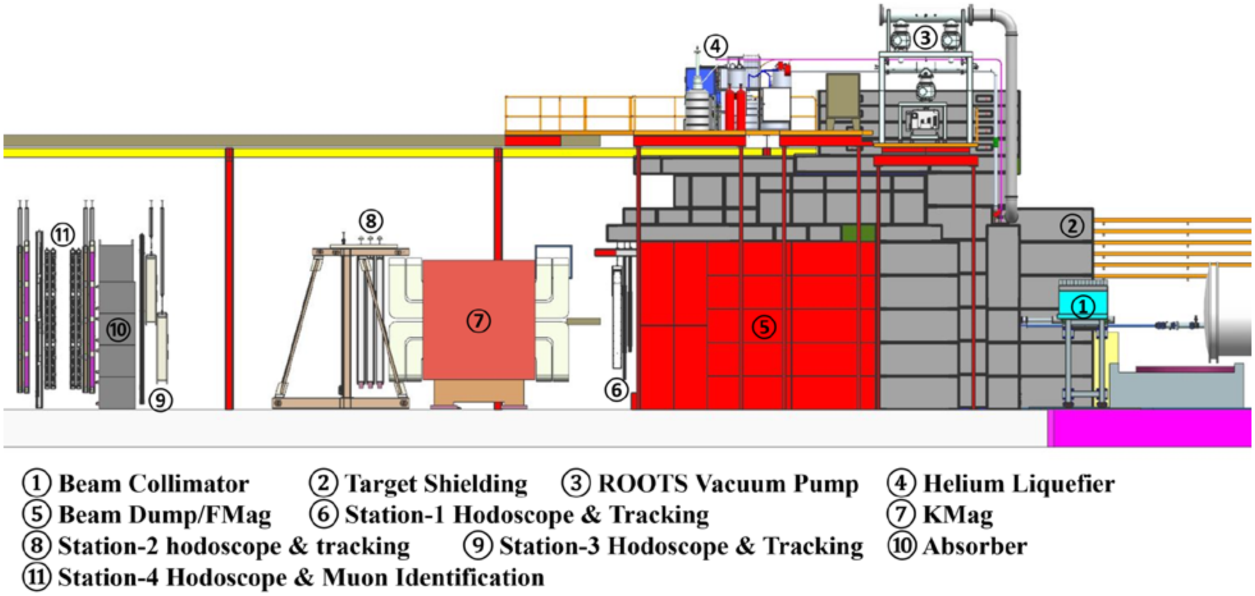

Figure 3: Schematic of E1039 spectrometer and equipment

III. PERSONNEL AND INSTITUTIONS:

Lead Pesonnel:

Spokesperson: Andi Klein, Los Alamos National Lab (LANL)

CoSpokesperson: Dustin Keller, University of Virginia (UVa)

Target Construction and Installation: Dustin Keller, UVa

Commissioning: Andi Klein, LANL

DAQ and operations: Kun Liu, LANL

Data anlysis: K. Nakano, Tokyo Institute of Technology

Fermilab Point of Contact (POC): Richard Tesarek

Other personnel working on the project are listed in the table below. "NA" Indicates that the person has no FNAL ID number at the date this table was formed. The names in bold face are the PIs of the respective institutions.

Abilene Christian University	USA	M. Daugherity	16604V	Faculty
		D. Isenhower	04976V	Faculty
		R. Towell	05139V	Faculty
		S. Watson	17167V	Physicist
Argonne National Laboratory	USA	D. Geesaman	03478V	Physicist
		P. Reimer	06433V	Physicist
University of Colorado, Boulder	USA	J. Katich	NA	Postdoc
		E.R. Kinney	04898V	Faculty
		P.-J. Lin	14622V	Grad Student
Fermi National Accelerator Laboratory	USA	C. Brown	2493N	Physicist
		C. Johnstone	6975N	Physicist
		R. Tesarek	12680N	Physicist
University of Illinois, Urbana-Champaign	USA	A. Chen	05949V	Physicist
		N. Makins	07674V	Faculty
		J.-C. Peng	04157V	Faculty
KEK, Tsukuba, Ibaraki	Japan	**S. Sawada**	14233V	Faculty

Los Alamos National Laboratory	USA	M. Brooks	NA	Physicist
		C. da Silva	NA	Physicist
		M. Durham	34710V	Physicist
		A. Klein	04284V	Physicist
		D. Kleinjan	17968V	Physicist
		X. Li	34365V	Physicist
		K. Liu	15878V	Physicist
		M. Liu	08406V	Physicist
		J. Mirabal-Martinez	15403V	Engineer/Tech
		P. McGaughey	NA	Physicist
		M. Yurov	NA	Posdoc
		M. Jen	NA	Postdoc
		S. Uemura	NA	Postdoc
		A. Tkatchev	NA	Engineer
		A. Wickes	NA	Grad Student
University of Michigan, Ann Arbor	USA	**W. Lorenzoen**	13786V	Faculty
		S. Sawada	14233V	Postdoc
		R. Raymond	14315V	Faculty
		D. Morton	31374V	Grad Student
		M. Scott	32723V	Grad Studnet
Mississippi State University	USA	T. Badman	NA	Grad Student
		L. El Fassi	14155V	Faculty
University of New Hampshire, Durham	USA	S. Li	NA	Grad Student
		E. Long	NA	Faculty
		K. Slifer	NA	Faculty
		R. Zielinski	NA	Grad Student
RIKEN, Wako, Saitama	Japan	**Y. Goto**	07095V	Physicist
Rutgers University	USA	A. Tadepalli	15820V	Grad Student
		R. Gilman	04243V	Faculty
Thomas Jefferson National Accelerator Facility	USA	J.-P. Chen	NA	Physicist
		C. Keith	NA	Physicist
Tokyo Institute of Technology	Japan	**K. Nakano**	14489V	Faculty
		T.-A. Shibata	13915V	Faculty

University of Virginia, Charlottesville	USA	D. Crabb	04057V	Faculty
		D. Day	NA	Faculty
		D. Keller	13081V	Postdoc
		J. Zhang	NA	Postdoc
Yamagata University	Japan	N. Doshita	NA	Faculty
		T. Iwata	NA	Faculty
		Y. Miyachi	13629V	Faculty
New Mexico State University	USA	**S. Pate**	17365V	Faculty
		V. Papavassiliou	4743V	Faculty
		H. Yu	35419V	Postdoc
		F. Hossain	36073V	Grad Student
University of Colombo	Sri Lanka	**G.D.N.Perera**	34626V	Faculty
		V.P. Dasnayake	NA	Grad Student

IV. EXPERIMENTAL AREA AND OTHER CONSIDERATIONS:

4.1 LOCATION

4.1.1 The experiment will take place in the NM4 hall.

4.1.2 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.

4.1.3 Lab space is needed for wire chamber repair (Lab 6).

4.2 EXPERIMENTAL EFFORT CONDITIONS

4.2.1 AREA INFRASTRUCTURE

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

Fermilab will be responsible for decomissioniong 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 collimater. 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 connetions 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.

4.2.2 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.

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

4.2.3 ELECTRONICS AND COMPUTING NEEDS

See Appendix I for summary of PREP equipment pool needs.

We will continue to utilize all the Fermilab electronic/computing facilities and resources that have been provided to E906 collaboration, with additional support of 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 (24 x7 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 experiment log and shift management

4.2.4 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 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

4.2.5 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

V. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

Task	Primary Institute	Secondary Institute
Spectrometer		
Restart Management	Fermilab	Los Alamos
Target		
Hardware	Virginia	Los Alamos, Michigan
Controls	Los Alamos	Virginia, New Hampshire
Station 1		
Hodoscope	Abilene Christian	Riken
MWPC	Colorado	Fermilab
MWPC Readout	Fermilab	
Station 2		
Hodoscope	Abilene Christian	Riken
Drift Chamber	Mississippi State	Fermilab
Drift Chamber Readout	Mississippi State	Fermilab
Station 3		
Hodoscope	Abilene Christian	RIKEN
Drift Chamber	KEK	Kyoto, Tokyo Tech
Drift Chamber Readout	KEK	Kyoto, Tokyo Tech
Station 4		
Hodoscope	Abilene Christian	RIKEN
Hodoscope Readout	Academia Sinica	Abilene Christian
Prop. Tubes	Los Alamos	
Prop. Tube Readout	Los Alamos	
DAQ	Argonne	Los Alamos
Trigger	Michigan	Argonne
Gas System	Illinois	Fermilab
Monte Carlo Software	New Mexico State	Abilene Christian, Argonne, Los Alamos, Maryland
Offline Reconstruction	New Mexico State	
Analysis	Tokyo Tech	Virginia, Los Alamos, New Mexico State
Online Monitoring	**Illinois**	

VI. RESPONSIBILITIES BY INSTITUTION – FERMILAB

6.1 FERMILAB PARTICLE PHYSICS DIVISION:

- Remove E906 target and disassembe 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, using a combination of Wilson Hall and near the experimental area, 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.

6.2 FERMILAB SCIENTIFIC COMPUTING DIVISION

6.2.1 SUMMARY OF PREP EQUIPMENT POOL NEEDS.

- See Appendix I.

6.2.2 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.

- Access to grid resources, including Open Science Grid and FermiGrid.

6.3 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

6.4 Fermilab Accelerator Division

- Provide beam as discussed in 4.2.2
- Install collimator
- Provide, maintain, and operate the necessary equipment for the safe and efficient transport of primary beam to the experiment.

6.5 Fermilab Collaborators

R. Tesarek will be the liason physicist for the experiment with FNAL. He will provide support for the running of the experiment. C. Johnstone will provide support for the beamline and beam instrumentation package. D. Christian will be initially involved in restarting the QIE and transfer knowledge to R. Tesarek.

6.5.1 Summary of Costs

Organization	Installation			Operations*		
	Labor (FTE)	**Materials & Services (k$)**	**Source of Funds**	**Labor (FTE)**	**Materials & Services (k$)**	**Source of Funds**
Particle Physics Division	0.9	740	NP	1.0	30	HEP Non-base
Accelerator Division	0.4	82	NP	1.5	30	HEP Non-base
Scientific Computing Division	0	0	N/A	0.4	0	HEP Non-base
ESH&Q Section	0.125	0	HEP Non-base	0.25	0	HEP Non-base
Totals Fermilab				2.75	60	
Collaborating Universities and Labs	5	3000	LANL LDRD & NP	6	65	NP

*Operations expenses are listed for FY19 and FY20. For FY18 the values are 50% of these and include the demolition of the E906 target pile and maintenance of the NM beamline.

VII. 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 Spokesperson 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.

VIII. SIGNATURES:

The Spokesperson is the official contact and is responsible for forwarding all pertinent information to the rest of the group, arranging for their training, and requesting ORC or any other necessary approvals for the experiment. The spokesperson is 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.

____________________________________ 4 / 17 / 2018

Spokesperson E1039

The following people have read this TSW:

____________________________________ 4 / 18 / 2018

PPD Head

____________________________________ 4 / 24 / 2018

AD Head

____________________________________ / / 2018

SCD Head

____________________________________ 4 / 18 / 2018

ESH&Q Head

IX. 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

X. 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:

^{106}Ru (2.2μCi), ^{106}Ru (3.4μCi)

^{137}Cs (2.2μCi)

^{55}Fe (2.1μCi), ^{55}Fe (4.1μCi)

^{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	(used by E906)
Custom VME Time to Digital Converters	(used by E906)
Custom power distribution for SiPM	(used by E906)
Custom photomultiplier tube bases	(used by E906, one base design modified for thermal management)
Custom VME board for NMR measurement	(LANL designed, electrical LANL safety passed)

Nuclear Materials:

None

Other Equipment:

5T split Helmhotz coil superconducting magnet

Max field at closest accessible point:	600G
Power requirements:	75A at 10V
Liquid Helium reservoir volume:	135 l
Liquid Nitrogen reservoir volume:	70 l

140 GHz microwave tube:

max power: 30W (enclosed volume)

Mechanical Structures:

Supports for hodoscopes and chambers (used by E906)

Elevated platform: target stand

Vacuum Vessels:

Volume:	~70 l
Operating pressure:	0.13 mPa
Window diameter:	4 cm
Window thickness:	TBD
Window material:	TBD

Pressure Vessels:

None

Cryogenics:

1. Helium liquefier system:
   a. storage capacity 500 liter (2 dewars)
   b. production capacity 200 liter/day
2. Liquid Nitrogen
   a. storage capacity 6000 liter outside tank

Other Hazards:

Oxygen deficiency hazard due to magnet quench.