FERMILAB-PROPOSAL-1025

Fermilab

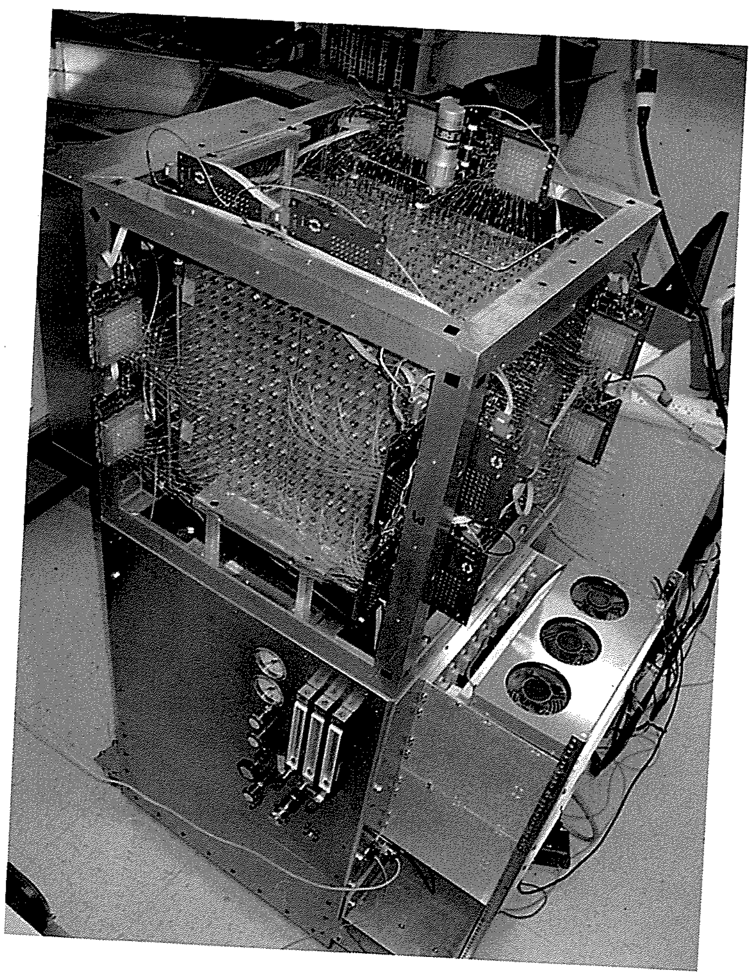
Directorate

MEMORANDUM OF UNDERSTANDING

T-1025

IU SciBath-768 Detector Tests in MI-12

February 11, 2012



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INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of Department of Physics and Center for Exploration of Energy and Matter, Indiana University, who have committed to participate in detector tests to be carried out during the 2012 Fermilab Neutrino program.

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

Description of Detector and Tests:

The experimenters propose to test their prototype "SciBath-768" detector [1] in the MI-12 building for 3 months (February-April) in Spring 2012. The major goal of this effort is to measure or limit the flux of beam-induced neutrons in a far-off-axis (> 45°) location of the Booster Neutrino Beamline (BNB). This flux is of interest for a proposed coherent neutral-current neutrino-argon elastic scattering experiment [2]. A secondary goal is to collect more test data for the SciBath-768 to enable better understanding and calibration of the device.

The SciBath-768 detector successfully ran for 3 months in the MINOS Underground Area in Fall 2011 as testbeam experiment T-1014 [3] and is currently running above ground in the MINOS service building.

For the run proposed here, the experimenters are requesting: space in MI-12 in which to run the SciBath detector during February-April 2012 while the BNB is operating; technical support to help with moving the equipment on site; access to power, internet, and accelerator signals; and a small office space from which to run and monitor the experiment.

Background and Motivation:

The original motivation for the SciBath detector was the FINeSSE experiment [4], proposed at Fermilab, which had the goal of precisely reconstructing neutrino-nucleon neutral current scattering events ($\nu N \rightarrow \nu N$) in order to extract information on the strange quark contribution to the nucleon spin. This is a challenging measurement as the event signature is a single short proton track within a large detector. One of the main goals of the MINOS-area-run was to show that the SciBath technology is well-suited for this application.

A 30-channel "proof-of-principle" device was built and tested at the Indiana University Cyclotron Facility with 200 MeV protons and cosmic-ray muons [5]. Those initial tests showed the promise of the method and allowed for some design tuning. The "Scibath-768" prototype was built and commissioned at Indiana University, then transported to Fermilab in Fall 2011 for the MINOS-area tests.

The main goal for running the Scibath-768 detector in the MI-12 area is to measure or limit the flux of beam-induced neutrons in a far-off-axis (> 45°) of the Booster Neutrino Beamline (BNB). This neutron flux is of particular interest for a proposed coherent neutral-current neutrino-argon elastic-scattering (coherent-NCνAs) experiment [2]. Beam-coincident single-scattter neutrons in the coherent-NCνAs experiment are a serious possible background and, therefore, the desire to measure beam-induced neutron flux near the BNB with the SciBath-768 detector.

The MI-12 building is positioned over a 10.8 m wide, 26.4 m long and 8.7 m deep underground target station. There are no instruments or infrastructure within ~7 m of the target building. The existing radioactive shielding at BNB target area (MI-12) is extensive and carefully thought out in order to satisfy the Fermilab radioactive safety regulations [6]. The neutrino production target is located ~7 m underground of the surface building. The shielding pile consists in total of 2.6 m thick (in elevation) iron blocks (1,600 tons), additional 2.5 m-thick concrete shielding blocks (300 tons), and special custom-sized steel blocks (40 tons) above and below the horn module. The neutron flux at 10 m from the target with this shielding is estimated conservatively to be, $\Phi = 1.8 \times 10^{-3}$ n/cm^2/yr [7].

The expected neutron interaction rate is only a few tens of events/ton/yr. Therefore, the expected neutron flux is far from observable using a kg scale detector in a few-day time-scale, if the estimation is correct. Although the estimated beam-induced neutron background is sufficiently low, it is also true that predicting neutron leakage rates through massive shielding material is notoriously difficult. For example, a small gap between shielding blocks may potentially cause serious leakage of neutron fluxes. In addition, neutrons may be created from secondary processes such as muon spallation. Therefore measuring the beam-coincident neutrons at the experimental site is crucial and necessary. An initial survey of the neutron flux at the MI-12 building using a kg-scale commercial liquid scintillator detector will be carried out. Then, the experimenters propose to use the 70 kg, (45cm)^3 SciBath-768 neutral particle detector for a more sensitive estimation of neutron flux at the MI-12 building.

Using the estimated neutron flux provided above, the 70 kg, 30%-efficient SciBath-768 detector should see only 0.24 beam-related neutron events in a 3 month run. If the detector indeed observes zero beam-related neutrons, that will set a 90% upper bound of 440 events/ton/year from neutron interactions in a ton-scale liquid-argon detector.

I. PERSONNEL AND INSTITUTIONS:

Spokesperson and Physicist in charge of Beam Tests: Rex Tayloe

Fermilab liaison: Jim Volk

The group members at present are:

	Institution	Collaborator	Rank/Position	Other Commitments
1.1	Indiana University	R. Cooper	Postdoc	
		L. Garrison	Graduate student	
		T. Thornton	Undergraduate	
		L. Rebenitsch	Graduate student	
		Rex Tayloe	Assoc. Prof	MiniBooNE, SciNOvA
1.2	Fermilab	Fritz DeJongh	Scientist II	
		Ben Loer	Research Associate	
		Erik Ramberg	Scientist II	
		Jonghee Yoo	Wilson Fellow	

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

2.1 LOCATION

2.1.1 The apparatus for the beam test(s) will be located in the MI-12. The detector and associated equipment requires floor space of minimum dimension $2.8 \times 3.3\ m^2$. A plan view of the proposed layout, required space, and suggested location in MI-12 area is shown in Appendix I.

2.1.2 The experimenters request a desk in an office on site at Fermilab from which to run the experiment and monitor the detector. The experimenters will, after an initial setup/debug period estimated to be about 2 days, run the experiment remotely.

2.2 BEAM

2.2.1 BEAM TYPES AND INTENSITIES

Particles: Search for beam-correlated background neutrons near the BNB production target.

2.2.2 BEAM SHARING

The experiment will run parasitically to the MiniBooNE experiment on the BNB. The only effect on BNB experiments may be request for a shutdown if setting up the experiment in MI-12 requires it. The current proposed location within MI-12 does not require a BNB shutdown.

2.2.3 RUNNING TIME

The estimated duration of this experiment is 3 months while the BNB is running with beam on target. The experimenters realize that 3 months of running may not be possible due to equipment failure or other unforeseen conditions.

2.3 EXPERIMENTAL CONDITIONS

2.3.1 AREA INFRASTRUCTURE AND ELECTRONICS NEEDS

The proposed location of the experiment within MI-12 is shown in Appendix I.

The experiment will need:

- A beam-on-target trigger signal to insert into the data stream (with possible technical support for setup). This has already been worked out with the MiniBooNE collaboration as they utilize the same signals within MI-12.
- Access to an internet connection with minimum 100Mb/s rate
- Access to 120V/20A power. Total power estimated to be not more than 2kW.
- Technical support to assist in moving the experimental equipment into the MI-12 area from its current location at the MINOS service building.

2.3.2 DESCRIPTION OF DETECTOR

The active volume of the SciBath-768 detector consists of 768 1.5 mm diameter ultraviolet-to-blue wavelength-shifting (WLS) fibers immersed in liquid scintillator. There are 256 fibers aligned along each of the 3 axes in a rectangular coordinate system and arranged in a 16 x 16 grid with a spacing of 2.5 cm. The fibers penetrate the 0.5 inch thick aluminum sides of a (45 cm) cube. One end of the WLS fiber is glued into a brass plug and screwed into the box wall. The other end is glued into a stainless steel piston which is free to slide a small distance within a double O-ring system that contains the liquid. The detector is held at a slight overpressure (1 psi) in order to maintain a slight tension on the fibers. Figure 1 shows the (45 cm)^3 detector cube with the fiber arrangement and the cover figure shows the cube in the support frame.

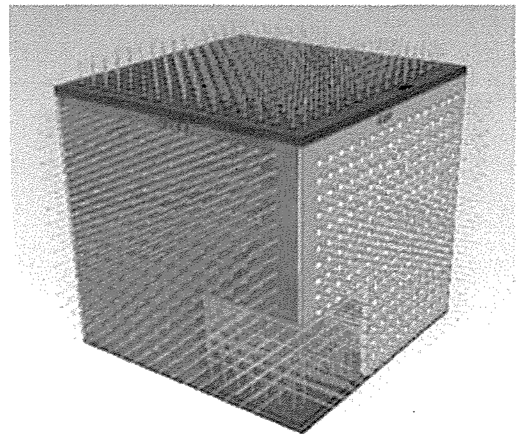

Figure 1: Schematic view of the SciBath-768 (45 cm)^3 detector cube.

The WLS fibers are mated at one end to clear fibers immediately outside of the aluminum detector walls. These ≈1m long clear fibers are bundled into groups of 64 and routed to VME crates attached to the support structure of the detector. Each bundle terminates in a 64-fiber plastic "cookie" mounted on a custom-built backplane in the VME crate. Hamamatsu 64-anode photomultipliers (MAPMT) attached to the readout cards mate with the fiber cookies so that the fibers align precisely with the 1.7 mm pixels of the MAPMTs. The other end of the WLS fiber is mated to a pulsed LED system that will provide a calibration source for the detector.

The "integrated readout module" (IRM) readout cards combine the readout function with mechanical support for an attached MAPMT. The IRM cards are housed in a VME crate; however the crate is a simple shell with no power supply or parallel readout bus. The power supply is housed in a separate crate and readout is accomplished via ethernet. The rear "backplane" area of the crate accepts the optical fiber bundles. The IRM boards were custom-built at IU and consist of 20 MHz flash ADCs, FPGAs, and an embedded microcontroller which allows on-board data processing and data transfer via ethernet.

The liquid scintillator consists of mineral oil, 11% psuedocumene, and 1.5 g/l PPO resulting in a peak emission wavelength of 370 nm. An additional wavelength shifter (such as bis-MSB), commonly added to liquid scintillator to increase attenuation length, is not necessary for the operation of this detector. The (45 cm)^3 cube, when filled, contains 82 liters of scintillator. A nitrogen gas (N_2) system is used to displace oxygen and water within the scintillator and to provide the slight (1 psi) overpressure in the detector cube. A reservoir tank with capacity of 104 liters is utilized to store the liquid for transport, to provide a buffer volume for N_2 bubbling, and to allow the detector cube to be completely drained as needed. The entire system is protected from pressures over 5psi or vacuum by two protection valves in the N_2 system. These will also protect the cube and overflow tank. The liquid scintillator and N_2 plumbing arrangement (including the over/under pressure protection valves) is shown schematically in Fig. 2.

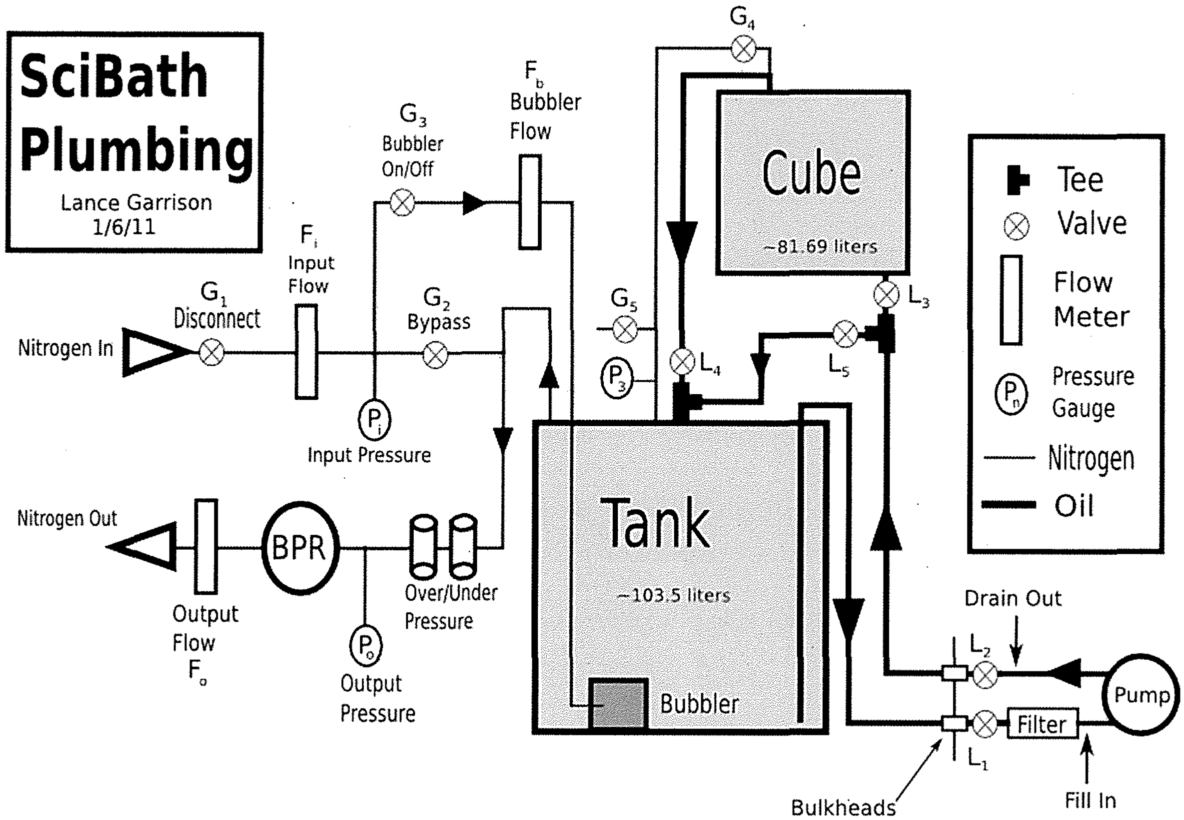

Figure 2: SciBath-768 liquid scintillator oil and N_2 plumbing schematic.

The $(45\ \text{cm})^3$ cube containing the active detector volume and WLS fibers is installed at the top of a custom-built 2 m tall aluminum frame which is mounted on heavy duty casters as shown in the cover photo. Also installed within the aluminum structure is the plumbing system (including the liquid scintillator reservoir tank), the LED calibration system, PMTs and readout cards. The bottom of the detector structure is liquid-tight and functions as a secondary scintillator containment volume in case of any leaks. The entire detector frame will sit in a tertiary container resulting in a three-level containment system to guard against liquid scintillator leaks.

External connections to the detector structure are few so as to allow the detector to be easily moved. These connections consist of 40V and 1000V DC power to the readout/PMT system, 120V AC power for assorted power supplies, several NIM format trigger signals, ethernet, and N_2 gas. A half-height 19in rack is used to house the supporting equipment. This rack will be located next to the detector frame and is completely disconnected for transport. A proposed layout of these racks and equipment is shown in Appendix I.

2.3.3 Safety Considerations and Operational Readiness

The SciBath-768 setup has been reviewed for a run in the MINOS underground area in September 2011. Another review was conducted after the detector was setup for an above ground run in the MINOS service building in February 2012. Electrical and liquid handling safety documents were generated for these reviews and are available. Operational Readiness Clearance was approved after both of these reviews.

One safety feature of note that was installed before running underground was a smoke detector interlock protecting the SciBath-768 electronics rack. This interlock system shuts off power to the detector if smoke/fire is detected in the electronics rack.

2.4 Schedule

The Experimenters are proposing to run the SciBath-768 detector at Fermilab in the MI-12 building for 3 months in Spring 2012. It is acknowledged that there is no guarantee of a protons on target quota.

III. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

3.1 INDIANA UNIVERSITY:

- IU SciBath detector including the following existing hardware components:
  - liquid scintillator
  - optical fibers
  - containment vessels
  - photomultiplier tubes
  - data acquisition hardware
  - computers
  - local network equipment
  - monitoring computer

Total existing items [$250k]

IV. Responsibilities by Institution – Fermilab

4.1 Fermilab Accelerator Division:

4.1.1 No access to Booster Neutrino Beam enclosures is required, only parasitic use of beam time as outlined in Section II. The Fermilab Accelerator Division will be responsible for coordinating overall activities in MI-12 [1.0 person-weeks]

4.1.2 A beam-on-target trigger signal to insert into the experiment data stream.

4.2 Fermilab Particle Physics Division:

4.2.1 Technical support to assist in moving the experimental equipment into and out of the MI-12 area (forklift and/or crane work). [0.5 person-weeks]

4.2.2 A desk in a visitor area on site, at Fermilab from which to run the experiment and monitor the detector.

4.2.3 Access to 120V, 20A electrical outlets with total power estimated to be less than 2kW

4.3 Fermilab Computing Division

4.3.1 Access to an external internet connection in MI-12 with minimum 100Mb/s rate. (Note: this may fall under the domain of accelerator division and should be added to 4.1 above).

4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.

4.4.2 Provide necessary training for experimenters.

V. SUMMARY OF COSTS

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Particle Physics Division	0.0	0.5
Accelerator Division	0	1.0
Computing Division	0	0
Totals Fermilab	$0.0K	1.5
Totals Non-Fermilab	$250K	40

VI. Special Considerations

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

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

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

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

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

6.6 The Spokesperson will undertake to ensure 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. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Division management.

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

At the completion of the experiment:

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

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

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

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

VII. References

[1] R. Cooper et al., SciBath: A Novel Tracking Detector for Measuring Neutral Particles Underground, arXiv:1110.4432 (2011).

[2] S. Brice et al, R&D for Measurement of Coherent Neutral Current Neutrino-Nucleus Scattering at Fermilab(2011).

[3] R. Tayloe et al, MOU for T-1014: IU SciBath-768 Detector (2011).

[4] L. Bugel et al. [FINeSSE Collaboration], "A Proposal for a near detector experiment on the booster neutrino beamline: FINeSSE: Fermilab intense neutrino scattering scintillator experiment," arXiv:hep-ex/0402007.

[5] R. Tayloe et al., "A large-volume detector capable of charged-particle tracking," Nucl. Instrum. Meth. A 562, 198 (2006).

[6] I. Stancu et al., Technical Design Report for the MiniBooNE Neutrino Beam, internal note, May 13, (2001).

[7] J. Yoo,First order estimation of the neutron flux at Booster Neutrino Beam target (MI-12),

SIGNATURES

Rex Tayloe, Experiment Spokesperson — 3/20/2012

Michael Lindgren, Particle Physics Division, Fermilab — 3/6/2012

Roger Dixon, Accelerator Division, Fermilab — 3/6/2012

Peter Cooper, Computing Division, Fermilab — 3/6/2012

Martha Michels for Nancy Grossman, ES&H Section, Fermilab — 3/6/2012

Greg Bock, Associate Director for Research, Fermilab — 3/6/2012

Stuart Henderson, Associate Director for Accelerators, Fermilab — 3/7/2012

APPENDIX I: AREA LAYOUT

This section shows the size, required space, and proposed location of the Scibath-768 experiment within MI-12. The estimated total weight of all equipment is ≈ 350 kg (≈700 lbs). There is some flexibility exactly where the subcomponents are placed within the MI-12 area. The desired location is on the south (upstream) end of the building.

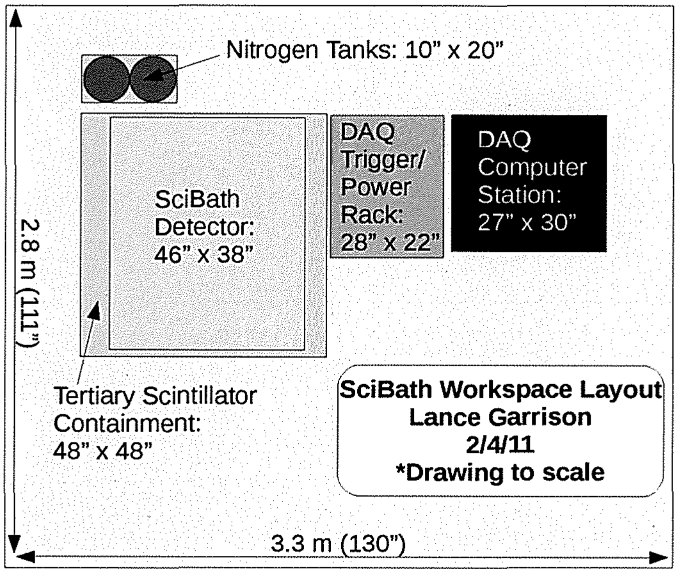

Figure 3: Space envelope required for the SciBath-768 detector and associated equipment. There is some flexibility to rearrange this to accomodate to existing space.

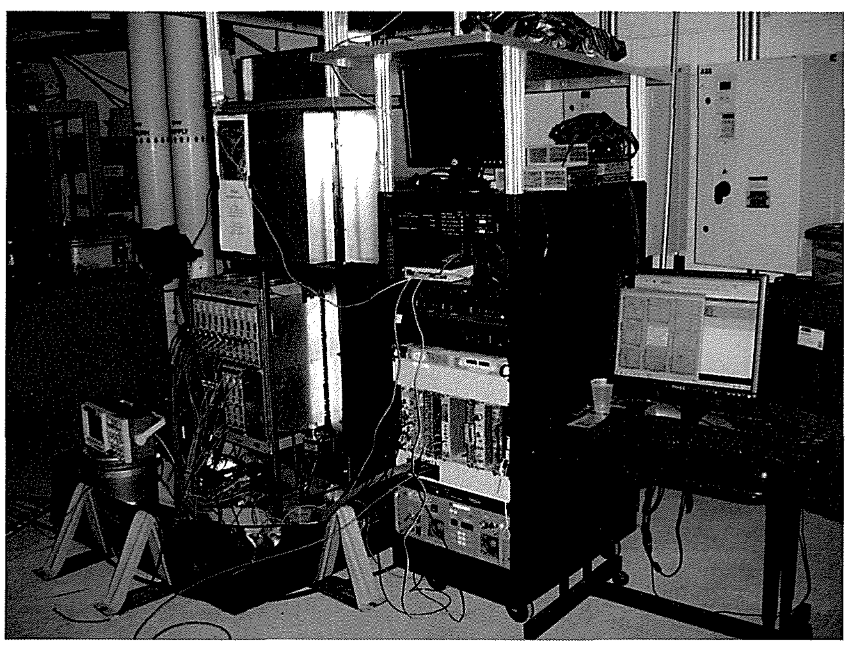

Figure 4: Photo of SciBath-768 as currently (2/12) configured at the MINOS service building.

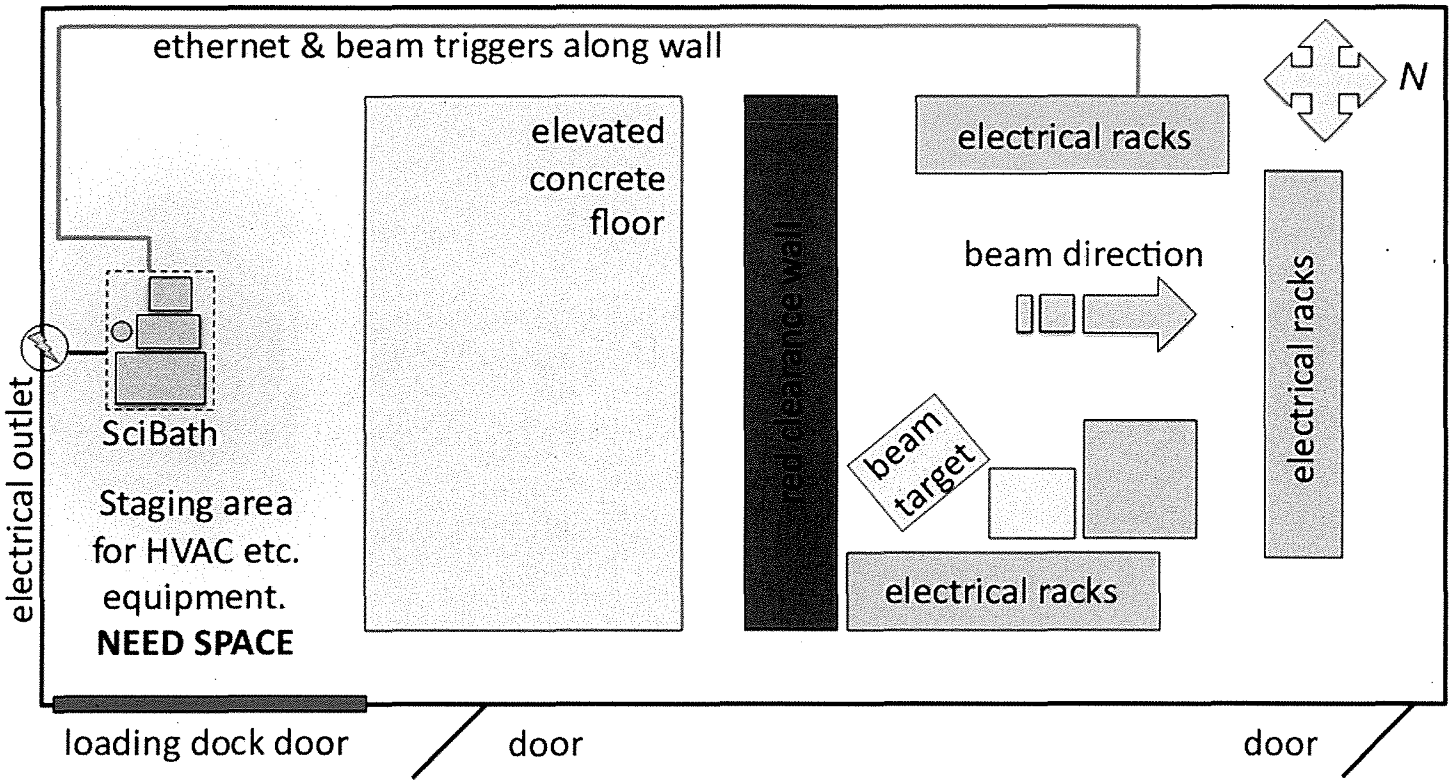

Figure 5: Proposed location for SciBath-768 detector setup within MI-12 at the South end of the building. The exact location on the south end of building is negotiable.

APPENDIX II: - HAZARD IDENTIFICATION CHECKLIST

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

Notes:

- HV is that for PMT bases (~1kV, 1mA).
- Scintillation oil is mineral oil with 10% pseudocumene.

Flammable Gases or Liquids		**Other Gas Emissions**		**Hazardous Chemicals**		**Other Hazardous /Toxic Materials**
Type:		Type:	Nitrogen gas		Cyanide plating materials	List hazardous/toxic materials planned for use in a beam line or an experimental enclosure:
Flow rate:		Flow rate:	<= 1liter/min		Hydrofluoric Acid	
Capacity:		Capacity:			Methane	
Radioactive Sources		**Target Materials**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
	Temporary Use		Lithium (Li)	X	Scintillation Oil	
Type:			Mercury (Hg)		TEA	
Strength:			Lead (Pb)		TMAE	
Lasers			Tungsten (W)		Other: Activated Water?	
	Permanent installation		Uranium (U)			
	Temporary installation		Other:	**Nuclear Materials**		
	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:			Capacitor Banks	**Mechanical Structures**		
Wattage:		X	High Voltage (50V)		Lifting Devices	
Class:			Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP		Scaffolding/ Elevated Platforms	
			Modified Commercial/PREP		Other:	
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:		Inside Diameter:			Beam line magnets	
Operating Pressure:		Operating Pressure:			Analysis magnets	
Window Material:		Window Material:			Target	
Window Thickness:		Window Thickness:			Bubble chamber	

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.

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