Experimental Operations Plan

LArIAT (T-1034)

Fermi National Accelerator Laboratory

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1   INTRODUCTION

Fermilab test experiment T-1034, the **LAr**TPC **I**n **A** **T**estbeam experiment (LArIAT), will use the full 3D-imaging, excellent particle identification (PID) capability, and precise calorimetric energy reconstruction of LArTPCs that currently represents the most advanced experimental technology for neutrino physics.

The ICARUS collaboration pioneered this technology in Europe. Interest in LArTPCs in the US has rapidly grown in recent years. First, the ArgoNeuT LArTPC [1] experiment collected neutrino data in the NuMI beam line at FNAL in 2009-10 and is still producing physics results. This is followed by MicroBooNE [2], which is now in its commissioning phase. In 2012, the Deep Underground Neutrino Experiment (DUNE, formerly LBNE) [3] made the LArTPC technology its choice for the far detector and advanced to CD-1 approval at the beginning of 2013. In addition, the LArTPC technology is recognized as a powerful tool in searches for proton decay, especially in SUSY-favored decay modes which include a kaon, such as the K+-antineutrino decay mode.

LAr detectors have been selected for these experiments because they promise excellent particle identification capabilities and calorimetric resolution, but only through experimental testing can these features be characterized in detail. Of particular interest

are features of electromagnetic shower reconstruction relevant to the separation of electron and gamma showers, determination (without a magnetic field) of the sign of a muon via its endpoint capture or decay, and the recombination of charge as ionizing tracks drift to the wire planes.

The LArIAT program takes advantage of existing investments in LArTPC development to enable the best performance of future investments, first in MicroBooNE, and also in DUNE and other future LArTPC detectors. In addition, the program described here will greatly help to train the next generation of experimentalists to develop these detectors toward the massive scales needed for long baseline oscillation physics and underground science.

2 SCIENCE

Calibration is a critical step toward understanding the output response of any detector. In particular, every new detector (e.g., tracker, calorimeter) must be calibrated before physics information can be extracted. A comprehensive characterization of LArTPC performance is now considered of great interest and impact for the development of the medium- and long-term Intensity Frontier program in the U.S. Specifically, this characterization is required for particles such as γ, $e^{\pm}$, $\mu^{\pm}$, $\pi^{0,\pm}$, $K^{\pm}$, p, p-bar, in the range of energies from a few hundred MeV to 2 GeV, as shown in Figure 1 (left), relevant to the forthcoming short baseline experiment MicroBooNE, and also to future experiments like SBND [4] and the Long Baseline (underground) LAr detectors for neutrino physics and proton decay searches (DUNE) [3].

The Fermilab Test Beam Facility (FTBF) is the ideal place to perform these studies, providing not only a range of selectable known energies, but also a complete set of selectable types of different particles in both polarities, Figure 1 (right). The test beam also provides a controlled environment in which to tune simulations and to develop/validate the off-line software tools for particle identification (PID), calorimetry, and event reconstruction without relying solely on simulation.
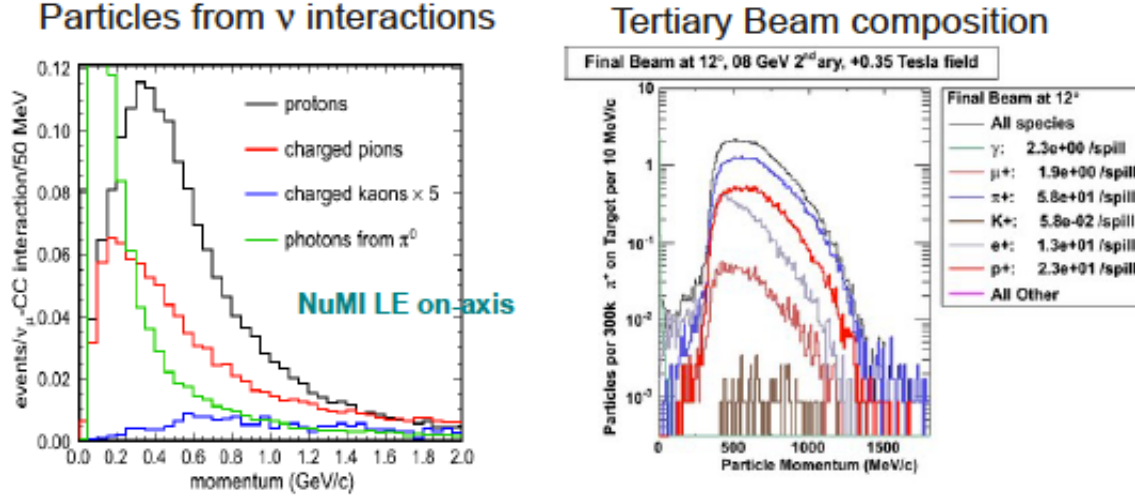
Figure 1: Momentum spectra of particles emerging from neutrino interactions with the NuMI low energy beam configuration (left), compared with the momentum spectra of test beam particles produced with the LArIAT low energy tertiary beam.

The detector that will be exposed to a test beam must reproduce as closely as possible (though at reduced size) all technical features of the final detector. Therefore, the "standard" (single phase) LArTPC scheme, with multiple wire-planes read-out geometry for 3D imaging, fine wire spacing and low-noise cold electronics, is the necessary choice for best informing the design and exploitation of all LAr detectors included in the present U.S. neutrino program.

LArIAT Phase-1 repurposes the fine-grained LArTPC from ArgoNeuT for an extended physics run with low momenta charged particles, selected from the MCenter tertiary beam at FTBF.

The LArIAT Phase-1 science goals are described in further detail below, but can be summarized as follows:
  (1) Experimental determination of the e to γ-initiated shower separation
  (2) Development of criteria for charge sign determination
  (3) Single track calibration and optimization of particle identification methods
  (4) Characterization of anti-proton stars in argon

2.1   Experimental determination of electron-gamma shower separation

The capability for e-vs.-γ shower separation (e.g., signal CC ν_e vs. NC π^0 background) is the key feature that led to the technology choice of LArTPCs for both short- and long-baseline neutrino detectors presently under construction or planned in the U.S. The separation efficiency and sample purity of electron-induced vs. photon-induced showers have never been experimentally measured, and current understanding relies solely on MC simulations. Only the initial part of the shower is relevant for e/γ separation (because the γ converts to an (e^+e^-) pair, producing double ionization in the first portion of the track at the shower start); an experimental test can be performed using a small volume LArTPC (such as the ArgoNeuT TPC). Characterization with electron (and bremsstrahlung

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photon) beams, see Figure 2, will provide experimental confirmation for the separation efficiencies, further strengthening the physics case for both MicroBooNE (identification of the low-energy ν_e excess observed by MiniBooNE) and DUNE (measurement of the CP violating phase from oscillation into electron (anti)neutrinos). Data from the test beam will readily enable more reliable separation criteria/algorithms in the LArSoft offline reconstruction code, thus benefiting multiple LArTPC experiments.
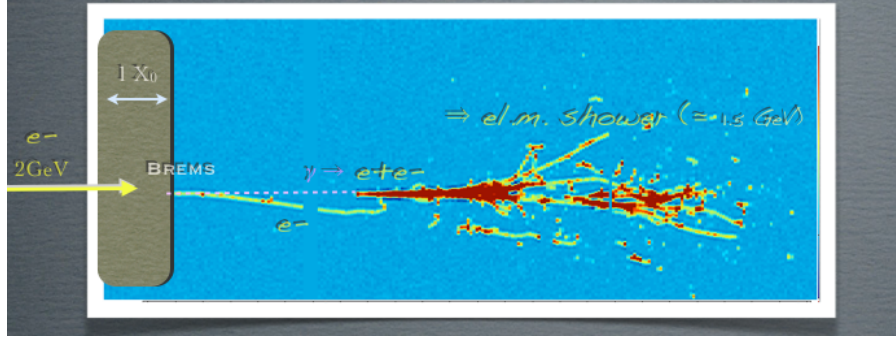

Figure 2: MC simulation (LArIAT TPC) of γ EM shower induced by electron bremsstrahlung of the parent electron entering from the left. The γ conversion into an e^+e^- pair initiates a shower that is well separated from the parent electron track in the LArTPC volume.

2.2   Development of criteria for charge-sign determination

The sign of a particle's charge (without magnetic field) can be obtained for stopping particles in LArTPC by statistical analysis based on topological criteria. For example, μ^+ undergo decay only, with e^+ emission of known energy spectrum. Stopping μ^- may either decay or be captured by nuclei. In argon, the capture probability is about 76%, accompanied by neutron and γ emission. μ^--capture can thus be topologically separated from μ^+-decay (by detection of a delayed Michel electron track), as shown in Figure 3. However, systematic study of the processes following μ^--capture in argon have never been performed and LArTPC sign-determination capability has never been explored. Beams with selectable polarity will provide data for direct measurement of the sign separation efficiency (and purity) for muons as well as for pions (and potentially also for kaons). In addition, capture topology and identification of the decay/capture products will further constrain the capability to charge-ID the primary lepton in muon neutrino CC interactions of particular interest for CP violation, and for validating the reaction models implemented for argon nuclei in the GEANT4 simulation package [5].
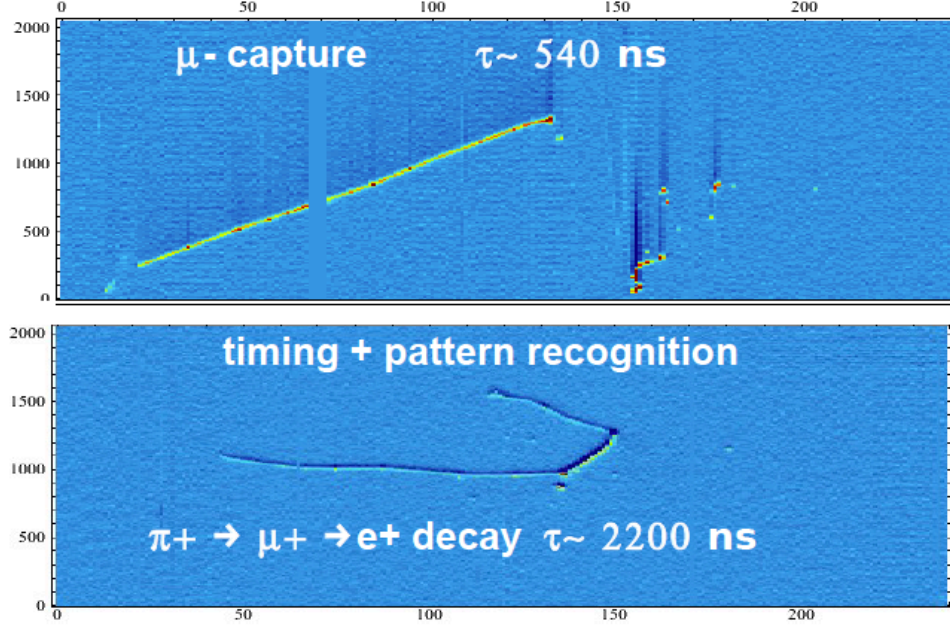
Figure 3: ArgoNeuT data showing capture-like and decay-like topologies.

2.3 Single track calibration and optimization of particle identification methods

Single-track calibration is needed to precisely/accurately establish the relationship between collected ionization charge at the TPC wires and the energy deposited in LAr by incident particles. This calibration is achieved by performing measurements of electron-ion recombination in argon [6,7,8,9]:

(1) over the most possible extended range of energy deposition rates (dE/dx)
(2) for different electric field values (in the typical ~0.3-1.0 kV/cm range for LArTPC operation)
(3) at different track-to-electric-field angles.

These measurements will augment the present knowledge of the fundamental properties of liquid argon as an active detection medium and, correspondingly, enhance the calorimetric energy resolution of LArTPCs.

A pure low-momentum beam of muons, pions, kaons and protons that penetrate and slow down to stop in the TPC will be used to perform these studies. A modest volume LArTPC (like the existing ArgoNeuT detector) is sufficient for this task.

The dependence of the recombination to the electric field (strength and direction) in liquid noble gases is not fully understood, particularly for high ionization densities, and determined [10] through data fit with semi-empirical models [11]. Data above 15-20 MeV/cm from the ICARUS measurements [12] are sparse and statistically limited. Electron recombination in highly ionizing stopping protons and deuterons was more recently studied in the ArgoNeuT detector [13]. The data are well modeled by either a Birks model or a modified form of the Box model. The dependence of recombination on the track angle with respect to the electric field direction was found to be much weaker

than the predictions of the Jaffe columnar theory and by theoretical/computational simulations.

The high accuracy and statistical precision of the test beam data will be fundamental to achieving an in-depth understanding of the recombination mechanisms in LAr and an optimal way to best model their effects within the LArSoft off-line reconstruction and detector simulation package for future LArTPC experiments in the U.S. [14].

Optimization of particle identification methods will make use of the energy deposited along the track, once precisely determined from the single track calibration, combined with the 3D imaging information. This allows for (dE/dx) vs. residual range reconstruction of each track contained in the LArTPC volume. Efficient particle identification can thus be obtained; this represents one of the key features of the LArTPC technology, relevant for neutrino oscillation experiments and proton decay searches.

High statistics test beam data will allow experimental determination of:
- proton/kaon identification efficiency and purity/rejection factor
- kaon to π/μ identification efficiency and purity/rejection factor

The PID information, based on direct measurement with beam particles of known type, will greatly enhance confidence in the estimate of signal to background separation for future nucleon decay searches and current/forthcoming neutrino cross-section studies with LArTPC detectors (ArgoNeuT/MicroBooNE).

2.4   Characterization of anti-proton stars in argon

Low momentum anti-protons, if available in the test beams even at very low rate, may allow the first study of hadron star topology from p-pbar annihilation at rest in argon (pbar-Ar reaction). $\pi^{\pm}$, π^0, $K^{\pm}$, $K_{L,S}$, ... multiplicity in hadron stars can be accurately determined with a LAr imaging detector. This information is considered very relevant for nnbar-oscillation searches with future large LArTPC underground detectors.

Models for simulation of anti-proton annihilation at rest are the subject of continuous development within GEANT4 (e.g., Ref. [5]: CHIPS, FRITIOF, LEP aka. GEISHA). Validation from experimental data is of great interest, as model predictions vary widely in the multiplicity and energy spectra for the secondaries produced.

2.5   Summary

In summary, the test beam run with LArIAT will provide a large amount of useful data for a complete understanding of the fundamental mechanisms of energy release in a LAr target, immediately translating into calorimetric energy resolution improvement and enhancement of particle identification capability of LArTPCs.

As test beam data are accumulated, the LArSoft code will be improved through the optimization and development of new data-driven algorithms and methods for both off-

line analysis and detector response simulation, providing a truly state-of-the-art software package for all LArTPCs in the U.S. The GEANT4 modules for annihilation/capture at rest simulation of pbar and π, K will benefit from comparisons with experimental data.

The first to benefit from the test beam outputs is the present generation of LArTPC experiments, ArgoNeuT and MicroBooNE, for all of their relevant physics topics, from exclusive channel cross-section measurements (where robust and reliable PID is a necessary requisite for accurate neutrino interaction products recognition), to sterile ν searches with best signal CC ν_e-to-NC π^0 background separation capability. But in addition, DUNE will profit from higher confidence in the estimate of signal to background separation from MC simulations, and later on from data analysis. Training of (young) physicists during extended beam operation and real data analysis is also an invaluable add-on in view of future Short & Long Baseline and underground LArTPC experiments.

3   EXPERIMENTAL DESIGN

The LArIAT Phase-1 experimental program at FTBF capitalizes on the availability of the existing hardware from the ArgoNeuT experiment. The experiment is located in the MCenter beamline at the FTBF, and makes use of the available beam of secondary pions to impinge on a tertiary target. The tertiary beamline (target, collimator, and magnets) was adopted from the MINERvA test beam effort, and was optimized for LArIAT needs. The secondary and tertiary beam settings can be chosen to select a range of particle types and momenta, and these settings will be adjusted as necessary during data-taking to collect particle species and momentum ranges of interest for our analyses.

The layout of the LArIAT experiment includes two main parts: the LAr-related components and the (tertiary) beam-related components. The LAr-related part consists of the LArTPC detector and the LAr scintillation light detector, the LArTPC read-out cold electronics, the LAr cryostat (containing both the LArTPC and the scintillation light collection system detectors), and the cryogenic/recirculation system connected to the cryostat for LAr cooling and purification. The beam-related part consists of a series of beam counters (TOF, MWPC, Aerogel Cerenkov, Veto scintillator paddles) aligned along the LArIAT tertiary beam line for particle ID tagging and momentum selection, shown in Figure 4.
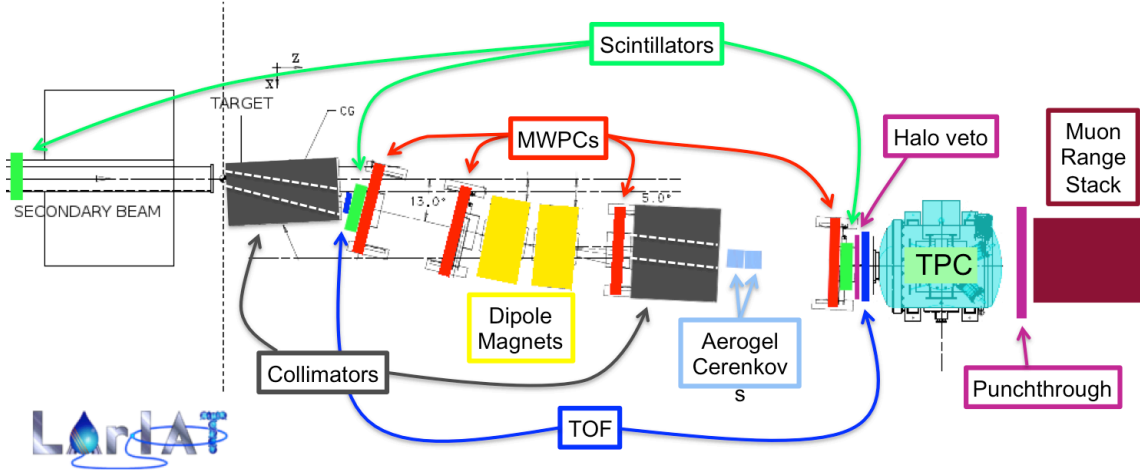
Figure 4: LArIAT beamline layout. Beam enters the MC7 enclosure from the left in this image. It impinges on a copper target located just upstream of the first iron collimator to create the tertiary beam.

The vacuum-insulated cryostat and the inner detector TPC are components obtained from ArgoNeuT. The TPC wire planes were restrung, since the detector had been stored in unstable environmental conditions for several years before it was brought for reuse as LArIAT. The active volume of the TPC is appropriate for the proposed LArIAT physics program. A detailed description of these components can be found in the ArgoNeuT technical paper [1].

4   THE LArIAT COLLABORATION

4.1   Organization and Governance

The LArIAT collaboration presently consists of ~60 Ph.D. physicists and ~10 students from 22 institutions in 4 countries: Italy, Japan, the United Kingdom, Brazil, and the United States.

LArIAT has an Institutional Board consisting of one representative from each collaboration institution. The Institutional Board approves and modifies the collaboration bylaws, admits new institutions and senior members to the collaboration, and sets shift, authorship, and publication policies.

The scientific leadership of the LArIAT collaboration consists of two elected co-spokespersons, who are advised by the Institutional Board.

To carry out the mission of the experiment, the spokespersons have appointed several working group leaders charged with various tasks as outlined in Figure 5. Going from left to right at the top level in that figure, the working groups are:

- Accelerator Liaison, who is charged with coordinating the maintenance and tuning of the MCenter secondary and tertiary beams.
- Computing Liaison, who is responsible for consulting with FNAL Computing to develop annual budget plans to support LArIAT computing, and for overseeing collaboration resources dedicated to data management and simulations. Support for LArIAT computing is covered in the LArIAT-FTBF TSW [6].
- DAQ Coordinator, who is responsible for development and maintenance of the LArIAT data acquisition system, and for oversight of data quality monitoring.
- Trigger Coordinator, who is charged with development and maintenance of the trigger system.
- Run/Assembly Coordinator, who is responsible for coordinating all activities related to the assembly, commissioning, and data-taking in the MC7 enclosure. The Run Coordinator works with leaders of each subsystem to facilitate progress toward the ORC, and coordinates day-to-day activities during run-taking. In consultation with the spokespersons, the Run Coordinator will direct and decide the priority and scheduling of detector systems development and maintenance. The Run Coordinator has responsibility for scheduling shifts, maintaining shift procedures, and maintaining the systems expert on-call list. The Run Coordinator will also be the primary contact between the experiment and the Fermilab Test Beam Facility and will be responsible for bi-weekly reports at the All Experimenters' Meeting.
- Physics Analysis Coordinator, who is charged with oversight of the physics working groups and coordination among the groups to identify areas of common interest. The coordinator works with analysis groups to set and facilitate progress towards analysis milestones.
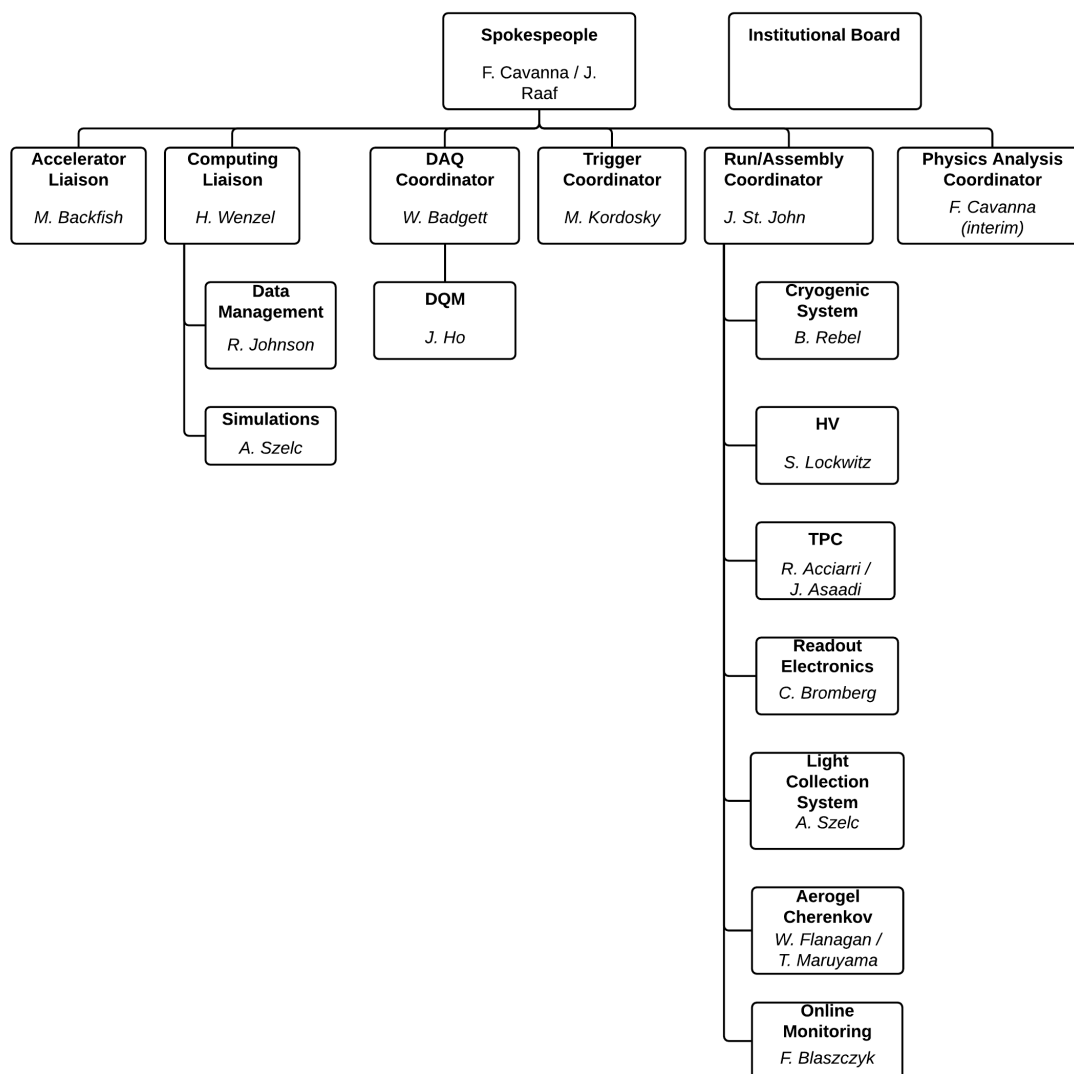
Figure 5: The LArIAT Collaboration Organization Chart

4.2   Run Coordination

In executing the run plan, the Run Coordinator will be assisted by a team of Deputy Run Coordinators chosen in consultation with the spokespersons. The Run Coordinator and the team of Deputy Run Coordinators will bear primary responsibility for shifter on-call support, control room maintenance, and reporting bi-weekly at the All Experimenters' Meeting.

Seven working groups report to the Run Coordinator:
- The Cryogenic working group is charged with development, maintenance, and support of the cryogenic argon system.

- The <u>HV</u> group is charged with development, maintenance, and online support of the detector hardware related to high voltage for the TPC drift field.
- The <u>TPC</u> group is charged with development, maintenance, and online support of the Time Projection Chamber.
- The <u>Online Monitoring</u> group is charged with development, maintenance, and online support of tools to monitor data quality and with giving regular feedback on the performance of detector hardware.
- The <u>Readout Electronics</u> group is responsible for development, maintenance, and online support of the cold electronics that read out the TPC data.
- The <u>Light Collection</u> group is responsible for development, maintenance, and online support of the light collection system in the cryostat.
- The <u>Aerogel Cherenkov</u> group is responsible for development, maintenance, and online support of the aerogel devices that are part of the beamline particle ID system.
- The <u>Beamline Detectors</u> group is responsible for development, maintenance, and online support of the MWPCs and scintillator paddles that make up the remainder of the beamline particle ID system.

4.3   Shifts

Shifts for running the LArIAT experiment are shared equally by all of the Ph.D. physicists and graduate students. In addition to regular shifters, Controlled Access Leaders are on call to provide assistance when problems arise that are beyond the expertise of the shifters. The shifters' responsibilities are to follow the run plan set out by the Run Coordinator, to see that the detectors are running properly, and to see that the data is of high quality, as determined from the diagnostic online monitoring.

Shifts are run 24/7 when there is liquid argon in the cryostat, regardless of whether the beam is on or off. Eventually we plan to move to remote shifts in the ROC-W control room in Wilson Hall, and also to carry out remote shifts at institutions outside of Fermilab. It is anticipated that the shift policy will evolve as the running becomes more routine.

5   FERMILAB ROLES AND RESOURCES

The LArIAT experiment receives support mainly from the Accelerator Division (AD), Fermilab Computing (FC), Particle Physics Division (PPD), and the Neutrino Division (ND).

5.1   Accelerator Division

The <u>Accelerator Division</u> is responsible for commissioning, operation, and maintenance of the primary proton beam line, the target station, and the secondary beam line. AD is responsible for maintenance of all existing standard beamline elements (SWICs, loss monitors, etc.), instrumentation, controls, clock distribution, and power supplies. The line

of demarcation between Accelerator Division and Particle Physics Division responsibilities is at the upstream end of the MC7 enclosure.

The Accelerator Division will also be responsible for monitoring intensity and beam quality of the primary proton beam and the secondary beam. Scalers and beam counter readouts are made available via ACNET to the MCenter control room, where a connection to the beam console and remote logging are available. The test beam energy and beam line elements are under the control of the AD Operations Department Main Control room (MCR), but the tertiary magnet settings are also controllable by LArIAT shifters.

The LArIAT experiment depends on support from a number of departments within AD. The External Beams group from AD provides a liaison to LArIAT. The deliverables and services expected from each of these groups are described below.

The External Beams Department is the proprietor of the MC7 tertiary beamline. The department provides a Beamline Coordinator who is in charge of beamline operations and serves as the point of contact for LArIAT questions involving the beam. The Beamline Coordinator's responsibilities concern both operational status and requests from LArIAT for changes in the beamline. The External Beams Department contains personnel who are experts in various elements of the design, operation and troubleshooting of any beamline, and are called upon by the Beamline Coordinator as needed. Position and focus of the beam on the experimental devices under test is under the control of the MCR. Control of the tertiary devices that provide these functions may be delegated to the experimenters as long as it does not violate the Shielding Assessment or have potential for significant equipment damage.

The AD ES&H Department has ES&H oversight responsibility for the AD areas of the FTBF facility, and the PPD ES&H Department has oversight responsibility for the PPD areas (MC7 enclosure). Oversight is also provided for radiation safety in the region of the tertiary beam through access control keys, enclosure interlocks, and beam inhibit critical devices.

The integrated effect of running beam for LArIAT and other SY120 beams will not reduce the neutrino flux by more than an amount set by the Office of Program Planning, with details of the scheduling to be worked out between the experimenters and the Office of Program Planning.

5.2   Fermilab Computing

The Fermilab Computing's Core Computing and Scientific Computing Divisions (CCD, SCD) support the needs of the LArIAT experiment computing through provision, maintenance, and support of common, and in some cases experiment-specific, core and scientific services and software.

The Computing Liaison's responsibilities include maintaining excellent communications between the experiment and CCD/SCD as well as attention to ensuring the computing

needs, agreements, issues and other relevant items between the experiment and Fermilab Computing are addressed in a timely and mutually agreed upon manner.

The tables below give the list of the services supported for LArIAT computing operations, as agreed in the LArIAT (T-1034) TSW with the FTBF [15].

Core Services:	
Authentication and Directory Services	Standard KCA and DNS services
Database Hosting	Database hosting and database infrastructure used by LArIAT at Fermilab.
Network Services	Standard support. Essential LArIAT-related network devices should be supported for 24x7 service.
Networked Storage Hosting	Support for BlueArc home area and data disks; part of the data processing, simulation and analysis scientific computing system support
Service Desk	Issue and notification reporting, handling and tracking.

Scientific Services	
DAQ & Controls	Run control developed with support from the Computing Sector for LArIAT DAQ. Artdaq, including custom input drivers, for the data acquisition system software.
Grid and Cloud Computing	Batch processing on Grid accessible systems at Fermilab as well as offsite through the Open Science Grid. Jobsub and other software for processing and analysis.
Scientific Collaboration Tools	LArIAT code repositories hosted through cdcvs.fnal.gov, redmine, and the electronic logbook application.
Scientific Computing Systems	Support for interactive, batch processing, simulation and analysis computing systems at Fermilab. Hosting of some scientific databases.
Scientific Data Management	SAM, IFDH, FTS and other data handling software and systems.
Scientific Data Storage and Access	Enstore-based tape storage services. Tape handling and curation. dCache-based data disk services and systems.
Scientific Databases	Applications and database infrastructure for identified LArIAT online and offline databases
Scientific Frameworks	The art offline framework, the LArSoft framework
Scientific Software	SoftReltools, ROOT, and other software tools.
Simulation Software	Support for Geant4.

In general, the LArIAT collaboration is responsible for repair and maintenance of LArIAT electronics components, often with technical support from the Physics Research Equipment Pool (PREP). The table below lists the current responsibilities.

System	Responsibilities
High Voltage Supplies	Repair or replacement by Fermilab LArIAT and AD
Low Voltage Supplies	Repair or replacement by Fermilab PREP
Scintillator paddles & PMTs	Repair and maintenance by Fermilab LArIAT and FTBF
MWPCs	Repair and maintenance by FTBF
Aerogel Cherenkov detectors	Repair and maintenance by UT Austin and KEK
Cold Electronics & D2S Cards	Repair and maintenance by Michigan State University
CAEN digitizers	Repair and maintenance by LArIAT/Neutrino Division
NIM logic	Repair or replacement by Fermilab PREP
Synoptic/ACNET	Repair and maintenance by Fermilab AD
Cryogenic system	Repair and maintenance by Fermilab PPD and ND
Detector Control & Monitoring System	Repair and maintenance by Boston University
Data Acquisition System	Maintenance by ND with assistance from several collaborating institutions

5.3   Neutrino Division

The newly formed Neutrino Division is responsible for the operation of the LArIAT experiment and experiment-related activities at Fermilab.

The Neutrino Division provides an administrative organization for the Fermilab staff working on LArIAT, as well as a center for experimental operations, data analysis and future planning. It also provides the funds for the operation and maintenance needs of the LArIAT Detectors.

The Neutrino Division provides office space for both resident and visiting LArIAT collaborators. Office space provided is commensurate with the amount of time spent at Fermilab.

5.4   Particle Physics Division

The Particle Physics Division is responsible for those parts of the LArIAT facility in the Fermilab Test Beam Facility for which it is the landlord. This includes the MCenter control room, and the MC7 enclosure where LArIAT is located.

The LArIAT experiment shares space with various tests and other experiments. Access to the areas is controlled via training and access keys.

6   SPARES

The following table lists current spares and anticipated FY16 purchases.

Item	Spares	# used in LArIAT	Anticipated purchases FY16	Comments
CAEN V1740 digitizers	0	9		
CAEN V1751 digitizers	0	2		
CAEN V2718 VME master	0	1		
CAEN V1495 FPGA trigger	0	1		
CAEN A3818 PCI-to-VME bridge	1	1		
CAEN VME crate and PS	1	1		
MWPCs	3	4		FTBF-owned
ASIC boards	2	9		
Glassman HV PS	1	1		
LV PS	1	2		
Wiener VME chassis	1	1		
Wiener power supply	0	1		

7   BUDGETS AND RESOURCES

7.1   LArIAT Operations Budget

The cost of running LArIAT with its temporary cryogenic system is roughly $700/day, which is entirely due to the cost of delivery and filling of the external dewar with LAr once per week. A minor modification to the phase separator should provide ~10-15% savings on the daily cost. This modification is currently underway, in preparation for LArIAT's Run 2.

A full-scale permanent cryogenic recirculation and purification system contracted through Eden Cryogenics exists, and this could be installed in the MCenter enclosure for a future run or as cryogenic infrastructure for future tenants of MC7. The full-scale system is more cost efficient, but requires significant resources to install and operate. Because of the extra resources and costs needed to install it, the decision was made within Neutrino Division to continue operating the existing "temporary" system for the foreseeable future.

8   RUN PLAN

The first data-collecting run of LArIAT took place before the Summer 2015 shutdown. This was a ~2-month run using the temporary cryogenic system described above, which was installed and tested during the end of 2014 and first half of 2015. Run 1 of LArIAT collected data from April 30, 2015 until the Fermilab summer shutdown (July 3, 2015). During this time, the experiment collected a good sample of single and double-track data. Preliminary analyses are underway for charged pion cross sections, optimization of particle identification for various particle species, and initial light collection studies to determine the feasibility of this novel implementation for future LArTPC neutrino experiments. The first analysis results are expected by the end of 2015.

The LArIAT collaboration is also currently analyzing Run 1 data in order to understand which beam tuning should be chosen to provide the most useful data for Run 2. The second data-collecting run of LArIAT is planned to begin in February, 2016, still using the temporary cryogenic system. Although the summer shutdown will end on October 5, 2015, there is a planned period during which no beam will be sent to MCenter and MTest (expected January 11 – February 12, 2016), and the decision was made to delay the start of the second run to avoid wasting argon during the beam-off period, and to allow the collaboration to focus its efforts on analysis to understand what extra data will be useful.

During the 2015 Summer Shutdown, the collaboration opened the cryostat in order to modify the circuit for bias voltage distribution (which provides bias voltage to the wire planes). This activity also served to inform us of the actual amount of time needed to move upstream detectors out of the way and to execute the flange-opening procedure. This is useful information to have in the case of future requests to do quick tests in the LArIAT TPC or cryostat. In total, the uncabling, moving of upstream detectors, and opening of cryostat took less than a week; closing and recabling is expected to take a similar amount of time. By doing this, LArIAT has demonstrated its flexibility and possibility to have quick turn-around on R&D tests that could benefit DUNE, MicroBooNE, and other LArTPC experiments.

APPENDIX A: LIST OF ACRONYMS

ACNET	Accelerator Control Network
AC	Aerogel Cherenkov
AD	Accelerator Division
ArgoNeuT	Argon Neutrino Test (FNAL T-962)
ASIC	Application-Specific Integrated Circuit
BlueArc	Name of a computer network storage device manufacturer
CAEN	Name of a particle physics instrumentation manufacturer
CC	Charged Current
CCD	Core Computing Division
CD-1	Critical Decision 1 (DOE)
CHIPS	Cherenkov detectors In mine PitS R&D experiment
CP	Charge-Parity
DAQ	Data Acquisition System
DNS	Domain Name Server
DUNE	Deep Underground Neutrino Experiment
EM	Electromagnetic
Enstore	A tape storage access and management system
ES&H	Environment, Safety, and Health
FC	Fermilab Computing
FTBF	Fermilab Test Beam Facility
FTS	File Transfer Service
FY	Fiscal Year
HV	High Voltage
ICARUS	Imaging Cosmic And Rare Underground Signals
IFDH	Intensity Frontier Data Handling
KCA	Keon Certificate Authority
LAr	Liquid Argon
LArIAT	LArTPC In A Testbeam
LArTPC	Liquid Argon Time Projection Chamber
LBNE	Long Baseline Neutrino Experiment
LV	Low Voltage
MC	Monte Carlo (simulation)
MCR	Main Control Room
MC7	Meson Center 7 area
MicroBooNE	Micro Booster Neutrino Experiment
MINERvA	Main INjector ExperRiment for ν-A interactions
MWPC	Multi-Wire Proportional Chamber
NC	Neutral Current
ND	Neutrino Division
NuMI	Neutrinos from the Main Injector
PID	Particle Identification
PPD	Particle Physics Division
PREP	Physics Research Equipment Pool
PS	Power Supply

ROC-W	Remote Operations Center – West
SAM	Sequential Access with Metadata
SCD	Scientific Computing Division
SUSY	Supersymmetry
SWIC	Segmented Wire Ionization Chamber
SY120	Switchyard 120
TOF	Time of Flight
TPC	Time Projection Chamber
TSW	Technical Statement of Work (formerly MOU)

APPENDIX B: COLLABORATION INSTITUTIONAL RESPONSIBILITIES

The following list represents a snapshot of the responsibilities of LArIAT institutions (as of October 2015). In each case, a total FTE collaborator count follows the institution name. When there are specific responsibilities of the institution, they are broken out in lists that follow. Participation in the experiment which applies generally (for example, analysis, shifts, supervision of students) is not broken out in these smaller totals.

Federal University of ABC, Brazil (UFABC) / 0.5 FTE
  0.4 FTE Software

Federal University of Alfenas, Brazil (UNIFAL-MG) / 0.2 FTE
  0.1 FTE Simulations & Software

Boston University / 0.6 FTE
  0.1 FTE Detector Monitoring
  In-kind contributions: TPC wire planes, bias voltage distribution boards
  Undergraduate contributions: detector commissioning, shifts

University of Campinas, Brazil (UNICAMP) / 3.4 FTE
  0.3 FTE Simulations / 0.7 FTE Calibration

University of Chicago / 2.0 FTE
  0.3 Light System / 0.4 FTE Data Quality / 0.2 FTE DAQ development
  Undergraduate contributions: shifts

University of Cincinnati / 0.83 FTE
  0.25 FTE Run Coordination / 0.4 FTE DAQ development
  In-kind contributions: Halo veto scintillator, punch-through scintillators

Fermilab / 4.05 FTE
  0.4 FTE Light System Simulations / 0.45 FTE Detectors Assembly / 0.05 FTE Software / 0.1 FTE Beams Liaison / 0.1 FTE Cryo System

Federal University of Goias, Brazil (UFG) / 1.2 FTE
  0.5 FTE Software / 0.1 FTE Beam Instrumentation

Istituto Nazionale di Fisica Nucleare, Italy (INFN) / 0.8 FTE
  In-kind contribution: Cryogenic PMTs

KEK / 1.0 FTE
  0.5 FTE Calibrations
  In-kind contributions: Aerogel Cherenkov detector

Louisiana State University / 1.45 FTE
      0.75 FTE Software / 0.2 FTE Simulations

University of Manchester, UK / 1.25 FTE
      0.2 FTE MC Coordination / 0.2 FTE Light System installation & maintenance

Michigan State University / 0.2 FTE
      In-kind contributions: LAr readout electronics (partial NSF support)

University of Minnesota, Duluth / 0.05 FTE
      0.05 FTE Beamline Design

University of Pittsburgh / 0.1 FTE

Syracuse University / 1.0 FTE
      0.4 FTE TPC assembly/commissioning / 0.3 FTE Software Coordination
      In-kind contributions: TPC refurbishment

University of Texas, Arlington / 0.8 FTE

University of Texas, Austin / 0.5 FTE
      0.2 FTE Simulations / 0.2 FTE Operations
      In-kind contributions: Aerogel Cherenkov detector
      Undergraduate contributions: shifts, beamline simulations

University College London / 0.5 FTE
      0.25 FTE Simulations

William & Mary / 0.1 FTE
      In-kind contribution: Trigger system (NSF support)

Yale University / 0.5 FTE
      0.4 FTE Software
      In-kind contribution: Cryostat modifications
      Undergraduate contributions: shifts

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